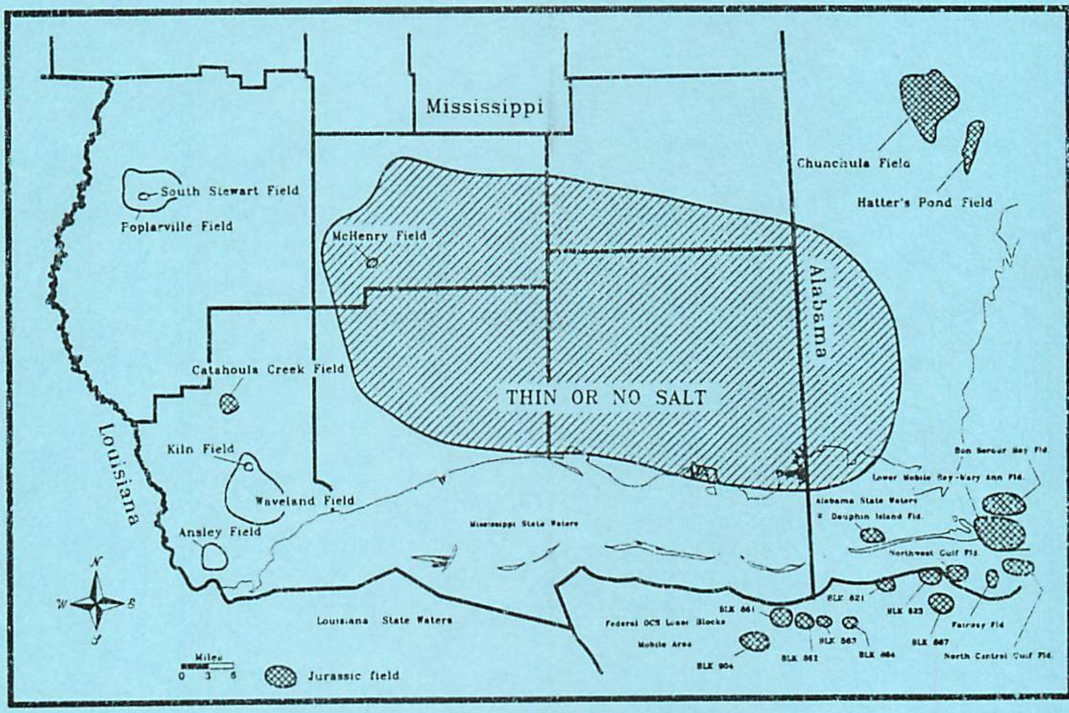
THE PETROPHYSICAL CHARACTERISTICS OF JURASSIC RESERVOIRS OF THE COASTAL MISSISSIPPI COUNTIES AND ADJACENT STATE WATERS

Stephen D. Champlin

OPEN-FILE REPORT 42



MISSISSIPPI OFFICE OF GEOLOGY

Department of Environmental Quality

S. Cragin Knox
State Geologist

Energy and Coastal Division

January, 1996

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S. Cragin Knox
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Mississippi Office of Geology

ABSTRACT

The purpose of this study is the determination of petrophysical characteristics observable for Jurassic reservoirs in the study area; these characteristics are important for hydrocarbon production from those reservoirs. The study area consists of the three Mississippi coastal counties, Hancock, Harrison, and Jackson, and Mississippi's state waters offshore. Within the study area only one Upper Jurassic gas field has been discovered. The field is Catahoula Creek Field, which is located onshore in Hancock County in the western portion of the study area and is productive of gas from Cotton Valley sands below 19,000 feet.

Well log and core data from dry hole exploratory wells in the study area were used to supplement the limited reservoir data at Catahoula Creek. There are a total of nine wildcat wells which have penetrated the Jurassic in the study area. In the study area the Jurassic wildcat drilling density equals approximately

one wildcat well per 290 square miles. Because of this lack of data in the study area, published information on the following Upper Jurassic fields in southwestern Alabama, both onshore and offshore, are included: Chunchula Field (Smackover), Hatter's Pond Field (Smackover), Hatter's Pond Field (Norphlet), and Lower Mobile Bay-Mary Ann Field (Norphlet).

Structurally, the three coastal counties and offshore state waters of Mississippi occupy the southern flank of the Wiggins Arch, an area of positive Paleozoic basement features, and the related Hancock Ridge. The Jurassic stratigraphic section in the study area consists of over 5,000 feet of clastics, evaporites and carbonates at depths below 17,000 feet to 24,000 plus feet. The section of importance to this study is the Upper Jurassic which is made up of, from oldest to youngest, the Norphlet Formation, the Smackover Formation, the Haynesville Formation (including a Frisco City equivalent granite wash and the Buckner Anhydrite), and the Cotton Valley Group.

Additionally, a review of Mississippi's statewide cumulative Jurassic oil and gas field production current to 12/31/94 was undertaken and is included as part of this study.

ACKNOWLEDGMENTS

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INTRODUCTION

The purpose of this study is the determination of petrophysical characteristics observable for Jurassic reservoirs in the study area; these characteristics are important for hydrocarbon production from those reservoirs. The study area consists of the coastal Mississippi counties, Hancock, Harrison, and Jackson, and the state's adjacent offshore waters (Figure 1). The primary petrophysical characteristics of interest to the study are porosity and permeability. By recognizing these factors and establishing petrophysical guidelines which may be used to indicate the potential of commercial oil and gas production, future exploration in the Mississippi coastal counties and state waters will be greatly aided, possibly resulting in increased domestic oil and gas reserves.

By using existing geophysical well logs (density and neutron logs) and available core information for both productive and non-productive wells on file with the Mississippi State Oil and Gas Board, the Mississippi Office of Geology, and private oil and gas industry sources, the above mentioned objectives were determined to the extent possible using accepted interpretive methods. Collected or published core data and published oil and gas field data from Jurassic fields in adjacent areas of Mississippi, the Federal offshore waters, southwestern Alabama, and Alabama state waters, were used to supplement the

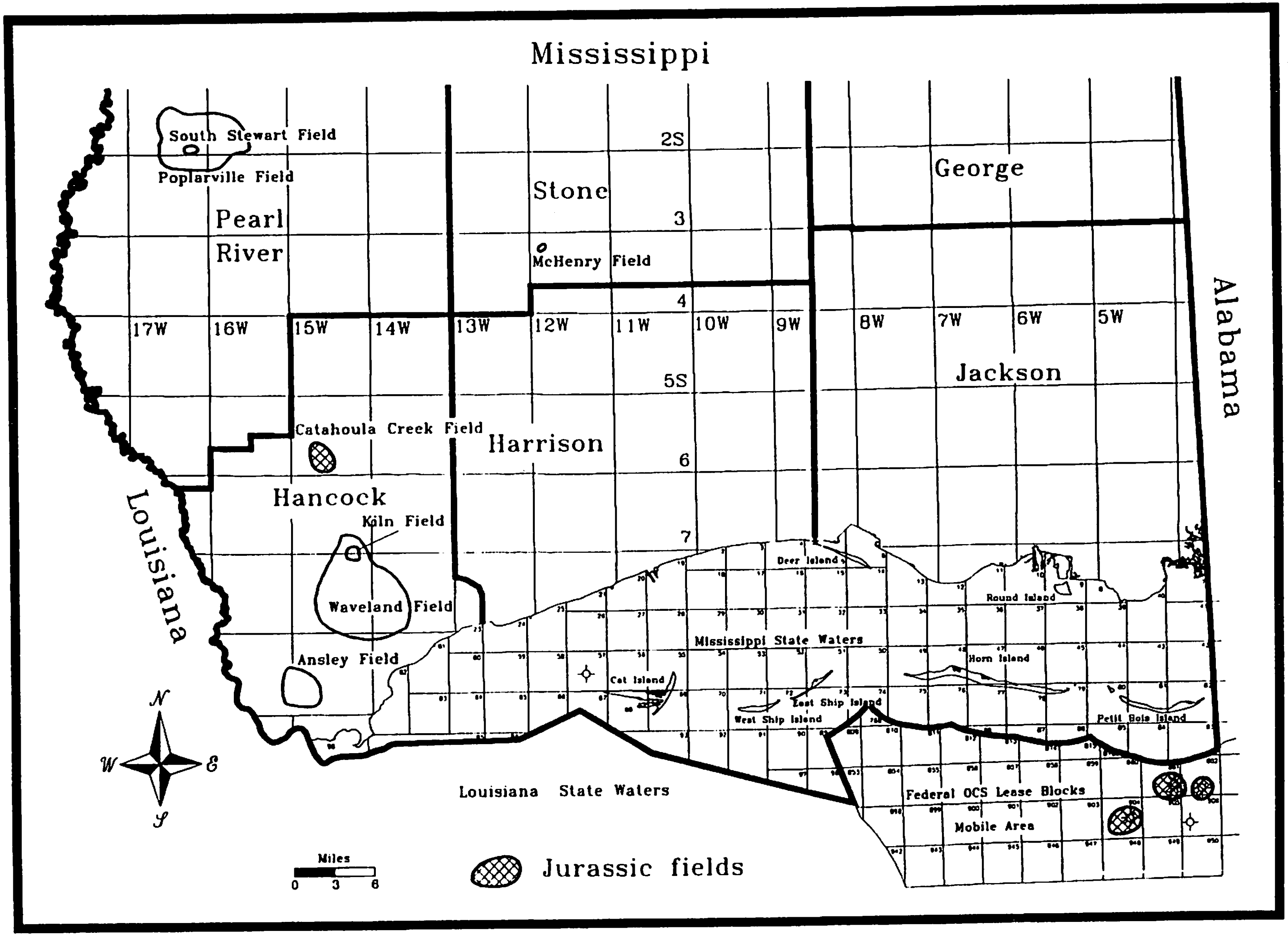


Figure 1. Index map of the Mississippi coastal counties and adjacent offshore areas of the study area (Ericksen and Thieling, 1993).

information gathered in the study area because of the small number of wells drilled in the study area which have penetrated the Jurassic and the fact that only one Jurassic gas field is present in the study area. Additionally, a review of Mississippi's statewide cumulative Jurassic oil and gas field production current to 12/31/94 was undertaken and included as part of this study.

GENERAL GEOLOGY

Structurally, the three coastal counties and offshore state waters of Mississippi occupy the southern flank of the Wiggins Arch and the related Hancock Ridge (Figure 2). Rhodes and Maxwell's 1993 paper titled "Jurassic stratigraphy of the Wiggins Arch, Mississippi" provides an excellent analysis and interpretation of the Jurassic structure and stratigraphy over the study area. Rhodes and Maxwell had access to a significant amount of seismic and other data in the Wiggins Arch area acquired by Mobil Oil and Shell Oil between 1985 and 1991, including information from several wells the companies had drilled in the area.

For the purposes of this study the actual location of the Wiggins Arch is delineated using the same definition as Rhodes and Maxwell (1993), that being the region where the Louann Salt is absent over basement highs or too thin for

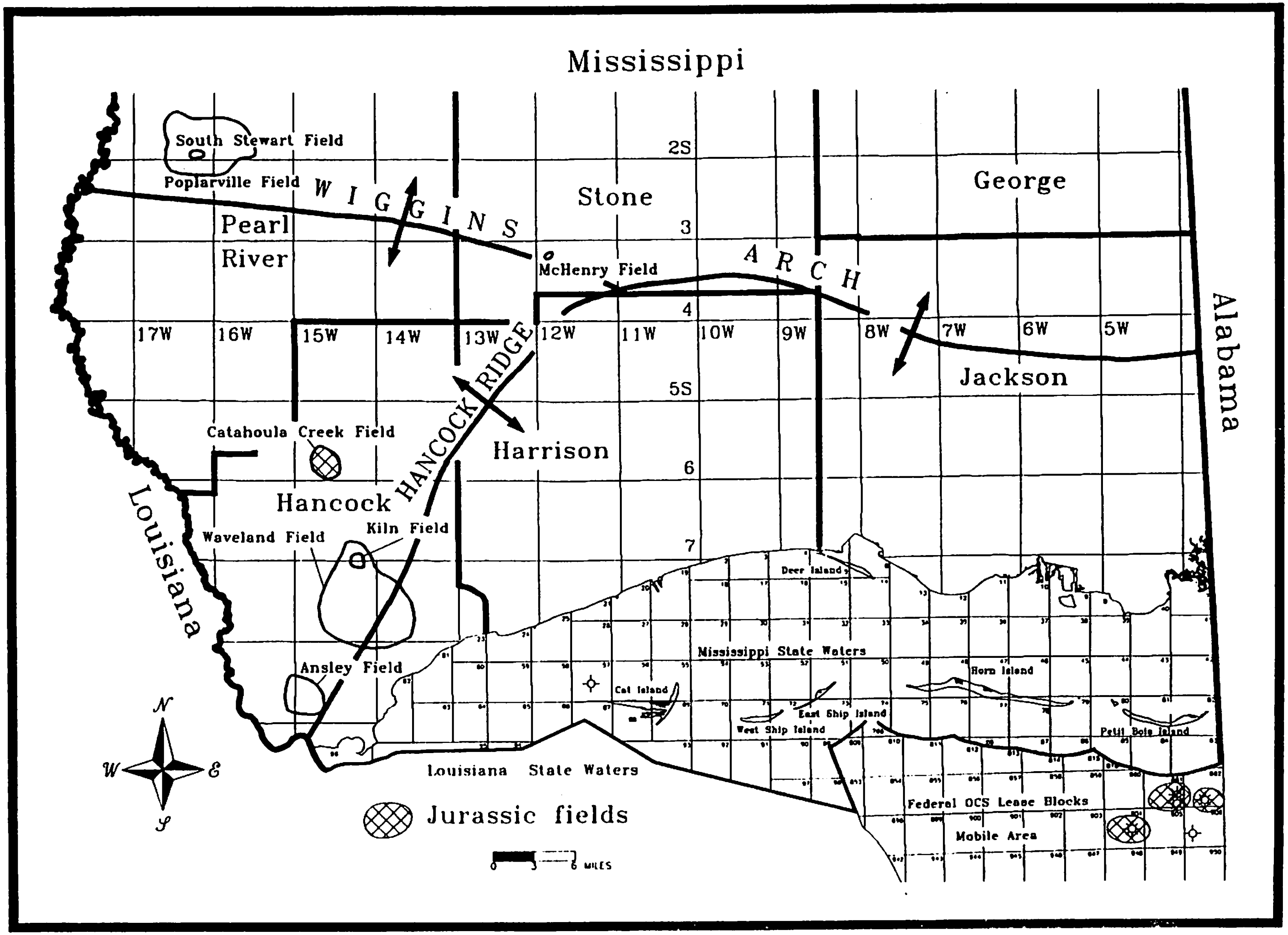


Figure 2. Index map of study area with major structural features (Ericksen and Thieling, 1993).

halokinesis (Figure 3). Differential compaction and sedimentation across Paleozoic basement highs are the primary factors affecting Jurassic structure on the Wiggins Arch. These highs formed mountains at the edge of a Norphlet desert, and large islands throughout most of the Jurassic transgression. On the flanks of the Wiggins Arch, downdip in all directions, salt pillows and associated faulting form the primary structural features (Rhodes and Maxwell, 1993). Regional structural features bordering the Wiggins Arch are the Mississippi Interior Salt Basin to the north, the Mobile Graben and Pollard Fault System to the east, and the Mississippi/Alabama Shelf offshore to the southeast (Figure 4).

The Jurassic stratigraphic section in the study area consists of over 5,000 feet of clastics, evaporites and carbonates (Ericksen and Thieling, 1993). The Late Jurassic excluding the Cotton Valley was primarily a time of transgression. This was interrupted by two regressions which allowed the deposition of the Norphlet and what appears to be Frisco City time equivalent clastic sections (Rhodes and Maxwell, 1993). Mississippi's coastal counties and state waters were part of a region where basinward shelf-edge migration was occurring (Petty et al., 1994).

This shelf-edge migration combined with the presence of the Paleozoic highs of the Wiggins Arch area created a wide range of depositional environments. Well log correlations over any distance are difficult because of

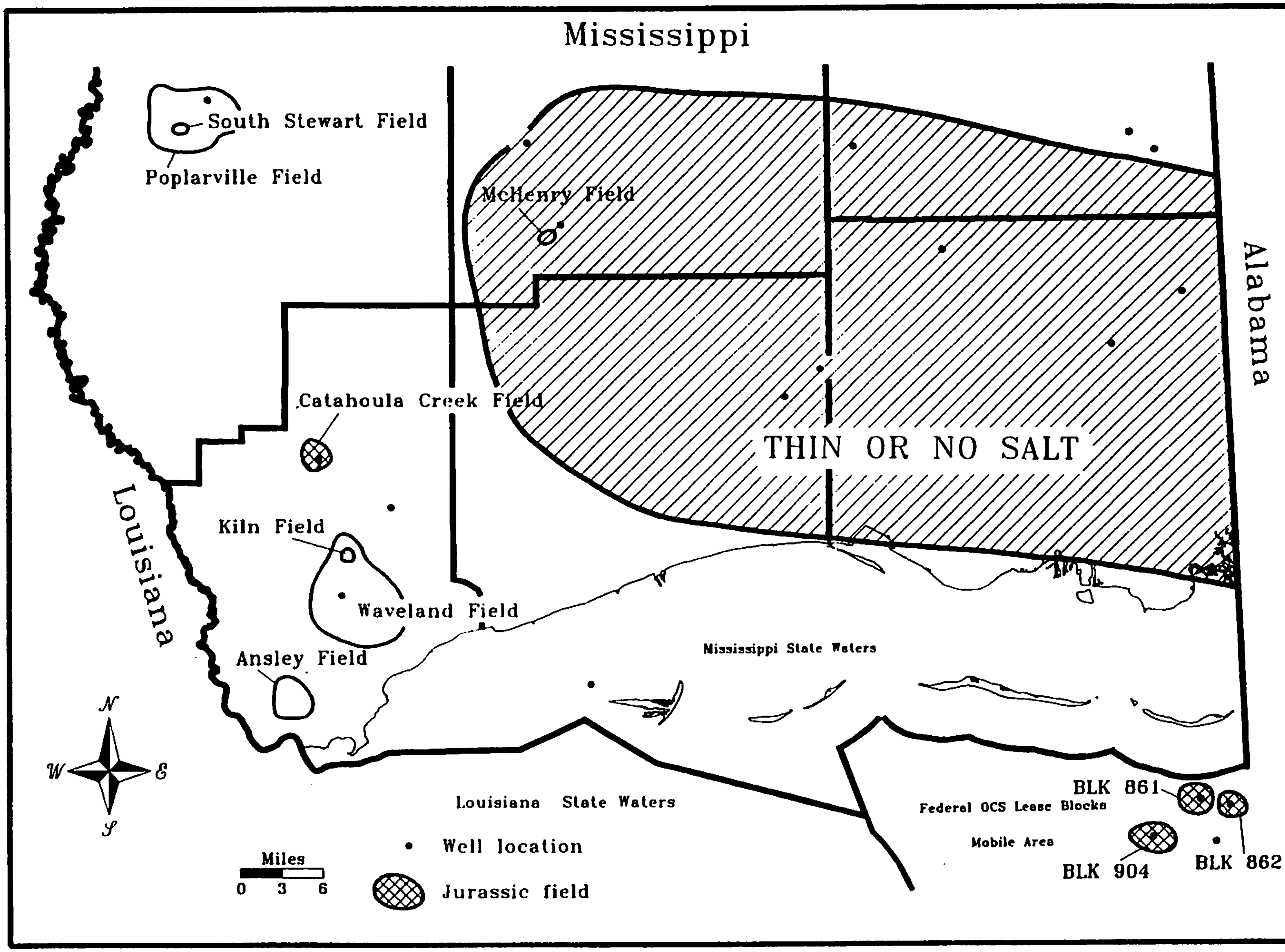


Figure 3. Map showing area of thin or no salt on Wiggins Arch (modified from Rhodes and Maxwell, 1993).

