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Wrapping up loose ends: crafting a manuscript from a undergraduate senior research thesis

By Nick Wondolowski (SSU alumni, 2016)

The Process: As an undergraduate senior at Salem State University I did my senior research project with Brad Hubeny. For those who know Brad, this means studying mud. During my senior year I collected and studied gravity-piston sediment cores and seismic sub-bottom data from the Potomac River, a major tributary of Chesapeake Bay. I will explain this in more depth later, but in this study we were able to constrain relative sea level using 5,000-year-old oyster shells preserved in our sediment cores, which we interpreted as belonging to a shallow water coastal fringe reef. During my time as a student I presented my research at the National and Regional (North Eastern) GSA conferences, and at the end of the year I wrote up my undergraduate thesis. As I was actively trying to get into graduate school, I felt that my work on the project had not been completed, as it was not published in an academic journal. After discussing the quality of my work and what work remained with co-authors, I decided to continue crafting my thesis into a manuscript worth submission. Although I had believed that my senior thesis was 80-90% on its way to being published, I have since learned that the last 10% can be just as difficult as the first 90%. As it turns the last 10% is commonly full of everything which you ignored or swept under the rug. Although some of these things (proper citation, data uncertainty, proper comparison to past literature, proper formatting… ect.) can be tedious, I have now learned their importance, and how to properly address them. During the winter of 2019 I finally submitted

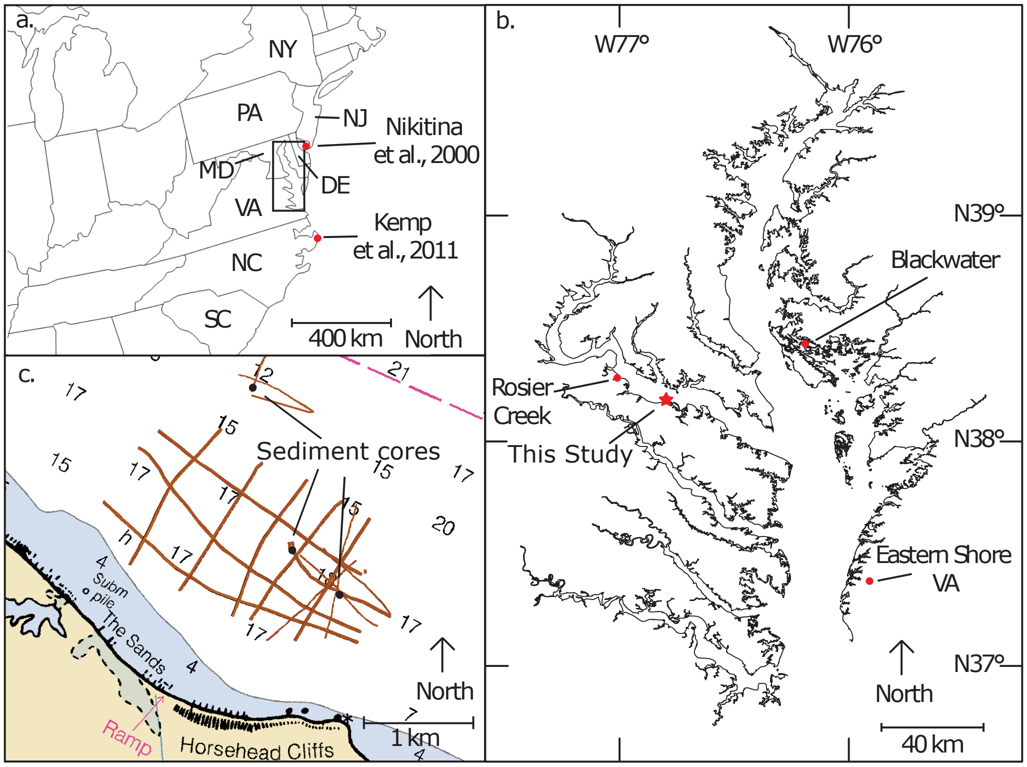

Figure 1. (a) Maps of United States Atlantic coast. Black rectangular inset shows the location of Fig.1b. (b) Map of Chesapeake Bay. Red star shows the location the present study area (Fig. 1c) off the coast of Westmoreland State Park in the Potomac River. (c) Study area. Black dots represent sediment cores collected for this project. Brown lines represent seismic sub-bottom lines.

my manuscript, titled “Late Holocene relative sea level and glacio-isostatic adjustment from the Potomac River, USA utilizing fringe reef oysters and seismic sub-bottom geophysical data” to Marine Geology. Although this was a lot of work, I am now the only PhD student in my cohort at University of Pittsburgh to have submitted an article as first author to be published in an academic journal. The experience was overall rewarding.

