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Geochemistry of platinum-group elements and mineral composition in chromitites and associated rocks from the Abdasht ultramafic complex, Kerman, Southeastern Iran

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ABSTRACT

The Abdasht complex is a major ultramafic complex in south-east Iran (Esfandagheh area). It is composed mainly of dunite, harzburgite, podiform chromitites, and subordinate lherzolite and wehrlite. The podiform chromitites display massive, disseminated, banded and nodular textures. Chromian spinels in massive chromitites exhibit a uniform and restricted composition and are characterized by Cr# [= Cr / (Cr + Al)] ranging from 0.76 to 0.77, Mg# [= Mg/(Mg + Fe^{2+})] from 0.63 to 0.65 and TiO_2 < 0.2 wt.%. These values may reflect crystallization of the chromian spinels from boninitic magmas. Chromian spinels in peridotites exhibit a wide range of Cr# from 0.48 to 0.86, Mg# from 0.26 to 0.56 and very low TiO_2 contents (averaging 0.07 wt.%). The Fe^{3+}# is very low, (<0.08 wt.%) in the chromian spinel of chromitites and peridotites of the Abdasht complex which reflects crystallization under low oxygen fugacities.

The distribution of platinum group elements (PGE) in Abdasht chromitites displays a high (Os + Ir + Ru)/(Rh + Pt + Pd) ratio with strongly fractionated chondrite-normalized PGE patterns typical of ophiolitic chromitites. Moreover, the Pd/Ir value, which is an indicator of PGE fractionation, is very low (<0.1) in the chromitites.

The harzburgite, dunite and lherzolite samples are highly depleted in PGE contents relative to chondrites. The Pd_N/Ir_N ratios in dunites are unfractionated, averaging 0.72, whereas the harzburgites and lherzolites show slightly positive slopes PGE spidergrams, together with a small positive Ru anomaly, and their Pd_N/Ir_N ratio averages 2.4 and 2.3 respectively. Moreover, the PGE chondrite and primitive mantle normalized patterns of harzburgite, dunite and lherzolite are relatively flat which are comparable to the highly depleted mantle peridotites.

The mineral chemistry data and PGE geochemistry indicate that the Abdasht chromitites and peridotites were generated from a melt with boninitic affinity under low oxygen fugacity in a supra-subduction zone setting. The composition of calculated parental melts of the Abdasht chromitites is consistent with the differentiation of arc-related magmas.

1. Introduction

Mafic-ultramafic complexes occur in various tectonic settings and information about their petrogenesis informs models of tectonics and crustal evolution (e.g. Su et al., 2011; Thanh et al., 2014). Moreover, ultramafic complexes from different tectonic settings provide information about the paleogeodynamic history and crustal evolution in continental and oceanic regions (e.g. Ghosh et al., 2013).

Chromian spinel is well established alteration-resistant petrogenetic indicator of the tectonic setting of ultramafic–mafic complexes. The mineral chemistry of chromian spinel is used to establish the geotectonic setting of ultramafic rocks (e.g. Bonatti and Michael, 1989). Thus, chromian spinels provide a way to distinguish supra-subduction zone (SSZ) from mid-oceanic ridge (MOR) ultramafic–mafic complexes (e.g. Arai et al., 2006; Dare et al., 2009).

The composition of chromian spinels depends on the physicochemical conditions of fractional crystallization and is particularly sensitive to the differences in oxidation state of the mantle (variations in oxygen fugacity) and degree of partial melting in SSZ and MOR environments (e.g. Caran et al., 2010; Dare et al., 2009; Grammatikopoulos et al., 2011; Kapsiotis et al., 2009; Kapsiotis et al., 2011).

Thirty-one ultramafic complexes are known in an E–W trending belt of 60 km length and 5–10 km width in the Haji Abad-Esfandagheh district of the Kerman province in south-east Iran, constituting Iran's

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second largest chromite producer after the Faryab (or Asminon) ore deposits (Fig. 1a). These include the Abdasht, Sikhuran, Soghan and Colkahan complexes (Jannessary et al., 2012).

The Abdasht ultramafic complex (McCall, 1985; Jannessary et al., 2012; Najafzadeh and Ahmadipour, 2014b) is exposed in southeastern Iran and hosts podiform chromitite orebodies (collectively known as the Abdasht Mine), which have been mined discontinuously since the 1960s and represent one of the principal Cr sources in Iran. Previous workers (Ahmadipour, 2000; Ahmadipour et al., 2003; Sabzehei, 1974) suggested that the Abdasht chromitites and associated rocks are likely part of mantle diapir (similar to Soghan mafic–ultramafic complex), but they provided no discussion about the petrogenetic significance of the distribution of PGE.

In this study, the Abdasht peridotites and chromitites were investigated through field investigations of geological relationships, petrographic studies, mineral chemistry, and whole-rock geochemistry (platinum-group elements). The paper has two main goals. The first is to determine the origin and tectonic setting of the Abdasht ultramafic complex, and the second is to elucidate the nature of the lithospheric mantle section in the Esfandagheh area. This study provides the first comprehensive description of PGE and their distribution in podiform chromitites and associated rocks from the Abdasht ultramafic complex.

2. Regional geology

The Iran plate was a part of Gondwanaland during the Permian, probably until the Triassic (Wensink, 1981) and subsequently drifted from the Gondwana to join Eurasia. The northern part of the plate was at about its present location relative to Eurasia during the Cretaceous (Lemaire et al., 1997).

