MAGMA RISE AND ACCUMULATION

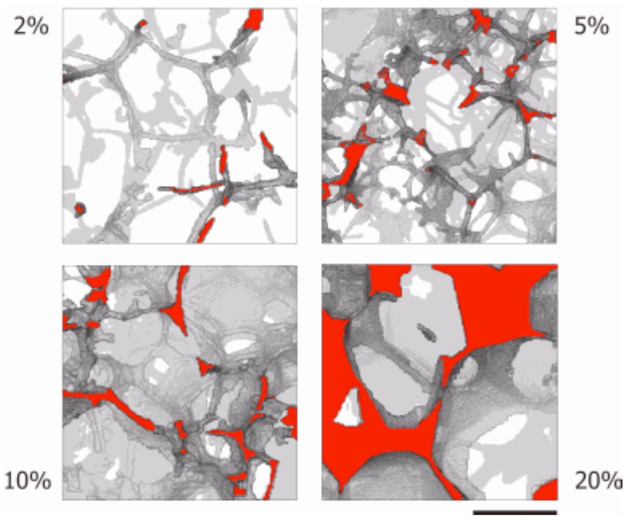
L. Pioli

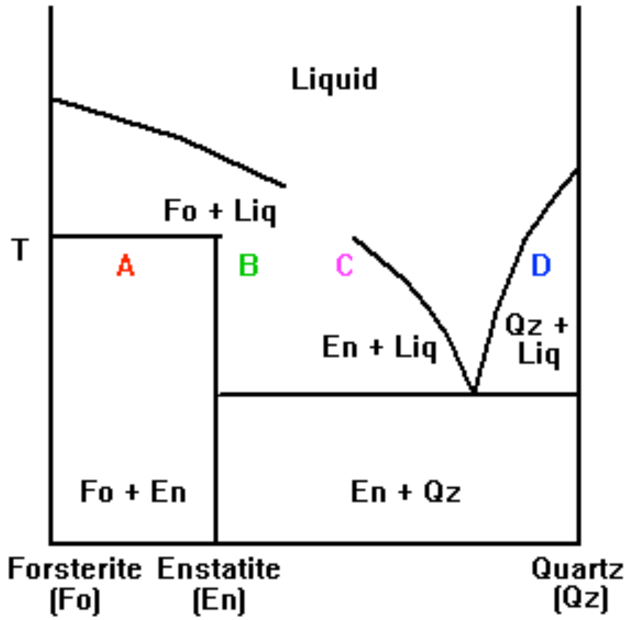
Magma ascent

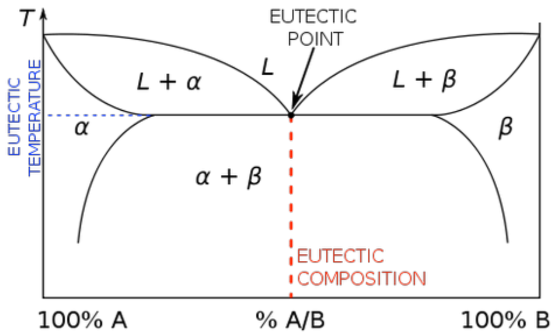
- During rise in the crust, magmas undergo cooling, crystallization, degassing
- They can be stored in reservoirs (*magma chambers*)
- They also generate seismic waves while moving along fractures in the upper crust

Question: how does cooling- crystallization and degassing affect magma properties?

Rock melting



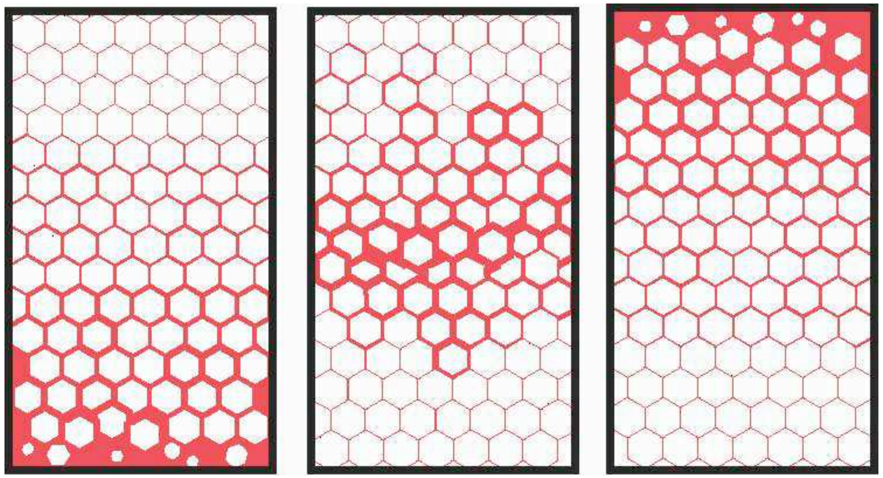




Magma accumulation and migration

Darcy's law (for permeable flow)

