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CHAPTER 38

Mississippi Fan Sedimentary Facies, Composition, and Texture

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Abstract

Eight different sedimentary facies recognized in the Mississippi Fan sediments drilled during DSDP Leg 96 are defined on the basis of lithology, sedimentary structures, composition, and texture. Pelagic biogenic sediments are of minor importance volumetrically compared with the dominant resedimented terrigenous facies. Clays, muds, and silts are most abundant at all sites, with some sands and gravels within the mid-fan channel fill and an abundance of sand on the lower fanlobe. Facies distribution and vertical sequences reflect the importance of sediment type and supply in controlling fan development.

Introduction

This contribution documents the sedimentary facies recovered at the nine Mississippi Fan Sites during DSDP Leg 96 and summarizes the preliminary results of our sedimentological analyses.

Other chapters in this publication outline the general geological framework (Chapter 21) and certain specific attributes of the fan (Chapters 40, 42). The following points, however, are worth emphasizing for this facies analysis. The Mississippi Fan is a relatively large, mud-dominated, elongate-type fan [1,2]. The immediate source area is a major delta and prograding shelf with shifting submarine canyons. Very rapid fan construction occurred throughout the Pleistocene, with a complex interplay of sedimentary, sea-level, and tectonic controls on fan development.

The nine fan sites were drilled to depths of between about 150 and 525-m subbottom depth and were cored continuously. Core recovery was best in the top 80 to 100 m although, in most cases, a good suite of wire line logs has enabled us to interpret lithologies in the deeper parts of wells where core recovery was lower.

Sedimentary Facies

Eight sedimentary facies are recognized in Mississippi Fan sediments on the basis of lithology, sedimentary structures, composition, and texture (Fig. 1) (see also Chapters 40, 42, 44, 46). Calcareous biogenic sediments are volumetrically minor, but significant at certain horizons. They can be divided into two facies on the basis of the carbonate content. Terrigenous sediments are dominant and can be divided into six distinct facies, ranging from the finest-grained clays and muds to coarser-grained pebbly muds and gravels. There is some gradation between facies, and locally all occur intermixed within disturbed units.

1. *Oozes and Muddy Oozes*

The biogenic sediments are a minor but ubiquitous facies that were recovered as a relatively thin unit (5 to 50 cm) at the surface of most sites. Staining with Rodamin-B dye commonly showed that none of the organisms recovered were living, so that the actual thickness of the unit on the seafloor is probably slightly greater than the core interval obtained. The facies also occurs as a thick unit (about 30 m) at the base of the deepest hole penetrated on the lower fan (Site 615).

In the surficial biogenic layer, there is no internal bedding or other primary sedimentary structure visible. The sediment appears homogeneous and is probably thoroughly bioturbated. It is very poorly sorted, with a fine-sand to silt-size grade for the biogenic component and a variable fine-silt to clay grade, terrigenous admixture. It is a yellowish brown, marly calcareous ooze in which planktonic foraminifers are dominant, nannofossils and siliceous or-

