BUREAU OF ECONOMIC GEOLOGY
The University of Texas at Austin
Austin, Texas 78712

W. L. Fisher, Director

Report of Investigations—No. 73

Depositional Systems in the Woodbine Formation (Upper Cretaceous), Northeast Texas

By

William B. Oliver

1971

Second Printing, July 1976
Third Printing, October 1982

CONTENTS

ILLUSTRATIONS

DEPOSITIONAL SYSTEMS IN THE WOODBINE FORMATION (UPPER CRETACEOUS), NORTHEAST TEXAS

William B. Oliver[1]

ABSTRACT

The Woodbine Formation is composed largely of terrigenous sediment eroded from Paleozoic sedimentary and weakly metamorphosed sedimentary rocks of the Ouachita Mountains in southern Oklahoma and Arkansas and subsequently deposited in a complex of nearshore environments along the margins of the broadly subsiding Northeast Texas Basin. Three principal depositional systems are recognized in Woodbine rocks—a fluvial system, a high-destructive delta system, and a shelf-strandplain system. Their recognition is based on a regional outcrop and subsurface investigation in which external geometry of framework sands was integrated with lithology, sedimentary structures, fossil distribution, and bounding relationships.

Two components of the fluvial system, a tributary channel sand facies and a meander belt sand facies, are developed in the Dexter Member (lower Woodbine) northeast of a line from Dallas to Tyler. To the south and southwest, a high-destructive delta system is persistent throughout the entire Woodbine section. The three component facies of the delta system are: progradational channel-mouth bar sands; coastal barrier sands, deposited along shore adjacent to the channel mouth; and prodelta-shelf muds. The Lewisville (upper Woodbine) shelf-strandplain system, developed in the northern third of the basin marginal to principal deltaic facies, is composed of two facies: shelf muds and strandplain sands, accumulated along shore.

Near the end of Woodbine deposition, but before transgression by Eagle Ford seas, emergence of the Sabine Uplift resulted in erosion of Woodbine sediments, which were subsequently redeposited along margins of the uplift as the Harris Sand.

The close correspondence of Woodbine oil and gas fields with deltaic and strandplain sands suggests that on a regional scale facies distribution is as important as structure in governing the occurrence of hydrocarbons.

INTRODUCTION

The Woodbine Formation (Upper Cretaceous) consists mostly of terrigenous rocks that crop out in a narrow irregular band up to 20 miles wide in Texas, Oklahoma, and Arkansas. Outcrop is approximately along a line from Temple in Central Texas, to Lake Texoma on the Red River, and thence eastward along the Red River through southern Oklahoma to Murfreesboro in southwestern Arkansas. In subsurface, the Woodbine underlies a 45-county area bounded by the outcrop on the north and west, the Sabine Uplift on the east, and by a line from Temple to College Station on the south. The area of this study (fig. 1) includes the extent of the formation within Texas.

The economic importance of the Woodbine as a petroleum reservoir is well established. Additionally, Woodbine sands serve as a principal fresh-water aquifer along an extensive band near the outcrop, and raw materials for ceramic products produced by the Acme Brick Company in Denton come from clay beds in the formation.

The Woodbine Formation has been the subject of numerous studies since beds now recognized as Woodbine were first referred to by travelers in frontier Texas. A survey of work published before 1932 concerning the Woodbine was made by Adkins (1933, pp. 408-409); an updated survey has been made recently by Dodge (1969). Early work was largely descriptive, concerned with mapping, describing, and naming units. More recently,

[1] Continental Oil Company, Denver, Colorado.

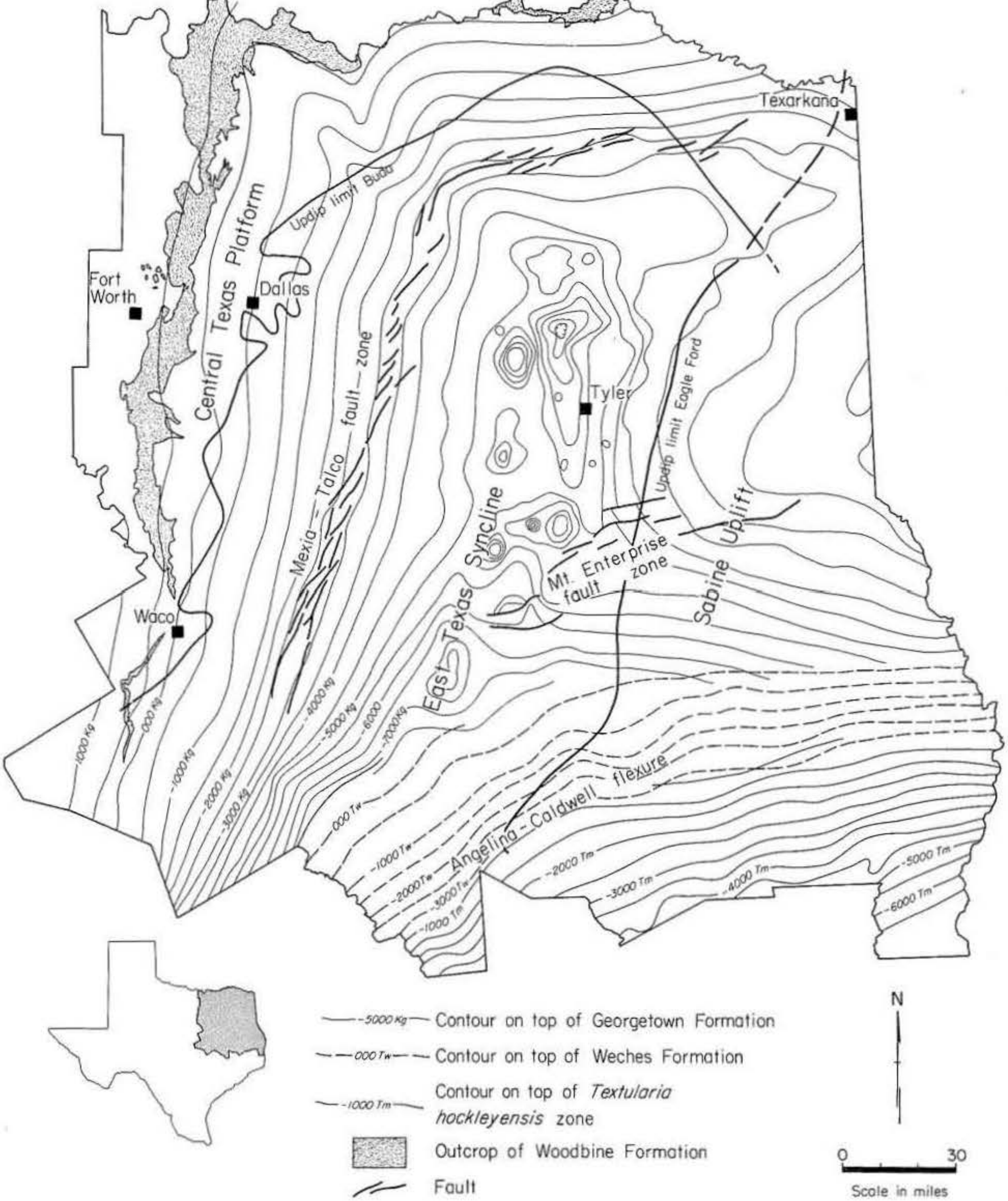

FIG. 1. Index map of study area and major structural features of northeast Texas. Modified from Sellards and Hendricks (1946).

environmental interpretations have been attempted, principally based on outcrop investigations. A summary of these has been published by Dodge (1969). Not included by Dodge is a regional subsurface study of Mesozoic units in northeast Texas in which generalized facies distribution of the Woodbine was illustrated (Nichols, 1964).

The purpose of this study is to integrate outcrop observations with subsurface data to provide a basis for delineating the regional depositional framework of the Woodbine Formation. Subsurface control includes nearly 400 electric logs, located approximately on 10-mile centers throughout the area, and cuttings from wells in selected locations (fig. 2). From these data, isopach maps and stratigraphic cross sections were prepared to establish three-dimensional relationships and geometry of principal facies. Outcrop observations of lithology, sedimentary structures, bounding relationships, and fossil occurrence supplemented subsurface control. The Woodbine outcrop has been mapped by previous workers. It is hoped that delineation of principal depositional systems and component facies will provide the genetic framework for more meaningful future detailed studies throughout the formation.

Assistance of the following persons is gratefully acknowledged: W. L. Fisher, Bureau of Economic Geology, who suggested and supervised this investigation; L. F. Brown, Jr., and P. U. Rodda, Bureau of Economic Geology; R. L. Folk, L. J. Turk, C. A. Caughey, Department of Geological Sciences, The University of Texas at Austin; W. E. Galloway, Continental Oil Company, and E. R. Killian, Texaco Inc., who read the manuscript and made helpful suggestions; C. V. Proctor, Jr., J. H. McGowen, Bureau of Economic Geology, and others who provided many helpful suggestions and criticisms. Acknowledgment is also made to G. H. Baum, Texas Water Development Board, for access to the electric log library of that agency, to the Well Sample Library of the Bureau of Economic Geology for the use of well cuttings, and to the Continental Oil Company for permission to publish this paper.

TERMINOLOGY—THE DEPOSITIONAL SYSTEM CONCEPT

Several attempts to correlate formal Woodbine stratigraphic units into areas away from originally described localities have been made (Hazzard et al., 1947; Bergquist, 1949; Lozo, 1951; Lee, 1958; Beall, 1964; Dodge, 1969; and others). Resolution and correlation of stratigraphic units is not the intent of this investigation. Terminology used is derived from the concept of depositional systems as applied by Fisher and McGowen (1967). As so used, depositional systems are defined as large-scale, genetically related units characterized by specific associations of component facies. Discrimination of individual facies is based on genetically significant criteria including external geometry, distribution of lithologies and fossils, sedimentary structures, and lateral and vertical relationships with other facies within a system.

Three-dimensional analysis of facies tracts in Holocene depositional provinces provides models for the recognition of ancient depositional systems. Specific Holocene analogues for Woodbine depositional systems are considered with the characterizations of individual systems.

REGIONAL SETTING

The basin in which the Woodbine was deposited was a broadly subsiding seaway that encompassed the central, actively subsiding East Texas Syncline, flanked to the east and west by more stable areas (fig. 1). Adjacent to the central trough, or East Texas Syncline, on the west was a relatively stable area commonly called the Central Texas Platform, underlain by metamorphic rocks of the buried Ouachita System. To the east and southeast, the Sabine Uplift bordered the trough, although it probably was not emergent until near the end of Woodbine deposition (Barrow, 1953, p. 136; Granata, 1963, p. 75). To the north, the entire basin was bounded by the Ouachita System (southeastern Oklahoma and southern Arkansas), which was a source of sediment for Woodbine depositional systems. Structural activity in northeast Texas during Woodbine deposition included growth-faulting along the Mexia-Talco zone (a system of vaguely defined grabens which roughly parallels the Woodbine outcrop), faulting in the Mt. Enterprise fault zone in the south-central portion of the basin, and growth of numerous salt domes throughout the central basin area (Barrow, 1953).

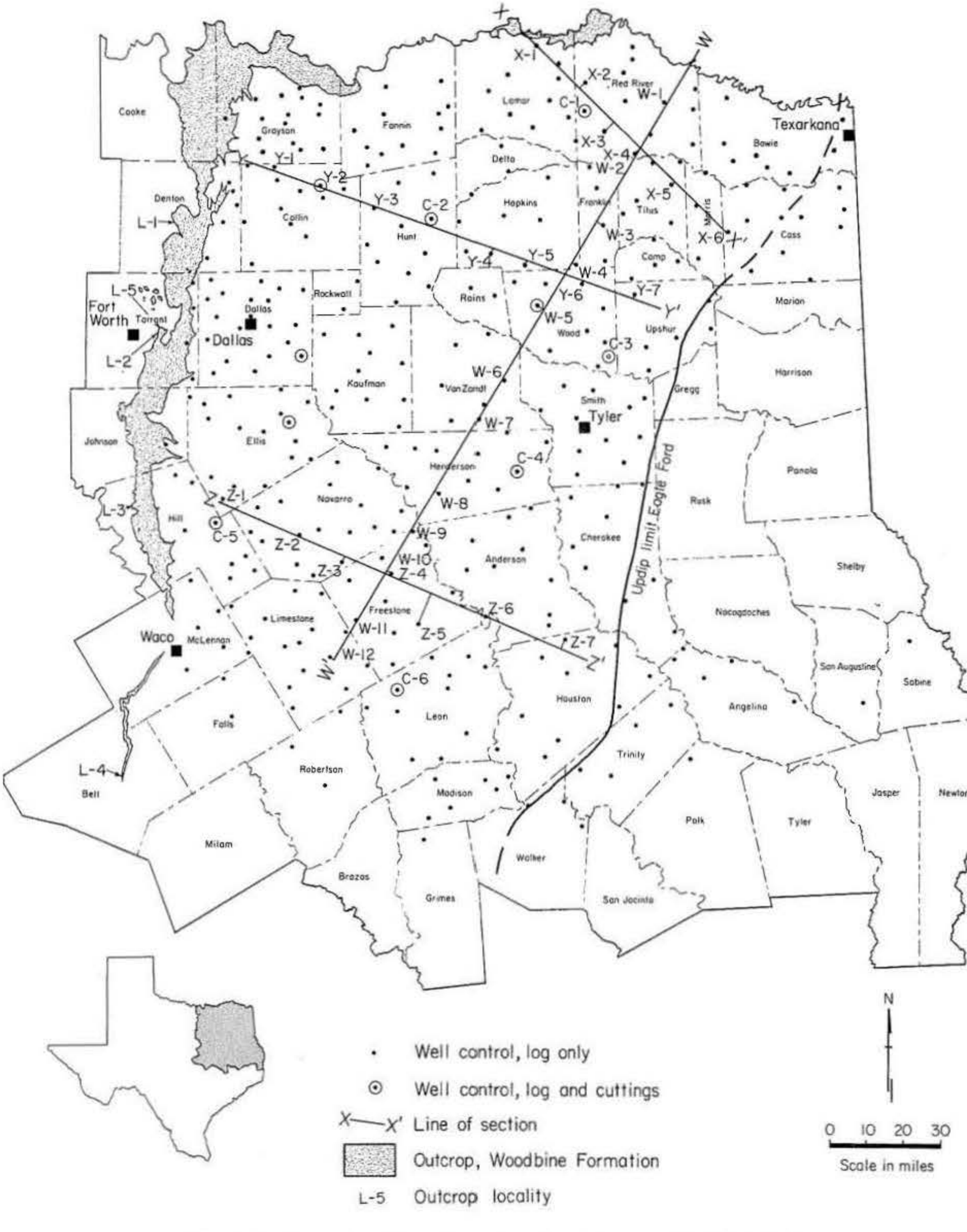

FIG. 2. Well control and location of cross sections and outcrop localities.

