Depositional Styles from Miocene through Pleistocene in the North-Central Gulf of Mexico: An Historical Reconstruction

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Abstract

The Minerals Management Service, U.S. Department of the Interior, has recently classified the producible sands from the approximately 1,100 fields across the northern Gulf of Mexico into groups of genetically related plays defined by production, chronostratigraphy, lithostratigraphy, and structure. Each field was assigned a structural code, and each producible sand was classified by depositional environment. Correlation of the type logs with biostratigraphic and seismic data established 13 chronozones from lower Miocene to upper Pleistocene. Sands within each chronozone were classified as transgressive, aggradational, progradational, or submarine fan facies. Hydrocarbon plays encompassing all discovered resources were mapped for each chronozone.

This paper describes the distribution and continuity of hydrocarbon plays in the Louisiana OCS comprised of discovered resources in sands deposited by the ancestral Mississippi River delta. Pronounced changes in depositional styles and hydrocarbon-prone areas are observed from the lower Miocene through the Pleistocene as the ancestral Mississippi River delta migrated basinward and across offshore Louisiana.

Lower Miocene hydrocarbon plays are restricted to the western portion of the Louisiana shelf. A marked eastward migration of the depocenters occurred in middle Miocene. During the upper Miocene, the depocenter began migrating to the west and extended significantly basinward. Throughout the Pliocene and Pleistocene the depocenter migrated basinward and westward. The distributions of known hydrocarbon plays provide an organized framework for exploration analogs.

Introduction

The Minerals Management Service (MMS), Gulf of Mexico OCS Region, is responsible for leasing and oversight of exploration and production in the northern Gulf of Mexico and Atlantic Outer Continental Shelf (OCS). The MMS maintains an extensive library of geologic and reservoir engineering data, including all well logs, all available paleontological reports, and complete records of production. These data have been organized into a Gulf-wide geologic framework to better fulfill the MMS's regulatory responsibilities.

Discovered resources are classified as known resources, unproved reserves, and proved reserves depending on economic, technical, contractual, or regulatory criteria (Melancon et al., 1994). Fields containing proved reserves were arranged by producible sands into 72 plays. The proved reserves plays were defined primarily on the basis of geologic age and depositional facies. These plays comprise 23,000 reservoirs with associated engineering and production data from 9,500 productive sands and 1,100 fields.

The proved reserves plays will be published by The University of Texas Bureau of Economic Geology (BEG) as part of the atlas series of northern Gulf of Mexico gas and oil reservoirs. Volume one analyzes Miocene and older plays and will be published in late 1995. The atlas series is part of an extensive gas and oil play delineation program sponsored by the Gas Research Institute (GRI), the Department of Energy (DOE), and the MMS covering the Gulf of Mexico, the onshore Gulf Coast, and Mid-continent areas. Working under the oversight of the BEG are the MMS, State geological surveys, and a technical advisory committee composed of gas and oil companies (committee members are listed in the acknowledgments).

Previous Gulf Coast research efforts that focused on regional play analysis identified major oil plays in onshore Texas (Galloway et al., 1983), major gas plays in onshore Texas (Galloway, 1989), and major gas plays in the central and eastern Gulf Coast (Bebout et al., 1992). Hydrocarbon play analysis was also a subsidiary component of studies that emphasized depositional facies, structural style, and hydrocarbon resources for individual groups of strata (Morton et al., 1985), such as the Plio-Pleistocene (Morton et al., 1991), middle and upper Miocene (Morton et al.,1988), lower Miocene (Kiatta, 1971; Galloway et al., 1986), and the Oligocene Frio Formation (Galloway et al., 1982; Hamlin, 1989). A recent discussion of the Gas and Oil atlas series by Seni et al. (1994) presented example plays from the lower Miocene of Texas State waters and described the production-based play methodology.

This paper presents hydrocarbon plays in the Louisiana OCS which are expanded beyond the production-based play methodology. Hydrocarbon plays encompass all discovered resources: the proved reserves plays, expired fields without production, and wells containing electric log indications of hydrocarbons. These hydrocarbon plays were used for the 1995 National Gas and Oil Assessment. This paper describes the distribution and continuity of the hydrocarbon plays comprised of discovered resources in sands deposited by the ancestral Mississippi River delta system from lower Miocene through the Pleistocene.

Methods

The MMS defined chronozones in the northern Gulf of Mexico on the basis of benthic foraminifera biostratigraphic zones that have been correlated across the Gulf using well log and seismic data (Reed et al., 1987). The twenty-six chronozones identified by Reed et al. (1987) are grouped into 13 chronozones from the Miocene to the Pleistocene for this study (Fig. 1). Major flooding surfaces, identified in well cuttings, are important reference horizons for the 13 chronozones.

