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Super-Si garnet exsolution kinetics denotes multistage mantle exhumation

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Previous decompression experiments have shown that super-Si garnet decomposes to normal garnet + pyroxene, which supports that natural analogues (found in mantle xenoliths, diamond inclusions, peridotite massifs) record up to several hundreds of kilometre exhumation, all proposed to apply to contrasting geological scenarios including mantle convection, kimberlite magmatism and plate tectonics. To verify this proposition we used glass powder with a 'pyrolite minus olivine' composition for polycrystalline dry super-Si garnet synthesis (18 GPa, 1600 °C, 2 1/3 h) and subsequent decompression (10 GPa, 1450 °C, 0–12 h). All samples recovered after decompression share a coronitic texture of new grains of garnet + pyroxene that surround relic super-Si garnet. Quantified XRD spectra show transformed volumes are similar, $\sim$40 %, that mark a rapid decrease of the transformation rate within the first minutes of the decompression runs. Fitted kinetic data does not fulfil conditions for steady nucleation and growth. The Tschermak's component of corona clinopyroxene is four times higher than that of equilibrium clinopyroxene synthesised along with each decompression experiment. Element concentration profiles (TEM EDS) and element mapping (FE-SEM EDS) across the corona microstructure show steep but discontinuous Al concentration gradients at both relic and corona garnet grain margins. Transformation rate and mineral chemistry suggest that volume diffusion (1) exceeds decompression induced initial partial breakdown of super-Si garnet and (2) will be rate limiting for exsolution to reach equilibrium.
Modelled Si–Al and Si–Al–Mg interdiffusion in garnet at different water contents in combination with geological cooling rates suggests that diffusion distances exceed metamorphic garnet grain sizes of $\leq$1 cm within the amphibolit facies, unless dry conditions apply. In contrast, mantle garnet of 1–2 cm in size may allow for up to two types of pyroxene precipitiation, depending on the garnet origin. Exsolution of diamond inclusions occurred prior to lithosphere transit, but is sensitive to internal pressure and hence kinetically difficult to interpret.
We suggest that the breakdown of natural super-Si garnet forms two distinct decomposition microstructures, a corona type and a lamellae type, depending on whether diffusion distances exceed the garnet grain size or not. Diffusion distances and statistics on natural occurrences of the lamellae type decomposition microstructure comply with an origin within the SCLM during secular cooling of the Earth. Given the affinity of super-Si garnet breakdown microstructure occurrence to Archaean areas at global scale, models for craton stabilisation require the inclusion of processes that allow garnet bearing SCLM growth in the garnet peridotite stability field. Preceeding shallower stages would have erased the microstructural record.