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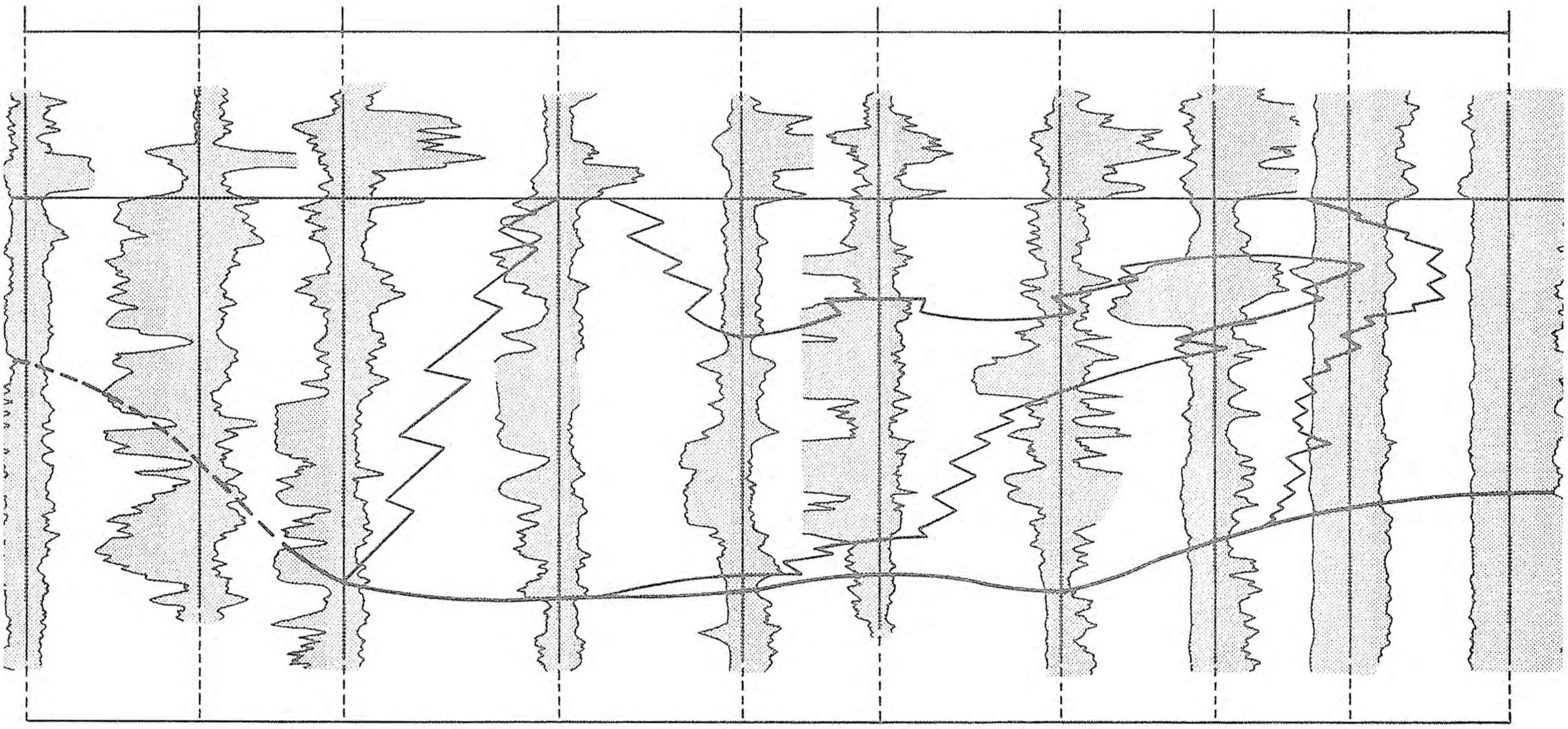
(Lower Cretaceous), Northeast Texas–Oil, Gas, and Groundwater Resources

BY
CHARLES A. CAUGHEY



BUREAU OF ECONOMIC GEOLOGY
THE UNIVERSITY OF TEXAS AT AUSTIN
AUSTIN, TEXAS 78712
W.L. FISHER, DIRECTOR
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Second Printing, 1985

QAe4362

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DEPOSITIONAL SYSTEMS IN THE PALUXY FORMATION (LOWER CRETACEOUS), NORTHEAST TEXAS— OIL, GAS, AND GROUNDWATER RESOURCES

by

CHARLES A. CAUGHEY[1]

ABSTRACT

The Paluxy Formation is a stratigraphic unit which is composed of sandstone and shale and extends across the northern part of the East Texas embayment. Paluxy deposits were derived from sedimentary rocks to the north, and they accumulated in shoreface and coastal plain environments associated with an irregular southward regression of the shoreline. Preserved in the sedimentary mass are three major depositional systems: a centrally located delta system, a fluvial system in the north, and a strandplain system in the west.

The delta system is wave dominated, composed largely of marine-influenced sediments aligned along depositional strike. Sand isolith maxima, associated with stacked coastal barrier deposits, outline the cuspate shape of the delta system. Two principal delta lobes are recognizable; these are centered in Hunt and in Wood Counties. The fluvial system consists of a broad, sandy meanderbelt facies which thins northward into discrete channel complexes separated by floodbasin deposits. The strandplain system blankets the western embayment margin with coalescent beach ridge and associated shoreface and coastal lake deposits.

Strandplain sands provide small to moderate quantities of groundwater that are generally suitable for uses other than irrigation. Fluvial system deposits furnish local areas with water for irrigation and for domestic and municipal supply. Major oil and gas accumulations occur in deltaic coastal barrier and fluvial meanderbelt facies.

INTRODUCTION

The Lower Cretaceous Paluxy Formation is a relatively thin and continuous stratigraphic unit composed of sandstone and shale which occurs throughout the northern part of the East Texas embayment. It commonly ranges from 200 to 400 feet (61 to 122 m) in thickness and forms a distinct lithic break between carbonates of the underlying Glen Rose and overlying Goodland Formations. Paluxy aquifers furnish water for domestic, public supply, farm, and industrial uses in areas along and adjacent to the outcrop belt, and significant oil and gas accumulations occur farther

[1]Continental Oil Company, 1105 General Mouton, Lafayette, La. 70505

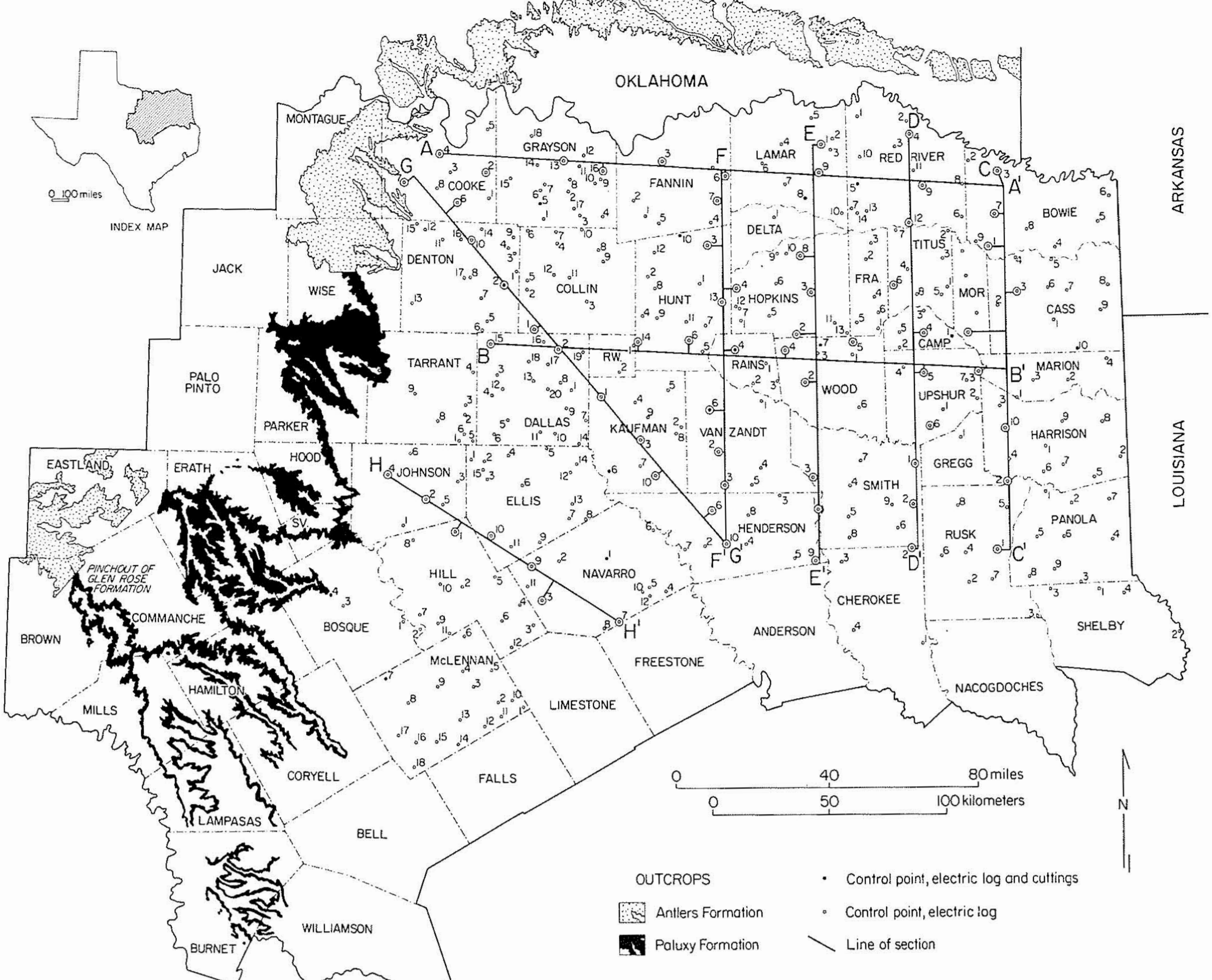

Figure 1. Location map. Numbers refer to control points listed in appendix. Outcrop of Paluxy and Antlers Formations after Miser (1954) and Fisher and Rodda (1967).

downdip to the south and east. The objectives of this report are (1) to describe regional aspects of Paluxy sedimentation in northeast Texas and (2) to relate this depositional framework to the nature and distribution of associated groundwater and petroleum resources.

The study is based on a grid of 356 electric logs distributed across 62 counties in northeast Texas (fig. 1). Electric log interpretations are supplemented by lithic descriptions of 91 outcrop localities and cuttings and core from 16 boreholes. The investigation was conducted as a master's thesis at the Department of Geological Sciences, The University of Texas at Austin (Caughey, 1973).

I acknowledge the guidance of W. L. Fisher, Bureau of Economic Geology, and A. J. Scott and L. J. Turk, Department of Geological Sciences. L. F. Brown and J. H. McGowen, Bureau of Economic Geology, and C. V. Proctor, Continental Oil Company, discussed outcrop features and directed me to some of the Paluxy exposures. Brown also reviewed the manuscript and suggested improvements. J. N. Russell provided access to the well log library of the Texas Water Development Board, and M. L. Morrow supplied borehole cuttings for examination from the Bureau of Economic Geology well sample and core library. Continental Oil Company provided cores from two exploratory boreholes.

STRUCTURAL FRAMEWORK

The study area is located near the northern margin of the coastal plain, where a wedge of post-Paleozoic strata expands gulfward from a thin section lapping over and discordant with the beveled edge of the arcuate Ouachita front. The Paluxy was deposited in the broadly subsiding East Texas embayment, an inlet in the Gulf basin localized by a flexure of the Ouachita foldbelt. The eastern flank of the embayment extended over the Sabine uplift, which acted as a stable platform during Paluxy deposition and was not actively uplifted until the end of the Comanchian (Granata, 1963, p. 73-74). The center of the embayment was less stable and marked by a north-south-trending central trough, the Tyler basin (fig. 2). The southern margin of the East Texas embayment is not well defined, although at least a partial restriction existed. The embayment may have been closed to the south at times, then at other times open to the Gulf (Murray, 1961, p. 124).

The structural trend for the Paluxy was set by a regional gulfward tilting of the area started during deposition of the upper part of the underlying Glen Rose (Forgotson, 1956, p. 92). Source areas to the north were rejuvenated concurrently with downwarping of principal depositional basins in northeast Texas and in Louisiana. A more stable platform area remained in the southern part of East Texas (Granata, 1963, p. 73-74). Its presence is indicated by a southerly thinning of the Paluxy Formation and a facies change from shale to limestone.

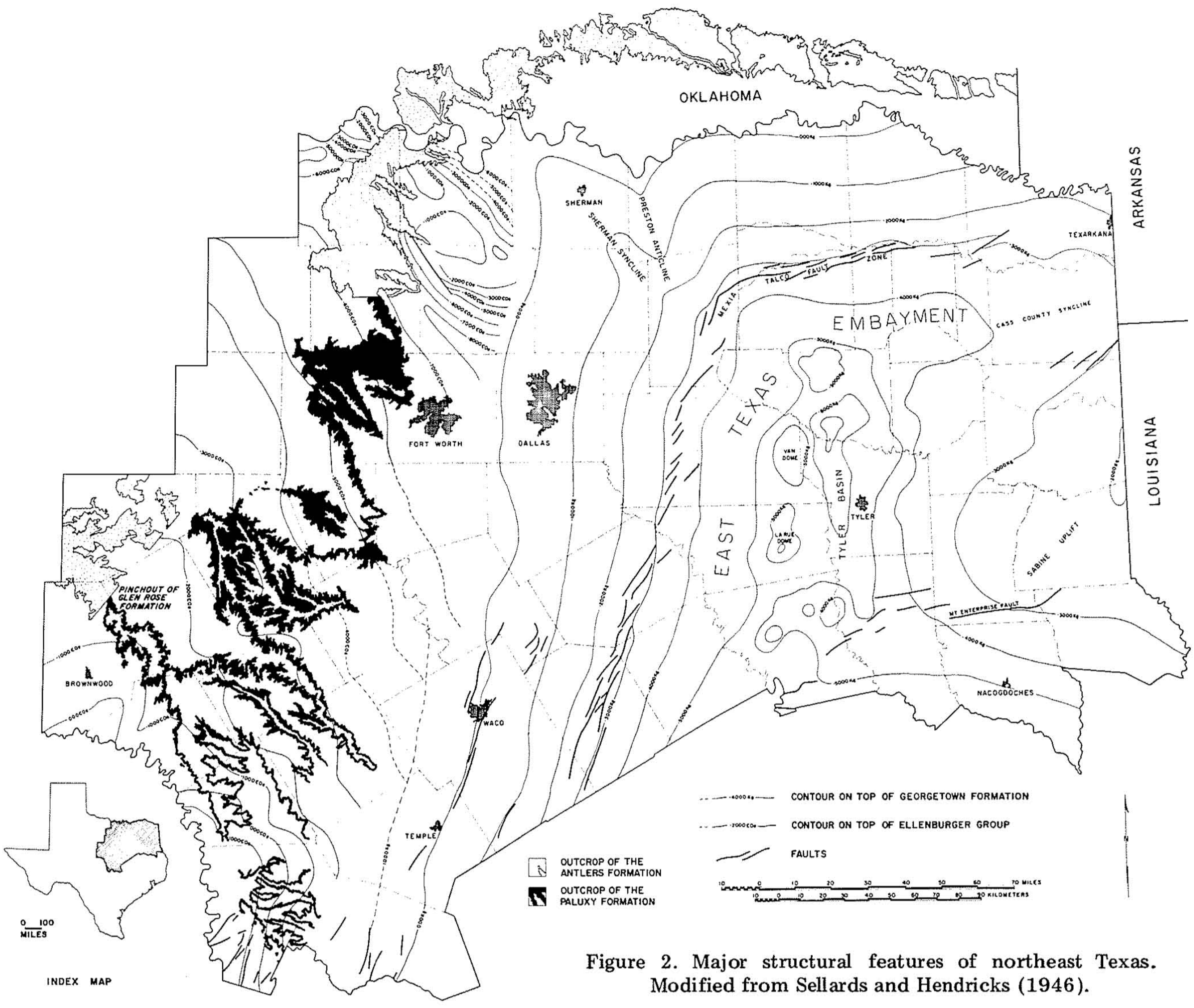

Figure 2. Major structural features of northeast Texas. Modified from Sellards and Hendricks (1946).

The structural setting strongly influenced the regional extent, relative thickness, and gross lithic composition of the Paluxy. In a pattern common to Lower Cretaceous terrigenous components of the East Texas embayment, thick subsurface sections in the unstable central basin thin toward outcrops along the northern and western basin margins and grade gulfward into porous shelf limestones of the southern platform.

Structural activity during Paluxy deposition included movements associated with salt domes and major fault zones. Most or all of the Mexia-Talco faults were active (Barrow, 1953, p. 126), forming a system of embayment-margin grabens, which may reflect tension between the subsiding sedimentary mass in the central basin and the more stable basin margins (Spencer, 1969, p. 102, 336). Some movement occurred in faults associated with the Sabine uplift, including the main Rodessa fault and faults of the Mt. Enterprise zone (Barrow, 1953, p. 126-127; Murray, 1961, p. 121).

STRATIGRAPHIC RELATIONSHIPS

The Paluxy Formation crops out in an irregular band about 40 miles (65 km) wide trending north from Burnet, Burnet County, to Decatur, Wise County (fig. 3). In the subsurface, it extends across northeast Texas into Louisiana and Arkansas. The southern boundary of the Paluxy is transitional with shale and sandstone beds grading into marl and limestone of the Walnut Formation

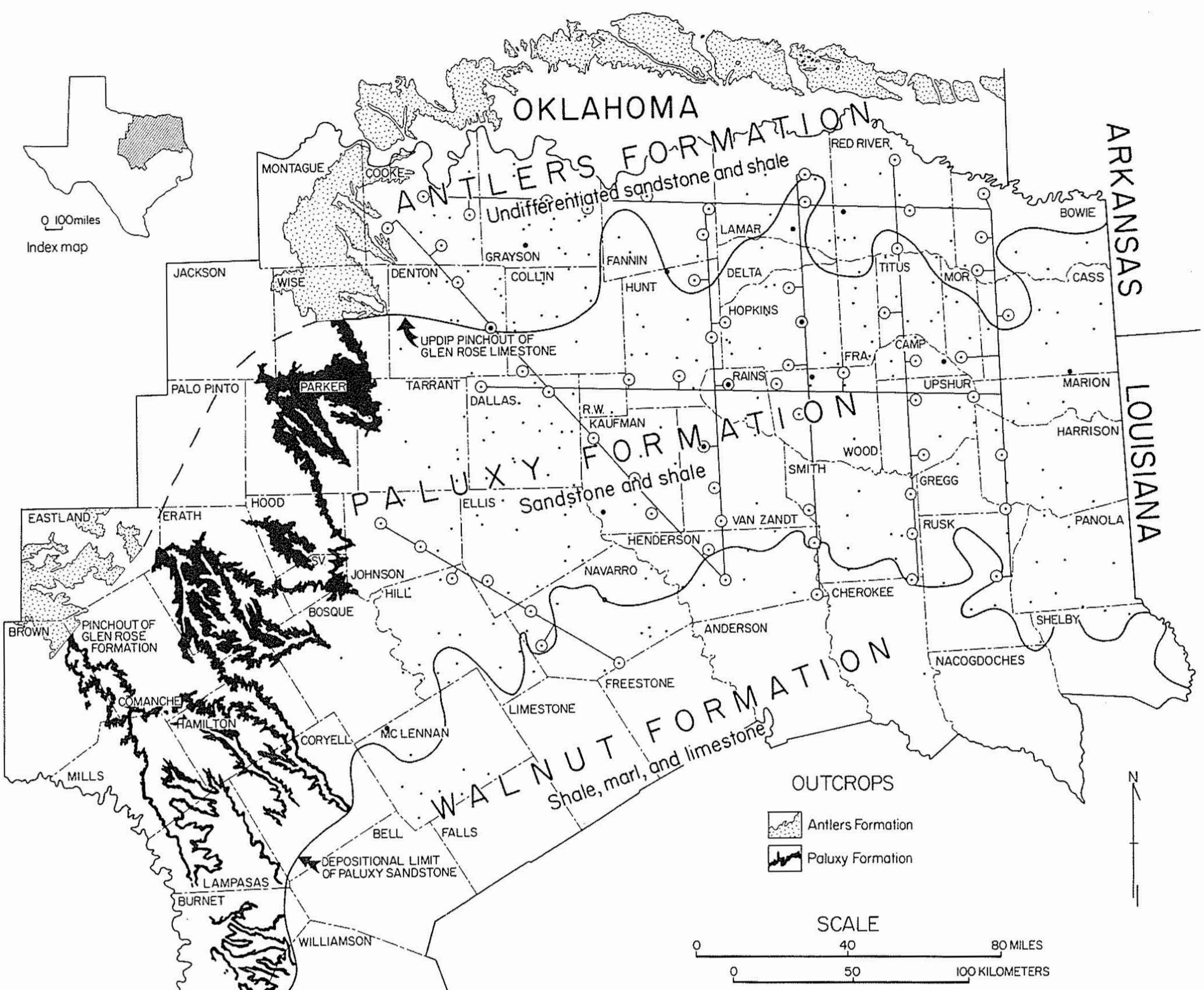

Figure 3. Distribution of Paluxy Formation and related stratigraphic units, surface and subsurface, northeast Texas.

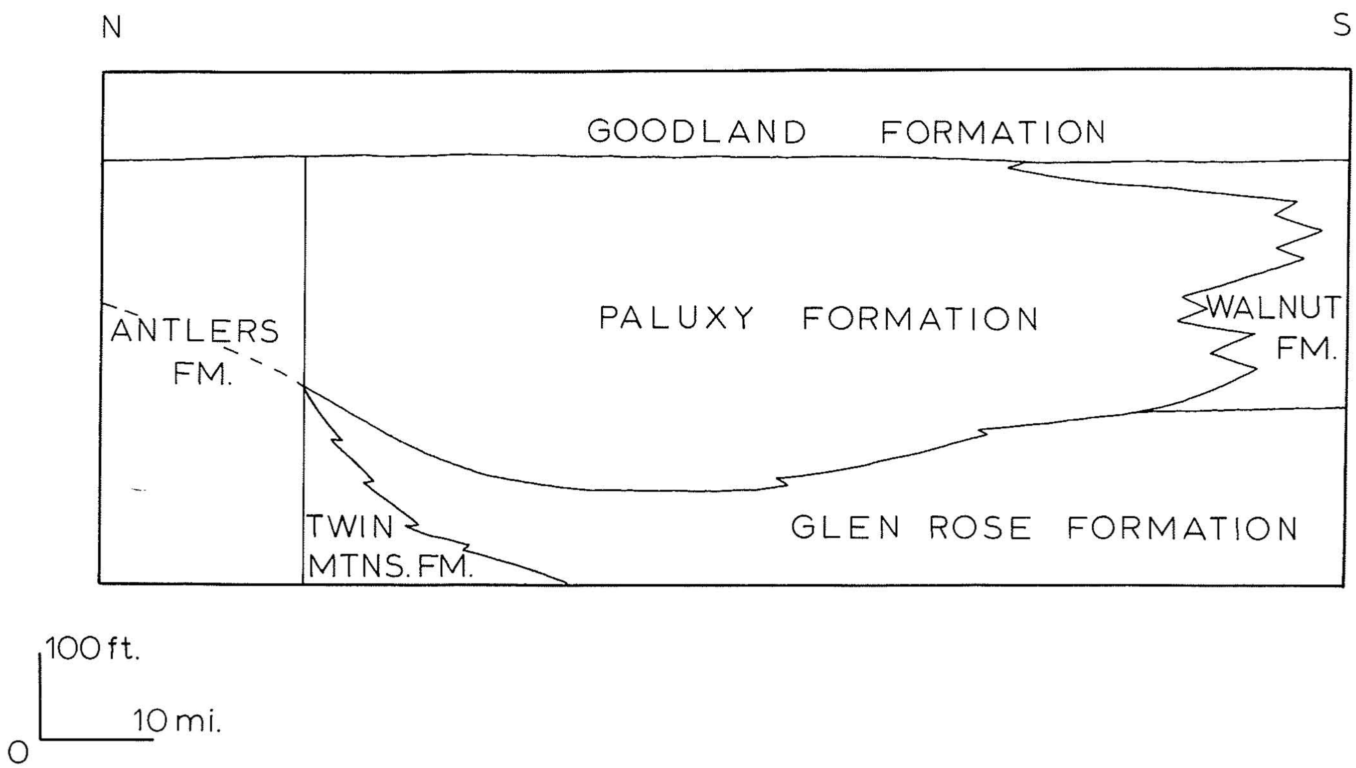

Figure 4. Stratigraphic relationships among the Antlers, Twin Mountains, Glen Rose, Paluxy, Walnut, and Goodland Formations in northeast Texas.

along a line between Hill and Panola Counties. The northern and extreme western boundaries are set at the pinchout of limestones in the subjacent Glen Rose Formation, beyond which the Paluxy is not differentiated from underlying clastic deposits of the Twin Mountains Formation (fig. 4). The Glen Rose pinchout crops out in west-central Texas and again near Decatur, where it extends eastward in the subsurface across northeast Texas and into Arkansas. North and west of the pinchout, the combined Paluxy-Twin Mountains sequence comprises the Antlers Formation (Fisher and Rodda, 1966, p. 8, 11). The Antlers crops out in west-central Texas and in an arcuate belt extending from the Paluxy outcrop northward across Oklahoma and into Arkansas. From the outcrop belt, the Antlers extends east and south into the subsurface of Oklahoma, Texas, and Arkansas (fig. 3).

SEDIMENTARY FACIES

Sedimentary facies in the Paluxy are differentiated on the basis of lithic composition, fossil content, and regional trends of sandstone distribution. Lithologic and paleontologic information derive from outcrop specimens, borehole samples, and cores. A sandstone isolith map for the Paluxy interval (fig. 5), compiled from electric logs, illustrates the distribution and orientation of major sandstone accumulations.

Five principal facies are discernible in the Paluxy, and one of these, the coastal barrier facies, is further divisible into two subfacies. Carbonates of the Walnut Formation constitute an additional facies type which is correlative with the terrigenous clastic lithofacies of the Paluxy. Figure 6 shows the areal distribution of these seven facies components of the Paluxy Formation.

