Journal of Volcanology and Geothermal Research xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Journal of Volcanology and Geothermal Research

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

Softening of sub-continental lithosphere prior rifting: Evidence from clinopyroxene chemistry in peridotite xenoliths from Natash volcanic province, SE Egypt

M.A. Abu El-Rus [a,*], G. Chazot [b], R. Vannucci [c], H.A. Gahlan [a,1], G.Y. Boghdady [d], J.-L. Paquette [e]

[a] Geology Department, Faculty of Science, Assiut University, 71516, Egypt
[b] Université de Brest (UBO), UMR 6538, Domaines Océaniques, Institut Universitaire Européen de la Mer, place Copernic, 29280 Plouzané, France
[c] Dipartimento di Scienze della Terra e dell'Ambiente, Università di Pavia, Via Ferrata, 127100 Pavia, Italy
[d] Mining Department, Faculty of Engineering, Assiut University, Assiut 71516, Egypt
[e] Laboratoire Magmas et Volcans, Université Blaise Pascal – OPGC, 63038 Clermont-Ferrand, France

ARTICLE INFO

Article history:
Received 19 December 2015
Received in revised form 23 June 2016
Accepted 15 July 2016
Available online xxxx

Keywords:
Sub-continental lithosphere
Carbonatite metasomatism
Chromatographic enrichment
Thermal gradient
Mantle plumes

ABSTRACT

Major and trace element compositions were determined for well-preserved diopside relics in highly altered mantle xenoliths from Natash volcanic province, south Eastern Desert of Egypt, to unravel the major magmatic processes that occurred within the lithospheric mantle long time before the Red Sea rift. The diopside shows a limited compositional range as for mg# (0.89–0.92), Al_2O_3 (3.52–5.60 wt%), andTiO_2 (0.15–0.35 wt%), whereas it is characterised by a larger variability as for Na_2O (0.23–1.83 wt%) and, in particular the trace elements. The latter identify two main diopside types: 1) CPX-I has low abundances of incompatible elements, spoon-like REE patterns, small negative anomalies in Ti and Zr and a positive anomaly in Sr; and 2) CPX-II has high abundances in incompatible elements, REE patterns with steady enrichment from HREE to LREE patterns and marked negative anomalies in Ti and Zr. The range of REE patterns in the mantle section can be explained by 7–22% batch melting of the primitive mantle followed by varying degrees of trace element chromatographic exchange. CPX-I underwent only small-scale reactive porous flow metasomatism at the percolation front, whereas CPX-II resulted from large-scale rock–melt interaction close to the melt source. Trace element abundances of CPX-II suggest equilibration with carbonatite-like melts that bear close similarities with the carbonatites that enriched the lithosphere in the southern part of the Arabian plate. The similarity of the P-T gradients recorded by the Natash and southern part of Arabian lithospheres, as well as their re-fertilisation by similar, carbonatite-like agents, is consistent with the presence of a mantle plume at the base of the lithosphere after accretion of the Arabian-Nubian Shield in Late Precambrian. The plume material was fossilized due to secular cooling and became part of the lithospheric mantle before the eruption of the Natash volcanic in Late Cretaceous.

1. Introduction

One of the most important rift zones on Earth is the Red Sea region that records all the evolutionary stages from early rift-fracture stage to seafloor spreading. The Arabian-Nubian Shield (ANS) bounding the Red Sea is characterised by the occurrence of several dispersed small- to medium size intra-plate lava provinces that sometimes brought to the surface a wide variety of crust and mantle xenoliths (e.g. Kuo and Essene, 1986; McGuire, 1998a,b; Nasir et al., 1992; Chazot et al., 1996, 1997; Ali and Arai, 2007; Krienitz and Haase, 2011). Though most of these lavas are not related to rift structures, their occurrence is clearly related to the continental rifting (e.g. Almond, 1986a,b; Bell and Tilton, 2001; Mohamed, 2001; Kieffer et al., 2004; Furman et al., 2006a,b; Furman, 2007; Lucassen et al., 2008; Endress et al., 2011). Therefore, the study of xenoliths from the intra-plate eruptions in ANS is of particular interest to unravel the lithosphere-asthenosphere interactions which occurred since the ANS accretion in Late-Proterozoic and preceding or accompanying the Red Sea rifting in the last 30 Myr (e.g. El-Gaby et al., 1988; Blusztajn et al., 1995).

