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Sedimentological features of lateritic and saprolitic horizons in a mid-slope lavaka, Central Highlands, Madagascar

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Madagascar is characterized by a world-record erosion rate, especially in the Central Highlands and the vicinity of Lake Alaotra. As a consequence of the high erosion rate several specific erosional landforms develop in the area. Among them an inverted teardrop-shaped geomorphic feature, the lavaka, meaning 'hole' in Malagasy, is very typical in the hilly landscape. These unique features are widespread in Madagascar though somewhat similar patterns can also be found in Congo, South Africa and Brazil. In these areas, material from the lavakas is washed down from the hillsides into the streams and rivers after every heavy rain (1500-1800 mm/yr). The high sediment load from the eroded lavakas can damage the infrastructure (collapses roads, bridges and buildings) and may destroy agricultural land (swamp fields).

The distribution of lavakas is very diverse: despite the same climatologic, geological environment and anthropogenic effects a large difference in density of lavakas can be observed. For this reason it cannot be fully constrained how lavakas form and develop. Their formation is affected by natural factors (hydrological and climatic effects, geology, tectonics, vegetation, etc.) and also by anthropogenic influences (deforestation, grassland burning, overgrazing).

The basic condition for the formation of lavakas often includes the petrographic characteristics of the area. Lavaka-generating substrates can be separated into two main weathered units: thin upper laterite (less than one meter) and thicker deeper saprolite (several tens of meters) on the crystalline basement.

This study focuses on a mid-slope lavaka, in the area of Tsiafahy, in Madagascar's Central Highlands. To ascertain the composition of the material and to evaluate the hydraulic conductivity of the lateritic and saprolitic profile on precambrian magmatic basement, we investigated the grain size distribution and mineral composition of an active lavaka.

Our results show the significance of water on slope stability. The calculated hydraulic conductivity values from laterite indicate (at least one order of magnitude) higher value than in the saprolite, but each layer have very low hydraulic conductivity. In the saprolite can be also identified two separated horizons. The difference between laterite and saprolite are reflected also in the mineralogical compositions, primarily through the presence of gibbsite in the lateritic profile. In the total profile quartz and kaolinite are predominant. The observed features can be interpreted as an indication for ferrallitization which generates a deep weathered ferralsol zone.

The preferable leakage in the saprolite is enhanced by the higher modal abundance of the coarser grains relative to the laterite. The coarser grains are cemented by kaolinite, iron-oxihidroxide and calcite. These minerals are dominant in the fine-grained fraction which may be easily mobilized by water causing high erodibility that facilitates headward erosion of deeper saprolitic horizon.

Due to its low hydraulic conductivity the penetration of the rainfall through the laterite is a slow process. Thus, the top layer protects the lower strata from erosional removal; however, presence of cracks in the lateritic horizon may speed up the removal of the top layer paving the way to reach the lower, more erodible saprolite.