

Magma migration and accretion within the fractured and hydrated mantle at oceanic slow/ultraslow-spreading centers

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The formation of oceanic lithosphere at various types of spreading centers is a crucial process in plate tectonics material cycling from the Earth's interior to surface. Under the spreading centers, the mantle melt extraction system initiates deep in the asthenosphere and develops differentially into the lithosphere. Such system has been well studied for fast spreading centers, through natural ophiolites, geophysical explorations and numerical modelling. However, those beneath slow to ultraslow oceanic spreading centers remain elusive and are hard to be well characterized by deep drilling into present-day oceanic lithosphere.

In this study, we chose the Purang ophiolite, a typical product from a slow/ultraslow-spreading center, in the western Yarlung Zangbo suture zone (South Tibet). A network of gabbro-norite intrusions in its northwestern serpentinized mantle, spanning an area of approximately $10 \times 30 \text{ m}^2$, has been observed and characterized in detail here. These veins with widths of several centimeters to 1-2 m intrude into the fractures within the highly serpentinized harzburgite wall rocks, with a clear contact and thin pyroxenite boundaries. The gabbro-norite intrusions show two forms: coarse-grained type (single stage) and early coarse-grained type intruded by later finer-grained veins (multi-stage). The single-stage veins crystallized from an episode of magma injection, with gradual changes of whole-rock compositions from the vein's edge to its core. Conversely, multi-stage veins resulted from multiple melt intrusions, showcasing abrupt decreases in mineral grain sizes and enrichments in Mg#, CaO, Al_2O_3 and Na_2O contents in the later magmatic stage. Within each stage of products, systematical element variations imply that they formed within small and closed magma channels. Mineral CSD analysis suggests that the crystallization time within the mantle fractures is of at least ~ 527 - 1075 days for the coarse-grained veins while ~ 121 - 178 days for the finer-grained veins. Such veins represent the micro-magma channels within the hydrated mantle. These features of magmatic framework and evolution demonstrate that fractures in the shallow hydrated mantle have acted as vital intermediate conduits for magma migration and accretion from the asthenosphere to the crust at slow to ultraslow spreading centers.