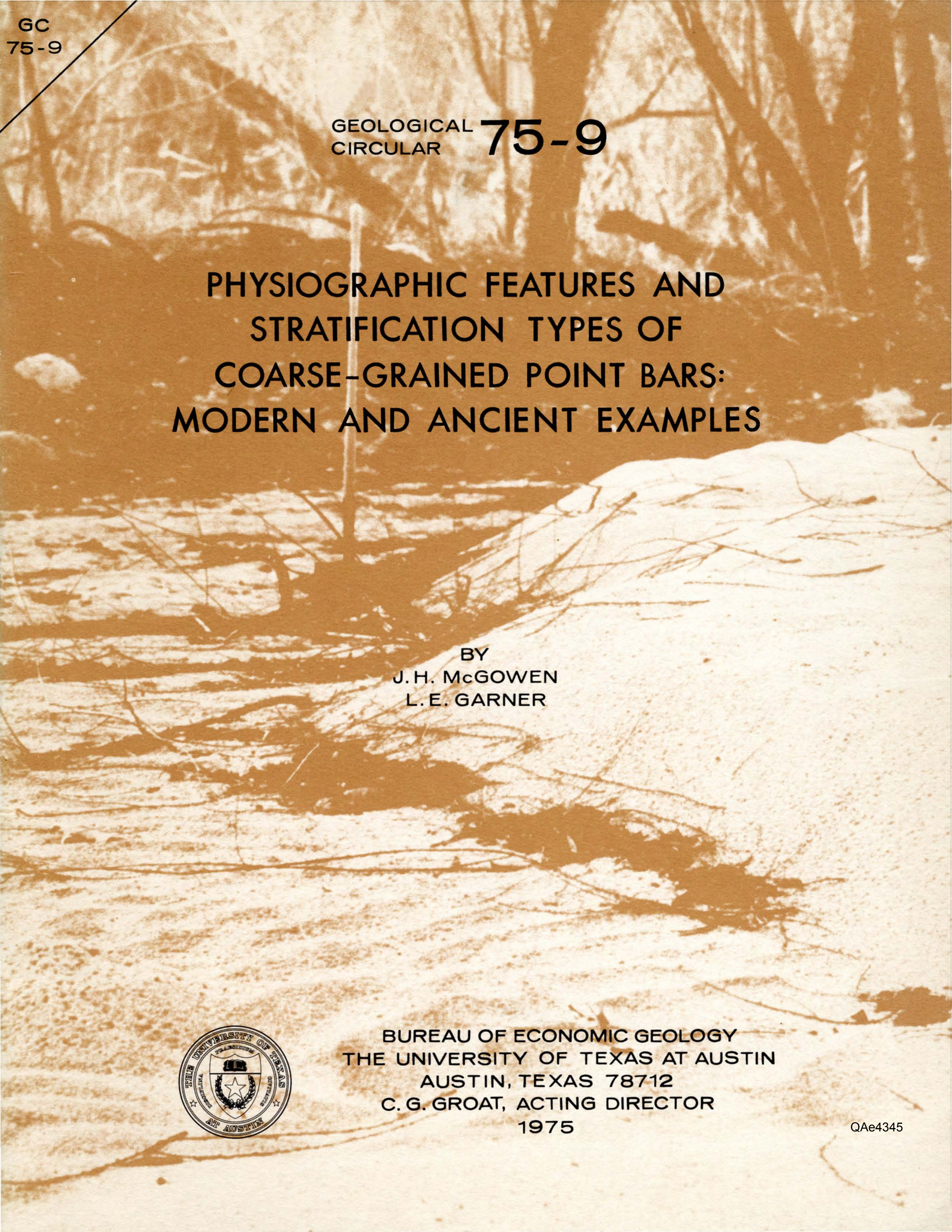

GEOLOGICAL CIRCULAR 75-9

PHYSIOGRAPHIC FEATURES AND STRATIFICATION TYPES OF COARSE-GRAINED POINT BARS: MODERN AND ANCIENT EXAMPLES

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J. H. McGOWEN
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PHYSIOGRAPHIC FEATURES AND STRATIFICATION TYPES OF COARSE-GRAINED POINT BARS: MODERN AND ANCIENT EXAMPLES

J. H. McGowen and L. E. Garner

SUMMARY

Primary sedimentary structures in modern point-bar deposits of the Amite River in Louisiana and the Colorado River in Texas are analogous to features observed in Eocene Simsboro and Pleistocene Colorado River deposits of the Texas Gulf Coastal Plain.

Short-duration peak flow, channel pattern, average stream gradient of about 2 to 3 ft/mi, and bank stabilization by dense vegetation are major parameters controlling the depositional pattern of coarse sand and pebble gravel of the Amite and Colorado Rivers. Stratification is directly related to specific depositional features and consists of: large-scale trough-fill cross-stratification in the scour pool; trough-fill cross-stratification and foreset cross-stratification in the lower point bar; parallel laminae, large foreset cross-stratification, and trough-fill cross-stratification in the chute bar; parallel-inclined laminae, climbing ripple laminae, and mud drapes in the chute fill; and parallel-inclined laminae, mud drape, and foreset cross-stratification in overbank, floodplain deposits.

Fundamental differences between point bars of bed-load streams (low suspended load/bed-load ratio) and mixed-load streams (high suspended load/bed-load ratio) are that upper point-bar sediments with small trough sets and parallel-inclined laminae occur only in fine-grained (mixed load) fluvial deposits, and large-scale foresets of chute bars are common to coarse-grained (bed load) fluvial deposits but are not found in fine-grained fluvial deposits. Upward-fining sequences, characteristic of fine-grained fluvial deposits, are uncommon in sediments deposited by bed-load streams such as the Amite and Colorado Rivers.

The Simsboro Sandstone consists mainly of scour-pool, lower point-bar, and chute-bar sediments. Chute-fill and floodplain deposits are preserved only in the highest stratigraphic sequence. Pleistocene Colorado River deposits display the same sequence of stratification types as the Simsboro but are composed of coarser material.

INTRODUCTION

Regional surface and subsurface mapping (Fisher and McGowen, 1967, 1969) demonstrates that the Simsboro Sandstone of the Wilcox Group (Eocene) in Texas was deposited in a fluvial environment updip from a large lower Wilcox delta system. Interest in study of the Simsboro was generated when observations in an area thought to represent a highly meandering segment of this ancient fluvial system displayed a sequence of primary sedimentary structures not previously reported in modern or ancient point-bar deposits.

Standard fluvial and point-bar models, described in Bernard and Major (1963), Allen (1965), and Visher (1965), indicate an upward fining of sediment and vertical succession of stratification types from trough-fill cross-stratification, parallel or horizontal lamination to ripples. However, in the Simsboro fluvial sequences no systematic change in grain size is apparent, and vertical sequence of trough-fill cross-stratification, small foreset cross-stratification and small trough-fill cross-stratification, and large foreset cross-stratification differ from the sequence of these standard fluvial models. The Simsboro is made up of sandstone bodies (generally less than 10 percent overbank mud) that are up to 30 miles wide and from 12 to 200 feet thick.

Clues to the origin of the Simsboro were sought in the modern Amite River (near Baton Rouge, Louisiana) and the modern Colorado River of Texas (fig. 1). These two rivers are bed-load streams, characterized by relatively low sinuosity and high gradient, bank stabilization by vegetation, and excessively high discharge of short duration. Sequences of primary sedimentary structures in point bars of these two modern streams, the Simsboro Sandstone, and Pleistocene Colorado River deposits are similar. The following discussion deals with characteristics of the modern Amite and Colorado sediment, Simsboro Sandstone (Eocene), and Colorado River deposits (Pleistocene).

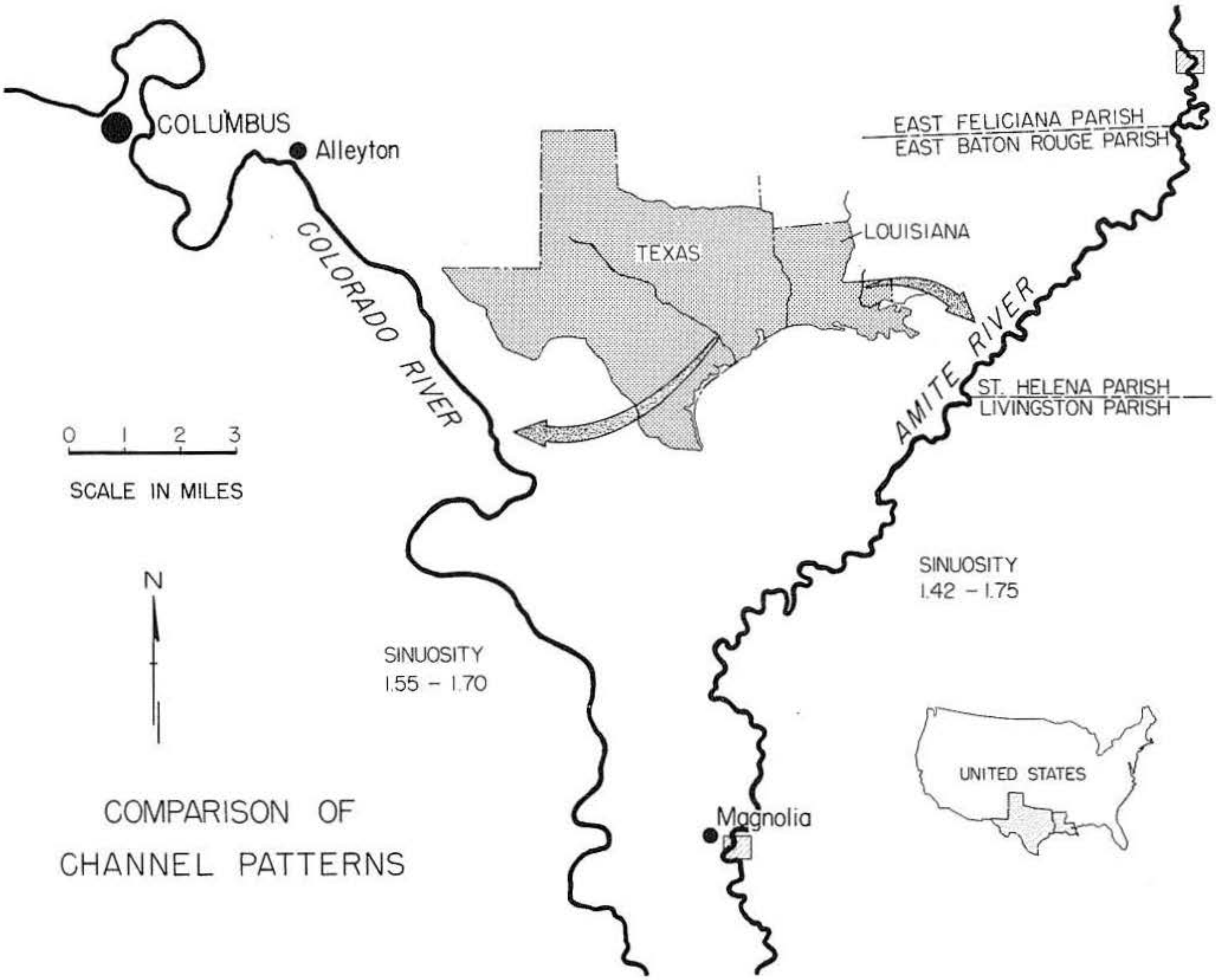

Fig. 1. Channel pattern and sinuosity of the Colorado River (Texas) and the Amite River (Louisiana). Mileage scale applies to the enlarged scale of the rivers.

MODERN SYSTEMS: AMITE AND COLORADO RIVERS

GENERAL SETTING

The Amite River of Louisiana and the Colorado River of Texas have many comparable features. Both are relatively small, although the Colorado drains a larger area (about 42,000 sq mi) than does the Amite (about 3,000 sq mi).

Stream patterns and gradients were determined from 7.5-minute topographic maps. Using the method of Leopold and others (1964), the sinuosity of the Colorado and the Amite are within the range of 1.5-1.75 and 1.4-1.7, respectively (fig. 1). Average gradient of the Amite is about 3.2 ft/mi, with that of the Colorado about 1.7 ft/mi. Both are bed-load streams that transport coarse sand and pebble to cobble gravel throughout most of their extent.

Discharge of the two streams is comparable in pattern and in volume (fig. 2). Flow through the Amite and Colorado is less than 5,000 cfs (cubic ft/sec) 95 percent of the time. High discharge of about 50,000 cfs for the Amite and 150,000 cfs for the Colorado occurs about 5 percent of the time. These streams are "flashy" when compared to rivers such as the Atchafalaya (Louisiana), which has a continuous flow with a high discharge over a longer period of time. Observations were made when both the Amite and Colorado were in low-flow stage, and flow conditions under which many of the physiographic features developed are interpretive, not observational. In the Amite, the water was clear, and no bed-load transport was observed; in the Colorado, fine to medium sand was being transported as linguoid-cuspate ripples along the backs of transverse bars in crossovers. A crossover is a relatively straight channel segment that lies between two meanders.

Discharge curves are different for the Atchafalaya and Colorado and Amite Rivers. Mixed-load streams (Schumm, 1960, 1968), such as the Atchafalaya, commonly have a more sinuous or meandering pattern than do bed-load streams characterized by high bed-load/discharge ratio. This study indicates that the type of discharge (flashy or continuous) is also a critical factor controlling channel pattern and hence the types of primary sedimentary structures present in the larger accretionary features.

Banks of the Amite and Colorado Rivers are resistant to erosion primarily because they are densely vegetated. Were the vegetation cover absent or sparse, these two streams probably would have a braided pattern. Resistance to erosion of banks of mixed-load streams is related to a high clay content of overbank material (topstratum).

