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Existence of Quaternary ankaramites among Tertiary flood basalts at Koutaba (Bamoun Plateau, Western Cameroon): petrology and isotope data

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Кватернерни анкарамити всред терциерните базалтови покрови на Кутаба (платото Бамун, Западен Камерун): петрология и изотопни данни

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Резюме. Платото Бамун е част от Камерунската вулканска линия (CVL). Подобно на другите вулкански плата (Бамилеке, Адамауа) то е формирано следствие на ефузивна дейност. Изградено е от пукнатинни базалти (51,8–46,7 Ma), свързани с централни вулкани с възраст 45,5–44 Ma и с кватернерни моногенни вулкани. Последните са изградени както от експлозивни, така и от ефузивни продукти, всред които са и анкарамитовите потоци (0,82 Ma) с призматична напуканост в района на Кутаба. Това са мафични скали (42,8 < SiO_2 < 43,6 тегл.%), ненаситени по отношение на SiO_2 (12,9 < CIPW normative Ne < 14,9 тегл.%). REE отношения (30 < La_N/Yb_N < 31 и 19 < Ce_N/Yb_N < 20) и изотопните данни (0,703263 < $^{87}Sr/^{86}Sr$ < 0,703285; 0,518670 < $^{143}Nd/^{144}Nd$ < 0,512877) са подобни на тези в повечето лави на CVL. Анкарамитите на Кутаба произлизат от астеносферен мантиен източник от HIMU тип.

Ключови думи: анкарамити, алкален вулканизъм, Терциер, Кватернер, K/Ar възраст, изотопи (Sr, Nd), мантиен резервоар, плато Бамун, Камерунска вулканска линия.

Abstract. The Bamoun Plateau is one of the main plateaus of the Cameroon Volcanic Line (CVL). Like the other plateaus (Bamileke, Adamawa), it was emplaced by an effusive volcanism. This produced fissural basalts (51.8–46.7 Ma) extruded by central volcanoes (45.5 to 44 Ma) and recent (Quaternary) monogenic volcanoes. These recent volcanoes have been built by both explosive and effusive volcanisms from which ankaramite flows (0.82 Ma) were emplaced. These ankaramites outcrop in the form of prisms at Koutaba. They are mafic (42.8 < SiO_2 < 43.6 wt.%) and silica undersaturated (12.9 < CIPW normative Ne < 14.9 wt.%). REE ratios (30 < La_N/Yb_N < 31 and 19 < Ce_N/Yb_N < 20) and isotope data (0.703263 < $^{87}Sr/^{86}Sr$ < 0.703285; 0.518670 < $^{143}Nd/^{144}Nd$ < 0.512877) are similar to main lavas of the CVL. The Koutaba ankaramites originated from an asthenospheric mantle source of HIMU type.

Key words: ankaramite, alkaline volcanism, Tertiary, Quaternary, K/Ar ages, isotopes (Sr, Nd), mantle reservoir, Bamoun Plateau, Cameroon Volcanic Line.

Along the CVL, the Bamoun Plateau lies within longitudes 10°40'–10°56' E and latitudes 5°36'–6°00' N, covering an area of about 900 km^2. The flood basalts are essentially transitional basalts that outcrop in the western part, mainly near Bangourain and Foumban, while alkaline basalts outcrop in the south-eastern part, around Foumban and Koutaba (Moundi et al., 1996; Moundi, 2004; Moundi et al., 2007). The Bamoun flood basalts (BFB) represent the oldest dated lavas from the CVL ($^{40}K/^{40}Ar$ ages of 51 and 46 Ma, Ménard et al., 2002; Moundi, 2004; Moundi et al., 2007). The Precambrian granito-gneissic bedrock mainly outcrops in the north of the Bamoun Plateau.

This paper presents new geochemical data of the Koutaba ankaramites, witness of a recent volcanism within the Bamoun flood basalts (BFB).

