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GEOCHEMISTRY OF TWO CRATER LAKES IN THE NEWBERRY CALDERA

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INTRODUCTION

East and Paulina Lakes are located side-by-side in the Newberry Caldera in the Newberry Volcanic Monument, Oregon separated only by a volcanic ridge of rhyolite approximately 2000m wide. Despite their proximity to each other, these two lakes have vastly different water and sediment chemistries, suggesting disparate hydrologic sources. This is highlighted by the concentrations of two very toxic metals in the sediments, mercury and arsenic. Paulina Lake has ~15ppb Hg and up to 250ppm As whilst East Lake has up to 3500ppb Hg and only ~25ppm As. Previous studies propose that these lakes are fed by one volcanic input that branches off to deliver a Hg-rich gaseous phase to East Lake and an As-rich hydrothermal input to Paulina Lake (Lefkowitz 2015). As part of a larger KECK study. We sampled each lake for water and sediment in addition to the hot springs surrounding each lake to further constrain their geochemical evolution. Early results indicate differences in organic input to each lake, with East Lake having on average 3 times the amount of TOC (~6%) with a carbon isotopic value of -20‰, while Paulina Lake's organic input is lower (2%) with a more terrestrial isotopic signal (~ -26‰). The sediment's pore waters also vary from lake to lake: Paulina Lake has ~4.5ppm and ~40ppm Cl and SO_4, respectively, while East Lake has concentrations that are approximately half that. Finally, East Lake has been previously reported to have two isotopically distinct methane pools in its waters: a ^{13}C-enriched end member (~-30‰) in its deep water (likely a *thermogenic* source), and a pool nearer to the surface with $\delta^{13}C$ of ~-50‰ that may suggest a *biogenic* component (Varekamp 2015). We are examining the microbial populations in the water column via DNA analysis to further help identify possible sources.

BACKGROUND AND WATER COLUMN

East and Paulina lakes are fresh water lakes exhibiting standard temperature profiles and experience seasonal overturn. East Lake has a volume of 0.86×10^8 m^3, maximum depth of 55 m, and an average depth of 20 m. Paulina Lake has a volume of 3.1×10^8 m^3, a maximum depth of 76 m, and an average depth of 50 m. Additionally East Lake has a water level up to 15 m above that of Paulina lake. Corrected conductivity profiles for both lakes, displayed in Figure 1, show that Paulina lakes conductivity increases somewhat steadily from .507-.522 2 mʊ/c. East Lake's conductivity varies greatly starting at 0.362 2 mʊ/c then dropping to 0.353 2 mʊ/c around 16m depth then increasing to 0.359 2 mʊ/c at the bottom of the lake. In Figure 2, Paulina Lake shows and increase in O_2 saturation levels for the first 10 m of the profile indicating the extent of the photic zone, or at least the extent of photosynthesis in the water column. O_2 saturation for Paulina Lake drops steadily below 10m depth. Additionally, Figure 2 shows East lake's O_2 saturation levels are more confusing, dropping sharply in the first meter, then steadying for the next five, hits a low point at 6m depth only to continue to climb in saturation level for the remainder of the profile.

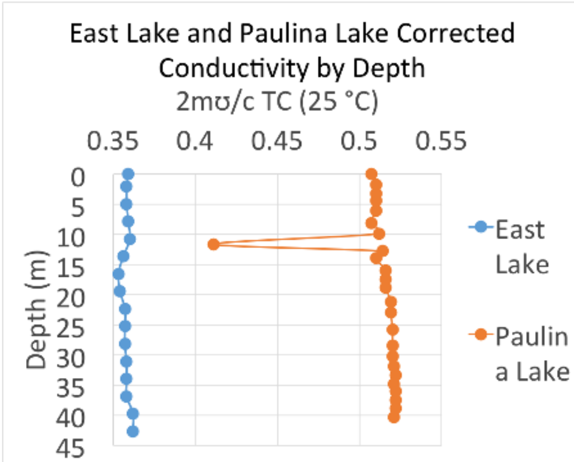

Figure 1. Shows the corrected conductivity for East and Paulina Lake profiles. The outlier in the Paulina profile is not indicative of the conductivity at that depth and was perhaps casued by a run-in with a fish.

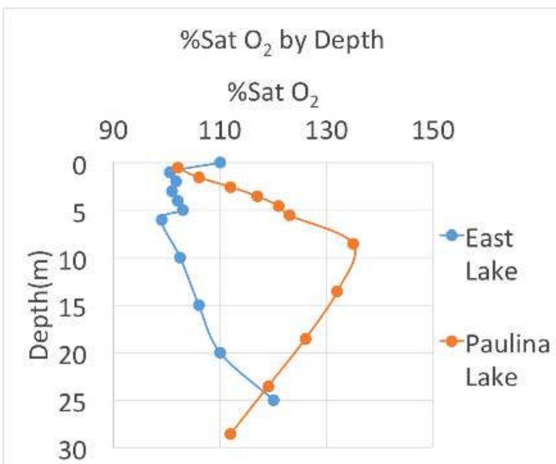

Figure 2. Shows the %Sat O2 for both lakes' profiles. East Lake is shown to initially lose saturation, then increase with depth while Paulina Lake shoes the opposite trend.

