

Numerical modelling of a cooling magma chamber: microstructure record of crystal settling

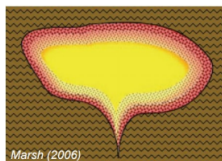
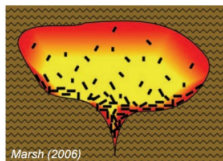
Vít Beran
Charles University, Prague
vit.beran@matfyz.cuni.cz

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Research gap

Magma bodies represent a complex intersection of fluid mechanics, geochemistry, petrology, and geological processes.

1. Is convection in magma reservoirs **longevous** or short-lived?
2. Equilibrium crystallisation or **fractional crystallisation**?
3. Which mechanisms of fractional crystallisation prevail (in-situ vs. **crystal settling**)?
4. Do magma chambers even exist in the classical sense (**big-tank** vs. mushy lenses)?



Are plutons assembled
over millions of years by
amalgamation from small
magma chambers?

Allen F. Glazner, Department of Geological Sciences,
CB#1313, University of North Carolina, Chapel Hill, North
Carolina 27599, USA, aglazner@unc.edu

John M. Bartley, Department of Geology and Geophysics,
University of Utah, Salt Lake City, Utah 84112, USA

Drew S. Coleman, Walt Gray, and Ryan Z. Taylor**,
Department of Geological Sciences, CB#1313, University of
North Carolina, Chapel Hill, North Carolina 27599, USA

Comments on 'On Convective Style and Vigor in
Sheet-like Magma Chambers' by Bruce D. Marsh

by HERBERT E. HUPPERT¹ AND J. STEWART TURNER²

¹*Institute of Theoretical Geophysics, University of Cambridge, 20 Silver Street,
Cambridge CB3 9EW, UK*

²*Research School of Earth Sciences, Australian National University, Canberra 2601,
Australia*

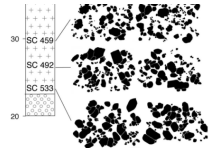
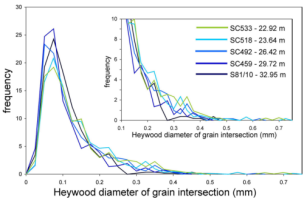
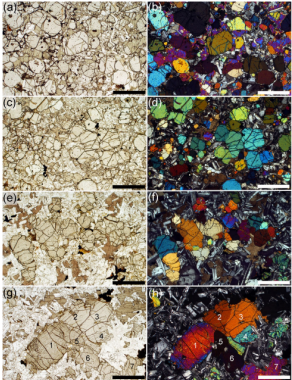
(Accepted 20 February 1991)

Clues about crystal settling?



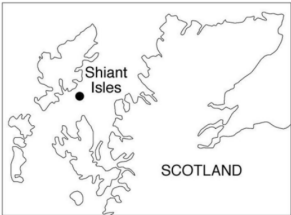
1989, 1991). The disagreement could be resolved if consensus could be reached over the interpretation of features preserved in exposed examples of fully solidified intrusions. Evidence used to argue for convection includes: the preservation of depositional and erosional structures in the floor cumulates of the Skaergaard intrusion, indicative of significant flow of magma across the floor (Irvine et al. 1998); the development of identical mineral assem-

Holness (2017)



Crystal settling and convection in the Shiant Isles Main Sill

Marian B. Holness¹ · Robert Farr² · Jerome A. Neufeld^{1,3,4}



Olivine cargo



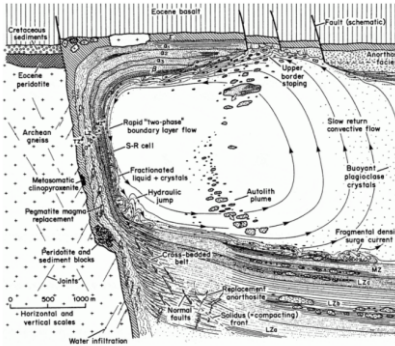
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Holness (2017)

