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The Queen City Formation in the East Texas Embayment: A Depositional Record of Riverine, Tidal and Wave Interaction

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THE QUEEN CITY FORMATION IN THE EAST TEXAS EMBAYMENT: A DEPOSITIONAL RECORD OF RIVERINE, TIDAL AND WAVE INTERACTION[1]

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ABSTRACT

Five distinct facies are recognized in the Eocene Queen City exposures between the Trinity River valley and the Louisiana state boundary. These facies (fluvial, deltaic, tidal flat, barrier, and tidal delta) display diagnostic suites of physical and biogenic structures. Sandstones within these facies exhibit substantial differences in paleocurrent pattern.

Fluvial influx was mainly from the northwest, with subordinate contributions of sediment from the east. A marginal alluvial and upper deltaic plain was transected by fluvial channels of fluctuating bedload to suspended load proportions and variable preservtion potential. Along the northwestern embayment margin, small, high-constructive shoal water deltas and crevasse subdeltas developed and prograded across the shallow Reklaw shelf. Barriers may have originated as destructive components of delta abandonment or as contemporaneous strike-fed features marginal to the main delta complex to the west. In either event, barriers are poorly preserved, possibly because of transgressive ravinement, but more likely because they were never developed on a major scale. Extensive backbarrier or bay-margin intertidal and subtidal flats and shoals reflect the interplay of tidal and wave-generated processes, leaving a characteristic record of variable physical energy and flow patterns. Flood-tidal deltas formed at the mouths of microtidal estuaries and, like some modern analogues, they were significantly larger than comparable mesotidal features. The inferred flood-tidal delta deposits also exhibit features reflecting storm processes.

Regional depositional patterns were largely controlled by: 1) location of the east Texas embayment with respect to the major deltaic depocenter, resulting in an eastward decrease in sediment supply; 2) configuration of the broadly funnel-shaped embayment and wide shelf, which may have augmented tidal range; and 3) transition from overall progradational character, with local transgressions, to a major marine transgression that culminated in shelf sedimentation of the overlying Weches Formation.

INTRODUCTION

The Queen City Formation (Eocene) records a predominantly regressive episode during the repeated shoreline transgressions that characterized Eocene deposition on the northern Gulf Coast (Fisher, 1964). Local transgressive marine units are present to varying degree within the generally regressive Queen City succession. In east Texas (fig.1) a major high-constructive delta system attained its maximum development west of the axis of the east Texas embayment (Guevara and Garcia, 1972). The degree of marine influence increased eastward concurrently with the reduction in terrigenous influx. Facies changes reflecting the limits of detrital sedimentation occur near the Texas-Louisiana state boundary where Queen City sands pinch out into marine shelf deposits of the Cane River Formation. Similarly there is an upward increase in the proportion of marine reworked sands in the Queen City Formation, signalling the onset of the succeeding Weches transgression.

Gross stratigraphic relations for the Queen City Formation in east Texas are illustrated in figure 2, together with the approximate positions of outcrops studied. These outcrops preserve details of the fluvial to marine transition and include a remarkably well-exposed suite of coastal facies. This paper examines the facies characteristics and interrelationships of fluvial, deltaic, barrier, and backbarrier deposits. The backbarrier deposits include several examples of flood-tidal deltas with associated lagoonal and tidal-flat facies.

FLUVIAL FACIES

Two distinct fluvial associations are recognized: 1) multiple bedload channels comprising sand fill with negligible fine-grained topstratum; and 2) thicker, more argillaceous channel-fill units showing characteristic upward-fining patterns from sand to silt or mud, with low-angle channel margin accretion surfaces. Both types are readily identified with established fluvial models, and thus will not be treated at length. Bearing in mind the cautionary note of Jackson (1978) regarding the unreliability of certain recognition criteria, these two associations need not necessarily represent mutually distinct fluvial environments (*e.g.*, braided vs. meandering). Instead they may be end members in a complexly fluctuating fluvial continuum in which selective preservation has been a vital factor.

Bedload Channels

Superimposed, sand-filled channels have a preserved thickness of between 30 and 200 cm and large width-depth ratios. The channels exhibit thick planar cross-bed sets that are ascribed to accretion on the margins of transverse braid bars