Three principal depositional systems are delineated in the Woodbine Formation in northeast Texas—a fluvial system, a high-destructive delta system, and a shelf-strandplain system. The fluvial system, preserved in the Dexter Member (lower Woodbine), is dominant north and northeast of a line from Dallas to Tyler. Migration of the drainage network toward the east throughout Woodbine delta building and continued subsidence of the area previously occupied by the fluvial system resulted in submergence of much of that area during deposition of the Lewisville Member (upper Woodbine). To the south and southwest, the high-destructive Freestone delta system is persistent throughout the entire Woodbine section. It occupies a broad, continuous belt approximately perpendicular to the regional paleoslope delineated by the trend of the fluvial system. Portions of the system crop out in the area from Johnson to Falls counties; however, major development occurs in the subsurface to the east of the outcrop. In central portions of the basin deltation was continuous; upper portions of the delta system likely were derived at least in part from reworked Woodbine clastics eroded from the Sabine Uplift.

FLUVIAL SYSTEM

The Dexter fluvial system occupies most of the northern one-third of the Northeast Texas Basin; it crops out chiefly along the Red River from Cooke County eastward and is continuous in the subsurface southward from the outcrop to a line extending from Dallas to Tyler. Downslope it grades to facies of the high-destructive delta system. Principal fluvial axes are shown by subparallel, elongate isopachous highs, which trend from north-south to northeast-southwest (fig. 3).

Allen (1965, pp. 130-139) summarized published literature concerning Holocene fluvial deposition. With investigations included in his report as a basis, three-dimensional models of fluvial deposition have been developed, which serve as models in the interpretation of ancient sediments. Among them, Bernard and Major (1963), Visher (1965), and Allen (1965) proposed models of point-bar deposition in which upward fining of grain size and a characteristic vertical succession of stratification types were described. McGowen and Garner (1970) described a model of deposition in point bars of streams with relatively high proportions of bed load to suspended load. They designated such deposits as coarse-grained point bars and noted that in contrast to previously described models, upward fining of sediments is not common in the coarse-grained model and that the vertical sequence of stratification types is different.

Two component facies commonly encountered in Holocene fluvial deposits are recognized in the Dexter fluvial system, a tributary facies and a coarse-grained meander belt facies. Distinction between the two is based mainly on differences in external geometry of the sand bodies and the ratio of channel to overbank deposits. Minor textural differences also exist.

TRIBUTARY FACIES

In the northeasternmost Texas counties (Lamar, Red River, Bowie, Morris, and Cass), the tributary facies comprises essentially the entire Woodbine section. Channel sand and gravel deposits are shown on isopach maps as discrete, elongate sand bodies separated by interchannel areas largely devoid of sand (fig. 3). Axes of elongation of channel sands are subparallel to dendritic in plan view. Section X-X′ (fig. 4), perpendicular to elongation of tributary channel deposits, illustrates their cross-sectional shape and bounding relationships. Individual sand units range from 5 to 20 miles in width and vary in thickness from 10 feet in the north and northeast to more than 100 feet in the south. Nowhere in the facies does the ratio of channel to nonchannel deposits exceed one-half. Channels are erosional at the base, truncating progressively younger underlying units basinward. In southwestern Arkansas, channel sands and gravels rest unconformably on steeply dipping sandstones and shales, whereas in the north-central portion of the study area, Woodbine channels overlie the Buda Limestone of Early Cretaceous age.

Woodbine tributary deposits fit the standard point-bar models of Visher, Allen, and Bernard and Major in at least one respect: They are coarse grained at the base, with lag gravels common, and become progressively finer upward in the sequence, grading into overbank muds at the top. Two typical channel sequences are recognized in cuttings from Magnolia Oil Company No. 1 J. N. Henry in Red River County (fig. 2, C-1). Basal channel lags are very poorly sorted gravelly sand, including various mixtures of quartz, chert, and rock fragments, the size of which varies from granules 2.5 mm in diameter to medium sand. Quartz and chert pebbles up to 10 mm in diameter were also noted in samples. Upward in the sequence, medium sand is the dominant constituent; sand decreases both in mean size and abundance toward the top as overbank deposits, mainly gray, brown, and red mudstones, are encountered.

The electric log pattern typical of channel sequences in the Dexter is illustrated by the logs of many wells penetrating the facies (fig. 4). The sharp initial deflection of the SP and resistivity curves corresponds to the juxtaposition of lithologies across an erosional lower boundary, and the gradually decreasing response at the top of the massive sand reflects a gradual transition from relatively clean channel fill to greater amounts of overbank muds. Admittedly, the shape of electrical curves is in response to a complex of borehole variables of which permeability (indirectly lithology) is only one; however, a definite correlation between facies and E-log configuration was noticed in this and previous studies (Fisher, 1969; Kruger, 1968).

The tributary facies is poorly exposed in Texas, making observation of vertical sequences of stratification types impossible. Trough crossbeds of the Dexter Member that occur in isolated outcrops in northern Lamar and Red River counties are distin-

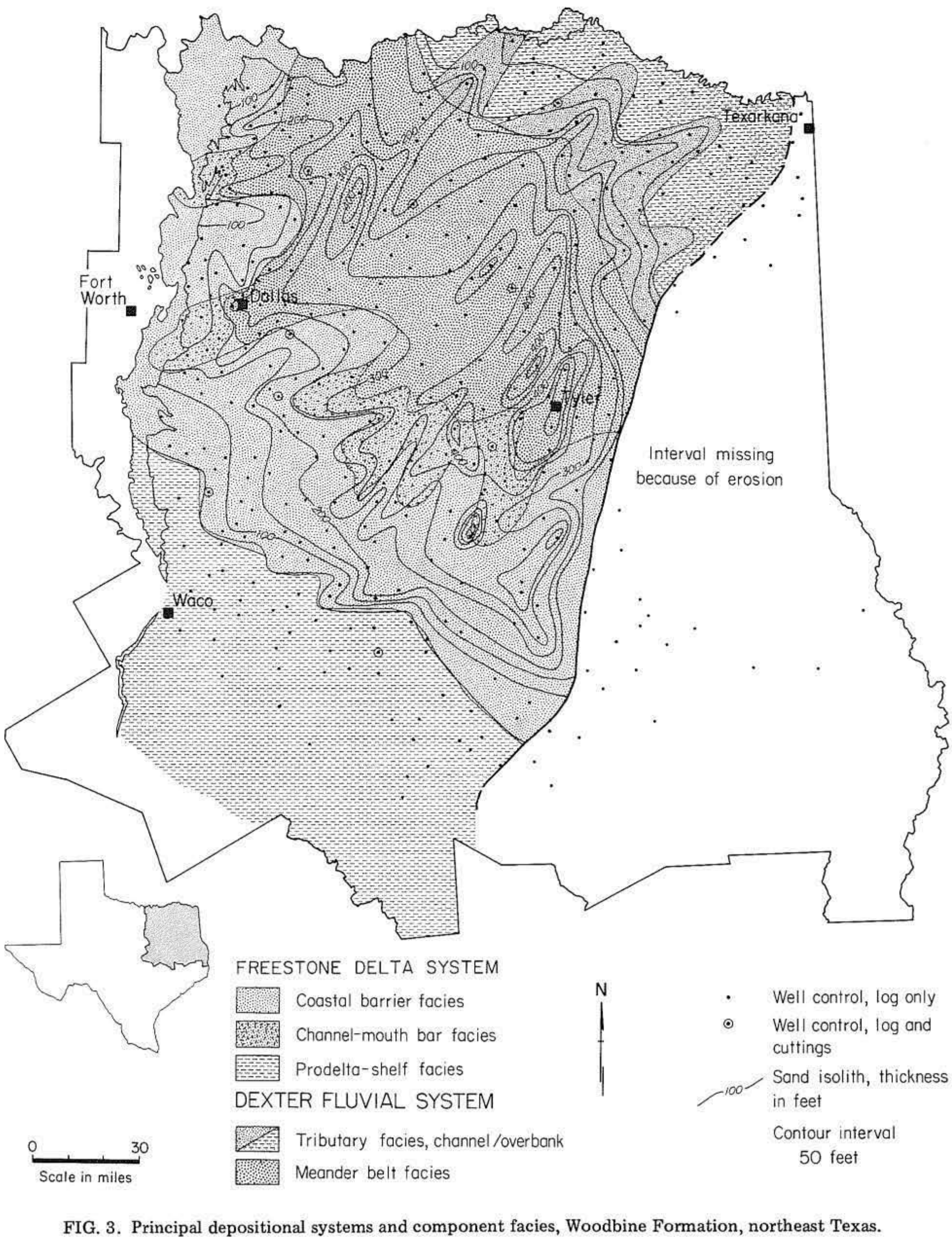

FIG. 3. Principal depositional systems and component facies, Woodbine Formation, northeast Texas.

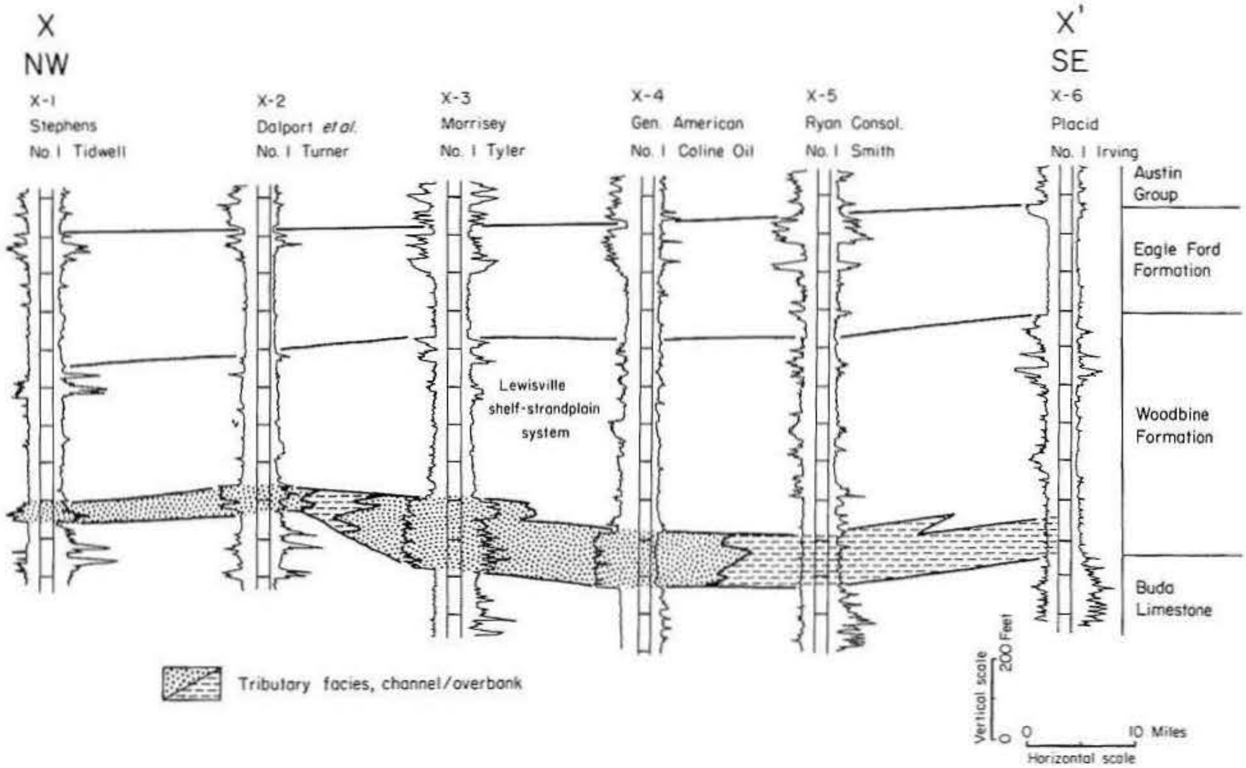

FIG. 4. Cross section, tributary facies of Dexter fluvial system.

guished only with difficulty from terrace deposits of the Holocene Red River fluvial system. Lenses of sandstone enclosed by sandy clay, in which prints of leaves occur, crop out near Arthur's Bluff (Lamar County) on the Red River (Ross et al., 1928) and are thought to represent isolated tributary channels. An extensive gravel unit at the base of the Woodbine and gravel lenses higher in the section occur in outcrop in southwestern Arkansas. These gravels, described by Ross et al. (1928) and Adkins (1933), are largely pebble- and cobble-sized novaculite and other chert varieties, and rock fragments. Interbedded with the sands and gravels in southwestern Arkansas are volcanic tuffs and lenses and layers of red, brown, and gray shale containing leaves and carbonized wood.

MEANDER BELT FACIES

The meander belt facies occupies a broad belt 50 to 75 miles wide immediately down paleoslope from the tributary facies. As the most basinward of the fluvial facies, it interfingers to the south and southwest with the coastal barrier facies of the high-destructive delta system. Sand is the dominant constituent of the facies, comprising practically the entire section in some areas. Interchannel deposits of overbank muds are not well developed.

