Report of Investigations No. 137

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Mary K. McGowen
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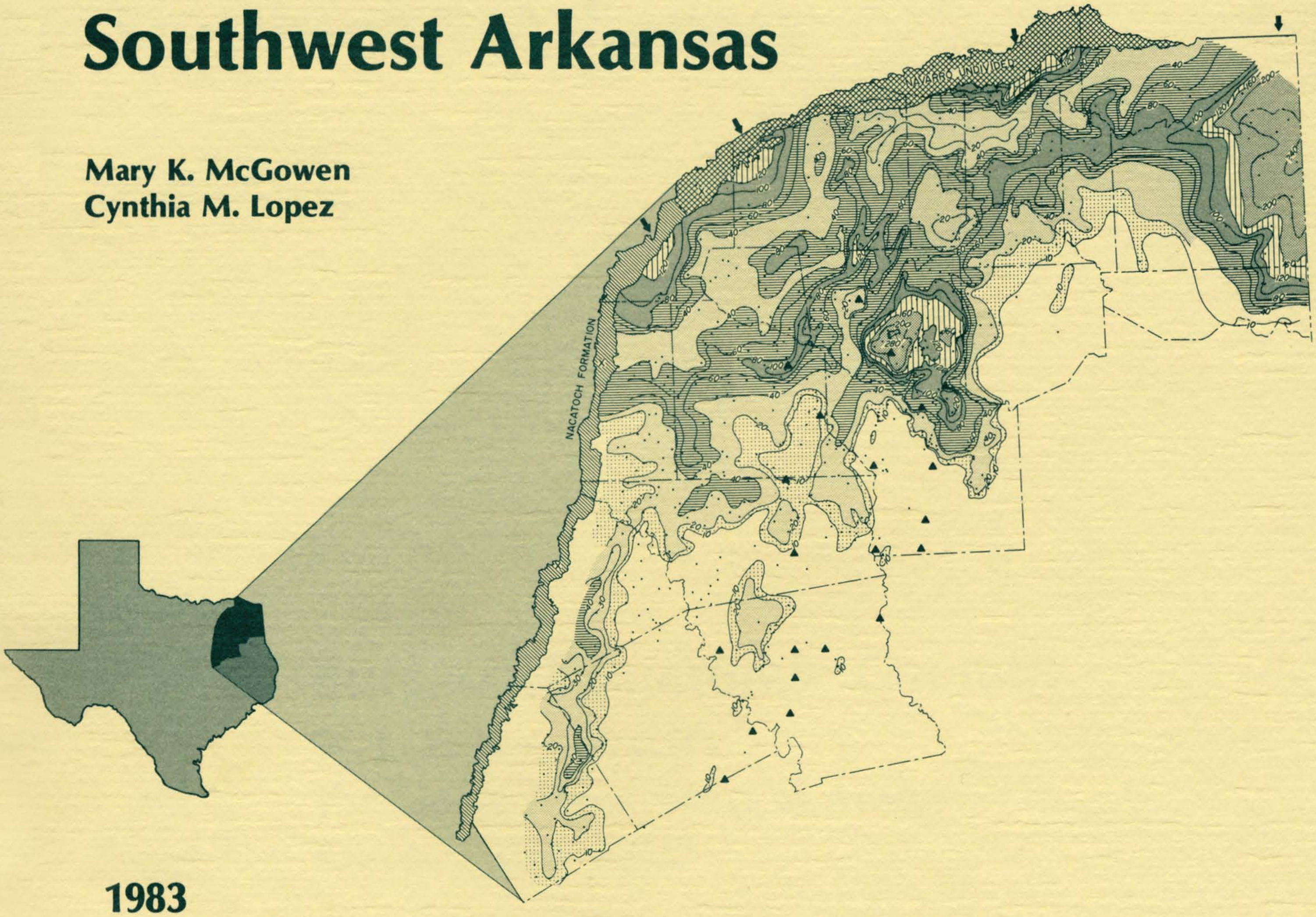

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Bureau of Economic Geology
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ABSTRACT

The Nacatoch Formation of the East Texas Basin is the middle formation of the Navarro Group and consists of marine sandstones and mudstones derived largely from source areas to the northwest, north, and northeast of the East Texas Embayment. Terrigenous clastics were supplied to the Nacatoch Basin by a major northeastern dispersal system originating in southwest Arkansas. Three minor fluvial-delta systems contributed sediment in southern Red River, Delta, and Hunt Counties, Texas.

Five facies are recognized in Nacatoch outcrops in southwest Arkansas: tidal-flat, tidal-channel, tidal-inlet-associated, shoreface, and shelf facies. In northeast Texas, a delta sequence occurs in south-central Hunt County, and shelf sandstones and mudstones are present in Navarro and Kaufman Counties. The lateral association of deltaic deposits and tidal-flat sequences, together with the type, scale, and distribution pattern of inferred tide-produced structures, suggests that tides within the upper microtidal to lower mesotidal range (3 to 8 ft; 1 to 2.5 m) occurred in the East Texas and North Louisiana Embayments during deposition of the Nacatoch Formation.

The Nacatoch Formation in the East Texas Basin is restricted to the northern and western parts of the basin. The sandstone bodies trend mainly northeast to southwest in the northern part of the basin and north to south along the western margin. In the southern half of the basin, the Nacatoch Formation consists of mudstones.

In the subsurface of the East Texas Basin, the Nacatoch Formation can generally be subdivided into nearshore and shelf deposits. Nearshore sequences include deltaic deposits in the north and the northwest parts of the basin that are located downdip from surface exposures of the same facies. Two thick net-sand axes, oriented perpendicularly to the outcrop belt, extend southward into the basin. Orientation of these sand axes changes abruptly to become parallel within the dominant northeast-southwest trend, suggesting that the delta was dominated by tides and waves. It is inferred that interdeltaic areas were sites of short barrier islands, broad tidal inlets with associated tidal deltas, and tidal flats. Offshore deposits can be arbitrarily divided into a lower and an upper sandstone sequence separated by 50 to 100 ft (16.6 to 33.3 m) of marine mudstone. Sandstone bodies of the lower sequence are elongate, exhibit gradational lower boundaries and abrupt upper contacts, and grade laterally into muddy sandstones and mudstones. Sandstones composing these depositional sequences are well sorted, calcitic, glauconitic, fine to medium grained, and contain shell fragments. The sandstone bodies are interpreted to be offshore bars, which have a geometry derived primarily from tidal currents. Sandstones of the upper sequence compose a fairly continuous sheet sand; textures and composition are similar to sandstones of the lower sequence.

Tectonism, coincident with deposition, controlled local sandstone distribution patterns. Development of rim synclines concomitant with salt dome growth considerably affected the thickness and distribution of the Nacatoch Formation; for example, thick Nacatoch sections exist around Hainesville salt dome in Wood County, Texas. Other piercement domes associated with salt withdrawal basins that were active during Nacatoch deposition are Steen, Mt. Sylvan, East Tyler, Brooks, and Bethel.

Few sandstones occur in the Nacatoch Formation in the southern part of the East Texas Basin. These thin, laterally discontinuous sandstone bodies do not threaten the hydrologic integrity of salt domes now being investigated to determine their feasibility for nuclear waste storage.

Sandstones within the Nacatoch Formation in the East Texas Basin are important shallow oil and gas reservoirs. Hydrocarbon reservoirs from the Nacatoch Formation are restricted to the shelf-sand facies. However, hydrocarbon entrapment appears to be more a function of structural closure than of depositional facies. Hydrocarbons are produced from Nacatoch fields developed over the Van salt dome in Van Zandt County and along the Mexia-Talco fault system trend near the western margin of the basin.

Keywords: Nacatoch Formation, Navarro Group, Upper Cretaceous, northeast Texas, southwest Arkansas, East Texas Basin, sedimentation, deltaic environment, shelf environment, sedimentary structures.

INTRODUCTION

The Nacatoch Formation of the East Texas Basin was investigated as part of the East Texas Waste Isolation project being conducted by the Bureau of Economic Geology for the U.S. Department of Energy. This study was designed to determine (1) depositional framework of the basin during deposition of the Nacatoch Formation, (2) effect of salt dome evolution on sand distribution, (3) oil and gas resource potentials of the Nacatoch, and (4) distribution of the Nacatoch Formation around Oakwood and Keechi salt domes, which are being evaluated as potential disposal sites for radioactive waste.

The East Texas Basin extends over approximately 16,800 mi² (43,570 km²) in northeast Texas. The western and northern limits of the basin are the Mexia-Talco fault system; the eastern boundary is the Sabine Uplift, and the southern margin is the Angelina-Caldwell Flexure (fig. 1). The East Texas Basin was connected to the North Louisiana Basin by the northeastward-trending Pittsburg syncline (Murray, 1961; Stehli and others, 1972), also known as the Cass County syncline (Granata, 1963). The two basins were separated by the Sabine Uplift. In the subsurface, the Nacatoch Formation is restricted to the northern and western parts of the East Texas Basin.

Descriptions and environmental interpretations presented in this report are based on data derived from outcrops in northeast Texas and southwest Arkansas and from regional subsurface studies in the East Texas Basin. Electric logs from approximately 1,500 wells in the basin provided most of the subsurface data for this study and are on file at the Bureau of Economic Geology; cross-section wells are listed in Appendix A. Well cuttings from 31 wells in 10 counties (Bowie, Cass, Titus, Hopkins, Wood, Smith, Anderson, Cherokee, Rains, and Freestone) and sidewall cores from 2 wells in Cass County and 1 well in Leon County were examined and described.

Field work included investigation of some of the numerous surface exposures in Hempstead and Clark Counties in southwest Arkansas. Geologic conditions and processes that influenced deposition of the Nacatoch Formation in southwest Arkansas are inferred to have been similar to those within the East Texas Basin. Outcrops in northeast Texas are few and of poor quality compared with those in Arkansas.

PREVIOUS WORK

The Nacatoch Formation was first noted by Veatch (1906) in Arkansas, where he described a series of sandy beds overlying the Marlbrook Marl and underlying the Arkadelphia Marl. A 50-ft- (14.9-m-) thick sand unit exposed in Nacatoch Bluff on the Little Missouri River in Clark County, Arkansas, was designated as the type locality. Dane (1929) later placed the base of the Nacatoch Formation at the top of the Saratoga Chalk.

In northeast Texas, the Nacatoch was designated as the middle sand unit of the Navarro Group (Sellards and others, 1932). Table 1 shows the relation between the surface units in Arkansas and those in northeast Texas. Because it is poorly exposed east of Hunt County, the Nacatoch is included in the undivided Navarro Group (Barnes, 1966).

Several regional subsurface studies addressed the stratigraphic and structural development of the East Texas Embayment (Barrow, 1953; Coon, 1956; Granata, 1963; Nichols and others, 1968; and Stehli and others, 1972).

Table 1. Generalized relation among the surface stratigraphic units composing the Navarro Group of Arkansas, Louisiana, and northeast Texas.

	Northeast Texas	Arkansas-Louisiana
Navarro Group	Kemp Clay Nacatoch Sand Neylandville Marl	Arkadelphia Marl Nacatoch Sand Saratoga Chalk
	Taylor Group	Taylor Group

STRATIGRAPHY

The Nacatoch Formation that crops out in northeast Texas is the middle formation of the Navarro Group; it occurs above the Neylandville Marl and below the Kemp Clay (table 1). This threefold division is valid as far south as northern Limestone County and as far north as Hunt County, Texas (Barnes and others, 1966, 1970, 1972). East of Hunt County, the

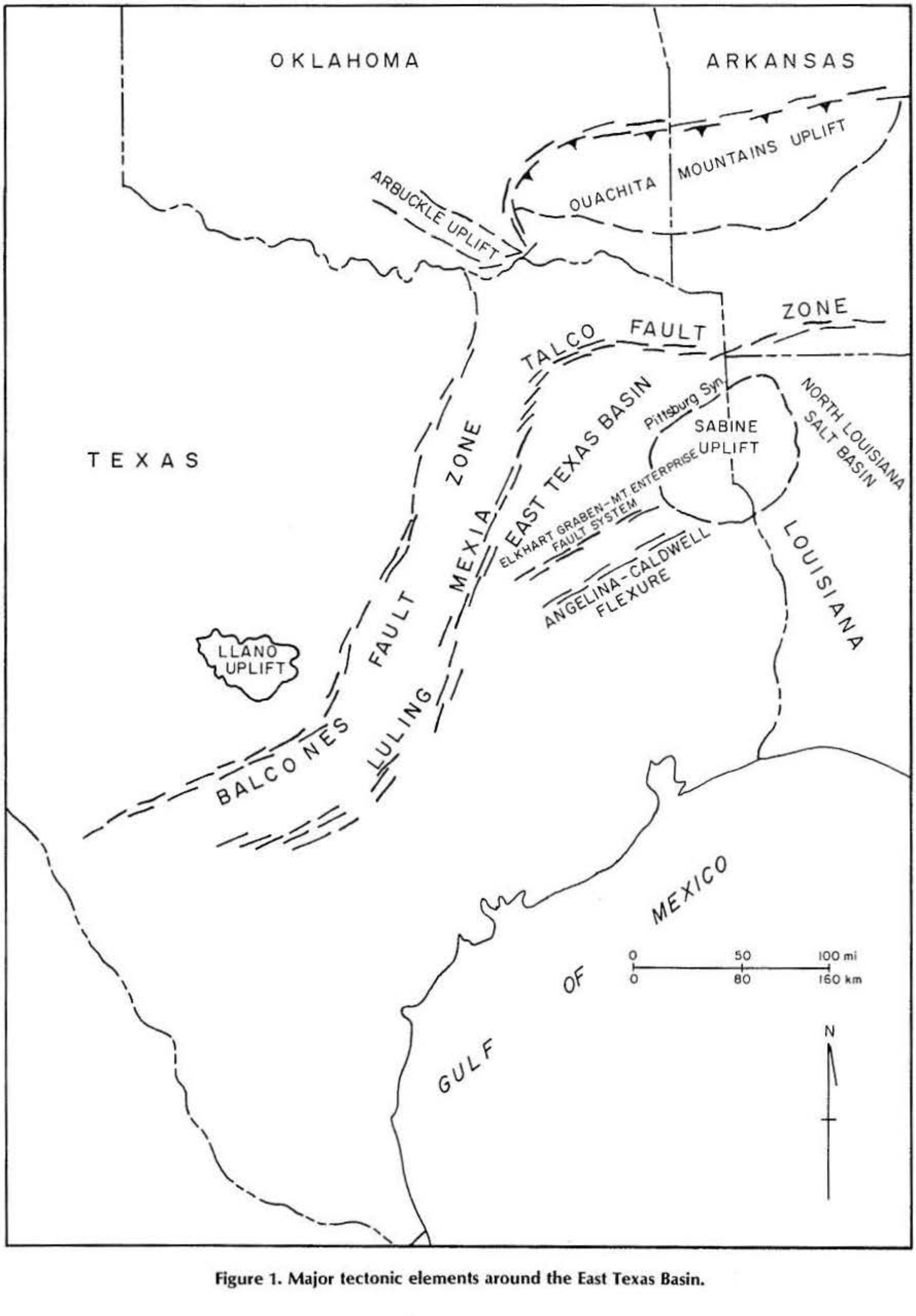

Figure 1. Major tectonic elements around the East Texas Basin.

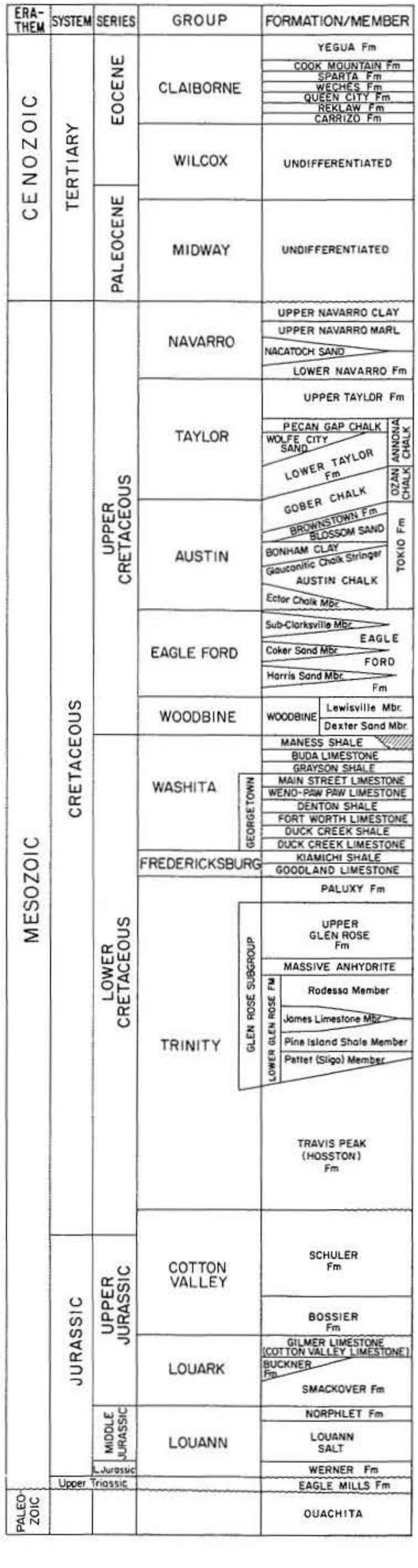

Figure 2. Stratigraphic section, Mesozoic and Cenozoic strata, East Texas Basin (modified from Nichols and others, 1968; Kreitler and others, 1980).

units are mapped collectively as the undivided Navarro Group.

In the subsurface of the East Texas Basin, the Navarro Group was informally subdivided into Upper Navarro Clay, Upper Navarro "Marl," Nacatoch Sand, and Lower Navarro Clay by Guevara and Giles (1979) (fig. 2). This investigation deals with two lithogenetic units: the Nacatoch Formation, a clastic unit composed of nearshore and shelf deposits, and the Upper Navarro Marl, a transgressive shelf deposit.

Within the subsurface, sandstones of the Nacatoch Formation are restricted to the western and northern parts of the basin. The formation comprises alternating sequences of sandstone and mudstone, except in the southern part of the basin and over the Sabine Uplift where it grades into mudstones and thin, discontinuous sandstones. Sandstones are generally well sorted, very fine to fine grained, calcitic to unconsolidated, glauconitic, and commonly contain shell fragments. Intervening mudstones and sandy mudstones are also glauconitic and contain shell material, foraminifers, and varying amounts of carbonized plant fragments. In some parts of the basin, sandstones within the Nacatoch Formation can be divided into a lower and an upper sequence separated by 100 to 200 ft (33 to 66 m) of shelf mudstone.

The contact between the Nacatoch Formation and the overlying Upper Navarro Marl is abrupt and easily distinguished. Typically, on electric logs, the SP (spontaneous potential) deflection is a low negative response, and resistivity values are moderate to high for the Upper Navarro Marl. In contrast, the Nacatoch Formation is generally less resistive than the Upper Navarro Marl, except in those parts of the basin that contain fresh water.

The name "Upper Navarro Marl" was assigned to a series of sandy mudstones and calcareous mudstones that overlie the Nacatoch Formation around Hainesville Dome (Guevara and Giles, 1979). Although the composition of this formation varies within the basin, this name was adopted for this study in preference to introducing new terminology. Around the margins of the basin, the formation is generally sandy, slightly glauconitic mudstone or hard, calcareous, slightly glauconitic, very fine grained sandstone and siltstone containing shell fragments. This marginal facies grades laterally into calcareous mudstone in the deeper parts of the basin. Near the Sabine Uplift, the lower part of the Upper Navarro Marl consists of erratic, thin sandstones and mudstones that grade upward into calcareous mudstone. The equivalent interval in Anderson and

Cherokee Counties is chalk, according to Branson (1951) and Webb (1951).

Regardless of lateral facies, the Upper Navarro Marl is a mappable unit in the subsurface and can be distinguished by use of electric logs from the underlying Nacatoch Formation, except along the northern margin of the basin where the Nacatoch Formation contains fresh water and exhibits positive SP deflection and moderate to high resistivity values. The widespread distribution of the Upper Navarro Marl, which can be correlated throughout the basin, suggests that this unit is a transgressive sequence deposited during a decline in the supply of terrigenous clastics. The erratic, thin sandstones within the lower part of the unit were deposited during local reworking of the Nacatoch Formation.

TECTONIC FRAMEWORK

A limited amount of data on the pre-Mesozoic subsurface is available for the Gulf of Mexico region. Most workers think that the East Texas Embayment developed from one of the megashear zones, rift grabens, or aulacogens that formed along the margins of the Gulf of Mexico during the Mesozoic (Wood and Walper, 1974), probably coincident with the breakup of Pangea and the separation of North and South America (Beall, 1975; Burke and Dewey, 1973; Moore and Del Castillo, 1974; Wood and Walper, 1974). Available evidence suggests that, except for possible slight downwarping caused by sediment loading (Turk, Kehle and Associates, 1978) and uplift of the Sabine area (Granata, 1963), the basement in the basin has remained fairly stable (Agagu and others, 1980).

TECTONIC PROVINCES

Northeast Texas is informally subdivided into three tectonic provinces (Nichols and others, 1968): (1) the Mexia-Talco fault zone, (2) the Sabine Uplift, and (3) the East Texas salt basin.

Mexia-Talco Fault Zone

The Mexia-Talco fault zone is a series of en echelon normal faults and grabens that displace Mesozoic to Eocene strata (Nichols and others, 1968). The zone delineates the northern and western depositional limits of the Louann Salt (Agagu and others, 1980). The fault system is thought to owe its displacement mainly to downdip flow of the Louann Salt (Turk, Kehle and Associates, 1978). Minor movement occurred along the fault zone during Navarro time (Hager and Burnett, 1960).

Sabine Uplift

The Sabine Uplift has been a structural feature adjacent to the East Texas Embayment since Jurassic time (Granata, 1963). The ancestral Sabine Uplift was a north-northeast-trending, stable structural platform characterized by depositional basins (grabens) to the east and west: the North Louisiana and the East Texas Basins, respectively (Granata, 1963; Payne, 1952; Forgotson, 1954; Waters and others, 1955). The two basins were connected by the Pittsburg syncline, a northeastern extension of the East Texas Basin located between the Mexia-Talco fault system to the north and the Sabine Uplift to the south. On the basis of isopach maps, Murray (1961) suggested that this connection occurred primarily during Late Cretaceous and Cenozoic time. Structure maps by Stehli and others (1972; figs. 10 and 11) of the base and the top of the Upper Cretaceous Series also indicate that a structural low occurred in this area.

The ancestral Sabine platform shifted eastward to its present location during late Coahuilan and early Comanchean time (Murray, 1961) and was a stable or slightly positive area during the Late Cretaceous. Nacatoch sands are absent over the Sabine Uplift, whereas the overlying Upper Navarro Marl thickens over the uplift.

East Texas Salt Basin

The East Texas salt basin is commonly referred to as the Tyler Basin. It is situated in the central part of the East Texas Embayment and represents the structurally deepest part of the embayment. It comprises both the "Updip Belt" and the Northeast Texas Basin discussed by Nichols and others (1968).

The strata dip into the basin from the Mexia-Talco fault zone on the north and west and from the Sabine Uplift on the east (fig. 3). The basin axis plunges generally south-southwest, locally interrupted by a discontinuous salt anticline coincident with the Elkhart graben - Mount Enterprise fault system (fig. 1).

Three subbasins originated within the East Texas Basin during the Late Cretaceous (fig. 3) (Agagu and others, 1980): the Mineola Basin, located around Hainesville Dome; the La Rue Basin, located around Bethel Dome; and the Noon Day Basin, beneath the cities of Tyler, Noon Day, and Cuney. These subbasins are bounded by generally discontinuous complementary anticlines, interrupted by several local uplifts and rim synclines that surround salt diapirs. More than 35 salt structures have been observed in the basin (fig. 4).

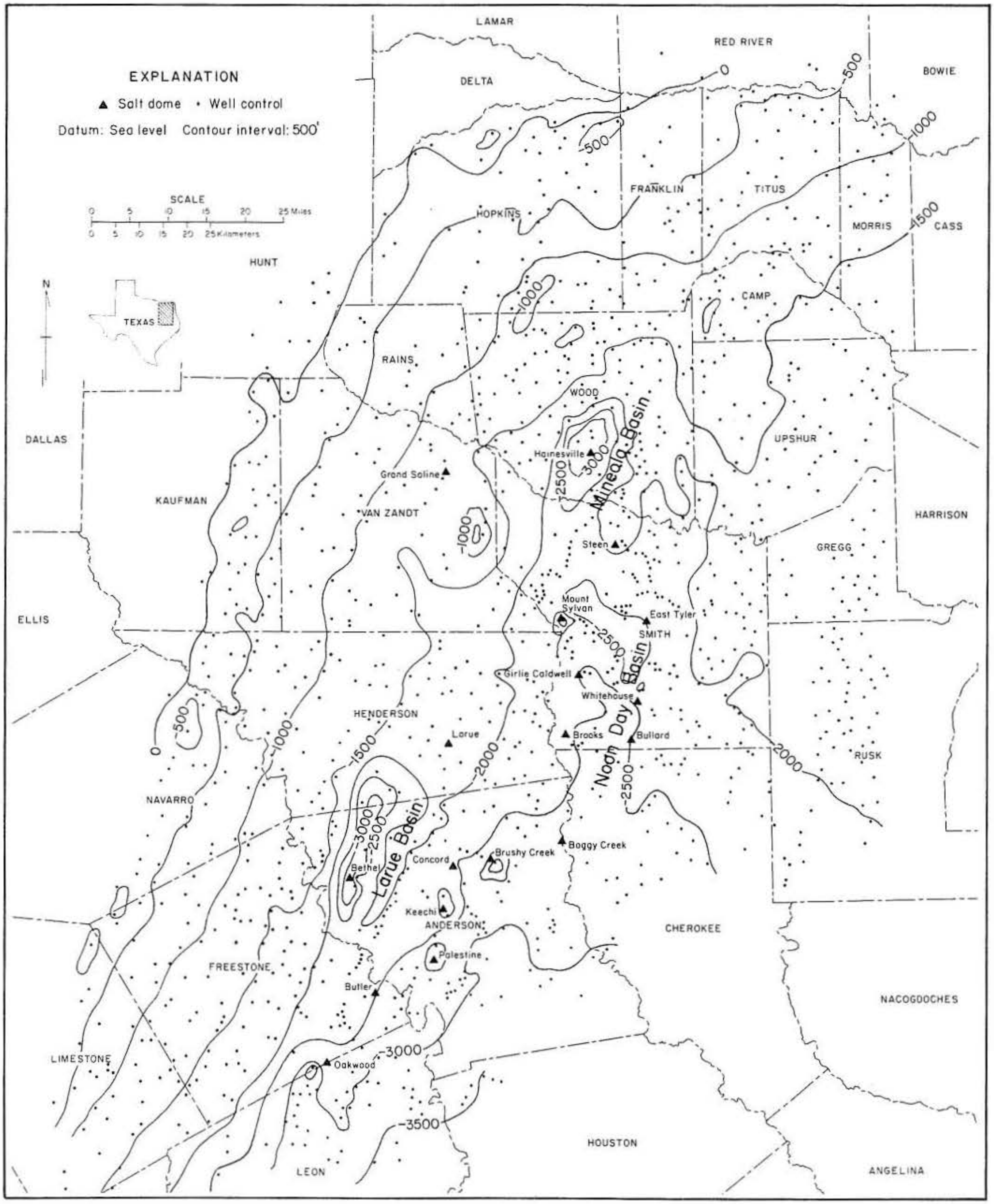

Figure 3. Structure contour map of base of Upper Navarro Marl. Late Cretaceous subbasins, defined by Agagu and others (1980), are included (Kreitler and others, 1980).

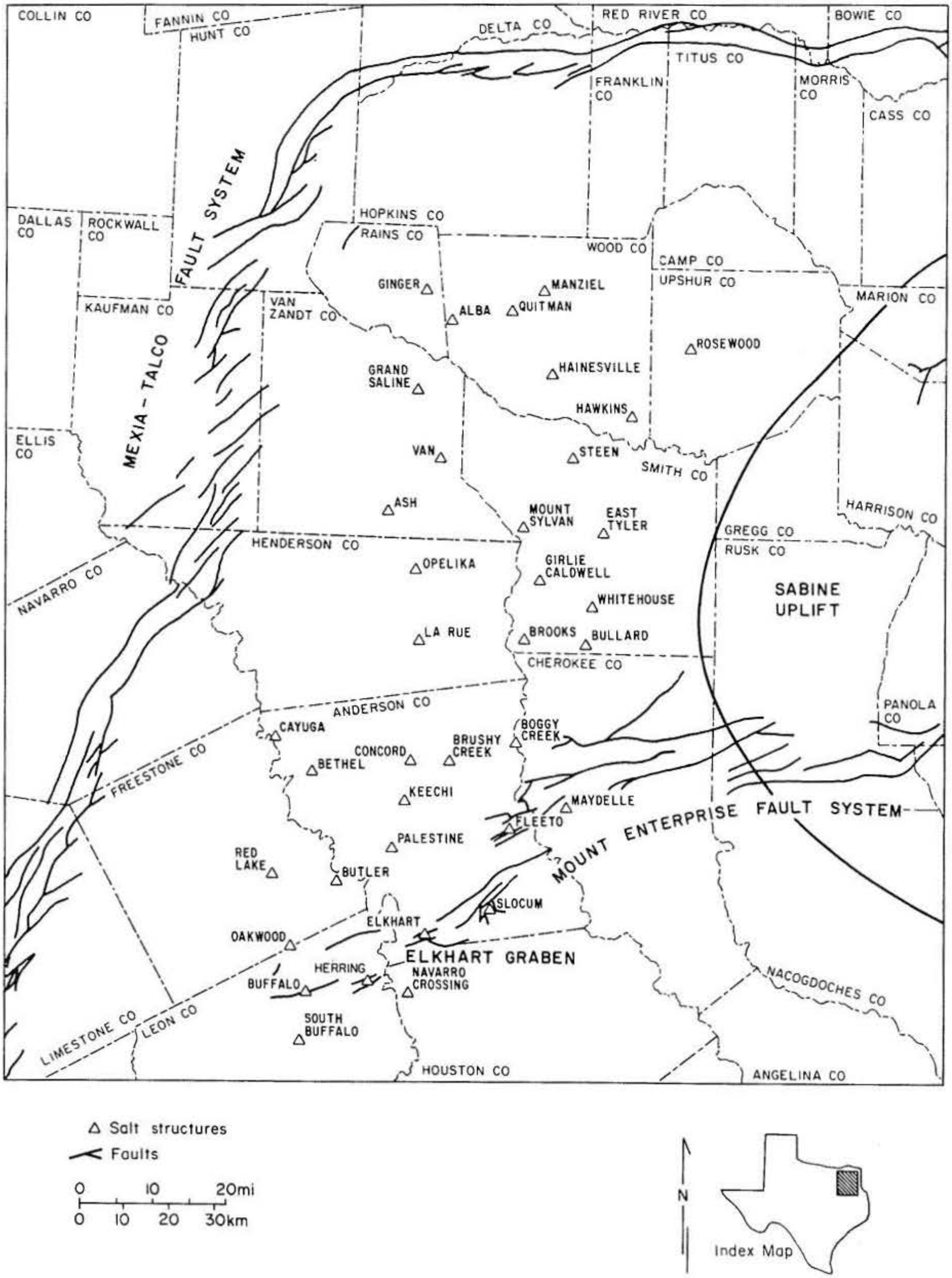

Figure 4. Salt domes and major fault systems, East Texas Basin (Kreitler and others, 1981).

