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Geochemical signature variation of pre-, syn-, and post-shearing intrusives within the Najd Fault System of western Saudi Arabia

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ABSTRACT

Late Precambrian intrusive rocks in the Arabian–Nubian Shield emplaced within and around the Najd Fault System of Saudi Arabia feature a great compositional diversity and a variety of degrees of deformation (i.e. pre-shearing deformed, sheared mylonitized, and post-shearing undeformed) that allows placing them into a relative time order. It is shown here that the degree of deformation is related to compositional variations where early, usually pre-shearing deformed rocks are of dioritic, tonalitic to granodioritic, and later, mainly post-shearing undeformed rocks are mostly of granitic composition. Correlation of the geochemical signature and time of emplacement is interpreted in terms of changes in the source region of the produced melts due to the change of the stress regime during the tectonic evolution of the Arabian–Nubian Shield. The magma of the pre-shearing rocks has tholeiitic and calc-alkaline affinity indicating island arc or continental arc affinity. In contrast, the syn- and post-shearing rocks are mainly potassium rich peraluminous granites which are typically associated with post-orogenic uplift and collapse. This variation in geochemical signature is interpreted to reflect the change of the tectonic regime from a compressional volcanic arc nature to extensional within-plate setting of the Arabian–Nubian Shield. Within the context of published geochronological data, this change is likely to have occurred around 605–580 Ma.

1. Introduction

Granitic magmatism and tectonic extension play an important role in the stabilization of cratonic crust (Schöne et al., 2008). The Arabian–Nubian Shield was formed during the collision between East and West Gondwana and was stabilized in the Neoproterozoic by intrusion of abundant plutons of mainly granitic composition (Patchett and Chase, 2002; Stern et al., 2004). The cratonization process of the Arabian–Nubian Shield was also associated with the formation of the largest pre-Mesozoic shear zone on Earth: the Najd Fault System (Stern, 1985; Abu-Alam et al., 2013).

The Najd Fault System extends for several thousand kilometers cutting across the entire shield from the Arabian part to the Nubian part across the Red Sea (Stern et al., 2004; Fig. 1a). The activity of the shear zone occupied the last 90 myr of the Pan-African orogeny when the tectonic regime changed from compression to transpression and finally to extension (Kröner and Stern, 2004). Cross-cutting relationships between the intrusive rocks and the Najd Fault System constrain the relative age of the intrusion to the activity of the shear zone. The geochemical and isotopic characteristics of the intrusive rocks offer therefore the possibility to follow the change in the tectonic setting during the activity of the Najd Fault System.

To provide an overview over the change in the stress regime and the tectonic setting during the Najd Fault System activity, intrusive rocks were sampled from different plutons that intrude, and/or are deformed, by the branches of the Najd Fault System, in particular, the Ajjaj–Qazaz shear zone of western Saudi Arabia. These rocks are studied petrologically and geochemically. The field relations between these plutons and the shear zone will be discussed to constrain the relative age to the shearing and the changes in geochemical signature are used to constrain changes in the tectonic setting. Our tectonic model is then correlated with existing geochronological ages from the region and elsewhere in the Arabian–Nubian Shield.