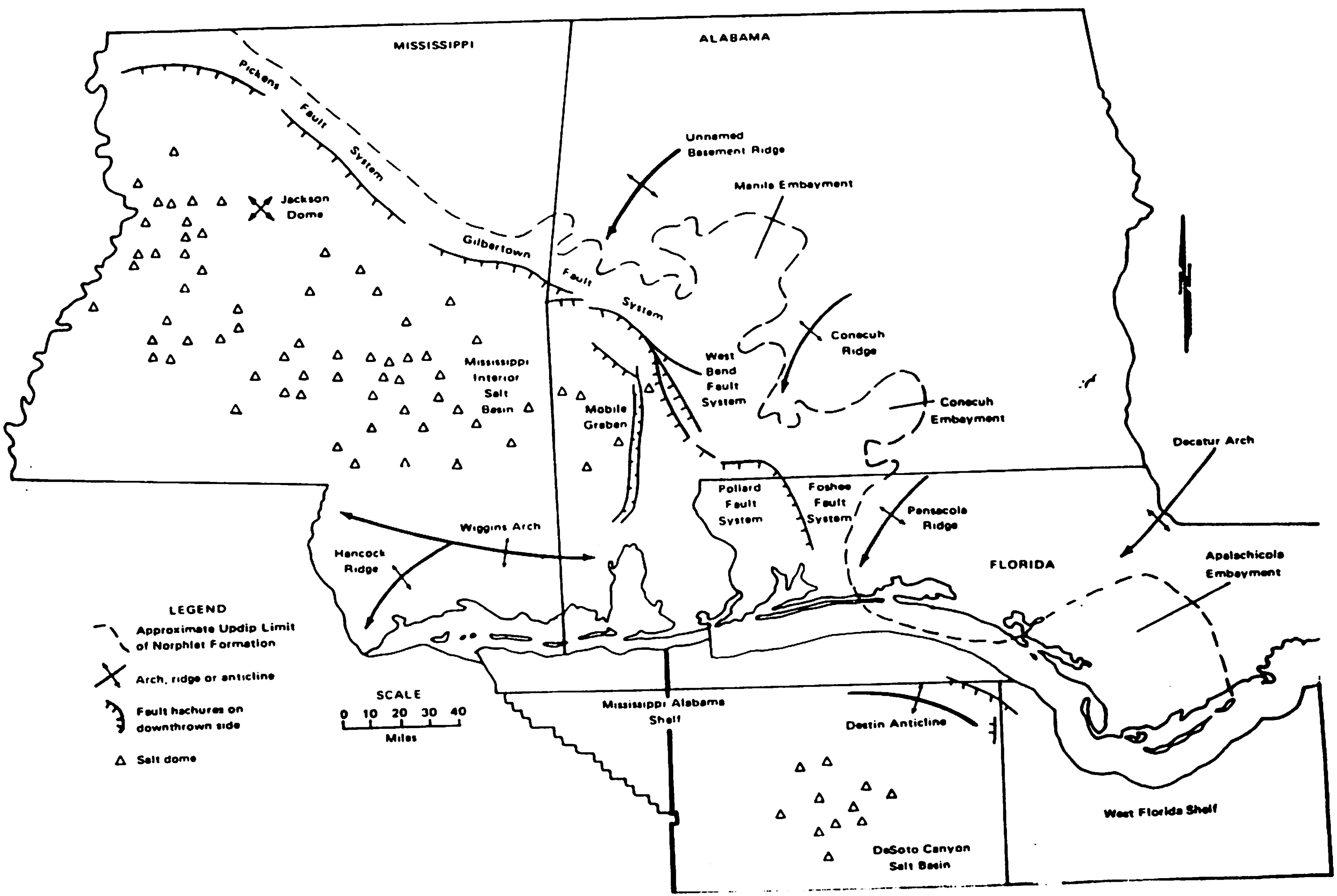


Figure 4. Map showing regional features of MAFLA area (from Mancini et al., 1986).

this. The section of importance to this study is the Upper Jurassic which is made up of, from youngest to oldest, the Cotton Valley Group, the Haynesville Formation (including an apparent Frisco City Sand equivalent and the Buckner Anhydrite), the Smackover Formation, and the Norphlet Formation (Figure 5). These are the Upper Jurassic oil and gas productive formations in Mississippi, Alabama, and the panhandle of western Florida.

RESERVOIR PETROPHYSICAL CHARACTERISTICS

The primary reservoir petrophysical characteristics of concern in this study are porosity and permeability. This is because of the general lack of reservoirs, reservoir data, and other information available on the study area. Within the three-county Mississippi coastal and offshore state waters study area only one Upper Jurassic gas field has been discovered. The field is Catahoula Creek Field which is located onshore in Hancock County and is productive of gas from Cotton Valley sands below 19,000 feet. Because of the lack of oil or gas producing Upper Jurassic reservoirs in the study area, geophysical well log and core data from dry hole exploratory wells that have encountered porous Upper Jurassic sands and carbonates have been incorporated to supplement the field data from Catahoula Creek Field. A total of nine Jurassic wildcat wells have been drilled in the study area (one well offshore and eight wells onshore).

Era	System	Series	Unit		Lithology
MESOZOIC	CRETACEOUS	UPPER	SELMA GROUP		Chalk, massive chalk, shale
			EUTAW FORMATION		Sandstone, glauconitic sandstone, shale
			TUSCALOOSA GROUP	Upper	Sandstone with shale and claystone interbeds
				Marine	Shale with sandy streaks and thin sandstone beds
				Lower	Sandstone, thin to massive with shale interbeds
		LOWER	LOWER CRETACEOUS UNDIFFERENTIATED		Sandstone, fine to medium grained with traces of nodular limestone, thin anhydrite unit near middle
	?	? — ?			
	JURASSIC	UPPER	COTTON VALLEY GROUP		Sandstone, fine to coarse grained, conglomeratic in part, with traces of metamorphic rock fragments, shale and sandy shale, thin limestones locally
			HAYNESVILLE FORMATION		Shale, thin anhydrite, dolomitic limestone, sandstone beds
			BUCKNER ANHYDRITE		Anhydrite, thin, silty, anhydritic and dolomitic shale beds
			SMACKOVER FORMATION		Limestone, microcrystalline to crystalline, oolitic in part, dolomitic in part, grades to dolomite; grades to shale and siltstone downdip
			NORPHLET FORMATION		Sandstone, fine grained, quartzose, calcareous in part; grades to shale and siltstone downdip
			PINE HILL ANHYDRITE		Anhydrite with salt interbeds where present
		MIDDLE	LOUANN SALT		Salt, massive with thin anhydrite and shale beds
			WERNER FORMATION		Anhydrite with sand and metamorphic rock fragments
	TRIASSIC		EAGLE MILLS FORMATION		Sandstone, arkosic with red shale

Figure 5. Generalized Mesozoic stratigraphic column for southeastern Mississippi and southwestern Alabama (modified from Mink et al., 1987).

This equates to one Jurassic wildcat well drilled per 225 square miles onshore and one Jurassic wildcat well per 800 square miles offshore. For the entire study area the Jurassic wildcat drilling density equals approximately one wildcat well per 290 square miles. The wells are listed along with their locations in Table 1 and their locations are shown in Figure 6 which is an index map of the study area.

Field data and structure maps are included for Upper Jurassic fields located in the areas of southwestern Alabama onshore, Alabama offshore state waters, and Federal OCS waters immediately adjacent to the study area. In recent years several Upper Jurassic Norphlet gas fields have been discovered in the federal offshore waters and Alabama's offshore state waters adjacent to Mississippi's offshore state waters. The locations of these fields are shown in Figure 7 which is a general field location map covering extreme southwestern Alabama, the Alabama offshore state waters, the Mississippi study area, and adjacent federal offshore waters.

Cotton Valley

The Cotton Valley Group, which ranges in thickness from 1,100 to 5,000 feet within the study area, is Upper Jurassic in age and generally conformably overlies the Haynesville Formation. In the study area the Cotton Valley consists

Hancock County

Operator	Well Name	Location
Hunt Energy	#1 Rhoda Lee Brown	Section 28-T6S-R15W
Hunt Energy	#1 Crosby	Section 22-T8S-R15W
Saga	#1 Seal 18-14	Section 18-T7S-R14W

Harrison County

Operator	Well Name	Location
Mobil	#1 Anderson	Section 28-T5S-R9W
Mobil	#1 USA	Section 1-T6S-R10W

Jackson County

Operator	Well Name	Location
Amoco	#1 Cumbust	Section 13-T5S-R6W
Champlin	#1 International Paper	Section 13-T4S-R8W
Conoco	#1 Middleton	Section 35-T4S-R5W

Mississippi Offshore State Waters

Operator	Well Name	Location
Chevron	#1 State of Miss.	Mississippi Sound Blk. 57

Table 1. Name and location of well logs reviewed for the study.

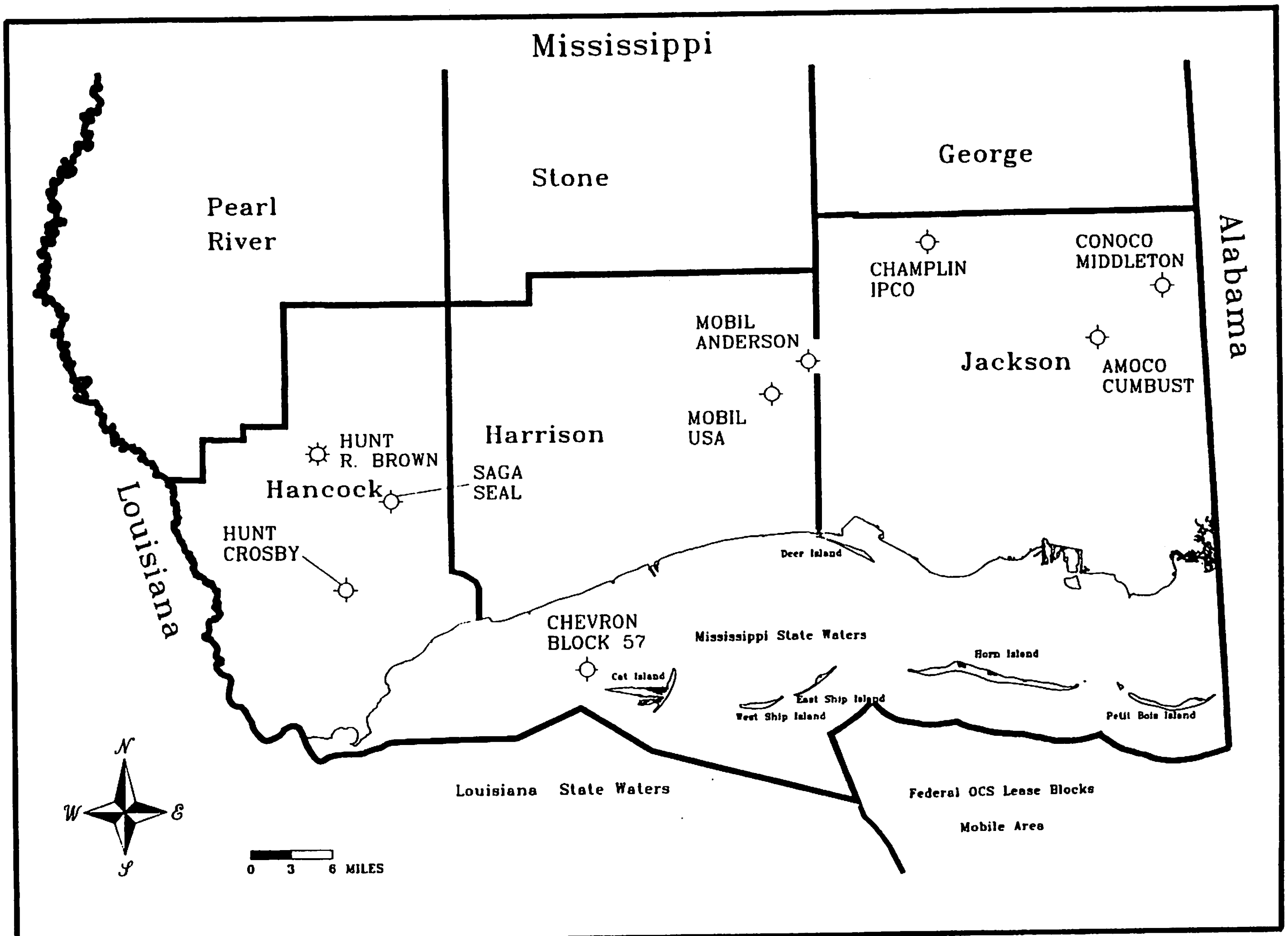


Figure 6. Index map showing location of wells reviewed in the study area.

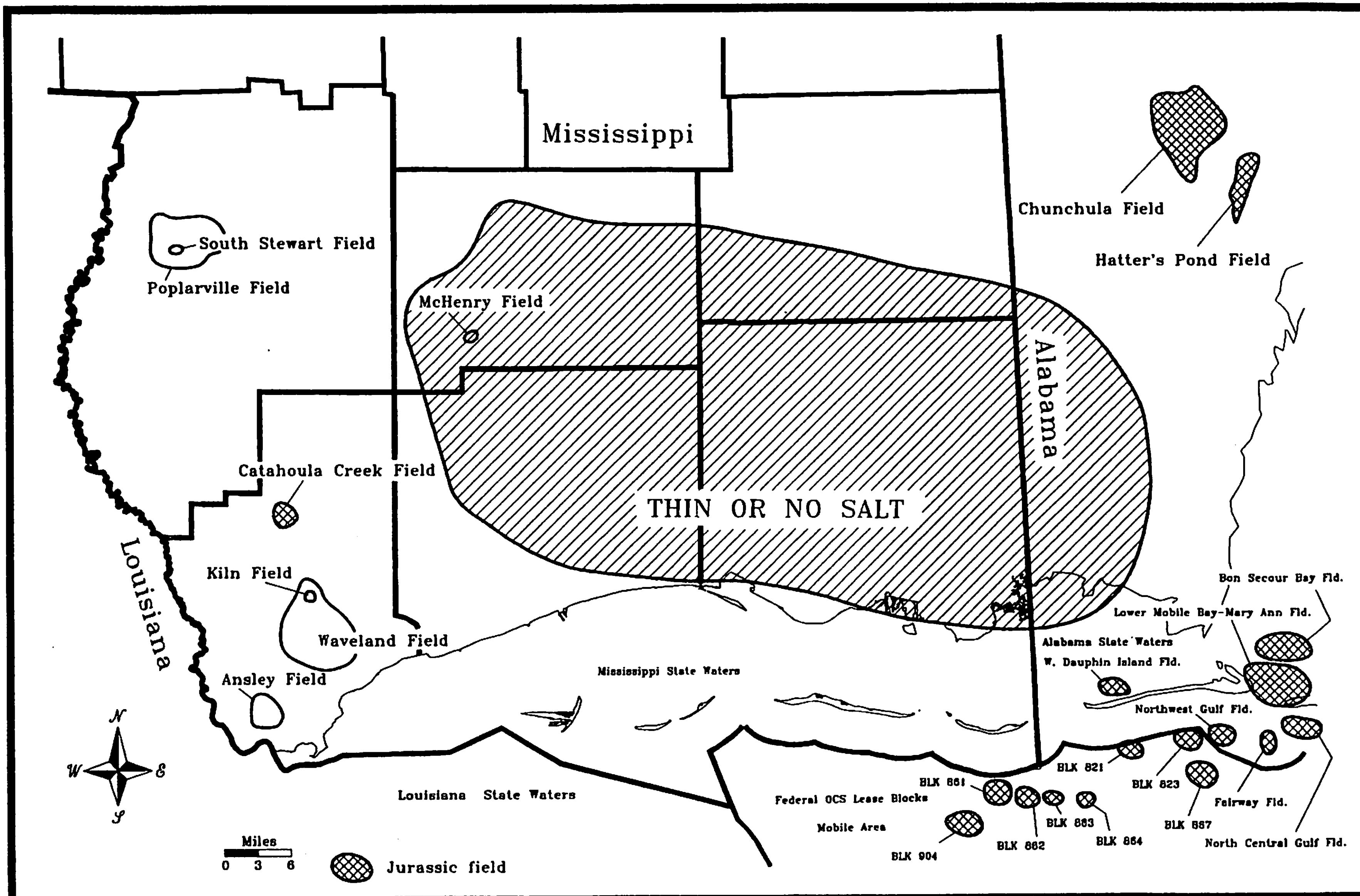


Figure 7. Map showing the locations of Jurassic fields in the study area, southwestern Alabama, and Federal OCS Mobile area.

of alternating sandstones, shales, carbonates, and minor amounts of anhydrite (Ericksen and Thieling, 1993). Various depositional systems are interpreted to have been present in Mississippi during Cotton Valley time. Across the central area of Mississippi two delta systems existed separated by an interdeltaic area and bounded to the south by a barrier bar system. A strand plain system was present in southeastern Mississippi, caused by the positive influence of the Wiggins Arch (Moore, 1983) (Figure 8).

To date Catahoula Creek Field is the only field productive of commercial quantities of natural gas from Upper Jurassic-age sediments in the three-county Mississippi coastal and offshore state waters area. Potentially, new Cotton Valley discoveries are possible on similar type features as the Catahoula Creek Field structure and, additionally, in structural closures above Paleozoic basement highs where Cotton Valley sands are draped across these features. The Mobil, #1 Anderson well in Harrison County encountered six different mudlog gas shows in Cotton Valley sands between 16,600 feet and 17,700 feet. Cross plotted porosities from the neutron/density log are in the 5% to 6% range.

Catahoula Creek Field

Catahoula Creek Field was discovered by the Hunt Energy Corporation, No. 1 Rhoda Lee Brown well which was completed on August 14, 1981, and is

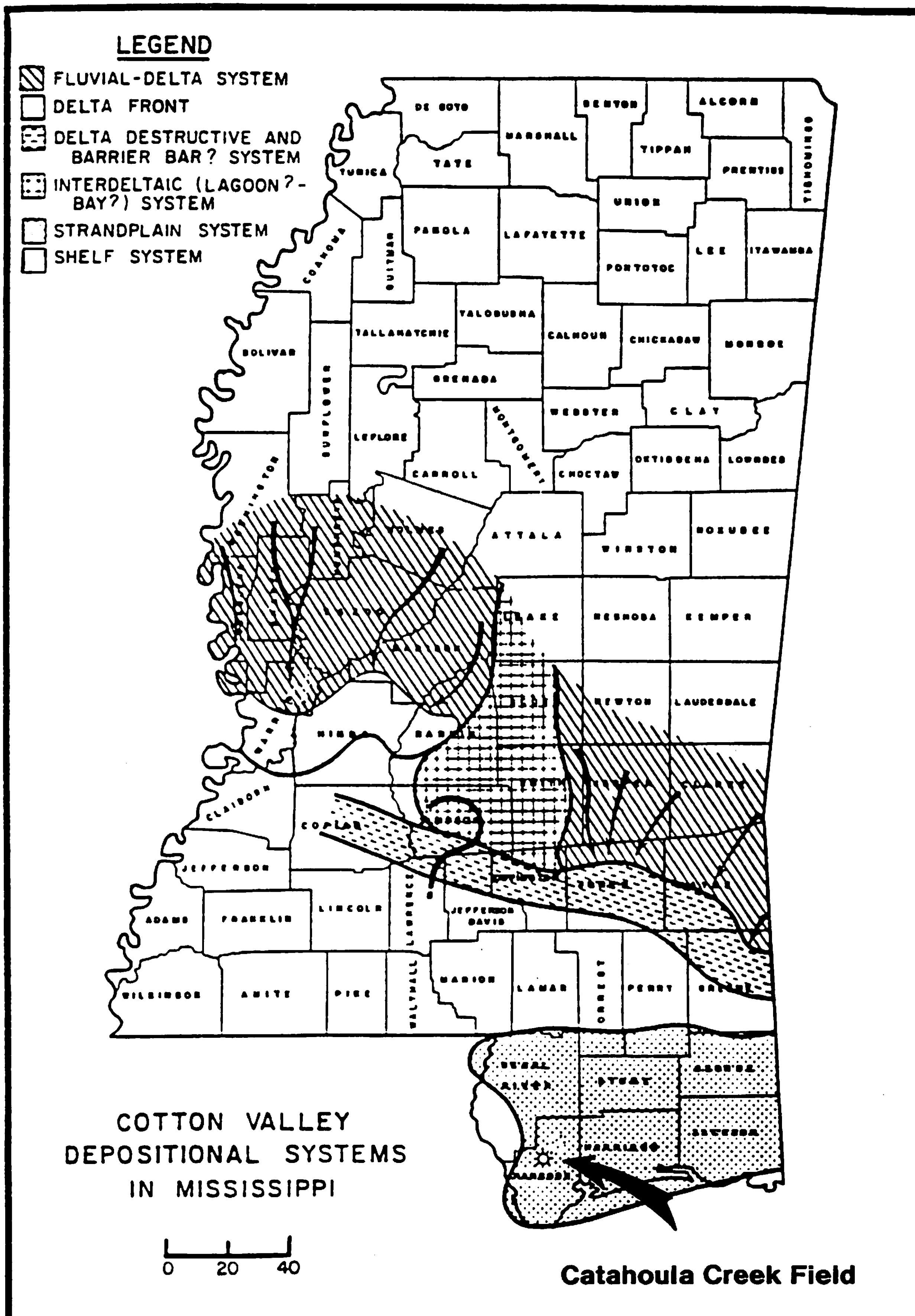


Figure 8. Cotton Valley depositional systems in Mississippi (modified from Moore, 1983).

located in Section 28, T6S-R15W, Hancock County, Mississippi. Field and reservoir data are listed in Table 2. The well was completed from perforations between 19,820 and 20,196 feet in Lower Cotton Valley sandstones. During the initial production test the well flowed 7,030 MCFGPD, 48 BWPD, on a 30/64 inch choke with a flowing tubing pressure of 6,549 psi. Bottom hole pressure was 16,297 psi (Mississippi Geological Society, 1986) (Table 2). Stabilized flow rates of 10-13 MMCFGPD were measured with FTP of 9100-9250# through 28/64 inch choke (Sannes and Hancock, 1982). As reported to the Mississippi State Oil and Gas Board, the gas stream contained 32 ppm H_2S and 4.8% CO_2.

