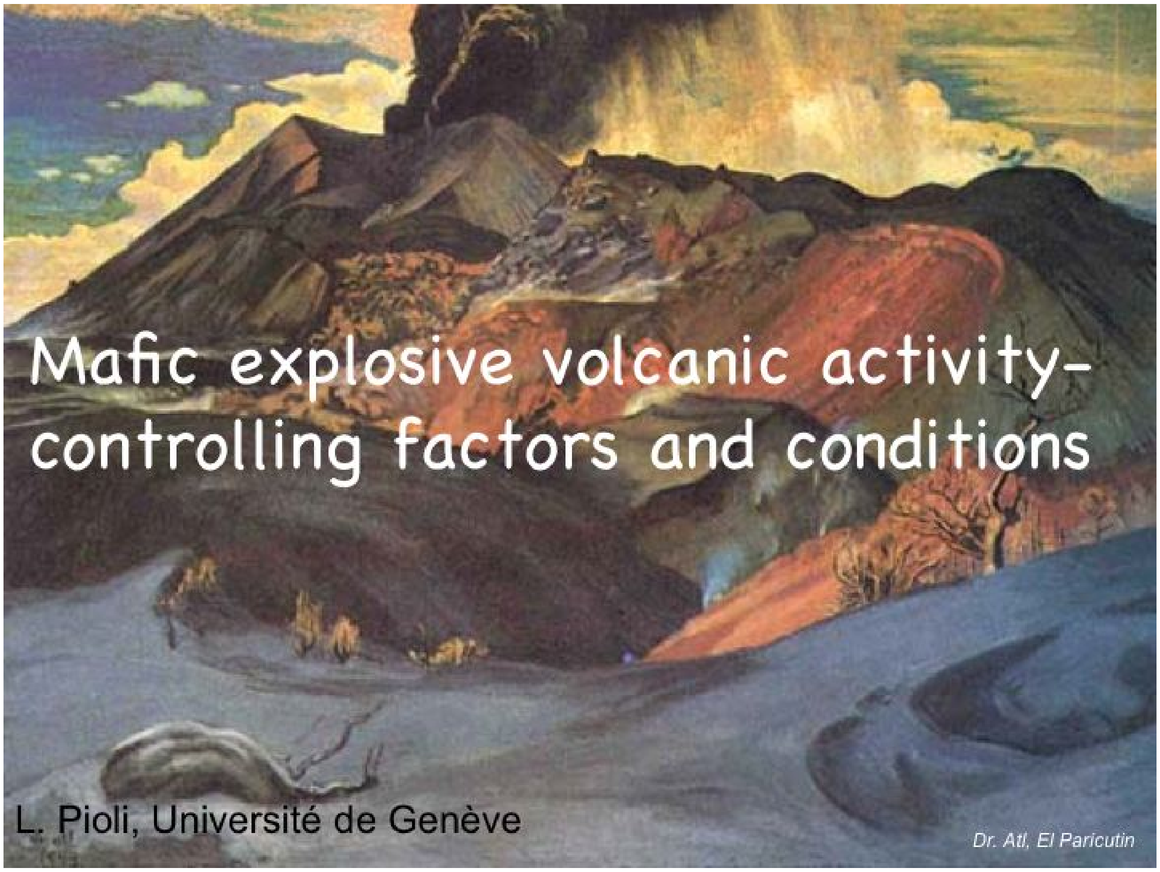


Mafic explosive volcanic activity- controlling factors and conditions

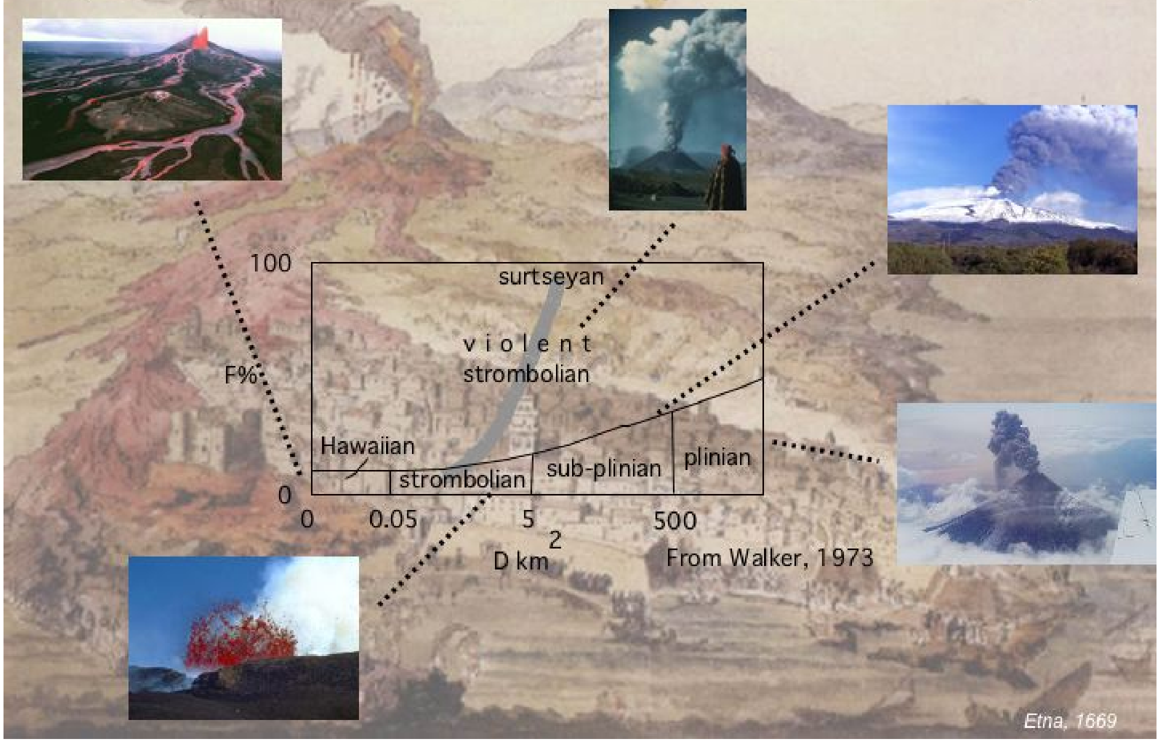
L. Pioli, Université de Genève

Dr. Atl, El Paricutin

Misconceptions on basaltic eruptions

- Basaltic magmas are typically volatile-poor
- Basaltic eruptions rarely produce voluminous amounts of ash and lapilli
- ‘Explosive’ basaltic eruptions are rare events

An empirical classification



From Walker, 1973

Etna, 1669

Length, frequency, characteristics

- A few hours to several years
- Single explosions spaced up to < 1s