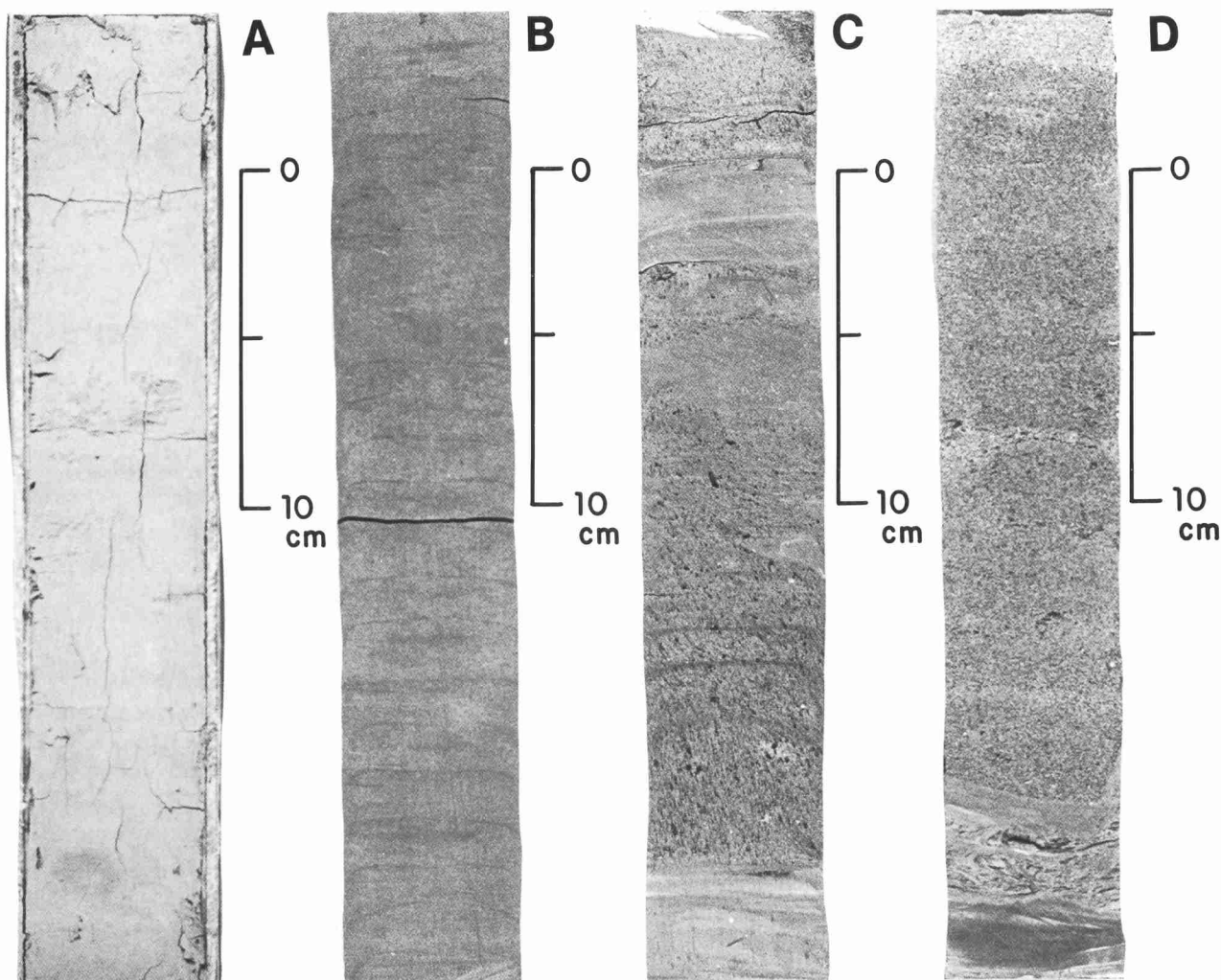


Figure 1. Photographs of seven of the sedimentary facies from Mississippi Fan cores (subbottom depths correspond to top of each photograph). (A) Ooze, very fine-grained, nannofossil dominant (Site 615; 480.9 m). (B) Mud with very thin, dark mud laminae (Site 616; 306.0 m). (C) Silty mud, poorly-sorted and carbonaceous near base grading up to fine mud (Site 615; 192.4 m). (D) Sand, lower part of medium-thick graded sand bed (Site 623; 65.9 m). (E) Silt-laminated mud, occurring as probable graded laminated units (Site 621; 158.6 m). (F) Pebbly mud (Site 621; 195.5 m). (G) Grave (Site 621; 214.3 m).

ganisms form less than 10% of the sediment, and terrigenous material comprises up to 25% of the sediment. Rare, black, authigenic iron-sulphide-rich mottles are present.

