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CHAPTER 40

Drilling Results on the Middle Mississippi Fan

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Abstract

The middle-fan area of the youngest Mississippi fanlobe is a convex-shaped aggradational body with a sinuous, migratory channel located along its apex. The middle-fan/lower-fan boundary corresponds to a change from the sinuous channel pattern to one of lateral switching and abandonment. Sites drilled in the mid-fan channel indicate an upward-fining fill, commencing with gravel and ending with clay. The overbank deposits are primarily muddy with some silty and very-fine sandy turbidites. Sedimentation rates during the Late Wisconsin age for both the channel fill and overbank areas are about 12 m/1000 yr.

Introduction

The middle-fan area of the youngest Mississippi fanlobe commences at the base of slope at a water depth of about 2000 to 2400 m and merges with the lower fan at about 3000 to 3200 m (Bouma and others, Chapter 21). While the upper fan area is basically a conduit with some overall aggradational characteristics, the middle fan is an active aggradational system (Bouma and others, Chapters 21, 36). The fanlobe in the middle-fan area is lenticular in cross-section, with a maximum width of about 200 km and a maximum thickness of about 400 m. Morphologically, the mid-fan consists of a channel-levee complex centered along the apex of the fanlobe and is flanked by extensive overbank deposits.

The mid-fan channel is highly sinuous in nature, asymmetric in cross-section, and bounded morphologically by levees. Near the mid-fan drill sites, the channel width is 3 to 4 km and its bathymetric relief ranges from 25 to 45 m. Downfan, the dimensions of the channel and its sinuosity decrease.

Analyses of side-scan sonar images (GLORIA, Sea MARC I, and EDO) show a wide variety of morphologic features (Fig. 1) [1–3]. Lineations and bedforms suggestive of sand-sized deposits are present on the surficial channel floor [3]. Drilling indicated that this sand-sized material consists of foraminiferal ooze. Features that are morphologically similar to fluvial ridge and swale structures are observed on both side-scan sonar records and high resolution seismic reflection profiles (Figs. 1 and 2). Several other side-scan sonar images adjacent to the channel also encourage a comparison with fluvial morphology (Fig. 1). Away from the channel, side-scan sonar images show only low-relief irregularities [1,3].

Reconstructions of channel development, using watergun and airgun seismic reflection profiles, suggest several depositional episodes in both the channel and overbank environments (Stelting and others, Chapter 41). The lowermost part of the present channel fill corresponds to the top of a zone of acoustically high amplitude reflections on seismic profiles. This zone is much wider than the present channel floor, suggesting lateral migration during the most active periods of fanlobe construction (Fig. 3).

Four sites were drilled in the upper region of the middle fan; two in the present channel and two outside the channel (Fig. 1). Site 621 is located in the axis (thalweg) of the channel on the outer side of a meander; Site 622 is on the inner side ("pointbar") of the next meander loop downchannel. Site 617 is in one of the swales on the inside of the meander loop about 4.8-km southwest of Site 621. Site 620 is located outside the zone with ridge and swale features, in overbank deposits about 18-km northeast of the channel.

