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Geochronology and petrology of the Early Carboniferous Misho Mafic Complex (NW Iran), and implications for the melt evolution of Paleo-Tethyan rifting in Western Cimmeria

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ABSTRACT

We report new petrological, geochemical and geochronological data from the Misho Mafic Complex (NW Iran), which represents a significant component of the West Cimmerian domain in Paleo-Tethys. The Misho Mafic Complex (MMC) mainly consists of gabbros crosscut by abundant basaltic dykes and the overlying basaltic sheeted dyke complex. Gabbros are intrusive into the Precambrian continental basement representing the northern margin of Gondwana. The U–Pb zircon age of a leucogabbro dyke reveals that the igneous emplacement age of the MMC is 356.7 ± 3.4 Ma (Early Carboniferous). The gabbros and basaltic dykes are represented by (1) a subgroup of rocks showing normal mid-ocean ridge basalt (N-MORB) affinity, and (2) another subgroup of rocks displaying plume-type MORB (P-MORB) affinity. These subgroups of rocks are coeval. The N-MORB rocks have almost flat N-MORB normalized incompatible element patterns, low Th/Yb, Ta/Yb, Zr/Y ratios, and high Zr/Nb ratios. The P-MORB rocks show significant OIB-type trace element signatures, such as enrichments in Th, Ta, Nb and light rare earth elements (LREE) with respect to N-MORB composition, high Th/Yb, Ta/Yb, Zr/Y ratios, and low Zr/Nb ratios. Petrogenetic modeling suggests that N-MORB rocks were generated by ~13% partial melting of a depleted MORB mantle (DMM) source, whereas P-MORB rocks were generated by ~4–6% partial melting of a DMM source metasomatized by variable proportions of OIB-type (plume-type) enriched components. The mantle melting for both N-MORBs and P-MORBs appears to have started initially deep in the garnet-facies mantle, and then shifted to shallow levels in the spinel-facies mantle where it experienced higher degrees of melting. The MMC collectively formed as a product of interaction between a depleted MORB-type asthenosphere and plume-type material. Its mafic–ultramafic rocks represent an early Carboniferous magmatic event developed during the continental break-up of the northern edge of Gondwana that led to the opening of Paleo-Tethys, that was originally triggered by a mantle plume. This model is consistent with well-documented late Devonian–early Carboniferous mantle plume activity to the east, along the Paleo-Tethys margins in central-eastern Asia, and suggests that the initial rift-drift tectonics of Paleo-Tethys was strongly affected by plume-related magmatism and associated lithospheric weakening at a regional scale.

1. Introduction

The geodynamic evolution and reconstruction of the Paleo-Tethyan oceanic realm have received much attention during the last two decades (e.g., Dercourt et al., 1986; Gealey, 1988; Kalvoda and Babek, 2010; Metcalf, 2002; Muttoni et al., 2009; Sengor et al., 1984; Zanchi et al., 2009). Northern Iran is a key area for understanding the Paleo-Tethys evolution in the W Cimmerian sector towards its western end. However, remnants of Paleo-Tethyan oceanic crust are scarce in this area and only occur along the northern border of the Alborz orogenic belt (Lensch and Davoudzadeh, 1982) (Fig. 1a). It is widely accepted that the tectonic evolution of the Paleo-Tethyan ophiolites involved the northward (present-day coordinates) subduction of the Paleo-Tethyan ocean floor and the subsequent collision between the Iranian Cimmerian microcontinent and the Turan plate (southern part of Laurasia).

Apart from those ophiolites cropping out in the north Alborz range, the Paleo-Tethyan oceanic crust has been also reported from the East Misho Mountains in northwest Iran (Fig. 1b; Asadian et al., 1994). These purported Paleo-Tethyan oceanic crustal remnants – hereafter called Misho Mafic Complex (MMC) – include gabbros and dolerite dykes but their age, composition, and tectonic setting of formation are still poorly known. The fact that the Misho gabbros are intrusive into a Pre-Cambrian continental basement raises the question of whether the

