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Supra-subduction and mid-ocean ridge peridotites from the Piranshahr area, NW Iran

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ABSTRACT

The Piranshahr metaperidotites in the northwestern end of the Zagros orogen were emplaced following the closure of the Neotethys ocean. The ophiolitic rocks were emplaced onto the passive margin of the northern edge of the Arabian plate as a result of northeastward subduction and subsequent accretion of the continental fragments. The metaperidotites have compositions ranging from low-clinopyroxene lherzolite to harzburgite and dunite. They are mantle residues with distinct geochemical signatures of both mid-ocean ridge and supra subduction zone (SSZ) affinities. The abyssal peridotites are characterized by high Al_2O_3 and Cr_2O_3 contents and low Mg-number in pyroxenes. The Cr-number in the coexisting spinel is also low. The SSZ mantle peridotites are characterized by low Al_2O_3 contents in pyroxenes as well as low Al_2O_3 and high Cr-number in spinel. Mineral chemical data indicate that the MOR- and SSZ-type peridotites are the residues from ~15–20% and ~30–35% of mantle melting, respectively. Considering petrography, mineralogy and textural evidence, the petrological history of the Piranshahr metaperidotites can be interpreted in three stages: mantle stable stage, serpentinization and metamorphism. The temperature conditions in the mantle are estimated using the Ca-in-orthopyroxene thermometer as $1210 \pm 26\,^{\circ}C$. The rocks have experienced serpentinization. Based on the textural observations, olivine and pyroxene transformed into lizardite and/or chrysotile with pseudomorphic textures at temperatures below 300 °C during the initial stage of serpentinization. Subsequent orogenic metamorphism affected the rocks at temperatures lower than 600 °C under lower-amphibolite facies metamorphism.

1. Introduction

Ophiolites represent former fragments of oceanic lithosphere, now tectonically emplaced on land.

Most Tethyan ophiolites occurring in the eastern Mediterranean region are interpreted as fragments of supra-subduction zone (SSZ)-generated oceanic lithosphere (Pearce et al., 1984; Robertson, 1994; Dilek et al., 1999, 2007; Parlak et al., 2002; Dilek and Flower, 2003; Saccani and Photiades, 2004; Dilek and Furnes, 2009).

The Tethyan ophiolites with SSZ characteristics are widely interpreted to have formed in incipient arc–forearc settings shortly before their emplacement on continental margins. Shervais (2001) reviewed the petrological and geochemical signatures of SSZ ophiolites and suggested that these ophiolites experienced a sequence of events during their evolution in response to the change in tectonic setting from oceanic lithosphere formed at mid-ocean ridges to the initiation of subduction. Recent studies on many Tethyan ophiolites have shown that these ophiolites, particularly their upper mantle components, have records of a complex magmatic, geochemical and tectonic evolution, spanning different geodynamic settings within the same ocean basin. Some examples of ophiolites with both mid-ocean ridge (MOR)- and SSZ-type affinities include Pindos ophiolites in Greece (Saccani and Photiades, 2004), Troodos ophiolites in Cyprus (Portnyagin et al., 1997), Lycian and Antalya ophiolites in SW Turkey (Aldanmaz et al., 2009), Harmancik ophiolites in NW Turkey (Uysal et al., 2009, 2013), Kermanshah (Allahyari et al., 2010; Saccani et al., 2013) and Neyriz (Rajabzadeh and Nazari Dehkordi, 2012) ophiolites in the Main Zagros Fault Zone, Nain (Mehdipour Ghazi et al., 2010) and Oman ophiolites (Python and Ceuleneer, 2003; Yamasaki et al., 2006; Tamura and Arai, 2006; Dare et al., 2009; Clénet et al., 2010; Goodenough et al., 2010).

The Iranian ophiolites of Zagros are part of a 3000 km long belt that extends from Troodos in Cyprus, to Smail in Oman (Fig. 1a). The ophiolites at either end of this belt are the best studied in the world (e.g. Pearce and Robinson, 2010; Dilek and Furnes, 2009; Dilek et al., 2007; Garfunkel, 2006; Godard et al., 2003, 2006; Robertson, 1998, 2002; Floyd et al., 1998; Şengör, 1990; Albaster et al., 1982,

