FORMATION AND TRANSFORMATION PROCESSES OF IRON DURICRUST SYSTEM UNDER TROPICAL HUMID ENVIRONMENT

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INTRODUCTION

Most of the studies performed in Africa on lateritic profiles addresse the iron duricrusts formed either under dry tropical contrasted climate (Nahon, 1976 ; Leprun , 1979 ; Ambrosi, 1984 ; Mazaltarim, 1989 ; Boeglin, 1990), or under humid equatorial climate (Muller et al., 1981; Muller, 1987). These authors have regarded the iron duricrusts either in term of geomorphological distribution at a large scale, or in term of petrological differentiation at the scale of profiles and minerals, and recently in terms of geochemical signature for exploration follow up works (Matheis, 1981 ; Butt, 1987 ; Colin et al., 1989 ; Freyssinet, 1990 ; Roquin et al., 1990). Considering that each investigation method has to be applied to a whole system, we propose here to globally study the formation and the transformation processes of iron duricrust systems developed under a tropical humid environment in the Dembia-Zemio area of the Central African Republic. The aim of this study, is to determine the weathering processes leading to the formation and transformation of iron duricrust systems from geomorphological, petrological, mineralogical and chemical analyses, and to point out the relationships between the secondary weathering minerals and the trace elements.

GEOGRAPHIC AND GEOLOGIC SETTING

The Dembia-Zemio area is located in the southeastern part of the Central Africa Republic (Fig.1). This area corresponds to a transitional climatic domain between the humid equatorial zone of the intracratonic congolese basin, and the dry tropical contrasted climate of the intracratonic tchadian basin. The climate is humid tropical. The mean annual rainfall is about 1600 mm, the mean annual temperature is 25°C and the mean relative humidity is 80%.

The landscape consists of plateaus ranging from 600 to 650 m in elevation and weakly inclined slopes cut out by straight and deep thalwegs (Fig.1). The indurated lateritic mantle consists of a patchwork of (1) massive iron duricrusts on high plateau, (2) dismantled iron duricrusts in forested areas, (3) nodular iron duricrusts on bare slopes and on low plateaus which are purple reddish (4) or ochre brownish (5) colored (Fig.1), accounting respectively fro (1) 10.45%, (2) 20.7%, (3) 31.6%, (4) 30.75% and (5) 6.5%.

The fresh rocks have not been in situ observed. Previous regional mappings reported that the bedrock consists of Birrimian amphibolitc-pyroxenitic complex (Mestraud, 1982).

SPATIAL DISTRIBUTION, PETROGRAPHICAL AND MINERALOGICAL PATTERNS OF THE WEATHERING PROFILES.

Three iron duricrust systems can be spatially and petrologically distinguished on high plateaus (1), slopes (2) and low plateaus (3) (Fig.1 and 2).

The detailed petrological study allows to draw the main features of the weathering profiles, and the vertical and lateral relationships between the three systems.

A given system is characterized by petrographical features which express either as inherited material from an other system or as specific material in situ formed. This is obviously illustrated by :

- The occurence of indurated goethitic mottled clay layer at the base of the soft nodular layer within the high plateau profile (Fig.2), which prefigures the iron duricrust of the slope system.
- The remnants of massive iron duricrust within the slope nodular iron duricrust derived from the high plateau system.
- The presence of a thick indurated goethitic mottled clay layer within the bare profile similar to the iron duricrust of the low plateaus.
- The soft nodular layers contain two populations of nodules. Elongated nodules which preserve the parental fine bedded structure, called lithomorphous by Beauvais (1989), and the polyedric ones with a pedogenetic structure called argilomorphous in senegalese iron duricrust by Nahon (1976). Some nodules exhibit goethitic cortex developing at the expense of hematitic cores reflecting hydratation processes of hematite. These nodules either are derived from overlying nodular iron duricrust or are in situ formed.
- The saprolite of the slope profile consists (1) of kaolinitic domains which preserve the initial structure of the parent rock, and (2) of gibbsitic domains with pedoturbated structure. The gibbsite develops by hydratation of the kaolinite (Beauvais, 1989), according to the increasing of pores size.

The saprolite of the low plateau system is essentially kaolinitic with a richness in quartz compared to the saprolite of the other system.

It is clear that the evolution of the three systems undergoes vertically and laterally from parental rock to iron duricrust trough inherited or supergene phases which are transitional relays of kaolinization-gibbsitization (saprolite) and hematitization-goethitization (upper layers) processes.

GEOCHEMICAL PATTERNS OF THE SAPROLITIZATION AND THE FERRUGINIZATION PROCESSES.

