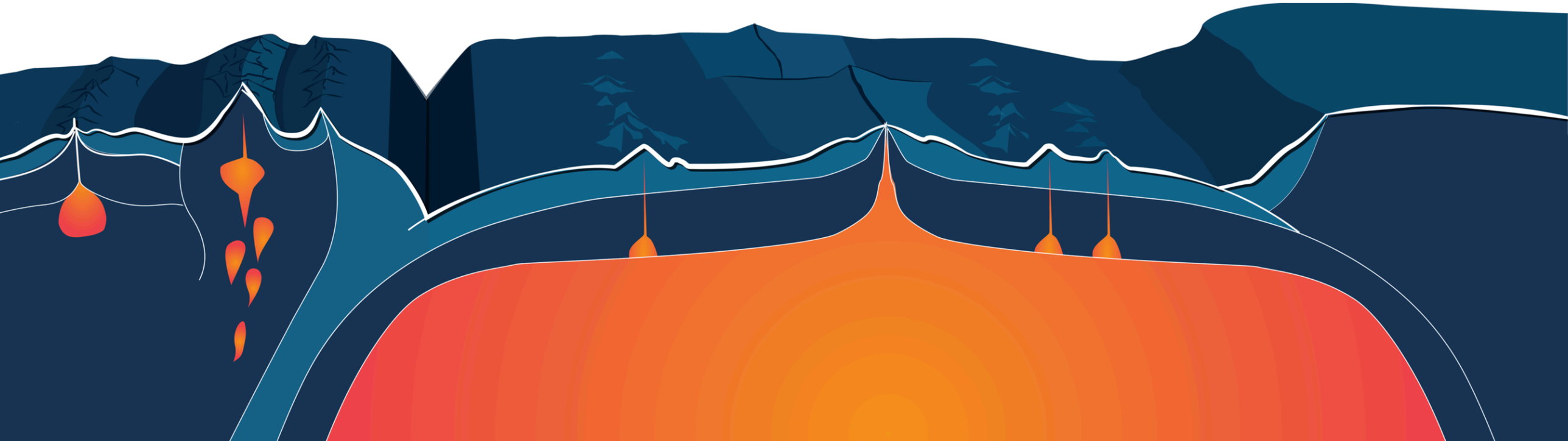
