RESERVOIR CHARACTERIZATION AND MODELING: NORTH BLOWHORN CREEK FIELD, VOCATION FIELD, AND WOMACK HILL FIELD

BOTTOM LINE

Understanding the principles of reservoir characterization and modeling for the complex reservoirs present in Mississippi/Alabama fosters additional oil and gas development and production. These principles are best illustrated through case studies showing how available data is gathered, analyzed and interpreted.

KEY WORDS:
Depositional and Diagenetic Environments
Geological Modeling
Integrated Field Studies

PROBLEM ADDRESSED

Significant oil and natural gas remain in mature, geologically complex reservoirs. In designing rework, redevelopment or improved oil recovery projects, operators must first understand the reservoir, then implement development activities matched to the reservoir's characteristics. Identifying the depositional and diagenetic environment of a given reservoir is a key aspect of geological modeling.

TECHNOLOGY OVERVIEW

Womack Hill Field, Choctaw and Clark Counties, Alabama. Pruet Production Co. and the Center for Sedimentary Basin Studies at the University of Alabama, in cooperation with Texas A&M University, Mississippi State University, University of Mississippi, and Wayne Stafford and Associates are undertaking a focused, comprehensive, integrated and multidisciplinary study of Upper Jurassic Smackover carbonates (DOE Class II Reservoir), involving reservoir characterization and 3-D modeling and an integrated field demonstration project at Womack Hill Oil Field Unit, Choctaw and Clarke Counties, Alabama, Eastern Gulf Coastal Plain.

The principal objectives of the project are: increasing the productivity and profitability of the Womack Hill Field Unit, thereby extending the economic life of this Class II Reservoir and transferring effectively and in a timely manner the knowledge gained and technology developed from this project to producers who are operating other domestic fields with Class II Reservoirs.

Based on a workshop sponsored by PTTC's Eastern Gulf Region on August 14, 2002 in Jackson, Mississippi

SPEAKERS:

Improved Oil Recovery from Upper Jurassic Smackover Carbonates through the Application of Advanced Technologies at Womack Hill Oil Field, Choctaw and Clarke Counties, Eastern Gulf Coastal Plain
Ernest A. Mancini

Reservoir Characterization and Modeling of the Upper Jurassic Smackover Shoal and Reef Facies in the Vocation Field, Monroe County, Alabama
Juan Carlos Llinas

Reservoir Characterization and Modeling, North Blowhorn Creek Oil Field, Lamar County, Alabama
Brian Panetta

The Womack Hill Oil Field, Choctaw and Clarke Counties, Alabama was discovered in 1970 with the drilling of the Carlisle Unit 16-4 No. 1 well. Oil was discovered in Upper Jurassic Smackover carbonate shoal lithofacies at a depth of 11,432 to 11,442 ft. A waterflood project was initiated in the western portion of the field in 1975. To date, 30.7 million barrels of oil have been produced from the field. Estimated reserves for the field are 119 million barrels of oil. Additional oil reserves are projected to be recovered through the application of advanced technologies that optimize reservoir management.

Reservoir characterization and 3-D geologic modeling of the Smackover carbonate shoal reservoirs are being utilized to improve field-scale reservoir management in the field. Reservoir characterization has shown that the Smackover is productive from three carbonate shoal reservoirs that occur in three vertically stacked shallowing upward cycles (A, B and C). The cycles consist of a sequence comprised of carbonate mudstone/wackestone at the base and ooid grainstone at the top. Porosity in the grainstone has been enhanced through dissolution and dolomitization. Porosity is chiefly interparticle and dolomite intercrystalline with grain moldic, intraparticle and vuggy types.

