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Late Pan-African granite emplacement during regional deformation, evidence from magnetic fabric and structural studies in the Hammamat–Atalla area, Central Eastern Desert of Egypt

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ABSTRACT

Field investigations, microstructural observations, and magnetic fabric analyses revealed a polyphase, late Pan-African deformational evolution in the Um Sheqila–Um Had (595 Ma) composite pluton and in the Hammamat and Atalla areas of the Central Eastern Desert of Egypt in Ediacaran times. Major stages are early shortening (NNW–SSE), subsequent strike-slip (NW–SE shear zones), and late shortening (NW–SE). Strain studies on pebbles and xenoliths together with AMS data show a predominance of shallow, NW–SE trending X axes or magnetic lineations, associated with steep, NW–SE striking magnetic foliations. Magnetic fabrics and microstructures indicate a tectonic fabric in the Um Sheqila–Um Had granitoid plutons, which is dominated by steep NW–SE striking foliations and shallow NW–SE trending lineations, similar to those in the high-angle Atalla Shear Zone. There is a change of lineation directions from ESE–WNW at Um Sheqila (oldest) to NW–SE to Um Had II (youngest). This pattern may indicate an influence of strike-slip and is also consistent with NE–SW compression. This holds also true for the asymmetry of the contact aureole, which is extended towards NW, parallel with the trend of the magnetic lineation. The character and orientation of the deformation pattern in the Um Sheqila–Um Had plutons and the Atalla Shear Zone is thus similar to the pattern of the late shortening phase. The intrusion of the Um Sheqila–Um Had granitoid rocks, therefore, took place before the late shortening stage, but postdates early deformation, which, according to published data, was associated with lithospheric thinning in the Central Eastern Desert. Therefore, these Pan-African plutons do not represent the earliest post-deformational intrusions but a late stage of syn-deformational magmatic activity. At a regional scale, this deformation with steep foliations and shallow lineations may also be related with lateral escape tectonics. The pluton emplacement, the importance of transcurrent shear zones, and the low lithospheric thickness in the area are not consistent with tectonic elements at the Pan-African orogenic margin but imply a more internal position for the Wadi Hammamat area.

1. Introduction

Although the Pan-African basement of the Central Eastern Desert (CED) in Egypt has been the focus of various studies in the last decades, there is still an ongoing debate about the tectonic setting and structural interpretation of the most striking features of this area, the elliptical dome structures as exposed in the Gabal El Sibai, the Gabal Meatiq or the Um Had area (see recent discussions by Johnson et al., 2011; Fritz et al., 2013 and references therein). There are several models being discussed for the formation of these dome structures: (i) the domes are structural culminations related to polyphase compression (e.g. Abdeen and Greiling, 2005), (ii) crustal extension and formation of metamorphic core complexes (e.g. Sturchio et al., 1983), (iii) gneiss domes formed at releasing bends of large-scale strike-slip faults (e.g. Fritz et al., 1996, 2002). Fowler and Osman (2001) interpreted the granitoid and gneissic rocks of the Um Had area as forming another one of the CED gneiss domes. In this context, the Um Had pluton (Fig. 1) is interpreted as post-tectonic granitoid, which mimics the pre-existing dome structure. Furthermore, recent studies argued that the Um Had pluton is the earliest post-deformational pluton in the Eastern Desert and thus