The light bluish-gray to yellowish gray oozes recovered near the base of Site 615 are also relatively homogeneous and structureless when observed visually (Fig. 1A). However, there are subtle grain size variations within an overall normally graded sequence that extends through the upper 28 m of recovered section. This ooze grades from a thin (10 cm) coarse gravelly layer at the base, with chalk and shelf-depth bioclastic debris up to 15 mm in size, through a shelly, foraminiferal-rich nannofossil ooze to a very fine-grained, pure nannofossil ooze in the top several meters. The biogenic material consists of a high percentage of re-

worked Cretaceous, Pliocene, and Pleistocene forms as well as some contemporary Pleistocene planktonics. This sequence overlies approximately 1 m of very fine-grained Pleistocene pelagic nannofossil ooze and calcareous mud without reworked fauna.

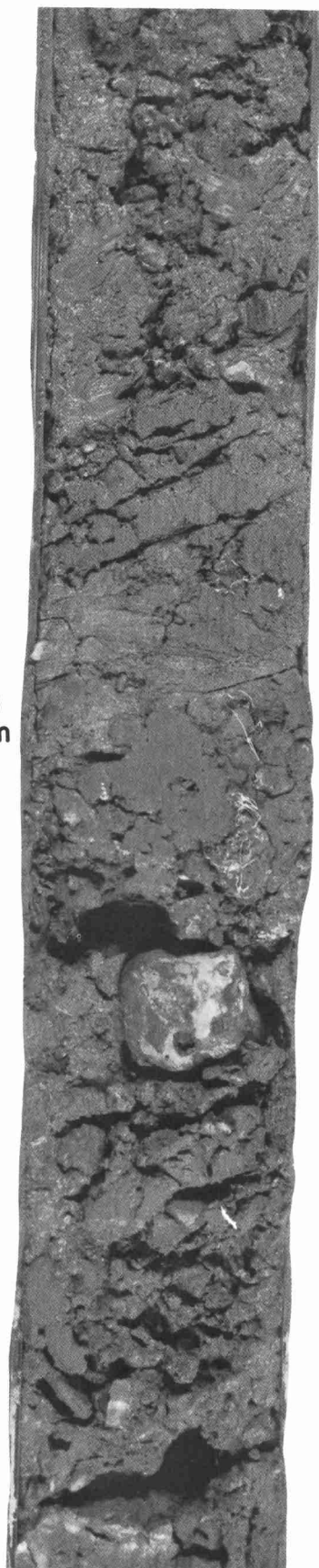
2. Calcareous Muds

There is a complete gradation between the biogenic oozes and calcareous mud facies, the distinction being made on the basis of carbonate percent. At some sites, the surficial biogenic-rich layer contains less than 50% CaCO_3 and is more properly termed "calcareous mud." It is structure-



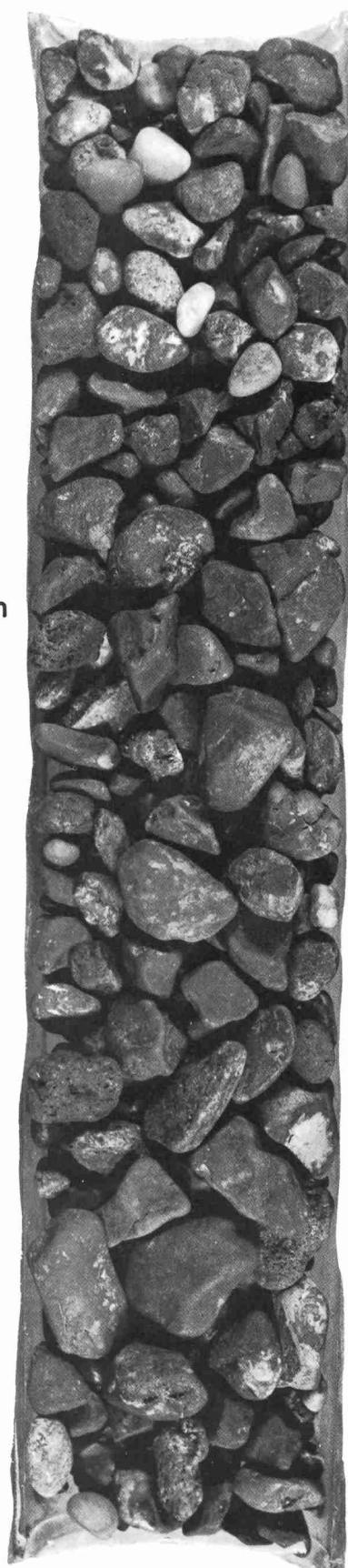
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less, fine-grained, and has a poorly-sorted admixture of sand-sized planktonic foraminifers, calcareous nannofossils, rare siliceous biogenics, and terrigenous silt and mud.

