Lithos 208–209 (2014) 281–297

Contents lists available at ScienceDirect

Lithos

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

Melilite-bearing lavas in Mayotte (France): An insight into the mantle source below the Comores

Anne-Aziliz Pelleter [a,1], Martial Caroff [a,*], Carole Cordier [b,c], Patrick Bachelery [d], Pierre Nehlig [e], Delphine Debeuf [f], Nicolas Arnaud [g]

[a] UMR CNRS no 6538 Domaines Océaniques, Institut Universitaire Européen de la Mer, Université de Brest, 6 avenue Victor Le Gorgeu, CS 93837, F-29238 Brest Cédex 3, France
[b] Université Grenoble Alpes, ISTerre, F-38000 Grenoble, France
[c] CNRS, ISTerre, F-38041 Grenoble, France
[d] Laboratoire Magmas et Volcans, UMR no 6524 CNRS-IRD-Université Blaise Pascal, Observatoire de Physique du Globe de Clermont-Ferrand, 5, rue Kessler, F-63038 Clermont-Ferrand Cédex, France
[e] Bureau de Recherches Géologiques et Minières, 3, avenue Claude-Guillemin, BP 36009, F-45060 Orléans Cédex 2, France
[f] Laboratoire GéoSciences Réunion, Faculté des Sciences et Technologies, 15, avenue René Cassin, CS 92003, F-97744 Saint-Denis Cédex 9, La Réunion, France
[g] Géosciences Montpellier, UMR 5243, CC 60, Université Montpellier 2, Place E. Bataillon, F-34095 Montpellier Cédex 5, France

ARTICLE INFO

Article history:
Received 4 April 2014
Accepted 15 September 2014
Available online 22 September 2014

Keywords:
Comores
Ocean island basalts
Olivine melilitite
HIMU
Mantle heterogeneity
Metasomatism

ABSTRACT

Ocean island basalts (OIB) from the Comores archipelago (Indian Ocean) display mineralogical and geochemical features different from the other Indian OIB. We present here new geochronological data ($^{40}Ar/^{39}Ar$), major and trace element compositions and isotopic (Sr, Nd, Pb) ratios of silica-undersaturated alkaline rocks from Mayotte, the oldest island of the Comores. Two trends are defined using major element composition: (1) a highly silica-undersaturated trend which includes basanites, (melilite-bearing) nephelinites, intermediate lavas and phonolites from the southern part of the island and (2) a moderately silica-undersaturated trend which is mainly represented by alkali basalts, basanites, intermediate lavas and phonolites from the northern part of the island. Both trends could be explained, to some extent, by variable degrees of partial melting. Normative larnite-bearing olivine melilitites and nephelinites exhibit, in addition to their high silica-undersaturation, elevated concentrations in CaO (>12 wt.%) and P_2O_5 (up to 1.35 wt.%). These exceptional rocks would result from low degree deep partial melting of a CO_2-metasomatized source in the presence of carbonate (probably dolomite) and apatite. Igneous rocks from southern and northwestern shield volcanoes are characterized by a radiogenic Pb composition, revealing the existence of a HIMU (high $\mu = {}^{238}U/{}^{204}Pb$) component in their source. Its influence decreases from the main building stage (>10.6–~3.0 Ma) to the post-shield stage for the benefit of a depleted MORB-mantle (DMM) component, especially in the north central rocks. This feature would reflect increasing melting degrees of the depleted dominant source, bearing small-scale HIMU heterogeneities progressively consumed with time. The HIMU signature might have been introduced in the Comorian lithospheric mantle by thermal erosion or delamination of a continental lithosphere during the Gondwana break-up. The other islands of the Comores archipelago (Moheli, Anjouan and "La Grille" type lavas from Grande Comore) display also a DMM–HIMU mixing trend. Only a few lavas from Grande Comore ("Karthala" type) and one sample from Mayotte show the clear EM1 contribution ($^{87}Sr/^{86}Sr > 0.7035$) of the Comorian plume.