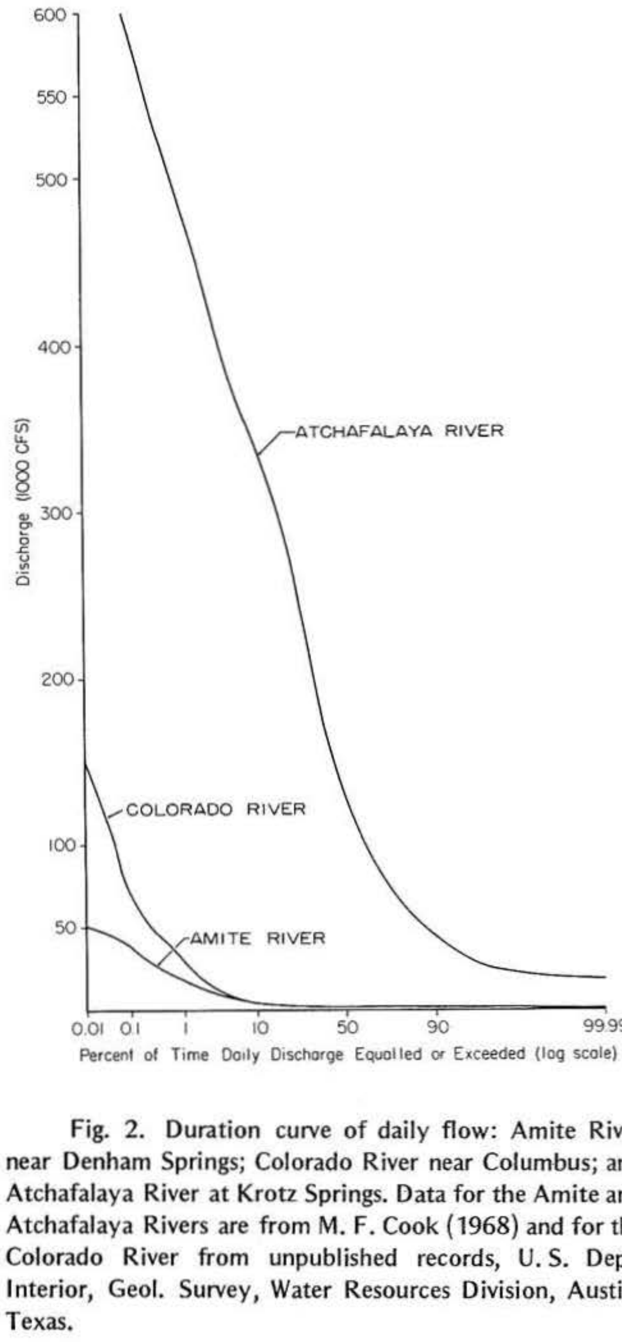

Fig. 2. Duration curve of daily flow: Amite River near Denham Springs; Colorado River near Columbus; and Atchafalaya River at Krotz Springs. Data for the Amite and Atchafalaya Rivers are from M. F. Cook (1968) and for the Colorado River from unpublished records, U. S. Dept. Interior, Geol. Survey, Water Resources Division, Austin, Texas.

PHYSIOGRAPHIC FEATURES

Observations were made on two point bars on the Amite River in East Feliciana and East Baton Rouge Parishes, Louisiana. The Colorado River was observed throughout its course from Smithville, Texas, in Bastrop County, to Matagorda Bay, a distance of about 165 miles. A plan sketch (fig. 3) of the Magnolia bar on the Amite illustrates the principal physiographic features of point bars along these streams. These include the concave or cut bank, channel with scour pool, and convex or sedimentation bank with chute, chute bar, and lower point bar.

Concave Bank

The concave bank is heavily vegetated. Sediment is contributed to this area only during extreme flood when topstratum deposits of clayey silt to muddy fine sand accumulate. Deposits within 0.5 to 0.75 foot below the surface have been completely mixed by plant roots. The upper 0.5 foot consists of alternating wavy laminae of clayey silt to muddy fine sand and plant debris, produced by unequal deposition around thick clumps of vegetation (grain-size terminology after Folk, 1954).

Dense vegetation retards lateral cutting by the stream. All along the course of the Amite, large trees, uprooted by bank caving, occur along both the convex bank and in the scour pool. Russell (1967) states that optimum conditions for bank caving occur after a flood crest has passed, particularly if the stage falls rapidly. Discharge curves for the Amite (fig. 2) indicate a rapid fall in flood stage. With the next flood stage, some trees are removed from the scour pool and are deposited downstream along the convex bank.

Scour Pool

Scour pools make up the deeper part of the stream adjacent to the concave bank. When observations were made (during low-flow stage) no material was being transported as bed load, and surface velocity of the Amite was in the 2- to 3-ft/sec range. Maximum observed water depths in the scour pools were 3 to 6 feet (fig. 4). The only features observed on the channel floor were scour troughs, about 1 to 2 feet deep, 5 to 8 feet wide, and up to 50 feet long. These troughs were scoured through pebbly coarse sand and bottomed in sandy pebble to cobble gravel. Scour troughs commonly develop downstream from large trees that slumped into the scour pool from the adjacent concave bank. Filling of these scour pools results in trough-fill cross-stratification.

Lower Point Bar

A broad flat area termed lower point bar occupies a position between the low-water level to the toe of the lowermost chute bar (fig. 3). Maximum height of the lower point bar above low-water line is about 2 feet, and the bar surface slopes at about 1 to 2 degrees toward the scour pool. Near the juncture of the lower point bar and low-water level (figs. 3 and 4), slope toward the scour pool increases abruptly to about 8 degrees. The low-slope angle results from a general increase in bar height downstream and toward the convex bank. The higher angle is produced by reworking of lower point-bar deposits as flood stage subsided to its present position. Most of the upper surface of the bar is featureless with no preserved bed forms. Some sand has been removed by the wind, and locally patches of granule gravel cover the surface. At distal end of the bar (area of trenches 5 and 6, fig. 3), an avalanche face with about 6 inches of relief is preserved. Generally, the part of the bar facing the scour pool is a smooth surface similar to the swash zone of beaches. This surface is traversed in a few places by rill marks and gullies.

Three stratification types are common in the lower point bar, all suggesting deposition under tranquil flow conditions (Albertson and others, 1966; Williams, 1967). Trough-fill cross-stratification and foreset cross-stratification probably form concurrently under similar flow conditions, whereas parallel laminae (fig. 4) form later as flood stage continues to decrease. Similar stratification types have been reported from straight reaches of the Rio Grande (Harms and Fahnestock, 1965) and from braided streams (Ore, 1963). Observations on Colorado River crossovers suggest that stratification of these deposits is probably the same as in lower point bars of the Amite.

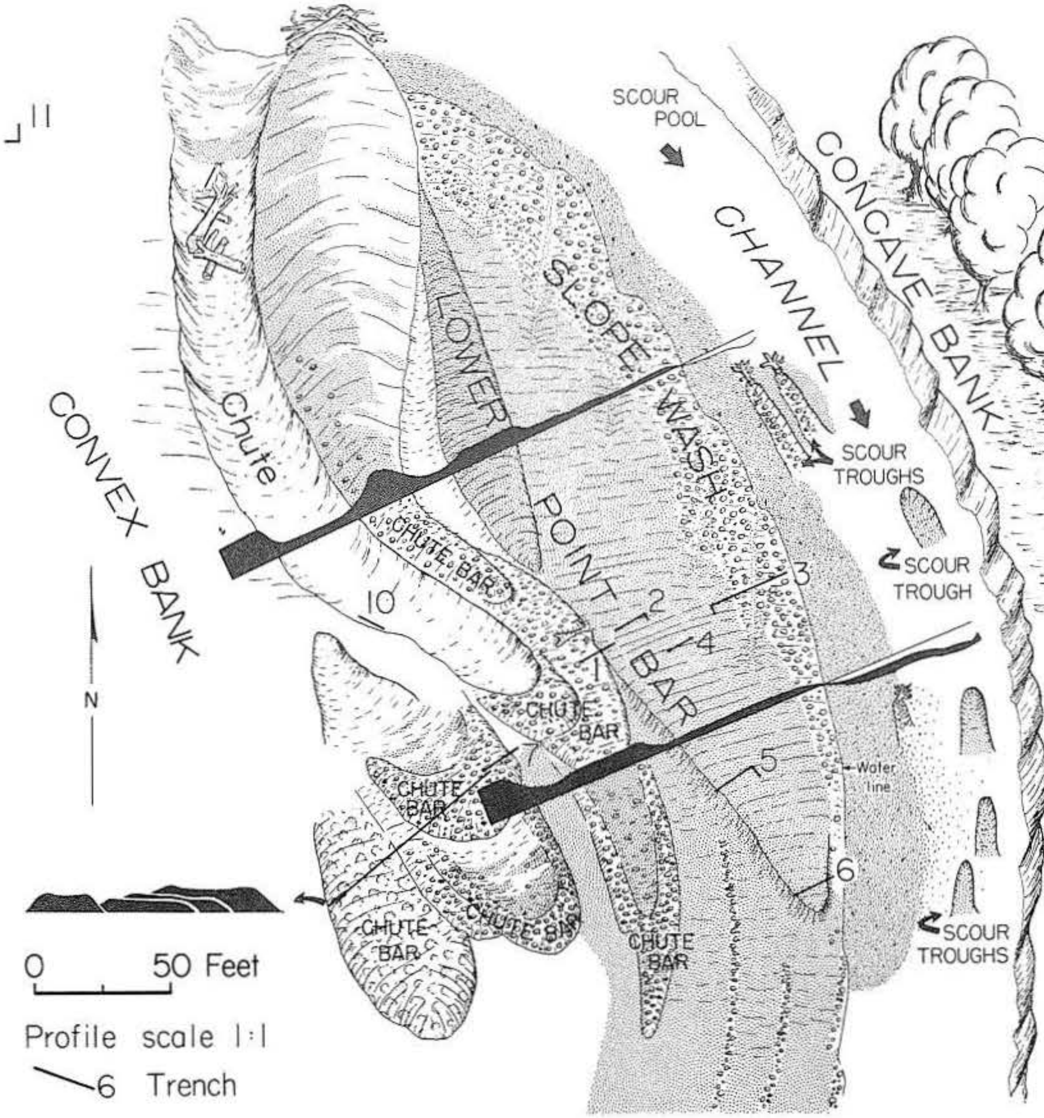

Fig. 3. Plan view (sketch) of coarse-grained point bar and trench localities near Magnolia, Louisiana.

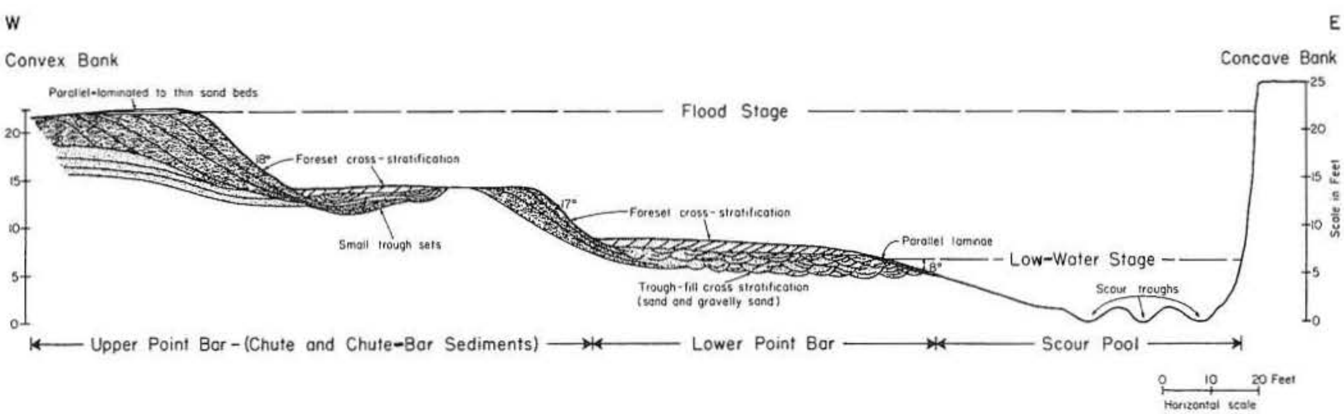

Fig. 4. Profile and stratification types from scour pool to crest of highest chute bar; coarse-grained point bar near Magnolia, Louisiana. Profile through trenches 3, 2, 1, and 7 (fig. 3).

Trough-fill cross-stratification of Amite River lower point bars is 2 to 6 inches thick and 1 to 4 feet wide (fig. 5); those of the Colorado are 2 to 3 feet deep and a few tens of feet long (fig. 6). Height of transverse bars on the Amite is 5 to 8 inches, whereas those of the Colorado are on the order of 0.5 foot to 2 feet thick (fig. 6). Scour troughs commonly occur downcurrent from transverse bars on both the Amite and Colorado Rivers. Trough axes of the Amite deposits trend toward the channel at angles of 6 to 28 degrees and away from the channel at angles up to 7 degrees. Foreset cross-strata of the transverse bars dip at about 25 degrees in a 40- to 50-degree oblique direction away from the channel trend. The parallel laminae (developed by slopewash) occupy a zone about 10 to 15 feet wide perpendicular to the river course.

Chutes And Chute Fill

Chutes develop on convex sides of streams during extreme floods when the thread of maximum surface velocity shifts from the concave toward the convex bank. Many, but not all, chutes are initiated as scours downcurrent from uprooted trees. Chutes on the Amite are 4 to 6 feet deep, 15 to 20 feet wide, and several hundred feet long. They are characterized by relatively steep sides, flat bottoms, and slightly sinuous trends. They are deepest at the junction with the main channel and decrease in depth steadily downcurrent where scour gives way to deposition in the form of lobate chute bars. Chutes on the Colorado range from: (1) sinuous features several hundred yards long, several tens of feet across, with a maximum observed depth of 10 to 15 feet, to (2) broad, shallow, poorly defined features. A gravel floor is common to chutes of both the Amite and Colorado.

