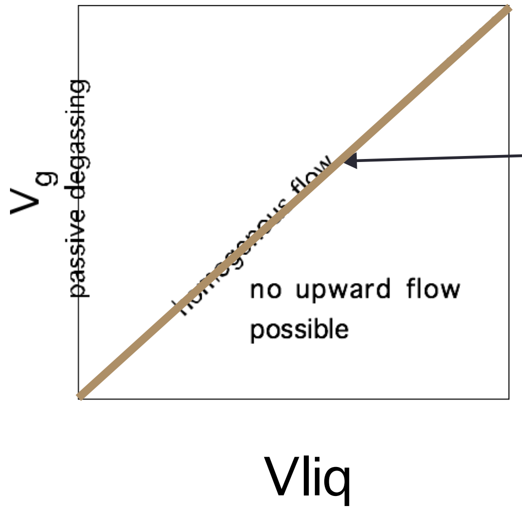
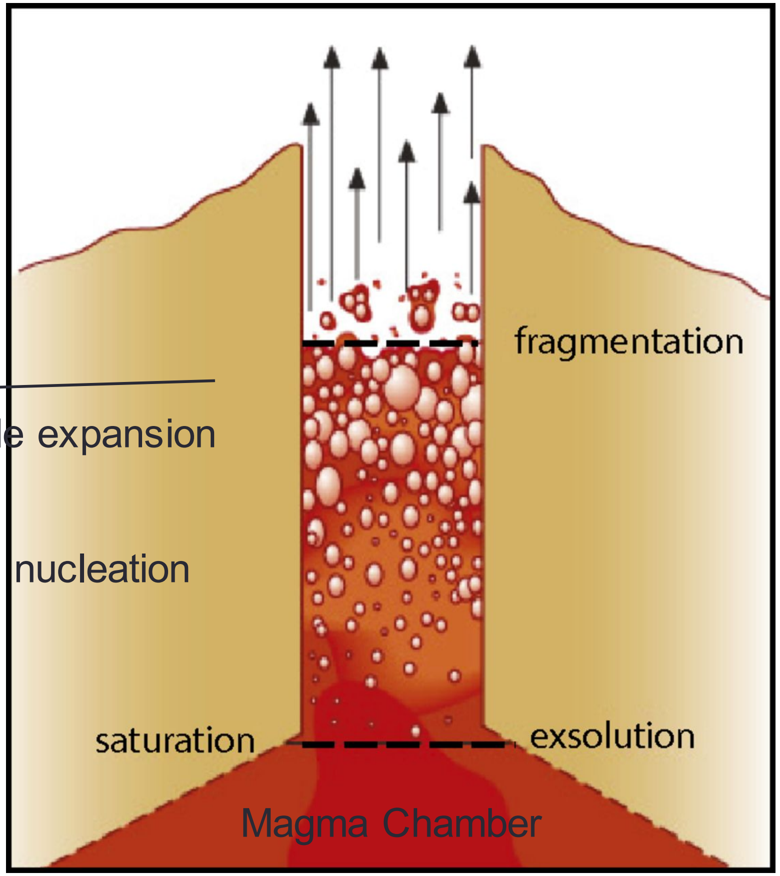
ERUPTIVE REGIMES

Laura Pioli

Conduit flow(s)



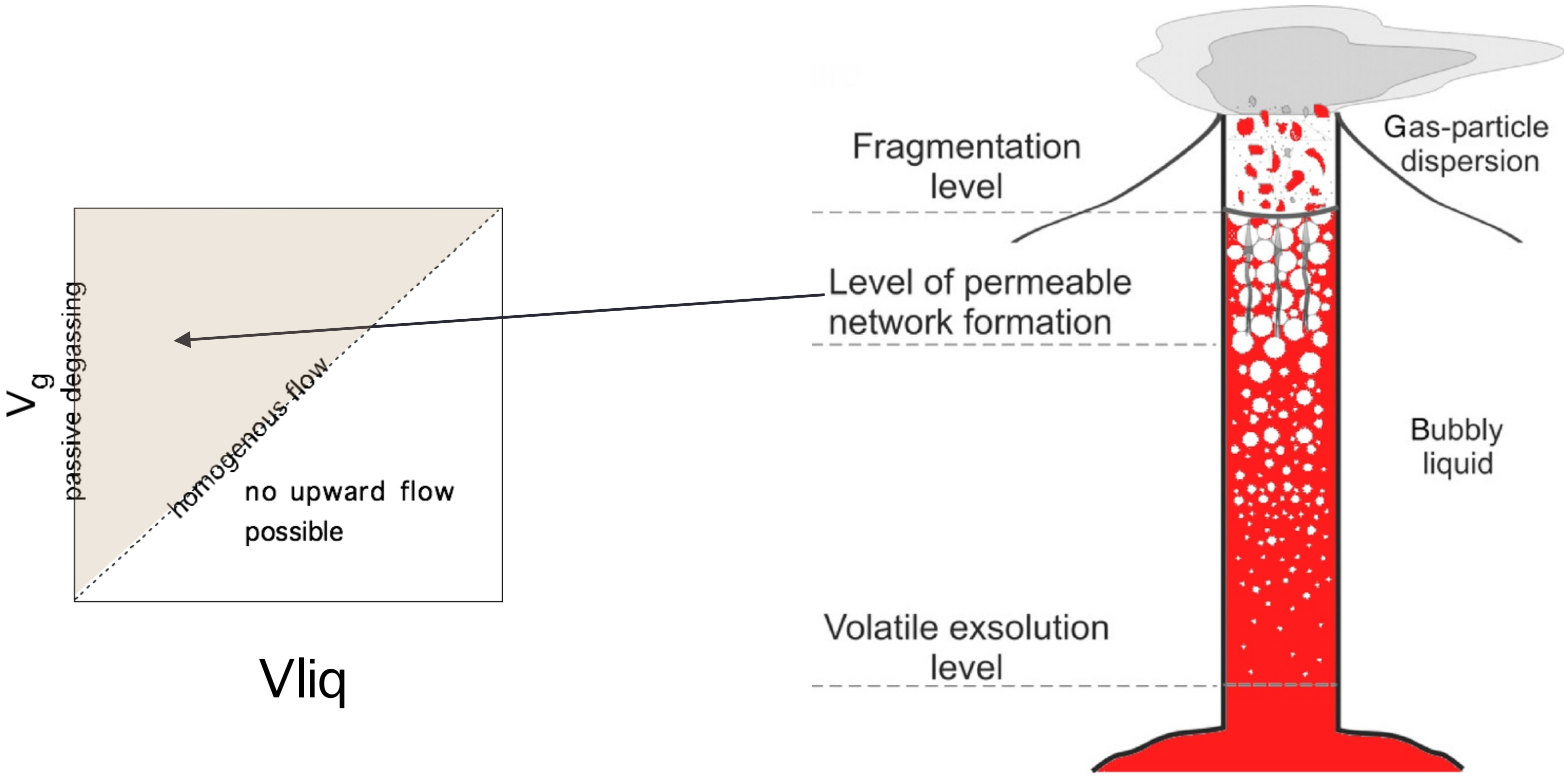


Gas-solid particles suspension

Bubbly liquid

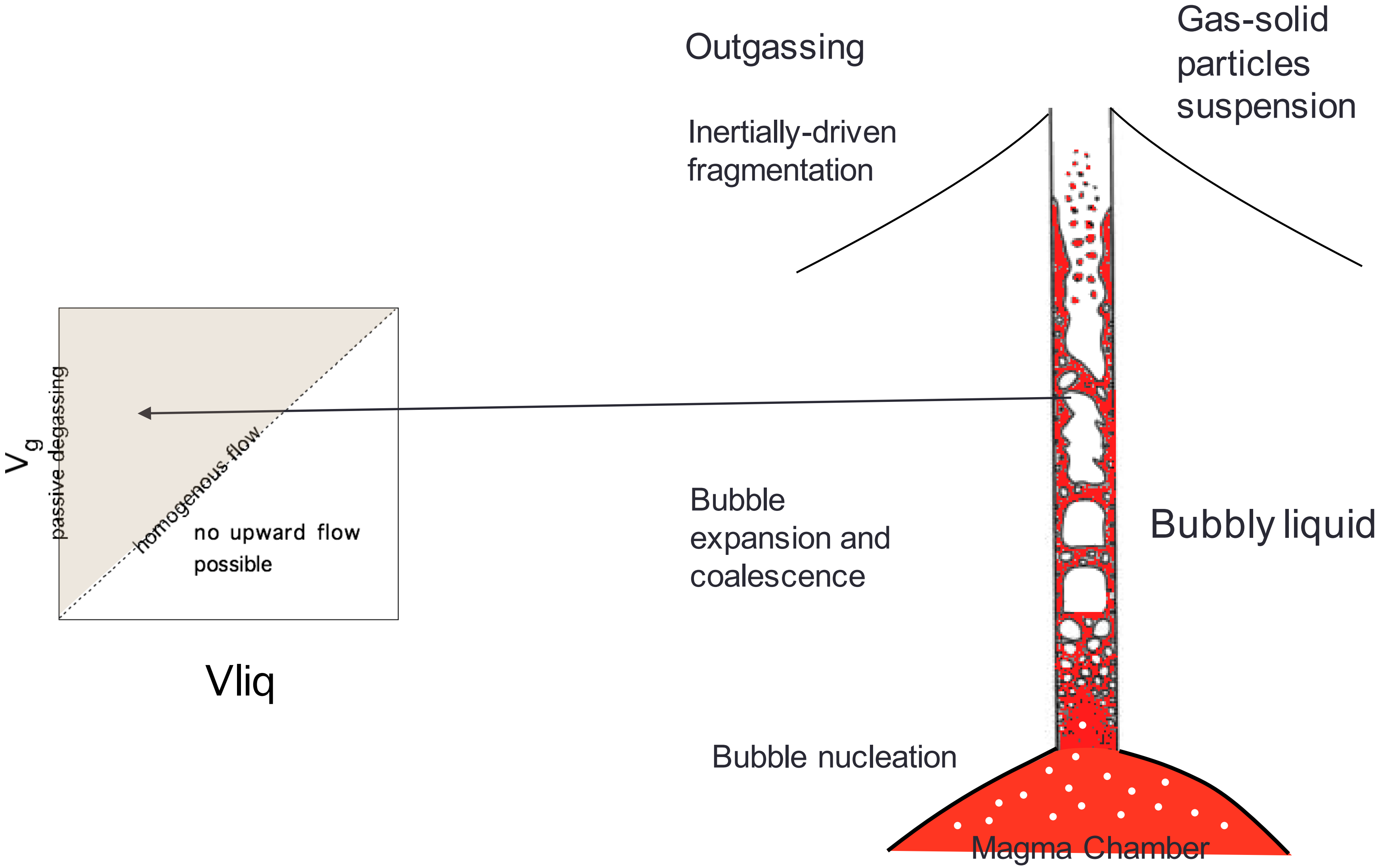
Cashman and Sparks, 2013

Conduit flow(s)



