CONDUIT PROCESSES

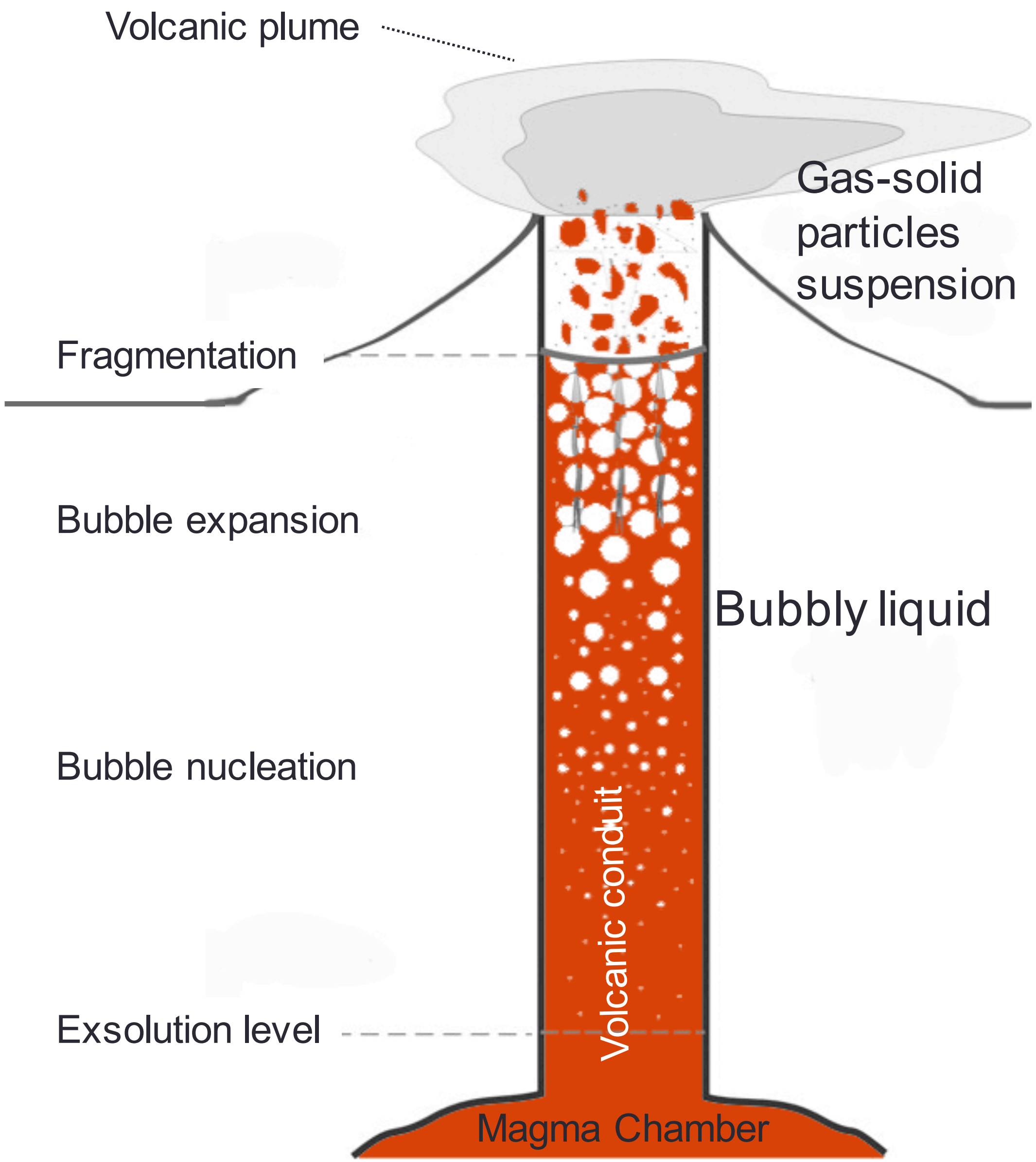
L. Pioli

How does magma look like?

Conduit processes

The primary role of volcanic gases

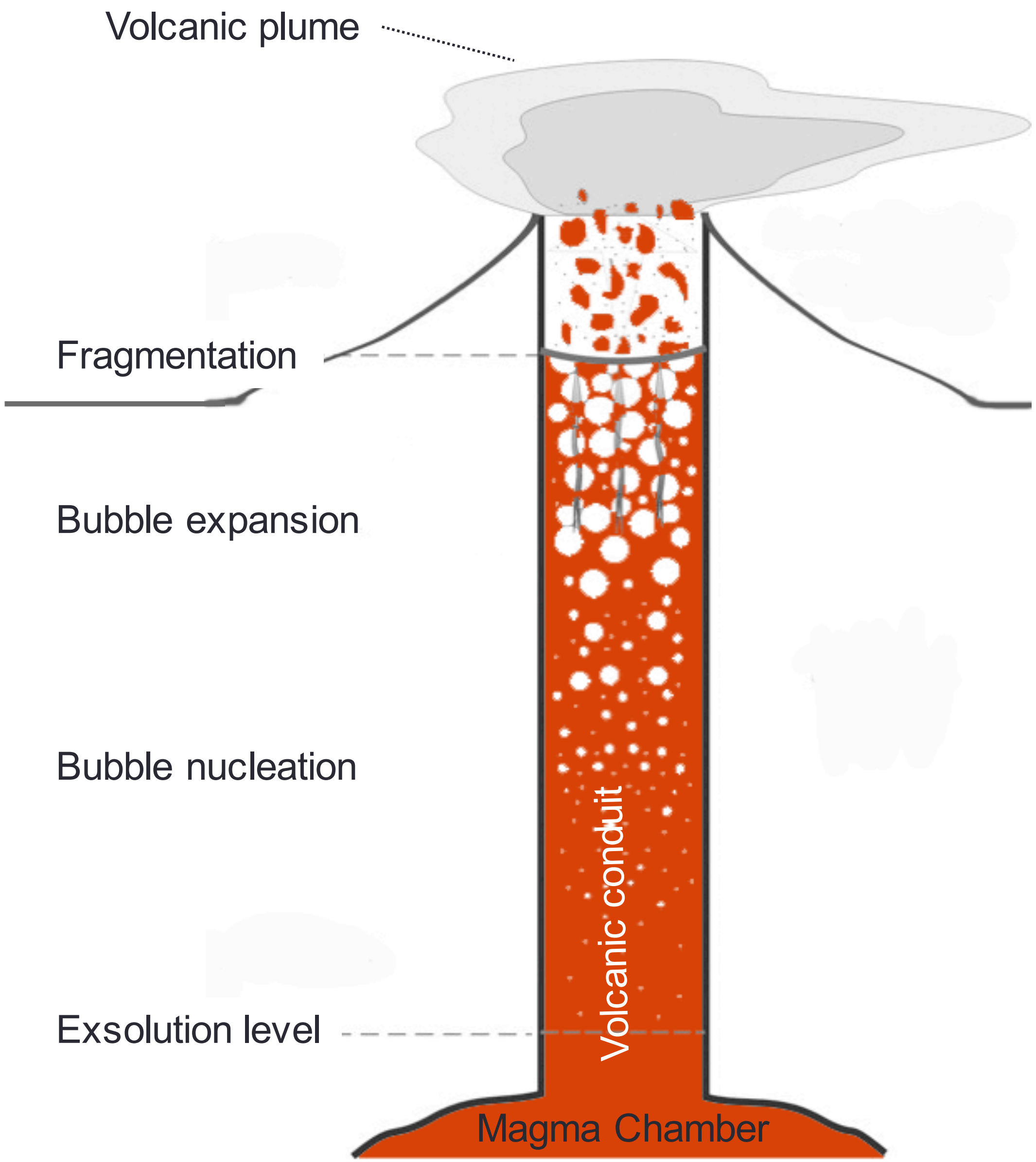
- Volcanic gases (H_2O, CO_2, S, Cl and F compounds) are dissolved in the magma at high depths
- As the magma rises, they exsolve accordingly to their solubilities
- If most of the gas quietly leaves the system before the magma reaches the surface- the eruption is effusive (lava flows)
- Magma fragmentation and explosion: require overpressure---- sudden decompression of gas bubbles or gas segregation



