Engaging and Retaining Students in the Geosciences at Two-Yar Colleges (2YC) through Undergraduate Research focused on Scientific Ocean Drilling

Kusali Gamage[1] , Leslie Davis [1], Hugh Daigle[2], Chammi Miler[2] , Katerina Petronotis[3]
[1]Austin Community College, Austin, TX. [2] University of Texas, Austin, TX. [3] IODP Texas A&M

Approach

Field activity

propagation of research into existing introductory geology courses

Goals

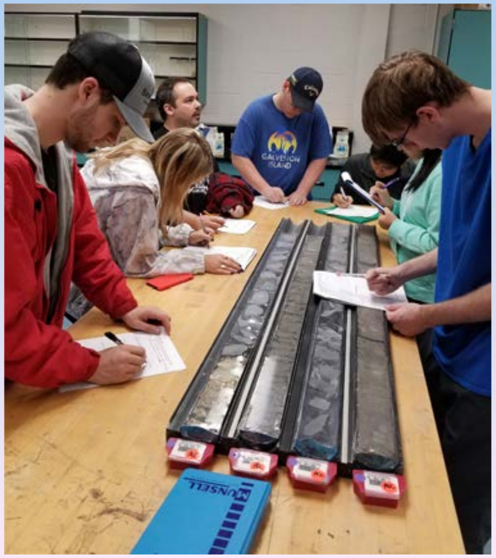
- *To elevate interest in and attract students from non-science fields and other STEM fields*
- *To create awareness of career opportunities in geosciences*
- *To help students envision the pathway from 2YC to a career in geoscience*

Activities & Materials

Pre-Field Activity
- *inquiry-based exercises adopted from the JOIDES Resolution & SERC websites*
- *Core photos & data*

Gulf Coast Repository Visit
- *Cores, Smear slides*
- *Panel discussion with IODP staff*

Post-Field Activity
- *Oral presentation*



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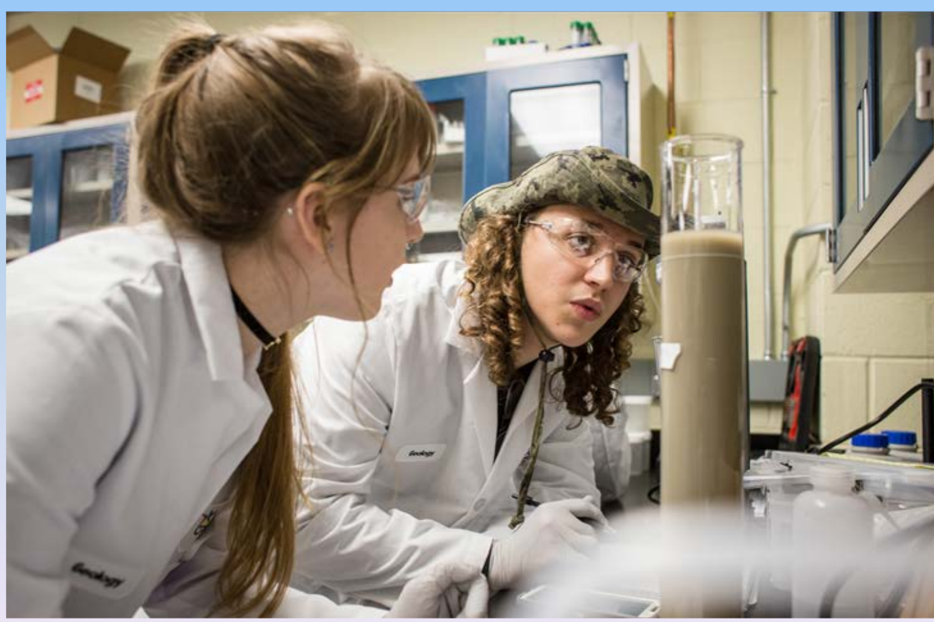
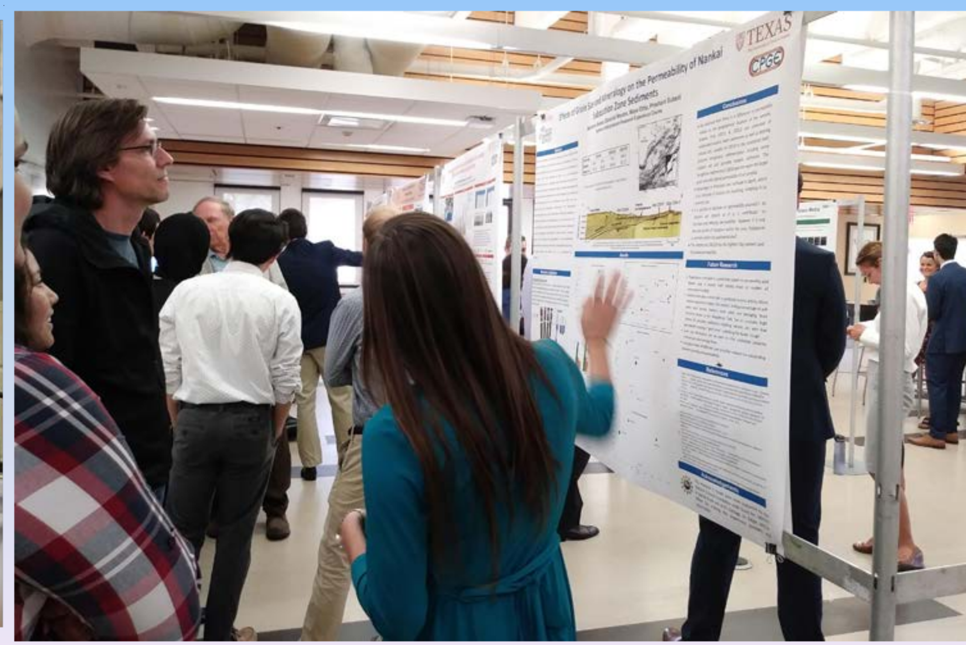
Approach	*Goals*	*Activities & Materials*
Summer Undergraduate Research Experience Course (SUREC) *intense inquiry-based learning (12 week, 3 credit hour, stipend-supported positions)*	• *To provide cutting edge undergraduate research experiences during the second year* • *To increase transfer rates*	*Core material, core data etc.* *Research posters (AGU virtual poster, UT summer poster symposium)*





