Gondwana Research 24 (2013) 727–741

Contents lists available at SciVerse ScienceDirect

Gondwana Research

journal homepage: www.elsevier.com/locate/gr

Mantle sources and magma evolution beneath the Cameroon Volcanic Line: Geochemistry of mafic rocks from the Bamenda Mountains (NW Cameroon)

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ARTICLE INFO

Article history:
Received 5 April 2012
Received in revised form 26 October 2012
Accepted 12 November 2012
Available online 8 December 2012

Handling Editor: I. Safonova

Keywords:
Cameroon Volcanic Line
Bamenda Mountains
Mafic lavas
Crustal contamination
Mantle sources
Pyroxenites

ABSTRACT

We report the mineralogy, geochemistry and geochronology of the mafic rocks from the Bamenda Mountains, part of the Cameroon Volcanic Line (CVL), in order to discuss the origin and evolution of the magmas in this part of the CVL. Mafic rocks in the Bamenda Mountains are basanites, basalts, hawaiites and mugearites with an alkaline affinity. K–Ar ages have been obtained on 10 samples and range from 17.6 Myr to present. Trace element and isotopic compositions (Sr–Nd–Pb) show that some samples among the oldest are slightly contaminated by a crustal component with high La/Nb and $^{87}Sr/^{86}Sr$ ratios and low Pb isotopic ratios. The mafic rocks strongly resemble OIB in their trace element compositions. Some samples possess a positive Sr and Eu anomaly which cannot be explained by a process of plagioclase accumulation. These anomalies are also observed in some pyroxenites found as xenoliths in the Adamawa volcanic province further north. Furthermore, non-contaminated samples have high Pb isotopic ratios and point towards an HIMU component similar to the St. Helena mantle plume. We propose that the Bamenda mafic magmas with positive Sr and Eu anomalies were formed by hybridization of asthenospheric melts with melts formed by the partial melting of pyroxenites. Samples without these anomalies result from the hybridization of the same asthenopheric melts with melts coming from the metasomatized, amphibole-bearing, lithospheric mantle.

1. Introduction

Intraplate mafic magmatism generally has a wide chemical diversity especially in its trace element and radiogenic isotope composition. The variations are considered to arise from chemically heterogeneous sources deep in the mantle (e.g., Stracke et al., 2005 and references therein), but the interaction between upwelling plume and the lithospheric mantle or the crust is another possibility to produce chemical diversities (e.g., Class and Goldstein, 1997; Bourdon et al., 1998; Class et al., 1998; Claude-Ivanaj et al., 1998; MacDonald et al., 2001; Lundstrom et al., 2003; Rankenburg et al., 2005; Yokoyama et al., 2007), making much more complicated to fully understand magma generation processes in continental intraplate tectonic settings.

The Cameroon Volcanic Line (CVL) is a chain of 12 Cenozoic volcanic massifs running for approximately 1600 km from the island of Annobon in the Gulf of Guinea to Lake Chad (Fig. 1a). It can be divided into three zones: the oceanic sector (Annobon, Sao Tome and Principe), the continent/ocean boundary (c.o.b.: Bioko, Etinde and Mt. Cameroon) and the continental sector. The continental sector is marked by a trend of large massifs including the Manengouba, Bambouto, Bamenda and Oku mountains (Fig. 1b). Fitton and Dunlop (1985) found geochemical similarity in trace elements and Sr isotopes for basalts from both the oceanic and continental sectors, and suggested that these magmas are derived from sub-lithospheric depths without further interaction with the overlying lithosphere. Halliday et al. (1988, 1990), however, reported anomalously high $^{206}Pb/^{204}Pb$ ratios (up to 20.5) for the c.o.b. volcanoes, compared with relatively lower (19–20) $^{206}Pb/^{204}Pb$ ratios for the oceanic and continental sector volcanoes. With the combination of other tracers such as Sr, Nd and O isotopes, they demonstrated that such a high $^{206}Pb/^{204}Pb$ signature was created by the remelting and U/Pb fractionation during melt migration in the St. Helena fossil plume head as it cooled after emplacement 125 Myr ago. The study concluded that Cameroon line magmas are currently derived from a zone in the upper portions of the fossil plume in the lithospheric mantle. This model implies that the observed Pb isotope anomaly did not derive from metasomatized lithosphere. Recent research of helium isotopes for the CVL showed MORB-like $^3He/^4He$ ratios for the oceanic and continental sectors and HIMU-OIB-like ratios for the c.o.b. (Aka et al., 2004), which can consistently be explained by the fossil plume remelting model.

