

Trace Element Fingerprints Of Wildfire In the Pedosphere: Results From The 16-Mile Fire, Pennsylvania

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ABSTRACT

Wildfires are fleeting events with distinctive effects on soil and water quality. Soil mineralogical properties can be altered, which can change a soil's chemistry. Forest fires can also change the structure of the soil, making it less permeable, leading to an increase in runoff and erosion into nearby waterbodies. Furthermore, the impulse influx of burned biomass adds aluminum, calcium, magnesium, manganese, phosphorus, potassium, and silicon, though these elements are common within many parent materials. Identification of unique trace elements within biomass ash could determine whether such signatures exist in the soil and water following a fire.

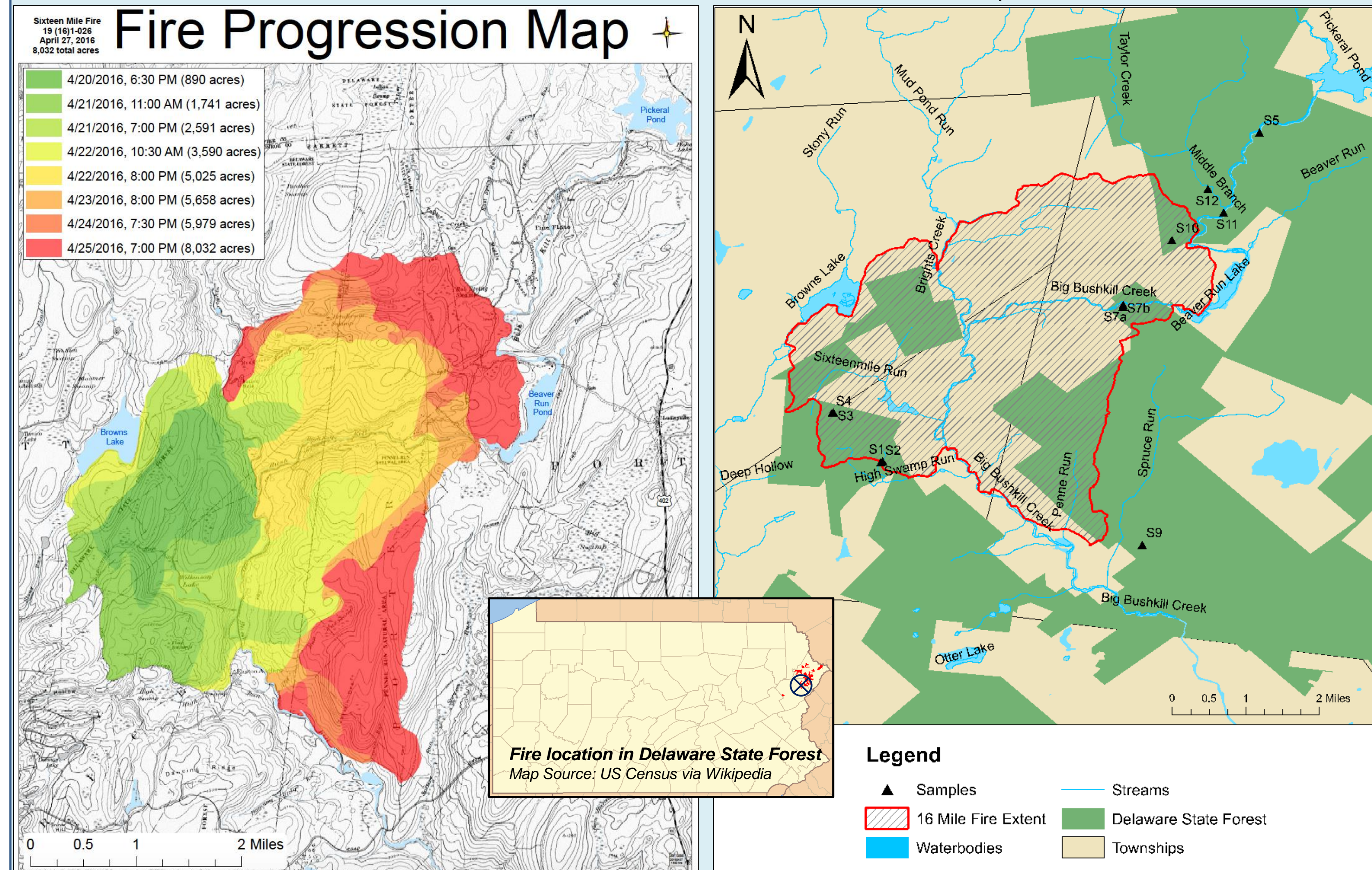
We examined a recent wildfire within the Delaware State Forest, Pennsylvania, to gain an understanding of the pedosphere major and trace chemistry after the fire, and the connection to surface hydrology. We collected soil and water samples within (impacted) and just outside (control) the 16Mile (April 2016) wildfire, and used inductively coupled plasma mass spectrometry of soil samples to determine postfire major and trace element chemistry. Minor but elevated amounts of iron, magnesium, titanium, and zinc provided fire ash signatures in the postfire soil. There is at least some persistence of the elements in the impacted soil more than six months following the fire. Using geographic information system (GIS) methods, results were extrapolated to understand how this affected the surrounding watershed. This investigation builds a more complete understanding of seldom researched fire impacts in Appalachian deciduous forests, with implications for water resource management and forest resource management. The study's importance is amplified by the potential increase in wildfires in areas with less precipitation and rising temperatures due to climate change.

