

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

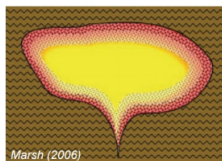
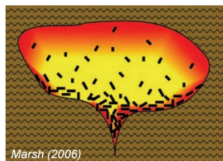
Vít Beran
Charles University, Prague

September 14, 2026

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?

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

by HERBERT E. HUPPERT¹ AND J. STEWART TURNER²

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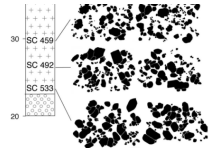
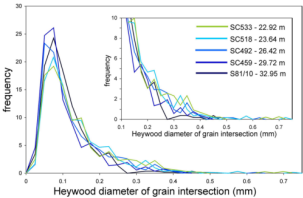
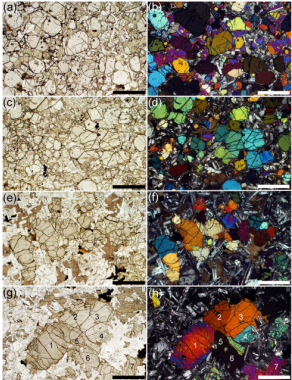
(Accepted 20 February 1991)

Clues about crystal settling?



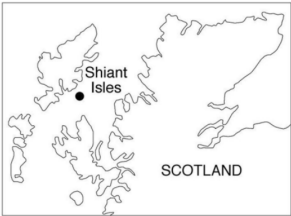
1989, 1991). The disagreement could be resolved if consensus could be reached over the interpretation of features preserved in exposed examples of fully solidified intrusions. Evidence used to argue for convection includes: the preservation of depositional and erosional structures in the floor cumulates 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



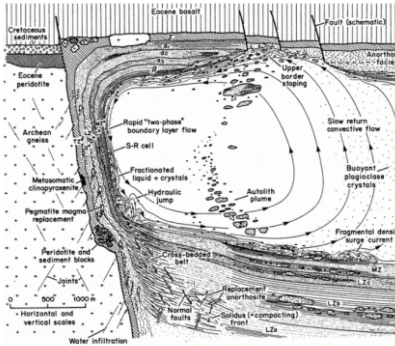
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Holness (2017)

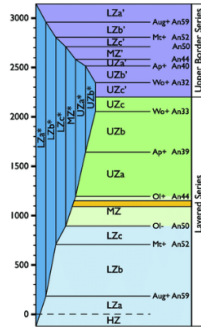
Clues:

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

Skaergaard (aka petrological laboratory)



Stratigraphic thickness of LS and UBS (metres)

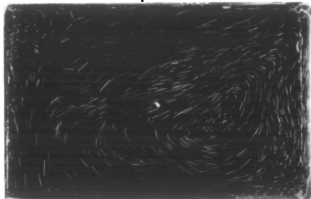


McBirney 1996



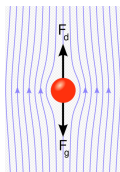
Formation of cumulate: crystal settling

Dust-like particle



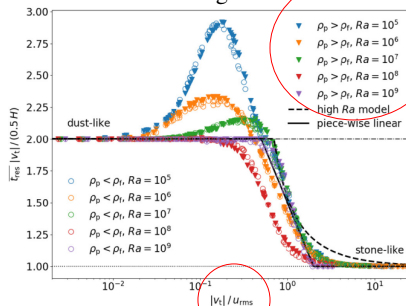
Martin & Nokes (1989)

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

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

Patočka et al. (2022)





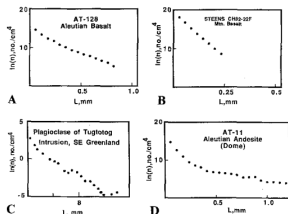
Crystal size distribution (CSD) in rocks and the kinetics and dynamics of crystallization

I. Theory

CSDs aka MICROSTRUCTURE

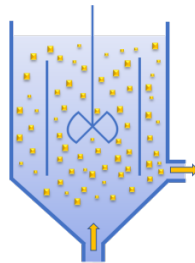
Bruce D. Marsh

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)