The sandstone isolith map provides the regional framework for facies analysis. In the north-central and northeast parts of the area, isolith contour lines are oriented approximately parallel to paleoslope. Discrete, dip-oriented sand-

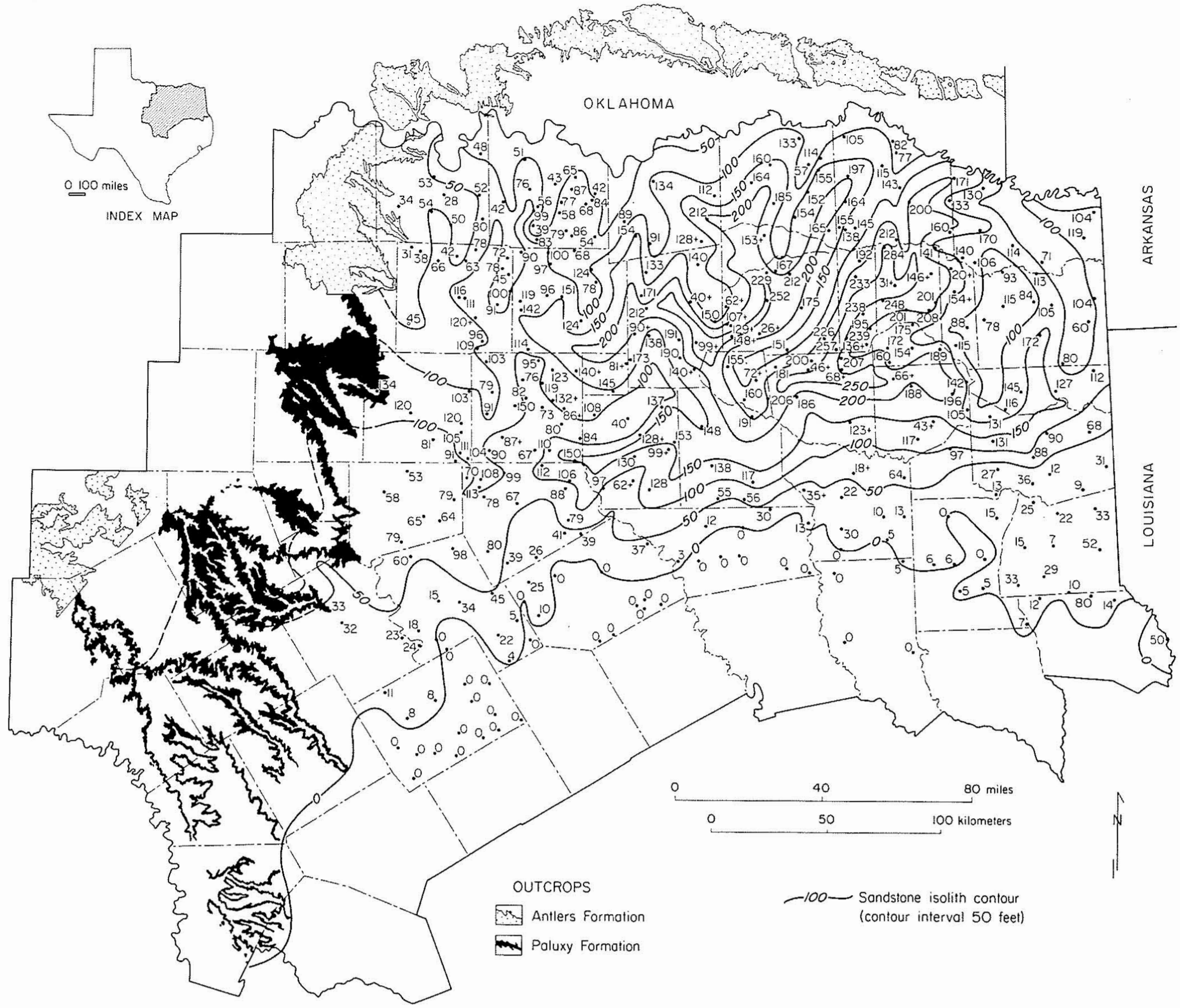

Figure 5. Sandstone isolith map for the Paluxy and upper part of the Antlers Formations in northeast Texas.

stone accumulations in this region merge basinward and ultimately terminate downdip against a broad, strike-oriented sandstone concentration. Two facies are recognized in the dip-oriented deposits:

1. *Channel-fill and floodbasin facies.* Digitate sandstone concentrations with muddier intervening deposits are present across the northern row of Texas counties from Fannin to Bowie. These elongate sandstone accumulations exhibit net thicknesses ranging from 150 feet to over 200 feet (46 to 61 m), and they consist of sandstone units from 10 to 100 feet (3-30 m) thick which are stacked in a multistory configuration. Individual sandstone units have an abrupt base and characteristically show grain sizes which become finer upward. Sand and mud components are not distributed uniformly, but they are present in approximately equal amounts for the facies as a whole. Mudstones contain abundant plant fragments and leaf impressions, and thin-bedded lignites occur locally.

2. *Meanderbelt facies.* Broader sandstone accumulations are present to the south, in Hopkins, Franklin, and Titus Counties. Shales are interstratified with the sandstones and are more uniformly distributed laterally, but they constitute less than half of the total section. Sandstone isolith values range from 140 to over 250 feet (43-76 m). Individual sandstone units vary from 30 to more than 100 feet (9-30 m) in thickness; they display a sharp

basal contact followed by an irregular fining-upward sequence.

Sandstone isolith contours for the Paluxy trend approximately parallel to depositional strike in most of the central, southern, and western parts of northeast Texas. Three facies are recognized in these predominantly strike-oriented deposits:

1. *Coastal barrier facies*. The sandstone isolith pattern in the central and southern parts of the area is dominated by an extensive, strike-oriented accumulation. Here deposits with a net sandstone thickness of 150 feet (46 m) or more define two large cusps, which extend east-west for 150 miles (240 km) in a broad band averaging about 20 miles (30 km) wide. Net sandstone values decrease uniformly in a downdip direction from a thickness of 250 feet (76 m) in the center of the accumulation to an almost total absence of sand at the basinward margin of the Paluxy. Two subfacies are differentiated within this continuum. Moderately thick (40 to 100 feet, 12 to 30 m) sandstone beds are included in the *proximal subfacies*; these show coarsening-upward sequences and are intercalated with thinner mudstone and shale units. Sandstone isolith maxima centered in Hunt and Wood Counties contain thicker sandstone units (100 to 270 feet, 30 to 82 m) which tie updip into thick sand trends of the meanderbelt facies. These sandstones show a well-developed upward gradation from burrowed, silty sand-

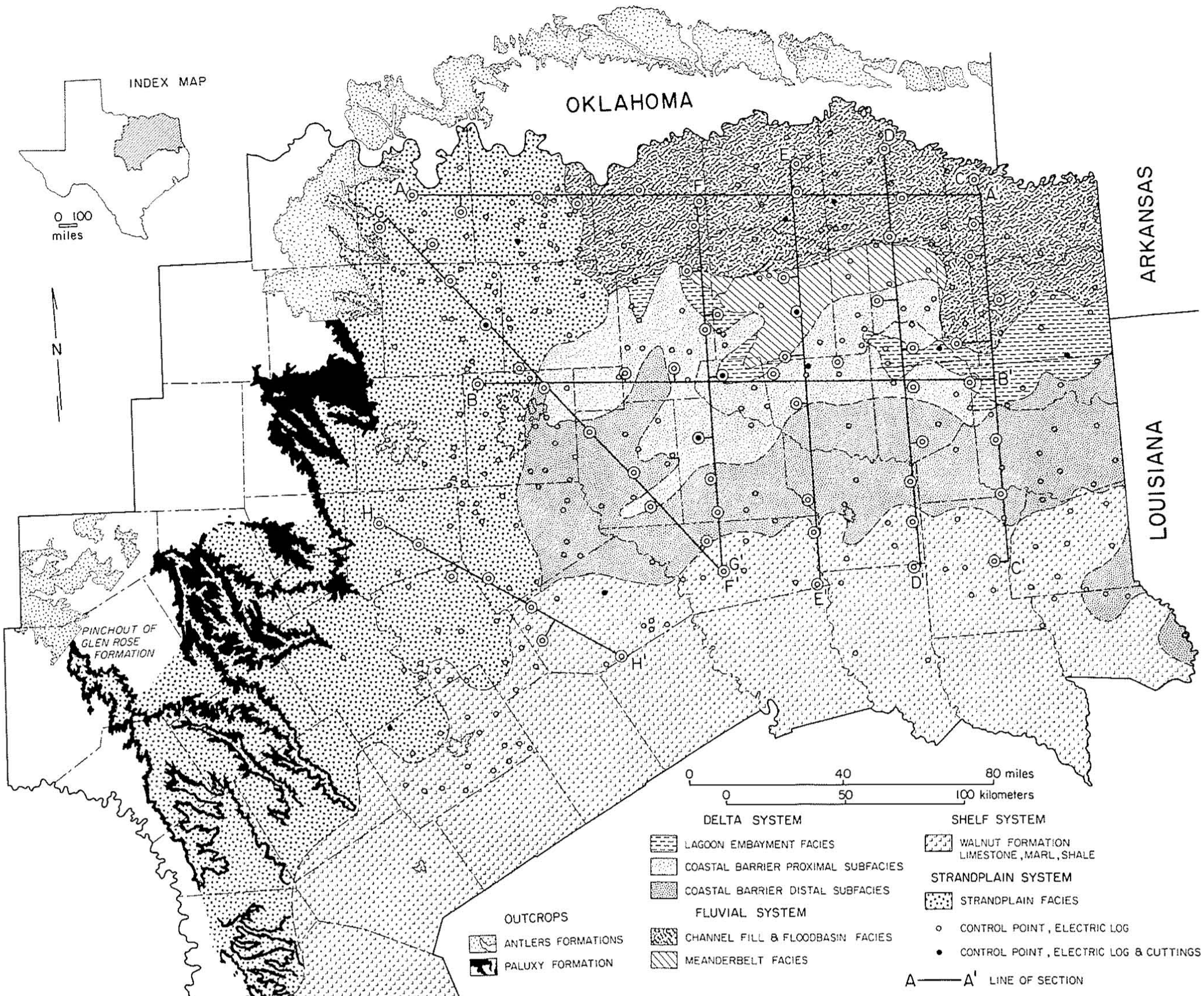

Figure 6. Depositional systems and facies, Paluxy Formation and equivalent lithostratigraphic units, northeast Texas.

stone and shale into clean, well-sorted sandstone containing some plant debris and widely scattered shell fragments. The *distal subfacies* is recognized in downdip areas where sandstone beds are thin (15 to 60 feet, 5 to 20 m), and vertical sequences consist of a random interstratification of sandstone and shale lentils. Oyster shell fragments, finely macerated plant detritus, and burrows are common in the distal deposits.

2. *Lagoon facies*. Local embayments occur along the updip (north) margin of strike-oriented sandstone accumulations. Deposits in these areas consist of intercalated sandstone and shale lentils which are 10 to 50 feet (3 to 15 m) thick, and sandstone content varies from 17 to 51 percent of the total section. Lithic boundaries are sharp, with units of well-sorted sandstone and massive to laminated mudstone arranged in random vertical sequences. Burrows and plant fragments are present in both lithic types.

3. *Strandplain facies*. Sand distribution in the western part of the area is more uniform. The sandstone isolith pattern for these deposits consists of broadly spaced contours which extend irregularly along strike. Net sandstone values range from 150 feet (46 m) in Dallas and Collin Counties to a basinward pinchout of sandstone into facies of the Walnut Formation in Coryell, McLennan, Hill, and Navarro Counties. Strandplain deposits consist largely of sandstone, which occurs as isolated lentils and as laterally extensive sheets. Individual sandstone units vary from 1 to 50 feet (30 cm to 15 m) in thickness or even thicker (up to 90 feet, or 27 m) adjacent to sand accumulations located along strike to the east. Coarsening-upward sequences are discernible in some of the thicker sandstone units. Interbedded mudrocks are laminated shales or burrowed or massive mudstones. Carbonized plant fragments and silicified wood are widespread in these deposits, and pelecypod casts and shell fragments occur locally.

DEPOSITIONAL SYSTEMS

Depositional systems are process-related, rock-stratigraphic units composed of associated sedimentary facies (Fisher and McGowen, 1969, p. 30-31; Scott and Fisher, 1969, p. 10). Their recognition is based on both specific characteristics of the component facies, such as shape, boundary relationships, and vertical and lateral sequences of lithic units, fossils, structures, and textures, as well as features of the system as a whole, including overall form, sandstone isolith trends, and distribution of framework (sand) and nonframework (mud) elements. Three depositional systems are recognizable in the Paluxy: a fluvial system in the northern part of the area, a centrally located delta system, and a strandplain system in the west.

FLUVIAL SYSTEM

The Paluxy fluvial system is developed extensively across the northern margin of the East Texas embayment. Fluvial deposits are recognized in the subsurface from the northern tier of Texas counties eastward into Louisiana, and they continue northward into Oklahoma and southward to a gradational contact with deltaic facies in the central basin area. Along the western margin of the basin, in Grayson and Collin Counties, the fluvial system grades transitionally into strandplain facies.

The fluvial system does not crop out in Texas, although minor fluvial facies associated with the western strandplain occur locally in exposures of that system. Fluvial deposits are present in Antlers outcrops of southeastern Oklahoma, but rocks related to the Paluxy are not distinguished in this area from those stratigraphically equivalent to the subjacent Twin Mountains Formation.

Two facies are recognized in the fluvial system. The channel-fill and floodbasin facies is northernmost, characterized by an elongate to branching sandstone isolith pattern, multistory sandstone configuration, presence of lignites, and moderate amount of overbank muds. The meanderbelt facies is transitional between the channel-fill and floodbasin facies and major delta lobes to the south; it is characterized by a broader, more uniform sandstone isolith pattern, multilateral sandstone configuration, scarce lignite beds and lower mud content.

CHANNEL-FILL AND FLOODBASIN FACIES

The channel-fill and floodbasin facies occupies the northeast and north-central portion of the study area (fig. 6). It includes the Paluxy and stratigraphically equivalent parts of the Antlers Formation across all of Fannin, Lamar, Red River, and Bowie Counties and adjacent parts of Grayson, Collin, Delta, Morris, and Cass Counties. Although roughly equal amounts of sandstone and mudstone characterize the facies as a whole, sandy sections occur in distinct, north-south-trending belts. These are indicated on the sandstone isolith map (fig. 5) by a series of elongate sandstone thicks.

Sandstones within the dip-oriented belts occur as fining-upward, channel-fill units. Individual sandstone units vary in thickness from 10 to about 100 feet (3 to 30 m), thickening downdip. Vertical sequences through sandstone units are characterized by a sharp base, floored by coarse sand or granule-sized lags which grade upward into very fine sand and mud. The fining-upward sequence is observed in well cuttings and on electric logs. In the Whithead and Dahl No. 1 Barr well, a Lamar County wildcat, two distinct fining-upward sequences are recognizable (fig. 7). Channel-fill units are composed of very coarse to medium sandstone and include relatively little mudstone. Upward in the sequence, the mud content increases as the mean size of the sand-sized fraction declines, resulting in gradation into mudstone and very fine sandstone. Electric log profiles through the sandstone units show abrupt basal deflections and gradational tops, although the widespread occurrence of brackish to fresh water in shallow deposits partially obscures this pattern.

Channel-fill and floodbasin sandstones are composed predominantly of quartz. They are friable to slightly indurated and cemented with calcite or, rarely, with pyrite or limonite. White is the most common color, although red, yellow, brown, and green colors are also present. The sandstones are texturally immature to submature, with some mature and supermature samples. Sand grains are subrounded to well rounded with high sphericity, commonly resulting in textural inversions. Plant fragments are the only abundant fossils.

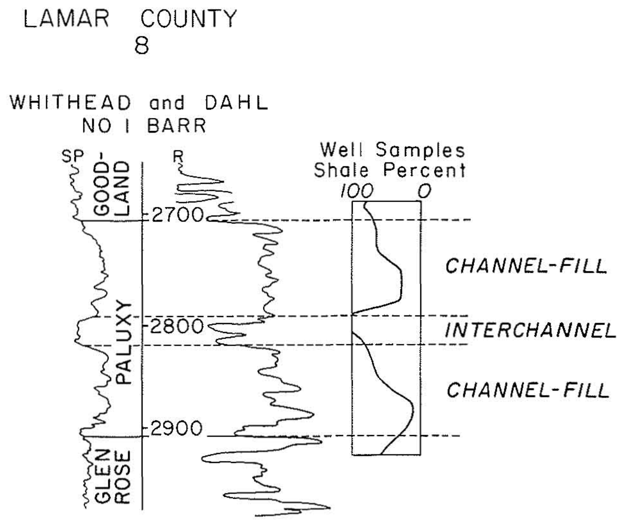

Figure 7. Representative electric log pattern and shale content of channel sequences in the channel-fill and floodbasin facies, Paluxy fluvial system.

Plant fragments and leaf impressions are particularly common in the mudrocks. Local lignite beds also occur associated with mudstones in both channel and interchannel areas. The mudstones are composed largely of expansible clays; they are structureless to laminated and contain small features resembling root mottles. Mudstone samples are predominantly black or gray, but white, yellow, and green shades also occur.

The sandstone and mudstone components of the channel-fill and floodbasin facies extend south to grade into the broader, sandy deposits of the meanderbelt facies in northern Hunt, Hopkins, Franklin, and Titus Counties. In Cass County, along the eastern margin of the study area, channel-fill and floodbasin facies change southward into embayment deposits of the lagoon facies. The western limit of the channel-fill and floodbasin facies, in Grayson County, is marked by marine-reworked deposits of the strandplain system (fig. 8).

Channel-fill and floodbasin deposits are bounded to the south and west by fluvial meanderbelt, deltaic, and strandplain deposits, and they extend eastward into Arkansas and northward into Oklahoma. Boundary relationships and distribution of sandstone and mudstone components are illustrated by dip-oriented cross sections through the facies (figs. 9-12).

Based on subsurface information, the channel-fill and floodbasin facies represents a floodplain

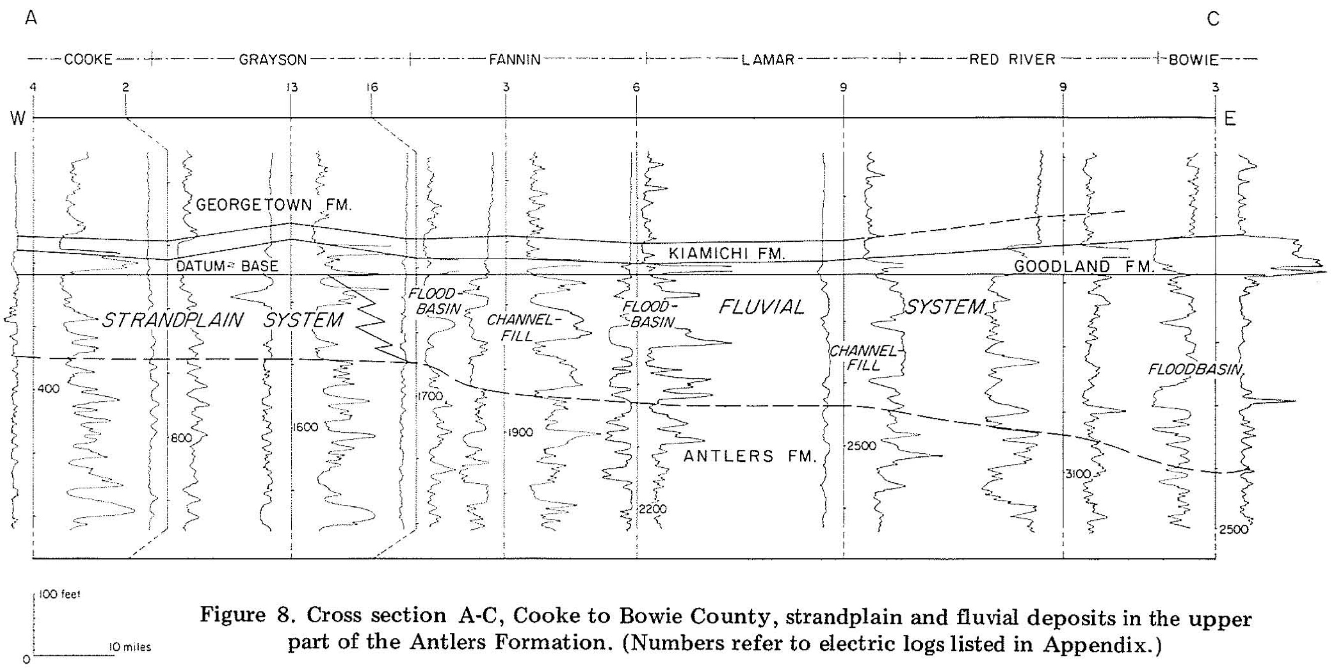

Figure 8. Cross section A-C, Cooke to Bowie County, strandplain and fluvial deposits in the upper part of the Antlers Formation. (Numbers refer to electric logs listed in Appendix.)

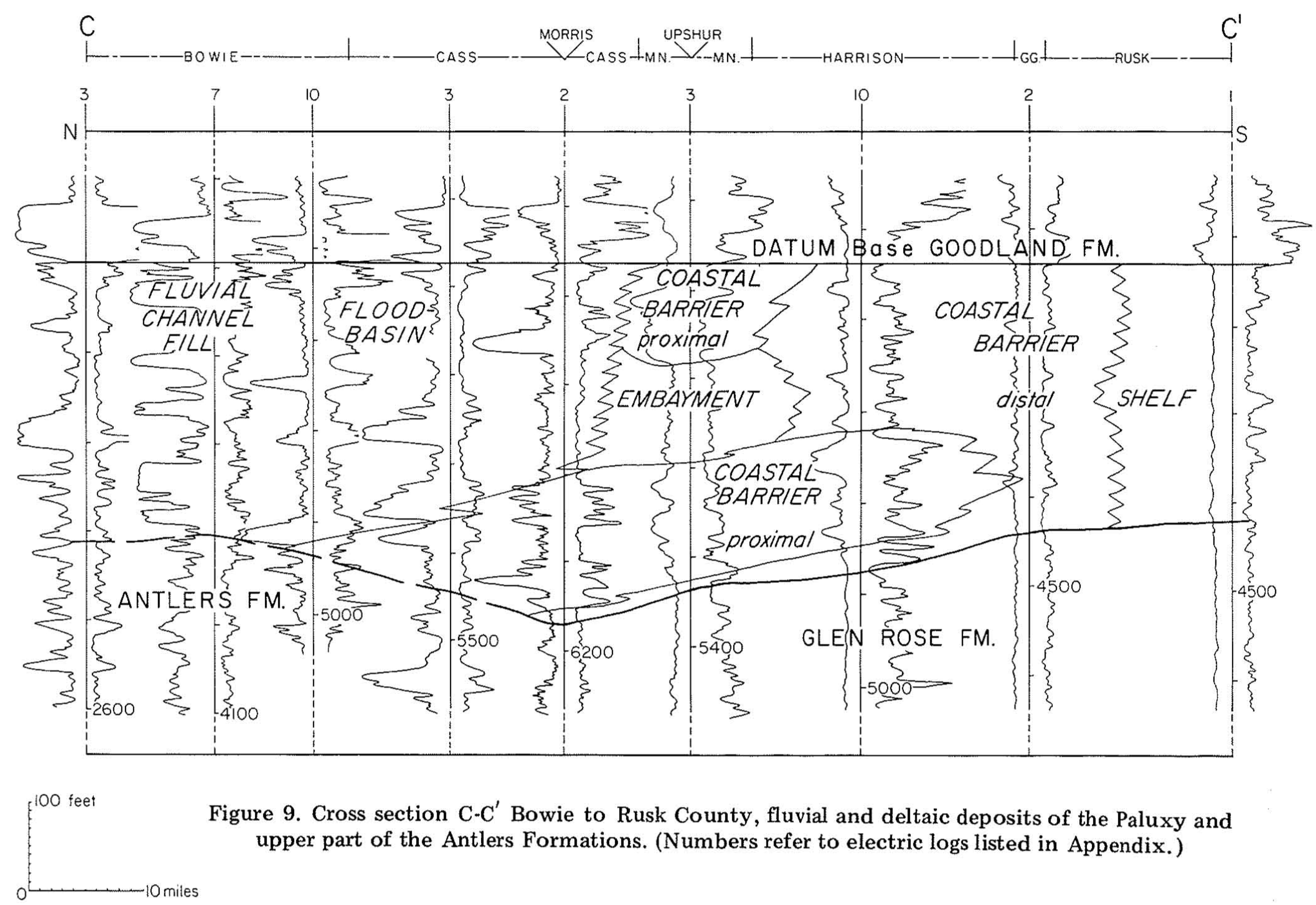

Figure 9. Cross section C-C′ Bowie to Rusk County, fluvial and deltaic deposits of the Paluxy and upper part of the Antlers Formations. (Numbers refer to electric logs listed in Appendix.)

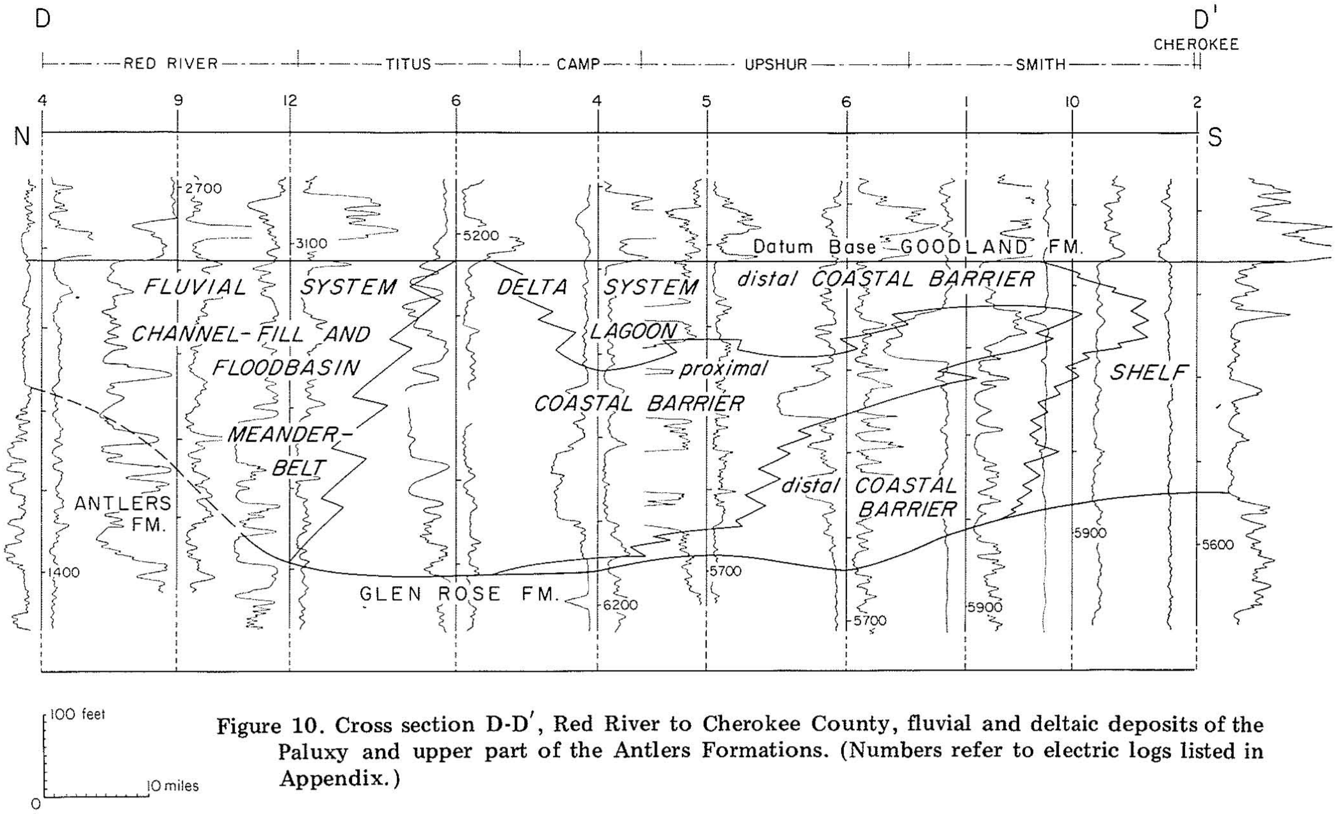

Figure 10. Cross section D-D′, Red River to Cherokee County, fluvial and deltaic deposits of the Paluxy and upper part of the Antlers Formations. (Numbers refer to electric logs listed in Appendix.)

constructed by streams draining gulfward from headwaters probably located in Oklahoma and Arkansas. Channel-fill characteristics of fining-upward sequences, confinement to meanderbelts with intervening floodbasin deposits, and multistory stacking arrangement are typical features of laterally accreting point bars in a relatively high suspended-load system (Allen, 1965, p. 125-127, 138-143, 163-167; McGowen and Garner, 1970).

