Thermal and kinematic history of subcontinental lithosphere: Mantle xenoliths from Colorado plateau and Rio Grande rift

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The subcontinental lithosphere evolves on a geological time scale as a result of the thermal and dynamic interaction with the asthenosphere causing surface tectonics and magmatism. It is important to understand the processes operated in the lithosphere-asthenosphere boundary zone (LABZ) for better understanding the evolution of the subcontinental lithosphere (Sleep, 2005; Stwüve, 2008). Fragments of mantle materials bought to the surface by magmas, usually called ‘mantle xenoliths,’ provide direct and instantaneous information of the LABZ, such as temperature, composition, and microstructures, with specification of depth. The derivation depths of xenoliths are usually estimated with geobarometry base on chemical compositions of the constituent minerals. This is not an easy task because most of minerals in xenoliths have various heterogeneities induced by a change in temperature, pressure, and system composition, which may provide us very useful information on dynamic history operated in LABZ. The aim of this study is to estimate the xenolith derivation depths accurately after specifying appropriate mineral pairs for proper application of geobarometry by quantifying thermal and kinematic history of xenoliths, from which dynamics processes operated in LABZ is clarified. The target areas are the Thumb from the Colorado plateau and the Potrillo from the Rio Grande rift, which are neighboring regions but have contrasting topography and seismic structures from the crust to the asthenosphere.

We examined five samples from Thumb, three garnet peridotites and two spinel peridotites, and five spinel peridotite samples from Potrillo. All garnet grains in the Thumb samples shows extensive decomposition via reaction with olivine into aggregates consisting of spinel and pyroxenes (±plagioclase) with diverse size change, suggesting decompression. Clinopyroxene, orthopyroxene, and olivine in most of peridotites from Thumb and Potrillo shows chemical zoning, suggesting that all xenoliths recorded transient state. We extensively examined Ca zoning in olivine and orthopyroxene using a diffusion model. We clarified minerals, components, and their position in grains, representing a chemical equilibrium with specification of the corresponding events or stages for appropriate geobarometry. We were able to estimate pressure and temperature changes with specification of anchor “equilibrium stages” for Thumb in the Colorado plateau. The deepest xenolith (~3GPa) underwent decompression >>~100 years before the eruption with insignificant sign of heating or cooling. The shallowest xenoliths (~ 2GPa) underwent a decompression by ~2GPa from the garnet stability field accompanied by slow earlier heating and later cooling (~10^5 years), which was followed by a isobaric short heating event for >>~100 yrs before eruption. There are two distinctive xenoliths groups in Potrillo in the Rio Grande rift. One group giving higher pressure (~1.6GPa) in the spinel stability field underwent a heating event after a slow cooling event. The other group giving lower pressure (~0.3GPa) in the plagioclase stability field underwent a decompression and heating event.

We proposed the model of lithosphere-asthenosphere interaction beneath the Colorado plateau - Rio Grande rift area on the basis of our xenolith study. Before the activity of Navajo volcanic field including Thumb at ~25Ma, a thick cratonic lithosphere was subjected to active upwelling beneath the Colorado plateau, which heated the lithosphere to thin it by thermal and chemical erosion. The lithosphere thinning drove uplift of the entire lithosphere to from highland of the Colorado plateau. In later time before the magma activity of the Rio Grande rift ~0.08Ma, eastern periphery of the lithosphere beneath Colorado plateau, where the lithosphere was thinner, was streched to cause passive upwelling of asthenospheric mantle to form low-lying topography of the Rio Grande rift.

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