Reconstructing the History of Past Inundations in Lake Daija, Lake Amida, and Lake Ryuoo and Analyses of their Intensities

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1. Background

I have been working on my research project from the summer 2011. The experimental work was carried out at Prof. Jonathan Woodruff's laboratory in the Geosciences Department of the University of Massachusetts at Amherst. Development of my interest in Geosciences was catalyzed by a set of events that were coincidental. The research opportunity I found in Prof. Woodruff's lab was partly due to my good fortune in terms of geography –being a resident in a town with a Geosciences laboratory, partly due to inspiring role models around me, and lastly due to my keenness to accomplish some worthy results.

My interest in the Geological Sciences grew out of a summer I spent in Kyushu, Japan at the end of my 9th grade. Within a short span of two months, I experienced a typhoon, a cloudburst, visited coastal areas with built-up seawalls to protect against tsunamis, and a watched volcanic gases spewing from a live volcano at Mount Aso. The visit to Mount Aso was a special experience, not only in terms of natural beauty, but also in terms of its geologic history. There, I learned about the history of volcanic eruptions dating back some 90,000 years and also learned about the formation of a caldera which is now a rich agricultural basin. This piqued my curiosity to learn about the geological processes controlling such phenomena.

In 10th grade an opportunity came along, sponsored by the US Department of State to become an environmental ambassador to Norway to study their energy and eco-management systems. I was fortunate to be selected for this trip, which actually occurred deep in the winter. There, in the midst of deep northern freeze, I was awestruck by the Northern Lights. I realized that the earth is an active place and there was very little that I knew about the forces that control and shape this planet. These experiences were the formative influences in my interests in the earth sciences.

I was fortunate to have my elder sister as a role model. While in her junior year, she conducted research in molecular biology, and entered the Siemens-Westinghouse competition. Graduating from high school at the age of 16, she went on to obtain her BS and MS in Electrical Engineering at the age of 20, and started publishing her research while she was still an undergraduate student. This inspired me to strike out in research on my own. I sought opportunities in Geosciences and soon found my mentor Prof. Jonathan Woodruff at the University of Massachusetts.

1.1. Research Goals

My research work involved analyzing sediments from three coastal lakes in Japan to reconstruct history of past inundations. The sediments were collected from the lake bottom in the form of vertical cylindrical cores from the approximately the center of the lakes. Sediments collected from anywhere else would not be a stable archive of past inundations as they may get washed or shift with further inundations. Then the sediments were analyzed for grain size and content of organic and in organic materials on a layer by layer basis. The deposition dates for layers were obtained from carbon dating, while the layer thickness was obtained from X-radiography. Collectively, the data allows us to construct past history of inundations.

All the three lakes that are target of this study are situated on the coast, such that whenever tsunami happens, seawater washes into these lakes. When the suspended particles from the seawater settle at the bottom, we get a layer of sediment from sea sourced material. The lakes also collect rain water from land surface. Thus, whenever there is a strong rain, muddy water flows into the lakes, with the mud eventually settling into the bottom. These sediments are sourced from materials found in the land. Sea sourced material is rich in calcium while the stream/land sourced materials are rich in iron. Thus analyzing the materials not only allows us to establish a *timeline* for the flooding, but also the *source* of the flooding. Seawater may also flood in because of typhoons. However, typhoons are usually associated with strong rain and in that situation we end up with sediment made up of *both* land and sea-sourced materials. Thus, fine analysis of sediments also allows for disambiguation of events.

2. Research Description

In the following, I will describe briefly the target area of study and the experimental methods used in this project. The laboratory work was conducted under supervision of Dr. Kinuyo Kanamaru and Prof. Jonathan Woodruff. I had worked on a number of experiments in the overall project, while the complementary data were generated by Prof. Woodruff and Dr. Kanamaru.

2.1. Study area

The area of study covers three lakes: Lake Daija, Lake Amida and Lake Ryuoo

Lake Daija (32.247200 N, 129.985760 W) that literally translates to serpent is situated in Kamumoto Prefecture, less than 50 km from Nagasaki. Folklore holds that two serpents lived in this lake. When the two serpents combined, a typhoon occurred resulting in extreme agricultural and economic losses. One serpent lived in freshwater while the other lived in saltwater. While a sandbar separates freshwater from ocean water, it is not fully closed; salty water may come into the lake and mix with freshwater.

Lake Amida (32.220793 N, 132.062400 W) is situated in Ehime Prefecture. It is located on the westernmost coast of Shikoku island. The lake is 260 meters from east to west and 420 meters from north to south. Two rivers deposit into the lake; one from the south, and the other from the northeast. The watershed area is 8.6 times larger than the surface area of the lake.

