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Genesis and tectonic setting of ophiolitic chromitites from the Dehsheikh ultramafic complex (Kerman, southeastern Iran): Inferences from platinum-group elements and chromite compositions

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ABSTRACT

Chromitite bodies of various sizes associated with dunite envelopes have been found in the Dehsheikh ultramafic massif, in the southeastern part of the outer Zagros ophiolite belt. The chromitites occur as layered and lenticular bodies, and show both magmatic and deformational textures, including massive, disseminated, banded and nodular types. The Dehsheikh chromitites display a variation in Cr# [100 × Cr / (Cr + Al)] from 69 to 78, which is typical of high-Cr chromitites. The Al_2O_3 and TiO_2 contents of chromites range from 10.3 wt.% to 16.9 wt.% and 0.12 wt.% to 0.35 wt.%, respectively. The Al_2O_3, TiO_2, and FeO/MgO values calculated for parental melts of Dehsheikh chromitites are within the range of boninitic melts. Chondrite-normalized distribution patterns of platinum-group elements show relative enrichments in Ru, Ir, and Os, and depletions in Rh, Pd, and Pt that are typical of chromitites associated with ophiolites formed by high degrees of mantle partial melting. The presence of Na-rich amphibole inclusions in chrome grains, together with the mineralogical and chemical composition of the chromitites and estimates of their parental melt compositions are used to help establish the tectono-magmatic setting. It is shown that the Dehsheikh massif is an ophiolite formed in a suprasubduction zone setting. We suggest that the composition of the rocks in this section was influenced by hydrous partial melts which might be formed in the subduction zone. Variable melt/rock interaction produced melt channel networks in the dunite which allowed the parental melt of the chromitite to percolate through them. Similar characteristics have been observed in other ophiolite complexes from the outer Zagros Iranian ophiolitic belt; these are believed to be the product of magmatism in a fore-arc environment.

1. Introduction

The origin of podiform chromitites and the nature of their geodynamic setting are still not completely understood. The composition of chromite minerals depends mostly on the degree of partial melting of the mantle sources and consequently reflects the parental magma (c.f. Rollinson, 2008) and also the geodynamic setting in which they formed (e.g., Cai et al., 2012; Dick and Bullen, 1984; Ghosh et al., 2013). Chromite chemical composition is often indicative of the source and bulk geochemistry of parental melts. For example, high Cr chromitites (Cr# > 0.60) may have crystallized from boninitic magmas, whereas high Al chromitites (Cr# < 0.60) may be derived from MORB-like tholeiitic magmas (Arai et al., 2011; Kamenetsky et al., 2001; Melcher et al., 1997; Zaccarini et al., 2011). The occurrence of podiform chromitites and their geochemical composition can be related to two main geodynamic settings, i.e., within supra-subduction zones and spreading centres in back-arc basins (e.g., Arai and Yurimoto, 1994, 1995; Nicolas, 1989; Roberts, 1988; Zhou and Robinson, 1997). Chromite can also be used as a petrogenetic indicator to help establish the composition of the primary mantle source.

The concentration and relative distribution of platinum-group elements (Ru, Rh, Pd, Os, Ir, and Pt) in mafic and ultramafic igneous rocks are controlled by processes such as partial melting, fractional crystallization, and degree of S-saturation of the magma. Depending on the melting temperature and geochemical affinity, the PGE have been divided into two sub-groups (Barnes et al., 1985): Ir-group elements (IPGE: Os, Ir, Ru) have high melting temperature (>2300 °C), whereas the Pd-group PGE (PPGE: Rh, Pt, Pd) are controlled by much lower melting temperatures (<2000 °C). Podiform chromitites are presently regarded