MEANDERBELT FACIES

Southward from the channel-fill and floodbasin facies in the north-central counties of northeast Texas (Lamar, Red River, and Delta), the Paluxy Formation thickens markedly over an area including four-fifths of Hopkins County and northern halves of Franklin and Titus Counties (fig. 6). Sandstone constitutes a larger percentage of the expanded section and is more uniformly distributed laterally. The appearance of thicker, more persistent sandstone units roughly coincides with the hinge line where abrupt thickening starts and marks the northern boundary of the meanderbelt facies. To the south, the facies grades into various marine-influenced deposits of the major Paluxy delta lobes. Intercalation with the marine facies occurs, and thin marine accumulations are recognized locally at the top and base of the Paluxy interval.

The more uniform distribution of sandstone in the meanderbelt facies is reflected in broadened contours on the sandstone isolith map. Two fluvial axes are evident within the facies, where sand content ranges from 65 to 80 percent of the interval and well-developed sandstone units exceed 100 feet (30 m) in thickness. In the intervening area, sandstone makes up only about half of the section and commonly occurs in units 30 to 40 feet (9 to 12 m) thick. Alignment of this area with the western margin of the Tyler basin is an indication of regional tectonic influence on depositional patterns.

Individual meanderbelt sandstones display erosional bases, incising underlying sandstone and mudstone deposits. Lateral coalescence of individual sandstone units forms multilateral sandstone bodies, with erratic and discontinuous fining-upward sequences caused by paucity of mud and by interference between preserved channel-fill segments. Fine-grained deposits are poorly developed in the meanderbelt facies, except in the narrow zone between the major fluvial axes. The mud fraction present includes expansible clays, locally described as benthonitic and ashy in oil field reports (Wendlandt and Shelby, 1948, p. 439; Amis, 1951, p. 370). Small amounts of lignite and carbonaceous shale are also present.

Multilateral sandstones, poorly developed topstratum muds and lignites, and lack of uniform fining-upward sequences are characteristics of high-bedload, low-sinuosity streams (Allen, 1965, p. 125-127, 164; McGowen and Garner, 1970). These channels are not confined to narrow belts but instead sweep back and forth across a broad meanderbelt. Preserved sediments are segmented as a result of the continuing channel scour, and they consist predominantly of lag deposits and lower point-bar sequences.

FLUVIAL MODEL

The Paluxy fluvial system constitutes a regressive alluvial plain which furnished detritus to prograding shoreline deposits of the delta system. Channel-fill and interchannel accumulations extend southward from the sandy, undifferentiated Antlers Formation fringing source areas of Paleozoic rocks in Oklahoma. Basinward development of the channel-fill and floodbasin facies ultimately terminated in stable flank areas where increased marine influence resulted in gradation into marginal embayment and strandplain deposits. In the central area, channel-fill complexes merge downdip into broad meanderbelts. The meanderbelt facies extends over progradational deltaic deposits, and it includes fluvial deposits of the delta plain.

The downdip change in facies composition from discrete, multistory channel-fill sandstones with intervening floodbasin deposits to thick, multilateral channel-fill accumulations of the

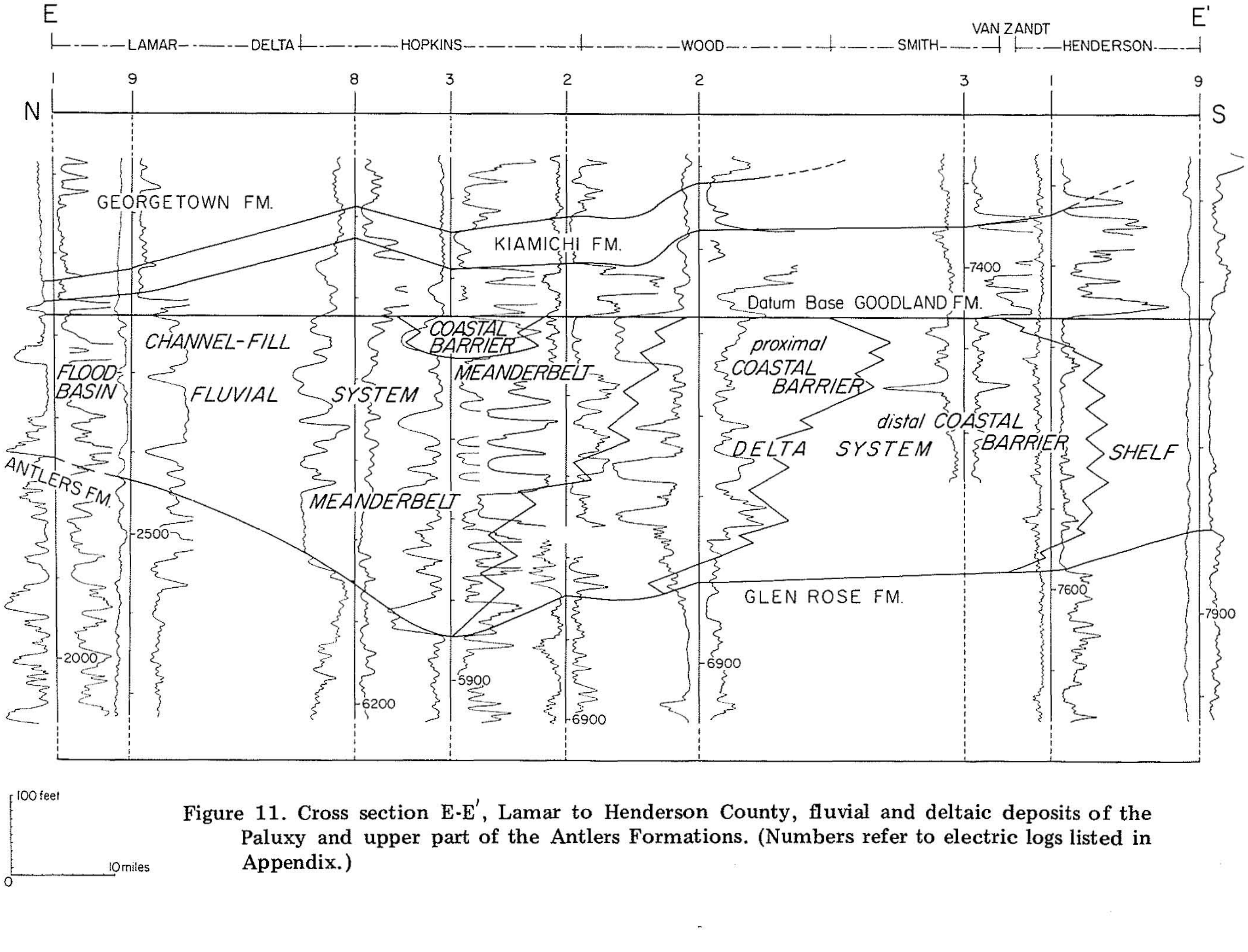

Figure 11. Cross section E-E′, Lamar to Henderson County, fluvial and deltaic deposits of the Paluxy and upper part of the Antlers Formations. (Numbers refer to electric logs listed in Appendix.)

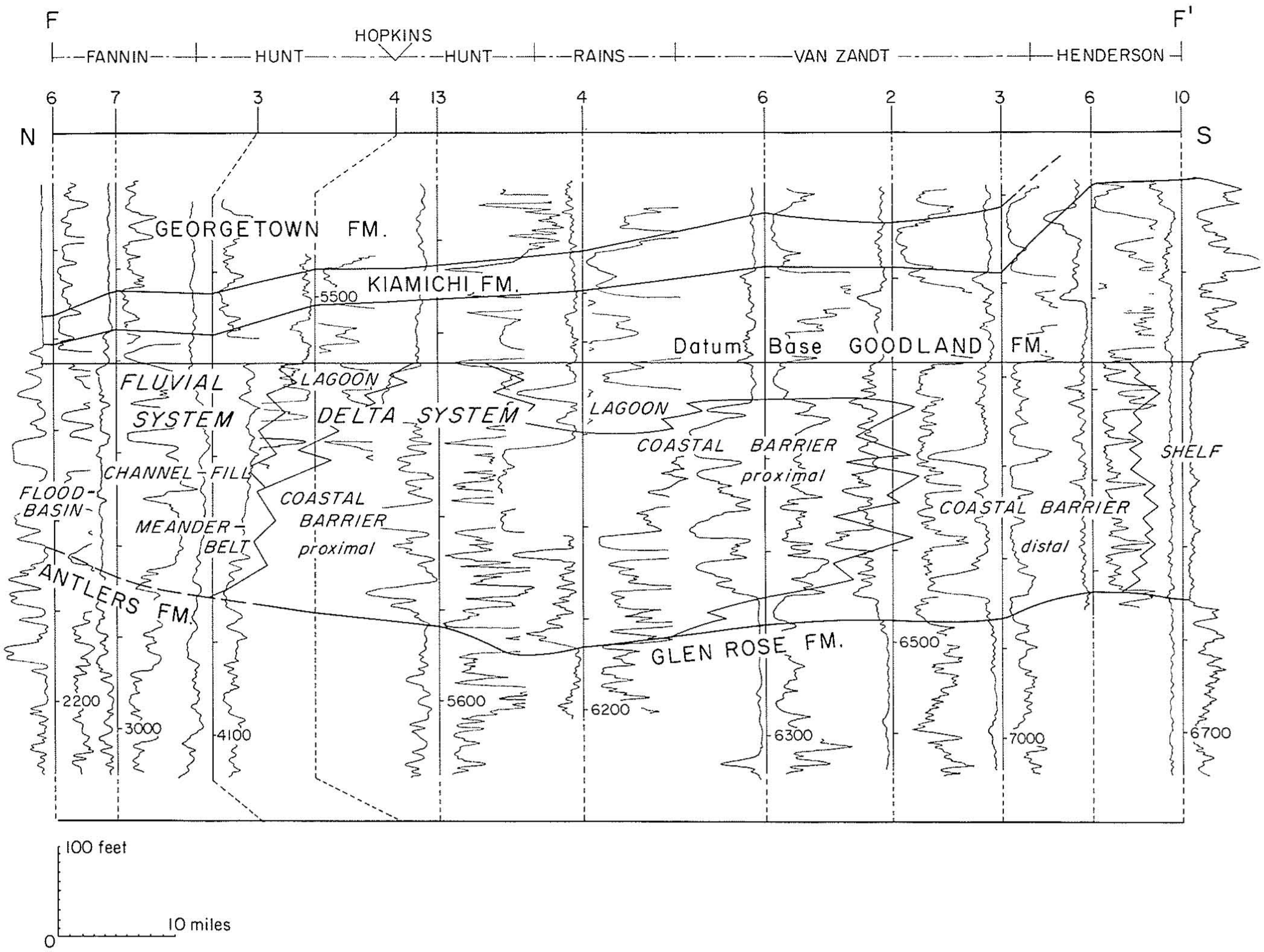

Figure 12. Cross section F-F′, Fannin to Henderson County, fluvial and deltaic deposits of the Paluxy and upper part of the Antlers Formations. (Numbers refer to electric logs listed in Appendix.)

meanderbelt facies roughly coincides with the Mexia-Talco fault zone. The Mexia-Talco system includes faults active during Paluxy deposition (Barrow, 1953, p. 126), and thickening of the Paluxy Formation occurs across some fault segments. These growth faults mark the transition from fluvial feeder channel deposits to alluvial deposits of the delta plain.

Meanderbelt deposits were subject to local marine reworking, as distributary outlets shifted and delta lobes were abandoned. The extent of the meanderbelt facies, fringed basinward by marine-influenced coastal barrier and lagoon deposits, indicates that extensive progradation downdip did not take place. The efficiency of marine reworking in keeping pace with deltation is evidenced by vertical persistence of facies. Cessation of deltation brought local redistribution of channel sands as the alluvial deposits foundered, followed by burial of deltaic and fluvial deposits under advancing shelf carbonate facies.

DELTA SYSTEM

The Paluxy delta system occupies the northern part of the Tyler basin and adjacent areas in the central portion of the East Texas embayment. It is the most extensive of the Paluxy depositional systems; deltaic deposits occur in the subsurface of all or parts of 25 counties (fig. 6).

Thickness of the delta system varies from more than 400 feet (122 m) near principal depocenters to 180 feet (55 m) along the distal (basinward) margin. The delta system is gradational with the fluvial meanderbelt and channel-fill and floodbasin facies to the north, shelf marls of the Walnut Formation to the south, and the strandplain system to the west.

Recognition of the system as deltaic is based on relationship to surrounding deposits, overall shape, and characteristics of component facies. Deltas are defined by Scott and Fisher (1969, p. 10) as river-fed depositional systems resulting in irregular shoreline progradation. The Paluxy delta system is associated with a major fluvial system to the north. Progradation in a south-southwestward direction is indicated by stratigraphic relationships between delta clastic sediments and shelf marls and by diagnostic lithic sequences within the delta system. The trend of the system, shown in plan view on the sandstone isolith and lithofacies maps (figs. 5 and 6), resembles an irregular, cuspate band oriented approximately parallel to depositional strike (normal to paleoslope).

The delta system consists of two general facies types. The coastal barrier facies includes strike-oriented sandstone accumulations which rim the delta complex in a broad band and grade basinward into shelf marl and limestone. Coastal barrier deposits thicken into principal deltaic depocenters which are downdip from major fluvial axes; there the facies is characterized locally by thick, progradational sandstone sequences and by elongate, dip-oriented sandstone isolith maxima. The lagoon facies occurs between fluvial and coastal barrier deposits in areas away from major fluvial axes. Lagoonal deposits consist of sandstone units which do not show distinctive shoreface sequences and which are interbedded with mudrocks.

COASTAL BARRIER FACIES

Coastal barrier deposits cover a large portion of 17 Texas counties: Upshur, Camp, Titus, Wood, Franklin, Hopkins, Rains, Van Zant, Kaufman, Hunt, Rockwall, Collin, Dallas, Ellis, Smith, Gregg, and Harrison. The coastal barrier facies forms a broad band stretching from Louisiana westward to a transitional contact with the strandplain system in Dallas and Ellis Counties (fig. 6). The band engirds the entire delta system, and it grades basinward into shale, marl, and limestone of the Walnut Formation.

Major accumulations of sandstone occur in the updip portion of the coastal barrier facies, and these are included in the proximal subfacies. Proximal coastal barrier deposits occupy two large, strike-oriented cusps that narrow updip and tie with dip-oriented sandstone thicks of the fluvial meanderbelt facies. Downdip areas, where shale constitutes half or more of the section, are included in the distal subfacies.

Proximal Subfacies.—The proximal subfacies averages 20 miles (32 km) in width and extends east-west for 120 miles (190 km) across the central part of northeast Texas (fig. 6). Margins of the subfacies display distinctive if somewhat irregular patterns: the southern edge describes two large cusps, concave to the south, and the northern edge is contorted into a more intricate pattern of sharp northerly projections and broad southerly indentations.

The sandstone isolith pattern conforms with the general facies outline. The dominant trend is a strike-oriented sandstone accumulation following the basinward margin. Normal to this primary trend, a secondary series of digitate sandstone thicks is developed which coincides with projections along the updip (northern) facies margin. The largest of these projections contain net sandstone values of 250 feet (76 m) or more, the thickest sand accumulations of the Paluxy delta system, and they join updip with north-south-trending sandstone concentrations in the fluvial meanderbelt facies.

Individual sandstone units in the proximal subfacies commonly range from 40 to 100 feet (12 to 30 m) in thickness, and they are separated by thinner lenses and tongues of mudstone and shale. Facies changes along dip result in the sandstone units' grading northward into interbedded sandstone and lagoonal mudstone of the lagoon facies and southward into marine shale and silty mudstone of the distal coastal barrier subfacies. Greater facies continuity is maintained along strike, although individual sandstone units vary significantly from well to well.

Vertical sequences through the coastal barrier units consist of clean sandstone beds that increase in number and thickness from underlying marine shales and silty sandstones to units 20 to 50 feet (6 to 15 m) thick of well-sorted sandstone. Electric logs for the coastal barrier facies show progressive increases in spontaneous potential deflections topped by sharp, blocky patterns for each barrier sequence. This trend reflects the gradual increase in sand content through the shoreface up into lagoon deposits of well-sorted sandstone interbedded with mudstone or local distributary channel-fill sandstone. In the Amerada No. 3 Faulk, a well in the Coke field, north-central Wood County, a coastal barrier sequence occurs in the interval from 6,300 to 6,550 feet (fig. 13). A coarsening-upward in grain size is indicated on the electric log by an irregular increase in spontaneous potential deflections from the base of the unit to an abrupt return at the top, forming a crude funnel-shaped pattern. This profile reflects an upward transition from interbedded shales and thin silty sandstones of lower shoreface environments to thick upper shoreface and distributary channel units, which are capped with mudstones that accumulated in a destructive phase after this lobe was abandoned. The sample log prepared from well cuttings shows the progressive increase in sandstone, although absolute sandstone percentages appear to be diluted by shale cavings from overlying units. A corresponding increase in textural maturity of the sand-sized fraction occurs upward into the thick sandstone units. The coarsest deposits are consistently in the fine sand range, reflecting the limited spectrum of grain size available.

Sandstones of the coastal barrier facies are fine- to very fine-grained quartzarenites. Mature and supermature textures are predominant, although the entire range of textural maturity is present. The sandstones are slightly calcitic but friable, and they locally contain oyster shell fragments and foraminifer tests. Some units are extensively burrowed. Grains range from subround to well rounded; frosting and polish are common surface features. Finer grained deposits occur in tongues and lenses interbedded with the sandstones and consist of black, calcitic siltstone and shale with burrows, local shell fragments, and scarce carbonized plant fragments.

The broad, extensive accumulation of proximal coastal barrier deposits suggests that the barriers formed during active deltation, with an abundant sediment supply furnished from local distributary outlets. Dip-oriented sections across the facies show an offlapping deltaic sequence, where barriers accreted basinward over prodelta and shelf deposits. Figure 14, a strike-oriented section across the delta system, contains coarsening-upward coastal barrier deposits (e.g., Rains County No. 4 and Wood County No. 5) overlain by blocky sandstones which probably represent distributary channel-fill deposits.

Coastal barrier facies also occur in the Paluxy Formation as isolated deposits not associated with the main delta system. Such barriers are thin, discontinuous units fringing fluvial deposits, and they are overlain by marine shale and limestone. In the Benedum No. 1 Spencer, located in east-central Hopkins County (Hopkins log 3, section E-E′, fig. 11), a thick section of fluvial meanderbelt deposits is overlain by very fine, texturally supermature sandstone. This sandstone unit is burrowed and contains shell fragments; it is a very porous, friable, slightly calcitic quartzarenite with traces of pyrite. Above the clean sandstone is a thin burrowed, immature silty sandstone, which is overlain by black, sparry limestone of the Goodland Formation. The sandstone is interpreted to be a local destructive unit reworked from fluvial channel-fill deposits.

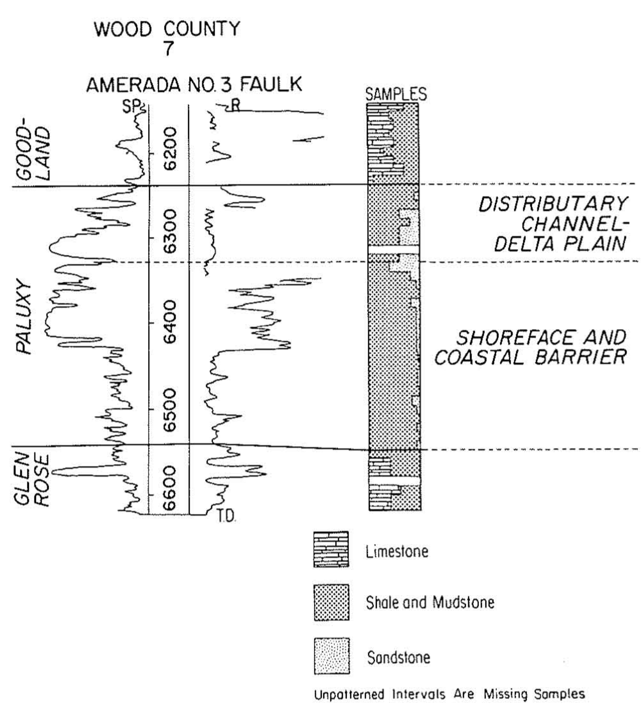

Figure 13. Representative electric log pattern and lithologic log, proximal coastal barrier facies, Paluxy delta system.

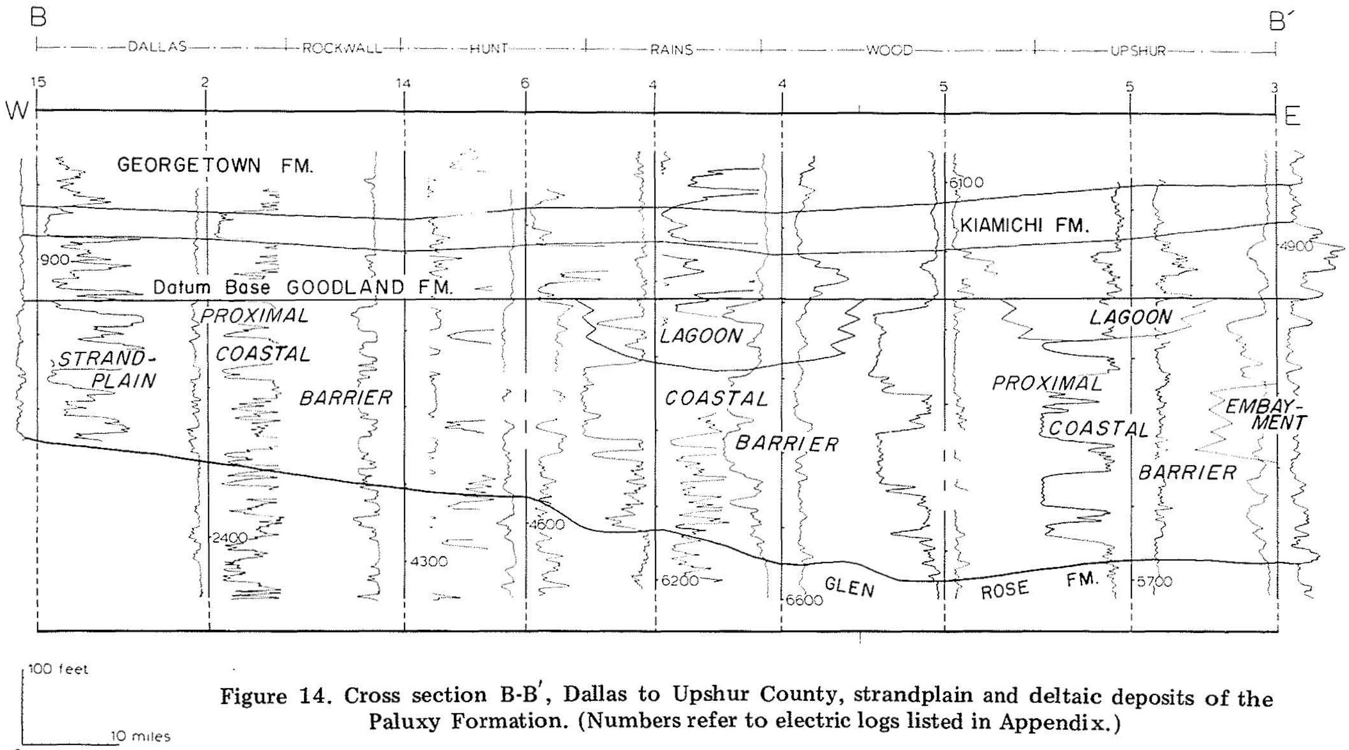

Figure 14. Cross section B-B′, Dallas to Upshur County, strandplain and deltaic deposits of the Paluxy Formation. (Numbers refer to electric logs listed in Appendix.)

Distal Subfacies.—The distal subfacies marks the basinward margin of the Paluxy delta system. This portion of the coastal barrier facies appears in plan view as an east-west-oriented band separating arenaceous deltaic deposits from basinal limestone, marl, and shale of the Walnut Formation (fig. 6). It extends across the southern margins of the study area from the Louisiana border to a western termination against the Paluxy strandplain system. The distal subfacies is a tabular unit of sandstone and shale which grades updip into thicker sandstone accumulations in other deltaic facies, downdip into carbonates, and along strike into predominantly sandstone facies of the strandplain system.

The distal subfacies is recognized in eastern Ellis, northeastern Navarro, southwestern Kaufman, southeastern Dallas, northern Henderson, southern Van Zant, northern Smith, southern Wood and Upshur, all of Gregg, northernmost Panola, all of Harrison, and southern Marion Counties. The southern edge of the facies exhibits several lobate extensions, including two isolated occurrences in far eastern Panola and Shelby Counties. These lobes are considered to be salients from an eastward extension of the facies in northwestern Louisiana.

The distal subfacies varies from a maximum observed thickness of 370 feet (113 m) in Harrison County to a minimum of 180 feet (55 m) in Ellis County. A general east-to-west thinning trend within these limits is modified only by slight thickening adjacent to major depocenters. Along dip, the facies thins slightly basinward, as shown in cross sections C-C′, D-D′, E-E′, and F-F′ (figs. 9-12).

Sandstone isolith trends (fig. 5) show sandstone concentrations to be strike oriented and to decrease uniformly basinward. Sandstone percentages vary in an almost identical manner; sandstone content remains constant along strike but diminishes sharply downdip from values in excess of 50 percent near other deltaic facies to less than 10 percent along the basinward margin of the coastal barrier facies. Sandstone beds pinch out downdip into shale, which then grade into marl and limestone facies of the Walnut Formation.

Distal coastal barrier sandstones are very fine grained and range in thickness from less than 1 to 60 feet (30 cm to 18 m). They are interstratified with shale and mudstone. The sandstones are generally silty, friable to moderately indurated with calcite cement, and have moderate to high porosity. Textural maturity ranges from immature to mature. Polished and frosted grains occur in texturally mature sandstones. Glauconite, pyrite, and traces of limonite are minor constituents of the sandstones. Bedding varies from disturbed wavy laminations to unlaminated, bioturbated units. Preserved biota include shell and plant fragments. Finely divided carbonaceous material is present in the sandstones and adjacent shale units, with rare occurrences of small lignite clasts. Interbedded with the sandstones are black, finely laminated shales and gray, massive mudstones. Plant fragments, some replaced by pyrite, occur in shale partings and in the mudstones. Small, distinct burrows, filled with sand or mud, are present in the shale units. Mudstones are mottled and contain few distinguishable structures.

Electric log patterns for the distal subfacies reflect the interbedding of shale and porous sandstone units. Compared to patterns for the proximal subfacies, shale partings in distal facies are better developed at the expense of sandstone. With thicker shale breaks and less abundant sandstone, deltaic progradational sequences are partially obscured in the random intercalation of sandstone and shale lentils. Individual sandstones are not laterally extensive, and they are difficult to trace even with closely spaced well control in oil and gas producing areas. As sandstone beds thin and disappear downdip, the expanded shale section is augmented with limestone stringers. The southern boundary for the coastal barrier facies is placed at the transition from sandstone and shale deposits to sections consisting of shale and limestone facies.

The distal subfacies includes sediments deposited in an area transitional between nearshore-paralic and open-shelf environments. As a physiographic entity, the Paluxy shelf consisted of a broad, stable area of relatively uniform subsidence located downdip from more mobile deltaic depocenters. Terrigenous sedimentation was concentrated on the inner margin of the shelf and was largely directed by development of the deltaic facies to the north. Marl and limestone accumulated farther seaward on the shelf, culminating in a carbonate bank along the Angelina-Cauldwell flexure (Nichols, 1964, p. 17).

