Deep-Water Northern Gulf of Mexico Hydrocarbon Plays

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Abstract

The geologic setting in the deep-water (depths > 305 meters {1,000 feet}) Gulf of Mexico is very favorable for the existence of large, commercial hydrocarbon accumulations. These areas have active salt tectonics that create abundant traps, underlying mature Mesozoic source rocks that can be observed expelling oil and gas to the ocean surface, and good quality reservoirs provided mainly by submarine fan deposits. Despite the limited amount of drilling in the deep-water Gulf of Mexico, 11 deep-water accumulations have been discovered which, when developed, will rank in the top 100 largest fields in the Gulf of Mexico. Proved field discoveries have added over 1 billion barrels of oil equivalent to Gulf of Mexico reserves, and unproved field discoveries may add an additional billion barrels of oil equivalent.

The Minerals Management Service of the United States Department of the Interior, has completed a gulf-wide review of over 1,086 oil and gas fields and placed every pay sand in each field into one of several hydrocarbon plays. Plays are defined by chronostratigraphy, lithostratigraphy, structure, and production. Seven productive hydrocarbon plays include reservoirs located in the deep-water northern Gulf of Mexico. Regional maps illustrate the productive limits of each play. In addition, field data, dry holes, and wells with sub-economic pay were added to define the facies and structural limits for each play. Areas for exploration potential are identified for each hydrocarbon play. A type field for each play is chosen to demonstrate the play's characteristics.

Introduction

The deep-water Gulf of Mexico is already proving to have very significant gas and oil production and it will have an even larger impact on gas and oil reserves in the Gulf of Mexico in the future. By the end of 1993, one billion barrels of oil equivalent (BOE) had been discovered in deep-water Gulf of Mexico proved fields. These reserves are contained in 16 proved deep-water fields located in more than 305 meters (1,000 feet) of water. It is significant that in this relatively small number of deep-water proved fields are hydrocarbon reserves representing seven large hydrocarbon plays (large both in gas and oil volume and areal extent) already producing in shallower water depths. Figure 1 is a map of the Gulf of Mexico showing the 16 proved oil and gas fields used in selecting the seven deep-water hydrocarbon plays. The hydrocarbon plays selected for discussion all share one criterion: each play has at least one proved field that is in greater than 305 meters (1,000 feet) of water. These deep-water proved fields contain more than 1.3 billion barrels of oil equivalent reserves; in contrast, the seven plays they represent contain over 5.9 billion barrels of oil equivalent in 1,128 pay sands (Fig. 2). In this paper we describe each of the seven hydrocarbon plays and include a map for the play that delineates the proved productive outline. The areal extent of the play's productive outline is important since the area down-dip of this outline has high exploration potential. This down-dip area greatly expands the range for future deep-water exploration beyond the limited area of the existing deep-water fields that contain reserves in the play. The map will also highlight areas of good sand development and indicate opportunities for good reservoir development down-dip of the proved productive outline. This paper also provides an estimate of the natural geologic limit for the play's frontier exploration area. In addition, graphs that illustrate the hydrocarbon reserves and pool size distribution are provided for each play.

Also on the deep-water fields map (Fig. 1) are two recent discoveries: Mars Field (now a proved field) in Mississippi Canyon 807, and the Mickey Field in Mississippi Canyon 211. These two fields contain hydrocarbon reserves in an eighth frontier play. This play will also be briefly discussed due to the large reserves identified, however production has not yet been established.

We represent the efforts of many individuals in the U. S. Department of the Interior, Minerals Management Service (MMS), Gulf of Mexico OCS Region. The paper combines results from two ongoing projects at the MMS. The first is the Offshore Northern Gulf of Mexico Atlas Project, done in conjunction with The University of Texas, Bureau of Economic Geology, the Gas Research Institute, and the U. S. Department of Energy. The second is the MMS 1995 National Assessment Review. Results from these projects will be available in print within the next year.

The geologic setting in the deep-water Gulf of Mexico is favorable for the existence of commercial hydrocarbon accumulations. The deep-water area has active salt tectonics that create abundant traps out to and beyond the Sigsbee Escarpment. The deep-water area also has underlying mature Mesozoic source rocks. Evidence of mature source rocks in the deep-water area include (1) ocean bottom vents expelling gas and oil, and (2) natural oil slicks seen at the ocean's surface by aircraft and satellite photos (McDonald et al., 1993). Wells located south of the current productive play limits encounter widespread reservoir-quality turbidite sands.

Methods

The MMS has completed a review of 1,086 *proved* gas and oil fields in the Gulf of Mexico and has placed all pay sands in each field into a hydrocarbon *play*. All pay sands in the same play in a field combine to make a *pool* and the reserves for each pool and its dominant *sand type* were determined. An estimate of a play's *natural geologic limits* was made from the area of existing production, plus *unproved* reserves, and other points of well control (also known as scientific successes or dry holes). The explication of these terms follows and is based on MMS (Melancon, 1994) and SPE (SPE, 1987) usage.