Conduit processes

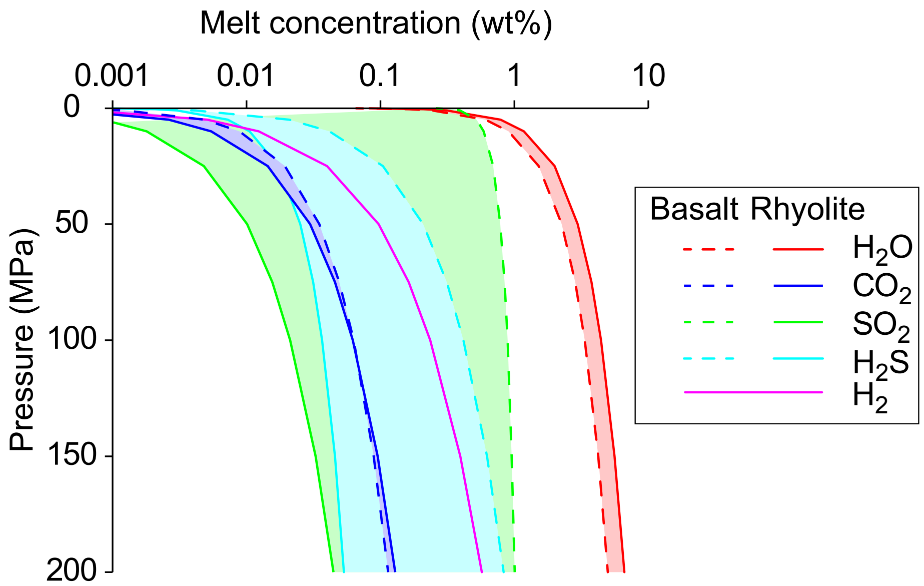
The primary role of magma rheology

- Viscosity is controlled by its composition- (SIO_2, volatile content) ,crystal content (I.e. solid load) and temperature
- Magma has Newtonian to Bingham to shear thinning rheology!
- Lower viscosities favor pre-eruptive outgassing- effusive eruptions

