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NATURAL GAS PLAYS IN JURASSIC RESERVOIRS OF SOUTHWESTERN ALABAMA AND THE FLORIDA PANHANDLE AREA

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ABSTRACT

Three Jurassic natural gas trends can be delineated in southwestern Alabama and the Florida panhandle area. These include a deep natural gas trend, a natural gas and condensate trend, and an oil and associated natural gas trend. Trends are recognized by hydrocarbon types, basinal positions, and relationships to regional structural features. Within these natural gas trends, eight distinct natural gas plays can be identified. Plays are recognized by characteristic hydrocarbon traps and reservoirs.

The deep natural gas trend includes the Mobile Bay area play that is characterized by structural hydrocarbon traps associated with salt tectonism and Norphlet sandstone reservoirs at depths exceeding 20,000 feet. The natural gas and condensate trend includes the Mississippi interior salt basin play, the Mobile graben play, the Wiggins arch complex play, and the Pollard fault system play. The Mississippi interior salt basin play is typified by salt-related structural and combination hydrocarbon traps and Smackover dolomitized oolitic, oncolitic, and peloidal grainstone and packstone reservoirs at depths of approximately 16,000 feet. The Mobile graben play is exemplified by salt-induced structural hydrocarbon traps and Smackover dolostone and Norphlet sandstone reservoirs at depths ranging from 12,400 to 18,400 feet. The Wiggins arch complex play is characterized by structural and combination hydrocarbon traps associated with stratigraphic pinch-outs and salt flow. These traps are salt-related and occur along the flanks of paleohighs associated with the Wiggins arch complex. Smackover dolostone reservoirs at depths ranging from 16,100 to 18,400 feet are typical of this play. The Pollard fault system play is typified by salt-induced structural hydrocarbon traps and reservoirs at depths of approximately 15,000 feet. These reservoirs are Smackover dolomitized oolitic and peloidal grainstones and packstones and Norphlet sandstones. The oil and associated natural gas trend includes the Gilbertown and West Bend fault systems play, the Foshee fault system play, and the basement ridge play. The Gilbertown and West Bend fault systems play is exemplified by salt-related structural or combination traps and Smackover dolomitized oolitic, oncolitic, and peloidal grainstone and packstone reservoirs and Norphlet sandstone reservoirs at depths ranging from 11,000 to 14,000 feet. The Foshee fault system play is characterized by structural and combination hydrocarbon traps related to salt movement and Smackover dolomitized peloidal grainstone and packstone and Norphlet sandstone reservoirs at depths of approximately 15,000 feet. The basement ridge play, which is typified by structural and combination traps associated with the Conecuh and Pensacola-Decatur ridge complexes and Smackover oolitic and peloidal grainstone and packstone and algal boundstone and Haynesville sandstone reservoirs at depths ranging from 11,800 to 15,500 feet, has potential for significant undiscovered natural gas.

INTRODUCTION

Since the 1967 discovery of oil in the Smackover Formation at Toxey field, Choctaw County, Alabama, and the 1968 discovery of gas condensate in the Norphlet Formation at Flomaton field, Escambia County, Alabama, Jurassic strata (Fig. 1) have become the primary hydrocarbon exploration targets in southwestern Alabama and the Florida panhandle area. The discovery in 1979 of significant quantities of natural gas in Norphlet sandstones in the Mobile Bay area first demonstrated the potential of the Norphlet in coastal and offshore Alabama. The 1986 oil discovery in the Haynesville Formation at Frisco City field, Monroe County, Alabama, has shown the potential of the Haynesville in southwestern Alabama. Presently, 77 fields are producing natural gas from Jurassic reservoirs in the area of study (Fig. 2). Cumulative production from these fields through 1989 includes 674 million barrels (MMB) of oil and condensate and 1.76 trillion cubic feet of gas (TCFG).