Proved reserves can be estimated with reasonable certainty to be recovered under current economic conditions. These are existing fields and discoveries that are producing or have a commitment to develop such as approved development plans. *Unproved reserves* are capable of producing hydrocarbons in paying quantities but are less certain than proved reserves to be recovered. These are fields that currently have no commitment to be developed. A *Play* is a group of genetically related hydrocarbon reservoirs or pools defined on the basis of depositional origin, age (*chronozone*), geographic outline, structure, and trap style. A *Pool* includes all reservoir sands in a field that are in the same play. A field may include reservoir sands from more than one play. The hydrocarbon volumes used in the graphs associated with each of the seven plays, are pool volumes, not field volumes. A *Chronozone* is a stratigraphic succession of rocks that were deposited during an interval of time usually containing the top of a particular biostratigraphic zone. The top of the chronozone can be correlated geologically and/or confirmed by analyzing seismic data. Thus, the top of a chronozone and the top of the biozone are not always the same. Figure 3 shows the 13 divisions of the Miocene, Pliocene and Pleistocene. We will discuss UPL, MPL,

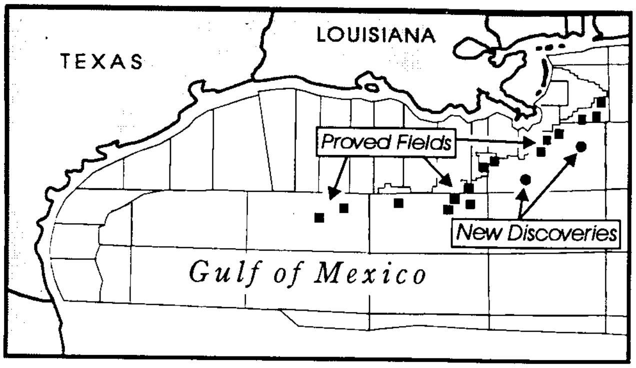

Figure 1. Map of proved fields and new discoveries in deep-water fields, northern Gulf of Mexico.

PLAY NAME	NUMBER OF POOLS	DEEPEST WATER DEPTH	RECOVERABLE BOE	NUMBER OF PRODUCING SANDS
UPPER PLEISTOCENE FANS	33	2178'	571,951,407	141
MIDDLE PLEISTOCENE FANS	45	2172'	547,310,460	116
LOWER PLEISTOCENE FANS	110	2864'	2,557,108,060	497
UPPER PLIOCENE FANS	44	2864'	1,380,454,962	187
LOWER PLIOCENE FANS	23	1467'	263,579,846	95
LOWER UPPER MIOCENE FANS	18	1376'	236,862,591	57
UPPER MIDDLE MIOCENE FANS	13	3318'	354,164,058	35
TOTALS	286	.	5,911,431,384	1128

Figure 2. Miocene, Pliocene and Pleistocene Fan Play summary.

SYSTEM	SERIES	CHRONO. GROUPINGS	BIOCHRONOZONES
QUATERNARY	Pleistocene	UPL	*Sangamon Fauna*
		MPL	*Angulogerina "B" 1 st*
		LPL	*Lenticulina 1*
TERTIARY	Plio-cene	UP	*Buliminella 1*
		LP	*Textularia "X"*
	Miocene	UM3	*Robulus"E"/Bigenerina"A"*
		UM1	*Discorbis 12*
		MM9	*Bigenerina 2*
		MM7	*Bigenerina humblei*
		MM4	*Amphistegina "B"*
		LM4	*Discorbis "B"*
		LM2	*Siphonina davisi*
		LM1	*Lenticulina hanseni*
	Oligo-cene	FA1	*Marginulina idiomorpha*

Figure 3. Stratigraphic Subdivisions and Chronozones of the Miocene, Pliocene and Pleistocene.

and LPL plays in the Pleistocene; the UP, and LP plays in the Pliocene; and the UM1 and MM9 plays in the upper and middle Miocene. Two recent field discoveries in a frontier play of uppermost Miocene (UM-3) age will be discussed. The natural geologic limit outlines the boundary of genetically related facies. The natural geologic limit may be defined by sand limit, facies change, structural change, or any other attribute that limits the area in which the play can be found. In part, *natural geologic limits* may be restricted by limited well control or increasing depth of burial.

