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Petrogenesis of Bir Madi Gabbro-Diorite and Tonalite-Granodiorite Intrusions in Southeastern Desert, Egypt: Implications for Tectono-Magmatic Processes at the Neoproterozoic Shield

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Abstract. The Neoproterozoic rocks of the Bir Madi area, south eastern desert, comprise a Metagabbro-Diorite Complex (GDC) and a Tonalite-Granodiorite Suite (TGrS). The GDC has a weak tonalitic to strong calc-alkaline character and is made up of olivine gabbro, hornblende gabbro, diorite and monzodiorite. The olivine gabbro is characterized by abundance of augite and labradorite with pseudomorphic serpentine. The hornblende gabbro is mainly composed of hornblende, labradorite, andesine and minor amounts of quartz with or without augite. The diorite consists essentially of andesine, hornblende, biotite and quartz. The GDC is compositionally broad, with a wide range of SiO_2 (46-57 %) and pronounced enrichment in the LILE (Ba and Sr) relative to the HFSE (Nb, Y and Zr). The GDC rocks exhibit petrological and geochemical characteristics of arc-related mafic magmas, derived possibly from partial melting of a mantle wedge above an early Pan-African subduction zone of the Neoproterozoic Shield. The tonalite and granodiorite have a calc-alkaline affinity and show the geochemical signatures of I-type granitoids. The TGrS contains amphibolite enclaves and foliated gabbroic xenoliths. Based on the field evidence and geochemical data, the GDC and TGrS are not related to a single magma type through fractional crystallization. The presence of microgranular amphibolite enclaves in the tonalitic rocks suggest against their generation by partial melting of a mantle-derived basaltic source. The tonalitic magma originated from partial melting of an amphibolitic lower crust by anatexis process at a volcanic arc regime during construction of the Arabian-Nubian Shield. Fractional crystallization of K-feldspar and biotite gave more developed granodiorite variety from the tonalitic magma. The gabbroic xenoliths are similar in the chemical composition to the investigated metagabbros. They are incompletely digested segments from the adjacent metagabbro rocks incorporated into the granitic magma through an assimilation process.

Introduction

The Neoproterozoic rocks of the eastern desert, Sinai, northern Sudan and western Saudi Arabia are collectively termed the Arabian-Nubian Shield (ANS) (Gass, 1981). The ANS is considered as one of the best examples of crustal growth through terrain accretion of intra-oceanic mantle-derived magmas, initial island arcs and micro-continents during the 950-550 Ma Pan-African event (Vail, 1983). It thus, represents juvenile arc development by subduction-related accretion in an oceanic environment (Stern, 1994). The occurrence of ophiolitic sutures and their association with voluminous calc-alkaline rocks have led most investigators to agree that the shield regions evolved by juxtaposition of a series of island arcs with later development of continental magmatic arcs (Abdel-Rahman and Martin, 1987). The Pan-African crustal components of the eastern desert consist mainly of gneisses, ophiolitic serpentinites and metagabbros with tholeiitic metabasalts, metasediments, island arc metavolcanics and metagabbro-diorite, older granitoids, Dokhan volcanics, Hammamat sediments, younger gabbros and younger granitoids (El-Gaby et al., 1988).

The Neoproterozoic gabbroic rocks of Egypt have been subdivided in various ways (Basta and Takla, 1974; Takla et al., 1981; Ghoneim et al., 1992; El-Sheshtawi et al., 1995; Basta, 1998; Khalil, 2005). These rocks are essentially classified as older and younger gabbros (Takla et al., 1981). The older gabbros are regionally metamorphosed and are considered as a member of ophiolitic sequence (i.e. ophiolitic metagabbro: El-Sharkawi and El-Bayoumi, 1979) or island arc assemblage. The syntectonic gabbro-diorite intrusives have a calc-alkaline affinity and are interpreted to be belonging to island arc association (El-Gaby et al., 1990). The emplacement of the gabbro-diorite plutonisms occurred at around 987-830 Ma (Hashad, 1980; Abdel-Rahman and Doig, 1987). Thus, they represent the earliest phase of crustal growth in the Nubian Shield of Egypt (Abdel-Rahman, 1990). The younger gabbros occur as small, fresh, unmetamorphosed intrusions comprising norite, norite-gabbro, olivine gabbro and troctolite varieties (Basta and Takla, 1974). These gabbros mainly represent the late tholeiitic/ calc-alkaline, post-tectonic mafic magmatism of the Pan-African event, which was emplaced before the younger granitoids (Hassan and Hashad, 1990).

Granitoid rocks constitute a major component of the basement outcrop in Egypt (40%), which in general are classified into two main distinct groups: older and younger granitoids (Akaad and Noweir, 1980). According to Harris et al. (1984) and Stern and Hedge, (1985), the older granitoids comprise syn-tectonic calc-alkaline tonalite-