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Late Neoproterozoic Alkaline Intrusives in Huqf Sediments: A New Reservoir Target in Southern Oman

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Extended abstract

Penetrations of Huqf sediments in the central part of Block 56, a coastal block some 200 km north east of Salalah in southern Oman have revealed the presence of voluminous granitoid intrusions over intervals up to 80m thick and separated by screens of heterolithic sediments. Sub-horizontal chilled margins in core against host rock indicate the intrusives take the form of decametre-scale, often composite igneous sills.

Compositional data

Using two separate parameter sets and based on their major oxide contents the granitoids plot in the monzonite and syenite fields within the alkaline domain (Figure 1). They both lie on a fractionation trend from a modelled gabbro-diorite parent magma whose composition can be achieved by adding appropriate fractionation assemblages back into the respective compositions of monzonite and syenite.

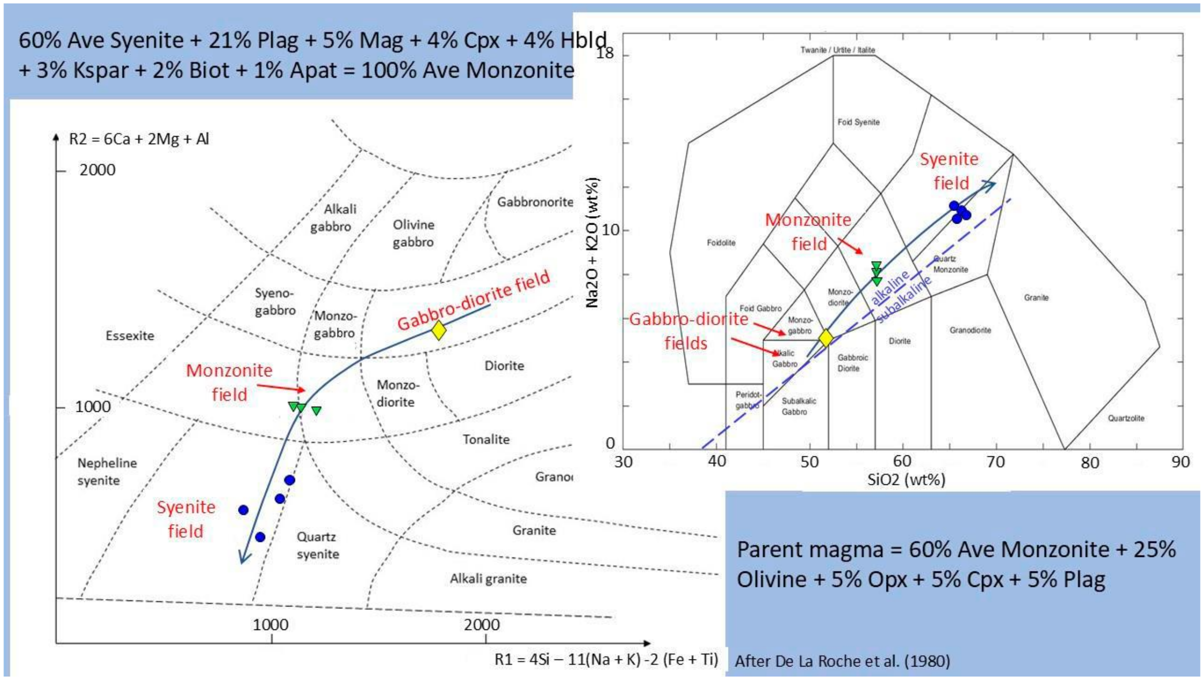

Figure 1. *Compositional plots for monzonites (green triangles) and syenites (blue circles) from Block 56 Huqf penetrations. The monzonites and syenites lie on a fractionation trend shown in the blue arrow from a modelled gabbro-diorite parent magma (yellow diamond) whose composition is achieved by adding back the purported fractionation assemablages shown in the two equations. Plag: plagioclase fedspar; Mag: magnetite; Cpx: clinopyroxene; Opx: orthopyroxene; Hbld: hornblende; Kspar: potassium feldspar; Biot: biotite; Apat: apatite. Compositional plot templates from Rollinson (1993).*