Several periods of scour-and-fill are indicated in the chutes of the Magnolia bar on the Amite. However, only two distinct levels of chute-bar development are present. The position of upstream segments of chutes remains relatively stable, while the distal segments shift as a result of current deflection by older bars or by flood level (fig. 3).

During extreme flood, most of the coarse-grained traction load is transported through the chute. Fine-grained sediment that is characteristic of chute fill accumulates during falling flood stage. Inactive chutes also serve as settling basins. Much of the sediment that fills these chutes appears to have been carried in suspension because stratification parallels the channel cross section. Individual depositional episodes are recorded as a lower sand unit and an upper mud drape (mud drape consists of clay- and silt-size particles that settled out of suspension from stagnant water). The mud is extensively root mottled. Stratification types of the sand units are climbing ripple laminae at, or near, the base of the chute and parallel-inclined laminae along the banks (fig. 7). Migration direction of ripples is downchannel and toward the chute banks. Parallel-laminated beds are on the order of 0.5 foot thick, and dip toward the chute floor at angles of 20 to 30 degrees.

Chute Bars

Chute bars are both lateral and vertical accretionary depositional features; they are lobate in plan and develop downcurrent from chutes (fig. 3). Chute bars are the most prominent depositional features on both the Amite and Colorado. These bars occupy various elevations, determined by the flood height, along the convex bank. Bars that develop during maximum flood stage attain maximum height (the same elevation as the adjacent floodplain) and areal distribution. Present height of chute bars is 5 to 8 feet on the Amite and commonly 4 to 10 feet on the Colorado, although a few attain heights in excess of 20 feet (fig. 8). Point dunes, depositional features similar to chute bars, have been produced experimentally by Hickin (1969). He has also observed point dunes forming in streams tributary to the lower Hawkesbury River, Australia; these streams were in the bankfull stage.

Chute bars form only under rapid-flow conditions of extreme flood. In flood stage, the Amite covers an area up to half a mile wide, and the channel assumes a relatively straight course. Sediment in the chute probably was transported as a heavy fluid layer, using the term of Jopling (1965) to describe the zone of heavy concentration of both bed load and suspension of sediment near the bed of the stream.

Recently deposited chute bars display a simple accretion sequence of stratification types consisting of (1) thin, parallel-laminated to wavy-

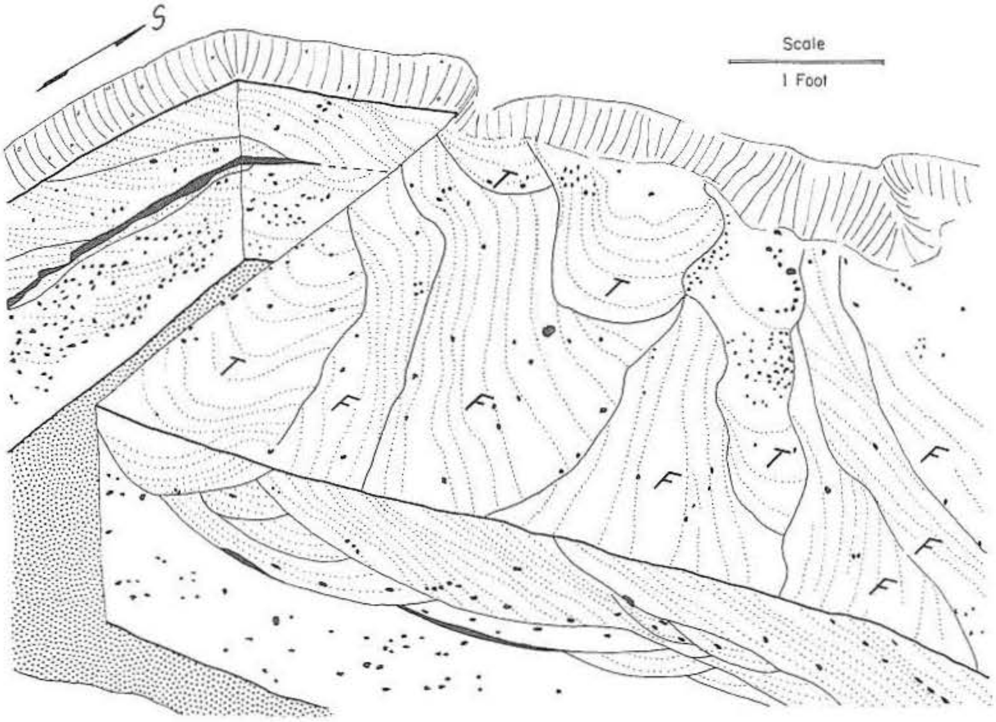

Fig. 5. Stratification types of lower point bar near Magnolia, Louisiana found in trench 5 (fig. 3); vertical and horizontal view. Trough-fill cross-strata (T) and foreset cross-strata (F). View is downstream.

Fig. 6. Lower point-bar bed forms of the Colorado River; transverse bars (F) with a gravel-veneered upper surface, and scour troughs (T) and foresets of transverse bars accentuated by windblown sand. Downstream is to the left. Shovel handle (about 3.5 feet long) in right center of photo for scale.

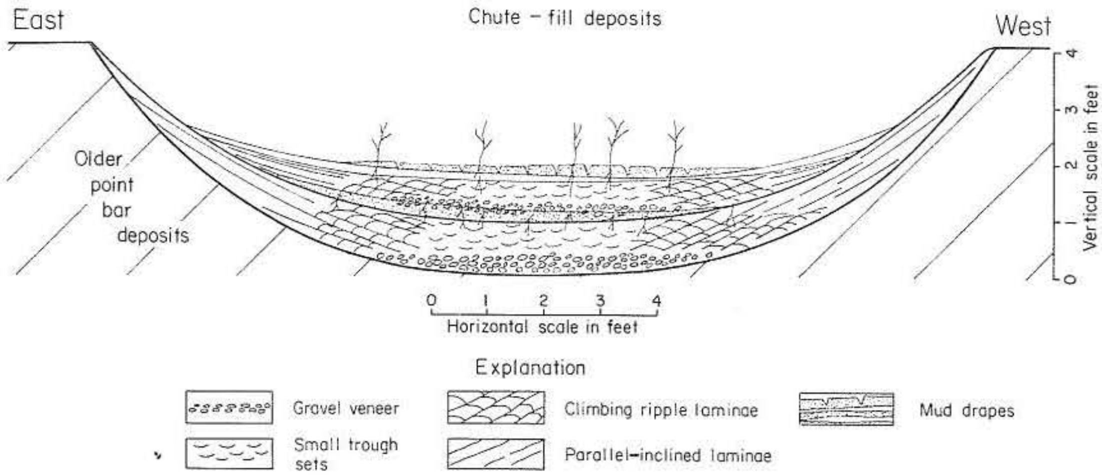

Fig. 7. Chute deposits of the Magnolia point bar.

Fig. 8. Front of a large lobate chute bar on the Colorado River about 35 miles downstream from Columbus. Height of this bar is about 20 feet. This bar is a compound feature representing several depositional events. The boat in the left center of the photograph is 14 feet long.

bedded topstrata that grade laterally and downcurrent into (2) large-scale foreset cross-strata that have high surface slopes (15 to 20 degrees) at the top, decreasing toward the bottom, and grading into (3) essentially horizontal laminae of the bottomset beds. Depressions lateral to chute bars are filled with: (1) foreset cross-strata, 2 to 4 inches thick, that dip away from the channel; (2) trough-fill cross-strata with axes parallel to the trend of the river; (3) thin, discontinuous sand lenses; and (4) small trough sets comprised of muddy fine sand (fig. 4).

Older chute bars commonly display more than one accretionary event with older deposits showing truncation near the top at onset of deposition of the next overlying unit (fig. 9). Angle of inclination of foresets within chute bars ranges from 17 to 25 degrees.

Scour of a chute and initial bar construction are contemporaneous. Gravel and coarse sand probably were transported as a heavy fluid layer where flow was confined to the chute. As chute depth decreases, in a downchannel direction, flow was no longer confined and much of the material carried in the heavy fluid layer was dropped. Sand is carried in suspension beyond the foreset face into the zone of backflow where it accumulates as parallel laminae or ripples (fig. 10). Flow spreads radially away from the distal chute and sediment disperses to form a lobate sand body (fig. 11). Dip direction of the foresets may parallel the channel trend or may be at high angles to the trend, depending upon the sector of the bar observed. The occurrence of parallel-bedded gravel and gravelly sand of the topsets, poor segregation of grain sizes along the foresets, low angle of inclination along the toe, and presence of bottomsets and some regressive ripples indicate that chute bars are products of rapid-flow conditions.

Floodplain Deposits

Floodplain deposits accumulate under extreme flood conditions such as those reported by McKee and others (1967) for the 1965 flood of Bijou Creek, Colorado. On the convex side of the Amite, floodplain deposits were laid down contemporaneously with chute bars with which they merge laterally. Most sediment that accumulates in the floodplain area is brought in as

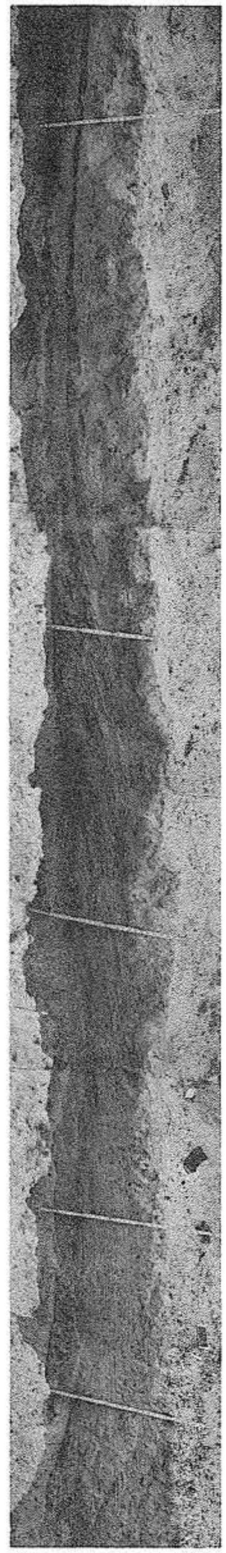

Fig. 9. Stratification in the uppermost chute bar near Magnolia, Louisiana (trench 7, fig. 3). At least two depositional episodes are recorded in this bar. Foresets (accentuated by granule to pebble gravel) have apparent dips of 10 to 18 degrees toward the river. Muddy fine sand (dark bands to the left of the photo) accumulated in a depression flanking the bar. View is downchannel.

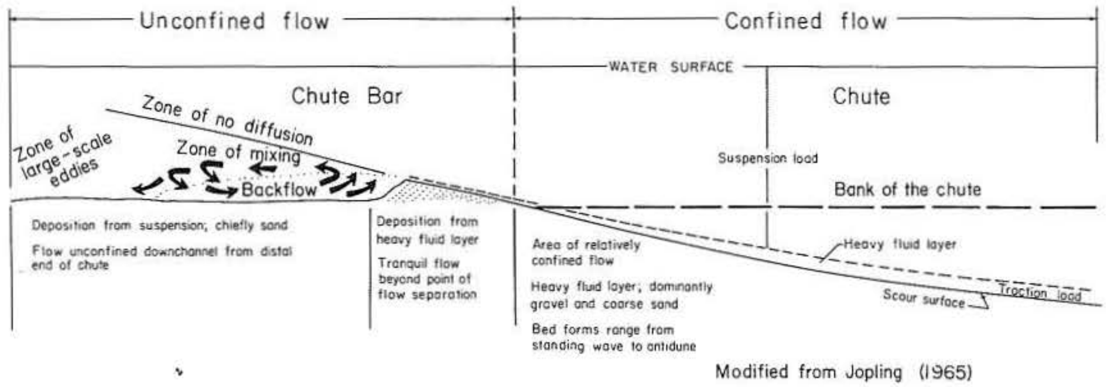

Fig. 10. Inferred flow conditions during the initial development of a chute bar. Section is parallel with the chute axis; flow is from right to left.

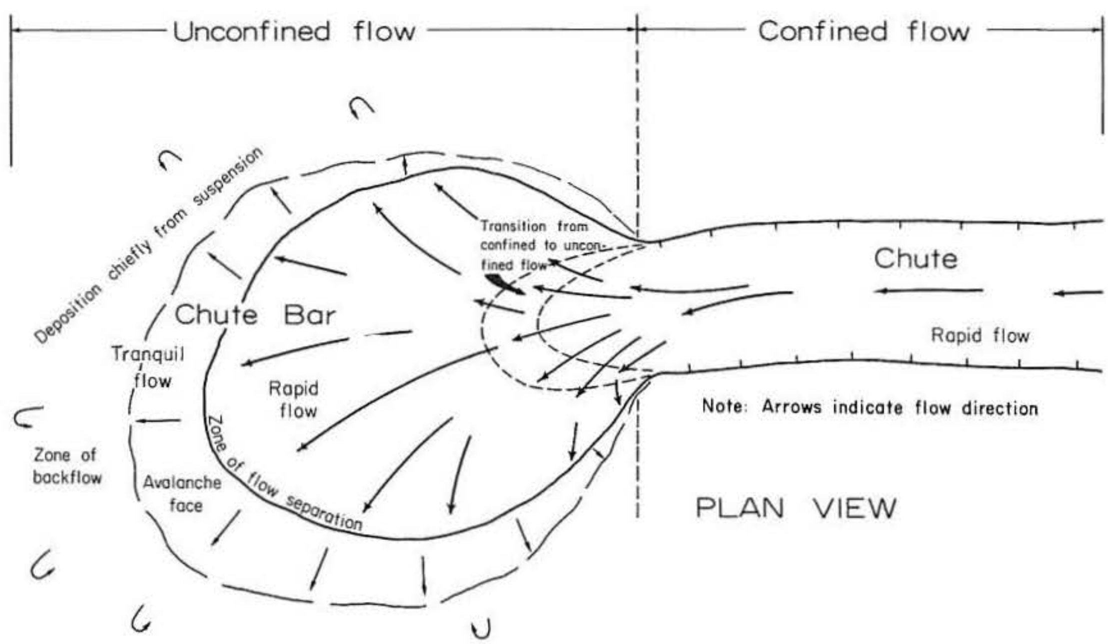

Fig. 11. Inferred current pattern through a chute and across a chute bar.

