

# Geotechnical Properties of Tidal Flat Muds: Responses to Tangential and Normal Stresses

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Award Number: N00014-02-1-0663

## LONG-TERM GOALS

The long-term goal is a quantitative and mechanistic understanding of the response of mud flat sediments to tangential and normal stresses and how these relate to the erosion rates of mud flats.

## OBJECTIVES

The rate of muddy sediment erosion is very difficult to predict, yet it is crucial to know in predicting the evolution of mud flats as a result of natural or anthropogenic perturbations. Our objective is to determine if fracture strength of muddy sediments is a predictor of erosion rate.

## APPROACH

Working at the Willapa Bay, Washington State, USA (Figure 1), study site:

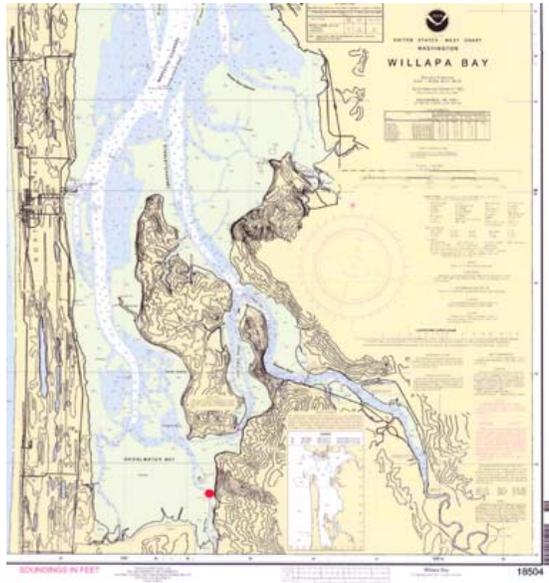
- (1) Measurement of the values of the primary elastic geotechnical parameters (Young's modulus) as functions of sediment depth, organic matter content, temperature, grain size and porosity. (M. Barry)
- (2) Determination of the fracture strength of these sediments, i.e.,  $K_{IC}$ , using our *in situ* probe, see Fig. 2. (B. Johnson)
- (3) Establish any correlations between these various parameters, using linear elastic theory and LEFM. (B. Boudreau)

# Report Documentation Page

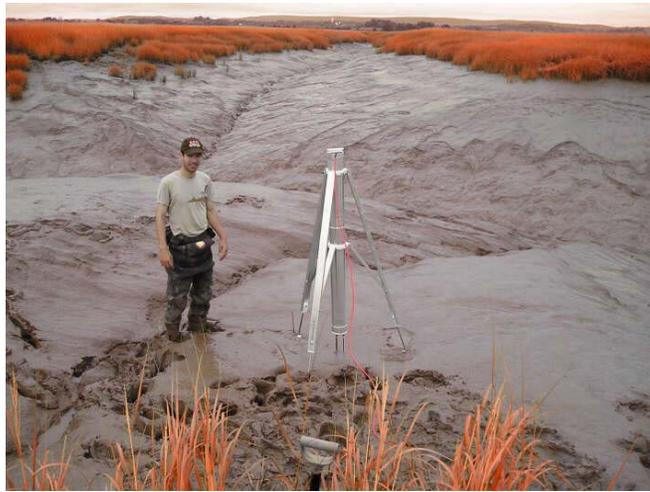
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OMB No. 0704-0188

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1. REPORT DATE <b>2008</b>		2. REPORT TYPE		3. DATES COVERED <b>00-00-2008 to 00-00-2008</b>	
4. TITLE AND SUBTITLE <b>Geotechnical Properties of Tidal Flat Mud: Responses to Tangential and Normal Stresses</b>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>Dalhousie University, Department of Oceanography, Halifax, Nova Scotia B3H 4J1, Canada,</b>				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release; distribution unlimited</b>					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			



**Figure 1. Map showing the Willapa Bay DRI study site. The red dot indicates the location of our in situ measurements.**



**Figure 2. The K-probe ( $K_{1C}$ ) deployed in a muddy tidal flat sediment. (PhD student Mark Barry for scale.)**

(4) Measure erodibility of the site sediments through field measurements using a rotary flume from the Bedford Institute of Oceanography. (P. Hill, in collaboration with Pat Wiberg, Tim Milligan and others).

## WORK COMPLETED

In Spring and Summer of 2008 we concentrated on improvements to and testing of both our Young's modulus (E-probe) and  $K_{IC}$  (K-probe) in situ instruments. In particular, the E-probe was modularized and given a tripod housing (Figure 3).



