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ASSEMBLY of the OMAN-UAE OPHIOLITE: EVIDENCE for a MULTI-PHASE MAGMATIC HISTORY

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The Oman-UAE ophiolite (also known as the Semail ophiolite) is one of the largest and best preserved ophiolite complexes in the world. Most of the ophiolite lies in Oman, where it has been widely studied (e.g. Glennie *et al.*, 1974; Lippard *et al.*, 1986; Boudier and Juteau, 2000). The northern blocks of the ophiolite fall within the United Arab Emirates (UAE), and have been the subject of much less study, with some specific aspects covered and a few reconnaissance studies (Cox *et al.*, 1999; Searle and Cox, 1999; Nicolas *et al.,* 2000a, b). This paper presents an overview of a detailed field and geochemical study of the ophiolite in the UAE, carried out by the British Geological Survey under contract to the Ministry of Energy of the UAE (Styles et al 2006).

The Oman-UAE ophiolite was formed during the Cretaceous, around 95 Ma (Warren et al., 2005, Styles et al 2006) as part of the Neo-Tethyan ocean floor. The entire ophiolite exposure extends for approximately 600 km and comprises twelve blocks, separated by faults (Lippard *et al.*, 1986). Of these blocks, the northernmost two - Khor Fakkan and Aswad – lie almost entirely within the UAE. The detailed mapping showed that both these blocks consist of two tectonic units (Figure 1). The northern part of the Khor Fakkan block comprises rocks of the mantle section of the ophiolite, while the upper southern part is largely the crustal sequence of gabbros with a thinner unit of mantle rocks beneath. The Aswad block similarly consists of a lower northern unit entirely of mantle rocks while the upper part preserves the entire ophiolite sequence from mantle harzburgite in the west to upper crustal pillow lavas in the east. The components of the blocks are separated by high-temperature ductile shear zones. The two blocks are separated by a complex major fault zone, the Wadi Ham Fault, that records early ductile shearing in mylonites and later brittle faulting.

The Aswad block in the south contains a complete 'classic' ophiolite sequence from mantle harzburgite through a complex Mantle Transition Zone (MTZ) into a crustal sequence of layered gabbro, high-level gabbro, sheeted dyke complex and basaltic pillow lavas. There is only a thin lava sequence in the UAE, with no sedimentary horizons or obvious breaks in sequence but the lavas continue upwards across the border in Oman. The pillow lavas, sheeted dykes and high-level gabbros all have MORB-like chemical composition, similar to the V1 or Geotimes lavas in Oman (Alabaster et al 1982, Godard 2003). Pillow lavas in the UAE are more primitive and

MORB-like, and show less of a subduction zone signature, than those previously reported from Oman. These features are consistent with formation in a mid ocean ridge environment.

The regional mapping revealed that there are very extensive areas of gabbros that intruded the ocean ridge sequence described above. In the southern part of the Aswad block the younger gabbros comprise around 70% of the crustal section by area and contain xenoliths of layered and high-level gabbro up to several km in size. This intrusive complex seems to be centred around an area about 10 km NW of Hatta where there are abundant intrusions of coarse-grained wehrlite, tonalite and 'vinaigrette' (a mixed mafic-felsic intrusive breccia). From this centre there are large sill-like northerly extensions at two main horizons, roughly along the lower contact of the layered gabbro, near the boundary with the MTZ and along the top of the layered gabbro close to the boundary with the high-level gabbros. The younger gabbros were divided in to two lithological types, known as the "Bithnah" and "Fujairah" facies. The Bithnah facies is dominant in the western, stratigraphically lower parts and is dominantly a medium to fine gabbro that is often shot through with sheets of splintery microgabbro and is spatially associated with ductile shear zones. It intrudes the layered gabbro, MTZ and locally down into the harzburgite. The Fujairah facies is dominant in the stratigraphically higher, eastern, parts and is characterised by its variability and multiphase origin. Xenoliths of earlier dolerite are widely developed. It also shows a wispy layering in many places and often contains later vein arrays of tonalite (± hornblende), or vinaigrette. It intrudes the layered gabbro and lower parts of the high-level gabbro.

Wehrlites are often associated with the younger gabbros and occur mostly in sill-like bodies but also as more coherent masses up to a few km^2 in extent. The intrusive relations show that wehrlite intrusions both pre-date and post-date phases of the younger gabbros, indicating that they are a component of a late polyphase magmatic event. The wehrlites are most abundant in the layered and Fujairah gabbro but are also found in the high-level gabbros and, rarely, in pillow lava. Wehrlites are also abundant in the mantle transition zone.

