DOE/BC/14946-6
(OSTI ID: 792247)

**BASIN ANALYSIS OF THE MISSISSIPPI INTERIOR SALT BASIN AND
PETROLEUM SYSTEM MODELING OF THE JURASSIC SMACKOVER
FORMATION, EASTERN GULF COASTAL PLAIN FINAL REPORT AND
TOPICAL REPORTS 5-8 ON SMACKOVER PETROLEUM SYSTEM
AND UNDERDEVELOPMENT RESERVOIRS**

Final Report
August 23, 1996-August 22, 2001

By
Ernest A. Mancini
T. Markham Puckett
William C. Parcell
Juan Carlos Llinas
David C. Kopaska-Merkel
Roger N. Townsend

Date Published: February 2002

Work Performed Under Contract No. DE-FG22-96BC14946

The University of Alabama
Tuscaloosa, Alabama

**National Energy Technology Laboratory
National Petroleum Technology Office
U.S. DEPARTMENT OF ENERGY
Tulsa, Oklahoma**

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, expressed 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.

This report has been reproduced directly from the best available copy.

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

and

Topical Reports 5-8 on Smackover Petroleum System and
Underdevelopment Reservoirs

By
Ernest A. Mancini
T. Markham Puckett
William C. Parcell
Juan Carlos Llinas
David C. Kopaska-Merkel
Roger N. Townsend

March 2002

Work Performed Under DE-FG22-96BC14946

Prepared for
U.S. Department of Energy
Assistant Secretary for Fossil Energy

Virginia Weyland, Project Manager
National Petroleum Technology Office
P.O. Box 3628
Tulsa, OK 74101

Prepared by
Center for Sedimentary Basin Studies
The University of Alabama
Box 870338
Tuscaloosa, AL 35487-0338

TABLE OF CONTENTS

Abstract.....	v
Executive Summary.....	1
Introduction.....	5
Geologic Setting.....	7
Stratigraphy.....	10
Biostratigraphy.....	13
Petroleum Traps.....	14
Petroleum Reservoir and Seal Rocks.....	25
Reservoir Rocks.....	25
Seal Rocks.....	31
Smackover Source Rocks.....	32
Petroleum System.....	46
Underdeveloped Reservoir.....	48
Conclusions.....	50
References.....	55
Appendix 1.....	63
Appendix 2.....	73
Appendix 3.....	79

ABSTRACT

The Smackover Formation, a major hydrocarbon-producing horizon in the Mississippi Interior Salt Basin (MISB), conformably overlies the Norphlet Formation and is conformably overlain by the Buckner Anhydrite Member of the Haynesville Formation. The Norphlet-Smackover contact can be either gradational or abrupt. The thickness and lithofacies distribution of the Smackover Formation were controlled by the configuration of incipient paleotopography. The Smackover Formation has been subdivided into three informal members, referred to as the lower, middle and upper members.

Structural or combination traps characterize Smackover hydrocarbon accumulations in the MISB area. Halokinesis is the principal process that formed these traps. Salt movement of the Jurassic Louann Salt has produced a complex array of salt-related structures in this basin. These structures include peripheral salt ridges, low relief salt pillows, salt anticlines and turtle structures, and piercement domes. The northern limit of the MISB is delimited by the regional peripheral fault trend. This trend includes a series of en echelon faults associated with the Pickens, Gilbertown, West Bend extensional fault and half graben systems. In the area immediately north and updip of the regional peripheral fault trend, Smackover traps consist of anticlinal structures associated with basement paleotopographic highs.

The major petroleum reservoirs in the Smackover Formation occur in the upper part of the formation. These upper Smackover strata consist of upward-shoaling mudstone to grainstone parasequence sets that accumulated as part of the late highstand systems tract deposits of an Upper Jurassic (Oxfordian to Kimmeridgian) depositional sequence. These deposits represent higher energy, normal, open-marine intertidal to subtidal facies. These lithofacies were deposited in shoal flank, shoal crest, lagoonal and subtidal marine environments of a carbonate shoal complex. Reservoir-grade rocks (greater than 6% porosity and more than 0.1 md permeability) are ooid and peloidal grainstone and packstone beds characterized by primary interparticle, grain-moldic, dolomite-intercrystalline and vuggy porosity. Coral-microbial and microbial reef facies of the upper Smackover also have significant reservoir potential. These strata consist of bafflestone and boundstone beds that accumulated as part of the early highstand systems tract deposits of the Upper Jurassic (Oxfordian to Kimmeridgian) depositional sequence. These lithofacies were deposited in reef crest, reef flank, back-reef, and forereef environments of a reef complex. Reservoir-grade rocks are bafflestone and bindstone beds characterized by primary shelter, fenestral enhanced, dolomite-intercrystalline and vuggy porosity.

Although the primary control on reservoir quality in Smackover reservoirs is the fabric of the depositional lithofacies, diagenesis plays a significant role in modifying reservoir architecture. Of the diagenetic events, multiple dolomitization and dissolution events probably had the greatest influence on reservoir development and quality. While the dolomitization created only minor amounts of intercrystalline porosity, it significantly enhanced permeability. It also stabilized the lithology which reduced the potential for later porosity loss due to compaction. The dissolution events enlarged primary (interparticle and shelter) and early secondary (moldic and intercrystalline) pores. While the dissolution did not create large amounts of new porosity, it did expand existing pore throats and enhanced permeability. Locally, the development of fracture systems also served to increase permeability. While diagenesis has a significant influence on Smackover reservoir quality, it generally does not alter the geographic distribution of reservoir-grade rock. The development and distribution of reservoir-grade rock is primarily a function of depositional processes.

The upper Smackover is capped by subaerial evaporites of the Buckner Anhydrite Member of the Haynesville Formation. The anhydrites conformably overlie the carbonate rocks of the Smackover. These evaporites act as a barrier to vertical petroleum migration, and thus are effective seal rocks.

The organic-rich laminated, lower to middle Smackover carbonate mudstones are the petroleum source rocks for Smackover hydrocarbons and are the principal source rocks for the petroleum source rocks for other reservoirs in the Mississippi Interior Salt Basin. Hydrocarbon expulsion from the Smackover source rocks commenced during the Early Cretaceous and continued into the Tertiary. Hydrocarbon migration associated with the Smackover source rocks in the basin was initiated in the Early Cretaceous and continued into the Late Cretaceous and Tertiary. The hydrocarbon migration model for the basin would suggest that reservoirs and traps first sourced from Smackover carbonates in the Early Cretaceous would contain immature oils, while reservoirs and traps sourced in the Late Cretaceous and Tertiary would contain mature oils and gas condensates.

To date, more than 259 million barrels of oil and 1.4 Tcf of natural gas have been produced from 88 Smackover fields in the salt anticline play of the MISB. Opportunities exist for continued exploration for similar undrilled salt features in the basin and for the evaluation of the reservoir potential of Smackover carbonates on salt structures that are productive from shallow Cretaceous horizons. Although Smackover reservoirs are productive in the MISB, these reservoirs are underdeveloped. Carbonate lithofacies associated with carbonate shoal complexes provide an excellent exploration target, especially in the deeper parts of the central portion of the basin. Microbial reef facies are potential reservoirs throughout the basin.

EXECUTIVE SUMMARY

The northeastern Gulf of Mexico, including the eastern Gulf Coastal Plain, remains a largely unexplored region for oil and natural gas. The region contains numerous basins with a host of siliciclastic and carbonate formations having a high potential for hydrocarbon accumulations. To date, however, petroleum system studies have not been performed in the basins in this region. Further, independent companies that are drilling the majority of the wells in the region do not have the resources to conduct petroleum system studies. These companies maintain that the accessibility of oil and natural gas information is the single-most important factor critical to the search for new hydrocarbon resources. To facilitate petroleum exploration efforts in the eastern Gulf Coastal Plain, a comprehensive analysis, including petroleum system studies, of the Mississippi Interior Salt Basin (MISB) has been undertaken.

The Gulf of Mexico is a divergent margin basin characterized by extensional rift tectonics and wrench faulting. The history of the Gulf of Mexico includes a phase of crustal extension and thinning, a phase of rifting and sea-floor spreading and a phase of thermal subsidence. The structural and stratigraphic framework of the region, including the MISB, was basically established during the Triassic and Jurassic. The MISB is a major negative structural feature in the northeastern Gulf of Mexico. This extensional basin was an actively subsiding depocenter throughout the Mesozoic and into the Cenozoic. Halokinesis of the Jurassic Louann Salt has produced a complex of structural features in the northeastern Gulf of Mexico. Paleotopography also had a significant impact on the distribution of sediment, and positive areas within basins and along basin margins provided sources for Mesozoic terrigenous sediments.

The Smackover Formation, a major hydrocarbon-producing horizon in the MISB, conformably overlies the Norphlet Formation and is conformably overlain by the Buckner Anhydrite Member of the Haynesville Formation. The Norphlet-Smackover contact can be either gradational or abrupt. The thickness and lithofacies distribution of the Smackover Formation were controlled by the configuration of incipient paleotopography. The Smackover Formation has been subdivided into three informal members, referred to as the lower, middle and upper members.

Structural or combination traps characterize Smackover hydrocarbon accumulations in the MISB area. Halokinesis is the principal process that formed these traps. Salt movement of the Jurassic Louann Salt has produced a complex array of salt-related structures in this basin. These structures include peripheral salt ridges, low relief salt pillows, salt anticlines and turtle structures, and piercement domes. The northern limit of the MISB is delimited by

the regional peripheral fault trend. This trend includes a series of en echelon faults associated with the Pickens, Gilbertown, West Bend extensional fault and half graben systems. In the area immediately north and updip of the regional peripheral fault trend, Smackover traps consist of anticlinal structures associated with basement paleotopographic highs.

The major petroleum reservoirs in the Smackover Formation occur in the upper part of the formation. These upper Smackover strata consist of upward-shoaling mudstone to grainstone parasequence sets that accumulated as part of the late highstand systems tract deposits of an Upper Jurassic (Oxfordian to Kimmeridgian) depositional sequence. These deposits represent higher energy, normal, open-marine intertidal to subtidal facies. These lithofacies were deposited in shoal flank, shoal crest, lagoonal and subtidal marine environments of a carbonate shoal complex. Reservoir-grade rocks (greater than 6% porosity and more than 0.1 md permeability) are ooid and peloidal grainstone and packstone beds characterized by primary interparticle, grain-moldic, dolomite-intercrystalline and vuggy porosity. Coral-microbial and microbial reef facies of the upper Smackover also have significant reservoir potential. These strata consist of bafflestone and boundstone beds that accumulated as part of the early highstand systems tract deposits of the Upper Jurassic (Oxfordian to Kimmeridgian) depositional sequence. These lithofacies were deposited in reef crest, reef flank, back-reef, and forereef environments of a reef complex. Reservoir-grade rocks are bafflestone and bindstone beds characterized by primary shelter, fenestral enhanced, dolomite-intercrystalline and vuggy porosity.

Although the primary control on reservoir quality in Smackover reservoirs is the fabric of the depositional lithofacies, diagenesis plays a significant role in modifying reservoir architecture. Diagenesis occurred in both eogenetic (carbonates influenced by surface-derived fluids of marine, fresh water, or brine origin) and mesogenetic (carbonates influenced by connate or formation fluids during burial) environments. Eogenetic processes include: biogenic micritization of carbonate grains; precipitation of fibrous aragonite or Mg calcite, marine cements; physical compaction; evaporative dolomitization; precipitation of meteoric-phreatic, Mg calcite cements; fabric-selective, meteoric-vadose dissolution; and precipitation of dolomite and anhydrite through brine reflux. Of the diagenetic events, multiple dolomitization and dissolution events probably had the greatest influence on reservoir development and quality. While the dolomitization created only minor amounts of intercrystalline porosity, it significantly enhanced permeability. It also stabilized the lithology which reduced the potential for later porosity loss due to compaction. The dissolution events enlarged primary (interparticle and shelter) and early secondary (moldic and

intercrystalline) pores. While the dissolution did not create large amounts of new porosity, it did expand existing pore throats and enhanced permeability. Locally, the development of fracture systems also served to increase permeability. The most important processes that destroyed porosity in the Smackover of the eastern MISB were marine phreatic calcium-carbonate cementation, anhydrite cementation, burial calcite cementation (associated with dedolomitization and calcitization of anhydrite). While diagenesis has a significant influence on Smackover reservoir quality, it generally does not alter the geographic distribution of reservoir-grade rock. The development and distribution of reservoir-grade rock is primarily a function of depositional processes.

The upper Smackover is capped by subaerial evaporites of the Buckner Anhydrite Member of the Haynesville Formation. The anhydrites conformably overlie the carbonate rocks of the Smackover. These evaporites act as a barrier to vertical petroleum migration, and thus are effective seal rocks.

The organic-rich laminated, lower to middle Smackover carbonate mudstones are the petroleum source rocks for Smackover hydrocarbons and are the principal source rocks for the petroleum source rocks for other reservoirs in the MISB. Smackover samples from the lower and middle carbonate mudstones average 0.81% total organic carbon. Because much of the Smackover has experienced advanced levels of thermal maturity, the total organic carbon values were higher in the past prior to the generation of crude oil. The dominant kerogen types in the Smackover are algal (microbial) and amorphous.

The generation of hydrocarbons from Smackover carbonate mudstones was initiated at 2,438 to 3,353 m (8,000 to 11,000 ft) during the Early Cretaceous and continued into the Tertiary throughout much of the MISB. The thermal maturation profiles for wells located updip or along the northern margin of the basin indicate that the Smackover source rocks in this area are thermally immature and did not generate oil, while wells located in the center of the basin and along the southern margin of the basin adjacent to the Wiggins Arch show that the Smackover source rocks are late mature. In the vicinity of the Jackson Dome, hydrocarbon gas generation begins at a depth of 4,572 m (15,000 ft).

Hydrocarbon expulsion from the Smackover source rocks commenced during the Early Cretaceous and continued into the Tertiary. Initiation of oil expulsion began first in the central portion of the basin in mid-Early Cretaceous and peaked during the late Early Cretaceous in this area. In the south-central portion of the basin, north of the Wiggins Arch, oil expulsion was initiated in the Early Cretaceous and peaked in the early Late Cretaceous, while

in the eastern portion of the basin oil expulsion commenced during the Late Cretaceous and continued into the Tertiary. During the Late Cretaceous and continuing into the Tertiary, peak oil expulsion occurred in areas in the northern portion of the basin but not along the northernmost margin of the basin.

Hydrocarbon migration associated with the Smackover source rocks in the basin was initiated in the Early Cretaceous and continued into the Late Cretaceous and Tertiary. The main oil migration pathways during the Early Cretaceous were from the basin center westward into salt anticlinal features and northward into traps associated with paleotopographic basement structures and with the Pickens-Gilbertown extensional fault systems and from the south-central portion of the basin northward into developing salt traps and southward along the Wiggins Arch. These migration trends were maximized in the early Late Cretaceous. In addition, during the Late Cretaceous, oil migration occurred from the basin center eastward into salt anticlinal features and into fault traps associated with the Mobile Graben. This hydrocarbon migration model for the basin would suggest that reservoirs and traps first sourced from Smackover carbonates in the Early Cretaceous would contain immature oils, while reservoirs and traps sourced in the Late Cretaceous and Tertiary would contain mature oils and gas condensates.

The Smackover petroleum system is a self-contained system. Petroleum source rocks, reservoir rocks, and seal rocks are all within this unit. Anhydrite beds of the uppermost Smackover and the overlying Buckner Anhydrite Member of the Haynesville Formation serve as the petroleum seal rocks. Reservoir-grade carbonates are part of the upper Smackover beds. The lower and middle, organic-rich Smackover beds serve as the petroleum source rocks. The source potential of these beds has been optimized by the combination of favorable conditions of deposition, preservation, and subsequent burial and thermal histories. The generation of crude oil from these source rocks was initiated at a level of thermal maturity of 0.55% Ro in the Early Cretaceous and concluded at a level of thermal maturity of 1.5% Ro in the Late Cretaceous or Early Tertiary. Hydrocarbon expulsion commenced during the Early Cretaceous and continued into the Tertiary. Peak expulsion was during the Late Cretaceous. Hydrocarbon migration was generally long distance (80 km or 50 mi) and was initiated in the Early Cretaceous and continued into the Tertiary.

Regional and local reservoirs in the MISB and adjacent areas have produced approximately 1.9 billion barrels of oil and more than 6.3 Tcf of gas from Jurassic, Cretaceous and Tertiary reservoirs in 552 fields. Hydrocarbons were discovered from Upper Jurassic Smackover carbonate rocks in 1966 in the MISB. To date, more than 259 million

barrels of oil and 1.4 Tcf of natural gas have been produced from 88 Smackover fields in the salt anticline play of the MISB. Opportunities exist for continued exploration for similar undrilled salt features in the basin and for the evaluation of the reservoir potential of Smackover carbonates on salt structures that are productive from shallow Cretaceous horizons. Although Smackover reservoirs are productive in the MISB, these reservoirs are underdeveloped. Carbonate lithofacies associated with carbonate shoal complexes provide an excellent exploration target, especially in the deeper parts of the central portion of the basin. Microbial reef facies are potential reservoirs throughout the basin. The Smackover Formation is the most productive reservoir in the regional peripheral fault trend play when the fields associated with the Mobile Graben are considered as part of this play. Smackover carbonates have produced more than 138 million barrels of oil and 439 Bcf of natural gas from 24 fields. Opportunities exist for continued exploration along the regional peripheral fault trend. The basement ridge play, which lies updip and north of the regional peripheral fault trend, is characterized by pre-Jurassic paleotopographic basement highs. Six fields associated with the Choctaw Ridge Complex are productive from this play. These fields have produced more than 2.5 million barrels of oil and 320,000 Mcf of natural gas. Opportunities exist for continued exploration in the basement ridge play; however, to date, these petroleum traps have had a smaller areal extent (1-2 sq. mi.) as compared to the salt related traps in the salt anticline and regional peripheral fault trend plays.

INTRODUCTION

The northeastern Gulf of Mexico, including the eastern Gulf Coastal Plain, remains a largely unexplored region for oil and natural gas. The region contains numerous basins with a host of siliciclastic and carbonate formations having a high potential for hydrocarbon accumulations. To date, however, petroleum system studies have not been performed in the basins in this region. Further, independent companies that are drilling the majority of the wells in the region do not have the resources to conduct petroleum system studies. These companies maintain that the accessibility of oil and natural gas information is the single-most important factor critical to the search for new hydrocarbon resources.

To facilitate petroleum exploration efforts in the northeastern Gulf of Mexico, a comprehensive analysis of the MISB (Figure 1), including petroleum systems, has been undertaken. This basin was selected for study because it is the largest basin in the region, extending from Louisiana eastward into Alabama, has produced the most petroleum (1.9 billion barrels of oil and 6.3 trillion cubic feet of natural gas), has the highest potential for identifying

Figure 1 - Location map of the Mississippi Interior Salt Basin and related structural features.
Modified from Pilger (1981).

underdeveloped plays and reservoirs, and represents the largest subsurface well log, core and geophysical database of the basins in the eastern Gulf Coastal Plain. The purpose of this paper is to provide the information gathered and analyses performed relating to the Smackover petroleum system in the MISB.

GEOLOGIC SETTING

The Gulf of Mexico is a divergent margin basin characterized by extensional rift tectonics and wrench faulting (Miller, 1982; Pilger, 1981; Salvador, 1987; Winkler and Buffler, 1988). The history of the Gulf of Mexico includes a phase of crustal extension and thinning, a phase of rifting and sea-floor spreading and a phase of thermal subsidence (Nunn, 1984). The structural and stratigraphic framework of the region, including the MISB (Figure 1), was basically established during the Triassic and Jurassic (Salvador, 1987).

Based on the distribution of crust type, Sawyer et al. (1991) proposed the following as a model for the evolution of the Gulf of Mexico and related MISB. The Late Triassic-Early Jurassic early rifting phase is characterized by large and small half-grabens bounded by listric normal faults and filled with nonmarine siliciclastic sediments (red-beds) and volcanics. The Middle Jurassic phase of rifting, crustal attenuation and the formation of transitional crust is characterized by the evolution of a pattern of alternating basement highs and lows and the accumulation of thick salt deposits in the lows. The Late Jurassic phase of sea-floor spreading and oceanic crust formation in the deep central Gulf of Mexico is characterized by a regional marine transgression as a result of crustal cooling and subsidence. Subsidence continued into the Early Cretaceous, and a carbonate shelf margin developed along the tectonic hinge zone of differential subsidence between thick and thin transitional crust.

Mesozoic and Cenozoic strata of the northeastern Gulf of Mexico were deposited as part of a seaward-dipping wedge of sediment that accumulated in differentially subsiding basins on the passive margin of the North American continent (Martin, 1978). Basement cooling and subsidence resulted in filling of the accommodation space throughout the Jurassic. Structural elements that affected the general orientation of these strata include basement features associated with plate movement and features formed due to halokinesis of Jurassic salt. The basement surface is dissected by the regional basement rift system that consists of a rift-related trend of divergent wrench-type basement faults and associated grabens and half grabens (Mink et al., 1990). The major basement faults are the northwest-southeast trending Florida-Bahamas and Pearl River transfer faults. The graben system is a result of rifting and its geometry is a reflection of the direction of plate separation (MacRae and Watkins, 1996). The major positive

basement features that influenced the distribution and nature of Mesozoic deposits onshore are the Wiggins Arch complex, Choctaw ridge complex, the Conecuh ridge complex, and the Pensacola and Decatur ridge complex (Figure 2). These structural elements, such as the Choctaw, Conecuh, Pensacola, and Decatur ridge complexes, are associated with the Appalachian fold and thrust structural trend that was formed in the late Paleozoic by tectonic events resulting from convergence of the North American and African-South American continental plates. The Wiggins Arch complex may represent an elevated horst block associated with crustal extensional and rifting (Miller, 1982; Sawyer et al., 1991). This basement feature may be a remnant of the rifted continental margin of North America. The Wiggins Arch consists of pre-rift Paleozoic metamorphic and granitic rocks (Cagle and Khan, 1983).

Paleotopography had a significant impact on the distribution of sediment, and positive areas within basins and along basin margins provided sources for Mesozoic terrigenous sediments (Mancini and Mink, 1985). The MISB is a major negative structural feature in the northeastern Gulf of Mexico. This extensional basin was an actively subsiding depocenter throughout the Mesozoic and into the Cenozoic. Based on gravity data, Wilson (1975) interpreted the MISB to be an area of attenuated granitic continental crust. Crustal thinning resulted from tectonic extension of the lithosphere during the rifting of the Gulf in the early Mesozoic. This attenuation of the crust established a subsiding basin cratonward of the rifted and elevated continental margin (Wood and Walper, 1974).

Halokinesis of the Jurassic Louann Salt has produced a complex of structural features in the northeastern Gulf of Mexico (Martin, 1978). Salt-related structures include diapirs, anticlines, and extensional fault and half graben systems. Structural elements resulting from salt movement include the regional peripheral fault trend, the Mobile graben, and numerous salt domes and anticlines. Halokinetically-related structural deformation was initiated probably during the Late Jurassic and possibly as early as the Oxfordian (Dobson and Buffler, 1997).

The regional peripheral fault trend is comprised of a group of genetically related, *en echelon* extensional faults and half grabens that are associated with salt movement. According to Hughes (1968) and Martin (1978), these half grabens and grabens were formed from late Jurassic to Miocene time and are closely related with salt flowage. Bishop (1973) believed that gravity creep and active differential subsidence during the late Jurassic in addition to salt flowage were important in the formation of the regional peripheral fault trend. Onshore, this trend is composed of the Pickens, Gilbertown, West Bend, Pollard, and Foshee fault systems and offshore, the Pensacola-Destin fault system has been interpreted as part of this trend (Kemmer and Reagan, 1987). The trend approximates the updip limit of

Figure 2 - Structural features in the Mississippi Interior Salt Basin area.

thick Jurassic salt (Martin, 1978). The faults of the regional peripheral fault trend are generally parallel or subparallel to regional depositional strike and are normal, down-to-the-basin or antithetic faults that form grabens that are generally 8 to 13 km (5 to 8 mi) across (Murray, 1961). The faults are listric with fault dips ranging from 35° to 70° and with displacements on major faults ranging from 61 to 610 m (200 to 2,000 ft) in the Jurassic section (Mancini and Mink, 1985). The Mobile graben, which is considered to define the eastern limit of the MISB but is not part of the regional peripheral fault trend, represents a more mature stage of halokinesis as evidenced by an association with diapiric features. The regional basement rift system influenced movement along the regional peripheral fault trend (Mink et al., 1990).

STRATIGRAPHY

The Smackover Formation conformably overlies the Norphlet Formation and is conformably overlain by the Buckner Anhydrite Member of the Haynesville Formation (Figure 3). The Norphlet-Smackover contact can be either gradational or abrupt (Mancini and Benson, 1980). In some areas, such as Mobile County, Alabama, dolomitic sandstone of the uppermost Norphlet Formation grades into silty dolomite of the lowest Smackover. In Escambia County, Alabama, quartzose sandstone of the Norphlet is sharply overlain by carbonate mudstone of the Smackover. A variable contact between the Norphlet and Smackover is also observed in Mississippi, where Dinkins (1968) described difficulty in identifying the contact at some localities, such as Rankin County, where there is a transitional zone of about 9 feet between the Norphlet and the Smackover, and a sharp contact at other localities.

The thickness and lithofacies distribution of the Smackover Formation were controlled by the configuration of incipient paleotopography. For example, the Smackover is thick in the MISB, but thins dramatically (in fact, is absent) over paleotopographic highs, such as the Wiggins Arch (Cagle and Khan, 1983; Rhodes and Maxwell, 1993; Tew et al., 1993). Halokinesis was initiated as early as the latter part of Smackover time, uplifting certain areas, such as the Pool Creek area in Jones County, Mississippi (Dinkins, 1968). The deeper water lithofacies of the lower Smackover are also absent over basement highs (Benson, 1988; Rhodes and Maxwell, 1993; Benson et al., 1996, 1997).

The Smackover Formation has been subdivided into three informal members, referred to as the lower, middle and upper members (Benson, 1988). The following discussion on the three members is based on the work of Benson (1988). The lower member is comprised of a relatively thin interval of 1) algal (microbial) laminite, 2) intraclastic

System	Series	Stage	Group	Formation		Member		
				Mississippi	Alabama			
Paleogene	Oligocene	Rupelian	Vicksburg					
	Eocene	Priabonian	Jackson	Yazoo Clay				
		Bartonian	Claiborne	Moodys Branch Formation Cockfield Formation		Moodys Branch Gosport Sand		
				Cook Mountain Formation		"upper Lisbon"		
		Lutetian		Kosciusko Sand		"middle Lisbon"		
				(Cane River) Zilpha Shale Winona Fm. Tallahatta Fm.		"lower Lisbon" Tallahatta Fm.		
		Ypresian	Wilcox	Wilcox undifferentiated	Hatchetigbee Formation Tuscahoma Formation Nanafalia Formation			
	Paleocene	Selandian	Midway	Midway undiff. "Jackson Gas Rock"	Naheola Formation Porters Creek Clay			
		Danian						
	Cretaceous	Upper Cretaceous	Maastrichtian	Selma				
Campanian								
Santonian			Eutaw Formation		Tombigbee Sand			
Coniacian			Tuscaloosa	Upper Tuscaloosa Formation				
Turonian				Marine Shale				
Cenomanian				Lower Tuscaloosa Formation				
Lower Cretaceous		Albian	Washita- Fredericksburg undifferentiated	Dantzler Formation				
			Andrew Formation					
				Paluxy Formation				
				Mooringsport Formation				
				Ferry Lake Anhydrite				
				Rodessa Formation				
		Aptian	James Limestone/ Pine Island Shale					
			Sligo Formation/ Hosston Formation					
			Triassic	Upper Jurassic	Tithonian	Schuler Formation		Dorcheat Shongaloo
					Kimmeridgian	Haynesville Formation		Buckner Anhydrite
					Oxfordian	Smackover Formation		"Brown Dense"
				Middle Jurassic	Callovian	Norphlet Formation		
Bathonian	Louann Salt				Pine Hill Anhydrite			
Bajocian								
Aalenian	Werner Anhydrite							
Lwr. Jurassic	Hettangian? Rhaetian?		Eagle Mills Formation					

Figure 3 - Stratigraphy of the Mississippi Interior Salt Basin.

wackestone/packstone, and 3) peloidal-oncoidal packstone/wackestone. The lower member ranges from a few feet to more than 100 feet in thickness. This member is thinnest near the centers of the depositional basins and thickest in the updip areas.

The algal (microbial) laminite lithofacies is light-gray to tan mudstone with well-developed laminations. Fossils are generally absent, but terrigenous material, including clay minerals, mica, and silt are common. The intraclastic packstone/wackestone lithofacies is typically light-gray to tan, with intraclasts consisting of tabular fragments of laminated mudstone. The peloidal-oncoidal packstone/wackestone lithofacies is typically tan to medium gray in color and is dominated by peloids, which may comprise up to 75% of the lithology. Oncoids in this lithofacies range from 5 to 40 mm in diameter. Bioturbation is common. The lower Smackover member lithologies are commonly dolomitized and very pyritic.

The middle member of the Smackover is characterized by light brown to medium gray skeletal peloidal wackestones interbedded with laminated carbonate mudstones. The matrix is typically argillaceous. Bioturbation ranges from nonbioturbated to intensely burrowed. Limestone dominates the member, but dolomite occurs locally. Interbedded with the skeletal/peloidal wackestones are intervals of dark-gray to black, laminated, carbonate mudstones. These mudstones are organic rich and highly argillaceous. The thickness of the middle member of the Smackover is inverse of the lower member, that is, the middle member is absent in updip areas and is thickest in the depositional sub-basins, reaching a maximum of 400 feet in the MISB.

The upper Smackover member consists of a complex sequence of lithologies, dominated by coarsening upward cycles of peloidal, oncoidal, and oolitic packstones and grainstones. The upper Smackover member, therefore, differs from the lower and middle members by the presence of higher-energy lithofacies. Cycle thickness ranges from less than 5 feet to approximately 30 feet, with cycle thickness decreasing upwards. Peloids, including *Favreina*, are abundant in this member, which also contains scattered skeletal grains. The upper part of the cycles consists of light-gray to tan, tabular cross-bedded, oolitic grainstones. Subaerial exposure surfaces occur within the grainstone intervals. The cycles are capped by thin beds of nodular to massive anhydrite.

The dominant lithologies of the upper member are variable according to location. In the northern updip areas of the MISB, the upper member is dominated by peloidal and oncoidal grainstones and packstones interbedded with peloidal and skeletal packstones and wackestones with a restricted invertebrate fauna; algal (microbial) particles are

abundant. The upper member in the Manila sub-basin contains significant amounts of terrigenous silt and clay, and consists of argillaceous peloidal wackestones and packstones interbedded with argillaceous mudstones and calcareous shales (Wade et al., 1987). In southwest Alabama and in the northern part of the MISB in Choctaw and Clarke Counties, digitate, laminar, or domal microbial boundstones are common (Baria et al., 1982). These boundstone reefs developed seaward of ooid shoals around paleotopographic highs. Dolomitization is very common in the upper member of the Smackover, especially in updip areas, and has obliterated original depositional fabric.

Historically, the Smackover Formation in the MISB is subdivided into an upper member and a lower member (Brown Dense Limestone) (Badon, 1974; Dinkins, 1968). The upper member of the Smackover is generally coarse grained and quite sandy in specific areas, whereas the lower member (Brown Dense Limestone) typically consists of more micritic lithologies, although, again, sandstone can be common.

Dickinson (1962) used a tripartite subdivision of the Smackover for the MISB, similar to the one described above by Benson (1988), with a lower, dark gray to black, laminated, pyritic limestone, a middle unit consisting of light brown to light gray limestone containing much dolomite, and an upper sandy and/or oolitic unit.

Smackover reservoirs generally occur in the upper part of the formation. See Appendices 1 through 3.

BIOSTRATIGRAPHY

Precise determination of the age of the Smackover in the MISB has been difficult because of the rarity of age-diagnostic fossils in this formation. Studies of the age of the Smackover include Imlay (1940; 1943; 1980), Imlay and Herman (1984) and Young and Oroliz (1993). Considerable work has been published on ammonites from chronostratigraphic equivalent units in Mexico, which is summarized in Salvador (1987). Corals from the Smackover Formation of Arkansas were described by Wells (1942). Imlay and Herman (1984) reported wells in the southeastern United States from which ammonites were obtained, including one in Mississippi (Shell McNair #1, in Hinds County). Ammonites from the middle and upper portions of the Smackover include species of *Ochetoceras*, *Proscaphites*, *Dichotomosphinctes*, *Discosphinctes*, *Orthosphinctes*, *Idoceras*, and *Euaspidoceras*, indicating a late Middle to Late Oxfordian age. The occurrence of *Discosphinctes* at the top of the lower fifth of the Smackover from Morehouse Parish, Louisiana, indicates that the lower portion of the Smackover is also of Oxfordian Age. Also reported from the Gilmer Limestone (carbonate equivalent of the Haynesville Formation, according to Forgotson and Forgotson (1976)) is the occurrence of *Idoceras* of Late Oxfordian or Early Kimmeridgian Age. Young and Oroliz

(1993) reached a similar conclusion regarding the age of the Smackover, based on fossils occurring in a core collected in the Cotton Valley Field, Webster Parish, Louisiana. Upper Oxfordian ammonites collected from the upper one-third of the Smackover include *Lithacosphinctes?*, *Pseudorthosphinctes*, *Orthosphinctes*, *Ardescia*, *Ochetoceras* (*Cubaochetocera?*), *Euaspidoceras* (subgen. indet.), *Orthosphinctes*, *Praeataxioceras?*, *Glochiceras* sp. gr., *Amplicanaliculatum*, and *Passendorferia*. Ammonites collected from the lower two-thirds of the core include *Dichotomoceras* gr., *Anconensis*, *Otosphinctes?*, *Dichotomosphinctes* sp., *Lissoceratoides?* sp., *Ochetoceras* or *Cubaochetoceras* sp., and “*Discosphinctes*” sp. gr. The presence of “*D.*” sp. gr. *acandai* indicates a Middle Oxfordian Age. Thus, a Middle-Upper Oxfordian Age assignment of the Smackover Formation, at least in northern Louisiana, is reasonable.

PETROLEUM TRAPS

Structural or combination traps characterize Smackover hydrocarbon accumulations in the MISB area (Mancini et al., 1990). Halokinesis is the principal process that formed these traps. Salt movement of the Jurassic Louann Salt has produced a complex array of salt-related structures in this basin. These structures include peripheral salt ridges, low relief salt pillows, salt anticlines and turtle structures, and piercement domes (Hughes, 1968; Montgomery and Ericksen, 1997). These features form the majority of the petroleum traps in the basin. The basin contains at least 53 documented salt domes with crests less than 6,000 feet from the surface, and two of the domes (Richton and Tatum salt domes) occur less than 1,000 feet from the surface (Thieling and Moody, 1997). The hydrocarbons trapped in 88 Smackover fields (Table 1) in the basin are a result of salt-related structural or combination traps. Combination traps are generally porosity or permeability terminations occurring counter to regional dip associated with halokinetically generated structures (Tew et al., 1993). See Appendix 3 for structural maps for Smackover fields in the basin. These maps illustrate the salt-related petroleum traps associated with these fields.

Smackover petroleum traps vary according to position in the basin. Variation is evident regarding the degree of salt-related deformation, depending on the original thickness of the Louann Salt. Along the northern margin of the basin, where the Louann was thin, deformation was relatively minor, producing gentle pillow structures. With progressive thickness of original salt, the structures resulting from salt deformation increase in complexity from high-relief, faulted anticlines to diapiric structures. The eastern portion of the MISB (approximately the eastern third

Table 1. Hydrocarbon production from the Smackover Formation in fields in the Salt Anticline Play of the Mississippi Interior Salt Basin.

Field name	Reservoir	County	Oil (bbls)	Gas (mcf)
Churchula	Smackover gas condensate	Mobile	62,324,085	345,720,761
Pachuta Creek	Smackover oil	Clarke	52,790,798	24,713,763
West Nancy	Smackover oil	Clarke	19,635,630	13,108,631
Chatom	Smackover gas condensate	Washington	16,346,118	186,314,315
South Cypress Creek	Smackover oil	Wayne	12,536,180	3,519,914
Lake Como	Smackover oil	Jasper	11,742,251	17,880,844
Tallahala Creek	Smackover oil	Smith	10,125,459	15,604,344
East Nancy	Smackover oil	Clarke	6,395,161	3,277,103
Nancy	Smackover oil	Clarke	5,502,096	3,445,648
Tallahala Creek East	Smackover oil	Smith	4,804,179	3,958,626
Lake Utopia	Smackover oil	Jasper	4,769,778	3,132,809
Goodwater	Smackover oil	Clarke & Wayne	4,479,915	7,805,286
Prairie Branch	Smackover oil	Clarke	4,257,462	2,967,243
Chaparral	Smackover oil	Wayne	3,533,360	1,896,891
Cypress Creek	Smackover oil	Wayne	3,337,117	748,449
Turkey Creek	Smackover oil	Choctaw & Clarke	3,086,854	154,294
Silas	Smackover oil	Choctaw	2,413,130	2,537,130
Pool Creek	Smackover oil	Jones	1,881,062	648,351
Crosby's Creek	Smackover gas condensate	Washington	1,858,044	5,511,535
Harmony	Smackover oil	Clarke	1,788,594	639,827
Wolf Creek	Smackover oil	Wayne	1,641,102	1,496,859
Otho	Smackover oil	Smith	1,578,637	418,200
West Paulding	Smackover oil	Jasper	1,411,468	239,797
Shubuta	Smackover oil	Clarke	1,343,854	992,319
Stafford Springs	Smackover oil	Jasper	1,299,345	3,721,346
Cold Creek	Smackover oil	Mobile	1,273,635	1,358,044
Barber Creek	Smackover oil	Scott	1,156,813	409,252
Southeast Chatom	Smackover gas condensate	Washington	1,020,790	5,811,373
Barnett	Smackover oil	Clarke	978,191	286,206
Watts Creek	Smackover oil	Clarke	958,936	197,364
East Barber Creek	Smackover oil	Scott	917,620	572,576
Clear Creek	Smackover oil	Wayne	906,154	1,200,088
Vossburg	Smackover oil	Jasper	890,423	277,612
Copeland	Smackover gas condensate	Washington	829,568	14,210,043
North Shubuta	Smackover oil	Clarke	801,112	2,135,553
South State Line	Smackover gas	Greene	722,191	30,782,540
Bay Springs	Smackover oil	Jasper	615,622	478,624
Healing Springs	Smackover gas condensate	Washington	594,848	8,085,870
West Clara	Smackover oil	Wayne	564,124	288,910
South Paulding	Smackover oil	Jasper	485,092	253,436
Gin Creek	Smackover oil	Choctaw	440,700	470,938
Winchester	Smackover oil	Wayne	405,029	124,302
Zion Chapel	Smackover oil	Choctaw	381,503	752,808
Bienville Forest	Smackover oil	Smith	380,118	179,251
South Wolf Creek	Smackover oil	Wayne	351,257	78,457

Table 1. continued

Field name	Reservoir	County	Oil (bbls)	Gas (mcf)
Diamond	Smackover oil	Wayne	324,497	554,246
Red Creek	Smackover gas condensate	Washington	321,213	5,763,913
Addie Mae	Smackover oil	Clarke	288,795	89,157
Mike Creek	Smackover oil	Clarke	246,983	14,891
Beaver Dam	Smackover oil	Jasper	226,253	15,001
Boyce	Smackover oil	Wayne	221,407	309,768
Waynesboro	Smackover oil	Wayne	185,582	454,983
Sumrall	Smackover oil	Clarke	168,041	1,039
South Harmony	Smackover oil	Clarke	162,804	3,511
North Clara	Smackover gas	Wayne	141,179	628,392
West Pineville	Smackover oil	Smith	138,487	30,938
Gulf Crest	Smackover oil	Mobile	136,135	109,372
North Hiwannee	Smackover gas	Wayne	130,123	506,286
Turnerville	Smackover oil	Mobile	124,203	184,260
Reedy Creek	Smackover oil	Jones	120,999	322,037
Garland Creek	Smackover oil	Clarke	88,034	3,025
Paulding	Smackover oil	Jasper	85,389	41,910
Shongelo Creek	Smackover oil	Smith	83,900	63,031
Puss Cuss Creek	Smackover oil	Choctaw	69,683	57,258
Tallabogue Creek	Smackover oil	Smith	64,598	22,770
Sylvarena	Smackover oil	Smith	55,982	52,542
West Heidelberg	Smackover gas	Jasper	41,800	14,553
Souwilpa Creek	Smackover oil	Choctaw	40,678	241,589
South Cold Creek	Smackover oil	Mobile	31,687	38,679
East Paulding	Smackover oil	Jasper	29,762	4,882
Union Grove	Smackover oil	Smith	20,463	0
Pineville	Smackover oil	Smith	19,034	602
Mize	Smackover oil	Smith	18,312	11,375
Bowling Creek	Smackover oil	Smith	13,494	0
Benton	Smackover gas	Yazoo	13,278	122,014
Missionary	Smackover oil	Jasper	11,909	0
East Yellow Creek	Smackover oil	Wayne	11,307	0
West Barnett	Smackover oil	Jasper	6,511	1,621
Thomasville	Smackover gas	Rankin	4,230	436,056,945
Stage Coach Road	Smackover oil	Clarke	2,536	7,325
Stringer	Smackover oil	Jasper	1,534	0
Fluffer Creek	Smackover oil	Clarke	444	0
Southwest Piney Woods	Smackover gas	Rankin	0	117,912,024
Piney Woods	Smackover gas	Rankin	0	67,343,612
Johns	Smackover gas	Rankin	0	65,257,655
Harrisville	Smackover gas	Simpson	0	35,917,374
Pisgah South	Smackover gas	Rankin	0	547,000
Black Creek	Smackover gas	Perry	0	6,900
		Totals	259,206,671	1,451,120,012

of the basin, exclusive of the Alabama portion) is characterized by subparallel, linear salt ridges. This area can be referred to as the Salt Ridge Subprovince of the MISB. Pachuta Creek Field is an example of a trap associated with a linear salt ridge (Figure 4). The trap consists of a faulted, elongated anticline. In the western portion of the basin, the salt-related features are characteristically high-relief, domal structures that are subcircular in map view. This area can be referred to as the Salt Dome Subprovince of the MISB. Cypress Creek Field is an example of a trap associated with a high-relief domal feature (Figure 5). The strategies for oil and gas exploration in these two areas differ considerably. For Smackover exploration, only the low-relief, generally non-piercing structures are sought; high-relief structures typically pierce through the Smackover.

The northern limit of the MISB is delimited by the regional peripheral fault trend (Figure 2). This trend includes a series of en echelon faults associated with the Pickens, Gilberttown, West Bend extensional fault and half graben systems. These petroleum traps have been interpreted to be associated with stratal movement resulting from the differential competencies of the underlying Paleozoic basement rock versus salt. The hydrocarbons trapped in 24 fields (Table 2) north of the MISB are associated with the regional peripheral fault trend. The Mobile Graben, which defines, in part, the eastern limit of the MISB, is included with the regional peripheral fault trend because it also occurs near the limit of thick Louann Salt and Smackover fields in this area are fault related. However, the Mobile Graben is not part of the regional peripheral fault trend. Womack Hill Field is an example of a trap associated with the Gilberttown fault system (Figure 6). See Appendix 3 for structural maps for Smackover fields associated with the regional peripheral fault trend and Mobile Graben.

In the area immediately north and updip of the regional peripheral fault trend, Smackover traps consist of anticlinal structures associated with basement paleotopographic highs. Louann Salt is thin or absent in this area. These paleohighs are part of the Choctaw Ridge Complex and other unnamed ridge complexes (Figure 2). The Wiggins Arch, which defines the southern limit of the MISB is a major pre-Jurassic basement paleohigh. The hydrocarbons trapped in six (6) fields (Table 3) are associated with basement paleotopographic highs. Petroleum traps are structural or combination traps. Structural traps are anticlines and faulted anticlines that are developed over these basement highs. Combination traps are porosity and/or permeability terminations on the flanks of these features. Toxey Field, which is an elongated anticline, is an example of such a field (Figure 7). The Jackson Dome represents

Figure 4 - Structure contour map of the top of the Smackover Formation in the Pachuta Creek field, Clarke County, Mississippi. Modified from Weber (1980).

Figure 5. Stratigraphic cross section through Cypress Creek salt dome, Perry County, Mississippi. Modified from Thieling and Moody (1997).

Table 2. Hydrocarbon production from Smackover reservoirs in the Regional Peripheral Fault Trend/
Mobile Graben Play of the Mississippi Interior Salt Basin.

Field name	Reservoir	County	Oil (bbls)	Gas (mcf)
Hatter's Pond*	Smackover gas condensate	Mobile	68,527,319	342,812,989
Womack Hill	Smackover oil	Choctaw & Clarke	30,254,904	14,991,869
North Choctaw Ridge	Smackover oil	Choctaw	8,435,823	4,415,926
Quitman	Smackover oil	Clarke	5,483,462	616,879
Sugar Ridge	Smackover oil	Choctaw	4,306,791	2,103,231
Choctaw Ridge	Smackover oil	Choctaw	3,990,829	1,872,281
Barrytown	Smackover oil	Choctaw	3,587,820	1,723,694
Chappell Hill	Smackover oil	Choctaw	2,257,764	921,612
Movico	Smackover oil	Mobile & Baldwin	2,246,206	2,878,869
Wimberly	Smackover oil	Choctaw	2,207,982	721,924
Bucatanna Creek	Smackover oil	Choctaw	1,223,254	452,650
Loring	Smackover gas	Madison	1,164,294	64,057,076
Mill Creek	Smackover oil	Choctaw	1,066,377	698,287
Little Mill Creek	Smackover oil	Choctaw	1,057,857	1,131,971
Bucatanna Creek	Smackover oil	Clarke	995,110	76
Bend West	Smackover oil	Clarke & Choctaw	729,950	237,694
West Barrytown	Smackover oil	Choctaw	646,392	228,418
Double Creek	Smackover oil	Clarke	116,123	0
Davis	Smackover oil	Clarke	68,075	0
East Quitman	Smackover oil	Clarke	37,612	0
Northwest Quitman	Smackover oil	Clarke	32,569	0
Missionary	Smackover oil	Jasper	11,909	0
Southwest Barrytown	Smackover oil	Choctaw	10,417	10,515
Mannassa	Smackover oil	Clarke	4,129	0
		Totals	138,462,968	439,875,961

*includes Smackover and Norphlet production

Figure 6. Structure contour map of the top of the Smackover Formation in the Womack Hill field, Choctaw and Clarke Counties, Alabama. Modified from Townsend (1986).

Table 3. Hydrocarbon production from the Smackover fields in the Basement Ridge/Wiggins Arch Play of the Mississippi Interior Salt Basin.

Field name	Reservoir	County	Oil (bbls)	Gas (mcf)
Toxey	Smackover oil	Choctaw	1,905,609	96,123
Melvin	Smackover oil	Choctaw	280,417	51,088
Pace Creek	Smackover oil	Clarke	186,821	13,419
Northeast Melvin	Smackover oil	Choctaw	103,014	13,695
Thornton Springs	Smackover oil	Choctaw	69,655	146,578
West Okatuppa	Smackover oil	Choctaw	6,961	0
		Totals	2,552,477	320,903

Figure 7 - Structure contour map of the top of the Smackover Formation in the Toxey field, Choctaw County, Alabama. Modified from Bolin et al. (1989).

an igneous intrusion in the basin proper. See Appendix 3 for structural maps for Smackover fields associated with paleohighs.

PETROLEUM RESERVOIR AND SEAL ROCKS

Reservoir Rocks

The major petroleum reservoirs in the Smackover Formation occur in the upper part of the formation. These upper Smackover strata consist of upward-shoaling mudstone to grainstone parasequence sets that accumulated as part of the late highstand systems tract deposits of an Upper Jurassic (Oxfordian to Kimmeridgian) depositional sequence (Figure 8) (Mancini et al., 1990). These deposits represent higher energy, normal, open-marine intertidal to subtidal facies. These lithofacies were deposited in shoal flank, shoal crest, lagoonal and subtidal marine environments of a carbonate shoal complex. Reservoir-grade rocks (greater than 6% porosity and more than 0.1 md permeability) are ooid and peloidal grainstone and packstone beds characterized by primary interparticle, grain-moldic, dolomite-intercrystalline and vuggy porosity.

Coral-microbial and microbial reef facies of the upper Smackover also have significant reservoir potential. These strata consist of baffestone and boundstone beds that accumulated as part of the early highstand systems tract deposits of the Upper Jurassic (Oxfordian to Kimmeridgian) depositional sequence (Figure 8). These lithofacies were deposited in reef crest, reef flank, back-reef, and forereef environments of a reef complex. Reservoir-grade rocks are baffestone and bindstone beds characterized by primary shelter, fenestral enhanced, dolomite-intercrystalline and vuggy porosity.

Deposition and distribution of Smackover shoal and reef reservoirs were significantly influenced by paleotopographic highs present during upper Smackover deposition, which includes extensions of the Appalachian structural trend (Choctaw Ridge Complex) and the Wiggins Arch, salt diapiric structures, and fault-related structures.

Although the primary control on reservoir quality in Smackover reservoirs is the fabric of the depositional lithofacies, diagenesis plays a significant role in modifying reservoir architecture. Diagenesis occurred in both eogenetic (carbonates influenced by surface-derived fluids of marine, fresh water, or brine origin) and mesogenetic (carbonates influenced by connate or formation fluids during burial) environments. Eogenetic processes include: biogenic micritization of carbonate grains; precipitation of fibrous aragonite or Mg calcite, marine cements; physical

Figure 8. Sequence stratigraphic interpretations of the Jurassic section in the eastern Gulf Coast.

compaction; evaporative dolomitization; precipitation of meteoric-phreatic, Mg calcite cements; fabric-selective, meteoric-vadose dissolution; and precipitation of dolomite and anhydrite through brine reflux (Figure 9).

The mesogenetic history of the Smackover reservoir includes: precipitation of coarsely crystalline, ferroan dolomite or ankerite cement that occurs as an overgrowth on earlier-formed dolomite crystals or as a pore fill; precipitation of coarsely crystalline, euhedral quartz crystals that occur as pore fills in vuggy pores; precipitation of very coarsely crystalline, poikilotopic, blocky, ferroan calcite cement; late-stage, nonfabric-selective dissolution of calcite and dolomite to produce vuggy pores; emplacement of hydrocarbons; chemical compaction that produces wavy to high amplitude stylolites; and the precipitation of coarsely crystalline, sparry baroque dolomite that fills vuggy pores which can be rimmed by hydrocarbon residue (Benson, 1985).

Of the diagenetic events, the multiple dolomitization and dissolution events probably had the greatest influence on reservoir development and quality. While the dolomitization created only minor amounts of intercrystalline porosity, it significantly enhanced permeability. It also stabilized the lithology which reduced the potential for later porosity loss due to compaction. The dissolution events enlarged primary (interparticle and shelter) and early secondary (moldic and intercrystalline) pores. While the dissolution did not create large amounts of new porosity, it did expand existing pore throats and enhanced permeability. Locally, the development of fracture systems also served to increase permeability.

The most important processes that destroyed porosity in the Smackover of the eastern MISB were marine phreatic calcium-carbonate cementation, anhydrite cementation, burial calcite cementation (associated with dedolomitization and calcitization of anhydrite). Pressure dissolution also served to decrease porosity to a lesser extent than the processes described above. Primary porosity was preserved where limited subsurface fluid movement or unusual fluid chemistry inhibited marine-phreatic cementation.

While diagenesis has a significant influence on Smackover reservoir quality, it generally does not alter the geographic distribution of reservoir-grade rock. The development and distribution of reservoir-grade rock is primarily a function of depositional processes.

Information on Smackover carbonate reservoirs comes from the published literature, wireline log analyses, core descriptions and thin-section descriptions. Appendix 1 lists references for fields in the MISB region. Appendix 3 presents descriptions of cores in the Smackover Formation, including more than 40 descriptions of reservoir rocks in

Figure 9 - Generalized paragenetic sequence for the Smackover Formation in the Mississippi Interior Salt Basin area. Modified from Mancini et al. (2000).

Alabama and Mississippi, plus descriptions of 35 additional Smackover cores from wells drilled as wildcats. These descriptions also include discussions and interpretations of the diagenetic histories of the Smackover.

The Smackover reservoirs in fields (Pachuta Creek, Harmony, West Nancy, East Nancy, Prairie Branch, Watts Creek, North Shubuta, Shubuta, and Goodwater) in Clarke County, Mississippi, were developed as part of a carbonate shoal complex (Badon, 1974). These upper Smackover lithologies were deposited under shallow open-marine conditions, and the vertical sequence of lithologies indicates a progressive shoaling upward and basin progradation of environments. The reservoirs in Harmony Field (Board of Supervisors 16-13), East Nancy Field (Masonite 17-13), and Goodwater Field (Johnston #1) consist of a lower ooid grainstone, a middle oncoidal grainstone, and an upper ooid grainstone. The lower ooid grainstone was deposited in a high-energy shoal environment. The middle oncoidal grainstone accumulated behind the shoal proper as landward shoal flank deposits. A ooid packstone/wackestone was deposited as subtidal sediments seaward of the shoal complex in shoal flank environments. The upper ooid grainstone accumulated as shoal crest sediments as high-energy shoal barrier beach deposits. The architecture of these grainstone reservoirs consists of pore systems comprised of primary interparticle porosity. Initial depositional porosity has been reduced through burial compaction and cementation. Coral-microbial reef facies (20 ft) are present in West Paulding Field (Meyers Estate 17-8), Jasper County, Mississippi (Baria et al., 1982).

The Smackover reservoirs in fields (Toxey, Choctaw Ridge, Turkey Creek, Womack Hill, Barrytown, North Choctaw Ridge, Sugar Ridge, Mill Creek, West Barrytown, Wimberly, Zion Chapel, Chappell Hill, Bucatunna Creek, Little Mill Creek, Puss Cuss Creek, Southwest Barrytown, Souwilpa Creek, West Bend, Silas and Gin Creek) in Choctaw County, Alabama, were principally developed as part of a carbonate shoal complex (Mancini and Benson, 1980; Benson and Mancini, 1984; McKee, 1990; Townsend, 1986; Kopaska-Merkel, Appendix 3, this report). The reservoirs in Choctaw Ridge Field (Rentz-Trice Unit 35-1), West Barrytown Field (Lewis Unit 4-16), Mill Creek (Trice 6-6), Silas Field (Chestnut Unit 9-1), Womack Hill Field (Turner Unit 13-6), Zion Chapel Field (Federal Land Bank #1), Little Mill Creek Field (Tims 8-2), and Bucatunna Field (Johnston Unit 14-14) consist of high-energy shoal crest ooid grainstone and shoal flank peloid grainstone (Appendix 3). The peloid grainstone reservoirs in Chappell Hill Field (Bolinger 26-7), West Bend Field (May 27-10), Barrytown Field (McIlwan 11-10), and Sugar Ridge Field (Lovett 27-6) are tidal channel and tidal bar lithofacies that accumulated in a tidal flat complex

(Appendix 3). The reservoirs in Toxey Field (Bolinger 13-4) Souwilpa Field (Pinkerton 9-12) and Gin Creek Field (Bolinger Heirs 32-5) include shoal ooid grainstone and tidal flat peloid grainstone (Appendix 3). The architecture of these grainstone reservoirs consists of pore systems comprised chiefly of secondary grain-moldic and intraparticle porosity. Dolomite intercrystalline, vuggy and fracture porosity can also be a major contributor to the pore system of these reservoirs. Depositional interparticle porosity is not as common in the easternmost part (Alabama portion) of the MISB as in the central part of the MISB (Mississippi portion) largely because of extensive burial compaction and early cementation (Benson, 1985). Dissolution and dolomitization are critical diagenetic processes that enhance and/or create porosity in these grainstone reservoirs. Reef facies are also potential reservoirs in Choctaw County. Microbial reef facies (2 ft) are present in Choctaw Ridge Field (Rentz-Trice Unit 35-1) and Womack Hill Field (Turner 13-25) (Kopaska-Merkel, Appendix 3), and coral-microbial reef boundstone (20 ft) occurs in Melvin Field (Land Brothers #1) (Baria et al., 1982).

The Smackover reservoirs in fields (Chatom and Crosbys Creek) in Washington, Alabama, were developed as high- to moderate-energy carbonate shoreface and shoal deposits (Mancini and Benson, 1980; Benson and Mancini, 1984; Fowler, 2000; Kopaska-Merkel, Appendix 3, this report). The peloidal ooid grainstone reservoirs in the Chatom Field (Unit 21-15) are carbonate shoreface and shoal deposits, and the peloidal grainstone in the Crosby Creek Field (Darby Dees 3-3) is part of a carbonate shoal complex (Appendix 3). The architecture of these grainstone reservoirs consist of pore systems comprised chiefly of secondary grain-moldic porosity. Secondary intraparticle, dolomite intercrystalline and vuggy and depositional interparticle porosity also contribute to the pore systems of these reservoirs. Dissolution and dolomitization are important diagenetic processes that create and/or enhance porosity, while early cementation and burial compaction act to destroy porosity. Reef facies are potential reservoirs in Washington County. In the IJAMS 19-2 core, 60 feet of microbial boundstone was described (Kopaska-Merkel, Appendix 3, this report).

The Smackover reservoirs in fields (Churchula and Hatter's Pond) in Mobile County, Alabama, were developed in a high-energy shoal complex (Mancini and Benson, 1980; Benson and Mancini, 1982, 1984; Kopaska-Merkel and Mann, 2000). The reservoirs in the Hatter's Pond (Peter Klein 3-14) and Churchula (Davis 1-11) consist of high-energy shoal crest ooid dolograins and moderate energy shoal flank skeletal, peloidal dolograins. These reservoirs are highly altered by the favorable diagenetic processes of dissolution and dolomitization. The architecture

of these grainstone reservoirs consists of pore systems comprised of secondary dolomite intercrystalline and vuggy porosity. The processes of burial compaction and cementation acted to reduce porosity. Microbial reefs are reservoirs in the Gulf Crest Field (Unit 5-2) where 10 to 15 feet of reef boundstone reservoir occurs (Kopaska-Merkel, Appendix 3, this report). Porosity in the reef facies includes dolomite intercrystalline and vuggy porosity.

Seal Rocks

The upper Smackover is capped by subaerial evaporites of the Buckner Anhydrite Member of the Haynesville Formation. The anhydrites conformably overlie the carbonate rocks of the Smackover. These evaporites act as a barrier to vertical petroleum migration, and thus are effective seal rocks. Mann (1988) described the petrology, diagenesis and depositional history of the Buckner in northeastern Mobile County, Alabama. The anhydrite averages about 155 feet in thickness, and is dominated by bedded massive, bedded mosaic, bedded nodular, bedded nodular mosaic and mosaic fabrics. Several shallowing-upward cycles were observed. The cycles begin with selenite facies in which bedded nodular mosaic and bedded mosaic fabrics often display a vertical alignment of anhydrite nodular pseudomorphs after gypsum. The selenite crystals were precipitated on the sediment surface possibly below wave base but within the photic zone. Overlying the selenite is gypsarenite, which is characterized by laminations in which ripples and low-angle cross beds indicate clastic deposition above wave base. Stromatolites formed in relatively quiet water areas. The subaqueous evaporites commonly grade upward into a poorly laminated anhydrite containing burrow structures, detrital silt, and possible root structures, which may indicate gypsite facies which formed in the zone of soil moisture. Often overlying this gypsite facies are probable storm deposits and tidal-flat sabkha deposits. The sabkha deposits occur at the top of the cycles.

The Buckner Anhydrite Member of the Haynesville Formation is generally considered to be the massive anhydrite at the base of the Haynesville (Dinkins, 1968; Oxley et al., 1967; Tolson et al., 1983). These evaporitic deposits were probably formed in a restricted paleoenvironment landward of a significant barrier, that is, the Wiggins Arch. As such, the Buckner occurs along a fairly narrow subcrop belt. The Haynesville isopach map of Oxley et al. (1967) clearly shows the updip and downdip limits of the Buckner in Mississippi. In Mississippi, the downdip limit of the Buckner is generally subparallel to the updip limit of the Haynesville at a distance of approximately 10-15 miles, except for an area in northwestern Jasper County, where the entire Haynesville Formation is anomalously thin. There is no Buckner in this area. Also, in northern Rankin County, the Buckner extends much further downdip

(Oxley et al., 1967). In downdip areas, the lower Haynesville becomes an interval of interbedded sandstone, limestone, anhydrite, and shale (Twinner, unpublished).

The Buckner is present throughout southwest Alabama except for the extreme updip and downdip regions (Tolson et al., 1983). The Conecuh Ridge/Wiggins Arch complex probably caused more restricted circulation in southwestern Alabama than in the more open conditions in southern and southwest Mississippi, hence the generally wider distribution of the Buckner subcrop belt. Also, the MISB margin curves from an east-southeast orientation in the vicinity of the Gilbertown-West Bend Fault Zones to a north-south orientation paralleling the western limit of the Mobile Graben, resulting in depositional strike to curve in a similar direction. Therefore, it should be expected that north-south cross sections in southwestern Alabama (i.e., Washington and northern Mobile Counties) would show little depositional change within specific units, except those due to local uplifts such as the Chatom and Macintosh salt domes.

SMACKOVER SOURCE ROCKS

The organic-rich laminated, lower to middle Smackover carbonate mudstones are the petroleum source rocks for Smackover hydrocarbons and are the principal source rocks for the petroleum source rocks for other reservoirs in the MISB. These observations are consistent with previous studies, such as those by Nunn (1984), Oehler (1984), Nunn and Sassen (1986), Sassen and Moore (1988), Driskill et al. (1988), Claypool and Mancini (1989), and Mancini et al. (1993). These previous workers have recognized that the Smackover is an effective regional source rock of the MISB.

Organic geochemical source rock (Table 4) and oil (Table 5) analyses performed as part of this study, in combination with those of Oehler (1984), Sassen et al. (1988), and Claypool and Mancini (1989), indicate that the petroleum source rock potential of the lower and middle Smackover carbonate mudstones of the MISB has been optimized by the combination of favorable conditions of deposition, preservation, and subsequent burial and thermal histories.

Smackover samples from the lower and middle carbonate mudstones average 0.81% total organic carbon (Claypool and Mancini, 1989). Because much of the Smackover has experienced advanced levels of thermal maturity, the total organic carbon values were higher in the past prior to the generation of crude oil (Sassen and Moore, 1988). Organic carbon contents of up to 4.55% have been measured in these carbonate mudstones (Table 4). These present

Table 4. Analyses of potential Smackover source rocks, Mississippi Interior Salt Basin.

Well name	County	Depth (ft)	TOC (wt %)	Organic type	TAI	Tmax (°C)	HI
Weissinger Lumber #1	Issaquena ⁺	8,451	0.36	Am	3+	430	66
Flora Johnson #1	Newton ⁺	11,775	0.26	Am	2	431	134
Toney et al. #1	Clarke ⁺	14,443	0.38	Am	2	428	139
Masonite 25-14	Clarke ⁺	14,586	0.24	Am	2+	429	91
Myers Estate 17-8	Jasper ⁺	14,732	0.40	Am	2	426	142
USA Rubie Bell #1	Scott ⁺	14,902	0.48	Am	2+	431	137
Bishop-Cookey #1	Wayne ⁺	15,541	1.35	Am	3	427	27
R. M. Thomas #1	Smith ⁺	16,554	0.27	Am	3	432	62
Grief Bros. #1	Jasper ⁺	17,015	0.44	Am	2	433	54
McFarland #1	Jones ⁺	19,865	0.28	Am	3	410	25
Crain et al. 1-4	Rankin ⁺	20,179	0.24	Am	3+	420	50
Crown Zellerbach #1	Simpson ⁺	23,981	4.55	Am	3+	367	23
Jackson #1	Choctaw ⁺⁺	10,532	0.30	Am	2-	--	--
Bolinger 3-4	Choctaw ⁺⁺	10,610	0.07	Am	2-	--	42
Stewart 6-5	Choctaw ⁺⁺	12,245	0.24	Am	2-	--	22
Chestnut 9-1	Choctaw ⁺⁺	13,651	0.09	Am	2-	--	20
Smith Land et al. #1	Choctaw ⁺⁺	13,724	0.09	Am	2-	--	11
Britton #1	Washington ⁺⁺	16,101	0.08	Am	3	--	12
Chatom 2-01	Washington ⁺⁺	16,167	0.19	Am	3	--	10
Jacintoport Corp. #1	Mobile ⁺⁺	18,309	0.89	Am	3-	--	--
Foster 10-6	Washington ⁺⁺	19,359	0.25	Am	3	--	4

⁺Mississippi⁺⁺Alabama

Table 5. Analyses of Smackover crude oil samples, Mississippi Interior Salt Basin.