For the purpose of this study the MMS sand classification scheme was greatly simplified, (Fig. 4). Sands were grouped into two broad categories, a sharp-based fining upwards log sequence indicative of cut and fill deposition and a coarsening upwards log sequence suggestive of prograding deposition. The sands were further subdivided into "strong" or "weak" sand development classes depending on their sand-shale ratio. Sharp-based, strongly fining upwards sequences suggest channel deposits or amalgamated sand sheets and are indicative of good down-dip reservoir sand quality. In contrast to these strongly developed sands, the remaining classes show much weaker sand quality and are judged as not encouraging

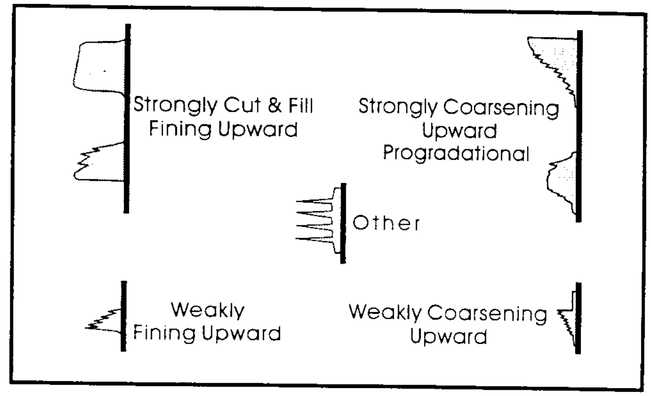

Figure 4. Sand Classification System.

for good downdip sand development. The weakly developed fining upwards sequences indicate sand-poor systems or possible levee deposits, and, weakly developed coarsening upwards sequences are suggestive of interchannel, interlobe or distal fan deposits.

For the seven submarine fan plays described in this paper, 12% of the 1,128 pay sands are in deep-water (305 meters {1,000 feet}), however they contain 22% of the recoverable reserves.

The plays will be described starting with the younger upper Pleistocene plays and proceeding through the older Miocene plays. Each description includes a map showing the proved productive outline of the play, the areas of strong sand development, and the natural geologic limit for the play in the Western and Central portions of the Gulf of Mexico. The natural geologic limit for all the plays was similar in that their northern limit was defined by a change to a progradational facies from a fan facies, their southern limit defined by the Sigsbee Escarpment where down-dip well control could support deep-water sand deposition that far south, and to the east and west by sand limits defined by well control. All reserve volume figures are based on data as of October 31, 1994.

Results

Upper Pleistocene Fans

The Upper Pleistocene Fan play outline (Fig. 5) stretches in a band from the East Breaks area to the Grand Isle area and contains proved reserves of over 571 MMBOE. The play has a large exploration area. The best sand development is seen in the Green Canyon/Garden Banks boundary area. The southern extension of the play to the Sigsbee Escarpment is supported by the excellent sands in the play interval in down-dip wells, especially the OCS G 11643-1 well in Keathley Canyon Block 255.

The proved hydrocarbon reserves are contained in 33 pools and in 141 pay sands. Four deep-water fields have reserves in this play: Garden Banks 387, Green Canyon 75, Green Canyon 184, and Green Canyon 29 (Fig. 5a). The Garden Banks 387 field, fourth largest pool in the play, is located in 664 meters (2,178 feet) of water and has a

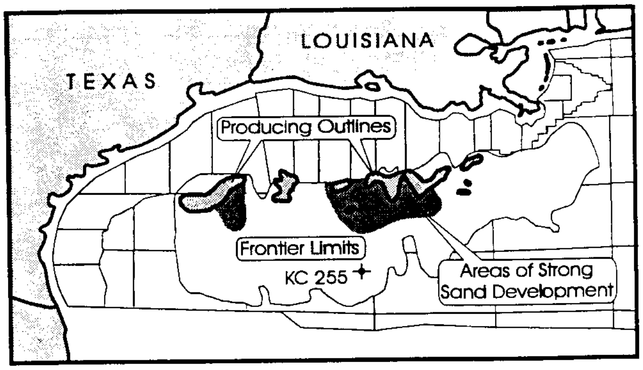

Figure 5. Upper Pleistocene Fan Plays Map.

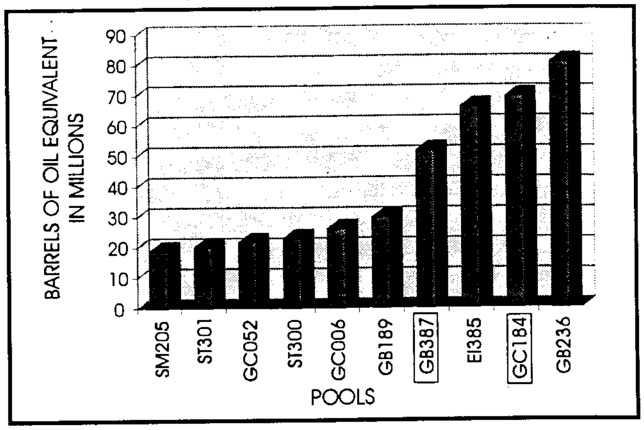

Figure 5a. Graph showing recoverable in place hydrocarbons (BOE) for the ten largest pools in the upper Pleistocene Fan Plays. Pools from deep-water fields are outlined.