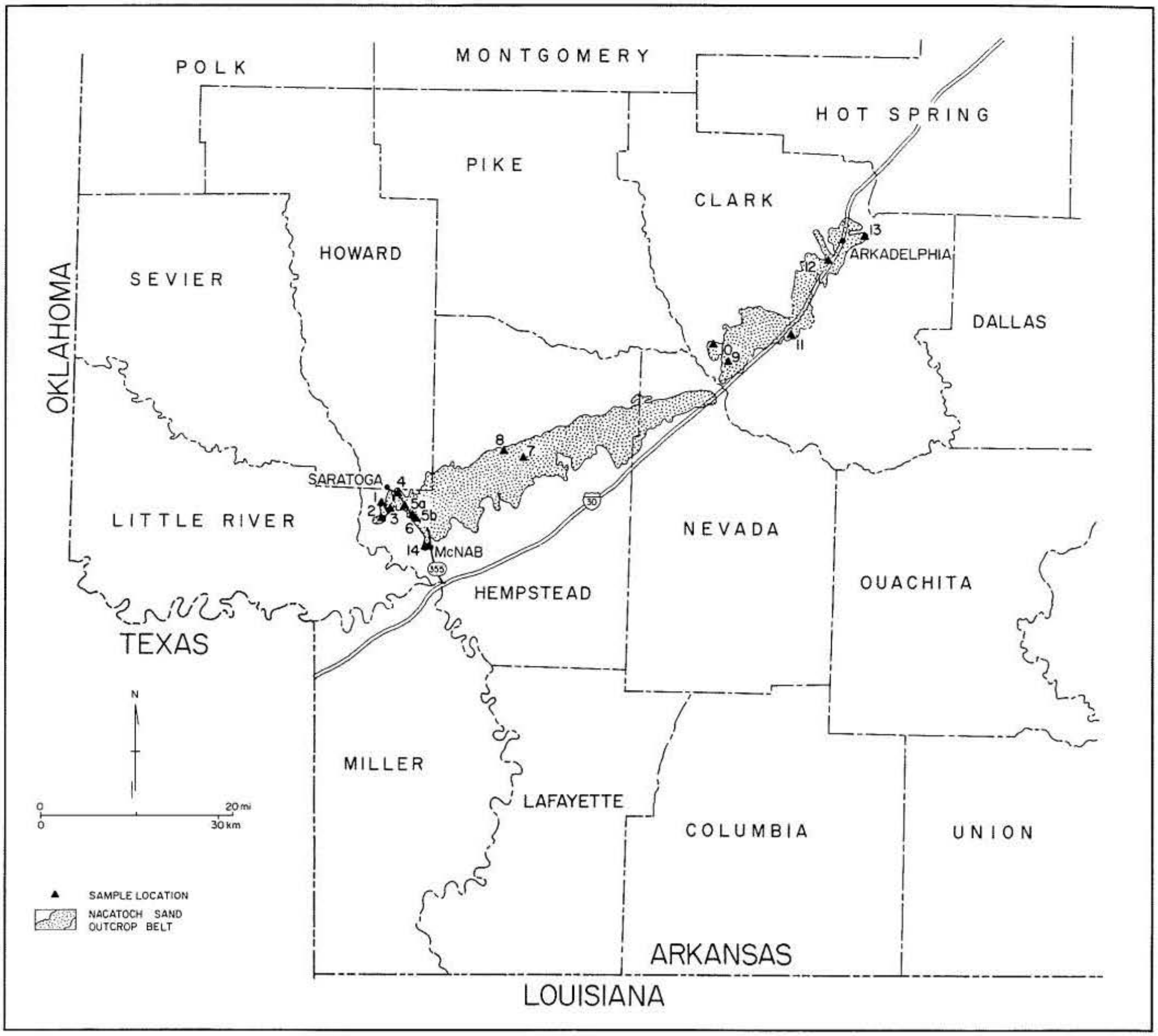

Figure 5. Index map with sample locations, southwest Arkansas. See table 4 for location descriptions.

SURFACE STUDIES

GENERAL FRAMEWORK

Surface exposures of the Nacatoch Formation were studied to support regional depositional interpretations. Five paleoenvironments were interpreted from Nacatoch outcrop observations in southwest Arkansas: tidal flat, tidal channel, a tidal-inlet association, shoreface, and shelf. In northeast Texas, deltaic and shelf deposits were interpreted from observations in outcrop: a deltaic-influenced deposit is exposed in a sand pit west of Campbell in Hunt County, and glauconitic, highly fossiliferous shelf sands crop out as resistant, cemented lenses and concretionary boulders in Navarro and Kaufman Counties.

OUTCROP OBSERVATIONS IN SOUTHWEST ARKANSAS

Locations of outcrops that were studied in southwest Arkansas are noted in figure 5. Outcrops are described and depositional environments are inferred.

Table 2. Locations of outcrops and inferred depositional environments, southwest Arkansas.

Location number	Location	Depositional environment
2	Approximately 4.5 mi (7.2 km) S-SW of Saratoga on State Hwy 32, Hempstead County	shoreface
3	Millwood Lake; excavation site for material used in earthen dam, Hempstead County	shoreface?
4	Sand pit 1 mi (1.6 km) S of Saratoga on State Hwy 355, Hempstead County	tidal flat
5a	Road cut 2.5 mi (4 km) S of Saragota on State Hwy 355, Hempstead County	tidal flat
5b	Road cut 3 mi (4.8 km) S of Saratoga on State Hwy 355, Hempstead County	tidal flat
6	Road cut 4 mi (6.4 km) S of Saratoga on State Hwy 355, Hempstead County	shoreface
7	Immediately N of Washington, Hempstead County	greensand (inner shelf)
9	2 mi (3.2 km) N of intersection, Interstate 30 and State Hwy 51, Clark County	tidal-channel fill
10	1 mi (1.6 km) S of Oklahoma on U. S. Hwy 51, Clark County	greensand (inner shelf)
11	1 mi (1.6 km) S of intersection, Interstate 30 at State Hwy 53, Clark County	tidal flat
12	Sand pit 2 mi (3.2 km) S of Arkadelphia on Interstate 30, Clark County	tidal-inlet facies
13	Dane's (1929) High Bluff section on Ouachita River at Arkadelphia, Clark County	inner shelf and lower shoreface
14	Dane (1929) section W of McNab on St. L. S. F. Railroad, Hempstead County	shoreface

Tidal Deposits

Tidal-flat surficial deposits observed in outcrop in southwest Arkansas (Locations 4, 5a, 5b, 11; table 2) are either mixed-flat or sand-flat deposits as defined by Reineck (1975). Most observed sedimentary structures are small scale, which may imply that tidal ranges in southwest Arkansas during Nacatoch time were not as great as those flooding the Dutch tidal flats today (Reineck, 1975). Marsh and mud-flat deposits were not observed, possibly because the complete tidal-flat sequence is not preserved in outcrop. Characteristic bed forms and sedimentary structures of mixed flats, sand flats, and tidal-channel deposits are listed in table 3.

Facies relationships interpreted to be of tidal-flat origin consist of alternating current-rippled sands with clay drapes and crossbedded sands (figs. 6 through 10). Both small-scale channel-fill (tidal creek) (fig. 8) and large-scale channel-fill (tidal channel) deposits were observed (fig. 9).

Current-rippled sands are very fine to fine grained, angular to well rounded, glauconitic and micaceous; sand-sized clay pellets and mud clasts as large as 2 inches (5 cm) in diameter are common. Rippled bed forms are preserved by mud drapes (figs. 6, 7, and 10). Excellent examples of flaser beds occur at Location 5b (fig. 10). Walled and unwalled burrows are concentrated in zones containing mud drapes (fig. 7).

Alternating cross-stratified deposits (figs. 6, 7, and 10) are composed of glauconitic, micaceous, angular to well-rounded, fine- to medium-grained quartz sand; sand-sized mud pellets are mixed with the quartz sand, and gravel-sized rip-up mud clasts are common. Individual foresets are 3 to 12 inches (7.6 to 30.4 cm) thick, and mud clasts are commonly concentrated along foresets (fig. 6). Crossbedding is bidirectional. Some of the thicker crossbedded sand units were probably deposited as sand waves (note fig. 10, Sequence C). Sand waves as depositional features associated with intertidal deposits have been described by Reineck (1975), Evans (1965), Klein (1976), and Larsonneur (1975).

Evidence of a mixed or lower (sand) tidal-flat origin includes vertical relationships composed of (1) alternating bed sets of different bed types (wavy and lenticular sets alternating with crossbedded sand sets), (2) bidirectional crossbeds, indicating reversals of flow

Table 3. Characteristics of tidal-flat facies and tidal-channel-fill facies.

Subenvironment	Characteristics
Mixed flats	Sandy mud; flaser, wavy, lenticular, and finely interlayered sand/mud beds deposited by alternating tidal current and slack water phases; bioturbation (Reineck, 1975).
Sand flats	Very fine sand; small-scale crossbeds of current-ripple origin; current-ripple cross-stratification and clay drapes; herringbone crossbeds; laminated sand; flaser beds; rare bioturbation (Reineck, 1975); reactivation surfaces (Reineck, 1977).
Tidal-channel fill (especially important in mixed flats) (Reineck, 1976)	Fine to medium sand and mud clasts. Ripple cross-laminated sands with silty clay drapes deposited during slack water periods between tides; interbedded layers of rip-up mud clasts and shell debris (Reineck, 1975; Evans, 1975; and Van Stratten, 1954).
	Cross-stratified bed sets commonly 3 to 4 ft (1 to 1.2 m), maximum of 12 ft (3.6 m) (Evans, 1965); bidirectional crossbeds (Reineck, 1975).
	Scour features.

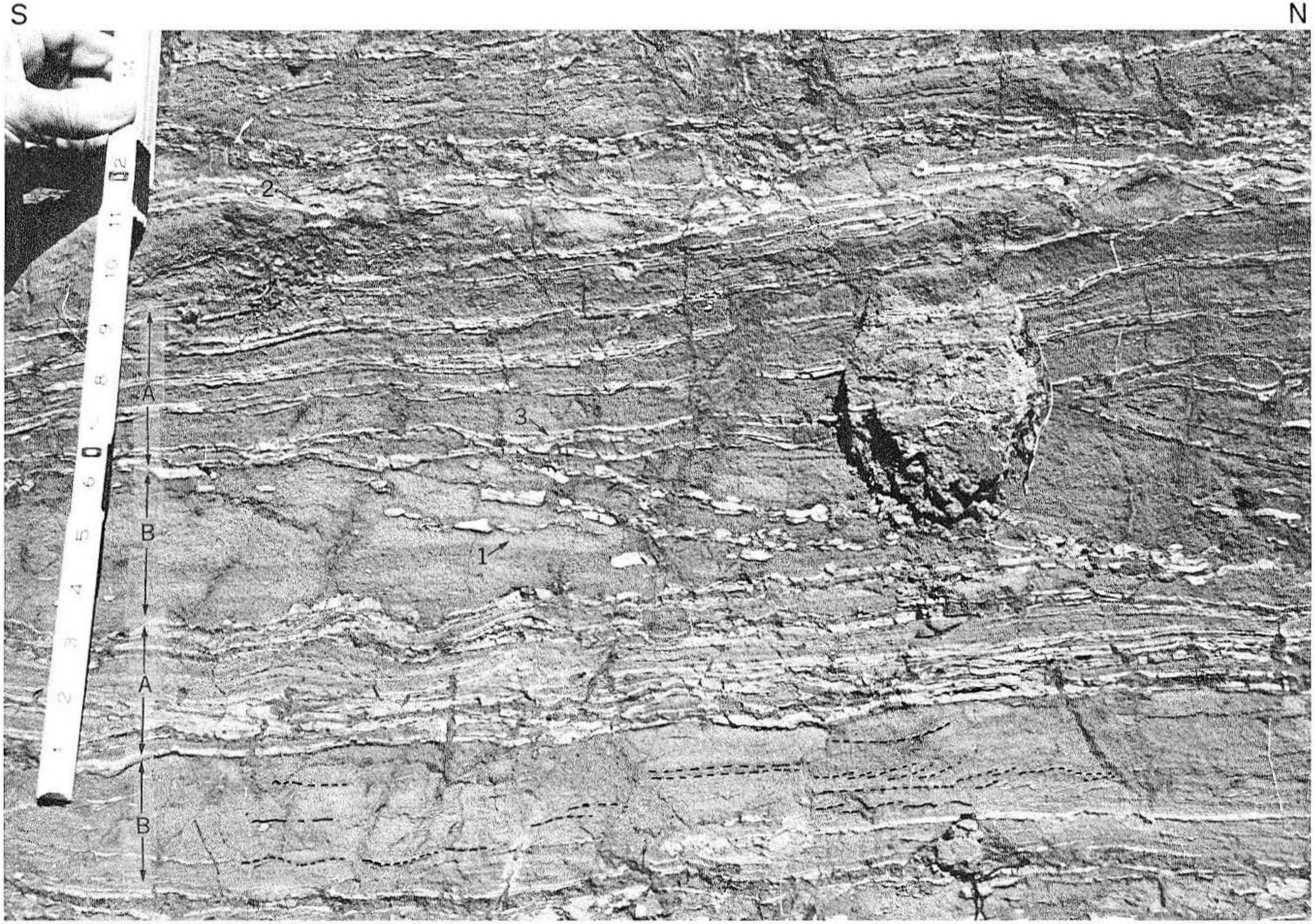

Figure 6. Tidal-flat deposits (Location 5a). Alternating current-rippled and foreset crossbedded sands. Unit A: current-rippled sands contain mud drapes (1) and scattered burrows (2). Unit B: foreset crossbedded sands contain mud rip-up clasts concentrated along foresets (3). Light-colored zones are mud drapes (1) and rip-up mud clasts (3). Individual foreset beds are 3 inches (7.6 cm) thick. Scale in inches.

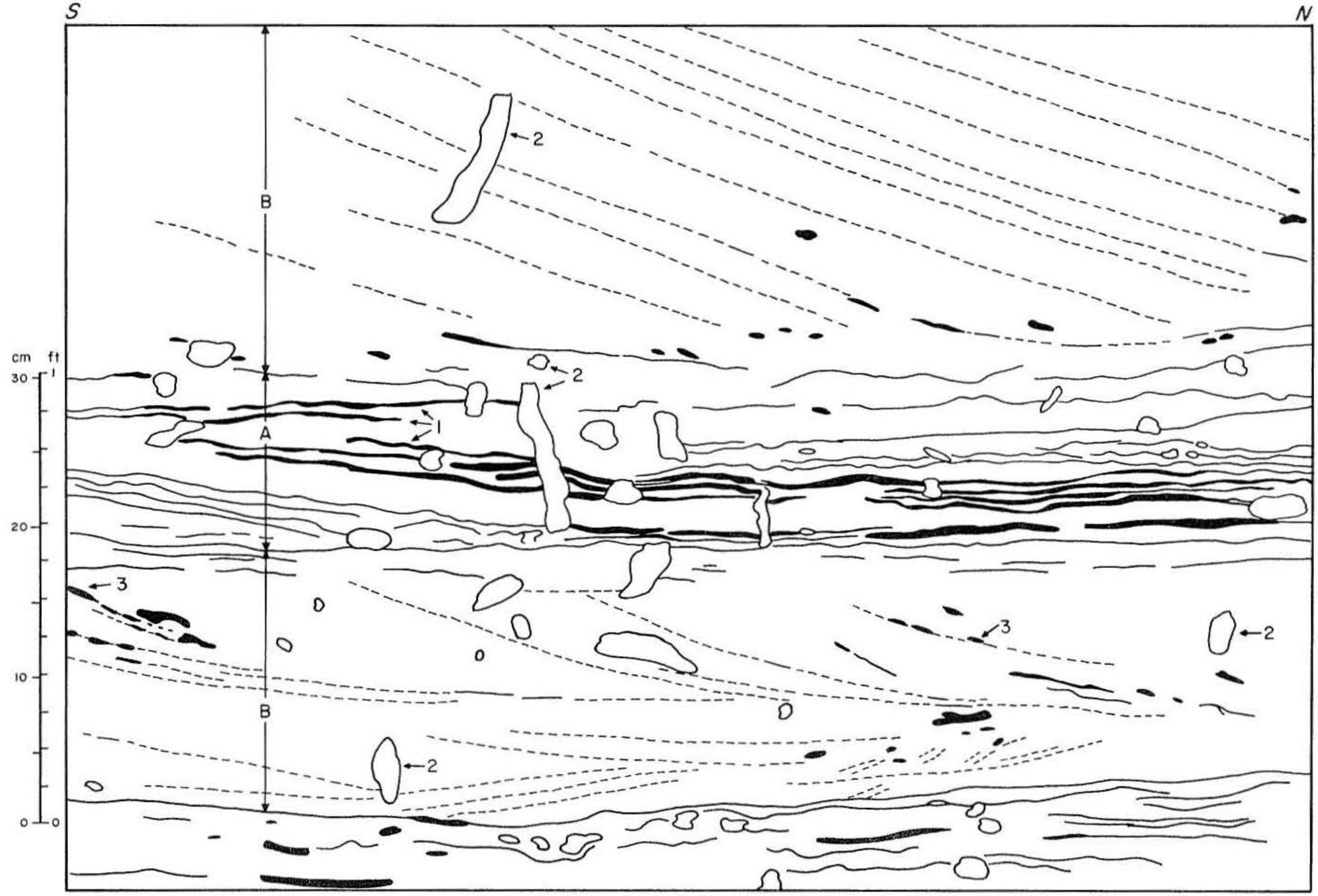

Figure 7. Tidal-flat deposit (Location 5a). Unit A: current-rippled sand containing mud drapes (1) and *Ophiomorpha* (2) concentrated in mud-rich zones. Unit B: crossbedded sands containing mud clasts (3) and scattered *Ophiomorpha* (2). Line drawing from photograph. Scale in inches.

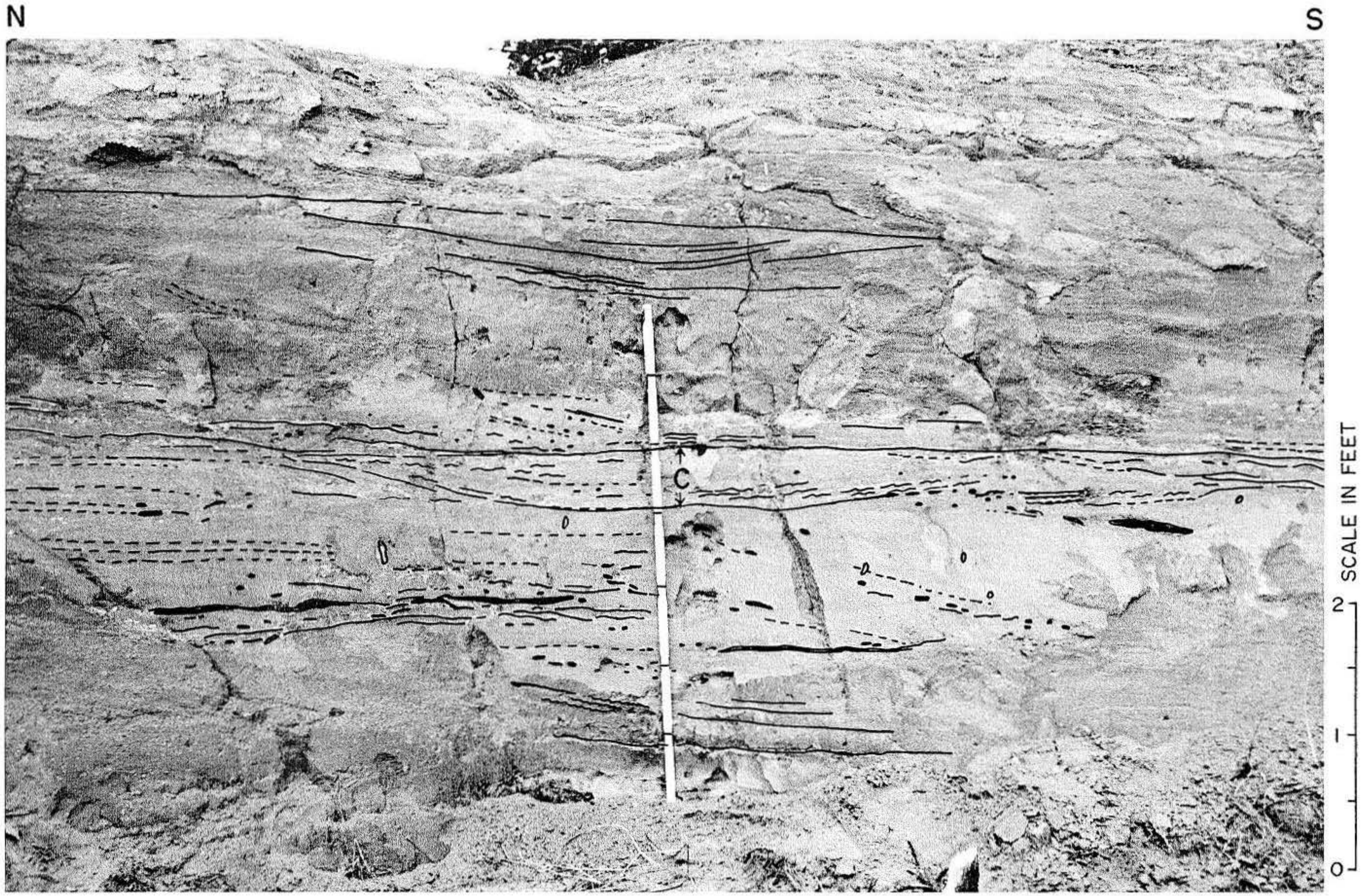

Figure 8. Tidal-flat deposits (Location 4). Current-rippled and foreset crossbedded sands and a small-scale channel-fill deposit (C). Channel is approximately 5 inches (12 cm) deep and 7 ft (2.1 m) wide. Face of pit is perpendicular to sediment transport direction. Climbing ripples are highlighted by clay drapes along channel margin. Scale in feet.

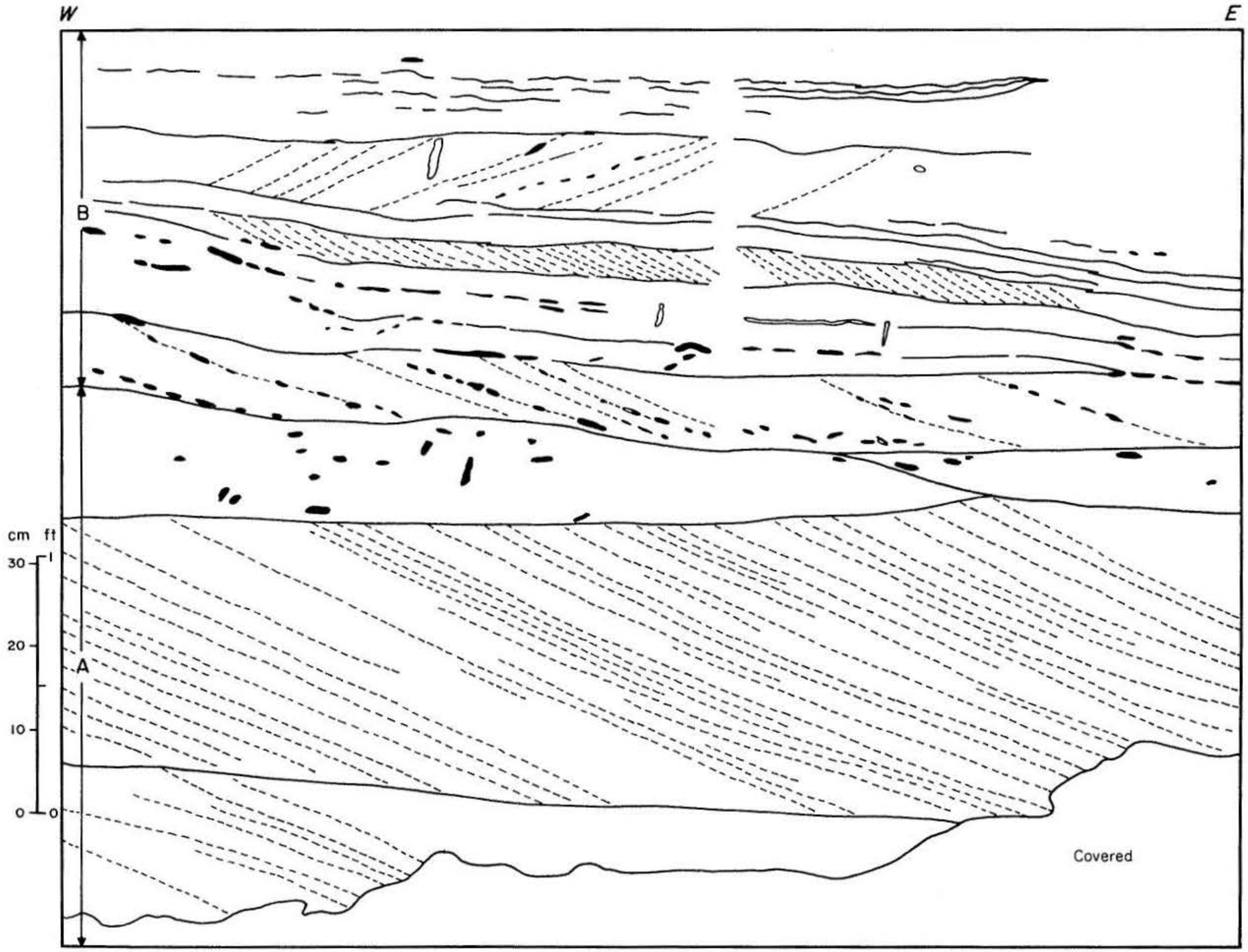

Figure 9. Tidal-channel fill (A) overlain by tidal-flat unit (B) composed of current-rippled sands and foreset crossbedded sands (Location 4). Individual trough cross-stratified sands in channel fill range from 1 to 1.5 ft (30.5 to 45.7 cm). Channel can be traced laterally for 30 ft (9 m). Line drawing from photograph.

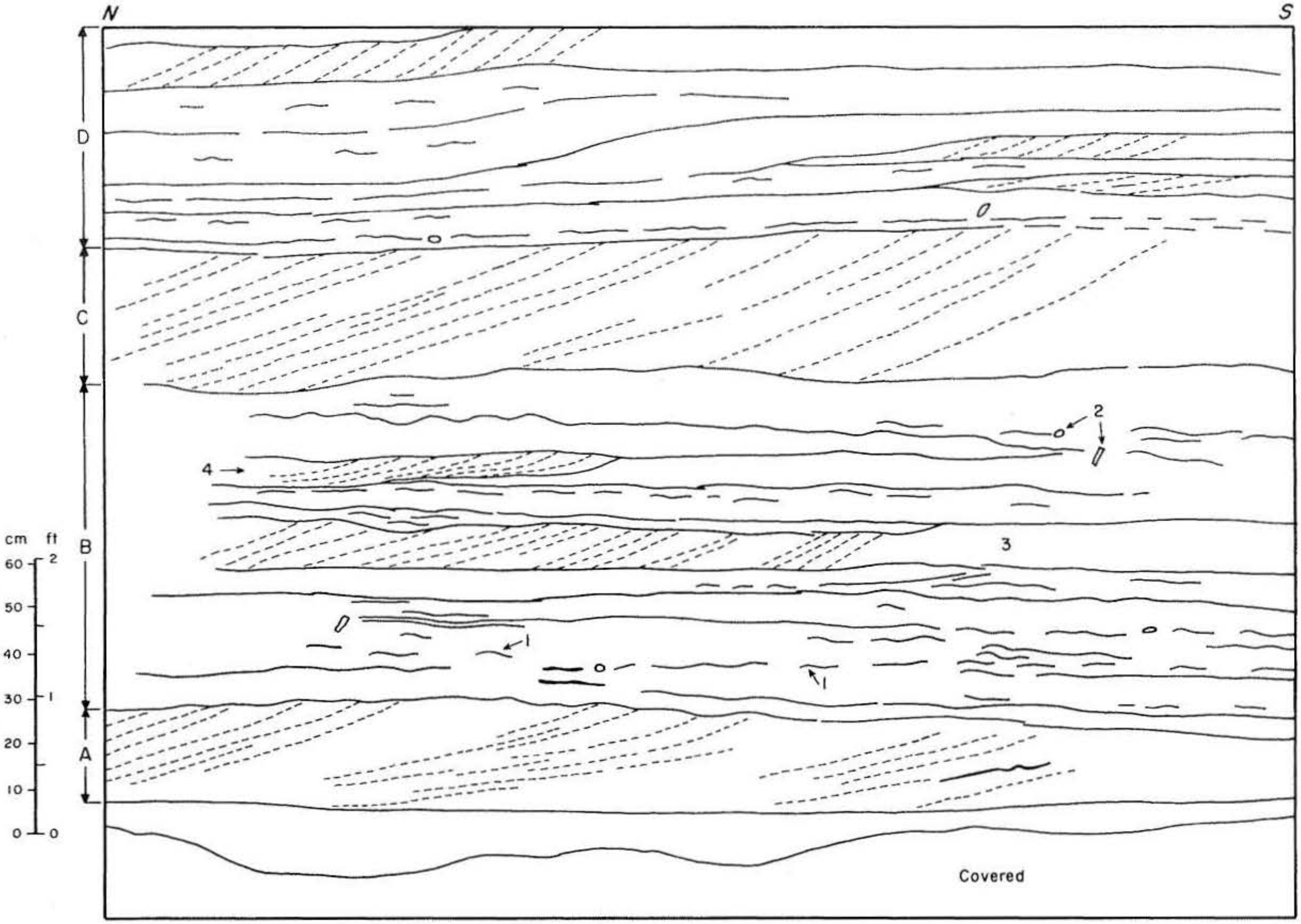

Figure 10. Tidal-flat deposits (Location 5b). Unit A: trough crossbedded tidal channel-fill sands containing rip-up mud clasts concentrated along faces of crossbeds. Units B and D: current-rippled sands displaying flaser bedding (1); rare burrows (2); foreset crossbedded sands (3); and thin channel-fill deposits (4). Unit C: foreset crossbedded sands. Scale of cross-stratified unit suggests that it may represent a sand wave. Unit D: alternating parallel-laminated to horizontally bedded current-rippled sands highlighted by mud drapes (1) and crossbedded sands (3) containing some thin channel-fill deposits. Line drawing from photograph. Scale in feet.

direction, (3) flaser beds, and (4) mud drapes over current-rippled beds, indicating deposition of suspended sediment during periods of slack water between ebb and flood tide (table 3).

Shoreface Deposits

Facies relationships at Locations 2, 3, 6, and 14 (fig. 5; table 2) are interpreted to be of shoreface origin. Two exposures (Locations 6 and 14) are located near previously described tidal-flat deposits (Locations 4, 5a, and 5b; fig. 6). The close association of well-developed shoreface deposits with tidal deposits suggests that a barrier system existed in front of the tidal flats, such as the barrier islands in front of the Wadden Sea tidal flats (Reineck, 1975). Salient characteristics of shoreface deposits are listed in table 4.

Shoreface deposits observed in the Nacatoch Formation are typically horizontally bedded to parallel-laminated, slightly glauconitic, slightly muddy, fine-grained sand (figs. 11 to 13). Thin, channel-fill deposits are present in the upper part of the shoreface sequences (fig. 11). *Ophiomorpha* occur throughout the shoreface deposits (Howard, 1972) but are more common in horizontally bedded sands of the lower shoreface (figs. 11 and 12).

