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Temporal Scales of Mass-Wasting Sediment Transport on the Mississippi River Delta Front Delineated by $^{210}Pb/^{137}Cs$ Geochronology

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ABSTRACT

Long known to be characterized by mass-wasting sediment transport, the Mississippi River Delta Front (MRDF) is a subaqueous apron of rapidly depositing and weakly consolidated sediment extending from the subaerial portions of the Birdsfoot Delta of the Mississippi River. In order to better understand spatio-temporal scales of controlling processes within the MRDF, twenty-eight piston cores up to 8.9 m in length were collected seaward of river channel outlets, then analyzed for magnetic susceptibility and gamma density, in the context of CHIRP sub-bottom seismic data collected by the U.S. Geological Survey. For this study, three cores were selected for study of sediment properties in three depositional environments (undisturbed proximal apron, medial mudflow gully, and mudflow lobe) and further analyzed for grain size, sediment fabric (X-radiography), and geochronology ($^{210}Pb/^{137}Cs$ radionuclides). Building on previous work (Keller et al., 2017; Coleman et al., 1980), data indicate mass wasting sediment transport processes can be detected anmeasured by diagnostic properties preserved in sediment cores. Within the mudflow gully and lobe core, homogenized $^{210}Pb/^{137}Cs$ activities within deposited sediment and corresponding stepped profiles of gamma density indicate the presence of dm- to m-scale mass failures with cm-scale seasonal variations throughout. ^{137}Cs (fallout from nuclear testing beginning in 1952, peaking in 1963) is present throughout the gully core indicating that medial gully sedimentary deposition since 1952 is greater than 580 cm (≥ 8.4 cm/yr or 0.84 m/decade). Rate of sediment accumulation observed in the undisturbed proximal apron adjacent to the medial gully is 2.6-5.4 cm/yr with ^{137}Cs being present only to 144cm an excess ^{210}Pb to 250cm and gamma density following a constant consolidation profile down core, indicating undisturbed, constant deposi-

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tion. Two temporal scales of proximal deltaic sedimentation are evident: (1) seasonal deposition by river flood events and related storm/cold front reworking of annual flood deposits; and (2) decadal deposition of mudflow deposits ≥0.8 m within gullies.

INTRODUCTION

The Mississippi River Delta Front (MRDF) is characterized by heavily channeled gullies cutting though rapidly deposited, poorly consolidated silts and clays coalescing into lobate structures down slope. Fine-grained deltaic systems, commonly forming in conjunction with river dominated deltas, owe significant overall source-to-sink sediment movement to landslides, which can transport massive amounts of sediment in a short period of time (Talling, 2014). Fine-grained subaqueous sediment failure as constrained by Nardin et al. (1979) describe gravity driven mass movement supported internally by the strength of the matrix creating a viscous fluid (Boggs, 2014). These flows are supported by their own poorly sorted mud matrix/interstitial water and prevent stratification as compared to more rigidly stratified subaqueous mass transport (i.e., turbidity currents). This cohesion, however, is not enough to prevent down slope flow, even in very low slope environments such as the MRDF at 0.5–1.5° (Obelcz et al., 2017).

Three distinct depositional environments within the MRDF have been identified: (1) an undisturbed proximal apron intersected by (2) medial mudflow gullies forming channels acting as conduits of sediment downslope; (3) mudflow lobes coalescing at the base of mudflows, distal of the immediate effects of mudflows. The stratigraphy within the mudflow gullies extending into the corresponding lobes, in contrast to neighboring undisturbed and prodelta environments, shows convolute, irregular bedding and visible unconformities at the base of depositional events (Keller et al., 2017; Coleman et al., 1980). The proximal nature of these failures to the coastline (≤20 km of the coast) put them in the vicinity of economically critical petroleum industry structures including pipelines and platforms, resulting in damage and in some cases ruinous monetary and ecological disaster (Taylor Platform, 2006). Though previous research has been conducted on mudflow features and events driven by major hurricanes, within the MRDF relatively little is known regarding the return periods of lower magnitude mudflows (0.5–3 m thick) as well as their triggering mechanisms. These temporal scales/return periods and how to better constrain gravity driven mud flows stratigraphically within the MRDF is the major goal of this study.