Field	County	Depth (ft)	°API gravity	Sulfur ³ (%)	C ₁₅₊ HC ⁴ (%)	C ₁₅₊ asphaltene ⁵	C ₁₅₊ saturate ⁵ (%)	C ₁₅₊ aromatic ⁵ (%)	C ₁₅₊ NSO comp. ⁵ (%)	Saturate/aromatic	Pristane/phytane	CPI	δ ¹³ C sulfate (‰)	δ ¹³ C aromatic (‰)
Pachuta Creek ¹	Clarke ⁺	13,065	37.6	--	73.4	4.9	49.8	39.7	5.6	1.25	<1	<1	-25.6	-24.7
West Nancy ¹	Clarke ⁺	13,981	39.9	--	71.0	2.3	55.4	36.6	5.7	1.51	<1	<1	-25.7	-24.8
East Nancy ¹	Clarke ⁺	13,678	39.5	--	66.1	2.9	57.0	36.0	4.1	1.58	<1	<1	-25.6	-25.5
South Paulding ¹	Jasper ⁺	14,652	37.9	--	65.7	3.7	60.7	32.6	3.0	1.86	<1	<1	-25.8	-24.3
Barrytown ²	Choctaw ⁺⁺	11,840	41.9	1.0	55.3	25.2	44.2	5.5	25.1	8.0	<1	<1	-23.7	-23.2
Bucatan Creek ²	Choctaw ⁺⁺	12,156	34.3	2.0	62.7	6.5	40.9	34.4	18.2	1.2	<1	<1	-24.2	-24.0
Chappell Hill ²	Choctaw ⁺⁺	11,412	34.0	1.7	62.1	10.8	41.6	31.7	5.9	1.3	<1	<1	-23.9	-23.7
Choctaw Ridge ²	Choctaw ⁺⁺	12,049	37.5	1.4	56.7	17.3	49.9	24.7	8.1	2.0	<1	<1	-24.0	-23.9
Little Mill Creek ²	Choctaw ⁺⁺	12,370	45.5	0.9	45.0	33.2	37.8	17.9	11.1	2.1	<1	<1	-23.3	-23.0
Melvin ²	Choctaw ⁺⁺	11,189	17.3	4.5	68.1	29.7	20.4	35.2	14.7	0.6	<1	<1	-24.6	-24.4
Mill Creek ²	Choctaw ⁺⁺	12,340	39.9	0.8	60.5	3.9	52.0	25.9	18.2	2.0	<1	<1	-24.0	-23.7
North Choctaw Ridge ²	Choctaw ⁺⁺	11,780	34.3	1.7	62.1	5.7	44.4	33.6	16.3	1.3	<1	<1	-23.9	-23.8
Puss Cuss Creek ²	Choctaw ⁺⁺	13,542	38.6	1.2	62.0	19.2	50.1	22.6	8.1	2.2	<1	<1	-24.2	-23.7
Silas ²	Choctaw ⁺⁺	13,578	39.5	0.9	48.5	19.9	50.7	22.5	6.9	2.3	<1	<1	-24.2	-23.7
Sugar Ridge ²	Choctaw ⁺⁺	11,650	33.4	1.9	67.6	17.5	45.5	24.0	13.0	1.9	<1	<1	-23.9	-23.8
Toxey ²	Choctaw ⁺⁺	10,524	17.1	5.2	63.6	29.1	20.4	35.0	15.5	0.6	<1	<1	-24.0	-23.7
Turkey Creek ²	Choctaw ⁺⁺	12,389	40.5	0.8	53.0	21.0	49.8	20.9	8.3	2.4	<1	<1	-24.1	-23.7
West Barrytown ²	Choctaw ⁺⁺	12,064	43.2	1.0	50.5	30.7	40.3	22.7	6.3	1.8	<1	<1	-23.5	-23.3
Wimberly ²	Choctaw ⁺⁺	11,300	35.1	2.0	62.9	6.8	42.3	33.7	17.2	1.3	<1	<1	-23.9	-23.7
Zion Chapel ²	Choctaw ⁺⁺	14,078	40.3	1.0	56.9	21.6	50.4	20.9	7.1	2.4	<1	<1	-24.1	-23.7
West Bend ²	Choctaw/Clarke ⁺⁺	12,430	37.2	0.8	56.9	23.5	44.0	26.8	5.6	1.6	<1	<1	-24.0	-23.8
Womack Hill ²	Choctaw/Clarke ⁺⁺	11,268	36.0	1.2	55.7	19.5	46.4	22.4	11.7	2.1	<1	<1	-23.6	-23.5
Chatom ^{*2}	Washington ⁺⁺	16,286	50.2	1.0	22.8	16.8	48.7	25.5	9.0	1.9	>1	1	-21.4	-21.8
Copeland ^{*2}	Washington ⁺⁺	16,758	46.8	1.1	12.9	16.9	7.8	50.0	25.3	0.2	nd	<1	-21.1	-21.5
Chunchula ^{*2}	Mobile ⁺⁺	18,434	56.0	0.2	36.2	36.8	44.4	6.3	12.5	7.0	>1	1	-23.9	-22.1
Cold Creek ²	Mobile ⁺⁺	18,476	49.8	0.1	55.2	19.9	57.5	6.1	16.5	9.4	>1	<1	-24.3	-23.0
Hatter's Pond ^{*2}	Mobile ⁺⁺	18,334	53.3	0.1	32.1	31.7	43.1	4.9	20.3	8.8	>1	1	-24.0	-22.1
South Cold Creek ²	Mobile ⁺⁺	18,470	51.4	0.1	50.5	13.0	61.8	6.3	18.8	9.8	>1	<1	-24.6	-23.3

*Condensate fields: nd (analyzed but not determined); ⁺Mississippi; ⁺⁺Alabama.

¹From Sassen (1989).

²From Claypool and Mancini (1989).

³Percent of crude oil or gas condensate.

⁴Sum of the solvent-free weights of heptane and benzene eluates from Baker column chromatography, as percent of whole oil or condensate.

⁵Percent of C₁₅₊ fraction, by conventional alumina/silica-gel column chromatography.

organic carbon contents are significantly less than the original total organic carbon contents. To adjust for the loss of organic carbon due to the thermal maturation process, the conversion equation of Daly and Edman (1987) was used. Thermally immature Smackover mudstones with pyrolysis $T_{\max}$ values of 422 to 424°C have hydrogen index values of 656 mg HC/g TOC, while mature Smackover mudstones with $T_{\max}$ values of 447 to 453°C have hydrogen index values of 50 mg HC/g TOC (Sassen and Moore, 1988).

The dominant kerogen types in the Smackover are algal (microbial) and amorphous (Claypool and Mancini, 1989; Oehler, 1984; Sassen et al., 1987). In updip areas near the paleoshoreline, the Smackover includes herbaceous kerogen (Wade et al., 1987). In the basin area, Smackover samples exhibit thermal alteration indices of 2⁻ to 4 (Claypool and Mancini, 1989; Oehler, 1984; Sassen et al., 1987). These values represent an equivalent vitrinite reflectance (R_o) of 0.55 to 3.0% (Sassen and Moore, 1988).

The generation of crude oil from source rocks in the MISB is interpreted to have been initiated at a level of thermal maturity of 0.55% R_o (435°C $T_{\max}$; 2 TAI) and concluded at a level of thermal maturity of 1.5% R_o (470°C $T_{\max}$; 3 TAI) (Nunn and Sassen, 1986; Sassen and Moore, 1988). This requires a depth of burial of 3 km or 9,840 feet according to Driskill et al. (1988). Nunn and Sassen (1986) reported that the generation of crude oil in the MISB was initiated at a depth of 3.5 km or 11,500 feet. The generation of crude oil is believed to have been initiated from basinal Smackover carbonate mudstones in the Early Cretaceous, and the generation and migration of low to intermediate gravity crude oil is interpreted to have continued into Cenozoic time (Driskill et al., 1988; Nunn and Sassen, 1986; Sassen and Moore, 1988). Updip Smackover carbonate mudstones are thought to have generated low gravity crude oil beginning in the Late Cretaceous or 20 my later than the basinal mudstones (Driskill et al., 1988). At a depth of burial of 5 to 6 km (16,400 to 19,700 ft), the Smackover mudstones are thought to be over-mature for the generation of crude oil (Driskill et al., 1988; Nunn and Sassen, 1986). The low to intermediate crude oils that migrated into reservoirs were subjected to thermal cracking with depth of burial and time (Claypool and Mancini, 1989; Sassen and Moore, 1988). Most authors agree that the Jurassic and Early Cretaceous sediments experienced a rapid rise in temperature associated with rifting (190 to 165 my) and that for the past 60 to 75 my there has been little change in paleotemperature (Driskill et al., 1988; Nunn, 1984). This trend translates into a paleogeothermal gradient of 72°C/km during the Jurassic, of 58°C/km during the Early Cretaceous and of 28 to 33°C/km today (Nunn, 1984; Smith et al., 1981). Conductivities of 3 to 6×10^{-3} cal/cmsec°C have been measured

for strata in the basin (Nunn, 1984; Smith et al., 1981). Heat flows of $1.0 \mu\text{cal}/\text{cm}^2\text{sec}$ are typical of the basin except in updip areas ($0.9 \mu\text{cal}/\text{cm}^2\text{sec}$ and in the vicinity of the Jackson Dome ($1.5 \mu\text{cal}/\text{cm}^2\text{sec}$) (Smith et al., 1981). Bottomhole temperatures for strata buried to 6,400 m (21,000 ft) are 193°C (380°F) in the basin area, and the present-day geothermal gradient is 1.8 to $2.9^\circ\text{C}/100 \text{ m}$ (1.0 to $1.6^\circ\text{F}/100 \text{ ft}$) (Wilson, 1975). As a result of thermal maturity modeling and calibration with thermal maturation indices, elevated heat flows are evident in the south-central and central portions of the basin and in the vicinity of the Jackson Dome and suppressed heat flow values occur in the northern or updip portions of the basin.

From thermal maturation profiles for wells in the study area, a hydrocarbon generation and maturation trend can be observed. In wells in much of the basin, the generation of hydrocarbons from Smackover carbonate mudstones was initiated at 2,438 to 3,353 m (8,000 to 11,000 ft) during the Early Cretaceous and continued into the Tertiary throughout much of the MISB (Figures 10 and 11). The thermal maturation profiles for wells located updip or along the northern margin of the basin indicate that the Smackover source rocks in this area are thermally immature and did not generate oil (Figure 10a b,c), while wells located in the center of the basin and along the southern margin of the basin adjacent to the Wiggins Arch show that the Smackover source rocks are late mature (Figure 11c d). In the vicinity of the Jackson Dome, hydrocarbon gas generation begins at a depth of 4,572 m (15,000 ft). This hydrocarbon generation and maturation trend can be seen on the cross sections in Figures 12 through 14.

Hydrocarbon expulsion from the Smackover source rocks commenced during the Early Cretaceous and continued into the Tertiary (Figure 15). Initiation of oil expulsion began first in the central portion of the basin in mid-Early Cretaceous and peaked during the late Early Cretaceous in this area (Figure 15d). In the south-central portion of the basin, north of the Wiggins Arch, oil expulsion was initiated in the Early Cretaceous and peaked in the early Late Cretaceous (Figure 15e), while in the eastern portion of the basin oil expulsion commenced during the Late Cretaceous and continued into the Tertiary (Figure 15c). During the Late Cretaceous and continuing into the Tertiary, peak oil expulsion occurred in areas in the northern portion of the basin (Figure 15a, b) but not along the northernmost margin of the basin. The hydrocarbon expulsion profiles for the wells are in agreement with the thermal maturation profiles. The timing of the commencement of oil expulsion is consistent with the tectonic, depositional, burial and thermal histories of the basin as evidenced by the cross sections in Figures 12 through 14. The Smackover hydrocarbon expulsion profiles support a long range (80 km or 50 mi) migration model for

a)

b)

c)

d)

Figure 10. Thermal maturation profiles for wells: API Number (a) 23-055-00066, (b) 23-093-20011, (c) 23-023-00270, and (d) 23-121-20025. See Figure 12 for locations of wells.

a)

b)

c)

d)

Figure 11. Thermal maturation profiles for wells: API Number (a) 23-061-20028, (b) 01-129-00012, (c) 23-049-20032, and (d) 23-111-00069. See Figure 12 for locations of wells.

Figure 12. Location map for regional structural cross sections (a) and regional structural cross section A-A' (b1) and maturity profile A-A' (b2).

Figure 13. Regional structural cross section (B-B' (a1) and maturity profile B-B' (a2) and regional structural cross section C-C' (b1) and maturity profile C-C' (b2). See Figure 12 for location of cross sections.

Figure 14. Regional structural cross section D-D' (a1) and maturity profile D-D' (a2) and regional structural cross section E-E' (b1) and maturity profile E-E' (b2). See Figure 12 for location of cross sections.

a)

b)

c)

d)

e)

LEGEND

Figure 15. Hydrocarbon expulsion plots for wells: API number (a) 23-121-20025, (b) 01-129-00012, (c) 01-129-20012, (d) 23-049-20032, and (e) 23-111-00069. See figure 12 for locations of wells.

Smackover crude oil in that the thermal maturity and hydrocarbon expulsion profiles for wells located in fields producing low gravity crude oil show that the Smackover source beds, to date, have not reached the thermal maturity level to expel Smackover oil (Figure 10a, b, c). Evans (1987) and Sassen (1990) also published information in support of long-range hydrocarbon migration in the MISB area.

Hydrocarbon migration associated with the Smackover source rocks in the basin was initiated in the Early Cretaceous and continued into the Late Cretaceous and Tertiary (Figure 16). The main oil migration pathways during the Early Cretaceous were from the basin center westward into salt anticlinal features and northward into traps associated with paleotopographic basement structures and with the Pickens-Gilbertown extensional fault systems and from the south-central portion of the basin northward into developing salt traps and southward along the Wiggins Arch (Figure 16b). These migration trends were maximized in the early Late Cretaceous (Figure 16c). In addition, during the Late Cretaceous, oil migration occurred from the basin center eastward into salt anticlinal features and into fault traps associated with the Mobile Graben. The direction and timing of the hydrocarbon migration pathways are consistent with the tectonic and depositional histories of the basin, the concept of a long migration model for Smackover crude, and previously published works of Nunn and Sassen (1986), Driskill et al. (1988), and Sassen and Moore (1988). This hydrocarbon migration model for the basin would suggest that reservoirs and traps first sourced from Smackover carbonates in the Early Cretaceous would contain immature oils, while reservoirs and traps sourced in the Late Cretaceous and Tertiary would contain mature oils and gas condensates.

Such a model is supported by the evidence for Smackover trap formation. Subsurface structural maps and cross sections based on well log and seismic reflection data indicate that Jurassic Louann Salt movement began in the late Oxfordian to early Kimmeridgian, as shown by salt anticline development in the northeastern portion of the basin. Growth of these salt anticlines ceased during the Early Cretaceous because the salt supply which drove growth was exhausted at this time (Figure 17a). Although salt movement along the Gilberttown fault system was initiated in the Kimmeridgian, trap formation and faulting continued into the Tertiary (Figure 17b). This delay allowed for Smackover oil migration north of this fault zone and into Smackover traps associated with Paleozoic paleotopographic basement features.

This model is also in agreement with the data that suggests that Smackover microbial carbonates were the source of the oil in Upper Jurassic, Lower Cretaceous and Upper Cretaceous reservoirs associated with faulted salt

Figure 16. Maps of Smackover-sourced hydrocarbon migration across the Mississippi Interior Salt Basin at 0 Ma (a), 103 Ma (b), 122 Ma (c), and 150 Ma (d).

Figure 17. Smackover petroleum traps: salt anticline trap at (a) Pool Creek, Jones County, Mississippi (modified from Hughes, 1968), and (b) extensional fault trap at North Choctaw Ridge field Choctaw County, Alabama, along Gilbertown fault system (modified from Qi et al. 1998). See figure 18 for locations of fields and respective API oil gravity values.

anticlines and the Pickens-Gilbertown fault systems. Even after cessation of growth of the salt anticlines, stratal movement and faulting continued in association with these structures due to sediment accumulation, burial and differential subsidence providing the opportunity for oil to migrate into shallower horizons. Maturation of these oils would continue through geologic time with depth of burial and cooking time.

An examination of the gravities of the oils from Smackover fields in the basin reveals that the updip Smackover oil fields associated with basement traps north of the Pickens-Gilbertown fault systems have low gravity oils (17 to 26° API) or immature oils. The oil fields along the Gilberttown fault system have intermediate gravity oils (37 to 47° API) (Figure 18). On the other hand, Smackover fields located in the eastern portion of the basin and Mobile Graben generally have high gravity oils and gas-condensates (41 to 64° API). Of course, the deeper subsurface burial of these reservoirs would result in continued maturation and thermal hydrocarbon cracking. Interestingly, the low gravity oils associated with basement traps at depths of less than 3,353 m (11,000 ft) were never buried deep enough for further maturation and, therefore, probably represent the oil gravity at the time of migration. The Smackover fields and associated reservoirs in the eastern portion of the basin are at subsurface depths of 4,877 m (16,000 ft) where moderately mature oils would be expected, based on the thermal maturity profiles. However, mature oil and gas-condensate are found in these fields (Table 5 and Figure 18). The presence of gas-condensate at these depths is supportive of the proposed hydrocarbon migration pathway model for the basin. The mature oils and gas condensates migrating into these traps along the eastern margin of the basin were generated and expelled during the Late Cretaceous and Tertiary. Further, the gas condensates in this area have a geochemical and isotopic composition unlike the gas condensates along the Mobile Graben that are in reservoirs buried to 5,486 m (18,000 ft) (Claypool and Mancini, 1989). The Smackover fields located near the Jackson Dome and along the Wiggins Arch are natural gas fields. The higher heat flow characteristics of the hydrocarbons in these areas is due to the volcanic activity associated with the Jackson Dome and the deep depth of burial of the Smackover in the central portion of the basin.

PETROLEUM SYSTEM

The Smackover petroleum system is a self-contained system. Petroleum source rocks, reservoir rocks, and seal rocks are all within this unit. Anhydrite beds of the uppermost Smackover and the overlying Buckner Anhydrite Member of the Haynesville Formation serve as the petroleum seal rocks. Reservoir-grade carbonates are part of the

upper Smackover beds. These reservoirs include ooid, peloidal and oncoidal grainstone and packstone, dolograins, dolostone and coral-microbial and microbial boundstone. The grainstone and packstone accumulated as shoal crest and shoal flank deposits as part of a carbonate shoal complex and as tidal channel and channel bar deposits as part of a tidal flat complex. Porosity in these reservoirs is chiefly depositional interparticle and secondary grain-moldic, intraparticle, dolomite-intercrystalline, vuggy and fracture. The coral-microbial and microbial boundstone accumulated as Smackover reefs in association with pre-Smackover paleohighs. Porosity in these reservoirs is chiefly depositional shelter, enhanced fenestral, and secondary dolomite-intercrystalline and vuggy. Dissolution and dolomitization are important diagenetic processes that acted to enhance and/or create porosity. Burial compaction and early cementation are processes that served to destroy porosity.

The lower and middle, organic-rich Smackover beds serve as the petroleum source rocks. These laminated carbonate mudstone beds are subtidal in origin and contain abundant amounts (up to 4.55% measured organic carbon) of microbial and microbial-derived amorphous kerogens. The source potential of these beds has been optimized by the combination of favorable conditions of deposition, preservation, and subsequent burial and thermal histories. The generation of crude oil from these source rocks was initiated at a level of thermal maturity of 0.55% Ro in the Early Cretaceous and concluded at a level of thermal maturity of 1.5% Ro in the Late Cretaceous or Early Tertiary. Hydrocarbon expulsion commenced during the Early Cretaceous and continued into the Tertiary. Peak expulsion was during the Late Cretaceous. Hydrocarbon migration was generally long distance (80 km or 50 mi) and was initiated in the Early Cretaceous and continued into the Tertiary.

UNDERDEVELOPED RESERVOIRS

The initial discovery of hydrocarbons in the MISB occurred in 1930 when natural gas was encountered in Hinds and Rankin Counties, Mississippi, in the Selma Chalk by the Jackson Gas & Fuel Corporation No. 1 Mayes well. This discovery led to the establishment of the Jackson gas field. However, the first discovery associated with a salt feature in the basin occurred in Yazoo County, Mississippi, when Tinsley Field was established in the Selma/Eutaw/Upper Tuscaloosa reservoirs by the drilling of the Union Producing Company No. 1 G.C. Woodruff well. Since those initial discoveries, regional and local reservoirs in the MISB and adjacent areas have produced approximately 1.9 billion barrels of oil and more than 6.3 Tcf of gas from Jurassic, Cretaceous and Tertiary reservoirs in 552 fields.

Hydrocarbons were discovered from Smackover carbonate rocks in 1966 in the MISB. To date, more than 259 million barrels of oil and 1.4 Tcf of natural gas have been produced from 88 Smackover fields in the salt anticline play of the MISB (Figure 2). Discovered petroleum traps in this basin consist of structural and combination traps. These traps are related to salt movement. Structural traps include peripheral salt ridges, low-relief salt pillows, salt anticlines and turtle structures, and piercement domes. Combination traps are generally porosity and permeability terminations associated with salt-generated structures. Opportunities exist for continued exploration for similar undrilled salt features in the basin and for the evaluation of the reservoir potential of Smackover carbonates on salt structures that are productive from shallow Cretaceous horizons. 3-D seismic surveys are proven to be very effective tools in exploration for these structures and in the evaluation of established fields. Although Smackover reservoirs are productive in the MISB, these reservoirs are underdeveloped. In particular, carbonate lithofacies associated with carbonate shoal complexes provide an excellent exploration target, especially in the deeper parts of the central portion of the basin. Dolograinstone and dolostone reservoirs in the eastern portion of the basin produce oil and natural gas from depths greater than 18,000 feet. Porosity is chiefly secondary dolomite-intercrystalline and vuggy. Microbial reef facies are potential reservoirs throughout the basin. In the eastern portion of the MISB, microbial reef facies of up to 60 feet have been described, and this facies is a reservoir in the eastern part of the basin. In the central portion of the basin, coral-microbial reef facies of up to 20 feet have been documented. The key is to delineate pre-Smackover paleotopographic high structures (basement or salt ridges) which the reef organisms can colonize, grow and develop into a reef feature.

The regional peripheral fault trend, which lies near the updip limit of Louann Salt (Figure 2), is characterized by salt-related structural features associated with the Pickens, Gilbertown, and West Bend extensional fault and half graben systems. The petroleum play along the regional peripheral fault trend was discovered in 1940, but oil was not discovered until 1966 from Smackover carbonates in this play. Now, the Smackover Formation is the most productive reservoir in this play when the fields associated with the Mobile Graben are considered as part of this play. Smackover carbonates have produced more than 138 million barrels of oil and 439 Bcf of natural gas from 24 fields (Table 2). Because Hatter's Pond Field is unitized, the state regulatory agency commingles production from the Smackover and Norphlet Formations in the production records. Therefore, in this report, this production is assigned to the Smackover Formation. Opportunities exist for continued exploration along the regional peripheral fault trend.

The structural relations are extremely complex in this play. Although 3-D seismic surveys are being used to define structural plays, the nature of the faulting, the timing of fault movement, and the nature of the trapping mechanisms require further study to improve the exploration success in this play. Smackover carbonate shoal and tidal flat facies are proven reservoirs, and porosities are chiefly depositional interparticle and secondary grain-moldic in ooid and peloidal grainstone. Fracture porosity is also evident in these reservoirs. The nature and the cause of these fractures requires additional study.

The basement ridge play, which lies updip and north of the regional peripheral fault trend, is characterized by pre-Jurassic paleotopographic basement highs. The Wiggins Arch, which lies along the southern margin of the MISB, is also considered as part of the basement ridge play (Figure 2). Jurassic Louann Salt is essentially absent or is extremely thin over these paleohighs. The basement ridge play was discovered in 1967. Six fields associated with the Choctaw Ridge complex are productive from this play. These fields have produced more than 2.5 million barrels of oil and 320,000 Mcf of natural gas (Table 3). Opportunities exist for continued exploration in the basement ridge play; however, to date, these petroleum traps have had a smaller areal extent (1-2 sq. mi.) as compared to the salt related traps in the salt anticline and regional peripheral fault trend plays. The reserves associated with the Smackover fields discovered are generally around 5 million barrels of oil. 3-D seismic surveys are very effective in delineating these paleohighs. Although carbonate shoal and tidal flat facies are productive reservoirs in this play, the reef facies are clearly underdeveloped. Coral-microbial boundstones are potential reservoirs in the basement ridge play in the vicinity of the Choctaw Ridge complex. In addition, to the east along the Conecuh Ridge complex, microbial reef boundstone beds are prolific oil reservoirs attaining thicknesses of 150 feet (Mancini and Parcell, 2001). However, the areal extent of these buildups (1-2 sq. mi.) limits their economic success.

CONCLUSIONS

The northeastern Gulf of Mexico, including the eastern Gulf Coastal Plain, remains a largely unexplored region for oil and natural gas. The region contains numerous basins with a host of siliciclastic and carbonate formations having a high potential for hydrocarbon accumulations. To date, however, petroleum system studies have not been performed in the basins in this region. Further, independent companies that are drilling the majority of the wells in the region do not have the resources to conduct petroleum system studies. These companies maintain that the accessibility of oil and natural gas information is the single-most important factor critical to the search for new

hydrocarbon resources. To facilitate petroleum exploration efforts in the eastern Gulf Coastal Plain, a comprehensive analysis, including petroleum system studies, of the MISB has been undertaken.

The Gulf of Mexico is a divergent margin basin characterized by extensional rift tectonics and wrench faulting. The history of the Gulf of Mexico includes a phase of crustal extension and thinning, a phase of rifting and sea-floor spreading and a phase of thermal subsidence. The structural and stratigraphic framework of the region, including the MISB, was basically established during the Triassic and Jurassic. The MISB is a major negative structural feature in the northeastern Gulf of Mexico. This extensional basin was an actively subsiding depocenter throughout the Mesozoic and into the Cenozoic. Halokinesis of the Jurassic Louann Salt has produced a complex of structural features in the northeastern Gulf of Mexico. Paleotopography also had a significant impact on the distribution of sediment, and positive areas within basins and along basin margins provided sources for Mesozoic terrigenous sediments.

The Smackover Formation, a major hydrocarbon-producing horizon in the MISB, conformably overlies the Norphlet Formation and is conformably overlain by the Buckner Anhydrite Member of the Haynesville Formation. The Norphlet-Smackover contact can be either gradational or abrupt. The thickness and lithofacies distribution of the Smackover Formation were controlled by the configuration of incipient paleotopography. The Smackover Formation has been subdivided into three informal members, referred to as the lower, middle and upper members.

Structural or combination traps characterize Smackover hydrocarbon accumulations in the MISB area. Halokinesis is the principal process that formed these traps. Salt movement of the Jurassic Louann Salt has produced a complex array of salt-related structures in this basin. These structures include peripheral salt ridges, low relief salt pillows, salt anticlines and turtle structures, and piercement domes. The northern limit of the MISB is delimited by the regional peripheral fault trend. This trend includes a series of en echelon faults associated with the Pickens, Gilbertown, West Bend extensional fault and half graben systems. In the area immediately north and updip of the regional peripheral fault trend, Smackover traps consist of anticlinal structures associated with basement paleotopographic highs.

The major petroleum reservoirs in the Smackover Formation occur in the upper part of the formation. These upper Smackover strata consist of upward-shoaling mudstone to grainstone parasequence sets that accumulated as part of the late highstand systems tract deposits of an Upper Jurassic (Oxfordian to Kimmeridgian) depositional sequence.

These deposits represent higher energy, normal, open-marine intertidal to subtidal facies. These lithofacies were deposited in shoal flank, shoal crest, lagoonal and subtidal marine environments of a carbonate shoal complex. Reservoir-grade rocks (greater than 6% porosity and more than 0.1 md permeability) are ooid and peloidal grainstone and packstone beds characterized by primary interparticle, grain-moldic, dolomite-intercrystalline and vuggy porosity. Coral-microbial and microbial reef facies of the upper Smackover also have significant reservoir potential. These strata consist of bafflestone and boundstone beds that accumulated as part of the early highstand systems tract deposits of the Upper Jurassic (Oxfordian to Kimmeridgian) depositional sequence. These lithofacies were deposited in reef crest, reef flank, back-reef, and forereef environments of a reef complex. Reservoir-grade rocks are bafflestone and bindstone beds characterized by primary shelter, fenestral enhanced, dolomite-intercrystalline and vuggy porosity.

Although the primary control on reservoir quality in Smackover reservoirs is the fabric of the depositional lithofacies, diagenesis plays a significant role in modifying reservoir architecture. Diagenesis occurred in both eogenetic (carbonates influenced by surface-derived fluids of marine, fresh water, or brine origin) and mesogenetic (carbonates influenced by connate or formation fluids during burial) environments. Eogenetic processes include: biogenic micritization of carbonate grains; precipitation of fibrous aragonite or Mg calcite, marine cements; physical compaction; evaporative dolomitization; precipitation of meteoric-phreatic, Mg calcite cements; fabric-selective, meteoric-vadose dissolution; and precipitation of dolomite and anhydrite through brine reflux. Of the diagenetic events, multiple dolomitization and dissolution events probably had the greatest influence on reservoir development and quality. While the dolomitization created only minor amounts of intercrystalline porosity, it significantly enhanced permeability. It also stabilized the lithology which reduced the potential for later porosity loss due to compaction. The dissolution events enlarged primary (interparticle and shelter) and early secondary (moldic and intercrystalline) pores. While the dissolution did not create large amounts of new porosity, it did expand existing pore throats and enhanced permeability. Locally, the development of fracture systems also served to increase permeability. The most important processes that destroyed porosity in the Smackover of the eastern MISB were marine phreatic calcium-carbonate cementation, anhydrite cementation, burial calcite cementation (associated with dedolomitization and calcitization of anhydrite). While diagenesis has a significant influence on Smackover reservoir quality, it generally does not alter the geographic distribution of reservoir-grade rock. The development and distribution of reservoir-grade rock is primarily a function of depositional processes.

The upper Smackover is capped by subaerial evaporites of the Buckner Anhydrite Member of the Haynesville Formation. The anhydrites conformably overlie the carbonate rocks of the Smackover. These evaporites act as a barrier to vertical petroleum migration, and thus are effective seal rocks.

The organic-rich laminated, lower to middle Smackover carbonate mudstones are the petroleum source rocks for Smackover hydrocarbons and are the principal source rocks for the petroleum source rocks for other reservoirs in the MISB. Smackover samples from the lower and middle carbonate mudstones average 0.81% total organic carbon. Because much of the Smackover has experienced advanced levels of thermal maturity, the total organic carbon values were higher in the past prior to the generation of crude oil. The dominant kerogen types in the Smackover are algal (microbial) and amorphous.

The generation of hydrocarbons from Smackover carbonate mudstones was initiated at 2,438 to 3,353 m (8,000 to 11,000 ft) during the Early Cretaceous and continued into the Tertiary throughout much of the MISB. The thermal maturation profiles for wells located updip or along the northern margin of the basin indicate that the Smackover source rocks in this area are thermally immature and did not generate oil, while wells located in the center of the basin and along the southern margin of the basin adjacent to the Wiggins Arch show that the Smackover source rocks are late mature. In the vicinity of the Jackson Dome, hydrocarbon gas generation begins at a depth of 4,572 m (15,000 ft).

Hydrocarbon expulsion from the Smackover source rocks commenced during the Early Cretaceous and continued into the Tertiary. Initiation of oil expulsion began first in the central portion of the basin in mid-Early Cretaceous and peaked during the late Early Cretaceous in this area. In the south-central portion of the basin, north of the Wiggins Arch, oil expulsion was initiated in the Early Cretaceous and peaked in the early Late Cretaceous, while in the eastern portion of the basin oil expulsion commenced during the Late Cretaceous and continued into the Tertiary. During the Late Cretaceous and continuing into the Tertiary, peak oil expulsion occurred in areas in the northern portion of the basin but not along the northernmost margin of the basin.

Hydrocarbon migration associated with the Smackover source rocks in the basin was initiated in the Early Cretaceous and continued into the Late Cretaceous and Tertiary. The main oil migration pathways during the Early Cretaceous were from the basin center westward into salt anticlinal features and northward into traps associated with paleotopographic basement structures and with the Pickens-Gilbertown extensional fault systems and from the south-

central portion of the basin northward into developing salt traps and southward along the Wiggins Arch. These migration trends were maximized in the early Late Cretaceous. In addition, during the Late Cretaceous, oil migration occurred from the basin center eastward into salt anticlinal features and into fault traps associated with the Mobile Graben. This hydrocarbon migration model for the basin would suggest that reservoirs and traps first sourced from Smackover carbonates in the Early Cretaceous would contain immature oils, while reservoirs and traps sourced in the Late Cretaceous and Tertiary would contain mature oils and gas condensates.

The Smackover petroleum system is a self-contained system. Petroleum source rocks, reservoir rocks, and seal rocks are all within this unit. Anhydrite beds of the uppermost Smackover and the overlying Buckner Anhydrite Member of the Haynesville Formation serve as the petroleum seal rocks. Reservoir-grade carbonates are part of the upper Smackover beds. The lower and middle, organic-rich Smackover beds serve as the petroleum source rocks. The source potential of these beds has been optimized by the combination of favorable conditions of deposition, preservation, and subsequent burial and thermal histories. The generation of crude oil from these source rocks was initiated at a level of thermal maturity of 0.55% Ro in the Early Cretaceous and concluded at a level of thermal maturity of 1.5% Ro in the Late Cretaceous or Early Tertiary. Hydrocarbon expulsion commenced during the Early Cretaceous and continued into the Tertiary. Peak expulsion was during the Late Cretaceous. Hydrocarbon migration was generally long distance (80 km or 50 mi) and was initiated in the Early Cretaceous and continued into the Tertiary.

Regional and local reservoirs in the MISB and adjacent areas have produced approximately 1.9 billion barrels of oil and more than 6.3 Tcf of gas from Jurassic, Cretaceous and Tertiary reservoirs in 552 fields. Hydrocarbons were discovered from Upper Jurassic Smackover carbonate rocks in 1966 in the MISB. To date, more than 259 million barrels of oil and 1.4 Tcf of natural gas have been produced from 88 Smackover fields in the salt anticline play of the MISB. Opportunities exist for continued exploration for similar undrilled salt features in the basin and for the evaluation of the reservoir potential of Smackover carbonates on salt structures that are productive from shallow Cretaceous horizons. Although Smackover reservoirs are productive in the MISB, these reservoirs are underdeveloped. Carbonate lithofacies associated with carbonate shoal complexes provide an excellent exploration target, especially in the deeper parts of the central portion of the basin. Microbial reef facies are potential reservoirs throughout the basin. The Smackover Formation is the most productive reservoir in the regional peripheral fault

trend play when the fields associated with the Mobile Graben are considered as part of this play. Smackover carbonates have produced more than 138 million barrels of oil and 439 Bcf of natural gas from 24 fields. Opportunities exist for continued exploration along the regional peripheral fault trend. The basement ridge play, which lies updip and north of the regional peripheral fault trend, is characterized by pre-Jurassic paleotopographic basement highs. Six fields associated with the Choctaw Ridge Complex are productive from this play. These fields have produced more than 2.5 million barrels of oil and 320,000 Mcf of natural gas. Opportunities exist for continued exploration in the basement ridge play; however, to date, these petroleum traps have had a smaller areal extent (1-2 sq. mi.) as compared to the salt related traps in the salt anticline and regional peripheral fault trend plays.

REFERENCES

- Badon, C. L., 1974, Petrology and reservoir potential of the upper member of the Smackover Formation, Clarke County, Mississippi: Transactions of the Gulf Coast Association of Geological Societies, v. 24, p. 163-174.
- Baria, L. R., D. L. Stoudt, P. M. Harris, and P. D. Crevello, 1982, Upper Jurassic reefs of Smackover Formation, United States Gulf Coast: American Association of Petroleum Geologists Bulletin, v. 66, p. 1449-1482.
- Bearden, B. L., E. A. Mancini, and T. M. Puckett, 2000, Salt anticline play in the Mississippi Interior Salt Basin: Transactions of the Gulf Coast Association of Geological Societies, v. 50, p. 261-268.
- Benson, D. J., 1985, Diagenetic controls on reservoir development and quality, Smackover Formation of southwest Alabama: Transactions of the Gulf Coast Association of Geological Societies, v. 35, p. 317-326.
- Benson, D. J., 1988, Depositional history of the Smackover Formation in southwest Alabama: Transactions of the Gulf Coast Association of Geological Societies, v. 38, p. 197-205.
- Benson, D. Joe, and Ernest A. Mancini, 1982, Petrology and reservoir characteristics of the Smackover Formation, Hatter's Pond Field: Implications for Smackover exploration in southwestern Alabama: Gulf Coast Association of Geological Societies Transactions, v. 32, p. 67-75.
- Benson, D. Joe, and Ernest A. Mancini, 1984, Porosity development and reservoir characteristics of the Smackover Formation in southwest Alabama, *in* W.P.S. Ventress, D. G. Bebout, B. F. Perkins, and C. H. Moore, eds., The Jurassic of the Gulf Rim: Proceedings of the Third Annual Research Conference, Gulf Coast Section, SEPM Foundation, p. 1-17.

- Benson, D. J., E. A. Mancini, R. H. Groshong, J.-H. Fang, L. M. Pultz, and E. S. Carlson, 1997, Petroleum geology of Appleton Field, Escambia County, Alabama: Transactions of the Gulf Coast Association of Geological Societies, v. 47, p. 35-42.
- Benson, D. J., L. M. Pultz, and D. D. Bruner, 1996, The influence of paleotopography, sea level fluctuations, and carbonate production on deposition of the Smackover and Buckner Formations, Appleton Field, Escambia County, Alabama: Transactions of the Gulf Coast Association of Geological Societies, v. 46, p. 15-23.
- Bishop, W. F., 1973, Late Jurassic contemporaneous faults in north Louisiana and south Arkansas: American Association of Petroleum Geologists Bulletin, v. 57, p. 858-877.
- Cagle, J. W., and M. A. Khan, 1983, Smackover-Norphlet stratigraphy, south Wiggins Arch, Mississippi and Alabama: Transactions of the Gulf Coast Association of Geological Societies, v. 33, p. 23-29.
- Claypool, G. E., and E. A. Mancini, 1989, Geochemical relationships of petroleum in Mesozoic reservoirs to carbonate source rocks of Jurassic Smackover Formation, southwestern Alabama: American Association of Petroleum Geologists Bulletin, v. 73, p. 904-924.
- Daly, A. R., and J. D. Edman, 1987, Loss of organic carbon from source rocks during thermal maturation: American Association of Petroleum Geologists Bulletin, v. 71, p. 546.
- Davis, D. C., and E. H. Lambert, Jr., 1963, Mesozoic-Paleozoic producing areas of Mississippi and Alabama, v. 2, Mississippi Geological Society.
- Dickinson, K. A., 1962, The Upper Jurassic stratigraphy of Mississippi and southwestern Alabama: unpublished Ph.D. dissertation thesis, University of Minnesota, 165 p.
- Dinkins, T. H., Jr., 1968, Jurassic stratigraphy of central and southern Mississippi: Mississippi Geological, Economic and Topographic Survey Bulletin 109, Mississippi Bureau of Geology, Department of Natural Resources, 37 p.
- Dobson, L. M., and R. T. Buffler, 1997, Seismic stratigraphy and geologic history of Jurassic rocks, northeastern Gulf of Mexico: American Association of Petroleum Geologists Bulletin, v. 81, p. 100-120.
- Driskill, B. W., J. A. Nunn, R. Sassen, and R. H. Pilger, Jr., 1988, Tectonic subsidence, crustal thinning and petroleum generation in the Jurassic trend of Mississippi, Alabama and Florida: Transactions of the Gulf Coast Association of Geological Societies, v. 38, p. 257-265.

- Evans, R., 1987, Pathways of migration of oil and gas in the South Mississippi salt basin: Transactions of the Gulf Coast Association of Geological Societies., v. 37, p. 75-86.
- Forgotson, James M., and James M. Forgotson, Jr., 1976, Definition of Gilmer Limestone, Upper Jurassic formation, northeast Texas: American Association of Petroleum Geologists Bulletin, v. 60, no. 7, p. 1119-1123.
- Fowler, Heather E., 2000, Characterization and modeling of the Smackover reservoir, Chatom Field, Washington County, Alabama: unpublished thesis, University of Alabama, Tuscaloosa, 118 p.
- Hughes, D. J., 1968, Salt tectonics as related to several Smackover fields along the northeast rim of the Gulf of Mexico Basin: Transactions of the Gulf Coast Association of Geological Societies, v. 18, p. 320-330.
- Imlay, R. W., 1940, Lower Cretaceous and Jurassic formations of southern Arkansas and their oil and gas possibilities: Arkansas Division of Geology Information Circular 12, 64 p.
- Imlay, R. W., 1943, Jurassic formations of Gulf region [of North America including United States, Mexico, and Cuba]: American Association of Petroleum Geologists Bulletin, v. 27, p. 1407-1533.
- Imlay, R. W., 1980, Jurassic paleobiogeography of the conterminous United States in its continental setting: U. S. Geological Survey Professional Paper 1062, 134 p.
- Imlay, R. W., and G. Herman, eds., 1984, Upper Jurassic ammonites of the subsurface of Texas, Louisiana, and Mississippi: The Jurassic of the Gulf Rim, Proceedings of the Third Annual Research Conference, Gulf Coast Section, Society of Economic Paleontologists and Mineralogists Foundation, 149-170 p.
- Kemmer, D. A., and R. L. Reagan, 1987, Norphlet Formation (Upper Jurassic) sand erg-depositional model for northeastern DeSoto Salt Basin, eastern Gulf of Mexico: American Association of Petroleum Geologists Bulletin, v. 71, p. 576.
- Kopaska-Merkel, David C., and Steven D. Mann, 2000, Diagenetic control of reservoir quality in Chunchula Field (Smackover Formation), Mobile County, Alabama, Geological Survey of Alabama Circular 198, 27 p.
- MacRae, G., and J. S. Watkins, 1996, DeSoto Canyon Salt Basin: tectonic evolution and salt structural styles, *in* J. O. Jones, and R. L. Freed, eds., Structural Framework of the Northern Gulf of Mexico, Special Publication of Gulf Coast Association of Geological Societies, p. 53-61.

- Mancini, E. A., and D. J. Benson, 1980, Regional stratigraphy of Upper Jurassic Smackover carbonates of southwest Alabama: Transactions of the Gulf Coast Association of Geological Societies, v. 30, p. 151-163.
- Mancini, E. A., and R. M. Mink, 1985, Petroleum production and hydrocarbon potential of Alabama's coastal plain and territorial waters, *in* B. F. Perkins, and G. B. Martin, eds., Habitat of oil and gas in the Gulf Coast.: Fourth Annual Research Conference, v. 4: Austin, Texas, United States, Society of Economic Paleontologists and Mineralogists, p. 43-60.
- Mancini, Ernest A., and William C. Parcell, 2001, Outcrop analogs for reservoir characterization and modeling of Smackover microbial reefs in the northeastern Gulf of Mexico area: Gulf Coast Association of Geological Societies Transactions, v. 51, p. 207-218.
- Mancini, E. A., B. H. Tew, and R. M. Mink, 1990, Jurassic sequence stratigraphy in the Mississippi Interior Salt Basin of Alabama: Transactions of the Gulf Coast Association of Geological Societies, v. 40, p. 521-529.
- Mancini, E. A., B. H. Tew, and R. M. Mink, 1993, Petroleum source rock potential of Mesozoic condensed section deposits of southwest Alabama, *in* B. J. Katz, and L. M. Pratt, eds., Source Rocks in a Sequence Stratigraphic Framework: American Association of Petroleum Geologists Studies in Geology, v. 37, p. 147-162.
- Mann, S. D., 1988, Subaqueous evaporites of the Buckner Member, Haynesville Formation, northeastern Mobile County, Alabama: Transactions of the Gulf Coast Association of Geological Societies, v. 38, p. 187-196.
- Martin, R. G., 1978, Northern and eastern Gulf of Mexico continental margin: stratigraphic and structural framework: American Association of Petroleum Geologists Bulletin Studies in Geology, v. 7, p. 21-42.
- McKee, Don A., 1990, Structural controls on lithofacies and petroleum geology of the Smackover Formation: eastern Mississippi Interior Salt Basin, unpublished Masters thesis, University of Alabama, Tuscaloosa, 254 p.
- Miller, J. A., 1982, Structural control of Jurassic sedimentation in Alabama and Florida: American Association of Petroleum Geologists Bulletin, v. 66, p. 1289-1301.
- Mink, R. M., B. H. Tew, S. D. Mann, B. L. Bearden, and E. A. Mancini, 1990, Norphlet and pre-Norphlet geologic framework of Alabama and panhandle Florida coastal waters area and adjacent federal waters area: Geological Survey of Alabama Bulletin 140, 58 p.

- Montgomery, S. L., and R. L. Ericksen, 1997, Dry Creek Salt Dome, Mississippi Interior Salt Basin: American Association of Petroleum Geologists Bulletin, v. 81, p. 351-366.
- Murray, G. E., 1961, Geology of the Atlantic and Gulf Coastal Province of North America: New York, Harper & Brothers, 692 p.
- Nunn, J. A., ed., 1984, Subsidence histories for the Jurassic sediments of the northern Gulf Coast: thermal-mechanical model: The Jurassic of the Gulf Rim, Proceedings of the Third Annual Research Conference, Gulf Coast Section, Society of Economic Paleontologists and Mineralogists Foundation: Baton Rouge, p. 309-322.
- Nunn, J. A., and R. Sassen, 1986, The framework of hydrocarbon generation and migration, Gulf of Mexico continental slope: Transactions of the Gulf Coast Association of Geological Societies, v. 36, p. 257-262.
- Oehler, J. H., 1984, Carbonate source rocks in the Jurassic Smackover trend of Mississippi, Alabama, and Florida, *in* J. G. Palacas, ed., Petroleum Geochemistry and Source Rock Potential of Carbonate Rocks, v. 18, American Association of Petroleum Geologists Studies in Geology, p. 63-69.
- Oxley, M. L., E. Minihan, and J. M. Ridgway, 1967, A study of the Jurassic sediments in portions of Mississippi and Alabama: Transactions of the Gulf Coast Association of Geological Societies, v. 17, p. 24-48.
- Pilger, R. H., Jr., 1981, The opening of the Gulf of Mexico: implications for the tectonic evolution of the northern Gulf Coast: Transactions of the Gulf Coast Association of Geological Societies, v. 31, p. 377-381.
- Puckett, T. M., B. L. Bearden, E. A. Mancini, and B. J. Panetta, 2000, Topical report 3—petroleum plays and underdeveloped reservoirs in the Mississippi Interior Salt Basin, Tuscaloosa, Alabama, Center for Sedimentary Basin Studies and University of Alabama, p. 1-105.
- Rhodes, J. A., and G. B. Maxwell, 1993, Jurassic stratigraphy of the Wiggins Arch, Mississippi: Transactions of the Gulf Coast Association of Geological Societies, v. 43, p. 333-344.
- Salvador, A., 1987, Late Triassic-Jurassic paleogeography and origin of Gulf of Mexico Basin: American Association of Petroleum Geologists Bulletin, v. 71, p. 419-451.
- Sassen, R., 1990, Lower Tertiary and Upper Cretaceous source rocks in Louisiana and Mississippi; implications to Gulf of Mexico crude oil: American Association of Petroleum Geologists Bulletin, v. 74, p. 857-878.

- Sassen, R., and C. H. Moore, 1988, Framework of hydrocarbon generation and destruction in eastern Smackover trend: American Association of Petroleum Geologists Bulletin, v. 72, p. 649-663.
- Sassen, R., C. H. Moore, J. A. Nunn, F. C. Meendsen, and E. Heydari, 1987, Geochemical studies of crude oil generation, migration, and destruction in the Mississippi salt basin: Transactions of the Gulf Coast Association of Geological Societies, v. 37, p. 217-224.
- Sawyer, D. S., R. T. Buffler, and R. H. Pilger, Jr., 1991, The crust under the Gulf of Mexico, *in* A. Salvador, ed., The Gulf of Mexico Basin: Decade of North American Geology, v. J, p. 53-72.
- Shew, R. D., and M. M. Garner, 1990, Reservoir characteristics of nearshore and shelf sandstones in the Jurassic Smackover Formation, Thomasville Field, Mississippi, *in* J. H. Barwis, J. G. McPherson, and J.R.J. Studlick, eds., Sandstone Petroleum Reservoirs: New York, Springer-Verlag, p. 437-464.
- Smith, D. L., W. J. Dees, and D. W. Harrelson, 1981, Geothermal conditions and their implications for basement tectonics in the Gulf Coast margin: Transactions of the Gulf Coast Association of Geological Societies, v. 31, p. 181-190.
- Tew, B. H., R. M. Mink, E. A. Mancini, S. D. Mann, and D. C. Kopaska-Merkel, 1993, Geologic framework of the Jurassic (Oxfordian) Smackover Formation, Alabama and Panhandle Florida coastal waters area and adjacent federal waters area: Transactions of the Gulf Coast Association of Geological Societies, v. 43, p. 399-411.
- Thieling, S. C., and J. S. Moody, 1997, Atlas of shallow Mississippi salt domes: Mississippi Office of Geology Bulletin 131, 328 p.
- Tolson, J. S., C. W. Copeland, and B. L. Bearden, 1983, Stratigraphic profiles of Jurassic strata in the western part of the Alabama Coastal Plain: Geological Survey of Alabama Bulletin 122, 425 p.
- Townsend, R. N., 1986, The depositional environment and diagenesis of the upper Smackover member in Womack Hill field, Clarke and Choctaw Counties, Alabama: unpubl. M.S. thesis, Northeast Louisiana University, 97 p.
- Twiner, J. W., chairman, unpublished, Jurassic cross sections, Mississippi Geological Society.
- Wade, W. J., R. Sassen, and E. W. Chinn, 1987, Stratigraphy and source potential of the Smackover Formation of the northern Manila Embayment, southwest Alabama: Transactions of the Gulf Coast Association of Geological Societies, v. 37, p. 277-285.

- Weber, A. J., 1980, A look at Pachuta Creek Field: Oil and Gas Journal, v. 78, p. 128-132.
- Wells, J. W., 1942, Jurassic corals from the Smackover Limestone, Arkansas: Journal of Paleontology, v. 16, p. 196-206.
- Wilson, G. V., 1975, Early differential subsidence and configuration of the northern Gulf Coast basin in Southwest Alabama and Northwest Florida: Transactions of the Gulf Coast Association of Geological Societies, v. 25, p. 196-206.
- Winkler, C. D., and R. T. Buffler, 1988, Paleogeographic evolution of early deep-water Gulf of Mexico and margins, Jurassic to middle Cretaceous (Cenomanian): American Association of Petroleum Geologists Bulletin, v. 72, p. 318-346.
- Wood, M. L., and J. L. Walper, 1974, The evolution of the interior Mesozoic basin and the Gulf of Mexico: Transactions of the Gulf Coast Association of Geological Societies, v. 24, p. 31-41.
- Young, K., and F. Oloriz, 1993, Ammonites from the Smackover Limestone, Cotton Valley Field, Webster Parish, Louisiana, U.S.A.: Geobios, v. 15, p. 401-409.

Appendix 1

References for fields in the Smackover Formation in the Mississippi Interior Salt Basin area

Table A-1. References for fields producing from the Smackover Formation in the Mississippi Interior Salt Basin area.

Field Name	References
Addie Mae	none
Barber Creek	(Petzet, 1991)
Barber Creek East	none
Barnett	(Mississippi Geological Society, 1980)
Barnett West	(Davis and Lambert, 1963; Benson and Mancini, 1984; Mancini and Mink, 1985)
Barrytown	(Davis and Lambert, 1963; Benson and Mancini, 1984; Mancini and Mink, 1985; Bolin et al., 1989; Kopaska-Merkel et al., 1992)
Barrytown SW	(Bolin et al., 1989; Kopaska-Merkel et al., 1992)
Bay Springs	none
Beaver Dam	none
Belzoni	none
Benton	none
Bienville Forest	none
Black Creek	(Heydari, 1997)
Bowling Creek	none
Boyce	none
Bucatunna Creek	(Benson and Mancini, 1984; Mancini and Mink, 1985; Bolin et al., 1989)
Chaparral	(Fracogna, 1957; Moody and Sticker, 1992)
Chappell Hill	(Davis and Lambert, 1963; Benson and Mancini, 1984; Mancini and Mink, 1985; Bolin et al., 1989)
Chatom	(Davis and Lambert, 1963; Kornfeld, 1972; Strahan, 1975; Strahan and Green, 1975; Benson and Mancini, 1984; Feazel, 1985; Mancini and Mink, 1985; Galicki, 1986; Bolin et al., 1989; Kopaska-Merkel et al., 1992)
Choctaw Ridge	(Davis and Lambert, 1963; Benson and Mancini, 1984; Mancini and Mink, 1985; Bolin et al., 1989; Mancini et al., 1991a; Mancini et al., 1991b)
Choctaw Ridge North	(Davis and Lambert, 1963; Myers, 1975; Benson and Mancini, 1984; Mancini and Mink, 1985; Bolin et al., 1989)
Churchula	(Davis and Lambert, 1963; Boone and Moore, 1975; McCaslin, 1975; McNabb, 1975; Miller et al., 1982; Galicki, 1986; Barrett, 1988; Bolin et al., 1989; Kopaska-Merkel et al., 1994)
Clara North	none
Clara West	(Davis and Lambert, 1963)
Clear Creek	(Petzet, 1990)
Cold Creek	(Benson and Mancini, 1984; Mancini and Mink, 1985; Bolin et al., 1989; Kopaska-Merkel et al., 1992)
Cold Creek South	(Benson and Mancini, 1984; Mancini and Mink, 1985; Bolin et al., 1989; Kopaska-Merkel et al., 1992)
Copeland	(Kornfeld, 1972; Benson and Mancini, 1984; Mancini et al., 1984; Mancini and Mink, 1985; Bolin et al., 1989)
Crosby's Creek	(Bolin et al., 1989)
Cypress Creek	(Davis and Lambert, 1963)
Cypress Creek South	(Davis and Lambert, 1963)
Davis	none
Diamond	none
Double Creek	none
Fluffer Creek	(Galicki, 1986)

Field Name	References
Fomosla	none
Garland Creek	none
Gin Creek	(Bolin et al., 1989)
Goodwater	(Davis and Lambert, 1963)
Gulf Crest	(Bolin et al., 1989)
Harmony	(Davis and Lambert, 1963; Lieber and Carothers, 1983)
Harmony South	(Davis and Lambert, 1963)
Harrisville	(Shew, 1991)
Hatter's Pond	(Benson et al., 1981; McCaslin, 1981; Benson and Mancini, 1982; Petzet, 1985; Galicki, 1986; Worrall, 1988; Mink et al., 1990; Murray and Benson, 1990; Murray, 1991; Liro et al., 1993; Ginger et al., 1995)
Healing Springs	(Benson and Mancini, 1984; Mancini and Mink, 1985; Bolin et al., 1989)
Heidelberg West	none
Hiwannee North	none
Horseshoe Lake	(Galicki, 1986)
Johns	(McCunn et al., 1982; Galicki, 1986; Barrett, 1987)
Lake Como	none
Lake Utopia	(Jackson and Harris, 1982)
Little Mill Creek	(Bolin et al., 1989)
Loring	(Frasco, 1957; Stuart and Kozik, 1977)
Mannassa	none
Melvin	(Benson and Mancini, 1984; Mancini and Mink, 1985; Bolin et al., 1989)
Mike Creek	none
Mill Creek (AL)	(Davis and Lambert, 1963; Benson and Mancini, 1984; Mancini and Mink, 1985)
Missionary	(Fischer, 1974; Galicki, 1986)
Mize	(Mississippi Geological Society, 1963)
Movico	(Galicki, 1986; Bolin et al., 1989)
Nancy	(Davis and Lambert, 1963; Fischer, 1978; Jackson and Harris, 1982; Devery, 1987)
Nancy East	(Davis and Lambert, 1963; Oxley and Herlihy, 1971; Fischer, 1978; Jackson and Harris, 1982; Mancini et al., 1985)
Nancy West	(Davis and Lambert, 1963; Jackson and Harris, 1982)
Northeast Melvin	none
Otho	none
Pace Creek	(Bolin et al., 1989; Kopaska-Merkel et al., 1992)
Pachuta Creek	(Davis and Lambert, 1963; Weber, 1980b, a; Bliefnick and Mariotti, 1988; Evans, 1988)
Paulding	none
Paulding East	none
Paulding South	none
Paulding West	none
Pineville	none
Pineville West	none
Piney Woods	none
Piney Woods Southwest	none
Pisgah South	(Studlick, 1990)

Field Name	References
Pool Creek	(Davis and Lambert, 1963; Minihan and Oxley, 1966; Evans, 1988; Brewer and Groshong, 1993)
Prairie Branch	(Davis and Lambert, 1963; Fischer, 1978; Jackson and Harris, 1982; Mancini et al., 1985)
Puss Cuss CRreek	(Benson and Mancini, 1984; Mancini and Mink, 1985; Bolin et al., 1989; Kopaska-Merkel et al., 1992)
Quitman	(Davis and Lambert, 1963; Fischer, 1978)
Quitman East	none
Quitman Northwest	none
Red Creek	(Benson and Mancini, 1984; Mancini and Mink, 1985; Bolin et al., 1989; Kopaska-Merkel et al., 1992)
Reedy Creek	(Davis and Lambert, 1963)
Shongelo Creek	(Sticker, 1994b)
Shubuta	(Davis and Lambert, 1963)
Shubuta North	(Davis and Lambert, 1963)
Silas	(Davis and Lambert, 1963; Bolin et al., 1989; Kopaska-Merkel et al., 1992; Kopaska-Merkel, 1993, 1994)
Southeast Chatom	(Kopaska-Merkel et al., 1992)
Souwilpa Creek	(Benson and Mancini, 1984; Mancini and Mink, 1985; Bolin et al., 1989; Kopaska-Merkel et al., 1992)
Stafford Springs	none
Stage Coach Road	none
State Line South	(Kornfeld, 1972; Thomson et al., 1987; Thomson and Stancliffe, 1990)
Stringer	none for Smackover
Sugar Ridge	(Davis and Lambert, 1963; Myers, 1975; Benson and Mancini, 1984; Mancini and Mink, 1985; Bolin et al., 1989)
Sumrall	none
Sylverina	none
Tallabogue Creek	none
Tallahala Creek	(Davis and Lambert, 1963; Sticker, 1994b, a)
Tallahala Creek East	(Sticker, 1994a)
Tchula Lake	(Tedesco, 1999)
Thomasville	(Stuart and Kozik, 1977; Olsen, 1982, 1983; Galicki, 1986; Shew and Garner, 1986; Shew, 1987; Shew, 1990; Shew and Garner, 1990; Shew, 1991)
Thornton	none
Thornton Springs	none
Toxey	(Davis and Lambert, 1963; Benson and Mancini, 1984; Mancini and Mink, 1985; Bolin et al., 1989)
Turkey Creek	(Benson and Mancini, 1984; Mancini and Mink, 1985; Bolin et al., 1989)
Turnerville (AL)	(Bolin et al., 1989)
Union Grove	none
Vossburg	none
Watts Creek	(Fischer, 1978)
Waynesboro	none
West Bend	(Baria, 1983; Benson and Mancini, 1984; Mancini and Mink, 1985; Mancini et al., 1985; Bolin et al., 1989; Mancini et al., 1990; Mancini et al., 1991a; Mancini et al., 1993)
West Okatuppa	none

Field Name	References
Wimberly	(Davis and Lambert, 1963; Benson and Mancini, 1984; Mancini and Mink, 1985; Bolin et al., 1989)
Winchester	none
Wolf Creek	(Davis and Lambert, 1963)
Wolf Creek South	none
Womack Hill	(Davis and Lambert, 1963; Myers, 1975; Benson and Mancini, 1984; Mancini and Mink, 1985; Townsend, 1986; Bliefnick and Mariotti, 1988; Bolin et al., 1989; Kopaska-Merkel et al., 1992)
Yellow Creek East	none
Zion Chapel	(Davis and Lambert, 1963; Benson and Mancini, 1984; Mancini and Mink, 1985; Bolin et al., 1989)

References

- Baria, L. R., 1983, Smackover platform sand bodies; a Bahamas model: Transactions of the Gulf Coast Association of Geological Societies, v. 33, p. 11.
- Barrett, M. L., 1987, The dolomitization and diagenesis of the Jurassic Smackover Formation, Southwest Alabama [Doctoral thesis]: Johns Hopkins University, 383 p.
- , 1988, Stratigraphy of Smackover Formation (Upper Jurassic), Southwest Alabama; eustatic and tectonic influences on depositional patterns: American Association of Petroleum Geologists Bulletin, v. 72, no. 2, p. 158.
- Benson, D. J., and Mancini, E. A., 1982, Petrology and reservoir characteristics of the Smackover Formation, Hatter's Pond Field; implications for Smackover exploration in southwestern Alabama: Transactions of the Gulf Coast Association of Geological Societies, v. 32, p. 67-75.
- , 1984, Porosity development and characteristics of the Smackover Formation in southwest Alabama, *in* Third Annual Research Conference, Gulf Coast Section, Society of Economic Paleontologists and Mineralogists Foundation, Baton Rouge, p. 1-17.
- Benson, D. J., Mancini, E. A., and Wilkerson, R. P., 1981, Hatter's Pond Field; complex combination trap in Smackover and Norphlet formations (Upper Jurassic), Southwest Alabama: American Association of Petroleum Geologists Bulletin, v. 65, no. 5, p. 899.
- Bliefnick, D. M., and Mariotti, P. A., 1988, Paleoenvironmental and diagenetic reservoir characterization of the Smackover Formation, Jay Field, west Florida: Society of Economic Paleontologists and Mineralogists Core Workshop No. 12, p. 516-559.
- Bolin, D. E., Mann, S. D., Burroughs, D., Moore, H. E. r., and Powers, T. J., 1989, Petroleum atlas of southwestern Alabama, Atlas Series - Geological Survey of Alabama: Tuscaloosa, Alabama, Geological Survey of Alabama, 218 p.
- Boone, P. A., and Moore, D. B., 1975, Chunchula Field; giant in the making?: American Association of Petroleum Geologists Bulletin, v. 59, no. 9, p. 1723-1724.
- Brewer, R. C., and Groshong, R. H., Jr., 1993, Restoration of cross sections above intrusive salt domes: American Association of Petroleum Geologists Bulletin, v. 77, no. 10, p. 1769-1780.
- Davis, D. C., and Lambert, E. H., Jr., 1963, Mesozoic-Paleozoic producing areas of Mississippi and Alabama, Mississippi Geological Society.
- Devery, D. M., 1987, Oil and gas exploration in Mississippi; first half of 1987: Mississippi Geology, v. 8, no. 2, p. 9.
- Evans, R., 1988, Geological and geochemical determination of generation and migration of hydrocarbons in the South Mississippi salt basin; multiple sources, multiple pathways, *in* Waterman, A. S., and Miano, S. P., eds., Geochemistry of Gulf Coast oils and gases; their characteristics, origin, distribution, and exploration and production significance; Ninth annual research conference, Gulf Coast Section, Society of Economic Paleontologists and Mineralogists Foundation; program and abstracts.: Annual Research Conference. Gulf Coast Section. Society of Economic Paleontologists and Mineralogists. Program and Abstracts: Dallas, Texas, Society of Economic Paleontologists and Mineralogists, Gulf Coast Section, p. 4-5.

- Feazel, C. T., 1985, Diagenesis of Jurassic grainstone reservoirs in the Smackover Formation, Chatom Field, Alabama, *in* Roehl, P. O., and Choquette, P. W., eds., Carbonate petroleum reservoirs.: New York, New York, Springer-Verlag, p. 357-367.
- Fischer, V. N., 1974, Northeast-southwest stratigraphic cross section of the Jurassic sediments, Newton County to Jasper County, Mississippi, Cross Section 3, Mississippi Geological Society.
- , 1978, Northeast-Southwest cross section of the Jurassic sediments, Choctaw County, Alabama to Clarke County, Mississippi, Cross Section 5, Mississippi Geological Society, 1 sheet, 29" X 56" p.
- Frascogna, X. M., 1957, Mesozoic-Paleozoic Producing Areas of Mississippi and Alabama, Mississippi Geological Society, 139 p.
- Galicki, S. J., 1986, Mesozoic-Paleozoic Producing Areas of Mississippi and Alabama: Jackson, Mississippi, Mississippi Geological Society.
- Ginger, E. P., Thomas, A. R., George, W. D., and Stoudt, E. L., 1995, Reservoir characterization and modeling of the Jurassic Smackover and Norphlet Formations, Hatters' Pond unit, Mobile County, Alabama, *in* Stoudt, E. L., and Harris, P. M., eds., Hydrocarbon Reservoir Characterization: Geologic Framework and Flow Unit Modeling, SEPM Short Course No. 34: Houston, Society of Economic Paleontologists and Mineralogists, p. 227-316.
- Heydari, E., 1997, The role of burial diagenesis in hydrocarbon destruction and H₂S accumulation, Upper Jurassic Smackover Formation, Black Creek Field, Mississippi: American Association of Petroleum Geologists Bulletin, v. 81, no. 1, p. 26-45.
- Jackson, J. B., and Harris, P. M., 1982, Jurassic petroleum geology of southwestern Clarke County, Mississippi: Transactions of the Gulf Coast Association of Geological Societies, v. 32, p. 45-57.
- Kopaska-Merkel, D. C., Mann, S. D., and Schmoker, J. W., 1994, Controls on reservoir development in a shelf carbonate; Upper Jurassic Smackover Formation of Alabama: American Association of Petroleum Geologists Bulletin, v. 78, no. 6, p. 938-959.
- Kopaska-Merkel, D. C., 1993, Influence of pore-throat morphology on permeability of a carbonate beach deposit: Annual Meeting Abstracts - American Association of Petroleum Geologists Bulletin and Society of Economic Paleontologists and Mineralogists, v. 1993, p. 131.
- , 1994, Pore-throat morphology in the Upper Jurassic Smackover Formation of Alabama: Journal of Sedimentary Research, Section A: Sedimentary Petrology and Processes, v. 64, no. 3, p. 524-534.
- Kopaska-Merkel, D. C., Moore, H. E., Mann, S. D., and Hall, D. R., 1992, Establishment of an oil and gas database for increased recovery and characterization of oil and gas carbonate reservoir heterogeneity (Appendix 1 - Volume 3): Department of Energy, FG22-89BC14425.
- Kornfeld, J. A., 1972, Southwest Alabama gets new gas-condensate play: World Oil, v. 175, no. 4, p. 78-79.
- Lieber, R. B., and Carothers, M. C., 1983, Harmony Field, Clarke County, Mississippi: a true stratigraphic trap: Transactions of the Gulf Coast Association of Geological Societies, v. 33, p. 139-144.
- Liro, L. M., Burnett, T., Dawson, W. C., Katz, B. J., Priddy, G., and Robinson, V. D., 1993, A petroleum system's lifestyle, Hatter's Pond Field, Mobile County, Alabama: Annual Meeting Abstracts - American Association of Petroleum Geologists Bulletin and Society of Economic Paleontologists and Mineralogists, v. 1993, p. 138-139.
- Mancini, E. A., and Mink, R. M., 1985, Petroleum production and hydrocarbon potential of Alabama's coastal plain and territorial waters, *in* Third Annual Research Conference, Gulf Coast Section, Society of Economic Paleontologists and Mineralogists Foundation, Baton Rouge, p. 43-60.
- Mancini, E. A., Mink, R. M., and Bearden, B. L., 1984, Upper Jurassic Norphlet Formation; new frontier for hydrocarbon prospecting in the central and eastern Gulf of Mexico regions: American Association of Petroleum Geologists Bulletin, v. 68, no. 4, p. 502.
- , 1985, Upper Jurassic Norphlet hydrocarbon potential along the regional peripheral fault trend in Mississippi, Alabama, and the Florida Panhandle: Transactions of the Gulf Coast Association of Geological Societies, v. 35, p. 225-232.
- Mancini, E. A., Mink, R. M., Tew, B. H., and Bearden, B. L., 1990, Natural gas plays in Jurassic reservoirs of southwestern Alabama and the Florida Panhandle area: American Association of Petroleum Geologists Bulletin, v. 74, no. 9, p. 1503.
- Mancini, E. A., Mink, R. M., Tew, B. H., Kopaska-Merkel, D. C., and Mann, S. D., 1991a, Oil plays in Smackover reservoirs of the eastern Gulf Coastal Plain: American Association of Petroleum Geologists Bulletin, v. 75, no. 3, p. 628.
- , 1991b, Upper Jurassic Smackover oil plays in Alabama, Mississippi and the Florida Panhandle: Transactions of the Gulf Coast Association of Geological Societies, v. 41, p. 475-480.

