

High-temperature hydrothermal activities around suboceanic Moho: An example from diopsidite and anorthosite in Wadi Fizh, Oman ophiolite



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ABSTRACT

Reaction products between hydrothermal fluids and uppermost mantle harzburgite-lowermost crustal gabbro have been reported along Wadi Fizh, northern Oman ophiolite. They are named mantle diopsidite (MD) or crustal diopsidite (CD) depending on the stratigraphic level. They construct network-like dikes crosscutting structures of the surrounding harzburgite or gabbro. The MD is mainly composed of diopsidic clinopyroxene, whereas the CD is of diopsidic clinopyroxene and anorthitic plagioclase. Here, we report a new reaction product, crustal anorthosite (CA), from the lowermost crustal section. The CA is always placed in the center of the CD network, and mainly consists of anorthitic plagioclase with minor titanite and chromian minerals such as chromite and uvarovite.

Aqueous fluid inclusions forming negative crystals are evenly distributed in minerals of the CA. The fluid inclusions contain angular-shaped or rounded daughter minerals as calcite or calcite-anhydrite composite, which were identified by Raman spectroscopic analysis. We estimated their captured temperature at 530 °C at least by conducting microthermometric analysis of the fluid inclusions. Furthermore, we examined their chemical characteristics by direct laser-shot sampling conducted by laser ablation-inductively coupled plasma-mass spectrometer (LA-ICP-MS). The results indicate that the trapped aqueous fluids contain an appreciable amount of Na, but no K and Cr.

Hydrothermal fluids involved in the CA formation transported Cr, which was probably taken up from chromite seams in the uppermost mantle section. Cr got soluble by forming complexes with anions as SO_4^{2-} , CO_3^{2-} and Cl^- . In addition, these hydrothermal fluids transported Fe, Mg and trace elements (Ti, Sr, Y, Zr and rare-earth elements) governing whole-rock chemical compositions of the MDs, CDs and CAs. Our estimation for the condition of CA formation yielded rather low temperatures (530–600 °C), which indicates a later stage production of the CA than the MD and CD (~800 °C). A series of high-temperature hydrothermal events had been significantly contributed to the chemical flux occurring around the Moho, boundary between the mantle and crustal sections.

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1. Introduction

Deep-seated high-temperature hydrothermal activity beneath a mid-ocean ridge has been speculated on the basis of petrologic and isotopic studies on the Oman ophiolite (e.g., Bosch et al., 2004; Kawahata et al., 2001; Nicolas et al., 2003; Yamaoka et al., 2012), a slice of oceanic lithosphere obducted on land. However, evolutionary processes of such

high-temperature hydrothermal activity have been left unclear owing to a lack of continuous observations of footprints after the hydrothermal fluid flow. Hence, contributions of the high-temperature hydrothermal flows to chemical flux in the deep oceanic lithosphere are vague; which elements are transported via hydrothermal fluids around mantle/crust boundary?

Possible high-temperature hydrothermal products, diopsidites and related rocks, have been pervasively discovered in the mantle section of the Oman ophiolite (Python et al., 2007, 2011). The diopsidite is recognized as a Ca-rich lithology, resulting from Ca-metasomatism of mantle peridotite (Python et al., 2011). Ca-metasomatized mafic

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lithologies have been previously reported as rodingites, which mainly consist of Ca-rich silicates as hydrogarnet, prehnite, tremolite and diopside (e.g., Bach and Klein, 2009; Frost et al., 2008). Rodingitization that is a metasomatic process induces a removal of Si with or without addition of Ca in rocks associated with mantle peridotite undergoing serpentinisation at low temperatures (Bach and Klein, 2009; Coleman, 1963). A thermodynamic reaction model implied that high temperatures, i.e., 800 °C (Python et al., 2007), are not necessary, but lower ones, i.e., 200–300 °C are appropriate for diopside formation, if precursor rocks are gabbro or clinopyroxenite (Bach and Klein, 2009). Therefore, accurate temperature estimation will yield one of significant constraints on unraveling diopside formation as well as deep-seated hydrothermal activity.

Discovery of a series of diopsidites cropped out around a boundary between the mantle and crustal sections of the northern Oman ophiolite provide us with a trail of high-temperature hydrothermal fluid flow across the boundary (Akizawa and Arai, 2014; Akizawa et al., 2011;

Arai and Akizawa, 2014). Results of their chemical analyses combined with petrographical observations strongly indicate that hydrothermal fluids involved in diopsidization mobilized and transported an appreciable amount of Cr and rare-earth elements (Akizawa and Arai, 2014; Arai and Akizawa, 2014). Arai and Akizawa (2014) predicted that they had formed at around 500–800 °C by considering the relationship of their mineral assemblages.

