# Towards Scaling Laws for the Interpretation of Igneous Structures

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Abstract

Igneous structures are complex features preserved in the solidified rocks of large magma chambers. They provide a record of the complex events which once occurred in liquid and partially crystallized magma. To be able to interpret this record, one needs at least a time-scale for crystallization and a basis for comparing the different processes. This paper focusses on the role of crystallization. We make a dimensional analysis of the crystallization equations with kinetic effects. Given characteristic values for the rates of nucleation and crystal growth, $I_m$ and $Y_m$, the crystallization time-scale is $(I_m.Y_m^{\ 3})^{-1/4}$. Scaling laws are derived for the crystallization parameters, including the thickness of the crystallization interval, i.e. the moving region where magma is crystallizing and where the local crystal volume fraction varies. The crystal size scales with $(I_m.Y_m^{\ 3})^{-1/4}$. Laboratory crystallization experiments and petrological observations constrain the peak nucleation and growth rates to be about 1 $cm^{-3}.s^{-1}$ and $10^{-7}cm.s^{-1}$respectively. Therefore, the crystallization time-scale is about $10^5$ s. In basic and ultrabasic magma chambers, this is significantly larger than the time for convective instability at the roof. This implies that undercooled and partially crystallized magma is unstable. In granitic systems where viscosity is much higher, magma congeals in-situ before the onset of convective instability. Although cooling occurs, the viscosity increase due to temperature and crystallinity prevents instability. The consequences are that convection is weak and that crystallization proceeds without disturbance. This can explain a marked contrast between the igneous structures of basic and granitic intrusions.

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