In contrast to the tributary channel pattern of isolated, elongated sand bodies surrounded by interchannel muds, isoliths of the meander belt facies depict a laterally persistent "blanket" sand geometry, in which individual channels are poorly defined (fig. 3). Pettijohn et al. (1965, p. 134) proposed the term "multilateral" for this type of fluvial sand unit, suggesting that it is a composite of multiple channels of various trends coalescing to form a laterally extensive body of sand. Allen's figure 35C (1965, p. 164) illustrates development of the geometry of multilateral sand bodies. Recognition of individual multilateral sands in the Dexter meander belt facies is not possible with the spacing of control used in this study; however, several elongated isopachous highs oriented roughly parallel to regional paleoslope approximate the location of major fluvial axes. These north-south and northeast-southwest-trending axes (fig. 3) are separated by less sandy areas in which overbank deposits are more extensive. Nowhere in the facies, however, do overbank muds comprise more than 20 percent

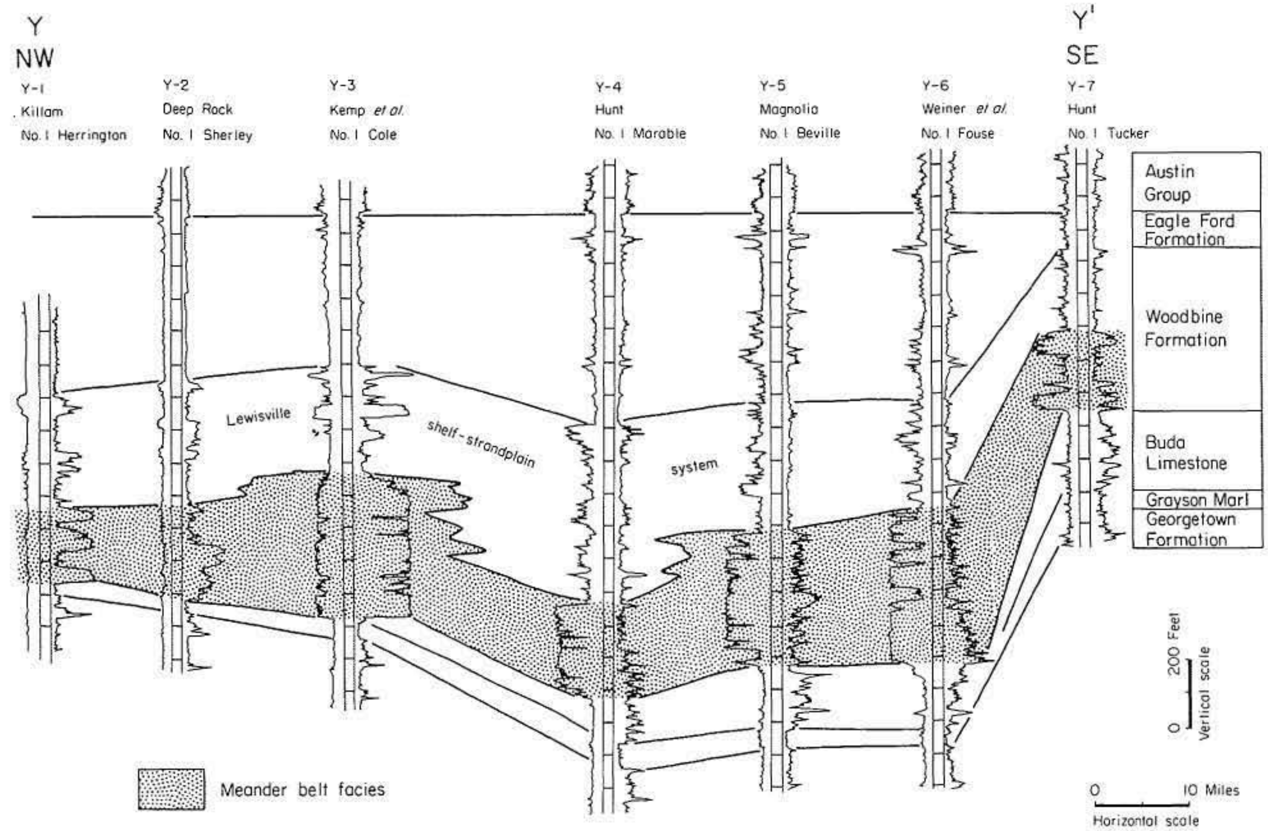

FIG. 5. Cross section, meander belt facies of Dexter fluvial system.

of the section. Channel sands are massive, varying in thickness from 380 feet in major axial areas to 180 feet in intervening areas. Sections intersecting the meander belt facies perpendicular to elongate axes emphasize the overall uniformity of sand thickness throughout the facies and illustrate bounding relationships (erosional) with the underlying Buda Limestone (fig. 5).

Channel sequences in this facies are similar to those of the tributary channel facies in several respects. Mineralogy of constituent grains is similar. Channel deposits are characterized by erosional lower boundaries and consist of products of channel lag and point-bar deposition. Stratification types include festoon trough-fill crossbedded sands in the lower parts of sequences, overlain by tabular planar foreset beds of moderate size deposited in lower point bars. Large-scale foreset beds, deposited as chute bars, and other chute-fill deposits occur upward in the sequence in some areas. Stratification types characteristic of upper point-bar deposition in standard (fine-grained) models are absent. Unlike the tributary channel facies, meander belt channel deposits do not exhibit the pronounced "fining upward" property characteristic of the standard point-bar model, primarily because constituents of the facies are of a rather uniform size throughout.

Deposits of the meander belt facies are present in outcrop of the Dexter Member. Lithology of the member is predominantly sandstone interbedded with minor lenses and other irregular layers of silty and sandy clay. Sands are largely composed of fine, subrounded to subangular, quartz grains with abundant siderite or hematite grains and fragments of lignitic material scattered throughout. Most sands in outcrop are heavily cemented by hematite and form moderate bluffs. Clays are commonly silty or sandy and are tan mottled with red, brown, and yellow hematite stain. Exposures of the Dexter are numerous but restricted in lateral and vertical extent so that complete channel sequences are not commonly exposed.

The sequence that crops out in a railroad cut of the Gulf, Colorado, and Santa Fe Railway 4.4 miles due east of Argyle in central Denton County (Appendix, L-1) exhibits most typical Dexter stratification types (fig. 6). Trough-fill cross-

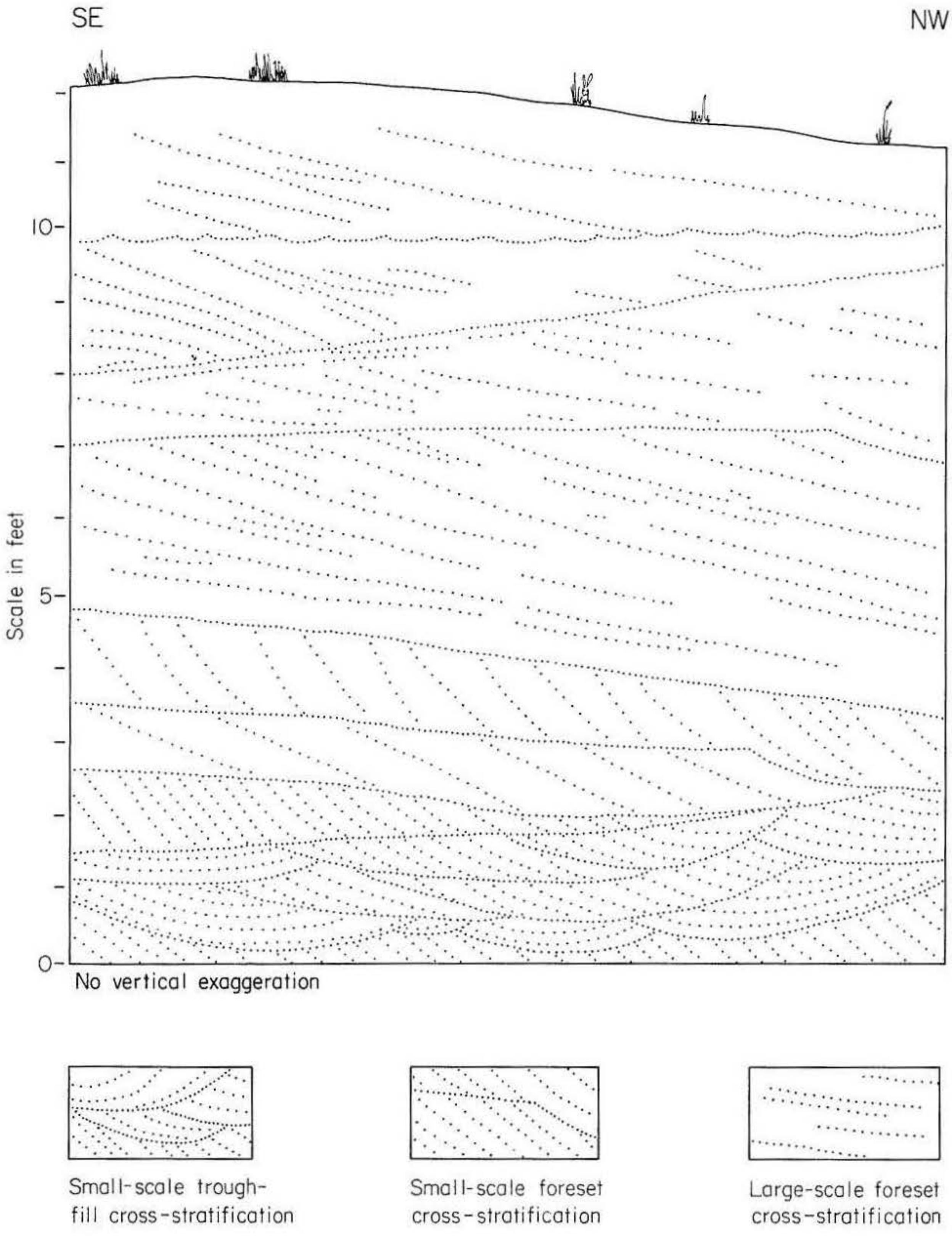

FIG. 6. Sequence of stratification types, Dexter fluvial system. Railroad cut, 4½ miles east of Argyle, Texas (Appendix I, L-1).

stratification and foreset cross-stratification, both interpreted as lower point-bar deposits, make up the entire section. The lower 5 feet of section exposed is dominated by small concave erosional scours or troughs less than 6 inches deep and 6 to 12 inches wide, filled with laminae of fine sand which either parallel or intersect the lower surface at a low angle. Larger foreset units, mostly less than 2 feet thick and bounded by broad, almost planar surfaces, are the dominant bedding type throughout the remaining 25 feet of exposed section.

Several sequences of channel fill of the meander belt facies are recognized in cuttings from Stanolind Oil and Gas Company No. 1 M. C. Caston, which penetrated a section in Hunt County near a major multilateral sand axis (fig. 2, C-2). Grain size of channel deposits in the Caston well is coarser than at outcrop, with medium sand (mean 0.4 mm) and fine sand (mean 0.15 mm) comprising the bulk of the fill and coarse to very coarse sand occurring in lesser amounts. Constituent grains are largely quartz; however, green and white mica flakes, volcanic rock fragments, lignite particles, and euhedral volcanic quartz grains also occur. Most sands are tan to greenish white and are moderately sorted, although some of the coarser sands are poorly sorted. Mudstones in cuttings from the Caston well are commonly gray, tan, brown, red, and purple, and most are silty or sandy. Finely macerated bits of lignitic material and mica flakes are abundant throughout the section. Similar sections, including isolated conglomerates, have been described in the core record of Humble Oil & Refining Company No. 1 Floy K. Williams in the Hawkins field, Wood County (Wendlandt et al., 1946, pp. 1836-1838), (fig. 2, C-3), and in other wells located throughout the area. Electric log patterns of such wells are similar to those of the tributary facies, although individual sands are much thicker, and the "fining upward" pattern is not as common (fig. 5).

HIGH-DESTRUCTIVE DELTA SYSTEM

The high-destructive Freestone delta system, developed immediately downslope from the Dexter fluvial system, is by far the most significant Woodbine depositional system in terms of volume of sediment deposited, areal extent, and occurrence of petroleum. In plan view the system occupies a broadly arcuate belt approximately 100 miles wide, extending from the Sabine Uplift on the southeast to the outcrop on the west (fig. 3). Sandstone is the dominant lithology in the landward half of the system; on a regional scale, isopachs of deltaic sands trend perpendicular to major fluvial axes. To the south and southwest, prodelta and shelf muds comprise the bulk of the section.

High-destructive delta systems differ basically from high-constructive types such as the Mississippi (Holocene) and Rockdale (Eocene) systems in the relative amounts of fluvial and marine influence evidenced in gross facies composition. Fisher (1969, p. 239) discussed the differences as follows:

> The fluvial or fluvially influenced facies of the system are constructive, that is, they are the product of progradation and aggradation. Marine facies in delta systems result from reworking or modification of fluvially introduced sediments, and in the context of deltation, comprise destructional facies. Delta systems made up of a large proportion of fluvially influenced (constructive) facies are considered *high-constructive* systems; systems consisting predominantly of marine-influenced (destructive) facies are *high-destructive* systems.

Holocene examples of high-destructive deltas include the Appalachicola River delta of the northeastern Gulf of Mexico, the Rhone River delta on the northern Mediterranean coast, the Tabasco coast of Mexico, the Surinam coast in northern South America (Holocene-Pleistocene), and numerous others (Fisher, 1969). In terms of areal extent, and distribution and composition of component facies, the Surinam coast is considered analogous to the coastline along which the Woodbine was deposited. This system comprises a series of coastal barriers or beach ridges which coalesce laterally to form a continuous coastline only locally interrupted by fluvial channels (fig. 7).

