Petrographic and geochemical characteristics of mantle peridotites of Edessa ophiolite (North Greece)

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Abstract

The Edessa ophiolite represents remnants of an oceanic lithosphere obducted onto Palaeozoic-Mesozoic marble and schists during Upper Jurassic to Lower Cretaceous (Decourt *et al.*, 1977, Michailidis, 1990). The ophiolitic rocks include several tectonic units that are considered to be the northwards continuation of the Veria-Naousa ophiolite (Pe-Piper and Piper, 2002, Saccani *et al.*, 2008, Rogkala *et al.*, 2017). Petrographic, geological and geochemical evidence indicates that this ophiolite complex consists of both mantle and crustal suites (Rogkala *et al.*, 2019). It includes serpentinised harzburgite with high degree of serpentinisation, lherzolite, diorite, gabbro, diabase and basalt. This study presents new data on petrographic characteristics and geochemical compositions of mantle peridotites from this ophiolite, especially serpentinised harzburgite and minor lherzolite. The serpentinised harzburgite displays dark green colour and local relic pyroxenes with moderate to intense mantle deformation features, such as banding and foliation. Locally, it encloses lenses, pods or elongated bodies (up to few meters) of chromitite, which according to their texture and mode of occurrence, are classified as massive and disseminated podiform bodies. Moderately lherzolite is an infrequent, medium-grained rock, which is characterised by greenish black to dark green colour and conchoidal fracture. It occurs as relic, irregular bodies up to a few meters, surrounded by harzburgite. Local lherzolite slivers are repeated in the mantle domain of Edessa due to a series of imbricated thrusts occurring through the area.

The petrographic description of the serpentinised harzburgite and lherzolite has been conducted in polished-thin sections from 35 samples, which have been collected throughout the whole exposure. The serpentinised harzburgite has been intensively serpentinised. The primary mineralogy constitutes less than 5% of the mode and comprises clinopyroxene, Cr-spinel and chromite (Figure 1a). Clinopyroxene appears as subhedral porphyroclasts. The Cr-spinel crystals and chromite are subhedral to euhedral and scanning electron microscopic observation revealed that infrequently they show an irregular distribution of ferritchromite and Cr-bearing magnetite compositional areas, at their rims. Serpentine is the main alteration product showing mesh, ribbon, bastite and intersertal textures. Chlorite and magnetite are also products of hydrothermal alteration of the serpentinised harzburgite. Lherzolite displays mainly porphyroclastic texture (Figure 1b). Its primary mineralogy includes olivine (40-60 vol%), orthopyroxene (30-40 vol%), clinopyroxene (5-25 vol%) and spinel (up to 5 vol%). Rare Fe-Ni-Co sulphides with Cu coexist with spinel. Olivine displays porphyroclastic grains and smaller neoblasts. Orthopyroxene porphyroclasts exhibit local kink-bands, undulatory extinction and exsolution lamellae of clinopyroxene. Olivine and orthopyroxene porphyroclasts surrounded and partly replaced by neoblastic olivine (Figure 1b). Clinopyroxene occurs as porphyroclastic and neoblastic grains in the recrystallised matrix (Figure 1b). Spinel is of aluminous composition and forms subhedral to euhedral grains with lobate boundaries, which veined and surrounded by a rim of garnet and sulphides. Various serpentine, chlorite, tremolite and magnetite are observed due to subsequent hydrothermal alteration.

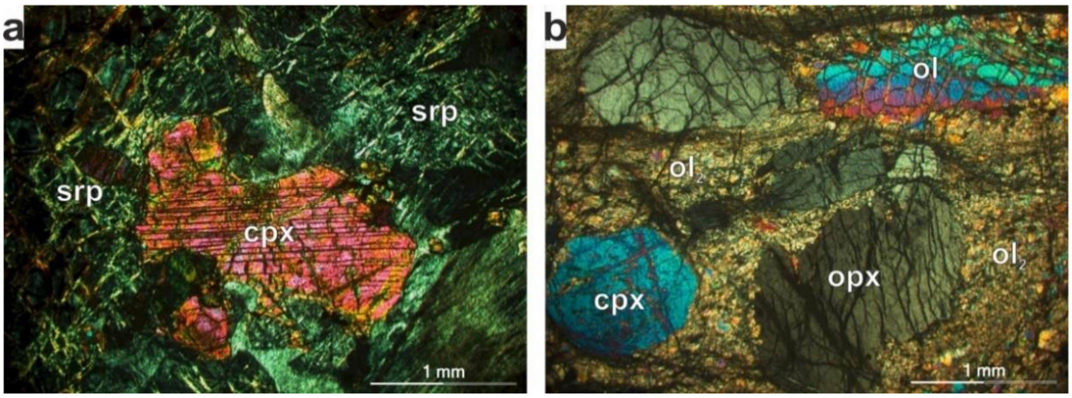

Figure 1. Textural characteristics of mantle peridotites from Edessa ophiolite: a) Photomicrograph of porphyroclastic clinopyroxene in serpentinised harzburgite surrounded by serpentine, b) Photomicrograph of porphyroclastic olivine, clinopyroxene and orthopyroxene in lherzolite surrounded by neoblastic olivine (cpx: clinopyroxene, srp: serpentine, ol: olivine, ol_2: neoblastic olivine, opx: orthopyroxene).

