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U–Pb detrital zircon provenance of the Saramuj Conglomerate, Jordan, and implications for the Neoproterozoic evolution of the Red Sea region

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ABSTRACT

The latest stage in the evolution of the northernmost Arabian-Nubian Shield is characterized by the development of volcano-sedimentary successions. In Jordan the Saramuj Conglomerate Formation is considered to be one of these post-tectonic basins. It is polymict and poorly sorted with wide range of clast compositions, roundness and size. We present the first SIMS U–Pb dating of detrital zircons from two sandstone samples representative for the conglomerate matrix and of four clasts from the Saramuj Conglomerate for provenance and age determinations. The relative probability curve for the matrix samples indicates a major contribution (85%) from c. 600 to 650 Ma, subclusters at 624 and 640 Ma, a minor source from 700 to 750 Ma, and a clear gap between 650 and 700 Ma. These ages are consistent with those obtained from andesitic, rhyodacitic, granitic and gneiss clasts (624, 642, 650 and 734 Ma respectively). In contrast to the adjacent volcano-sedimentary successions in the Elat area, Sinai and the Eastern Desert, no ages older than 750 Ma were found. The good match between the known ages of the nearby exposed basement with the matrix ages and the immature nature of the sediments implies that the principal input was locally derived erosional detritus. The age of the youngest 10 detrital zircons at c. 615 Ma represents the maximum age of deposition, which is consistent with the stratigraphic position of the Saramuj Conglomerate. Clast ages of 642 Ma and 650 Ma are interpreted as evidence for a magmatic source that has not been recognized in SW Jordan. This study implies that the volcano-sedimentary successions in the northernmost Arabian-Nubian shield may be broadly coeval but have distinct provenance and therefore evolved as isolated basins. Furthermore, U–Pb zircon provenance analysis allows us to recognize igneous products that are no longer preserved and/or exposed in the region.

1. Introduction

The northernmost exposures of the Arabian-Nubian Shield (ANS) occur in the basement complexes of Jordan (Fig. 1). The ANS is a collage of juvenile Neoproterozoic crustal fragments derived from intra-oceanic island arcs of the Mozambique Ocean. These were accreted during closure of the Mozambique Ocean, in association with the collision between East and West Gondwana, i.e., during East African Orogeny (Bentor, 1985; Kröner, 1985; Vail, 1985; Stoeser and Camp, 1985; Stern, 1994, 2002; Abdelsalam and Stern, 1996; Stein and Goldstein, 1996; Jarrar et al., 2003; Stoeser and Frost, 2006; Stern and Johnson, 2010). The ANS is bounded to the east and west by pre-Neoproterozoic crust (Stacey and Hedge, 1984; Sultan et al., 1990; Whitehouse et al., 1998, 2001; Abdelsalam et al., 2002; Johanson and Woldehaimanot, 2003; Meert, 2003). The pre-Neoproterozoic crust in the northern part of the ANS has been reworked, as documented by U–Pb zircon geochronology (Sultan et al., 1990; Hargrove et al., 2006; Ali et al., 2009a,b; Be'eri-Shlevin et al., 2009; Breitkreuz et al., 2010; Morag et al., 2011). The tectono-magmatic evolution of the northern part of ANS is divided into two stages: an early part (880–740 Ma) representing the island arc accretion stage (Jarrar, 1985; Kröner et al., 1990, 1994; Bea et al., 2009; Morag et al., 2011, 2012) and a later post-collisional stage (680–580 Ma). The late Neoproterozoic post-collisional stage peaks at 630–620 Ma and is characterized by the intrusion of calc-alkaline and alkaline granitoids (Beyth et al., 1994; Jarrar et al., 2003; Be'eri-Shlevin et al., 2009b; Eyal et al., 2010; Morag et al., 2011). Continental collision resulting from convergence between East and West Gondwana took place between 650 and 625 Ma (Stern, 1994) and is consistent with the age of the youngest deformed granitoids in the northern ANS (630 Ma, Jarrar, 1985; Be'eri-Shlevin et al., 2009b). The transition from a compressional to an extensional setting occurred at 610–600 Ma (Stern, 1994; Garfunkel, 1999; Genna et al., 2002; Jarrar et al., 2003) and was terminated by uplift and