FIELD LOCATION

The 16 Mile Fire, active in April, 2016, is within the Delaware State Forest (northeast Pennsylvania), which burned over 8000 acres. The region has numerous tributaries that feed into the Bushkill Creek that eventually drain into the Delaware River. Using geographic information science (GIS) spatial analysis, two watersheds were modeled, highlighting the hydrological movement that goes through the fire extent.

Fire progression map of the 16-Mile Fire (Hazen, 2016).

Map of 16-Mile fire extent and surrounding area, Delaware State Forest, PA.



METHODS

Sampling: Soil sampling took place in two time frames, 1-2 months (T1) and 8-10 months (T2) after the fire occurred. Shallow soil pits were dug to collect samples at according horizons and included ash that was left on the surface.

Lab methods: Soil and ash samples were oven dried, then soil, ash and rock samples were pulverized to a fine powder, combined with lithium metaborate flux and fused in a muffle furnace at 1050°C. The molten sample was then dissolved in a 7% HNO₃ solution to a 500x dilution factor. Further dilution to 10,000x was done making it suitable for inductively coupled plasma mass spectrometry (ICP-MS) analysis. Samples as well as USGS rock standards were analyzed with ICP-MS for major elements as well as V, Cr, Co, Ni, Ga, Rb, Sr, Y, Zr, Nb, Cs, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, Pb, Th, and U.