Natash volcanics in southeastern Egypt (~90 Ma, Hashad and El-Reedy, 1979) form one of the extensive alkaline lava provinces (Fig. 1) related to continental rifting in the east Africa (Higazy and El-Ramly, 1960; El-Gaby et al., 1988; Madani, 2000; Mohamed, 2001). Within this volcanic province, a suite of anhydrous spinel-peridotite mantle xenoliths is found in some olivine basalt flows (Madani, 2000). Despite the fact that these xenoliths are largely serpentinized and altered to various degrees into carbonate, large parts of clinopyroxene and, at less extent, Cr-spinel are

* Corresponding author at: Geology Department, Assiut University, Assiut 71516, Egypt.
E-mail address: aliabuelrus@yahoo.com (M.A. Abu El-Rus).
[1] Present address: Geology and Geophysics Department, College of Science, King Saud University, Kingdom of Saudi Arabia.

http://dx.doi.org/10.1016/j.jvolgeores.2016.07.004
0377-0273/© 2016 Elsevier B.V. All rights reserved.

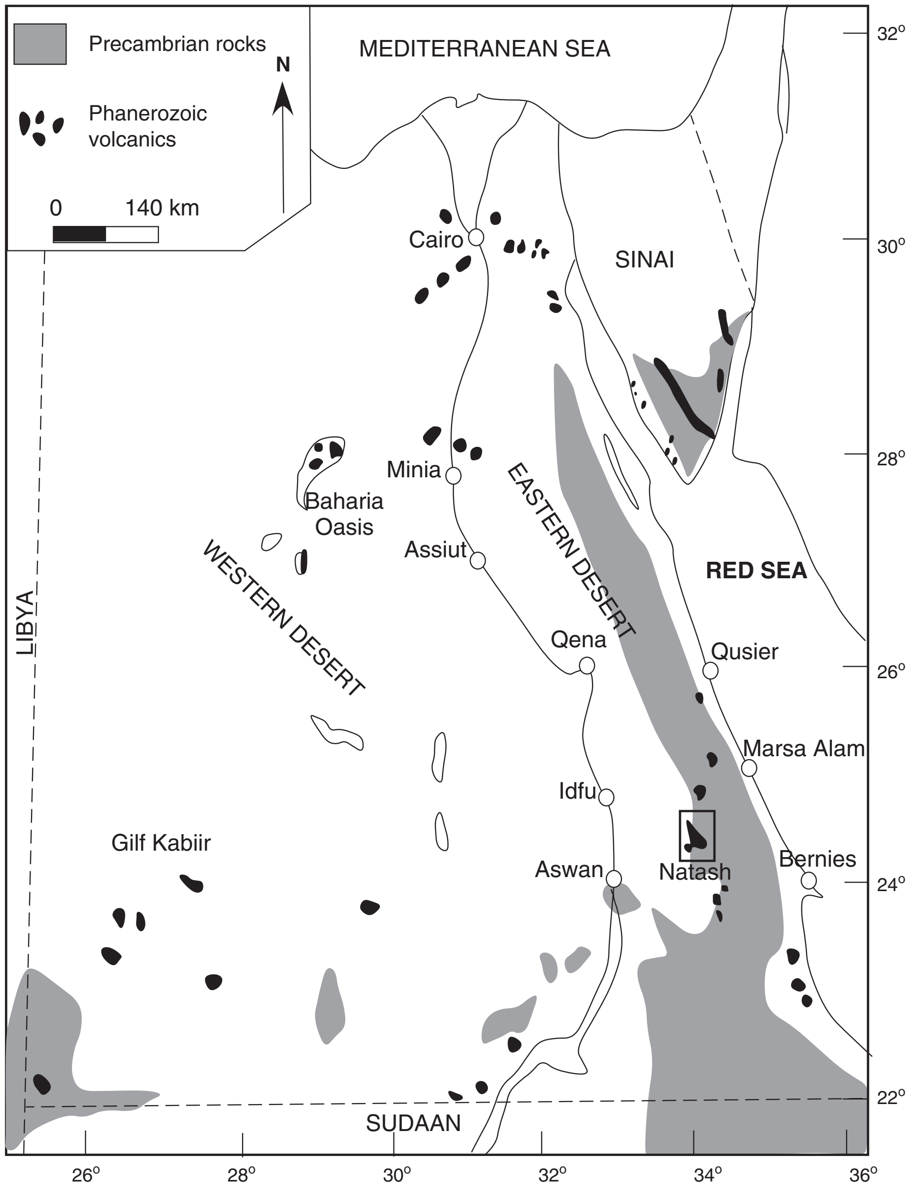

Fig. 1. Map showing the locations of main Phanerozoic intraplate basalt eruptions in Egypt. The locations are taken from CONOCO (1987), Franz et al. (1987), Moghazi (2003) and field work of first author.

still preserved. As clinopyroxene is the main trace element carrier in anhydrous spinel peridotites (e.g. Johnson et al., 1990; Bizimis et al., 2000; Pearson et al., 2004), its trace element composition may provide valuable information on the mantle processes such as melting, metasomatism and subsolidus re-equilibration (e.g. Rivalenti et al., 1996). Moreover, clinopyroxene relics may preserve high temperature chemical signatures even if the remaining peridotite mineral assemblage has been severely altered (Machado et al., 1986; Johnson et al., 1990; Johnson and Dick, 1992; Bizimis et al., 2000). Therefore, we used the composition of clinopyroxene from Natash peridotites to unravel the evolutionary processes that this lithospheric mantle sector underwent through time. The data, together with theoretical modelling, are