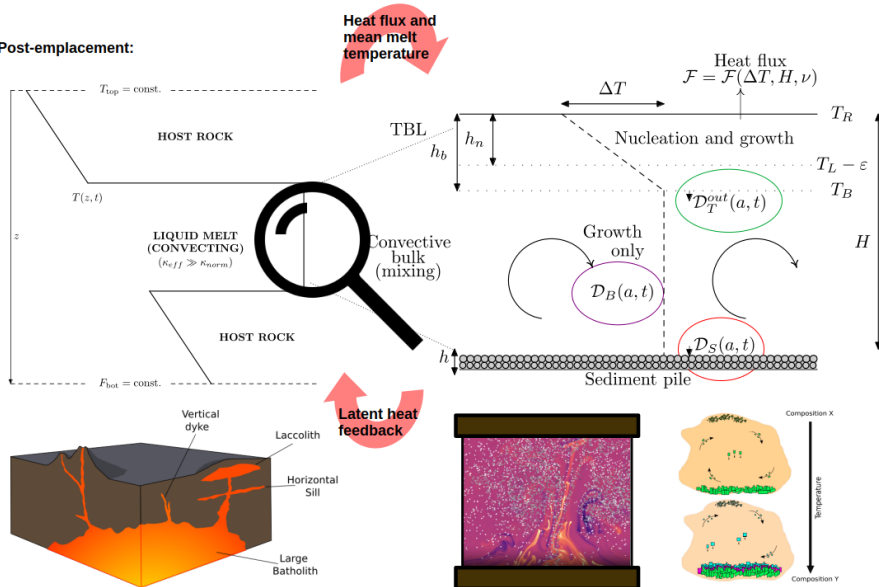


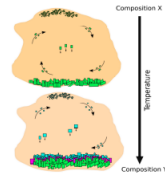
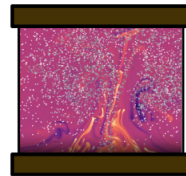
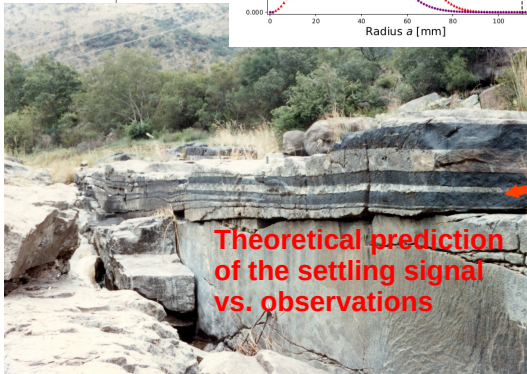
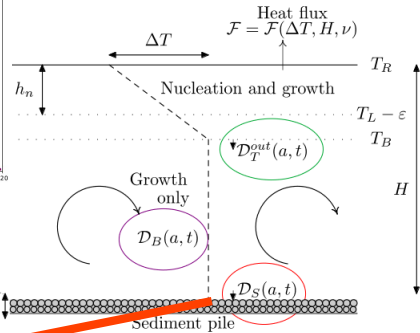
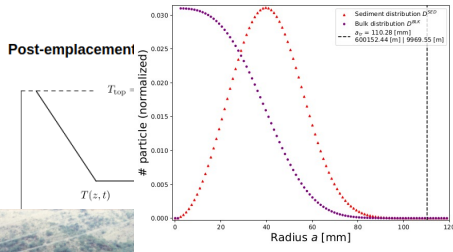
Marsh (1988): often predicts log-linear distributions, modified by further processes.

