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Mantle wedge serpentinites: A transient reservoir of halogens, boron, and nitrogen for the deeper mantle

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ABSTRACT

Fluorine (50–650 ppm), bromine (0.03–0.3 ppm), iodine (0.03–0.4 ppm), boron (20–100 ppm) and nitrogen (5–45 ppm) concentrations are elevated in antigorite-serpentinites associated with the Tso Morari ultrahigh-pressure unit (Himalayas) exhumed from >100 km depth in the mantle wedge. These fluid-mobile elements are likely released with fluids from subducted marine sediments on the Indian continental margin to hydrate overlying forearc serpentinites at shallow depths. Of these, F and B appear to remain in serpentinites during the lizardite-antigorite transition. Our results demonstrate serpentinites as transient reservoirs of halogens, B, and N to at least 100 km depth in the mantle wedge, and likely deeper in colder slabs, providing a mechanism for their transport to the deeper mantle.

INTRODUCTION

Subduction is the mechanism for transferring fluids and fluid-mobile elements (FMEs) from surface reservoirs to Earth's mantle. Serpentinites facilitate this process due to their high water content (≤16 wt%) and wide stability. Abyssal serpentinites are hydrated by seawater, and mantle wedge serpentinites by fluids from the subducting slab. During subduction of the former and dragging down of the latter by mantle flow, serpentine changes from lizardite to antigorite at 300–350 °C (Evans et al., 2013) and dehydrates at 600–700 °C (70–200 km depth; Schmidt and Poli, 1998).

Recent studies of serpentinites highlight their importance for hosting chlorine, bromine, iodine, and boron in the mantle (e.g., Snyder et al., 2005; Kodolányi et al., 2011; Kendrick et al., 2011, 2013; Debret et al., 2014), but reports including fluorine, particularly in antigorite (atg)-serpentinites, are limited (John et al., 2011; Pagé and Hattori, 2017; Kendrick et al., 2018). Furthermore, the abundance of nitrogen in serpentinites is not well known (Philippot et al., 2007; Halama et al., 2014), despite evidence for the subduction of N to the deep mantle (e.g., Marty and Dauphas, 2003). We report halogen, B, and N abundances in deep (>100 km) mantle wedge atg-serpentinites and discuss the role of serpentinites in their transport to the deeper mantle.

GEOLOGICAL SETTING AND SAMPLES

The Ladakh area of the northwestern Himalaya represents a terrane formed during subduction of the Neotethys, and subsequent collision of the Indian continent with Eurasia (Guillot et al., 2001). The Tso Morari ultra-high pressure (UHP) unit—composed of metasedimentary rocks and eclogite lenses—represents this subducted margin, which reached 3.9 GPa and 750 °C (Mukherjee et al., 2003). The unit is bounded to the north by the Zildat fault, which contains lenses of massive serpentinite (100 × 500 m; Fig. 1) with no reaction zones with adjacent rocks. The close association of the serpentinites with the UHP unit, and similar deformation, suggest their exhumation from >100 km depth (Guillot et al., 2001), consistent with the presence of secondary olivine replacing serpentine (Fig. DR1 in the GSA Data Repository[1]).

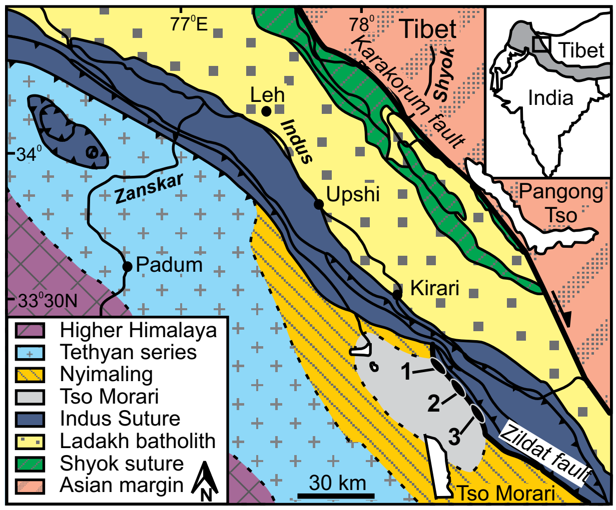

Figure 1. Geological map of the Ladakh area, northwestern Himalaya. Samples from serpentinite lenses (labeled 1 [samples CH187, CH422, CH423], 2 [CH98A,B, CH430, CH433], and 3 [CH146]) along the northern edge of the Tso Morari ultra-high-pressure massif. Solid circles are villages and towns. Map modified after Guillot et al. (2001) and Hattori and Guillot (2007).

The serpentinites, collected from the interior of lenses, are composed of antigorite (> 90%) with minor secondary olivine, magnetite, relic chromite, talc, chlorite, and rare chrysotile veinlets (Table DR1). High concentrations of bulk Cr (~2000 ppm), Ni (>2000 ppm), and Ir-type platinum group elements, and high Cr# in chromite, confirm their protolith as highly depleted mantle (DM) peridotites (Guillot et al., 2001; Hattori and Guillot, 2007). Sample descriptions are in the Data Repository.

[1]GSA Data Repository item 2018323, sample petrography, method details and data tables, is available online at http://www.geosociety.org/datarepository/2018/ or on request from editing@geosociety.org.

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