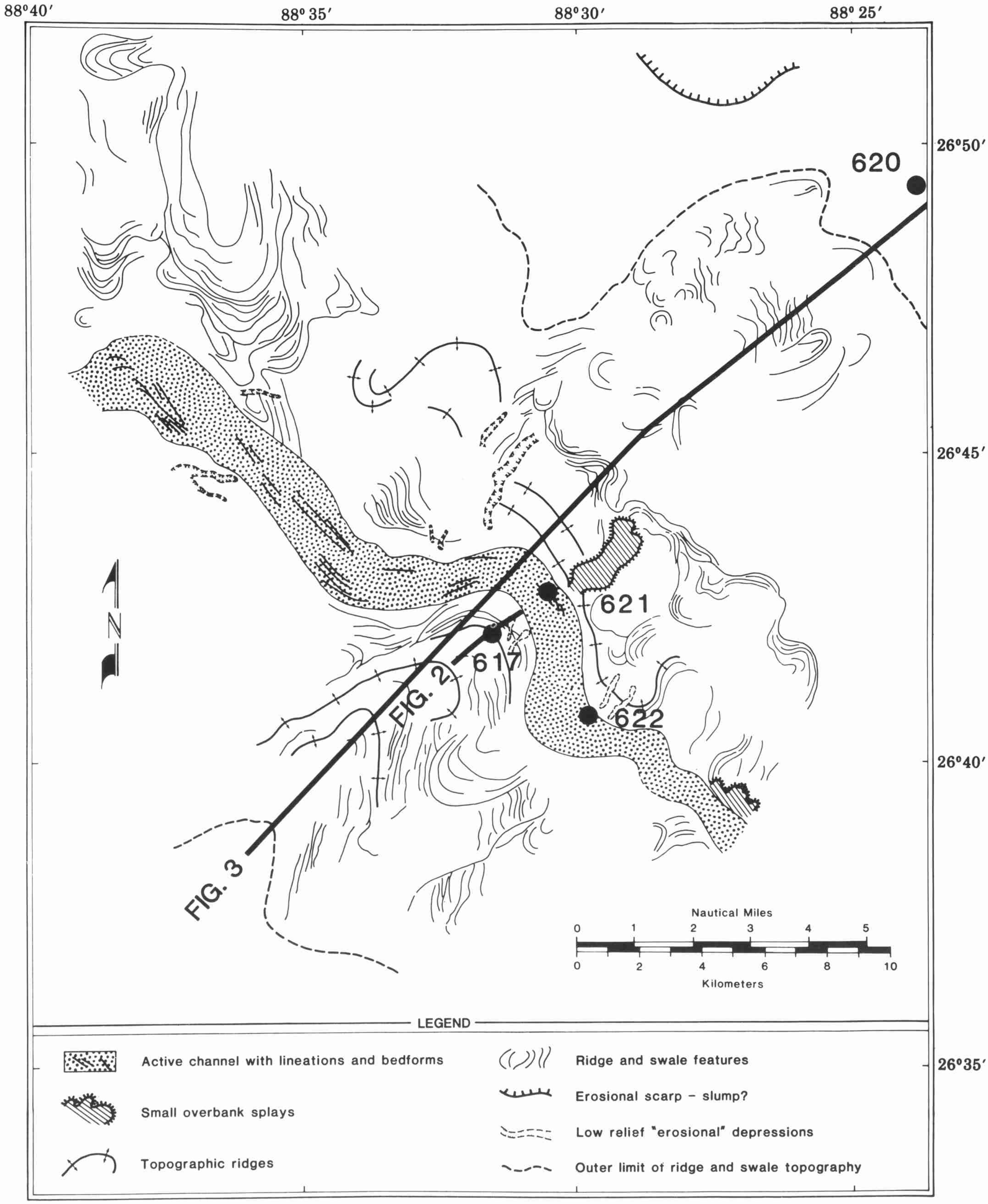

Figure 1. Morphologic features of the middle-fan region as mapped from side-scan sonar. Locations of the DSDP drill sites and seismic reflection profiles (shown in Figures 2 and 3) are indicated.