Fisher (1969, p. 260) summarized high-destructive deltas in terms of a number of characteristic features that are also largely analogous to Woodbine delta development. (1) The source is relatively local and is drained by numerous small to moderate braided or meandering channels that are generally less than 200 miles long and are relatively uniformly spaced along basin margins. (2) Volume of sediment input of fluvial systems is moderate and the proportion of bed load to suspended load is high. Rate of sediment input is sporadic, such that constructional and destructional facies are interrelated. Coastal progradation is slight to moderate compared with high-constructive systems. (3) Constructional sequences are poorly developed. Because meandering

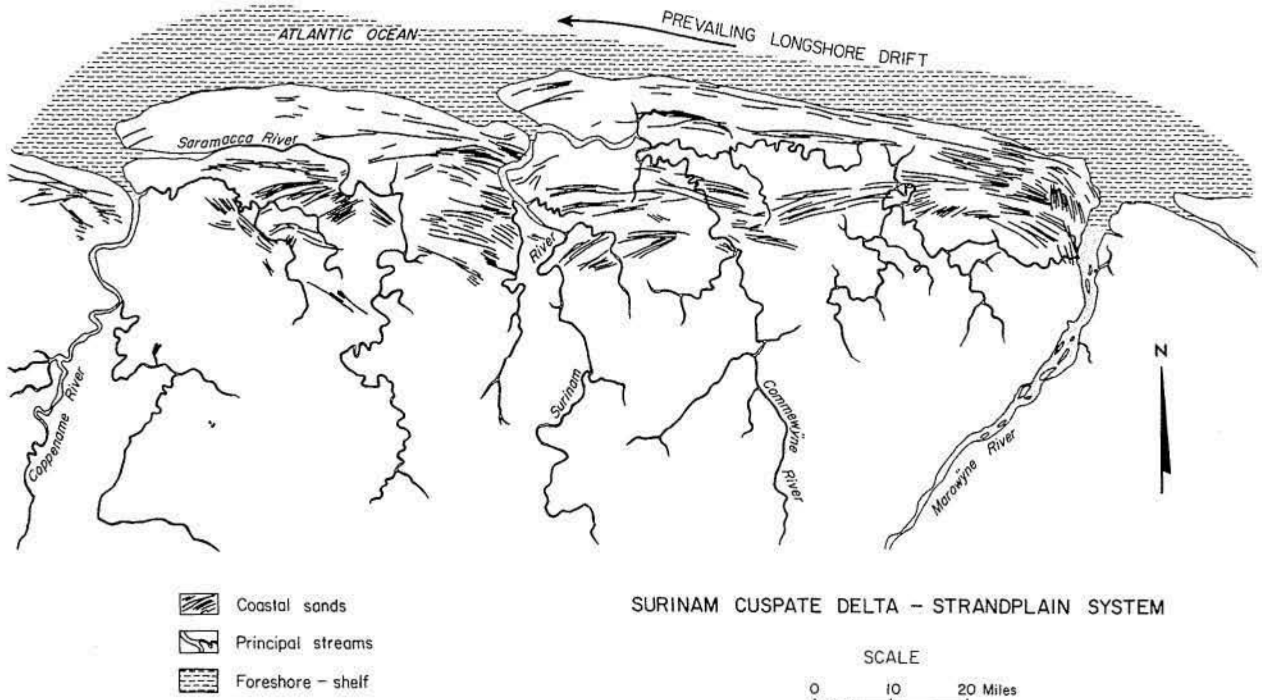

FIG. 7. Principal depositional environments, Surinam coast, northern South America. From Fisher (1969) modified from Price (1954) after Lindeman (1953).

fluvial channels extend out onto the delta plain, the accumulation of thick organic deposits is interrupted and, therefore, not extensively represented in the rock record. (4) Destructional marine facies are volumetrically important and are developed contemporaneously with constructional facies. Extensive transgressions, resulting in embayments with associated strandplain development along their margins, are common. (5) Coastal barriers are well developed proximal to areas of maximum discharge; however, extensive strike-fed systems are lacking. (6) Associated delta flank systems are also poorly developed. (7) The prodelta facies is relatively thin, commonly no thicker than other deltaic facies, and is similar compositionally to non-deltaic shelf facies. (8) Individual lobes are chevron-shaped to cuspate in plan view with axes subparallel to regional strike. (9) Sand/mud ratio is relatively high, and as a result muddy delta plain aggradational deposits are not well developed and fluvial channels are poorly stabilized.

Three distinct component facies of the Woodbine delta system are recognized: progradational channel-mouth bar sands; coastal barrier sands, developed lateral to the channel mouth; and prodelta-shelf muds seaward of the coastline (fig. 8). Criteria for delineating the various deltaic facies include external geometry of facies, position relative to other facies within the system, lithologic composition, sequences of lithology and stratification, and nature of bounding relationships.

PROGRADATIONAL CHANNEL-MOUTH BAR FACIES

In contrast to their counterparts in high-constructive deltas, which are distinct distributaries well stabilized by levees, channels supplying sediment to high-destructive deltas are meandering fluvial channels, and hence their deposits in the rock record are not distinct from facies of the fluvial system. Progradational sequences, which commonly underlie rocks of the meander belt facies in areas proximal to the basinward or downslope limit of the fluvial system, are, however, interpreted as channel-mouth bar deposits.

The progradational nature of such deposits is revealed by a progressive coarsening of sediment upward in the sequence from clay-sized material to fine sand, the result of deposition of bed-load material over progressively finer material previously deposited seaward from the point of fluvial discharge. Channel-mouth bar sands are generally slightly finer

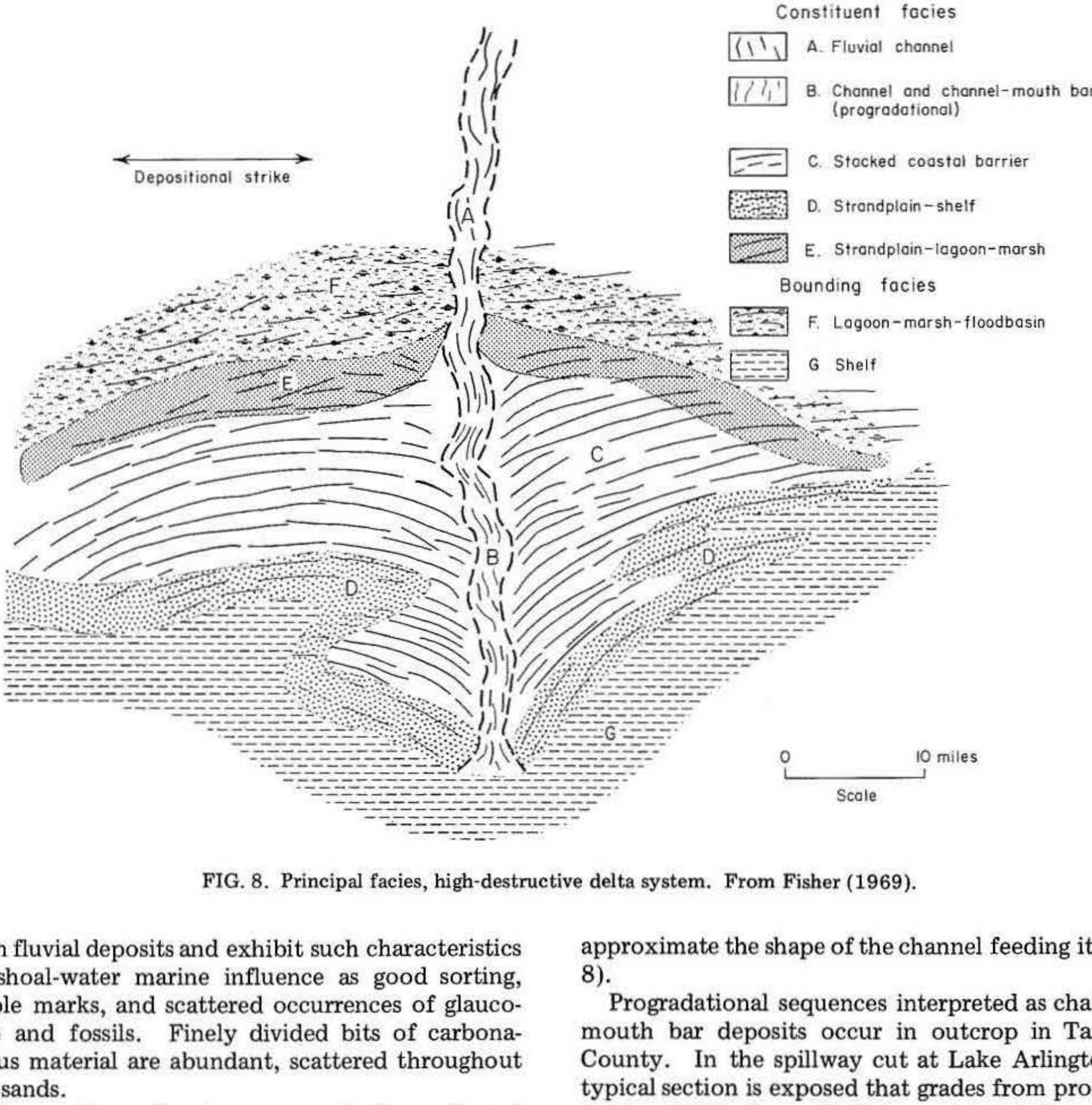

FIG. 8. Principal facies, high-destructive delta system. From Fisher (1969).

than fluvial deposits and exhibit such characteristics of shoal-water marine influence as good sorting, ripple marks, and scattered occurrences of glauconite and fossils. Finely divided bits of carbonaceous material are abundant, scattered throughout the sands.

The position of such sequences both areally and vertically with respect to bounding facies is important, inasmuch as progradational sequences may also be deposited in depositional environments other than channel-mouth bars. In vertical section, channel-mouth bar facies gradationally overlies muds of the prodelta facies and is in turn overridden by channel sands of the meander belt facies. Laterally associated facies are coastal barrier sands. External geometry of the channel-mouth bar facies in high-destructive deltas is not well defined, primarily because the bar is transitional with laterally flanking coastal barrier sands; however, shape should approximate the shape of the channel feeding it (fig. 8).

Progradational sequences interpreted as channel-mouth bar deposits occur in outcrop in Tarrant County. In the spillway cut at Lake Arlington, a typical section is exposed that grades from prodelta muds at the base, through a progradational sequence, and into channel sands of the meander belt facies at the top (Appendix, L-2). The section has been described by Dodge (1969). The lower shale (prodelta) is dark gray and thinly bedded, containing a few thin lenses of siltstone or fine sandstone near the top. Sand and silt lenses increase in abundance, and shale becomes progressively more sandy as the transitional boundary into the channel-mouth bar facies is crossed. Lower portions of this facies are tan argillaceous sandstones containing a few irregular layers of gray sandy shale. Sands become progressively less argillaceous and shale interbeds less abundant upward in the section, grading into thinly bedded (1 inch to 4 inches) fine sandstone which is well sorted and locally ripple marked. Overlying the channel-mouth bar facies are festoon and foreset crossbedded, ferruginous-cemented sandstones of the Dexter meander belt facies.

The existence of the channel-mouth bar facies in the subsurface is interpreted from similar progradational sequences described in lithologic logs of wells drilled in areas near the basinward limit of fluvial channel progradation. The Texas Company No. 1 E. T. Brown in Henderson County (fig. 2, C-4) penetrated a progradational sequence at the base of the Dexter meander belt facies. Location of that well is very near the basinward limit of a major fluvial axis. The sequence represented by cuttings from the well (5,379 to 5,510 feet) coarsens progressively upward from gray, sandy and silty, calcitic, and slightly fossiliferous mudstone into sandy siltstone that is slightly glauconitic and finally into fine to medium, well-sorted sandstone.

The electric log pattern corresponding to the progradational sequence in the subsurface is suggestive of an inverted "Christmas tree" (fig. 9). Initial deflection of the SP curve is weak and irregular, reflecting thin sands and relatively large amounts of mud in basal portions of the sequence. Upward in the sequence deflection becomes progressively greater, in response to increasing proportions of relatively clean sand.

COASTAL BARRIER FACIES

Laterally adjacent to the channel-mouth bar facies along depositional strike is the coastal barrier facies (fig. 3). Sands of this facies are well developed in the Woodbine outcrop in Hill and Johnson counties and eastward in the subsurface to Cherokee and Houston counties, where the facies intersects the Sabine Uplift. Maximum sand thickness in the facies is oriented perpendicular to the major fluvial axes in a broadly arcuate trend. Locally, sand patterns approximate chevrons or cusps, the apexes of which point basinward, roughly depicting individual delta lobes (fig. 8). Coastal barriers are strike-fed and parallel the coast and are accumulated by marine processes. As a result, dominant characteristics of the facies are marine. Sands are largely quartzose, the finest and best sorted of deltaic deposits. Low-angle crossbeds, horizontal laminations, and ripple cross laminations are dominant stratification types. Some sands are fossiliferous and glauconitic, and small amounts of very finely divided carbonaceous material are scattered throughout. Individual sand units are less than 100 feet thick and are separated