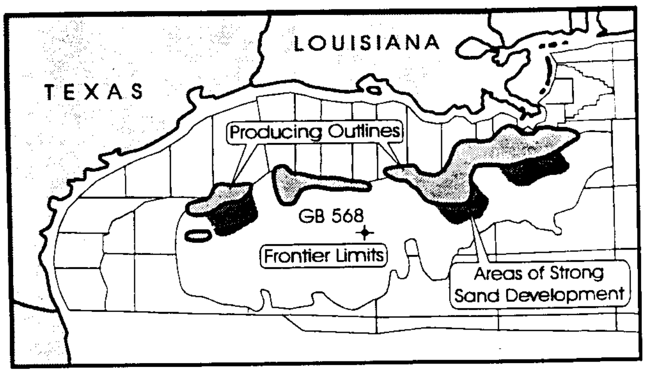

Figure 6. Middle Pleistocene Fan Plays Map.

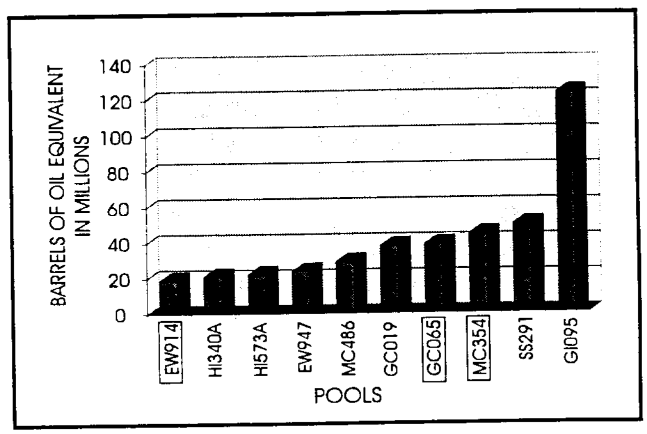

Figure 6a. Graph showing recoverable in place hydrocarbons (BOE) for the ten largest pools in the middle Pleistocene Fan Plays. Pools from fields in deep-water are outlined.

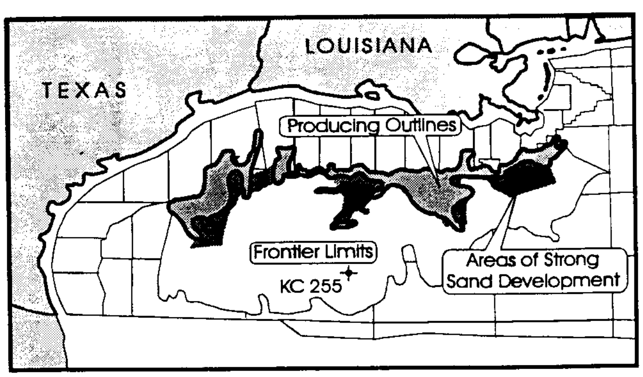

Figure 7. Lower Pleistocene Fan Play Map

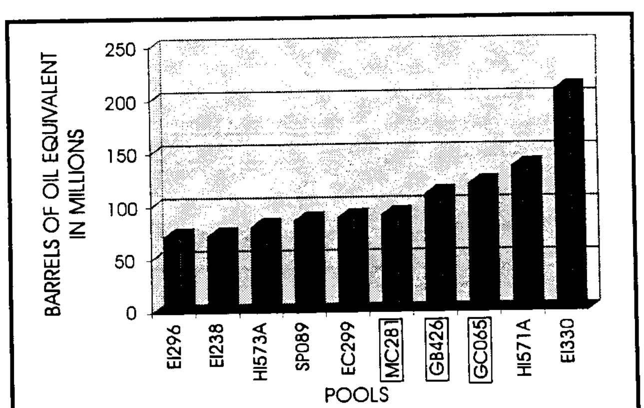

Figure 7a. Graph showing recoverable in place hydrocarbons (BOE) for the ten largest pools in the lower Pleistocene Fan Plays. Pools from fields in deep-water are outlined.

