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Research paper

A comparative review of petrogenetic processes beneath the Cameroon Volcanic Line: Geochemical constraints

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ABSTRACT

The origin and petrogenesis of the Cameroon Volcanic Line (CVL), composed of volcanoes that form on both the ocean floor and the continental crust, are difficult to understand because of the diversity, heterogeneity, and nature of available data. Major and trace elements, and Sr-Nd-Pb isotope data of volcanic rocks of the CVL spanning four decades have been compiled to reinterpret their origin and petrogenesis. Volcanic rocks range from nephelinite, basanite and alkali basalts to phonolite, trachyte and rhyolite with the presence of a compositional gap between SiO_2 58–64 wt.%. Similarities in geochemical characteristics, modeled results for two component mixing, and the existence of mantle xenoliths in most mafic rocks argue against significant crustal contamination. Major and trace element evidences indicate that the melting of mantle rocks to generate the CVL magma occurred dominantly in the garnet lherzolite stability field. Melting models suggest small degree (<3%) partial melting of mantle bearing (6–10%) garnet for Mt. Etinde, the Ngaoundere Plateau and the Biu Plateau, and <5% of garnet for the oceanic sector of the CVL, Mt. Cameroon, Mt. Bambouto, Mt. Manengouba and the Oku Volcanic Group. The Sr-Nd-Pb isotope systematics suggest that mixing in various proportions of Depleted MORB Mantle (DMM) with enriched mantle 1 and 2 (EM1 and EM2) could account for the complex isotopic characteristics of the CVL lavas. Low Mg number ($Mg^{\#} = 100 \times MgO/(MgO + FeO)$) and Ni, Cr and Co contents of the CVL mafic lavas reveal their crystallization from fractionated melts. The absence of systematic variation in Nb/Ta and Zr/Hf ratios, and Sr-Nd isotope compositions between the mafic and felsic lavas indicates progressive evolution of magmas by fractional crystallization. Trace element ratios and their plots corroborate mantle heterogeneity and reveal distinct geochemical signatures for individual the CVL volcanoes.

1. Introduction

Volcanic rocks of continental rifts have received considerable attention in recent years. However, the diversity in their composition means they are not explainable by a single process (Jung and Masberg, 1998). Although continental and oceanic intraplate magmas show considerable variation in trace element abundances and ratios, they are typically more enriched in incompatible trace elements than basalts erupted at subduction zones and mid-ocean ridges (MORs). As a result, trace element modeling for petrogenesis of intraplate magmas invariably requires their derivation from a mantle source that is chemically distinct from the upper-mantle magma source that produces the MORBs (Weaver, 1991). Continental intraplate rift magmatism is geochemically similar to ocean island basalts (OIB) (Weaver, 1991) and is thought to be generated from a convectively upwelling asthenosphere during continental extension associated with the formation of rift systems (Zou et al.,

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2000). The upper mantle beneath intraplate rift-related Cenozoic volcanoes is thought to have experienced metasomatism in the past (Wilson and Downes, 1991). These processes result in the production of hydrous minerals (amphibole and phlogopite), a range of accessory mineral phases, and enrichment in incompatible elements (Wilson and Downes, 1991; Wedepohl et al., 1994).

Unique to other intraplate rift related volcanoes, the Cameroon Volcanic Line (CVL) in West Africa, consists of a chain of Cenozoic volcanoes developed on both the Atlantic oceanic floor and the continental crust of the African plate (Fig. 1). There is no evidence of systematic age migration from one volcano to another (Lee et al., 1994; Marzoli et al., 2000; Aka et al., 2004) as observed in a typical hot spot settings such as the Hawaii-emperor chain. These complex characteristics (clear volcano alignment but lack of a consistent time-space migration) of the CVL have generated some debate concerning its origin. Geological (Grunau et al., 1975; Gorini and Bryan, 1976; Freeth, 1978; Sibuet and Mascle, 1978; Fitton, 1980; Morgan, 1983; Burke, 2001), geochemical (Fitton and Dunlop, 1985; Deruelle et al., 1991; Lee et al., 1994; Njonfang et al., 2011), structural (Moreau et al., 1987; King and Anderson, 1995), geophysical (Fairhead, 1988; Fairhead and Binks, 1991; Meyers et al., 1998; King and Ritsema, 2000; Reusch et al., 2010; Milelli et al., 2012) and geochronological (Dunlop and Fitton, 1979; Aka et al., 2004) data have been used to develop complementary models to explain the origin of the CVL. Overall, mafic rocks of the CVL show chemical features consistent with plume activity outlined by their OIB major and trace elements and radiogenic isotope characteristics (Mbassa et al., 2012).