LAGOON FACIES

The lagoon facies occupies a discontinuous band between fluvial deposits updip to the north and coastal barrier deposits basinward to the south (fig. 6). The facies is best developed along the eastern half of the delta system, where it dominates the Paluxy section in an irregular belt ranging from 5 to 20 miles (8 to 32 km) wide, stretching east-west across the southeastern corner of Franklin, most of Camp, parts of northern Upshur, southern Morris, the northern half of Marion, and the southern half of Cass Counties. It is also the principal facies in small regions located in northern Hunt County and northwestern Rains, southwestern Hopkins, and northwestern Wood Counties.

Sandstone isolith values for the lagoon facies are lower than adjacent deposits. Instead of showing a consistent pattern for the facies, net sandstone contour lines are strongly influenced by trends in adjoining fluvial and coastal barrier facies.

The lagoon facies consists of laminated to massive mudstones and shales interbedded with very fine-grained sands and sandstones. Lithic boundaries are sharp, with rock units arranged randomly in vertical sequence. Electric logs for the facies are characterized by sharp offsets in the spontaneous potential curve reflecting the series of abrupt lithic changes, as illustrated by the Tidewater No. 1 Roberts well in eastern Camp County (fig. 15).

Sandstone content in the lagoon facies varies from 17 to 51 percent, depending on proximity to sandstone accumulations in adjacent coastal barrier deposits. The sandstone is a calcitic and gypsiferous quartzarenite that is gray to white or locally red, yellow, or green. It is porous to very porous and friable with textures ranging from immature to supermature. Carbonized plant debris occurs as particles from tiny flecks to fragments over 3 mm in diameter. Pyrite and limonite occur locally as cement or in petrified plant remains. Burrows and closely spaced, parallel laminae are the only structures recognizable in the sandstones, which are mottled. Glauconite pellets occur locally in large burrow fillings.

Interbedded mudstones and shales are gray to black and abound with plant fragments and pyrite. Small amounts of thin-bedded lignite are present. Shales are finely laminated and mudstones are structureless; burrows are locally abundant in each. Calcite and gypsum occur as cementing agents, and gypsum is also present in scarce, euhedral crystals.

Geographic distribution and facies associations of these deposits are typical for lagoonal or coastal lake sediments. Sandstones of the coastal barrier facies received the brunt of marine wave energy, allowing muds to accumulate in quieter waters impounded inland. Precipitation of gypsum may have been associated with saline groundwater or with reducing conditions accompanying the decay of plant detritus. The lithofacies map (fig. 6) shows that the major lagoonal development is in embayments flanking principal delta lobes.

Two occurrences of lagoonal deposits may be distinguished within this framework. The first is illustrated in cross sections D-D′ and F-F′ (figs. 10 and 12) and consists of deposits formed in local depressions updip from thick, coastal barrier accumulations. The landward margin of these lagoonal deposits may border alluvial coastal plain (fluvial meanderbelt and channel-fill and flood-basin) or beach (coastal barrier) sediments. Proximity to active coastal processes made the lagoons vulnerable to incursions of windblown sand and washover fans. Deposits consist of interbedded lagoonal mudstone and barrier-derived sandstone, representing transitional environments which shifted in response to the changing coastline. This type of lagoonal deposit is associated with the updip border of the delta system away from principal depocenters, and it includes all of the lagoon facies west of Morris County.

The second type of lagoonal deposit is an extension of the first beyond the easternmost limit of proximal coastal barrier facies. Here the belt of lagoon facies expands to maximum width and spreads across portions of Morris, Cass, and Marion Counties. Cross section C-C′ (fig. 9) shows that these lagoonal deposits grade directly downdip into distal coastal barrier deposits; well-developed coastal barriers are located stratigraphically above or below and do not constitute a persistent seaward restriction. The area is interpreted as a marginal embayment developed on the delta flank as the result of sediment dispersal patterns and prevailing shoreline configuration. Sediment sources included deltaic distributary outlets to the west and possibly to the east (in Louisiana) and direct fluvial input from the north. The absence of extensive wave winnowing may be due in part to the structural framework of the far eastern portion of the East Texas embayment (fig. 2). The Cass County syncline forms a structural depression coincident with the marginal embayment deposits, intersecting the regional depositional strike at a high angle.

An areally extensive and vertically persistent lagoonal facies was not developed behind the Paluxy system of coastal barriers. Instead, lagoon facies comprise: (1) local accumulations behind barrier bars and flanking principal depocenters, including alternating lagoonal mudstones and well-

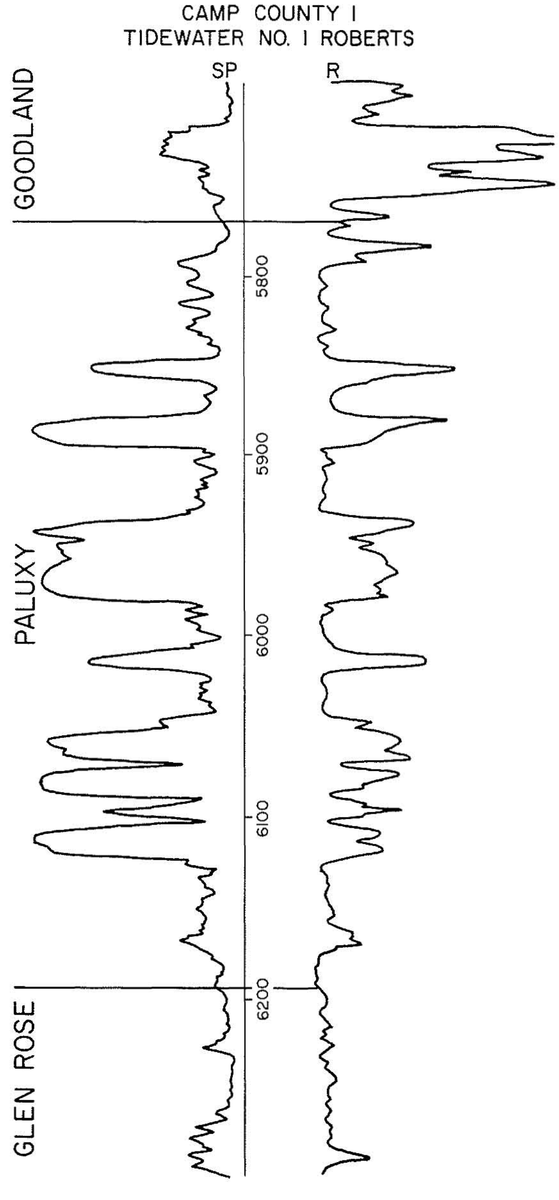

Figure 15. Representative electric log pattern, lagoon-embayment facies, Paluxy delta system.

sorted barrier sandstones in ratios ranging up to 50 percent sandstone, and (2) a marginal embayment subfacies located on the eastern flank of the delta system, consisting predominantly of mudstone.

DELTA MODEL

Classification.—Deltaic facies in the Paluxy Formation were deposited within wave-dominated, high-destructive delta systems. Deposits of the Paluxy delta system accumulated predominantly under the influence of waves and associated littoral currents. Sediments were introduced into the depositional basin through dip-oriented, meandering distributaries and reworked along strike. The strike orientation of the deltaic coastal barrier and lagoon facies indicates the final dominance of marine over fluvial processes.

Characteristics of the Paluxy delta system compare favorably with those listed by Fisher (1969) for salient features of high-destructive delta systems shown in table 1. The Paluxy deviates from the pattern noted for other Holocene and pre-Holocene high-destructive systems in one major respect: recognition of an independent strandplain system flanking the delta. Flanking strandplains have previously been included as facies of high-destructive deltas, but the Paluxy strandplain is extensive enough to merit separate treatment. The presence of a separate strandplain system in the Paluxy results from the geomorphology of the depositional basin, its structural framework, and the resulting sediment dispersal patterns.

Holocene Analog.—The Rhone delta extends across 65 kilometers (40 miles) of the French Mediterranean coast, projecting two cuspate lobes into the northern Golfe du Lion. The eastern delta lobe is prograding seaward at annual rates of up to 30 meters (98 feet; Oomkens, 1970, p. 200), while the western lobe is now largely abandoned and slowly receding (Kruit, 1955, p. 382).

Major features of the Holocene Rhone delta are illustrated in figure 16. The Paluxy delta system resembles the Rhone complex in gross composition, facies distribution, net sand (sandstone) pattern, and overall shape. These similarities and abundant information available on the Rhone make it a suitable Holocene analog for sedimentary processes active in deposition of the Paluxy delta system.

Net sand (sandstone) patterns for the Rhone and Paluxy delta systems are characterized by a primary, strike-oriented trend, which is centered on the coastal barrier facies. The geometry of both delta systems is cuspate, as a result of marine redistribution of sediments debouched at distributary outlets. Advancement of the Rhone in direct response to fluviatile supply is now in progress only at the mouth of the principal distributary, the Grand Rhone, while advancement by beach accretion occurs at several locations (Kruit, 1955, p. 381-383). Fluctuating sediment supply in an area of constant marine reworking results in erratic progradation, with phases of deltaic advancement alternating with marine destruction and transgression.

The sporadic nature of the development of various regions of the Rhone delta, as documented by Russell (1942), Kruit (1955), and Oomkens (1970), owes largely to shifting of distributary channels. Major distributaries meander across the delta plain and are subject to gradual loss or sudden abandonment through avulsion and crevassing.

Delta plain sedimentation as a downdip extension of meanderbelt facies indicates that the Paluxy distributaries also shifted across the subaerial delta. The extensive development of channel sands flanked by minor accumulations of overbank mud is comparable to the Rhone delta plain, where low-lying natural levees along the network of active and abandoned channels fence off the intervening floodbasins into clay-lined coastal lakes. Minor amounts of carbonaceous matter are preserved as lignite in the Paluxy and peat in the Rhone delta plain sediments.

Coastal basins along the seaward margin of the Rhone delta are highly saline in summer and are used for industrial salt production (Kruit, 1955, p. 370-372, 386-387). The corresponding Paluxy lagoon facies does not contain bedded evaporites, but the occurrence of gypsum may indicate hypersaline conditions. Features common to both lagoonal deposits of the Rhone and those recognized in the Paluxy include an abundance of clay and silt, local peat horizons (lignite in the Paluxy), mottling from roots and burrows, the ubiquitous occurrence of plant detritus, and intertonguing with adjacent coastal barrier sands (Oomkens, 1967, p. 268-271).

Table 1. Comparison of sedimentological characteristics for high-destructive delta systems and the Paluxy delta system of northeast Texas

SALIENT FEATURES OF HIGH-DESTRUCTIVE DELTA SYSTEMS (from Fisher, 1969, p. 260) Holocene examples: Rhone, Apalachicola, Tabasco coast, Surinam coast, Po.	FEATURES OF THE PALUXY DELTA SYSTEM Wave-dominated, high-destructive delta system. Lower Cretaceous of northeast Texas.
SOURCE AREA local, basin margin; on order of 200 miles; fluvial system and facies relatively uniformly developed along edge of depositional basin; streams heading delta system meandering and braiding.	SOURCE AREA local, basin margin approx. 150 miles to N. and NE.; reworked Cretaceous and older sediments of N. Tex., Okla., Ark., and NW. La.; fluvial system consists of channels draining into two principal meanderbelt systems feeding the major delta lobes.
SEDIMENT INPUT moderate volume and sporadic rate of input; constructional and destructional phases interrelated and not vertically distinct; slight to moderate coastal progradation.	SEDIMENT INPUT moderate; varied geographically, resulting in limited lateral extent and thickness of individual units; construction-destruction phases indistinguishable, except in delta plain facies with local occurrences of marine reworked channel sands; coastal progradation moderate.
CONSTRUCTIONAL FACIES local and aerially restricted; in situ carbonaceous deposits not well developed; distributary channels generally of meanderbelt type.	CONSTRUCTIONAL FACIES consist of very local channel-mouth bar facies and poorly developed meanderbelt delta plain facies; lignites rare; plant debris scattered through deltaic deposits but volumetrically insignificant.
DESTRUCTIONAL FACIES extensive, developed contemporaneously with construction; marine transgressions commonly far inland with extensive shallow embayments; commonly associated with nondeltaic (strandplain, coastal barrier) systems; high proportion of marine reworked sediments in delta systems.	DESTRUCTIONAL FACIES extensive and contemporaneous with construction; marine transgressions inland are evidenced by reworked fluvial sands in fluvial meanderbelt facies; shallow embayment deposits occur behind and intercalated with coastal barriers; marine reworked sediment comprises most of the delta system volume.
ASSOCIATED SYSTEMS generally cannot support large-scale laterally associated depositional systems; local barrier bar and strandplain facies included in delta system.	ASSOCIATED SYSTEMS coastal barriers included in delta system; independent strandplain is thin but laterally extensive along strike to west of the delta system and developed as a result of geomorphology of the depositional basin, local wave energy and longshore currents, and local sediment supply from the basin margin.
DELTA FLANK SYSTEMS are poorly developed as independent systems.	DELTA FLANK SYSTEM included in delta system; persistent embayment to east, result of structural configuration of depositional basin.
PRODELTA relatively thin, generally no thicker than other delta facies and commonly indistinguishable from nondeltaic shelf muds.	PRODELTA indistinguishable from thin, bioturbated shelf mud.
SHAPE chevron to cuspate with axes subparallel as well as perpendicular to regional depositional strike; few lobes.	SHAPE cuspate; principal sand axes best developed parallel to strike with secondary component developed perpendicular (dip oriented); two major depocenters make overall geometry bilobate.
SAND/MUD RATIO relatively high; distributaries commonly not well stabilized; muddy aggradational deposits not well developed as part of delta plain facies.	SAND/MUD RATIO high for delta system as a whole; sediments are fine to very fine sand with lesser quantities of silt and clay; lack of distributary stabilization results in meanderbelt configuration of delta plain deposits.
	STRUCTURAL FRAMEWORK partially restricted basin on cratonic margin, undergoing broad basinal subsidence with differential rates of downwarping and positive areas associated with salt structures localizing depocenters.

Discharge of the Rhone varies widely, fluctuating with seasonal melting of alpine snow and with rainfall in the drainage basin. Discharge measurements of Beaucaire, in the apex of the delta, range from a maximum of 13,000 cubic meters per second recorded in 1840 to a minimum of 360 cubic meters per second in 1921 (Kruit, 1955, p. 366). The stage of the river has an important effect on distribution of sedimentary facies, with seasonal variations changing the salinity of depositional environments across the entire delta plain. Additionally, the floodbasins rely on floodstage crevassing and overbanking for sediment supply. Floods occurred annually until dikes were constructed; now the floodbasin supply of sediments is restricted to breaches in the dikes (Kruit, 1955, p. 380). Extreme flooding promotes crevassing and modification of the distributary pattern.

Sporadic rate of sediment input is a characteristic feature of wave-dominated, high-destructive

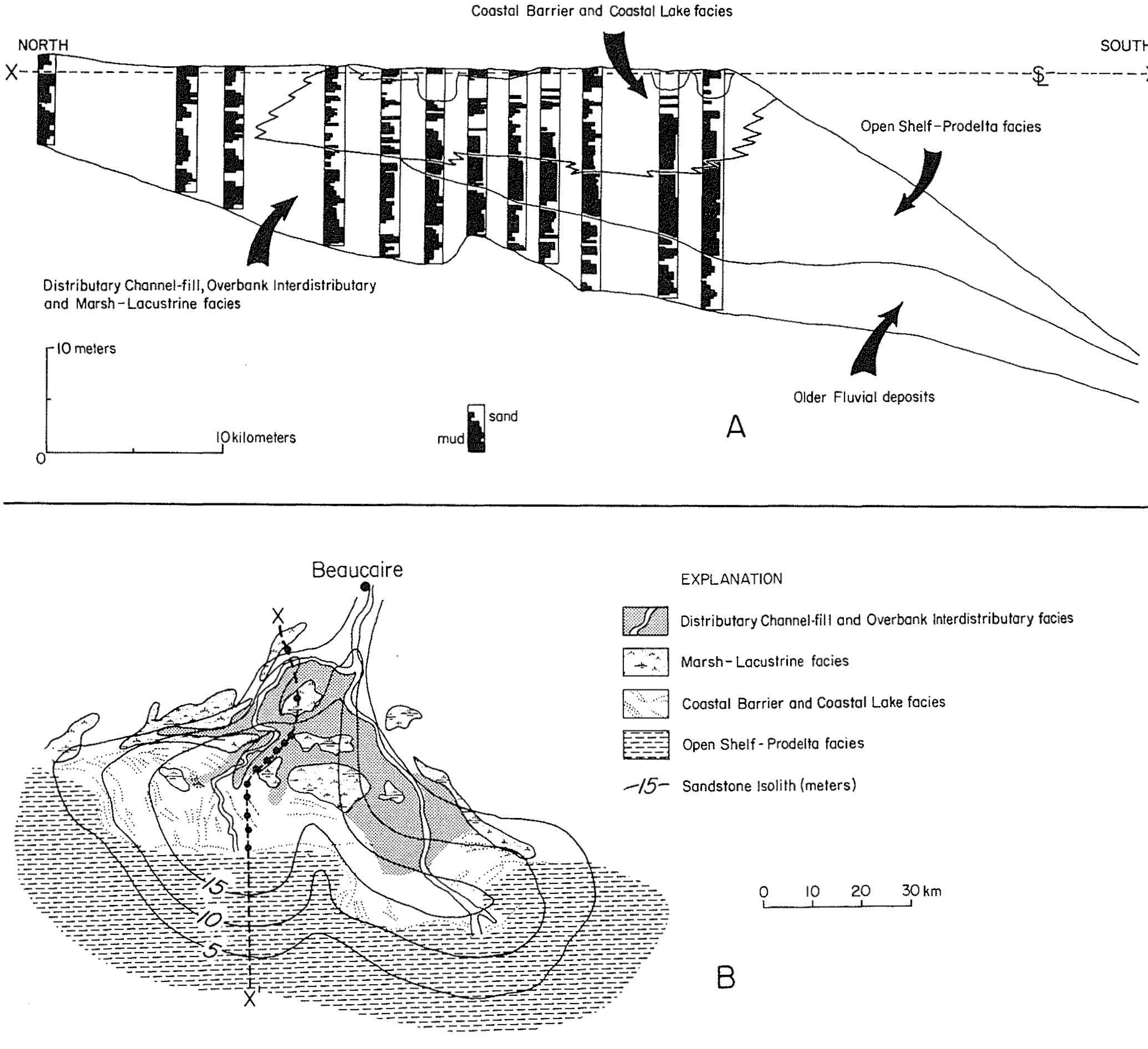

Figure 16. Principal depositional environments of the Holocene Rhone Delta, France. A. North-south cross section showing principal facies. Modified from Oomkens (1967). B. Sand isolith and surface facies distribution map. From Fisher (1969). Adapted from Kruit (1955) and Oomkens (1967).

delta systems (table 1). Variations in discharge have strongly influenced the construction of the Rhone delta and are considered to have been of similar importance in development of analogous Paluxy deposits.

STRANDPLAIN SYSTEM

STRANDPLAIN FACIES

Facies of the Paluxy fluvial and delta systems are flanked to the west by thinner deposits of coalescing sandstone and intercalated mudrock lentils which compose the strandplain system. Individual sandstone units are limited in lateral extent and occur either isolated by shale breaks or merged into widespread, multilateral sandstone sheets. These deposits of sandstone sheets, isolated sandstone lentils, and intervening shale, argillaceous limestone, and mudstone beds are assembled in a sequence extending with uniform thickness across the western third of northeast Texas to the Paluxy outcrop (fig. 6). They grade basinward into thinner accumulations of shelf mudstone and marl deposits, as illustrated by section H-H′ (fig. 17). To the north, strandplain deposits thin slightly and are recognized successively in the Paluxy and subsurface Antlers Formations. The area occupied by the strandplain system includes all or parts of Cooke, Grayson, Wise, Denton, Collin, Parker, Tarrant, Dallas, Brown, Bosque, Comanche, Hamilton, Erath, Hood, Somervell, Hill, and Ellis Counties. In addition, a narrow tongue extends southward from principal exposures to crop out in Mills, Coryell, Lampasas, and Burnet Counties, ending as a feather edge of sandstone in the basal Walnut Formation. The westward extent of the strandplain system is limited by erosional retreat of the outcrop belt and by the pinchout of Glen Rose limestone stringers separating lithically similar Paluxy and underlying Twin Mountains facies.

The strandplain system was recognized in the subsurface north of the Glen Rose pinchout by correlating the interval in the topmost Antlers corresponding to Paluxy deposits to the east and south. This section loses identity toward the Antlers outcrop in Wise and Montague Counties, and no attempt was made to analyze depositional facies in the exposed Antlers Formation.

Distinguishing characteristics of the strandplain system include presence of coalescent sandstone sheets, thin and relatively uniform regional sediment distribution, strike-oriented sandstone isolith pattern, and gradation along strike into fluvial and deltaic facies and downdip into basinal carbonate and shale facies. Components are similar to marine-influenced facies of the delta system, although thinner and more extensive. Significant fluvial constructive facies are lacking.

The sandstone isolith pattern for the strandplain system is dominated by an irregular band of thick sandstone extending westward from the coastal barrier facies of the delta system (fig. 5). This thick sandstone is bounded approximately by the 100-foot (30-m) sandstone isolith; it crops out in Parker County and trends southwesterly from there to the western limit of Paluxy exposures in northwestern Erath County. The band curves around muddy, basinward deposits, reflecting the regional trend of distribution along strike. Boundary irregularities, particularly to the north, indicate the presence of internal complexities and local variations in the overall facies pattern. Thickness of the strandplain system varies up to 237 feet (72 m) adjacent to the coastal barrier facies to the east. Uniform thinning away from this area occurs to the northwest and southwest, with a more gradual decrease along the west-trending net sandstone axis. Cross section G-F′ (fig. 18) illustrates thinning away from coastal barrier facies; cross section B-B′ (fig. 14) shows the slight thinning westward along the thick sandstone trend. Section A-C (fig. 8) shows that thickness is uniform across the northern part of the strandplain and into the channel-fill and floodbasin facies of the fluvial system.

Strandplain sequences consist of intercalated sandstone and shale beds in observed ratios from 12 to 79 percent sandstone. Lowest sandstone percentages occur in two areas: along the gradational contact with shelf carbonates and mudstone to the south and adjacent to fluvial floodbasin deposits in the northeastern part of the system. The central part of the strandplain is consistently sandier, with sections through the elongate sandstone isolith maximum yielding sandstone values greater than 50 percent and intervening areas ranging from 37 to 50 percent.

Individual sandstone units are thickest (up to 90 feet, or 27 m) adjacent to deposits of the coastal barrier facies. Sandstone units farther west reach a maximum thickness of 50 feet (15 m) or less. Like the laterally contiguous barriers, these sandstone deposits are strike oriented and locally display progradational spontaneous potential profiles, although more random patterns characterize the system as a whole. The sandstone units thin progressively downdip into interbedded shale and thin sandstone beds. Ultimately, strandplain deposits grade into carbonate and shale facies of the Walnut Formation. The sandstone units retain their character updip, within a thinning sequence that grades into fluvial deposits in the northeastern corner of the strandplain. No extensive lagoonal deposits are recognized, although thin lenses of lagoonal mudstones occur throughout the system.

Strandplain sandstone deposits are porous and fine to very fine grained, grading southward into very fine-grained sandstone and siltstone. The sandstones are composed almost entirely of quartz, with traces of pyrite and iron oxides throughout

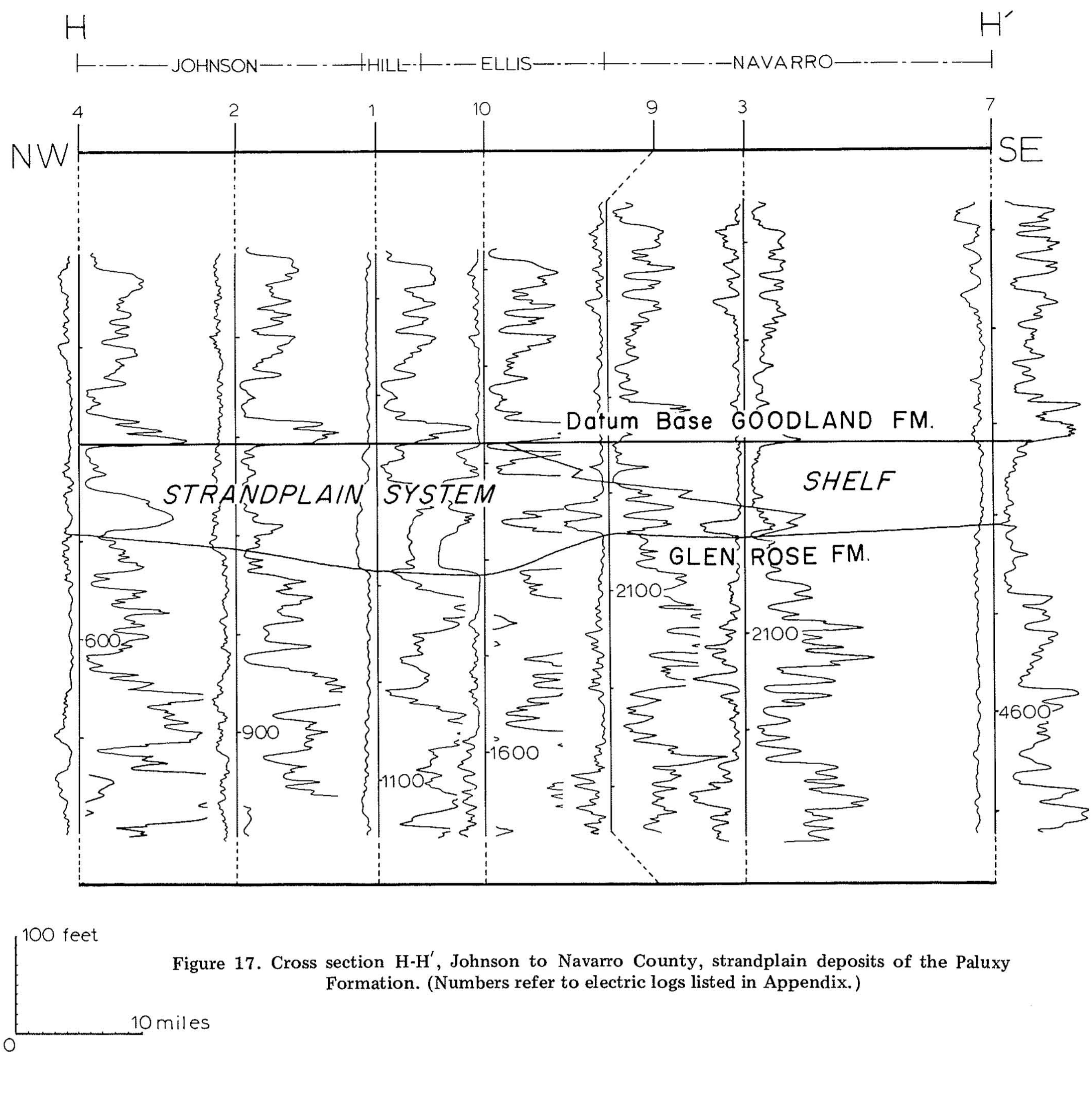

Figure 17. Cross section H-H′, Johnson to Navarro County, strandplain deposits of the Paluxy Formation. (Numbers refer to electric logs listed in Appendix.)

