DEPARTMENT OF THE INTERIOR

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Geologic Framework for Petroleum Assessment of the Western Gulf Basin, Province 112

By

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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INTRODUCTION

The Western Gulf basin Province 112, of Region 6, extends from the Rio Grande to Chandeleur Sound off the eastern extremity of the Mississippi delta, and from the inner edge of the Gulf Coastal Plain to the seaward edge of the involved coastal states' territorial waters (fig. 1). The southern boundary along the seaward limit of State waters exhibits an offset, marking the expansion of State waters from three miles off Louisiana to three leagues (10.36 miles) off Texas. The province includes the southern portions of the States of Texas and Louisiana and encompasses more than 115,000 square miles. It is contained within the greater Gulf of Mexico depositional basin, of Mesozoic and Cenozoic age, and is bordered on the north by the Bend Arch and Fort Worth basin, East Texas basin and the Louisiana-Mississippi salt basins. The purpose of this report is to summarize the geologic framework of the province and to identify the plays which were used in the assessment of oil and gas resources as reported in Mast and others (1989).

GEOLOGIC HISTORY

The Gulf of Mexico basin, in which the province resides, formed on the southern passive margin of the North American continent as a relatively small ocean basin when the African and South American continents began to drift southeasterly during early Mesozoic time (Walper and Miller, 1985). The basin gained its present form from a combination of rifting and intrabasin sedimentary-tectonic processes during and after the Mesozoic Era (Murray and others, 1985).

During the early stage of continental separation in Triassic time, five complex systems of rhombic grabens or rift basins (Rio Grande embayment, East Texas basin, North Louisiana basin, Mississippi Interior basin, and the Apalachicola embayment) were formed on thinned continental crust and became the landward margin of the northern Gulf of Mexico basin (fig. 2). Structurally positive elements which separate the rift basins are the San Marcos arch, the Sabine arch, the Monroe arch, and the northeast extension of the Wiggins arch (Martin, 1984).

A broad continental platform developed across the northern Gulf basin as a result of mid-Jurassic to Late Cretaceous subsidence. An early Cretaceous carbonate reef trend (shown in figs. 1 & 3) formed along the shelf edge of the continental platform from Mexico to offshore South Florida (Martin, 1978) and defines the late Mesozoic shelf margin.

A massive influx of clastic sediments during Cenozoic time resulted in accumulation of a thick sequence of offlapping prisms of terriginous sediments in depocenters seaward of the Mesozoic shelf edge in the central and western parts of the northern Gulf basin (figs. 4 and 5). A shift of the depocenters from south Texas to south-central Louisiana caused the seaward-prograding continental shelf to be best developed off Louisiana by Neogene time (Martin, 1978).

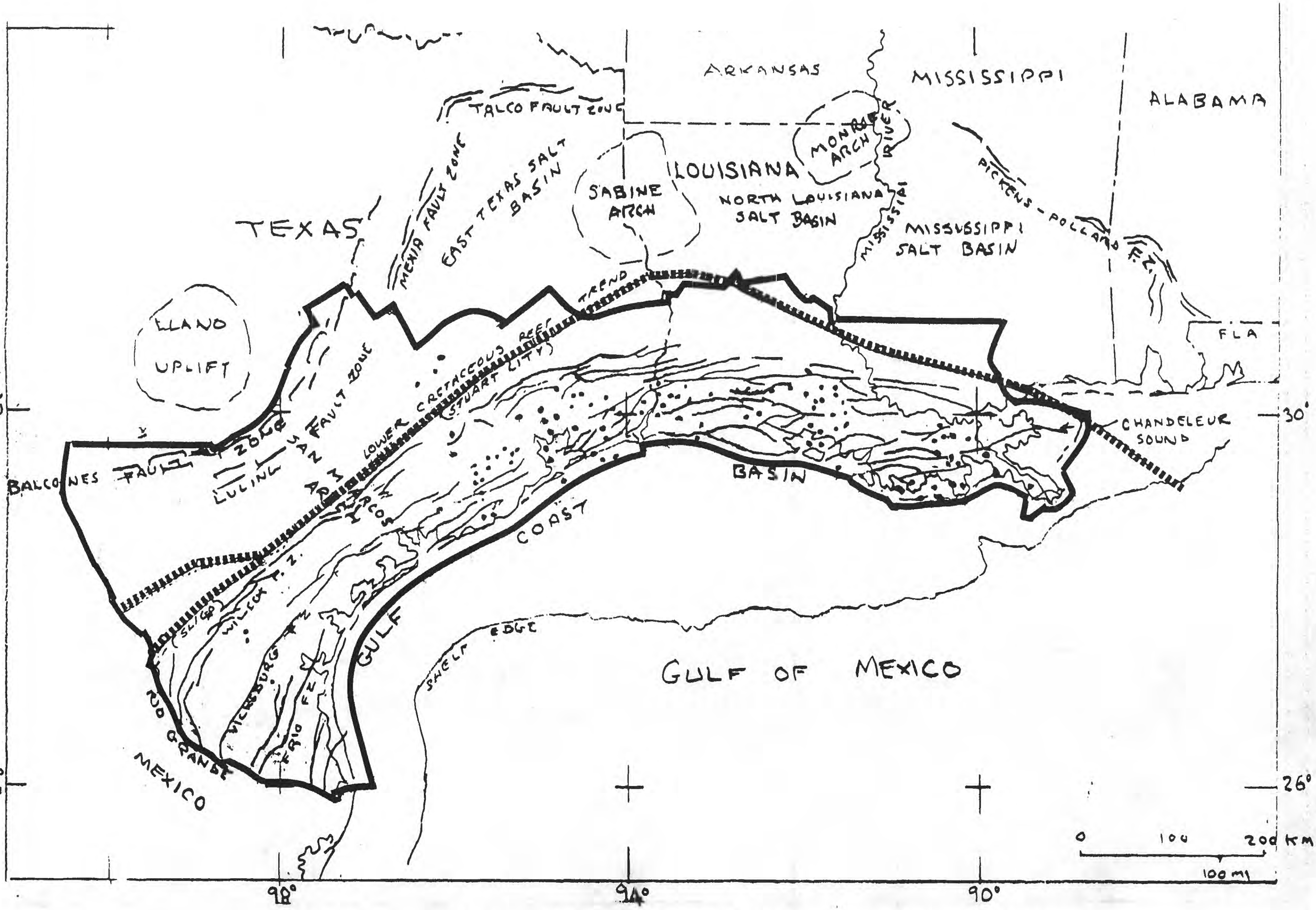

Fig. 1. Index map of the Western Gulf basin, showing major structural elements and Lower Cretaceous reef trend. Western Gulf basin Province outline shown by heavy frame.

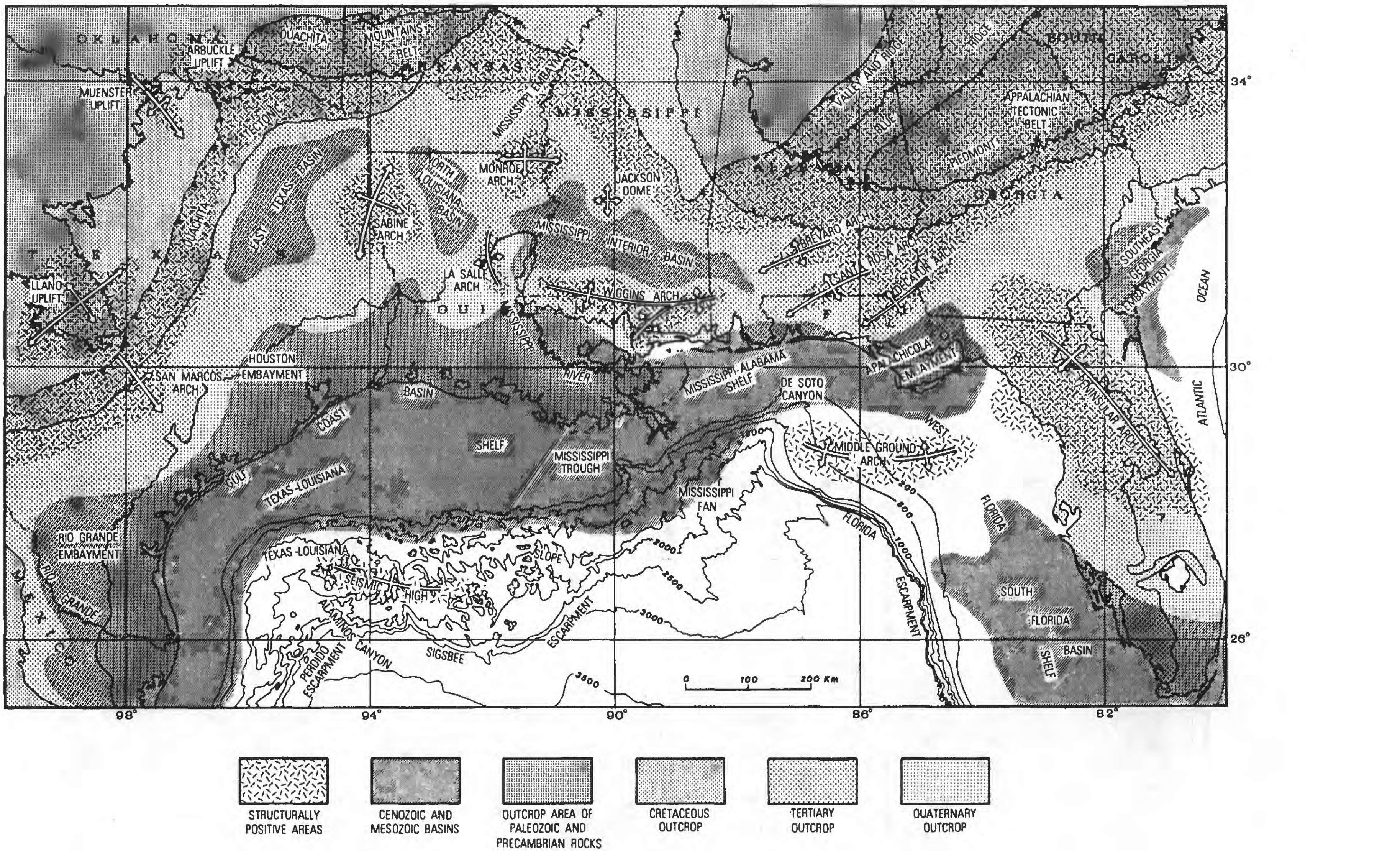

Figure 2. Generalized geologic map showing structurally positive areas, sedimentary basins, and subsea topography of northern and eastern Gulf of Mexico regions. Contour interval, 200 m. (from Martin, 1978).

