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Age, geochemical characteristics and petrogenesis of Cenozoic intraplate alkaline volcanic rocks in the Bafang region, West Cameroon

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ABSTRACT

The origin of the volcanism in the Cameroon Volcanic Line and the nature of its mantle sources are still highly controversial. We present major and trace element compositions as well as Sr–Nd–Pb–Hf isotopic results on mafic and intermediate lavas from the Bafang area in the central part of the Cameroon Volcanic Line. The lavas range from basanites and basalts to hawaiites and mugearites with an alkaline affinity and were emplaced between 10 and 6 Ma ago. The evolution from basalts and basanites to more differentiated rocks involved fractionation of olivine, clinopyroxene and Fe–Ti oxides, but the isotopic compositions show that crustal contamination processes affected some magmas during their ascent in the crust. Basalts and basanites originated from a garnet-bearing mantle source and their differences are mostly due to variable degrees of partial melting. The isotopic composition of the uncontaminated samples imply the participation of three distinct mantle components, the depleted MORB mantle (not dominant), an enriched component and a Pb radiogenic component similar to the source of the Mount Cameroon. Combined with previously published isotopic data from the Cameroon Volcanic Line, our new results indicate that the source of the volcanism mostly reside in the lithospheric mantle and is different from what can be expected from the melting of a mantle accreted from or modified during the emplacement of the St. Helena mantle plume.

1. Introduction

The role of the lithospheric mantle in the petrogenesis of continental basalts is difficult to evaluate, as its nature and composition are known to be highly variable, and sometime not easily distinguishable from deeper mantle sources. The genesis of intraplate alkaline basalts remains therefore a matter of considerable debate. This volcanism is the subject of many geochemical investigations on large continental flood basalt (CFB) provinces as well as smaller volcanic fields (Jung and Masberg, 1998; Zou et al., 2000; Barry et al., 2003). The contamination of the asthenospheric mantle by lithospheric material, recognized in the geochemistry of some CFB, is classically accounted for by lithospheric delamination (e.g. McKenzie and O'Nions, 1995) or ancient subduction processes (e.g. Hoffmann, 1988). However, there is increasing evidence that melts originated in the asthenosphere can interact with the lithospheric mantle en route to the surface (Chazot et al., 1996; Wulff-Pedersen et al., 1996; Class and Goldstein, 1997) and lead to these intermediate geochemical signatures.

The Cameroon Volcanic Line (CVL) appears as a SW–NE straight line (Fig. 1) displaying a "swell and basin" geometry. It is a chain of 12 Cenozoic and Quaternary volcanic massifs covering approximately 1600 km from Annobon Island in the Gulf of Guinea to Lake Chad, and active from Eocene to the Present (Déruelle et al., 2007 and references therein). The chain can be splitted into a continental and an oceanic part, which is a unique feature for Africa and even for the world (Déruelle et al., 1991, 2007). In more details three distinct zones can be identified: 1 – the oceanic sector (Annobon, Sao Tome and Principe), 2 – the continent/ocean boundary (c.o.b.: Bioko, Etinde and Mt. Cameroon) and 3 – the purely continental sector. This last part of the chain is constituted of tens to a hundred of kilometers-scale volcanic massifs including Manengouba, Bambouto, Bamenda and Oku mountains as shown in Fig. 1. Early on, Fitton and Dunlop (1985) recognized geochemical similarities between trace elements and Sr isotopes of basalts from both oceanic and continental sectors. Based on these data, they suggested that these melts were extracted from sub-lithospheric depths without interaction with the overlying lithosphere. Later

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on, Halliday et al. (1988, 1990) reported anomalously high $^{206}Pb/^{204}Pb$ ratios (up to 20.5) for lavas from the c.o.b., with lower $^{206}Pb/^{204}Pb$ ratios (19–20) for volcanic rocks from the oceanic and continental sector. These results, combined to Sr, Nd and O isotopes, suggested that the high $^{206}Pb/^{204}Pb$ signatures are due to the recent remelting of the St. Helena fossil plume head within the lithospheric mantle, after that U/Pb fractionation occurred during melt migrations as the plume head was cooling down about 125 Myr ago. As a consequence, in this model, the Pb isotope anomaly observed in volcanic rocks from the CVL, cannot be derived from metasomatized lithosphere. Moreover, this fossil plume model is consistent with a recent helium isotopes study of Aka et al. (2004), who reported MORB-like $^{3}He/^{4}He$ ratios (from 7.85 to 8.31Ra, where Ra is the atmospheric ratio) for melts from both oceanic and continental sectors associated with HIMU-OIB-like He ratios for the c.o.b (from 4 to 6Ra). In this paper, we present new K–Ar ages, major and trace element concentrations and Sr–Nd–Pb–Hf isotopes of mafic lavas from Bafang in western Cameroon in order to further investigate magma generation in this area.