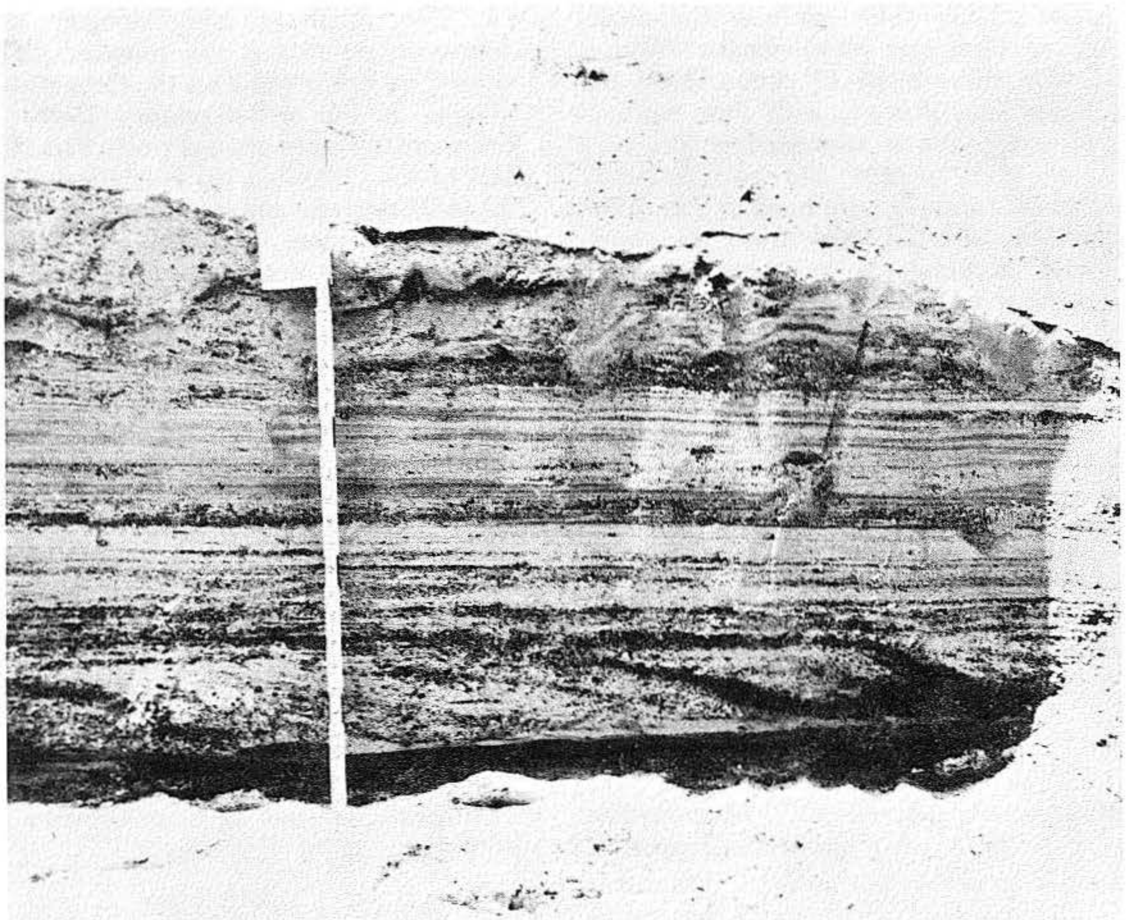

Fig. 12. Stratification of floodplain deposits on the convex bank of the Magnolia bar (trench 11, fig. 3). About 2 feet of flood deposits representing a single depositional event directly overlie a 1- to 2-inch mud and silt unit. Lower sand and gravel is a foreset unit (angle of inclination increases to the right) that grades upward into parallel-laminated sand and gravel. Upstream is to the right. Scale is extended 2.5 feet.

traction load. During extreme flood, the floodplain is a part of a wide shallow river. In this situation the characteristics of Amite floodplain deposits differ significantly from the fine-grained overbank deposits of mixed-load streams.

A typical sequence of stratification types for sparsely vegetated areas of the floodplain (trench 11, fig. 3) is from base to top: (1) foreset cross-strata comprised of granule to pebble gravel that thicken and dip upstream and grade upward into (2) a 1- to 2-foot sequence of parallel laminae made up of alternating sand and gravel in the lower part and dominantly sand in the upper part (fig. 12). Commonly, scour fills of gravel and gravelly sand succeed the upper parallel-laminated gravel and sand unit. Small plant roots penetrate the upper foot of these deposits. The sequence from foreset cross-strata through parallel laminae was deposited during extreme flood; foresets probably developed during rising stage and parallel laminae in extremely shallow water during the falling stage. As flood stage lowered, deposition was within gullies that trend toward the river; these deposits are characterized by scour-fill structures.

Some modern coarse-grained point bars display physiographic features and sequences of stratification types which differ from those just described; they do not have well-developed chutes, prominant lobate chute bars, or lower point bars. The process of bar formation is the same on all coarse-grained point bars; however, broad, ill defined, gravel-floored chutes apparently prevent development of lobate chute bars.

A coarse-grained point bar near Columbus, Texas (fig. 13) illustrates physiographic features associated with these kinds of chutes. Here the chute is broad and shallow, with little surficial evidence of scour, and is expressed chiefly as a pavement of chert pebble and cobble gravel. Low-relief levees form the right bank of this chute; where flow was diverted away from the chute, gravelly sand accumulated as transverse bars. Foresets of the levee deposits generally dip toward the scour pool. Soon after levees are constructed, they are stabilized by willow trees. Downstream the chute becomes wider, gravel size decreases, and gravelly sand and sand accumulate as transverse bars with attendant scour troughs.

Wind has played an important role in modifying the distal part of the Columbus point bar. All evidence of fluvial bed forms has been obliterated, and the surface is characterized by low-relief elongate dunes stabilized by vegetation.

The relatively high, lobate, chute bars commonly present at the downcurrent termini of chutes are not present on the Columbus bar. Also missing is the well-developed lower point bar common to coarse-grained point bars. The convex side of the Columbus bar is relatively steep (about 20 to 25 degrees) and from 5 to 6 feet above water level at low-water stage. The coarse-grained point bar is made up dominantly of foreset cross-strata and trough-fill cross-strata; these are the diagnostic stratification types of lower point-bar deposits, where lobate chute bars are well developed.

An ancient fluvial sequence dominated by foreset cross-strata and trough-fill cross-strata could be either lower point-bar, chute-bar, crossover, or braided-stream deposits. A regional study of the sand body may be required in order to make the distinction among these deposits, or if exposures are adequate the vertical and lateral succession of stratification types should suffice.

MECHANICS OF POINT-BAR DEVELOPMENT

Most point-bar accretion is accomplished during extreme flood when the channel tends to straighten its course through a shift of the thread of maximum surface velocity toward the convex bank (fig. 14). Trees undercut from the concave bank and temporarily stored in the scour pools become part of the float load during succeeding floods.

The flow-régime concept (Simons and Richardson, 1961) that relates flow conditions, sediment transport, and bed forms was developed for bed-load material in the medium sand range (0.28 mm to 0.45 mm). Development of bed forms in material with a median diameter greater than 0.6 mm can best be related to tranquil or rapid flow, based on Froude number (Albertson and others, 1966). The extreme range of material that comprises the Magnolia bar on the Amite River is very fine sand to pebble gravel; mean size ranges from fine to very coarse sand. The mean size and extreme size range almost exclude the development of ripple and dune-with-ripple bed forms. Small trough sets, stratification produced by ripple bed forms, and parallel laminae produced by plane bed forms are rare in these deposits. In flume studies using coarse sand, median diameter 1.35 mm, Williams (1967) found that transitional and plane bed forms did not develop between dunes and antidunes.

Not all of the depositional features of the Amite and Colorado Rivers can be related to the flow-régime concept, nor can their development be specified in terms of specific Froude numbers. However, during extreme flood, rapid flow is dominant along the convex bank, particularly in chute and chute-bar areas. Under these flow conditions, the bed forms expected immediately upstream from the chute bars are standing waves or antidunes. Most of this sediment is transported through and not stored in the chute. Flow velocity decreases as sediment and water move downstream beyond the confines of the chute and spread radially away from the distal chute. The initial bar aggrades, decreases the water depth, and allows plane bed forms to develop. Downstream, beyond the bar crest, water depth increases allowing development of relatively steep foresets. The sudden increase in water depth further decreases the flow velocity and sand carried in suspension settles out, locally forming bottomsets. Tranquil flow exists in the shadow of chute bars.

Floodplain deposits are also a product of extreme flood. A single depositional episode is characterized by a lower foreset cross-stratification

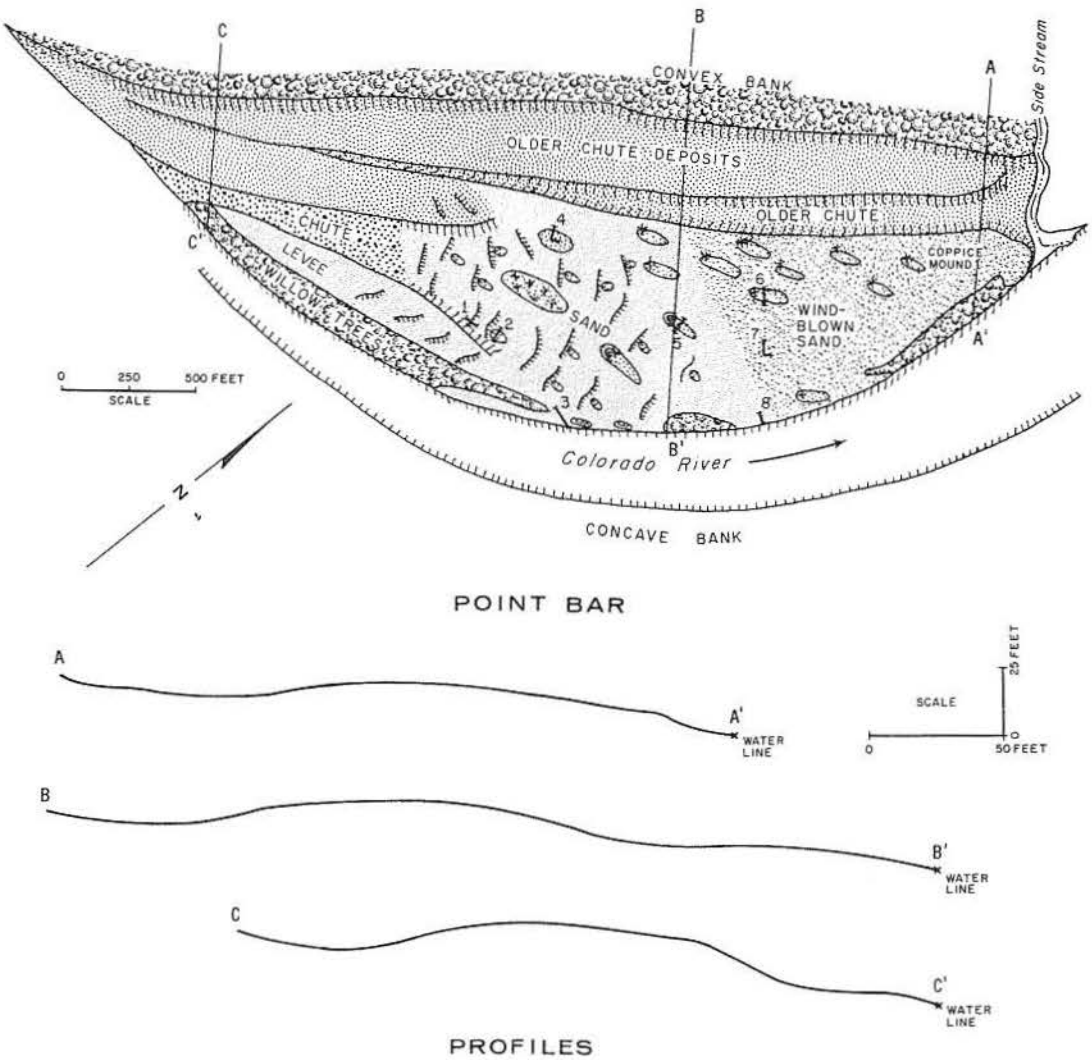

Fig. 13. Plan view (sketch) of a point bar near Columbus, Texas. The gravel-floored chute becomes wider and loses its identity downchannel. The chute grades into chute-bar deposits with transverse bar and scour-trough bed forms. Farther downchannel, aeolian processes have obliterated the fluvial bed forms.

unit (sandy granule to pebble gravel) that is transitional with an overlying parallel-laminated unit (granule-bearing coarse sand at the base and a medium sand near the top). Normally this couple is interpreted as lower-flow régime for foresets and upper-flow régime for parallel laminae. The writer's interpretation, based on field observations, discharge data, and the work of Albertson and others (1966), Simons and others (1965), and Williams (1967), is that the foreset cross-strata were laid down by rapid flow (fig. 15) at about flood crest, and parallel laminae (also a product of rapid flow) developed as water depth decreased by either decrease in flood stage or by aggradation. Foreset cross-strata dip to the north (upstream) at angles greater than 10 degrees. The dip angle and transition with the overlying parallel laminae eliminate the possibility of antidune origin of these foresets. When foresets were laid down, flow direction at this point on the floodplain was to the north (fig. 14).