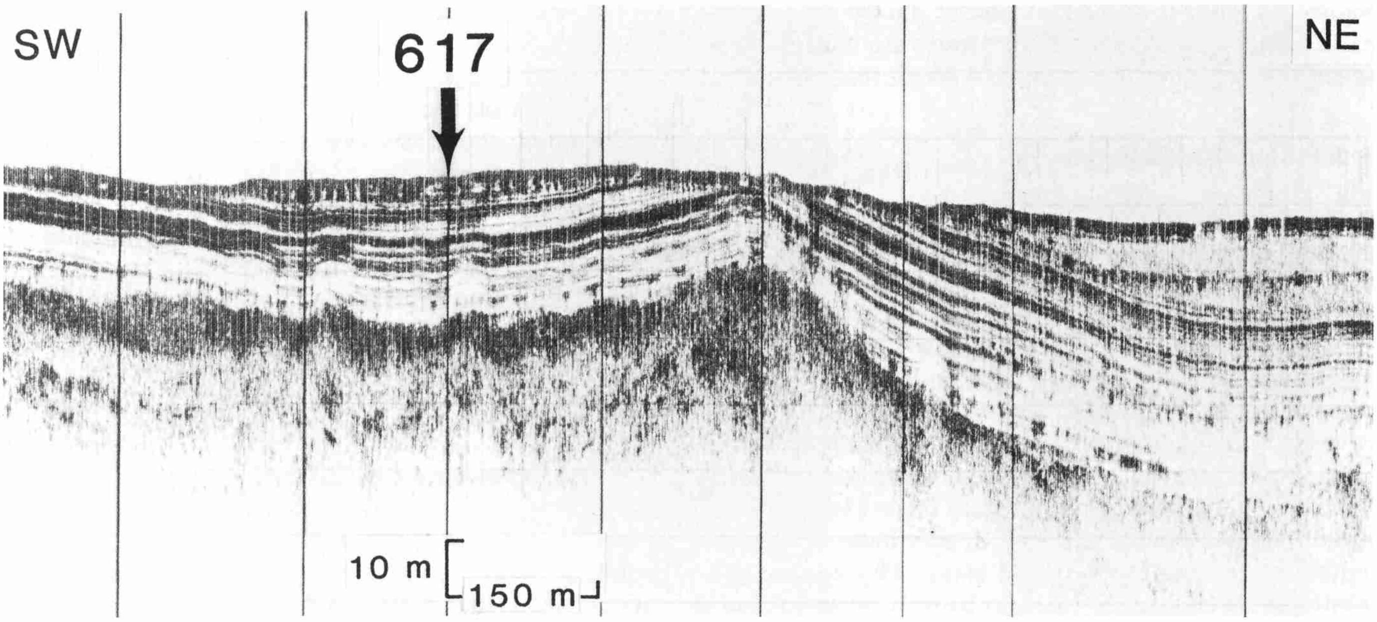

Figure 2. High resolution (4.5 kHz) EDO deep-towed seismic reflection profile over ridge and swale topography near Site 617. Conformable fill, truncation of reflectors over the top of the ridges, and a deeper seismically opaque zone are shown. See Figure 1 for location. (Printed by permission of D. B. Prior; Louisiana State University, Coastal Studies Institute).

Seismic Stratigraphy

Single- and multichannel seismic reflection profiles over the middle fan show a chaotic alternation of semitransparent to strongly reflective, irregular, more or less continuous to discontinuous, parallel reflectors [4,5]; high amplitude reflectors beneath the modern channel correspond to the lower channel fill (Fig. 3) (Stelting and others, Chapter 41). Generally, the higher the resolution of the seismic system, the more distinct these different seismic facies become (Bouma and others, Chapter 36).

Over the ridge and swale area, near Site 617, a very high resolution 4.5-kHz record from the EDO deeptow system shows erosion over the tops of the ridges. Acoustically,

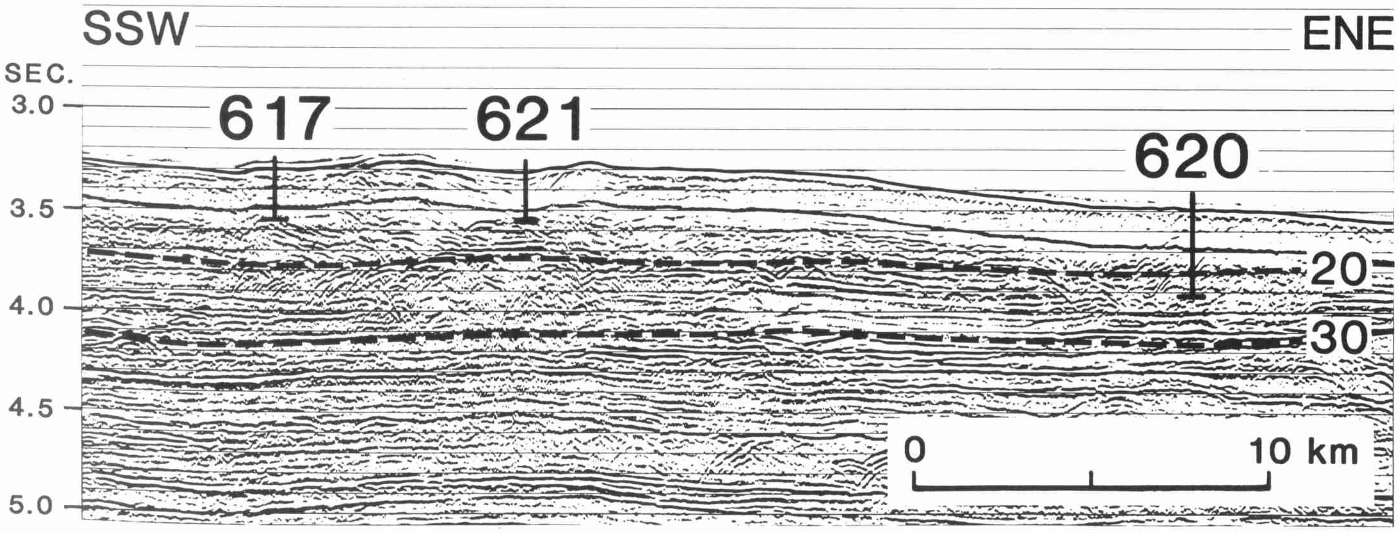

Figure 3. Multichannel seismic reflection profile (Line MC 11-A) over the middle-fan region. Major seismic reflectors "20" and "30", seismic facies (including high amplitude reflectors beneath modern channel), and the location of Sites 617, 621, and 620 are shown. See Figure 1 for location. (Printed by permission of R. T. Buffler; University of Texas, Institute for Geophysics).

sediments filling the swales generally show a conformable pattern. Both the ridges and the swales are underlain by a seismically opaque zone on these 4.5-kHz records (Fig. 2).