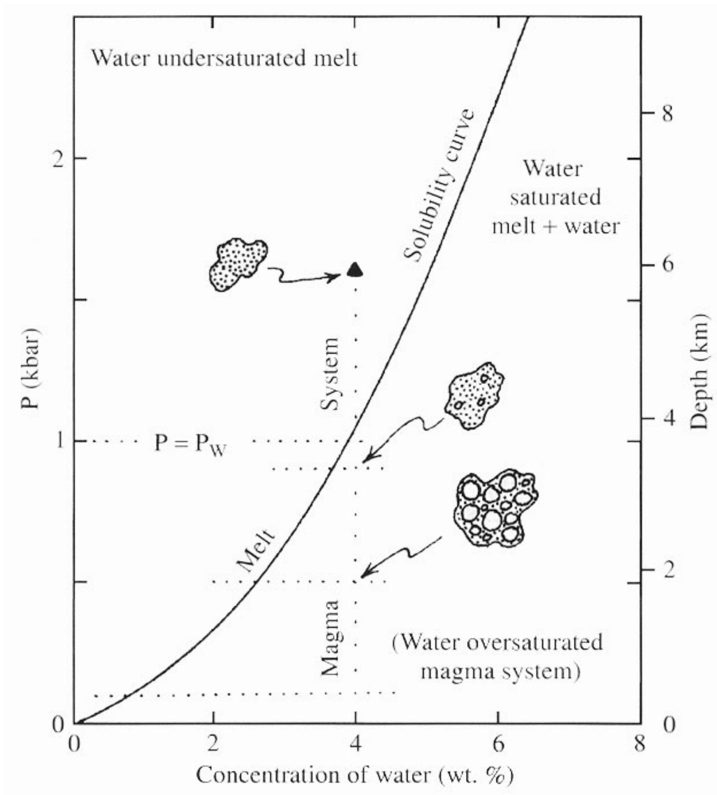


Magma degassing: volatile solubility

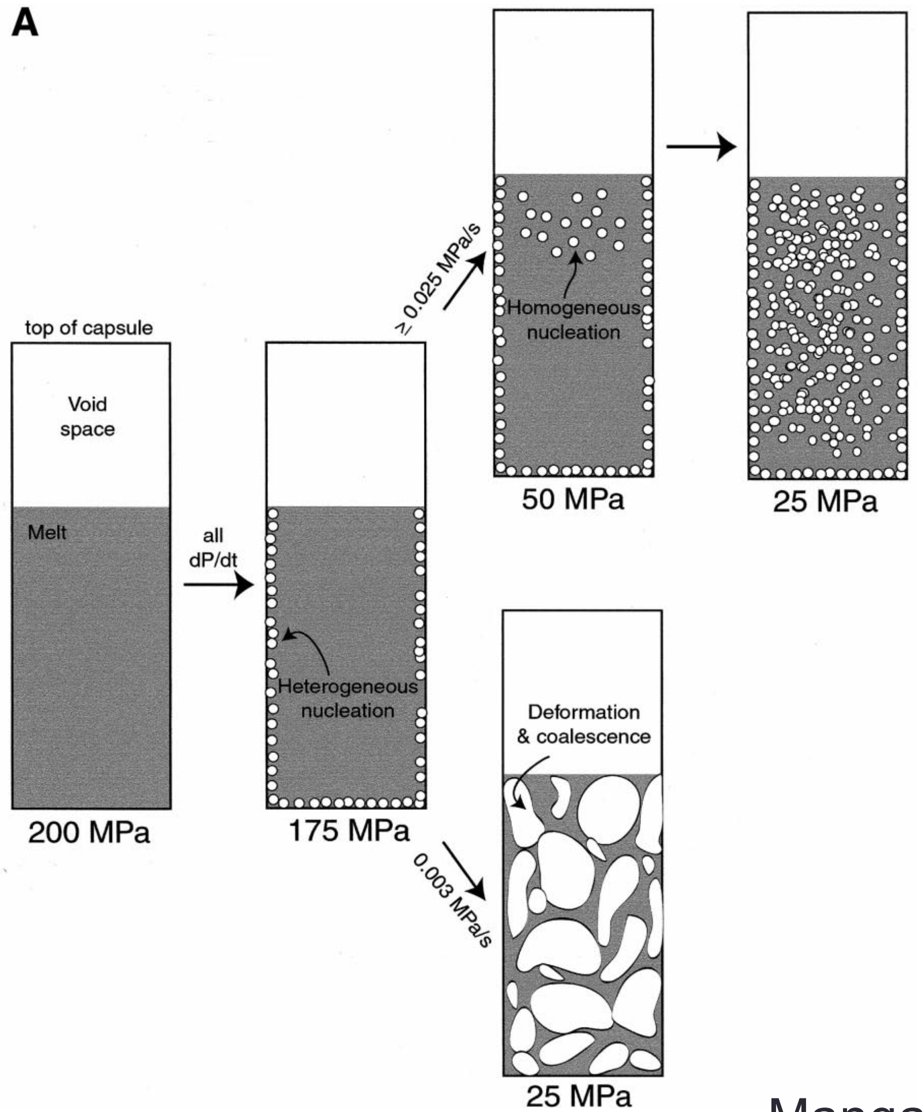
Generic solubility curves

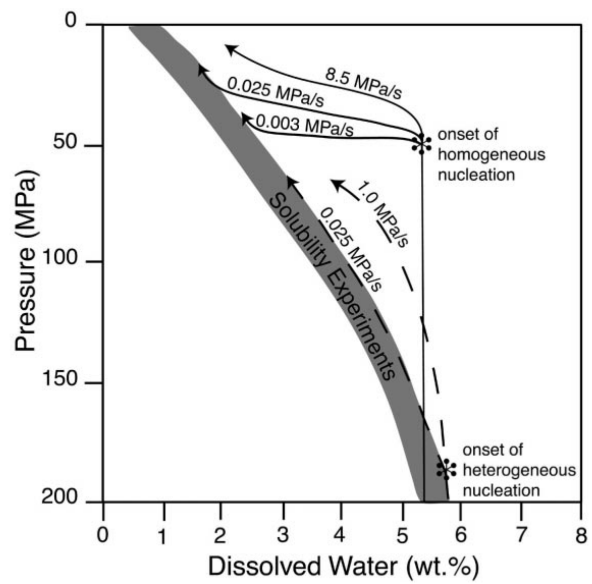


Burgisser and Degruyter, 2016



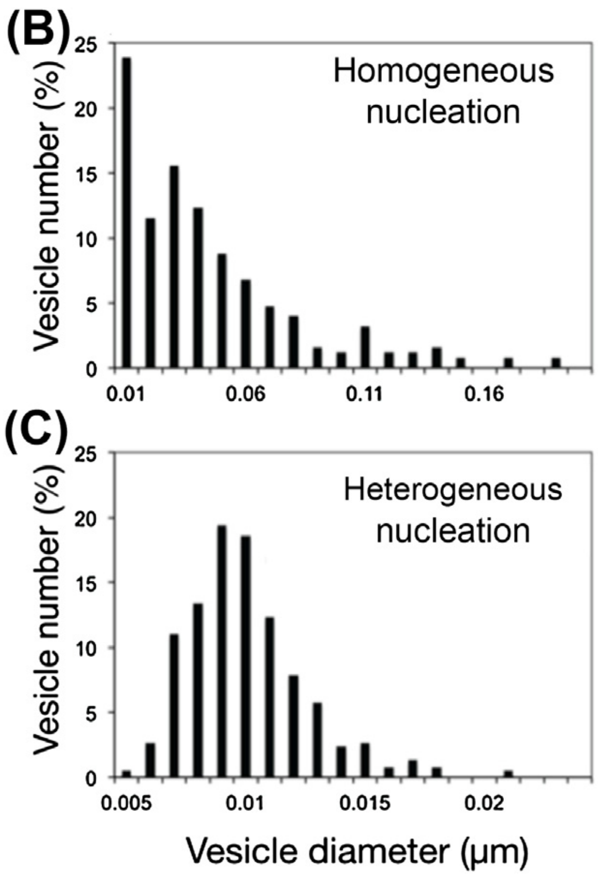
Bubble nucleation





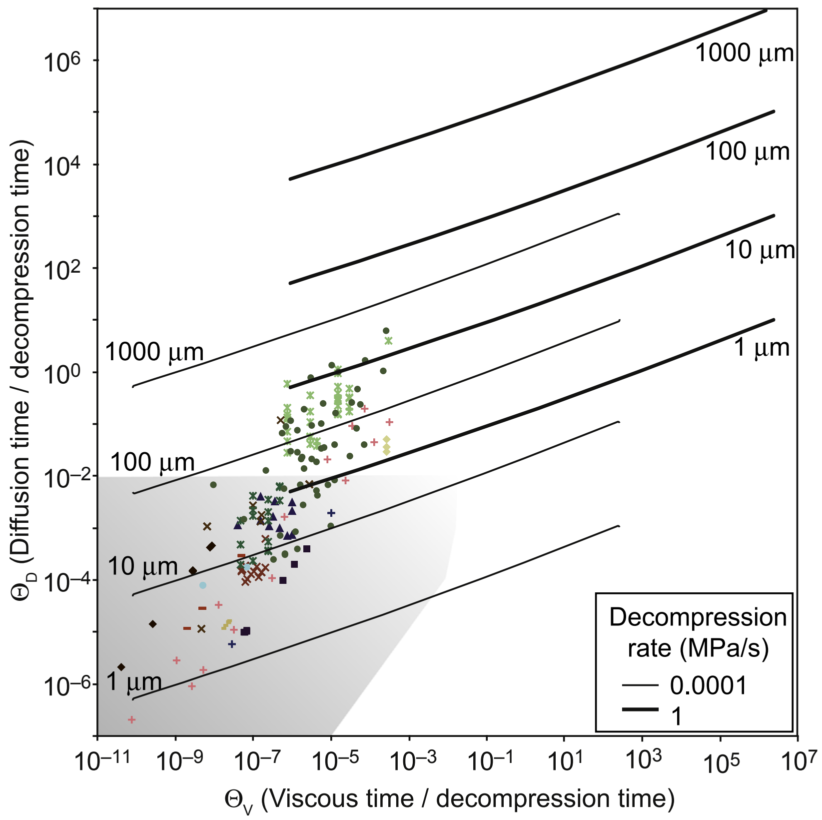
Mangan and Sisson, 2000

Bubble nucleation