- , 1993, Macroscopic reservoir heterogeneity in Upper Jurassic Smackover Formation oil plays, Southwest Alabama: Annual Meeting Abstracts - American Association of Petroleum Geologists Bulletin and Society of Economic Paleontologists and Mineralogists, v. 1993, p. 144.
- McCaslin, J. C., 1975, Deep gas strikes expand Alabama exploration: Oil and Gas Journal, v. 73, no. 6, p. 93.
- , 1981, Alabama's Hatter's Pond called a classic field: Oil and Gas Journal, v. 79, no. 29, p. 87-88.
- McCunn, H. J., Ward, G. D., and Cox, C., 1982, Johns Field, upper Smackover, Mississippi, *in* Bebout, D. G., Moore, C. H., Jr., Ventress, W. P. S., and Carney, J. L., eds., The Jurassic of the Gulf rim.: Annual Research Conference: Dallas, Texas, Society of Economic Paleontologists and Mineralogists, Gulf Coast Section, p. 54-63.
- McNabb, D., 1975, Major finds spur score of Southeast U.S. deep tests: Oil and Gas Journal, v. 73, no. 17, p. 27-30.
- Miller, J. A., Richart, J. M., and Samsel, H. S., 1982, Depositional and diagenetic facies, Smackover Formation, Churchula Field, Alabama: American Association of Petroleum Geologists Bulletin, v. 66, no. 5, p. 607.
- Minihan, E. D., and Oxley, M. L., 1966, Pre-Cretaceous geology of Pool Creek Field, Jones County, Mississippi: Transactions of the Gulf Coast Association of Geological Societies, v. 16, p. 35-43.
- Mink, R. M., Tew, B. H., Mann, S. D., Bearden, B. L., and Mancini, E. A., 1990, Norphlet and pre-Norphlet geologic framework of Alabama and panhandle Florida coastal waters area and adjacent federal waters area, Geological Survey of Alabama Bulletin 140, 58 p.
- Mississippi Geological Society, J., Mississippi, 1963, Mize Field, Smith County, Mississippi, *in* Davis, D. C., and Lambert, E. H., Jr., eds., Mesozoic-Paleozoic producing areas of Mississippi and Alabama; Vol. II.: Jackson, Mississippi, Mississippi Geological Society, p.; unpaginated.
- , 1980, Barnett Field, Clarke County, Mississippi, Mesozoic-Paleozoic producing areas of Mississippi and Alabama; Vol. 2, Suppl. 8.: Jackson, Mississippi, Mississippi Geological Society, p.; unpaginated.
- Moody, J. S., and Sticker, E. E., 1992, The geology of three Mississippi field; Trimble, Thanksgiving and Chaparral (extension): American Association of Petroleum Geologists Bulletin, v. 76, no. 9, p. 1464-1465.
- Murray, B. S., 1991, Characterization of the Smackover Reservoir, Hatter's Pond Field, Mobile County, Alabama [Masters thesis]: University of Alabama, 274 p.
- Murray, B. S., and Benson, D. J., 1990, Characterization of the Smackover reservoir in Hatter's Pond Field, Mobile County, Alabama: Abstracts with Programs - Geological Society of America, v. 22, no. 4, p. 52.
- Myers, J. D., 1975, There's more Jurassic oil in Southeast U.S: Oil and Gas Journal, v. 73, no. 45, p. 248-250.
- Olsen, R. S., 1982, Depositional environment of Jurassic Smackover sandstone, Thomasville Field, Rankin County, Mississippi: Transactions of the Gulf Coast Association of Geological Societies, v. 32, p. 59-66.
- , 1983, Depositional environment of Jurassic Smackover sandstones, Thomasville Field, Rankin County, Mississippi: Oil and Gas Journal, v. 81, no. 46, p. 232-234, 236.
- Oxley, M., and Herlihy, D. E., 1971, Geology and geophysics of East Nancy field, Clarke County, Mississippi: Transactions of the Gulf Coast Association of Geological Societies, v. 21, p. 66.
- Petzet, G. A., 1985, Gas cycling to boost Hatter's Pond recovery: Oil and Gas Journal, v. 83, no. April 29, 1985, p. 56-57.
- , 1990, One Smackover field 2 years after discovery: Oil and Gas Journal, v. 88, no. 30, p. 51.
- , 1991, Deep Smackover wildcat starting in lightly drilled Mississippi area: Oil and Gas Journal, v. 89, no. 2, p. 72.
- Shew, R. D., 1987, Isotopic and petrographic evidence for a thermochemical sulfate reduction origin of high H (sub 2) S concentrations in central Mississippi: Abstracts - Society of Economic Paleontologists and Mineralogists Midyear Meeting, v. 4, p. 77.
- , 1990, Depositional and diagenetic controls on reservoir quality and gas composition in a mixed siliciclastic/carbonate setting, Thomasville Field, Mississippi: American Association of Petroleum Geologists Bulletin, v. 74, no. 5, p. 762.
- , 1991, Upward-shoaling sequence of mixed siliciclastics and carbonates from the Jurassic Smackover Formation of central Mississippi, *in* Lomando, A. J., and Harris, P. M., eds., Mixed carbonate-siliciclastic sequences.: Society of Economic Paleontologists and Mineralogists Core Workshop, Society of Economic Paleontologists and Mineralogists, United States, p. 135-167.
- Shew, R. D., and Garner, M. M., 1986, Geologic study and engineering review of the Jurassic Smackover Formation of Thomasville Field, Rankin County, Mississippi: Transactions of the Gulf Coast Association of Geological Societies, v. 36, p. 283-294.
- , 1990, Reservoir characteristics of nearshore and shelf sandstones in the Jurassic Smackover Formation, Thomasville Field, Mississippi, *in* Barwis, J. H., McPherson, J. G., and Studlick, J. R. J., eds., Sandstone Petroleum Reservoirs: New York, Springer-Verlag, p. 437-464.

- Sticker, E. E., 1994a, The Tallahala Creek Complex, Smith County, Mississippi; the crest is not always the best: American Association of Petroleum Geologists Bulletin, v. 78, no. 9, p. 1479.
- , 1994b, Trapping styles in Mississippi, Alabama Haynesville reservoirs: Oil and Gas Journal, v. 92, no. 15, p. 103-106.
- Strahan, R. K., 1975, Geology of Chatom Field, Washington County, Alabama: American Association of Petroleum Geologists Bulletin, v. 59, no. 9, p. 1731.
- Strahan, R. K., and Green, M., 1975, Geology of Chatom Field, Washington County, Alabama: Transactions of the Gulf Coast Association of Geological Societies, v. 25, p. 121.
- Stuart, C. A., and Kozik, H. G., 1977, Geopressuring mechanism of Smackover gas reservoirs, Jackson Dome area, Mississippi: Journal of Petroleum Technology, v. 29, no. 5, p. 579-585.
- Studlick, J. R. J., 1990, A giant carbon dioxide accumulation in the Norphlet Formation, Pisgah anticline, Mississippi, in Barwis, J. H., McPherson, J. G., and Studlick, J. R. J., eds., Sandstone Petroleum Reservoirs: New York, Springer-Verlag, p. 181-203.
- Tedesco, W. A., 1999, An eolian facies within the Upper Jurassic Smackover Formation, Tchula Lake field, Mississippi: Proceedings of the American Association of Petroleum Geologists Annual Meeting, San Antonio, Texas, p. A137-138.
- Thomson, A., and Stancliffe, R. J., 1990, Diagenetic controls on reservoir quality, eolian Norphlet Formation, South State Line Field, Mississippi, in Barwis, J. H., McPherson, J. G., and Studlick, J. R. J., eds., Sandstone Petroleum reservoirs: New York, Springer-Verlag, p. 205-234.
- Thomson, A., Stancliffe, R. J., and Shew, R. D., 1987, Reservoir quality, sediment source, and regional aspects of Norphlet Formation, South State Line Field, Greene County, Mississippi: American Association of Petroleum Geologists Bulletin, v. 71, no. 5, p. 622.
- Townsend, R. N., 1986, The depositional environment and diagenesis of the Upper Smackover Member in Womack Hill Field, Clarke and Choctaw counties, Alabama [Masters thesis]: Northeast Louisiana University, 97 p.
- Weber, A. J., 1980a, A look at Pachuta Creek Field: Oil and Gas Journal, v. 78, no. 49, p. 128-132.
- , 1980b, Pachuta Creek (Smackover) Field, Mississippi: Transactions of the Gulf Coast Association of Geological Societies, v. 30, p. 233-242.
- Worrall, J. G., 1988, Deposition and diagenesis of the Jurassic Smackover Formation: Hatter's Pond field, southwest Alabama [unpublished M.S. thesis]: The University of Texas, 237 p.

Appendix 2

Cored and perforated intervals in wells from the Smackover Formation in the Mississippi Interior Salt Basin area

Table A-2. Fields, API numbers, locations and depths of cored intervals in fields producing from the Smackover Formation in the Mississippi Interior Salt Basin area.

Productive wells					
Mississippi					
Field	API	County	cored interval	perforated interval	trap
Barber Creek	23-123-00049	Scott	14,070-15,220 (QC)	14,548-14,588 (Hvl & uppr Smk)	structural-faulted anticline
Barnett	23-023-20414	Clarke	13,305-13,370.5 (CC)	13,316-13,362	structural-faulted anticline
Bienville Forest	23-129-20065	Smith	14,108-14,141 (QC)	14,132-14,140	structural-anticline
Cypress Creek	23-153-20007	Wayne	12,683-12,955 (QC)	12,713-12,808	structural-faulted anticline
Fluffer Creek	23-023-20461	Clarke	14,125-14,591* (QC); 14,125-14,154* & 14,531- 14,591* (CC)	15,421-429 (Norphlet)	stratigraphic/structural--pinchout of sand on anticline
Harmony	23-023-20125	Clarke	12,522-12,570 (QC)	12,490-12,536	stratigraphic-oolitic gs pinchout
Johns	23-121-20087	Rankin	19,034-19,091 (QC)	18,795-18,810	structural-faulted anticline
Lake Como	23-061-20173	Jasper	16,375-16,980 (CC)	17,044-072 (Smk "B"); 16,374- 632 (Smk "A")	structural-faulted anticline
Lake Utopia	23-061-20140	Jasper	14,799.5-14,814 (QC)	14,780-14,792	structural-faulted anticline
Nancy	23-023-20026	Clarke	13,347-13,566 (QC)	13,452-468; 13,406-425	Stratigraphic/structural-anticline & updip loss of p&p
North Hiwannee	23-153-20240	Wayne	14,620-15,678 (QC)	15,604-15,680 (Norphlet)	structural-faulted anticline
North Shubuta	23-023-20208	Clarke	14,207-14,918 (QC)	14,197-224; 14,240-253; 14,257- 266	structural-faulted anticline
Pachuta Creek	23-023-20627	Clarke	13,000-13,040" (QC)	12,956-12,998	structural-anticline, faulted in places
South Paulding	23-061-20507	Jasper	14,548-14,672 (WC)	14,500-14,615	structural(?)--anticline
Sumrall	23-023-20639	Clarke	13,333-13,373 (QC)	13,370-374; 13,390-400	structural-faulted anticline
Tallahala Creek	23-129-20005	Smith	15,467-15,681 (QC)	15,259-273; 15,482-492	stratigraphic-faulted anticline
West Clara	23-153-20086	Wayne	11,924-13,466; 13,282- 13,466* (QC)	13,491-13,513; 13,211-13,231	structural - fault
West Nancy	23-023-20222	Clarke	13,811-13,994 (QC)	13,868-880 (Smk); 13,768- 784(Bcknr)	structural-anticline
West Paulding	23-061-20074	Jasper	14,537-14,793 (QC)	14,619-14,696	structural(?)--anticline
Wolf Creek	23-153-20113	Wayne	15,327-15,423* (QC)	15,287-15,300	structural-faulted anticline

(Note: Bcknr = Buckner Member of the Haynesville Formation; Smk = Smackover Formation; Hvl = Haynesville Formation; QC = quarter core; CC = core chips.)

Table A-2. Fields, API numbers, locations and depths of cored intervals in fields producing from the Smackover Formation in the Mississippi Interior Salt Basin area.

Alabama					
Barrytown	01-023-20113	Choctaw	11,824-11,848	11834-48, 11875-85	structural-faulted anticline
Chappell Hill	01-023-20202	Choctaw	11,390-11,500	11392-412	structural-anticline
Chappell Hill	01-023-20370	Choctaw	11,297-11,353	11,340-45; 11,270-96	structural-anticline
Chatom	01-129-20074	Washington	16,000-16,134	16081-92	structural-anticline
Chatom	01-129-20075	Washington	16,080-16,200 (Bcknr-Smk)	16100-14, 16161-81	structural-anticline
Chatom	01-129-20069	Washington	16,020-16,111	16051-77, 16083-103 (Norphlet)	structural-anticline
Choctaw Ridge	01-023-20011	Choctaw	11,969-12,023	11968-82, 11970-80, 11982-88	structural-faulted anticline
Churchula	01-097-20141	Mobile	18,390-18,507	18472-82	structural/stratigraphic-anticline
Copeland	01-129-20079	Washington	16,240-16,287* (Bcknr)	16302-10, 16242-45, 16282-84, 16851-71, 16798-822	structural-anticline
Crosby's Creek	01-129-20065	Washington	16,381-16,409	16,382-16,410	structural-anticline
Gulf Crest	01-097-20282	Mobile	18,625.5-18,695	18630-38, 18656-60	structural-anticline
Hatters Pond	01-097-20299	Mobile	18,000-18,160	Production In Norphlet	structural-faulted anticline
Hatter's Pond	01-097-20330	Mobile	18,277-18,530	18,300-62; 18,380-410	structural-faulted anticline
Little Mill Creek	01-023-20205	Choctaw	12,372-12,400*	12358-70	structural/stratigraphic-anticline
Mill Creek	01-023-20163	Choctaw	12,388-12,405	12399-404	structural-anticline
Silas	01-023-20239	Choctaw	13,680-13,777	13,745-86	structural-faulted anticline
Souwilpa Creek	01-023-20239	Choctaw	13,680-13-718*	13745-86	structural/stratigraphic-anticline
Sugar Ridge	01-023-20136	Choctaw	11,700-11,788	11731-35	structural-faulted anticline
Thornton Springs	01-023-20376	Choctaw	11,236-11,281	11,238-47; 11,256-61	structural-anticline
Turnerville	01-097-20253	Mobile	18,366-18,386*	18394-420	structural/stratigraphic-anticline
West Bend	01-025-20116	Choctaw & Clarke	12,408-12,488	12424-30	structural-faulted anticline
West Okatuppa Creek	01-023-20348	Choctaw	10,602-10,625	10586-91, 10594-607	structural-anticline
Womack Hill	01-025-20105	Choctaw & Clarke	11,420-11,448	11428-38	structural-faulted anticline
Zion Chapel	01-023-20197	Choctaw	14,016-14,096	14004-10, 14013-23	structural-faulted anticline
			* = not in productive interval		

(Note: Bcknr = Buckner Member of the Haynesville Formation; Smk = Smackover Formation; Hvl = Haynesville Formation; QC = quarter core; CC = core chips.)

Table A-3. Information for cored interval in non-productive Smackover wells in the Mississippi Interior Salt Basin area.

Alabama			
Non-productive field wells			
West Barrytown	01-023-20106	Choctaw	12,213-12,261
Bucatunna Creek	01-023-20236	Choctaw	12,242-12,276
Gin Creek	01-023-20292	Choctaw	13,442-13,491
Silas	01-023-20176	Choctaw	13,601-13,663
Toxey	01-023-20006	Choctaw	10,571-10,630
Non-productive wildcats			
wildcat	01-023-20082	Choctaw	13,547-13,645 (Hv); 13,666-13,735 (Smk); 14-143-14,178 (Norphlet)
wildcat	01-023-19977	Choctaw	10,297-10,577
wildcat	01-023-20000	Choctaw	12,477-12,500; 12,524-12,574 (Smk)
wildcat	01-023-20001	Choctaw	12,478-12,507; 12,527-12,574
wildcat	01-023-20096	Choctaw	12,909-12,934
wildcat	01-023-20102	Choctaw	12,922-12,980 (Smk)
wildcat	01-023-20157	Choctaw	13,473-13,455
wildcat	01-023-20185	Choctaw	14,017-14,088
wildcat	01-023-20201	Choctaw	13,274-13,305
wildcat	01-023-20206	Choctaw	13,209-13,266
wildcat	01-023-20324	Choctaw	12,809-12,851 (Smk); 13,120-13,130 (Norphlet)
wildcat	01-023-20341	Choctaw	12,920-12,937
wildcat	01-023-20345	Choctaw	13,209-13,270
wildcat	01-023-20373	Choctaw	12,777-12,833 (Smk)
wildcat	01-097-20011	Mobile	18,800-18,836; 20,008-20,014
wildcat	01-097-20134	Mobile	18,622-18,682.5
wildcat	01-097-20296	Mobile	18,622-18,760
wildcat	01-097-20329	Mobile	18,266-18,390
wildcat	01-129-20001	Washington	13,175-13,203 (Hv)
wildcat	01-129-20002	Washington	16,076-16,711
wildcat	01-129-20046	Washington	12,272-12,360 (Smk)
wildcat	01-129-20047	Washington	15,719-15,750
wildcat	01-129-20051	Washington	19,750-19,811
wildcat	01-129-20056	Washington	16,582-16,685 (Smk)
wildcat	01-129-20067	Washington	16,508-16,518; 16,528-16,530 (Smk)
wildcat	01-129-20070	Washington	17,407-17,417 (Smk)
wildcat	01-129-20072	Washington	17,679-17,739
wildcat	01-129-20078	Washington	13,441-13,457 (Smk)
Mississippi			
Non-productive wells			
Double Creek	23-023-20522	Clarke	11,596-11,614 (top Smk) (QC)
Fomola	23-053-20018	Humphreys	9380-9440 (QC)
West Barnett	23-023-20501	Clarke	13,209-13,245 (Bcknr?) (QC)
			* = not in productive interval

Appendix 3

Descriptions of cores and cuttings from wells in the Smackover Formation in the Mississippi Interior Salt Basin area

Explanation of Symbols Used on Graphic Core Logs

Rock Types

Limestone
Dolostone
Sandstone
Sandy carbonate
Pre-Jurassic basement

Components (lithology column)

Planar Stromatolite
Domal stromatolite
Pisoid
Oncoid
Peloid
Favreimid fecal pellets
Gastropod
Mollusk
Echinoderm
Fossil
Coated Grain
Ooid
Intraclast
Tuberoïd
Carbonate breccia
Noncarbonate breccia
Imbricated clasts
Anhydrite
Bottom-nucleated anhydrite
Keystone vugs
Dolomitic
Paleosol
Desiccation cracks
Borings

Dunham Textures

Boundstone
Grainstone
Packstone
Wackestone
Mudstone

Particle Size Column

Particles and Matrix
Dolomite Crystals
Particle Ghosts

Sedimentary Structures

Nodular
Cross Bedded
Ripple
Wavy
Domal Features
Emersion Surface
Emersion Surface, significant relief
Emersion Surface with solution pipe
Tepee Structure
Laminae
Fenestral fabric

Pore Types

Moldic
Secondary Intraparticle
Primary Interparticle
Intercrystalline
Vuggy
Fossomoldic
Cement moldic

Bioturbation Textures

Intensity 1
Intensity 2
Intensity 3
Intensity 4
Intensity 5

Sample Types

Thin Section
---	--------------

Description of core from Barber Creek field, Scott County, Mississippi
by Roger Townsend

API # 23-123-00049

Barber Creek Field
Scott County, MS

Pan American Petroleum Corp. #1 USA Rubie Bell
18-5N-8E, Scott Co., MS

QC 14,070-15,220

Core File # C-34.0-.75

Pf: 14,548-14,588 IPF 228 BO, 0 BW (40.5 gty)

Core Description: 14,070-15,220

14,070-89	Siltstone, gray-pink-red, shaley, limy, laminated
14,090-91	Limestone, gray, ooid grainstone
14,092-101	Siltstone, gray-pink-red, shaley, limy, laminated
14,102-25	Missing
14,126-85	Siltstone, gray-pink-red, shaley, limy, laminated
14,186-91	Sandstone, white-pink, fine grained, tite, lime cement, some x-bedding
14,192-291	Siltstone, gray-pink-red, shaley, limy, laminated
14,292-356	No Core
14,357-66	Limestone, gray, micritic, crystalline, no grains, some laminations
14,367-74	Siltstone, gray-pink-red, shaley, limy, laminated
14,375-78	Limestone, gray-white, grainstone, very fine grained, coated grains
14,379-82	Limestone, gray, mudstone, laminated
14,383-84	Limestone, gray, packstone with ooids, fossils and some sand grains
14,385-86	Limestone, gray, grainstone with ooids, fossils and some sand grains
14,387	Limestone, gray mudstone, no grains, crystalline
14,388	Limestone, gray, grainstone with ooids, fossils and sand grains
14,389	Limestone, gray, mudstone, no grains
14,390	Sandstone, white, fine grained with lime cement
14,391-96	Limestone, gray, mudstone, no grains
14,397	Limestone, dolomitic, gray-tan, laminated, no grains
14,398-99	Limestone, gray mudstone, abundant sand grains
14,400	Limestone, gray wackestone, some ooids and fossils
14,401	Limestone, tan, grainstone with ooids and fossils
14,402-17	Limestone, gray, mudstone, laminated, bioturbated, slightly dolomitic
14,418-21	Limestone, gray, wackestone, some ooids and fossils
14,422-38	Dolostone, tan-buff, dense, some laminations & bioturbation, no grains
14,439-62	Sandstone, light gray-white, fine grained, tite, lime cement
14,463-70	Limestone, light gray, mudstone with sand grains, laminated, bioturbated
14,471-78	Limestone, light gray, mudstone, abundant fractures and bioturbation
14,479-98	Limestone, light gray, mudstone, dolomitic
14,499-540	No core
14,541-48	Anhydrite, gray-white, nodular

14,549-58	Dolostone, brown, sucrosic, possible ooid ghosts, good porosity, oil stain
14,559-60	Limestone, gray, ooid grianstone, some stylolites and cross bedding
14,561-63	Dolostone, brown, sucrosic, possible ooid ghosts, good porosity, oil stain
14,564-69	Missing
14,570-72	Limestone, gray, mudstone, sandy, laminated
14,573-74	Sandstone, buff, fine grained, lime cement
14,575-79	Limestone, gray packstone with sand, fossils and ooids
14,580-85	Limestone, tan, mudstone, laminated, bioturbated
14,586-97	Sandstone, light gray-white, fine grained, lime cement
14,598-600	Sandstone, tan, fine grained, dolomite cement
14,601-12	Sandstone, light gray, fine grained, lime cement, laminated
14,613-22	Siltstone, light gray, very fine grained, lime cement, laminated
14,623-31	Dolostone, tan, sucrosic, very fine, limy, oil stain
14,632-57	Limestone, gray, mudstone, dense, laminated
14,658-71	Dolostone, tan, mudstone, dense, laminated, bioturbated
14,672-92	No core
14,693-702	Dolostone, tan, mudstone, dense, laminated, bioturbated
14,703-07	Missing
14,708-25	Dolostone, tan, mudstone, dense, laminated, bioturbated
14,726-73	Limestone, gray mudstone, dense, some laminations, bioturbation
14,774-84	Dolostone, tan, mudstone, some bioturbation
14,785-93	No core
14,794-817	Dolostone, tan, mudstone, some bioturbation
14,818-29	Limestone, gray, mudstone, dense, some laminations, bioturbation
14,830-33	No core
14,834-35	Limestone, gray, dense mudstone, some bioturbation
14,836-56	Dolostone, dark gray, dense, mudstone, some bioturbation
14,857-90	Limestone, gray, dense mudstone, some bioturbation
14,891-916	Dolostone, dark gray, dense, mudstone, some bioturbation
14,917-19	Limestone, gray, dense, mudstone, some bioturbation
14,919-23	Missing
14,924-41	Dolostone, dark gray, dense, mudstone, some bioturbation
14,942-45	Limestone, dark gray-black, dense, mudstone
14,946-60	Dolostone, dark gray, dense, mudstone
14,961-78	Limestone, black dense, mudstone
14,979-83	Missing
14,984-95	Limestone/shale, black. thin laminations, very dense, mudstone
14,996-15,036	Limestone, dark gray-black, thinly laminated
15,037-205	Shale, dark gray-black, thinly laminated
15,205-220	Shale, light- dark gray, very platy and “rotten”, falling apart

GRAIN SIZE/ENERGY FROM TOP TO BOTTOM:

14,070-498	Haynesville Formation
14,499-540	No core
14,541-548	Buckner Anhydrite (Bottom 9 feet)
14,549	TOP OF SMACKOVER
14,549-563	Grainstone, high energy
14,570-572	Mudstone, low energy
14,573-574	Sandstone, lime cement
14,575-579	Packstone, moderate energy
14,580-585	Mudstone, low energy
14,586-622	Sandstone and siltstone, lime and dolomite cement
14,623-15,036	Mudstone, low energy, limestone and dolostone
15,037-220	Shale, low energy

Description of core from Barnett field, Clarke County, Mississippi
by Roger Townsend

API # 23-023-20414

Barnett Field
Clarke Co., MS

Skelly Oil Co. #1 Matt Eddins
32-2N-14E, Clarke Co., MS

CC 13,305-13,370.5

Core Chips File # 4090.0-.4

Pf: 13,316-13,362 IPF 354 BO, 212 MCFG (38.1 gty)

Core Chip Description: 13,245-13,370

13,245-47	Limestone, dark gray, dolomitic, dense, micritic
13,248-57	Anhydrite, white-gray
13,258	Limestone, dark gray, dense, micritic
13,259	Anhydrite, white-gray
13,260	Limestone, dark gray, dense, micritic
13,261-70	Anhydrite, white-gray
13,271-72	Limestone, light gray, ooid grainstone, fine grained
13,273-74	Limestone, light gray, ooid packstone, fine grained
13,275-80	Limestone, light gray, ooid grainstone, fine-medium grained
13,281	Limestone, light gray-buff, dense, micritic
13,282-83	Anhydrite, white-gray
13,284	Sandstone, light gray, fine grained, lime cement
13,285-91	Anhydrite, gray
13,292-94	Limestone, light gray, ooid grainstone, very fine grained, some sand
13,295	Sandstone, tan, fine grained, lime cement, some ooids
13,296-97	Limestone, gray, ooid grainstone, fine-coarse grained, poor sorting
13,298-301	Sandstone, tan, medium grained, lime cement, some ooids
13,302	Limestone, light gray, ooid grainstone, some pisolites, poor sorting
13,303-04	Missing core
13,305	Sandstone, tan, lime matrix, some ooids
13,306-12	Limestone, tan, ooid grainstone, fine grains, some sand
13,313	Limestone, gray, ooid packstone, dense
13,314-16	Sandstone, white, fine grained, lime matrix, fair porosity
13,347-51	Limestone, light gray, ooid grainstone, fine-very fine grained, fair porosity
13,352-53	Limestone, light gray, dense, micritic
13,354-57	Limestone, light gray, ooid grainstone, fine-medium grained
13,358	Limestone, light gray, ooid packstone, medium grained
13,359-67	Limestone, buff, dense, micritic
13,368-70	Limestone, light gray, ooid grainstone, fine-medium grained

GRAIN SIZE/ENERGY FROM TOP TO BOTTOM:

13,245-270	Mudstone & anhydrite, low energy
13,271-272	Grainstone, high energy
13,273-274	Packstone, moderate energy
13,275-280	Grainstone, high energy
13,281-283	Mudstone & anhydrite, low energy
13,284	Sandstone, lime matrix
13,285-291	Anhydrite, low energy
13,292-294	Grainstone, high energy
13,295	Sandstone, lime matrix
13,296-297	Grainstone, high energy
13,298-301	Sandstone, lime matrix
13,302	Grainstone, high energy
13,305	Sandstone, lime matrix
13,306-312	Grainstone, high energy
13,313	Packstone, moderate energy
13,314-16	Sandstone, lime matrix
13,347-351	Grainstone, high energy
13,352-353	Mudstone, low energy
13,354-357	Grainstone, high energy
13,358	Packstone, moderate energy
13,359-367	Mudstone, low energy
13,368-370	Grainstone, high energy

Figure A-1 - Structure contour map of the top of the Smackover Formation in the Barnett and Pachuta Creek fields, Clarke County, Mississippi. Modified from Davis and Lambert, 1963.

Depositional and diagenetic histories of Smackover Formation based on core from
McIlwain 11-10 No. 1 well, Permit No. 1818
Barrytown Field, Choctaw County, Alabama
by David C. Kopaska-Merkel

Depositional History

This core begins with silty dolomitic well sorted pellet grainstone that passes abruptly upward to dolomitic *Parafavreina* wackestone and crystalline dolostone. All these strata are inferred to have been laid down in a subtidal lagoon. The crystalline dolostone passes abruptly upward to dolomitic pellet grainstone with coarse and cemented lenses (11,831-11,835 ft). Upward, the lenses become more laterally continuous and many are fractured (short, vertical fractures that do not affect the rock outside the lenses). These strata were deposited on a tidal flat that prograded the (filled) lagoon. Several coarse storm layers (between 11,828 and 11,831 ft) contain ooids and bivalve shells. Within the interval bearing the coarse storm layers, the cemented layers are not obviously coarser than the surrounding less-cemented strata. Coarse storm layers are absent from the uppermost 3 feet of the core. Here, the amount of anhydrite increases upward gradually. The anhydrite occurs as small nodules found in discrete layers. At the top of this interval, anhydrite pseudomorphous after gypsum disks is found in an inch-thick layer just below the basal 1/2 foot of a coastal-sabkha succession at the top of the core. The percentage of dolomite increases upward through this same three-foot-thick interval from 5 to 10 percent at the base to about 85 percent in and above the gypsum-pseudomorph layer, and then to 100 percent over about a 10th of an inch just below the sabkha. The basal sabkha strata consist of a laminated zone of abundant stylolites, dolomite, and coarse replacive anhydrite. Reservoir lithofacies 1 extends from the top of the core to 11,838.5 ft.

Diagenetic History

Laterally elongate nodules and layers up to about one inch in thickness were penecontemporaneously cemented by calcium carbonate and vertically fractured. Because the lower boundaries of the cemented nodules/layers are abrupt, they are inferred to have formed subaerially. Gypsum crystals precipitated in the uppermost part of the core, just below a sabkha deposit. Interparticle calcium-carbonate cementation in particle-supported strata followed nodule formation and gypsum precipitation, but either preceded or was penecontemporaneous with chemical compaction of ooids and with mechanical compaction of bivalves in coarse storm layers. These processes essentially destroyed the primary pore system. Pervasive but incomplete fabric-selective dolomitization, particle dissolution (these two processes creating a secondary pore system), and precipitation of replacive anhydrite laths, occurred somewhat later; timing uncertain. Stylolitization followed dolomitization and anhydrite precipitation.

Figure A-2 - Detailed core log, Mcllwain 11-10 No. 1 well, Permit No. 1818, Barrytown field, Alabama.

Figure A-3 - Structure contour map of the top of the Smackover Formation in the Barrytown field, Choctaw County, Alabama. Modified from Bolin et al. (1989).

Description of core from Bienville Forest field, Smith County, Mississippi
by Roger Townsend

API # 23-129-20065

Bienville Forest Field
Smith Co., MS

Lone Star Prod. Co. #A-1 Federal 744
14-4N-9E, Smith Co., MS

QC 14,108-14,141

Core Chip File # C-403.0

Pf: 14,132-14,140 IPP 7 BO, 121 BW (33.9 gty)

Core Chip Description: 14,108-14,141

14,108-16	Anhydrite, white-gray
14,117-19	Sandstone, white, fine-medium grained, fair porosity, friable
14,120-22	Missing Core
14,123	Sandstone, white, fine-medium grained, fair porosity, friable
14,124	Missing Core
14,125-27	Sandstone, white, fine-medium grained, fair porosity, friable
14,128-39	Sandstone, white-tan, fine grained, fair porosity, friable
14,140-41	Missing Core

NOTE: No carbonate rock to describe

Depositional and diagenetic histories of Smackover Formation based on core from
Placid Johnson 14-14 #1, Permit No. 2753
Bucatan Creek field, Choctaw County, Alabama
by David C. Kopaksa-Merkel

Depositional history

Smackover strata in the core are dominated by oolitic pellet grainstone and pelletal ooid grainstone, indicating high-energy shoal deposition with possible minor backshoal shallow subtidal deposition. The abundance of oncoids at certain horizons suggests either a flood-tidal delta, periodically becoming inactive to allow growth of oncoids, or a backbarrier lagoonal environment in which oncoids grew, but with frequent washovers of ooids. As a generally high-energy environment is indicated by the dominance of cross-bedded and cross-laminated ooid grainstone throughout much of the core, a flood-tidal delta interpretation is preferred. Ooids, pellets, and oncoids dominate the core below 12,249 feet; less-common particles are intraclasts and *Parafavreina* pellets. At the top of the section, above a 3-foot missing interval, nodular anhydrite, replacive after ooid- or pellet grainstone, and partially to entirely dolomitized ooid grainstone are interbedded. This suggests that the water body in which Smackover strata were deposited had been filled or nearly filled by this time, and either a coastal sabkha developed, or that a brining-upward trend culminated in formation of a hypersaline lagoon in which gypsum was precipitated. Alternatively, as the calcium sulfate appears to be largely replacive (nonfelted nodules, discrete laths that are most common near stylolites, and pore-filling anhydrite cement), it could be post-depositional, derived from sulfate that refluxed downward from the overlying Buckner.

Diagenetic history

This peculiar reservoir is brown in color and was previously interpreted as dolostone. In fact, most of the section contains only about 5-10 percent dolomite, and only the top

few feet contain actual dolostone. The cause of the brown color appears to be solid hydrocarbons in pores as well as possible disseminated opaque material.

Nearly the entire section contains minor evidence of particle interpenetration, but this process was significant only locally. Apparently, early marine-phreatic cementation (thick pore-rimming first-generation marine [aragonite?] cements are obvious throughout, and later pore-filling cements are widespread) created a rigid framework before much compaction could occur. This phase of cementation reduced interparticle pores and occluded interparticle pore throats. In places, this cement framework collapsed and formed a cement-shard grainstone fabric with intershard porosity. In lithofacies 2 (12,249-12,256 ft), a period of meteoric-vadose diagenesis preceded marine-phreatic cementation, as indicated by abundant micritic meniscus cement. Both this episode of vadose cementation, and the subsequent marine-phreatic cementation, must have preceded deposition of the overlying lithofacies-4 strata, which would have been accompanied by reflux of hypersaline fluids.

Small amounts of anhydrite associated with stylolites, including stylocumulates up to 0.1 inches thick, occur above 12,264 feet, and scattered anhydrite laths are ubiquitous. In the uppermost part of the core (lithofacies 4), coarsely crystalline anhydrite has selectively filled some oomolds; other ooids are either dolomite, or are completely nonselectively replaced by nodular anhydrite.

Figure A-4 - Detailed core log, Johnson Unit 14-14 No. 1 well, Permit No. 2753, Bucatunna Creek field, Alabama.

Figure A-5 - Structure contour map of the top of the Smackover Formation in the Bucatunna Creek field, Choctaw County, Alabama. Modified after Bolin et al. (1989).

Depositional and diagenetic histories of Smackover Formation based on core from Midroc & Watkins Bolinger 26-7, Permit No. 2426
Chappell Hill field, Choctaw County, Alabama
by David C. Kopaska-Merkel

Depositional history

The basal portion of the core (below 11,484 ft) consists of bioturbated lime mudstone, fractured early (sedimentary brecciation), at an intermediate time (before stylolitization), and late (hairline fractures transecting all other features). Some of the second group of fractures are clearly tectonic, and resulted from application of a stress field with a vertical maximum component. The sedimentary breccia (11,495-11,496 ft) contains anhydrite, later calcite, and yet later hydrocarbons in the fractures. *Parafavreina* are rare, but occur locally as wackestone layers on the order of 1/2 inch thick. This lime mudstone was deposited below wave base in a well-oxygenated subtidal setting. The absence of body fossils suggests that the depositional environment was probably a restricted lagoon.

Upward shallowing is indicated by an abrupt increase in the abundance of *Parafavreina*, the appearance of gastropods and a variety of fossil fragments, and a possible exposure surface or hardground. Further evidence of upward shallowing to subaerially exposed conditions consists of (1) brown micritic patches, layers, and anastomosing networks, interpreted as immature paleosols, (2) mudstone and wackestone nodules floating in brown micrite, interpreted as remnant host rock in more mature paleosols, and (3) the pervasive presence of abundant shrinkage cracks (mainly in mudstone layers) and other fractures in the basal 30 feet of the core. The top of the lowest shallowing upward interval in the core is at about 11,472 feet.

This mudstone and *Parafavreina* wackestone interval (11,467-11,484 ft) is capped by a coarse mollusk wackestone (11,465-11,467 ft); some of the bivalves are articulated. This indicates that the mollusks are *in situ*, which in turn suggests more normal marine conditions, possibly due to improved circulation with the open ocean. These strata are overlain by bioturbated mudstone with scattered bivalve fragments (11,450-11,465 ft).

The lower part of the core, just described, is interpreted as a shallowing-upward/deepening-upward sequence. The upper 60 feet of the core record unequivocal evidence of upward shallowing.

The bioturbated lime mudstone just mentioned grades upward to peloid wackestone and lesser peloid packstone, interbedded with burrowed or bored digitate and massive cryptalgal bodies (possibly thrombolitic, but more likely recrystallized stromatolites), interlaminated with, and containing pockets of, peloid wacke-packstone. These are clearly shallow subtidal deposits formed in a protected and restricted environment that excluded consumers of microbial mats; probably a shallow lagoon that was becoming once again isolated from the open sea.

This interval is succeeded by a thin transitional zone (11,437-11,439 ft) containing abundant shells of herbivorous cerithid-like gastropods, small pellets, *Parafavreina* pellets, microbial laminites, desiccation cracks, less-common bivalves, and nodules of impermeable limestone containing the ghosts of small pellets and of *Parafavreina*. This interval records rapid upward shallowing to peritidal conditions.

Overlying the strata just described is a small-pellet and *Parafavreina*-bearing small-pellet grainstone (11,432-11,437 ft), which contains a succession of at least 11 calcitic crusts (each 1/4 to 1 inch thick) preserving the ghosts of both kinds of pellets. These crusts are continuous or discontinuous (some brecciated), have distinct upper and lower surfaces, are transected by abundant desiccation cracks, and contain small tepee structures. They represent a (series of) caliche horizon(s) formed during a prolonged period of subaerial exposure. Fossil fragments, including gastropods and bivalves, are ubiquitous but uncommon. This is the top of the second shallowing upward interval in the core (11,432 ft). Because the two lowest shallowing upward intervals in this core are capped by inferred paleosols, absolute sea-level fall is implicated in their formation.

The pedogenic interval is succeeded by upward-shoaling tidal-flat deposits consisting of *Parafavreina*-bearing small-pellet grainstone and lesser thrombolitic and microbially laminated strata, with small scoured channels and ripple-cross-laminated intervals, overlain by intertidal

Parafavreina-bearing small-pellet grainstone containing numerous thin layers with equant and laminar fenestrae (11,419-11,432 ft). A few calcitic nodules are scattered through this interval, but are not closely associated with fenestrae. This is the third shallowing upward interval in the core, and could have any of a variety of causes.

The fenestral interval is overlain by an upward-deepening succession that is dominated by thoroughly bioturbated small-pellet grainstone, but which includes microbial laminite, scattered fenestral intervals, *Parafavreina*, a 2 1/2-inch-thick graded storm deposit, and mollusks, especially bivalves, in the lower part. The minor constituents decrease in abundance upward, and the small pellets become very well sorted; these facts suggest extreme restriction. The intensity of burrowing does not diminish upward, however, and as exposure features are absent, the tidal flat is interpreted to have been flooded by a shallow subtidal lagoon.

Renewed upward shallowing (above 11,413 ft; the fourth shallowing upward interval in the core), probably due to either decreased subsidence or eustatic sea-level fall, is indicated by the disappearance of *Parafavreina* and the gradual appearance in the uppermost 7 feet of the core of anhydrite pseudomorphs of lenticular gypsum crystals. The gypsum crystals increase in abundance upward, and change from simple discoids (indicating uppermost intertidal conditions with high temperatures, low- to moderate organic content, and moderate salinities), to twinned discoids which indicate increased salinity (or increased organic-matter content, which is not likely) (Cody and Cody, 1988, Jour. Sed. Pet., v. 58, p. 247-255). Development of true sabkha conditions is not indicated.

The core is capped by 5 feet of crystalline dolostone, which contains fenestrae, uncommon partially healed shrinkage cracks, and possible microbial laminite; it is therefore interpreted as an intertidal succession formed after a reduction in salinity.

A note on the bioturbation in this core: where distinct ichnofossils are discernable, they are all large, simple, unbranched tubes, near-normal to bedding, and 1/2 to 1 cm in diameter. These are tentatively identified as *Ophiomorpha*, based on their co-occurrence with abundant *Parafavreina*.

Diagenetic history

Early diagenesis strongly affected this core. The lowermost 30 feet of core represent an immature paleosol horizon, which apparently formed before deposition of overlying strata. Higher in the core (11,430-11,437 ft) is a caliche zone about 7 feet thick containing lithified crusts, some brecciated before deposition of overlying strata. Vertical permeability must have been reduced by the more continuous crusts but locally enhanced in the more brecciated layers. Authigenic gypsum grew penecontemporaneously in intertidal deposits near the top of the core, and several intervals contain equant and laminar fenestrae.

Dolomite is found throughout the entire core, but the percent of dolomite varies on a scale of less than 1 inch from less than 1 percent to more than 99 percent for most of the core. One interval of dolostone (11,419-11,430 ft; at least 50 percent dolomite) 11 feet thick has a gradational lower boundary but a sharp upper boundary, indicating that dolomite formed before deposition of overlying strata.

Virtually all dolomitization was particle-selective (although fabric preservation is poor where the percent of dolomite is high). Locally in the upper part of the core scattered individual rhombs of fine- to very-fine sand size predominate over other kinds of dolomite crystals (but compose less than 25% of the rock). Early dolomitization prevented particle deformation or overcompaction except near hard objects that existed very early (e.g., calcium-carbonate nodules). Dolomitization post-dated nodule formation. Some (but not most) wispy stylolites have halos of near-complete dolomitization, indicating that late dolomitization occurred during or after pressure solution. Hence, at least two episodes of dolomitization are indicated; the early episode appears to be responsible for most of the dolomite, because particle-selective dolomite that is not associated with features that resulted from overcompaction or pressure solution, and that is more complete inside large burrows, accounts for most of the dolomite. The top 5 feet of core are different. Here, dolomitization yielded smaller crystals, was virtually complete, and did

not preserve preexisting fabric. Very early hypersaline dolomitization is a possibility for this interval.

This core is severely fractured; at least three episodes are indicated. Early fractures are syndepositional: brecciation of semi-lithified sediments at two or three intervals, and shrinkage fracturing of the lower part of the core as well as of the peritidal intervals higher in the section. Later fractures are vertical or near-vertical, and do not cut across stylolites. The later fractures are filled with calcite, anhydrite, and siderite (?) cements; some contain solid black hydrocarbons. Of the three cements, calcite precipitated before anhydrite; the hydrocarbons postdate all cements. The latest fractures are of two kinds: high-angle complementary sets of compressional fractures, some with displacements of several mm (all healed with cements, mainly calcite), and high-angle very long hairline fractures transecting all other features (not observed to interact with the tectonic fractures).

COMMENTS

The pore system in this core is somewhat enigmatic because the pores are difficult to see at low magnification. At least the top 24 feet are oil-stained, yet in most of this interval no significant porosity is visible under the binocular microscope. Pelmoldic porosity is important in dolomitic pellet grainstone of lithofacies 1, but the relative amounts of different pore types are not known accurately because the pelmoldic pores are not evident during routine core examination. This is because the pellets are small and fabric preservation is poor.

Figure A-6 - Detailed core log, Midroc & Watkins Bolinger 26-7 No. 1 well, Permit No. 2426, Chappell Hill field, Choctaw County, Alabama, upper part of core.

Figure A-7 - Detailed core log, Midroc & Watkins Bolinger 26-7 No. 1 well, Permit No. 2426, Chappell Hill field, Choctaw County, Alabama, lower part of core.

Figure A-8 - Structure contour map of the top of the Smackover Formation in the Chappell Hill and Wimberly field area, Choctaw County, Alabama. Modified from Davis and Lambert (1963).

Depositional and diagenetic histories of Smackover Formation based on core from
Phillips Chatom Unit 21-15 No. 3-03, Permit No. 5355, X No. 1491
Chatom field, Washington County, Alabama
by David C. Kopaska-Merkel

General Notes

This core lies entirely within the Smackover Formation, and contains brine-pond deposits capping a high-energy shoal succession. The core is in good condition, and most specimens are clearly in place.

Stratigraphy

Smackover Formation

TOP OF CORED INTERVAL = 16,025 feet

BASE OF CORED INTERVAL = 16,110.5 feet

Depositional Environment

The basal 47.5 feet of core are interpreted as shoal deposits. The succession grades up from peloid dolograinstone (16,110.5 to 16,063 feet) to dolomitic peloid grainstone (up to 16,085 feet) to anhydritic dolomitic peloid grainstone. Most particles are very fine sand size spheroids, and are probably superficial ooids. This is inferred by comparison to very fine ooid grainstone thin sections in well Permit No. 7044 nearby, and from the excellent sorting and abundant cross bedding in the inferred shoal deposits. Gastropods occur near the base of the core, and an emersion surface at 16,067 feet is associated with a rounded intraclast about 2 cm long and 1.5 cm thick. The intraclast consists of laminated peloid dolograinstone, and may have formed as beachrock.

Above 16,063 feet the core consists of 3 feet of anhydrite in the form of vertically oriented nodules, overlain by 10 feet of interbedded laminated crystalline dolostone and anhydrite (most is laminated, some exhibits contorted bedding or equant nodules). Except

for the dolostone layers, there is only a few percent dolomite in this interval. These strata were deposited in a brine pond. Considering the paleogeographic location, this pond probably formed within a depression on top of the salt-cored anticline that is now Chatom Field. If so, the pond's lateral extent will be a mile or less in any direction.

Brine-pond deposits are overlain by 9 feet of lagoonal strata (16,050 to 16,041 feet). These strata consist of peloidal mudstone, wackestone, packstone, and grainstone forming an upward shoaling succession. If these strata are indeed lagoonal then they record either a relative sea-level rise or breaching or submergence of some barrier that permitted evaporite deposition. Alternatively, the pond could have been flooded by storms, permitting carbonate deposition in the former brine pond.

Overlying the lagoonal deposits the uppermost 16 feet of core are interpreted as the deposits of intertidal and supratidal flats. These strata are dominated by very fine pellet (or superficial ooid) grainstone and dolograinstone (like the reservoir in Permit No. 7044). The pellets or superficial ooids are very well sorted, but the strata contain fine to very coarse sand sized peloids concentrated chiefly in the bases of graded beds ranging in thickness from a few centimeters to tens of centimeters in thickness. The graded beds are interpreted as storm deposits. This interval contains scoured surfaces (e.g., 16,033 feet), trough (16,039 feet) and planar-tabular cross laminae (with alternating current directions; 16,040-16,041 feet), tepee structures (16,038-16,039 feet), well developed desiccation cracks (16,037-16,039 feet), anhydrite pseudomorphs after gypsum discoids (16,033-16,037.5 feet), and a red-stained emersion surface (16,035 feet) overlain by a gypsiferous wedge ranging in thickness from 1 to 7 cm, that may be a residue of an evaporite layer. These features are all consistent with deposition on a tidal flat.

Diagenetic Characteristics

The reservoir in this core, like that of most MISB Smackover fields, was shaped by dissolution of nonskeletal particles and concomitant or subsequent dolomitization. Most pores are moldic or vuggy, with lesser intercrystalline and secondary intraparticle porosity. The most unusual feature of the pore system in this core is the development of up to 15 percent or more porosity in dolomitic limestone between 16,096 and 16,073 feet.

The earliest diagenetic products observed in this core are penecontemporaneous: tepee structures, syndepositional gypsum discoids, desiccation cracks, and incipient paleosol developed below the emersion surface at 16,035 feet. Particle-rimming cement cannot be seen clearly without thin sections, but is probably marine and also penecontemporaneous. Certainly some penecontemporaneous marine cement was precipitated, indicated by the formation of a hard layer that was ripped up and redeposited as intraclasts in the upper part of the shoal interval (e.g., 16,067 to 16,068 feet). Of these early diagenetic processes, marine cementation (which inhibited later chemical compaction) was the only one significant to reservoir development. The only interval in which chemically compacted strata were observed is a thin layer of herringbone cross lamination between 16,040 and 16,041 feet. Some individual cross laminae exhibit elephantine peloids and are intercalated between noncompacted layers.

The most significant shallow burial diagenetic processes were particle dissolution and dolomitization, which chemically stabilized the reservoir and converted the initial primary interparticle pore system to a secondary moldic pore system. The timing of these processes is unknown, but they predated significant chemical compaction and postdated the formation and deposition of intraclasts (16,067 to 16,068 feet).

Later diagenesis included fracturing, stylolitization, and dehydration of gypsum. High-amplitude sawtoothed stylolites are scattered through most of the carbonate strata in the core. These stylolites may not have significantly affected the reservoir because the regions of densest stylolites are mainly nonporous intervals between 16,040 and 16,050 feet and 16,091 and 16,101 feet.

Figure A-9 - Detailed core log, Chatham Unit 20-14 No. 1-04 well, Permit No. 7044, Chatham field, Alabama, upper part of core.

Figure A-10 - Detailed core log, Chatom Unit 20-14 No. 1-04 well, Permit No. 7044, Chatom field, Alabama, lower part of core.

Figure A-11 - Detailed core log, Phillips Chatom Unit 21-15 No. 3-03 well, Permit No. 5355, Chatom field, Alabama, upper part of core.

Figure A-12 - Detailed core log, Phillips Chatom Unit 21-15 No. 3-03 well, Permit No. 5355, Chatom field, Alabama, lower part of core.

Figure A-13 - Structure contour map of the top of the Smackover Formation in the Chatom field, Washington County, Alabama. Modified from Bolin et al. (1989).

Depositional and diagenetic histories of Smackover Formation based on core from Rentz-Trice Unit 35-1 No. 1 well, Permit No. 1427
Choctaw Ridge field, Choctaw County, Alabama
by David C. Kopaska-Merkel

Depositional History

The basal part of this core consists of anhydritic dolomitic mudstone which includes 1 foot of domal stromatolite at 12,002 to 12,003 feet. The lower part of this core also includes a surface coated with a thin layer of dark laminae at 12,020 feet. This surface is a hardground or submarine exposure surface coated with laminar microbial boundstone. These strata were deposited under low-energy conditions in a shallow subtidal restricted setting. These fine-textured strata are abruptly overlain by cross laminated pellet and ooid grainstone which was almost certainly laid down in a submarine high-energy setting. They record progradation of a high-energy shoal into the area penetrated by this core. These strata may have been deposited by a complex of tidal sand ridges like those found at the edge of the Tongue of the Ocean in the Bahamas or by a tidal inlet associated with progradation of a barrier island. Some of the pelletal layers exhibit cross laminae with tangential basal terminations, which suggests the migration of 3D dunes and formation of trough cross laminae.

Diagenetic History

There are a few possible anhydrite pseudomorphs after gypsum. The earliest unequivocal diagenetic processes that affected this core were interparticle calcium-carbonate cementation, followed by partial dolomitization (complete in a few intervals) and widespread dissolution of mineralogically unstable particles. The latter process was responsible for formation of the bulk of the pore system. Later diagenetic processes included formation of replacive anhydrite crystals, stylolitization, fracturing (at least two episodes, one before and one after stylolitization), anhydrite cementation in fractures, and

associated anhydrite replacement along preexisting stylolites as well as in proximity to the anhydrite-cement-filled fractures but not along stylolites. Dedolomitization by calcium carbonate was another late diagenetic process; its timing relative to the other late processes is unknown.

Figure A-14 - Detailed core log, Rentz-Trice Unit 35-1 well, Permit No. 1427, Choctaw Ridge field, Alabama.

Figure A-15 - Structure contour map of the top of the Smackover Formation in the Choctaw Ridge field, Choctaw County, Alabama. Modified from Bolin et al. (1989).

Figure A-16 - Detailed core log, Union Davis 1-11 No. 1 well, Permit No. 2584, Churchula field, Mobile County, Alabama -- lower part of core.

Figure A-18 - Structure contour map of the top of the Smackover Formation in the Chunchula field, Mobile County, Alabama. Modified from Bolin et al. (1989).

Figure A-19 - Structure contour map of the top of the Smackover Formation in the Cold Creek field, Mobile County, Alabama. Modified from Bolin et al. (1989).

Figure A-20 - Structure contour map of the top of the Smackover Formation in the South Cold Creek field, Mobile County, Alabama. Modified from Bolin et al. (1989).

Figure A-21 - Structure contour map of the top of the Smackover Formation in the Copeland field, Washington County, Alabama. Modified from Bolin et al. (1989).

Depositional and diagenetic histories of Smackover Formation based on core from
Darly Dees 3-3 No. 1 well, Permit No. 5115
Crosbys Creek field, Washington County, Alabama
by David C. Kopaska-Merkel

Depositional History

The entire core consists of laminated and cross laminated pellet and oolitic pellet dolograine. Ooids are most abundant just above 16,400 feet, and are not found between 16,384 and 16,390 feet. Gastropods and bivalves are uncommon below 16,403 feet. These strata were deposited on a high-energy beach, indicated by the abundance of low-angle cross strata, coupled with abundant trough cross strata and local fenestrae. The beach was probably developed on an island formed by early halokinesis of the Louann Salt along the western Washington County salt ridge (Mann and Kopaska-Merkel, 1992).

Diagenetic History

The earliest diagenetic fabric is pore-rimming calcium-carbonate cement (which also fills shelter voids associated with mollusks). This cement may have formed in the marine-phreatic diagenetic environment. Primary porosity is preserved in the upper part of the core (down to 16,390 ft); this interval may have been above the marine-phreatic zone. Subsequently, the rock was pervasively fabric-selectively dolomitized, and mineralogically unstable particles were leached. Later diagenetic processes included minor fracturing, further calcite cementation, growth of replacive anhydrite nodules, and stylolitization.

Figure A-22 - Detailed core log, Daryl Dees 3-3 No. 1 well, Permit No. 5115, Crosbys Creek Field, Alabama.

Figure A-23 - Structure contour map of the top of the Smackover Formation in the Crosbys Creek field, Washington County, Alabama. Modified from Alabama Oil and Gas Board docket number 1-28-8813A, 1-28-8814 and 1-28-8814.

Description of core from Cypress Creek field, Wayne County, Mississippi
by Roger Townsend

API # 23-153-20007

Cypress Creek Field
Wayne Co., MS

The Brandon Co. #27-1 Unit
27-10N-6W, Wayne Co., MS

QC 12,683-12,955

Core File # C-97.0-.4 C-146.0-.4 C-138.0-.8

Pf: 12,713-12,808 IPF 112 BO, 55.5 MCFG, 0 BW (30.5 gty)

Core Description: 12,683-12,955

12,683-86	Dolomitic Anhydrite, white-brown, interbedded, oil stained
12,687-88	Anhydrite, light gray dense, no porosity, no stain
12,689	Dolomite, brown, sucrosic, fair porosity, oil saturated
12,690	Dolomitic anhydrite, gray-brown, interbedded, poor porosity
12,691-96	Anhydritic Dolomite, tan, dense, crystalline, poor porosity, oil stain
12,697-700	Anhydrite, light gray, bedded, dense, no porosity
12,701-07	Dolomite, tan, crystalline, poor porosity, oil stain
12,708-11	Anhydritic Dolomite, gray, dense, crystalline
12,712-13	Dolomite, brown, sucrosic, crystalline, good porosity, oil saturated
12,714	Anhydritic Dolomite, light gray, dense, crystalline, no stain
12,715	Dolomite, brown, sucrosic, crystalline, fair porosity, oil saturated
12,716-33	Anhydritic Dolomite, light gray, bedded, dense, no stain
12,734	Dolomite, brown, sucrosic, crystalline, fair porosity, oil saturated
12,735	Anhydritic Dolomite, light gray, bedded, dense, no stain
12,736-44	Dolomite, brown, sucrosic, crystalline, fair porosity, oil saturated
12,745-54	Dolomite, dark gray-tan, dense, crystalline, poor porosity, oil stain
12,757-63	Dolomite, brown, sucrosic, crystalline, fair porosity, oil saturated
12,764-71	Dolomite, tan-gray, dense, some anhydrite nodules, no porosity
12,772-79	Dolomite, brown, sucrosic, crystalline, fair porosity, oil saturated
12,780-81	Dolomite, light tan, dense, crystalline, poor porosity, oil stain
12,782-85	Dolomite, brown, sucrosic, crystalline, fair porosity, oil saturated
12,786-87	Dolomite, tan-gray, dense, poor porosity, no stain
12,788-99	Dolomite, brown, sucrosic, crystalline, fair porosity, oil saturated
12,800-04	Dolomite, tan, dense, poor porosity, poor stain
12,805-24	Dolomite, brown, sucrosic, crystalline, fair porosity, oil saturated
12,825-63	Dolomite, gray, sucrosic, crystalline, fair porosity, no oil, sm anhy
12,864-72	Lime, light gray, ooid grainstone, poor sorting, fossils, asphaltic
12,873-80	Dolomite, light gray, crystalline, possible ooid ghosts
12,894-925	Lime, buff, micritic, dense, crystalline

12,926-40	Lime, buff-gray, micritic, dense, some stylolites
12,941-55	Lime, buff-gray, micritic, dense, thin laminations

NOTE: All carbonate rock from 12,683 to 12,863 lacks any evidence of grain texture. Apparently the dolomitization process has masked all grains that may be present so that all evidence of their existence has disappeared. Perhaps examination of the rock in thin section will reveal the presence of grains.

GRAIN SIZE/ENERGY FROM TOP TO BOTTOM:

12,683-735	Anhydritic Dolomite, shallow, low energy, evaporitic
12,736-863	Dolomite, interbedded dense and sucrosic, see "Note" above
12,864-872	Grainstone, high energy
12,873-880	Probably Grainstone, high energy
12,894-955	Mudstone, low energy

Figure A-24 - Structure contour map of the top of the Smackover Formation in the Cypress Creek field, Wayne County, Mississippi. Modified from Davis and Lambert (1963).

Figure A-62 - Structure contour map of the top of the Smackover Formation in the South Cypress Creek field, Wayne County, Mississippi. Modified from Davis and Lambert (1963).

Figure A-26 - Structure contour map of the top of the Cotton Valley Group in the Diamond field, Wayne County, Mississippi. Modified from Davis and Lambert (1963).

Description of core from Double Creek field, Clarke County, Mississippi
by Roger Townsend

API # 23-023-20522

Double Creek Field
Clarke Co., MS

Goldsberry-Midrock & Watkins #1 Rolison et al
6-1N-18E, Clarke Co., MS

QC 11,596-11,614

Core File # 626.0-.1

D & A XWDW @ 1800-2100

Core Description: 11,596-11,614

11,596-98	Limestone, tan-brown, fossiliferous, bioturbated, wackestone, oil saturated
11,599-02	Limestone, tan-brown, oolitic grainstone, oil saturated
11,603-03	Limestone, tan-brown, oolitic, fossiliferous, packstone, oil saturated
11,604-05	Limestone, buff, micritic, fossiliferous, packstone, some oil stain
11,606-09	Limestone, buff, ooid packstone, poor sorting, pisolites, some oil stain
11,610-14	Limestone, brown, fossiliferous, bioturbated, wackestone, oil saturated

GRAIN SIZE/ENERGY FROM TOP TO BOTTOM:

11,596-598	Wackestone, low to moderate energy
11,599-603	Grainstone, high energy
11,604-609	Packstone, moderate energy
11,610-614	Wackestone, low to moderate energy

Description of core from Fluffer Creek field, Clarke County, Mississippi
by Roger Townsend

API # 23-023-20461

Fluffer Creek Field
Clarke Co., MS

CNG Prod. Co. #1 Masonite 25-14
25-1N-14E, Clarke Co., MS

QC 14,125-14,591

Core Chips File # C-437.0-.1

Pf: 15,421-429 Norphlet IPF 210 BO, 94 MCFG, 0BW (35.3 gty)

Core Chip Description: 14,125-14,154 & 14,531-14,591

14,125-26	Limestone, gray, dense, micritic
14,127	Limestone, dolomitic, dark gray, dense, crystalline
14,128	Limestone, gray, very dense, micritic
14,129-44	Anhydrite, white-gray
14,145-54	Limestone, dark gray, dense, micritic
14,531	Limestone, gray, dense, micritic
14,532-49	Limestone, gray, ooid grainstone, very fine-medium grained
14,550-75	Limestone, gray, dense, micritic
14,576-78	Limestone, gray, dense, micritic, fossils
14,579	Anhydrite, white, weathered, grainy
14,580-82	Limestone, gray, ooid grainstone, fair porosity
14,583-86	Limestone, gray, dense, micritic, possible ooid ghosts
14,587-88	Limestone, gray, dense, micritic
14,589	Limestone, gray, ooid packstone, dense
14,590-91	Limestone, gray, ooid grainstone, fair porosity

GRAIN SIZE/ENERGY FROM TOP TO BOTTOM:

14,125-154	Haynesville Formation , Mudstone & anhydrite, low energy/evaporitic
14,531	Mudstone, low energy
14,532-549	Grainstone, high energy
14,550-579	Mudstone & anhydrite, low energy
14,580-582	Grainstone, high energy
14,583-588	Mudstone, low energy
14,589	Packstone, moderate energy
14,590-591	Grainstone, high energy

Description of core from Fomosla field, Humphreys County, Mississippi
by Roger Townsend

API # 23-053-20018

Fomosla Field
Humphreys Co., MS

Byron Oil Industries #1 Barrett et al
23-16N-2W, Humphreys Co., MS

QC 9380-9440

Core File # C-683.0-.5

D & A No Production

Core Description: 9380-9440

9380-81	Sandstone, red, dense, silty, very fine grained, some shale laminae
9382-83	Shale, light gray-guff-tan, thinly bedded, some anhydrite
9384-90	Anhydrite, white-gray, bedded, some small shale streaks
9391	Sandstone, light gray, very fine grained, dense
9392	Shale, light gray, silty, laminated
9393-94	Sandstone, light gray-buff, fine grained, dense, some laminae
9395-416	Sandstone, dark gray-tan, fine grained, fair porosity, friable, laminated
9417-19	Shale, dark tan, looks like rip-up clasts or mud balls
9420-29	Sandstone, dark gray-tan, fine grained, abundant laminae, friable

Note: No carbonate rocks to describe

Depositional and diagenetic histories of Smackover Formation based on core from Elf Aquitaine
Bolinger Heirs 32-5 #1, Permit No. 3312
Gin Creek field, Choctaw County, Alabama

by David C. Kopaska-Merkel

Depositional history

The base of this core penetrates bioturbated lime mudstone (13,491-13,501 ft), deposited in a subtidal setting on a protected marine shelf (the Mississippi Interior Salt Basin). The dearth of body fossils suggests some restriction, but the presence of burrows indicates at least some oxygen in the bottom sediments. The succession is capped with an eroded subaerial exposure surface (13,488 ft).

This lagoonal(?) mudstone is overlain by several feet of microbial laminite containing fenestral pores (13,486.5-13,488 ft). This upward shoaling succession is overlain by a thick sequence of oolitic and peloidal grainstone, with intercalated microbial boundstone layers and lesser lime mudstone. Most of the particle-supported rocks are laminated or cross laminated, and many consist of graded layers about an inch thick. The grainy layers contain oncoids, microbially coated particles, and mollusks. The microbial layers are both laminar and domal, and contain desiccation cracks, fenestrae, scattered particles, and some burrows. Hiatal surfaces are common, and many truncate burrows (or were burrowed into when they were exposed at the sediment surface). This stratigraphic sequence, mainly assigned to lithofacies 1, was probably deposited in a shallow, near-shore lagoon. Intermittent evidence of exposure indicates shoaling to peritidal conditions, and thin cross-laminated oolitic grainstone layers are probably washover deposits. The predominantly pelletal grainstone and packstone which composes the bulk of this deposit are interpreted as having formed within the lagoon.

Overlying the dominantly peloidal rocks (13,459.3-13,480 ft) is a coarsening upward sequence of cross-laminated ooid grainstone assigned to lithofacies 2, which was deposited on a

high-energy beach (13,459.3-13,450.5 ft). These strata contain pisoids (oversize ooids), coated grains, oncoids, intraclasts, mollusk fragments, peloids, and unidentifiable fossil fragments.

Anhydrite consists of ≤ 10 percent replacive laths and mold-filling cement.

The ooid-grainstone interval is overlain by a thin transition zone (13,450.5-13,449.5 ft) overlain by nodular anhydrite that has replaced peloidal ooid grainstone (13,449.5-13,447 ft), which in turn is overlain by anhydritic peloid ooid dolograins of lithofacies 3 (13,441.8-13,447 ft).

The base of the transition zone consists of a few inches of well rounded dolomitic sandstone (30 percent of interval) and nodular anhydrite (70 percent of interval). This is overlain by about 6 inches of dolomitic pelletal ooid packstone with 25 percent anhydrite. A series of closely spaced erosion surfaces caps this material. The last erosion surface is overlain by 6 inches of dolomitic pelletal ooid packstone/grainstone, which is nonporous.

The transition zone is overlain by crystalline white anhydrite that contains ghosts of pellet ooid grainstone. The entire anhydrite layer may have formed by replacement of carbonate.

Above the massive nodular anhydrite is a succession of pellet, ooid, and pellet-ooid dolograins, which coarsens upward overall. These strata locally have been 50 percent replaced by nodular anhydrite in the lower part, but the bulk of this interval contains only local replacive anhydrite (especially in the coarser layers). Most of this interval contains only pelmoldic porosity (and locally to 25 percent but the top 1.5 feet contain mainly oomoldic porosity and intercrystalline porosity).

Regional stratigraphic considerations (c.f., Mann and Kopaska-Merkel, 1992) suggest that this altered interval above the anhydrite layer represents flooding of the beach during the initial phase of a relative sea-level rise that ultimately resulted in subaqueous anhydrite deposition during earliest Buckner time. This interpretation is supported by the upward increase in

abundance of pellets relative to ooids, as well as by the sulfate- and dolomite replacement of calcium carbonate.

Diagenetic history

The following discussion applies to the entire core except the uppermost part, which has suffered a somewhat different diagenetic history, described in a following paragraph. Possibly the earliest diagenetic fabric is found at the base of the core, where anhydrite after discoidal gypsum crystals is found in a two-foot-thick interval. This indicates an early infusion of high-salinity fluids into these subtidal marine strata. Diagenesis, as recorded in the particle-supported strata in this core, began with formation of marine isopachous particle-rimming cement. This was followed by partial dolomitization, mostly preferentially affecting particles. In the ooid grainstone in the upper part of the core, patches of nonfabric-selective dolomite were observed in close association (at most one foot vertical separation) with fabric selective dolomite. Fabric-selective dolomitization preceded massive leaching and both mechanical and chemical compaction, whereas nonselective dolomitization appears to have occurred after both leaching and compaction. Stylolitization, formation of replacive anhydrite laths, and minor formation of dolomite cement in particle molds clearly postdates leaching, but relative timing is otherwise uncertain. Dolomite-cemented fractures postdate stylolitization.

In the upper part of the core, wholesale replacement of peloid ooid grainstone by anhydrite (including precipitation of anhydrite cement in particle molds) followed interparticle cementation and particle leaching. What carbonate was not replaced by anhydrite is entirely dolomitized. It seems likely that anhydritization followed partial dolomitization, but this is not certain.

Figure A-27 - Detailed core log, Bolinger Heirs 32-5 No. 1 well, Permit No. 3312, Gin Creek field, Alabama.

Figure A-28 - Structure contour map of the top of the Smackover Formation in the Gin Creek field, Choctaw County, Alabama. Modified from Bolin et al. (1989).

Figure A-29 - Structure contour map of the top of the Smackover Formation in the Goodwater field, Modified from Davis and Lambert (1963).

Depositional and diagenetic histories of Smackover Formation based on core from Arco-Gulcrest
Unit 5-2 No. 1 well, Permit No. 5226
Gulf Crest field, Mobile County, Alabama
by David C. Kopaska-Merkel

Depositional History

The core described here comprises part of one shoaling upward cycle that begins with subtidal and ends with supratidal strata.