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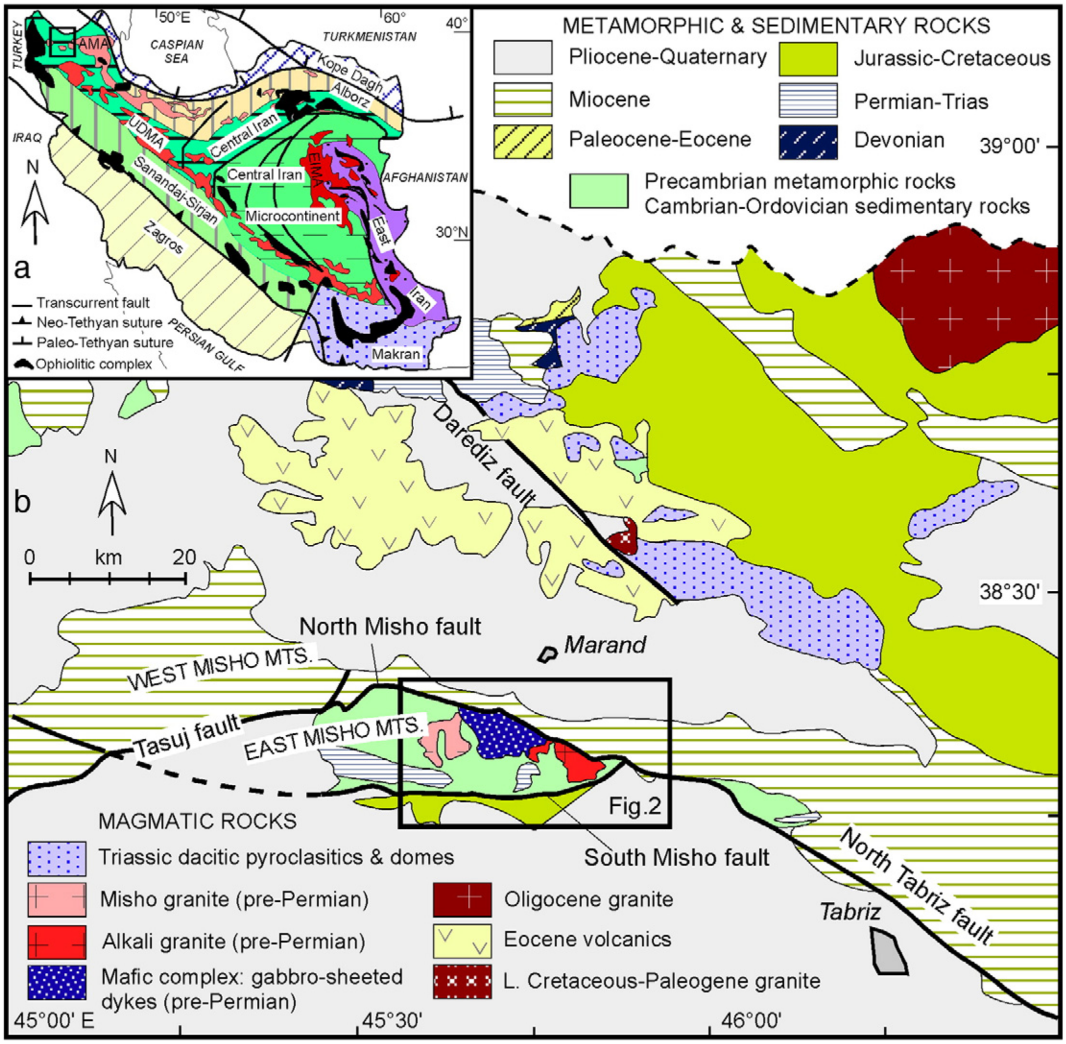

Fig. 1. (a) Generalized tectonic map of Iran (modified from Alavi, 1991; Allahyari et al., 2010; Stöcklin, 1968). The box indicates the area shown in Fig. 1b. (b) Simplified geological map of the north Azerbaijan Province of Iran (modified after Eftekharnejad et al., 1989). The box indicates the study area shown in Fig. 2.

MMC represents a typical ophiolite of seafloor spreading origin (Dilek and Furnes, 2011).

Magma generation during continental break-up generally is accounted for by asthenospheric upwelling and lithospheric extension and is characterized by basaltic melts commonly showing OIB (ocean island basalt) and MORB (mid-ocean ridge basalt) affinities (e.g., Gorring et al., 2003; McKenzie and Bickle, 1988). In the Chinese sector, the tectonic regime that triggered rifting and opening of the Paleo-Tethyan Ocean involved mantle plume(s) activity with abundant volcanism including both normal (N) and enriched (E) MORBs and alkaline OIBs (Dai et al., 2011; Guo et al., 2004; Xiao et al., 2008 and references therein). By contrast, the Paleo-Tethyan ophiolites in northern Iran are generally represented by intra-arc products that formed during the closure of this ocean (Bagheri and Stampfli, 2008; Weber-Diefenbach et al., 1986; Zanchetta et al., 2009). Based on limited data, Mehdizadeh-Shahri (2008) proposed the occurrence of tholeiitic rocks associated with the pre-rifting of Paleo-Tethys in W Cimmeria. Nonetheless, the tectonic regime(s) that triggered rifting and opening of the Iranian sector of Paleo-Tethys still are not constrained. Of particular importance is whether the mantle plume(s) activity played a major role in the evolution of the western sector of Paleo-Tethys, as they did in its eastern domain.

In order to address this question, and to better constrain the geological and geochemical evolution of the Iranian sector of the Paleo-Tethyan evolution, we have undertaken a systematic study of the MMC. We report new U–Pb zircon age, mineral chemistry, whole-rock major and trace element data from the MMC. We then discuss the age, nature and origin of the gabbros and basaltic dykes, and the nature of mantle sources beneath the continental margins of Paleo-Tethys in its western sector and their relationship to the tectonic evolution of the Paleo-Tethyan Ocean.

2. Regional geology and structure of the MMC

The geologically poorly known Misho Mountains are located to the SW of the city of Marand in the East Azerbaijan province of NW Iran. The Misho Mountains are part of the Central Iran Domain (Fig. 1a), which consists of a Precambrian crystalline basement, Paleozoic platform sediments, and Cambrian to Triassic sedimentary and magmatic rocks representing Gondwana marginal terranes (Alavi, 1991; Stöcklin, 1968). The Misho Mountains are bounded both in the north and the south by two dextral, oblique-strike slip Cenozoic fault systems: the North and South Misho faults, respectively (Figs. 1b, 2). These faults are responsible for the uplift of the Precambrian to Jurassic formations as a major positive flower structure (Eftekharnejad et al., 1989). The North Misho fault is likely to be a segment of the major North Tabriz fault (Fig. 1b), which extends for about 600 km from north-central Iran to Azerbaijan and then into eastern Turkey (Darvishzadeh, 1991; Eftekharnejad, 1975). The Tasuj fault,