Amphibole as a witness of chromitite formation and fluid metasomatism in ophiolites

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**Abstract**

Here we present new occurrences of amphibole in a suite of chromitites, dunites, and harzburgites from the mantle sequence of the Lycian ophiolite in the Tauride Belt, southwest Turkey. The amphibole occurs both as interstitial grains among the major constituent minerals and as inclusions in chromite grains. The interstitial amphibole shows generally decreasing trends in Na\(_2\)O and Al\(_2\)O\(_3\) contents from the chromitites (0.14–1.54 wt\% and 0.04–6.67 wt\%, respectively) and the dunites (0.09–2.37 wt\%; 0.12–11.9 wt\%) to the host harzburgites (<0.61 wt\%; 0.02–5.41 wt\%). Amphibole inclusions in chromite of the amphibole-bearing harzburgites are poorer in Al\(_2\)O\(_3\) (1.12–8.86 wt\%), CaO (8.47–13.2 wt\%), and Na\(_2\)O (b.d.l.–1.38 wt\%) than their counterparts in the amphibole-bearing chromitites (Al\(_2\)O\(_3\) = 6.13–10.0 wt\%; CaO = 12.1–12.9 wt\%; Na\(_2\)O = 1.11–1.91 wt\%). Estimated crystallization temperatures for the interstitial amphibole grains and amphibole inclusions range from 706 to 974 °C, with the higher values in the latter. A comparison of amphibole inclusions in chromite with interstitial grains provides direct evidence for the involvement of water in chromitite formation and the presence of hydrous melt/fluid metasomatism in the peridotites during initial subduction of Neo-Tethyan oceanic lithosphere. The hydrous melts/fluids were released from the chromitites after being collected on chromite surfaces during crystallization. Different fluid/wall rock ratios are thought to have controlled the crystallization and composition of the Lycian amphibole and the extent of modification of the chromite and pyroxene grains in the peridotites. Considering the wide distribution of podiform chromitites in this ophiolite, the link between chromitite formation and melt/fluid metasomatism defined in our study may be applicable to other ophiolites worldwide.

**Keywords:** Amphibole, peridotite, chromitite, hydrous melts/fluids, ophiolite

**Introduction**

Podiform chromitites are a special category of chromium ore deposit found only in ophiolites, where they typically form just below the petrologic Moho (Cassard et al. 1981; Zhou et al. 1994). Hydrous fluids are widely thought to have played a vital role in chromitoid formation in ophiolites (e.g., Matveev and Ballhaus 2002; Johan et al. 2017; Su et al. 2020, 2021), and they are commonly preserved as fluid inclusions and/or hydrous minerals (such as phlogopite and amphibole) in the chromite grains of chromitites, dunites and harzburgites (Melcher et al. 1997; Sachan et al. 2007; Zhou et al. 2014; Rollinson et al. 2018). These hydrous minerals and fluid inclusions are considered to represent crystallization products of trapped melts that were clearly hydrous and estimated to have contained up to 4 wt\% water (Sobolev and Chaussidon 1996; Falloon and Danyushevsky 2000; Matveev and Ballhaus 2002). However, recent studies have proposed that post-magmatic processes (e.g., hydrothermal alteration, metamorphism), locally aided by deformation, could modify the original composition of chromite in chromitites (e.g., Rassios and Smith 2000; Satsukawa et al. 2015; Kapsiotis et al. 2019). Such processes could also potentially produce hydrous inclusions in chromite during sub-solidus annealing (e.g., Lorand and Ceuleneer 1989). Therefore, the role of water in the formation of chromitite in ophiolite is still unclear.

Although interstitial amphibole crystals have rarely been reported in ophiolitic chromitite (Melcher et al. 1997; Rollinson 2008), they have been increasingly found in ophiolitic peridotites (e.g., Liu et al. 2010; Rospabé et al. 2017; Çelik et al. 2018; Slovenc and Šegvič 2018), fore-arc peridotites (e.g., Chen and Zeng 2007; Nozaka 2014), and mantle-wedge peridotite xenoliths (e.g., Coltori et al. 2004; Ionov 2010). The amphibole in these peridotites has mostly been attributed to hydrous fluid/melt metasomatism related to subduction processes. Thus, determining the potential links between fluid metasomatism in peridotites, the formation of podiform chromitites, and water extracted from subducting slabs could provide additional insights into the role and source(s) of fluids involved in these processes.

In this contribution, we report a newly discovered suite of interstitial amphibole grains in chromitite, dunite, and harzburgite