Provenance of a Soil Atop a Terrace Along the Harpeth River in Tennessee Using Immobile Trace Element Concentration Ratios

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BRIEF. A soil and bedrock pair was compared using immobile trace element concentration ratios to discover the origin of the soil.

ABSTRACT. Soil is formed by the weathering of parent material and is influenced by other factors such as climatological, anthropogenic, biological, and topographical factors. In Middle Tennessee, there are several potential parent materials, including: (1) bedrock; (2) alluvium; and (3) loess. The soils could have formed from any combination of these end-members. When the limestone bedrock is weathered it leaves behind chert and quartz, the primary components of soil found in Middle Tennessee (Breitburg *et al.*, 1996). Huckemeyer (1999) found a loess mantle, a layer of windblown dust of Pleistocene age, atop terraces along the Harpeth River and suggested that this was a second source of parent material. The goal of this project was to test the hypothesis that the parent material for soils atop one of these terraces along the Harpeth River is bedrock. We collected soil and bedrock samples and analyzed them using a LA-ICP-MS and SEM to measure immobile trace element concentration ratios. The results for the soils were compared against those of the bedrock to determine if the soil is derived by weathering of the bedrock. The immobile trace element concentration ratios of the soil and the rock were different, implying that there could be loess in the soil.

INTRODUCTION.

Soil is an important part of an ecosystem that is necessary for life on Earth. Soil is formed primarily by the weathering of parent material. Other factors such as human involvement, climate, organisms and topography also effect the development of the soil. Middle Tennessee bedrock is made up of limestone that has a large proportion of silt. Weathering of limestone leaves behind these impurities as a residue. In the Harpeth River Valley, in Middle Tennessee, weathering leaves behind chert and quartz [1]. This is one of the parent materials of the soils in this region. Huckemeyer (1999) found evidence for a second source of parent material for these soils called loess atop river terraces along the Harpeth River. Loess is aeolian, silt-sized sediment that was left behind by glaciers. According to the AGI Glossary of Geology (4th ed., 1997) loess is "windblown dust of Pleistocene age, carried from desert surfaces, alluvial valleys, and outwash plains, or from unconsolidated glacial or glaciofluvial deposits uncovered by successive glacial recessions but prior to invasion by a vegetation mat." Huckemeyer (1999) suggested that the loess found in this area is Peoria Loess from the Mississippi River Valley deposited during the Quaternary Glacial Period.

To test Huckemeyer's (1999) observations, soils and bedrock samples were collected from a location with a low slope and high altitude, atop a terrace that was last active 100,000 years ago. The samples were then analyzed for immobile trace element concentrations using the LA-ICP-MS (Laser Ablation Inductively Coupled Plasma Mass Spectrometer) and the SEM (Scanning Electron Microscope). These are used to compare the soil's composition to that of the rock to see if the parent material of the soils was the residue from the weathering of the bedrock. If the results indicate that the soils did not form solely from the bedrock, then it is possible that there was another source of parent material, such as loess.

MATERIALS AND METHODS.

Collecting the Sample.

In the lab, the computer program ArcGIS was used to find the desired soil and bedrock pair, slope, and elevation atop a river terrace surface dating to ~100,000 years ago from Huckemeyer (1999). Once the desired location was found, a small group was taken to the location to start the excavation. One hole was excavated to expose the soil horizons. Horizons were identified by Munsell color and apparent silt, clay, and organic matter content. The thickness of each horizon was measured using a ruler. Two gallons of both horizon B1 and B2 were collected into gallon sized bags for easy transport back to the lab. Soil density samples were taken for both B1 and B2. Bedrock samples were also taken from an exposure at an adjacent cliff.

Processing the Sample.

To make an epoxy mount the soil that was collected from the excavation site was crushed using a mortar and pestle. The sample was then sieved through a 1 mm sieve to remove any small rocks, branches, or any remaining large organics. The crushed and sieved soil was heated in a muffle furnace at 850°C for 4 hours. The samples of the collected bedrock were put into a shatter box with a steel puck to pulverize the rock into a fine dust. The cooked soil sample and the pulverized rock sample were each mixed with $LiBO_2$ in a 2:1 ratio of sample to LiBO2. The mixture was put into a graphite crucible in a high-temperature muffle furnace at 1100°C for 5 minutes. This created a glass bead. The glass beads placed into epoxy with copper wire to form a 1" mount. The copper wire was used to aid in the identification of the glass beads. The mount was allowed to cure for one day and then polished.