Howard (1972) has observed a distinctive pattern in biogenic structures in shoreface deposits. The lower shoreface sequence begins with laminated sands having only a few burrows. The number of burrows increases upward to the top of individual beds where burrows are terminated by erosion. The sequence of burrows is then repeated (fig. 12). Lower shoreface environments also support a predominance of suspension-feeding organisms rather than a deposit-feeding assemblage (Howard, 1972). Lower shoreface deposits overlain by upper shoreface deposits is typified by a vertical relationship composed of laminated to thinly bedded sands with common occurrences of *Ophiomorpha*. The vertical sequence is overlain by thin channel-fill sands and ripple-laminated and trough cross-laminated sands with rare occurrences of *Ophiomorpha* (Howard, 1972; Reinson, 1979).

The most complete shoreface deposit observed in outcrop is a measured section (Dane, 1929) located west of McNab (Location 14; table 2). Unit A consists of 15 ft (4.6 m) of white to light-gray, slightly glauconitic, slightly carbonaceous, moderately well sorted, fine-grained quartz sand containing about 5 percent sand-sized clay pellets (fig. 14). The sands range from burrowed and structureless to parallel laminated and horizontally bedded with mud drapes. The degree of burrowing decreases upward; some beds have been thoroughly bioturbated.

Table 4. Characteristics of shoreface sequence.

Subenvironment	Characteristics
Lower shoreface	Very fine to fine-grained sand with intercalated layers of silt and sandy mud; planar laminated beds; strong bioturbation common (Reineck, 1975; Reinson, 1979).
Upper shoreface	Fine to medium-grained clean sands with minor amounts of silt; low-angle wedge-shaped sets of planar laminae, but ripple laminae and trough cross-laminae common, truncated laminae bed sets common; bioturbation weak but increases downward (Reineck, 1975; Reinson, 1979).

Ophiomorpha (fig. 14) and unwalled burrows are abundant; *Arenicolita*, u-shaped burrows, and other unidentified walled burrows are less common. Unit A is interpreted to be a lower shoreface deposit.

Unit B is composed of beds that range from 0.5 to 2 ft (15 to 60 cm) thick and that display mud drapes. Bed sets are characterized by unidirectional foreset cross-strata exhibiting numerous reactivation surfaces (fig. 15). Some thin, trough-filled crossbedded, channel-fill deposits occur within Unit B. The unit consists of light-gray, slightly glauconitic, well-sorted quartz sand containing less than 5 percent clay pellets. Unit B is capped by a layer of hard, calcareous sandstone containing abundant fragments of *Ostrea owenana* Shumard (Dane, 1929). Unit B is inferred to have been deposited within an upper shoreface environment.

Shoreface and Tidal-Inlet-Associated Deposits

At Location 12 (fig. 5; table 2) a shoreface deposit 22 ft (6.7 m) thick is overlain by 28 ft (8.5 m) of channel-fill deposits (figs. 16, 17, and 18). Lower shoreface deposits eroded by a channel-fill unit of this magnitude suggests that this was a migrating tidal-inlet and barrier-island complex. Upper shoreface deposits are absent and are presumed to have been eroded during lateral migration of the channel (inlet).

Unit A, the lower 4.4 ft (1.3 m) of the section, is characterized by alternating parallel-laminated, dark-gray muds containing distinct sand laminae and very fine grained, current-rippled sands displaying clay drapes (fig. 17). Individual sand beds are up to 3 inches (7.5 cm) thick. The mud and sand beds contain some glauconite and abundant finely disseminated carbonaceous (plant) material, which reflects the proximity to the tidal channel (tidal inlet); the amount of carbonaceous material decreases upward. Unwalled burrows are abundant, and *Ophiomorpha* are rare (fig. 17). Unit A becomes sandier upward.

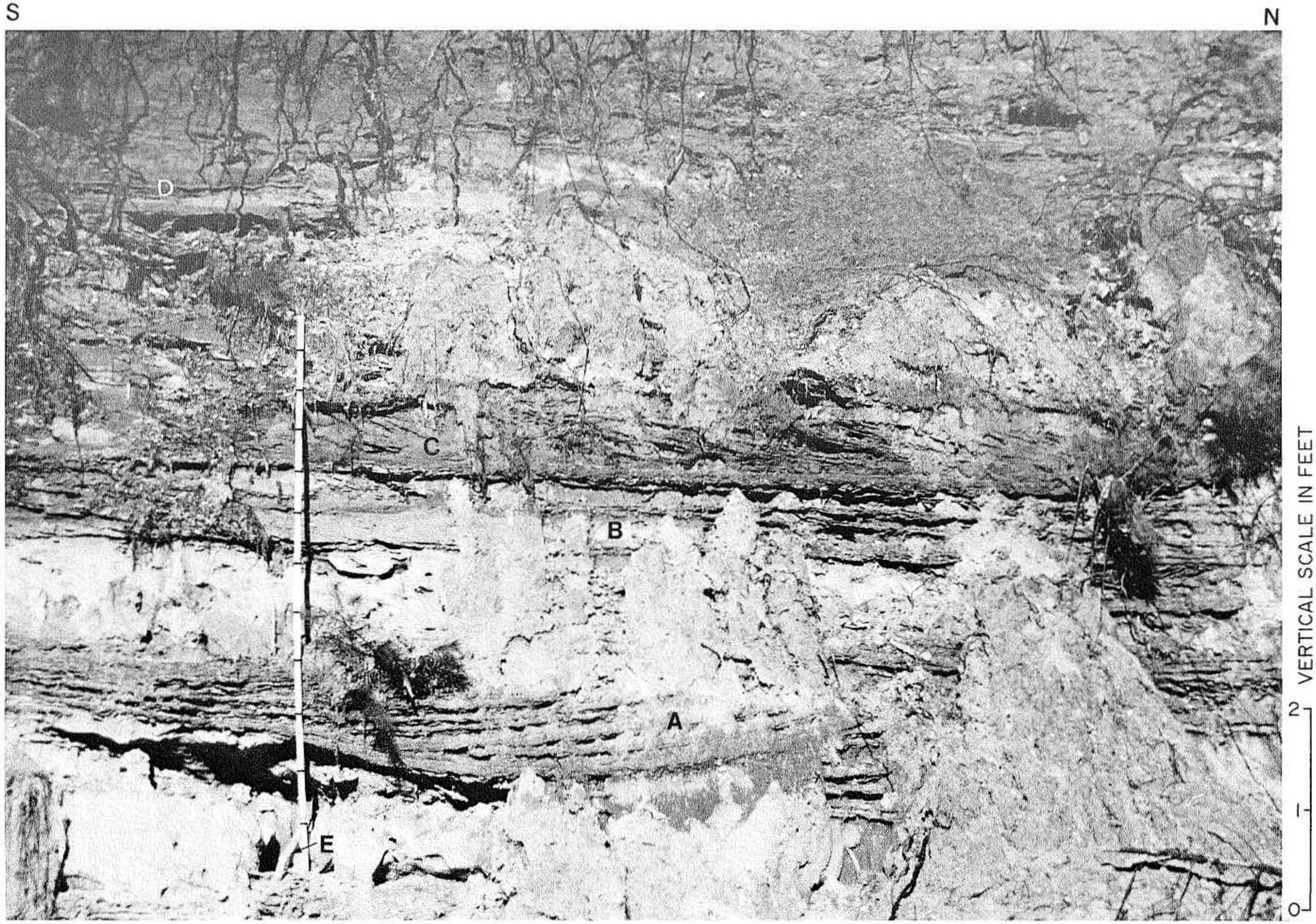

Figure 11. Upper shoreface deposits composed of thin channel-fill and trough crossbedded sands (A), horizontally bedded sands (B), foreset crossbedded sands (C), ripples (D), and *Ophiomorpha* (E) in lower part. Scale in feet (Location 6).

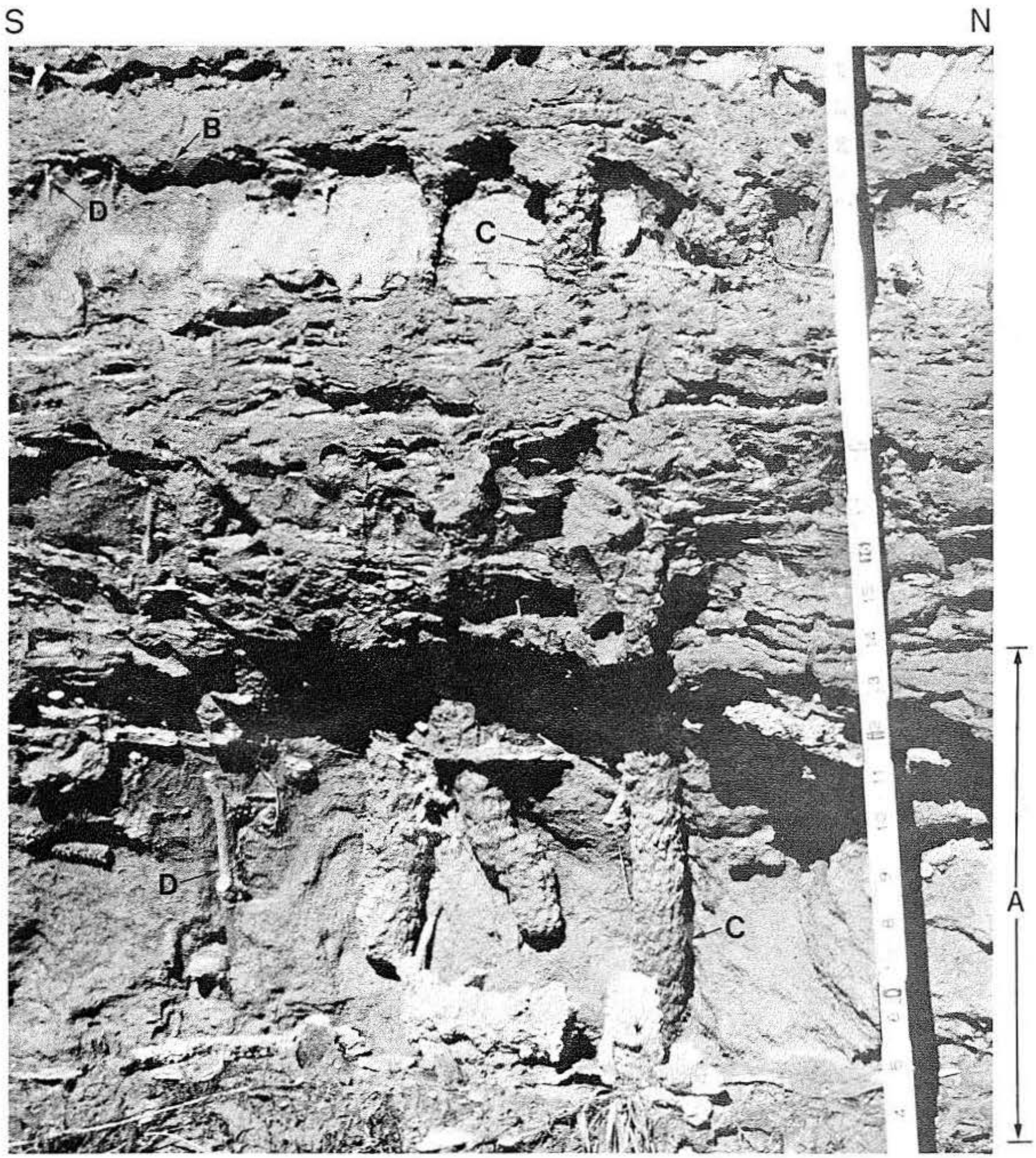

Figure 12. Lower shoreface deposits composed of alternating parallel-laminated to horizontally bedded sands (Location 6). Burrows increase upward within each unit (A) and are terminated by erosional surface (B). Large, vertically oriented *Ophiomorpha* (C) and *Asterosoma* (D). Scale in inches.

Unit B is composed of highly bioturbated sandy mud 2.1 ft (0.6 m) thick (fig. 16). Remnants of primary structures, parallel laminae of mudstone, and very fine grained sandstones are rare. Above this interval, 5 ft (1.5 m) of the section is covered by debris.

Unit C is composed of 16 ft (5 m) of horizontally bedded, current-rippled sand beds displaying clay drapes; minor occurrences of alternating clay and sand laminae also occur within this unit (fig. 16). Sands are slightly glauconitic, moderately well sorted, and very fine to fine grained. Unwalled burrows and *Ophiomorpha* are present. Zones of higher mud concentration are more intensely burrowed. Some thin channel-fill deposits were observed.

Unit D is a tidal channel-fill deposit 22 ft (6.5 m) thick (figs. 16 and 18). The contact between C and D is horizontal and erosional. Holocene tidal channels that cut into a sand substrate are typically wide and shallow (Oomkens, 1979). Nacatoch tidal-channel facies is white, slightly glauconitic, crossbedded, fine-grained quartz sand that contains less than 5 percent sand-sized clay pellets and granule- to cobble-sized

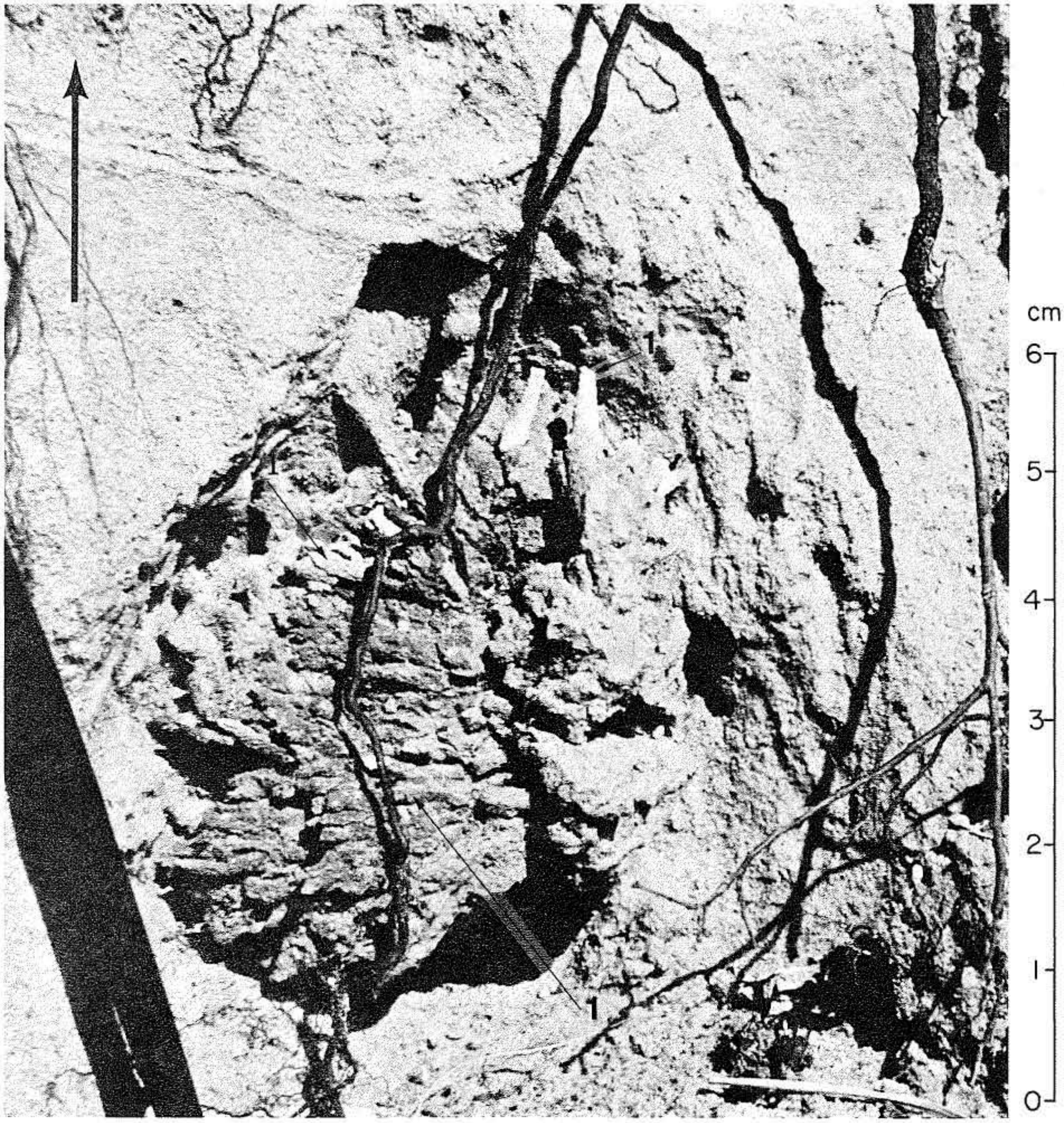

Figure 13. Burrows (probably *Asterosoma*) radiating outward from central axis (Location 6). Pen for scale is 5.5 inches (14 cm) long.

rip-up mud clasts. Trough-filled cross-strata are the dominant stratification type; some foreset crossbeds were observed (fig. 18). Individual crossbed sets range from 0.33 to 1.5 ft (10 to 46 cm) thick and are bidirectional, thus displaying a herringbone pattern (fig. 18). Rip-up mud clasts are concentrated along foresets and on erosional surfaces between sets of crossbeds. Grain size is apparently uniform throughout the unit; burrows are rare.

Unit E, the upper 6 ft (1.8 m) of the exposure, is also a channel-fill deposit, but the scale of crossbed sets is smaller and the mud content is higher (fig. 16). Mud drapes that separate crossbed sets, rip-up mud clasts, and mud balls occur within the unit; burrows are more numerous than in the underlying zone, especially in muddy beds. Bidirectional crossbeds are also characteristic of this deposit.

In addition to the facies described, Dane (1929) mentioned several occurrences of greensand within the Nacatoch Formation, which, in this report, are interpreted to be shallow marine shelf sands (fig. 5, Locations 7 and 10). Greensands locally consist of as

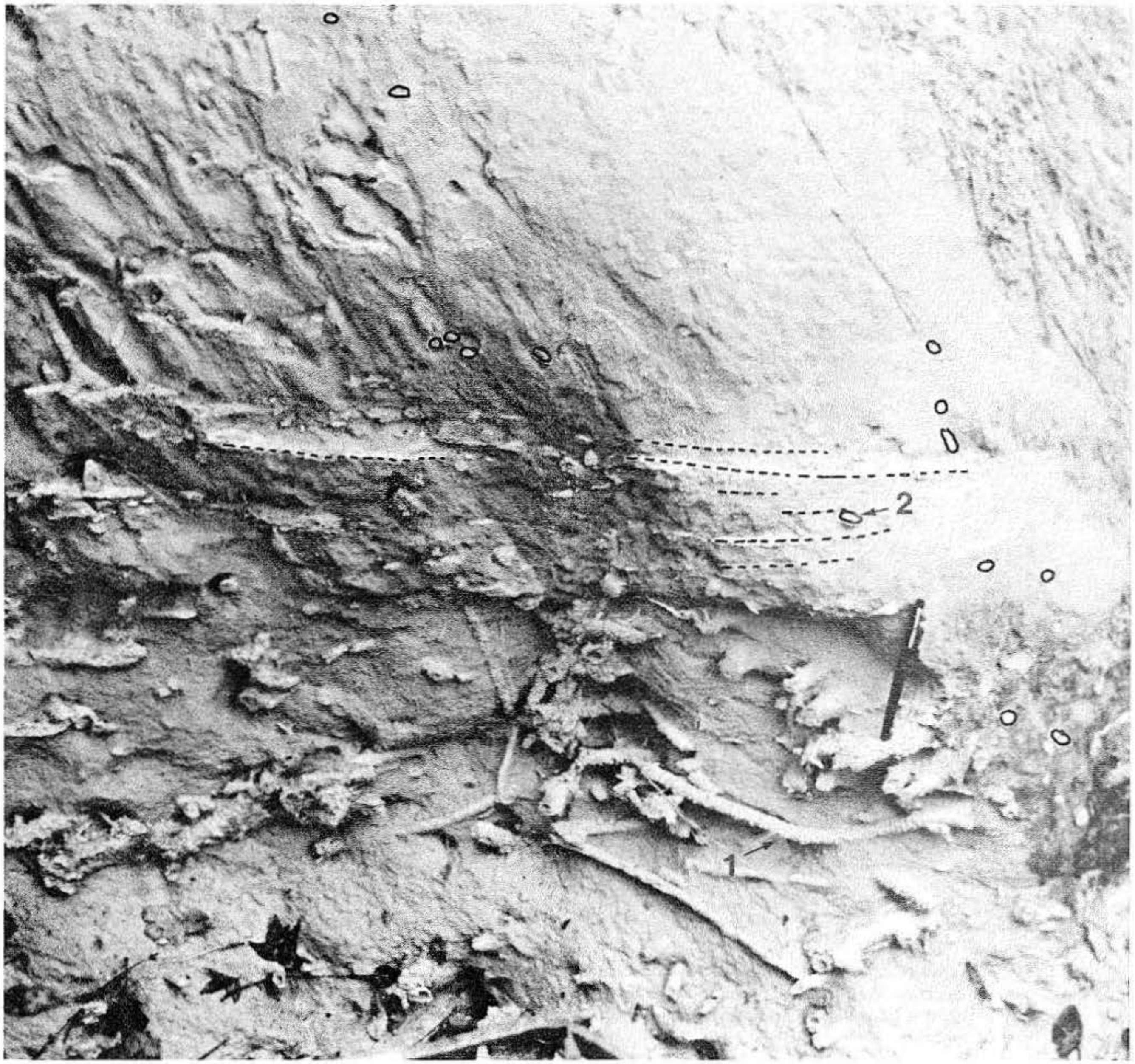

Figure 14. Shoreface deposit (Location 14). Unit A: structureless to parallel-laminated sands contain mud drapes (indicated by dashed lines) and abundant *Ophiomorpha* (1). Circles outline cross sections of walled burrows (2). Pen for scale is 5.5 inches (14 cm) long.

much as 80 percent glauconite. In the Nacatoch, greensands are highly fossiliferous, glauconitic sands that contain whole and fragmented shells of *Ostrea falcata, Exogyra costata, Coryphaea vesicularis,* and *Inoceramus* sp. (Dane, 1929). A well-developed shelf faunal assemblage was observed in Dane's (1929) measured section on the Ouachita River at Arkadelphia (fig. 6, Location 13). At this locality, the lower beds are hard, calcareous, glauconitic sandstone lenses containing boulder-sized concretions enclosing whole shells and fragments of *Inoceramus, Baculites, Belemnitella, Ostrea,* and crustacean remains (Dane, 1929). This basal section is overlain by massive, highly bioturbated, very fine grained quartz sands, which accumulated in a lower shoreface environment.

OUTCROP OBSERVATIONS IN NORTHEAST TEXAS

Outcrops in northeast Texas are limited in number and generally of poor quality. Nevertheless, two facies

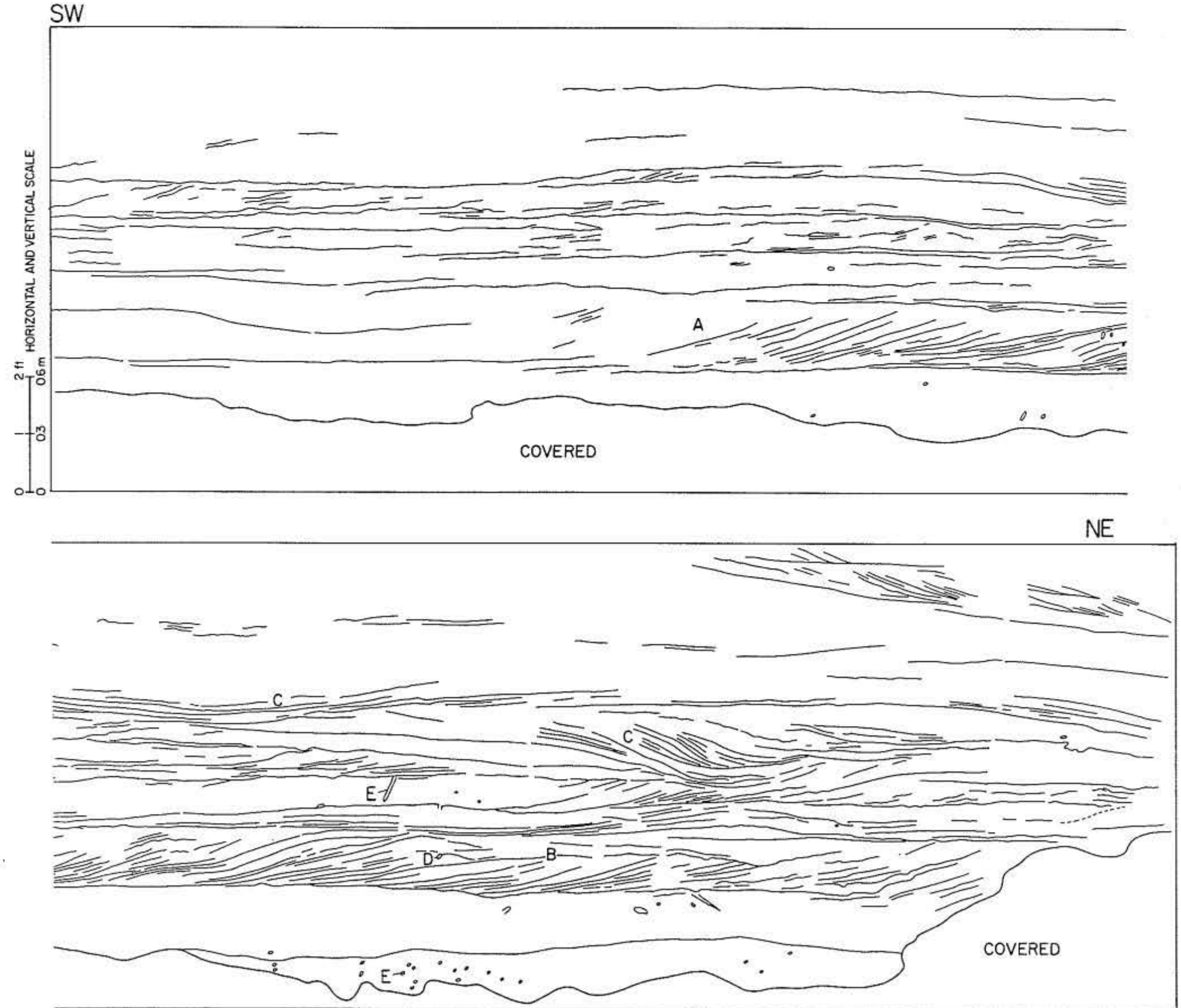

Figure 15. Shoreface deposit (Location 14). Unit A (not included; note figure 14): exposed in gully below level of railroad cut. Unit B: composed of unidirectional foreset cross-stratified sand (A) highlighted by clay drapes (B) and numerous reactivation surfaces (C). Beds range from 0.5 to 2 ft (15 to 60 cm) thick. Some trough cross-strata occur within thin channel-fill deposits (D). Burrows are scattered throughout deposit (E). Line drawing from photomosaic.

representing paleoenvironments were identified from the outcrops marginal to the East Texas Embayment. In the northwest part of the basin in Hunt County, Texas, a crevasse splay sequence is exposed in a sand pit west of Campbell. Along the western part of the basin south of Hunt County, glauconitic, highly fossiliferous shelf sands are exposed (fig. 19).

Shelf Deposits

The Nacatoch Formation crops out along the western margin of the East Texas Basin. Resistant, discontinuous, calcareous sandstone lenses and boulder-sized concretions characterize the Nacatoch outcrop belt. Similar concretionary lenses were observed in calcareous mudstones overlain by a vertical sequence of lower and upper shoreface deposits in southwest Arkansas. In Navarro and Kaufman Counties, Texas, the Nacatoch is composed of light- to medium-gray, calcareous, glauconitic, fossiliferous, very fine grained sandstone containing a distinctive open-marine fauna: *Baculites, Inoceramus, Nostoceras, Helicoceras, Oxybeloceras,* and *Turitella* (Sellards and others, 1932) (table 5). Additional fossil locations are described by Sellards and others (1932). These sandstones are probably of

Table 5. Locations of outcrops and inferred depositional environments, northeast Texas.

Location number	Location	Depositional environment
H-1	1.2 mi (1.9 km) W of intersection of Interstate Highway 30 and Farm Road 513, west of Campbell, Hunt County, Texas.	Deltaic
K-1	North of Kaufman in barrow ditch approximately 1 mi (1.6 km) west of intersection of a dirt road with Farm Road 987, Kaufman County, Texas.	Inner shelf
N-1	Approximately 2.75 mi (4.3 km) north of Southern Pacific Railroad underpass on U. S. Highway 75 near Corsicana, Navarro County, Texas.	Inner shelf

shelf origin and indicate that the shoreline was located far inland from the present outcrop.

Deltaic Deposits

In outcrop, deltaic deposits are limited to crevasse splay deposits that accumulated in a brackish to marine subenvironment within a lower delta-plain environment. The presence of *Ophiomorpha*, pelecypods, and rare glauconite supports this interpretation. Approximately 20 ft (6 m) of section exposed in the pit can be divided into five distinctive units, identified as Units A through E.

Unit A is a dark-gray, calcitic, muddy to moderately sorted, very fine grained quartz sandstone (fig. 20). The sandstone contains abundant carbonized plant fragments as long as 6 mm and rare whole and fragmented shells of ribbed and smooth pelecypods. The sandstone is thoroughly bioturbated; primary sedimentary structures are not preserved. Thickness of this unit is unknown since it crops out at the water's edge. The abundance of carbonized plant fragments and biogenic structures, the presence of pelecypods, the lack of primary sedimentary structures, and the mottled appearance suggest that the unit represents a marsh deposit.

Unit B consists of 5 ft (1.5 m) of massive, slightly glauconitic, very fine grained sandstone containing abundant *Ophiomorpha* (figs. 20 and 21).