Sedimentary Characteristics

Sediments recovered from the four mid-fan sites can be divided into eight sedimentary facies. The characteristics, mineralogy, and texture of each of these sedimentary facies are described in more detail by Stow and others (Chapter 38) and Roberts and Thayer (Chapter 47). Several of these facies are minimally represented in the mid-fan cores (i.e., the calcareous facies comprise < 0.5% of total core recovered; Table 1 in Stow and others). To simplify the discussion of lithologic characteristics, we consider only the following five groups of sedimentary facies: 1) gravels and pebbly muds, 2) sands and silts, 3) silty muds, 4) silt-laminated muds, and 5) muds and clays. These basic sedimentary facies are identical to Stow's descriptions in Chapter 38 except for the combination of gravels with muddy gravels and pebbly muds and the elimination of oozes, muddy oozes, and calcareous muds.

Because the Mississippi Fan is commonly characterized as a dominantly muddy system, the most surprising facies is the one with gravels and pebbly muds at the base of the channel sites (Sites 621 and 622). The clean gravels (Fig. 4A), recovered at the bottom of Site 621, contain clasts ranging from about 2-mm to 2.5-cm in length and appear to be both clast-supported and normally graded. It is possible, however, that the gravels were washed clean of interpebble sands during the raising of the core barrel, thus creating a minor artificial sorting of the gravels. The pebbly muds (Fig. 4B) are poorly sorted, with the maximum clast sizes up to 3.4 cm (long axis) at Site 621 and 1.5 cm at Site 622. These sediments form structureless beds in which pebbles and sand granules are matrix-supported.

Sands and silts (Fig. 4C) comprise an important sedimentary facies in the lower part of the two channel sites, but they are nearly absent from the overbank sites. These predominantly sandy silts occur in beds from 0.5-cm to 3.0-m thick and are typically interbedded with muds or silty muds.

The characteristics of the sands and silts differ between the two channel sites. At Site 621 (thalweg site), they commonly occur as thin, inclined, and contorted layers (0.5 to 10-cm thick) interbedded with mud. At Site 622 (pointbar site), they comprise beds (0.8 to 3.0-m thick) of very finely laminated or structureless, relatively clean, sandy silt.

Silty muds occur as distinct interbeds in all four mid-fan sites and comprise about 6% of the recovered sediments. They are distinguished from the mud and clay facies by an increased abundance of sand and silt, but are not distinguishable from silt-laminated muds on well logs. The silty muds occur in beds ranging from a few centimeters to a meter in thickness and are typically normal graded.

Silt-laminated muds contain common to very abundai silt layers ranging from very thinly laminated (< 1 mm) t very thinly bedded (1 to 3 cm) (Figs. 4D,E). The silt-lan inated muds are one of the major facies at the mid-fan site: constituting about 38% of the recovered section. It is th dominant facies at Site 617 (82%), and comprises abou 24% of the total recovered section in the channel site (generally occurring only in the lower part).

Muds and clays are the dominant facies on the mid-fai comprising about 52% of the total recovered section at th four sites. They are the dominant lithology at the overban sites, are common in the upper parts of the channel fil and occur as thin interbeds in the lower part of Site 621

Vertical Lithological Characteristics

Core recovery at the four middle-fan drill sites was ger erally good in the upper 80 to 90 m, but decreased dras ically below that depth (Chapter 36). A suite of well log run at all sites (except Site 617) allowed us to fill in th gaps produced by the incomplete core recovery. Wire lin logs can provide information on lithologies, but not on sec imentary facies. Therefore, the following discussion c lithological characteristics as well as the sedimentary co umns in Figures 5 and 6 present interpretative lithologic: information resulting from correlative studies between ac tual core lithologies and well-log data.

A thin cover of Holocene ooze and calcareous muds (1 to 25-cm thick) occurs at the top of all four drill sites. Thes calcareous sediments overlie detrital muds, silts, an coarser sediment of Late Pleistocene age. All sites drille in the middle fan penetrated only into the Upper Wisconsi glacial stage (Ericson Zone Y [6]; Kohl and others, Chapte 39).