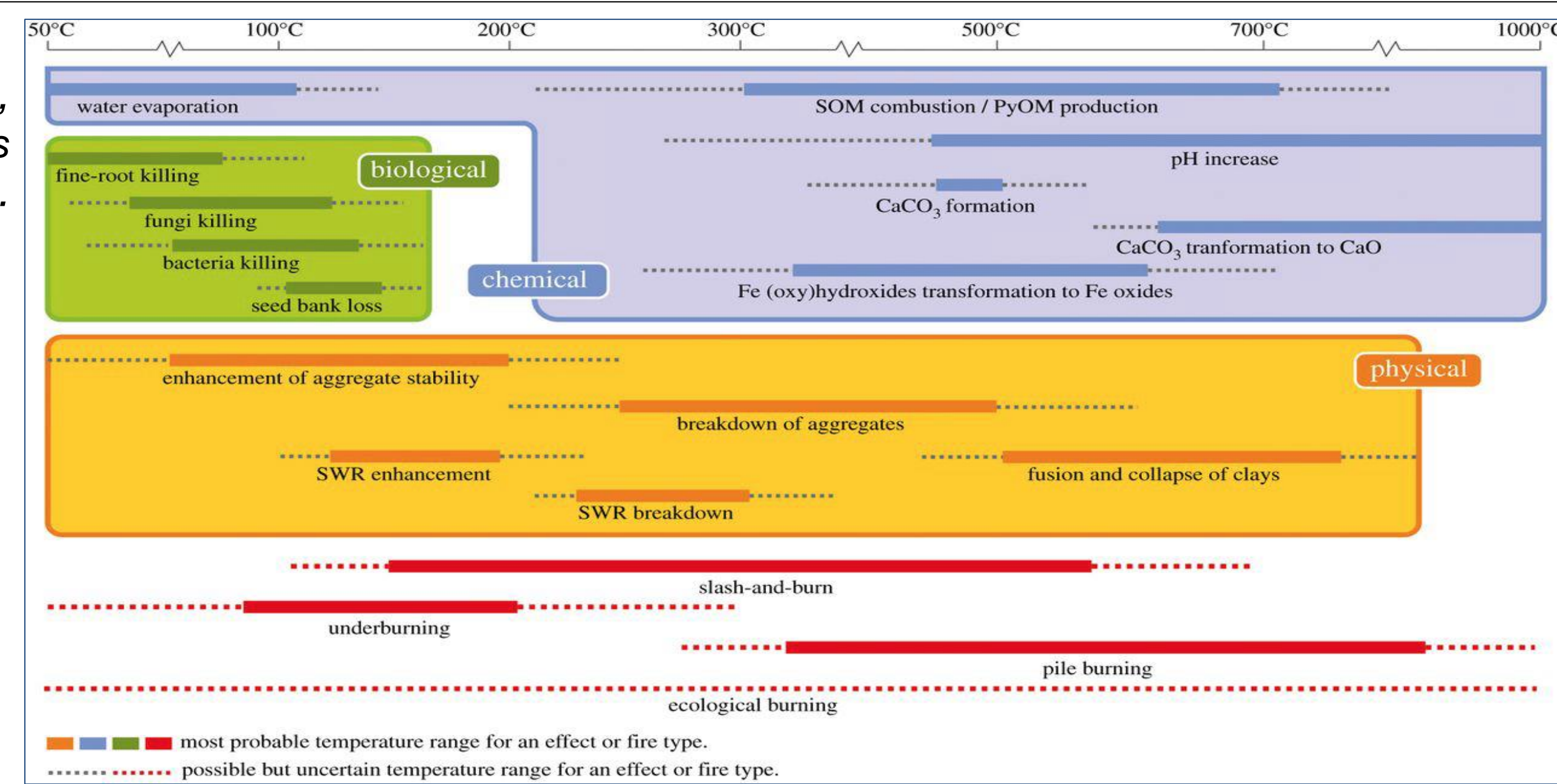
GIS Analysis: Using existing fire extents and digital elevation models (DEM) provided by the Pennsylvania Department of Conservation and Natural Resources (PADCNR) and Pennsylvania Spatial Data Access (PASDA), data was analyzed in ESRI ArcGIS to interpret concentrations of Cu, Ba at sampled sites. The hydrology spatial analyst tools were used to model the watershed in which the 16-mile fire occurred. Slope was calculated to identify if samples sites lie in areas of possible erosion.

