Atlas of Northern Gulf of Mexico Gas and Oil Reservoirs— Volume 1. Miocene and Older Reservoirs

Play Analysis Procedures

by

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INTRODUCTION

This report summarizes activities conducted during the second year of the Northern Gulf of Mexico Oil and Gas Resource Atlas Series program. Funded by the Gas Research Institute, the U.S. Department of Energy, and the U.S. Department of the Interior's Minerals Management Service, investigations began in October 1992, with the Bureau of Economic Geology as lead technical contractor. The objective of this program is to develop an atlas of hydrocarbon plays by integrating geologic and engineering data for oil and gas reservoirs with large-scale patterns of depositional basin fill and geologic age. The oil and gas atlas of the Gulf of Mexico will provide a critically compiled, comprehensive reference, which is needed to more efficiently develop reservoirs, to extend field limits, and to better assess the opportunities for intrafield exploration. The play atlas series will provide an organizational framework to aid development in mature areas and to extend exploration paradigms from mature areas to frontier areas deep below the shelf and into deep waters of the continental slope. In addition to serving as a model for exploration and education, the offshore atlas will aid resource assessment efforts of State, Federal, and private agencies by allowing for greater precision in the extrapolation of variables within and between plays. Classification and organization of reservoirs into plays have proved to be effective in previous atlases produced by the Bureau, including the Texas oil (Galloway and others, 1983) and gas atlases (Kosters and others, 1989), the central and eastern Gulf Coast gas atlas (Bebout and others, 1992), and the Midcontinent gas atlas (Bebout and others, 1993).

OBJECTIVES

The objective of the program is to produce a reservoir atlas series of the Gulf of Mexico that (1) classifies and groups offshore oil and gas reservoirs into a series of geologically defined reservoir plays, (2) compiles comprehensive reservoir play information that includes descriptive and quantitative summaries of play characteristics, cumulative production, reserves, original oil and gas in place, and various other engineering and geologic data, (3) provides detailed summaries of representative type reservoirs for each play, and (4) organizes computerized tables of reservoir engineering data into a geographic information system (GIS). The primary product of the program will be an oil and gas atlas series of the offshore northern Gulf of Mexico and a computerized geographical information system of geologic and engineering data linked to reservoir location.

BACKGROUND STATEMENT

The Offshore Northern Gulf of Mexico Oil and Gas Resource Atlas Series is a cooperative research effort managed by the Bureau of Economic Geology as lead technical contractor. Funding for the program is supplied by the Department of Energy (DOE) through the Morgantown Energy Technology Center (METC) and the Bartlesville Program Office (BPO), the Gas Research Institute (GRI), and the Department of the Interior's Minerals Management Service (MMS). The State of Louisiana Center for Coastal, Energy, and Environmental Resources and the Geological Survey of Alabama are subcontractors for research in their respective State waters.

The need to find additional hydrocarbons is directing exploration in the Gulf of Mexico toward historically productive areas on the shelf and frontier trends on the slope. Systematic synthesis of information on oil and gas resources for the offshore area is needed for the continued success of exploration, development, and resource assessment in the area. We are responding to this need through a coordinated research effort to develop a gas and oil atlas series about the offshore northern Gulf of Mexico. Efficient offshore development requires improved understanding of the controls on the location and distribution of gas and oil reservoirs for field extension and infill drilling.

Our play methodology includes identifying structural and depositional style, constructing composite type logs and type log cross sections, and integrating geologic data from type reservoirs. We emphasize progradational, aggradational, and retrogradational depositional styles and submarine-fan depositional facies because they strongly influence the distribution of reservoir-quality sands and sandstones. For example, submarine-fan reservoirs of the *Lenticulina* chronozone in the High Island Area of Texas State waters compose a play controlled by the distribution of reservoir sandstone. In contrast, structural style is typically the key determinant of the trapping mechanism. A play of middle Miocene reservoirs that is structurally controlled forms the Corsair trend in the Federal OCS of Brazos and Mustang Areas. The extent of hydrocarbon plays depends largely on the distribution of depositional and diagenetic facies containing favorable reservoir rocks. Hydrocarbons are trapped where structures coincide with favorable facies. The lower Miocene of offshore Texas is a useful area in which to apply these concepts of play analysis because depositional style and facies are well described and the extensional structural style is relatively uniform.

PLAY-ANALYSIS PROCEDURE

White (1980) and Galloway and others (1983) defined a play as a group of reservoirs genetically related by depositional origin, structural style or trap type, and nature of source rocks and seals. The generalized play-analysis procedure we used for the offshore gas and oil atlas program is as follows: (1) define chronozones, (2) outline area of production for chronozones, (3) collect engineering and geologic data for each reservoir within chronozones, (4) identify reservoirs on field type logs, (5) correlate reservoirs, depositional styles, and chronozones on strike and dip cross sections with type logs, (6) outline plays by grouping depositionally and structurally similar reservoirs, (7) synthesize defining attributes of each play, (8) identify and describe type reservoirs within each play, (9) tabulate reservoir engineering data for each play, and (10) write play descriptions.

Chronostratigraphy

Play analysis begins with identification and correlation of chronozones. Chronozones provide a temporal framework for grouping reservoirs in the Gulf of Mexico. In the absence of formations, chronozones are typically defined on the basis of biostratigraphic zones. In order to correlate reservoirs within strata of the same age, we employ an MMS-based chronostratigraphic synthesis of the Gulf according to biostratigraphic zones (fig. 1) (Reed and others, 1987). Major flooding surfaces and their biostratigraphically rich faunal assemblages are important reference horizons for this chronostratigraphic subdivision. The 26 chronozones identified by the MMS are grouped into 16 chronozones for the Atlas program.

Depositional Style

Three depositional styles used as primary defining attributes of plays in the offshore Gulf atlas are retrogradation (transgression), aggradation, and progradation (fig. 2). These depositional styles define the large-scale patterns of basin fill in the Gulf of Mexico and provide a framework for predicting sand-body trends, reservoir distribution, and reservoir quality. We identify the depositional styles by using spontaneous potential (SP) log patterns as well as water depth, paleoecological depth zones, seismic lines, and structure. We also identify submarine fans as a primary depositional defining attribute and substitute depositional style. Although submarine fans are not confined to a single depositional style, they are identified uniquely because they are important reservoirs on the slope and below the shelf.

We chose to identify depositional styles instead of depositional facies or systems tracts because styles (1) capture the appropriate scale of geologic variability for a basinwide resource investigation, (2) dovetail with the existing chronostratigraphic divisions in the Gulf, (3) are readily interpreted from logs, and (4) avoid the complications inherent in local depositional events. Although a basinwide analysis of sequence stratigraphic systems tracts or genetic stratigraphic sequences would be useful, such an analysis is beyond the scope of this project. The depositional styles correlation grid is an important first step to such a study.

