DISTRIBUTION OF SELECTED ELEMENTS IN SOILS OF THE CONTERMINOUS UNITED STATES

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Preferred session for poster - Environmental/Applied Geochemistry (note this is intended to be a companion poster to the Cannon et al poster on mineralogy from this survey)

Introduction

In 2007, the U.S. Geological Survey initiated a low-density (1 site per 1,600 square kilometers; 4,857 sites in total) geochemical and mineralogical survey of upland soils of the conterminous United States (U.S.). Organic soils were intentionally omitted from the sampling protocol. Three soil samples were collected using hand tools from each site; (1) a sample from a depth of 0 to 5 centimeters, (2) a composite of the soil A horizon, and (3) a deep sample targeted to a depth of about 1 meter, if possible. Depending on profile development, the deep sample likely represents a soil B or C horizon, which for simplicity is referred to here as the soil C horizon. The <2-millimeter fraction of each sample was analyzed for a suite of 45 major and trace elements following near-total multi-acid digestion. The major mineralogical components in samples from the soil A and C horizons were determined by a quantitative X-ray diffraction method. Details of the survey and all data are available from Smith et al. (2013).

Maps showing predicted element and mineral concentrations were interpolated from actual soil data for each soil sample type by an inverse distance weighted (IDW) technique (Smith et al., 2014). Map patterns for selected elements are presented that illustrate varying influences on soil geochemistry across the conterminous United States. A companion presentation describes soil mineralogy from this USGS survey in detail.

Results

The map pattern for molybdenum (Mo) in the soil C horizon demonstrates the influence of parent materials of varying composition. Molybdenum in the soil C horizon has a median value of 0.83 mg/kg, and a maximum value of 94.7 mg/kg. In bedrock, Mo has low concentrations in mafic rocks and sandstone, with higher concentrations in felsic rocks and shale. Ore deposits containing Mo (and a suite of related elements including As, Bi, Cu, Sb, Sn, Te, W, and Zn) are widespread throughout the west. In

Figure 1, enriched Mo values (warm colors) in the soil C horizon is spatially related to varying soil parent materials.

Where soil parent materials contained little original Mo, soils typically have less than the median concentration of Mo (cooler colors in Figure 1). Most of these soils have high quartz concentrations, for example, soils developed on residual sandstone and/or sandy eolian deposits and glacial deposits. Other elements that have patterns similar to Mo due to an influence from a felsic or black shale component in soil parent materials include As, Be Cs, Li, Sb, Sn, U, and W.

