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UPPER JURASSIC SMACKOVER OIL PLAYS IN ALABAMA, MISSISSIPPI AND THE FLORIDA PANHANDLE

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ABSTRACT

Five Smackover (Upper Jurassic, Oxfordian) oil plays can be delineated in the eastern Gulf Coastal Plain. These include the basement ridge play, the regional peripheral fault trend play, the Mississippi Interior Salt basin play, the Mobile graben fault system play, and the Wiggins arch complex play. Plays are recognized by basinal position, relationships to regional structural features, and characteristic petroleum traps. Within two plays, subplays can be distinguished based on oil gravities and reservoir characteristics. Reservoirs are distinguished primarily by depositional setting and diagenetic overprint.

The basement ridge play is updip of the regional peripheral fault trend where the Jurassic Louann Salt is thin or absent; structures in this trend formed on pre-Jurassic basement rocks. The basement ridge play is characterized by structural and combination traps. Reservoirs in the Choctaw ridge complex subplay are peritidal, partially to completely dolomitized, oolitic, peloidal, and oncoidal grainstone. Reservoirs of the Conecuh and Pensacola-Decatur ridge complexes subplay are subtidal to supratidal oolitic, oncoidal, intraclastic, and peloidal dolograinstone and dolopackstone, fenestral dolostone, quartz sandstone, and algal doloboundstone. The regional peripheral fault trend play is basinward of the updip limit of the Louann Salt and is typified by salt related structural features. These structural features occur in association with the Pickens, Gilbertown, West Bend, Pollard, and Foshee fault systems and are generally parallel to the basin margin. The regional peripheral fault trend play is exemplified by salt-related structural and combination traps. Reservoirs of the Pickens, Gilbertown, and West Bend fault systems subplay are peritidal, nondolomitic to completely dolomitized, oolitic, oncoidal, and peloidal grainstone. Reservoirs of the Pollard and Foshee fault systems subplay are subtidal to supratidal, partially to completely dolomitized, peloidal grainstone to wackestone, and dolomitized algal boundstone. The Mississippi interior salt basin play is downdip from the Pickens and Gilbertown fault systems and is characterized by structural and combination traps associated with salt tectonism in this basin. Reservoirs are peritidal, nondolomitic to completely dolomitized, oolitic and peloidal grainstone and packstone. The Mobile graben fault system play is located along the eastern limit of the Mississippi interior salt basin and is typified by salt-induced structural and combination traps and Smackover peritidal peloidal and oolitic dolograinstone to dolowackestone and dolostone reservoirs. The Wiggins arch complex play is in a downdip basinal position and is characterized by structural and combination-petroleum traps associated with stratigraphic thinning and salt flow. The traps occur along the flanks of pre-Mesozoic paleohighs associated with this complex. Reservoirs are subtidal to supratidal peloidal, oolitic and oncoidal dolograinstone and dolopackstone, thrombolitic dolostone, and crystalline dolostone.

INTRODUCTION

The Upper Jurassic (Oxfordian) Smackover Formation is the most prolific geologic unit producing oil and condensate in the area of eastern Mississippi, Alabama, and panhandle Florida. In the area of study, 135 fields have produced oil and/or condensate from Smackover reservoirs. Cumulative production from these fields through 1989 includes 797 million barrels of oil and condensate.

This paper examines parameters related to the occurrence of petroleum in the Smackover fields of the study area and provides evidence that distinct petroleum plays can be recognized by studying field characteristics. In recognizing plays, emphasis is placed on basinal position, relationships to regional structural features, and characteristic petroleum traps. Oil gravities and the depositional setting and diagenetic overprint affecting reservoir formation are used as supplementary criteria for each play.