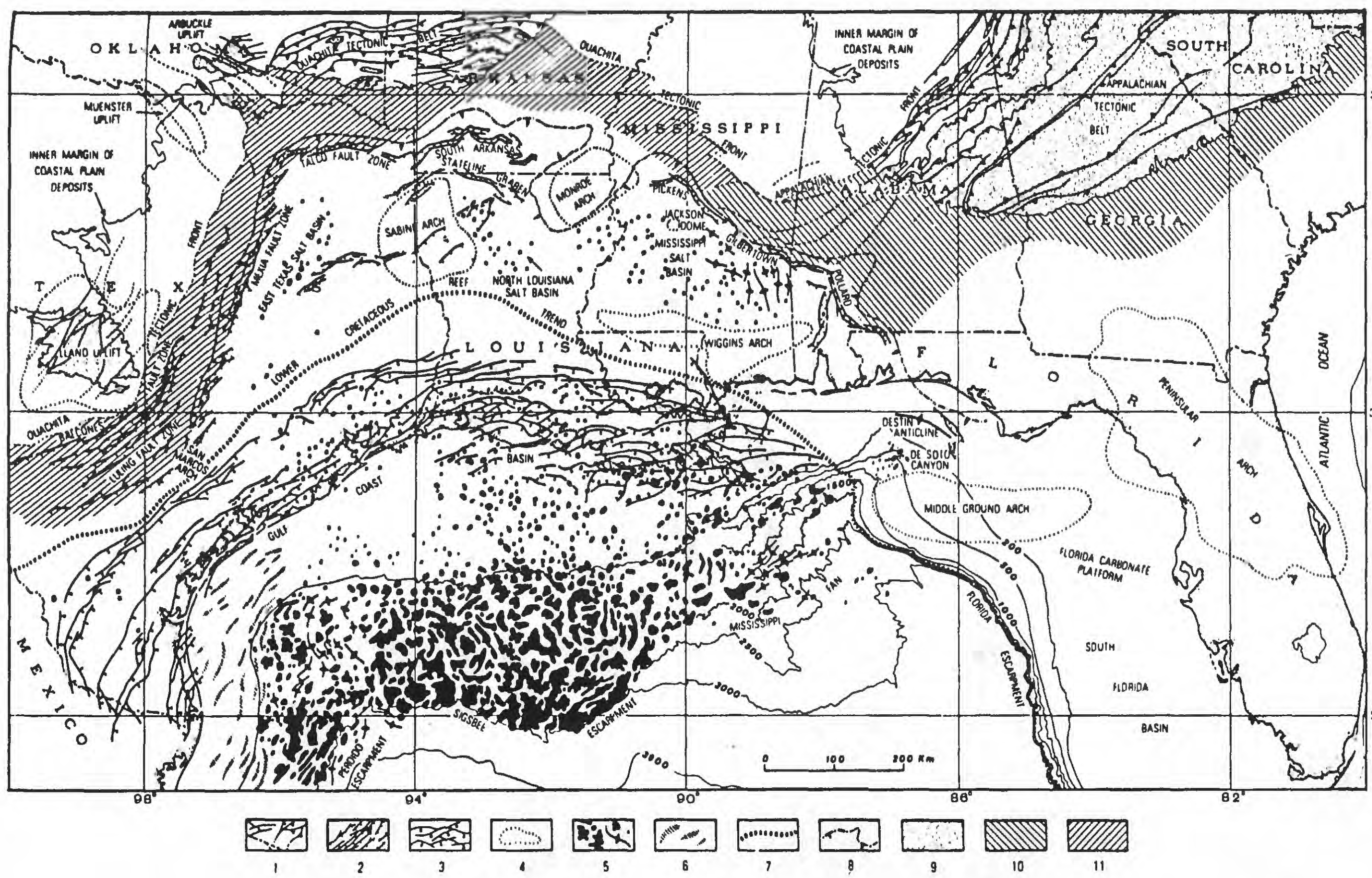

Figure 3. Tectonic map of northern Gulf of Mexico region (after Martin, 1978). Compiled mainly from Flawn et al (1961), Bryant et al (1969), Hickey et al (1972), Braunstein et al (1973), Bebout and Loucks (1974), King and Beikman (1974), King (1975), and Thomas (1976), and unpublished U.S. Geological Survey data. Explanation of patterns and symbols: (1) Normal fault, hachures on downthrown side; (2) Reverse fault, sawteeth on overthrust plate; (3) Fault of undetermined movement; (4) Broad anticline, or arch, of regional extent; (5) Salt diapirs and massifs indicating relative size and shape; (6) Salt anticlines and swells (nondiapiric) showing general trend; (7) Shale domes and anticlines showing general size and trend; (8) Plutonic and volcanic rocks of Mesozoic ages exclusive of basement complexes and Triassic diabase sills; (9) Updip limits of Louann Salt; (10) Down dip limits of deep wells reaching rocks of Ouachita tectonic belt; (11) Uplifts of exposed Paleozoic strata and crystalline basement rocks; (12) Trend of Lower Cretaceous shelf -margin reef system; (13) Inner margin of Cretaceous and Tertiary Coastal Plain deposits. Scale: 1° lat. equals 110 km.

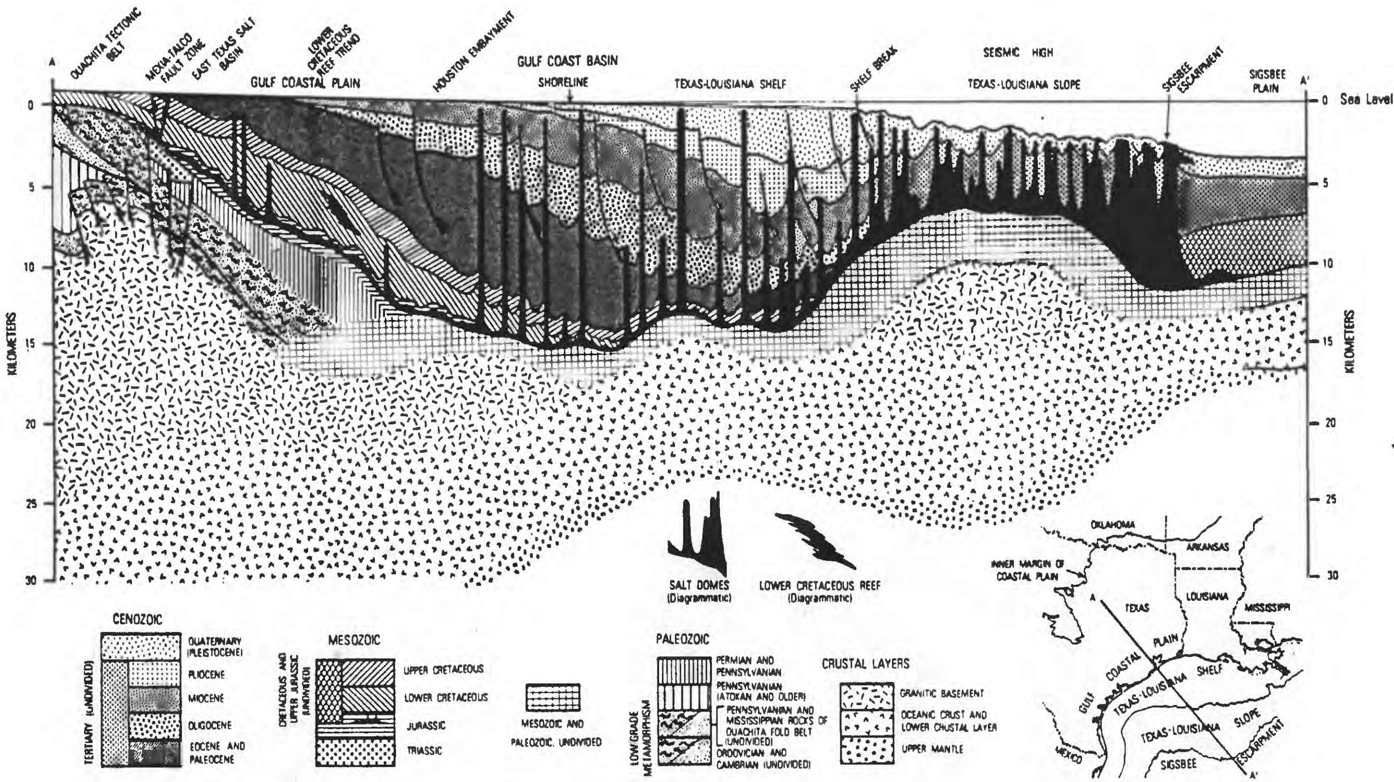

Fig. 4. Generalized cross section of northern Gulf of Mexico margin, showing offlapping wedges of Cenozoic rocks and influence of salt flowage and growth faulting in the northern Gulf basin. Modified after Martin (1978).

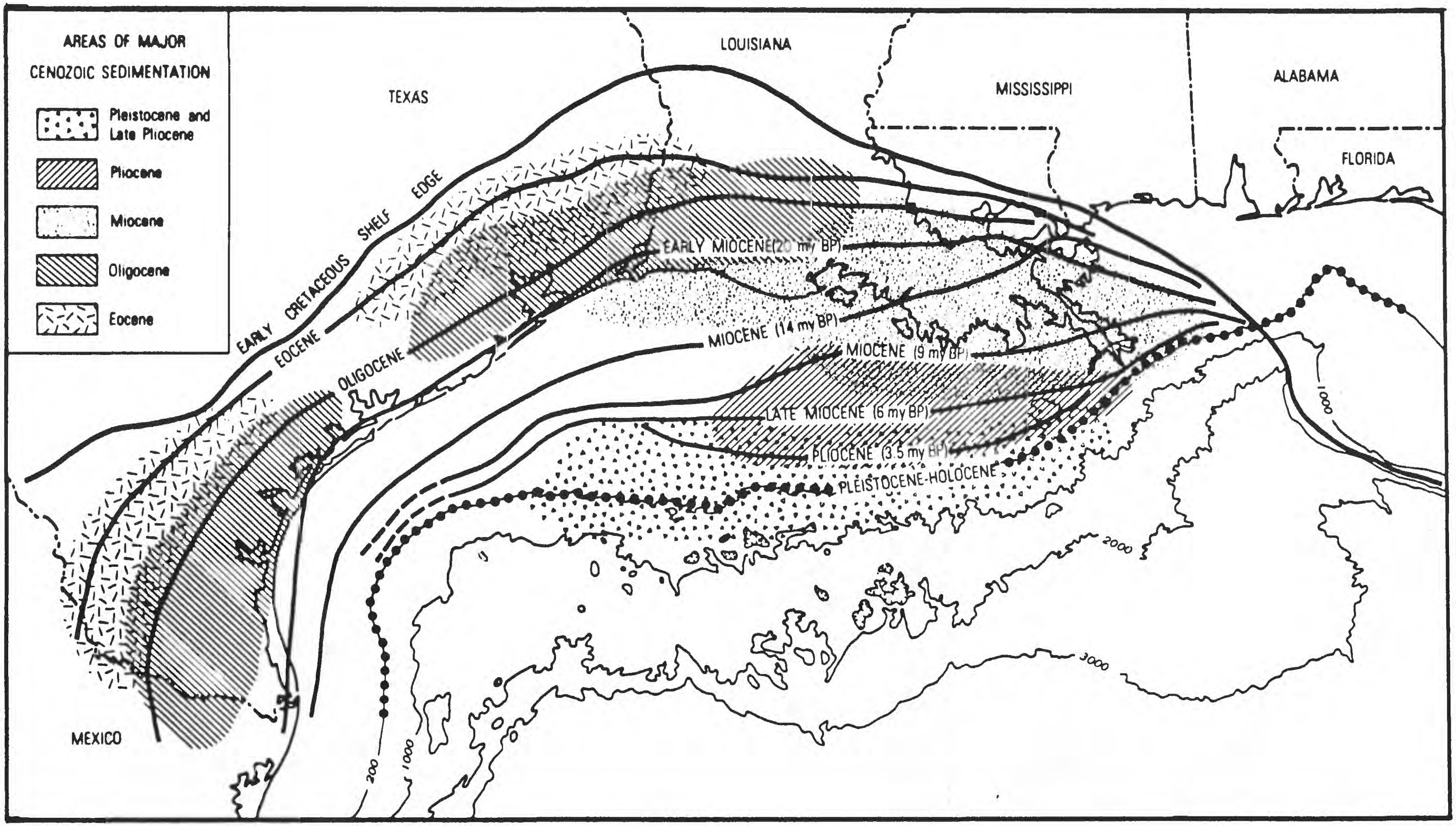

Fig. 5. Sketch map showing paleoshelf edges in Gulf Coast basin and distribution of major Tertiary depocenters. Modified from Hardin (1962), Woodbury and others (1973), Caughey (1975), and McGookey (1975).

STRUCTURE

The Gulf basin is a gently dipping regional homocline or geocline, bounded on the northern rim by complex arcuate systems of normal faults (Balcones-Luling, Mexia-Talco, South Arkansas, and Pickens-Gilbertown-Pollard fault systems) that determine the structural and depositional strike from south Texas to the West Florida shelf (Murray, 1961) (fig. 3). These fault systems are the updip limits of thick Jurassic Louann Salt deposits (Bishop, 1973). A relatively thin section of Louann Salt-Late Jurassic sedimentary rocks extends north of the fault system in the East Texas, north Louisiana, and Mississippi interior basins (Murray and others, 1985).

Much of the basin has been deformed by uplift, folding, and faulting associated with plastic flowage of Louann Salt and masses of underconsolidated Cenozoic shale (fig. 4). Widespread fields of salt domes and diapirs have resulted (Lehner, 1969; Martin, 1984), and shale domes and ridges have formed across the Texas Lower Coastal Plain and offshore Texas and Louisiana (Bruce, 1973). A series of arcuate systems of Cenozoic, principally down-to-the-basin, faults occur from the Rio Grande to the east side of the Mississippi Delta. These large faults, termed syndepositional faults by Shinn (1971) and growth faults by Hardin and Hardin (1961) and Ocamb (1961), formed contemporaneously with deposition and characterize the region.