$$q = \frac{K}{\eta}\frac{dP}{dx}$$



Melt accumulation

No compaction

Compaction

Gravitational compaction

permeability

$$K = \frac{d^2\phi^n}{C}$$

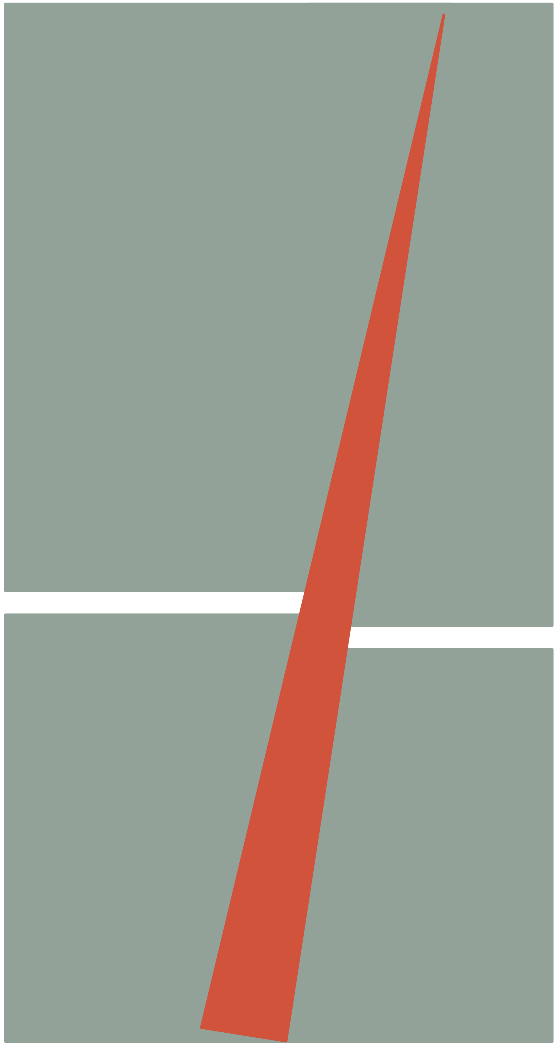
$$K = \frac{\phi^3}{bC^2S^2(1-\phi)^2}$$

Magma accumulation and migration

Matrix η	Compaction time	Compaction time (years)	Time for significant melt extraction 50m (years)	Time for significant melt extraction 50km (years)
10^{14}	7.4	2E+3	38.6	3.7E+4
10^{16}	7.4 x 10	2E+4	190	3.7E+4
10^{18}	7.4 x 10^2	2E+5	15000	3.7E+4
10^{20}	7.4 x 10^3	2E+6	1.5E+6	3.85E+4
10^{22}	7.4 x 10^4	2E+7	1.5E+8	1.85E+4

Melt composition	Melt η	Separation velocity (m/year)	Compaction time (years)
Dry rhyolite	5E+11	2.8E-12	5.5E+8
Wet granite	7.4 x 10	2.8E-5	1.8E+5
Basalt	7.4 x 10^2	1.42	8E+2
Carbonatite	7.4 x 10^3	280	56