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GEOLOGIC SETTING

The Smackover Formation is a regionally extensive carbonate unit that subcrops around the rim of the Gulf Coastal Plain. In the eastern Gulf Coastal Plain, the Smackover has been interpreted to have been deposited on a carbonate ramp (Ahr, 1973; Mancini and Benson, 1980) that was locally modified by preexisting paleotopography. In general, the unit dips gently to the south and southwest. The Smackover is dissected by a series of salt-movement related extensional faults and grabens. The regional peripheral fault trend, which rims the Gulf Coast basin, includes the most pronounced of these faults and grabens (Fig. 1). In the study area, the regional peripheral fault trend is subdivided into the Pickens, Gilbertown, West Bend, Pollard, and Foshee fault systems. Another important fault system, the Mobile graben, forms the eastern border of the Mississippi interior salt basin, which was one of three major

Jurassic depocenters in the study area. The other two were the Manila and Conecuh embayments. The Lower Mobile Bay fault system in the Mobile Bay area was also halokinetically generated. Large basement-related paleohighs significantly influenced Smackover deposition and the distribution of lithofacies; these consist of the Wiggins arch complex, which includes the Wiggins arch and the Baldwin high, and the Choctaw, Conecuh, and Pensacola-Decatur ridge complexes.

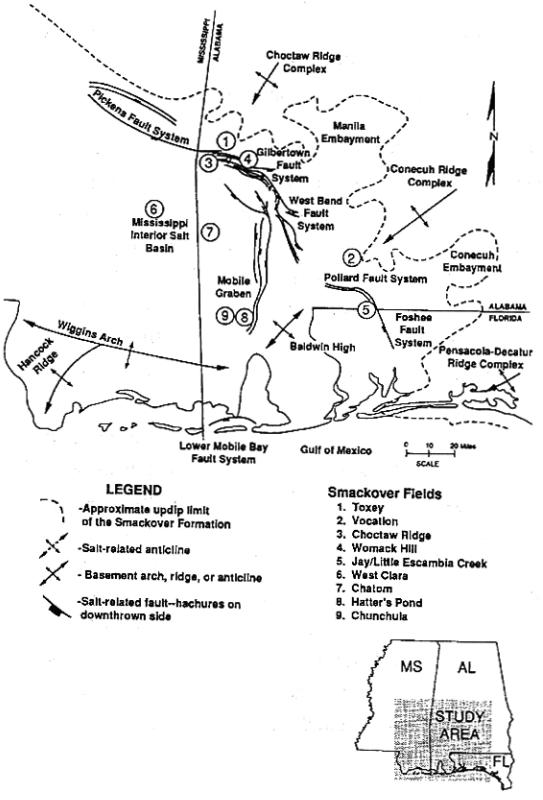

Figure 1. Major structural features of the region and the location of selected Smackover fields.

STRATIGRAPHY

The Smackover Formation overlies the Norphlet Formation; the contact of these units can be either gradational or abrupt. Based on ammonites recovered from the lower part of the Smackover, the formation has been assigned a late Oxfordian age (Imlay, 1945; Salvador, 1987). The Smackover generally ranges from less than 50 feet to more than 550 feet thick in the three-state area. In certain areas the formation is absent on the crests of paleohighs.

Three distinct lithofacies associations have been recognized for the Smackover (Moore, 1984; Benson, 1988) (Fig. 2). The lower Smackover generally consists of intertidal to subtidal, algally laminated mudstone and peloidal-oncoidal wackestone and packstone (Benson, 1988). The middle Smackover is dominated by subtidal, laminated mudstone with minor subtidal peloidal and skeletal wackestone and packstone near the top of the unit (Mancini and Benson, 1980; Benson, 1988). *Favreina* are locally abundant. The mudstone is rich in algal and amorphous organic material and is the petroleum source rock for Smackover hydrocarbons in the study area (Sassen *et al.*, 1987; Claypool and Mancini, 1989). The upper Smackover consists of subtidal to intertidal oolitic, oncoidal, and peloidal grainstone and packstone, which is interbedded with intertidal to supratidal laminated mudstone that is commonly anhydritic (Mancini and Benson, 1980). The tests of cerithid gastropods are locally abundant. Much of the upper Smackover has been pervasively dolomitized. Upper Smackover strata occur in a stratigraphic succession of stacked, upward-shallowing cycles that grade from subtidal rocks at the bases of the cycles to supratidal rocks at the tops (Mancini *et al.*, 1990). Subtidal to intertidal algal boundstone is important in the upper Smackover in parts of the study area, particularly in association with basement-related paleohighs (Baria *et al.*, 1982).