We recognize that in some fields nearly every sandstone is a hydrocarbon reservoir, and in those instances the structural style is more important than depositional style in controlling reservoir distribution. Examples of reservoirs that are structurally controlled include middle Miocene reservoirs associated with the Corsair trend and various reservoirs in the Louisiana OCS over salt structures. Plays based solely on structural style are of limited exploration utility in mature areas

SYSTEM	SERIES	ATLAS CHRONO.	CHRONO-ZONES	BIOCHRONOZONES
QUATERNARY	Pleistocene	UPL	UPL-4	Sangamon Fauna
			UPL-3	*Trimosina* "A" 1 st
			UPL-2	*Trimosina* "A" 2 nd
			UPL-1	*Hyalinea* "B"/*Trimosina* "B"
		MPL	MPL-2	*Angulogerina* "B" 1 st
			MPL-1	*Angulogerina* "B" 2 nd
		LPL	LPL-2	*Lenticulina* 1
			LPL-1	*Valvulineria* "H"
TERTIARY	Plio-cene	UP	UP	*Buliminella* 1
		LP	LP	*Textularia* "X"
	Miocene	UM3	UM-3	*Robulus* "E"/*Bigeneria* "A"
			UM-2	*Cristellaria* "K"
		UM1	UM-1	*Discorbis* 12
		MM9	MM-9	*Bigenerina* 2
			MM-8	*Textularia* "W"
		MM7	MM-7	*Bigenerina humblei*
			MM-6	*Cristellaria* "I"
			MM-5	*Cibicides opima*
		MM4	MM-4	*Amphistegina* "B"
			MM-3	*Robulus* 43
			MM-2	*Cristellaria* 54/*Eponides* 14
			MM-1	*Gyroidina* "K"
		LM4	LM-4	*Discorbis* "B"
			LM-3	*Marginulina* "A"
		LM2	LM-2	*Siphonina davisi*
		LM1	LM-1	*Lenticulina hanseni*
PALEOGENE	Oligocene	FA1	Oligocene Frio-Anahuac	*Marginulina idiomorpha*

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Figure 1. Chronostratigraphic subdivisions and biostratigraphic zones used in Gulf of Mexico. Modified from Reed and others (1987).

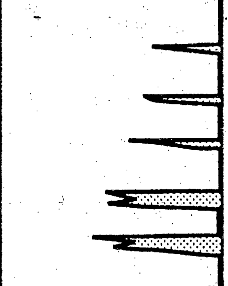
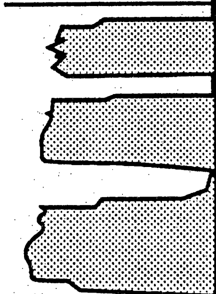
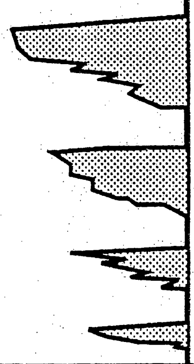
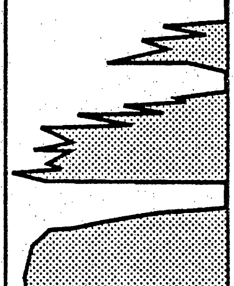
SP LOG SHAPE	DEPOSITIONAL STYLE/FACIES	CHARACTER
	RETROGRA-DATIONAL	Commonly upward-fining log character, rarely upward-coarsening; thin sandstone bodies, upward-thickening retrogradational package of sandstone bodies separated by thicker mudstones
	AGGRA-DATIONAL	Thick, blocky to upward-fining log character; stacked sandstone bodies separated by thinner mudstones
	PROGRA-DATIONAL	Commonly upward-coarsening log character, rarely upward-fining; thin to thick sandstone bodies; upward-thickening, progradational package of sandstone bodies separated by subequally thick mudstones
	DEEP-SEA FAN	Variable sandstone body thickness patterns; includes thick to thin, blocky to upward-fining log character, sharp-based sandstones; also, serrated, thin to thick sandstones; thick mud-stone at top; singular or stacked package of sandstone bodies; commonly upward-fining package

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Figure 2. Depositional styles, sand-body characteristics, and associated idealized SP log shapes.

where all such structures are well mapped. Depositional style remains a robust attribute of plays were reservoirs are structurally controlled as well as in areas where reservoirs are depositionally stratified. Plays defined on the basis of depositional style thus remain suitable for hydrocarbon exploration in structurally dominated areas.

Depositional styles are important elements of two common models that organize packages of reservoir-quality strata: (1) sequence stratigraphic systems tracts (Vail, 1987; Van Wagoner and others, 1988) and (2) genetic stratigraphic sequences (Galloway, 1989). The internal architecture of both models is similar; the difference lies in the choice of sequence boundaries. Sequence stratigraphic systems tracts (Vail, 1987; Van Wagoner and others, 1988) are unconformity-bounded packages comprising highstand systems tracts, lowstand systems tracts, and transgressive systems tracts. In contrast, genetic stratigraphic sequences (Galloway, 1989) are bounded by flooding surfaces and comprise progradational systems tracts, lowstand progradational complexes, and retrogradational systems tracts.

For the atlas program, we use flooding surfaces as primary genetic boundaries because (1) the abundance of biostratigraphic information typically coincides with the boundaries of most MMS chronozones in the Gulf of Mexico and (2) major flooding surfaces in the Gulf of Mexico are more readily identified on type logs and seismic lines than are unconformities. The chronozones do not correspond to sequence stratigraphic cycles because they are one-half cycle out of phase and chronozones typically include two or three third-order cycles (Haq and others, 1987).

Type Logs

Type logs were chosen for each field to identify the style and position of all reservoirs. All productive reservoirs, chronozones, biozones, paleobathymetric zones, and depositional styles are identified on each type log (fig. 3). Large fields may require a composite type log in order to capture all reservoirs because of expanded sections across growth faults and intrafield stratigraphic variations.