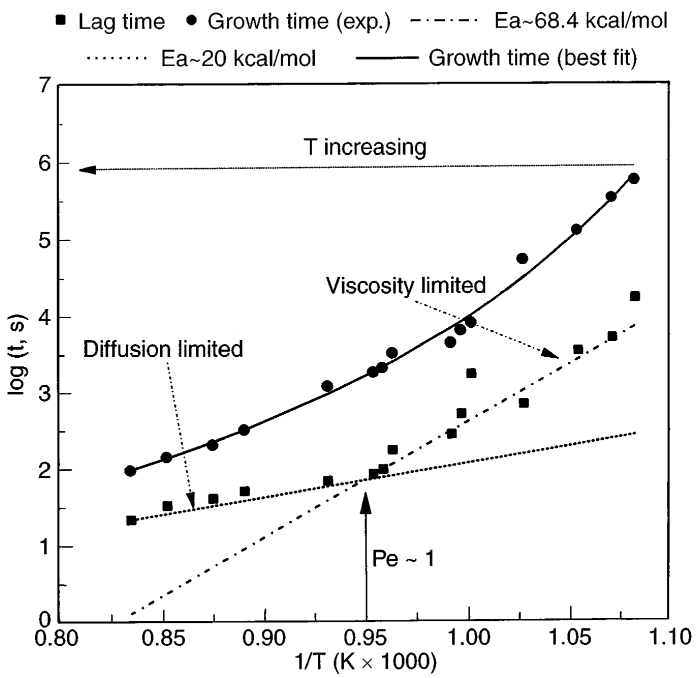
Mangan and Sisson, 2000

Bubble growth



Burgisser and Degruyter, 2016

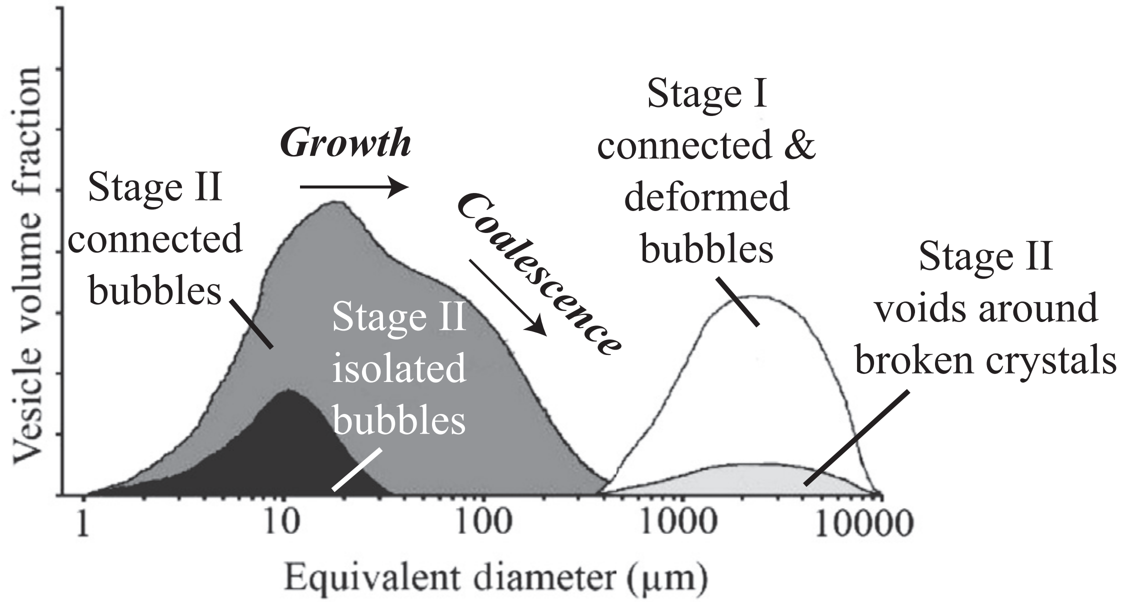
Bubble growth



Expansion

Diffusion

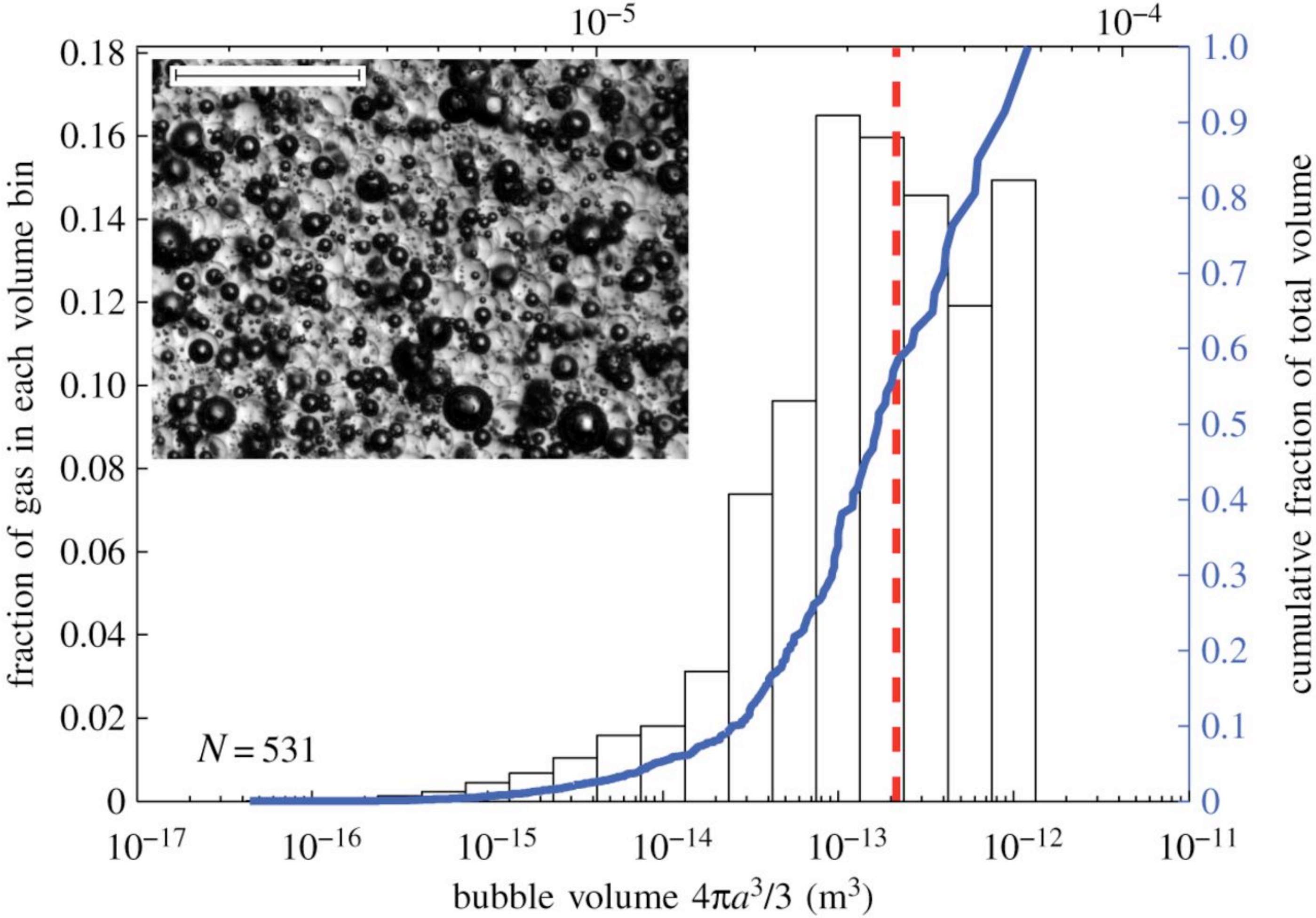
Bubble size distribution



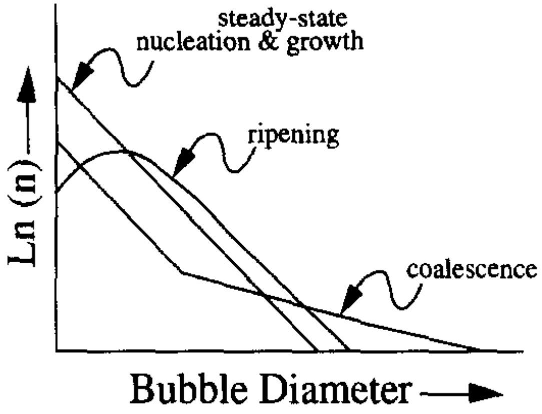
Giachetti et al., 2010

Bubble size distribution

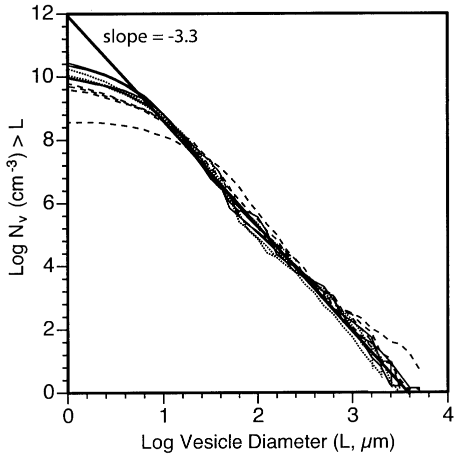