Analytical methods

Whole rock geochemical analyses

Whole rock geochemical analyses were prepared at Eidgenössische Technische Hochschule (ETH), Zurich, Switzerland. The major elements were determined by X-Ray Fluorescence (XRF) on glass. The powders, melted after ignition and $Li_2B_4O_7$ addition (in the ratio of 1/5) in platinized gold drying ovens at 1150 °C, were analyzed with the Philips (PW 1404) automatic sequential spectrometer at "Eidgenössische Materialprungsanstalt" (EMPA), Dubendorf, Switzerland. The results were then corrected for deviation, background and material effect. Loss of ignition (LOI) was obtained by calorimetry after ignition of the powders and of FeO. CIPW norms were calculated on an anhydrous basis according to Middlemost (1989). Trace element concentrations were determined by XRF using batteries, and 10 grams of the rock powder of the samples were analyzed using the "Background" synthetic method in which the major element concentrations are known. The detection limit is 3–10 ppm. The REE were analyzed by ICP-MS (Inductively Coupled Plasma Mass Spectrometry) with ELAN5000 Perkim Elmer Sciex at the EMPA, calibrated with pure standard solutions, with a detection limit of 1–10 ppb. For all these analyses, the USGS reference samples were used for calibration.

Mineralogical analyses

The mineralogical analyses of the rocks were done at ETH, Zurich. The minerals (polished thin sections) were analyzed with the CAMECA SX50 microprobe equipped with 5 crystal spectrometers. The incident ray was fixed at 12 kV and 20 nA for a total time of measurement up to 96 s. Eleven elements were analysed with variable peaks of 10 s (Si, Al, Ca, Mg, Na, K) or 24 s (Fe, Cr, Ti, Mn, Ni) while a PAP calculation automatically corrected the raw data of the quantitative mineral analyses; this is a modification of the ZAF correction procedure. The Super Probe JEOL 8600 was used to obtain a regrouping of all the images of the deviated electrons. Mineral standardization calculations were carried out as follows: clinopyroxene 6 cations and 12 charges; plagioclase 5 cations and 16 charges; titaniferous oxides 2 cations and 6 charges; olivine 3 cations and 8 charges.

Isotope analyses (Sr and Nd)

Isotopic analyses were carried out at the Centre de Recherche Pétrographique et Géochimique (CRPG) of Nancy, France. The samples were first dissolved in a mixture of Hf, HNO_3 and HCl and isotopic compositions were measured using the Finnigan CHECHMATE 262-RPQ apparatus.

Geochronological analyses (K-Ar)

Geochronological analyses (K-Ar) were done at the Université de Bretagne Occidentale, Brest, France. The age determinations were done on a "whole rock" fraction of the samples: groups of grains (diameter 0.30 to 0.15 mm) were taken for the measurement of mass spectrometry, the isotopic composition of argon and the concentration of radiogenic argon (^{40}Ar). The "whole rock" concentration of potassium was determined by atomic absorption spectrometry and found to be 0.77%. The ages were calculated using the constants recommended by Steiger and Jager (1977), and the uncertainties by standard deviation calculations using the Mahood and Drake (1982) equations.

Petrography and mineralogy

The ankaramites are found within the Koutaba fissural alkaline basalts, which is a part of the Bamoun flood basalts (BFB). Good outcrops are abundant around the Mamevouo region. They form prisms (10 to 30 cm in diameter as true and false colonnades in a sector of 4 by 2 km (Fig. 2). Here, the direction of inclination of the false colonnades and their extension show that the lava flows originated from joints of strike N90. These outcrops are generally of flat relief but may form locally volcanic cones with gentle sloping sides (about 20°).

The Koutaba ankaramites are dark grey in colour and their textures are porphyritic microlitic. The same mineral phases are found as phenocrysts and as microlites: clinopyroxene constitutes 55 vol.% of the whole rock, coexisting with olivine (15 vol.%), plagioclase (10 vol.%) and titaniferous oxides (6 vol.%). Moreover glass (14 vol.%) coexists with microliths in the groundmass. This mineralogical composition is clearly different from that of the BFB, which contain more than 50 vol.% of plagioclase, less developed clinopyroxene, and little or no olivine. The chemical analyses of the main mineral phases of the