The Product: In this study we utilize seismic sub-bottom data ground-truthed with lithologic and geochemical data from dated sediment cores to reconstruct the RSL history in the Potomac River off Westmoreland State Park, Virginia, for the past 5,000 cal yr BP (Figure 1). We identified a fringing Crassostrea virginica reef (dates ranging 4870±76 - 5002±157 cal yr BP), which occupied a reworked sand sheet at the base of a late Holocene transgressive sequence. Fringe reef C. virginica live at minimum habitat depths of 0.6m allowing them to provide improved constraints on regional sea-level compared to non-fringe reef oysters. We combine this new seismic data and C. virginica chronology with sediment core data from nearby Rosier Creek salt marsh to construct a regional RSL record.

This new regional RSL record, modeled with a 2nd order polynomial, indicates that the rate of RSL rise has decrease over the last 5,000 years at a rate of 0.53 mm/kyr. The long-term trend of 1.56±0.12 mm/yr is higher than the late Holocene relatively stable global mean sea level (GMSL) (<0.3 mm/yr rise since 5,000 cal yr BP) observed in most studies (Figure 2). If as suspected sediment compaction is minimal, then the deviation from the eustatic curve is interpreted as subsidence due to glacio-isostatic adjustment (GIA). GIA is the result of the decaying glacial forebulge, which formed adjacent to the Laurentide Ice Sheet during the last glacial maximum (LGM, marine isotope stage 2 (MIS2)). The decreasing subsidence rate over the last 5,000 years can be explained by a relaxation of glacial forebulge subsidence as the mantle approaches a new isostatic equilibrium from glacial unloading (Figure 2).

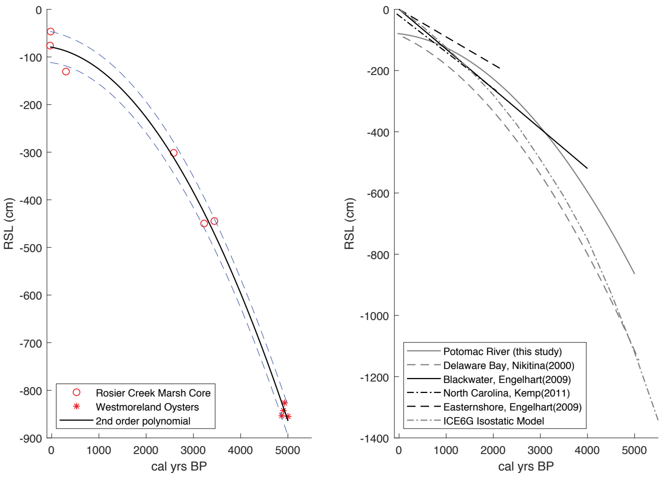

Figure 2. (a) Sea level curve composed of salt marsh sea level proxies and constraints from Rosier Creek (circles) and basal fringe reef oysters (stars). Black line shows the 2nd order polynomial not forced through the origin, and dashed blue lines show error bounds, which bound greater than 50% of model predictions. Due to the negligible effect from other RSL variables and late Holocene GMSL change, the RSL curve here is interpreted to reflect GIA. (b) RSL curve from Fig. 2 a. as well as other referenced regional curves and the ICE6G isostatic model. The decreasing rate of RSL rise seen in our curve may be caused by relaxation of the MIS 2 glacial forebulge.

A Thirsty Earth: Chen Cai’s research sheds light onto the Earth’s interior water cycle

By Rebecca Wright

At Washington University in St. Louis, Chen Cai’s doctoral research has focused on investigating the amount of water inside Earth, and the extent it travels between the surface and subsurface (Cai et al., 2018). Though not many people think of water when considering the interior of Earth, it plays a vital role in the formation of magma, lubrication of the earthquake-producing fault zones, and other geologic processes.

The tectonic setting of subduction zones provided the most likely cause as to how water is transferred into the interior Earth. When a tectonic plate undergoes subduction (whether it be the subduction of an oceanic plate under a continental plate, or an older oceanic plate subducting under a younger oceanic plate), oceanic crust, upper mantle rock, sediments, and the seawater trapped in the minerals of these materials are pulled down into the Earth’s mantle.