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as sub-economic sources of the IPGE (Uysal et al., 2007a, 2007b). Ophiolite complexes with minor occurrences enriched in PPGE have been identified in the Shetland ophiolite in Scotland (Prichard et al., 1986; Brough et al., 2015), Acoje in the Zambales ophiolite in the Philippines (Bacuta et al., 1990), the Vourinos ophiolite (Greece; Konstantopoulou and Economou-Eliopoulos, 1991), Berit ophiolite (Turkey; Kozlu et al., 2014), and Al'Ays ophiolite (Saudi Arabia; Prichard and Brough, 2009; Prichard et al., 2008). The PGE abundance patterns record information about the genesis of ophiolitic chromitites and the peridotites that contain them (e.g., Akmaz et al., 2014; Garuti et al., 1997; Hamlyn et al., 1985; Naldrett, 1981; Uysal et al., 2009a, 2009b; Zhou et al., 1998).

In this paper, we present major element geochemical data and PGE concentrations for chromitites from the Dehsheikh ophiolitic massif to establish the nature of the chromitite parental melt and to infer both the tectonic setting and conditions of formation.

2. Geological background and field relationships

The Dehsheikh massif is one of the ultramafic massifs of the ophiolite belt in the southeastern Sanandaj–Sirjan zone and the main Zagros thrust belt (Fig. 1a). The Zagros fold thrust belt is part of the Bitlis–Zagros collision zone extending NW–SE from eastern Turkey through northern Iraq and the length of Iran to the Strait of Hormuz and into northern Oman; it was formed as an accretionary prism by a process of subduction of the Arabian plate beneath the Central Iranian plate (Shafaii Moghadam et al., 2010). The Upper Cretaceous Zagros ophiolites constitute the central parts of the Late Cretaceous Tethyan ophiolite belt, which extended for ~3000 km from Cyprus to Oman (Shafaii Moghadam et al., 2013). The Zagros ophiolites lie along the northeastern flank of the Zagros Fold Thrust Belt, which was formed during the late Cretaceous episode of subduction initiation on the northern side of the Neo-Tethys and show a fore-arc lithosphere (Fig. 1a) (Shafaii Moghadam et al., 2010). The Zagros ophiolites comprise two parallel belts; Fig: 1) an inner belt containing the Nain–Dehshir–Baft ophiolites, and 2) an outer belt consisting of the Kermanshah, Neyriz and Esfandagheh–Haji Abad ophiolites. The Esfandagheh–Haji Abad region is a tectonically active zone comprising several ultramafic–mafic complexes including the Soghan (Ahmadipour et al., 2003; Najafzadeh and Ahmadipour, 2014), Abdasht (Jannessary et al., 2012), Sikhoran (Ghasemi et al., 2002), and Dehsheikh (Peighambari et al., 2011) with combined chromite reserves of eight million tonnes at a grade between 30% and 53% Cr_2O_3). This region also contains the Sargaz–Abshur metamorphic complex including mica schist, amphibolites and greenschists (Sabzehei, 1974), a Jurassic–Cretaceous sedimentary–igneous association containing flysch, turbidites, and Calpionella limestone, and coloured mélange zones, such as Siahkuh and south Dowlatabad mélanges, granitoid bodies, and predominantly Palaeozoic to Tertiary Zagros sedimentary units.

McCall (1997) regarded the area in Fig. 3 as the southern margin of the Sanandaj–Sirjan–Bajgan–Durkan zone sliver separated from the Neyriz ophiolites. Shahabpour (2005) interpreted the ophiolite mélanges as a segment of the Neyriz ophiolite belt that is part of the southeastern edge of the main Zagros thrust belt. The Dehsheikh complex and other ultramafic–mafic complexes in the Esfandagheh–Haji Abad region have been interpreted as Alpine-type peridotites within

