Najd-Related Transpressional Deformations in the Atalla Shear Zone (Eastern Desert, Egypt)

Zakaria Hamimi, Wael Hagag, Samir Kamh, and Asmaa El-Araby

Abstract

The Atalla Shear Zone (ASZ) is a NW-oriented mega-shear that belongs to the Najd-Shear Corridor in the Central Eastern Desert of Egypt. The present study focused on the structural and tectonic evolution of the ASZ throughout integrated space-born optical-based mapping and structural-field work. The ASZ area comprises a Neoproterozoic rock succession including serpentinites, island-arc assemblage of metasediments and metavolcanics, Dokhan Volcanics, Hammamat Sediments, and granitoids. A lithological mapping was carried out using Landsat-8 (ETM+) and ASTER, and the image processing techniques included false color composites (FCC), principal component analysis (PCA), and RGB band ratios (BR). The predominant trends were ENE-WSW and NE-SW. The transcurrent shearing related to ENE-WSW shortening in the ASZ resulted in prominent transpressive shear structures among which we find shear-related folds, imbricated fans and antiformal stacks, and passive-roofed- and domino-style-thrust duplexes. A reasonable structural history involving four successive deformation phases (D1–D4) was established. D_1 was recorded within the amphibolitic enclaves found at Um Baanib area. D_2 was a syn-accretion shortening stage, concurrent with the E–W assembly of Gondwana-lands, and responsible for the W- and WSW-propagated thrusts and thrust-related folds. D_3 and D_4 were post-accretion phases that resulted in formation of the Najd-related ASZ with sinistral sense of shearing. The emplacement and exhumation of the Meatiq Gneiss Dome, and also the deposition of the Hammamat Volcanosedimentary Sequence in fault-controlled sags and pull-apart, are believed to be post-accretion and associated with the D_3 phase.

Z. Hamimi (✉) · W. Hagag · A. El-Araby
Department of Geology, Faulty of Science, Benha University, Banha, 13518, Egypt

S. Kamh
Department of Geology, Faculty of Science, Tanta University, Tanta, 31527, Egypt

Keywords

Atalla shear zone • Najd-related transpression • Pan-African belt • Arabian-Nubian shield

1 Introduction

In the Eastern Desert of Egypt, the Najd Shear System (NSS) still has problematic issues that need to be addressed. The time, sense, and scale of shear are the most important of these issues. The present work was an integrated study using remote sensing techniques and structural-field mapping to investigate the shear criteria and discuss the deformation history; another objective was to set up a model depicting the tectonic evolution of the Atalla Shear Zone (ASZ; Fig. 1). Structurally, the study area can be classified into three main domains (e.g., Akaad and El-Ramly 1960, Akaad and Noweir 1980, Abd El-Wahed 2010): Meatiq Domain (MD); Atalla Shear Zone Domain (ASZD); and Wadi Hammamat Domain (WHD). The processing of remote sensing data enabled high-resolution discrimination for the different lithologies and structural elements, hence constructing a modified geological map for the ASZ. Furthermore, the structural setting and tectonic evolution of the ASZ would be addressed within the frame of the NW–SE-oriented Najd Shear System, which crosses the central part of the Arabian Shield for 1300 km and passes through the Eastern Desert of Egypt forming the so-called Najd Shear Corridor.

2 Materials and Methods

The remote sensing data used in the present study include both ASTER and Landsat-8. These images are preprocessed and processed using different remote sensing techniques

M. Meghraoui et al. (eds.), *Advances in Geophysics, Tectonics and Petroleum Geosciences*,
Advances in Science, Technology & Innovation, https://doi.org/10.1007/978-3-030-73026-0_113