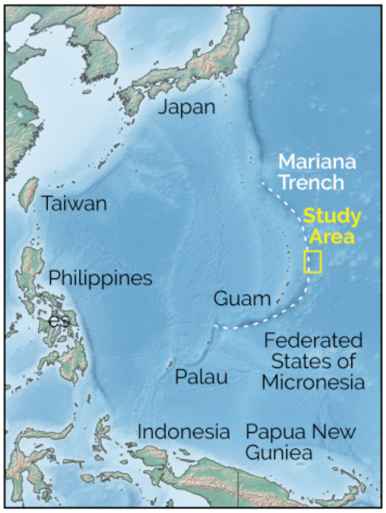

Figure 3. Map of the Mariana Trench located in Western Pacific from (Oetting, 2019). Chen Cai’s study location is indicated by the yellow box.

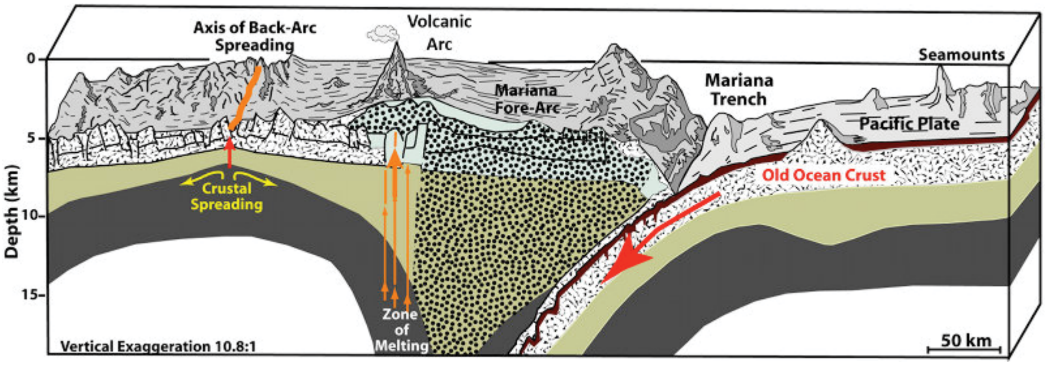

Figure 4. Cross-section of the Mariana Trench highlighting the subducting Pacific plate (from https://oceanexplorer.noaa.gov/okeanos/explorations/ex1605/background/geology/welcome.html)

Cai focused his study on the oceanic subduction zone, the Mariana Trench in Western Pacific (Figure 3, 4). At the Mariana Trench, the 150 million-year-old Pacific Plate is being subducted under the younger Mariana Plate. Cai’s hypothesis centers around the idea that the older the age of the subducting plate, the colder the plate will be, and since it will be more difficult to heat the cold plate up, this will retain more water and transfer it to Earth’s interior. Hence, “water can be withheld in older subducting slabs to deeper depths” (Oetting, 2019).

Cai’s study implemented passive-source seismology techniques to obtain a better depth calculation than active-source seismology techniques would have offered; in fact these cannot resolve structures deeper than 10 kilometers beneath the seafloor. Twenty seismographs were deployed on the ocean bottom around the trench and seven land-based seismographs were deployed on islands nearby. Data was collected for about a year.

Results from the year of data collection were unexpected. At depths of approximately 24-30 kilometers below the seafloor, in the subducting Pacific Plate, slow velocities of seismic shear waves were detected, indicating the abundance of thickly layered hydrous minerals (such as serpentine). Serpentine is a hydrous mineral and forms from the interaction of mafic minerals and water. Serpentine appears to be stable at colder temperatures in older subducting slabs. The discovery contradicts the global average thickness of hydrous minerals of 2 kilometers estimated from active-source seismology methods. “The increased d depth of hydrated minerals in the subducting slab indicates that 4.3 times more water is being introduced into the Mariana Subduction Zone, and subsequently carried to depths below 100 kilometers, than previously thought." (Oetting, 2019).

When previous studies are recalculated based on Cai's findings, the extent of water that reaches Earth's interior is nearly three times more than anticipated. There are some discrepancy with this finding. If three more times the water is going into the Earth, then it would act as a catalyst and the amount that comes out from volcanic emission and degassing should increase as well. If this trend continued, then the ocean would cease to exist. Although, this estimate is based on our current understanding of degassing and the amount of water that is released during volcanic activity, which is poorly understood.