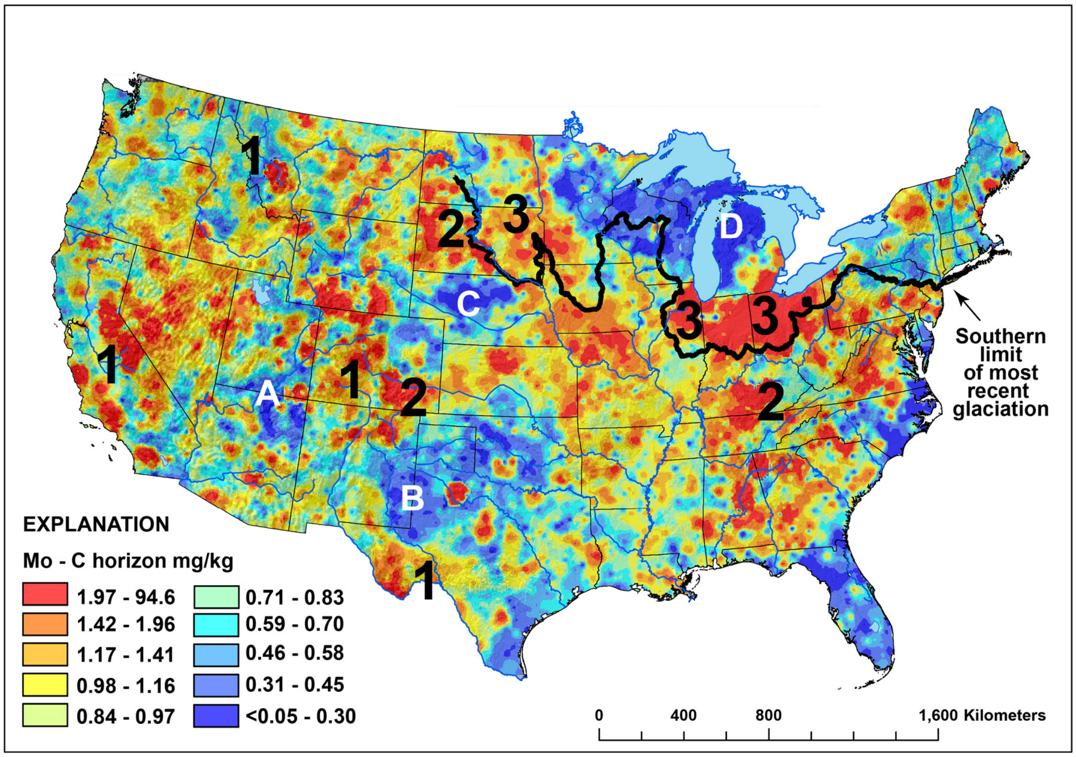

Figure 1. Molybdenum in the soil C horizon. High Mo concentrations resulting from high Mo concentrations in soil parent materials are related to 1) residual felsic rocks (locally enhanced in Mo because of mineralization), 2) residual black Devonian shale or gray Cretaceous shale, and 3) shale clasts that have been eroded and transported by glacial ice and deposited in till. Areas with low Mo concentrations include quartz-rich soils in A) the Colorado Plateau, B) the High Plains, C) the Nebraska Sand Hills, and D) sandy till and outwash plains.

The distribution of Na in the soil C horizon provides a good example of climate effects on soil chemistry across the nation (Fig. 2). Sodium-rich plagioclase, a major mineral controlling Na concentrations in soils, is a common component of many igneous and metamorphic rocks and derived unconsolidated deposits. The distribution of Na in soils from many areas closely follows the pattern for soil plagioclase concentrations in soil parent material. With time in a sufficiently humid climate, plagioclase breaks down, releasing Na which is leached out of the soil profile. In high rainfall areas such as the southeastern U.S., old weathered soils that originally contained plagioclase are highly leached and thus Na deficient. Differences in Na concentrations in soils on either side of the southern glacial limit in southern Indiana and Ohio may reflect differences between younger and older soils derived from similar parent materials. Other soluble elements that show similar patterns from the effects of weathering include Ba, Ca, K, Sr, and Rb.

In parts of Nevada and Utah, high Na concentrations are in playa soils that have only a limited plagioclase component. In these arid settings, strong capillary rise of surface groundwater creates surficial layers of soluble salts. For soils collected in playas, high Na often correlates with the occurrence of likely secondary dolomite, aragonite, or calcite.

