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

Qi-Qi Pan1,2,3,*, Yan Xiao1,2,*, Ben-Xun Su2,3,4, Xia Liu2,3,4, Paul T. Robinson4, Ibrahim Uysal5, Peng-Fei Zhang6, and Patrick Asamoah Sakyi7

1State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China
2Innovation Academy for Earth Science, Chinese Academy of Sciences, Beijing 100029, China
3University of Chinese Academy of Sciences, Beijing 100049, China
4Key Laboratory of Mineral Resources, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China
5Department of Geological Engineering, Karadeniz Technical University, 61080-Trabzon, Turkey
6Department of Earth Sciences, the University of Hong Kong, Pokfulam Road, Hong Kong, China
7Department of Earth Science, School of Physical and Mathematical Sciences, University of Ghana, P.O. Box LG 58, Legon-Accra, Ghana

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 Na2O and Al2O3 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 Al2O3 (1.12–8.86 wt%), CaO (8.47–13.2 wt%), and Na2O (b.d.l.–1.38 wt%) than their counterparts in the amphibole-bearing chromitites (Al2O3 = 6.13–10.0 wt%; CaO = 12.1–12.9 wt%; Na2O = 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 chromitite 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 Chausssid 1996; Fallool 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 chrome 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; Slovenec and Šegvič 2018), fore-arc peridotites (e.g., Chen and Zeng 2007; Nozaka 2014), and mantle-wedge peridotite xenoliths (e.g., Coltorti 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...