- Mild to strong fluctuations in intensity
- Some explosions coexist with lava flows
- Commonly eruptions start from fractures
- Multiple vents

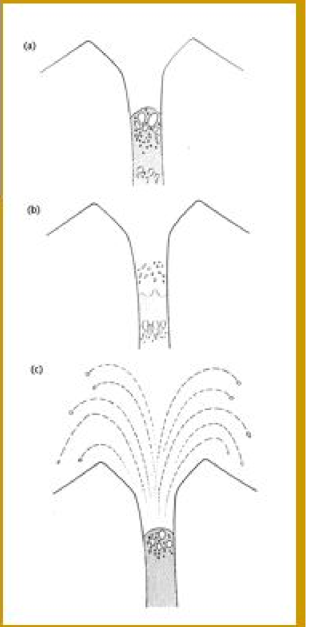
Hawaiian eruptions

From fissures to central conduit
Fire fountains or curtains
H= 100-500 (1600) m
MER= 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)

Violent strombolian activity

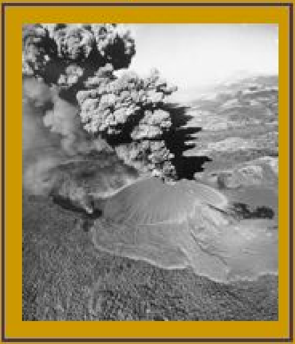
•Both cone and sheet-forming

•Associated with lava flows

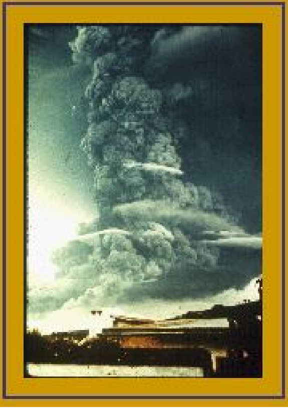
•Pulsatory, non sustained dynamics

•High ash-charged columns

Parìcutin,
Mexico
(1943-1951)



