Journal of Volcanology and Geothermal Research 327 (2016) 539–553

Contents lists available at ScienceDirect

Journal of Volcanology and Geothermal Research

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

Exotic lamproites or normal ultrapotassic rocks? The Late Miocene volcanic rocks from Kef Hahouner, NE Algeria, in the frame of the circum-Mediterranean lamproites

Michele Lustrino [a,b,*], Samuele Agostini [c], Youcef Chalal [d], Lorenzo Fedele [e], Vincenzo Stagno [a], Francesco Colombi [a], Abdellah Bouguerra [f]

[a] *Dipartimento di Scienze della Terra, Sapienza Università di Roma, P.le A. Moro, 5, 00185 Roma, Italy*
[b] *CNR, Istituto di Geologia Ambientale e Geoingegneria, c/o Dipartimento di Scienze della Terra, Università degli Studi di Roma La Sapienza, P.le A. Moro, 5, 00185 Roma, Italy*
[c] *CNR, Istituto di Geoscienze e Georisorse, Via Giuseppe Moruzzi, 1, 56124 Pisa, (Italy)*
[d] *Faculté des Sciences de la Terre, Université Houari Boumediene, BP 32 El Alia Bab-Ezzouar El Alia, 16111 Alger, Algeria*
[e] *Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse (DiSTAR), Università degli Studi di Napoli Federico II, Via Mezzocannone 8, 80134 Napoli, Italy*
[f] *Université Mohamed El Bachir El Ibrahimi de Bordj Bou Arréridj El-Anasser, 34030 Alger, (Algeria)*

ARTICLE INFO

Article history:
Received 22 July 2016
Received in revised form 27 September 2016
Accepted 27 September 2016
Available online 30 September 2016

Keywords:
Lamproite
Ultrapotassic rocks
Algeria
Mediterranean
Subduction

ABSTRACT

The late Miocene (11–9 Ma) volcanic rocks of Kef Hahouner, ~40 km NE of Constantine (NE Algeria), are commonly classified as lamproites in literature. However, these rocks are characterized by an anhydrous paragenesis with plagioclase and Mg-rich olivine phenocrysts, set in a groundmass made up of feldspars, pyroxenes and opaque minerals. Thus, we classify the Kef Hahouner rocks as ultrapotassic shoshonites and latites, having $K_2O > 3$ wt.%, $K_2O/Na_2O > 2.5$, $MgO > 3–4$ wt.%, $SiO_2 < 55–57$ wt.% and $SiO_2/K_2O < 15$.

All the investigated samples show primitive mantle-normalized multi-element patterns typical of orogenic (arc-type) magmas, i.e. enriched in LILE (e.g. Cs, Rb and Ba) and LREE (e.g. La/Yb = 37–59) with respect to the HFSE, peaks at Pb and troughs at Nb and Ta. Initial isotopic ratios are in the range of $^{87}Sr/^{86}Sr = 0.70874–0.70961$, $^{143}Nd/^{144}Nd = 0.51222–0.51223$, $^{206}Pb/^{204}Pb = 18.54–18.60$, $^{207}Pb/^{204}Pb = 15.62–15.70$ and $^{208}Pb/^{204}Pb = 38.88–39.16$.

The Kef Hahouner volcanic rocks show multi-element patterns similar to the other circum-Mediterranean lamproites and extreme Sr, Nd and Pb isotopic compositions. Nevertheless, the abundant plagioclase, the presence of Al-rich augite coupled with high Al_2O_3 whole rock compositions (9.6–21.4 wt.%), and the absence of phlogopite are all at inconsistent with the definition of lamproite. We reviewed the rocks classified as lamproites worldwide, and found that many of these rocks, as for the Kef Hahouner samples, should be actually defined as "normal" potassic to ultrapotassic volcanic rocks. Even the grouping of lamproites into "orogenic" and "anorogenic" types appears questionable.