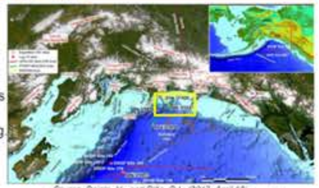
SUREC 2018

Effect of Mineralogy and Chemical Properties on Clay Swelling Samples from OffShore Southern Alaska

Summer Undergraduate Research Experience Course

Aysheh Abushanab, Austin Arnold, Angelique Bargo, Harry Khuc, Kamea Leach

Introduction

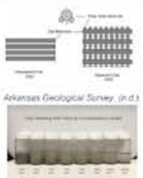

Source: Daigle, H., and Piña, O.L. (2017, April 18)

Understanding clay swelling is vital to the petroleum industry in how it contributes to ground pressure which could cause faults, leading to oil well damage and affecting oil recovery. Many methods such as hydraulic fracturing use NaCl in order to reduce clay swelling.

To understand clay swelling, we studied samples taken from expedition 341 at site U1420 from the IODP database to look at the chemical properties that clay exhibits. Swelling is described by water entry into the interlayer spacing between clay particles. Within our experiments, we defined clay swelling as the dispersion of clay particles in brine solutions. Due to the general effect of salt drawing out water, we hypothesized that with a low salinity, clay swelling is present.

First, we looked at the relationship between brine concentrations to understand the effect of salt on clay surfaces. We further investigated pH vs. zeta potential (ζ) and ion exchange to observe the dissociation and isomorphous substitutions processes that occur. There is also understanding that our samples had different mineralogy, which indicate different clay structures that can contribute to swelling. Exploring these properties can help us understand the tectonic processes that formed the fold and thrust belt of the Pamplona Zone.

Theory

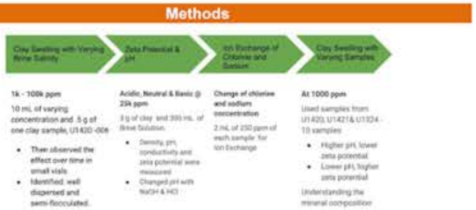

Arkansas Geological Survey. (n.d.)

- Osmotic swelling is the result of cation exchange on clay surfaces within the brine solution. Due to a change in surface charge, water enters the interlayers in order to balance the concentration of cations. The water's polarity helps to weaken the electrostatic attraction between the interlayers, causing repulsion and therefore swelling.
- Specifically with NaCl brine: Na^+ ions are monovalent, so more ions can occupy the interlayer, increasing the van der Waals forces associated with interlayer bonding.