Unit C consists of approximately 5 ft (1.5 m) of mostly massive, slightly glauconitic, fine-grained sandstone exhibiting zones that have been intensively burrowed (figs. 20 and 22). Both walled and unwalled burrows are present within the highly burrowed zones, which attain a maximum thickness of 1 ft (0.3 m). Low-angle crossbeds and thin channel-fill deposits exist at a few localities. Rip-up mud clasts commonly occur at the base of the channels. Unit C

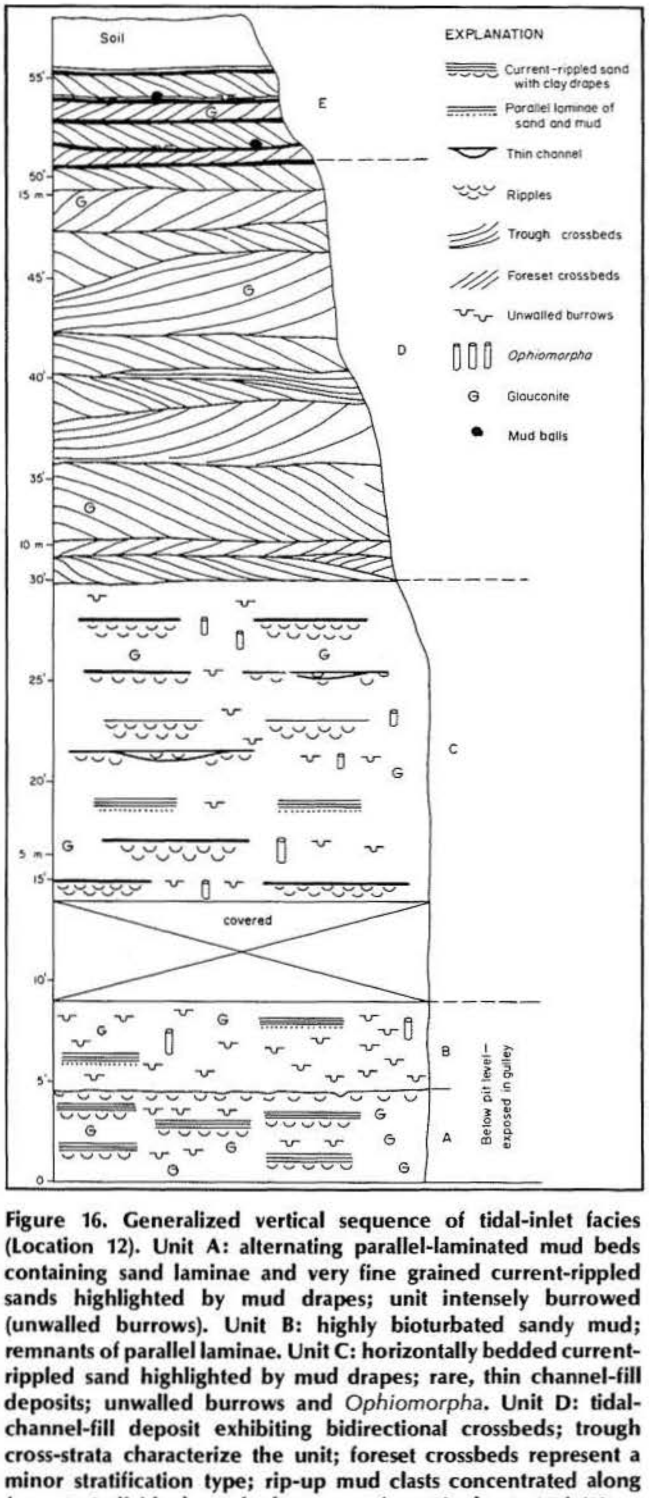

Figure 16. Generalized vertical sequence of tidal-inlet facies (Location 12). Unit A: alternating parallel-laminated mud beds containing sand laminae and very fine grained current-rippled sands highlighted by mud drapes; unit intensely burrowed (unwalled burrows). Unit B: highly bioturbated sandy mud; remnants of parallel laminae. Unit C: horizontally bedded current-rippled sand highlighted by mud drapes; rare, thin channel-fill deposits; unwalled burrows and *Ophiomorpha*. Unit D: tidal-channel-fill deposit exhibiting bidirectional crossbeds; trough cross-strata characterize the unit; foreset crossbeds represent a minor stratification type; rip-up mud clasts concentrated along foresets. Individual crossbed sets range from 4 inches to 1.5 ft (10 cm to 0.5 m) thick. Unit E: same depositional style as Unit D but with small-scale channel-fill deposits and more mud.

was probably deposited periodically, followed by periods of slow deposition or nondeposition when the upper part of the sand was reworked by burrowing organisms. Thin channel-fill deposits of

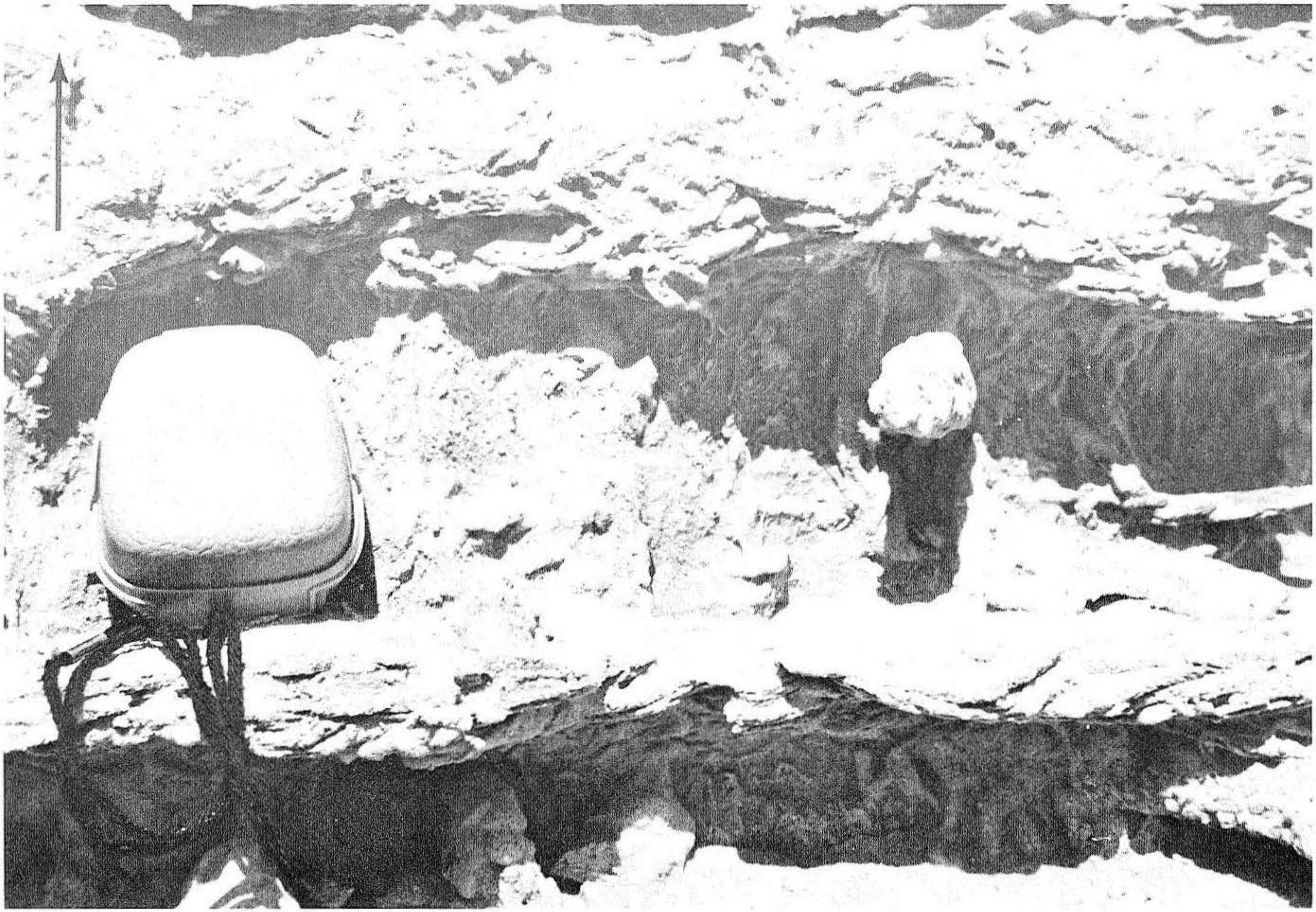

Figure 17. Tidal-inlet facies (Location 12). Unit A: intensely burrowed, parallel-laminated muds and sands. Burrows are unwalled and made by deposit feeders. Light meter case for scale.

Figure 18. Tidal-channel fill (Location 12). Unit D (fig. 16): bidirectional crossbedded sands display herringbone pattern. Trough-fill cross-strata (A) are dominant stratification type. Foreset cross-stratified sands (B) were observed but represent a minor stratification type. Individual crossbed sets are 4 inches to 1.5 ft (10 cm to 0.5 m) thick.

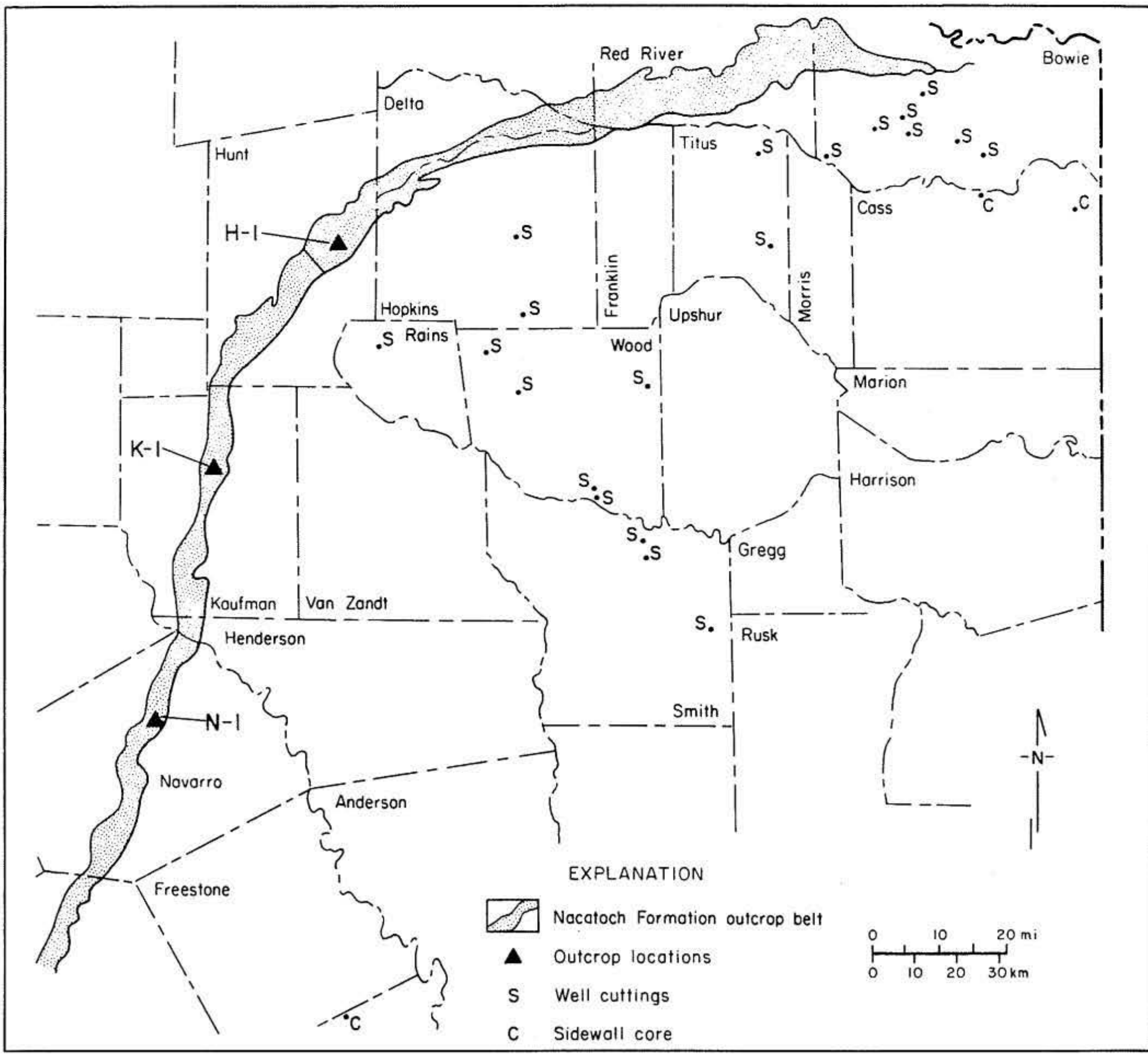

Figure 19. Index map of northeast Texas showing outcrop localities and wells that provided drill cuttings and sidewall cores, Nacatoch Formation.

this unit are also indicative of short periods of erosion and deposition associated with flooding.

Unit D is composed of approximately 2.5 ft (0.75 m) of horizontally bedded, slightly glauconitic, fine-grained sandstone (figs. 20, 22, and 23). Evidence of shallow erosion (thin channel-fill deposits) was also observed within this unit. Burrows are rare except for the upper 0.5 ft (15 cm), which is intensively burrowed.

Units B, C, and D are interpreted to be splay-front sands associated with a crevasse splay deposit that was prograding into a marine environment. Sediment was deposited in erratic pulses related to flooding within the fluvial system.

Unit E consists of approximately 4 ft (1.2 m) of trough crossbedded, fine-grained sandstone (figs. 20 and 23). The vertical relationship of beds and associated sedimentary structures suggests that this deposit may represent a small distributary-channel fill.

Evidence supporting the interpretation that the Nacatoch Formation of southern Hunt County accumulated in a deltaic regime includes the following:

(1) Subsurface studies indicate a significant influx of terrigenous clastics from the northwest (p. 32).
(2) Sedimentary structures and interbedded zones of intensive burrowing suggest that rapid rates of sedimentation occurred in pulses; these sediment pulses alternated with longer periods of slow deposition or nondeposition, as indicated by an abundance of biogenic structures. Periods of rapid sediment influx and scouring of the underlying (older) deposits were coincident with river flooding.

SUBSURFACE STUDIES

Approximately 1,500 electric logs (fig. 24) were used to construct an isopach map of the Upper Navarro Marl (fig. 25), a structural map of the base of the Upper Navarro Marl (fig. 3), and a net-sand map of the Nacatoch Formation (fig. 26). Forty-nine cross sections were constructed by Wood and Guevara (1981) across the basin, and six of these sections are included in this report. Regional sections show the distribution and lateral variation of lithic units within the Nacatoch Formation. The SP curve was used to tabulate net-sand values in the Nacatoch, except along the northwest and northern parts of the basin where it contains fresh water, which results in a neutral to positive SP response. For these wells (less than 1 percent of the total number of wells), it was necessary to use the resistivity curve to determine net-sand values. Net-sand values based on resistivity curves may be slightly higher than values based on SP curves because thin, resistive siltstones that commonly occur within the Nacatoch Formation cannot be distinguished from fresh-water sands by resistivity. The error in the net-sand value is small and has a negligible effect on net-sand patterns.

Sidewall cores and well cuttings were examined to determine composition and texture of sandstones and mudstones and to interpret paleoenvironments of sandstone and mudstone facies (fig. 19; Appendix B). Sidewall cores from two wells in Cass County (Humble Oil and Refining Company, Methodist Home No. 1, and Kamon and Howe, Savage No. 1) and one well in Leon County (Letco, TOH No. 2-A, a hydrologic test well drilled for the Bureau of Economic Geology, East Texas Waste Isolation study by the U. S. Department of Energy) are described in figure 19 and Appendix B. Rotary drill cuttings from 31 wells were also examined.

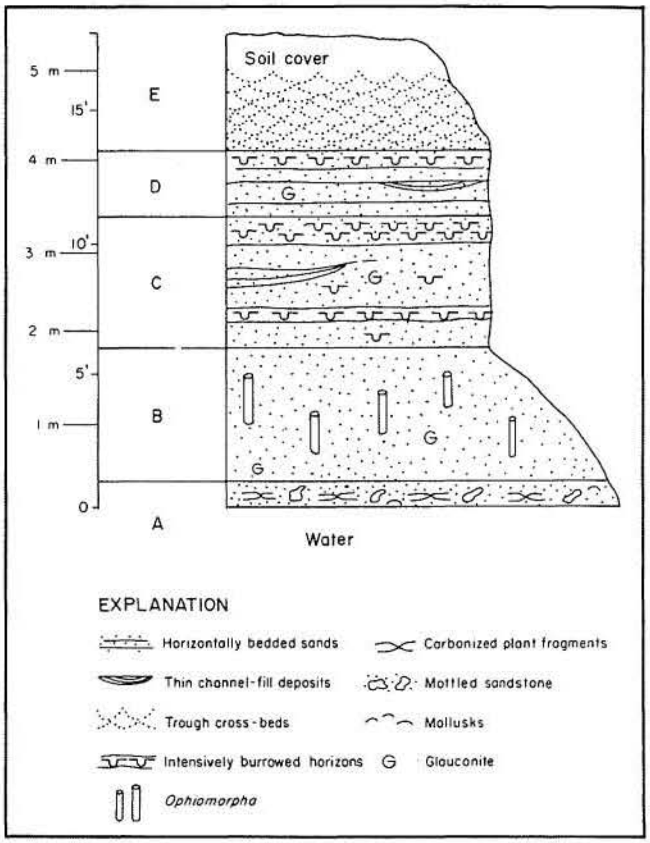

Figure 20. Delta-associated units (Locality H-1, Hunt County). Generalized vertical section of outcrop showing sequence and thickness of depositional units. Unit A: dark-gray, mottled, muddy sand. Abundant carbonized plant fragments and rare whole and fragmented mollusks. Unit B: massive, slightly glauconitic, very fine grained sand containing *Ophiomorpha*. Unit C: mostly massive, fine-grained sand containing intensely burrowed zones and rare thin channel-fill deposits. Unit D: horizontally bedded sand containing rare thin channel-fill deposits and rare burrows, except for intensely burrowed upper 0.5 ft (15 cm). Sequence E: trough crossbedded sand.

Sample descriptions and electric log patterns for selected wells are included in Appendix B.

Limitations in the data base include the following:

(1) Well spacing in parts of the basin precludes mapping and correlation of individual sand bodies.
(2) Conventional core was unavailable to determine sedimentary structures and vertical sequences within the Nacatoch Formation.
(3) Well casing precludes obtaining electric log information in the shallow subsurface. Also, the Nacatoch is a fresh-water aquifer in the shallow subsurface, making it difficult to correlate electric logs of wells containing fresh water with downdip wells containing more saline fluids.
(4) Outcrops in northeast Texas are of limited use because of poor exposure.

Figure 21. Delta-influenced unit (Locality H-1, Hunt County). Massive sand containing abundant *Ophiomorpha*. Rock pick for scale. (Unit B of figure 20.)

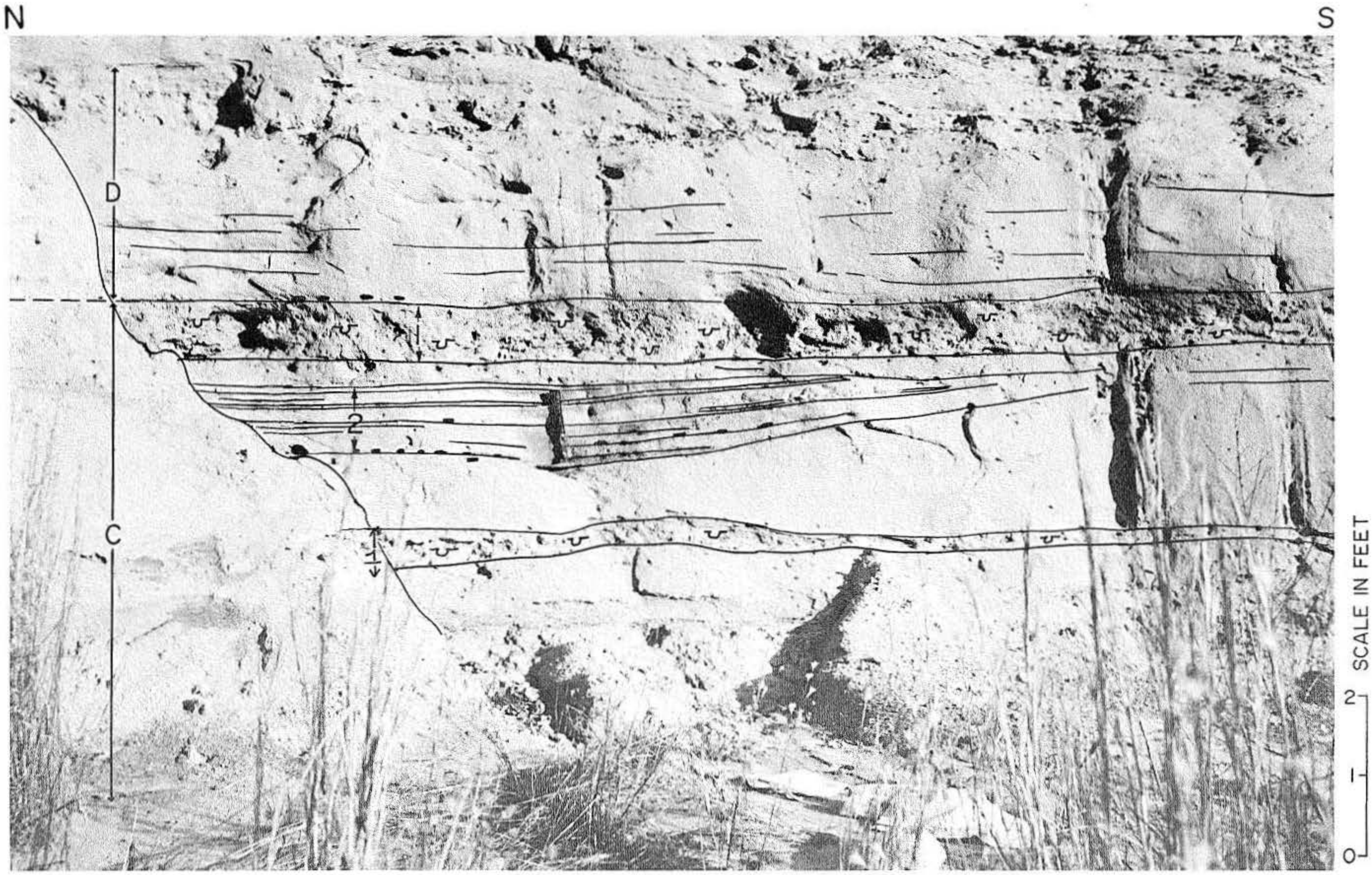

Figure 22. Delta-influenced unit (Locality H-1, Hunt County). Units C and D of figure 20. Unit C: massive sand contains intensely burrowed zones (1) and a thin channel fill (2). Unit D: horizontally bedded sand.

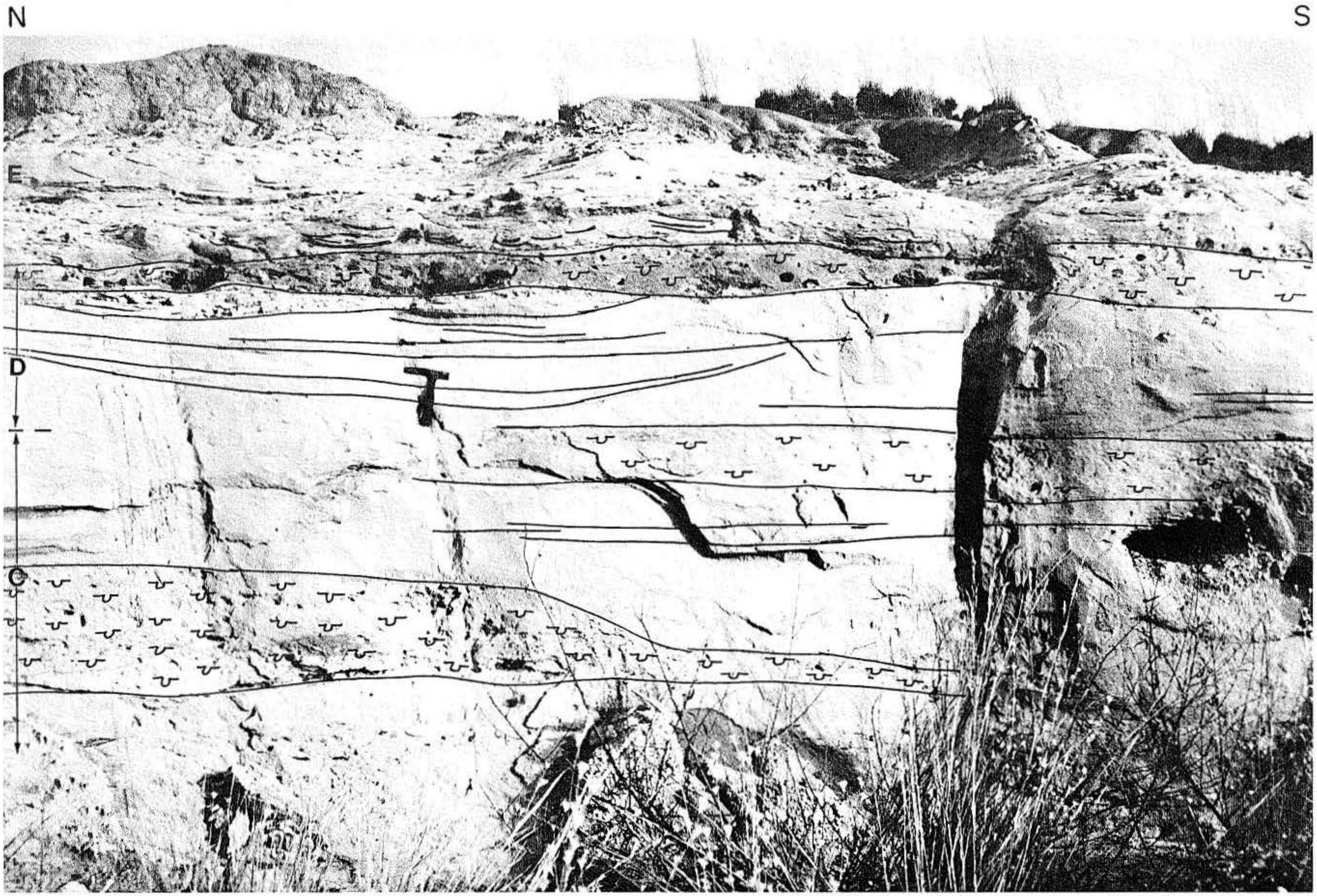

Figure 23. Delta-influenced unit (Locality H-1, Hunt County). Units C, D, and E of figure 20. Unit C: massive sand containing intensely burrowed zones. Unit D: horizontally bedded sand contains thin channel fill. Unit E: trough crossbedded sands. Rock pick for scale. (Photograph taken immediately south of figure 22.)

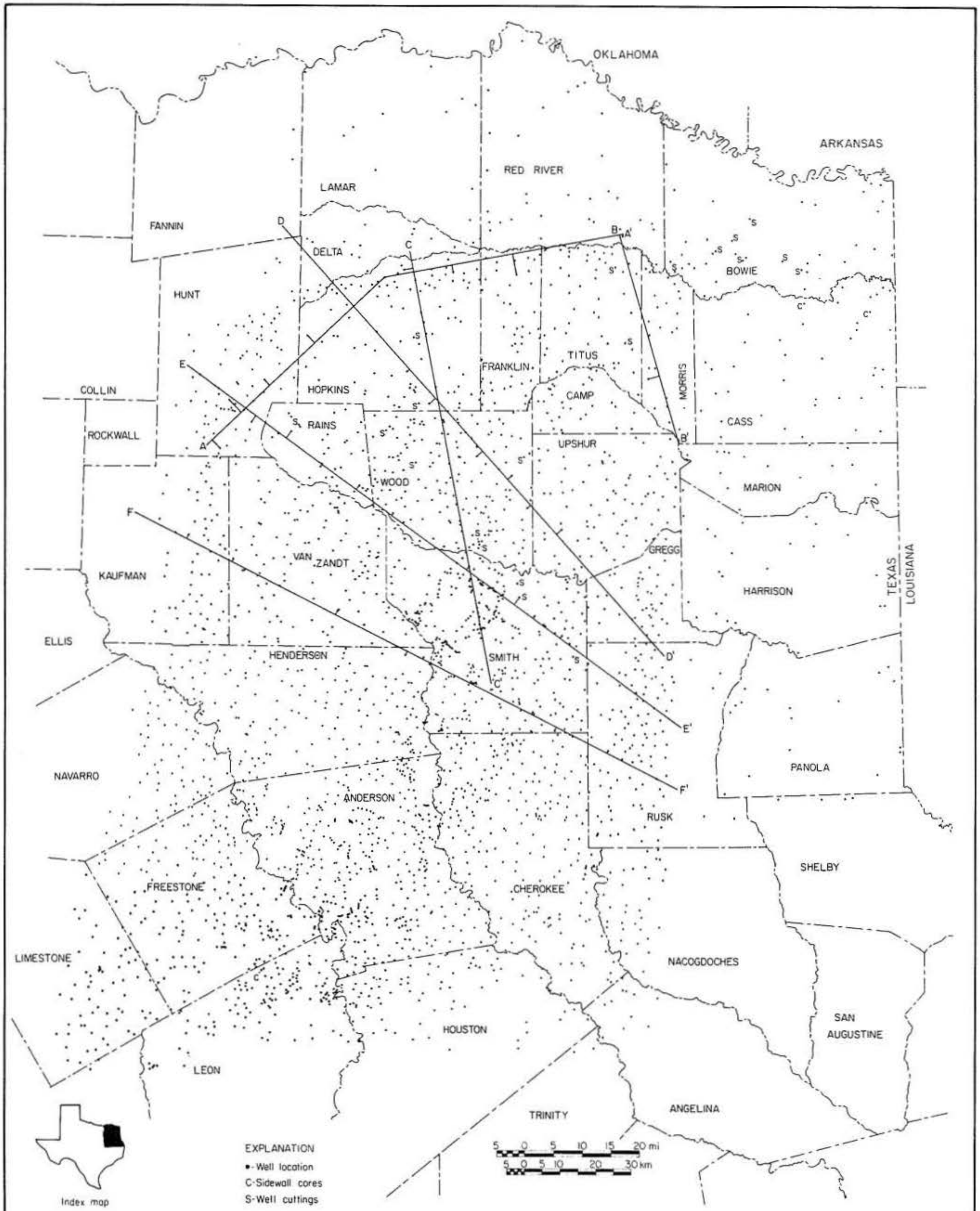

Figure 24. Index map of East Texas showing location of well control, cross sections, and wells that provided sidewall cores and drill cuttings, Nacatoch Formation.

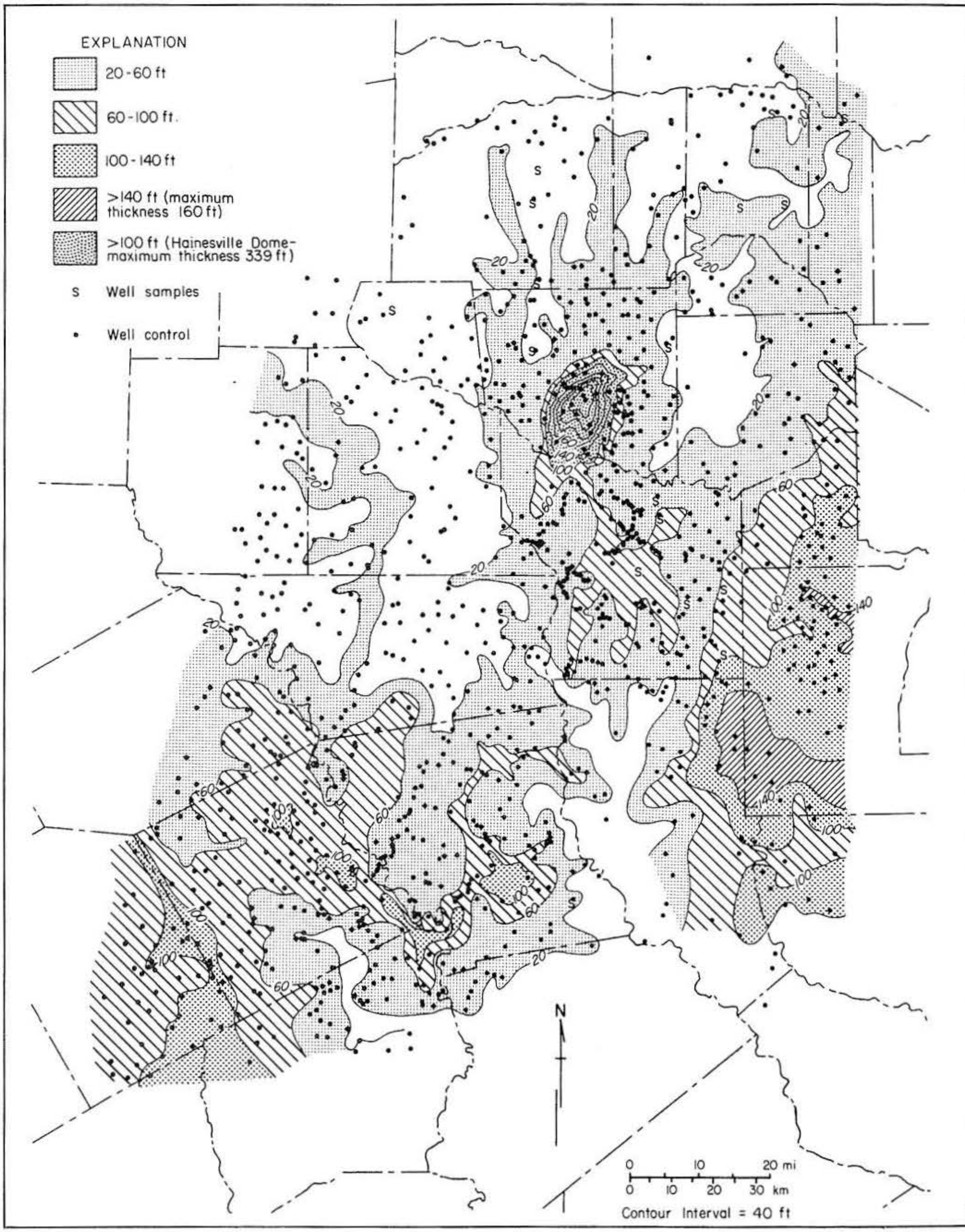

Figure 25. Isopach map of Upper Navarro Marl, East Texas Basin.