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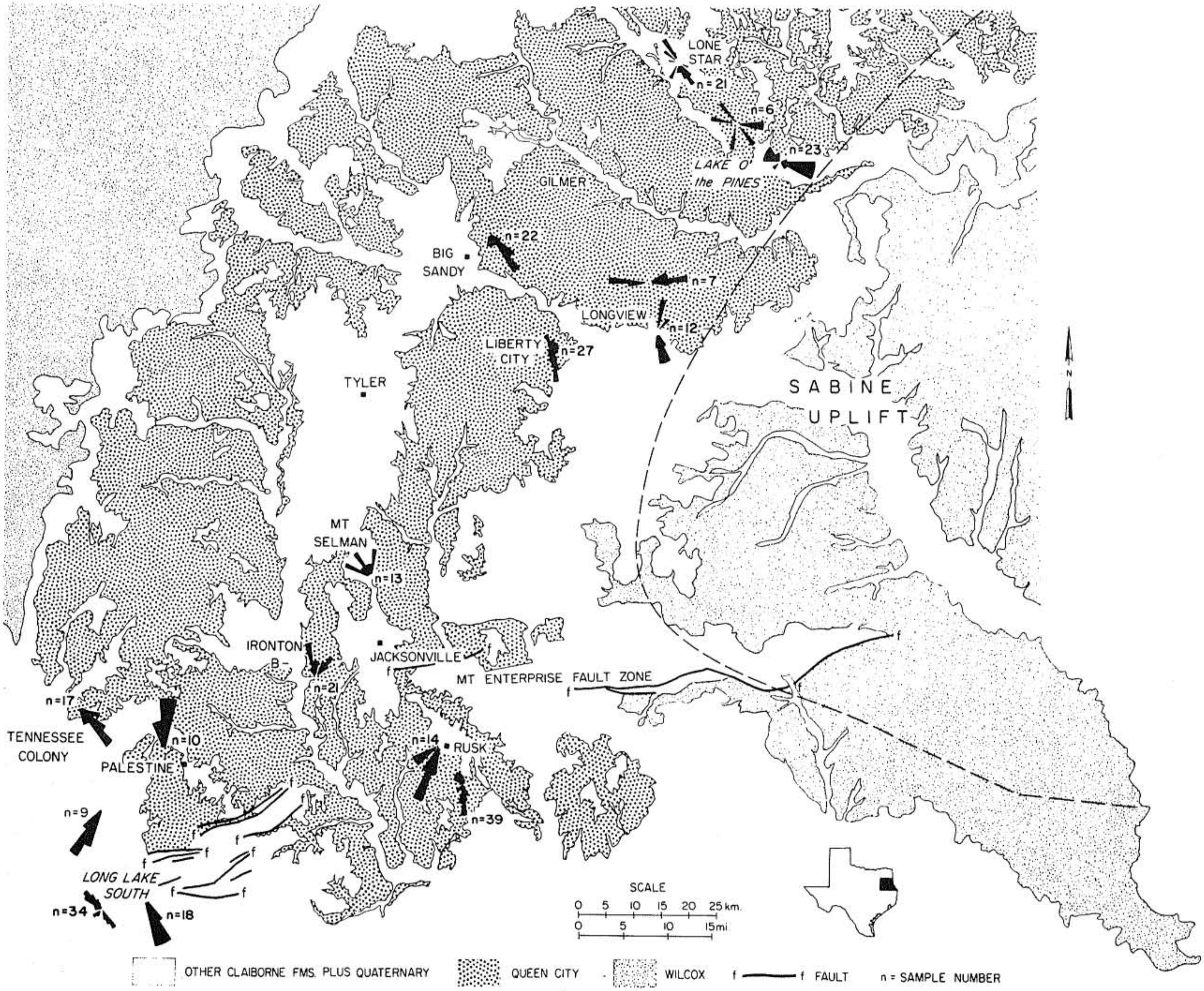

Figure 1. Queen City outcrop area in east Texas with paleocurrent distributions at major outcrop localities. Paleocurrent data for Lake O' The Pines in part after Fortier (1975).

(Collinson, 1970; Smith, 1971, among others). Compound cross-bedding, reactivation surfaces, and upper flow regime plane-bed intercalations suggest fluctuations in river stage.

Abundant mudclasts, particularly above a scoured base, and the absence of argillaceous topstratum, attest to a low preservation potential of overbank fines. These were presumably eroded during the frequent changes in channel position and flow intensity.

Mixed-Load Channels

Erosively-based sequences up to 5 m thick comprise basal cross-bedded sands with scattered mudclasts overlain gradationally by interlayered sand, silt, and clay (fig. 3). Within the channels, large-scale surfaces that dip at angles up to 12° (epsilon cross-bedding; Allen, 1963) are ascribed to point-bar accretion. Intrasets of trough and planar cross-beds are inclined obliquely along strike of the point-bar surfaces; small-scale cross-laminations ascending the point-bar surfaces are thought to preserve helical flow patterns around meander bends.

The uppermost silty clays of more completely preserved sequences show root penetration and lignitic streaks. Rare silty units with gentle dips may be topstratum levee deposits; in places these levees are traversed by small, steep-sided scour channels up to 150 cm thick that possibly originated by crevassing processes.

Clay-filled abandoned channels are commonly associated with the mixed-load fluvial subfacies. Their asymmetrical form is one of the most reliable criteria for a meandering origin (Jackson, 1978).

DELTAIC FACIES

Small-scale high-constructive delta deposits are preserved: 1) in regular upward-coarsening, locally scoured sequences up to 8 m thick; and 2) as highly irregular, erosively-based, broadly lenticular sandstones overlying carbonaceous bay shales. The former pattern (fig. 4) is attributed to the systematic progradation of small, fluvially-dominated deltas, possibly comparable with the Guadalupe and Colorado deltas of the modern Texas coast (Donaldson *et al.*, 1970; Kanes, 1970). An analogous backbarrier setting, or possibly a sand-starved embayment, is envisaged for the accumulation of organic rich muds and silts that comprise the lower part of many Queen City deltaic sequences. These shaly deposits are commonly pyritic and sulfurous, attesting to a highly reducing environment; elsewhere they are somewhat less reduced and are chocolate colored or sideritic.

Overlying the lower shales are distal bar silts and sands that are characterized by low amplitude wave ripples of variable trend. These wave-formed structures give way upward to current-generated structures of progressively increasing scale within thin delta front sheetsands. Repetitive three-part vertical arrangements of plane-beds, ripples, and clay attest to abrupt pulses of sediment influx followed by waning flow. These plane-bedded and trough cross-bedded delta front sands are scoured by numerous small distributary channels of variable internal geometry and general southerly orientation. Some of these channels, such as those at Ironton (fig. 1), contain evidence of bidirectional flow, which possibly resulted from tidal processes.

The chaotic sands of the second delta type suggest catastrophic influx, which can result from floods and breaching of levees. The generally massive, diapirically-intruded sands indicate rapid sediment dumping, and contain sporadic scour and fill structures. *Ophiomorpha* occurs in association with curved burrows resembling those produced in protected sand beaches, flats, and sandy marshes by the sand fiddler crab (Allen and Curran, 1974). The laterally adjacent and underlying lenticular and flaser bedded sands, silts, and muds may indicate weak tidal processes in a delta-margin or interdis-