Cerro Negro, Nicaragua (1968)



Fuego,
Guatemala
(1974)

Violent strombolian activity

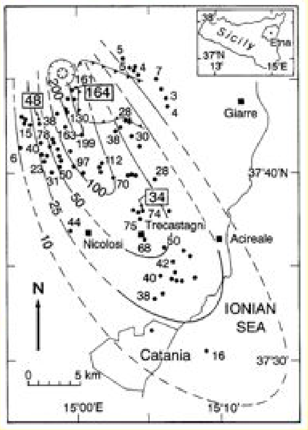
- Lava flow emission typically contemporaneous with explosions, usually from lateral vents
- Shallow gas segregation

Tolbachick, Kamchatka (1975)

Plinian-subplinian activity

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

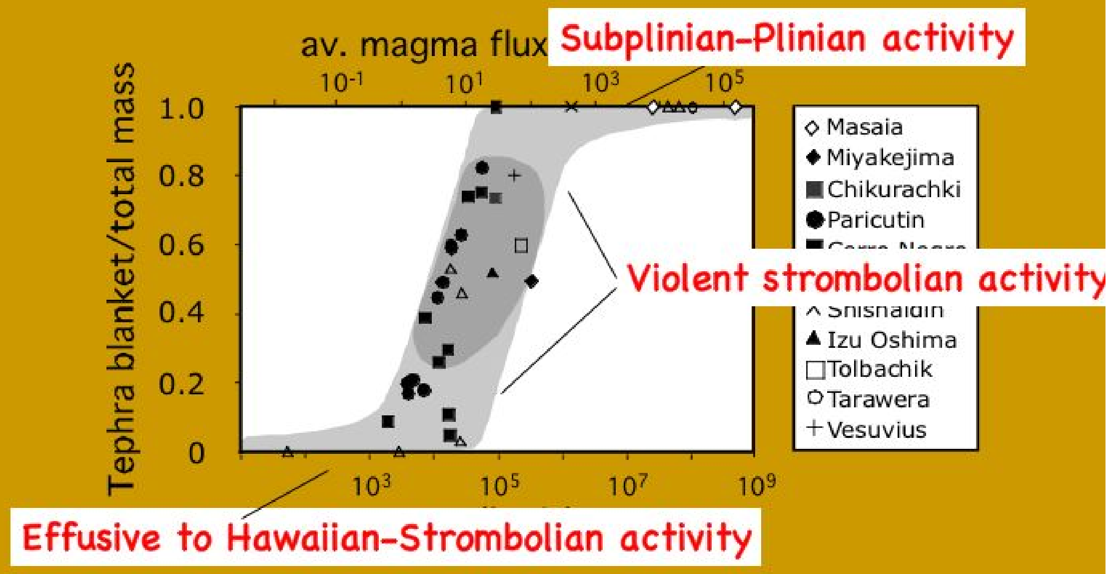
Shishaldin, Alaska (1999)



Etna (122 bc)