Analyzing Samples.

Once the epoxy mount was cured and polished, the Laser Ablation- Inductively Coupled Plasma- Mass Spectrometer (LA-ICP-MS) used to analyze the chemical composition for 10 spots on each sample. A Scanning Electron Microscope (SEM) was used to assess the chemical homogeneity of the samples. The raw data collected from the LA-ICP-MS was imported into the data processing program, Glitter, for analysis of the immobile trace element concentration ratios.

RESULTS.

Once the samples were analyzed with the SEM, it was determined that the samples were homogenous. The immobile trace element concentration ratios were then calculated by the LA-ICP-MS and graphed.

Immobile Trace Element Concentration Ratios.

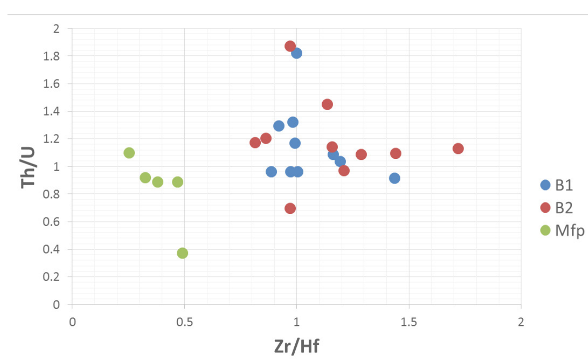

Figure 1. Graph showing the immobile trace element ratios taken from the LA-ICP-MS. This particular graph shows the ratio between zirconium/hafnium and thorium/uranium. Note that the composition of the bedrock (Mfp) does not match the compositions of the B1 and B2 soil horizons.

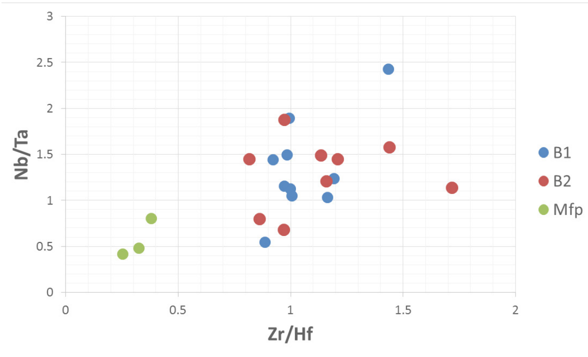

Figure 2. Graph showing immobile trace element concentration ratios, collected from the LA-ICP-MS, specifically zirconium/hafnium and niobium/tantalum. The composition of the bedrock (Mfp) does not match the compositions of the B1 and B2 soil horizons.

DISCUSSION.

Immobile trace elements are left behind during the weathering of bedrock. Other elements weather away overtime, however immobile trace elements will remain in the soil. If the immobile trace element concentration ratios were the same between two soils, then they would be the same age. The analysis of the trace element concentration ratios suggests the Mfp bedrock and the soils have different immobile trace element concentration ratios. If the soil did come from the residue left behind by the weathering of the rocks, then we would expect the ratios would be the relatively similar. However the ratios are different, implying that the soil was not produced solely by weathering of the bedrock. This means that there is a possibility of a loess mantel on the terrace. The mineral zircon was found in the soil sampled for this experiment. Zircon can be dated using uranium and lead isotopes. The ages of the zircons found in the soils can then be compared to ages of zircons found in the rock to determine if they are the same in the soil and bedrock. If they are not, then it can be assumed that the soil was not produced solely by weathering of the bedrock, but was transported from another source location.

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REFERENCES.

1. Breitburg E., *et al.*, *Curr Res Pleistocene.* 13 (1996).
2. Huckemeyer JL., Vanderbilt University Press, Nashville, TN (1999).

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