The iron content and the trace element signatures clearly identify the saprolite layers. The forested slope saprolite is the iron-richest and it is signed by transition elements as Mn, V, Ni, Co, Cr and Cu, whereas the earth alkalis as Sr, Ba, rare earth elements as La, Ce, Yb and also Y concentrate in the low plateau saprolite which is iron-depleted (Fig.3).

On the other hand, the iron duricrusts are not well differentiated by their trace elements composition either for transition elements or earth alkali and rare earth elements (Fig.3).

From the saprolite to the iron duricrust, the layers have a specific mineralogical signature pointing out the lateral and vertical evolution of saprolitization and ferruginization development. In contrast, the trace elements signatures of the saprolite layers are not preserved in the upperlying layers at the scale of bulk samples, revealing thus the partial loss of the parental memory during increasing ferruginization processes.

The statistical analysis of the mineralogical and the geochemical datas permits to specify the geochemical behaviour of trace elements during the weathering processes. The results obtained from the principal component analysis and the extracted factor scores from the varimax analysis point out 6 factors accounting for 94% of the total variance (Fig.4). The two first and the sixth factors highlight the opposite evolutional pathways between saprolitization and ferruginization processes.

The first factor evidences on the one hand, the cluster "hematite- Fe- V" (negative correlation) which characterizes the ferruginization, and on the other hand the cluster "kaolinite- Si- Al- Ti- Y- Yb" (positive correlation) which signes the saprolitization (Fig.4).

The second factor stresses out the antagonism between the hematite and the "goethite- P- Zn- Cu- Sc- Y" cluster (negative correlation), reflecting the geochemical opposition between the two ferruginization pathways. The first is characterized by the hematite-rich massive or nodular iron duricrusts and the second is expressed by the goethite-rich nodular iron duricrusts or the indurated mottled clay layers (Fig.4).

The sixth factor associates the gibbsite and alumina, reflecting the gibbsitization processe which substitutes for the kaolinization one within the saprolite and the iron duricrusts of the slope profiles (Fig.4).

The third, the fourth and the fiftf displays respectively, (1) "P- Sr- Ba- La- Ce- Eu" cluster, (2) "quartz- Zr- Nb" cluster, and (3) "Mn- Ba- Co- Ni- Zn" cluster.

CONCLUSIONS.

The formation and the transformation of the iron duricrust systems of the Dembia-Zemio area are however a function of discriminating saprolitization and ferruginization processes in terms of kaolinite-gibbsite and hematite-goethite formation.

During the ferruginization processe, goethite-rich low graded layers succeed to hematite-rich high graded layers accoording to the pore size and water activity increasing (Didier et al., 1985 ; Tardy and Nahon, 1985 ; Trolard and Tardy , 1987).

During the saprolitization processe, kaolinite transforms into gibbsite under more humid and best drainage conditions.

In this way, the trace element behaviour is a function of the saprolitization and the ferruginization processes intensity, and however of the secondary minerals formation.

In the first stage, earth alkalis as Sr and Ba, rare earth elements as La, Ce for the "light" (LRE) and Eu, Lu and Yb for the "heavy" (HRE) are mainly correlated to the kaolinite, whereas the transition elements as Mn, V, Ni, Co, Cr, Zn and Cu have a good afinity for the Fe-oxyhydroxides. In the second stage, the trace element-partitioning increases with ferruginization processes development. Sr, Ba and Eu, Lu, Yb are rapidly released out of the profiles, whereas La and Ce remain with the kaolinite. On the other way, the transition elements are either released (Ni, Co, Zn) or concentrated with goethite (P, Mn, Cu and Sc). For their part, the elements as Ti, Zr and Nb belonging to the heavy minerals behave as an ubiquitous residual phase along the weathering profiles.

The saprolitization processe however preserves the geochemical inheritance of parent rocks, whereas the ferruginization processe deletes it. On the other hand, it appears as a better indicator of pedoclimatic environment changes.