Structurally the field is a faulted anticline with normal faulting downthrown to the south-southwest and was probably created by deep salt movement. Figure 9 is a structure map contoured on the top of the Lower Cotton Valley. Three wells have produced gas in the field, including the discovery well. Cumulative gas production for the field as of 12/31/94 is 5,578,180 MCF of gas and 707,476 barrels of water (Table 3 and Figure 10).

The reservoir sands at Catahoula Creek Field have been interpreted as being part of an offshore barrier island complex (Ericksen and Thieling, 1993). A total of 114 net feet of gas sand was indicated in eleven different zones of porosity. Matrix porosity of 4 to 18% was measured and matrix permeabilities of .1 to .3 millidarcies were indicated. Permeabilities are enhanced by vertical

CATAHOULA CREEK FIELD

Cotton Valley reservoir
Hancock County, Mississippi

LOCATION:

Township 6 South, Range 15 West, Hancock County, Mississippi.

DISCOVERY DATA:

Company: Hunt Energy Corporation
Well: #1 Rhoda Lee Brown
Completion date: August 14, 1981
Formation: Cotton Valley (Jurassic)
Perforations: 19,820'-20,196'
Potential: 7,030 MCFGPD; 48 BWPD; 30/64" Choke; 6,549 # FTP

TYPE OF TRAP:

Upthrown fault closure
Depositional environment: Barrier bar complex

RESERVOIR ROCK LITHOLOGY:

Sandstone - Light gray, fine grained, non-calcareous, well sorted, and moderately cemented, with micaceous shale laminae.

RESERVOIR DATA:

Reservoir:	Cotton Valley
Elevation:	130' DF
Average depth:	20,000' (19,820'-20,196')
Spacing:	640 acres
Estimated productive area:	1280 acres
Average pay thickness:	114'
Average porosity:	8.5%
Average permeability:	.01-4.0 md.
Average water saturation:	20 to 30%
Oil or gas/water contact:	-
Formation volume factor:	-
Bottom hole temperature:	417 degrees F
Bottom hole pressure (original):	16,297 #
Bottom hole pressure (current):	-
Gravity oil/condensate:	-
Gravity gas:	-
Original oil/gas in place:	-
Drive Mechanism:	Gas depletion/water drive
Primary recovery:	-
Estimated ultimate recovery:	-

Table 2. Catahoula Creek Field data (modified from Mississippi Geological Society, 1986).

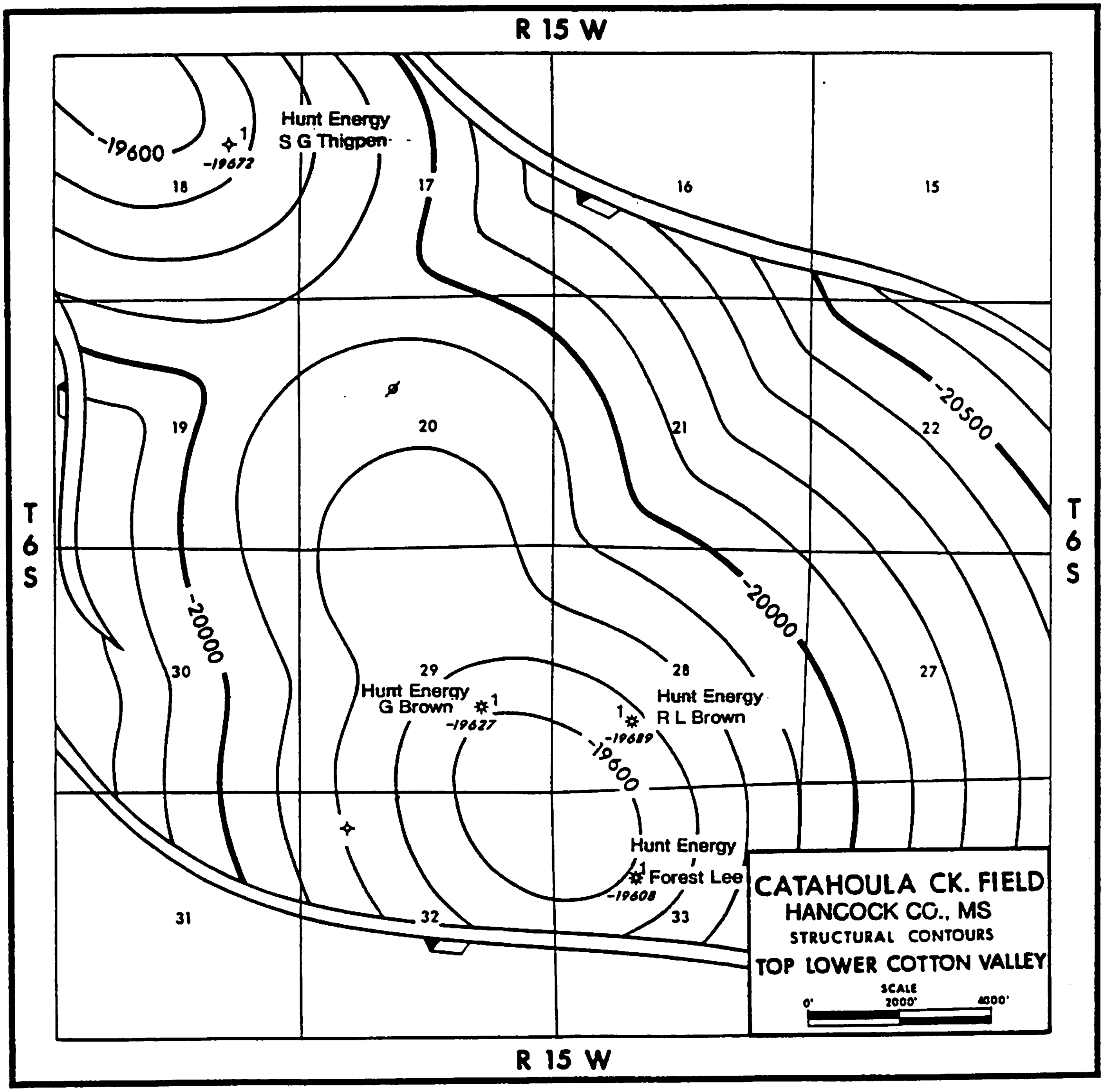


Figure 9. Catahoula Creek Field structure map, top of Lower Cotton Valley (modified from Mississippi Geological Society, 1986).

CATAHOULA CREEK FIELD, COTTON VALLEY GAS PRODUCTION

YEAR	# OF WELLS	ANNUAL PRODUCTION OIL BBLS.	ANNUAL PRODUCTION GAS MCF	ANNUAL PRODUCTION WATER BBLS.	CUMULATIVE PRODUCTION OIL BBLS.	CUMULATIVE PRODUCTION GAS MCF	CUMULATIVE PRODUCTION WATER BBLS.
81	0	0	**0**	0	0	**0**	0
82	2	0	**552,588**	9,706	0	**552,588**	9,706
83	2	0	**2,165,159**	128,334	0	**2,717,747**	138,040
84	2	0	**1,021,630**	146,896	0	**3,739,377**	284,936
85	2	0	**539,251**	124,066	0	**4,278,628**	409,002
86	1	0	**234,098**	72,247	0	**4,512,726**	481,249
87	2	0	**239,160**	13,710	0	**4,751,886**	494,959
88	2	0	**138,606**	9,197	0	**4,890,492**	504,156
89	2	0	**87,279**	6,208	0	**4,977,771**	510,364
90	2	0	**57,260**	172,049	0	**5,035,031**	682,413
91	2	0	**99,720**	22,245	0	**5,134,751**	704,658
92	2	0	**73,546**	1,888	0	**5,208,297**	706,546
93	1	0	**214,862**	0	0	**5,423,159**	706,546
94	2	0	**155,021**	930	0	**5,578,180**	707,476

Table 3. Catahoula Creek Field annual and cumulative production data (from Mississippi State Oil and Gas Board annual production reports, 1981-94).

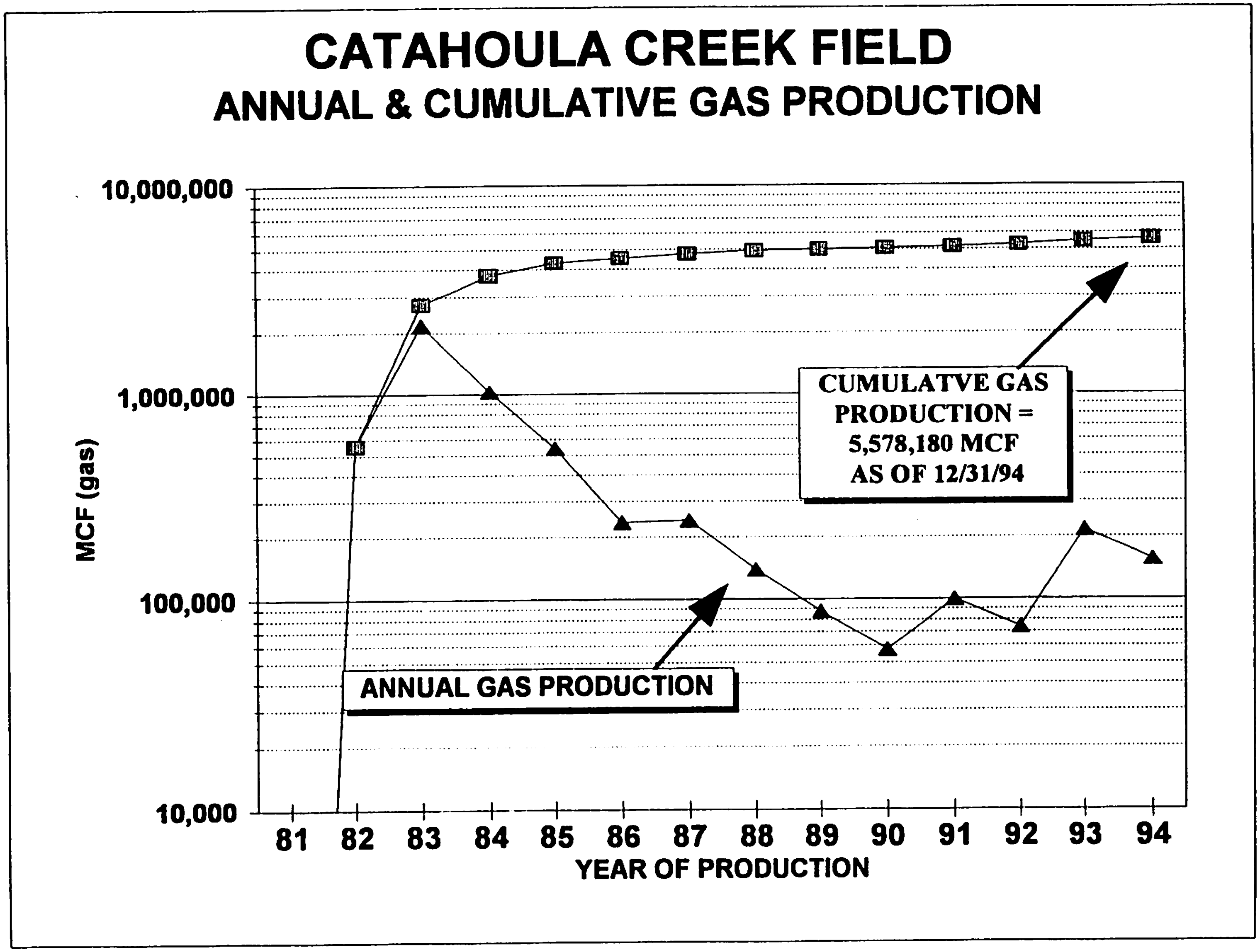


Figure 10. Graph of Catahoula Creek Field annual and cumulative gas production.

fracturing which has measured permeabilities ranging from 1 to 4.3 millidarcies; this explains the high flow rates during testing (Sannes and Hancock, 1982). The lithological descriptions and measured porosities and permeabilities from conventional cores cut in the two productive development wells at Catahoula Creek Field are included as figures 11 and 12.

Haynesville

Haynesville sediments in the study area range in thickness from 200 to 800 feet and have been described as a sequence of evaporites and associated sediments including shales, sands, and limestones. A conventional core cut in the Hunt, #1 Crosby in Hancock County, Mississippi (western onshore portion of the study area), from 23,733 to 23,765 feet was described as predominantly gray shale and siltstone with some very fine-grained sand (Ericksen and Thieling, 1993). Measured porosities in the sands ranged from 0.8% to 2.3% with all measured pemeabilities being less than .01 millidarcies. Presently there is no known oil or gas production from the Haynesville in the study area; however, potential traps may be present in the Frisco City on the flanks of several Paleozoic highs on the Wiggins Arch.

Three wells in the study area encountered section that appears to be equivalent to the Frisco City Sand of southern Alabama. The Mobil, #1 USA well

Figure 11. Lithological description of conventional core from the Hunt Energy, #1 Gordon Brown well, Catahoula Creek Field (Petro-Hunt Corporation).

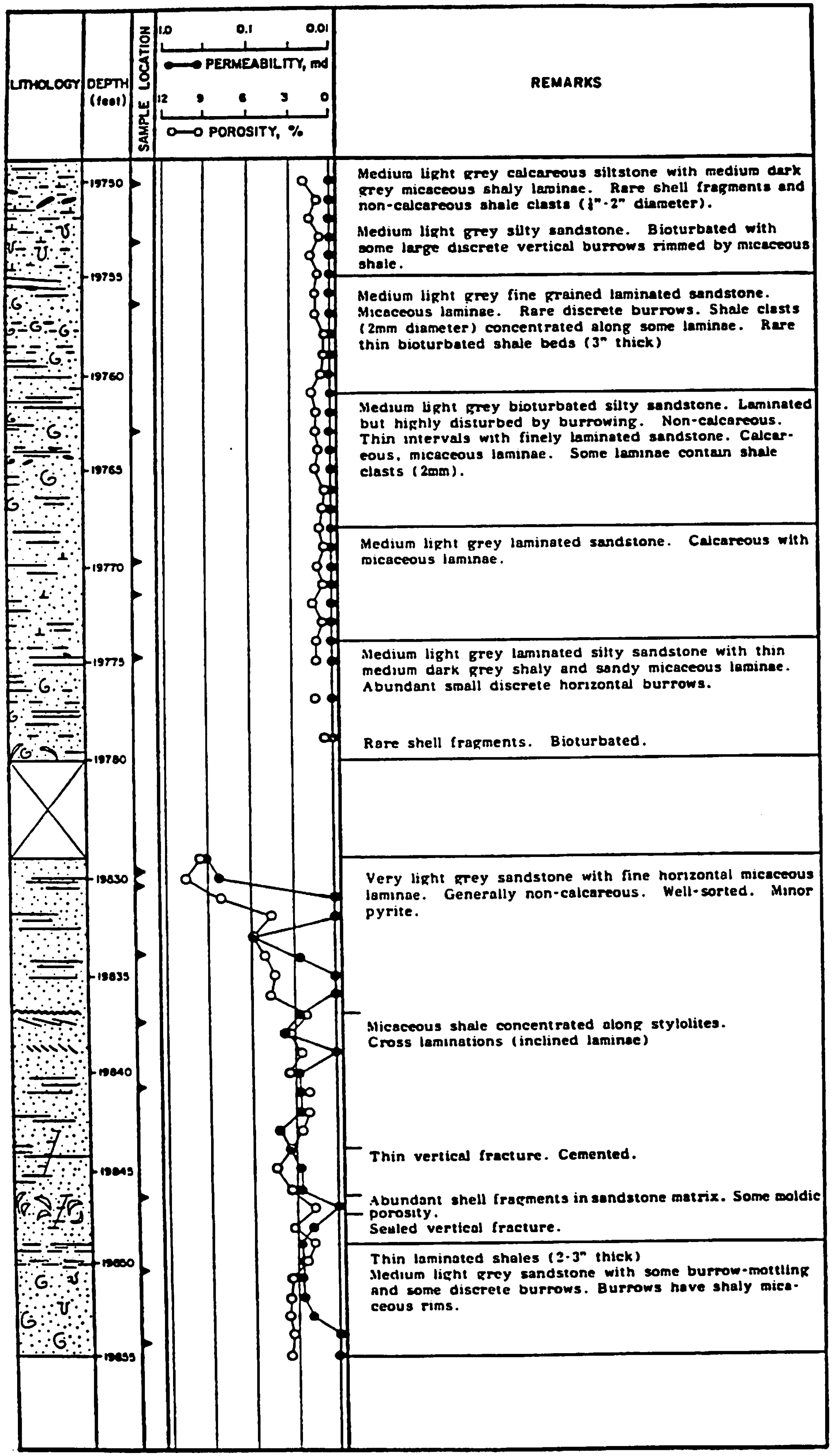


Figure 12. Lithological description of conventional core from the Hunt Energy, #1 Forest Lee well, Catahoula Creek Field (Petro-Hunt Corporation).

