Controls on the Distribution of ASARCO Heavy Metals in Tacoma-Area Lakes

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Introduction and Background

- From 1890 - 1986, the ASARCO (American Smelting and Refining Company) smelter processed lead ores and later copper ores high in arsenic to produce metals for commercial use. This ultimately resulted in high levels of heavy metals in lake sediment and soil across a 1000 m² area of the Puget Sound region (Figure 1).
- Peak loading times of heavy metals in lake sediments do not correspond to peak production times, and appear years after smelter operations were discontinued in 1986.
- Highest metal concentrations are appearing in the top 20 cm of lake-bottom sediment for each lake, suggesting that heavy metals are still being delivered into the lakes or that metals are moving upward through sediment column.
- Despite being processed during different times, peak lead and copper loading appears to occur at the same time.

Objectives

- Verify whether heavy metals are currently being delivered to lakes
- Determine whether heavy metals continue to move through the sediment column after deposition, and if so, how?
- Define what processes are causing heavy metals to be distributed
- Investigate what effects the rate of sedimentation has on the distribution of heavy metals

Area of Study and ASARCO Plume

- Figure 2. Map of lakes of study. American Lake (AL), Gravelly Lake (GL), Lake Killarney (LK), Lake Louise (LL), and Waughop Lake (WL) are highlighted.

Methods (Field Approaches)

- Monthly Sediment Trap Sampling: Sediment traps were deployed at the deepest part of each lake to determine the sedimentation rate and if the flux of heavy metals being cycled into the lake via distribution are an accurate reflection of lake bottom sediments. Every once a month, the attached poly bottle was replaced with a new poly bottle.
- Soil Sampling: Depending on access and availability, soils samples from the top 8-15 cm were collected and homogenized from the perimeter of each lake. Samples were collected to investigate whether heavy metal increases in lake sediments are a result of surface run-off.
- Core Sampling: A core of the uppermost 78 cm of lake sediment was taken from Lake Killarney and extruded in lab at 1-2 cm intervals at a time. Samples were taken to determine distribution of metals in lake-bottom sediments.

Methods (Lab Approaches)

- Heavy Metal Analysis: Sediments collected from soil, sediment trap, and the core were dried, pulverized, and digested for analysis by ICP-OES to identify changes in sediment chemistry over time and provide chronological reconstruction of anoxic conditions and biological activity in lake sediments. Core samples were also analyzed by the ICP-MS at UW Tacoma.
- Total Digestion Experiment: An American Lake core sample was subjected to a more aggressive form of leaching (10 ml of 20% HNO₃ and 2 ml of conc. HNO₃) to understand what metal concentrations are biased due to remaining undigested sediment.

Heavy Metal Deposition History

- Approximations of the age of the core were made by determining when the Europeans would have settled in the West which should match with an increase in P content in the sediment column.
- Profiles do not match what would be expected of smelter history. Although the transition from Pb to Cu processing began during the early 1900s, the element concentrations begin to rise at the same time. This suggests that metals are moving through the sediment column.

Heavy Metal Ratios

- Increase in Fe/Mn ratios suggests that hypolimnion has become more reducing over time.
- Lakes with higher Fe/Mn appear to also have higher Pb/Cu.
- Variation in Pb/Cu profiles suggests these elements are mobile in the sediment column.
- Sediment profile from lake to lake differs, though all should have received the same fallout.

Conclusions

- Soil samples collected around the lakes contain lower metal contents than the lake sediment, indicating local soil erosion is not the source of high Cu and Pb contents in surface sediments.
- Heavy metal profiles for Lake Killarney show maximum Pb and Cu contents near the surface; this is not what would be expected based on the history of ASARCO smelter operations.
- Metal profiles and ratios (e.g., Pb/Cu) vary from lake to lake, not what would be expected for airborne deposition.
- All data obtained thus far appear to indicate that heavy metals are mobile in sediment of Tacoma area lakes.

Future Work

- Pb-210 dating of Lake Killarney core to determine what the timescale is on the core.
- Collection of more sediment trap samples to determine heavy metal contents of sediment currently entering lakes.

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