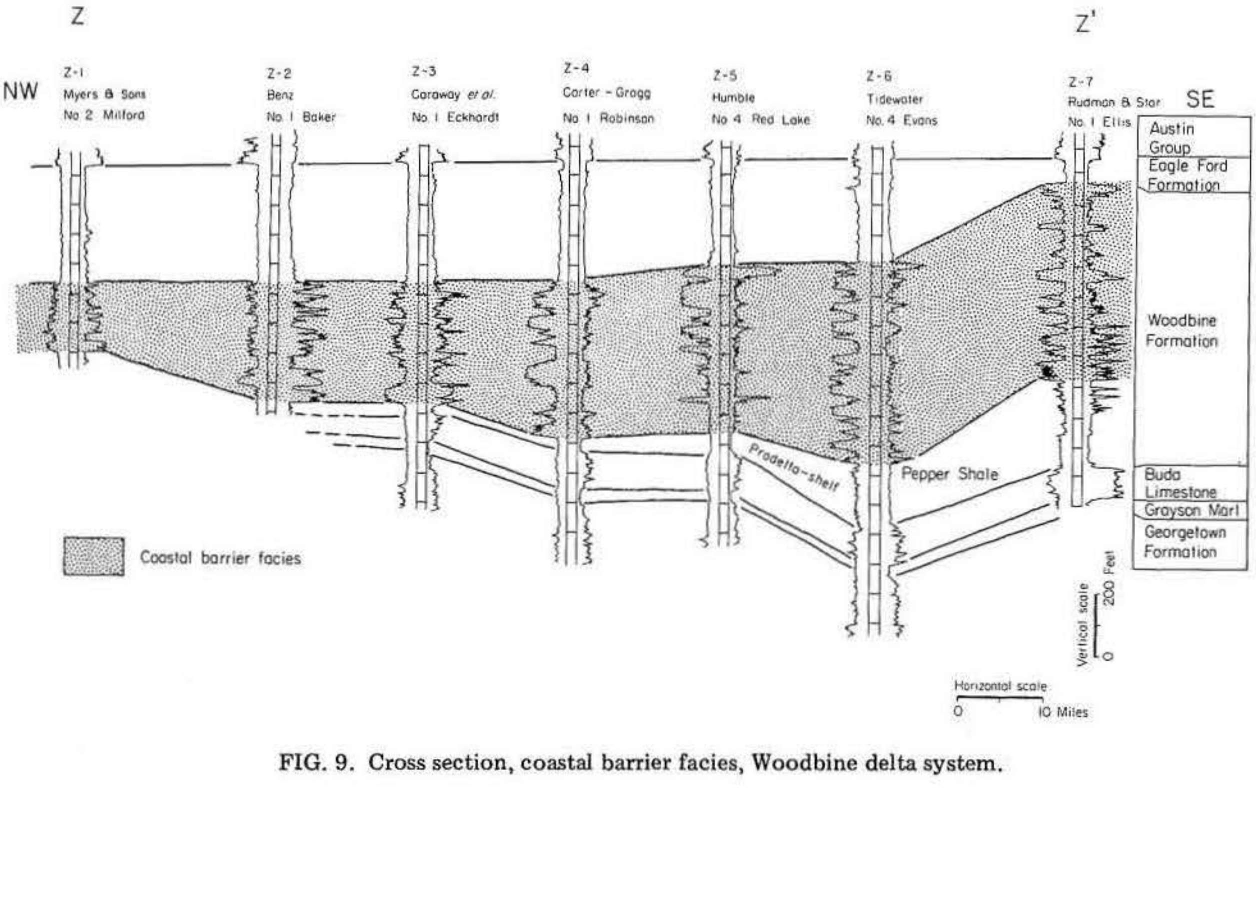

FIG. 9. Cross section, coastal barrier facies, Woodbine delta system.

by shale units; aggregate thickness of sand in the coastal barrier facies commonly exceeds 300 feet. Section Z-Z′ (fig. 9), taken approximately parallel to depositional strike through the facies, illustrates the interbedding of relatively thin, discrete, coastal barrier sands with shale tongues. Composition of shale interbeds is largely a function of the position relative to the coastline at time of accumulation. Those sands developed offshore as barrier bars or islands are interbedded with shelf- and prodelta-type muds, whereas sands developing landward in a strandplain environment tend to be separated by muds typical of lagoonal or marsh development. Figure 8 illustrates the areal relationship of coastal barriers to associated facies within an individual delta lobe.

Outcrop examples of coastal barrier sand development in Woodbine rocks are numerous in Hill and Johnson counties, but exposures are widely scattered areally and limited in vertical extent (Appendix, L-3). External geometry of sand bodies in outcrop is difficult to ascertain because of poor control; however, maximum thicknesses appear to be somewhat isolated in parallel belts, the axes of which trend approximately east-west, coincident with the orientation of near-outcrop isoliths (fig. 3).

Lee (1958) described the petrography of Woodbine rocks that crop out in northwestern Hill County. Lower Woodbine sands, the "Dexter Formation" of Lee's terminology, are mostly moderately sorted and vary in mean grain size from coarse silt to very fine sand. Upper "Lewisville Formation" sands (Lee's terminology) are well sorted; their mean grain size varies from coarse silt to fine sand. Lee found mineral composition to be almost entirely quartz, of which metamorphic quartz and chert represented a very small percentage. Marine fossils occur throughout the section in Johnson and Hill counties; however, they are much more abundant in the upper sands and lower shale. Stephenson (1952) described a varied fauna from numerous localities in the area. Sedimentary structures in the facies consist entirely of parallel bedding, low-angle crossbedding, and ripple marks. Bedding is accentuated by hematite cement concentrated along the less permeable laminae. Individual sand units in outcrop are less than 25 feet thick and are interbedded with dark gray to brown shale. These are massive to thinly bedded and fissile, locally sandy, and contain moderate amounts of lignite fragments. Clay ironstone concretions occur in minor amounts, and jarosite crusts and selenite crystals occur within cracks and along bedding planes.

The coastal barrier sand facies is recognized in the subsurface chiefly by occurrence in well cuttings of sequences comparable to those previously described in outcrop. In the Phillips Petroleum Company No. A-1 Posey (fig. 2, C-5) in eastern Hill County, a number of sand units less than 25 feet thick occur interbedded with shale. Sands are mostly fine and very fine grained, consisting of medium to well-sorted quartz grains weakly cemented with calcite. Minor amounts of finely divided lignitic material, pyrite crystals, and glauconite occur in some sands. Interbedded mudstones are gray, silty, and contain abundant very fine carbonaceous debris. Marine fossils, mostly oysters and gastropods, and minor amounts of white silty micrite also occur at various levels throughout the sequence.

Electric log patterns corresponding to coastal barrier sequences are distinctive; as illustrated by section Z-Z′ (fig. 9), numerous discrete "box-shaped" deflections from the baseline of SP and resistivity curves depict vertically stacked, individual coastal barrier sands isolated by shales. Individual sands are relatively thin and fairly evenly spaced vertically in the sequence, and deflections at the base of individual sands are normally sharp.

PRODELTA-SHELF FACIES

Underlying and interfingering shoreward with coastal barrier and channel-mouth bar sands is the prodelta-shelf facies, representing the most basinward deposition of the Freestone delta system. Rocks of this facies are largely dark, laminated, locally sandy mudstones which contain moderate to large amounts of finely divided carbonaceous debris such as lignite and lignitized wood. Marine fossils and burrows occur in the prodelta-shelf facies somewhat more commonly than in its counterpart in high-constructive delta systems in which rate of sediment accumulation is so great that fossil remains are volumetrically insignificant. They are by no means abundant, however. Thickness of the facies increases regularly toward central parts of the basin, attaining maxima of not more than 300 feet throughout most of its extent. An exceptionally thick accumulation of prodelta-shelf muds occurs in an isolated area encompassing Madison, southwestern Leon, and southern Houston counties, probably because this was a center of sediment influx throughout Buda and Woodbine deposition, and was not affected by the erosion evidenced along basin margins.

In outcrop, the prodelta-shelf facies is preserved in Woodbine mudrocks, including parts of the Pepper Shale in Bell, McLennan, and Hill counties and the lower shale (recently designated the Rush Creek Member by Dodge, 1969) to the north. In Tarrant County (Appendix, L-2), Rush Creek beds are gray, black, and brown shales and thinly bedded sands, which comprise roughly the lower 25 to 30 feet of the section. Shales, which occur mostly in upper portions of the member, are thinly laminated in parallel beds less than 1 inch thick and contain considerable amounts of fine sand-sized fragments of carbonaceous debris. Near the top of the member shales become progressively more sandy and are interbedded with increasing numbers of thin silt and sand lenses, as they grade into channel-mouth bar and coastal barrier sands. A marine fauna (including ammonites, pelecypods, gastropods, and foraminifers) has been described from the Rush Creek beds by several workers, notably Adkins (1933) and Stephenson (1952).

To the south in Hill, Johnson, and Bell counties, the prodelta-shelf facies is present in rocks designated the Pepper Shale, or Pepper Formation. The exact stratigraphic relationship of the Pepper with beds designated Rush Creek has been the subject of considerable controversy, as summarized by Lozo (1951); however, their continuity is demonstrated by north-south cross sections to the east of the outcrop. At the type locality in Bell County (Appendix, L-4), the Pepper is a thinly laminated, purplish-black, noncalcareous shale with abundant jarosite films and selenite crystals occurring on bedding planes and in fractures. Faunal remains in Pepper shales include arenaceous foraminifers and ammonites and mollusks preserved either as impressions or as thin pearly shells (Adkins, 1933).

Rocks of similar lithology have been recovered in the cuttings of numerous wells penetrating portions of the facies in the subsurface. In Placid Oil Company No. 1 Joe S. Weakley in Leon County (fig. 2, C-6), most of the Woodbine section is of lithology similar to that previously described from outcrop. Shales are dark, sandy, and noncalcareous and contain fragments of lignite and fossil shells.

SHELF-STRANDPLAIN SYSTEM

The Lewisville (upper Woodbine) Member of the northern third of the basin was deposited along an extensive coastline marginal to active deltas and is considered distinct genetically from facies of the delta system. Thickness and stratigraphic relationships illustrated in north-south cross sections suggest that upper portions of the delta system are in part correlative with Lewisville deposits.

Mudrocks are dominant volumetrically in the Lewisville Member; they account for the entire section in some areas, notably in Fannin and Lamar counties. Sands occur in relatively narrow lenticular bands oriented predominantly north-south and isolated by intervening muds. Two component facies of the system are distinguished largely on a basis of gross lithology: shelf muds and strandplain sands, accumulated along embayment margins by longshore drift.

SHELF FACIES

The shelf facies developed in the Lewisville Member comprises largely shales. They are bluish gray to black, finely laminated to massively bedded, and contain a varied marginal marine fauna which includes mollusks, ammonites, and arenaceous foraminifers (Stephenson, 1952). Minor amounts of finely divided lignitic material also occur in some of the shales. These rocks are analogous to sediments deposited in a gulf-bottom environment along the southwestern Louisiana coast (Byrne et al., 1959).

One of the most complete sections of the shelf facies of the Lewisville Member is exposed in the Trinity River bank east of FM 157 in Tarrant County (Appendix, L-5). Dodge (1952) described a 106-foot section of which about 70 feet is attributed to deposition in a shallow marine environment. Clays described are dominantly yellow to dark gray, thinly bedded, and include numerous thin irregular laminae of yellow and tan sand, mostly 2 to 6 inches thick. Some of the sands are hematite-cemented and contain molds of small mollusks. Selenite crystals and clay-ironstone concretions are common, particularly in upper portions of the section. Very thin layers of lignite, mostly less than 2 inches thick, occur near the middle of the section.

The interval between 1,100 and 1,200 feet, logged from cuttings from Deep Rock Oil Company No. 1 W. M. Shirley in Collin County (fig. 2, Y-2), is composed largely of rocks similar lithologically to those previously described in outcrop. Sandy mudstone is the dominant lithology. It is dark gray, slightly calcareous, and contains minor amounts of very fine carbonaceous matter and quartz silt. Very fine flakes of mica and authigenic pyrite crystals also occur. Interbedded sands are white to tan, mostly fine grained, slightly calcitic, and contain glauconite, sedimentary rock fragments, and finely comminuted carbonaceous material. Shell material and fish scales occur at various levels throughout the section.

STRANDPLAIN FACIES

In gross geometry, sands of the strandplain facies are parallel lenticular bodies, oriented dominantly north-south, and are isolated by muds (fig. 10). Sand bodies are not persistent in any one area but rather occur at various locations, both areally and in vertical sequence, reflecting the various locations of the embayment margin throughout Lewisville deposition. Individual Lewisville sands are commonly less than 50 feet thick, and maximum aggregate thickness of sands is 135 feet. Sands are mostly fine grained, gray to tan, glauconitic, and commonly ripple marked. Massive accumulations of oyster shells are the most commonly observed fossils; however, a varied macro-fauna has been

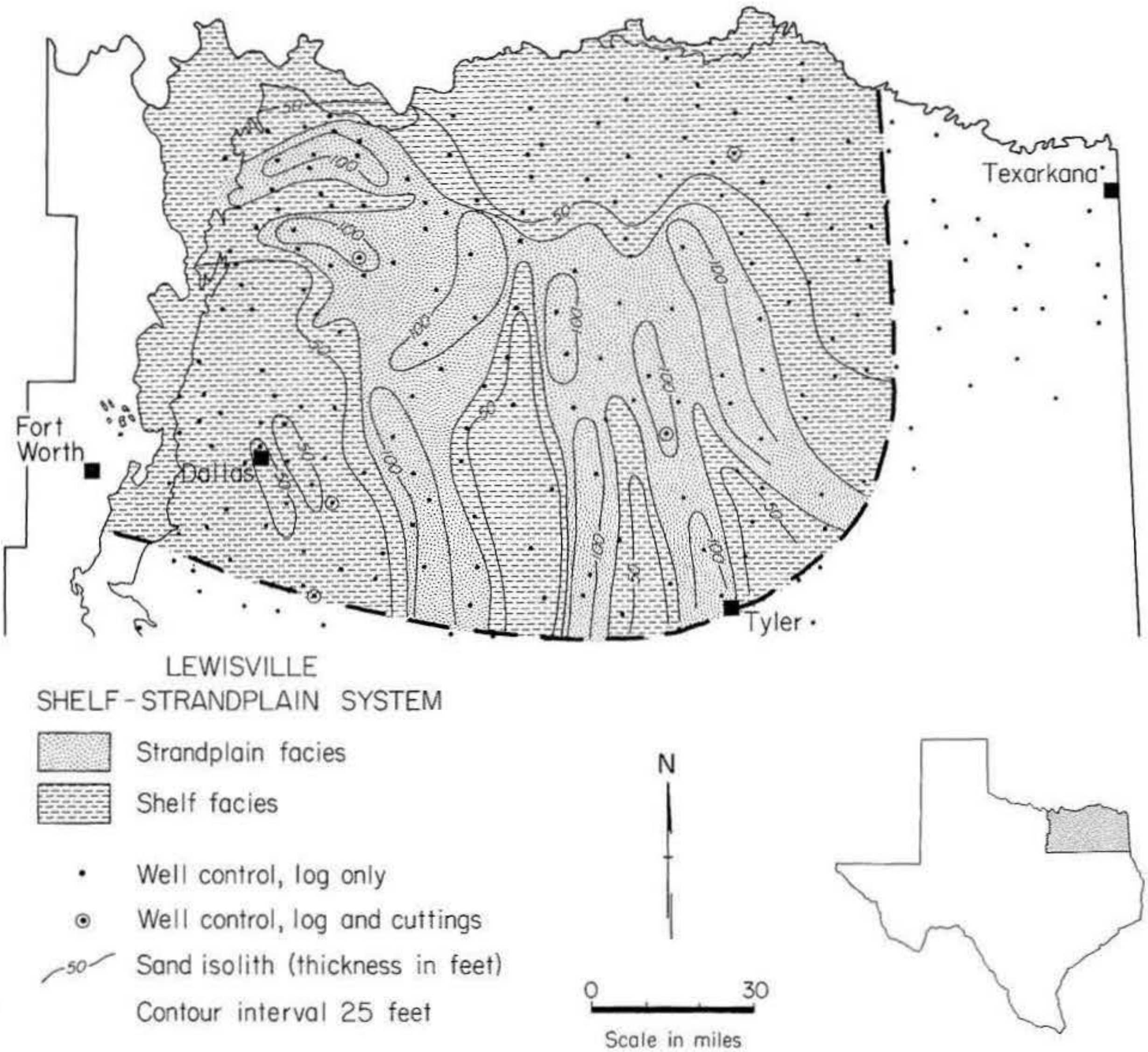

FIG. 10. Sand isopach and distribution of facies, Lewisville shelf-strandplain system.

described by Stephenson (1952) from Lewisville sands. Fossilized tree trunks and lenses of lignitized material occur locally in muds associated with many of the larger sand bodies. These sediments are analogous to those being accumulated as Holocene strandplain or chenier deposits (Byrne et al., 1959).