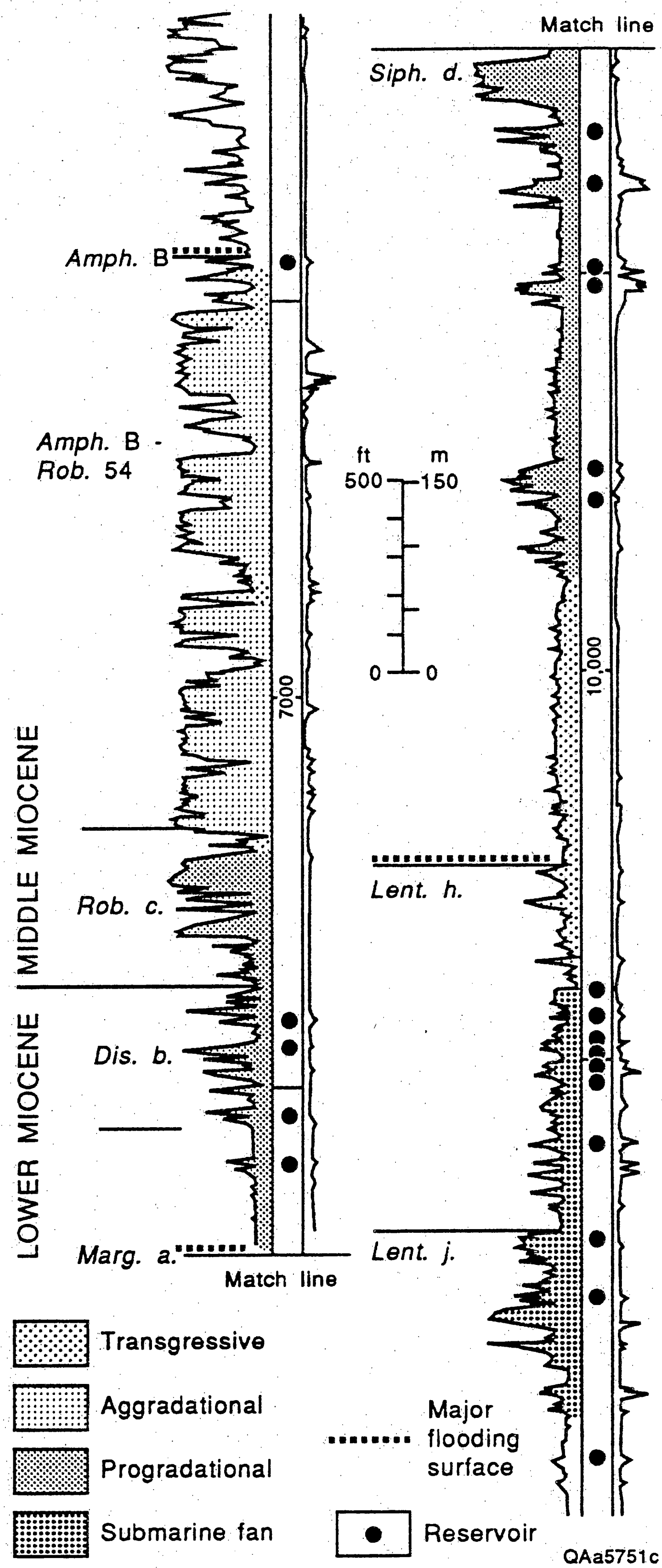


Figure 3. Type log showing depositional styles, major flooding surfaces, reservoirs, and biozones for High Island Block 24-L field.

Play Analysis

Cross sections based on type logs are used to correlate reservoirs within a chronostratigraphic and depositional style framework and form one basis for grouping reservoirs into plays. A strike-oriented cross section of the upper Texas coast illustrates the depositional styles and reservoir distribution of the Miocene section (MM-4 to LM-1) (fig. 4). Depositional styles include submarine-fan *Lenticulina* sandstones, progradational *Lenticulina*, *Siphonina d.*, and *Discorbis b.* sandstones and mudstones, aggradational *Amphistegina* B to *Robulus c.* sandstones, and transgressive sandstones and mudstones of *Amphistegina* B (fig. 4). The progradational depositional style and the submarine-fan facies contain abundant reservoirs, whereas the aggradational and retrogradational (transgressional) styles are relatively barren.

Twenty-four plays and two subplays of Miocene and Oligocene reservoirs have been identified in the Texas State offshore area. Offshore Oligocene (Frio–Anahuac Formations) reservoirs are present in two regions of the Texas offshore (Hamlin, 1989): a southern region of Mustang and Matagorda Areas and a northern region of Galveston Area. Distal Frio reservoirs, currently productive offshore, include shelf and slope sandstones associated with extensive shelf-margin progradation. Miocene reservoirs are present in Texas State waters from South Padre Area to High Island Area and extend south into the Federal OCS and east into Louisiana State waters.

Miocene Plays

The lower Miocene is the primary hydrocarbon-producing zone in the Texas State offshore area, and gas is the dominant hydrocarbon. Lower Miocene production extends a short distance into the Federal OCS. In the Federal OCS, middle Miocene strata are highly productive in rollover structures assoicated with the Corsair trend just downdip of the State–Federal boundary (Morton and others, 1988). Three examples of major lower Miocene plays in the Galveston and High Island Areas will be discussed. Miocene plays in offshore Texas State waters have produced 3.1 Tcf of gas and 37.6 MMbbl of oil. Miocene reservoirs below the *Amphistegina* B chronozone are the most

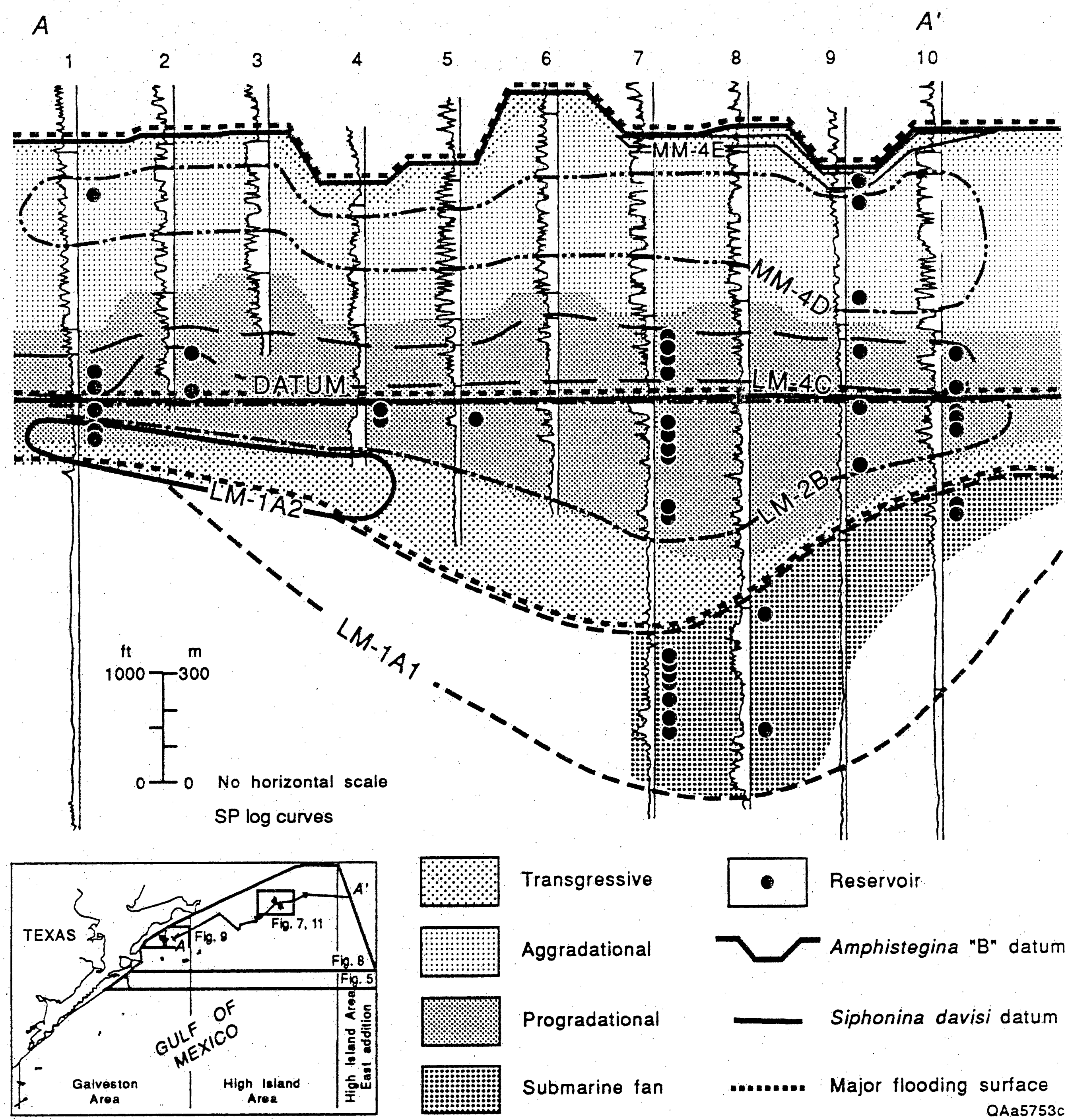


Figure 4. Strike-oriented type log cross section showing depositional styles for Galveston and High Island Areas. The progradational depositional style and submarine-fan facies contain the most numerous and largest reservoirs. Inset map shows location of figures 4, 5, 7, 8, 9, and 11.

productive in the Texas State offshore waters. Lower Miocene production is predominantly gas; subordinant volumes of oil are associated with salt domes in updip plays. The structural style is characterized by major extension of the lower Miocene shelf margin. Rollover anticlines and listric growth faults are the primary traps.