Objective

- To determine how varying ion concentrations can affect clay swelling
- To understand the chemical properties of the electrical double layer associated with varying ion concentrations and pH levels
- To determine how different clay structures produce different levels of swelling
- To demonstrate how the ion exchange capacity can induce osmotic swelling

Methods



Materials and Instrumentation

Apparatuses Used	
Zeta Potential Probe	Ion Exchange Machine

Mineralogy

Panjaitan, N. (2013)

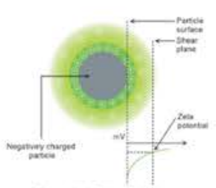
- Whether it has a 1:1 or 2:1 structure can also affect the amount of swelling. Quartz, kaolinite, and pyrite are minerals that have low interlayer spacing as a result of their 1:1 chemical structure[3]. These molecules experience less swelling due to there being little room for water to enter within the interlayers.

Ion Exchange

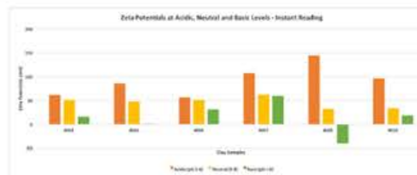
IODP 341 U1420 - ICS Data				
Sample	$\Delta[Cl^-]$ ppm	$\Delta[Cl^-]$ %	$\Delta[Na^+]$ ppm	$\Delta[Na^+]$ %
#003	712.02	0.07%	544.76	0.05%
#004	3609.9	0.36%	2462.7	0.25%
#006	573.84	0.06%	462.24	0.05%
#007	2681.1	0.27%	1850.0	0.19%
#008	9848.2	0.98%	6604.8	0.66%
#010	7194.2	0.72%	4854.2	0.49%

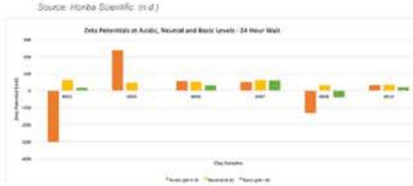
- This data table shows the amount of substitutions occurred within a filtered 250 ppm sample. We do this to show how this can affect net charge.
- Sample 008 has the most sodium ions to induce interlayer bonding. However, chlorine substitutions can also nullify this charge, causing electrostatic repulsion of the interlayers.

Zeta Potential (ζ)



Source: Horiba Scientific. (n.d.)





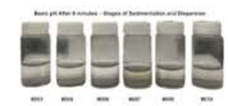
Over a period of time, dissociation took a toll on the ζ trends. This significantly affects the charge surface and the behavior of swelling vs. non-swelling clays.

IODP 341 - Amount of Acid/Base Used		
Sample	HCl (moles)	NaOH (moles)
#003	1.37×10^{-3}	1.00×10^{-3}
#004	1.84×10^{-3}	1.00×10^{-3}
#006	5.49×10^{-4}	1.00×10^{-3}
#007	1.65×10^{-3}	1.00×10^{-3}
#008	5.49×10^{-4}	1.86×10^{-3}
#010	1.65×10^{-3}	5.00×10^{-4}

Data Analysis

IODP 341 U1420 Sample	Unbuffered pH - Stages of Sedimentation and Dispersion
#003	In 18 hours, major sedimentation with minor dispersion.
#004	In 18 hours, major sedimentation with minor dispersion.
#006	After 24 hours, solution is mostly dispersed with minor aggregation.
#007	In 18 hours, major sedimentation with minor dispersion.
#008	After 12 hours, complete sedimentation, little to no dispersion.
#010	After 5 hours, complete sedimentation, little to no dispersion.

IODP 341 U1420 Sample	Basic pH - Stages of Sedimentation and Dispersion
#003	In 8 minutes, complete sedimentation.
#004	In 8 minutes, complete sedimentation.
#006	In 8 minutes, complete sedimentation.
#007	In 8 minutes, complete sedimentation.
#008	In 8 minutes, complete sedimentation.
#010	In 8 minutes, complete sedimentation.



- Of the 3 properties observed, mineralogy, ion exchange, and zeta potential (ζ) vs. pH, ζ data seems to reflect the best how well clay swells or not.
- Acidic solutions result in a high ζ due to dissociation. Along with the brine solutions of NaCl, there is more signs of isomorphous substitutions and this results in higher cations occupying the interlayer. This will help with interlayer bonding, reducing swelling. The opposite occurs for basic solutions.

