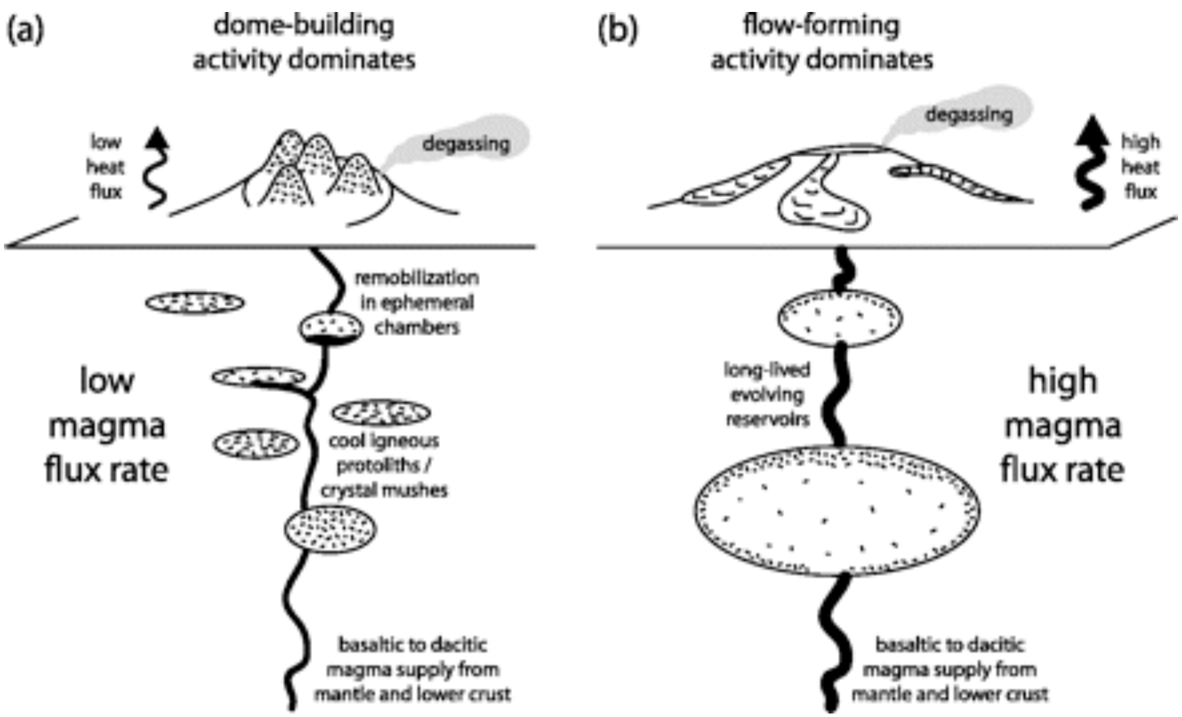
LAVA DOME ERUPTIONS

Laura Pioli

Effusive eruptions



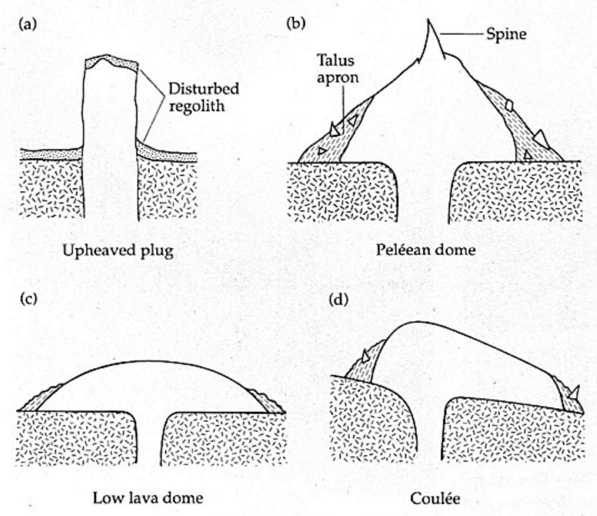
Lava domes are masses of viscous lava growing above the vent or at shallow depth (cryptodomes)

Lava dome eruptions

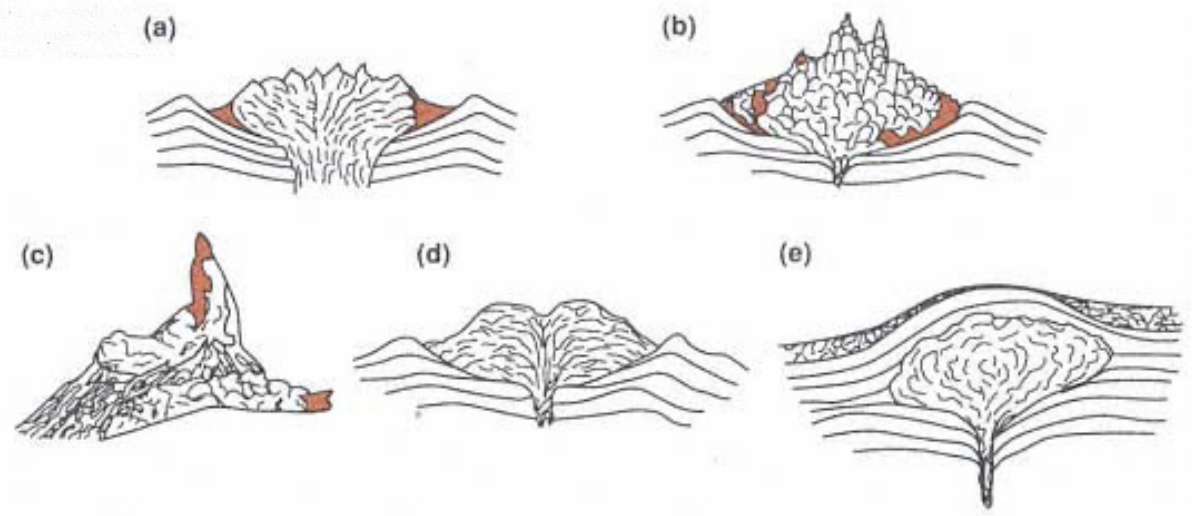
- Domes of silica-rich lava (andesite-rhyolite), typically tens-hundreds of metres high
- Domes grow over months-years, punctuated by collapse events and explosive eruptions
- Highly hazardous – can generate pyroclastic flows that destroy settlements on volcano flanks
- High viscosity magma: 10^6 to 10^{14} Pa s (due to high SiO_2, plus degassing, crystallisation and cooling)
- Examples include Unzen, Montserrat, Colima, Popocatepetl, Merapi & MStHelens

- Key problem: how to predict dome collapse and explosions

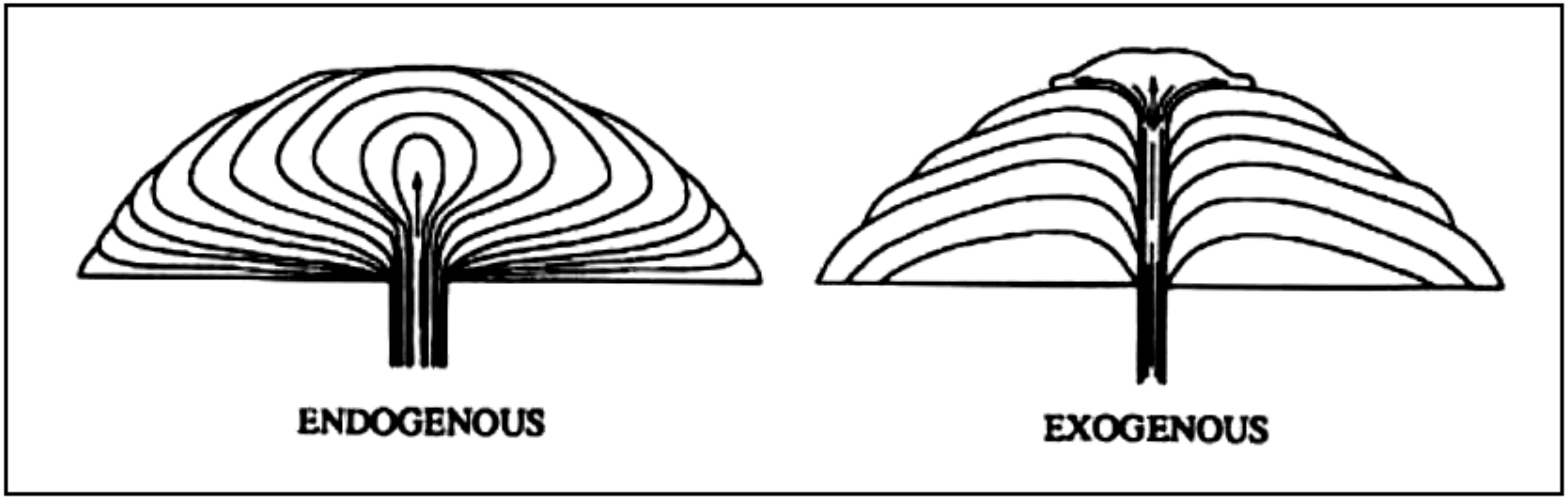
Domes classification



Upheaved, exogenous
Peleean;
Vent spine
Exogenous, with lobes
Intrusive dome



An overview of lava dome eruptions



- The flow dynamics (strain pattern) control dome growth
- Flow is restricted to small volumes – SHEAR ZONES
- But – how do these shear zones form?