1. Introduction

Lamproites are among the most peculiar volcanic rocks erupted during the Cenozoic in the circum-Mediterranean region. Numerous studies described their mineralogy and the extreme enrichment in both incompatible and compatible elements, as well as their strongly Sr-radiogenic and Nd-unradiogenic signatures, which find no counterpart in typical mantle-derived melts (Venturelli et al., 1984a; Peccerillo et al., 1988; Conticelli et al., 1992, 2009; Conticelli and Peccerillo, 1992; Peccerillo and Martinotti, 2006; Prelevic et al., 2005; Tommasini et al., 2011; Lustrino et al., 2011). Over the last four decades, several authors have tried to propose a classification for potassium-rich rocks, including the lamproite group (Sahama, 1974; Scott Smith and Skinner, 1984; Mitchell, 1985; Foley et al., 1987; Mitchell and Bergmann, 1991; Woolley et al., 1996). Niggli (1923) first used the term "lamproite" to identify a clan of rocks with *k* [molar $K_2O/(K_2O + Na_2O)$] and *mg* [molar $MgO/(MgO + FeO + Fe_2O_3 + MnO)$] values >0.80 (Mitchell and Bergman, 1991). The name lamproite is derived from ancient Greek meaning glistening, and refers to the characteristic presence in these rocks of shiny phenocrysts of phlogopite.

According to the IUGS classification, lamproites must fit the mineralogical criteria proposed by Mitchell and Bergman (1991), i.e. they must have widely varying amounts (5–90 vol.%) of titanian (2–10 wt.%) and Al_2O_3-poor (5–12 wt.%) phlogopite phenocrysts, titanian (5–10 wt.%)

* Corresponding author at: Dipartimento di Scienze della Terra, Sapienza Università di Roma, P.le A. Moro, 5, 00185 Roma, Italy.
E-mail address: michele.lustrino@uniroma1.it (M. Lustrino).

http://dx.doi.org/10.1016/j.jvolgeores.2016.09.021
0377-0273/

poikilitic tetraferriphlogopite (i.e., phlogopite with Fe^{3+} instead of Al in tetrahedral coordination) in the groundmass, titanian (3–5 wt.%) and K_2O-rich (4–6 wt.%) richterite, forsteritic olivine, Al_2O_3-poor (<1 wt.%) and Na_2O-poor (<1 wt.%) diopside, non-stoichiometric Fe^{3+}-rich leucite (1–4 wt.% Fe_2O_3) and Fe-rich sanidine (1–5 wt.% Fe_2O_3). As common accessory phases these rocks contain apatite, priderite [$(K,Ba)(Ti,Fe^{3+})_8O_{16}$], perovskite ($CaTiO_3$), magnesio-chromite ($MgCr_2O_4$) and rare jeppeite [$(K,Ba)_2(Ti,Fe^{3+})_6O_{13}$], armalcolite [$(Mg,Fe^{2+})Ti_2O_5$], shcherbakovite [$(K,Na,Ba)_3(Ti,Nb)_2Si_4O_{14}$] and ilmenite ($FeTiO_3$).

According to the whole-rock chemical scheme by Foley et al. (1987), lamproites are ultrapotassic (molar $K_2O/Na_2O > 3$), commonly peralkaline [molar $(K_2O + Na_2O)/Al_2O_3 > 1$)], often perpotassic (molar $K_2O/Al_2O_3 > 1$) volcanic rocks with Mg# [$Mg/(Mg + Fe^{2+})$] > 70, typically with FeOT and CaO < 10 wt.%, high Ba (>2000 ppm, commonly > 5000 ppm) and variable to very high TiO_2 (1–7 wt.%), Zr (>500 ppm), Sr (>1000 ppm), La (>200 ppm) and F (0.2–0.8 wt.%).