METHODS

Core Collection

A 2017 cruise of the Point Sur in collaboration with BOEM and the LSU Coastal Studies Institute collected cores off the Southwest Pass of the Mississippi River (Fig. 1) collected fourteen 3-8 m cores approximately 15 km offshore in 10–80 m water depth, three of which were split and analyzed from each of the above mentioned depositional environments. Radionuclides analyzed were ^{210}Pb (natural ^{238}U, $t_{1/2}$ = 22.2 yr), and ^{137}Cs (anthropogenic ^{238}U, $t_{1/2}$ =30.1 yr) in units of decay per minute per gram (dpm/g). Subsamples were collected at 12 cm intervals, dried, ground, and contained within sealed plastic Petri dishes 6 cm in diameter (~5–13 g of material). Samples were then placed in calibrated Canberra gamma detectors and counted for a period of 24 hr; gamma emission peak areas were analyzed with Genie 2000 software. Sediment accumulation rates from ^{210}Pb are calculated using a two parameter (depth vs. activity) exponential decay regression in SigmaPlot (v. 13.0). A typical ^{210}Pb profile (for our purposes defined as gradual) decays exponentially with depth and can be utilized to date relative sediment depositional rates up to 5 half-lives (111 yr) (Appleby, 2008; Keller et al, 2017). Bulk (gamma) density was obtained by a GEOTEK Multisensor Core Logger (MSCL) on whole sediment cores. Analysis of gamma densi-