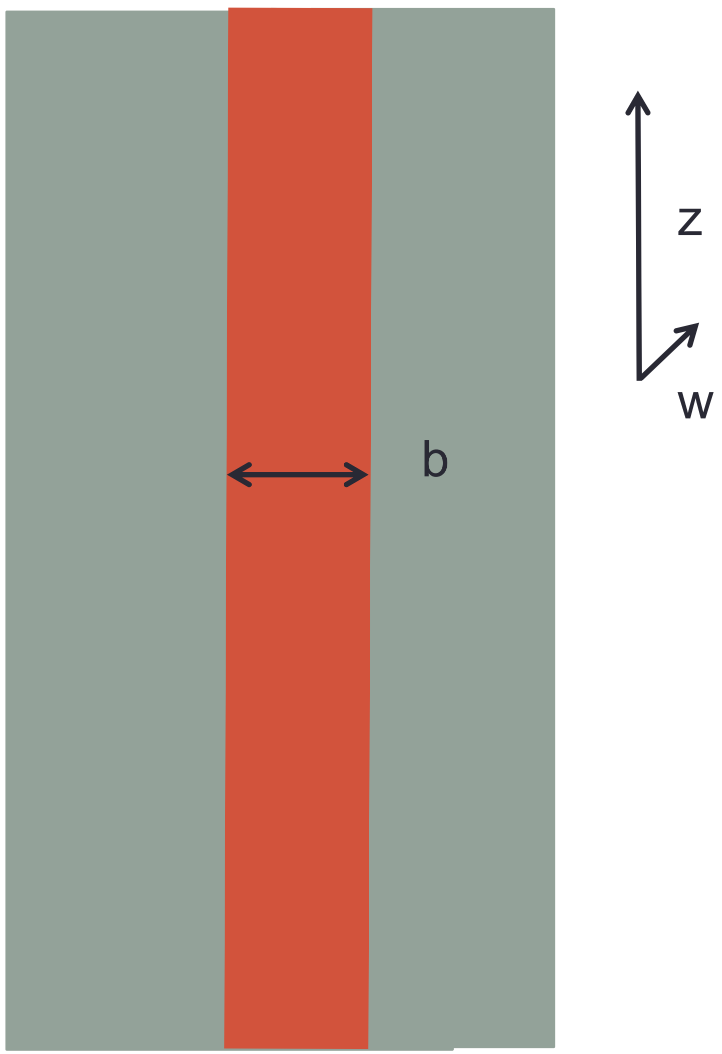
Dike formation



A rocks breaks under the action of a stress

Fracture propagates from the tip where the stress concentrate

Flow within dikes

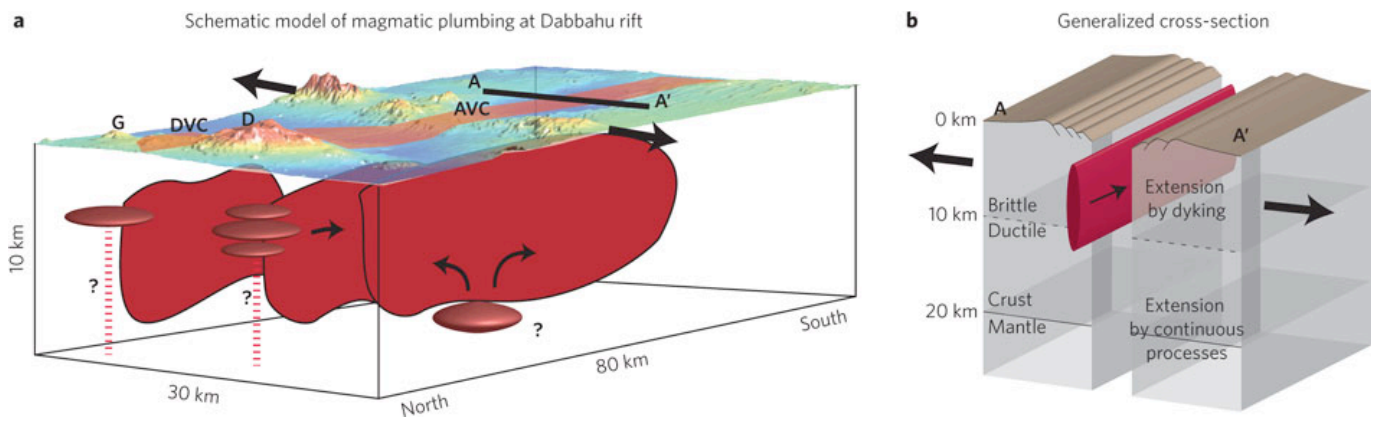


P= non hydrostatic magma pressure

$$Q = -\frac{w}{3\eta} b^3 \frac{dP}{dz}$$