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

Mild to high explosivity transition

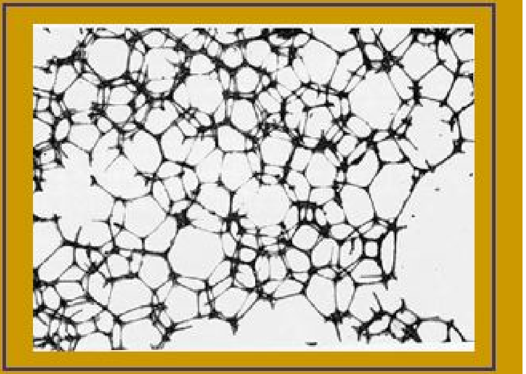


Subplinian-Plinian activity

Violent strombolian activity

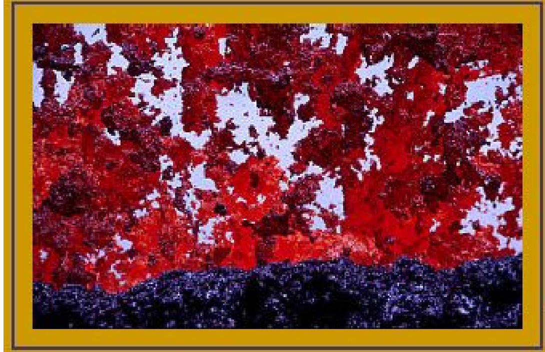
Effusive to Hawaiian-Strombolian activity