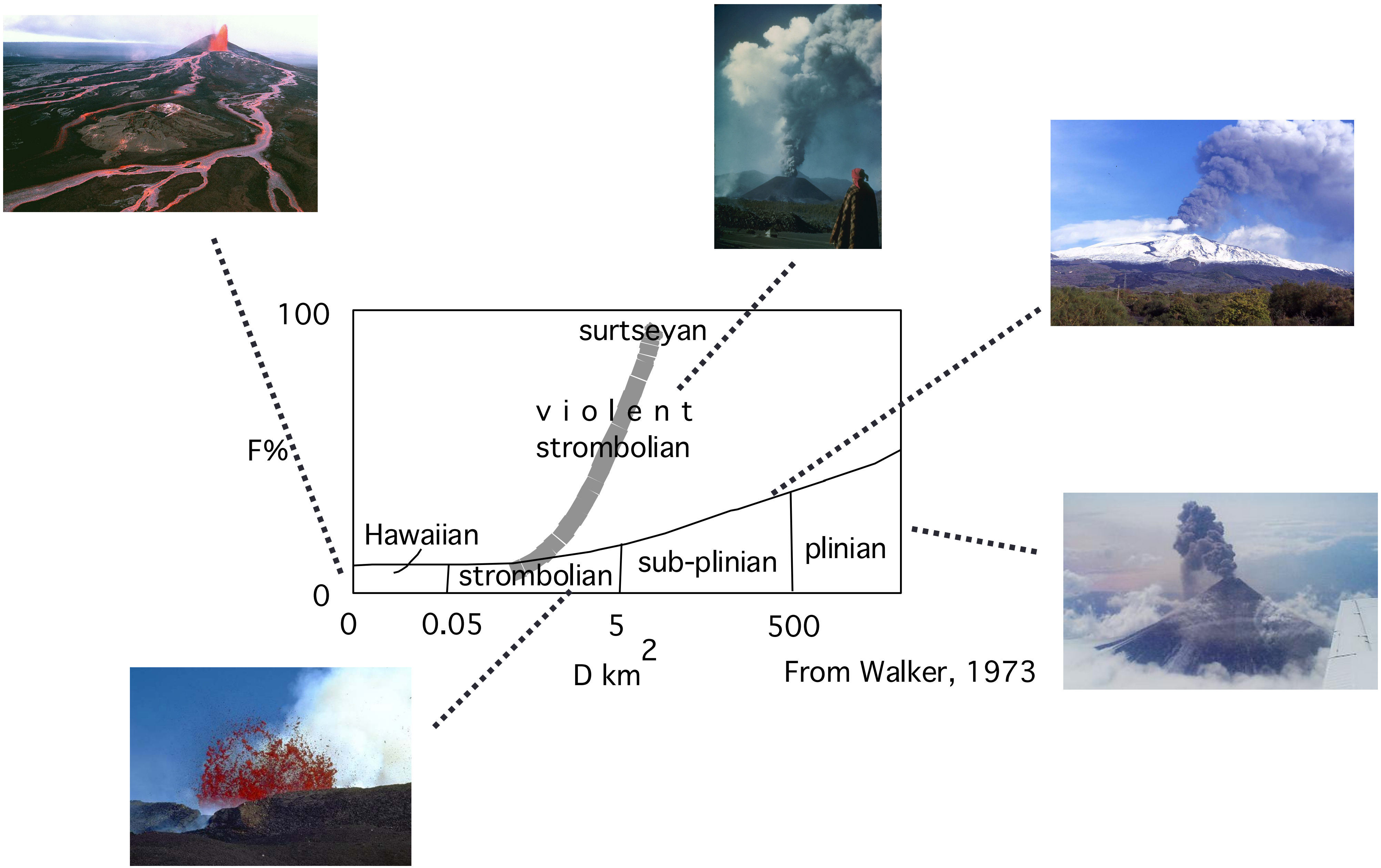
Muller et al., 2008

Conduit flow(s)



Jaupart and Vergniolle, 1986

Walker’s classification

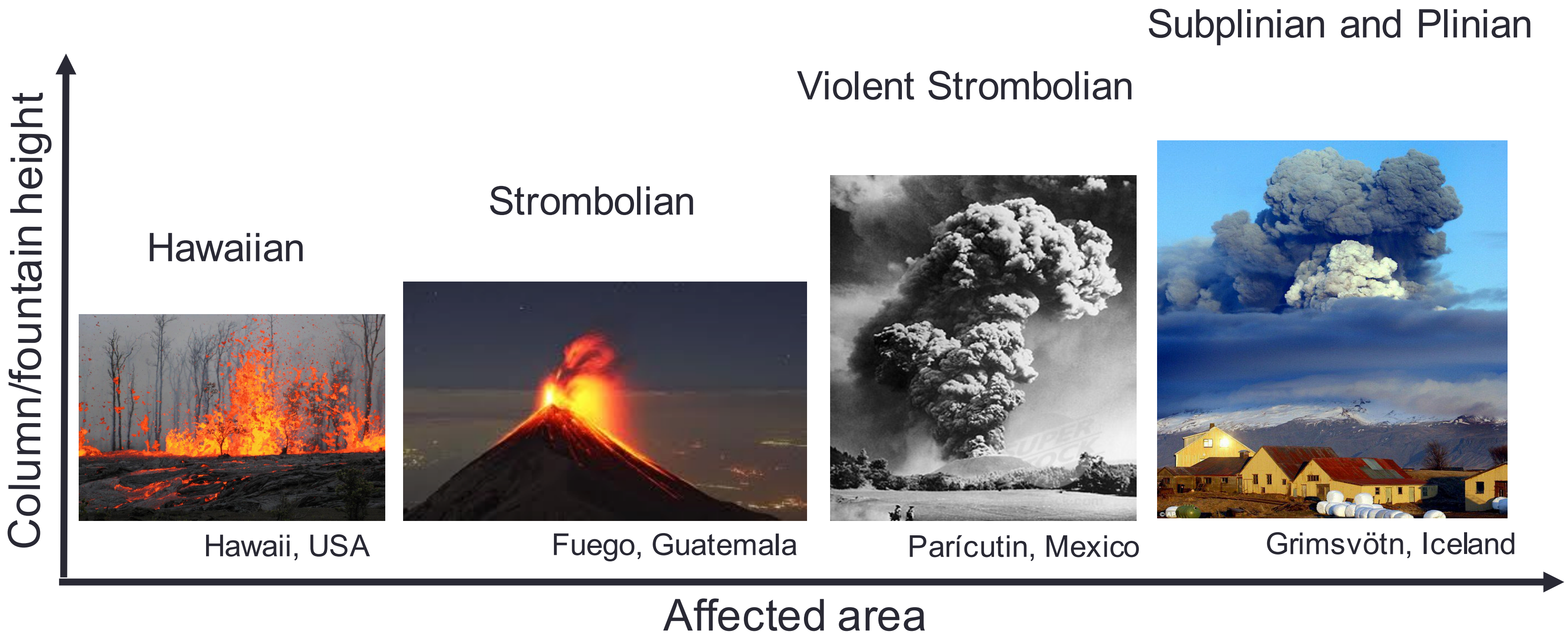


From Walker, 1973

Explosive regimes- low viscosity magmas

- Large variability of eruptive style, even within a single eruption
- Complex hazard assessment

