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Distribution of duricrusted bauxites and laterites on the Bamiléké plateau (West Cameroon): Constraints from GIS mapping and geochemistry

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ABSTRACT

Estimation of the mineral resources potential is an important issue for most of developing countries. The spatial distribution of bauxites and lateritic land surfaces on the Bamiléké plateau (West Cameroon) has been investigated with a Boolean modeling process into a GIS environment on the basis of geological constraints such as elevation, rock and soil types, and landscape morphology. Field observation and SRTM (Shuttle Radar Topographic Mission) data allowed the differentiation of two lateritic land surfaces separated by a minimum altitude difference of about 60 m. These surfaces constrained by favorable rock types, slope steepness and soil types provided a potential lateritic bauxitic area of 381 km^2 (17.2% of the total study site). Field validation and the integration of legacy spatial data resulted in an area of 60.1 km^2 for potential bauxitic ores, i.e. obviously duricrusted bauxitic surfaces (with 47.8 km^2 in the upper surface and 12.3 km^2 in the lower surface). Alumina contents obtained from duricrust samples were analyzed by geostatistical methods and classical kriging interpolation to discriminate between bauxitic and ferruginous laterites. This highlighted a geochemical trend from higher alumina values on the upper surface (40–66 wt.%) to lower values on the lower surface (13–44 wt.%). Finally, our study documents two duricrusted lateritic surfaces arranged in a staircase manner and having different geochemical characteristics. The total bauxitic-rich surface is distributed in five spots throughout the study area and covers 56.2 km^2, while ferruginous laterites occupy a spot of 3.9 km^2. GIS mapping approach of lateritic land surfaces, accounting for reliable constraints, might be promising for larger scale investigations of mineral resources in Cameroon.

1. Introduction

Many Third World Countries rely mainly on their natural resources to sustain their economic development. In Cameroon, the exploitation of mineral resources has traditionally been a significant component of the economy (Ntép Gweth, 2009). However, precise knowledge on the potential of these resources is generally limited by a lack of geo-exploration tool required for their reliable and comprehensive assessment and classification at the national-wide level. In this country, the most widespread ore deposits are lateritic bauxites, representing the 6th reserve in the world. Bauxites occur in the Adamaoua and Western regions, and have been previously studied by many authors (Hiéronymus, 1973; Momo Nouazi et al., 2012; Morin, 1985; Nicolas and Eno Belinga, 1969; Nyobe, 1987) using classical approaches of field survey and laboratory analyses. Today, GIS and remote sensing tools permit more accurate mapping of such resources by integrating favorable geological constraints in a GIS-based model.

Our study aimed at satisfying the practical need for supporting bauxite exploration in Cameroon with up-to-date maps, by defining the relation between bauxitic deposits and their geological environment. For this purpose, we used a GIS-modeling approach, based on a well-established procedure, which was previously tested in several studies on mineral potential assessment (Boroushaki and Malczewski, 2008; Carranza et al., 1999; Cheng and Agterberg, 1999; Guha et al., 2013; Harris et al., 2008; Robinove, 1989; Thole et al., 1979; Varnes, 1974; Zadeh, 1965). The approach deals with GIS-based geologically constrained mineral potential mapping, a multistage strategy for delineating mineralized zones (Reeves et al., 1990). Multivariate and multisource geo-exploration datasets were combined to enhance favorable geologic features indicative of mineral deposit (Bonham-Carter, 1994; Hodgson, 1990). Using the Boolean model of Varnes (1974) and Robinove (1989), our interest is to know whether the spatial criteria linked to the genetic environment and landscape distribution of bauxites can be used to define predictive map of bauxite occurrence for further field exploration and geochemical survey.

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2. Physiography of the study area

The study site lies between longitudes 09°56′–10°20′E, and latitudes 05°18′–5°45′N and covers an area of 2209 km^2 within the Bamiléké plateau extending between 09°44′–10°33′E, and 04°10′–05°56′N in West Cameroon (Fig. 1a and b). The Bamiléké plateau covers the southern part of the West Cameroon highland (Fig. 1a) between the Bamoun plateau in the east, the Grassfields in the north and the Mbô plain in the south and west (Fig. 1b). The climate is sub-equatorial, influenced by high altitudes, with 1600–2000 mm mean annual rainfall and 18 °C–20 °C for the mean annual temperature. The main morphological feature of this area is the Mount Bambouto, culminating at the altitude of 2725 m (Fig. 1b), which is the third most important volcano of the Cameroon Volcanic Line (Déruelle et al., 1991).

The Cameroon Volcanic Line consists of a wide Cenozoic volcanic complex extruded through the Neoproterozoic Panafrican granito-gneissic basement, which is also intruded by mafic and felsic plutons (Kwekam et al., 2010). The volcanic complex is known to be the parent material for the plateau Bamiléké bauxites. The new ^{40}K–^{40}Ar geochronological data showed three main periods of volcanic activity extending from the Miocene (Burdigalian) (Marzoli et al., 1999) to the Pliocene (Nkouathio, 2006; Nkouathio et al., 2008), and uncommon lava spots extending up to ~0.5 My (Kagou Dongmo et al., 2010). Lava geochemistry shows a trend extending from basanites to trachytes or phonolytes.