BACKGROUND

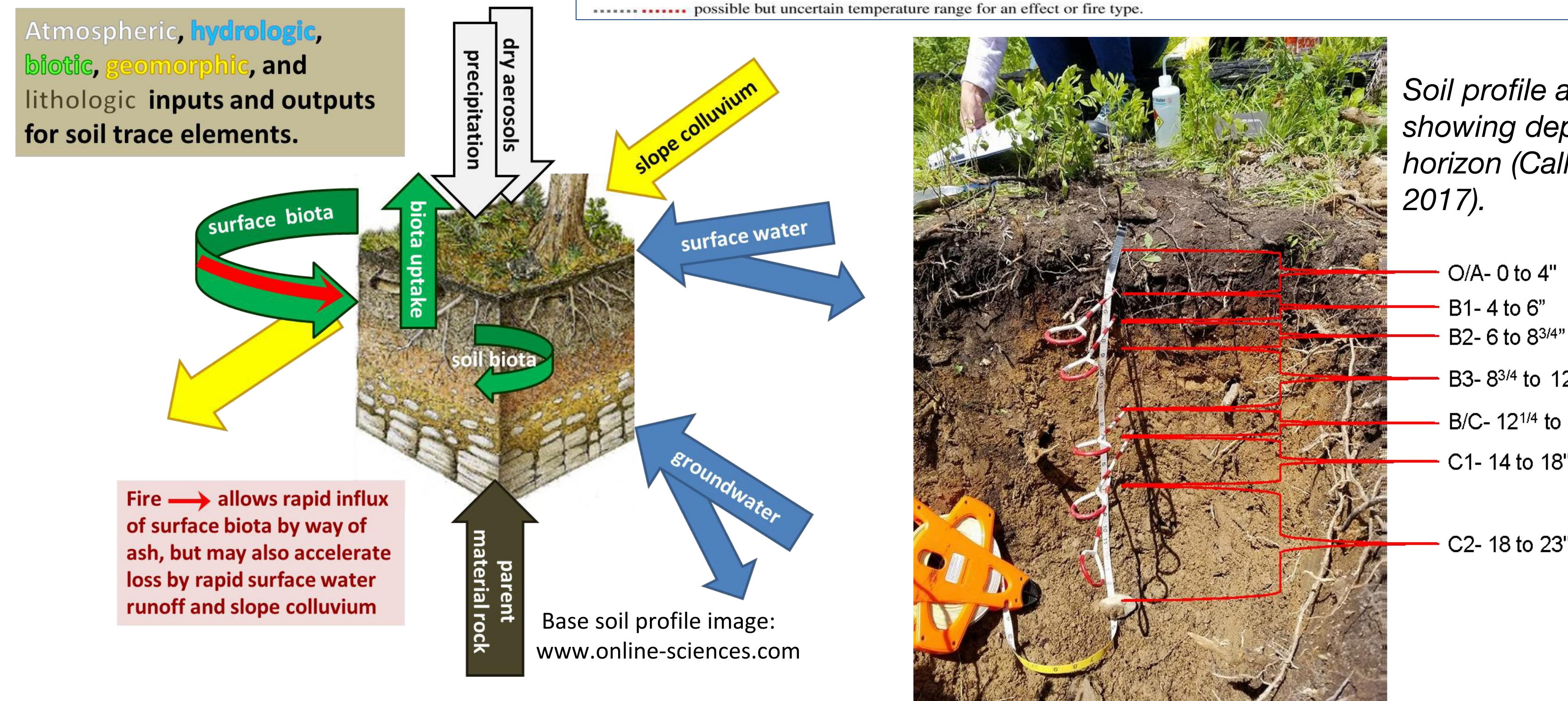
Basis of the research question: Is there a fire ash chemical signature or "fingerprint" in the soil?

- Santin and Doerr (2016) presented a variety of physical and chemical impacts by fire on the soil environment.
- Etiegni and Campbell (1991) identified major, minor, and trace elements found in sawdust ash.
- Simonson's (1959) soil process/system model (mass balance) of additions, removals, transformations, and translocations, provides a basis for a conceptual understanding of soil chemical composition.
- Minor and trace elements found in the soil derive specifically from these additions and removals.
- Are there **specific** elements, unique to a sudden influx of ash from a fire, that are distinguishable from elements native to the soil, i.e. not confused with the parent material composition or the chemistry of the soil water? Also, is there a difference, in terms of composition or quantity, of certain elements associated with the biota that may also be present in the soil from slow organic decomposition?
- Ongoing and future research will determine the fate of the signature elements in the soil: transformations or temporary storage with soil minerals and humic colloids, loss to the surface and groundwater (see accompanying posters in this session), and uptake back into the vegetation).
- **Therefore, an ideal fire signature element would be:**
 1. Different than and unique from those found in the bedrock/parent material and groundwater;
 2. Noticeably apparent after a fire;
 3. Persistent after a fire for some period of time; relatively immobile in the soil.