The very bottom 50 cm of recovered section at Site 615 is a brownish-colored calcareous mud with up to 15% foraminifers and nannofossils that underlies the nannofossil ooze. It is mainly structureless or, in part, indistinctly laminated.

3. Clays and Muds

This sedimentary facies represents the very finest-grained terrigenous sediments recovered, including the fine muds and true clays, having between 60 and 90% clay-size fraction and generally less than 0.5% sand-size material. These sediments occur in thin to very thick units, commonly without any clear bedding or primary sedimentary structures. Probable bioturbational mottling, however, is rare so that the homogeneity appears primary. In other cases, there are rare, very thin, silt laminae or a distinct color banding, commonly accentuated by dark-colored, iron-sulphide-rich bioturbationally mottled layers. Much of the apparently structureless muds have a very subtle, regular banding (Fig. 1B) only evident on close inspection or on X-radiographs (Chapter 44).

These clays and muds are dominantly terrigenous (quartz, feldspar, and clay minerals), with a small (< 5%) percentage of calcareous nannofossils, including both contemporary Pleistocene and reworked Pliocene forms. In the upper parts of the mid-fan channel sites, they locally occur as dark-colored gas-disrupted muds.

4. Silty Muds and Muddy Silts

The coarser-grained muds and poorly sorted silts form a facies gradational with the finer clays and muds. They contain between 10 and 60% clay and up to approximately 5% sand. This sedimentary facies forms beds from about 5 cm to 1 m or more in thickness, or occurs as very thick, essentially unbedded, visually structureless intervals. Silt-sized quartz and clay minerals are the dominant components, with minor feldspar, carbonate grains, micas, lignite, and heavy minerals. Many of the grains appear to be partially altered or coated with iron-oxides.

This facies also includes distinctive dark-colored lignite-bearing, silty mud beds, ranging from about 5 to 50 cm in thickness. These lignite-bearing beds occur in three main types: 1) those that are completely structureless with gradational contacts; 2) those that are organized into distinct beds, in some cases with indistinct normal grading and floating mud clasts; and 3) those that occur as clearly graded beds, commonly forming part of a thicker graded bed from laminated silt or sand at the base to fine-grained homogeneous mud or clay at the top (Fig. 1C).

5. Silt-Laminated Muds

The most common sediments at many of the sites are silt-laminated muds, occurring over intervals of a few centimeters to a few tens of meters in thickness. This sedimentary facies ranges from uniform muds with only 5 to 10% thin silt laminae to muds with over 50% silt laminae and thin silt beds (Fig. 1E). Visually observable laminae frequency may reach 400 to 500 per meter of section. However, the very thin silt laminae are difficult to resolve visually and X-radiographs show a still greater abundance in parts. The thicker laminae commonly show internal parallel lamination or micro-cross lamination and slight normal grading. The bases are commonly sharp, locally scoured, loaded, and with flame structures; the tops may be sharp or gradational.

In many cases, the laminae are more or less regularly spaced and apparently ungrouped. However, at least three types of groupings or graded laminated units are recognized, each ranging from about 3 to 10 cm in thickness: 1) units of up to 10 to 15 laminae that show a regular upward decrease in thickness and grain size of laminae; 2) units with fewer silt laminae that grade upwards through gray, reddish, and gray-black mottled mud, and 3) more irregular units with discontinuous and lenticular laminae showing load, flame, and micro-slump structures indicative of very rapid deposition.

