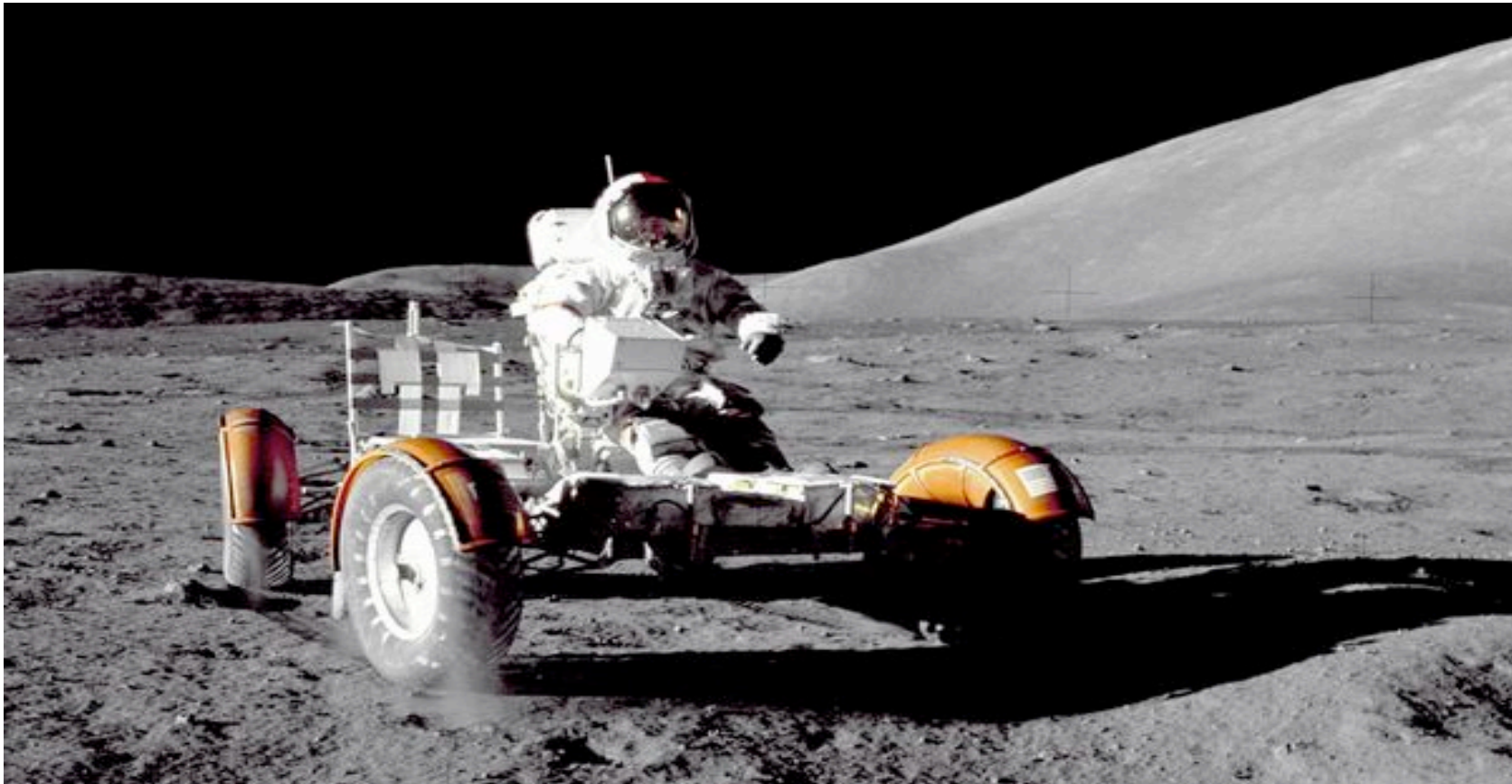


Does gravity has an effect on slow shear granular rheology?



A. Singh, V. Magnanimo, K. Saitoh & S. Luding



Multi Scale Mechanics

NASA.org

University of Twente

Granular matter



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Avalanches?

