Improved Penetrometer Performance in Stratified Sediment for Cost-Effective Characterization, Monitoring and Management of Submerged Munitions Sites

(SERDP MR18-1233)

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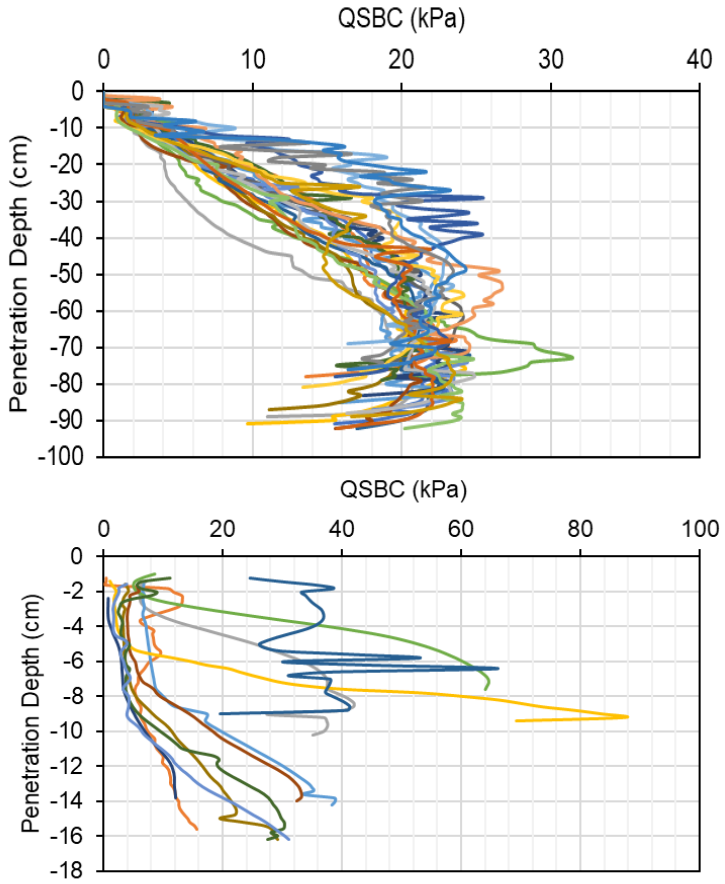
2019 | Enhancing DoD's Mission Effectiveness

Problem Statement

Sediment stratification at the uppermost surface of subaqueous sediments can vary in dimensions, physical characteristics and geomechanical behavior.

This impacts munition deposition, burial depth and stability, as well as most surveying methods, and can lead to significant issues with munition detection, monitoring and munition site management.



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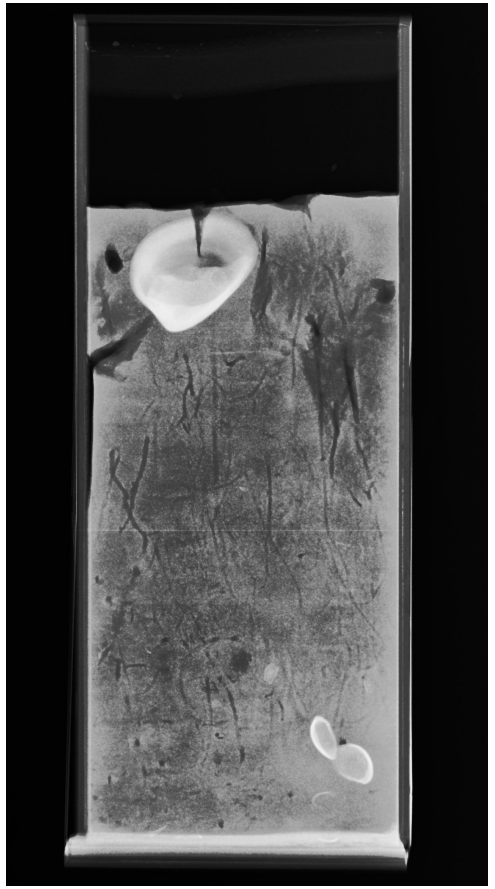
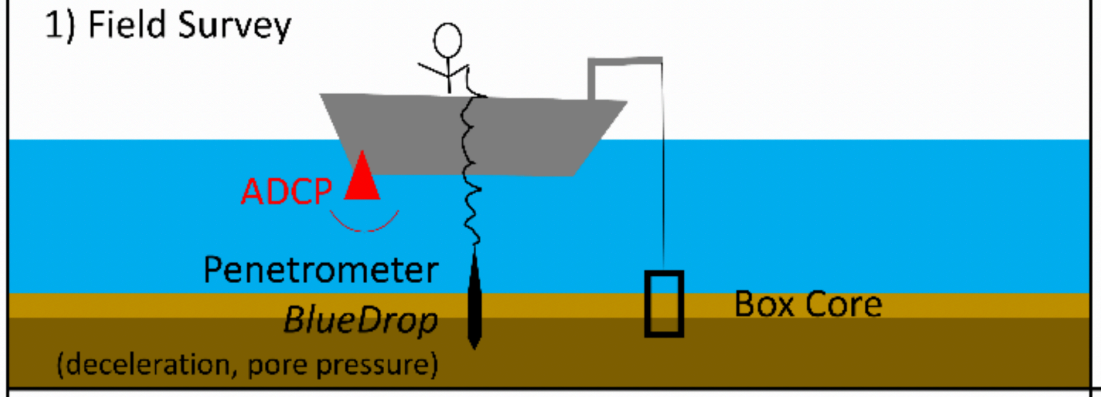
Problem Statement

Sediment stratification is rarely being considered due to a lack of methods to determine these information rapidly and reliably. There is also still a gap of knowledge regarding the geomechanical properties.



Technical Approach

1) Field Survey



2) Laboratory

Sedimentology
(high vertical resolution)

- Grain size analysis
- Bulk density
- Permeability
- Organic content
- X-ray imaging
- Erodibility

Geotech

- Friction angles
- Cohesion
- Shear strength
- Bearing strength
- Void ratios

3) Analysis & Research Tasks

- Determine differences in geomechanical properties of the different surficial seafloor layers (muddy and sandy environments, respectively).
- Assess potentially uncertainty of current survey and monitoring strategies resulting from geomechanical differences of surface layers.
- Correlate PFFP in-situ measurements to geomechanical properties.
- Establish relationships to estimate relevant geomechanical properties from the PFFP measurements.

4) Development of Investigation Framework & Proof-of-Concept

- Development of an assessment framework to conduct a rapid site investigation of seafloor surface layering in support of UXO site characterization and monitoring.
- Proof-of-concept at a known UXO site.