Outcrop observations of Lewisville rocks are well documented. Taff (*in* Taff and Leverett, 1893) reported a purplish-blue to black clay containing lenses of argillaceous lignite up to 20 feet thick, immediately above Dexter beds in the banks of Timber Creek, near Lewisville in Denton County. Gradationally overlying the lignitic clay is a 25-foot thick sequence of thinly laminated tan sandstone which contains several masses of oyster shells described as reefs by Taff. Shuler and Millican (1932, p. 15), working in the same area, noticed marked lenticularity of sandstone bodies they considered to have been built by "along-shore or other marine currents in the neritic zone." Bergquist (1949) also noted that lenticularity was a common feature in Lewisville sands that crop out along the Red River. He described as characteristic of the Lewisville, glauconitic sandstone and shales similar to those described by Taff. Most lignites and lignitic shales in the area studied by Bergquist occur in his Red Branch Member, between the oyster-bearing sandstones of the Lewisville and the massive crossbedded sands of the Dexter. Dodge (1965) described an "offshore bar" in the Lewisville Member, exposed in a road cut (now covered) on FM 303 near Arlington in Tarrant County. The sand body is lenticular, with its long axis oriented approximately N. 10° W., and overlies brown lignitic shales. The association of lenticular marginal marine sands with marsh deposits, common to all foregoing examples, is considered analogous to Holocene chenier development discussed by Byrne et al. (1959).

The interval from 1,200 to 1,300 feet penetrated by the Deep Rock well previously mentioned includes a sequence of lithologies similar to those described in outcrop. The interval immediately overlies sands of the Dexter fluvial system and is in turn overlain by rocks of the shelf facies. About 30 feet of impure lignite and lignitic shale is basal to the sequence; it is succeeded upward in the section by a fine- to medium-grained, moderately well-sorted sandstone, consisting of well-rounded quartz and sedimentary rock fragments cemented with sparry calcite. Shell material is abundant in the cuttings.

INDIVIDUAL WOODBINE DELTA LOBES

Delineation of individual lobes in the Woodbine high-destructive delta system is difficult because gross geometry of deltaic sand units reflects a continuous aggregate of coastal barriers coalesced laterally between depositional centers by redistribution of deltaic sands along strike. The continuity of barrier development along the Holocene-Pleistocene Surinam coast illustrates the result of coalescing coastal barriers between high-destructive delta lobes (fig. 7). Additionally, as the Dexter fluvial system migrated laterally, depositional centers shifted in response, with the result that individual delta lobes were not persistent in any one area throughout the extent of delta building.

Two general centers of sediment influx are suggested by the distribution of Woodbine fluvial axes (fig. 11). One, comprising two fairly distinct lobes, is preserved in lower portions of the Woodbine in north-central Texas. Much of the western extent of the Dexter fluvial system was deposited by streams which fed these lobes with sediment derived largely from local sources in southern Oklahoma. A second locus of deposition, located in the central basin area, encompasses a complex of multiple discharge centers in which individual lobes are indistinguishable. Deltas were persistent in this area throughout Woodbine deposition, fed by a network of streams represented by extensive Dexter fluvial deposits in northeastern portions of the basin. These streams presumably drained an area which included southwestern Arkansas as well as southern Oklahoma.

SOURCE AREAS OF WOODBINE SEDIMENTS

Integration of regional sand dispersal patterns within the Woodbine with the results of petrographic provenance studies by previous workers suggests a complex source, contributing sediments derived from terrains that included sedimentary, metamorphic, and igneous rocks. Early investiga-

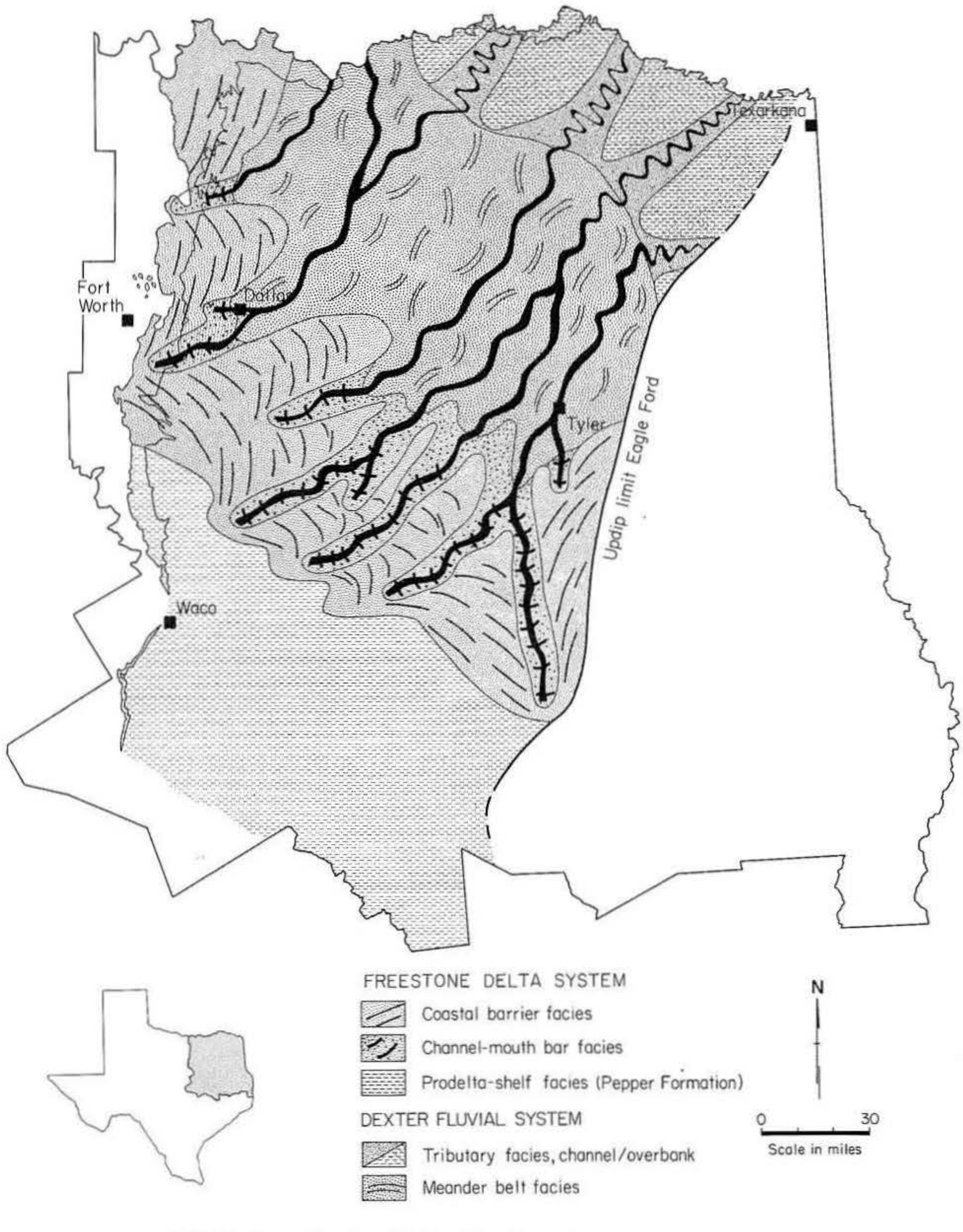

FIG. 11. Depositional model, Woodbine Formation, northeast Texas.

tors noted that Woodbine sands and gravels of southwest Arkansas were interbedded with large amounts of volcanic material locally derived from the Cretaceous Centerpoint volcanic area (Ross et al., 1928). Other workers recognized volcanic materials both as constituent grains and as matrix material in Woodbine rocks in outcrop and in subsurface. Among them, Bergquist (1949) described as typical, tuffaceous Woodbine sand composed of fine-grained, well-rounded quartz grains and scattered flakes of green mica in a greenish, normally calcitic, tuffaceous matrix. Associated shales described by Bergquist were also in part micaceous. In the present study, similar sands and shales were recognized in well cuttings.

A. S. Cotera (1956) investigated the petrography of the uppermost Woodbine sand in subsurface cores from a seven-county area in the south-central portion of the study area. He described predominately quartz, including metamorphic and common varieties, volcanic rock fragments, chloritic clay, glauconite, chert, feldspar, micas, and a number of heavy minerals common to most sandstones. Kyanite and staurolite, considered diagnostic of a high-rank metamorphic source, were, however, notably absent. As a result of his study, Cotera postulated two distinct major sources, one to the east in the southern Appalachians contributing metamorphic constituents (mostly metaquartzite) to the Woodbine, and a second to the north in the Ouachita Mountains and the mid-continent region supplying the bulk of the remaining minerals (plutonic and sedimentary). Additionally, Cotera acknowledged the contribution of the Centerpoint volcanic area in southwestern Arkansas, although he implied that it was of relatively minor importance.

Subsequent investigators of Woodbine petrology, Lee (1958) and Beall (1964), observed mineral suites like Cotera's with the exception that Lee noted minor amounts of kyanite and staurolite and Beall reported traces of staurolite. Their conclusions regarding Woodbine source areas generally agreed with Cotera's. Dodge (1965) reported a suite similar in most respects to those of previous workers except that orthoclase comprised an abnormally large percentage (12 to 30 percent) of the constituents. He concluded (p. 34) that the sandstone was partially derived from older sedimentary rocks to the west and partially from sedimentary and igneous rocks in the Arbuckle Mountains area of Oklahoma.

As depicted by elongated isopach maxima (fig. 3), Woodbine fluvial axes are oriented predominantly north-south and northeast-southwest; their updip extremities lie unconformably upon Paleozoic rocks of the Ouachita and Arbuckle Mountains in southwestern Arkansas and southern Oklahoma. These areas, as potential sources of Woodbine sediments, encompass a wide range of sedimentary rock types, as well as moderate amounts of volcanic and plutonic igneous rocks and weakly metamorphosed sediments. All Woodbine constituents, including metamorphic quartz, could conceivably have been derived from rocks similar to those now exposed in these areas.

No evidence for a source to the east in the southern Appalachians was encountered in the present study; however, neither may such a source be entirely discounted as a contributor of minor amounts of high-grade metamorphic materials, on the basis of present evidence. As suggested by Lee (1958, p. 68), the Sabine Uplift probably did not constitute a barrier to the alleged westward movement of material from the southern Appalachians by longshore currents until near the end of Woodbine deposition.

DEPOSITIONAL HISTORY

Following or near the end of deposition of the Buda Limestone, an episode of uplift in the northeast Texas area resulted in erosion of the Buda west and north of a line roughly parallel to the present Woodbine outcrop. The progressive thinning and eventual absence of the Buda in cross sections intersecting this line have been attributed by most investigators to sub-aerial erosion. Additional evidence for erosion includes the following: Erosional remnants of Buda Limestone have been reported in outcrop in Hill County (Adkins, 1933) and in Denton County (Winton, 1925). Beall (1964) noted thin lenticular "shelly shale" zones with erosional contacts that included numerous reworked Del Rio fossils and suggested that they represented eroded Del Rio and Buda material accumulated by marine processes. Dodge (1952) reported a similar basal conglomerate that contained reworked Grayson (Del Rio) material occurring near Arlington in Tarrant County. Bergquist described a locality in Grayson County in which a basal conglomerate containing abundant *Gryphaea mucronata* is "channelled through the lower part of the Grayson marl to rest on Main Street limestone" (1949, sheet 2).

Transgressive marine deposits immediately overlie the eroded Washita surface throughout much of northeast Texas. Basal shales containing marine fossils represent initial Woodbine deposition in southern and western portions of the study area, including lower parts of the Rush Creek Member and the Pepper Shale of formal outcrop terminology (fig. 12, A). Thin, locally conglomeratic sandstones occur at the base of the lower shale in some areas, representing deposition along a transgressive shoreline. Quartzose constituents were supplied by longshore transport from the northeast, and minor amounts of locally derived material were generated from the eroded Washita surface. Beall (1964, p. 122) suggested a major deltaic dispersal center to the west, apparently located in Johnson County, that derived its sediment from the Paleozoic outcrop to the north and west in Oklahoma. No evidence to support this suggestion was advanced by Beall, and none has been encountered in the literature or in the present study.