Magma storage regions

- Midcrustal depths (3-15 km) beneath volcanoes



Wright et al., 2006

Afar region, Africa

Magma storage regions

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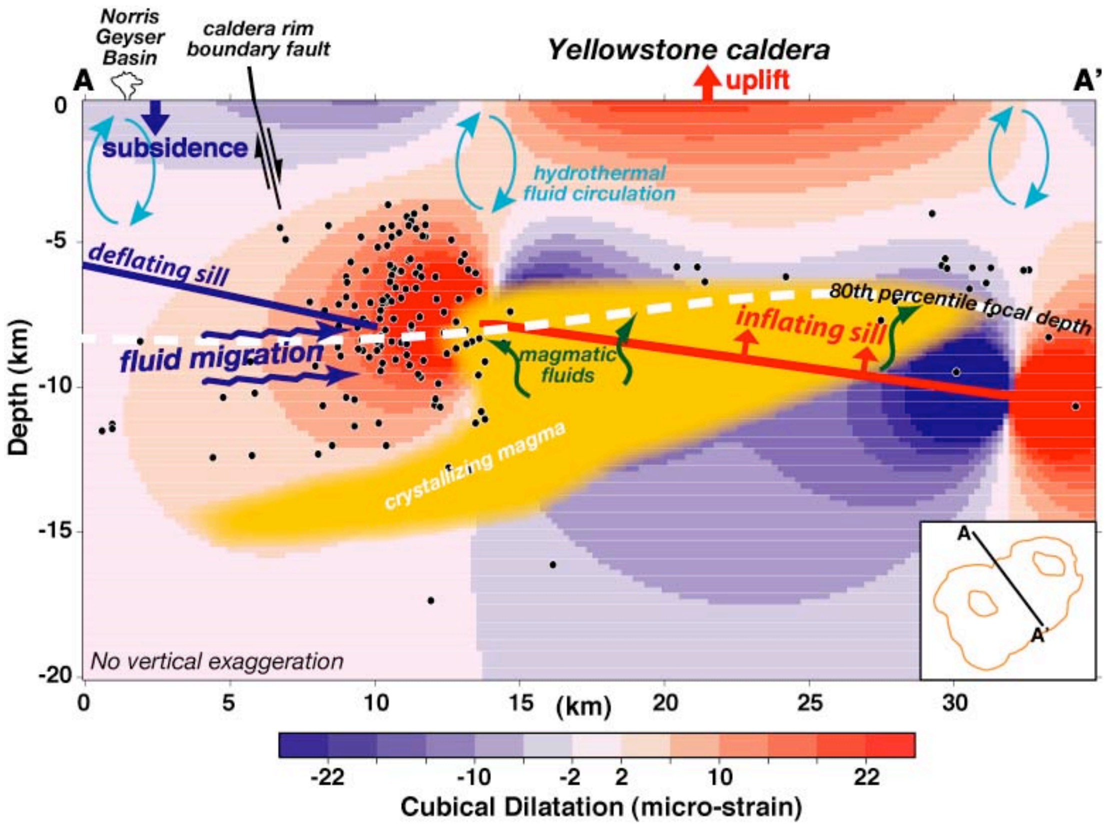
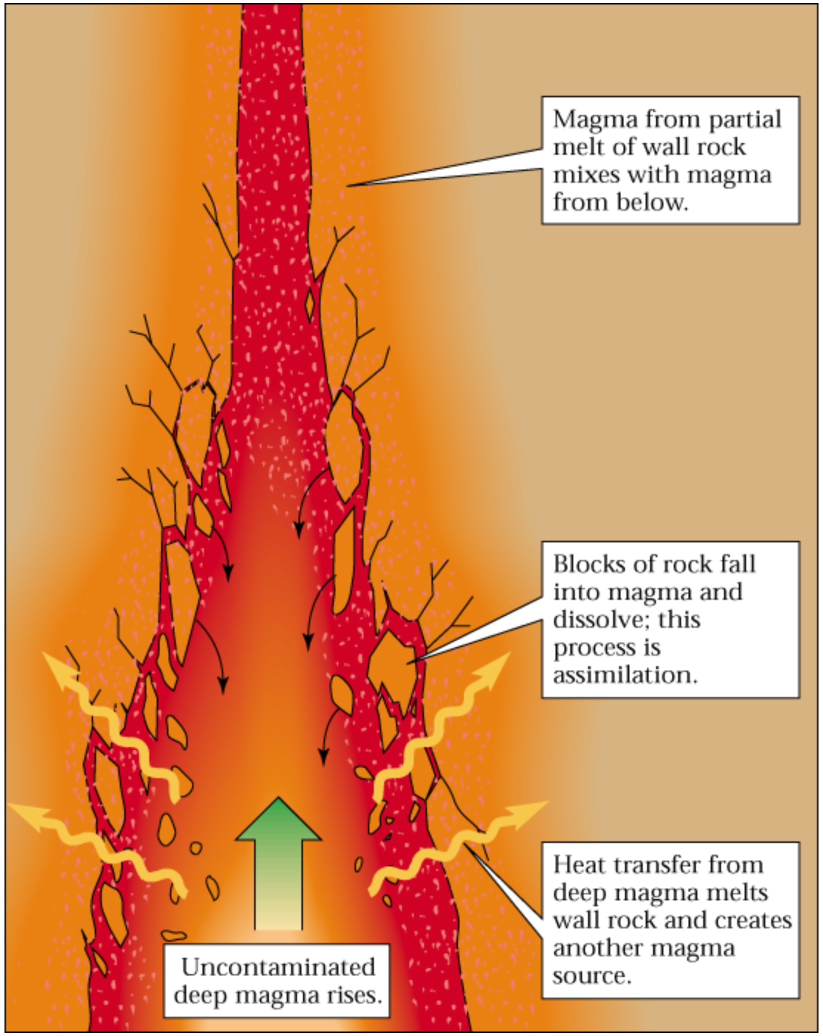