Technical Approach

1) Field Surveys – Phase 1

Completed at the following main sites:

- Pamunkey River (mud)
- Clay Bank (mud) [plus site re-visit with diver cores]
- Lower York River (sand)
- Naval Weapons Station (mud)
- Sarah's Creek (sand)
- King's Creek (sand)
- Coast Guard Station (sand)
- Goodwin Island
- Ferry Point (mud)

Additional data sets:

- Piankatank River, VA (sand; coll. with VIMS & UNC)
- James River, VA (mud & sand; coll. with NRL)
- Sydney Harbour, NS (mud; collaboration CBU)
- Delaware Bay, DE (mud & sand; collaboration with UDel)

Technical Approach

1) Field Surveys – Phase 1

Methods:

- Portable free fall penetrometer deployments
  - On average 10 deployments in closer proximity
  - At least one pore pressure dissipation test per site
- Sediment sampling
  - Box coring
  - Ponar grab sampling
  - Gravity coring (mud) & vibrocoring (sand)
  - Diver push cores
- Acoustic measurements
  - Acoustic Doppler current profiler (ADCP)
  - Chirp sonar
  - Rotary side scan sonar (in some locations)
- Conductivity-temperature-depth (CTD)

Technical Approach

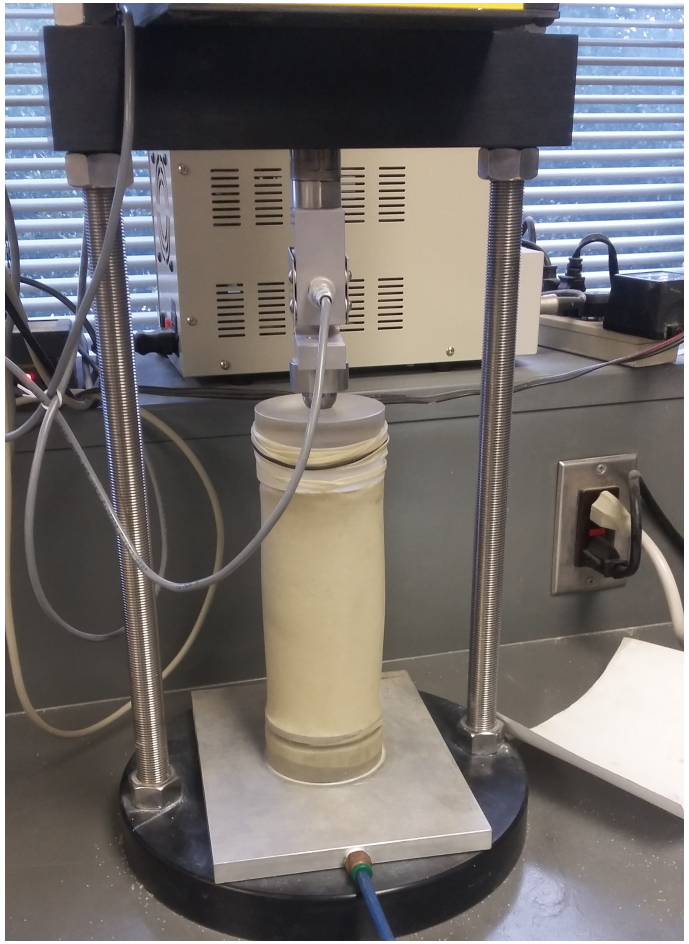
2) Laboratory measurements

Geotech:

- Bulk density, void ratios, porosity, permeability
- Undrained shear strength, friction angle, cohesion (triaxial shear testing, direct shear, lab mini vane shear)
- Consolidation testing (oedometer)

Sedimentology

- Core X-ray reflectance scanning
- Grain size (in vertical increments of 1-10 cm)
- Organic content
- Erodibility



Technical Approach

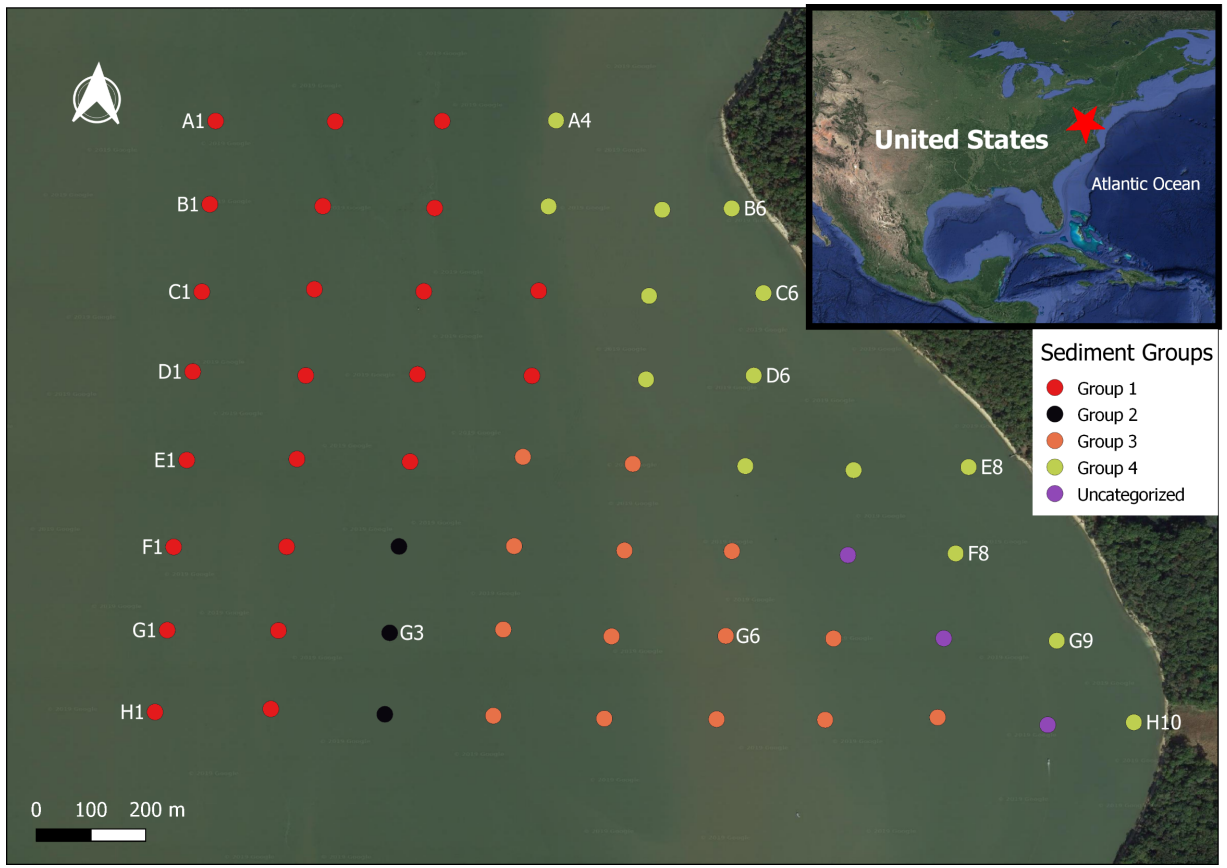
3) Data interpretation & correlation of geomechanical properties

- Quantify differences in geomechanical properties for surficial seabed layers for muddy and sandy sites
- Correlate portable free fall penetrometer (PFFP) results with geomechanical properties
- Estimate relationships to determine relevant geomechanical properties from PFFP measurements.
- Determine potential impacts on current site investigation methods.