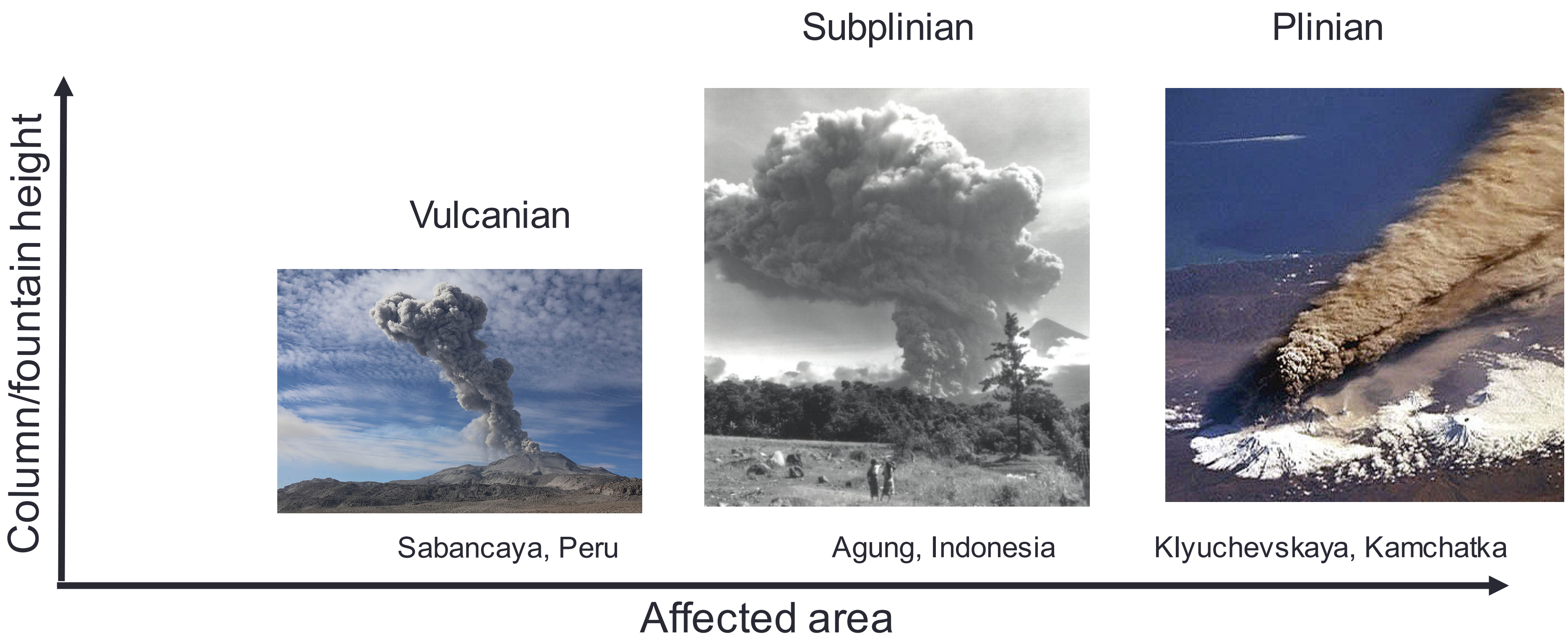
- Large variability of initial gas composition (H_2O, CO_2)



Explosive regimes- high viscosity magmas

- Large variability of eruptive style, even within a single eruption
- Complex hazard assessment

- Usually water rich and CO_2 poor



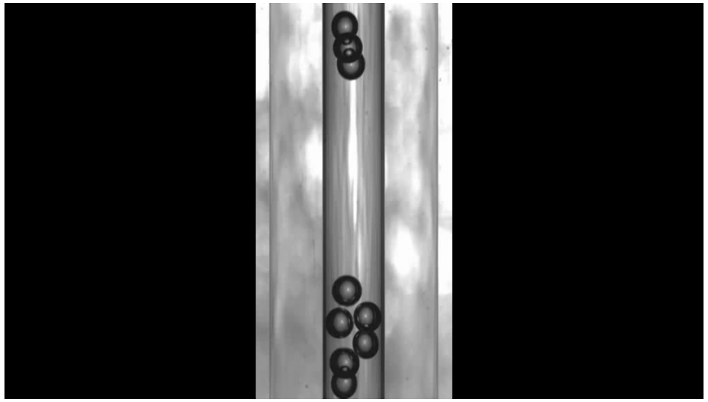
Why mafic explosivity is limited

- Low magma viscosity promotes efficient **outgassing** through bubble rise - favors gas segregation- decreases explosivity

- Low viscosity magma affects **fragmentation** - decreased efficiency of brittle fragmentation- high explosivity events requires anomalous high viscosity

The fundamental role of separate two-phase flow processes

- The magma viscosity is so low that gas bubble can rise through the melt.
- There is a separation between gas and melt and this phenomenon has strong impact on the eruption dynamics
- It also allow the gas to SEGREGATE and eventually leave the system before the eruption. The process of gas output in non eruptive time is called MAGMA OUTGASSING



Open-conduit outgassing dynamics

- Mafic volcanoes emit up to 10^3 tons of gas/day
- At central volcanoes, extensive degassing occurs at the summit vent(s) in non-eruptive periods- but it is also frequently associated with small explosion (Strombolian activity)
- Degassing fluctuations can be associated to onset of eruptions
- In low viscosity magmas, outgassing occurs in specific separated two-phase flow regimes
- Degassing is often accompanied by seismic and infrasonic tremor

Stromboli, Italy

Does gas segregation play a primary role in the eruptive style?

- Differentiation of eruptive activity within the same eruption and at the same time
- Gas segregation can decrease or enhance explosivity (i.e. violent strombolian activity)

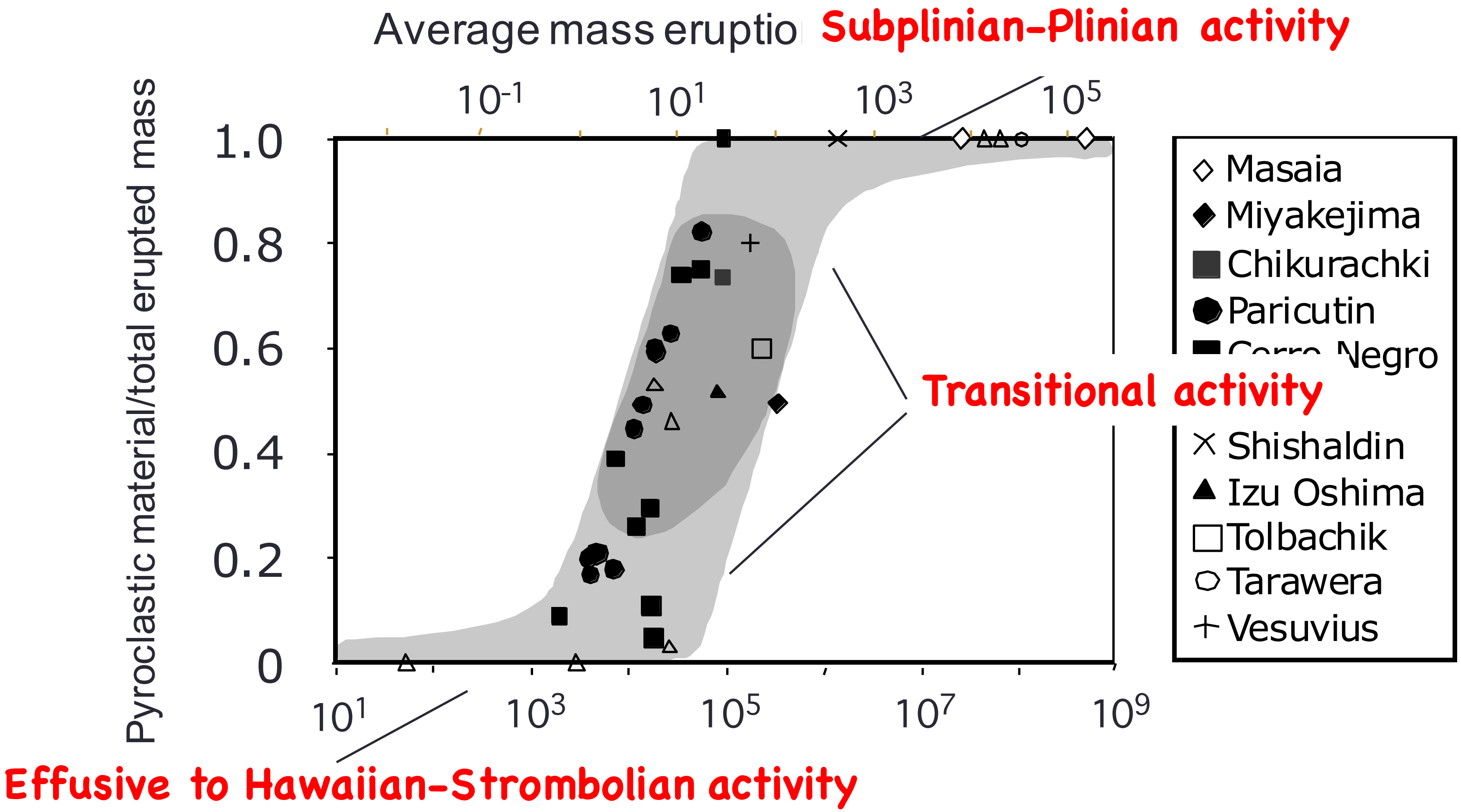
Etna, Italy

Violent strombolian activity

- Lava flow emission typically contemporaneous with explosions, usually from lateral vents
- Shallow gas segregation

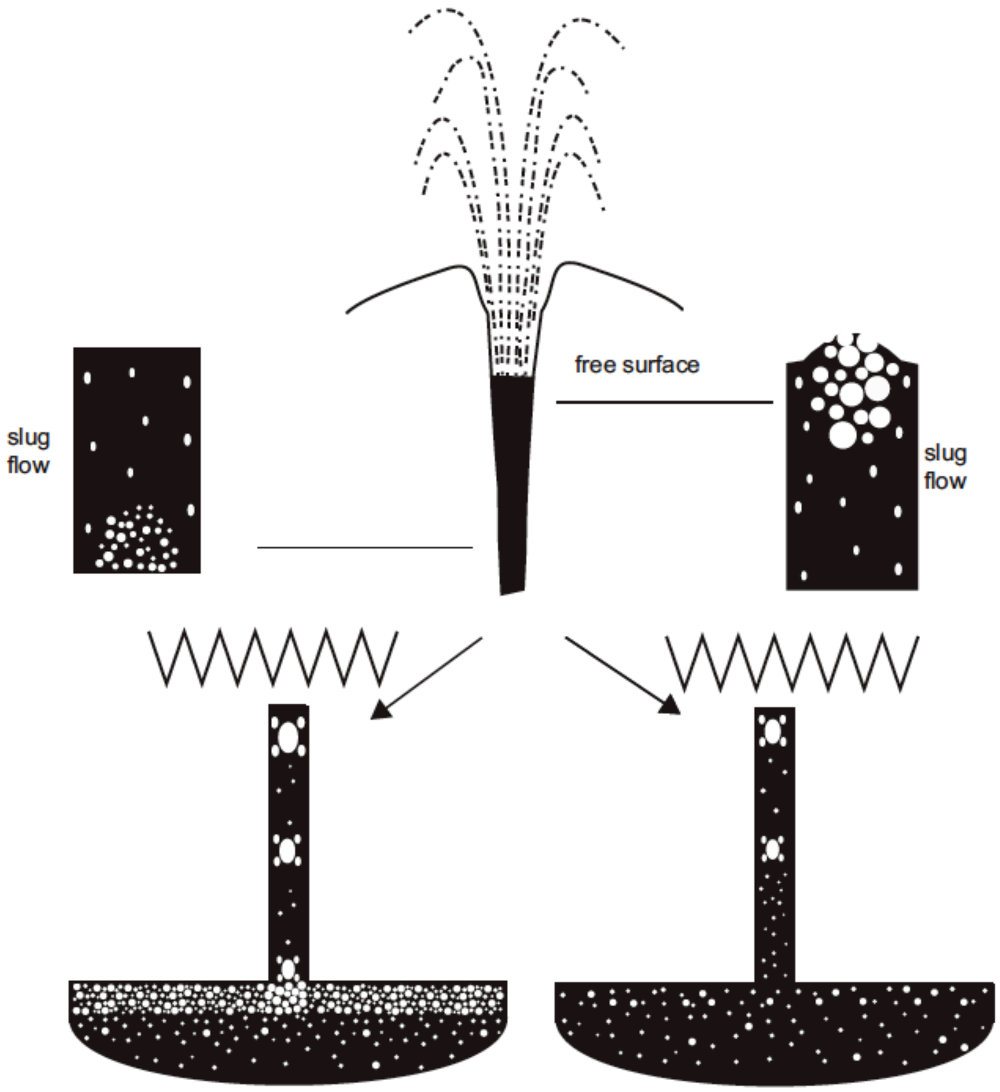
Tolbachick, Kamchatka (1975)