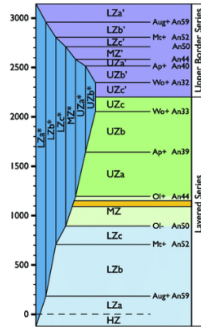
Clues:

- fining / coarsening
- layering
- symmetry of upper and lower zones

Skaergaard (aka petrological laboratory)



Stratigraphic thickness of LS and UBS (metres)

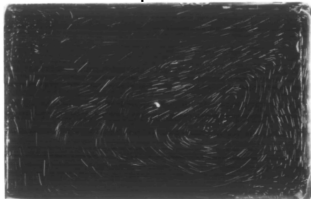


McBirney 1996



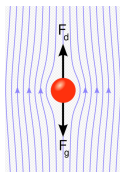
Formation of cumulate: crystal settling

Dust-like particle



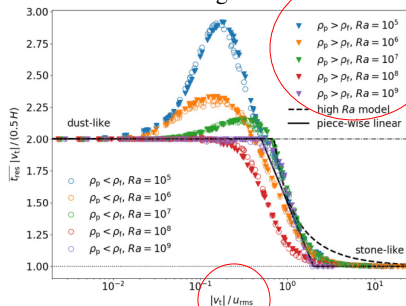
Martin & Nokes (1989)

Stone-like particle



$$|v_t|(a) = \lambda a^2, \quad \lambda = \frac{2g \Delta \rho}{9 \nu \rho_f}$$

Rayleigh number – convection vigor:



J. Mungall - Howard Street Robinson Lecture

Residence time of inertial particles in 3D thermal convection:
Implications for magma reservoirs

Vojtěch Patočka^{a,*}, Nicola Tosi^b, Enrico Calzavarini^c

^a Faculty of Mathematics and Physics, Department of Geophysics, Charles University, Prague, Czech Republic

^b Institute of Planetary Research, German Aerospace Center (DLR), Berlin, Germany

^c Univ. Lille, ULR 7512 - Unité de Mécanique de Lille - Joseph Boussinesq (UML), F-59000 Lille, France

Patočka et al. (2022)





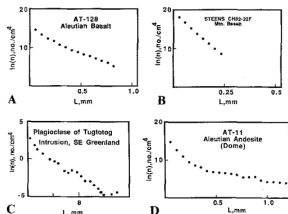
Crystal size distribution (CSD) in rocks and the kinetics and dynamics of crystallization

I. Theory

CSDs aka MICROSTRUCTURE

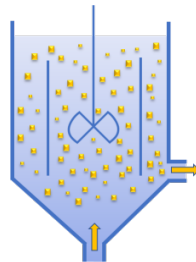
Bruce D. Marsh

Department of Earth and Planetary Sciences, The Johns Hopkins University, Baltimore, MD 21218, USA



Marsh 1988

Fig. 1 A–D. Examples of fairly typical plagioclase crystal size distributions (CSDs) of volcanic rocks from the Aleutian Islands (AT) Steens Mtn., Oregon, and the Tugtutog intrusion of southeast Greenland. Population density (n , actually $\ln(n)$) in units of numbers of crystals per size (L) per volume (i.e. no. per cm^3) is plotted against crystal size L (mm)

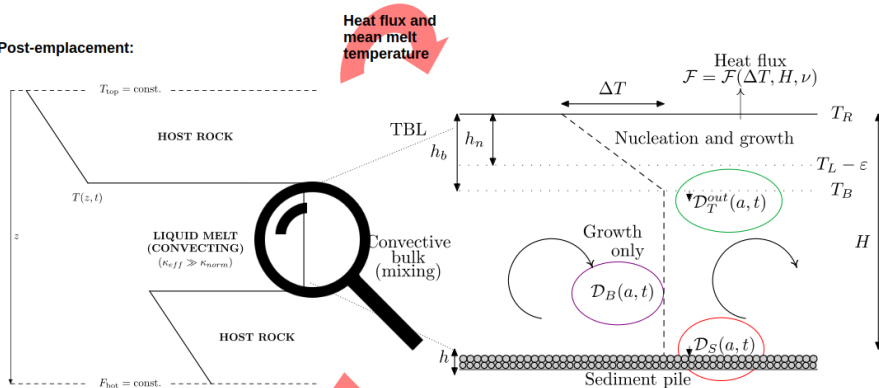


Marsh (1988): often predicts log-linear distributions, modified by further processes.