Technical Approach

4) Development of an investigation framework and proof-of-concept (Field study – phase 2)

- Penetrometer measurements were carried out rapidly along a grid near Blossom Point, MD.
- The sediment bed was classified into 4 groups based on the penetrometer results (within < 12 hours!).
- The groups are further characterized from detailed penetrometer data analysis.
- Validation from sediment cores.



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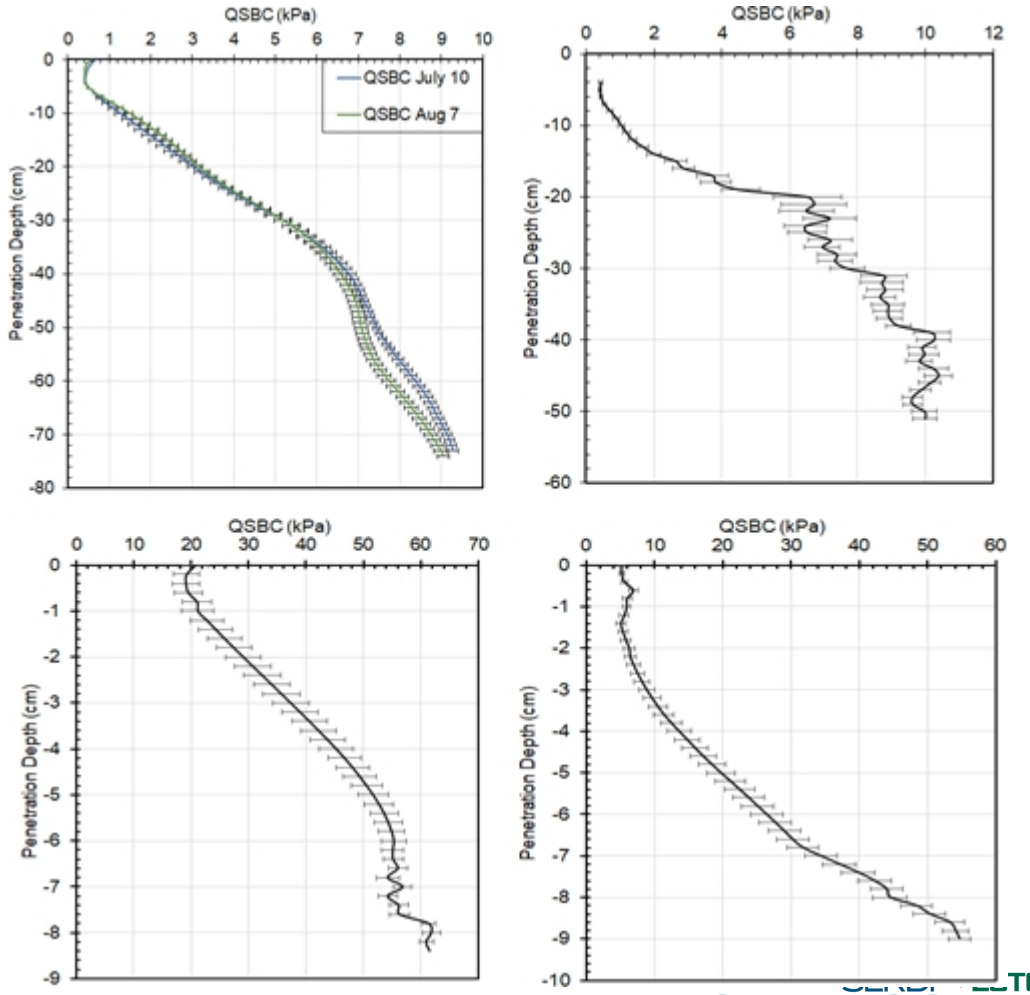
Results

1) **Different sediment types can rapidly and clearly be distinguished.**

Mud

Sand



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Results

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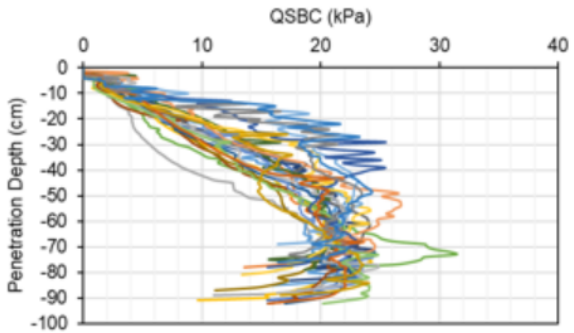
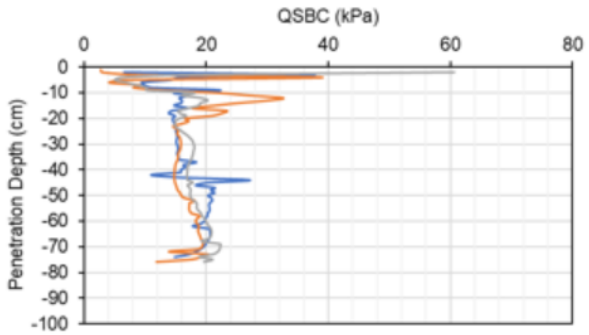
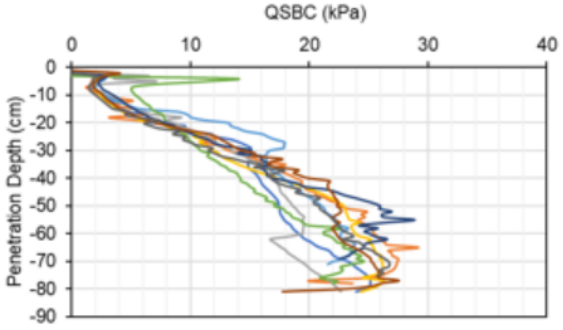
This enabled a rapid classification of different river bed groups during the proof of concept experiment.



