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ASSESSING THE GRAIN SIZE OF LEGACY SEDIMENTS AND POTENTIAL FOR HEAVY METAL CONTAMINATION IN ROCKBRIDGE COUNTY, VA

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INTRODUCTION

In Rockbridge County, VA studying legacy sediment grain size and elemental abundances elucidates decades of major flood events, land use changes, and the presence and mobility of heavy metals. Chesapeake Bay drains a huge catchment that includes the Maury River watershed in western Virginia (Fig. 1). The Maury River provides water for many communities (Fig. 2), making it vital to monitor and study the water and sediments for potential contaminants. Inorganic metals of concern include both manganese and lead (Niemitz et al., 2012; Kiracofe et al., 2017). Manganese can be toxic and harmful to humans - especially infants and children - at chronic low levels (Bjørklund et al., 2017). The occurrence of these elements in sediments can be traced back to the underlying lithology and the mining history of the region.

Over the decades, impounded reaches and their connected floodplains accumulated sediments and may have captured heavy metals. Now, because of dam removal, the concern is remobilization. Though it is uncertain whether these heavy metal elements will be linked in the sediment with larger precipitated particles or in clays as bonded cations. Smaller clay particles have higher surface area and may be able to adsorb and absorb toxic elements depending on water redox and pH characteristics. On the other hand, larger particles may include heavy metal oxides and hydroxides which have been deposited in the legacy sediments (Pavlowsky et al., 2017).

The focus of this research is on the grain size and heavy metal composition of a 2.6 m stratigraphic column taken from sediment layers that accumulated behind a dam at Polecat Hollow (Fig. 2). Correlations between grain size and metal elements within the stratigraphic column can signify aspects about the environment of deposition.

Figure 1. A map of the State of Virginia showing the locations of the towns of Lexington and Buena Vista relative to the Maury River, James River, and to Chesapeake Bay.

BACKGROUND

The Maury River drains from the Valley and Ridge Province of Western Virginia and meets the James River at a confluence south of the towns of Lexington and Buena Vista (Fig. 1). The Maury River watershed is mainly located in Ordovician age limestone, sandstone and dolostone deposits of the Beekmantown, Lincolnshire Edinberg and Martinsburg Formations near Goshen Pass (Wilkes et al., 2007). The lithology includes deposits high in manganese, and mineralization along faults in the area has created ores valuable enough to mine. There is evidence for extensive mining in Rockbridge County, including 23 mines or quarries and 17 foundries (Wilde, 2022). Three of these mines were located near our sample site, close to the town of Lexington (Wilde,

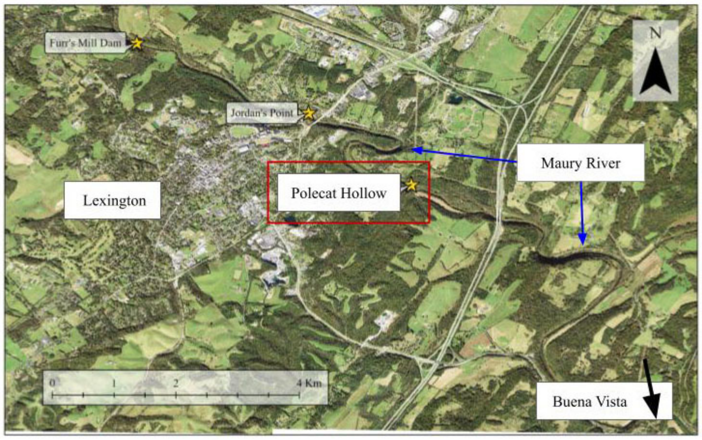

Figure 2. An aerial photograph of the town of Lexington with three of our sample sites shown along the Maury River and depicted by the yellow stars; Polecat Hollow is outlined by a red box. Aerial photo obtained from USGS Earth Explorer (EROS) database.

2022).

Over 64 different dam structures have been built in Rockbridge County, many of them now have been breached or removed (Wilde, 2022). Reid's Lock and Dam at Polecat Hollow existed from prior to 1863 until 1930 when it was removed. There are two recorded historic floods for the time during which Reid's Lock and Dam were operational, one in 1893 and one in 1896 (USGS, 2022). This is pertinent because higher volumes of water are able to transport more sediment and larger grain sizes.

Grain size analysis determines the distribution of the diameter of particles within a sample. Creating grain size distributions (GSD) for each sample shows the nature of the grain size spread, from which I interpret the differences between layers. In addition, this study explores manganese, lead, and iron abundances by examining the interactions of these heavy metals with clay rich layers and then large sand abundant layers.

METHODS

Field Sampling

We collected both sediment samples at eight different sites concentrated mostly within the Maury River watershed. The focus of this research on grain size changes through time includes only sediment samples collected from Reid's Lock and Dam, colloquially referred to as Polecat Hollow (sample site KDPH, Fig. 2). KDPH is located just downstream of the town of Lexington.