Shear fracture of magma

Deforming magma may either flow or fracture:

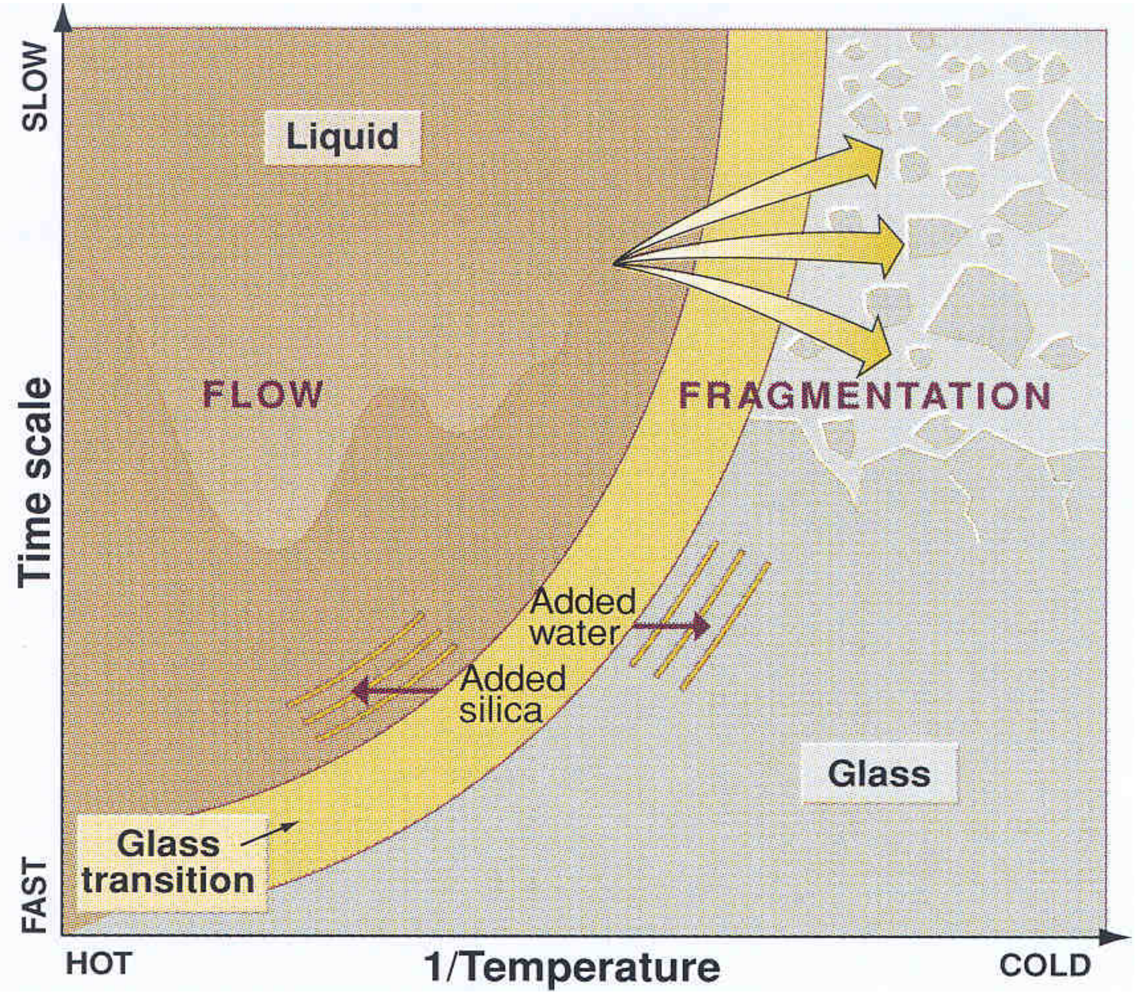
High temperatures, low strain rates: flow

Lower temperatures, high strain rates: fracture

This is due to the *viscoelasticity* of the melt, as described the previous class on fragmentation. The transition from liquid-like to solid-like behaviour in silicate melts is known as *the glass transition*

Shear fracture of magma

The glass transition: flow or fracture in magma



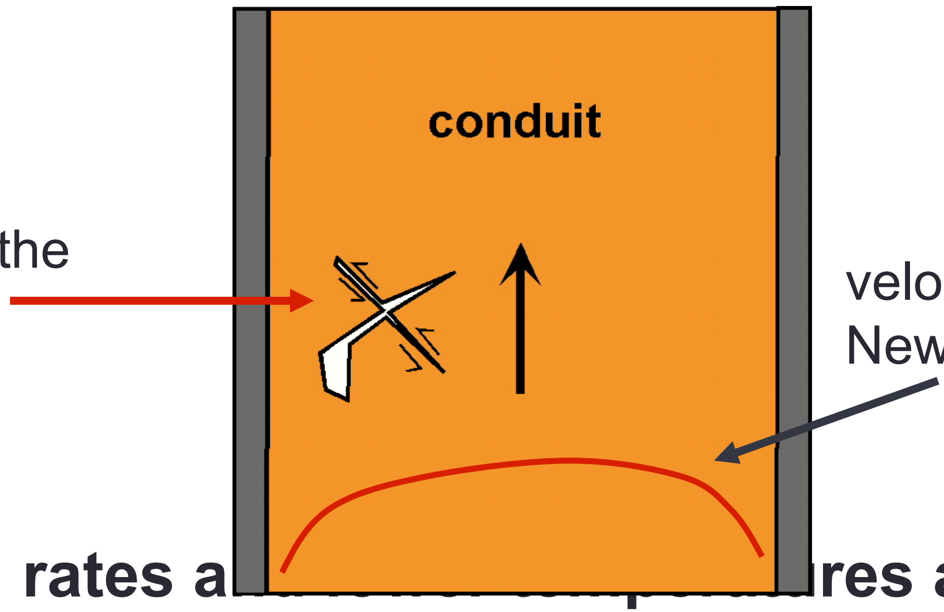
Shear fracture of magma

From deformation experiments by Dingwell and Webb: silicate melts will fracture if strain rate × viscosity is greater than a certain value (10^8 Pa).

This is because viscous flow of the melt is too slow to allow the stresses to relax – so the stresses rise until the melt fractures.

where magma will fracture?