3. Methods

3.1. Conceptual model of bauxite occurrence

A conceptual and exploration model for evaluating the bauxite potential of the Bamiléké plateau was built based on geological criteria (Carranza, 2002; De Araújo and Macedo, 2002; Hodgson, 1990; Reeves et al., 1990). We used the Boolean model for examining the spatial relation of geological features, which is based on a reclassification of the input maps into only two classes (Bonham-Carter, 1994; Carranza et al., 2008; Harris et al., 2001; Robinove, 1989; Thiart and De Wit, 2000; Varnes, 1974), i.e., the maximum and minimum evidential score classes (0 or 1). Reclassified maps are combined logically according to a set of steps so-called inference network (Fig. 2), which reflects the inter-relationships of processes controlling the occurrence of a geo-object and spatial features indicating the presence of this geo-object (Carranza, 2002; Carranza, 2009). Finally, the output of combined evidential maps via Boolean logic modeling is a two-class map. The first class represents locations where all of the prospective recognition criteria are satisfied, while the second class represents locations where at least one is unsatisfied (Carranza, 2009).

The study was carried out with ILWIS GIS software (ITC ILWIS Unit, 2001) using a three step methodology including: (i) gathering spatial data into a GIS, (ii) extracting spatial evidential data and creating derivative maps to be used as spatial evidence of bauxite mineralization, and (iii) integrating the spatial evidence map to create bauxitic potential map and validating the predictive map (Bonham-Carter, 1994).

3.2. Analysis of constraints

In our study, the criteria or constraints from the rock types, landscape morphology (elevation ranges and slopes), and soil types were defined at a scale of 1:255.000 and linked to delineate favorable zones on the Bamiléké plateau. These zones are potentially duricrusted land surfaces areas with alumina-rich surface materials, which are characterized by thick and extremely leached soils (Hiéronymus, 1973; Momo Nouazi et al., 2012; Nyobe, 1987).

Lateritic bauxites are known to form mainly by chemical weathering of rocks in which low silica content favors crystallization of gibbsite instead of kaolinite (Tardy, 1997). However, many other studies have also described bauxite formation from a variety of parent materials

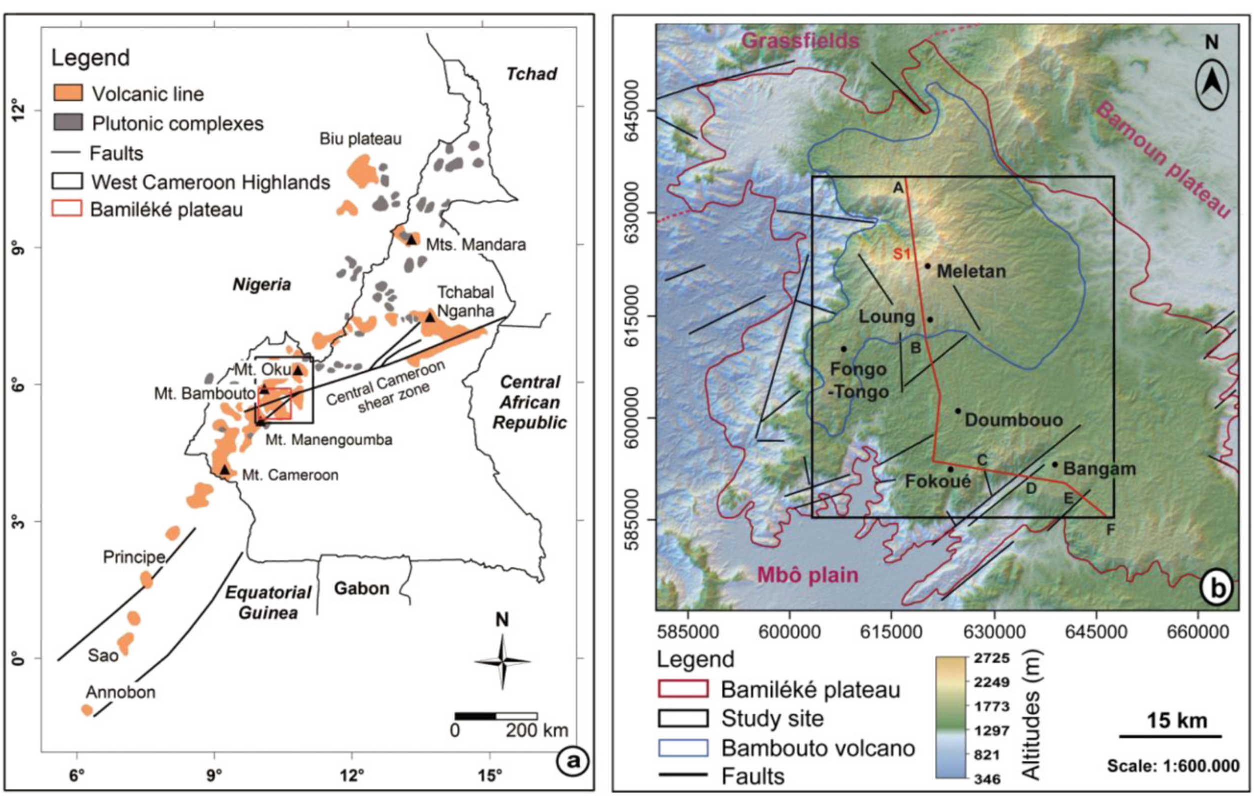

Fig. 1. a) Localization and structure of the Cameroon volcanic line (from Ballentine et al., 1997; and Ngako et al., 2006); b) morphology of the Bamiléké plateau. Letters A to F mark the major morphological changes along the cross section shown in Fig. 4.