The younger magmatic suite show a number of petrographic and geochemical features that distinguish them from the early MORB suite. Gabbros show a crystallisation sequence of clinopyroxene before plagioclase and early formation of orthopyroxene in some cases, features not seen in the early suite. There are several groups of mafic dykes that cross cut the early MORB suite and are clearly belong to the second suite. The majority of these dykes are characterised by LREE depletion, although some samples have more 'u-shaped', boninitic patterns with depletion of the MREE. They are geochemically similar to the clinopyroxene-phyric and Lasail units identified by Alabaster et al. (1982). All these features suggest that the later suite have formed from hydrous magmas in contrast to the anhydrous MORB suite.

The MTZ, between the mantle harzburgite and layered gabbro is up to several hundreds of metres thick in many parts of the UAE and shows a complex relationship between rock types. The lower part consists of massive dunite that is overlain by a "Mixed Unit" of mafic and ultramafic rocks. The lower part is dominated by impregnated dunites, passing up to olivine-pyroxenites and pyroxenites while higher still, a complex igneous mélange of pyroxenites, wehrlites and gabbros is typical. Much of the gabbro is comprised of disrupted and stoped xenolithic blocks of layered gabbro. A substantial part of the pyroxene-rich Mixed Unit is thought to be the deeper part of the late magmatic suite.

The Oman-UAE ophiolite in the Aswad block therefore shows clear evidence of formation during two magmatic cycles. The first was probably at a mid ocean ridge where anhydrous melts produced rocks with typical MORB chemical features. Our mapping has revealed that a second phase is very extensive in the UAE part of the ophiolite, where it constitutes around 50% of the exposure. This is apparently far higher than recorded from Oman, though it is possible that the true extent of second phase magmatism has not been recognised there. The second mgmatic phase involved hydrous magmas that have geochemical signatures similar to those generated in island-arc settings. It is consequently suggested that the UAE section of the ophiolite shows a transition, first in a ridge environment, followed by initiation of subduction where the second magmatic stage was generated.

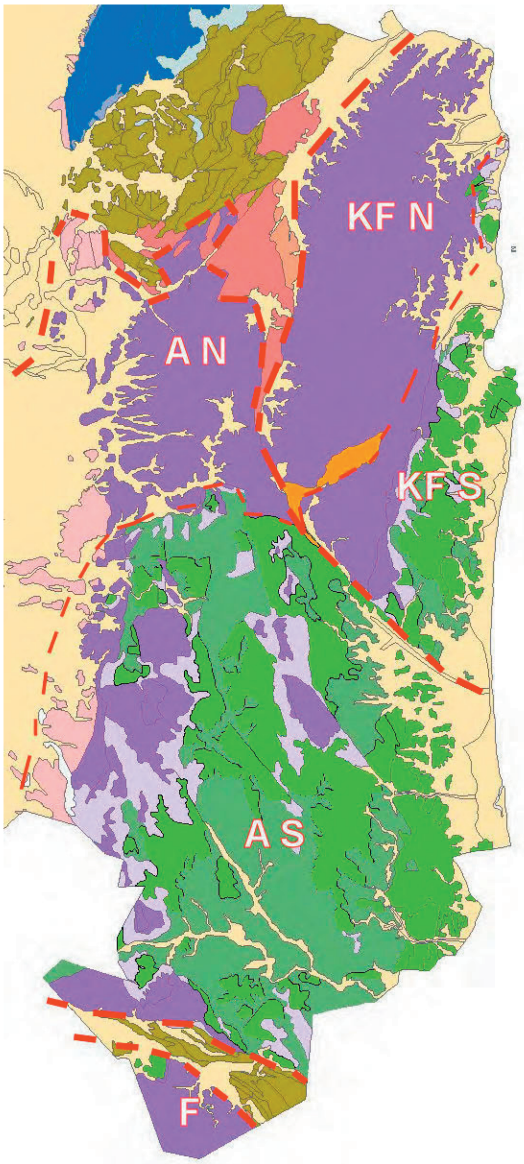

Figure 1. Simplified geological map of the Oman-UAE ophiolite in the UAE. KF N Khor Fakkan north, KF S Khor Fakkan south, A N Aswad N, A S Aswad S, F Fizh. Mantle harzburgite dark purple, Mixed Unit light purple, early crustal sequence bright green, later crustal sequence dark green, block bounding thrusts

and faults thick line, internal shear zones thin line. Non-ophilite units, platform carbonates blue, sedimentary rocks of Dibba and Hatta zones brown, metamorphic rocks of Masafi-Ismah window pink, metamorphic rocks of Bani Hamid window orange, sedimentary rocks of the foreland basin pale pink, Quaternary deposits beige.

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