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1342-937X/$ – see front matter
http://dx.doi.org/10.1016/j.gr.2012.11.009

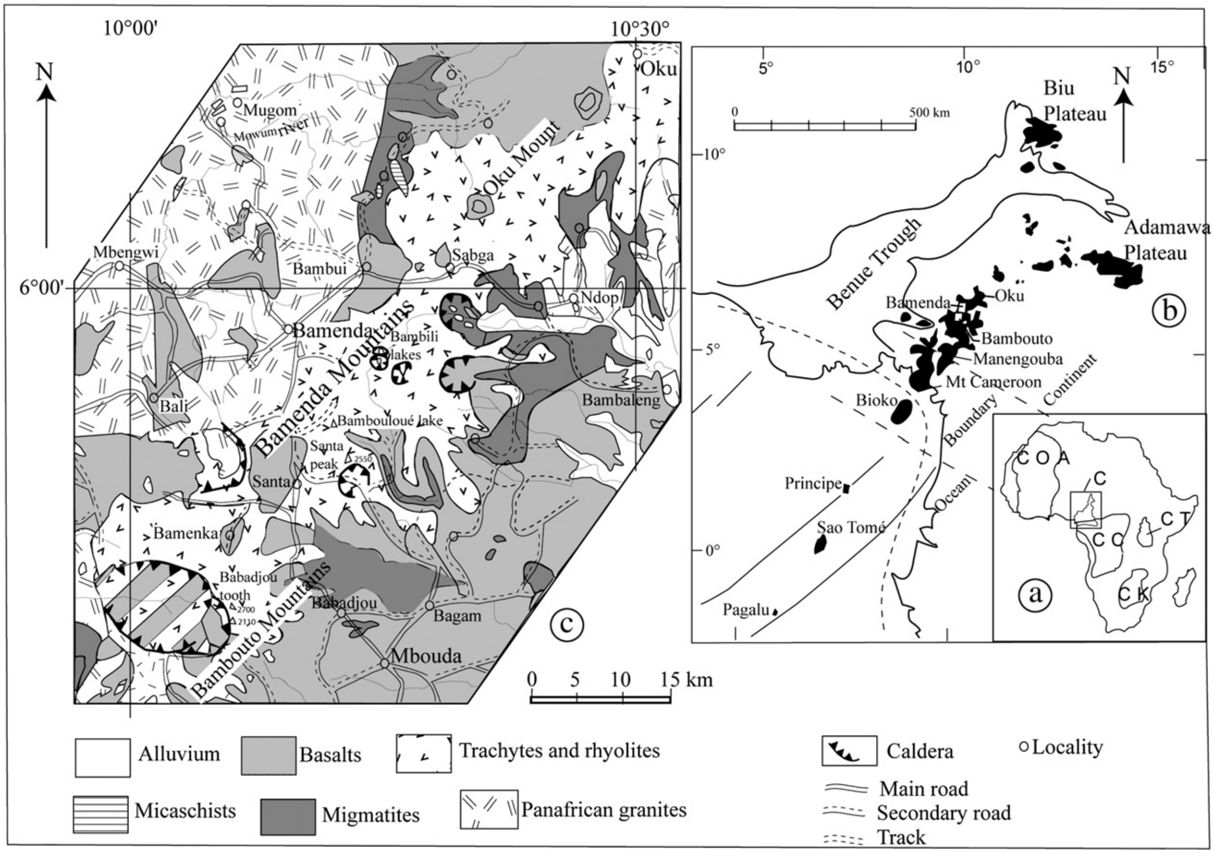

Fig. 1. (a) Location of Cameroon in Africa; (b) location of the Bamenda Mountains along the Cameroon Line showing the location (black) of the Cameroon line volcanic rocks (adapted after Halliday et al. (1988)); the boundary between continental and oceanic crust is taken from Emery and Uchupi (1984) and oceanic transform faults are from Sibuet and Mascle (1978); (c) Simplified geological map of the Bamenda area. C = Cameroon; COA = West African craton; CC = Congo craton; CT = Tanzanian craton; CK = Kalahari craton. African cratons are after Kampunzu and Popoff (1991).

The Bamenda Mountains are characterized by the predominance of felsic lavas over mafic ones (Kamgang et al., 2007, 2008, 2010). We report major elements, trace elements, ages and Sr–Nd–Pb isotopes of the Bamenda lavas in order to give further constraints on the magma generation.

2. Geological setting

The Bamenda Mountains are located between N 5°40′–6°10′ and E 10°00′–10°30′ and culminate at 2621 m. They constitute with the Bambouto Mountains to the SW and the Oku massif to the NE, the three central volcanic massifs belonging to the volcanic centers of the Western Cameroon Highlands (WCH, Fig. 1c). Their basement consists of Pan-African granitoids (Toteu et al., 2001; Nzolang et al., 2003; Nzolang, 2005). The petrological and geochemical features of the Bambouto Mountains and Oku massif are more or less established (Marzoli et al., 1999, 2000). The common features of these volcanic massifs are the predominance of felsic lavas over the mafic ones.