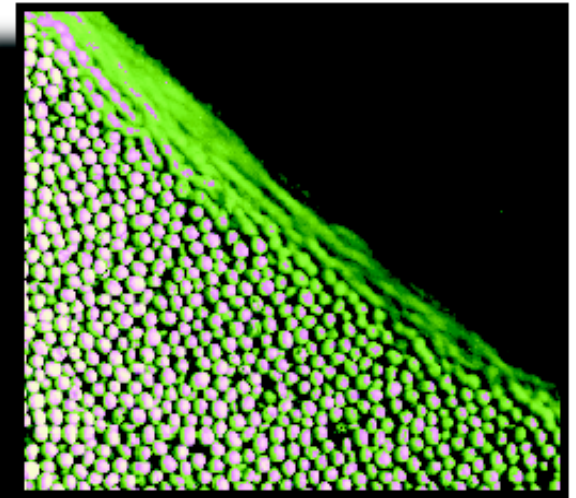
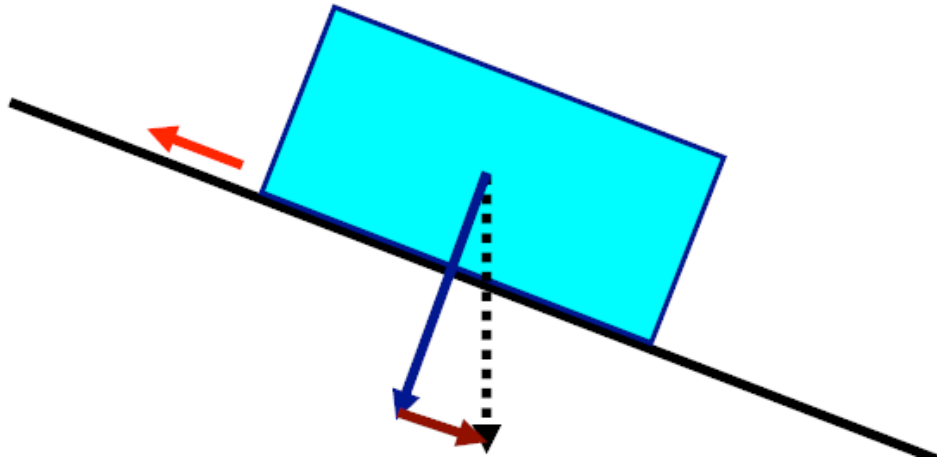