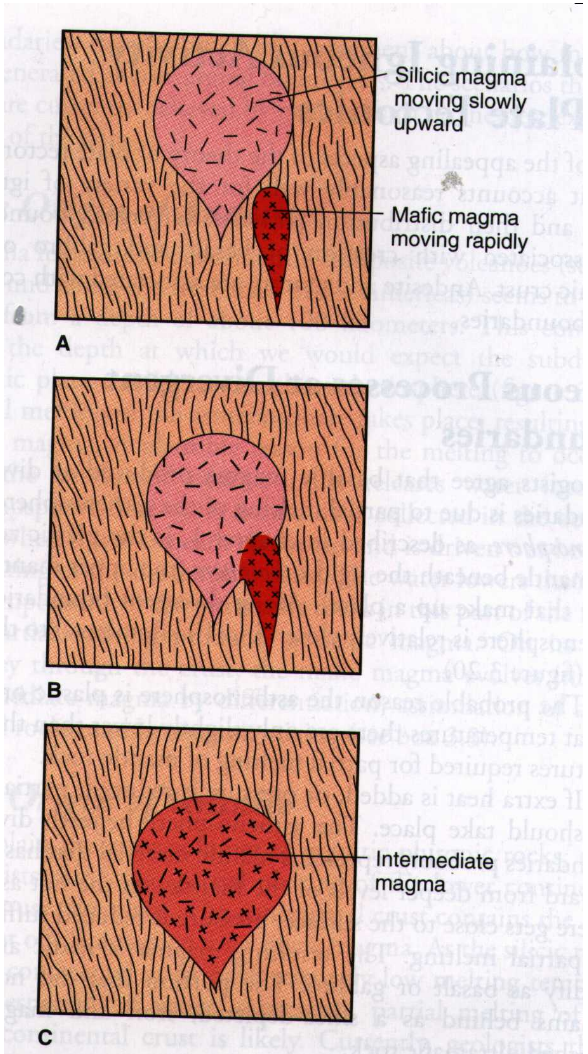
Lung-Chang et al., 2007

Differentiation processes

assimilation

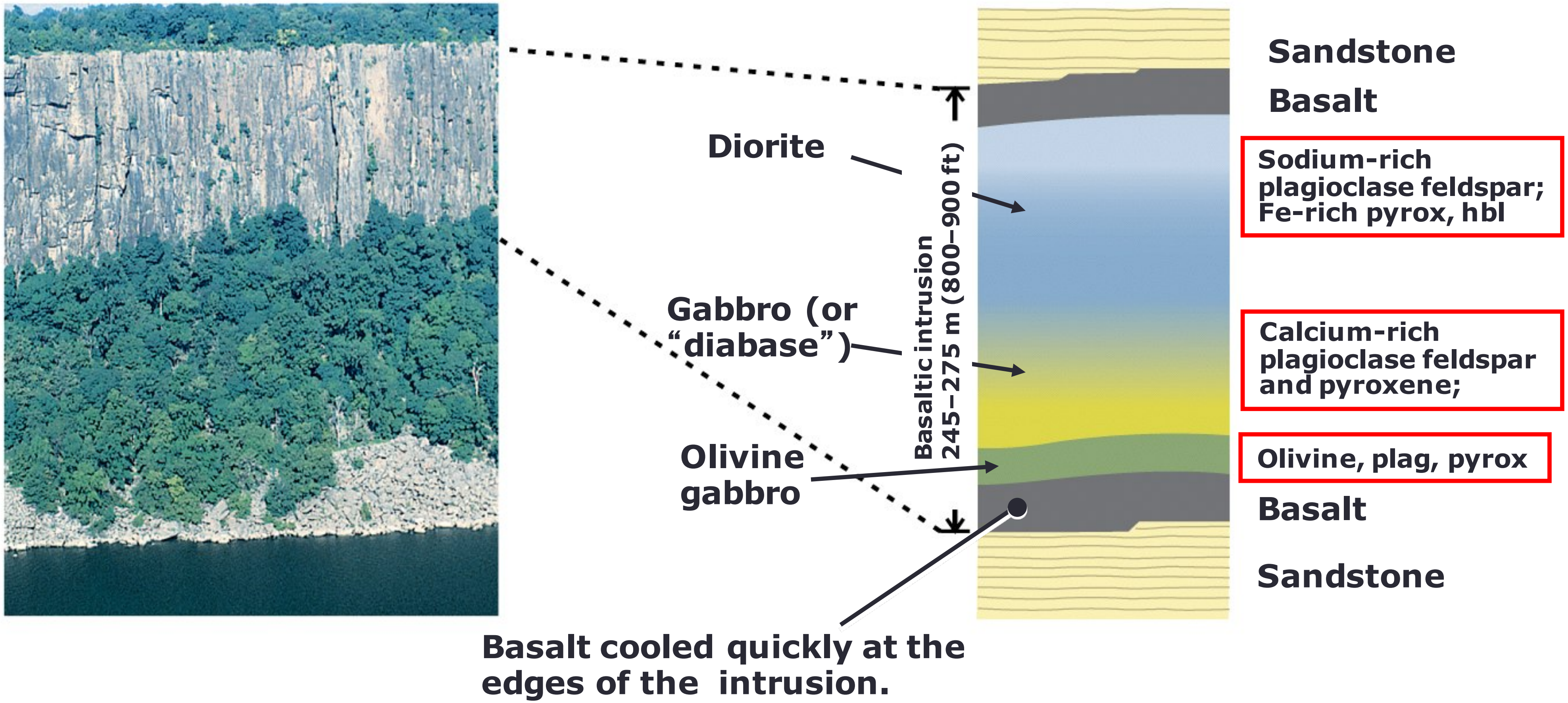


mixing

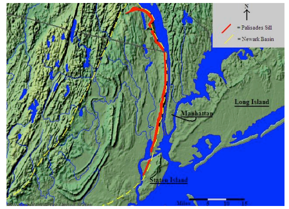


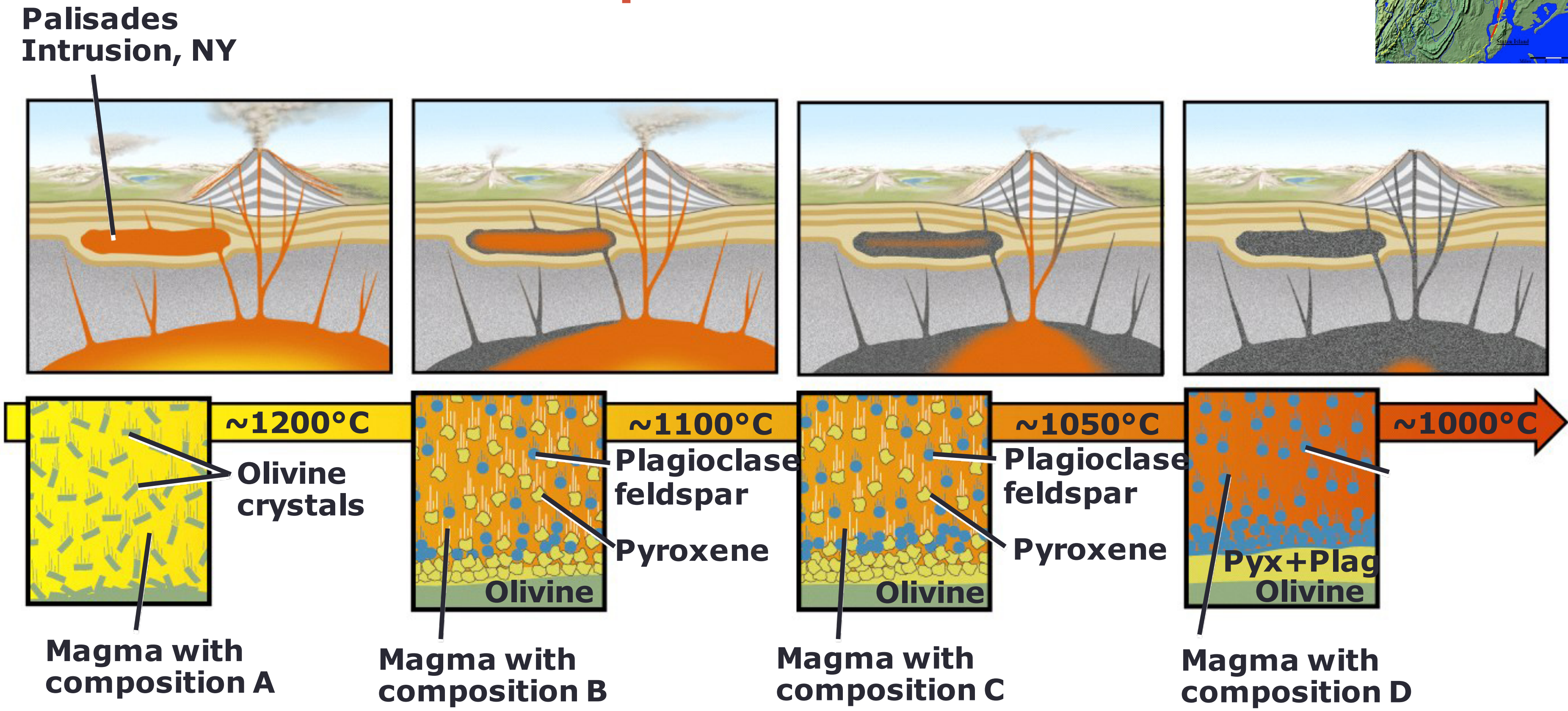
Differentiation processes

Crystal segregation/fractional crystallization



Differentiation processes





Olivine crystallizes first.

