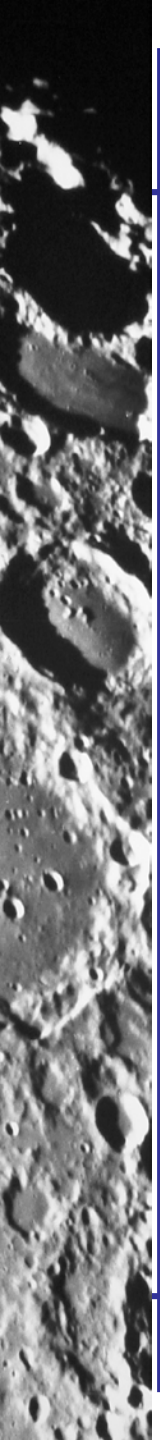
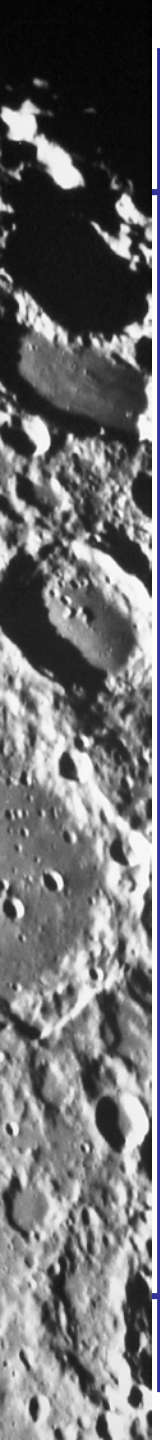


Lunar Analogue Terrains

Briefing Topic:

Magma Viscosity and Lava Flow Velocity, Earth and Moon

David A. Kring



Magma Viscosity

The viscosity of magma, including extruded lava, depends on 4 parameters:

- Composition
  - Viscosity increases when there are more bridging oxygens
    - when there is more silica
    - when there is less water
    - when there is less K_2O
- Temperature
  - Viscosity increases as temperature decreases
- Gas content
  - Viscosity increases as volatile (H_2O, CO, etc.) content decreases
- Amount of solid material
  - Viscosity increases as the amount of crystals or other entrained material increases
  - Effective viscosity = $\eta_e = \eta_f (1 - 1.35\ C)^{-2.5}$
    - where C = proportion of suspended particles

Magma Viscosity

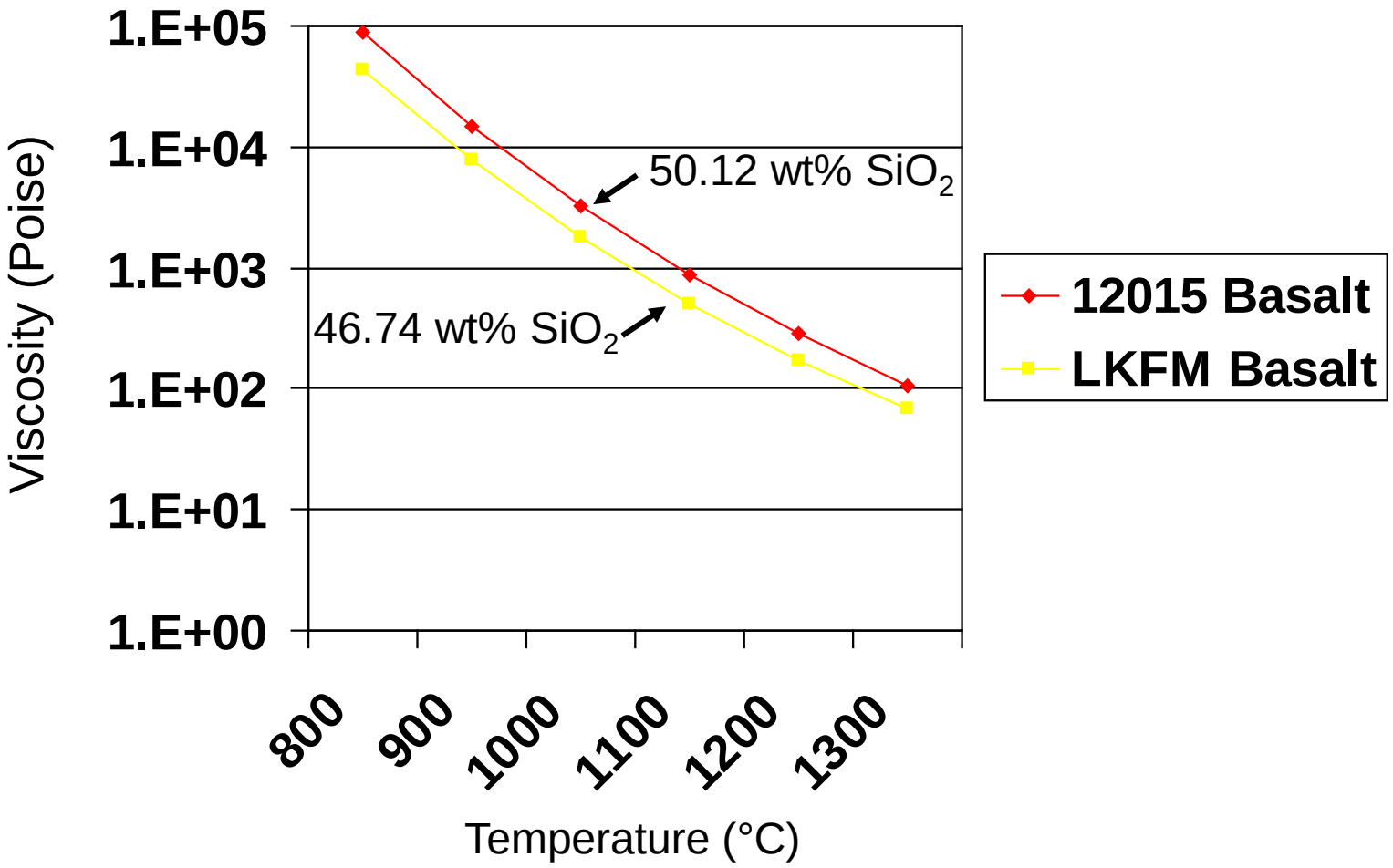
- Amount of solid material (continued)