Mink et al. (1985) and Mancini et al. (1986) recognized three Jurassic trends based upon hydrocarbon types, basinal positions, and relationships to regional structural features in the Eastern Gulf of Mexico region. These trends include an oil trend, an oil and condensate trend, and a deep natural gas trend. These authors utilized the trends to determine the potential of the Eastern Gulf of Mexico region. The objective of this paper is to evaluate the information that has become available since 1986 and to integrate these data with previous studies in order to identify natural gas plays in the Jurassic reservoirs of southwestern Alabama and the Florida panhandle area. The natural gas resource of the Eastern Gulf of Mexico region represents an important energy source for the nation. Delineation of the natural gas plays in the area has practical application in the assessment of the potential of this resource.

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SERIES	STAGE	ROCK UNIT
Lower Cretaceous	Berriasian	Cotton Valley Group
----- ? -----	--- ? ---	
Upper Jurassic	Tithonian	
	Kimmerid-gian	Haynesville Formation
		Buckner Anhydrite Member
	Oxfordian	Smackover Formation
		Norphlet Formation
		Pine Hill Anhydrite Member
----- ? -----	--- ? ---	
Middle Jurassic	Callovian	Louann Salt
		Werner Formation
Lower Jurassic/ Upper Triassic		Eagle Mills Formation
		Undifferentiated Paleozoic rocks

Figure 1. Stratigraphic column for the Triassic and Jurassic strata of southwestern Alabama and the Florida panhandle area.

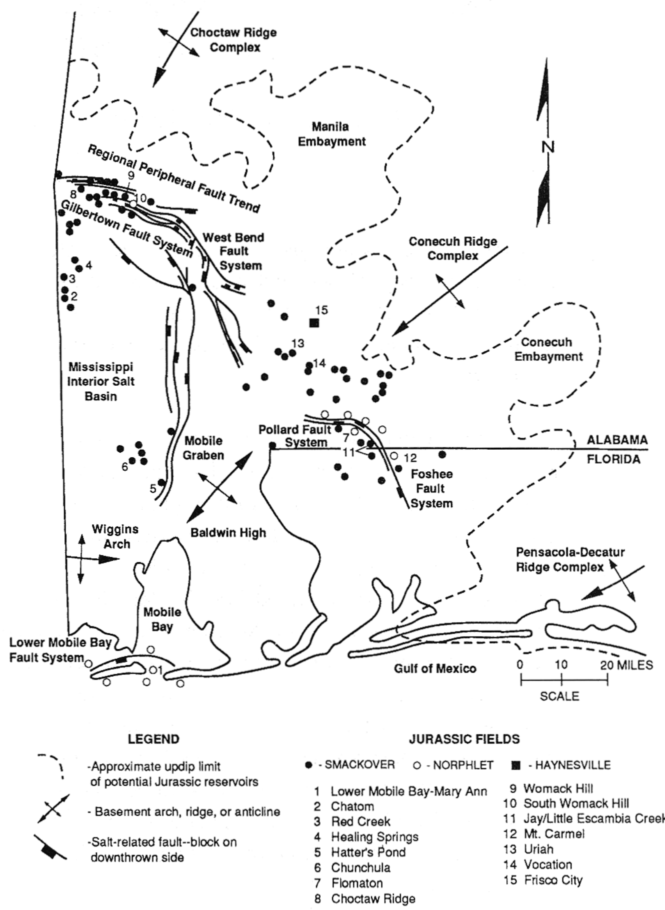

Figure 2. Map of major structural features and Jurassic fields of southwestern Alabama and the Florida panhandle area.

STRUCTURAL SETTING

The most pronounced structural elements in the study area are a group of related, largely en echelon extensional faults and grabens which are associated with salt movement and are referred to as the regional peripheral fault trend. This fault trend lies basinward of the updip limit of Jurassic Louann Salt. In the area of study, the peripheral fault trend includes the Gilbertown, West Bend, Pollard, and Foshee fault systems. Faults in the trend are parallel or subparallel to regional strike and are normal, up- or down-to-the-basin faults. Fault planes are listric and generally exhibit dips from 40° to 60°. Displacements of 200 feet to more than 2,500 feet have been interpreted for faults in the trend.

