PS Latest Quaternary Regional Sedimentation Processes in the U.S. Gulf of Mexico Exclusive Economic Zone (EEZ)*

John E. Damuth[1] and Hilary C. Olson[1]

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Abstract

Interpretation of very high-resolution (3.5 kHz) seismic facies reveals that turbidity-current, mass-transport (MTD), and bottom-current depositional processes have all contributed to the regional sediment distribution throughout the U.S. Exclusive Economic Zone (EEZ) in the northern Gulf of Mexico. Piston cores from these deposits confirm the interpretations of these processes and show that most were deposited during the Last Glacial sea-level lowstand. The eastern half of the EEZ is dominated by the Mississippi Submarine Fan, which is composed of mud-rich channel-levee complexes on the upper and middle fan, and sandy lobes on the lower fan. Although MTDs were previously mapped from the east side of the fan, our 3.5 kHz data reveals the total distribution of MTDs across the western side. The 3.5 kHz data also shows seismic facies consistent with very sandy deposits throughout the lower fan. In contrast, the western EEZ is dominated by intraslope mini-basin systems, and turbidity currents have deposited large volumes of sands into these basins canyons.

Although most of these systems do not traverse the entire intraslope area, the extensive Bryant Canyon system allows turbidity currents to bypass through all the mini-basins via fill-and-spill processes and form the large Bryant Submarine Fan, which extends hundreds of km seaward from the Sigsbee Escarpment. In contrast, the smaller Rio Grande Submarine Fan was deposited in an intraslope plateau. The 3.5 kHz seismic facies and piston cores indicate a sand-rich fan with numerous small, un-leveed channels that appear to show a braided channel system. MTDs are ubiquitous throughout the mini-basins, along the upper continental slope and at the eastern base of the Sigsbee Escarpment. Cores confirm that the majority of MTDs are mostly muddy debris flows with mud clasts of variegated colors, but sandy debris flows also occur in some mini-basins. Deformation, folds and faults in some cores indicate slump or slide deposits. The East Breaks Slide Complex is the largest MTD complex of slump/slide blocks and debris flows and extends from the shelf edge downslope for >100 km. Most MTDs were deposited during the Last Glacial (MIS 2) lowstand. Three large regions of migrating sediment waves occur on the Sigsbee Abyssal Plain and were formed by bottom current circulation of the Loop Current. Sediment waves also occur locally along the base of the Sigsbee Escarpment in conjunction with previously reported erosional furrows.

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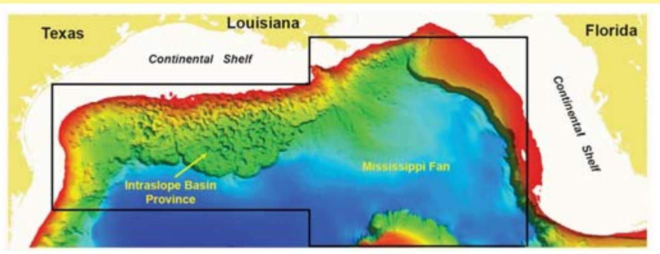
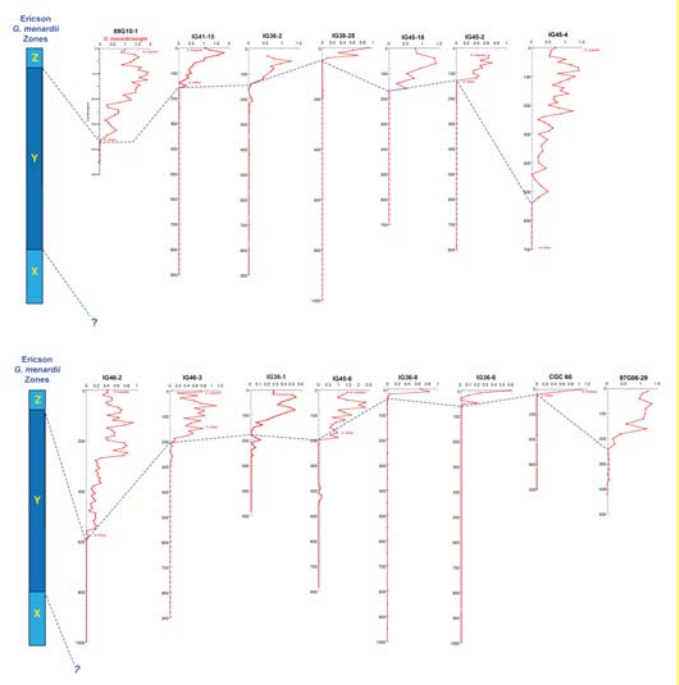
Interpretation of very high-resolution (3.5 kHz) seismic facies reveals that turbidity-current, mass-transport (MTD), and bottom-current depositional processes have all contributed to the regional sediment distribution throughout the U.S. Exclusive Economic Zone (EEZ) in the northern Gulf of Mexico. Piston cores from these deposits confirm the interpretations of these processes and show that most were deposited during Last Glacial sea-level lowstand. The eastern half of the EEZ is dominated by the Mississippi Submarine Fan, which is composed of mud-rich channel-levee complexes on the upper and middle fan and sandy lobes on the lower fan. Although MTDs have been mapped previously from the east side of the fan, our 3.5 kHz data reveals the total distribution of MTDs across the western side. The 3.5 kHz data also shows seismic facies consistent with very sandy deposits throughout the lower fan. In contrast, the western EEZ is dominated by intraslope mini-basin systems and turbidity currents have deposited large volumes of sands into these basins canyons. Most of these systems do not traverse the entire intraslope area, but the Bryant Canyon system allows turbidity currents to bypass through all the mini-basins via fill-and-spill processes and form the large Bryant Submarine Fan, which extends hundreds of km seaward from the Sigsbee Escarpment. In contrast, the smaller Rio Grande Submarine Fan was deposited in an intraslope plateau. The 3.5 kHz seismic facies and piston cores indicate a sand-rich fan with numerous small, un-leveed channels that appear to show a braided channel system. MTDs are ubiquitous throughout the mini-basins, along the upper continental slope and at the eastern base of the Sigsbee Escarpment. Cores confirm that the majority of MTDs are mostly muddy debris flows with mud clasts of variegated colors, but sandy debris flows also occur in some mini-basins. Deformation, folds and faults in some cores indicate slump or slide deposits. The East Breaks Slide Complex is the largest MTD complex of slump/slide blocks and debris flows and extends from the shelf edge downslope for >100 km. Most MTDs were deposited during the Last Glacial (MIS 2) lowstand. Three large regions of migrating sediment waves occur on the Sigsbee Abyssal Plain and were formed by bottom current circulation of the Loop Current. Sediment waves also occur locally along the base of the Sigsbee Escarpment in conjunction with previously reported erosional furrows.

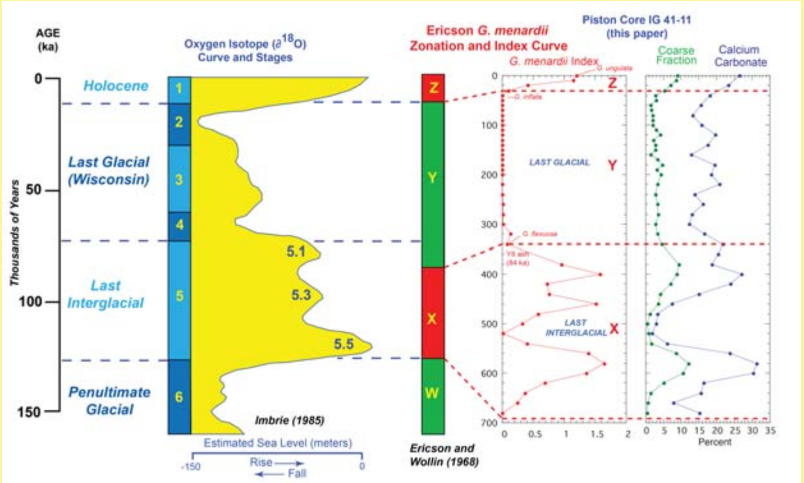


Location of study area. See echo-character map in central panel.

