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Texture constraints on crystal size distribution methodology: An application to the Laki fissure eruption

Kim A. Cone[1,*,†], Richard F. Wendlandt[1], Katharina Pfaff[1], and Omero F. Orlandini[2]

[1]Department of Geology and Geological Engineering, Colorado School of Mines, 1516 Illinois Street, Golden, Colorado 80401, U.S.A.
[2]Geological Sciences, University of Colorado Boulder, UCB 399, Boulder, Colorado 80309, U.S.A.

Abstract

Modeling crystal size distributions often requires the extraction of 2D discrete crystal lengths to calculate 3D volumetric equivalences. These apparent lengths are obtained from digital images that exploit different physical and chemical characteristics of samples, and the choice of image type can affect the interpretation of crystal length measurements, thus affecting crystal size distribution modeling. To examine method- and texture-based effects on extracting crystal size distributions, we obtained plagioclase length measurements from two texturally opposing basaltic lava samples from the well-documented Laki fissure eruptions of 1783–1784. Using approaches that consider inherent texture-based limitations of 2D image types, we employed manual tracing and imaging software to extract plagioclase crystal lengths from three types of images: (1) photomicrographs from polarized-light microscopy, (2) backscatter electron images from scanning electron microscopy, and (3) energy-dispersive X-ray maps from automated mineralogy. Our results demonstrate that (1) phenocrysts ($L \geq 150$ μm) and groundmass plagioclase ($L < 150$ μm) in our basalt samples appear with multiple aspect ratios, while the latter also display greater nucleation densities as crystal size population are continuously refined over increasingly smaller crystal lengths; (2) complex crystal clusters must be manually dissected into their discrete crystal components to produce meaningful crystal size distributions; (3) localized electron backscatter diffraction analysis reveals mild preferred orientation in complex clusters and groundmass, the latter confirmed by variations in crystal size distributions between orthogonal backscatter electron images; and (4) method-induced variations in both aspect ratio and crystal length determination can produce a wide range of kinetic interpretations that pose challenges for cross-research comparisons. For phenocrysts, compensating for clustering and fracturing through manual tracing remains the most effective method, while groundmass populations can be addressed with high-resolution (micrometer-scale) automated scanning electron microscopy for deciphering late-stage eruptive behavior. A texture-focused protocol should be established, as any kinetic information derived from crystal size distribution analyses across multiple studies employing multiple approaches cannot otherwise be directly compared.

Keywords: Plagioclase, crystal size distributions, aspect ratio, basalt, textural analysis, crystallization kinetics, automated mineralogy, EBSD, Laki; Dynamics of Magmatic Processes