The Bamenda Mountains (Kamgang et al., 2007, 2008, 2010) are one of the most important volcanoes of the Cameroon Line in north-western Cameroon. They are mainly made up of mafic and felsic lavas with very small amounts of intermediate terms (benmoreite). Mafic lavas mostly consist of basanites, alkaline basalts, hawaiites and mugearites.

3. Analytical procedures

Mineral analysis of Bamenda mafic lavas was performed using a Cameca Camebax electron microprobe at Nancy I, France (15 kV accelerating potential, 10–12 nA current and 10 s counting time per element). The main mineralogical data are given in Table 1.

Thirty eight samples have been analyzed for major and trace elements. Samples were crushed in a steel jaw crusher and reduced to fine powder in agate mortars. Powders were analyzed for major oxides and Sc by inductively coupled plasma-atomic emission spectrometry (ICP-AES), and for other trace elements by inductively coupled plasma-mass spectrometry (ICP-MS) at the Centre de Recherches Pétrographiques et Géochimiques (CRPG, Nancy, France). Precision is 0.5% for major elements, and variable for trace element contents: 2–5% in the range 50–150 ppm, 2–10% in the range 10–50 ppm, and 5–25% in the range 0–10 ppm. The REEs are measured with a general precision of 5%, and a precision always better than 10% (Morel, CRPG, personal communication 1997). More details about the analytical procedures can be found in Carignan et al. (2001).

Sr and Nd isotopic compositions were measured at "Magmas et Volcans" laboratory, Blaise Pascal University, Clermont-Ferrand, France.

Table 1
Main mineralogical characteristics for Bamenda mafic lavas.

	Basanite	Basalt	Hawaiite	Mugearite
Olivine (Fo)	62–87	52–85	54–70	42–50
Ca-rich Cpx				
Wo	46–52	44–46	44–47	41–45
En	34–41	38–41	34–39	29–38
Fs	11–15	15–16	14–17	17–29
Mica (X_{Mg})	–	–	Phlogopite 0.70–0.82	–
Feldspathoids	Nepheline	–	–	–
Plagioclase (An)	1–66	9–81	5–61	8–55
Titanomagnetite (Usp)	48–86	77–85	76–79	73–77
Apatite			+	+
Calcite		+	+	+