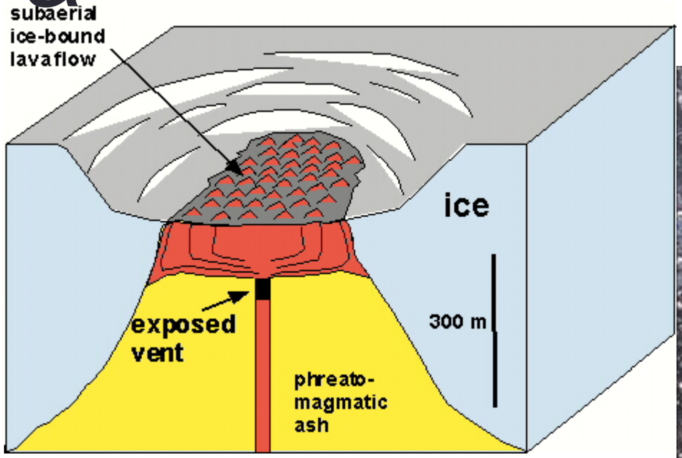
Shear fracture of magma



high strain rates and lower temperatures at conduit wall → fracture

Shear fracture and faulting in lava

a



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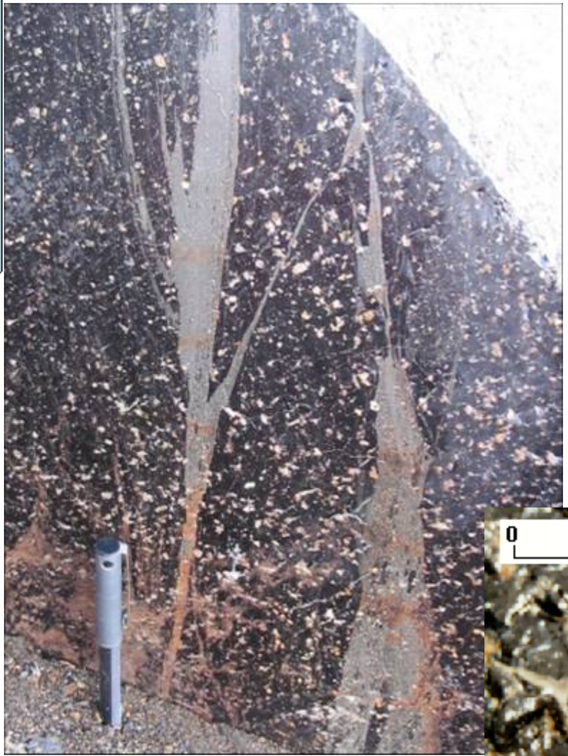

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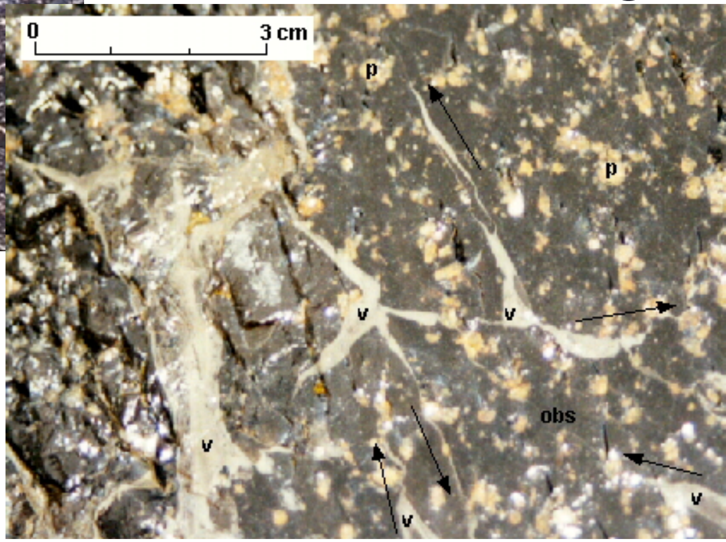


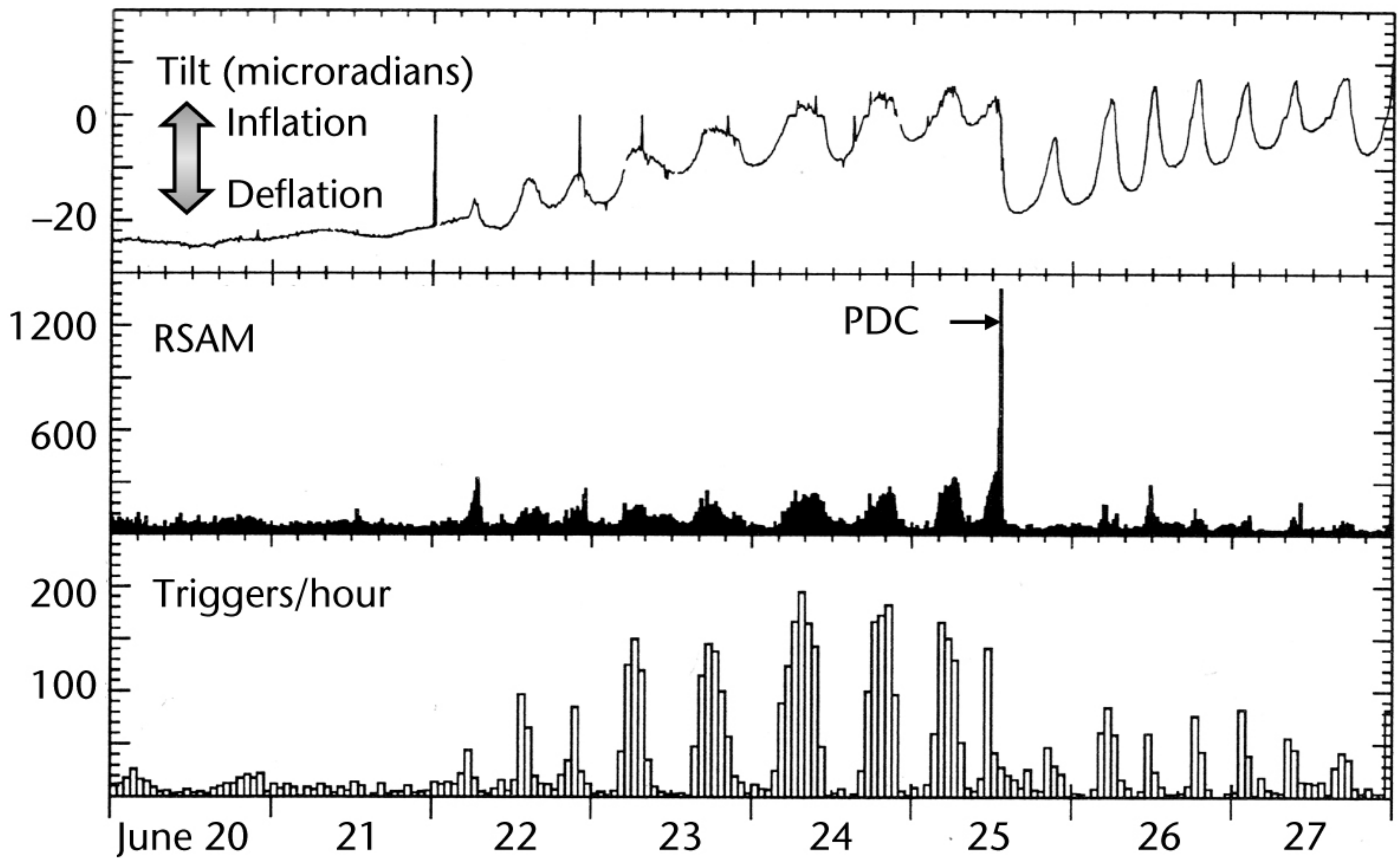
Montserrat 1997

Mount St Helens 2004

Mount St Helens 2006-8

Cycles of tilt (inflation and deflation)

Data from June 1997, Montserrat.