STRATIGRAPHY

The sedimentological history of the Gulf basin has been one of shelf progradation that began when Triassic clastic redbeds were deposited in rift basins on an unconformable surface of Paleozoic and Precambrian sedimentary, igneous, and metamorphic rocks. The Mesozoic and Cenozoic stratigraphic sequence is shown in figure 6. Early Jurassic time was a period of limited deposition, consisting of anhydrites, salt, shales, and sandstones. However, throughout the Middle(?) Jurassic epoch, great thicknesses of Louann salt were deposited in the northern Gulf basin. In Late Jurassic time, clastic sequences were deposited in the rift basins, followed by formation of a carbonate ramp that controlled deposition of Late Jurassic formations from south Texas to south Florida (Budd and Loucks, 1981). Toward the end of the Late Jurassic epoch, the northern Gulf basin was flooded by open seas. Clastic marine sediments are dominant in northeast Texas, northern Louisiana, southern Mississippi, and southwestern Alabama-Florida Panhandle (Murray and others, 1985).

Clastic sedimentation continued into Early Cretaceous time and extended across large areas of the northern Gulf basin, onlapping Late Jurassic terrigenous rocks. As subsidence slowed and the supply of terrigenous clastic materials waned, a shallow epicontinental sea covered the western coastal plain and regions to the south and west (Rainwater, 1970). A carbonate depositional regime prevailed along the periphery of the basin, and limestones, dolomites, and interbedded anhydrites were deposited on broad banks. Reef building and detrital carbonate accumulations developed on the seaward edges of the shallow banks (Budd and Loucks, 1981; Mitchell-Tapping, 1981). Lower Cretaceous strata in south Texas consist mostly of shallow-marine carbonate rocks deposited over broad shelf areas (Bebout and others, 1981), while interbedded carbonate and siliciclastic rocks of neritic origin are predominant in younger Lower Cretaceous rocks to the east (Rainwater, 1971).

Late Cretaceous seas expanded over the region and shallow-water carbonates of the Gulfian Series were deposited on older rocks (Holcomb, 1971). Upper Cretaceous strata of the Gulfian Series are represented mainly by transgressive sandstones, shales, marls, and chalks. Locally, reef-like carbonate beds accumulated on the Monroe uplift and the Jackson dome, and around volcanic cores in south Texas (Murray and others, 1985).

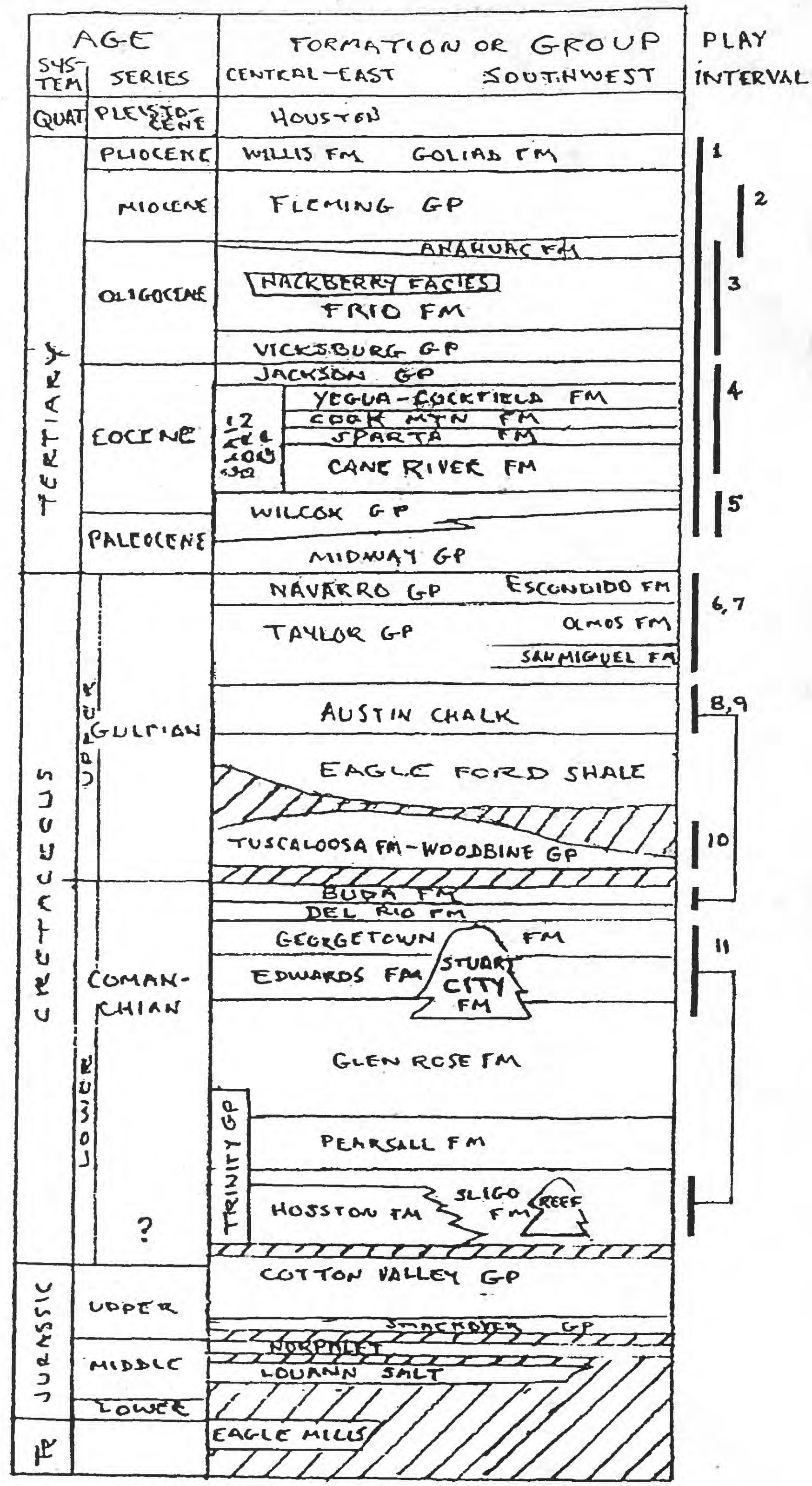

Fig. 6. Generalized stratigraphic column of the Mesozoic and Cenozoic rocks of the Western Gulf basin. Play intervals: 1) Southeast Texas-South Louisiana Salt play; 2) Coastal Miocene and Anahuac play; 3) South Texas Frio-Vicksburg play; 4) South Texas Upper Eocene play; 5) Wilcox play; 6) Southern Maverick basin play; 7) Northern Maverick basin play; 8) South Texas Chalk play; 9) Louisiana Chalk play; 10) Tuscaloosa-Woodbine play; and 11) South Texas-Louisiana Reef play.

During early Cenozoic time, sands and muds derived from northern and western sources were deposited in the East Texas and Louisiana-Mississippi salt basins. Successively younger wedges of offlapping strata formed as the shelf margin prograded and as the primary depocenters shifted both laterally and seaward. Basinward of the Mesozoic shelf edge, thick successions of alternating sandstones and shales were deposited as pulses into the rapidly subsiding basin, resulting in Cenozoic sequences prograding about 240 m (386 km) seaward (figs. 4 and 5) and reaching cumulative sediment thicknesses of 50,000 ft (15240 m) or more on the Louisiana-Texas Continental Shelf in the vicinity of the modern Mississippi delta and within the Western Gulf province (Martin, 1984). To the east, the carbonate environments that had prevailed during Mesozoic times persisted more or less during Cenozoic times. Land-derived clastic sediments from north and northwestern source areas were deposited on the northern end of the Florida platform as minor components of Tertiary carbonate environments (Rainwater, 1971).

SOURCE ROCKS AND THERMAL HISTORY

Petroleum source rocks are present in the northern part of the Gulf basin, which includes the Western Gulf province, in both Mesozoic and older Cenozoic rocks. Basinal facies of the Cretaceous succession provide organic-rich rocks which, combined with the thermal history of the basin, have been generally favorable for generation of hydrocarbons. The oil-generation window for Paleocene to Oligocene sedimentary rocks ranges from about 8,700 to 13,000 ft (2652 to 3962 m) based upon studies by Dow (1978), with onset of thermal-gas generation by conversion of crude oil at greater depth (Dow, 1978; Galloway and others, 1982). Generally, Miocene hydrocarbon production in Louisiana is from thermally immature progradational facies, which overlie older, thermally mature slope and rise facies. Galloway and others (1986) stated that indigenous oil and gas generation in the lower Miocene of Texas appears to be limited to the thermally mature lower Miocene expansion zone, basinward of the Oligocene shelf margin. The upper Miocene section of Texas appears to be above the oil-maturation interval and all hydrocarbons (except for biogenic gas) are probably derived either by upward migration from older formations or by lateral, updip migration from basinward time-equivalent marine units (Morton and others, 1988).

TRAPS AND RESERVOIRS

Oil and gas traps in the region are varied. In the Western Gulf province, traps developed by faulting and folding account for significant quantities of hydrocarbons along the basin boundary fault systems, such as the Balcones-Luling fault system (Murray and others, 1985). There, hydrocarbons are produced from closures on both upthrown and downthrown blocks and reservoirs are primarily Upper Jurassic and Cretaceous carbonates and sandstones, and sandstones of Tertiary (Eocene) age (Newkirk, 1971). Stratigraphic variations provide significant contributions.

Large quantities of oil and gas are associated with the down-to-the-basin growth faults across the Texas and Louisiana lower coastal plain and in adjoining State waters. The reservoirs are in anticlinal closures on both upthrown and downthrown fault blocks and in traps against fault planes, antithetic faults, and up-to-the-basin normal faults. Production is from Paleocene to Pliocene age sandstones, in which, facies changes to siltstones and shales frequently affect the lateral extent and quality of the reservoir rock. Significant quantities of natural gas also have been discovered in a somewhat similar setting in closures in deep Cretaceous sandstones of the Tuscaloosa and Woodbine formations on the downthrown side of growth faults basinward of the Cretaceous shelf margin in south-central Louisiana and Texas, respectively (Smith, 1985).

Salt-related structures in the Western Gulf province are productive as anticlines over salt domes and ridges, in caprocks of piercement domes, as fault structures on crestal and flank positions of domes, as structures between closely spaced salt masses, from terminations of reservoir strata against salt bodies, and from stratigraphic traps formed by reservoir sandstones onlapping salt shoulders (Halbouty, 1979). Salt structures in the Texas and Louisiana lower coastal plain and coastal waters produce primarily from sandstone reservoirs of Cenozoic age.

Fracturing in reservoir rocks, in particular of the Austin Chalk, facilitates production of many oil and gas fields. The foci many of these fractures are along the Mesozoic hinge lines of the basin, as exemplified by the Austin Chalk-Buda Lime trends along the margin of the underlying paleo shelf (Scott, 1977; Stapp, 1977, Grabowski, 1981).

Comparisons of trap types of giant oil and gas fields (fields larger than 100 MMBOE) in the overall Gulf basin reveal that 81 percent are structural, 17 percent are combination, and 2 percent are stratigraphic traps (Murray and others, 1985). Approximately 89 percent of producing zones in these fields are sandstones deposited in fluviatile-deltaic environments; however, many more recent discoveries have been from prodeltaic and marine facies. Multiple, stacked producing horizons are common. Limestone and limestone/sandstone reservoir rocks are secondary; most are shallow-water, nearshore to shelf facies. However, significant quantities of hydrocarbons have ben found in salt-dome caprocks and in fractured chalks and limestones (Murray and others, 1985).

EXPLORATION HISTORY

Oil and gas exploration began in the northern part of the Gulf basin in 1865, and the first successful oil well was completed there in East Texas in 1866 (Tyler and others, 1985). In the part of the basin assessed as the Western Gulf basin Province of this report, exploration began in the late 1800's and resulted in the discovery of the prolific Spindletop Dome and the Saratoga Dome Fields in Texas in 1901, followed by the Jennings Field in Louisiana.

The number of giant fields found within the Western Gulf basin Province in each decade since the turn of the century rose steadily from 4 fields in 1900-1909 to 47 fields in 1930-1939. The discovery rate dropped to 26 fields in 1940-1949 and then began a rapid decline to 1 giant field discovered in the decade of 1970-1979. These giants account for more than 75 percent of the petroleum thus far discovered (Foote, 1989).

PETROLEUM POTENTIAL

Crude oil and natural gas production, reserves, and undiscovered resources of both the Gulf Coast Region and the Western Gulf basin province are shown in table 1. The mean values of undiscovered recoverable conventional resources for the Western Gulf basin Province are estimated to be approximately 3 BBO (billion barrels of oil) and 65 TCFG (trillion cubic feet of gas). This constitutes more than 70 percent of the undiscovered resource estimated for the entire region (Region 6, of Mast and others, 1989).

Although the province is maturely explored, substantial areas and volumes of known and possible reservoir rocks remain to be explored at depth. Future discoveries can be expected within and by extension of producing trends, from deeper plays within producing trends, and from new plays in the lesser explored areas (Holcomb, 1971; Newkirk, 1971; Shinn, 1971; Curtis, in press).