The upper shoal (shoal A) is the most productive due to increased dolomitization. Reservoir modeling has demonstrated that lateral barriers to flow are present across the field from west to east as a result of lithofacies changes in the shoal sequences. Seismic data indicate a fault in the central area of the field. The reservoir pressure differential that exists between the wells in the western portion of the field and the wells in the eastern portion of the field is attributed to the presence of this fault. The three shoal reservoirs are, in part, vertically separated by the carbonate mudstone at the base of the three shoaling upward cycles. Knowledge of the Smackover heterogeneity and potential compartmentalization of the reservoir in the field is resulting in the design of an improved hydrocarbon production strategy for the carbonate shoal reservoirs in Womack Hill Oil Field.

Vocation Field, Monroe County, Alabama. This study focuses on Vocation Field located in southwestern Alabama, in the eastern margin of the Manila Sub-basin, along the western flank of the Conecuh Ridge. Vocation was discovered in 1971 and since then the field has produced 2.3 million barrels of oil. The structure is a Paleozoic basement high associated with the Triassic/Jurassic rifting event. The reservoir in the field is the Upper Jurassic Smackover Formation, which overlies siliciclastic deposits of the Norphlet Formation in the margins of the structure and onlaps crystalline basement rocks in updip positions. Smackover deposition was initiated as a result of a rapid relative sea level rise (transgressive event) that partially submerged the basement paleohigh and led to the development of microbial reef buildups on the northeastern flank of the structure during the "catch-up" phase of the carbonate system. Changes in the depositional environment and a decrease in the rate of relative sea level rise initiated the "keep-up" phase characterized by the aggradation and finally progradation of shallow subtidal and peritidal sediments of the upper part of the Smackover Formation.

According to the depositional model, the microbial boundstones are equivalent to the peloidal wackestones and laminated carbonate mudstones of the middle Smackover accumulated in downdip areas with greater water depths.

Based on core and thin section descriptions, five subenvironments were interpreted for Smackover deposits: sub-base level, microbial reef complex, shallow lagoon, shoal complex, and sabkha-tidal flat. These subenvironments define an overall aggradational to progradational shallowing-upward marine cycle developed in an evaporate-carbonate setting. The reef and shoal complexes are the main and potential petroleum reservoirs. Significant boundstone accumulations were deposited on the north and eastern side of the basement structure due to restricted environmental conditions that favored the establishment and growth of the microbial reefs there.

Petrographic descriptions indicate that the Smackover Formation was affected by extensive dolomitization and different episodes of carbonate, cementation, compaction, and dissolution that occurred in the eogenetic and mesogenetic environments. The most important diagenetic events for the enhancement of the reservoir properties include: (1) extensive dolomitization that not only generated new porosity but also enhanced permeability, (2) early calcite cementation that preserved primary porosity from later compaction, (3) selective dissolution of aragonite allochems that produced moldic pores especially significant in the oolitic grainstone facies, (4) deep burial non-fabric selective dissolution that yielded vuggy and channel pores, characteristic of the reef facies, and (5) fracturing. The variability in the depositional textures and the superposition of various types of diagenetic events experienced by these rocks produce significant changes in porosity and permeability as indicated by core analyses and thin section observations. Despite the numerous and complex diagenetic modifications, the original depositional fabric controls the distribution of the potential reservoirs in the shoal grainstone and the microbial reef lithofacies, which are the main exploration targets.

The prospective facies in the microbial reef complex are characterized by boundstones with thrombolitic reticulate texture, and shelter and vuggy porosities. Thickness of the microbial reef complex varies from 0 to near 200 ft, porosity ranges between 1 and 34 % with an average of 12 %, and permeability varies between 0.1 and 5700 md with an average of 135 md. Unfortunately this facies is normally found below the oil-water contact.

The prospective facies in the shoal complex is characterized by ooidal/peloidal dolograinstones and packstones with moldic, intergranular and intercrystalline porosities. Thickness of the shoal complex varies from 10 to 100 ft. Producing wells range between 20 and 40 ft. The wells with higher thickness are in peripheral locations with the shoal facies under the oil-water contact. Porosity ranges between 4 and 15 % with an average of 10 % and permeability is between 0.1 and 1600 md with an average of 70 md.

