Gas flow through porous media with regard to comets and asteroids

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Experimental scheme
Glass beads

\[ d = 0.250 - 0.355 \text{ mm} \]

\[ d = 0.125 - 0.200 \text{ mm} \]
Analogue Materials

JSC-Mars 1

UK 4 sand

JSC-1 Lunar

UCF/DSI-CI-2 Asteroid Simulant (Exolith Lab)
Measurement

Pumping and then stepwise increase of gas flow from 0.15 mg/s till 19.2 mg/s
Analysis

Sum of viscous flow and Knudsen flow (Mason and Marrero 1970*)

\[ \bar{p} \frac{B_0}{\mu} + D_K = -\frac{RTFx}{MA(p - p_0)} \]


- $A$ ... sample cross section [m$^2$]
- $B_0$ ... gas permeability [m$^2$]
- $D_K$ ... Knudsen diffusion coefficient [m$^2$ s$^{-1}$]
- $F$ ... mass flow [kg s$^{-1}$]
- $M$ ... molar mass of gas (air) [kg mol$^{-1}$]
- $p$ ... downstream pressure [Pa]
- $p_0$ ... upstream pressure [Pa]
- $\bar{p}$ ... mean pressure [Pa]
- $R$ ... gas constant [J mol$^{-1}$ K$^{-1}$]
- $T$ ... temperature [K]
- $x$ ... sample height [m]
- $\mu$ ... viscosity coefficient [kg m$^{-1}$ s$^{-1}$]
Permeability of glass bead fractions

Permeability decreases with decreasing bead size.

The graph shows the permeability of different glass bead fractions, measured in square meters, as a function of the diameter of the fractions in millimeters. The permeability decreases as the diameter of the beads decreases, indicating that smaller beads have lower permeability.

For example, the permeability of the 0.045 - 0.063 mm fraction is approximately $10^{-10}$ square meters, while the permeability of the 3.85 - 4.83 mm fraction is approximately $10^{-12}$ square meters.
Asteroid replicas

Glass replicas of the original Asteroid simulant according to its particle size distribution with various amounts of the smallest glass beads.
Permeability of Asteroid simulant and variations

Permeability values of replicas behave according to the amount of smallest beads within the sample (as expected).

No uniform picture regarding the original Asteroid material due to irregular packing of sample (see next slide).
Random packing of Asteroid Simulant
Findings after measurement

Glass: 0.045 – 0.063 mm

Asteroid simulant

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Conclusion

• Investigation of 11 glass bead fractions and 4 analogue materials

• Gas permeability $B_0$ values ranging between $(10^{-13} - 10^{-8}) \, m^2$

• Glass beads: permeability decreases with decreasing bead size

• Analogue materials: the greater the amount of small fractions, the lower the permeability

• More densely packed sample shows a lower permeability

• Shape of the grains significantly influences the packing of the sample
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