Substantial natural gas resources are estimated for deep-seated, salt-related traps and fault-related traps on the lower coastal plain and coastal waters of Texas and Louisiana. A south Texas analog of Upper Jurassic and Cretaceous stratigraphic traps on the west flank of the East Texas basin has not been adequately tested and the Smackover Formation and the lower part of the Buckner Formation are prospective (Budd and Loucks, 1981).

TABLE 1.--Cumulative production, estimated reserves and estimated undiscovered recoverable conventional resources (as 12/31/86).

Production and reserve estimates for Region 6 are from Mast and others (1989) and for Province 112, derived from Energy Information Administration (1987). All estimates of undiscovered resources from Mast and others (1989).

	Cum Produc-. tion	Measured Reserves	Inferred + Indicated Reserves	Estimated undiscovered recoverable resource F95	F5	Mean
Region 6, Gulf Coast:						
Oil (BB)	43.1	3.7	5.7	2.4	6.7	4.2
Gas (TCF)	285.6	33.6	42.3	51.2	123.6	82.5
Western Gulf basin, Province 112:						
Oil (BB)	23.7	1.5	Not reported	1.6	5.2	3.0
Gas (TCF)	208.0	27.3	Not reported	38.7	99.8	64.8

Within the Late Cretaceous Gulfian Series, large quantities of both oil and gas are expected to occur in fractured chalks and limestones of the Austin Chalk-Eagle Ford in the trend across south Texas and extending into south central Louisiana near the southern line of Mississippi (Scott, 1977; Grabowski, 1981; Galloway and others, 1983). Possibilities for significant natural gas and oil discoveries are promising in sandstones of the Woodbine (Tuscaloosa) Formation in the deeper areas south of the Sabine arch across southeast Texas and southwest Louisiana and into the deep Tuscaloosa gas trend of south-central Louisiana (Harrison, 1980; Smith, 1985).

Future discoveries of oil and gas in Cenozoic rocks will be almost exclusively from sandstone reservoirs. The more significant discoveries are to be expected in the well-hidden traps in maturely explored areas, downdip extensions of plays (particularly natural gas) which have not been extensively explored, and new, deeper gas plays in downthrown blocks of regional growth faults and in continental slope facies.

The following discussion of plays deals with those believed to have significant potential for undiscovered oil and gas resources. Some plays are excluded which have been important during the exploration history of the province (Cook, 1979) but are now virtually exhausted, even though having contributed substantial resources. Those oil and gas plays, which include the Luling Fault Zone and Atascosa-Karnes troughs, and structural, stratigraphic, and diagenetic traps in the Mesozoic shelf carbonates elsewhere along the northern margin of the Western Gulf basin Province, were assessed in the aggregate. Highly speculative plays, such as possiblities of a south Texas equivalent of the Upper Jurassic traps of the East Texas basin, and the Smackover Formation and the lower part of the Buckner Formation in south Texas, were assessed with the above plays. Those parts of the updip Tuscaloosa shelf sandstone play, which fell within the Western Gulf basin Province, were assessed with that play in the adjoining North Louisiana and Mississippi salt basins.

OIL AND GAS PLAYS ASSESSED IN THE WESTERN GULF BASIN PROVINCE

Southeast Texas-South Louisiana Salt Play:

This play encompasses the occurrence of oil and gas in salt-related structures and combination traps within a piercement dome dominated portion of the Western Gulf basin province (figs. 4, 6 & 7). Principal reservoirs are sandstones of Eocene through Pliocene age, primarily early Eocene Wilcox Group, Eocene Yegua Formation, Oligocene Frio Formation and Miocene Fleming Group sandstone zones (Woodbury and others, 1973; Morton and others, 1988). Basal Pleistocene reservoirs contribute some hydrocarbon resources along the very southern part of the play in southeastern Louisiana. Most reservoirs represent a mixture of deltaic facies. Many fields produce from multiple zones, occasionally exceeding 10 in number, and individual pay thicknesses range from less than 10 ft (3 m) to over 200 ft (61 m). Reservoir characteristics are often excellent, with porosities sometimes averaging over 30 percent. Caprock calcite reservoirs have been historically important and local reef limestone reservoirs occasionally are present in the Miocene section.

Source rocks are probably present in basinal facies of the Cretaceous succession and in the slope and rise facies of the older Cenozoic sequence. The thermal histories of these strata are conducive to generating hyrocarbons, particularly for Mezozoic rocks, and the oil generation window for overlying Paleocene to Oligiocene rocks ranges from about 8,700 ft (2652 m) to 13,000 ft (3962 m). Generally, Miocene hydrocarbon production in Louisiana is from reservoirs in thermally immature progradational facies, which overlie older thermally mature slope and rise facies. Galloway and others (1986) stated that indigenous oil and gas generation in the lower Miocene of Texas appears to be limited to the thermally mature lower Miocene hinge or expansion zone, basinward of the Oligocene shelf margin. The upper Miocene section of Texas appears to lie above the oil-maturation interval and all hydrocarbons, except biogenic gas, are probably derived either by upward migration from older formations or by lateral, updip migration from basinward time-equivalent marine units.

Traps associated with salt domes and salt ridges dominate the play. Traps include simple and complex anticlines over piercement and deep-seated domes and ridges, complex fault structures on the flanks of piercement domes, caprocks, terminations of reservoir strata against diapir walls or overhangs, and stratigraphic traps formed by reservoir truncation, or by sandstones onlapping salt shoulders or shale masses. In addition, structures between closely spaced salt masses and anticlinal folds and growth faults in interdomal areas are important. Deep water turbidite sandstones of Oligocene age (Hackberry sandstones), that have been transported downslope through submarine channels into basinal areas, also provide additional combination and stratigraphic traps (Ewing and Reed, 1984). Traps and reservoir characteristics are amply illustrated by Galloway and others (1983).

This play has had a long history of exploration. Since the initial discoveries of Spindletop and Saratoga Fields in 1901, approximately 400 oil fields larger than 1 MMBO and 477 gas fields larger than 6 BCFG of recoverable resources have been discovered, accounting for over 17.9 BBO and 130 TCFG in the play. This play has been the single largest oil and gas play in the province. The largest field in terms of recoverable oil is Conroe Field, with over 735 MMBO, and the largest gas field is Katy Field, with approximately 10 TCF. Both fields are located in Texas.

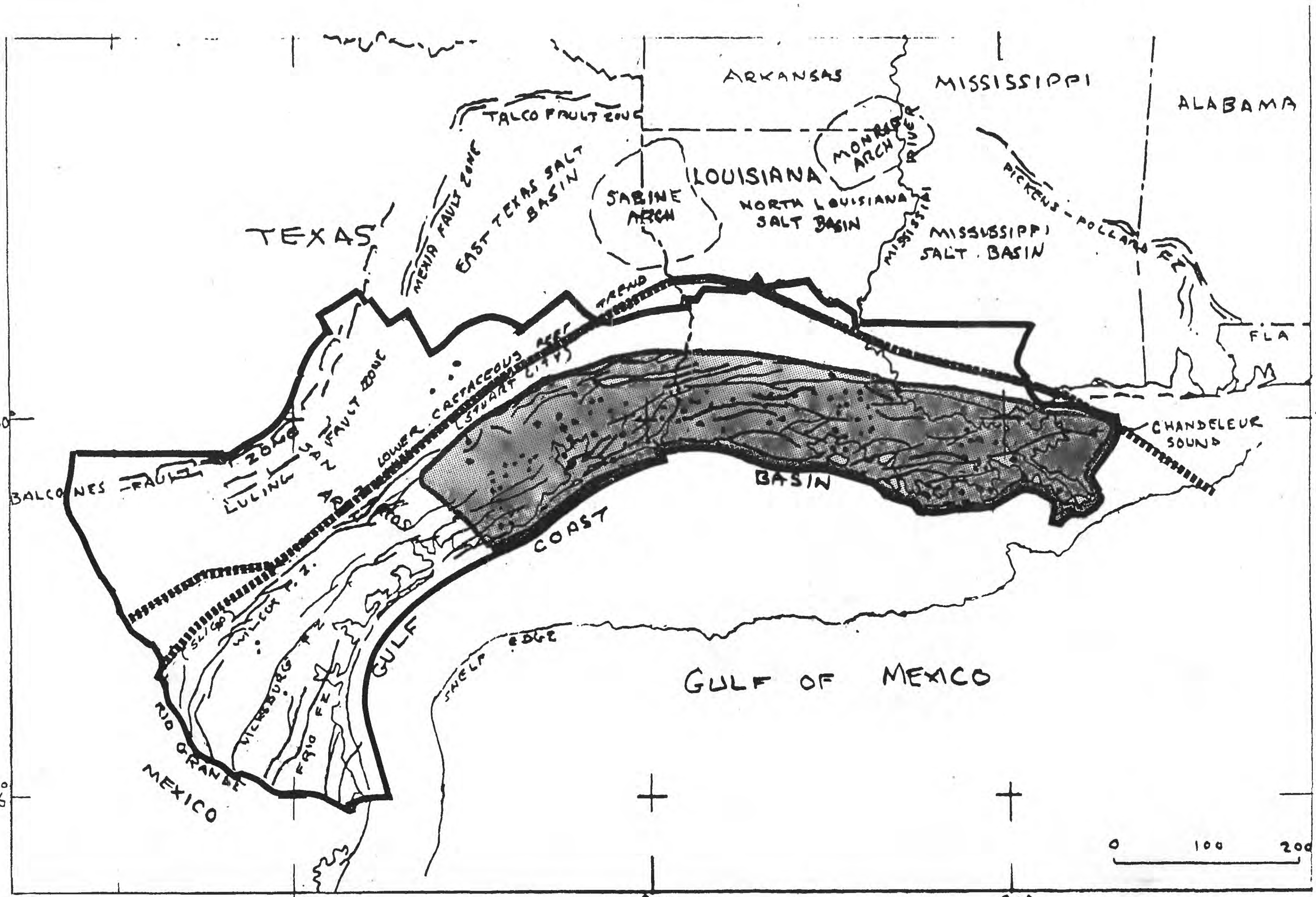

Fig. 7. Map showing area of Southeast Texas-South Louisiana Salt play.

Exploration is in a mature stage of development and future exploration will be primarily for smaller and more subtle and complex structural and combination traps. The play ranges in depth from less than 1,000 to 23,000 ft (305 to 7010 m), and mostly gas is expected as exploration focuses on deeper parts of the play, including basinal or slope sandstone reservoir facies ponded in interdomal areas or onlapping growth features.

Coastal Miocene and Anahuac Play:

This play contains nonassociated gas in sandstones of Miocene and Oligocene age in the south Texas Coastal Fault Zone and minor amounts of oil (figs. 6 & 8). Reservoirs are sandstones of the Miocene and the underlying Oligocene Anahuac Formation. Sandstones are barrier, strandplain and deltaic in origin. Pay thickness of individual reservoirs range from 4 ft to 40 ft (1 to 12 m), typically averaging 10 ft to 20 ft (3 to 6 m). Reservoirs are of excellent quality, with porosities averaging 25 percent to 34 percent in the fields reported.

Source rocks are probably either associated or subjacent Frio/Anahuac slope, shelf and prodelta mudstones and, locally, lower Miocene shelf mudstones. Vertical migration into many of the shallower producing zones appears to have taken place.

Traps are primarily in anticlines and faulted anticlines associated with growth faults. Scattered salt domes are also present. Drilling depths in the play range from about 1,000 ft (305 m) to approximately 23,000 ft (7010 m).

The first significant discovery in this play was in 1922. Approximately 55 gas fields and 4 oil fields larger than 6 BCF and 1 MMBO in size have since been discovered, accounting for approximately 104 MMBO and 3.3 TCFG. The largest oil field is Willamar Field, including West Willamar, which contained 90 MMBO and 375 BCFG, and the largest gas field is Collegeport Field, at 540 BCF. Future potential in this play, which will be primarily in deeper areas, is estimated to be mostly for gas.

South Texas Frio-Vicksburg Play:

This play describes the occurrence of oil and gas in stratigraphic, structural and combination traps in the growth fault systems of the Gulf coast, involving sandstones principally of Oligocene age with incidental reservoirs in the lower Miocene (figs. 6 & 9). The play is bounded on the northwest by the Wilcox fault zone; most existing production is associated with the Vicksburg and Frio fault zones. The architecture of the Frio component of this play has been comprehensively described by Galloway and others (1982).