  For example:

  The viscosity of a basalt magma composed of 25% entrained crystals will be 10 times more viscous than a basalt magma w/o crystals.

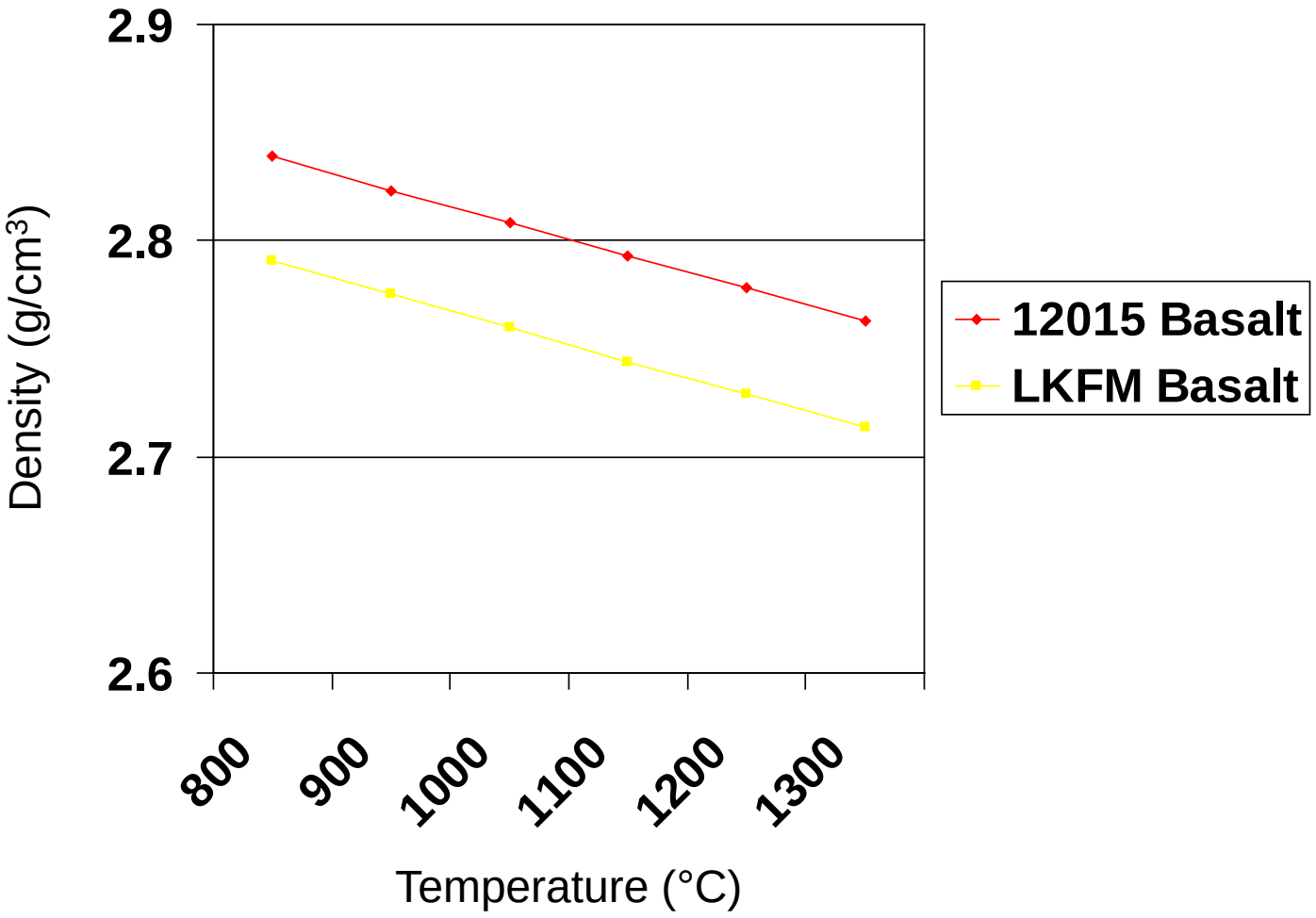
  A basalt magma with 25% crystals would not be able to erupt in an effusive manner (i.e., as a typical lava flow), although it could still erupt explosively.

