SEDIMENT FACIES AND ARCHITECTURE OF AMAZON FAN REVEALED BY ODP LEG 155 DRILLING

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Introduction

Although Amazon Fan is one of the largest deep-sea fans in the world, it is typical of "mud rich" fans developed on passive margins. Prior to ODP drilling in 1994, architectural elements and the distribution of sedimentary facies within Amazon Fan were inferred from high-resolution seismic, GLORIA side-scan sonar, SeaBeam swath-mapping and piston-core data (Damuth and Kumar 1975; Damuth and Embley 1981; Damuth et al. 1983a, 1983b, 1988; Manley and Flood 1988; Flood et al. 1991.; Pirmez 1994; Pirmez and Flood 1995) In particular, these studies revealed that distributary channels have highly meandering planforms and are perched on natural levee systems. The aggradational channel-levee system is thus recognized as the basic depositional unit of the fan (Fig. 1). High-amplitude reflections (termed HARs) observed beneath the channel axis were interpreted as coarse-grained channel-fill deposits (Fig. 1). More laterally extensive high-amplitude reflections packets (termed HARPs) at the bases of channel-levee systems were interpreted as coarse sediment deposited either from flows spreading laterally outward from a channel mouth (i.e. depositional lobe), or from flows issuing through a crevasse in a levee during an avulsion event (i.e. crevasse splays) (Figs. 1, 2). Although only one channel-levee system was active at any given time, repeated channel avulsion developed groups of overlapping channel-levee systems, or channel-levee complexes across the upper to middle fan surface. In addition, large, regionally extensive mass-transport deposits overlying portions of channel-levee systems were recognized on the modern fan surface (Damuth and Embley 1981) and seismic data showed that older levee complexes buried within the fan are also separated by similar thick, mass-transport deposits (Manley and Flood 1988) (Fig. 1).

Results of Drilling during ODP Leg 155

ODP Leg 155 cored >4 km of sediment from 17 drill sites on Amazon Fan. Excellent continuous sections were recovered from all four major submarine-fan elements (Fig. 1) including: (1) levee/overbank deposits of a variety of ages, (2) channel-fill deposits (HAR units), (3) depositional-lobe and crevasse-splay deposits (HARP units), and (d) surficial and buried mass-transport deposits. Terrigenous sediments comprise the vast majority of the cored intervals. Wire-line logs in combination with Formation MicroScanner TM (FMS) images allowed interpretation of ~400 m of coarse-grained intervals of little or no core recovery. (see Flood, Piper, Klaus et al. 1995 and Flood, Piper, Klaus and Peterson 1997 for detailed results of Leg 155 drilling).

The levee or overbank deposits are constructed of seven interbedded facies (Fig. 1). Color-banded mud and clay are most common (Fig. 1). Interbeds of coarser sediment are rare to abundant and are predominantly organized (e.g. x-stratified, graded) and disorganized (structureless) silt laminae and thin beds (<10 cm); medium and thick silt beds are common to rare, respectively. Organized sand beds also occur, but are much less common than silt beds.

Sediments cored from the axis of the modern Amazon Channel and the underlying HAR units are predominantly thick-bedded, coarse facies (Fig. 1). The most prevalent facies is disorganized structureless to chaotic, poorly sorted, fine-to-coarse sand; large mud clasts are common. Beds range up to several meters in thickness. Medium-to-thick-bedded, fine-to-medium organized sands (e.g. graded, x-stratified) are also common to abundant. Some intervals of deformed to chaotic mud occur and apparently represent localized sediment failure (e.g. levee walls) and mass-transport within the channels.

The coarsest and thickest sand beds occur in the thick, laterally extensive HARP units at the bases of individual channel-levee systems (Fig. 1) and in lower-fan deposits, which presumably represent coalescing depositional lobes (i.e. HARPs) extending downfan from the mouths of the leveed channels. Wire-line logs and rare pebbles suggest that some intervals of little to no core recovery are thick beds of disorganized gravel or sandy gravel. More commonly, HARPs and lower-fan deposits contain medium-to-thick (up to12 m) beds of disorganized structureless to chaotic sand. Poorly sorted medium-to-coarse sand with large mud clasts is common. Medium-to-thick organized sand beds (e.g. graded, x-stratified) of fine to medium sand are also common. These facies support the interpretation that HARP units form by deposition of coarse sediment issuing from the mouth of a channel as the channel-levee system progrades down-fan; or as crevasse splays developed in response to avulsion events along channels.