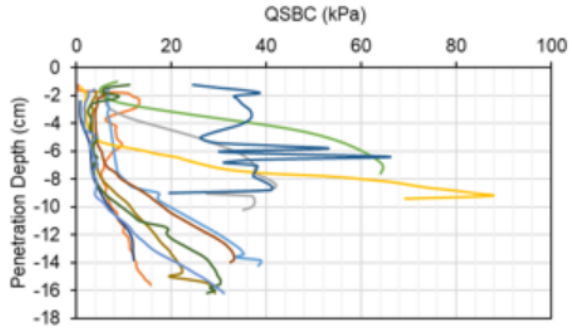
Group 1-Clay



Group 2-Clay



Group 3-Clay



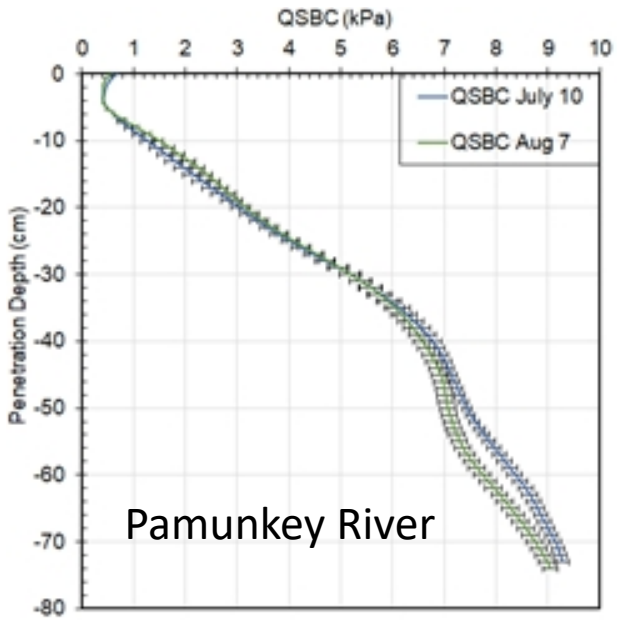
Group 4-Sand

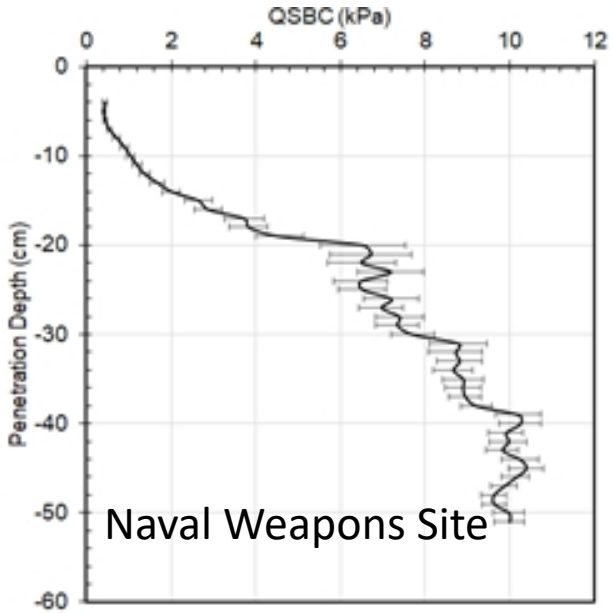
See poster by Dennis Kiptoo!

Results

1) **Different sediment types can rapidly and clearly be distinguished.**

2) **Significant differences in the geotechnical signatures can be identified between sites of one sediment type.**





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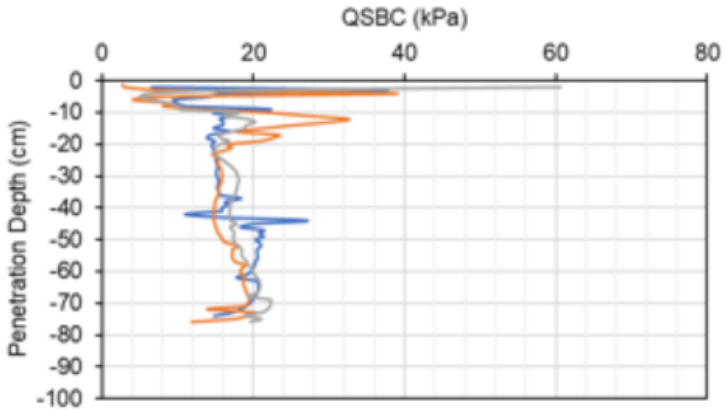
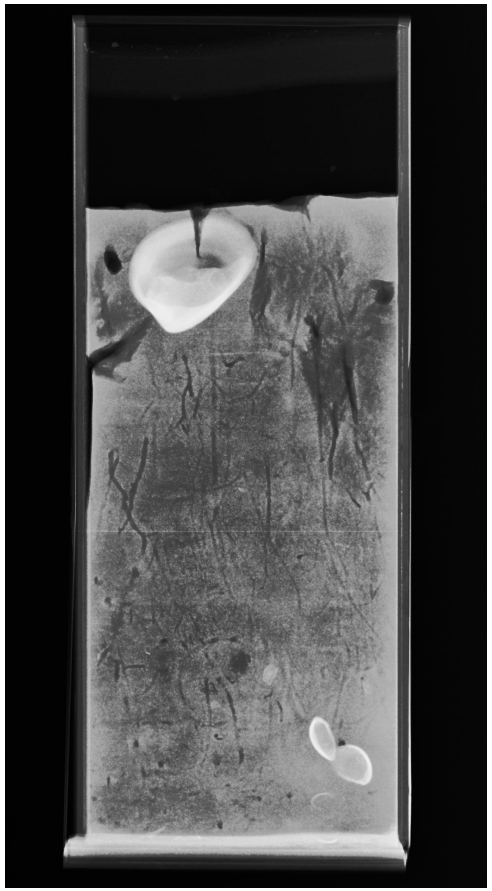
This includes differences caused by benthic life and biogenic processes.



Group 2-Clay



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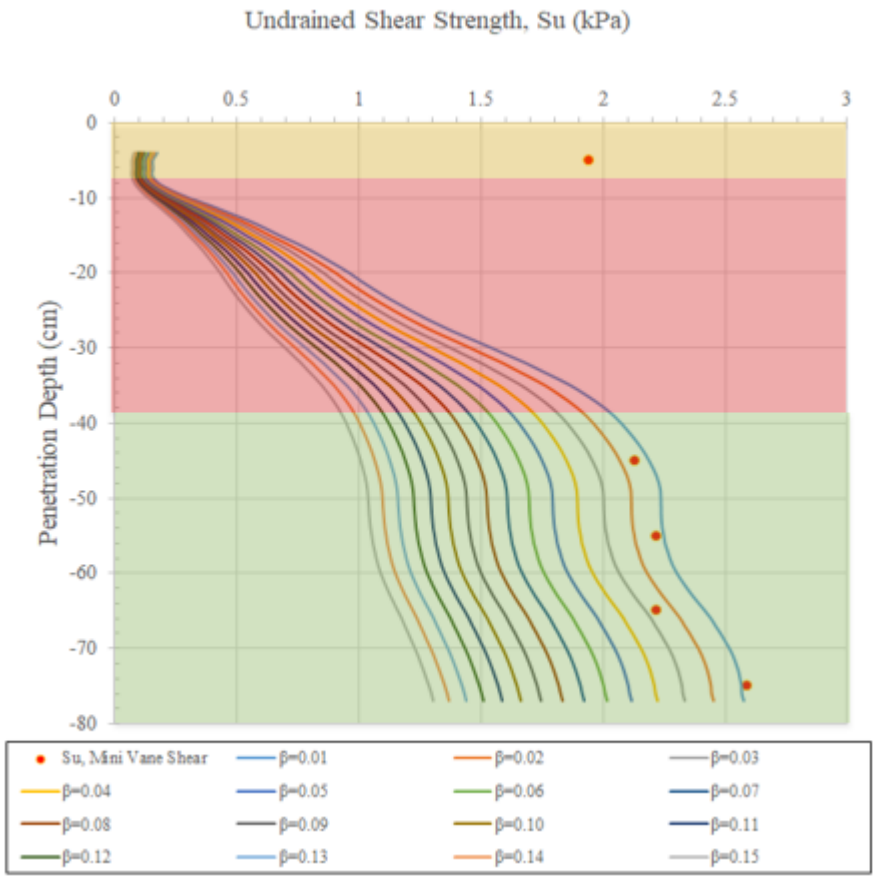
This also includes stratification in terms of layers of different sediment strength.