Reservoirs are primarily fluvial, deltaic, shoreline and neritic sandstones of the Frio Formation and Vicksburg Group, including incidental Anahuac and lower Miocene sandstones. Multiple pays are common and individual reservoirs are typically 10 to 50 ft (3 to 15 m) thick. Reservoir porosities average about 30 percent. Slope facies of these sandstones may be found in downdip positions but are expected to be of poorer reservoir quality due to greater depths of burial.

Source rocks are probably associated Frio/Anahuac slope, shelf and prodelta mudstones and, locally, lower Miocene shelf mudstones. Vertical migration into shallow producing zones also appears to have taken place.

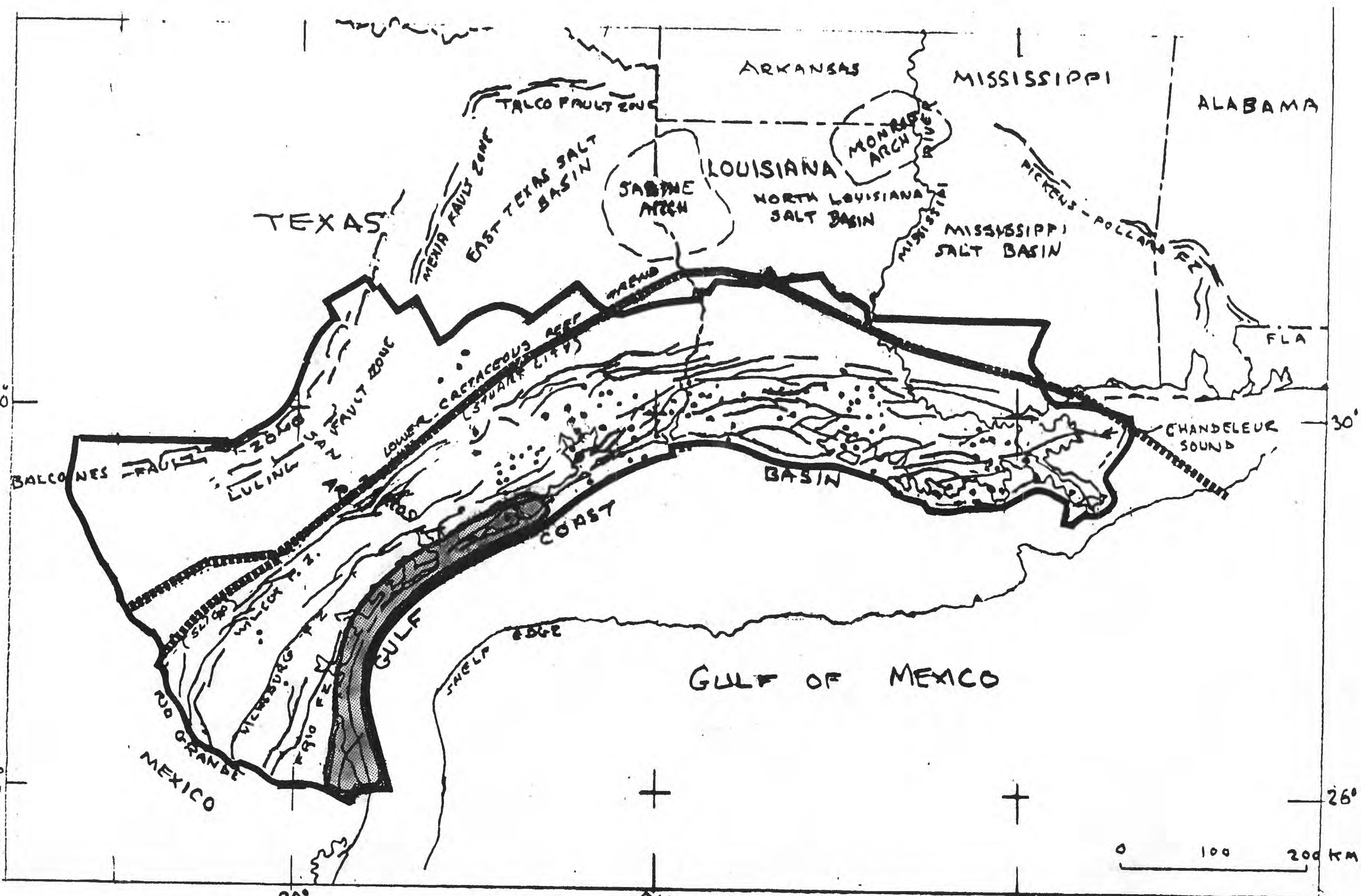

Fig. 8. Map showing area of Coastal Miocene and Anahuac play.

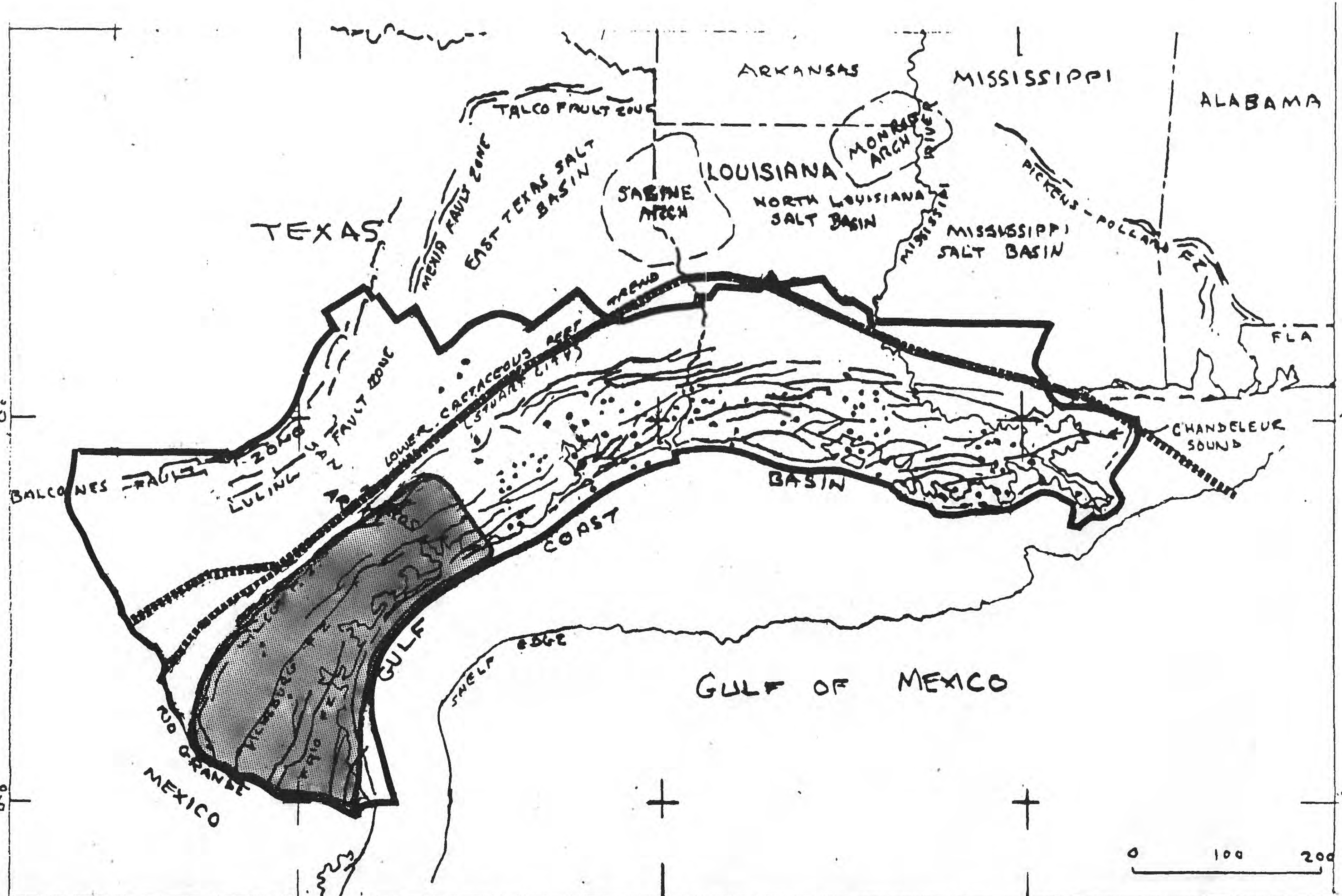

Fig. 9. Map showing area of Frio-Vicksburg play.

Traps are typically anticlines and faulted anticlines within the flexure and growth fault systems, primarily of the Frio and Vicksburg Fault Zones. Many combination traps result from sandstone pinchouts on structures within this trend. Potential traps are also believed to exist in downdip basinal and slope reservoir facies onlapping fine-grained slope sediments in downdip areas of the play. Drilling depths range from less than 1,000 ft (305 m) to more than 22,000 ft (6706 m).

Exploration in the play began about 1908. To date, 211 oil fields and 378 gas fields larger than 1 MMBO and 6 BCFG, respectively, have been discovered and account for approximately 5 BBO and more than 75 TCFG, making this, historically, the second largest play in the Western Gulf province. The largest oil and gas fields are, respectively, Greta-Tom O'Connor Field, with 915 MMBO and Agua Dulce-Stratton Field, with 6.6 TCFG (and about 150 MMBO).

South Texas Upper Eocene Play:

This play encompasses the occurrence of oil and gas in sandstones of middle to late Eocene age in structural and combination traps of south Texas, principally associated with the Wilcox fault zone (figs. 6 & 10). Reservoirs are primarily sandstones of Jackson and Claiborne Groups and equivalents, the most important of which are sandstones of the Yegua-Cockfield Formations. Deltaic and barrier bar/strandplain facies predominate as reservoir rocks. Considerable stratigraphic variability exists in these reservoirs, but average porosities are generally good and typically range from 25 percent to 35 percent. Producing fields often have multiple pay zones.

Probable source rocks are marine shales of Paleocene and Eocene age. The oil generation window for these rocks ranges from about 8,700 to 13,000 ft (2652 to 3962 m), with thermal gradients becoming progressively higher to the south where the play becomes more gas prone.

Traps are generally anticlines or fault closures on noses, combined with sandstone facies changes and pinchouts, occasional associated with salt domes. Most of the structures are growth structures related to the Wilcox fault zone and to subordinate systems of growth faults and flexures north of the major Vicksburg flexure. Drilling depths range from around 1,000 ft (305 m) to about 16,000 ft (4877 m).

The first significant discovery in the play was in 1908. More than 109 oil fields and 36 gas fields larger than 1 MMBO or 6 BCFG in size, respectively, have since been discovered and account for approximately 820 MMBO and 2.9 TCFG. The largest oil field discovered is Government Wells, with 108 MMBO, and the largest gas field is Sejita Field, with 450 BCFG.

Wilcox Play:

This play encompasses the occurrence of gas and oil in sandstones of the late Paleocene-Eocene Wilcox Group in structural and combination traps of the coastal plain of Texas and Louisiana (figs. 6 & 11). The play involves mainly anticlinal and fault structures related to systems of growth faults shelfward of the regional flexure of the Vicksburg fault zone.

Reservoirs are alluvial, deltaic and strandplain sandstones, which show considerable stratigraphic variation but are of generally good reservoir quality. Many fields are characterized by multiple pay zones. Reservoir characteristics tend to be good and many fields have reservoir porosities of 20 to 30 percent.

Probable source rocks are marine shales of Paleocene and Eocene age; source rocks may also include Mesozoic basinal facies. The oil generation window for these rocks ranges from about 8,700 to 13,000 ft (2652 to 3962 m), with thermal gradients being higher to the south.