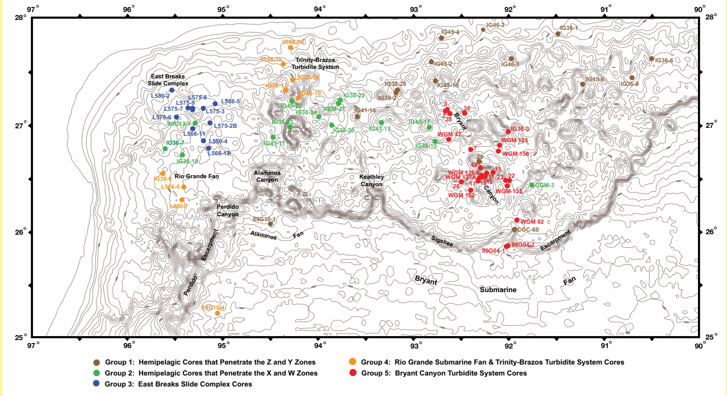


G. menardii index cuves for hemipelagic cores that penetrate only the Z and Y zones. Core locations shown in Group 1 in the location map above.

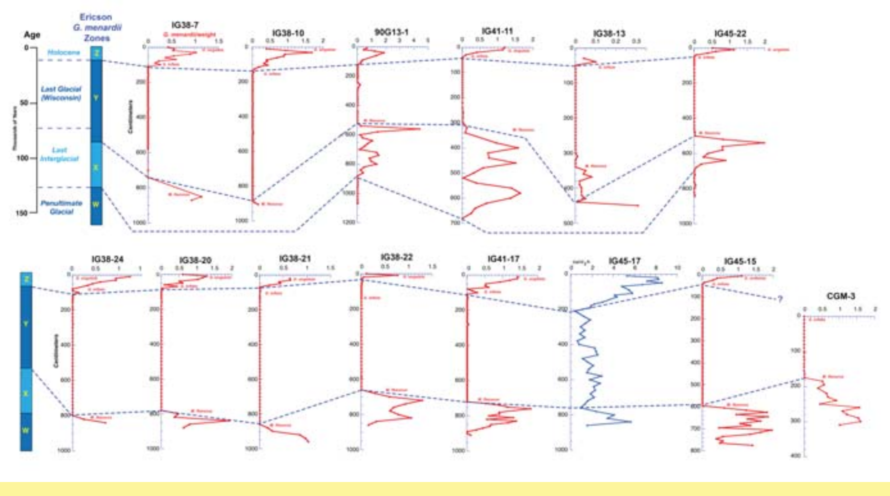
Biostratigraphy of Piston Cores



Relationship of Late Quaternary climatic zones (glacial and interglacial cycles) as determined from oxygen-isotope stratigraphy for the past 150,000 years (e.g., Imbrie, 1985) to biostratigraphic zonation of piston cores based on *Globorotalia menardii* zonation (Z, Y, etc.) developed by Ericson and Wollin (1968), and on fluctuations of calcium-carbonate and coarse-fraction content down core. Examples of these fluctuations compared with marine isotope stages (MIS 1-5) and the *G. menardii* zones (Z to X) are shown for piston core IG 41-11 from the present study. The Y8 Ash Layer, which is dated at approximately 84 ka (Kennett and Huddleston, 1972; Ledbetter, 1984; Rabek et al., 1985), occurs at approximately the X/Y boundary (85 ka; Kohl and DSDP Leg 96 Shipboard Scientists, 1985) in the core. Other biostratigraphic markers used include *G. ungulata*, *G. inflata*, and G. *menardii flexuosa*. Estimated sea-level based on the oxygen-isotope curve is also from Imbrie (1985).

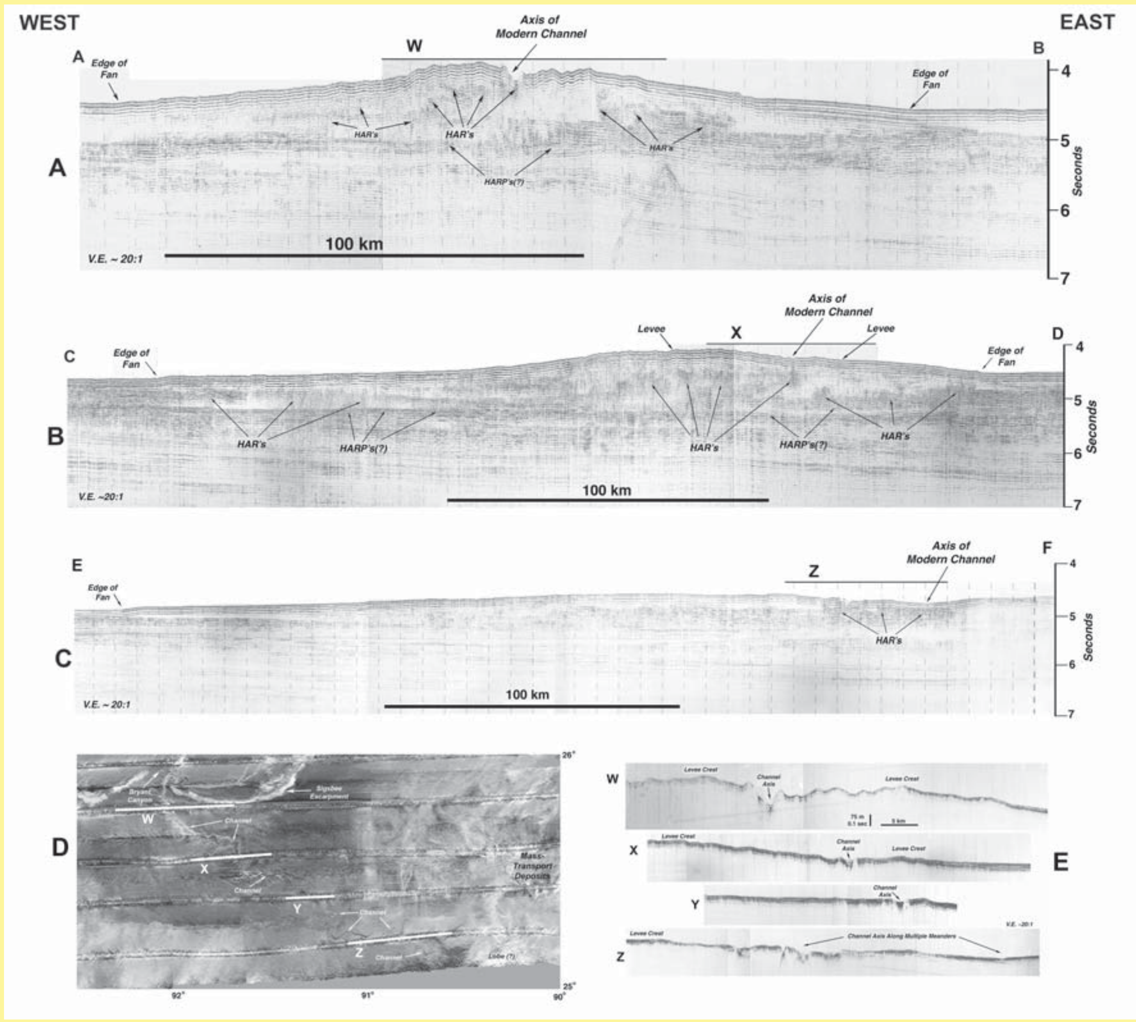


Locations of piston cores with biostratigraphic data used in this study (from Olson and Damuth, 2016).



