



UNIVERSITÉ
DE GENÈVE



Gravity currents in volcanology

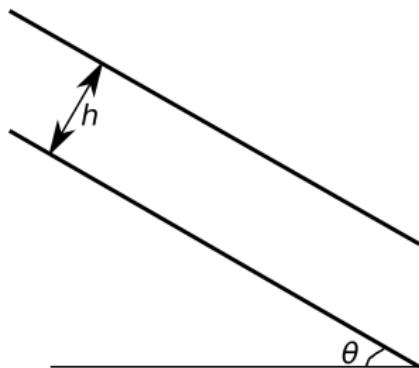
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Lava flows - Flow on a slope

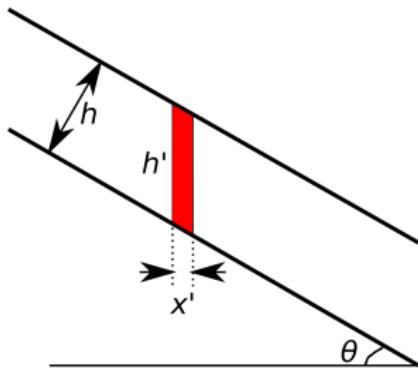
Consider flow of a viscous fluid on a slope



Want to determine shear stress at base of flow

Shear stress = Force per unit area exerted on ground

Lava flows - Flow on a slope



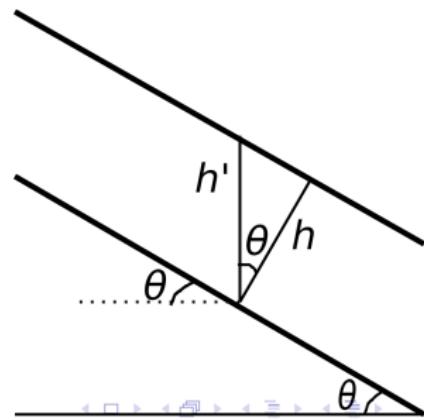
Consider a volume of a thin slice

$$V = h'x'd$$

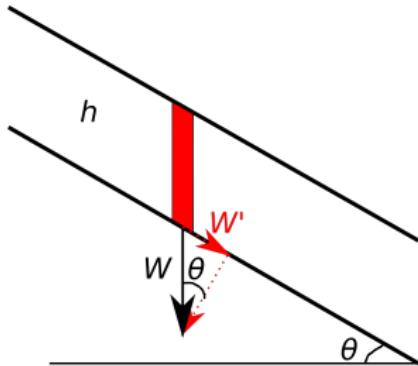
where d = width of flow
So, total weight of column:

$$W = \rho V g = \rho h' x' d g$$

$$h' = \frac{h}{\cos \theta}$$
$$W = \frac{\rho h x' d g}{\cos \theta}$$



Lava flows - Flow on a slope



Downslope component of weight:

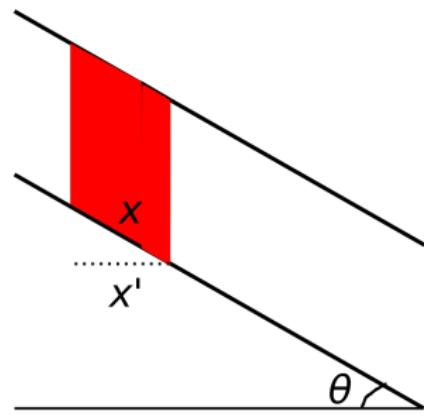
$$W' = W \sin \theta$$

$$W' = \frac{\rho h x' d g \sin \theta}{\cos \theta}$$

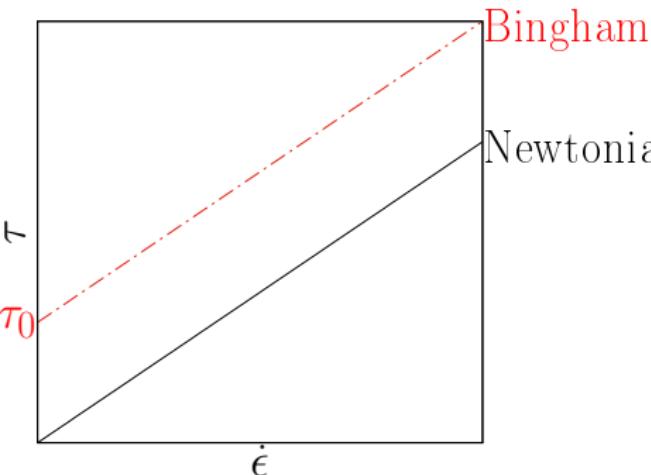
$$\text{Area under column } A = Xd = \frac{x'd}{\cos \theta}$$

