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Neoproterozoic SHRIMP U–Pb zircon ages of silica-rich Dokhan Volcanics in the North Eastern Desert, Egypt

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ABSTRACT

Chronology of Neoproterozoic volcanosedimentary successions remains controversial for many regions of the Arabian–Nubian Shield, including the Dokhan Volcanics of NE Egypt. New U–Pb zircon SHRIMP ages have been obtained for 10 silica-rich ignimbrites and two subvolcanic dacitic bodies, mapped as Dokhan Volcanics, from the North Eastern Desert of Egypt. Crystallization ages range between 592 ± 5 and 630 ± 6 Ma (Early Ediacaran). Apparently, the late consolidation of the Arabian–Nubian Shield was accompanied by the evolution of isolated volcanic centres and basin systems which developed during a period of approx. 40 Ma, independently in space and time and probably under changing tectonic regimes. The obtained age data together with other previously published reliable ages for Dokhan Volcanics suggest two main pulses of volcanic activity: 630–623 Ma and 618–592 Ma. Five samples contain inherited zircons, with ages of 669, 715–746, 847 and 1530 Ma, supporting models that North Eastern Desert crust is mainly juvenile Neoproterozoic crust.

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1. Introduction

Outcrops mapped as Dokhan Volcanics (DVs) are abundant in the Eastern Desert of Egypt, especially in the northern part; furthermore outcrops are known from the Sinai peninsula (Fig. 1). The DVs form a part of the Eastern Desert Basement Complex (EDBC) which represents the northwestern segment of the Arabian–Nubian Shield (ANS).

The studied DVs are intercalated with Hammamat Sediments (HS) constituting a thick sequence of Neoproterozoic volcanosedimentary successions in some areas like in Gebel El Urf (Eliwa et al., 2010), Gebel El Kharaza, and Wadi Bali. Other areas like Gebel Mongol are dominated by DVs (Figs. 1 and 2). With respect to the DV outcrops in the northern EDBC, it is still discussed whether these volcanics represent relicts of a larger continuous volcanic province or whether the silica-rich ignimbrites and andesitic lavas formed in separated basin systems distributed in space and time which developed under different tectonic regimes. Another unsolved issue is the relation of the DVs to the abundant Neoproterozoic granitoid complexes in the EDBC.

Precise radiometric ages of the volcanic rocks in the EDBC are an essential prerequisite for a consistent reconstruction of the late consolidation of the ANS. They facilitate a stratigraphic correlation between volcanic centres, a correlation between volcanic and plutonic events, timing of tectonic activity, and a chronostratigraphic allocation of basin development with its sedimentary fill. Furthermore, precise ages of the volcanic rocks help to constrain chronologically paleoclimatic information gained from the so far fossil-free HS.

Previous ages obtained using different dating techniques resulted in a wide spread of data with large uncertainties, often interpreted as long period of DV activity (Bentor and Eyal, 1987; Beyth et al., 1994; Jarrar et al., 2003; Stern, 1979; Stern and Hedge, 1985; Willis et al., 1988). By applying in situ U–Pb geochronology we attempted to produce more accurate and reliable age data for DVs collected from many locations in the NED (Fig. 1) and thus to explore possible regional orogenic and magmatic trends.

Based on Neoproterozoic Nd model ages (Stern, 2002) the ANS is generally accepted as juvenile crust which was formed by amalgamation of intra-oceanic arc/back arcs with subordinate microcontinental plates (e.g. El Sayed et al., 1999; Gass, 1981; Kröner, 1991; Kusky et al., 2003; Pallister et al., 1988; Stern et al., 1988; Stern, 1994; Stoeser and Camp, 1985). There is still no general consensus on the evolution of the ANS from the accretion

