Regional-scale soil geochemistry in northern California: Natural and anthropogenic sources of soil constituents

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The U.S. Geological Survey's (USGS) Geochemical Landscapes project, which has as its long-term goal a soil geochemical survey of North America, is presently in a pilot study phase. One pilot study is being conducted along a latitudinal transect in California from Marin County north of San Francisco to the Nevada border. In addition to assessing sampling and analytical methodologies for the larger-scale North American survey, the goals of this pilot study are to evaluate geologic and anthropogenic controls on soil geochemistry, determine the bioaccessibility of elements in the soil through selective leach studies, and characterize the role of soils in determining shallow groundwater chemistry.

In support of these goals, we have chemically analyzed nearly 2,000 archived soil samples including 1,300 shallow (0-30 cm) soils collected in 1980 during the National Uranium Resource Evaluation (NURE) Program from El Dorado, Placer, Sutter, Sacramento, Yolo, and Solano Counties. The NURE samples are supplemented by 100 soil profiles from across the entire transect. Comparison of the NURE soil geochemical results with independently determined K, U, and Th data from an aeroradiometric survey shows close agreement, providing confirmation that the NURE soil chemistry data is representative of surface soil chemistry.

Several elements of environmental concern including Cr, Ni, As, and Pb, occur at elevated concentration in the NURE samples. The geometric mean for Cr and Ni in soils of the conterminous U.S. is 37 and 13 ppm, respectively, whereas surface soil samples from the foothills of the Sierra Nevada Mountains have elevated Cr (400-6,000 ppm) and Ni (500-5,000 ppm) contents. These high concentrations are spatially correlated with outcrops of ultramafic (UM) rocks. In addition, Cr (100-300 ppm) and Ni (100-500 ppm) concentrations are also high in the Sacramento Valley, west of the Sacramento River, suggesting the transport of these elements from a source to the west.

We hypothesize that Cr and Ni in soils immediately overlying UM rocks may be transformed to a more bioaccessible form as alluvium is weathered and transported from the UM source rocks to the valley. Data from simulated human gastric fluid extractions suggest that Cr and Ni in weathered alluvial soils of the Sacramento Valley are nearly two times more leachable than in soils found near the UM belts. Likewise, Cr and Ni from alluvial soil are proportionately more soluble in a serum-based cell line extraction fluid (a complex organic mixture that may mimic element release during long-term particle exposure to bodily fluids) than in samples from UM belts.

Shallow groundwater data from the Sacramento Valley indicate higher Cr content in groundwater on the western side of the valley compared to the eastern side and the foothills ultramafic belt; a result that may also reflect the increase in bioaccessibility of Cr in alluvial soils. Chromium exists in two oxidation states; Cr(VI), which is soluble, highly toxic and a known carcinogen, and Cr(III), which is relatively insoluble and less toxic. We are presently determining the speciation of Cr(III) and Cr(VI) in soils with high Cr content.

The abundance of the ultramafic suite of elements is controlled by geologic and sedimentologic processes. In contrast, data show elevated Pb concentrations (up to 2,300 ppm) in the soils surrounding urban areas, while non-urban areas are similar to the U.S. geometric mean (16 ppm). Simulated gastric fluid leach data show that Pb in urban areas is up to 80% leachable, relative to about 40% in the less-developed valley and mountainous regions, suggesting that elevated Pb in urban areas is highly bioaccessible. Elevated As content in soil (up to 80 ppm) is spatially associated with the Mother Lode gold belt in the foothills of the Sierra Nevada Mountains. We hypothesize that this As enrichment is partially due to natural weathering of As-rich pyrite (FeS_2) associated with gold ores and partially due to disturbance of these materials by mining activities.