Progradation of principal Woodbine depositional systems from the north and northeast apparently began contemporaneous with deposition of transgressive deposits in the south and west (fig. 12, A). Sands and gravels of the Dexter fluvial system lie immediately above eroded Lower Cretaceous rocks in northeasternmost Texas, southeastern Oklahoma, and southwestern Arkansas (fig. 13). In areas down depositional slope, basal transgressive shales are gradationally overlain by sands and shales of the Freestone delta system. Figure 12, B, illustrates paleogeography of northeast Texas during maximum progradation of Freestone deltas.

Streams feeding Freestone deltas had migrated far to the east by the time Lewisville beds were deposited, as indicated by the complete absence of fluvial development in upper Woodbine rocks throughout most of the area previously occupied by the Dexter fluvial system. Modification of the drainage network likely was initiated by renewed uplift in southern Arkansas which progressively extended toward the southwest, through northwestern Louisiana and into the Sabine Uplift area of northeast Texas. Despite this lateral shift in sediment supply, the delta system is persistent throughout the entire Woodbine section in central portions of the basin. Paleogeography of northeast Texas near the end of Freestone delta building included the extensive Lewisville embayment to the north of principal deltas (fig. 12, C).

Following or near the end of Woodbine deposition, material eroded from the Sabine Uplift was redeposited along its flanks by nearshore processes (probably fed by fan-deltas), forming a discrete sand body (informally denoted Harris Sand in this study) that has been variously correlated with the Eagle Ford and Woodbine Formations. In cross sections that intersect the uplift in Trinity County, the sand appears to be distinct from both Eagle Ford and Woodbine sands. In the Houston-Walker-Madison County area, the Harris forms a massive wedge-shaped fan of sand, which thickens to approximately 400 feet adjacent to the uplift. A similar, though not so pronounced, example of Harris Sand development occurs in the Texarkana area, and it is likely that sands genetically related to the Harris occur in other areas marginal to the uplift. Figure 12, D, illustrates the distribution of environments during deposition of the Harris Sand.

Nichols (1964) noted the potential of sands designated Harris in the present study as petroleum reservoirs along the Angelina-Caldwell flexure, suggesting that they were deposited in deltaic and other nearshore marginal marine environments. Because of the paucity of well control in this area and the difficulty with which the Harris is recognized, little in the way of refinement of Nichols'

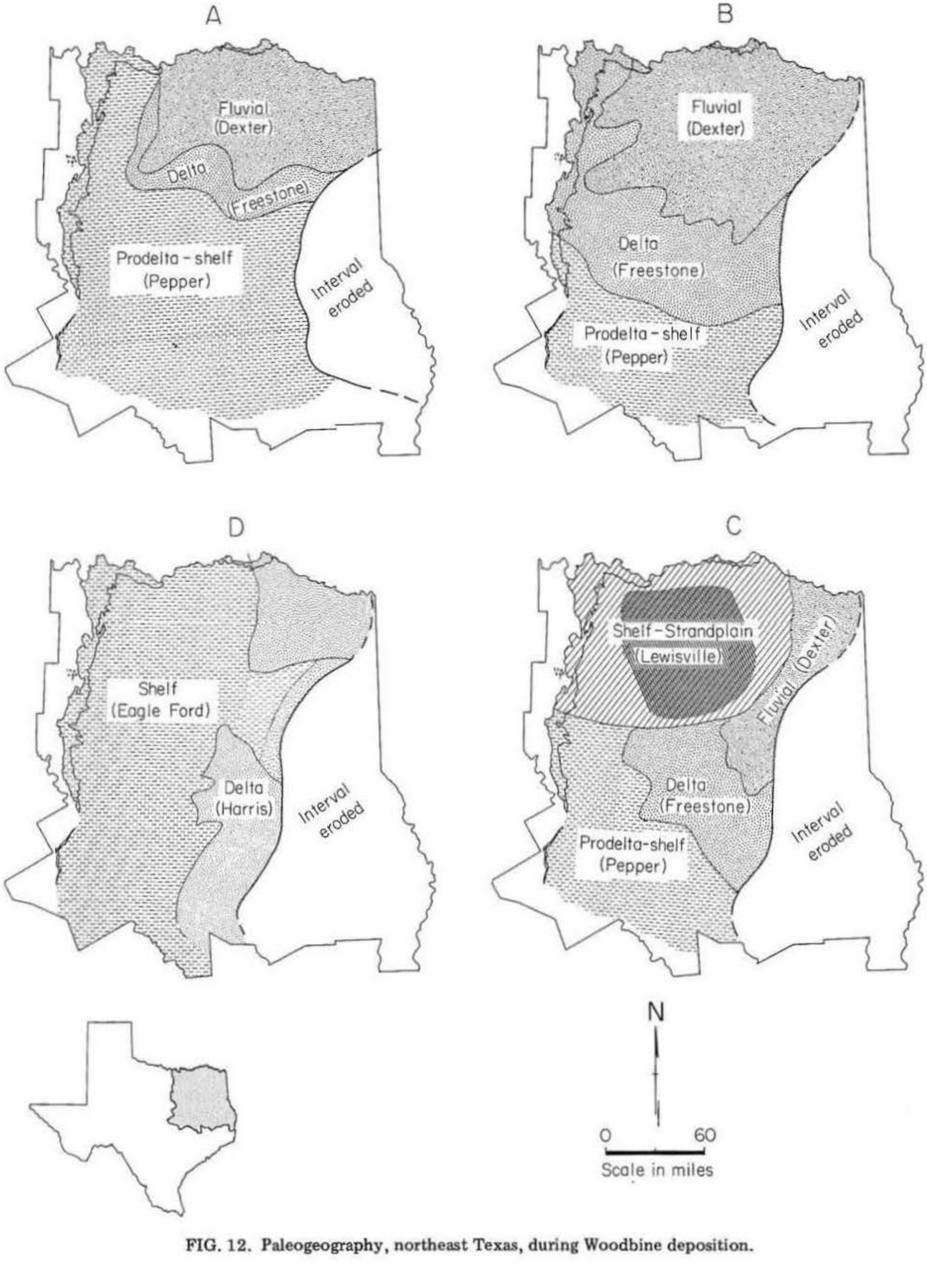

FIG. 12. Paleogeography, northeast Texas, during Woodbine deposition.

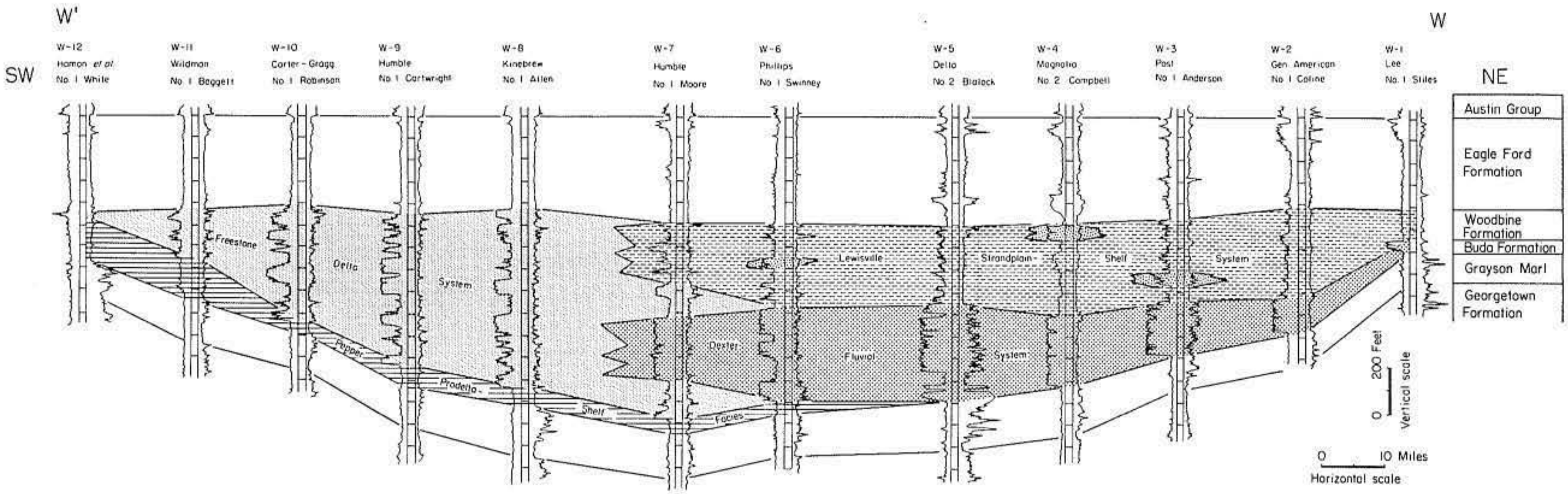

FIG. 13. Cross section, parallel to paleoslope, Woodbine Formation, northeast Texas.

observations has been accomplished by this study.

To the west of the Sabine Uplift, Eagle Ford shale was deposited contemporaneous with Harris Sand development. As basin subsidence exceeded influx of sand to Harris fan-deltas, Eagle Ford seas transgressed the uplift, terminating Woodbine deposition in northeast Texas.

OCCURRENCE OF OIL AND GAS

Facies control of oil and gas occurrence on a regional scale is evidenced by the close correspondence of Woodbine producing trends to distribution of depositional systems (fig. 14). By far the most productive system-related trend is deltaic, predominantly comprising the coastal barrier sand facies. Significant production is also related, however, to strandplain sands of the Lewisville shelf-strandplain system.

Woodbine fields have resulted from a variety of structural traps, including faults, salt domes, and other domal features, as well as from more subtle stratigraphic-type traps such as those created by facies changes and erosional truncations. On a regional scale, facies control is at least as important as structure. Necessary conditions for the formation and accumulation of petroleum occur in both Woodbine productive trends. Thin, well-sorted sands interbedded with and isolated by organic-rich prodelta-shelf and marsh mud, create an association of potential reservoir, reservoir seal, and source beds in close proximity. Deltaic facies are, of the two, the more favorable in that sand bodies are more abundant due to vertical stacking of coastal barriers. It is from sands of this nature that the preponderance of oil and gas is produced in the East Texas field.

In addition to the coincidence of Woodbine production with deltaic and strandplain sands, many large-scale structural features productive from other horizons are conspicuously barren in the Woodbine due to lack of concurrence with a productive trend. A notable example is the Mexia-Talco fault zone north of Kaufman County (fig. 1). With the exception of two minor fields in Hunt County, this structural zone does not coincide with sands of the productive strandplain trend.

SUMMARY

The Woodbine Formation comprises largely terrigenous sediments eroded from Paleozoic sedimentary and weakly metamorphosed sedimentary rocks of the Ouachita Mountains in southern Oklahoma and southwestern Arkansas, and subsequently deposited in a complex of nearshore environments marginal to a broadly subsiding basin that encompassed most of northeastern Texas. Recognition of three distinct depositional systems in Woodbine rocks—a fluvial system, a high-destructive delta system, and a shelf-strandplain system—is based on a regional outcrop and subsurface investigation (fig. 15). In this study, external geometry of framework sands was evaluated with the added dimension of outcrop observations of lithology, sedimentary structures, fossil occurrence, and bounding relationships.

The Dexter (lower Woodbine) fluvial system, composed of two facies—a tributary channel facies and a meander belt facies—is located in the north and northeast part of the basin. Inasmuch as the facies are similar in gross lithology, stratification types, and bounding relations (erosional) with underlying units, their distinction is based largely on external geometry of sands in the facies and the ratio of channel to non-channel deposits.

Three component facies are recognized in the Freestone high-destructive delta system dominant to the south and southwest of the fluvial system—a prodelta facies, composed almost entirely of muds; a channel-mouth bar sand facies; and a coastal barrier sand facies, developed adjacent to channel-mouth bars. The two sand facies are alike in terms of general lithology and stratification types and are laterally transitional with each other. Hence position with respect to bounding facies, both areally and vertically, is important in distinguishing the two. Additionally, the channel-mouth bar facies is characterized by a distinct progradational sequence at its base.