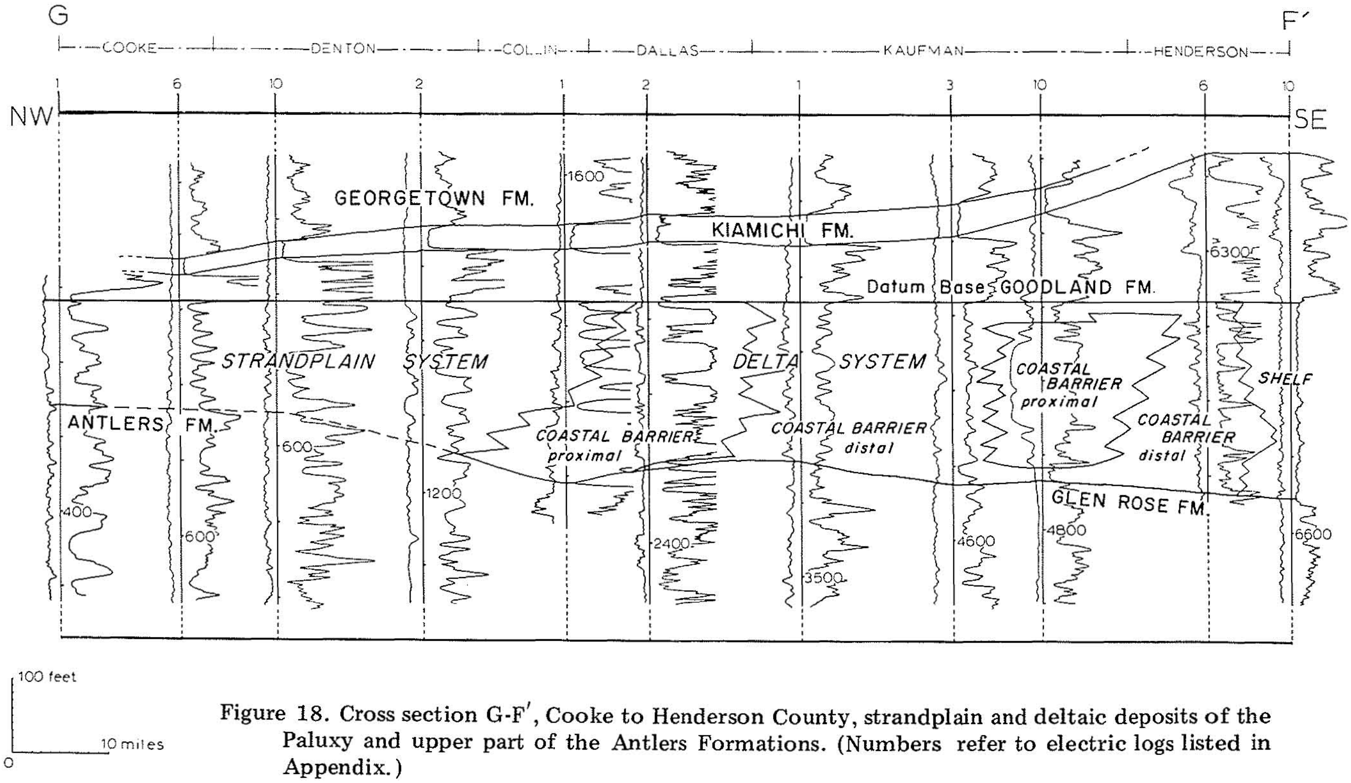

Figure 18. Cross section G-F′, Cooke to Henderson County, strandplain and deltaic deposits of the Paluxy and upper part of the Antlers Formations. (Numbers refer to electric logs listed in Appendix.)

and local occurrences of glauconite. Colors typically range from dull yellow to glistening white, although shades of red, green, and brown also occur. The sandstone units weather to black or red on the outcrop. Grain shapes vary from subangular to rounded, with both extremes observed in single outcrops. Surface textures are dull, polished, or frosted. Sandstones are friable or are slightly indurated with sparry calcite cement; occurrences of well-indurated calcitic sandstone are scarce. Limonite concretions are locally abundant. Submature to mature textures characterize most sandstone samples, although gradation into adjacent mudrocks produces immature textures.

Massive sandstone units are highly porous and rarely fossiliferous. Thinner sandstone beds are sparsely fossiliferous, with silicified wood, carbonized plant fragments, and traces of lignite most abundant. Pelecypod casts and shell fragments are widely distributed. Boone (1966, p. 33) reported dinosaur tracks in northwestern Bosque County, and Atlee (1962, p. 17) found ostracods, vertebrate teeth and bones, and gar scales in Mills County.

Horizontal lamination and low-angle cross-bedding (fig. 19) are the dominant sedimentary structures in the sandstone strata. Cross-cutting relationships of gently dipping wedge sets are observable in good exposures. Scattered occurrences of more steeply inclined, massive sandstone beds (fig. 20) interrupt the continuity of sub-horizontal stratification. Festoon and tabular cross-beds occur locally in sequences dominated by horizontal, gently dipping, or moderately dipping beds. Detectable stratification ranges in thickness from about 2 mm to 1 m. Thicker units appear homogeneous, but burrowing (fig. 21) and minute cross-laminations (fig. 22) are discernible where accentuated by cementation and iron staining.

Intercalated fine-grained deposits range from laminated shales to massive mudstones. No pure clay horizons were noted in outcrop or borehole samples; all contain silt and most have at least traces of sand. Colors of the mudrocks are black to gray or red gray and locally variegated. The mudrocks are sparsely fossiliferous, with pelecypod casts and shell fragments occurring locally and plant detritus scattered along bedding planes. Mudstones appear churned, although individual burrows are rare. Shale and mudstone units are uncemented to calcitic, grading locally into thin, argillaceous limestone beds.

Paluxy mudrocks occur in close association with sandstone units. Churned mudstones with pelecypod fragments form the basal, fine-grained portion of coarsening-upward shoreface sequences. Well-sorted beach sandstone facies are adjacent to lentils of black, carbonaceous shale and red-black, barren mudstone which are interpreted to be coastal lake and swale deposits.

Extensive regressive sheets of coalescent beach sands, interstratified with marine and coastal lake muds, are typical deposits of modern strandplains. Sediment is introduced through weak distributaries and transported by longshore drift, reworked by waves, and stored in shoreface and beach deposits. Beach accretion maintains a broadly cuspate coastline, with minor salients flanking distributary outlets. Distributary abandonment is highlighted by a readjustment of the strandline as the old outlet is planed off by wave action and deposition is focused at the new distributary mouth. The resulting geomorphic and stratigraphic features are illustrated by strandplains active along the Mexican coast of Tabasco (Psuty, 1965, 1967) and Nayarit (Curray and Moore, 1964; Curray and others, 1969) and the Guiana-Surinam coast of South America (Brouwer, 1953; Vann, 1959).

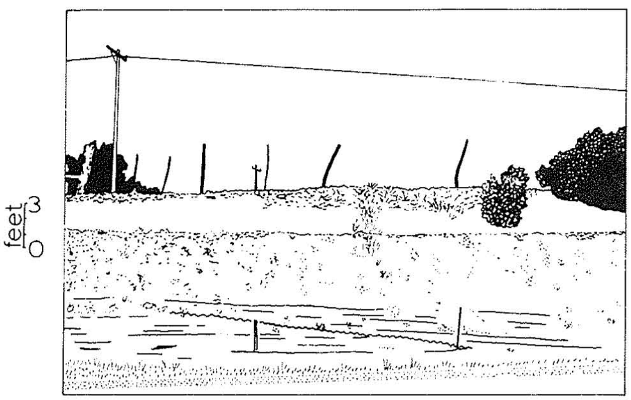

Figure 19. Somerville County locality 1, low-angle cross-bedding sets in strandplain deposits of the Paluxy Formation.

Figure 20. Bosque County locality 4, Paluxy strandplain deposits of massive sandstone beds dipping approximately 20° S 60° E, truncated and overlain by horizontal oyster biomicrite beds of the Walnut Formation.

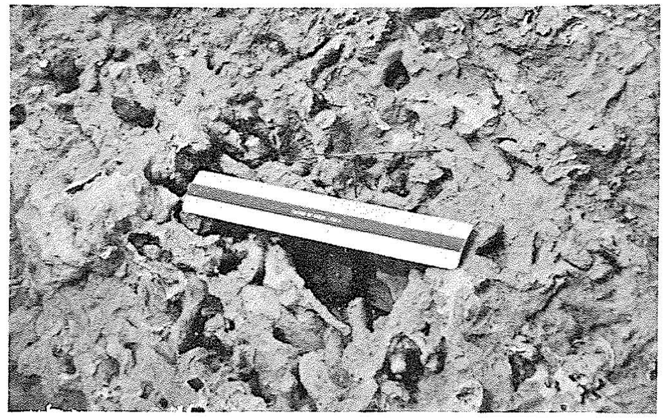

Figure 21. Coryell County locality 1, sandstone with small, anastomosing burrows, in strandplain deposits of the Paluxy Formation.

Sedimentary features observed at the outcrop in the Paluxy Formation are similar to those reported from Holocene strandplains. Well-sorted sandstone with horizontal and low-angle stratification is the dominant sediment type. Silty shoreface sandstones, sparsely fossiliferous but mottled and burrowed, grade upward into the mature beach deposits of leached and massive to finely laminated sandstone.

Moderately dipping sand beds characterize a variety of modern paralic depositional environments. Small units of local extent may represent berm, washover, or swale-fill deposits. More extensive units in the Paluxy (fig. 20) resemble lateral accretion deposits of migrating tidal inlets, such as described by Hoyt and others (1964, p. 175) from barrier islands along the Georgia coast. The maximum relief observed on moderately dipping beds in the Paluxy is 20 feet (6 m), although measurement was limited by poor exposures. Units are composed of calcitic, submature to mature, very fine-grained sandstone. Both dull and frosted grains are present. The sandstone is arranged in parallel units 1 to 2 feet thick (0.3 to 0.6 m), dipping from 7 to approximately 20 degrees. The moderately dipping beds are truncated at the top and are overlain by horizontal sandstone or fossiliferous limestone. The lower portion of the dipping

Figure 22. Erath County locality 1, limonitic sandstone with small-scale, trough cross-stratification, in strandplain deposits of the Paluxy Formation.

beds contains burrows and, at Bosque County locality 4, abundant carbonized plant fragments.

Lagoonal deposits are represented by rare lenses of sandy mudrocks in the clean beach sandstone complexes, indicating deposition in coastal lakes and swales rather than an extensive lagoon system. These deposits include laminated shale with carbonized plant detritus, traces of lignite, and burrows, as well as barren and massive mudstone.

Small cut-and-fill channel deposits occur throughout the Paluxy outcrop. Major alluvial deposits, however, are recognized only adjacent to fluvial facies in the northeast corner of the strandplain. In this area, channel-fill sandstones are up to 60 feet (18 m) in thickness, and they have an erosional base followed by an irregular fining-upward sequence. As illustrated in section A-C (fig. 8), these strandplain deposits are laterally associated with the channel-fill and floodbasin facies of the fluvial system to the east. Strandplain channel-fill sandstone deposits can be differentiated from adjacent fluvial system deposits because they are thinner, associated with strandplain-beach deposits, and lack distinct channel and interchannel areas. Major channel-fill deposits are confined to the thin, northeastern margin of the strandplain, coincident with a sandstone isolith depression. Irregular sandstone isolith contours in this area indicate confluence of dip-oriented channel and strike-oriented strandplain trends.

Channel-fill deposits are the coarsest of the strandplain system. A channel deposit cropping out in east-central Parker County (locality 1) consists of medium- to fine-grained sandstone in trough and tabular crossbedded sets scoured into gray silty shale. Laterally associated shoreface deposits are no coarser than fine-grained sandstone. In Grayson County (locality 5), the Humble Oil and Refining Company No. 1 Fallon well penetrates a 30-foot (9 m) channel-fill sequence from 1,290 to 1,320 feet. Granule conglomerate and coarse to medium sandstone overlie more typical strandplain deposits of very fine sandstone and mudstone. The channel-fill sandstone and conglomerate is submature, with grains subangular to rounded, and it is overlain by red and black shale. Conglomerate, along with variegated shale and traces of lignite, are characteristic of fluvial channel-fill deposits in the northeastern corner of the strandplain. Sequences containing these channel-fill deposits grade eastward into facies of the fluvial system, which lack significant marine deposits.

STRANDPLAIN MODEL

The strandplain system developed as a shifting complex of nearshore depositional environments on the western flank of deltaic depocenters. Gradation into deltaic facies demonstrates deposition contemporaneous with active deltation, and it indicates that deltaic sediments that were swept alongshore constituted a source for the strandplain deposits. The prevalence of beach and shoreface deposits reflects the relative importance of littoral sedimentation in strandplain accretion.

Alluvial deposits are present in abundance only in the northeast corner of the strandplain system. This concentration of fluvial facies may indicate initial deposition of a small, high-destructive delta lobe, which was abandoned as more favorable sites developed in rapidly subsiding areas to the east. Longshore drift then furnished sufficient detritus from new areas of active deltation to allow coastal accretion of a strandplain. Occurrence of local, fluvial channel-fill deposits in the predominantly marine-influenced strandplain deposits of the Paluxy outcrop indicates that small fluvial systems persisted along the basin margin. This dip feeding of material from older Cretaceous and Paleozoic rocks exposed along the landward side of the developing coastal plain augmented the supply of detritus carried along strike from prograding delta lobes to the east. Uniform accretion of the strandplain was interrupted by sporadic supply from the delta system, interference from local drainages and tidal inlets, and shifting, mud-accreting environments of swales and coastal lakes. The resulting sedimentary mass is a thin, extensive complex of lenticular sandstone deposits, separated by marine and lagoonal mudstone.

SEDIMENT DISPERSAL

SOURCE AREAS

Fluvial channel-fill complexes, marked by sandstone isolith maxima, extend north and northeast from deltaic depocenters to principal source areas in southeastern Oklahoma and western Arkansas. The presence of multiple channel systems indicates that major source areas were distributed along a broad sector of the basin margin, as shown diagrammatically in figure 23. Available source materials include subjacent rocks exposed in the Ouachita foldbelt of Oklahoma and Arkansas. Atlee (1962, p. 18) postulated Upper Jurassic sediments "which probably occurred to the northeast in Arkansas" as the source for Paluxy deposits in northeast Texas. Upper Jurassic rocks may have contributed sediments directly to the Paluxy as Atlee suggested, or these sediments may have been recycled through intervening basal Cretaceous (Antlers) deposits.

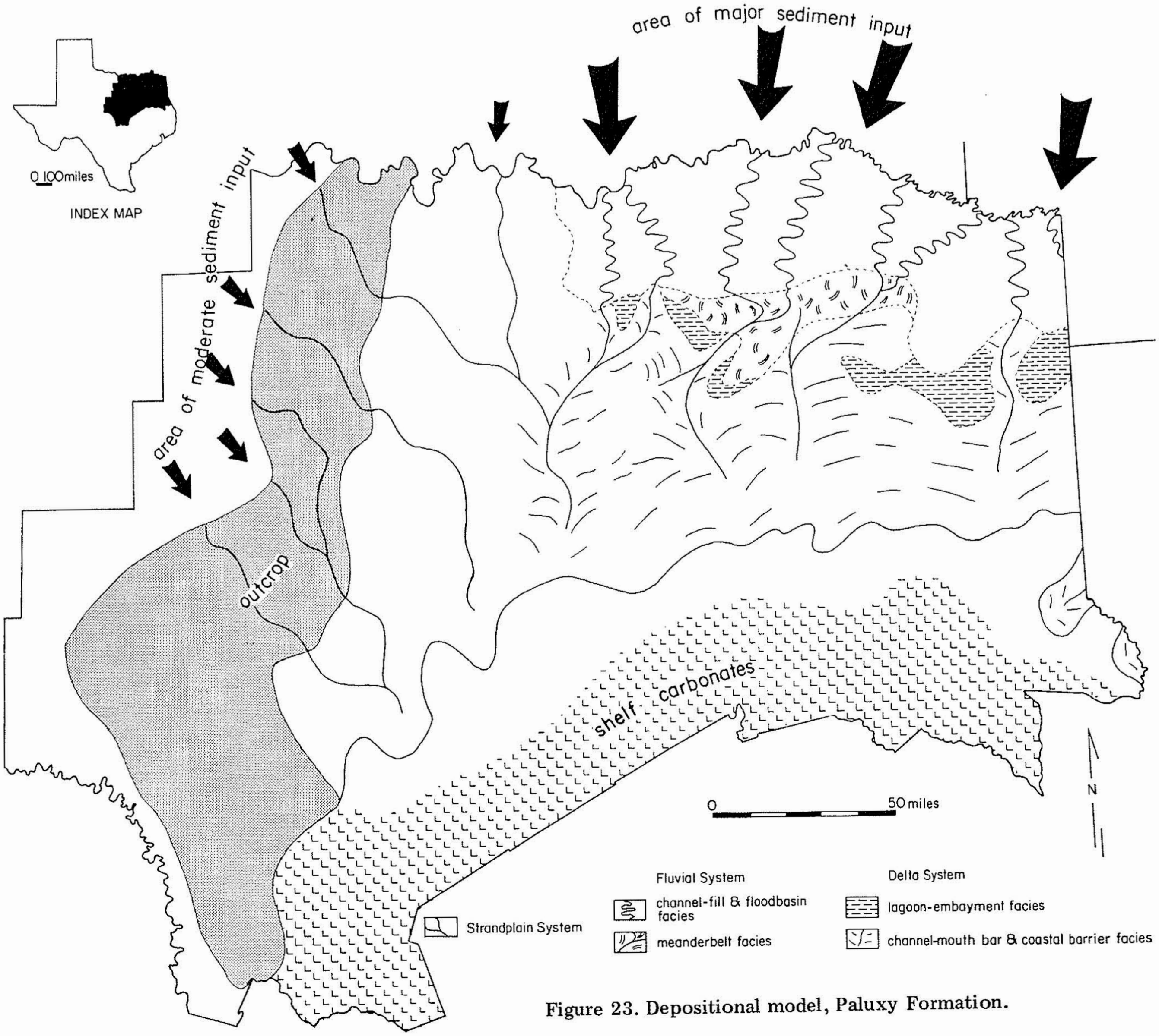

Figure 23. Depositional model, Paluxy Formation.

Alluvial deposits in the strandplain system are poorly developed, are limited in lateral extent, and lack vertical persistence. Sediment supplied to the strandplain from the western basin margin was probably augmented with detritus funneled through the fluvial system into deltaic deposits to the east. Source rocks supplying sediment to the strandplain included Pennsylvanian and basal Cretaceous rocks cropping out to the northwest and west.

Rocks formed from intrabasinal components comprise a very small part of the Paluxy. Thin, silty, and sandy limestone beds are present in deposits of the strandplain and delta systems. Lignite beds are rare but widely dispersed through the Paluxy deposits.

DISPERSAL PATTERNS

Sandstone elements of the fluvial system are oriented along dip, reflecting sediment transport down paleoslope from sources to the north into centrally located deltaic depocenters. Sandstone accumulations in the channel-fill and floodbasin facies represent conduits for sediment transport, with intervening areas serving to collect muddy, overbank deposits. The channel complexes merge downdip into broad, sandy meanderbelt facies. Channels shifted laterally across the meanderbelt area, supplying sediment to areas of active deltation. These channel systems became subject to abandonment and marine reworking as distributary patterns changed.

Dip-oriented facies components terminate downdip against coastal barrier deposits of the delta system. Sand discharged at distributary outlets was reworked into the strike-oriented coastal barrier deposits. Mud settled in lower energy environments, in coastal lakes and offshore areas fringing shelf carbonates. Variations in wind, wave, and current energy and the changing deltaic environments caused intercalation of mudstone and sandstone deposits in marginal areas. Shifting distributaries, successive progradation and abandonment of delta lobes, and differential subsidence combined to selectively preserve some deposits, while others were thoroughly reworked.

Deposits of the strandplain system accreted to the west of deltaic depocenters, as sediments which were swept alongshore were incorporated into the advancing coastal plain. Sandstone units are aligned along strike in beach and shoreface deposits, coalescing laterally into extensive sand sheets. Mud collected in lower energy lagoonal and lower shoreface environments, which graded basinward into shelf marl and limestone facies. Alluvial channels crossing the strandplain supplied additional sediments from the basin margin and added a minor dip component to strandplain sandstone trends.

STRUCTURAL INFLUENCE

Sediment dispersal patterns in the Paluxy Formation are closely related to the tectonic framework of the East Texas embayment. The two principal depocenters, including thickest sediment accumulations and the maximum development of stacked coastal barrier and distributary channel-fill deposits, occur in the north and northwestern parts of the Tyler basin. Sedimentation in this unstable area was localized by structural embayments separated by a ridge of salt uplifts. The northeastern extension of the Tyler basin, the Cass County syncline, is oriented obliquely to paleoslope and marks a persistent marginal embayment on the eastern flank of the delta system.

The Paluxy Formation is thinner in more stable, outlying areas. Fluvial deposits thin updip as they extend northward from the delta system to the northern embayment margin, with a major change in facies composition (meanderbelt to channel-floodbasin) across the Mexia-Talco fault system. To the southeast, the Sabine uplift area contains stable platform deposits of the lagoon and distal coastal barrier facies. The western margin of the embayment includes deposits of the strandplain system, developed over stable elements of the buried Ouachita system.

RESOURCES

Natural resources associated with the Paluxy in northeast Texas consist predominantly of oil and gas accumulations and groundwater. The importance of the Paluxy Formation as an oil reservoir was established with the discovery of the giant Talco field (Franklin and Titus Counties) in 1936. Paluxy production had been established in 73 fields by 1974, for a cumulative total of more than 429 million barrels of oil and approximately 50 million MCF (thousand cubic feet) of natural gas (tabulated from International Oil Scouts Association, 1975). Aquifers in the Paluxy and Antlers Formations furnish water for domestic, farm, public supply, and industrial uses in areas along and adjacent to the outcrop belt.

Additional resources are confined to the Paluxy outcrop. Industrial sand is mined near Glen Rose, Somervell County, for uses as "molding sand, pottery sand, and pulverized sand and silica flour" (Girard, 1970, p. 21). According to Fisher and Rodda (1967, p. 22), sand deposits of sufficient quality for industrial use are present in the Paluxy outcrop north of the Brazos River. Fine grain size and induration restrict mining of the Paluxy as construction sand, although some use is indicated by borrow pits along highways through the outcrop area. Quaternary alluvium deposits incorporating directly recycled Paluxy sand are exploited locally.

Soils developed on the outcrop Paluxy are fine-grained, sandy loams well suited for cotton, peanuts, sorghums, and fruits (Atlee, 1962, p. 21). Brown (1963, p. 21) described soils in the vicinity of the triple junction of Somervell, Erath, and Bosque Counties, noting that the Paluxy soils produce less forage grass than soils derived from the overlying Walnut Formation. Proctor (1969, p. 15) stated that Paluxy soils are subject to lowered productivity induced by exhaustive production and erosion.

GROUNDWATER

Paluxy sandstone facies are charged with fresh to slightly saline water (less than 3,000 milligrams dissolved solids per liter) along a broad band extending eastward from the outcrop belt (fig. 24). Paluxy aquifers in this area are a major source of groundwater, which is exploited principally for domestic and stock use near the outcrop and for municipal and industrial supply in deeper wells downdip to the east.

The downdip limit of reservoir sandstones restricts Paluxy aquifers to the southeast in Coryell, McLennan, Bosque, Hill, and Navarro Counties. Thin sandstone beds near this limit furnish water for domestic use and are supplemented with other sources to supply small municipalities. Porous and permeable sandstones are present to the east and northeast where development of water resources is limited by increasing depth to the Paluxy and by progressively higher salinities. Highly mineralized water occurs downdip to the south and east. The approximate extent of fresh to slightly saline water is indicated on figure 24.

OUTCROP

Groundwater along the Paluxy outcrop is tapped by shallow wells for small local consumers. It is not widely exploited in the southern and central areas where the outcrop is highly dissected (Fiedler, 1934, p. 10; Atlee, 1962, p. 21). To the north, the Paluxy crops out over large areas of Parker and southern Wise Counties and constitutes a major source of water.

Limestone units of the Glen Rose Formation pinch out in central Wise County, and northward the Paluxy and underlying Twin Mountains Formations merge into an undifferentiated sandy sequence constituting the Antlers Formation. The Antlers or "Trinity Sand" is exposed over a wide belt which extends northward through Montague and western Cooke Counties and curves slightly eastward to enter Oklahoma. Alternative water sources in the underlying Paleozoic strata are discontinuous in this area (Peckham and others, 1963, p. 68; Bayha, 1967, p. 11), and Antlers groundwater is an important resource.

SUBSURFACE

East of the outcrop, the Paluxy and Antlers aquifers furnish large quantities of water for both public supply and industrial uses. Occurrence of artesian, fresh to slightly saline water is restricted by the Paluxy-Antlers outcrop to the west and north, by the presence of saline water to the southeast, and by a lack of reservoir sandstones to the south.

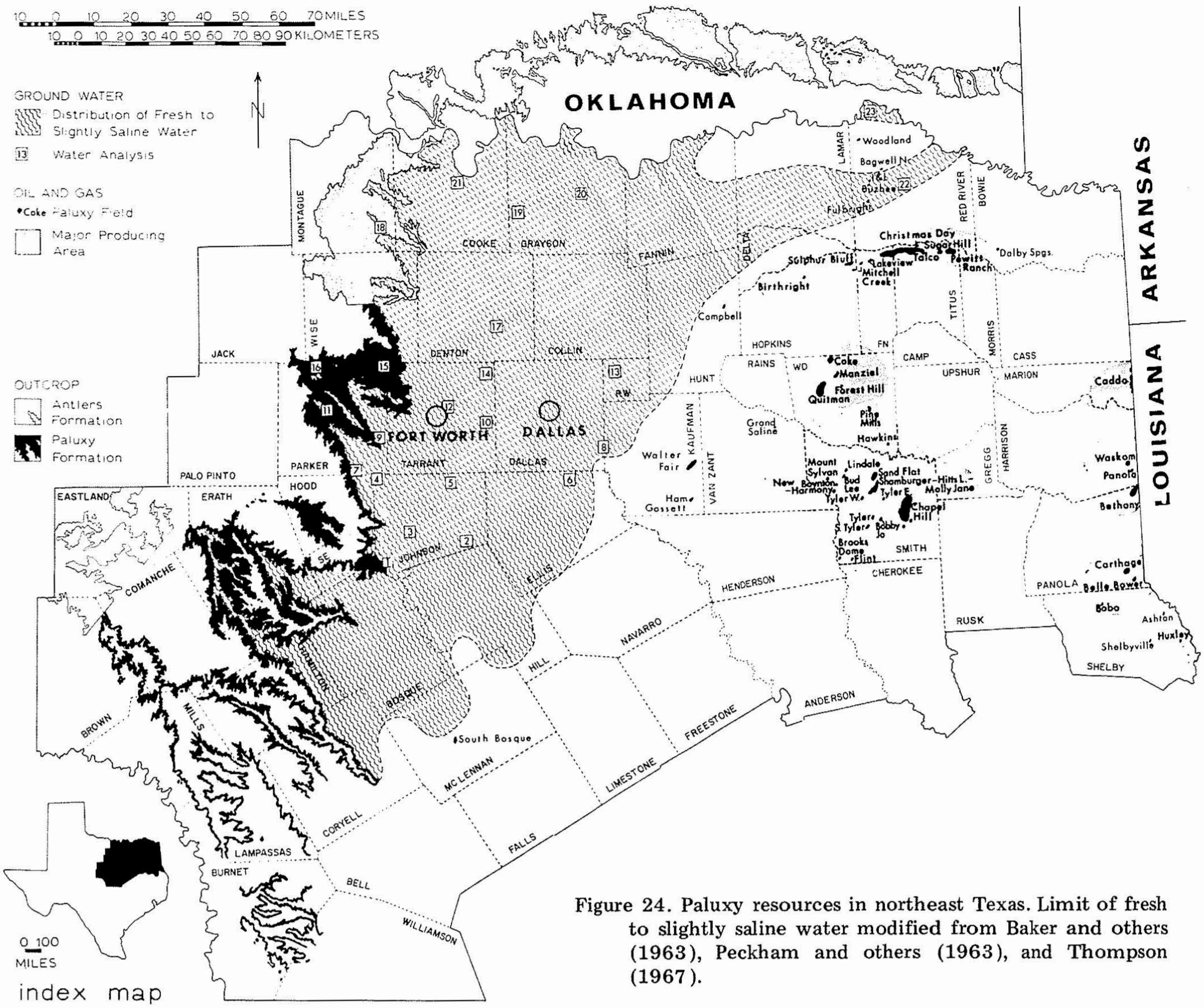

Figure 24. Paluxy resources in northeast Texas. Limit of fresh to slightly saline water modified from Baker and others (1963), Peckham and others (1963), and Thompson (1967).