High Island and Galveston Areas host three examples of lower Miocene plays: LM-1A1, LM-1A2, and LM-2B (fig. 5). The defining attributes of submarine-fan *Lenticulina* play LM-1A1 are listed in table 1. Plays LM-2B and LM-1A2 comprise progradational reservoirs from the *Siphonina davisi* and *Lenticulina* chronozones, respectively. Annual production of all reservoirs in each play shows the long-term temporal trend of increasing production from deeper reservoirs (fig. 6). The shallow play LM-2B had an initial increase in gas production from 1970 to 1974 and a second higher peak from 1979 to 1981. Production from the play LM-1A2—progradational *Lenticulina*—peaked from 1977 to 1980. The latest surge in production, from 1980 to 1983, came from the deeply buried LM-1A1, the submarine-fan *Lenticulina* play.

Lower Miocene Play LM-1A1—Submarine-Fan *Lenticulina*

Lower Miocene play LM-1A1 comprises the oldest lower Miocene reservoirs and extends across the High Island Area and into State waters of western Louisiana. Production is from *Lenticulina* submarine-fan sandstones in Texas and from *Planulina* sandstones in Louisiana State waters (Caughey, 1981). The structural style is characterized by fault blocks in rollover anticlines. Gas is the dominant type of hydrocarbon.

High Island Block 24-L field produces gas from a series of *Lenticulina* reservoir sandstones (I, J, J-SER, KC, KG, and KL reservoirs) in seven individual fault blocks. The configuration of *Lenticulina* reservoir sandstones at High Island Block 24-L field indicates production from J-SER and KG reservoirs in fault blocks D and K (fig. 7). High Island Block 30-L field, which has produced 119 Bcf, contains the most productive reservoirs in the play.

Exploration for submarine-fan sandstones of the *Lenticulina* chronozone has been hampered by significant depth of burial (12,000 to greater than 18,000 ft) and by erratic distribution of

Table 1. Defining attributes of lower Miocene play LM-1A1.

Defining attribute—Deep-water, gas-rich, submarine-fan facies of middle to upper slope associated with submarine canyon, submarine fan, or failed embayment of continental margin during *Lenticulina* chronozone. Two *Lenticulina* chronozone plays are differentiated on basis of depositional environment: LM-1A1 (updip progradational deltaic play) and LM-1A2 (downdip submarine-fan play).

Hydrocarbon type—Geopressured gas.

Reservoir facies—Aggradational submarine-fan channel and overbank facies along State/Federal boundary. Reservoirs in submarine-fan systems are very fine to fine sandstone of two types: (1) blocky, sharp-based, channel facies and (2) serrated mudstone and very fine sandstone of overbank and levee facies. Reservoirs are often perforated throughout entire sand body. Trends of thick sandstone are dip oriented.

Structural style—Fields and reservoirs are associated with major rollover anticlines and growth faults along the lower Miocene continental margin.

Trapping mechanism—Downthrown fault blocks of rollover anticlines associated with growth faults; also, upthrown and tilted fault blocks between growth faults.

Possible hydrocarbon source—Subjacent slope mudstones and underlying Frio/Anahuac shelf and slope mudstones.

Exploration maturity—Relatively immature in submarine-fan subplay because of burial depths of 12,000 to 16,000 ft.

Frontiers—Stratigraphic traps in updip pinch-out of slope sandstones; deeper pool extensions.

Intraplay limitations—Deep burial, increase in depth of reservoirs downdip.

Boundaries—Loss of reservoir sandstone away from localized embayed or failed margin; loss of reservoir sandstone downdip, updip, to southwest, and northeast; and loss of high-quality thick net sandstone away from dip-oriented axes.

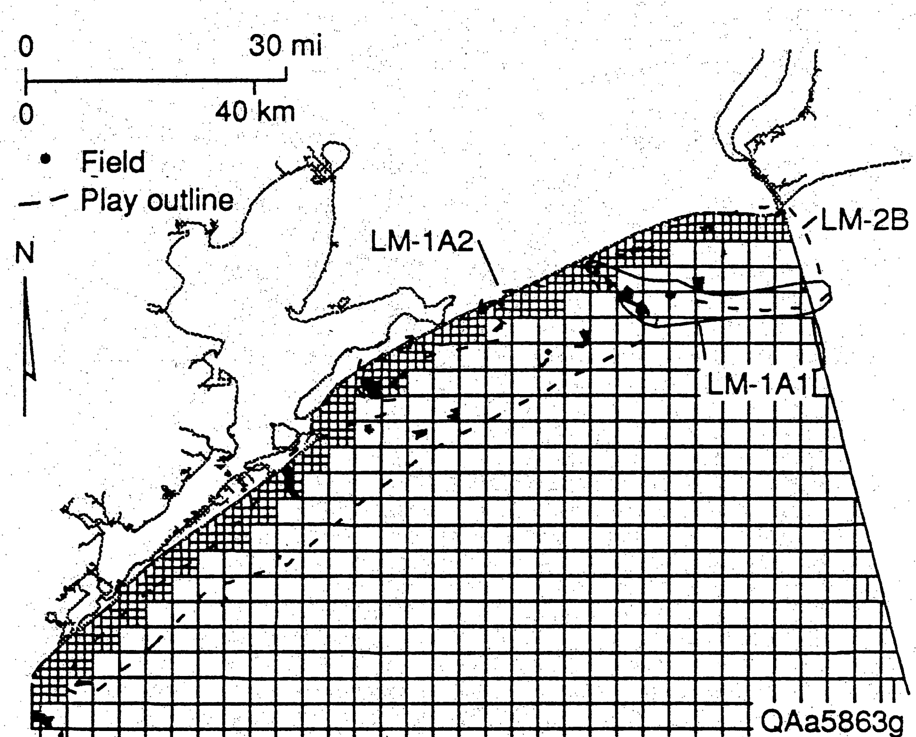


Figure 5. Map of lower Miocene plays (LM-1A1, LM-1A2, and LM-2) in the Texas State offshore and the High Island and Galveston Areas. Map location is indicated on inset map of figure 4.

