Exploring the effects of a time- and space-dependent eruption efficiency

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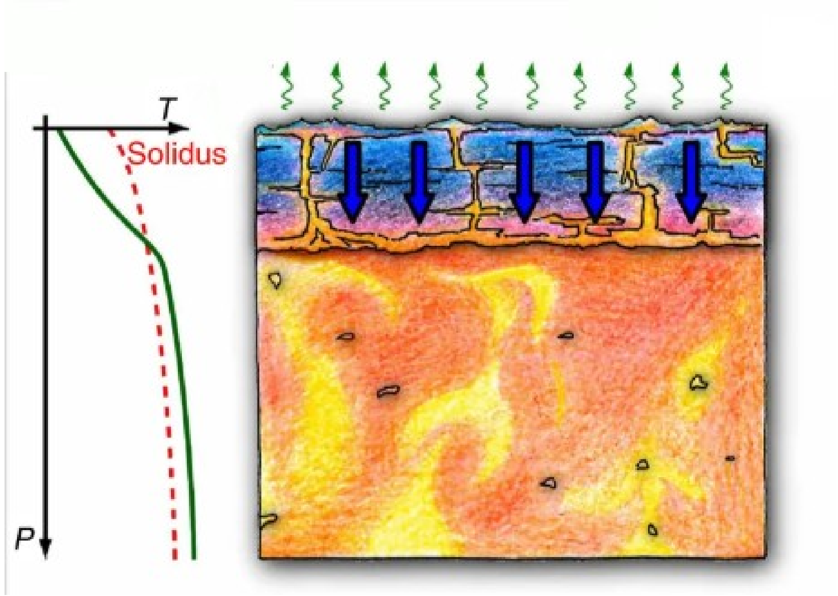
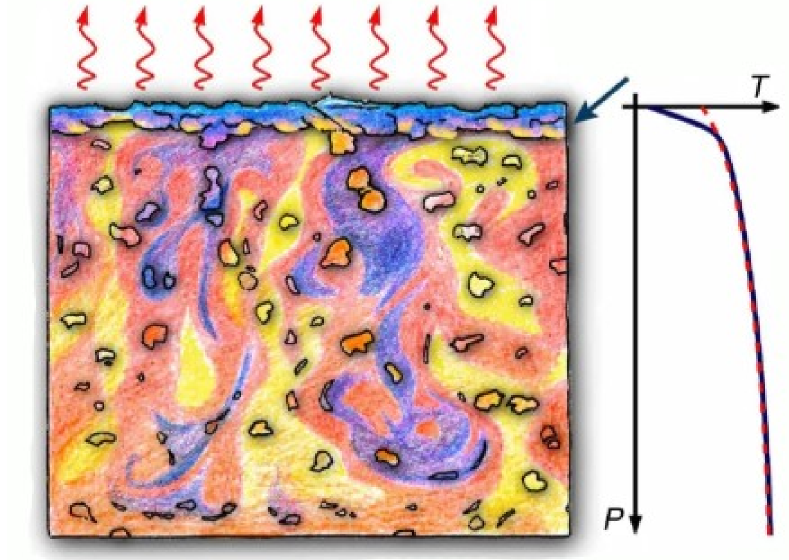
For a 4 minute video use the following link:
https://youtu.be/xiWalke2PUk

Why is Eruption efficiency important?

high eruption efficiency:
- Extrusive
- Melt is placed at the top of the crust and cooled
- A thick cold crust
- Stagnant convection regimes

Low eruption efficiency:
- Intrusive
- Melt is placed at the bottom of the crust and stays warm
- A thin hot crust
- Mobile convection regimes