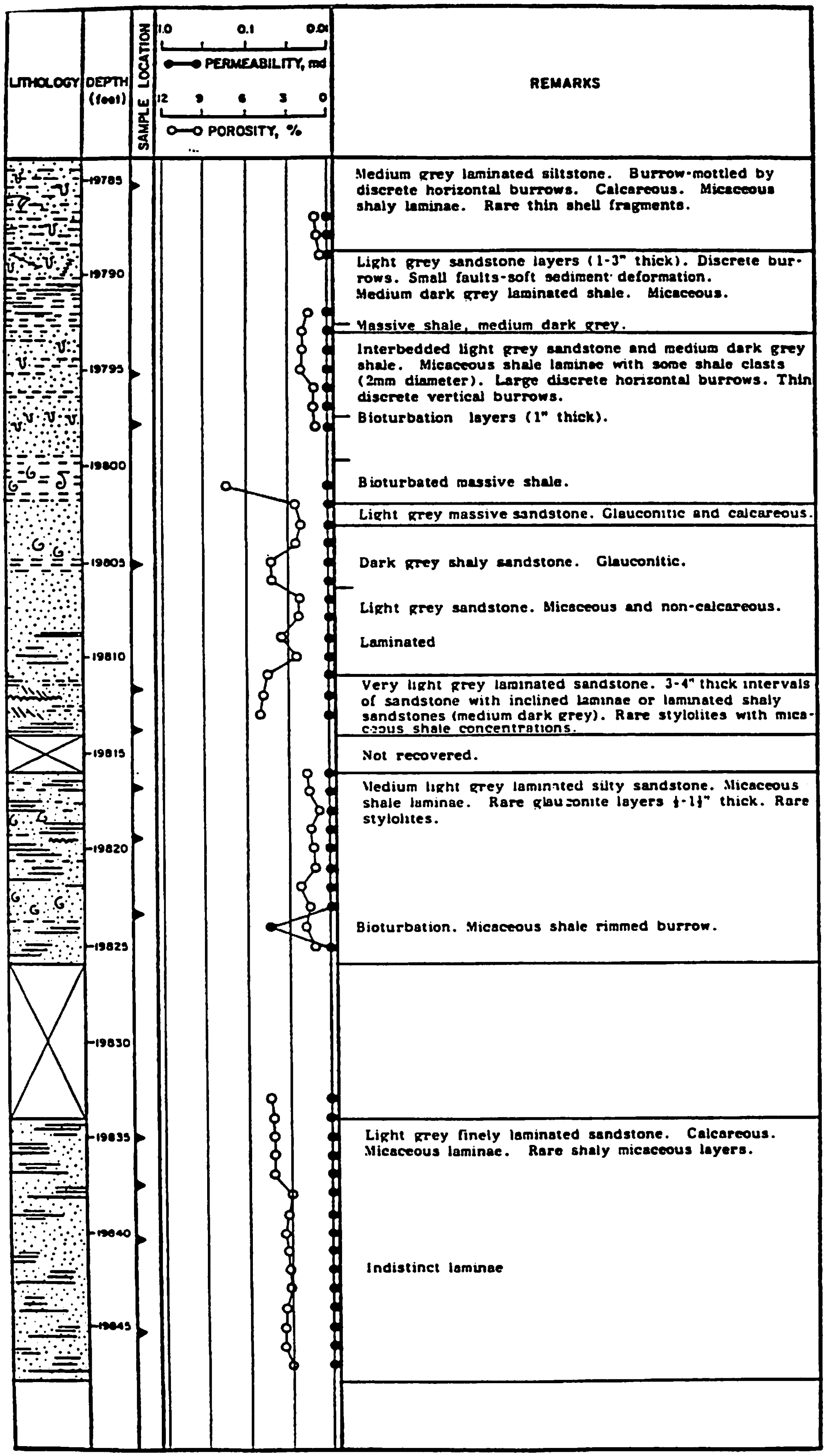
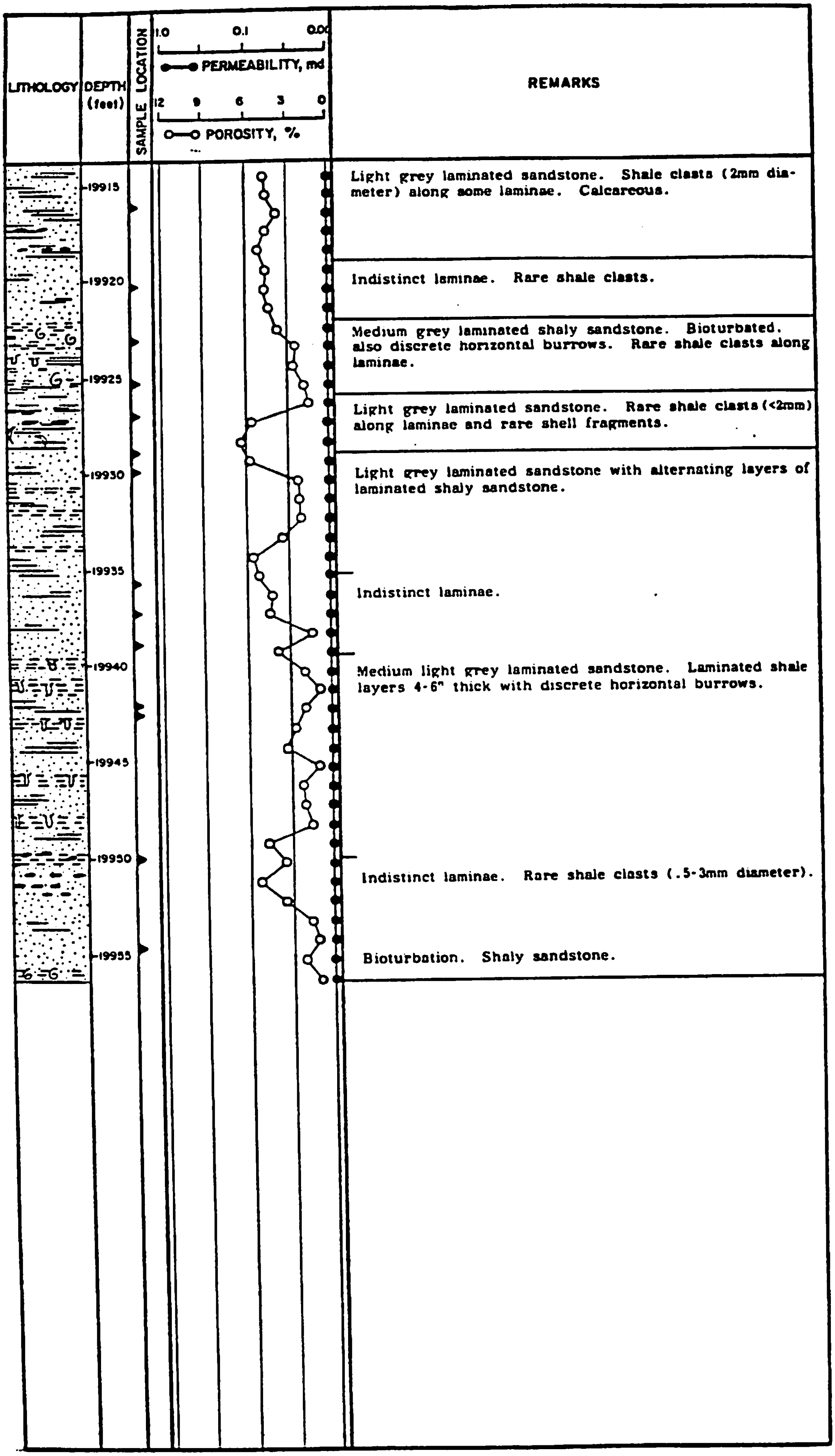


Figure 12. (Continued) Lithological description of conventional core from the Hunt Energy, #1 Forest Lee well, Catahoula Creek Field (Petro-Hunt Corporation).



in Harrison County penetrated 200 feet of granite wash, underlain by 70 feet of Buckner anhydrite. The Mobil, #1 Anderson well also encountered 70 feet of granite wash overlying basement several miles to the northeast of the Mobil, #1 USA well. The section is believed to have been deposited as alluvial fans off the flanks of several exposed Paleozoic highs on the Wiggins Arch (Figure 13). The granite wash deposits are probably facies equivalent as well as time equivalent to the Alabama Frisco City Sand (Rhodes and Maxwell, 1993). Cross plotted porosities from the two wells' nuetron/density logs range from 3% to 6%. The third well, which is the Chevron Block 57, located in Mississippi's western offshore state waters, encountered a 230 foot thick zone of clean white quartzose sand which Petty et al. (1994) concluded was Frisco City equivalent, thus extending the Frisco City Sand 20 miles southwest of the Wiggins Arch. The environment of deposition would have to be dissimilar because of the distance from the crest of the Wiggins Arch and the difference in described lithology.

The Buckner member of the Haynesville is present off the flanks of the exposed Paleozoic highs of the Wiggins Arch (Figure 13) and is generally described as massive white anhydrite. Thicknesses range from zero to 80 feet. The Buckner is not believed to be a potential reservoir in the study area.

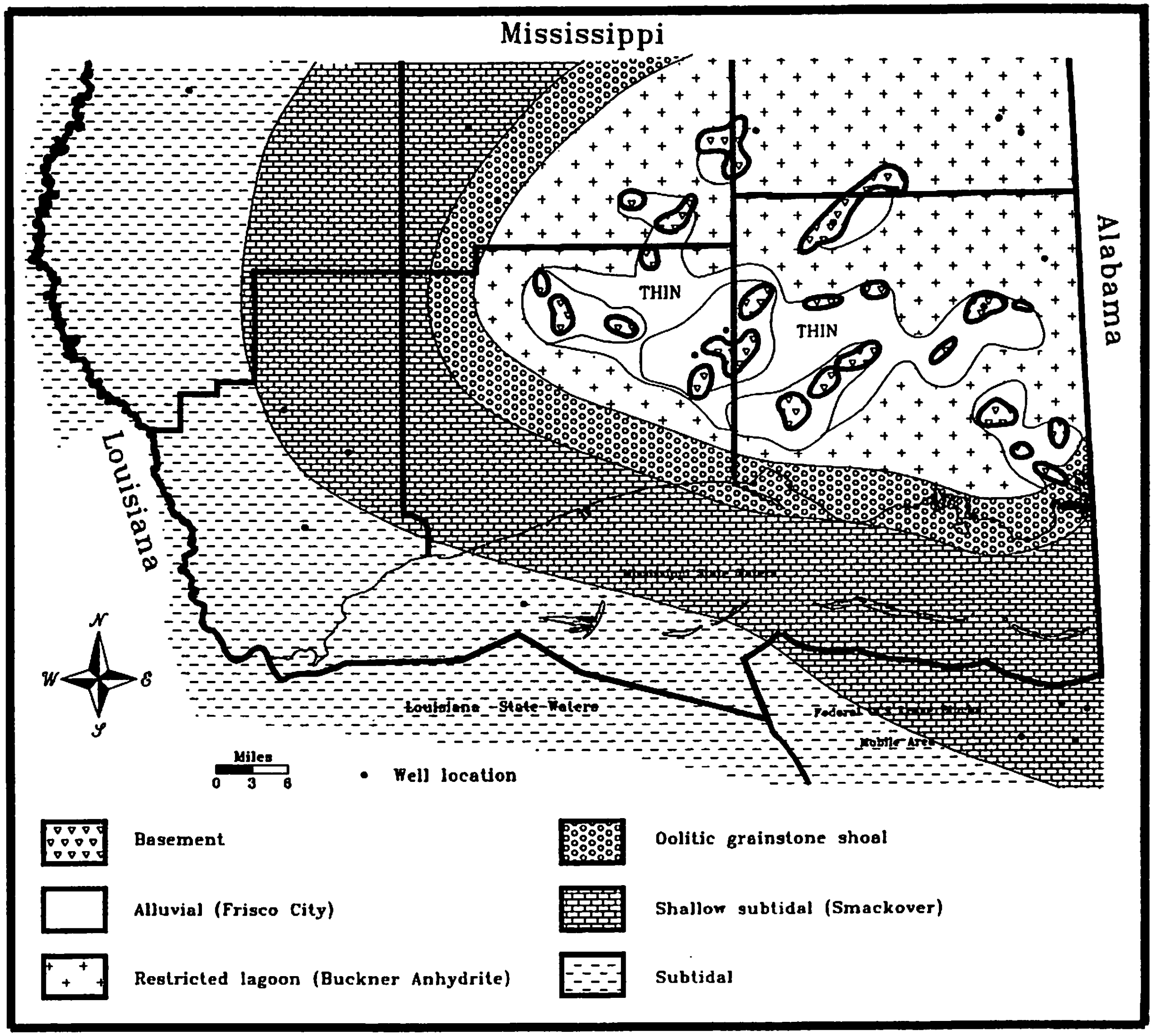


Figure 13. Late Smackover, Buckner, and early Haynesville facies map of the study area (modified from Rhodes and Maxwell, 1993).

Smackover

The Smackover Formation, which ranges in thickness from 0 to 900 feet within the study area (Ericksen and Thieling, 1993), is Upper Jurassic in age and usually conformably overlies the Norphlet Formation. The upper Smackover is predominantly a moderate to high energy subtidal, intertidal, and supratidal dolomitized wackestone to grainstone. The lower Smackover, the "brown dense," is generally a low-energy mudstone deposited during a marine transgression following Norphlet deposition (Mancini and Benson, 1980). In the study area the Smackover is encountered at depths below 18,500 feet and deeper. No Smackover oil or gas fields are currently present in the study area.

In the study area three types of Smackover depositional environments are indicated to be present by Rhodes and Maxwell's work. They are as follows: a belt of grainstone shoals surrounding the Wiggins Arch, a lagoonal facies updip of the shoals, and the open-marine mudstones downdip of the shoals (Rhodes and Maxwell, 1993). With the onset of the regression which eventually led to deposition of the Frisco City granite wash off the exposed Paleozoic highs, the Smackover shoals moved downdip and built up, creating a belt of well-developed oolitic shoals surrounding the Wiggins Arch. This further restricted the updip lagoonal areas and allowed deposition of the Buckner anhydrite to begin (Figure 13).

The Buckner is thickest updip of the restricting Smackover shoals, thin or absent in the beltway of the restricting shoals, and absent downdip of the shoals (Rhodes and Maxwell, 1993). The above described sequence of deposition sets up the potential for stratigraphic oil and gas traps in the upper Smackover shoal beltway, downdip of the thicker contemporaneously deposited Buckner anhydrite (Figure 13). The Buckner could form both lateral updip and vertical seals to trap hydrocarbons in the upper Smackover grainstone shoals. In the study area no wells have actually penetrated the upper Smackover shoal beltway, but several wells in Stone County and George County, which are north of and adjacent to the study area, are shown to have penetrated this facies on the north flank of the Wiggins Arch by Rhodes and Maxwell's work. The Mobil, #1 USA well encountered 300 feet of Smackover composed of primarily sucrosic dolomite. Total dolomitization has masked the original texture, but grainstones are the primary facies. Analysis of sidewall core samples from the well between 19,374 feet and 19,444 feet in the Smackover indicated porosities between 5.5% and 10.1% (Rhodes and Maxwell, 1993).

The two nearest Smackover fields in southwestern Alabama are Chunchula Field and Hatter's Pond Field, located in Mobile County to the east of and adjacent to the study area (Figure 7). The Smackover at both fields is described as dolostone with primary porosity being intercrystalline. A brief discussion of these two fields follows.

Chunchula Field

The Smackover production at Chunchula Field was discovered by the Union Oil Co. Of California, #1 International Paper Co. 22-13 well located in Section 22, T1S-R2W, Mobile County, Alabama. Field and reservoir data are listed in Table 4. The discovery well was completed January 4, 1974, flowing 1,158 BCPD and 2,650 MCFGPD on a 16/64 inch choke with 2,475 psi from perforations at 18,421-18,438 feet in the Smackover. Initial reservoir pressure was 9,255 psi (Table 4) (Bolin et al., 1989).

Structurally the field is a broad, low-relief anticline probably created by salt movement. Figure 14 is a structure map contoured on the top of the Smackover Formation. Chunchula Field is a combination trap with a loss of permeability to the north and northeast and the gas/water contact varies considerably. Average net pay thickness for the field is 34 feet (Kopaska-Merkel et al., 1993). The productive area for the Smackover is 22,113 acres (Bolin et al., 1989).

CHUNCHULA FIELD

Smackover reservoir
Mobile County, Alabama

LOCATION:

Townships 1 & 2 South, Range 1 & 2 West, Mobile County, Alabama.

DISCOVERY DATA:

Company: Union Oil Co. Of California
Well: #1 International Paper Co. 22-13, Section 22, T1S-R2W
Completion date: January 4, 1974
Formation: Smackover (Jurassic)
Perforations: 18,421'-18,438'
Potential: 1,158 BCPD & 2,650 MCFGPD; 16/64" Choke; 2,475 # FTP

TYPE OF TRAP:

Structural/stratigraphic (anticline)

RESERVOIR ROCK LITHOLOGY:

Dolostone
Depositional environment: Subtidal, high energy

RESERVOIR DATA:

Reservoir:	Smackover
Elevation:	-
Average depth:	-
Spacing:	Fieldwide unit
Estimated productive area:	22,113 acres
Average pay thickness:	34'
Average porosity:	12%
Average permeability:	2.0 md.
Average water saturation:	19%
Oil or gas/water contact:	- 18,255' to -18,310' subsea
Formation volume factor:	-
Bottom hole temperature:	-
Bottom hole pressure (original):	9,255 psi
Bottom hole pressure (current):	-
Gravity oil/condensate:	61 (condensate)
Gravity gas:	-
Original oil/gas in place:	-
Drive Mechanism:	Gas depletion drive
Primary recovery:	-
Estimated ultimate recovery:	-

Table 4. Chunchula Field Smackover reservoir data (from Bolin et al., 1989).

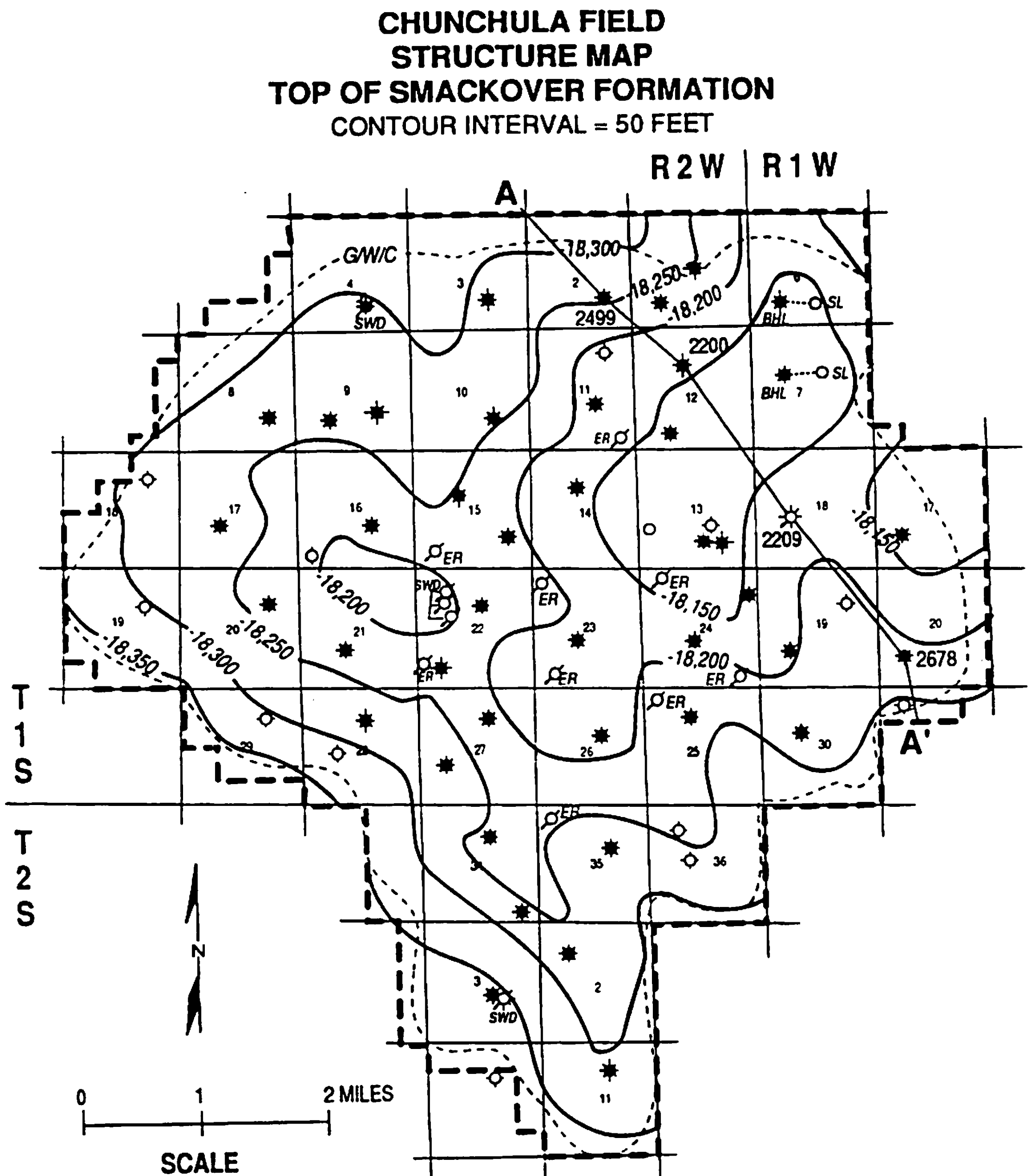


Figure 14. Chunchula Field structure map, top of Smackover (from Bolin et al., 1989).

The Smackover reservoir at Chunchula Field is described as a dolostone with the primary porosity being dominated by intercrystalline pores. Interparticle, moldic, secondary intraparticle, and vuggy porosity are present and important, however. The average porosity and permeability for the reservoir rock are 12.9% porosity and 6.2 millidarcies of permeability (Kopaska-Merkel et al., 1993). Bolin et al. (1989) reported the average porosity to be 12% and average permeability to be 2.0 millidarcies. The depositional environment is interpreted as subtidal and high energy (Bolin et al., 1989).

Hatter's Pond Field

The Smackover production at Hatter's Pond Field was discovered by the Getty Oil Company, #1 Peter Klein 3-14 well located in Section 3, T2S-R1W, Mobile County, Alabama. Field and reservoir data are listed in Table 5. The discovery well was drilled to a total depth of 18,358 feet and completed December 2, 1974, flowing 2,166 BCPD and 6,198 MCFGPD on a 17/64 inch choke with 3,270 psi from perforations at 18,042-18,060 feet in the Smackover. Initial reservoir pressure was 9,108 psi (Table 5) (Bolin et al., 1989). The Norphlet was also determined to be productive.

Structurally the field is a north-south oriented, faulted anticline bounded to the east by a large down-to-the-east-southeast fault associated with the

HATTER'S POND FIELD

Smackover reservoir
Mobile County, Alabama

LOCATION:

Townships 1 & 2 South, Range 1 West, Mobile County, Alabama.

DISCOVERY DATA:

Company: Getty Oil Company
Well: #1 Peter Klein 3-14, Section 3, T2S-R1W
Completion date: December 2, 1974
Formation: Smackover (Jurassic)
Perforations: 18,042'-18,060'
Potential: 2,166 BCPD & 6,198 MCFGPD; 17/64" Choke; 3,270 # FTP

TYPE OF TRAP:

Upthrown faulted anticline

RESERVOIR ROCK LITHOLOGY:

Dolostone
Depositional environment: Subtidal, high energy

RESERVOIR DATA:

Reservoir:	Smackover (commingled with Norphlet Formation)
Elevation:	-
Average depth:	18,050'
Spacing:	Fieldwide unit
Estimated productive area:	6,418 acres
Average pay thickness:	59'
Average porosity:	12%
Average permeability:	2.0 md.
Average water saturation:	30%
Oil or gas/water contact:	-18,300' subsea
Formation volume factor:	-
Bottom hole temperature:	-
Bottom hole pressure (original):	9,108 psi
Bottom hole pressure (current):	-
Gravity oil/condensate:	61 (condensate)
Gravity gas:	-
Original oil/gas in place:	-
Drive Mechanism:	Gas depletion drive
Primary recovery:	-
Estimated ultimate recovery:	-

Table 5. Hatter's Pond Field Smackover reservoir data (from Bolin et al., 1989).