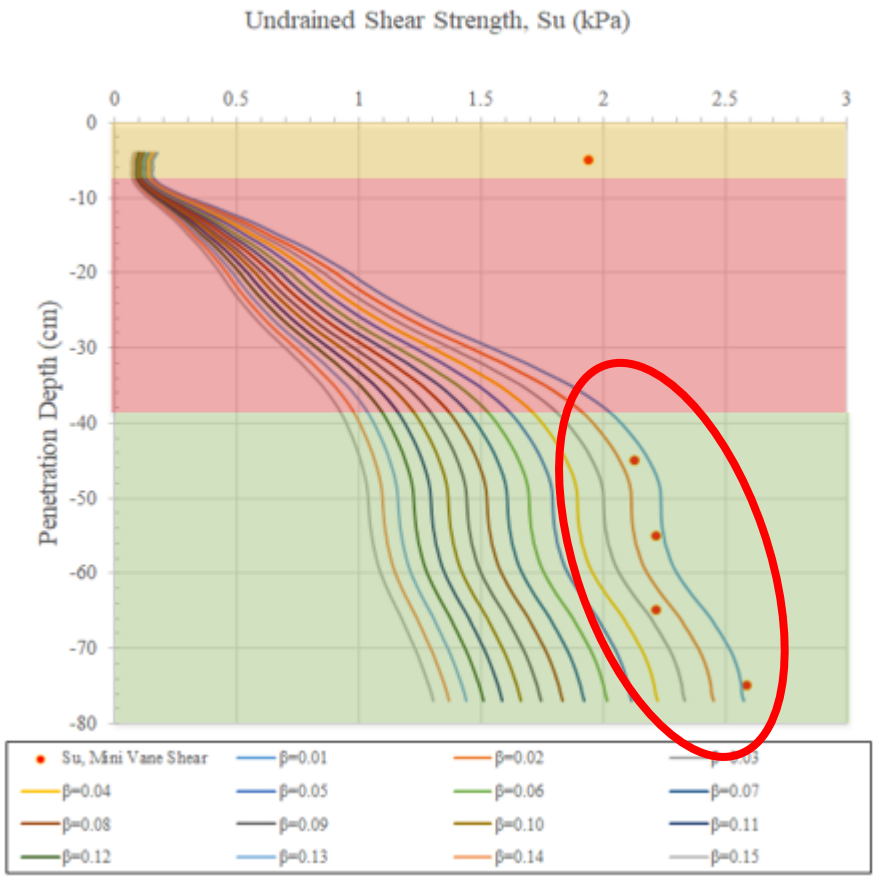


Results

1) Different sediment types can rapidly and clearly be distinguished.

2) Significant differences in the geotechnical signatures can be identified between sites of one sediment type.

3) Geomechanical properties such as shear strength, relative density, and friction angle can be derived from the penetrometer data.



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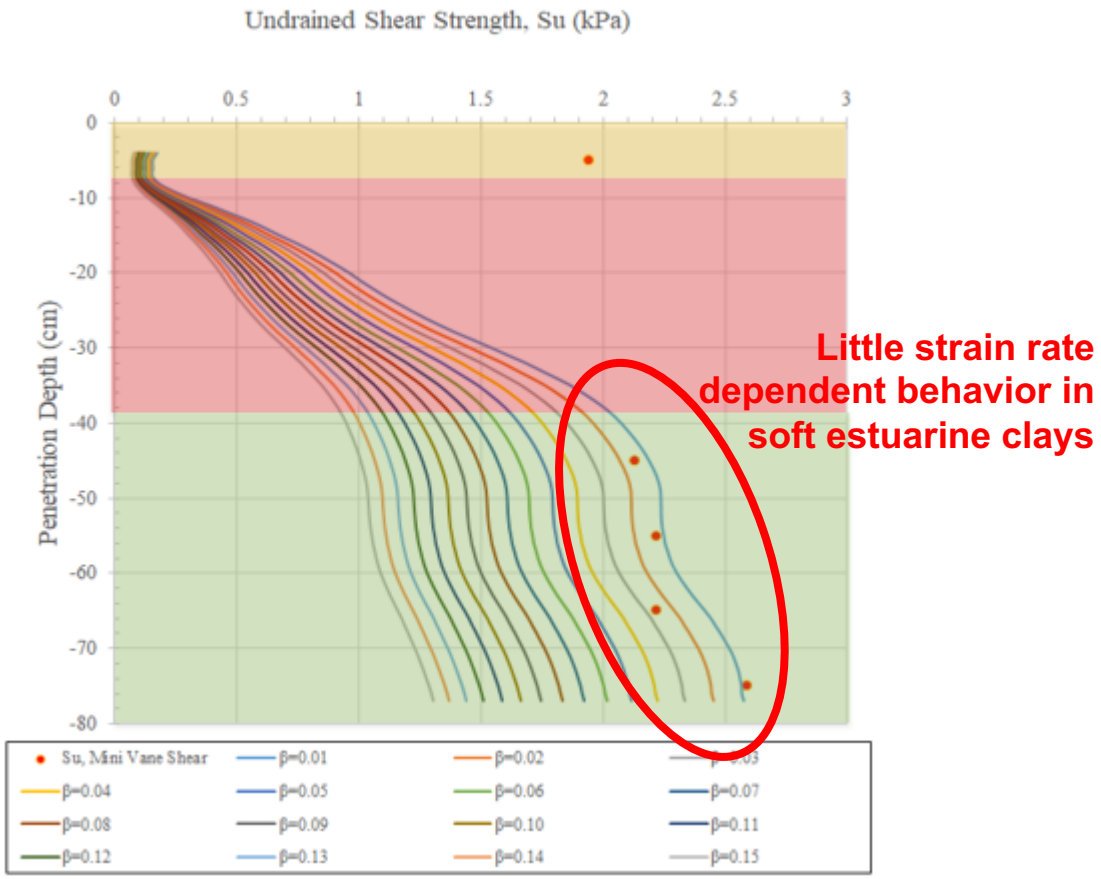

Kiptoo et al. (*in prep.*)