Lower point-bar deposits (trough-fill and foreset cross-strata) developed in water deeper than any of the other convex bank units. Stratigraphic relationships indicate that trough-fill cross-strata probably formed concurrently with chute bars (fig. 4) and that foresets (transverse bars) are younger. Mean size of lower point-bar deposits is in the medium to coarse sand size; extreme range is silt to small pebble gravel. A higher rate of sediment transport is indicated for the trough-fill

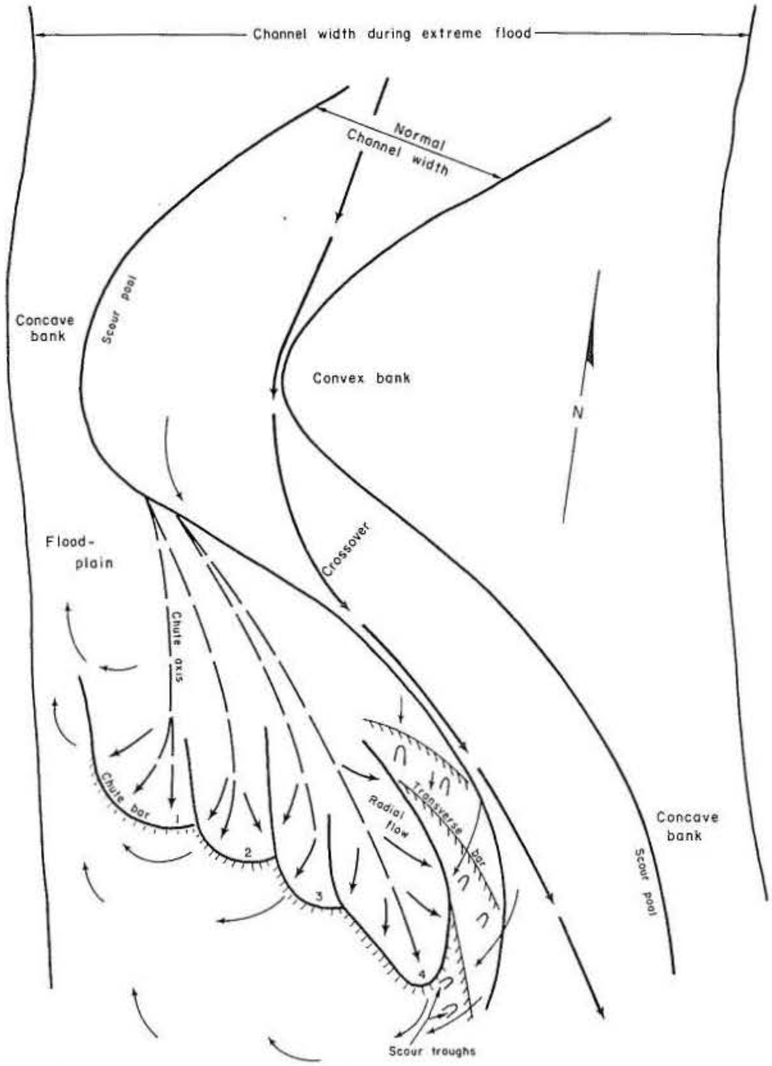

Fig. 14. Interpretive flow pattern during extreme flood: Upcurrent segments of chutes tend to maintain a fixed position, whereas the distal segments generally migrate toward the channel with each succeeding flood. Flow pattern changes beyond the chute bars and may be locally directed in an upchannel direction.

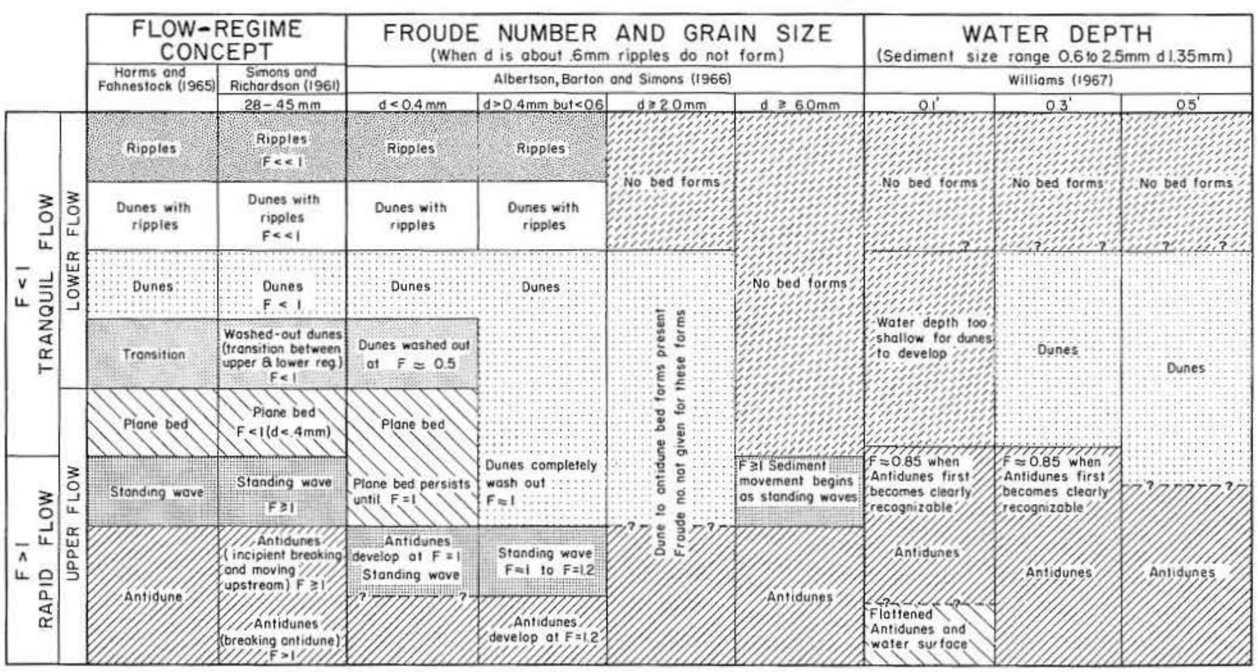

Fig. 15. Variation of bed forms with changes in grain size and/or flow conditions.

cross-strata than for foreset cross-strata. This conclusion is based on stratigraphic relationships with chute bars and on experimental work of Williams (1967). He observed that as rates of sediment transport increased (when the bed form was dunes), the dune height increased, spacing between crests decreased, and the dune crests developed irregular and curving fronts. At lower sediment transport rates, dune height decreased, spacing between crests increased, and the crests were oriented perpendicular to flow and extended completely across the flume. Development of trough-fill cross-stratification was under rapid-flow conditions when bed forms were relatively high dunes with short crests that were probably concave downcurrent. Bed forms that produced the foreset cross-strata were well preserved on the lower point bar when the study was made; these were continuous, slightly sinuous crested dunes or transverse bars. Transverse bars were the last bed forms developed and were probably the product of slower sediment transport rates (tranquil flow) than the underlying trough-fill cross-stratification. In the interpretation presented here, trough-fill cross-strata were produced during extreme flood when sediment transport rates were greatest and foreset cross-strata formed under a slower transport rate as flood stage was decreasing.

ANCIENT SYSTEMS

EXAMPLES OF ANCIENT COARSE-GRAINED POINT-BAR DEPOSITS

Ancient fluvial deposits that display vertical sequences of stratification types similar to those present in point bars of the Amite River (Louisiana) and Colorado River (Texas) are common in Tertiary and some Pleistocene deposits of Texas. This sequence of structures occurs in Simsboro Sandstone, Carrizo Sandstone, and Bryan Sandstone (Eocene of Texas) and in Colorado River terraces (Pleistocene, Travis County, Texas). Stratification in these ancient deposits varies slightly from modern analogues in scale and perhaps in dip angle of foresets. Mean size of modern and most of the ancient coarse-grained point-bar deposits is comparable, with the exception of the Pleistocene Colorado River deposits which are somewhat coarser.

Simsboro Sandstone

The Simsboro Sandstone was interpreted by Fisher and McGowen (1967, 1969) as a highly meandering channel facies of the Mount Pleasant Fluvial System (Wilcox Group). This fluvial system was the main feeder channel for the lower Wilcox (Eocene) Rockdale Delta System which in the subsurface of the Texas Gulf Coast Basin attains thicknesses of 4,000 to 8,000 feet. The fluvial sands occurring updip of the delta system consist of sand bodies made up of several coalescing channel-lag, lower point-bar, and chute-front deposits that accumulated chiefly as multilateral, coarse-grained meanderbelt units. Sand bodies are up to 30 miles wide and up to 200 feet thick. They are characterized by repeated vertical sequences consisting (from base to top) of moderate- to large-scale trough cross-stratification, moderate-scale foreset cross-stratification, and large-scale foreset cross-stratification. Only uppermost parts of main sand units show a gradation to overbank muds (Fisher, 1969).

Outcrop of the Simsboro extends in Texas from northern Freestone County southward to central Bastrop County, Texas, where it breaks up into numerous thin sands and interbedded mud units characteristic of strandplain deposits (Fisher and McGowen, 1967, 1969). Extensive outcrops of the Simsboro in Milam County, Texas, permit reconstruction of vertical sequences of stratification types. Locally, in Milam County, distributary channels and fine-grained meanderbelt sequences underlie the coarse-grained meanderbelt sands of the Simsboro. Because there is a gradual change upward in the stratigraphic section from fine-grained to coarse-grained point bars, both appear to be genetically related.

Vertical sequences preserved in the Simsboro (fig. 16) include from base to top: (1) large trough-fill cross-strata, (2) foreset cross-strata with small trough-fill cross-strata, and (3) large-scale foreset cross-strata. Upper parts of large foresets and floodplain deposits were not observed in the Milam County area; this is the result of lateral migration of the Simsboro streams. Variability of primary sedimentary structures in a downchannel direction are also indicated in figure 16.

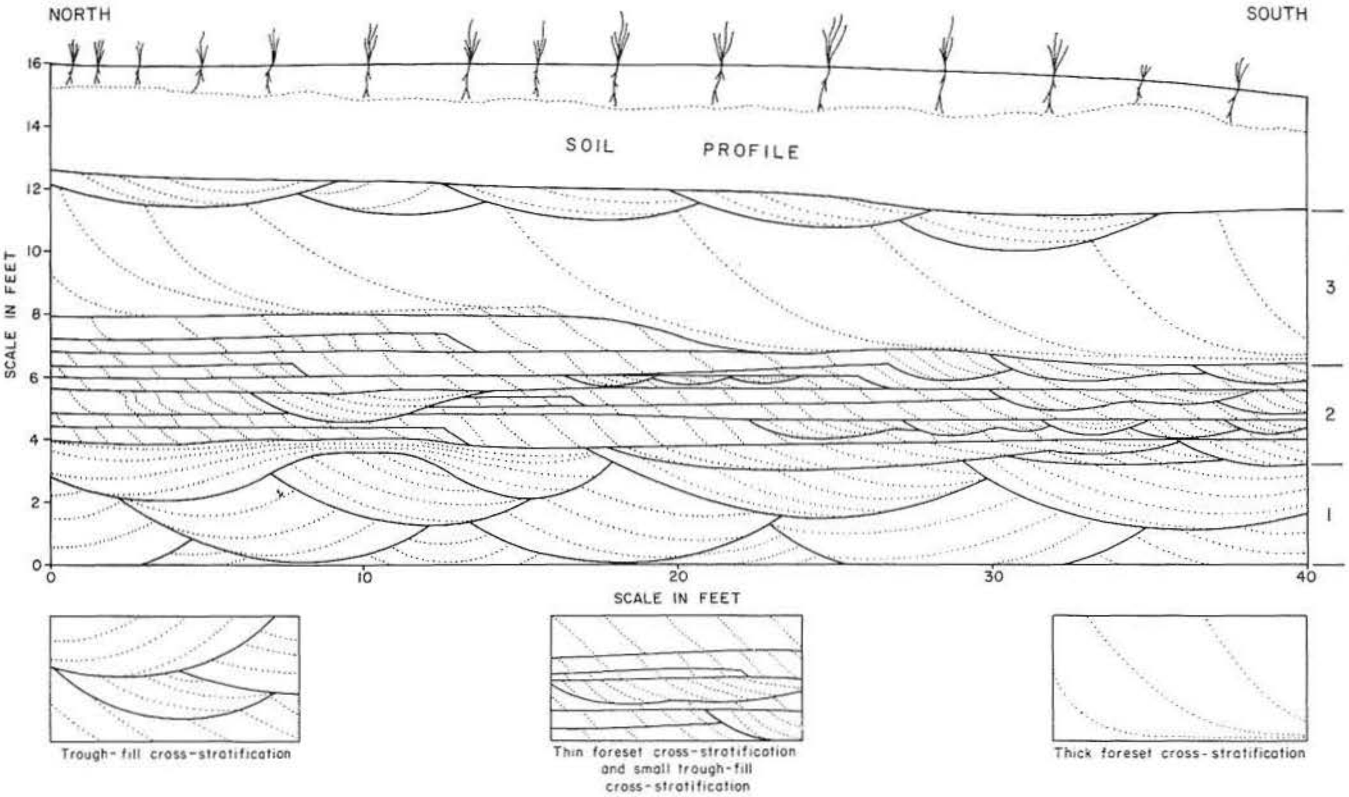

Fig. 16. Vertical succession of stratification types in the Simsboro Sandstone, Milam County, Texas.

