GARNET MICROSTRUCTURES FROM AN ULTRA-DEEP (>185 KM) OROGENIC PERIDOTITE

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ABSTRACT

Relic majoritic (or super-silicic) garnets were recently discovered within orogenic garnet peridotites at the island of Otroy, Western Gneiss Region, W. Norway (Van Roermund and Drury, 1998; Van Roermund et al., 1999). However within the Otroy garnet peridotites relic majoritic garnet microstructures are rare and the petrogenetic relationship(s) between relic majoritic- and "normal" garnet is unknown. For this reason we have made a detailed SEM study of microstructures and solid-phase inclusions present exclusively within all garnets from the Otroy garnet peridotites.

MAJORITIC GARNET MICROSTRUCTURES AND CHEMISTRY

The super-silicic garnet microstructure is characterised by the following microstructural elements:

a) Majoritic garnet nodules consist of polycrystalline garnets ranging in size from 2 to 8 mm. Garnet-garnet grain boundaries are straight or gently curved, triple point junctions are common, interstitial orthopyroxenes decorate some garnet-grain boundaries.
b) In the larger garnet grain cores two pyroxene exsolution needles occur 5-10 μm thick and oriented // $<111>_{grt}$. The relative vol% between exsolved cpx and opx is 1: 9.
c) Two-pyroxene-bearing garnet-cores are surrounded by 2 mm thick precipitation-free rims.

Backscattered scanning electron microscopy was used to estimate the amount of majorite component present in garnet nodules before exsolution. Large interstitial orthopyroxenes at garnet grain boundaries comprise up to 3.6 vol.%. In the garnet grain cores the maximum pyroxene content is 1 vol.%. Including both types of pyroxene-exsolution the maximum amount of exsolved pyroxene is 3.6-4.0 vol.%. This corresponds to pressure estimates around 6-6.5 GPa and a minimum depth of origin for the Otroy garnet peridotites in the range of 185-200 km.

Microprobe analyses of exsolved pyroxenes and garnet-host reveal homogeneous mineral compositions, except for Al_2O_3 wt% in opx. The most dominant Al_2O_3 wt% value in opx is 0.7-0.8. Estimated PT conditions for mineral-chemical equilibration, using standard geothermobarometric methods, indicate upper mantle conditions around 805 ± 40°C and 3.2 ± 0.2 GPa. These PT estimates correspond to cold continental lithosphere conditions at depths of around 105 km.

From a combination of both depth estimates it can be concluded that the microstructural memory extends backwards to twice as great a depth-range than can be obtained by thermobarometric methods.

In addition to the exsolved two pyroxenes we have found native nickel-particles as solid inclusions in relic majoritic garnets. This is indicative for relatively reduced oxygen fugacity conditions. The nickel particles are surrounded by complex symplectitic coronas involving Ni-Al oxide, Orthopyroxene, SiO_2 and Ni-bearing garnet.

NON-MAJORITIC GARNET MICROSTRUCTURES AND CHEMISTRIES

The following solid-phases occur as inclusions in "normal" pyrope-rich garnets:

a) Ni-Fe-Cu sulfides. Two types occur: 1) co-linear trails of rounded particles less than 1 μm in size and interpreted to represent precipitation along healed cracks. 2) Coarsened irregular-shaped inclusions up to 50 μm in size. The latter are often present in clusters.
b) (Fe-) Ti (oxide??) needles (oriented // $<111>_{grt}$).
c) (Fe-) Ti -oxides randomly precipitated or decorating dislocations.
d) Isolated spinel needles and precipitates. With respect to the garnet host two types occur: oriented and randomly distributed crystals.
e) Recrystallised garnet 2 - spinel - cpx/amphibole - orthopyroxene (± Ni-Fe-Cu sulfides) mineral assemblages.

In addition to the various solid-garnet-inclusions garnet-deformation microstructures are present including naturally decorated dislocations. In thin-section garnet is often heavily fractured, and a penetrative crack-spacing down to the micron-scale is not uncommon. More widely-spaced or more heterogeneously fractured garnets exhibit the following microstructural domains:

i) in between the cracks garnet is geometrically strained and deformation-induced microstructures such as undulous extinction and cross-hatched deformation bands are visible. This is recognised by the local non-isotropic nature of garnet. Within some of the strained domains dislocations are identified due to the fact that micron-sized particles have been precipitated along the dislocation cores. TEM and attached analytical facilities demonstrate that the solid inclusions are titanium-oxides, most likely rutile.
ii) In between the cracks garnet is fully isotropic and strain-free. Within such domains randomly oriented solid inclusions are recognised one order of magnitude larger than the precipitates that decorate dislocations in strained garnet domains.

All solid garnet inclusions and deformation microstructures predate the well-known two-pyroxene-spinel corona's that surround garnet and form due to the instability of the mineral assemblage garnet-olivine.

All garnet microstructures are consistent with a poly-

cyclic exhumation model involving diapiric upwelling of deep-mantle peridotites to lithospheric depths followed by isobaric-cooling down to normal continental lithosphere conditions. Crustal incorporation occurs during renewed-subduction of continental crust during continental collision subsequently followed by final exhumation.

REFERENCES

van Roermund H.L.M. and Drury M.R., 1998. Ultra-high pressure (P>6GPa) garnet peridotites in Western Norway: exhumation of mantle rocks from >185 km depth. Terra Nova, 10: 295-301.

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