Pictorial Article

Melt migration and upper mantle evolution during incipient arc construction: Jurassic Eastern Mirdita ophiolite, Albania

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Fig. 1 Geological map showing the distribution of peridotite massifs and crustal units in the Mirdita ophiolite, and other relevant tectonic units in Albania. Inset shows the Mirdita ophiolite (MO) as part of the Tethyan ophiolite system (shaded dark gray) in the Balkan peninsula and in the Alps–Apennines. Peridotite massifs (from north to south): Trp, Tropoja; Krb, Krabbi; Gom, Gomsiqe; Puk, Puka; Kuk, Kukes; Lur, Lura; Blq, Bulqize. Locations of samples depicted in Figures 2b–5 are marked (•).
Well-preserved suprasubduction zone (SSZ) ophiolites provide a natural laboratory to investigate crustal and upper mantle structure and composition of arc-forearc lithosphere, and its spatial and temporal evolution. The structural architecture and geochemical fingerprint of SSZ ophiolites present a snapshot of multiple episodes of melting following subduction initiation in former ocean basins (Dilek & Furnes 2009). We have studied the crustal and mantle units in the Jurassic Mirdita ophiolite in Albania (Fig. 1) to document the mode and nature of magmatic, metasomatic, and tectonic processes of melt generation and their interplay during formation of SSZ oceanic crust.

The Mirdita ophiolite occurs in a nearly 40-km-wide belt bounded by the conjugate passive margin sequences of the Apulia (west) and Pelagonia (east) microcontinents (Fig. 1). Mafic–ultramafic massifs in the west (i.e. Krabbi, Puka, Gomsqi) consist mainly of lherzolite and plagioclase lherzolite, whereas those in the east (i.e. Kukes, Lura, Bulqize) contain harzburgite and dunite with major chromite deposits (Fig. 2a). The internal structure and chemical composition of the crustal units also show major variations across the Mirdita zone. The extrusive sequence in the Western Mirdita ophiolite (WMO) is locally up to 650 m thick and consists mainly of pillow lavas with minor sheet flows and hyaloclastic breccias. Pillow lavas rest directly on the serpentinitized peridotites and gabbrons, and are locally overlain by a 5- to 20-m-thick chert layer. Lavas and rare individual dikes in the WMO are composed of basalt and basaltic andesite, and are tholeiitic with a narrow range of SiO₂ (47–50 wt%). The nearly 1.1-km-thick extrusive sequence in the Eastern Mirdita ophiolite (EMO) includes pillow to sheet flows ranging in composition from basalt and basaltic andesite at the bottom to andesite, rhyodacite, boninite, and rhyolite in the upper part (Fig. 2a; Dilek et al. 2008). Boninitic dikes and lavas commonly cross-cut and/or overlie the earlier formed extrusive rocks. The EMO dikes and lavas straddle the tholeiitic–calc-alkaline boundary and show a wide range of SiO₂ (52–70 wt%). There is a clear geochemical progression from initially mid-oceanic ridge basalt (MORB)-like lavas to...
island-arc tholeiites to boninites in the crustal evolution of the EMO.

The crust–mantle boundary is represented by a less than 1-km-thick sequence of layered mafic–ultramafic cumulates composed mainly of dunite–pyroxenite intercalations (Fig. 2b). The rocks immediately below are made of harzburgite and harzburgite–dunite (Figs 2b, 3a) cross-cut by networks of orthopyroxenite veins (Fig. 4) ranging from 1 cm to 3 m in width and showing sharp, dyke-like contacts with their host harzburgite and dunite. Dunite is associated with ubiquitous chromitite layers (Fig. 3b). Orthopyroxenite consists mainly of large (up to 10 cm across) orthopyroxene (opx) grains with small amounts of spinel and olivine. Some orthopyroxenites locally contain amphibole (Fig. 5a) and clinopyroxene (cpx). In thin-section, we can see the primary olivine to have been replaced by large opx grains (Fig. 5b). This texture and the presence of hydrous minerals (amphibole) indicate that the orthopyroxenite formed by the reaction of the pre-existing olivine with silica-rich, hydrous melts. The orthopyroxenite may hence represent a reaction product between the migrating melt and the host peridotite in the EMO upper mantle, whereas the harzburgite is likely to be the residual, depleted peridotite of the partial melt that produced the orthopyroxenite.

The partial melt from which the orthopyroxenite formed was boninitic in composition, representing a Si-rich melt that was migrating through the mantle harzburgite (Umino & Kushiro 1989). This boninitic melt produced the late-stage boninitic dikes and lavas in the EMO (Fig. 2a). We infer that the harzburgite–dunite–orthopyroxenite suite depicts melt–residue relationships and melt migration patterns in the mantle wedge during the incipient arc construction stage of the Eastern

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**Fig. 3** (a) Harzburgite (H)–dunite (D) relationships in the upper mantle sequence in the Eastern Mirdita ophiolite. (b) Dunite–chromitite intercalations within the harzburgite, which is not shown in the photograph. The dunite–chromitite banding is more than 3 m thick in this outcrop.

**Fig. 4** Networks of orthopyroxenite veins in the harzburgite (H). (a) Photograph, and (b) line-drawing.
Mirdita ophiolite. Lherzolitic peridotites (cpx-bearing harzburgite to lherzolite) structurally lower in the EMO mantle sequence probably represent the residue after MORB extraction. Our future studies in the Mirdita ophiolite should provide new insights on melt migration and upper mantle evolution during incipient arc construction.

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