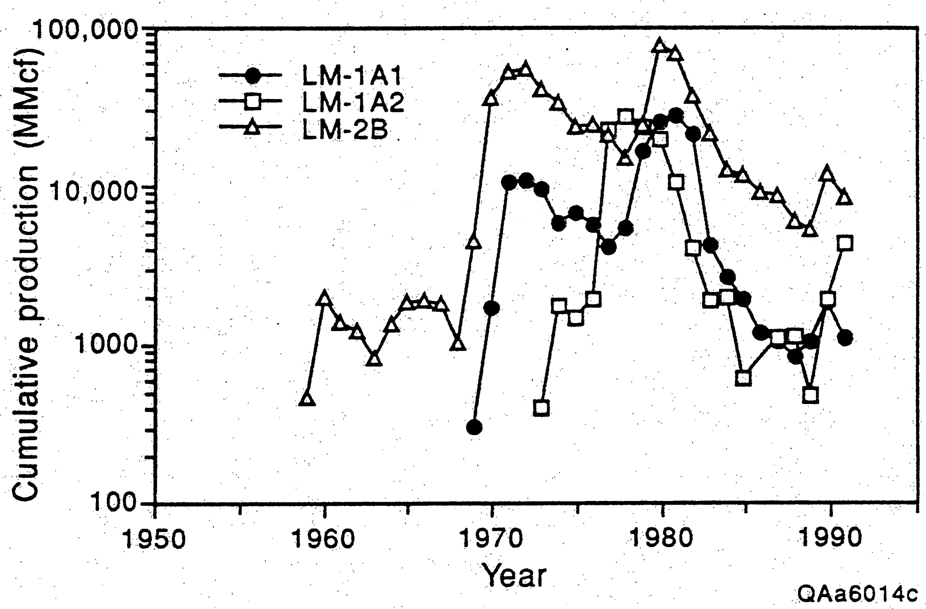


Figure 6. Graph of annual production from all reservoirs in lower Miocene plays LM-1A1, LM-1A2, and LM-2B.

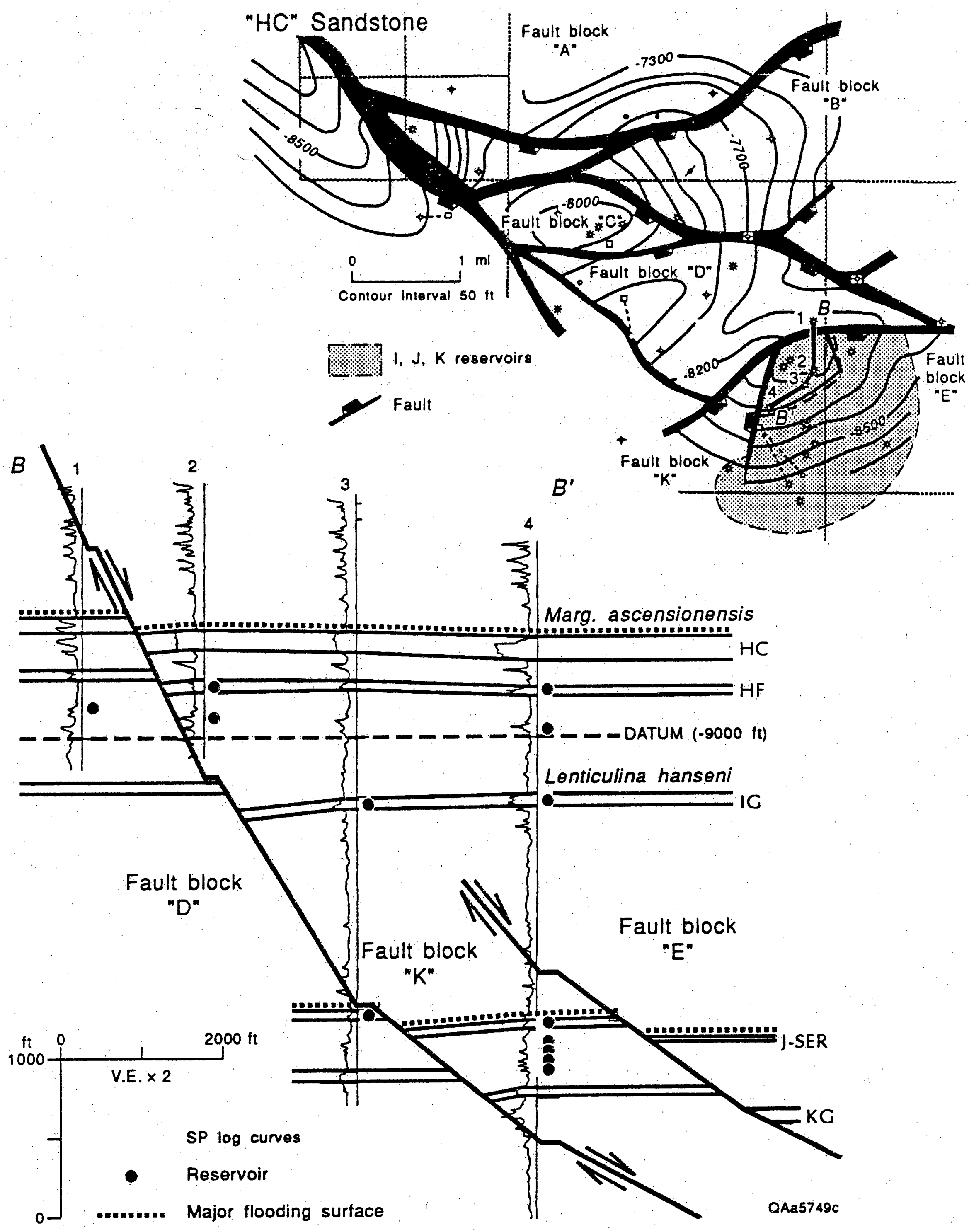


Figure 7. Structural cross section of submarine-fan *Lenticulina* play LM-1A1 at High Island Block 24-L, J-SER, and KG reservoirs in fault blocks D and K. Note that the structure-contour map indicates the location of I, J, and K reservoirs, but the structure of the HC reservoir is illustrated because of greater well control. Map location is indicated on inset map of figure 4. Structure-contour map modified from Fowler and others (1986).

reservoir sandstone bodies. A map of maximum sandstone illustrates the thickness of the single thickest sandstone body in the *Lenticulina* chronozone in a part of the High Island and Galveston Areas (fig. 8). The updip thinning and downdip coalescence of thick maximum sandstone supports the submarine-fan interpretation. The accumulation of thick *Lenticulina* sandstone is related to submarine canyon and fan lobe deposition or to failure of the *Lenticulina* shelf margin and filling of a submarine embayment (Morton, 1993).

Lower Miocene Play LM-1A2—Progradational *Lenticulina*

Lower Miocene play LM-1A2 also extends across the High Island Area into State waters of western Louisiana. Gas is the dominant type of hydrocarbon that is produced. Peak play production was 26 Bcf in 1978; however, production has climbed in the 1990's as a result of recent discoveries on subtle structures in nearshore Texas State land at Pirate's Cove and State Tract 60 fields. Block 176-S (L-1 and L-2A), Galveston 175-S (L-1), and Shipwreck (L-1 and L-2) fields and reservoirs produce gas from progradational reservoirs in fault traps and rollover anticlines in the Galveston Area (fig. 9). Shipwreck (L-1 and L-2) reservoirs have produced 107 Bcf and are the most productive *Lenticulina* reservoirs. The structural style of this play is dominated by rollover anticlines and expansion-zone listric normal faults (fig. 10). The salt dome in the center of figure 10 is a relatively isolated structure rooted at the zone of décollement in the Oligocene.