Channel Sites

The two channel sites (Sites 621 and 622) are similar i overall lithologic properties, each showing a basically fir ing-upward sequence (Fig. 5). Both holes bottomed i coarse-grained sediment (about 13 m of gravel and sand a Site 621 and about 15 m of interbedded pebbly mud an mud at Site 622). Above the basal gravelly sections, ther is a thick section (about 100 m) of interbedded muds an sands that generally fine upward. The lower part of thi interbedded section consists of interbedded silty muds an sands (to about 141-m subbottom at Site 621 and to abou 134-m subbottom at Site 622). Clayey mud is the dominar lithology in the upper part of the interbedded section a Site 621 (about 141 to 86-m subbottom). The mud is slightl siltier in the same interval at Site 622 (about 134 to 92-r subbottom) and contains few sand layers. Above the ir terbedded interval, muds and clays are dominant and ar rarely interrupted by thin bedded silts and sands. The basi

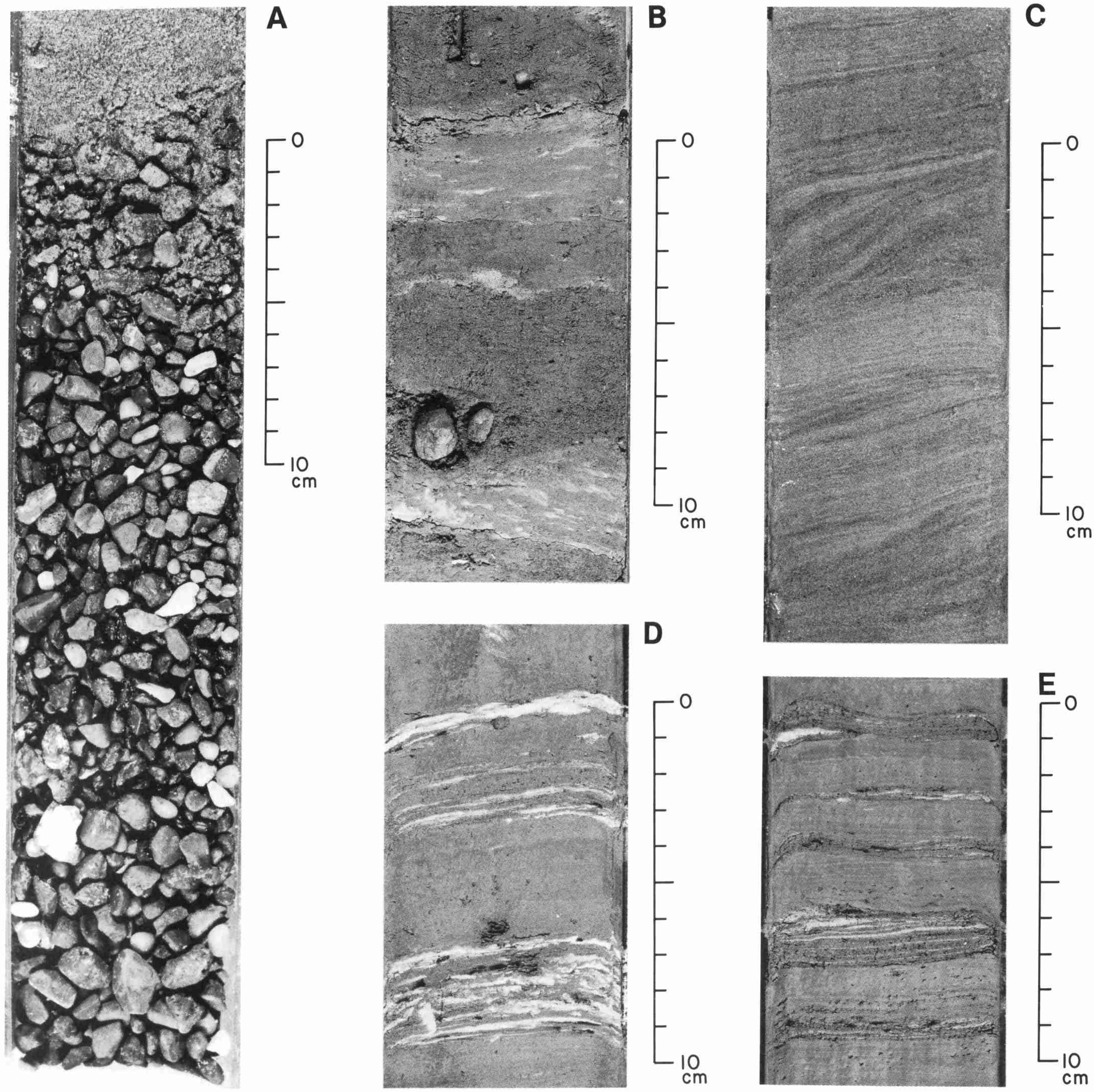

Figure 4. Photographs showing characteristics of selected sedimentary facies (subbottom depths correspond to top of each photograph). (A) Gravel overlain by sand (Site 621; 213.9 m). (B) Pebbly mud (Site 622; 197.7 m). (C) Sandy silt (Site 622; 156.2 m). (D) Silt-laminated mud (Site 621; 158.7 m). (E) Silt-laminated mud (Site 622; 93.4 m).

difference between these two sites is that the sandy section at Site 622 is about 40 to 50-m thicker than at Site 621 (Fig. 5). This difference is common in fluvial systems in which the pointbar deposits have a thicker sand section than the thalweg fill.

