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Mineral inclusions in garnet crystals and their application in studies of high and ultrahigh pressure rocks

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Mineral inclusions in crystals like garnet, zircon or clinopyroxene play a key role in identifying ultrahigh-pressure (UHP) metamorphic rocks and in deciphering their metamorphic (P) - temperature (T) history. In this contribution, we address the questions related to the modification of garnet interiors mediated by H2O and/or CO2 fluids released either from the mineral inclusions or from the exterior source.

The data presented are based on experimental studies of eclogitic garnets containing various mineral inclusions and on petrologic studies of natural rocks from several HP and UHP complexes.

An experimental study on eclogitic garnets with different min¬eral inclusions (including hydrous phases and carbonates) from several subduction-related complexes reveals considerable modification of garnet interiors at temperatures of 700–1100°C and a pressure of 3-4 GPa, representative of different diamond-bearing metamorphic UHP terranes. Epidote, amphibole, and chlorite inclusions in the garnets underwent dehydration melting over the entire experimental PT range. In the presence of aqueous fluids, carbonate minerals in the inclusions began to melt at 800 °C and 3 GPa. Melting gave rise to new garnet, with the composition controlled by the chemistry of the primary inclusions and by PT run conditions. Garnet either grew directly from the melt or formed by metasomatic replacement of host garnet walls, leaving residual melt at the substitution front in the latter case. Partial melting of inclusions decreased the mechanical strength of the garnet host and led to local shearing. The following diagnostic criteria for melt in metamorphic garnet may be formulated on the basis of the experimental study: (1) (sub-) euhedral garnet grows within the inclusion and/or xenomorphic garnet replaces the garnet host; (2) newly formed garnet is characterized by a composition different from the garnet host; (3) the inclusion surface is features characteristic wedge-shaped ledges or radial wavy fractures filled by melt or products of its recrystallization.

The increase of pressure and temperature during subduction will generally affect the P-V-T behaviour of the host and its inclusions in a significantly different way. A simple elastic model for various included minerals in garnet was used to show how the P-T trajectories of the spherical inclusions of different minerals deviate from the P-T path of the rock. Assuming only 5 % volume expansion due to the dehydration melting of the inclusion, the overpressure generated by the inclusion may reach 1.7 GPa. The increasing strain may finally rupture the host crystal, producing the radial cracks observed in the experimental runs.

The experimental results were used to interpret observed features in the samples of a diamond-bearing and a diamond-free carbonate-silicate rock from the Kumdy-Kol deposit in the Kokchetav Massif and inclusions in garnet from the eclogite from Faro, Yukon-Tanana terrain, Canada.

We also discuss origin of unusual inclusions in the garnet from the diamondiferous gneisses of Saxonian Erzgebirege which provide evidence on the both (1) presence of supercritical UHP liquid in the rock and (2) non precipitated origin of oriented lamellae in the garnet host. The studied dimondiferrous gneiss is composed of garnet, phengite (replaced by biotite), plagioclase and quartz as major rock-forming miner¬als. Garnet contains polyphase diamond-bearing inclusions consisting of quartz±phengite±phlogopite±rutile±titanite±apatite. We found two polyphase inclusions of 100-200 μm in diameter in a single garnet host show a tendency to negative crystal shape and surrounded by radial fractures of garnet around the inclusions. In addition, the inclusions are surrounded by halos consisting of numerous inclusions of size less than 1 μm. Morphology of the halos is identical to the well known decrepitation halos of melt and fluid inclusions in deep seated magmatic rocks suggesting similar mechanism of their formation. Most of garnet grains contain very tiny oriented needles (up to 2*200 μm) of rutile as well as of Na- and K-Mg phases. Since precipitation of K-Mg phase is impossible from the K-free garnet (below 10 GPa), the source of K should be located out of the garnet structure. Accordingly we assume that these oriented inclusions are not precipitated from the garnet host but resulted from interaction between garnet and coexisting supercritical liquids situated either in the matrix of the rock, or in the inclusions in garnet during the rock exhumation.

The described above modifications of garnet interiors mediated by fluids has important consequences for thermobarometry, fluid-inclusion studies and for the rheology of (U)HP rocks.