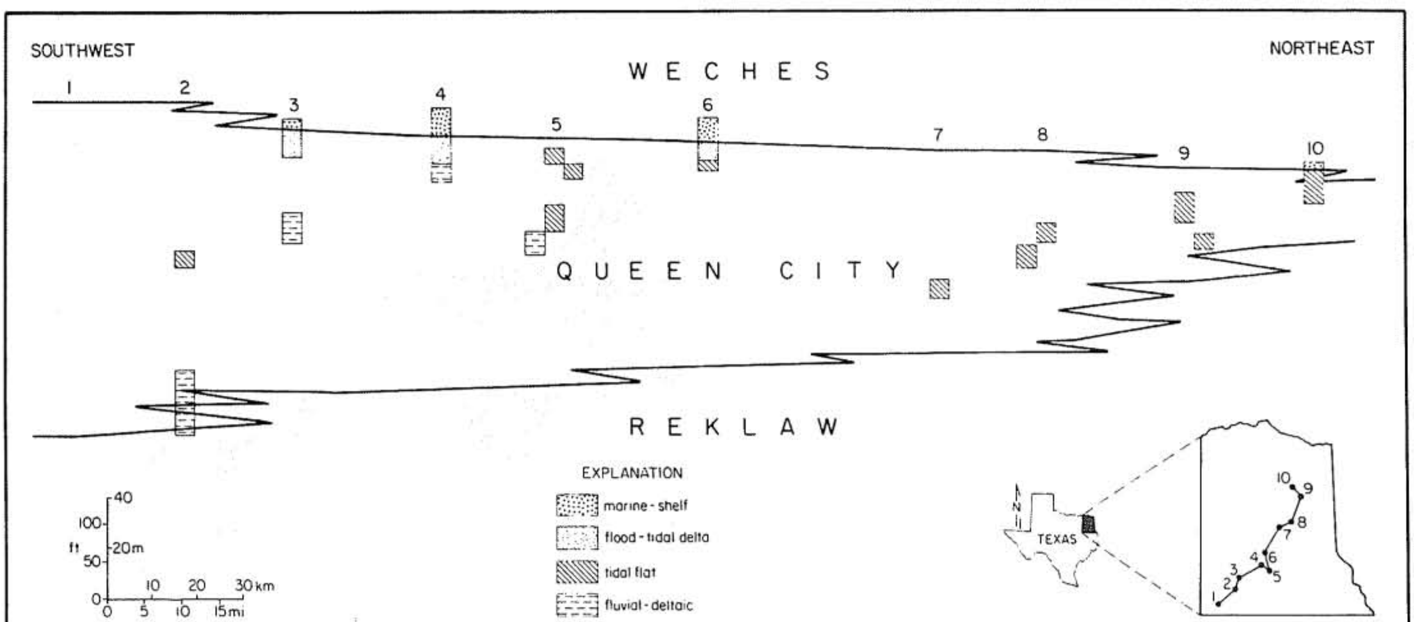

Figure 2. Schematic cross section showing eastward thinning of Queen City Formation and relationship to Reklaw and Weches Formations. Numbers refer to localities: 1. Leon County, 2. Long Lake South, 3. Palestine, 4. Ironton, 5. Rusk, 6. Mt. Selman, 7. Liberty City, 8. Longview, 9. Lake O' The Pines, 10. Lone Star.

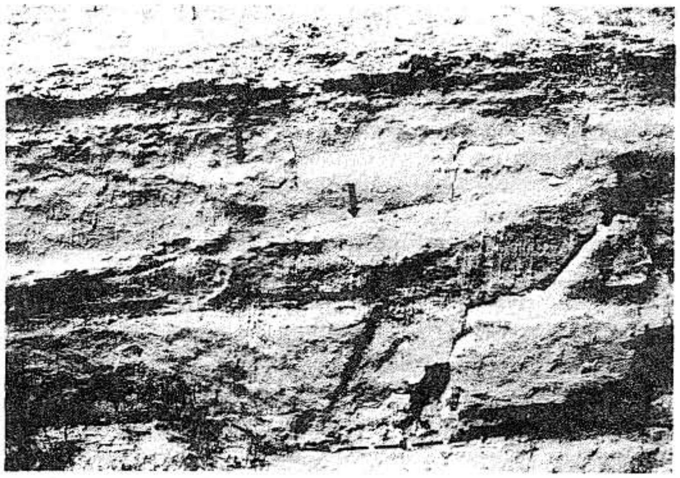

Figure 3. Upward-fining mixed-load channel deposits with dashed line at pebbly, erosive base; inclined lateral accretion surfaces arrowed. Tennessee Colony.

tributary bay subject to episodic high rates of crevasse sedimentation.

BARRIER FACIES

Barrier facies are sparsely represented in outcrop, suggesting either limited initial development or subsequent destruction. The only clear example, near Gilmer, has been documented by Guevara and Garcia (1972). Bioturbated sands, with *Ophiomorpha* and vestiges of plane-bedding, presumably of foreshore origin, enclose a thin layer of carbonaceous backbarrier muds to landward. These are overlain by bay muds and sands followed by a regressive delta sequence.

TIDAL FACIES

A distinctive and widespread facies comprises thinly bedded, fine to very fine grained sand with frequent argillaceous interbeds. Mud is present as thin drapes on rippled surfaces, as partings along foresets and set boundaries, and as persistent rhythmic intercalations several cm thick. Two subfacies, tide-dominated sands and mixed sand-mud (heterolithic) tidal flats, are distinguished on the basis of sand to mud ratio and by scale and type of internal stratification.

Tide-Dominated Sands

Well-sorted quartzose, locally pelletiferous, sands show a combination of small-scale planar and trough cross-bedding, washed-out dunes, plane-bedding, and ripple cross-lamination. Mud partings are ubiquitous but are generally eroded in part (fig. 5a). Locally derived mudclasts are scattered throughout, and are concentrated in shallow scours. These scours are remarkably uniform in depth. At Lone Star (fig. 1) values of 80, 126, 100, and 120 cm are obtained from four such features, and comparable depths are seen elsewhere. Near Rusk (fig. 1) a larger channel is filled laterally by wave-rippled (fig. 5b), inclined sand beds with thin clay partings. Unlike fluvial channels, clay content decreases upward in these tidal channels.

Foreset azimuths show marked dispersal and in most cases are bipolar, trimodal, or polymodal (fig. 1). Herringbone reversals of successive sets are observed (fig. 5a), but more commonly sets of more or less constant azimuth are grouped in cosets, with directional variation occurring between cosets. At other localities bimodality is weakly developed, with infrequent reversals, commonly of smaller scale sets (fig. 5c). Small ripples are superimposed transversely on larger bedforms, yielding paleocurrent modes approximately at right angles.