South Area.—The depositional limit of aquifer sandstone development is broadly coincident with the southern limit of the strandplain system, extending irregularly northeastward across McLennan, Hill, and Navarro Counties. Thin sandstone beds occur farther south within the Walnut shale and marl sequence, but these deposits contain more highly mineralized water (Holloway, 1961, p. 12; Atlee, 1962, p. 21).

From Navarro County northeastward, aquifer development is more continuous, and salinity becomes the limiting factor. The southern segment of the saline water boundary was mapped by Thompson (1967); fresh to slightly saline water occurs west of a line from northern Navarro County across eastern Ellis County. Thompson (1967, p. 55-56) estimated that an additional 1,000 acre-feet per year (1.2 million cubic meters per year) is available from the Paluxy, with expected well yields as high as 200 gallons per minute (760 liters per minute). Paluxy water tested in Ellis County is soft but high in total dissolved solids. The water is not suitable for sustained irrigation due to high residual sodium carbonate values and sodium adsorption ratios (Thompson, 1967, p. 48-49, 112).

As mapped by Peckham and others (1963, plate 5), the subsurface depth to the Paluxy increases uniformly from the outcrop belt to the downdip limit of fresh to slightly saline water. The Paluxy becomes shallower westward from almost 2,500 feet (762 m) at the saline water boundary in eastern Ellis County to 830 feet (253 m) near the Johnson-Ellis County line, and to Paluxy outcrops along the Brazos River in westernmost Johnson County. The shallower depth in Johnson County is an advantage for small water consumers and results in increased exploitation. Paluxy water is also used there for public supply and industry. Extensive production has resulted in declining water levels, and the potential for increased withdrawals is largely dependent upon amount of increased development in the recharge area to the west and population centers to the north (Thompson, 1969, p. 30-31, 39-40).

Water analyses in table 2 show that the total dissolved solid content decreases westward across Johnson County from 1,060 milligrams per liter at Grandview in the southeastern corner of the county to 351 milligrams per liter near the western outcrop. The fluoride content at Grandview, 7.2 milligrams per liter, was highest among the 14 percent of the Paluxy analyses reported by Thompson (1969, p. 36) that exceed the 1.6 milligrams per liter U. S. Public Health Service limit for the area. Water from shallow wells in the western part of the county is hard (more than 60 milligrams calcium carbonate per liter) but chemically suitable for irrigation, whereas deeper supplies to the east are soft but unfit for sustained irrigation because of high sodium adsorption ratios (Thompson, 1969, p. 36, 79-84).

Thickness of saturated sandstone varies from less than 40 to more than 100 feet (12 to 30 m) across the southern part of the fresh to slightly saline water area (Thompson, 1967, p. 50-55, fig. 13; Thompson, 1969, p. 39, fig. 14). Greatest thicknesses of saturated sandstone occur in western Ellis and eastern Johnson Counties and are reflected by the sandstone isolith pattern (fig. 5).

Central Area.—From eastern Ellis County, the saline water boundary extends northeastward across Kaufman County where it intersects and follows the curving Mexia-Talco fault zone across Hunt County (Baker and others, 1963, p. 43; Peckham and others, 1963, p. 51, pl. 5). The southeastern corner of Dallas County also is included in the area of greater than 3,000 milligrams per liter total dissolved solids (saline water), because Thompson (1967, p. 51, fig. 13) indicates that no fresh water occurs in the Guiberson and Lucy No. 1 Moyer well (Dallas County locality 21). The Seagoville analysis (table 2, analysis no. 8) from two miles (3 km) north of the area is also nearly saline. Total solids content decreases uniformly westward from the saline water boundary to the outcrop.

Paluxy water in Dallas, Tarrant, Denton, Collin, and Rockwall Counties is soft and "of good quality over large areas" (Peckham and others, 1963, p. 55). Analyses generally fall within public health standards except near the saline water boundary, where samples exceed recommended limits for dissolved solids, fluoride, and sulphate content. Morgan (1965, p. 204) stated that in Dallas County "the waters of the Paluxy are much better, chemically speaking, than those of the Trinity [Twin Mountains] in most respects," but he made no mention of water quality trends within the Paluxy.

In Denton County, an early report by Winton and Hawley (1926, p. 44) said that the Paluxy water "is of poorer quality than that of the Trinity [Twin Mountains]." Leggat's (1957, p. 81, 175-180) report on Tarrant County is more comprehensive:

> The water from the Paluxy sand generally is suitable for domestic, public stock, and some industrial supplies. On the whole it is superior to the waters from the underlying Travis Peak Formation [Twin Mountains] and Glen Rose limestone, being softer and considerably less mineralized.

Water analyses from the central area indicate the Paluxy water chemistry limits its use for irrigation. In northeastern Tarrant County, attempts started in 1954 to produce water from the Paluxy, Glen Rose, and Twin Mountains ("Travis Peak") aquifers but were halted in 1955 "pending determination of the chemical quality of the water" (Leggat, 1957, p. 78).

Thickness and net sandstone content of the Paluxy Formation increase northeastward to Rockwall and central Collin Counties. Local irregularities within this regional trend affect water-producing characteristics of the Paluxy; in Tarrant County, Leggat (1957, p. 72) attributed variations in specific capacities (rates of yield per unit drawdown) of Paluxy wells "primarily to changes in lithology and secondarily to variations in well construction." In Dallas County, Foster

Table 2. Selected analyses of groundwater from the Paluxy and Antlers Formations in northeast Texas

[1]Number	1	2	3	4	5	6	7	8	9	10	11
[2]Reference	2	2	2	2	2	1	5	3	5	4	5
Prod. Interval or Well Depth	300	802-846	393-442	330	714-734	1425	50	2860	212	1074	148
Collection	7/66	8/66	8/66	2/43	7/66	4/65	3/50	4/54	3/50	2/54	11/49
[3]Aquifer	p	p	p	p	p	p	p	p	p	p	p
[4]SiO_2	11	11		18	11		18	43	19	14	20
[4]Fe				.20		.17		.2		.16	
[4]Mn											
[4]Ca	3.7	3.0		68	.8		171	10	72	1.7	58
[4]Mg	2.6	1.6		19	.4		11	5	14	.7	21
[4]Na	171	408		34a	222		63a	857	13a	278	32a
[4]K	1.4	2.3			.9					.9	
[4]HCO_3	414	684	502	314	474	628	365	561	282	488	309
[4]SO_4	68	251	27	42	56		42	1201	23	158	209
[4]Cl	14	39	5.8	14	12	56	147	142	7.8	23	10
[4]F	0.7	7.2		.4	1.2			3.6	.2	1.4	1.8
[4]NO_3	1.0	0		.5	0		74	0		2.8	
[4]PO_4											
[4]B		1.9								.51	
[4]Total Solids	477	1060	530	351	548		777	2525	298	721	324
[4]Hardness—$CaCO_3$	20	14	4	248	4	24	472	46	237	7	231
%Na	95	98			99		23		11	99	23
Sodium Adsorption Ratio	17	47			48						
[5]Residual Sodium Carbonate	6.40	11.1	8.15		8.10	12.6					
[6]Spec Conduct	803	1700	862		908	2260	1230		495	1160	542
pH	7.9	8.3	8.6	7.4	8.4	9.1	8.0		7.9	8.3	7.7
[4]CO_3	0	4	22	0	12	83					

[1]Number refers to location on figure 23.

[2]References:
1. Thompson (1967, p. 112)
2. Thompson (1969, 79-84)
3. Peckham and others (1963, p. 39)
4. Leggat (1957, p. 177-178)
5. Stramel (1951, p. 53-55)
6. Baker (1960, p. 149)
7. Baker and others (1963, p. 44)
8. Bayha (1967, p. 73)

Table 2. (Continued)

12	13	14	15	16	17	18	19	20	21	22	23
3	3	4	4	5	3	8	6	7	7	7	7
590	3342	700	26	60	870	200	1522	1518	943	2058	406
6/61	11/55	9/49	11/50	11/49	5/60	4/64	8/58	N.D.[7]	N.D.	N.D.	N.D.
p	p	p	p	p	p	a	a	a	a	a	a
12	23	14	22	24	14	22	15	13	12	17	11
	.5	0			.01		.02	.08	0	.06	7.8
		1.6									
1.0	5	.9	68	86	1.0	105	1.0		1.2	4.0	48
.3	1		5.6	67	0	18	.4	1.0	.2	1.6	7.8
250a	355	231	25a	49a	240	16	208	232	218	508a	26
		7.6			.07		.5	1.3	.9		3.2
500	561	478	119	384	504	357	443	426	459	778	188
102	215	101	19	74	83	66	40	46	43	140	17
19	53	14	88	145	15	9	32	82	34	230	30
1.0	1.8	0.6			.6	.2	.3	.3	.2	5.2	.2
0	0	2.0	7.2	2.0	.8	0	1.0	1.8	1.2	0	0
		.27					.24	.3	1.2	1.7	
631	956	611	294	657	605	412	516	588	540	1290	242
4	17	8	192	490	2	336	4	8	4	16	152
99		97	22	18	99		99	98	99	99	27
54					74		45	35	47	55	.9
1010		1000	547	1140	984	683	837	994	885	2110	420
8.5	8.6	8.8	7.4	7.5	8.5	7.5	8.7	8.3	8.5	8.0	7.0

[3]Aquifer: p: Paluxy Fm
a: Antlers Fm

[4]Values in mg/l; "a" values = Na+K

[5]Values in milli-equivalents

[6]Values in micro-ohms at 25°C

[7]No data available

(1965, p. 146-148) mapped the distribution of Paluxy sequences consisting of 75 feet (23 m) or more of sand in individual units over 25 feet (7.6 m) thick. These "good thick net porous sands" occur in discontinuous bands oriented northeast-southwest and parallel to sandstone isolith trends in the area (fig. 5).

The most extensive exploitation of the Paluxy aquifer is centered around the Fort Worth-Dallas metropolitan area of Tarrant and western Dallas Counties. Development began early in this region, and Hill reported in 1901 (p. 565) that the Paluxy "is the reservoir which is most used by the people, there being some 250 wells from this source alone in Fort Worth." From 1890 to 1961, increasing withdrawals caused a net decline of 300 feet (91 m) in Fort Worth area water levels, and partial dewatering of the Paluxy extended westward to the outcrop (Peckham and others, 1963, p. 56).

The limitations of the Paluxy aquifer in the central area led to reliance on other water sources for large supplies, and Peckham and others (1963, p. 56) reported a decline in total annual municipal and industrial pumpage from the Paluxy beginning in about 1955. Plummeting water levels and partial dewatering of the aquifer largely resulted from concentrated pumpage in a small area. Although individual Paluxy wells produce as much as 400 gallons per minute (1,500 liters per minute), accompanying drawdowns are severe.

North Area.—Beyond the northern limit of Glen Rose Limestone beds, the Paluxy merges into the upper part of the Antlers or undifferentiated "Trinity sands" aquifer. The Antlers aquifer extends northward across Grayson and eastern Cooke Counties and eastward into Fannin County. Limestone beds at the base of the Paluxy are recognizable in borehole cuttings and on electric logs from areas in Fannin, Lamar, and Red River Counties. Baker and others (1963, p. 41) recognized the Paluxy as distinct from the Antlers "south and east of a northeast trending line representing the updip limit of the Glen Rose Limestone through central Fannin County," although water production from this area is slight and information is scanty. The Antlers crops out to the west in Cooke, Montague, and Wise Counties and to the north in northernmost Grayson County and southern Oklahoma (fig. 24).

Highly mineralized water underlies the fresh to slightly saline water in the Antlers aquifer from central Cooke County eastward (Baker and others, 1963, p. 43). The basal zone of saline water incorporates progressively more of the aquifer with depth, occupying all of it south of the saline water boundary in Delta, Lamar, and Red River Counties. Slightly saline water occurs between the saline wedge and overlying fresh water.

The salinity gradient increases irregularly with depth, due to the influence of major structural features and regional variations in permeability on the extent of the highly mineralized water zone. Saline water occupies most of the Antlers along the crest of the Preston anticline in northern Grayson County (fig. 2) and may be responsible for chloride contamination of wells in the heavily pumped area around the city of Sherman (Baker and others, 1963, p. 43, 51). The presence of saline water north of Sherman is attributed by Baker (1963, p. 29) to movement of groundwater toward outlets in exposures along the crest of the Preston anticline, in northernmost Grayson County, where outcrops are at lower elevations than recharge areas to the north and west. Flushing of connate water toward northern Grayson County ceased with development of large wells to the south, which reversed the groundwater gradient.

A lobate mass of saline water extends westward from McCurtain County, Oklahoma, across Red River, Lamar, and Fannin Counties, Texas (fig. 24). The presence of fresh water to the north and slightly saline water south of this mineralized wedge is indicated by water analyses (table 2). Baker and others (1963, p. 42) interpreted this configuration to be a result of permeability differences:

> The movement of groundwater presumably is impeded to a large degree by low permeabilities of the Paluxy Sand in the wedge of highly mineralized water.

The saline water mass occupies the updip portion of the Paluxy channel-fill and floodbasin facies, which consists of thin channel-fill sandstones and fine-grained interchannel deposits. These muddy, alluvial deposits may restrict groundwater flow, but there is no obvious conduit in the upper Antlers and Paluxy allowing dilution of connate water south of the saline concentration. Possibilities for bypassing the low-permeability strata include selective flow through the more permeable channel deposits and transmission in lower Antlers sands with potentially higher hydraulic conductivities.

Exploitation of Antlers and Paluxy water in the northern area is primarily for public supply and industry (Baker and others, 1963, p. 45; Peckham and others, 1963, p. 41). Utilization for domestic and stock purposes is limited to small amounts extracted in areas near the outcrop. The water chemistry is generally within the limits set by the U. S. Public Health Service for public supply; analyses exceeding these standards in dissolved solids and fluoride content listed in table 2 are from slightly saline water south of the highly mineralized wedge in Red River County.

Water salinity is also significant in northern Grayson County, where dissolved solids in the lower part of the aquifer contaminate deeper wells serving the city of Sherman. The water chemistry is generally not favorable for irrigation, although a few irrigation wells have been drilled near the outcrop in northern Grayson and Red River Counties. The water near the outcrop is hard but in deeper wells it is soft, with a higher overall dissolved solid content. For agricultural uses, the "sodium and salinity hazards are medium to very high" in water produced from depths below 500 to 600 feet (150-180 m; Baker, 1963, p. 45).

Wells in the Antlers aquifer produce about 200 gallons per minute (760 liters per minute) on the average, with pumping rates ranging up to 700 gallons per minute (2,650 liters per minute; Baker and others, 1963, p. 49; Peckham and others, 1963, p. 41). Specific capacities range from less than 1 to 14 gallons per minute per foot (1.2 to 16 liters per minute per m). Proper well spacing is, therefore, an important consideration in development of areas requiring heavy pumpage.

Studies by Peckham and others (1963, p. 55-59) and Baker and others 1963, p. 47-52) indicate that groundwater resources of this northern area make it the most favorable region for increased exploitation of the Paluxy and Antlers aquifers.

CONCLUSIONS

Water in the Paluxy and Antlers aquifers ranges from hard, fresh water near the outcrop to soft water with a dissolved solids content increasing with depth. Saline water occurs east of a line that extends from the southern limit of reservoir sandstone, in Navarro County, north-northeastward across eastern Ellis, the southeastern corner of Dallas, and central Kaufman and Hunt Counties (fig. 24). The saline water boundary curves northeastward along a segment of the Mexia-Talco fault zone in eastern Hunt County, and it extends across Delta and Red River Counties to the Oklahoma border.

Two major saline water masses exist within the fresh to slightly saline water area: one along the apex of the Sherman anticline in northern Grayson County (fig. 3) and another to the east in northern Lamar, Red River, and Fannin Counties. The eastern occurrence occupies muddy deposits of the Paluxy channel-fill and floodbasin facies, and it probably results from obstruction of groundwater flow by the low hydraulic conductivity of these deposits.

Depositional features also affect the hydrological character of the Paluxy strandplain system, which is the largest source of groundwater. Porous sandstone occurs in thin, widespread sheets. Specific capacities are inconsistent but low, reflecting the fine to very fine grain size and the complex microfacies of the strandplain system.

Paluxy groundwater is used extensively for domestic and municipal supply purposes, and in some areas it is exploited for industrial uses. Water chemistry restricts irrigation to a few areas near the outcrop.

Exploitation of groundwater resources has been concentrated in the centrally located Fort Worth-Dallas area, resulting in partial dewatering of the Paluxy aquifer. Prudent well spacing will improve production in this region. The most favorable area for additional development is the north; smaller additional resources are located south of the Fort Worth-Dallas area.

OIL AND GAS

The influence of sedimentary facies on hydrocarbon accumulations is evident in the regional distribution of Paluxy oil and gas fields (table 3). Producing trends occur within recognized deposi-

Table 3. Production data for Paluxy oil and gas fields in northeast Texas (arranged by depositional facies)[1]

Field	Producing Wells Jan. 1, 1974	API Grav.	Production Dates	Total Oil Jan. 1, 1974 (barrels) [2]	Total Gas Jan. 1, 1974 (MCF) [4]
STRANDPLAIN SYSTEM					
South Bosque	23	42	1901-	229,351	361
FLUVIAL CHANNEL-FILL					
Bagwell North	0	28	1958-1959	140	N.D.[3]
Buxbee	1	32	1950,1957-	18,171	N.D.
I and L	12	33	1955-	428,884	N.D.
Woodland	0	14	1956	473	N.D.
FLUVIAL INTERCHANNEL					
Dalby Springs	0	18	1952-1957	38,878	N.D.
Fulbright Paluxy	0	gas	1956-1957	0	N.D.
FLUVIAL MEANDERBELT					
Bagwell South	2	29	1969-	157,992	57,160
Birthright	0	53	1954-1958	59,790	N.D.
Christmas Day	1	33	1956-	99,927	N.D.
Lakeview	0	23	1949-1952	62,266	N.D.
Mitchell Creek	2	18	1948-	1,083,964	N.D.
Mitchell Creek North	0	18	1970-	1,224	6
Pewitt Ranch	104	19	1949-	18,126,161	N.D.
Sugar Hill	0	18	1952-1968	170,708	N.D.
Sugar Hill Lower	1	19	1969-	24,783	50
Sulphur Bluff	52	23	1936-	29,434,209	N.D.
Talco	628	24	1936-	233,109,950	N.D.
DELTAIC COASTAL BARRIER: PROXIMAL					
Campbell	0	32	1943-1952	374,690	N.D.
Coke	27	28	1942-	15,377,477	N.D.
Forest Hill	0	32	1970-	5,303	N.D.
Grand Saline	1	14	1963-	62,834	N.D.
Manziel	44	32	1943-	16,036,500	N.D.
Manziel SE Paluxy	0	36	1971	705	N.D.
Quitman	82	41	1942-	50,985,923	N.D.
Quitman Paluxy South	0	18	1959	5,440	N.D.
Quitman Northwest Pa	14	40	1959-	2,492,494	N.D.
DELTAIC COASTAL BARRIER: DISTAL					
Ashton	0	39	1928-1931	N.D.	N.D.
Belle Bower	9	gas	1968-	N.D.	5,121,553
Bethany	16	gas	1918-	N.D.	15,077,779
Bethany SE Paluxy	1	gas	1973	N.D.	24,795
Bobby Jo	0	66	1950-1952	30,674	N.D.
Bobo Paluxy 3485	0	58	1965	10	24,708
Boynton	0	33	1946-1960	299,368	N.D.

[1] Source: International Oil Scouts Association (1975, part II).

[2] Figures do not include condensate. Cumulative condensate production for all Paluxy fields in northeast Texas was 246,546 barrels January 1, 1974

Table 3. (Continued)

Field	Producing Wells Jan. 1, 1974	API Grav.	Production Dates	Total Oil Jan. 1, 1974 (barrels) [2]	Total Gas Jan. 1, 1974 (MCF) [4]
DELTAIC COASTAL BARRIER: DISTAL (Continued)					
Brooks Dome	0	26	1960-1963	1,199	N.D.
Bud Lee	3	32	1949-	596,799	N.D.
Caddo	N.D.	44	1916-	N.D.	N.D.
Carthage Paluxy	14	gas	1953-	N.D.	14,409,262
Chapel Hill	12	42	1940-	6,207,504	N.D.
Chapel Hill East Oil	0	16	1959	2,972	N.D.
Chapel Hill East Gas	0	gas	1959	N.D.	409,958
Chapel Hill E 5600	2	20	1967	27,049	74
Chapel Hill South	0	gas	1960	N.D.	147,295
Chapel Hill S Pa S	2	gas	1958	N.D.	6,140,456
Chapel Hill West Pa	0	69	1960-	N.D.	2,182,192
Chapel Hill 5700	0	20	1959	13,015	N.D.
Chapel Hill Paluxy	5	gas	1938-	N.D.	N.D.
Girlie Cauldwell W Pa	1	42	1973-	5,772	8
Ham Gossett Paluxy L.	0	39	1954-1960	24,106	N.D.
Ham Gossett SE Paluxy	6	39	1962-	792,495	77,949
Hawkins Paluxy Lower	0	42	1963-1968	28,935	146,136
Hitts Lake	26	27	1953-	7,675,401	N.D.
Huxley	1	69	1964-	N.D.	3,593,383
Lindale	0	38	1962	11,682	N.D.
Molly Jane	8	32	1962-	2,009,475	399,381
Mount Sylvan	4	35	1946-	1,232,377	N.D.
New Harmony	0	34	1964-1966	129,842	N.D.
Panola Paluxy	0	57	1958-1964	N.D.	N.D.
Pine Mills Paluxy	5	31	1952-	1,428,435	N.D.
Sand Flat	41	28	1944-	18,145,713	N.D.
Shamburger Lake	32	33	1957-	16,394,451	N.D.
Shamburger Lake S.	1	27	1968-	102,915	18,412
Shelbyville	0	gas	1941	not produced	
Tyler	6	45	1948-	1,383,690	N.D.
Tyler Paluxy Lower	0	20	1963	17,220	112,604
Tyler S2	4	34	1965-	371,683	401,821
Tyler South Pa	3	30	1959-	529,297	N.D.
Tyler South Pa "B"	0	38	1960	7,391	N.D.
Tyler South S2	0	25	1960	13,483	N.D.
Tyler South Pa West	0	40	1965	302	N.D.
Tyler South 7695	1	32	1966-	32,458	N.D.
Tyler West Bankhead	2	36	1963-	533,817	N.D.
Tyler West Paluxy	0	28	1961	6,898	N.D.
Tyler West 7850	0	23	1965	18,601	N.D.
Tyler West Paluxy B	1	34	1973	15,501	N.D.
Tyler West 7850 N.	0	23	1969-	20,989	N.D.
Tyler East Paluxy B	0	36	1963-	41,159	4,922
Tyler East 7100	1	30	1959-	82,546	N.D.
Walter Fair	9	30	1949-	2,605,668	N.D.
Waskom Paluxy	2	gas	1963-	N.D.	N.D.

[3] N.D.: no data available.

[4] MCF: thousand cubic feet.

tional facies, and configuration and distribution of reservoirs are determined by facies characteristics. Depositional limits of sandstone elements are important in restricting the migration of hydrocarbons and in determining the amount of structural modification, if any, most favorable for retention of oil and gas (table 4). Facies control of organic detritus may also be important. Barrow (1953, p. 176-181) suggested that absence of sufficient organic source material may explain the presence of apparently favorable but unproductive structures.

Production from the strandplain system is restricted to the small South Bosque field, where oil accumulation occurs in a thin sandstone basinward from principal strandplain system deposits. The channel-fill and floodbasin facies contain a minor updip trend, consisting of six marginal fields. Larger accumulations occur in the thick fluvio-deltaic sandstones of the meanderbelt facies, trapped by early movement along faults of the Mexia-Talco system. Downdip production occurs in two coastal barrier trends, with moderately thick proximal reservoirs in traps associated with major structural features (principally located in the Tyler basin area) and thinner distal facies reservoirs in traps formed by stratigraphic pinchouts in combination with local structures.

The fluvial meanderbelt facies accounts for nearly two-thirds of the cumulative oil production (fig. 25), reflecting the influence of the giant Talco field. Talco productivity peaked in the early 1950s, and numerous discoveries in deposits of the delta system have accounted for a steadily increasing fraction of Paluxy energy resources from this system.

Production data are tabulated from International Oil Scouts Association (1975) except where otherwise noted.

MINOR PRODUCING AREAS

South Bosque Field.—The South Bosque field is located in southern McLennan County (fig. 24), in an area just south of the downdip extremity of Paluxy strandplain deposits. The pay zone is a 0.5- to 3-foot (15-91 cm) thick "lower Walnut sand" (Price, 1951a, p. 26) within the predominantly shale and carbonate sequence. Accumulation is attributed to porosity and permeability pinchouts and a small anticlinal closure (Price, 1951b, p. 355). Adkins' (1923, p. 93-99) structure map of the South Bosque field shows two low relief anticlinal structures with closure largely inferred.

The presence of oil at South Bosque was known as early as 1890, when a few barrels were bailed from a water well (Price, 1951a, p. 24). Significant production was established in 1901 (1902, according to Price) and reached a cumulative total of 229,351 barrels in 1974.

The South Bosque reservoir is typical of the thin, discontinuous sandstone beds interbedded with limestone and shale occurring along the basinward margin of the strandplain system. The general lack of hydrocarbon accumulations discovered in these deposits may be attributed to fresh-water flushing in the shallow subsurface, noted in the South Bosque reservoir by Atlee (1962, p. 22).

Updip Trend.—A minor updip trend occurs in the fluvial channel-fill and floodbasin facies north of the principal deltaic depocenters and major producing areas. Discoveries are limited to six very small fields in Red River and Bowie Counties. Cumulative production for these fields amounted to 486,546 barrels of oil in 1974, with only the I and L field of Red River County still producing significant quantities in 1973.

Updip production was established with the 1950 discovery of Buzbee field in Red River County. Buzbee was extended in 1957, but production declined to 231 barrels in 1973. Discovery of the Dalby Springs Paluxy field in 1952 extended production into Bowie County, although Dalby was abandoned five years later after recovery of only 38,878 barrels of oil. The I and L field, largest of the updip trend, was located in 1955. More recent discoveries have been in Red River County and are marginal at best: the Woodland 1770 Sand, discovered and abandoned in 1956 with a cumulative production of 473 barrels of oil; the Fulbright Paluxy field, discovered in 1956 and abandoned in 1957 (no production listed); and the Bagwell North Paluxy field, discovered in 1958 and abandoned after three months and 140 barrels of oil.

