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The Nabitah fault zone, Saudi Arabia: A Pan-African suture separating juvenile oceanic arcs

Michael J. Flowerdew[a,*], Martin J. Whitehouse[a], Douglas B. Stoeser[b]

[a] Swedish Museum of Natural History, Box 50007, SE-104 05 Stockholm, Sweden
[b] United States Geological Survey, MS973, Denver Federal Center, Denver, CO 80225, USA

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ABSTRACT

U-Pb zircon ion-microprobe geochronology, whole rock geochemistry and feldspar Pb and Sm-Nd isotopic analyses carried out on granitoid rocks along a transect across the Nabitah fault zone suggest that it separates two juvenile oceanic arc terranes which differ in age and geochemical character. The Tathlith–Malahah terrane situated to the east of the fault zone comprises the Tathlith arc which developed through an older volcanic and sedimentary succession. Plutonic rocks associated with the Tathlith arc formed between *c.* 700–670 Ma and are younger than those from the 750–720 Ma Tarib arc within the Al Qarah terrane, situated to the west of the fault zone. Intrusions from both the Tarib and Tathlith arcs have positive εNd values and feldspar Pb signatures that are consistent with juvenile crustal additions. A tectonic model is presented for the evolution of the Nabitah fault zone: the Tathlith arc developed on and through the Tarib fore arc as a consequence of subduction roll back. Back arc spreading, promoted by collision of a continental mass to the south, created a separate Tathlith–Malahah terrane. Continued convergence of the continent inverted the back arc basin and counter-clockwise rotation formed the Nabitah fault zone. The fault zone does not represent a major suture zone between the western juvenile arc terranes and the more evolved eastern arc and continental terranes, as had previously been speculated.

1. Introduction

Formation of the Arabian-Nubian Shield was complete after the final closure of the Mozambique Ocean in the Late Neoproterozoic (Cooper et al., 1979; Johnson et al., 2011; Stoeser and Camp, 1985). The shield comprises a collage of juvenile arc terranes (Fig. 1) that broadly young from west to east, consistent with progressive arc accretion onto the Sahara megacraton (Stoeser and Frost, 2006). The eastern shield contains the Palaeoproterozoic Khidda terrane (Fig. 1; Agar et al., 1992; Stoeser et al., 2001; Whitehouse et al., 2001a) and the Archaean Al-Mahfid terrane (Whitehouse et al., 1998; Windley et al., 1996), older continents that were largely remobilized during their accretion with the arc terranes.

Geochronology and isotope geochemistry is necessary to disentangle the tectonics of this complex episode of terrane assembly. Previous studies have identified an abrupt change in chemistry across the Hulayfah–Ad Dafinah fault zone (Fig. 1; Stoeser and Camp, 1985). The chemical change signifies contamination of sediment derived from the older continents and/or a change in the mantle and lithospheric sources for the melts on the eastern side of the fault zone (Stoeser and Frost, 2006). The geochemical data adds a complexity to an otherwise simple model for progressive accretion from west to east, and has led to the suggestion that the Hulayfah–Ad Dafinah fault zone represents part of a major suture zone. Commonly referred to the Nabitah suture zone (Schmidt et al., 1979), the Hulayfah–Ad Dafinah fault zone separates the accreted arc terranes to the west (western terranes) from a coherent continental block to the east that comprises oceanic arc and continental terranes (eastern terranes) and is cited as an extension of the junction between west and east Gondwana in east Africa (Quick, 1991; Shackleton, 1996; Windley et al., 1996).

Opposing views exist regarding the southward continuation of the Hulayfah–Ad Dafinah suture zone. Either it extends south along the Nabitah fault zone (Fig. 1) in view of its strong deformation, amphibolite-facies metamorphism, voluminous syn-orogenic plutonism and the numerous serpentinite bodies that exist along this structure (Frisch and Alshanti, 1977; Schmidt et al., 1979; Shackleton, 1996). Alternatively, the suture zone continues southeast along the Ruwah fault zone and further below the Phanerozoic cover (Johnson and Kattan, 2001).

