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New insights into the accretion of the Arabian-Nubian Shield: Depositional setting, composition and geochronology of a Mid-Cryogenian arc succession (North Eastern Desert, Egypt)

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ABSTRACT

The accretionary phase of the northern Arabian-Nubian Shield (ANS) is poorly constrained. For the first time, this study combines facies analysis, geochemistry, LA-ICP-MS U–Pb zircon geochronology and biotite and hornblende $^{40}Ar/^{39}Ar$ geochronology on a Mid-Cryogenian volcano-sedimentary succession situated in the North Eastern Desert (NED). The c. 550 m thick Wadi Malaak succession (WMS) non-conformably overlies c. 750 Ma granitoids and is, in turn, overlain by c. 617 Ma Dokhan Volcanics and Hammamat Group sediments on an angular unconformity. Facies evolution of the WMS switched from an alluvial plain receiving medial to distal felsic ignimbrite sheets to a lacustrine system with mafic phreatomagmatic activity, and then developed back to a subaerial environment with bimodal volcanism. Facies analysis suggests humid paleoclimatic conditions; (peri-)glacial features have not been detected. Reconnaissance geochemistry of WMS samples indicates a compositional range of volcanic and volcaniclastic rocks from basalt to rhyolite with calc-alkaline affinities. Incompatible trace element and REE patterns indicate formation in a subduction setting. Selected tectonic classification diagrams suggest a continental arc setting. U–Pb LA-ICP-MS analyses on zircon extracted from two felsic ignimbrites resulted in ages of 725 ± 7 Ma and 717 ± 8 Ma, constraining formation of the WMS to the Mid-Cryogenian. Hornblende and biotite separated from a subvolcanic gabbro that obviously had intruded the WMS yielded $^{40}Ar/^{39}Ar$ cooling ages of 747 ± 10 Ma and 743 ± 10 Ma, respectively. These $^{40}Ar/^{39}Ar$ ages are thus in conflict with the U–Pb crystallization ages. This is explained by the presence of excess Ar in biotite and hornblende. The new data presented here indicate that the WMS developed during the waning phase of Mid-Cryogenian ANS accretion, prior to the onset of Sturtian glaciation. It is the first known record of c. 720 Ma arc volcanism in the northernmost ANS.

1. Introduction

The Neoproterozoic was an important growth phase of continental crust (Stern, 2008); a period which is well exposed in the Arabian-Nubian Shield (ANS, Fig. 1). The formation of the shield followed initial rifting and break-up of Rodinia (870–800 Ma) with the final closure of the Mozambique Ocean and collision between east and west Gondwana fragments occurring 650–600 Ma ago (Jacobs and Thomas, 2004). Production of juvenile crust in the ANS mainly occurred in the Mid-Cryogenian from 800 to 690 Ma (Stern, 1994; Stern and Johnson, 2010). However, studies on respective supracrustal rocks in Egypt (referred to as 'Metavolcanics' including associated metasediments) and Saudi Arabia are scarce.

El-Ramly (1972) was among the first to describe metavolcanic rocks in the southern part of the Egyptian Eastern Desert (South Eastern Desert, SED, Stern and Hedge, 1985). For metavolcanic rocks in the Central Eastern Desert (CED) Stern (1981) introduced a subdivision based on stratigraphic position and composition into "Older Metavolcanics" (OMV) representing an oceanic crust association and non-ophiolitic arc-related "Younger Metavolcanics" (YMV). There is currently no subdivision for Cryogenian metavolcanics in the Northern Eastern Desert (NED).

The subdivision of metavolcanic rocks into OMV and YMV is widely used for the whole Eastern Desert, although recent studies suggest that this practice is questionable. For instance, Ali et al. (2009) and Andresen et al. (2009) indicated that OMV and YMV