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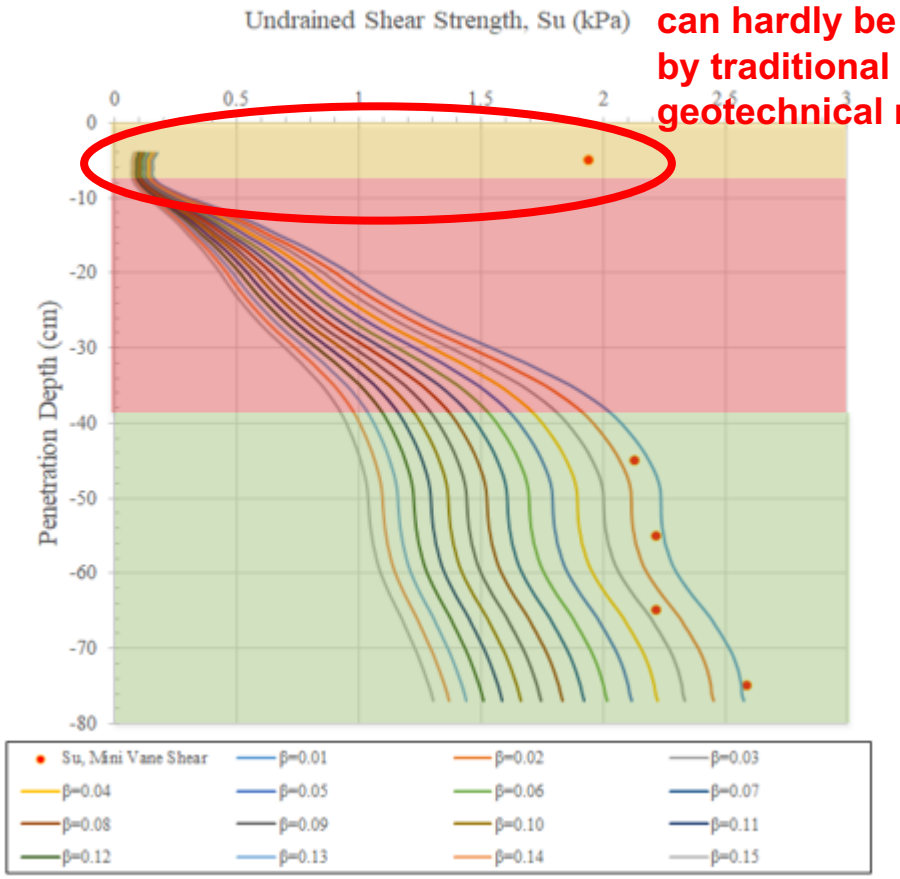
Extremely soft top layers can hardly be captured by traditional geotechnical methods



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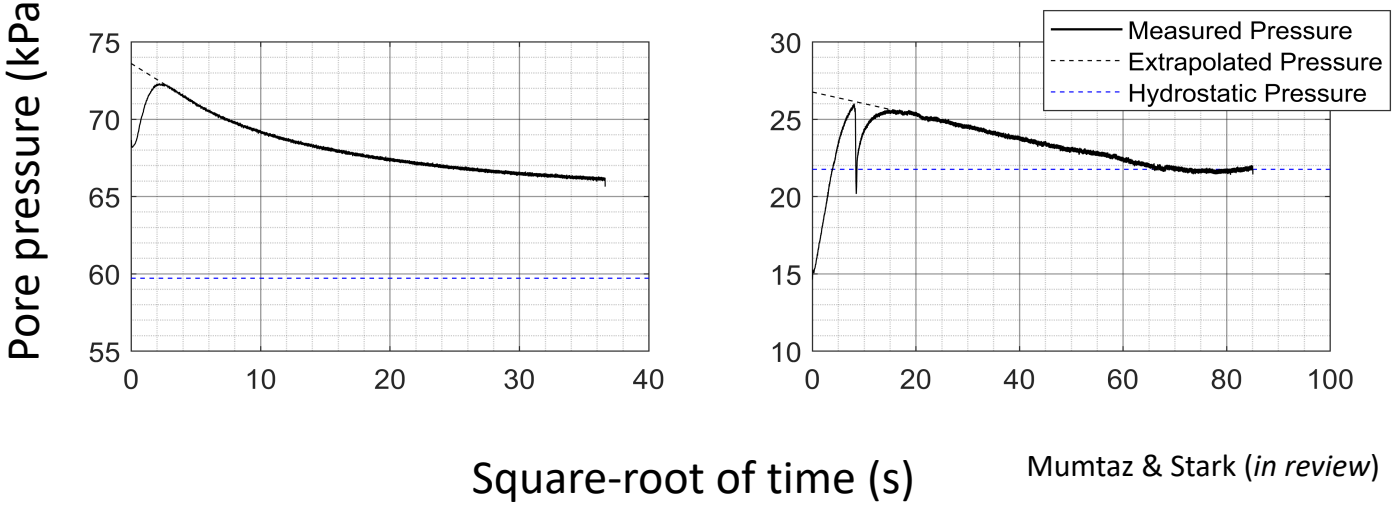
measured pore pressure dissipation curves (in mud)

→ determine time to 50% of excess pore pressure dissipation

→ estimate in-situ coefficient of consolidation and permeability



Mumtaz & Stark (*in review*)

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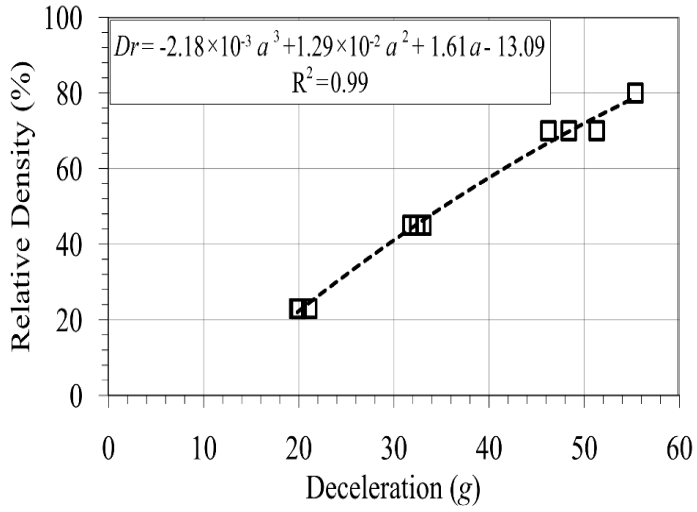

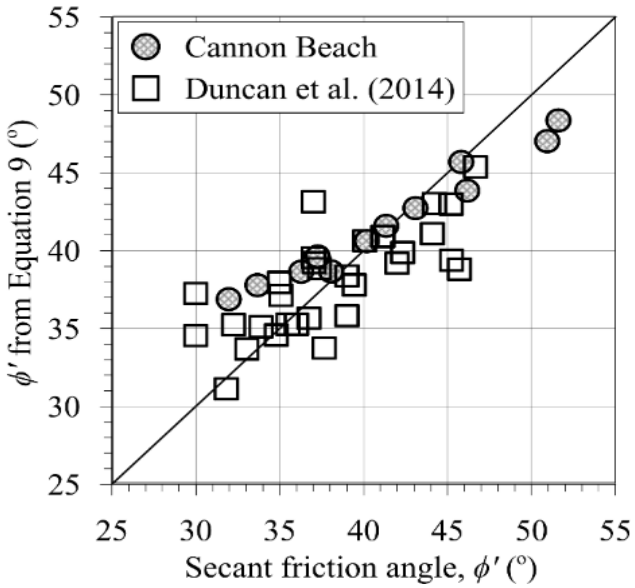

Albatal et al. (2019)