Effects of fires on soils chemical, biological, and chemical properties (from Santin & Doerr, 2016).

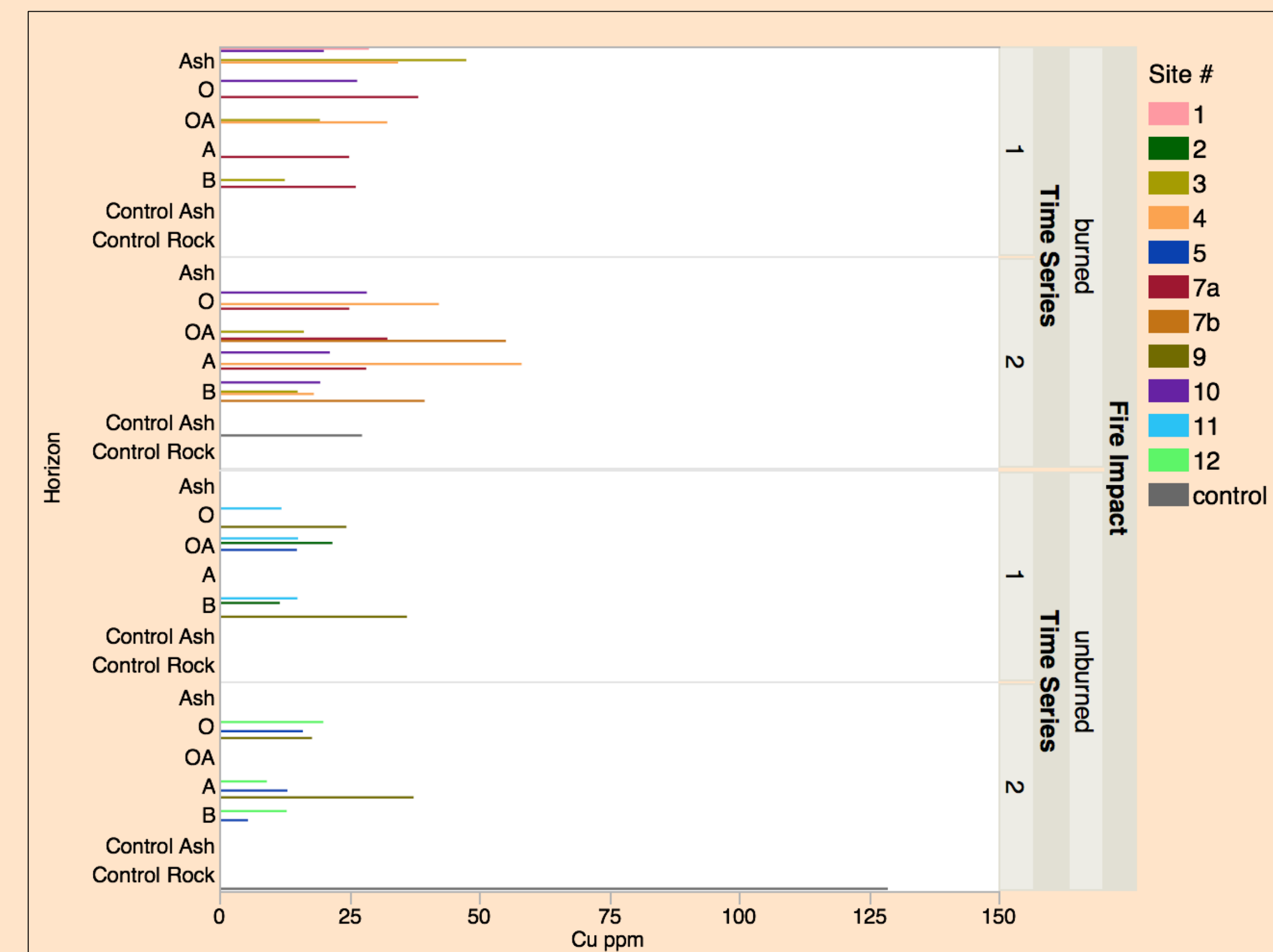
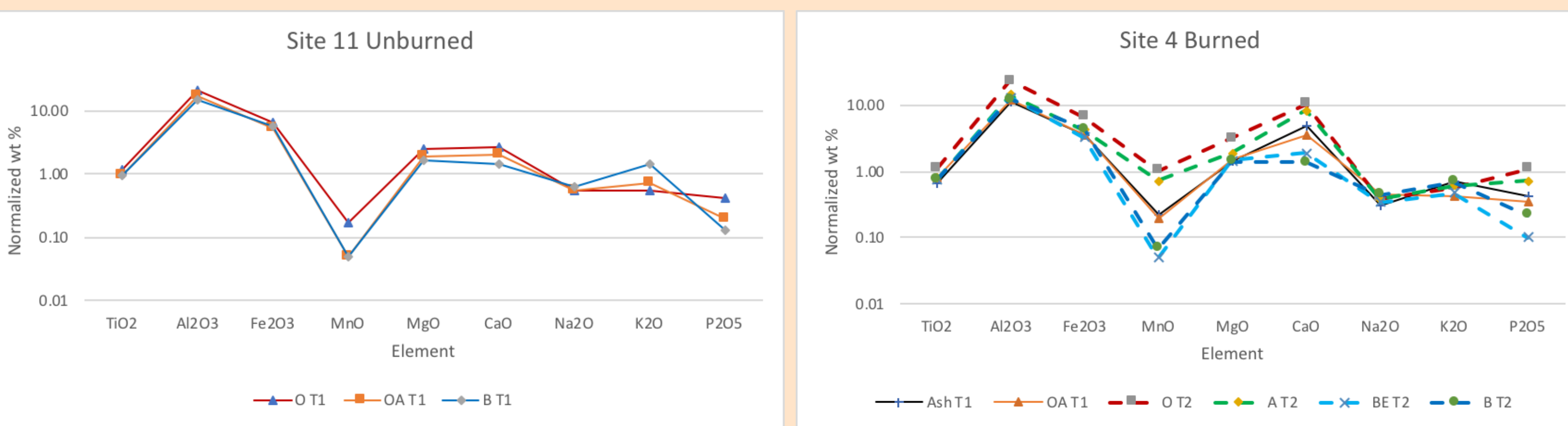