Avalanche on Earth

Avalanche–Analogy with Friction



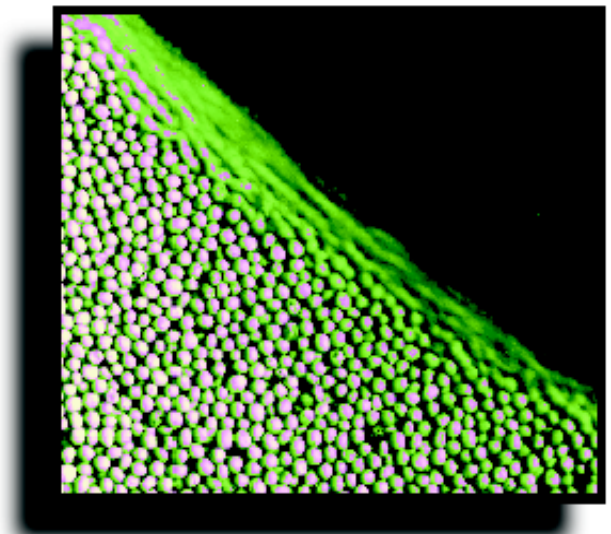
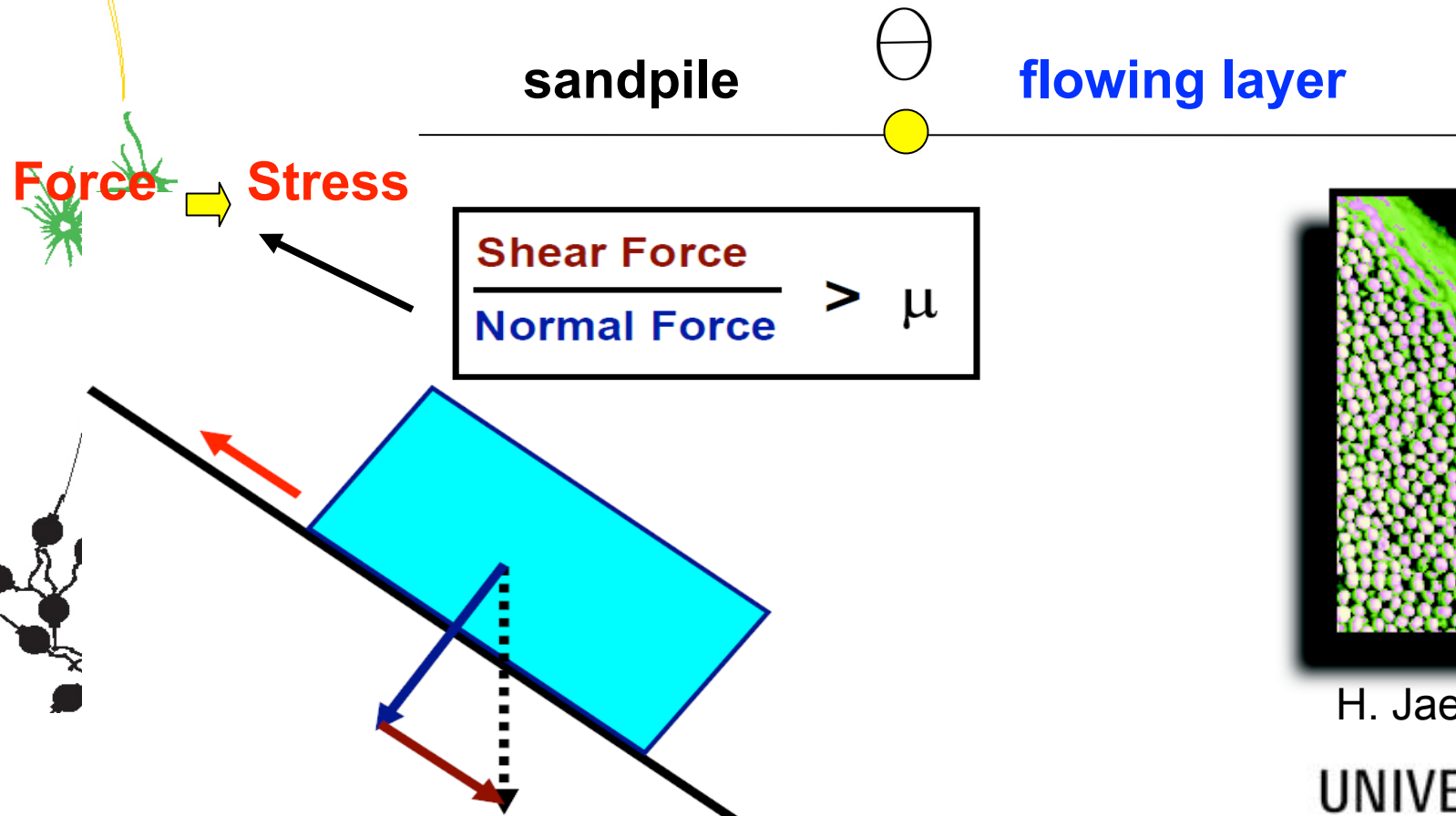
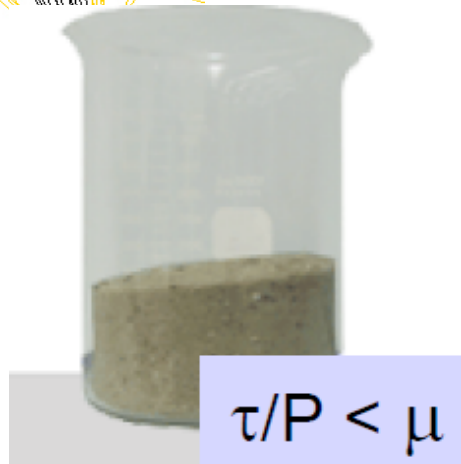
$$\frac{\text{Shear Force}}{\text{Normal Force}} \leq \mu$$



