

Temperature-time constraints on majoritic garnet exhumation from breakdown experiments

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Majoritic garnet - the major aluminium mineral phase in the lower half of the Earth's upper mantle and in the mantle transition zone - decomposes partially to completely to garnet-pyroxene intergrowths when occurring at shallower levels which makes the breakdown mineral microstructure a unique recorder of deep reaching exhumation processes. Here we use synthetic majoritic garnet in disequilibrium decompression experiments to show that the chemistry of the breakdown products are controlled by the silicon diffusivity and by that by the ambient temperature conditions during and after decompression. Sluggish silicon diffusivity even at upper mantle temperatures suggests chemically equilibrated minerals in granular exsolution microstructures after majoritic garnet precursors as found in kimberlite xenoliths and diamond inclusions require a sub-continental lithospheric mantle residence prior to exhumation towards the surface.

Polycrystalline majoritic garnet ($X_{Mj}0.55$, grain size <5 microns) was synthesised from powdered glass with a "pyrolite minus olivine" composition at 18 GPa and 1600 degrees C for 140 min. Subsequently, the recovered synthetic majoritic garnet and the powdered glass starting material were both subjected to 10 GPa and 1450 degrees C for times between 1 and 12 h to breakdown the majoritic garnet and to produce the corresponding equilibria mineral phases simultaneously. Analyses of the recovered disequilibria samples using FE-SEM with EDS suggest that majoritic garnet crystals broke down peripherally by first forming an intercrystalline network of grains of tschermakitic pyroxene ($X_{Ts}0.25$, grain size 1 micron) that subsequently interacted with the remaining majoritic garnet cores ($X_{Mj}0.55$) to form low-tschermaks pyroxene ($X_{Ts}0.12$) and a garnet composition slightly lower in majorite component ($X_{Mj}0.50$). Equilibria samples contrast with low-majoritic garnet ($X_{Mj}0.25$) and virtually tschermaks-free pyroxene ($X_{Ts}0.02$).

Collectively, the data implies a two-stage breakdown process. Rapid phase transformation of majoritic garnet rims to tschermakitic pyroxene forms a granular decomposition microstructure. Subsequent sluggish mineral-chemical equilibration of the two mineral phases to ambient pressure-temperature conditions is consistent with the slow diffusivity of silicon in natural diopside (Bejina & Jaoul, 1996), a conclusion supported by "frozen" diffusion profiles in natural analogues (Sautter & Harte, 1988). Dodson closure temperatures calculated for silicon self diffusion in pyroxene show that extreme cooling rates of kimberlite magma with mantle xenolith cargo suppress chemical equilibration of pyroxene precipitates 10 microns and larger in size from majoritic garnet. By implication, slow cooling rates and/or long time integrated residence at upper mantle temperatures are necessary to explain the chemical equilibration of granular precipitates occurring in kimberlites. As a consequence, granular mineral microstructures after majoritic garnet precursors are related to the growth history of sub-continental lithospheric mantle.

Sautter V. & Harte B. (1988), *Journal of Petrology*, 29:1325-1352

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