Evidence of marine influence is provided by a trace fossil assemblage that includes *Ophiomorpha* (fig. 6), spreite-filled burrows with protrusive and retrusive arrangements, and several varieties of surface trails including *Scolicia*. Furthermore, dispersed sand-sized pellets are glauconitic.

By comparison with the work of Klein (1970) and De Raaf and Boersma (1971) among others, the patterns of paleocurrent dispersal are attributed to changes in tidal current direction; clay drapes are interpreted as a product of high-tide slack water settling of suspended muds. Other features of this facies that are common in a tidal environment are scour channels or "washouts," reactivation surfaces, superimposed structures of different scale and orientation, alternating sets of large- and small-scale cross-bedding (fig. 5d), and lenticular and flaser bedding (Van Straaten, 1954; Klein, 1970; De Raaf and Boersma, 1971; Reineck, 1972).

Along the North Sea coast a large proportion of the tide and wave transported sand-sized material is concentrated in the shallow subtidal zone as sandbars transected by

Figure 4. Superimposed upward-coarsening shaol-water delta deposits (sequences 1 and 2), Trinity River exposure.

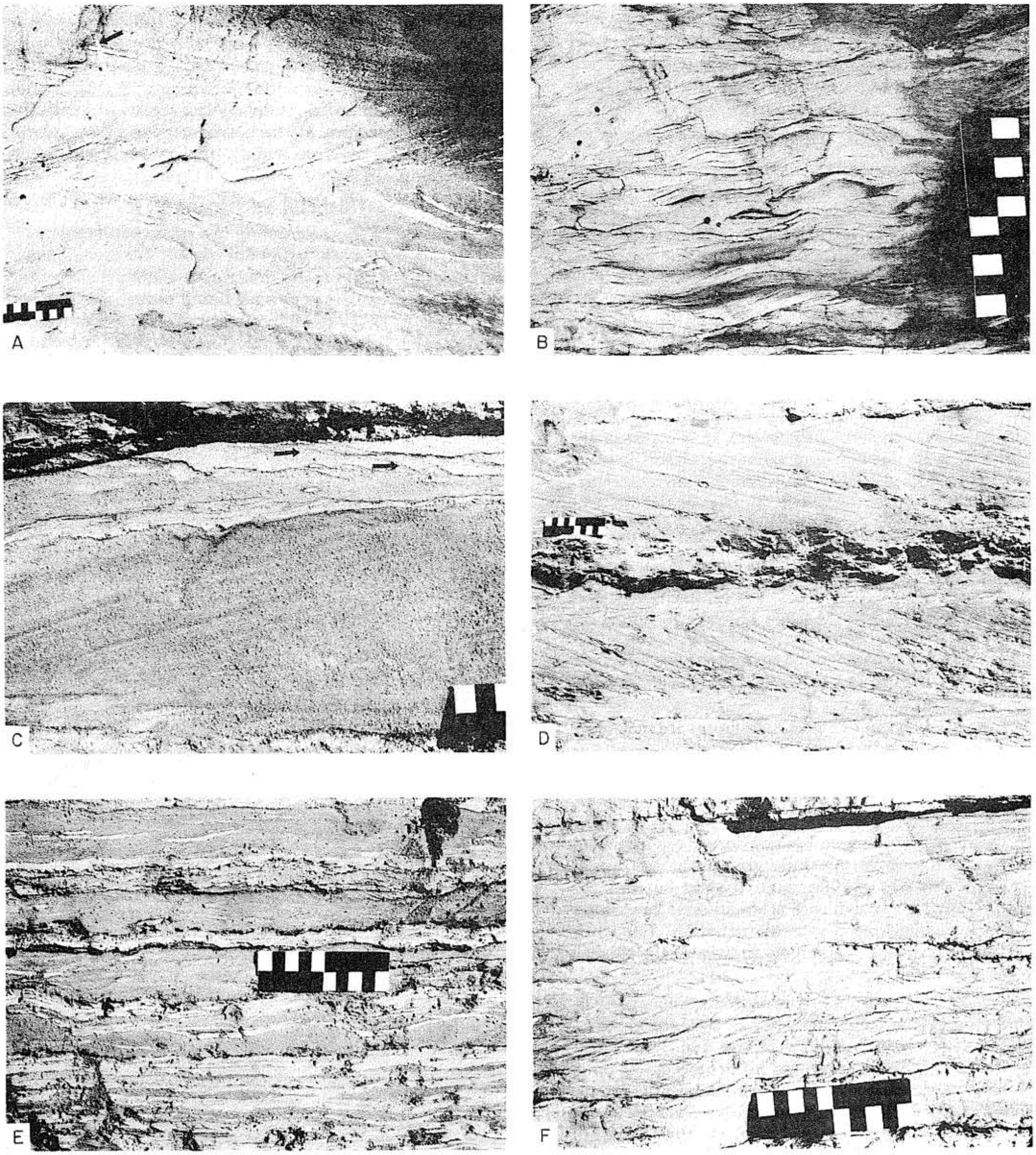

Figure 5. A, Partially eroded clay drapes on herringbone cross-bed foresets. Note subvertical burrow (arrowed). B, Wave-rippled inclined beds filling channel. C, Clay-draped, partly burrowed cross-bed set overlain by small-scale foresets (arrowed) of opposite direction. D, Alternating sets of large- and small-scale cross-bedding with clay clasts and burrows. E, Cross-lamination of variable direction, clay drapes, undulatory streaks, and flaser bedding. F, Cross-lamination wih abrupt reversals in direction and changes in dip angle. Scales are 10 cm.

channels, and as a belt of sand along the low tide level (Van Straaten, 1954; Reineck, 1972, 1975). An analogous setting is envisaged for the tide-dominated sands of the Queen City Formation. This is supported by the presence of thin plane-bedded units with minor internal discordances and rare non-walled vertical burrows at the top of bimodally cross-bedded sands at Long Lake South and the southern outcrop at Longview (fig. 1). These swash-type deposits probably originated on a low tide terrace, and thus mark the top of transgressive sequences.