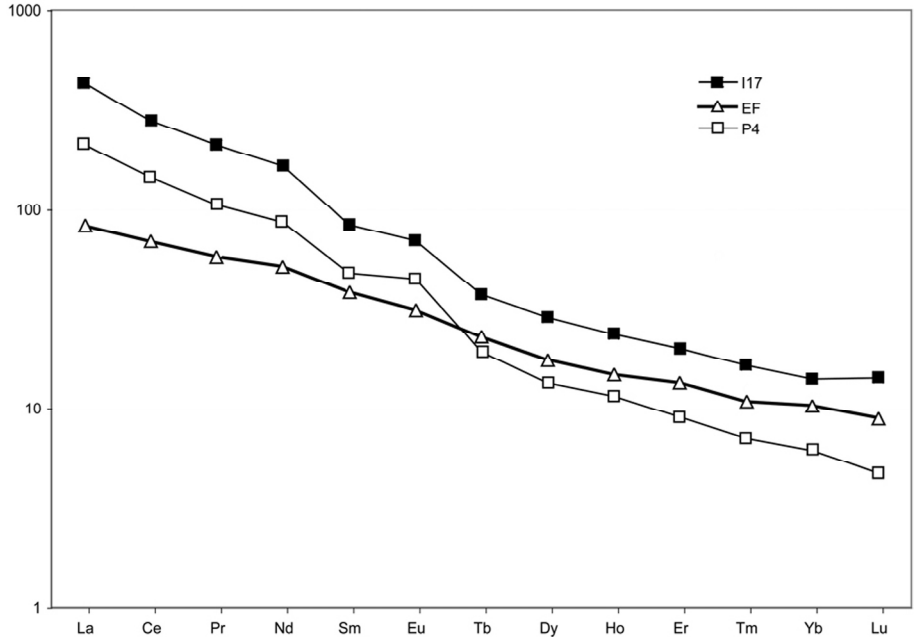

Fig. 5. REE spectra for representative samples ankaramites of Koutaba (I17) and of Bamoun flood basalts (EF transitional and P4 alkaline) normalised to chondrites according to Sun and McDonough (1989)

Фиг. 5. REE хондрит-нормирани (хондрити по Sun, McDonough, 1989) криви на представителни анализи на анкарамити от Кутаба (I17) и на покровните базалти на Бамун (EF-преходноалкални и P4-алкални)

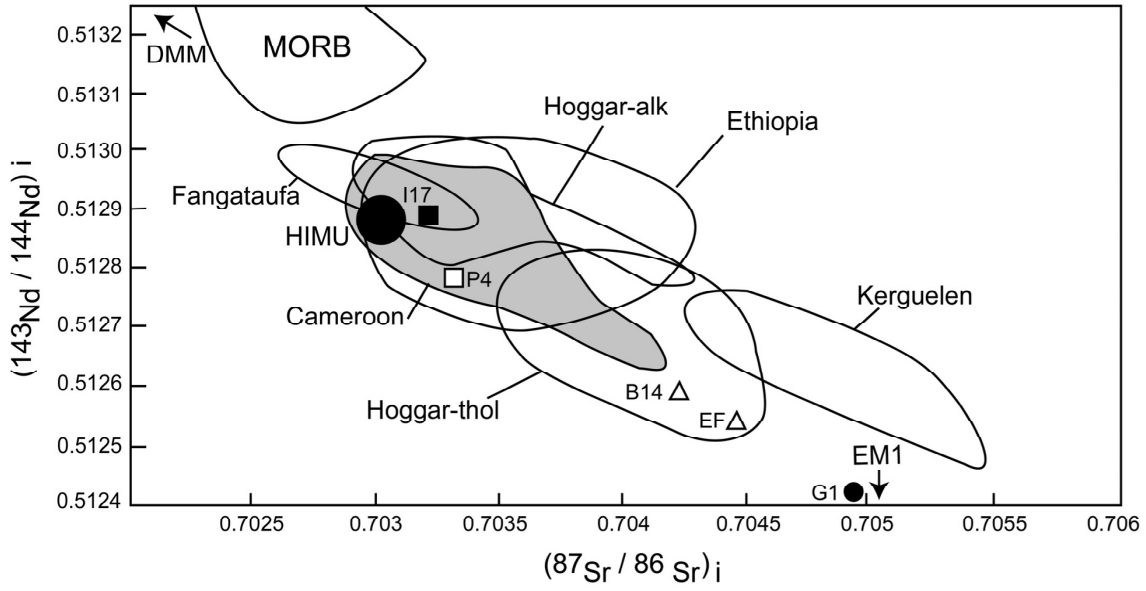

Fig. 6. Nd and Sr isotopic diagram
Analyses: ankaramite (I17); alkaline flood basalt of the Bamoun Plateau (P4); transitional flood basalts of the Bamoun Plateau (EF and B14); gabbro (G1)