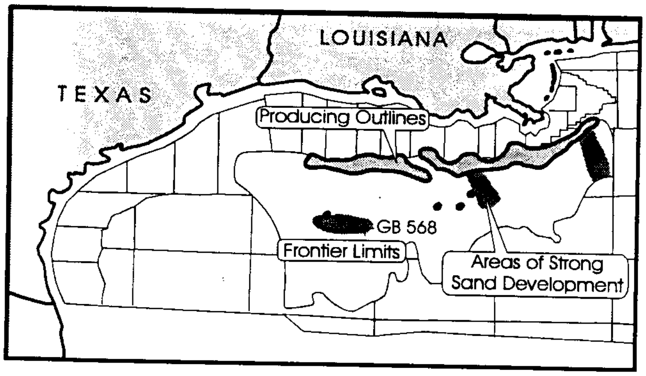

Figure 8. Upper Pliocene Fan Play Map.

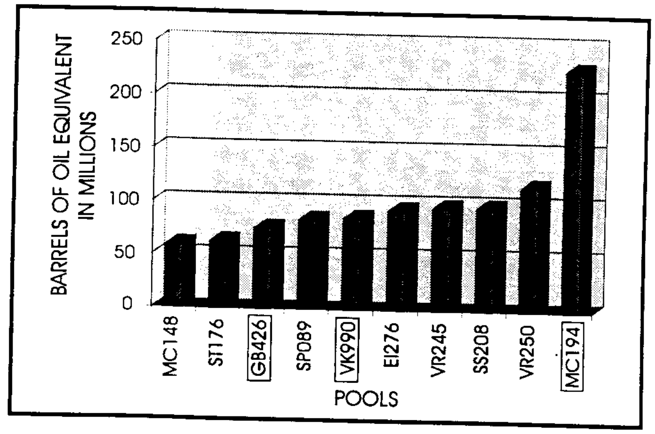

Figure 8a. Graph showing recoverable in place hydrocarbons (BOE) for the ten largest pools in the upper Pliocene Fan Plays. Pools from fields in deep-water are outlined.

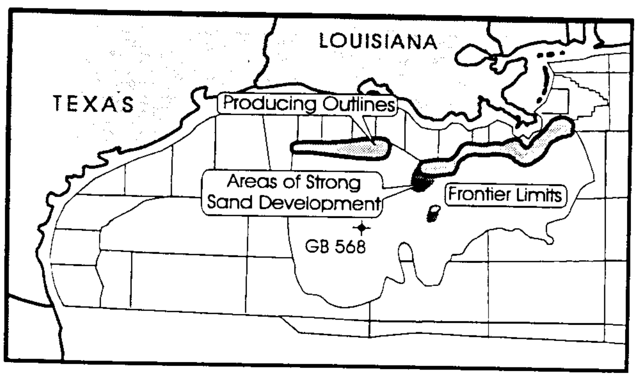

Figure 9. Lower Pliocene Fan Play Map.

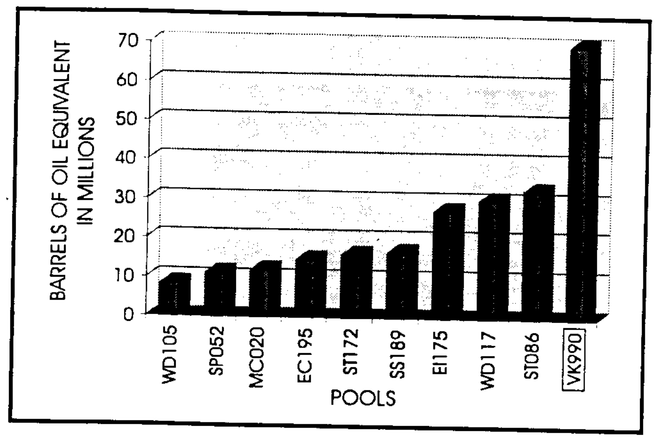

Figure 9a. Graph showing recoverable in place hydrocarbons (BOE) for the ten largest pools in the lower Pliocene Fan Plays. Pools from fields in deep-water are outlined.

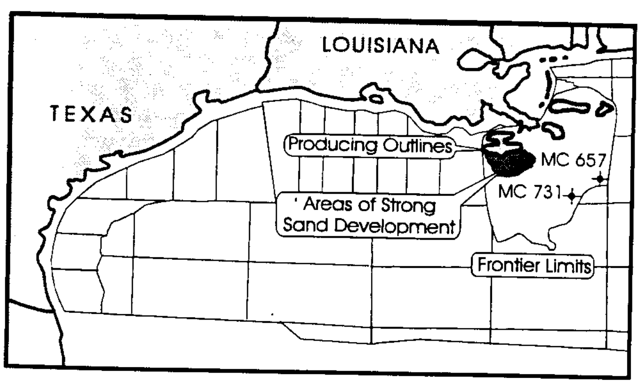

Figure 10. Lower upper Miocene Fan Play Map.