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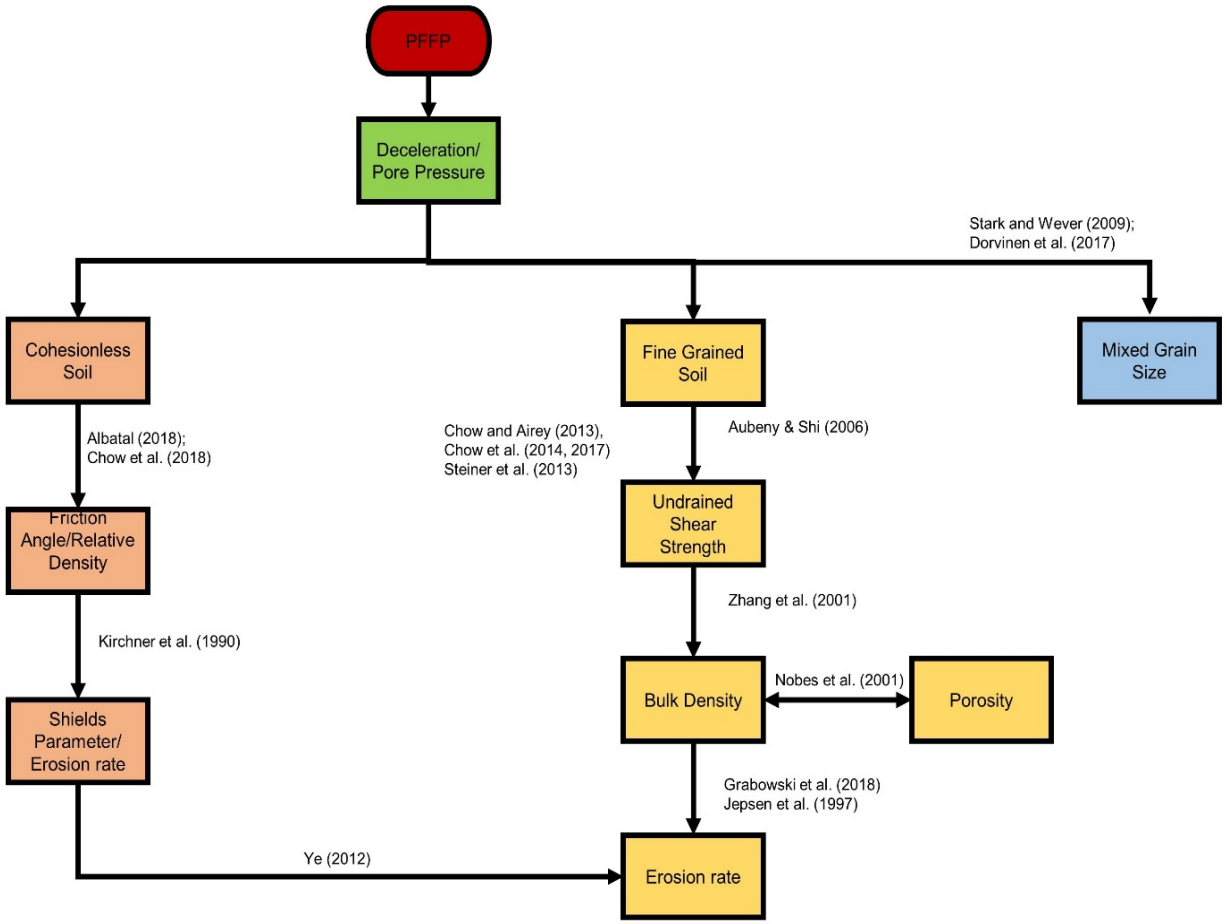

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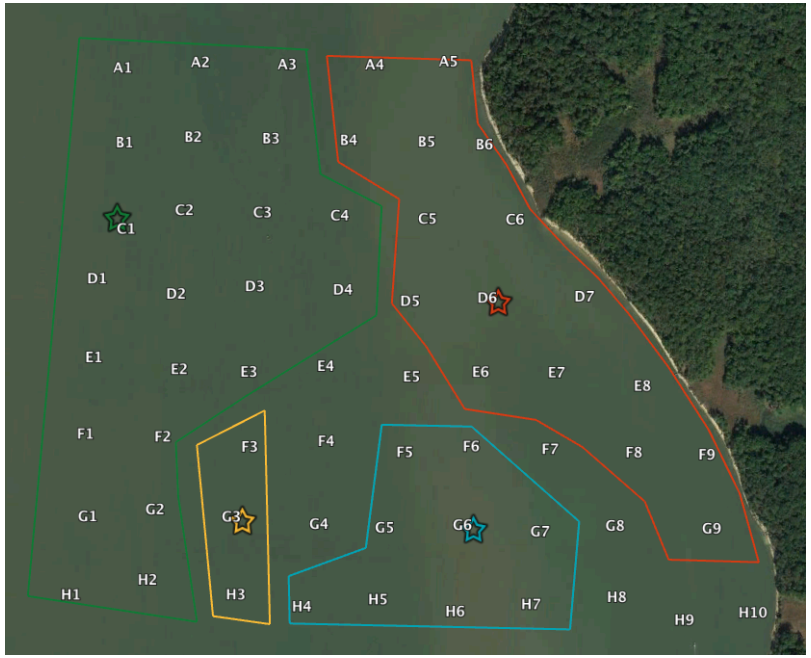
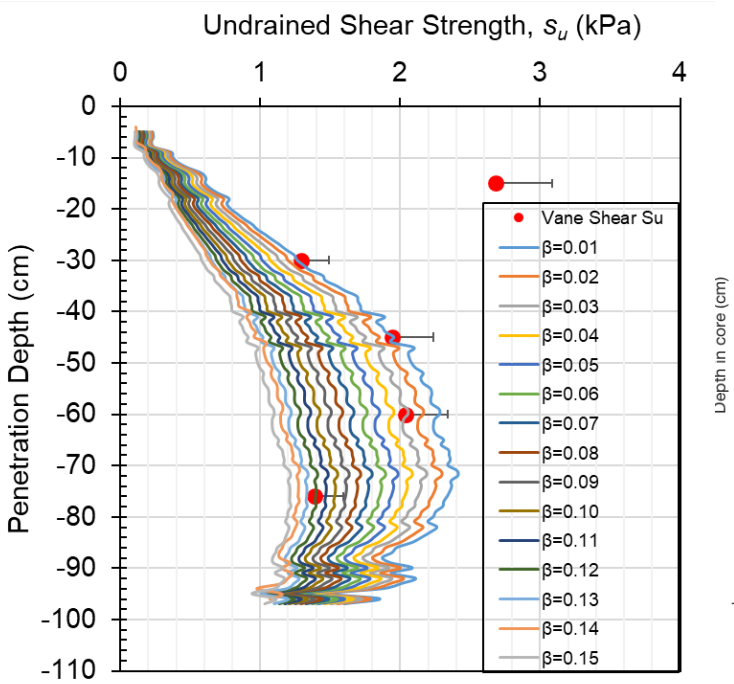
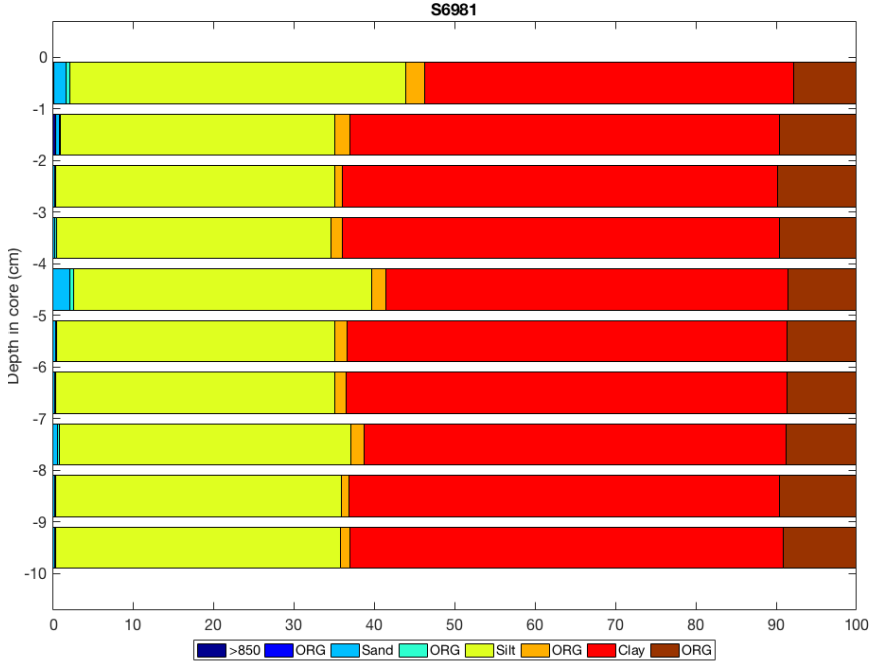
Ongoing steps…