The role of gas segregation in low viscosity systems



Pioli et al., 2009, JVGR

Two models for separate flow…



Foam collapse

(Vergniolle and Jaupart, 1986)

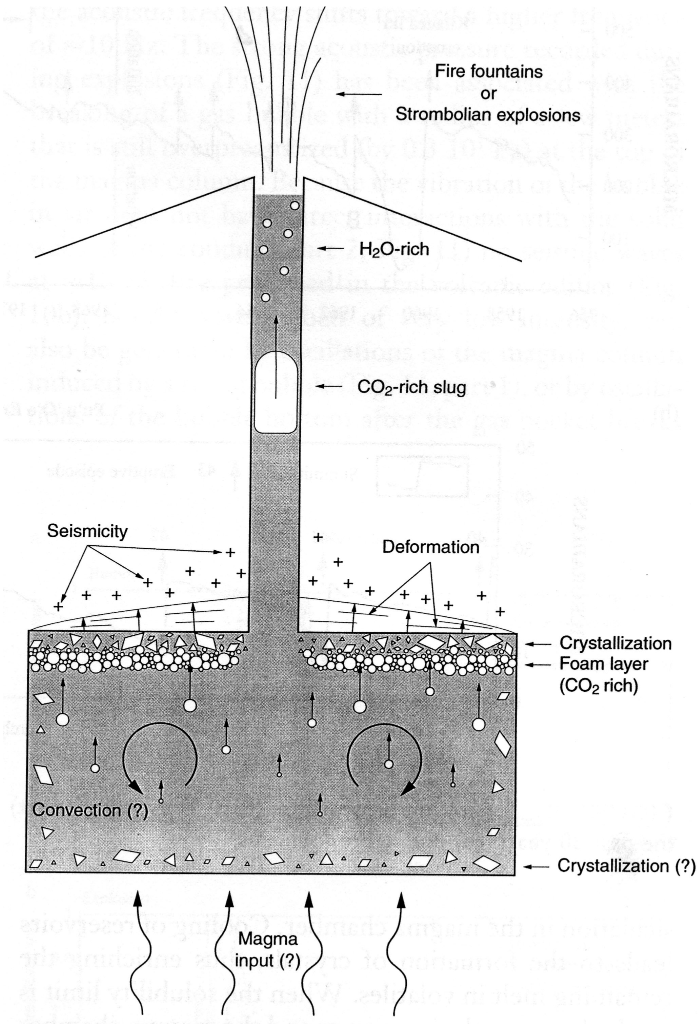
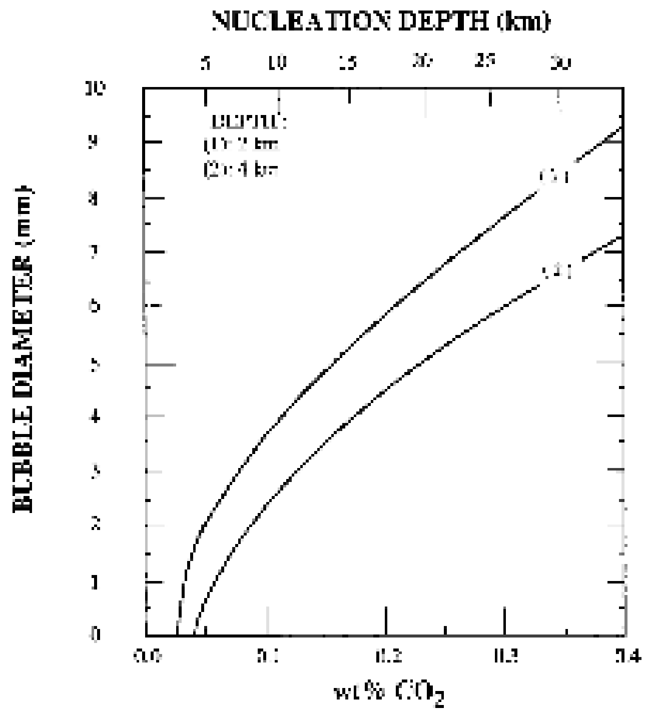


FIGURE 7 Sketch of a basalt volcano and phenomena related to magma storage and eruption.

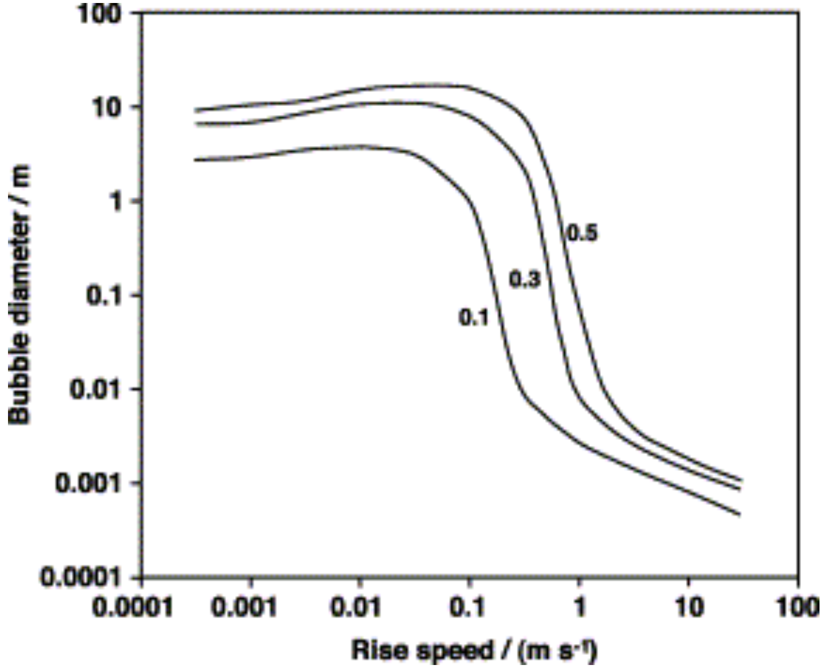


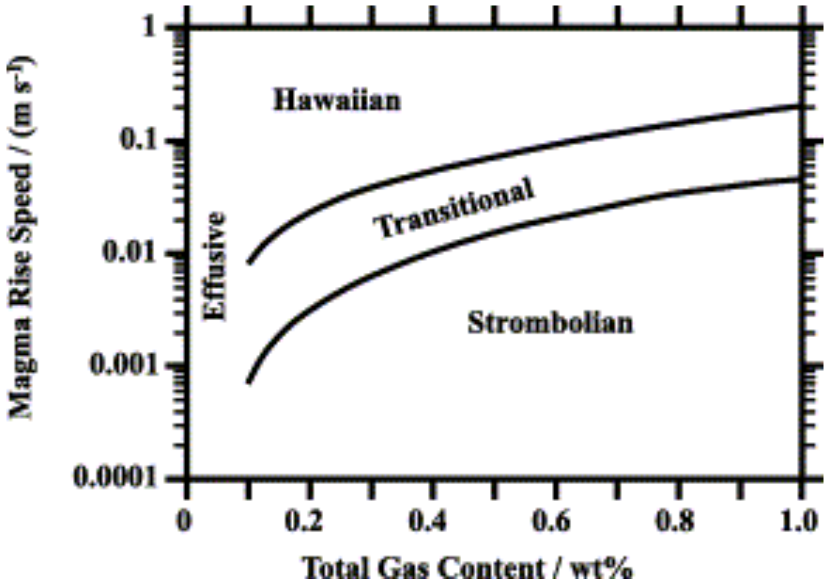
Eruptions are CO_2-driven

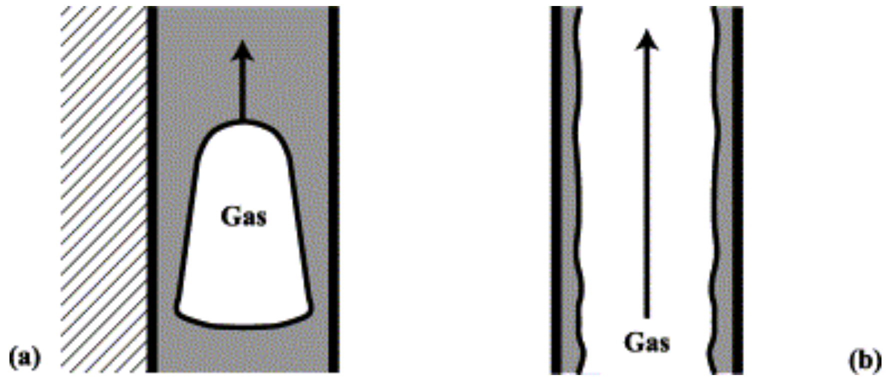
Magma rise speed model

(Head and Wilson, 1994)