Mobile Graben Fault System. The structure has over 700 feet of structural relief and resulted from salt movement along the western side of the fault system. Figure 15 is a structure map contoured on the top of Smackover porosity. The productive area for the Smackover is 6,418 acres (Bolin et al., 1989). Average net gas pay is 59 feet (Kopaska-Merkel et al., 1993). It was determined that the Smackover and Norphlet reservoirs were in communication and had the same gas/water contact of approximately -18,300 feet subsea. In 1985 the field was unitized and production from the Smackover and Norphlet was commingled (Kopaska-Merkel et al., 1993). Cumulative commingled Smackover and Norphlet condensate and gas production for the unitized field unit as of 12/31/94 was 55,462,350 barrels of condensate and 239,339,117 MCF of gas. Monthly production for December 1994 was 289,888 barrels of condensate and 1,633,598 MCF of gas.

The Smackover reservoir at Hatter's Pond Field is described as a dolostone (Bolin et al., 1989) with the primary porosity being dominated by intercrystalline pores (Kopaska-Merkel et al., 1993). Total Smackover porosity ranges from 1.2% to 24.4% and averages 9.4%. Total Smackover permeabilities range from 0.01 to 177 millidarcies. Actual reservoir porosity and permeabilities average 13.5% porosity and 10.6 millidarcies of permeability (Kopaska-Merkel et al., 1993). Bolin et al. (1989) reported the average porosity as 12% and

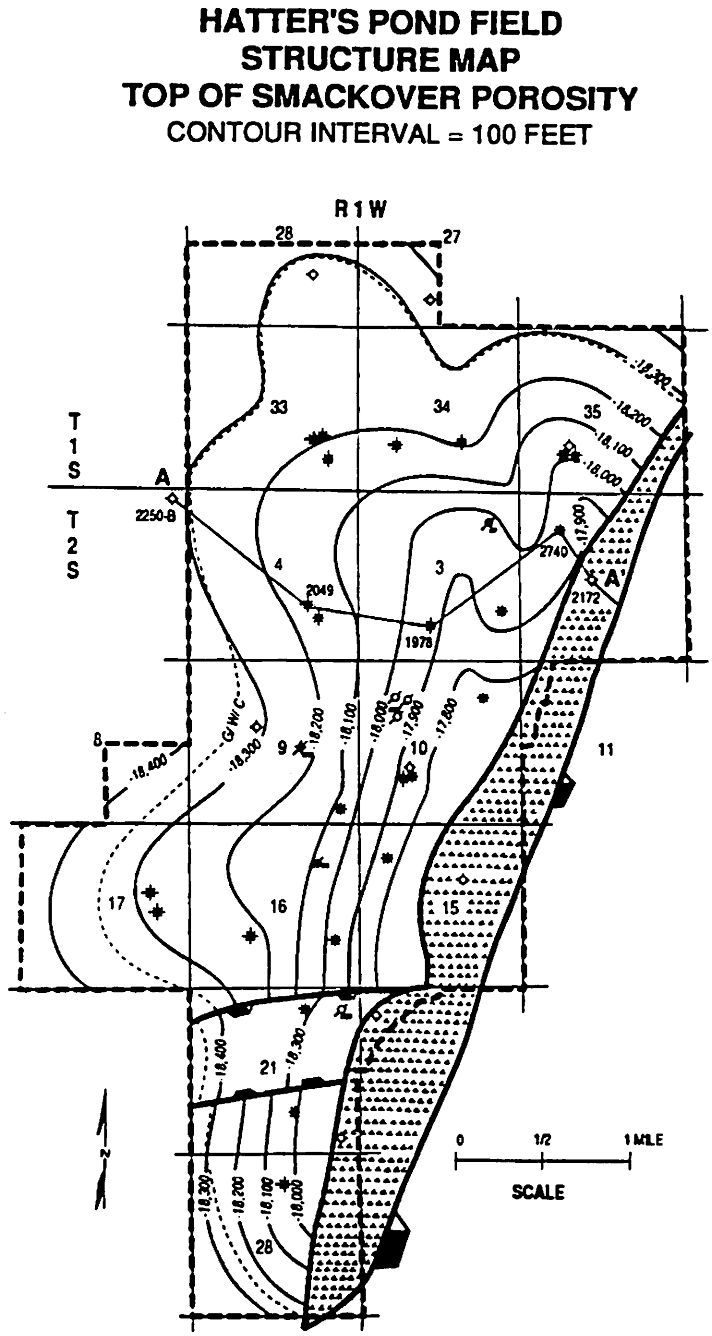


Figure 15. Hatter's Pond Field structure map, top of Smackover (from Bolin et al., 1989).

average permeability to be 2.0 millidarcies. The depositional environment is interpreted as subtidal and high energy (Bolin et al., 1989).

Norphlet

The Norphlet Formation, which ranges in thickness from 0 to 300 feet within the study area (Ericksen and Thieling, 1993), is Upper Jurassic in age and unconformably lies above the Louann Salt. The Norphlet is encountered at depths below 18,600 feet onshore and below 20,000 feet offshore. In the study area, Norphlet oil and gas production has not been established as of late 1995. However, with three Norphlet gas discoveries in the Federal OCS Mobile Area immediately south of Mississippi's eastern offshore state waters (Figure 7), the established deep Norphlet gas production to the east in Alabama's offshore state waters (Figure 7) and recently published studies on the area, it is apparent that two areas for possible future successful exploration are present in the study area. One area is on the crest of the Wiggins Arch in Norphlet alluvial fans situated on the flanks of Paleozoic highs (Figure 16). The second area is in Mississippi's eastern offshore state waters in Norphlet eolian sands (Figure 16).

As a result of the work done by Rhodes and Maxwell (1993) and the drilling of several wells by Mobil and Shell, it has been shown that the Norphlet is present in the central and eastern onshore portion, as granite wash alluvial

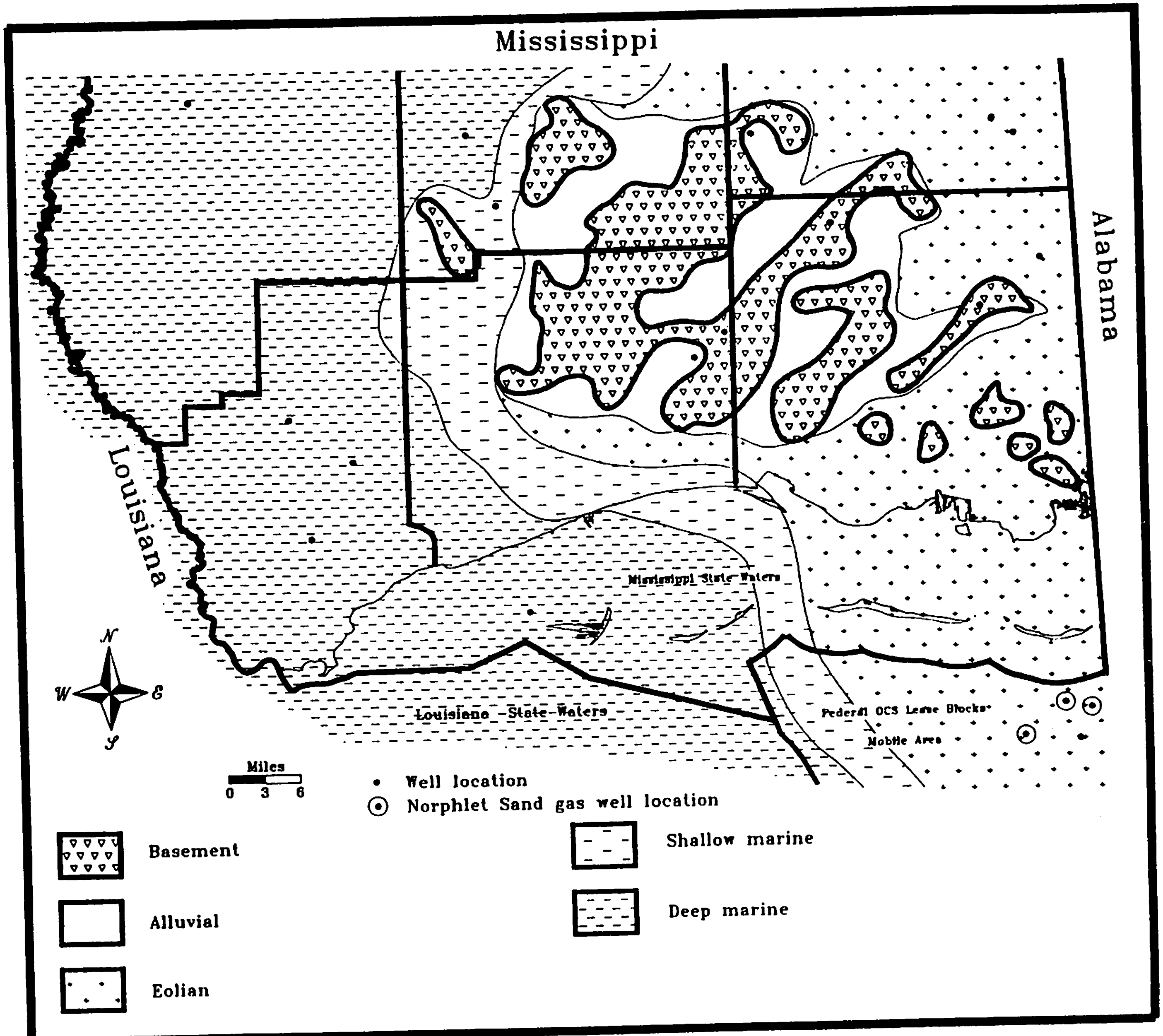


Figure 16. Norphlet facies map for the study area (modified from Rhodes and Maxwell, 1993).

fan deposits off the flanks of several of the Paleozoic highs on the Wiggins Arch (Figure 16). These deposits do not extend significantly downdip, however. The Mobil #1 USA well in eastern Harrison County encountered what is described as 180 feet of a granite wash below the Smackover (Rhodes and Maxwell, 1993). Cross plotted porosities from the well's neutron/density log ranged between 2 and 6%.

The Norphlet eolian facies is also interpreted as being present in the eastern onshore Jackson County area and Mississippi's eastern offshore state waters. Petty et al. (1994) stated that Norphlet sand was also present in the Chevron Block 57 well located in Mississippi's western offshore state waters. An estimated 8 to 10 foot sand identified by paleontological and sample description is picked at 23,340 feet to 23,348 feet measured depth on the well's induction log (Petty et al., 1994). The depositional environment is not believed to be eolian, but more probably marine (Petty, personal communication, 1995). This would be the westernmost presence of Norphlet sand seen in the northeastern Gulf area.

Structurally, Mississippi's eastern offshore state waters area is located far enough downdip of the Wiggins Arch that the Louann Salt is thick enough for halokinesis (figures 3 and 7). An east-west trending system of faults, referred to as the Lower Mobile Bay fault trend, is present in the offshore of Alabama (Mink and Bearden, 1986) which, when combined with salt pillowing, plays an important part in the trapping of the deep Norphlet gas reserves there and in Federal OCS waters. A recent seismic interpretation of data covering the eastern area of Mississippi's state waters around Petit Bois Island (Ericksen and Thieling, 1993) reveals that at the near top of Norphlet level the Lower Mobile Bay fault trend probably extends into Mississippi waters and sets up several areas of possible production similar to those seen in Mobile area blocks 861, 862, and 904, which are gas productive from deep Norphlet sands just south of Mississippi's state waters, in Federal OCS waters (Figure 17). In 1992, Unocal reported testing of its Mobile Block 904, #1 well. Located approximately four and one half miles from Mississippi's three-mile state waters boundary, the well was drilled to a total depth of 22,400 feet and encountered a reported 185 feet of Norphlet gas pay. The well flowed at a rate of 97.6 MMCFGPD through a 42/62 inch choke from perforations between 22,130 and 22,290 feet measured depth. The well's flow rate is the highest reported in the Mobile OCS and also one of the highest reported in the entire Gulf of Mexico (Southeastern Oil Review, 1992). In December 1993, Chevron reported testing of the No. 8 well in Mobile Block 861. The well flowed 57 MMCFGPD from below 21,000 feet (Hart's Oil and Gas World, 1994). This well is located only about two and one half miles south of Mississippi's three-mile state waters boundary.

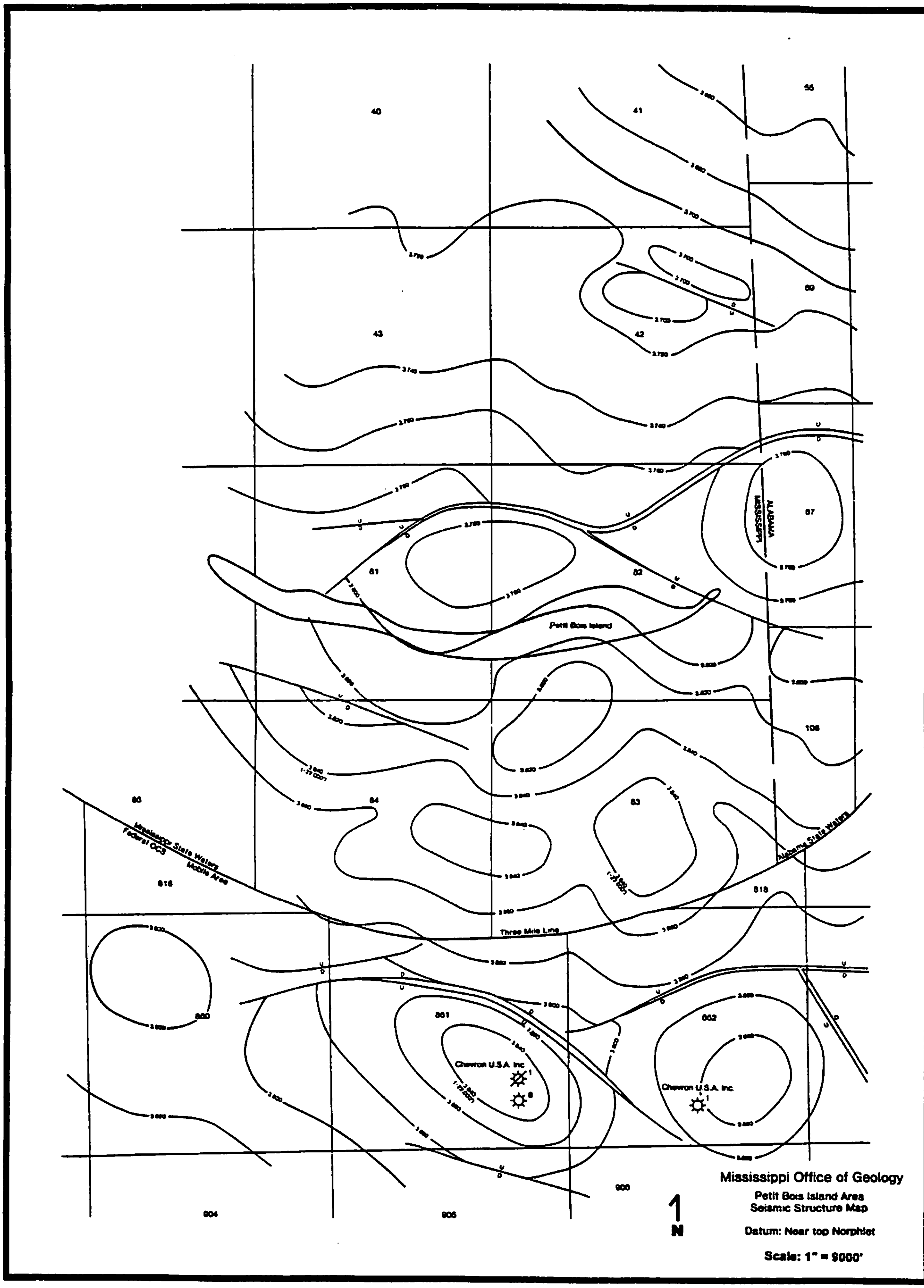


Figure 17. Seismic structure map, near top of Norphlet, Petit Bois Island area, state waters of Mississippi (modified from Ericksen and Thieling, 1993).

Reservoir characteristics (porosities and permeabilities in particular) should be similar in the eastern offshore Mississippi state waters as they are in the Norphlet fields of offshore Alabama and Federal OCS waters because of common depth of burial, depositional environments, and probable similar diagenetic histories. Secondary porosity created by decementation and dissolution is important in the deeper Norphlet reservoirs (Marzano et al., 1988). Average porosities for the Norphlet reservoirs in the Alabama offshore state waters range from 10 to 15% (Schmoker and Schenk, 1994). Permeabilities can range up to 120 millidarcies. Information is presented next on two Alabama fields, one offshore and one onshore, and the Norphlet discoveries in Blocks 861 and 862 in the Federal OCS waters adjacent to Mississippi's offshore area.

Hatter's Pond Field

The Norphlet production at Hatter's Pond Field was discovered by the Getty Oil Company, #1 Peter Klein 3-14 well located in Section 3, T2S-R1W, Mobile County, Alabama. Field and reservoir data are listed in Table 6. The discovery well was drilled to a total depth of 18,358 feet and completed December 2, 1974, flowing 1,416 BCPD and 4,389 MCFGPD on a 18/64 inch choke with 2,346 psi from perforations at 18,180-18,200 feet in the Norphlet. Initial reservoir pressure was 9,186 psi (Table 6) (Bolin et al., 1989). The Smackover was also determined to be productive in this well.

HATTER'S POND FIELD

Norphlet reservoir
Mobile County, Alabama

LOCATION:

Townships 1 & 2 South, Range 1 West, Mobile County, Alabama.

DISCOVERY DATA:

Company: Getty Oil Company
Well: #1 Peter Klein 3-14, Section 3, T2S-R1W
Completion date: December 2, 1974
Formation: Norphlet (Jurassic)
Perforations: 18,180'-18,200'
Potential: 1,416 BCPD & 4,389 MCFGPD; 18/64" Choke; 2,346 # FTP

TYPE OF TRAP:

Upthrown faulted anticline

RESERVOIR ROCK LITHOLOGY:

Sandstone
Depositional environment: Eolian dune and interdune, wadi, and transgressive marine.

RESERVOIR DATA:

Reservoir:	Norphlet (commingled with Smackover Formation)
Elevation:	-
Average depth:	18,100'
Spacing:	Fieldwide unit
Estimated productive area:	4,556 acres
Average pay thickness:	146'
Average porosity:	10%
Average permeability:	.5 md.
Average water saturation:	30%
Oil or gas/water contact:	-18,300' subsea
Formation volume factor:	-
Bottom hole temperature:	-
Bottom hole pressure (original):	9,186 psi
Bottom hole pressure (current):	-
Gravity oil/condensate:	59 (condensate)
Gravity gas:	-
Original oil/gas in place:	-
Drive Mechanism:	Gas depletion drive
Primary recovery:	-
Estimated ultimate recovery:	-

Table 6. Hatter's Pond Field Norphlet reservoir data (from Bolin et al., 1989).

Structurally the field is a north-south oriented, faulted anticline bounded to the east by a large down-to-the-east-southeast fault associated with the Mobile Graben Fault System. The structure has over 700 feet of structural relief and resulted from salt movement along the western side of the fault system. Figure 18 is a structure map contoured on the top of Norphlet porosity. The productive area for the Norphlet is 4,556 acres. Early in field development it was determined that the Smackover and Norphlet reservoirs were in communication and had the same gas/water contact of approximately -18,300 feet subsea. In 1985 the field was unitized and production from the Smackover and Norphlet was commingled (Kopaska-Merkel et al., 1993). Cumulative commingled Smackover and Norphlet condensate and gas production for the unitized field unit as of 12/31/94 was 55,462,350 barrels of condensate and 239,339,117 MCF of gas. Monthly production for December 1994 was 289,888 barrels of condensate and 1,633,598 MCF of gas.

The Norphlet Sand reservoir at Hatter's Pond Field is an eolian sandstone deposited in an arid environment. The top of the Norphlet sand was then reworked by a marine transgression (Mancini et al., 1985). Most of the pores in the Norphlet at Hatter's Pond Field are formed by decementation of anhydrite or calcite and dissolution of grains (Honda and McBride, 1981). Average porosity in the Norphlet is 10% and average permeabilities are .5 millidarcies (Bolin et al., 1989).