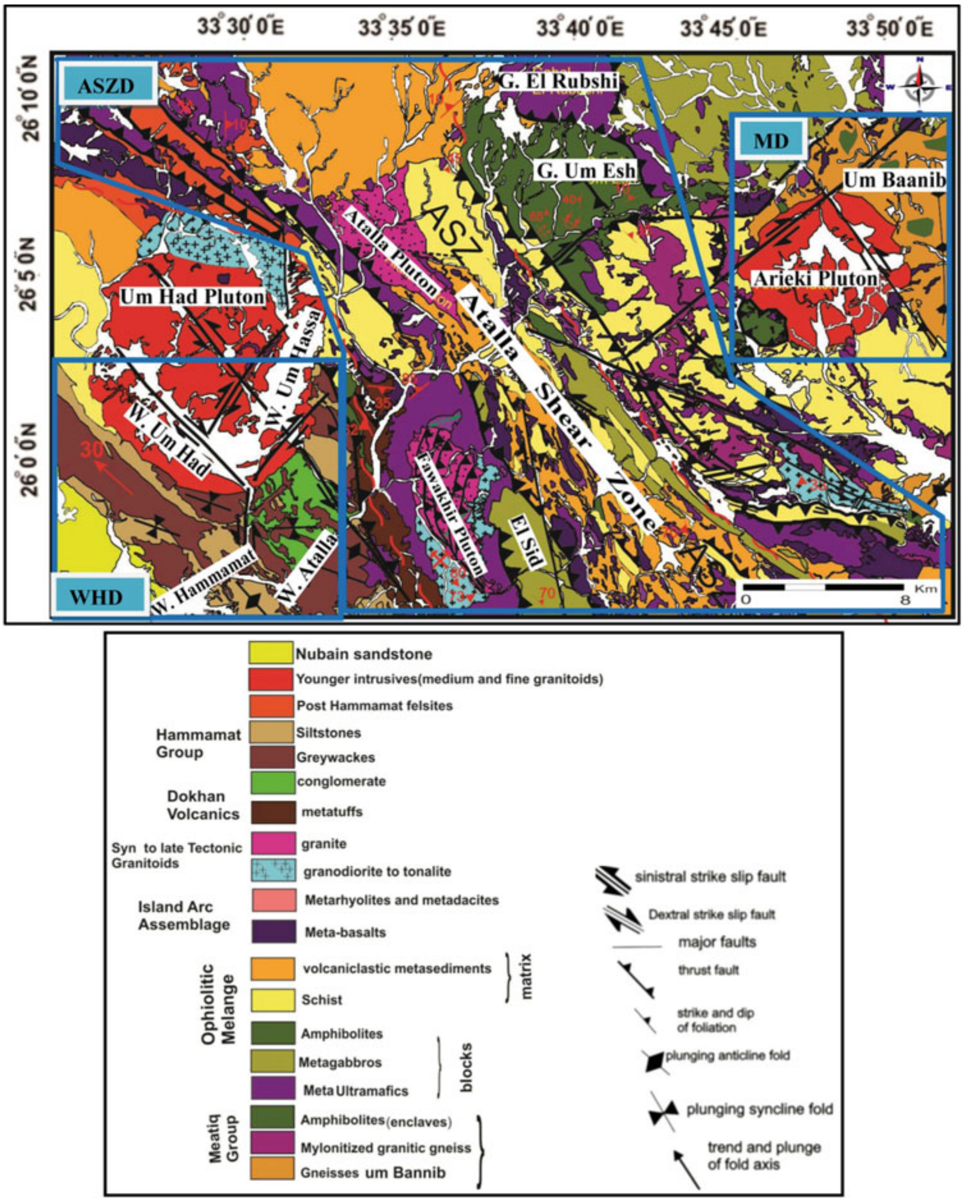

Fig. 1 Geological map of the Atalla Shear Zone and its environs (this study); MD: Meatiq Domain, ASZD: Atalla Shear Zone Domain, and WHD: Wadi Hammamat Domain

such as false color composite (FCC), principal component analysis (PCA), minimum noise fraction (MNF), and band rationing (BR). The satellite images were analyzed and processed using different software including ENVI 5.1, Erdas Imagine 9.2 and ArcGIS (10.1). For lineament extraction, some software, such as PCI Geomatica, were used. Rock Work, Steronet, surfer and Global Mapper software have also been applied during the study. Such techniques allowed us to discriminate various lithologies in the study area including gneisses, ophiolitc mélange, island-arc assemblage, Dokhan volcanics, Hammamat Sediments, Atalla felsites, and different granitoids. During the field work, lithological and structural contacts were checked, as well as many representative field photographs were taken. All the data collected were integrated to define the structural elements and describe the nature of tectonic movements deforming the Atalla Shear Zone. About 120 thin sections were prepared for the petrographic investigation of the different rock units. Based on the previous geological maps published on the study area and the remote sensing images, modified geological and structural maps were constructed. Some structural cross sections and sketches, as well as a 3D tectonic model, were made to depict the deformational stages and tectonic evolution of the study area.