Movement of the Jurassic Louann Salt has resulted in a network of structures in southwestern Alabama and the Florida panhandle area (Martin, 1978). Structures include salt diapirs, massifs, and pillows, growth faults, and extensional fault and graben systems caused or accentuated by salt movement. The Mobile graben of southwestern Alabama is an example of a large graben system resulting from salt flow. The Lower Mobile Bay fault system, which is located south of the Wiggins arch complex in the Mobile Bay area, also is associated with salt tectonism. Numerous anticlines and faulted anticlines related to the movement of salt are located downdip of the extensional faults associated with the regional peripheral fault trend.

Large, basement-related paleohighs also are present in the area of study. Paleohighs include the Wiggins arch complex, which consists of the Wiggins arch, the Baldwin high and associated paleohighs, and the Choctaw, Conecuh, and Pensacola-Decatur ridge complexes (Fig. 2). These paleohighs greatly influenced the distribution of Jurassic sediments and served as major sources for terrigenous clastic deposits (Mancini et al., 1985).

The Mississippi interior salt basin (Fig. 2) is a broad, prominent depression on the basement surface. This sedimentary basin was an actively subsiding depocenter throughout the Jurassic (Wilson, 1975). The Manila and Conecuh embayments (Mancini and Benson, 1980) and the Mobile Bay area also served as Jurassic depocenters.

STRATIGRAPHY

The Middle to Upper Jurassic stratigraphic section in southwestern Alabama and the Florida panhandle area includes terrigenous clastics, carbonates, and evaporites, which were deposited principally in an arid climatic setting (Mancini et al., 1985). Middle and Upper Jurassic strata include the Werner Formation, the Louann Salt, the Norphlet Formation, the Smackover Formation, the Haynesville Formation, and the Cotton Valley Group (Fig. 1). The Werner Formation is an evaporite sequence that includes primarily anhydrite with minor shale, sandstone, and conglomerate and represents the initial incursion of marine water into the Gulf of Mexico basin (Salvador, 1987). The Louann Salt consists of silty, sandy, massive halite with interbedded anhydrite. The upper part of the Louann is the Pine Hill Anhydrite Member. The Norphlet Formation is predominantly a continental terrigenous clastic deposit consisting of conglomeratic sandstones and quartz-rich sandstones. Deposition was in alluvial fan and plain, fluvial (wadis), eolian dune and interdune, and playa lake environments. Sandstones reworked by marine processes occur at the top of the formation (Mancini et al., 1985). Deposition of the overlying Smackover carbonate sequence was associated with a major Jurassic transgressive event in the Gulf of Mexico region. The Smackover Formation consists of carbonate mudstone, oolitic, oncolitic, and peloidal wackestone, packstone and grainstone and algal boundstone. These carbonate rocks accumulated in subtidal to supratidal environments in a carbonate ramp depositional setting (Ahr, 1973; Mancini and Benson, 1980). The primary source of hydrocarbons in the Jurassic reservoirs in the study area is believed to be Smackover carbonate mudstones (Claypool and Mancini, 1989). The Haynesville Formation overlies the Smackover and includes evaporites, carbonates and terrigenous clastics. The lower part of the Haynesville is the Buckner Anhydrite Member, which Mann (1988) determined to have accumulated in subaqueous and subaerial environments. The middle and upper Haynesville sediments represent subtidal to continental deposition (Oxley et al., 1967). According to Tolson et al. (1983), the Cotton Valley Group, which overlies the Haynesville, consists of conglomeratic sandstones, shale and coal. The Cotton Valley was deposited in marginal marine to continental environments.

NATURAL GAS TRENDS AND PLAYS

Three Jurassic natural gas trends can be delineated in southwestern Alabama and the Florida panhandle area (Fig. 3). These include a deep natural gas trend, a natural gas and condensate trend, and an oil and associated natural gas trend. Trends are recognized by hydrocarbon types, basinal positions, and relationships to regional structural features. Within these natural gas trends, eight distinct natural gas plays can be identified. Plays are recognized by characteristic hydrocarbon traps, which are generally controlled by the dominant structural element involved, and reservoirs, which are distinguished primarily by depositional setting and diagenetic overprint.