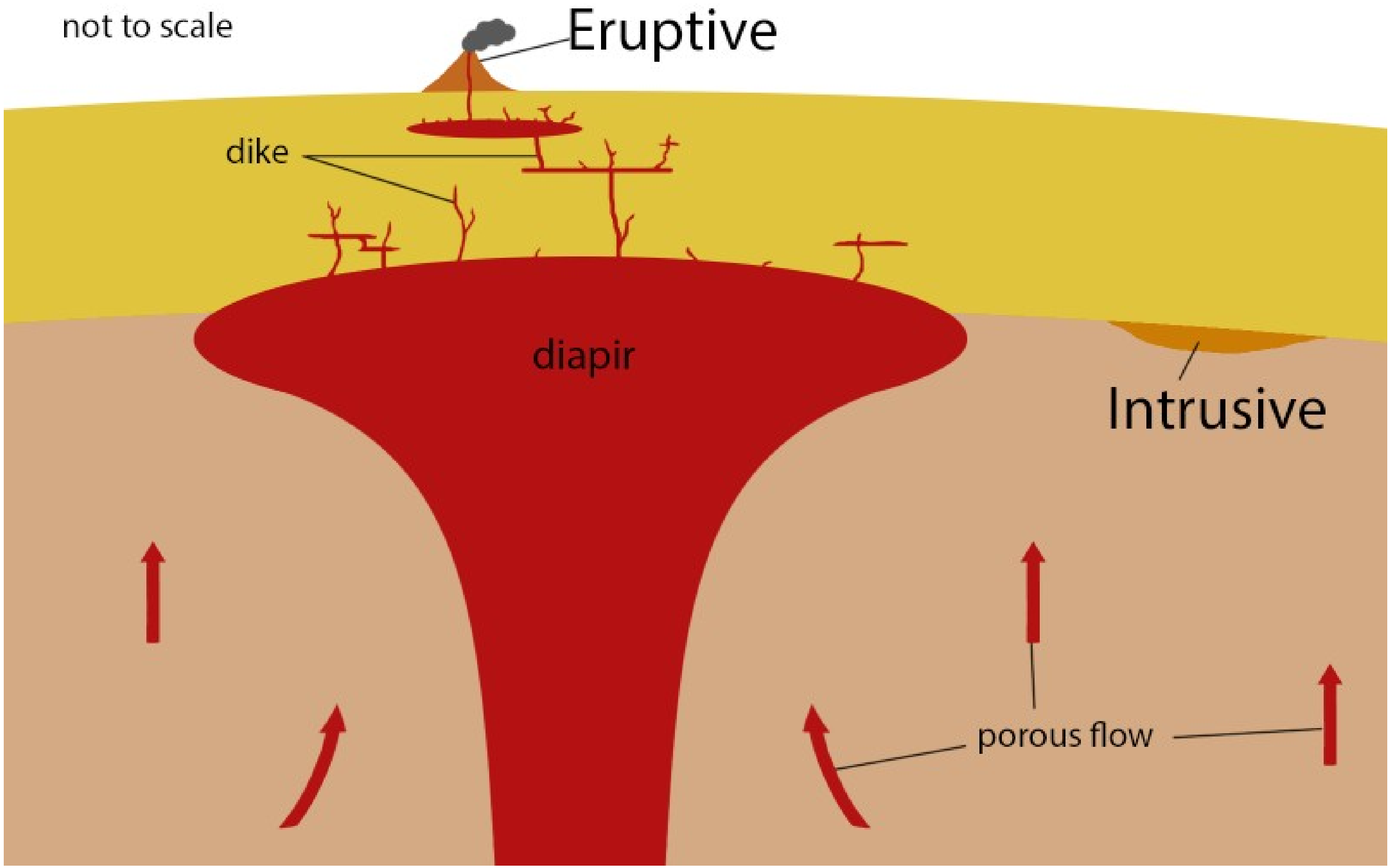
Lourenço et al. (2018)

What determines how eruptive a system is?

Melt tranport via:
- Porous flow
- Diapirism
- Diking

These are all characterized by buoyancy of the melt.

Diking is additionally inhibited by crustal strength



Formalism:

Melt Pressure:

If there is more melt in the system; a higher fraction of melt should erupt.

$$P_m = \int_{z_l}^{0} g f_m (\rho_s - \rho_m)\, dz$$

Local stress state:

Diking is inhibited by compressive horizontal stresses:

$$Stressterm = \frac{1}{z_c} \int_{z_c}^{0} \frac{\sigma_{ys} - \sigma_{xx}}{\sigma_{ys}(z_c)}\, dz$$

$$Eruptivity = \frac{P_m}{P_0} * stressterm = \frac{P_m}{P_0 z_c} \int_{z_c}^{0} \frac{\sigma_{ys} - \sigma_{xx}}{\sigma_{ys}(z_c)}\, dz$$