- Magma rise speed dependent dynamics
- Threshold V=0.1 m/s
- Eruptions are H_2O driven







Fragmentation dynamics

- Magma viscosity, bubble and crystal volume fraction and size distribution

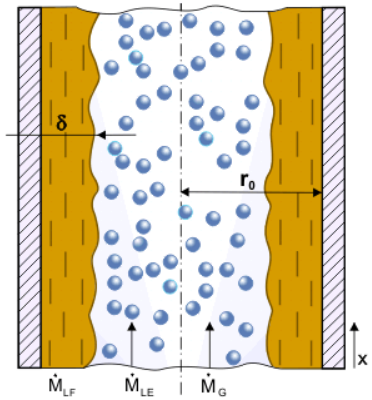
- Brittle fragmentation
- Stress, strain rate,
- and/or decompression rate

- Ductile fragmentation
- Surface tension, inertial forces,

flow regimes

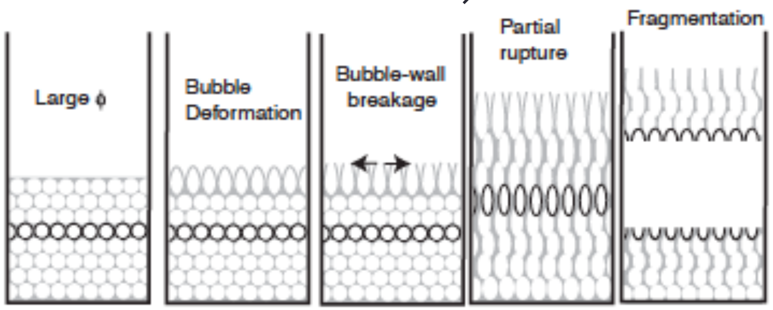
Fragmentation dynamics

Fountaining



Annular flow

(1) Shear instability (Kelvin-Helmholtz instability),
(2) Acceleration instability (Richtmyer-Meshkov)
(3) Stretching and thinning (Rayleigh-Plateau instability).



Namiki and Manga, 2004

Bubble expansion

Bubble burst

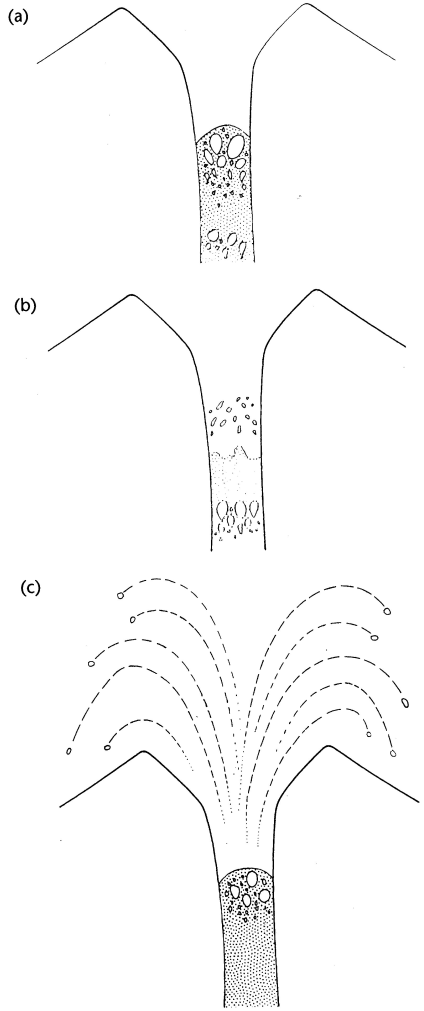
Hawaiian eruptions

From fissures to central conduit
Fire fountains or curtains
H= 100-500 (1600) m
Mass Eruption Rate= 50-1000 m^3/s
Gas/magma~70:1
Associated to lava flows
Mainly cone-forming

Puu Oo, Hawaii

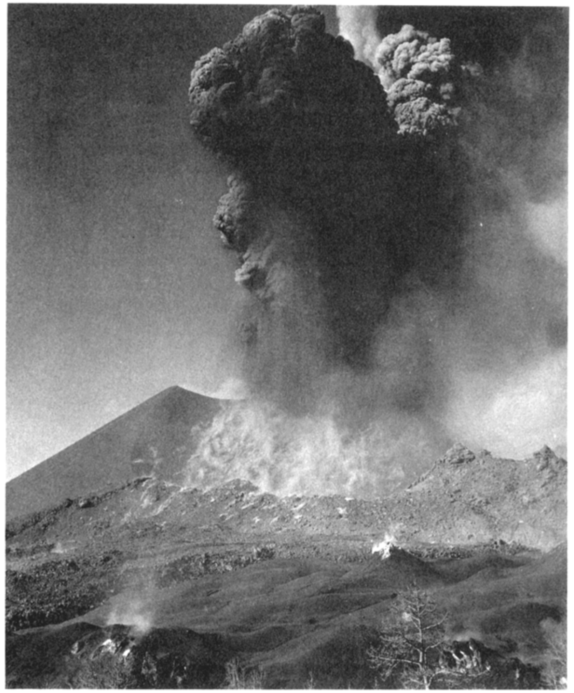
Strombolian eruptions

H= 100-500 m
Fountain structure
MER= 10^{-3} -10 m^3/s
Gas/magma~10000:1
Explosion frequency:
10^0-10^2/hour
Typically cone forming



Increasing explosivity…

- Violent strombolian
- Surtseyan
- Subplinian
- Plinian



Paricutin-Mexico (1943)

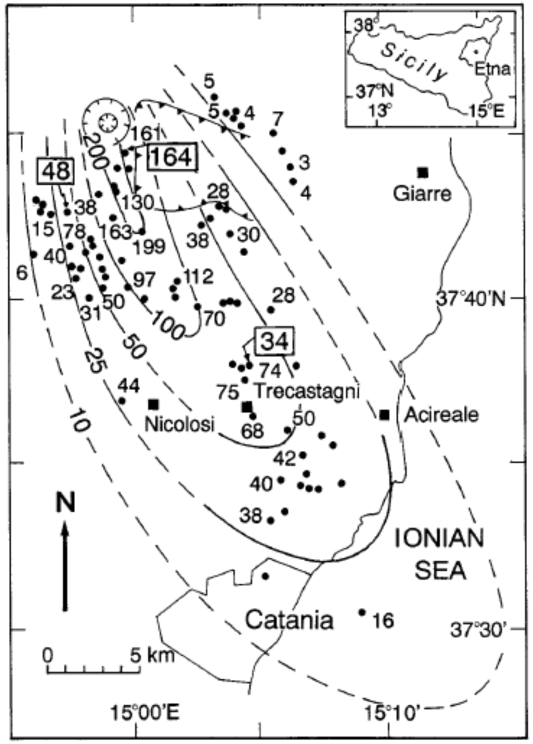
Etna (2002-2005)

Plinian-subplinian activity

Eruption column height: 20-32 km (Plinian)
>8-10km (Subplinian)

Shishaldin, Alaska (1999)

Etna (122 bc)



KNOWN PLINIAN ERUPTIONS:
Etna, 122 b.c.; Tarawera, 1886; Masaya, 60 and 2 ka b.p.

Violent strombolian activity

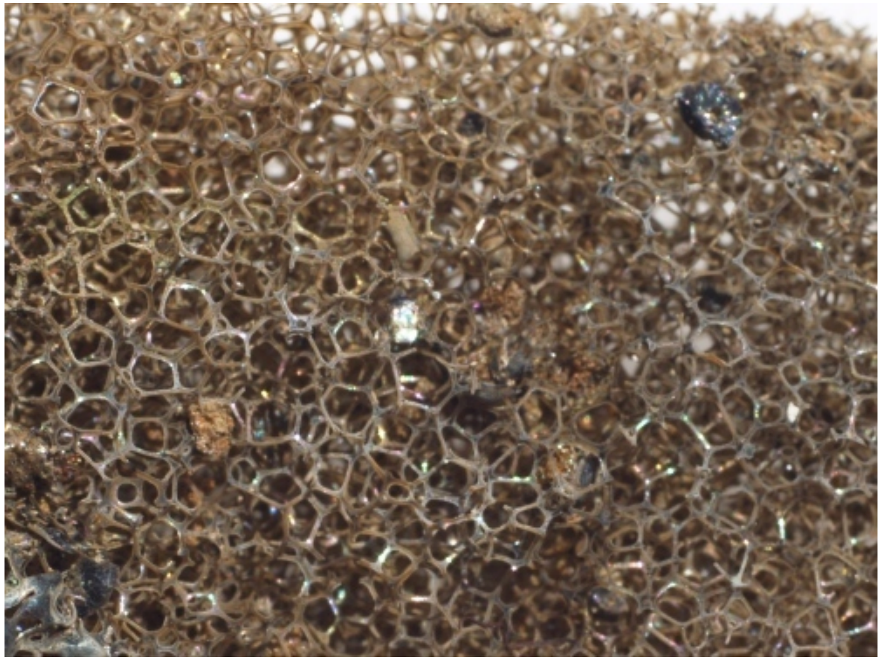
- Both cone and sheet-forming
- Associated with lava flows
- Pulsatory, non sustained dynamics
- High ash-charged columns

