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Neoproterozoic structural evolution of the NE-trending Ad-Damm Shear Zone, Arabian Shield, Saudi Arabia

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ABSTRACT

The Ad-Damm Shear Zone (AdSZ) is a major NE- (to NNE-) trending fault zone separating Jiddah and Asir tectonic terranes in the Neoproterozoic Juvenile Arabian Shield (AS). AdSZ is characterized by the development of dextral transcurrent shear-sense indicators and moderately to steeply NW plunging stretching lineations. It is mainly developed under high amphibolite-to greenschist-facies conditions and extends ~380 km, with an average width ~2–4 km, from the conspicuous Ruwah Fault Zone in the eastern shield to the Red Sea Coastal plain. It was believed to be one of the conjugate shears of the NW- to NNW-trending sinistral Najd Shear System. This assumption is, based on the noteworthy dextral shear criteria recorded within the 620 Ma mylonitic granite of No'man Complex. A total shear-zone strike length exceeding 117 km is carefully investigated during this study to reconstruct its structural evolution. Shear-sense indicators and other field observations including overprinting relations clearly demonstrate a complicated Neoproterozoic history of AdSZ, involving at least three phases of deformations (D_1–D_3). Both D_1 and D_2 phases were of contractional regime. During D_1 phase a NW–SE compression led to the formation of NE-oriented low-angle thrusts and tight-overturned folds. D_2 is represented by a NE–SW stress oriented that led to the development of an open folding. D_3 is expressed by the NE–SW intensive dextral transcurrent brittle–ductile shearing. It is overprinting the early formed fabrics and played a significant role in the creation of AdSZ and the mega-scale related folds. Such deformation history reflects the same Neoproterozoic deformation regime recognized in the NE-trending shear zones in the Arabian–Nubian Shield (ANS).

1. Introduction

The Arabian–Nubian Shield (ANS) consists mainly of Neoproterozoic basement rocks exposed on the flanks of the Red Sea. It is represented by Arabian Shield (AS) in the western Arabia and Nubian Shield (NS) in the northeastern Africa. Stern and Johnson (2010) believed that the shield constitutes one of the largest best exposed tracts of juvenile Precambrian continental crust on the Earth and its history is intimately linked with a Neoproterozoic "Supercontinental Cycle" (Worsley et al., 1986). This cycle began with the rifting, break-up and fragmentation of Rodinian Supercontinent in the early Cryogenian (Meert and Torsvik, 2003), continued with the opening and closing of one or two oceanic basins (Stern, 1994; Collins and Pisarevsky, 2005), and ended with the convergence of fragments of East and West Gondwana and the formation of the new supercontinent of "Greater Gondwana" (Stern, 1994) or "Pannotia" (Dalziel, 1997). Johnson et al. (2011) believed that the ANS underwent final assembly and accretion to the Saharan Metacraton (SM) (Abdelsalam et al., 2002, 2011) concurrent with the assembly of eastern and western Gondwana during the late Cryogenian–Ediacaran (650–542 Ma). The ANS formed by accretion of individual terranes with different protolith ages (Johnson et al., 2011). Terrane analysis of the shield is based on isotopic compositions; structural, geochronologic, and lithostratigraphic differences, and the presence of serpentinite-decorated and transcurrent shear zones (Johnson, 2006). Older AS terranes include Jiddah (870–740 Ma; Kröner et al., 1991; Reischmann et al., 1992) and Asir (850–750 Ma; Johnson and Woldehaimanot, 2003), intermediate terranes include Midayan (780–710 Ma; Hedge, 1984; Ali et al., 2010), and younger terranes include Ar Rayan (>670; Stoeser and Stacey, 1988) and Ad

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Dawadimi (674 ± 6 Ma; Cox, 2011). The contacts between terranes comprise (l) sutures composed of ophiolite-decorated shear zones; (2) cryptic or unimpressive shear zones that may be original sutures, faults superimposed on original sutures or post-suturing structures; and (3) post-amalgamation fault zones that may be unrelated to original suturing events (Johnson and Woldehaimanot, 2003). Ages of these contacts are shown in Fig. 1 (Johnson et al., 2011). The two prominent features in western AS; Bi'r Umq Suture and Ad-Damm Shear Zone (AdSZ) posses ages of 780–750 Ma (Hargrove et al., 2006) and 620–540 Ma (Johnson et al., 2011), respectively. The ADSZ appears to be relatively young structure but its origin is not entirely established. The Nu'man complex crops out as irregular batholith on either side of the AdSZ. The complex age is uncertain. Fleck and Hadley (1982) obtained a Rb–Sr isochron age of 542 ± 23 Ma from a sheared Nu'man granite gneiss in the AdSZ, but this probably indicates the age of redistribution of Sr during Cambrian movement rather than the emplacement age (Johnson, 2006).