Type logs are constructed for each field in the Louisiana OCS to identify chronozones, producible sands, and depositional styles. Each type log is a composite of field wells so that all productive sands in a field are represented. All reservoirs in each field are correlated to the appropriate sand body on the composite type log (CTL). Each CTL is subdivided into one or more of the four depositional facies. The depositional facies are transgressive, aggradational, progradational, and submarine fan (Fig. 2). The facies are identified primarily by SP shape, but also include other criteria such as paleoecozones, sand content, and intra-facies relationships. Submarine fans are identified by thick, often serrated, blocky sands with thick overlying shale intervals bearing deep-water paleobathymetry. Chronozones and depositional facies are then correlated between fields across the Gulf of Mexico. Other wells with known hydrocarbon resources and unproved reserves were correlated to nearby composite type logs from fields with proved reserves.

Discussion

The limits of known hydrocarbons for the Central Gulf of Mexico have been mapped on the basis of depositional facies for 13 chronozones from lower Miocene through upper Pleistocene. All OCS blocks with production from each chronostratigraphic facies were mapped and used with wells containing significant hydrocarbon shows to define the known hydrocarbon limits for each play. The individual productive blocks could not be shown at the scale of the figures. For each play, the natural geologic limits represent the downdip extent of producible quality sand.

Lower Miocene

The earliest hydrocarbon plays observed on the Louisiana OCS are of lower Miocene age and occur in a very localized area near the Texas-Louisiana border. Throughout the lower Miocene, deposition was restricted to the western portion of the present-day Louisiana shelf. Only progradational and submarine fan facies are observed during the lower Miocene.

LM-1 (lower Miocene - *Lenticulina hanseni*)

Lower Miocene 1 (LM-1) sediments represent the basinward fringe of the ancestral Mississippi deltaic deposition (Fig. 3). The major depocenter for the delta system is located landward of the present-day coast. Small areas of hydrocarbon occurrence from progradational and submarine fan facies extend from state waters in western Louisiana and eastern Texas to the Federal OCS of High Island, Sabine Pass, West Cameron and East Cameron Areas.

LM-2 (lower Miocene - *Siphonina davisi*)

Progradational facies of the lower Miocene (LM-2) chronozone extend eastward along the current western Louisiana shoreline into East Cameron Area (Fig. 4). Submarine fan facies occur in the same general area as LM-1 submarine fan facies, although they are slightly less extensive in area.

LM-4 (lower Miocene - *Marginulina "A"* to *Discorbis "B"*)

Progradational facies of the lower Miocene (LM-4) chronozone extend farther offshore in the same area as in LM-1 and LM-2 chronozones (Fig. 5). Submarine fan facies with known hydrocarbons are limited to one block in this chronozone.

Middle Miocene

A pronounced eastward migration of the ancestral Mississippi River depocenter occurred in the middle Miocene. By late middle Miocene, progradational sediments are deposited east of the present-day Mississippi River delta. Submarine fan deposition extends into the South Pass and Viosca Knoll Areas.

MM-4 (middle Miocene - *Gyroidina "K"* to *Amphistegina "B"*)

The middle Miocene (MM-4) chronozone contains the earliest productive aggradational and transgressive depositional styles in the Louisiana OCS. The ancestral Mississippi River delta system prograded the paleoshoreline near the current location of the western Louisiana shoreline (Fig. 6). Progradational and submarine fan facies extend farther offshore and eastward than in the LM-4 chronozone. All four depositional styles (submarine fan, progradation, aggradation and transgression) are found in offshore Louisiana during this time.

MM-7 (middle Miocene - *Cibicides opima* to *Bigenerina humblei*)

The middle Miocene (MM-7) chronozone includes productive aggradational facies which are closer to the current shoreline and smaller in areal extent when compared to MM-4 (Fig. 7). Progradational and transgressive facies are more extensive and occur slightly farther offshore than in MM-4 and the area of hydrocarbon occurrence extends slightly eastward from that of MM-4. Submarine fan facies with discovered hydrocarbons are observed only along the eastern margin of MM-7 deposition.

MM-9 (middle Miocene - *Textularia "W"* to *Bigenerina 2*)

The productive limits of the MM-9 chronozone has expanded greatly to extend from western Louisiana to the east of the current Mississippi River delta (Fig. 8). Hydrocarbons are found in submarine fan facies off central Louisiana in the Eugene Island and Ship Shoal Areas. The middle Miocene (MM-9) chronozone contains the earliest observed productive progradational facies in offshore eastern Louisiana. The South Pass and Viosca Knoll Areas east of the present-day Mississippi River delta contain producible submarine fan facies. The only aggradational facies with pay within this chronozone in the Central Gulf of Mexico occur off the coast of Mississippi and Alabama. These facies were deposited by the ancestral Mobile River system. No transgressive facies which contain hydrocarbons are observed in this chronozone.

Upper Miocene

The ancestral Mississippi River depocenter began migrating to the west during the upper Miocene. Deposition extends significantly basinward across the Louisiana OCS, especially during late upper Miocene. Submarine fan facies with associated hydrocarbons extend across Mississippi Canyon Area and are observed in Green Canyon and Garden Banks Areas.

UM-1 (upper Miocene - *Discorbis 12*)

During deposition of the upper Miocene (UM-1) chronozone, the main depocenter for the Mississippi River system is near the current coast of central Louisiana (Fig. 9). As a result, hydrocarbon plays extend across western Louisiana to Alabama. Progradational facies are observed off the entire coast of Louisiana. Submarine fan facies with hydrocarbons extend significantly seaward into the Mississippi Canyon Area in three predominant lobes. Aggradational facies from the Mobile River system in offshore Mississippi and Alabama are more extensive than in MM-9. No transgressive facies with associated hydrocarbons are observed in this chronozone.