Lower Miocene Play LM-2B—Progradational *Siphonina davisi*

Lower Miocene play LM-2B extends across High Island Area into Galveston Area and from western Louisiana State waters into the Federal OCS. Gas is the dominant type of hydrocarbon that is produced. The depositional style is progradational facies of shelf-margin deltas. The *Siphonina davisi* chronozone comprises two to three progradational packages that are 200 to 500 ft thick. Toward the southwest, *Siphonina davisi* sandstones thin and pinch out from the major deltaic lobe

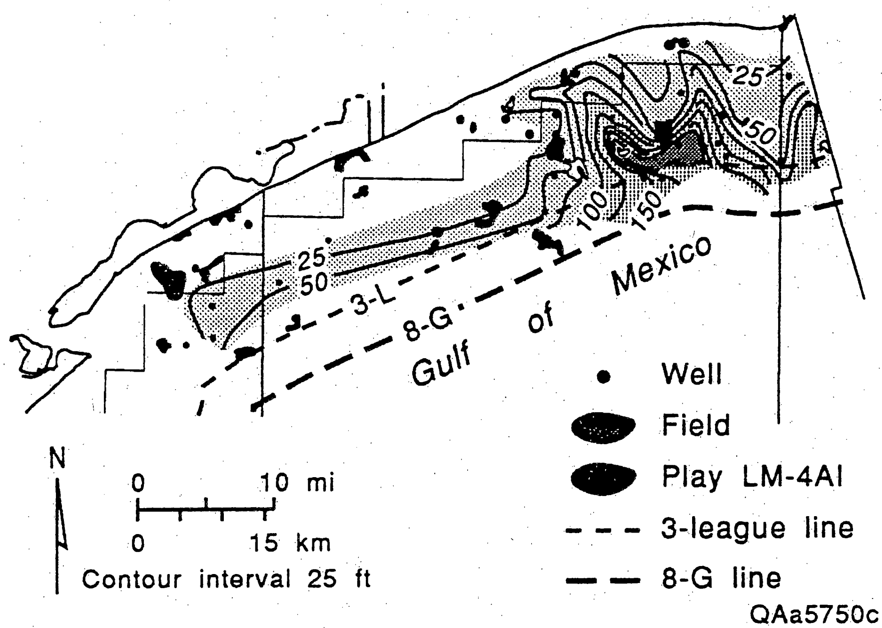


Figure 8. Map of maximum thickness of individual sand bodies in *Lenticulina* chronozone in High Island Area. Log character, ecological zonations, and sharp-based SP character indicate that thick *Lenticulina* sandstones probably represent submarine-fan and canyon sandstones. Map location is indicated on inset map of figure 4.

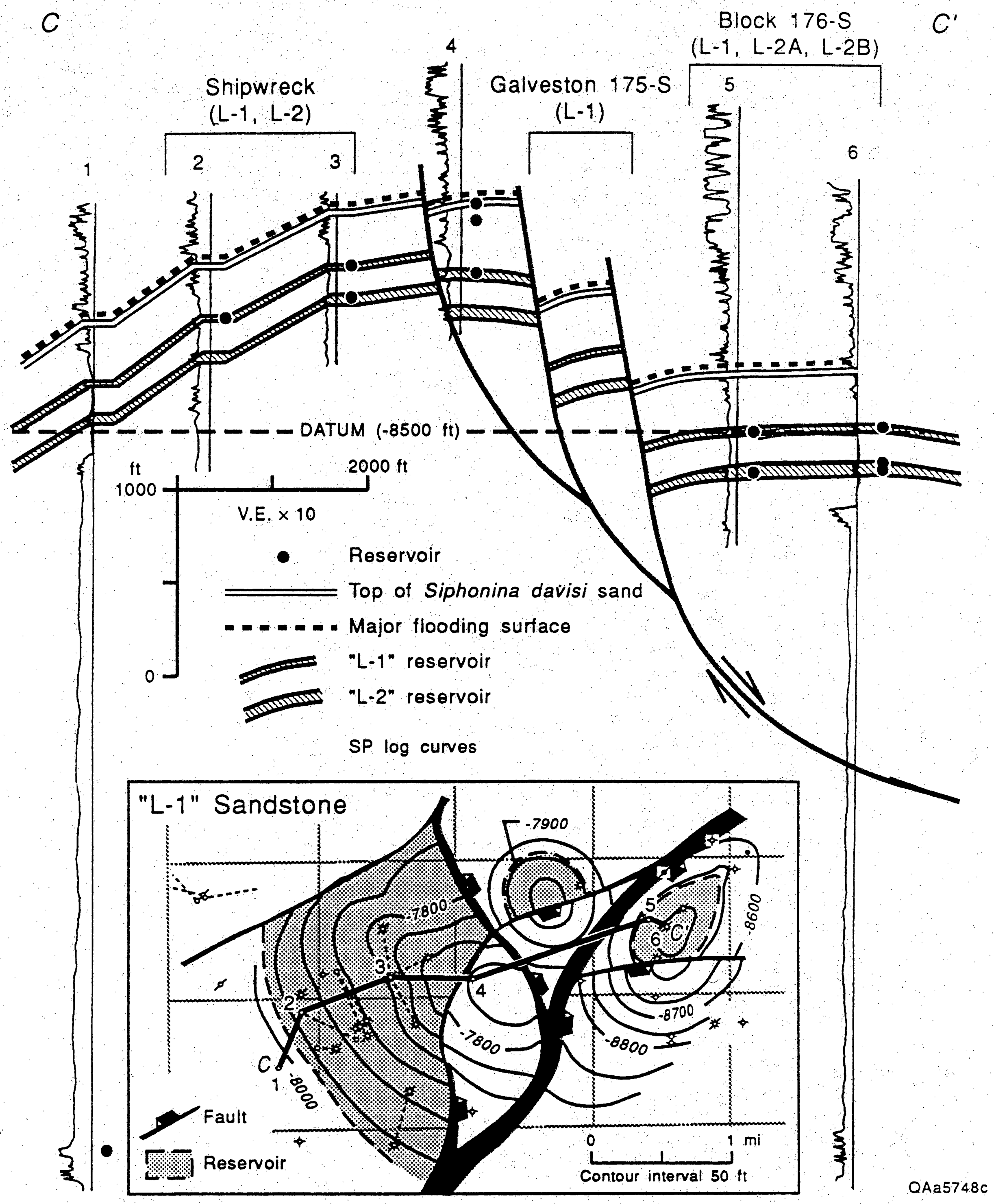
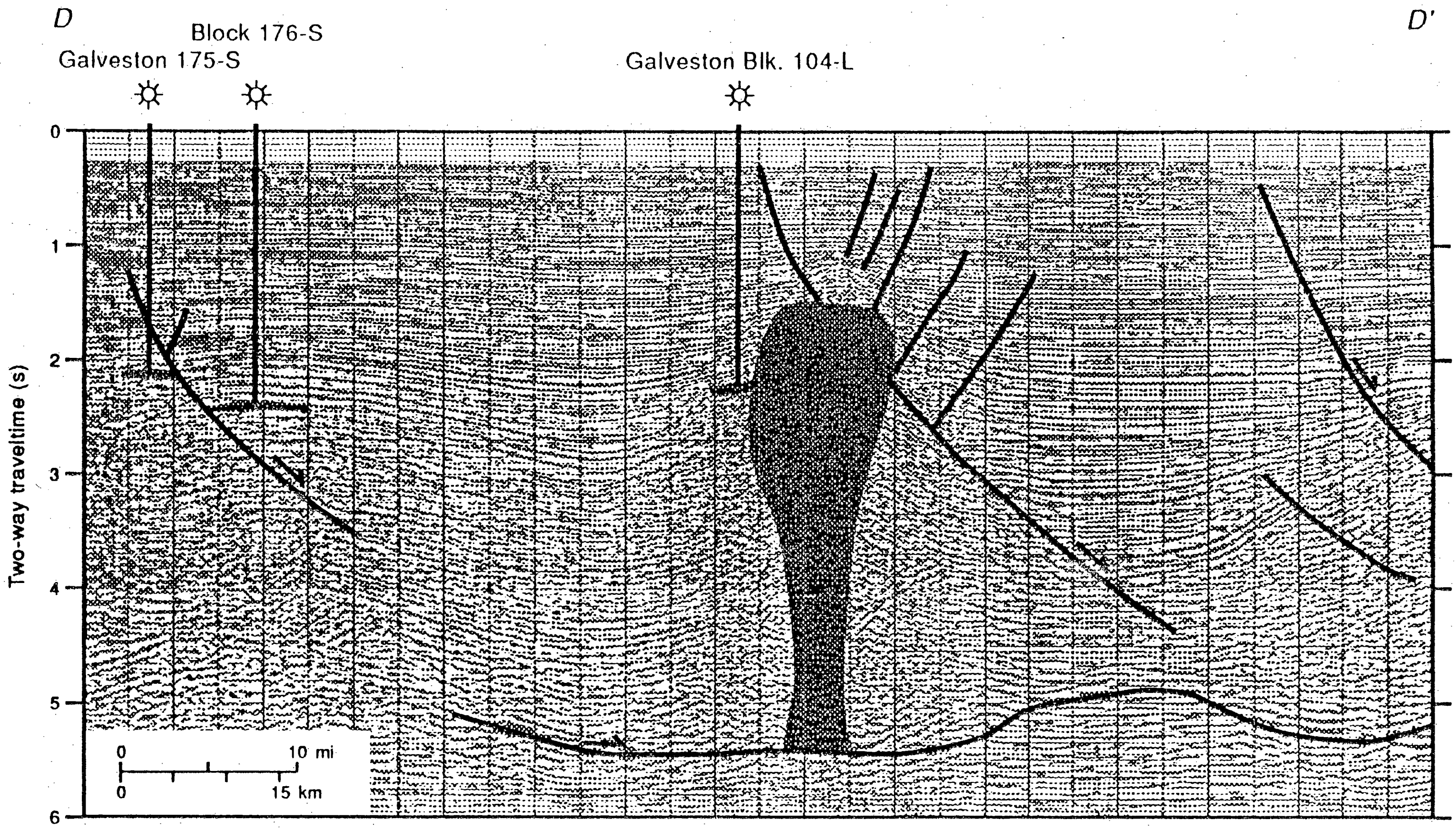
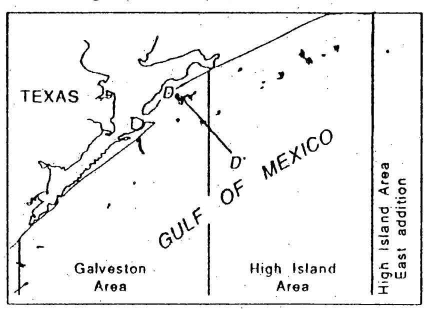