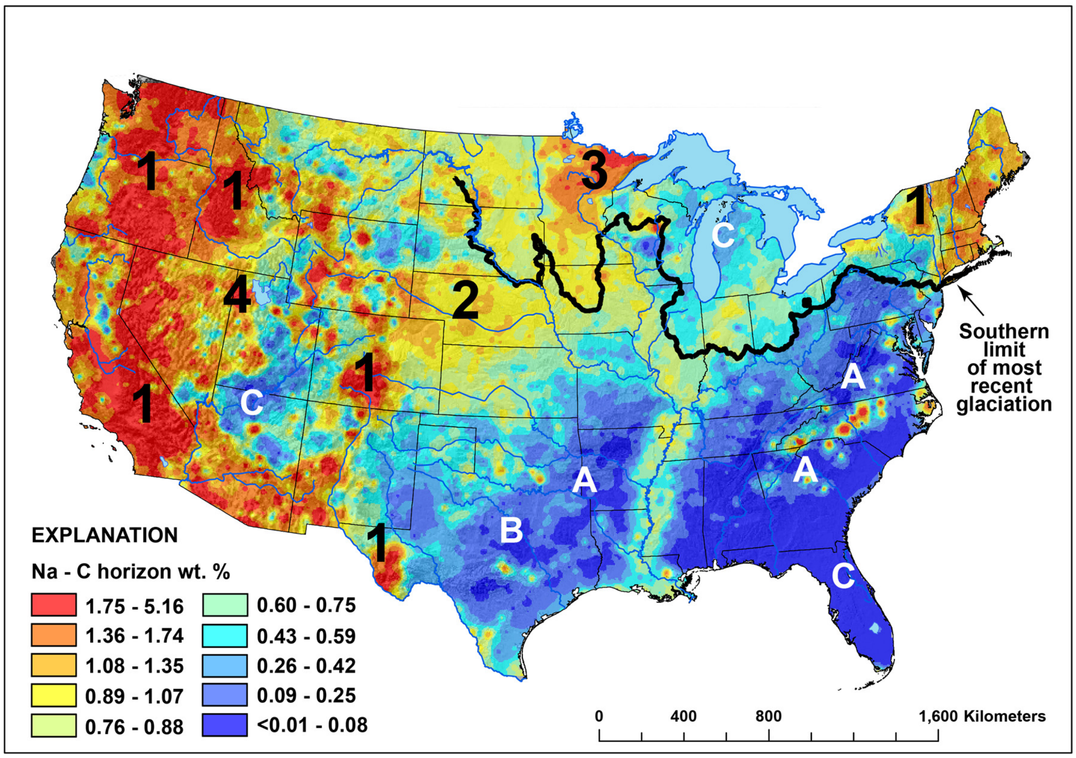

Figure 2. Sodium in the soil C horizon. High Na concentrations likely related to the presence of plagioclase in the soil parent material occur in areas dominated by 1) residual mafic and intermediate rocks, 2) plagioclase-rich eolian deposits, and 3) till with a Precambrian rock provenance. Soils developed on playa deposits (4) with little plagioclase can also have high Na concentrations. Areas with very low Na concentrations include highly weathered soils where plagioclase has dissolved and Na has leached from the soil profile (A), calcareous soils (B), and quartz-rich soils (C).

Soils are essential for human existence, and humans have repaid the favor by manipulating the natural condition of soil. Much of this manipulation has come through tillage and the need to stimulate plant growth through the addition of supplemental essential plant nutrients. Phosphorus is one of these important essential nutrients.

Because of soil deficiencies, P-rich animal manures and mined rock phosphate converted to phosphate fertilizer have been widely applied to many agricultural fields. Possible anthropogenic loading for P to soils is evaluated by comparing P concentrations in the soil A horizon to P concentrations in deeper soils (soil C horizon) (Fig. 3).