Stratification types interpreted as scour-pool fillings adjacent to the concave bank are large-scale trough-fill cross-strata (fig. 17). Frazier and Osanik (1961) reported a 40-foot section of point-bar sand composed entirely of festoon crossbedding exposed in a large excavation cut into an abandoned and partly filled meander loop of the lower Mississippi River. These deposits were laid down near the convex bank below low-stage stream level, and the festoon crossbedding formed in response to scour-and-fill accompanying downstream migration of sand waves. Stratification types reported by Frazier and Osanik are for a highly meandering fluvial system (a mixed-load stream) with a discharge different from an ancient bed-load stream like the Simsboro. Large-scale trough-fill cross-strata of the Simsboro are 9 to 12 feet wide, 1.5 to 2 feet thick, and have dip angles of 16 to 33 degrees along the flanks; length of scours is not known. Sequences of large trough-fill cross-strata thicker than 5 feet have not been observed in the Simsboro.

Overlying and laterally gradational with the large-scale trough-fill cross-strata are small trough-fill cross-strata and foreset cross-strata (fig. 16). Because of the coarse grain size of the Simsboro deposits, ripple cross laminae (small trough sets) did not develop. These two stratification types (small trough-fill cross-strata and foreset cross-strata) are interpreted as lower point bar, analogous to transverse bars and scour troughs generally developed above low-stage stream level on the modern Amite and Colorado Rivers. Similar stratification types, based on bed forms observed in the Colorado River, may also be typical of transverse bars in crossover deposits of bed-load streams. Maximum observed thickness of the foreset and small trough-fill units is about 4 feet. Foresets (fig. 18) are 2 to 11 inches thick (most are less than 5 inches) and have apparent dips of 17 to 60 degrees; most are in the 27- to 30-degree range. Trough-fill units (fig. 19) are 4 to 18 feet long, 4 to 10 inches thick, 1 to 3 feet wide, and have apparent dips (parallel to trough axes) of 13 to 22 degrees.

Individual foreset units are traceable in a downcurrent direction for a few tens of feet where they generally grade into small trough-fill cross-strata. Commonly, an upcurrent sequence of several thin foreset cross-strata becomes a single,

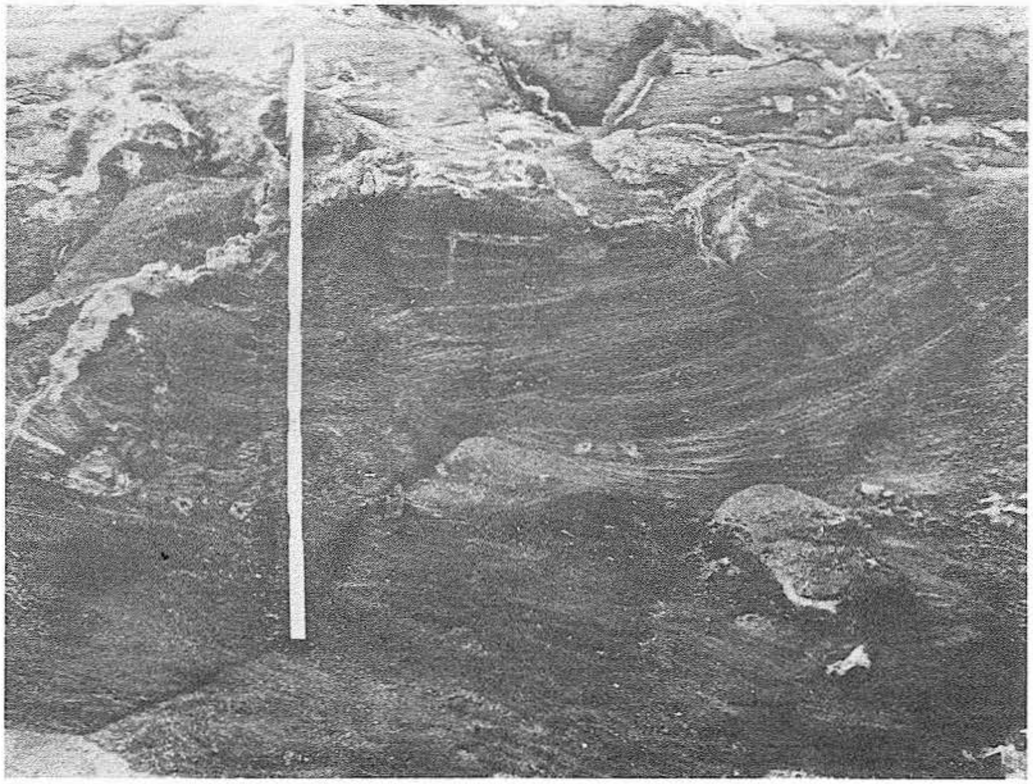

Fig. 17. Large trough-fill cross-strata in the Simsboro Sandstone, Milam County, Texas. Stratification is accentuated by kaolinitic clay clasts and granule-size quartz and chert. Leaching along fractures and plant roots produced the mottles. Length of rule is 3 feet.

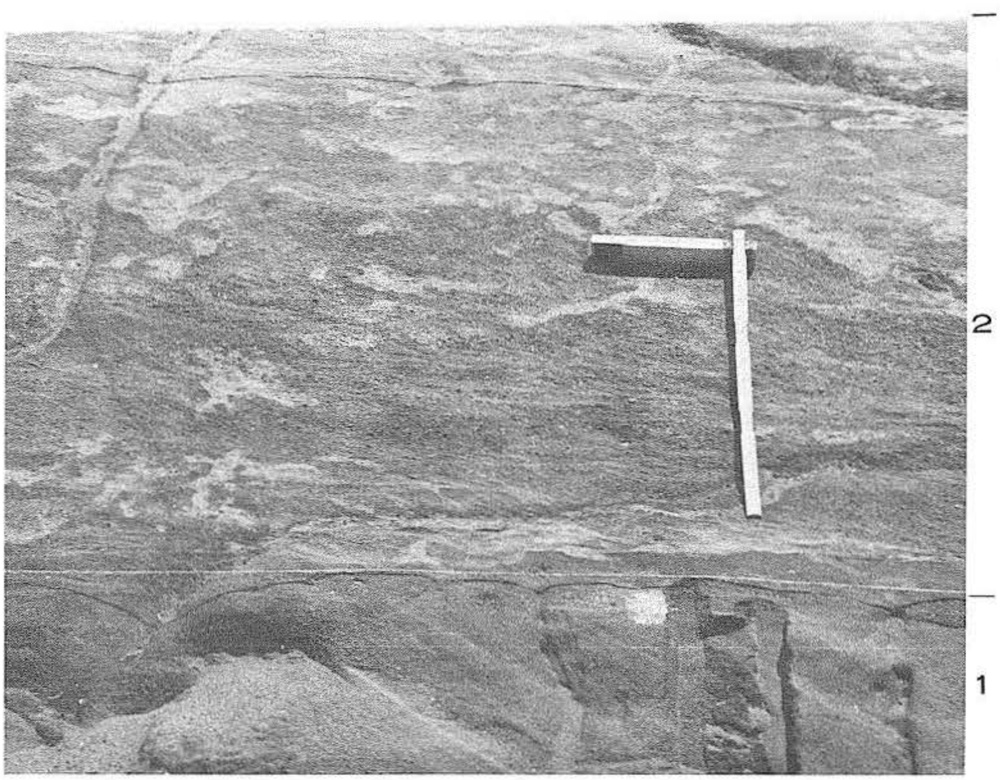

Fig. 18. Sequence of (1) foreset cross-strata, and (2) foreset cross-strata and small trough-fill cross-strata of the Simsboro Sandstone, Milam County, Texas. Beds are interpreted as lower point-bar deposits. Foresets display alternating sand and granule gravel laminae. Length of vertical segment of rule is 1.5 feet.

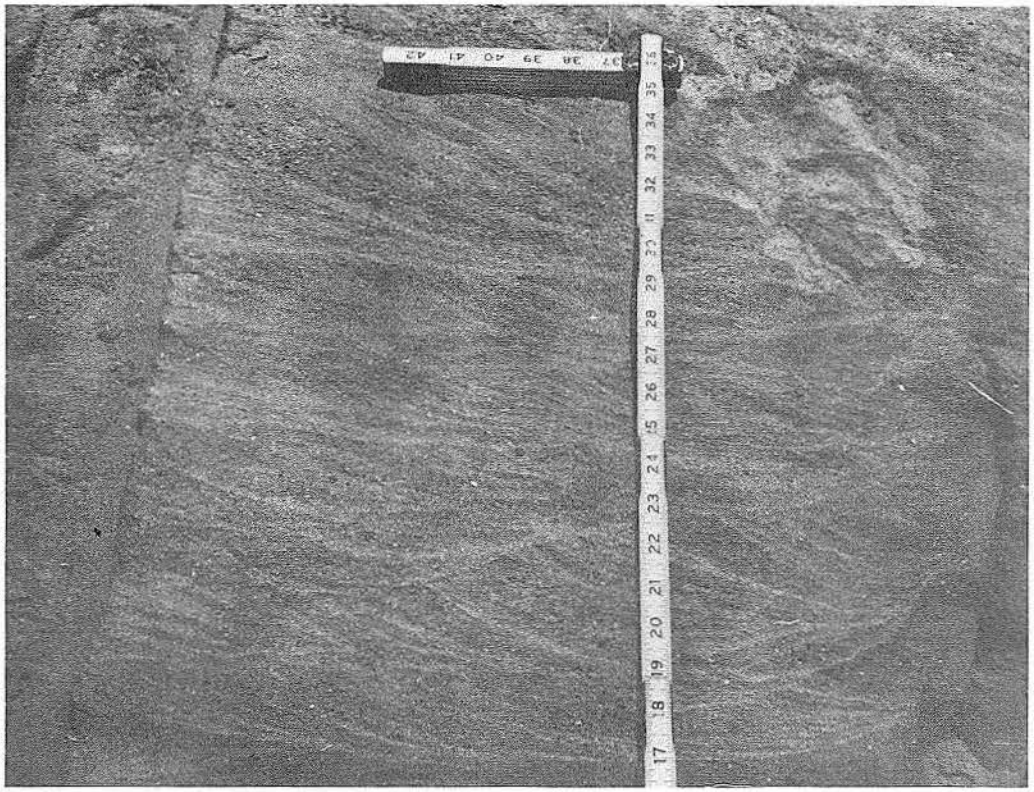

Fig. 19. Trough-fill cross-strata of the lower point bar, Simsboro Sandstone, Milam County, Texas. Scale in inches.

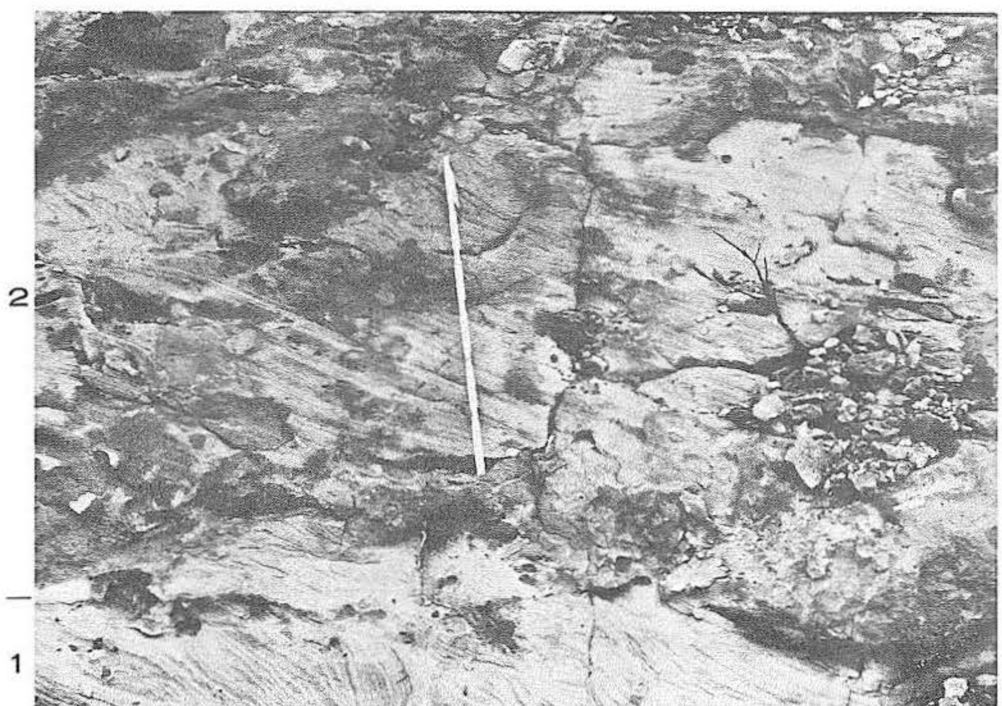

Fig. 20. Thick foreset cross-strata (2), interpreted as chute-bar deposits, overlie thin foreset cross-strata (1) of the lower point bar, Simsboro Sandstone, Limestone County, Texas. Length of rule is 3 feet.

thick, foreset unit downcurrent. Stratification of this type probably developed as a consequence of rising water level conditions (Jopling, 1963). Characteristically, the thinner foresets have the highest dip angles. Dips greater than the angle of repose resulted from slumping along the avalanche faces of transverse bars when a sudden drop in river stage lowered water level to a position below the transverse bar.

Depositional units with structures analogous to chute bars of the Amite and Colorado Rivers are relatively thick foreset cross-strata (fig. 16). Commonly the total thickness of individual foreset units is not preserved and only in the stratigraphically highest parts of the Simsboro are upper point-bar and overbank sediment intact (McGowen, 1968). Preserved thickness of large-scale foreset cross-strata is 3 to 5.5 feet (fig. 20), approximating the scale of chute bars on the Amite but considerably less than maximum height (up to 20 feet) of Colorado River bars. Apparent dips of foresets are 9 to 44 degrees; most are about 30 degrees. Foresets flatten toward the toe and grade laterally into thin parallel-laminated bottomsets 2 to 4 inches thick, with apparent dips of 1 to 3 degrees. Infrequently associated with parallel laminae are thin foreset cross-strata about the same thickness as the bottomsets. These probably represent transverse bars laid down contemporaneously with chute bars but in deeper water where tranquil flow conditions were dominant.