Figure 9. Structural configuration of progradational *Lenticulina* play LM-1A2 at Shipwreck L-1 and L-2 reservoirs, Galveston 175-S L-1 reservoir, and Block 176-S L-1, L-2, and L-2B reservoirs. Map location is indicated on inset map of figure 4.





PLAY	CHRONOZONE	PRODUCTIVE FACIES	TRAP STYLE
LM-2B	*Siphonina davisi*	Progradational deltaic sandstone	Salt dome
LM-1A2	*Lenticulina*	Progradational shelf/deltaic sandstone	Rollover anticline

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Figure 10. Seismic line illustrating structural style associated with listric growth faults trapping reservoirs in progradational *Lenticulina* play LM-1A2 and salt dome structure in progradational *Siphonia davisi* play LM-2B.

centered in the State part of the High Island Area. Downdip in the Federal OCS, *Siphonina davisi* reservoirs compose a submarine-fan play.

The structural style of this play is characterized by extension and listric growth faults at the lower Miocene continental margin. Tilted fault blocks and rollover anticlines form most of the traps. Flank traps against salt domes, as at Galveston Block 104-L, form a secondary structural style. In addition to structurally controlled traps, stratigraphic entrapment of hydrocarbons is affected by sand-body pinch-outs at High Island 30-L, High Island 31-L, and Galveston 102-L.

The HC reservoir of High Island Block 24-L field is the type reservoir of play LM-2B (fig. 11). Cumulative production from the HC reservoir totals 185 Bcf from four separate fault blocks. *Siphonina davisi* sandstones form laterally continuous wave-dominated, shelf-margin deltaic sand bodies that are segmented by normal faults into a series of fault-block reservoirs (fig. 10).

Conclusions

The gas and oil atlas series of the Gulf of Mexico will provide the comprehensive reference needed to more efficiently develop reservoirs, to extend field limits, and to better assess opportunities for intrafield exploration and development in a mature gas and oil province. The classification and organization of reservoirs into plays on the basis of depositional style, structural style, and reservoir properties have proven to be effective in the Texas oil and gas atlases, the Midcontinent gas atlas, and the central and eastern Gulf Coast gas atlas. Regional play analysis provides a logical basis for simultaneously evaluating both field reserve-growth potential and opportunities for extension exploration in mature plays. Examples of play analysis from the lower Miocene of offshore Texas demonstrate the usefulness of the procedure for synthesizing reservoir data. Although the lower Miocene reservoirs of offshore Texas represent a mature part of the Gulf Coast Basin, deep-water submarine-fan objectives in the *Lenticulina* chronozone provide a useful analog for exploration in other submarine-fan reservoirs on the shelf and slope and in subsalt settings.

A GIS system will facilitate advanced analysis of spatially linked geologic and reservoir engineering data that are keyed to field and play location.

