19. LATE PLEISTOCENE SEISMIC STRATIGRAPHY OF THE MISSISSIPPI FAN[1]

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ABSTRACT

The Mississippi Fan comprises a minimum of seven individual depositional units, called fan lobes. The two most recent fan lobes, penetrated during DSDP Leg 96, were deposited during the late Wisconsin glacial. The morphology of the youngest fan lobe is dominated by a channel-overbank complex which traverses nearly its entire length. Systematic downfan changes in the nature of the channel system, distribution of the seismic facies, and seafloor gradient suggest division of the youngest fan lobe into four major regions: canyon, upper fan, middle fan, and lower fan. Two of these regions—the middle fan and the lower fan—were drilled during Leg 96.

The seismic character of the continental slope adjacent to the canyon is similar to that of the upper fan because of the influence of diapiric activity and the erosional/depositional processes within the channel complex. South of the diapirs, however, the seismic character of the upper fan becomes more compatible with the middle fan. This change reflects the transition from an erosional mode in the canyon area to a predominantly aggradational mode downfan.

The middle fan is characterized by an aggradational channel located along its apex. This leveed channel system is highly sinuous and migratory in nature. The channel fill, drilled at Sites 621 and 622, consists of a zone of high-amplitude reflectors (channel-lag deposits) in its lower part overlain by semitransparent to transparent reflections (silts and muds). Seismically, the fine-grained overbank sediments (Sites 616, 617, and 620) are characterized by laterally extensive, structureless, transparent zones (north of the channel) or by predominantly discontinuous, parallel reflectors (south of the channel).

The lower fan region can be subdivided into two areas. In its upfan area (Sites 623 and 624), randomly scattered, buried channels suggest frequent shifting, infilling, and abandonment. The extension of discontinuous, parallel reflectors from these channels suggests lateral distribution of sediment by nonchannelized turbidity currents. In its downfan portion (Sites 614 and 615), the modern channel is barely discernible morphologically and bifurcates before terminating. Seismically, this area consists of continuous parallel to discontinuous parallel reflectors.

INTRODUCTION

The Mississippi Fan, a large, broad, arcuate accumulation of predominantly Pleistocene sediments, is located in the eastern Gulf of Mexico (Fig. 1). Fan growth has been most strongly influenced by periodic input of mainly fine-grained sediment from the Mississippi River system in response to changes in sea level. Although the basin is bounded on parts of three sides by escarpments, its overall configuration had only minor controlling effects on fan construction (Feeley et al., 1984; Bouma, Coleman, Meyer, et al., 1985).

Early reports on the Mississippi Fan concentrated on the surficial sediments, depositional processes, and shallow seismic characteristics (Huang and Goodell, 1970; Walker and Massingill, 1970; Davies, 1972). A regional evaluation of the internal structure, seismic characteristics, and general growth patterns was initially reported by Stuart and Caughey (1976), and by Moore et al. (1978, 1979). In preparation for Deep Sea Drilling Project (DSDP) Leg 96, marine surveys on the Mississippi Fan collected side-scan sonar data simultaneously with medium- to high-resolution seismic data. These studies identified a sinuous channel and defined the shallow subbottom features adjacent to the channel/overbank complex (Garrison et al., 1982; Kastens and Shor, 1985). These data were used to identify potential drill sites for Leg 96.

Recent studies, using side-scan sonar and seismic reflection data together with the drilling results, have produced new findings on the internal seismic structure, depositional processes, and growth patterns (Bouma et al., 1983/84; Bouma, Stelting, et al., 1985; Feeley et al., 1984, 1985). These investigators defined eight major reflectors, seven of which can be correlated across the Mississippi Fan. Correlation of these reflectors with foundation borings along the rim of the Mississippi Canyon and upper continental slope and with DSDP drill sites in the western Gulf of Mexico has established tentative ages for these major reflectors (see Bouma, Coleman, and Meyer, this volume; Coleman et al., 1983; Bouma, Coleman, Meyer, et al., 1985). The ages of the uppermost reflectors, referenced in this chapter, are as follows:

Horizon 0: present seafloor

Horizon 10: middle late Wisconsin; difficult to trace regionally

Horizon 20: late Wisconsin, 40–55 $\times$ 10^3 yr. ago

Horizon 30: early Wisconsin, 75–100 $\times$ 10^3 yr. ago

Horizon 40: middle Pleistocene.

[1] Bouma, A. H., Coleman, J. M., Meyer, A. W., et al., *Init. Repts. DSDP*, 96: Washington (U.S. Govt. Printing Office).

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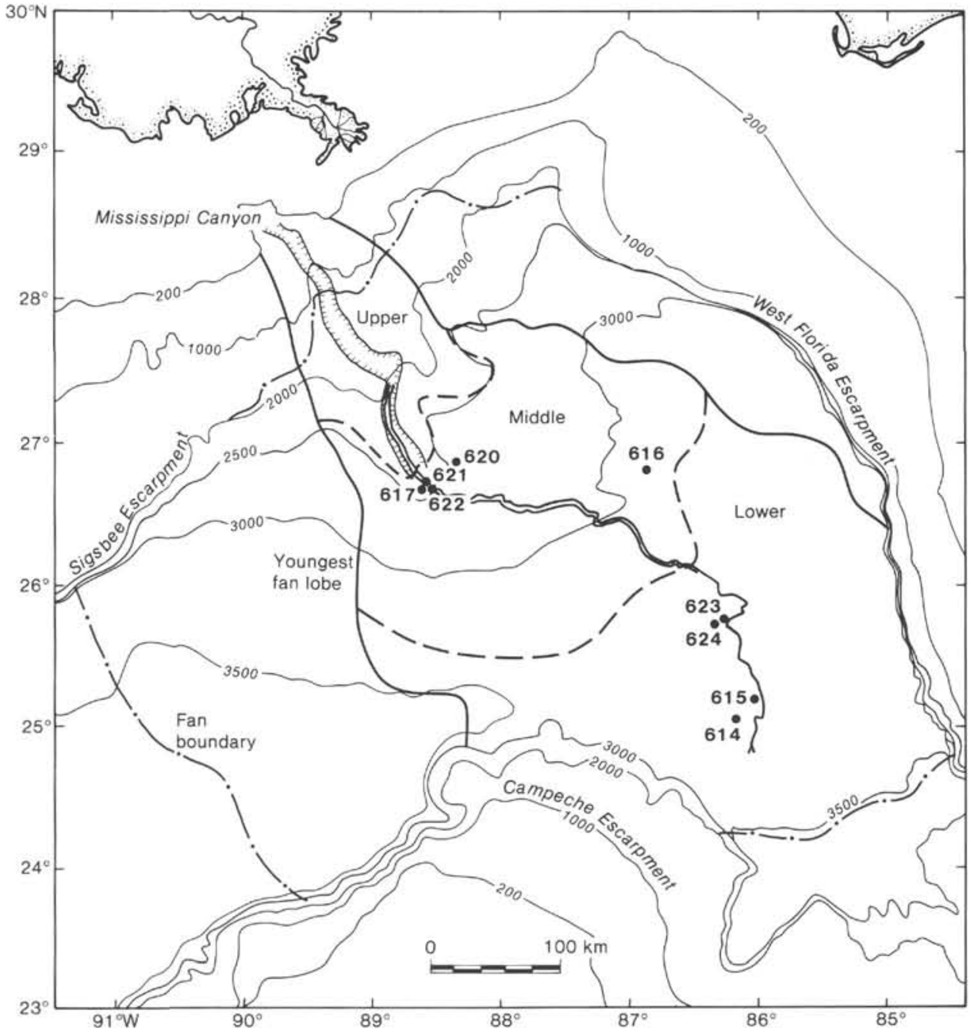

Figure 1. Mississippi Fan, Gulf of Mexico. Outline of youngest fan lobe, fan divisions (denoted by dashed lines), channel pattern, DSDP Sites 614–617 and 620–624, major structural components, and general bathymetry (in meters) shown. Modified after Bouma et al. (1983/84). Fan boundary represents the total accumulation of all fan deposits.

These major seismic reflectors allow us to subdivide the Mississippi Fan into individual depositional units, called fan lobes, defined as distinct depositional units bounded by relatively continuous seismic reflectors. The fan lobe is dominated by a channel–overbank complex (Figs. 1, 2) and was deposited during a relatively short geological interval. As emphasized by Bouma, Coleman, Meyer, et al. (1985), each fan lobe is a complex unit; it may consist of more than one discrete body if different source areas were active at more or less the same geological time interval.

The youngest Mississippi fan lobe is defined as the unit which lies between the seafloor and seismic Horizon "20" (Bouma, Stelting, et al., 1985). Biostratigraphic results from DSDP Leg 96 indicate it was deposited during late Wisconsin glacial time (Kohl et al., 1985, and this volume).

Based on morphologic characteristics, seismic facies distribution, and seafloor gradient, the youngest fan lobe can be divided into four major regions (Fig. 1). These are (1) an upslope erosional canyon (Mississippi Canyon); (2) an upper fan with a large, erosional channel in the northern part, becoming aggradational downfan; (3) an aggradational middle fan that is convex in cross section, with a sinuous, axial channel; and (4) an aggradational lower fan with one recently active channel and several abandoned ones (Bouma et al., 1983/84; Bouma, Stelting, et al., 1985). During Leg 96, five sites were drilled in the middle-fan and four sites in the lower-fan region.

The channel–overbank complex that dominates the youngest Mississippi fan lobe changes morphologic character across the fan (Bouma et al., 1983/84; Bouma, Stelting, et al., 1985). These changes are related to changes in the depositional processes at any given point on the fan and, as such, produce distinct seismic characteristics for the different regions of the fan (Mitchum, 1985). The seismic characteristics in the different regions

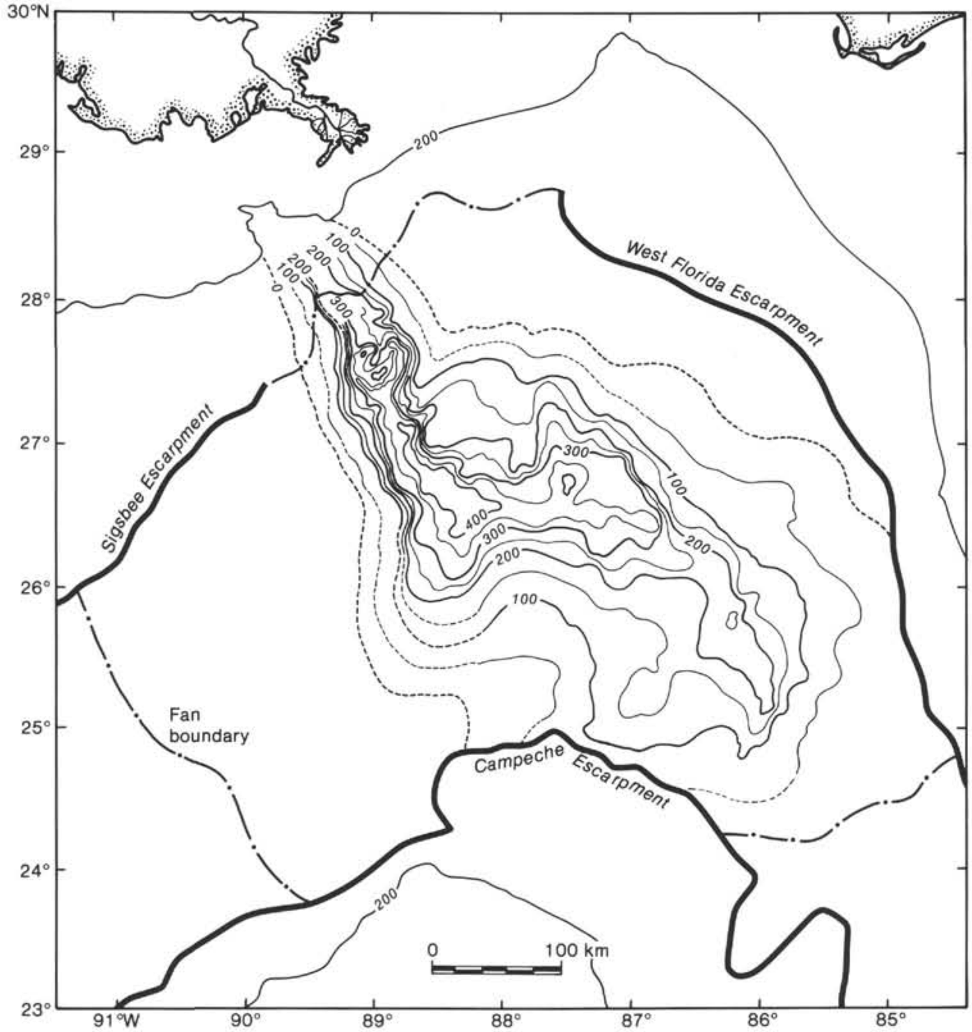

Figure 2. Isopach map of the youngest Mississippi Fan lobe. Maximum accumulations coincide with the channel complex. Isopach contours in meters. Modified after Bouma et al. (1983/84). Dashed line denotes either insufficient data or shallowing of reflector at seafloor. The 200-m isobath corresponds to shelf break.

of the youngest fan lobe, especially as related to the drilling results of Leg 96, are the primary subject of this chapter.

