Crystal size distributions of garnets in the Bushveld contact aureole, eastern Transvaal area, South Africa

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Crystal size distributions (CSDs) of garnets were investigated in the Bushveld contact metamorphic aureole. Their CSD shapes show lognormal to quasi-lognormal distributions. Contrary to expectation from a relatively long metamorphic history of the aureole, Ostwald ripening was not a dominative growth mechanism for the garnets investigated in this study.

The Bushveld Complex, the largest igneous complex in the world, is situated in the Transvaal area, South Africa. The Bushveld mafic magma intruded into the Transvaal Supergroup about 2.0 billion years ago and caused a contact metamorphism to the surrounding Pretoria sedimentary rocks. The metamorphic grade decreases laterally from northwest to southeast along the strike of the Pretoria sediments and vertically from the contact of the Bushveld Complex to the lower horizons of the Pretoria Group. Changes of mineral assemblages in the lateral direction are most clearly identified in the lower horizons in the Timeball Hill Formation of the Pretoria Group. The changes are, in ascending order of metamorphic grade, chlorite, chlorite-chloritoid, chlorite-chloritoid-staurolite-(biotite), biotite-staurolite-chlorite, and biotite-staurolite-andalusite-(garnet-chlorite). Changes of mineral assemblages in the Silverton Formation of the Pretoria Group are more clearly observed in the vertical direction than the lateral direction. The changes are, in ascending order of metamorphic grade, from chlorite- (biotite) through biotite-cordierite-andalusite-chlorite, biotite-cordierite-andalusite, and biotite-cordierite-andalusite-K-feldspar to biotite-cordierite-orthopyroxene. The two series of mineral assemblages are grouped in type 2b and 1c of the contact metamorphic facies series of Pattison and Tracy (1991), respectively.

P-T conditions were estimated by several available geothermometers and the GASP geobarometer. Resulted metamorphic conditions of the Pretoria Group in the eastern Bushveld contact aureole increase from 440-490 C at 0.33 GPa (aureole margin) to 800-840 C at 0.15 GPa (contact of the Bushveld Complex). The calculated conditions are supported by phase analyses in the model KFMASH system. Distribution of temperatures along a section, vertical to the strike of the Pretoria sediments, represents a metamorphic thermal gradient (60 to 95 C/km) at intrusion time of the Bushveld mafic layers. The peak temperature profile was simulated using a one-dimensional heat transfer model from an infinite sheet-like magma intrusion. Calculated peak temperature profile shows a maximal thermal curve of ca. 65 C/km. The heat transfer simulation gave an estimate for duration of the Bushveld contact metamorphism to be more than 2 million years, which shows relatively long thermal history of the aureole.

Several garnet-bearing hornfelses in the studied contact aureole were investigated for CSDs. We adopted the method provided by Eberl et al. (1998) to investigate CSDs. They used raw or normalized data of crystal sizes, shapes of CSDs, to examine crystal growth mechanisms. Their theory was experimentally confirmed by Kile et al. (2000) using calcite nucleation and growth. Three basic theoretical shapes of CSDs introduced by Eberl et al. (1998) are (1) asymptotic, (2) lognormal, and (3) LSW (Ostwald ripened) distributions. Measured CSDs represented as histograms with normalized axes were compared with theoretical shapes of CSDs. Results show that CSDs of garnets in the studied hornfelses have lognormal to quasi-lognormal distributions. Some samples show slight increase of mean crystal sizes. The measured CSDs represent few similarities with the LSW distribution. The garnets were, therefore, formed by decaying-rate nucleation and surface-controlled growth in an open system. The slight increase of mean crystal sizes may be accomplished by supply-(transport-) controlled growth, random ripening, or both of them in the later stage of mineral growth.