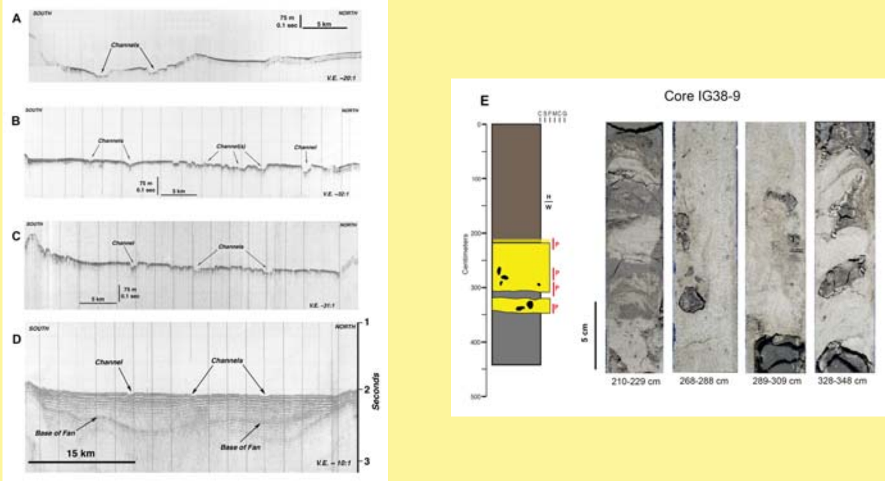
G. menardii index curves for hemipelagic cores that penetrate the X and W Ericson zones. Note that a calcium-carbonate curve (%) is used for Core IG 45-17 because no *G. menardii* index curve was determined. Core locations are shown in Group 2 in the location map above.

A Bryant Submarine Fan

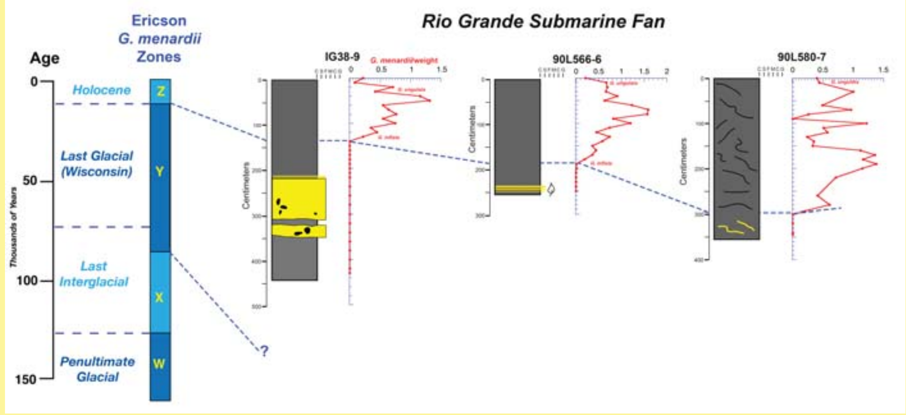


(A-C) Air-gun seismic profiles across the Bryant Fan (locations on echo character map in center panel). Note modern channel on fan surface. Also note high-amplitude reflections (HARs), which indicate older, buried sandy channel fills. (D) GLORIA side-scan sonar mosaic from the Bryant Fan (location in Box A in map in central panel). Note the single meandering modern channel on the present sea floor that may end in a lobe(?) deposit in the southeast corner of the area. Also note the high reflectivity mass-transport deposits at the east edge of the study area, which are the distal deposits of the Western Mass-transport Deposit (MTD) on Mississippi Fan mapped on the echo-character map in the central panel. GLORIA image is from EEZ-SCAN 85 Scientific Staff (1987). (E) 3.5 kHz profiles (W-Z) across the modern fan channel (locations in D).

B Rio Grande Submarine Fan

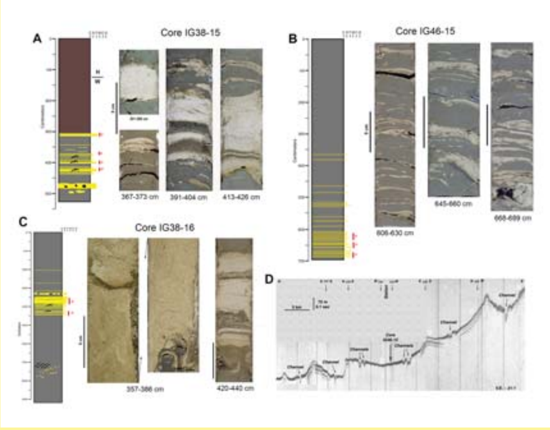


(A-C) 3.5 kHz profiles across Rio Grande Fan (location in Box B on echo character map in central panel). Note the small, unleveed channels. The fan surface returns Echo Type 3 (prolonged echoes), which suggests sand-rich sea-floor sediments. (D) Air-gun profile across Rio Grande Fan (along 3.5 kHz line C) showing fan thickness and possible buried channels. (E) Piston core IG38-9 from Rio Grande Fan showing examples of silt and/or sand laminae and beds, which appear to be turbidites or sandy debris flows with mud clasts. Core log shows bed-by-bed lithologies. Photos show close-up sections of core lithology. Locations of photos are shown by red bars labeled "P" along the core logs. H/W next to core indicates the location of the Holocene/Wisconsin boundary based on foraminiferal biostratigraphy shown below. Sands in these cores were deposited during the Wisoncin (Last Glacial). Locations of cores shown in Box B, central panel and Group 4 on map to left in this panel.

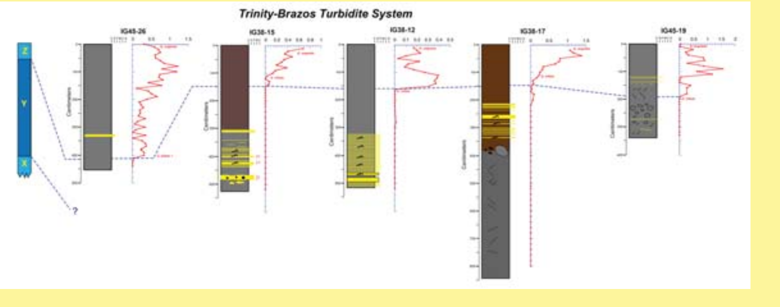


Graphic core logs from Rio Grande Submarine Fan showing bed-by-bed core lithology correlated to *G. menardii* index curves to demonstrate the relationship of redeposited sediments (e.g., mass-transport deposits, turbidites, and related sandy deposits) to the Last Glacial (Wisconsin) and Holocene interglacial cycles. All discrete beds composed of silt-, sand-, or gravel-sized particles (yellow) on the core logs regardless of their actual colors. The particle size of each bed is represented by the extension of the bed to the right of the log for a length proportional to the particle sizes from clay to gravel. The scale at the top right of each log shows these sizes with labels for clay (C), silt (S), fine-to-coarse sand (F, M, C), and gravel (G). Cores with beds containing exotic mud clasts of variegated colors are schematically represented. Core locations in Group 4 on map to left.

C Trinity-Brazos Turbidite System

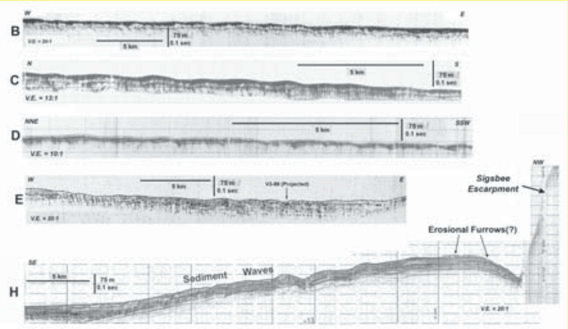


(A-C) Examples of piston cores from the Trinity-Brazos mini-basin turbidite system showing examples of silt and/or sand beds. Core logs show bed-by-bed lithologies. Photos show close-up sections of core lithology. Locations of photos are shown by red bars labeled "P" along the core logs. H/W next to a core indicates the approximate location of the Holocene/Wisconsin boundary (see adjacent figure). (D) 3.5 kHz profile showing multiple crossings of a leveed channel that feeds the mini-basin system. Locations of cores and profile are shown in Box C on map on central panel.

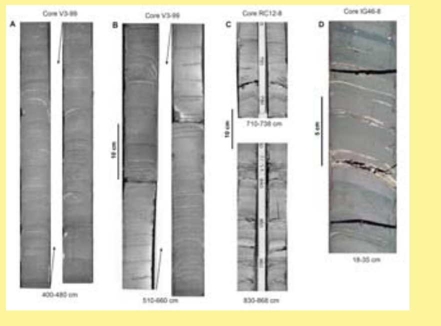


Graphic core logs from the Trinity-Brazos Turbidite System showing bed-by-bed core lithology correlated to *G. menardii* index curves which show the relationship of redeposited sediments (e.g., mass-transport deposits, turbidites and related sandy deposits) to the Last Glacial (Wisconsin) and Holocene interglacial cycles. All discrete beds composed of silt-, sand-, or gravel-size particles are colored yellow on the core logs. The particle size of each bed is represented by the extension of the bed to the right of the log. The scale at the top right of each log shows these sizes with labels for clay (C), silt (S), fine-to-coarse sand (F, M, C), and gravel (G). Cores with beds containing exotic mud clasts of variegated colors are schematically represented. Locations of cores are shown in map on the left (Group 4) and in Box C on map on central panel.