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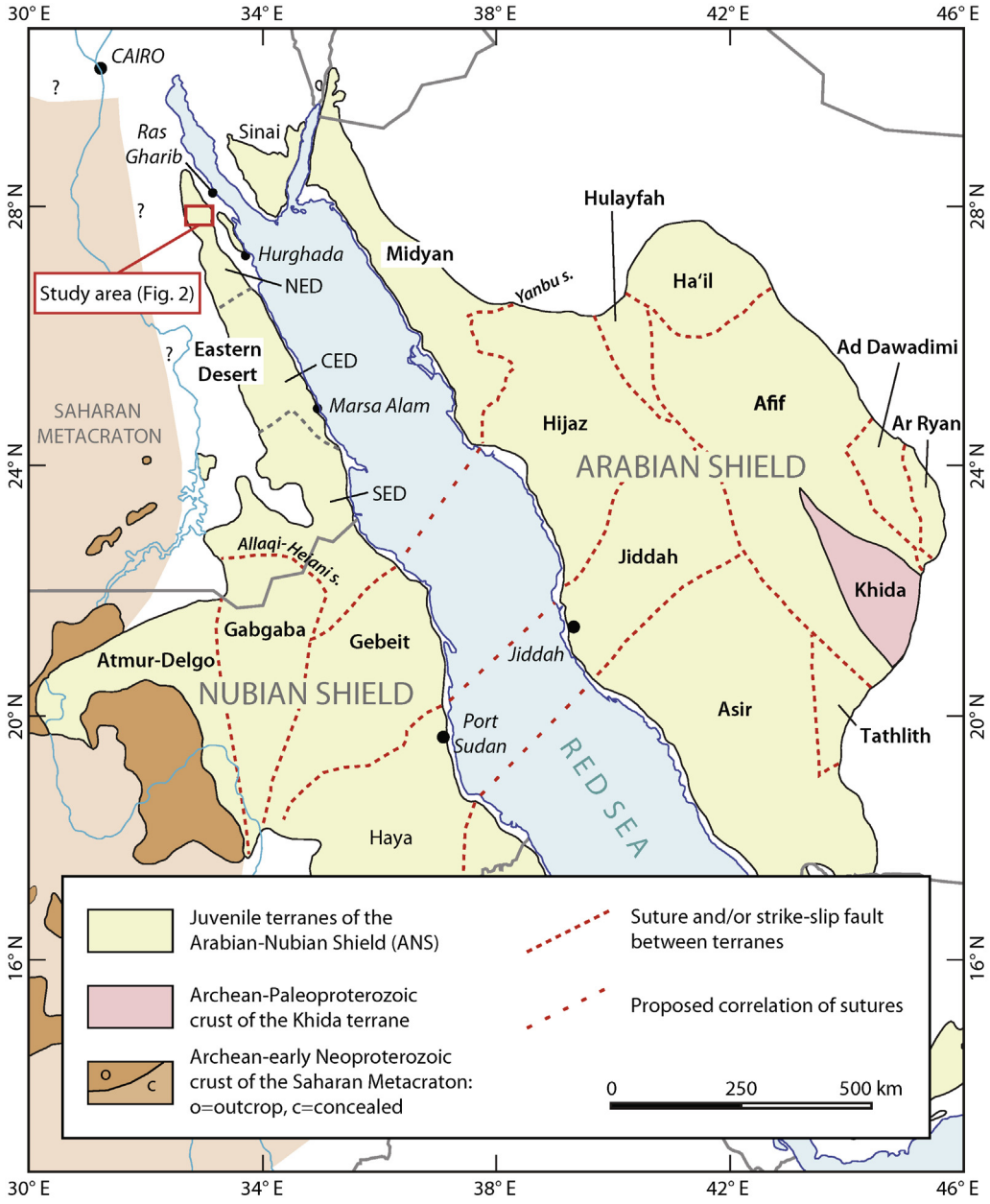

Fig. 1. Overview of the Arabian-Nubian Shield with its terranes and proposed correlations of the latter through the Red Sea (modified after Johnson et al., 2011). NED = North Eastern Desert, CED = Central Eastern Desert, SED = South Eastern Desert (Stern and Hedge, 1985).

overlap in time and that in some areas OMV basalts may even be slightly younger than YMV lavas. Consequently, a new stratigraphic subdivision for Eastern Desert metavolcanics is required, which presupposes new geochronological and stratigraphic studies.

In this contribution we present detailed investigations of a non-ophiolitic, greenschist-metamorphic volcanosedimentary succession (Wadi Malaak succession, WMS) cropping out between Gebel El Kharazah and Gebel Kifri in the NED (Fig. 2). We use lithofacies analysis, geochemistry and geochronology (U–Pb, Ar–Ar) to discuss the WMS basin evolution, the paleoclimatic conditions, and its role for the Cryogenian ANS assemblage.

2. Metavolcanics and associated intrusives in the northernmost ANS

Stern (1981) subdivided Cryogenian layered rocks in the CED into OMV, intervening sediments and YMV. The OMV are described by Stern (1981) as monotonous successions of aphyric pillow basalts with rare sedimentary intercalations. Associations with mafic to ultramafic units such as gabbros and serpentinites occur frequently. In the CED, the OMV are conformably overlain by immature volcanogenic sedimentary rocks intercalated with banded iron formation, cherts and marls. Diamictites in this stratigraphic position have been investigated e.g. by Ali et al. (2010a). The YMV are characterized by the abundance of andesitic porphyritic and more felsic lithologies, volcaniclastic sedimentary rocks as well as the absence of pillow lava piles and serpentinites. The OMV are thought to represent former oceanic crust whereas the YMV are mostly described as being island arc-related (e.g. Stern, 1981; Khalil, 1997).

In the last two decades progress has been achieved regarding the chronostratigraphic control of Mid-Cryogenian magmatic rocks in the northern ANS. Associated with the Allaqi-Heiani suture (SED, Fig. 1), an arc-type metadacite (YMV) overlying a 730 ± 6 Ma ophiolitic gabbro yielded a SHRIMP U–Pb zircon age of 733 ± 7 Ma (Ali