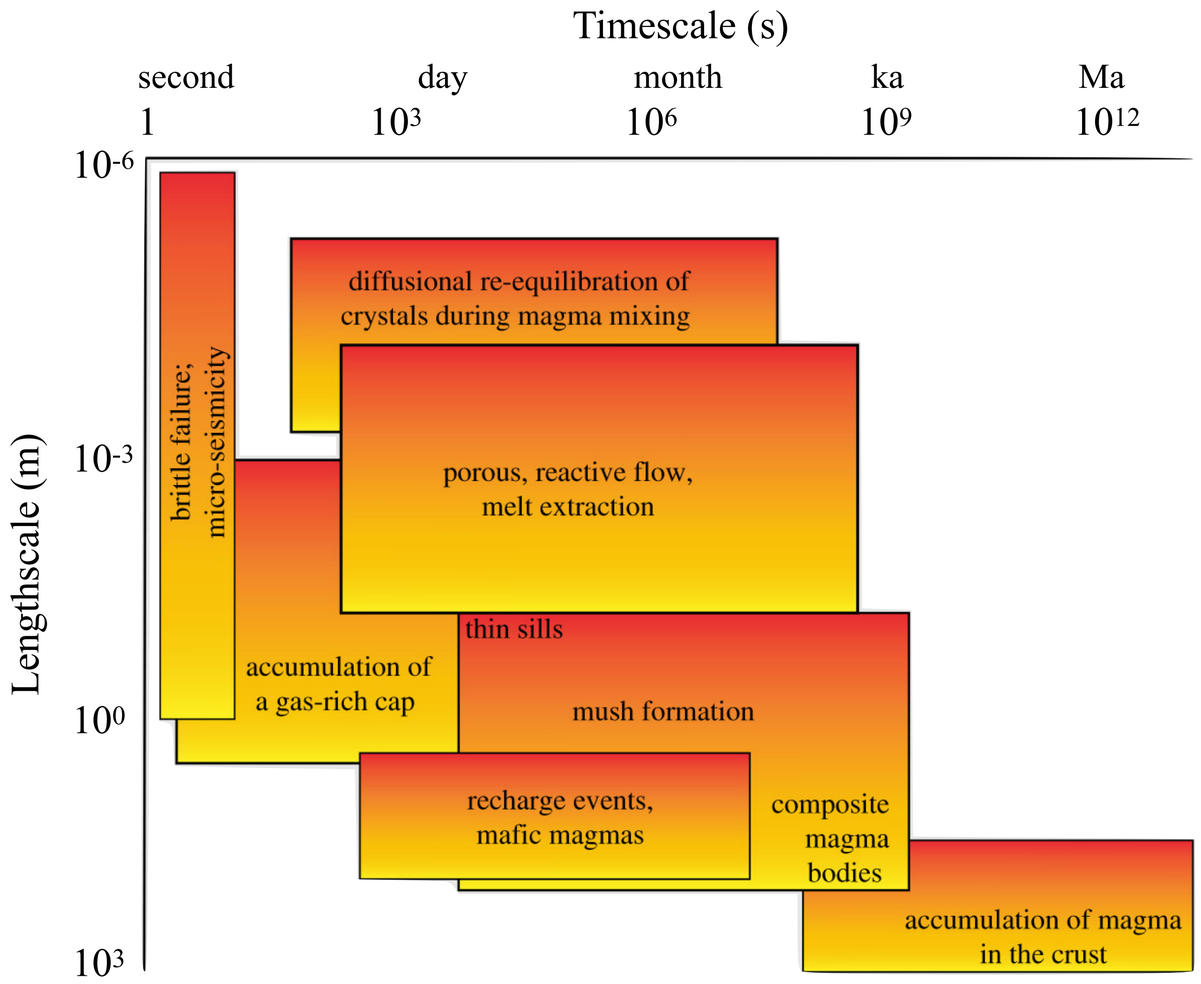
Magma Underground