Heterolithic Tidal Deposits

This facies comprises sand and mud in approximately equal proportion, generally as 0.2 to 4.0 cm alternations (fig. 5e). The sands are fine to very fine grained and micaceous in part; the mud is mostly light gray and finely laminated but is locally carbonaceous or even lignitic. Linear and polygonal desiccation cracks are observed in association with rare evaporite casts.

The sands show a remarkable variety of small-scale bedforms. In the classification of High and Picard (1976) these include current-generated ripples (linguoid and cuspate), wave ripples (linear, combined flow, and infrequent oscillation types), and interference ripples ("tadpole nests," ladderbacks, cuspate, and secondary forms). Ripple trends are variable, with wide dispersion of azimuths, although weak bipolarity is developed locally. Wave ripples characteristically show low-angle, form discordant, bidirectional cross-lamination with undulatory lower set boundaries, superimposed chevron laminae, pinching and swelling of form sets, in patterns similar to those described by De Raaf *et al.* (1977). Figure 5f illustrates bidirectional "wave knitted" cross-lamination with frequent reversals and changes in dip angle (De Raaf *et al.*, 1977, fig. 11). Other small-scale features produced by a combination of wave and current processes include linsen and flaser bedding and undulatory silt and sand streaks (fig. 5e).

Thicker sand units (up to 30 cm maximum) are markedly lenticular, commonly scour-based, and contain mudclasts or coalified woody debris. Plane-bedding and high-angle cross-bedding in undirectional or herringbone patterns are the most common structures in these units.

Trace fossils are widespread but nowhere is the bioturbation intense. Surface crawling traces are seen on the tops of sand units, which also contain small tubular burrows. In places, thin sands show evidence of small-scale reworking by minute organisms, or "cryptobioturbation" (Howard, 1978). *Ophiomorpha* occurs sparingly in some of the thicker sands.

The above evidence points to a marginal marine, periodically emergent environment characterized by textural segregation due to alternating conditions of high and low physical energy. Bedload sedimentation was influenced by currents and waves of variable direction. Such conditions are encountered in response to tide-dominated processes along the North Sea coast (Van Straaten, 1951, 1963; Reineck, 1972; De Jong, 1977) and elsewhere. On the North Sea coast tidal and meteorologically-induced processes commonly act in concert to provide the characteristic textural alternations (Reineck and Wunderlich, 1969). Linsen and flaser bedding is one of the most common structures of tidal flats (Reineck, 1972). Broad, scour-based sandy units with intraclasts were possibly deposited in the shallow tidal "washouts" described by Van Straaten (1951). Lignitic intercalations may have originated by differential settling of storm-suspended particles of lagoonal vegetation.

Vertical successions up to 1 m thick of alternating sand and clay commonly show an upward reduction in grain size and thickness of each couplet. In a demonstrable backbarrier setting, as at Mount Selman (fig. 1), this pattern may record abrupt increases in sediment supply from seaward, possibly due to storm breaching of the barrier followed by a gradually diminishing sediment supply, upon which tidal effects were superimposed.

Tidal Flat Sequences

Regressive tidal flats, consisting of a sandy belt below and along the low-tide mark, with mud content increasing landward through the mixed sand-mud flats to mudflats along the high-tide mark, generate upward-fining sequences (Evans, 1965; Reineck, 1967). Similar vertical arrangements result from lateral migration of tidal channels (Van Straaten, 1963). These vertical sequences have been recognized in the rock record as an estimator of paleotidal range (Klein, 1971). Vertically accreting tidal-flat deposits of a fluctuating shoreline may consist of superimposed sharply-based, upward-fining regressive sequences, with little or no record of inter-

Figure 6. Subvertical walled burrow in herringbone cross-bedded sand with clay drapes and clasts. Note upward-convex burrow-fill (arrowed). Scale in cm.

vening transgressions (Beukes, 1977), or the record may be more complex, with both transgressive upward-coarsening and regressive upward-fining patterns discernible (Wunderlich, 1970).

In the Queen City Formation several transgressive sequences are preserved, for example at Long Lake South and Lone Star, where the pattern is clearly related to the onset of Weches transgression. Elsewhere, as at the northern Longview outcrop and east of Lake O' The Pines (fig. 1), there is a vertical admixture of sandy and heterolithic tidal-flat facies showing very little cyclicity. Because of the sporadic and imperfect development of upward-fining cycles, the strong likelihood of facies stacking, and the lack in most cases of clear evidence of subaerial emergence in the sandy facies, these sequences cannot be used as even a general indicator of tidal range during Queen City deposition. The flood-tidal delta deposits are likely to be more reliable in this respect.

FLOOD-TIDAL DELTA FACIES

Three exposures at Ironton, Mount Selman, and Highway 19 north of Palestine (fig. 1) show major sand bodies deposited by consistently landward-directed currents. At Ironton (fig. 7) and Mount Selman these sand bodies are bounded to landward by carbonaceous finer grained sediments of inferred lagoonal origin. At each of the three exposures the sandbodies and their lateral equivalents are overlain by transgressive shelf deposits of the Weches Formation.

The external geometry and internal arrangement of textures and structures are best illustrated at Ironton (fig. 7) where the upper Queen City Formation is well exposed in three closely-spaced, laterally extensive outcrops A, B, and C. The lower parts of A and B are predominantly upward-coarsening regressive deltaic deposits showing some tidal modification, particularly in the channels. These regressive deposits are erosively overlain by fine-grained sands dominated by major low-angle master bedding surfaces dipping northward (landward) at 2-3°, between which are planar cross-beds of similar azimuth and subordinate troughs and ripples. Rare callianassid burrows provide evidence of marine influence. In addition there are isolated non-walled vertical tubular escape burrows up to 40 cm long.

The planar foresets show remarkably regular clay intercalations (fig. 8) which thicken toward the lower set boundary, but in many cases blanket the entire foreset. These patterns suggest orderly, periodic, and frequent changes in current energy which would not be possible under uniform flow conditions. Quite distinct from these are layers of small, reworked mudclasts. Foreset dip angles are variable and low angle foresets commonly grade into rippled toesets with clay alternations. Ripple orientation is inconsistent with the foreset directions. Some ripple cross-laminae climb the foresets obliquely whereas others are directed essentially along the strike of the foresets, reflecting variable current direction.