SEISMIC STRATIGRAPHIC ANALYSIS

The acoustic characteristics of the youngest fan lobe were studied using approximately 15,000 km of medium- and high-resolution seismic data (Fig. 3). The various acquisition systems ranged from an array of large air guns to a large sparker system to smaller high-resolution air guns and water guns (Fig. 3). The surficial morphologic characteristics and position of the channel complex were described earlier, using side-scan sonar (GLORIA, Sea MARC I, EDO) and sub-bottom profiler data (Garrison et al., 1982; Prior et al., 1983; Kastens and Shor, 1985).

The seismic stratigraphic framework used herein was established by Bouma, Stelting, et al. (1985) and is generally in agreement with the framework proposed by Feeley et al. (1984). Depth conversions for correlating core depths with seismic depths and for isopach mapping are based on the velocity function derived from downhole velocity surveys acquired from industrial boreholes along the Mississippi Canyon margin (see Fig. 3 in the introductory chapter, this volume).

Seismic Facies Analysis

Seismic facies identification in the youngest fan lobe basically follows the procedures outlined by Sangree and Widmier (1977), Mitchum et al. (1977), and Stuart and Caughey (1977). Facies characteristics are based on internal reflection configurations and external geometries. Use of the various seismic acquisition systems resulted in variations within the same facies. Therefore, the seismic facies were standardized by comparing the different systems at intersection points or at locations where the lines were parallel and separated by only a short distance.

Eight distinct seismic facies were identified, as follows: (1) chaotic reflections (c); (2) high-amplitude reflectors (HAR); (3) parallel, continuous reflectors (Pc);

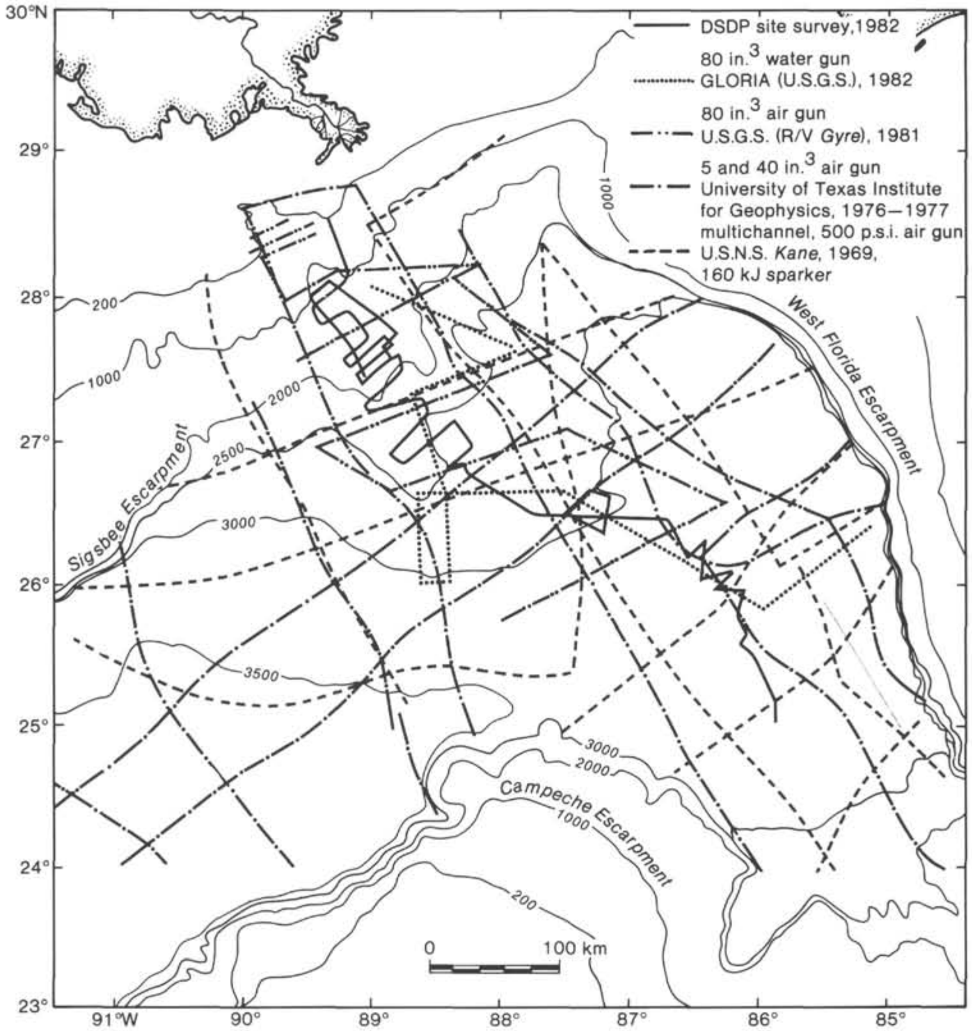

Figure 3. Seismic data coverage on the Mississippi Fan. Bathymetric contours in meters.

(4) parallel, discontinuous reflectors (Pd); (5) parallel, irregular, discontinuous reflectors (Pb); (6) semitransparent reflections (sT); (7) transparent reflections (T); and (8) seismic sequences (SS). A detailed description of these seismic facies is presented in Table 1.

SEISMIC CHARACTERISTICS OF THE YOUNGEST FAN LOBE

Mississippi Canyon/Continental Slope

The continental slope region adjacent to the fan extends as a relatively narrow band north of the Mississippi Fan (Fig. 4). It is typified by an irregular bathymetry, resulting mainly from diapirism. Both this region and the northern portion of the upper fan (north of 27°20′N) are underlain by diapirs, either isolated structures or massive salt ridges (Fig. 4) (Martin, 1984; Walters, 1985). The most prominent geomorphic feature on the continental slope is the Mississippi Canyon, a nearly filled trough that formed by retrogressive slope failure and slumping (Coleman et al., 1983; Bouma, Coleman, and Leg 96 Scientists, 1985; Walters, 1985).

Seismic reflection profiles crossing the Mississippi Canyon show the erosive character of the canyon (Fig. 5). Acoustically, the fill is characterized mainly by semitransparent reflections; chaotic reflectors are commonly observed along the base. Discontinuous, parallel reflectors and intermittent, chaotic reflections within the fill suggest that the canyon was filled in several discrete stages. The irregular (hummocky) character of the discontinuous, parallel reflectors (seismic facies Pb) within the canyon fill may be the result of sediment failure along the adjacent canyon walls. Numerous scars along the canyon margin have been documented by Coleman et al. (1983); the resulting slump deposits may constitute a relatively high volume of the canyon fill. A possible slump structure can be observed at the northeastern margin of the canyon in Figure 5.

Soil foundation borings in and adjacent to the canyon support the interpretation that the lower part of the canyon fill consists of slumped muds and silts (Coleman et al., 1983). The upper part of the fill consists mainly of upper Wisconsin prodelta clays; these finely laminated clays contain silt and sand stringers with shallow-

Table 1. Description of seismic facies.

Seismic facies	Symbol	Description
Chaotic	c	Chaotic, diffractions common; frequency and amplitude variable; typically mounded.
High-amplitude reflectors	HAR	High amplitude, low continuity; mainly convex upward; truncate each other.
Parallel, continuous	Pc	Parallel to subparallel; high amplitude and good continuity (tens of kilometers); occur as couplets or single; may grade to other parallel forms.
Parallel, discontinuous	Pd	Parallel to subparallel; medium to high amplitude; medium continuity (less than tens of kilometers); occur as couplets or single; may grade to other parallel forms.
Parallel, irregular, discontinuous	Pb	Hummocky (convex upward); low to medium amplitude; low continuity (less than one to a few kilometers); commonly associated with semitransparent or chaotic reflections.
Semitransparent	sT	Low- to medium-amplitude zones of scattered reflections (commonly irregular, discontinuous, parallel reflectors) with no preferred orientation; patches intermediate with chaotic reflections.
Transparent	T	Intervals devoid of reflections; irregular, discontinuous, parallel reflectors locally.
Seismic sequences	SS	Combination of several seismic facies. "Intraslope-basin-type cycle": semitransparent to transparent reflections at base (chaotic reflections common), grades through discontinuous, parallel to continuous, parallel reflectors.

water fauna (Woodbury et al., 1978; Coleman et al., 1983).

Upper Fan

The upper-fan region of the youngest fan lobe begins at about 1200 m water depth; the lower boundary region more or less coincides with the base of slope (Fig. 1) (Bouma, Stelting, et al., 1985). The surface morphology of this area is characterized by a slightly irregular topography in the northern part (because of salt diapirs) and by a slightly convex-shaped bulge in the southern part. The most prominent geomorphic feature is a wide, nearly filled channel complex which trends almost down the center of the upper fan (Fig. 4).

The upper fan is the most complex region of the youngest fan lobe. This region constitutes the transition between the erosive character of the Mississippi Canyon and the aggradational nature of the middle fan. Both the seismic characteristics and the depositional patterns within the channel and in the overbank area change downfan. Additional complications result from postdepositional deformation associated with diapiric uplift (see disruption of channel floor in Fig. 6).

Seismically, the channel fill consists primarily of semitransparent reflections (facies sT). Seismic facies Pd and Pb divide the fill into separate units and suggest a cyclic channel fill (Fig. 7). Chaotic reflections (facies c) occur along the channel margins and commonly disrupt the parallel reflections. The overbank area is dominated by facies sT in the northern region, and by facies Pb and Pd in the southern region (Figs. 6, 7).

The transition from an erosional to a more depositional channel system occurs within the diapiric region in the northern part of the upper fan. Seismic lines which cross the channel near the apex of the fan lobe show a deep, nearly filled erosional channel (Fig. 7A). The chaotic-semitransparent reflections (facies c, sT) in the lower part of the channel are inferred to consist primarily of mass-movement deposits. Above the thick, lower semitransparent unit (Fig. 7A), the channel fill displays alternating semitransparent and parallel seismic facies (turbidity current and hemipelagic deposits?). The truncation of overbank reflectors by the channel suggests that there has been little, if any, interaction between depositional processes in the channel and the overbank (i.e., overbank spilling). In the southern part of the diapiric region, the basal part of the channel is still erosive, but the upper part is predominantly depositional (Fig. 7B). Reflector continuity suggests that the overbank deposits may be more closely related to depositional events within the channel complex.