Cycling is due to complex inter-relationships and feedbacks between degassing, crystallization, rheology and magma ascent

Ascent → water exsolution → crystallization → viscosity increase

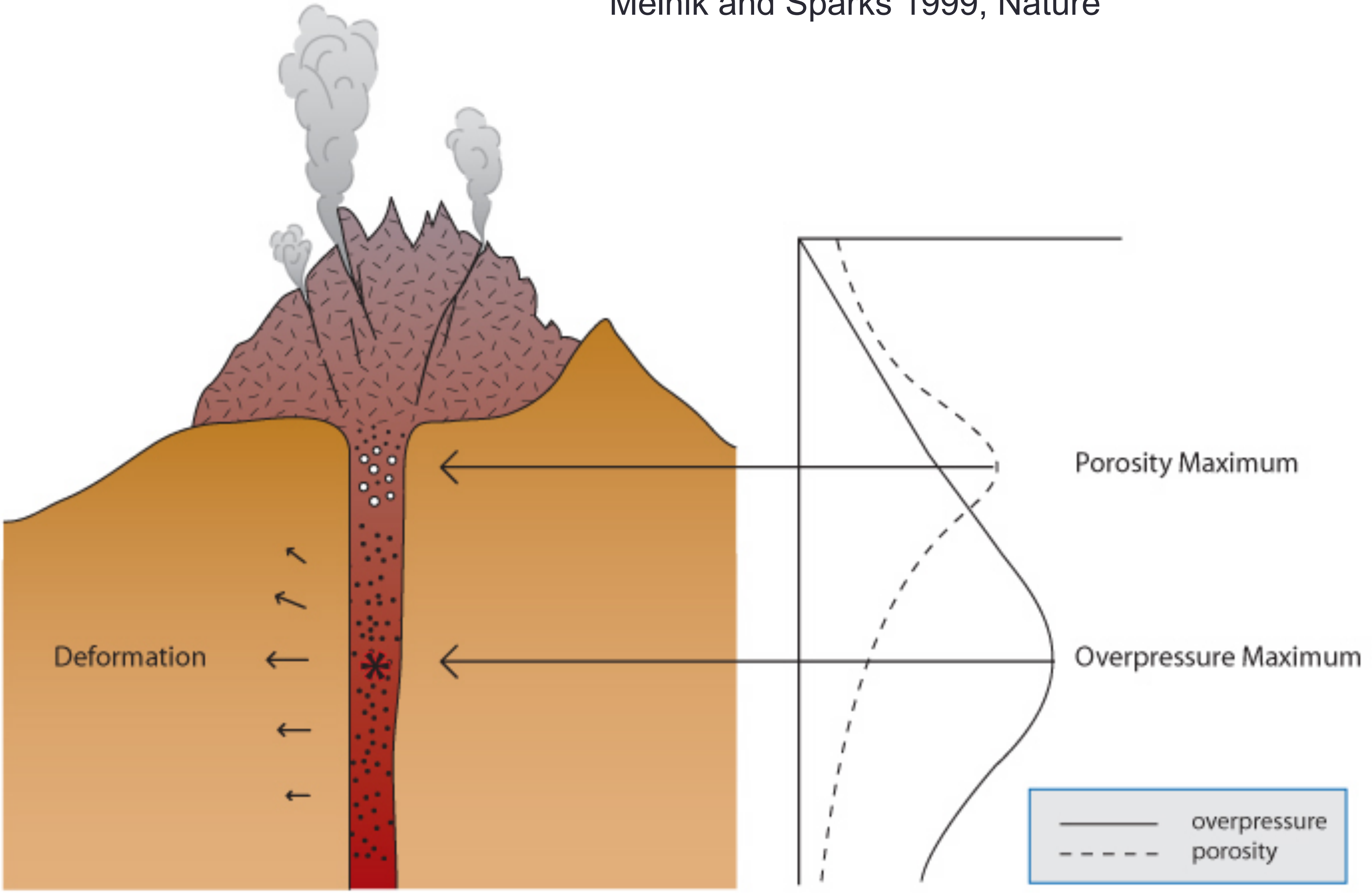
↓

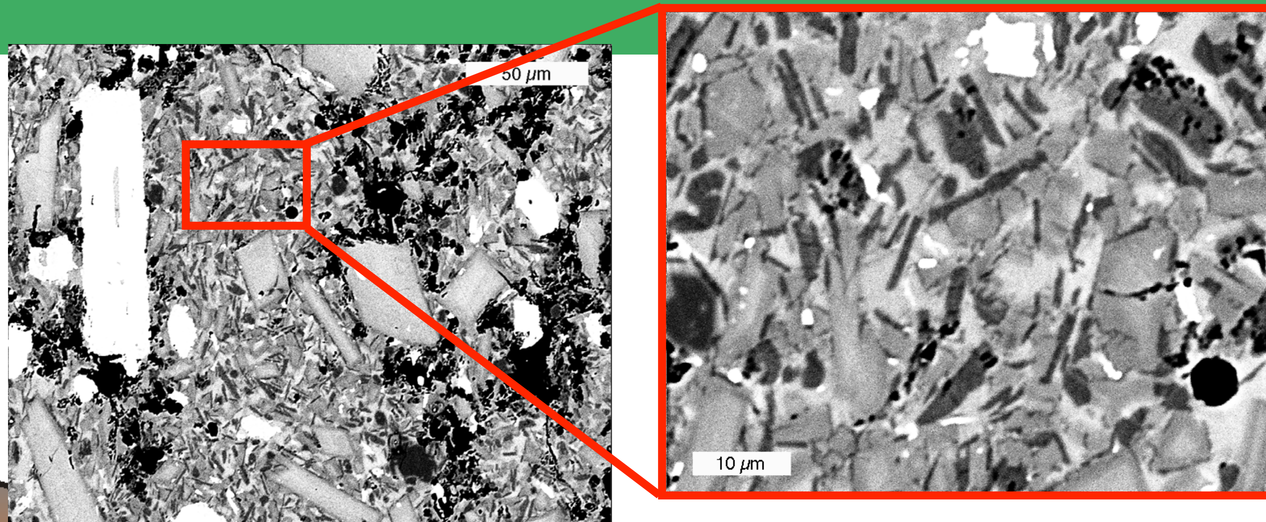
Slow ascent allows more time for crystallization and gas loss

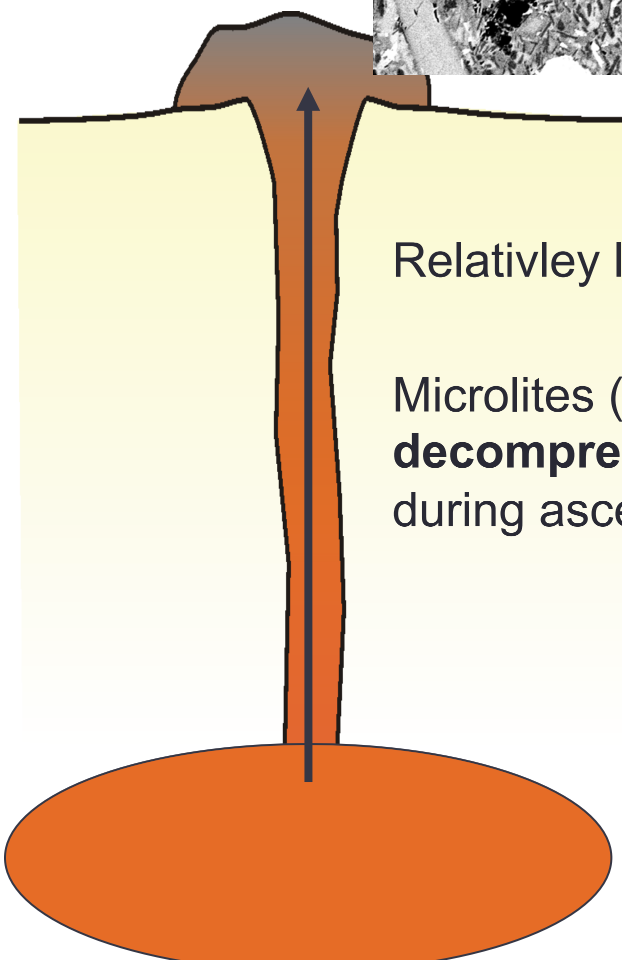
If the conduit become "plugged" then pressure builds expanding the conduit walls below the plug (causing tiltmeters to tilt) and generates seismicity

Eventually the pressure is great enough for the plug to flow up and the tiltmeters tilt back