The deep natural gas trend includes the Mobile Bay area play (Fig. 3). This trend is characterized by natural gas from deep Norphlet reservoirs located in a downdip basinal position south of the Wiggins arch complex.

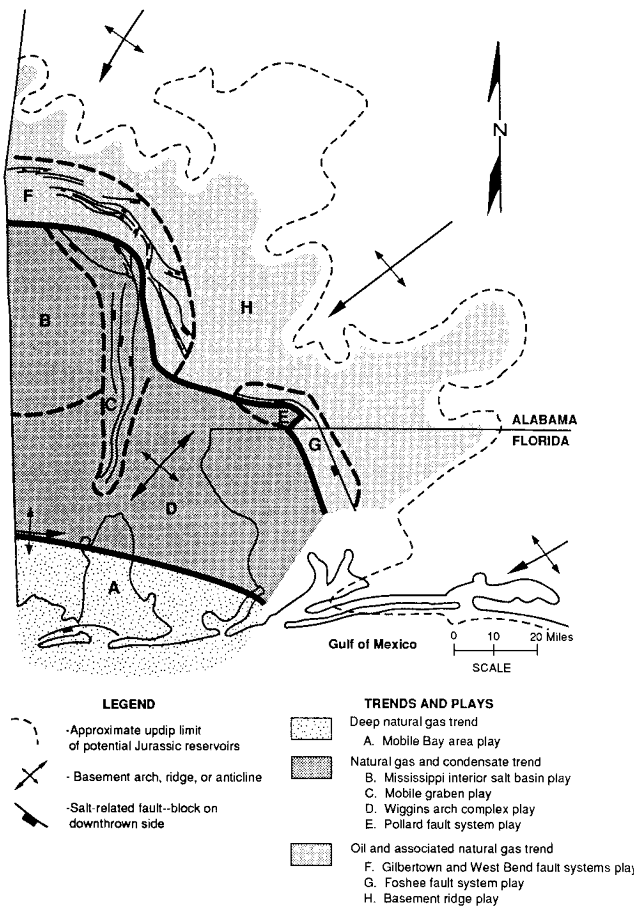

Figure 3. Jurassic natural gas trends and plays of southwestern Alabama and the Florida panhandle area.

The Mobile Bay area play was discovered in 1979 by Mobil Oil Exploration and Producing Southeast, Inc., with the drilling of the Alabama Block 76-1 well in state coastal waters. This led to the establishment of the Lower Mobile Bay-Mary Ann field (Fig. 2). To date, six Norphlet fields have been established in the state coastal waters area. Production was initiated from the Lower Mobile Bay-Mary Ann field in 1988. Cumulative production from this field over the past two years exceeds 22 billion cubic feet of gas (BCFG). Recoverable reserves of 5 to 8 TCF of natural gas are estimated for the Norphlet Formation in Alabama's coastal waters area (Mancini et al., 1987).

The Mobile Bay area play is characterized by Norphlet sandstone reservoirs exhibiting primary and secondary porosity at depths exceeding 20,000 feet. Only eolian sandstones have been proven productive to date in the Mobile Bay area play. Norphlet sandstones attain thicknesses of over 600 feet in the Mobile Bay area. Net pay thicknesses average 155 feet for the play. Porosity includes primary intergranular, secondary intergranular produced from grain dissolution and decementation, and secondary intragranular developed as a result of partial feldspar grain dissolution. Reservoir porosities average 12 percent, and permeabilities average 1 md for the play.

Norphlet gas accumulations in the Mobile Bay area play occur in structural traps formed by salt tectonism. Early movement of Louann Salt formed large, low-relief, faulted, anticlinal, salt-pillow features, which trend generally east-west. The hydrocarbon trap for the Lower Mobile Bay-Mary Ann field is typical of traps in the Mobile Bay area play. This trap is a broad, low-relief, east-west trending, elongated, faulted salt anticline. The anticline is formed by rollover into a down-to-the-south fault and is dissected by interior faults. These faults are part of the Lower Mobile Bay fault system.