High pH → **Low Zeta Potenial** → **Swelling**   **Low pH** → **High Zeta Potenial** → **Flocculation**

Conclusions

- In high salinity, sedimentation occurs much faster than in lower salinity.
- Mineralogy contributes to the amount of substitutions that can take place as well as how much interlayer spacing there is.
- Minerals with a 1:1 structure have low swelling potentials.
- An high value of $\Delta[Na^+]$ and $\Delta[Cl^-]$ indicates a high zeta potential, leading to less swelling due to stronger electrostatic attraction between the interlayers. This is supported by the ion exchange data for samples 008 and 010 which exemplified the highest amount of exchanges and high zeta potential (acidic). This reflects the fastest rate of sedimentation.
- Our data has shown that zeta potential vs. pH has the most significant effect on clay swelling when compared with ion exchange and mineralogy.

Future Works

- Due to the variability of zeta potential, we want to replicate this experiment again to observe the trend over time. We would also like to observe the threshold for which zeta potential value induces swelling or how well it correlates with swelling time by using a lower brine concentration.
- Another idea would be to compare ion exchange capacity at different pH's to observe the change of sodium and chloride concentrations.
- Explore the proportionalities of these properties and the middle ground in which clay dispersion and sedimentation are both observed.
- Use a different brine solution such as KCl to observe different swelling properties.

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SUREC 2018

Effects of Grain Size and Mineralogy on the Permeability of Nankai Subduction Zone Sediments

McKenna Alvarez, Ezequiel Montes, Maya Ortiz, Prashant Subedi

Summer Undergraduate Research Experience Course

Abstract

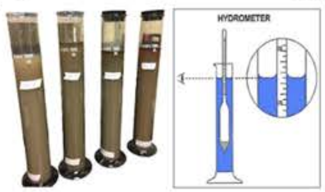
Physical properties of marine sediments have been widely studied both in academic and industrial research. Permeability is one such physical property that has been closely studied for its importance in fluid flow. This study focused on grain size, and mineralogical composition in clay-rich sediments from the Nankai Trough and their effects on permeability. The Nankai Trough samples represented the incoming undisturbed sediments from the Philippine Sea Plate and deformed sediments from the accretionary prism. Grain size was calculated using the hydrometer experiment. The permeability increases with grain size in the undisturbed sediments, however in the disturbed sediments this relationship was not observed. The percent of volcanic ash was determined by the presence potassium ions using ion exchange. The presence of volcanic ashes increased with depth while lowering the permeability of the undisturbed incoming sediments. Anomalies observed in permeability values may relate to the volcanic ash content as it is a contributor to microporosity.

Materials & Methods

The Hydrometer Experiment

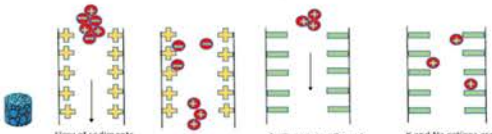
To measure the grain size distributions a sample was dried and then saturated in hexametaphosphate and deionized water. Then using a Hydrometer the density of the fluid was taken over time. By Stokes law (v) sediments will separate according to their densities giving us an accurate reading of grain size distribution based on the changing density of the water.

$$v_t = \frac{2}{9}\frac{r^2(\rho - \sigma)g}{\eta}$$



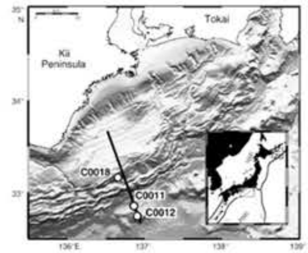
Ion Exchange Experiment

We measured the ion exchange capacity among our samples soaked in 10,000 ppm NaCl brine. The exchange of ions within the Chronostratigraphic anion and cation exchange. Based on the surface charges of our samples in powder form, the capture of negative and positive ions will conclude a small set of mineralogical data. Here we utilized the Potassium ion (K+) as it is an indicator of volcanic activity. As Volcanic ash is dissolved within sediment, it releases K+ and absorbs Ca2+.



