Iron legacy leaves soil high in manganese

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Research assistant Jennifer Williams (Earth and Environmental Systems Institute) points out soil properties to post doctoral scholar Lin Ma (geosciences) during soil sample collection at the Shale Hills Critical Zone Observatory. The researchers sampled 21 sites along a ridge at Shale Hills. They took core samples from the surface down to bedrock. At 20 of the sites they found elevated manganese. The core samples, which are about 12 inches long, encompass about 7,000 years of soil formation. Photo Credit: Mark Selders Photography

(PhysOrg.com) -- Iron furnaces that once dotted central Pennsylvania may have left a legacy of manganese enriched soils, according to Penn State geoscientists. This manganese can be toxic to trees, especially sugar maples, and other vegetation.

The research, which quantified the amounts of manganese in soil core samples, was part of work done at the Shale Hills Critical Zone Observatory funded by the National Science Foundation.

"Our group's focus was to study the soil chemistry," said Elizabeth M. Herndon, graduate student in geosciences. "We saw excess manganese in the soil and decided that we needed to quantify the manganese and determine where it came from."

Typically, manganese in soils comes from the disintegration of the bedrock as soil forms. Bedrock in this area is shale and the average amount of manganese in the shale is about 800 parts per million. However, the researchers found 14,000 parts per million of manganese in some of the soil samples. This is more than 17 times as much manganese as in the bedrock.

The researchers sampled 21 sites along a ridge at Shale Hills. They took core samples from the surface down to bedrock. At 20 of the sites they found elevated manganese. The core samples, which are about 12 inches long, encompass about 7,000 years of soil formation.

"We needed to quantify how much extra manganese there actually was in the samples," said Herndon. "While soil formation puts manganese into the soil, chemical weathering and physical erosion remove manganese from the soil, so we used a mass balance model to account for these inputs and outputs."

The researchers found that "53 percent of manganese in ridge soils can be attributed to atmospheric deposition from anthropogenic sources." They reported their results online in *Environmental Science and Technology*.

"Because the amount of manganese in the soil was highest near the surface, the added manganese was very likely industrial pollution," said Herndon.

This area of central Pennsylvania was the site of numerous iron furnaces

beginning in the late 1700s. While some furnaces stayed in operation into the 20th century, most were abandoned by the 1860s. The legacy of the ores and fuels they burned remained behind in the soil.

Although the researchers, who include Herndon, Lixin Jin, postdoctoral fellow in geosciences, and Susan L. Brantley, professor of geosciences and director of the Penn State Earth and Environmental Systems Institute, knew there was added manganese, they needed to show that the element came from industry. They looked at a location near a steel mill in Burnham, in Mifflin County and found a similar pattern of manganese concentrations in the soil suggesting that the steel mill was the source of the manganese.

They also examined datasets for soils across the United States and Europe and found that a majority of these soils have excess manganese. This may indicate that manganese pollution is not just a local phenomenon but could be widespread throughout industrialized areas.

Because manganese is naturally found in soils and is readily taken up and cycled by trees, the researchers looked to see if the pattern of manganese deposition matched that of areas where trees were manipulating the manganese. In those cases, trees move manganese from deep in the soil creating deficits near the bedrock, but concentrate the manganese nearer the surface. According to Herndon, the manganese pattern did not show a depletion near bedrock and the case for industrial pollution was strengthened.

Manganese is an exceptionally reactive element and is considered toxic if inhaled, but its presence in the soil, where it occurs naturally and is less likely to be inhaled, is not typically a danger to humans. Trees, however, may be adversely effected. While sugar maples can be detrimentally affected if they have a manganese deficiency, too much manganese can be toxic especially for saplings. High levels of

manganese can also damage other vegetation and crops.

"Manganese oxides could also change the chemical properties of the soil," said Herndon. "Even if the sources of manganese pollution are no longer active, the remnants remain in the soil. I find it interesting that we have to consider the kinds of contamination left over from the past that might impact us today."

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