The natural gas and condensate trend includes the Mississippi interior salt basin play, Mobile graben play, the Wiggins arch complex play, and the Pollard fault system play (Fig. 3). The trend is characterized by the production of natural gas, condensate, and high gravity oils. The condensate (148 MMB) produced in the study area is from this trend. Located in an intermediate basinal position, the trend is generally basinward of the regional peripheral fault trend and includes the Wiggins arch complex.

The Mississippi interior salt basin play was discovered in 1970 by Phillips Petroleum Company with the drilling of the Williams "AA" No. 1 well in Washington County, Alabama, which led to the establishment of Chatom field (Fig. 2). To date, six Smackover fields have been established in the Mississippi interior salt basin play. Cumulative production from this play exceeds 16 MMB of liquid hydrocarbons and 125 BCFG.

In the Mississippi interior salt basin play, Smackover dolomitized oolitic, oncolitic, and peloidal grainstones and packstones which accumulated in subtidal to intertidal environments are the principal reservoir rocks. Net pay thicknesses average 24 feet for the play. Porosity includes primary interparticulate and secondary grain-moldic and intercrystalline dolomite. Reservoir porosities average 18 percent, and permeabilities average 11 md for the play. Production is generally from below 16,000 feet.

Hydrocarbon traps in the Mississippi interior salt basin play are salt-related structural or combination traps. Combination traps consist of porosity or permeability pinch-outs on halokinetically generated anticlines or structural noses. For example, at Chatom field (Fig. 2), the trap is a northwest-trending salt anticline that is affected by minor faulting on the southeast. The trap at Red Creek field is a northeast-trending salt anticline associated with a permeability pinch-out on the crest of the structure. At Healing Springs field, the trap is formed by a permeability barrier across a structural nose.

The Mobile graben play was discovered in 1974 by Getty Oil Company with the drilling of the Peter Klein 3-14 No. 1 well in Mobile County, Alabama, which led to the establishment of the Hatter's Pond field (Fig. 2). To date, three Smackover and Norphlet fields have been established in the Mobile graben play. Cumulative production from this play exceeds 40 MMB of liquid hydrocarbons and 149 BCFG.

The Mobile graben play is characterized by Smackover subtidal to intertidal dolostone and Norphlet marine and eolian sandstone reservoirs at depths of 12,400 to 18,400 feet. The average net pay thickness for the play is 70 feet. Sandstone porosity is predominantly intergranular resulting from both primary depositional pore space and diagenetic secondary grain dissolution and decementation. A significant amount of intragranular (feldspar dissolution) porosity also is evident in the sandstones. The Smackover has been pervasively dolomitized in the Mobile graben area, and Smackover reservoir lithofacies are primarily dolostones exhibiting intercrystalline, grain-moldic, and vuggy porosity. Average reservoir porosity for the Smackover reservoirs is 15 percent, and average carbonate reservoir permeability is 40 md. Average porosity for Norphlet reservoirs is 10 percent, and average sandstone permeability is 0.5 md.

Structural hydrocarbon traps in the Mobile graben play can be characterized as salt anticlines or faulted, salt-pierced anticlines. The trap at Hatter's Pond field, which is typical of the Mobile graben play, involves salt flow along the west side of the Mobile graben fault system. This salt movement has resulted in a northeast-trending, faulted, salt-pierced anticline.

The Wiggins arch complex play was discovered in 1974 by Union Oil Company of California with the drilling of the International Paper Company No. 22-13 well in Mobile County, Alabama, which led to the establishment of Chunchula field (Fig. 2). To date, eight Smackover fields have been established in the Wiggins arch complex play. Cumulative production for this play exceeds 47 MMB of liquid hydrocarbons and 150 BCFG.

