The impact of humans on the geochemical landscape

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Vladimir Vernadsky, a pioneer of geochemistry, recognized as long ago as 1945 that “Man under our eyes, is becoming a mighty and ever-growing geological force”. Earth scientists are now documenting the accelerating influence of humans on the planet. A striking example is that continental sediment transport driven by agriculture and urbanization now dominates natural processes by an order of magnitude. Soil erosion in the continental US has been profoundly affected by cultivation over a relatively short period of settlement. Erosion yields in many areas are now exceeding 20 Mg/ha/y. We are only just beginning to appreciate the global implications of the loss of undisturbed soils and ecosystems on element cycling and biological sustainability.

Earth surface processes are in part reflected in what A.I. Perel’man called the geochemical landscape – a term that embodies the interactions of the lithosphere with the hydrosphere, atmosphere and biosphere. The mining and burning of coal provides a conspicuous example of the extensive geochemical landscape modification by humans. The Appalachian coal basin spans nearly the entire eastern US and its coal is locally quite rich in Hg and As. Continental scale geochemical data sets show that As in both stream sediment and soil throughout the coal producing region is 5-10 times higher than in adjacent areas. Atmospheric deposition of Hg originating from coal combustion, has resulted in advisories against fish consumption in over 30% of US lakes. Atmospheric Hg transport is now recognized as a global issue.

The Central Valley of California is another region characterized by extensive modification during human habitation. Originally an inland sea, the northern valley is now totally transformed by dikes and levees to sustain agriculture and urbanization. An extensive geochemical survey of the valley shows that both Hg and placer Au mining on the east and west sides of the valley and massive sulfide mining to the north have significantly altered the geochemical landscape. of valley soil. These geochemical impacts can be traced down the Sacramento River and into the San Francisco Bay.

As a famous naturalist, Aldo Leopold said, “The reaction of land to occupancy determines the nature and duration of civilization”. We need to heed his admonition.

Geochemical landscape studies of geogenic trace elements in Northern California, USA

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The Sacramento Valley of northern California receives sediment from three bordering mountain ranges: Sierra Nevada (east), Coast Ranges (west), and Klamath Mountains (north). The weathering and transport of sediment from these source areas into the Sacramento Valley results in distinct spatial patterns of geogenic trace elements as revealed by detailed geochemical mapping. Mining of massive sulfide deposits in the Klamath Mountains to the north has resulted in elevated contents of Zn, Cd, As, and Cu in soil adjacent to the Sacramento River. Serpentinized ultramafic rocks and associated soils in the Coast Ranges and Sierra Nevada have elevated concentrations of Cr from 1700 to 10,000 mg/kg. Fluvial transport of Cr has resulted in elevated Cr concentrations in valley soil (37-1420 mg/kg) relative to the continental average value (37 mg/kg). Eastern valley soil Cr content has been diluted by voluminous input of low Cr sediment from placer mining. Historic Hg mining in the Coast Range accelerated weathering of Hg-mineralized serpentinite, resulting in elevated concentrations of Hg (up to 0.9 mg/kg) in western valley soils.

Chromium is a human health concern because of its potential toxicity. Cr(III) that dominates natural sources is non-toxic and essentially immobile at circumneutral pH, whereas Cr(VI) is highly soluble and potentially toxic. In source and alluvial soils, chromite ($[Mg,Fe^{2+}][Cr^{3+},Al,Fe^{3+}]_2O_4$), a refractory spinel, is the primary source of Cr(III), but some oxidation of Cr is suggested by elevated Cr concentrations up to 50 □g/L in some valley ground waters. In an effort to understand the variables controlling the oxidation of geogenic Cr in the valley, we are applying chemical extraction techniques, scanning electron microscopy, magnetic susceptibility measurements, and microbial soil incubations to the study of several cores of valley soil (up to 30 m depth). This core material contains up to 2200 mg/kg total Cr. Although the soil has a relatively high Cr(III) oxidation potential (up to 26 mg/kg) attributed to abundant Mn oxides, only a minute fraction of total Cr is present *in situ* as Cr(VI) (up to 42 □g/kg). Our results indicate that pathways for the oxidation of geogenic Cr exist in Sacramento Valley soils and may be enhanced by certain agricultural land uses.