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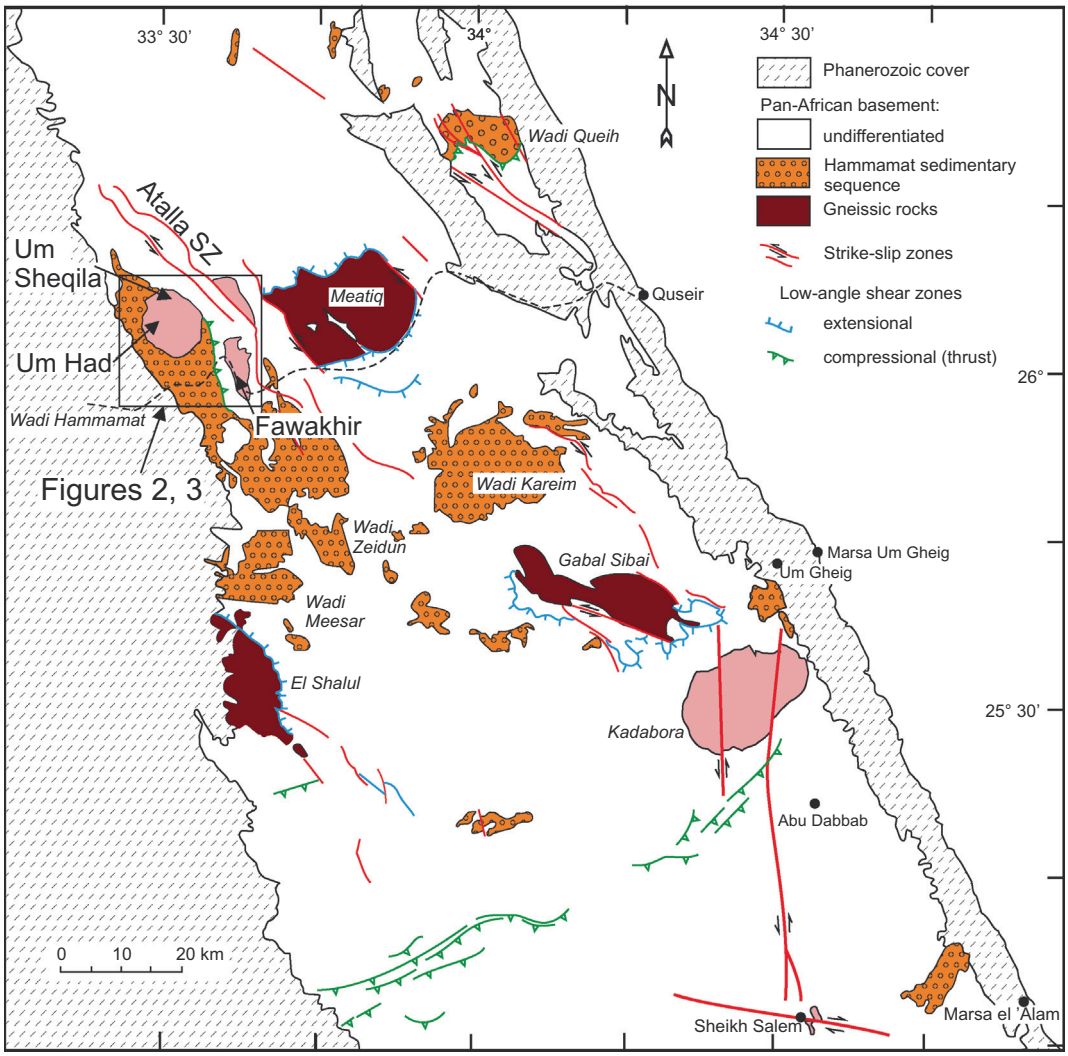

Fig. 1. Tectonic sketch map of the Pan-African basement in the Central Eastern Desert of Egypt, showing the major domal structures cored by gneissic rocks, and the location of selected late Pan-African plutons (red). The studied plutons (Um Had, Um Sheqila, Fawakhir) are located in the NW part of the map, where the location of a satellite image (Fig. 2) and a detailed geologic map (Fig. 3) is indicated. Modified from Conoco (1987) and EGSMA maps; SZ: shear zone. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

may be a time marker for the end of Pan-African tectonic activity in the region (Johnson et al., 2011). The evolution of the dome structures in the Central Eastern Desert is intimately related to the emplacement of plutons of mostly granitoid composition. As a consequence of these relationships between deformation and melt emplacement, the older intrusives are strongly deformed, often into orthogneisses, whilst the younger ones retain most of their primary fabric (e.g. El-Gaby et al., 1988, 1990; Hussein et al., 1982). Such a situation requires detailed structural studies in order to distinguish the different intrusives and establish their relative age. Historically, this situation led to many controversies on the character and absolute age of the different granitoids in the Eastern Desert of Egypt, culminating in the question whether the orthogneisses, for example, are of pre- or early Pan-African age. It was an eminent contribution of the late Samir El Gaby to make the discussion on these problems prominent, very lively, and ultimately very fruitful for the study of the Eastern Desert basement towards a better understanding of Pan-African orogeny.

In order to assess the fabrics of the Um Had and related plutons together with their country rocks, the authors carried out structural field work and took oriented samples for the study of the anisotropy of the magnetic susceptibility (AMS; e.g. Hrouda, 1982; Borradaille, 1988, 1991; Tarling and Hrouda, 1993). The AMS studies are complemented by microstructural studies. Based on these data, the regional structural elements in the Atalla zone and the Hammamat sediments and their tectonic significance are discussed, in particular the syn- or post-emplacement character of the intrusion. Further discussion also tackles the regional tectonic implications of the recent results.

2. Geological setting and structural evolution

The Central Eastern Desert of Egypt is a key area for the geological exploration of the Arabian–Nubian Shield (ANS) as a whole. Part of the area is covered by what is known as the oldest geological map, the so-called Turin papyrus (e.g. Hume, 1934; Harrell and Brown, 1992; Walther, 1994). The first comprehensive description by Hume (1934) was followed by numerous studies, which are summarized in the recent review by Johnson et al. (2011). Accordingly, this part of the ANS can be subdivided into two main tectonostratigraphic units, a lower tier comprising medium- to high grade metamorphic rocks also referred to as "infrastructure" (tier