Crustal Storage, Transport, and Evolution of Magma

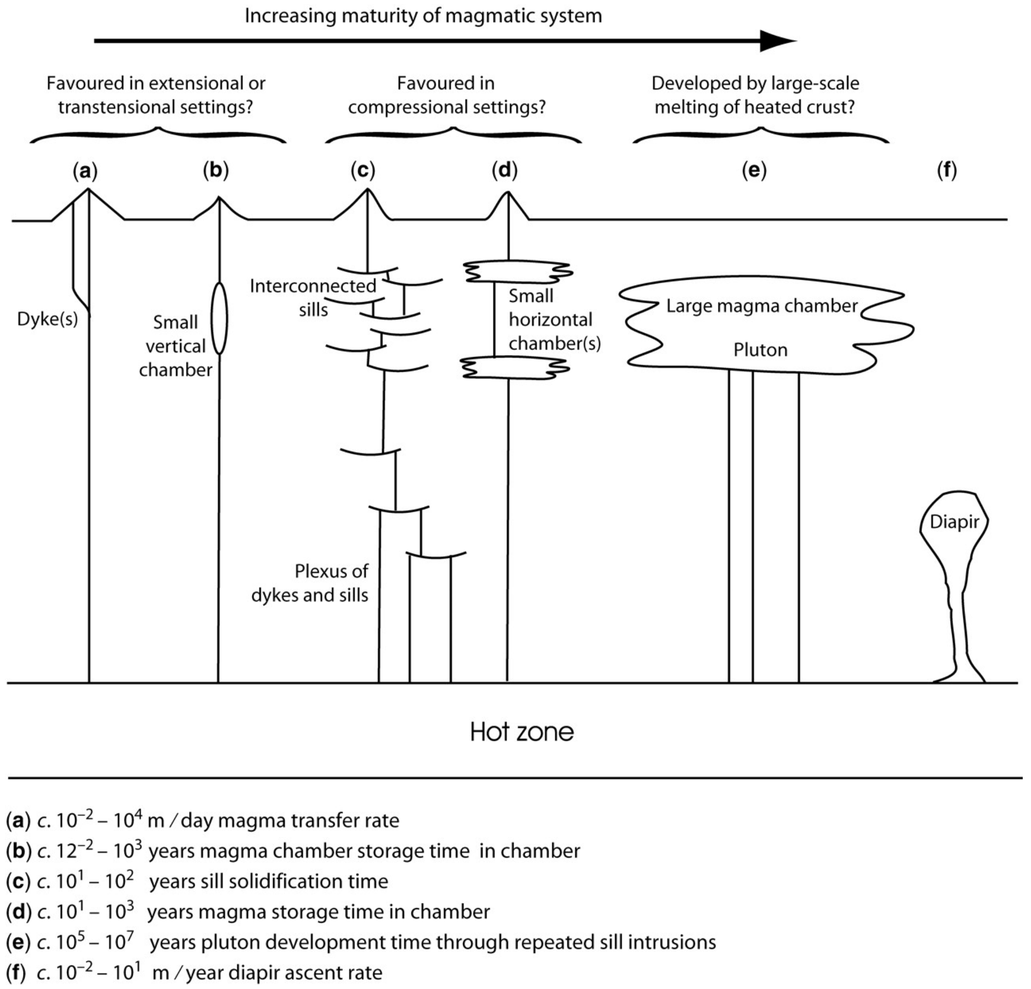
- Activity localized to plate boundaries and mantle plumes.
- Establishes thermal and chemical gradients that influence chemical exchange, subsurface biological activity.
- Controls processes of volcanic unrest and associated hazards.
- Lengthscales, timescales, and physical/ rheological properties, span orders of magnitude.