The approximately 210-m section cored at each of the two channel sites probably represents deposition during the later phase of aggradation of the youngest fanlobe. The gravel, pebbly mud, and sand recovered at the bottom of each hole correspond to the top of the seismically, high amplitude, reflection zone (Fig. 3), suggesting that this seismic zone characterizes coarse-grained sediment and that such material could be interpreted as channel-lag deposits (Chapter 41). The fining-upward trend [7] probably

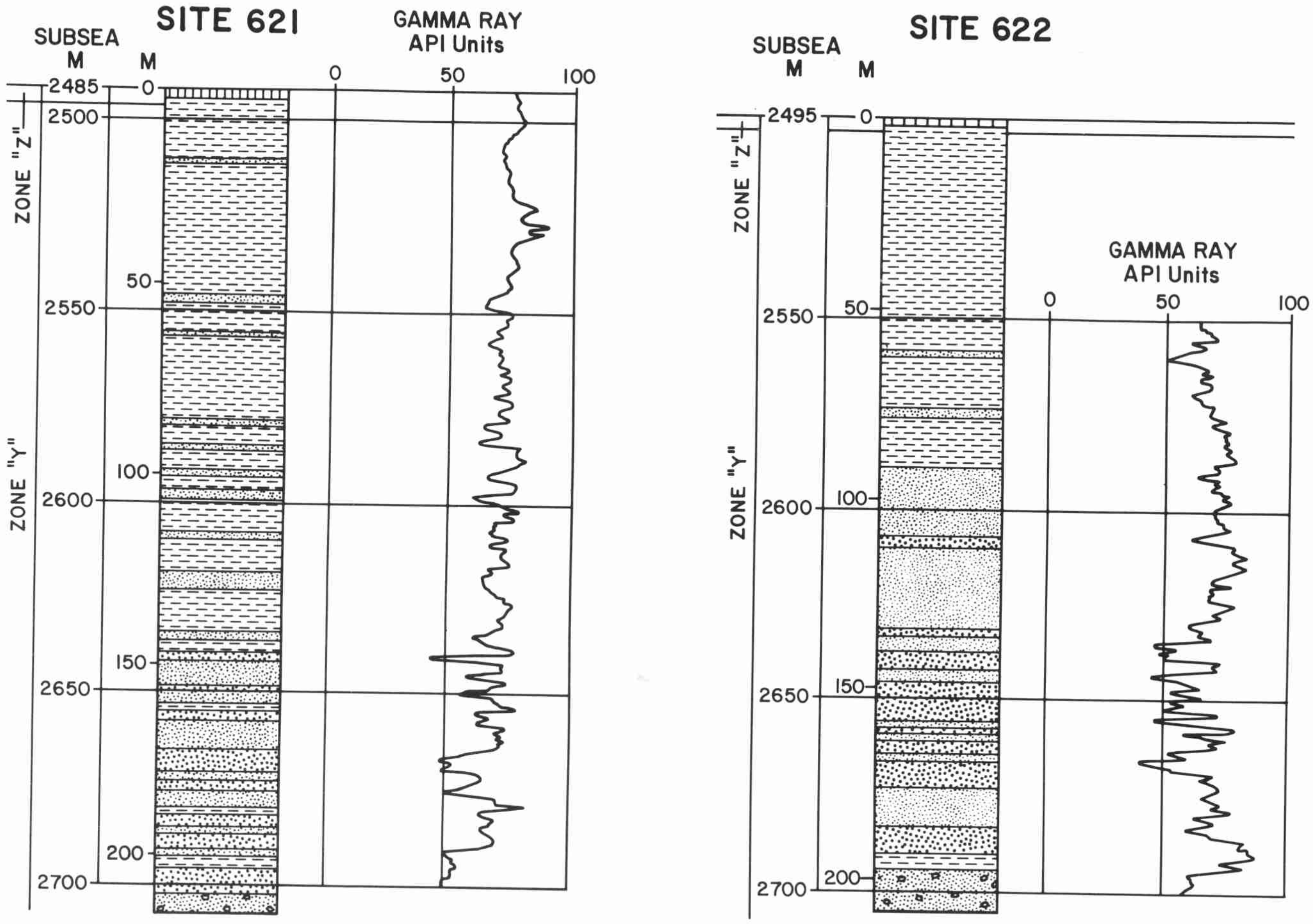

Figure 5. Interpretative lithostratigraphic summary of channel sites (Sites 621 and 622) showing age, lithology, and gamma-ray log response. See Figure 6 for legend. Summaries based on recovered sediment and well log data; actual core recovery and observed lithologies given in reference 9.

indicates a change in the depositional mode (waning phase) and, finally, abandonment or inactivity of the system as the sea level rose to its present high stand.