Melnik and Sparks 1999, Nature





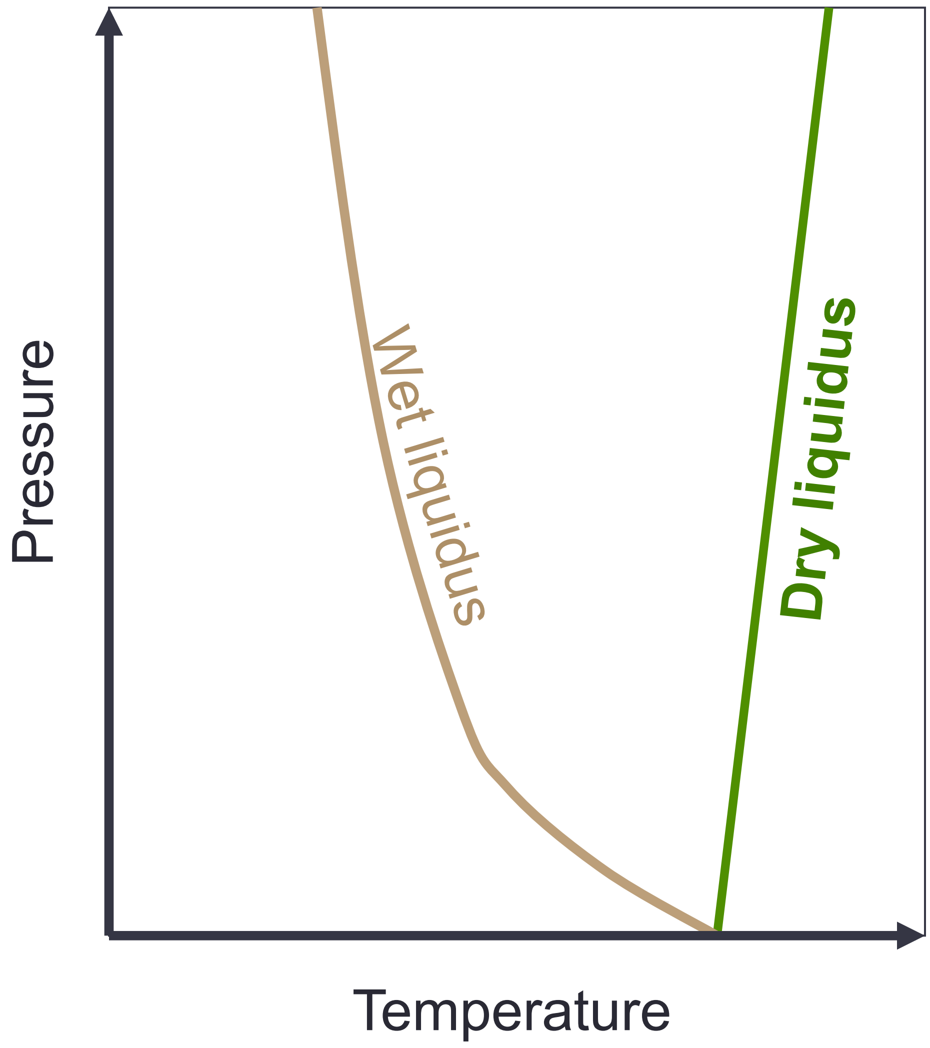


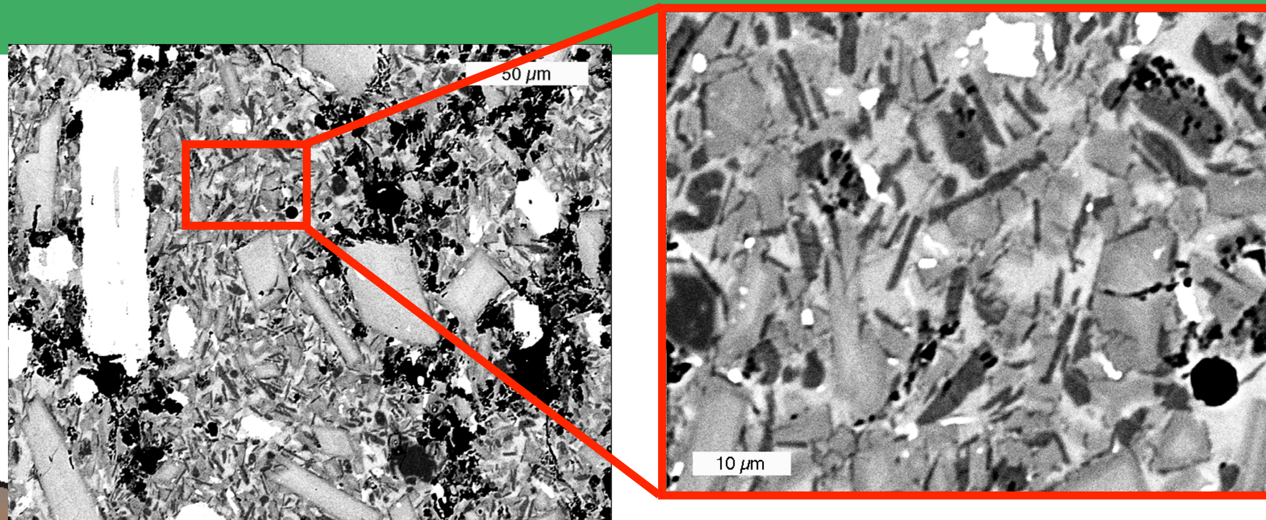
Relativley little cooling in the conduit

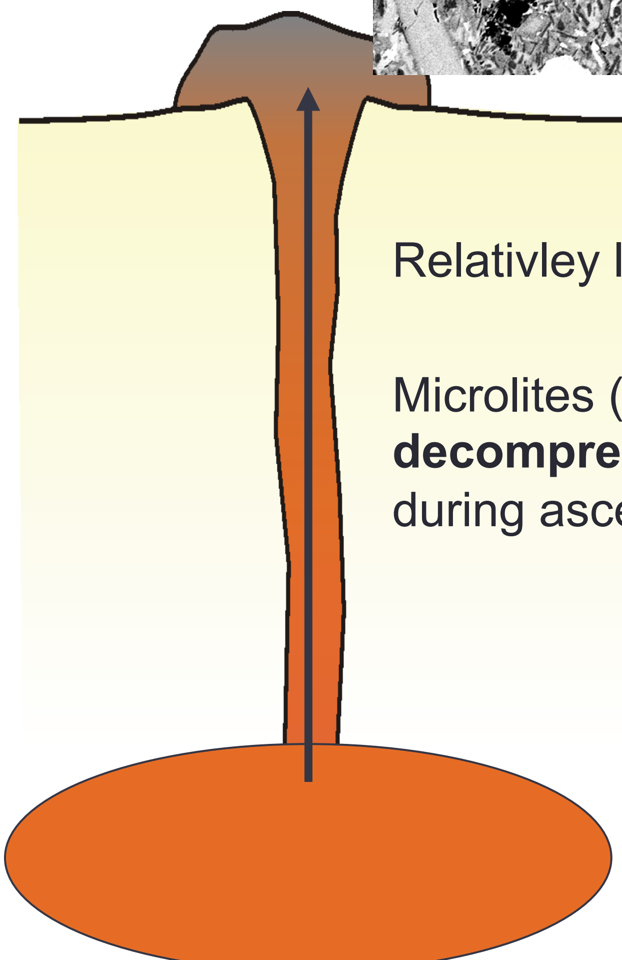
Microlites (small crystals) grow due to **decompression** of water-saturated magma during ascent

Phenocrysts (larger crystals) form in magma storage region where the magma slowly cools

Why does decompression cause the water-saturated magma to crystallize?