D Bottom-Current Deposits



3.5 kHz profiles showing examples of migrating sediment waves (Echo Type 4). (B-D) Migrating sediments waves from the western Sigsbee Abyssal Plain and eastern Bryant Fan (Type 4) echoes, labeled D on map in central panel. (E) Sediment waves from east of the Sigsbee Escarpment. (H) Small field of sediment waves ~ 15 km from the base of the Sigsbee Escarpment. Note the zone of erosion at the base of the escarpment, which returns small overlapping hyperbolic echoes. These echoes are apparently returned from erosional furrows. Locations of profiles shown on map in central panel in areas of Type 4 Echoes.



Close-up photos of piston cores showing examples of sediments interpreted as bottom-current deposits. The sediments have numerous continuous and discontinuous silt laminae and thin beds. Some contain cross-stratification and mud-draped ripples. Cores V3-99 and RC12-8 were taken from the large areas of migrating sediment waves (Echo Type 4). Core IG46-8 was taken at the base of the Sigsbee Escarpment in an area affected by bottom-current activity. Locations of cores shown on map in central panel in areas of Type 4 echoes.

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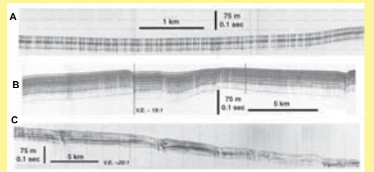
Department of Earth and Environmental Sciences, University of Texas at Arlington[1]

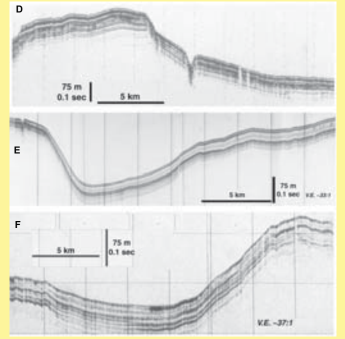
3.5 kHz ECHO TYPES (SEISMIC FACIES)

Type 1A



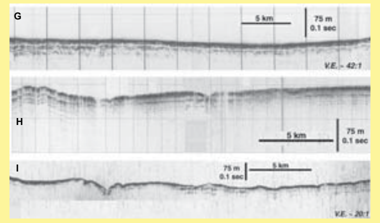
Sharp Bottom Echoes with Continuous Parallel (Conformable) Sub-bottom Reflections Recorded from Flat to Gently Rolling Sea Floor. Pelagic and Hemipelagic Sediment, Turbidites.

Type 1B



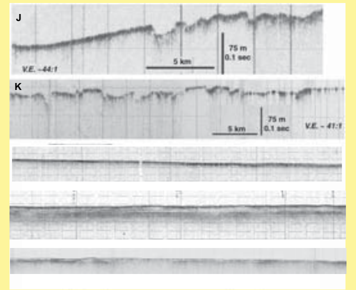
Sharp Bottom Echoes with Continuous Parallel (Conformable) Sub-bottom Reflections Recorded from Hummocky to Very Hilly Sea Floor. Pelagic and Hemipelagic Sediments.

Type 2



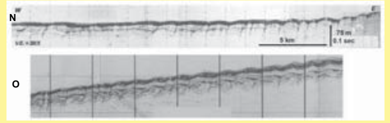
Semi-prolonged Bottom Echoes with Discontinuous, Parallel Sub-bottom Reflections. Moderately Sandy Sediments, Possible Interbedded MTDs.

Type 3



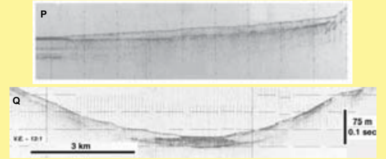
Prolonged Bottom Echoes Generally with No Sub-bottom Reflections or Single Discontinuous Sub-bottoms. Very Sandy Sediments, Turbidites & MTDs

Type 4



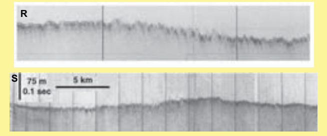
Sharp Bottom Echoes with Sub-parallel or Disconformable to Convergent Sub-bottom Reflections which Appear to be Migrating Wave Forms. Bottom-Current and Contourite Deposits, Mud with Thin Silt/Fine Sand Lamine and Beds.

Type 5



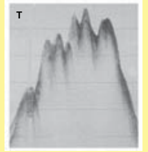
Sharp to Prolonged Bottom Echoes with Transparent or Non-Reflective Internal Character (No Sub-bottoms) Commonly Contained in External Forms that Display Irregular Wedge, Mound, Fill or Lens Shapes. Muddy Debris Flows, but also Can Be Very Sandy.

Type 6



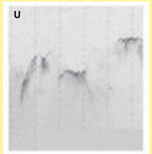
Small, Regular, Overlapping to Singular Hyperbolic Bottom Echoes with Varying Vertex Elevations; Sub-Bottom Reflections Are Absent to Very Rare. MTDs, Mainly Slumps and Slide Blocks.

Type 7



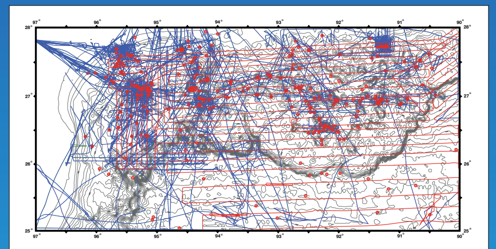
Large, Single Irregular Hyperbolic Bottom Echoes with Widely Varying Vertex Elevations; Sub-bottoms Absent. Moderately Rugged Seafloor Topography. Steep Seamounts, Continental Slope, Diapirs; No Sedimentary Information.

