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The Latitudinal Gradient of Rainfall, Mineralogy, Albedo and Magnetic Susceptibility in West Africa

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Abstract

In order to investigate the effect of climate on soil and surface sediment properties we examined four transects around the Sahara Desert. The transects were located in Mali, Niger, Benin, Togo, Egypt and Morocco and, with the exception of Egypt, each crossed a significant climatological rainfall gradient. The Egyptian transect was designed to characterize one of the driest portions of the Sahara Desert. Our study included laboratory measurements of mineralogy (XRD), elemental composition (XRF), grain size, optical reflectance (lab), magnetic susceptibility (MS)and remanences. In addition, albedo was determined from

the MODIS satellite imagery from space. Many of our laboratory measurements exhibited variations with the rainfall gradient. Iron oxides (hematite and goethite), kaolinite, Al2O3, and TiO2 increased with increasing rainfall whereas SiO2, illite, and grain size decreased with increasing rainfall. Both laboratory-determined reflectivity and satellite-determine albedo decreased as rainfall increased. In part, this decrease in reflectivity/albedo with increasing rainfall appears to be the result of hematite, the dominant coloring agent for the soil in this region and the origin of the 'red' Sahel. The physical interpretation of these results centers on rainfall as a long-term leaching agent of surface material, and the control of physical properties by specific mineralogy. SiO2 is highly reflective and iron oxides are strongly absorptive in the visible range. The solubility of SiO2 in rainwater is orders of magnitude larger than all the iron oxides, with hematite the least soluble. It has long been recognized that leaching by rainfall produces dark red laterite in the near-surface oxidizing environment, a prominent geological feature throughout the high rainfall belt of West Africa. Laterite beds represent simultaneous enrichments of all iron oxides and a reduction in SiO2 by leaching. In the Sahara desert where rainfall is minimal (<10 mm/yr), SiO2 is concentrated, and in conjunction with eolian surface abrasion, produces the highest reflectivity/albedo values in Africa. MS and ferrimagnetic mineral concentrations also increase with increasing rainfall and, of all the laboratory analyses, exhibits the highest correlation to rainfall. The alternating wetting and drying conditions - tropical wet dry climate of the Sahel and the Mediterranean climate of Morocco – enhance the production of secondary ferrimagnetic oxides