UM-3 (upper Miocene - *Cristellaria "K"* to *Robulus "E"/Bigenerina "A"*)

Aggradational and progradational facies and hydrocarbon plays are more extensive in the upper Miocene (UM-3) chronozone than in UM-1 and occur slightly farther offshore (Fig. 10). Transgressive facies lie above the aggradational facies offshore central Louisiana. Widespread hydrocarbon-bearing submarine fan facies extend significantly seaward across the Mississippi Canyon Area. Isolated submarine fan facies contain hydrocarbons in Green Canyon and Garden Banks Areas.

Pliocene

During the Pliocene, all productive facies extend farther basinward than in upper Miocene. The progradational hydrocarbon play is predominantly located off the current Louisiana coastline. The submarine fan hydrocarbon play expands in Garden Bands and Green Canyon Areas.

LP (lower Pliocene - *Textularia "X"*)

Aggradational and transgressive facies in the lower Pliocene (LP) chronozone extend westward and seaward when compared to UM-3 (Fig. 11). Aggradational facies are deposited across the entire Louisiana offshore. Progradational facies extend farther offshore than in the UM-3 chronozone. The submarine fan productive area has increased off south central Louisiana from that in UM-3. An isolated area of hydrocarbon-bearing submarine fan facies occurs in Ewing Banks and Green Canyon Areas.

UP (upper Pliocene - *Buliminella 1*)

Hydrocarbons are found in aggradational and progradational facies of the upper Pliocene (UP) chronozone across the entire offshore Louisiana (Fig. 12). Transgressive, aggradational, and progradational facies are located slightly farther basinward than in LP. The hydrocarbon limits of the submarine fan facies expand into deep water across a wide area from Garden Banks to Viosca Knoll Areas.

Pleistocene

Hydrocarbon plays in the Pleistocene extend even farther basinward and are prevalent off western and central Louisiana. Very little production from middle and upper Pleistocene plays is observed east of the current Mississippi River delta. The main depocenter for the ancestral Mississippi River in the Pleistocene is located substantially seaward of the present-day western Louisiana shoreline.

LPL (lower Pleistocene - *Valvulineria "H"* to *Lenticulina 1*)

Productive areas in the lower Pleistocene (LPL) chronozone are predominately offshore in Federal waters and cover most of the current shelf area (Fig. 13). Deposition in eastern offshore Louisiana is in approximately the same location as UP. However, in western offshore Louisiana deposition of all facies extends considerably basinward from UP. Hydrocarbon occurrence in deep-water offshore Louisiana from the LPL submarine fan facies is concentrated in three main lobes in Garden Banks, Green Canyon, and Mississippi Canyon Areas. Submarine fan facies deposition with associated hydrocarbons extend to the west into the Texas offshore.

MPL (middle Pleistocene - *Angulogerina "B"*)

Sand deposition from the middle Pleistocene (MPL) chronozone is not observed east of the present-day Mississippi River delta (Fig. 14). Aggradational, progradational, and submarine fan facies move basinward off central and western Louisiana from the LPL chronozone. Hydrocarbon plays occur away from the coastline in western Louisiana. The submarine fan hydrocarbon play is narrower than in LPL.

UPL (upper Pleistocene - *Hyalinea "B"* to Sangamon Fauna) (Fig.15)

Aggradational facies of the upper Pleistocene (UPL) chronozone move farther basinward than in the MPL chronozone. A small area of transgressive facies with hydrocarbons is observed off the present-day Mississippi River delta. Progradational and submarine fan facies occupy the same approximate area as in MPL. The main depocenter for the Mississippi River system is located offshore western Louisiana.

Conclusions

During the lower Miocene, the depocenter of the ancestral Mississippi River delta system was located onshore near the present-day coastline in western Louisiana. From LM-1 through MM7 the depocenter migrated eastward onshore and only the outer fringe of deltaic and submarine fan facies are observed offshore. By late middle Miocene (MM-9), the ancestral Mississippi River delta system has migrated to an area onshore along the central Louisiana coastline. Outer fringes of progradational and submarine fan facies are observed for the first time offshore eastern Louisiana. During the UM-1 chronozone, the main depocenter for the Mississippi River system was near the current coast of central Louisiana. The depocenter began migrating toward the west during the UM-3 chronozone. Throughout the Pliocene and Pleistocene, the main depocenter of the ancestral Mississippi River system was migrating basinward and westward. By the upper Pleistocene, the main depocenter for the Mississippi river system was in offshore western Louisiana, but had moved substantially seaward from the current shoreline.

The distributions of known hydrocarbon plays within depositional facies and chronozones provide an organizational framework for exploration analogs for the Central Gulf of Mexico. By utilizing this information, and understanding the relationships of the different facies, a predictive tool is available to identify the location of favorable areas for unexplored hydrocarbon accumulations and their reservoir types.

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