Where not obscured by the bubble pulse, overbank deposits are lenticular in shape and thin onto the diapiric highs. Low-amplitude parallel reflectors (continuous to discontinuous) are the most common reflectors within the mainly semitransparent lenses in the north; they increase in abundance downfan. Chaotic reflectors (facies c) are common locally (see Fig. 6, below 2030 hr.) and suggest that mass-movement processes are important near diapirs and along the channel margin.

South of the diapirs, the channel/overbank complex assumes an aggradational character (Fig. 7C). A thinner, cyclic, channel fill is still indicated by the seismic record. In addition, a shift of the channel axis to the northeast suggests that the upper-fan channel is migratory where it is aggradational (see discussion of middle-fan channel). A slight increase in the amplitude of the parallel facies (Fig. 7C) may indicate that the corresponding deposits are more heterogeneous. This would imply that the coarse-grained deposits described in the middle fan extend upchannel for some distance (Stelting et al., 1985).

Middle Fan

The boundary between the upper- and middle-fan regions is placed at about 2200 m water depth and is marked by a change in gradient that corresponds to the base of slope. The middle fan grades into the lower fan at a water depth of about 3100 m. The middle fan is lenticular in cross section; its apex rises 330–400 m above the surrounding seafloor (Fig. 8). The middle fan is the area of major deposition; the area north of the channel complex generally has sediment thicknesses in excess of 300 m; maximum thicknesses (>400 m) occur adjacent to the channel in the transition zone between the upper and middle fan (Fig. 2).

An aggradational channel complex, about 10 to 20 km wide, is located along the apex of the middle fan lobe. Recent surveys using side-scan sonar imaging (GLORIA,

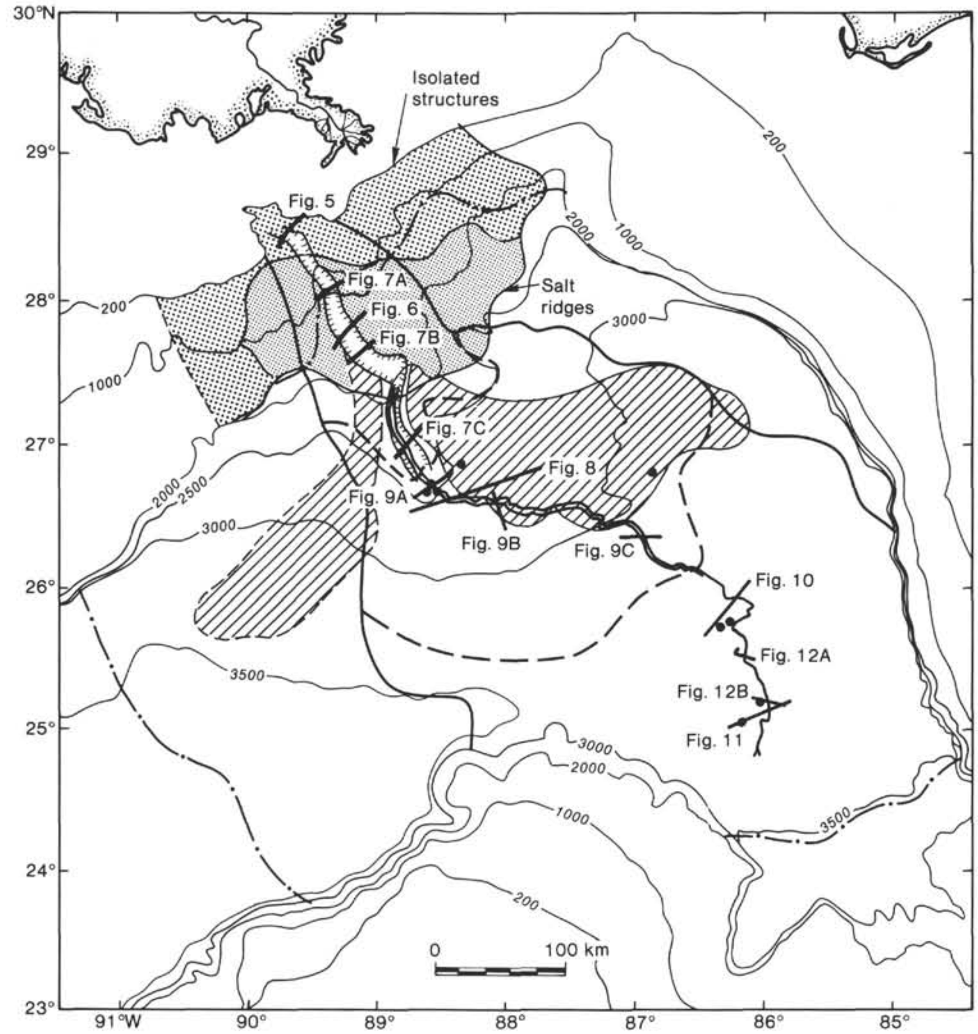

Figure 4. Map showing location of seismic reflection profiles in Figures 5 to 12 and DSDP drill sites (unlabeled dots). Stippled areas (continental slope and upper fan) denote the two diapiric provinces (after Martin, 1984); hachured pattern (middle fan) shows major "slump" areas (modified after Bouma et al., 1983/84; Walker and Massingill, 1970). Bathymetric contours in meters.

Sea MARC I, and EDO) and high-resolution seismic profiling have identified a leveed, sinuous channel that ranges from 0.5 to 4.0 km in width within the channel complex (Garrison et al., 1982; Prior et al., 1983; Kastens and Shor, 1985).

Overbank Characteristics

Transparent seismic reflections (T) are the dominant facies north of the modern channel complex (Fig. 8). This facies comprises all of the youngest fan lobe (above Horizon "20") north of the channel and is the most abundant facies in the underlying fan lobe (between Horizons "20" and "30"). Its areal distribution coincides with the area that Walker and Massingill (1970) interpret as consisting of slump deposits (Fig. 4). The seismic character outside this "slump" area, however, is dominated by parallel reflectors.

Previous investigators had postulated that this transparent seismic facies results from the homogeneity of the sediments or consists of slump, slide, or debris flow deposits (Stuart and Caughey, 1976; Moore et al., 1978). Relative to this question, the drilling results are not conclusive. Both Sites 616 and 620 penetrated the transparent seismic facies (Figs. 4, 8). The upper 100 m of upper Wisconsin sediment recovered at Site 616 is characterized by numerous dipping units (dips ranging up to 65°) separated by disturbed and shear zones (see Site 616 chapter, this volume). The deposits are interpreted to be fine-grained sediments that were later re-emplaced by mass-movement processes in a manner resembling shingles. Site 620 was drilled at the western margin of the "slump" area (18 km from the channel thalweg, Fig. 4); the recovered section consists mainly of silty clay and clay (see Site 620 chapter, this volume). Generally speaking, sediments recovered at Site 620 were quite homogeneous; inferred mass-movement deposits were rare.

South of the channel complex, parallel reflectors are the dominant seismic facies (Fig. 8). The parallel reflectors are present in all three seismic facies types: continuous (Pc); discontinuous (Pd); and irregular, discontinuous (Pb). Lateral grading from one facies to the other is common. Their distribution can be summarized as fol-

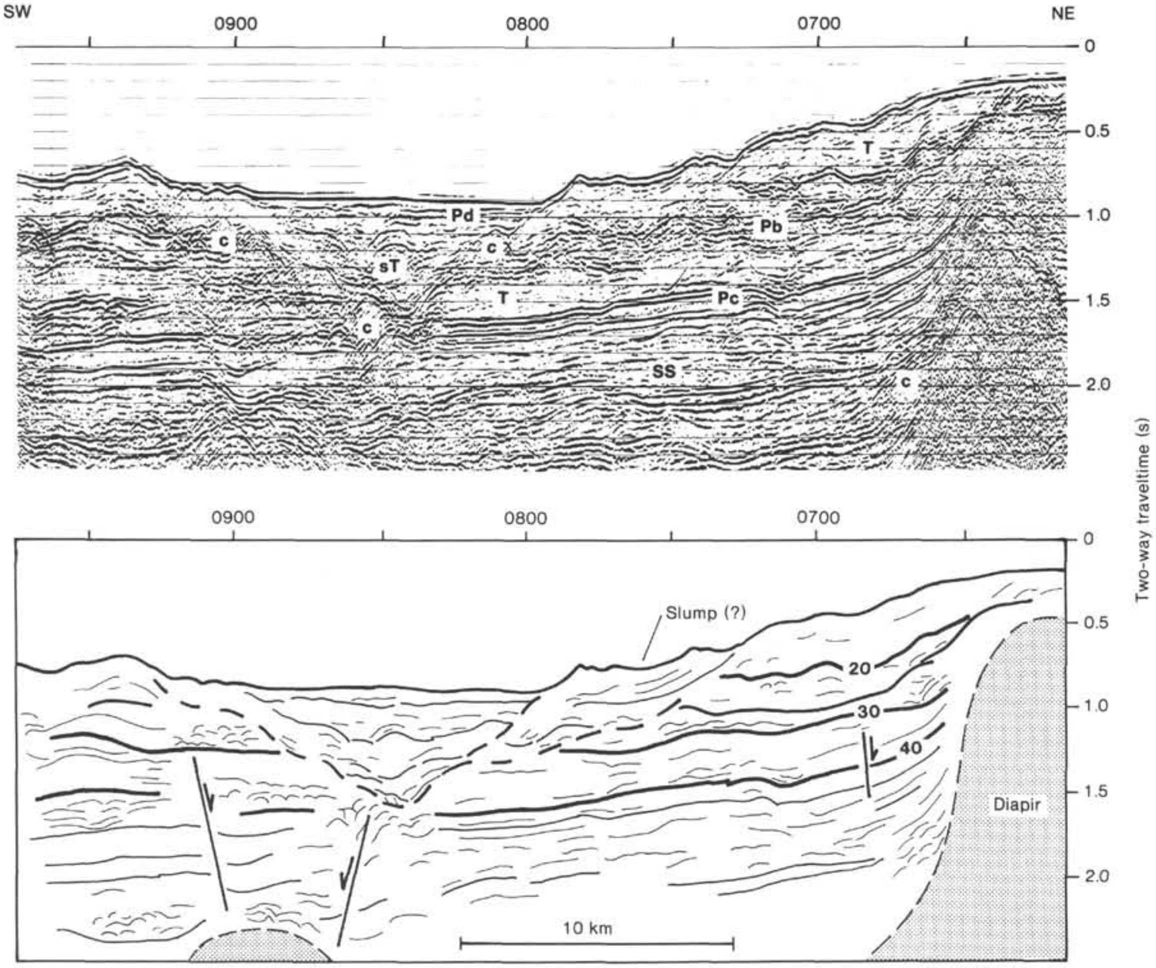

Figure 5. Multifold seismic profile and line drawing over continental slope showing Mississippi Canyon (dashed in line drawing) and interaction between sedimentation and diapirism (Line MC-27). See Figure 4 for location, Table 1 for seismic facies symbols, and Bouma, Coleman and Meyer (this volume) for discussion of the major seismic Horizons 20, 30, and 40.

lows: facies Pb is most common adjacent to the channel complex; facies Pd predominates in the intermediate areas; and facies Pc characterizes the more distal regions of the middle fan. Thick, lenticular patches of transparent reflections are commonly intermixed. Although no holes were drilled in this region, the paucity of pelagic deposits in the middle-fan drill sites suggests that the parallel seismic facies in this region represent turbidites, in which the increased abundance of coarser-grained sediments (silt and sand) results in sufficient acoustical impedance to produce the parallel-layered seismic signature. The mixture of transparent patches is probably the result of local mass movement (slumps, slides); this interpretation is consistent with the drilling results at Sites 616 and 620.