Geochemical data and its interpretation are challenging for the CVL system, because of large variation. Lavas from the CVL range from mafic end-members e.g., nephelinite, basanite and alkali basalt to felsic end-members e.g., phonolites, trachytes and rhyolites. Available data show that some volcanoes (Mt. Etindé, Mt. Cameroon and Bui Plateau, Fig. 1) are composed only of mafic lavas while others (Mounts Manengouba, Bambouto, the Oku Volcanic Group or OVG and the Ngaounderé Plateau) are bimodal, with the presence of a Daly gap. The degree of differentiation of lavas varies from one volcano to another with no well-defined trend. There is heterogeneity even at a local scale within each central volcano (Nkouandou and Temdjim, 2011) which is thought to be due to a different degree and depth of partial melting (Marzoli et al., 2000; Kamgang et al., 2013). The CVL magmatism is characterized by

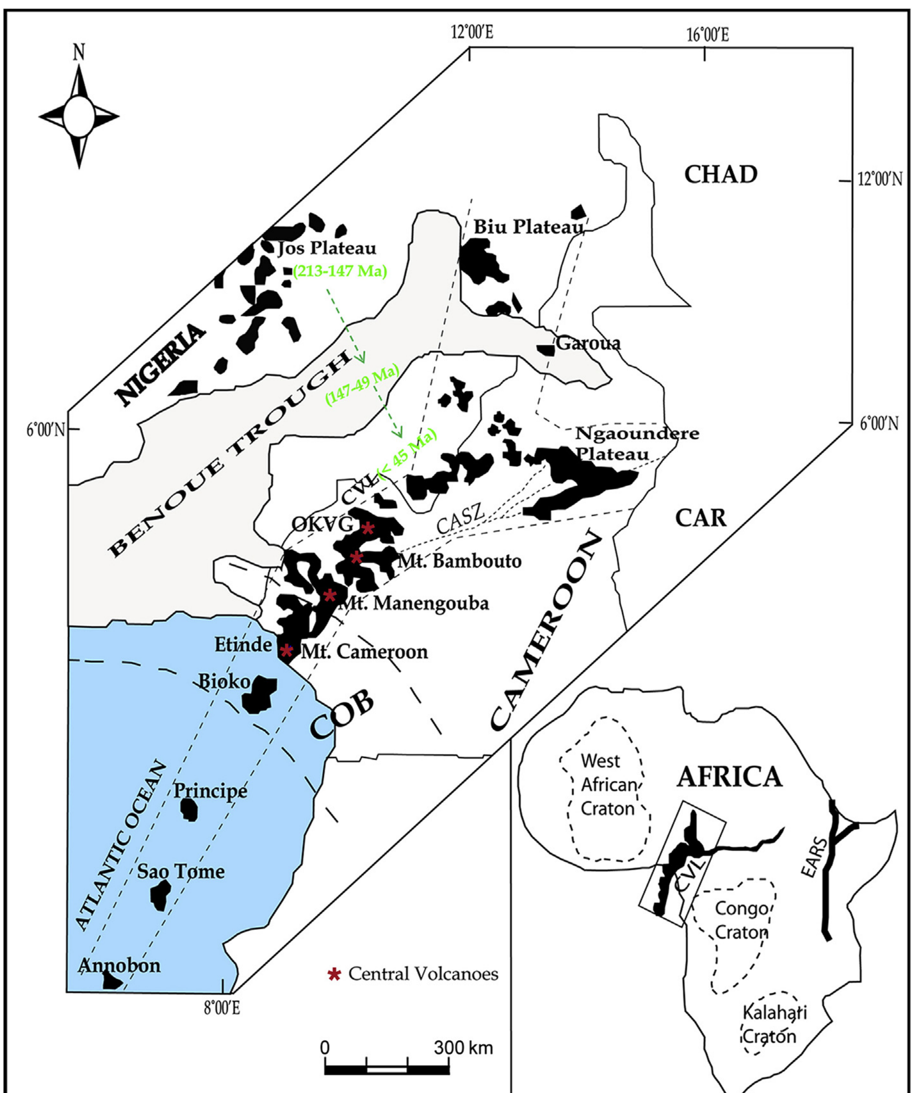

Figure 1. Location of the Cameroon Volcanic Line. COB = Continent Ocean Boundary, CAR = Central African Republic, CASZ = Central African Shear Zone, EARS = East African Rift System (Modified from Marzoli et al., 2000; Rankenburg et al., 2005; Ngako et al., 2006; Nkouathio et al., 2008).