Timescales & Lengthscales



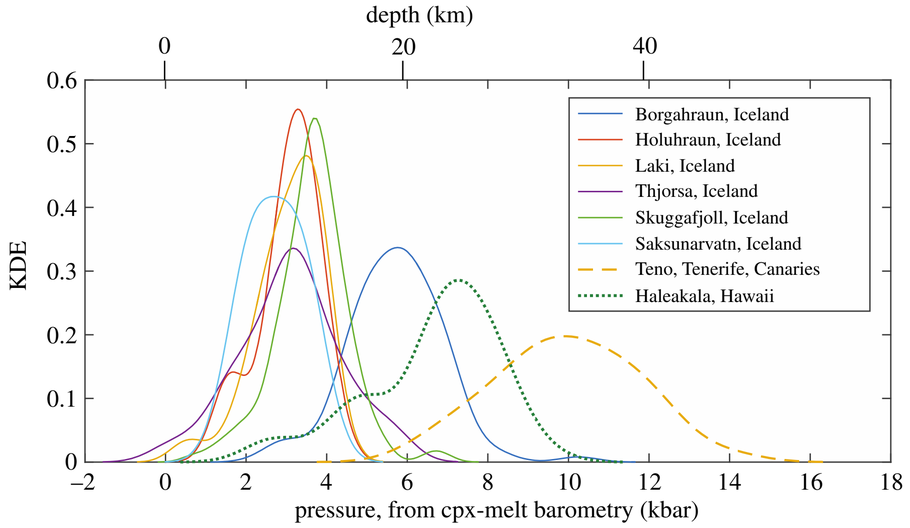
Edmonds et al., 2019



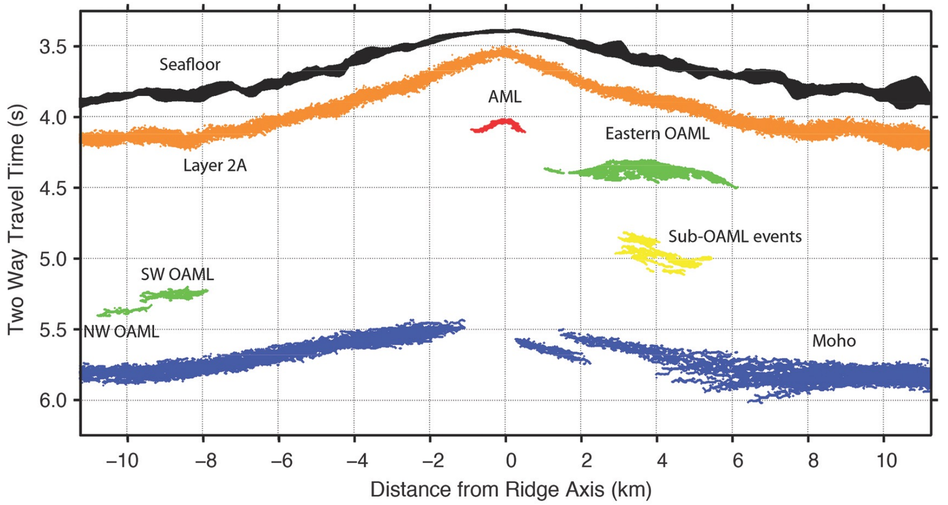
(**a**) *c.* 10^{-2} – 10^{4} m / day magma transfer rate
(**b**) *c.* 12^{-2} – 10^{3} years magma chamber storage time in chamber
(**c**) *c.* 10^{1} – 10^{2} years sill solidification time
(**d**) *c.* 10^{1} – 10^{3} years magma storage time in chamber
(**e**) *c.* 10^{5} – 10^{7} years pluton development time through repeated sill intrusions
(**f**) *c.* 10^{-2} – 10^{1} m / year diapir ascent rate

Zellmer & Annan, 2008

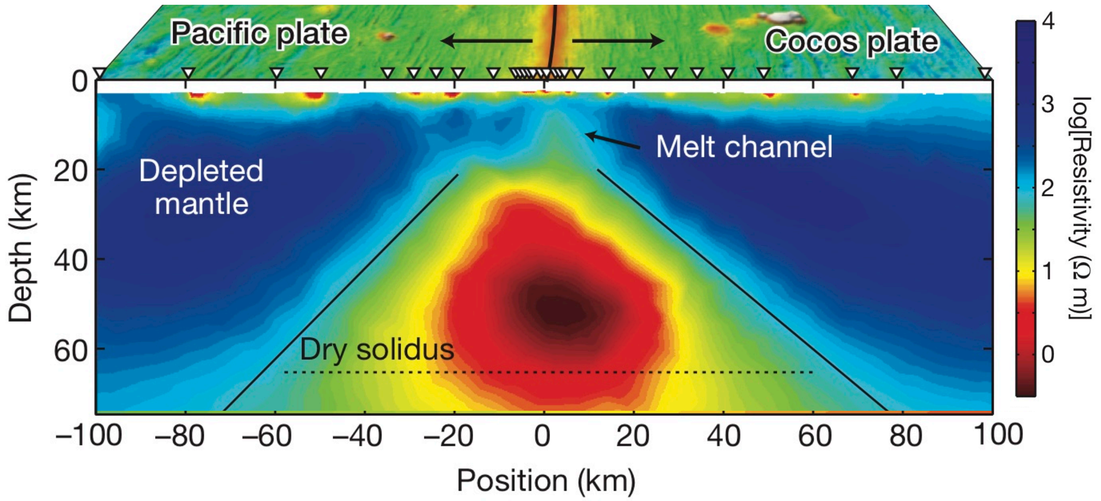
Simple question: Where is the magma?