Relativley little cooling in the conduit

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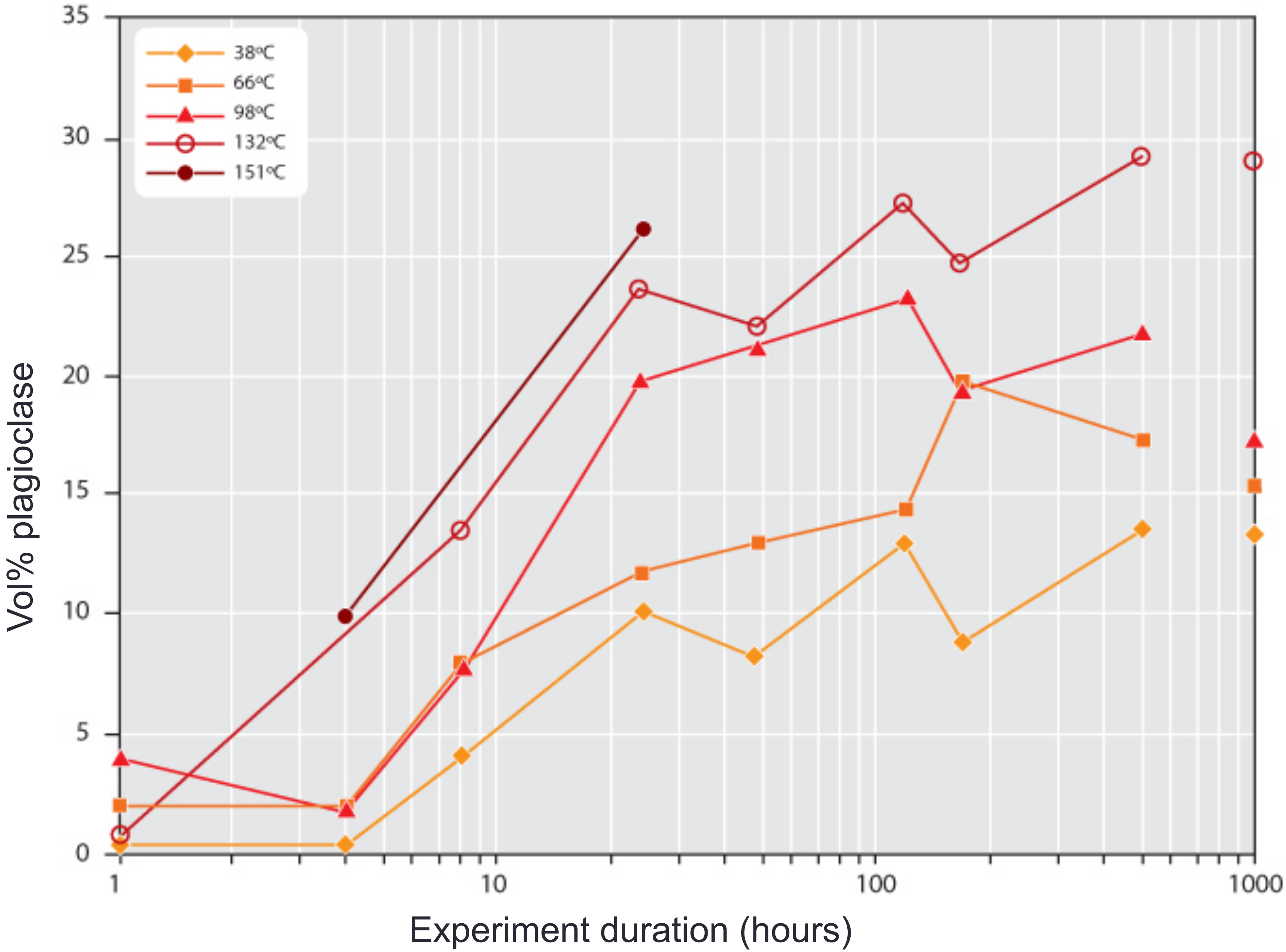
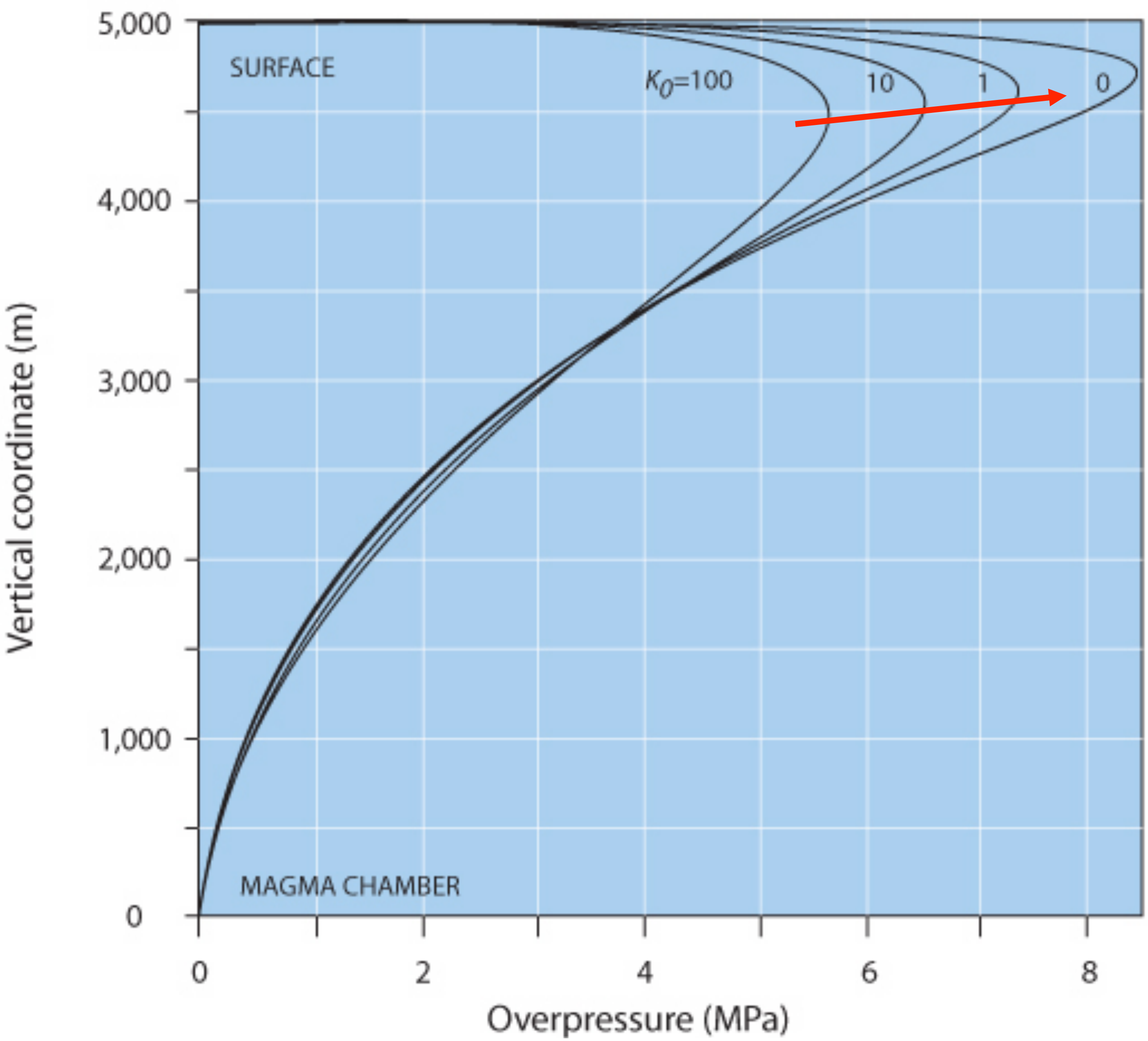
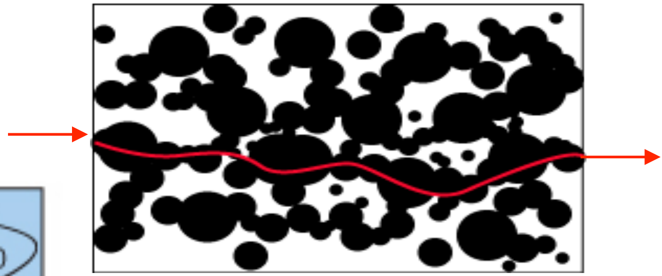
Crystallization of microlites requires time!