The Wiggins arch complex play generally is characterized by relatively thin Smackover peritidal dolostone reservoirs at depths ranging from 16,100 to 18,400 feet. Net pay thicknesses average 22 feet for the play. Porosity types in the dolostones include intercrystalline, grain-moldic, and vuggy. Smackover reservoir porosities average 12 percent, and permeabilities average 4 md for the play.

Hydrocarbon traps in the Wiggins arch complex play are salt-related structural or combination traps consisting of anticlines and structural noses associated with stratigraphic pinch-outs and salt flow. These traps occur along the flanks of paleohighs associated with the Wiggins arch complex. The trap at Chunchula field, which is typical of the Wiggins Arch complex play, is an anticlinal structure associated with salt tectonism.

The Pollard fault system play was discovered in 1968 by Humble Oil and Refining Company with the drilling of the Bernice S. Wessner, et al. No. 1 well in Escambia County, Alabama, which led to the establishment of Flomaton field (Fig. 2). To date, one Smackover field and one Norphlet field have been established in the Pollard fault system play. Cumulative production for this play exceeds 49 MMB of liquid hydrocarbons and 703 BCFG.

The Pollard fault system play is typified by Smackover subtidal to intertidal dolomitized oolitic and peloidal grainstone and packstone reservoirs and Norphlet eolian, marine, and wadi (fluvial) sandstone reservoirs at depths of approximately 15,000 feet. Net pay thicknesses average 52 feet for the play. Sandstone porosity types include primary (depositional) intergranular, secondary intergranular (solution-enlarged), and intragranular (grain dissolution and decementation). Porosity in the Smackover is primary interparticulate and secondary grain-moldic and intercrystalline dolomite. Reservoir porosities average 14 percent, and permeabilities average 10 md for the play.

Hydrocarbon traps in the Pollard fault system play are salt-related structural traps occurring upthrown to the Pollard fault system. Commonly, these anticlinal structures, which dip into the fault system, are truncated by faults, and this truncation and juxtaposition of reservoir lithofacies against impermeable rocks on the downthrown side of the fault, in part, forms the trap. Flomaton field (Fig. 2) is typical of fields in the Pollard fault system play. The trap consists of a low-relief, faulted salt anticline and the primary trapping mechanism is a large down-to-the-north fault that truncates an anticlinal nosing trend.

The oil and associated natural gas trend includes the Gilbertown and West Bend fault systems, the Foshee fault system, and the basement ridge plays (Fig. 3). The trend is characterized by the production of medium gravity oil and associated natural gas. More than 99 percent of the oil (522 MMB) produced in the area of study is from this trend. Located in an updip basinal position, the trend is generally north of the regional peripheral fault trend.

The Gilbertown and West Bend fault systems play was discovered in 1967 by Pruet and Hughes Operating Company with the drilling of the Trice No. 1 well in Choctaw County, Alabama, which led to the establishment of the Choctaw Ridge field (Fig. 2). To date, 20 Smackover and Norphlet fields have been established in the Gilbertown and West Bend fault systems play. Cumulative production for this play exceeds 53 MMB of liquid hydrocarbons and 26 BCFG.

The Gilbertown and West Bend fault systems play is characterized by Smackover dolomitized oolitic, oncolitic, and peloidal grainstone and packstone reservoirs which accumulated in subtidal to intertidal environments and Norphlet marine and eolian sandstone reservoirs at depths ranging from 11,000 to 14,000 feet. The average net pay thickness for the play is 36 feet. Sandstone porosity types include primary and secondary intergranular. Smackover porosity is primary interparticulate and secondary grain-moldic and intercrystalline dolomite. Reservoir porosities average 21 percent, and permeabilities average 133 md for the play.

Hydrocarbon traps in the Gilbertown and West Bend fault systems play include salt-induced structural and combination traps. Structural traps are either salt anticlines or faulted salt anticlines, and combination traps are generally porosity and permeability pinch-outs on the flanks of salt anticlines or salt-related anticlinal noses. Womack Hill field (Fig. 2) is a typical Smackover field in the Gilbertown and West Bend fault systems play. The trap is an east-west trending, faulted anticline developed upthrown to a down-to-the-south fault produced by halokinesis. Localized permeability barriers are present in the central portion of the field. South Womack Hill field (Fig. 2) is a Norphlet field, and the trap is a faulted salt anticline occurring between down-to-the-north and down-to-the-south faults which have produced a narrow, elongate horst.