Products of eruptions-Hawaiian



- reticulite

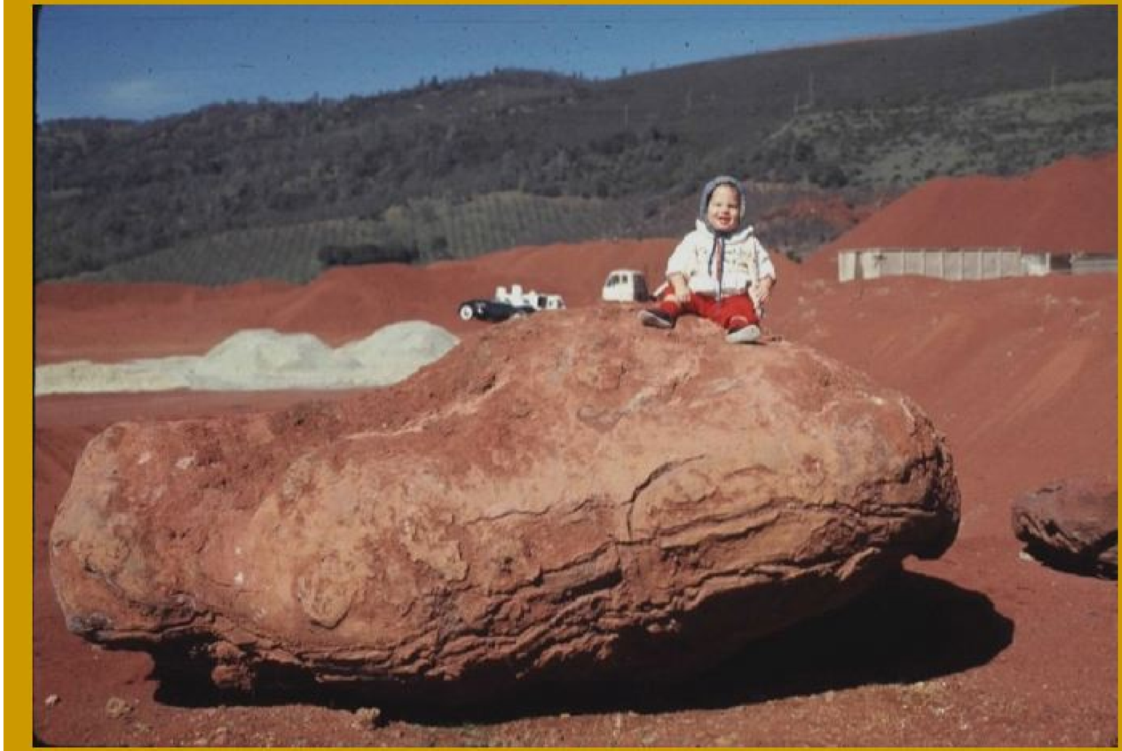
Products-Hawaiian to Strombolian



spatter

Products -Hawaiian to Strombolian

bombs



Strombolian scoria

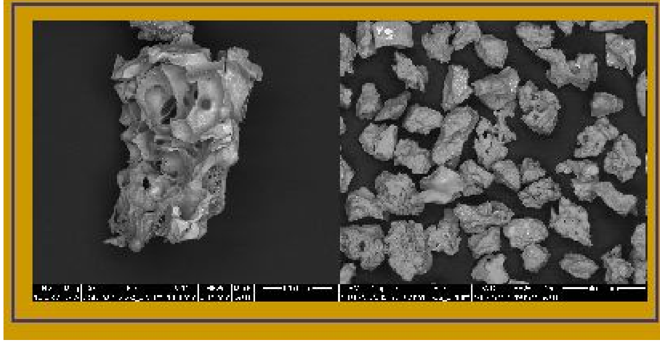
Strombolian activity- scoria cones

- Scoria and spatter accumulate around the vent
- Grain flow

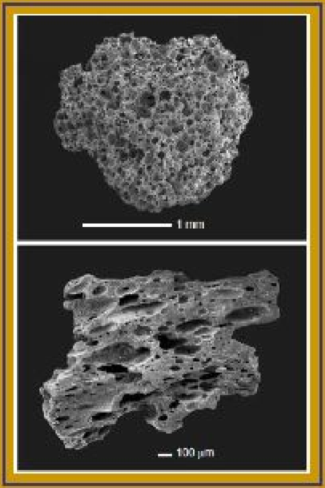