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

ParMaCH: Parameterised model of a cooling magma chamber

Post-emplacment:



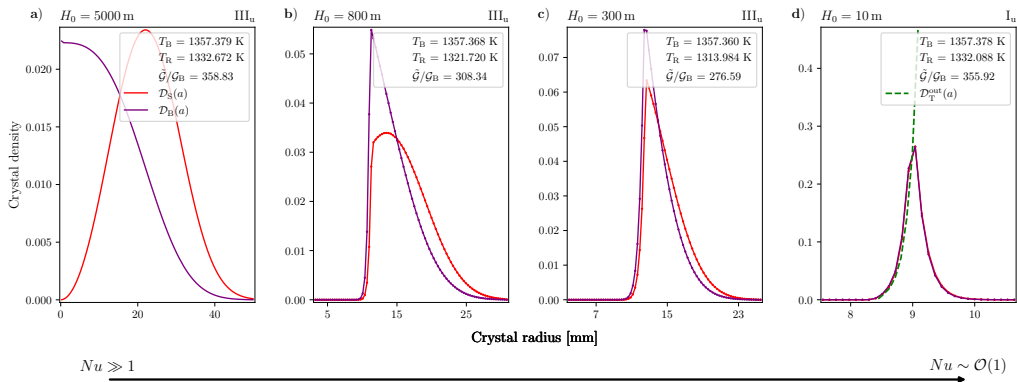


Crystal settling signature I (growth in the TBL)

SUSPENDED

SEDIMENT

TBL

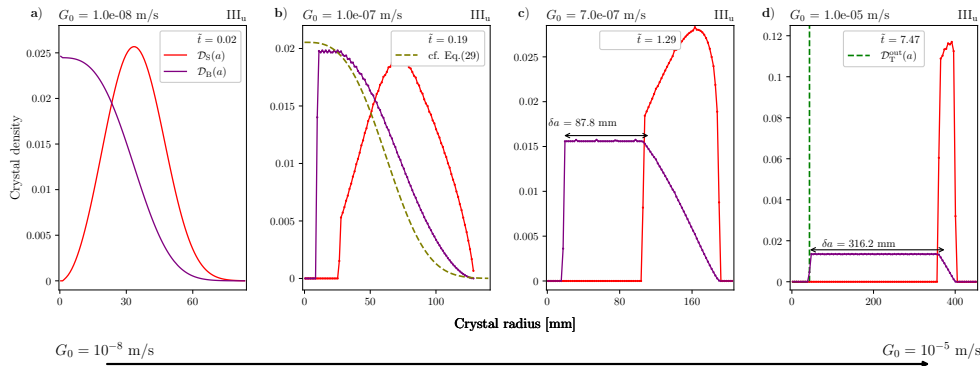


Crystal settling signature II (dust-like — stone-like transition)

SUSPENDED

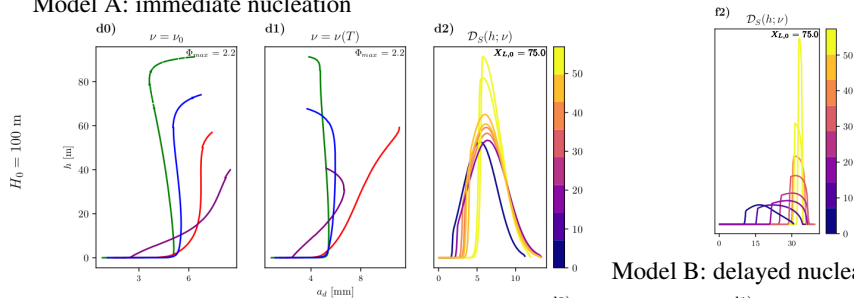
SEDIMENT

TBL



Crystal size grading in the cummulate

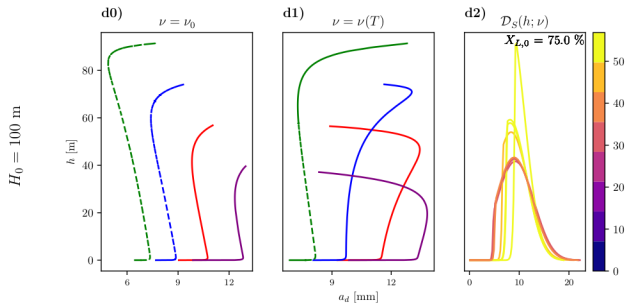
Model A: immediate nucleation



Model B: delayed nucleation

Crystal size grading:

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





Thank you for your attention!