The thick, regionally extensive mass-transport deposits on the fan surface and buried within the fan contain mainly chaotic muddy facies that clearly indicate large-scale sediment failure and mass-transport (e.g. slumps, debris flows) down-fan (Fig. 1). These deposits consist predominantly of thick intervals (tens of meters) of deformed or chaotic mud with mud clasts and blocks, or discordant, contorted, folded, faulted, and truncated beds. Thick intervals of disorganized pebbly or gravelly mud and sandy mud are common, and intervals of homogeneous, structureless mud (possibly undeformed blocks) also occur.

During periods of glacio-eustatic sea-level lowstand and early rise, individual channel-levee systems aggraded at very rapid rates (up to 30m per 1000 yrs), and entire levee complexes of multiple channel-levee systems formed during a single 100 ka (4^{th} order) glacial/interglacial period. Thin intervals of pelagic and/or hemipelagic biogenic muds drape inactive channel-levee systems and lower-fan areas away from the active channel-levee system (Fig. 1). Holocene and previous glacio-eustatic sea-level highstands of the Quaternary have caused the entire Amazon Fan to become temporarily inactive for short periods (~10 k.a.) by forcing the locus of Amazon River sedimentation landward to the inner shelf, and thereby cutting off the large terrigeneous sediment supply to the fan. As a result, only a thin (< 1 m) layer of calcareous biogenic mud (Fig. 1) has slowly accumulated across the fan entire during the Holocene (Damuth et al. 1988). Similar thin intervals of biogenic mud recovered deeper in the fan attest to previous periods of fan inactivity during older interglacials (Flood, Piper, Klaus et al., 1995). These biogenic mud intervals represent condensed sections equivalent to at least portions of transgressive (TST) and highstand (HST) systems tracts and maximum flooding surfaces (MFS) in the Vail/Exxon conceptual sea-level model.

Conclusions

The Leg 155 cores show that despite it's classification as a "mud-rich" submarine fan, many elements of the Amazon Fan (HARs, HARPs, lower-fan lobes) actually contain very thick sand deposits (Fig. 1), some of which are laterally extensive and therefore form potentially good reservoir sands. Stacked, coarse channel-fill deposits (HARs) in a channel-levee system can be >10's of meters thick, up to kilometers wide and extend for 10's of km down fan. Coarse deposits that form HARP units beneath channel-levee systems (Fig. 1) and depositional lobes on the lower fan comprise much more laterally extensive sand deposits, which can contain stacked sand units 10's to 100's of meters thick and several 10's of km in width and length. The Amazon Fan demonstrates that some elements of so called "mud-rich" submarine fans can contain extensive coarse deposits, which should exhibit good lateral and vertical continuity and, thus, provide excellent reservoir potential. Such reservoirs would be enclosed in muddy levee/overbank and mass-transport deposits, which should provide good seals.