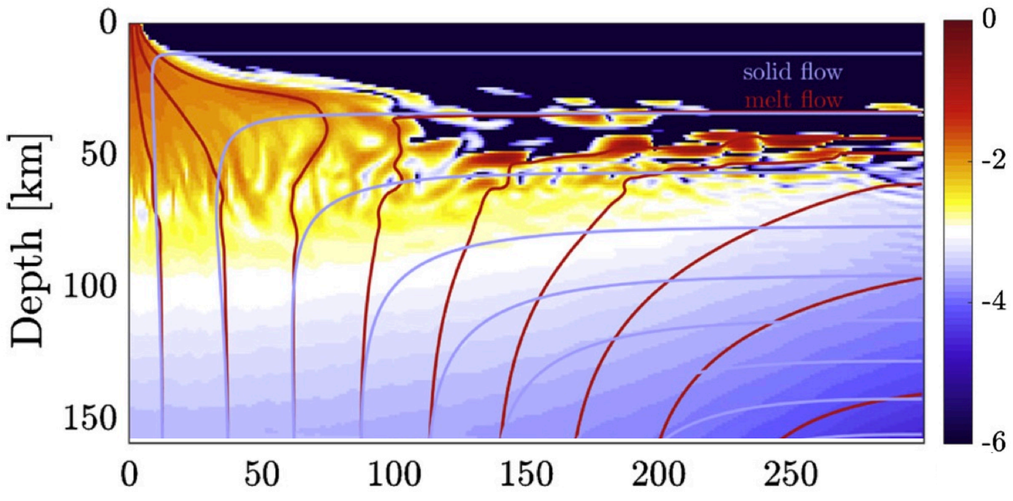
Edmonds et al., 2019



Canales, Carbotte, et al.