This facies is compositionally and texturally very similar to the silty mud and muddy silt facies, being fine-grained and dominantly terrigenous, but with a much better sorting in terms of separation of the silt and clay fractions. The silts locally include significant angular detrital carbonate and, more rarely, volcanic ash.

6. Silts and Sands

Silts and sands are a common facies in parts of the fan, and occur in intervals from less than 10 cm to over 10 m in thickness. Sand loss by wash out and section increase by flow-in during the coring process mean that some of the thickest (1.5 to 10 m) sandy intervals recovered probably do not represent single bed thicknesses (see Chapter 36).

The thicker beds commonly appear to be structureless, whereas most of the thinner sand and silt beds show some internal sedimentary structures. Many of the beds show clear positive grading (Fig. 1D). These are commonly organized in partial Bouma T_a to T_b sequences with massive, parallel, and cross-laminated divisions. The bottom contacts are invariably sharp and commonly loaded or scoured; the upper contacts are either sharp or gradational.

Grain size varies both within and between beds. The maximum size at the base of the thicker beds is as much as 5 mm (pebble-sized). The mean size is most commonly fine to medium sand (125 to 250 μm), and there is a high proportion of silt. The larger grains are commonly well-

rounded, spherical or elongate, and highly polished. The thinner beds tend to be better-sorted, medium to coarse silt-sized (16 to 63 μm), and with a maximum size rarely exceeding 150 μm (fine sand). The finer grains are often highly angular and irregular in shape. There are rare medium- to coarse-grained thin sand beds.

The sands and silts are dominantly terrigenous and quartzose with minor biogenic material.

7. Muddy Gravels and Pebbly Muds

This is a relatively rare facies encountered only at the two mid-fan channel sites in intervals up to 4-m thick (Chapter 40). Pebbles are as much as several centimeters in diameter, very poorly sorted, and set in a clay-silt-sand matrix (Fig. 1F). There are no bedding or internal structures evident. Clasts include chert, quartz, jasper, mudstones, and shell fragments.

8. Gravels

True clast-supported gravel was recorded only in a 60 cm-thick section near the base of Site 621 in the channel thalweg (Fig. 1G). Clasts range up to 3 cm in size, are very poorly sorted, and have a composition similar to that of the pebbly mud facies. The clasts are mostly rounded to subrounded in shape, and show an abrupt grading over a few centimeters into overlying medium-grained sands. The coring process may have washed out any fine-grained matrix and disturbed any original structure that might have been present.

Sediment Composition

There is a broad compositional similarity of sediments within any one facies, as well as between many of the facies. This uniformity is reflected in the sand and silt mineralogy (thin-section and grain-mount data), clay mineralogy (X-ray diffraction analyses), inorganic geochemistry (X-ray fluorescence spectrometry), and carbonate content (bomb analyses). Standard analytical techniques were used in each case.

1. Sand and Silt Mineralogy

The sand and sandy silt beds are uniformly terrigenous (95 to 98%). Quartz is the dominant mineral, with secondary feldspars, micas, and carbonates, and accessory heavy minerals, glauconite, and lithic fragments. The heavy mineral suite commonly includes amphiboles, pyroxenes, epidote, zircon, tourmaline, and opaque grains. The small biogenic fraction (2 to 5%) comprises foraminifers, shallow-water shell debris, and lignitic material.

The generally finer-grained, thin silt laminae show a similar composition to the thicker sand beds but commonly have, in addition, a variable and significant proportion (10 to 25%) of clastic carbonate material of undetermined origin. The silt laminae as well as the dispersed silt fraction of the silty mud and muddy silt facies appears relatively richer in altered or iron-stained grains of indeterminate composition. Volcanic ash is locally important.

2. Clay Mineralogy and Inorganic Geochemistry

The less than 4- μm size fraction from all eight facies types (120 samples) was analyzed by X-ray diffraction and semi-quantitative estimates of mineral abundances made from peak-height and peak area measurements. A generalized "average" value shows that the four main clay minerals identified (kaolinite, chlorite, illite, and smectite) are each present in comparable proportions, although smectite is locally more abundant, quartz and feldspars occur in lesser amounts (about 8 and 5%, respectively), and calcite, dolomite, and aragonite are variably present in minor quantities.