P_m	= melt pressure
g	= gravitational acceleration
f_m	= melt fraction
ρ_s	= density of the solid
ρ_m	= density of the melt
z_l	= zl thickness of the lithosphere
z_c	= thickness of the crust
σ_{ys}	= plastic yield stress
σ_{xx}	= compressive horizontal stress

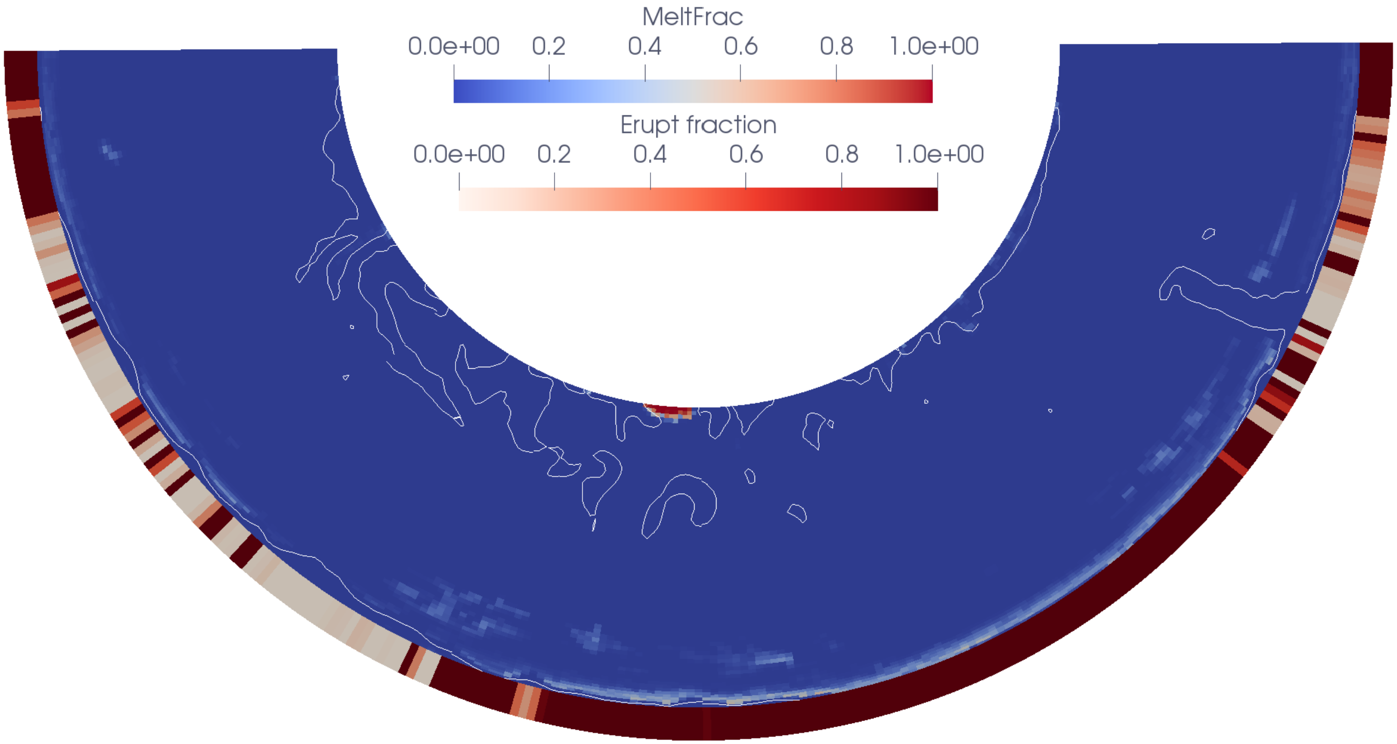
Results

Erupt fraction has spatial variation.

Erupt fraction is higher above regions with a lot of melt.

This strong correlation with the amount of melt can be seen in all models.

This indicates that the eruption efficiency is mainly dependent on the amount of melt and less so on the stress-state.

