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Mobilization and redistribution of major and trace elements in two weathering profiles developed on serpentinites in the Lomié ultramafic complex, South-East Cameroon

Paul-Désiré Ndjigui [a,*], Paul Bilong [a], Dieudonné Bitom [a], Abdoulaye Dia [b]

[a] *Department of Earth Sciences, University of Yaoundé I, P.O. Box 812, Yaoundé, Cameroon*
[b] *Institut des Sciences de la Terre, Université Cheikh Anta Diop, B.P. 5396, Dakar-Fann, Senegal*

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Abstract

The behaviour of major and trace elements have been studied along two serpentinite weathering profiles located in the Kongo-Nkamouna and Mang North sites of the Lomié ultramafic complex.

The serpentinites are characterized by high SiO_2 and MgO contents, very low trace, rare earth and platinum-group element contents. Lanthanide and PGE contents are higher in the Nkamouna sample than in Mang North. Normalized REE patterns according to the CI chondrites reveal that: (i) all REE are below chondrites abundances in the Mang North sample; (ii) the $(La/Yb)_N$ ratio value is higher in the Nkamouna sample (23.72) than in the Mang one (1.78), this confirms the slightly more weathered nature of the Nkamouna sample. Normalized PGE patterns according to the same CI chondrites reveal a negative Pt anomaly in the Mang sample. The Nkamouna sample is characterized by a flat normalized PGE pattern.

All element contents increase highly from the parent rock to the coarse saprolite.

In the weathering profiles, Fe_2O_3 contents decrease from the bottom to the top contrarily to Al_2O_3, SiO_2 and TiO_2. The contents of alkali and alkaline oxides are under detection limit.

Concerning trace elements, Cr, Ni, Co, Cu, Zn and Sc decrease considerably from the bottom to the top while Zr, Th, U, Be, Sb, Sn, W, Ta, Sr, Rb, Hf, Y, Li, Ga, Nb and Pb increase towards the clayey surface soil. Chromium, Ni and Co contents are high in the weathered materials in particular in the saprolite zone and in the nodules.

REE contents are high in the weathered materials, particularly in Nkamouna. Their concentrations decrease along both profiles. Light REE are more abundant than heavy REE. Normalized REE patterns according to the parent rock reveal positive Ce anomalies in all the weathered materials and negative Eu anomalies only at the bottom of the coarse saprolite (Nkamouna site). Positive Ce anomalies are higher in the nodular horizon of both profiles. An additional calculation method of lanthanide anomalies, using NASC data, confirms positive Ce anomalies ($[Ce/Ce^*]_{NASC} = 1.15$ to 60.68) in several weathered materials except in nodules ($[Ce/Ce^*]_{NASC} = 0.76$) of the upper nodular horizon (Nkamouna profile). The $(La/Yb)_N$ ratios values are lower in the Nkamouna profile than in Mang site.

PGE are more abundant in the weathered materials than in the parent rock. The highest contents are obtained in the coarse saprolite and in the nodules. The elements with high contents along both profiles are Pt (63–70 ppb), Ru (49–52 ppb) and Ir (41 ppb). Normalized PGE patterns show positive Pt anomalies and negative Ru anomalies.

The mass balance evaluation, using thorium as immobile element, reveals that:

– major elements have been depleted along the weathering profile, except for Fe, Mn and Ti that have been enriched even only in the coarse saprolite;
– all the trace elements have been depleted along both profiles, except for Cr, Co, Zn, Sc, Cu, Ba, Y, Ga, U and Nb that have been enriched in the coarse saprolite;

* Corresponding author. Tel.: +237 99 54 37 74; fax: +237 22 22 62 62.
E-mail address: lndjigui@yahoo.fr (P.-D. Ndjigui).

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– rare earth elements have been abundantly accumulated in the coarse saprolite, before their depletion towards the top of the profiles;
– platinum-group elements have been abundantly accumulated in the coarse saprolite but have been depleted towards the clayey surface soil.

Moreover, from a pedogenetical point of view, this study shows that the weathering profiles are autochtonous, except in the upper part of the soils where some allochtonous materials are revealed by the presence of zircon grains.

