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Ferricrete biochemical degradation on the rainforest–savannas boundary of Central African Republic

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ABSTRACT

In southeastern Central African Republic the lateritic weathering mantles are capped by 2 to 5 m thick ferricretes, which previously formed under a seasonal tropical climate. The actual humid tropical climatic conditions result in the biophysical disaggregation of the ferricretes everywhere the forest develop that lead to a soil formation composed of ferricrete relicts and ferruginous nodules embedded in a soft bioturbated micro-aggregated clay-ferruginous matrix. The potential effect of the biological activity (e.g., termites) on the soil and vegetation dynamics and therefore on the evolution of the previous consolidated ferricrete is discussed. Following its mechanical disaggregation by the forest tree roots, the ferricrete underwent a chemical degradation under the combined effect of hydration and redox conditions, which result from the biodegradation and oxidation of the organic matter. The transformation of the ferricrete into a soft bioturbated micro-aggregated clay-ferruginous soil matrix implies the hematite dissolution, and the kaolinite transformation into gibbsite, which may characterize a late “bauxitization” (secondary gibbsitization of kaolinite) of previous ferricrete profiles linked to a late Quaternary environmental (climate and vegetation) change. However, the geochemical and mineralogical patterns of the matrix not only reflect the geochemistry of the parental ferricrete but also depend on the physical transfers of quartz and heavy minerals from the lower horizons of the profile. Hence, the use of geochemical indexes such as Ti and/or Zr for mass balance calculations in the lateritic weathering profiles is precluded because these supposedly inert chemical elements are not simply accumulated by *in situ* chemical weathering process.

1. Introduction

Long term rock chemical weathering throughout the intertropical zone led to the formation of several tens meters of lateritic weathering profiles, many being capped by 2 to 10 m thick ferricretes. From the bottom to the top, a ferruginous lateritic weathering profile is generally composed of a saprolite, a mottled clay horizon, a soft ferricrete and/or a soft nodular horizon and a ferricrete (Nahon, 1986; Tardy, 1997; Beauvais, 1999). The ferricretes developed under a seasonal tropical climate and represent the ultimate stage of the ferruginization process that started earlier in the mottled clay horizon (Tardy and Nahon, 1985; Nahon, 1986, 1991; Thomas, 1994; Tardy, 1997; Beauvais, 1999). With the increasing ferruginization, the geochemical signature of parent rocks is progressively blurred until nearly complete deletion in the ferricrete (Tardy et al., 1988; Tardy, 1997). The large intertropical areas over which the ferricretes actually outcrop suggest paleoclimatic changes towards drier conditions (Tardy and Roquin, 1998) that led to the degradation of the vegetation cover with a consecutive mechanical erosion of the upper leached horizon, which previously overlay the buried ferricrete (Büdel, 1982; Millot, 1983; Butt, 1987).

However, the exposed ferricretes may disaggregate and geochemically degrade under the wet and warm climatic conditions characterizing the rainforest environments (Novikoff, 1974; Nahon et al., 1989; Thomas, 1994; Tardy, 1997). The degradation of previously consolidated ferricretes implies a complete reorganization of the uppermost part of the profile under the effects of biological activity and almost permanent moisture. Therefore, the disaggregated ferricrete is progressively transformed into soil containing blocks and debris of ferricrete of various sizes including centimeter size ferruginous nodules embedded in a bioturbated micro-aggregated clay-ferruginous matrix similar to that of many red ferruginous tropical soils. Such a transformation is investigated (1) by comparing the main geochemical outlines of an undisturbed ferricrete profile and a disaggregated-ferricrete horizon, and (2) by defining the geochemical differentiation pattern of two disaggregated-ferricrete horizons at the top of lateritic weathering profiles profile developed upon different parent rocks. The biophysical and geochemical processes involved in the ferricrete degradation are discussed. In particular, the potential role of the biological activity (e.g., termites) on the degradation processes of previous undisturbed ferricrete profiles is approached.