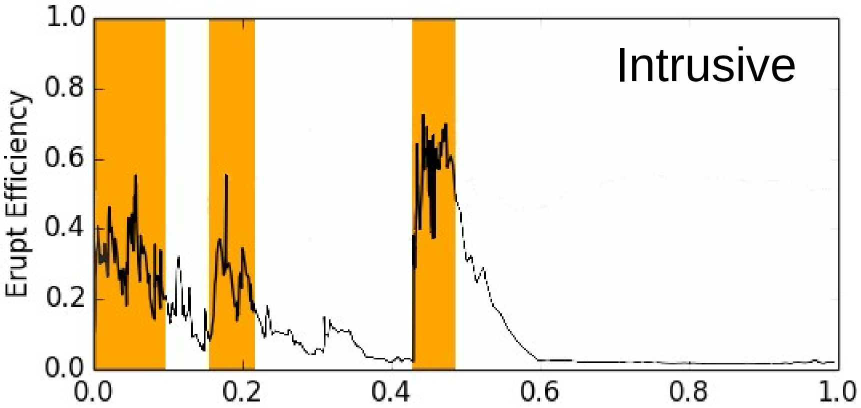


The white lines show the contours of basaltic crust

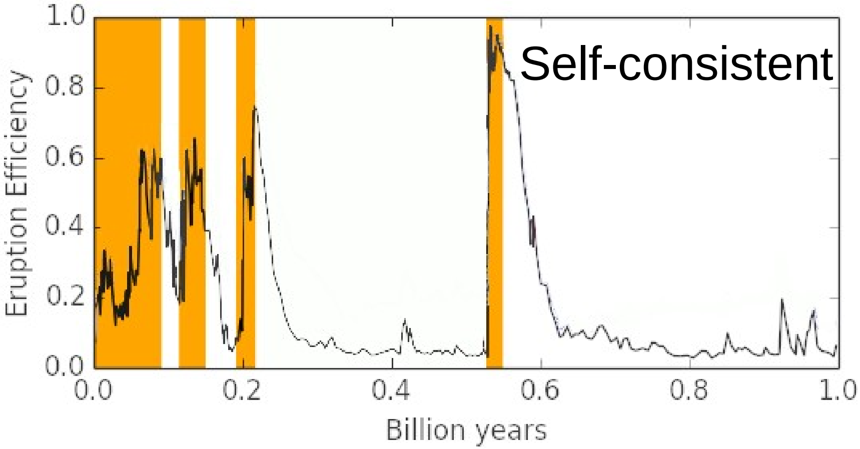
Results

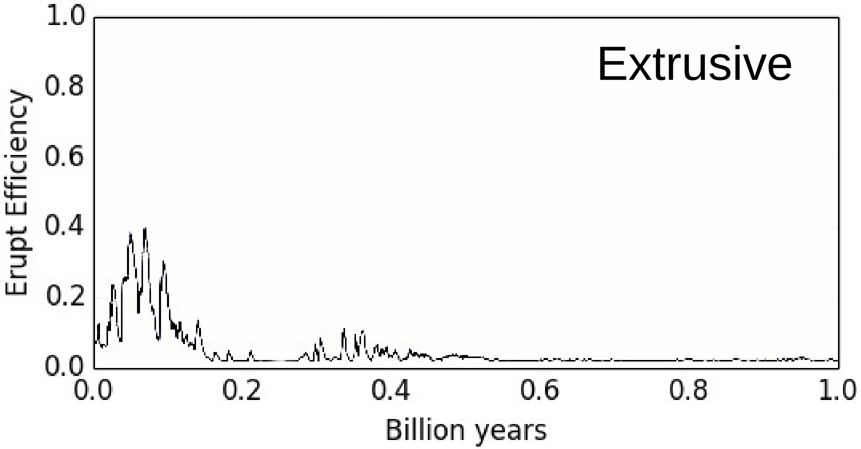
The mobile periods (orange) are similar between the intrusive and the self-consistent case

The eruption efficiency is higher during mobile periods



Orange: mobile periods





Eruption efficiency is the normalized result of the eruptivity equation, in the intrusive and extrusive scenario this is not applied and set to be constant. In the self-consistent scenario the value of the eruption efficiency is the result of the eruptivity equation i.e. what is displayed in the graph.