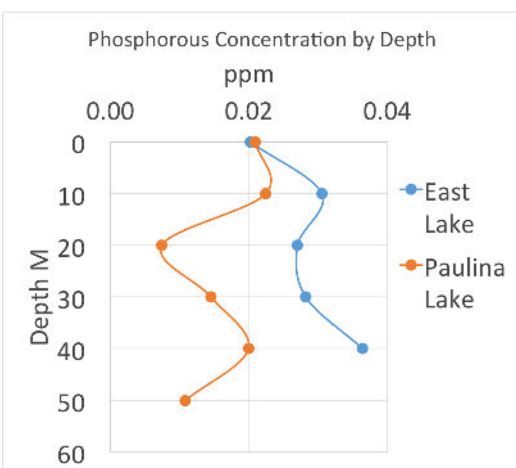

Figure 3. Shows the P concentration in the water profiles for both Lakes. Paulina Lake decreases in P concentration with depth while East Lake increases in P concentration with depth.

PHOSPHOROUS AND NUTRIENT PROFILES

Nutrient profiles run at the deepest parts of each lake continue to show the difference between the two lakes. Concentrations of major cations in each lake show that, excepting P and Ca, Paulina Lakes has significantly more nutrients than East Lake. The difference in concentration ranges from 50% more concentrated to as much as 300% higher concentration of a single cation in Paulina Lake than in East Lake. The Ca values for both lakes remain almost the same concentration throughout the depth profile. Figure 3 demonstrates that the P values vary greatly for both lakes, starting at near the same concentration, then East Lake's concentration increases with depth in an Z-shaped curve, while Paulina Lake's concentration of P decreases with depth in an S-shaped curve. When combined with the relatively lighter $\delta^{13}C$ values from Paulina Lake's sediment, shown in figure 4, this P data suggests more bioactivity in Paulin Lake than East Lake.

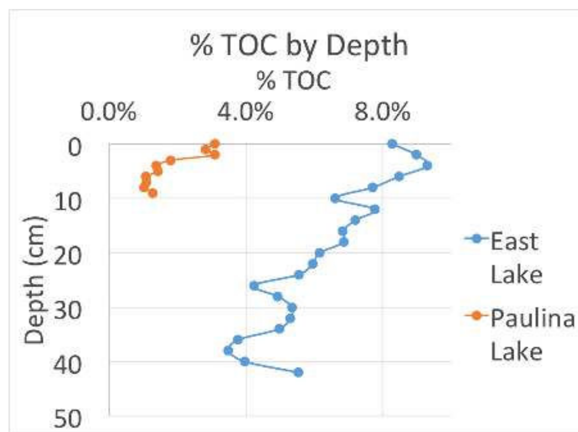

Figure 4. Shows the TOC values for sediment cores of both Paulina and East Lakes. This data was taken using an EA and shows that East Lake, in general, has about twice as much or 4% more TOC than Paulina Lake

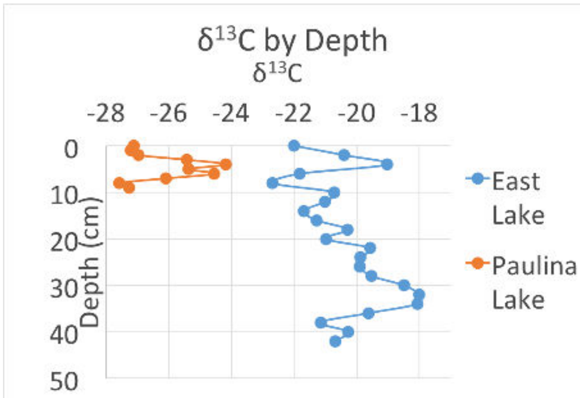

Figure 5. Shows the δ13C for sediment cores of both East and Paulina Lakes. As shown, Paulina Lake has more depleted Carbon than East Lake in its sediments by about 5ppm.

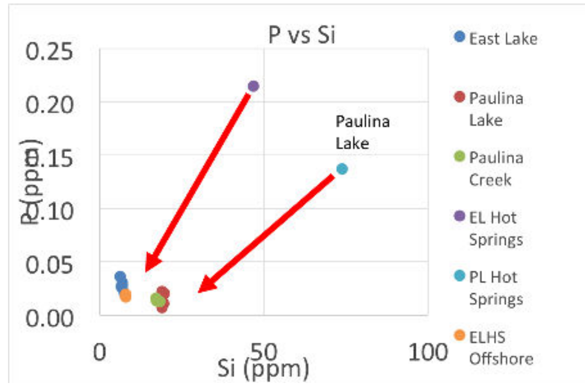

Figure 6. Shows the P and Si concentrations for East and Paulina Lakes, as well as their respective hot springs, graphed against each other. They demonstrate a dilutive relationship of about 33% between the hot spring "source" and the lakes.

