Chemical equilibration of Grt-Pyx exsolution microstructures at mantle UHP prior to crustal UHPM in orogenic peridotite, China

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Mineral exsolution microstructures of garnet and pyroxene in orogenic peridotites (tectonically exhumed mantle fragments) bear witness to precursor mineral phase P-T conditions that are important for the reconstruction of either ultra-high pressure (UHP) metamorphic continental subduction zones or an earlier evolution of the lithospheric mantle.

Garnet lamellae that occur in cm-scale porphyroclastic ortho- and clinopyroxene enclosed in orogenic garnet peridotite from Xugou, Su-Lu, China, are 20-100 micro-m in width, several mm in length, regularly distributed and widely spaced. Thin sections perpendicular to the [001] axis of pyroxene suggest that garnet precipitated parallel to the (100) and (010) planes of pyroxene, consistent with an origin by exsolution. A second generation of exsolution in orthopyroxene is evident from Cr-spinel lamellae that are a few micro-m in width, several hundred micro-m in length, regularly distributed sub-parallel garnet and narrowly spaced. Both exsolved Al phases in orthopyroxene are associated and partly interlaced with clinopyroxene lamellae similar in size. We interpret the microstructure in both porphyroclastic pyroxenes to have formed from precursor pyroxenes by successive exsolution that involved Al, Cr and Ca. Steep Ca isopleths (CMAS system) and Cr-Al systematics (FMASCr system) constrain exsolution occurred during near isobaric cooling. Quantification of the precursor phases using major element compositions (analysed by EMPA) of the exsolved phases in combination with 2D image analysis of the microstucture yields 0.033-0.038 Ca per 6 oxygen and 1.3-2.4 mol% Tschermak component in precursor orthopyroxene and 6.1-7.0 mol% Tschermak component in precursor clinopyroxene, corresponding to confining minimum T of 1200 degrees C and 1600 degree C at 5 GPa respectively.

In contrast, the partitioning of REE (analysed by SIMS, LA-ICP-MS) between clinopyroxene and garnet are steeper (in chondrite-normalised plots) than those reported from both HT (1380-1260 degrees C) and LT (1080-870 degrees C) mantle xenoliths (Schmidberger and Francis, 2001, Journal of Petrology, 42, 1095-1117) and thus indicates a chemical equilibration of the lamellae-type mineral exsolution microstructure in the two types of porphyroclastic pyroxene at relatively low T (less than 870 degrees C).

Porphyroclastic orthopyroxene has flat compositional profiles with 0.20 wt% Al2O3 showing chemical equilibration. The peridotite matrix assemblage composed of garnet + orthopyroxene + clinopyroxene + olivine +/- phlogopite records a strain-induced recrystallization and lacks precipitates in mineral cores. Matrix orthopyroxene cores have 0.12 wt% Al2O3 content. Geothermobarometry on garnet-orthopyroxene mineral pairs indicate 5.6 GPa / 760 degrees C and 6.3 GPa / 840 degrees C for the exsolved and recrystallized microstructure, respectively. These P-T estimates derived from the same mineral phases preserved in two structurally different positions overlap with the range in metamorphic condition reported for the peak UHP metamorphism in the region (5-7 GPa and 780-870 degrees C). However, the lack of precipitates in recrystallized mineral assemblage replacing the porphyroclastic minerals implies prograde recrystallization destroyed the exsolution microstructure prior to the peak UHP metamorphism. Furthermore, equilibration conditions of the exsolution microstructures are below those of cold (old) cratonic geotherms implying equilibration occurred in a mantle wedge above a subduction zone.

We conclude that petrogenesis of the Xugou orogenic peridotites requires formation of mineral exsolution microstructures during near isobaric cooling from minimum 1200 degrees C in the lithospheric mantle at depth of c. 170 km before chemical equilibration before deformation and incorporation of the mantle fragments into continental crust during prograde metamorphism related to subduction of continental lithosphere that culminated at 200 km depth.