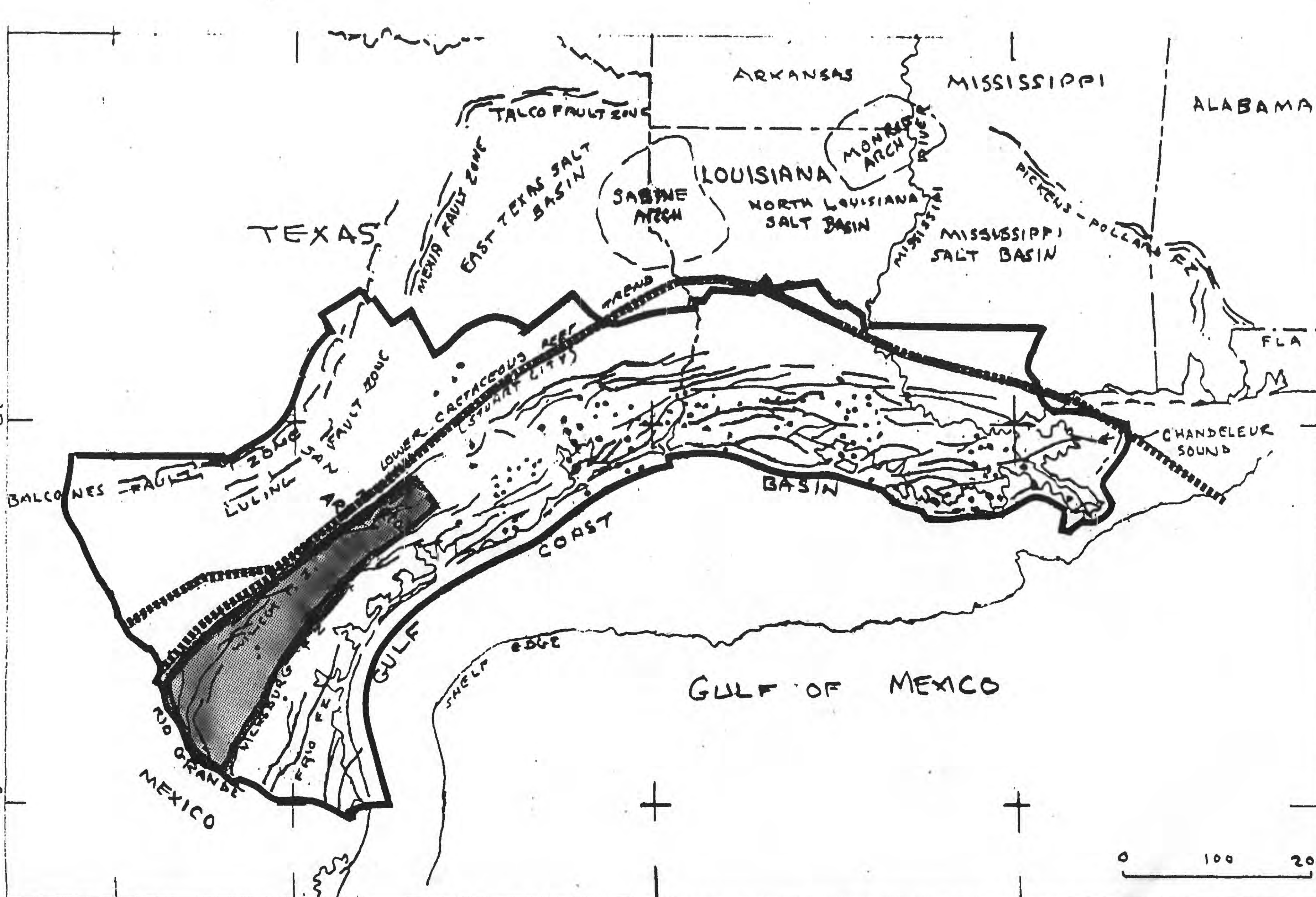

Fig. 10. Map showing area of South Texas Upper Eocene play.

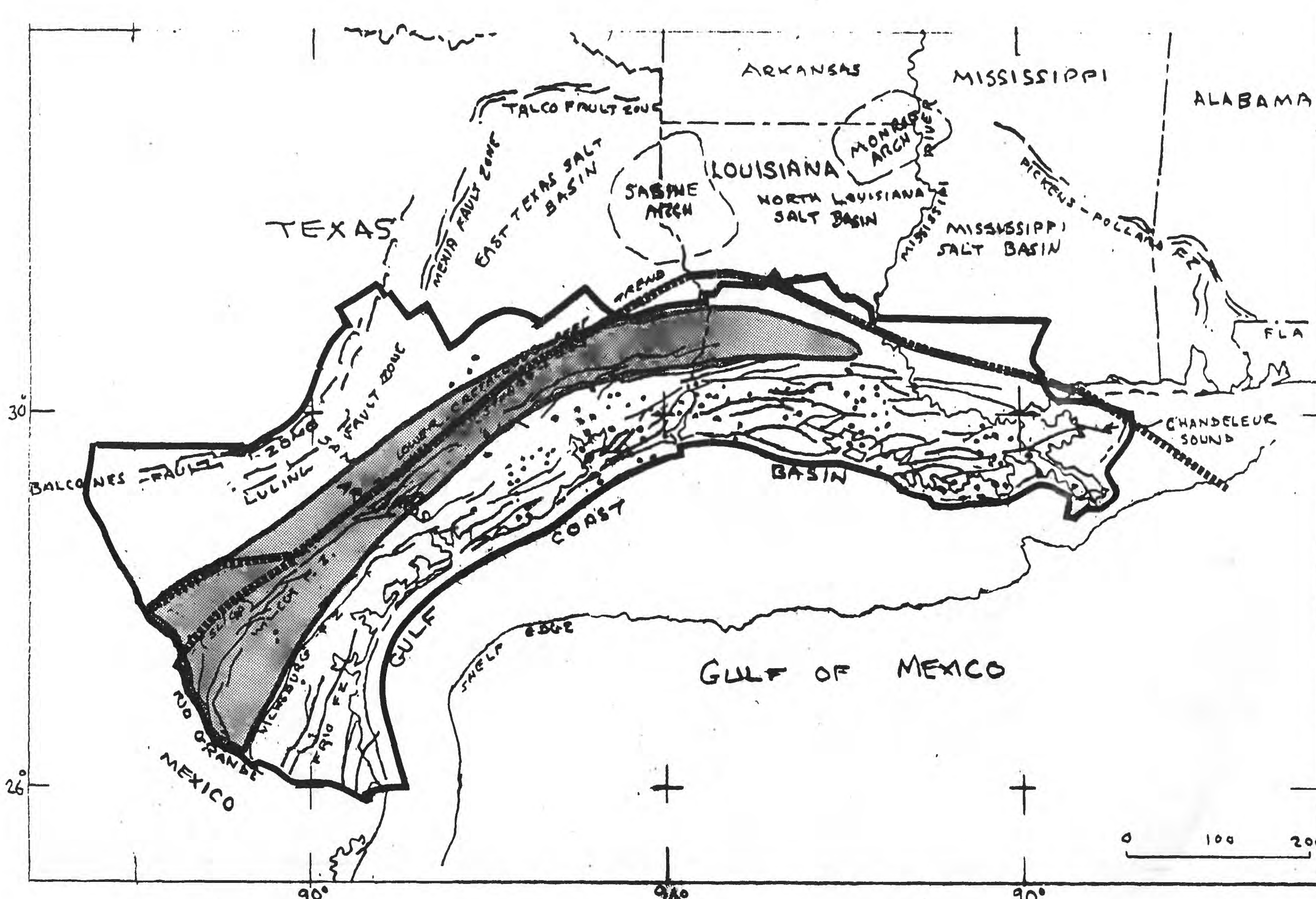

Fig. 11. Map showing area of South Texas Wilcox play.

Traps are generally anticlines or fault closures on noses and anticlines, combined with sandstone facies changes and pinchouts. Most of the features are growth structures related to systems of growth faults and flexures north of the major Vicksburg flexure. Excessive drilling depths south of this zone essentially limit the play.

Since the first significant discovery in the play in 1926, exploration has remained active. To date 69 oil fields and 257 gas fields larger than 1 MMBO or 6 BCFG have been discovered, accounting for more than 500 MMBO and approximately 19.3 TCFG. The largest oil field is Ville Platte in Louisiana, with 62.4 MMBO, and the largest gas field is Sheridan Field in Texas, with 1.7 TCFG.

Exploration in the play will be focused in deeper areas, where gas is the primary commodity. Drilling depths range from about 1000 ft (305 m) to approximately 22,000 ft (6076 m).

Southern Maverick basin Play:

This play involves exclusively nonassociated gas in combination and stratigraphic traps on the Cretaceous shelf in part of the Rio Grande Embayment and contains primarily shelf sandstones of Upper Cretaceous age as reservoirs. The play area encompasses the southern extremity of the Maverick basin of south Texas (figs. 6 & 12).

Reservoirs are diverse, containing deltaic, coastal barrier, delta front and prodelta sandstones of the Navarro and Taylor Groups. Principal reservoirs are in the San Miguel and Olmos Formations. According to Galloway and others (1983), individual field reservoirs are interpreted to be complex and to contain numerous heterogeneities. Sandstone reservoirs typically have average porosities of 15 percent to 27 percent and pay thicknesses range from 20 to 107 ft (6 to 33 m).

Source rocks are probably basinal shale facies of the Cretaceous. All are in a gas generative state due to the type of organic matter and level of thermal maturity.

Traps are stratigraphic and combination, mostly involving faults and faulted anticlines, facies changes in reservoir sandstones, reservoir truncations by unconformities, and diagenetic traps. Drilling depths range from 4,000 to 12,000 ft (1219 to 3658 m).

This play developed largely in the 1960's and 1970's. To date, 12 gas fields larger than 6 BCFG in size have been discovered, accounting for more than 400 BCFG and a small amount of liquids. The largest field is Southwest Catarina Field, with 114 BCFG.

Northern Maverick basin Play:

The play is characterized by the occurrence of oil and gas in sandstones of Late Cretaceous age in structural and stratigraphic traps in the northern part of the Maverick basin of south Texas (figs. 6 & 13). Reservoirs are Navarro and Taylor Group sandstones, primarily in the San Miguel and Olmos Formations.

Reservoirs are diverse, ranging from deltaic, coastal barrier, delta front and prodelta sandstones, such as found at Big Wells Field. Middle neritic turbidite channels and fans deposited on the upper shelf are reported as primary reservoirs at A.W.P. Field. According to Galloway and others (1983), reservoirs are interpreted to be complex and to contain numerous heterogeneities. Consequently, although reservoir porosities tend to be high, averaging between 19 percent and 28 percent in several fields, oil recovery efficiencies tend to be low.

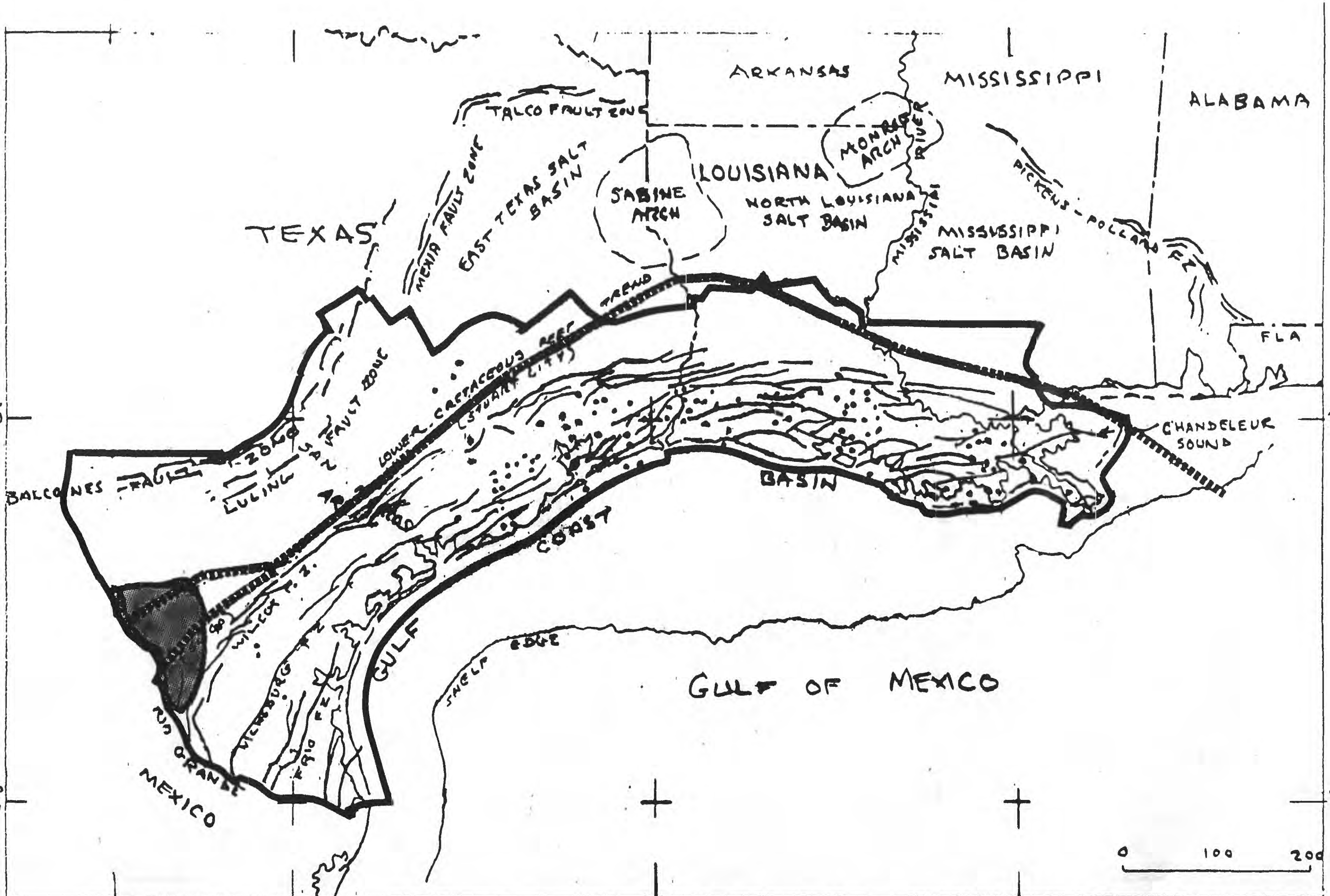

Fig. 12. Map showing area of Southern Maverick basin play.