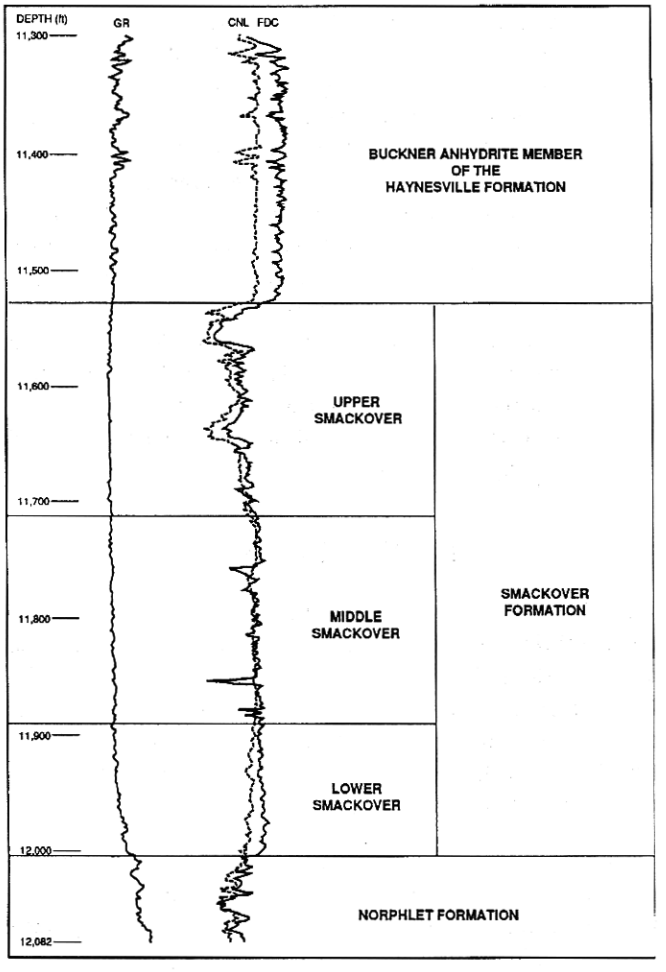

Figure 2. Type log illustrating Smackover lithofacies.

The Smackover is conformably overlain by the Buckner Anhydrite Member of the Haynesville Formation. In the Mississippi interior salt basin, the basal Buckner consists of subaqueous evaporites, whereas in basin marginal areas, the basal

Buckner strata include salina and sabkha deposits (Lowenstein, 1987; Mann, 1988).

OIL PLAYS

Five Smackover oil plays can be delineated in the area of eastern Mississippi, Alabama, and panhandle Florida (Fig. 3). These include the basement ridge play, the regional peripheral fault trend play, the Mississippi interior salt basin play, the Mobile graben fault system play, and the Wiggins arch complex play. Within the basement ridge play, the Choctaw ridge complex subplay and the Conecuh and Pensacola-Decatur ridge complexes subplay can be recognized. The Pickens, Gilbertown, and West Bend fault systems subplay and the Pollard and Foshee fault systems subplay compose the regional peripheral fault trend play.

The basement ridge play is updip of the regional peripheral fault trend where the Jurassic-Louann Salt is thin or absent. The play was discovered in 1970 by E. L. Erickson Company with the drilling of the Scott Paper Company, S. H. Bolinger No. 4-8 well in Choctaw County, Alabama, which led to the establishment of the Toxey field (Fig. 1). To date, 36 fields have been established in the play. Cumulative production through 1989 exceeds 11 million barrels of oil and condensate.

