Gravity currents in volcanology

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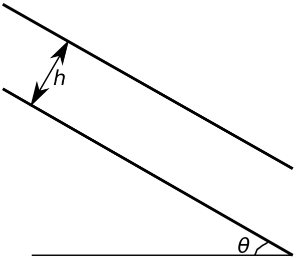
22nd November 2019

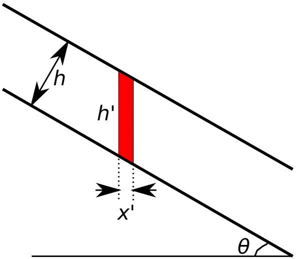
Consider flow of a viscous fluid on a slope



Want to determine shear stress at base of flow

Shear stress = Force per unit area extered on ground

Lava flows - Flow on a slope



$$h' = \frac{h}{\cos\theta}$$

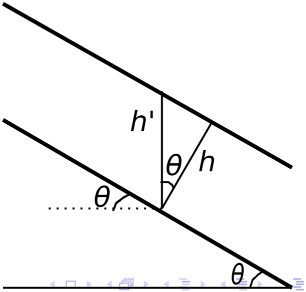
$$W = \frac{\rho h x' d g}{\cos\theta}$$

Consider a volume of a thin slice

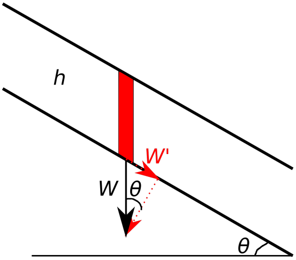
$$V = h' x' d$$

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

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



Lava flows - Flow on a slope



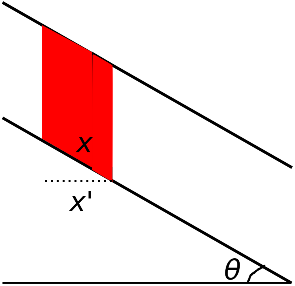
Area under column $A = Xd = \frac{x' d}{\cos\theta}$
Shear stress:

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

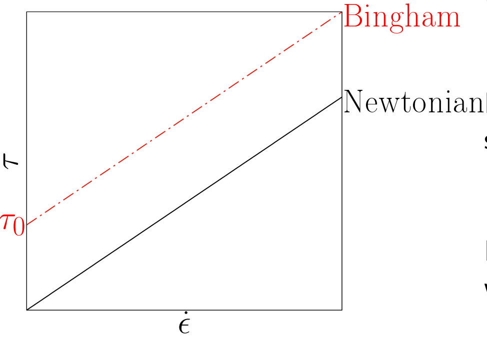
Downslope component of weight:

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

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



Lava flow rheology



Crystal-free lavas behave as Newtonian fluids

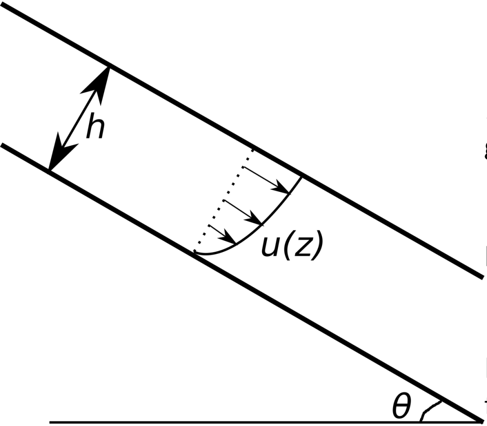
Partially crystallised lavas have a yield stress τ_0

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 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
- Vesivularity