Shear stress:

$$\tau = \frac{W'}{A} = \rho g h \sin \theta$$



Lava flow rheology



Crystal-free lavas behave as Newtonian fluids

Bingham

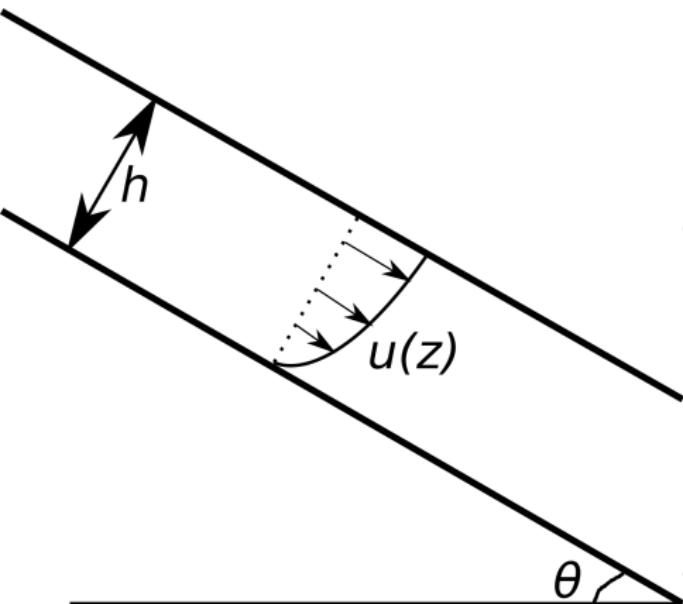
Newtonian Partially crystallised lavas have a yield stress τ_0

Lavas have a minimum thickness below which they cannot flow:

$$h_0 = \frac{\tau_0}{\rho g \sin \theta}$$

This thickness depends on the topography

Jeffrey's model for lava flow velocity



Mean velocity inside a channel:

$$\bar{u} = \frac{h^2 \rho g \sin \theta}{B\eta}$$

B = constant depending on channel geometry

Expression is valid for a Newtonian lava

More complicated models for Bingham fluids

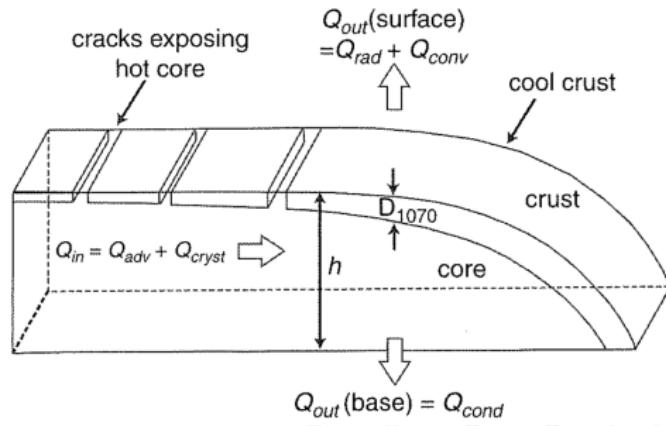
Controls on lava flow

Lava flow rates and morphology depend on:

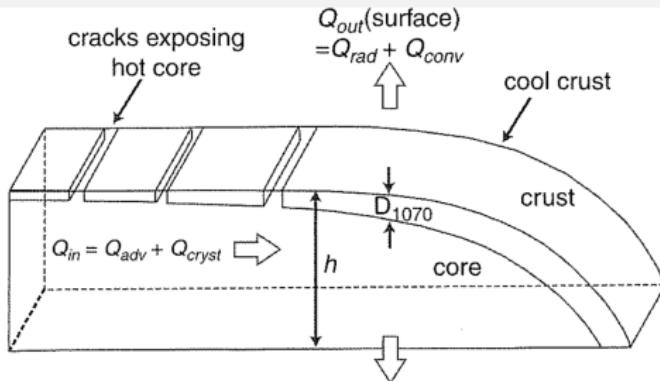
- Topography
 - Slope angle
 - Channel geometry (if it exists)
- Rheology
 - Viscosity
 - Yield stress

Rheology is most difficult to assess - it depends on:

- Composition
- **Temperature**
- Crystallinity
- Vesicularity



Heat loss from the flow



• Radiation $Q_{out}(\text{base}) = Q_{cond}$

- Emission of heat through EM radiation
- Flux determined from Stefan-Boltzmann law

$$q_{\text{rad}} = \epsilon \sigma (T_{\text{surf}}^4 - T_a^4)$$

- ϵ = Emissivity
- σ = Stefan-Boltzmann constant
 $= 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$

• Conduction

- Direct molecular contact
- Heat flux (W m^{-2}) given by a diffusive term

$$q_{\text{cond}} = -k \frac{dT}{dx}$$

- k = Thermal diffusivity

• Convection

- Heat transported through fluid movement
- Heat flux given by

$$q_{\text{conv}} = h(T_{\text{surf}} - T_a)$$

- $h = \square$ Constant

'A'a

Brecciated surface and basal **crusts**

Coherent **core** which remains fluid during activity

Typically 0.5 - 20 m thick

Clinkers - Broken blocks within the crust

Forms in lavas of higher viscosity



Pāhoehoe

Smooth, glassy, coherent surfaces

Surface folds called **ropes**

Individual units have a **lobate** shape

Individual flow can consist of
100s-1000s of lobes

Normally low effusion rates and low
viscosity

Crust is thin but thickens with time

New lobes **breakout** through
fractures in crust

Typical thicknesses from 3 - 40 cm



Block lavas

Typical of intermediate to rhyolitic lavas

Crust has large blocky surface

Blocks are relatively smooth compared to 'a'a

Coherent core

10s-100s m thick

Crystal rich



Lava domes

Mound of viscous lava and rock around the vent

Can be crystal-poor or crystal-rich

Crystal-poor domes are rhyolitic

Crystal-rich domes span compositional spectrum

Common at convergent margins

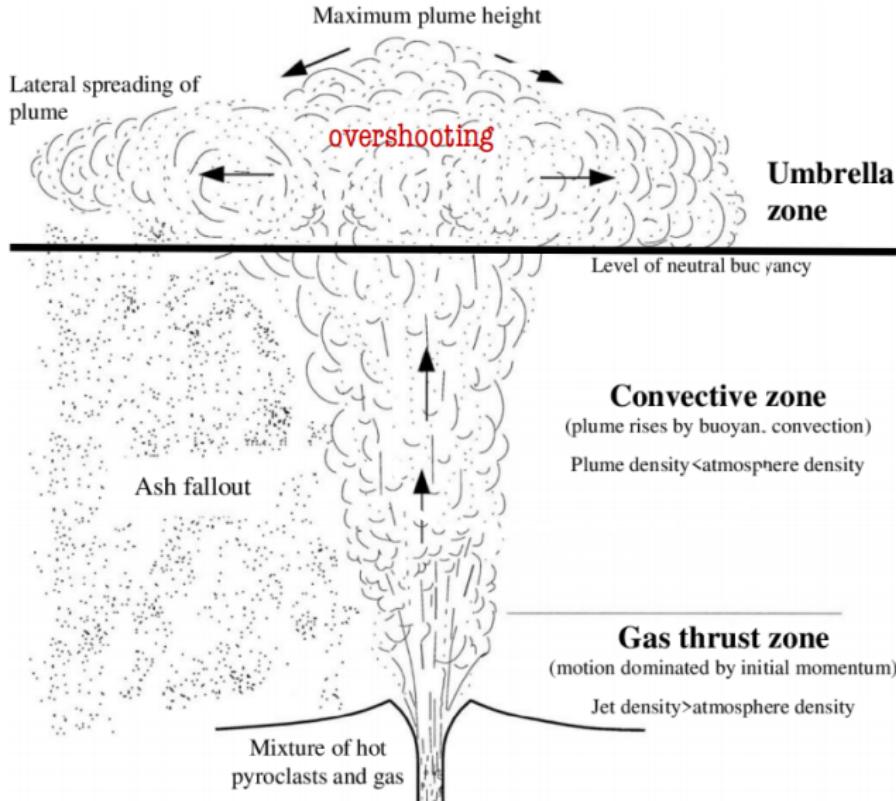
Unstable collapse is a considerable hazard