Pyroxene and plagioclase feldspar crystallize.

Pyroxene and plagioclase gradually change in composition.

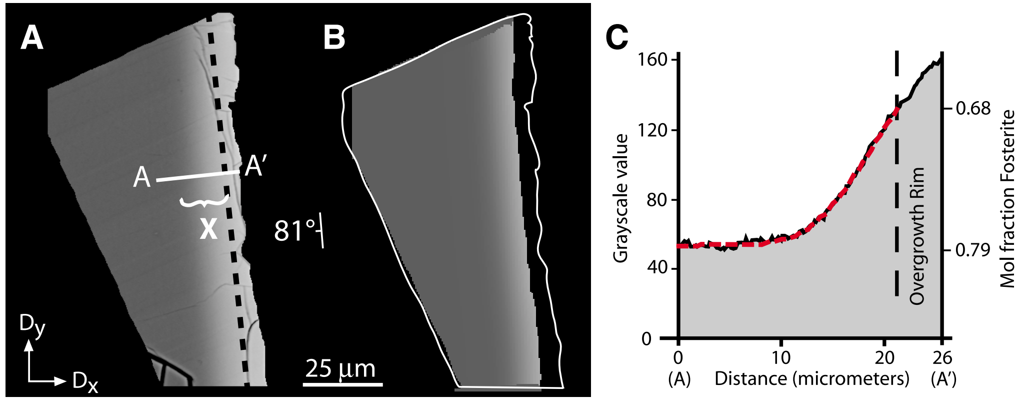
Plagioclase feldspar continues to crystallize.

Magma ascent -Petrologic tools

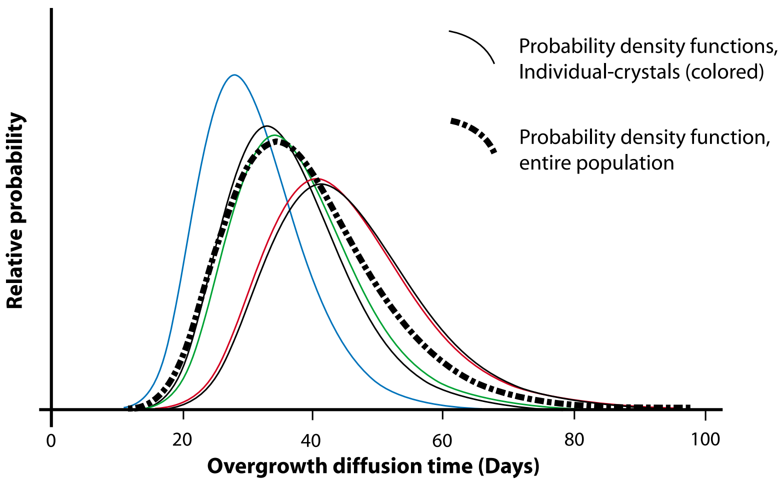
- Diffusion profiles in crystals
- Crystal size distribution
- Xenolith transport
- Xenolith-melt reactions
- Reaction rims
- Groundmass crystallization

Crystal zonation

Santorini 1925-28: basaltic andesite enters in a dacite magma chamber and a mixed magma was erupted. Olivine crystals were carried by the basaltic andesite. Fe-rich rims formed. Diffusion profiled were used to constrain pre-eruptive timing to 15-75 days.

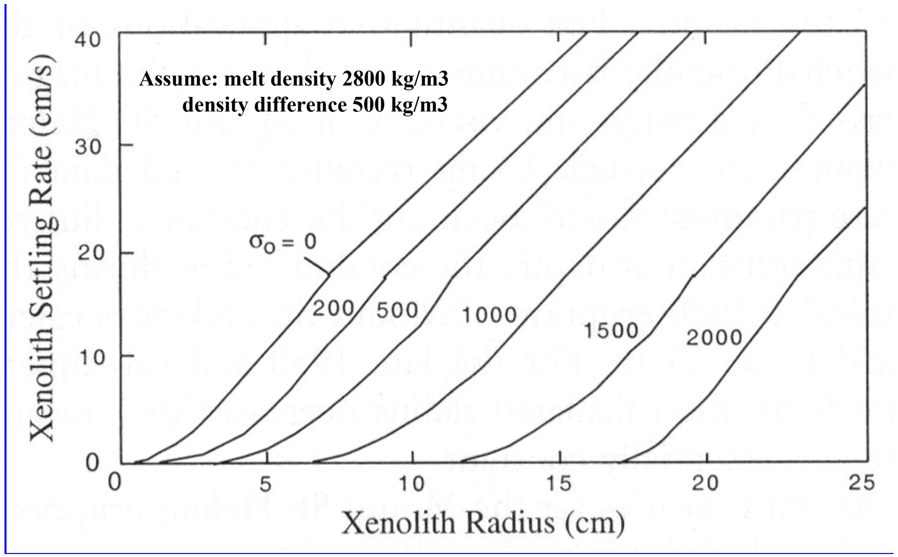


Martin et al., 2008



Xenolith transport

- Mantle xenoliths may be carried by magma to the surface
- Denser than the magma, they tend to settle down. The magma has to rise faster than the settling velocity to transport them up
- Main parameters controlling settling velocity: $\Delta\rho$, η, σ