The basal section of the core (below 18,680 ft) records deposition of microbial laminite in a low-energy setting on a broad, restricted north-facing shelf on the south margin of the Mississippi interior salt basin.

This is overlain by 14 ft of planar-e unimodal dolostone that contains ghosts of peloids and appears to be intensely bioturbated. These strata were probably deposited under slightly less restricted conditions (better water circulation leading to lower salinities and temperatures), which permitted development of an active and abundant community of burrowers.

From 18,667 to 18,656 ft the core consists of domal and lesser wavy laminated thrombolite: a microbial (probably cyanobacterial) reef. The reef contains scattered peloids. The overlying strata record destruction of the reef and progradation of a shallow moderate-energy backreef lagoon (18,656 to 18,633 ft). These strata consist of a complex intercalation of thrombolite and mixed-particle grainstone. The grainstone is dominated by peloids (mostly ellipsoidal fecal pellets), but also contains tuberoids, coated grains, ooids, oncoids, gastropods, pelecypods, echinoderm ossicles, fragments of free-living and encrusting forams, calcareous sponges and calcareous algae. Most of these particle types are also incorporated within the thrombolite, which has a matrix of very fine to fine-textured peloid grainstone. The common ooids in this section could not have formed here; they

may have been washed off of the grainstone shoals that developed in the Chunchula field area to the southeast.

These strata are overlain by 1.5 ft of well-sorted pellet dolograins, which is partially replaced by anhydrite. This in turn is overlain by nodular and enterolithic anhydrite that was deposited on a sabkha. Minor microbial laminite and vertically oriented nodular anhydrite record the former presence of ephemeral microbial crusts and brine ponds.

Diagenetic History

The most-obvious diagenetic process to affect this core is partially fabric-selective dolomitization. This affected the lower part of the core, and occurred fairly early during burial. The uppermost part of the carbonate section was penecontemporaneously dolomitized by hypersaline fluids associated with development of the overlying sabkha. Minor dissolution of allochems was followed by dolomite cementation in vugs and shelter pores; most of these pores were later occluded by anhydrite cement. Anhydrite nodules scattered through most of the core were probably formed at the same time, under conditions of deep burial, though some exhibit felted-aligned tangential fabric, and could be penecontemporaneous. Widespread stylolitization was another significant deep-burial diagenetic process.

Figure A-30 - Detailed core log, Arco-Gulfcrest Unit 5-2 No. 1 well, Permit No. 5226, Gulf Crest field, Alabama.

Figure A-31 - Structure contour map of the top of the Smackover Formation in the Gulf Crest field, Mobile County, Alabama.
Modified after Alabama Oil and Gas docket number 1-28-885.

Description of core from Harmony field, Clarke County, Mississippi
by Roger Townsend

API # 23-023-20125

Harmony Field
Clarke Co., MS

Masonite Corp. #1 Masonite-Kirkland
20-2N-15E, Clarke Co., MS

QC 12,522-12,570

Core File # C-105.0-.3

Pf: 12,490-12,536 IPF 511 BO, 244 MCFG, 0 BW (38 gty)

Core Description: 12,522-12,570

12,522-43	Lime, tan-gray, ooid grainstone, poor porosity, some laminations
12,544	Lime, tan-gray, crystalline, possible ooid ghosts, laminated
12,545-47	Lime, gray, micro-crystalline, dense, abundant laminations
12,548-49	Lime, tan, crystalline, possible ooid ghosts, some laminations
12,550-53	Lime, gray, ooid grainstone, fossils, some laminations
12,554-59	Lime, gray, ooid packstone, crystalline, fossils
12,560	Lime, gray, micritic, crystalline, abundant laminations
12,561-63	Lime gray, ooid packstone, fossils, laminations
12,564-66	Lime, gray, dense, micritic, mottled with nodular anhydrite
12,567-68	Lime, gray, ooid grainstone, dense
12,569-70	Lime, gray, ooid packstone, fossils, abundant bioturbation

GRAIN SIZE/ENERGY FROM TOP TO BOTTOM:

12,522-544	Grainstone, high energy
12,545-547	Mudstone, low energy
12,548-553	Grainstone, high energy
12,554-559	Packstone, moderate energy
12,560	Mudstone, low energy
12,561-563	Packstone, moderate energy
12,564-566	Mudstone, low energy
12,567-568	Grainstone, high energy
12,569-570	Packstone, moderate energy

Figure A-32 - Structure contour map of the top of the Smackover Formation in the Harmony field, Clarke County, Mississippi. Modified from Davis and Lambert (1963).

Figure A-33 - Structure contour map of the top of the Smackover Formation in the South Harmony field, Clarke County, Mississippi. Modified from Davis and Lambert (1963).

Depositional and diagenetic histories of Smackover Formation based on core from Getty
Hatters Pond Unit 10-3 #1 well, Permit No. 6846
Hatter's Pond field, Mobile County, Alabama
by David C. Kopaska-Merkel

Depositional history

Smackover deposition in this well began as Smackover seas transgressed over and reworked Norphlet sand. Deposition progressed from Norphlet foreshore and shoreface sand deposits to Smackover subtidal and intertidal carbonate deposits, represented by horizontal microbial laminae. Possible ooids and/or peloids occur in these laminae, probably washed up from nearby subtidal areas during high tides or storms. As transgression continued, a 2.5-foot thick layer of ooid shoals spread across the microbial laminae, representing a brief change from low- and moderate-energy to high-energy conditions. These shoal deposits are overlain by about 20 ft of microbial domal thrombolite, with a particle-supported matrix of ooids and peloids, probably deposited in a moderate-energy lagoon. These microbial boundstone and ooid shoal deposits, extending from the base of the Smackover to 18,131 ft, comprise lithofacies 1.

The microbial boundstone is in turn overlain by low to moderate energy peloidal wackestone to packstone (18,086-18,131 ft), indicative of calmer, deeper water. This is lithofacies 2 and is probably predominantly a wackestone, but intense dolomitization has made it difficult to discern textures. Small (1-3 sq. in.) areas of possible solution breccia are scattered throughout the facies, except they are absent from the basal 13 ft. Displacive anhydrite nodules are associated with these patches and it is possible that these breccia zones were caused by dissolution of anhydrite nodules. The occurrence of these nodules suggests increased salinity, possibly due to reduced circulation caused by seaward shoals.

As the transgression of Smackover seas continued, the lagoonal wackestone of lithofacies 2 was covered initially by shoal-margin grainstone containing pelecypod bioclasts and grapestone. Some cross-bedding is apparent and indicates intermittent high-energy pulses in a

moderate-energy setting. This interval is only about two ft thick (there is one foot of core missing at its base) and is superposed by a one-foot thick interval of high-angle cross-bedded ooid peloid grainstone. The cross beds indicate the progradation of dunes in a high-energy environment. Immediately overlying these strata is an ooid grainstone 2.5 ft thick that is partially microbially bound. Ooids are probably mixed with peloids. The ooid grainstone is overlain by a 3.5 foot thick breccia zone. Breccia fragments are composed of the same lithology as the ooid grainstone below. Subaerial exposure is indicated by the rounding of breccia fragments and the occurrence of solution pipes. Part of the brecciated interval consists of an intraclastic grainstone. The breccia zone is overlain by a subtidal thrombolitic microbial boundstone containing oncoids, peloids and ooids. Microbial influence on deposition quickly diminished and the boundstone is succeeded by an oncoid-bearing, peloid, ooid grainstone with minor influence from microbial binding. This grainstone continues, with a varying amount of microbial influence, for about 11 ft (There is about 1.5 ft of missing core in this interval.), and is overlain by seven ft of ooid grainstone. This is in turn overlain by another microbial boundstone that has been brecciated with fractures filled by anhydrite, probably representing another period of exposure. Above that there is about 0.5 ft of peloidal grainstone with some ooids. This completes lithofacies 3, which is predominantly an ooid shoal and shoal-margin facies, and spans the interval from 18,052 to 18,086 ft. Above that there is 7 ft of missing core.

All Smackover strata above the 7 ft of missing core are nonreservoir. The lowest interval above the missing core is 16 ft of heavily stylolitized, subtidal, slightly dolomitized, peloid packstone containing some ooids. This is overlain by about 1.5 ft of high-energy shallow subtidal, oncoid-bearing, peloid ooid intraclast grainstone, which is in turn overlain by intertidal to supratidal, bioclast-bearing, peloid packstone. Above that is a microbial boundstone containing fenestral porosity and desiccation cracks, which indicate exposure. A paleosol

containing caliche glaebules overlies the microbial boundstone and is in turn succeeded by at least a foot of microbial boundstone overlain by 3.5 ft of missing core.

Above the 3.5 ft of missing core are about 3.5 ft of bioclast- and oncoid-bearing, ooid, and possibly intraclast grainstone, possibly washover deposits. Above this is about a foot of microbial boundstone containing pisolites. That is succeeded by about 8 ft of fossil peloid wackestone to packstone containing rip-up clasts and probable oncoids, probably deposited in a shallow lagoon that was subjected episodically to storms. At one point in this facies there is a half-foot layer of nodular anhydrite indicating a short period of increased salinity. The low-energy lagoonal strata are overlain by nodular anhydrite of displacive and replacive origin, again indicating increased salinity.

Diagenetic history

Intense dolomitization of the original CaCO_3 was the dominant process from 18,155 ft at the base of the Smackover, to approximately 18,052 ft. Seven ft of missing core separates this dolomite from 40 ft of limestone. The top seven ft of the Smackover, which overlies the limestone, is also intensely dolomitized. The Smackover is conformably overlain by the Buckner Anhydrite.

Although the original fabric of the lower dolostone is highly altered, it is commonly possible to make facies designations and to some extent understand the early diagenesis. The first diagenetic events were micritization of ooids that were washed into low energy mud-rich settings and lithification of soft pellets. Compaction of lime mud also occurred soon after deposition. Grapestone formed adjacent to ooid shoals in moderate-energy settings. In grainstone facies isopachous rim cement formed penecontemporaneously mostly in a marine phreatic environment. Dissolution of framework grains probably began soon after cementation, as did dolomitization. The cement was dolomitized as were surviving framework grains.

Dolomite crystals generally range in size from 20 to 80 micrometers where replacing framework grains and from 50 to 150 micrometers where they grew into pore space. Dolomite crystals are slightly smaller in the wackestone facies, ranging from 10 to 70 micrometers for replacement dolomite.

Anhydrite as well as dolomite cement formed in the grainstone facies. Oomolds are commonly filled with anhydrite cement. In the wackestone facies, anhydrite occurs as displacive nodules indicating penecontemporaneous intrasediment growth. Nodules are often lens-shaped, indicating that they are gypsum pseudomorphs; and there are no inclusions, which might indicate replacement. Precipitation of gypsum implies that salinity must have been elevated to nearly four times normal marine salinity. The environment, which is interpreted to have been lagoonal, must have been highly restricted at times. Later, anhydrite replaced dolomite as evidenced by dolomite inclusions within anhydrite nodules. These nodules commonly occur preferentially inside possible oncoids. Brecciation is associated with some of these anhydrite nodules indicating later dissolution of anhydrite. Brecciation in the wackestone facies is interpreted to have occurred during burial diagenesis. There is one case of brecciation in boundstone-grainstone strata that overlie ooid peloid grainstone. Some breccia fragments have been slightly rounded indicating reworking. Isopachous cement occurs around many fragments. The dominant porosity is vuggy, possibly due to meteoric dissolution.

Stylolites are common in all facies, but are most common in the wackestone facies. Anhydrite cement occurs within gaps in the vertical parts of stylolites. Vertical fractures occur sporadically and are typically filled with anhydrite cement and less commonly with baroque dolomite.

The overlying limestone is from 0 to 40 percent dolomitized. The fabric begins with peloid, ooid, oncoidal, and intraclastic packstone, and grainstone and bioclasts are also common.

The rock is virtually tight with original porosity plugged by calcite and minor dolomite and anhydrite cement. The first generation of cement is a thin isopachous rim followed by sparry calcite filling the rest of the pore spaces. Interparticle porosity is minor as is vuggy porosity.

Above this is a microbial boundstone with fenestral and sheet-crack plugged porosity. These pores are lined with a rim of isopachous cement, probably originally aragonitic, and a later isopachous rind of dolomite cement. The rest of these large pores are filled with either calcite or anhydrite cement. Much of the original anhydrite cement has been replaced by calcite. Desiccation cracks and sheet cracks are associated with the fenestral porosity.

Above the boundstone is a paleosol. In this zone are light gray glaebules of microcrystalline low-magnesian calcite. The glaebules are surrounded by dark gray blocky sparry calcite. Randomly distributed interglaebule pores were plugged by first a rind of isopachous dolomite cement and then by blocky sparry calcite cement. Also associated with this paleosol are small karst features. Dissolution has created an irregular erosional topography in sharp contact with overlying microbial laminae.

Pisoids occur throughout much of this limestone. These pisoids have isopachous cortical laminae that alternate between calcite and dolomite. They are inferred to be replacive in origin.

The last 7 ft of the top of the Smackover is composed of finely crystalline dolomite in which the original fabric was highly altered but not destroyed. The dolomite has replaced microbially influenced grainstone composed of peloids, intraclasts, oncoids, and bioclasts. A thin zone of fenestral porosity occurs. Pores are plugged by a CaCO_3 rim cement, followed by an isopachous dolomite cement, and anhydrite which has been partially replaced by calcite. This dolomite has many fractures filled by anhydrite cement. Nearly all of this dolomite zone is virtually tight with original porosity occluded. A minor amount of particle moldic porosity has survived. Anhydrite nodules occur in increasing amounts toward the overlying Buckner

Anhydrite Member of the Haynesville Formation, suggesting reflux dolomitization from Buckner brines.

Figure A-34 - Detailed core log, Hatters Pond Unit 10-3 No. 1 well, Permit No. 6846, Hatters Pond field, Alabama, upper part of core.

Figure A-35 - Detailed core log, Hatters Pond Unit 10-3 No. 1 well, Permit No. 6846, Hatters Pond field, Alabama, lower part of core.

Depositional and diagenetic histories of Smackover Formation based on core from Four
Star Hatter's Pond Unit 21-7 No. 2 well, Permit No. 10361
Hatter's Pond-Gas Field, Mobile Co., Alabama. Core number X-1682.
by David C. Kopaska-Merkel

Depth intervals: 18,277 to 18,406, 18,410 to 18,419, 18,430 to 18,463, 18,490 to 18,530 ft.

Thin sections: None.

General information: This core includes partial sections of the Norphlet Formation and the basal Smackover Formation.

Lithostratigraphic unit(s): Norphlet Formation and Smackover Formation.

Lithofacies: The lower 51.9 m (170.3 ft) of this core (18,359.7 to 18,530 ft) consist of fine to coarse cross-stratified sandstone assigned to the Norphlet Formation. Cross-strata are thicker than about 0.15 m (0.5 ft). The actual bed-set thickness is unknown; however, three thick depositional units are indicated by three cycles that fine upward from poorly sorted fine to coarse sandstone to well sorted fine sandstone. The partial lower cycle (about 26 meters or 84 ft in thickness) extends from the base of the core to about 18,446 ft, the complete middle cycle (about 19 meters or 61 ft in thickness) extends from about 18,446 ft to about 18,385 ft, and the partial upper cycle (about 8 meters or 25 ft in thickness) extends from about 18,385 to 18,359.7 ft. The relatively coarse and poorly sorted sandstone at the base of the middle cycle is characterized by low-angle cross strata that abruptly overlie fine high-angle cross strata of the uppermost part of the lower cycle. The basal portion of the upper cycle contains only traces of cross stratification. The sandstone is highly porous (at least 20 percent), and most porosity is filled with black, solid, hydrocarbon residue. Traces of pyrite occur at many horizons and consist of sand-size clusters of microcrystalline and silt-size crystals, as well as silt- and sand-size imperfect cubic crystals. Dolomite and silica cement in cross strata ranging from about a millimeter to about a centimeter in thickness exclude hydrocarbons from these layers, which are relatively impermeable and consequently light in color.

This unit is overlain by fine to medium laminated sandstone, the uppermost part of the Norphlet Formation (18,349.8 to 18,359.7 ft). This unit contains ripple-form laminae and fine to medium sand size black flat detrital fragments.

The Norphlet/Smackover contact in this core is gradational over about 0.49 m (1.6 ft). This transitional interval consists of sandy dolostone and is assigned to the Smackover Formation. The unit consists of intercalated sand-rich and sand-poor laminae; overall, the abundance and size of sand grains decrease upward. The unit also contains ripple cross-laminae and syndepositional fractures with throw on the order of 1 mm. Dolomite crystals are microcrystalline to fine silt size and crystal form is unknown.

The Smackover Formation in this core is divided into three lithofacies. Lithofacies 1 corresponds to the interval from 18,342.5 to 18,349.8 ft (including the Norphlet/Smackover transitional interval) and is 2.2 m (7.3 ft) thick. The unit is

dominated by silt-size dolostone. Lithofacies 2 corresponds to the interval from 18,304 to 18,342.5 ft and is 11.7 m (38.5 ft) thick. This unit consists of a highly altered (and entirely dolomitized) sponge-microbial mound. Lithofacies 3 corresponds to the interval from the top of the core to 18,304 ft and is 8.2 m (27 ft) thick. This unit consists of anhydritic silt size to very fine dolostone that preserves little or no primary fabric.

Lithofacies 1 (2.2 m; 7.3 ft) is a transitional facies from the siliciclastic uppermost Norphlet to the overlying carbonate strata of the Smackover Formation. The basal 0.49 m (1.6 ft) consists of sandy dolostone. The unit consists of intercalated sand-rich and sand-poor laminae; overall, the abundance and size of sand grains decrease upward. The unit also contains ripple cross-laminae and syndepositional fractures with throw on the order of 1 mm. Dolomite crystals are microcrystalline to fine silt size and crystal form is unknown. Overlying the transition zone are 1.4 m (4.5 ft) of silt size laminated to medium bedded dolostone. Thin sandy laminae (no more than 15 percent sand) in the lower to middle part of this interval give way in the upper part to dolostone containing only scattered sand particles. The uppermost part of lithofacies 1 consists of crinkly laminae overlain by irregular laminae that are internally clotted. Porosity in lithofacies 1 is nil; the unit is devoid of calcium carbonate.

Lithofacies 2 (11.7 m; 38.5 ft) is dominated by dolostone exhibiting highly altered fabrics. The lower part of the unit (up to 18,328 ft) is thinly laminated to thin bedded; stratal surfaces are undulatory or uneven and probable erosion surfaces with up to 3 cm of relief were observed between 18,330 and 18,331 ft. Within laminae, the fabric appears to be a vuggy or moldic peloid grainstone, in which particles ranging in size from fine to very coarse are commingled. Much of the rock contains no evidence of particles, and faintly visible surfaces that do not approximate the horizontal are observable throughout the interval; concentric laminae or cauliflower-like shapes are locally recognizable. Preservation is poor, but gastropods, oncoids, and calcareous sponges (ovoid porous patches 3 to 6 cm long containing regular patterns of equant, elongate, or branching openings, lined with white dolomite cement, and 150 to 300 μ m in diameter) have been tentatively identified. The upper part of the unit is thin to thick bedded but intrastratal fabrics are similar to those in the lower part of lithofacies 2. Between 18,323 and 18,324 ft is a 1.5 cm thick brecciated layer of microcrystalline nonporous dolostone. Particles include bivalves, possible cephalopods, sponges, oncoids, and gastropods. Between 18,310 and 18,311 ft a cluster of 1-mm diameter tubules may represent a sponge different from others observed in this core. The uppermost 1.2 m (4 ft) of the unit contain possible horizontal fenestrae lined with dolomite cement.

Matrix dolomite in lithofacies 2 is planar-e, and chiefly of very fine sand size. Cavities are either lined with fine sand size planar-e dolomite cement or with extremely fine pyrite. Some cavities are partly filled with fine to medium dolomite, as well as lesser microcrystalline and silt size pyrite and very coarse sprays of anhydrite; a few voids in the upper part contain fine to medium saddle dolomite. Minor quartz cement in fractures predates dolomite cement. A trace of coarse blocky calcite cement in vugs in the upper part of lithofacies 2 postdates other cement phases and is the only calcium carbonate in the unit. Porosity in lithofacies 2 ranges from about 10 to 25 percent in the lower part to 15 to 40 percent in the upper part.

It should be emphasized that lithofacies 2 is highly altered, and that inferences about its depositional fabric and faunal composition must be considered tentative.

Lithofacies 3 (8.2 m, 27 ft) consists of massive anhydritic microcrystalline to silt size dolostone. Anhydrite is dominated by white displacive nodules of very fine loaves or of very coarse to extremely coarse laths, some felted, but also includes clear cement laths in fractures. Porosity in this facies averages about 10 percent.

Depositional Environment: The sandstone in the lower part of the core, assigned to the Norphlet Formation, consists chiefly of large-scale cross strata with coarser tangential bases. This interval is interpreted record deposition in an eolian dune field. The uppermost Norphlet consists of laminated sandstone containing ripple-form laminae and black detrital flakes. These strata may have been reworked on a tidal flat during the end-Norphlet transgression.

A thin sandy dolostone forms a transition from the siliciclastic Norphlet to the overlying carbonate Smackover Formation, and is assigned to the Smackover Formation. The alternation of sand-rich and sand-poor laminae in this interval suggests a tidal influence (supported by the presence of ripple cross-laminae) but there is no evidence of subaerial exposure. The transition interval grades up into slightly sandy laminated dolostone in which the abundance of sand decreases upward. The two units together record progressive burial of palimpsest Norphlet sands. The basal Smackover strata are interpreted as subtidal marine and may record the deepest paleowater depth of the core.

Overlying the sandy dolomite is a 12 m (40 ft) thick carbonate mound. The basal part of the mound is a thin unit of microbial laminite in which crinkly stromatolite is overlain by irregularly laminated clotted thrombolite. Most of the mound consists of highly altered dolostone that is interpreted as sponge-bearing microbially bound mixed-particle peloid grainstone or packstone. Well preserved microbial boundstone successions commonly contain units consisting of microbially bound grainstone or packstone. Examples from Smackover cores in Alabama are dominated by peloids, ooids, oncoids, or all three (e.g., Permit No. 6846, Hatter's Pond Unit 10-3 No. 1 well, Hatter's Pond Field, Mobile County, Alabama, described by S. D. Mann in Kopaska-Merkel and others, 1992; Permit No. 2769, Wilson Unit 30-12-A No. 1 well, wildcat, Washington County, Alabama, 12,307.8 ft, described by Kopaska-Merkel, 2000, p. 124; and Permit No. 1599, B. C. Quimby 27-15 No. 1 well, Vocation field, Monroe County, Alabama, basal portion of core, described by Kopaska-Merkel and others, 1992). The co-occurrence of non-gravitational stratification, calcareous sponges (which in the Alabama Smackover are nearly restricted to mound settings), and inferred relict grainstone in the Hatter's Pond Unit 21-7 No. 2 core indicates that the mound penetrated in this core was dominated by grainy boundstone. This inference is further supported by a similar interpretation of a section in another core in the same field (S. D. Mann in Kopaska-Merkel and others, 1992). Possible horizontal fenestrae in the upper part of the mound succession in the Hatter's Pond Unit 21-7 No. 2 core suggests a peritidal setting. Overlying anhydritic dolostone is tentatively interpreted as a tidal-flat deposit because it overlies peritidal boundstone and contains displacive anhydrite nodules.

Diagenetic History: In this section only diagenesis of the Smackover Formation is discussed.

Displacive anhydrite nodules formed syndepositionally in lithofacies 3 and syndepositional microgrowth faulting provide the only visible evidence for penecontemporaneous diagenesis in this core.

The two most obvious diagenetic processes that affected the Smackover core from this well are dolomitization and dissolution. At least three episodes of dolomitization and two of dissolution are indicated. Matrix dolomite pervasively replaced calcium carbonate in this core. Subsequently or synchronously, dissolution of relict calcium carbonate generated numerous molds and vugs, which were later lined by white very fine planar-e dolomite cement. Fenestrae are lined with the same dolomite phase. Burial diagenesis included stylolitization and associated fracturing, as well as formation of high-angle long fractures not associated with stylolites. Many fractures, showing no evidence of dissolutional enlargement, are occluded by anhydrite and dolomite cement, which is inferred to have precipitated not long after the fractures opened. Some of these fractures also contain silica cement which, where present, is the earliest cement phase. This fracture-filling dolomite may be synchronous with the pore-lining dolomite. A second episode of dissolution removed relict calcium carbonate from the partially dolomitized matrix, leaving dolomite vug and mold linings "floating" in a highly porous brown dolomite matrix; some fractures were dissolutionally enlarged at this time. Pyrite and anhydrite cement and minor saddle dolomite cement partially filled voids lined with early dolomite cement as well as some second-generation nonlined voids. Blobby anhydrite nodules composed of very fine loaves are probably syndepositional, but later formation of anhydrite is indicated by common anhydrite cement. Anhydrite nodules consisting of extremely coarse clear laths may be alteration products of early nodules, but some have boundaries formed by the termini of large anhydrite laths and therefore either formed late or were enlarged late. Minor calcitization of anhydrite nodules consisting of extremely coarse clear laths in the upper part of the core may have occurred relatively late.

Figure A-36. Graphic core log of Permit No. 10361 well, Four Star Hatter's Pond Unit 21-7 No. 2, Hatter's Pond Field, Mobile Co., Alabama--detailed core log, lower part.

Figure A-37--detailed core log, lower-middle part.

Figure A-38--detailed core log, upper-middle part.

Figure A-39--detailed core log, upper part.

Figure A-40--summary graphic core log and digitized geophysical logs.

Figure A-41 - Structure contour map of the top of the Smackover Formation in the Hatter's Pond field, Mobile County, Alabama. Modified from Bolin et al. (1989).

Figure A-42 - Structure contour map of the top of the Smackover Formation in the Healing Springs field, Washington County, Alabama. Modified from Bolin et al. (1989).

Figure A-43 - Structure contour map of the top of the Smackover Formation in the Horseshoe Lake field, Humphreys and Holmes Counties, Mississippi. Modified from Galicki (1983).

Description of core from Johns field, Rankin County, Mississippi
by Roger Townsend

API # 23-121-20087

Johns Field
Rankin Co., MS

Tomlinson Interest #1 Caley Jones
33-4N-5E, Rankin Co., MS

QC 19,034-19,091

Core Chips File # C-589.0

Pf: 18,795-18,810 IPF 7,850 MCFG

Core Description: 19,034-19,091

19,034-72	Sandstone, dark gray-black, quartz sand, fair porosity
19,073-74	Sandstone, dark gray-black, laminated, lime cement
19,075-91	Sandstone, dark gray-black, laminated, dolomitic, tight, fine grained

No carbonate rocks to describe

Figure A-44 - Structure contour map of the top of the Snackover Formation in the Johns field, Rankin County, Mississippi. Modified from Galicki (1983).

Description of core from Lake Como field, Jasper County, Mississippi
by Roger Townsend

API # 23-061-20173

Lake Como Field
Jasper Co., MS

Texas Pacific Oil #1 Hayes
4-1N-11E, Jasper Co., MS

CC 16,375-16,980

Core File # C-11.0-.4

Pf: 17,044-072 Smk "B" IPF 75 BO, 86 MCFG, 17 BW (46 gty)

Pf: 16,374-632 Smk "A" IPF 1375 BO, 1,800 MCFG, 0 BW (46 gty)

Core Description: core chips 16,375-16,980

16,375-91	Sandstone, gray, fine grained, lime matrix, poor porosity
16,392-434	Sandstone, gray, fine grained, lime matrix, fair inter-granular porosity
16,435	Sandy limestone, gray, micritic, dense, no porosity
16,436-51	Limestone, gray, dense, crystalline, no porosity, some calcite crystals
16,452	Limestone, dolomitic, gray, dense, micritic, no porosity
16,453-57	Sandstone, gray, very fine grained, dolomite matrix,
16,458-62	Dolomite, gray, dense, no porosity
16,463-73	Sandstone, gray, fine grained, dolomite matrix, fair porosity
16,474	Sandy limestone, gray, micritic, dense, poor porosity
16,475-76	Limestone, gray, micritic, dense, no porosity
16,477-98	Limestone, light gray, ooid grainstone, dolomite grains in lime matrix
16,499-16,899	No core
16,900	Sandstone, light gray, lime matrix, dense, no porosity
16,901-908	No core
16,909-31	Sandstone, gray, fine grained sand in dolomite matrix, very poor porosity
16,932	Dolomite, black, dense, micritic, no porosity
16,933-43	Sandstone, gray, fine grained sand in dolomite matrix, very poor porosity
16,944-45	Dolomite, gray, dense w/ abundant sand grains, very poor porosity
16,946-47	Dolomite, black, dense, micritic
16,948-50	Limy dolomite, black, dense, micritic
16,951-60	Limestone, black, dense, micritic
16,961	Dolomite, tan, dense, micritic, some anhydrite
16,962-64	Sandy dolomite, gray, dense, micritic, some anhydrite
16,965	Limy dolomite, gray, dense, micritic, some anhydrite
16,966-80	Limestone, black, dense, micritic, some anhydrite

GRAIN SIZE/ENERGY FROM TOP TO BOTTOM:

16,375-435	Sandstone in lime matrix
16,436-452	Limestone, dense, micritic, low energy
16,453-457	Sandstone in dolomite matrix
16,458-462	Dolomite, dense, micritic, low energy
16,463-474	Sandstone in dolomite matrix
16,475-476	Limestone, dense, micritic, low energy
16,477-498	Limestone, ooid grainstone, low energy
16,900	Sandstone in lime matrix
16,909-943	Sandstone in dolomite matrix
16,944-980	Lime and Dolomite, dense, micritic, low energy

Description of core from Lake Utopia field, Jasper County, Mississippi
by Roger Townsend

API # 23-061-20140

Lake Utopia Field
Jasper Co., MS

Amoco Prod. Co. #1 Phillips Unit 1-4
1-1N-13E, Jasper Co., MS

QC 14,799.5-14,814

Core File # C-224.0-.2

Pf: 14,780-14,792 IPP 101 BO, 13 BW (37.1 gty)
Treat 14,780-14,792 IPF 332 BO, 94 MCFG, 0BW (36 gty)
Made XWDW @ 6456-6506

Core Description: 14,799-14,844

14,799-807	Sandstone, tan-brown, massive, fine grained, friable, fair porosity
14,808-11	Sandstone, tan-gray, fine grained, poor porosity, thin shale laminae
14,812-22	Sandstone, tan-brown, massive, fine grained, friable, fair porosity
14,823-25	Sandstone, dark gray-black, very asphaltic
14,826-44	Dolomite/anhydrite, black-buff, heavily fractured &/or bioturbated

Figure A-45 - Structure contour map of the top of the Smackover Formation in the Lake Utopia, Prairie Branch, Nancy, and East Nancy fields, Clarke and Jasper Counties, Mississippi. Modified from Jackson and Harris (1982).

Depositional and diagenetic histories of Smackover Formation based on core from Tims
8-2 No. 1 well, Permit No. 2463
Little Mill Creek field, Choctaw County, Alabama
by David C. Kopaska-Merkel

Depositional History

The lower part of this core (base to 12,390 ft; lithofacies 2) was probably deposited in a tidal inlet. The core consists of pelletal ooid dolograins; the dominant sedimentary structure is planar-tabular cross-bed sets. Ripple cross laminae, planar laminae, and trough cross beds are also present. There is no evidence of exposure, but there is evidence of penecontemporaneous soft-sediment faulting.

In the upper part of the core (lithofacies 1), the sediment is coarser and better sorted, consisting primarily of ooid dolograins. Bedding is almost entirely absent, which is interpreted as the result of sediment remobilization by mass-movement processes that would have destroyed lamination or cross-lamination. These strata are interpreted to record filling of the tidal inlet.

The uppermost foot of core is very well sorted laminated ooid dolograins containing outsize interparticle pores interpreted as keystone vugs. This may be the deposit of a beach formed on the barrier island that prograded across the inlet.

Diagenetic History

Early pore-lining cementation was followed by dolomitization that was incomplete in some intervals. The nondolomitized material consists of portions of some particles plus pore-filling cement that probably formed after dolomitization. Substantial particle dissolution accompanied dolomitization. This was followed by both brittle and ductile compaction. Certain thin layers have been completely squashed ductilely and are nonporous. Thicker intervals have been extensively shattered brittlely and contain incipient intershard porosity. Later fracturing, resulting in formation of long, subvertical

fractures, was followed by anhydrite cementation and replacement of calcium carbonate by anhydrite. Pyritization of anhydrite was one of the latest diagenetic processes, probably associated with hydrocarbon migration.

Figure A-46 - Detailed core log, Tims 8-2 No. 1 well, Permit No. 2463, Little Mill Creek field, Alabama.

Figure A-47 - Structure contour map of the top of the Smackover Formation in the Little Mill Creek field, Choctaw County, Alabama. Modified from Bolin et al. (1989).

Figure A-48 - Structure contour map of the top of the Smackover Formation in the Loring field, Madison County, Mississippi. Modified from Frascogna (1957).

Depositional and diagenetic histories of Smackover Formation based on core from Trice
6-6 No. 1 well, Permit No. 2145
Mill Creek field, Choctaw County, Alabama
by David C. Kopaska-Merkel

Depositional history

The lower part of the core (12,397-12,404.5 ft) is interpreted to have been deposited on a high-energy shoreface. Pellet ooid, ooid pellet, and minor pellet grainstone exhibit low-angle cross-strata of variable orientation and inclination that are interpreted as hummocky cross-strata. Oncoids, gastropods, bivalves, composite ooids, and well-rounded intraclasts are minor constituents. There is one well-rounded clast of dark inclusion-rich anhydrite, which was probably washed off a nearby sabkha (perhaps on the crest of the Mill Creek field structure).

These strata are overlain by intercalated inferred tidal-flat, beach, and sabkha deposits. Gastropod-bearing ooid oncoid grainstone with lithified and eroded crusts is interpreted as possible tidal-flat deposits, but these strata could have been lithified subaqueously or on a beach. These are overlain by planar-tabular cross-laminated pellet ooid grainstone, laminated pellet grainstone, and trough cross-laminated pellet ooid grainstone, interpreted as beach deposits. Ooid grainstone almost entirely replaced by anhydrite in the form of anastomosed nodules containing coarse clear crystals (sabkha deposit; 12,394 ft) overlies the inferred beach strata. The top part of the core is dominated by ooid grainstone that is massive or low-angle cross-laminated, some containing keystone vugs, interbedded with layers of dark anhydrite formed by replacement of ooid grainstone. Boundaries between these two rock types are diagenetic, not depositional, and some of the carbonate strata are brecciated. These are interpreted as intercalated beach and sabkha deposits. The brecciation suggests dissolution of a highly soluble mineral such as halite, possibly deposited in a salt pan on the sabkha.

Diagenetic history

Early pore-lining cementation was followed by penecontemporaneous lithification (probably submarine) and reworking to form composite ooids and intraclasts. Gypsum crystals grew in the sediment that now forms the upper part of the core (12,391-12,392 ft). This was followed by minor chemical compaction, partial to near-total dolomitization, and dissolution of relict calcium-carbonate. Dolomitization was incomplete in the lower part of the core, and the percent of dolomite increases upward to about 15-30 percent at 12,394 feet. Above this point, some parts of the core are entirely dolomitized (e.g., 12,392.5-12,394 ft) but others contain less than 30 percent dolomite (e.g., 12,391-12,392.5 ft). The upper part of the core (above 12,394 ft), in addition to containing more dolomite, also contains black solid hydrocarbons and locally abundant pyrite in the form of micronodules and small nodules up to about 0.5 inches across. Later diagenetic processes included minor additional dolomitization (timing uncertain but post-dissolution and probably pre-fracturing and stylolitization, because dolomite is neither found in fractures nor clustered along stylolites), stylolitization, fracturing, replacive anhydrite formation and anhydrite cementation (after both fracturing and stylolitization), pyritization and calcitization of anhydrite.

Fabric-selective dolostone may have formed after hydrocarbon migration in Mill Creek field. In this core an oil-water contact is indicated by hydrocarbon staining about 2 feet above a 7-inch layer containing solid bitumen (at 12,390.5 ft). Below this layer most primary interparticle porosity was occluded and secondary intraparticle porosity was abundantly created in slightly (trace to 25 percent) dolomitized limestone. Above the bitumen-bearing layer, dolomitization was complete in some intervals, primary porosity was preserved, and some sulfate was reduced to pyrite (perhaps as a result of oxidation of

hydrocarbons). Because the boundary between dolostone and partially dolomitized limestone is so close to the inferred oil-water contact, significant dolomitization may have followed hydrocarbon migration. Alternatively, the hydrocarbons could have preferentially migrated into already existing dolostone, bypassing the porous but less permeable dolomitic limestone. This alternative is likely because carbonate precipitation is generally thought to be inhibited by the presence of liquid hydrocarbons in the pores.

Figure A-50 - Detailed core log, Trice 6-6 No. 1 well, Permit No. 2145, Mill Creek field, Alabama.

Figure A-53 - Structure contour map of the top of the Smackover Formation in the Mill Creek field, Choctaw County, Alabama. Modified from Bolin et al. (1989).

Figure A-54 - Structure contour map of the top of the Smackover Formation in the Movico field, Baldwin and Mobile Counties, Alabama. Modified from Bolin et al. (1989).

Description of core from Nancy field, Clarke County, Mississippi
by Roger Townsend

API # 23-023-20026

Nancy Field
Clarke Co., MS

Getty Oil Co. #1 Masonite
14-1N-14E, Clarke Co., MS

QC 13,347-13,566

Core File # C-100.0-.17

Pf: 13,452-468 IPF 570 BO, 350 MCFG, 0 BW (33 gty)

Pf: 13,406-425 IPP 49 BO

Core Description: 13,347-13,566

13,347-56	Anhydrite, white-gray, nodular
13,357	Dolomite, buff, dense, micritic, bioturbated, some anhydrite
13,358-63	Anhydrite, white-gray, nodular
13,364-66	Dolomite, buff, dense, micritic, bioturbated, some anhydrite
13,367-75	Anhydrite, white-gray, nodular
13,376-79	Dolomite, buff, dense, micritic, bioturbated, some anhydrite
13,380	Limestone, dark gray, ooid grainstone, fine grained
13,381	Limestone, dark gray, ooid packstone, fine grained
13,382-85	Limestone, gray-tan, dense, micritic, bioturbated, some anhydrite
13,386	Anhydrite, white-gray, nodular
13,387	Dolomite, buff, dense, micritic
13,388-89	Limestone, dark gray, dense, micritic
13,390	Dolomite, buff, dense, micritic, bioturbated
13,391-93	Anhydrite, white-gray, nodular
13,394-98	Dolomite, buff, dense, micritic, bioturbated, some anhydrite
13,399-402	Anhydrite, white-gray, nodular
13,403	Limestone, dark gray, dense, micritic, laminated
13,404	Dolomite, buff, dense, micritic
13,405	Anhydrite, white-gray, nodular
13,406	Limestone, dark gray, dense, micritic
13,407	Dolomite, buff, dense, micritic
13,408	Anhydrite, white-gray, nodular
13,409-10	Limestone, dark gray, dense, micritic
13,411-15	Anhydrite, white-gray, nodular
13,416-17	Dolomite, brown dense, micritic, oil saturated
13,418	Anhydrite, white-gray, nodular
13,419	Limestone, dark gray, dense, micritic, some anhydrite
13,420	Anhydrite, white-gray, nodular
13,421-26	Limestone, dark gray, dense, micritic, some anhydrite
13,427-47	Anhydrite, white-gray, nodular
13,448-51	Sandstone, gray, fine grained, lime matrix, fair porosity

13,452-61	Limestone, gray-tan, ooid grainstone, fine grained ooids, good porosity
13,462-66	Limestone, tan, ooid grainstone, medium grained, fossils
13,467	Limestone, tan, ooid/fossil packstone
13,468-70	Limestone, tan, dense, micritic, no grains, no porosity
13,471-75	Limestone, tan, ooid grainstone, fine-medium grained, fair porosity
13,476-78	Limestone, tan, dense, micritic, no grains, no porosity
13,479	Limestone, tan, dense, ooid packstone, abundant fossils
13,480-82	Sandstone, tan, lime matrix
13,483-96	Limestone, tan, ooid grainstone, fair porosity, some fossils
13,497	Sandstone, gray, fine grained sand in lime matrix
13,498	Limestone, tan, ooid wackestone, dense
13,499-503	Limestone, tan, ooid packstone, dense, ooids and pellets
13,504-06	Limestone, tan, ooid grainstone, medium grained, abundant fossils
13,507-14	Limestone, tan, ooid/fossil grainstone, medium-coarse grained
13,515-16	Limestone, tan, ooid grainstone, medium grained, some anhydrite
13,517-18	Limestone, tan, ooid packstone, poor sorting, some fossils
13,519-39	Limestone, tan, ooid grainstone, fine-coarse grained, poor sorting
13,540-47	Limestone, tan, ooid grainstone, fine grained, good sorting
13,548-49	Limestone, tan, ooid packstone, dense
13,550-52	Limestone, tan, dense, micritic, no grains
13,553-54	Limestone, tan, ooid packstone, dense, poor sorting, some fossils
13,555-56	Limestone, tan, ooid grainstone, very fine grained, fair porosity
13,557-60	Limestone, tan, ooid grainstone, fine-medium grained, some fossils
13,561	Limestone, tan, dense, micritic, no grains
13,562-63	Limestone, tan, ooid grainstone, very fine grained, no fossils
13,564	Limestone, tan, dense, micritic, no grains
13,565-66	Limestone, tan, ooid grainstone, fine-medium grained, poor sorting

GRAIN SIZE/ENERGY FROM TOP TO BOTTOM:

13,347-379	Mudstone & anhydrite, low energy
13,380	Grainstone, high energy
13,381	Packstone, moderate energy
13,382-447	Mudstone & anhydrite, low energy
13,448-451	Sandstone, lime matrix
13,452-466	Grainstone, high energy
13,467	Packstone, moderate energy
13,468-70	Mudstone, low energy
13,471-475	Grainstone, high energy
13,476-478	Mudstone, low energy
13,479	Packstone, moderate energy
13,480-482	Sandstone, lime matrix
13,483-496	Grainstone, high energy
13,497	Sandstone, lime matrix
13,498	Wackestone, low/moderate energy
13,499-503	Packstone, moderate energy
13,504-516	Grainstone, high energy
13,517-518	Packstone, moderate energy
13,519-547	Grainstone, high energy
13,548-549	Packstone, moderate energy
13,550-52	Mudstone, low energy
13,553-554	Packstone, moderate energy
13,555-560	Grainstone, high energy
13,561	Mudstone, low energy
13,562-563	Grainstone, high energy
13,564	Mudstone, low energy
13,565-566	Grainstone, high energy

Figure A-56 - Structure contour map of the top of the Smackover Formation in the East Nancy field, Wayne County, Mississippi. Modified from Davis and Lambert (1963).

Figure A-57 - Structure contour map of the top of the Smackover Formation in the North Choctaw Ridge field, Choctaw County, Alabama. Modified from Bolin et al. (1989).

Description of core from North Hiwannee field, Wayne County, Mississippi
by Roger Townsend

API # 23-153-20240

North Hiwannee Field
Wayne County, MS

Inexco Oil Co. #1 Bishop-Cooley
21-10N-7W, Wayne Co., MS

QC 14,620-15,678

Core File # C-612.0-.19

Pf:15,604-15,680 Norphlet IPF 600 BO, 1,200 MCFG (45.2 gty)

Core Description: 14,620-15,678

14,620-28	Limestone, dark gray, mudstone, dense, laminated
14,629-30	Anhydrite, gray-white, nodular
14,631-55	Limestone, dark gray, mudstone, dense, laminated
14,656-63	Anhydrite, gray-white, nodular
14,664-71	Limestone, dark gray, mudstone, dense, laminated
14,672-80	Anhydrite, gray-white, nodular
14,681-15,532	No core
15,533-36	Dolostone, tan-brown, sucrosic, oil stained, no grains
15,537-40	Missing
15,541-85	Shale, dark gray, thinly laminated
15,586-93	Sandstone, tan, medium grained, friable, good porosity
15,594-600	Missing
15,601-02	Sandstone, tan, medium grained, friable, good porosity
15,603-15	Siltstone, light gray, sandy, tite, bioturbated, cross-bedded
15,616-22	Sandstone, light gray, fine grained, cross-bedded, very clean
15,623-28	Sandstone, light gray, fine grained, bioturbated
15,629-62	Sandstone, light gray, very fine grained, some cross bedding
15,663-78	Sandstone, pink-red, very fine grained, some cross-bedding & mica

GRAIN SIZE/ENERGY FROM TOP TO BOTTOM:

14,620-680	Haynesville Formation, low energy, evaporitic
15,533-536	Dolostone, no indication of grains or energy
15,541-585	Shale, low energy
15,586-678	Sandstones & Siltstones, no carbonate rock to describe

Description of core from North Shubuta field, Clarke County, Mississippi
by Roger Townsend

API # 23-023-20208

North Shubuta Field
Clarke Co., MS

Exchange Oil & Gas # 1 Evans
35-1N-15E, Clarke Co., MS

QC 14,207-14,918

Core File # C-198.0-.14

Pf: 14,197-224, 240-253,257-266 IPF 780 BO, 900 MCFG, 0 BW (43.8 gty)

Core Description: 14,207-14,345

14,207-08	Limy Dolomite, Gray to buff, very fine grained, crystalline, pelloidal packstone
14,209	Dolomite, Tan, very fine grained, crystalline, pelloidal grainstone with oomoldic porosity
14,210-11	Limy Dolomite, Gray to buff, very fine grained, crystalline, pelloidal mudstone with stylolites
14,212	Dolomite, Gray to buff, very fine grained, crystalline, mudstone with micro porosity and some vuggy porosity
14,213-14	Dolomite, Gray, very fine grained, crystalline, ooid packstone with abundant vuggy porosity
14,215-22	Limy Dolomite, Gray to buff, crystalline, ooid grainstone with abundant vuggy porosity, ooids are larger with depth
14,223-25	Limy Dolomite, Gray to buff, crystalline, grainstone with inter-bedded fine and coarse grained oolites, some stylolites
14,226-34	Limy Dolomite, Gray to buff, ooid grainstone fining upward from medium-coarse oolites at bottom to very fine oolites at top with poor to good inter-granular porosity
14,235	Limy Dolomite, Gray to buff, crystalline, ooid grainstone, some bedding of poorly sorted grains, no porosity
14,236-40	Limy Dolomite, Tan, very fine grained, crystalline, poor micro-crystalline porosity
14,241	Limy Dolomite, Tan, crystalline, no grains, no porosity
14,242-43	Limy Dolomite, Tan, crystalline, very fine grained grainstone with poor micro-crystalline porosity
14,244-46	Limy Dolomite, Tan, crystalline, no grains, no porosity
14,247-50	Limy Dolomite, Tan, crystalline, oolitic grainstone that coarsens downward with poor inter-granular porosity, some asphalt
14,251	Limy Dolomite, Gray to tan, crystalline, no grains, no porosity
14,252	Limy Dolomite, Gray to tan, crystalline, very fine grained oolitic grainstone with no porosity
14,253	Limy Dolomite, Tan, crystalline, poorly sorted fine to coarse grained oolitic grainstone with no porosity

14,254	Limy Dolomite, Tan, crystalline, no grains inter-crystalline porosity
14,255-57	Limy Dolomite, Tan, crystalline, Very fine grained oolitic grainstone with inter-granular porosity
14,258-59	Limy Dolomite, Gray to tan, crystalline, no grains, no porosity, dense, possible ooid "ghosts"
14,260-65	Limy Dolomite, Gray to tan, poorly sorted fine to coarse grained grainstone with poor to fair inter-granular and inter-crystalline porosity
14,266-67	Limy Dolomite, Tan, very fine grained, crystalline with ooid "ghosts", no porosity
14,268-70	Limy Dolomite, Tan, poorly sorted ooid packstone, very poor to no porosity
14,271	Limy Dolomite, Tan, crystalline, no grains, no porosity, dense
14,272-73	Limy Dolomite, Tan, crystalline, poorly sorted ooid grainstone, dense with no porosity
14,274	Limy Dolomite, Gray to tan fine grained ooid grainstone with poor porosity
14,275-77	Limy Dolomite, Tan, crystalline, very small grains, no porosity, dense
14,278	Limy Dolomite, Tan, very fine grained ooid grainstone, poorly sorted, poor inter-granular porosity
14,279-81	Limy Dolomite, Gray to tan, crystalline, ooid grainstone, no porosity
14,282	Limy Dolomite, Tan, crystalline, very fine ooid "ghosts", no porosity
14,283-89	Limy Dolomite, Tan, crystalline, poorly sorted fine to coarse grained ooid grainstone with no porosity
14,290-304	Limy Dolomite, Tan, crystalline, wackestone, no porosity, dense, occasional anhydrite nodules and stylolites
14,305-345	Limy Dolomite, Tan, micro-crystalline, mudstone, no porosity, dense micrite mud with occasional anhydrite and stylolite

GRAIN SIZE/ENERGY FROM TOP TO BOTTOM:

14,207-212	Fining upward from grainstone to mudstone, decreasing energy
14,213-221	Grainstone, onkoid, high energy
14,222-235	Grainstone, interfingering onkoid/ooid, high energy
14,236-248	Grainstone, ooid, high energy
14,249-286	Grainstone, interfingering onkoid/ooid, high energy
14,287-289	Packstone, onkoid, moderate energy
14,290-303	Wackestone, low to moderate energy
14,304-326	Mudstone, some anhydrite, low energy
14,327-345	Mudstone and Wackestone, low energy

Figure A-58 - Structure contour map of the top of the Smackover Formation in the Shubuta and North Shubuta fields, Clarke County, Mississippi. Modified from Davis and Lambert (1963).

Figure A-59 - Structure contour map of the top of the Smackover Formation in the Pace Creek field, Clarke County, Alabama. Modified from Bolin et al. (1989).

Description of core from Pachuta Creek field, Clarke County, Mississippi
by Roger Townsend

API # 23-023-20627

Pachuta Creek Field
Clarke Co., MS

McCormick Operating Co. #1 McCleod Est.
31-2N-15E, Clarke Co., MS

QC 13,000-13,040

Core File # C-699.0-.3

Pf: 12,956-998 IP Swb 240 BO, 10 BW (33.4 gty)

Core description: 13,000-13,040

13,000-03	No recovery
13,004-11	Lime, tan-gray, ooid grainstone, well sorted, fining up, fossils
13,012-17	Missing core
13,018-19	Lime, tan-gray, ooid grainstone, medium grained, fossils
13,020-22	Lime, tan-gray, ooid grainstone, fine grained, no fossils
13,023-24	Lime, tan-gray, ooid grainstone, medium grained
13,025-27	Lime, tan-gray, ooid grainstone, coarse grained
13,028-32	Lime, tan-gray, ooid grainstone, medium grained
13,033-40	No recovery

GRAIN SIZE/ENERGY FROM TOP TO BOTTOM:

13,003-032 Grainstone interfingering fine-coarse grained, high energy

Figure A-60 - Structure contour map of the top of the Smackover Formation in the Pachuta Creek field, Clarke County, Mississippi. Modified from Weber (1980).

Figure A-61 - Structure contour map of the top of the Smackover Formation in the Pickens field, Yazoo, Holmes, Attala, and Madison Counties, Mississippi. Modified from Frew (1992).

Figure A-62 - Structure contour map of the top of the Norphlet Formation (proxy for the top of the Smackover Formation) in the South Pisgah, Goshen Springs, and Holly Brush Creek fields, Rankin County, Mississippi. Modified from Studlick et al. (1990).

Figure A-63 - Structure contour map of the top of the Smackover Formation in the Pool Creek field, Jones County, Mississippi. Modified from Minihan and Oxley (1966).

Figure A-64 - Structure contour map of the top of the Smackover Formation in the Prairie Branch field, Clarke County, Mississippi. Modified from Davis and Lambert (1963).

Figure A-65 - Structure contour map of the top of the Smackover Formation in the Puss Cuss Creek field, Choctaw County, Alabama. Modified from Bolin et al. (1989).

Figure A-66 - Structure contour map of the top of the Smackover Formation in the Quitman field, Clarke County, Mississippi.

Figure A-67 - Structure contour map of the top of the Smackover Formation in the Red Creek field, Washington County, Alabama. Modified after Bolin et al. (1989).

Depositional and diagenetic histories of Smackover Formation based on core from Hughes & Hughes Pruet Pinkerton 9-12 No. 1 well, Permit No. 2776, core number X-1236.

Silas Field, Choctaw Co., Alabama
by David C. Kopaska-Merkel

Depth intervals: 13,680 to 13,777 ft.

Thin sections: None.

General information: This core includes a section of the upper part of the Smackover Formation and the lower part of the Buckner Anhydrite Member of the Haynesville Formation. The formation contact is preserved. The lower part of the core was whole, but the core had been slabbed above 13,718 ft. I slabbed certain pieces of core below 13,718 ft.

The core-derived lithologic data best match geophysical log response if the top of the core is correlated to a log depth of 13,713 ft, for an adjustment of 33 ft. This is an unusually large adjustment but the sharp density contrast at the formation boundary makes it difficult to be mistaken about this correlation.

Lithostratigraphic unit(s): Smackover Formation and Buckner Anhydrite Member of Haynesville Formation.

Lithofacies: The Smackover Formation in this core is assigned to three lithofacies. Lithofacies 1 (13,732.2 to 13,777 ft; 13.7 m or 44.8 ft thick) is dominated by dolomitic limestone and calcareous dolostone. The concentration of dolomite in lithofacies 1 ranges from a trace to about 90 percent of the rock. Dolomite in this unit is silt size and planar-e in form. In some strata dolomite preferentially replaced particles but in others dolomite

preferentially avoided particles. Recognizable particles are few and much of this unit is inferred to be mud supported. A rippled lamina between 13,772 and 13,773 ft suggests particle support though primary texture could not be discerned in this layer in slabbed core. Also, one lamina of peloid packstone was recognized between 13,764 and 13,765 ft. Strata range from thin laminae to medium beds; stratal thickness generally increases upward. The middle and upper parts of lithofacies 1 contain subhorizontal burrows ranging from 7 to 20 mm in diameter; many of the burrows are severely flattened by compaction. The burrows could have been made by thalassinidean shrimp. Although few unequivocal thalassinidean pellets were observed in this core, numerous oblong peloids of fine to medium size between 13,764 and 13,768 ft are tentatively identified as thalassinidean. The concentration of anhydrite in this unit ranges from a trace to about 10 percent. Anhydrite consists of clear very fine to fine anhedral or anhedral to euhedral gray laths, mostly very fine to fine but up to several millimeters across. Anhydrite laths occur both disseminated and clustered; many clusters are lensoid or equant and up to 1 or 2 centimeters across. Above 13,738 ft traces of well-rounded siliciclastic silt and very fine sand are disseminated and occur within peloids. Other particles found in this unit include small oncoids, bivalves, and intraclasts. Minor intercrystalline porosity was observed in the middle part of this unit.

Lithofacies 2 (13,710.8 to 13,732.2 ft; 6.5 m or 21.4 ft thick) is dominated by dolomitic grainstone. Dolomite ranges from a trace to 100 percent of this unit, and is dominantly microcrystalline and silt size. Dolomite crystals large enough to show their crystal form are planar-e. Dolomite preferentially replaces particles in this unit; between 13,717 and 13,718 ft particles and cement filling the centers of interparticle voids have

been dolomitized whilst an initial phase of pore-rimming cement is still calcium carbonate. The unit grades up from very fine fecal-pellet grainstone to poorly sorted fecal-pellet ooid grainstone. Other particles in this unit include intraclasts, gastropods, bivalves, fossil fragments, *Parafavreina*, and pisoids up to more than 3 mm in diameter (associated with ooids). Some particles are chemically compacted. Strata in this unit range from thin laminae to thin beds, but most are very thin beds. Planar-tabular cross bedding is common and trough-shaped ripple cross lamination is observed at several horizons. The base of the unit is defined by an extremely poorly sorted lamina in which particles range from very fine to extremely coarse. The basal 1.8 m (6 ft) of this unit contain traces of siliciclastic silt and very fine sand; this material was not observed in the upper part of lithofacies 2. Domal and overlying planar crinkly laminae occur at the very top of lithofacies 2. Anhydrite locally accounts for about 1 percent of lithofacies 2 but in general is present only in trace amounts. Most anhydrite in this unit consists of gray-brown anhedra that line fractures. Clear anhydrite in fractures is much less abundant because fractures are quite narrow. Other anhydrite consists of scattered fine to medium gray-brown anhydrite anhedra and light gray-brown anhydrite that replaced particles. Many anhydrite crystals in this unit are corroded. Where sawtooth stylolites truncate fractures, fracture-filling clear anhydrite cement has been partially replaced by calcium-carbonate cement. Lithofacies 2 is far more porous than underlying strata; pores are chiefly moldic and secondary intraparticle, a result of preferential dolomitization of particles in this unit. Porosity ranges up to 35 percent though certain strata are essentially nonporous.

Lithofacies 3 (13,694.9 to 13,710.8 ft; 4.8 m or 15.9 ft thick) is dominated by thinly laminated to thin bedded dolomitic mudstone overlain by dolomitic fecal-pellet ooid grainstone. Grainstone strata grade upward from very well sorted fine fecal-pellet grainstone to poorly sorted intraclastic oolitic fecal-pellet grainstone to bimodal intraclastic oolitic fecal-pellet grainstone with thin laminae of ooid pellet grainstone, to less well sorted intraclastic pelletal ooid grainstone and finally to bimodal oolitic fecal-pellet grainstone at the top of the formation. The unit contains 5 to 93 percent dolomite with the dolomite content highest at the base and in the uppermost 0.6 m (2 ft). Dolomite in the lower part of this unit is silt to very fine sand size but grades up to dominantly microcrystalline and fine silt size dolomite in the upper part of the unit. All dolomite crystals large enough to see clearly are planar-e. Particles other than ooids and fecal pellets include intraclasts and peloids. Low-angle cross laminae characterize the basal foot of this lithofacies. Randomly oriented anhydrite discs up to 3 mm long, some joined to form small rosettes, are found between 13,700 and 13,700.5 ft. Laterally elongate lensoid voids filled with white to light gray anhydrite cement were observed between 13,698 and 13,699.3 ft. The anhydrite content increases upward from trace amounts in the lower half of the unit, to between 1 and 3 percent in the upper half of the unit. In the uppermost foot, anhydrite content increases upward sharply from 10 to 15 percent anhydrite cement in interparticle porosity in the lower part to about 25 percent small gray anhydrite nodules just below the the formation boundary. Anhydrite in lithofacies 3 below 13,696 ft is dominated by disseminated gray anhedra; extremely coarse laths disseminated or concentrated along fractures and wispy stylolites; white cement in primary voids; and, above 13,700 ft, small gray nodules and rare white displacive

nodules. Porosity in the lightly dolomitized lower part of lithofacies 3 is nil, whereas above 13,697.6 ft porosity grades up from a few percent of intercrystalline porosity below 13,697 ft to between 10 and 15 percent vuggy, moldic, secondary intraparticle, and intercrystalline porosity (secondary intraparticle dominant) above 13,697 ft. However, the uppermost 0.15 m (0.5 ft) of the formation is tight because abundant particle molds are plugged with anhydrite.

The uppermost part of the core is dominated by anhydrite and is assigned to the Buckner Anhydrite Member of the Haynesville Formation. This unit contains little or no calcium carbonate, and consists of dolomitic anhydrite, minor anhydritic dolostone, and (at the top) about 0.2 m (0.7 ft) of argillaceous anhydrite. Layers of anhydritic dolostone are dominated by very fine to fine fecal-pellet dolograinstone and fine to medium peloid dolograinstone. Ripples are observed within dolostone at several horizons. Dolostone layers at 13,684.3 ft and 13,681 ft directly overlie exposure surfaces. A third exposure surface at 13,683.7 ft lies within an anhydrite succession. Anhydrite within dolostone units consists of disseminated needles; white or gray nodules; and cement that fills fractures, interparticle pores, and moldic pores. Most anhydrite units are nodular; dolomite in these units separates anhydrite nodules. However, between 13,691.4 and 13,686.2 ft, laminae to very thin beds of two rock types are intercalated in roughly equal proportions. Nodular or massive anhydrite is intercalated with pellet dolostone that has been more than half replaced by disseminated anhydrite needles and replacive nodules. Nodular anhydrite strata contain vertically oriented nodules at several horizons in the lower part of the unit; higher in the section anhydrite contains low-angle cross lamination, an exposure surface, desiccation cracks, and remnants of fecal-pellet

grainstone texture preserved as patterns of inclusions within anhydrite. Some dolostone layers contain minor intercrystalline porosity.

Depositional Environment: The basal portion of the core (up to 13,739 ft) is interpreted as a low-energy subtidal marine deposit. Apparent mud support and a scarcity of sedimentary structures indicating sediment reworking support this interpretation and abundant simple subhorizontal burrows are consistent with it.

Strata between 13,729 and 13,719 ft are assigned to a tidal depositional setting on the basis of abundance of very fine fecal-pellet grainstone, thin coarser grainstone units that could be tempestites, low-diversity fauna dominated by mollusks, and especially by gastropods.

Overlying the inferred tidal-flat deposits are much coarser grainstone strata assigned to a shoal setting. This inference is supported by the coarse mud-free texture, abundant cross stratification, abundant ooids and pisoids, and association with inferred tidal-flat deposits.

Shoal deposits are overlain by back-barrier lagoonal lime mudstone from 13,711 to 13,701 ft.

Overlying the lagoonal deposits are tidal-flat deposits containing anhydrite pseudomorphs after gypsum disks, which form intrasedimentarily in the intertidal zone, laminar fenestrae, and a complex succession of nonskeletal grainstone strata including numerous coarse laminae that could be tempestites or spring-tide deposits.

Buckner strata in this core were deposited near the margin of a saltern, as indicated by the co-occurrence of vertically oriented anhydrite nodules pseudomorphous after subaqueous gypsum crystals with desiccation cracks and exposure surfaces.

Diagenetic History: Syndepositional diagenetic processes that affected this core included carbonate cementation (rim cementation, intraclast formation), gypsum growth within sediment, and formation of displacive anhydrite nodules. Early postdepositional diagenesis included additional carbonate cementation in primary pores, dehydration of gypsum, carbonate dissolution and concomitant dolomitization, and compaction. Burial diagenesis was dominated by anhydrite remobilization and precipitation (as a replacement phase and as cement) and pressure dissolution. Other burial diagenetic processes included minor pyrite formation associated with anhydrite diagenesis, calcitization of anhydrite and late calcite precipitation, and fracturing. Major conduits for fluid migration in the burial setting included fractures, stylolites, and burrows.

The primary pore system was almost completely destroyed by carbonate cementation and lesser compaction and late anhydrite cementation. Carbonate dissolution was the major factor controlling secondary porosity development whereas dolomitization strongly affected permeability enhancement. Fractures temporarily enhanced permeability but the fractures did not remain open. Formation of nonporous dolostone in some areas prevented development of a permeable secondary pore system. The secondary pore system was partially destroyed by anhydrite cementation and pressure dissolution, and possibly also by dolomite cementation.

Figure A-68 - Detailed core log, Chesnut Unit 9-1 No. 1 well, Permit No. 2205, Silas field, Alabama.

Figure A-69 - Structure contour map of the top of the Smackover Formation in the Silas field, Choctaw County, Alabama. Modified from Bolin et al. (1989).

Description of core from South Paulding field, Jasper County, Mississippi
by Roger Townsend

API # 23-061-20507

South Paulding Field
Jasper County, MS

Davis Oil Co. #1 Bergin
23-2N-12E, Jasper Co., MS

WC 14,548-14,672

Core # 813.0-.34

Pf: 14,560-14,615 IPF 69 BO, 46 MCFG, 18 BW (38 gty)

Core Description: 14,548-14,672

14,548-50	Anhydrite, white-gray, nodular
14,551-92	Missing
14,593-603	Limestone, gray, ooid grainstone, poor sorting, some fossils & asphalt
14,604-12	Sandstone, gray, very fine grained, lime cement, tite
14,613-19	Sandstone, tan, very fine grained, dolomite cement, tite
14,620-23	Sandstone, gray-white, very fine grained, lime cement
14,624-28	Limestone, gray, peloidal grainstone, dense
14,629-35	Limestone, gray, mudstone, dense
14,636-39	Sandstone, tan, dolomite cement, very fine grained
15,640-47	Sandstone, gray, fine grained, lime cement
15,648-50	Limestone, gray, mudstone, dense
14,651-64	Sandstone, gray, fine grained, lime cement
14,665-70	Missing
14,671-73	Limestone, gray, mudstone, dense

GRAIN SIZE/ENERGY ROM TOP TO BOTTOM:

15,548-550	Anhydrite, low energy, evaporitic
14,593-603	Grainstone, high energy
14,604-623	Sandstone, very fine grained
14,624-628	Grainstone, high energy
14,629-635	Mudstone, low energy
14,636-647	Sandstone, very fine grained
14,648-650	Mudstone, low energy
14,651-664	Sandstone, lime cement
14,671-73	mudstone, low energy

Figure A-70 - Structure contour map of the top of the Smaclover Formation in the Southwest Barrytown field, Choctaw County, Alabama. Modified from Bolin et al., 1989.

Figure A-71 - Structure contour map of the top of the Smackover Formation in the Southwest Piney Woods field, Rankin and Simpson Counties, Mississippi. Modified from Galicki (1986).

Depositional and diagenetic histories of Smackover Formation based on core from Pinkerton 9-12 No.
1 well, Permit No. 2776
Souwilpa Creek field, Choctaw County, Alabama
by David C. Kopaska-Merkel

Depositional history

The core described here is from a dry hole located a few hundred feet outside the field boundary. This core is probably not truly representative of the reservoir in the one well in the field, because the basal massive subaqueous anhydrite of the Buckner is substantially thicker in this well (11 feet versus 6 feet). This anhydrite unit is inferred to be a distinct stratigraphic unit based on the remarkably consistent log response of the overlying interval in the two wells. This well was located in a paleotopographic low relative to the producing well in the field, and the upper Smackover probably consists of lower energy strata. Also, analysis of density-log patterns suggests that the top of the core is extremely close to the top of the Smackover (at most a few feet below the top).

The basal part of the core (13,710.5-13,718 ft) consists of pelletal, oolitic, and oncoidal dolograstone containing intraclasts. These strata are primarily laminated, but are trough cross-laminated at the base. Most layers are well to moderately well sorted, but the particle size varies dramatically among laminae, and many laminae either fine or, less commonly, coarsen upwards. Based on stratigraphic associations, these strata are interpreted as washover deposits.

The overlying 5.5 feet consists of peloidal dolomitic laminar and domal boundstone. The abundance and distribution of peloids is unclear because they are poorly preserved. These strata are interpreted as lagoonal deposits. Following a 4-foot gap in the core are anhydritic and dolomitic pellet pack-grainstone (13,697-13,701 ft). The pellets are extremely well sorted, and these strata contain desiccation cracks and fenestrae. The anhydrite replaces gypsum discoids. These strata are interpreted to have formed on intertidal to supratidal flats. This interval is overlain by 2 ft of oolitic

pellet dolograinstone containing cauliflower anhydrite nodules, suggesting supratidal deposition. The uppermost part of the core consists of alternating anhydrite and dolomite layers. The anhydritic layers are dominated by nodular mosaic anhydrite. The amount of dolomite in the anhydrite layers varies, and in some intervals containing little dolomite, some anhydrite nodules appear to be vertically elongated. The dolomitic layers are anhydritic microbial laminites that contain peloids, desiccation cracks, and fenestrae. The tops of some anhydrite layers appear to be erosional, and, in the uppermost foot of the core, there appears to be an overhung erosion surface in microbial laminite. The amount of anhydrite decreases upwards, suggesting upward deepening from sabkha and salina deposits to tidal-flat deposits.