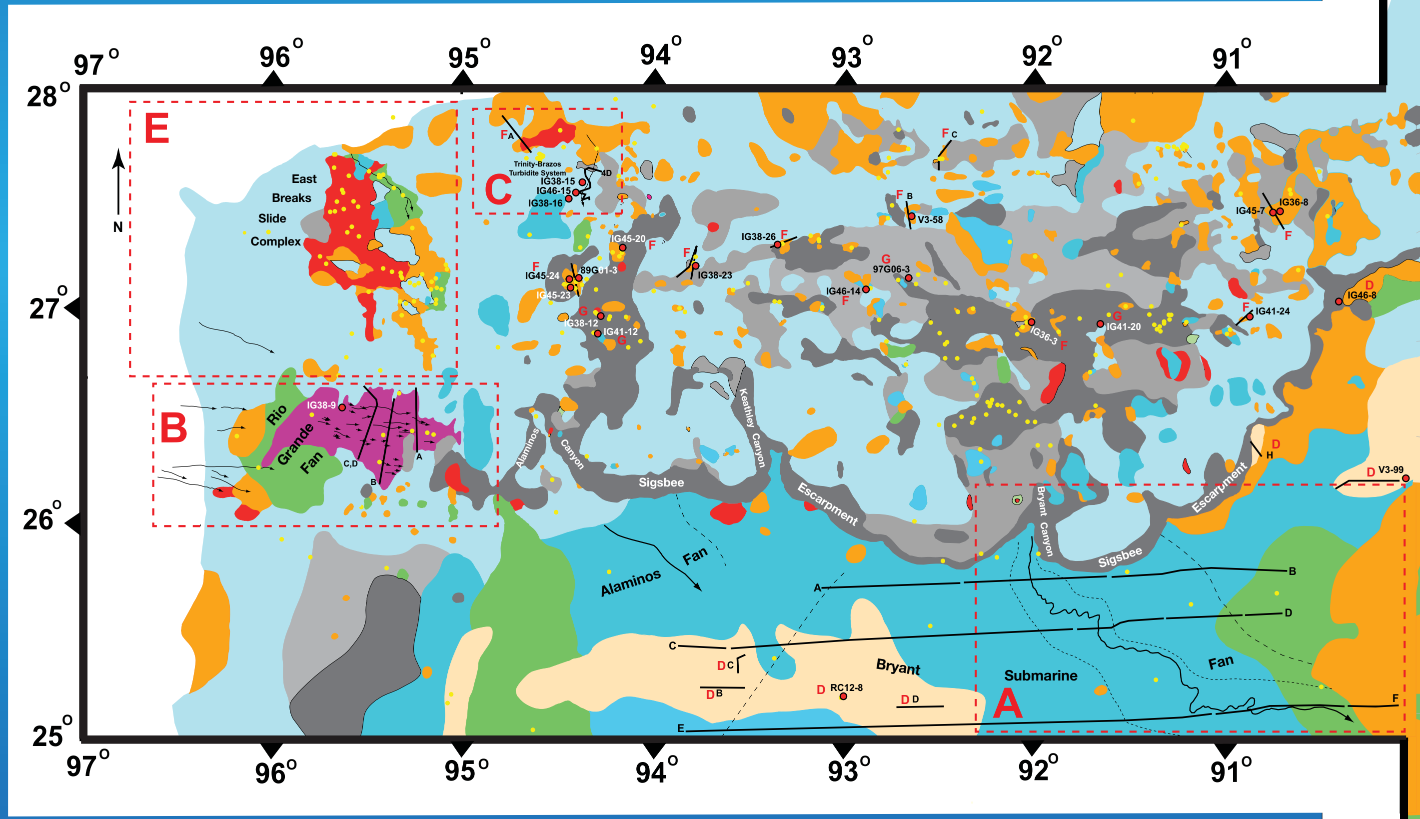
Type 8



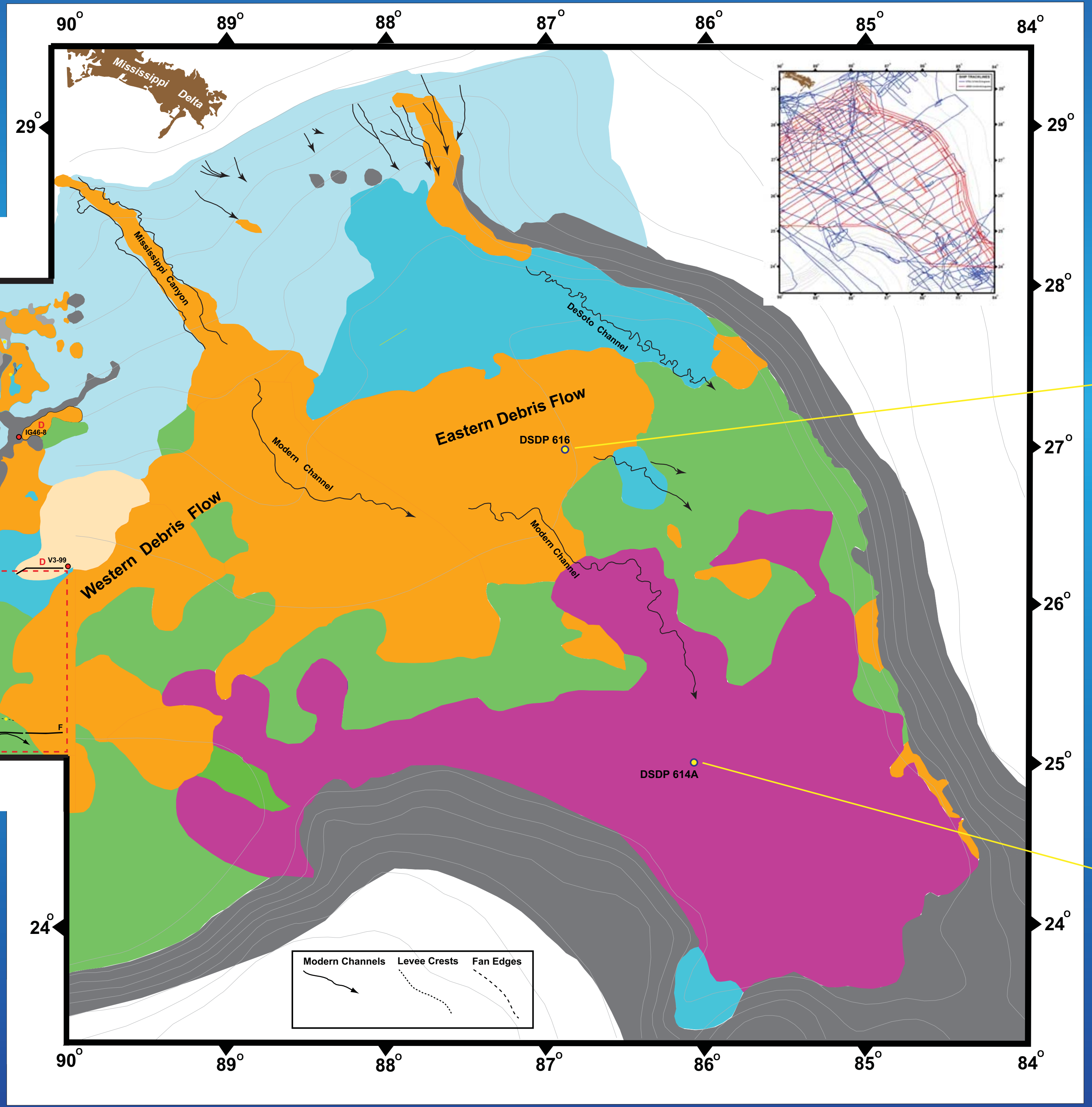
Large, Overlapping, Irregular Hyperbolic Bottom Echoes with Widely Varying Vertex Elevations; Sub-bottoms Absent. Very Rugged Seafloor. Steep Seamounts, Continental Slope, Diapirs; No Sedimentary Information.

Intraslope Basin Province

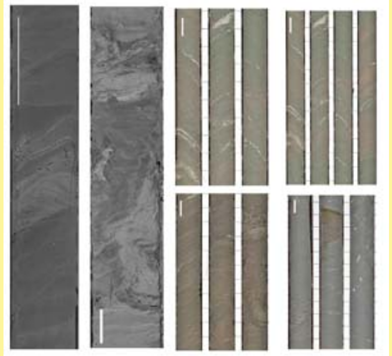




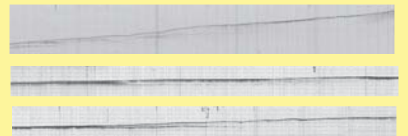
Mississippi Fan



DSDP HOLE 616

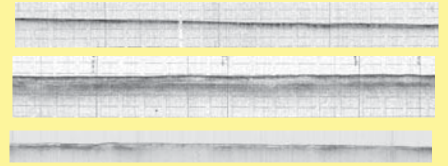


Close-up photographs of cores from DSDP Hole 616 which were taken in the large Eastern Debris Flow deposits of the Mississippi Fan (location at left). The uppermost sediments from the upper to middle fan are dominated by large debris flows as shown by the echo character map at left where most of this region returns sharp-to-prolonged bottom echoes (Type 5 below) with transparent internal character (no sub-bottoms) consistent with debris flows. Common external forms are irregular wedge, mound, or fill shapes. The deformed sediments and mudclasts in the cores above confirm the echo characer interpretation. The examples below show the downslope western edge of the Western Debris Flow. In the present study we have tried to more accurately map the distribution of the Western Debris Flow. Scale bar on cores = 5 cm.



DSDP HOLE 614

Close-up photographs of cores from DSDP Hole 614 which was taken on the lower portion of the Mississippi Fan (location at left). The sediments from the lower fan are mainly thick sands deposited by turbidity currents and related sandy debris flows. As the echo character map at left shows, most of the lower fan returns prolonged echoes (Type 3) similar to the sections shown below. Prolonged echoes are generally returned from very sandy sediments. Scale bar = 5 cm.