Average gravity of the oil from these fields varies from API 14° to 33°, approximately the same as that from the much larger fault zone

Table 4. Influence of sedimentary facies on petroleum accumulation in the Paluxy Formation, northeast Texas

STRANDPLAIN SYSTEM	Thin (200 ft; 60 m) interval of sand-rich deposits that grade basinward into mudstone and marl of the Walnut Formation. The only hydrocarbon production associated with these deposits (South Bosque Field) is from a thin sandstone lentil isolated within impermeable Walnut mudrocks.
Fairway	The South Bosque Field, in south-central McLennan County, is the only producer.
Size and Depth of Production	One small, very shallow (500 ft; 150 m) field.
Reservoir and Trap	Thin (3 ft; 1 m) sandstone pay trapped by stratigraphic pinchout and possibly by a low-relief anticlinal structure.
Petroleum Type and Origin	42° API gravity oil and small amounts of associated gas. Probably derived by local migration from marine shale and micritic limestone source rocks.
Exploratory Potential	Offsets to subsurface hydrocarbon shows or random drilling may lead to discoveries comparable to South Bosque. Lack of permeable reservoir rocks limits the potential of the mud-rich Walnut facies. Strandplain sandstones updip connect with the outcrop and are saturated with freshwater.
FLUVIAL CHANNEL-FILL AND FLOODBASIN FACIES	Digitate, north-trending sandstone accumulations with muddier intervening deposits. Petroleum production has been limited to four small fields aligned along a single sandstone concentration in western Red River County and one small field in south-western Bowie County.
Fairway	Western Red River County and the Mexia-Talco fault zone east of Titus County.
Size and Depth of Production	Small to very small, shallow (1,600 to 4,400 ft; 490 to 1,300 m) fields.
Reservoir and Trap	Thin (3 to 14 ft; 1 to 4 m) sandstone pays trapped by minor stratigraphic changes and faults. Compactional subsidence around channel-fill sandstones causes subtle structural nosing and may contribute to closure.
Petroleum Type and Origin	14 to 33° API gravity oil and very minor amounts of associated gas. This is nearly identical with fault zone production from the fluvial meanderbelt facies to the south. The distribution of fields in western Red River County indicates that channel-fill sand-stones acted as a migration conduit connecting with petroleum sources in the Mexia-Talco system.
Exploratory Potential	Additional fields of similar size may be found by detailed mapping of channel-fill sandstones and structure. Established production indicates that a migration link with the Mexia-Talco fault zone is required.
FLUVIAL MEANDERBELT FACIES	Thick (140-250 ft; 43-76 m) accumulations of sandstone with lesser amounts of shale. Individual sandstone units are lenticular and vary from 30 to over 100 ft (9 to 30 m) in thickness.
Fairway	Mexia-Talco fault zone in Hopkins, Franklin, and Titus Counties.
Size and Depth of Production	Small to very large fields, including the giant Talco pool, producing from moderately shallow depths (4,300 to 5,000 ft; 1,300 to 1,500 m).
Reservoir and Trap	Thin to thick (4 to 42 ft; 1 to 13 m) sandstone pays in upthrown and downthrown traps along faults of the Mexia-Talco system. Lentils of impermeable sandstone and sandy mudstone impede reservoir drainage.

Table 4. (Continued)

Petroleum Type and Origin	18 to 33° API gravity oil and very minor amounts of associated gas. The lack of organic-rich mudrocks and the presence of dead oil in older, more deeply buried strata indicates the possibility of vertical migration along faults from underlying, breached reservoirs.
Exploratory Potential	Detailed structural mapping utilizing well log and seismic control might lead to additional discoveries within the limits of established production, but little space remains to explore. A facies boundary with shaly floodbasin deposits marks the eastern limit of the trend; the western limit is more ambiguous and may relate to the distribution of petroleum sources. Use of organic geochemistry to identify the origin of fault zone oil accumulations could help evaluate the possibility of a major westward extension of the producing trend.
PROXIMAL COASTAL BARRIER SUBFACIES	Thick (40 to 100 ft; 12 to 30 m) sandstone units separated by thinner lenses of mudstone and shale. Vertical stacking of sandstone beds results in an aggragate sandstone thickness of 100 to 270 ft (30 to 82 m).
Fairway	The northern Tyler Basin in north-central Wood County.
Size and Depth of Production	Very small to large fields producing from moderate depths (4,400 to 6,800 ft; 1,300 to 2,100 m).
Reservoir and Trap	Moderate to thick (10 to 55 ft; 3 to 17 m) pays in clean, porous sandstone trapped by faulted anticlines and fault closures.
Petroleum Type and Origin	14 to 41° API gravity oil probably derived by lateral migration from basinal mudrocks.
Exploratory Potential	Large fields were all discovered in the 1940s. Exploitation drilling will probably continue to add discoveries to multipay accumulations, but the potential for major new fields hinges on finding large structures yet untested in the Paluxy.
DISTAL COASTAL BARRIER SUBFACIES	Thin (less than 3 ft to about 60 ft; 1 to 20 m), strike-oriented sandstone units interbedded with shale and mudstone, which constitutes 50% or more of the total section. Sandstone units are not laterally extensive, and sharp stratigraphic changes are common.
Fairway	A band about 50 miles wide (80 km) extending east-west from Kaufman and northern Henderson Counties into Louisiana. Production is concentrated in the central Tyler Basin (Smith County) and Sabine uplift areas.
Size and Depth of Production	Very small to large fields producing from shallow to moderate depths (2,300 to 9,600 ft; 700 to 2,900 m).
Reservoir and Trap	Thin to thick (3 to 50 ft; 1 to 15 m) sandstone pays in combination structural/stratigraphic and stratigraphic traps. Reservoir sandstones are fine grained and commonly silty.
Petroleum Type and Origin	Production varies from heavy oil (API gravity 16°) to gas and condensate. This wide range may relate to differences in organic source materials or thermal history; the predominance of stratigraphic trapping indicates local migration from intercalated or laterally associated mudrocks.
Exploratory Potential	New field and new pay discoveries should continue as stratigraphic relationships are defined around favorable structural features.

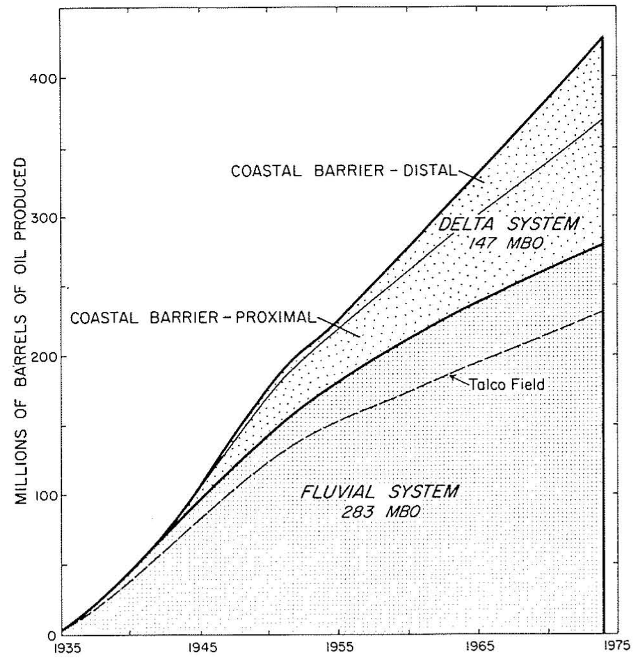

Figure 25. Cumulative oil production from the Paluxy Formation in northeast Texas, 1935 to 1974. Tabulated from International Oil Scouts Association Yearbooks.

fields—excepting Birthright—to the south and west. The updip fields are shallow, with Dalby Springs producing from 4,367 feet (1,331 m) and the remainder from depths less than 2,500 feet (760 m). Pay sections are thin, ranging from 3 feet (1 m) at Fulbright to a maximum of 14 feet (4 m) at the I and L field. Trapping mechanisms include structural and stratigraphic features (Love and others, 1957, p. 1,175; Koonce and Battan, 1959, p. 1,297).

Updip accumulations may derive from petroleum sources in the Mexia-Talco fault zone. Five of the fields occur within or immediately adjacent to an elongate concentration of channel-fill sandstones that extends northward from the fault zone. The sixth, Dalby Springs, is located within the Mexia-Talco system and is fault trapped (Eaton, 1953, p. 1,420).

Potential reservoirs in the updip trend include fluvial channel-fill and other lenticular sandstone bodies emplaced by marine reworking of fluvial deposits. Careful analysis of local depositional patterns, paths for petroleum migration, and structures may lead to more discoveries. The record of established producers indicates that new reserves will be hard won.

MAJOR PRODUCING AREAS

Fault Zone Trend.—Major production of Paluxy oil began in 1936 with the discovery of the giant Talco field, located along the Mexia-Talco fault zone in northwestern Titus and northeastern Franklin Counties. The find at Talco quickly sparked discoveries in adjacent areas to the east and west, and in 1974 cumulative production for the fault zone trend accounted for 66 percent of the total Paluxy oil from northeast Texas. The Talco pool alone produced more than 54 percent of this total.

As detailed by Wendlant and Shelby (1948, p. 432-434), the Talco structure is a faulted anticline which was located by surface mapping, core drilling, and dry wildcats that bottomed in the Woodbine Formation. Deeper discoveries in the East Texas basin led to a successful Paluxy test at Talco in March, 1936. Development of the new field was rapid, and by the close of the year, 177 wells had produced 1,387,000 barrels of oil.

The Talco discovery led to rapid testing of other previously known fault zone structures. A prospect at Sulphur Bluff, Hopkins County, was also confirmed by shallow wildcats which were drilled and abandoned. A Paluxy test was located "shortly after" (Amis, 1951, p. 370) the Talco discovery in March, 1936, and completed in July.

Further delineation of fault zone structures with seismic exploration led to a significant discovery in 1948 at Mitchell Creek, located southeast of Sulphur Bluff in Hopkins County (Smith, 1951a, p. 238). This success contributed to the discovery of the Lakeview field 4 miles (6 km) to the northeast in 1949 (Ratcliff, 1951, p. 185). Seismic work also aided in location of the large Pewitt Ranch field in 1949, extending Titus County production east of the Talco pool (Tefft, 1951, p. 296). Subsurface evidence indicating another trap between the Talco and Pewitt Ranch accumulations then led to discovery of the Sugar Hill field in 1952 (Eaton, 1953, p. 1,423).

Continued exploration along the fault zone brought the 1954 discovery of the small Birthright field in north-central Hopkins County, the westernmost producer in the fault zone trend. Christmas Day field was the next small discovery, located in 1956 in the graben area 2.5 miles (4 km) north of the Talco field (Love and others, 1957, p. 1,174).

Minor discoveries added later were the Sugar Hill Paluxy Lower and Bagwell South Paluxy fields in 1969 and the Mitchell Creek North Paluxy field in 1970. Recent activity in the Birthright area (Oil and Gas Journal, 1974) may extend production farther west.

The fault zone trend consists of 11 fields, aligned along the Mexia-Talco fault zone from central Hopkins to eastern Titus Counties (fig. 24). Average gravity of the oil produced from these fields ranges from API 18° to 33°, with the exception of 53° gravity oil extracted from the maverick Birthright field. Major oil reservoirs occur in thick, meanderbelt channel-fill sequences faulted against impermeable shale. The reservoirs consist of medium- to fine-grained, lenticular sandstone units in producing sequences averaging 42 feet (13 m) thick at Sulphur Bluff and 35 feet (11 m) at Talco. Producing sandstones are partially isolated by local intercalations of muddy or "ashy" sandstone, sandy shale, and redbeds. Regarding interconnection of the individual sandstone units, Wendlandt and Shelby (1948, p. 448) report that at Talco:

> Although most of the sands are intercommunicating, the connection is rather poor between some of them, as indicated by their pressure behavior. In two places in the (Talco) field, isolated sand lenses containing salt water were found above the field water level.

An exception to the lenticularity and interrupted communication is the thin, extensive "Stringer Sand" capping the Paluxy sequence at Talco (Wendlandt and Shelby, 1948, p. 448-449; Shelby, 1951, p. 375). The Stringer sand is fossiliferous and fine grained; it probably represents marine reworking of meanderbelt deposits as a delta lobe foundered.

Production from thick meanderbelt sandstones has been restricted to the narrow segment where early movement along the Mexia-Talco faults formed traps. Accumulations may further be limited by availability of sufficient organic matter for hydrocarbon generation. Residual oil in Glen Rose and Smackover Formations beneath the Paluxy at Talco (Wendlandt and Shelby, 1948, p. 445) indicates that oil might have migrated from deeper reservoirs breached by faulting.

The marginal size of the Birthright field and unsuccessful prospecting of structures in western Hopkins and Delta Counties (Hager and Burnett, 1960, p. 339) dampen chances for a major extension of the trend to the west. Sedimentary facies changes to the east may limit discoveries in this direction to smaller fields characteristic of the channel-fill and floodbasin facies, such as Dalby Springs Paluxy field in Bowie County. Location of additional production within the present limits of the trend will require more detailed resolution of the structural history of the area.

Downdip Production.—Fields south of the fault zone trend, located in areas dominated by coastal barrier and channel-mouth bar facies, accounted for 34 percent of the cumulative Paluxy oil and virtually all of the gas production as of January 1, 1974. This downdip production includes two trends, broadly coincident with the distribution of coastal barrier subfacies and differentiated by geographic location of fields, characteristics of producing reservoirs, nature of entrapment, and sequence of exploration and discovery. The South Bosque field is an isolated occurrence associated with the strandplain system to the west and is not considered part of either of the deltaic trends; it is discussed separately above.

Proximal Trend.—Discoveries in the coastal barrier proximal subfacies began after Paluxy oil was found at the Talco and Sulphur Bluff fields to the north. A domal structure was delineated in northern Wood County by seismic exploration and developed in 1942 as the Coke field. A major discovery, Coke demonstrated the potential for downdip Paluxy production and rekindled interest in local structures which were untested at Paluxy depths. Drilling began shortly afterwards at the "Quitman prospect" (Scott, 1948, p. 419-420), a faulted anticline 12 miles (19 km) to the south, and resulted in the discovery of an even larger field late in 1942. The Quitman structure had earlier been located by seismic surveys, and the structure was confirmed by a shallow (Woodbine) wildcat in 1935. The interest in a deeper test was generated by continuing Glen Rose and Paluxy discoveries throughout northeast Texas and was further encouraged by the success at neighboring Coke field (Scott, 1948, p. 419-420; Smith, 1951b, p. 315).

Development of the Quitman structure included discovery of numerous pay zones, with two Paluxy additions (Quitman Paluxy South and

Quitman Northwest Paluxy) in 1959. The original discovery remained the largest of the Quitman fields, and with a cumulative production of almost 51 million barrels by 1974, it is the most prolific accumulation in the downdip Paluxy.

Another faulted anticline 6 miles (10 km) to the northeast was drilled shortly after production was established at Quitman, and this resulted in the 1943 discovery of the Manziel field. Like Quitman, the Manziel structure had been indicated earlier by surface mapping, seismic work, and a dry Woodbine test. Manziel developed into the third and last of the multimillion-barrel proximal trend discoveries; more recent Wood County developments have been confined to the extensions to the Quitman field and a thin Paluxy pay that was added to the Forest Hill field in 1970.

West of Wood County, coastal barrier production has been established in two small, isolated fields. Westernmost is Campbell field in Hunt County, marking the northwestern corner of all Paluxy production and more than 20 miles (32 km) away from the nearest Paluxy field. The Campbell field is located along the western sector of the Mexia-Talco fault zone and was found in 1943 following seismic exploration in the area (Branson, 1951, p. 50). Accumulation at Campbell is in a thin, fault-trapped reservoir, which produced 374,690 barrels of oil before abandonment in 1952.

Production in the area between Wood County and the Campbell field was initiated in 1963 with the discovery of a Paluxy reservoir associated with the Grand Saline salt dome, Van Zant County (Fox, 1964, p. 917). Grand Saline has been a one-well field, with cumulative production to 1974 of 62,834 barrels of oil. This very small field is isolated more than 15 miles (24 km) from the nearest Paluxy production at Quitman to the northeast.

The proximal trend fields occur typically in thick, sandy sequences characteristic of this part of the coastal barrier facies. Individual reservoir sandstones are lenticular and intercalated with shale and, at Manziel, with "streaks of fossiliferous limestone, porous and permeable" (Ring and Watts, 1951, p. 214). Some interconnection of sandstone units is indicated by common oil-water interfacies in the major fields and by generally uniform water encroachment with continued production. Reservoirs are moderately thick, from approximately 10 feet (3 m) for the two small western fields (Campbell and Grand Saline) to 20 feet (6 m) at Manziel, 35 feet (11 m) at Quitman, and 55 feet (17 m) at Coke. Gravity of the produced oil varies from API 14° to 41°.

Proximal coastal barrier fields are associated with major structural features, which are necessary to form effective traps in the thick sandstone reservoirs; lagoonal mud deposits updip are not extensive or persistent enough to form a depositional seal. The major accumulations were discovered by probing deeper into structures found earlier in the search for Woodbine Formation oil. Recent activity has been confined to adding pays to existing fields.

Distal Trend.—Production from the distal coastal barrier subfacies is concentrated in three general areas, with 11 fields around the Sabine uplift, 39 fields in the central portion of the Tyler basin, and 3 fields in the Kaufman County sector of the Mexia-Talco fault zone. The first discoveries were in the Sabine uplift area, beginning with a Paluxy pay zone found in 1916 at Caddo field in Marion County, Texas, and Caddo Parish, Louisiana. Flesh and Peek (1951, p. 43) stated that the field was discovered by random drilling and that the Paluxy accumulation resulted from "lenticular sands and truncated sand wedges."

Another important 1916 development was the discovery of the Bethany field of Panola and Harrison Counties. Bethany was confirmed when a wildcat located on the basis of surface geology blew out in the shallow Nacatoch sand (Kitchens, 1951, p. 11). Paluxy discoveries were made later as successively deeper pay zones at Bethany were exploited. Kitchens (1951, p. 12) attributes the accumulations at Bethany to two anticlinal closures, which are modified by porosity variations in each reservoir.

Continued surface and subsurface exploration in the area led to the 1924 discovery of Waskom field, in Harrison County, 4 miles (6 km) north of Bethany (Loetterle, 1951b, p. 406). Records are incomplete on early development of the multiple Waskom pays; Grimm and Howe (1925, p. 333-334) state that "deep Bethany gas-sand" production had been established in one well up to March, 1925, at a depth corresponding to Loetterle's (1951b, p. 409) gas sand in the Paluxy. Two Paluxy gas wells were producing at Waskom in 1974.

Marginal discoveries were made in Shelby County at Ashton in 1928 (gas and oil), East Shelbyville in 1941 (gas), and Bobo in 1964 (gas). Ashton and East Shelbyville were abandoned without significant production (Clark, 1951, p. 6; Damm, 1951, p. 111), while the Bobo field has been produced in dual completion with a somewhat more prolific Glen Rose reservoir. Slightly more substantial Paluxy gas production was discovered in Shelby County with a 1964 addition to the Huxley field, producing over 3.5 million MCF by 1974.

Further Panola County developments occurred with a Paluxy extension of the Carthage field in 1952 and discovery of the Belle Bower field in 1968, both of which are multimillion-MCF gas producers. Northward in Harrison County, the Panola Paluxy field was discovered in 1958 and abandoned in 1964 with no listed production.

The distal trend was extended westward to the Tyler basin with the 1940 discovery of Paluxy gas at the Chapel Hill field, southeastern Smith County (National Oil Scouts and Landmen's Association, 1941, p. 371). The faulted anticline at Chapel Hill was located by geological mapping of the surface and verified with seismic surveys and dry Woodbine wildcats (National Oil Scouts Association of America, 1939, p. 319-320; Thompson, 1951, p. 77). Deeper drilling brought a Rodessa gas discovery in 1938 and a dual Paluxy gas/Pettit oil find in late 1939 or 1940. Later development of the area resulted in additional Paluxy field designations in 1958, 1959, 1960, and 1967.

The Sand Flat field in north-central Smith County has a similar history. As detailed by Wendlandt (1951, p. 345), a favorable structure was recognized on the basis of surface geology as early as 1927. A 1938 wildcat proved the Woodbine dry, temporarily discouraging further activity. Paluxy and Glen Rose successes in other parts of northeast Texas generated interest in a deeper test of the Sand Flat prospect. Seismic surveys refined knowledge of the structure, and the discovery well was located and completed in the Paluxy in 1944. The field was extended to the Rodessa two months later, but the Paluxy pay remained the dominant producer.

The Hitts Lake field was discovered 1 mile (1.6 km) southwest of Sand Flat field in 1953. Hunt and O'Connor (1954, p. 1,200) reported that accumulation "appears to be controlled by faulting," although "lateral variation in the Paluxy sandstone is of primary importance."

A third major reservoir in the Sand Flat area was discovered in 1957 at Shamburger Lake field, 0.5 mile (.8 km) east of Hitts Lake. Bancroft (1958, p. 130) describes structure in the field as a "fault segment on (an) anticlinal ridge." Production at Shamburger Lake was extended in 1969 with the discovery of the Shamburger Lake South field.

Soon after the Sand Flat discovery, a 1944 Glen Rose (James Lime) discovery 6 miles (10 km) south of Tyler opened production in southern Wood County. The South Tyler field is developed in a domal uplift or "convex trap," which was located by seismic surveys (Turner, 1951, p. 364). A similar structure 4 miles (6 km) to the north was tested in 1948 and completed in the Paluxy as the Tyler field. Torrans (1951, p. 397) characterizes the Tyler reservoir as "spotty and irregular," with hydrocarbons trapped in "lenticular sands on a domal anticline." Additional Paluxy pays were developed at Tyler in 1963 and 1965. Development of the area continued with Paluxy extensions to the South Tyler field in 1959, 1960, 1965, and 1966. The small Tyler East 7100 Sand field was discovered 5 miles (8 km) southeast of Shamburger Lake in 1959, followed by the Tyler East Paluxy "B" discovery 1,700 feet (518 m) to the north in 1963. The Tyler West Paluxy field was completed southwest of Hitts Lake in 1961 and extended in 1963, 1965, 1969, and 1973. A faulted structure 1.5 miles (2.4 km) west of the Sand Flat field was developed in 1962 as the Molly Jane Paluxy field, and the single well Girlie Cauldwell field was discovered 5 miles (8 km) southeast of Tyler in 1973.

Northwestern Smith County contains five small oil fields grouped near the center of the Tyler basin. The first and largest of these discoveries was made at Mount Sylvan in 1946. Hays (1951, p. 242) described the Mount Sylvan field as a "depositional pinchout trap; stratigraphic wedging-out of Paluxy porous sand."

Before the Mount Sylvan completion, a test was begun 2 miles (3 km) to the east which resulted in discovery late in 1946 of the Boynton field. According to Richardson (1951, p. 35), stratigraphic pinchouts of the Boynton reservoir "suggest an elongate bar sand, developed 20 feet

[6 m] higher in the stratigraphic section than the producing sand in the Mount Sylvan field to the west." A small anticlinal nose is considered coincident with the sandstone development. Production ceased at Boynton in 1960 with a cumulative total of less than 300,000 barrels of oil.

The Bud Lee field was discovered 1.5 miles (2.4 km) northeast of Boynton in 1949. Production at Bud Lee is from a small faulted anticline, restricted by "extreme lenticularity of the single producing sand" (Loetterle, 1951a, p. 37). Development of the area continued with very small Paluxy discoveries at Lindale Northeast (3 miles (5 km) northeast of Bud Lee) in 1962 and New Harmony (2 miles (3 km) southwest of Baynton) in 1964.

Northward in Wood County, distal coastal barrier production is restricted to Paluxy extensions of the large, multi-reservoir Hawkins and Pine Mills fields. Both fields are associated with major structural features. Paluxy production at Hawkins occurred from 1963 to 1968, for a cumulative total of 28,935 barrels of oil and 146,136 MCF of casing-head gas. Pine Mills Paluxy production has been more substantial, with almost 1.5 million barrels extracted since discovery in 1952 and five wells operating at the close of 1973.

The westernmost distal trend fields occur in the facies segment transected by the Mexia-Talco fault system, in eastern Kaufman County. The first and largest of these discoveries was the Walter Fair field, a fault-trapped accumulation found in 1949 after an extended exploration effort, which included surface mapping, core drilling, and unsuccessful wildcats (Moore, 1951, p. 402). Remaining activity in the area has been confined to Paluxy additions to the Ham Gossett field, located about 10 miles (16 km) to the south of Walter Fair. The Ham Gossett Paluxy Lower field was discovered in 1954 but abandoned in 1960, with a cumulative production of less than 25,000 barrels of oil. More substantial production was established with the discovery of Ham Gossett Southeast Paluxy field in 1962, totaling 792,495 barrels of oil by 1974.

The distal trend includes 53 fields located in a 50-mile- (80-km-) wide swath extending across 130 miles (209 km) of northeast Texas from Kaufman County to Louisiana. Included are 16 fields which have individually produced more than 1 million barrels of oil or MCF gas and 15 fields which failed to produce 50,000 barrels or MCF. Production is concentrated around three major tectonic elements, the Sabine uplift, the Tyler basin, and the Mexia-Talco fault zone, with large and small production extremes occurring in each.

Individual hydrocarbon reservoirs in the trend are characteristically lenticular and local in extent, "posing," as Loetterle noted for the Mount Sylvan area, "a formidable dry hole hazard" (1951, p. 37). Producing sandstones are predominantly thin, except in the Sand Flat and Shamburger Lake areas of the Tyler basin. The reservoir sandstones are friable to indurated, range from poorly sorted to well sorted, and are intercalated with shale and thin limestone beds. Fields produce from either single sandstone beds or sequences of thin-bedded sandstone and sandy shale. Isolated sandstones form separate reservoirs in multipay fields such as Bethany and Chapel Hill.

Oil produced from the distal trend varies in gravity from API 16° to 69°. The trend also includes all 10 of the Paluxy gas/condensate fields, which are concentrated around the Sabine uplift and in the Chapel Hill area of the Tyler basin.

Distal trend accumulations are characteristically influenced by depositional limitations of reservoir sandstones, but structural features are also important. While a few fields may be simple stratigraphic traps, most reservoirs show evidence of later modification of original depositional configuration.

Development of the distal trend has accounted for a steadily increasing portion of the total Paluxy oil and gas production (fig. 25). New field discoveries and extensions to existing fields should continue this trend as detailed stratigraphy around favorable structural features is refined.

SUMMARY

Paluxy deposits were derived from Mesozoic and Paleozoic sedimentary rocks exposed along the northern and western periphery of the East Texas embayment. Principal source areas were located to the north in Oklahoma and Arkansas; these furnished detritus to a southward-accreting coastal plain. To the west, sediments were locally derived and incorporated into strandplain deposits which veneer the western margin of the embayment.

Three depositional systems are discernible within the Paluxy and equivalent lithostratigraphic units. The distribution of these systems and their component facies is illustrated on diagrammatic cross sections oriented along depositional dip (fig. 26) and strike (fig. 27).

A fluvial system is preserved in the subsurface along the northern margin of the East Texas embayment. Fluvial facies extend southward and thicken down paleoslope from southeastern Oklahoma. A thin interval of stacked channel-fill sandstones and intervening flood basin muds, which is present along the Texas-Oklahoma border, grades southward into the thick sequence of multilateral sands locally interbedded with top stratum muds typical of the Talco field area in northern Titus County.

The fluvial system grades downdip into a delta system situated in the central basin area. The delta complex is the thickest and most widespread of the Paluxy systems. The delta lobes are cuspate in plan view and consist predominantly of stacked sandstone units, which are strike oriented and separated by intercalations of marine and lagoonal mudstone. Gulfward, the delta sandstones thin into a sequence of burrowed shale and marl and ultimately grade into shelf marl and limestone facies.