Core Site	C0018A		C0012D	C0011D
Sample	12H-9	36X-2	7H-5	18H-9
Depth (m)	107.59	305.63	156.48	167.27

These samples were taken from the Integrated Ocean Drilling Program Expedition 333



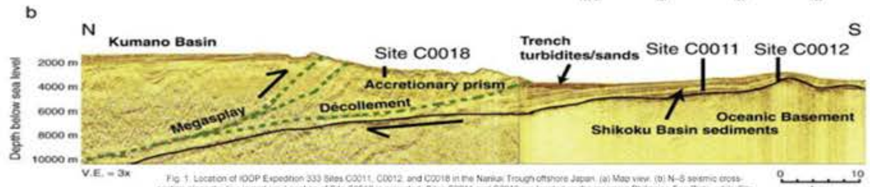
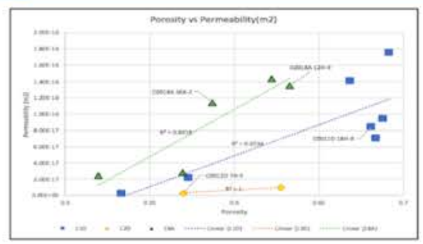
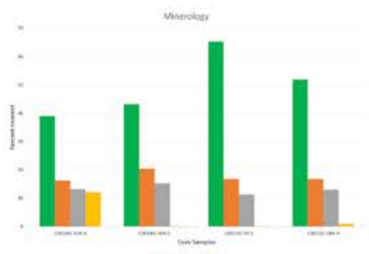
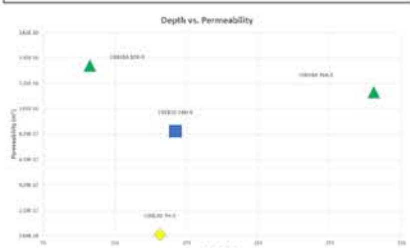


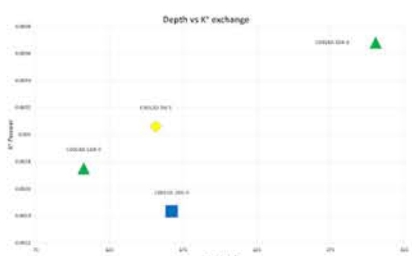
Fig. 1. Location of IODP Expedition 333 Sites C0011, C0012, and C0018 in the Nankai Trough offshore Japan. (a) Map view. (b) N–S seismic cross-section along the line in part (a). Location of Site C0018 is projected. Sites C0011 and C0012 are located on the incoming Philippine Sea Plate, while Site C0018 is located in a slope basin above the accretionary prism.

Results









Conclusions

- We observed that there is a difference in permeability related to the geographical location of the samples. Samples from C0011 & C0012 are comprised of undisturbed oceanic basin sediments as well as layering volcanic ash. Locality of C0018 to the continental shelf, procures terrigenous sedimentation including some volcanic ash and accreted oceanic sediments. The terrigenous sediments at C0018 give the region the larger grain sizes and highest permeability of our samples.
- Percentages in Potassium ions increased in depth, which is an indicator of Volcanic ash dissolving, morphing in to smectite clay.
- It is possible to attribute our permeability anomaly's to Volcanic ash content as it is a contributor to microporosity affecting permeability. However it is not the only source of Potassium within the area. Potassium is common within the continental shelf.
- The sample site C0012D has the highest Clay content and the lowest permeability.

Future Research

- These factors could result in a predictable pattern on permeability and directly relate to tectonic shelf stability based on models of overpressures building.
- Sedimentation plays a direct role in predicting tectonic activity.More detailed research on Volcanic Ash content, finding a percentage of ash within each sample. Nankai's most active and damaging fault structures known as the Megathrust fault, has an unusually high content of saturated sediments including volcanic ash, with low permeability creating a "weak zone" underlying the Nankai Trough.
- Grain size distribution can be used to infer predictable patterns methane gas could emerge from.
- Using glass beads of different sizes to further research the relationship between porosity and permeability.

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Success & Challenges

Field Activity
- ***~160 students***
- ***91% agreed it was a good way to learn about the subject matter***
- ***78% agreed that it had a positive effect on their interest in science***

SUREC
- ***24 students***
- ***100% agreed that their research experience has prepared them for a job***
- ***92% agreed that doing research confirmed their interest in their fields of study***
- ***83% transferred to a four-year institution***

Challenges @ 2YCs
- *lack of funding (student stipends etc.)*
- *lack of faculty commitment*