This play is characterized by structural and combination traps. Structures formed in association with pre-Jurassic basement paleotopography. Structural traps are anticlines or faulted anticlines that developed over basement highs. Combination traps are porosity and/or permeability terminations on the flanks of anticlines or faulted anticlines.

Petroleum reservoirs in the Choctaw ridge complex subplay are peritidal, partially to completely dolomitized, oolitic, peloidal, and oncoidal grainstone. Reservoirs produce heavy oils with gravities of 18 to 26°API at depths ranging from 10,200 to 10,900 feet. Reservoir pore systems in this subplay are dominated by molds of nonskeletal particles and by secondary intraparticle pores (partial molds). Dolomitization was primarily fabric selective and therefore had little effect on the pore system (Kopaska-Merkel and Mann, 1991).

Toxey field in Choctaw County, Alabama, is typical of Smackover fields in the Choctaw ridge complex subplay. The petroleum trap at Toxey field is an east-west trending anticline with two distinct areas of structural closure above the oil/water contact. Reservoir lithofacies at Toxey field include partially to completely dolomitized, oolitic, peloidal, and oncoidal grainstone. Dominant pore types are moldic and secondary intraparticle pores, with lesser amounts of intercrystalline porosity. Mean reservoir porosity and geometric mean permeability are 22% and 23 md, respectively.

Reservoirs of the Conecuh and Pensacola-Decatur ridge complexes subplay are subtidal to supratidal, oolitic, oncoidal, intraclastic, and peloidal dolograinstone and dolopackstone, fenestral dolostone, quartz sandstone, and algal doloboundstone. Reservoirs in this subplay produce intermediate to light oils with gravities of 32 to 54°API. Reservoir depth ranges from 12,600 to 15,500 feet. Reservoir pore systems in this subplay are variable. Dolomitization was fabric selective in some areas but was more commonly fabric destructive. Therefore, most pore systems have substantial amounts of intercrystalline porosity. In addition to intercrystalline pores, moldic and secondary intraparticle pores are common. Fracture pores are locally important because they dramatically enhance permeability.

Vocation field, Monroe County, Alabama (Fig. 1), is characteristic of the Conecuh and Pensacola-Decatur ridge complexes subplay. The hydrocarbon trap in Vocation field is a combination trap that involves porosity and permeability terminations both updip and downdip of a "halo" which surrounds a basement paleohigh. Smackover strata are absent on the paleohigh, suggesting that the feature was exposed during deposition of the unit. The reservoir interval in the field is developed in oolitic and peloidal dolograinstone. The pore system contains interparticle, moldic, and intercrystalline porosity. Mean porosity is 13%, and geometric mean permeability is 14 md.

The regional peripheral fault trend play is basinward of the updip limit of Louann Salt and is typified by salt-related structural features. These features are associated with the Pickens, Gilbertown, West Bend, Pollard, and Foshee fault systems and are generally parallel to the basin margin. The 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. 1). To date, 44 fields have been established in the play. Cumulative production through 1989 exceeds 605 million barrels of oil and condensate.

This play is characterized by salt-related structural and combination traps. Structural traps in the regional peripheral fault trend play are either salt anticlines or faulted salt anticlines, and combination traps are generally permeability terminations on the flanks of salt anticlines or salt-related anticlinal noses.

Petroleum reservoirs in the Pickens, Gilbertown, and West Bend fault systems subplay are peritidal, nondolomitic to completely dolomitized, oolitic, oncoidal, and peloidal grainstone and produce intermediate oils with gravities of 23 to 47° API at depths ranging from 11,000 to 12,500 feet (Fig. 3). Reservoir pore systems are dominated by moldic and secondary intraparticle pores, but some reservoir intervals (especially near the top of the Smackover) contain substantial amounts of interparticle porosity which has the potential to greatly enhance permeability (Kopaska-Merkel and Mann, 1991). Certain reservoir intervals in this subplay are dominated by intercrystalline pores, as a result of locally nonselective dolomitization. These intercrystalline-dominated intervals are similar to the reservoirs of the Conecuh and Pensacola-Decatur ridge complexes subplay, but most reservoirs of the Pickens, Gilbertown, and West Bend