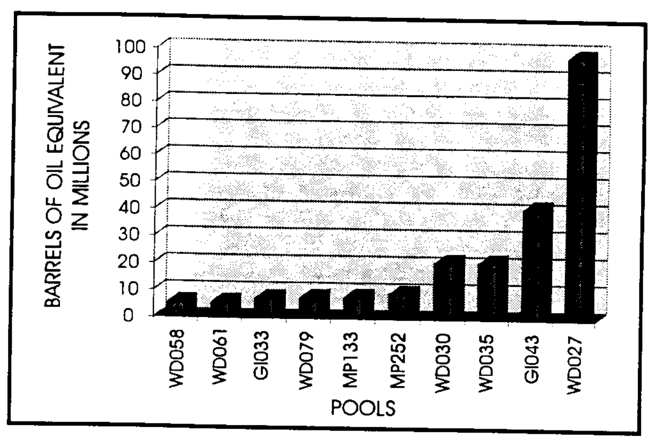

Figure 10a. Graph showing recoverable in place hydrocarbons (BOE) for the ten largest pools in the lower upper Miocene Fan Plays.

volume of 51 MMBOE in 4 pay sands. Well logs show that the sands are dominantly sharp-based fining upwards sequences.

Middle Pleistocene Fans

The middle Pleistocene Fan play outline (Fig. 6) extends in a band from the East Breaks area to the Mississippi Canyon area and contains proved reserves of over 547 MMBOE. The play has a large exploration area and the best sand development is in the East Breaks, Green Canyon, and Mississippi Canyon areas. The potential down-dip extension of the play south to the Sigsbee Escarpment is supported by good reservoir sands in the OCS G 12662-1 well in Garden Banks Block 568.

The proved hydrocarbon reserves are contained in 45 pools and in 116 pay sands. Seven deep-water fields have reserves in this play:

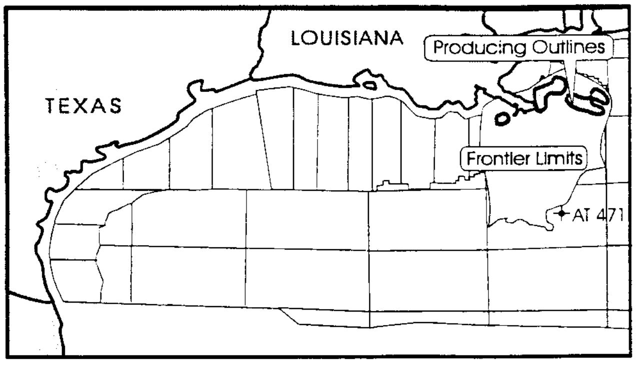

Figure 11. Upper Middle Miocene Fan Play Map

Green Canyon 75, Green Canyon 116, Green Canyon 65, Ewing Banks 914, Mississippi Canyon 194, Mississippi Canyon 281, and Mississippi Canyon 354 (Fig. 6a). The Green Canyon Block 65 field, fourth largest pool in the play, is located in 412 meters (1,352 feet) of water and has a pool volume of 38 MMBOE in 13 pay sands. The reservoir sands include both sharp-based fining upwards sequences and coarsening upwards sequences.

Lower Pleistocene Fans

The lower Pleistocene Fan play is the largest play in the deep-water Gulf of Mexico containing proved reserves of over 2,557 MMBOE. The lower Pleistocene Fan play extends in a band from the East Breaks area to the Mississippi Canyon area (Fig. 7). The plays large exploration area has a natural geologic limit defined to the north by a change to progradational facies, to the south by the Sigsbee Escarpment and to the east and west by potential sand limits. The down-dip extension of the play to the Sigsbee Escarpment is supported by good potential reservoir sands in the Keathley Canyon Block 255 well, OCS G 11643-1. The best sand development in the play is in central and eastern East Breaks, eastern Garden Banks, eastern Green Canyon and in the Mississippi Canyon areas.

The proved hydrocarbon reserves are contained in 110 pools and in 497 pay sands. Ten deep-water fields have reserves in this play: Garden Banks 387, Garden Banks 426 (Auger Field), Green Canyon 29, Green Canyon 65, Green Canyon 75, Green Canyon 116, Mississippi Canyon 109, Mississippi Canyon 194, Mississippi Canyon 281, and Mississippi Canyon 397 (Fig. 7a). The Garden Banks Block 426 field, the fourth largest pool in the play, is located in 873 meters (2,864 feet) of water and has a pool volume of 109 MMBOE in six pay sands. The sands are generally sharp-based fining upwards sequences.

Upper Pliocene Fans

The upper Pliocene Fan play is the second largest play by hydrocarbon volume in the deep-water Gulf of Mexico and contains proved reserves of over 1,380 MMBOE. The upper Pliocene Fan play extends in a band from the High Island area to the Viosca Knoll area (Fig. 8). The play has a large exploration area, and the best sand development is seen in the Mississippi Canyon area. The down-dip extension of the play to the Sigsbee Escarpment is supported by reservoir-quality sands in the OCS G 12662-1 Garden Banks Block 568 well.

