PRF# DNI-57764
Project Title: Investigating Advective and Diffusive Controls on Fine-Grained Sediment Transport and Deposition
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The purpose of this project is to investigate the controls on depositional patterns as a function of grain size, with particular interest in the controls on the deposition of silt and other very-fine-grained sediments. Over this second year, we (a) have performed additional work experimentally investigating the geotechnical behavior of weakly consolidated fine sediments, and (b) have augmented this with field measurements of depositional trends in a field setting.

Amanda Whaling, whose MS thesis was supported by DNI funding (Whaling, 2018), completed and submitted a paper that investigated fine sediment removal from the foreset of the Wax Lake Delta, Louisiana. Between March 2015 and May 2016, the Wax Lake Delta experienced a rather large flood. While we expected that the delta front would be depositional, a great deal of the area was actually net erosional (Figure 1A; EarthArxiv Preprint: https://osf.io/urcyv/; in revision at *Estuaries and Coasts*). This was surprising to us, as the landform is unequivocally depositional of timescales of a few years or longer. One option, which we cannot rigorously test given the data collected, is that compaction of the deposit resulted in bed lowering. Another option is that entrainment processes, such as waves, may be essential in moderating the depositional patterns of fine sediments relative to coarse ones. A final option is that the anomalously large flood could have maintained shear stresses large enough to produce erosion.

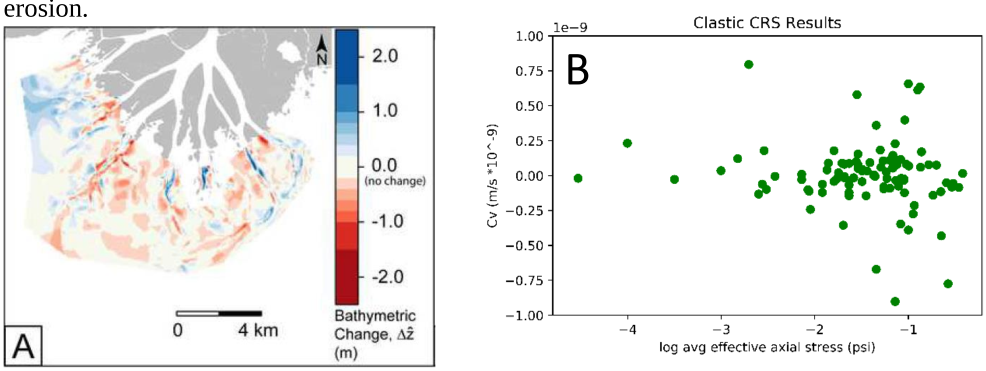

Figure 1. A) Measurement of bathymetric change on the Wax Lake Delta over one year, including a significant flood. The significant areas of bed lowering (red) prompted a reassessment of the timing and patterns of fine grained deposition. B) Results of consolidation test for kaolinite representative of a clastic delta front. C_v = *coefficient of consolidation, as a function of effective stress. Average* $C_v = 3.78\text{x}10^{-10}$.

To further test the geotechnical properties of delta front sediments, Sam Zapp and Kelly Sanks, MS students funded by PRF conducted controlled rate-of-strain consolidation tests on a triazial load frame in accordance with ASTM D4186 in order to obtain coefficient of consolidation (C_v) estimates for weakly consolidated fine-grained samples created to mimic delta front and marsh deposits. While this method showed some success by estimating C_v (See figures 1B) the results were difficult to reproduce because the bulk densities and imposed strain rates were at the low end of repeatable behavior with standard triaxial test equipment. The mean C_v values were $3.78\text{x}10^{-10}$ for the clastic sediment and $7.11\text{x}10^{-10}$ for a marsh proxy composed of pure kaolinite. The marsh proxy value was larger, as expected for a material that is more prone to consolidation. However, values for both materials were atypically low relative to most sediments in the field, and more consolidation tests will be run during the project's final period to test for reproducibility.

Analysis of field-scale grain-size trends has progressed significantly over the past year, and is nearing the submission stage. Models for estimating the ratio of coarse to fine sediments in bed deposits (the key unknown in our proposal) were tested with 100 grab samples on a delta front previously analyzed by an undergraduate honors student (Seth Gilchrist) funded by this grant. We found that coarse-to-fine ratios are not well predicted by advection settling models when the fine fraction is silt sized, because there is nearly always enough fluid shear in coastal systems to keep a significant fraction of silt entrained, and that delta fronts can sometimes be net erosional (see Whaling and Shaw, in revision; Fig. 1A). Hence, we have moved to a new model that introduces includes entrainment rates as well as settling rates (a less simple, but more explanatory model).