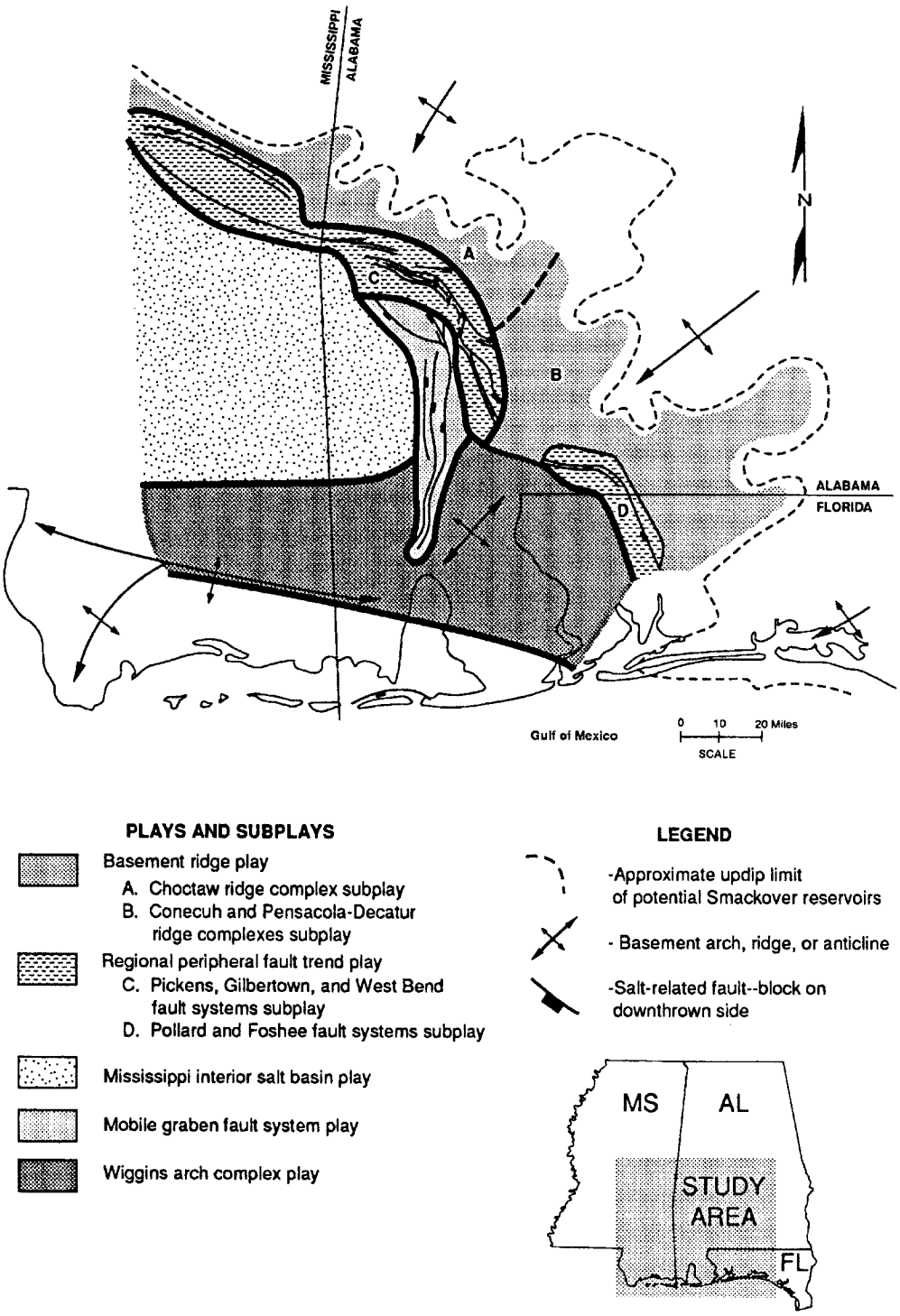

Figure 3. Smackover oil plays of eastern Mississippi, Alabama, and the panhandle of Florida.

fault systems subplay are like those of the Choctaw ridge complex subplay. These latter reservoirs are dominated by moldic and secondary intraparticle pores, and dolomitization does not control pore system characteristics because the preexisting rock fabric has been preserved (Kopaska-Merkel and Mann, 1991).