Adjacent and to the north of principal deltaic facies, in much the same area previously occupied by the Dexter fluvial system, is the shelf-strandplain system represented in the Lewisville Member (upper Woodbine). Based on differences in gross lithology, two facies are delineated—the shelf mud facies, composed largely of shales; and the strandplain facies, composed of rather isolated, elongate sand bodies

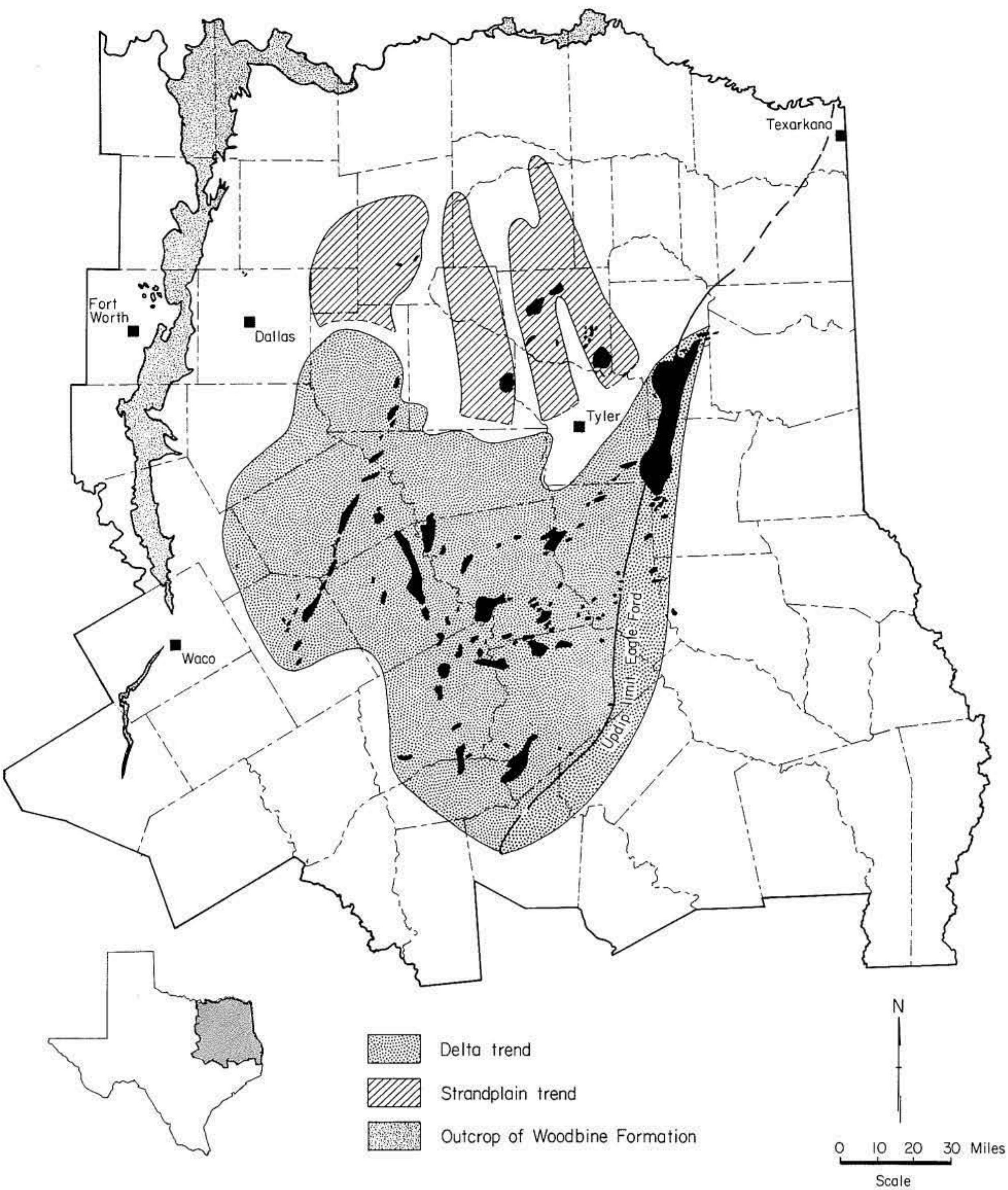

FIG. 14. Occurrence of oil and gas, Woodbine Formation, northeast Texas. Modified from Sellards and Hendricks (1946).

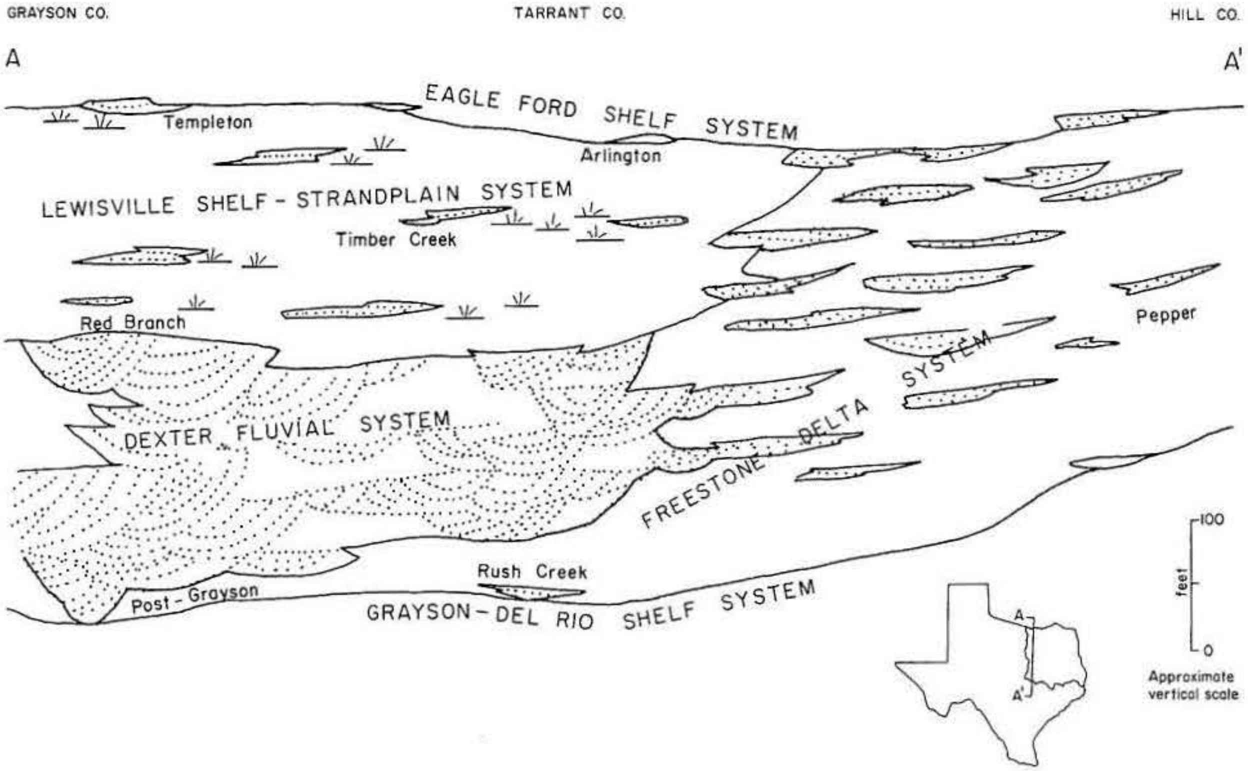

FIG. 15. Diagrammatic Woodbine outcrop section, Grayson County to Hill County, Texas. Names on the section apply to outcrop stratigraphic units named by earlier workers.

accompanied by thin lenses of impure lignite and lignitic shale.

Renewed uplift in southwestern Arkansas, initiated during deposition of upper Woodbine rocks, progressed toward the southwest into the Sabine Uplift area. This resulted in the erosion of Woodbine material, which was subsequently redeposited as the Harris Sand. With continued subsidence of the basin and cessation of sediment influx to Woodbine depositional systems, a regional transgression by the Eagle Ford shales inundated all but the most eastward portions of the basin.

REFERENCES CITED

ADKINS, W. S. (1933) The Mesozoic systems in Texas, *in* The geology of Texas, Vol. I, Stratigraphy: Univ. Texas Bull. 3232 (Aug. 22, 1932), pp. 239-518.

ALLEN, J. R. L. (1965) A review of the origin and characteristics of Recent alluvial sediments: Sedimentology, vol. 5 (special issue), pp. 91-191.

BARROW, T. D. (1953) Mesozoic stratigraphy and structural development of the East Texas Basin: Stanford Univ., Ph.D. dissertation, 222 pp. (unpublished).

BEALL, A. O. (1964) Fabric and mineralogy of Woodbine sediments, east-central Texas: Stanford Univ., Ph.D. dissertation, 171 pp. (unpublished).

BERGQUIST, H. R. (1949) Geology of the Woodbine Formation of Cooke, Grayson, and Fannin counties, Texas: U. S. Geol. Survey, Oil and Gas Inv. Prelim. Map 98, 2 sheets.

BERNARD, H. A., and MAJOR, C. F., JR. (1963) Recent meander belt deposits of the Brazos River: An alluvial "sand" model: Bull. Amer. Assoc. Petrol. Geol., vol. 47, p. 350.

BYRNE, J. V., LEROY, D. O., and RILEY, C. M. (1959) The chenier plain and its stratigraphy, southwestern Louisiana: Trans. Gulf Coast Assoc. Geol. Socs., vol. 9, pp. 237-259.

COTERA, A. S. (1956) Petrology of the Cretaceous Woodbine Sand in northeast Texas: Univ. Texas, Austin, M.A. thesis, 189 pp. (unpublished).

DODGE, C. F. (1952) Stratigraphy of the Woodbine Formation in the Arlington area, Tarrant County, Texas: Field and Laboratory, vol. 20, pp. 66-78.

_________ (1965) Genesis of an Upper Cretaceous offshore bar near Arlington, Texas: Jour. Sed. Petrology, vol. 35, pp. 22-35.

_________ (1969) Stratigraphic nomenclature of the Woodbine Formation, Tarrant County, Texas: Texas Jour. Sci., vol. 21, pp. 43-62.

FISHER, W. L. (1969) Facies characterization of Gulf Coast Basin delta systems, with some Holocene analogues: Trans. Gulf Coast Assoc. Geol. Socs., vol. 19, pp. 239-261.

_________ and McGOWEN, J. H. (1967) Depositional systems in the Wilcox Group of Texas and their relationship to the occurrence of oil and gas: Trans. Gulf Coast Assoc. Geol. Socs., vol. 17, pp. 105-125. *Reprinted as* Univ. Texas, Bur. Econ. Geology Geol. Circ. 67-4.

GRANATA, W. H., JR. (1963) Cretaceous stratigraphy and structural development of the Sabine Uplift area, Texas and Louisiana: Shreveport Geol. Soc. Ref. Rept., Vol. V, pp. 50-95.

HAZZARD, R. T., BLANPIED, B. W., and SPOONER, W. C. (1947) Notes on correlations of the Cretaceous of East Texas, south Arkansas, north Louisiana, Mississippi, and Alabama: Shreveport Geol. Soc. Ref. Rept., Vol. II, pp. 472-481.

KRUGER, W. C., JR. (1968) Depositional environments of sandstones as interpreted from electrical measurements—an introduction: Trans. Gulf Coast Assoc. Geol. Socs., vol. 18, pp. 226-241.

LEE, H. L. (1958) Woodbine strata of northwest Hill County, Texas: Univ. Texas, Austin, M.A. thesis, 69 pp. (unpublished).

LINDEMAN, J. (1953) The vegetation of the coastal region of Suriname, *in* Vegetation of Suriname: vol. 1, pt. I, Kemink en Zoon N. V., x, 135 pp., Utrecht.

LOZO, F. E. (1951) Stratigraphic notes on the Maness (Comanche Cretaceous) Shale, *in* The Woodbine and adjacent strata of the Waco area of Central Texas: Fondren Sci. Ser. No. 4, Dallas, pp. 65-91.

McGOWEN, J. H., and GARNER, L. E. (1970) Physiographic features and stratification types of coarse-grained point bars: Modern and ancient examples: Sedimentology, vol. 14, pp. 77-111.

NICHOLS, P. H. (1964) The remaining frontiers for exploration in northeast Texas: Trans. Gulf Coast Assoc. Geol. Socs., vol. 14, pp. 7-22.

PETTIJOHN, F. J., POTTER, P. E., and SIEVER, R. (1965) Geology of sand and sandstone—conference: Indiana Univ., Indiana Geol. Survey and Dept. Geology, 205 pp.

PRICE, W. A. (1954) Environment and formation of the chenier plain: Texas A&M Research Foundation Project 63, ONR Contract N7onr-48706, 15 pp.

ROSS, C. S., MISER, H. D., and STEPHENSON, L. W. (1928) Water-laid volcanic rocks of early Upper Cretaceous age in southwestern Arkansas, southeastern Oklahoma, and northeastern Texas: U. S. Geol. Survey Prof. Paper 154-F, pp. 175-202.

SELLARDS, E. H., and HENDRICKS, LEO (1946) Structural map of Texas (3d ed., revised): Univ. Texas, Bur. Econ. Geology.

SHULER, E. W., and MILLICAN, O. M. (1932) Lingual deposition in the Woodbine sands along Copperas Branch, Denton County, Texas: A study in marine sedimentation: Field and Laboratory, vol. 1, pp. 15-21.

STEPHENSON, L. W. (1952) Larger invertebrate fossils of the Woodbine Formation (Cenomanian) of Texas: U. S. Geol. Survey Prof. Paper 242, 50 pp.

TAFF, J. A., and LEVERETT, S. (1893) Report on the Cretaceous area north of the Colorado River: Texas Geol. Survey, 4th Ann. Rept. (1892), pp. 239-354.

VISHER, G. S. (1965) Fluvial processes as interpreted from ancient and Recent fluvial deposits, *in* Primary sedimentary structures: Soc. Econ. Paleont. and Mineral., Spec. Pub. No. 12, pp. 116-132.

WENDLANDT, E. A., SHELBY, T. H., JR., and BELL, J. S. (1946) Hawkins field, Wood County, Texas: Bull. Amer. Assoc. Petrol. Geol., vol. 30, pp. 1830-1856.

WINTON, W. M. (1925) The geology of Denton County: Univ. Texas Bull. 2544, 86 pp.

APPENDIX

Location of representative exposures of facies described in text and shown on figure 2.

L-1 — Railroad cut on Gulf, Colorado, and Santa Fe Railway, near its intersection with FM 407, approximately 4½ miles east of Argyle, Denton County, Texas. Stratification typical of meander belt facies of the Dexter fluvial system is well exposed in extensive cuts along both sides of the roadbed.

L-2 — Spillway cut on Lake Arlington south of Spur 303 in Arlington, Tarrant County, Texas (described by Dodge, 1969, pp. 50-51). Approximately 10 feet of prodelta shale at the foot of the cut is gradationally overlain by sand of the progradational channel-mouth bar facies. Typical crossbedded Dexter meander belt sand truncates the channel-mouth bar near the top of this exposure.

L-3 — Road cut on northwest side of FM 934, 3.2 miles southwest of Osceola, Hill County, Texas (Lee, 1958). Thin-bedded to faintly ripple-bedded fine sandstone containing abundant finely divided wood fragments is representative of coastal barrier facies of the Freestone delta system.

L-4 — Cut-bank on east side of Bird Creek, approximately 100 yards northeast of the intersection of U. S. Highway 81 and FM 817, near the city limits of Temple, Bell County, Texas. This is the type locality of the Pepper Shale as described by Adkins (1933, p. 418). The Pepper is interpreted as prodelta shale, the most basinward of Freestone delta system deposits.

L-5 — Cut-bank of Trinity River immediately east of its intersection with FM 157 in Tarrant County (Dodge, 1952). Approximately the upper 70 feet of this section (mostly gray shale containing thin lenses of sand) represents shelf facies of the Lewisville shelf-strandplain system.