Doug Wiens (Cai's graduate advisor and coauthor of the study) says: "A lot of water is actually released from magma before it comes to the volcano. In fact, how much water actually diffuses through the crust is not known very well" (Oetting, 2019).

Cai's and his colleagues' study have answered many questions but have also brought light to new questions to be answered.

Sources:
Cai, C., Wiens, D.A., Shen, W. and Eimer, M., 2018. Water input into the Mariana subduction zone estimated from ocean-bottom seismic data. Nature, 563(7731), p.389.
Oetting, J., 2019. Thirsty mantle: Subduction zones swallow more water than thought. EARTH Magazine.

Mineral of the Month

Moldavite!

By Kristen Anastopoulos

Moldavite is a deep green tektite, that has been collected by meteorite/mineral enthusiasts and cut into faceted and cabochon gemstones that is used for jewelry since the 1800's.

14.8 million years ago a meteorite impact in southern Germany occurred, forming a silica-rich green glass called Moldavite. It is understood that the meteorite hit from the southwest direction with such a high velocity it caused the host rock to melt and splatter across Czech Republic, Austria and Germany. This melt solidified so quickly when it was in the air that the atoms couldn't arrange themselves to have a crystalline structure. This classifies Moldavite as a mineraloid, a naturally occurring, inorganic solid with a fixed chemistry but no crystalline structure. Moldavite can be anywhere from light green to deep green in color with a hardness of 5.5 on Mohs scale. The chemical formula of Moldavite is: Variable SiO_2 (+Al_2O_3), it can be transparent/translucent and can have inclusions of gas bubbles. Moldavite is found in Middle to Upper Miocene age sediments. It occurs as droplet shaped particles that are severely scratched due to the erosion of acidic subsurface waters.

Much of the material that hosted Moldavite has been eroded and buried over the millions of years after the impact, resulting in limited deposits of this mineraloid only found in very specific areas of Czech Republic, Austria and Germany.

Sources: (1) King, Hobart. "Moldavite." Quartz: Quartz Mineral Information and Data., 1995, www.mindat.org/min-10860.html.
(2) King, Hobart M. "Moldavite." Geology, 2000, geology.com/gemstones/moldavite/.

An explosive start to a new job in Hawaii

By Tricia Nadeau (Ex-Visiting Assistant Professor at SSU)

Hello Viking Geologists! Many of you don't know who I am, but some of you juniors and seniors might have been lucky enough to have me for Dynamic or Evolving Earth back in 2016 or 2017. After Salem State, I took a position at Ohio University. But, after only a few months in Ohio, I was offered a dream job researching volcanic gases at the Hawaiian Volcano Observatory (HVO). Of course, petrology class is important(!), so I had to finish the year at OU. But it meant that all through spring semester of 2018, I got to plan the really amazing research I was going to get to do on Hawaiian volcanoes like Kīlauea. Little did I know then that Kīlauea had its own plans for 2018, and for me. On May 3, the day before I gave the petrology final exam in Ohio, a whole new eruption began.

For background, Kīlauea is a hot spot shield volcano that erupts not only from the summit, but also from two rift zones radiating from that summit. In 1983, an eruption began in the middle east rift zone (MERZ), creating a new vent called Puʻu ʻŌʻō. Puʻu ʻŌʻō ended up erupting for decades, and in 2008, a lava lake also appeared at the summit. For the next ten years, both sites erupted simultaneously. But on April 30, the Puʻu ʻŌʻō vent suddenly collapsed after ~2 weeks of inflation. Magma that had built up beneath the MERZ migrated downrift to the lower east rift zone (LERZ). The intrusion reached Leilani Estates, where it began erupting on May 3. Like so many basaltic eruptions do, the LERZ eruption began with a linear set of fissures (24 total) before focusing fountaining activity at one primary vent (Fissure 8). Ejecta from the fountains built up a tephra cone that grew to ~40 m tall in weeks. At the same time, lava pouring out of the cone established a fast-moving, deep lava channel that reached to the ocean. Of course, you can't drain that much magma that quickly from a volcano without consequences. As magma progressively left Kīlauea's summit region, significant effects were felt there too. Contrary to what your professors (including me) probably taught you, shield volcanoes don't only have runny lava flows. They can get explosive, and Kīlauea did. In mid-May, ash explosions began at the summit, causing the closure of Hawaiʻi Volcanoes National Park and the evacuation of the HVO facility within the park. Eventually the ashy aspect stopped, but the daily earthquakes that accompanied the explosions continued. It turned out that we were seeing caldera collapse in action – each event was actually a collapse with energy equivalent to an M5.3 earthquake, and caldera blocks dropped meters at a time. In total, the maximum subsidence was more than the height of the Empire State Building (~500 m).