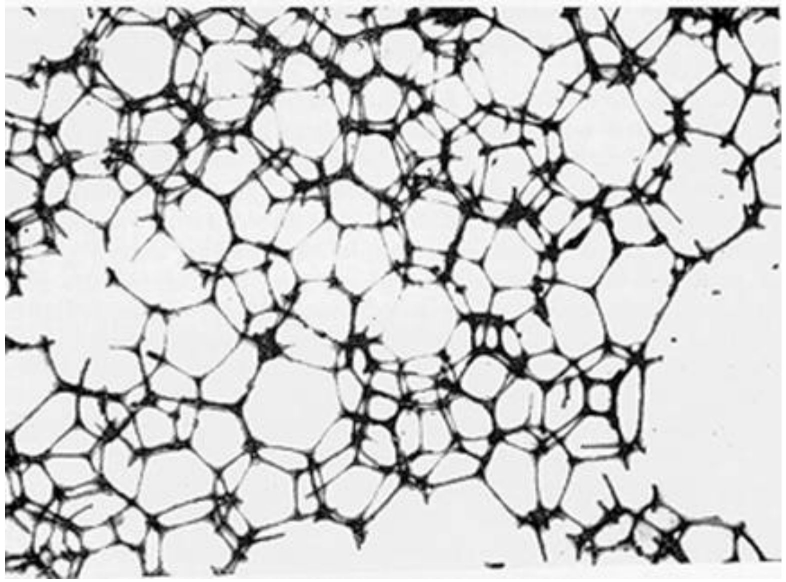
Parìcutin, Mexico (1943-1951)

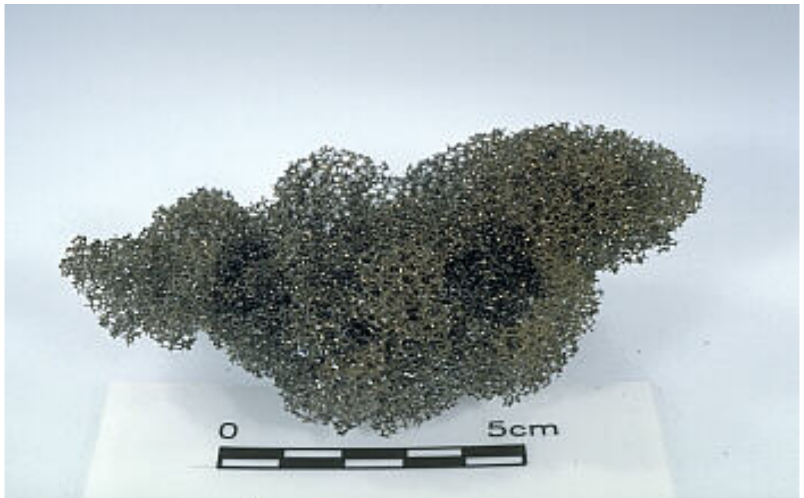
Cerro Negro, Nicaragua (1968)

Fuego, Guatemala (1974)

