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Neogene cratonic erosion fluxes and landform evolution processes from regional regolith mapping (Burkina Faso, West Africa)

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ABSTRACT

The regionally correlated and dated regolith–paleolandform sequence of Sub-Saharan West Africa offers a unique opportunity to constrain continental-scale regolith dynamics as the key part of the sediment routing system. In this study, a regolith mapping protocol is developed and applied at the scale of Southwestern Burkina Faso. Mapping combines field survey and remote sensing data to reconstruct the topography of the last pediplain that formed over West Africa in the Early and Mid-Miocene (24–11 Ma). The nature and preservation pattern of the pediplain are controlled by the spatial variation of bedrock lithology and are partitioned among large drainage basins. Quantification of pediplain dissection and drainage growth allows definition of a cratonic background denudation rate of 2 m/My and a minimum characteristic timescale of 20 Ma for shield resurfacing. These results may be used to simulate minimum export fluxes of drainage basins of constrained size over geological timescales. Background cratonic denudation results in a clastic export flux of ~4 t/km^2/year, which is limited by low denudation efficiency of slope processes and correlatively high regolith storage capacity of tropical shields. These salient characteristics of shields' surface dynamics would tend to smooth the riverine export fluxes of shields through geological time.

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1. Introduction

Interactions between landform evolution and regolith production and mobility over shields exert first-order controls on the source, pathways and fluxes of sediments and solutes over very large emerged surfaces on geological timescales (e.g., Fairbridge and Finkl, 1980; Millot, 1983). Constraining these interactions on continental scales is therefore relevant to quantifying the contribution of shields, as opposed to that of orogens, to global sediment budgets and biogeochemical cycles in the context of long-term Cenozoic climate cooling (Ollier and Pain, 1996a; Molnar, 2004; Willenbring and von Blanckenburg, 2010; Goudie and Viles, 2012; Willenbring et al., 2013; Larsen et al., 2014). Large-scale studies of regolith transfers are also necessary for "source to sink" analyses of coupled drainage areas and sedimentary basins. The present contribution aims to quantify long-term landform evolution, regolith mobility and erosional export fluxes over a large region representative of shields' sediment routing systems.

Tropical shields are mantled by lateritic regoliths derived from intense rock weathering. Such lateritic covers are subject to remobilization by slope and fluvial processes, and the reworked regoliths are commonly re-weathered after transport (Ollier and Pain, 1996b). Renewed periods of regolith production by weathering and remobilization by pedimentation lead to the formation of composite landscapes consisting in a mosaic of lateritic paleo-landsurface remnants of various generations. Such landscapes are spectacularly preserved throughout Sub-Saharan West Africa, a region of more than 4.5 million km^2 over which a long-recognized Cenozoic regolith–paleo-landsurface sequence has been dated (Beauvais et al., 2008) and correlated (Beauvais and Chardon, 2013).

Here we develop a field- and remote sensing-based regolith–landform mapping protocol applied over Southwestern Burkina Faso (Fig. 1). The investigated area is large (ca. 300 × 300 km) and exposes the most widespread, type geologic and morphoclimatic configuration of the West African surface (granite–greenstone terrains and flat sandstones in the Guinean and Soudanian climatic zones i.e., between 10 and 13°N; Fig. 1). Given the constrained chronological framework of regolith–landform production over the sub-region, the selected area is therefore suitable for the characterization of landscape and regolith