Diagenetic history

The earliest diagenetic processes recorded by this core are syndepositional or penecontemporaneous: growth of gypsum disks within the sediment, desiccation cracking, and supratidal anhydrite precipitation. These were followed by early calcium-carbonate rim cementation and subsequent mechanical compaction, which resulted in spalling of cement rims on ooids. Important later diagenetic processes included stylolitization, gypsum dewatering, and dolomitization, followed by additional fracturing and calcium-carbonate cementation. This was followed by a second episode of dolomitization (late dolomite replaced late pore-filling calcium-carbonate cement) and by pyrite formation, the latter probably caused by sulfate reduction. Other diagenetic processes include minor particle dissolution and local brecciation in the salina deposits, which might be due to evaporite dissolution.

Figure A-72 - Detailed core log, Pinkerton 9-12 No. 1 well, Permit No. 2776, Souwilpa Creek field, Alabama.

Figure A-73 - Structure contour map of the top of the Smackover Formation in the Souwilpa Creek field, Choctaw County, Alabama. Modified from Bolin et al. (1989)/

Depositional and diagenetic histories of Smackover Formation based on core from Lovett
27-6 No. 1 well, Permit No. 1903
Sugar Ridge field, Choctaw County, Alabama
by David C. Kopaska-Merkel

Depositional history

The basal portion of this core consists of laminated *Parafavreina* peloid wackestone. This is abruptly overlain by variable laminated mixed-fossil intraclast peloid *Parafavreina* wacke-packstone deposited under normal-marine conditions below wave base (11,733-1,771 ft). Portions of this succession are dolomitic. The amount of dolomite ranges from 0 to more than 95 percent but averages considerably less than 50 percent. The dolomite occurs as scattered euhedral rhombs, as partial centripetal replacement of particles, or both. Lithofacies 2 is the interval from 11,733 to 11,739 feet. Overlying a 6-foot gap in the core from 11,733 to 11,726.5 ft is a cerithid-bearing pellet dolograinstone with bivalves and ooids, that grades up to a cerithid pellet grainstone which is locally cross laminated or laminated. The fossils and ooids occur in thin coarse layers typically 1 particle thick that are interpreted as strandline or storm deposits. These strata were probably deposited on a prograding tidal-flat complex. The cerithid pellet grainstone passes upward (at 11,715 ft) to intraclast ooid pellet grainstone (laminated and cross laminated) and thence to laminated and cross laminated dolomitic cerithid intraclast ooid pellet grainstone, with a 3-foot-thick oncoid grainstone at the top of the core. These strata are also interpreted as tidal-flat deposits, except the uppermost oncoidal layer. This may represent a slight deepening to shallow subtidal conditions. Lithofacies 1 is the entire interval above the gap in the core.

The tidal-flat deposits just described (11,726.5 to 11,703 ft) can be further classified into the deposits of various subenvironments. These strata include a substantial amount of cross-laminated rock that is rich in ooids (some is dominated by ooids; 11,713

to 11,708 ft). These strata were probably laid down in tidal channels. The tidal-channel deposits grade up to a little more than 3 feet (11,708 to 11,704 ft) of low-angle cross laminated ooid grainstone, which were probably laid down on a beach.

The overlying oncoid grainstone probably formed either in abandoned tidal channels, slightly offshore in deeper water, or possibly on intertidal/subtidal flats outside of tidal channels. The oncoidal interval consists of at least 3 (the core terminates within this lithology) coarsening-upward cycles, which may result from cyclic fluctuation in energy conditions or in relative sea level.

Diagenetic history

Penecontemporaneous dolomitization is proven by the presence of dolomitic intraclasts recycled into upper-Smackover strata that were later partially dolomitized. There is also first-generation dolomite pore-lining cement that must have formed relatively early. Dissolution of mineralogically unstable particles occurred fairly early, before much compaction and before calcite cementation. Later processes included stylolitization, pyrite precipitation, and fracturing (which were all roughly synchronous) and anhydrite precipitation. Anhydrite in this core consists of cement (in particle molds and in fractures) and of replacive laths. At least some anhydrite formed after dissolution of mineralogically unstable particles, and some after fracturing, but some could have formed early as well. Silica nodules are found near the base of the core; these formed late (after compaction was essentially complete). The single most important porosity-forming process operating on these strata was dissolution of mineralogically unstable particles. The core has been incompletely dolomitized, and dolomitization contributed

little to formation of secondary pore systems. Most pores are either particle molds or secondary intraparticle pores.

Figure A-74 - Detailed core log, Lovett 27-6 No. 1 well, Permit No. 1903, Sugar Ridge field, Alabama, upper part of core.

Figure A-75 - Detailed core log, Lovett 27-6 No. 1 well, Permit No. 1903, Sugar Ridge field, Alabama, lower part of core.

Figure A-76 - Structure contour map of the top of the Smackover Formation in the Sugar Ridge field, Choctaw County, Alabama. Modified from Bolin et al. (1989).

Description of core from Sumrall field, Clarke County, Mississippi
by Roger Townsend

API # 23-023-20639

Sumerall Field
Clarke Co., MS

Clements Energy, Inc, #2 Tony
19-1N-16E, Clarke Co., MS

QC 13,333-13,373

Core File # C-701.0-.3

Pf: 13,370-374 IPP 38 BO, 232 BW (30.1 gty)
Add Pf: 13,390-400, 424-434 and made XWDW

Core Description: 13,333-13,373

13,333-36	Limestone, dark gray, very dense, micritic, occasional anhydrite
13,337	Limestone, dark gray, coarse crystalline, inter crystalline porosity
13,338	Limestone, dark gray, very dense, micritic, no porosity
13,339-41	Anhydrite, bedded and nodular
13,342	Limestone, light gray, dense, some calcite crystals, no porosity
13,343	Shale, black-gray, thinly laminated
13,344-46	Limestone, light gray, dense, some calcite crystals, no porosity
13,347-54	Limestone, dark gray, dense, laminated, no porosity, some calcite crystals
13,355	Limestone, light tan, microcrystalline w/very fine ooid ghosts,
13,356-57	Limestone, light tan, microcrystalline, very fine grained ooid grainstone
13,358-60	Limestone, light tan, ooid grainstone w/crystalline lime matrix,
13,361-63	Limestone, gray, very dense, micritic, no porosity, some stylolites
13,364	Limestone, gray, micro-crystalline, some calcite crystals, some stylolites
13,365-67	Limestone, gray, micritic, no porosity, some anhydrite crystals
13,368-69	Dolomite, light gray, micritic, no porosity, some anhydrite
13,370	Limestone, dark gray, laminated, ooid ghosts, no porosity
13,371-73	Limestone light tan, ooid grainstone, crystalline lime matrix, poor porosity

GRAIN SIZE/ENERGY FROM TOP TO BOTTOM:

13,333-38	Mudstone, dense lime, very low energy
13,339-41	Anhydrite, evaporitic, very low energy
13,342-43	Shale, laminated, very low energy
13,344-54	Mudstone, lime, very low energy
13,355-62	Grainstone, high energy
13,363-69	Mudstone, lime and dolomite, very low energy
13,370-72	Grainstone, oolitic lime, high energy
13,373	Mudstone, dense lime, low energy

Description of core from Tallahala Creek field, Smith County, Mississippi
by Roger Townsend

API # 23-129-20005

Tallahala Creek Field
Smith Co., MS

Shell Oil Co. et al #1 Fanny James
5-1N-9E, Smith Co., MS

QC 15,467-15,681

Core File # C-60.0-.3

Pf: 15,259-273 & 15307-322 IPF 525 BO, 735 MCFG (47 gty)

Pf: 15,482-492 IPF 870 BO, 1,184 MCFG, 0 BW

Pf: 13,770-782 Gas Lift 12 BO, 55 MCFG, 326 BW (38.1 gty)

Core Description: 15,467-15,681

15,467-70	Dolomitic Lime, dark gray, VFG ooid ghosts, crystalline, dense
15,471	Lime, dark gray, VFG ooid ghosts, crystalline, dense
15,472-74	Lime, dark gray, ooid grainstone, VFG, dense
15,475	Lime, dark gray, wackestone, VFG, dense
15,476-77	Lime, dark gray, crystalline, dense, no grains
15,478	Dolomitic Lime, dark gray, crystalline, dense, possible ooid ghosts
15,479	Lime, buff, crystalline, dense, no grains
15,480-82	Dolomitic Sand, buff, friable, good porosity
15,483	Dolomite, tan, micro-crystalline, very dense, laminated
15,484	Dolomitic Sand, buff, friable, good porosity
15,485-86	Limy Sand, buff, friable, fair porosity
15,487-90	Lime, dark gray, crystalline, dense, no grains, laminated
15,491-92	Lime, buff, crystalline, dense, no grains
15,493-94	Limy Dolomite, dark gray, micro-crystalline, dense, no grains
15,495-96	Lime, dark gray, micro-crystalline, dense, no grains
15,502-05	Lime, dark gray, crystalline, dense, no grains, laminated
15,506-19	Lime, black, micro-crystalline, very dense, asphalt saturated
15,520-21	Lime, black, micro-crystalline, dense, laminated, asphaltic
15,522-23	Lime, dark gray, crystalline, dense, no grains
15,524	Lime, black, micro-crystalline, very dense, asphalt saturated
15,525-29	Lime, dark gray, crystalline, dense, some laminated, no grains
15,530-32	Dolomitic Lime, buff, crystalline, dense, no grains
15,533-38	Lime, dark gray, crystalline, dense, no grains
15,539-40	Lime, buff, micritic, very dense, no crystals
15,541-43	Dolomite, brown, micro-crystalline, dense, no grains
15,544	Lime, black, micrite, very dense, no crystals
15,545-47	Lime, dark gray micrite, very dense, no crystals
15,548	Dolomitic Lime, buff, micrite, very dense, no crystals

15,562	Lime, tan, micrite, very dense, no crystals
15,563-67	Dolomite, tan, micritic, few anhydrite crystals
15,568-78	Lime, gray, micritic, crystalline, dense, no grains
15,579-81	Dolomite, tan, micritic, crystalline, dense, no grains
15,582-83	Limy Dolomite, tan, micritic, crystalline, dense, no grains
15,584-87	Lime, dark gray, fine grained ooid grainstone, some fossils
15,588-90	Lime, dark gray, micrite, dense, no grains
15,591-94	Lime, dark gray, medium grained ooid grainstone
15,595-98	Lime, dark gray, micrite, dense, no grains
15,599-601	Dolomite, tan, crystalline, no grains, some anhydrite crystals
15,602	Lime, dark gray, coarse grained ooid packstone
15,603-04	Lime, dark gray, micrite, dense, crystalline, no grains
15,605	Lime, dark gray, medium grained ooid packstone
15,606-09	Lime, dark gray, micrite, dense, crystalline, no grains
15,610-11	Dolomitic Lime, tan, micritic, dense, some anhydrite crystals
15,612-17	Dolomite, tan, micritic, dense, no grains
15,618-19	Lime, dark gray, micritic, very dense, no grains
15,622-26	Dolomite, tan, crystalline, dense, no grains
15,627-34	Limy Dolomite, tan-gray, crystalline, dense, no grains
15,635	Lime, gray, ooid packstone
15,636	Lime, gray ooid grainstone, some anhydrite
15,637	Lime, dark gray, ooid ghosts, dense, crystalline
15,638-40	Lime, dark gray, micritic, dense, crystalline
15,641-42	Lime, dark gray, fine-medium grained ooid grainstone
15,643	Lime, dark gray, micritic, dense, no grains
15,644	Lime, dark gray, fossiliferous ooid grainstone
15,645	Stylotized zone
15,646-47	Lime, buff, crystalline, dense, no grains
15,648	Lime, tan, ooid packstone
15,649-50	Lime, tan, micritic, dense, no grains
15,651-54	Anhydrite, some interbedded dolomite
15,655-57	Lime, dark gray, medium-fine grained ooid grainstone
15,658	Lime, dark gray, micritic, dense, no grains
15,659	Dolomite, tan, crystalline, dense, no grains
15,660-62	Anhydrite, nodular, mottled with dolomite
15,663-67	Dolomite, tan, crystalline, dense, no grains
15,668-70	Dolomite, salt & pepper, crystalline with abundant asphalt
15,671	Dolomite, tan, micritic, dense, no grains
15,672-78	Lime, dark gray-tan, micritic, crystalline, dense, some fossils
15,679-81	Dolomite, tan, crystalline, dense, no grains

GRAIN SIZE/ENERGY FROM TOP TO BOTTOM:

15,467-474	Grainstone, VFG ooids, high energy
15,475	Wackestone, VFG ooids, moderate energy
15,476-479	Micrite, No grains low energy
15,480-486	Sandstone, fluvial
15,487-583	Micrite, no grains, low energy
15,584-587	Grainstone, fine grained ooids, high energy
15,588-590	Micrite, no grains, low energy
15,591-594	Grainstone, medium grained ooids, high energy
15,595-601	Micrite, no grains, low energy
15,602	Packstone, coarse grained ooids, moderate energy
15,603-604	Micrite, no grains, low energy
15,605	Packstone, medium grained ooids, moderate energy
15,606-634	Micrite, no grains, low energy
15,635-657	Grainstone, abundant interbedding of grainstone-packstone-micrite-anhydrite with some fossils, mostly high energy
15,658-681	Micrite, no grains, low energy

Figure A-77. Structure contour map of the top of the Smackover Formation in the Tchula Lake field, Holmes County, Mississippi. Map courtesy of Bill Tedesco (University of Mississippi), Rick Major (University of Mississippi), and Larry Baria (Jura-Search, Inc.).

Figure A-78 - Structure contour map of the top of the Smackover Formation in the Thomasville field, Rankin County, Mississippi. Modified from Galicki (1986).

Figure A-79 - Structure contour map of the top of the Smackover Formation in the Thornton Springs field, Choctaw County, Alabama. Modified from Alabama Oil and Gas Board docket number 7-17-9510A.

Depositional and diagenetic histories of Smackover Formation based on core from Placid Bolinger
No.13-4, Permit No. 1412
Toxey field, Choctaw County, Alabama
by David C. Kopaska-Merkel

Depositional history

The basal part of the core (10,620-10,630 ft; all but the top one foot of this interval is lithofacies 3) consists of intercalated ooid grainstone (some with oncoids) and pellet grainstone, representing a hard-pellet shallow subtidal lagoonal environment either being prograded by a flood tidal delta, or experiencing intermittent washover deposition from a nearby barrier. The pellet grainstone is significantly burrowed, contains a 2-inch-thick cross-lamina set (dune?), and locally contains abundant coated grains and oncoids.

This is succeeded by ooid grainstone (10,610.5-10,620 ft), alternately bioturbated and cross-laminated, representing tidal-delta deposition. In the upper part, this sequence includes desiccation-cracked micritic crusts, interlaminated microbial dolomudstone containing intraclasts of pellet grainstone and pellet grainstone, and small-scale trough cross laminae, indicating intermittent intertidal, supratidal, or tidal-channel deposition as the tidal delta aggraded.

The tidal delta is overlain by a thick tidal-flat succession (10,574-10,610.5 ft) dominated by ooid grainstone, but including laminated dolomudstone, herringbone cross-stratification, calcite-filled fenestrae in pellet grainstone, common cerithid-type moderately high-spired gastropods in ?gastropod-pellet grainstone, organic-rich wispy laminae, increased amounts of anhydrite, *Parafavreina* grainstone, and bored surfaces, all indicating or consistent with tidal-flat deposition.

The succession is capped by two thin washovers of well sorted ooid grainstone, separated by ?supratidal dolostone with ?fenestrae. Lithofacies 1 is the interval from 10,594-10,621 ft and lithofacies 2 is the top of the core: 10,571-10594 ft.

Diagenetic history

Early diagenetic events included nearly ubiquitous rim cementation in particle-supported rocks, and penecontemporaneous dolomitization of supratidal muds. Locally, lack of early cement permitted chemical overcompaction of particle-supported sediments; elsewhere, pore-filling cement formed throughout much of the section, with less-prevalent regions of particle interpenetration and particle crushing distributed throughout the core.

Most of the upper part of the core consists of dolostone, or calcitic dolostone. The lower part of the core is dominated by slightly dolomitic limestone, but includes intervals of dolostone and calcitic dolostone. No obvious pattern, other than the general upward increase in dolomite concentration, is observed.

The most common kind of pore system in this core is a combination of secondary intraparticle and lesser moldic porosity in partially dolomitized grainstone. This porosity was generated by partial particle-selective dolomitization, either preceding or contemporaneous with leaching of relict calcium carbonate within particles. This is indicated by the spongy appearance of porous dolomitized particles, and their coexistence with nonporous crystalline dolomite particles and nonporous calcitic particles. The latter suggests that the leaching of calcium carbonate may have been caused by dolomitization, and that this relationship occurred on a scale of single particles. This in turn suggests the operation of chaotic processes during dolomitization and dissolution controlling the diagenetic products produced at a given point. Local cement-moldic porosity in dolomitized ooid grainstone indicates leaching of calcitic cement during or after dolomitization as above. Locally the dolomitization was not fabric selective, and here porosity appears to be both secondary intraparticle and intercrystalline, possibly due to slower dolomitization with more complete obliteration of preexisting fabric. At the top of the core, and in a few other intervals, microvuggy intraparticle porosity within ooids is a variation on the already-stated theme.

Small amounts of anhydrite (some with associated pyrite) occur throughout the core as replacive laths and small replacive masses. Anhydrite is more abundant in the tidal-flat deposits of the upper part of the core, but no nodular anhydrite is observed. All is replacive, and locally, ghosts of pellets are visible.

Figure A-80 - Detailed core log, Bolinger No. 13-4 well, Permit No. 1412, Toxey field, Alabama.

Figure A-81 - Structure contour map of the top of the Smackover Formation in the Toxey field, Choctaw County, Alabama. Modified from Bolin et al/ (1989).

Figure A-82 - Structure contour map of the top of the Smackover Formation in the Turkey Creek field, Choctaw County, Alabama. Modified from Bolin et al. (1989).

Depositional and diagenetic histories of Smackover Formation based on core from PFI,
R.J. Newman, Jr., et al., 21-11 No.1, Permit No. 4412
Turnerville field, Mobile County, Alabama
by David C. Kopaska-Merkel

Depositional history

This short core may not be representative of the reservoir in Turnerville Field. The 20 feet of rock cored includes 15 feet of permeable strata. These consist of peloid dolopack-grainstone and oncoidal peloid dolopack-grainstone. Most of the oncoidal layers exhibit markedly bimodal particle-size distributions, and many are normally graded. The individual layers measure about an inch to several tens of inches in thickness; a few are cross laminated, but most are massive. A series of normally graded layers between 18,379 and 18,382 feet exhibit sole marks interpreted as load casts. (Coarse, basal grainstone overlies fine-textured mudstone and wackestone, and is displaced into the underlying muddy layers to the extent that isolated pods of the overlying coarse material are observed within the underlying finer layers.) These graded layers are probably tempestites, and may have been deposited as turbidites.

One horizon near the middle of the core (18,378-18,379 ft) is fenestral and desiccation cracked, indicating short-lived subaerial exposure.

The depositional setting for this core is interpreted as a shallow marine shelf that was periodically affected by severe storms. Shoaling (either a result of autogenic sediment upbuilding or early structural movement) may have locally permitted development of tidal flats and short-lived subaerial exposure of the sediment surface. Alternatively, progradation of a tidal-flat complex from a nearby island could have been responsible for shoaling at Turnerville Field. This interpretation is consistent with regional paleogeography.

Diagenetic history

Pervasive dolomitization has severely altered the reservoir in Turnerville Field, making interpretation of depositional fabrics uncertain, and transforming the pore system to one dominated by intercrystalline porosity. Anhydrite occurs as felted (displacive, early) nodules, replacive nodules, replacive laths, and (locally) pore-filling cement. Minor authigenic pyrite is associated with some anhydrite. A low density of stylolites and solution seams indicates that pressure solution was less important here than in many Smackover cores. Calcite cement occurs in close association with some stylolites, many of which also have halos of low-porosity dolostone. This suggests that both calcite and dolomite were precipitated during pressure solution, and without significant migration of ions away from growing stylolites.

Figure A-83 - Detailed core log, R. J. Newman Jr. et al. 21-11 No. 1, Permit No. 4412, Turnerville field, Alabama.

Figure A-84 - Structure contour map of the top of the Smackover Formation in the Turnerville field, Mobile County, Alabama. Modified from Bolin et al. (1989).

Description of core from Vossburg field, Jasper County, Mississippi
by Roger Townsend

API # 23-061-20156

Vossburg Field
Jasper Co., MS

Getty Oil Co. #1 Trotter 33-6
33-2N-13E, Jasper Co., MS

QC 14,610-15,305

Core File # 414.0-.17

Pf: 14,662-14,672 IPF 216 BO, 152 MCFG, 14 BW (40 gty)

Core Description: 14,610-15,305

14,610-27	Sand, light gray-white, lime cement, poor porosity
14,628-39	Lime, gray, dense, micritic, no grains
14,653	Lime, gray, dense, micritic, no grains
14,654-59	Anhydrite, light gray-white, nodular, massive
14,660-62	Lime, gray, dense, micritic, no grains
14,663-69	Anhydrite, light gray-white, nodular, massive
14,670-81	Sand, gray-tan, fine grained, lime cement
14,682-86	Anhydrite, light gray-white, nodular, massive
14,687	Shale, gray, silty
14,694-95	Shale, gray, silty
14,696-713	Sand, tan-gray, fine grained, well sorted, lime cement
14,714-19	Sand, tan-gray, fine grained, thin shale laminations
14,720	Lime, dark gray, dense, micro-crystalline
15,185-240	Lime, gray-tan, micritic, fossils, some stylolites
15,241	Lime, gray-tan, micritic, laminated
15,242	Dolomite, brown, sucrosic, crystalline, oil saturated
15,243-52	Anhydritic Dolomite, brown-gray, micritic, dense
15,253-56	Limy Dolomite, gray, dense, micritic, occasional fossil
15,257-60	Lime, gray, dense, micritic, occasional fossil
15,267-78	Lime, gray-tan, dense, micritic, some stylolites
15,294-300	Lime, gray-tan, dense, micritic, some stylolites
15,301-05	Dolomite, tan, dense, micritic

GRAIN SIZE/ENERGY FROM TOP TO BOTTOM:

14,610-627	Sandstone, lime cement
14,628-669	Mudstone, lime & anhydrite, shallow, low energy, evaporitic
14,670-681	Sandstone, lime cement
14,682-686	Anhydrite, shallow, low energy, evaporitic
14,687-695	Shale, deep water, low energy
14,696-719	Sandstone, lime cement
14,720	Mudstone, low energy
15,185-242	Mudstone, low energy
15,243-252	Anhydrite, shallow, low energy, evaporitic
15,253-305	Mudstone, low energy

Description of core from West Barnett field, Clarke County, Mississippi
by Roger Townsend

API # 23-023-20501

West Barnett Field
Clark Co., MS

Larco Drilling Co. #1 Eddins 18-13
18-2N-14E, Clarke Co., MS

QC 13,209-13,245 Buckner?

Core File #: C-525.0-.3

D & A Never Produced

Core Description: 13,209-13,245

13,209-10	Missing
13,211	Limestone, gray, ooid, pisolitic, fossiliferous, grainstone
13,212	Limestone, gray, ooid, grainstone
13,213-21	Sandstone, light gray, fine grain with limestone matrix
13,222-27	Limestone, gray, ooid, pisolitic, fossiliferous, grainstone
13,228-30	Limestone, gray, ooid grainstone, fine grain, well sorted
13,231	Limestone, gray, ooid, pisolitic, fossiliferous, grainstone
13,232	Limestone, gray, ooid, grainstone, fine grain, well sorted
13,233	Limestone, gray, ooid, grainstone, medium grain, well sorted
13,234	Limestone, gray, ooid, grainstone, coarse grain, well sorted
13,235-38	Limestone, gray, ooid, packstone, coarse grain, well sorted
13,239-45	Limestone, gray, micritic, dense, occasional pisolite & laminae

GRAIN SIZE/ENERGY FROM TOP TO BOTTOM:

13,211-212	Grainstone, high energy
13,213-221	Sandstone, lime cement
13,222-234	Grainstone, high energy
13,235-238	Packstone, moderate energy
13,239-245	Mudstone, low energy

Figure A-85 - Structure contour map of the top of the Smackover Formation in the West Barnett field, Jasper and Clarke Counties, Mississippi. Modified from Davis and Lambert (1963).

Depositional and diagenetic histories of Smackover Formation based on core from Pruet & Hughes-Pelto Lewis U. 4-16 No.1, Permit No. 1757
West Barrytown field, Choctaw County, Alabama
by David C. Kopaska-Merkel

Depositional history

Because most of this core consists of crystalline dolostone, depositional environments are difficult to determine.

The basal 1.5 ft of the core (lithofacies 4) consist of cryptocrystalline, impermeable and nonporous dolostone, which may have been lime mudstone or wackestone of a subtidal low-energy environment.

The bulk of the core (12,222-12,259.5 ft) consists of what was apparently ooid grainstone, some cross laminated, most bioturbated, almost certainly representing some sort of high-energy shoal complex. The pervasive bioturbation indicates that much of the sequence was deposited subtidally, and experienced periods of low water energy. Also, intercalated dark, wavy laminated layers interpreted as microbially laminated lime muds, and several emersion surfaces, indicate intermittent tidal-flat conditions. Near the top of this part of the core (just below the missing section) herringbone cross stratification indicates the presence of reversing tidal currents, and coarse layers containing ?oncoids suggest the presence of back-barrier facies. Lithofacies 1 is the 37.5-foot interval just described whose top is the base of the missing section.

Two ft of core directly above the missing section (lithofacies 3) consists of limestone. The lower foot of core consists of pellet grainstone containing desiccation cracks and replacive anhydrite after discoidal gypsum, indicating deposition on a tidal flat. An emersion surface separates this facies from overlying ooid grainstone containing abundant anhydrite laths but apparently no former gypsum, and exhibiting low-angle cross lamination, indicating that this sediment was deposited on a beach.

The topmost three ft of core (lithofacies 2) consist of ooid dolograinstone forming a thick set of cross strata. These were probably deposited in a tidal channel that incised the beach deposits as a result of lateral migration of a tidal inlet, or by creation of a new inlet by a major storm.

Diagenetic history

The early phases of diagenesis for the bulk of this core are obscured by pervasive dolomitization. For the most part, this was nonselective, and the most important pore type is intercrystalline, but moldic pores after spherical particles (most probably ooids) are also abundant in much of the section. This suggests that some ooids resisted dolomitization and were subsequently leached. However, dolomite crystal faces lining some large vugs indicate that at least minor dolomitization occurred after formation of the molds.

Burrows are more porous and permeable than surrounding rock, and burrows are also commonly filled with material originally different from their hosts (e.g., ooid grainstone in burrows surrounded by pellet grainstone).

A single interval of brecciated rock (13,235.5-13,237 ft) was apparently an ooid grainstone. Brecciation may have been caused by gravity displacement of firm (and therefore brittle) sediments that were either incipiently cemented or gained their rigidity from organic binding.

Minor replacive anhydrite formed throughout the core, probably before stylolitization because it is not concentrated near stylolites; it is locally associated with pyrite. The pyrite commonly fills oomolds, and thus postdates mold formation. A few anhydrite nodules composed of felted masses of large laths occur in the topmost dolomitized portion of the core. Nearby, pyrite tends to replace preexisting carbonate, not to fill pores, and selects ooid cortices preferentially.

More importantly for the pore system, near-vertical fractures extend either upward or downward, but mainly downward, from strata-parallel stylolites. These fractures post-date

dolomitization, but apparently predate stylolitization, or formed at the same time, for they never cross stylolites. The fractures are partially filled with clear or white anhydrite cement, and post-anhydrite black solid hydrocarbons. These reached the fractures through the stylolites, as indicated by the hydrocarbon distribution (absent from fractures far from stylolites, and filling some molds of ooids near stylolites). Thus, hydrocarbon migration postdates all other observed events.

The topmost part of the core contains interparticle porosity in ooid dolograins. This porosity is locally filled with black solid hydrocarbons. A prominent layer of rim cement coats all particles, and the interparticle porosity is always separated from the particles by the layer of rim cement. Some of the interparticle porosity is filled with anhydrite cement, which does not appear to co-occur in a single pore with the black hydrocarbons, in this part of the core. Another important pore type in this part of the core is secondary intraparticle porosity; intercrystalline porosity within dolomitized ooids, probably formed by partial dolomitization and subsequent leaching of calcium carbonate. Intercrystalline porosity is locally common; it is found between ooids and probably formed by partial dolomitization of pore-filling calcium-carbonate cement, and subsequent leaching of the relict calcium carbonate. If this interpretation is correct then much of the interparticle porosity could be secondary.

In summary, the pore system was created by dolomitization and leaching, either synchronously or in that order. Near-vertical fractures enhanced permeability, then were partly occluded by anhydrite, were later transected by bedding-parallel stylolites, and later partially filled with hydrocarbons that reached them through the stylolites (at least in some cases). Trivial amounts of porosity were locally occluded by anhydrite and pyrite cements before hydrocarbon migration.

Figure A-86 - Detailed core log, Lewis Unit 4-16 No. 1, Permit No. 1757, West Barrytown field, Alabama.

Depositional and diagenetic histories of Smackover Formation based on core from May
27-10 No. 1 well, Permit No. 2647
West Bend field, Clarke County, Alabama
by David C. Kopaska-Merkel

Depositional history

The lower part of this core consists of laminated and bioturbated anhydritic dolomitic intraclast coated-grain ooid *Parafavreina* peloid pack-grainstone with an exposure surface just above the base. Common echinoderm fragments and rare bryozoan fragments are found in the upper part of this interval (12,460.5-12,468 ft). Lithofacies 2 is the interval from 12,461 to 12,483 ft. These strata were deposited in a moderate-energy restricted shallow-subtidal shelf environment in which the degree of restriction decreased upward, probably to approximately normal marine conditions. These strata were probably deposited in a backbarrier (lagoonal) setting, as indicated by the interpretation of overlying strata that is given below. Overlying strata consist of dolomitic anhydritic bioturbated lime mudstone containing anhydrite pseudomorphs after gypsum. These strata were probably deposited in a hypersaline lagoon. They are overlain by anhydritic dolomitic coated-grain peloid ooid grainstone with *Parafavreina*, mostly laminated but some cross laminated (12,437-12,445 ft), which grades up to a similar lithology intercalated with domal microbial boundstone. Overlying rocks are dolomitic oncoid ooid grainstone (12,422.5-12,426 ft). These grade up to laminated (lesser cross laminated) pellet ooid dolograins (12,410.5-12,422.5 ft). The rocks just described represent a succession of backbarrier facies (washover, tidal delta, near-barrier subtidal lagoon) from relatively strongly influenced by the proximity to a barrier (lower lithofacies 1), to relatively strongly influenced by the lagoon (upper lithofacies 1), back to barrier dominated (lithofacies 3; 12,411-12,420 ft). Lithofacies 1 is the interval from 12,420 to 12,445 ft. This probably represents the shifting positions of a single barrier

island. These strata grade up to anhydritic dolostone and thence to intercalated anhydritic dolostone and nodular anhydrite that is relatively free of matrix. These strata were formed in a sabkha which contained evaporitic ponds.

Diagenetic history

Penecontemporaneous diagenetic processes included formation of desiccation cracks, intrasediment precipitation of discoidal gypsum crystals, very early calcium-carbonate cementation, and formation of displacive anhydrite nodules. These events were followed by relatively early dolomitization and dissolution of mineralogically unstable particles. Later events included fracturing, stylolitization, and formation of replacive anhydrite nodules. Later still was a second episode of calcium-carbonate cementation, calcitization of anhydrite, and pyrite formation. The reservoir is dominated by secondary intraparticle porosity with lesser moldic, intercrystalline, and primary interparticle porosity. The process of particle dissolution was critical to pore-system evolution; dolomitization was the second most important process.

Figure A-88 - Detailed core log, May 27-10 No. 1 well, Permit No. 2647, West Bend field, Alabama

Figure A-89 - Structure contour map of the top of the Smackover Formation in the West Bend field, Choctaw and Clarke Counties, Alabama. Modified from Bolin et al. (1989).

Description of core from West Clara field, Wayne County, Mississippi
by Roger Townsend

API # 23-153-20086

West Clara Field
Wayne Co., MS

The Brandon Co. #4 USA 3-14
3-7N-8W, Wayne Co., MS

QC 11,924-13,466

Core File #: C-476.0-.13

Pf: 13,491-13,513 IPF 526 BO, 260 MCFG, 0BW (39.2 gty)

Pf: 13,211-13,231 250 BW

Pf: 11,927-11,947 IPF 52 BO, 256 MCFG, 136 BW (44.1 gty)

Pf: 11,936-11,950 IPF 199 BO, 75 MCFG, 0 BW (41 gty)

Pf: 12,394-12,400 IPF 157 BO, 59 MCFG, 0 BW (40 gty)

Pf: 11,933-951 & 11,759-763 IPF 238 BO, 202 MCFG, 0 BW (44 gty)

Pf: 12,075-12,090 IPP 121 BO, 22 BW (41 gty)

Core Description: 13,282-13,466

13,282-84	Limestone, buff, oolitic, grainstone, fine grain, well sorted
13,285-90	Limestone, gray, micrite, very dense, small thin laminal, small fracture
13,291-96	Limestone, buff, micrite, very dense, small thin laminal, small fracture
13,297-99	Missing
13,300-22	Limestone, buff, micrite, very dense, small thin laminal, small fracture
13,323-432	No core
13,433-66	Limestone, gray, micritic, occasional fractures & stylolites

GRAIN SIZE/ENERGY FROM TOP TO BOTTOM:

13,282-284	Grainstone, high energy
13,285-322	Mudstone, low energy
13,323-432	No core
13,433-466	Mudstone, low energy

Description of core from West Nancy field, Clarke County, Mississippi
by Roger Townsend

API # 23-023-20222

Nancy, West Field
Clarke Co., MS

Getty Oil Co. #1 W A Goodwin 5-12
5-1N-14E, Clarke Co., MS

QC 13,811-13,994

Core File # C-217.0-.12

Dual Producer:

Pf 13,868-880 Smk IPF 317 BO, 165 MCFG (40.9 gty)

Pf 13,768-784 Buck IPF 333 BO

Core Description: 13,811-13,994

13,811-13	Anhydrite, white-gray, nodular
13,814-15	Limestone, gray-tan, grainstone w/ sand and ooids, laminated
13,816-22	Limestone, gray-tan, ooid grainstone, medium grained, sandy
13,823-24	Limestone, gray-tan, ooid grainstone, fine grained, sandy
13,825-35	Anhydrite, white-gray, nodular
13,836-42	Limestone, tan-buff, micritic, vuggy porosity
13,843-48	Limestone, tan-gray, dense, micritic w/ stylolites
13,849-72	Limestone, tan, ooid grainstone, very fine to fine grained
13,873-76	Limestone, tan-gray, very fine grained packstone, poor porosity
13,877-88	Limestone, tan, ooid grainstone, very fine grained, some fossils
13,889-91	Limestone, tan, ooid grainstone, medium grained
13,892-902	Limestone, tan, ooid grainstone, fine-coarse grained, poor sorting
13,903-18	Limestone, tan, ooid grainstone, medium-coarse grained, fair sorting
13,919-29	Limestone, tan, ooid grainstone, medium-coarse grained, poor sorting
13,930-34	Limestone, tan, ooid packstone, fine grained, some fossils
13,935-39	Limestone, tan, ooid grainstone, fine-coarse grained, some fossils
13,940-43	Limestone, tan, ooid grainstone, fine-coarse grained, pisolitic
13,944-48	Limestone, tan-gray, ooid grainstone, medium grained, w/ bitumen
13,949	Limestone, tan-gray, ooid grainstone, very fine grained, well sorted
13,950-51	Limestone, tan-gray, dense, micritic
13,952	Limestone, tan-gray, ooid grainstone, very fine grained, well sorted
13,953-60	Limestone, tan-gray, ooid grainstone, medium-coarse grained, well sorted
13,961-63	Limestone, tan-gray, ooid packstone, fine grained, some fossils
13,964-65	Limestone, tan-gray, wackestone, some fossils
13,966-72	Limestone, tan-gray, ooid grainstone, abundant fossils, some pisolites
13,973-94	Limestone, tan-gray, ooid grainstone, fine-coarse grained, pisolitic, fossils

GRAIN SIZE/ENERGY FROM TOP TO BOTTOM:

13,811-813	Anhydrite, low energy, evaporitic
13,814-824	Grainstone, high energy
13,825-835	Anhydrite, low energy, evaporitic
13,836-848	Mudstone, low energy
13,849-872	Grainstone, high energy
13,873-876	Packstone, moderate energy
13,877-949	Grainstone, high energy
13,950-951	Mudstone, low energy
13,952-960	Grainstone, high energy
13,961-963	Packstone, moderate energy
13,964-965	Wackestone, moderate-low energy
13,966-994	Grainstone, high energy

Figure A-90 - Structure contour map of the top of the Smackover Formation in the West Nancy field, Clarke and Jasper Counties, Mississippi. Modified from Davis and Lambert (1963).

Depositional and diagenetic histories of Smackover Formation based on core from Fina
Oil & Gas Land 6-1 No. 1, Permit No. 5776
West Okatuppa Creek field, Choctaw County, Alabama
by David C. Kopaska-Merkel

Depositional history

The basal foot of this core consists of metamorphic basement rock, which is overlain by very poorly sorted conglomerate of metamorphic rock fragments (MRFs). In the basal portion of the conglomerate section, clasts are angular, up to 1.5 cm in diameter, and fine upward from dominantly fine-coarse to dominantly fine-medium sand size. Matrix is fine-coarse peloid grainstone with dolomite cement. The top of the conglomerate is at 10,619 ft, and is inferred to have been deposited in an alluvial fan. The conglomerate is overlain by two ft of peloid dolograins with metamorphic rock fragments, overlain in turn by lime mudstone also containing angular MRFs to very coarse sand size. The mudstone layer is interpreted as a mud flow deposit, and the underlying peloid dolograins as subtidal lagoonal material. This interval is capped by an emersion surface containing vertical cracks filled with poorly sorted MRF conglomerate; this surface is interpreted as a paleosol. The paleosol is overlain by about one foot of ripple cross-laminated conglomerate consisting of a lower particle-supported layer and an upper matrix-supported layer. Particles are angular MRFs and range up to about 1.25 mm in diameter. This stratum may be a storm deposit. It is immediately overlain by a one-foot-thick layer consisting of pellet dolograins containing MRFs abruptly overlain by a similar deposit that is about half MRFs. Load casts are present at the contact between these two 6-inch units.

The overlying 11 ft of core (10,613 to 10,602 ft) is dominated by medium to coarse sand size ooid grainstone. This deposit contains two thin normally graded conglomerate layers in the top foot of core. The conglomerates are a few inches thick and

consist of angular MRFs with pisoid ooid grainstone matrix (pisoids to about 3 mm in diameter). The ooid grainstone interval is interpreted as a beach deposit because it overlies terrestrial sediments.

Diagenetic history

The earliest recognized diagenetic process is soil formation, which was penecontemporaneous. Curving fractures in the peloid dolograins between 10,618 and 10,617 ft may have formed in firm sediment before interparticle calcite cementation. Interparticle calcite cementation, if not penecontemporaneous, must have occurred before significant burial. In the absence of thin sections, the cementation environment (e.g., marine phreatic vs. vadose) cannot be determined.

Dissolution of carbonate particles and dolomitization were prominent early burial diagenetic processes, followed by further fracturing and stylolitization. White anhydrite cement filled the early-burial fractures; a third generation of fractures were filled by calcite burial cement. Calcite also replaced some of the fracture-filling anhydrite. Brown anhydrite laths fill fractures between 10,605 and 10,606 ft; these are of unknown age.

Late burial diagenesis included continued stylolitization, pyrite and marcasite formation, and hydrocarbon migration. Precipitation of pyrite and marcasite may have been facilitated by sulfate reduction in the presence of hydrocarbons. There may be a second generation of anhydrite cement, because anhydrite-filled fractures cross-cut calcite-filled fractures between 10,619 and 10,620 ft.

Much porosity is primary interparticle (51.5 percent), which is common in the Mississippi Smackover but unusual in the Smackover of Alabama. This might be due to ooid mineralogy (calcite instead of aragonite) or to early mineralogical stabilization by

diagenetic fluids. However, the only evidence of unusual diagenesis in this core is the abundance of metamorphic rock fragments, which might have affected fluid chemistry.

Figure A-91 - Detailed core log, Land 6-1 No. 1 well, Permit No. 5776, West Okatuppa Creek field, Alabama.

Figure A-92 - Structure contour map of the top of the Smackover Formation in the West Okatuppa Creek field, Choctaw County, Alabama. Modified from Alabama Oil and Gas Board docket number 6-23-8822.

Description of core from West Paulding field, Jasper County, Mississippi
by Roger Townsend

API # 23-061-20074

West Paulding Field
Jasper co., MS

Getty Oil Co. #1 Bd. Of Supervisors 16-6
16-2N-12E, Jasper Co., MS

QC 14,537-14,793

Core File #: C-254.0-19

Pf: 14,619-14,696 IPF 300 BO, 72 MCFG, 6 BW (36.5 gty)

14,537	Limestone, dark gray, laminated, dense, micritic
14,538-42	Dolomite, anhydritic, tan, laminated, bioturbated, dense
14,543	Anhydrite, dolomitic, tan-gray, laminated, bioturbated, dense
14,544-53	Anhydrite, white-gray, nodular
14,554	Sandstone, white, anhydritic, fine grain
14,555-58	Limestone, dark gray, micritic
14,559-73	Anhydrite, white-gray, nodular, occasional dense lime streak
14,574-77	Limestone, dark gray, dense, micritic
14,578-86	Anhydrite, white-gray, nodular
14,587	Limestone, dark gray, dense micritic
14,588-99	Anhydrite, white-gray, nodular
14,600-35	Missing
14,636-60	Sandstone, light gray-tan, fine grain, lime cement, some bedding plains
14,661-64	Missing
14,665-70	Sandstone, light gray-tan, fine grain, lime cement, some bedding plains
14,671-73	Missing
14,674-75	Limestone, tan, oolitic grainstone, fine grain, fair porosity
14,676-77	Limestone, tan-gray, fossiliferous, packstone, poor porosity
14,678-82	Limestone, tan-gray, oolitic, fossiliferous, grainstone, poor sorting, fair porosity
14,683-90	Missing
14,691-92	Limestone, tan oolitic, grainstone, fair porosity
14,693-94	Missing
14,695-97	Limestone, tan, oolitic, grainstone, fair porosity, very fine grain
14,698-04	Sandstone, white-tan, very fine grain, limestone matrix, thinly laminated
14,705	Limestone, dark gray, oolitic, fossiliferous, packstone, poor sorting
14,706-27	Limestone, dark gray, micritic, occasional fossil & stylolite & bioturbated
14,723-24	Missing
14,725-27	Limestone, dark gray, fossiliferous-oolitic-pisol, grainstone, very poor sorting
14,728	Limestone, dark gray, fossiliferous-oolitic-pisol, packstone, very poor sorting
14,729-37	Limestone, dark gray, micritic, occasional fossil, occasional stylolite

14,738-41	Limestone, dark gray, fossiliferous-oolitic-pisol, packstone, very poor sorting
14,742-44	Sandstone, gray, lime cement, fine grain
14,777-83	Limestone, tan, dense, micritic
14,784-85	Sandstone, white, lime cement, very fine grain
14,786-87	Missing
14,788-89	Limestone, gray, oolitic, fossiliferous, pisol, grainstone, poor sorting
14,790-91	Limestone, tan, oolitic, grainstone, very fine grain, well sorted
14,792-93	Missing

GRAIN SIZE/ENERGY FROM TOP TO BOTTOM

14,537-599	Anhydrite, low energy, evaporitic
14,600-635	Missing
14,636-671	Sandstone, lime cement
14,672-697	Grainstone/packstone, high to moderate energy
14,698-704	Sandstone, lime cement
14,705-724	Packstone/mudstone, moderate to low energy
14,725-728	Grainstone/packstone, high to moderate energy
14,729-741	Packstone/mudstone, moderate to low energy
14,742-744	Sandstone, lime cement
14,745-776	No core
14,777-783	Mudstone, low energy
14,784-787	Sandstone, lime cement
14,788-791	Grainstone, high energy

Figure 93 - Structure contour map of the top of the Smackover Formation in the West Paulding and South Paulding fields, Jasper County, Mississippi. Modified from Baria et al. (1982).

Figure A-94 - Structure contour map of the top of the Smackover Formation in the Wimberly field, Choctaw County, Alabama. Modified from Bolin et al. (1989).

Description of core from Wolf Creek field, Wayne County, Mississippi
by Roger Townsend

API # 23-153-20113

Wolf Creek Field
Wayne Co., MS

Pruet & Hughes Co. #1 Stanley Unit 23-2
23-10N-8W, Wayne Co., MS

QC 15,327-15,423

Core File # C-120.0-.6

Pf: 15,287-15,300 IPF 504 BO, 504 MCFG, 0BW (43 gty)

Core Description: 15,327-15,423

15,327-29	Sandstone, dark gray, fine grained, lime matrix
15,330-33	Limestone, dark gray, ooid grainstone, fine-medium grained, poor sorting
15,334-35	Limestone, dark gray, dense, some sand grains
15,336-37	Limestone, dark gray, ooid grainstone, fine-medium grained, poor sorting
15,338-43	Limestone, dark gray, ooid/onkoid grainstone, some fossils
15,344-52	Missing core
15,353	Limestone, dark gray, dense wackestone, few ooid grains
15,354-55	Limestone, dark gray, dense ooid packstone, no porosity
15,356-58	Limestone, dark gray, ooid grainstone, very fine grained, poor porosity
15,359-63	Limestone, dark gray, ooid grainstone, fine-coarse grained, poor sorting
15,364	Limestone, tan, ooid grainstone, very fine grained, fair porosity
15,365-67	Limestone, tan, ooid grainstone, fine-coarse grained, poor sorting
15,368	Limestone, tan, ooid/onkoid packstone, poor sorting, some anhydrite
15,369	Limestone, tan, ooid grainstone, very fine grained, good sorting
15,370-81	Limestone, tan, ooid grainstone, fine-coarse grained, poor sorting, fossils
15,382-84	Limestone, tan, dense, micritic
15,385	Limestone, tan, ooid packstone, dense
15,386-88	Limestone, tan, ooid grainstone
15,389	Limestone, tan, ooid grainstone, poor sorting, abundant fossils
15,390	Limestone, tan, ooid/onkoid grainstone, poor sorting, abundant fossils
15,391-92	Limestone, tan, ooid grainstone, medium grained, good sorting
15,393	Limestone, dark gray, very dense, micritic
15,394-97	Limestone, tan, ooid/onkoid packstone, poor sorting, fossils
15,398-400	Limestone, tan, ooid wackestone, fine-coarse grained, some fossils
15,401-03	Limestone, tan, ooid packstone, medium grained, some fossils
15,404-07	Limestone, tan, ooid grainstone, medium grained, some fossils
15,408-09	Limestone, tan, ooid packstone, fine-medium grained, poor sorting
15,410-14	Limestone, dark gray, dense, micritic, no grains
15,415	Limestone, tan, ooid packstone, fine-medium grained, poor sorting
15,416	Limestone, tan, ooid grainstone, fine-medium grained, poor sorting
15,417-21	Limestone, tan, ooid packstone, coarse grained

15,422-23 Limestone, tan, dense micritic, no grains

GRAIN SIZE/ENERGY FROM TOP TO BOTTOM:

15,327-329	Sandstone, lime matrix
15,330-333	Grianstone, high energy
15,334-335	Mudstone, low energy
15,336-343	Grainstone, high energy
15,353	Wackestone, low to moderate energy
15,354-355	Packstone, moderate energy
15,356-367	Grainstone, high energy
15,368	Packstone, moderate energy
15,369-381	Grainstone, high energy
15,382-384	Mudstone, low energy
15,385	Packstone, moderate energy
15,386-392	Grainstone, high energy
15,393	Mudstone, low energy
15,394-397	Packstone, moderate energy
15,398-400	Wackestone, low to moderate energy
15,401-403	Packstone, moderate energy
15,404-407	Grainstone, high energy
15,408-409	Packstone, moderate energy
15,410-414	Mudstone, low energy
15,415	Packstone, moderate energy
15,416	Grainstone, high energy
15,417-421	Packstone, moderate energy
15,422-423	Mudstone, low energy

Figure A-95 - Structure contour map of the top of the Smackover Formation in the Wolf Creek field, Wayne County, Mississippi. Modified from Davis and Lambert (1963).

Depositional and diagenetic histories of Smackover Formation based on core from Turner
13-25 No. 1 well, Permit No. 2327
Womack Hill field, Clarke County, Alabama
by David C. Kopaska-Merkel

Depositional history

The base of this core consists of domal microbial boundstone overlain by sandy peloid ooid dolograstone, which grades up to domal microbial doloboundstone, which in turn grades up to anhydritic dolostone with exposure surfaces and graded layers (11,440-11,441 ft). These strata were deposited in a subtidal lagoon shoaling upward to a tidal flat. These strata are overlain by anhydritic *Parafavreina* peloid dolostone with exposure surfaces, grading up to anhydritic dolostone of uncertain origin. There are discontinuous clay drapes and abundant anhydrite in this interval, and it is overlain by strata inferred to have been laid down in a tidal flat to sabkha setting, hence these strata were probably deposited on a tidal flat. The interval described so far, 11,431 to 11,448 ft, is lithofacies 1. They are overlain by a thin interval of anhydritic silty dolostone with anhydrite nodules that could be pseudomorphous after gypsum. These strata also include laminar boundstone and abundant quartz silt; they were probably deposited on a tidal flat. (Perhaps in the gypsum mush zone, which would be subtidal.) These strata are overlain by nodular anhydrite with silty dolomitic matrix and include possible cross laminae as well as inch-thick matrix-rich/matrix-poor cycles. These strata were probably deposited on a sabkha. They grade up to nodular anhydrite with vertically oriented nodules, which were probably deposited as subaqueous gypsum crystals, and with an upward-decreasing amount of matrix. The nodules increase in size upward, and there is an anhydritic dolomite layer with calcium-carbonate cement at 11,422 to 11,423 ft. These strata appear to record an upward-deepening from sabkha to brine pond (salina).

Diagenetic history

Penecontemporaneous diagenetic processes included formation of gypsum crystals and anhydrite nodules. Early postdepositional diagenetic processes included calcium-carbonate cementation, followed by dolomitization and leaching, and then fracturing. Later events included stylolitization, pyrite formation, and replacive anhydrite formation. Still-later events included calcium-carbonate cementation and calcitization of anhydrite.

Figure A-96 - Detailed core log, Turner 13-25 well, Permit No. 2327, Womack Hill field, Alabama.

Depositional and diagenetic histories of Smackover Formation based on core from
Federal Land Bank No. 1 well, Permit No. 2372
Zion Chapel field, Choctaw County, Alabama
by David C. Kopaska-Merkel

Depositional history

The lower part of this core is a dolomitic anhydritic bioturbated micropellet grainstone. The basal portion contains anhydrite pseudomorphs of gypsum rosettes. The pellets average about 0.004 inches (100 μ m) in diameter and are extremely uniform in size and shape. The pellets are poorly preserved and not obvious everywhere in this core, but they are apparently ubiquitous. These strata were laid down in a well oxygenated low-energy lagoon that occasionally experienced restriction and elevated salinity values. They pass upward into similar rocks that contain very little dolomite or anhydrite (14,052-14,066 ft). These rocks contain thin oolitic layers (which also contain intraclasts and oncoids), an erosion surface, and come to be well laminated and locally cross laminated upward. These strata record the progradation of an oolitic shoal toward the region sampled by the core. These strata grade up to laminated pellet grainstone (14,036-14,052 ft), which suggests a retreat of the shoal and a return to subtidal low-energy conditions below wave base. Subsequently, the barrier prograded back across the area, laying down sediments that are now laminated pellet ooid dolograins with brecciated zones, erosion surfaces, cross laminated zones, and bivalves, intraclasts, and fossil fragments (14,026-14,036 ft). The preponderance of seemingly laminated strata in this interval suggests beach deposition, in which case the cross laminated lower part could represent shoreface deposition or spit-platform growth. These strata grade up to pellet dolograins with dolomitic crusts and erosion surfaces, intercalated with thin layers of nodular anhydrite (some relatively pure). Parts of these two intervals (14,022.5-14,034 ft) are lithofacies 1. These strata were deposited on an upper tidal flat, on a sabkha that

prograded the tidal flat, and in brine ponds that developed on the sabkha. They grade up to intercalated laminated anhydritic pellet dolograins and dolomitic nodular anhydrite/anhydritic dolomudstone; typical sabkha deposits.

Diagenetic history

Penecontemporaneous diagenetic processes affecting this core include precipitation of gypsum rosettes within the sediment, formation of dolomitic crusts, and growth of displacive anhydrite nodules. Early diagenesis included dolomitization (and precipitation in primary interparticle voids of dolomite rim cement), followed by pore-filling calcite cementation in those same voids, and the dissolution of mineralogically unstable particles. Later diagenetic processes included further dolomitization, formation of replacive anhydrite nodules and laths, fracturing, chemical overcompaction (especially of ooids), and additional calcite cementation (e.g., in the fractures). Still-later events included stylolitization and replacement of anhydrite by both dolomite and calcite.

The pore system in these rocks was created primarily by particle dissolution, but fracture porosity is widespread and was probably important to permeability development. Primary interparticle porosity is locally significant in the upper part of the core, and intercrystalline porosity (?) is found in several intervals.

Figure A-97 - Detailed core log, Federal Land Bank No. 1 well, Permit No. 2372, Zion Chapel field, Alabama, upperpart.

Figure A-98 - Detailed core log, Federal Land Bank No. 1 well, Permit No. 2372, Zion Chapel field, Alabama, lower part.

Figure A-99 - Structure contour map of the top of the Smackover Formation in the Zion Chapel field, Choctaw County, Alabama. Modified from Bolin et al. (1989).

Descriptions of Wildcat Wells in Alabama
By David C. Kopaska-Merkel

Choctaw County

**Placid Jackson No. 1 well,
Permit No. 1330, wildcat, Choctaw Co., Alabama. Core number X-298.**

Depth intervals: 10,297 to 10,578 ft. The core-derived lithologic data best match geophysical log response if the top of the core is correlated to a log depth of about 10,302 ft, for a downward adjustment of the core of 5 ft.

Thin sections: None.

General information: This core includes a section of about half of the Smackover Formation in an updip location. The core was previously described in summary fashion by Mancini and Benson (1980).

Lithostratigraphic unit(s): Smackover Formation.

Lithofacies: The Smackover Formation in this core is assigned to eight lithofacies. Lithofacies 1 (10,578 to 10,534 ft; 13.4 m or 44 ft thick) is dominated by light-colored (bleached and chalky) very poorly sorted peloid packstone. The basal 6.2 m (20.5 ft) of lithofacies 1, the interval below 10,557.5 ft, consists of bleached peloid packstone/wackestone in which two rock types are intercalated. Layers exhibiting little or no compaction, tight matrix, and well preserved particles alternate with layers exhibiting considerable chemical compaction, wispy stylolites, and poorly preserved particles. In this latter lithology, only the very fine peloids are clearly discernible, and original rock

textures of the two rock types may have differed. Strata range from laminae to medium beds; very thin to thin beds dominate. Peloids are the most common particles; other particles include (in approximate order of decreasing abundance) fossil fragments, oncoids, bivalves, *Parafavreina*, quartz silt and very fine sand, ooids, echinoid spines, gastropods, cephalopods, and solitary corals (?). Overall, this unit becomes less well sorted upwards via the addition of both finer and coarser particles. Fossils coarser than 2 mm are scattered throughout. Oncoids, many nucleated on bivalve fragments, range up to 3.5 cm in diameter. Other oncoids contain gray-brown anhydrite anhedral or anhydrite laths up to several millimeters long, as is common in the Smackover. Uncommon burrows are more than 2 cm in diameter. The unit contains very little dolomite, but microcrystalline dolomite locally replaced peloids. Gray-brown or clear anhedral anhydrite laths and clear anhydrite crystals within particle molds account for less than 1 percent of the rock. A few small clusters of anhydrite crystals consist of cores of clear crystals surrounded by gray-brown anhedral. Fractures are short (no longer than a few centimeters) and commonly but not invariably associated with low-amplitude sawtooth stylolites. Fractures contain clear anhydrite crystals or are open. Minor euhedral quartz cement occurs within particle molds. The pore system in the basal portion of lithofacies 1 is dominated by moldic and secondary intraparticle pores; porosity ranges from nil to about 20 percent, but averages less than 5 percent. The chalky surface texture of this unit suggests that secondary microporosity (not visible in slabbed core) is significant.

Overlying the basal unit is about 1.4 m (4.5 ft) of very thin to medium bedded peloid packstone. This unit grades upward from nonporous rock that is darker than underlying material to a succession of intercalated dark dense and light porous (bleached and chalky)

limestone. Peloids dominate, and particles in this unit are less diverse than below, but include fossils, bivalves, ooids, oncoids, and ostracodes, in approximate order of decreasing abundance. Some oblong peloids could be thalassinidean pellets but poor preservation prevents definite identification. Many bivalves are large and thick shelled; some are articulated. Fractures were filled by anhydrite, which also partially replaced oncoids and bivalves. Porosity in this unit consists of moldic, secondary intraparticle, and vuggy pores, and accounts for no more than a few percent of the rock.

The upper part of the unit just described grades up into a very thin to thin bedded very poorly sorted peloid fossil pack-grainstone that is about 0.3 m (1 ft) thick. This unit differs from underlying strata chiefly in that fossils are more abundant and diverse. The unit contains echinoid spines, intraclasts, and abundant small benthic foraminifera. As below, some large thick-shelled bivalves are articulated. Moldic, secondary intraparticle, and vuggy pores account for just a few percent of the rock.

A 0.9 m (3 ft) thick brecciated interval lies between 10,349 and 10,352 ft. Dark dense clasts up to 0.6 m (2 ft) across are embedded in a lighter porous (bleached and chalky) matrix containing abundant wispy stylolites. No evidence of rotation of clasts was observed. Contacts between light matrix and dark clasts are of two kinds. Some contacts are gradational over a few millimeters or less. In other cases light and dark areas with sharp boundaries are separated by dissolution seams. Bleached particles occur in clasts and dark patches are found in light areas. The margins of clasts are light, and the rock grades over a millimeter or so from intensely bleached rims to dark gray-brown dense limestone that is characteristic of clast interiors. At the base of the brecciated interval is at least 3 cm of thinly laminated argillaceous lime mudstone, overlain by a dissolution seam

0.5 to 1 cm thick. All contacts between packstone, mudstone, and dissolution seam are sharp. Locally, strata are not planar and horizontal but undulose. Both clasts and matrix exhibit similar depositional textures and particle types. Depositional rock types include mixed peloid packstone, *Parafavreina* packstone, fossil packstone to wackestone, and mixed particle wackestone. Particles include, in approximate order of decreasing abundance, peloids, small ovoid pellets, *Parafavreina*, fossil fragments, bivalves, intraclasts, oncoids, gastropods, encrusting foraminifera (on oncoids and bivalves), echinoid spines, ostracodes, and possible sponges. Dolomite content ranges from a few percent to about 80 percent, averaging about 15 percent. Most dolomite in this interval is microcrystalline, but some crystals are as large as silt size. Porosity in this unit ranges from a few percent to (locally) about 25 percent; pores are molds, secondary intraparticle voids, vugs, and (uncommonly) fractures.

The uppermost 4.6 m (15 ft) of lithofacies 1 consists of laminated to medium bedded peloid packstone, much of which is bleached and chalky. Between 10,547 and 10,548 ft the boundary between dense dark carbonate and bleached chalky carbonate is vertical. Above 10,544 ft this unit is strongly dominated by bleached carbonate, whereas the lower 1.5 m (5 ft) consists of roughly equal parts bleached and nonbleached intervals. Bleached intervals consist of chalky spheroids with abrupt to gradational boundaries (glauabules) up to 7 cm across in a soft matrix with scattered relatively unaltered (relict) clasts up to 6 cm across. Maximum glauabule size increases upward. Particles include, in approximate order of decreasing abundance, peloids, *Parafavreina*, small ovoid pellets, bivalves, fossil fragments, intraclasts, gastropods, small benthic foraminifera, ooids, echinoid spines, and *Palaxius* (a thalassinidean pellet similar to *Parafavreina*). Dolomite (a trace to a few

percent) is dominated by silt-size rhombs. Anhydrite, present in trace amounts, consists of clear cement in particle molds and in fractures as well as white laths. Pyrite is locally associated with wispy stylolites. Some fractures are cemented with calcite rather than anhydrite. Porosity in this unit ranges from 10 to 15 percent and is dominated by moldic, secondary intraparticle, and vuggy pores, with lesser fracture porosity.

Lithofacies 2 (10,511 to 10,534 ft; 7 m or 23 ft thick) is dominated by dark gray-brown thinly laminated to very thin bedded foraminiferal peloidal argillaceous mudstone. Particles include peloids, fine benthic foraminifera, fossil fragments, bivalves (some articulated), and a trace of very fine quartz sand in the uppermost 0.15 m (0.5 ft). Foraminifera are more abundant in more argillaceous layers and are preferentially preserved in stylolitized intervals. The unit contains up to 85 percent dolomite in the uppermost 0.15 m (0.5 ft), including dolomite cement in fractures, but no dolomite in the rest of lithofacies 2. Anhydrite (present in trace amounts) consists of clear cement in fractures and vugs and extremely coarse laths in patches up to several millimeters across. Finer white anhydrite crystals form clusters as large as medium sand size. Some fractures contain calcite cement rather than anhydrite or dolomite cement. Porosity is essentially nil in lithofacies 2.

Lithofacies 3 (10,499 to 10,511 ft; 3.7 m or 12 ft thick) is dominated by thinly laminated to medium bedded (mostly thin bedded or thinner) dolomitic peloid packstone. However, strata in the lower part of the unit grade upward from peloid mudstone. Vertical burrows 8 to 9 mm in diameter are common in the lower part of the unit. Clusters of pyrite framboids are locally common. Particles include, in approximate order of decreasing abundance, peloids, fine pellets, *Parafavreina* (medium to coarse sand

size), gastropods, bivalves (some articulated), fossil fragments, foraminifera, and *Palaxius*. The fine pellets in this unit contain central lumens, are ovoid to cylindrical, and probably are thalassinidean (perhaps *Helicerina*, a small thalassinidean pellet previously reported from the Smackover on the Saint Stephens ridge; Kopaska-Merkel, 2000). Borings no larger than 1 mm in diameter are associated with exposure surfaces in the basal foot of the unit. Exposure surfaces in this unit are slightly irregular and closely spaced, but do not exhibit discernible discoloration or encrustation. Dolomite ranges from traces to (locally) nearly 100 percent of the rock, but averages a few percent in the upper part of the unit and less than 1 percent in the lower part. Anhydrite consists of clear cement in fractures and within the body cavities of articulated bivalves, as well as anhedral gray-brown laths. Porosity in this unit is nil.

Lithofacies 4 (10,446 to 10,499 ft; 16.2 m or 53 ft thick) is dominated by laminated to thick bedded dolomitic ooid grainstone. Cross strata are locally discernible. Particles include, in approximate order of decreasing abundance, ooids, coated grains, peloids, fossil fragments, pisoids, bivalves, intraclasts, *Parafavreina*, undifferentiated thalassinidean pellets, *Palaxius*, quartz sand and silt, gastropods, ostracodes, and echinoid spines. Thalassinidean fecal pellets are common and widespread in this unit, though not sufficiently abundant to affect rock names or appear on graphic core logs. *Palaxius*, which elsewhere in the Smackover is extremely rare, is sufficiently common in this core so that more than a dozen specimens were positively identified in slabbed core. Burrows are horizontal or vertical and range from 3 to 8 mm in diameter. A boring between 10,496 and 10,497 ft is quite different from those observed deeper in the core. The boring is 1.5 mm in diameter and lined with calcite that is transversely ribbed on the outside. The

lining is 100 to 125 μm thick and consists of a white inner layer and a clear outer layer. The ribs or annulae are spaced 50 to 75 μm apart. The boring is sinuous, branched, and was originally probably more than 1 cm long. Dolomite ranges from microcrystalline to very fine sand size, but most is silt size. Dolomite ranges from absent to 100 percent of the rock, but averages between 5 and 20 percent. Dolomite preferentially replaced particles, especially ooid cortices. Anhydrite occurs in several forms in this unit, including gray-brown laths along and adjacent to sawtooth stylolites, scattered or clustered dark or clear gray laths (some with associated pyrite) accounting for up to 5 percent of the rock, and clear anhydrite cement in particle molds and primary interparticle pores accounting for up to 5 percent of the rock. In general, the concentration of anhydrite increases upward in this unit, but variation in anhydrite concentration within any single meter is nearly as great as that in the entire lithofacies. Chemical and physical interparticle compaction are both observed in this unit, but not together. Chemical compaction of particles is pronounced below the exposure surface at 10,466.5 ft, which exhibits 1.5 cm of relief. Most strata in lithofacies 4 exhibit little evidence of compaction. Porosity in this unit is dominated by secondary intraparticle, and to a lesser extent moldic and primary interparticle pores. Minor pore types include intercrystalline, vuggy, and fracture pores. Porosity ranges from 5 to 50 percent, but averages 25 to 30 percent.

Lithofacies 5 (10,389 to 10,446 ft; 17.4 m or 57 ft thick) is dominated by dolomitic mudstone and (in the upper part) microcrystalline dolostone. The basal 10.6 m (34.7 ft) of lithofacies 5 consists of laminated to thin bedded nonporous rubbly dolomitic mudstone. Recognizable particles include peloids, fossils, bivalves (both thick-shelled and thin-shelled; some are articulated), thalassinidean pellets, and echinoid spines. Dolomite is

microcrystalline and accounts for a trace to about 25 percent of the rock, averaging less than 5 percent. Dolomite preferentially replaced particles, but some dolomite is disseminated or forms partial haloes around bivalves. Anhydrite discoids up to 1.5 mm long are common in three intervals: between 10,424 and 10,425 ft, between 10,417 and 10,419 ft, and between 10,413 and 10,416 ft. Other anhydrite, which accounts for as much as several percent of the rock, consists of gray-brown anhedral crystals that are disseminated or clustered throughout the unit, extremely coarse laths that are associated with or partially replace large robust bivalve shells, and nodules with clear extremely coarse centers and dark rims. Some of the clusters of dark anhedral anhydrite crystals are located within large burrows. Porosity in this unit is nil.