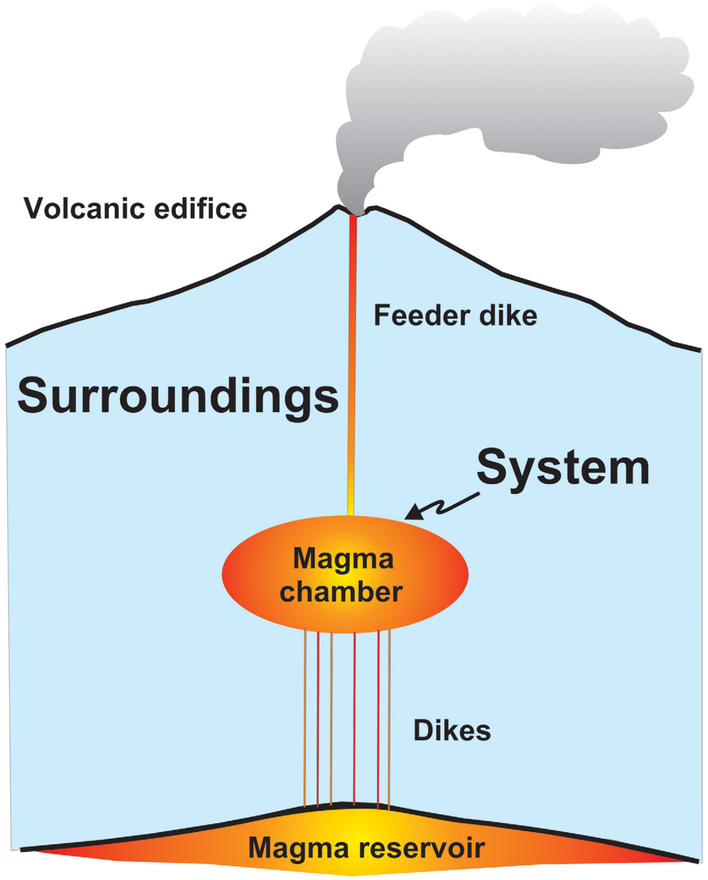


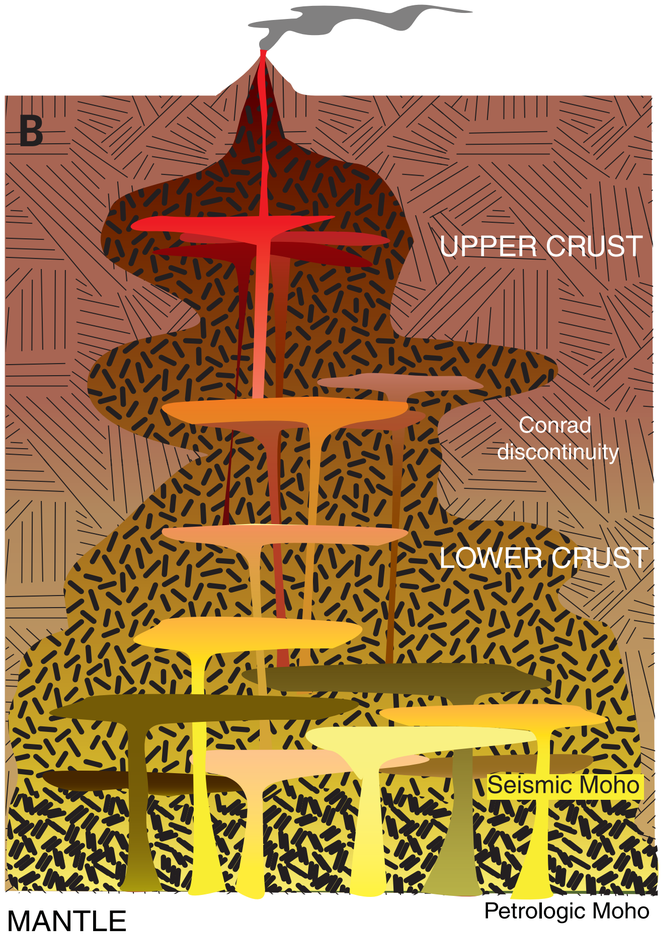
Key et al., 2013



Keller et al., 2017

Evolving conceptual models

