Evidence for suboceanic small-scale convection from a “garnet” -bearing lherzolite xenolith, Aitutaki Island, Cook Islands

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Garnet peridotite xenoliths have been rarely reported from suboceanic mantle. Due to their rare occurrence, the petrographic and geochemical characteristics of garnet-bearing oceanic peridotite xenoliths provide precious information on the nature of the suboceanic lithosphere and asthenosphere and their mantle dynamics. We examined a lherzolite xenolith included in olivine nephelinite lava from Aitutaki Island, a member of the Cook-Austral volcanic chain. The lherzolite xenolith contains reddish fine-grained (<5 μm in size) mineral aggregates (FMA) consisting of olivine, plagioclase, spinel, native iron, and nepheline, which have been thought as a breakdown product of orthopyroxene (Fodor et al.,1982; New Zealand Journal of Geology and Geophysics, 25, 67−76). The native iron and nepheline grains are euhedral to subhedral and are locally in direct contact, whereas the olivine, plagioclase and spinel are anhedral and show a symplectic microstructure. The olivine grains show high concentrations around the FMA. Where present a cluster of anhedral chromian spinel grains, locally isolated from each other at least in two dimensions, is always enclosed by the FMA. Such spinel grains show identical crystallographic orientations, suggesting that they originally formed a large equant single grain, which was later partially decomposed to have an extremely irregular three-dimensional morphology. Calcite veins a few tens of μm-thick were observed in the chromian spinel, and a tiny (~a few tens of μm) calcite grain is included in the FMA. Bulk major-element and trace-element compositions of FMA are close to those of pyrope-rich garnet stable in the garnet-bearing peridotite. These observations and analytical results corroborate that the FMA are decomposed pyrope-rich garnet, which was transformed from an aggregate of aluminous spinel and pyroxenes leaving the olivine margin and chromian spinel. Orthopyroxene and clinopyroxene grains show slight but clear chemical heterogeneity characterized by increase in Al, Ca and Cr from the grain center to the rim of orthopyroxene, and increase in Al and Cr from the grain center to the rim with monotonous increase in Ca of clinopyroxene. The Al and Ca zoning patterns can be modeled by diffusional exchange induced by pressure and temperature (P-T) changes with keeping surface concentration in equilibrium with the other coexisting phases. The results indicate that the lherzolite xenolith underwent isothermal decompression on a timescale longer than millions of years. Because the reaction of pyroxenes + aluminous spinel →olivine + pyrope-rich garnet, identified by the microstructure, may have resulted from an increase in pressure, we hypothesize that the mantle including the lherzolite xenolith was initially dragged down and then brought up by small-scale sublithospheric convection with the direction of rolling along the Cook-Austral volcanic chain controlled by the oceanic plate motion. The last P-T condition shortly before xenolith entrainment and transport to the surface was calculated at 2.13±0.01 GPa and 1100±2 ºC, GPa, where experimental results show garnet is stable in the peridotite system. The formation of native iron and nepheline grains probably occurred associated with a redox reaction between a C-bearing fluid and the pyrope-rich garnet. The olivine-plagioclase-spinel matrix formed later during the upward entrainment by a strongly Si-undersaturated alkaline magma. The lherzolite xenolith was finally transported by a nephelinite magma and erupted in Aitutaki Island at ~2 Ma

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