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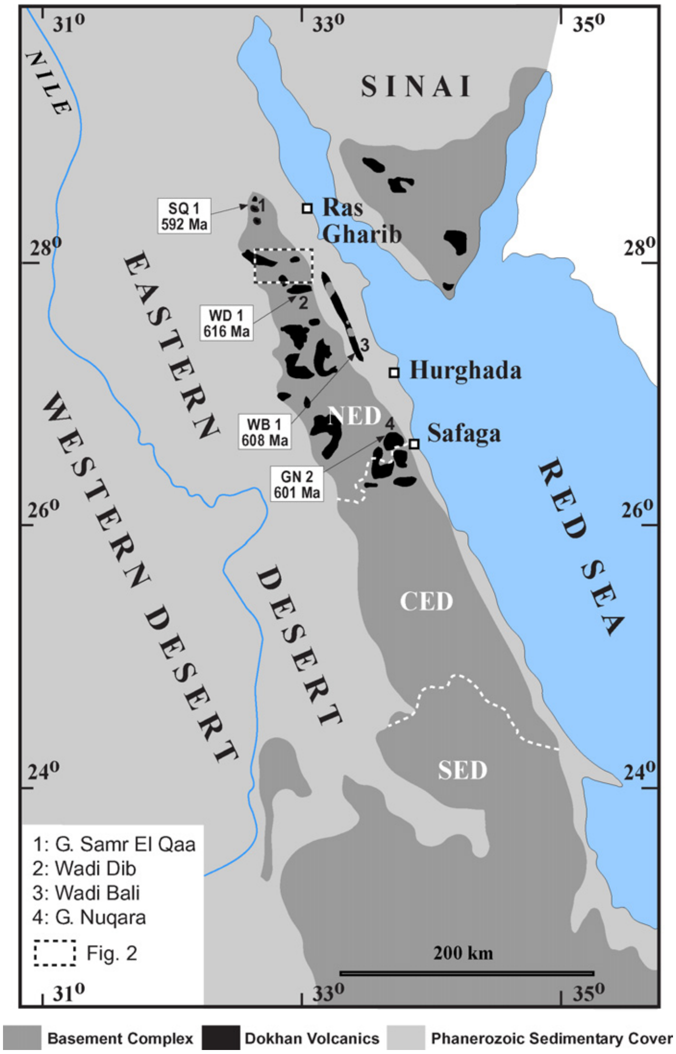

Fig. 1. Regional map of the Egyptian Eastern Desert and Sinai basement complexes. The Dokhan Volcanics (DVs) are displayed as black coloured areas within the remaining dark grey undifferentiated basement areas (modified from Moghazi, 2003). The approximate boundaries between the North Eastern Desert (NED), Central Eastern Desert (CED) and South Eastern Desert (SED) according to Greiling et al. (1994) are shown as dashed lines. Approximate areas of the Phanerozoic sedimentary cover disconformably overlying the basement complex are light grey patches. The numbers 1, 2, 3 and 4 refer to sampling localities of dated rocks outside Fig. 2 (Ras Gharib segment, dashed box). The dated samples and their U–Pb ages are enframed within rectangles.

phase to the subsequent cratonization during the collision of parts of proto-East and proto-West Gondwana (Abdeen and Greiling, 2005; Jacobs and Thomas, 2004). In the present study dating of inherited zircons and old relict cores has been carried out in order to further illuminate the chronostratigraphic structure of the Neoproterozoic EDBC crust.

2. Geological setting

2.1. Outline on previous studies

The EDBC represents the north western part of the ANS. Stern and Hedge (1985) recognized three distinctive basement terrains in the Eastern Desert of Egypt; namely North Eastern Desert (NED), Central Eastern Desert (CED) and South Eastern Desert (SED) (Fig. 1). Based on radiometric ages and distribution of diagnostic rock units in the Eastern Desert, they stated that the oldest rocks occur in the SED, while the youngest rocks occur in the NED. Cryogenian volcanism is represented by ophiolitic and arc-related volcanic rocks (850–620 Ma; Hashad, 1980; Stern and Hedge, 1985), which were subjected to low-grade regional metamorphism and are known as the "Older and Younger Metavolcanics" of the EDBC (Ali et al., 2009; Stern, 1981).