Lamproites are classically divided into "anorogenic" and "orogenic" types on trace element and Sr-Nd isotopic grounds (Mitchell and Bergman, 1991). The circum-Mediterranean lamproites are considered as the best representative among the orogenic varieties (e.g., Conticelli et al., 2009; Tommasini et al., 2011). Compared to the anorogenic group, the orogenic lamproites usually are SiO_2- and K_2O-rich, CaO-, Al_2O_3- and Na_2O-poor, and have higher K_2O/Al_2O_3 and Mg#. In addition, orogenic lamproites are also characterized by less-extreme high field strength elements (HFSE) enrichment compared to large ion lithophile elements (LILE) and rare earth element (REE) fractionation. Orogenic lamproites are Pb-enriched, Ti-, Nb- and Ta-depleted and show a wide range of $^{87}Sr/^{86}Sr$ (0.7035–0.7230), coupled with a narrower $^{143}Nd/^{144}Nd$ variation (mostly 0.5119–0.5128), with Sr ratios more radiogenic than the Bulk Silicate Earth (BSE) and Nd ratios less radiogenic than the ChUR estimate. A comparison between worldwide anorogenic and orogenic lamproites shows the trace element distribution is not correlated with Sr-Nd-Pb isotopic ratios. As treated more in detail in the discussion section, the chemistry of the lamproites is associated with subduction processes. As a consequence, these magmas should all be defined as orogenic, meaning that their mantle source was modified during previous subduction phases. The orogenic adjective has, therefore, a geochemical rather than geological or tectonic meaning.

Lamproitic volcanism in young (Tertiary-Quaternary) circum-Mediterranean orogenic belts including active margin, whose products are referred to as "orogenic lamproites" by Nelson (1992), are reported from several localities such as SE Spain (Nixon et al., 1984; Venturelli et al., 1984a, 1988; Nelson et al., 1986; Contini et al., 1993; Toscani et al., 1995; Benito et al., 1999; Turner et al., 1999; Duggen et al., 2005; Conticelli et al., 2009; Pérez-Valera et al., 2013; Prelevic et al., 2013), SW and NW Turkey (Savaşçin and Oyman, 1998; Francalaci et al., 2000; Innocenti et al., 2005; Çoban and Flower, 2006, 2007; Akal, 2008; Ersoy et al., 2008, 2014; Yilmaz, 2010; Prelevic et al., 2012, 2013), Serbia and Macedonia (Cvetkovic et al., 2004; Prelevic et al., 2004, 2005, 2008, 2013; Altherr et al., 2004; Pe-Piper et al., 2014), Bulgaria (Vladykin et al., 2001; Buzzi et al., 2010), Greece (Pe-Piper and Piper, 2007; Pe-Piper et al., 2014), Corsica-Tuscany (Conticelli et al., 1992, 2002, 2007, 2009, 2013; Conticelli, 1998; Peccerillo et al., 1988; Avanzinelli et al., 2009), Pannonian Basin (Seghedi et al., 2008), Western Alps (Venturelli et al., 1984a, 1984b, 1988; Owen, 2008; Conticelli et al., 2009), Bohemian Massif (Krmicek et al., 2011, 2016) and Algeria (Raoult and Velde, 1971; Vila et al., 1974; Kaminskiy et al., 1993).

In this study we present petrographic, major and trace element, as well as Sr-Nd-Pb isotope data for samples collected from the Kef Hahouner volcanic body, NE Algeria. Based on our interpretation we point out that the rocks from this area have been improperly classified as lamproites. We also highlight the difficulty to classify ultrapotassic rocks and the conflicting results obtained using mineralogical vs. whole-rock chemical criteria to distinguish among the different types. A review of the circum-Mediterranean and worldwide lamproites highlights that only a small set would fit the accepted classification schemes, including the subdivision into orogenic and anorogenic types.

