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Neoproterozoic contaminated MORB of Wadi Ghadir ophiolite, NE Africa: Geochemical and Nd and Sr isotopic constraints

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ABSTRACT

The ophiolitic metabasalts (pillowed and sheeted dikes) of Wadi Ghadir area, Eastern Desert, Egypt, were analyzed for their major, trace and rare earth elements, Nd and Sr isotopes and the chemistry of their plagioclase, amphibole and chlorite was also reported. Geochemically these rocks range from tholeiitic basalt to basaltic andesite. The generally low MgO, Cr and Ni and high Zr contents are consistent with derivation of these rocks from an evolved magma. The high TiO_2 contents (mostly between 1.76% and 2.23%) classify Wadi Ghadir ophiolitic metabasalts as MORB ophiolite. The chondrite-normalized REE patterns of most samples display small LREE-enrichment with $(La/Yb)_n$ ranging from 1.44 to 2.56. The MORB-normalized spider diagram shows variable LILE abundances, which are either similar to or enriched relative to MORB, and most samples display small Nb depletion. The abundances of some LILE (Ba, Rb and K) as well as Na and Si were modified by post-magmatic seafloor hydrothermal alteration. Enrichment of the least mobile LILE (Th & U) indicates that Wadi Ghadir ophiolitic metabasalts are akin to C (contaminated)-MORB. These geochemical characteristics are similar to BABB modified by contamination.

Wadi Ghadir metabasalts have low initial Sr ratios (0.7010–0.7034) which are similar to those of MORB, while their $\varepsilon_{Nd(t)}$ values (+7.7–+4.5) are either more or less positive than the value of depleted mantle (DM). The more positive $\varepsilon_{Nd(t)}$ values indicate DM source for these basalts, while the less positive $\varepsilon_{Nd(t)}$ values reflect the involvement of slightly older component in Wadi Ghadir ophiolite. We suggest that the parent magma of metabasalts was contaminated by slightly older material, most probably oceanic-arc crustal rocks, which caused enrichment in LREE, and by analogy LILE, but did not significantly affect Nd isotopic systematics or modify Sr isotopes.

Such contaminated MORB character also revealed by other ophiolitic metavolcanics in the Central Eastern Desert, contrasting the N-MORB character of the Gerf ophiolite in the South Eastern Desert. Moreover, the present work suggests the increase of the degree of contamination of the ophiolitic metabasalts from south to north in the Central Eastern Desert.

1. Introduction

According to Robertson (2002), an ophiolite is "an oceanic magmatic complex comprising ultramafic rocks at the base, with variable amounts of harzburgite, lherzolite and dunite (commonly serpentinized), overlain by layered/non-layered gabbroic rocks, then by mainly basaltic extrusive rocks, with, or without, a sheeted dike complex, and including a cover of pelagic deep-sea sediments". Neoproterozoic ophiolites are abundant in the Arabian–Nubian Shield (ANS) of NE Africa and Arabia and range in age from 690 to 890 Ma (Stern et al., 2004). The Precambrian rocks of the Eastern Desert of Egypt represent the northern tip of the Nubian Shield. Ophiolites of Egypt are mainly dismembered (Basta et al., 1983; Ries et al., 1983; Zimmer et al., 1995; Farahat et al., 2004) and restricted to the Central and Southern Eastern Desert. These ophiolites are interpreted to be formed in back-arc (e.g. Basta et al., 1983; Berhe, 1990; El-Sayed et al., 1999; Takla et al., 2002; Abd El-Rahman et al., 2009), or fore-arc setting (Azer and Stern, 2007). Among the ANS ophiolites, the Gerf complex is the only Precambrian ophiolite with N-MORB chemistry, where the pillowed basalts and sheeted dikes originally formed in a major ocean basin (Zimmer et al., 1995).

Wadi Ghadir ophiolite is one of the best preserved sections through late Proterozoic upper oceanic crust anywhere in the world (Kröner et al., 1992). It is located in the southern part of the Central Eastern Desert south of Mersa Alam town (Fig. 1).

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The ophiolite of Wadi Ghadir area comprises ultramafic rocks, gabbroic rocks, sheeted dikes and pillowed basalts (El-Sharkawy and El-Bayoumi, 1979; Basta, 1983). The ophiolitic metavolcanics of Wadi Ghadir are interpreted to be developed at oceanic spreading centers (El-Bayoumi, 1980), in back-arc setting (Basta, 1983; Abd El-Rahman et al., 2009), or in continental back-arc basin (Farahat et al., 2004). El-Bayoumi (1980) suggested that Wadi Ghadir basalts are more differentiated than typical MORB and believed that they are plume basalts which originated from stratified and enriched low velocity zone at the initiation of spreading. Farahat et al. (2004) concluded that these ophiolitic metabasalts have transitional within-plate basalt to island-arc basalt features, which are characteristic of basalts formed in continental back-arc basins. Moreover, they suggested that such rocks were originated through mixing between a depleted mantle-derived magma and an enriched crustal melt at crustal levels, somewhat similar to an AFC (assimilation and fractional crystallization) process.