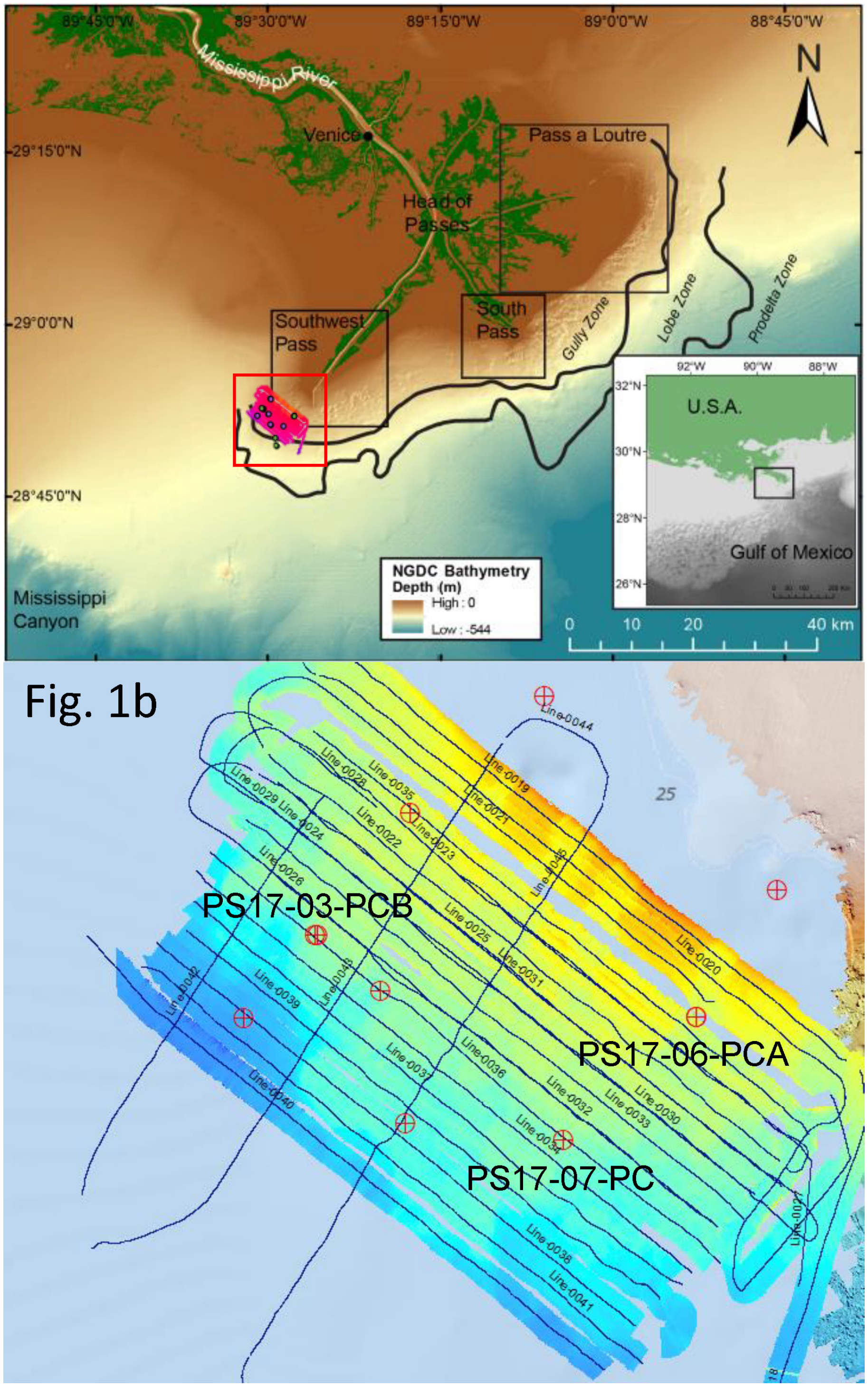

Figure 1. (a) Mississippi River Delta Front proximal to the subaerial structures of the Balize lobe "birdsfoot" (modified after Maloney et al., 2018). Study area highlighted in red. (b) Results of the 2016 Point Sur bathymetric survey of the Southwest Pass and selected cores.

ty relies on sections deviating from a constant consolidation profile (defined as a gradual increase in density downcore resulting from uniform deposition and compaction). X-radiography was performed on split piston core halves and imaged on the Samsung Model SP501 detector panel combined with a Min X-ray HF-8015+dlp X-ray generator in 30 cm sections and processed with ImageJ/Adobe Suite software (3.4-5.4 mÅ at 50–60 keV). Grain sizes were collected at 12 cm intervals, deflocculated utilizing 0.5% sodium phosphate, and processed with hydrogen peroxide to eliminate organic material for analysis utilizing Beckmann-Coulter Laser Diffraction Particle Size Analyzer (Model LS–13–320).

RESULTS

Radiochemistry (Fig. 2)

PS17–03–PCB: has a relatively uniform exponential decay profile with sawtooth variation at decimeter scale from 100 to 215 cm. ^{137}Cs is present from the surface to 144 cm.