Lake Ryuoo (33.37238 N, 132.36 W) is situated in Ehime Prefecture. It is located off the coast of Shikoku Island. Because of the proximity of Lake Amida (23.64 km west), data from Lake Amida can be compared to confirm event layers.

2.2. Methods/Procedures

The cores were collected from the lake bottoms. The location for coring was determined by the seismic profiles that exhibited best depositional sequence in terms of length and completeness for each sedimentary basin. Lake Daija and Lake Amida sediment cores were collected in 2010, while sediments from Lake Ryu were collected in 2012 by Prof. Woodruff and his cohorts.

Multi-proxies for this study include magnetic susceptibility, loss-on-ignition, grain size, high-resolution X-radiograph and elemental composition data. I conducted grain size and loss on ignition (LOI) experiments while the dating and X-radiography was performed by other members of the laboratory.

Loss of ignition (LOI) is a method of measuring the amount of organic material in the sediment layer. After water from the sediment is evaporated, the organic material is burnt off. The lighter the deposition layer appears in the X-Radiograph of the sediment, the denser that layer is indicating mineral grains and clastic material. Organic materials such as carbon, hydrogen, and nitrogen are lighter than other materials like iron, and titanium thus LOI can confirm that a dense layer has less organic material. Through the process of LOI, the porosity of sediment can be determined. Porosity measures the amount of space between sediment. The more porous sediment is the more organic material it contains. Porosity is another method of confirming organic material with the X-Radiograph. I measured Loss on Ignition for various sections of sediment from Lake Daija, Lake Amida in 2011, and for all of eight meters from Lake Ryuoo in 2012.

Grain size is taken by a Coulter Particle Counter to determine whether an event layer occurred. If the grain size taken for subsequent layers varies widely, it indicates an event layer. Because the differences in grain size are subtle, it is difficult to be certain of an event layer. Grain size data is categorized in terms of “D_”. The number following “D” indicates that percentage of grain has a smaller than the number indicated. I conducted grain size analysis on sediments from lake Daija and Lake Amida in 2011. Depth of event layers serve as proxy for intensity of events.

2.3. Research Findings

An important part of this research was analysis of data. By applying X-radiography, dense layers were identified. The dense layers contain more inorganic materials indicating major event layers. Layers were then studied for their porosity and grain size. Porosity is the amount of space between grains of sediment. Sediments that are more porous contain a higher inorganic content. A change in grain size can provide evidence of dense layers. Sediment cores were also dated using carbon dating techniques. Event layers can provide resolution about historical events in history. Sedimentological techniques provided evidence of typhoons during Mongol Invasions, dated Hoei earthquake, and several minor events.

Sediments were analyzed for their elemental composition. Finding the content of radioactive materials in sediment provided information about historical events. For example, a high amount of Cs 137 was found in 1963 from cores. It was also found that prior to 1950, there was no Cs 137 in the sediment. This data provide information about when anthropogenic radioactive materials were tested in the atmosphere and when testing reached its apex. Thus, sedimentological techniques can be used as archaeological tools. Higher levels of calcium and strontium indicate ocean-sourced materials while higher levels of iron oxide, mica and quartz indicate land surface-sourced materials. The source of chemical elements can become a proxy for differentiating between different inundative events. For example, if a deposit exhibits a high concentration of ocean-sourced materials like calcium and strontium, *and* river-sourced materials like silicon and titanium, a typhoon may have occurred. If a deposit exhibits only ocean-sourced materials, the inundation is likely from tsunamis. Analysis of magnetic susceptibility can also detect the presence of ferro-magnetic elements which can be a proxy for differentiating various inundative events. As discussed previously, the event layers not only provide a time-line and intensity of events, but also their source allowing past history of inundation to be reconstructed.

2.4. Importance and Significance

This research allows past major inundations to be dated and characterized for source, bringing direct benefits to science and society. An accurate record of past inundations, their spatial scope and intensities help us improve the prediction models for future events. This is a research area for the meteorologists. Improved prediction and better planning for coastal flooding prevent major losses.

2.5. Lessons

This research has been an enriching experience. I had taken chemistry during my sophomore year of high school. At that time, I related chemistry to everyday usage of chemical products such as chemical cleaners, fuels, synthetic products and pharmaceuticals. Applying chemistry as a tool opened my eyes in a completely new direction. It also showed me how we can apply laboratory techniques with powers of observation and generalization to learn about past. As my study progressed, one of the objectives became validating sediment archives with known history of major inundations from the recent past. In that process, within the errors of resolution, we validated the oral history of typhoons of 1274 and 1281, the years of failed Mongol invasions of Japan, when entire armadas sank due to calamitous storms. The connection between history, archaeology and science was the best lesson from this research. I no longer view history, archaeology and laboratory science as disconnected silos of knowledge. I learned the importance of team work in large scientific experiments and also learned the serendipitous nature of important findings.