The proved hydrocarbon reserves are contained in 44 pools and in 187 pay sands. Eight deep-water fields have reserves in this play: Ewing Banks 914, Garden Banks 426, Green Canyon 65, Green Canyon 116, Mississippi Canyon 109, Mississippi Canyon 194, Mississippi Canyon 397 and Viosca Knoll 990 (Fig. 8a). The Mississippi Canyon 194 field is the largest pool in the play with 226 MMBOE in proved reserves. The field is located in 309 meters (1,013 feet) of water and the reserves are contained in 17 pay sands. These sands are predominantly weakly developed coarsening upwards sequences.

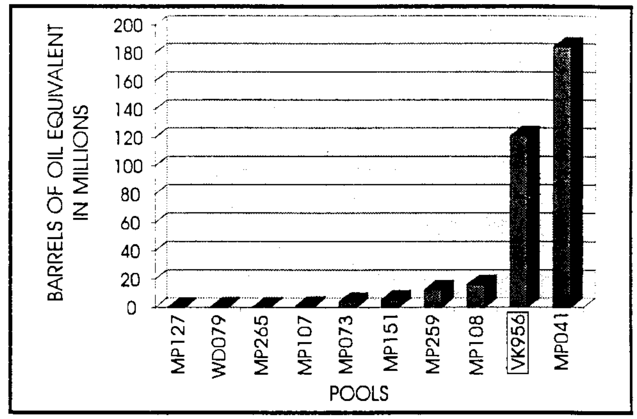

Figure 11a. Graph showing recoverable in place hydrocarbons (BOE) for the ten largest pools in the upper middle Miocene Fan Plays. Pools from fields in deep-water are outlined.

Lower Pliocene Fans

The lower Pliocene Fan play has more modest proved reserves of over 263 MMBOE and a smaller producing area when compared to the previous two plays. The lower Pliocene Fan play outline extends in a band from Garden Banks area to Mississippi Canyon area (Fig. 9). The play's moderate exploration area has a natural geologic limit defined in the north by a change to progradational facies, to the south by the Sigsbee Escarpment, and to the east and west by potential sand limits. The best sand development is in the eastern Green Canyon area. The down-dip extension of the play is supported by good sands in the Garden Banks Block 568 well (OCS G 12662-1).

The proved hydrocarbon reserves are contained in 23 pools and in 95 pay sands. Three deep-water fields have reserves in this play: Green Canyon 65, Mississippi Canyon 194, and Viosca Knoll 990 (Fig. 9a). The Viosca Knoll 990 Field is the sixth largest pool in the play with 69 MMBOE in proved reserves. The field is located in 446 meters (1,467 feet) of water and the reserves are contained in four pay sands. These sands are predominantly weakly developed coarsening upwards sequences.

Lower Upper Miocene Fans

The lower upper Miocene Fan play contains proved reserves of 237 MMBOE. The play outline extends in a band from Mississippi Canyon area to Main Pass area (Fig. 10). The play has a small exploration area, and the best developed sands are seen in the West Delta and South Pass areas. At first appearance, the play's potential in the deep-water portions of the Gulf of Mexico appears low; however, several wells in Mississippi Canyon area favor additional discoveries for the play in the deep-water Gulf. The Mississippi Canyon 731 (OCS G 7955-1) well in the southern part of the block and the Mississippi Canyon 657 (OCS G 8496-1) well near the eastern boundary of the block contain strongly developed reservoir sands in the lower upper Miocene Fan play interval.

The hydrocarbon reserves are contained in 18 pools and in 57 pay sands. Only one deep-water field has reserves in this play, the Viosca Knoll 783 field. The Viosca Knoll 783 Field has only 1 MMBOE associated with this play and is not among the top 10 pools in this play (Fig. 10a). The Viosca Knoll 783 field is located in 420 meters (1,376 feet) of water and the reserves are contained in one pay sand. This sand exhibits an indefinite log character.

Upper Middle Miocene Fans

The upper middle Miocene Fan play's outline stretches in a band from Mississippi Canyon area to Main Pass area (Fig. 11). The play contains over 354 MMBOE. The play's moderate exploration area has a natural geologic limit defined in the north by a change to progradational facies, to the south by the Sigsbee Escarpment, and to the east and west by potential sand limits. Overall, the play shows only weak sand development; however, there are two wells that indicate good quality reservoir sands are present locally. First, the Viosca Knoll 956 field shows good sand development in 1009 meters (3,318 feet) of water in this play interval. Even more important is the Atwater 471 well (OCS G 8512-1), located south of the natural geologic limits of the play as defined by the Sigsbee Escarpment, that contains good sands in the play interval. Since this well is located down-dip of the southernmost limits of the play, it is more than likely that good reservoir sands exist updip of this well in the play area.