1. Introduction

Olivine melilitites are alkaline and ultracalcic basic igneous rocks rich in melilite, a calcic sorosilicate, and devoid of feldspar. They are thought to be produced by a low degree of partial melting of a CO_2-rich mantle source in both continental and oceanic contexts (Dasgupta et al., 2007; Gudfinnsson and Presnall, 2005). In continental zones, they are found at or near rifting zones, often in association with carbonatites. In the African continent, (olivine) melilitites have been observed in Sahara (Dautria et al., 1992), East African Rift (Bailey et al., 2005; Dawson, 2012; Mattsson et al., 2013), South Africa (Janney et al., 2002; Rogers et al., 1992), and Madagascar (Melluso et al., 2011). In oceanic setting, the olivine melilitites are produced in intraplate volcanoes (Hoernle and Schmincke, 1993; Maaløe et al., 1992). They correspond generally to post-erosional, late units (Brey, 1978). In the vicinity of the African continent, olivine melilitites have been collected in Gran Canaria (Brey, 1978; Hoernle and Schmincke, 1993) and Cape Verde Islands (Brey, 1978). Several authors have highlighted

* Corresponding author.
E-mail addresses: anne-aziliz.pelleter@univ-orleans.fr (A.-A. Pelleter), caroff@univ-brest.fr (M. Caroff).
[1] Present address: UMR CNRS no 7327, Institut des Sciences de la Terre d'Orléans, Université d'Orléans, 1A rue de la Férolerie, 45071 Orléans, France.

http://dx.doi.org/10.1016/j.lithos.2014.09.012
0024-4937/

the chemical resemblance, for incompatible trace element and isotopic ratios, between (olivine) melilitites and ocean island basalts (OIB), sometimes with a HIMU (or high μ, where $\mu = {}^{238}U/{}^{204}Pb$) affinity (Janney et al., 2002; Rogers et al., 1992; Wilson et al., 1995).

The Comores archipelago, composed of four volcanic islands (Mayotte, Anjouan, Moheli, and Grande Comore) is located in the Mozambique Channel between the continental blocks of Africa and Madagascar (Fig. 1). The initial volcanism period of the oldest island – Mayotte – onto the ocean floor is estimated to be ca. 15–10 Ma (Nougier et al., 1986), whereas the Karthala volcano of Grande Comore (the youngest island) is still active.

The mantle beneath the Comores is probably metasomatized, with modal amphibole and/or phlogopite (Class and Goldstein, 1997; Späth et al., 1996). In fact, Coltorti et al. (1999) evidenced a CO_2-related cryptic metasomatism episode beneath Grande Comore. The origin of the Comores volcanism is attributed by Hajash and Armstrong (1972) and Emerick and Duncan (1982) to the upwelling of a mantle plume. Nougier et al. (1986) proposed that the Comorian magmas derive from the upper mantle, beneath an ocean–continent transitional crust structured by old and deep lithospheric fractures, which were reactivated during the late Tertiary. Four Comores lavas – one sample from Moheli and the three analyzed samples from Anjouan (Reisberg et al., 1993; Salters and White, 1998; Späth et al., 1996) – have a more radiogenic Pb composition than the other Indian OIB. They display an isotopic signature close to that of the Atlantic islands near the western African coast, as Cape Verde and Canary Islands (Sushchevskaya et al., 2013).

The present study of Mayotte Island (Comores archipelago), based on new petrological and geochemical data, reveals the coexistence of a large number of melilite-bearing (including olivine melilitites) and HIMU-like lavas (with ${}^{206}Pb/{}^{204}Pb > 20$). Mayotte Island is thus a good example for studying the genesis of melilite-bearing lavas and their relation with a specific mantle composition.

2. Geological setting

Mayotte is the oldest island of the Comores archipelago (Fig. 1), emplaced, while intraplate, in an active tectonic area. The present-day geography of the area is the consequence of the Permian–Trias Karoo NW-SE rifting, which resulted in the separation between Gondwana and Indian–Madagascan continental blocks (Malod et al., 1991; Piqué, 1999). The oceanic basins of Somalia and Mozambique opened during the Jurassic, while the Madagascar Island drifted southwards along the Davie Ridge. The main part of the sedimentary products in the Mozambique Channel results from the erosion of the Davie Ridge builded during an Eocene compression phase (Leclaire et al., 1989). Since the middle Miocene, the tectonic regime in the Mozambique Channel is dominated by E-NE–W-SW extension, also identified in the East African Rift and in Madagascar (Bertil and Regnoult, 1998; Piqué, 1999).