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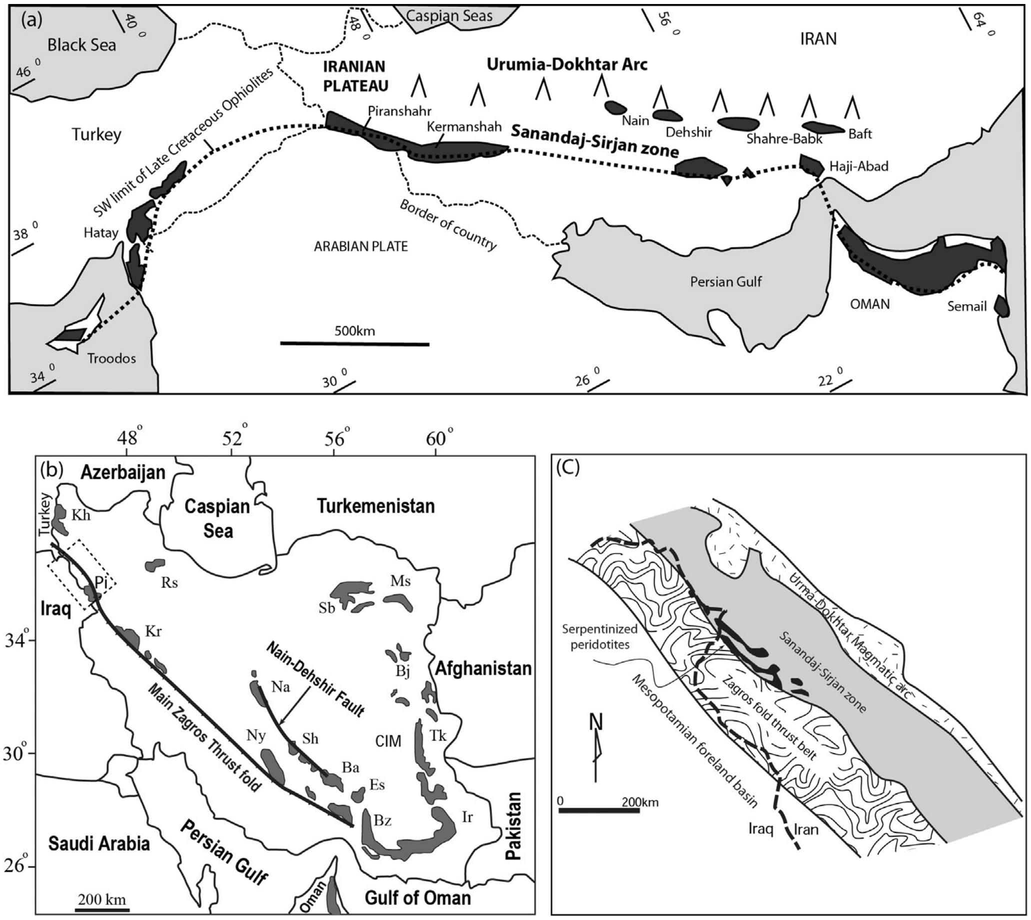

Fig. 1. (a) Upper Cretaceous ophiolitic belt of SW Asia between Cyprus and Oman and location of the Zagros ophiolitic belt (modified after Blome and Irwin, 1985). (b) Distribution of the ophiolites in Iran. Kh: Khoy, Pi: Piranshahr, Rs: Rasht, Kr: Kermanshah, Ny: Neyriz, Bz: Bande-Zyarat, Ir: Iranshahr, Es: Esfandagheh, Ba: Baft, Sh, Shahre-Babak, Na: Nain, Sb: Sabzevar, Ms: Mashhad, Bj: Birjand, Tk: Tchehel Kureh. (c) The Zagros orogen at the Iran and Iraq border consists of four main units including Urmia-Dokhtar magmatic arc, Sanandaj-Sirjan zone, Zagros fold-thrust belt and the Mesopotamian foreland basin.

among others). In contrast the Upper Cretaceous ophiolites of the Iranian Zagros are still poorly known (Fig. 1b). Ophiolites occur at the NW end of the Zagros orogen in the Kurdistan region at the Iran and Iraq border. The most important ophiolitic complexes at this part of the Zagros orogen are Penjwin and Mawat ophiolites in Iraq (Aswad et al., 2011; Aziz et al., 2011; Mohammad, 2011) and Kermanshah (Allahyari et al., 2010; Saccani et al., 2013), Sarve-Abad (Allahyari et al., 2013) and Piranshahr ophiolites (this study) in Iran. Aswad et al. (2011) concluded a forearc setting for the ophiolites in NE Iraq, based on chemistry of primary spinels in serpentinized peridotites. Aziz et al. (2011) reported Sr model ages of 80–110 Ma for ophiolite formation and/or serpentinization above an intra-oceanic supra-subduction zone. The ophiolites are metamorphosed at upper greenschist facies condition (Mohammad, 2011).

Extensive studies are carried out on the Kermanshah ophiolite by Allahyari et al. (2010) and Saccani et al. (2013). Allahyari et al. (2010) preformed a detailed study on Kermanshah ophiolite and showed that foliated gabbros of this ophiolite represent a portion of MOR oceanic crust, while some lherzolites are residual MOR mantle, which are subsequently trapped in a supra-subduction zone. Based on these facts, they proposed a geodynamic model in which a MOR lithosphere was generated in the Triassic. An intra-oceanic island arc was formed in Lower Late Cretaceous and the residual MOR mantle (depleted lherzolite) was trapped in the supra-subduction zone. Eventually ophiolitic rocks were obducted on the Arabian passive continental margin carbonates during Late Cretaceous. Saccani et al. (2013) suggested a model for the Kermanshah ophiolite similar to Ligurian Tethys, with exception that OIB-type components linked to the uprising of MORB-type depleted asthenospheric mantle had a pronounced influence on formation of Kermanshah ophiolite.

The Piranshahr ophiolite located along the Main Zagros Thrust Zone is spatially close to the NE Iraq and Kermanshah ophiolites. There is no published account on this ophiolite. Detailed investigations on this ophiolite, which links the NE Iraq ophiolites to Iranian Zagros ophiolites provide information to interpret the evolution of the Neotethys in the Middle East.

This paper presents the first petrological and mineralogical studies on the obscure Piranshahr ophiolite. The chemical compositions of the analysed minerals in the peridotites are used to determine the origin and evolution of the investigated rocks. The evolution of the Piranshahr ophiolite is studied in the framework of the model proposed by Allahyari et al. (2010) and Saccani et al. (2013).

2. Geological setting and field relations

The Piranshahr ophiolite is located along the Zagros suture zone, between the Sanandai-Sirjan zone and the Zagros fold thrust belt (Fig. 1c) in NW Iran. The Zagros orogen at the Iran and Iraq