2. Geological setting and sampling sites

The rocks investigated in this study are from the Kef Hahouner volcanic body located ~40 km W-NW of Guelma town and ~40 km NE the city of Constantine, NE Algeria (Fig. 1). Together with Tunisia and Morocco, Algeria constitutes the westernmost zone of the Africa-Eurasia collision. A Neogene to Quaternary magmatic activity occurred in scattered centers all along North Africa that formed an ~1200 km-long and ~50 km-wide volcanic belt parallel to the coast, whose details are provided by Maury et al. (2000), Lustrino and Wilson (2007) and Lustrino et al. (2011). Here only very general concepts are summarized.

Algeria is mainly composed by three structural domains, from north to south: the Maghrebides (hinterland domain), the Atlas, and the Sahara platform (foreland domain). The Maghrebides hinterland is made of (from North to South) the Kabylie crustal wedge, the Flysch domain and the External zone (Tell-Rif), corresponding to the African paleomargin. The main tectonic units of North Algeria are represented by the Greater and Lesser Kabylie. During Oligocene-Miocene, the southeastward slab roll-back of the Apennine-Maghrebide subduction zone triggered the fragmentation of the Alboran-Kabylia-Peloritani-Calabria (AlKaPeCa) orogenic prism (e.g., Carminati et al., 2012).

The age of the calcalkaline volcanism in North Africa generally decreases from northeastern Algeria (~18 Ma) towards the east (Tunisia, ~14–8 Ma) and the west (Morocco, ~12–5 Ma). Several studies reported a transition to more alkaline products during the Quaternary (Maury et al., 2000; Coulon et al., 2002; Duggen et al., 2005; Abbasene et al., 2016).

The studied rocks from the Kef Hahouner area belong to NE Algeria Miocene magmatism dated between 9 and 12 Ma (Bellon and Brousse, 1977; Kaminskiy et al., 1993). The outcrop area features a small steeply dipping dike-like volcanic body, several tens of meters thick, which can be followed for about 1.2 km. The volcanic rocks are classified in the literature as fortunites (i.e., hyalo-enstatite-phlogopite lamproites; Kaminskiy et al., 1993), the likely source of small diamonds found in

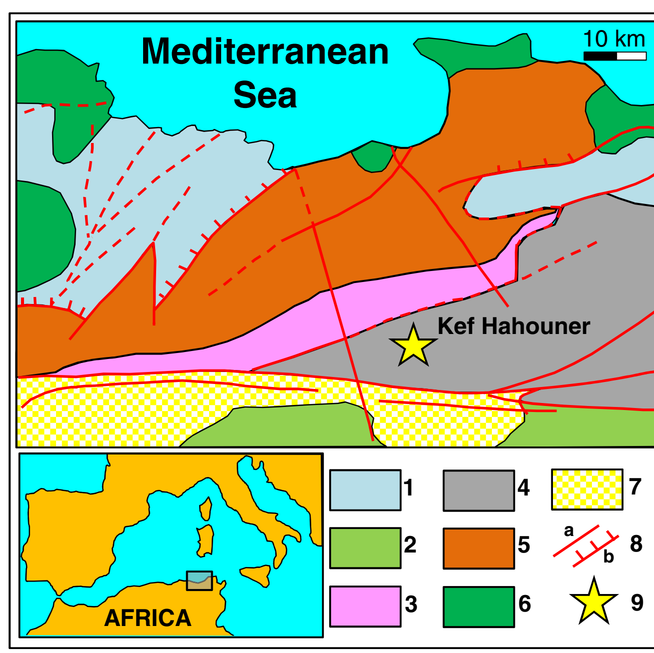

Fig. 1. Geological sketch map of the study area, modified after Kamininskiy et al. (1993). 1: crystalline massifs; 2: Jurassic-Eocene platform cover; 3: anti-formal arc with folded-metamorphic basement; 4: outer subzone of peri-Kabylia flysch zone; 5: peri-Kabylia flysch zone with slices of metamorphic basement rocks, inner subzone of peri-Kabylia zone; 6: Miocene magmatic bodies; 7: late orogenic (post-overthrust) basin; 8: major faults (a) and thrusts (b); 9: outcrop area.