Womack Hill field in Choctaw and Clarke Counties, Alabama (Fig. 1), is typical of Smackover fields in the Pickens, Gilbertown, and West Bend fault systems subplay. The petroleum trap at Womack Hill is an east-west trending, faulted anticline developed upthrown to a down-to-the-south fault resulting from halokinesis. Localized permeability barriers

occur in the central portion of the field, and two areas of distinct structural closure occur above the oil/water contact. Reservoir lithofacies in the field include partially to completely dolomitized oolitic and peloidal grainstone. Mean porosity is 14.4%, and geometric mean permeability is 0.39 md.

Reservoirs of the Pollard and Foshee fault systems subplay are subtidal to supratidal, partially to completely dolomitized, peloidal grainstone to wackestone and dolomitized algal boundstone. Production is light oil of 46 to 54° API gravity at depths of 14,700 to 15,700 feet. Reservoir pore systems in the Pollard and Foshee fault systems subplay are dominated by intercrystalline pores with a high percentage of moldic and secondary intraparticle pores. Because these moldic and secondary intraparticle pores are connected by networks of intercrystalline pores, the reservoir characteristics of this subplay are controlled by the intercrystalline pores (Kopaska-Merkel and Mann, 1991).

Jay/Little Escambia Creek field, in Escambia County, Alabama, and the panhandle of Florida (Fig. 1), typifies the Pollard and Foshee fault systems subplay. The petroleum trap 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. Reservoir lithofacies at Jay/Little Escambia Creek include peloidal dolopackstone and lesser amounts of peloidal dolowackestone and dolograinstone and partially to completely dolomitized algal boundstone. The pore system contains substantial amounts of intercrystalline, moldic, and secondary intraparticle pores. Mean porosity is 11%, and geometric mean permeability is 0.38 md.

The Mississippi Interior Salt basin play is downdip of the Pickens and Gilbertown fault systems and is characterized by salt-related structural features. The play was discovered in 1966 by Pan American Petroleum Corporation with the drilling of the U.S.A.-GM&O No. 1 well in Wayne County, Mississippi, which led to the establishment of the West Clara field (Fig. 1). To date, 44 fields have been established in the play. Cumulative production through 1989 exceeds 92 milion barrels of oil and condensate.

Petroleum traps are structural and combination traps associated with salt tectonism in the basin. Structural traps include salt anticlines or faulted salt anticlines. Combination traps consist of porosity or permeability terminations on halokinetically generated anticlines or structural noses.

Reservoirs are peritidal, nondolomitic to completely dolomitzed, peloidal and oolitic grainstone and packstone locally containing oncoids. Production is intermediate to light oils of 35 to 64°API gravities and condensates at depths of 13,300 to 16,314 feet. Reservoir pore systems in the northen part of this play are dominated by secondary oomolds and intraooid pores and are similar to the pore systems of the Pickens, Gilbertown, and West Bend fault systems subplay. An unusual type of pore system occurs in the northernmost part of this play. Crushed cement frameworks containing intershard porosity are common in the Smackover in this area. These cement frameworks surrounded nearly pure particle moldic porosity prior to being crushed. Crushing of the cement framework enhanced the connections among particle molds through formation of microfractures supported by cement shards (Kopaska-Merkel and Mann, 1991). In the southern part of this play, in the central part of the Mississippi Interior Salt basin, peloids and, therefore, secondary pelmolds and intrapeloid pores predominate. As in the Pickens, Gilbertown, and West Bend fault systems subplay to the north, the Mississippi interior salt basin play contains minor reservoir intervals dominated by intercrystalline pores.