Channel Characteristics

Channel-fill deposits in the middle fan are principally characterized by high-amplitude reflectors (facies HAR), semitransparent reflections (facies sT), and transparent reflections (facies T). Facies Pb is commonly intermixed with the high-amplitude reflectors (Fig. 9). Based on a detailed comparison of the middle-fan meander belt sites (Sites 617, 620–622), Stelting et al. (1985) proposed the following lithofacies/seismic facies correlation for the middle fan channel. (1) The high-amplitude reflectors correspond to interbedded gravel, sand, and mud deposited at the base of the channel (channel-lag deposits; Sites 621 and 622). (2) The semitransparent reflections indicate sandy and silty "point bar" deposits (well developed at Site 622). (3) The transparent reflections, making up the upper part of the channel fill, typify clay and silt (Sites 621 and 622).

Sedimentary characteristics in the cores suggest that turbidity currents (both high- and low-density) and debris flows were the principal transport processes within the channel system (Stow et al., this volume; introductory chapter, this volume). Downfan changes in channel configuration are most likely the result of changes in these processes and of the volume of sediment maintained in turbulent suspension (i.e., carrying capacity). The variation in channel configuration and the migratory nature of the middle-fan channel are shown in Figure 9.

The first middle-fan channel crossing in Figure 9 is over Sites 617 and 621 (Figs. 4, 9A). The channel at this location is about 4 km wide and has a topographic relief of about 35 m. The base of the youngest fan lobe is truncated by the basal deposits of the channel, suggest-

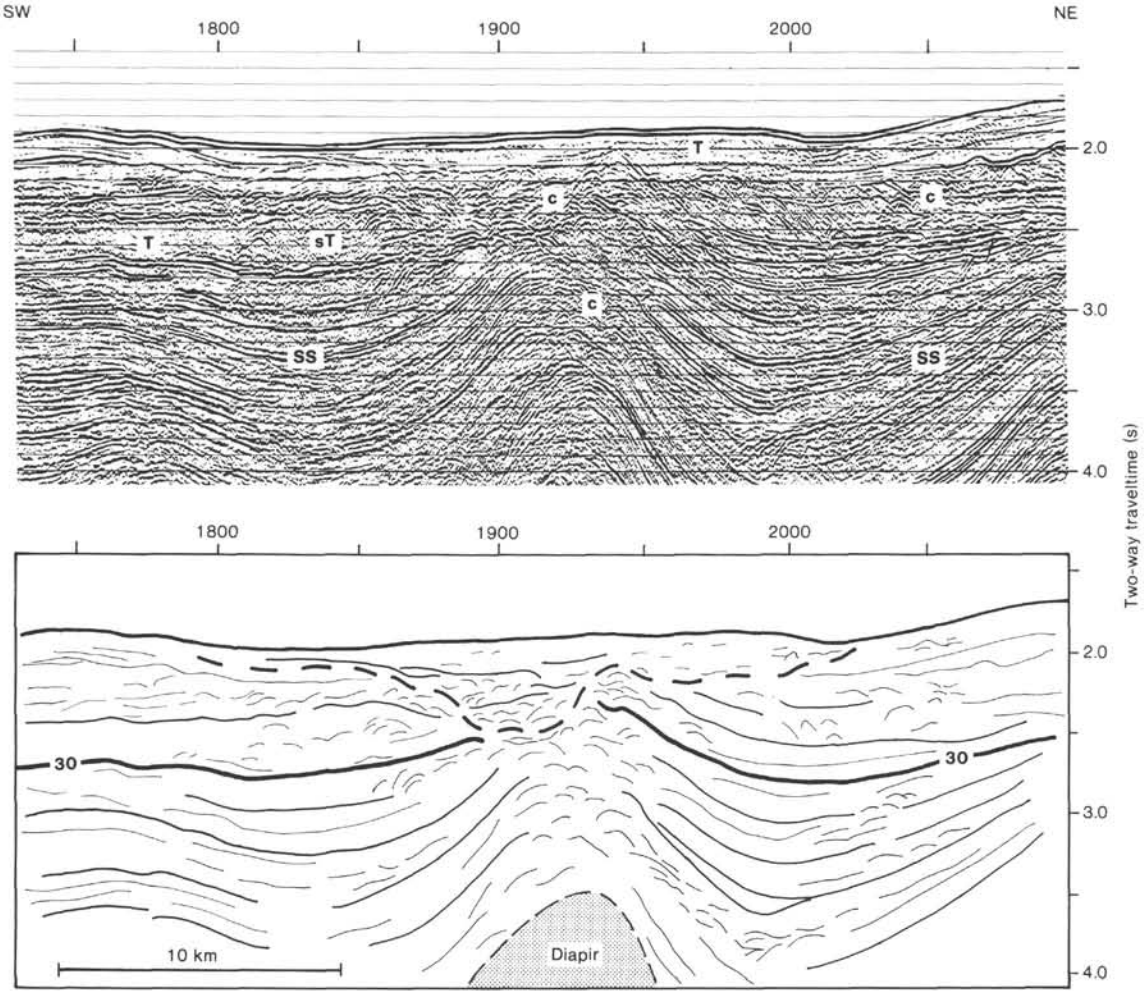

Figure 6. Multifold seismic profile and line drawing across upper fan showing modern channel (dashed in line drawing), intraslope-basin-type seismic sequences, and salt tectonics (Line MC-14). See Figure 4 for location; Table 1 for seismic facies symbols.

ing that channelization was initiated early in the development of the fan lobe. The lower part of the channel fill consists of high-amplitude reflectors (channel-lag deposits). The configuration of the reflectors suggests that the channel has migrated to the northeast and aggraded about 200 m (250 ms). Transparent reflections above the lag deposits indicate a muddy channel fill about 200 m (250 ms) thick. The lack of sandy material at the overbank sites (Sites 617, 620) suggests that channel relief was sufficient to prevent overbank spilling of the coarse fraction (Bouma, Coleman, and Leg 96 Scientists, 1985; introductory chapter, this volume).

A second line crossing the channel 60 km downfan from Site 621 shows that the width has decreased to about 3 km and the topographic relief to about 30 m (Figs. 4, 9B). This line crosses the channel over a meander loop. At this location, the channel system is migrating to the southeast. The initial channel, as denoted by the high-amplitude reflectors at the base of the channel, appears to have been at an oblique angle to this crossing. Development of the meander loop is suggested by the adjacent channel deposits (side-scan images collected during the site survey show two meander loops at this location). Distribution of the high-amplitude reflectors suggests that the channel migrated about 2.2 km and aggraded about 350 m (430 ms) at this location. The transparent seismic facies, interpreted as representing a muddy fill in the upper part of the channel, is only about 115 m (145 ms) thick.

The final middle-fan channel crossing is about 140 km downfan from Site 621 (Fig. 4) and is markedly different from that of the other two examples (Fig. 9C). The surface expression of the channel is much smaller, 1.5 km wide with about 18 m of relief. The aggradational channel complex is 6.5 km wide and rises about 40 m above the adjacent seafloor. This crossing shows that the channel has migrated about 2 km to the west and aggraded about 240 m (300 ms). It is significant that the high-amplitude reflectors extend to the seafloor. A muddy fill (indicated by transparent seismic facies), if present, probably is not more than 20 to 25 m thick. Therefore, much of the mud fill observed in the upper part of the channel crossings upfan (Figs. 9A, B) either did not extend this far downfan or, more likely, became unconfined and spread out across the overbank areas by this point. The irregular, discontinuous parallel reflectors (facies Pb) suggest that the channel shoaled, allowing the coarse-grained fraction of turbidity currents to spill over the channel more readily and deposit more sandy material in the overbank areas. However, no sites were drilled during Leg 96 to test this hypothesis.

Lower Fan

The lower fan begins at a water depth of about 3100 m and extends southeastward to the 3400 m isobath on the Florida abyssal plain. The lower-fan region is identifiable by a change in the nature of both the channel and the seismic characteristics, together with a reduction in seafloor gradient.

The lower-fan morphology is characterized by a poorly defined surficial channel complex that trends down the center of the fan lobe (Fig. 4) (O'Connell et al., 1985). This complex is about 5 km wide and is bordered by low topographic ridges (Bouma et al., 1983/84; Bouma, Stelting, et al., 1985). The channel decreases both in dimension and sinuosity downfan. A zone with several indistinct, subparallel echoes on side-scan sonar images trends subparallel to the modern channel; these features are interpreted as representing relict morphology from several older, abandoned channels, although apparently only one channel was active at any given time. Bifurcation is commonly observed near the downfan terminus of the channels.

Seismic profiles across the lower fan are characterized by parallel reflectors separated by thin units that contain wavy, segmented, tilted events, intermixed with transparent patches (Figs. 10, 11).

A seismic profile across the upfan portion of the lower fan (near Sites 623 and 624) shows numerous cut-and-fill features in both Wisconsin-age fan lobes (Fig. 10). Sediments recovered at these two sites, especially Site 623, consist of interbedded sands and muds, interpreted as alternating channel and overbank deposits (O'Connell et al., 1985). This interpretation appears to be consistent with the seismic section, which shows numerous cut-and-fill geometries interrupting the parallel reflectors (Fig. 10). In addition to the shallow channel geometries inferred in Figure 10, the parallel reflectors extending away from the channels tend to be lenticular in shape, suggesting that the density currents that flowed down the channel became less confined by the channel depression, resulting in sheet-sand deposition lateral to and beyond the channel termination.

The seismic section near the downfan terminus of the channel (Fig. 11) is significantly different from the previous profile. The reflectors are flatter, more continuous, and generally exhibit less divergence than those to the north. Channel geometries, including the modern channel, are no longer seismically discernible. Correlation of the seismic data with the predominantly sandy/silty sediment recovered at Sites 614 and 615 supports the idea of "sheet-sand" deposition (O'Connell et al., 1985). The lateral continuity of the parallel reflectors is relatively poor: they are intermixed with semitransparent to transparent patches. This observation implies that the lateral extent of the individual depositional units is also restricted. The high-amplitude triplet which corresponds to Horizon 30 identifies the carbonate debris-flow deposits encountered near the bottom of Site 615 (Brooks et al., this volume).

Channel Characteristics

An upfan channel crossing, about 20 km south of Sites 623 and 624, is shown in Figure 12A. Although this channel crossing is 185 km downchannel from the middle-fan crossing in Figure 9C, the physical dimensions have not changed drastically. The width of the channel is 1.2 km (versus 1.5 km) and it has a topographic relief of about 15 m (versus 18 m). Noticeably absent in the seismic profile are the high-amplitude reflectors that are so prominent on the middle fan. This channel is apparently centered between two buried topographic highs (highlighted in Figure 12A), which are inferred to be older "depositional lobes." These highs suggest that the position of the channel was controlled by preexisting topography.

