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Tracking the Oman Ophiolite to the surface — New fission track and (U–Th)/He data from the Aswad and Khor Fakkan Blocks, United Arab Emirates

Joachim Jacobs [a,b,*], Robert J. Thomas [c,1], Anna K. Ksienzyk [a], István Dunkl [d]

[a] University of Bergen, Department of Earth Science, P.O. Box 7803, N-5020 Bergen, Norway
[b] Norwegian Polar Institute, Fram Centre, N-9296 Tromsø, Norway
[c] British Geological Survey, Nicker Hill, Keyworth, Nottingham NG12 5GG, UK
[d] Geoscience Centre, University of Göttingen, Goldschmidtstr. 3, 37077 Göttingen, Germany

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ABSTRACT

The Oman Ophiolite in the United Arab Emirates (UAE) was formed in a supra-subduction zone environment at about 95 Ma and was almost immediately obducted onto the eastern margin of Arabia. The timing of obduction is well constrained, but the post-obduction tectonic, uplift and exhumation history of the ophiolite and associated rocks are less well understood. We present twenty-one new fission track and (U–Th)/He analyses of apatite and zircon from the Hajar Mountains. The data show that the Oman Ophiolite had a complex exhumation history to present exposure levels in the Khor Fakkan and Aswad Blocks, resulting from at least three distinct exhumation events: 1) initial ophiolite obduction between ca. 93 and 83 Ma is characterised by tectonic exhumation and rapid cooling, as revealed by zircon (U–Th)/He and apatite fission-track data, but it is not associated with major erosional exhumation; 2) data from the lower part of the ophiolite and the metamorphic sole document a second exhumation event at ca. 45–35 Ma, interpreted to represent an early phase of the Zagros orogeny that led to reactivation of pre-existing structures and the differential exhumation of the Khor Fakkan Block along the Wadi Ham Shear Zone. This event led to significant erosional exhumation and deposition of a thick sedimentary succession in the Ras Al Khaimah foreland basin; and 3) Neogene exhumation is recorded by ca. 20–15 Ma apatite (U–Th)/He data and a single apatite fission track date from the lowermost part of the metamorphic sole. This event can be linked to the main phase of the Zagros orogeny, which is manifested in large fans with ophiolite-derived debris (Barzaman Formation conglomerates). During this period, the metamorphic sole of the Masafi window stayed at temperatures in excess of ca. 120 °C, corresponding to ca. 4 km of overburden, only later to be eroded to present day levels.

1. Introduction

The Oman Ophiolite complex (aka. the "Semail Ophiolite") is widely acknowledged as Earth's finest example of an obducted ophiolite slab. The Oman Ophiolite formed in a supra-subduction setting and was obducted onto the eastern margin of Arabia in late Cretaceous times (Fig. 1). The complex has been well studied in both Oman and latterly in the United Arab Emirates (UAE) and the geological history up to the time of emplacement on the Arabian continental margin in the UAE is reasonably well known (e.g. Cox et al., 1999; Goodenough et al., 2010, 2014; Nicolas et al., 2000; Peters and Kamber, 1994; Searle and Cox, 1999; Searle et al., 2014; Styles et al., 2006). During obduction high-T metamorphism is recorded in the metamorphic sole footwall rocks with localised melting and the emplacement of small granitic bodies (Styles et al., 2006).

To date however, the post-Cretaceous exhumation and erosion history of the ophiolite is poorly constrained. How much of the ophiolite has been eroded since obduction? What was its initial thickness? How quickly was it eroded to its present level? Were all segments of the ophiolite exhumed at the same time and to the same level? The Khor Fakkan Block shows a slightly deeper lithosphere section (predominated by mantle rocks) than the Aswad Block, from which it is separated by a structural discontinuity. An important question is, when and how the two blocks were finally juxtaposed into their present configuration? The Oman Ophiolite in the UAE lies in a relatively close proximity to the Cenozoic Zagros orogen (Fig. 1), a major mountain belt that resulted from the Palaeogene closure of the Neotethys Ocean and the collision of

* Corresponding author at: University of Bergen, Department of Earth Science, P.O. Box 7803, N-5020 Bergen, Norway. Tel.: +47 45698960.
E-mail address: joachim.jacobs@geo.uib.no (J. Jacobs).
[1] Present address, Council for Geoscience, P.O. Box 572, Bellville 7535, South Africa.