Overbank Sites

The overbank sites (Sites 617 and 620) are not directly correlatable because of their differing distances from the channel. Site 617 (4-km southwest of the channel) was drilled to a depth of 191 m and contains somewhat coarser sediment than was recovered at Site 620 (18-km northeast of the channel). Site 617 was proposed to examine the type of sediments that constitute the ridge and swale structures and to discover how much coarse material (turbidites) was deposited directly adjacent to the channel. Site 620 was expected to consist of numerous thin-bedded turbidites, thought to characterize overbank or interchannel deposits in studies on ancient turbidite systems [8]. The drill sites, however, did not support these working hypotheses (Chapter 36).

The lowermost 108 m (191 to 83-m subbottom) of Site 617 (Fig. 6) represents a minor coarsening-upward sequence of dominantly silt-laminated muds, with the frequency of silt laminae increasing from a minimum of 6% near 162-m subbottom to 18% of the total volume at 85-m subbottom. This lower part is overlain by a 38-m interval of silt-laminated mud (83 to 45-m subbottom); abundant silt laminae averages 35% of the total volume. The uppermost 45 m comprises a weakly defined fining-upward sequence, beginning with silt-laminated muds (45 to 18-m subbottom), in which the silt laminae decrease in frequency upward and are topped by structureless muds and clays. The silt laminae are typically very thin with sharp bases. Deformation in the form of inclined and contorted layers is most prevalent at this site.

It was intended to drill through at least the upper two fanlobes at Site 620 to combine time-stratigraphy with lithological characteristics of overbank deposits. At 422-m subbottom depth, however, friction on the drill string forced abandonment of deeper objectives. Because the originally intended penetration at this site was 750 m, a rotary drilling/