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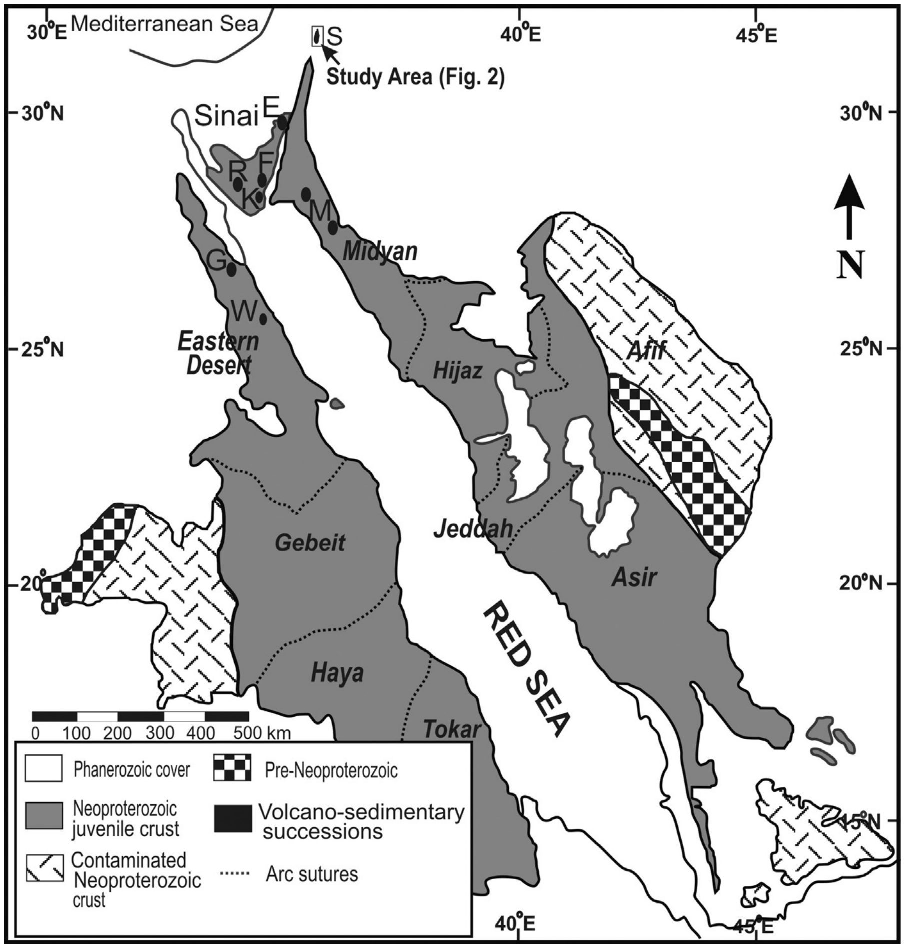

Fig. 1. General map of the Arabian-Nubian Shield including the locations of some volcano-sedimentary successions. S = Saramuj Conglomerate (Jordan), E = Elat Conglomerate (Israel), R = Rutig, K = Kid and F = Ferani successions (Sinai), G = Jebel Um Tawat and W = Wadi Igla (Hammamat-Dokhan deposits, NE desert), M = Minaweh Formation (Midyan terrane, Saudi Arabia); modified after Morag et al. (2011) and references therein).

erosion of the upper continental crust. The ANS became a stable continental region by the early Cambrian at ~542 Ma (Garfunkel, 1999; Johanson and Woldehaimanot, 2003).

A common feature characterizing the final stage of late Neoproterozoic evolution in the northernmost ANS is the presence of volcano-sedimentary sequences (cf. Fig. 1). In the Eastern Desert of Egypt it is represented by the Dokhan volcanics and Hammamat group sediments. The ca. 630–590 Ma Dokhan volcanic rocks are mainly calc-alkaline and intermediate to felsic in composition (Basta et al., 1980; Stern and Gottfried, 1986; Wilde and Youssef, 2000, 2001; Moghazi, 2003; Breitkreuz et al., 2010), while the associated Hammamat group sediments comprise mainly immature terrigenous clastics with abundant conglomerate (Akaad and Noweir, 1969, 1980; Willis et al., 1988; Eliwa et al., 2010). In Sinai volcano-sedimentary successions are exposed in several places and named after their locations, such as Kid-Malhak, Ferani, Rutig, Sa'al-Zaghra, Iqna and Khashabi. They are equated with the Dokhan–Hammamat succession of the Eastern Desert (Shimron, 1980; Bentor, 1985; El-Gaby et al., 1991, 2002; Moussa, 2003; Azer, 2007; El-Bialy, 2010). Recent U–Pb detrital zircon ages from the volcano-sedimentary succession of the Wadi Kid area (620–590 Ma: Samuel et al., 2011; Moghazi et al., 2012) and the Wadi Rutig and Gebel Ferani regions (620–595 Ma: Be'eri-Shlevin et al., 2011) also place them in the same range as the Dokhan-Hammamat succession from the Eastern Desert. In southern Israel U–Pb detrital zircon ages from the Elat conglomerate and associated volcanics (605–580 Ma) are consistent with their correlation to the volcano-sedimentary successions in the Eastern Desert and Sinai (Morag et al., 2012). In northern Saudi-Arabia the ca. 600 Ma (Clark, 1985) Minaweh Formation of the Midyan terrane contains molasse sediments that may also be considered equivalent. In Jordan the volcano-sedimentary succession is represented by the Saramuj Conglomerate Formation and Haiyala Volcanoclastic Formation (Jarrar et al., 1991, 1993). The age of the Saramuj Conglomerate is constrained by the intrusion of a 595 Ma (Jarrar et al., 1993) monzogabbro in Wadi Qunai. Furthermore, the Saramuj Conglomerate unconformably overlies the ~610 Ma (Jarrar, 1985) Turban granite in Wadi Abu Barqa. Correlations with other volcano-sedimentary successions in the northern ANS are unverified. The geodynamic evolution and depositional setting of these volcano-sedimentary successions in the northern ANS are interpreted as the result of NW-SE crustal extension during the latest stages of Pan-African Orogenesis (Blasband et al., 2000).

The introduction of single crystal isotope dating techniques has led to a revolution in provenance studies of clastic sediments. The conglomerates, which record short transport distances in the range of 10 to hundreds km (Ferguson et al., 1996), are particularly useful in tracing proximal sources as has recently been demonstrated by Wanders et al. (2004 and references therein).

We present the first quantitative assessment of Saramuj Conglomerate clast composition and geometry, and secondary ion mass spectrometry (SIMS) U–Pb detrital zircon provenance study of the Saramuj Conglomerate. Zircon ages from the matrix and clasts in the Saramuj Conglomerate reflect the source(s) of its erosional detritus and are therefore likely to relate to magmatic events of the northern ANS. In addition, these provenance results facilitate