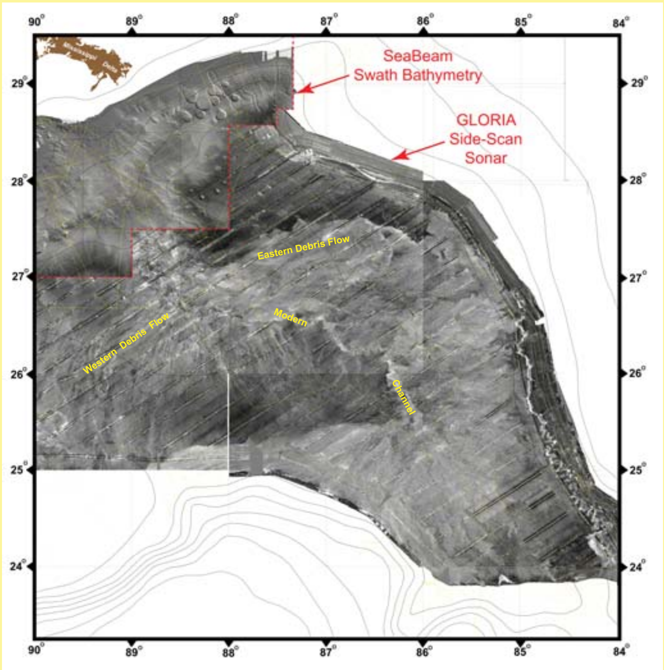
Echo Character Map

Map showing regional distribution of 3.5 kHz echo character (high-resolution seismic facies) for the Intraslope Basin Province and the Mississippi Deep-Sea Fan in the northern Gulf of Mexico. The legend at left shows classification and description for the 8 types of echoes observed in this area, as well as examples of each echo type (1-8). Black lines show locations of 3.5 kHz and air-gun seismic profiles shown in the figures on this poster. Labels refer to profile numbers in the figures. Air-gun profiles on Bryant Deep-Sea Fan (dashed red box A) are labeled AB, CD, and EF. Yellow and red circles show locations of piston cores; red circles locate cores shown in figures on this poster. Red dashed boxes show locations of study areas labeled A, B, C, and E which are displayed on the left and right poster panels. Panels on left and right labeled D, F and G have cores and 3.5 kHz profiles widely spaced throughout the area. These are identified on the map with corresponding red letters before the core label or profile.

Damuth, J.E., and Olson, H. C., 2015, Latest Quaternary sedimentation in the northern Gulf of Mexico intraslope basin province I: Sediment facies and depositional processes, Geosphere, v. 11, no. 6, p. 1689-1718.

Olson, H.C., Damuth, J.E., and Nelson, H.C., 2016, Latest Quaternary sedimentation in the northern Gulf of Mexico intraslope basin province II: Stratigraphic analysis and relationship to glacioeustatic climate change, Interpretation, v. 4, no. 1, p. 81-95.

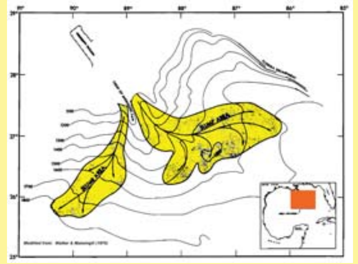
Mississippi Fan



NOAA SeaBeam swath bathymetry (upper fan) and U.S.G.S. GLORIA long-range side-scan sonar (middle and lower fan) mosaics of the Mississippi Fan. The GLORIA mosaic is from EEZ-SCAN 85 Scientific Staff (1987).

Mass-Transport Deposits

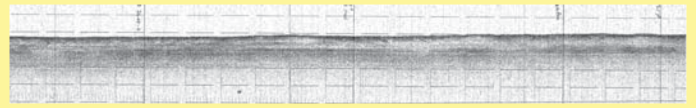
The occurrence of very large mass-transport deposits on Mississippi Fan was first suggested by Walker and Massingill (1970). Based on a few widely spaced regional lines they interpreted the distribution of large eastern and western mass-transport deposits as shown in the map below.



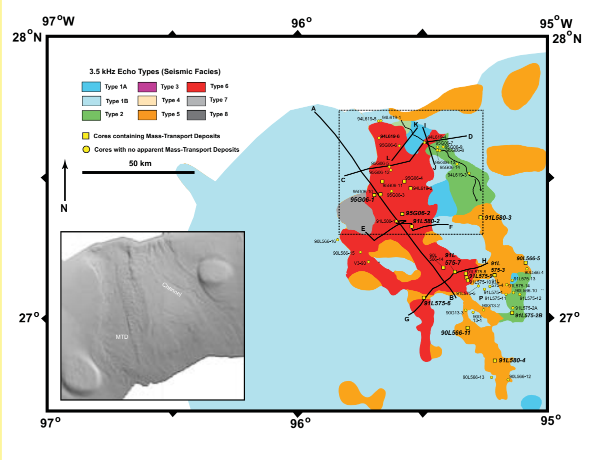
Drilling during DSDP Leg 96 penetrated the Eastern Debris Flow and recovered mass-transport deposits in the top 100 m of the sea-floor sediments. Examples of the deformed sediments with mud clasts are shown in the photographs in the central panel and confirm the MTD interpretation. The GLORIA side-scan sonar mosaic (top figure) provided better surficial definition and distribution of the Eastern and Western debris flows. Although the Eastern Debris Flow has subsequently been well defined by other studies, the distribution and extent of the Western Debris Flow has never been well defined. On the GLORIA mosaic (EEZ-SCAN 85 Scientific Staff, 1987) the distribution and boundaries are somewhat unclear. We interpreted and mapped the Western Debris Flow using 3.5 kHz echo character map (on central panel). The Type 5 echoes, which are diagnostic of debris flows show the approximate extent of the debris flow (central panel) based on the echo character mapping. Some portions of the 3.5 records through this area show poor penetration and thus the echo type may be uncertain. Portions of Type 2 echoes within the area of Type 5 echoes may also be returned from the debris flow. The reflectivity on GLORIA mosaic suggests that the debris flow may be composed of many flows. Some of the 3.5 kHz records show overlapping flows. The 3.5 kHz record below from the southwest downslope edge of the debris flow is an example of three separate overlapping flow lobes.

Lower Fan Prolonged Echoes (Type 3)

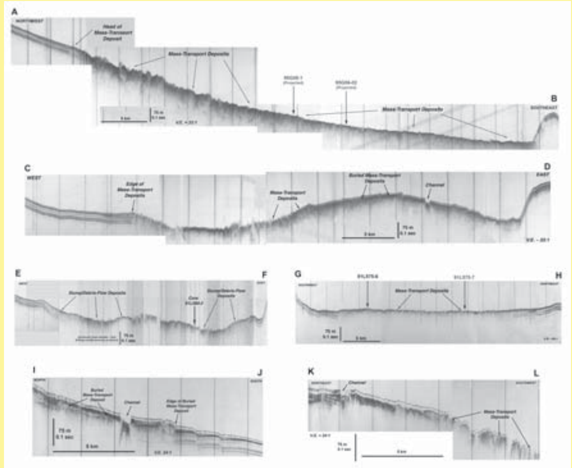
Most of the lower fan returns Type 3 echoes which show some variabiliy from very prolonged to more semi-prolonged (see examples on central panel). Penetration is variable along most tracks and may show vague, discontinuous sub-bottoms in some areas. Prolonged echoes (Type 3) have always been returned from very sandy sea-floor sediments in many areas of the continental margin and abyssal plains throughout the world. Drilling during DSDP Leg 96 on the lower fan recovered thick sandy turbidites and some debris flows. The photographs on the central panel show these types of sandy sediments recovered from DSDP Hole 614. Based on the wide distribution of prolonged echoes throughout the lower Mississippi Fan, we can predict that the entire lower fan has very sand-rich sediments.