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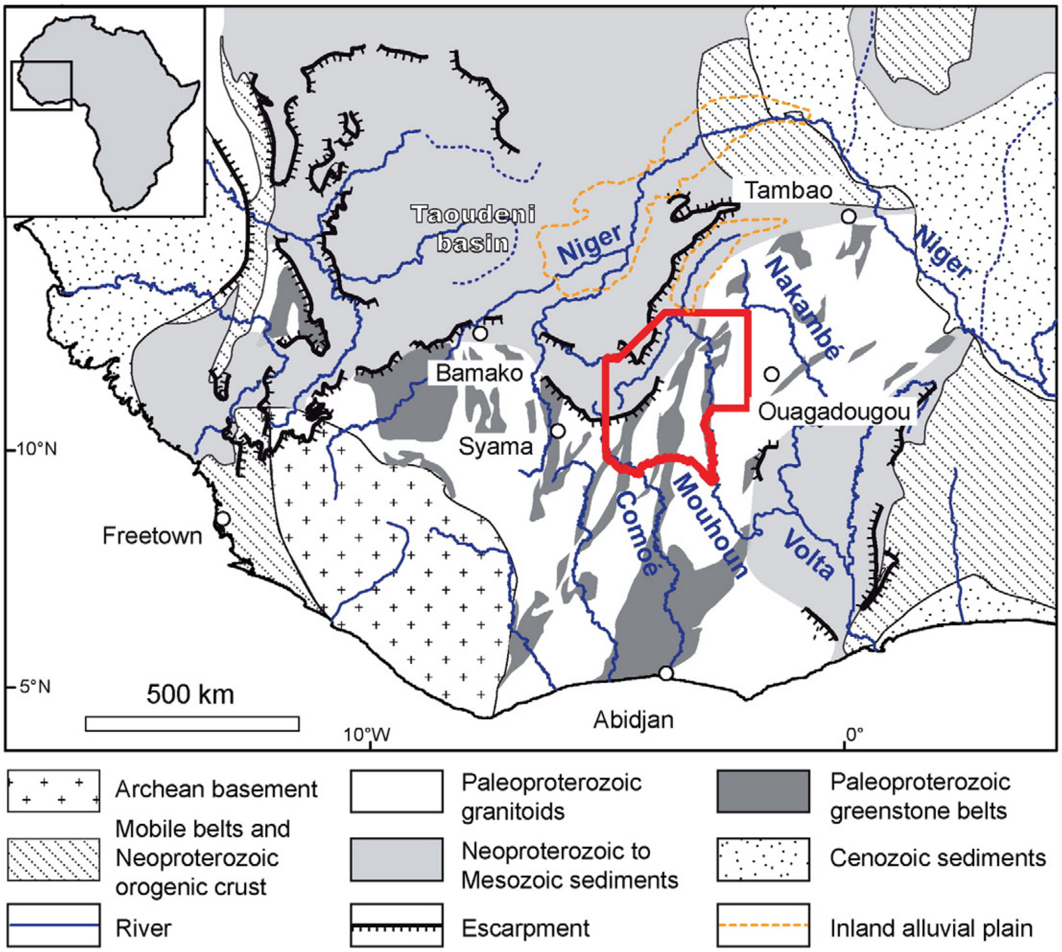

Fig. 1. Simplified geology of sub-Saharan West Africa. The study area is shown by a red frame (map modified from Feybesse et al., 2006).

dynamics and the quantification of long-term (10^6–10^7 years) erosion representative of shields surfaces. Regoliths are studied here both as in-situ produced or transported sediments and as paleo-landscape remnants. The obtained regolith–landform map allows evaluation of the nature, distribution and preservation of regolith mantles derived from a pediplain elaborated during the Early and Middle Miocene (ca. 24–11 Ma) over the sub-region. Based on this map, a topographic reconstruction of the pediplain is used to visualize regolith redistribution on slopes during pedimentation and to evaluate landscape and drainage evolution after its abandonment 11 Ma ago. Quantification of post-11 Ma dissection of the pediplain leads to estimate a type-erosion flux for shields, emphasizing the low capacity of slope and alluvial processes to remove and export regolith mantles.

2. Geomorphological and geological background

2.1. The West African geomorphic sequence and its regoliths

The following summary of the West African sequence of stepped lateritic paleo-landsurfaces (Fig. 2a) is based mostly on the works of Michel (1959, 1973, 1974), Eschenbrenner and Grandin (1970), Boulangé et al. (1973), Grandin (1976), and Boulangé and Millot (1988) (see Chardon et al., 2006; Beauvais and Chardon, 2013).

Each member in the sequence has a distinct regolith cover and geomorphic character. The first two members of the sequence are the bauxitic and so-called Intermediate surfaces, which bear thick in-situ formed regoliths capped by bauxites and ferricretes, respectively. Bauxites are the end-product of a period of enhanced chemical weathering that started in the Late Cretaceous and culminated in the Mid-Eocene. Bauxites seal a topography called the African Surface, which makes the present-day envelope of the West African relief. The Intermediate surface corresponds to a differentiated landscape carved in the African bauxitic surface. The following three stepped paleo-landsurfaces of the sequence are glacis (French term for pediments) called the High, Middle and Low glacis. Glacis surfaces are commonly covered by a detrital layer issued from degradation of earlier landforms. Each glacis has undergone weathering after pedimentation, indicating repeated transitions from arid or semi-arid pedimentation to seasonally contrasted or wet tropical weathering. Weathering periods generally ended with the formation of a ferricrete cementing the glacis surfaces and their detrital cover. Today, glacis occupy an overwhelming part of the West African landsurface (Beauvais and Chardon, 2013; Grimaud, 2014). The sequence is best preserved in the Sahelian and Soudanian climatic zones. The glacis, having undergone relief inversion, show evidence of degradation further south under the humid climate of the forest zone (Grandin, 1976). Though originally defined in the French-speaking countries, the sequence or elements of the sequence have been formally or implicitly identified and mapped in other countries of the sub-region (e.g., Fölster, 1969; Grandin and Hayward, 1975; Bowden, 1987; Durotoye, 1989; Thomas, 1980, 1994; Teeuw, 2002; see Beauvais and Chardon, 2013; Grimaud, 2014).

The Lower to Mid-Eocene age of peak weathering and abandonment of the bauxitic surface had long been stratigraphically bracketed (e.g., Millot, 1970). In absence of any stratigraphic constraints or radiometric data, the three glacis were thought to reflect Quaternary glacial–interglacial climatic cycles having led to the dissection of the