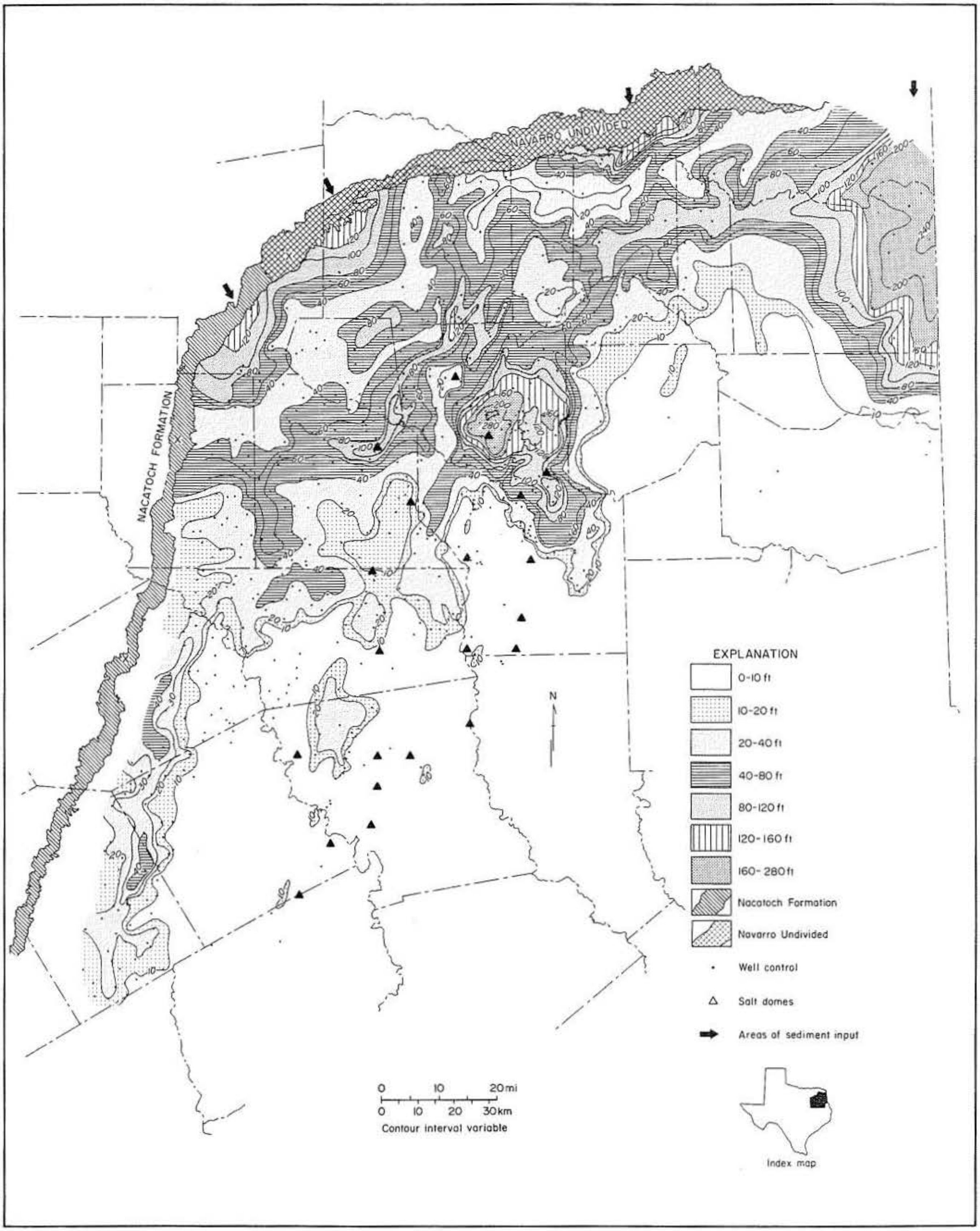

Figure 26. Net-sand map, Nacatoch Formation, East Texas Basin, showing outcrop of the Nacatoch Formation and surface sample locations.

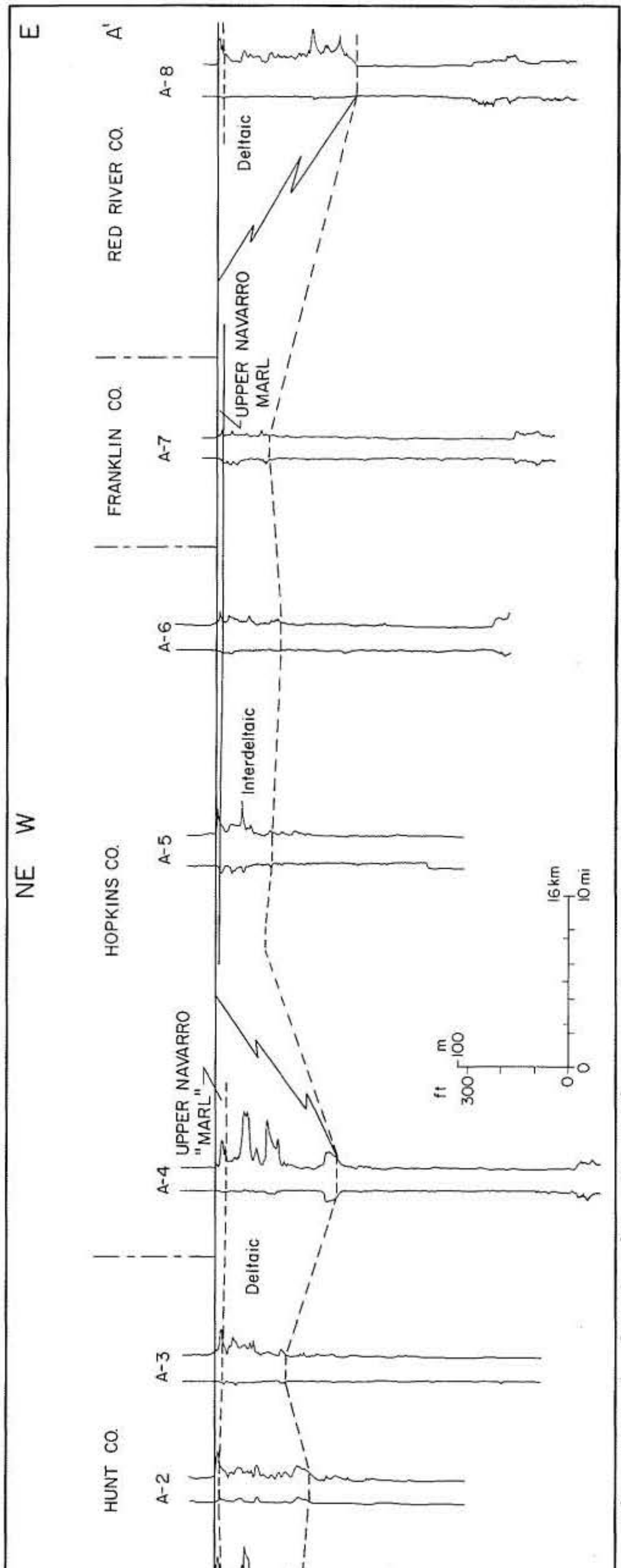

Figure 27. Regional stratigraphic section A-A' across northwest and northern part of East Texas Basin, showing deltaic and interdeltaic facies.

FACIES DISTRIBUTION PATTERNS IN THE NACATOCH FORMATION

The Nacatoch sand facies are principally restricted to the western margin and the northern parts of the East Texas Basin (fig. 26). In central Henderson, Smith, Upshur, and southern Morris Counties, the Nacatoch sandstones grade southward and eastward into mudstone. A few thin, laterally discontinuous sandstones occur downdip in Anderson, southeastern Freestone, and northern Leon Counties; these sandstone beds probably accumulated in rim synclines associated with salt domes. Thin, erratic sands and muddy sandstone also exist in the area of the Sabine Uplift.

A net-sand map of the Nacatoch Formation (fig. 26) does not outline the geometry of individual sand bodies, but does indicate directions of sediment input, thick sand axes, and local sandstone depocenters controlled by salt withdrawal. Most terrigenous clastics were introduced into the East Texas Basin during Nacatoch time in Cass and Bowie Counties, Texas, and southwest Arkansas. Lesser volumes of sediment entered the basin from the north through southern Red River, Delta, and Hunt Counties (fig. 26).

In reconstructing paleoenvironments, the following observations are pertinent:

(1) Deltaic (splay) deposits were observed in outcrop in southern Hunt County (figs. 20 to 23) updip from an area of a high net-sand value within the adjacent subsurface.
(2) Basinward, the Nacatoch Formation generally consists of laterally discontinuous, coarsening-upward marine sandstones alternating with marine mudstones.
(3) Net-sand contours indicate an increase in sand thickness to the northeast, culminating in a maximum of 250 ft (76 m) in northern Cass County.
(4) Salt tectonism locally controlled sediment distribution.

Nearshore Deltaic Facies

The updip occurrence of deltaic (splay) deposits in a sand pit in southern Hunt County (figs. 20 to 24), in conjunction with subsurface net-sand distribution patterns (figs. 26 and 27), supports the interpretation of small delta systems in the northwest part of the basin. The fluvial system that supplied terrigenous clastics to this part of the basin was not observed in outcrop; this may be because of poor exposures, or the system may have been located north of the outcrop.

Net-sand distribution patterns in the subsurface of Hunt and Hopkins Counties show a high net-sand system normally oriented to the outcrop belt (fig. 26).

A smaller high net-sand trend is located in southern Red River and Titus Counties. Orientation of net-sand trends changes abruptly in northwest Van Zandt, southern Hunt, Hopkins, northern Franklin, Titus, and Morris Counties from northwest-southeast and north-south to northeast-southwest, an indication that sedimentation rates were slow, marine processes were dominant, and deltaic sands were subjected to reworking by waves and currents.

Electric log response through this facies association is blocky, coarsening upward, and fining upward (fig. 28). The coarsening-upward resistive pattern exhibited by the upper sands may be amplified by freshening-upward pore fluids. Fining-upward sequences may represent fluvial channel deposits; however, the low-density well spacing precludes mapping of individual sand bodies. Interdeltaic areas are characterized by interbedded thin sands and mudstones. Individual sands generally average less than 10 ft (3.3 m) thick. The deltaic facies were not described because well cuttings are not available for wells within this area. Net-sand values range from about 40 to 150 ft (13.3 to 50 m) within the inferred deltaic facies to 20 to 40 ft (6.6 to 13.3 m) in interdeltaic areas.

Shelf Facies

Basinward in the subsurface of the East Texas Basin, the Nacatoch Formation is generally characterized by elongate, laterally discontinuous sand bodies within the lower part of the formation and an upper sand unit composing a fairly continuous sheet sandstone. The two zones are separated by 50 to 100 ft (16.6 to 33.3 m) of marine mudstone (figs. 29 to 31). Drill cuttings indicate that the sandstones are texturally similar: generally clean, well sorted, calcitic, glauconitic, fine grained, containing some shell material and rare foraminifers (Appendix B). Intervening mudstones are also glauconitic, calcareous, and contain shell material, foraminifers, and minor amounts of fine-grained carbonized plant fragments (Appendix B). Samples indicate that sharp resistive peaks on electric logs record the occurrence of hard, calcite-cemented sandstone or thin shell beds. Although the textures of the sandstone intervals appear to be similar, net-sand contours suggest that they are genetically different.

The lower interval is composed of individual sandstone bodies that are elongate, average 30 ft (10 m) thick, have gradational lower boundaries and abrupt upper contacts, and grade laterally into marine mudstones. These sandstone bodies are separated from nearshore deposits along the northern part of the basin by marine mudstone. The basinal sandstone bodies in the lower unit are restricted to a northeast-southwest-trending belt in the northern part of the basin in Franklin, southern Titus, Camp, northwestern Upshur, Wood, and Van Zandt Counties. During early Nacatoch time sediment input was predominantly from the northeast, and minor amounts of terrigenous clastics were supplied from the north and northwest.

Locally, the lower sandstones exhibit fining-upward electric log patterns (Texas, Morris Gas Unit #1, Hopkins County; Appendix B). Glauconite and shell fragments indicate that these units are marine in origin. Marine composition, fining-upward textures, and limited areal extent suggest that the sandstones probably represent marine channel-fill deposits. Because well spacing is greater than the area of the sand facies, the geometry of these inferred channels cannot be determined by mapping.

Net-sand contour patterns of the upper sandstone unit are different from those of the lower zone. Rather than consisting of discrete sand bodies that average 30 ft (10 m) thick, the upper sandstone composes a fairly continuous sand sheet. Strong northeast-southwest orientation exhibited by the lower sandstone within the northern part of the basin is not as apparent on net-sand maps of the upper unit, which displays a north-south orientation.

Sand Depocenter in Cass and Bowie Counties, Texas

The Nacatoch Formation exhibits a maximum net-sand thickness of 250 ft (76 m) in northern Cass County. This high sand area represents a local depocenter that was located in an area of greater subsidence (Cass County syncline) between the Sabine Uplift and the Mexia-Talco fault system. Net-sand contours of the Nacatoch Formation in southwestern Arkansas (Miller, Lafayette, Columbia, and Union Counties) indicate that the high sand facies in Cass County thins to the northeast (Dolloff and others, 1967).

Sandstones in sidewall cores and well cuttings from Bowie and Cass Counties (Appendix B) are calcitic to friable, glauconitic, shell bearing, fine to medium grained, and well sorted. Intervening mudstones contain shell fragments, foraminifers, and glauconite. In the subsurface of southern Arkansas, the Nacatoch Formation is white to light gray, calcitic to friable, glauconitic, well sorted, fine to medium grained, and contains shell fragments and some beds of white, finely crystalline limestone (Granata, 1963; Dolloff and others, 1967). Downdip in Louisiana, the Nacatoch Formation becomes increasingly calcareous, grading into a gray to white fossiliferous and argillaceous chalk containing thin beds of very fine grained calcareous sandstone and siltstone (Granata, 1963; Berryhill and others, 1968). Updip, in outcrop, well-developed tidal-flat, shoreface, and shelf sequences have been described in southwest Arkansas (see section titled "Outcrop Observations in Southwest Arkansas").

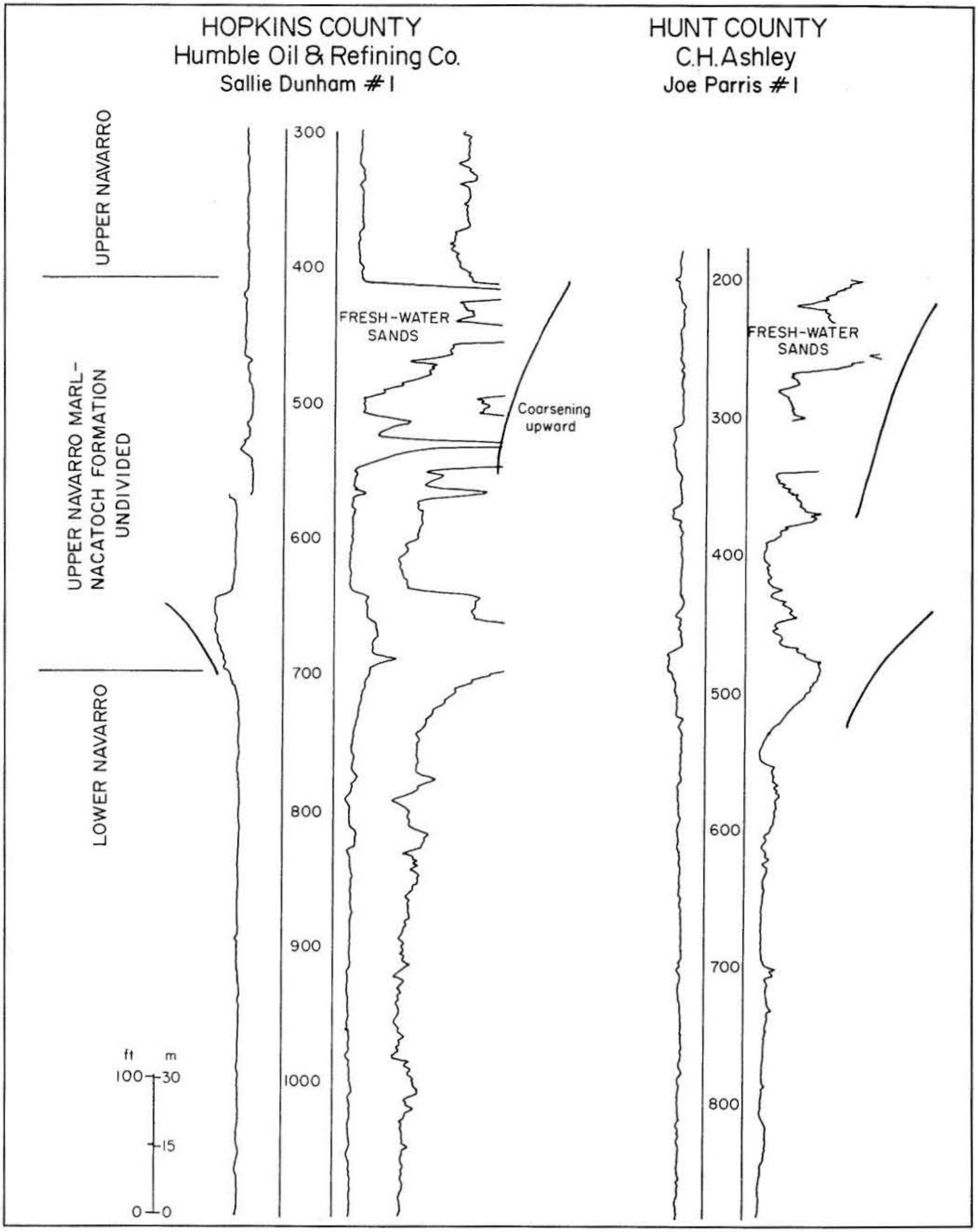

Figure 28. Electric log patterns from delta-influenced units in northwest part of the East Texas Basin. Vertical sequence includes a lower, coarsening-upward sandstone bed and an upper, thicker coarsening-upward sandstone unit separated by about 100 ft (33 m) of mudstone.

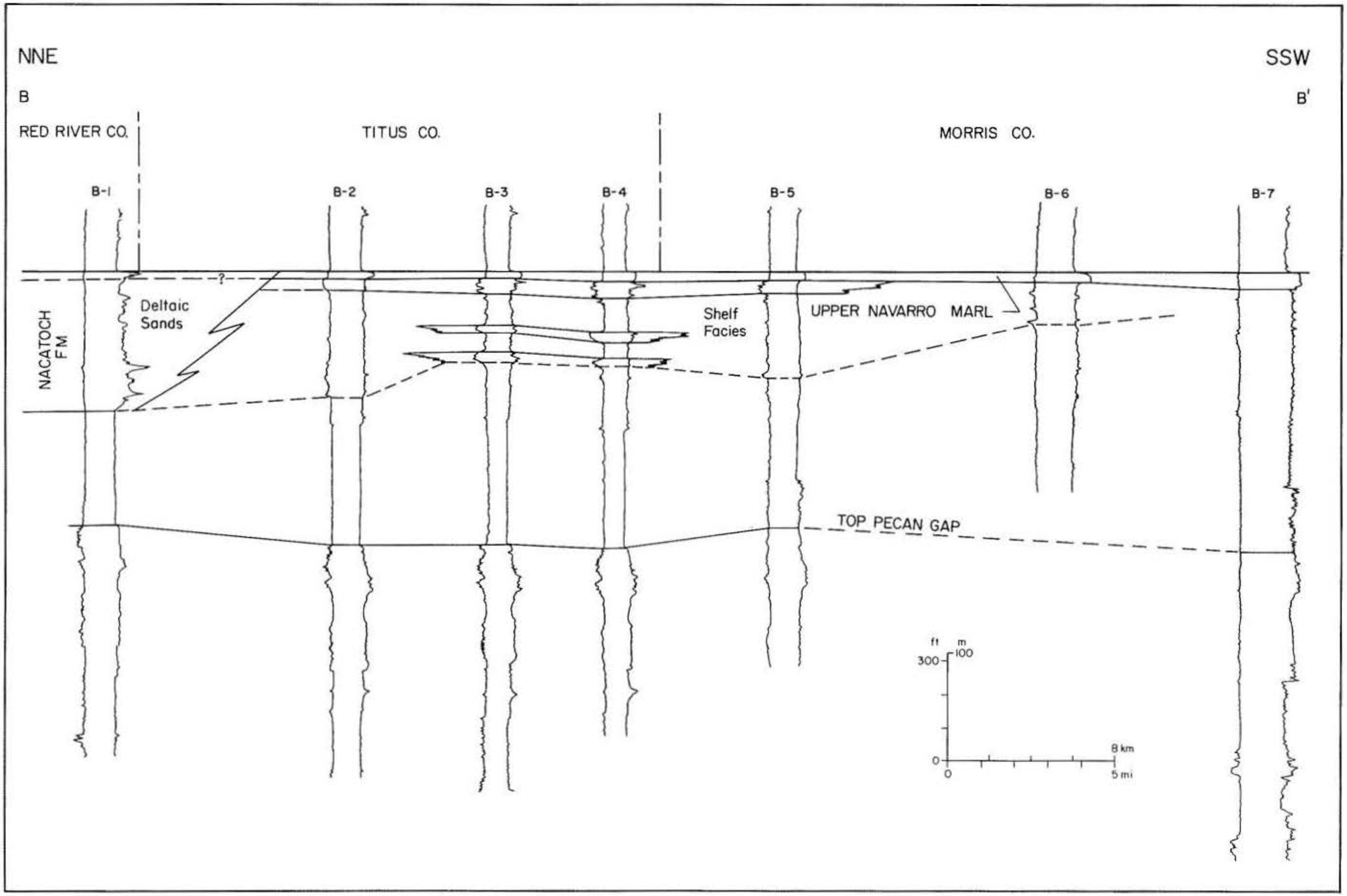

Figure 29. North-south regional stratigraphic section B-B′ across the eastern part of the East Texas Basin.

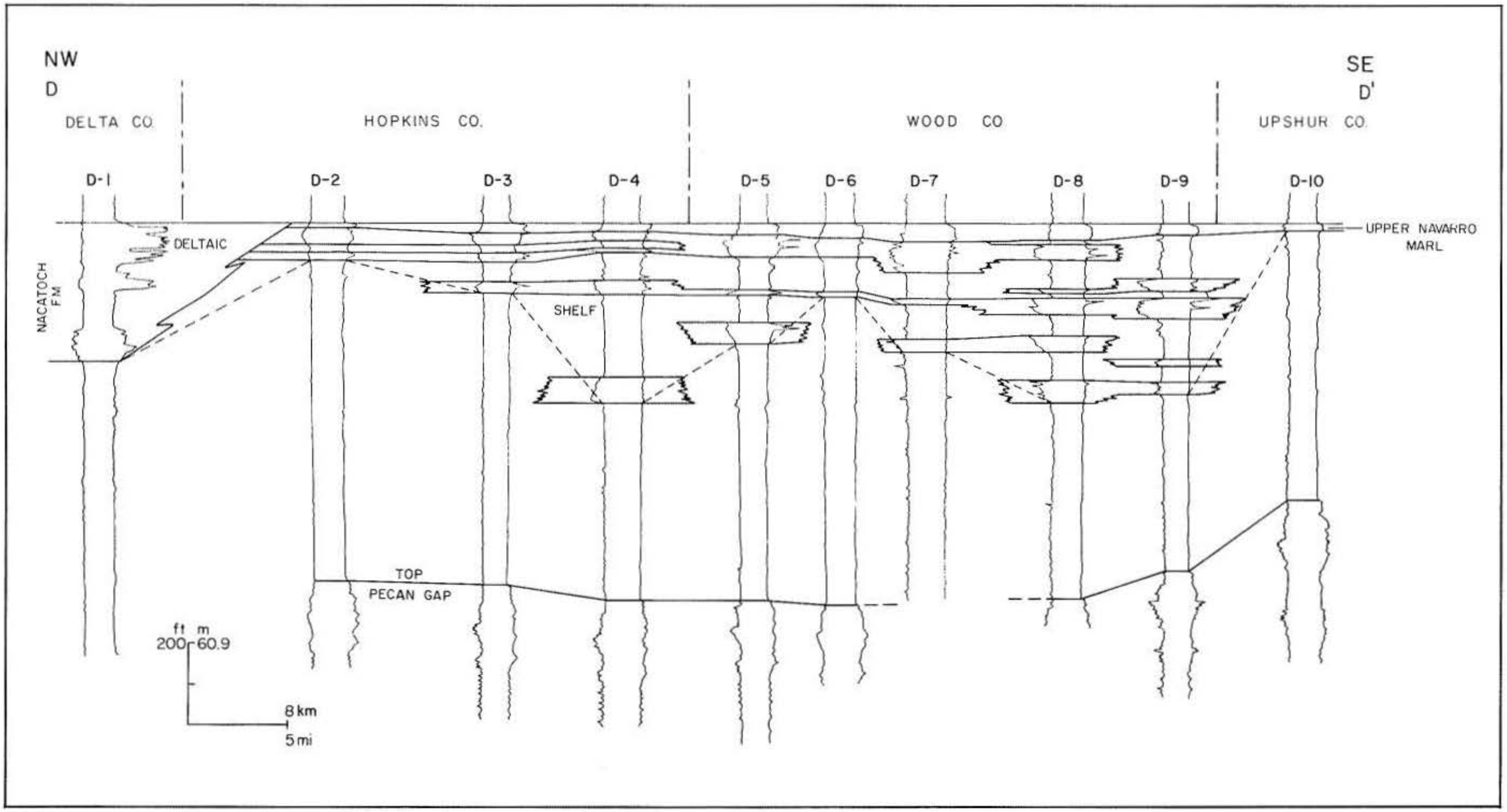

Figure 30. Northwest-southeast regional stratigraphic section D-D′ across part of the deltaic and shelf facies of the Nacatoch Formation.

Salt Tectonism

Tectonism, coincident with deposition, locally controlled sandstone distribution. Development of rim synclines, concomitant with salt dome growth, considerably affected the thickness and distribution of the Nacatoch Formation and the Upper Navarro Marl. For example, a thick section of sand was deposited in the rim syncline around Hainesville Dome in Wood County (figs. 32 to 38). The Nacatoch Formation thickens from an average of 60 ft (18 m) in northern Wood County to a maximum of 289 ft (88 m) in the central part of the Mineola Basin (fig. 32). Thickest accumulations of the Nacatoch Formation occur north and south of the dome (figs. 36 and 37). The northeast-southwest trend exhibited by net-sand contours suggests that geometry was controlled partly by marine processes. Growth of the Hainesville Dome was initiated during Late Jurassic or Early Cretaceous time (Locke, 1978). Sediments were preserved as the area subsided because of salt withdrawal contemporaneous with sediment loading and flank collapse. The rim syncline may have represented a bathymetric low during Nacatoch time, and this would have further enhanced the entrapment of sand.

The thick Nacatoch sequence around Hainesville Dome is divisible into a lower and an upper unit (fig. 35). The lower unit comprises two or three individual sand bodies separated by 20 to 30 ft (6 to 9 m) of mudstone. The sandstones display coarsening-upward textures, abrupt upper contacts, and gradational lower contacts.

The upper sandstone unit is separated from the lower sandstones by approximately 100 ft (30 m) of mudstone and is characterized by a more blocky SP curve than that of the lower sandstones. Isopach contour patterns of the lower and upper sandstones indicate two east-northeast- to west-southwest-trending sand depocenters (figs. 36 and 37). Sand thicks are located on the north-northwest and the south-southeast sides of the dome. Thickness trends of these sandstones suggest a northeastern source.

Other piercement domes with smaller salt withdrawal basins that were actively subsiding during Nacatoch deposition are Steen, Mount Sylvan, East Tyler, Brooks, and Bethel Domes (fig. 5). However, Nacatoch net-sand thicknesses are much less than those in the Hainesville rim syncline because these domes were farther from the source areas.

FACIES DISTRIBUTION IN THE UPPER NAVARRO MARL

The Upper Navarro Marl, recognizable only in the subsurface, occurs throughout the East Texas Basin (figs. 25 and 38). Updip, the Upper Navarro Marl is partly equivalent to the Kemp Clay. Around the margins of the basin, it is generally composed of hard, sandy, slightly glauconitic mudstone or hard, calcareous, slightly glauconitic, very fine grained sandstone and siltstone containing shell fragments. In deeper parts of the basin, the Upper Navarro Marl is a calcareous mudstone.

Around the Sabine Uplift, the lower part of the formation is sandy mudstone grading upward into calcareous mudstone. This part of the marl can be traced as far south as the Elkhart-Mount Enterprise fault system.

The sandy and silty facies of the Upper Navarro Marl range in thickness from 10 to 30 ft (3 to 9 m). Calcareous mudstone facies range from approximately 30 ft (9 m) to a maximum of 338 ft (103 m) near Hainesville Dome (fig. 38). Minor amounts of sandy mudstone and very fine grained sandstone occur on the Sabine Uplift in the lower part of the formation. The Upper Navarro Marl also thickens to the south and east over the Sabine Uplift.

Regional correlations show that some strata previously designated as Nacatoch are equivalent to the Upper Navarro Marl as defined in this study. For example, a sequence of thin, erratic sandstones that has produced petroleum in the Pleasant Grove and Lone Star Fields of Rusk County correlates with the Upper Navarro Marl and not the Nacatoch Formation, as previously inferred. The Nacatoch Formation is composed of mudstone facies in these fields (fig. 39).

The widespread occurrence of the Upper Navarro Marl suggests that the interval accumulated as a transgressive and subsequent shelf deposit when the influx of terrigenous clastics sharply decreased at the end of Nacatoch time. Sandy mudstone facies resulted from marine reworking of upper Nacatoch sands.

OIL AND GAS PRODUCTION

Nacatoch sands in the East Texas Basin are significant shallow oil and gas reservoirs. However, production has been limited to two areas: the Van salt dome and a trend along the western margin of the basin coincident with the Mexia-Talco fault system (fig. 40). This western trend continues southwestward outside the study area. Hydrocarbons in the Nacatoch Formation have been reported from areas along the Mount Enterprise fault system and peripheral to the Sabine Uplift. However, regional studies indicate that the shallow producing horizons described as Nacatoch in these areas are correlative with the Upper Navarro Marl.