The Foshee fault system play was discovered in 1970 by Humble Oil and Refining Company with the drilling of the St. Regis No. 1 well in Santa Rosa County, Florida, which led to the establishment of the Jay field (Fig. 2). To date, ten Smackover and Norphlet fields have been established in the Foshee fault system play. Cumulative production for this play exceeds 460 MMB of liquid hydrocarbons and 575 BCFG.

The Foshee fault system play is typified by subtidal to intertidal Smackover dolomitized peloidal grainstone and packstone and Norphlet eolian, marine and wadi (fluvial) sandstone reservoirs at depths of approximately 15,000 feet. The average net pay thickness for the play is 51 feet. Sandstone porosity is primary and secondary intergranular and secondary intragranular. Smackover porosity includes grain-moldic and intercrystalline dolomite. Reservoir porosities average 16 percent, and permeabilities average 29 md for the play.

Structural and combination hydrocarbon traps related to salt movement characterize the Foshee fault system play. Structural traps are either salt anticlines or faulted salt anticlines, and combination traps are porosity and permeability pinch-outs on the flanks of anticlines or anticlinal noses. The trap at Jay/Little Escambia Creek field (Fig. 2) is a northeast-trending salt anticline developed downthrown to the Foshee fault. A Smackover porosity and permeability barrier developed across an anticlinal nose, and this barrier serves as the northern seal. Norphlet traps in the Foshee fault system play are structural, such as at Mt. Carmel field (Fig. 2) where the trap is a faulted salt anticline developed upthrown to the Foshee fault.

The basement ridge play was discovered in 1970 by Getty Oil Company with the drilling of the Rufus Garrett 12-7 No. 1 well in Monroe County, Alabama, which led to the establishment of the Uriah field (Fig. 2). To date, 22 Smackover and Haynesville fields have been established in the basement ridge play. Cumulative production for this play exceeds 9 MMB of liquid hydrocarbons and 14 BCFG.

The basement ridge play has potential for significant undiscovered natural gas resources. The play is characterized by Smackover subtidal to intertidal dolomitized oolitic and peloidal grainstone and packstone and algal boundstone reservoirs and Haynesville shallow marine sandstone reservoirs at depths ranging from 11,800 to 15,500 feet. The average net pay thickness for the play is 27 feet. Haynesville sandstone porosity is principally primary and secondary intergranular. Smackover porosity includes primary interparticulate and secondary grain-moldic and intercrystalline dolomite. Reservoir porosities average 12 percent, and permeabilities average 62 md for the play.

Hydrocarbon traps in the basement ridge play include structural and combination traps associated with the Conecuh and Pensacola-Decatur ridge complexes. Structural traps are anticlines developed over basement highs and combination traps are porosity and permeability pinch-outs on the flanks of anticlines or faulted anticlines. Vocation field (Fig. 2) is associated with a Smackover combination trap that includes four distinct areas of structural closure on a generally east-west trending anticline. Porosity and permeability barriers and Smackover pinch-outs occur on the southwestern flank of Vocation field. Frisco City field (Fig. 2) is a combination Haynesville trap associated with a generally east-west trending anticline. The anticline is truncated to the south by a basement high and to the east by a down-to-the-east fault.

CONCLUSIONS

1. Three Jurassic natural gas trends can be delineated in southwestern Alabama and the Florida panhandle area; these trends include a deep natural gas trend, a natural gas and condensate trend, and an oil and associated natural gas trend.
2. Eight distinct natural gas plays can be identified in these trends; these plays include the Mobile Bay area play, the Mississippi interior salt basin play, the Mobile graben play, the Wiggins arch complex play, the Pollard fault system play, the Gilbertown and West Bend fault systems play, the Foshee fault system play, and the basement ridge play.

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NOTES