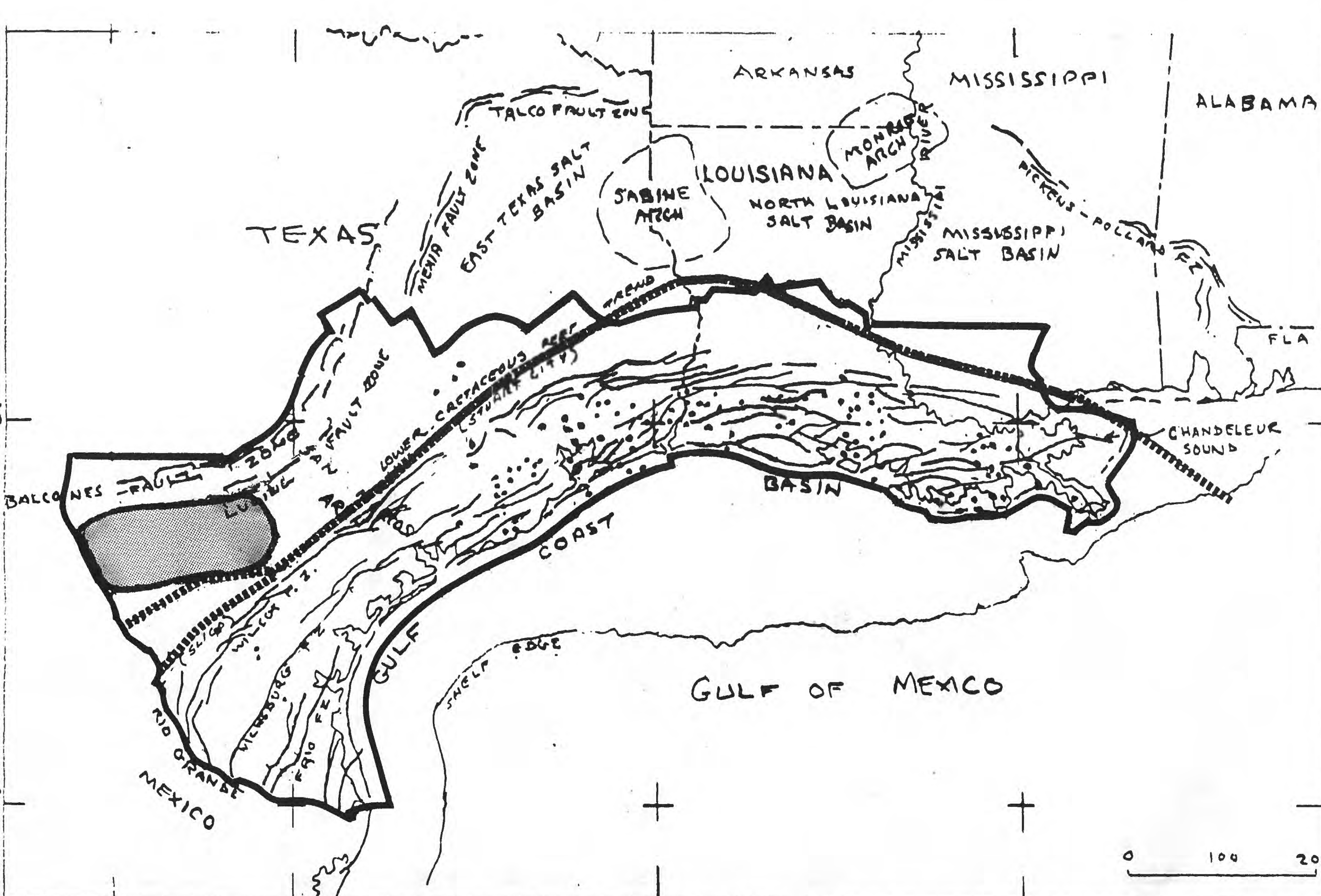

Fig. 13. Map showing area of Northern Maverick basin play.

Source rocks are probably basinal shale facies of the Cretaceous sequence.

Traps are structural, stratigraphic and combination, and involve faults and faulted anticlines, facies changes in sandstones, and reservoir truncations by unconformities. Drilling depths range from 1,000 ft (305 m) to more than 17,000 ft (5182 m).

The first significant discovery in the play was in 1911. Approximately 32 oil fields and 10 gas fields have since been discovered and account for approximately 315 MMBO and 640 BCFG, respectively. The largest fields are Big Wells Field (including Northeast Big Wells) with 78 MMBO, and Winn-Dulce Field, with 60 BCFG. We anticipate an increasing gas component in future expansion of the play.

South Texas Chalk Play:

This play is defined by the occurrence of oil and gas in fractured chalk and micrite reservoirs of the Cretaceous Austin Chalk and Buda Lime, extending from south Texas to south central Louisiana (figs. 6 & 14). The geographic limits of the play are essentially defined by the area of optimal fracturing, which occurs in a regional linear trend, 5-15 miles wide. The foci of the fractures are at the older Mesozoic hinge lines of the basin, resulting in fracture trends along the overlapped paleo shelf edges. Crude oil is the predominant commodity in the updip fields, but natural gas is more prevalent in fields near or over the Mesozoic hinge lines. For assessment purposes, the play is treated as a single large occurrence or accumulation which is limited geographically by the development of fracturing sufficient to allow economic production.

Reservoirs are fractured chalks, largely open marine foraminifer- and coccolith-bearing lime micrites of the Austin Group, and fractured lime micrites of the Buda Formation. Fracturing is often more intense near faults. Thickness of the Austin reservoir is as much as 800 ft (244 m), while the Buda reservoirs are substantially thinner, generally ranging from 70 to 100 ft (21 to 31 m).

Source rocks have been identified as organic-rich shelf or ramp facies chalks and shales that lie within the Austin Chalk Group, and calcareous, organic-rich mudstone of the underlying Eagle Ford Shale, and most of the hydrocarbon is believed to be generated locally (Grabowski, 1981; 1984).

Hydrocarbons appear to be stratigraphically trapped within a very fine grained reservoir rock by internal porosity and permeability variations. The presence of structure appears to be incidental to hydrocarbon accumulation, other than controlling the distribution of fracturing which is essential for economic exploitation; the two largest fields, Pearsall and Giddings Fields, are located along homoclines. Drilling depths range from about 5,000 to 17,000 ft (1524 to 5182 m).

Exploration in this play has continued for several years, the initial discovery of Pearsall Field having been made in 1935. The play has been very sensitive to prices of oil and gas. The recent advent of horizontal drilling has stimulated considerable activity in this play and prospects appear attractive for continued growth. Approximately 300 MMBO and 1.1 TCFG has been reported discovered in this play. Giddings is the single largest producing area with approximately 170 MMBO and 796 BCFG in the Austin-Buda.

This play was separated into oil and gas components for purposes of assessment. Oil is located predominantly in the updip area and gas in the downdip area near the Cretaceous shelf margin.

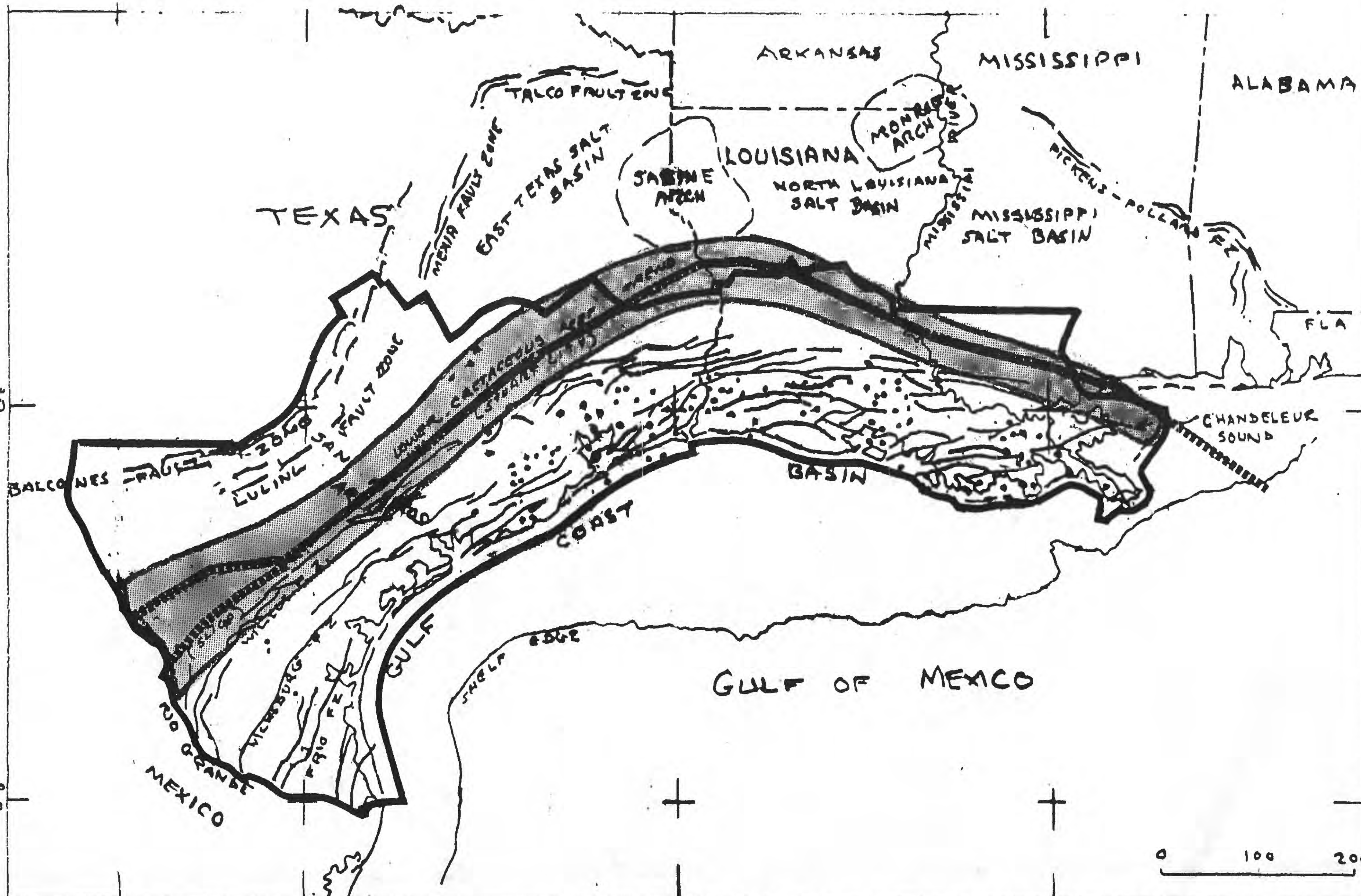

Fig. 14. Map showing area of Chalk plays of South Texas and Louisiana.

Louisiana Chalk Play:

This play encompasses the occurrence of oil and gas in fractured chalk reservoirs of the Upper Cretaceous Austin Chalk and Buda Lime formations, extending across south central Louisiana (figs. 6 & 14). It can be viewed as a continuation of the previously described South Texas chalk play, although separately assessed.

Reservoirs are fractured chalks and limestones, and the limits of the play are essentially defined by the area of optimal fracturing, which is thought to occur in a linear trend, 5 mi (8 km) to 15 mi (24 km) wide. The foci of the fractures are at the Mesozoic hinge lines of the basin, producing the Austin Chalk-Buda Lime fracture trends along overlapped paleo shelf edges. The play is treated as a large occurrence or accumulation which is limited geographically by the development of fracturing sufficient to allow economic production. Drilling depths range from about 7,000 ft (2134 m) to 12,000 ft (3658 m).