H. Jaeger's webpage

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Analogy with Friction

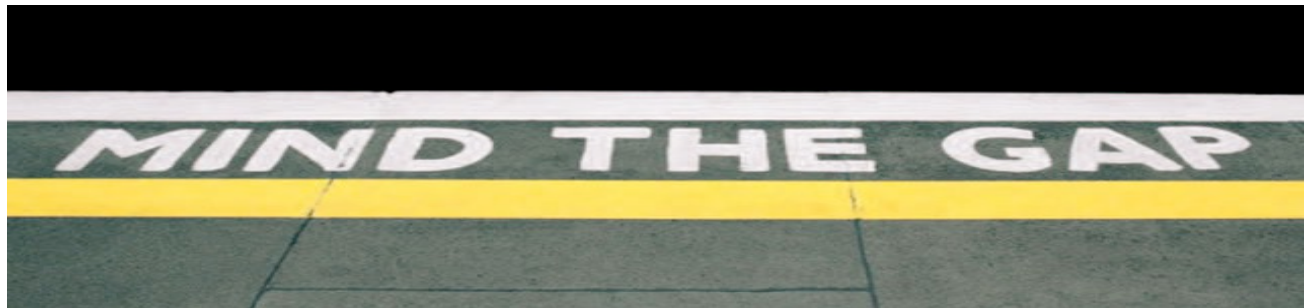


H. Jaeger's webpage

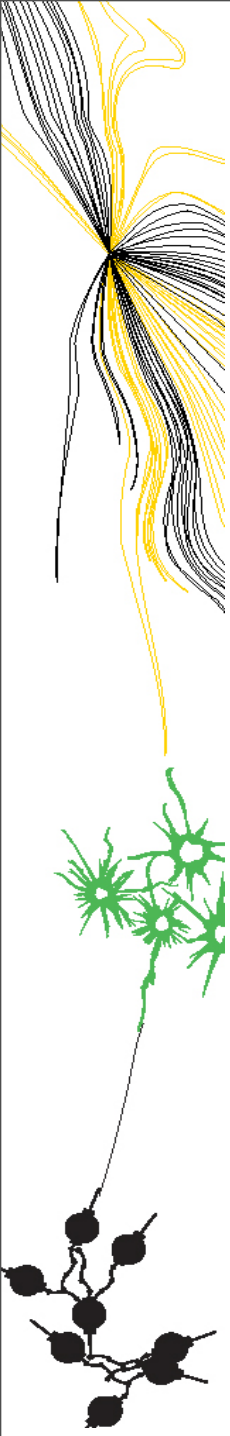
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How does material behave?

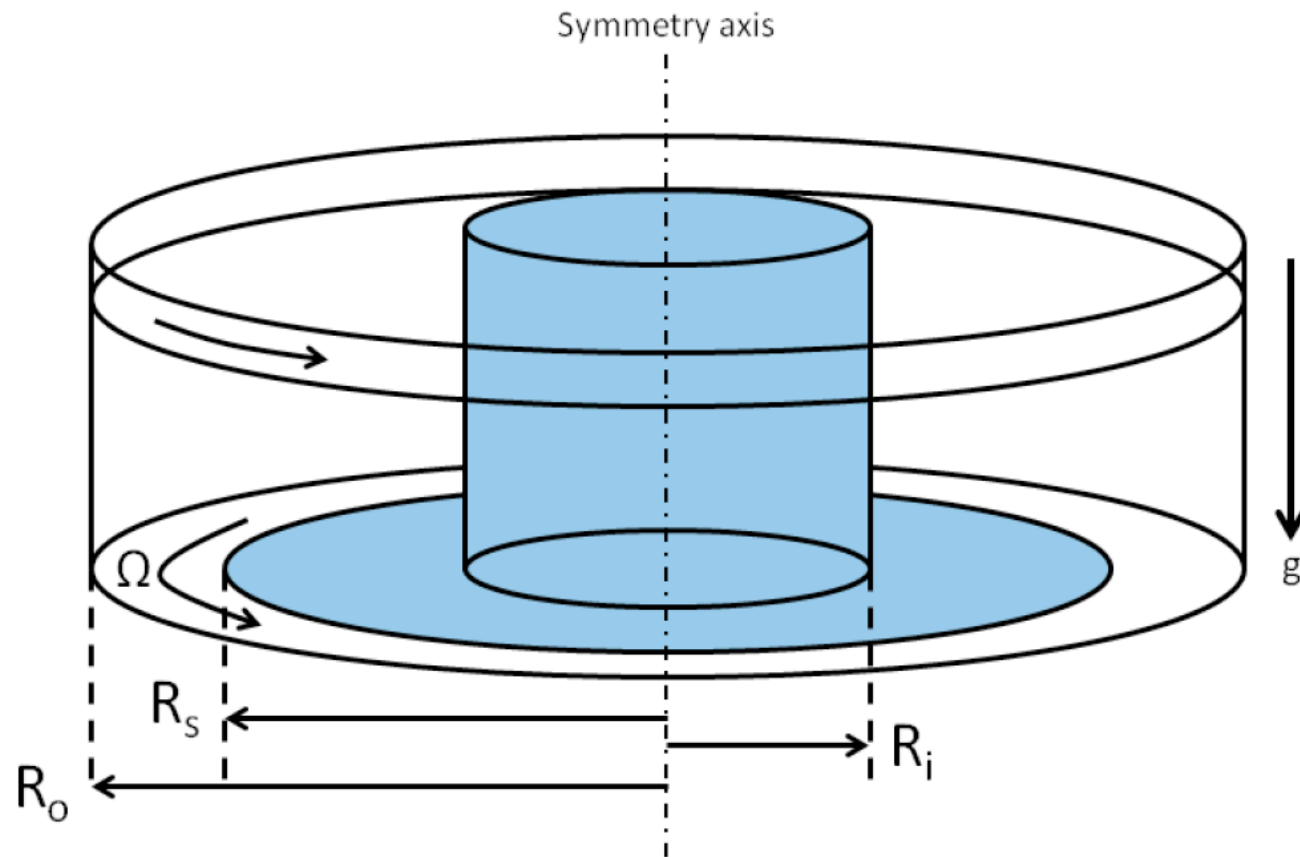
- Friction at contact.
- External compression.