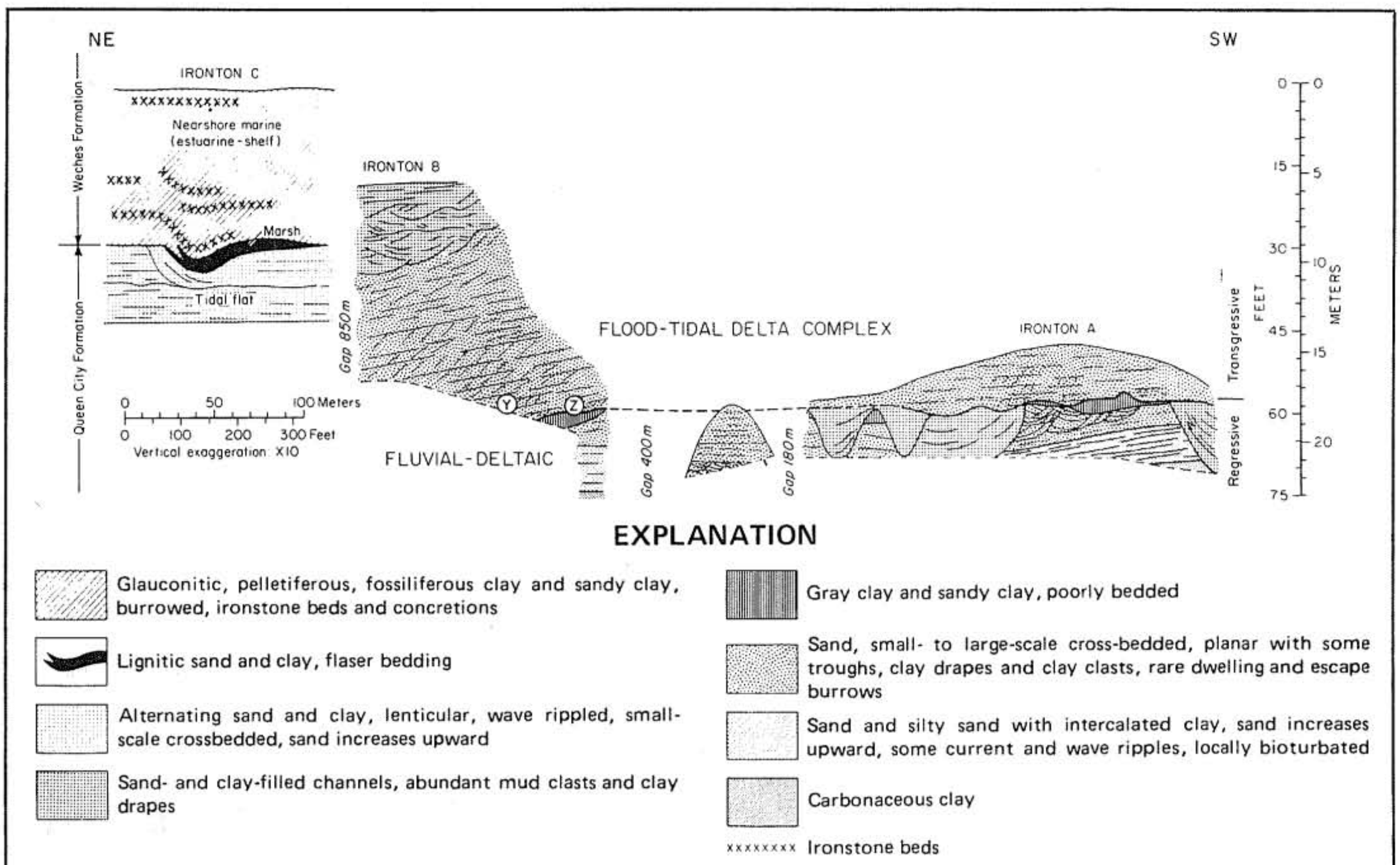

Figure 7. Generalized stratigraphic cross section of Ironton exposures A, B and C showing lithologies and environmental interpretations. Positions of figures 8 and 9 indicated.

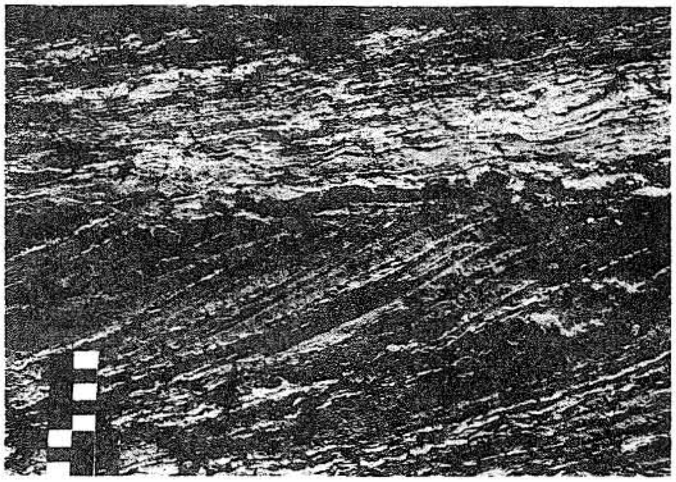

Figure 8. Ironton B foresets of variable angle, some rippling of lower foresets, and abundant clay drapes. Location within outcrop shown by Z in figure 7. Scale in cm.

Planar cross-bed sets attain maximum thicknesses of 140 cm (fig. 9); these thick sets are interspersed with thinner sets of around 20 cm. Subordinate troughs show a similar range of thicknesses but are far more variable in direction, in many cases cutting transversely across planar cross-bed sets. The degree of scouring increases upward. The upper part of Ironton B (fig. 7) is composed of multiple interlocking scour channels up to 2 m deep. These show a complex fill of sand and clay with abundant ripup clasts.