At Polecat Hollow, we sampled from the northern side of the channel about 100 m upstream of the dam remnants. The process began with scraping away any accumulated colluvium to create a vertical 2.6 m stratigraphic column. A tape measure was placed with 0 cm at the top horizon, or ground surface level and measured down to water level. We took ~10 g samples every 10 cm by using a lab grade steel spatula (Fig. 3). During collection, descriptions of the layering included the apparent grain size, color, and texture.

Sample Preparation

Removal of organic matter from each of the 16 samples chosen for grain size analysis ensured the complete separation of particles. The process involved repeatedly allowing 4-8 g samples to bathe in 30% hydrogen peroxide until the organics were absent from the sample (ISO, 2009). I deduced this by watching the samples during addition of H_2O_2, and stopping the process once they ceased to generate gas by oxidation. Finally, I included Sodium Hexametaphosphate to ensure particle separation. Samples did not require sieving during preparation; all of the samples contained only particles < 2 mm when they were collected.

Grain Size Analysis

At Whitman College the Mastersizer 3000 by Malvern Instruments collects grain size data through a multistep process ending with laser diffraction. The method begins with adding processed sediment to a swirling water bath to an obscuration of laser light between 10 and 15%. The water bath then sonicates the sample for a minute to ensure complete suspension and separation of particles. Next, the water and sample feed continually through a tube into the laser chamber. The sample analysis procedure was set to take 5 measurements of each batch and at least 3 distinct batches were run for each sample from KDPH. For example, the sample collected at a depth of 20 cm at Polecat Hollow would be analyzed with three separate aliquot runs, as PH-20a, PH-20b and PH-20c. The laser collects data by shooting light through the water and suspended grains and collects information about the angles of diffracted light.

Figure 3. A photo of one of the stratigraphic columns studied by our team. We sampled starting at the top using the tape measure, flags for marking, and lab spatulas to collect the sample. The same method was used at KDPH.

Collected GSD data used in interpretation included the D10, D50 and D90 (distribution percent which is the size of the particle below which exists the given percent distribution), the percent sand, silt, clay, and the percent volume density of particles for 100 bins from 0.01 microns to 3500 µm in diameter. The distinctions for clay, silt, and sand were < 4 µm, 4-62.5 µm and > 62.5 µm respectively. These GSD graphs expressed each of the three measured batches and the calculated average of three runs (Fig. 4).

RESULTS

Grain size distribution of the KDPH stratigraphic sequence varies from sand dominant to silt dominant in somewhat rhythmic layers. Overall, silt is usually most abundant at depths greater than 20 cm. Figure 4 displays a typical GSD from a layer with high clay content - 50 cm (PH-50) - and one with high sand content at 140 cm (PH-140). The sample PH-50 shows slight bimodal distribution with a small peak centering around 0.5 µm and a broad peak at 50 µm. In contrast, PH-140 shows a single peak near 100 µm with a slight skew towards smaller grain size. To compare the percent sand, silt, and clay, PH-50 shows 20% clay, 72% silt, and 7% sand whereas PH-140 has 6% clay,

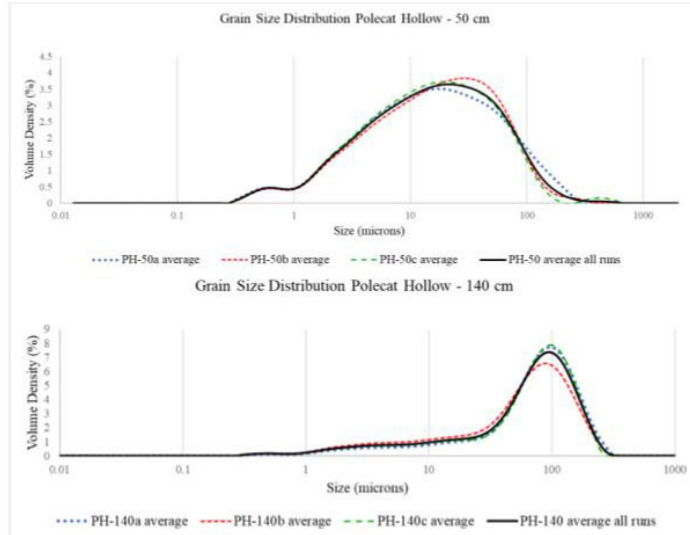

Figure 4. Two grain size distribution graphs, one from a depth of 50 cm and another from 140 cm. The red, green, and blue lines are the three measured runs. The black line is the calculated average of the three runs and shows the average GSD for these samples.

26% silt, and 68% sand.

Mean grain sizes for the entire stratigraphic profile sampled ranged from 11.7 µm to 197.6 µm (Fig. 5).The largest mean grain size of 198.6 µm was recorded at depth 0 cm. The average of all sample means (the average D50) is 56.8 µm. The average percent clay in the 16 samples was 12% with the average silt and sand being 49% and 39% respectively; although there were large ranges of variability in both silt and sand percent volumes. Silt dominates samples in three layers and sand is most abundant in four layers of the column at KDPH.

I performed X- Ray Diffraction analysis to determine the mineral identities present and found quartz as the only distinguishable mineral.