Although the volcano morphology in the Comores archipelago is rather consistent with a chronological progression of the volcanism northwestwards (freshest reliefs in Grande Comore; presence of a coral reef only in Mayotte and, to a less extend, in Moheli: Fig. 1), the K–Ar geochronological data of the archipelago suggest a more complex history (Fig. 1). With the exception of Grande Comore, in which old lavas do not crop out, each island displays a Neogene volcanic activity (shield stage?) together with a more recent one. The oldest subaerial lavas of the archipelago are found in Mayotte, consistently with its eroded morphology and the presence of a large coral reef. Only one coarse-grained rock of Anjouan is older (11.1 ± 0.5 Ma, Nougier et al., 1986), very different from the shield lavas (from 3.9 ± 0.3 Ma to 1.5 ± 0.2 Ma, Nougier et al., 1986). However, no dating is available for the rocks constituting the submarine flanks of the islands. It is therefore very difficult to reasonably establish, or not, a chronological progression of volcanism throughout the archipelago.

Mayotte is located 300 km westward of Madagascar and 70 km southwestward of Anjouan (Fig. 1). It is constituted of two main volcanic islands (Grande Terre and Petite Terre: 348 km² and 16 km² in surface, respectively) and around twenty islets, within a lagoon of 1100 km² bordered by a 160 km-long coral reef (Fig. 2a). Grande Terre is a north-south lengthened island, culminating at 660 m (Bénara Mount). The emerged reliefs correspond to the superstructure of two coalescent eroded shield volcanoes, subsiding for 1.5 Ma (Debeuf, 2004; Nehlig et al., 2013). Petite Terre is a 5 km-long island located 4 km eastward of Grande Terre (Fig. 2d).

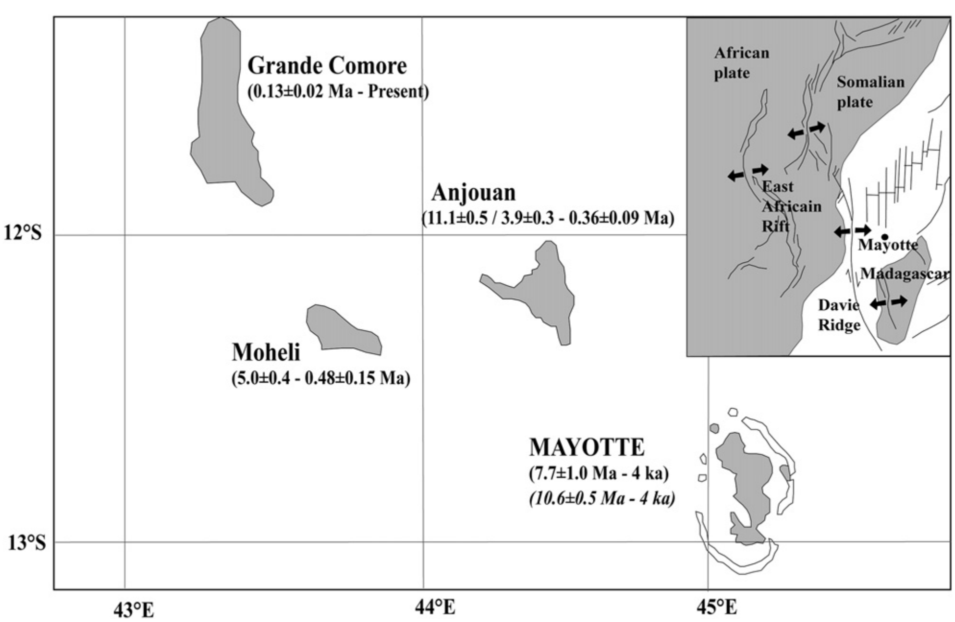

Fig. 1. The Comores archipelago. K–Ar age ranges are indicated for each island: Grande Comore (2 data by Hajash and Armstrong (1972) and Emerick and Duncan (1982)); Moheli (12 data by Emerick and Duncan (1982) and Nougier et al. (1986)); Anjouan (8 data by Hajash and Armstrong (1972); Emerick and Duncan (1982) and Nougier et al. (1986)); Mayotte (34 data by Hajash and Armstrong (1972); Emerick and Duncan (1982) and Nougier et al. (1986), and one relative age determined by Zinke et al. (2003), for a pumice layer interbedded in the lagoon stratigraphic succession). The value of 11.1 Ma of Anjouan corresponds to a remote value measured on a syenitic xenolith. The Mayotte new age range of Table 1 is indicated in italic. Inset: Mayotte in its geodynamical context.