The lowermost channel crossing (50 km downfan from the previous crossing) is directly adjacent to Site 615 (Fig. 12B). Channel dimensions are about 700 m wide, with 10 m relief. The continuity and flat character of the seismic reflectors directly below the channel suggest that those sediments were not deposited from the modern channel and also supports the idea that the channels on the lower fan are ephemeral (O'Connell et al., 1985). Sedimentation from this channel likely affected only the surficial sediments. The small scale of the channel exposed at the surface demonstrates that interpretation of similar-sized, buried channels in medium-resolution seismic records may not be possible (e.g., the morphologic expression is not apparent in Fig. 11).

CONCLUSIONS

1. The youngest fan lobe of the Mississippi Fan was deposited during the late Wisconsin glacial (after 55×10^3 yr. ago); the base of the fan lobe corresponds to seismic Horizon "20." Systematic downfan changes in the nature of the channel system, distribution of the seismic facies, and seafloor gradient allow this fan lobe to be divided into four major regions: canyon, upper fan, middle fan, and lower fan.

2. Seismically, the youngest fan lobe is characterized by eight distinct seismic facies (Table 1). The distribution of these facies reflects changing depositional processes across the fan lobe. Semitransparent and transparent reflections (seismic facies sT and T) dominate the canyon and upper-fan channel fill, the upper part of most of the middle-fan channel, and the "slump" areas in the middle fan; they are observed as thin patches in the overbank areas and are a minor seismic facies on the lower fan. Chaotic reflections (seismic facies c, a relatively minor facies) are commonly associated with seismic facies sT and T, particularly within the channel fill in the diapiric region (north of 27°20′N). Parallel reflectors are dominant in all overbank areas (except the "slump" areas) and in the lower fan. This reflector type consists of three discrete seismic facies: parallel, continuous reflectors (Pc); parallel, discontinuous reflectors (Pd); and parallel, irregular, discontinuous reflectors (Pb).

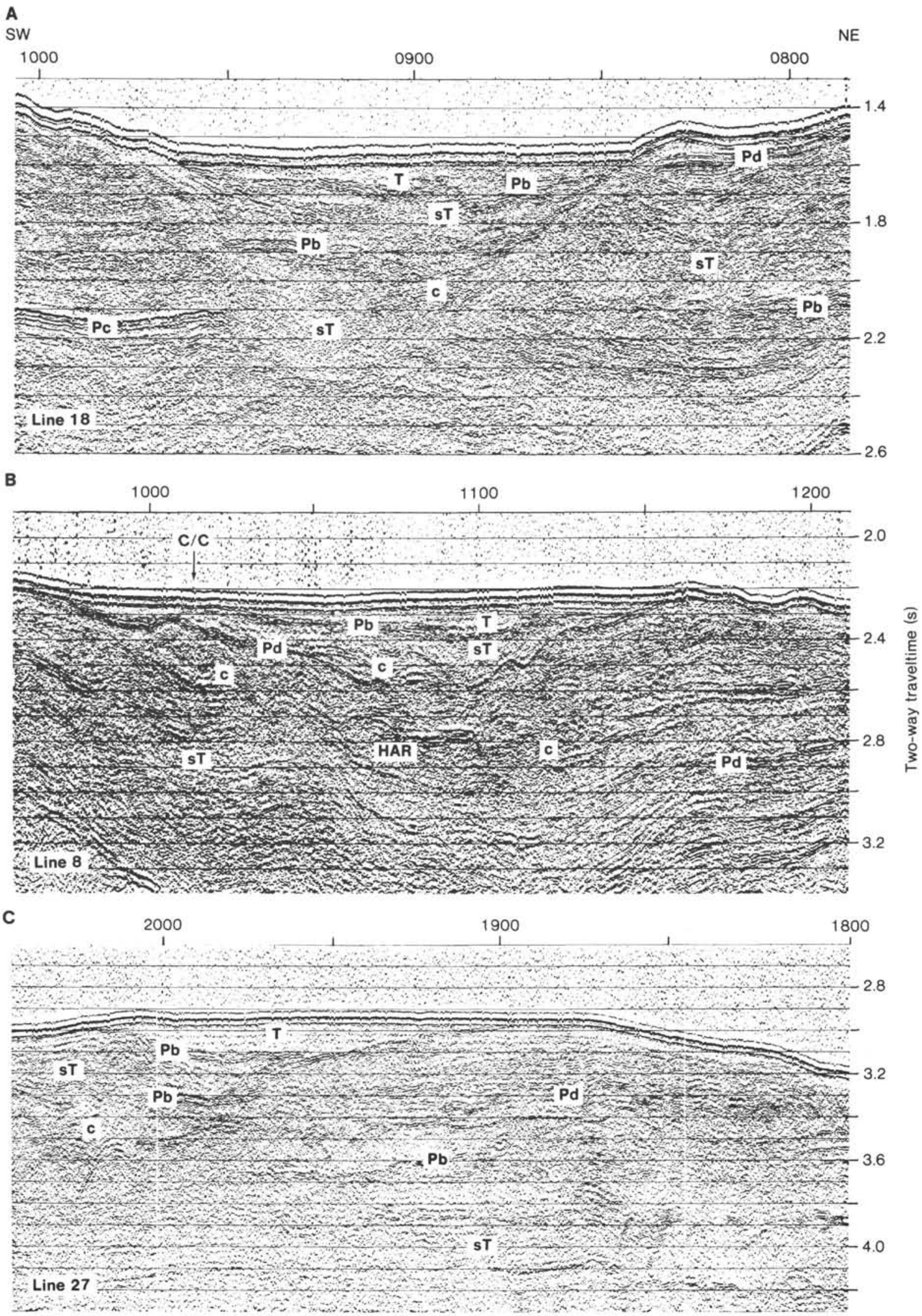

Figure 7. High-resolution (80 cu. in. water gun) seismic profiles and corresponding line drawings showing characteristics of upper fan channel (dashed in line drawings). Lines (R/V *Conrad*) identified on seismic profiles. See Figure 4 for location; Table 1 for seismic facies symbols. C/C = course change.

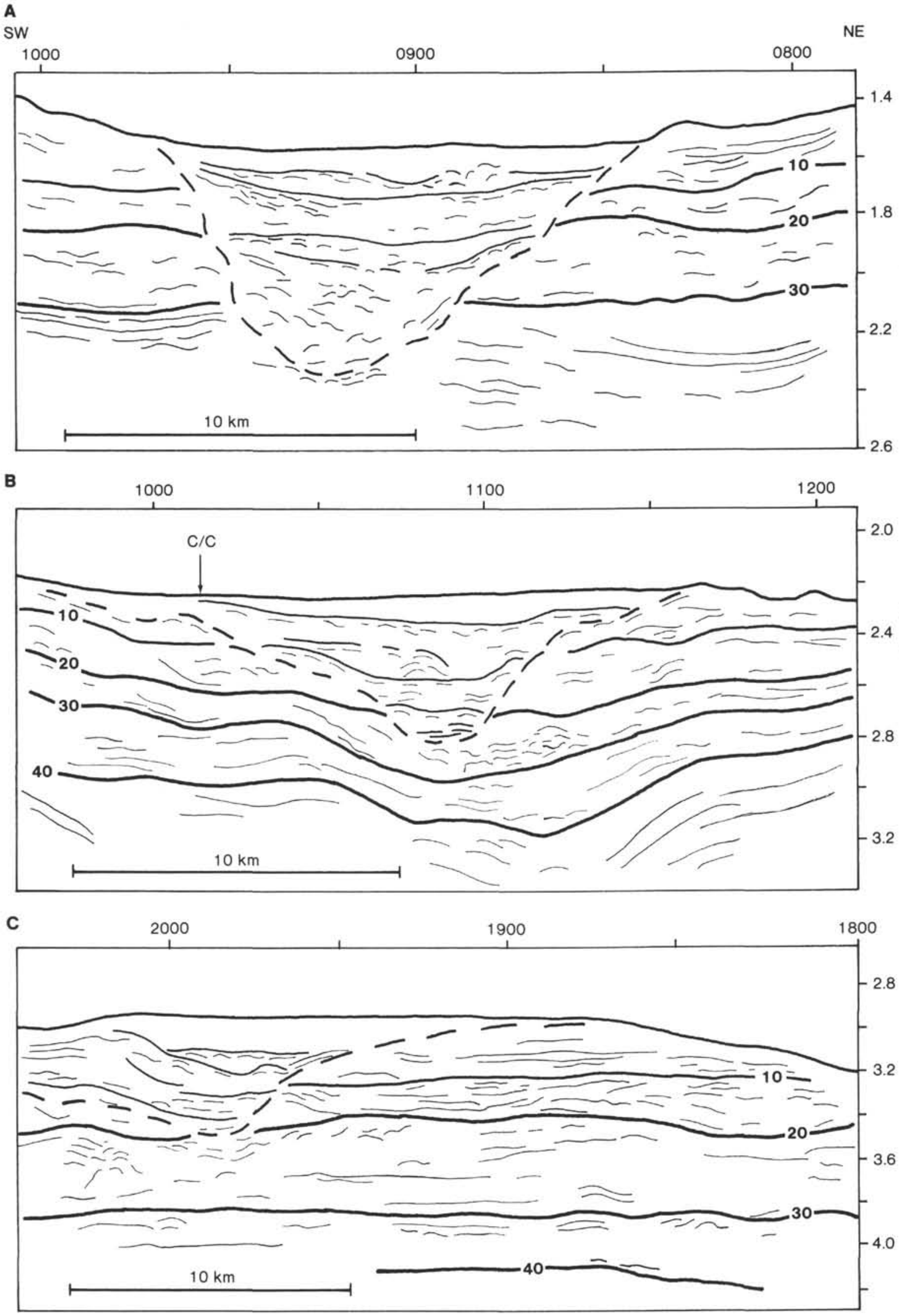

Figure 7 (continued).