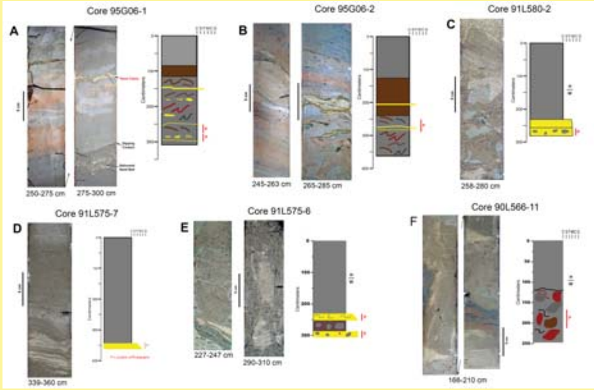
E East Breaks Slide Complex



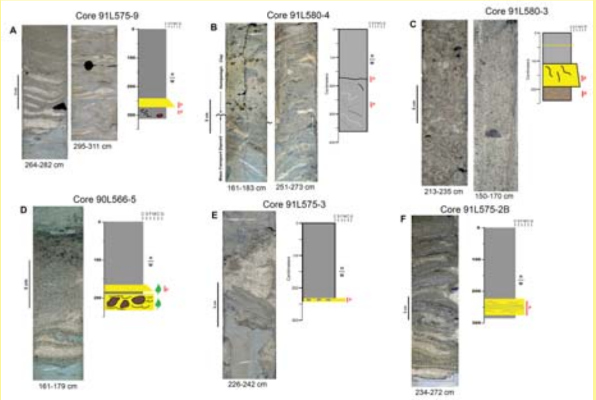
Enlarged 3.5 kHz echo-character map of the East Breaks Slide Complex. Black lines show locations of 3.5 kHz profiles (shown to the right). The western portion of the complex returns mainly Type 6 echoes, which indicate rough topography indicative of slump and slide blocks. Type 5 echoes represent debris flows. Yellow squares indicate cores that contain mass-transport deposits (MTDs) (examples shown below). Inset shows shaded SeaBeam (NOAA) swath bathymetry of the upslope portion of the complex (box shows location). The SeaBeam bathymetry shows rough topography in the western portion of the complex consistent with slumps and slide blocks. In contrast, the SeaBeam shows a prominent channel on the upper part of the eastern portion of the complex. The 3.5 kHz records to the right show this channel overlies buried debris flow. However, the lower eastern portion of the complex downslope from the channel shows MTDs as evidenced by Type 5 echoes. Location of this map shown by red dashed box E on map in center panel.



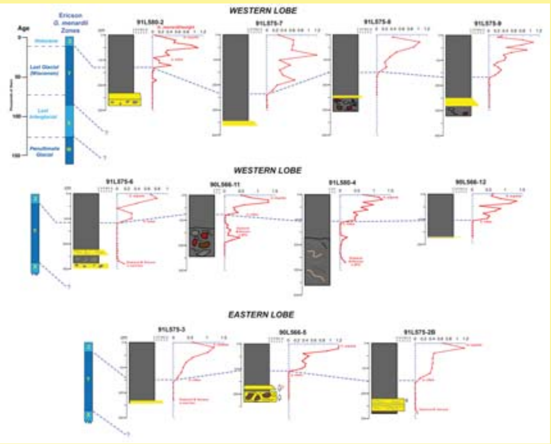
3.5 kHz profiles across the East Breaks Slide Complex. Location of profiles are shown in map at left. Dip profile AB down the middle of the western portion of the complex shows the head of the mass-transport deposit (MTD). Note the echo character is predominantly Type 6 echoes, which is indicative of deposits with large slump and slide blocks. Strike profile CD across the entire upper portion of the complex shows the zone of MTDs and erosion on the western portion and a zone of buried MTDs overlain by thin layer of well-stratified sediments on the eastern portion of the complex. Note the occurrence of the prominent sea-floor channel on this portion of the complex. Profiles IJ and KL show this channel and the buried MTD complex below. This buried MTD has been eroded by the channel. Profiles EF and GH across the middle and lower parts of the western portion of the complex show mainly Type 6 echoes, which are indicative of deposits with large slump and slide blocks. Note the abrupt edge of the buried MTD beneath the channel in profile IJ.



Piston cores showing examples of debris-flow deposits from the western portion of the East Breaks Slide Complex. Note the deformed mud clasts of various shapes and sizes and exotic, variegated colors. (A) Core 95G06-1 shows exotic mud clasts, as well as deformed sand beds and sharp dipping contacts. (B) Core 95G06-2 shows highly deformed mud clasts with exotic colors. (C) Core 91L580-2 contains a sandy debris flow (with angular, deformed mud clasts at its base), which is overlain by a sandy, slightly graded bed. (D) Core 91L575-7 bottoms in a sandy graded bed. (E) Core 91L575-6 contains a sandy debris flow at its base, which is overlain by a muddy debris flow. This bed is overlain by a graded sand bed, which also appears to show some deformation. (F) Core 90L566-11 contains a mass-transport deposit (MTD) that shows flowage, deformation, and large exotic mud clasts of variegated color. The particle size of each bed is represented by the extension of the bed to the right of the log. The scale at the top right of each log shows these sizes with labels for clay (C), silt (S), fine-to-coarse sand (F, M, C), and gravel (G). The Holocene/Wisconsin boundary determined by biostratigraphic zonation is shown by H/W beside the core logs in (C), (E), and (F) (see biostratigraphic zonations of cores in figure below). MTDs and sand beds in these cores were deposited during the Last Glacial (Wisconsin).

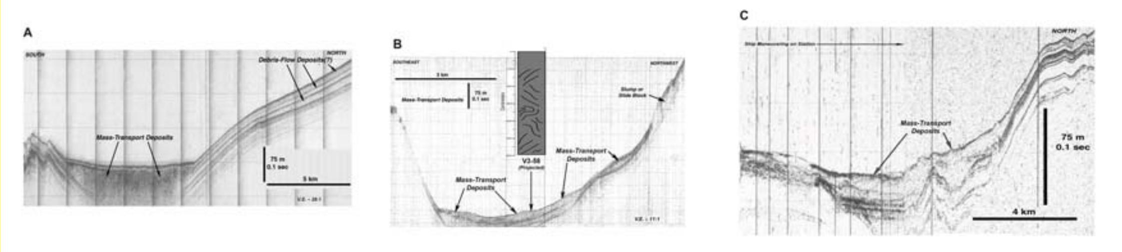


Additional piston cores showing examples of debris-flow deposits from the East Breaks Slide Complex. Note the deformed mud clasts of various shapes and sizes and exotic, variegated colors. (A) Core 91L575-9 bottoms in a muddy debris flow with deformed mud clasts and is overlain by a graded sand bed (dark-grey spots are voids in core). (B) Core 91L580-4 is near the distal end of the East Breaks Complex and dontains a muddy mass-transport deposit (MTD) with deformed mud clasts. (C) Core 91L580-3 contains a thick, sandy debris flow with mud clasts. (D) Core 90L566-5 contains an undisturbed, normally graded silt and/or sand bed above a thick, sandy debris flow with large mud clasts. These beds also contain abundant organic material. (E, F) Cores 91L575-3 and 91L575-2B contain sandy debris flows with mud clasts, deformation, and flowage. The particle size of each bed is represented by the extension of the bed to the right of the log. The scale at the top right of each log shows these sizes with labels for clay (C), silt (S), fine-to-coarse sand (F, M, C), and gravel (G). The Holocene/Wisconsin boundary determined by biostratigraphic zonation (see figure below) is shown by H/W beside the core logs in A, B, D, E, and F. MTDs and sand beds in these cores were deposited during the Last Glacial (Wisconsin).

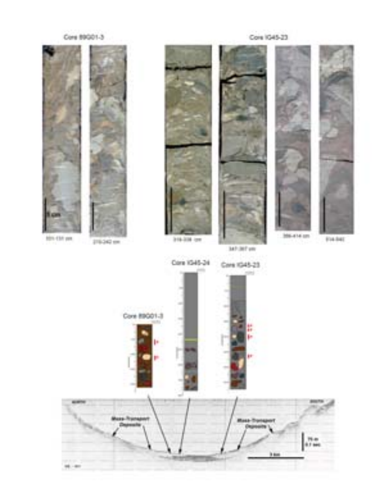


Graphic core logs from the East Breaks Slide Complex showing bed-by-bed core lithology correlated to *G. menardii* index curves to show the relationship of redeposited sediments (e.g., mass-transport deposits, turbidites and related sandy deposits) to the Last Glacial (Wisconsin) and Holocene interglacial cycles. All discrete beds composed of silt-, sand-, or gravel-size particles are colored yellow. The particle size of each bed is represented by the extension of the bed to the right of the log. The scale at the top right of each log shows these sizes with labels for clay (C), silt (S), fine-to-coarse sand (F, M, C), and gravel (G). Cores with beds containing exotic mud clasts of variegated colors are schematically represented on the graphic logs. Locations of cores are shown on map in left panel (Group 3).