Products of eruptions-Hawaiian

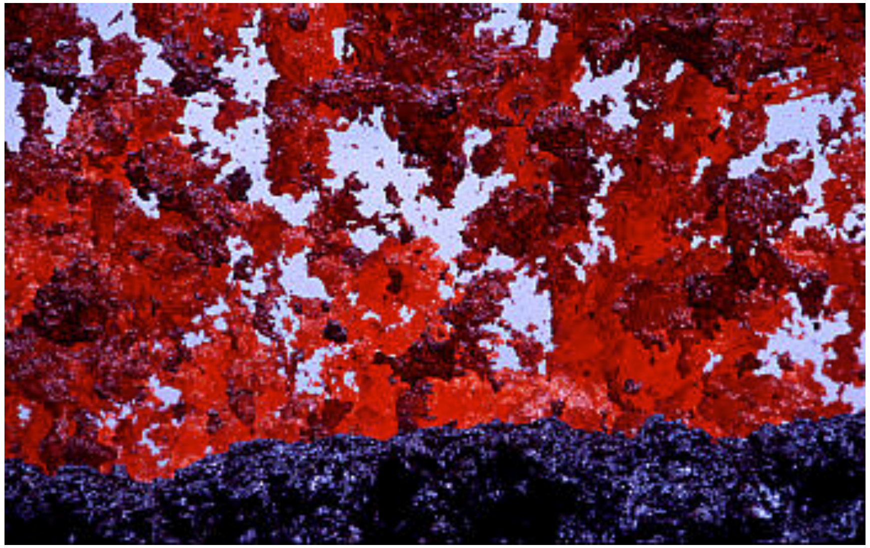


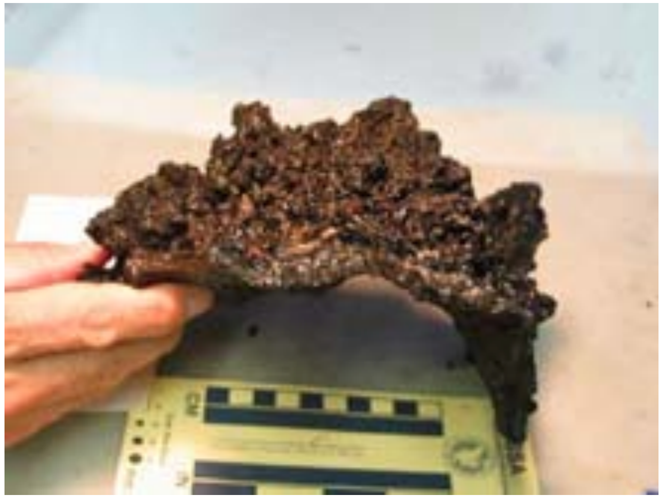




- reticulite

Products-Hawaiian to Strombolian



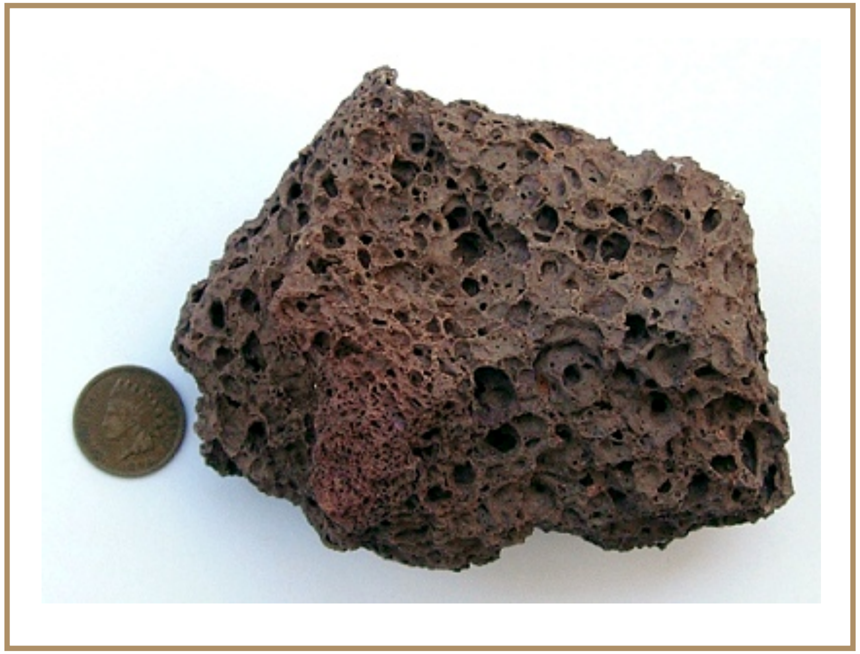


spatter

Products -Hawaiian to Strombolian

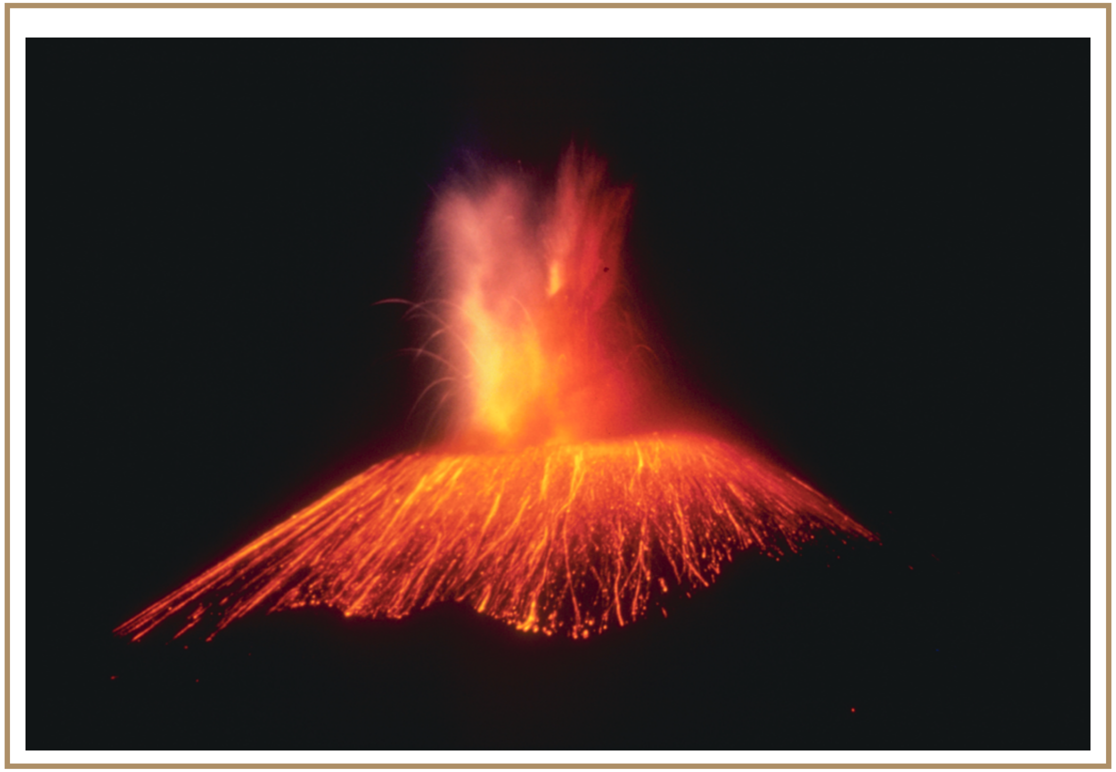
bombs

Strombolian scoria



Very thick walls between bubbles
Typically reddish or black

Strombolian activity- scoria cones

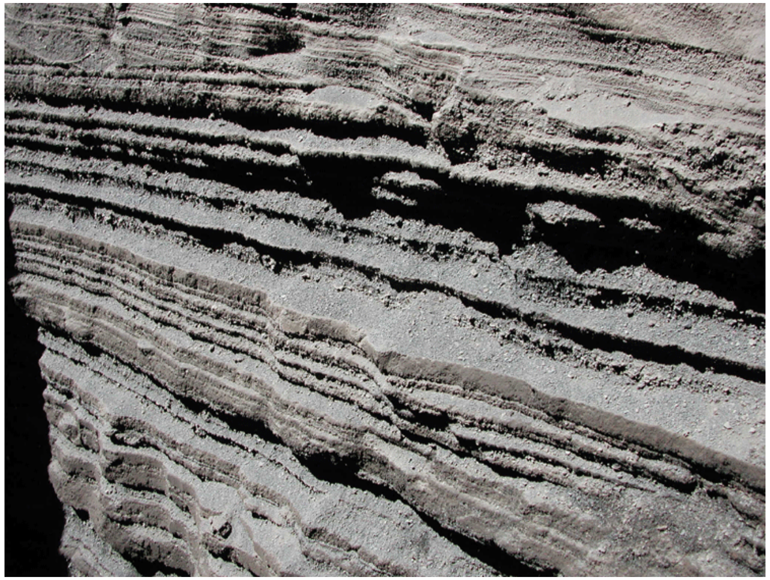


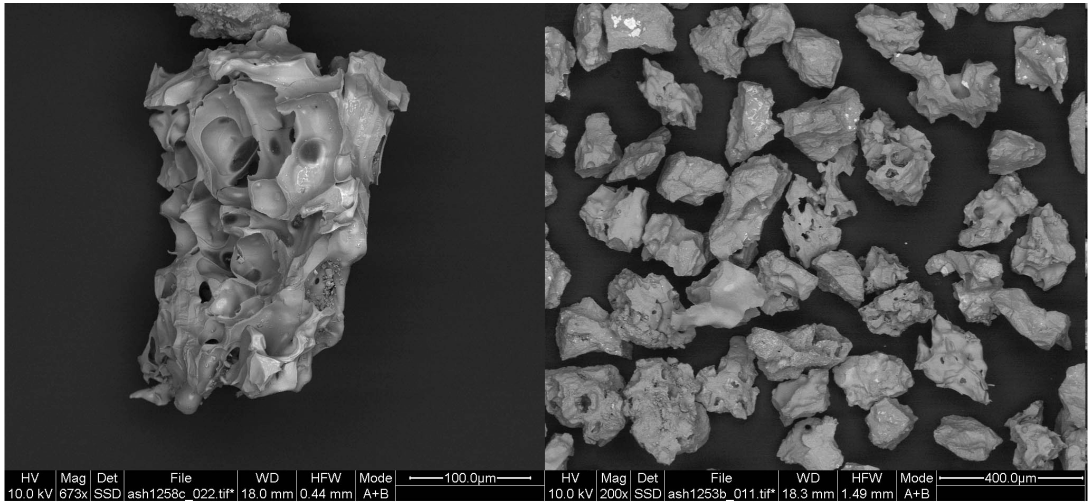
•Scoria and spatter accumulate around the vent
•Grain flow

