Thermal interaction of the lithosphere and asthenosphere revealed from internal variations of pressure-temperature history in orogenic peridotite complexes

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Dynamics of interaction between lithosphere and asthenosphere in their boundary zones (LABZ) plays an important role in transferring heat, material, and momentum from the earth’ s interior to the surface. Orogenic peridotites provide direct and high-resolution information for better understanding mantle processes taking place in the boundary zone. However, their exhumation obscure the information on dynamics operating in LABZ, while they could be driven and affected by processes taking place in and beneath the LABZ. This issue leads to ambiguity in the link between magmatism, relevant to whole-rock chemical characteristics, and exhumation of peridotite complexes, relevant to deformation and subsolidus reactions. Bodinier et al. (2008) actually pointed out two possible formation scenarios for plagioclase peridotites in orogenic peridotite complexes: subsolidus reaction from spinel peridotites and open magmatic processes in the plagioclase peridotite facies in the shallow mantle. In the context of lithosphere-asthenosphere interaction, it is crucial to discriminate these two possibilities. Spatial and temporal changes of pressure and temperature within an orogenic peridotite complex can be used to better constrain its history of decompression and magmatism. By exploiting the advantage of size of orogenic peridotite complexes, these data may provide valuable constraints on the LABZ dynamics.

Here, we examine internal variations of thermal and decompression history of three orogenic peridotite complexes: Ronda, Pyrénées, and Horoman. They exhibit diverse geological and petrologic characteristics providing an excellent chance of comparative study. The common feature of these orogenic peridotites is decompression from the garnet peridotite facies deeper than ~50km. In this study, we focus on garnet-related reaction microstructures, which are powerful tools to resolve pressure-temperature history because of their high hysteresis as compared with suppressed hysteresis of chemical zoning in minerals. Garnet and its breakdown products show contrasting features among the three. (1) Garnet was completely decomposed in both peridotite and pyroxenite lithologies in Horoman with formation of symplectite in slightly depleted peridotites; garnet rarely remains in both peridotite and pyroxenite lithologies with extensive formation of symplectite and kelyphite in Ronda; and garnet is completely decomposed into two-pyroxene spinel symplectite in peridotites but well preserved with partial formation of kelyphite rim and veinlets in pyroxenites in Pyrénées. (2) Coarse-grained granular olivine-plagioclase assemblage in both fertile peridotite and pyroxenites is common in Horoman; formation of olivine-plagioclase assemblage forming fine-grained intergrowth in fertile peridotites and pyroxenites is common with its extent being spatially variable in Ronda; and formation of olivine-plagioclase assemblage rarely in pyroxenites and very rarely in fertile peridotites in Pyrénées. These contrasts suggest: (1) high-temperature decompression path all through its ascent in Horoman; (2) low-temperature in deeper levels but relatively high-temperature decompression path in shallower levels in Ronda; and (3) high-temperature decompression path in deeper levels followed by rapid cooling in shallower levels in Pyrénées. Combined with pressure-temperature path deduced from chemical zoning and microstructure related to exsolution and dissolution in pyroxenes, we propose that the shallow high-temperature decompression of Ronda was caused by heating in the plagioclase peridotite facies and that the high-temperature decompression of Horoman by heating over a wide depth range deeper than the plagioclase peridotite facies. Pyrénées is probably intermediate of these two cases. The contrasting modes of thermal perturbation may imply different mechanisms of lithosphere-asthenosphere interaction, such as active upwelling vs. passive upwelling.

Keywords: lithosphere-asthenosphere boundary, pressure-temperature history, orogenic peridotite