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Numerical Setup



Split-bottom ring shear cell:

- Driven from bottom and outside walls.
- The geometry leads to **wide** shear bands.

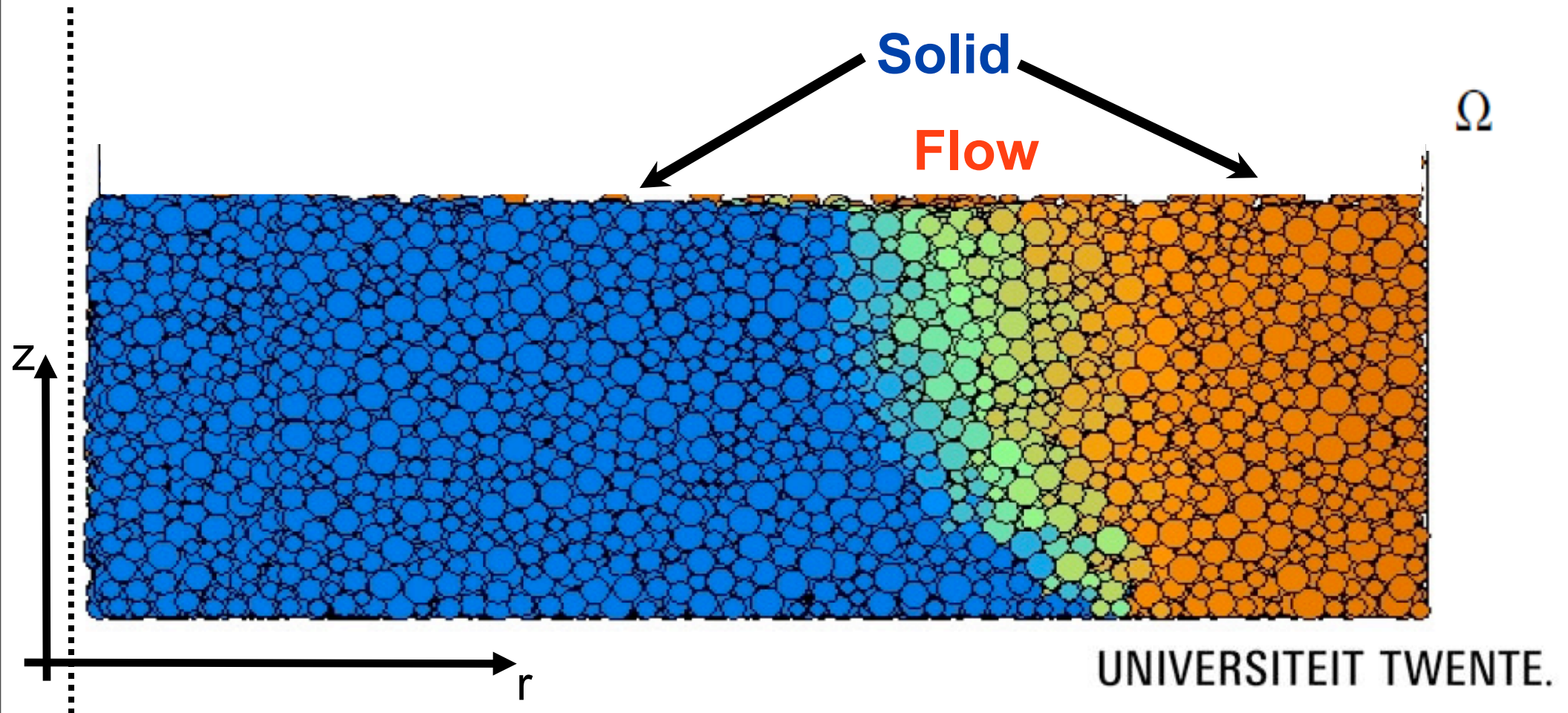
D. Fenistein and M. Van Hecke, *Nature*, 425, 256 (2003).