Northeastward (landward) of the proximal tidal delta is a sequence comprising basal tidal-flat facies (flood-oriented, small-scale cross-bedded with some reversals, vertical burrows, and clay partings), overlain by lignitic muds and sands with flaser bedding. A major channel cut into the tidal-flat deposits contains a concentration of glauconitic pebbles along with clay ironstone and fine carbonaceous debris. Above this are fossiliferous, glauconitic shelf deposits characteristic of the Weches Formation. Thus the Ironton C succession suggests a sheltered lagoonal or estuarine environment subject to increasing marine influence.

The erosive base of the Ironton B sands, the landward paleocurrents, clay drapes, and complex juxtaposition of structures suggest an origin related to inlet dynamics. Landward gradation of the sands into low-energy estuarine deposits indicates that the sand may represent an inner shoal or flood-tidal delta.

Assuming an Eocene shoreline configuration similar to the modern Gulf of Mexico, tidal range was probably small. Nevertheless, some of the largest flood-tidal deltas are associated with microtidal estuaries (Nummedal *et al.*, 1977; Reinson, 1977). For example, the flood-tidal delta of the Miramichi estuary (New Brunswick) is developed with a tidal range of 1.1 m. It is exceptionally large and entirely subaqueous, with a surface covered with flood-oriented sandwaves and a poorly developed ebb shield (Reinson, 1977). A situation comparable to the Miramichi estuary is envisaged for flood-tidal deltas of the Queen Formation. Barrier islands associated with the flood-tidal deltas were poorly developed and sporadically distributed, thus facilitating the exchange of a substantial tidal prism. Bedload sedimentation corresponded to maximum flood-tide velocities, which in a microtidal situation, are significantly greater than ebb velocities (Nummedal *et al.*, 1977). Tidal inflow, flood-tide velocities, and attendant sediment transport were probably augmented by storm processes. Settling of suspended mud occurred during slack water corresponding to the maximum tidal advance. Progressive rise in sea level brought flood channels of the inlet ramp across the top of the distal sediment wedge causing local erosion and sand redistribution. Features comparable to the Queen City flood-tidal delta facies are recognized in the Carboniferous of eastern Kentucky by Barwis and Horne (1979), who ascribe them to a flood-tidal delta origin under a small tidal range.

The Mount Selman exposure (fig. 1) shows abrupt landward gradation of lenticular, scour-based sands into heterolithic tidal-flat deposits with desiccation cracks (fig. 10). Associated with these sediments is a complex of plane-bedded sands containing broad troughs. Considering their lateral equivalence to carbonaceous, bioturbated sands in an outcrop to the north, these plane-bedded sands were probably of barrier overwash origin. A close relationship between overwash and inlet-related processes on modern coasts has been stressed by Leatherman (1979). The washover sands overlie a major channelized unit composed predominantly of longshore-directed troughs with silt interbeds and callianassid burrows. This is interpreted as a backbarrier channel which

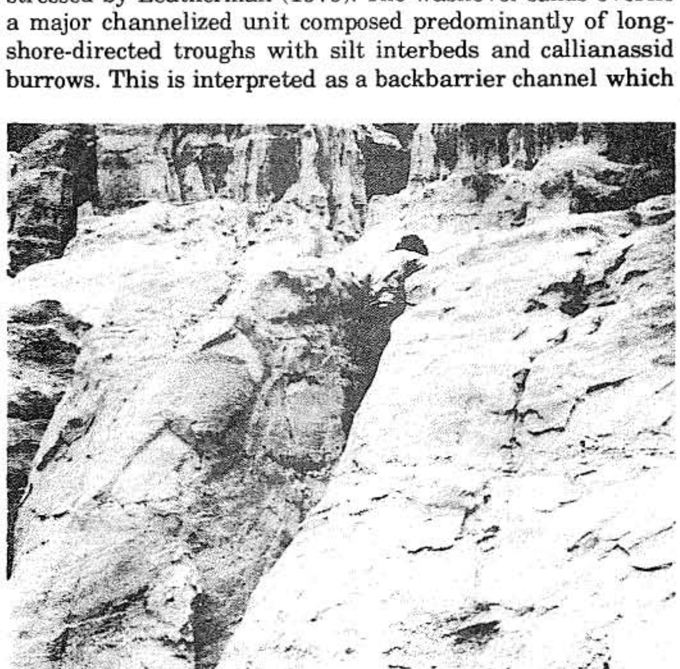

Figure 9. Thick sets of northward-inclined planar cross-beds, Ironton B. Location within outcrop shown by Y in figure 7.

funneled onshore flow to an adjacent inlet.

The outcrop north of Palestine (fig. 1) exhibits northward overlapping sand sheets with planar and trough cross-beds as at Ironton. Within the sands there are local concentrations of *Ophiomorpha*. The southern (seaward) end of the outcrop is channeled, containing large interlocking troughs capped with onshore-dipping cross-lamination. A thin plane-bedded unit extending across the seaward end of the sand body was possibly produced by wave swash following infilling of the channels, which may have been related as much to washover processes as inlet dynamics. Immediately above this level is the transgressive Weches contact.

PALEOGEOGRAPHIC SYNTHESIS

The western section of the east Texas embayment received maximum terrigenous influx supplied by the eastern flank of a major high-constructive delta system that extended along strike into central Texas (Guevara and Garcia, 1972). Sediment also may have been contributed by westward littoral drift from an Appalachian source (Sartin and Brooks, 1977), and the Sabine uplift possibly shed a limited amount of detritus westward into the embayment.

Figure 11 is a schematic and highly generalized reconstruction of facies tracts. Because of the frequent and widespread changes in shoreline position that characterized Queen City deposition in parts of the east Texas embayment, this reconstruction portrays the "average" setting prior to the Weches transgression.

The fluvial plain/upper delta plain in the northwest was traversed by channels of two distinct types, which elsewhere have been ascribed customarily to braided and meandering modes. Field relationships suggest, however, that these modes coexisted in a single dynamic system, possibly comparable to the Red River (Schwartz, 1978), but somewhat smaller. The fluvial system terminated in small high-constructive deltas, some of which prograded rapidly across the shallow Reklaw shelf; others were restricted to backbarrier or bayhead settings. Delta switching, crevassing, and development of subdeltas produced thin, vertically repetitive and laterally overlapping upward-coarsening sequences.