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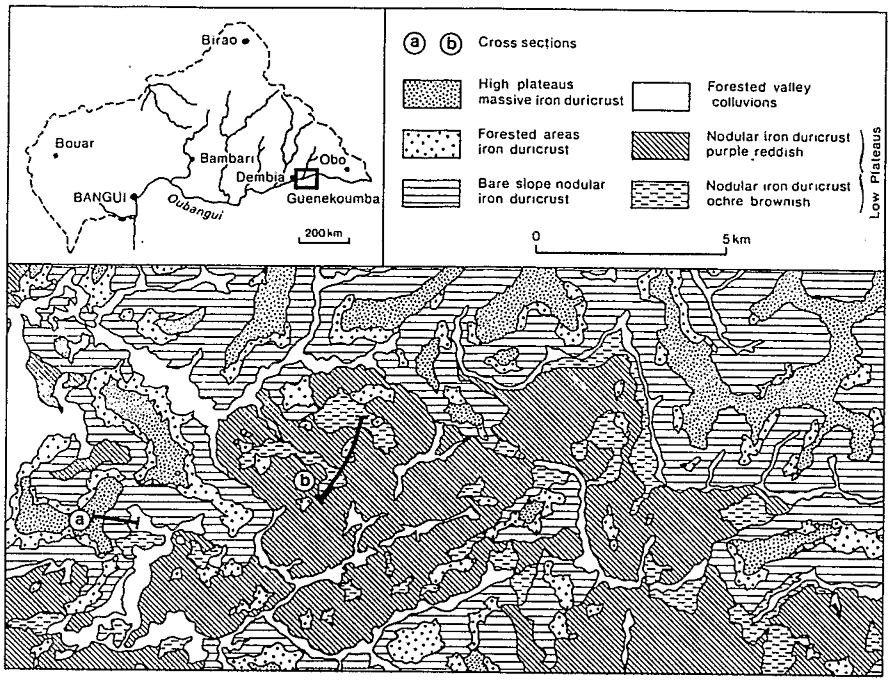

Figure. 1 - Geographical setting of the Demnia-Zemio area and geomorphological surficial layers relationships.

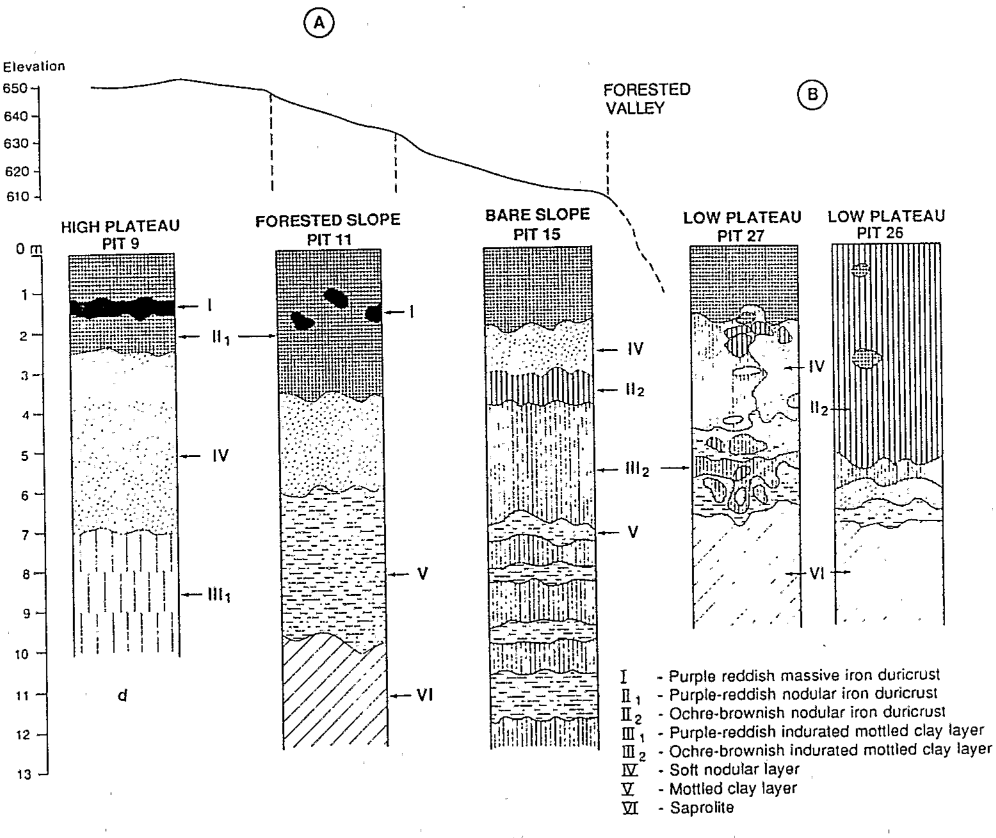

Figure. 2 - Sketch of weathering type-profile corresponding to **(a)** and **(b)** cross sections.

