Crystal growth in heterogeneous magmas – 3D visualization and self-affine fractal statistics

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Trace element composition of alkali feldspar crystals chosen from two calc-alkaline plutons (Hercynian Karkonosze and Archaean Closepet) of mixed origin have been investigated. Each feldspar was analyzed along several transects from margin to margin using LA ICP MS (usually 1200-1600 measurements along 1-1.5 cm).

The 3D visualization of the trace element distribution shows, that although the feldspars grew in similar heterogeneous magmas (i.e. mixed, mantle- and crust-derived liquids), they display very different growth textures. Karkonosze feldspars are strongly zoned. The Closepet feldspars are almost homogeneous. Relatively small and irregular variation in the trace element contents makes their growth morphology patchy. The crystals from both plutons show also different fractal statistics. Hurst exponent or roughness exponent (H) has been determined for compatible trace element patterns along each traverse in each crystal. The value of Hurst exponent, for zones reflecting intensive chemical mixing in the Karkonosze crystals, ranges from 0.06 to 0.47, which emphasizes strong non-linear dynamics of the system. The zones, which grew in slightly contaminated felsic magma exhibit $H \geq 0.5$. The process goes over longer path than random walk and shows increasing persistence with decreasing hybridization. The fractal statistics of Closepet feldspars reveal that trace elements were constantly incorporated chaotically into the grown crystals and independently of the degree of mixing. Both end-member magmas present the highest degree of chaos ($H \sim 0.30$), which decreased during mixing. The systems of mixed magmas are believed to present chaotic behavior. We observe that such a system can show anti-persisitent behavior or anti-persistent changing into persistent behavior. Most probably, the obeserved differences depend on the structures of both mixed melts in each investigated system.

Extreme sulfur isotope variation in the Dry Creek massive sulfide deposit, east-central Alaska

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The Dry Creek (Red Mountain) Zn-Pb-Cu-Ag-Au volcanogenic massive sulfide (VMS) deposit is within a Late Devonian-Early Mississippian (360±3 Ma) sequence of graphitic peralkaline (comenditic) tuff and graphitic argillite [1]. *In situ* sulfur isotope values were determined by LA-ICP-MS with spot sizes of ~25-40 μm and a 2σ instrumental precision of ±0.3 per mil. SIMS analysis yields similar results (e.g., pyrite in one sample: -43.4 to -41.7 per mil, avg = -42.7 per mil, n = 6, by LA; -45.8.0 to -38.8 per mil, avg = -42.7 per mil, n = 4, by SIMS). The range in $\delta^{34}S$ values determined by LA for 15 samples (190 analyses of pyrite, sphalerite, galena, chalcopyrite, tetrahedrite) is -48.0 to 23.1 per mil, which overall at 71.1 per mil is more than twice the largest range for VMS sulfides in an individual deposit [2].

Different sample types have the following $\delta^{34}S$ values (1) sulfides in semi-massive and massive sulfide -11.2 to 8.7 per mil; (2) framboidal pyrite in massive sulfide -17.2 to -15.0 per mil, and 6.7 to 6.9 per mil; (3) disseminated pyrite and sphalerite in graphitic tuff -48.0 to -37.3 and -3.5 to 9.0 per mil; (4) early pyrite in quartz-fluorite-sulfide feeder veins -36.3 to -22.6 per mil, with late sphalerite, galena, and pyrite in these veins 15.2 to 23.1 per mil; (5) disseminated pyrite associated with HFSE and REE minerals in peralkaline rhyolite plugs -4.5 to 3.5 per mil. Possible sulfur sources are (1) anoxic pore waters ($\delta^{34}S_{H2S}$ strongly negative), (2) disproportionated SO_2 from peralkaline magma ($\delta^{34}S_{SO2}$ near 0 per mil), (3) anoxic bottom waters under closed-system conditions ($\delta^{34}S_{H2S}$ strongly positive), and (4) 360 Ma seawater sulfate ($\delta^{34}S_{SO4}$ ~21 per mil). Our *in situ* $\delta^{34}S$ data are crucial for understanding the VMS mineralization because individual grain analyses coupled to textural observations allow processes to be related to the formation of each phase.

[1] Dusel-Bacon *et al.* (2004) *Geol. Soc. Amer. Bull.* **116**, 989-1015. [2] Huston (1999) *Rev. Econ. Geol.* **8**, 157-179.