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Geochemical Studies of North American Soils: Results from the Pilot Study Phase of the North American Soil Geochemical Landscapes Project

A regional-scale study of chromium and nickel in soils of northern California, USA

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Abstract

A soil geochemical survey was conducted in a 27,000-km^2 study area of northern California that includes the Sierra Nevada Mountains, the Sacramento Valley, and the northern Coast Range. The results show that soil geochemistry in the Sacramento Valley is controlled primarily by the transport and weathering of parent material from the Coast Range to the west and the Sierra Nevada to the east. Chemically and mineralogically distinctive ultramafic (UM) rocks (e.g. serpentinite) outcrop extensively in the Coast Range and Sierra Nevada. These rocks and the soils derived from them have elevated concentrations of Cr and Ni. Surface soil samples derived from UM rocks of the Sierra Nevada and Coast Range contain 1700–10,000 mg/kg Cr and 1300–3900 mg/kg Ni. Valley soils west of the Sacramento River contain 80–1420 mg/kg Cr and 65–224 mg/kg Ni, reflecting significant contributions from UM sources in the Coast Range. Valley soils on the east side contain 30–370 mg/kg Cr and 16–110 mg/kg Ni. Lower Cr and Ni concentrations on the east side of the valley are the result of greater dilution by granitic sources of the Sierra Nevada.

Chromium occurs naturally in the Cr(III) and Cr(VI) oxidation states. Trivalent Cr is a non-toxic micronutrient, but Cr(VI) is a highly soluble toxin and carcinogen. X-ray diffraction and scanning electron microscopy of soils with an UM parent show Cr primarily occurs within chromite and other mixed-composition spinels (Al, Mg, Fe, Cr). Chromite contains Cr(III) and is highly refractory with respect to weathering. Comparison of a 4-acid digestion (HNO_3, HCl, HF, $HClO_4$), which only partially dissolves chromite, and total digestion by lithium metaborate ($LiBO_3$) fusion, indicates a lower proportion of chromite-bound Cr in valley soils relative to UM source soils. Groundwater on the west side of the Sacramento Valley has particularly high concentrations of dissolved Cr ranging up to 50 μg L^{-1} and averaging

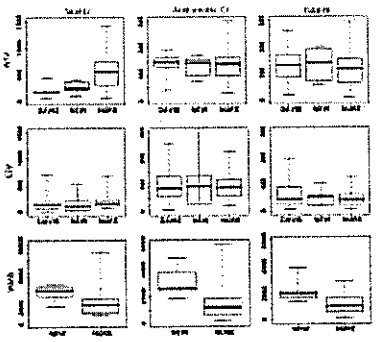

Fig. 3. Box plots showing statistical analysis of concentrations of total Cr, acid-soluble Cr, and total Ni between datasets (Davis, New and NURE) in each region (WSV, ESV and WMB). All concentrations are in units of mg/kg. Vertical lines show the range in concentrations, the boxes are bounded by the 25th and 75th percentile values, and the bold line represents the median value.

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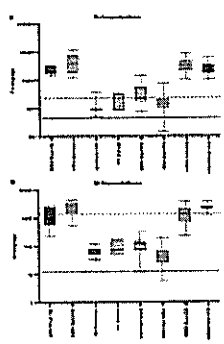

Fig. 4. Box plots showing (a) Cr and (b) Ni concentrations in rocks and soils grouped by location. Abbreviations on the *x*-axis are (from left); CRO – ultramafic rocks and soils associated with the Coast Range Ophiolite, GV – rocks and soils associated with the Great Valley Sequence in the Coast Range, WSV – soils that are located west of the Sacramento River and spatially located within Quaternary alluvium units, ESV – soils that are located east of the Sacramento River that are located within the mapped Quaternary alluvium, WMB – soils and rocks that are associated with the Western Metamorphic Belt located in the western foothills of the Sierra Nevada. Values in parentheses indicate the number of samples within each group. The solid horizontal lines are the geometric mean for Cr (37 mg/kg) and Ni (13 mg/kg) in soils in the conterminous US (Shacklette and Boerngen, 1984) and the dashed horizontal lines are the EPA human health soil screening levels for Cr (210 mg/kg) and Ni (1600 mg/kg) (USEPA, 2007).

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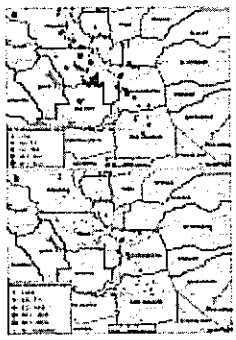

Fig. 8. Maps showing the study area including county boundaries, lakes and rivers. The graduated symbols show the location of groundwater samples with size indicating (a) Cr concentrations in μg/L and (b) Ni concentrations in μg L^{-1}. Triangles in (b) represent samples that were below the detection limit for Ni.

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Table 1. Statistical summary of rock and soil data by dataset for: Coast Range Ophiolite (CRO), Great Valley Sequence (GV), western Sacramento Valley (WSV), Eastern Sacramento Valley (ESV), and the western metamorphic belt (WMB). Datasets include: the NURE archive, the University of California, Davis archive, and newly-collected samples. The mean values were calculated as arithmetic means and Std Dev represents the standard deviation of the mean. Rows in bold lettering show the data used to classify groups presented in Fig. 4 and Fig. 7.

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