Major, trace and rare earth elements data from the mantle peridotites from the Edessa ophiolite were performed at Bureau Veritas Mineral Laboratories at Vancouver (Canada). Major element analyses were carried out using an XRF spectrometer and a sequential spectrometer (ICP-ES). Trace elements and rare earth elements were determined on totally digested samples by inductively coupled plasma-mass spectrometry (ICP-MS) in the same laboratory. Detection limits for major and trace elements range from 0.01 wt.% to 0.04 wt.% and from 0.01 ppm to 10 ppm, respectively. The analytical precision calculated from replicate analyses is better than 3% for most major elements and better than 5% for trace elements. Lherzolite is richer in SiO_2, TiO_2, Al_2O_3 and CaO than the serpnetinised harzburgite. Low CaO and Al_2O_3 contents in serpentinised harzburgite are consistent with low clinopyroxene abundance. The serpentinised harzburgite shows higher Mg# [$100*Mg^{2+}/(Mg^{2+}+Fe^{2+})$] ranging from 82.27 to 84.79 than the lherzolite (82.33-83.74). Trace element abundances are also highly variable among the mantle peridotites. More specifically, lherzolite is richer mainly in V, Sc, Ga and Y compared to the harzburgite. On the other hand, the serpentinised harzburgite exhibits higher Co, Zn, Ni and Cr abundances than the lherzolite. The total rare earth element (REE) inventory of the Edessa peridotites is variable, ranging between 0.20 to 4.74 ppm. They exhibit a more limited range of heavy REE (HREE = Er + Tm + Yb + Lu = 0.00-1.04 ppm) abundances compared to that of light REE (LREE = La + Ce + Pr + Nd = 0.20-2.50 ppm) and middle REE (MREE = Sm + Eu + Gd + Tb + Dy + Ho = 0.00-1.88 ppm). Lherzolite displays higher REE concentrations with respect to serpentinised harzburgite. Lherzolite is characterised by relatively LREE-depleted primitive mantle-normalised REE patterns, exhibiting a nearly linear increase from LREE to HREE (Figure 2). Most of them bear resemblance to abyssal peridotites in terms of primitive mantle-normalised REE profiles (Niu, 1997), especially in MREE and HREE segment. The serpentinined harzburgite shows higher depletion in MREE and HREE compared to abyssal peridotites, whereas their REE patterns reaching up to and below to the field of SSZ-type peridotites (Figure 2).

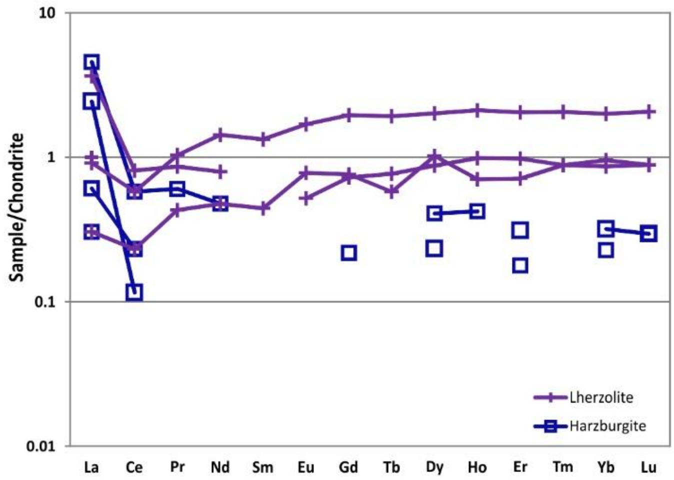

Figure 2. Chondrite-normalised REE patterns of peridotites and from the Edessa ophiolite. Normalising values are after McDonough and Sun (1995).

Lherzolite formed by low to moderate degrees of partial melting and subsequent melt-rock reaction in an oceanic spreading setting. On the other hand, refractory harzburgite formed by high degrees of partial melting in a supra-subduction zone (SSZ) setting. Petrographical characteristics and geochemical compositions of the mantle peridotites suggest that the Edessa oceanic mantle evolved from a typical mid-ocean ridge (MOR) oceanic basin to the mantle wedge of a SSZ. This scenario explains the higher degrees of partial melting recorded in harzburgite, as well as the overprint of primary geochemical characteristics in the Edessa peridotites.

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