Nacatoch production is restricted to shelf-sand facies, although hydrocarbon occurrence is probably

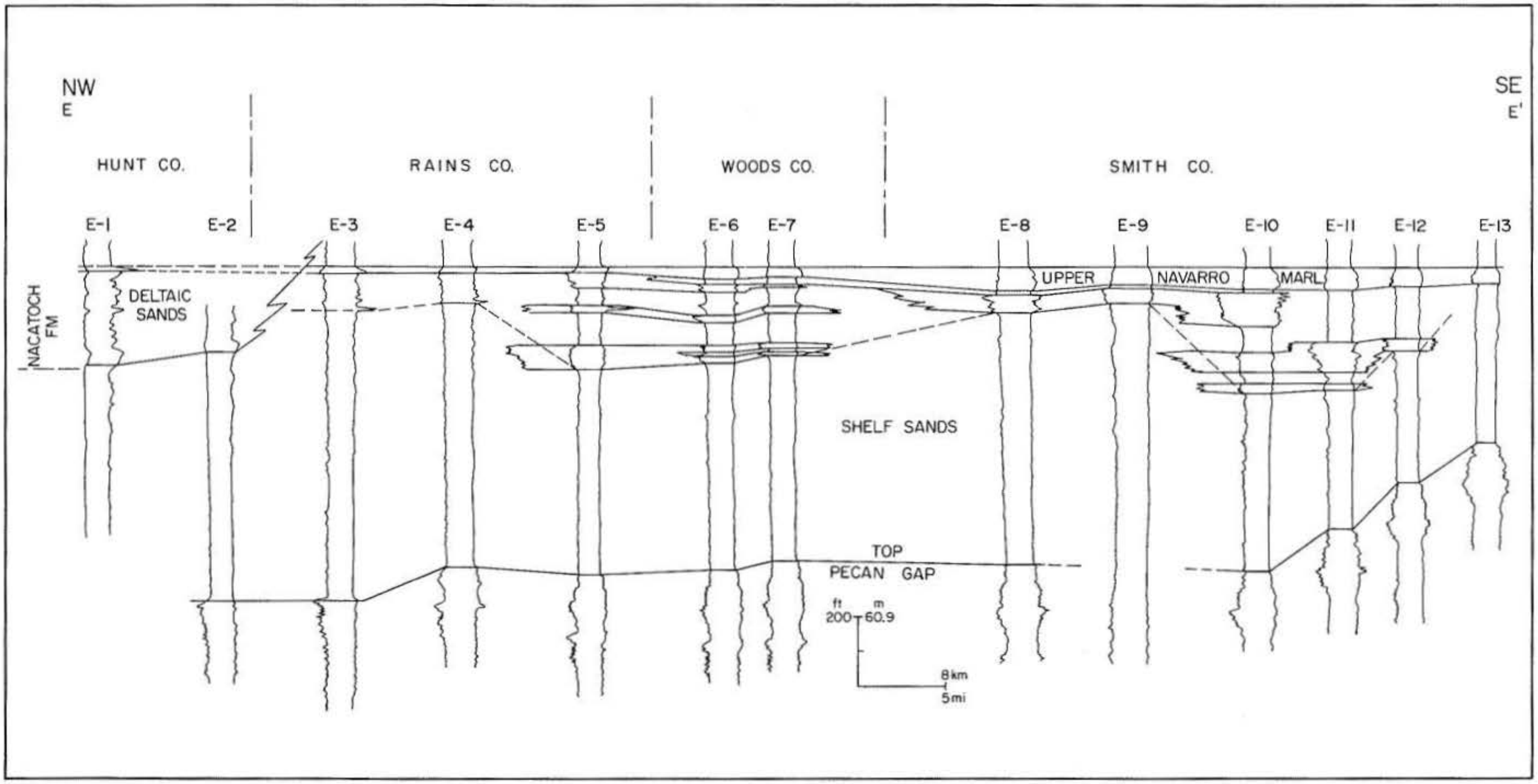

Figure 31. Northwest-southeast regional stratigraphic section E-E′ across part of the deltaic and shelf facies of the Nacatoch Formation.

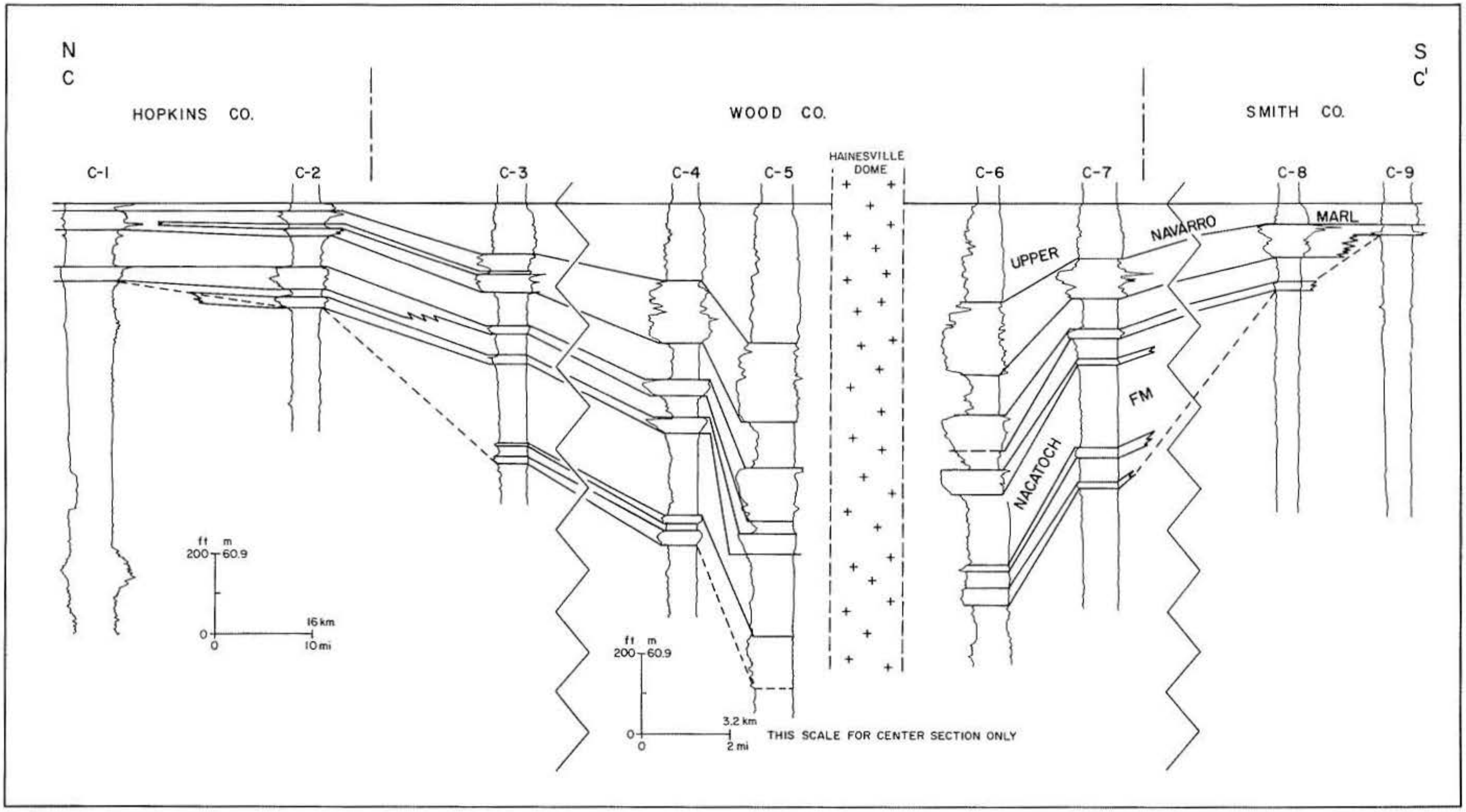

Figure 32. North-south regional stratigraphic section C-C′ showing influence of Hainesville Dome on distribution of the Nacatoch Formation.

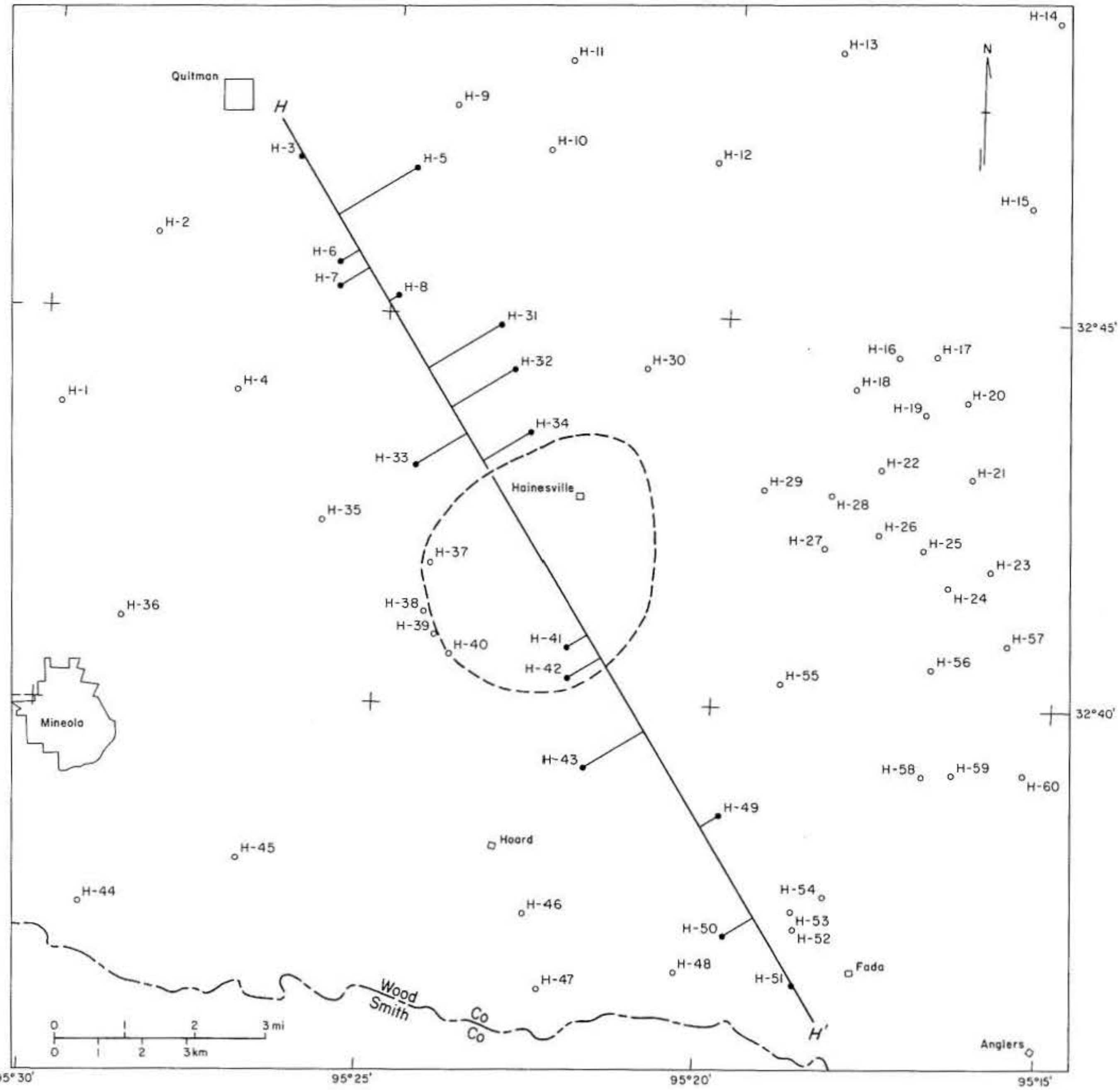

Figure 33. Index map showing well control and line of cross section H-H' across Hainesville Dome, East Texas Basin.

more a function of the location of these sands coincident with structural closure rather than of facies control. Facies characteristics of Nacatoch shelf sands meet favorable reservoir criteria. Sand bodies are clean and well sorted, generally have good porosity, and grade laterally and vertically into shelf muds that restrict the migration of hydrocarbons.

MEXIA-TALCO FAULT TREND

The Mexia-Talco fault system is a series of en echelon normal faults and grabens that mark the updip limit of the Louann Salt within the East Texas Basin. Significant hydrocarbon accumulations occur in the Nacatoch shelf-sand facies along the western margin of the basin (fig. 40), where closure is against upthrown sides of southeast-dipping normal faults. Minor hydrocarbon accumulations occur on low-relief anticlines within the grabens (Nichols and others, 1968). Production figures are not available for many of the fields because total production values, rather than production from individual producing zones, are recorded.

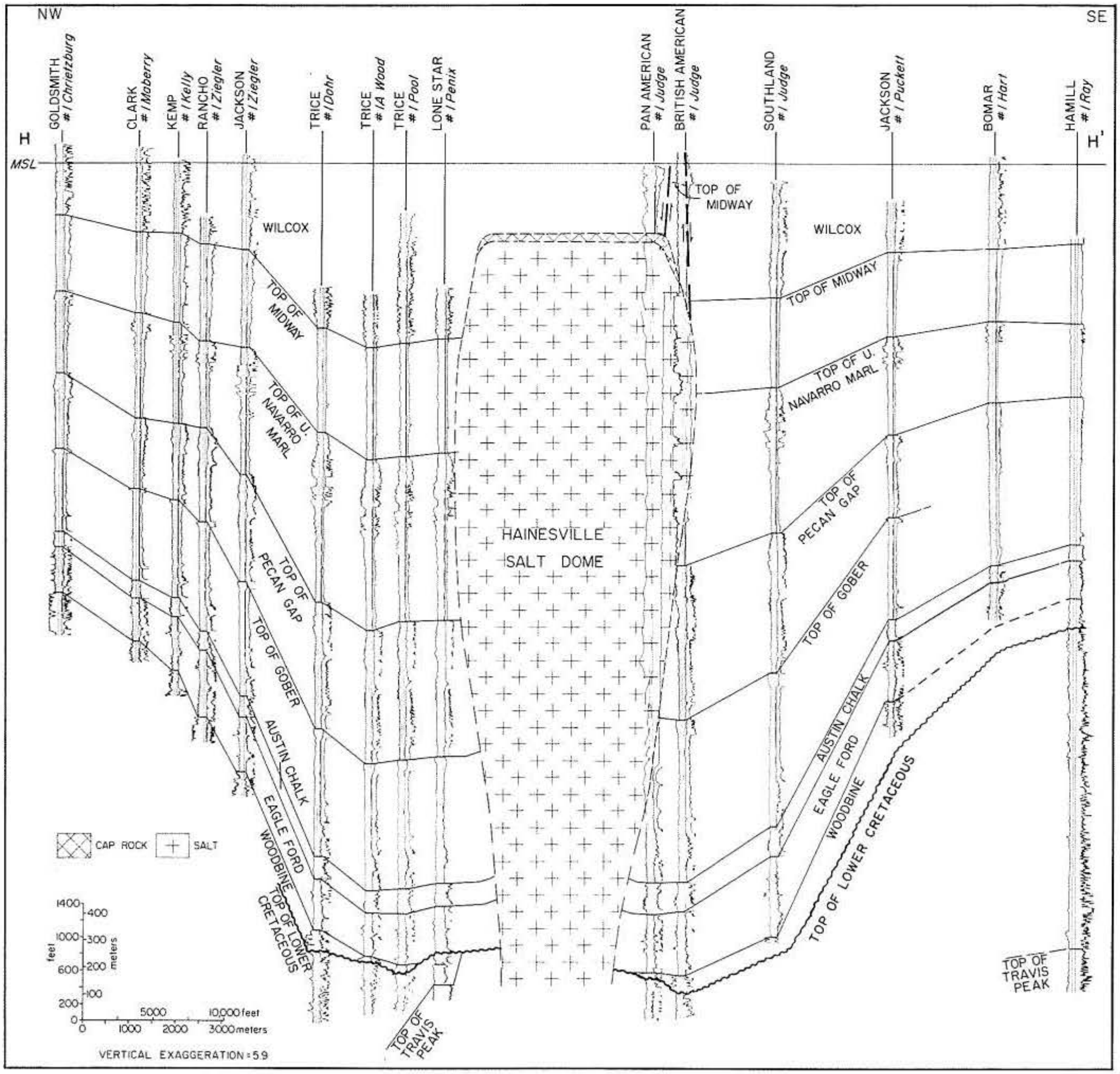

Figure 34. Structure section H-H', Hainesville Dome (Guevara and Giles, 1979). Nacatoch Formation is thickest north of dome.

VAN SHALLOW FIELD

The Van Shallow Field is located in east-central Van Zandt County (fig. 40). Nacatoch production is associated with closure along faults on the north flank of the dome. Producing sands are from 15 to 20 ft (4.6 to 6 m) thick and are interpreted as shelf sands. Oil produced from the Nacatoch is thought to have originated in the Woodbine Formation and migrated upward along fault planes (Liddle, 1936). Over a 56-year period, the Nacatoch sands have produced 1,842,432 barrels of oil.

Thick Nacatoch sections associated with other salt domes such as Hainesville Dome have been nonproductive. Kehle (1971) explained that a reversal of the original dip occurred after flank collapse, allowing hydrocarbon accumulations to migrate away from the dome back into the relatively higher interdomal areas. The lack of production from Nacatoch sands over deep-seated salt domes such as Hawkins Dome can

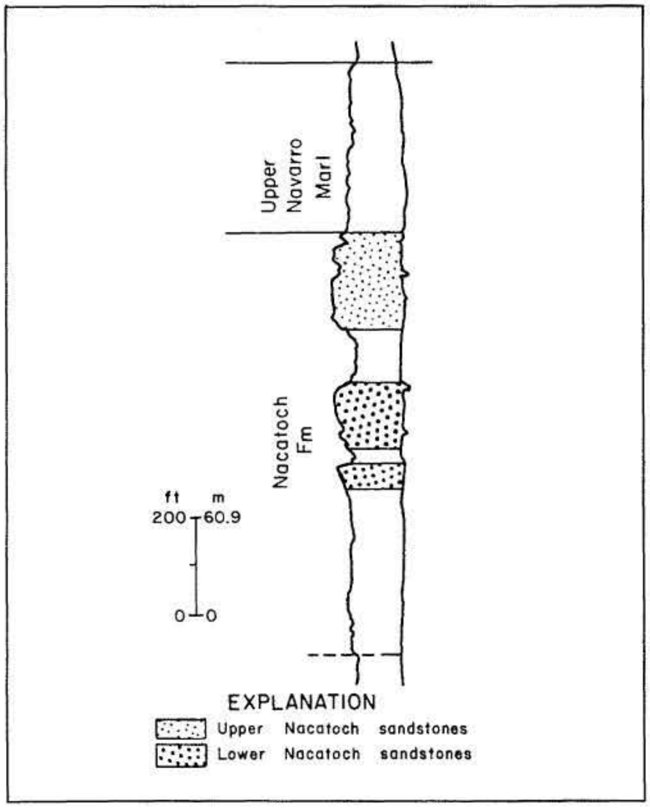

Figure 35. Typical electric log, Nacatoch Formation, Hainesville Dome. Indicates mapped intervals on figures 36, 37, and 38.

probably be attributed to poor closure, characteristic of younger uplifted sections, over anticlinal structures associated with these domes.

DEPOSITIONAL HISTORY

The Navarro Group was deposited during a period of global sea-level rise (Vail and others, 1977). Nacatoch deposition followed an extended period of deposition of shelf muds, marls, and chalks during Taylor and early Navarro time and reflects a minor uplift in the landmass bordering the basin to the north. Terrigenous clastics, supplied to the basin from the north and northeast, accumulated on a relatively stable, shallow shelf. The rate of sediment influx was apparently slow enough to be significantly influenced by marine processes, such as tides and waves.

According to Kehle (1971), the southern margin of the East Texas Basin was a shelf edge that separated shallow water from the deeper water of the open ocean. The approximate position of the paleoshoreline in the northern part of the East Texas Basin and southwestern Arkansas is documented by the occurrence of nearshore deposits in outcrop, deltaic splay deposits in northeast Texas, and tidal-flat sequences in southwest Arkansas. The position of the shoreline along the western margin of the basin is difficult to determine. A marine shelf environment indicated by highly fossiliferous, concretionary sandstone ledges in Navarro and Kaufman Counties suggests that during Nacatoch time the shoreline was located some distance to the west of the present outcrop belt.

During the Late Cretaceous, a broad connection existed between the Gulf Basin and the Atlantic Ocean across the Florida Peninsula arch and Cuba (Rainwater, 1976). The configuration of the embayment, plus the unrestricted circulation between the shallow shelf seas and the open ocean, would have promoted development of greater tides and currents (Off, 1963) during the Cretaceous than are now operating in the modern Gulf of Mexico. The position of the Cretaceous seaway must also be considered in a study of the paleocurrents and shoreline within the East Texas Embayment. Williams and Stelck (1975) showed that during the early Maestrichtian (Navarro Group, fig. 2), the Cretaceous seaway was connected to the Gulf of Mexico (fig. 41). Upper Maestrichtian (Upper Navarro Clay) deposits have not been observed in the interior of North America, an indication that the seaway was closed by the end of the Cretaceous (Williams and Stelck, 1975; Kauffman, 1977). If the seaway had been open during Nacatoch deposition, current patterns and intensities could have been profoundly affected, and the present embayment would be quite different.

The lateral association of deltaic splay deposits in Texas and tidal-flat deposits in southwest Arkansas suggests two possibilities. First, tides within the upper, microtidal, range (0 to 6 ft, 0 to 2 m) or lower, mesotidal, range (6 to 12 ft, 2 to 4 m) were operative in the East Texas and the North Louisiana Embayments during deposition of the Nacatoch Formation, or second, slow rates of sedimentation caused morphological features more typical of a mesotidal rather than a microtidal range. The South Carolina shoreline, where tides are generally less than 6 ft (2 m), is an example of a microtidal area, and yet features are more typical of a mesotidal coast (Colquhoun, 1969; Finley and Humphries, 1976; Hubbard and Barwis, 1976). These conditions are attributed to the slow rates of sedimentation.

Hayes and others (1976) suggested redefining the microtidal-mesotidal boundary at 1 m (3 ft) because morphological features formed in tidal ranges from 3 to 6 ft (1 to 2 m) are similar to those formed in the mesotidal range. Upper microtidal and mesotidal coasts generally experience the interaction of both

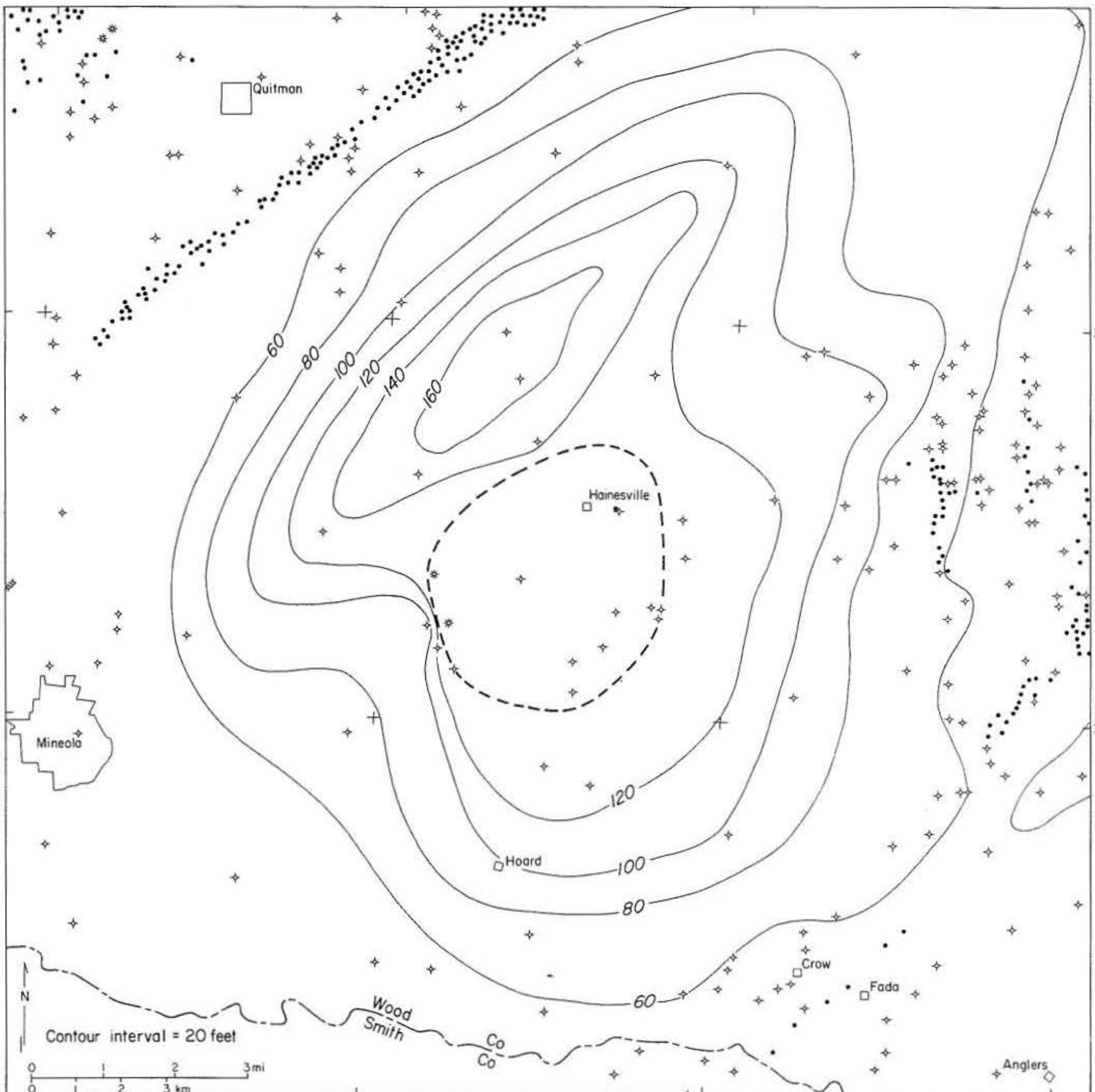

Figure 36. Net-sand map of lower Nacatoch sandstones, Hainesville Dome.

tides and waves, and their deposits are much more complex than those of coasts dominated by either tides or waves. Modern examples of mixed-energy coasts include the east coast of the United States, the inlets on the northeastern Gulf of Alaska, the northwestern contiguous United States, and the Wadden Sea of northwestern Europe (Harrison, 1975; Hayes and others, 1976; Boothroyd, 1978). Hayes and others (1976) listed depositional systems that might be expected along mixed-energy coasts: deltas (not as well developed as those of microtidal coasts), short barrier islands with wide tidal inlets in interdeltaic areas, large and numerous tidal deltas, and complex sedimentary patterns controlled by wave energy and

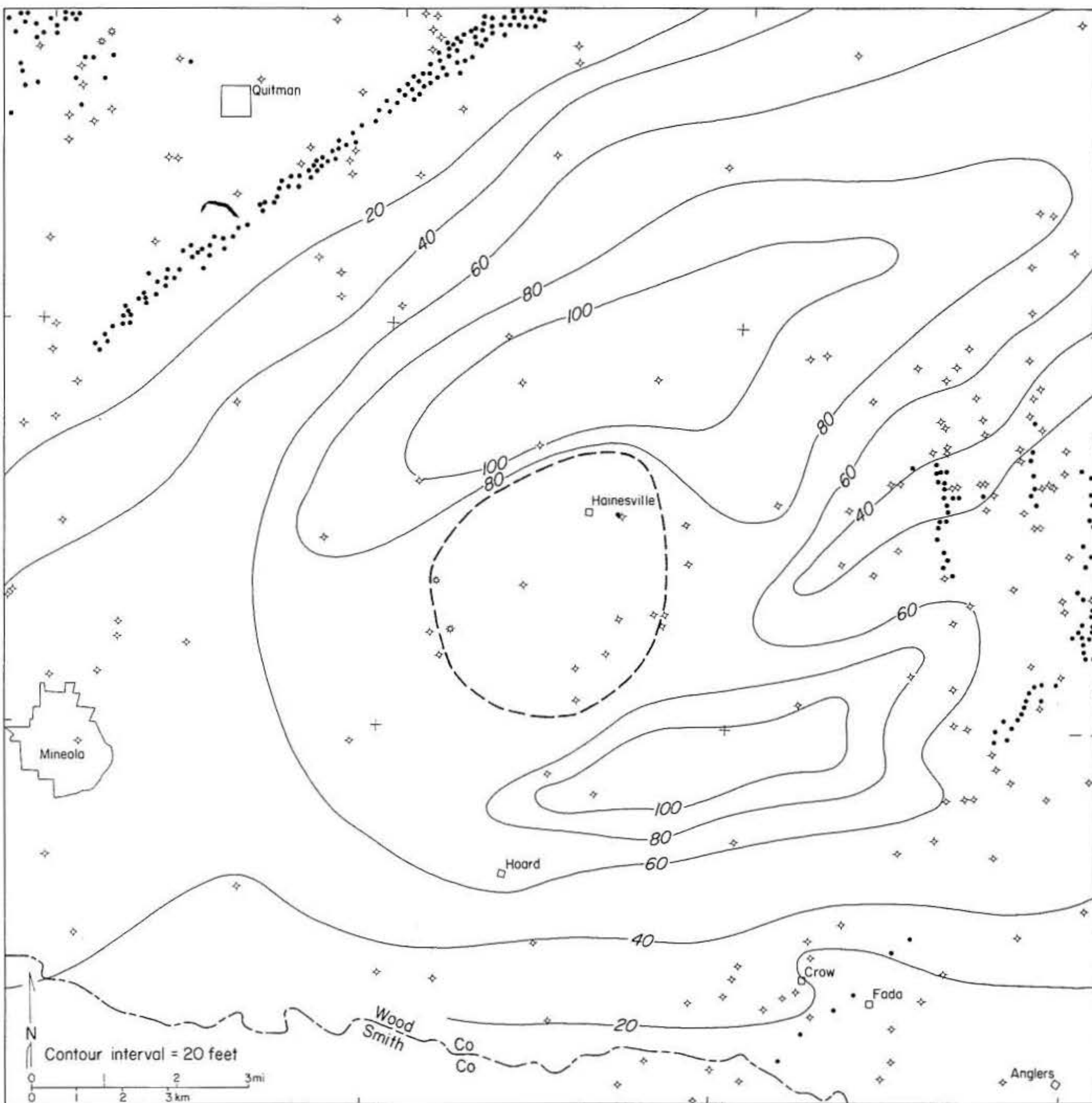

Figure 37. Net-sand map of upper Nacatoch sandstones, Hainesville Dome.

tidal currents. Tidal-flat sequences or salt-water marshes occur behind the barrier islands.