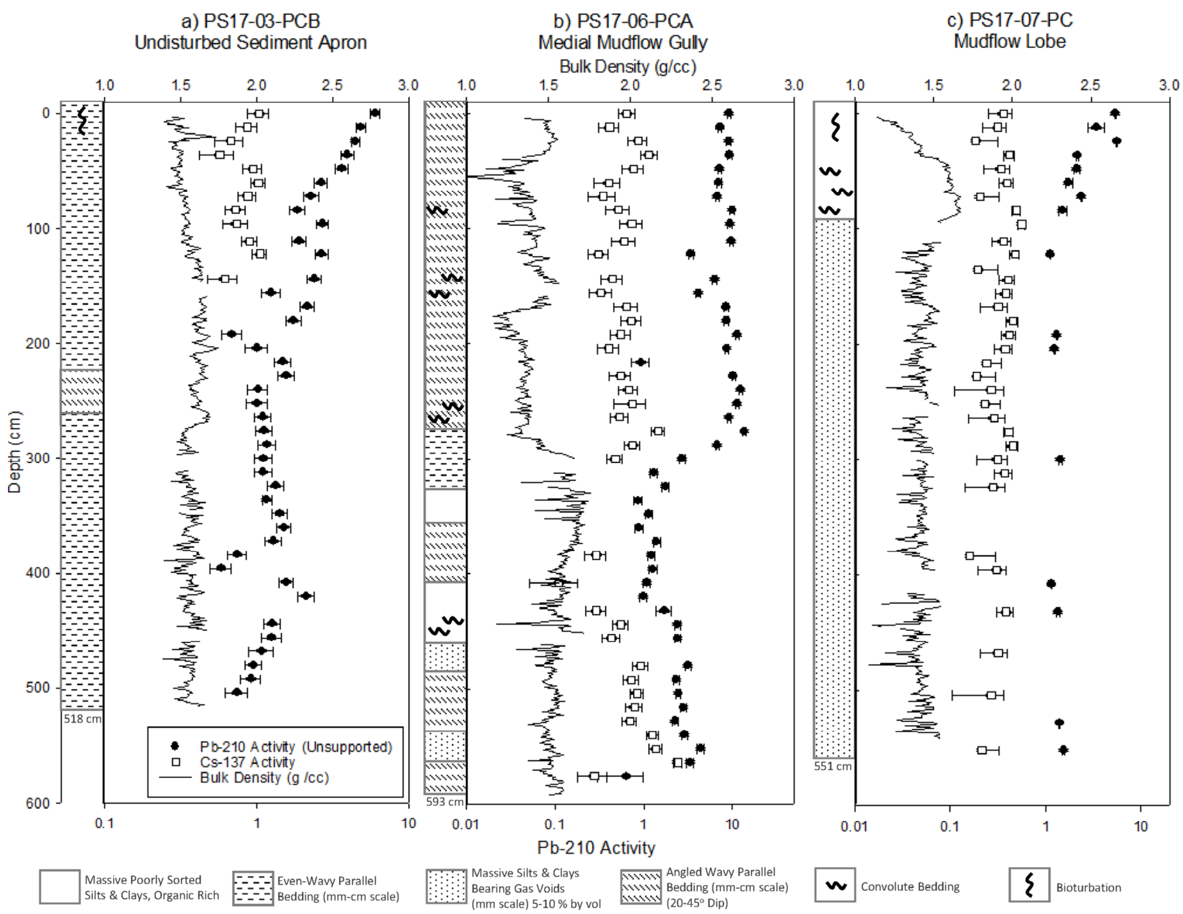

Figure 2. ^{210}Pb activity (log scale), ^{137}Cs activity (linear), and bulk density (linear) plotted against depth (cm) for three representative environments: (a) undisturbed sediment apron, (b) medial mudflow gully, and (c) mudflow lobe.

PS17–06–PCA: Three distinct layers are present: ^{210}Pb content is homogeneous from 0–264 cm, then gradually decreasing in activity from 264 cm to 312 cm; there is a homogeneous layer of lower activity from 312 cm to the base of the core (580 cm). ^{137}Cs displays homogeneous activity throughout the core, breaking from ~300–380 cm, corresponding with a marked increase in grain size

PS17–07–PC: ^{210}Pb shows a stair-step variation in the upper 84 cm in two major sections, 0–24 cm and 24–84 cm. This pattern transitions into a sawtooth pattern at sub–24 cm intervals extending to the base of the core. Homogeneous ^{137}Cs is also present to the base of the core.

Supporting Methods

PS17–03–PCB: Profiles of mean grain size show cm-scale sawtooth variation between 5.5–6.8 Φ throughout the core. An ~4 Φ spike at 15 cm representing a possible hydrodynamic event is present; for the remainder of the core, the grain-size profile varies between 5–8 Φ. Bulk density displays a steady increase down core but with cm scale sawtooth variation. A peak exists corresponding with the grain size peak observed at 15 cm and marked decrease at 300 cm. (Fig. 2a)

PS17–06–PCA: Grain size displayed cm scale variation (6–8 Φ). There is a marked decrease at ~190 cm down to ~312 cm, then a marked increase to 4.98 Φ at 432 cm (corresponding with a dip in ^{210}Pb and ^{137}Cs activity). Bulk density contains cm scale sawtooth variation throughout, Reduction in density corresponding with ^{210}Pb variations (meter scale) (Fig. 2b).

PS17–07–PC: Grain size shows sawtooth variation (cm scale) but no significant larger scale variation (6–8 Φ). Bulk density contains a large scale increase from 0 to 95 cm, then a subsequent rapid decrease back to a standard consolidation profile for the remainder of the core (Fig. 2c).

SUMMARY

PS17–03–PCB (undisturbed sediment apron), displayed the most uniform exponential ^{210}Pb profile and bulk density consolidation profile of the three cores, representing idealized deposition primarily derived from a hypopycnal sediment plume. The calculated regression shows a 2.45 cm/yr depositional rate down core to 84 cm and a more rapid depositional period from 84 cm to 226 cm resulting in a 4.39 cm/yr rate. Another decimeter scale variation at 400 cm can be observed but as it is comparable to fluctuations in supported ^{210}Pb is possibly below the ^{210}Pb basement. This compared with the ^{137}Cs basement at 144 cm indicating a rate of 2.28 cm/yr showing lower rates of deposition as compared to adjacent gully cores (PS17–06–PCA). The lower rates calculated from ^{137}Cs could be explained by the 12 cm sampling resolution, as in the actual Cesium basement existing between 144 cm and 156 cm, or levels of ^{137}Cs being below detectable levels further down core. PS17–06–PCA (medial gully core) shows meter-scale layering of sediment properties, discerned by ^{210}Pb stair-step profiles combined with corresponding reduction in bulk density. The only exception in the ^{210}Pb profile is a layer between 276–312 cm that may represent a mudflow hiatus (Keller et al., 2017; Obeltz et al., 2017)with the reduced profile slope of ^{210}Pb (.275 cm/yr) indicating a drastic reduction in deposition and a possible resumption in river plume deposits. Homogenized ^{137}Cs continuing to the base of the core also indicates rapid/recent sedimentation originating from proximal undisturbed environments. When combined with bulk density reductions, homogenous ^{210}Pb layers indicate two separate mass wasting events within the core depth separated by a period of reduced deposition (presumably river plume sediment delivery) (Keller et al., 2017)