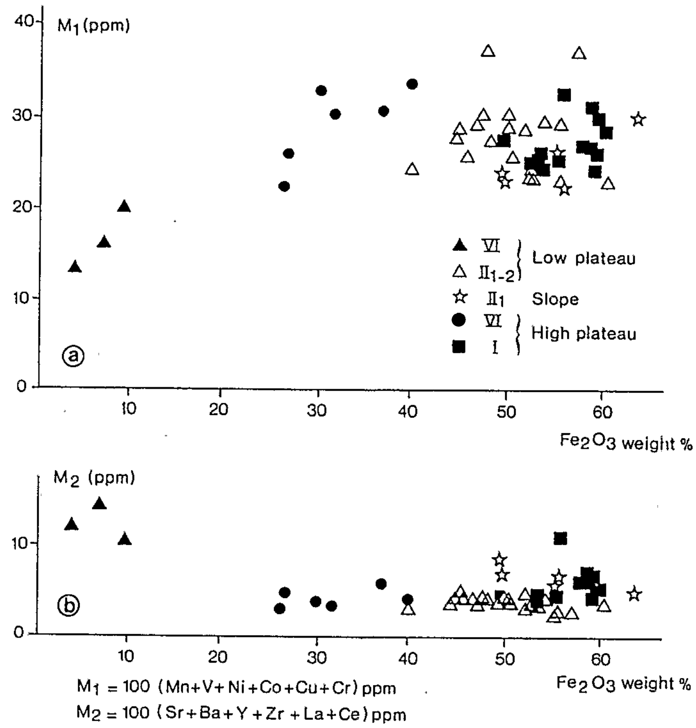

Figure. 3 - Trace element contents of saprolites compared to iron duricrusts (a - M_1 = 100 (Mn + V + Ni + Co + Cu + Cr) versus Fe_2O_3 ; **b** - M_2 = 100 (Sr + Ba + Y + Zr + La + Ce) versus Fe_2O_3).

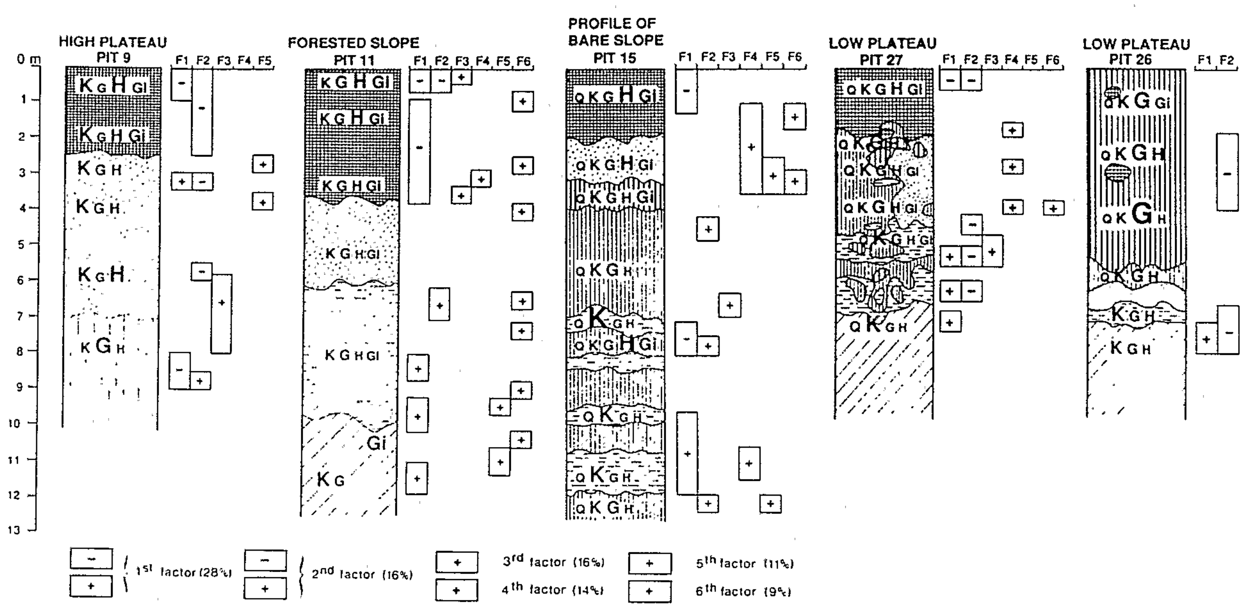

Figure. 4 - Relationship between principal component analysis results and samples from weathering profiles (semi-quantitative XRD results are given for each sample ; Q : quartz ; K : kaolinite ; G : goethite ; H : hematite ; Gi : gibbsite ; **X** : very abundant ; X : abundant ; X :fairly abundant ; x : less abundant ; x : scarse).

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