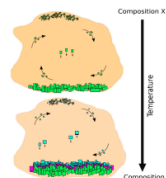
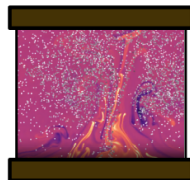
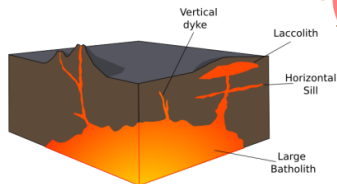
Log-linear CSD, however, implies the process is not size-selective!

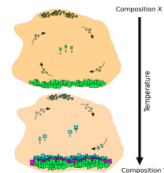
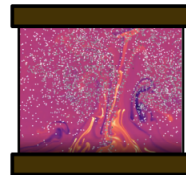
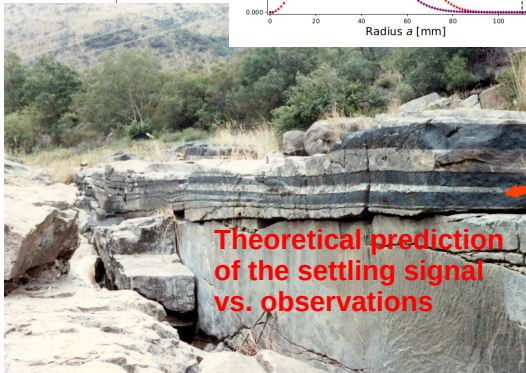
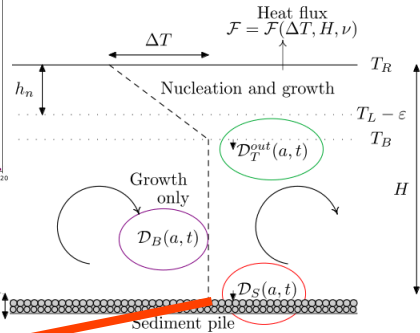
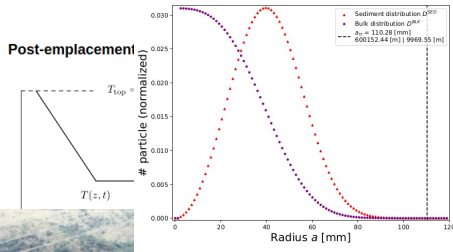
ParMaCH: Parameterised model of a cooling magma chamber

Post-emplacement:



Latent heat feedback



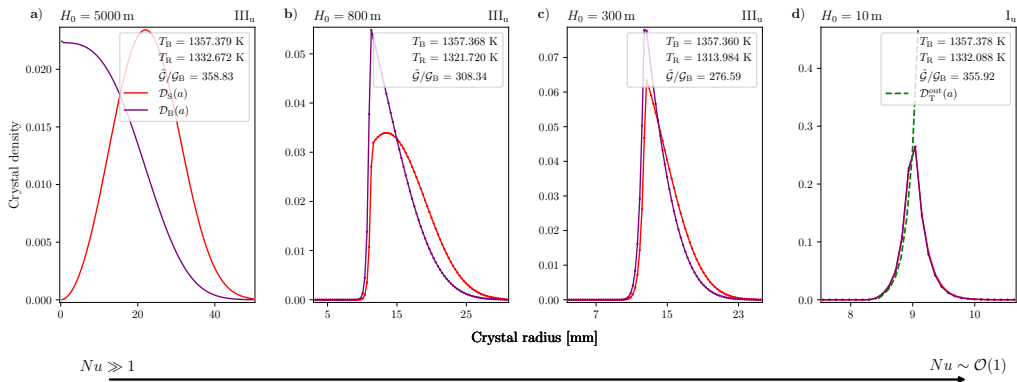


Crystal settling signature I (growth in the TBL)