3 Results and Discussion

The present study is an attempt to reappraise the geological and structural setting of the Atalla Shear Zone and its surroundings including Meatiq, Fawakhir, Um Had and Hammamat areas (located in the central Eastern Desert, Egypt) aided by remote sensing and GIS techniques. Remote sensing data were used to discriminate between the different rock units in the study area. This distinction between the rocks was accompanied by a detailed structural-field investigation of the base for a modified map compared to the previous maps (e.g., Akaad and El-Ramly 1960; Amer et al. 2010; Hassan et al. 2017). The remote sensing results were verified through the field work and petrographic investigation. The processes of image enhancement include different techniques. True color composite (TCC), false color composite (FCC), principal component analysis (PCA), minimum noise fraction (MNF) and band ratioing (BR) were applied to enhance the discrimination rate between the different rock units. As a consequence, the Neoproterozoic basement succession exposed in the study area was classified into eight groups including different rock units complemented by the field work and petrographic study. The groups include Meatiq Group, Ophiolitic Melange, island-arc assemblage, Syn- to late-tectonic granitoids, Dokhan Volcanics, Hammamat Sediments, post-Hammamat Felsites, and younger intrusives. Meatiq Group includes Gneisses (Gn), Mylonitized Granitic Gneiss (MGn) and Amphibolites. Ophiolitc Mélange includes blocks and matrix where blocks include metaultramafics, metagabbros, and amphibolites while matrix includes schists (talc schist, actinolite schist, tremolite talc schist, muscovite schist, and graphite schist), and volcaniclastic metasediments. Island-arc assemblage is represented by metabasalts. Syn- to late-tectonic granitoids represented by different plutons include Abu Ziran, Um Sheqila, Fawakhir, and Atalla Plutons. Dokhan Volcanics are represented by metatuffs and metabasalts. Hammamat Sediments include metaconglomerates, metagreywackes, and metasiltstones. Post-tectonic intrusives are represented by Arieki and Um Had granitic plutons.

As the ASTER channels are more continuous in the (SWI) bands than of Landsat-8, ASTER is the best for the minerals identification (Crosta et al. 2003). Several spectral indices were used for the mineral detection and among them are b7/b6 to distinguish muscovite and b5/b4 to distinguish biotite, chlorite, and amphiboles (ferrous silicates) (Hewson et al. 2001, 2005) while b5/b3 used to distinguish mafic minerals (ferrous iron, Fe 2+) (Rowan and Mars 2003). In the present study, the automatic methods for lineament extraction based on the edge filtering techniques were applied. Shaded relief images extracted from digital elevation model (DEM) are used by applying eight sun azimuths including 0°, 45°, 90°, 125°, 180°, 225°, 270°, and 315°, and the image resulting from combining the eight angles was used for the lineament extraction. In the case of 0° and 180° angles, the E–W, NW–SE, and NE-SW trends are detected, and E–W trend is the dominant. In the case of 45° and 225° angles, NW–SE trend is the dominant trend. In the case of 90° and 270° angles, N–S, NW–SE, and NE–SW trends are recorded and the dominant trend is N–S. In the case of 135° and 315°, NE–SW and E–W trends are recorded, and the dominant trend is NE–SW. In the case of combined shaded relief image, NE–SW, N–S, and NW–SE trends are recorded and NE–SW is the dominant trend.

In the Meatiq Domain, foliations associated with thrusts are deflected, folded, and transposed into the foliation within the high strain zone of the NW–SE striking ASZ. Foliations in the Meatiq Domain are moderately SE dipping parallel to the axial plane of NE–SW trending folds. Different types of lineations were recorded plunging gentle to moderate to NW and SE. Thrusts in the Meatiq Domain are directed toward the Um Baanib Area. The NW–SE ASZ is the major and most important shear zone in the study area. The main foliations in the ASZ strike NW–SE and dip mainly to NE. Several kinematic indicators, including S-C fabrics and asymmetric boudins, isolated a symmetric objects, folds and mica fish were recognized and reflect sinistral sense of shearing. In the Um Esh Area, the earlier NE–SW dextral shear is overprinted by NW–SE sinistral shear. Within the Wadi Hammamat Domain, foliations strike NW–SE and dip mainly to NE. Thrust faults and folds with NE–SW trend were recorded and associated with NW–SE compression that prevailed just after the deposition of the Hammamat Sediments (Greilling et al. 1994; Abdel Wahed 2010). Strike-slip faults cut all structures in the study area and can be considered as the youngest phase of deformation and the latest event of brittle deformation. Strike-slip faults occur in two sets. The first one is right-lateral NE–SW strike-slip faults cut by the youngest NW–SE left-lateral strike-slip faults. The two sets of strike-slip faults are not conjugate. Within the Atalla Shear Zone, transpression is very common especially in the Fawakhir area within the Fawakhir Granite and Fawakhir Serpentinites. Transpression is represented in the form of strike-slip duplexes and a positive flower structures.

