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# The Mantle Transition Zone history of Tibetan chromitites: experimental constraints

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## Abstract

The Tibetan ophiolites crop out along the Yarlung-Zangbo suture zone between the Indian plate and the Lhasa block. Podiform chromitites in the Luobusha ophiolite (southeastern Tibet) are typically lens-shaped and surrounded by dunite envelopes, enclosed in well-preserved depleted harzburgites. Previous studies have shown that these chromitites were formed in shallow mantle wedge ( $\sim < 30$  km). However, ultra-high pressure (UHP) minerals (e.g., diamond, coesite and TiO<sub>2</sub>-II), and unusual super-reducing phases (e.g., native Fe, SiC and Fe-Ni alloy), have been identified from the podiform chromitites and the host harzburgite layers. Recent studies have also revealed numerous exsolution lamellae of MgSiO<sub>3</sub> and diopside, and rare coesite, within chromite grains. These identifications challenge the traditional hypotheses about the origin of podiform chromitites associated with ophiolites. The coesite and diopside-exsolution bearing chromitites undoubtedly experienced UHP metamorphism. However, the depth of metamorphism and origin of this exotic rock are still debatable.

In this study, we have carried out new experimental studies in the chromite+SiO<sub>2</sub>, chromite+diopside and pyrolyte+chromite systems to constrain the depth of metamorphism of the Tibetan chromitites. In the chromite+SiO<sub>2</sub> system, the experimental results demonstrate that chromite is stable up to 14 GPa and decomposes to eskolaite (Cr<sub>2</sub>O<sub>3</sub>) and a modified ludwigite-structured phase [(Fe, Mg)<sub>2</sub>(Al, Cr)<sub>2</sub>O<sub>5</sub>] at higher pressures, thus placing an approximate maximum depth for chromite crystallization and/or metamorphism. The ludwigite-structured phase has significant implications for understanding phase transformations and Cr incorporation/partitioning of minerals in the MTZ. In the chromite+diopside system, the CaFe<sub>2</sub>O<sub>4</sub>-structured phase was observed at  $\sim 14$ -18 GPa, where it can contain  $\sim 7$ -8 wt% of CaO and  $\sim 3$ -5 wt% of SiO<sub>2</sub>. Therefore, the former presence of the CaFe<sub>2</sub>O<sub>4</sub>-structured phase from the MTZ can explain the exsolution of diopside and coesite from the chromite. Further experiments in the pyrolyte+chromite system indicate that chromite cannot coexist with the mantle mineral assemblages at depths around the 410-km seismic discontinuity. Partial-melting experiments show that garnet, rather than melt, incorporates most of the Cr available in peridotites at such depths. The results therefore indicate that chromite (or its high-pressure polymorphs) cannot directly crystallize in the deep mantle, and contradict the "deep crystallization" model for the chromitites. We suggest that the Tibetan chromitites formed under shallow conditions, and later have experienced conditions near the top of the MTZ after being deeply subducted. During the tectonics/buoyancy-driven ascent of the enclosing peridotites, the CaFe<sub>2</sub>O<sub>4</sub>-phase transformed to chromite at depths of  $\sim 400$  km, accompanied by the simultaneous exsolution of diopside and coesite, which were then preserved during transport to shallow depths. These observations provide a new window into the processes of mantle geodynamics, and constraints on mantle convection.

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