Vesicularity



Bubble size distribution

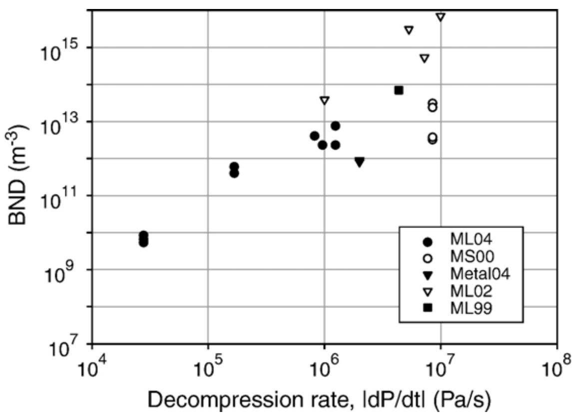


Bubble size distributions patterns from Mangan and Cashman (1996)



Cumulative plot from Klug and Cashman (2002)

Bubble number density

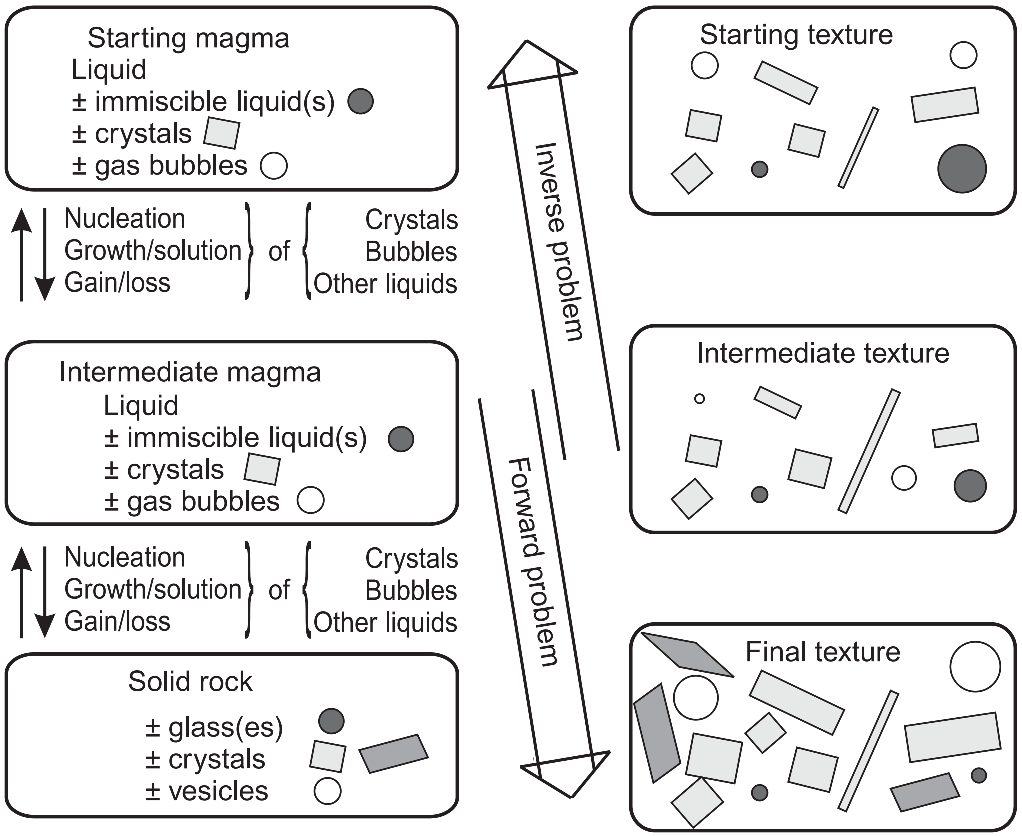


$$\left|\frac{dP}{dt}\right| = 3.5 \cdot 10^{14} \cdot D \cdot \sigma^2 \cdot P_W^{-0.33} \cdot T^{-0.5} N_V^{-0.66}$$