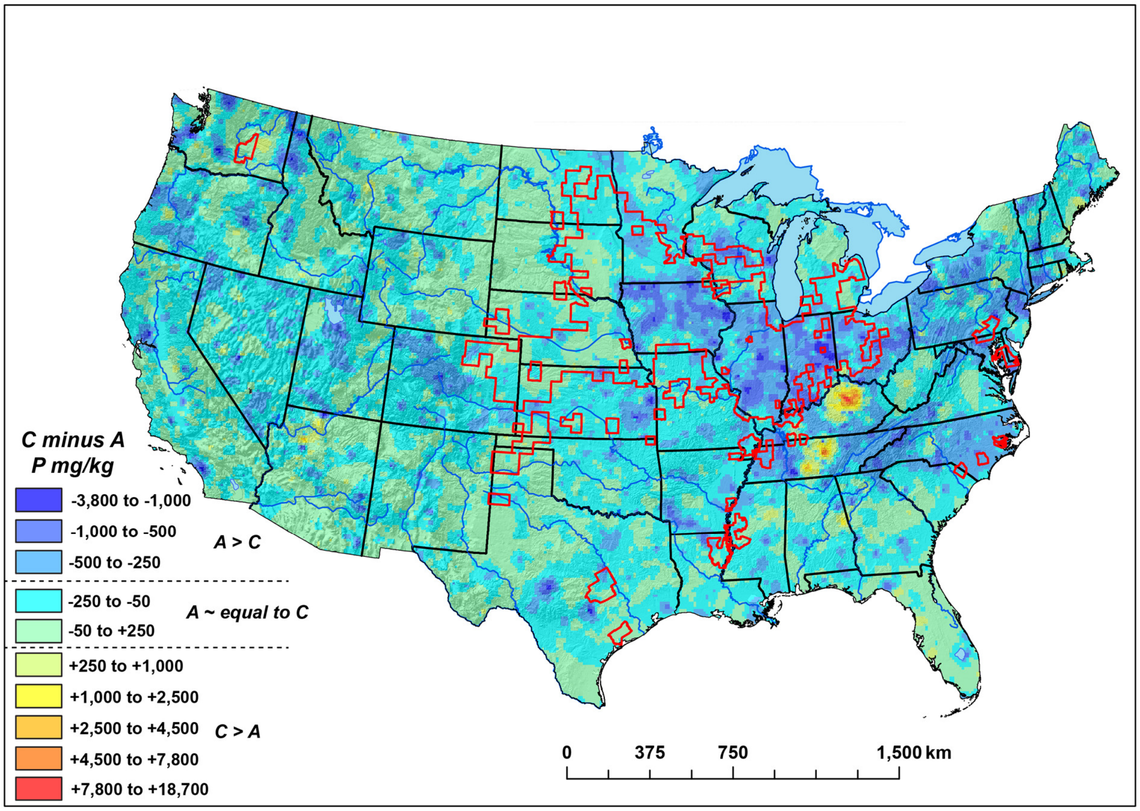

Figure 3. Phosphorus in the soil C horizon *minus* P in the soil A horizon. Corn production greater than 15 million bushels per county is designated by red outlined areas (2010 statistics; U.S. Department of Agriculture, National Agricultural Statistics Service). Soils naturally high in P because of phosphatic soil parent materials (yellow to red) contrast with soils that have enriched P in top soils compared to deeper soils (blues).

In Figure 3, concentrations of P in the soil A horizon have been subtracted from concentrations of P in the soil C horizon. Warmer colors indicate that deeper soils are enriched in P compared to surface soils, and cooler colors indicate surface soil P enrichment. Soils in central Kentucky and Tennessee that developed on residual phosphatic limestone have the highest soil C horizon concentrations found in this survey (yellow-red areas; Fig. 3), whereas agricultural soils across the Upper Midwest have about a two-fold higher concentration of P in the soil A horizon compared to deeper soils. These higher concentrations of P in surface soils correspond roughly to an area called the ‘Corn Belt’ (red outlined area, Fig. 3). This surface enrichment may be attributed to inputs of phosphorus fertilizer or animal manure. Soil texture also may have a role in P retention as agricultural soils tend to be more clay-rich than nonagricultural soils. Thus, the distribution of P in soils across the conterminous United States is dependent on the original P concentration of the soil parent material, P transformations and movement during soil formation (weathering and leaching), and likely human activities**.**

Summary

This new data array provides a three-dimensional framework of soil geochemistry and mineralogy. Spatial differences in geochemistry and mineralogy at continental and regional scales can be tied to distinctive soil parent materials modified by climate-related processes such as weathering and glaciation. Element distributions among the three soil samples from each site reveal human influences superimposed on natural soil background concentrations. This new data set represents a major step forward from prior national-scale soil geochemistry data and, along with a soil archive of all samples, provides a robust soil data framework for the United States now and into the future.

References

SMITH, David B., CANNON, William, F., WOODRUFF Laurel G., SOLANO, Federico, KILBURN, J.E. & FEY, D.L. 2013. Geochemical and mineralogical data for soils of the conterminous Untied States. U.S. Geological Survey Data Series 801, 19 p. [http://pubs.usgs.gov/ds/801/]

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