Iron in soils of a marine terrace chronosequence: the development of structured heterogeneity

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Quantifying the biogeochemical evolution of soils during pedogensis is an important step towards the understanding of the mechanistic processes involved in soil development. Soils of marine terraces near Santa Cruz, CA exhibit primary mineral weathering and increasing Fe concentration over time, with soil ages ranging from 60ka to 225ka. The oldest soils exhibit prominent reticulate mottling in the B-horizon with striking color segregations, here designated as gray, orange and white. Mottling is characterized by self-organized heterogeneity on a centimeter to decimeter scale. Unlike redoximorphic mottles, which form in carbon-rich oxygen-poor low-lying soils, the carbon-poor Santa Cruz terrace soils are well oxygenated during most of the year—although perched water tables do form during the (Mediterranean climate) rainy season. The goal of this study is to deduce a mechanistic model of mottle formation.

Differences in the physical and chemical characteristics between the various mottle zones, identified by colors, are indicative of the processes through which the self-organizing structures have formed. Separates of mottles by color have measurable differences in particle size, carbon content, Fe isotopes, specific surface area, and X-ray diffraction mineralogy. White and orange mottles are silty-sand in grain size, whereas the gray mottles have a high clay content, which accounts for the high surface area. The average Fe concentrations of the mottles are: gray 0.63%, white 1.22%, and orange 4.74%. The average C contents are gray 0.21%, white 0.08%, and orange 0.10%. Higher C content in the gray mottles is suggestive of more root and fungal activity in the gray mottles. The XRD data are consistent with the gray zone being highly weathered with fewer primary minerals. We hypothesize that development of mottling in these soils is the result of long term rhizogenic reactions. Root and fungal exuded organic acids reduce pH, mobilize Fe and other metals through organo-metal complexation, and begin a cascade of microbial and chemical reactions which over time results in morphological heterogeneity.