The proved hydrocarbon reserves are contained in 13 pools and in 35 pay sands. One deep-water field contains reserves in this play, the Viosca Knoll 956 field (Fig. 11a). The Viosca Knoll 956 Field is the second largest pool in the play with over 121 MMBOE in recoverable reserves. The field is located in 1,009 meters (3,318 feet) of water and the reserves are contained in 6 pay sands. These sands are strongly developed fining upwards sequences.

Uppermost Miocene Fans

As mentioned earlier, a frontier play now is contributing to the reserves in the deep-water Gulf of Mexico: the uppermost Miocene Fan play. In the past year (1994) Shell Offshore Inc. has announced development plans at the Mississippi Canyon 807 (Mars Field) and Exxon has a discovery at Mississippi Canyon 211 (Mickey Field). The two discoveries will likely add more than 500 MMBOE to deep-water Gulf of Mexico proved reserves. The play at the end of 1993 contained over 200 MMBOE of proved recoverable reserves in 19 pools and in 65 pay sands in shelf fields. The two recent discoveries at the Mars and Mickey fields suggest a large potential exploration area for the play throughout much of the Mississippi Canyon area in the deep-water Gulf of Mexico. In addition, the presence of excellent sands in the OCS G 11643-1 Keathley Canyon 255 well not only extends the play limits to the west, but also supports extending the play down-dip to the Sigsbee Escarpment. It is to be expected that there will be future discoveries in the upper Miocene Fan play.

Discussion

A review of the 7 plays suggests that the lower Pleistocene Fan Play and the upper Pliocene Fan Play have the highest exploration potential. These two plays are ranked highest due to the large size of their exploration area, the large volume of gas and oil in existing fields, the projection of good reservoir sands down-dip of these existing fields, and the observation that the two plays appear to become more oil prone down-dip. Another factor enhancing their exploration potential is the possibility for encountering pays in one or more of the shallower plays. The upper Pleistocene fan and middle Pleistocene fan plays extend over much of the same Gulf of Mexico area.

Conclusions

The 16 proved deep-water fields and their 34 pools contain pay sands that are members of seven hydrocarbon plays. These seven hydrocarbon plays extend from shallower waters of the Gulf of Mexico where they have a wide lateral extent. The seven plays comprise a total of 218 fields and 286 pools (Fig. 2). This links the small number of deep-water fields and pools into a much larger and more widespread population of fields and pools in the shallower waters of the Gulf of Mexico. This is important in that the area downdip of the current productive play outline has a high exploration potential yet is largely untested owing to water depths that exceed 305 meters (1,000 feet). Since the productive outline for each play covers a much larger area than would be indicated by simply outlining the area of the limited number of deep-water fields, it greatly expands the range for future deep-water exploration.

It is important to recognize that within the productive outline of a play there are areas of better reservoir sand quality. This is useful in projecting the presence of good sand potential down-dip of these areas.

Although not the topic of this paper, the 252 pools in shallower water depths not only provide a great wealth of analog engineering data but can also provide long histories of production to aid in understanding the new deep-water fields. These data will be included in the Offshore Atlas to be published in late 1995.

Acknowledgements

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References

Melancon, J. M., S. M. Bacigalupi, C. J. Kinler, D. A. Marin and M. T. Prendergast, 1994, Estimated proved oil and gas reserves, Gulf of Mexico Outer Continental Shelf, December 31, 1993: U. S. Department of the Interior, Minerals Management Service OCS Report MMS 94-0045, 49 p.

MacDonald, I. R., N. L. Guinasso, Jr., S. G. Ackleson, J. F. Amos, R. Buckworth, R. Sassen, and J. M. Brooks, 1993, Natural oil slicks in the Gulf of Mexico visible from space: Journal of Geophysical Research, v. 98, no. C9, p. 16351-16364.

North American Commission on Stratigraphic Nomenclature, 1983, North American stratigraphic code: The American Association of Petroleum Geologists Bulletin, v. 67, p. 841-875.

Reed, C. R., C. L. Leyendecker, A. S. Kahn, C. J. Kinler, P. F. Harrison, and G. P. Pickens, 1987, Correlation of Cenozoic sediments Gulf of Mexico outer continental shelf, Part I: Galveston Areas offshore Texas through Vermilion Area offshore Louisiana: OCS Report MMS 87-0026: New Orleans, La., U. S. Department of the Interior Minerals Management Service, Gulf of Mexico OCS Region Office, 35 p.

Society of Petroleum Engineers (SPE), 1987, Definitions for oil and gas reserves: Journal of Petroleum Technology, May 1987, p. 577-578.