



# Mineral chemical composition and geodynamic significance of peridotites from Nain ophiolite, central Iran

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## ABSTRACT

The peridotites from north of the town of Nain in central Iran consist of clinopyroxene-bearing harzburgite and lherzolite with small lenses of dunite and chromitite pods. The lherzolite contains aluminous spinel with a Cr number ( $Cr^{\#} = Cr/[Cr + Al]$ ) of 0.17. The Cr number of spinels in harzburgite and chromitite is 0.38–0.42 and 0.62, respectively. This shows that the lherzolite and harzburgite resulted from <18% of partial melting of the source materials. The estimated temperature is  $1100 \pm 200$  °C for peridotites, the estimated pressure is  $<15 \pm 2.3$  kbar for harzburgites and  $>16 \pm 2.3$  kbar for lherzolites and estimated  $f_{O_2}$  is  $10^{-1 \pm 0.5}$  for peridotites. Discriminant geochemical diagrams based on mineral chemistry of harzburgites indicate a supra-subduction zone (SSZ) to mid-oceanic ridge (MOR) setting for these rocks. On the basis of their  $Cr^{\#}$ , the harzburgite and lherzolite spinels are analogous to those from abyssal peridotites and oceanic ophiolites, whereas the chromites in the chromitite (on the basis of  $Cr^{\#}$  and boninitic nature of parental melts) resemble those from SSZ ophiolitic sequences. Therefore, the Nain ophiolite complex most likely originated in an oceanic crust related to supra-subduction zone, i.e. back arc basin. Field observations and mineral chemistry of the Nain peridotites, indicating the suture between the central Iran micro-continent (CIM) block and the Sanandaj–Sirjan zone, show that these peridotites mark the site of the Nain–Baft seaway, which opened with a slow rate of ocean-floor spreading behind the Mesozoic arc of the Sanandaj–Sirjan zone as a result of change of Neo Tethyan subduction régime during middle Cretaceous.

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## 1. Introduction

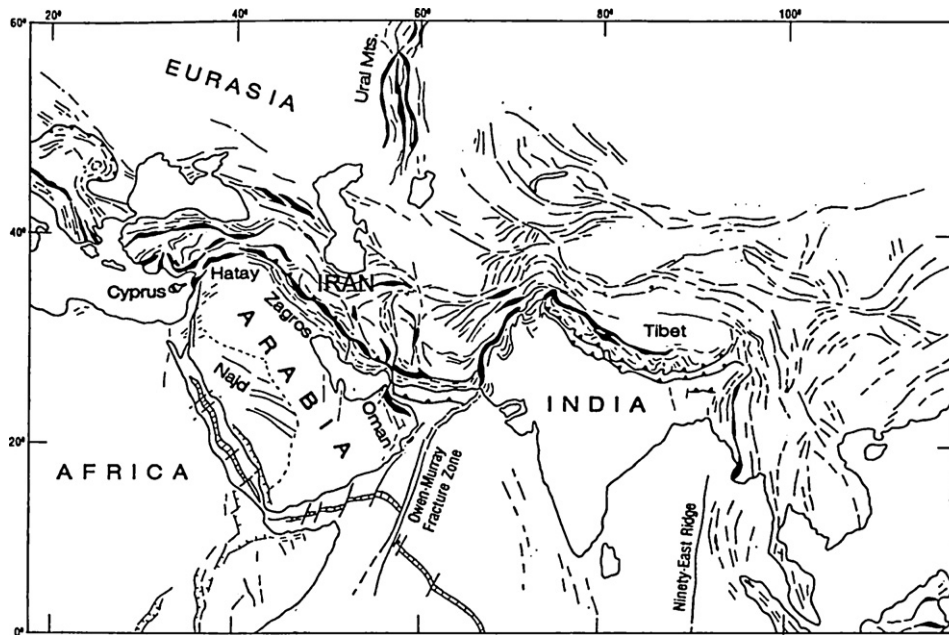
Ophiolites in Iran are part of the Tethyan ophiolite belt of the Middle East (Figs. 1 and 2). They link the Middle Eastern and Mediterranean Hellenides–Dinarides ophiolites (e.g. Turkish, Troodos, Greek and East European) to more easterly Asian ophiolites (e.g. Pakistani and Tibetan) (Shojaat et al., 2003). Based on their geography, the Iranian ophiolites may be classified into four groups (Takin, 1972; Stöcklin, 1974; McCall, 1997): (A) ophiolites of northern Iran along the Alborz range, (B) ophiolites of the Zagros Suture Zone, including the Neyriz and Kermanshah ophiolites, which appear to be coeval with the Oman (Smail) ophiolite emplaced onto the Arabian continental margin (e.g. Ricou, 1971; Coleman, 1981), (C) unfragmented ophiolites of the Makran accretionary prism which includes Remeshk/Mokhtar Abad ophiolites, and (D) ophiolites and “coloured mélanges” that mark the boundaries of the central Iranian micro-continent (CIM), including Shahre-Babak,

Nain, Baft, Sabzevar and Tchehel Kureh ophiolites. The CIM is composed of the Yazd, Posht Badam, Tabas and Lut blocks.