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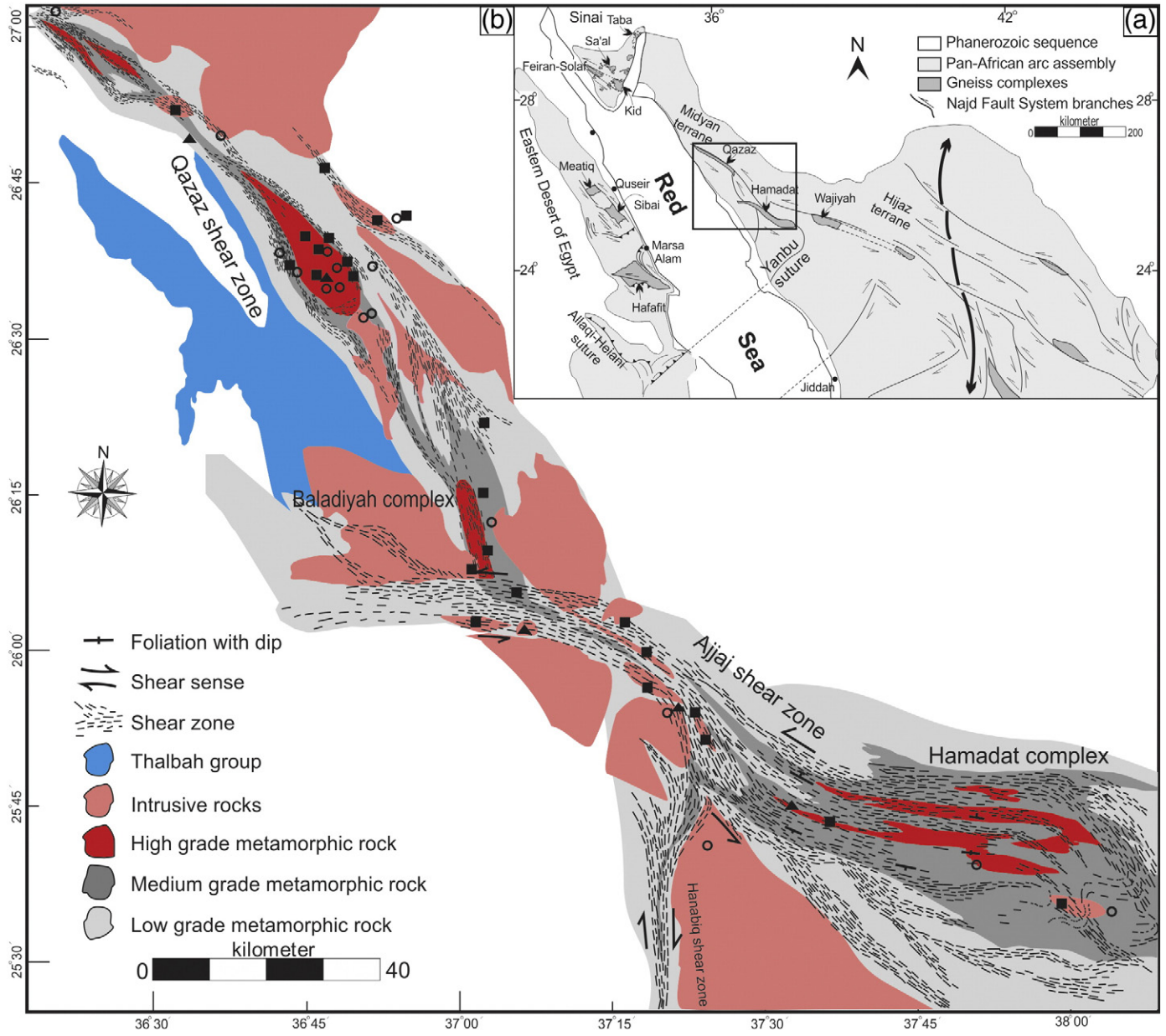

Fig. 1. a) Geometry of the Arabian–Nubian Shield with location of Ajjaj–Qazaz shear zones in relation to the Najd Fault System as a whole. The location of study area is marked in the inset with box (modified after Abu-Alam and Stüwe, 2009). b) Deformation and metamorphic map with foliation traces of the Ajjaj–Qazaz shear zone with illustration of the main intrusive plutons and sample location (samples are shown as solid triangles and open circles for the pre-shearing deformed diorite and granodiorite–tonalite rocks, respectively; filled squares represents the syn- and post-shearing granitic rocks). Symbols are the same in all figures.

2. Geological setting

The Arabian–Nubian Shield is made up of juvenile crust composed of mostly low-grade metasedimentary and metavolcanic rocks that were derived from oceanic island arc volcanism (Collins and Pisarevsky, 2005; Hargrove et al., 2006; Stern, 2002, 2008; Ali et al., 2010; Stern and Johnson, 2010). It contains a few percent of dismembered ophiolites that were derived from the Proterozoic Mozambique ocean floor (Abu-Alam and Hamdy, 2014). Also high-grade metamorphic rocks exhumed from underneath this sequence occur as tectonic windows in both extensional settings (Greiling and Rashwan, 1994; Fritz et al., 1996) and in compressional settings (Abu-Alam and Stüwe, 2009; Meyer et al., 2014). The entire sequence is unconformably overlain by non- to weakly metamorphosed, deformed molasse sediments (known as the Hammamat Group in the Nubian side of the shield and as Thalbah Group in the Arabian side), which were deposited in the Ediacaran in terrestrial post-amalgamation basins (Shalaby et al., 2006; Abd El-Wahed, 2010; Genna et al., 2002). The whole succession was formed during the Pan-African orogeny which involved the breakup of Rodinia and the subsequent collision between East and West Gondwana (Fritz et al., 2013; Abu-Alam et al., 2013). The Neoproterozoic collision is associated with a variety of tectonic processes including subduction, terrane accretion, and continental collision and rifting (Johnson et al., 2011). Magma generation and intrusion of plutonic rocks were associated with each individual tectonic process.

These plutons have different chemical compositions ranging from gabbroic to granitic composition but granitoid plutons represent the majority of these bodies. Traditionally, based on the abundant studies that have been performed in the Egyptian part of the shield, these intrusives in the Arabian–Nubian Shield are classified into two