Keywords: Cameroon; Serpentinites; Laterites; Major elements, Trace elements

1. Introduction

The southern Cameroon basement is essentially made up of rocks belonging to the Congo Craton and the Pan-African metamorphic belt (Lasserre and Soba, 1976). This part of the Pan-African metamorphic belt has been subjected to various weathering processes that have controlled the distribution of major and trace elements (Temgoua et al., 2002; Bitom et al., 2003).

The weathering of serpentinites (in the South-East part of the basement) has led to secondary mineralization dominated by chlorites, smectites, talc, goethite, maghemite, hematite, kaolinite and gibbsite (Yongué-Fouateu et al., 2006). This weathering has also liberated some chemical elements that show various types of behaviour in the weathering profile.

For example, Yongué-Fouateu et al. (2006) showed that highest concentrations of nickel and cobalt are located in the saprolite zone. In contrast, weathering mobilises uranium through dissolution of primary minerals from the coarse saprolite whereas thorium precipitates in situ (Moreira-Nordemann and Sieffermann, 1979). Muller and Calas (1989) showed that U and Th concentrations increase slightly from the bottom to the top of a profile on gneiss at the forest-savanna boundary in Cameroon.

The REE studies have proved their redistribution along the weathering profile instead of being carried away in solutions (Middelburg et al., 1988; McLennan, 1989). REE were leached from the top and accumulated at the bottom of the profile. They were adsorbed at the interfaces of the new formed clay minerals, Fe-oxides and residual minerals (Decarreau et al., 1979; Laufer et al., 1984). Under hot-humid climatic conditions, enrichment of light REE upon heavy REE is observed (Balashov et al., 1964).

Very few studies have documented the behaviour of REE, Th and U in tropical weathering profiles (Muller and Calas, 1989; Braun et al., 1990; Marker and de Oliveira, 1990; Boulangé and Colin, 1994; Braun et al., 1998). In South Cameroon particularly, the study of these elements in soils remain limited to investigations of lateritic profiles on syenite in the rainforest environment (Braun et al., 1990; Braun et al., 1993) and of soil sequence hosted in gneiss at the forest-savanna boundary zone (Braun et al., 1998). The geochemistry of PGE in ultramafic rocks is well understood as compared to that of PGE in weathered materials from these ultramafic rocks (Bowles et al., 1994; Salpéteur et al., 1995; Tashko et al., 1996; Traoré et al., 2006). No previous investigations have been carried out on the behaviour of trace, rare earth and platinum-group elements in laterites related to ultramafic rocks in the Central African rainforest. The aim of this study is to document and explain the mobilization and redistribution of major and trace elements in relation with the different stages of serpentinite weathering along lateritic profiles of two separate bodies of the Lomié ultramafic complex in the South-East of Cameroon.

2. Geographical and geological setting

The Lomié ultramafic complex is located in South-East Cameroon (Fig. 1), with a rainfall of about 1650 mm per year and an average temperature of 23.5 °C, typical of dense humid forests (Letouzey, 1985). Such climatic conditions are suitable for supergene weathering leading to the formation of red ferrallitic soils (Yongué-Fouateu et al., 2006). The ultramafic complex is part of the South Cameroon plateau, with a moderate hilly geomorphology (750 m) and large swampy valleys.

The Lomié ultramafic complex is composed of serpentinites (among which the Kongo-Nkamouna and the Mang North site are found; Figs. 2 and 3) embedded in metamorphic rocks of Mbalmayo and Yokadouma series (micaschists, schists, quartzites and gneiss) after Seme Mouangué (1998).

The Kongo-Nkamouna body covers a surface area of 90 km^2 in the northern part of the Lomié ultramafic complex, between latitudes 3 °15′–3°23′N and longitudes 13°40′–13°55′E. This body is surrounded by micaschists and quartzites (Fig. 2).

The 63 km^2 ultramafic body of Mang North is located in the North East to that of the Kongo-Nkamouna, between latitudes 3°19′–3°21′ N and longitudes 14°7′–14°11′E (Fig. 3). It is surrounded by schists and the profile sampled for this study is on the eastern side of the Boumba river interfluve (Fig. 3).

3. Sampling and analytical procedures

Two rock samples were collected, one (NK6) in the Kongo-Nkamouna ultramafic body (Fig. 2) and the second (MA6) in the Mang North site (Fig. 3).