Geophysical Research Abstracts
Vol. 21, EGU2019-16860, 2019
EGU General Assembly 2019
© Author(s) 2019. CC Attribution 4.0 license.

Crystal rotations and alignment in spatially varying magma flows: Two-dimensional examples of common subvolcanic flow geometries

Rémi Vachon, Mohsen Bazargan, and Christoph Hieronymus
Uppsala, Geocentrum, Geophysics, Uppsala, Sweden (remi.vachon@geo.uu.se)

Elongate inclusions immersed in a viscous flow generally rotate at a rate that is different from the local angular velocity of the fluid. As a result, the inclusions tend to orient themselves into a coherent pattern commonly referred to as shape-preferred orientation (SPO). The SPO of the particles can be used as a strain marker that allows reconstruction of the fluid's velocity field. Moreover, the SPO of elongate crystals is one of the main mechanisms that lead to anisotropy of magnetic susceptibility (AMS), which allows rapid measurement of average crystal orientations. A robust model is therefore highly desirable that can link the AMS measurements of the exposed flow to the complete velocity field when the flow was active. Much of the previous work on the dynamics of flow-induced particle rotations has been focused on spatially homogenous flows with large-scale tectonic deformations as the main application. Here, we show how the method can be extended to cover flows that vary in space as well as time, such as magma with embedded crystals moving through the volcanic plumbing system. Additionally, we introduce an evolution equation for the probability density function (PDF) of crystal orientations. The PDF evolution is coupled with the Navier-Stokes equation governing the flow, thus yielding a PDF of crystal orientations at every position. The overall correctness of the evolution equation as well as the accuracy of the numerical method are demonstrated by rigorous testing. We then apply this new theory to a number of simple, two-dimensional flow geometries commonly encountered in magmatic intrusions, such as flow from a dike into a reservoir and from a reservoir into a dike, isothermal flow inside an inflating or deflating reservoir, and thermal convection in a magma chamber. We confirm some of the previous general findings. For example, near channel walls, the flow is often parallel to the bounding surface, and the resulting simple shear flow causes preferred crystal orientations that parallel the boundary. On the other hand, where pure shear deformation dominates, there is a tendency for crystals to orient themselves in the direction of the most tensile strain rate. This occurs not only near the center of certain flows, but also along the boundaries of a deflating magma chamber and in thermal convection where the convective currents turn away from the chamber walls, thus leading to crystal orientations perpendicular to the bounding surface. Flows impinging on a boundary are instead characterizing by a most tensile strain rate that is parallel to the surface, thus leading to boundary-parallel crystal orientations. In the field, this local pattern due to an impinging flow may be difficult to distinguish from that due to simple shear flow along the wall. In other words, while a given flow will always result in a unique pattern of crystal orientations, it is generally impossible to infer the local flow field from only a local observation of the crystal PDF. Overall, we find that the crystal orientation patterns agree well with results from analogue experiments where similar geometries are available.