Can grow **endogeneously** or **exogeneously**

Often associated with **vulcanian** explosions



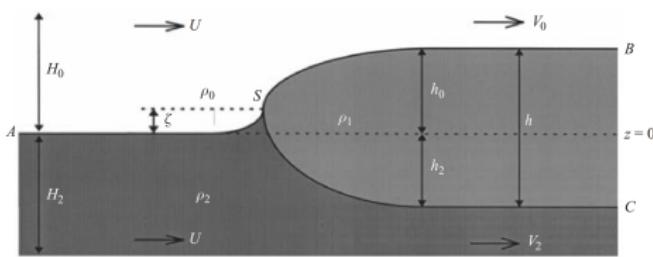
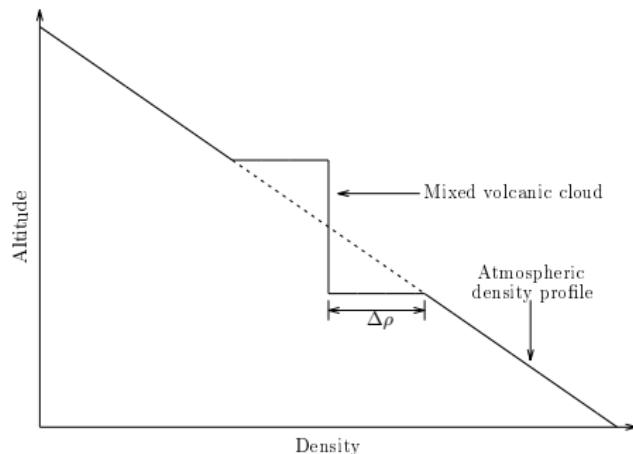
Spreading umbrella clouds



Spreading umbrella clouds



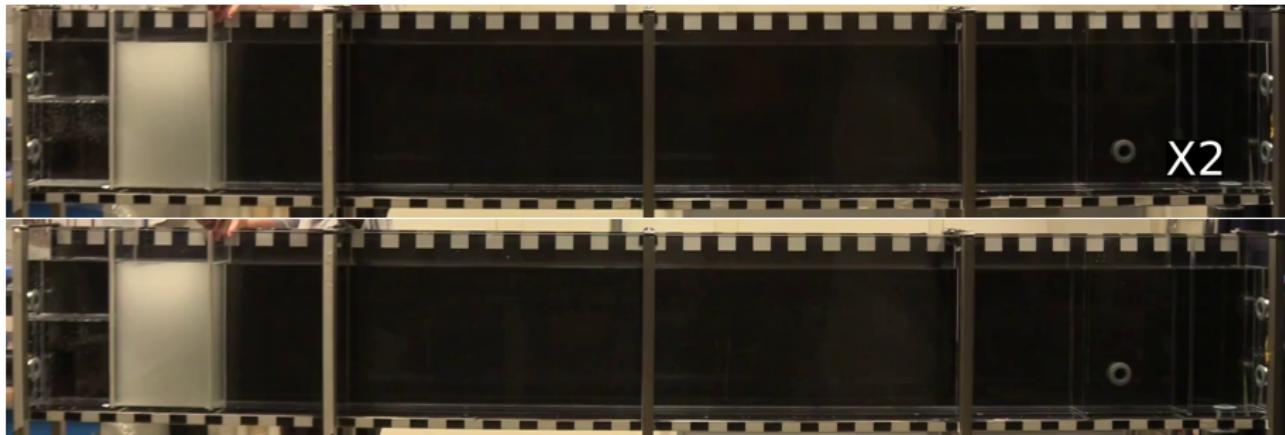
Radially spreading gravity current



Velocity depends on:

- Flux
- Density of mixture

Spreading umbrella clouds: Experimental modelling

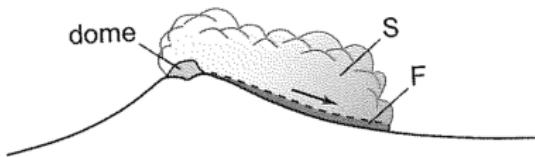


Shear at the base of the cloud can inhibit fallout

Fallout can change density difference

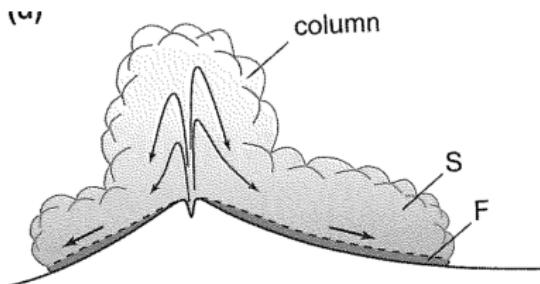
Models of deposition from spreading clouds used to infer eruption parameters from deposit characteristics

Collapsing plume



Dome collapse

- Front slope of dome becomes oversteep
- Material avalanches down slope



Column collapse

- Erupted jet doesn't become buoyant
- Material falls back to the ground

Lateral blast

- Ground motion depressurises shallow magma
- Rapid expansion of volatiles mobilises more material