BSD decompression meter of Toramaru (2006)

D= diffusivity, σ=surface tension, T= temperature (K), P_W=initial saturation pressure, N_V = bubble number density

Magma crystallization

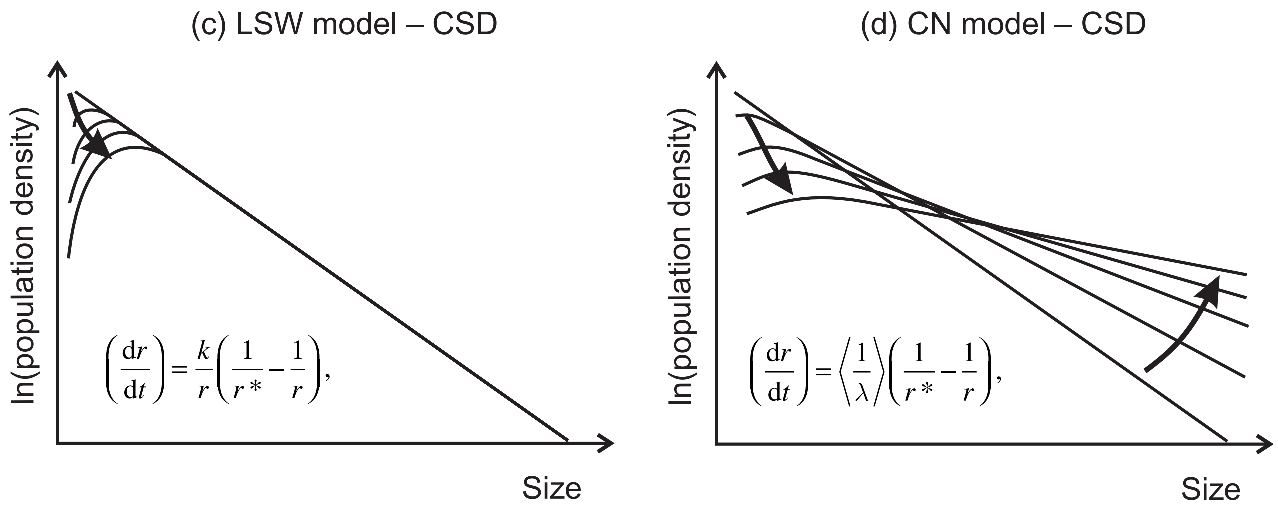


Higgins, 2011

Crystal Number and Size Distributions

- They vary enormously across igneous rocks
- Cooling and crystallization CAN be decoupled; for example if crystallization is controlled by the rate of removal of heat by the system
- Avrami number: Thermal vs. kinetic time scale

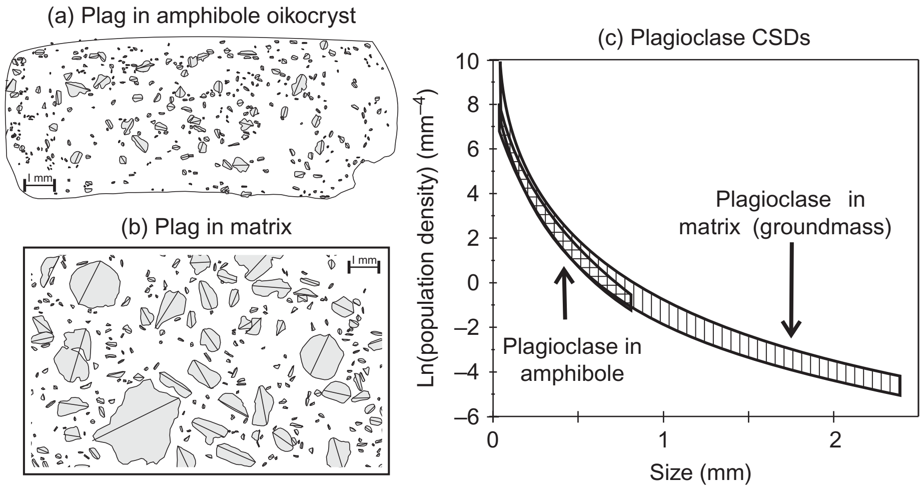
CSDs



Higgins, 2011

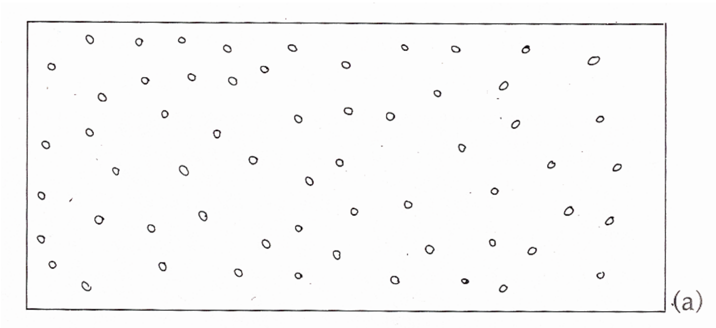
LSW= Lifshitz-Sloyzov-Wagner model (coarsening limited by nucleation)
CN= Communicating Neighbors model (diffusion length scale depends on the distance between crystals

Example of CSDs

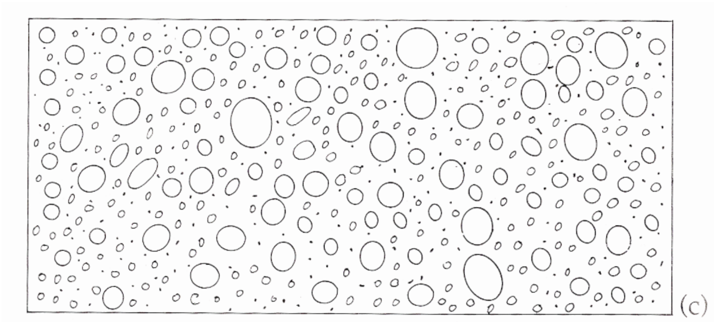


Montserrat volcano. Higgins (2011)

