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Sizes and spatial relationships of crystals in granitic plutons: Exploring the crystallization gaps, heterogeneous nucleation, and mechanical clustering of crystals

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Quantitative measurements on magmatic textures provide an important insight into nucleation and growth rates as well as mechanical effects such as crystal settling and melt extraction in magma reservoirs. Crystal size distribution (CSD) measurements and spatial analysis are routinely applied to dilute volcanic suspensions but comparable data on holocrystalline multiphase plutonic rocks are uncommon. We present quantitative description of CSDs and spatial relationships for all rock-forming minerals from an intrusive suite of the Fichtelgebirge/Smrčiny granite batholith in central Europe. This composite body represents two spatially unrelated chambers, consisting of peraluminous biotite, two-mica, and tourmaline-muscovite granites, crystallized as texturally diverse batches covering equigranular, serial porphyritic, and hiatal porphyritic fine- to coarse-grained types. All granite samples exhibit straight to concave-up CSDs in the natural log of population density *vs.* crystal size projection. Straight CSDs were only found in fine-grained biotite-rich granites representing early crystallizing roof facies of the batholith. For all other samples, the slope decreases from -65 to nearly 0 mm^{-1} as grain size increases. The curvature can result from superposition of two quasilinear segments. It cannot be produced by two separate crystallization events because the population of larger grains is about 10 times more abundant by volume than the fine one. Instead, we propose that the concave-up CSDs developed *in situ*, with enhanced nucleation and/or reduced growth rates during the final stage of solidification. Spatial analysis and measurements of contact relationships reveal significant clustering of crystals except near the roof of the batholith. The clustering index decreases to 0.6 for the smallest crystals (random = 1), Ripley's L-function reaches 0.8 mm, and the clusters are mineral sensitive: pairs of like phases appear to be more clustered than the unlike pairs. The observed parameters were reproduced by a three-dimensional numerical model with time-dependent nucleation and growth rates, and with variable degree of clustering induced by changing the ratio of homogeneous *vs.* heterogeneous nucleation rate, between <1 and 10 mm. Number of the neighboring grains increases linearly with the actual crystal size, from 5 to 45 per mm of size of parent crystal, in nature and it is well reproduced by the numerical model. In some samples of muscovite and two-mica granites, however, the number of the neighbors surrounding plagioclase and alkali feldspar increases more rapidly and it indicates mechanical agglomeration of crystals. The measurements indicate that the chamber roof underwent one-stage undisturbed crystallization where mechanical effects were very limited. In the batholith interior, the combined effects of heterogeneous nucleation and mechanical agglomeration of crystals become significant. The former effect is documented by the predominance of the like pairs. Our analysis demonstrates that coupling of size and spatial textural measurements with numerical modeling provides a powerful tool for deciphering crystallization and mechanical effects in natural magma chambers.