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Thermal state of the upper mantle and the origin of the Cambrian-Ordovician ophiolite pulse: Constraints from ultramafic dikes of the Hayachine-Miyamori ophiolite

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Abstract

Ophiolite pulses, which are periods of enhanced ophiolite generation and emplacement, are thought to have a relevance to highly active superplumes (superplume model). However, the Cambrian-Ordovician pulse has two critical geological features that cannot be explained by such a superplume model: predominance of subduction-related ophiolites and scarcity of plume-related magma activities. We addressed this issue by estimating the mechanism and condition of magma generation, including mantle potential temperature (MPT), from a ~500 Ma subduction-related ophiolite, the Hayachine-Miyamori ophiolite. We developed a novel method to overcome difficulties in global MPT estimation from an arc environment by using porphyritic ultramafic dikes showing flow differentiation, which have records of the chemical composition of the primitive magma, including its water content, because of their high pressure (~0.6 GPa) intrusion and rapid solidification. The solidus conditions for the primary magmas are estimated to be ~1450 °C, ~5.3 GPa. Geochemical data of the dikes show passive upwelling of a depleted mantle source in the garnet stability field without a strong influence of slab-derived fluids. These results, combined with the extensive fluxed melting of the mantle wedge prior to the dike formation, indicate sudden changes of the melting environment, its mechanism, and the mantle source from extensive fluxed melting of the mantle wedge to decompressional melting of the sub-slab mantle, which has been most plausibly triggered by a slab breakoff. The estimated MPT of the sub-slab mantle is ~1350 °C, which is very close to that of the current upper mantle and may reflect the global value of the upper mantle at ~500 Ma if small-scale convection maintained the shallow sub-slab mantle at a steady thermal state. We, therefore, conclude that the Cambrian-Ordovician ophiolite pulse is not attributable to the high temperature of the upper mantle. Frequent occurrence of slab breakoff, which is suggested by our geochemical compilation of Cambrian-Ordovician ophiolites, and subduction termination, which is probably related to the assembly of the Gondwana supercontinent, may be responsible for the ophiolite pulse.

Keywords: Thermal state of upper mantle, ophiolite pulse, mantle potential temperature, slab breakoff, Hayachine-Miyamori ophiolite, ultramafic dike; New Advances in Subduction Zone Magma Genesis