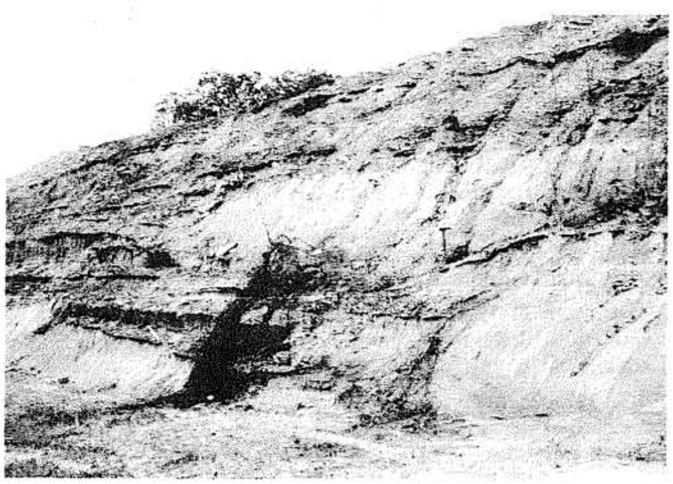

Figure 10. Lenticular, scour-based sands at Mt. Selman interfingering northward (away from viewer) with tidal flat muds and sands.

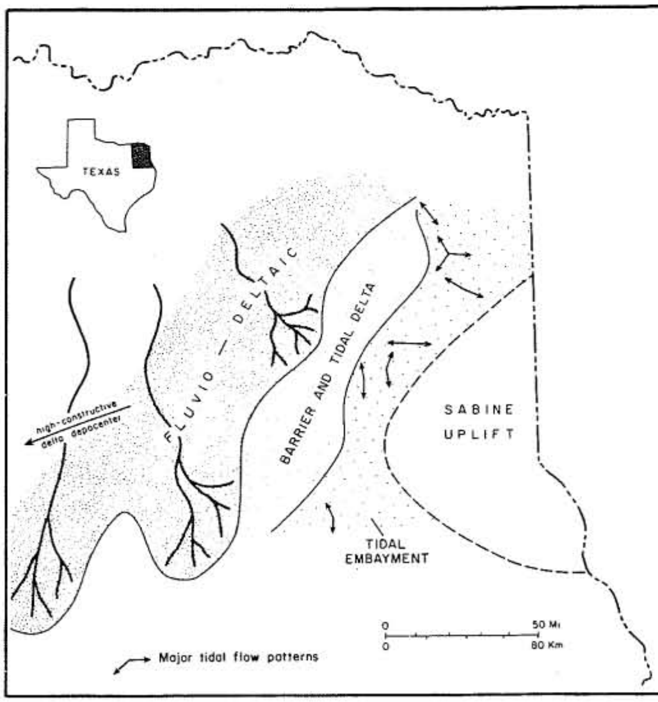

Figure 11. Schematic reconstruction of major Queen City facies tracts in the east Texas embayment.

Barriers, which originated by wave reworking of abandoned delta lobes or as strike-fed sands transported by longshore currents, appear to have been sporadically developed. The coastline was backed by broad tidal flats, coastal lakes, and estuarine reentrants, probably comparable in aspect to the Dutch Wadden Sea. Tidal range at one of the Wadden barriers is as low as 170 cm (De Jong, 1977), yet this is large compared with tidal ranges in the Gulf of Mexico (up to 60 cm), and is probably greater than the Eocene tides that influenced Queen City deposition. Nevertheless, some degree of local amplification over the average for the Gulf (Fortier, 1975) could have been brought about by the wide shelf (Redfield, 1958), the broadly funnel-shaped coastal configuration, or by convergence and constriction of flow around the Sabine uplift, connecting northeastward with the Mississippi embayment. A more remote possibility of augmented tides arises from Rainwater's (1967) Paleocene and Eocene reconstruction of a broad marine connection with the Atlantic Ocean across the Yucatan Peninsula, peninsular Florida and Cuba. Although these waters were generally shallow, there may have been some amplifying effect on tidal exchange. In addition to Fortier's (1975) observation of possible enhanced tidal range at Lake O' The Pines, Stenzel (1953, p. 99) finds evidence in Cherokee County of significant tidal processes during Queen City deposition. In an account of the Claiborne Group of the Brazos River valley, Scott (1963, pp. 13, 20), conjectures that "the tidal range was greater than that of the present Gulf." It is possible that the slightly enhanced tidal processes postulated herein were generated by meteorological processes such as "wind tides" which could account for rapid fluctuations in water depth, energy, and current and wave direction. Indeed, marked "tidal" characteristics have been described elsewhere in unequivocal fresh water deposits (Van Dijk *et al.*, 1978). However, the Queen City deposits show far closer resemblance to Holocene tidal flat analogues, and their wide areal extent and relationship to other clastic deposits suggest astronomical control. This conspicuous development of tidal characteristics does not imply a large tidal range, but may indicate that tidal effects were more pronounced because of the relatively low intensity of other physical processes. Increased dominance of tidal facies eastward was probably in response to a reduction in clastic influx.

Restriction of the flood-tidal delta deposits to the top of the Queen City Formation, and their vertical and lateral relationships to a locally transitional boundary with the Weches Formation, implies that their origin was related to the initial phase of marine transgression, which would have promoted barrier destruction and breaching of inlets (Leatherman, 1979). They may also reflect the importance of storm processes on a microtidal coast (McGowen and Scott, 1975).

Within the Weches Formation, Kaiser (1974) recognizes a lower, southward-thinning, quartz-rich, shallow water facies overlain by glauconitic (chamosite) shelf sand and mud. Kaiser resolved an apparent inconsistency between the iron geochemistry and salinity of original formation water by demonstrating that siderite in the Weches Formation transgressively overlying Queen City tidal deposits in the northern part of the east Texas embayment is a product of groundwater alteration of chamosite, rather than of primary nonmarine origin.

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