

マントル組成不均質の成因に関する新仮説：660km不連続面におけるスラブの脱水

A new mechanism to produce chemical heterogeneity of Earth's mantle: Slab dehydration at 660-km phase boundary

*中尾 篤史^{1,2}、岩森 光^{1,2}、中久喜 伴益³

*Atsushi Nakao^{1,2}, Hikaru Iwamori^{1,2}, Tomoeki Nakakuki³

1.東京工業大学大学院理工学研究科地球惑星科学専攻、2.海洋研究開発機構基幹研究領域地球内部物質循環研究分野、3.広島大学大学院理学研究科地球惑星システム学専攻

1.Department of Earth and Planetary Sciences, Tokyo Institute of Technology, 2.Department of Solid Earth Geochemistry, Japan Agency for Marine-Earth Science and Technology, 3.Department of Earth and Planetary Systems Science, Hiroshima University

Introduction

Dehydration-hydration processes are thought to be essential for creating chemical heterogeneity in the Earth's mantle: e.g., the mantle geochemical end-member "HIMU" likely represents recycling of an extremely dehydrated oceanic crust, and mantle geochemical hemispheres (Iwamori and Nakamura, 2012) seem to be originated from dehydration-hydration reactions in subduction zones. We investigate behaviors of hydrophilic components during mantle convection and water transport using a self-consistent numerical model in order to reveal the chemical evolution of Earth's mantle with geophysical validity.

Methods

A 2-D fluid mechanical simulation with following characteristics is conducted.

- (1) Free convection of whole-mantle scale without synthetic forces (Tagawa et al., 2007).
- (2) Phase diagrams of hydrous peridotite and hydrous basalt (Iwamori, 2007) to introduce hydration and dehydration reactions.
- (3) Realistic constitutive and state equations for the hydrous rocks to make (1) and (2) interactive.
- (4) Transport of multiple elements that can be partitioned between mantle rocks and aqueous fluid using a Marker-in-Cell technique.

Results and Discussion

During slab subduction, dehydration reactions occur at specific p-T conditions. Then instantaneous aqueous fluid enriched in hydrophilic components and less-hydrated residue minerals depleted in the components are produced. The aqueous fluid is assumed to be immediately incorporated into dry rocks through which the fluid percolates. The transported hydrophile elements are assumed to precipitate with the fluid. In each run, three major dehydration and fractionation processes are reproduced as follows.

[Process 1] (Depth < 200 km; under-arc process) Associated with dehydration of the subducted slab, discharge of highly hydrophilic elements results in depletion of the slab subducting into deeper mantle. The hydrophilic elements are deposited into the overlying lithosphere. This process does not contribute to global redistribution of hydrophile elements, because of high viscosity in the cold region. The depleted layer is fixed along the subducting slab for a long time.

[Process 2] (Depth = 660 km; slab penetration process) When the slab penetrates into the lower mantle, the hydrophiles are continuously emitted depending on their partition coefficients during dehydration associated with wet-Rw → Pv + MgO + Aq transition. This process helps heterogeneity in terms of the hydrophile elements to horizontally expand. During the slab penetration process, the depleted rock as a product of 660-km dehydration is produced just below the phase boundary, and descends into the deeper mantle.

[Process 3] (Depth = 410 km; upwelling wet plume process) If the water-saturated layer is formed just above the 660-km phase boundary, wet plumes enriched in the hydrophiles ascend due to their buoyancy. After plumes reach the 410-km phase boundary, dehydration by $Wd \rightarrow Ol$ transition and the corresponding fractionation of the hydrophiles occur. However, the depleted plume tails are not well separated from the enriched plume head.

Among them, [Process 2] is the most efficient process for creating and distributing the geochemical heterogeneity. [Process 2] with wet plumes and aqueous porous flows from the 660-km phase boundary involves a possible mechanism to produce the observed geochemical hemispheres representing a hydrophile-rich part (eastern hemisphere) and a depleted part (western hemisphere) (Iwamori and Nakamura, 2012).

キーワード：親水性微量元素、水輸送、マントル対流、660km地震波不連続面、マントル組成不均質、元素分別
Keywords: hydrophilic trace elements, water transportation, mantle convection, 660-km phase boundary, chemical heterogeneity of mantle, element partition