Chatom field in Washington County, Alabama (Fig. 1), is typical of Smackover fields in the Mississippi Interior Salt basin play. The petroleum trap at Chatom field is a northwest-trending salt anticline that is affected by minor faulting on the southeast. Reservoir lithofacies in the field include peloidal dolograinstone and dolostone. Both intercrystalline and pelmoldic pores are common. Mean porosity is 15%, and geometric mean permeability is 1.21 md.

The Mobile graben fault system is located along the eastern limit of the Mississippi interior salt basin and is characterized by salt-related structural features. The 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. 1). To date, three fields have been established in the play. Cumulative production through 1989 exceeds 42 million barrels of oil and condensate.

Hydrocarbon traps are salt-related structural and combination traps. Structural traps in the Mobile graben fault system play can be characterized as salt anticlines, faulted salt anticlines, or faulted, salt-pierced anticlines. Combination traps are produced by porosity and permeability terminations in association with these features.

Reservoirs are peritidal peloidal and oolitic dolograinstone to dolowackestone and dolostone occurring at depths ranging from 12,300 to 18,500 feet. Production from these reservoirs includes crude oil with intermediate to light gravities of 41 to 61° API and condensates. Reservoir pore systems in this play are dominated by intercrystalline pores. However, in the northern part of the play, moldic and interparticle pores are common. Reservoirs in this play are similar to those of the Pickens, Gilbertown, and West Bend fault systems subplay.

Hatter's Pond field in Mobile County, Alabama (Fig. 1), is characteristic of Smackover fields in the Mobile graben fault system play. The trap at Hatter's Pond field 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 in which hydrocarbons have accumulated. Reservoir lithofacies at Hatter's Pond field are thrombolitic,

oolitic, and peloidal dolostone and oolitic and peloidal dolowackestone to dolograinstone. Pores are dominantly intercrystalline, with lesser numbers of moldic and secondary intraparticle pores. Mean porosity is 14%, and geometric mean permeability is 2.71 md.

The Wiggins arch complex play is in a downdip basinal position and is characterized by salt and basement related structural features. The 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 the Chunchula field (Fig. 1). To date, eight fields have been established in the play. Cumulative production through 1989 exceeds 45 million barrels of oil.

The hydrocarbon traps occur along the flanks of pre-Mesozoic paleohighs associated with this complex and are structural and combination traps associated with stratigraphic thinning and salt flow. Traps include anticlines and structural noses.

Reservoirs are subtidal to supratidal, peloidal, oolitic, and oncoidal dolograinstone and dolopackstone, thrombolitic dolostone, and crystalline dolostone occurring at depths of 16,200 to 18,350 feet. These reservoirs produce light oils of 44 to 61° API gravities. Pore systems in this play are dominated by intercrystalline pores and are similar to those of the Mobile graben fault system.

Chunchula field is typical of Smackover fields in the Wiggins arch complex play. The hydrocarbon trap at Chunchula field is a salt-related anticlinal structure. Predominant reservoir lithofacies are thrombolitic and peloidal dolostone and oncoidal, peloidal and oolitic dolopackstone and dolograinstone. Pores are dominantly intercrystalline. Mean porosity is 11%, and geometric mean permeability is 0.67 md.

CONCLUSIONS

1. Five Smackover oil plays including the basement ridge play, the regional peripheral fault trend play, the Mississippi Interior Salt basin play, the Mobile graben fault system play, and the Wiggins arch complex play, can be delineated in the area of eastern Mississippi, Alabama, and panhandle Florida.

2. Within the basement ridge play, the Choctaw ridge complex subplay and the Conecuh and Pensacola-Decatur ridge complexes subplay can be recognized.

3. Within the regional peripheral fault trend play, the Pickens, Gilbertown, and West Bend fault systems subplay and the Pollard and Foshee fault systems subplay can be identified.

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