HATTER'S POND FIELD
STRUCTURE MAP
TOP OF NORPHLET FORMATION

CONTOUR INTERVAL = 100 FEET

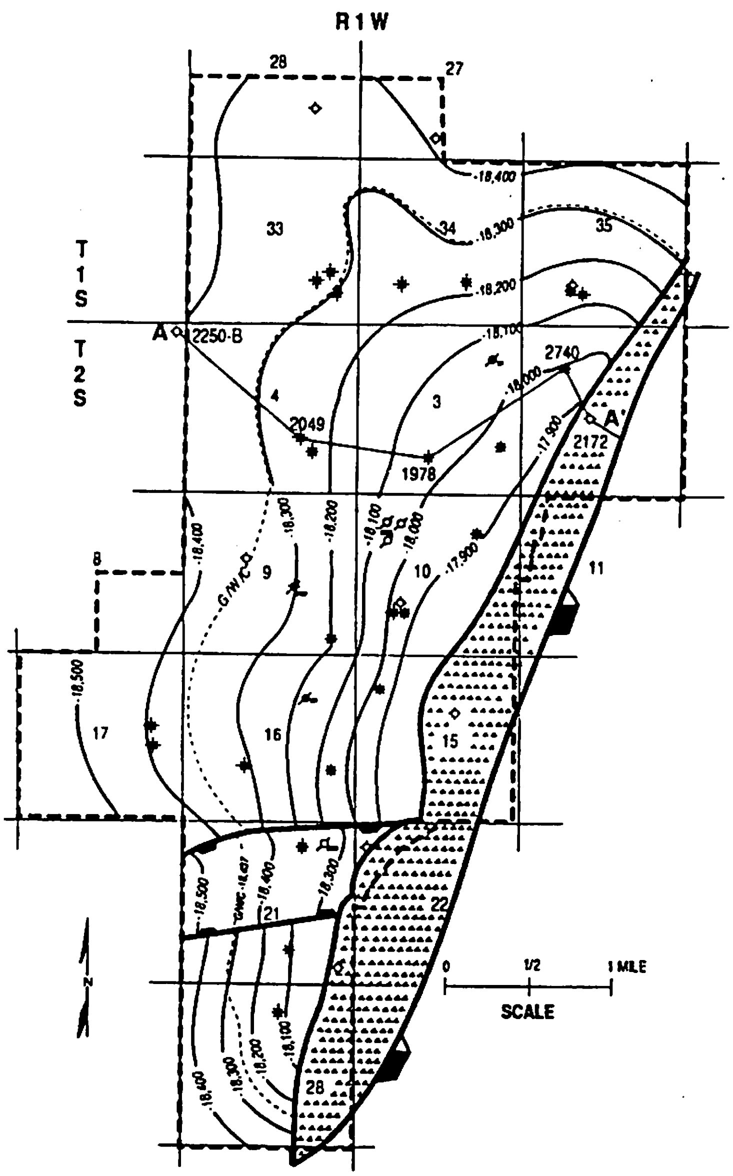


Figure 18. Hatter's Pond Field structure map, top of Norphlet (from Bolin et al., 1989).

Lower Mobile Bay-Mary Ann Field

Lower Mobile Bay-Mary Ann Field was discovered by the Mobil Oil Exploration & Producing Southeast, Inc., State Lease 347, #1 well located in Block 76 of Alabama's offshore state waters. Field and reservoir data are listed in Table 7. The field area includes Alabama Blocks 76, 77, 94 and 95. The discovery well was drilled to a total depth of 21,113 feet and completed December 28, 1979, flowing 12,200 MCFGPD on a 28/64 inch choke with 2,996 psi from perforations at 20,634-20,873 feet. The well encountered 283 feet of gas pay in the Norphlet Sand (Marzano et al., 1988). Initial reservoir pressure was 11,330 psi and temperature was 414 degrees Fahrenheit (Table 7) (Bolin et al., 1989). Gas composition analyzed as the following: 84.85% methane, 0.61% ethane, 0.04% propane, 9.02% H_2S, 5.12% CO_2, 0.36% N_2, and a gas gravity of .666 (Mink et al., 1987).

Structurally the field is a broad, low relief, east-west oriented anticline bounded to the north by the large down-to-the-south Lower Mobile Bay fault and dissected by several smaller faults. The structure was created by the combination of salt movement and faulting. Figure 19 is a structure map contoured on the top of Norphlet porosity. Six wells have been drilled in the field with tested wells flowing gas from the Norphlet at rates from 10.5 to 19.4 MCFGPD (Bearden, 1987). Five wells in the field have contributed to the field's

LOWER MOBILE BAY-MARY ANN FIELD

Norphlet reservoir
Baldwin and Mobile Counties, Alabama
Offshore state waters

LOCATION:

Blocks 76, 77, 94, and 95, Lower Mobile Bay Area, Baldwin and Mobile Counties, Alabama, offshore state waters.

DISCOVERY DATA:

Company: Mobil Oil Exploration & Producing Southeast, Inc.
Well: State Lease 347 #1, 2543-OS-3B, Block 76
Completion date: December 28, 1979
Formation: Norphlet (Jurassic)
Perforations: 20,634'-20,873'
Potential: 12,200 MCFGPD; 28/64" Choke; 2,996 # FTP

TYPE OF TRAP:

Faulted anticline

RESERVOIR ROCK LITHOLOGY:

Sandstone
Depositional environment: Eolian dune and interdune, transgressive marine

RESERVOIR DATA:

Reservoir:	Norphlet (Jurassic)
Elevation:	-
Depth:	20,634'-20,873'
Spacing:	Fieldwide unit
Estimated productive area:	9,261 acres
Average pay thickness:	191'
Average porosity:	11%
Average permeability:	1 md.
Average water saturation:	30%
Oil or gas/water contact:	G/W -20,876' subsea
Formation volume factor:	-
Bottom hole temperature:	414 degrees F
Bottom hole pressure (original):	11,330 psi
Bottom hole pressure (current):	-
Gravity oil/condensate:	-
Gravity gas:	.67
Original oil/gas in place:	-
Drive Mechanism:	Gas depletion
Primary recovery:	-
Estimated ultimate recovery:	-

Table 7. Lower Mobile Bay-Mary Ann Field Norphlet reservoir data (from Bolin et al., 1989).

LOWER MOBILE BAY - MARY ANN FIELD
STRUCTURE MAP
TOP OF NORPHLET POROSITY
CONTOUR INTERVAL = 100 FEET

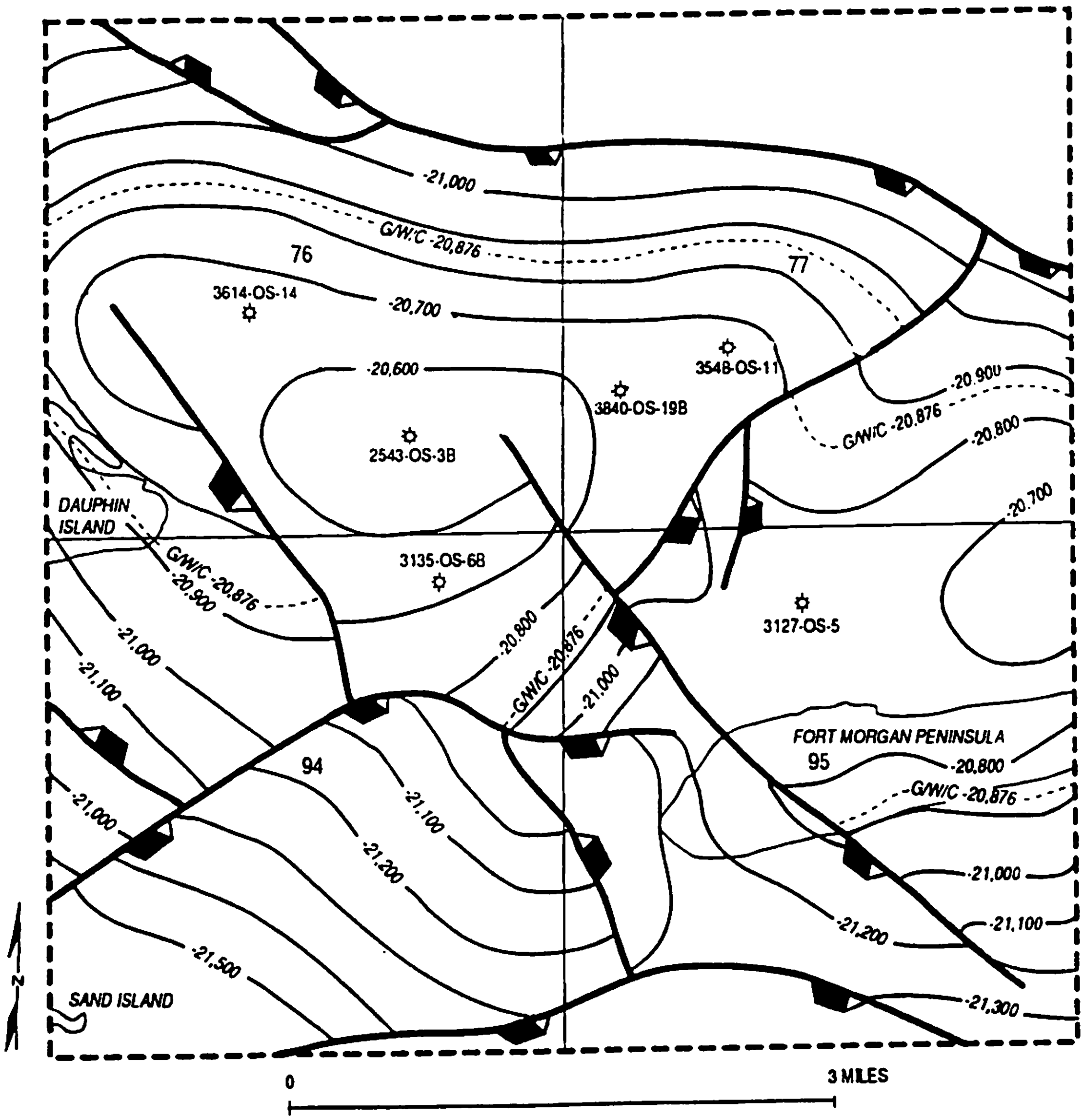


Figure 19. Lower Mobile Bay-Mary Ann Field structure map, top of Norphlet (from Bolin et al., 1989).

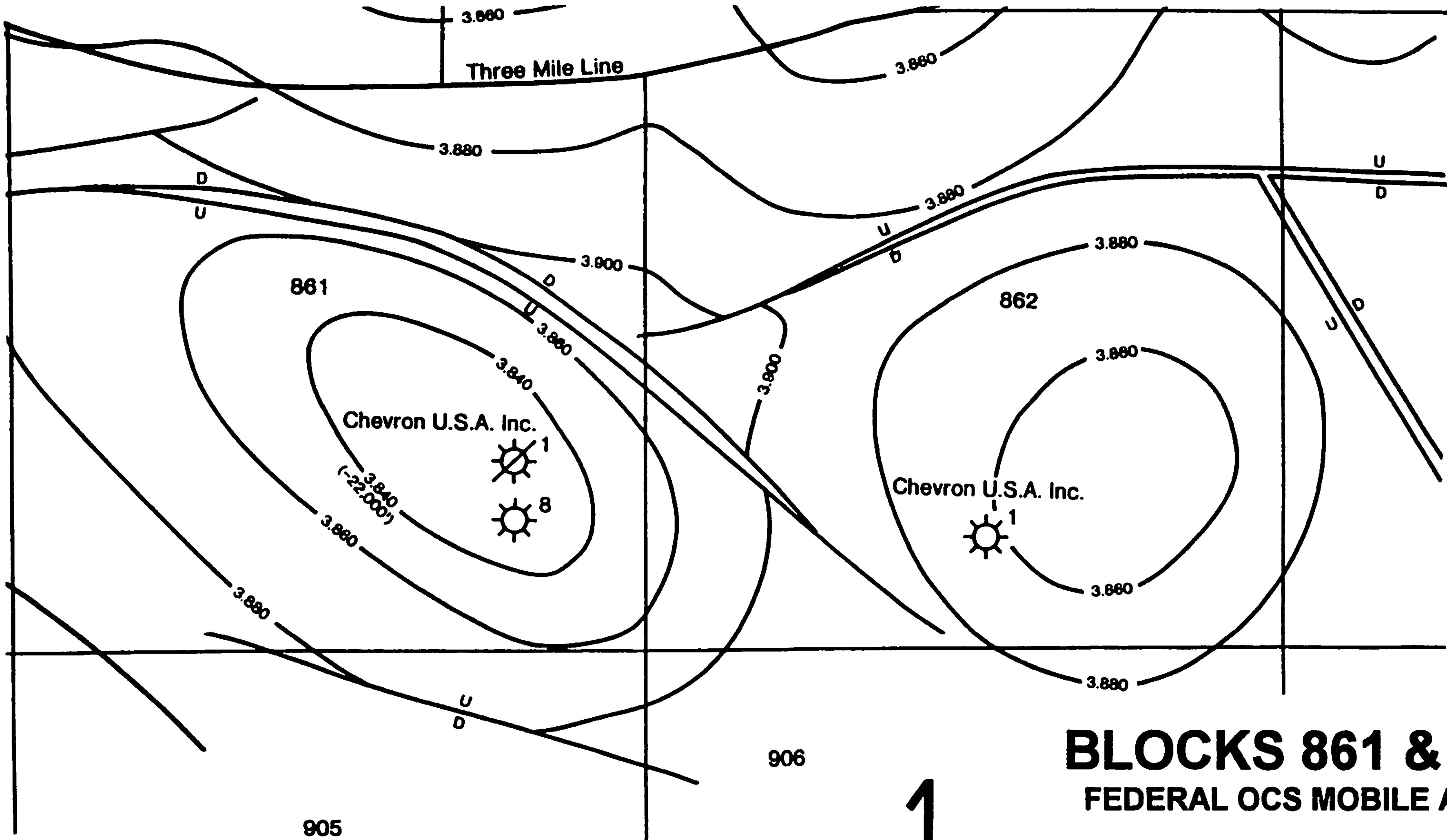
gas production. Cumulative gas production for the field from five producing wells as of 12/31/94 was 10,878 barrels of condensate and 163,364,057 MCF of gas. Monthly production for December 1994 was 2,190 barrels of condensate and 3,196,237 MCF of gas.

The primary reservoir for the Lower Mobile Bay-Mary Ann Field is an eolian sandstone deposited in an arid environment. The top of the Norphlet sand was then reworked by the marine transgression which eventually led to deposition of Smackover carbonates. This marine reworked section has very low porosity and little permeability, and is considered to form the seal for the reservoir in conjunction with the low perm carbonates of the Lower Smackover. The better reservoir rock is the eolian sand which has not been reworked by the marine transgression. Average porosity and permeabilities are 12% and 4 millidarcies (Marzano et al., 1988). Bolin et al. (1989) reported the average porosity as 11% and average permeability to be 1.0 millidarcy. Porosity and permeabilities range up to 17% porosity and 120 millidarcies of permeability (Marzano et al., 1988). These high porosities are not normally seen at depths below 20,000 feet and are believed to be the result of a combination of preserved primary and secondary enhanced porosity. The Norphlet sand in the field area has undergone several episodes of cementation and decementation (Marzano et al., 1988).

OCS Blocks 861 and 862

In 1985, Chevron, U.S.A., Inc., began drilling its first test well in Mobile Block 861. The well was drilled to a total depth of 21,416 feet and encountered high pressure in the Norphlet. A reported underground blowout occurred, charging shallow zones which were unprotected by casing. Several shallow relief wells were drilled, as well as two deeper wells in an attempt to intersect the well bore of the out-of-control well. Before the completion of the relief wells the first well bridged over (Ericksen and Thieling, 1993). A replacement well was drilled in 1991 on the block, and in December 1993 Chevron reported testing of the No. 8 well in Mobile Block 861. The well flowed 57 MMCFGPD from below 21,000 feet (Hart's Oil and Gas World, 1994). Additionally, a Norphlet test well has also been drilled and completed in Mobile Block 862, the block adjacent to Block 861 to the east. No information or test data have been released as yet by the operator for this well.

Figure 20 is a portion of a seismic structure map, contoured on near the top of Norphlet porosity, which covers blocks 861 and 862 (modified from Ericksen and Thieling, 1993). The map shows two separate anticlinal closures, one in Block 861 and one in Block 862, with associated faulting to the north and east of each structure. The structures are probably both caused by salt pillowing.



BLOCKS 861 & 862

FEDERAL OCS MOBILE AREA

Seismic Structure Map
Datum: Near top of Norphlet

Scale: 1" = 4000'
Contour interval: .020 ms
Interpretation: W. L. Harper

Figure 20. Seismic structure map, near top of Norphlet, Federal OCS Blocks 861 and 862, Mobile area (modified from Ericksen and Thieling, 1993).

Reservoir data for the two block discoveries are not available, but well logs indicate thick and porous Norphlet sand was encountered by both the Block 861, # 8 well and the Block 862, # 1 well. Approximately 460 feet of porous Norphlet sand was encountered by the Block 861, #8 well between 21,650 feet and 22,117 feet measured depth. Cross plotted porosity values from the neutron/density log ranged from 8% to 19%. The logs for the Block 862 well indicated that the well had encountered at least 135 feet of Norphlet sand between 21,928 feet and 22,075 feet measured depth. Cross plotted porosity values from the well's neutron/density logs ranged from 6% to 16%.

MISSISSIPPI JURASSIC OIL AND GAS PRODUCTION

Since the 1951 discovery of oil and gas in the Smackover at Tinsley Field, Yazoo County, Mississippi, the Jurassic has been an important hydrocarbon producing target for explorationists in Mississippi. A brief discussion of Mississippi's Jurassic oil and gas/condensate production follows.

Three Upper Jurassic hydrocarbon trends in the southern Mississippi/Alabama area can be delineated. These trends are recognized by hydrocarbon types, basinal position, and relationship to regional structural features (Mancini et al., 1986). The three trends generally parallel each other, trending northwest to southeast across central and southern Mississippi, extending to the southeast into Mississippi's state offshore waters, through southwestern Alabama onshore, Alabama's state offshore waters, into Federal offshore waters, and the panhandle of Florida (Figure 21).

An Upper Jurassic oil trend is identified in the area north of the regional peripheral fault trend (Figure 21). Salt anticlines and basement highs created the primary petroleum traps in this trend with Smackover grainstones, boundstones, dolostones, and Norphlet marine, eolian and wadi sandstones being the principal reservoirs (Mancini et al., 1986). The central trend onshore is the Upper Jurassic oil and gas-condensate trend. It is defined as onshore between the regional peripheral fault trend and the Wiggins Arch (Figure 21). This trend has the largest areal extent of the three trends in Mississippi and includes most of the Jurassic oil and gas production in Mississippi. The principal petroleum traps were created by salt anticlines and extensional faults. Fluvial-deltaic sandstones of the Cotton Valley, carbonates and fluvial-deltaic sandstones of the Haynesville, grainstones, packstones, dolostones, and marine sandstones of the Smackover are the principal reservoirs (Mancini et al., 1986).

A third trend, which includes the study area, is an Upper Jurassic deep natural gas trend. It can be delineated onshore south of the Wiggins Arch and

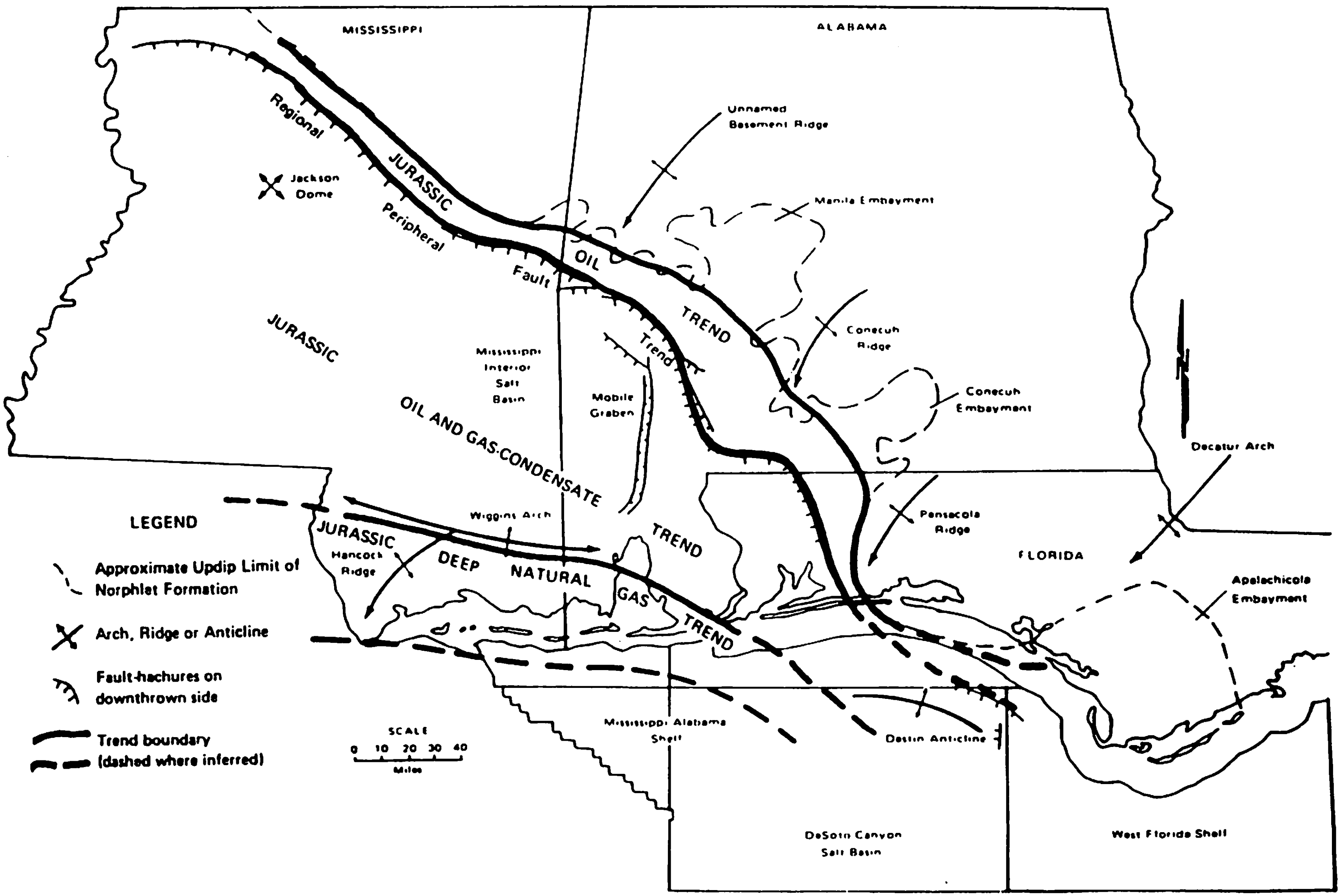


Figure 21. Map showing Jurassic hydrocarbon trends, MAFLA area (from Mancini et al., 1986).

extends into the Mississippi-Alabama shelf area offshore (Figure 21). The known petroleum traps are faulted anticlines which are salt related. Deltaic-strand plain sandstones of the Cotton Valley and eolian sandstones of the Norphlet are the producing reservoirs (Mancini et al., 1986). In recent years, numerous Norphlet gas fields have been discovered which produce from eolian sandstones below 20,000 feet in the Alabama offshore state waters to the east and Federal offshore waters just south and east of Mississippi's eastern offshore state waters (figures 7 and 16). This indicates that the eastern portion of the state's offshore waters has excellent potential for the future discovery of deep Norphlet gas reservoirs.