Fine particles -Hawaiian

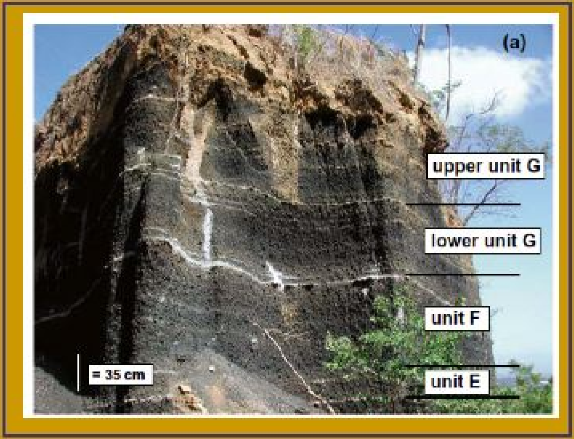
- Pele’s Hair
- Pele’s tears

Ash - higher explosivity



Plinian activity- tephra blanket





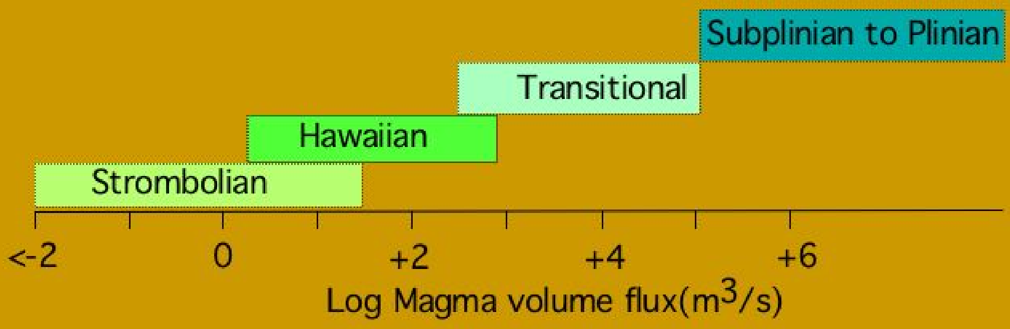
Fontana Lapilli,
Masaya volcano
(Nicaragua)

From Costantini et al., 2009

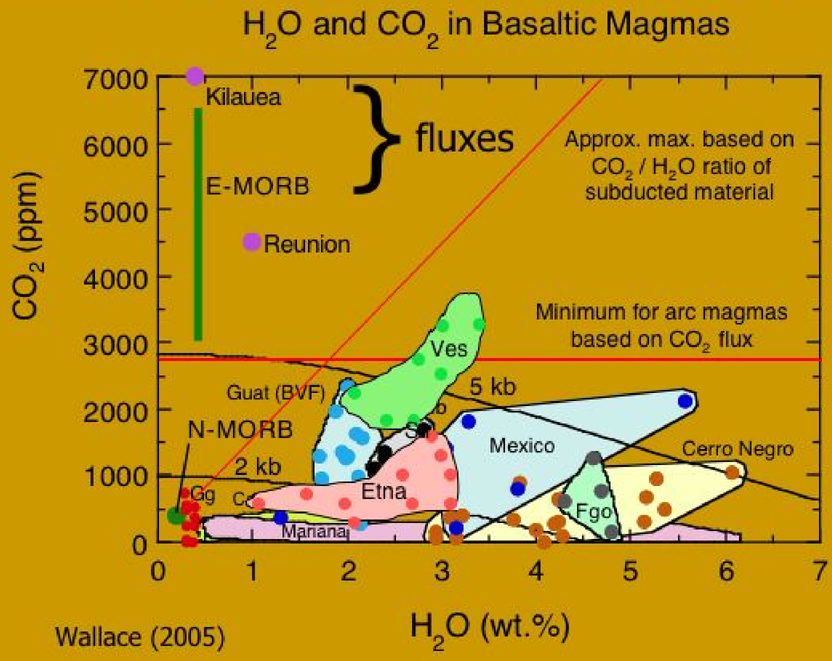
Main factors controlling explosivity of mafic magmas