MIXING AND SOURCES

When compared to the hot spring waters of each lake, the hot springs are being treated as an endemic source member for each lake, both lakes show a 33% dilution in major nutrients and cations. Paulina Lake contains much more Si in its waters than East lake, almost 300% more with East lake values averaging around 7ppm and Paulina Si values averaging around 20ppm, this is seen clearly in both Figures 6 and 7. This could be explained by the hydrothermal vent that is proposed to feed Paulina Lake by Lefkowitz. Paulina and East Lake contain almost the same concentration of calcium in their profiles. This has to be derived from the volcano, as the catchment for both lakes is too small to have any real impact on water chemistry. However, the Paulina Lake Hot Springs Ca concentration is 50% higher than the ~20ppm average for both lakes reading 32.35ppm.

FUTURE WORK

Work still to be done surrounding the methane in the lakes. Currently, we are waiting on everal RNA*Later* filters to be analyzed for archaea, bacteria, and prokaryotes. Specifically, we will be looking to identify methanogens in the water column. Additionally, we are waiting on isotope results for δD and $\delta^{13}C$ of the methane in the water column. Methane isotope data from a previous study (Varekamp 2015) identifies two distinct pools of methane in the lakes.

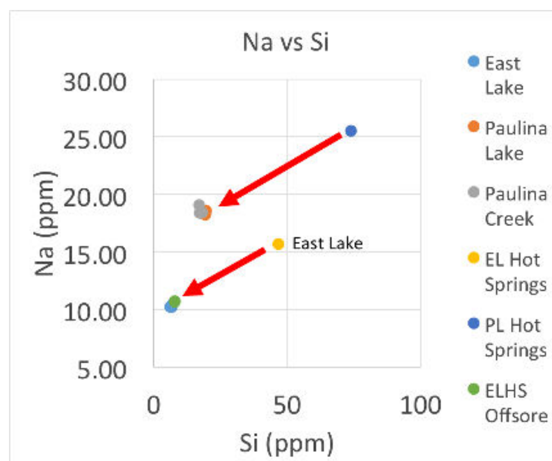

Figure 7. Shows the Na and Si concentrations for East and Paulina Lakes, as well as their respective hot springs, graphed against each other. This again demonstrate the dilutive relationship of about 33% between the hot spring "source" and the lakes.

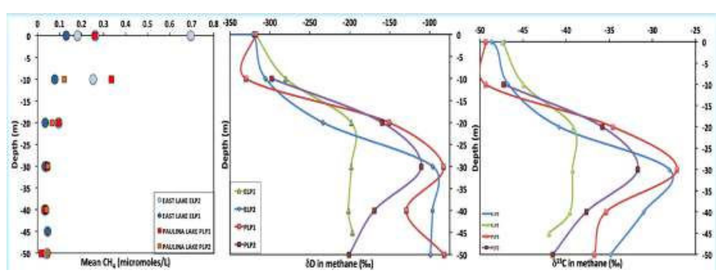

Figure 8. Shows the isotope data collected by Varekamp (2015). Note that the Carbon isotopes match average isotopic values for atmospheric methane at the top of the water column. However, the Deuterium values are much more depleted than the values for standard atmospheric methane. The isotopic pools at the base of the water column share thermogenic signatures.

An isotopically enriched pool at the base of the water columns for each lake with a thermogenic signature, and an isotopically depleted pool at the top of the water column for each lake. This area is of particular interest as the $\delta^{13}C$ values are typical of atmospheric methane, but the δD values are approximately 300% depleted when compared to typical atmospheric methane reading ~ -300ppm.

East and Paulina Lakes are very different chemically as shown by the nutrient data. Despite being fed by the same volcano, the two lakes have very different values for most elements and nutrients excepting Ca and P. The current hypothesis is that East Lake is fed by a gaseous input from the volcano. This would explain the large amount of Hg in East Lake as the Hg would burn off into the gaseous input. Paulina lake is then fed by a hydrothermal input from the Newberry Volcano (Lefkowitz) this would explain the difference in Si concentrations. The data from the springs for each lake show a clearly dilutive relationship between the lakes and the “source” material. Paulina Creek is also slightly more diluted than Paulina Lake as its outlet. The Carbon isotope data and P data also give an approximation of the biologic activity in each lake. Pending data on the methane in the water column may also provide more interesting results to com.

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