Geochronology

U-Pb dating of zircon separates from the intrusives gives two concordant ages, one at 561 ± 10Ma which we take to be the crystallization age and one at 1173 ± 30Ma which we attribute to xenocrystic contamination. This latter observation is of particular interest given the general view that Oman basement represents a collage of juvenile arcs less than 900 Ma old (eg Alessio et al., 2018). The evidence for xenocrystic contamination in our samples indicates the presence of a relic of old Arabian continental crust through which the intrusives were emplaced. The 561 ± 10Ma age also places a minimum age on the Huqf Supergroup in an otherwise poorly dated interval (Bowring et al., 2007).

Late Neoproterozoic magmatism in the Oman region

The products of Late Neoproterozoic magmatism are widely scattered around the greater Oman region. In Figure 2 the trace element geochemistry of the Block 56 intrusives and other examples of Late Neoproterozoic magmatism are used to investigate their tectonic setting by means of the Zr/Nb/Y discriminant diagram of Meschede (1986). In common with entrained exotic Late Neoproterozoic volcanic blocks in the Qarn Sahmah salt dome in the Ghaba Salt Basin (Thomas et al., 2015), the Block 56 intrusives plot in the within plate fields. By contrast exotic volcanic blocks in the salt domes of the Arabian Gulf and Zagros region of Iran are clearly separated and plot more in the volcanic arc field.

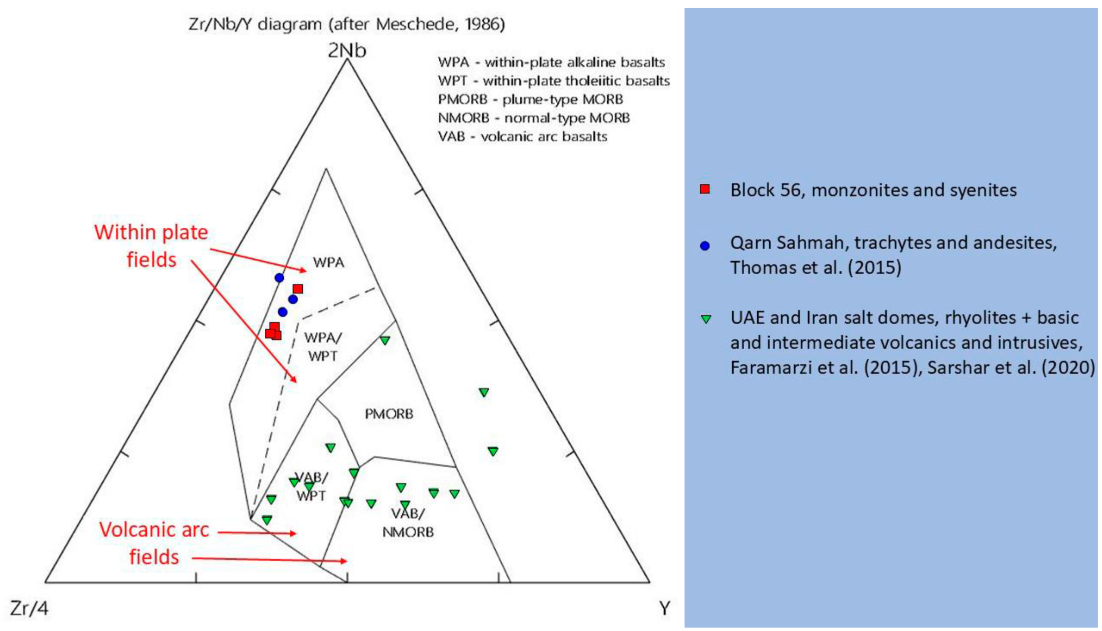

Figure 2. *Trace element geochemical plots for Block 56 intrusives and other examples of Late Neoproterozoic magmatism in the greater Oman area. Details in text. Geochemical templates from Rollinson (1993).*

In the Late Neoproterozoic during the final stages of the amalgamation of the Gondwana supercontinent the northern margin of this amalgamating collage of microplates was rimmed by a south dipping subduction zone (Callegari et al., 2020). As a result, a volcanic edifice built up which led to restricted circulation behind it and the development of the salt basins. Contemporaneous igneous activity is represented by the various volcanic and plutonic rocks discussed here. The magmas show decreasing arc affinity and increasing alkalinity from north to south. Thus the alkaline magmas of Block 56 and in Qarn Sahmah probably represent magmatism within attenuated continental crust in a retro-arc setting. This notion is supported by the evidence from both Block 56 and Qarn Sahmah of inherited zircons as old as 2500 Ma.