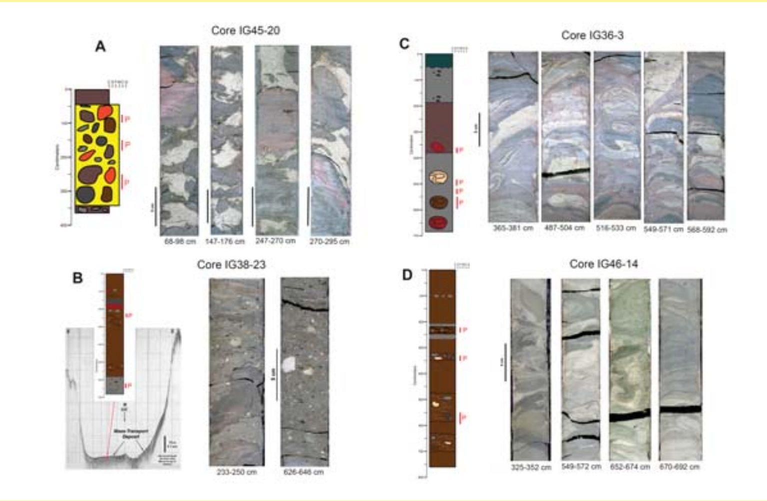
F Mass-Transport Deposits in Intraslope Basins



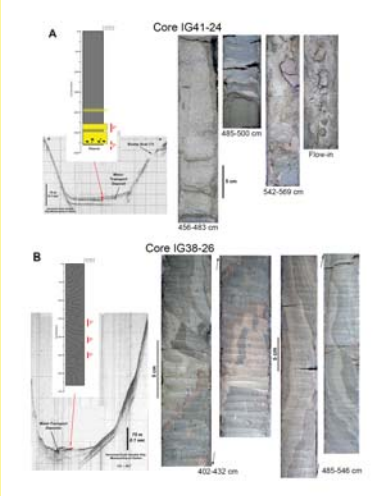
(A-C) 3.5 kHz echograms across three intraslope mini-basins showing examples of mass-transport deposits (MTDs) that return Type 5 echoes. (A) Debris-flow deposits with a thin layer of hemipelagic sediment or turbidite on top. The basins' north wall appears to have multiple MTDs. (B) Russel Basin shows multiple MTD events in the basin floor and a slump or slide block on the basin wall. Core V3-58 contains deformed and folded beds interpreted as a slump deposit. (C) This basin shows multiple, thick MTDs. Location of core and profiles are in map on central panel.



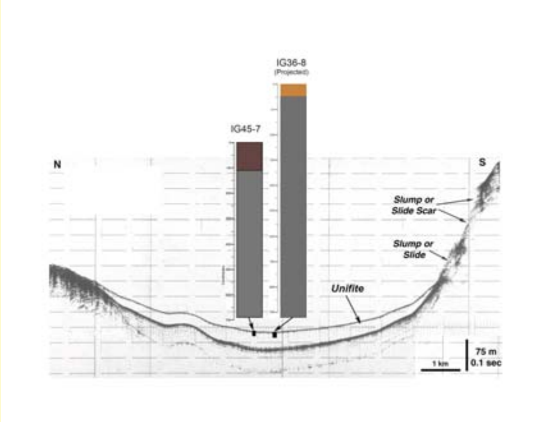
Examples of muddy debris-flow deposits from Barton Basin. The cores contain large, sometimes deformed, mud clasts of various sizes and variegated colors. The 3.5 kHz profile at bottom shows multiple debris flows in the basin floor. Locations of cores and profile are shown in map on central panel.



Piston cores showing additional mass-transport deposits (MTDs) from several mini-basins. (A) Core IG45-20 from Gyre Basin showing debris flow with large clasts of variegated colors and a sandy matrix. (B) Core IG38-23 from a basin just east of Gyre Basin showing muddy debris flow with numerous small- to medium-sized mud clasts. The Type 5 echo character on the 3.5 kHz profile shows MTDs in the basin floor and core location (note ship course reversal at C/C). (C) Core IG36-3 from Bienville Basin showing muddy MTD with highly deformed mud clasts of variegated sizes and colors. Note deformation, flowage, and isometric folds. (D) Core IG46-14 from Frazier Basin showing MTD with deformed, flowed, and folded mud clasts. Locations of cores and profile are shown in map on center panel.

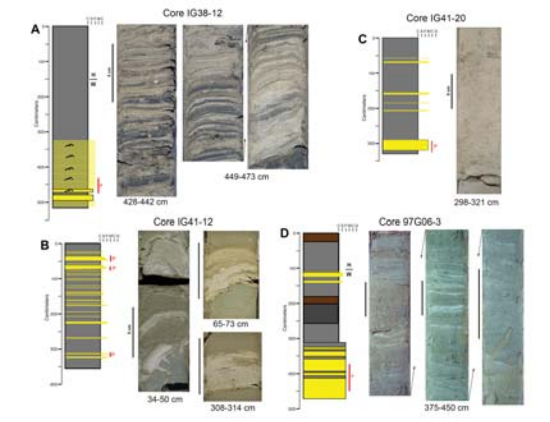


(A) Core IG41-24 from mini-basin floor taken in a mass-transport deposit. The 3.5 kHz profile shows a mass-transport deposit which returns Echo Type 5 on the north side of the basin floor and well-stratified hemipelagic and/or turbidite deposits on the south side. The MTD is overlain by thin, well-stratified sediments similar to those on the south side. The core has hemipelagic sediments in the upper 450m. This interval is underlain by a thick (~50cm), sandy debris flow (with mud and rock clasts) that appears to be recovered from the zone of Type 5 echoes. Note that the flow-in at the base of the core also contains sand with numerous rock and mud clasts. (B) Core IG38-26 contains an MTD with folded, faulted, and flowed sediments indicative of slump deposits. The 3.5 kHz profile shows core was taken from a region of irregular relief on the basin floor, which, based on the core, may be a slump block. Locations of cores and profiles shown on map in center panel.



A 3.5 kHz profile across a mini-basin showing a transparent deposit (Echo Type 5) interpreted as a unifite deposit. Also note small slump or slide and evacuation zone on side of basin. Piston cores contain homogeneous gray clays typical of unifites. Location of profile and cores are shown on map in center panel.

G Turbidity Currents



Examples of piston cores from mini-basins showing silt and/or sand beds deposited by turbidity currents and related gravity-controlled flows: (A and B) from Horseshoe Basin; (C) from Terrebone Basin; and (D) from Bryant Canyon. Core logs show bed-by-bed lithologies. The particle size of each bed is represented by the extension of the bed to the right of the log. The scale at the top right of each log shows these sizes with labels for clay (C), silt (S), fine-to-coarse sand (F, M, C), and gravel (G). Photos show close-up sections of core lithology. Locations of photos are shown by red bars labeled "P" along the core logs. H/W next to a core indicates the location of the Holocene/Wisconsin boundary based on foraminiferal biostratigraphy and calcium-carbonate fluctuations (see figure below). Sands in these cores were deposited during the Wisconsin (Last Glacial). Locations of cores and profile are shown in map on central panel.

Graphic core logs of cores from the Bryant Canyon Turbidite System showing bed-by-bed core lithology correlated to *G. menardii* index curves to show the relationship of redeposited sediments (e.g., mass-transport deposits, turbidites and related sandy deposits) to the Last Glacial (Wisconsin) and Holocene interglacial cycles. All discrete beds composed of silt-, sand-, or gravel-size particles are colored yellow. The particle size of each bed is represented by the extension of the bed to the right of the log. The scale at the top right of each log shows these sizes with labels for clay (C), silt (S), fine-to-coarse sand (F, M, C), and gravel (G). Cores with beds containing exotic mud clasts of variegated colors are schematically represented on the logs. Locations of cores are shown on map (Group 5) on left panel.