The Nain ophiolites make up the northern parts of the Nain–Baft ophiolitic belt (Davoudzadeh, 1972; Arvin and Robinson, 1994). The Nain ophiolite is interpreted either as a result of the occurrence of a narrow seaway like Red Sea, between the Lut block and the active margin of the Iranian block (Sanandaj–Sirjan zone, e.g. Berberian and King, 1981), or as an arc basin of a Tethyan subduction system, which was active from upper Triassic to Quaternary (e.g. Desmons and Beccaluva, 1983; Ghazi and Hassanipak, 2000). Shahabpour (2005), Agard et al. (2006) and Mehdipour Ghazi (2008) advanced the view that this ophiolite is formed during late Cretaceous at the site of the Nain–Baft back arc basin. Alavi (1994) believes that the suture zone between Arabia and Eurasia runs along the Nain–Baft ophiolite. The study by Arvin and Robinson (1994) on the basaltic lavas from the Baft area reports two types of basalts, MORB-like lavas and transitional tholeiitic basalts similar to within plate basalts. They suggested a mid-oceanic ridge-related setting for the ophiolites. Based on the mineral chemistry of peridotites, we suggest a back arc setting for the Nain ophiolites here. Also using field relations (very thick radiolarites strata) and mineral

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**Fig. 1.** Generalized tectonic map showing the distribution of ophiolites along the Tethys suture. Black areas indicate ophiolites and "coloured mélange" zones. From Coleman (1981).

chemical features of peridotites, we show that the rate of spreading was slow in the Nain area, resulting in a deep basin rather than a shallow seaway (e.g. Arvin and Robinson, 1994). Other aspects such as partial melting rate of the source region and  $P$ – $T$  and  $f_{O_2}$  condition of equilibration of peridotites are used to put constraints on the geodynamic setting.

According to the tectonic setting in which they were formed, ophiolites can be classified into mid-oceanic ridge (MOR) or supra-subduction (SSZ) types (Pearce et al., 1984; Shervais, 2001). The mantle peridotites of SSZ ophiolites are mainly composed of harzburgite (HOT) and the peridotites of MOR are mainly composed of lherzolite (LOT) (e.g. Qiu et al., 2006). As an old and dense oceanic crust subducts into the mantle, a gap forms between the sinking slab and the upper plate. Asthenosphere flows into this gap. This causes decompression of the flowing asthenospheric

materials, which in turn causes partial melting. Fluids released from the subducting slab enhance melting (Shervais, 2001; Stern and Bloomer, 1992). The combination of decompression and fluid effects results in a high degree of partial melting and formation of refractory lavas (e.g. boninites) leaving harzburgites behind (Shervais, 2001). This can explain the HOT nature of the mantle sequence associated with SSZ ophiolites. SSZ ophiolites can form at both back arc basins (BAB) and fore-arc extension zones. The main geochemical features of SSZ ophiolites include enrichment in large ion lithophile elements (K, Rb, Cs, and Th) and light rare earth elements and depletion in high field strength elements (Ti, Ta, Hf, and Nb) relative to normal MORB (Pearce, 1982; Wood, 1980; Shervais, 2001). Also, rocks from ZSZ indicate higher  $f_{O_2}$  than normal MORB. Petrologically the sequence of crystallization in typical MORB is olivine–plagioclase–clinopyroxene, while in the SSZ it is olivine–clinopyroxene–plagioclase (Cameron et al., 1980; Hebert and Laurent, 1990).

Taylor and Martinez (2003), Martinez and Taylor (2002), Ulmer (2001), Sobolov and Chaussidon (1996), Danyushevsky (2001) and other researchers have discussed the chemical characteristics of basalts from back arc basins (specially high  $f_{O_2}$  and high  $H_2O$  content) along with melting condition of the source materials. Taylor and Martinez (2003) have shown that both "arc-like" lavas (containing low Na, Ti and Fe and high  $H_2O$  and Ba/La) and MORB-like lavas can be found in a back arc setting. According to their findings, the crust becomes more MORB-like further away from the island arc and subducted slab. This shows that the chemistry of basalts cannot confirm an SSZ setting unequivocally. The study of peridotites associated with ophiolitic rocks can help to decipher either a MOR or an SSZ setting for ophiolites.

Peridotites appear in the lower parts of ophiolites, as xenoliths in some alkaline rocks or in orogenic massifs. Mineral chemistry of ophiolitic peridotites, especially chemistry of Cr-spinel, strongly depends on the physico-chemical conditions of magmatic crystallization. Also the geotectonic setting of the host peridotites can be inferred from the mineral chemistry (e.g. Bonatti and Michael, 1989).

The goal of this paper is to use field relations, petrographic analyses and mineral chemistry to determine the partial melting rate,



**Fig. 2.** Distribution of different ophiolite complexes in Iran. Kh: Khoy, 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.

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