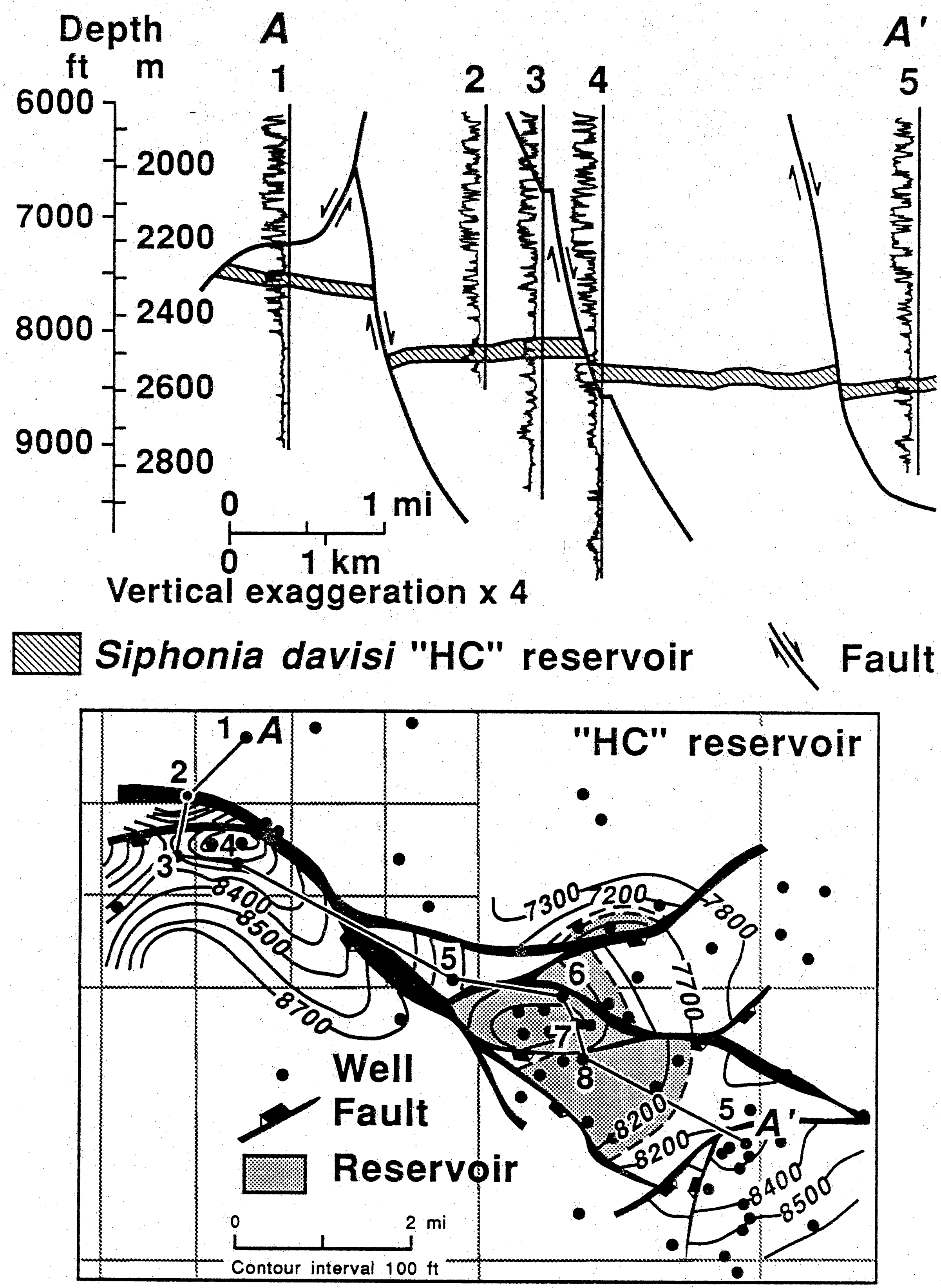

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Figure 11. Structural cross section and structure-contour map of progradational *Siphonia davisi* play LM-2B at High Island Block 24-L HC reservoir. Map location is indicated on inset map of figure 3. Structure map modified from Fowler and others (1986).

REFERENCES

Bebout, D. G., White, W. A., Garrett, C. M., and Hentz, T. F., eds., 1992, Atlas of major central and eastern Gulf Coast gas reservoirs: The University of Texas at Austin, Bureau of Economic Geology, 88 p.

Bebout, D. G., White, W. A., Hentz, T. F., and Grasmick, M. K., eds., 1993, Atlas of major Midcontinent gas reservoirs: The University of Texas at Austin, Bureau of Economic Geology, 85 p.

Caughey, C. A., 1981, Deltaic and slope deposits in the *Planulina* trend (basal Miocene), southwestern Louisiana (abs.), *in* Recognition of shallow-water versus deep-water sedimentary facies in growth-structure affected formations of the Gulf Coast Basin: Society of Economic Paleontologists and Mineralogists, Gulf Coast Section 2d Annual Research Conference, Abstracts, p. 20–21.

Fowler, J., Houston, J., Mitchell, D., and Slater, J. A., 1986, High Island Block 24-L field, Jefferson County, *in* Typical oil and gas fields of southeast Texas V, part II: Houston Geological Society, p. 291–294.

Galloway, W. E., 1989, Genetic stratigraphic sequences in basin analysis 1: architecture and genesis of flooding-surface bounded depositional units: American Association of Petroleum Geologists Bulletin, v. 73, no. 2, p. 125–142.

Galloway, W. E., Ewing, T. E., Garrett, C. M., Tyler, Noel, and Bebout, D. G., 1983, Atlas of major Texas oil reservoirs: The University of Texas at Austin, Bureau of Economic Geology, 139 p.

Hamlin, H. S., 1989, Hydrocarbon production and exploration potential of the distal Frio Formation, Texas Gulf Coast and offshore: The University of Texas at Austin, Bureau of Economic Geology Geological Circular 89-2, 47 p.

Haq, B. U., Hardenbol, L., and Vail, P. R., 1987, Chronology of fluctuating sea levels since the Triassic (250 million years ago to present): Science, v. 235, p. 1156–1167.

Kosters, E. C., Bebout, D. G., Seni, S. J., Garrett, C. M., Jr., Brown, L. F., Jr., Hamlin, H. S., Dutton, S. P., Ruppel, S. C., Finley, R. J., and Tyler, Noel, 1989, Atlas of major Texas gas reservoirs: The University of Texas at Austin, Bureau of Economic Geology, 161 p.

Morton, R. A., 1993, Attributes and origins of ancient submarine slides and filled embayments: examples from the Gulf Coast Basin: American Association of Petroleum Geologists Bulletin, v. 77, no. 6, p. 1064–1081.

Morton, R. A., Jirik, L. A., and Galloway, W. E., 1988, Middle–upper Miocene depositional sequences of the Texas coastal plain and continental shelf: geologic framework, sedimentary facies, and hydrocarbon plays: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 174, 40 p.

Reed, J. C., Leyendecker, C. L., Khan, A. S., Kinler, C. J., Harrison, P. F., and Pickens, G. P., 1987, Correlation of Cenozoic sediments, Gulf of Mexico Outer Continental Shelf: U.S. Department of the Interior, Minerals Management Service, OCS Report MMS 87-0026, variously paginated.

Seni, S. J., Desselle, B. A., and Standen, Allan, 1994, Scope and construction of a gas and oil atlas series of the Gulf of Mexico: examples from Texas offshore lower Miocene plays: Gulf Coast Association of Geological Societies Transactions, v. 44, p. 681–690.

Vail, P. R., 1987, Seismic stratigraphy interpretation using sequence stratigraphy, part 1, seismic stratigraphic interpretation procedure, *in* Bally, A. W., ed., Atlas of seismic stratigraphy: American Association of Petroleum Geologists Studies in Geology 27, v. 1, p. 1–10.

Van Wagoner, J. C., Posamentier, H. W., Mitchum, R. M., Vail, P. R., Sarg, J. F., Louitit, T. S., and Hardenbol, J., 1988, An overview of the fundamentals of sequence stratigraphy and key definitions, *in* Wilgus, C. K., and others, eds., Sea-level changes: an integrated approach: Society of Economic Paleontologists and Mineralogists Special Publication 42, p. 39–45.

White, D. A., 1980, Assessing oil and gas plays in facies-cycle wedges: American Association of Petroleum Geologists Bulletin, v. 64, no. 8, p. 1158–1178.