The delta flanks grade laterally along strike (fig. 27) into thinner sequences of strike-distributed sandstone and bay and marine mudstone. To the west, these constitute a strandplain system, which is extensively developed on the western basin margin. Sediment sources for the strandplain system included direct fluvial supply and longshore drift from areas of active deltation. Basinward, sandy deposits of the strandplain system grade into shelf carbonates of the Walnut Formation.

Major Paluxy resources consist of groundwater on the western basin margin and oil and gas accumulations in the central basin area. Groundwater is exploited for municipal, domestic, and industrial uses along a broad band extending eastward approximately 60 miles (97 km) from the Paluxy-Antlers outcrop. The occurrence of fresh to

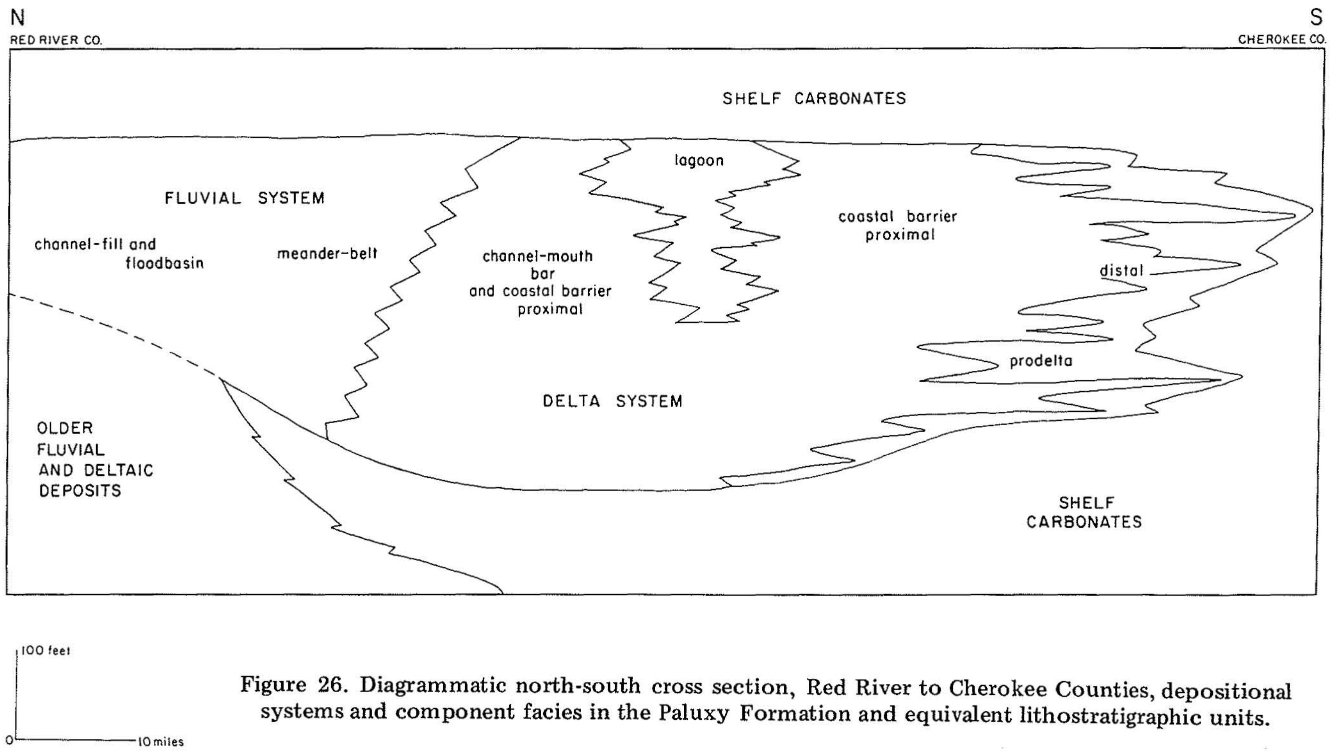

Figure 26. Diagrammatic north-south cross section, Red River to Cherokee Counties, depositional systems and component facies in the Paluxy Formation and equivalent lithostratigraphic units.

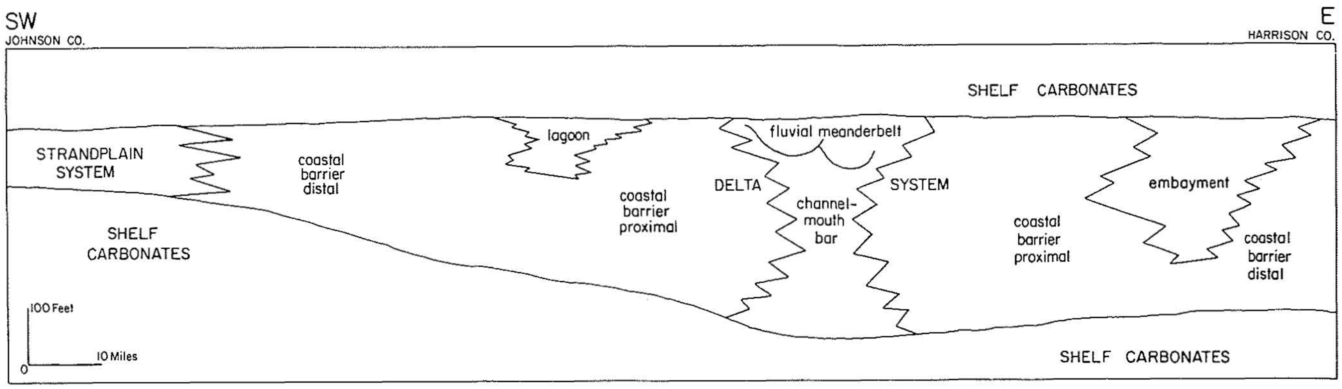

Figure 27. Diagrammatic west-east cross section, Johnson to Harrison Counties, depositional systems and component facies in the Paluxy Formation and equivalent lithostratigraphic units.

slightly saline water (less than 3,000 milligrams of dissolved solids per liter) is restricted by the depositional limit of strandplain sands to the south, by the progressive deterioration of ground-water quality with increasing aquifer depth to the east, and by retention of saline water in muddy, fluvial deposits to the north. The very fine grain size and complex microfacies of the strandplain aquifer are reflected in highly variable but low specific capacities.

Major petroleum accumulations occur in deposits of the fluvial meanderbelt and deltaic coastal barrier facies. Fluvial sands form reservoirs along the northern part of the Mexia-Talco fault zone in traps created by early movement of major faults. Two trends are associated with the coastal barrier facies. Thick, well-developed coastal barrier and channel-mouth bar sandstones form oil reservoirs of the proximal trend; these accumulations are located in the central Tyler basin area and are associated with major structural features. The distal trend comprises downdip accumulations of oil and gas in thinner coastal barrier sandstone facies. Distal reservoirs are affected by downdip pinchout of sand, and most accumulations occur either as stratigraphic traps or in association with minor structural features.

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APPENDIX

ELECTRIC LOG AND SAMPLE LOCALITIES

	Name	New Sand in Feet, Goodland-Glen Rose (or Equivalent) Interval
BOSQUE COUNTY		
1.	Meadows No. 2 Lake Whitney water well	23
2.	Meadows No. 1 Smith Bend water well	24
3.	Meadows No. 4 Meridian water well	32
4.	Outcrop locality, road cut on gravel road 2.2 miles northeast from intersection with State Highway 6, 6.7 miles north of intersection of State Highways 6 and 22	33
BOWIE COUNTY		
1.	Watburn Oil No. 1 Clark	106
2.	Sutton No. 1 Newkirk	171
3.	Lytle and Hughes No. 1 Howard	130
4.	Gulf No. 1 Veach	130
5.	Barnsdale Oil No. 1 Hill	119
6.	Northern Ordinance No. 1 Lumpkin	104
7.	Coats No. 1 Hall	170
8.	Gulf Coast and David Crow No. 2 Simms Estate	114
9.	Tidewater No. 2 Dalby and Joiner	140
CAMP COUNTY		
1.	Tidewater and Seaboard No. 1 Roberts	189
2.	Phillips No. 1 Dodson	160
3.	Columbian Fuel No. 1 Braudaway	175
4.	American Petrofina No. 1 Grammer	154
5.	Gulf No. 1-A Pearson	172
CASS COUNTY		
1.	Amerada No. 1 Frost Estate	172
2.	Palcid No. 1 Irvin	78
3.	Hinton No. 1 Betts	115
4.	Humble Oil and Refining No. 1 Harris	93
5.	Phillips and Amis A. Starr No. 1 Leonard	113
6.	Humble Oil and Refining No. 1 Guerin	84
7.	King No. 1 Riley	105
8.	Shell No. 1 Smith	104
9.	Arkla No. 1 Brooks Brothers	60
10.	Messenger No. 1 Singleton	80

CHEROKEE COUNTY

1.	Humble Oil and Refining No. 1 Maness	0
2.	Sinclair No. 1 O'Neal	5
3.	Humble Oil and Refining No. 1 Curtiss *et al.*	0
4.	Standard Oil of Texas No. 1 Acker	0

COLLIN COUNTY

1.	Layne Texas No. 1 Texas State Research water well	114
2.	Stanolind No. 1 Newsome	142
3.	Killam No. 1 Wilburn	124
4.	Humble Oil and Refining No. 1 Wester	97
5.	Texas Power and Light No. 1 Trinity Test	119
6.	Hunter No. 1 Hill	90
7.	Killiam No. 1 Herrington	100
8.	Deep Rock No. 1 Sherley	124
9.	Holbert No. 1 Watkins	78
10.	Port Bolivar No. 1 Durning	68
11.	Layne Texas No. 1 McKinley water well	151
12.	Humble Oil and Refining No. 1 Simms	96

COOKE COUNTY

1.	Frederick Electric No. 1 Coursey	34
2.	Northern Pump Company No. 9 Wilson	52
3.	Sohio No. 1 Breeding	28
4.	Layne Texas No. 6 Cantonment (Gainesville)	53
5.	Couch Oil No. 1 Lamb	48
6.	Kirksmith No. 1 Luttmer	50
7.	Seitz No. 1 Reynolds	80
8.	Couch Oil No. 1 Lewis	54

CORYELL COUNTY

1.	Outcrop locality, barditch along State Highway 36 south of Morgan Creek, 1.6 miles southeast of Jonesboro	

DALLAS COUNTY

1.	Layne Texas No. 2 Mesquite water well	86+
2.	Myers and Sons Federal Works Agency Docket	123
3.	Myers and Sons No. 5 Irving water well	79
4.	North American Aviation No. 1 water well	91
5.	Myers and Sons No. 2 Duncanville	87+
6.	Myers and Sons No. 2 Cedar Hill water well	90
7.	Layne Texas No. 2 Seagoville Internment Camp	84+
8.	Myers and Sons No. 1 Buckner Orphans Home	132+
9.	Myers and Sons No. 44 Dallas water well	80
10.	Layne Texas No. 1 Gilmer water well	110

DALLAS COUNTY (CONTINUED)

11.	Layne Texas No. 3 Lancaster water well	67
12.	Myers and Sons No. 42 Dallas water well	150
13.	Layne Texas No. 3 Dallas Power and Light	82
14.	Guiberson and Lucy No. 1 Moyer	150
15.	Myers and Sons No. 1 Dallas Power and Light	103
16.	Myers and Sons No. 3 Richardson water well	95
17.	Layne Texas No. 43 Dallas water well	119
18.	Texas Water Wells No. 45 City of Dallas	76
19.	Myers and Sons No. 1 Rowlett water well	140+
20.	Layne Texas No. 1 Dallas Power and Light Test	73

DELTA COUNTY

1.	West Texas Tool Service Enloe and Lake Creek water well	153+

DENTON COUNTY

1.	Huber No. 1 Lowe	100
2.	Standard of Kansas No. 1 Hart	91
3.	Libscomb and Ferrando No. 1 Martin "A"	45+
4.	Bond No. 1 Brooks	78
5.	Myers and Sons No. 3 City of Lewisville	96
6.	Tyrell No. 1 Hoxsey	109
7.	Barnwell No. 1 City of Lake Dallas water well	120+
8.	Texas Company No. 1 Evers	111
9.	Texas Company No. 1 Routon	72
10.	Lowell No. 1 Schertz	63
11.	Witherspoon and McCarthy No. 1 Sullivan	66
12.	Hickey and Sons No. 1 Wade	38
13.	Deaton No. 1 McCormick	45
14.	Aubery and Tennant No. 1 Jones	78
15.	Hunt and Sands No. 1 Long	31
16.	Yettman *et al*. No. 1 Hughes	42
17.	Layne Texas No. 12-2 Denton water well	116

ELLIS COUNTY

1.	Prince *et al*. No. 1 Nifong	70
2.	Myers and Sons No. 3 Midlothian water well	108
3.	Myers and Sons No. 1 Salvation Army Camp	78
4.	Myers and Sons No. 1 Sardis Lone Elm water well	99
5.	Faulds Whitehead No. 1 Curtiss Hill	112
6.	Layne Texas No. 4 Waxahatchie water well	67
7.	Austex No. 1 Champion	41
8.	Stoddard No. 1 Smith	39
9.	Hughey and Carpenter No. 1 Feaster	26
10.	Lesco No. 1 Lesage	80
11.	Key Drilling and Development No. 1 South Ellis	39
12.	American Liberty No. 1 McClain	88

ELLIS COUNTY (CONTINUED)

13.	Cain No. 1 Patak	79
14.	Rutter *et al*. No. 1 Simms	106
15.	J. L. Myers No. 1 Texas Industries water well	113

ERATH COUNTY

1. Outcrop locality, barditch along county road 4 miles southeast of intersection with F. M. 1702, 1 mile northwest of Shiloh

FANNIN COUNTY

1.	Sun No. 1 Tucker	154
2.	Callery Inc. No. 1 Robinson	89
3.	Gilcrest No. 1 Boyd	134
4.	Layne Texas No. 1 Ladonia water well	128+
5.	D. and D. Oil No. 1 Brinkley	91
6.	Taylor No. 1 Jones	112
7.	Hawkins No. 1 Shelton	212

FRANKLIN COUNTY

1.	Hollandsworth No. 1 Aldridge	136+
2.	Stephens and American Liberty No. 1 Hale	233
3.	Humble Oil and Refining No. 3-S Penn Fee	192
4.	Post (Atlantic Refining) No. 1 Anderson	238
5.	Stevenson *et al*. No. 1 Caviness	239
6.	Tidewater No. 1 Gilbert	195

GRAYSON COUNTY

1.	Gibson and Holliman No. 1 Yeager	83
2.	Sinclair No. 1 Charles Brown	58
3.	Star No. 1 Whisenant	86
4.	Pan American No. 1 Umphress	54
5.	Humble Oil and Refining No. 1 Fallon	39
6.	Shell No. 1 Scoggins Unit	99
7.	Kimbell No. 1 Neffley	56
8.	Layne Texas No. 1 Sherman Russell water well	77
9.	Phillips No. 1 Aldine "A"	84
10.	Howell, Holloway, Howell No. 1 Molly Miller	68
11.	Hunt No. 1 Conner	87
12.	Continental No. 1 Armstrong	65
13.	Seitz Brothers and Dillard No. 1 Baker	43
14.	Magne No. 3 Freeman "B"	76
15.	Nortex No. 2 Dawkins	42
16.	Sinclair No. 1 Blackburn	42
17.	Star Oil No. 1 Hodgin	79
18.	Shell No. 2 Aetna Insurance Company	51

GREGG COUNTY

1.	Tidewater No. 1 Castleberry Unit	97
2.	Jones No. 1 Stinchcomb	13

HARRISON COUNTY

1.	Amerada No. 1 Rogers	88
2.	Fields No. 1 O'Banion	31
3.	Placid No. 1 Craver	131
4.	Fohs Oil No. 1 Sypert	27
5.	Williams No. 1 Furrh Estate	9
6.	Murphy No. 1 Matthew	36
7.	Stanolind No. 1 Cole	12
8.	Lone Star No. 1 Jones	68
9.	Rogers Lacy No. 1 Green	90
10.	Atlantic No. 1 Keasler	131

HENDERSON COUNTY

1.	Texas Company No. 1 Morse	13
2.	Roosth and Genecou No. 1 Smith	0
3.	Lone Star No. 3 Saylors	30
4.	Stanolind No. 1 Deupree	0
5.	Humble Oil and Refining No. 1 Mixon	0
6.	Humble Oil and Refining No. 1 Benge *et al.*	12
7.	Fair No. 1 Bradley	5
8.	Placid No. 1 Fisher-Bruno	0
9.	Cities Service No. 1 Garner	0
10.	Sanders and Murchison No. 1 Lewis	0

HILL COUNTY

1.	Hunt No. 1 Wright	98
2.	Layne Texas No. 3 Hillsboro Trinity water well	34
3.	Myers and Sons No. 2 City of Hubbard	0
4.	McCarthy No. 1 Daniel	5
5.	Phillips No. "A"-1 Posey	45
6.	Myers and Sons No. 1 Penelope water well	22
7.	Brandor No. 1 Shannon	18
8.	Humphrey No. 1 Osborne	60
9.	Myers and Sons No. 1 Aquilla water well	0
10.	Layne Texas No. 14 Hillsboro water well	15
11.	Merritt No. 1 Norris	0
12.	Wes-Tex Tool and Service No. 1 Mt. Calm	4

HOPKINS COUNTY

1.	Hunt No. 1 Marable	148+
2.	Magnolia No. 1 Beville	151

HOPKINS COUNTY (CONTINUED)

3.	Benedum No. 1 Spencer	175
4.	Killam No. 1 Smith	62+
5.	Byars Power Drilling No. 1 White	26+
6.	Phillips No. 1 Rhodes	252
7.	Snowden No. 1 Warren	129+
8.	Schneider and Corey No. 1 Strode	212
9.	Humble Oil and Refining No. 1 Campbell	229
10.	Mobil No. 1 Evans Unit	167
11.	Sun No. 1 Turner	226
12.	Campbell and Hill No. 1 Warren	107+
13.	Magnolia No. 2 Campbell Heirs	257

HUNT COUNTY

1.	Morrison *et al*. No. 1 Muller	40+
2.	Kemp No. 1 Cole	171
3.	Sun No. 1 Mabry	140
4.	Killiam No. 1 J. W. Fair	90+
5.	Fields No. 1 Meridith	140+
6.	Ohio No. 1 Popper	190
7.	Hunt No. 1 Burnett	99+
8.	American Liberty No. 1 McNatt	212
9.	McHenry No. 1 Neeley	138
10.	Humble Oil and Refining No. 1 Anderson	samples only
11.	Humble Oil and Refining No. 1 Graham	191
12.	Westmont No. 1 Clark	133
13.	Penn Oil No. 1 Parish	150
14.	Helms No. 1 Adams	173

JOHNSON COUNTY

1.	Stoner No. 1 Wallis Simpson water well	79
2.	Gray Drilling No. 1 Lockett	65
3.	Humble Oil and Refining No. 1 Dean	79
4.	Warren No. 1 Hanna	58
5.	Shell No. 1 Goodwin	64
6.	Layne Texas No. 2 Bethesda water well	53

KAUFMAN COUNTY

1.	Hunt No. 1 Sowell	108
2.	Superior No. 1 Phillips	153
3.	Gibson Drilling No. 1 Lupe	130
4.	Ownby No. 1 Lechner	42
5.	Sun No. 1 Rutledge	137
6.	Killam No. 1 Freeman	97
7.	American Liberty No. 1 Hall	62+
8.	Delphi Oil No. 1 Miller High	99+
9.	Whitely Drilling No. 1 Gardner	128+
10.	Humble Oil and Refining No. 1 Guy	128

LAMAR COUNTY

1.	Cosden No. 1 Adams	57
2.	McCutchen No. 1 Roberts	114
3.	Stephens No. 1 Hollis Tidwell	155
4.	Jones No. 1 Gambill	160
5.	Stratton, Delcambre, and Smith No. 1 McDonald	133
6.	Dillon No. 1 Smiley	164
7.	Henderson No. 1 Crowley	185
8.	Whithead and Dahl No. 1 Barr	154
9.	Crude Petroleum No. 1 Coursey	152
10.	Forrester *et al*. No. 1 Woodard	165

McLENNAN COUNTY

1.	Belcher No. 1 Smith	0
2.	Layne Texas No. 1 Trading House Creek	0
3.	Myers and Sons No. 1 Tiery	0
4.	Myers and Sons No. 1 Elm Mott School	0
5.	Korshaj No. 1 Ferguson	0
6.	Myers and Sons No. 2 City of West	no S. P. curve
7.	Muth No. 1 Freeman	11
8.	Triangle Pump and Supply No. 1 East Crawford	8
9.	Stoner No. 1 Easley	8
10.	Caraway No. 1 Slaughter	0
11.	Myers and Sons No. 1 Riesel School District	0
12.	Layne Texas No. 1 Texas Power and Light Lake Creek	0
13.	Caraway No. 1 O'Dowd	0
14.	West-Tex Tool Service No. 1 Levi Water Supply	0
15.	Myers and Sons No. 2 Lorena Water Supply	0
16.	C. M. Stoner No. 1 Spring Valley Water Supply	0
17.	Delta No. 1 Carl Horstmann	0
18.	C. M. Stoner Elm Creek Water Supply	0

MARION COUNTY

1.	Parsons No. 1 Hook	116
2.	Fair No. 4 Mason	127
3.	Hollandsworth No. 1 Wright	145
4.	Perryman and Coulston No. 2 Stiles Estate	112

MORRIS COUNTY

1.	Coats and Moore No. 1 Davis	154+
2.	Delaney No. 1 Halt	115
3.	Hunt No. 1 Robinson	88
4.	Sohio No. 1 Dutch Love	20+

NAVARRO COUNTY

1.	Heinen and Garonzik No. 1 Fortson	0

NAVARRO COUNTY (CONTINUED)

2.	Irish No. 1 Lee Lowe	0
3.	Rahal No. 1 Porter	10
4.	Brown and Wheeler No. 1 Gibson	0
5.	Collins No. 1 Greenlee	0
6.	Schneider *et al.* No. 1 Carter	37
7.	Humble Oil and Refining No. 1 Adams	0
8.	Caraway *et al.* No. 1 Eckhardt	0
9.	Wilson No.1 Sheppard	25
10.	Brown and Wheeler No. 1 Henderson	0
11.	Wadley No. 1 Crook	0
12.	Carter-Gregg No. 1 Lewis	0

PANOLA COUNTY

1.	Union Producing No. 1 Harrison Unit	25
2.	Rogers Lacy No. 2 Burnett Unit "10"	22
3.	Lillard No. 1 Parker	10
4.	Skelly No. 1 La Grone-Alexander Unit	52
5.	Skelly No. 1 Magham	15
6.	Hunt Oil No. 1 Dunaway	7
7.	Union Producing No. 1 Calvin Unit	33
8.	Chicago Corporation No. 1 McDaniel	33
9.	Arkla Gas Company No. 1 Graves	29

PARKER COUNTY

1. Outcrop locality, county road, 0.4 miles north of intersection with county road, 0.7 miles west of Aledo

RAINS COUNTY

1.	American Liberty No. 1 Republic Insurance	72+
2.	Sinclair No. 1 Greene	160
3.	Shell No. 1 Jones	206
4.	Hunt No. 1 Sparks	155

RED RIVER COUNTY

1.	Alan Drilling and C and R Producing No. 1 King	106
2.	White No. 1 Kurth Lumber	82
3.	Moore No. 1 Southern Pine Lumber	115
4.	Pozo and Beadle No. 1 Temple	77
5.	Magnolia No. 1 Henry	164
6.	Texas Harvey No. 1 York	160
7.	Voorhees and Shelton No. 1 Davis	155
8.	Magnolia No. 1 Cooper	133
9.	Texas Company No. 1 Solomon	200
10.	Dalport, Hager, Robinson No. 1 Turner	197

RED RIVER COUNTY (CONTINUED)

11.	Skidmore *et al.* No. 1 Cobb	143
12.	General American No. 1 Coline Oil	212
13.	Dennis No. 1 Howison	145
14.	Moore and Burton No. 1 Childress	138

ROCKWALL COUNTY

1.	Buster Farmer No. 1 Susie Herndon	81+
2.	Rotary Drilling *et al.* No. 1 Lewis	145

RUSK COUNTY

1.	Penn and Griffith No. 1 De Montrond	0
2.	Roberts and Murphy No. 1 Bane	5
3.	Pan American No. 1 Adams	7
4.	Chicago Drilling No. 1 Rayford	6
5.	Sinclair Prairie Oil No. 1 Markey	15
6.	Machin and Associates No. 1 Alexander Estate	6
7.	Trahan Drilling No. 1 Brady	5
8.	Robbins No. 1 Spear	0

SHELBY COUNTY

1.	Toto Gas No. 1 Peyton	80
2.	Humble Oil and Refining No. "B"-1 Kerr	50
3.	Javelin Oil No. 1 Youngblood	12
4.	Baker No. 1 Taylor	14

SMITH COUNTY

1.	Gulf Oil No. 1 Timms Unit	64
2.	Continental No. 1 Mayfield	13
3.	Delta No. 1 Gary	35+
4.	Hamm No. 1 House	22
5.	Phillips No. 1 Grelling	30
6.	American Petrofina and Grelling No. "B"-1 Wilson	5
7.	Cities Service No. "B"-1 Baker	18+
8.	Humble Oil and Refining No. 1 Sackett Estate	0
9.	Sinclair Prairie No. 1 Schofner	10

SOMERVELL COUNTY

1.	Outcrop locality, road cut, U. S. 67 at Ice Creek crossing, 1 mile west of the Glass Community	

TARRANT COUNTY

1.	Myers and Sons No. 5 City of Mansfield	91

TARRANT COUNTY (CONTINUED)

2.	Felker Trustee No. 1 Kramer	105
3.	Texas Water Wells No. 8 City of Arlington	120
4.	Fort Worth International Airport water well	103
5.	Shell No. 1 Lowe	104
6.	Bartlett Petroleum No. 1 Coble	111
7.	Layne Texas No. 2 Texas Water Company	134
8.	Myers and Sons No. 1 Kennedale water well	81
9.	Myers and Sons No. 4 Swift and Company	120

TITUS COUNTY

1.	Humble Oil and Refining No. 1 Stevens	201
2.	Sunray and British American No. 2 Pewitt	141
3.	Ryan Consolidated No. 1 Smith	146+
4.	King No. 1 Flanagan	31+
5.	McBee No. 1 Evins	208
6.	Lone Star No. 1 Hogue	248
7.	Hollandsworth No. 1 Harper	284
8.	Humble Oil and Refining No. 1 Searcy	201

UPSHUR COUNTY

1.	Perren No. 1 McClelland	43+
2.	Sinclair No. 1 Caudle	105
3.	Stanolind No. 1 Irvin	142
4.	Hunt No. 1 Tucker	66+
5.	Coats and Robbins No. 1 Fisk	188
6.	Patton No. 1 Adams	117
7.	Edison No. 1 Payton	196

VAN ZANDT COUNTY

1.	Delta No. 1 Gibson-Echols	191
2.	Humble Oil and Refining No. 1 McCord	138
3.	Delta Drilling *et al.* No. 1 Martin	55
4.	Cox and McMillan No. 1 Howell	117
5.	Humble Oil and Refining No. 1 Worley	56
6.	Meyer No. 1 Meredith	148

WOOD COUNTY

1.	Weiner, Freyer, and Halstead No. 1 Fouse	68+
2.	Mitchell No. 1 Cathey	186
3.	Sohio No. 1 Morgan	46+
4.	Stanolind No. 1 Peueto	181
5.	Gulf No. 1 Petty *et al.*	207
6.	Sinclair-Prairie No. 1 Collins	123+
7.	Amerada No. 3 Faulk	200