Soil inputs, transfers, and outputs of trace elements, based on the Simonson (1959) model.



Soil profile at Site 10, showing depths of each horizon (Callanan, 2017).

RESULTS

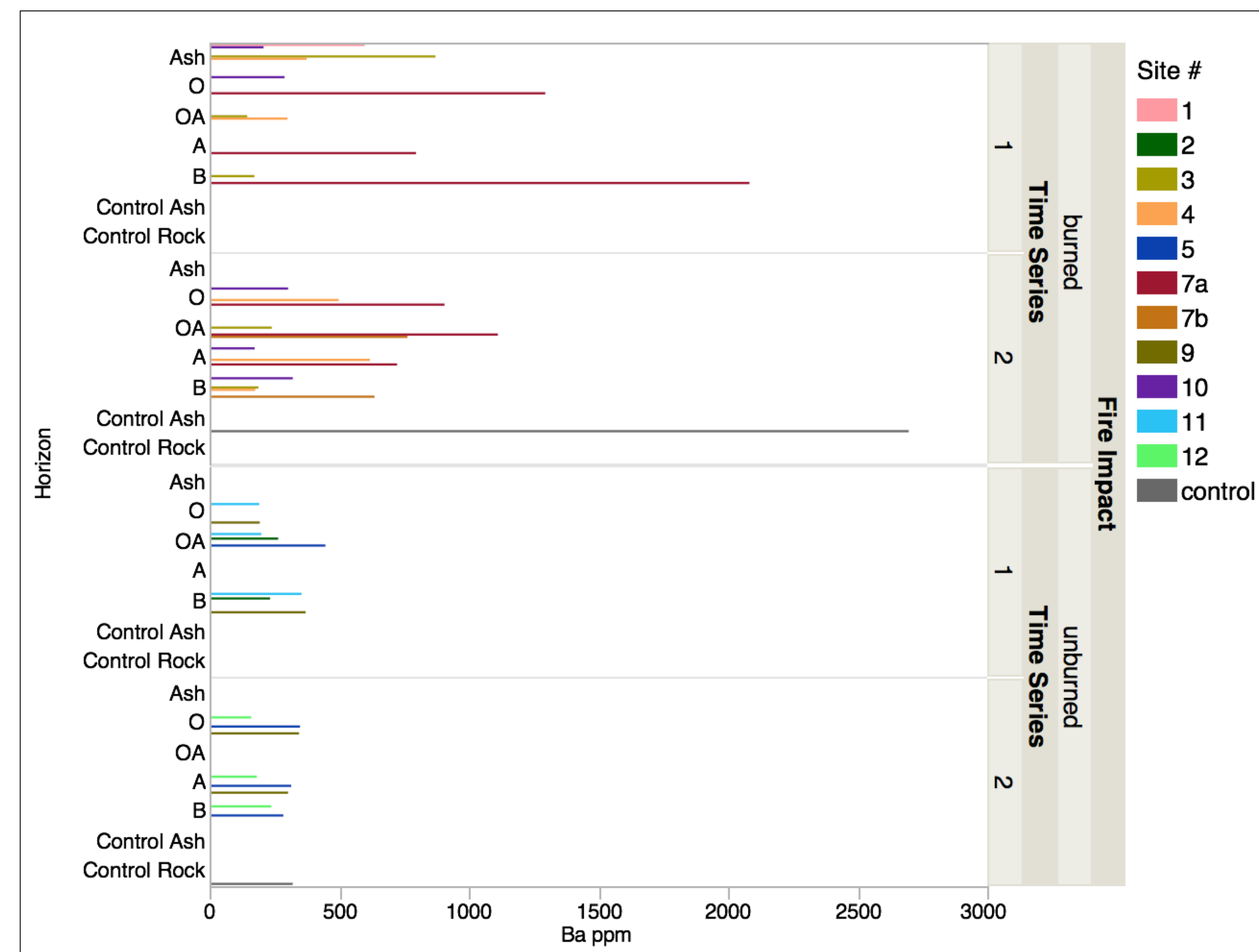


↑ Line graphs (above) show major elements comparing a burned and an unburned site. Higher concentrations and higher variability is seen in the burned samples.

← Bar graph (left) of sites comparing Cu ppm by horizon based on fire impact and time series, shortly after fire (T1) and several months after the fire (T2). "Control ash" is a sample of wood from the location later burned in the lab. "Control rock" is a sample of parent material sandstone (Catskill fmtn.) from the location.