In fact, the ranges of clay mineral abundances are quite large, although it is difficult to correlate this variability with differences in facies or location on the fan. The only apparent facies differences occur in the oozes and muddy oozes, which show relatively greater calcite and aragonite, and in the thick sands, which have relatively greater quartz and feldspar, a higher chlorite to kaolinite ratio, and a generally smaller clay-size fraction. It is partly these facies differences that are also reflected in the observed regional variations that show the lower-fan sites to have relatively more quartz and feldspar than the mid-fan sites, and the mid-fan overbank sites to have relatively more carbonate than the mid-fan channels or the lower-fan sites.

Inorganic geochemical data from some 150 ground whole-rock samples have still to be analyzed in detail. The generalized "average" composition of major element oxides is: SiO_2 (50 to 60%), Al_2O_3 (10 to 15%), $\text{FeO}/\text{Fe}_2\text{O}_3$ (4 to 6%), MgO (2 to 3%), CaO (2 to 4%), Na_2O (2%), and K_2O (2 to 5%) with minor amounts of MnO , TiO_2 and P_2O_5 . The SiO_2 abundance varies more widely than this range, but in an inverse relation with CaO and Al_2O_3 . Trace element abundances measured are all relatively low to average compared with data from other deep-sea sediments.

3. Carbonate Content

The percentage of carbonate was measured for over 200 samples and shows wide variation from 0 to more than 80%. The true oozes contain over 75% carbonate, the muddy oozes have an admixture of up to 50% terrigenous material, and the calcareous muds range from 10 to 50% carbonate. In each of these facies, the carbonate is dominantly pelagic

foraminifers and nannofossils; however, in the resedimented oozes at the base of Site 615, benthic foraminifers and shallow-water shell debris are also present.

The terrigenous facies mostly contain less than 10% carbonate (rarely up to 18%), and this component is a mixture of mainly reworked pelagic biogenics and carbonate silt of indeterminate origin. The lower-fan sites (Sites 614 and 615) average 2.8% and the mid-fan channel sites average 3.7% carbonate, whereas the overbank sites on both the mid-fan (Sites 616, 617, and 620) and lower-fan sites (Sites 623 and 624) average around 8% carbonate. These apparent regional differences may be related to facies differences, because there is less carbonate in both the silt-sand and clay-mud facies than in the silt-laminated mud facies.

Sediment Texture

The grain size characteristics just described for each of the separate facies were determined from some 120 granulometric analyses using the sieve and pipette method. The differences between sedimentary facies are clearly distinguished using either a triangular plot of sand-silt-clay percentage (Fig. 2a) or typical cumulative frequency curves (Fig. 2b). The thick-bedded coarser-grained sands and finest-grained clays are both relatively well-sorted, but with a distinct fine tail (hyperbolic curve). The silt-laminated muds appear less well-sorted with a broad fine tail (hyperbolic-logarithmic curve), although individual silt and mud laminae show much better sorting when analyzed separately. The silty mud facies are poorly sorted with a broad coarse tail (parabolic-logarithmic curve). Only a few analyses are presently available for the ooze and calcareous mud facies, and these generally show an irregular very poorly sorted distribution (logarithmic-tending curve).

All the sediments drilled are unconsolidated with moderate to very high water contents and porosity values. Physical property measurements are reported elsewhere (Chapter 43) and grain shape and surface texture analyses have not yet been completed.

Discussion

1. Facies Interpretation

Apart from the thin surface layer of calcareous muds and oozes slowly deposited by pelagic or hemipelagic settling, most of the sediment recovered shows evidence of resedimentation from shallower water. This evidence includes: 1) the very rapid rates of sedimentation (6 to 12 m/1000 yr) (Chapter 39); 2) the dominant terrigenous composition with land-derived plant material and a sparsity of contemporary planktonic tests (Chapters 39, 44); 3) the abundance of primary sedimentary structures suggesting deposition from turbulent suspension, debris flows, or sediment slides

(Chapters 44, 45); and 4) the almost complete absence of secondary biogenic structures.