Overlying the basal part of lithofacies 5 is a unit 4.1 m (13.3 ft) thick that consists of dolomitic peloid wacke-packstone, peloid dolowacke-grainstone, and microcrystalline dolostone. Particles in this unit, in approximate order of decreasing abundance, are peloids, bivalves, fossils, and thalassinidean pellets. Dolomite content of this unit ranges from a trace to more than 99 percent of the rock, and is highly variable within a single meter, but increases upward overall. Anhydrite includes nodules consisting of extremely coarse clear laths, gray-brown laths, or white cores with gray-brown margins. Above 10,405 ft are a few small white displacive anhydrite nodules. Porosity in the upper part of this unit is intercrystalline, moldic, and secondary intraparticle, accounting for up to 40 percent of the rock, but the lower part is nonporous.

The uppermost 2.7 m (9 ft) of lithofacies 5 consist of laminated to thin bedded microcrystalline dolostone. This unit exhibits indistinct mottled fabric throughout that defines equant or loaf-shaped blobs resembling glaeboles, breccia clasts, or burrows.

About 0.15 m (0.5 ft) below the top of lithofacies 5, a reddened surface with 1 cm of relief is underlain by abundant anhydrite laths. Particles in this unit include, in approximate order of decreasing abundance, peloids, bivalves, and gastropods. Calcite content of this unit locally approaches 15 percent, but throughout most of this interval calcite is limited to minor cement in fractures and traces of relict calcite embedded in dolostone. Anhydrite consists of gray-brown anhedral laths as well as extremely coarse elongate euhedral gray laths that occur either in clusters or enriched in certain laminae. Porosity in this unit is intercrystalline and accounts for only a few percent of the rock.

Lithofacies 6 (10,370 to 10,389 ft; 5.8 m or 19 ft thick) is almost entirely dolomitized and consists of peloid dolograinstone overlain by breccia which is in turn overlain by ooid dolograinstone. Nearly all of lithofacies 6 is brown and mottled, consisting of relatively dense nodules in a more argillaceous matrix. A thin interval between 10,370.5 and 10,372.5 ft is a homogeneous light tan color. The basal 2.7 m (9 ft) of the lithofacies consists of peloid dolograinstone with minor intercalated crystalline dolostone. Particles in this unit include peloids, fossils, intraclasts, undifferentiated mollusks, bivalves, gastropods, and possible oncoids. Relict calcite accounts for up to 5 percent of the rock in this unit, but averages less than 1 percent. Fractures are abundant, and where they intersect nodules, the fractures bend around the nodules. Gray-brown anhedral anhydrite laths occur in clusters up to 1.5 cm across; white nodules up to 4 cm across consist of extremely coarse anhydrite crystals. Anhydrite cement fills particle molds, some fractures, and fenestrae. Calcite cement fills some fractures and particle molds. Porosity in this unit averages about 25 percent and consists of moldic, secondary intraparticle, intercrystalline, and primary interparticle pores.

The middle part of lithofacies 6 (10,373.5 to 10,380 ft) is a breccia. At the time of deposition these strata consisted of molluscan peloid grainstone, which has since been entirely dolomitized and brecciated. Particles, in approximate order of decreasing abundance, include peloids, bivalves, fossils, intraclasts, and gastropods. Breccia clasts are well rounded, may have complex shapes, and range from less than 1 mm to at least 5.5 cm across. Breccia clasts grade from distinct clasts with sharp boundaries to nodules or mottles with diffuse boundaries. Near the base of the unit a geopetal indicator (particle mold containing internal sediment and younger cement) within a breccia clast records 30° of rotation. Anhydrite includes clear cement within particle molds, fractures, and fenestrae, and white nodules consisting of displacive felted laths. Calcite cement occupies some particle molds and fractures. Porosity in this unit (20 to 30 percent) is dominated by moldic and secondary intraparticle pores, with primary interparticle pores important locally.

The uppermost part of lithofacies 6 consists of thick bedded ooid dolograinstone. The base and top of this unit are brown and mottled whereas the middle part is light tan and its color is homogeneous. About half of the unit is cross stratified. Particles include, in approximate order of decreasing abundance, ooids, peloids, coated grains, fossils, gastropods, and bivalves. The concentration of dolomite in this unit ranges from 0 to nearly 100 percent. Dolomite is microcrystalline to silt size and its distribution is quite different from that of dolomite in deeper parts of the core. In this unit, dolomite preferentially replaced interparticle cement and ooid nuclei, but left many ooid cortices unaltered. Coarser dolomite crystals line voids and calcitic areas whereas the centers of dolomitized patches are microcrystalline. Anhydrite occurs as white nodules and clear

cement. Chemical and physical interparticle compaction are apparent in this unit, but were not intense. Porosity in this unit is low (less than 10 percent) and dominated by moldic, secondary intraparticle, primary interparticle, and intercrystalline pores.

Lithofacies 7 (10,324.5 to 10,370 ft; 13.9 m or 45.5 ft thick) is dominated by very thin to thick bedded dolomitic ooid grainstone, ooid peloid grainstone and pisoid ooid grainstone. Cross strata are discernible in about half of the unit. Two kinds of strata in the upper part of this lithofacies (above about 10,351 ft) may be tempestites. Normally graded strata range in thickness from a few centimeters to more than 10 centimeters (very thin to medium beds), and grade from maximum particle sizes of several millimeters at their bases to less than 1 mm at their tops. Other laminae to thin beds are not visibly graded, but are much coarser (maximum particle sizes of at least several millimeters) than intercalated strata (maximum particle sizes less than 0.5 mm). Fenestrae were observed between 10,341 and 10,342 ft, just below an exposure surface. A thin interval (10,364.5 to 10,365 ft) is brownish and mottled like much of the underlying lithofacies 6 but the rest of lithofacies 7 is light tan and is not mottled. Particles include, in approximate order of decreasing abundance, ooids, peloids, pisoids, coated grains, fossils, bivalves, gastropods, undifferentiated mollusks, intraclasts, oncoids, fragments of siliciclastic mudstone, solenoporacean algae, and colonial corals. Dark gray pyritic clasts of siliciclastic mudstone are scattered throughout this unit. The clasts are of coarse sand size or larger and most are platy. Fragments of solenoporacean algal thalli are common between 10,333.5 and 10,334.5 ft but were not observed elsewhere in the core. The fragments are cream colored, up to 4 mm long, and consist of bundles of tightly packed parallel tubules that are 30 to 60 μm in diameter (average 40 μm). In cross section the

tubules are round and irregularly arranged. No cross walls (c.f., *Solenopora jurassica*, Helm and Schülke, 1998) were observed in cross-sectional view. In longitudinal view, the cells are arranged radially rather than concentrically. The fragments do not provide information about colony external morphology. *Parachaetetes* sp. was reported from the Smackover of Louisiana by Crevello and Harris (1984). *Solenopora jurassica* is a similar species that has been reported from the Oxfordian of Germany (e.g., Helm and Schülke, 1998). The present material differs from *Parachaetetes* in its radial arrangement of cells and in the irregular arrangement of tubules (Rácz, written commun., 1965) and is therefore referred to *Solenopora* (?) sp. Dolomite is primarily of silt size, planar in form, and accounts for 0 to 100 percent of the rock. Average dolomite content is less than 20 percent. Anhydrite in this unit (which accounts for up to several percent of the rock) is dominated by white to clear laths that preferentially formed among particles. Some of this material is probably cement, but in many cases the margins of anhydrite bodies consist of euhedral laths that appear to penetrate the surrounding carbonate. Pyrite is locally associated with interparticle anhydrite. Some clear anhydrite cement fills particle molds and some fenestrae. Other fenestrae contain calcite cement or are open. Fractures in the lower part of the unit are filled with calcite cement. Minor amounts of interparticle chemical compaction characterize much of this lithofacies. The pore system in lithofacies 7 is dominated by primary interparticle porosity, and accounts for 10 to 30 percent of the rock, averaging 15 to 20 percent. Minor fenestral porosity was observed. Black solid hydrocarbon residue occurs in pores throughout lithofacies 7.

Lithofacies 8 encompasses the uppermost part of the core, from 10,297 to 10,324.5 ft (8.4 m or 27.5 ft thick) and is dominated by laminated to medium bedded ooid

dolograinstone. Lesser, but common, rock types include intraclast peloid ooid dolograinstone, peloid dolograinstone, pisoid ooid dolograinstone, and dolomitic ooid peloid grainstone. Strata in the lower part of lithofacies 8 are cross stratified; cross strata between 10,314 and 10,315 ft exhibit distinctly lower angles of cross lamination than elsewhere in this core. Closely spaced exposure surfaces characterize the uppermost meter (three feet) of core. An exposure surface at 10,322.5 ft is immediately overlain by a lamina of intraclast wackestone. The matrix of this stratum consists of microcrystalline dolomite, and intraclasts are fragments up to 1 cm across of the underlying ooid dolograinstone. Many strata in this unit are normally or inversely graded, some strata exhibit bimodal particle distributions, and dramatic differences in sorting, average particle size, and maximum particle size characterize adjacent strata. Particles, in approximate order of decreasing abundance, include ooids, peloids, pisoids, intraclasts, coated grains, and fossils. Skeletal material is far less abundant than in underlying strata. Dolomite in lithofacies 8 is chiefly of silt size and accounts for a trace to 100 percent of the rock. The average dolomite content is 50 to 60 percent but the actual value varies greatly from one meter to the next. The extremely fine crystal size of dolomite in most of this lithofacies has preserved many preexisting features, such as the single layer of rim cement binding ooids with hardened rinds and now-dissolved nuclei in some strata. Anhydrite discoids up to 4 mm across are common (as much as 5 percent of the rock) above 10,315 ft. Other anhydrite in this unit (as much as 5 percent of the rock locally) consists of clear cement and clear to light brown euhedral laths. Porosity in this lithofacies is dominated by moldic, secondary intraparticle, and primary interparticle pores. Porosity in lithofacies 8 is 15 to 40 percent, averaging about 25 percent.

Depositional Environment: The basal portion of this core (lithofacies 1) was deposited on a shallow subtidal shelf. This is indicated by the dominance of peloids, including thalassinidean fecal pellets, and by the lack of any exposure indicators. Biotic diversity is greater in this unit than is typical of the Alabama Smackover, and therefore the environmental setting is inferred to have been relatively open and the waters normal marine. Superimposed on the depositional features of lithofacies 1 are secondary characteristics indicating that the entire unit is a paleosol profile. Most of the rocks in this lithofacies are bleached and chalky, a dissolution pipe is preserved between 10,547 and 10,548 ft, and a pedogenic breccia is located between 10,349 and 10,352 ft. The breccia is interpreted as pedogenic because many clasts have gradational boundaries, the matrix is chalky and bleached, and there is no evidence of rotation or movement of clasts.

The pedogenically altered subtidal strata of lithofacies 1 are overlain by tidal-flat deposits assigned to lithofacies 2 and 3. These strata are thinly laminated to laminated, contain exposure surfaces (some bored), and lithofacies 2 contains abundant small benthic foraminifera. This is an extremely unusual facies for the Smackover of Alabama, in which free-living foraminifera are commonly very scarce.

Overlying strata assigned to lithofacies 4 are interpreted as shoal deposits with a minor admixture of tidal-flat deposition. These strata are dominantly oolitic, are cross stratified (in part), and most of this unit is fairly well sorted. This unit contains common *Palaxius*, which are extremely uncommon elsewhere in the Smackover. A single lined boring of unknown origin indicates syngedimentary lithification. A low-relief exposure surface occurs about at the base of the inferred tidal-flat deposits.

The lower part of lithofacies 5 (up to 10,425 ft) is interpreted as a shallow subtidal deposit, laid down during and immediately after a brief period of transgression. These muddy strata contain no exposure indicators and no high-energy deposits, yet there is also no evidence for a dramatic deepening, indicating that the sediment surface was likely not far below storm wave base. The sparse but diverse fauna, which includes echinoids, thalassinideans, and mollusks, suggests that normal marine conditions prevailed.

The overlying unit (10,412.5 to 10,425 ft) is characterized by mud-supported carbonates containing discoidal anhydrite. Discoidal anhydrite is commonly interpreted as dehydrated discoidal gypsum, which forms intertidally. Hence, this interval is considered to be a tidal-flat deposit.

The upper part of lithofacies 5 (up to 10,389 ft) is interpreted as a lagoonal deposit on the basis of four criteria. First, these strata lack exposure indicators, except for an inferred emersion surface near the top that is reddened and exhibits about 1 cm of relief. Second, evidence of high-energy water movement is lacking. Microcrystalline peloids are the most abundant particles, though intense dolomitization has obscured depositional texture in much of the unit. Finally, the unit is sandwiched between inferred tidal-flat deposits.

Most of lithofacies 6 (up to 10,373.5 ft) is thought to have formed on a tidal flat, because the unit contains fenestrae, thin coarse layers that are interpreted as tempestites, intraclasts, possible oncoids, and uncommon displacive anhydrite nodules.

The upper part of lithofacies 6, lithofacies 7, and the basal portion of lithofacies 8 combine to form an ooid-grainstone unit interpreted as a shoal deposit. This unit is dominated by ooids, which are associated with coated grains, pisoids, oncoids, and intraclasts, all indicating formation under high-energy conditions. Solenoporacean algae

and colonial corals are found at a few horizons in this unit, and indicate both energetic conditions and normal marine water chemistry. This unit is in general well sorted, though common thin coarse layers (many normally graded) suggest tempestites. Nearly half the unit is cross stratified, and in much of the remainder stratification is not observed; many of these layers could have been deposited as cross strata. Fenestrae and exposure surfaces (one dolomitized) are scattered through the unit, which contains common intraclasts at certain horizons, especially above exposure surfaces.

The uppermost part of the core is interpreted as a tidal-flat deposit. Anhydrite discoids, closely spaced exposure surfaces, abundant intraclasts, and abundant thin coarse layers (some normally graded) that are identified as tempestites all support this interpretation. Relatively low-angle cross lamination between 10,314 and 10,315 ft may indicate subaerial eolian dune formation.

Superimposed on the record of marine carbonate deposition in this core are two well-developed paleosols and two thin paleosols. The paleosols are described in the section on diagenetic history.

Overall this core records fluctuating sea levels but dominantly shallow-water marine deposition; the basal portion of the core was probably deposited in the deepest water. Based on geophysical log response and reported core depths, the core appears to represent slightly more than half of the Smackover Formation, with the top of the core being just below the boundary with the overlying Buckner. Hence, lithofacies 1 represents the top of the deeper water middle Smackover strata and the rest of the core corresponds to the dominantly peritidal and high energy upper Smackover. This interpretation is consistent with that of Mancini and Benson (1980), who briefly

described this core. The main difference in the present interpretation is the recognition of two major paleosols (described below).

Diagenetic History: The diagenetic history of this core is complex, and its description is limited by an absence of thin sections. However, the following discussion summarizes what has been observed in slabbed core.

Penecontemporaneous diagenesis in this core included the formation of marine pore-rimming cement in grainstones, intrasedimental growth of gypsum discoids, minor formation of displacive anhydrite nodules, lithification of exposure surfaces (some were bored), precipitation of pyrite framboids, and development of paleosols. Pyrite framboids are locally common in lithofacies 3; framboids are generally understood to form penecontemporaneously under reducing conditions not far below the sediment/water interface. Microcrystalline dolomite is common in this core, especially in lithofacies 5 and 6, within and directly below the upper thick paleosol. This dolomite may have formed penecontemporaneously either before or during soil development.

Paleosols are widespread in the Smackover Formation (e.g., Kopaska-Merkel and others, 1992; Kopaska-Merkel and Mann, 1993; Kopaska-Merkel, 1998b), but are commonly difficult to recognize because most are poorly developed. Most Smackover paleosols consist of relatively thin intervals that may be fractured, brecciated, dolomitized, or recrystallized, and that are capped by irregular surfaces that may be dolomitized, blackened, reddened, or recrystallized. Paleosols in this core are unusual (for the Alabama Smackover) because they are thick, leached, and bleached.

The deepest paleosol in this core encompasses the interval from 10,534 ft to the base of the core (and beyond). This paleosol is at least 13.4 m (44 ft) thick. The unit is dominantly light-colored (bleached) and chalky. Relict patches and layers of less-altered limestone are darker and less porous than the rest of the unit. A pedogenic breccia 0.9 m (3 ft) thick contains unaltered clasts in a bleached, chalky, and stylolitized matrix. This is not a mechanical breccia but one that developed in situ as part of the soil-formation process. The breccia clasts are not rotated, and many have gradational contacts with the surrounding matrix. A dissolution pipe penetrates the core a short distance above the breccia, as indicated by a vertical boundary between altered and unaltered limestone between 10,547 and 10,548 ft. Alteration is more intense higher in the paleosol. Above the dissolution pipe the paleosol is dominated by a soft matrix containing glaebules that increase upward in size to a maximum of about 7 cm. Both glaebules and matrix are bleached and chalky. However, the matrix includes scattered clasts of relatively unaltered limestone up to about 6 cm across.

The second (upper) paleosol is actually a complex of three paleosols, which may really be a single complex paleosol. Three altered zones between 10,364.5 and 10,398 ft (an interval of 10.2 m or 33.5 ft) are separated by two thin unaltered zones that together are only about 2 meters thick. This succession of three closely spaced paleosols is tentatively identified as a single complex paleosol for three reasons. First, the host rock was originally homogeneous ooid grainstone from slightly below the top of the lowest of the three paleosols to about the top of the uppermost paleosol. Occam's Razor suggests that in a homogeneous succession (with no evidence for sea-level fluctuation) fewer soil profiles are more likely. Second, the two upper paleosols are well developed but very thin

(about 0.15 m or 0.5 ft thick). However, most paleosols in the Smackover are poorly developed; a succession of three closely spaced well-developed paleosols is unlikely in this formation. Third, developing soils can bypass large areas of host rock, leaving them essentially unaltered, while overlying and underlying material is strongly affected by soil formation. In such a case, a 3-inch diameter core could appear to penetrate multiple paleosols separated by unaltered strata, when in fact only a single paleosol was present. The lower third of the lowest and thickest part of the tripartite paleosol is indistinctly mottled; the mottling probably represents incipient glaebule formation. The upper two-thirds of the thick part of the paleosol (most of lithofacies 6) is brown and mottled, consisting of relatively dense nodules in an argillaceous matrix. The nodules are interpreted as relatively unaltered limestone in a matrix of highly pedogenically altered material. Fractures are common and bend around “nodules,” indicating that they formed after “nodules” differentiated but before the rock became entirely rigid. The fractures probably formed during late pedogenesis. The middle part of lithofacies 6 is a pedogenic breccia containing clasts with diffuse boundaries. However, some clasts have sharp boundaries and a single geopetal structure indicates rotation of at least one clast. Two altered intervals each about 0.15 m (0.5 ft) thick are the middle and upper parts of the complex paleosol. These two intervals are brown and mottled, resembling the non-brecciated portion of the underlying thick paleosol interval. The three altered intervals are separated and overlain by light tan relatively unaltered marine carbonate.

Microcrystalline dolomite that appears to have formed relatively early is commonly associated with evaporites and its formation has been attributed to the action of hypersaline water. Inferred hypersaline microcrystalline dolomite is a minor component

of many Smackover cores in Alabama. In this core, microcrystalline dolomite occurs at many stratigraphic levels and is associated with a variety of rock types and original depositional settings. However, most of the microcrystalline dolomite in the core lies between 10,370.5 and 10,446 ft. This interval corresponds to the upper (complex) paleosol and the muddy carbonates that directly underlie it. In addition, the concentration of dolomite increases upward throughout this interval. It therefore seems likely that the dolomite was sourced from the exposure surface that forms the top of the complex paleosol. The small crystal size of the dolomite suggests that the dolomitizing fluid was hypersaline. The dolomite must have formed after paleosol development, because the highly altered and brecciated parts of the paleosol appear to be uniformly dolomitized.

Dolomitization (other than microcrystalline dolomitization) and concomitant dissolution or partial dissolution of calcium-carbonate particles occurred under burial conditions but relatively early. Originally grainy rocks contain coarser dolomite crystals than muddy rocks. The most notable exception is that microcrystalline dolomite in the upper (complex) paleosol replaced the entire paleosol, including coarse grainstone. This suggests that the bulk of matrix dolomite formed relatively early and in only a few episodes. A complex or late history of dolomitization would not likely have preserved the relationship between dolomite crystal size and depositional texture. Dolomitization and calcium-carbonate dissolution were followed by growth of replacive anhydrite that cuts across matrix dolomite, relict calcium-carbonate particles, and calcium-carbonate matrix. The varied color and morphology of replacive anhydrite laths suggests multiple episodes of anhydritization.

Fracturing occurred after formation of a rigid rock framework and after matrix dolomitization. It was followed by precipitation of anhydrite, calcite, and (uncommon) dolomite cement. These cements precipitated within fractures, but also within primary interparticle voids, particle molds, and vugs. Multiple episodes of formation of all three minerals are indicated by cross-cutting relationships and variations in crystal morphology observed in the core. Burial diagenesis also included pressure dissolution, which overlapped in time with fracturing. In grainstone strata both brittle and chemical interparticle dissolution were widespread but not intense. Both sawtooth and wispy stylolites are common in relatively pure and argillaceous strata, respectively. Some fractures are associated with sawtooth stylolites and probably formed as a result of stresses created by pressure dissolution. Uncommon larger pyrite crystals associated with wispy stylolites or with replacive anhydrite laths probably formed under burial conditions. Burial diagenesis ended with emplacement of hydrocarbons, which remain as solid black linings of some pores.

Figure A-100. Graphic core log of Permit No. 1330 well. Placid Jackson No. 1, wildcat, Choctaw Co., Alabama--detailed core log, lower part.

Figure A-101--detailed core log, lower middle part.

Figure A-102—detailed core log, upper middle part.

Figure A-103--detailed core log, upper part.

Figure A-104--summary graphic core log and digitized geophysical logs.

Pruet ALCO Land and Timber Co. No. 1 well

Permit No. 1400, wildcat, Choctaw Co., Alabama. Core number X-273.

Depth intervals: 12,477.7 to 12,507, 12,527 to 12,574 ft.

Thin sections: None.

General information: This core includes a partial section of the Smackover Formation.

Lithostratigraphic unit(s): Smackover Formation.

Lithofacies: The Smackover Formation in this core is divided into two lithofacies.

Lithofacies 1 corresponds to the interval from 12,527 ft to the base of the core and is 14.3 m (47 ft) thick. The unit is dominated by silt-size dolostone and dolomitic limestone with mud-supported peloidal depositional fabrics. Lithofacies 2 corresponds to the interval from the top of the core to 12,507 ft and is 8.9 m (29.3 ft) thick. This unit consists of fine to very fine pellet grainstone, in part dolomitic, and includes poorly sorted oolitic, fossiliferous, and intraclastic laminae.

Lithofacies 1 (14.3 m; 47 ft) is a generally mud-supported partially dolomitized low-porosity unit. Peloids are the most common particles, but this may result from poor preservation rather than primary textural characteristics. Dolomite is silt-size and planar-e. The basal 5.6 m (18.5 ft) consists of very thin to medium bedded dolomitic peloid wackestone and peloid dolowackestone. Peloids are spheroidal and chiefly medium to coarse; likely many of them are ooids. Most of this interval is bioturbated; burrows appear to range from about 1 mm to about 5 mm in diameter, are oblique to the horizontal, and are confined to single strata. The uppermost 0.46 m (1.5 ft) of this interval contains common echinoderm ossicles and a small microherm nucleated on an oncolite.

Traces of anhydrite include displacive nodules up to 2 cm across and small nodules composed of extremely coarse clear laths or gray subhedral to anhedral replacive laths.

The interval just described is overlain by about 1.4 m (4.5 ft) of silt size crystalline (planar-e) dolostone, which is in turn overlain by 3.4 m (11 ft) of predominantly particle-supported laminated to thick bedded peloidal dolomitic limestone. This unit is dominated by medium sand size peloids, some of which exhibit well-developed cement rinds. Echinoderm fragments are uncommon but widely distributed; anhydrite is similar to that in the lower part of the core, but displacive nodules are more common. Because of the small size of the dolomite crystals, crystal form is difficult to determine, but a limited amount of calcitization of dolomite appears to have affected the core between 14,546 and 14,547 ft.

The upper part of lithofacies 1 is dominated by laminated to thick bedded dolomitic peloidal limestone, with isolated laminae of oolitic or coated-grain packstone. Many of these coarse to very coarse particles have been chemically overcompacted to mere wisps. Some anhydrite in this interval is corroded.

Lithofacies 2 (8.9 m, 29.3 ft) is dominated by cross stratified or laminated to medium bedded well-sorted fine pellet grainstone, albeit with common poorly sorted laminae containing coated grains, fossil fragments, intraclasts, ooids, bivalves and gastropods, *Parafavreina*, oncoids, and echinoderm ossicles. Most of this unit contains silt size planar-e dolomite (constituting up to 80 percent of the rock in certain horizons between 12,486 and 12,490 ft). The dolomite is predominantly particle-selective. Anhydrite and dolomite cement are widespread in interparticle and moldic pores. Anhydrite laths and nodules are scattered throughout most of lithofacies 2 (except the uppermost 1.2 m [4

ft]); the nodules are both replacive and displacive. Laths are medium to very coarse sand size, gray, and poorly crystallized or corroded. Replacive nodules consist of gray laths like the isolated laths, or have clear cores and cloudy yellow-brown rims. Displacive nodules are clear or white and consist of very fine to medium acicular laths. Certain layers contain medium sand to very fine pebble size spheroidal particles that have been intensely vertically compressed by chemical compaction so that they resemble segments of wispy stylolites. In other layers, similar particles are not compacted at all. The associated fine pellets have not been visibly compacted anywhere in this unit. Black wisps and specks of sand size, probably organic material, were observed between 12,486 and 12,487 ft. Dedolomite is associated with anhydrite nodules between 12,485 and 12,487 ft.

The lower part of lithofacies 2 is porous (up to about 12,496 ft); the pore system consists of moldic, interparticle, and lesser vuggy pores. Porosity ranges from 5 to 30 percent, averaging about 15 percent, and grading up between 12,486 and 12,485 ft to essentially nil. Above 12,485 ft there is virtually no porosity in this core. The lower (porous) part of lithofacies 2 is not burrowed, whereas the upper (tight) portion contains burrows like those in the basal part of the core. The uppermost 1.0 m (3.3 ft) of core contain 1 to 2 percent anhydrite lenses 1 to 2 mm across.

Between 12,479 and 12,486 ft the core is cut by long, straight, narrow high-angle fractures that contain black solid hydrocarbons, open pore space, and dolomite and anhydrite cement, with cement being volumetrically dominant.

Depositional Environment: Poor preservation of primary depositional features makes most interpretations of the depositional environment uncertain. The basal portion of this

core (to 12,551 ft) appears to have been deposited in a low to moderate energy subtidal setting. The sediment supported a burrowing infauna and therefore water chemistry could not have been extreme. This inference is also supported by the widespread occurrence of a relatively diverse skeletal fauna, including echinoderm ossicles. Microbial boundstone is limited to scattered oncoids and one small microherm; high sedimentation rates and/or vigorous burrowing might have prevented mound growth.

Above 12,551 ft in lithofacies 1, particle-supported fabrics and variable stratal thicknesses suggest increased environmental energy as well as heterogeneity of sedimentation. This unit is interpreted as the product of localized shoaling. Both echinoderm ossicles and other fossils are more common than in the lower part of the core. Overlying the shoal deposit is a unit (12,527 to 12,540 ft) consisting of fine to medium peloidal strata containing thin oolitic laminae. In this interval, the diversity of fossil debris is similar to that of the underlying unit, but the abundance and size of particles decrease. Despite poor preservation of depositional features, a return to lower energy subtidal marine deposition is indicated.

Lithofacies 1 and 2 are separated by a gap of 6.1 m (20 ft).

Most of lithofacies 2 consists of fine pellet grainstone containing numerous poorly sorted coarser laminae. This rock type is similar to that of the shoal deposits in the central part of lithofacies 1. However, the pellets in lithofacies 2 are finer and better sorted than those of lithofacies 1, which most likely reflects source control. Fine extremely well sorted pellet sands are generally interpreted as monotaxonomic fecal-pellet assemblages. Also, although particles in relatively coarse laminae are more diverse, echinoderms are far less common than in the lower part of the core. Common particles in the coarser

laminae in lithofacies 2 include bivalves, gastropods, intraclasts, ooids, *Parafavreina*, and unidentified fossil fragments. Increasing environmental restriction is suggested by the faunal differences between lithofacies 1 and 2.

Much of the lower part of lithofacies 2 is cross-stratified. Cross-stratified layers are at least 10s of centimeters thick and are separated by extremely coarse and poorly sorted laminae. Lithofacies 2 is interpreted as a high-energy shoal deposit; the poorly sorted coarse layers may be tempestites. However, the uppermost 1.0 m (3.3 ft) of core contains gray-brown anhydrite lenses 1 to 2 mm across that account for up to 2 percent of the core. These are interpreted as dehydrated gypsum discoids, which form syndepositionally and intertidally. Accordingly, the uppermost meter of the core is inferred to have formed on a tidal flat that prograded across the shoal.

Diagenetic History: Penecontemporaneous diagenetic processes that affected this core include marine rim cementation that affected the shoal deposits in lithofacies 1 and intertidal intrasedimental gypsum precipitation in what is now the uppermost meter of the core.

Dolomitization and (to a lesser extent) dissolution have severely altered this core. Most of the dolomite consists of silt size planar-e rhombs that may have formed in a single diagenetic episode. Dolomitization was most intensive in the lower part of the core (lithofacies 1) and there is little dolomite in the upper part (lithofacies 2). The chief discernible effects of dissolution have been dissolution of particles (partial or complete) and formation of small vugs in the upper part of the core (lithofacies 2); little evidence of dissolution is apparent in lithofacies 1. Where particle molds are preserved (12,496 to 12,507 ft) there are only traces of dolomite, and molds do not contain cement crystals.

Above the zone of moldic porosity, dolomite chiefly occurs within particles. In this interval, dolomite replaced some particles entirely, replaced only the outermost portions of other particles, and left still other particles unaffected. Dolomite crystals within particles in this core are interpreted as replacive, because the dolomite crystals exhibit a very narrow size range, are oriented randomly with respect to particle boundaries, and are not associated with porosity. Also, some particles contain small patches of calcium carbonate whose complex shapes suggest they are relics left by incomplete dolomitization. The relative timing of dolomitization and dissolution in this core are not clear.

Anhydrite is scattered throughout the core in trace amounts, but (with the exception of the lenses in the uppermost meter) the timing of its formation or alteration is not clear. Anhydrite nodules are of several kinds: (1) extremely coarse clear laths, (2) gray subhedral to anhedral replacive laths, (3) white bulbous (displacive) masses of very fine loaves, (4) white displacive masses of fine felted laths, (5) white masses of microcrystalline crystals, and (6) fine to medium transparent laths in nodule cores surrounded by haloes of gray replacive anhydrite laths. In addition, corroded gray anhydrite laths are scattered through much of the core. Nodule types 3, 4, and 5 are relatively pristine whereas types 1, 2, and 6 appear to have been recrystallized. The displacive nodules must have formed before lithification, but recrystallized nodules may be altered displacive nodules or may have formed during burial. In general, the relative timing of anhydrite and dolomite diagenesis is unclear. However, at least some anhydrite nodules are surrounded by intensely dolomitized halos, indicating that at least some dolomite formed after some anhydrite.

Burial diagenetic processes included stylolitization and associated fracturing, followed by calcium-carbonate cementation within fractures. Other fractures are subvertical, occur in en echelon sets, are long relative to the diameter of the core, and contain solid black hydrocarbons as well as anhydrite and dolomite cement.

Between 12,546 and 12,547 ft at least some dolomite rhombs appear to be rounded and embayed and are inferred to have been partially replaced by the calcium carbonate that contacts them. Further details of the relationships between dolomite and calcite crystals in this core cannot be discerned without thin sections.

Figure A-105. Graphic core log of Permit No. 1400 well. Pruet ALCO Land and Timber Co. No. 1, wildcat, Choctaw Co., Alabama--detailed core log, lower part.

Figure A-106--detailed core log, upper part.

Figure A-107--summary graphic core log and digitized geophysical logs.

Exchange-Marr-General Crude White Smith Land Co. et al. No. 1 well,
Permit No. 1659, wildcat, Choctaw Co., Alabama. Core number X-495

Depth interval: 13,547-14,178 ft.

Lithostratigraphic unit(s): Norphlet Sandstone, Smackover Formation, Buckner
Anhydrite Member of Haynesville Formation

Lithofacies: This core is actually three separate cores: one in the Norphlet, one in the Smackover, and one in the Buckner.

The Smackover core is divided into two lithofacies. The lower 10.2 m (33.5 ft) of core are assigned to lithofacies 2 and consist of dolomitic limestone and lesser dolostone. The entire interval is moderately to strongly bioturbated. The shapes and sizes of particle ghosts suggest peloids, intraclasts, skeletal debris, and oncoids. Planar dolomite crystals are of silt to very fine sand size and clusters of them define ghosts of particles chiefly of very fine sand size. Patches of nonplanar pseudospar accounting for nearly all of the rock in some 0.3 m intervals between 13,714 and 13,719 ft suggest wholesale dedolomitization. Embayment of dolomite rhombs indicates dedolomitization, but does not reveal the proportion of dedolomite in the rock. Lithofacies 2 is characterized by plane laminae to thin beds. Porosity in lithofacies 2 is very low, and chiefly vuggy or particle moldic. Anhydrite is present in trace amounts throughout much of this lithofacies, but accounts for up to 30 percent of a few thin layers. Discoidal anhydrite crystals in the basal meter of core suggest the former presence of synsedimentary intrasedimental gypsum. Other anhydrite is in the form of (1) dark gray-brown laths (some corroded) that crosscut carbonate rock fabric, (2) clear cement within fractures, and (2) white nodules composed of felted laths. At least some fractures bearing anhydrite cement are associated with and transected by saw-toothed stylolites; dark gray-brown laths of anhydrite are clustered along some stylolites but are not corroded by the stylolites.

Lithofacies 3 (7.6 m; 25 ft), directly above lithofacies 2, is dominated by ooid pellet grainstone, ooid grainstone, and pellet grainstone, in order of decreasing abundance. Particles other than ooids and pellets include coated grains, intraclasts, and unidentified fossils. Much of lithofacies 3 exhibits a bimodal primary sedimentary texture and both normally and inversely graded laminae occur. Primary pore space contains calcium-carbonate rim cement, but a significant portion of the larger original pores contain relict primary interparticle porosity. Chemical overcompaction of ooids in certain laminae is substantial at the base of this lithofacies, where some ooids are nearly entirely flattened, and decreases sharply upward; overcompaction was not observed above 13,687 ft. All strata in this lithofacies are partially or entirely replaced by silt size dolomite rhombs. Where dolomitization is incomplete it is either selective or not; where dolomitization is selective, dolomite tends to replace particles or rim cement with the pattern varying from one lamina to the next. At least some of the calcium carbonate in this lithofacies is dedolomite (e.g., between 13,688 and 13,689 ft), but the percentage cannot be reliably estimated without thin sections. Strata in the lower part of lithofacies 3 are chiefly laminated to thinly bedded or cross-laminated with tangential bases. In the middle third of the unit, in addition to stratification and cross-stratification as below, keystone vugs or very small and equant fenestrae are common and some laminae are inversely graded. In the upper part of the unit, herringbone cross stratification and ripple cross-lamination are

associated with planar laminae to very thin beds. Porosity is chiefly moldic and secondary intraparticle, with lesser interparticle porosity. Porosity values range from a few percent to at least 40 percent; the average for the unit is 10 to 15 percent. Clear anhydrite laths occur in fractures associated with and terminated by saw-toothed stylolites at the base of lithofacies 3, as well as in primary interparticle pores and in keystone vugs throughout much of the unit. Traces of dark euhedral anhydrite laths are found locally. In the uppermost 1.3 m of this lithofacies, clear anhydrite laths account for up to 5 percent of the rock, fill primary voids and particle molds, and replace some particles. Fractures between 13,678 and 13,679 ft bend around particles and particle-rimming cement.

Depositional Environment: The cored interval in the Norphlet is interpreted to record interdune deposition because of the dominant horizontal stratification and lack of carbonate minerals.

Lithofacies 2 formed below fair-weather wave base on a marine shelf. Indicators include the lack of coarse particles and cross lamination, bioturbation, and fine matrix texture. However, the apparent presence of dehydrated discoidal gypsum near the base of the core suggests a peritidal setting, at least for that interval.

Lithofacies 3 immediately overlies lithofacies 2, and together they compose a shoaling upward succession. Lithofacies 3 records shoaling from inner shoreface through foreshore to tidal flat. Shoreface deposition is indicated by tangential cross strata, graded layers, coarse sediments, and the absence of exposure indicators. Foreshore deposition is suggested by keystone vugs, horizontal or low-angle cross lamination, and very coarse sediments. Herringbone cross stratification, ripple cross lamination, planar lamination, and finer texture in the upper part of the core suggest tidal-flat deposition.

Most of lithofacies 4 (Buckner Anhydrite) was deposited in a brine pond. Fluctuations in the balance between influx of water and evaporation caused major changes in the size of the pond. About 10 percent of lithofacies 4 was deposited on sabkhas and tidal flats that formed when the pond was relatively small.

Diagenetic History: Known diagenesis of the portion of this core from the Smackover Formation began with rim cementation, probably penecontemporaneously in the marine environment. If the discoidal anhydrite nodules near the base of lithofacies 2 are pseudomorphs of gypsum crystals then the gypsum formed penecontemporaneously and probably dehydrated soon after. White anhydrite nodules with felted laths also are likely penecontemporaneous. Dissolution of mineralogically unstable particles probably took place in the eogenetic realm. Dolomite is very fine to silt size, and may have a hypersaline origin. However, chemical overcompaction of ooids must have been completed before dolomite formation. Burial processes included replacement of carbonate by anhydrite, stylolitization and associated fracture formation, and later precipitation of anhydrite cement in the fractures. Dedolomitization and calcitization of anhydrite followed most other diagenetic events.

Figure A-108. Detailed core log, Exchange-Marr-General Crude White Smith Land Co. et al. No. 1 well, Permit No. 1659, wildcat, Choctaw Co., Alabama, lower part

Figure A-109. Detailed core log, Exchange-Marr-General Crude-White Smith Land Co. et al. #1 well, Permit No. 1659, wildcat, Choctaw Co., Alabama, lower-middle part

Figure A-110. Detailed core log, Exchange-Marr-General Crude-White Smith Land Co. et al. No. 1 well, Permit No. 1659, wildcat, Choctaw Co., Alabama, upper middle part.

Figure A-111. Detailed core log, Exchange-Marr-General Crude-White Smith Land Co. et al. No. 1 well, Permit No. 1659, wildcat, Choctaw Co., Alabama, upper part.

Figure A-112. Digitized geophysical well logs, core depositional environments, and sea-level curves (progradation to right), Permit No. 1659. SP=sponaneous potential log, D=density log, LL8=induction log

Mellon Creek Choctaw Lumber Co. No. 1 well

Permit No. 1715, wildcat, Choctaw Co., Alabama. Core number X-513.

Depth intervals: 12,909 to 12,933.5 ft.

Thin sections: Twelve thin sections were cut from this core: 12,909.5, 12,913, 12,913.5, 12,915, 12,919, 12,921, 12,923, 12,924, 12,925, 12,928, 12,930, and 12,932.

General information: This core includes a partial section of the Smackover Formation.

The core had been slabbed, but very small slabs were removed, so the flat areas are smaller than usual even though the core is of normal size. Four or five thin section billets had previously been removed.

Lithostratigraphic unit(s): Smackover Formation.

Lithofacies: The Smackover Formation in this core is assigned to one lithofacies.

Although the core is petrophysically diverse, it consists of two occurrences each of two intercalated rock types that were deposited in a common environment. Individual occurrences of the two rock types are too thin for useful division of this short core into four lithofacies. The core consists of intercalated peloid limestone and peloid dolostone, with minor variations. Most of the limestone is actually dedolomite, consisting of calcite with relict dolomite that may once have accounted for all or nearly all of the rock in dedolomitized intervals.

The basal 2.0 m (6.5 ft) of core appear to be dominated by gray-brown dolomudstone or dolowackestone overlain by crystalline dolostone. However, the preservation of primary features is poor throughout this unit, and it is possible that the entire unit was deposited as a pellet grainstone, as was the overlying unit (see below). Dolomite is planar-e and of silt size; pellets are of very fine sand size. The unit is thinly laminated to

medium bedded and is bioturbated. Burrows are subhorizontal and subvertical, with few visible branches, and range in diameter from 4 to 10 mm. The burrows appear to form a three-dimensional network with laminae containing subhorizontal burrows separating strata 1 to 8 cm thick containing subvertical burrows. Burrows are visible because they contain a different percentage of relict calcite than does the surrounding matrix.

However, percentages vary widely within the unit. Dolomite content ranges from 99 to as low as 10 percent locally, but averages more than 90 percent outside of burrows and between 10 and 20 percent within burrows. Constituent particles other than pellets include gastropods, unidentified fossil fragments, and bivalves. The unit contains a thinly laminated stratum consisting of calcareous dolomite (20 to 25 percent calcite) containing siliciclastic very fine sand, silt, and clay. This layer is of unknown thickness but has an abrupt, stylolitized, upper boundary. Between 12,929.5 and 12,930 ft the unit contains up to 25 percent anhydrite (averaging 5 to 10 percent) in the form of clusters of fine to medium anhedral equant crystals. Porosity in this unit ranges from 10 to 40 percent and generally increases upward. Pores are intercrystalline, moldic, and vuggy, but the pore system is dominated by intercrystalline pores.

Overlying the dolostone unit at the base of the core is a gray-brown dedolomitized unit that is 3.5 m (11.5 ft) thick. The unit is thinly laminated to medium bedded as below, but strata are thinner, on average, than in the underlying unit. The original extent of dolomitization is unknown, but dolomite crystals with rounded corners or embayed boundaries are widespread. Throughout much of the unit dolomite is chiefly in the form of extremely fine filaments like disordered spider webs, which are interpreted as the remains of rhombic crystals that have been almost entirely consumed. In most of the unit

dolomite accounts for less than 2 percent of the rock, but at the top and bottom the rock is locally as much as 50 percent relict dolomite. Most dolomite crystals are microcrystalline, but because they are dissolutional remnants they could once have been much larger. The unit, at least in large part, was deposited as a very well sorted very fine fecal-pellet grainstone. This primary texture is better preserved in some strata than others but traces of pellets are nearly ubiquitous. Gastropods and bivalves occur in isolation or are restricted to laminae a single shell thick. Subhorizontal burrows similar to those in the underlying unit are restricted to isolated very thin or thin beds. Anhydrite consists of corroded brown laths and clear cement in mollusk molds and in fractures, most of which are associated with sawtooth stylolites. Brown replacement anhydrite crystals line healed fractures. Some mollusk molds contain pore lining calcium-carbonate cement overlain by anhydrite cement that is in some cases overlain by relict moldic porosity. Some fractures associated with stylolites contain calcite cement instead of anhydrite cement. Other fractures are long, subvertical, and straight, and are not associated with stylolites; these fractures contain both calcite and anhydrite cement. Porosity is nil, except for fracture porosity near the top of the unit.

Above 12,915.5 ft is a unit 1.4 m (4.5 ft) thick consisting of brown microcrystalline to silt size dolostone that is thinly laminated to thin bedded. The average stratum is thinner than in the lower part of the core. This unit appears to have been deposited as a molluscan fecal-pellet grainstone similar to the underlying unit. However, dolomitization has destroyed evidence of primary texture in much of the unit and only between 12,913 and 12,914 ft is pellet grainstone unequivocally preserved. Particles include fine sand size very well sorted fecal pellets, scattered medium sand size peloids, gastropods, and other

fossil fragments. As in the underlying unit, fossils occur both in isolation and in layers one fossil thick. Evidence of burrowing is scanty, but suggests burrows of similar size to those in underlying units. Porous patches that are several millimeters to more than a centimeter across might be burrows or might have developed around burrows. Disturbed bedding in the lower part of the unit consists of bent, uneven, and possibly brecciated layers and suggests both plastic and brittle synsedimentary deformation. The only calcium carbonate in this unit consists of relict material within fossil fragments. Fractures in this unit are long, subvertical, and not associated with stylolites. Fractures contain clear anhydrite cement. Clear anhydrite cement is also found within mollusk molds and small brown anhydrite laths occur in the upper part of the unit. The pore system is dominated by intercrystalline pores, but includes moldic and secondary intraparticle pores, interparticle pores, and shelter pores (within gastropods). Porosity is 30 to 40 percent and permeability is high.

The uppermost part of the core (above 12,911 ft) is inferred to consist of dolomitic molluscan fecal-pellet grainstone, which at the time of deposition was probably virtually identical to the underlying dolostone. However, pellet grainstone is only unequivocally preserved in the uppermost 0.15 m (0.5 ft) of core. This unit is gray-brown and thinly laminated to thin bedded, and average stratal thickness is similar to that of the underlying dolostone. Particles other than fecal pellets include gastropods, bivalves, and other fossil fragments. Evidence of bioturbation is slight. The content of dolomite varies from a trace to about 30 percent. Dolomite content varies locally by at least 15 percent, but generally decreases upward within the unit. Dolomite crystals appear to vary more in size than in deeper parts of the core, or it may be that crystal size range is more readily determined

because the dolomite is dominated by disseminated planar-e crystals in a matrix of relict calcite. Anhydrite consists of clear cement replacing mollusks and disseminated brown anhydral replacive laths as below. Porosity is less than 5 percent, and consists of vugs and fossomolds that are restricted to certain layers. Some of the vugs approach 1 cm in thickness and exceed the width of the core in lateral extent. Matrix porosity is nil.

Depositional Environment: The entire core was deposited in a shallow lagoon or tidal-flat setting, as indicated by the prevalence of very well sorted fecal-pellet grainstone, the abundance of gastropods combined with the scarcity of any other body fossils, and the presence of several distinctive bedding features. These include the concentration of whole gastropods into thin laminae (tempestites; c.f., Kreisa, 1981), a possible emersion surface between 12,931 and 12,932 feet, and normal grading in thin beds of fecal-pellet grainstone between 12,925 and 12,926 feet. Gastropod wacke-packstone in a matrix of very-fine pellet grainstone is considered analogous to the whole-fossil packstone described by Kreisa (1981) as characteristic of carbonate storm deposits. Kreisa described the matrix of whole-fossil packstone storm layers as identical to material composing overlying strata. Likewise, the pellets in gastropod-bearing layers are identical to those in overlying pellet grainstone.

Diagenetic History: Syndepositional diagenesis of this core included early cementation in interparticle pores in grainstone and early lithification at the sediment-water interface during exposure. The virtual absence of compaction in this core attests to rapid and thorough cementation in the primary pore system. Soft-sediment deformation was early, but may have been post-depositional.

Diagenesis of the mollusks, which contain no dolomite, but do contain anhydrite cement, calcite cement, and possible relict calcite, presents a problem not soluble with existing data. One scenario would begin with dissolution of aragonitic mollusks. The filling of mollusk molds by anhydrite cement would have occurred early, and replacive anhydrite laths could have formed at this time. The anhydrite filling would have insulated the mollusks from the effects of pervasive dolomitization. Later, calcite cement would fill remnant moldic porosity. Alternatively, the aragonitic mollusks could have dissolved early and been replaced by low-magnesian calcite cement. Subsequent dolomitization would have affected high-magnesian calcite marine cement and fecal pellets, but not the stabilized mollusks. The low-magnesian calcite fill of mollusk molds could have partially dissolved during burial, followed by anhydrite cementation and later calcite cementation during calcitization of dolomite and anhydrite. Both of these scenarios are rather complex. The first requires two episodes of anhydrite precipitation, yet there is no independent evidence for early anhydrite precipitation, as there commonly is in the Smackover. The second scenario requires the early input of fresh water to precipitate low-magnesian calcite, for which the only credible independent evidence is the cavernous porosity near the top of the core.

Pervasive dolomitization probably was accompanied by dissolution of some of the remaining calcium-carbonate particles (chiefly fecal-pellets), indicated by the widespread development of pelmoldic porosity in dolostone. This may be when the cavernous porosity in the upper part of the core developed. Burial diagenesis included formation of sawtooth stylolites and associated fractures. At least some subvertical, long, tectonic fractures truncate against stylolites, and hence formed relatively early during or before

the major episode of pressure dissolution. Replacive anhydrite laths may have formed at this time. These laths later were corroded by calcite, perhaps when dolomite was calcitized. Calcitization of dolomite in the middle part of the core was extensive, and was not accompanied by porosity formation. This part of the core may have been almost entirely dolomitized and therefore most of the rock in this interval could be dedolomite. However, numerous traces of pellet grainstone texture are preserved in this interval. This suggests that dolomitization may not have been as pervasive as in the underlying and overlying dolostone units, in which primary texture is almost obliterated. If, as seems likely, that the dedolomitized interval was never fully dolomitized, the proportion of dedolomite may be less than that of pre-existing calcite. Following both dolomitization and dedolomitization, anhydrite and calcite cement partially occluded fracture porosity. The anhydrite cement was not calcitized, indicating that it is younger than both the replacive anhydrite and the dedolomite.

Figure A-113. Graphic core log of Permit No. 1715 well, Mellon Creek Choctaw Lumber Co. No. 1, wildcat, Choctaw Co., Alabama--detailed core log.

Figure A-114--summary graphic core log and digitized geophysical logs.

John Green, Jr., et al., 7-16 No. 1, Choctaw County, Alabama

PERMIT NO. 1740

The lower part of the core (below 12,967 ft) is dominated by peloidal dolomitic limestone. Primary rock fabric is difficult to determine because the entire unit has been strongly dedolomitized and consists chiefly of nonplanar microspar. Although the concentration of dolomite ranges from a trace to about 40 percent (averaging about 15 percent), the rock may once have been entirely dolomitized. Anhydrite pseudomorphs of gypsum discoids are common between 12,968 and 12,970 ft. Thin laminae (possibly desiccation cracked) between 12,970 and 12,971 ft may be microbial. An exposure surface at about 12,967.5 ft is underlain by a 1 mm layer of microcrystalline dolostone. The surface exhibits 5 mm of relief, is darkened, and the upper boundary of the dolomitized layer is sharp. Porosity in the lower part of the core averages less than 5 percent, but locally reaches 20 percent. Porosity is dominantly intercrystalline, solution-enlarged fracture, and vuggy associated with fractures.

The upper part of the core (above 12,967 ft) is dominated by nonskeletal grainstone containing pellets, ooids, and pisoids. Particles are poorly sorted or particle size is bimodally distributed in much of this interval. Strata are thin laminae to thin beds; many pairs of adjacent beds differ sharply in particle size. Anhydrite is locally pseudomorphous after gypsum discoids. Up to 2 percent siliciclastic sand is found between 12,934 and 12,950 ft. Sedimentary structures include planar stratification (most common), crudely graded laminae, rare herringbone cross-stratification, and wave ripple cross-stratification, as well as desiccation cracks, exposure surfaces, fenestral fabric, and crinkly planar laminae that are associated with fenestral pellet grainstone. Porosity ranges from about 5

to at least 25 percent, averaging between 5 and 10 percent. Most pores are primary interparticle, particle-moldic, and secondary intraparticle.

This core records a shoaling-upward succession from shallow subtidal to intercalated tidal-flat and shoal deposits on a storm-dominated shallow shelf. Supratidal deposition is suggested by the dolostone crust at 12,967.5 ft; other inferred tidal-flat deposits are interpreted as intertidal and subtidal because they contain crinkly laminae, microbially bound laminae (e.g., 12,936.5 ft), gypsum discoids, uncommon desiccation cracks, and fenestrae, but nothing diagnostic of supratidal conditions.

Contemporaneous diagenetic processes affecting this core included intrasedimentary growth of discoidal gypsum and precipitation of isopachous rinds of blunt prismatic calcium-carbonate cement in most pores. This cement is interpreted on the basis of morphology and distribution to have been deposited as marine high-magnesium calcite. The dolomitic crust at 12,967.5 ft may have formed contemporaneously in the same way that similar crusts form today on Caribbean islands (e.g., Land, 1985; Mazzullo and others, 1987).

Interparticle rim cementation was followed by particle-to-particle pressure dissolution, which destroyed between 10 and 90 percent of affected particles. Particles in some strata are partially or entirely dolomitized, including particles that were previously almost entirely destroyed by compaction. Compaction and deformation of particles is associated with hard surfaces in limestone (Sarkar and others, 1980). Several exposure surfaces are obvious in the core, but widespread particle deformation suggests that early lithification of these sediments was more extensive than is immediately apparent.

Post-dolomitization dissolution of relict calcium carbonate in particles led to development of moldic and secondary intraparticle porosity in most of the upper part of this core (above 12,967 ft). Late calcite and anhydrite cement occluded a significant proportion of relict porosity at some horizons.

The basal part of the core (12,967 to 12,980 ft) contains little or no trace of primary rock fabric and appears to consist chiefly of microspar that replaced dolomite. Higher in the core, some intervals (e.g., 12,954.5 to 12,957 ft) contain up to 99 percent microspar but lack evidence for dedolomitization. Much of the rest of the core preserves numerous primary features that would have been obliterated if the rock had been pervasively dolomitized and then dedolomitized. Microspar formation followed dolomitization but its timing relative to particle dissolution is unclear.

Dolomitization in this core was quite heterogeneous; oolitic grainstone at 12,936.5 and 12,926.5 ft is dolomitized and at 12,933.5 and 12,922.1 ft there is no dolomite. However, eogenetic cement, marine pore-rimming calcium carbonate, is essentially identical throughout the interval in question. The distribution of dolomite suggests that it formed from a fluid that was intermittently supersaturated, such as a mixture of meteoric water and sea water.

Figure A-115. Detailed core log, Walter, Williams, Harrell, & Mortimer, John Green Jr. et al. 7-16 No. 1 well, Permit No. 1740 wildcat, Choctaw Co., Alabama.

Figure A-116. Digitized geophysical well logs, core depositional environments, and sea-level curves (progradation to right), Permit No. 1740. SP=sponataneous potential log, D=density log, LL8=induction log

Pruet & Hughes Choctaw Lumber Unit 3-5 No. 1 well

Permit No. 2105, wildcat, Choctaw Co., Alabama. Core number X-747.

Depth intervals: 13,473 to 13,505 ft. The core-derived lithologic data best match geophysical log response if the top of the core is correlated to a log depth of about 13,475 ft, for an adjustment of 2 ft.

Thin sections: None.

General information: This core includes a section of the upper part of the Smackover Formation; the top of the core is a few feet below the top of the formation. The core was whole; I slabbed certain pieces of core.

Lithostratigraphic unit(s): Smackover Formation.

Lithofacies: The Smackover Formation in this core is assigned to two lithofacies.

Lithofacies 1 (13,503.5 to 13,505 ft; 0.46 m or 1.5 ft thick) is dominated by very thin to thin bedded very fine very well sorted burrowed fecal-pellet grainstone. Dolomite is virtually absent. This unit contains about 1 percent anhydrite in the form of gray corroded laths. A few pelmolds and partial pelmolds compose an ineffective pore system with only a few percent porosity.

Lithofacies 2 corresponds to nearly the entire core, and abruptly overlies lithofacies 1. The upper unit consists of intercalated pellet dolograinstone, ooid pellet dolograinstone, pellet ooid dolograinstone, and ooid dolograinstone. Ooid pellet dolograinstone is the most abundant rock type, and most of the unit is characterized by a distinctly bimodal particle-size distribution. The unit is composed of thin laminae to very thin beds, about half of which are cross stratified. Particles other than ooids and pellets are quite

uncommon. Skeletal particles are limited to a few fragmentary mollusks and one large high-spired gastropod in the uppermost 1.2 m (4 ft) of core. Several thin impermeable laminae were observed between 13,490 and 13,491 ft. The laminae are closely spaced, neither horizontal nor planar, and consist of 1 to 3 mm of nonporous microcrystalline carbonate with sharp upper and lower boundaries. The pore system consists of primary interparticle pores, molds, and partial molds (secondary intraparticle pores). The latter dominate volumetrically throughout most of the unit, but the interparticle pores strongly affect permeability in much of the unit. Porosity ranges from about 15 to as much as 60 percent; porosity values are lower in the uppermost 2.1 m (7 ft) of core because calcite fills some ooids and some interparticle voids. Calcite within ooids appears to be calcitized aragonite whereas calcite within interparticle voids is extremely coarse and clear; this is probably burial cement. Below 13,480 ft lithofacies 2 is completely devoid of calcite. Traces of anhydrite in the form of pore-filling and fracture-filling cement are scattered throughout much of lithofacies 2, but there is too little anhydrite to significantly affect the pore system anywhere in the lithofacies.

Depositional Environment: The basal portion of the core (lithofacies 1) is tentatively interpreted as a tidal-flat deposit. This inference is based on the dominance of extremely well sorted very fine fecal-pellet grainstone without any mud or coarser debris. The unit is moderately to heavily burrowed, which is consistent with a tidal-flat interpretation. In addition, the unit is overlain by a shoal deposit, which is also consistent with a tidal-flat setting.

Lithofacies 2 is interpreted as a shoal deposit because it contains abundant ooids, is mud-free, and much of it is cross-stratified. The particles consist of fecal pellets and

oids; in many strata the two are mixed together to make a bimodal deposit. These strata probably formed through mixing of ooids formed on the high-energy side of a shoal with fecal pellets formed in a nearby quiet-water setting, such as a back-barrier flat or abandoned tidal channel. The locus of deposition was probably a tidal channel that was intermittently active. Additional evidence includes ripple cross-laminae and possible emersion surfaces (between 13,490 and 13,491 ft). In addition, geophysical logs show that the top of the core is just a couple of meters (a few feet) below the basal Buckner saltern.

Diagenetic History: Penecontemporaneous diagenesis probably included marine cementation, for there is a considerable amount of dolomite rimming former particles. However, the timing, origin, and initial texture of this material cannot be determined though the overprint of dolomite. Chemical compaction of ooids in certain intervals (e.g., between 13,476 and 13,477 ft and between 13,494 and 13,495 ft) preceded dolomitization, and was intense in a few thin laminae. Early diagenetic products are dominated by dolomite and secondary pores formed by wholesale dissolution of fecal pellets and ooids. Smackover ooids in Alabama are aragonitic, but in many Alabama Smackover cores fecal pellets resisted dissolution and may have been calcitic. Burial diagenesis included fracturing, widespread stylolitization, and subsequent precipitation of anhydrite cement within fractures.

The basal 0.46 m (1.5 ft) of the core is hardly dolomitized, probably because it had lost all permeability through compaction and cementation before dolomitization. The uppermost 2.1 m (7 ft) of core contain some relict calcite. Some is probably primary, but

coarse, clear calcite within relict interparticle pores (and within a gastropod mold) may be burial cement.

Figure A-117. Graphic core log of Permit No. 2105 well. Pruet & Hughes Choctaw Lumber Unit 3-5 No. 1, Permit No. 2105, wildcat, Choctaw Co., Alabama--detailed core log,

Figure A-118--summary graphic core log and digitized geophysical logs.

Pruet & Hughes Chesnut Unit 21-4. No. 1 well

Permit No. 2277, wildcat, Choctaw Co., Alabama. Core number X-1341.

Depth intervals: 14,017 to 14,088 ft.

Thin sections: Twenty-five thin sections were cut from this core: 14088, 14085, 14079.5, 14077.5, 14074.5, 14074.4, 14073.1, 14073, 14072.9, 14070, 14069, 14066, 14063, 14060.5, 14058, 14057, 14056, 14053, 14050, 14046.6, 14046.4, 14045.5, 14043.5, 14043.4, and 14037.5.

General information: This core includes a section of the upper part of the Smackover Formation and the lower part of the Buckner Anhydrite Member of the Haynesville Formation. The formation contact is preserved. Most of the core was whole, but some pieces had been slabbed. I slabbed additional pieces. Many pieces are labeled with arrows pointing down, rather than up.

Lithostratigraphic unit(s): Smackover Formation, Buckner Anhydrite Member of the Haynesville Formation.

Lithofacies: The Smackover Formation in this core is assigned to three lithofacies.

Lithofacies 1 (14,079 to 14,088 ft; 2.7 m or 9.0 ft thick) is dominated by laminated to thin bedded dolomitic lime mudstone. Lithofacies 2 (14,064 to 14,079 ft; 4.6 m or 15.0 ft thick) is dominated by trough cross-stratified thin bedded nonskeletal grainstone.

Lithofacies 3 (14,042.5 to 14,064 ft; 6.6 m or 21.5 ft thick) is more diverse than underlying lithofacies. The unit includes a syndepositional breccia bed, trough cross-stratified grainstone, dolomitic limestone of unknown primary texture, nonskeletal dolograinstone, laminae of anhydrite pseudomorphs after bottom-nucleated subaqueous gypsum, and a subvertical structure that is either a dissolution pipe or syndepositional

fault plane. The uppermost part of the core (7.8 m or 25.5 ft thick) consists of interbedded anhydrite and anhydritic dolostone layers in which the relative abundance of anhydrite increases upward. This unit is assigned to the Buckner Member of the Haynesville Formation.

Lithofacies 1 (14,079 to 14,088 ft; 2.7 m or 9.0 ft thick) is dominated by laminated to thin bedded dolomitic lime mudstone. The basal 0.3 m (1.0 ft) of lithofacies 1 contains abundant burrows 1 to 3 mm in diameter that are subhorizontal or oblique and have spreiten. The style of preservation in this core makes it difficult to determine the depositional texture, which may not, after all, be mud-dominated. Particles include peloids and possible peloid ghosts, fossil fragments, and possible oncoids. The concentration of dolomite in this unit ranges from a trace to about 15 percent. Dolomite is planar-e and silt to very-fine sand size. Dolomite crystals are disseminated through the rock, but are concentrated in the residue of stylolites. Locally, dolomite appears to preferentially replace particles; elsewhere the concentration of disseminated dolomite is influenced by bioturbation fabrics. Also, dolomite forms halos around some anhydrite crystals. Most anhydrite consists of corroded gray laths, but anhydrite cement fills fractures associated with sawtooth stylolites. Porosity in this unit is nil.

Lithofacies 2 (14,064 to 14,079 ft; 4.6 m or 15.0 ft thick) is dominated by trough cross-stratified thin bedded nonskeletal grainstone. The basal 1.4 m (4.5 ft) of this unit consist of thin bedded dolomitic very well sorted very fine fecal-pellet grainstone. Just below 14,073 ft the rock consists of normally graded pellet ooid oncoid grainstone with oncoids to more than 1 cm in diameter. Much of the unit is composed of intercalated relatively coarse and relatively fine laminae. Strata between 14,074.5 and 14,078 ft

include 1 to 2 percent quartzose silt and very fine sand. Quartz occupies the nuclei of some peloids but many quartz particles are not enclosed within carbonate particles. Particles include pellets (dominant), ooids, oncoids, intraclasts up to 2 cm long (most oolitically coated; most larger ones are platy), and siliciclastic silt and sand. Dolomite resembles that in lithofacies 1 in abundance, distribution, and morphology. Anhydrite consists of corroded gray laths like those in lithofacies 1 and is scarce in the upper part of the unit. The entire unit is stylolitized; fractures associated with stylolites in the uppermost foot contain anhydrite cement. Porosity is primarily moldic but interparticle porosity is dominant between 14,068 and 14,070 ft. Porosity ranges from a trace to about 15 percent of the rock, generally increasing upward.

Lithofacies 3 (14,042.5 to 14,064 ft; 6.6 m or 21.5 ft thick) includes a syndepositional breccia bed about 0.46 m (1.5 ft) thick at the base of the unit, trough cross-stratified grainstone, dolomitic limestone of unknown primary texture, nonskeletal dolograins, laminae of anhydrite pseudomorphs after bottom-nucleated subaqueous gypsum, and a subvertical structure between 14,045 and 14,047 ft that is tentatively interpreted as a dissolution pipe associated with exposure and karstification at or near the end of Smackover time. The top of lithofacies 3 is the top of the Smackover Formation.

At the base of lithofacies 3 is a breccia bed unlike others previously reported from the Alabama Smackover. This unit, underlain and overlain by horizontal laminated to thin bedded strata, consists of domains of laminated to thin bedded gray dolomitic limestone that, internally, do not differ from enclosing strata. However, this unit consists of sharp-edged domains that range from a few centimeters to more than 10 centimeters across in which strata are not horizontal. Strata are inclined, even close to vertical, and in some

domains they are bent at angles up to about 45 degrees. Domain boundaries, though sharp, are curved, and some exhibit irregularities as if the strata were cohesive but not lithified when disrupted. Some domains are entirely enclosed by others, as if the enclosed domains were injected into the surrounding material. However, fluidization of strata appears to be restricted to the upper third of the breccia unit, in which continuous laminae are absent and dark wisps suggest near total disruption of laminae like those above and below the breccia. Low-angle disruptions of thin laminae beneath the breccia bed could be thrust faults with throws on the order of centimeters. The concentration of dolomite in the breccia bed ranges from 10 to 50 percent. Dolomite consists of silt size to very fine planar-e crystals. Anhydrite consists of trace amounts of corroded laths as in lithofacies 1 and 2. The pore system is intercrystalline; porosity is less than 5 percent.

The breccia bed is overlain by trough cross-stratified and laminated to very thin bedded dolomitic limestone 3.7 m (12 ft) thick that does not preserve the primary texture. Trough cross-stratification implies grainstone, but overlying flat-lying strata could have contained mud or even been mud supported. Dolomite ranges from 5 to 40 percent, generally decreasing upward, and, as in lithofacies 1 and 2, is concentrated at sawtooth stylolites. Fractures in this unit are long, thin, and near vertical. The lower part of the unit contains minor intercrystalline porosity.

Between 14049.5 and 14,050.5 ft lensoid anhydrite crystals up to 4 mm long account for 2 percent of medium-bedded dolomitic limestone. In other respects this unit resembles underlying strata.

The upper part of lithofacies 3 is dominated by pellet dolograinstone with thin laminae of pellet ooid dolograinstone. Particles other than ooids or pellets are limited.

Angular intraclasts up to 5 cm long composed of tan slightly anhydritic limestone were observed. A subvertical synsedimentary structure between 14,045 and 14,047 ft cuts through strata otherwise identical to those elsewhere in the unit. The basal portion of the structure consists of a low-amplitude sawtooth stylolite. The stylolite expands upward over a vertical distance of a millimeter or so into a cavity that expands and contracts upward, varying in width from less than 1 cm to more than 4 cm. The cavity's walls are sharp and uncoated but not angular; they are lined with framboidal pyrite. The cavity's content is a breccia whose clasts are rounded and relatively small (1 to 2 mm in maximum diameter). The color of the cavity fill is identical to that of the enclosing strata. Enclosing strata bend downward slightly adjacent to the cavity. The top of the cavity is not observed; the cavity either ends or exits the well bore between two adjacent pieces of core. At about 14,043.5 ft the core is crossed by a horizontal dissolution seam 2 mm thick. The seam is directly overlain by vertically oriented anhydrite crystals about 1 cm high that are embedded in pelletal and oolitic calcareous dolostone (5 to 20 percent calcite), characteristic of this unit. This stratum is overlain by about 0.4 m (1.25 ft) of similar calcareous dolostone containing laminae of vertically oriented anhydrite crystals. Discontinuity surfaces overlain by laminae of vertically oriented anhydrite crystals could be emersion surfaces. The dolomite content of this unit ranges from 60 to near 100 percent. The top of the Smackover Formation is drawn at 14,042.5 ft within a gradational transition zone. Below this horizon carbonate dominates, and most dolomite is calcareous. Above this horizon, the succession is evaporite dominated and no calcite was observed. Further, the only carbonate above this horizon is pelmoldic pellet dolograinstone with uncommon ooids, plugged with anhydrite cement and intimately

intercalated with nodular and laminated anhydrite. Finally, the abrupt increase in evaporite concentration above this horizon creates a distinctive signature on density logs, which are commonly used to map the formation boundary in this area. Anhydrite-plugged pellet dolograinstone plus nodular or laminated anhydrite is widely observed in the basal Buckner in the eastern MISB. Pores in the upper part of lithofacies 3 are intercrystalline and secondary intraparticle, but porosity is low.