Facies typical of modern mixed-energy coasts have been observed in outcrop in southwest Arkansas and northeast Texas. Five depositional environments were interpreted from surface exposures in southwest Arkansas: tidal flat (mixed flat, sand flat, or both), tidal-channel fill, tidal-inlet-associated facies, shoreface, and shallow shelf. Two depositional environments were identified in outcrop in northeastern Texas: deltaic-influenced units in southern Hunt County and highly fossiliferous shelf sands in Navarro and Kaufman Counties. Cretaceous tidal-flat sequences in Arkansas strongly resemble the sand and mixed tidal flats of the Wadden Sea described by Reineck (1975) (table 3); however, the dominance of small-scale sedimentary structures in Arkansas may suggest tidal ranges within the upper microtidal rather than the mesotidal range that is operative in the Wadden Sea. The change in depositional style to

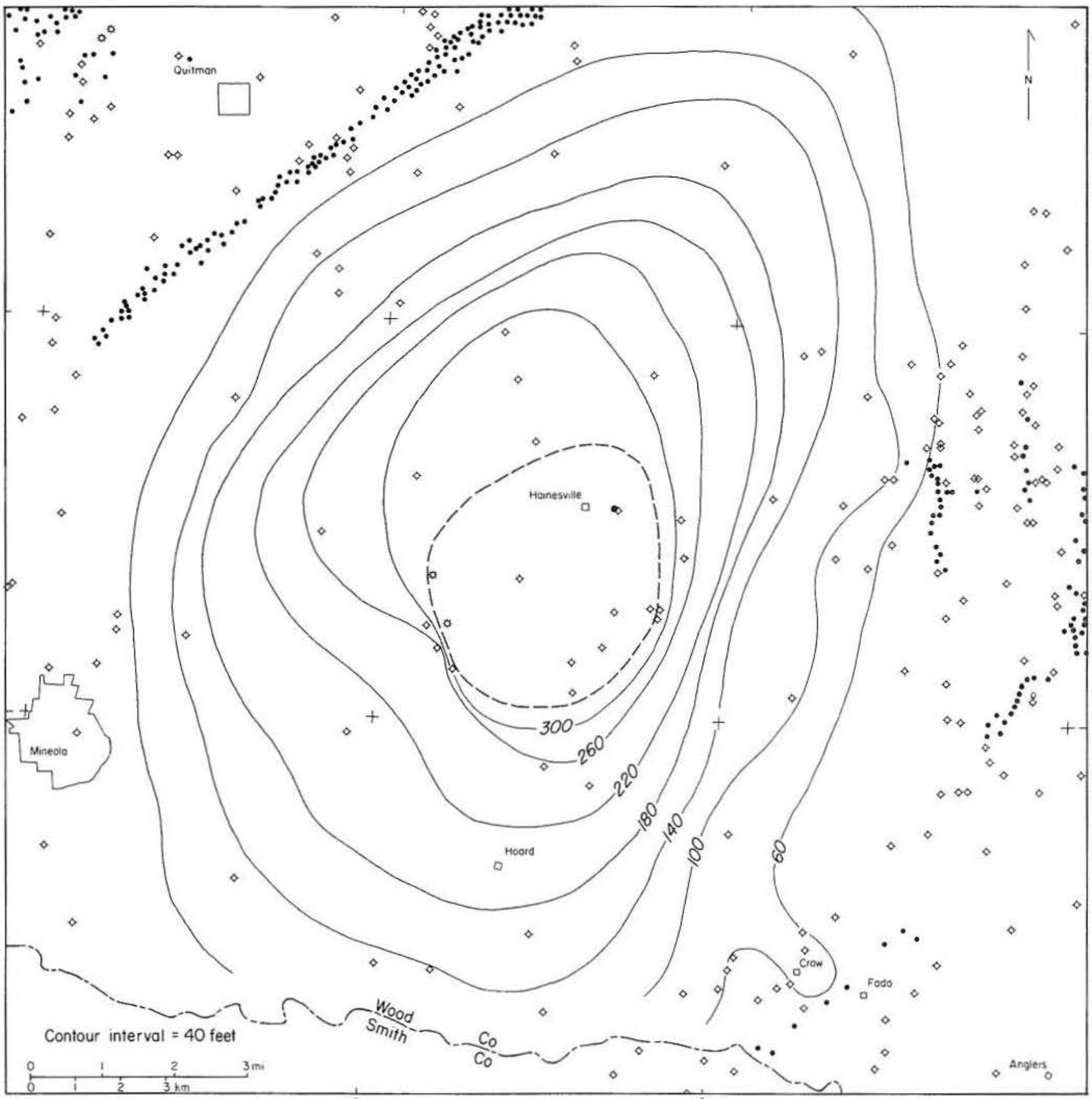

Figure 38. Isopach map of Upper Navarro Marl, Hainesville Dome.

small, marine-dominated deltas in the East Texas Basin indicates that tidal ranges may have decreased to the southwest.

The absence of Nacatoch sandstones over the Sabine Uplift suggests that the uplift was either a stable platform or was slightly positive during Nacatoch time, thus impeding sediment transport to the south. Terrigenous clastics bypassed the Sabine Uplift through a seaway located on the north. This seaway, known as the Cass County, or Pittsburg, syncline (Murray, 1961; Granata, 1963), connected the East Texas and the North Louisiana Basins (fig. 1). The seaway was probably a structurally unstable area between the Sabine Uplift to the south and the Ouachita belt to the north. Currents may have been accelerated through the narrow seaway and would have reworked and transported the sands southwestward. Sand trends within the East Texas Basin indicate that the dominant current flow was northeast to southwest. This area underwent more rapid

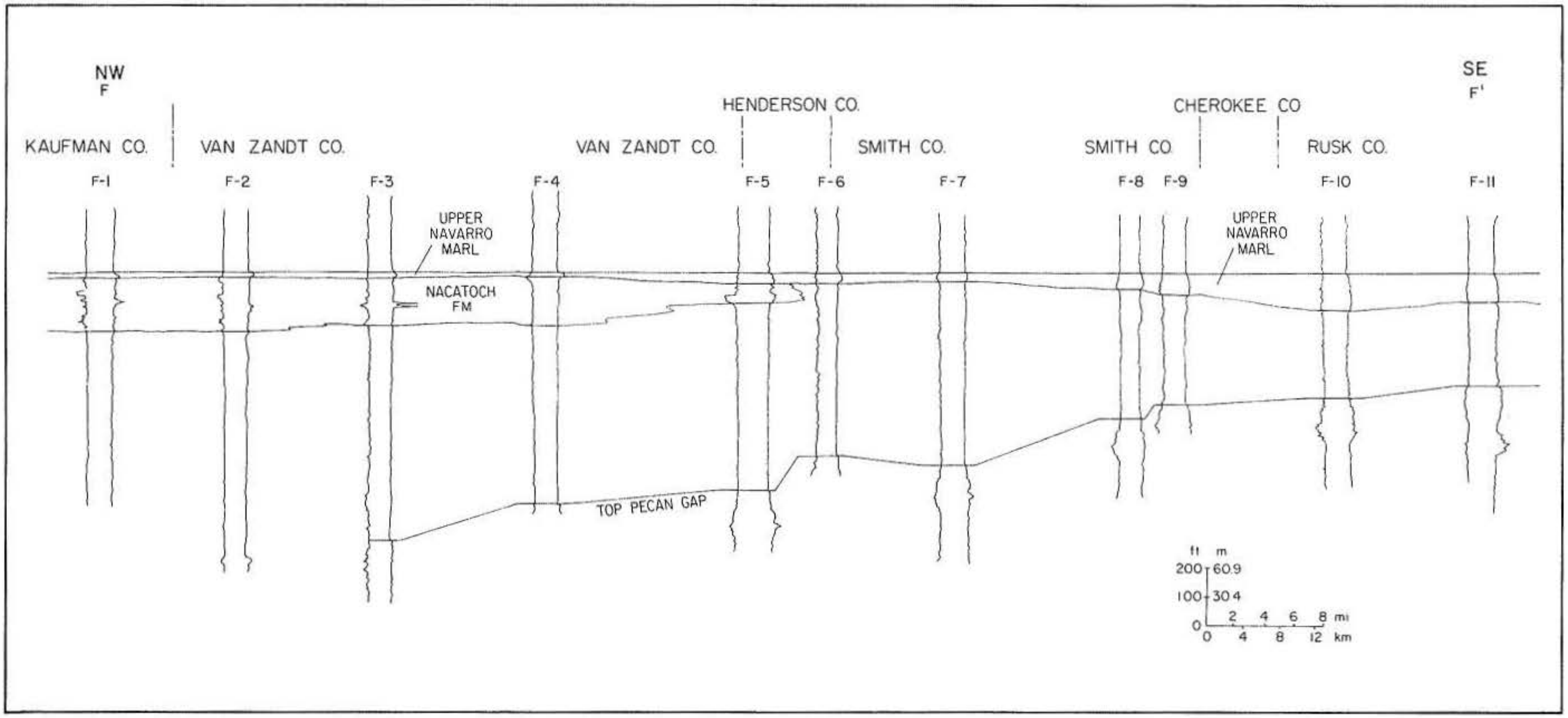

Figure 39. Regional stratigraphic section F-F' across East Texas Basin showing relation of Upper Navarro Marl and Nacatoch Formation.

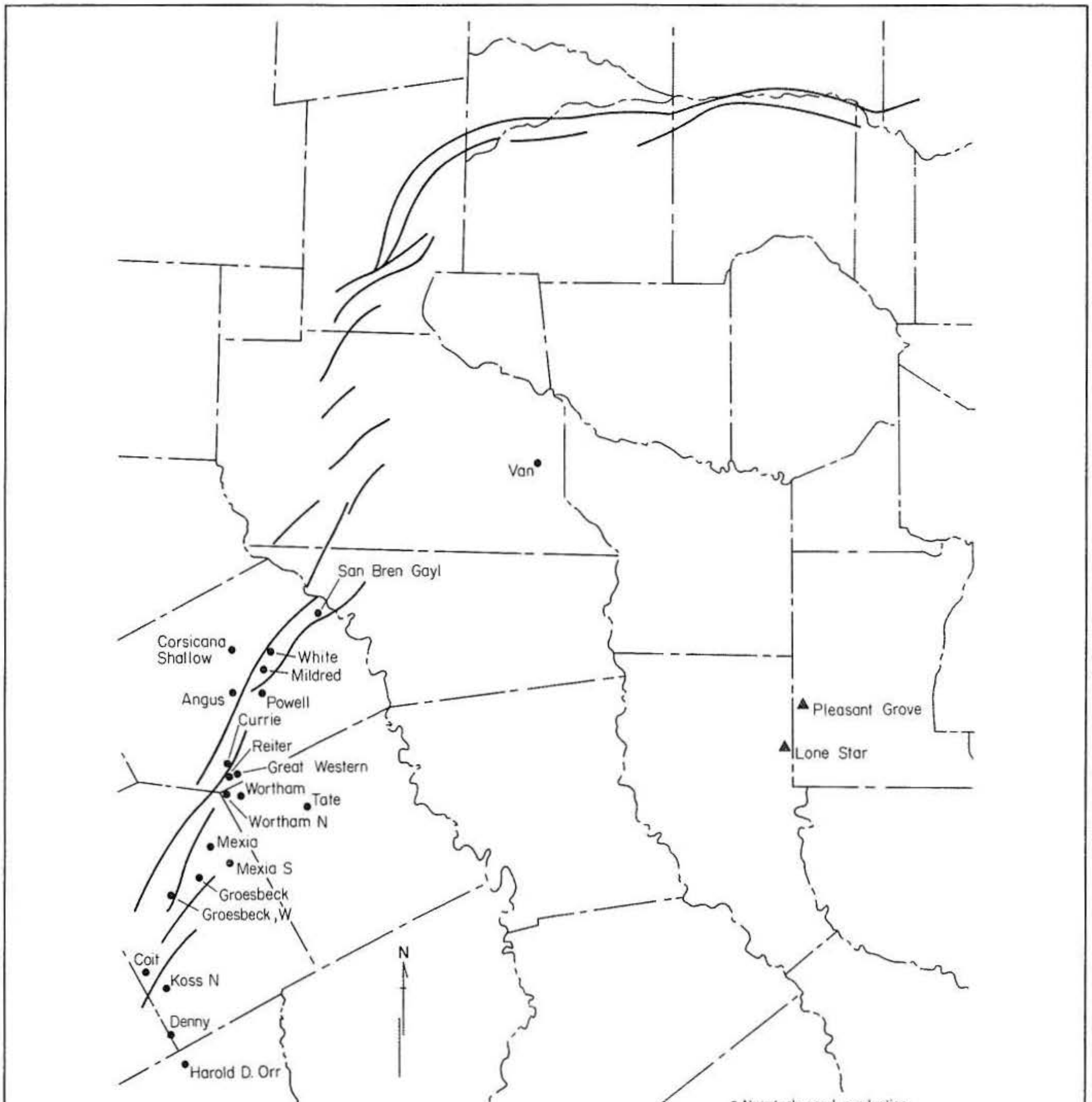

Figure 40. Oil and gas fields producing from Nacatoch Formation and Upper Navarro Marl, East Texas Basin.

subsidence than did surrounding areas, thereby creating a sand sink that accumulated and preserved a thicker section of sand. Dolloff and others (1967) indicated that Nacatoch sandstones of Arkansas attain maximum thickness near the Texas state line and thin gradually to the northeast. It is proposed that the high net sand was associated with an estuarine environment that supplied terrigenous clastics to the northeastern part of the East Texas Basin. Sands in well cuttings and sidewall cores from Bowie and Cass

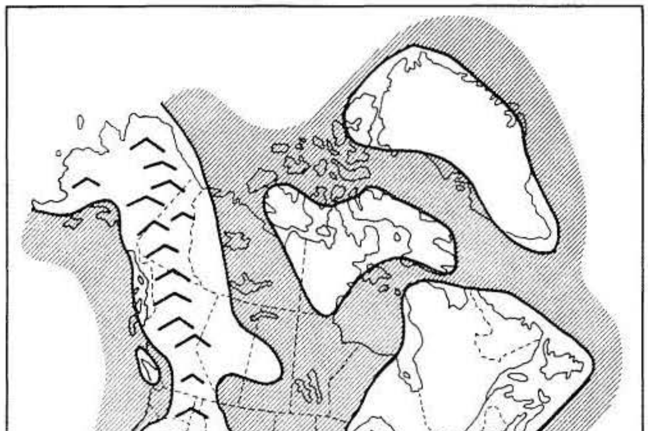

Figure 41. Paleogeographic map of Cretaceous seaway during early Maestrichtian (Williams and Stelck, 1975).

Counties (Appendix B) are well sorted and mature, an indication that the entire sequence was reworked by marine processes during deposition.

Within the subsurface of the East Texas Basin, the Nacatoch Formation can be divided into nearshore and shelf deposits. Nearshore environments consist of thin deltaic units deposited in small, marine-dominated deltas and of interdeltaic areas characterized by a higher mudstone facies. Some progradation is evident by net-sand highs in an approximately normal orientation to the main northeast-southwest trends within the basin; however, progradation was probably limited by the slow rates of sedimentation and the southwestward transport of sediments.

The shelf sequence can be arbitrarily divided into lower and upper sand units that are divided by 50 to 100 ft (16.6 to 33.3 m) of marine mudstone. The lower unit is composed of individual sandstone bodies that are generally linear in plan, average 20 to 25 ft (6.6 to 8.3 m) thick, have gradational lower boundaries and abrupt upper contacts, and grade laterally into marine mudstones (fig. 42A and B). Sandstone bodies are oriented northeast-southwest in the northern part of the basin and north-south in the western part. These sandstone bodies are interpreted to be sandbars that accumulated on the inner shelf. The upper sandstone unit comprises a fairly continuous sheet sand rather than the discrete sand bodies typical of the lower interval. This unit may reflect a period of shoreline progradation followed by a period of transgression caused by an increased rate of subsidence or rise in sea level when sands were extensively reworked and redistributed.

Textures, mineralogy, biological components (Appendix B), and geometry of individual sand bodies within the lower Nacatoch shelf facies resemble Upper Cretaceous sands that have been interpreted to be offshore bars, such as the Shannon Sand in Wyoming (Gill and Cobban, 1966; Asquith, 1974; Harms and others, 1975; Crews and others, 1976; Spearing, 1976; Seeling, 1978), the Frontier Sandstone in Wyoming (Tillman and Almon, 1979), sands within the Gallup Sandstone in New Mexico (Campbell, 1979), and the Viking Formation in Canada (Evans, 1970). Interpretations for all these studies were based largely on vertical sequences and structures observed in cores. Electric log patterns through the Nacatoch Formation resemble those from the Frontier Formation at the Spearhead Ranch Field (Tillman and Almon, 1979) (fig. 43).

Mike Boyles (personal communication, 1980) identified offshore bars in the Upper Mancos Formation (Upper Cretaceous) of northwestern Colorado. Excellent field exposures show that these sands are separated from the nearshore facies by shelf muds, and the paleocurrent indicates that the sands were derived from a source area located some distance north of the study area. Boyles suggested that shelf currents parallel to the shoreline transported sands to the offshore bar system.

Modern shelves can provide excellent transgressive models but do not apply to sequences deposited under conditions of regression or equilibrium (Johnson, 1978). However, the physical processes of modern shelves can be translated to studies of ancient environments. Harms and others (1975) suggested that by applying basic principles of hydraulics to a knowledge of sedimentary structures and sediment sequences, a valid depositional interpretation can be made without a well-established modern analog.

The sedimentary model proposed for deposition of shelf sandstones within the Nacatoch Formation (fig. 44) is adapted from a model proposed by Harms and others (1975). In general, sands derived from the dispersal system located in Cass and Bowie Counties were transported over a muddy substrate as discrete sand bodies by a dominant southwestwardly flowing shelf current. Additional sand was supplied to the inner shelf from the nearshore facies during storms by wind-induced ebb currents that transported the sand seaward (Hayes, 1967; Gienapp, 1973; Caston, 1976; Johnson, 1978; Morton, 1981) and by river-mouth bypassing during peak flood stage (Swift, 1974). The transport of sand to the shelf during storms by ebb

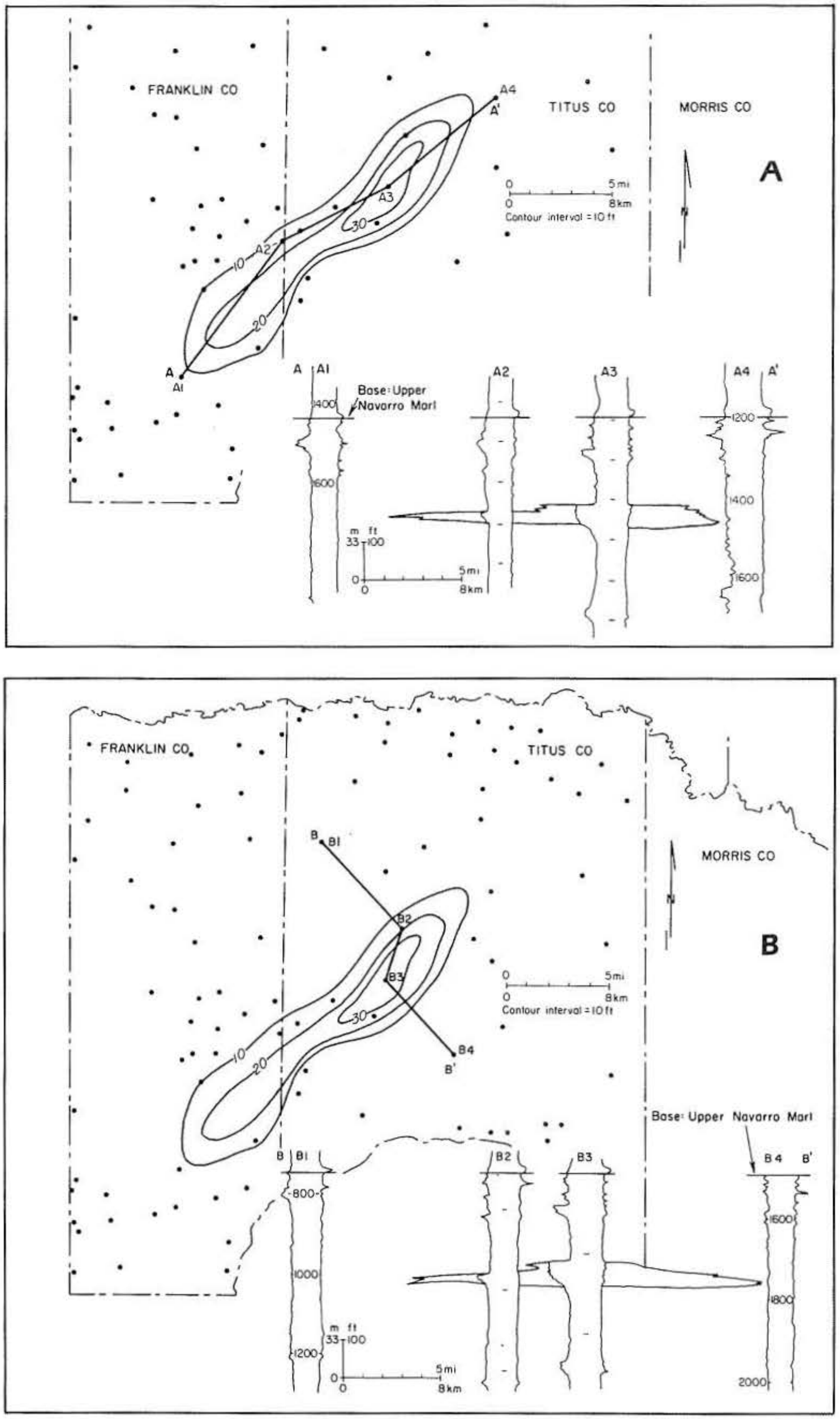

Figure 42A and B. Isopach map, shelf-sand body, Nacatoch Formation, showing (A) lateral gradation of sandstone into mudstone and (B) updip and downdip gradation into mudstone.

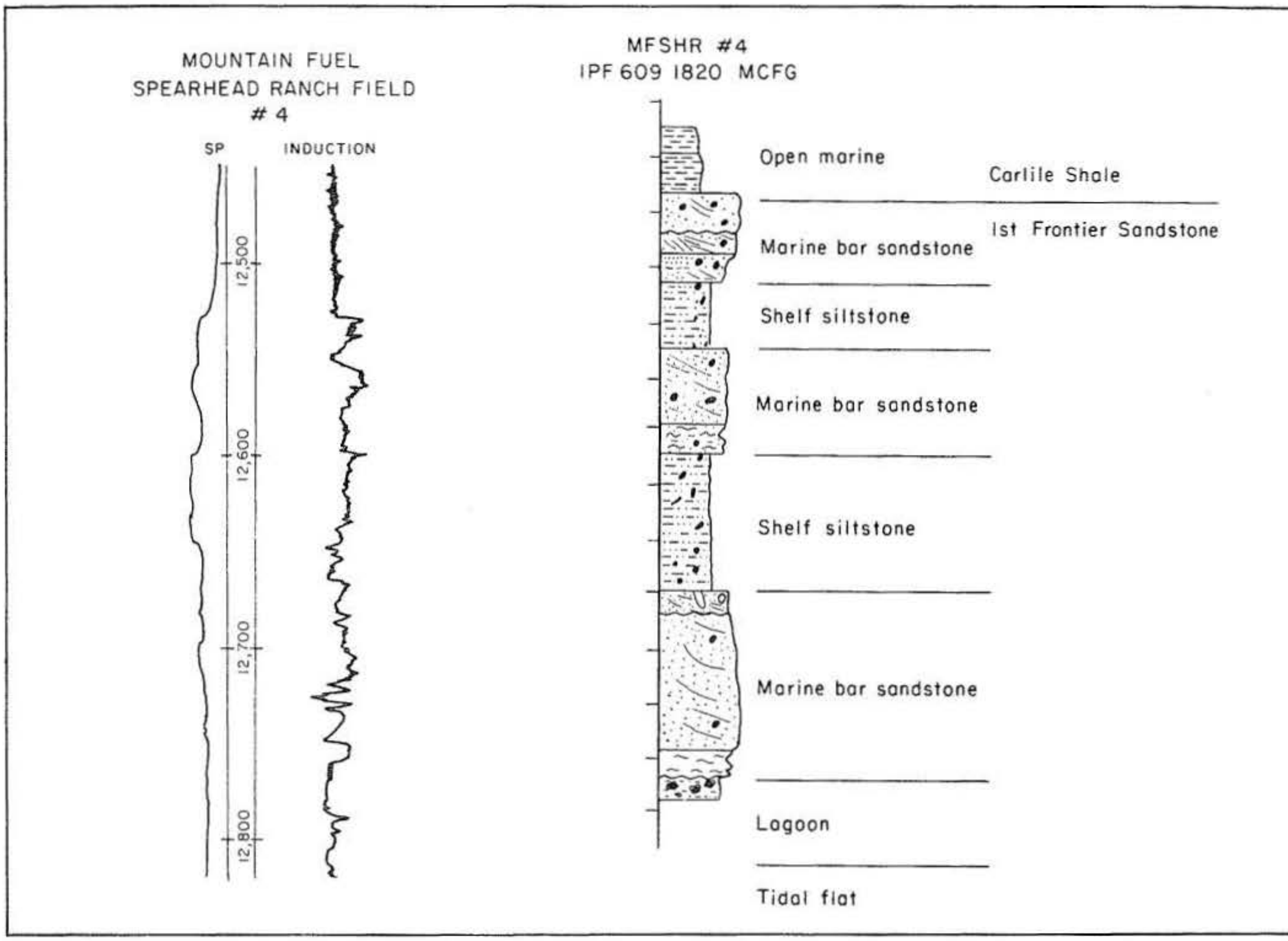

Figure 43. SP induction log, Frontier Formation (Upper Cretaceous), Wyoming, correlated with conventional core from same interval (Tillman and Almon, 1979).

flow currents has been documented by Hayes (1967), Gienapp (1973), Caston (1976), Johnson (1978), and Morton (1981); however, those storm deposits that were recorded are generally thin, ranging up to tens of centimeters thick. The significance of ebb flow currents and river bypassing in supplying sand to the inner shelf over extended periods of geologic time has not been evaluated.

When tidal currents of low to moderate velocities are enhanced by wave surge, especially under storm conditions (Johnson, 1978), they can be important sand dispersal agents on shallow shelves. Currents associated with storm conditions can suspend sand-sized sediment (Stride, 1976) and thereby increase the transport capability of tidal and wind currents. Lateral migration of sand ridges on the Atlantic shelf has been reported by Moody (1964) and Duane and others (1972). Sands on the Atlantic shelf are dominantly relict in origin, but the processes that transported these sands may have been similar to marine processes operating during Upper Cretaceous time. Off the Delaware coast, sand ridges migrated southward at an average rate of 10 ft (3 m) a year during a 42-year period. During a single storm in March 1962, a lateral southeastward migration of more than 250 ft (76 m) was recorded. Duane and others (1972) reported that sand ridges off the Virginia coast migrated southward at an average of 226 ft (69 m) during a 53-year period. Currents off the Atlantic coast are moderately intense and average 50 to 100 cm per second during a 12-month period (Hunt and others, 1977).

The distribution and thickness of shelf sands in the Nacatoch were locally controlled by actively subsiding salt withdrawal basins associated with piercement salt domes. The thickest accumulation of the Nacatoch Formation is in the Mineola Basin, the rim syncline associated with Hainesville Dome (fig. 26). Other piercement domes around which the Nacatoch thickens noticeably include Steen, Mount Sylvan, East Tyler, Brooks, and Bethel Domes (fig. 4). The Mexia-Talco fault system appears to have produced only minor effects on sand accumulation, except north of the Sabine Uplift, where more rapid

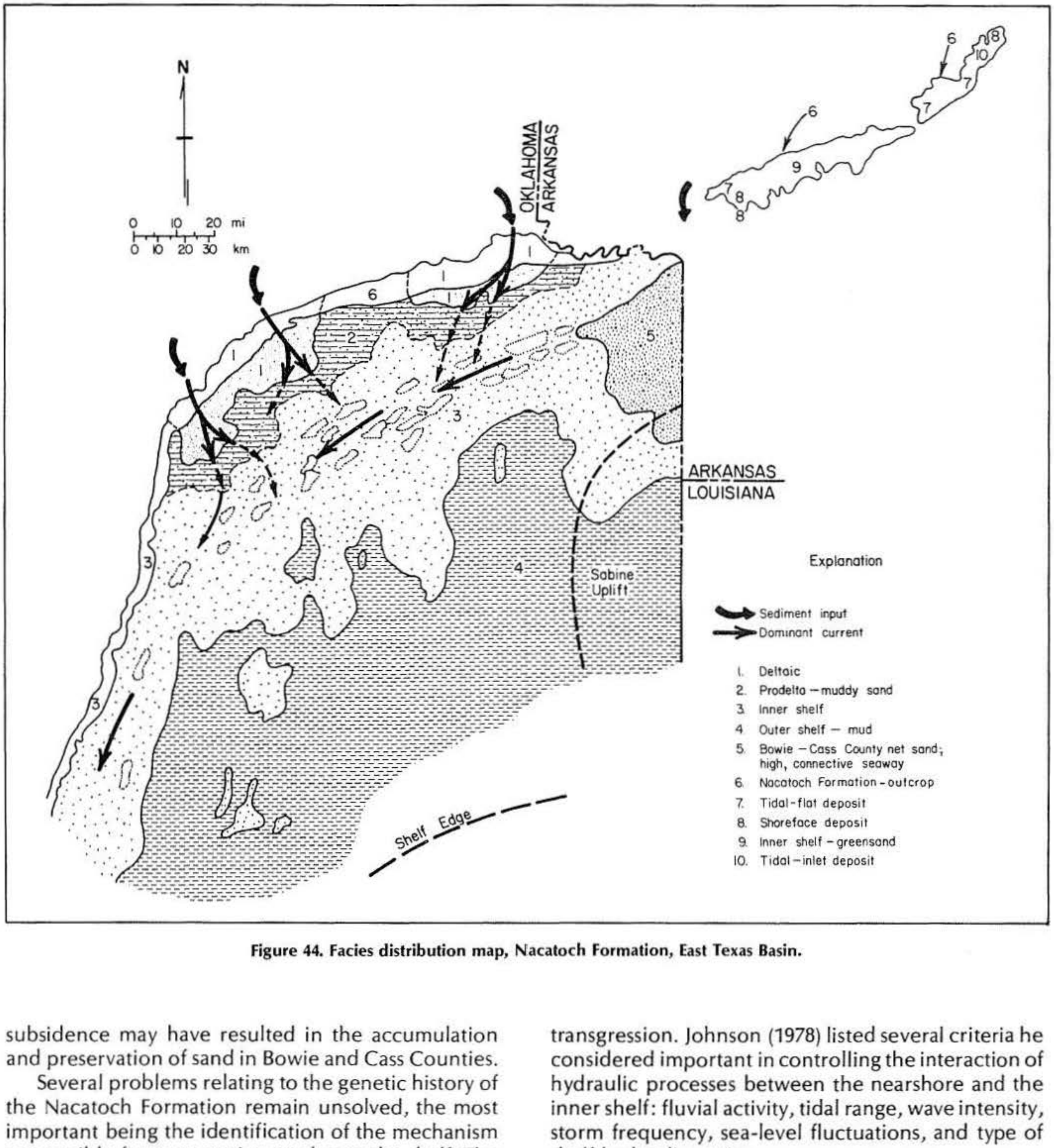

Figure 44. Facies distribution map, Nacatoch Formation, East Texas Basin.

subsidence may have resulted in the accumulation and preservation of sand in Bowie and Cass Counties.

Several problems relating to the genetic history of the Nacatoch Formation remain unsolved, the most important being the identification of the mechanism responsible for transporting sand onto the shelf. The transfer of sand from nearshore environments to the inner shelf is largely associated with the interaction of hydraulic processes. Understanding of the process controlling such interactions is incomplete, mostly because no modern analog exists for a stable shelf within a clastic regime that has slow sedimentation rates. Most of the modern shallow open shelves are covered with Pleistocene sands and gravels and still show the effects of the major post-Pleistocene transgression. Johnson (1978) listed several criteria he considered important in controlling the interaction of hydraulic processes between the nearshore and the inner shelf: fluvial activity, tidal range, wave intensity, storm frequency, sea-level fluctuations, and type of shelf hydraulic regime.

An extensive study of core material through the Nacatoch Formation would develop more information on the hydraulic process operating during Late Cretaceous time. The vertical sequence of beds as well as the types of primary structures should indicate the type and intensity of currents, thereby providing a more complete understanding of the nature of the depositional environments.