DISCUSSION

At the top of the column the larger grain size and lower relative abundances of Fe, Mn, and Pb suggest a distinct change in depositional environment, which is probably due to the removal of the dam in 1930.

The data show some positive correlation between median grain size (D50) and the abundance of Mn, Pb, and Fe (Fig. 5). At the top of the column, at 0 cm, we see the largest particle size. On the other hand, concentrations for Mn, Pb, and Fe are at low at the top

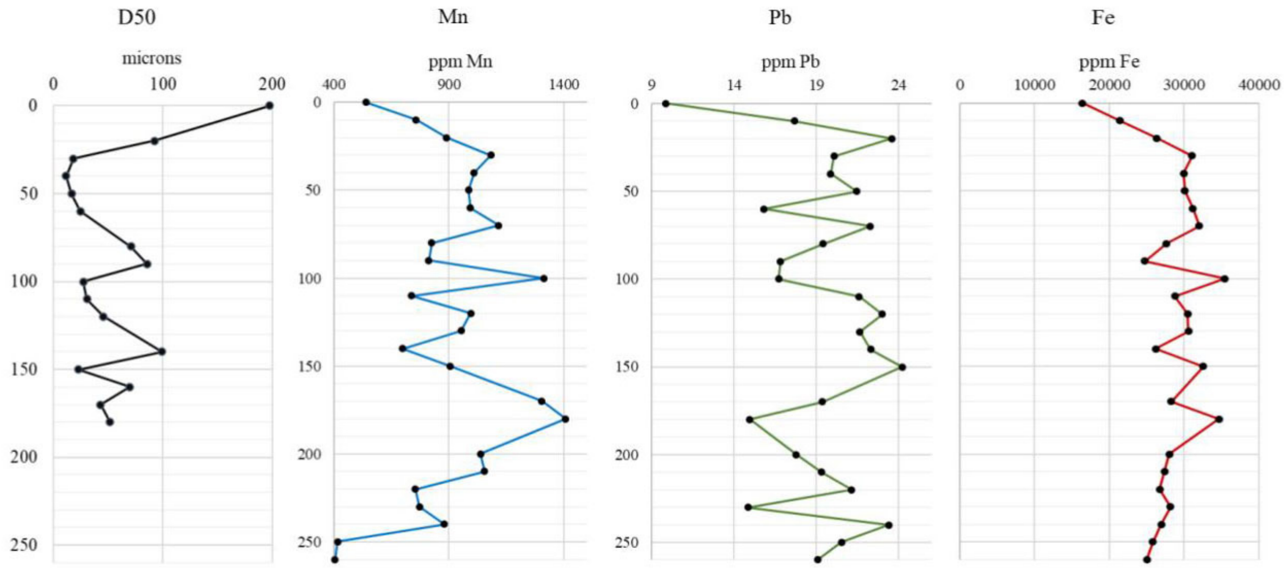

Figure 5. The average D50 value for each KDPH sample depicted stratigraphically and placed next to similarly oriented graphs depicting the abundance of Mn, Pb, and Fe throughout the column. The elemental abundance data gathered and provided by Madeline Holicky at Beloit College.

of the column (and the least abundant of all samples for both Fe and Pb. Following this trend, other spikes in D50 occur at depths of 90 and 140 cm. At these horizons, all metals have lower concentrations. This is consistent with the hypothesis that layers with larger particles will have overall lower surface area and therefore not allow as much heavy metal adsorption as smaller, more clay rich layers in the stratigraphic column. The sample depths with smaller mean grain sizes include 40, 100 and 150 cm. Between these three samples the variation of general elemental abundances fluctuates a bit more, though the trend shows overall greater concentrations of Mn, Pb, and Fe. This is especially apparent at a sample depth of 100 with Mn and Fe. The amount of Pb at this depth is low, which might suggest a complex relationship between abundance of Pb with the abundances of Mn and Fe - Mn and Fe tend to trend similarly throughout the column, with both showing alignment of peaks and troughs.

CONCLUSION

Grain size analysis of a stratigraphic column of millpond sediments along the Maury River in Rockbridge County elucidates the relationships between grain size and heavy metal abundances. The legacy sediments studied at Polecat Hollow have overall grain size means in the range of clay, silt and sand. The association of smaller particles with higher Mn and Fe abundance suggests the metals are correlated with clay abundance. The larger particles therefore are generally not compositionally inclusive of the highest amounts of Mn, Fe, and Pb. The larger sediments at the top of the column are likely associated with the removal of Reid's Lock and Dam signifying a distinct change in depositional environment. The top 30-40 cm of the stratigraphic column has much larger grain sizes, with lower levels of heavy metals. This can be pertinent for contamination studies and for monitoring the region. This also can inform the future of dam removal in relation to legacy sediment remobilization. Legacy sediments have overall grain size means in the range of silt and the active floodplain has much larger grain sizes, with lower levels of heavy metals. The history of land use in this column was more difficult to deduce because we lack age constraints and accumulation rates of sediments during the time the dam was active.

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