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2. Field description

The study area (“Haut Mbomou”) is located in southeastern Central African Republic (CAR) (Fig. 1a). The climate is humid seasonal tropical with a dry season from December to February and a mean annual rainfall of 1600 mm (Fig. 1a), a mean annual temperature of 25 °C and a mean annual relative humidity of the air of 80%. The southern part of CAR hosts forests belonging to the Congo–Guinean domain (Sillans, 1958), where *Terminalia superba*, *Albizia zygia*, *Triplochiton scleroxylon* and *Celtis* sp. are the main identified species (Boulvert, 1986; Beauvais, 1991).

The vegetation of the study area is a mosaic of grass savanna interspersed with patches of dense rain forest. About 79.3% of the total landsurface of the previous mapped area (545 km^2) is covered by grass savanna where consolidated ferricrete is outcropping on plateaus and hillslopes, while the rain forest occupies the remaining 20.7% where the ferricrete is disaggregated resulting in the formation of dismantled ferricrete soils (Beauvais and Roquin, 1996; Fig. 1b). The extension of forest against savanna in the Mbomou area was dated from the Holocene period using C isotopic analyses of organic matter in soils and alluvial sediments (Runge, 2002) that also characterize a climatic change towards more humidity. A semi-humid forest with *Anogeissus leiocarpus* and *A. zygia* effectively develops around the highest plateaus (10.6% of the total surface) at a topographic slope gradient change (Fig. 1c), while a Guinean selvage forest with *T. scleroxylon* and *Celtis* sp. occupies relatively incised thalwegs (10.1% of the total surface). A Soudano–Guinean savanna with *Daniella oliveri* and *Terminalia glaucescens* alternates with Graminaceae such as *Ctenium newtonii* and *Loudetia annua* (Sillans, 1958), where ferricrete effectively outcrops on the plateaus (Boulvert, 1986; Beauvais, 1991).

The degradation processes of the ferricrete are investigated on vertical profiles located in the forested transition area between the high plateaus and the bare hillslope (Fig. 1b and c), which carry massive or protonodular and protopisolitic ferricretes, respectively, as previously established from a combined geomorphological and petrological study of the main ferricretes in the “Haut–Mbomou” region (Beauvais and Roquin, 1996). In the “Haut–Mbomou” area, the moderate epeirogenesis resulted in insufficient river incision and erosion that did not allow a clear differentiation of stepped lateritic paleolandsurfaces (bauxitic and ferruginous) like those characterizing the West African landscapes (Eschenbrenner and Grandin; 1970, Michel, 1973; Grandin, 1976; see also Beauvais et al., 1999). The long-term (Cenozoic) climatic change gradient was higher in West Africa than in CAR (Tardy and Roquin, 1998). Paleoclimates evolved from humid to dry in West Africa, and from arid to seasonal humid tropical in CAR that led to continuous ferricrete formation during Tertiary (Beauvais, 1991; Beauvais and Colin, 1993; Tardy and Roquin, 1998) instead of successive development of bauxite and ferruginous glacis (pediments). However, the high plateaus and hillslopes or low plateaus of the “Haut–Mbomou” could be analogous of the West African intermediary and high glacis landsurfaces, respectively (Boulvert, 1996).

The “Haut–Mbomou” landscape is also characterized by “mushroom” termite mounds of *Cubitermes fungifaber*, which are systematically erected on gently sloping surfaces bearing a ferricrete (Fig. 2a), called “lakéré” (Sillans, 1958; Boulvert, 1986). Runge and Lammers (2001) counted five to six hundred termite mounds per hectare for an area of 75,000 km^2 (Mbomou plateau) that imply a denudation rate of