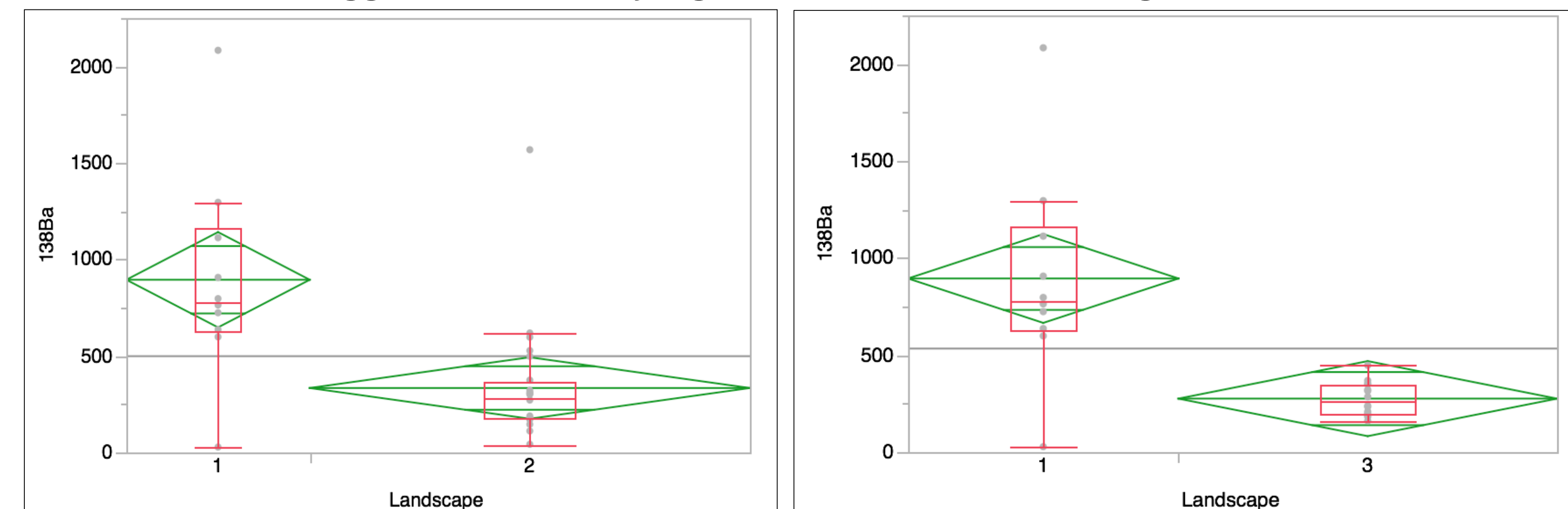
RESULTS (CONT'D)

Results from ICP-MS show variations between burned and unburned samples in the major elements calcium and manganese and within the trace elements copper and barium. Of these elements, copper and barium have higher concentrations and are considered to be fire signatures. Within the soil horizons the O and A have higher concentrations. Copper has higher concentrations in the second time interval compared to first time interval. Barium has relatively the same concentration between the two time intervals, with the highest concentration in the B horizon at site 7A. Copper and barium concentrations are higher in the burned area compared to the unburned areas.



Bar graph of sites comparing Ba ppm by horizon based on fire impact and time series. "Control ash" is a sample of wood from the location later burned in the lab. "Control rock" is a sample of parent material sandstone (Catskill fmtn.) from the location.

Terrain suggest a statistically significant influence on fire signatures in the soil.



Box chart graph of ANOVA analysis showing the difference of burned sites at low elevation near the creek (1) to unburned sites at low elevation near the creek (3) (p<0.0003).

Box chart graph of ANOVA analysis showing the difference of burned sites at high elevation near the creek (2) to unburned sites at high elevation near the creek (3) (p<0.0003).

CONCLUSIONS AND CONTINUING QUESTIONS

Most of the 16-mile fire occurred within one watershed, with tributaries including the Bushkill Creek flowing through the center of the fire. Major elements are both elevated and more variable within the fire, though many of the elements are similar to what would be in decomposing organic matter. Trace elements of Cu and Ba appear to be unique to the ash input, and are found in higher concentration (ppm) in the fire zone compared to samples above and below the fire extent. The signature appears to persist at least about a year.

Further research topics include:

- What are the dynamics of fire signatures in the soil profile?
- As ecological succession returns to this area sampling needs to be monitored to see if vegetation will sequester copper and barium. How does different burned vegetation contribute?
- Sampling should be continued at the same sites making sure the same soil horizons are collected each time interval to better monitor changes in geochemistry.
- What are impacts of terrain and microenvironment on fire signatures in soils?

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