North Blowhorn Creek Field, Lamar County, Alabama. North Blowhorn Creek Oil Field is located in the Black Warrior Basin, in northeastern Lamar County, Alabama. It was discovered in 1979 by Warrior Drilling and Engineering Co. Inc. and was developed on 80-acre well spacing. It was unitized in 1983. Waterflooding began that same year. The waterflood project only marginally increased field production. In 1992, a microbial permeability profile modification (MPPM) project began as a result of continued declining production. The original oil in place was estimated to be 16 million barrels, and to date, the field has produced nearly 6 million barrels of oil, making it the most prolific oil-producing field in the Black Warrior Basin. Currently, there are 20 water injection wells and 32 producers in the field. Production is from the Carter sandstone, at depths of 2,281-2,303 ft. The primary petroleum trap in the field is stratigraphic, caused by vertical and lateral grading of the sandstone into siltstone and shale.

The Carter sandstone is generally described as a grayish brown, massive, well sorted, subrounded to subangular, fine-grained quartz sandstone. It is composed of approximately 90% quartz. In the field, the Carter sandstone lies within the Carter interval, which consists of shale, siltstone, and sandstone. The Millerella limestone overlies the Carter and the Bangor limestone underlies it.

Two previous depositional models have been published for the Carter sandstone at North Blowhorn Creek Oil Field. The first model, proposed in the early 1980s, interprets the sandstone as having been deposited in distal bar to distributary channel environments associated with a constructive deltaic system. The second model, proposed in the early 1990s, interprets the Carter sandstone as being deposited as a barrier island spit complex. This complex was formed under delta destructive, wave-influenced conditions, in which marine reworking led to beach formation. The delta destructive conditions were a result of progradation onto a shallow carbonate bank during or shortly after lowstand, and continued further during marine transgression. Identified facies in the model include a shale and siltstone facies deposited in a muddy shelf environment, a sandstone facies deposited in a lower shoreface to foreshore environment, and a variegated facies deposited in backshore environment consisting of washover fan deposits and soil formation.

The depositional model proposed in this study interprets the Carter as having been deposited in a barrier island spit complex. However, the model differs from the earlier model in that no washover fan deposits are recognized. Seven depositional facies were identified: a restricted bay facies consisting of interbedded siltstone and shale, a lower shoreface facies, a foreshore/upper shoreface facies, an intertidal/subtidal facies consisting of reworked deposits, an intertidal facies consisting of tidal flat deposits, a marsh facies, and an open shelf facies consisting of shale and siltstone. This model indicates that the Carter sandstone at North Blowhorn Creek Oil Field was deposited as a prograding beach/barrier complex in a restricted marine environment characterized by spit accretion and later drowned and covered by open shelf deposits.

Acknowledgment
The research effort for these integrated field studies has been partially funded by the Department of Energy through its National Energy Technology Laboratory.

For information on PTTC's Eastern Gulf Region and their activities contact:

Ernest A. Mancini, Professor of Geology, University of Alabama,
Box 870338, 202 Bevill Building, Tuscaloosa, Alabama 35487
Phone 205-348-4319, Fax 205-348-0818, Email emancini@wgs.geo.ua.edu

CONNECTIONS:

Ernest A. Mancini
Center for Sedimentary Basin Studies and Department of Geological Sciences
University of Alabama
P.O. Box 870338
Tuscaloosa, AL 35487
Ph: 205-348-4319 Fax: 205-348-0818
Email: emancini@wgs.geo.ua.edu

Juan Carlos Llinas
Dept. of Geology, University of Alabama
P.O. Box 870338
Tuscaloosa, AL 35487-0338
Ph: 205-348-5095 Fax: 205-348-0818
Email: llina001@bama.ua.edu

Brian Panetta
Dept. of Geology, University of Alabama
P.O. Box 870338
Tuscaloosa, AL 35487-0338
Ph: 205-348-6569 Fax: 205-348-0818
Email: bpanetta@petromod.geo.ua.edu