Fine particles -Hawaiian

•Pele’s Hair
•Pele’s tears

Ash - higher explosivity



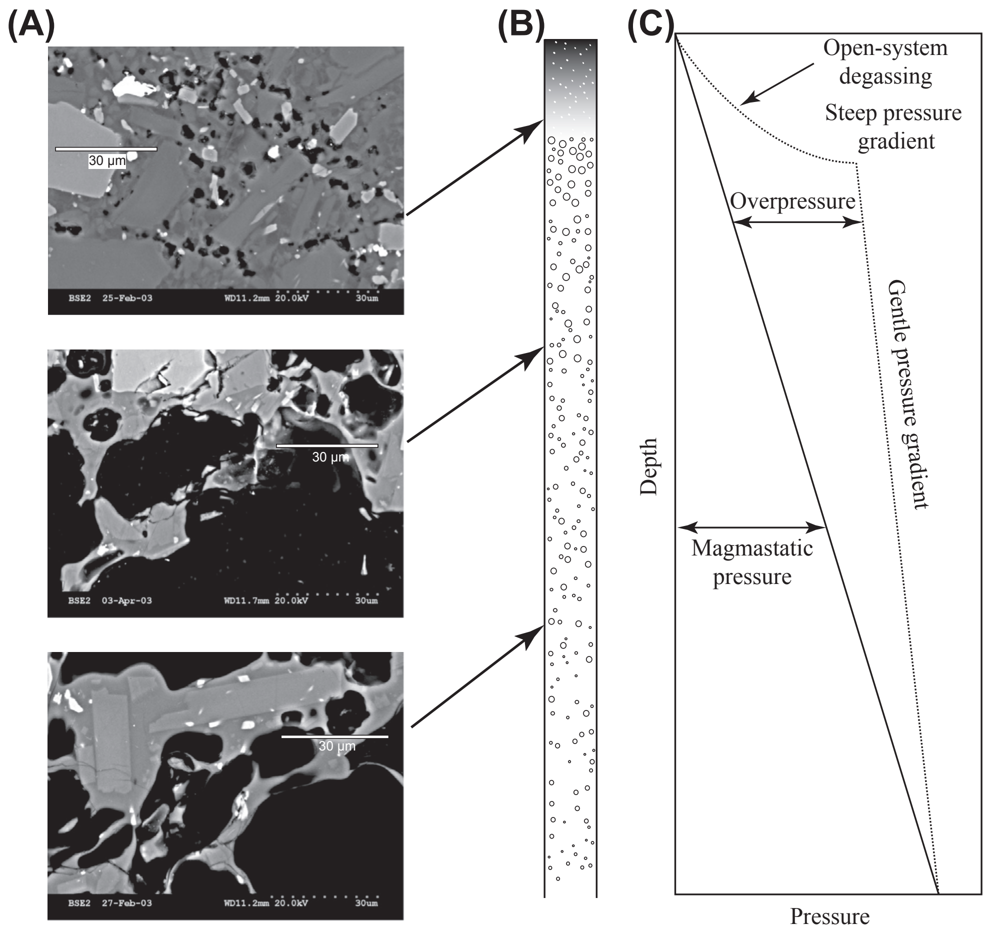


Vulcanian regimes

Mt St Helens, USA

Santiaguito, Guatemala

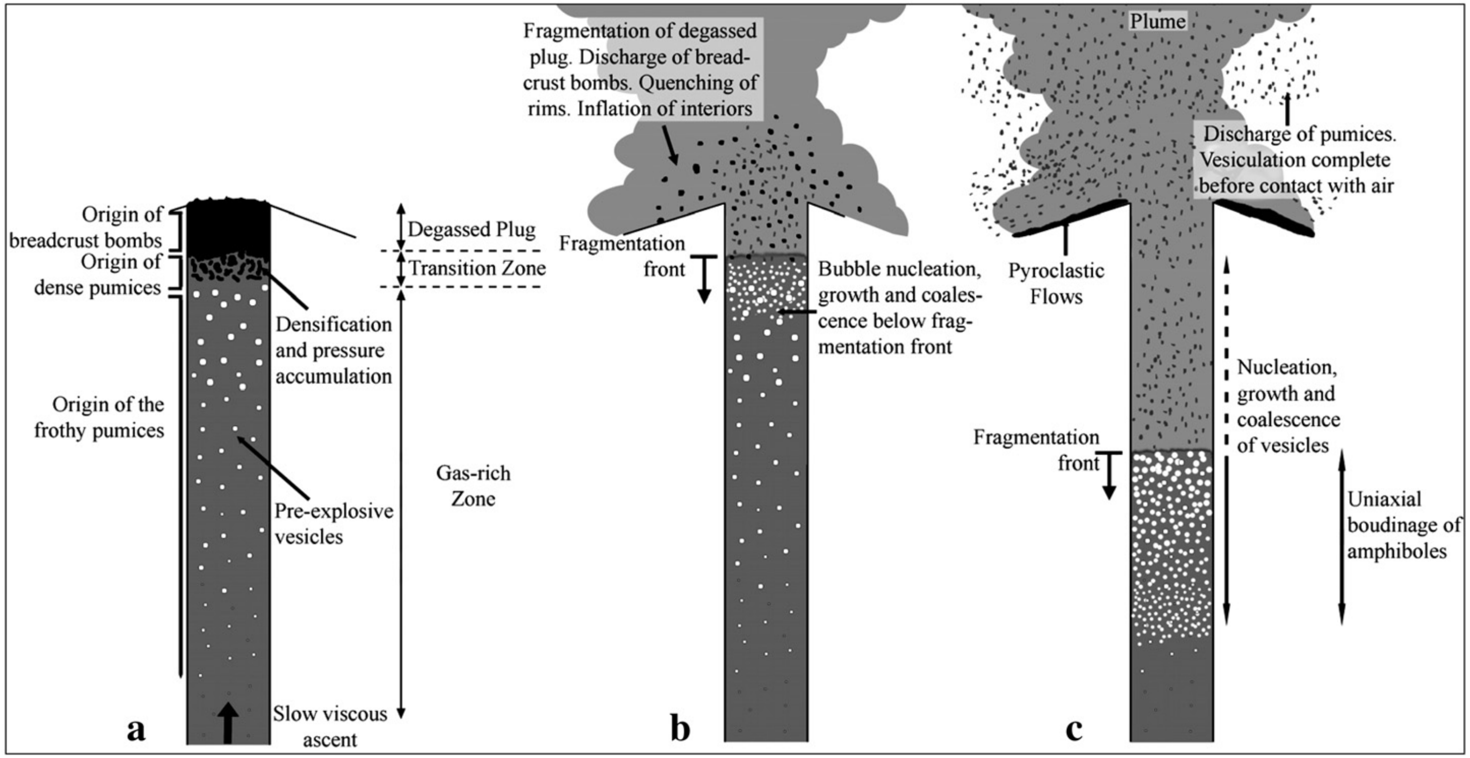
Conduit dynamics in Vulcanian eruptions



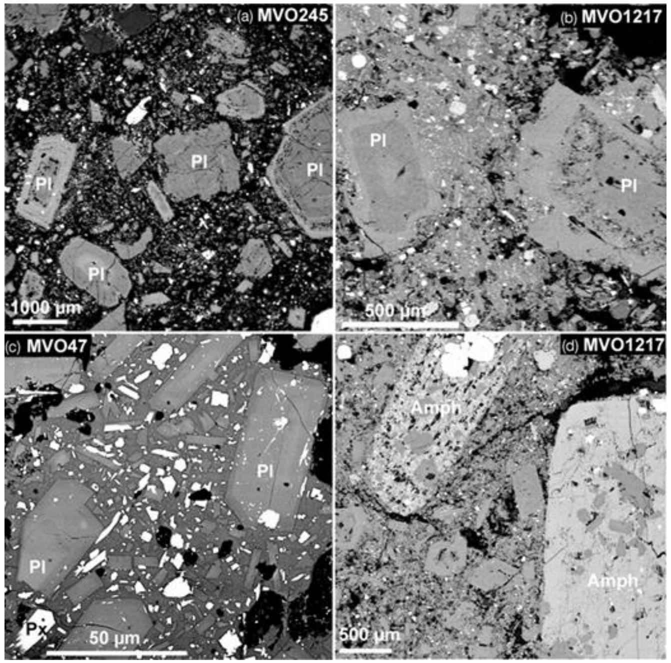
Montserrat Volcano

Clarke et al. 2007

Conduit dynamics in Vulcanian eruptions

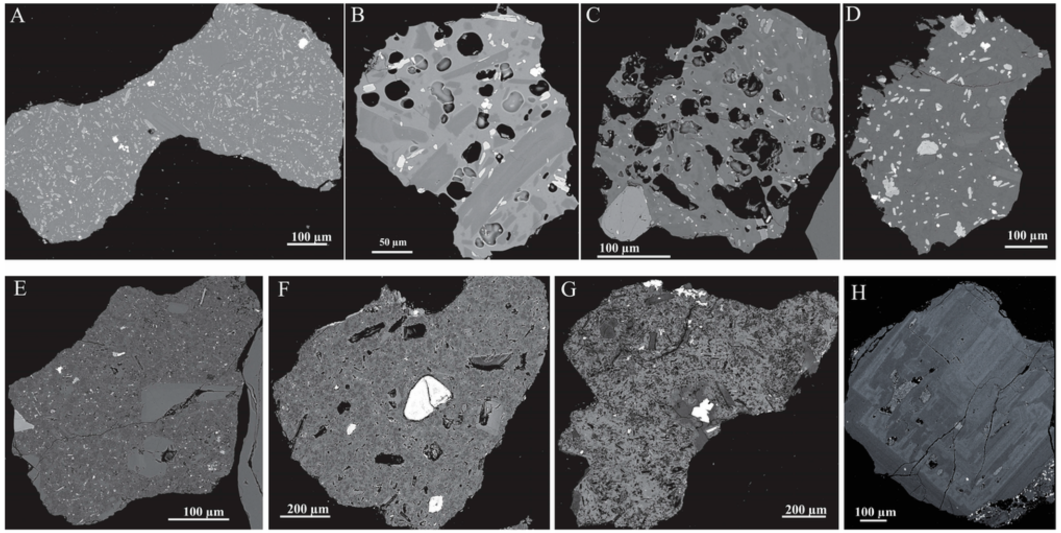


Vulcanian-Magma texture



Montserrat volcano

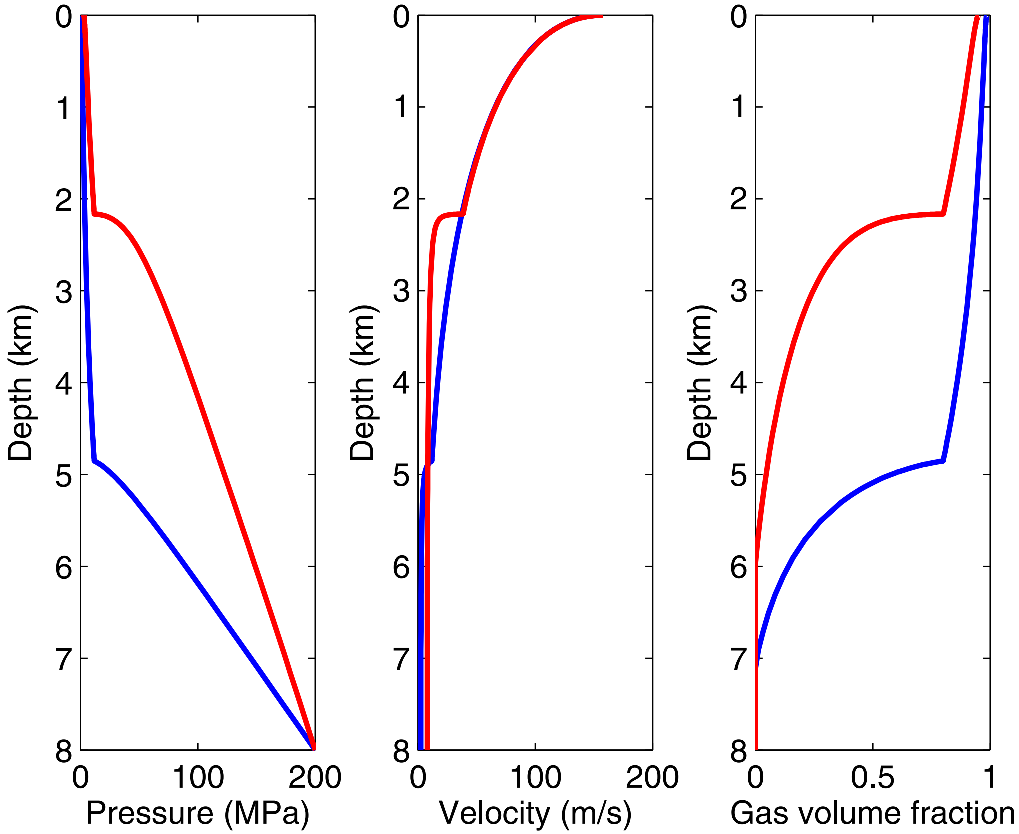
Couch et al., 2003



Sakurajima volcano

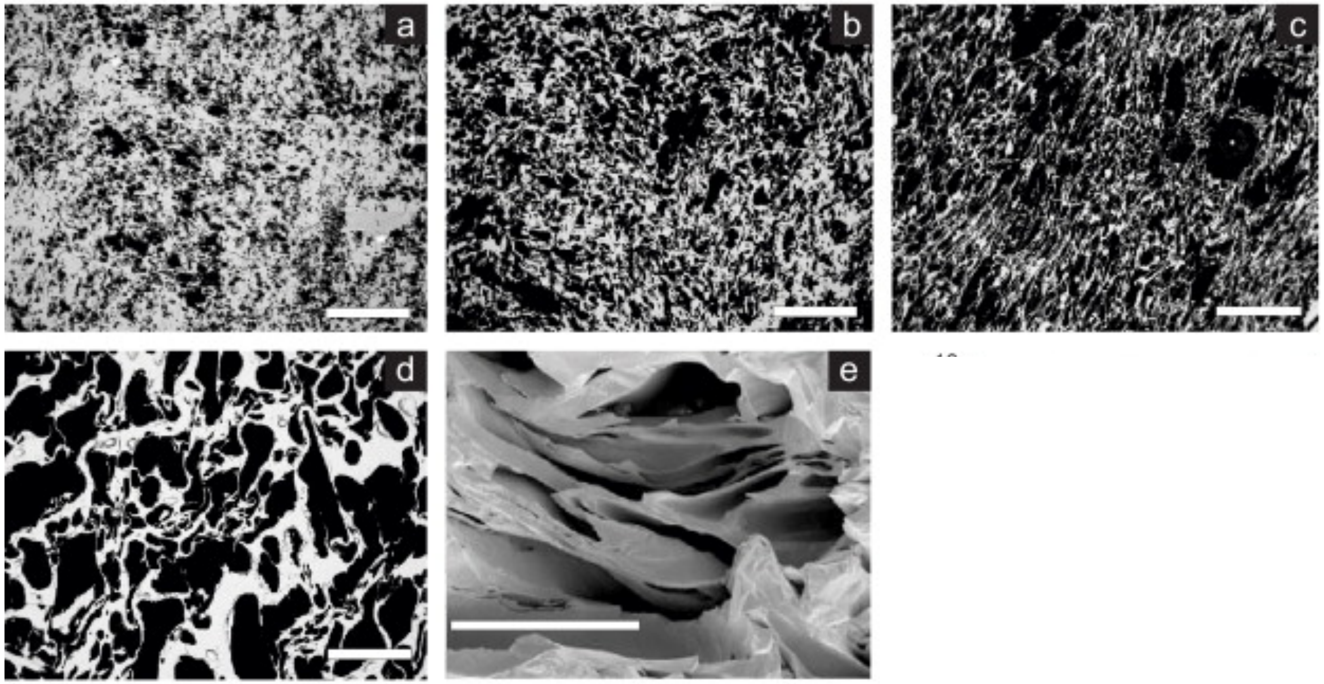
Kurniawan et al. 2016

Plinian regimes



Burgisser and Degruyter, 2016

Plinian-magma texture



Rust and Cashman, 2004