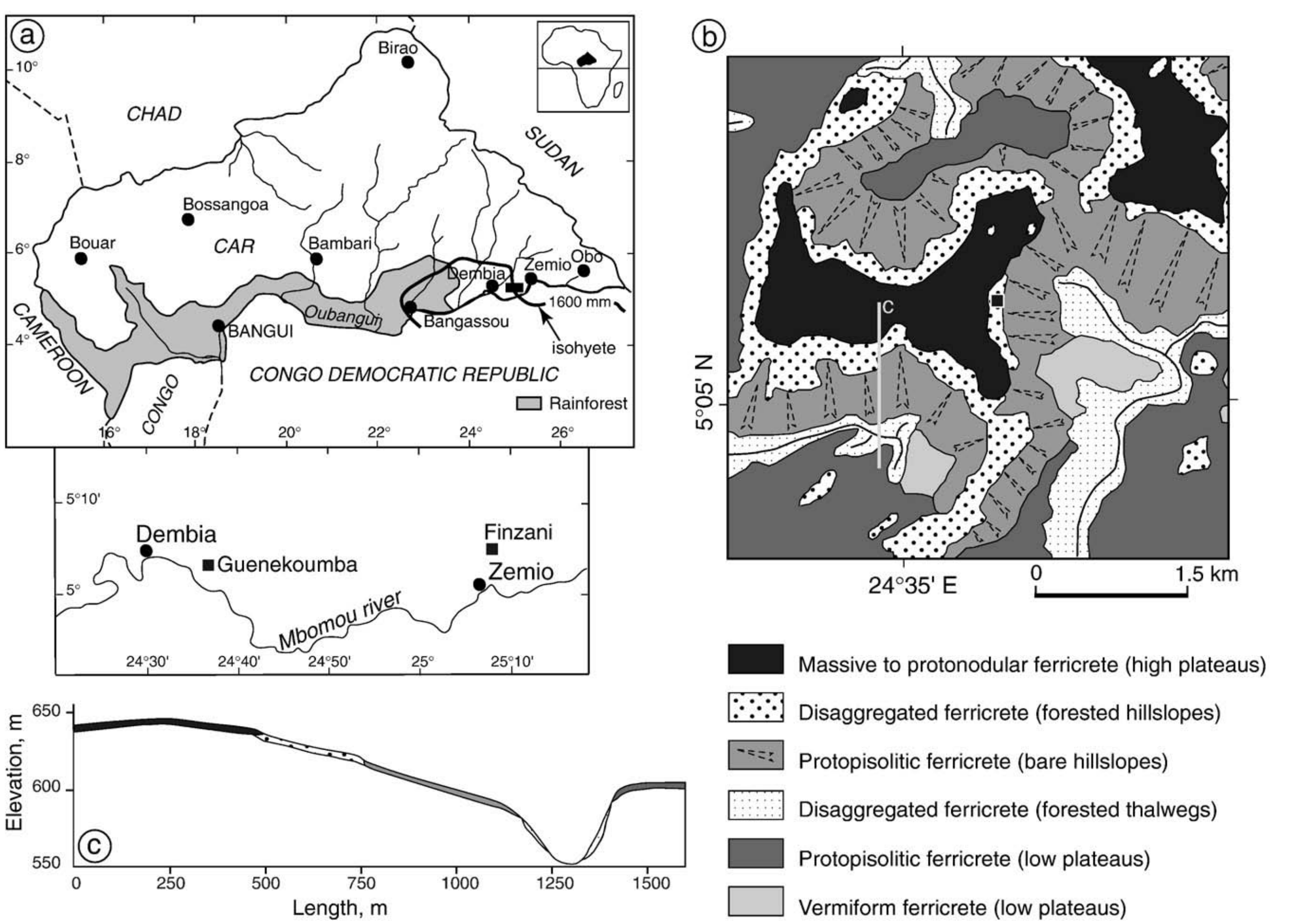

Fig. 1. (a) Location of the study area in Central African Republic (CAR). The black rectangle represents the previous mapped land area (Beauvais and Roquin, 1996; Beauvais, 1999). (b) Geomorphic distribution of the different forms of ferricrete. The black square is for the location of the disaggregated-ferricrete profile at Guénékoumba. (c) Geomorphological transect across c shown in (b).