- Magma rise rate/magma supply rate
- Volatile content; crystal content
- Conduit/dike geometry

Mass eruption rate and eruptive style



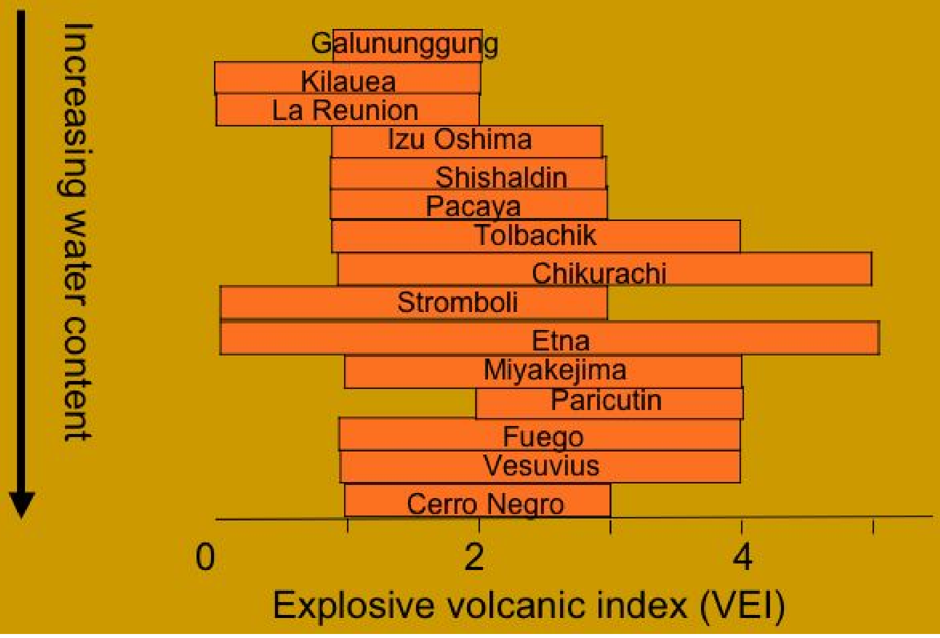
Main volatiles content



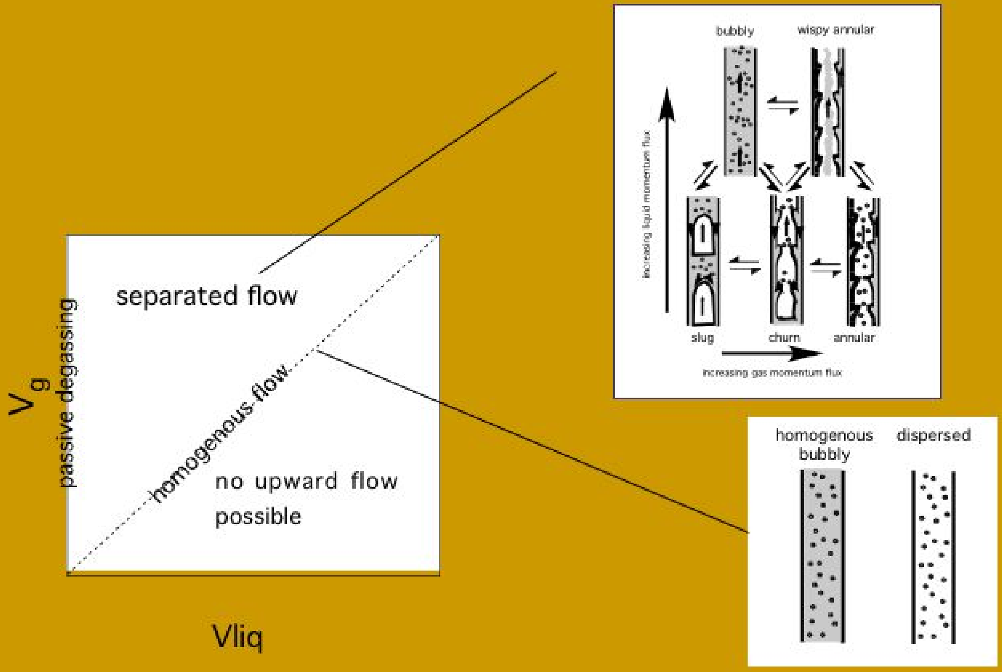
Data from melt inclusions

Wallace (2005)

Basalt explosivity and magma volatile content



Two-phase flow



Bubble rise within the melt

Basalts have viscosities ranging from 10-10^3 Pa*s depending on composition

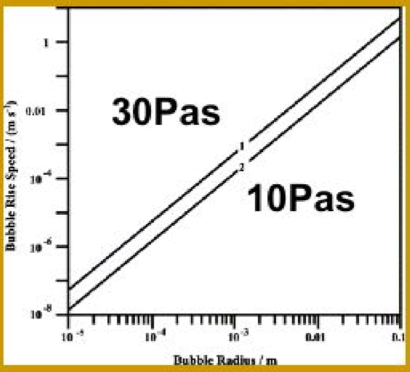
- At small Re single bubbles rise obeying the law:

$$U_\infty = k\frac{\rho g d^2}{\eta}$$

- With 2/9 (Hadamard -Rybczynski law) or $k=1/3$ (Stokes law) with increasing Re
- Large bubbles rise independently of their size

$$v = 1.54\left[\frac{\sigma g}{\rho_l}\right]^{0.25}$$

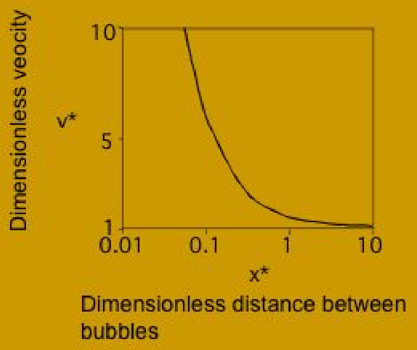
- But.. Single non interacting bubbles rarely exist in nature!

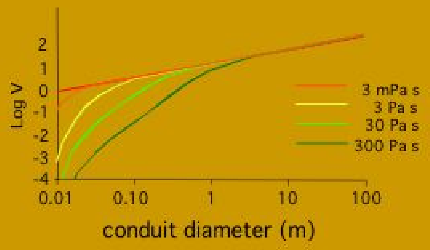


Wilson and Head (1981)

Bubble rise within the melt

In a train of bubbles, single bubble rise is affected by the wake of the previous bubble



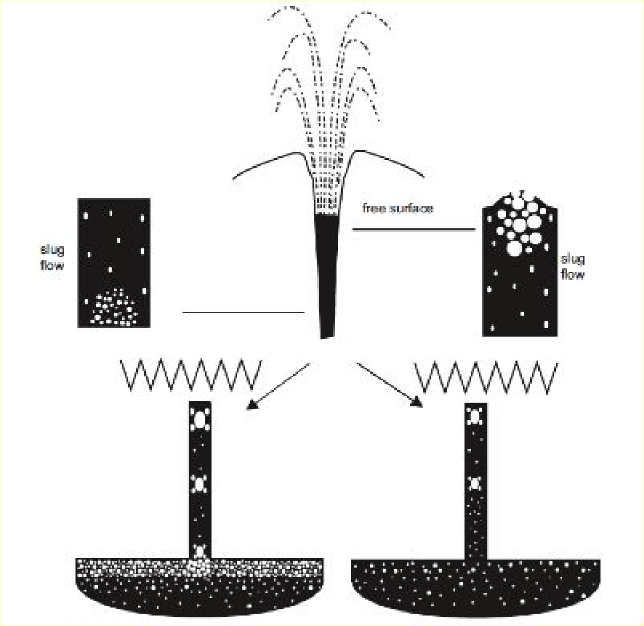


Bubbles almost as large as the conduit-
Taylor bubbles rise independently of their diameter and magma viscosity above d=1 m