SUSPENDED

SEDIMENT

TBL

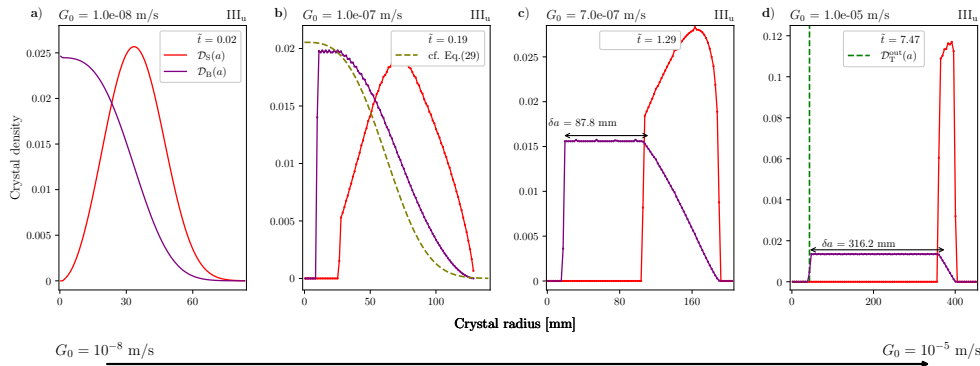


Crystal settling signature II (dust-like — stone-like transition)

SUSPENDED

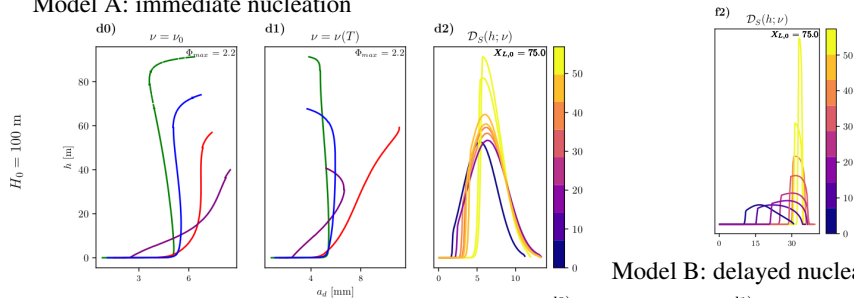
SEDIMENT

TBL



Crystal size grading in the cummulate

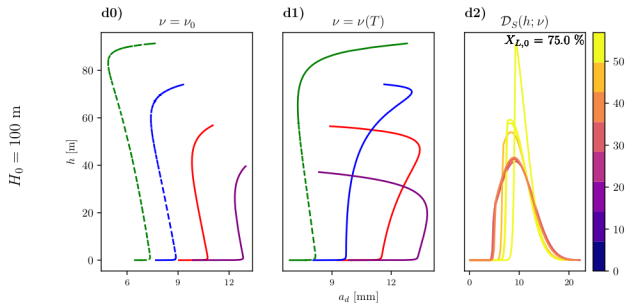
Model A: immediate nucleation



Model B: delayed nucleation

Crystal size grading:

$$\bar{a}'_d \sim \left(\frac{\nu'}{\nu} + \frac{\mathcal{G}'_B}{\mathcal{G}_B} + \frac{H'}{H} \right)$$



A stylized illustration of a person wearing a crown, rowing a small boat through a cavernous space filled with flowing lava. The lava is depicted in vibrant orange and yellow, contrasting with the dark, swirling blue and purple rock formations. Several tall, vertical columns of lava flow from the ceiling, creating a dramatic, hellish atmosphere. The text "Thank you for your attention!" is overlaid in a white, italicized serif font.

Thank you for your attention!