The paucity of geochemical and U-Pb zircon geochronological data in this region (Stern et al., 2010; Stoeser and Frost, 2006) has previously precluded a satisfactory assessment of which of

* Corresponding author. Present address: CASP, University of Cambridge, West Building, 181A Huntingdon Road, Cambridge CB3 0DH, UK. Tel.: +44 1223 760700.
E-mail address: michael.flowerdew@gmail.com (M.J. Flowerdew).

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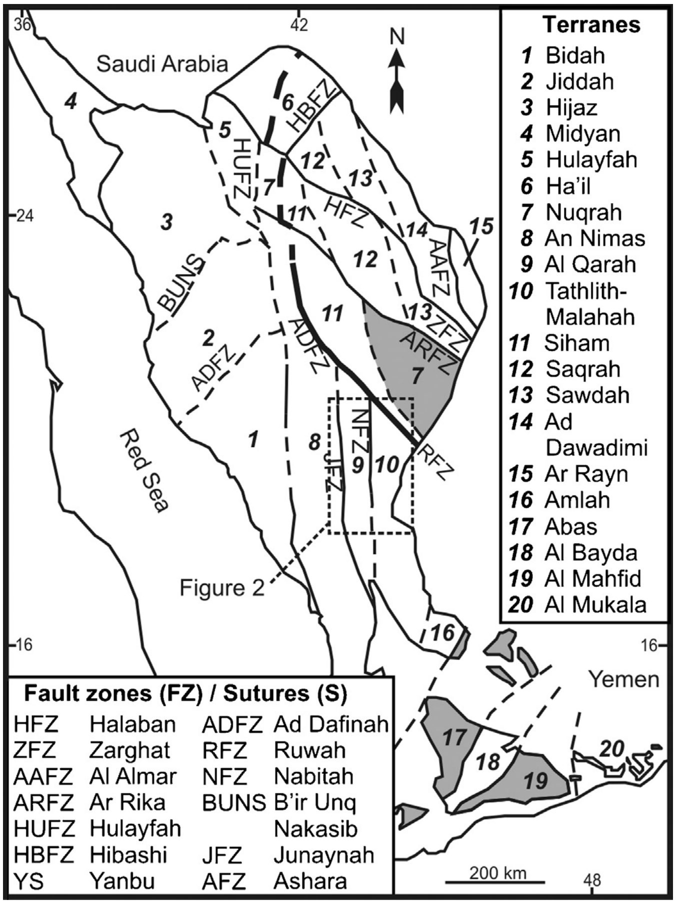

Fig. 1. Simplified terrane map for part of the Arabian-Nubian Shield, modified after Johnson (1998); Johnson and Woldehaimanot (2003); Stoeser and Frost (2006); Whitehouse et al. (2001b); Windley et al. (1996). Solid lines represent the location of terrane boundaries with some degree of confidence, dashed lines with less confidence. The bold lines represent the location of the suture that separates the western arc terranes from the eastern continental and arc terranes.

the two models is correct. For instance, just five Sm-Nd analyses are available from the region and the handful of U-Pb zircon geochronology was largely performed using multigrain samples which have yielded ages that are open to interpretation. Moreover, these data come predominantly from late tectonic rocks. Nevertheless, in the light the kinematic evolution and an evaluation of the geochemistry of the rocks which it separates, the Nabitah fault zone is recently interpreted to have played the less significant role in the evolution of the shield (Stern and Johnson, 2010; Stoeser and Frost, 2006). This latter view, if correct, generates potential confusion with regard to nomenclature because the Nabitah fault zone is attributed as the type structure for the suture which separates the eastern and western terranes (Frisch and Alshanti, 1977).