Origin and timing of porosity development

Matrix porosity is uncommon in igneous or metamorphic reservoirs from which production normally relies on oil storage in fractures. Where matrix porosity is present it normally is minor and related to dissolution of feldspars. In the Block 56 intrusives the feldspars are relatively stable and porosity is due to an apparently unique situation of ferromagnesian mineral dissolution. Thin sections reveal an interconnected network of angular pores within a framework of alkali feldspar laths (Figure 3A). This porosity is believed to have been created by dissolution of primary hornblende, of which only minor remnants occur, during an open system hydrothermal event with net loss of mineral components. Secondary biotite grew during this event at the expense of alkali feldspar; its late paragenesis is indicated by textures including mica flakes growing across feldspar twin planes and the presence of feldspar inclusions in optical continuity with surrounding feldspar crystals. Intimately associated with areas of biotite crystallisation are fine needles of apatite (Figure 3B). U-Pb dating of apatite separates gave Cretaceous ages (86 ± 18Ma and 105 ± 11Ma). Given their close spatial assocation we believe that the apatite formed at the same time as the biotite and the Cretaceous ages we obtained date the metamorphic and porosity creation event.

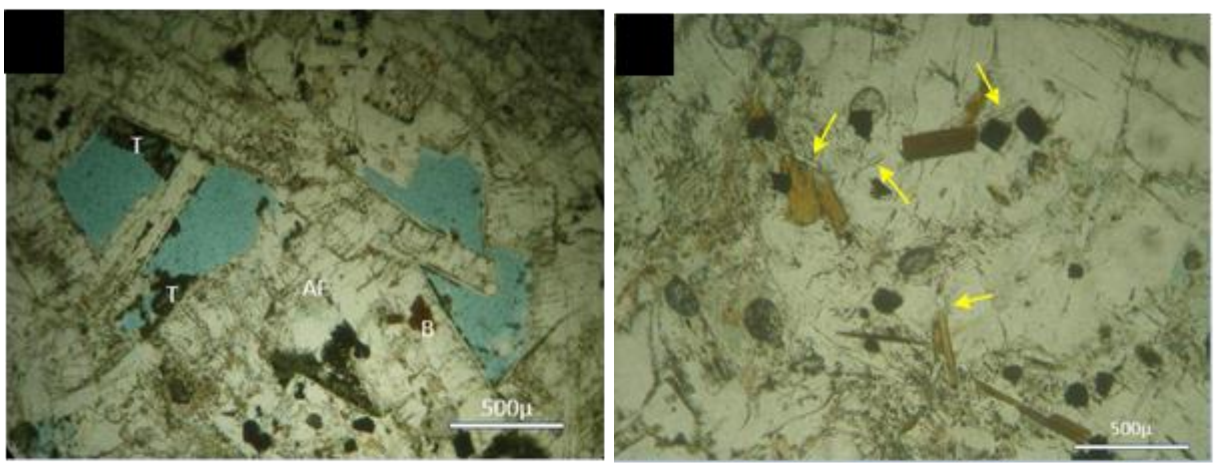

Figure 3. *Photomicrographs. A. Fracture connected network of angular dissolution pores within a framework of elongate alkali feldspar laths. T – titanite; AF – alkali feldspar; B- biotite. B. Euhedral crystals of clear apatite (arrowed) growing in close spatial proximity to biotite.*

The island of Masirah, 300km to the north-east along the eastern seaboard of Oman, may offer a clue to the origin of the purported hydrothermal event. A Mid Cretaceous uplift event is recorded in the stratigraphic record of the sediments above the ophiolite when deep water ribbon cherts were succeeded by reefal limestone (Immenhauser, 1996). Contemporaneous alkaline volcanism indicates this uplift was due to a thermal pulse, the effects of which are likely to have been felt on the eastern seaboard of Oman as plate reconstructions indicate the proximity of Masirah to this margin at the time (Gaina et al., 2015).