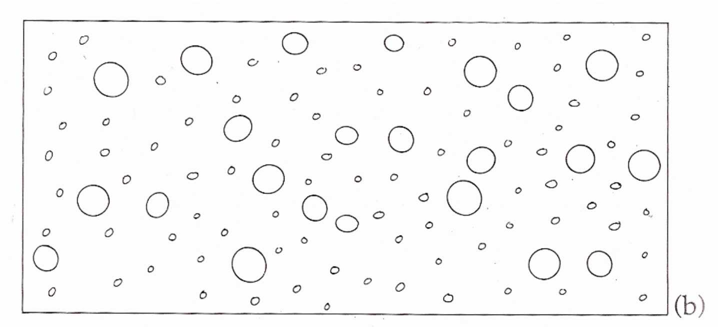
Homogenous flow and magma fragmentation



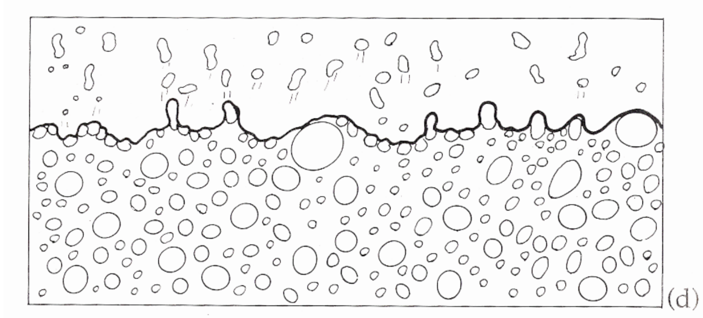
Bubble
Nucleation



Froth Saturation

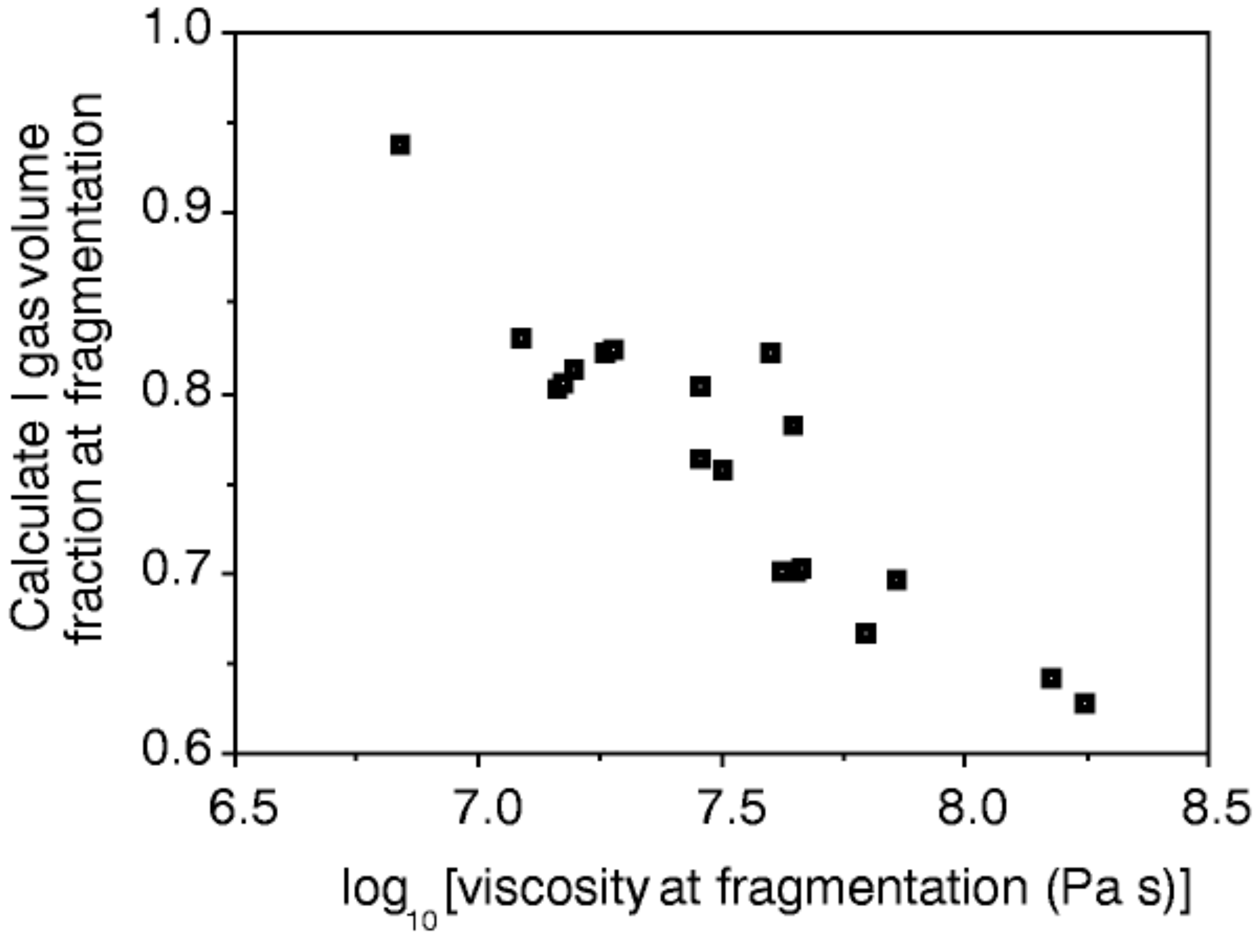


New Nucleii and
Growth



Fragmentation

Fragmentation/1

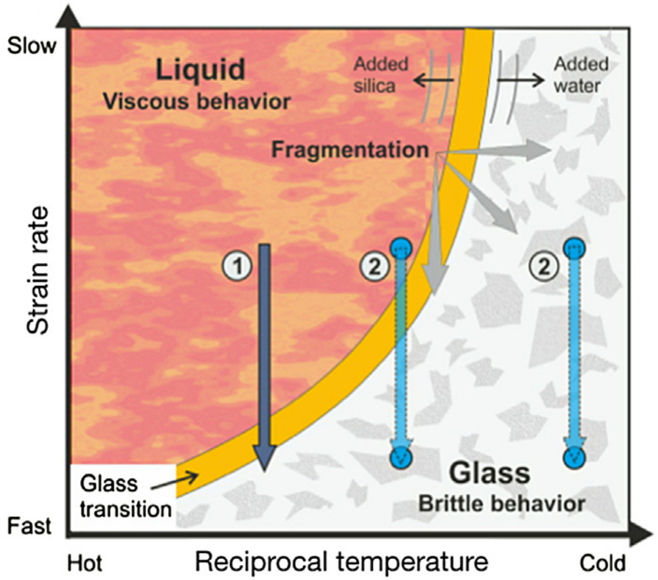


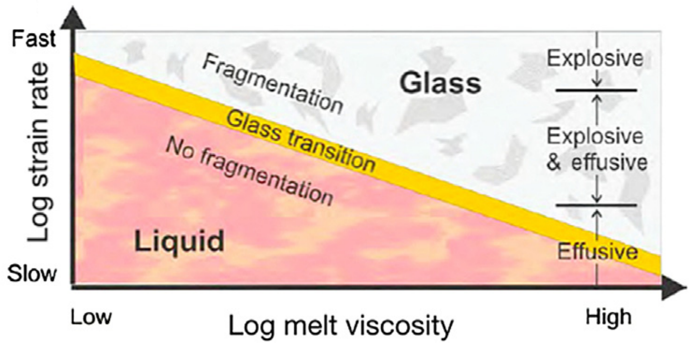
$$\frac{dv_z}{dz} > k\frac{1}{\tau} = k\frac{G_\infty}{\eta_s}$$