Source rocks are associated or downdip organic-rich facies of the Austin Chalk and underlying Eagle Ford Shale.

Exploration has been largely incidental to exploration for other targets. Following the discovery of Pearsall Field in Texas in 1935, consideration has been given to the economic possibilities of these reservoirs, however, activity in Louisiana has been light. In 1984, Austin Chalk production was established in West Feliciana Parish, Louisiana. As in Texas, activity has been very sensitive to prices of oil and gas. The recent advent of horizontal drilling has stimulated considerable activity in the Texas play and prospects appear attractive for expansion of an active exploration play in the Louisiana area. For purposes of assessment, this play was broken into separate oil and gas components.

Tuscaloosa-Woodbine Play:

This play encompasses the occurrence of oil and gas in sandstones of the Upper Cretaceous Woodbine Group and Tuscaloosa Formation, situated in anticlinal closures on the downthrown side of growth faults basinward of the Cretaceous shelf margin and in stratigraphic and combination traps resulting from sandstone pinchouts associated with these structures, or downslope across southeast Texas and south-central Louisiana (figs. 6 & 15).

Reservoirs are varied, ranging from deltaic sandstones to marine bars to downslope turbidite fan complexes (Siemers, 1978; Smith, 1985). Pay thicknesses range from 7 to 185 ft (2 to 56 m), but more typically are on the order of 20 to 80 ft (6 to 24 m). Reported average reservoir porosities range from 9 to 29 percent, but usually are from 12 to 25 percent. The occurrence of relatively high porosities in the more deeply buried sandstones has been attributed to secondary porosity development caused by selective grain dissolution and leaching of early iron-rich calcite cement.

Source rocks are generally fine grained, organic rich, Cretaceous marine to basinal facies rocks associated with the reservoirs. Locally, migration from other deeper or downdip sources may also have taken place. The play is primarily gas prone towards the southeast, where drilling depths exceed 17,000 ft (5182 m); gas fields in this deeper area contain considerable condensate.

Traps are growth faults and anticlines, combined with facies changes within the reservoir package, and porosity pinch-outs in lenticular submarine fan and continental margin sandstones that are isolated within thick mudstones. Drilling depths range from approximately 1000 ft (305 m) to more than 22,000 ft (6706 m).

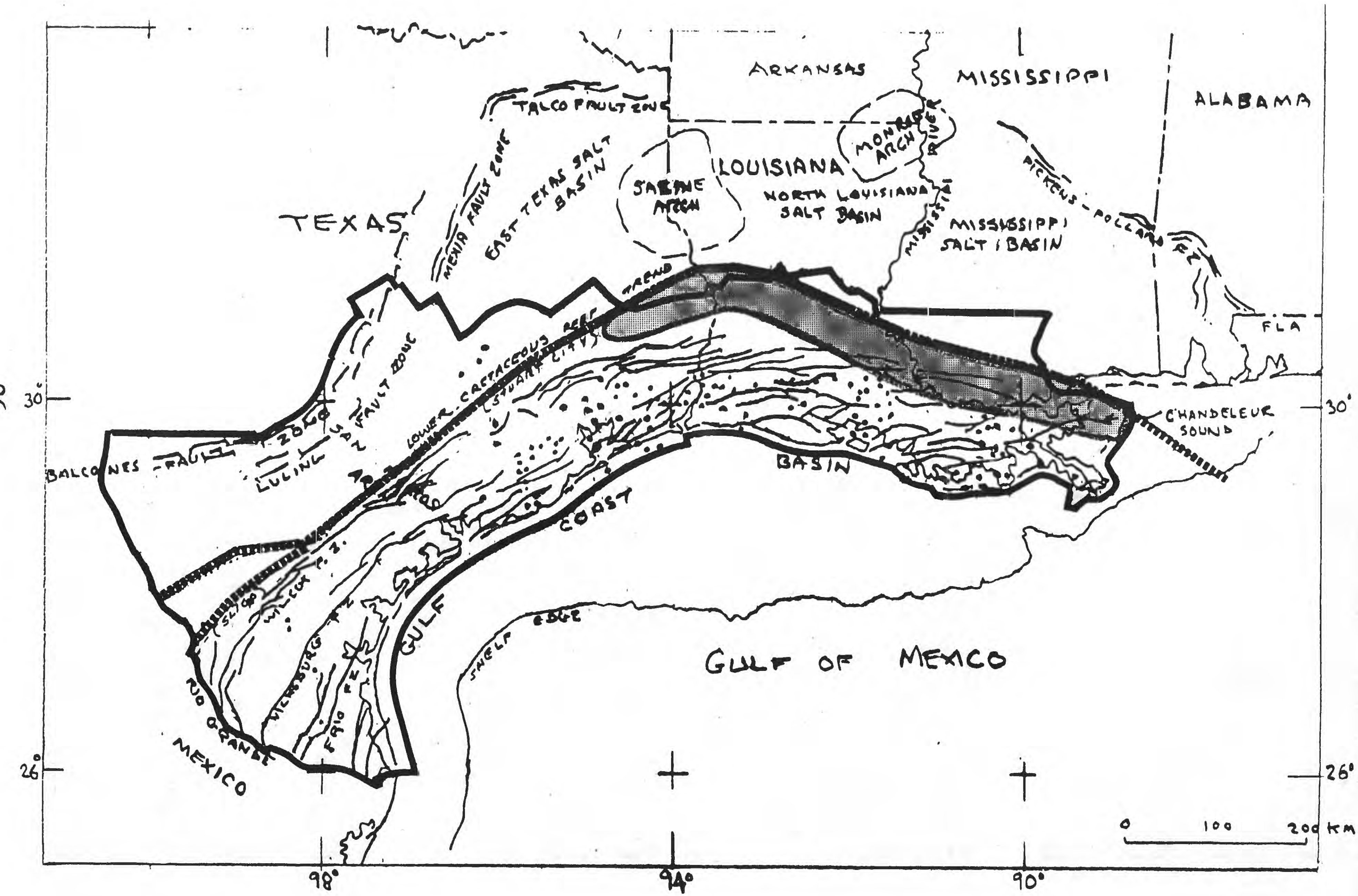

Fig. 15. Map showing area of Tuscaloosa-Woodbine play.

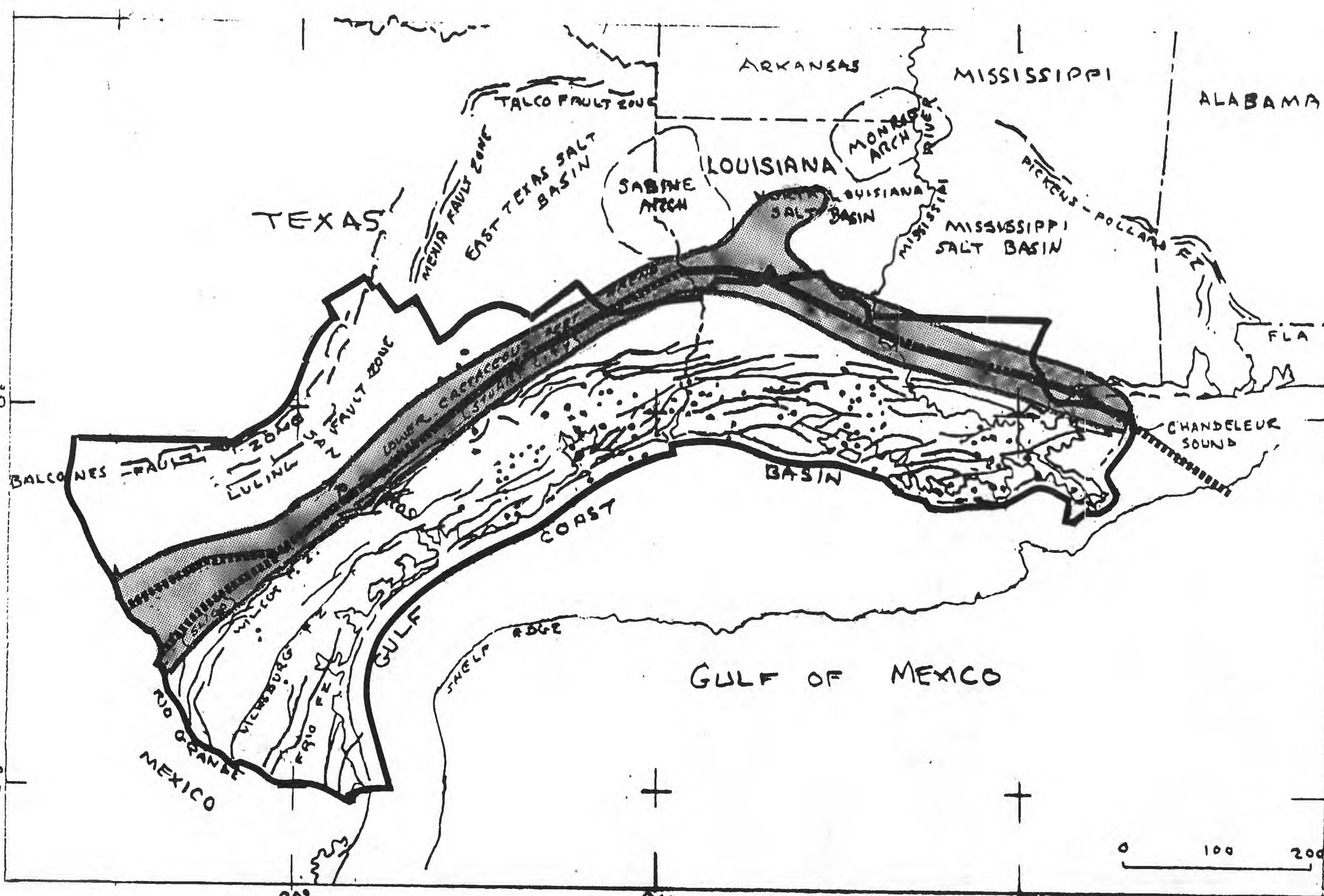

Fig. 16. Map showing area of Reef plays of Texas and Louisiana.

Exploration in the play began in the early 1970's. To the end of 1984, 3 oil fields and 15 gas fields greater than 1 MMBO or 6 BCFG had been discovered, accounting for approximately 100 MMBO, 2.2 TCFG, and a large amount of condensate. The largest oil and gas fields reported are Damascus Field with 84 MMBO and Port Hudson Field, with 390 BCFG. Harrison (1980) credits as much as 4 TCFG having been discovered in this play.

South Texas-Louisiana Reef Play:

This play is characterized by the occurrence of gas in shelf margin reefs and associated skeletal and oolite grainstones of the Lower Cretaceous Sligo and Stuart City limestones. The play is therefore defined by a narrow and linear trend of reef and shoal development at the shelf margin, extending along its entire length, commonly referred to as the Sligo and Stuart City trends (Herrmann, 1971; Bebout and Loucks, 1974; Bebout and others, 1981) (figs. 6 & 16).

Reservoirs are skeletal packstones/wackestones and boundstones of coralgal-caprinid (rudistid) bioherms, and coral-caprinid grainstone and coated-grain packstones of the associated detrital facies. Matrix porosity and permeability are generally poor but, in some cases, augmented by fracturing.

Source rocks are fine-grained downdip basinal facies, including pelagic lime mudstones, and black shaly lime mudstones, which are now largely in a gas generation phase. Migrated hydrocarbons are now widely distributed in reservoirs along the paleoshelf margin.

Traps are stratigraphic and combination, primarily involving closures along the crests of the reefs. Many traps along the reef trend, such as Stuart City Field, have more hydrocarbon column than mappable structural closure. Drilling depths range from about 10,000 ft (3048 m)to approximately 17,000 ft (5182 m).

The first significant discovery in the play, Dilworth Field, in Texas, was made in 1950. To date, one oil field and 12 gas fields greater than 1 MMBO or 6 BCF have been discovered. Black Lake Field, Louisiana, with approximately 50 MMBO, contains a very large gas cap of approximately 675 BCFG, and 69 MMB condensate (Bailey, 1978); the largest nonassociated gas field, North Word Field, Texas, is approximately 255 BCFG. Total discovered resources are approximately 1400 BCF gas and somewhat more than 50 MMBO. The most significant problem in development of this play has been the generally poor reservoir properties associated with the reef trends.

OCCURRENCES NOT ASSESSED

Not included in this assessment of conventional resources of the Western Gulf basin were such associations as gas in brines and geopressured shales of the Cenozoic sequence, or coalbed methane in areas of coal bearing rocks, or hydrocarbons in fractured shale reservoirs.

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