As of 12/31/94, 127 fields in Mississippi had produced oil and gas from Jurassic-aged reservoirs. Cumulative Jurassic oil and gas production to 12/31/94 was 285,865,141 barrels of oil and 1,306,477,396 MCF of gas. These totals represent 11.8% of the total cumulative oil and 16.9% of the total cumulative gas produced from all the oil and gas/condensate fields in the State of Mississippi. Mississippi's 1994 annual oil and gas production from Jurassic reservoirs totaled 4,342,947 barrels of oil and 55,528,552 MCF of gas.

The first Mississippi Cotton Valley production was established in 1958 at Soso Field in Jasper County. As of 12/31/94, 82.7 million barrels of oil/condensate and 1.09 billion cubic feet of gas had been produced from the

Cotton Valley in 45 of the 127 Jurassic fields in Mississippi. This production represents 28.94% of the total Jurassic oil/condensate and 8.37% of the total Jurassic gas produced in Mississippi (Table 8 and Figure 22). Mississippi's 1994 annual oil and gas production from Cotton Valley reservoirs totaled 1,183,673 barrels of oil and 3,998,730 MCF of gas. Individual field cumulative production for the Cotton Valley is presented in Table 9, in order of the year of field discovery. The average cumulative Cotton Valley production per field is 1,128,128 barrels of oil and 2,429,753 MCF of gas. Figure 23 is a Cotton Valley production index map showing field locations. Field locations are identified by numbers corresponding to the numbered field names in Table 9.

Mississippi's first Haynesville/Buckner production was discovered in 1969 at West Paulding Field in Jasper County. Oolitic grainstones of the Buckner are a minor hydrocarbon producer in east-central Mississippi. Generally, the Buckner is more important as a seal for Smackover reservoirs (Jackson and Harris, 1982). Sandstones in the Haynesville are the better oil and gas reservoirs. As of 12/31/94, 19.1 million barrels of oil/condensate and 176.8 billion cubic feet of gas had been produced from the Haynesville/Buckner in 19 of the 127 Jurassic fields in Mississippi. This production represents 6.69% of the total Jurassic oil/condensate and 13.53% of the total Jurassic gas produced in Mississippi (Table 8 and Figure 22). Mississippi's 1994 annual oil and gas production from Haynesville/Buckner reservoirs totaled 372,549 barrels of oil

MISSISSIPPI 1994 CUMULATIVE JURASSIC OIL & GAS PRODUCTION

	OIL (BBLS.)	% OF JURASSIC OIL PRODUCTION	GAS (MCF)	% OF JURASSIC GAS PRODUCTION
COTTON VALLEY	82,716,075	28.94%	109,338,919	8.37%
HAYNESVILLE/BUCKNER	19,123,202	6.69%	176,822,485	13.53%
SMACKOVER	172,186,725	60.23%	890,897,062	68.19%
NORPHLET	11,839,139	4.14%	129,418,930	9.91%
TOTALS	285,865,141	100.00%	1,306,477,396	100.00%

Table 8. Mississippi's 1994 cumulative Jurassic oil and gas production and percentage breakdown to formations (from Mississippi Oil and Gas Production Annuals, 1981-94).

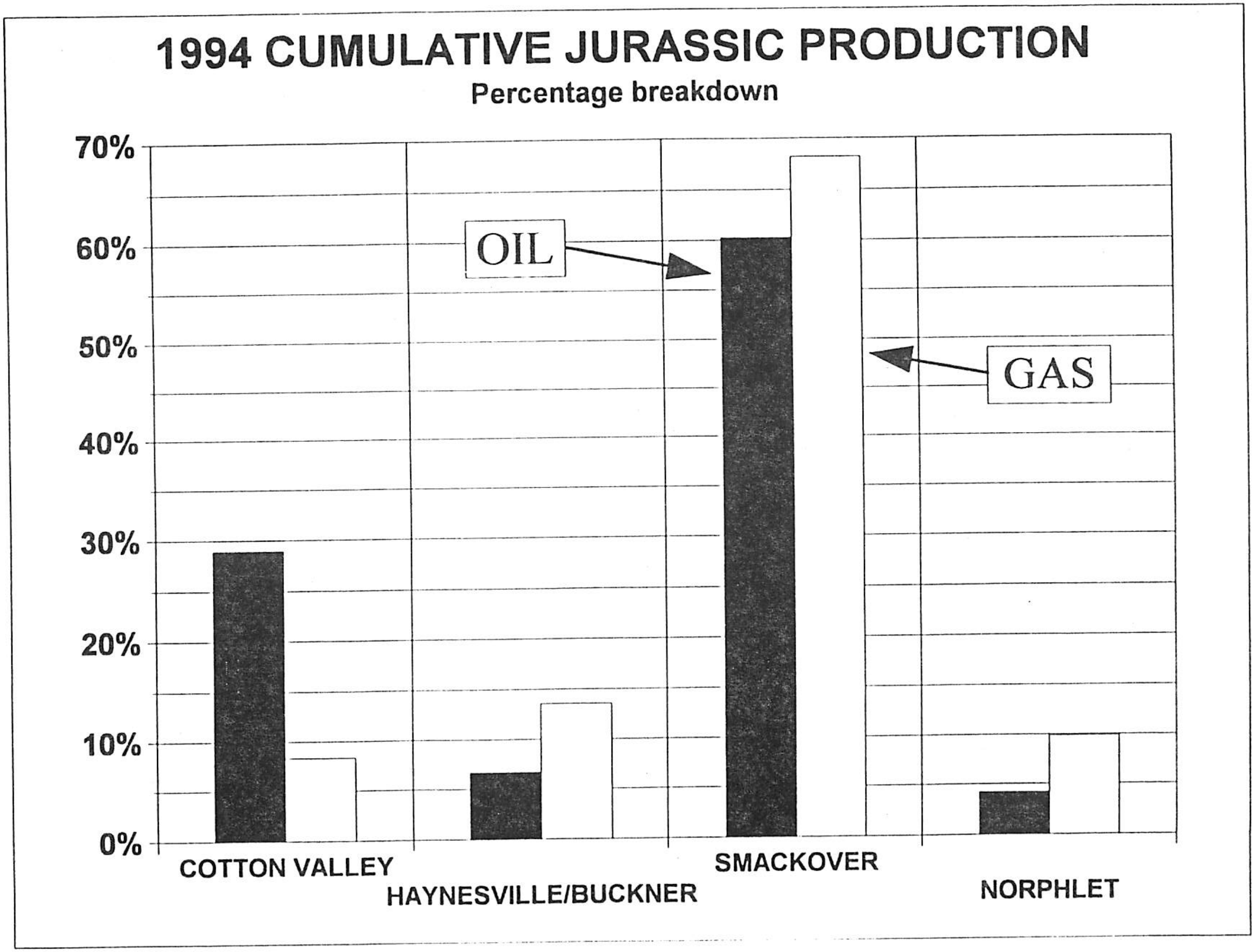


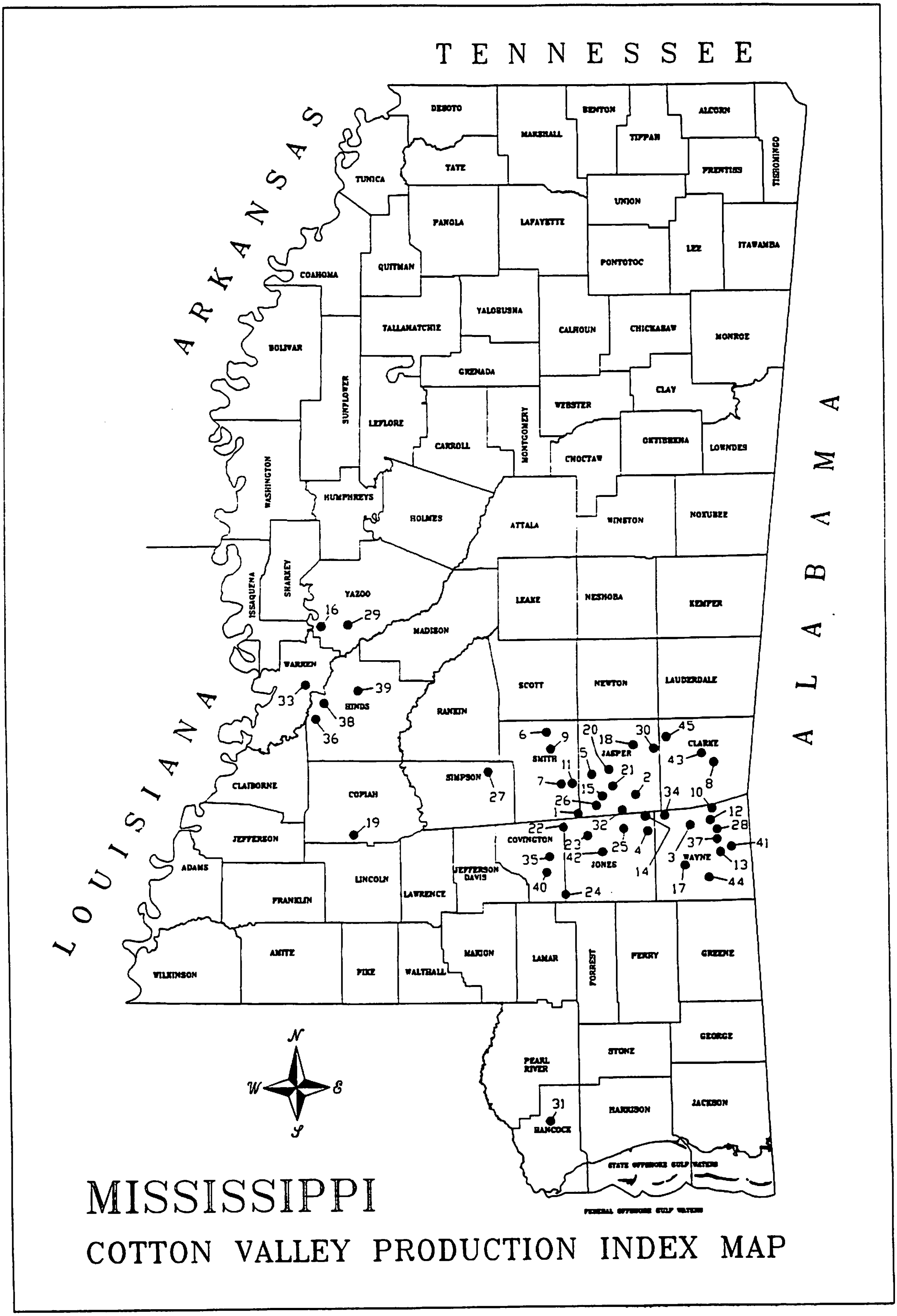
Figure 22. Graph showing percentage breakdown to formations of Mississippi's 1994 cumulative Jurassic oil and gas production.

Table 9. Mississippi's cumulative Cotton Valley production by field.

	FIELD *		COUNTY	OIL BBLS.	GAS MCF
1	Soso '58	Abandoned	Jasper	1,722,694	713,231
2	West Heidelberg '59		Jasper	7,210,189	498,624
3	West Yellow Creek '62		Wayne	1,697,354	565,670
4	Pool Creek '64		Jones	1,320,891	326,467
5	Bay Springs '65		Jasper	32,778,821	18,209,235
6	Lorena '65	Abandoned	Smith	31,690	3,587
7	Tallahala Creek '66		Smith	3,741,121	10,909,630
8	Quitman '66		Clarke	1,999,214	522,557
9	Shongelo '66		Smith	874,240	1,220,010
10	Chaparral '68		Wayne	18,139	495
11	East Tallahala Creek '68		Smith	1,321,703	1,260,510
12	Diamond '68		Wayne	4,898,541	2,229,448
13	Winchester '69		Wayne	190,649	65,645
14	Bryan '69		Jones	5,295,780	549,426
15	Stringer '69		Jasper	1,537,650	1,315,698
16	Satartia '70	Abandoned	Yazoo	12,377	82,124
17	West Clara '70	Abandoned	Wayne	32,846	17,430
18	Missionary '71		Jasper	1,251,017	4,248
19	Glancy '71	Abandoned	Copiah	870	94,172
20	McNeal '73		Jasper	3,501,685	5,500,834
21	Waldrup '73		Jasper	777,581	22,956
22	South Summerland '74	Abandoned	Jones	495,445	188,504
23	Calhoun '75		Jones	465,207	2,591,973
24	Shelton Creek '76	Abandoned	Jones	22,050	12,992
25	Reedy Creek '77		Jones	4,840,169	7,283,894
26	Mossville '77	Abandoned	Jasper	1,447	0
27	Martinville '77	Abandoned	Simpson	236,746	95,843
28	Mill Creek '79	Abandoned	Wayne	2,366	0
29	Mechanicsburg '80		Yazoo	114,134	3,055,076
30	Orange '80	Abandoned	Jasper	103,861	0
31	Catahoula Creek '81		Hancock	0	5,692,969
32	Sharon '81	Abandoned	Jasper	10,382	9,450
33	Bovina '82		Warren	21,411	12,850,724
34	West Eucutta '84		Wayne	136,947	0
35	Collins '84		Covington	3,976,785	4,530,320
36	Newman '84		Hinds	64,622	22,047,923
37	Waynesboro '85		Wayne	117,967	83,428
38	Edwards '85		Hinds	47,602	1,875,492
39	Bolton '87		Hinds	301,761	4,220,247
40	Seminary '88		Covington	126,552	119,301
41	East Waynesboro '89		Wayne	522,417	87,859
42	Tallahoma Creek '90		Jones	615,530	364,291
43	Peachtree '93		Clarke	120,371	9,173
44	Crawford Creek '94		Wayne	146,132	107,463
45	Enterprise '94		Clarke	11,119	0

Total number of Fields with Cotton Valley production = 45

Total oil produced = 82,716,075 BO
Total gas produced = 109,338,919 MCF
Cumulative production to 12/31/94.
*** Year of discovery**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UNION
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LAFAYETTE
ITAWAMBA
LEE
PONTOTOC
COAHOMA
QUITMAN
YALOBUSHA
TALLAHATCHIE
CALHOUN
CHICKASAW
MONROE
BOLIVAR
GRENADA
CLAY
SUNFLOWER
LEFLORE
WEBSTER
MONTGOMERY
CARROLL
OKTIBBEHA
LOWNDES
CHOCTAW
WASHINGTON
HUMPHREYS
HOLMES
ATTALA
WINSTON
NOXUBEE
SHARKEY
ISSAQUENA
YAZOO
LEAKE
NESHOBA
KEMPER
MADISON
WARREN
SCOTT
NEWTON
LAUDERDALE
HINDS
RANKIN
SMITH
JASPER
CLARKE
SIMPSON
CLAIBORNE
COPIAH
COVINGTON
JONES
WAYNE
JEFFERSON
ADAMS
LINCOLN
JEFFERSON DAVIS
LAWRENCE
FRANKLIN
WILKINSON
AMITE
PIKE
WALTHALL
MARION
LAMAR
FORREST
PERRY
GREENE
GEORGE
STONE
PEARL RIVER
HANCOCK
HARRISON
JACKSON
STATE OFFSHORE GULF WATERS
FEDERAL OFFSHORE GULF WATERS
N
S
E
W
MISSISSIPPI
COTTON VALLEY PRODUCTION INDEX MAP

Figure 23.

and 15,564,761 MCF of gas. The average Haynesville/Buckner cumulative production per field is 1,006,484 barrels of oil and 9,306,446 MCF of gas. Individual field production is presented in Table 10, in order of the year of field discovery. Figure 24 is a Haynesville/Buckner production index map showing field locations. Field locations are identified by numbers corresponding to numbered field names listed in Table 10.

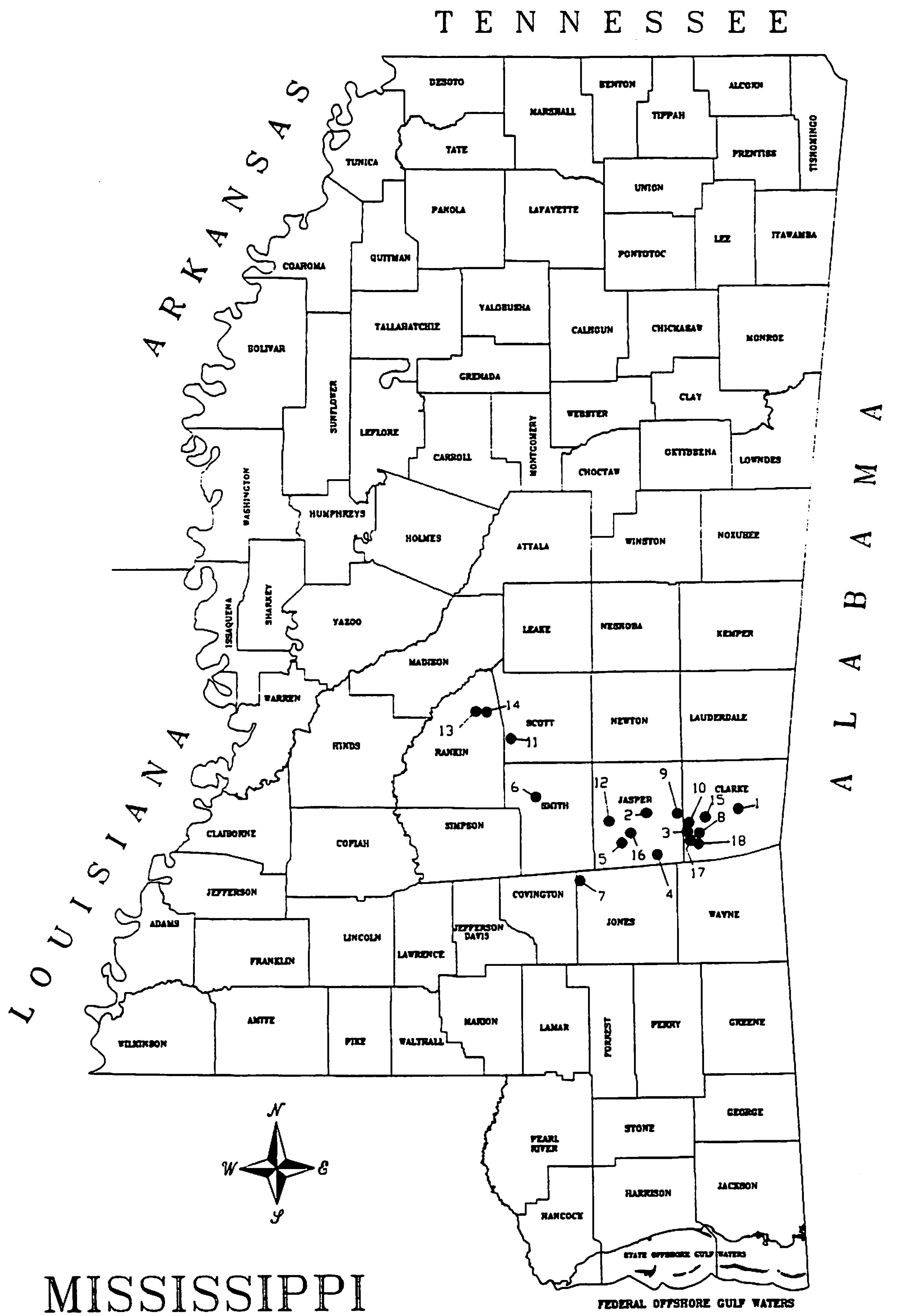
Since the 1951 discovery of Smackover oil and gas in Mississippi at Tinsley Field, which was later deemed uncommercial, 172.2 million barrels of oil/condensate and 890.9 billion cubic feet of gas have been produced from the Smackover in 87 of the 127 Jurassic fields in Mississippi, as of 12/31/94. This production represents 60.23% of the total Jurassic oil/condensate and 68.19% of the total Jurassic gas produced in Mississippi (Table 8 and Figure 22). Mississippi's 1994 annual oil and gas production from Smackover reservoirs totaled 2,633,915 barrels of oil and 27,284,459 MCF of gas. The average Smackover cumulative production per field is 1,979,157 barrels of oil and 10,240,196 MCF of gas. Individual field production is presented in Table 11, in order of the year of field discovery. Figure 25 is a Smackover production index map showing field locations. Field locations are identified by numbers corresponding to numbered field names listed in Table 11.