Gas loss by permeable flow is also a time-dependent processes





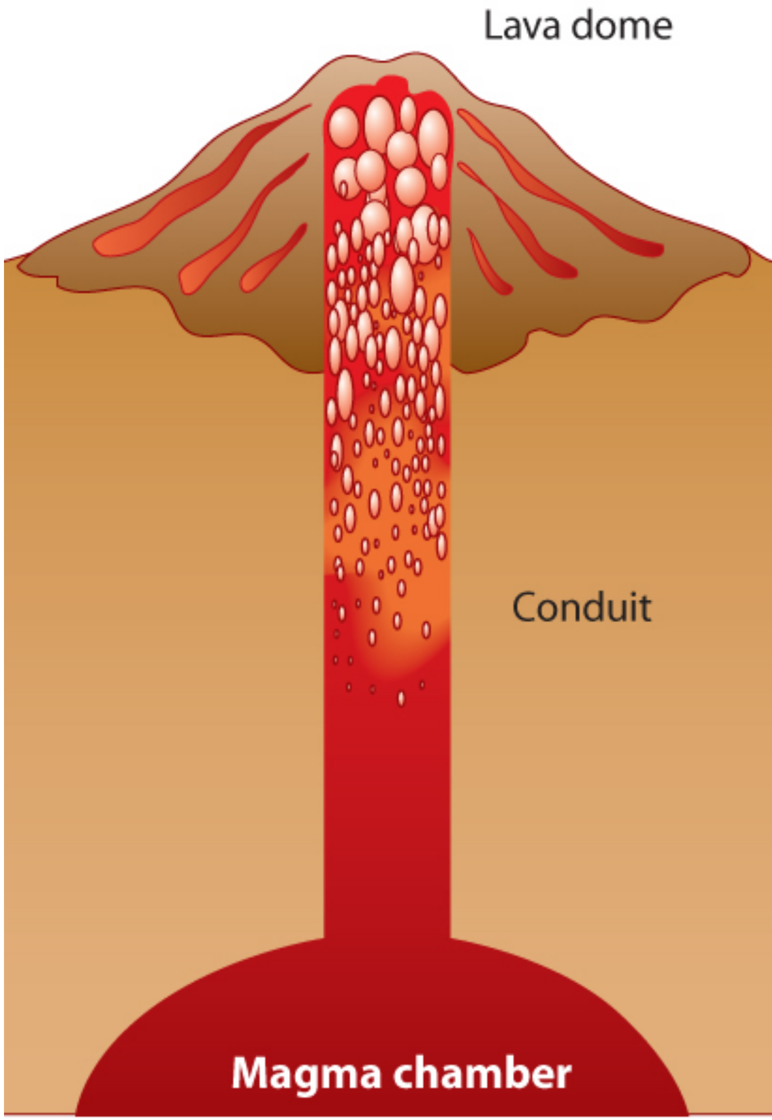
Overpressure increases with lower permeability because gas cannot escape fast enough to reduce the pressure

Three regimes are identified:

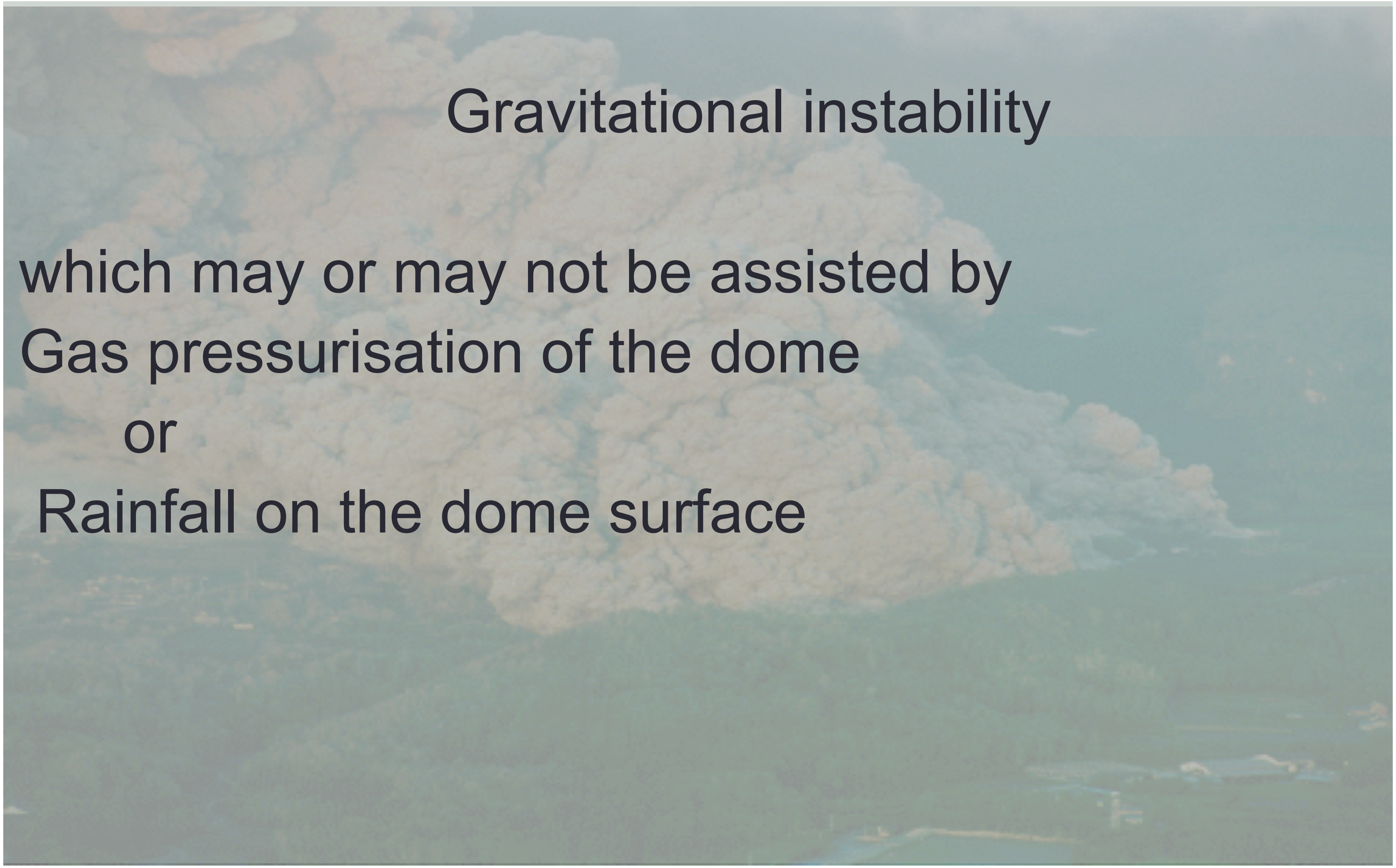
(1) the flow rate is so fast that little crystallization occurs during ascent, and the magma is relatively low in viscosity;

(2) the flow rate is sufficiently slow that extensive crystallization occurs and magma can erupt in a nearly solid state with very high viscosity and a yield strength;

(3) an unstable regime where the system fluctuates in periodic fashion between the two stable regimes.



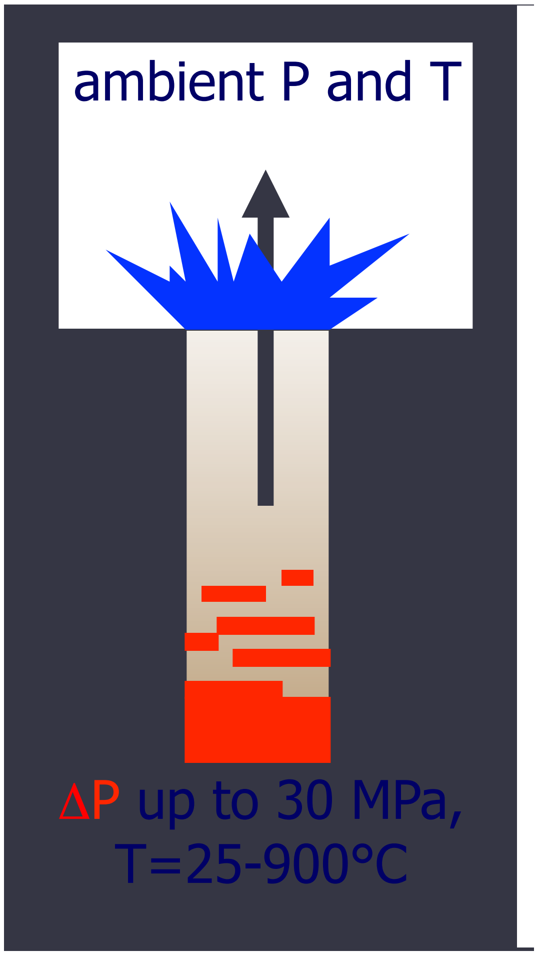
How and why do domes collapse?