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APPENDIX A

WELLS USED ON ISOPACH MAPS AND CROSS SECTIONS

Hainesville Dome area — Wood County
(Well symbols with "X" indicate wells used in cross section)

Well Code #	Company and Well Name	County
H-1	R. McKay Moore Starnes #1	Wood
H-2	W. H. Bryant L. Abraham #1	Wood
HX-3	J. Paul Goldsmith Chrietzberg	Wood
H-4	R. S. Peveto, P. O. Smith & Son, Cooper & Herring Jim Hunter #1	Wood
HX-5	Clark, Gabriel & Brasfield J. Maberry Estate #1	Wood
HX-6	Kemp Drilling Company Kelley #1	Wood
HX-7	Rancho, Ziegler #1	Wood
HX-8	F. R. Jackson & J. M. Deupree W. O. Ziegler #1	Wood
H-9	Pan American Petroleum J. E. Wilson, Jr. #1	Wood
H-10	William Tobian F. R. Carmichael	Wood
H-11	T. J. Johnson F. G. Kelly #1	Wood
H-12	F. R. Jackson W. J. Bowman #1	Wood
H-13	F. R. Jackson & B. A. Holman Kemp #1	Wood
H-14	Belco Petroleum Corp. L. B. Windham #1	Wood
H-15	Clark & Herschbach Burnett #1	Wood
H-16	Culberson & Caraway C. E. Burkett #1	Wood
H-17	Hollandsworth Bogan #2	Wood
H-18	Jackson & Deupree W. C. Bartlett #1	Wood
H-19	Harper M. V. Anders #1	Wood
H-20	Bert Fields Est. A. M. Carson #1	Wood
H-21	Bert Fields Est. Erisman #1	Wood
H-22	Phillips Morrison #1	Wood
H-23	Spence Laminack #1	Wood
H-24	Feazel Warner #1	Wood
H-25	Phillips et al. Griffis #3	Wood
H-26	Trice Production Co. Deanne Gill #1	Wood
H-27	Midwest McKnight #1	Wood
H-28	Hughey Operating Co. McKnight #1	Wood
H-29	General Crude Oil Co. F. W. Barnett #1	Wood
H-30	Jackson #1 Knight	Wood
HX-31	Trice Production Co. Dohr #1	Wood
HX-32	Trice Production Co. & Jackson Wood #1A	Wood
H-33	Trice Production Co. & Jackson Pool #1	Wood
HX-34	Lone Star Production Co. Penix #1	Wood
H-35	Delta Petroleum Inc. Beckham #1	Wood
H-36	Jackson & Robbins Wisenbaker #1	Wood
H-37	British American Oil Production Co. Amon Heirs #1	Wood
H-38	British American Oil Production Co. Warlick (Buffington #1)	Wood
H-39	British American Oil Production Co. Weisenhunt B-1	Wood
H-40	Hootkins Peacock #1	Wood
HX-41	Pan American & Hootkins Judge #1	Wood
HX-42	British American Production Co. Judge #1	Wood
HX-43	Southland Judge #1	Wood
H-44	Jackson Jackson #1	Wood
H-45	Jackson & Deupree York #1	Wood
H-46	Bennett & Sorrells Maglin #1	Wood
H-47	Jackson & Robbins Harrell #1	Wood
H-48	Voight Matthews #1	Wood
HX-49	Jackson & Dupree Puckett #1	Wood
HX-50	Bomar Hart #1	Wood
HX-51	Hamill Ray #1	Wood
H-52	Jackson & McGlothlin Moore Fee #1	Wood
H-53	Union (Manziel & Bridewell) Coker #1	Wood
H-54	W. D. A. Corp. Wright #1	Wood
H-55	Goldsmith & Halbert Drilling Co. Coats et al. #1	Wood
H-56	Clark & Herschbach Burnett #1	Wood

Well Code #	Company and Well Name	County
H-57	Sinclair-Prairie Collins #1	Wood
H-58	Hollandsworth Oil Co. Wood Co. Mining Corp #1	Wood
H-59	Hollandsworth Oil Co. Faulk #1	Wood
H-60	Trans-Texas Drilling Co. Rutter #1	Wood

Regional Cross Sections

Well Code #	Company and Well Name	County
A-1	American Liberty Oil Co. Barrow #1	Hunt
A-2	C. M. Ashby Joe Parrish #1	Hunt
A-3	Le Cuno Oil Co. R. Stevens #1	Hunt
A-4	Killam Smith #1	Hopkins
A-5	Mobil Oil Corp. Martin #1	Hopkins
A-6	Bert Fields Bassham #1	Hopkins
A-7	W. B. Hinton M & P National Bank of Mt. Vernon	Franklin
A-8	Coats & Moore Simons #1	Red River
B-1	Coats & Moore Simons #1	Red River
B-2	Coats Drilling Co. Broseco Corp. #1	Titus
B-3	Ryan Smith #1	Titus
B-4	Hoover Webb Est. #1	Titus
B-5	McBee & Moore Talley #1	Morris
B-6	McBee & Rudman Tidewell #1	Morris
B-7	Placid Ellison #1	Morris
C-1	Yarbrough Calloway #1	Hopkins
C-2	Donnie Petroleum Co. Welborn #1	Hopkins
C-3	Clark et al. Mayberry	Wood
C-4	Jackson & Deupree Ziegler #1	Wood
C-5	Lone Star Production Penix #1	Wood
C-6	Southland Judge #1	Wood
C-7	Jackson & Robbins Harrell #1	Wood
C-8	Fleming Crews #1	Smith
C-9	Lake & Voight Hardy #1	Smith
D-1	Talco Asphalt and Refining Co. Peek #1	Delta
D-2	Phillips Rhodes #1	Hopkins
D-3	Peveto & Byers Kenedy #1	Hopkins

Well Code #	Company and Well Name	County
D-4	Schneider et al. McLain #1	Hopkins
D-5	Byers & Western Consolidated Oil Co. Walker Est. #1	Wood
D-6	Dorfman Producing Company & Rudman Sharkey #1	Wood
D-7	Ninnell Exploration Co. Jarred #1	Wood
D-8	Gibson Saner #1	Wood
D-9	Fields Carlock #1	Wood
D-10	Jackson & Whitehurst Pool #1	Upshur
E-1	Ashby Parris #1	Hunt
E-2	Johnson & Gist Meredith #1	Hunt
E-3	Scott Brothers Washburn #1	Rains
E-4	Texaco, Inc. Reynolds Gas Unit #1	Rains
E-5	LaRue Gilley Est. #1	Rains
E-6	Jackson & Robbins Hackler #1	Wood
E-7	Jackson et al. Reynolds #1	Wood
E-8	McKnight & Voight Wheelis #1	Smith
E-9	Fender York #1	Smith
E-10	Ogg et al. McClung #1	Smith
E-11	Pure Oil Co. Brown #1	Smith
E-12	Coalston Drilling Co. Butler A-1	Smith
E-13	Phillips & Starr Warden Est. #1	Smith
F-1	Bass Rand #1	Kaufman
F-2	Barbro et al. Bobbitt #1	Van Zandt
F-3	Cities Service Whitton "A" #1	Kaufman
F-4	Burke et al. Howell #1	Kaufman
F-5	Clay & Walker Cade #1	Henderson
F-6	Stroube Hardee #1	Henderson
F-7	Gibson Massey #1	Smith
F-8	Sklar Shaw #1	Smith
F-9	Sands Willis #1	Smith
F-10	Whitehurst Sanders #1	Rusk
F-11	Voight Sweeny #1	Rusk

APPENDIX B

ELECTRIC LOG PATTERNS AND DESCRIPTIONS OF SIDEWALL CORES AND WELL CUTTINGS

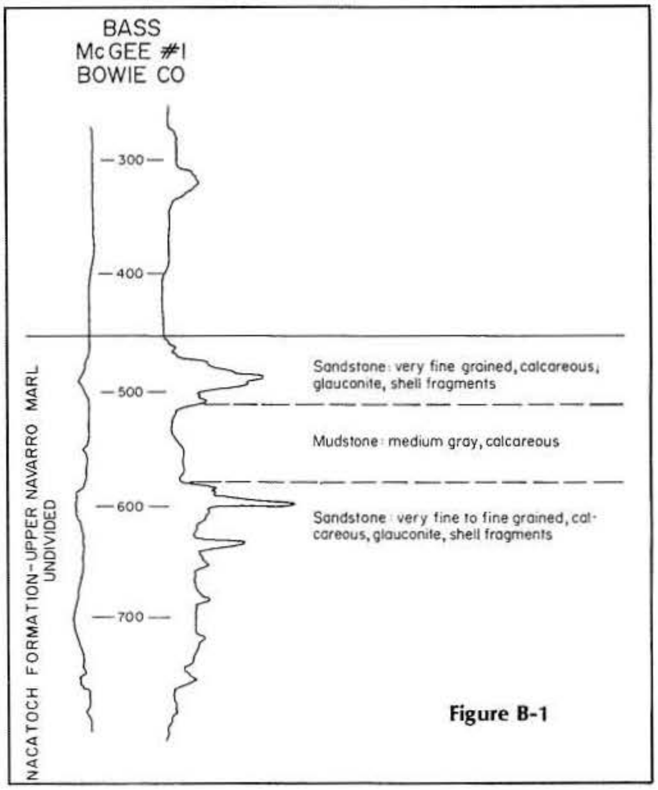
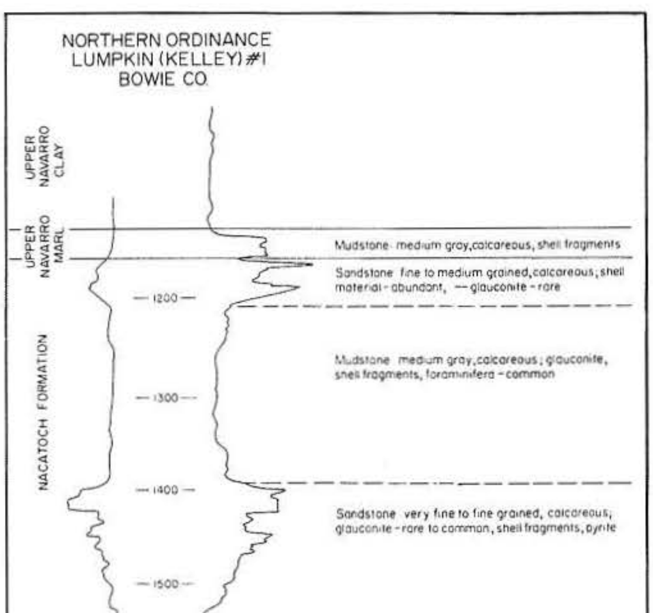


Figure B-1



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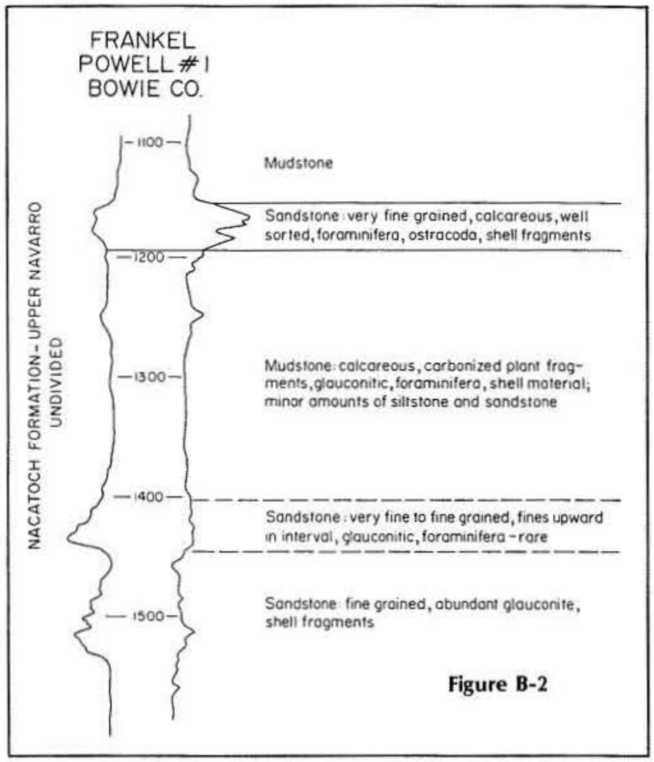
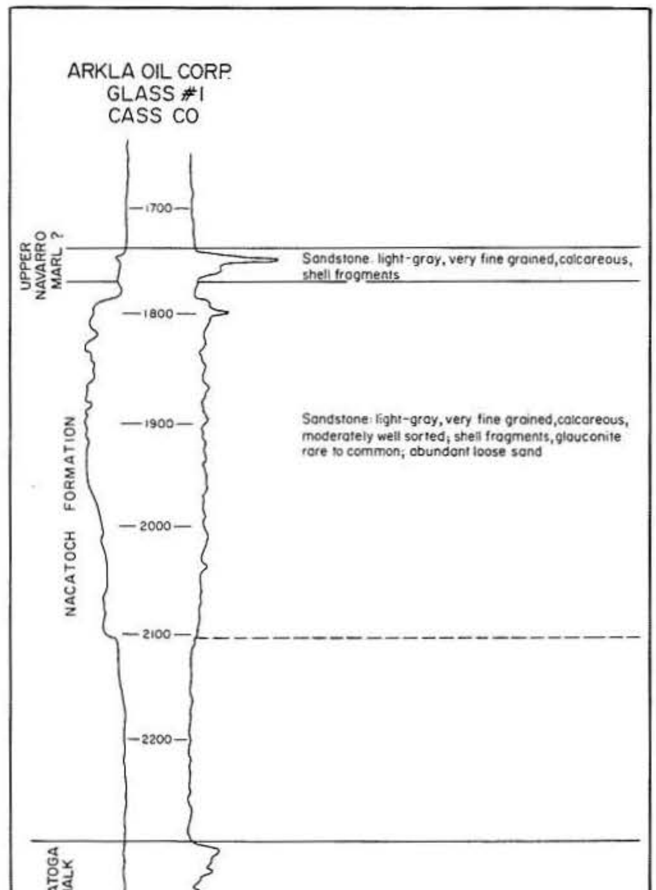


Figure B-2



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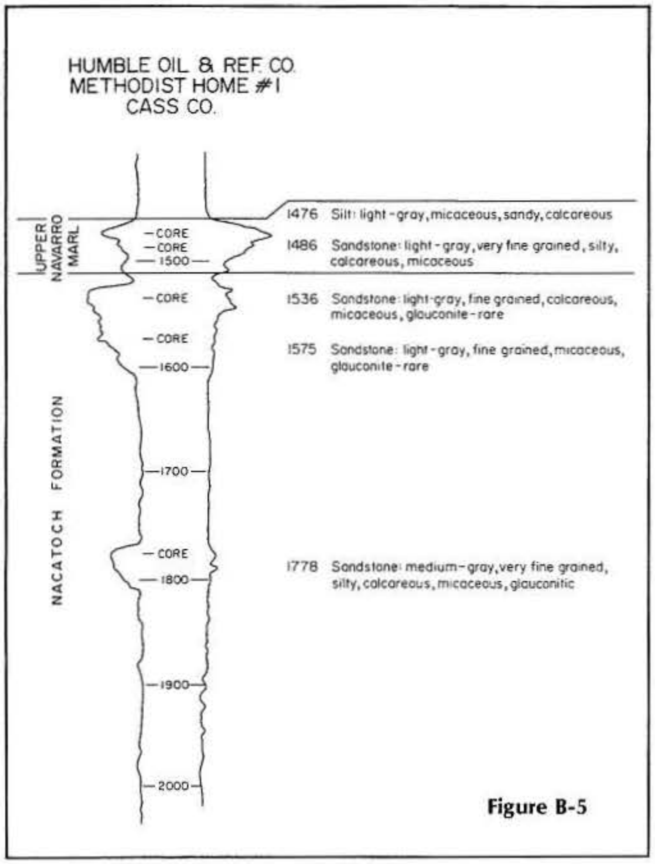

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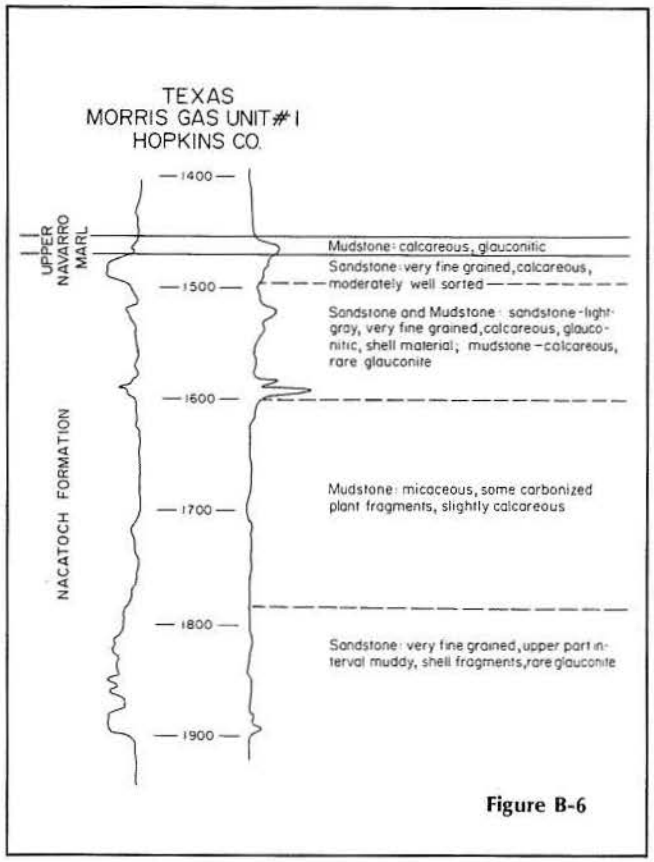

Figure B-6

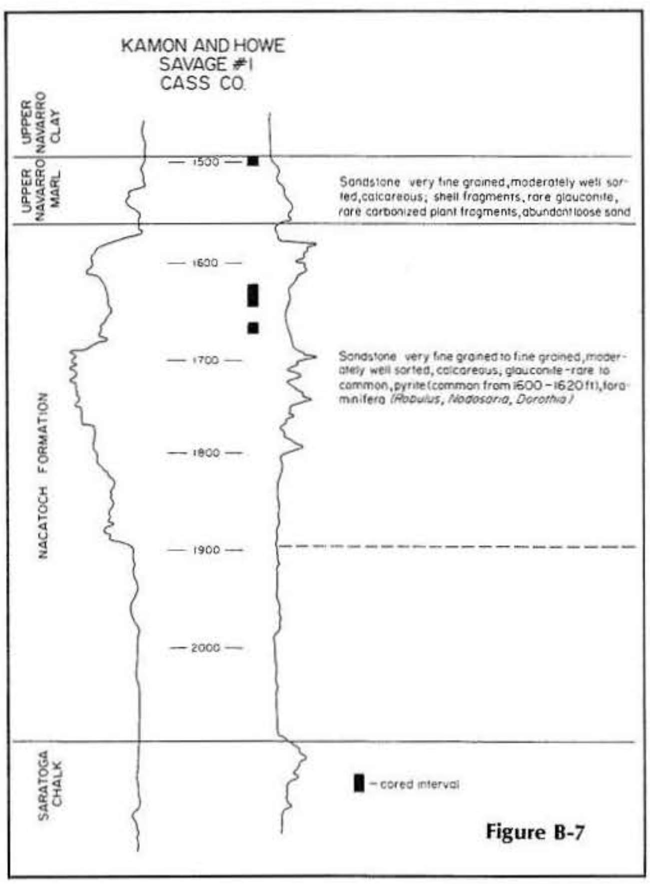

Figure B-7

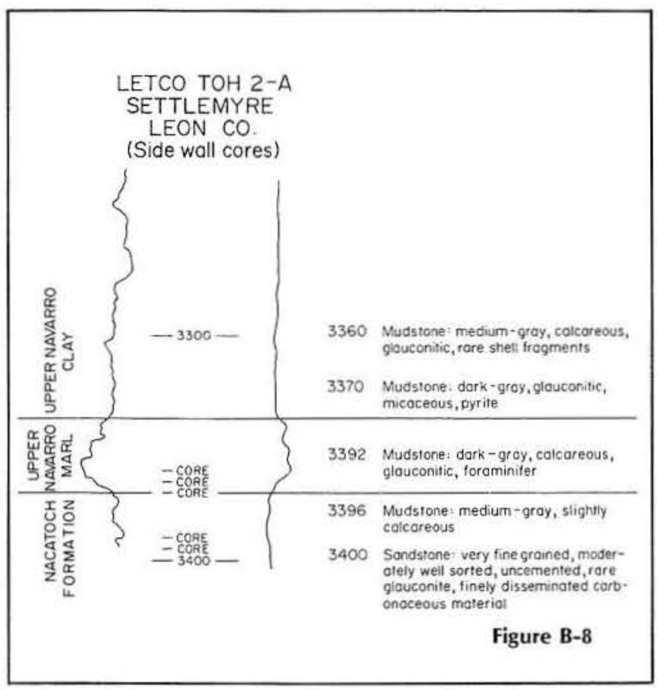

Figure B-8

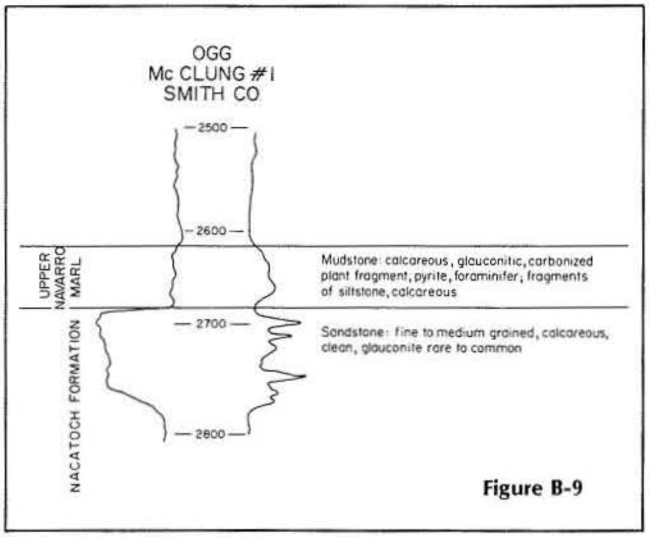

Figure B-9

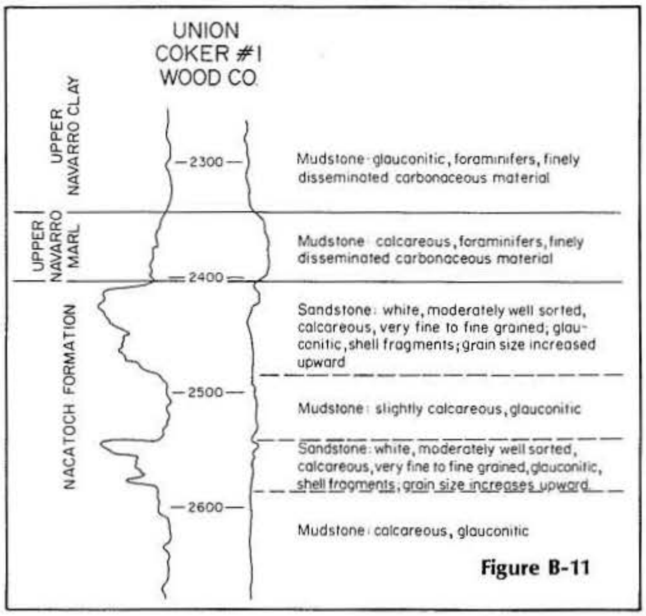

Figure B-11

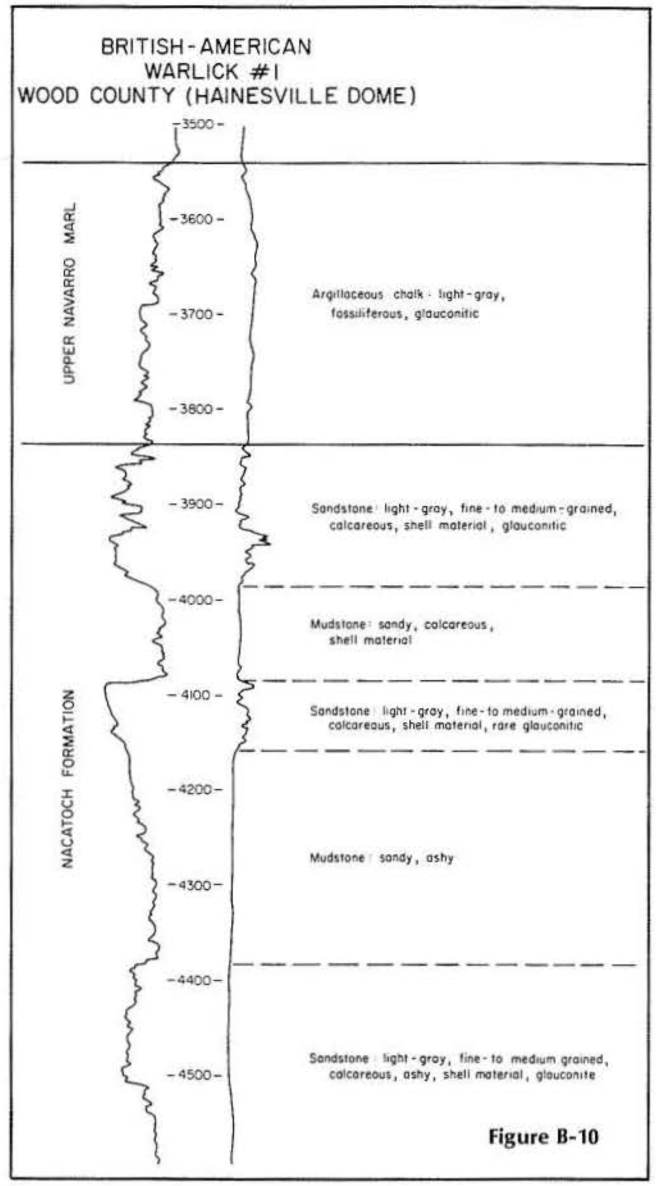

Figure B-10

APPENDIX C

THIN SECTION DESCRIPTIONS

SAMPLE NUMBER: A-7 shelf sand

LOCATION: 1.8 mi (2.95 km) northeast of Washington, Arkansas

GRAIN SIZE: Medium to fine sand

SORTING: Well sorted

FRAMEWORK COMPONENTS:

- Poly- and monocrystalline quartz
- Potash and plagioclase feldspars
- Siliceous rock fragments
- Carbonate rock fragments
- Glauconite
- Muscovite
- Foraminifer tests
- Shells

AUTHIGENIC MINERALS:

- Chamber-filling cements
  - Pyrite
  - Sparry calcite
- Pore-filling cements
  - Poikilotopic calcite
  - Micritic calcite
  - Mosaic calcite

DIAGENETIC FEATURES:

- Calcite replacing feldspathic framework grains
- Inversion of shell fragments to mosaic calcite

SAMPLE NUMBER: 478-93-21138

LOCATION: Bass, McGee #1, Bowie Co., Texas, 478 to 493 ft

GRAIN SIZE: Fine sand, both angular and rounded

SORTING: Well sorted

FRAMEWORK COMPONENTS:

Monocrystalline quartz
Microcline, perthite
Plagioclase
Glauconite
Inoceramus prisms
Foraminifer tests

AUTHIGENIC MINERALS: Pyrite

CEMENTS: Micritic to sparry calcite

DIAGENETIC FEATURES:

Loose packing of framework grains in calcite cement suggests early cementation and/or replacement of some framework constituents by calcite; grain "ghosts" visible in cement.

SAMPLE NUMBER: 623-38-21138

LOCATION: Bass, McGee #1, Bowie Co., Texas, 623 to 638 ft

GRAIN SIZE: Fine to very fine sand; angular to very angular

SORTING: Well sorted

FRAMEWORK COMPONENTS:

Quartz
Potash and plagioclase feldspars
Siliceous rock fragments
Glauconite
Foraminifer tests
Biotite

CEMENTS: Poikilotopic calcite

DIAGENETIC FEATURES:

"Bloated" biotite
Replacement of plagioclase by calcite along cleavage planes

SAMPLE NUMBER: A-6 shoreface

LOCATION: About 4 mi (6.4 km) south of Saratoga, Arkansas, on State Highway 355

HAND SPECIMEN: Very fine grained, light-yellow, friable sandstone, well sorted, with common glauconite

GRAIN SIZE: Very fine sand, very angular

SORTING: Well sorted

FRAMEWORK COMPONENTS:

Monocrystalline quartz
Potash and plagioclase feldspars
Metamorphic rock fragments
Siliceous rock fragments
Glauconite

MATRIX: Crushed feldspars altered to kaolinite

SAMPLE NUMBER: A-4 tidal deposit

LOCATION: 1 mi (1.6 km) south of Saratoga, Arkansas on State Highway 355

HAND SPECIMEN: Medium-grained, hematite-stained red sandstone with abundant sand- and gravel-sized clay clasts; biotite flakes abundant

GRAIN SIZE: Medium sand; angular and subrounded to rounded

SORTING: Moderately well sorted

FRAMEWORK COMPONENTS:

Monocrystalline quartz
Potash and plagioclase feldspars
Siliceous rock fragments
Siltstone clasts
Muscovite, biotite
Glauconite

MATRIX:

Clay skins (hematite-stained) around framework grains
Pseudomatrix of deformed clay clasts

SAMPLE NUMBER: A-3 shoreface

LOCATION: 1.5 mi (2.4 km) south of Saratoga, Arkansas on State Highway 234

GRAIN SIZE: Medium to fine sand; very round and angular

SORTING: Well sorted

FRAMEWORK COMPONENTS:

Monocrystalline quartz
Potash, plagioclase feldspars
Metamorphic and sedimentary rock fragments
Muscovite
Glauconite
Foraminifer tests

COMPOSITION: Q_{75} F_{22} R_3

CEMENT: Poikilotopic calcite

DIAGENETIC FEATURES:

Kaolinitized feldspars
Calcite cement replacing framework grains

SAMPLE NUMBER: A-12-C tidal inlet, channel fill

LOCATION: 2 mi (3.2 km) south of Arkadelphia, Arkansas, on Interstate 30

HAND SPECIMEN: Friable, buff-colored medium sand with gravel-sized clay clasts; some sand cemented with hematite-stained clay

GRAIN SIZE: Medium sand, very angular

SORTING: Very well sorted

COMPOSITION: Q_{85} F_{15} R_0, with accessory glauconite

CEMENT: Patchy kaolinite

DIAGENETIC FEATURES: Alteration of feldspars to kaolinite

SAMPLE NUMBER: A-12-a lower shoreface

LOCATION: 2 mi (3.2 km) south of Arkadelphia, Arkansas, on Interstate 30

GRAIN SIZE: Very fine sand to silt, very round and very angular

SORTING: Moderately well sorted

FRAMEWORK COMPONENTS:

Poly- and monocrystalline quartz
Feldspar
Siliceous rock fragments
Zircon
Biotite
Carbonaceous material
Glauconite

MATRIX: Oriented illite?

SAMPLE NUMBER: TK-1

LOCATION: Kaufman Co., Texas

HAND SPECIMEN: Light-green, very fine grained sandstone, fossiliferous; faint bioturbation

GRAIN SIZE: Very fine sand, very angular

SORTING: Well sorted

FRAMEWORK COMPONENTS:

Mono- and polycrystalline quartz
Potash and plagioclase feldspars
Siliceous rock fragments
Zircon
Glauconite
Shell fragments

CEMENTS: Poikilotopic calcite

MATRIX:

Hematite-stained clay
Kaolinite

DIAGENETIC FEATURES: Calcite replacing framework grains