There is a debate about the involvement of pre-Neoproterozoic crustal materials in the juvenile igneous rocks of the ANS (Stacey and Hedge, 1984; Pallister et al., 1988; Hargrove et al., 2006; Küster et al., 2008; Ali et al., 2009; Liégeois and Stern, 2010). In the present work we present new major, trace and REE analyses, mineral chemistry (plagioclase, amphibole and chlorite), and first time Sr and Nd isotopes of the ophiolitic metabasalts (pillowed and sheeted dikes) of Wadi Ghadir area (Wadi El-Beda and Gabal Ghadir). On the basis of these data the geotectonic setting of

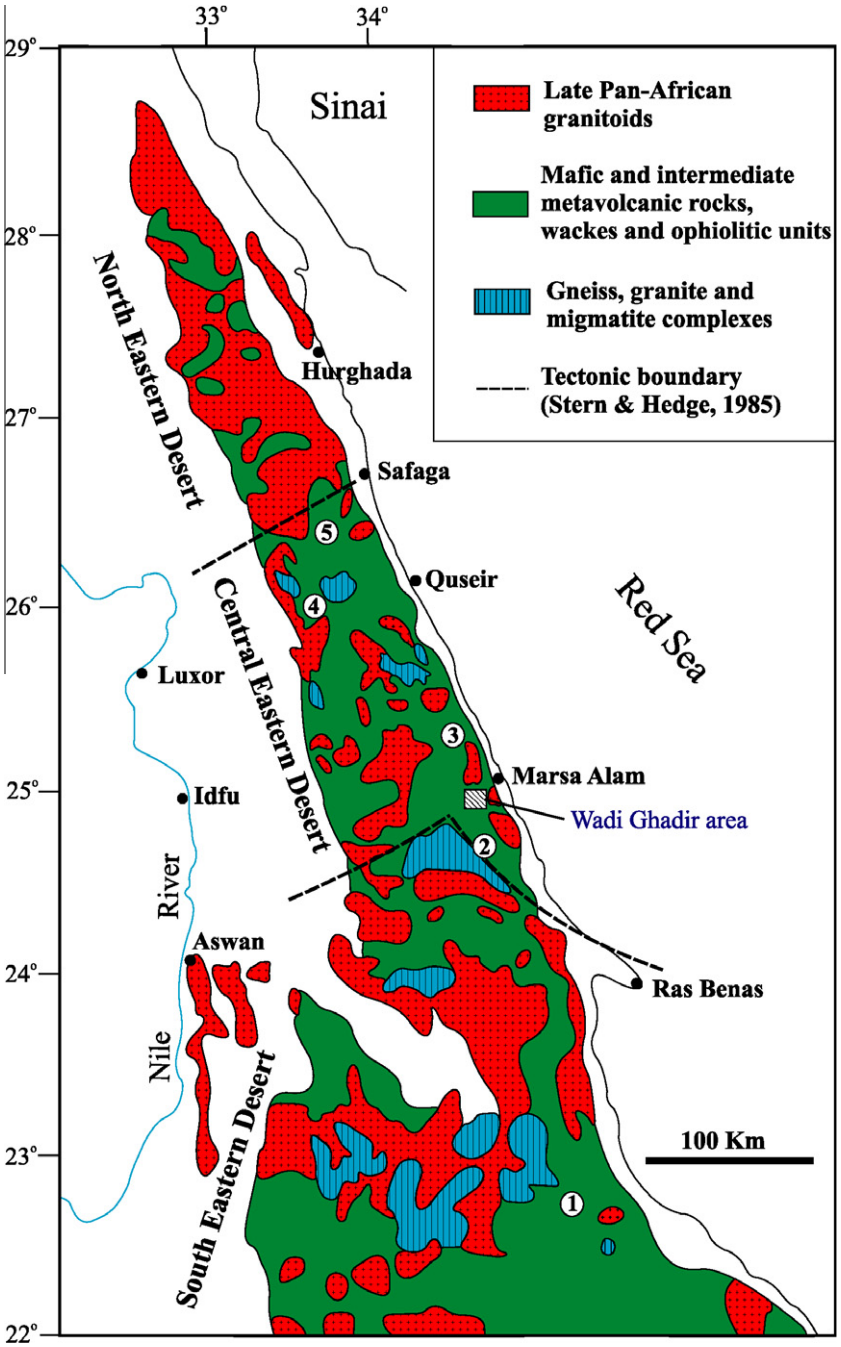

Fig. 1. A map for the Precambrian rocks of the Eastern Desert of Egypt (after Liégeois and Stern (2010)) with the location of Wadi Ghadir area and some ophiolitic metabasalts used in Section 8. 1. Gabal Gerf; 2. Wadi El Gemal; 3. Wadi Beririq; 4. El-Sid; 5. Abu Marawat. (See above-mentioned references for further information.).