In detail, however, there are certain aspects of these resedimented facies that still require interpretation. The clays and muds, in particular, although very rapidly deposited, are commonly structureless with little evidence of the type of flow from which they were deposited. In some cases, barely perceptible, very thin, darker-colored, mud laminae occur at a spacing of 1 to 3 cm through several meters of section. These appear to be primary in origin, rather than caused by coring disturbance, and are similar to the thick-bedded unifite muds studied by Stanley [3], perhaps representing deposition from very large, slump-derived, muddy turbidity currents. In other cases, there is color banding on a centimeter to decimeter scale, with irregular dark iron-sulphide mottling that suggests bioturbational activity. The sediments may have been deposited partly as thin-bedded mud turbidites and partly from relatively concentrated hemipelagic suspensions.

The silty mud and muddy silt facies are also enigmatic in their origin. Where graded, they are similar to the disorganized turbidites studied by Stow and Piper [4], perhaps resulting from very rapid deposition or from a poorly developed turbidity current. Where structureless, they might be better interpreted as having settled out of concentrated hemipelagic suspensions. The silt-laminated muds, in contrast, show clear evidence of deposition from normal, low concentration, turbidity currents, having many of the characteristics of fine-grained turbidites [4–6].

The thin- to very thick-bedded silts and sands commonly show evidence of deposition from high concentration turbidity currents [7], the thicker beds perhaps having been influenced by grain flow or fluidized flow in the final stages of deposition [8]. The structureless aspect of many of these thick sands and the possibility of coring disturbance make firm interpretation difficult. The apparent graded top of the lone gravel unit from the channel thalweg site also suggests turbidity current transport, whereas the pebbly muds presumably result from debris flows.

Mass movement is exhibited as local, small-scale, overturned folds and microfaults most commonly in the mid-fan levee site (Site 617) and less frequently within the channel and the lower-fan sites. The top 90 m of the section at Site 616 has undergone mass movement, as indicated by highly inclined lamination, overturned folds, and possible repeat sections. It is not yet clear whether this is indeed a single far-travelled megaslide, as proposed by Walker and Massingill on the basis of seismic evidence [9], or a series of large (10 to 15-m thick) slide blocks of perhaps more local origin.

2. Facies Distribution and Sequences

The percentage of different sedimentary facies present in the recovered section at each site is shown in Table 1. The

