A dust-soil-groundwater-dust cycle, Southwestern United States

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Dust inputs to arid southwestern U. S landscapes strongly influence soil particle size, which affects infiltration rates in the unsaturated zone, as well as soil chemical composition, which may affect groundwater chemistry. Our recent work demonstrates the active role that wet playas (depth to groundwater <10 m) play in dust emissions. Long-term monitoring (20 years) in the eastern Mojave and southern Great Basin reveals cyclic fluctuations in deposited dust that are controlled in part by the amount and seasonal distribution of rainfall and by the behaviour of different source types (wet playas, dry playas, and alluvium).

Deposition rates (fluxes) of silt-and clay-sized dust vary annually from about 2 to 20 $g/m^2/yr$. Sites throughout the study area respond to ENSO-related precipitation cycles; peaks in dust flux occur during consecutive dry years and also during very wet years. However, soluble-salt flux (~0.8 to 2.0 $g/m^2/yr$) increases only during periods of high winter-dominated rainfall that are preceded and accompanied by strong summer rains. A major control on dust emissions is the hydrologic condition of surface sediments. The silt-clay and soluble-salt fluxes increase during wet years at sites close to wet playas, whereas only silt-clay flux increases during drought periods at sites downwind of alluvial sources and "dry" playas with deeper groundwater (>10 m)

The presence of ground water just below playa surfaces (wet playas) creates efflorescent-salt rich, fluffy sediment that easily becomes airborne with gentle winds. As long as the water table remains below, but near, the playa surface, efflorescent salt production mixes with silt and clay to produce large quantities of dust. This process also enriches dissolved metal concentrations well above that found in the groundwater because huge quantities of ground water are continuously lost to evaporation. Trace metals such as As, U, Sb, and Li (As and U largely from salts, Sb and Li largely from silicates) are commonly enriched in both surface samples and dusts derived wet playas we have examined, including Owens (dry) Lake, Soda Lake, and Franklin playa, Calif. Soluble anion contents of dust samples fluctuate over three orders of magnitude (Cl and NO_3: 10^0-10^2 ppm, SO_4: 10^2-10^4 ppm). Seasonal (6-month) deposition rates of these anions suggest that dust inputs may be a significant source of solutes (Cl and NO_3: 10^{-2}-10^1 g/ha, SO_4: 10^{-1}-10^2 g/ha).

Solute sources in a tropical granitoid watershed, Luquillo, Puerto Rico

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Weathering reactions in soil, saprolite, and bedrock impart distinct signatures, which can be used to determine sources of solutes in natural waters. We are studying weathering and water flowpaths in the Rio Icacos watershed in the Luquillo Mountains, Puerto Rico, a USGS WEBB research site. Thick saprolites (up to 8 meters) are developed on early Eocene quartz diorite bedrock. Primary bedrock minerals (plagioclase, quartz, hornblende, biotite) weather at disparate rates and have widely differing Ge/Si and Sr isotope ratios. For example, plagioclase has Ge/Si=1.5 (µmol/mol) and $^{87}Sr/^{86}Sr$=0.7042 and is rapidly converted to kaolinite at the sharp bedrock/saprolite interface. In contrast, biotite, which survives the bedrock/saprolite interface, has Ge/Si= 6.1 (µmol/mol) and $^{87}Sr/^{86}Sr$=0.7827, and weathers more slowly within saprolite and the thin (~50 cm) overlying ultisol.

Ridgetop soil and saprolite pore waters, sampled by suction lysimeters installed at depths between 15 and 750 cm, show compositional differences that vary as a function of depth, reflecting predominant weathering reactions. Pore waters at depths approaching the bedrock/saprolite interface have low Ge/Si ratios (1.0-1.4) and $^{87}Sr/^{86}Sr$ (0.7052-0.7063), largely reflecting dissolution of plagioclase. Shallower pore waters have higher Ge/Si (2.3 – 4.0 µmol/mol) and increasingly radiogenic $^{87}Sr/^{86}Sr$ (up to 0.712), reflecting dissolution of biotite and secondary (Ge-enriched) kaolinite.

Stream water compositions in the Rio Icacos vary as a function of flow regime. At baseflow, which we interpret to reflect groundwater discharge to streams, stream compositions are similar to the deepest saprolite pore waters. During storm events, stream water Ge/Si increases with discharge to a maximum of about 2.2 µmol/mol, reflecting contributions of soil and saprolite water pushed out of pore spaces by infiltrating precipitation. A hydrograph separation model based on Ge/Si and [Si] suggests that stormflow is dominated by the soil water component, with groundwater contributing <10% of water flux at peak stormflow. We are currently testing these ideas with analyses of oxygen isotopes to constrain water sources, and U-series disequilibrium isotopes as an additional solute tracer.