PS17–07–PC (mudflow lobe) shows a stair-step pattern of ^{210}Pb in the upper 84 cm corresponding to a rapidly increasing bulk density and extending to a contact visible in X–radiography, overlying a homogenized, methane bearing deposit extending to the base of the core. This represents the toe of a mudflow system, extending the apron of sediment (1) onto Holocene prodelta deposits or (2) coalescing with another lobe. The notably smaller deposit thickness (averaging 36 cm) indicates it may be at the distal end of mudflow reach or resultant of a smaller flow. (Coleman et al., 1998; Talling, 2014)

CONCLUSIONS

(1) Mudflow deposits are present and identifiable down to/below core penetration depths of 6 m within mudflow gullies. ^{210}Pb indicates relatively large scale (0.5–1.5 m) mudflow deposits within gullies comprising the majority of sediment present as well as regular return periods within the same channel/gully. Areas of the Southwest Pass delta front subject to direct mass-wasting driven deposition indicate decadal depositional rates four times that of areas predominantly subjected to hypopycnal driven sedimentation.

(2) ^{137}Cs activity present to the base of cores analyzed that were collected throughout the lobe and medial gully environments. This indicates sediment accumulation over the last 63 yr at a rate of ≥0.8 m per decade. Future work may show a deeper ^{137}Cs basement than this study, increasing the sediment accumulation rate. The undisturbed proximal apron core shows a much lower accumulation rate independent of mass-wasting sediment delivery with an activity basement of 144cm with a rate of 0.22 m/decade over the last 63 yr.

(3) Supporting previous research (Keller et al., 2017), this data further indicates that mudflow deposits are identifiable in shallow section core analysis. ^{210}Pb layers "stair-stepping" down core combined with mass fluctuations in bulk density are diagnostic of sediment gravity flows.

REFERENCES CITED

Appleby, P. G., 2008, Three decades of dating recent sediments by fallout radionuclides: A review: The Holocene, v. 18, p.83–93.

Baldwin, W. E., S. D. Ackerman, C. R. Worley, W. W. Danforth, and J. D. Chaytor, 2018, High-resolution geophysical data collected along the Mississippi River Delta front offshore of southeastern Louisiana: U.S. Geological Survey Field Activity 2017–003–FA.

Boggs, S., Jr., 2014, Principles of sedimentology and stratigraphy, 5th ed.: Pearson Education, London, U.K., 608 p.

Chaytor, J. D., W. E. Baldwin, S. J. Bentley, M. Damour, D. Jones, J. Maloney, and K. Xu, 2020, Short- and long-term movement of mudflows of the Mississippi River Delta front and their known and potential impacts on oil and gas infrastructure: Geological Society, London, Special Publications, U.K., v. 500, p. 587–604.

Coleman, J. M., H. J. Walker, and W. E. Grabau, 1998, Sediment instability in the Mississippi River Delta: Journal of Coastal Research, v. 14, p. 872–881.

Keller, G., S. J. Samuel, I. Y. Georgiou, J. Maloney, M. D. Miner, and K. Xu, 2017, River-plume sedimentation and $^{210}Pb/^{7}Be$ seabed delivery on the Mississippi River Delta front: Geo-Marine Letters, v. 37, p. 259–272.

Maloney, J. M., S. J. Bentley, K. Xu, J. Obelcz, I. Y. Georgiou, and M. D. Miner, 2018, Mississippi River subaqueous delta is entering a stage of retrogradation: Marine Geology, v. 400, p. 12–23.

Obelcz, J., K. Xu, I. Y. Georgiou, J. Maloney, S. J. Bentley, and M. D. Miner, 2017, Sub-decadal submarine landslides are important drivers of deltaic sediment flux: Insights from the Mississippi River Delta Front: Geology, v. 45, p. 703–706.

Roberts, Harry H., 1997, Dynamic changes of the Holocene Mississippi River Delta plain: The delta cycle: Journal of Coastal Research, v. 13, p. 605–627.

Talling, P. J., 2014, On the triggers, resulting flow types and frequencies of subaqueous sediment density flows in different settings: Marine Geology, v. 352, p. 155–182.

NOTES