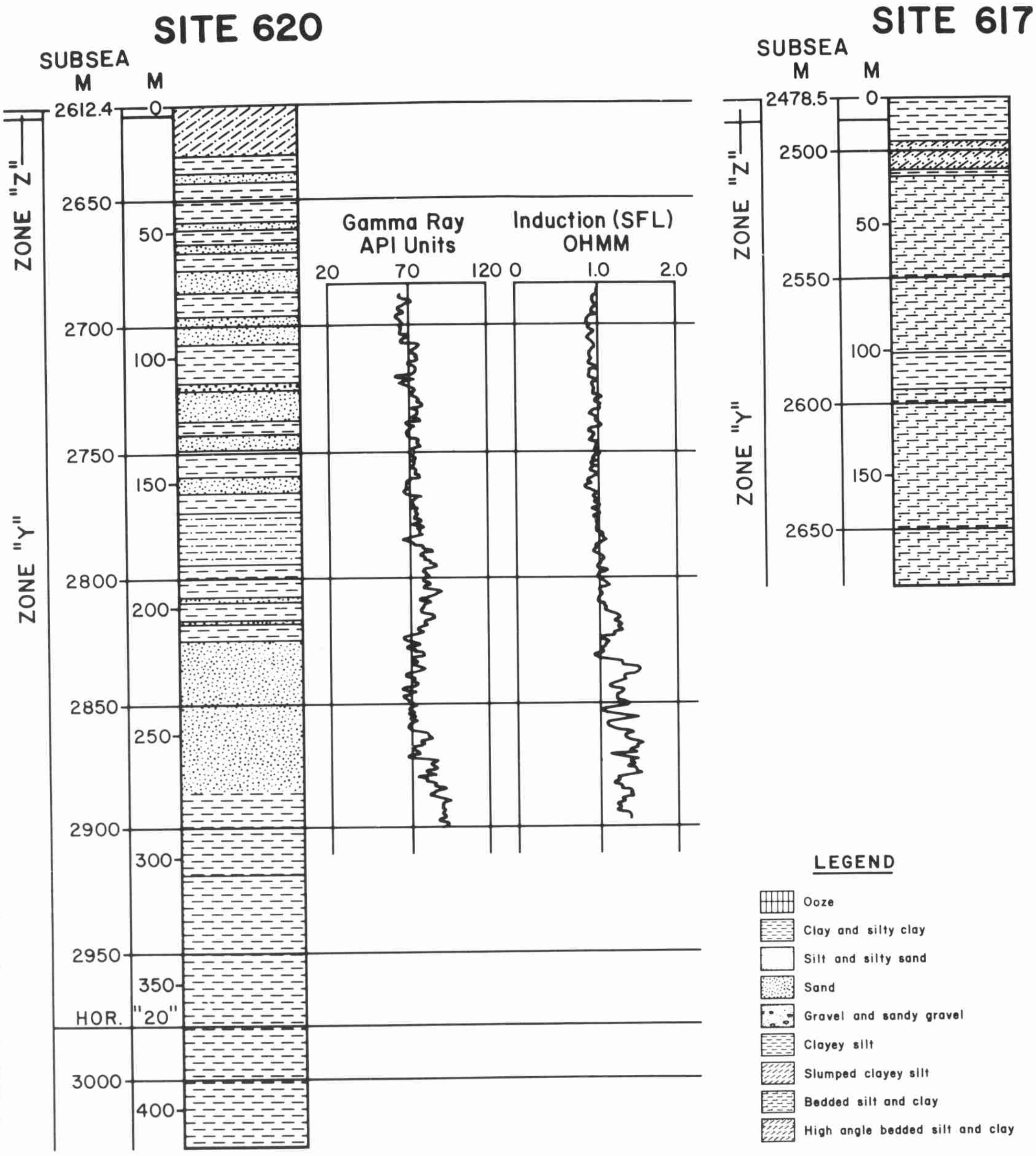

Figure 6. Interpretative lithostratigraphic summary of overbank sites (Sites 617 and 620) showing age, lithology, and gamma-ray and induction log responses (Site 620). Site 620 summary based on recovered sediments and well log data; see reference 9 for actual core recovery and observed lithologies.

coring system was used. Accordingly, the cores recovered were severely disturbed and sedimentary structures were not preserved (Chapter 36). Compositionally, the sediments are mostly muds and clays with rare silt laminae or very thin sandy turbidites (Fig. 6).

Two major slightly coarsening-upward lithological intervals, based primarily on well logs, can be suggested for Site 620. The lowermost interval extends from at least 289 m (the base of the logged interval) to 217-m subbottom; it might extend to the base of the cored interval at 422-m subbottom since no drastic lithological changes were observed below the well-logged interval. This basal interval starts with a clayey mud which changes rather abruptly into a silty mud at about 258-m subbottom. The well-log response suggests variability in the silt and clay contents of the mud (Fig. 6). Above 237-m subbottom, the silt component becomes dominant.

The second interval (from 217 to about 65-m subbottom) shows a similar, minor, coarsening-upward trend, but is lithologically more variable than the lower interval. The lower part of this upper section is composed mainly of clayey muds. Above about 155-m subbottom, the interval consists of interbedded silty muds and clayey muds with some coarse silt to fine sand intercalations.

The uppermost 65 m of the hole were extensively disturbed by the coring, and no adequate observations can be made on the relationship of this section to the underlying intervals.

Conclusion

Analyses of seismic reflection profiles, side-scan sonar images, and cores from the four drill sites show that the middle fan is the thickest part of the youngest fanlobe and that it is aggradational in nature. It is lenticular in cross-section, with a channel-levee complex along its apex. The channel has a sinuous course and is migratory in nature. The deepest core recovered from the channel fill contained a gravel-pebbly mud-sand lag deposit that is visible on seismic reflection profiles as a zone of acoustically high amplitude reflections. This high amplitude zone is several times wider than the present channel visible on the seafloor, suggesting a decrease in the size of the channel with time. The channel fill is primarily a fining-upward sequence.

The levee and overbank deposits are typically fine-grained, with only a minor amount of thin silty and sandy turbidites which rapidly decrease in number away from the channel.

Total sedimentation rates of the youngest fanlobe, both in the channel and overbank deposits, average nearly 12 m/1000 years (Kohl and others, Chapter 39). Although the present channel floor is only 30 to 45-m below its levees, seismic reconstructions suggest that the channel was two to three times deeper during active transport. Because of the high sediment accumulation rates and the reconstructed size of the channel, it is assumed that very large, together with smaller, density flows (debris flows and turbidity currents) moved through the channel. It is likely that the size of the flows decreased with time. Sand-sized and coarser material was basically transported below the levee crests and, therefore, was deposited within the channel margins, whereas enormous amounts of finer-grained sediments moved over the levees and were deposited in the overbank areas.

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