*Figure 3. The improved E-probe standing in the lab at Dalhousie. The expandable bladder, which is at the heart of the probe, is observable as the red "dot" at the base of the instrument tube.*

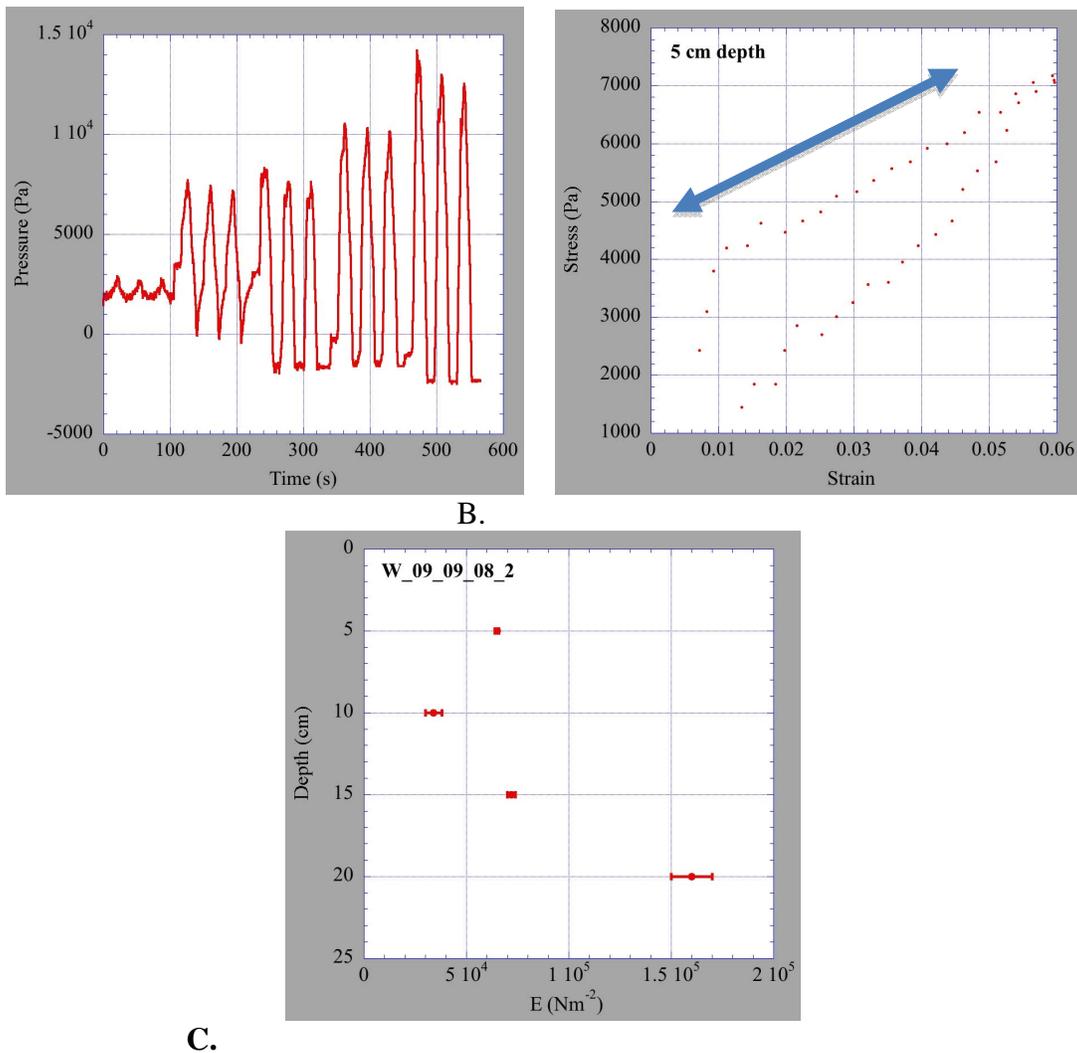
We spent the period 8-13 September, 2008, at Willapa Bay making the following measurements with our DRI colleagues:

- (1) Due to a simple, but unavoidable, technical problem, M. Barry made measurements of Young's modulus on only one core.
- (2) B. Johnson measured fracture strength on 4 sediment cores and an in situ site.
- (3) P. Hill/Pat Wiberg measured the erodibility on all the same sediment cores used by Johnson.

Early results are given below.