Tethyan ophiolites (i.e. Semail-Oman, Kizildag-Turkey, Troodos-Cyprus, etc.) are remnants of oceanic crust and/or supra-subduction zone assemblages that were formed during the closure of the Tethyan Ocean as a result of collision of the Gondwana and Eurasia continents. This closure produced an arcuate ophiolite belt extending from the Balkan Peninsula through Anatolian Taurus Mountains to the Iranian Main Zagros fold-thrust belt (or Main Zagros Thrust Fault) (Dilek et al., 2007). As part of this system, the ~2000 km-long Main Zagros fold-thrust belt, extending from southeastern Turkey through northern Syria and north- northeastern Iraq to western and southern Iran and into northern Oman, is interpreted to have formed during the closure of the Neo-Tethyan Ocean and subsequent oblique collision of the Afro-Arabian plate (Gondwanaland) with the Iranian micro-continent in the Late Cretaceous–Early Tertiary (Alavi, 2004).

The Abdasht ultramafic complex has a north–south trending shape, and is over 8 km long and 5 km wide. It is situated in south-east of

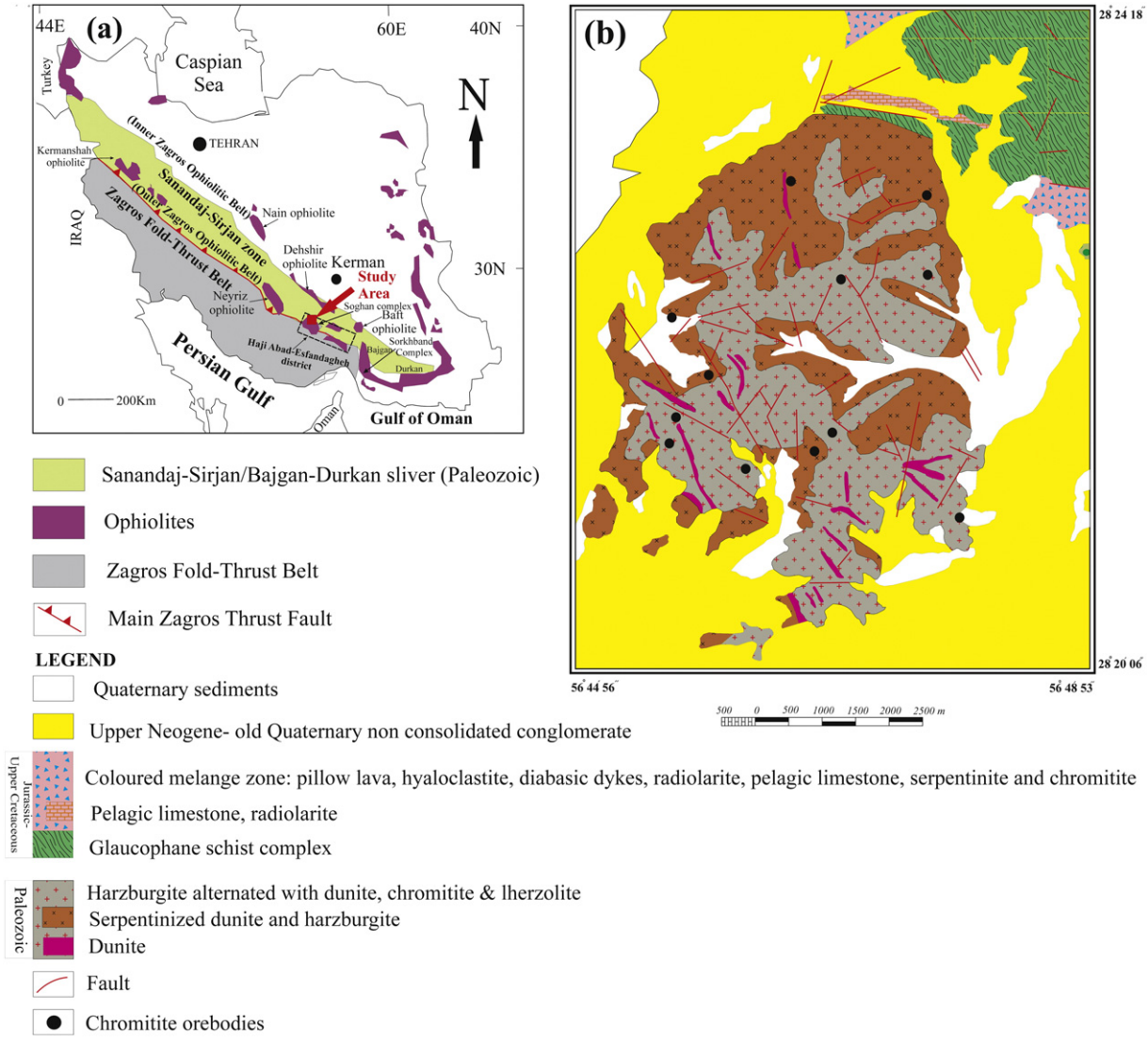

Fig. 1. a) Location of the study area within the Iranian ophiolitic belts and Sanandaj–Sirjan/Bajgan–Durkan (SS/BD) zone. Note the position of the inner (Nain–Dehshir–Baft) and outer (Kermanshah–Neyriz–Haji Abad-Esfandagheh) Zagros ophiolitic belts. b) Simplified geological map of the Abdasht ultramafic complex (modified after Ahmadipour, 2000).