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Approach

Micro-macro transition for steady flow

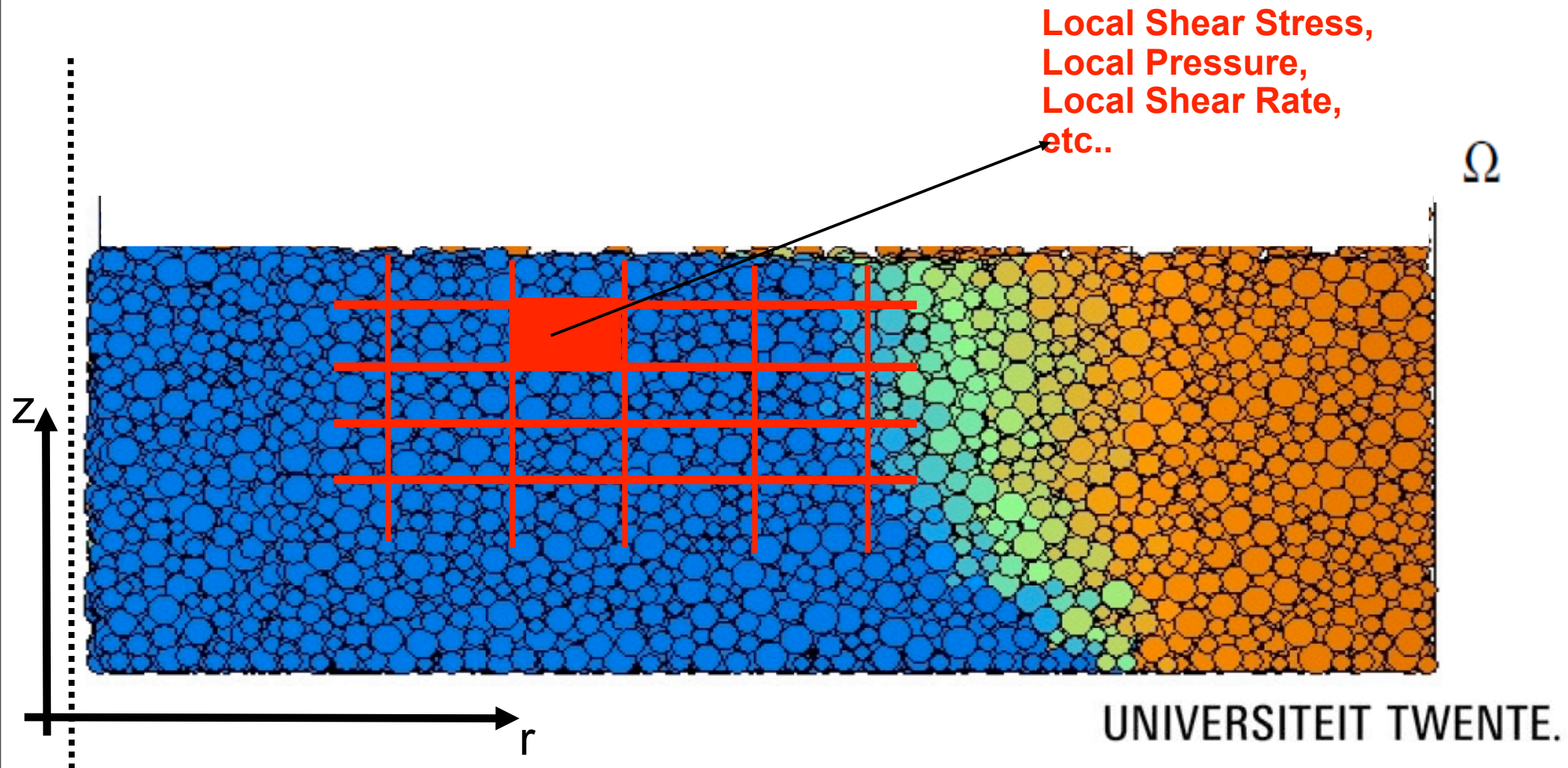
- DEM simulations.



Approach

Micro-macro transition for steady flow

- DEM simulations.
- Compute continuum quantities.