The present study outlines the structural evolution of the prominent NE-trending 620–540 Ma AdSZ which is considered as the tectonic contact between Jiddah and Asir Terranes in the Neoproterozoic Juvenile Arabian Shield (Fig. 1). Asir Terrane itself is composite, created by the amalgamation of several subterranes along one or more of the serpentinite-decorated shear zones that dominate the region, whereas the apparent temporal and spatial relations of the rocks of Jiddah Terrane suggest that the terrane was created by a northward migrating SE-dipping subduction zone (Johnson and Woldehaimanot, 2003). Davies (1984) considered the NE-trending dextral shears in the Arabian Shield as the conjugate shears for the NW to NNW shears of the NFS. The area under investigation is bounded by latitudes 21°00′00″ & 21°40′00″N and longitudes 40°00′00″ & 40°30′00″E. There is no previous detailed structural studies on the area with the exception of a part from the regional geologic map constructed by Moore and Al-Rehaili's (1989) (scale 1: 250.000) for the entire Makkah Quadrangle.

2. Remote sensing analysis

In the present study, the processing of Advanced Spaceborne Thermal Emission and Reflectance Radiometer (ASTER) data is integrated with detailed field investigations to unravel and decipher the Neoproterozoic structural evolution of the NE-trending AdSZ. ASTER data added much more information to our knowledge on the geology of the area. It was used to construct the field-base map that exhibits the relevant lithologies and structures in the study area. Analysis of ASTER data for lithologic discrimination was based on the relation between the spectral absorptance or emittance and the mineral composition of exposed lithologies. Two of techniques (False color composite (FCC) and band ratio) were applied.

2.1. ASTER data properties

The ASTER is a research facility instrument, launched on NASA's Terra satellite in December 1999, and produces two types of Level-1 data: Level-1A (L1A) and Level-1B (L1B). Any ASTER scene covers an area of approximately 60 km by 60 km. It has three sensors to measure and record the reflected and emitted Electromagnetic

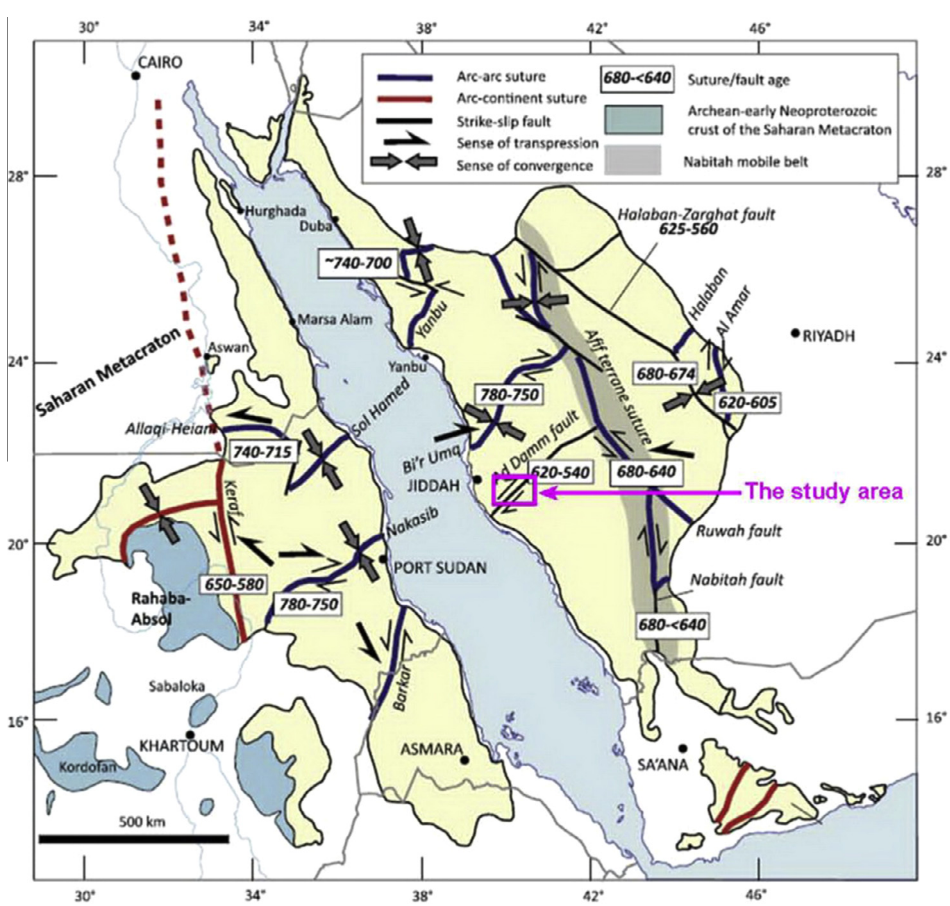

Fig. 1. Tectonic map of the ANS showing the location of the study area. The map exhibits terrane assembly in the ANS, inferred ages of suturing and fault movements and trajectories of amalgamation (after Johnson et al., 2011).