My role in this was to measure gases. That means both in situ measurements and remote spectroscopic methods, which use UV and IR wavelengths to detect gases in proportion to how much radiation the sensor receives. But the most critical measurement that citizens and officials were concerned with was the SO2 emission rate because SO2 is hazardous. In recent years, emissions averaged around 5,000 t/d of SO2, which was already relatively high and causing detrimental effects to human and plant health downwind of Kīlauea. But at the height of the LERZ eruption, Fissure 8 was emitting over 100,000 t/d of SO2. That is unprecedented at Kīlauea, at least since measurements of this type began back in the 1970s. After ~3 months, activity in both the LERZ and at the summit dropped off drastically on August 4; lava was last seen on September 4. Fortunately, no lives were lost, but >700 structures, including homes, a geothermal power plant substation, and a cell phone tower, were buried or burned as lava covered >13 square miles and created ~900 new acres of land. Up at the summit, roads and buildings in the national park were damaged. Our own HVO building is beyond repair; we'll move to new headquarters, and I won't ever get to use the nice, new, caldera-view office that had been freshly painted for me.

Still, for all that destruction, the eruption was incredible to witness and gave us at HVO a huge amount of data to study so that we better understand Kīlauea and basaltic eruptions. The eruption also provided a perfect opportunity to test data

Figure 5. (a) The lava fountain and growing tephra cone at Fissure 8, June 5, 2018. Before (b) and after (c) the summit collapse, Kilauea Volcano. (Photos courtesy of USGS)

collection methods that had not been used much, or at all, before. For one, given the accessibility of many fissures and lava flows, especially early in the eruption, HVO geologists and colleagues at the University of Hawai‘i, Hilo, were able to study the lava’s chemistry with nearly ‘real-time petrology’. Lava was sampled at least once a day and rushed to the university where it was analyzed by XRF within 24 hours. HVO was able to distinguish a change between the early lavas, which had been stored in the LERZ for decades, from new lavas later in the eruption that more closely resembled lava chemistry from further uprift. Lava from one fissure even turned out to be andesite, the first ever seen at Kīlauea. Basaltic magma from centuries ago had stayed in the rift zone, undergoing fractional crystallization, precipitating mafic minerals and becoming more silicic until the new intrusion in 2018 finally pushed the now andesitic melt to the surface. Bowen’s reaction series in real life! Another thing that was largely new about this eruption was the use of unmanned aerial systems (UAS, or “drones”). Thermal and visible cameras on the UAS provided data about channel width and flow rates, but also provided situational awareness, such as where channel overflows were likely and where houses might be threatened by advancing lava. In the gas group, we got to have some of our sensors mounted on UAS for the first time. This helped with determining the chemistry of eruptive gases – a collapsing caldera and lava fountain were too dangerous for us, but little UAS flew there easily. With data from UAS and on the ground, we could see not fractional crystallization, but fractional degassing – Kīlauea’s magma loses CO2 first, when it is deep under the summit, but then degasses SO2 as it moves down the rift to the fissures, where it also finally starts to degas the bulk of its halogen gases like HCl and HF.

Unfortunately, between grading exams in Ohio and organizing my move to Hawai‘i, I didn’t arrive to begin my job until late May. So I missed the eruption onset, but still got to have what could end up being a once-in-a-lifetime experience. I saw things that you normally only see in textbooks or on Youtube. You’ll all have to stick to seeing things online, but even that can be pretty impressive – be sure to check the “USGS Volcanoes” Twitter and Facebook or our own HVO website (https://volcanoes.usgs.gov/observatories/hvo/). There are amazing photos and videos from throughout the eruption, even a lava whirlwind! And when Kīlauea or Mauna Loa decides to wake up and erupt again, perhaps some of you will have graduated and ended up in a career that brings you out to Hawai‘i too.

For a more technical summary of the eruption, see: Neal, C.A. et. al., “The 2018 rift eruption and summit collapse of Kīlauea Volcano,” Science, 363, pp. 367-374 (2018), http://science.sciencemag.org/content/363/6425/367