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Mechanisms of Garnet Growth in High-pressure Mafic Garnet Granulite formed by Dehydration Melting of Hornblende-gabbronorite: Insights from the Jijal Complex (Kohistan paleo-arc Complex, N. Pakistan)

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We present a detailed SEM and HRTEM textural study of a unique natural example of garnet growth during amphibole dehydration melting preserved in the mafic-ultramafic Jijal complex (Kohistan complex, N. Pakistan). In this complex the transition from hornblende-gabbronorite to high-pressure garnet granulite crops out as a sharp (cm-scale) reaction front separating reactant (hb-gabbronorite) from product (garnet-granulite). This sharp transition preserves a snapshot of different stages of garnet growth during the transformation of hornblende gabbronorite to garnet granulite. Garnet growth involved the breakdown of hornblende and orthopyroxene, in the presence of plagioclase, to garnet, clinopyroxene and melt.

A fast kinetic is deduced from textural observations. At the reaction front, single amphibole crystals were transformed to single-crystal garnets with skeletal morphologies ("hopper" crystals) with a definite pattern of quartz inclusions. The onset of amphibole breakdown is marked by the transformation of amphibole crystals to garnet throughout reactive hetero-epitaxial nucleation of garnet at the amphibole-plagioclase interfaces. HRTEM observations indicate the existence of a three-dimensional fit of amphibole and garnet crystal lattices that allowed an interface-controlled growth of

garnet. The skeletal morphologies of garnet are accounted for by growth of garnet using the lattices of amphibole substrates as layouts. After garnet nucleation on amphibole substrates, garnet grew directly from the melt phase formed at the amphibole-plagioclase interfaces and under relatively high supersaturation conditions ("additive growth"). At this stage, the rate-limiting step for garnet growth was likely the dissolution rate of plagioclase. On the basis of available experimental observations, we propose that plagioclase dissolution involved the following kinetic steps: release of water during amphibole breakdown, plagioclase melting in presence of H_2O and, finally, accommodation of components in the structure of garnet and formation of H_2O-rich, low viscosity melt. The H_2O content of the melt hence controlled the overall rate of the reaction.

As the reaction progressed, the consumption of amphibole, the sluggish melting rate of plagioclase in absence of H_2O, and decreasing diffusion rates due to the separation of reactants by growing garnet, all reduced supersaturation and the garnet growth rate. This resulted in a change in the morphologies of garnet from dendritic to polyhedral ("reactive growth stage"). A final stage of Ostwald ripening resulted in the formation of large inclusion-free garnet porphyroblasts commonly observed in the garnet granulites farther away from the reaction front.