The uppermost part of the core, assigned to the Buckner Member of the Haynesville Formation, consists of intercalated laminated to medium-bedded anhydrite, anhydritic dolostone, equant nodular anhydrite, and nodular anhydrite with vertically oriented nodules, in order of decreasing abundance. The carbonate consists of pelmoldic pellet dolograinstone and pelmoldic oolitic pellet dolograinstone in which virtually all porosity is plugged by anhydrite cement. The carbonate strata also contain displacive anhydrite nodules, disseminated and clustered brown replacive anhydrite laths, and anhydrite nodules that occupy lensoid voids, as well as (locally) small pyrite crystals and black solid hydrocarbons. The carbonates also include strata with thin crinkly laminae or domical shapes. Traces of intercrystalline porosity are visible in some of the carbonate units but the dolomite is microcrystalline to silt size and fines upward.

Depositional Environment: Lithofacies 1 and the basal portion of lithofacies 2 are interpreted as subtidal restricted marine shelf deposits. This assignment is made on the basis of the inferred mud-supported characteristics of the strata, plus their location below shoal deposits in an upward-shallowing succession. Poor preservation of primary textural information in this unit leaves open the possibility that the strata were particle supported when deposited. The interval from 14,056 to 14,075 ft is interpreted as a shoal deposit.

Much of the unit is trough cross-stratified, normally graded, or both, and it is dominated by pellet grainstone and ooid pellet grainstone, with minor amounts of intraclasts and oncoids. A breccia deposit near the center of the shoal deposit (see description in previous section) is interpreted as a slump that formed in sediment whose coherency had been enhanced by biofilms but not by incipient cementation, for the clasts do not have sharp edges and strata within some clasts are bent. The breccia is overlain by a churned interval that is interpreted as a fluidized upper portion of the slump. This interval may have contained too much water to hold together during slumping. All together, the slump deposit is 1.1 m (3.5 ft) thick. The scale of slumping suggests a significant slope, but sedimentary structures do not suggest that the strata formed in a large migrating sand wave. The slump may have occurred where a migrating inlet or large tidal channel cut into firm but unlithified submarine shoal-margin deposits.

Inferred shoal deposits are overlain by 1.7 m (5.5 ft) of laminated to medium bedded dolomitic limestone that are interpreted as lagoonal. The lagoonal strata are in turn overlain by 2.1 m (6.75 ft) of inferred tidal deposits. These strata are assigned to a tidal environment of deposition because they are dominated by intercalated pelletal and ooid-pellet laminae that resemble peritidal tempestites, they contain angular intraclasts, they contain near the base discoidal anhydrite pseudomorphs after intertidal discoidal gypsum, and they include, near the top of the unit, a vertical structure interpreted as a karst feature (see description in previous section). The vertical structure is interpreted as a dissolution pipe, rather than a fault, because it dies out downward into a vertical stylolite over an interval of 10 cm; its sides are far from parallel; it is filled with sediment virtually identical to the surrounding strata; a lining of pyrite suggests colonization by bacteria

before final filling; surrounding strata on both sides of the feature bend downward, which would not be expected if the feature experienced fault-like displacement; and about 0.38 m (1.25 ft) above the top of the structure is a thick dissolution seam that could be an altered paleosol. Above the dissolution pipe and associated paleosol is a thin interval interpreted as a sabkha deposit. The strata in question consist of anhydritic pellet dolograinstone in which much of the anhydrite is in the form of vertically elongate nodules on the order of 1 cm in height that are interpreted as diagenetic alteration products of bottom-nucleated subaqueous gypsum that formed in ephemeral brine ponds. Anhydrite accounts for less than 40 percent of this interval, which is consistent with an origin as a sabkha. In addition, the unit overlies inferred tidal-flat deposits and underlies inferred saltern deposits.

The upper part of the core, assigned to the Buckner Anhydrite Member of the Haynesville Formation, is interpreted as a saltern deposit because it is dominated by relatively pure anhydrite, vertically oriented anhydrite pseudomorphs after bottom-nucleated subaqueous gypsum crystals are common, and the intercalated carbonates (oolitic pellet dolograinstone and pellet dolograinstone) could have formed (perhaps inorganically) in a temporarily freshened saltern. The vertically oriented anhydrite nodules in this interval are larger than those in the underlying inferred sabkha deposits: they range from a few centimeters to nearly 10 centimeters in height.

Diagenetic History: Syndepositional diagenetic processes whose products are visible in this core included intrasedimental growth of discoidal gypsum; soil formation with karst development; lithification of carbonate, probably on the sea floor (indicated by intraclasts); and formation of displacive anhydrite nodules. Early diagenesis involved

dehydration of gypsum; widespread precipitation of pore rimming cement in grainstone; precipitation of framboidal pyrite, which lines a karst feature and hence probably formed shortly after deposition; and penecontemporaneous hypersaline dolomitization of Buckner carbonate (but this could be primary dolomite). Later diagenesis included pervasive (but incomplete) dolomitization, followed or accompanied by widespread particle dissolution. Burial processes included formation of sawtooth stylolites with associated fractures, local formation of wispy stylolites, minor tectonic fracturing, and precipitation of anhydrite cement in both kinds of fractures and in particle molds. It is possible that aragonite particles dissolved and anhydrite cement precipitated in particle molds before dolomitization, and that the removal of sulfate from pore water facilitated concomitant or subsequent dolomitization. However, this is unlikely, because pellets are the dominant particles in this core, and most pellets in the Smackover are resistant to dissolution, indicating that they were originally composed chiefly of calcite, in contrast to mollusks and nonrecrystallized ooids, which are quite susceptible to dissolution and hence were probably aragonite. In the basal meter (few feet) of this core, fossil fragments (originally aragonite) have been dissolved and filled with anhydrite cement whereas associated peloids (originally calcite or magnesian calcite) are dolomite or calcite. Gray replacive anhydrite laths probably formed under burial conditions, but the timing relative to other diagenetic processes is unknown. Later, replacive anhydrite was centripetally calcitized. There is little or no evidence for chemical compaction of particles, indicating that physical and mineralogical stabilization was relatively rapid in this core.

Figure A-119. Graphic core log of Permit No. 2277 well. Pruet & Hughes Chesnut Unit 21-4 No. 1, wildcat, Choctaw Co., Alabama--detailed core log.

Figure A-120--summary graphic core log and digitized geophysical logs.

G & S School Land 16-1A No. 1 well

Permit No. 2404, wildcat, Choctaw Co., Alabama. Core number X-835.

Depth intervals: 13,274 to 13,305 ft.

Thin sections: None.

General information: This core includes a partial section of the Smackover Formation.

The core was whole, and large fragments (thicker than about 7.5 cm or 3 inches) could not be slabbed; therefore, units that tend to break into large pieces are less well known.

Lithostratigraphic unit(s): Smackover Formation.

Lithofacies: The Smackover Formation in this core is assigned to four lithofacies. These units are relatively thin, but differ greatly in pore-system characteristics and rock texture.

Lithofacies 1 (4.6 m or 15 ft in thickness) consists of dolomitic thin bedded and burrowed very well sorted fecal-pellet grainstone. Burrows are of three kinds. Subhorizontal burrows 6 to 8 mm in diameter with meniscate fill are probably feeding traces.

Subhorizontal burrows 1.5 to 2 mm in diameter appear to have formed after the larger burrows were made. Subvertical burrows 1.5 to 2 mm in diameter and up to several centimeters long transect the larger subhorizontal burrows and may have been made by the constructor of the 1.5 to 2 mm diameter subhorizontal burrows. Dolomite is planar-e, accounts for less than 1 to about 2 percent of the rock, and most is disseminated.

However, some dolomite crystals are clustered and appear to have replaced pellets.

Dolomite crystals are concentrated along low- and high-amplitude sawtooth stylolites.

Gray corroded laths of anhydrite account for less than 1 percent of the rock and anhydrite cement fills fractures associated with high-amplitude sawtooth stylolites. Porosity is very low; the pore system consists of scattered small vugs that appear to be pellet molds.

Lithofacies 2 (1.2 m or 4 ft) consists of laminated to thin bedded very well sorted fecal-pellet dolograinstone. Calcite content ranges from 0 to 2 percent. Dolomite is like that in lithofacies 1 except that it is concentrated along wispy stylolites as well as sawtooth stylolites. Porosity in this unit is up to about 20 percent but permeability is low. Less permeable layers are gray and more permeable layers are brown. The pore system consists of intercrystalline, moldic, and secondary intraparticle pores.

Lithofacies 3 (1.8 m or 6 ft) consists of very thin to thin bedded dolomitic limestone. Dolomite accounts for 1 to 20 percent of this unit, and is concentrated along stylolites as in lithofacies 1 and 2. Some dolomite also is associated with anhydrite crystals and some is aggregated into clusters of dolomite crystals of fine to medium sand size. The rock contains, over an interval of about 0.3 m (1 ft) in thickness, anhydrite lenses 1 to 2 mm long. In other parts of the unit, small corroded gray anhydrite laths are like those in lithofacies 1 and 2. Porosity in this unit is nil.

Lithofacies 4 (1.8 m or 6 ft) is dominated by thinly laminated to very thin bedded peloidal dolostone but is capped by 0.5 ft of trough cross-bedded and laminated to very thin bedded very fine to fine fecal-pellet dolograinstone containing white displacive chert nodules. The rock includes bivalves, desiccation cracks, other fractures. Long vertical fractures contain clear anhydrite cement, which also occupies other pores and accounts for up to 5 percent of the rock volume. Porosity in the lower part of the unit ranges from a trace to as much as 40 percent; porosity in the uppermost part of the unit is about 40 percent. More porous strata are brown and less porous strata gray.

Depositional Environment: This entire core is interpreted as having been deposited on a tidal flat. Very fine and very well sorted fecal-pellet grainstone is a typical tidal-flat rock

type. Lensoid anhydrite crystals are interpreted as dehydrated gypsum lenses, which are diagnostic of the intertidal zone. Displacive white anhydrite nodules and desiccation cracks at the top of the core suggest supratidal deposition.

Diagenetic History: Penecontemporaneous diagenetic processes affecting this core included gypsum precipitation and desiccation cracking of certain strata. Microcrystalline dolomite in the upper part of the core suggests supratidal penecontemporaneous dolomitization of lithofacies 4. Growth of calcium-carbonate cement in interparticle pore spaces took place relatively early but the morphology of cement crystals is not preserved. Most dolomite in this core probably formed in the burial diagenetic environment, perhaps about the same time as widespread particle dissolution. After dolomitization, wispy and sawtooth stylolites and associated fractures formed. Later, anhydrite cement filled some fractures and other pores. Gray replacive anhydrite laths formed after burial (perhaps when anhydrite cement precipitated), and were later corroded by calcite. The major regional diagenetic processes all affected this core, with the exception of dedolomitization. This is noteworthy, because dedolomitization intensely affected the Saint Stephens Ridge just a few miles to the east.

Figure A-121. Graphic core log of Permit No. 2404 well, G & S School Land 16-1A No. 1, wildcat, Choctaw Co., Alabama--detailed core log.

Figure A-122--summary graphic core log and digitized geophysical logs.

Midroc & Watkins Gatlin 1-4 No. 1 well

Permit No. 2464, wildcat, Choctaw Co., Alabama. Core number X-1348.

Depth intervals: 13,209 to 13,266 ft.

Thin sections: None.

General information: This core (17.52 m or 57.5 ft thick) includes a portion of the upper Smackover Formation. Core depths were adjusted downward by 9 ft to match the geophysical log characteristics.

Lithostratigraphic unit(s): Smackover Formation.

Lithofacies: The Smackover Formation in this core is assigned to two lithofacies.

Lithofacies 1 (13,220.2 to 13,266.5 ft; 14.11 m or 46.3 ft thick) is dominated near the base by dolomitic mudstone, overlain by calcareous dolostone, overlain in turn by fecal-pellet grainstone and dolograinstone. Lithofacies 2 (13,220.2 ft to the top of the core; 3.41 m or 11.2 ft thick) consists of dolomitic oolitic fecal-pellet grainstone overlain by ooid dolograinstone.

The basal part of lithofacies 1 (below 13,261 ft; 1.68 m or 5.5 ft thick) consists of laminated dolomitic peloid mudstone, mud-wackestone, and wackestone. Particles include peloids, possible oncoids, and possible tuberoids. Internal texture of preserved particles appears in slabbed core to be homogeneous and microcrystalline, which leaves external morphology the only support for inferences about particle origins. Crinkly thin planar or upwardly convex laminae were observed between 13,261 and 13,264 ft. Dolomite content ranges from a trace to about 20 percent; dolomite is microcrystalline to silt size and (where crystal form is determinable) planar-e. Particles are less intensely dolomitized than the microcrystalline matrix. Traces of corroded gray anhydrite laths are

scattered through the rock. Sawtooth stylolites are both subhorizontal and subvertical. Porosity is nil.

The basal unit is overlain by a thick interval (4.7 m or 15.5 ft) of laminated to medium bedded dolomitic mudstone. Uncommon small peloids and possible oncoids are similar to those found in the basal part of the core. Most of this unit is moderately bioturbated. Burrows are subhorizontal, up to more than 1 cm in diameter, and not visibly branched. A few burrows exhibit spreiten. Dolomite content ranges from a trace to about 90 percent, but for most of the unit the concentration of dolomite is between 10 and 25 percent. Dolomite morphology resembles that of the underlying unit. Anhydrite consists of gray laths either disseminated, clustered in burrows, concentrated along wispy stylolites, or concentrated near fractures; or clear equant crystals in concentrated in certain strata, clustered, or within fractures. Sawtooth stylolites occur throughout the unit, and wispy stylolites occur in the upper part. A dissolution seam between 13,246 and 13,247 ft contains a sub-millimeter layer of insoluble residue. Porosity is nil.

The central part of lithofacies 1 (13,230 to 13,245.5 ft; 4.7 m or 15.5 ft) is dominated by silt size to very fine planar-e dolostone, but contains thin intervals of mudstone. Particles consist of very fine siliciclastic sand disseminated in low concentrations in one or several strata, plus a few very fine peloids and ghosts of peloids in the upper part of the unit. Most of this unit is moderately bioturbated; burrows are similar to those in the lower part of the lithofacies. Anhydrite in this unit is like that in the underlying unit. However, anhydrite concentrations locally exceed 5 percent of the rock, and most of the anhydrite consists of gray anhedral to euhedral laths. Stylolites are less common than in

the lower part of the core. Porosity ranges from 5 to 15 percent; the pore system is intercrystalline.

The upper part of lithofacies 1 consists of medium bedded very fine fecal-pellet grainstone and slightly dolomitic grainstone. Burrowing is intense in the lower part of the unit but indeterminable in the upper part. Particles are dominated by very well sorted fecal pellets, but accessories include ooids, possible coated grains, fossil fragments, ostracodes, peloids larger than the fecal pellets, and intraclasts. Ooids and possible coated grains are common in the uppermost few tens of centimeters (foot or so) of the unit and sorting is accordingly poor in this interval. Dolomite is present in trace amounts through most of this unit (locally up to 10 percent) and is disseminated or preferentially replaces particles. Dolomite crystals are silt size and planar-e. Anhydrite in most of this unit consists of traces of gray laths and clear cement within fractures. Between 13,221 and 13,222 ft, in a layer a few centimeters thick, anhydrite discoids up to several millimeters across account for about 1 percent of the rock. The fractures are associated with a few sawtooth stylolites, which are common throughout the unit. Most of this unit is nonporous, but the uppermost meter or so contains scattered particle molds accounting for several percent porosity.

Lithofacies 2 grades upward from laminated to very thin bedded dolomitic fecal-pellet grainstone with intercalated laminae of dolomitic pellet ooid grainstone, through laminated to medium bedded pellet ooid dolograins, to laminated to thin bedded ooid dolograins at the top of the core. Almost the entire unit consists of cross strata, whose thicknesses range from less than 1 to more than 10 cm. Particles other than ooids and pellets include coated grains, peloids, oncoids, fossil fragments, and intraclasts. A

possible fenestra (plugged with anhydrite cement) was observed between 13,210 and 13,211 ft. Dolomite consists of silt size planar-e crystals that increase upward in abundance. Below 13,216 ft the concentration of dolomite ranges from a trace to more than 90 percent, but averages only a few percent; in most of this interval, dolomite preferentially replaces certain preexisting calcium-carbonate components (e.g., ooids) and avoids others (e.g., oncoids). There is no calcite above 13,216 ft. Anhydrite accounts for up to 2 percent of the rock in the lower half of this unit, including a stratum several centimeters thick containing discoidal crystals up to several millimeters across at about 13,217 ft. Clear anhydrite cement is locally abundant in particle molds and also occurs as gray euhedral laths. Between 13,210 and 13,211 ft much of the primary pore system is plugged with clear anhydrite cement. Anhydrite cement fills a fracture near the top of the core. The pore system in this unit consists of roughly equal parts interparticle, moldic, and secondary intraparticle pores. Porosity ranges from a few percent to about 50 percent; the average value is about 30 percent.

Depositional Environment: The lower part of the core (below 13,235.4 ft) is assigned to a subtidal marine or lagoonal depositional setting. The unit is mud supported and exhibits no exposure features or high-energy sedimentary structures. The overlying strata (up to 13,216.5 ft) were probably laid down on a tidal flat. This interval is dominated by very well sorted fecal-pellet grainstone, which is diagnostic of tidal flats in the Smackover on the northern flank of the MISB. Thin laminae of ooid pellet grainstone are interpreted as tempestites; discoidal anhydrite at two horizons is interpreted as a pseudomorph of discoidal gypsum, which forms intrastratally in the intertidal zone. The uppermost part of the core is dominated by cross-stratified ooid grainstone, and is accordingly interpreted as

a shoal deposit. Thus, the succession in the core is a classical upper Smackover upward shoaling cycle dominated by nonskeletal carbonates.

Diagenetic History: Penecontemporaneous diagenesis affecting this core included precipitation of intrastratal gypsum. Early diagenesis included formation of pore-rimming cement in grainstone. Dolomitization and concomitant dissolution of calcium-carbonate particles followed precipitation of calcium-carbonate cement on pore walls but preceded fracturing and anhydrite precipitation. Dolomite crystal size and form is homogeneous, suggesting that most or all dolomite was formed in a single episode. Burial diagenesis included stylolitization, fracturing, and later precipitation of anhydrite cement and replacive anhydrite laths. Because stylolites show no evidence of having affected dolomite distribution, I infer that dolomite formed before substantial pressure dissolution. Dolomite did not accumulate along stylolites, but most of the stylolites in this core could not have accumulated dolomite, because they occur either in dolostone or limestone that contains very little dolomite. This core contains little or no evidence of compaction other than the common stylolites.

Figure A-123. Graphic core log of Permit No. 2464 well. Midroc & Watkins Gatlin 1-4 No. 1, wildcat, Choctaw Co., Alabama--detailed core log.

Figure A-124--summary graphic core log and digitized geophysical logs.

Pruet ALCO Land and Timber Co. No. 1 well

Permit No. 5432, wildcat, Choctaw Co., Alabama. Core number X-1599.

Depth intervals: 12,920 to 12,937 ft.

Thin sections: Twelve thin sections were cut from this core: 12,920, 12,922, 12,924, 12,926.1, 12,928, 12,930, 12,932.5, 12,935 [a,b,c], 12,936, 12,937.

General information: This core includes a partial section of the Smackover Formation. The basal 1.2 m (4 ft) of core consist of rubble, and therefore the original positions of individual samples within this interval are uncertain.

Lithostratigraphic unit(s): Smackover Formation.

Lithofacies: The Smackover Formation in this core is assigned to a single lithofacies. The unit is dominated by pellet dolograinstone but contains laminae of oolitic pellet dolograinstone or pelletal ooid dolograinstone. The basal 0.9 m (3 ft) of core is incompletely dolomitized and consists of dendrolite (?), thrombolite, and mixed particle packstone.

The basal 0.15 m (0.5 ft) of core exhibits a fabric that contains fine to coarse particles (pellets, coated grains, intraclasts, tuberoids(?), ooids, fossil debris) suspended in a framework of faint anastomosing elements that average about 500 μm across. The framework appears to be dominated by subvertical elements connected by subordinate subhorizontal elements. These elements are structureless, contain faint transverse “septa”, or are composed of very fine to silt size pellets. This rock type grades upward over the next 0.40 m (1.2 ft) into dense mixed particle packstone (pellets, coated grains, ooids, intraclasts, oncoids, tuberoids, fossil debris, *Parafavreina*) in which vertical fabric elements grow progressively less evident upward and are absent from the upper part of the unit. The upper part of the unit contains oblique burrows about 5 mm in diameter. Dolomite (which partially and centripetally replaces some particles) grades up from a few percent near the base to 20 percent in the upper part of the unit. This unit contains several percent secondary intraparticle and vuggy porosity. The upper contact is sharp and slightly wavy but does not exhibit particle truncation, pitting, differential dolomitization, or discoloration.

This surface is overlain by 0.09 m (0.3 ft) of coarser mixed particle packstone containing a range of particles similar to that of the underlying unit, plus abundant tuberoids and disarticulated bivalves. Recumbent concave-up bivalves near the base of this unit are encrusted by thrombolites that are up to 2 cm high and roughly equant in shape. The thrombolites are structureless or contain faint tubular or peloidal inclusions. Thrombolite shape resembles that of molar teeth; thrombolites exhibit one to several attachments to the underlying bivalve shells and the upper surfaces of some thrombolites exhibit several blunt projections. Only trace amounts of dolomite are found in this unit. Secondary intraparticle, shelter, and vuggy porosity account for 5 to 10 percent of this unit.

The upper contact of the thrombolite-bearing packstone is not preserved. However, this unit is overlain by 0.3 m (1.0 ft) of very poorly sorted fine to extremely coarse thin- to medium-bedded mixed-particle packstone, which contains peloids, bivalves, echinoderms, ooids, coated grains, intraclasts, and fossil debris. A few percent of silt-size dolomite partially replaces some particles in this unit. Trace amounts of microvuggy porosity contain black hydrocarbon residue.

The remainder of the core consists of very fine thinly laminated to thin bedded or trough cross-stratified pellet dolograins with intercalated laminae of oolitic pellet dolograins and pelletal ooid dolograins. The coarser poorly sorted layers also include gastropods, bivalves, peloids, and fossil debris. Up to 12,926 ft, the unit contains bioturbated strata intercalated with undisturbed strata. Exposure surfaces with up to 2 cm of erosional relief are found between 12,932 and 12,933 ft and near the top of the core, and are associated with variation in porosity and stratal thickness. Exposure surfaces near the top of the core consist of a series of three closely spaced surfaces each about 1 mm thick. Ripple cross-lamination and wavy bedding are observed between 12,927 and 12,928 ft. The unit contains traces to 10 percent anhydrite and 0 to 25 percent calcite. Anhydrite consists of nodules composed of white laths or of gray laths as well as disseminated silt-size gray laths. Rectangular calcite patches may be calcitized anhydrite. Porosity ranges from about 5 to 60 percent, averaging about 25 percent. Most pores are moldic or interparticle, but the pore system also includes secondary intraparticle, vuggy, and intercrystalline porosity. Fractures contain anhydrite and dolomite cement whereas particle molds contain calcite cement. Sawtooth stylolites occur at a few locations in this core; some are associated with local relict calcium-carbonate. Above 12,925 ft the core is stained with oil.

Depositional Environment: The basal portion of the core is interpreted to record deposition in a shallow subtidal marine environment. The microbial boundstone suggests deposition within the photic zone but there is no evidence of emersion. Water energy must have been moderate; the rock is too well-washed for a low-energy setting, but high energy water would have toppled the small thrombolites.

The remainder of the core appears to record shoaling to near sea level. The trough cross strata in the lower part of the core probably record migration of a subaqueous dune, whereas the extremely fine laminated pelletal sand that dominates the bulk of the upper part of the core is a characteristic tidal-flat deposit. The coarser laminae may be tempestites, which are common on tidal flats. Other peritidal indicators include emersion surfaces, ripple-scale wavy bedding, and ripple cross-lamination. There are no indications of desiccation.

Diagenetic History: Penecontemporaneous diagenesis that affected this core included cementation of exposure surfaces.

Dolomitization, dissolution, and, to a lesser extent, anhydrite diagenesis, strongly affected this core. Dolomite is uniformly silt size and nearly ubiquitous in the core. Replacement of much of the pre-existing calcium carbonate by dolomite was followed by extensive dissolution of relict calcium carbonate, generating a largely secondary pore system. Later, minor calcium-carbonate cementation occluded some moldic pores. Probable calcitization of anhydrite may have taken place at the same time. The timing of

anhydrite diagenesis is unclear, though at least some anhydrite precipitated after fracturing and stylolitization under conditions of relatively deep burial.

Fracturing associated with stylolite formation took place in the burial environment, followed by cementation by anhydrite and dolomite.

Figure A-125. Graphic core log of Permit No. 5432 well. Hughes Eastern Choctaw Lumber Co. 12-8 No. 1, wildcat, Choctaw Co., Alabama--detailed core log.

Figure A-126--summary graphic core log and digitized geophysical logs.

Harkins Choctaw Lumber Co. U. 10-10 No. 1 well

Permit No. 5670, wildcat, Choctaw Co., Alabama. Core number X-1646.

Depth intervals: 13,209 to 13,269 ft.

Thin sections: None.

General information: This core includes a partial section of the Smackover Formation. The core was whole, and large fragments (thicker than about 7.5 cm or 3 inches) could not be slabbed; therefore, units that tend to break into large pieces are less well known. Also, recovery was very poor in the basal 2.7 m (9 ft) of the cored section.

Lithostratigraphic unit(s): Smackover Formation.

Lithofacies: The Smackover Formation in this core is assigned to two lithofacies. Lithofacies 1 (10.4 m or 34 ft in thickness) encompasses the lower part of the core, up to 13,235 ft. This somewhat heterogeneous unit includes partially and entirely dolomitized peloidal wackestone and packstone as well as dolostone in which depositional texture has been obliterated. Lithofacies 2 (corresponding to the upper part of the core; 7.9 m or 26 ft in thickness) is dominated by very fine fecal-pellet dolograinstone, but includes associated anhydritic mudstone, dolomitic mudstone, and crystalline dolostone.

The basal part of lithofacies 1 (below 13,258 ft) consists of laminated to very thin bedded dolomitic mixed-particle wacke-packstone. Particles include *Parafavreina*, gastropods as large as 4 mm across, and peloids (which predominate). The quality of preservation makes it difficult to estimate the abundance of *Parafavreina*, but they could account for several percent or more of the rock volume. Dolomite, which accounts for about 15 percent of the rock in the basal part of lithofacies 1, preferentially replaced particles but also occurs as disseminated rhombs. Dolomite is concentrated along wispy stylolites, not solely within the stylolites but as halos centered on the stylolites. Porosity is 10 percent or less, and consists of intercrystalline and secondary intraparticle pores, most associated with dolomite. Gastropods have been replaced by clear medium sand size anhydrite cement. Other anhydrite consists of gray-brown laths, many of which replaced peloids. Many peloids exhibit moderate levels of compaction.

Overlying the basal unit just described is 1.4 m (4.5 ft) of peloid dolowackestone. This unit differs from the underlying unit chiefly because it has been almost entirely replaced by dolomite. Relict calcite accounts for 1 to 10 percent of the rock. This unit is thin to medium bedded and porosity (here only intercrystalline) increases upwards to at least 15 percent. Gastropods and *Parafavreina* were not observed, but this may be an effect of the more-intense dolomitization.

This unit is in turn overlain by 2.0 m (6.5 ft) of thinly laminated to very thin bedded microcrystalline to silt size crystalline dolostone. Curving patterns of color variation suggest bioturbation in some strata. Relict calcite accounts for up to 10 percent of this unit, scattered medium sand size peloids are preserved, and anhydrite consists of gray-brown and yellow-brown laths, some in small nodules, as well as extremely coarsely crystalline white anhydrite nodules up to 5 mm across. The intensity of dolomitization is

diminished in the immediate vicinity of the white anhydrite nodules, but whether or not this results from dedolomitization cannot be determined without thin sections. Porosity is intercrystalline, and accounts for about 15 percent of rock volume. The unit contains one 0.15 m (0.5 ft) intercalation of peloid dolowackestone like that in the underlying unit.

A thin stratum (0.21 m or 0.7 ft thick) of laminated to very thin bedded peloid dolopackstone contains a patch more than 8 cm across with as little as 10 percent dolomite (preferentially replacing particles). This layer contains extremely coarsely crystalline white anhydrite nodules like those in the underlying unit.

The peloid packstone is overlain by 3.6 m (11.8 ft) of laminated to medium bedded crystalline dolostone (13,234.5 to 13,246.3 ft) that coarsens upward. The unit locally contains small pyrite blebs, wispy and sawtooth stylolites, fractures, and solid hydrocarbon residue. Some fractures are short, up to 1 mm across, and contain calcite cement or are healed by dolomitized carbonate that differs from the surrounding matrix in the concentration of dolomite. Through-going fractures contain clear anhydrite cement and solid hydrocarbons. Between 13,239 and 13,240 ft synsedimentary microfaults with throws of about 1 mm displace a tight layer less than 1 cm thick. Calcite cement fills fault-plane porosity. Porosity in this unit grades up from about 15 to about 20 percent.

The crystalline dolostone is overlain by a succession 2.6 m (8.5 ft) thick consisting of two intercalated rock types. The basal portion is 0.3 m (1 ft) of thin to medium bedded fine pellet dolograinstone. This unit, which contains no calcite, averages 40 percent porosity dominated by intercrystalline pores but containing moldic, secondary intraparticle, and fracture pores. The pellet dolograinstone is overlain by 1.1 m (3.5 ft) of anhydritic dolomitic lime mudstone. Dolomite content of this unit is 5 to 10 percent; anhydrite content in the basal 0.15 m (0.5 ft) is about 2 percent; only traces of anhydrite are found in the upper part of the unit. Anhydrite in the upper part of the unit consists of gray-brown laths, but in the basal portion, anhydrite crystals are relatively abundant, large (one to several millimeters long), and discoidal. This unit is overlain by 0.3 m (1 ft) of pellet dolograinstone like that previously described. Porosity is about 35 percent and permeability is far less than that in the deeper pellet dolograinstone. This in turn is overlain by 0.76 m (2.5 ft) of anhydritic dolomitic lime mudstone. This unit contains about 1 percent dolomite and a trace of anhydrite, some of which is discoidal.

This succession is overlain by 0.15 m (0.5 ft) of laminated to very thin bedded crystalline dolostone. This unit contains gray replacive anhydrite laths, 5 to 10 percent intercrystalline porosity, and no calcite.

Overlying this unit is 0.6 m (2.0 ft) of peloid dolograinstone, overlain in turn by 0.6 m (2.0 ft) of rock that could not be slabbled. The peloid dolograinstone is well sorted, fine, very thin to medium bedded, and contains no calcite. Porosity is 30 percent, mostly intercrystalline, and permeability is relatively low.

The uppermost part of the core (3.8 m or 12.5 ft) consists of very well sorted very fine laminated to thin bedded fecal-pellet dolograinstone. The unit consists of intercalated relatively tight gray laminae and thin, more porous, brown beds. Fossils are conspicuous but uncommon, most are gastropods and bivalves that were dissolved and partially to entirely filled by clear anhydrite cement. The unit also contains a small number of fine peloids like those dominating the underlying unit. This unit is characterized by 10 to 50 percent porosity (average 25 percent), which is dominated by moldic pores (most other pores are secondary intraparticle). Clear anhydrite cement occupies fractures as well as

fossil molds and is associated with traces of pyrite. The basal portion of the unit contains patches stained with solid hydrocarbon residue.

Depositional Environment: The lower portion of this core records deposition in a lagoonal or restricted shallow subtidal marine environment. Mud-supported rock textures, a predominance of spheroidal peloids, and the absence of any high-energy or exposure indicators support this interpretation. Abundant *Parafavreina* below 13,258 ft are most consistent with a shallow subtidal marine setting. The upper part of the core is, in part, intertidal and the succession is conformable, which precludes a deep-water origin for any part of this core.

Discoidal anhydrite crystals between 13,228 and 13,234 ft are interpreted as the dehydrated remains of discoidal intertidal syndepositional gypsum. An impermeable lamina between 13,239 and 13,240 ft is displaced by micro-growth faults, indicating syndepositional lithification. This lamina may be a hardground or subaerial exposure surface. Short, healed, fractures between 13,240 and 13,242 ft are desiccation cracks or some other kind of syndepositional fracture. The uppermost part of the core is nearly a monospecific microcoprolite grainstone, a rock type most common on tidal flats, and its most visible other particles are high-spired gastropods, also typical of tidal flats. Taken together, these observations suggest that the upper part of the core was deposited on a tidal flat, and that the entire core records a shoaling upward succession.

Diagenetic History: Penecontemporaneous diagenesis affecting this core included syndepositional lithification and fracturing and intrasediment gypsum precipitation. Early diagenetic processes included extensive interparticle cementation. Dolomitization (pervasive in some intervals) is obvious throughout the core and postdated cementation but predated widespread particle dissolution or significant compaction. The timing of the major episode(s) of dolomite formation is unknown. Burial diagenesis involved stylolitization, chemical compaction of individual particles, fracturing, and anhydrite precipitation. At least some dolomite formed during or after stylolitization, because some stylolites have halos more dolomitic than immediately superjacent or subjacent strata. Minor dedolomite in the vicinity of anhydrite nodules between 13,249 and 13,250 ft indicates that at least some anhydrite precipitation or recrystallization occurred after widespread dolomitization. Later burial processes included partial pyritization of anhydrite and precipitation of calcium-carbonate and anhydrite cement in fractures and other open pores.

Figure A-127. Graphic core log of Permit No. 5670 well. Harkins Choctaw Lumber Co. U. 10-10 No. 1, wildcat, Choctaw Co., Alabama--detailed core log,

Figure A-128--summary graphic core log and digitized geophysical logs.

Midroc Hunter Bolinger 26-10 No. 1 well
Permit No. 10215, wildcat, Choctaw Co., Alabama. Core number X-1659.

Depth intervals: 11,297 to 11,353.5 ft.

Thin sections: None.

General information: This core includes the contact between the Smackover Formation and the overlying Buckner Anhydrite. However, the formation contact is a fault plane, and the uppermost Smackover and basal Buckner are cut out of the core. The Smackover Formation in this core is saturated with oil. As a result, it is difficult to wet, etch, or stain the core, and rock texture and fabric are relatively obscure.

Lithostratigraphic unit(s): Smackover Formation and Buckner Anhydrite Member of Haynesville Formation.

Lithofacies: The Smackover Formation in this core (11,343 to base of core; 3.2 m or 10.5 ft thick) is relatively thin and homogeneous, and it is therefore assigned to a single lithofacies. The overlying anhydritic strata are not assigned to lithofacies.

Lithofacies 1 consists of dolomitic fecal-pellet grainstone, crystalline dolostone, and peloid dolograinstone, in ascending order. The entire succession is laminated to thin bedded. The basal 1 m (3.3 ft) of core consist of very well sorted fecal-pellet grainstone that has been partially dolomitized. The dolomite preferentially replaced fecal pellets. I estimate that about 25 percent of the rock has been replaced by dolomite, but poor staining caused by an oily rock surface makes this estimate imprecise. For the same reason, dolomite crystal morphology cannot be determined. Above the basal 0.3 m (1 ft) the rock contains about 1 percent anhydrite discoids up to several millimeters across. These crystals are concentrated in certain laminae and less abundant in intervening laminae. Porosity in this unit is as high as 15 percent locally, chiefly in the form of secondary intraparticle pores.

The dolomitic grainstone is overlain by about 0.06 m (0.2 ft) of dolomitic limestone/calcareous dolomite in which about 50 percent of the rock is silt-size to very fine planar-e dolomite. This unit contains several percent anhydrite in the form of small dark gray-brown anhedral laths. Depositional textures are not discernible. This unit is cut by high-angle, long fractures of negligible width. Some fractures are microfaults, and exhibit displacement of several millimeters. Net displacement across sets of microfaults can exceed 1 cm. Anhydrite occurs as scattered gray-brown anhedral laths. Porosity in this unit is intercrystalline, and amounts to between 5 and 10 percent of the rock volume.

The uppermost Smackover preserved in this core consists of peloid dolograinstone. In the lower part, particles appear to be very well sorted very fine fecal pellets as in the basal portion of the core. The uppermost 0.6 m (2 ft) of carbonate contains fine to medium peloids. Dolomite is silt size and planar-e throughout this interval. This unit is faulted like the underlying unit, but faults are more numerous, many contain anhydrite cement, and total displacement is greater. The abundance of faults increases upward to the top of the carbonate section. Porosity is chiefly intercrystalline at the base of the unit, gradually replaced upward by moldic and secondary intraparticle porosity. Open laminar

vugs as much as several millimeters in lateral extent, but less than one millimeter in height, are observed between 11,344 and 11,345 ft. Porosity in this unit is about 40 percent, increasing slightly upward. Concomitantly, particles become more readily identifiable upward, and it is possible that the rock was originally a fine to medium peloid sand throughout this interval.

Carbonate strata assigned to the Smackover Formation are abruptly overlain by laminated to thin bedded evaporites assigned to the Buckner Anhydrite Member of the Haynesville Formation. Stratification in the basal evaporites is far from horizontal, strata are gently curved, and stratal boundaries have a smeared appearance. Dip decreases upward and reaches a horizontal state at about 11,330 ft. Red-brown mudstone is intercalated with anhydrite above about 11,331.5 ft and accounts for about 50 percent of the rock below the missing section. Above the missing section, anhydrite is more abundant than mudstone, and the abundance of mudstone decreases upward. Vugs in the uppermost 0.46 m (1.5 ft) are interpreted to record the former presence of halite, probably dissolved during drilling. These vugs, and hence the inferred vanished halite, account for about 5 percent of the rock in the uppermost 0.3 m (1 ft).

Depositional Environment: The carbonate strata at the base of the core are interpreted as recording tidal-flat deposition. This is indicated by the presence of anhydrite discoids, probable former gypsum discoids, which form intrasedimentarily in the intertidal zone, and by abundant very fine fecal-pellet grainstone, a common tidal-flat rock type. The overlying anhydrite is nearly pure stratified anhydrite, likely deposited in the basal Buckner saltern. The presence of both red-brown mudstone and halite inclusions is consistent with this interpretation.

The interface between the two units is abrupt, sedimentologically unlikely, and associated with tilting, bending, and faulting of strata above and below the interface. Accordingly, this surface is interpreted as a fault plane.

Diagenetic History: Penecontemporaneous diagenesis included growth of gypsum discoids within the sediment. Early diagenesis included cementation of interparticle pore space in carbonate sand; this likely took place very early under the influence of marine water, but this cannot be determined in this core without thin sections. Dolomitization and particle dissolution affected the entire carbonate portion of the core, but timing of these events is not well constrained. The extremely fine crystal size of much of the dolomite suggests early hypersaline dolomitization, as does its top-down distribution within the Smackover. Both dolomitization and particle dissolution (which commonly occur together in the Smackover) probably predated faulting because the carbonate rock was rigid at the time of faulting and because there is no dolomite cement within fractures. Later diagenesis included pyrite authigenesis (minor), pressure dissolution, formation of replacive anhydrite, faulting and later precipitation of anhydrite cement in open faults. Hydrocarbon migration is the last diagenetic process for which evidence is clear.

Figure A-129. Graphic core log of Permit No. 10215 well, Midroc Hunter Bolinger 26-10 No. 1, wildcat, Choctaw Co., Alabama--detailed core log.

Figure A-130--summary graphic core log and digitized geophysical logs.

**Mitchell Paramount-Bolinger 19-16 No. 1 well,
Permit No. 10605, wildcat, Choctaw Co., Alabama. Core number X-1721.**

Depth intervals: 11,235 to 11,281 ft.

Thin sections: Nine thin sections were cut from this core: 11,253.3, 11,265, 11,269, 11,274.4, 11,276, 11,276.5, 11,279, 11,280.1, 11,280.6.

General information: This core includes a section of the upper part of the Smackover Formation. Anhydrite in this core is intercalated with porous and permeable carbonate, and is interpreted as part of the Smackover Formation. Correlation of core with geophysical logs suggests that massive anhydrite of the basal Buckner is less than 2 meters (6 feet) above the top of the core.

Reported core depths yield a geologic column that appears to be inconsistent with geophysical log response. Accordingly, the core is shifted 1.8 m (6 ft) down relative to the logs.

Lithostratigraphic unit(s): Smackover Formation.

Lithofacies: This core is divided into three lithofacies. Lithofacies 1 (11,267.2 ft to base of core; 4.2 m or 13.8 ft) is dominated by dolomitic *Parafavreina* wackestone with minor dolomitic *Parafavreina* packstone. Lithofacies 2 (11,247.2 ft to 11,267.2 ft; 6.1 m or 20 ft) consists of fecal-pellet dolograinstone grading up into dolomitic fecal-pellet grainstone. Lithofacies 3 (top of core to 11,247.2 ft; 3.7 m or 12.2 ft) consists of intercalated anhydrite and anhydritic fecal-pellet dolograinstone.

Lithofacies 1 (11,267.2 ft to base of core; 4.2 m or 13.8 ft) is dominated by dolomitic *Parafavreina* wackestone with minor dolomitic *Parafavreina* packstone. The unit is strongly bioturbated and characterized by differential cementation and compaction. The bioturbated fabric probably controlled cementation and compaction via permeability heterogeneity. Burrows are typically 0.7 to 3.1 cm across and most are subhorizontal or oblique. The *Parafavreina* vary widely in size and are preferentially dolomitized. As a consequence of dolomitization, lunules are poorly preserved. The *Parafavreina* are both clustered and disseminated; clusters are on the order of 1 to a few centimeters across. Laminae of *Parafavreina* packstone are uncommon. The unit ranges from thinly laminated to medium bedded; relatively thin and thick strata appear to be juxtaposed at random. Bivalves are locally common and are disarticulated or fragmental. Very fine ovoid fecal pellets are common in the upper part of the unit, and are comparable to *Parafavreina* in aggregate volume above about 11,274 ft. Small pellets in the lower part of the unit are interpreted as small *Parafavreina* rather than ovoid pellets, because the ovoid pellets in this unit are not dolomitized whereas many of the *Parafavreina* are dolomitized. Also, the small *Parafavreina* are cylindrical and form the fine tail of a continuous size distribution of *Parafavreina* (qualitative visual estimate). Dolomite in this unit is microcrystalline and ranges from a trace to 100 percent of the rock; average dolomite content is 40 to 50 percent. Dolomite replacement affected different components of the rock differently. Some but not all *Parafavreina* were dolomitized, few or no small pellets were dolomitized, and cement or matrix surrounding small pellets was

thoroughly dolomitized but only in certain local areas. Uncommon dense dolostone laminae appear to lack particles, but partially dolomitized patches show that the depositional texture was pellet wackestone or packstone. Long fractures in conjugate sets, some consisting in part of sets of en-echelon tear fractures, cut lithofacies 1 and in places the rock is brecciated. Displacement of more than 1 mm is discernible on some fractures. Fractures are cemented with anhydrite and calcite. Locally, dolomite concentration is reduced adjacent to fractures. Dolomite within burrows is slightly coarser than dolomite outside burrows in the upper part of lithofacies 1. Porosity in this unit is limited to scattered secondary intraparticle and intercrystalline pores. Relatively impermeable strata are gray, whereas more permeable strata are browner. Carbonate strata are compacted around light brown anhydrite anhedral, which locally account for up to 2 percent of the rock in this lithofacies. In the upper part of the unit anhydrite laths are clustered in burrows. Many anhydrite crystals are visibly embayed. Pellets are slightly to intensely compacted in much of lithofacies 1, but many pellets appear to retain their original shapes.

Lithofacies 2 (11,247.2 ft to 11,267.2 ft; 6.1 m or 20 ft) consists of fecal-pellet dolograinstone grading up into dolomitic fecal-pellet grainstone. Strata are thin laminae to medium beds, as in lithofacies 1. The fecal pellets dominating lithofacies 2 are very fine ovoid pellets, not favreids, though scattered *Parafavreina* are found in the unit. Gray, corroded anhydrite laths, both disseminated and clustered, are widespread in lithofacies 2 as in lithofacies 1. Permeable parts of this unit are brown and stained with oil. Nonstained portions of the core are gray.

The basal part (below 11,260.5 ft; 2 m or 6.7 ft thick) of lithofacies 2 is dominated by very fine fecal-pellet dolograinstone. Particles in this interval other than ovoid pellets include fossil fragments and *Parafavreina*. Dolomite crystals in the basal part of lithofacies 2 range from silt size to relatively coarse microcrystalline crystals.

The upper part of lithofacies 2 is dominated by dolomitic very fine fecal-pellet grainstone. Particles include ovoid pellets, *Parafavreina*, gastropods, bivalves, ostracodes, ooids, and unidentified fossil fragments. This unit is less intensely dolomitized and less intensely bioturbated than the lower part of the lithofacies. Between 11,253 and 11,254 ft are two bored, blackened, dense laminae, each about 1 cm thick. Both units originally consisted of fecal-pellet grainstone virtually identical to that of overlying and underlying strata. Between 11,251 and 11,252 ft several thin laminae of ostracodal mollusk pellet grainstone have sharp bases and may be weakly normally graded. Mollusk shells range from broken fragments to articulated bivalves, and account for about 10 percent of the rock within the mollusk rich laminae.

Silt-size dolomite in the upper part of lithofacies 2 ranges from a trace to about 60 percent of the rock, averaging about 25 percent of the rock. Dedolomite between 11,255 and 11,256 ft is recognized because dolomite rhombs are reduced to hair-like remnants.

Anhydrite cement has partially replaced many mollusk shells in the mollusk-rich laminae, replacive anhydrite laths form haloes around stylolites, and discoidal anhydrite crystals account for 1 or 2 percent of the rock in the uppermost 0.46 m (1.5 ft) of lithofacies 2. Porosity in the lower part of lithofacies 2 is dominated by vuggy secondary intraparticle pores and is slight. The upper part of lithofacies 2 is nonporous in part, but porosity exceeds 15 percent in some strata. The pore system includes moldic, secondary intraparticle, primary interparticle, fracture, and shelter pores.

Lithofacies 3 (top of core to 11,247.2 ft; 3.7 m or 12.2 ft) consists of intercalated anhydrite and anhydritic fecal-pellet dolograinstone. Lithofacies 3 overall is about 45 percent anhydrite and about 55 percent dolomite (calcite, clay, and pyrite are minor constituents). Fecal pellets are well sorted very fine to fine or very well sorted very fine ovoids. Dolomite fines upward from silt size to microcrystalline crystals.

The basal stratum of lithofacies 3 is about 0.15 m (0.5 ft) thick and consists of intercalated anhydritic dolostone and calcitic and dolomitic anhydrite. The proportion of carbonate material increases upward from about 45 to about 60 percent. At least the two basal anhydrite layers consist of vertically oriented chevrons of anhydrite within calcitic nuclei, draped by anhydritic fecal-pellet dolograinstone. The layers of chevron anhydrite appear to have nucleated on hiatal surfaces; the unit also contains a 5-mm thick black clay seam that may represent a prolonged interruption of carbonate sedimentation. This unit contains scattered ooids and fine peloids. Calcite cement in fractures and relict (or secondary) calcite elsewhere account for up to 15 percent of the rock locally.

Overlying this basal unit is about 0.37 m (1.2 ft) of intercalated dolostone and anhydrite that consists of 50 to 75 percent dolostone. This unit does not contain recognizable chevron crystals of anhydrite but in other respects is similar to the underlying unit. However, calcite is less abundant than below, and some fractures contain anhydrite cement rather than calcite cement. Locally, particles are calcitic in a framework of dolomite (which replaced cement or matrix). This unit contains uncommon ooids and traces of pyrite. Planar microlaminae at several horizons might be stromatolitic. Dolomitic strata contain minor intercrystalline porosity but are not strongly oil stained.

Overlying this unit is 0.21 m (0.7 ft) of porous and permeable oil-stained very-thin to thin bedded fecal-pellet dolograinstone. This unit is almost free of calcite, but does include anhedral anhydrite laths (as in underlying units) as well as anhydrite cement in fractures. The pore system is dominated by moldic and secondary intraparticle pores, accounting for 10 to 15 percent of the rock.

The oil-stained dolostone is overlain by 0.79 m (2.6 ft) of dolomitic anhydrite and minor intercalated dolostone. Most of this unit is mildly brecciated: cracks run through the entire interval, but displacements are on the order of a few millimeters or less. Fractures are filled with anhydrite cement. Dolostone strata or patches consist of anhydrite-plugged moldic fecal-pellet dolograinstone with some isolated moldic pores. Anhydrite layers are thinly laminated to thin bedded. Close to half of the anhydrite in this unit contains ghosts of pellets identical in size and shape to those in the intercalated dolostone.

Oil-stained anhydritic fecal-pellet dolograinstone with minor anhydrite interlaminae (0.27 m or 0.9 ft thick) overlies the unit just described. The unit contains little visible porosity despite the heavy oil stain. Planar microlaminae at one horizon might be stromatolitic.

Laminae to thin beds of nodular and laminar anhydrite with minor dolostone interlaminae 0.40 m (1.3 ft) thick overlie the oil-stained dolostone. This unit is lightly fractured; fractures contain anhydrite cement and extend through dolostone laminae and well into intervening anhydrite layers. Fractured portions of anhydrite layers contain abundant pellet ghosts.

The uppermost 1.52 m (5 ft) of core consist of anhydritic dolostone. The rock is thinly laminated to thin bedded fecal-pellet dolograinstone. Ripple cross laminae and

low-angle cross laminae are found in the upper part of the unit. Particles include ovoid pellets, gastropods, bivalves, peloids, ooids; fenestrae and desiccation cracks were tentatively identified. Dense laminae, partly replaced by anhydrite and transected by vertical fractures, are found between 11,237 and 11,238 ft. Relict calcite is present in trace amounts. Anhydrite occurs as cement filling fosso-, pel-, and oomolds and fractures, as well as replacive laths like those found deeper in the core. The uppermost 0.15 m (0.5 ft) of core is more intensely fractured than the remainder of this unit. Porosity in this unit averages at least 25 percent and reaches 50 percent locally. The pore system is dominated by moldic, secondary intraparticle, and interparticle pores, with minor intercrystalline pores. Parts of this unit are oil stained.

Depositional Environment: Lithofacies 1 is interpreted as a lagoonal deposit.

Parafavreina are abundant, and their distribution and association with large-bore burrows suggests that they are autochthonous. Small patches of *Parafavreina* packstone were probably deposited near burrow openings as is commonly observed in the Recent. The rock is mud-supported and contains no evidence of high-energy processes or subaerial exposure. However, uncommon laminae of *Parafavreina* packstone may represent wackestone winnowed by moderate-energy currents.

Rocks assigned to lithofacies 2 were deposited on a tidal flat. The very-fine pellet grainstone that dominates this facies is characteristic of tidal flats. Other features that suggest tidal-flat deposition include exposure surfaces; ripple cross laminae; extremely coarse, normally graded fossiliferous laminae that are interpreted as tempestites (c.f., Kreisa, 1981); uncommon ooids; and discoidal anhydrite interpreted as dehydrated discoidal gypsum, which forms intrasedimentarily in the intertidal zone. Further, association with low-energy marine strata below and evaporites above suggests peritidal deposition for this unit. The exposure surfaces are blackened and bored, which is most consistent with a subtidal origin and not with subaerial exposure. This kind of surface is likely a hardground, and could as easily be found in lagoonal or shoreface strata as in tidal-flat strata.

The lower part of lithofacies 3 is interpreted as a brine-pond deposit. However, this unit is less than 10 ft thick and is underlain and overlain by inferred tidal-flat deposits. Therefore, it is taken to record the presence of a supratidal evaporitic pond that formed and was filled late in Smackover time, rather than the far larger and longer-lived Buckner saltern (not cored in this well). Brine-pond deposition is inferred from the presence of vertically oriented chevron anhydrite nodules that are interpreted as dehydrated bottom-nucleated subaqueous gypsum. Carbonates in this interval are limited to very fine pellet dolograins, which could be autochthonous (biotically or physico-chemically precipitated) or allochthonous. Most of the dolomite in this unit is microcrystalline, which is consistent with its formation either as a primary precipitate or via syndepositional diagenesis in a saline lake, as is happening today in some of the lakes adjacent to the Coorong Lagoon.

The uppermost part of the core appears to record a return to tidal-flat (or beach?) deposition. Pellet dolostone resembles that already assigned a tidal-flat origin. Fractured exposure surfaces interpreted as syndepositionally lithified crusts, ripple cross laminae, and low-angle cross laminae all are consistent with a peritidal origin. Possible fenestrae and desiccation cracks also suggest tidal-flat deposition.

In sum, this core records part of a typical late-Smackover shoaling succession, modified by the presence of a supratidal pond that formed shortly before the end of Smackover deposition. (The top of the brine-pond deposit is about 4.6 m (15 ft) below the base of the Buckner saltern deposits, as inferred from comparison of the core and neutron-density log.)

Diagenetic History: Penecontemporaneous diagenesis of this core included intrasedimental growth of gypsum discoids, and lithification of submarine (and subaerial?) crusts. Early diagenesis included carbonate cementation in interparticle pores. Later diagenesis included, in approximate order of occurrence, chemical compaction of particles, dehydration of gypsum and concomitant cracking of carbonate strata, extensive stylolitization and other compaction, dolomitization and particle dissolution, growth of replacive anhydrite laths, fracturing, widespread replacement of dolomite by anhydrite, precipitation of anhydrite and calcite cement in fractures, corrosion of anhydrite, dedolomitization, and hydrocarbon migration. Chemical compaction of particles must have preceded both dolomitization and dissolution, for these two processes affected particles and matrix (or cement) differentially, making no distinction between compacted and noncompacted particles. Dolomite precipitation and particle dissolution probably were roughly synchronous, for dolomite crystals line many particle molds. These events probably took place after the bulk of stylolitization, because dolomite rhombs are not concentrated along stylolites. Anhydrite replacement of carbonate in lithofacies 3 is indicated by the common occurrence of pellet ghosts with a grainstone texture within anhydrite bodies. Because relatively short subvertical fractures transect both dolostone strata and adjacent anhydrite containing pellet ghosts, but not other associated anhydrite strata, it is suggested that dehydration of gypsum cracked early-lithified carbonate strata, followed at some later time by centripetal anhydritization of those fractured strata. Calcite cementation, corrosion of anhydrite, and dedolomitization may have been synchronous as they all involve growth of calcite and occurred relatively late.

Figure A-131. Graphic core log of Permit No. 10605 well. Mitchell Paramount-Bolinger 19-16 No. 1, wildcat, Choctaw Co., Alabama--detailed core log.

Figure A-132--summary graphic core log and digitized geophysical logs.

Descriptions of Wildcat Wells in Alabama
By David C. Kopaska-Merkel

Mobile County

Forest Betty Joe Anderson No. 1 well

Permit No. 1862, wildcat, Mobile Co., Alabama. Core number X-759.

Depth intervals: 20,008 to 20,014 and 18,800 to 18,836 ft.

Thin sections: None.

General information: This core includes partial sections of metasedimentary basement rocks, the uppermost Norphlet Formation, and the basal Smackover Formation. The core consists of large chips, not entire slabs, corresponding to less than one percent of the basement core and about 5 percent of the Norphlet and Smackover cores.

Lithostratigraphic unit(s): basement, Norphlet Formation, Smackover Formation.

Lithofacies: The lower core consists of 1.83 m (6 ft) of dark gray micaceous slate or phyllite. Strata are undulatory thin laminae resembling low-amplitude symmetrical ripples. Shear planes are at a high angle to bedding. Fractures are filled with coarse blocky calcite cement and doubly terminated euhedral quartz cement.

The lower 6.55 m (21.5 ft) of the upper core, from 18,814.5 to 18,836 ft, consists of poorly to moderately sorted very fine to coarse anhydritic sandstone that is assigned to the Norphlet Formation. The Norphlet core is not divided into lithofacies. The lowest 1.52 m (5 ft) of the Norphlet core consists of poorly sorted very fine to coarse gray or pink anhydritic sandstone that is thinly laminated to thin bedded or locally cross laminated. Particles are moderately to well rounded and of low to very high sphericity. Sorting and particle size varies among laminae. Calcium-carbonate cement and anhydrite cement are common; many calcium-carbonate cement crystals have deeply embayed margins. A trace of particle moldic porosity is lined with anhydrite cement. Relict interparticle porosity is very minor. Displacive white microcrystalline anhydrite nodules are up to 2 mm across and account for up to 3 percent of the core locally. Some nodules contain voids that may once have been occupied by other mineral phases.

A bed of nodular anhydrite 0.15 m (0.5 ft) thick overlies the unit just described. The lower part of the anhydrite bed is white and microcrystalline; this stratum is abruptly overlain by light gray anhydrite consisting of acicular crystals up to nearly 1 mm long.

The anhydrite is overlain by anhydritic yellow-brown to gray sandstone that is dominantly very fine to fine, but contains numerous slightly coarser layers (fine to medium; locally fine to coarse in the upper part). This unit is dominantly laminated to very thin bedded, but locally thinly laminated or thin bedded. Both calcium-carbonate and (more abundant) anhydrite cement fill primary pores; sand-size masses of microcrystalline pyrite are found between about 18,820 and 18,822 ft and may be replacive or cement. Sand-size pyrite crystals (modified pyritohedrons) are locally present. Microcrystalline white anhydrite nodules are generally a few mm across or smaller, vary in abundance among strata, and range from ovoid to (locally) anastomosing. Anhydrite accounts for between 5 and 15 percent of the rock. Relict interparticle porosity is very minor.

The contact between Smackover and Norphlet is not preserved.

One lithofacies is identified in the Smackover Formation in this core, corresponding to the interval from 18,800 to 18,814.5 ft. Unfortunately, pervasive extra fine to very fine planar-e and planar-s dark gray dolomite has virtually eradicated primary textures in this core. Possible ghosts of sand-size spheroidal particles suggest a peloidal wackestone or packstone (a common Smackover lithofacies). Possible larger subequant ghosts suggest oncoids or thrombotic microherms, which also would be unsurprising for the Smackover in the area of this core. Anhydrite nodules account for up to about 1 percent of the Smackover core; many nodules can be divided into central and peripheral regions. Nodule centers consist of equant sand-size clear to white anhydrite crystals; peripheral regions consist of transparent laths that look dark against the dark gray dolomite. Some anhydrite nodules are white and microcrystalline. Carbonate deposition was interrupted by 5 influxes of very fine to fine quartz sand, generating dolomitic sandstone/sandy dolomite layers that are 2 to 7 cm thick and that contain 1 to several percent pyrite in the form of sand-size microcrystalline nodules. Some quartz particles in these layers are cylindrical and between 150 and 250 μm in diameter.

Most of the Smackover in this core is laminated to very thinly bedded; the uppermost 0.61 m (2 ft) consist of thin to medium beds.

Depositional Environment: The Norphlet core is interpreted to record deposition on an evaporitic desert plain, as suggested by poor sorting and rounding and variable sphericity of sand particles coupled with the abundance of anhydrite (including a nodular anhydrite layer 0.15 m (0.5 ft) thick).

The depositional environments of Smackover strata in this core are not determinable.

Diagenetic History: Pervasive dolomitization has erased nearly all evidence of early diagenesis in the Smackover. Diagenetic processes that might have taken place before dolomitization include formation of the white cores of anhydrite nodules and precipitation of anhydrite and pyrite cement in sandstone laminae. Late diagenetic processes include pressure dissolution and associated fracturing, growth of anhydrite laths as halos around anhydrite nodules, precipitation of anhydrite cement in fractures, and pyrite precipitation, some at the margins of anhydrite nodules and some in sandstone laminae.

Figure A-133. Graphic core log of Permit No. 1862 well. Forest Betty Joe Anderson No.1, wildcat, Mobile Co., Alabama--detailed core log, lower part.

Figure A-134--detailed core log, upper part.

Figure A-135--summary graphic core log and digitized geophysical logs.

Roach Dr. Montel Moore Fdn. Trust 3-6 No. 1

Mobile Co., Alabama

Permit No. 2542, X No. 848

General Notes

This core lies entirely within the Smackover Formation, and is represented by core chips collected at one-foot intervals. The core is dominated by very-fine sand-sized planar-e dolostone; evidence of original depositional fabric is scarce and equivocal.

This well was drilled on the southern flank of the eastern part of the Mississippi interior salt basin, basinward of Churchula Field, and just east of Citronelle Field. Churchula Field lies on the basin rimming platform, but well PN 2542 may be located on the platform margin or within the basin proper, based on isopach and structural maps of the area.

Stratigraphy

Smackover Formation

TOP OF CORED INTERVAL = 18,622 feet

BASE OF CORED INTERVAL = 18,682.5 feet

Depositional Environment

The combination of fabric-destructive dolomitization and representation of the core only by small chips makes detailed depositional interpretation futile. At some intervals particles are clearly preserved, but their characteristics are not clear. Rectangular fine-medium sand sized peloids may be *Parafavreina* fecal pellets. Most other particles are very fine to medium sand sized and some appear to be coated – these could be ooids. A few larger patches may be particles; if they are they are probably oncoids or intraclasts. However, little more information could be discerned than what is represented on the graphic log.

Diagenetic Characteristics

In the absence of thin-section information only the obvious diagenetic effects can be recognized. Pervasive dolomitization ranges from 100 percent complete to 20 percent complete; most of the core is more than half dolomite. Most of the calcite appears to be relict and in intervals where particles could be recognized dolomite appears to have been matrix (or cement) selective, leaving most particles calcitic or partially dolomitized. However, in the top part of the core, within a 10-foot-thick interval containing essentially no calcite, a few percent of calcite was observed at 18,625 feet. This intercrystalline calcite may be cement. No calcite is preserved below 18,668 feet.

Below 18,632 feet there appears to be at least some porosity or calcite in every sample, and dolomite is very-fine sand sized and planar-e. Above 18,632 feet there is no porosity and no calcite (except as mentioned above), dolomite is silt sized and planar-s. This might be penecontemporaneous hypersaline dolomite, but I don't think so, because it is exceptionally pure and homogeneous.

Low-amplitude and wispy stylolites were observed in most samples between 18,666 and 18,633 feet. Small amounts of anhydrite in the form of small white nodules and dark laths was observed between 18,681 and 18,637 feet. About 10 percent of the sample collected at 18,623 feet consists of white anhydrite nodules between 0.25 and 1.5 mm in diameter. These appear to be recrystallized laths, but a few suggest the discoidal shapes of gypsum pseudomorphs.

Most porosity is intercrystalline; a few very small vugs (particle molds?) are preserved at 18,677 feet. Porosity exceeds 5 percent between 18,681 and 18,668 feet, with a maximum greater than 15 percent between 18,670 and 18,668 feet.

Figure A-136 Detailed core log, Roach Dr. Montel Moore Fdn Trust 3-6 No. 1 well, Permit No. 2542, wildcat, Alabama. Note - description based upon core chips (1-foot spacing).

ARCO Town Miller 25-14 well

Permit No. 6306, wildcat, Mobile Co., Alabama. Core number X-1531.

Depth interval: 18,622 to 18,759.1 ft.

Thin sections: Twelve thin sections were cut from this core: 18,722.8, 18,723.5, 18,726.5, 18,727.4, 18,728, 18,728.5, 18,729, 18,731.1, 18,733.7, 18,734.2, 18,735, 18,735.9.

General information: This core includes a complete section of the Smackover Formation, as well as the uppermost Norphlet Formation and the lower part of the Buckner Anhydrite Member of the Haynesville Formation. The basal Haynesville in this core is dominated by anhydritic shale, rather than anhydrite, as is more usual in southwest Alabama.

Lithostratigraphic unit(s): Norphlet Formation, Smackover Formation, Buckner Anhydrite Member of Haynesville Formation.

Lithofacies: Sandstone at the base of this core is not given a lithofacies number, and is assigned to the Norphlet Sandstone. The rock consists of 3.0 m (9.8 ft) of moderately to well sorted porous thinly laminated to thin bedded very fine to medium sandstone. The unit is anhydritic, pyritic, and stylolitic, and bioturbated (in part). In the lower part, symmetrical ripple-form laminae and normally graded laminae are associated with the poorest sorting observed in the unit. The uppermost 1.2 m (3.8 ft) contain up to 5 percent calcium carbonate in the form of very fine particles and particle-rimming cement, as well as minor silt-size planar-e dolomite pore-filling cement. The uppermost few tens of centimeters of sandstone contain up to 5 percent calcium-carbonate particles, a thick solution seam, abundant low-amplitude stylolites, a lens of silt-size planar-e dolostone that is more than 2 cm wide and up to 2.5 mm thick, planar-e silt-size pore-filling dolomite cement, ripple-form laminae and ripples, and crinkly thin laminae of silt-size planar-e dolostone.

Three lithofacies are identified in the Smackover Formation in this core. Lithofacies 1 corresponds to the interval from 18,735 ft to the base of the Smackover at 18,749.3 ft. Lithofacies 2 corresponds to the interval from 18,725 ft to 18,735 ft. Lithofacies 3 corresponds to the interval from the top of the Smackover at 18,722.3 ft to 18,725 ft.

Lithofacies 1 (4.36 m; 14.3 ft) is dominated by thinly laminated microbial dololaminite overlain by thinly laminated to thin bedded pellet dolograinstone (beds thicken upward). Dolomite accounts for nearly 100 percent of the lower part of lithofacies 1 (below the gap in the core); calcite in this interval consists of traces of relict calcite in particles and trace amounts of calcite cement in fractures. In the upper part of the lithofacies, calcite accounts for up to 95 percent of the rock but averages only a few percent, chiefly in the form of relict peloids, cement in fractures, and calcite that replaced anhydrite in vugs and nodules. Dolomite in lithofacies 1 consists of silt to very fine sand size planar-e rhombs. Porosity (estimated visually) ranges from 5 to 25 percent, increasing upward, and averages 15 percent. The lower part of the lithofacies includes small nodules of transparent anhydrite loaves; the upper part contains sand-size equant

anhydrite cement crystals in vugs and fractures that were co-precipitated with calcite and also partially calcitized.

Particles recognized in this lithofacies are limited to well sorted to very well sorted spheroidal peloids of fine sand size that are probably fecal pellets.

Sedimentary structures include thin laminae interpreted as microbial, burrows about 1.5 to 2.0 mm in diameter and trough-shaped ripples.

The pore system in the lower part of the lithofacies is dominated by intercrystalline pores (5 to 15 percent porosity), but in the upper (pelletal) interval, pores are moldic, secondary intraparticle, and intercrystalline (10 to 25 percent porosity).

Diagenetic components include replacive dolomite and dolomite cement, sawtooth stylolites, wispy stylolites, solution seams, small anhydrite nodules, and fractures emanating from stylolites. The fractures contain dolomite, calcite, and anhydrite cement.

Lithofacies 2 (3.05 m; 10.0 ft) is dominated by dolomitized microbial boundstone in a matrix of dolomitized peloid pack-grainstone. Boundstone accounts for between 10 and 100 percent of the rock, averaging about 40 percent. This is a minimum estimate; areas where the primary texture cannot be determined are assigned to the matrix, but some of these areas contain fractures whose style resembles that of fractures in boundstone.

