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Exsolution halos surrounding ruptured inclusions in garnets from UHT and UHP rocks

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Distinctive halos of rutile ± apatite needles and/or plates centered on quartz or multiphase inclusions with radial cracks in garnet are investigated. The quartz is likely former coesite and the multiphase inclusions are interpreted to be decrepitated fluid inclusions. We study samples from two localities: (1) ultrahigh-temperature (UHT) metapelitic gneisses from the Central Maine Terrane in Connecticut, USA (Ague et al., 2013) (rutile halos only) and (2) ultrahigh-pressure (UHP) diamondiferous saidenbachite from the Saxonian Erzgebirge (Massonne, 2003) (rutile and apatite halos). The rutile and apatite needles in the halos are typically oriented in three directions. Within the halos, garnet is depleted in Ti (and P if apatite is present). The halos extend about three inclusion radii away from the central quartz or multiphase inclusions.

We propose that the inclusion halos of rutile ± apatite formed by exsolution out of garnet due to rupturing of the central inclusions. The internal pressure of an inclusion in garnet can be larger than the surrounding lithostatic pressure if the entrapment pressure is maintained or if a large positive volume phase change occurs. A large pressure difference between an inclusion and host strains the host and causes deformation, which in turn produces dislocations and other defects. During exhumation the pressure difference between inclusions and the surrounding rock matrix can become so great that rupturing of the garnet occurs. The rupturing creates more dislocations and defects in the garnet with the dislocation density highest around the inclusion. The defects in the crystal structure are ideal nucleation sites for exsolved precipitates. Another factor assisting exsolution is the drop in pressure in the surrounding garnet caused by the rupturing which should in turn decrease the solubility of Ti and P in garnet.

To test the exsolution hypothesis, chemical reintegration of the Ti or P contents of the garnet in the halos plus the rutile or apatite precipitates was done using wide-beam electron probe microanalyzer methods. The reintegrated concentrations are consistent with the Ti or P being sourced from the garnet; no external sources for these elements were necessary. Additional hypothesis tests include: (1) The abundances of rutile ± apatite precipitates are highest closest to the ruptured inclusions as expected for strongly-localized stress and resulting deformation. (2) The radii of the halos are proportional to the radii of the ruptured inclusions. This is consistent with the elastic (pressure vessel) model for a strong single host crystal which predicts that stress will drop off proportional to the inverse of the radial distance cubed. (3) The rutile ± apatite inclusions are rare or absent elsewhere in the garnets, even where Ti or P concentrations are high.

The exsolved halos of rutile ± apatite demonstrate that strain can be important for driving mineral exsolution from garnet. For this process to occur, Ti ± P must be present in aluminous garnet. Elevated concentrations of these elements are typically found in garnets from HP, UHP, granulite, or UHT settings. Thus, the textures we describe are likely to be restricted to such metamorphic environments.