$$Grain\ Size\ Ratio = \frac{r_1 w_{s1} c_{s1}}{r_2 w_{s2} c_{s2}} \exp\left(\left(\frac{r_2 w_{s2}\ -\ r_1 w_{s1}}{q}\right) x f_e\right)$$

where r_i, w_{si}, and c_{si} are the ratio of near bed to depth averaged sediment concentration, settling velocity, and upstream concentration of a coarse fraction (i=1) and fine fraction (i=2), q is water flux, x = distance from source, and f_e is the fraction of settling flux that leaves the system (rather than staying entrained due to turbulence. When f_e is small (~0.05), this model predicts the changing of the grain size ratio far better than an advection settling model. Furthermore, the deposition rates calculated from the equation above show tapers that match the slope of the subaqueous delta foreset quite well (See figure 2, right). We take this as compelling evidence that grain size variations and foreset morphology are coupled and one can give information about the other. This work has been presented in seminars given at University of Arkansas (January 2019), Texas Christian University (November 2019). In Spring 2020, this work will be presented at University of Pennsylvania (in January) at the International Sedimentary Geoscience Congress (in April; Shaw et al. 2020), with the plan to submit it to *Sedimentology* in Summer 2020.

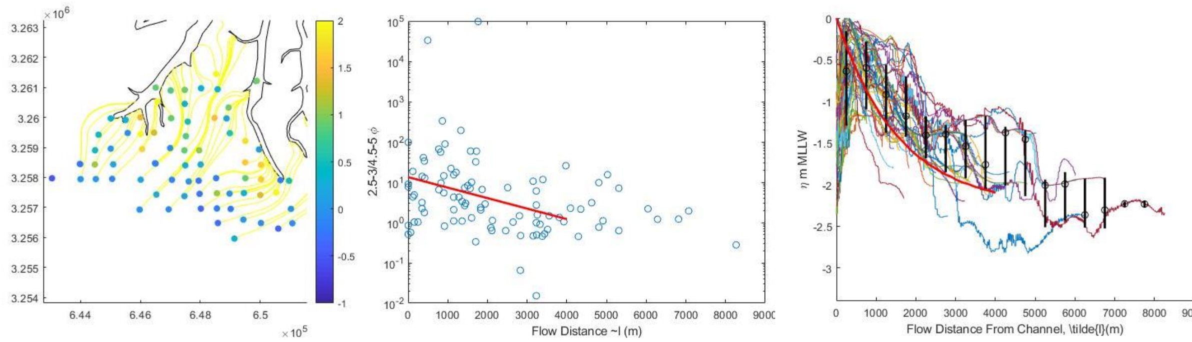

Figure 2. (left) Map of the logarithm of the fine sand (Phi = 2.5-3) to coarse silt (Phi = 4.5-5) ratio on the delta front of the Wax Lake Delta. Yellow lines show the approximate paths that the particles took from where they left distributary channels. (Middle) Grain Size Ratio plotted as a function of curvilinear travel distance from the distributary channel that supplied the sediment. The red regression line shows the fitted curve based on a new model. (Right) Topographic elevation of the delta as a function of the same curvilinear distance from the channel, with the red line showing the same model. The two graphs show that grain size trends and the morphology of a delta foreset are tightly coupled.

In Spring 2018, a team of the PI, a post-doc Robert Mahon, and graduate student, and an undergraduate conducted a field campaign to measure changes to fine-grained sediment transport with distance from a flooding delta. The project has moved forward rather slowly as the post-doc Dr. Mahon, left Arkansas to begin a tenure track faculty position at the University of New Orleans in Fall 2018. Robert has been active on this project at New Orleans, and has written a successful DNI grant to pursue further field work (60151-DNI8). I have slowed my work on this portion of the project in order to help Robert succeed in his tenure efforts. Michael Amos began working on this project in my lab, and has transitioned into the MS program at UNO working on the same project. He recently presented preliminary results at the AGU fall meeting in December 2019 (Amos et al. 2019).

Works Cited

Amos, M., Mahon, R.C., Shaw, J.B., Cathcart, C.A., 2019, Sediment transport dynamics and the evolution of subaqueous delta channel levees: AGU Fall Meeting, San Francisco, CA, EP23E-2254.

Shaw, J.S., Mahon, R.C., Gilchrist, S.G, 2020, Sedimentology of a Prograding Distributary Channel Network: SEPM International Sedimentary Geoscience Conference, Flagstaff, AZ

Whaling, A.R., 2018, Changes to Subaqueous Delta Bathymetry Following a High River Flow Event, Wax Lake Delta, USA, MS Thesis, https://scholarworks.uark.edu/etd/3044

Whaling, A.R., Shaw, J.B., (in revision), Changes to Subaqueous Delta Bathymetry Following a High River Flow Event, Wax Lake Delta, USA, Estuaries and Coasts, EarthArxiv: https://osf.io/urcyv/