The NED is characterized by the abundance of Ediacaran non-metamorphic volcanosedimentary successions, including interfingering DVs and HS (Fig. 1; Willis et al., 1988). Furthermore, granitoid complexes are abundant in the NED, whereas there is a general lack of ophiolites. The Precambrian granitoids in Egypt are represented by two main stages: the old stage, known as "Older Granitoids" (OG), comprises calc-alkaline syn-tectonic (900–700 Ma) diorite, tonalite, trondhjemite and granodiorite intrusions, while during the younger stage (690–520 Ma), known as "Younger Granitoids" (YG), late- to post-tectonic granodiorites, granites and alkali granites formed (El Gaby et al., 1988; Fleck et al., 1980; Jackson et al., 1984; Stern and Hedge, 1985; Stern and Gottfried, 1986; Stoeser and Elliot, 1980).

The intermontane HS, named after the type locality in Wadi Hammamat (Akaad and Noweir, 1980), consist of coarse alluvial conglomerates, fluvial sandstones and lacustrine pelites, which are partially volcanoclastic in composition (Eliwa et al., 2010; Grothaus et al., 1979; Holail and Moghazi, 1998). Willis et al. (1988) used eight HS samples to calculate a Rb–Sr age of 585 ± 15 Ma, which they interpreted to approximate closely the time of sedimentation. SHRIMP U–Pb ages of detrital zircons from HS in the NED yielded a minimum depositional age of 585 ± 13 Ma (Wilde and Youssef, 2002).

The term "Dokhan Volcanics" is after the type locality of Gebel Dokhan in the NED (Fig. 1). Here, DVs constitute a 1200 m thick sequence of acidic to intermediate lava flows, pyroclastics, ignimbrites, and hypabyssal porphyries that grade downwards into epizonal A-type granite plutons (Akaad and Noweir, 1980; El Ramly, 1972; El Shazly, 1977; Stern and Gottfried, 1986). In the NED, field relations indicate that granitoids both pre- and post-dates the DVs (e.g. Eliwa et al., 2010). However, some radiogenic ages also suggest a synchronous formation of DVs and granitoids.

The DVs from many outcrops have been investigated petrologically and geochemically since the 1980s (Fig. 1; Abdel Rahman, 1996; Abu EL-Leil et al., 1990; Basta et al., 1980; El Gaby et al., 1988, 1990, 1991, 2002; El Sayed et al., 2004; Eliwa, 2000; Eliwa et al., 2006; Mohamed et al., 2000; Stern and Gottfried, 1986). In addition, volcanosedimentary facies analysis was applied to better define the volcanic style and the depositional environment for the DVs (first results presented by Eliwa et al., 2010). These studies show that the DVs have been formed in subaerial environments and that they have medium- to high-K calc-alkaline affinities. In addition they exhibit a dominance of porphyritic texture and a composition of andesite, quartz andesite, dacite, rhyodacite and rhyolite. The DVs are generally non-metamorphosed. However, in some outcrops (e.g. Wadi Um Had and Wadi Kid area) the volcanosedimentary successions were subjected to low-pressure metamorphism (El Gaby et al., 1991; Kamal El Din, 1986).

Several studies have been carried out to reveal the magma genesis of the DVs and concluded that there was a significant role of fractional crystallization coupled with minor crustal contamination in the evolution of basaltic magma. However, interpretations of tectonic setting of the s are still controversial, especially whether they have been formed (I) in a subduction-related environment (Abdel Rahman, 1996; El Gaby et al., 1988, 1990; Hassan and Hashad, 1990; Ragab, 1987), (II) in a rift-environment associated with extension after crustal thickening (Fritz et al., 1996; Stern, 1994; Stern et al., 1984, 1988; Willis et al., 1988), or (III) during transition between subduction and extension (Eliwa et al., 2006; Mohamed et al., 2000; Ressetar and Monard, 1983).

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