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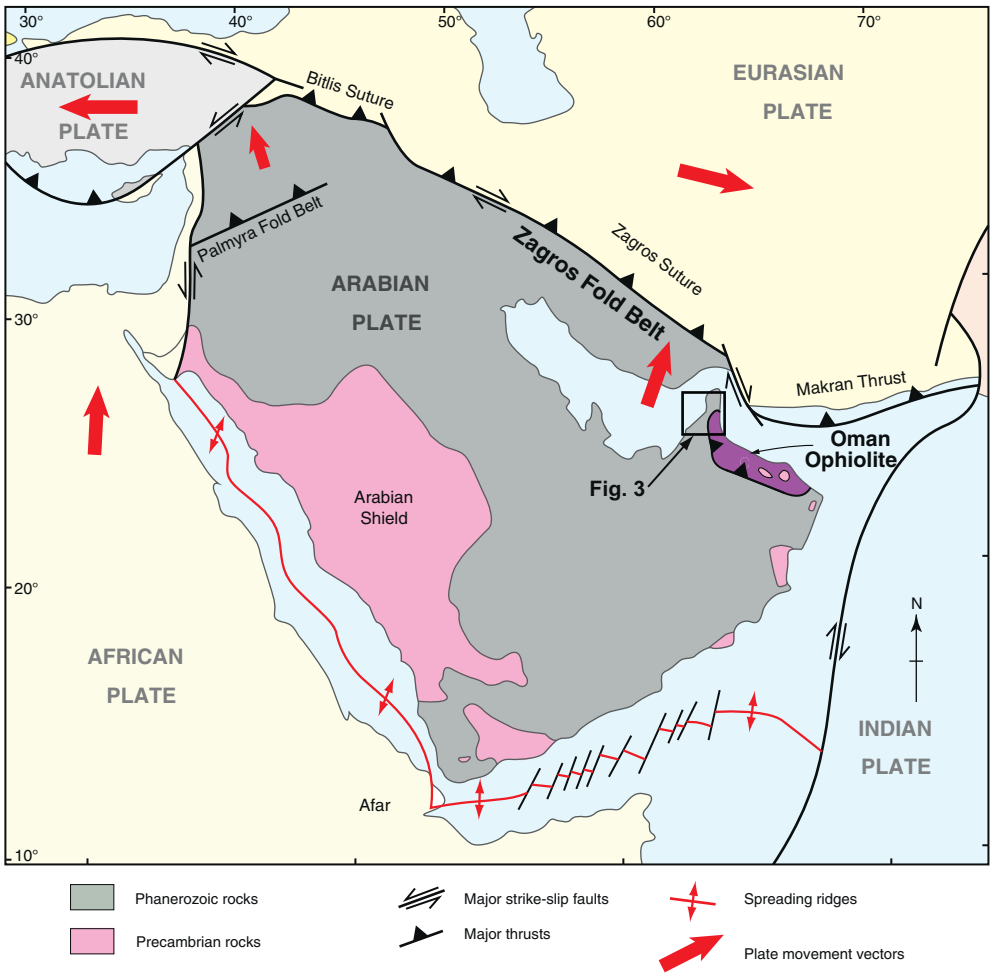

Fig. 1. Architecture of the Arabian Plate: tectonic and geological setting of the Oman Ophiolite, modified from Stern and Johnson (2010).

Arabia with Eurasia. To what extent did the final closure of Neotethys reactivate the ophiolite and did it lead to another exhumation pulse (or pulses) in the various segments? At present, the Oman Ophiolite in the UAE is exposed in the Hajar Mountains, which rise to some 1400 m above sea-level (Fig. 2). It remains unclear precisely when these mountains formed. Are they erosional remnants of the original late Cretaceous obduction phase and/or are they a product of reactivated tectonic uplift and exhumation in the foreland of the Zagros orogeny?

Published low-T thermochronological data, especially fission track and (U–Th)/He analyses of apatite and zircon that could help answer these questions are very sparse in the UAE with only one small dataset available (Tarapoanca et al., 2010). One of the main reasons for this is the shortage of apatite or zircon in the predominantly mafic and ultramafic lithologies. Furthermore, apatite fission track (AFT) analyses are hampered by the low U-contents of apatite in those few rock types where it does occur. This results in a lack of confined track length information for AFT analyses, which in turn prevents viable thermal history modelling. As a result of a major British Geological Survey mapping project between 2002 and 2005 in the UAE Ophiolite (Styles et al., 2006), a vast amount of detailed petrographic information was gained and apatite- and zircon-bearing lithologies and locations were identified. By these means it was possible to obtain enough samples with these minerals to form a representative dataset of AFT, zircon (U–Th)/He (ZHe) and apatite (U–Th)/He (AHe) dates.

2. Geological background

2.1. Geological setting of the Oman Ophiolite

The Oman Ophiolite complex is part of the chain of Alpine ophiolites, which extends across Europe and Asia and preserves remnants of late Palaeozoic to Mesozoic Neotethys ocean crust. It forms a large arcuate outcrop which stretches for over 500 km from the north-eastern coast of Oman, north-westwards to near Dibba in the UAE (Figs. 1 and 3). It has been segmented into 12 individual tectonically-bounded blocks, which include all the main components of a classic ophiolite complex (Lippard et al., 1986). The UAE contains the northernmost two segments, the Khor Fakkan and Aswad Blocks and a small part of the Fizh Block in the south (Fig. 4). The Khor Fakkan and Aswad Blocks are separated by the major Wadi Ham fault zone, which shows several periods of movement, the last of which shows a dextral sense of movement. The Aswad and Fizh Blocks are separated by the Hatta Zone, a faulted-bound sliver of unmetamorphosed Cretaceous continental margin to oceanic volcano-sedimentary rocks, which has been interpreted as having its origins as a transform fault zone (Robertson et al., 1990).

The Oman Ophiolite was obducted generally south-westwards onto the eastern margin of Arabia in late Cretaceous time. The eastern Arabian continental margin comprised Cryogenian crystalline basement unconformably overlain by Ediacaran volcanic and sedimentary rocks, in turn overlain by up to 8 km of Palaeozoic to Mesozoic (Tethyan) rocks