Investigating the CIA (Chemical Index of Alteration): Why parents matter

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Using soil chemistry to infer past climates assumes that a soil profile approaches a steady state chemical condition that reflects Mean Annual Precipitation (MAP) and Mean Annual Temperature (MAT). The "CIA-K" index ratios moles of $MgO+CaO+Na_2O$ (but not K_2O: hence "-K") to Al_2O_3 to infer MAP. The "S" index ratios Na_2O+K_2O to Al_2O_3 to infer MAT. Here we show that common sources of soil parent material give reasonable values of MAP and MAT; thus, it is difficult to ascertain geochemically whether soils attain a steady state in the context of a prevailing climate. In addition, controlling for a common parent, CIA-K and S do not correlate accurately with known MAP and MAT.

We applied the CIA-K and S indices to estimate apparent MAP and MAT [1] using characteristic whole-rock and sediment compositions from the literature. Such estimates are fictive because they do not represent soils, rather parent materials from which soils might be derived. Results of these calculations for MAP and MAT include: basalt (750 mm, 10 °C), granite (850 mm, 6 °C), North American Shale Composite (1000 mm, 11 °C), the crust (700 mm, 10 °C), dust (850 mm, 9°C), and river sediment (700-1500 mm, 6-16 °C). Such values, especially for MAP, are within the range of typical paleoclimate reconstructions.

Holocene sites bordering the Mississippi River further test accuracy of the CIA and S indices because these soils all have a likely common sediment source and duration of formation (c. 10kyr), but climate varies systematically from south (MAP = 1500 mm; MAT = 19 °C) to north (750 mm; 8 °C). B-horizon compositions imply virtually no variation in apparent MAT (11 to 10.5 °C), and only small changes in apparent MAP (1250 to 1000 mm).

A likely source of error in CIA-K and S is that they are not based on a mechanistic model of soil formation. A steady state soil transfers material from the parent source to the surface at a constant rate that balances soil production from parent material against removal of top layers. Different rates of soil removal will affect how material is chemically altered throughout the soil profile. And, while climate may influence soil chemistry, so, too will *in situ* and exogenous sources of sediment, erosion rates, downslope sediment transfer, etc., that may additionally preclude attainment of a steady state.

[1] Sheldon et al. (2002) *J Geol*, **110**, 687-696