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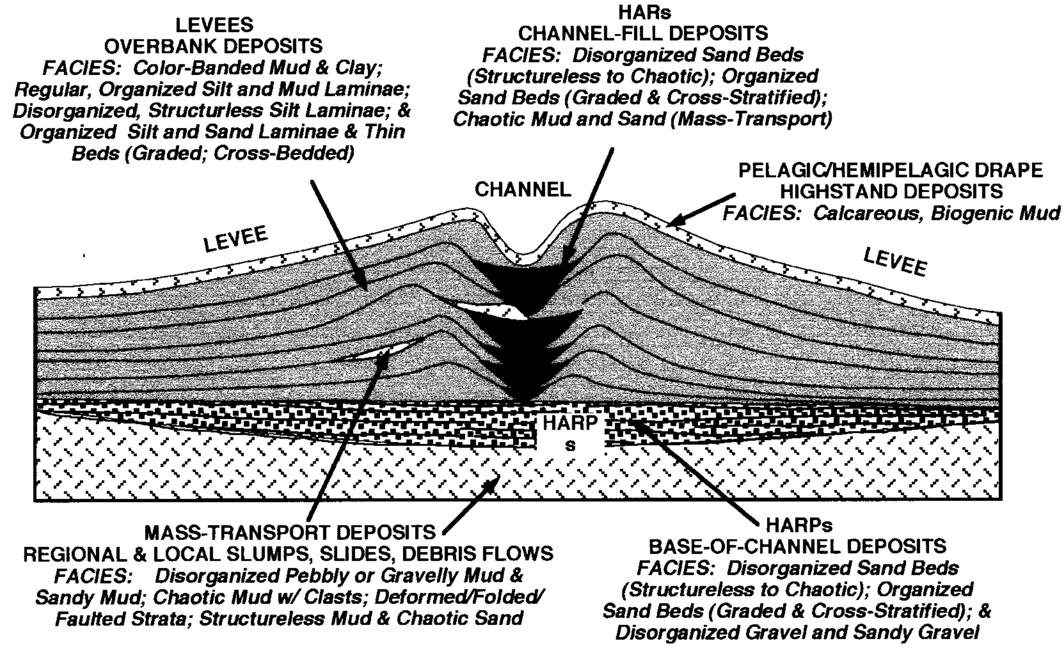

Figure 1. Distribution of sedimentary facies within acoustic units and turbidite elements of Amazon Fan. This schematic diagram shows a typical channel-levee system, the basic architectural unit of the upper to middle fan, and an under-lying regional-scale mass-transport deposit.

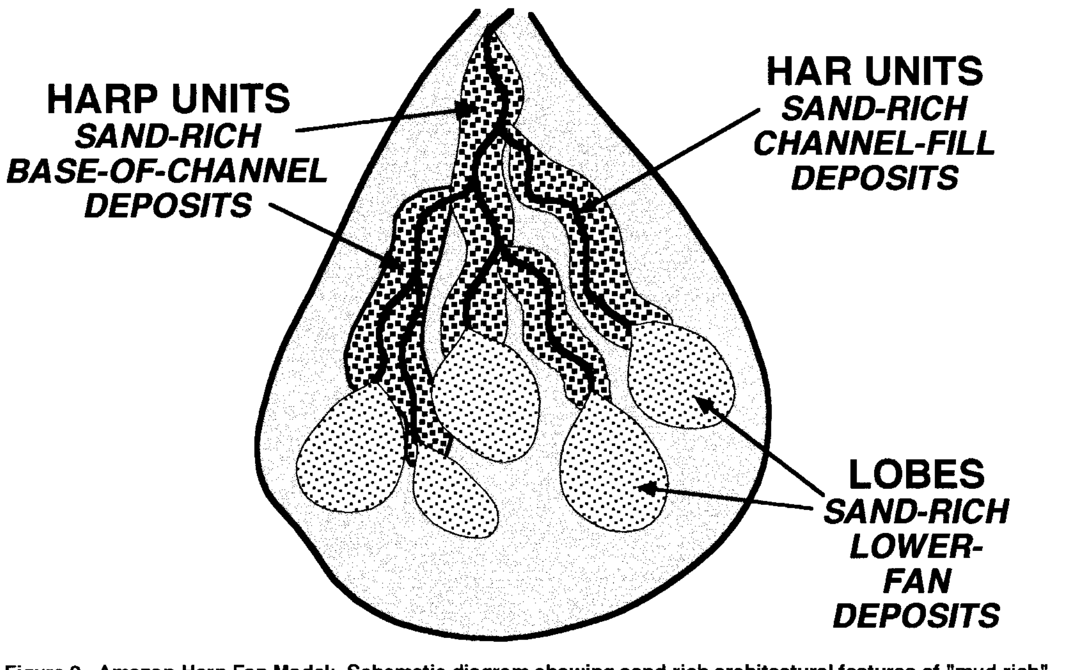

Figure 2. Amazon-Harp Fan Model: Schematic diagram showing sand-rich architectural features of "mud-rich" deep-sea fans based on Amazon Fan drilling. Previous conventional models for mud-rich fans did not recognize the sand-rich HARP Units, which suggest that extensive additional sand potential exists in these fans.