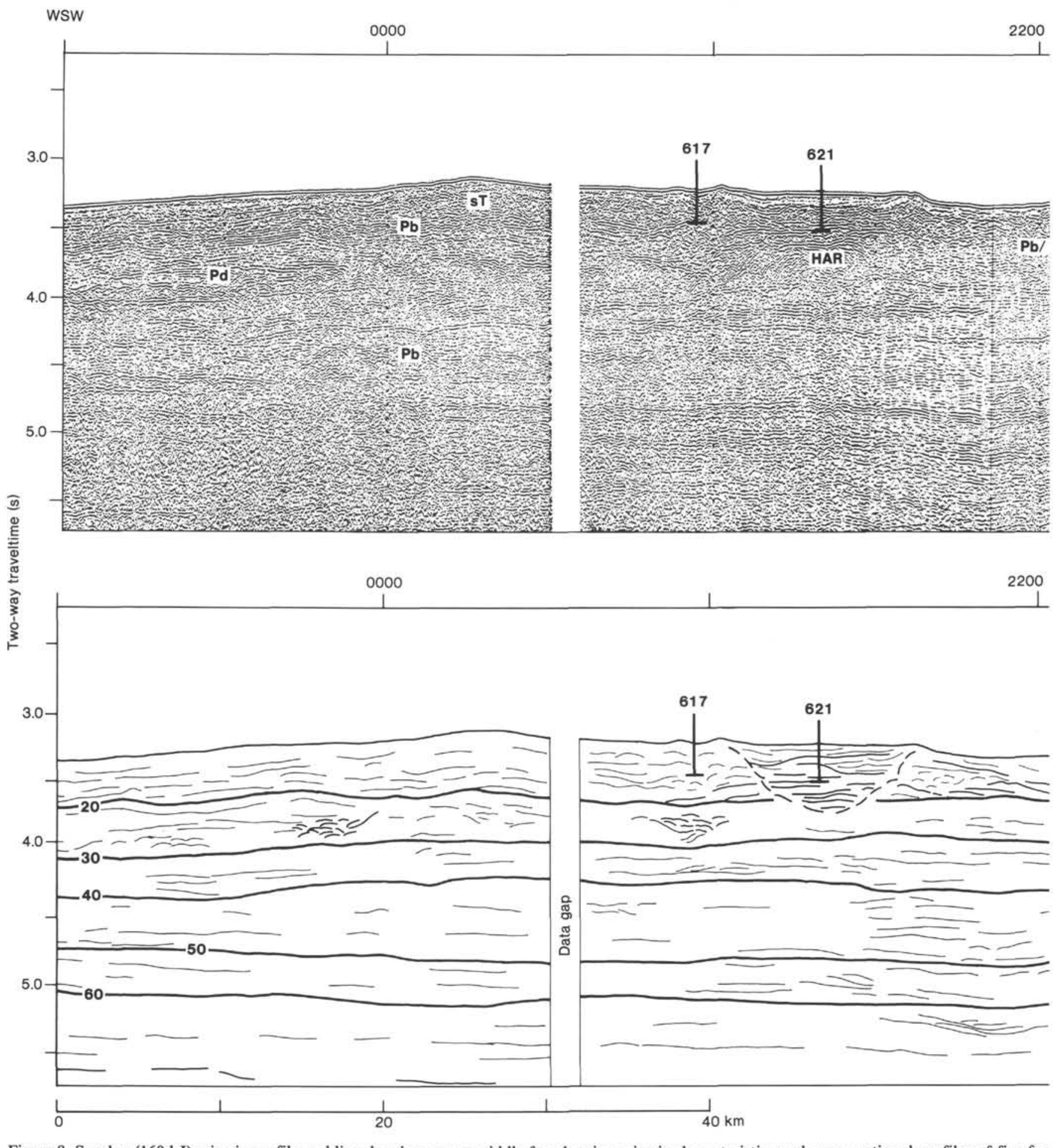

Figure 8. Sparker (160 kJ) seismic profile and line drawing across middle fan showing seismic characteristics and cross-sectional profiles of five fan lobes (U.S.N.S. *Kane*, Line KB-7). Tentative ages of major horizons listed in Bouma, Coleman, and Meyer (this volume). Extrapolation of Horizon 20 through "slump" area based on drilling results at Sites 616 and 620. Relative positions of Sites 617, 620, and 621 projected onto profile and drawing. See Figure 4 for location; Table 1 for seismic facies symbols.

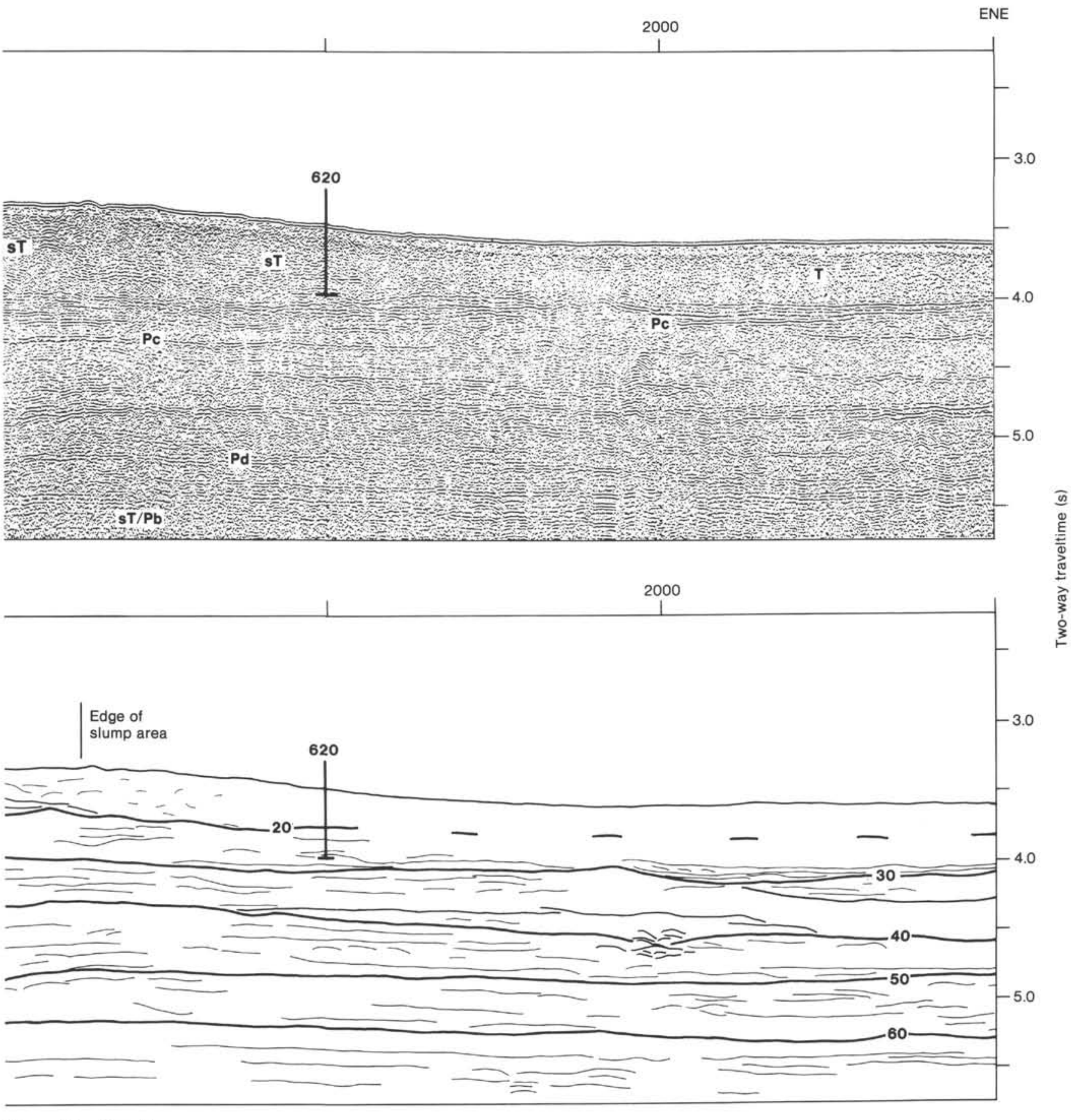

Figure 8 (continued).

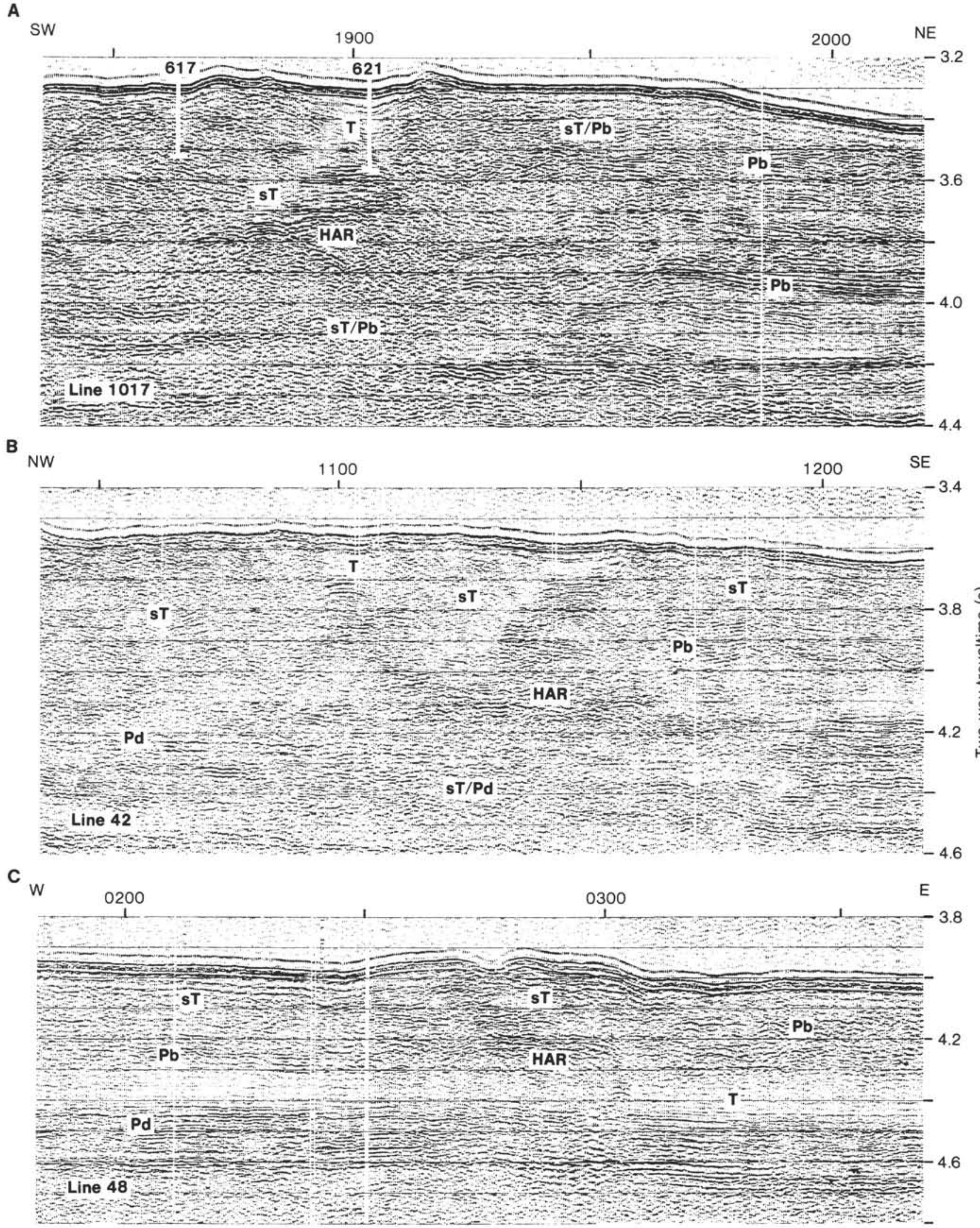

Figure 9. High-resolution (80 cu. in. water gun) seismic profiles and corresponding line drawings showing characteristics of middle-fan channel and location of Sites 617 and 621 (Fig. 9A). Lines (R/V *Conrad*) identified on seismic profiles. For a discussion of thalweg deposits in channel complex see text. See Figure 4 for location; Table 1 for seismic facies symbols.