In this study, we add temperature and chemical restrictions on hydrothermal fluids that invoked in the formation of diopside and associated rocks at deep oceanic lithosphere via minute fluid inclusion analyses. In addition, we present their whole-rock and in-situ mineral chemical compositions to unravel the mobility of concerned elements by the hydrothermal fluids. We consequently delineate a picture of high-temperature hydrothermal activities nearby the boundary between the mantle and crustal sections of the Oman ophiolite.

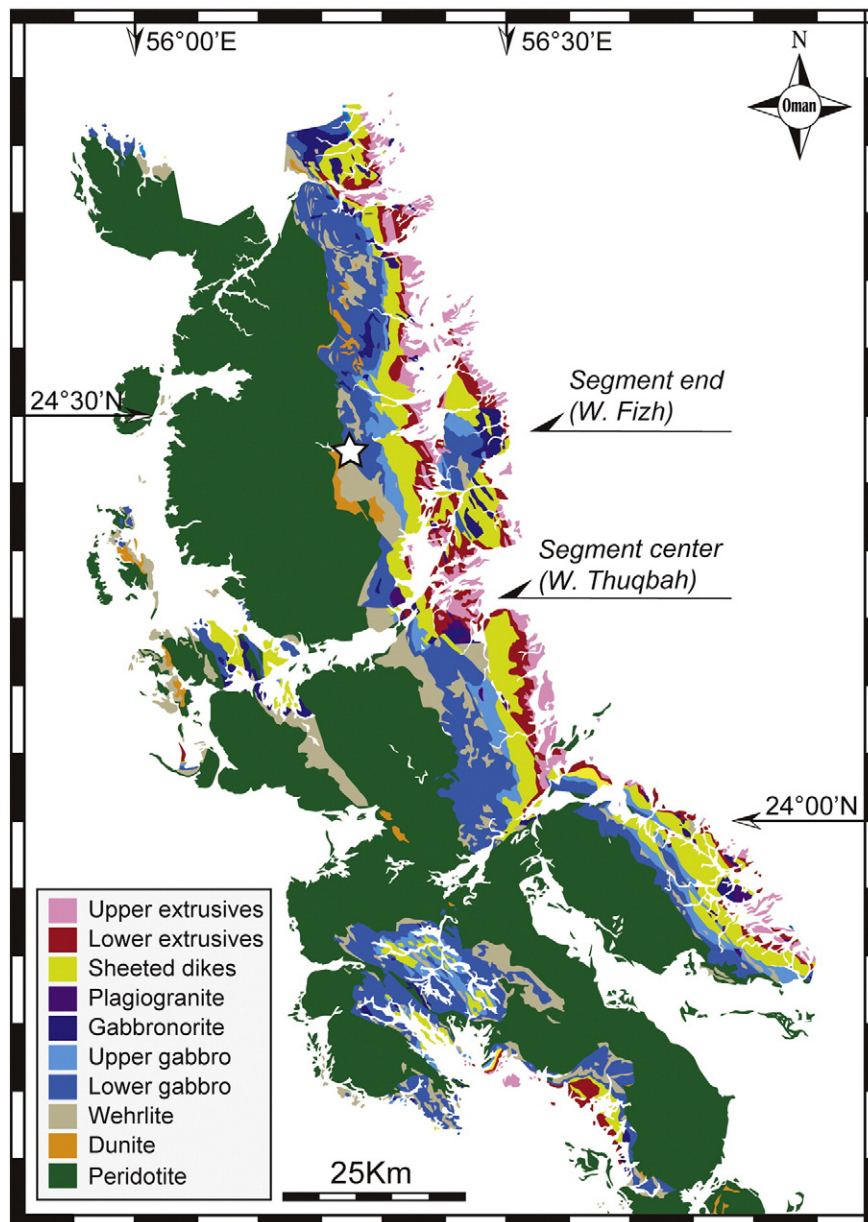


Fig. 1. Geological map of the central to northern Oman ophiolite. The locality shown by the star is located along Wadi Fizh, a possible segment end. Paleoridge segment structures are from Adachi and Miyashita (2003) and Miyashita et al. (2003). Modified from the 1:250,000 geological maps of Buraymi and Ibr (Ministry of Petroleum and Minerals, 1992a, 1992b).

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