Viscosities of (experimental) lunar basalts

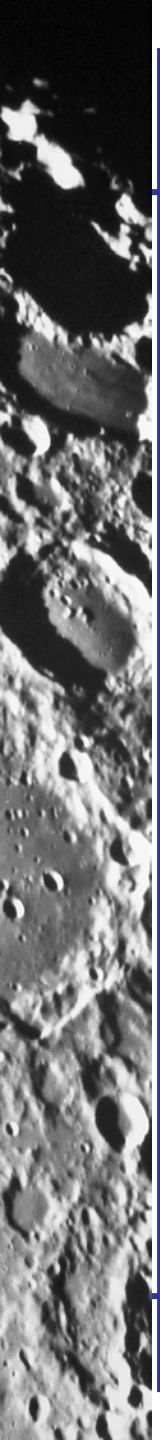


Kring and McKay (1983)

Densities of (experimental) lunar basalts



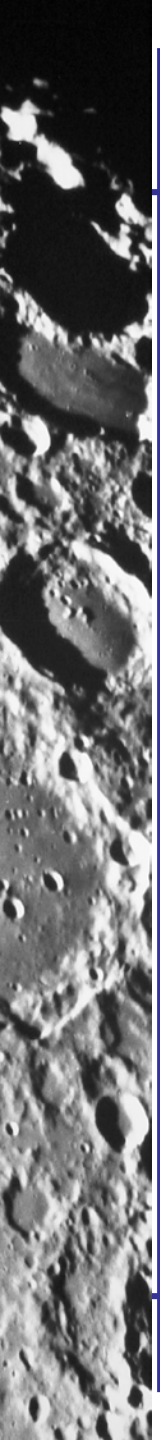
Kring and McKay (1983)



Viscosity in Planetary Magma Systems

Magma Type	Extrusion Temperature (K)	Extrusive Viscosity (Poise)	Liquid Density (g/cm^3)
Basalt			
Lunar (~40% SiO_2)	1600 - 1700	10	2.7
Tholeiite (~50% SiO_2)	1400 - 1500	10^2 - 10^3	2.6
Andesite (~62% SiO_2)	1300 - 1400	10^6 - 10^7	2.45
Rhyolite (~75% SiO_2)	1100 - 1200	10^{10} - 10^{11}	2.2
Common materials			
Glacier ice	270	10^{15}	
Honey	295	10^2	
Machine oil	295	1	

Note: 10 Poise = 1 Pa s



Lava Flow Velocity

The distance lava flows is primarily a function of:

- flow velocity
- cooling rate
- volume erupted
- eruption rate

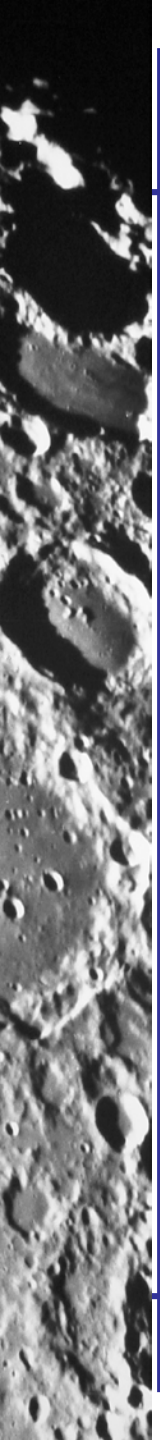
Mean velocity can be estimated from Jeffrey's equation for laminar flow

$$V = g (\sin \alpha) d^2 \rho / 3 \eta$$

Where V = mean velocity, g = gravity, d = flow thickness, α = slope angle, ρ = fluid density, and η = viscosity.

(this formulation does not account for temperature and viscosity gradients)

Flow velocities on the Moon are nearly 4 times faster than those on Earth, because of lower viscosity and higher density of lunar basalt, which more than offsets the lower lunar gravity. On Earth, basalt flows from 8 cm/s to 1500 cm/s (0.3 to 55 km/hr).



Lava Flow Velocity

$$V_{\text{(lunar basalts)}} \approx 4 \times V_{\text{(terrestrial basalts)}}$$

Properties of typical lunar and terrestrial basalts

	Terrestrial	Lunar
Solid density (g / cm^3)	2.8-3.0	3.4
Fluid density (g / cm^3)	2.6	2.95
Liquidus temperature (°C)	1150	1300
Viscosity (poise)	200	10
Thermal conductivity (cal / cm / s / °C)	3×10^{-3}	1.5×10^{-3}