Intensifying weathering and land-use in Iron Age Central Africa

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A major vegetation change occurred in Central Africa during the third millennium before present, when mature evergreen trees were abruptly replaced by savannas and secondary grasslands [1-3]. The consensus is that the forest disturbance was caused by a regional climate change [1-3]. However, this episode of forest clearance occurred contemporaneously with the migration of Bantu-speaking peoples from near the modern Nigeria-Cameroon border [4-7]. The so-called Bantu expansion led to diffusion of agriculture and iron smelting technology across Central Africa, with potential impacts on the environment [10]. Whether the Bantu farmers played an active role in the Central African deforestation event remains an open question.

Here we present major element (Al/K ratios) and radiogenic isotope (Nd, Hf) records from a marine sediment core recovered in the Gulf of Guinea, that permit the reconstruction of chemical weathering intensity in Central Africa for about the last 40,000 years. The data indicate a pulse of intensified weathering centered around 2,500 years ago, contemporaneous with the rainforest crisis. Evidence that this weathering event departs significantly from the long-term weathering fluctuations related to the Late Quaternary climate suggests that it was not triggered by natural climatic factors solely. Instead, we propose that the settlement of Bantu-speaking farmers in Central Africa at that time had a more pronounced environmental impact than initially thought.

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Rock micro-structure controls regolith thickness

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As feldspar transforms to clay, a zone of residual weathered material, regolith, forms on ridges of diabase and granite in the Piedmont Province, Virginia. In spite of similar erosion rates and the fact that Ca-rich plagioclase in diabase is expected to dissolve 10x faster, weathering has advanced 20x deeper into the granite compared to the diabase. This result runs counter to conventional wisdom that would predict a deeper weathering profile on the diabase. We explained this enigma by studying the nano- to micro-structural features of these two rocks in plagioclase reaction zone. Nano-pores (1 nm < d < ~5 μm) and micro-pores (> 3 μm) were studied by neutron scattering (NS) and micro-computed tomography (μ-CT), respectively. We found that granite has a larger connected micron-sized pore network than diabase as well as abundant micro-fractures around oxidizing biotite. In contrast, the plagioclase reaction zone in diabase has some regions of low porosity due to smectite and calcite precipitation. Therefore, we concluded that the regolith is 20x thinner on diabase because it supports only minimal fluid advection, while advective transport in granite is significant.

We explored this hypothesis with numerical modelling of plagioclase dissolution in diabase and granite. For diabase, the diffusion-only model yields shallow regolith with a thin reaction front -- as observed in the field. However, we could not model a deeper and thicker reaction front in granite with diffusion only. With advection in the numerical model, the reaction front in granite is wide and the regolith is deep, as observed.

Our results show that the difference in regolith thicknesses in the Piedmont is largely explained by different regimes of reactive fluid transport. Minimal advection creates shallow regolith and a thin reaction front in the more massive diabase. In contrast, significant advection occurred in the relatively fractured granite, producing deep regolith and a thick reaction front. At the grain-scale, infiltration of advecting fluid is controlled by texture (e.g., grain size distribution, porosity) and reaction-induced permeability. The parent lithology is an important factor in this latter permeability because oxidation of biotite at depth apparently accelerated pervasive fluid infiltration into the granite. If micro-structure is important in controlling the factor of 20x, then it is possible that felsic rocks such as granites generally develop thicker regolith profiles than diabase, regardless of age or location, under comparable geomorphological regimes. Such observations may help predict and explain regolith thickness in localities in many places around the globe.

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