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Cathodoluminescence and geochemical studies on crystal growth as a marker of magma mingling dynamics

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The crystallization history of of zoned K-feldspar phenocrysts in the Karkonosze granite (Bohemian Massif) reveals that the crystals grew in mingled magmas of contrasting compositions. Mixing-mingling in Karkonosze occurs between lamprophyric Ba-rich and granitic Ba-poor magmas (Słaby et al., 2006a; Słaby et al., 2006b). The mafic magma is also LREE rich. The opposite is true for the felsic melt. The growth mechanism and crystal composition have been investigated using cathodoluminescence (CL) and geochemistry; both account for different sets of data that, in combination, give a precise insight into the crystallization process. The K-feldspar crystals were profiled using microprobe point analyses and LA ICP MS. Thin section trace elements mappings (stage scan) of the investigated crystals have been taken. The crystals are zoned. Their chemistry is mainly controlled by the magma composition. Barium rich zones are also considerably enriched in LREE. Decrease of barium concentration is correlated with LREE depletion. Careful investigation on compatible-incompatible elements uptake suggests a process running not far from equilibrium. The trace element distribution, heterogeneous in different zones, but also heterogeneous within single zones in the phenocrysts, reflects a chaotic process of crystal feeding incidental to local magma heterogeneity. On the base of CL studies two types of morphology of the zones have been recognized: including or lacking resorption events. The zones differ in the intensity of the bluish CL colour caused by a variable density of Al-O–Al structural defects ($\sim$450 nm CL emission band) and by different concentrations of Fe^{3+} activators ($\sim$700 nm CL emission; Götze et al., 2000). In the zones with resorption textures, the dominance of the Al-O–Al related emission is noticeable. In turn,

Fe^{3+} activated CL emission (red) in the crystals lacking resorption events is more intensive than the blue emission band related to Al-O–Al defects. In some of them (but not all), clear variations of the Fe^{3+} activated red emission band, which correlates with the visible CL emission, can be seen. The zoned pattern revealed by CL is reduplicated in Ba mappings and profiles. Barium is the most sensitive geochemical indicator of magma mixing-mingling in the investigated system. Simultaneously, the progress in felsic magma hybridization is revealed by variations in crystal defect densities. These are reflected in the intensity of the Al-O–Al related CL emission ($\sim$450 nm) – linked characteristics that relate to coupled Ba-Al incorporation into the crystal structure. The differences in structural defect density revealed by cathodoluminesce and the crystal chemistry permit a proximate correlation with the degree of granitic magma hybridization. A calculation was performed, assuming dominating melt control on crystal growth and was simulated by fractionation models. The correlation between the two variables - the calculated progress in felsic magma hybridization and the CL feldspar structure factor - is high (R^2 = 0.7-0.9).

The heterogeneity of mixed-mingled magmas is well reflected in the crystal chemistry. That is why commonly the crystal growth process is reconstructed using mostly geochemical tools. However, when the crystal growth proceeds in a very dynamic, open system, these tools are not sufficient. The investigated crystals show, that their growth history can be more precisely revealed by a combination of geochemical and structural data. In this case, cathodoluminescence is a very useful and complementary method that provides additional data about growth mechanisms, which are difficult or impossible to obtain from the crystal chemistry alone. Indirectly, this complementary method gives also insight into the dynamics of magma mixing-mingling.

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