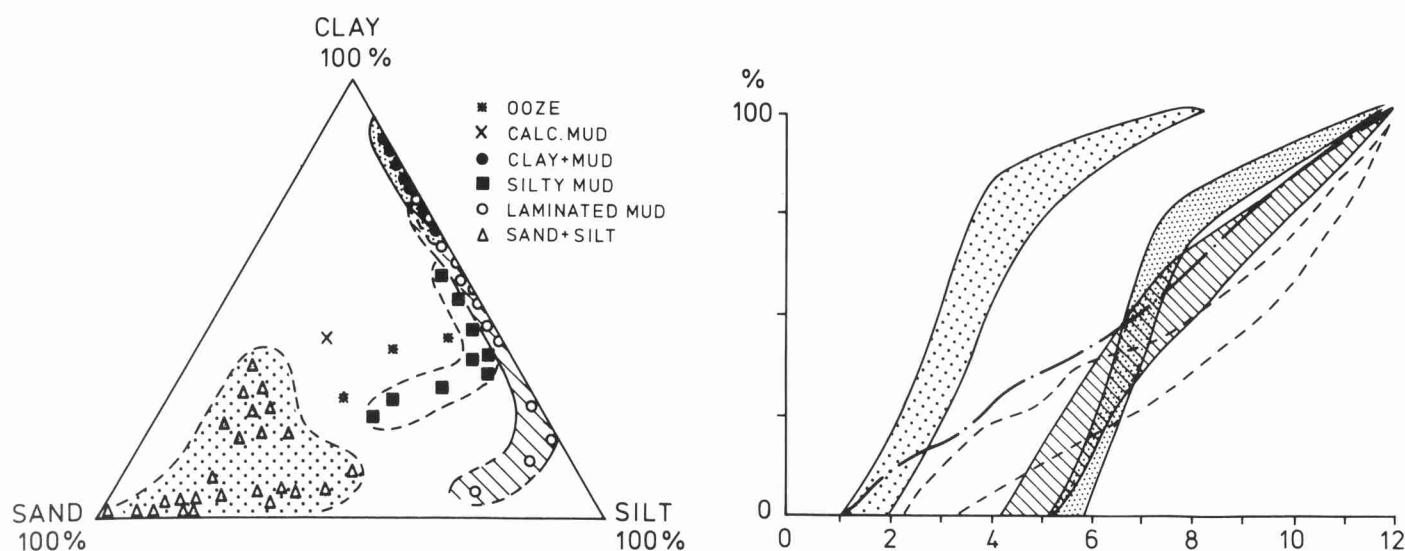


Figure 2. Grain size characteristics of Mississippi Fan sediments. (A) Triangular plot of sand-silt-clay percentages. (B) Typical cumulative frequency curves for different sedimentary facies.

biogenic facies are of minor importance, occurring only as a thin surface veneer over the fan and at the base of the deepest site. The fine-grained terrigenous facies are dominant everywhere. Silt-laminated muds are most abundant close to the channel on both the mid- and lower-fan, and also at Site 616 where they probably represent overbank deposits adjacent to a former channel. The clay and mud facies are more abundant both away from the channel and as thick, passive channel-fill deposits. The coarser-grained silt and sand facies are most abundant in mid-fan channel sites. Wire line logs suggest that core recovery was more complete in the fine-grained facies, so that actual percentages of sands and silts are relatively higher than recorded and might be as much as 60 to 70% on the lobes and 20% in the channels. Pebbly muds and gravels are a very minor facies, recovered only in the channels.

The vertical sequences in which the various facies occur are described in more detail in papers in this volume dealing specifically with the mid-fan and lower fan (Chapters 40, 42). We simply note here that although clear trends of grain

size and bed thickness are observed, vertical sequences are rather more variable than those classically related to fan deposits [8]. In particular: 1) the lower-fan lobe sites show coarsening-upward, fining-upward, blocky, and irregular sequences over tens of meters of section; 2) the mid-fan channel sites show somewhat irregular fining-upward sequences and a monotonous mud fill, and 3) the mid-fan levee and overbank sites show coarsening-upward, fining-upward, and symmetric sequences. Smaller-scale sequences over 2 to 10 m of section in the lower fan lobe sites might be considered similar in origin to the compensation cycles described by Mutti and Sonnino [10], although coarsening, fining and symmetrical sequences are all present.

References

- [1] Bouma, A. H., Stelling, C. E., and Coleman, J. M., 1983/84. Mississippi Fan: internal structure and depositional processes. *Geo-Marine Letters*, v. 3, pp. 147-154.

Table 1. Percentages of Different Sedimentary Facies in Recovered section at Each Mississippi Fan Site

Facies/Sites	Middle Fan					Lower Fan			
	Overbank		Channel		Margin	Lobe		Channel/Levee	
	617	620	621	622	616	614	615	623	624
1. Oozes and muddy oozes	0.1	0.1	0.2	0.1	0.1	1	17	0	<0.1
2. Calcareous muds	0.1	0	0	0	0	0.1	0.3	0	0
3. Clays and muds	16	72	68	50	22	14	10	28	38
4. Silty muds and muddy silts	2	8	10	4	10	23	10	10	5
5. Silt-laminated muds	82	20	14	33	65	14	25	56	56
6. Silts and sands	0	0	4	12	3	48	38	6	1
7. Muddy gravels and pebbly muds	0	0	3	0.5	0	0	0	0	0
8. Gravels	0	0	0.4	0	0	0	0	0	0