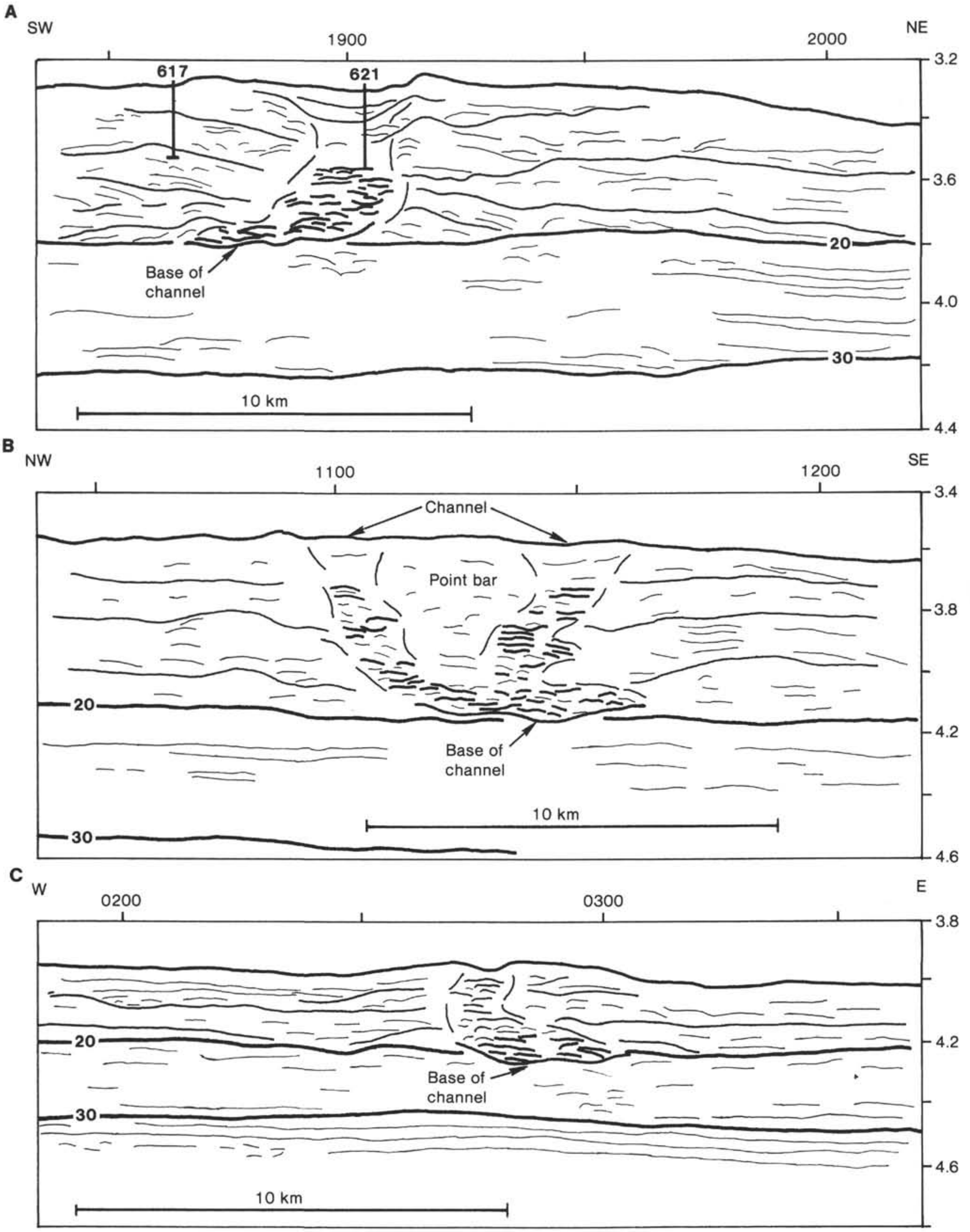

Figure 9 (continued).

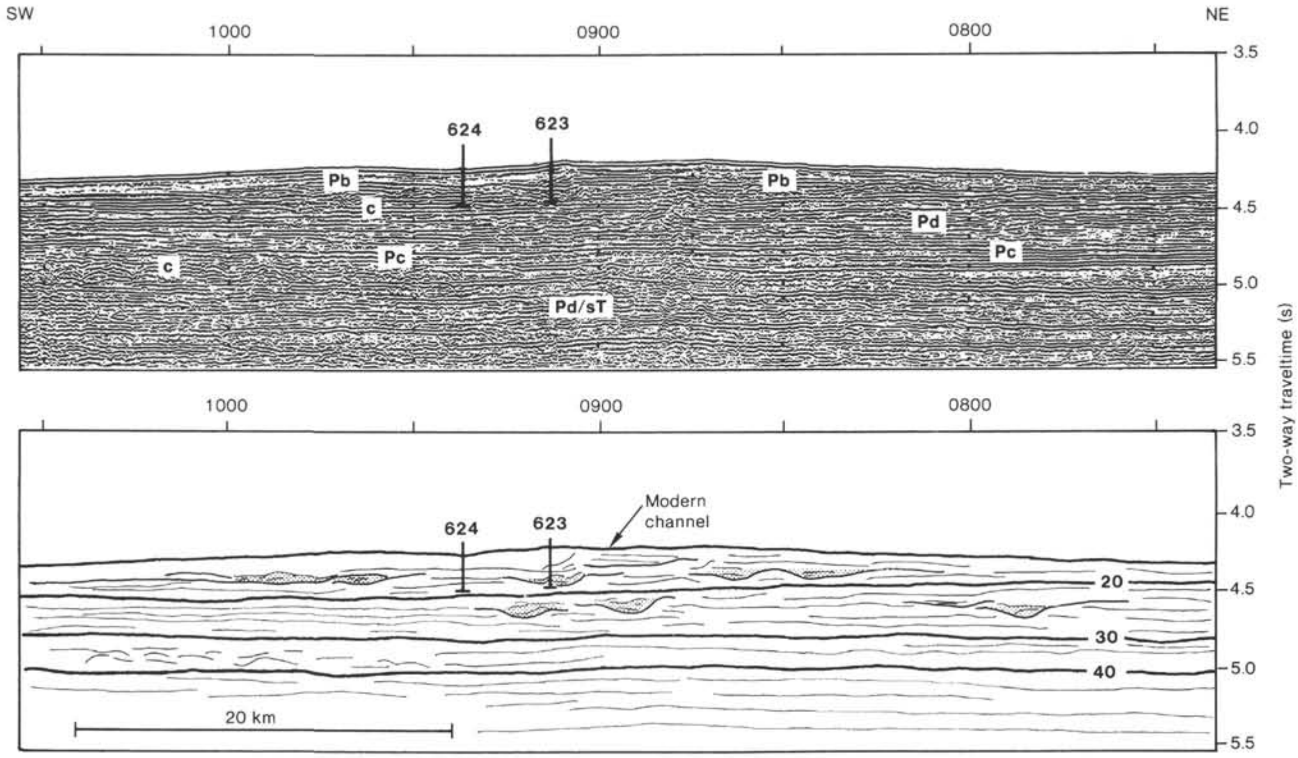

Figure 10. Sparker (160 kJ) seismic profile and line drawing over upfan region of the lower fan, showing inferred channels in Wisconsin fan lobes (U.S.N.S. *Kane*, Line KD-27). Relative positions of Sites 623 and 624 projected onto profile and drawing. See Figure 4 for location; Table 1 for seismic facies symbols.

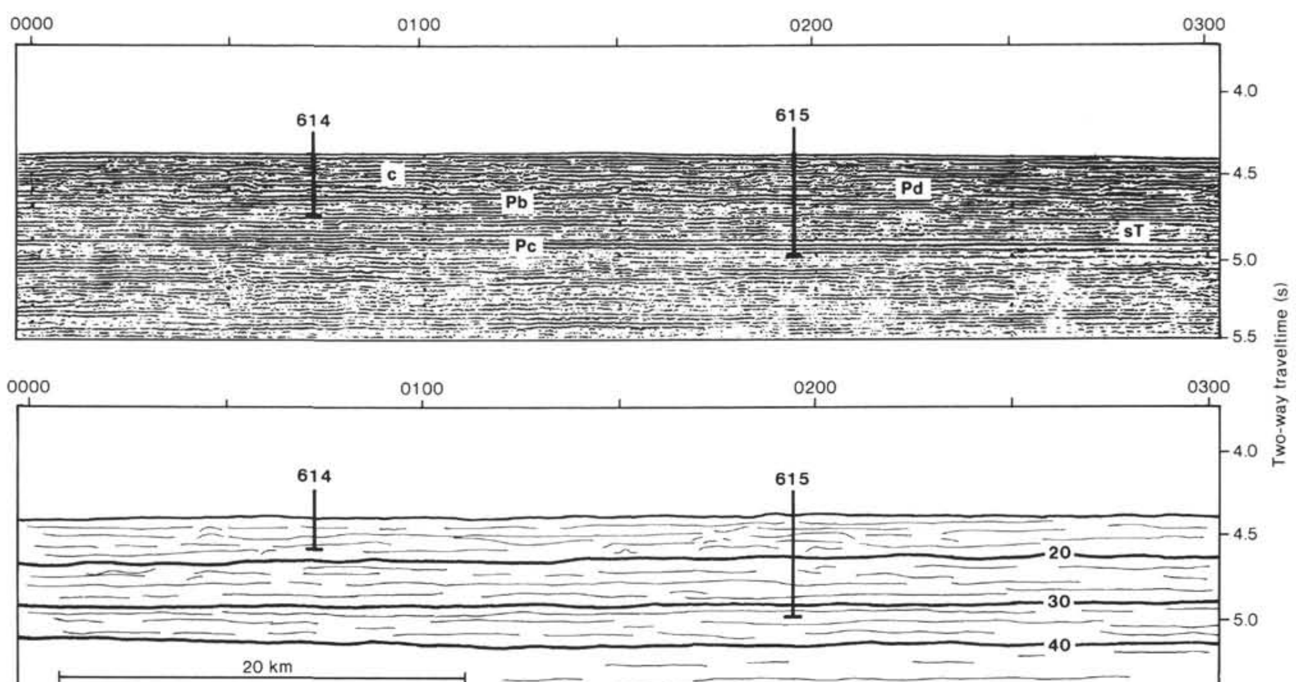

Figure 11. Sparker (160 kJ) seismic profile and line drawing over "distal" portion of lower fan showing seismic character in "sheet-sand" depositional area (U.S.N.S. *Kane*, Line KD-10). Relative positions of Sites 614 and 615 projected onto profile and drawing. See Figure 4 for location; Table 1 for seismic facies symbols.

Generally, the continuity of these reflectors increases away from the channel complex. High-amplitude reflectors (seismic facies HAR) are restricted to the basal part of the middle-fan channel and are the primary diagnostic feature of the channel in the middle-fan region. The final seismic facies, seismic sequences (SS), is composed of the other facies and is observed only in the northern region of the upper fan.

In the concept of a fan lobe, the canyon, upper fan, middle fan, and lower fan are distinguishable by the systematic downfan distribution of these seismic facies (Table 2). The erosional canyon and upper-fan areas are characterized by seismic facies sT and T; the aggradational middle fan consists of seismic facies HAR in the channel complex and seismic facies Pb, Pd, and Pc in the overbank areas; facies Pc and Pd dominate the aggradational lower fan, becoming more continuous (Pc) downfan.

3. The most prominent morphological feature of the youngest fan lobe is a leveed channel system. Downfan changes in the nature of this channel system reflect systematic changes in the depositional mode. The erosive character of the submarine canyon continues onto the northern part of the upper fan. South of the diapiric region (upper fan) the fan becomes aggradational in character, with a centrally located channel. This leveed channel is highly sinuous and migratory in nature, becoming smaller and less sinuous downfan. Whereas the middle-fan channel is confined within a meander belt, rapid deposition in the northern region of the lower fan, together with a decrease of channel gradient, may have caused the channel to shift positions periodically. Channels in the downfan part of the lower fan often bifurcate before they disappear visually, and the mode of deposition seems to change into "sheet-sand deposition."