2. Geological setting

The Bafang area is located within the Western Cameroon highlands (Bambouto, Bamenda and Oku Mountains) in the central part of the Cameroon Volcanic Line (Fig. 2). It lies between the Manengouba mountain in the South-West and the Noun Plain in the North. The studied area is geographically bounded by the latitudes 05°4′21″ and 05°13′38″ North and the longitudes 10°8′17″ and 10°19′38″ East and represents a surface of about 500 km^2. In this region, the Pan-African basement consists mainly of syntectonic granitoids (Dumort, 1968; Nguiessi and Vialette, 1994; Nguiessi et al., 1997; Nzolang et al., 2003). The lavas sampled in the Bafang area have mafic to intermediate composition, and no felsic rocks have been observed on the field. In this region, the vegetal cover is dense and the samples were therefore mostly recovered from artisanal quarries and small disseminated outcrops. Accordingly, no spatial continuity or stratigraphic relationship can be established between the samples.

3. Analytical methods

3.1. K–Ar geochronology

Potassium–argon ages were measured at the Université de Bretagne Occidentale, in Brest (France) on chips of whole rock lavas, 0.3–0.15 mm in size, that were prepared after crushing and subsequent sieving of the solid samples.

One aliquot of grains was powdered in an agate grinder for chemical attack of around 0.1 g of powder by 4 cc of hydrofluoric acid, before its analysis of K content by AAS (Atomic Absorption Spectrometry).

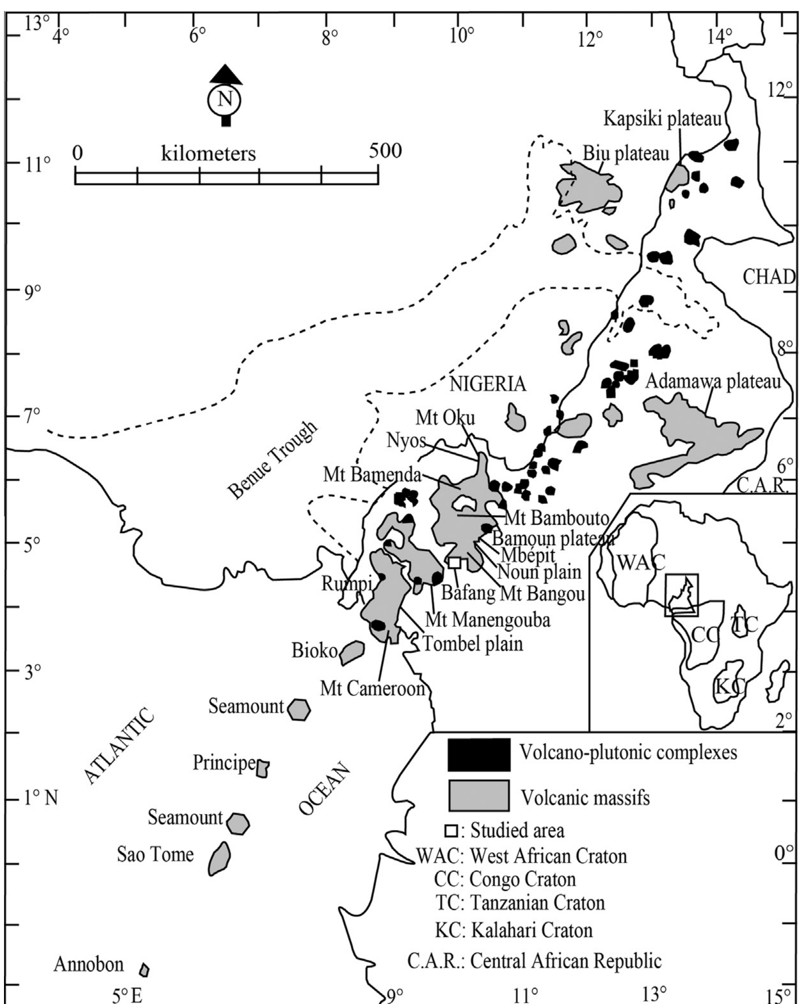

Fig. 1. Location of the Bafang area (white square) along the Cameroon Volcanic Line (adapted after Halliday et al., 1988). Location of seamounts after Burke (2001). Inset, bottom right is after Kampunzu and Popoff (1991).