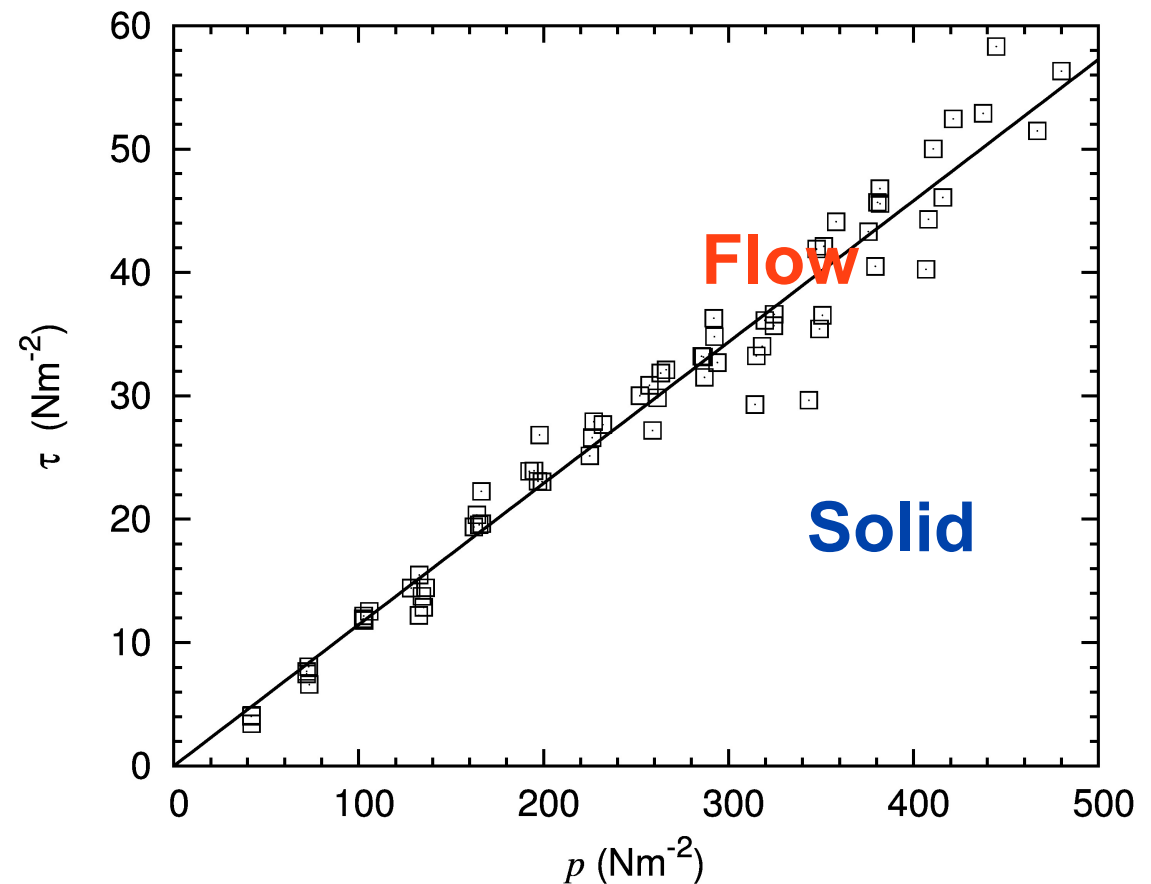


How material behaves?

- Friction at contact.
- Compression/gravity?