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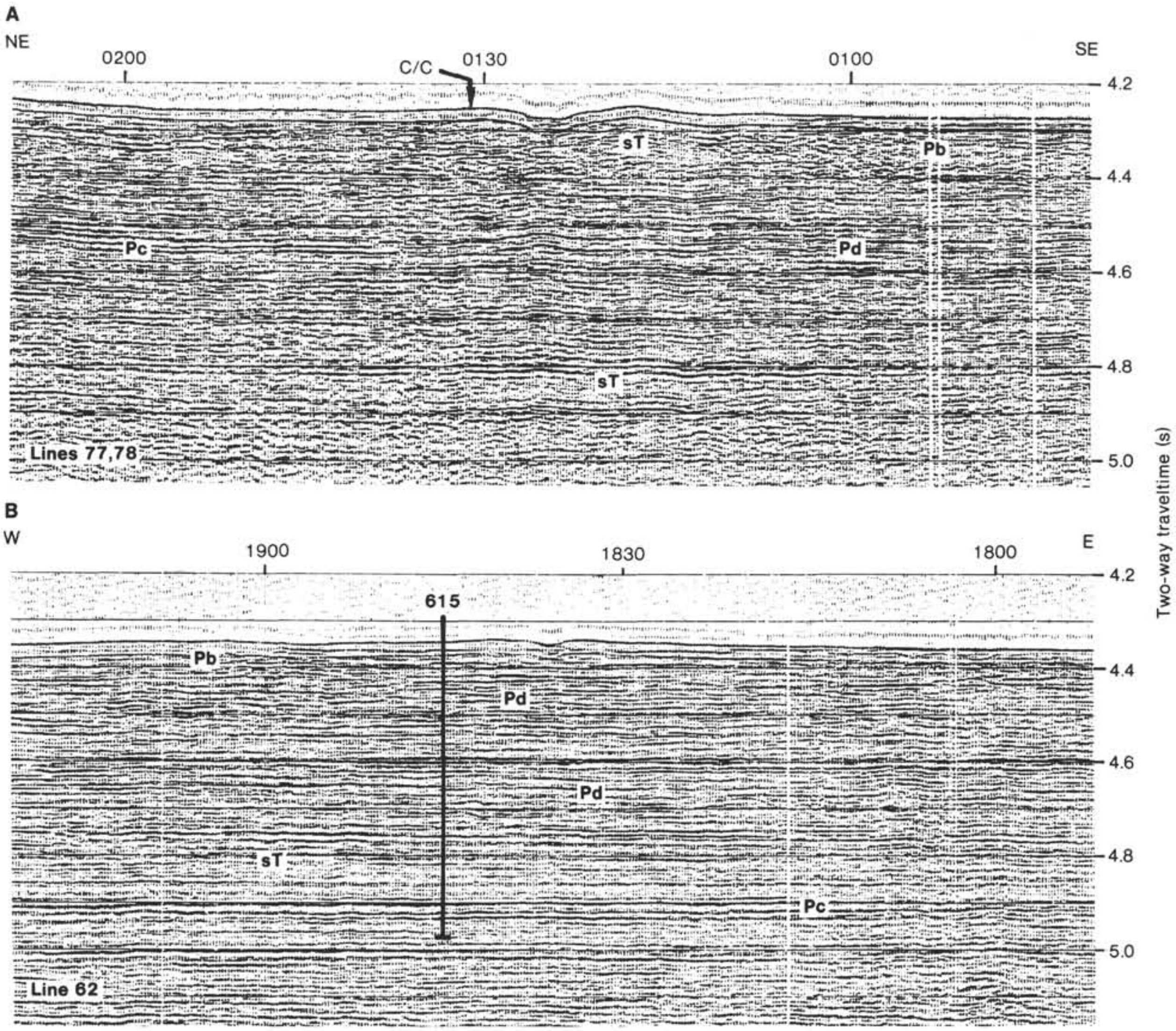

Figure 12. High-resolution (80 cu. in. water gun) seismic profiles and corresponding line drawings showing characteristics of lower-fan channel. Lines (R/V *Conrad*) identified on seismic profiles. Bold line ("paleobathymetry") on line drawing (A) at about 4.4 s denotes possible depositional lobes. See Figure 4 for location; Table 1 for seismic facies symbols. C/C = course change.

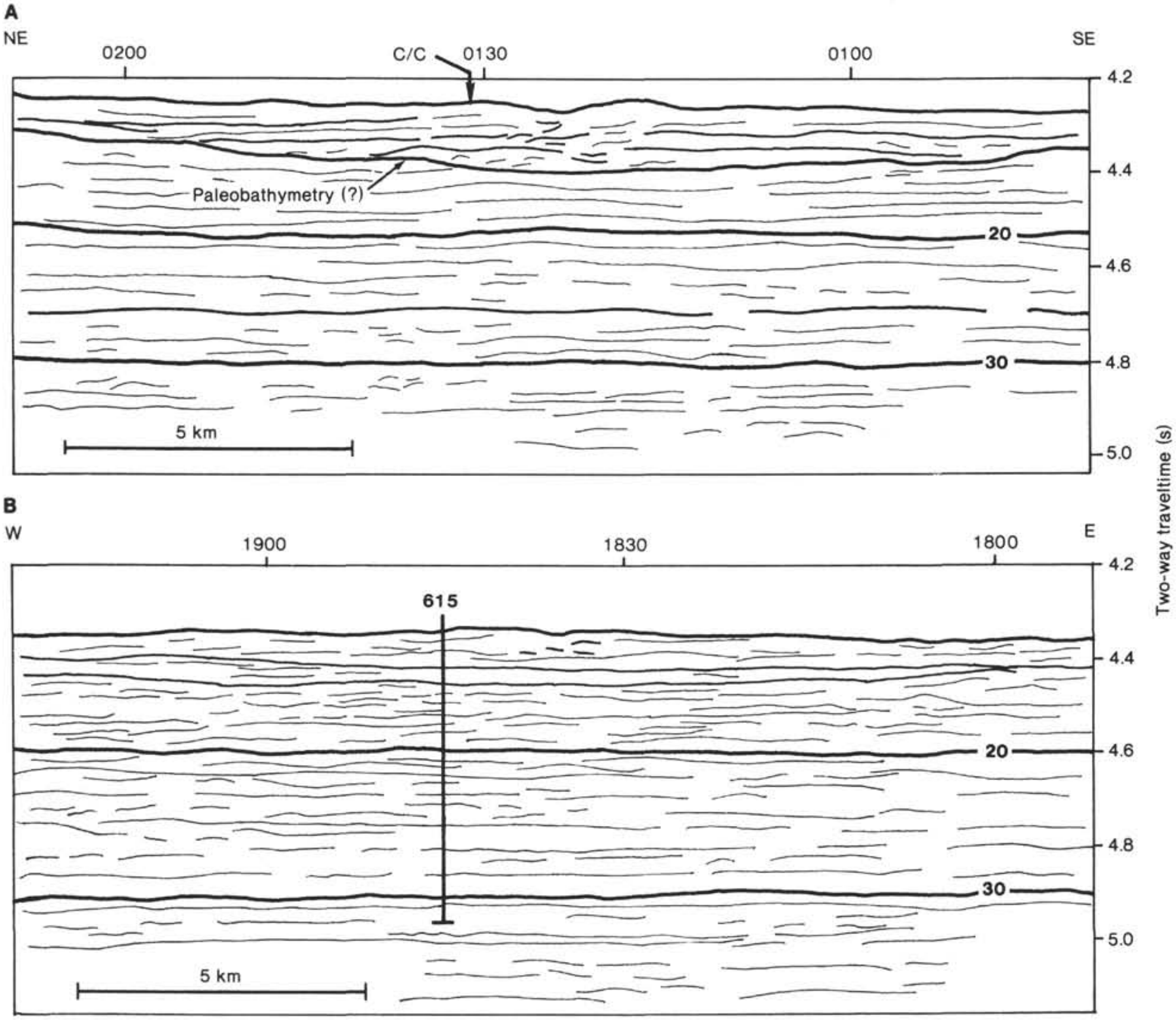

Figure 12 (continued).

Table 2. Summary of morpho-acoustic and sedimentologic characteristics of the youngest Mississippi fan lobe.

	Continental slope	Upper fan	Middle fan	Lower fan
Morphology				
Gradient	Continental slope: 1:40 to 1:90 (0.6°–1.4°) Canyon axis: 1:00 to 1:160 (0.4°–0.6°)	Overbank (average): 1:90 (0.64°) Channel axis: 1:125 to 1:200 (0.46°–0.29°)	Overbank, north of channel: 1:350 (0.16°) Overbank, south of channel: 1:160 (0.36°) Channel axis: 1:250 to 1:600 (0.23°–0.10°)	Overbank: 1:450 (0.13°) Channel axis: 1:500 (0.11°)
Longitudinal profile	Irregular	Slightly irregular to convex upward	Slightly convex upward	Smooth
Channel system	Primarily a conduit; width 8–18 km; relief 100–150 m (locally greater); channel fill 600–725 m.	Changes from erosional conduit (north) to an aggradational system (south); width 6–16 km; relief 20–100 m; channel fill 425–725 m.	Aggradational, sinuous, and migratory. Width 0.5–4.0 km; relief 25–50 m; channel fill 250–425 m.	Ephemeral, shifts laterally. Width typically 700–1200 m; relief 10–18 m; channel fill 50–125 m.
Seismics				
Overbank area	Continental Slope: irregular wedges bounded by discontinuous reflectors, including facies sT and Pb. Reflectors truncated by canyon; locally thinning and onlapping onto diapirs. Facies c common. Slump structures observed locally.	Lenticular wedges bounded by discontinuous reflectors, including facies sT and Pb. Wedges locally disrupted by diapirs in north; laterally more extensive in south. Facies c most common in diapiric region.	Facies sT to Pb adjacent to channel; downlap ontobase of fanlobe. Facies Pd to Pb with patches of sT south of channel. Extensive transparent zone ("slump area") north of channel.	Facies Pc to Pd with patches of sT; facies Pb to c (cut-and-fill geometries) common in upfan area.
Channel complex	Mississippi Canyon: thick semitransparent intervals separated by Pd intervals (cyclic ?). Facies c common to rare.	Cyclic (?) sequences of semitransparent intervals with facies Pb separated by facies Pd; upper sequence transparent. Sequences thin downfan; facies Pb increases in abundance. High-amplitude reflectors present as thin zone at base of channel. Facies c most common in diapiric region.	Facies HAR dominant; grade to facies sT on point bar side. Upper part channel fill transparent, with low-amplitude facies Pb; thins down-channel.	Modern channel determined more by topographic relief than seismic character; fill consists of facies Pb to sT (amplitude lower than in overbank area). Buried channels identified by small cut-and-fill geometries.
Lithology and facies	Dominated by fine-grained sediment. Canyon fill comprises slumped mud in lower part, laminated clays with silt and sand stringers in upper part. Fining- and thinning (?)-upward vertical sequences.	Dominated by fine-grained sediment. Silt and sand stringers common in overbank seaward of diapirs. Sands, gravels, and muds at base of channel; mainly mud above base. General fining- and thinning (?)-upward vertical sequences.	Overbank: dominantly fine-grained sediment; thin-bedded silty turbidites common adjacent to channel. Channel: sand and gravel interbedded with mud in lower part; clay with rare silt layers in upper part. Fining-upward sequences.	Interbedded sand and mud; mud dominant in upfan area, sand dominant in "sheet-sand" depositional area in the more distal region.
Sedimentary processes	Large-scale slope failure and slumping along canyon margins. Canyon: slumping and debris flows (primary); turbidity currents and hemipelagic sedimentation (secondary).	Slumping common along channel margins and adjacent to diapirs. Slumping, debris flows, and turbidity currents in channel. Hemipelagic deposition minor.	Large-scale slumping and sliding, and low-concentration turbidity currents in overbank. Slumps, fluidized debris flows, and high-concentration turbidity currents in channel. Hemipelagic deposition minor.	Predominantly turbidity currents, with channelized and overbank spilling (upfan area) and nonchannelized (distal area). Slumps and hemipelagic deposition minor.

Note: for facies descriptions see Table 1.