Field of other lavas from LVC (Mount Cameroun and Mount Manengouba, Halliday et al., 1990), fields of Fangataufa, French Polynesia (Bardintzeff et al., 1994); of tholeiite and of alkaline lavas of Hoggar (Taharaq, Algeria) (Aït-Hamou et al., 2000), of Ethiopia (Pik et al., 1999), of Kerguelen (Bardintzeff et al., 1994; Gautier et al., 1990); MORB and mantle compositions DMM (depleted), EM1 (enriched), HIMU, following Zindler and Hart (1986)

Фиг. 6. Nd и Sr изотопна диаграма
Анализи: I17 – анкарамит; P4 – покровен алкален базалт; EF и B14 – покровни преходноалкални базалти на платото Бамун; G1 – габро

Полето на другите лави на LVC (Маунт Камерун и Маунт Маненгуба) е по Halliday et al. (1990), на Фангатофа, Френска Полинезия – по Bardintzeff et al. (1994); на толеитите и алкалните лави на Хогар (Тахарак, Алжир) – по Aït-Hamou et al. (2000), на Етиопия – по Pik et al. (1999) и на о-в Каргелен (Индийски океан) – по Bardintzeff et al. (1994) и Gautier et al. (1990); MORB и мантийните състави DMM (обеднен), EMI (обогатен), HIMU са по Zindler, Hart (1986)

rather young. They are similar to those obtained on alkaline basalts of the CVL (including alkaline BFB), which group around 0.703325 and 0.51289 respectively (Halliday et al., 1988; Nono et al., 1994; Rankenburg et al., 2005). They are typical of the HIMU reservoir (high μ, where μ is $^{238}U/^{204}Pb$). They are clearly different from those of the transitional BFB (samples EF and B14) with average values 0.7045 and 0.5126 respectively that evidence the role of EM (Enriched Mantle) source.

The ankaramites of Koutaba have been emplaced during Quaternary ($^{40}K/^{40}Ar$ datation of 0.82 ± 0.05 Ma, Moundi et al., 2007; Table 2). The BFB, which are crosscut by these ankaramites are clearly older, dated of 51–46 Ma (Eocene) (Moundi, 2004; Moundi et al., 2007).

Discussion and conclusion

The Koutaba ankaramites, which crosscut basalts of the Bamoun Plateau in its south-eastern part, are mafic ($42.8 \leq SiO_2 \leq 43.6$ wt.%) and under-saturated ($12.9 \leq$ normative nepheline ≤ 14.9 wt.%). The crystallization of all the mineral phases has been probably influenced by a low silica activity and low oxygen fugacity. The temperature of the beginning of the crystallization is 1027 °C, with exsolution of titaniferous oxides at 966 °C.

Ce/Yb (71–74) and Sm/Yb (5.38–5.70) ratios witness that the ankaramites originate from a rather deep source (≥ 100 km) according to Nakamura (1974). The values of the Rb/Nb (0.42–0.50), Zr/Nb (3.02–3.20), Ba/Nb (9.22–10.65) and La/Nb (0.96–1.09) ratios as well as their low variation imply a single mantle source of the HIMU type for these rocks. According to the high Zr/Y (8.59–10.06), La_N/Yb_N (30–32) and Ce_N/Yb_N (19–20) values, the parental magmas of these ankaramites would have resulted from a relatively low degree partial melting from an asthenospheric mantle.

The low value of the $^{87}Sr/^{86}Sr$ ratio (0.703263–0.703285) and high initial value of $^{143}Nd/^{144}Nd$ ratio (0.512867–0.512877) are similar to those of alkaline basalts of the continental and oceanic domain of the CVL. They suggest only little or no crustal influence in the genesis of the magmas at the origin of the Koutaba ankaramites. According to their Quaternary age (0.82 Ma, $^{40}K/^{40}Ar$) the Koutaba ankaramites represent the evidence of a recent magmatic episode from an asthenospheric mantle source of HIMU type. They strongly differ from the Eocene (51–46 Ma) transitional and alkaline flood basalts of the Bamoun Plateau.

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