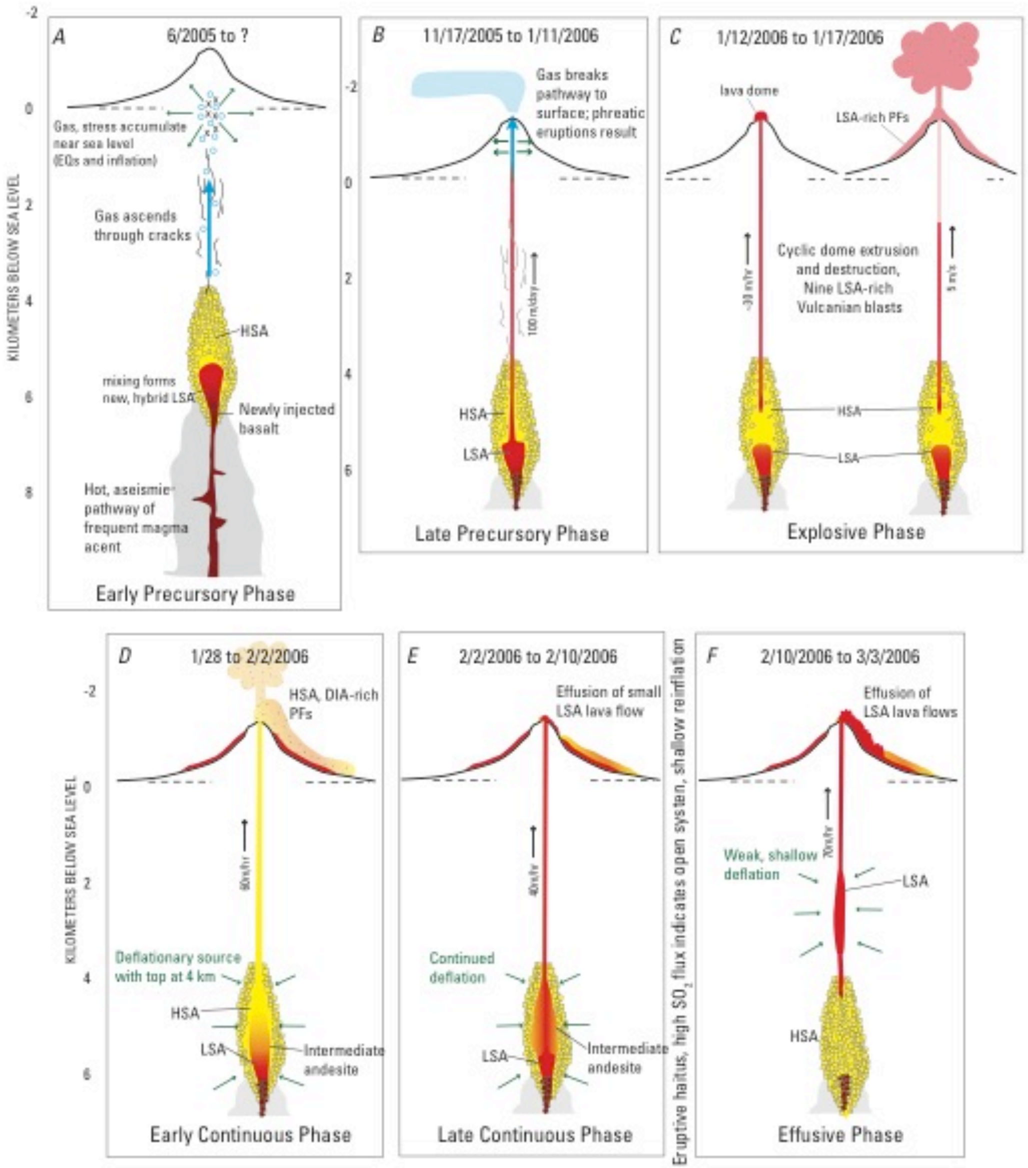
Petrologic tools- syneruptive ascent rates

- Available data:

Mt. St Helens	groundmass crystallization	1-3m/s
	Hornblende reaction rim	>0.18m/s
	extrusion rate	1-2m/s
Pinatubo (Filippine)	groundmass crystallization	>0.2 m/s
Arenal (Costa Rica)	groundmass crystallization	0.05-09 m/s

