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Effects of water on melt–peridotite reactions at 3 GPa: An experimental study with application to the formation of garnet orthopyroxenite in orogenic mantle

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The presence of garnet affects the geochemical properties of the upper mantle. Mantle peridotites can be transformed into garnet pyroxenites at moderate to high pressures via modification by silicate melts. However, the formation mechanisms of garnet pyroxenites in the orogenic mantle and the origins of variations in their mineral compositions are unclear. To better understand the effects of water on the lithology and mineral chemistry of garnet pyroxenites, we carried out experimental reactions between a hydrous basaltic andesite (4 wt.% water) and a spinel lherzolite in Au–Pd and Pt capsules at 2–3 GPa and 1300–1375°C using the reaction couple method. Control experiments without the addition of water were also conducted under the same conditions in graphite and Au–Pd capsules. The hydrous melt–peridotite reaction produced melt-bearing orthopyroxenites. In particular, a melt-bearing garnet orthopyroxenite and garnetite were formed at the melt–rock interface and on the melt side of the reaction couple, respectively, and the lherzolite transformed to garnet lherzolite at 3 GPa. In contrast, the control experiments produced a garnet clinopyroxenite at 2 GPa and an eclogite at 3 GPa. The garnet orthopyroxenite grew with increasing temperature and run duration, and garnet-rich and garnet-poor sections were generated at a higher temperature. Compared with previous experiments conducted at relatively high pressures (≥3 GPa) and low temperatures (≤1100°C), a high temperature is needed for the reaction to form garnet orthopyroxenite. The garnet orthopyroxenite and garnet peridotite produced in our experiments are similar to garnet orthopyroxenite dikes in orogenic massif peridotites, which highlights the importance of hydrous melt–peridotite reactions in the formation of such dikes. The mineral chemistry of our experimental products and natural samples suggests that subsolidus re-equilibration plays a significant role in causing the variations in mineral composition. Re-equilibration between the constituent minerals explains the low Mg# values of garnet and high Mg# values of orthopyroxene, as well as the low temperatures calculated using geothermometers. Modeling of the rare earth elements during the reaction and subsolidus re-equilibration provides insights into the trace element variability of orogenic mantle caused by hydrous melt–peridotite interactions. This work was supported by NSFC (grant 42422203).