In sections that are approximately parallel with channel trends, chute-fill deposits have not been recognized. However, broad symmetrically filled shallow scour features exposed in outcrop approximately transverse to channel trend are interpreted as chute-fill deposits. These are only 3 to 5 feet thick, up to 30 feet wide and consist of a lower parallel-laminated sand conforming to the configuration of the scour and overlain by structureless sandy mud. Sand sequences are a few inches to 1.5 feet thick, and muds are up to a foot thick.

Colorado River Terraces

A vertical succession of stratification types in Colorado River Pleistocene deposits (fig. 21) exposed in a quarry near Austin, Texas, is similar to those of the modern Amite and Colorado Rivers and the Eocene Simsboro Sandstone. The channel-floor deposit or scour-pool deposit (fig. 21, unit 1), is poorly exposed, but appears to be homogeneous granule to cobble gravel. This is succeeded by a 4- to 4.5-foot thick sequence with dominantly foreset cross-stratification and minor trough-fill cross-stratification (fig. 21, units 2-6). These units represent lower point-bar or crossover deposits. Foresets are 8 inches to 1.5 feet thick and have apparent dips of 5 to 29 degrees. Dip angles of foresets increase or decrease laterally along the quarry face. Where the angle of dip decreases, there is an accompanying decrease in grain size (such as unit 5), indicating that finer grained material was carried beyond the steeper gravel front in part as suspension load. Development of this lower angle foreset type was most likely during falling river stage at which time velocity near the bed surface increased. In the other foreset units, such as units 2 and 3, there is an increase in dip angle and a corresponding increase in bed thickness in the general direction of sediment transport. Change in dip angle probably represents the migration of a transverse bar, with the low angle being a section almost perpendicular to flow direction and higher angles generally parallel to transport direction. Ore (1963) reported an increase in thickness of transverse bars of braided streams in a downstream direction. Transverse bars (foresets) on the lower point bars of the modern Amite and Colorado Rivers thicken downstream. Features of this unit (lower point bar or crossover), not seen in previously mentioned areas, are small trough-sets (produced by either linguoid or cuspate ripples) and coarse sandy mud units that are root mottled. Large-scale foreset cross-strata, representing chute bars, are about 4 to 5 feet thick and show at least two depositional phases: (1) an initial gravel bar with parallel beds, which probably represents a section near the downcurrent end of initial bar development (apparent dip is to the north at about 3 degrees), and (2) the thicker foreset unit with dip angles greater than 30 degrees at the south end of the quarry and about 24 degrees near the north end. Several feet of soil are present at the top of this section and, as in Simsboro fluvial sequences, topset equivalents of chute bars and floodplain deposits are missing

The Colorado terraces contain the coarsest grained fluvial sediment observed in this study.

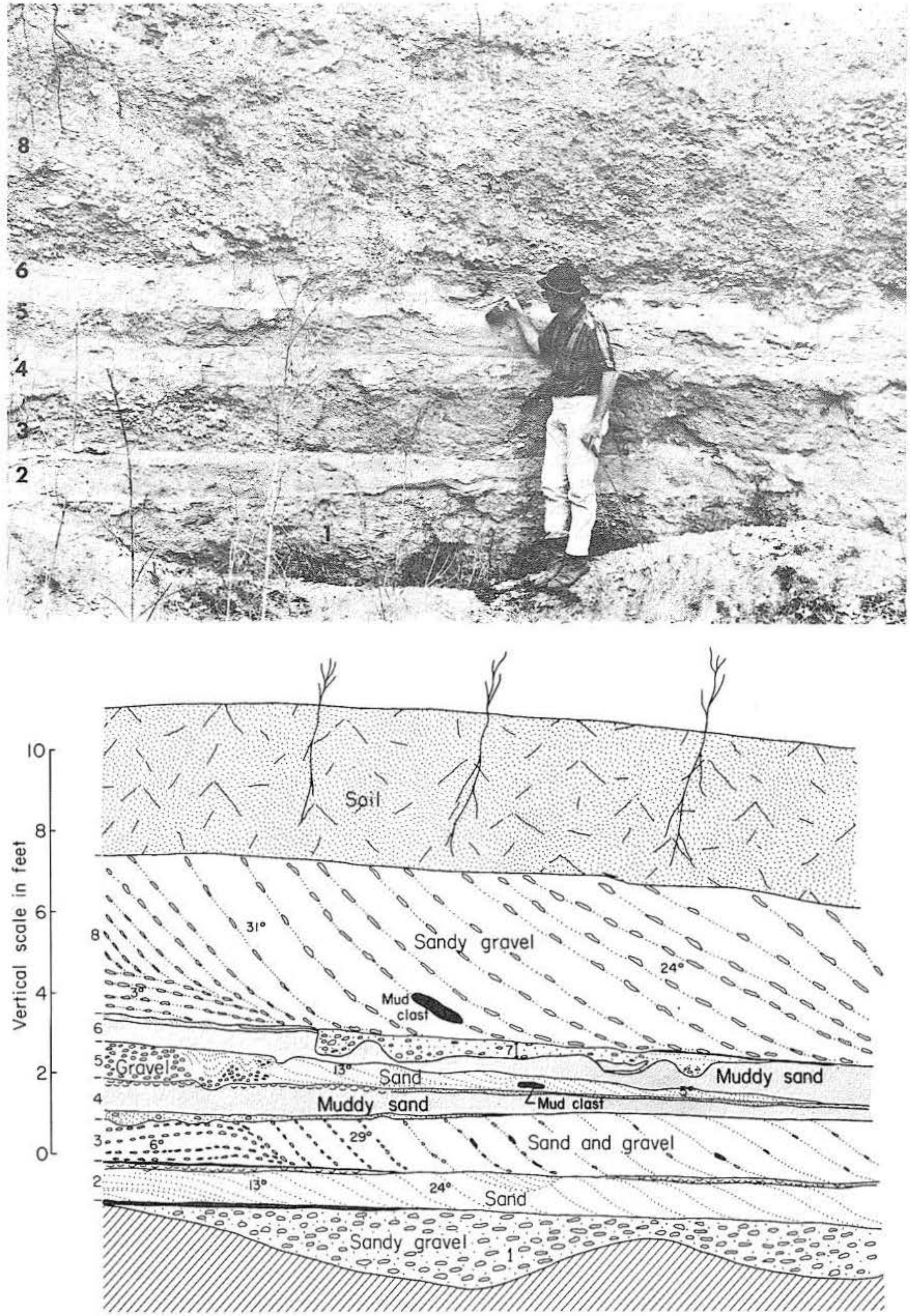

Fig. 21. Vertical succession of stratification types in Pleistocene fluvial deposits, Travis County, Texas. Channel lag (unit 1), lower point bar or crossover (units 2-7), and chute bar (unit 8). Fig. 21A is a photograph of the quarry face and 21B is a sketch accentuating stratification types and apparent dip angle for the various units.

Channel-floor sediment consists of poorly sorted gravel. Lower point bar and possibly crossover units are composed of coarse sandy mud, gravelly coarse sand, pebble and cobble gravel, and local thin clayey silt beds overlying small trough-sets of fine to medium sand. Chute-bar deposits consist of poorly sorted granule, pebble, and cobble gravel with a few locally derived mud-clast boulders. At the south end of the quarry, units 2, 3, and 5 have either parallel-laminated sand or gravel (or homogeneous gravel as in unit 5) that grades laterally into, or is in sharp contact with, foreset cross-strata. These beds are probably lower parts of chute bars that developed both prior to and contemporaneously with the topographically lower point bars or crossovers.

GRAIN-SIZE DATA

Statistical parameters of the modern Amite River deposits, Colorado River terrace material, and Simsboro Sandstone were determined using the method of Folk and Ward (1957). Samples were sieved at 1/4ϕ intervals, and data were processed by computer. Samples were taken for grain-size analysis from various physiographic units of the Amite point bar, and each sample from only one stratification type. In the ancient fluvial deposits, samples were taken from units interpreted to be analogous to those of the modern Amite and Colorado Rivers, and each sample from only one stratification type.

Figures 22 and 23 (plots of mean size vs. sorting and mean size vs. skewness, respectively)

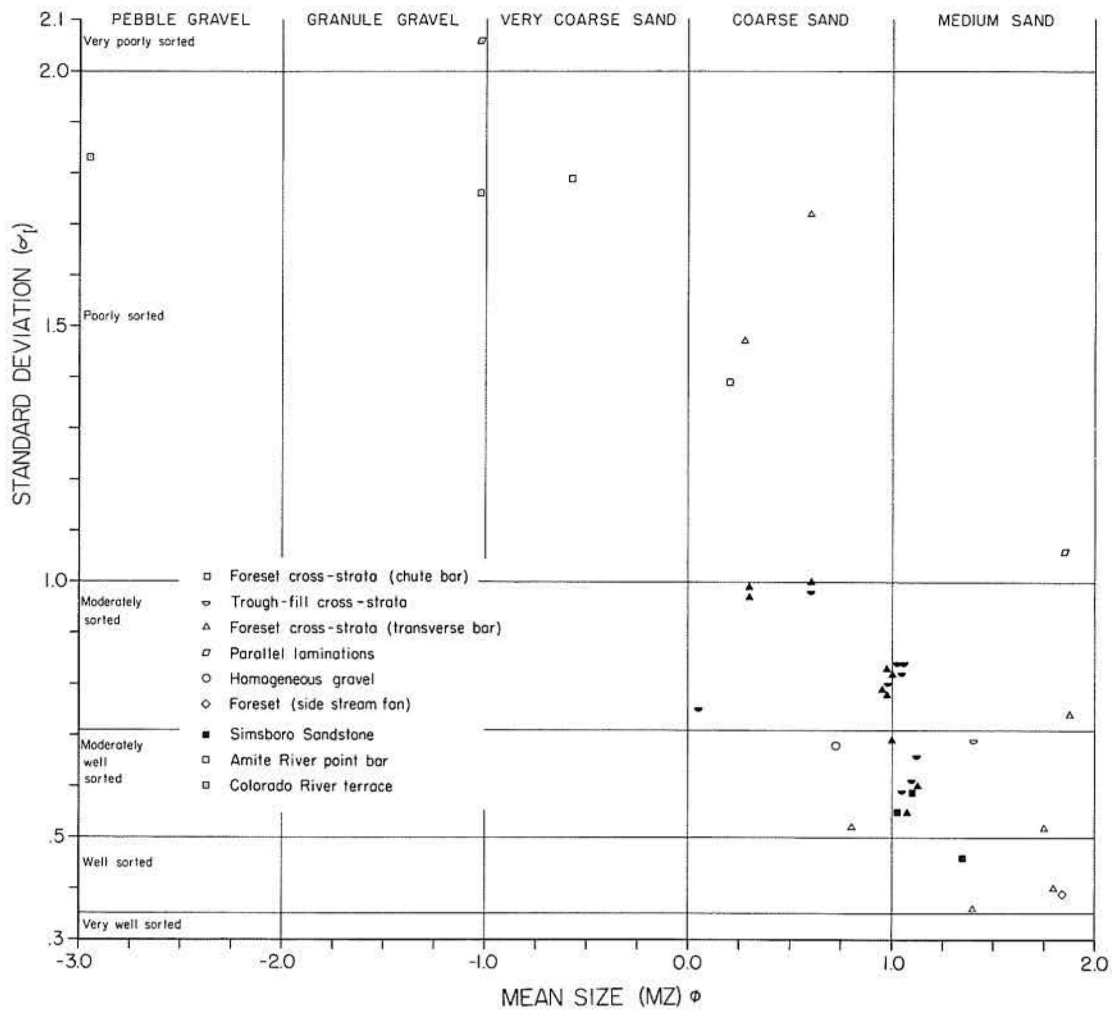

Fig. 22. Plot of mean size (Mz) versus inclusive graphic standard deviation (σ_I).

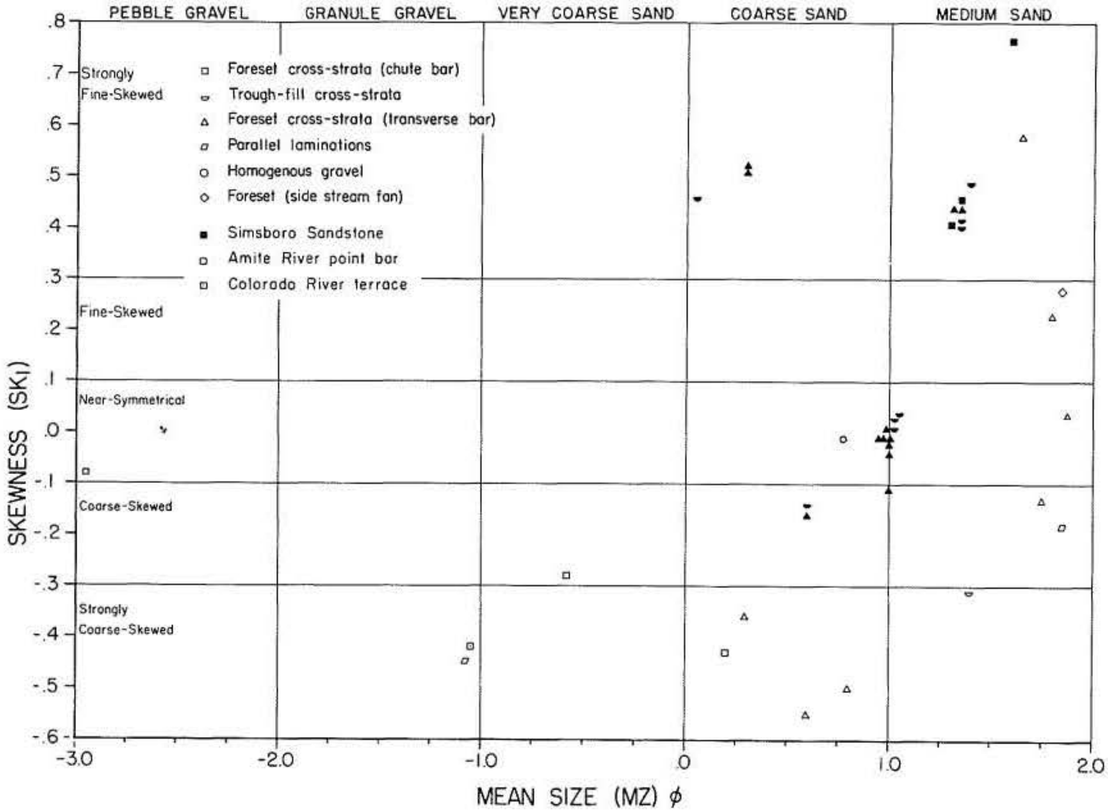

Fig. 23. Plot of mean size (Mx) versus inclusive graphic skewness (Sk_I).

graphically summarize some of the grain-size parameters of coarse-grained point-bar deposits. Statistical parameters vary considerably among samples of a particular point bar. Parameters are even more variable when deposits of two or more point bars are compared.