1) **Validation of field survey strategy in proof-of-concept study**



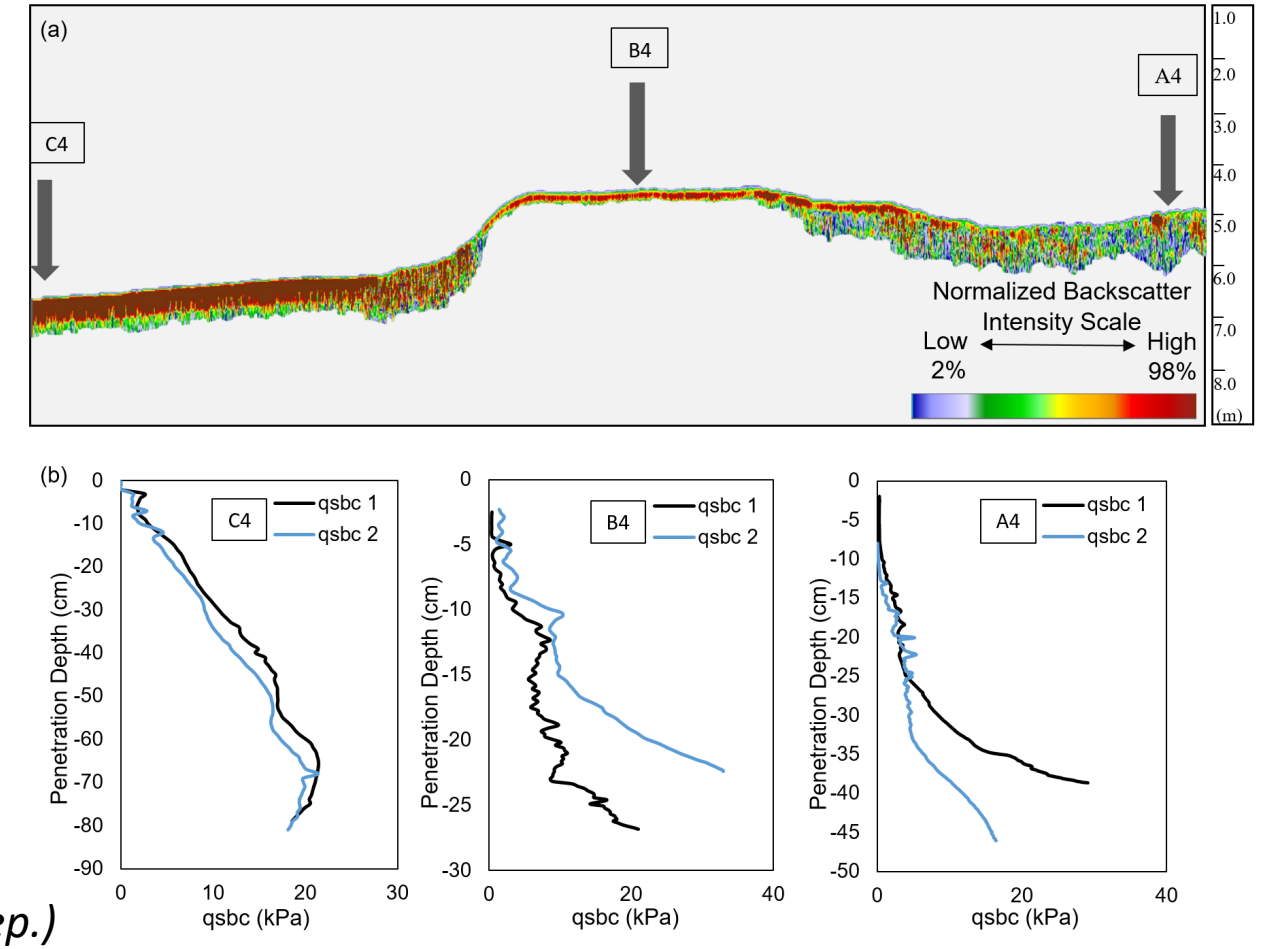




Ongoing steps…

2) Relevance for remote sensing techniques

ADCP, chirp, and side scan sonar measurement have been collected at the penetrometer data location. An initial comparison between acoustic and geotechnical data has been initiated.



Jaber et al. (*in prep.*)

Concluding Remarks

- A large data base of portable free fall penetrometer data co-located with sediment cores and acoustic measurements has been collected. Sediment core samples provided detailed information on geotechnical and sedimentological soil data.

- Correlations between geomechanical properties and the penetrometer data were established, expanded, and verified. The collected data set enables more work in this direction.

- Seabed stratification in the uppermost meter of sediment depth can lead to significant variations geomechnical seabed surface behavior (including transitions from high concentration suspension to low density soil behavior).

- Portable free fall penetrometers demonstrated to offer a rapid and cost-efficient option for a geomechanical investigation of uppermost seabed sediments (< 1 m sediment depth).