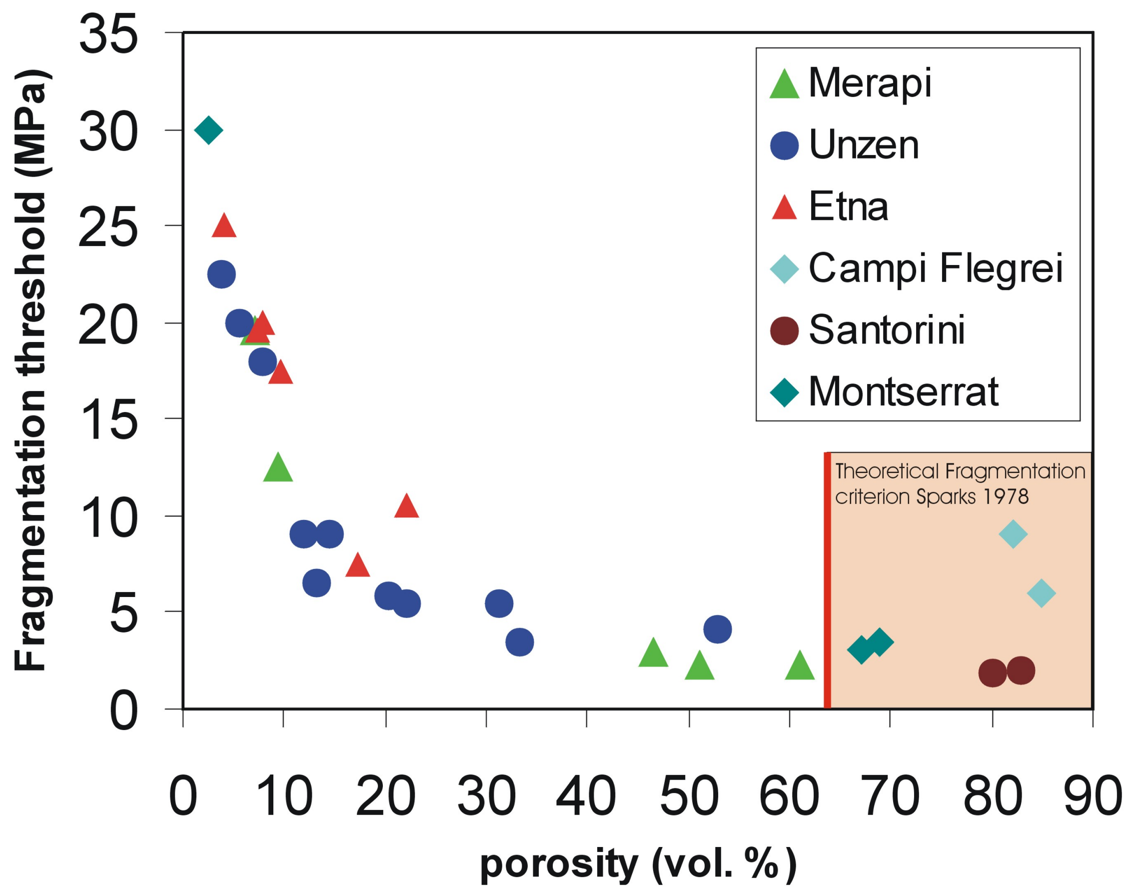


Gravitational instability

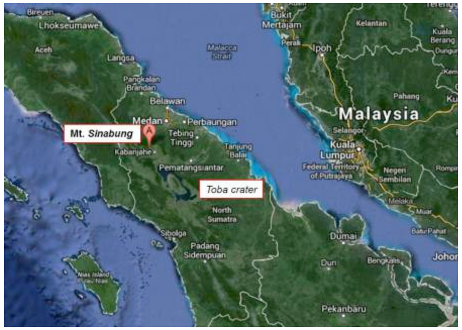
which may or may not be assisted by
Gas pressurisation of the dome
or
Rainfall on the dome surface

Major collapses can lead to explosive eruptions



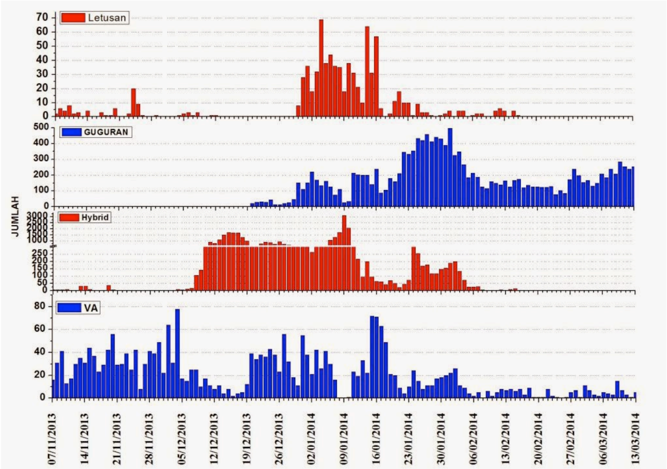


Mt. Sinabung, Sumatra, Indonesia



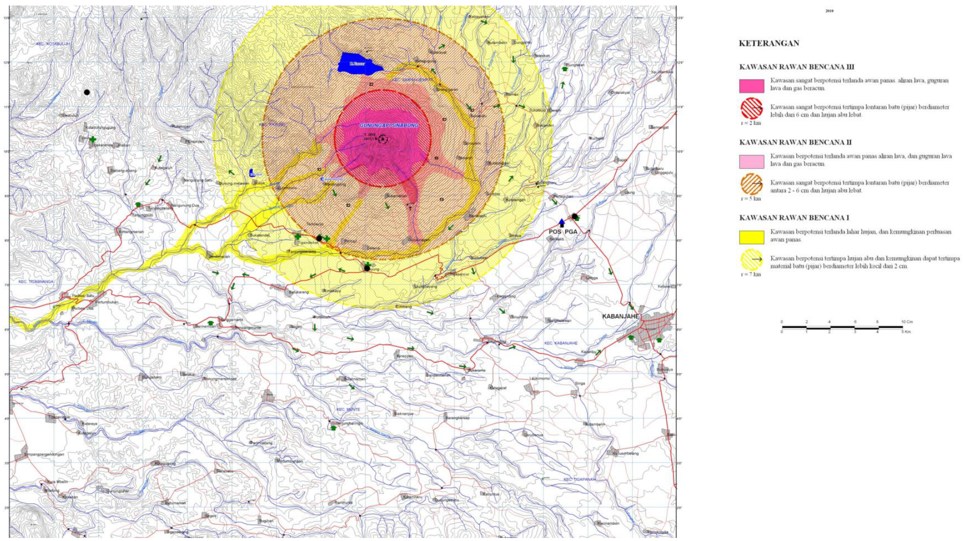
Previous eruption: Sept 2010

15 Sept 2013 start of ongoing eruption- first evacuations
17Sept -17 Dec several ash plumes up to 12 km high
28 Dec Lava dome
30 Dec first PDC
31 Dec-Feb 2014 Several PDC and ash plumes accompany dome growth and disruption
1 Feb 2014 PDC kills 16 people
5 October 2 km high ash plume and PDCs
Up to now: dome still growing, ash explosion, no PDC, finally people are evacuated.



12 Jan 2014

Mt. Sinabung, Sumatra, Indonesia



Disaster-prone region III (KRB III), is an area with high potential to be devastated by hot clouds, and lava flows, incandescent stones, intense ash fall and toxic gases.
It consists of two parts:
a. Disaster-prone areas of the mass flow (heat clouds, and lava flows), and toxic gases.
b. Disaster-prone areas to ballistic fallout and heavy ash fallout.

Disaster-prone region II (KRB II), is an area potentially stricken by hot clouds, lava flows, lava, ballistic (incandescent) and heavy ashfall. This area is divided into two parts:
a) Areas prone to mass flow (heat clouds, and lava flows).
b) Areas prone to hurl a stone material (incandescent) and heavy ashfall.

Disaster prone regions I (KRB I) is an area potentially devastated by lava and ash fall. If the eruption enlarged, then the area can be potentially affected by incandescent stones with diameters smaller than 2 cm. It is divided into two parts, namely:
a) Areas prone to mass flow (lava).
b) Areas prone to dropping material (ash and rain incandescent stones).

Official document by the Indonesian Geological Service, 2010

Villages at the foothill