Some generalizations can be made concerning grain-size distribution on coarse-grained point bars. There is no upward-fining trend such as has been reported for some fine-grained point-bar sequences (Allen, 1965; Bernard and Major, 1963; Visher, 1965). In some instances, the coarsest grained material accumulates as chute bars at a position level with, or slightly below, the floodplain. Commonly, the better sorted material accumulates as low-relief foresets on the lower point bar. Skewness appears to be related to mean size. The coarser material, which is also the poorest sorted, is generally coarse skewed, and the finer material varies from coarse- to fine-skewed. Poor sorting and coarse skewness of coarse material is attributed to deposition under rapid-flow conditions during extreme flood. Better sorting of the finer grained material is a function of (1) accumulation under tranquil flow conditions that allows a more complete fractionation of grain sizes, and (2) accumulation of sediment along channel segments nearer the coastal plain where stream gradient is lower, extreme range of grain sizes is reduced, and flood stage is less extreme.

COMPARISON OF FINE- AND COARSE-GRAINED POINT BARS

Fine-grained point-bar sequences herein refer to modern and ancient mixed-load stream deposits. The Brazos River of the Texas Coastal Plain, a mixed-load stream, is comparable in size to the Colorado River; data for this meanderbelt sequence are mostly from Bernard and Major (1963). A vertical section through a Brazos River point bar reveals, from bottom to top, a fining-upward sequence from gravel to fine sand and silt and the following sedimentary structures: (1) poor bedding; (2) giant ripple (or medium scale) crossbedding; (3) horizontal lamination; and (4) small ripple (or small scale) crossbedding. An ancient analogue of Brazos River point bars is the fine-grained fluvial sequence that underlies the Simsboro Sandstone in Milam County, Texas.

Comparison is limited to modern and ancient bed-load (or coarse-grained) and mixed-load (or fine-grained) fluvial systems of the Gulf Coastal Plain that developed within the same tectonic and depositional framework. The salient characteristics of bed-load and mixed-load streams and their deposits are indicated in table 1. These characteristics incorporate data from both modern and ancient deposits.

Table 1. Comparison of fine-grained and coarse-grained point-bar deposits.

	Fine grain	Coarse grain
Channel stability	High	Slight
Channel cross section	Relatively narrow, asymmetrical	Broad, shallow, symmetrical or asymmetrical
Sinuosity	High	Low
Gradient	Low	Moderate
Sand-facies geometry	Multistory, low sand/mud	Multilateral, high sand/mud
Vertical sequence of sedimentary structure	Climbing ripple laminae, small trough sets Parallel laminae, trough-fill cross-stratification and thin foreset cross-stratification Large trough-fill cross-stratification	Parallel laminae and thin foreset cross-stratification Thick foreset cross-stratification Thin foreset cross-stratification and small trough-fill cross-stratification Large trough-fill cross-stratification or homogeneous sediment
Grain-size trend	Upward fining	No trend

STRATIFICATION TYPES

Stratification types are directly related to channel pattern and physiographic features peculiar to a certain stream type. Fine-grained sediment is laid down chiefly by lateral accretion of point bars as the stream meanders. Coarse-grained sediment accumulates by lateral accretion of lower point bars and vertical accretion by chute-bar development.

A complete vertical sequence of stratification types is rarely preserved in ancient coarse-grained point-bar deposits; this was due chiefly to channel instability at time of deposition. A complete sequence from scour pool to floodplain is (fig. 24): (1) trough-fill cross-strata or homogeneous sediment (scour pool); (2) small foreset cross-strata and small trough-fill cross-strata (lower point bar); (3) large foreset cross-strata (chute bar); and (4) parallel laminae, small foreset cross-strata, and scour-and-fill (floodplain). Commonly, the preserved sequence includes only 1, 2, and 3 above.

Complete vertical sequences of stratification types are common in ancient fine-grained meander-belt deposits. Primary sedimentary structures in sand of this type (lower Wilcox, Milam County, Texas) range from large trough-fill cross-stratification (up to 18 feet across and 2 feet thick) to smaller, low-energy types such as small trough sets and climbing ripple laminae (fig. 25). Vertical sequences (from base to top of outcrop) of sedimentary structures at several points along the outcrop are similar although not identical. Upward in the section, sedimentation units thin, the scale of structures decreases, and sand-size clay clasts increase in abundance. Near the base of the section trough-fill cross-strata are dominant; these are succeeded by foreset cross-strata, parallel laminae, climbing ripple laminae, small trough sets, and trough-fill cross-strata. Small trough sets are the dominant primary sedimentary structures in the upper few feet; parallel laminae, climbing ripple laminae, and a few trough-fill cross-strata probably comprise no more than 15 to 20 percent of these upper beds. Mud drapes commonly mark the tops of genetically related sequences of structures. Some mud drapes are traceable for several tens of feet laterally and afford the opportunity to observe lateral succession of structure types. For the most part, stratification changes that occur in the vertical sequence (unrelated depositional units) also take place laterally within a single genetic unit. This sand body represents point-bar accretion by a highly meandering fine-grained fluvial system. The succession of facies in this area indicates that this part of the fluvial system was low on the coastal plain, and the sequence of structures suggests accumulation from slightly below mean low-water level to upper point bar (channel-lag deposits not exposed).

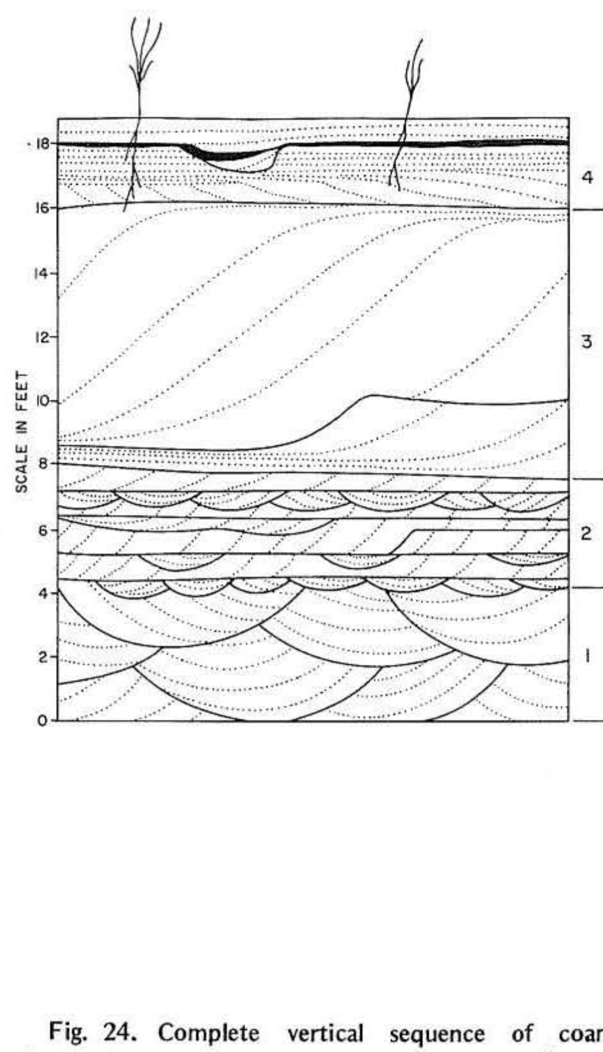

Fig. 24. Complete vertical sequence of coarse-grained point-bar stratification types. Scour-pool (unit 1), lower point-bar or crossover (unit 2), chute-bar (unit 3), and floodplain deposits adjacent to the convex bank (unit 4).

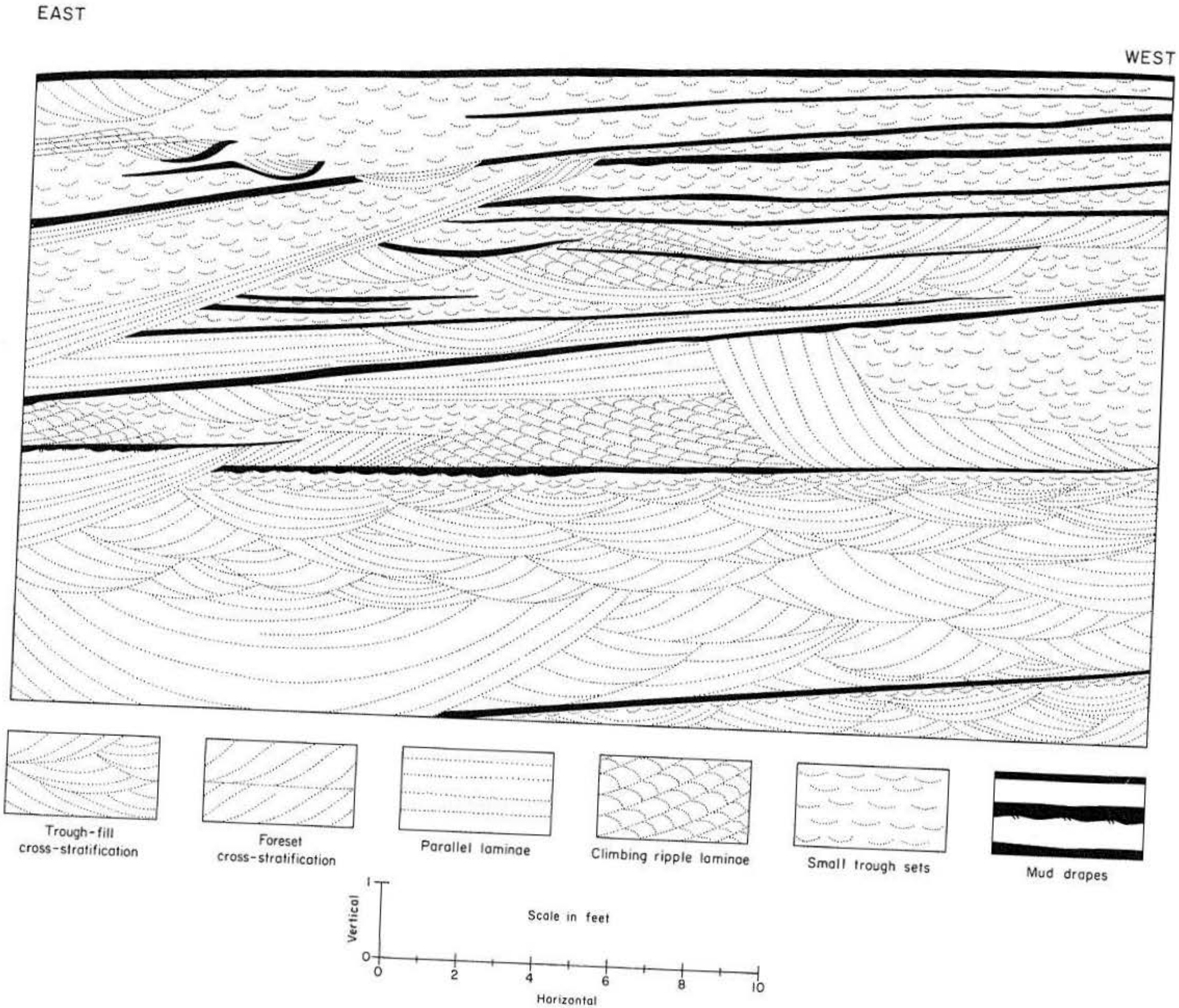

Fig. 25. Vertical sequence of fine-grained point-bar stratification types, lower Wilcox, Milam County, Texas. This section does not show a complete sequence from scour pool to levee, but it represents deposits from just below low-stage stream level to the upper part of the point bar. Migration of the meander was from west to east.

CONCLUDING REMARKS

Modern streams with short-duration peak discharge are characterized by relatively high gradients and straight to meandering channel patterns. These are bed-load streams (high bed-load/discharge ratio) with weak banks that are stabilized by dense vegetation. In the spectrum of fluvial systems, these streams occupy a position somewhere between braided and highly meandering channel patterns.

During extreme flood, these streams tend to straighten their courses, resulting in scouring of chutes along the convex bank. Some of the coarsest bed-load material, transported by the stream, passes through these chutes and accumulates as steep-front, lobate, gravel or sand bodies (chute bars), that are commonly at the same elevation as the floodplain. Contemporaneous with development of chute bars, but topographically lower (lower point bar), are dunes with short discontinuous crests. Sediment was transported across the floodplain, during extreme flood, as dunes where water was relatively deep and as plane bed forms where water was relatively shallow. With subsiding flood stage, continuous-crested dunes succeeded those with discontinuous crests on the lower point bar.

Each of these physiographic features (lower point bar, chute bar, and floodplain) is characterized by a unique association of stratification and textural types. Lateral migration of the channel produces a specific succession of stratification types that permits the recognition of ancient fluvial deposits that were laid down under similar physical processes.

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