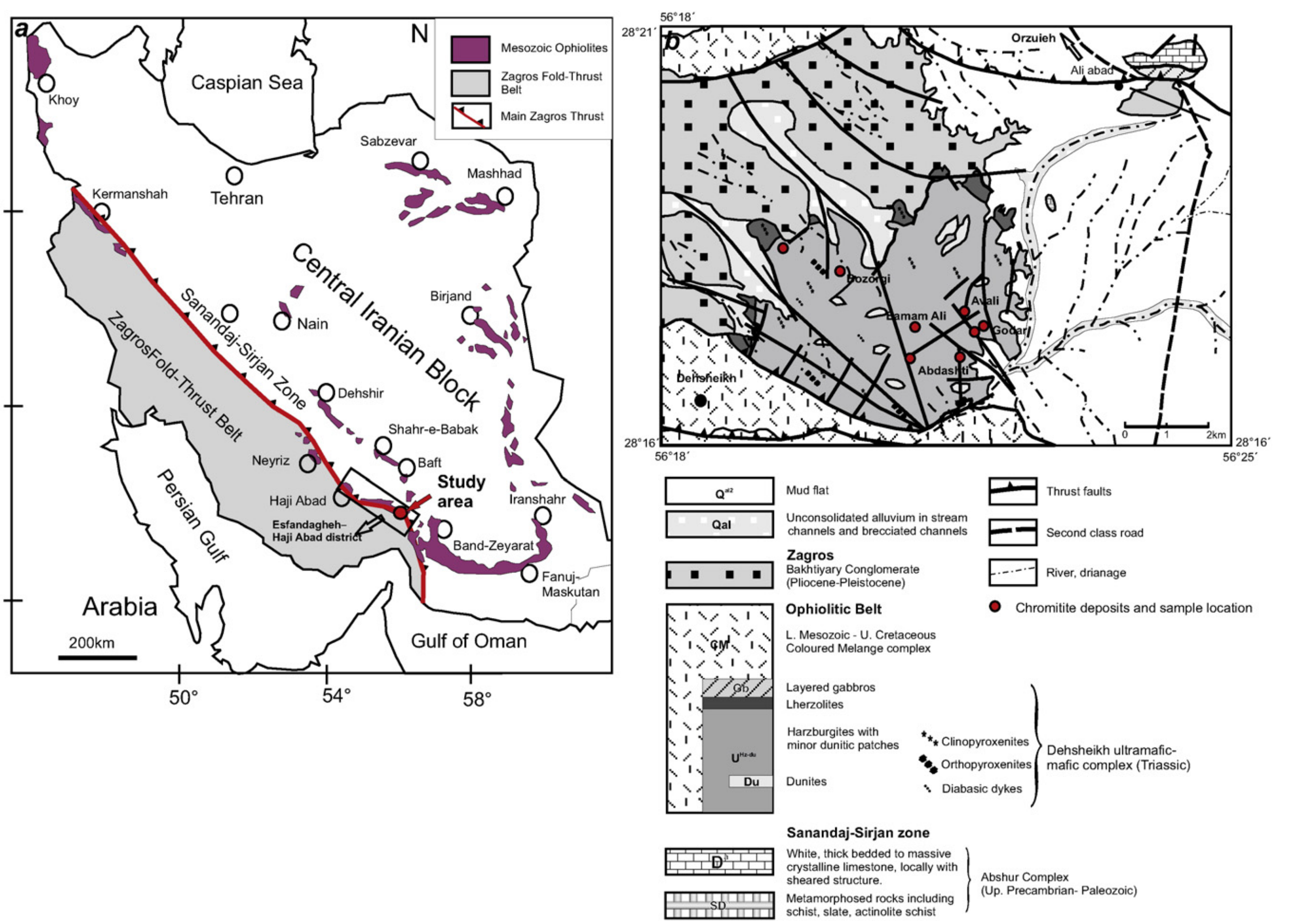

Fig. 1. a) Map showing the distribution of the Nain–Baft (inner) Zagros ophiolitic belt, the Kermanshah–Neyriz–HajiAbad (outer) Zagros ophiolitic belt, and the main Zagros thrust (MZT); b) Geological map of the Dehsheikh Massif with information on the position of chromite mines and sample localities.