This contribution aims to increase the number and reliability of geochemical and geochronological data from terranes situated either side of the Nabitah fault zone, so that the importance of the structure can more confidently be evaluated. Secondary ion mass spectrometry (SIMS) U-Pb zircon geochronology, major and trace element geochemistry, whole rock Sm-Nd and feldspar common Pb isotopic analyses are presented from seventeen pre- and syn-tectonic plutonic rocks that were collected along a transect across the Nabitah fault zone. The new data confirm that the Nabitah fault zone is not part of the major suture zone that separates the western and eastern terranes. A new tectonic model for the development of the Nabitah fault zone is presented in the light of these results.

2. Geological evolution of the terranes and the Nabitah fault zone

The Nabitah fault zone separates the Tathlith–Malahah terrane (Stoeser and Frost, 2006), which is situated east of the fault zone, from the Al Qarah terrane situated in to the west (Fig. 2; Schmidt et al., 1979; Stoeser and Stacey, 1988).

2.1. The Al Qarah terrane

The Al Qarah terrane (Schmidt et al., 1979) forms part of a collage of juvenile intra-oceanic arcs termed the Asir terrane (Kröner, 1985) or Asir composite terrane (Cooper et al., 1979; Kröner et al., 1992; Stoeser and Stacey, 1988). It comprises a succession of metavolcanic and metasedimentary rocks, andesite to dacite in compostion and metamorphosed to greenschist-facies, that is cut by a series of tonalitic and dioritic intrusions (Stoeser et al., 1983). The whole assembly relates to the evolution and growth of the Tarib arc and are labelled pre-orogenic on Fig. 2. The arc was active between 750 Ma and 720 Ma as indicated by multigrain U-Pb zircon and Rb-Sr whole rock age determinations from the plutonic rocks (Cooper et al., 1979; Fleck et al., 1980; Stoeser et al., 1983; Stoeser and Stacey, 1988).

2.2. Tathlith–Malahah terrane

The Tathlith–Malahah terrane (Stoeser and Frost, 2006) differs from the Al Qarah terrane in that it contains two distinct volcanic and sedimentary successions. The north of the terrane mostly comprises an upper series of greenschist-facies meta-andesite and meta-greywacke rocks with an arc affinity (Kellogg et al., 1986; Schmidt et al., 1979). This upper (Tathlith arc) succession either rests unconformably on, or is thrust onto a lower succession of amphibolite-facies biotite paragneiss and amphibolite (Greenwood, 1985; Kellogg, 1982; Kellogg et al., 1986). The southern part of the terrane, south of the Mulha fault zone, wholly comprises a succession at greenschist-facies metamorphic grade which contains a bimodal suite of basaltic and rhyolitic volcanic rocks. This southern succession is thought to have been deposited in a marine basin within a back arc environment (Bookstrom et al., 1989). Bookstrom et al. (1992) viewed these rocks to continue into the north of the terrane and correlated them with the lower, higher grade, succession.

The age and affinity for both of the successions is poorly understood. The lower succession in the south of the terrane is linked with the evolution of the 750–720 Ma Tarib arc (Greenwood, 1985), bringing into question the role of the Nabitah fault zone as a terrane boundary (see below). While the upper Tathlith arc succession is, in addition to the field evidence, thought to be younger (700–650 Ma) on the basis of multigrain U-Pb zircon geochronology from Tathlith arc plutons (Cooper et al., 1979; Stoeser and Stacey, 1988). The Tathlith arc is thought to have developed over and through the lower succession (Stoeser and Frost, 2006).

2.3. The Nabitah fault zone

The Nabitah fault zone contains abundant serpentinite bodies (Pallister et al., 1987a,b) and extends south of the Hulayfah–Ad Dafinah fault zone and separates the Al Qarah and Tathlith–Malahah terranes as described above. The fault zone was affected by dextral shearing throughout its ductile and later brittle history (Johnson and Kattan, 2001; Johnson and Woldehaimanot, 2003). U-Pb zircon SIMS geochronology of a granitic rock that cuts dextral ductile shear-fabrics, show that deformation along the fault zone occurred prior to *c.* 640 Ma (Johnson et al., 2001). U-Pb multigrain zircon and SIMS geochronology (Cooper et al., 1979; Johnson