used to put constrain on the mechanisms of mantle depletion and metasomatism as well as to define the nature and the sources of the metasomatic components that refertilised the lithospheric mantle. To constrain the geodynamic model for the evolution of lithospheric mantle beneath Nubian-Arabian plate before the Red Sea rifting, the present data for Natash clinopyroxene will be discussed in the framework of available knowledge on mantle xenoliths from rift-related lavas in the surrounding areas.

2. Geological setting

The Wadi Natash volcanic province is the largest Mesozoic exposure of volcanic rocks (560km^2, Crawford et al., 1984) in Egypt. The province is located at about 125 km NE of Aswan (Fig. 1) and consists of a thick plateau of stratified lava flows that are intercalated with the Cretaceous Nubian Sandstones (Hashad et al., 1982; Crawford et al., 1984; Madani, 2000; Mohamed, 2001), which bound the province from west, north and partly south (Fig. 2). To the east and locally south, the Natash volcanic province is juxtaposed directly against basement rocks by high angle normal faults. The volcanic pile in the Natash province was subdivided into three distinct flow units separated by two sequences of volcanoclastic sediments or by basal polymictic conglomerate beds, indicating temporal breaks in the pouring of magma eruptions (Crawford et al., 1984; Madani, 2000; Mohamed, 2001). Locally, the upper flow unit is capped from the east by a third volcanoclastic unit that may be covered by trachyte flows (Crawford et al., 1984). Each of the three flow units shows a gradual change in composition upwards from grey-green, porphyritic alkali olivine basalt to vesicular black, generally porphyritic, mugearite/benmoreite.

Please cite this article as: Abu El-Rus, M.A., et al., Softening of sub-continental lithosphere prior rifting: Evidence from clinopyroxene chemistry in peridotite xenoliths from Natash ..., J. Volcanol. Geotherm. Res. (2016), http://dx.doi.org/10.1016/j.jvolgeores.2016.07.004