Implication of separate flow for eruptive activity

- Gas segregation
- Effects on explosivity
- Overpressure buildup and bubble burst

Two models for separate flow…



Houghton and Gonnermann (2009)

Foam collapse

(Vergnoille and Jaupart, 1986)

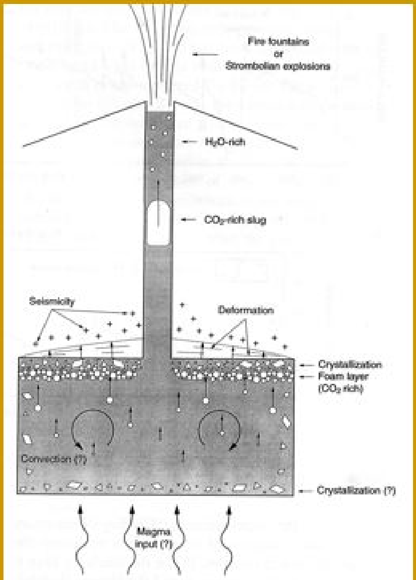
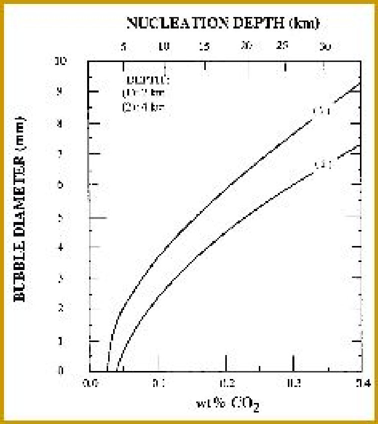


FIGURE 7 Sketch of a basalt volcano and phenomena related to magma storage and eruption.



Vergniolle and Jaupart (1990)

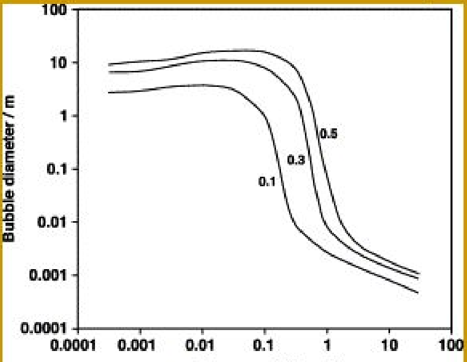
Eruptions are CO_2-driven

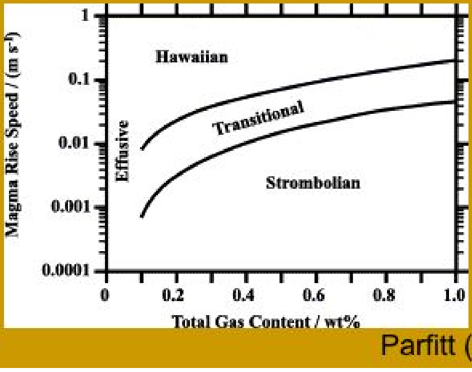
Vergniolle and Mangan (2000)

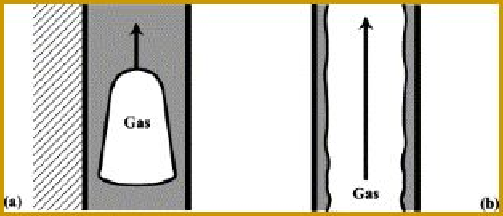
Magma rise speed model

(Head and Wilson, 1994)

- Magma rise speed dependent dynamics
- Threshold V=0.1 m/s







Parfitt (2004)

Two-phase flow of basaltic magmas in vertical cylindrical conduits