Four deformation phases (D_1–D_4) can be defined in the study area. D_1 is the oldest and documented within the xenoliths of amphibolites at Um Baanib area. D_2 is accretion-related stage that was associated with the general E–W convergence between East and West Gondwanan lands. D_3 represents a phase of extensional collapse formed due to N–S to NW–SE orogen-parallel extension and associated with the deposition of molasses sediments and exhumation of the Meatiq Core Complex. After the deposition of Hammamat Sediments, a short phase of compression was recorded and led to form NW-directed thrusts and NE trending synclines. D_4 is characterized by NW–SE sinistral transpression followed by NW–SE transcurrent shearing in relation to the Najd Shear Deformation.

4 Conclusions

- Detailed geologic mapping were obtained for the ASZ and its environs based on the integration of remote sensing data and intensive field work (Fig. 1).
- Four deformation phases (D_1–D_4) were documented from the structural analysis of the study area. D_1 is pre-accretion, D_2 is accretion-related, and D_3 and D_4 are post-accretion and Najd-related phases.

References

Abd El-Wahed, M.A.: The role of the Najd Fault System in the tectonic evolution of the Hammamat molasses sediments Eastern Desert, Egypt. Arab. J. Geosci. **3**, 1–26 (2010)

Akaad, M.K., El-Ramly, M.F.: Geological history and classification of the basement rocks of Central Eastern Desert of Egypt. Geol. Surv. Cairo, Egypt **9**, 1–24 (1960)

Akaad, M.K., Noweir, A.M.: Geology and lithostratigraphy of the Arabian Desert orogenic belt of Egypt between latitudes 25° 35 and 26° 30 N. Inst. Appl. Geol. Jeddah Bull. **3**, 127–135 (1980)

Amer, R., Kusky, T., Ghulam, A.: Lithological mapping in Central Eastern Desert of Egypt using ASTER data. J. Afr. Earth Sci. **56**, 75–82 (2010)

Crosta, A.P., Souza Filho, C.R., Azevedo, F., Brodie, C.: Targeting key alteration minerals in epithermal deposits in Patagonia, Argentina, using ASTER imagery and principal component analysis. Int. J. Remote Sens. **23**, 4233–4240 (2003)

Greilling , R.O., Abdeen, M.M., Dardir, A.A., EL Akhal, H., El Ramly, M.F., Kamal El Din, G.M., Osman, A.F., Rashwan, A.A., Ries, A. H., Sadek, M.F.: A structural synthesis of the Proterozoic Arabian Nubian shield in Egypt, vol 83, pp. 484–501. Springer, Berlin (1994)

Hassan, S.M., El-kazzaz, Y.A., Taha, M.M.N., Mohammed, A.T.: Late-Neoproterozoic basement rocks of Meatiq area, central Eastern Desert, Egypt: petrography and remote sensing characterizations. J. Afr. Earth Sci. **131**, 14–31 (2017)

Hewson, R.D., Cudahy, T.J., Huntington, J.F.: Geological and alteration mapping at Mt Fitton, South Australia, using ASTER satellite-borne data. IEEE Trans. Geosci. Rem. Sens. 724–726 (2001)

Hewson, R.D., Cudahy, T.J., Mizuhiko, S., Ueda, K., Mauger, A.J.: Seamless geological map generation using ASTER in the BrokenHill–Curnamona province of Australia. Rem. Sens. Environ. **99**, 159-172 (2005)

Rowan, L.C., Mars, J.C.: Lithologic mapping in the Mountain Pass, California area using Advanced Spaceborne thermal emission and reflection radiometer (ASTER) data. Remote Sens. Environ. **84**, 350–366 (2003)