Dolomite consists of silt to very fine sand size planar-e to planar-s replacive rhombs and very fine sand size planar-e cement. In much of lithofacies 2 dolomite crystals have been corroded by calcite. Calcite ranges from 5 to 90 percent of rock and consists of medium to coarse clear blocky cement crystals and cloudy replacive crystals. Between 18,726 and 18,732 feet, dedolomitization ranges from at least 10 percent to nearly complete.

Boundstone is chiefly in the form of microherms consisting of one or more dendritic microcrystalline elements (dendrolite). Microherms range from about 1 cm to several tens of centimeters in thickness and lateral extent. Some microherms are planar or contain planar as well as dendritic elements. Original shelter porosity as well as dissolutional porosity within microherms has been largely occluded by pore-rimming dolomite cement and later pore-filling calcium-carbonate cement. The matrix surrounding microherms has been dolomitized and subsequently dedolomitized (in part), hence primary depositional texture is difficult to determine. However, primary texture appears to have contained numerous fine to medium peloids, and the rock is interpreted as a peloid pack-grainstone.

Most particles are fine to medium peloids, but other particles include oncoids and fossil fragments.

Sedimentary structures include an emersion surface between 18,728 and 18,729 ft. However, most of the observable structures are very thin to thin planar beds. Fenestrae lined with dolomite cement occur between 18,726 and 18,727 ft.

Porosity (estimated visually) ranges from 5 to 15 percent, averaging 8 percent. Most pores are intercrystalline.

Diagenetic components (other than dolomite) include anhydrite, which consists of clear laths, nodules composed of clear laths up to several millimeters in length, small white nodules, extra coarse gray replacive laths, and clear cement in fractures. A major solution seam cuts the core between 18,731 and 18,732 ft. Fractures are short, straight or curved, locally en echelon or radiating from points, and contain anhydrite and calcium-carbonate cement. Some fractures are associated with stylolites. Dedolomitization is common between 18,726 and 18,732 feet, as indicated by embayed and skeletal dolomite rhombs.

Lithofacies 3 (0.82 m; 2.7 ft) is dominated by crystalline dolostone and peloid dolograinstone. The lowermost third of a meter (foot) consists of silt size crystalline dolostone containing poorly sorted peloids. This is overlain by 0.40 m (1.3 ft) of poorly sorted dolomitic peloid grainstone (average 70 percent dolomite). This layer in turn is overlain by a thin (0.09 m; 0.3 ft) layer of microcrystalline dolostone with about 5 percent calcite cement. This stratum is overlain in turn by a 1.5 cm thick layer of dolomitic peloid grainstone (60 percent dolomite) containing about 1 percent very fine to fine pyrite framboids. The uppermost carbonate strata in this core consist of intercalated dark crinkly thin laminae and light homogeneous microcrystalline dolomite, separated by solution seams.

Particles found in this unit are dominated by peloids, but also include intraclasts and fossil fragments.

Sedimentary structures include dark crinkly thin laminae, very thin to thin beds, and local bioturbation.

Porosity is intercrystalline in the lower part of the unit (crystalline dolostone and dolomitic peloid grainstone) but is nil in the uppermost part of the unit. Porosity values in lithofacies 3 are generally less than 5 percent.

Diagenetic components include silt size and microcrystalline dolomite, small anhydrite nodules consisting of transparent laths, anhydrite cement in fractures, and pyrite framboids. There is no evidence in this lithofacies of the dedolomitization that is so pervasive in lithofacies 2.

Smackover carbonates assigned to lithofacies 3 are overlain by anhydritic siliciclastic strata assigned to the Buckner Anhydrite Member of the Haynesville Formation. No lithofacies numbers are assigned to Buckner strata.

The basal 0.24 m (0.8 ft) of the Buckner in this core consists of nodular anhydrite (30 percent) intercalated with anhydritic gray shale (70 percent). Shale at the very base of the unit is darker in color and pyritic.

The basal Buckner is overlain by a thick succession (29.72 m; 97.5 ft) of intercalated red and gray shale and anhydrite. Most of the red shale is free of anhydrite; most of the gray shale is anhydritic (10 to 20 percent anhydrite) and laminated or very thinly bedded. Massive red mudstone strata up to 0.77 m (2.2 ft) in thickness are included with laminated and very thinly bedded sections under the name of red shale. Most of the anhydrite layers are laminated or nodular, but near the middle of the succession (18,683.3 to 18,684.3 ft) is a unit of chevron anhydrite that is 0.3 m (1.0 ft) thick and consists of thin to medium beds. Also, vertically oriented anhydrite nodules compose the laminae near 18,636 ft, 18,631 ft, 18,630 ft, and 18,627 ft and possible symmetrical ripples are found in the anhydrite laminae near 18,638 ft.

The Buckner core in this well is arbitrarily divided into two subequal parts at a 0.61 m (2 ft) thick missing section (18,680 to 18,682 ft). Anhydrite is more abundant, and red shale less so, in the upper part of the core. Also, whereas all red shale above the missing section is confined to the lower half of the upper interval, most of the anhydrite is found in the upper half of the upper interval. The gradational variation in characteristics of the Buckner in this core is well illustrated by comparing the proportion of gray shale to red mudstone to anhydrite below the missing section, where it approximates 35:12:1, to that ratio above the missing section, where it is about 6:1:1.

An interval about 2.89 m (9.1 ft) thick, from 18,634 to 18,643.1 ft, is characterized by subvertical fractures filled with two generations of mud (now lithified). The fractures vary greatly in width, begin and end abruptly, and do not extend very far. The broken edges of strata at fracture margins are smooth rather than sharp. Most fractures contain dark gray mud; some fractures contain light gray mud, and a few fractures contain peripheral dark gray mud and central light gray mud. Where the two colors of mud touch, the boundary is sharp.

Depositional Environment: This core penetrates the entire Smackover section, which is less than 10 meters (30 feet) thick at this location. Uppermost Norphlet strata in this core are thinly laminated to thin bedded very fine to medium sandstone. Regionally, the uppermost Norphlet is inferred to consist of eolian deposits reworked in the marine environment during transgression, but unequivocal evidence is lacking in this core. A shallow-marine or even tidal-flat setting is suggested by crinkly thin dolomitic laminae that are inferred to be microbial, ripples, dolomite and calcium-carbonate cement, and calcium-carbonate particles; these marine indicators are more abundant in the upper part of the sandstone core.

Norphlet sandstone is abruptly overlain by thinly laminated microbial dololaminite overlain by pellet dolograstone. These strata are interpreted as tidal-flat deposits primarily because they contain dololaminite, though abundant pellet grainstone also is common in tidal-flat deposits. The basal Smackover is capped by a 1.31 m (4.3 ft) gap in the core, which is overlain by a very thin to thin bedded grainstone of peloids coarser and less well sorted than those forming the pellet grainstone below the missing core. This thin interval above the gap lacks environmentally diagnostic features, but it is overlain by a 3.05 m (10 ft) thick microbial mound dominated by thrombolite and dendrolite of probable subtidal origin. The mound is capped by poorly sorted intraclastic peloid grainstone which was probably derived from the mound by erosion. The top of the carbonate section consists of dark crinkly thin laminae that are probably intertidal and microbial, and microcrystalline dolomite that is probably syndepositional and hypersaline. This latter inference is supported by the peritidal setting, by the small size of the dolomite crystals, and by proximity to the overlying Buckner evaporites. The upper part of the Smackover in this core consists of a single upward shoaling cycle a little more than 4 meters (about 14 feet) thick.

The remainder of this core (about 30 meters; about 100 feet) is assigned to the Buckner Anhydrite Member of the Haynesville Formation. The cored lower part of the Buckner Anhydrite in this well is dominated by laminated to thin bedded siliciclastic anhydritic mudstone and lesser anhydrite laminae. Most of the mudstone is gray, and the proportion of red mudstone decreases upward, whereas the proportion of anhydrite layers (inferred to have been deposited as gypsum) increases upward. The gray mudstone tends to be anhydritic, whereas the red mudstone tends to be free of anhydrite. Shrinkage cracks are uncommon. The succession appears to record deposition in an evaporitic lagoon that experienced high rates of detrital sediment input. Occasional incursions of fresh water diluted the lagoon and permitted the deposition of oxidized sediment. As time passed, these incursions became less frequent, perhaps because continued transgression caused the shoreline to retreat. At the same time, episodic gypsum-precipitating events

grew more frequent in response to a higher average salinity coupled with continuing salinity fluctuations, perhaps caused by inter-annual climatic variation.

Fracturing in the Buckner section between 18,634 and 18,643.1 ft in this core may result from gravitational processes on the relatively high-relief Wiggins Arch. Fracturing is inferred to be syndepositional, or nearly so, because the fractures have irregular boundaries, because features projecting from fracture boundaries into the fractures are smoothly rounded, and because the fractures are filled with what was, at the time of fracture filling, fluid mud. At least two events are indicated, separated by a significant span of time, because two distinct colors of mud were injected, and the younger fracture fill did not mix with the preexisting deposit.

Diagenetic History: Diagenetic fabrics in the Norphlet Formation that are visible in slabbed core are few. Probable calcium-carbonate cement occupies interparticle pores in the uppermost Norphlet. In the lower part of the Norphlet core, sand-size blebs of microcrystalline pyrite also occupy some primary pore spaces; smaller pyrite blebs are scattered throughout the cored interval in the Norphlet. Other diagenetic fabrics include low-amplitude sawtooth stylolites and dolomite. The stylolites are modified bedding surfaces and probably formed under burial conditions. The dolomite consists of 20-micrometer planar-e cement in primary pore space and also a lens (ripple?) of silt-size planar-e dolomite near the formation boundary. At a slightly higher horizon, a small flattened nodule of anhydrite consists of transparent very coarse laths.

Very little evidence pertaining to early diagenesis remains in the Smackover core. Much of the core originally consisted either of microbial boundstone or grainstone containing considerable shelter or interparticle porosity. These primary pores are now filled by pore-lining planar-e dolomite cement followed by blocky calcium-carbonate pore-filling cement. These phases also fill dissolutional voids in boundstone, which therefore must have formed relatively early. The original depositional components in the basal part of the Smackover core have been almost entirely replaced by planar-e dolomite, chiefly of silt size. Higher in the core, dolomitization was incomplete, but the precise degree of dolomitization has been obscured by subsequent dedolomitization. Dolomitization probably took place under conditions of shallow burial, after dissolution but before fracturing. However, a thin layer of microcrystalline dolostone 1.5 cm below nodular anhydrite at the base of the Buckner may be penecontemporaneous hypersaline dolomite. A thin layer of microcrystalline dolostone is common in the uppermost Smackover in Alabama. At the top of the Smackover a layer 1.5 cm thick contains about 1 percent pyrite framboids of very fine to fine sand size. The timing of pyrite formation is unknown. Burial diagenesis included formation of stylolites, which took several forms (sawtooth, solution seam, and wispy) depending on the clay content of the rock. Fractures are associated with stylolites and probably formed relatively late. Fractures are short, and are curved, en echelon, or radiate from points. Fractures are filled with anhydrite cement and minor amounts of later calcium-carbonate cement but no dolomite cement, and almost certainly postdate dolomitization. Anhydrite and calcium-carbonate cement also fill dissolutional vugs (some also contain early dolomite cement), and in some cases calcium carbonate replaced anhydrite both in vugs and in small nodules of white or transparent laths of anhydrite. This may be the same calcium-carbonate phase that formed dedolomite. Some anhydrite nodules are associated with stylolites.

Early diagenesis in the Buckner included penecontemporaneous formation of gypsum on and immediately below the floor of the Buckner evaporite lagoon as well as possible minor shrinkage fracturing. Shortly thereafter, firm Buckner strata were incipiently brecciated and the open fractures filled with mud. Later, a second episode of fracturing reopened some existing fractures and created some new ones; these were filled with a second generation of mud, lighter in color. Dehydration of gypsum to anhydrite occurred during burial.

Figure A-137. Graphic core log of Permit No. 6306 well. ARCO Town Miller 25-14, wildcat, Mobile Co., Alabama--detailed core log, lower part.

Figure A-138--detailed core log, upper part.

Figure A-139--summary graphic core log and digitized geophysical logs.

**Unit Manager Citronelle Unit C-12-6 No. 2 well,
Permit No. 10241, Citronelle Field, Mobile Co., Alabama. Core number X-1679.**

Depth interval: 18,267 to 18,387 ft.

Thin sections: None.

General information: This core includes a complete section of the Smackover Formation, as well as the uppermost Norphlet Formation and lowermost Buckner Anhydrite Member of the Haynesville Formation.

Lithostratigraphic unit(s): Norphlet Formation, Smackover Formation, Buckner Anhydrite Member of the Haynesville Formation.

Lithofacies: Sandstone at the base of this core is not given a lithofacies number, and is assigned to the Norphlet Sandstone. The rock consists of 0.76 m (2.5 ft) of very well sorted nonporous fine sandstone containing (in the upper 0.15 m; 0.5 ft) laminae about 1 mm thick of fine to medium sandstone. The lower 0.61 m (2 ft) of sandstone is massive, but the upper 0.15 m (0.5 ft) exhibits low-angle cross lamination. Also, the upper 0.15 m (0.5 ft) of cross-laminated sandstone contains substantial amounts of dolomite cement. Locally, the concentration of dolomite is too great to consist solely of cement; some of the dolomite must have replaced primary carbonate constituents.

Three lithofacies are identified in the Smackover Formation in this core. Lithofacies 1 corresponds to the interval from 18,354.7 ft to the base of the Smackover at 18,384.5 ft. Lithofacies 2 corresponds to the interval from 18,315.5 ft to 18,354.7 ft. Lithofacies 3 corresponds to the interval from the top of the Smackover at 18,296.8 ft to 18,315.5 ft.

Lithofacies 1 (9.08 m; 29.8 ft) is dominated by very thin to thin-bedded microbial doloboundstone, most of which is thrombolitic. Dolomite accounts for nearly 100 percent of lithofacies 1, and is dominated by silt to very fine sand size rhombs. Dolomite crystals lining pores are planar-e, but crystals in denser parts of the core are planar-e to planar-s. Porosity (estimated visually) ranges from less than 5 to about 15 percent, but averages 5 to 8 percent. The average porosity in commercial core analyses of this lithofacies is 6.7 percent, and the geometric mean permeability is 0.55 md. The core includes small nodules of transparent anhydrite loaves and scattered traces of pyrite.

Particles recognized in this lithofacies are limited to a single bivalve, but small spheroidal vugs are probably molds of peloids.

Sedimentary structures are essentially limited to planar laminae.

Porosity is likewise relatively homogeneous; the pore system is dominated by small vugs that are likely altered moldic pores. This interpretation is based on the size and distribution of the pores, even though no unequivocal peloids are known from the lithofacies.

Diagenetic components include replacive dolomite and dolomite cement, sawtooth stylolites, small anhydrite nodules, very small clusters of pyrite crystals, and fractures emanating from stylolites. The fractures contain dolomite cement (some baroque) and lesser anhydrite cement. Most of the pyrite is associated with stylolites.

Lithofacies 2 (11.95 m; 39.2 ft) is dominated by very thin to thin-bedded doloboundstone, dolostone, dolomitic limestone, dolomitic peloid grainstone, and peloid dolograinstone. Some boundstone strata are medium bedded. Most of the boundstone is probably thrombolite and a small minority is stromatolite. However, depositional texture has been obliterated in about half of this lithofacies. The content of dolomite ranges from about 5 to 100 percent, and decreases upward, in a general way, in this lithofacies. Dolomite textures in lithofacies 2 are essentially identical to those in lithofacies 1, except that where the content of dolomite is substantially less than 100 percent, a higher percentage of rhombs are planar-e. Porosity (estimated visually) ranges from nil to about 20 percent, but averages between 5 and 15 percent. Average porosity measured by commercial core analysis is 9.9 percent; geometric mean permeability is 0.91 md. Pyrite was not observed in this lithofacies, and anhydrite is less common than in lithofacies 1. Anhydrite includes small nodules of transparent loaves as below as well as gray-brown laths.

Particles include fine to medium-sand size microcrystalline peloids, fossil fragments, intraclasts (most microcrystalline), oncoids, very fine quartzose sand, gastropods, and coated grains. Peloids are by far the most common particles in this rock.

Sedimentary structures include planar laminae, ripple cross-laminae, and planar-tabular cross bedding. A peculiar vertical structure is most clear between 18,327 and 18,328 ft, but can be discerned with a lesser degree of clarity between 18,327 ft and the top of lithofacies 2. Vertical elements tend to be a few cm wide and have uneven lateral margins; they differ in color and commonly in dolomite content from adjacent elements. The elements may narrow or widen upwards, or may maintain a roughly constant width over a vertical distance typically between 5 and 10 cm. The origin of these vertical elements is uncertain, but they are tentatively identified as columnar thrombolites and inter-column depressions (filled with detrital carbonate whose primary texture has been nearly obliterated by diagenesis. In a few cases (e.g., 18,316 to 18,317 ft) elements that widen upward and are accordingly interpreted as inter-column depressions or channels contain basal lags of medium sand to very fine pebble size intraclastic peloid dolograinstone.

Porosity is variable in this lithofacies and the origins are obscure. Intercrystalline porosity in dolostone is widespread, but other pore types identified as moldic, secondary intraparticle, and vuggy probably all were controlled by depositional texture. Vugs are small, and most are probably altered moldic pores.

Diagenetic components are similar to those of lithofacies 1, with the addition of wispy stylolites. These commonly define the boundaries of domains interpreted as thrombolites or as inter-thrombolite sediment packages. Some moldic pores in the upper part of lithofacies 2 contain anhydrite cement. Also, the appearance of gray-brown anhydrite laths in the upper part of the lithofacies is significant. This is the most common kind of Smackover anhydrite, but is entirely absent from the lower part of the core (below 18,328 ft). Neither anhydrite nor dolomite crystals are corroded in this lithofacies.

Lithofacies 3 (5.70 m; 18.7 ft) is dominated by thinly laminated to medium bedded very fine to medium sand size dolomitic peloid grainstone in which bedding thickness decreases upward. Dolomite content in this lithofacies ranges from 5 to 80 percent; the concentration of dolomite is highest in the lower part of the lithofacies and lowest in the middle part. Dolomite crystals (silt to very fine sand size) are planar-e where they are

relatively loosely packed but planar-e or planar-s otherwise. At the very top of the lithofacies, an interval about 0.09 ft thick consists of microcrystalline dolostone that is relatively nonporous. Vertical elements outlined by wispy stylolites throughout this lithofacies hint at burrows 1 to 2 cm in diameter. Porosity (estimated visually) in most of lithofacies 3 is about 5 percent, but in the upper 3 ft (excluding the uppermost 0.09 ft) porosity ranges from 15 to 25 percent. Porosity measured by commercial core analysis in this lithofacies averages 6.26 percent; geometric mean permeability is 0.17 md.

Anhydrite is found throughout most of lithofacies 3 and consists of small blebs of transparent loaves, gray-brown laths (some slightly corroded) up to 2 mm long and (in the uppermost 0.6 m [2 ft] of the lithofacies) thick plates. The concentration of anhydrite is less than 1 percent in the lower part of the lithofacies but increases to as much as 10 percent in the upper 1.2 m (4 ft).

Particles include peloids (volumetrically dominant), fossil fragments, gastropods, intraclasts, and ooids.

Sedimentary structures consist chiefly of planar stratification, but also include indistinct vertical elements that might be thalassinidean burrows as well as ripple cross-lamination. In addition, a nonlaminated equant area may have been deposited as thrombolite.

Porosity in most of this lithofacies is dominated by intercrystalline pores. In the uppermost 0.91 m (3 ft) (excluding the top 0.03 m; 0.09 ft), the pore system is diverse, including moldic, secondary intraparticle, primary interparticle, and intercrystalline pores.

Diagenetic components are similar to those of lithofacies 2. Anhydrite is more abundant (10 percent) in the upper 1.22 m (4 ft) of the lithofacies than anywhere deeper in the core. Vertical wispy stylolites are also more abundant in lithofacies 3 than in deeper parts of the core.

Smackover carbonates assigned to lithofacies 3 are overlain by anhydrite strata assigned to the Buckner Anhydrite Member of the Haynesville Formation. No lithofacies numbers are assigned to Buckner strata. The basal 2.90 m (9.5 ft) of the Buckner (18,287.3-18,296.8 ft) consist of laminated to thin bedded anhydrite locally containing traces of pyrite. Some thin beds of anhydrite are enterolithic. Up to about 18,291 ft, the matrix among anhydrite nodules is dolomitic, but above that point it consists of reddish brown mud that exudes a muddy odor when damp.

Above the basal anhydrite unit is a succession of intercalated siliciclastic mudstone and anhydrite units that is 0.40 m (1.3 ft) thick. The anhydrite is overlain across a gradational contact by a layer of anhydritic reddish brown siliciclastic mudstone 0.18 m (0.6 ft) thick. The mudstone unit is overlain abruptly by a stratum of anhydrite 0.09 m (0.3 ft) thick. This layer consists of vertical anhydrite nodules in a matrix of reddish brown mudstone. The nodular anhydrite layer is in turn overlain by a massive anhydrite layer 0.12 m (0.4 ft) thick.

The intercalated mudstone and anhydrite is overlain by silty brown and gray siliciclastic mudstone 1.52 m (5 ft) thick, which is anhydritic in the lower and upper part but not the middle. Anhydrite consists of small blebs of transparent loaf-shaped crystals. The lower part of the unit is uniformly silty, but in the upper part, the silt is confined to laminae and small patches. The unit is very thin to thin bedded in the lower part but laminated to thin bedded in the upper part. The rock fractures conchoidally.

Thinly laminated to thin bedded gray argillaceous and silty anhydrite (18,279 to 18,281 ft) has gradational upper and lower contacts with anhydritic mudstone. Syndepositional faulting with displacement on the order of millimeters affected the upper part of the unit.

Reddish brown and grayish brown silty thinly laminated to thin bedded siliciclastic mudstone 1.28 m (4.2 ft) thick overlies the impure anhydrite unit. The unit is anhydritic in the upper and lower parts. The silt occurs as laminae and (more commonly) lenses. The unit is more reddish brown than grayish brown; the gray color is found in discrete laminae or (less commonly) blobs or nodules. At the top of the unit, grayish brown and reddish brown patches are intimately commingled on a millimeter scale. Particle size and color do not vary congruently.

The uppermost 2.38 m (7.8 ft) of core consist of thinly laminated to medium bedded anhydrite, which overlies the mudstone with an abrupt, slightly undulating, contact. The anhydrite is more argillaceous near its base and top. The unit is light gray to white, locally enterolithic or nodular, and dominantly microcrystalline. A 1-cm-thick bed near the base consists of fine to very fine sand size crystals, as do small blebs that are uncommon higher in the core.

Depositional Environment: This unusual core penetrates the entire Smackover section, yet is remarkably uniform. Uppermost Norphlet strata are low-angle cross-laminated well sorted fine sandstone with dolomite cement and coarser (fine to medium) thin laminae, probably eolian deposits reworked on a marine shoreface during transgression. Because the lowest Norphlet strata in this core lack dolomite cement, it could be that the core includes the basal transgressive strata of the Norphlet-Smackover sequence. However, the absence of dolomite cement in the lowest part of the core could simply result from a lack of porosity in that interval.

The uppermost Norphlet sandstone is immediately overlain by dolomitized thrombolite which, based on interpretations of other Smackover thrombolites in Alabama, was likely deposited within the photic zone. A mound or reef interval about 12 m (40 ft) thick, consisting almost exclusively of thrombolite, is overlain by a succession of interbedded peloid grainstone and thrombolite. This weakening of mound development and intercalation of mound and nonmound strata could have resulted from episodic changes in water chemistry or increases in water energy, possibly a by-product of progressive regional shoaling and restriction of water circulation during highstand deposition.

The upper 5.7 m (18.6 ft) of the Smackover in this core consist of dolomitic peloid grainstone. This grainstone records formation of a shoal that buried the last thrombolite mound in the region, likely a result of shallowing into a zone of wave energy too high for vigorous thrombolite growth. The grainstone contains at least some ooids, and, but for the vagaries of diagenesis, might be shown to be dominated by ooids.

The uppermost 0.03 m (0.09 ft) of the Smackover consists of peloid grainstone that has been replaced by microcrystalline dolomite. The small size of the dolomite crystals, as well as their stratigraphic position between Buckner evaporites above and Smackover carbonates below, suggests that the dolomite formed syndepositionally via the influence of hypersaline fluids.

Abruptly overlying the uppermost carbonate stratum of the Smackover is a succession about 9 m (30 ft) thick consisting of interbedded laminated anhydrite and siliciclastic mudstone. This interval is assigned to the Buckner Anhydrite Member of the Haynesville Formation. The core consists of more than 95 percent anhydrite in the lower and upper intervals (below 18,287.3 ft and above 18,274.8 ft), which strongly indicates subaqueous evaporite deposition in a saltern (cf., Mann, 1988, and references therein). Between the two layers of relatively pure anhydrite is a succession of mudstone, silty mudstone, anhydritic mudstone, and silty anhydritic mudstone. Most of this interval is reddish brown, with a lesser admixture of gray strata. This mixed succession is interpreted as recording deposition on a continental sabkha, though an 0.6-m (2-ft) thick unit from 18,279 to 18,281 ft was probably deposited in a brine pond.

Diagenetic History: The complex diagenetic history of this highly altered core cannot be evaluated in detail without thin sections. A few general observations are possible.

Syn depositional sea-floor cementation is indicated by intraclasts, observed at several depths in the core. Further evidence for syn depositional cementation includes thrombolites with near-vertical margins separated by channels containing lag deposits (including intraclasts).

The two most obvious diagenetic processes to affect this core are dolomitization and dehydration of gypsum to anhydrite. Relatively pure laminated anhydrite is generally interpreted as a dewatering product of gypsum diagenesis. In this core, this inference is supported by vertically oriented anhydrite nodules between 18,286 and 18,287 ft; this fabric is characteristic of dehydrated bottom-nucleated subaqueous gypsum crystals (e.g., Mann, 1988, and references therein). Most of the dolomite in this core is clearly replacive. However, limpid planar-e rhombs and baroque crystals in vugs and fractures are products of burial cementation. The replacive dolomite in most of this core consists of silt to very fine sand size planar-e to planar-s rhombs that could have formed in a variety of diagenetic environments. By contrast, microcrystalline dolomite in the uppermost 0.03 m (0.09 ft) of the Smackover probably formed penecontemporaneously from hypersaline fluids.

Dissolution of unstable carbonate particles strongly affected this core. Moldic and secondary intraparticle pores, as well as small vugs that are probably modified molds, are common and widespread in this core. Dissolution of the missing particles may have accompanied the major phase of dolomitization, as appears to have been the case in many Alabama Smackover cores that have been thin sectioned.

Volumetrically insignificant diagenetic phases include pyrite and anhydrite (in the Smackover). The pyrite consists of very small (sand size or smaller) clusters of minute crystals (silt size or smaller), as is usual for the Smackover. The pyrite crystals tend to be found near stylolites, suggesting a burial origin for the pyrite. The anhydrite in the Smackover in this core consists of millimeter-scale blebs of transparent loaf-shaped crystals. These resemble, but are smaller than, the nodules of anhydrite disseminated throughout the Smackover in some other Alabama cores. Gray-brown laths of anhydrite, more common in the Smackover elsewhere in Alabama, are found only above 18,328 ft. Also, the gray-brown anhydrite laths in most Smackover cores in Alabama are strongly corroded, but in this core corrosion of the anhydrite laths is local and very minor. Minor anhydrite cement fills moldic pores in the upper part of lithofacies 2.

Low-amplitude sawtooth and wispy stylolites indicate substantial pressure dissolution in the burial environment. Minor amounts of anhydrite cement are found within the sawtooth stylolites. Fractures in the Smackover in this core are short and emanate from sawtooth stylolites, indicating that they formed as a result of changes in the stress field caused by on-going pressure dissolution. The fractures contain planar and baroque dolomite and anhydrite cement.

Figure A-140. Graphic core log of Permit No. 10241 well. Unit Manager Citronelle Unit C-12-6 No. 2, Citronelle Field, Mobile Co., Alabama--detailed core log, lower part.

Figure A-141--detailed core log, upper part.

Figure A-142--summary graphic core log and digitized geophysical logs.

Descriptions of Wildcat Wells in Alabama
By David C. Kopaska-Merkel

Washington County

Coral D. J. Crager Jr. No. 1 well,
Permit No. 1456, wildcat, Washington Co., Alabama. Core number X-395

Depth interval: 13,175-13,203 ft.

Thin sections: none.

Lithostratigraphic unit(s): Haynesville Formation

Lithofacies: Three lithofacies are identified in this core (fig. 35). Lithofacies 1 corresponds to the cored interval from 13,194 to 13,203 ft. Lithofacies 2 corresponds to the middle of the core (13,185 to 13,194 ft). Lithofacies 3 corresponds to the upper part of the core (13,175 to 13,185 ft). The entire interval is siliciclastic.

Lithofacies 1 (2.7 m; 9 ft) consists of red claystone, with greenish mottles in the upper part. Lithofacies 2 (2.7 m; 9 ft) consists of friable siliciclastic sandstone. Sand particles are mostly medium to coarse, angular to subangular. The sandstone is dominated by quartz, but includes several percent rock fragments and clay clasts up to 1 cm in longest dimension. The lower part of lithofacies 2 consists of cross-stratified medium beds, with both planar-tabular and tangential cross strata (the latter with reactivation surfaces). Laminae containing concentrations of quartz particles, clay clasts, and other rock fragments up to 6 mm across separate bedsets of cross laminae. The cross stratified unit contains submillimeter micaceous clay partings. The upper part of lithofacies 2 is massive and coarser than the lower part. However, at the top, the sandstone is finer, micaceous, and argillaceous, and grades up into clay shale of lithofacies 3. The argillaceous sandstone of the uppermost part of lithofacies 2 contains micaceous clay seams slightly thicker than those in the cross-stratified unit. The clay seams in the argillaceous sandstone are about 6 cm apart at angles of about 15° to the horizontal. Lithofacies 3 (3 m; 10 ft) consists of micaceous green claystone with red mottles grading up to red claystone with green mottles and finally to unmottled red claystone in the uppermost 0.3 m. The basal 0.5 m of this lithofacies include intercalated burrowed argillaceous sandstone layers, and the green shale in this basal interval contains simple, straight, sand-filled cylindrical burrows 3 to 6 mm in diameter that are inclined to bedding.

Depositional Environment: This core records deposition on an arid alluvial plain. The sandy interval in the middle of the core is probably a wadi deposit. The massive upper part of the sandstone containing scattered clay clasts may be a debrite or slump deposit. The overlying green shale probably filled the inactivated channel.

Diagenetic History: Redox relationships indicated by color variation in the claystone and shale suggest soil formation both before channel formation and after channel filling. The green shale at the base of lithofacies 3 was evidently deposited and buried relatively quickly.

Figure A-143. Graphic core log of Permit No. 1456 well. (A) Detailed core log, Coral D. J. Crager Jr. No. 1 well, Permit No. 1456, wildcat, Washington Co., Alabama.

13,200

more than 3,000 feet of section omitted

Figure A-144 Digitized geophysical well logs, core depositional environments, and sea-level curves (progradation to right), Permit No. 1456. G=gamma ray log, D=density log. Depth in feet on left.

Coral Drilling L. E. Heinmiller No. 1

Washington Co., Alabama

Permit No. 1465, X No. S-64

General Notes

This core is woefully incomplete. Cores were cut from the Norphlet, lower Smackover, and Buckner, but for each of these three units what we have consists of groups of 1 to a few boxes (most intervals fewer than 10 ft of core) separated from one another by gaps of a few ft to about 8 ft. For the Smackover and Norphlet we have less than 50 % of the interval covered, whereas for the Buckner we have a bit more than half.

Further, mixing of lithologies in unexpected ways (i.e., Norphlet-type sandstone in the lower Smackover, and microlaminated argillaceous limestone intercalated over many boxes with wavy-laminated limestone in the lower Smackover) suggests the possibility that the core has been jumbled. I have assumed that the sandstone in the lower Smackover was out of place, but that everything else was in place.

Last, one box was not labeled as to depth. If the boxes were in order, then it belongs between 16,679 and 16,694 ft, in the Norphlet. I have placed it at 16,685-16,687.5 ft, which is about in the middle of the interval from which it probably came.

Stratigraphy

Norphlet Sandstone:

TOP OF CORED INTERVAL = 16,664 ft

BASE OF CORED INTERVAL = 16,711 ft

Gap in Core: 82 ft

lower Smackover Formation

TOP OF CORED INTERVAL = 16,542 ft

BASE OF CORED INTERVAL = 16,582 ft

Gap in Core: 405 ft

upper Smackover formation

TOP OF CORED INTERVAL = 16,128 ft

BASE OF CORED INTERVAL = 16,137 ft

Haynesville Formation (Buckner Member)

TOP OF CORED INTERVAL = 16,076 ft

BASE OF CORED INTERVAL = 16,128 ft

Depositional Environment

The deepest part of the core (16,664 to 16,711 ft) consists of fine to medium textured siliciclastic sandstone, attributed to the Norphlet Formation. Six ft of sandstone are planar-tabular cross-bedded; the rest appears structureless. However, the visible cross beds are made apparent by contained dark minerals whereas most of the apparently structureless rock contains few dark particles and hence little optical contrast. Between 16,666 and 16,667 ft the cross bedding is only faintly visible because of the scarcity of dark particles. The structureless rock may contain "invisible" cross-bedding.

Fractures with displacements of a few centimeters or less were noted at 16,694 to 16,695 ft and between 16,664 and 16,667 ft, at the top of the core.

Uncommon glauconite was noted between 16,667 and 16,668 ft.

The deepest part of the Norphlet core (16,699 to 16,711 ft) is extremely friable, and the boxes contain abundant disaggregated sand. Friability decreases upward as follows: the core from 16,694 to 16,696.5 ft is indurated; that from somewhere in the interval from 16,679 to 16,694 ft is moderately friable, as is the overlying core from 16,676 to 16,679 ft; the uppermost Norphlet cored interval, 16,664 to 16,668 ft is indurated, though the topmost foot is slightly less so than the rest. The Norphlet Sandstone in Alabama contains an uppermost portion, the "tight zone," which was reworked in the marine environment and which is characterized by greater induration (resulting from quartz cementation) than the underlying aeolian interval. Hence, the upper, indurated, portion of the core is interpreted as part of the reworked marine Norphlet. This interpretation is supported by log correlations, which suggest that the top of the Norphlet is fewer than 10 ft above the top of the preserved core. The underlying friable strata are interpreted as aeolian deposits, but the precise depositional environment cannot be ascertained from available data because of the dearth of sedimentary structures in the core.

The overlying core (16,542 to 16,582 ft) is assigned to the lower Smackover Formation on the basis of log correlations and lithology. The succession of strata indicated by the arrangement of core in the boxes may be misleading, for two reasons. First, in some places the core was sliced vertically, and opposing slices do not all match. Second, microlaminated argillaceous and carbonaceous limestone (herein called MLZ facies) is interbedded with other rock types through the entire cored interval, which is not impossible but unusual.

The lowermost box of limestone contains MLZ facies lime mudstone overlain by peloid packstone. The MLZ facies is light and dark gray limestone with laminae on the order of 1 to a few millimeters in thickness. The MLZ facies contains a significant proportion of silt and clay. Beds in the peloid packstone are up to tens of centimeters thick, if stylolites represent former bedding planes. The MLZ facies strata were deposited below storm wave base in a reducing environment. A nearshore stagnant lagoonal setting is suggested by the abundance of fine siliciclastic material, which is uncommon in the Smackover of the Mississippi Interior Salt Basin (MISB). The strata could have been deposited in a deeper, stratified water body and the siliciclastic material could have been shed from the nearby ridges of the Choctaw Ridge Complex; these ridges might still have been partially exposed when the cored strata were formed.

The overlying box (16,570 to 16,572 ft) contains peloid wacke/packstone and peloid grainstone. This box contains both massive and thinly laminated strata, but the laminated material is not MLZ type. Rather, it is peloid grainstone that is relatively free of siliciclastic or carbonaceous material. Some anhydrite nodules appear to be pseudomorphs of gypsum lenses, indicating penecontemporaneous or early burial hypersalinity. Overlying material (16,560 to 16,564 ft) consists of peloid wackestone and packstone with thin, wavy, or nodular bedding (some dolomitic) and MLZ facies lime mudstone. Some fractures predate development of nodular bedding, and could be penecontemporaneous. Badly preserved fossils probably include mollusks and benthic foraminifera.

Peloid dolomitic wackestone grades up into silty wavy bedded dolomitic lime mudstone to wavy bedded and laminated dolomudstone. Rounded intraclasts of dolomudstone in dolomitic mudstone indicate that dolomite is syndepositional.

The shallowest strata assigned to the lower Smackover, from 16,542 to 16,546 ft, consist of massive fossiliferous silty lime mudstone, MLZ facies, and wavy bedded fossiliferous lime mudstone in ascending order. Peloidal strata from 16,554 to 16,572 ft and overlying lime mudstone probably formed in a restricted lagoonal setting. Gypsum and some dolomite formed during deposition, possibly during short-lived hypersaline episodes caused by local relative sea-level fall and isolation of small basins. Early movement of the Louann Salt, movement on basin-rimming faults, and eustasy are possible causes of sea-level fluctuations responsible for syndepositional evaporite formation in this core.

The highest cored interval (16,076 to 16,137 ft) is more complete than the other two. The basal 9 ft consist of pellet dolograinstone assigned to the uppermost Smackover Formation. These strata contain 15 to 20 percent pelmoldic, pellet intraparticle, and possibly some interparticle porosity, and are high quality reservoir rock. Underlying the dolograinstone, just a few ft below the base of the core, is a several-foot-thick anhydrite layer identified from the density log of this well. Elsewhere in the eastern MISB, pellet

dolograinstone strata less than a foot in thickness and interbedded with sulfate evaporites have been interpreted as Buckner carbonates. However, the 9-foot interval of pellet dolograinstone in the core from Permit No. 1465 can be traced for at least several miles using electric log correlations into wells in which the underlying anhydrite layer appears to be laterally replaced by carbonate. Hence, the carbonate layer from 16,128 to 16,137 ft in the core from Permit No. 1465 is interpreted as the upper part of a unit of regional extent that is an integral part of the upper Smackover reservoir and of the Smackover carbonate lithosome. Further, the top of this unit is interpreted as an approximate time line, and therefore of stratigraphic significance, as discussed below.

The uppermost part of the core (above 16,128 ft) is dominated by anhydrite with up to a few percent of dolosilt and clay. Thickly laminated strata are most abundant, followed by layers exhibiting vertically oriented nodules, with massive beds and beds with equant nodules least common. Crumbly white anhydrite layers might have contained minor amounts (up to several percent) of halite (the core was probably cut with water and the halite might have dissolved during or after core collection). Dolomite layers occur from 16,097.5 to 16,100 ft (2.5 ft thick) and from 16,087 to 16,090 ft (3 ft thick). The lower dolostone is calcareous, with the percent dolomite ranging from about 40 to more than 95 percent, and the calcite is probably dedolomite. The shapes and arrangement of patches of the two minerals suggest the replacement of dolomite by calcite, but this cannot be determined with certainty without a thin section. Equant clots of dolostone could be the ghosts of peloids, ghosts of interparticle cement matrix, or purely diagenetic features. The upper dolostone is peloid dolograinstone grading up into stromatolitic microbial doloboundstone.

These strata are interpreted as a saltern deposit (see Mann and Kopaska-Merkel, 1992), a subaqueous evaporite formed in a hypersaline pond of great extent. Both vertically oriented nodules and massive or laminated relatively pure anhydrite are formed subaqueously. Only a 6-inch interval at the base of the evaporite could have formed in a sabkha. The two dolostone layers might have formed by direct precipitation in response to chemical changes in the water column, or they could have formed when basin waters were diluted so that other processes (e.g., biologically mediated processes) could precipitate carbonates.

Because evaporites precipitate geologically instantaneously (months to centuries), if the basal Buckner in this core formed in a saltern, then the Buckner-Smackover boundary is a timeline that should be correlatable throughout a large part of the eastern MISB. If the flooded portion of the basin changed size significantly during evaporite deposition then the base of the evaporite would not be synchronous throughout the entire area of subaqueous evaporite precipitation. However, this surface would still be approximately synchronous throughout large parts of the formerly flooded basin. Also, discontinuities within the evaporite, caused by salinity changes that would have accompanied major changes in water volume, might permit mapping of subbasins within which the surface could be considered a timeline.

Diagenetic Characteristics

The only diagenetic process obvious in the cored Norphlet Sandstone strata is lithification through cementation.

The diagenetic processes that most obviously affected the lower Smackover core are stylolitization, pyrite formation, anhydrite formation, and partial dolomitization. The concentration of dolomite ranges from about 5 percent to 40 percent of the rock, but the average is about 10 percent. Much dolomite consists of silt-sized planar-e crystals disseminated through the rock, but some particles are preferentially dolomitized. Some vugs contain anhydrite and calcite cement with dolomite that appears to replace some of the calcite and is therefore younger than both anhydrite and calcite cements. However, there is some penecontemporaneous dolomite, indicated by dolomudstone intraclasts in lime mudstone. Also, some dolomite is centripetally calcitized, indicating that at least some calcite formation postdated some dolomite formation. Probably there were multiple episodes of precipitation of calcite, dolomite, and anhydrite.

Uncommon fractures in the upper part of the core contain anhydrite cement.

Uppermost Smackover carbonates have been thoroughly dolomitized, and contain anhydrite nodules that are white or clear. Some nodules are mixed anhydrite and dolomite and are associated with high-amplitude stylolites. Particle-moldic and secondary intraparticle porosity of 15 to 25 percent records extensive particle dissolution.

Figure A-145 - Detailed core log, Coral L. E. Heinmiller No. 1 well, Permit No. 1465, wildcat, Washington Co., Alabama. Upper part of core (of 3), upper 5 mackover formation and lower Buckner Anhydrite.

Figure A-146 - Detailed core log, Coral L. E. Heinmiller No. 1 well, Permit No. 1465, wildcat, Washington Co., Alabama. Middle part of core, lower S mackover Formation.

Figure A-147 - Detailed core log, Coral L. E. Heinmiller No. 1 well, Permit No. 1465, wildcat, Washington Co., Alabama. Lower part of core (of 3), Norphlet Formation.

Midroc et al. Laubenthal Unit 34-4 No. 1

Washington Co., Alabama

Section 34, T5N, R1E

Permit No. 2844, X No. 1403

General Notes

This core had never been slabbed, and the following description is based on examination of the whole core, plus slabs made from selected core samples at 1 to 2 foot intervals.

This core lies entirely within the Smackover Formation, and consists chiefly of low-energy deposits. The top of the core is 97 feet below the top of the Smackover, and the entire core lies within the middle Smackover interval. Hence, according to conventional interpretations, these strata would have been deposited in the deepest, most distal, and most open environment experienced by the Smackover in this area.

The strata sampled by the core were probably deposited in about 100 feet of water, based on thickness of the overlying unit and aggradation to near sea level by the end of Smackover time, which is common in this area. Water depth could not have been much greater than 100 feet, because oncoids and microreefs are abundant throughout the section and probably were made by photosynthetic organisms.

The dolosilt that is a common component of Smackover carbonates in the eastern MISB is found throughout this core. The dolosilt is an early burial product that may have formed by brine reflux of fluids from the overlying Buckner saltern.

The core contains no significant porosity or permeability.

Stratigraphy

Smackover Formation

TOP OF CORED INTERVAL = 15,719 feet

BASE OF CORED INTERVAL = 15,749 feet

Depositional Environment

The basal 19 feet of core consist of peloid dolopackstone containing fossils, oncoids, and tuberoids, as well as microbial microreefs nucleated from oncoids. The microreefs are thrombotic, up to 2.5 cm thick, and about half are wider than the core (9 cm). Most microreefs contain multiple nucleating oncoids that were amalgamated during microreef growth.

Microreefs encompass 15 to 25 percent of the basal 2.5 feet of core. The microreefs contain abundant borings and incorporated fossils, including forams. The matrix in the basal few feet of core is a sparse packstone.

Overlying an 0.5 foot interval free of microreefs, they reappear, smaller and less abundant than below: most are less than 1.5 cm thick and less wide than the core, and they account for up to about 10 percent of the core. Microreefs above 15746 feet are bored, have a very open structure and incorporate bivalves, echinoderm ossicles (including echinoid spines), and abundant forams. The matrix above 15746 feet is a dense packstone.

Microreefs are larger above 15743 feet: up to 4.5 cm thick and most are wider than the core. Microreefs account for about 20 percent of the core above 15743 feet. Microreefs in this interval contain abundant forams, both encrusting and free-living forms. Microreefs decrease in size and abundance upwards to 15730 feet; in the upper part of this interval microreefs account for about 10 percent of the core and are 5-10 cm in width. The matrix also changes from a packstone below 15735 feet to a dense wackestone above that depth. Between 15740 and 15729 feet the matrix is bioturbated.

From 15730 to 15726 feet the core consists of *Parafavreina* peloid dolowackestone. This is overlain by *Parafavreina* intraclast peloid dolomitic wackestone, which overlies a possible exposure surface, followed by *Parafavreina* peloid packstone to 15721 feet. This interval contains a fragment of a colonial fossil that is interpreted as a worm tube. The interval also contains some cross laminated packstone; some of the cross laminae are slumped.

The uppermost 2 feet of core consist of packstone as below containing microreefs composed of very slightly amalgamated grounded oncoids. The microreefs contain bivalves and forams, are about 2 cm thick, account for about 10 to 15 percent of the core, and are up to about 6.5 cm wide. *Parafavreina* in the uppermost three feet of core can be positively identified as a new ichnospecies that is diagnostic of the Alabama Smackover (Rindsberg and Kopaska-Merkel in prep.).

Diagenetic Characteristics

Early cementation of microreefs limited their subsequent diagenetic alteration. However, replacive gray anhydrite and white anhydrite nodules within microreefs indicates that microreef cementation was not penecontemporaneous, but occurred under conditions of shallow burial. Some white anhydrite nodules have gray replacive anhydrite overgrowths; others have dolomite overgrowths. Anhydrite accounts for less than one percent of the matrix, but up to 15 percent of microreefs. Anhydrite formation was probably facilitated by breakdown of organic matter.

Much of the core has been replaced by dolosilt (percent of dolosilt ranges from 10 to 95), which preferentially replaced matrix rather than microreefs. The immunity of microreefs to dolosilt indicates that they were tightly cemented when the dolomite formed, probably under conditions of moderate burial.

Matrix dolomite and anhydrite are concentrated at stylolites, indicating that stylolites formed after these two minerals.

Vertical and high-angle fractures are common in this core, and because the well was drilled near the Mobile Graben, the fractures are assumed to be associated with Graben formation. The fractures postdate (crosscut) dolosilt formation and also postdate anhydrite formation; the fractures contain coarse calcite, dolomite, and quartz cement.

At 15741 feet some tuberoids and peloids are stained with hematite. The origin of this stain is unclear.

Figure A-148 - Detailed core log, Midroc et al. Laubenthal U. 34-4 No. 1 well, Permit No. 2844, wildcat, Alabama.

Placid IJAMS 19-2 No. 2

Washington Co., Alabama

Permit No. 2943, X No. 1463

General Notes

This core lies entirely within the Smackover Formation, and consists almost entirely of mixed-particle wackestone (peloids, fossil fragments, oncoids, tuberoids) containing microreefs of algal boundstone ranging up to 1.5 feet thick. Some of the reefs are less wide than the core (9 cm). Preservation of boundstone fabric in this core is unusually good for the Smackover; radiating nonbranching tubules about 75 micrometers in diameter are visible in many microreefs, oncoids, and tuberoids.

This well was drilled on the southern flank of the eastern part of the Mississippi interior salt basin, basinward of Chunchula Field. Chunchula Field lies on the basin rimming platform, but well PN 2943 is inferred to be located within the basin proper, based on isopach and structural maps of the area. Because microbial boundstone is ubiquitous in the core, the sea floor must have been within the photic zone during deposition of the entire interval. Further, the top of the cored interval is 31 feet below an 8-foot-thick anhydrite interval which almost certainly was deposited at sea level. This line of reasoning leads to an interpreted maximum water depth for the base of the core of 90 feet (assuming no subsidence). By extension, water depths much greater than 100 feet are unlikely for any of the Smackover on the southern flank of the basin. In the center of the basin, where the formation is up to 200 feet thicker, water depths could have been correspondingly greater. However, with a well-developed paleosol 88 feet below the top of the formation in PN 7044 at Chatom Field, the maximum water depth on that syndepositional structure is far less than the maximum thickness of the formation.

Stratigraphy

Smackover Formation

TOP OF CORED INTERVAL = 19,750 feet

BASE OF CORED INTERVAL = 19,811 feet

Depositional Environment

The basal two feet of this core consist of mixed-grain wackestone containing peloids, fossil fragments, bivalves, oncoids, tuberoids, and intraclasts; in light of the overlying 59 feet of microbial reef, these strata are interpreted as reef apron deposits, which were deposited on a restricted marine shelf below fair-weather wave base.

Overlying the reef-apron deposits is a succession 27 feet thick (top at 19,782 feet) consisting of intercalated microbial boundstone (microreefs) and wackestone like that at the base of the core. Microreefs are 1.5 to 10 cm apart stratigraphically, and about 1.5 to 10 cm in thickness. Many microreefs are less wide than the 9 cm wide core, but a minority of the thicker reefs extend completely across the core. Microreefs in the basal few feet of the boundstone section are smaller than stratigraphically higher examples: less than 5 cm wide.

Oncoids and microreefs may be structureless, but more commonly they are crudely concentrically laminated. Laminae are at least several 100 micrometers thick. Internal structure of laminae is clotted, nonexistent, or exhibits clusters of tubules (see next paragraph).

Remarkably for the Smackover, noodle-like tubules about 75 micrometers in diameter are clearly visible within many microreefs, tuberoids, and oncoids. Where present, the tubules underlie a structureless cortex that is about 300 micrometers thick. Tubules are bundled, nonbranched, and radiate from one or more centers within particles or reefs. Tubules have circular cross sections, are thin-walled, and are hollow. Some microbial reefs and oncoids exhibit more or less discrete clots on the order of 75 to 100 micrometers in diameter. Clots have simple subspherical shapes and smooth outlines, or appear to be clustered in cauliflower-like groups. These clots may be complex elements whose finer internal structure has been obliterated, or is not visible in slabbed core.

The tubules resemble the filaments of *Girvanella*, a well-known Paleozoic alga (or cyanobacterium), except they are as large as or slightly larger than the largest *Girvanella*, which ranges up to about 80 micrometers in diameter but averages much less (about 15 micrometers). The tubules also resemble the late Paleozoic alga *Garwoodia* (Wright, 1983) and even more the Jurassic-Cretaceous codiacean alga *Cayeuxia* (Johnson, 1961). Both *Garwoodia* and *Cayeuxia* are about the same size as the tubules observed in this core; because *Cayeuxia* is a common Jurassic form, the tubules are tentatively referred to that genus. *Cayeuxia* is a common component in oncoids, and the tubules seen in this core are found in oncoids, microreefs nucleated from oncoids, and tuberoids broken from oncoids and microreefs, which lends support to the taxonomic assignment. The clots resemble the Paleozoic alga (or cyanobacterium) *Renalcis*, but appear to be larger than most described examples of *Renalcis*. The tubules and clots are interpreted as algal, and the oncoids and microreefs are therefore interpreted as chiefly algal in origin.

The microreefs grew by amalgamation of oncoids, and oncoids up to 1 cm or more in diameter are common within and associated with microreefs. The microreefs are characterized by an open structure in which 1/3 or more of the rock volume within the microreef outline is matrix wackestone. Most microreefs and oncoids have cauliflower-like shapes characteristic of algal growth. However, between 19,798 and 19,794 feet, microreefs have scalloped boundaries and are up to 70 percent matrix. These microreefs are interpreted as the victims of boring organisms.

Evidence for fluctuating current velocities in this interval include overturned oncoids between 19,804 and 19,805 feet, and an oncoid between 19,785 and 19,786 feet that was rolled and rounded, then recolonized in place, and bears upright columns like ministromatolites. Water energy was typically insufficient to disrupt growth of small reefs little larger than large oncoids throughout deposition of this interval.

A relatively thick (1.5 feet) microbial reef overlies the interval just described.

Overlying the 1.5-foot-thick reef is another interval of intercalated microreefs and wackestone, terminated at 19,762 feet by a 1-foot-thick reef. Bored boundstone occurs between 19,774 and 19,771 feet and between 19,767 and 19,762 feet. Bivalve fragments and other fossils are abundant in the bases of many of the microreefs in this interval, suggesting that nucleation of microreefs was facilitated by the presence on the sea floor of hard substrates (storm lags?) and did not depend simply on the availability of immobile oncoids. Between 19,765 and 19,766 feet burrows about 1 cm in diameter are rendered visible by differential dolomitization. These burrows are of a size to have been made by Callianassid shrimp, but none of the fecal pellets of these shrimp (*Parafavreina* sp.), so abundant elsewhere in the eastern MISB and Alabama Smackover in general, were observed in this core.

The 1-foot-thick reef that caps the previously described section is remarkable because it shows evidence of intense boring. It is overlain by a poorly sorted extremely coarse packstone containing gastropods, bivalves, oncoids, tuberoids, a possible sponge, and numerous fine-medium sand sized peloids. This packstone is interpreted as a storm deposit. Packstone differing chiefly in its paucity of coarse fossil fragments characterizes the core up to 19,757 feet, and is overlain by intercalated packstone and wackestone layers 1 to 2 feet thick. Throughout this interval microreefs are smaller and less abundant than below, and bivalves, and especially gastropods, dark fine sand sized peloids, and intraclasts are far more abundant than below.

Benthic foraminifera and ostracodes are observed in this interval, as are both high-spired and medium-spired gastropods. Many of the intraclasts have nuclei of peloid tuberoid grainstone, and are encrusted by clusters of tubules (algal tufts) followed by oncoid-like structureless cortices a few hundred micrometers thick. The uppermost 6 feet of core, consisting of alternating wackestone and packstone that is coarse, dense, faunally diverse, and characterized by few and small microreefs compared to the rest of the core, appears to record higher energy conditions that were less hospitable for microreef growth. Incipient shoaling is suggested by the coarser and more abundant particles, including the abundance of coated grainstone intraclasts, which may have been shed from a nearby positive area (possibly the northern flank of the Wiggins arch).

The alternation throughout the core of “healthy” microreefs and bored microreefs (observed in the following intervals: 19,798-19,794 feet, 19,774-19,771 feet, and 19,767-19,755 feet) suggests alternating low-oxygen and high-oxygen conditions. Oxygen deficient water would exclude borers and thereby encourage microreef growth, whereas improved oxygenation would permit marine invertebrates, including borers, to thrive. The source of oxygenated marine water must have been the open Gulf of Mexico. Gulf water could have entered the MISB either through storm surge during periods of enhanced hurricane activity, or during periods of elevated sea level (either eustatic or tectonic). Storm activity is indicated by overturned oncoids at 19,804-19,805 feet, but this is not an interval containing bored microreefs. Also, the time intervals represented by the bored sections are more consistent with sea-level variation than with storm cyclicity.

The entire core was deposited under subtidal conditions (probably a few feet to a few tens of feet). Storm and wave influence were minor, and bottom waters alternated between restricted (probably caused by oxygen deficiency) and more hospitable. However, even at the best of times, grazers were uncommon enough to permit microbial “reef” growth.

Diagenetic Characteristics

Diagenesis of this core probably began early, but the most obvious diagenetic products formed under burial conditions. Disseminated planar dolosilt is widespread in the eastern MISB and it forms between 5 and 15 percent of the rock in most of this core. The dolomite is not distributed randomly: it is nearly absent from microbial features (microreefs, oncoids, and tuberoids). The uppermost foot of core is about 20 percent dolomite; locally up to about 70 percent.

The higher degree of dolomitization in the upper part of the core may result from sulfate reduction. Anhydrite is scattered throughout the core in two forms: white nodules and dark replacive laths that are most common within microreefs. Throughout the core anhydrite accounts for much less than 1 percent of the rock, but it is much more abundant in the uppermost foot of core (though still no more than 1-2 percent of the rock volume). Anhydrite is still more common above the core: the top of the core is 31 feet below an 8-foot-thick anhydrite stringer (density-log data).

Saw-toothed stylolites occur throughout the core as well, varying slightly in spacing and more common in the upper half of the core. Stylolites formed after dolomitization: dense concentrations of dolomite crystals clog many of the stylolites.

Figure A-149 - Detailed core log, Placid IJAMS 19-2 No. 2 well, Permit No. 2943, wildcat, Alabama.

Hughes Eastern Kirkland #1 13-2

Washington Co., Alabama

Permit No. 5929, X No. 1433

General Notes

This core lies entirely within the Smackover Formation, and consists chiefly of low-energy deposits. All lime mud has been recrystallized to pseudospar of silt size, and this, coupled with partial dolomitization, obscures depositional fabric.

Stratigraphy

Smackover Formation

TOP OF CORED INTERVAL = 17,679 feet

BASE OF CORED INTERVAL = 17,739 feet

Depositional Environment

The basal 33 feet of the core, from 17,739 to 17,706 feet, consists of slightly dolomitic lime mudstone. These strata were deposited below storm wave base in the middle of the eastern Mississippi interior salt basin.

The core as a whole exhibits an upward shoaling succession. Coated-grain peloid wackestone overlies the mudstone interval, and the abundance of particles increases upwards. The wackestone contains needle-shaped calcitic fossils that are 1 to 2 millimeters in diameter and up to about 3 centimeters long. These fossil may be cephalopod shells.

Fossil coated-grain peloid packstone overlies the wackestone, in the interval from 17,697 to 17,691 feet. At the base of the packstone, which is chiefly of medium sand size, is a poorly sorted coarse wackestone layer containing coarse sand size fossil fragments.

Above the packstone interval are 6 feet of wackestone and mudstone. A possible emersion surface within this interval (17,688.8 feet) is marked by fracturing below the surface and intraclasts above, by a marked change in stylolite density across the boundary (indicating a change in rock fabric or degree of lithification before stylolitization), and a color change across the boundary. Also, opaque, slightly corroded anhydrite laths increase in abundance below the surface and are much less common above the surface. Relief on the surface is about 1 centimeter. The surface is interpreted as a subaerial exposure surface and the anhydrite may replace gypsum lenses that grew penecontemporaneously.

The uppermost 6 feet of core consist of dolomitic grainstone grading up into dolograinstone. The lower 3 feet of grainstone are crossbedded and dominated by fecal pellets, with lesser coated grains and intraclasts. Sorting is poor because intraclasts range up to more than 1 centimeter in diameter. These strata contain tuberoids (fragments of boundstone), ooids, fossil fragments, possible *Parafavreina* pellets, and scattered displacive anhydrite nodules. These deposits record shoal development on, or migration over, the older low-energy subtidal strata. No emersion surfaces are obvious in this interval. However, intraclasts and tuberoids indicate penecontemporaneous cementation and subsequent erosion.

The overlying 3 feet of grainstone are similar in particle content, but are distinctly graded, in cycles ranging from 1 to 2 centimeters in thickness. Certain layers within this succession are abundantly fenestral; fenestrae contain anhydrite cement and lesser calcite cement. These fenestral graded grainstones are interpreted as tidal-flat storm deposits, by analogy with modern Bahamian tidal-flat sediments.

Diagenetic Characteristics

The diagenetic processes that most obviously affected the lower part of the core were recrystallization of lime mud to pseudospar and formation of wispy stylolites. Dolomite crystals, planar-e and of silt size, are ubiquitous but account for only about 10 percent of the rock below about 17,692 feet. Dolomitization predated formation of solution seams and sawtoothed stylolites; dolomite crystals are concentrated along stylolites but do not increase in density with increasing proximity to stylolites. As is typical of the Smackover in Alabama, some particles in wackestone and packstone are preferentially dolomitized, and some are conspicuously free of dolomite. Anhydrite laths are scattered throughout most of the core, but are only common in the upper part. Most anhydrite crystals are corroded by calcite, indicating anhydrite growth followed by centripetal calcitization. In the wackestone above the emersion surface at 17,688.8 feet are white displacive anhydrite nodules. These have haloes of dark corroded replacive laths, and must be penecontemporaneous (pre-lithification). It could be that all of the anhydrite in this core is penecontemporaneous, but the opaque replacive laths could have formed much later.

In grainstone strata in the upper part of the core, brittle compaction of calcite cement framework (now dolomite) indicates early lithification and particle dissolution.

Also restricted to the upper part of the core are fenestra-filling cements. Small fenestrae contain calcite and large fenestrae contain anhydrite. It is possible that the so-called large fenestrae are actually displacive anhydrite nodules. This is unlikely, because their shapes are characteristic of fenestrae, not anhydrite, and because the anhydrite crystals are much larger than those typically found in displacive nodules.

The dolomite in the inferred tidal-flat strata at the top of the core is finer than underlying dolomite and might have formed penecontemporaneously from hypersaline fluids. This is consistent with the interpretation of at least some of the anhydrite as penecontemporaneous.

Figure A-150 - Detailed core log, Hughes Eastern Kirkland 13-2 No. 1 well, Permit No. 5929, wildcat, Alabama.

PERMIT NO. 7200

The base of the core (up to 16,190.5 ft, fig. 29) is interpreted as a sabkha deposit because it contains abundant enterolithic, nodular, and laminated anhydrite. Most of this interval consists of anhydritic dolomite intercalated with anhydrite layers that account for 10 to 20 percent of the rock. Anhydrite layers are 0.3 m or less in thickness and probably formed within ephemeral brine ponds on a sabkha.

The sabkha deposits are overlain by strata (16,170 to 16,190.5 ft) interpreted as tidal-flat deposits. This inference is based on an association of pellet grainstone, displacive anhydrite nodules, tepee structures, probable exposure surfaces, ripple-scale trough cross strata, thinly laminated intervals that could be stromatolites, possible fenestrae, ubiquitous silt to clay size dolomite, and proximity to sabkha deposits.

The deepening trend recorded in this core continues with lagoonal strata preserved between 16,125.5 and 16,170 ft. A lagoonal origin is inferred because these strata are dominated by bioturbated mudstone lacking any evidence of exposure and because they overlie tidal-flat deposits. The lagoonal deposits are overlain abruptly by tidal-flat deposits extending upward to 16,107.5 ft. A tidal-flat origin for these strata is indicated by the abundance of very fine pellet grainstone, as well as association with inferred lagoonal and sabkha deposits.

The cored interval between 16,089.5 and 16,107.5 ft is interpreted to record deposition on a sabkha on which ephemeral brine ponds developed episodically. In addition to associations with peritidal strata, this inference is supported by the presence of pellet grainstone and anhydritic mudstone; the presence, but not dominance, of anhydrite containing vertically oriented nodules; a syndepositionally lithified lime mudstone crust; anhydrite pseudomorphs of discoidal gypsum; and planar stromatolites.

The uppermost part of the core is interpreted to record deposition in a saltern. This interval contains at least 85 percent nodular and laminar anhydrite, and no more than 15 percent microcrystalline dolomite. Sabkhas do not commonly contain this much anhydrite, so even though vertically oriented anhydrite nodules were not observed, the rocks are tentatively assigned to a saltern environment. Another line of evidence comes from the neutron-density log, which indicates that the uppermost part of the core corresponds to the basal portion of the thick Buckner anhydrite, previously shown to have been deposited in a saltern in the eastern MISB.

The neutron-density log for this well also reveals that the base of the core approximately corresponds to the base of the sabkha in this well.

Penecontemporaneous diagenetic products include lithified crusts, discoidal gypsum, nodular and laminar anhydrite and its presumed gypsum-crystal mush precursor, and hypersaline cryptocrystalline to silt size dolomite. Pellet grainstone exhibits only local compaction, and therefore must have been cemented early, though cement-crystal morphology cannot be determined in this core without thin sections.

Later diagenesis included particle dissolution, pyrite authigenesis, and precipitation of anhydrite cement in pelmolds. Particle dissolution probably preceded events listed below under the heading of burial diagenesis because it appears to have affected the entire core more or less homogeneously.

Burial diagenesis was dominated by stylolitization, formation of authigenic anhydrite laths, and late cementation within tension fractures associated with stylolites. Hydrocarbon migration appears to have followed all of the diagenetic events listed here

because solid hydrocarbons are found within tension fractures and because hydrocarbon emplacement would have halted cementation.

Figure A-151. Graphic core log of Permit No. 7200 well. (A) Detailed core log, Phillips Chatom U. 20-1 #1-05 well, Chatom field, Washington Co., Alabama, lower part.

Figure A-153 Digitized geophysical well logs, core depositional environments, and sea-level curves (progradation to right), Permit No. 7200. SP=spontaneous potential log, D=density log, SFL=induction log. Depth in feet on left.

PERMIT NO. 10255

The strata penetrated by this core (dominated by dolomitic fossiliferous pelletal mud-wacke-packstone) are remarkably uniform. All appear to record a quiet-water setting within the photic zone, interpreted as a subtidal marine shelf below fair-weather wave base. Large and heavy spinose bivalves were probably epifaunal; the spines may have functioned to keep the shells above a relatively soft substrate. Quartz silt and very fine sand, as well as clay suggested by the ubiquitous wispy stylolites, indicate siliciclastic influx, which may have affected sediment consistency.

The sediment was churned by burrowing shrimp who left their traces in the form of abundant fecal pellets as well as a strongly bioturbated sediment fabric. Echinoderm ossicles may belong to infaunal echinoids, which would be consistent with environmental inferences based on the bivalves and fecal pellets. At the very top of the core, silty oncoids suggest upward shoaling and the development of higher energy conditions at the sediment surface.

Fossils are common but the low-diversity fauna appears eurytopic; water may not have been normal marine.

The earliest known diagenetic events are precipitation of calcium-carbonate cement within hollow bivalve spines and the first episode of dolomitization. The earlier formed dolomite was controlled by bioturbation fabric, and hence probably formed before physical and chemical stabilization of the marine sediment. This dolomite is probably eogenetic and may have formed from sea water. There is no evidence of a hypersaline or hyposaline influence. Despite the ubiquitous anhydrite, there is no evidence for eogenetic evaporite deposition. The later dolomite formed during and/or after stylolite development, as indicated by its occurrence only along stylolites--this dolomite is mesogenetic and probably formed at considerable depth. However, it appears to have formed quickly (the crystals are very small), suggesting a short-lived event. Fractures formed during pressure solution contain calcite and anhydrite cement that formed at about the same time or slightly after mesogenetic dolomite. Later calcitization of anhydrite and formation of pyrite near anhydrite nodules may have occurred contemporaneously, because both processes probably involved sulfate reduction. It is not entirely clear when particle dissolution occurred; the presence of several different kinds of anhydrite, including replacive nodules, cement in fractures, and cement within particles previously partially dolomitized, suggests there may have been several episodes of anhydrite formation.

Figure A-154. Graphic core log of Permit No. 10255 well. (A) Detailed core log, ARCO R. Harrell 24-14 well, Permit No. 10255, wildcat, Washington Co., Alabama.

Figure A-155 Digitized geophysical well logs, core depositional environments, and sea-level curves (progradation to right), Permit No. 10255. SP=spontaneous potential log, D=density log, LLD=induction log. Depth in feet on left.