A source for the oil

Sidewall cores from one of the syenite bodies were found to be oozing light oil (Figure 4) which on the Terken plot (Terken et al., 2001) shows closest match to a Huqf source. Expulsion from Huqf source rocks in the salt basins is generally taken to be during the Ordovician from beneath thick Haima cover. However, had the oil been in place at the time of the mid Cretaceous thermal event then degradation of the oil in the form of precipitated asphaltenes might have been expected . Their absence and the low viscosity aspect of the oil go to prove that the oil was emplaced after the thermal event from maturing Huqf sources in shallower and cooler parts of the SOSB or indeed from the Tertiary Basin to the south where Haima is absent and only after sufficient thicknesses of Cenozoic sediments had accumulated there.

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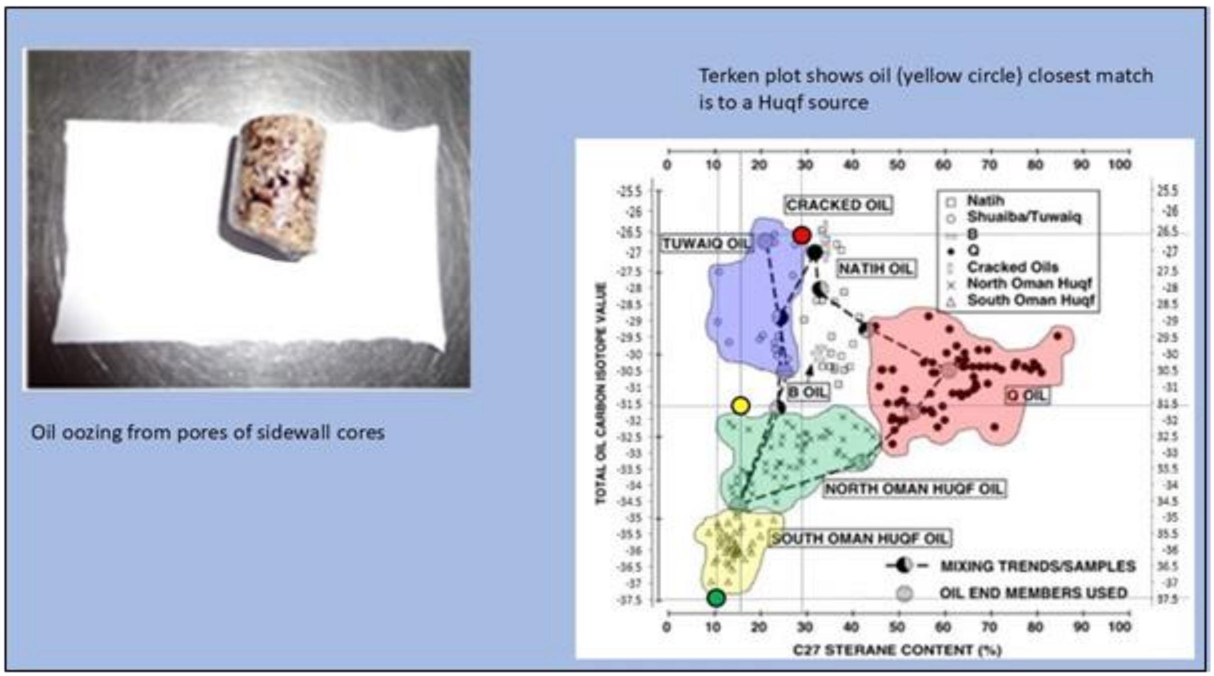

Figure 4. *Oil oozing from pores of sidewall core and a plot of the oil on the Terken plot (Terken et al., 2001).*

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