Table 10. Mississippi's cumulative Haynesville production by field.

	FIELD *		COUNTY	OIL BBLS.	GAS MCF
1	Quitman '66 **		Clarke	13,259,555	3,599,096
2	West Paulding '69		Jasper	336,347	1,295,031
3	West Nancy '70		Clarke	355,293	1,265,537
4	Stafford Springs '70		Jasper	59,326	257,665
5	Stringer '70		Jasper	489	147
6	Boykin Church '71		Smith	3,737	810
7	South Summerland '74		Jones	2,507,631	2,580,914
8	North Nancy '74		Clarke	28,865	1,427
9	West Barnett '75		Jasper	210,764	75,748
10	Barnett '75		Clarke	5,491	0
11	Morton '76		Scott	77,308	9,206
12	Bay Springs '78		Jasper	2,023,868	2,867,377
13	South Pisgah '81	(CO_2)	Rankin	0	151,664,061
14	Hollybush Creek '82	(CO_2)	Rankin	0	13,091,639
15	Pleasant Ridge '86		Clarke	86	0
16	Waldrup '88		Jasper	17,846	0
17	Prairie Branch '91		Clarke	146,465	99,350
18	Nancy '92		Clarke	90,131	14,477

Total number of Haynesville/Buckner fields = 18

Total oil produced = 19,123,202 BO
Total gas produced = 176,822,485 MCF
Cumulative production to 12/31/94.
*** Year of discovery**
**** Reported as the Cotton Valley 11,000', 11,150', and 11,175' sands to the Mississippi Oil and Gas Board.**



MISSISSIPPI
HAYNESVILLE PRODUCTION INDEX MAP

Figure 24.

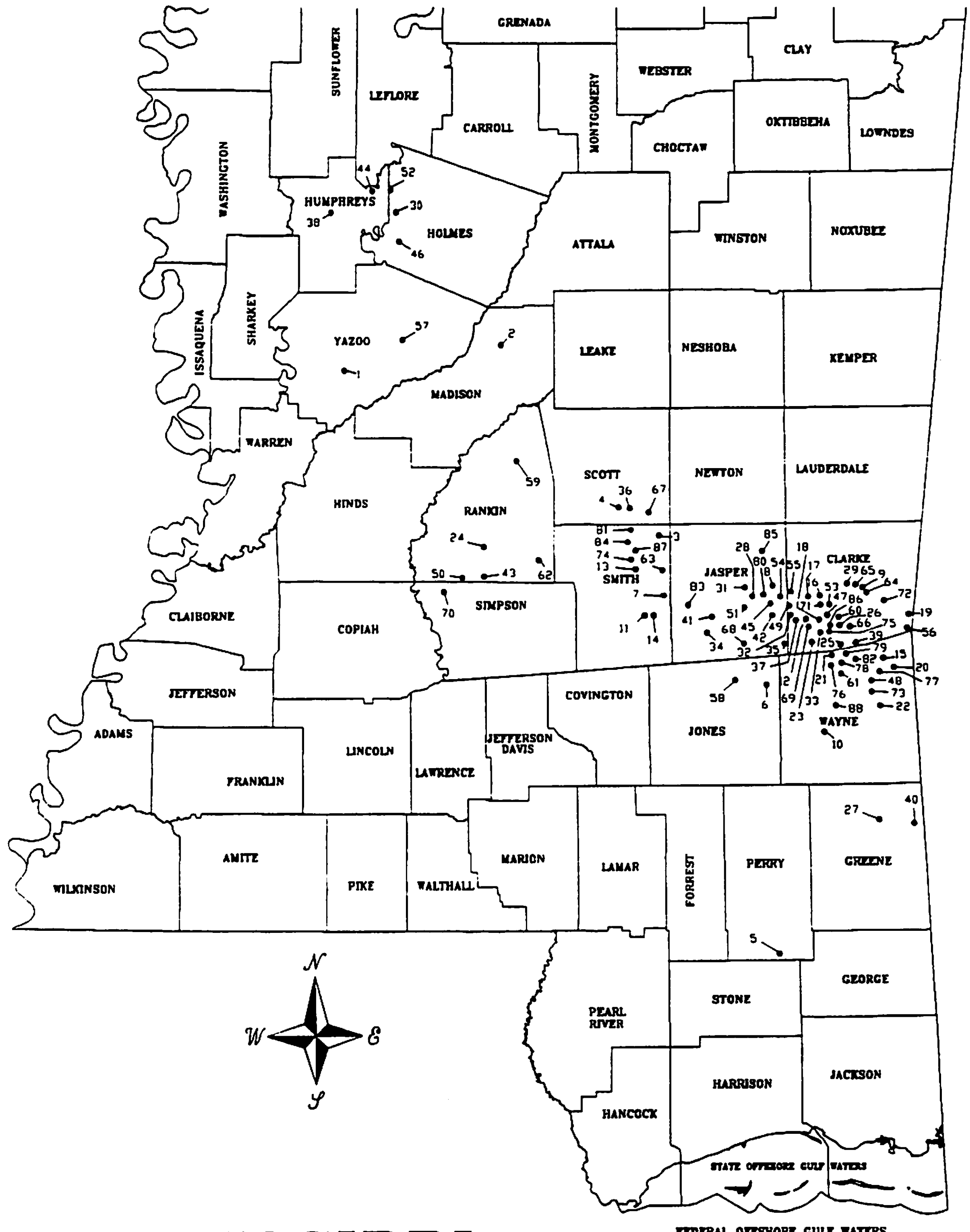
Table 11. Mississippi's cumulative Smackover production by field.

	FIELD *		COUNTY	OIL BBLS.	GAS MCF
1	Tinsley '51	Abandoned	Yazoo	NA	NA
2	Loring '54		Madison	1,164,294	64,057,076
3	Bienville Forest '63		Smith	380,118	179,251
4	Barber Creek '64		Scott	1,050,069	409,252
5	Black Creek '65	Abandoned	Perry	0	6,900
6	Pool Creek '65		Jones	1,881,309	648,351
7	Sylvarena '65	Abandoned	Smith	55,982	52,542
8	East Paulding '65		Jasper	29,762	4,882
9	Quitman '66		Clarke	5,431,042	609,067
10	West Clara '66		Wayne	564,124	288,910
11	Tallahala Creek '67		Smith	9,998,420	15,475,492
12	Nancy '67		Clarke	5,446,149	3,393,364
13	Shongelo Creek '67		Smith	85,621	63,031
14	East Tallahala Creek '67		Smith	4,767,503	3,945,625
15	Cypress Creek '68		Wayne	3,272,766	744,956
16	Harmony '68	Abandoned	Clarke	1,788,594	639,827
17	Pachuta Creek '68		Clarke	51,664,155	24,238,166
18	East Nancy '68		Clarke	6,307,320	3,240,637
19	Double Creek '68	Abandoned	Clarke	116,123	0
20	South Cypress Creek '68		Wayne	12,045,805	3,320,873
21	Wolf Creek '69		Wayne	1,582,794	1,490,972
22	Winchester '69		Wayne	323,602	124,302
23	Goodwater '69		Clarke	4,479,915	7,805,286
24	Thomasville '69		Rankin	4,230	405,198,468
25	Shubuta '69		Clarke	1,272,301	950,042
26	Watts Creek '69		Clarke	871,306	191,332
27	Jonathan '69	Abandoned	Greene	NA	NA
28	Paulding '69	Abandoned	Jasper	85,389	41,910
29	Davis '69	Abandoned	Clarke	68,075	0
30	Tchula Lake '69		Holmes	591,055	7,901,752
31	West Paulding '69		Jasper	1,385,049	239,797
32	West Nancy '70		Clarke	18,973,688	12,613,218
33	North Shubuta '70		Clarke	773,510	2,042,653
34	Stringer '70	Abandoned	Jasper	1,534	0
35	Stafford Springs '70		Jasper	1,000,305	2,827,438
36	East Barber Creek '70		Scott	853,035	504,837
37	Prairie Branch '70		Clarke	4,174,483	2,923,381
38	Belzoni '71	Abandoned	Humphreys	44,203	3,887
39	Garland Creek '71	Abandoned	Clarke	88,034	3,025
40	South State Line '71		Greene	603,865	27,088,245
41	Lake Como '71		Jasper	11,032,621	17,027,060
42	Lake Utopia '71		Jasper	4,697,932	3,127,725
43	Piney Woods '71		Rankin	0	63,049,795
44	Fomosla '71	Abandoned	Humphreys	135,543	1,475,586
45	Vossburg '72		Jasper	646,646	260,244

Table 11. (Continued) Mississippi's cumulative Smackover production by field.

	FIELD *		COUNTY	OIL BBLS.	GAS MCF
46	Thornton '73		Holmes	18,901	515,715
47	Hale '73	Abandoned	Clarke	1,018,285	270,554
48	Boyce '73	Abandoned	Wayne	221,407	309,768
49	Barnett '74		Clarke	940,081	278,954
50	S. W. Piney Woods '74		Rankin	0	112,116,350
51	South Paulding '75		Jasper	485,092	253,436
52	Horseshoe Lake '76		Holmes	783,036	7,160,539
53	South Harmony '76		Clarke	150,327	3,091
54	West Barnett '76	Abandoned	Jasper	6,511	1,621
55	Stagecoach Road '76	Abandoned	Clarke	2,536	7,325
56	Bucatunna Creek '77		Clarke	970,509	76
57	Benton '77	Abandoned	Yazoo	13,278	122,014
58	Reedy Creek '77	Abandoned	Jones	69,484	135,618
59	South Pisgah '78		Rankin	0	547,000
60	DeSoto '78	Abandoned	Clarke	56,176	0
61	East Yellow Creek '80	Abandoned	Wayne	11,307	0
62	Johns '80		Rankin	0	55,760,489
63	Pineville '80	Abandoned	Smith	19,034	602
64	East Quitman '81	Abandoned	Clarke	37,612	0
65	Northwest Quitman '81	Abandoned	Clarke	32,569	0
66	Sumrall '82		Clarke	168,041	1,039
67	Otho '82		Scott	1,516,738	417,869
68	W. Heidelberg '82		Jasper	41,800	14,553
69	Fluffer Creek '83	Abandoned	Clarke	444	0
70	Harrisville '84		Simpson	0	30,378,662
71	Pleasant Ridge '84		Clarke	216,107	51,480
72	Mannassa '85	Abandoned	Clarke	4,129	0
73	Waynesboro '85		Wayne	185,582	454,983
74	Bowling Creek '85	Abandoned	Smith	13,494	0
75	Mike Creek '86		Clarke	246,983	14,891
76	South Wolf Creek '86		Wayne	262,657	78,457
77	Diamond '87		Wayne	276,093	448,964
78	Clear Creek '88		Wayne	839,304	1,128,081
79	North Hiwanee '88		Wayne	98,338	381,274
80	Beaver Dam '89		Jasper	170,313	15,001
81	Tallabogue Creek '89		Smith	64,598	22,770
82	Chaparral '90		Wayne	2,657,530	1,247,964
83	Bay Springs '90		Jasper	504,410	417,358
84	Union Grove '90		Smith	20,463	0
85	Missionary '91		Jasper	11,909	0
86	Addie Mae '92		Clarke	212,421	63,830
87	West Pineville '92		Smith	88,476	14,576
88	North Clara '93		Wayne	12,479	53,001

Total number of fields with Smackover production = 88
Total oil produced = 172,186,725 BO
Total gas produced = 890,897,062 MCF
Cumulative production to 12/31/94.
*** Year of discovery**



MISSISSIPPI
SMACKOVER PRODUCTION INDEX MAP

Figure 25.

In 1967 the first Norphlet production was discovered at Pelahatchie Field in Rankin County. As of 12/31/94, 11.8 million barrels of oil/condensate and 129.4 billion cubic feet of gas have been produced from the Norphlet reservoirs at 15 of the 127 Jurassic fields in Mississippi. This production represents 4.14% of the total Jurassic oil/condensate and 9.91% of the total Jurassic gas produced in Mississippi (Table 8 and Figure 22). Mississippi's 1994 annual oil and gas production from Norphlet reservoirs totaled 152,810 barrels of oil and 8,680,602 MCF of gas. The average Norphlet cumulative production per field is 789,280 barrels of oil and 8,627,928 MCF of gas. Individual field production is presented in Table 12, in order of the year of field discovery. Figure 26 is a Norphlet production index map showing field locations. Field locations are identified by numbers corresponding to numbered field names listed in Table 12.

CONCLUSIONS

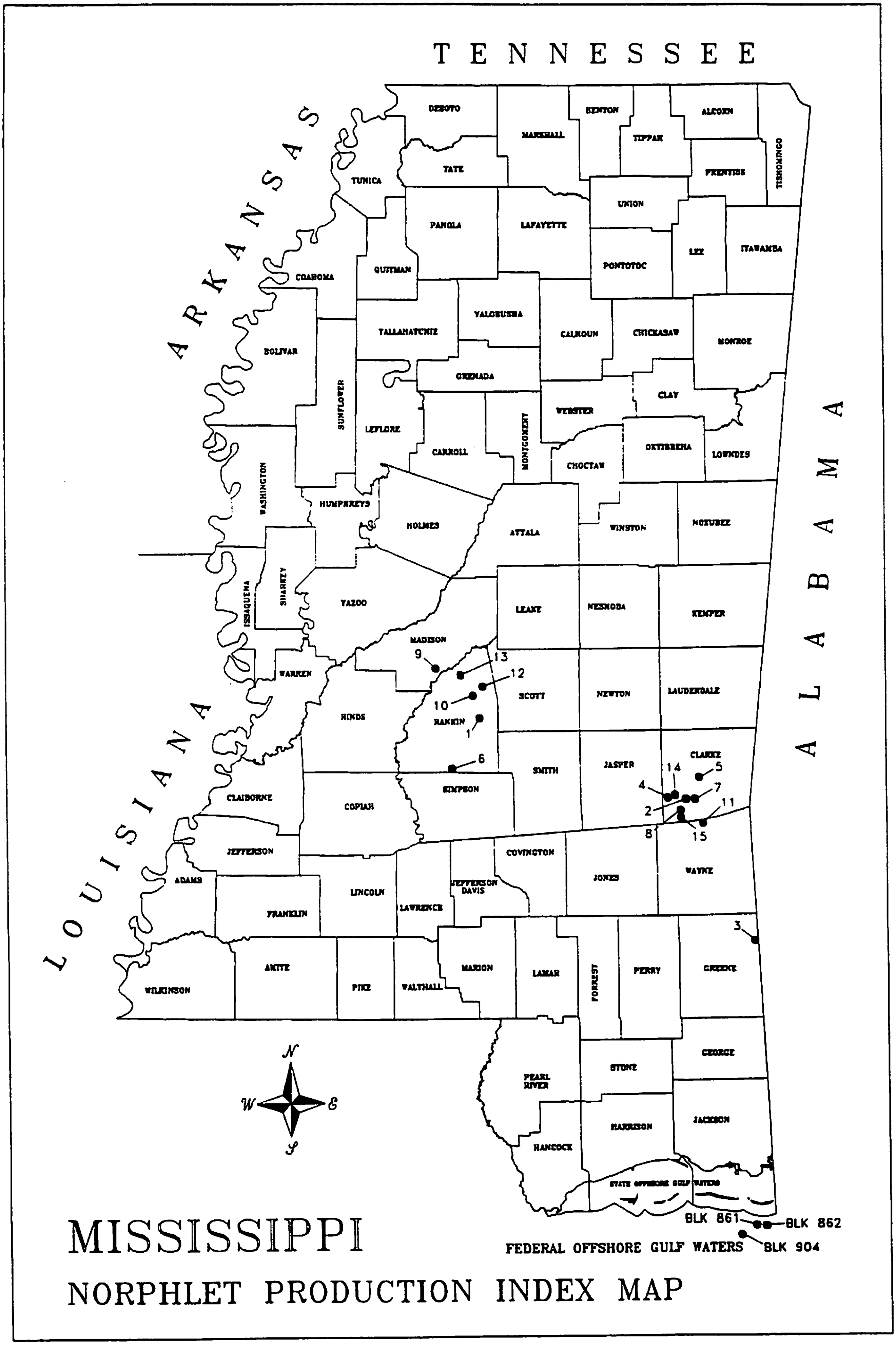
With only one Upper Jurassic-age discovery of deep natural gas production in the three coastal counties and offshore state waters of Mississippi, and a total wildcat drilling density of one well penetrating Jurassic rocks for every 290 square miles in an area that covers approximately 2,610 square miles, it can be said that much of Mississippi's coastal area and offshore waters is

Table 12. Mississippi's cumulative Norphlet production by field.

	FIELD *		COUNTY	OIL BBLS.	GAS MCF
1	Pelahatchie '67		Rankin	668,908	676,879
2	East Nancy '69		Clarke	4,451,333	1,061,074
3	South State Line '70		Greene	0	2,448,508
4	Prairie Branch '70		Clarke	4,726,285	1,665,836
5	Archusa Springs '71	Abandoned	Clarke	15,126	5,704
6	Piney Woods '76		Rankin	0	66,791
7	Watts Creek '76		Clarke	27,077	2,255
8	Fluffer Creek '76	Abandoned	Clarke	207,514	55,644
9	Gluckstadt '77	(CO2)	Madison	167	24,876,456
10	South Pisgah '78	(CO2)	Rankin	0	38,574,542
11	North Hiwannee '79		Wayne	321,906	653,737
12	Hollybush Creek '79	(CO2)	Rankin	0	5,713,934
13	Goshen Springs '80	(CO2)	Rankin	0	53,262,688
14	Nancy '86		Clarke	1,228,569	312,617
15	Goodwater '90		Clarke	192,254	42,265

Total number of Norphlet fields = 15

Total oil produced = 11,839,139 BO
Total gas produced = 129,418,930 MCF
Cumulative production to 12/31/94.
*** Year of discovery**



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BLK 862
BLK 904
FEDERAL OFFSHORE GULF WATERS
MISSISSIPPI
NORPHLET PRODUCTION INDEX MAP

Figure 26.

underexplored. The probable reasons for this are the initial drilling of mostly dry holes in the area, the lack of general data on the potential Jurassic reservoir rocks, the complicated stratigraphy and structure of the area, the rather poor cumulative gas production at the only gas field discovered in the area, depth of burial for most Jurassic sediments being below 16,000 to 20,000 plus feet, and low oil and gas prices.

Given the above stated facts, recently published information on the area and the establishment of deep Norphlet gas production in Alabama's state offshore waters and the Federal OCS waters adjacent to Mississippi's eastern offshore state waters indicate excellent exploration potential is present in the eastern half of the study area. Seismic interpretations indicate the presence of several deep Norphlet structures in the state's offshore waters adjacent to gas-productive areas in the Federal OCS waters. The seismic stratigraphic interpretations presented in Rhodes and Maxwell's work indicate potential areas and models for exploration in the Smackover grainstone belt around the flanks of the Wiggins Arch, as well as potential exploration targets in the Haynesville Frisco City granite washes on the flanks of Paleozoic highs which are similar to the Frisco City trend of southern Alabama. Additionally, gas shows encountered by the Mobil #1 USA well in eastern Harrison County show that Cotton Valley sands may be gas productive in structural traps above the Paleozoic highs on the Wiggins Arch.

Even with these positive points, the great depth of most of the Upper Jurassic sediments in the study area will probably cause additional drilling in the study area to depend on generally higher prices for oil and gas. Jurassic oil and gas production in Mississippi will continue to be an important economic resource to the state as shown by the review of Mississippi's Jurassic oil and gas production.

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