Papale, 1999

Fragmentation/2

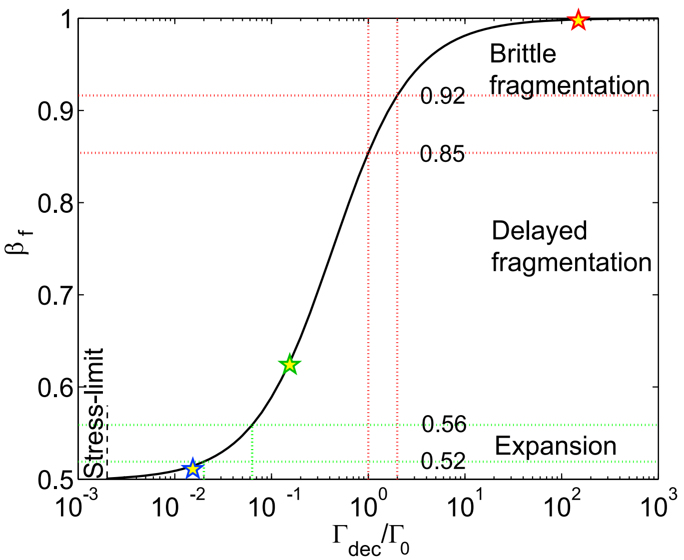
The glass transition: flow or fracture in magma





Cashman and Sheu (2016) Dingwell (1996)

Fragmentation/3



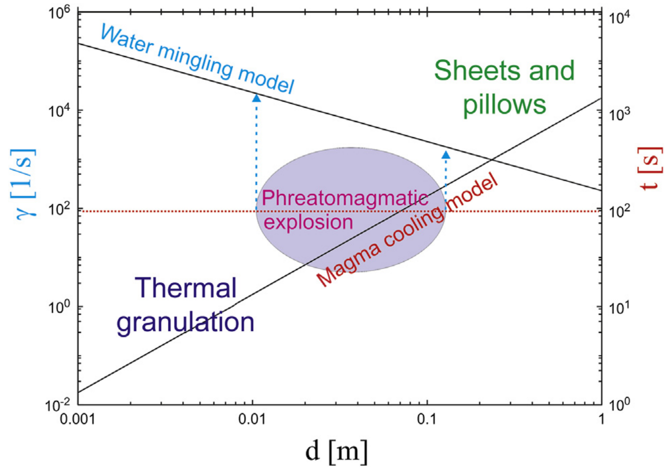
β_f=brittleness

Γ_{dec}=decompression rate

Γ_0=relaxation rate

Ichihara and Rubin, 2010

Magma water interaction

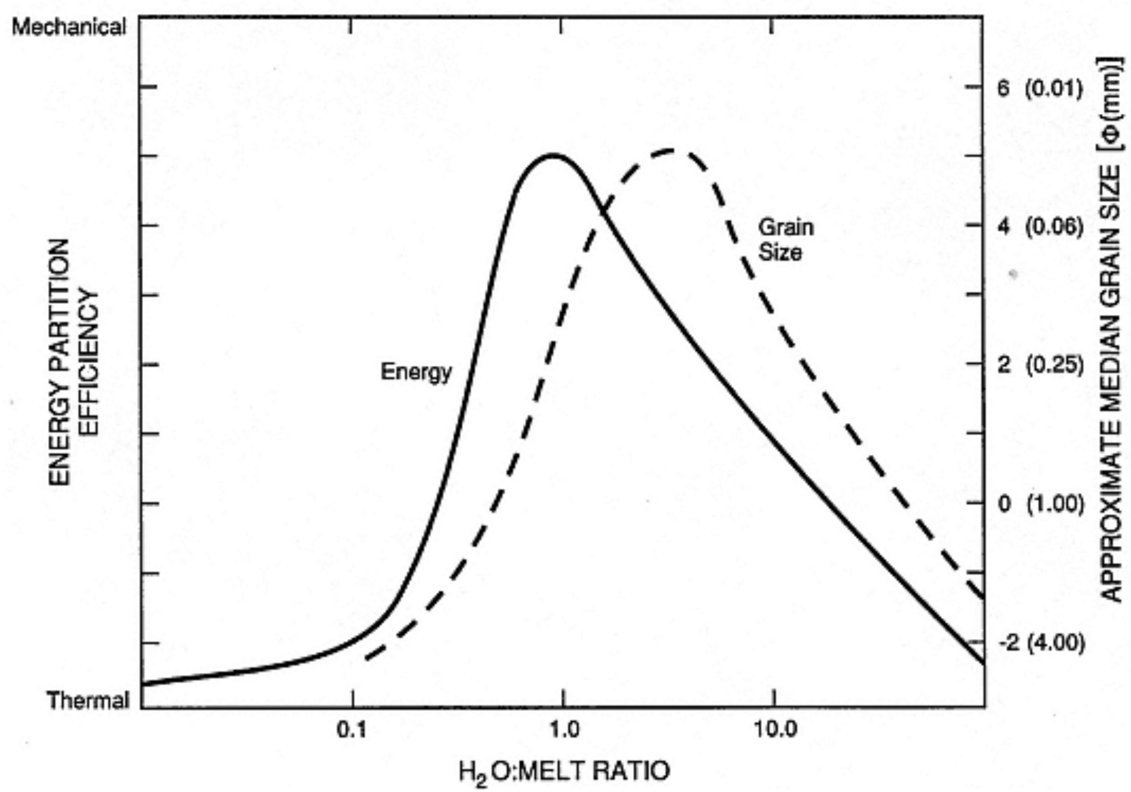


γ=shear rate

d=size of water domain within the magma

Zimanovski et al., 2016

Magma/water interaction



Wohletz and Heiken, 1992