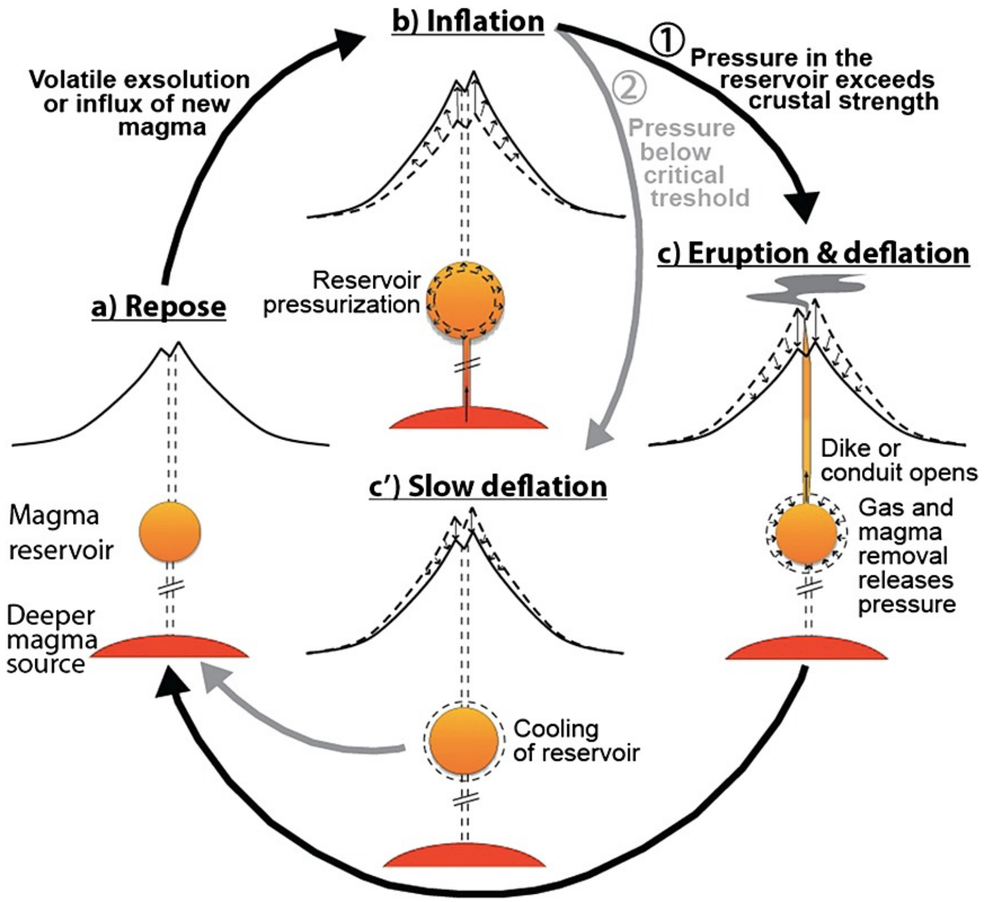




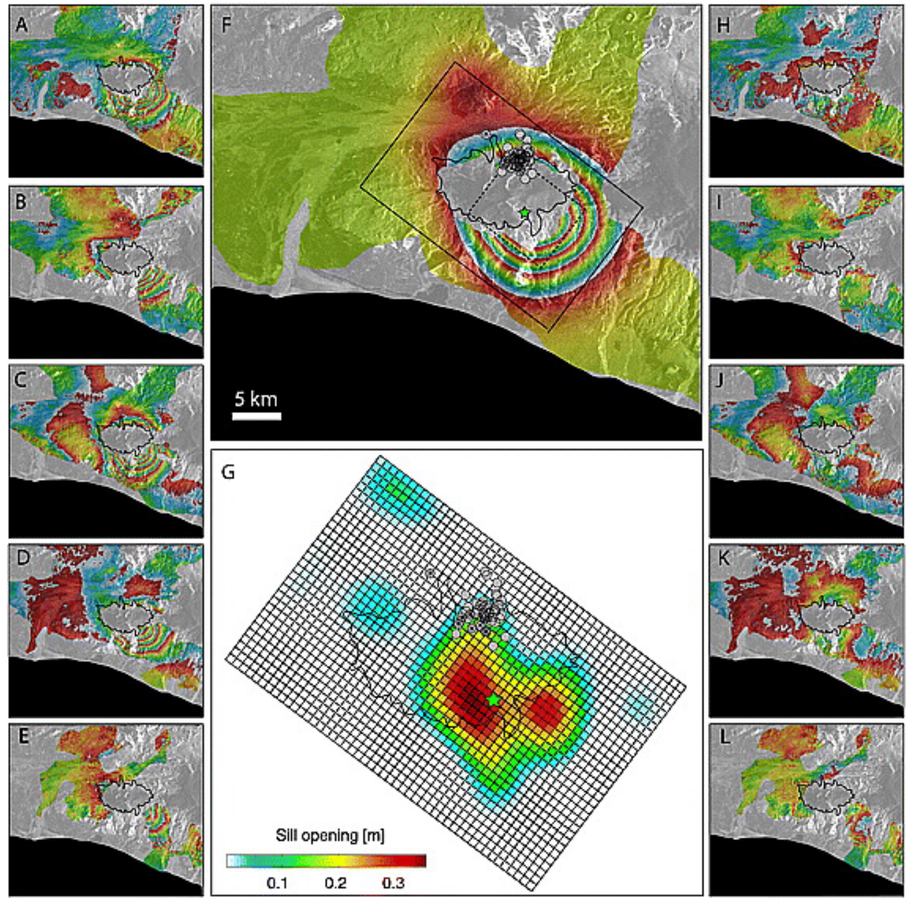
Simple: ‘balloon & straw’ conceptual model

Complex: trans-crustal magmatic systems (mush + melt)