## RESULTS

A) Young's modulus: Figure 4A is a plot of the change in pressure with time due to changing system volume as the E-probe is traversed down the sediment core (W-09-09-08-2). The peaks occur in groups of three, three for each depth measured. The first set of peaks (left) is above the sample in water only and the next four groups of peaks (moving right) represent 5cm, 10cm, 15cm, and 20cm, respectively. These pressure records are converted to stress-strain curves (Fig. 4 B) for each depth measured. The slope of the data in the stress-strain diagram is converted the value of Young's modulus (Fig. 4C) for that sediment, using the compressive slope (indicated by the blue arrow in Fig. 4B).

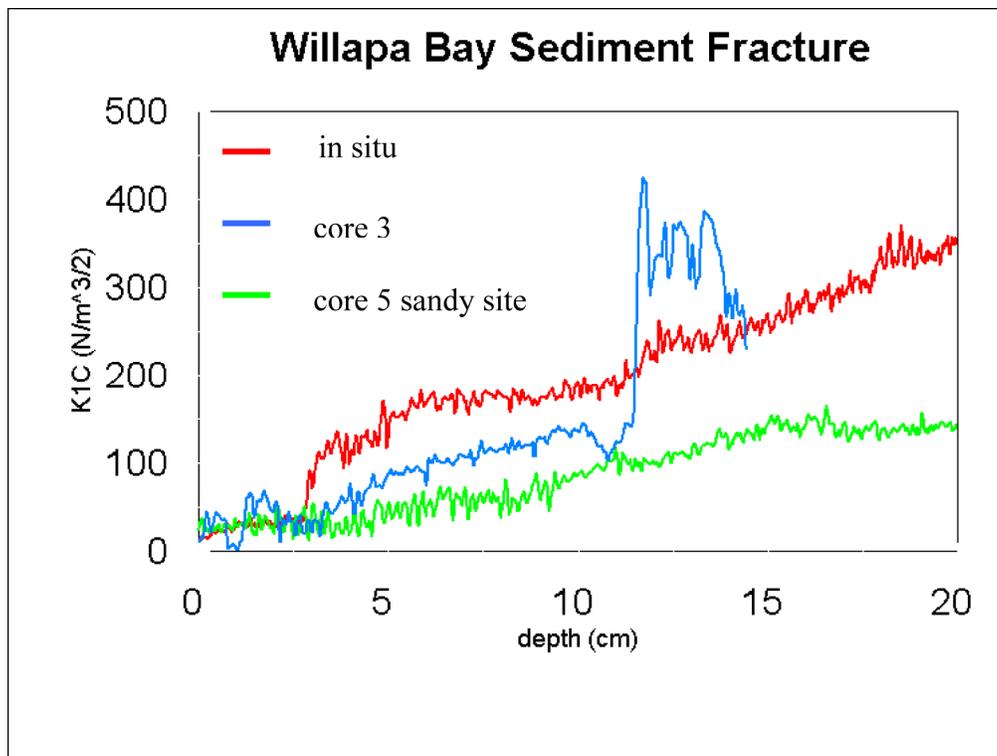


**Figure 4. A. Pressure record from the E-probe from core W-09-09-08-2. B. The stress-strain diagram for the sediment at 5c. The compressive slope (indicated by the blue line) is used to calculate  $E$ . C. The values of  $E$  as a function of depth for the W-09-09-08-2 core.**

Values of E for the Willapa Bay core are similar to values obtained previously by this group for sandy muds in Cole Harbour, Nova Scotia, Canada (i.e. on the order of  $0.1 \text{ MN m}^{-2}$ ). The increase in E with depth is due to compaction, which lowers the elasticity of the sediment.

B) Fracture strength with depth was measured on 4 cores, two of which are shown in Figure 5. In addition, we obtained an in situ profile at the site on the map in Fig. 1.

Cores 3 and 5 differed in their predominant grain size. Core 3 is muddier, while core 5 is sandier. Both sediments are nevertheless cohesive. The in situ sediment appeared to be even muddier than core 3 (but we lack quantitative data at this time). This trend corresponds to a general increase in  $K_{IC}$  in these sediments with mud content. In addition,  $K_{IC}$  increases in all cores with depth due to the effects of compaction, which causes strengthening of the sediment.



*Figure 5. Measured  $K_{IC}$  (tensile fracture strength) with depth in 2 cores from Willapa Bay and an in situ profile from the site indicated in Fig. 1.*

## IMPACT/APPLICATIONS

Will lead to better prediction of tidal flat stability and relevant geotechnical information, like trafficability.

## **RELATED PROJECTS**

None.

## **PATENTS**

The K-probe is being considered for patent. (pending)