From Brandon et al., 2014

Seismic tools-localization and migration of hypocenters



Agustine volcano 2006 eruption

Larsen et al. 2010

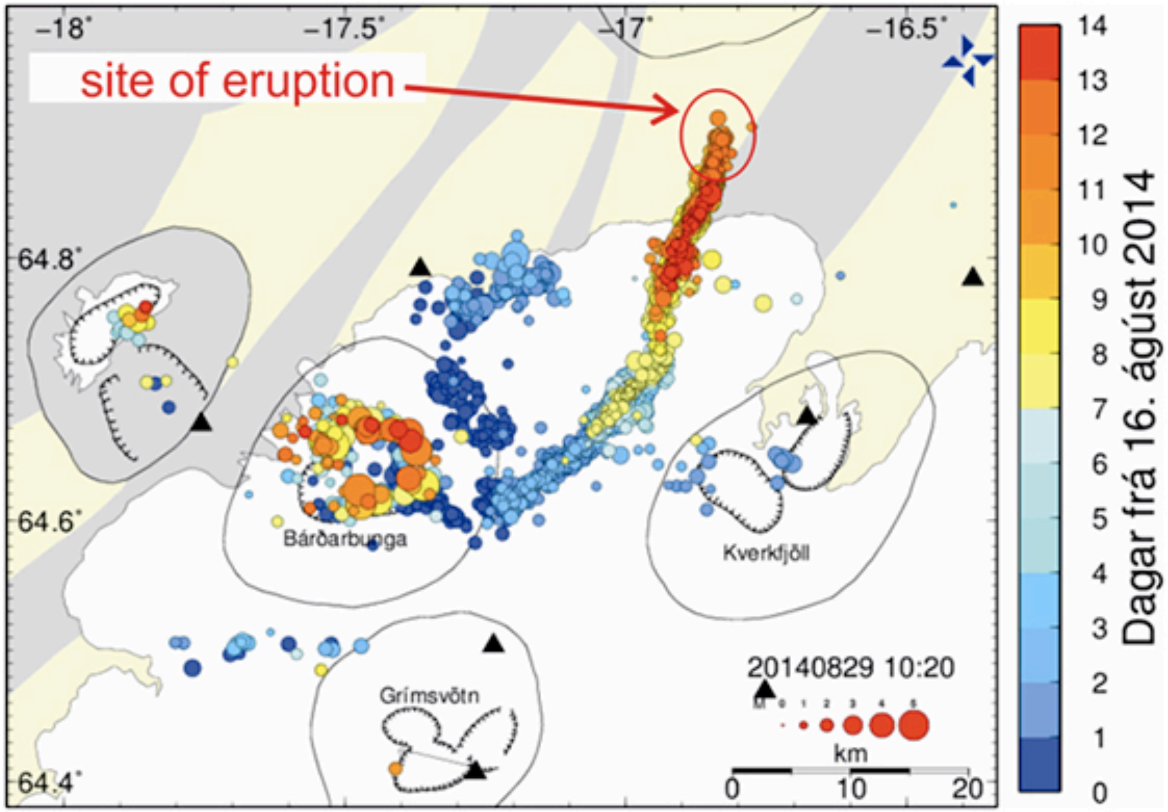
Seismic tools- upward migration of hypocenters

- Dyke propagation is outlined by seismic swarms, with hypocenters located in the surrounding rocks
- Tolbachik basalt 1975 ~0.1 km/h
- Kilauea E rift basalt, 0.1-5 km/h
- Izu basalt 1km/h
- Sakurajima andesite 1975, 0.3 km/day
- Pinatubo hybrid andesite 1991 0.5 km/day
- Unzen dacite 0.08 km/day

- EXERCISE: convert these quantities into m/s!

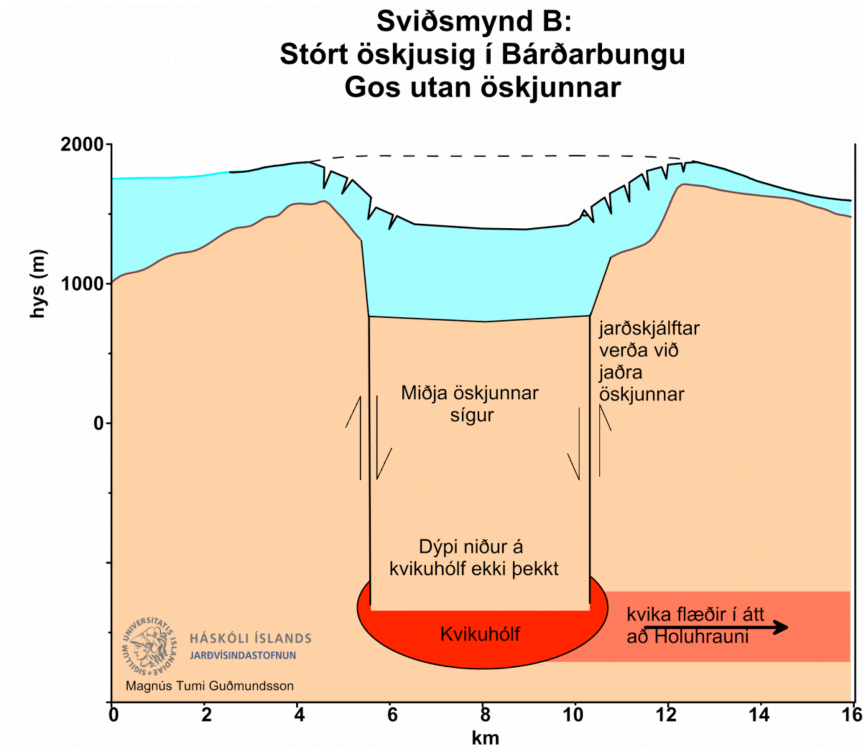
The Holorahun- Bardarbunga eruption 2014-5

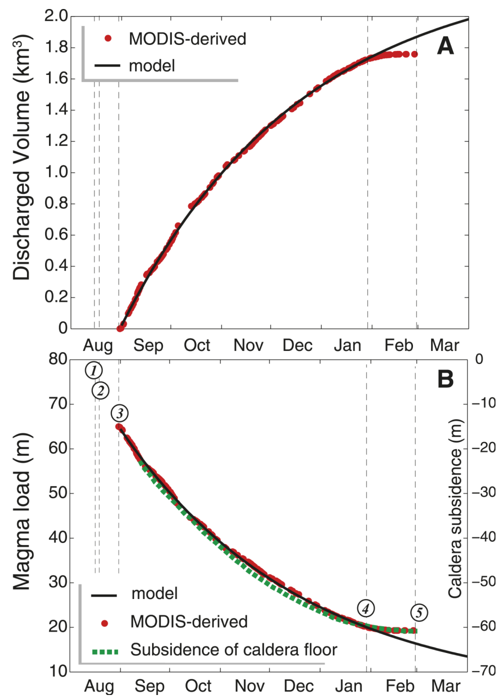
The Holorahun- Bardarbunga eruption 2014-5



Days after aug 16 2014

The Holorahun- Bardarbunga eruption 2014-5





Coppola et al., 2017