Results

Both intrusive and self-consistent have rapid drops in the average crustal thickness

This coincides with the start of mobile periods

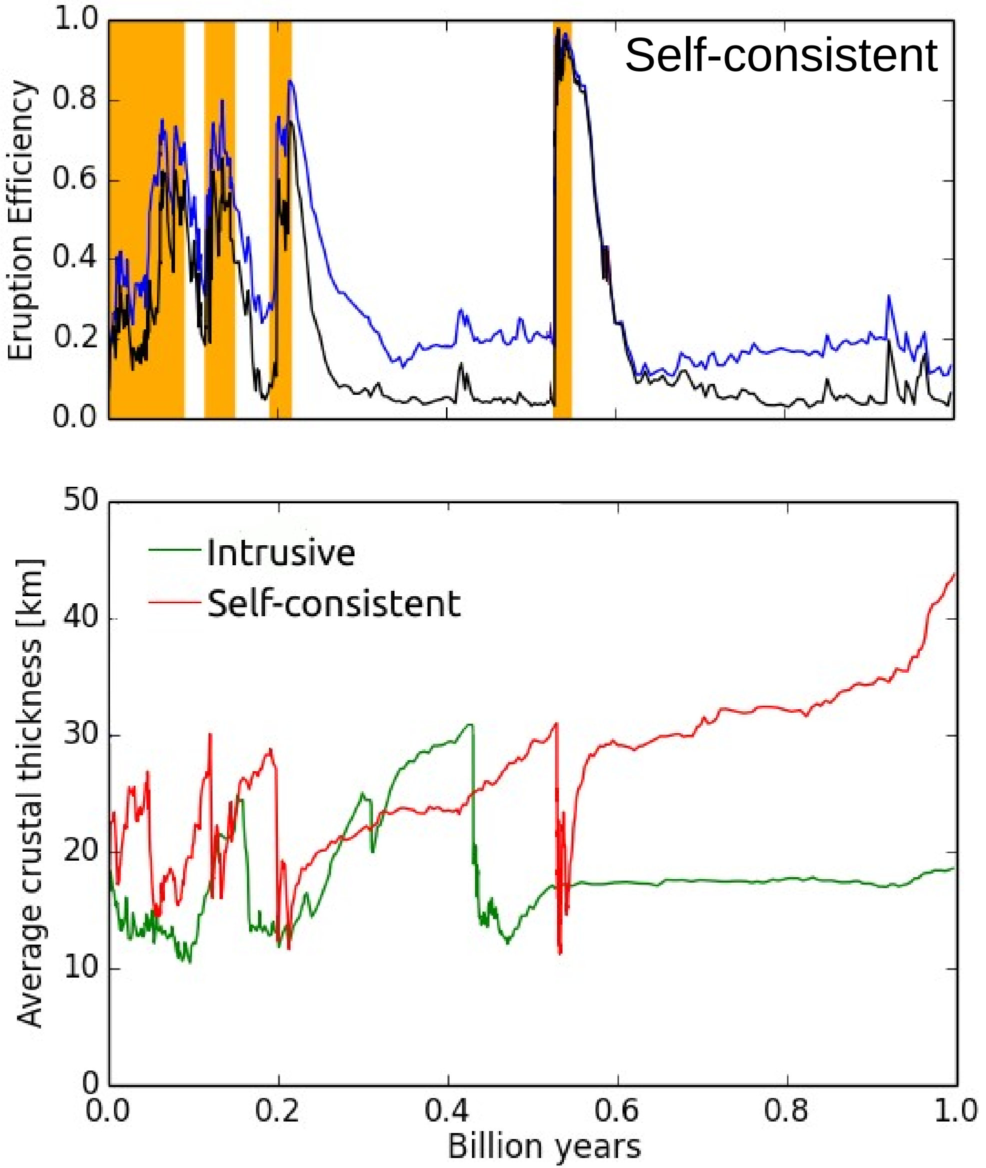
For the intrusive case the crust stays thin for a long time

In the self consistent case the crust rapidly thickens. This is due to the high eruptivity during the mobile periods

Having a self-consistent eruptivity leads to self-regulating behaviour:

- During mobile times the eruptivity is high and thick cold crust is produced

- During stagnant periods the eruptivity is low and thin weak crust is produced



Conclusion

- The eruptivity is mainly governed by the melt pressure.
- Mobile periods are more eruptive than stagnant periods.
- The time- and space-dependent eruptivity behaves mostly like an intrusive scenario.
- **The eruption efficiency can be made time- and space-dependent!**