Observing magma movement

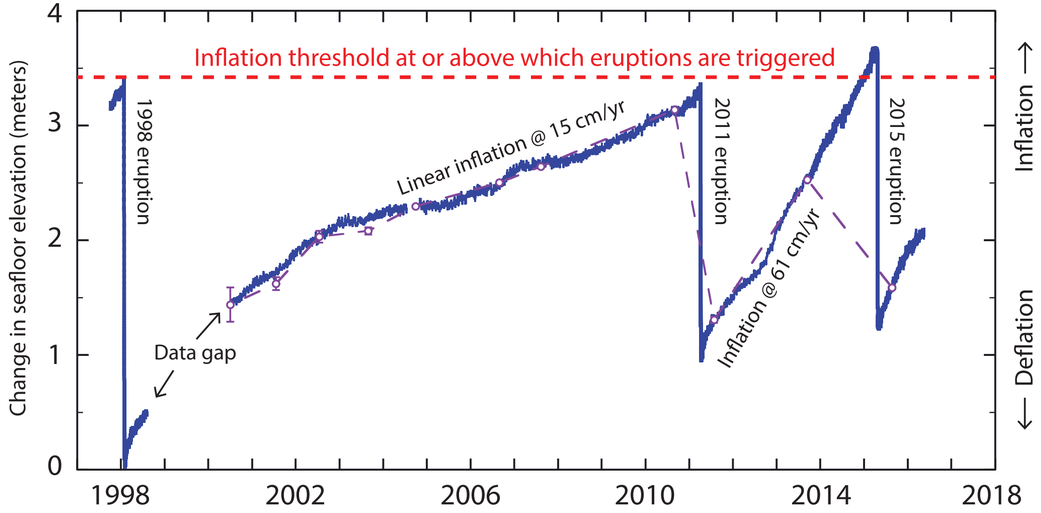


Choussard et al., 2013

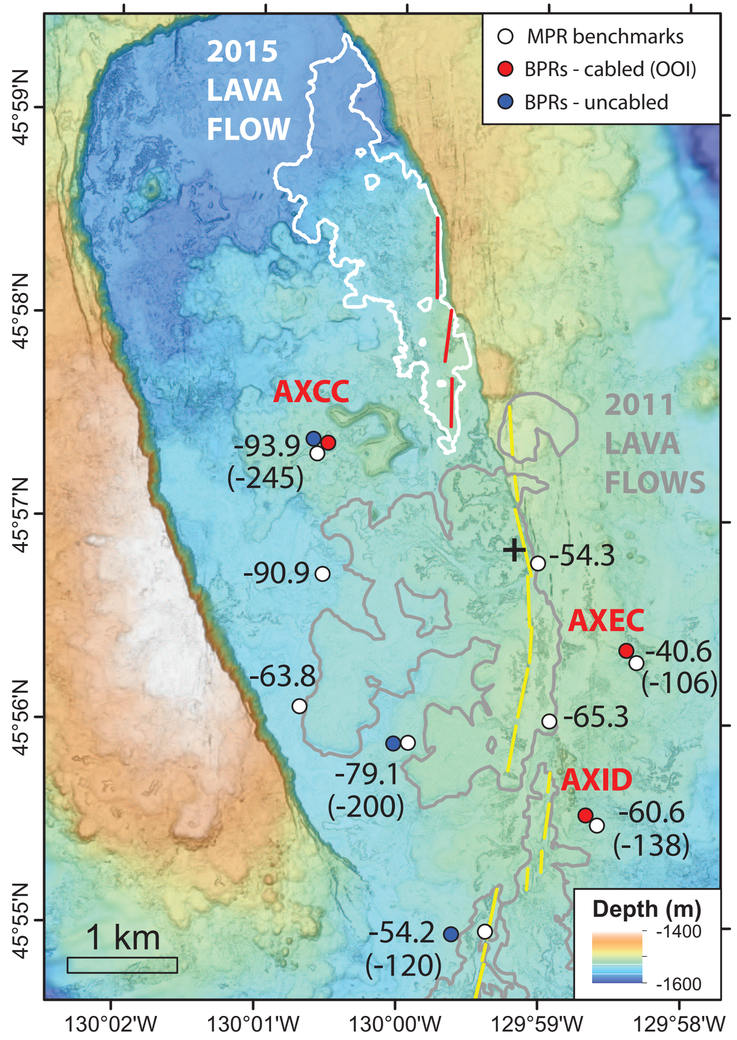


Pederson & Sigmundsson, 2004
[1994 Eyjafjallajökull]

Observing magma movement



Nooner & Chadwick, 2016



Challenges & Opportunities

What are the timescales of magma recharge events and does that influence the probability that they will lead to eruption?

- **Crystal chronometry: Analytical methods to resolve the timescales of magmatic events via diffusion chronometry require novel analytical techniques, experiments, and numerical models.**

What are the physical processes of melt extraction (e.g., compaction) in magmatic systems?

- **Laboratory experiments: Micro- and macro-scale physical processes in magmatic mush need to be resolved in order develop models that can, for example, predict reservoir failure.**

Why is inflation of shallow magma reservoirs not accompanied by deflation of deeper reservoirs?

- **Volcano monitoring: Improved temporal and spatial resolution of geophysical observations (e.g., deformation) are needed to test models and to probe deeper into magmatic systems; submarine systems are largely under sampled in this regard.**

Is volcanic unrest, eruption initiation, and cessation predictable?

- **Modeling: Integrative, multi-scale models of magmatic systems (mechanical, thermal, geochemical) are needed to tie together observational, analytical, and experimental data sets.**