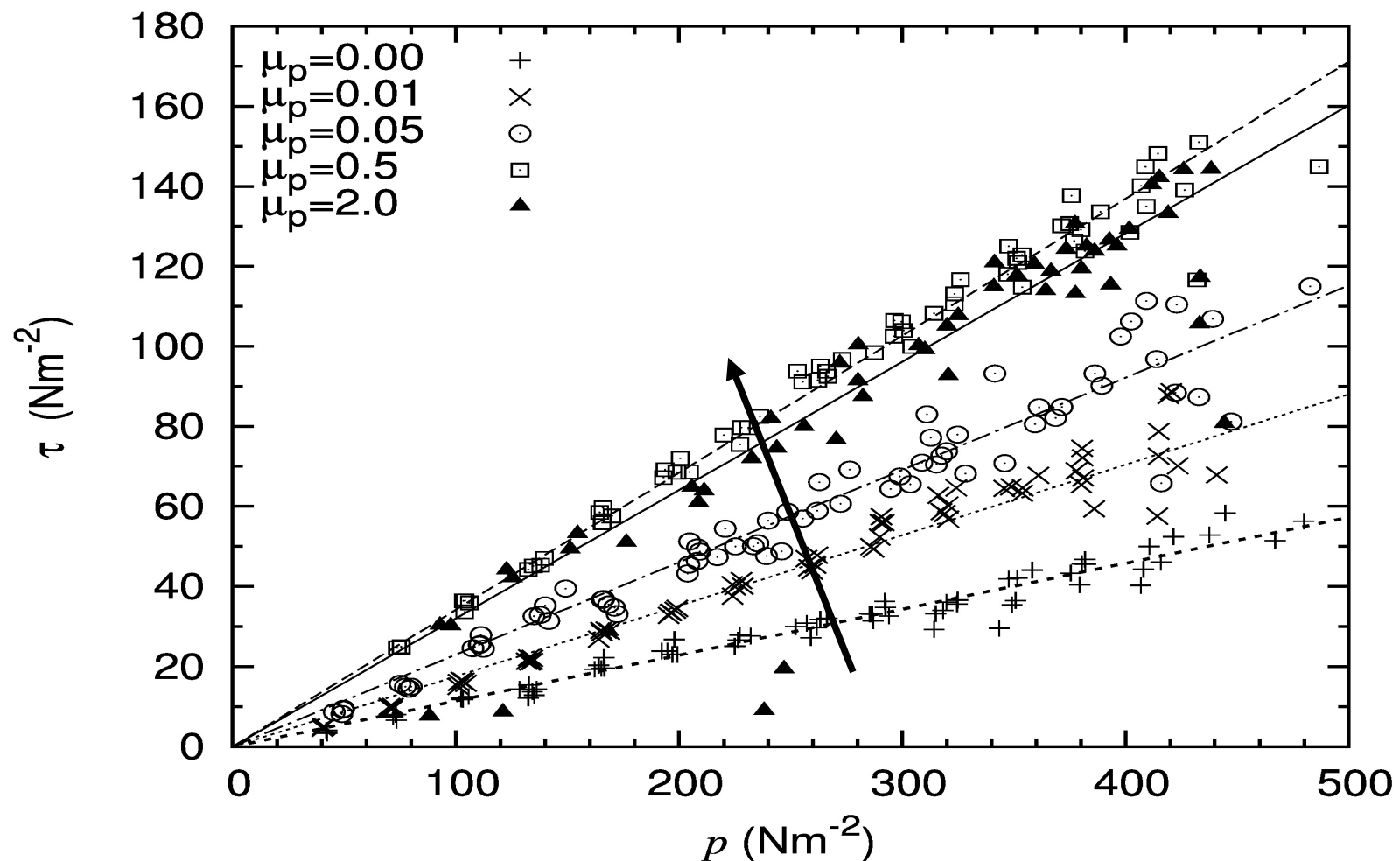
$$\mu = \frac{\tau}{p}$$

**Shear Resistance
of material**



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Friction at contact

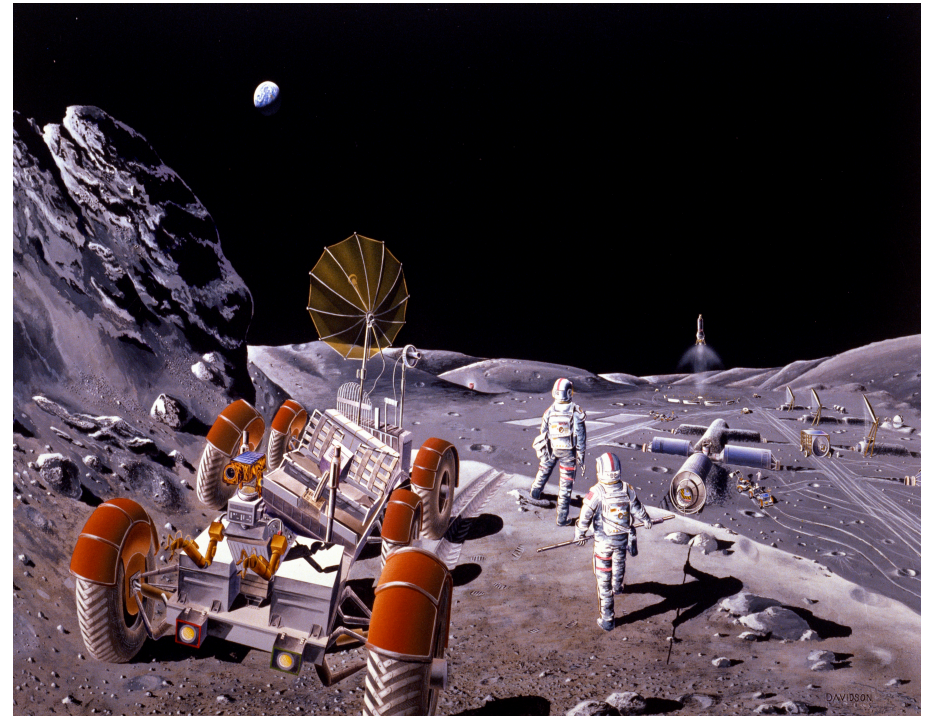


Shear resistance of the material **increases with friction**.

Avalanches?



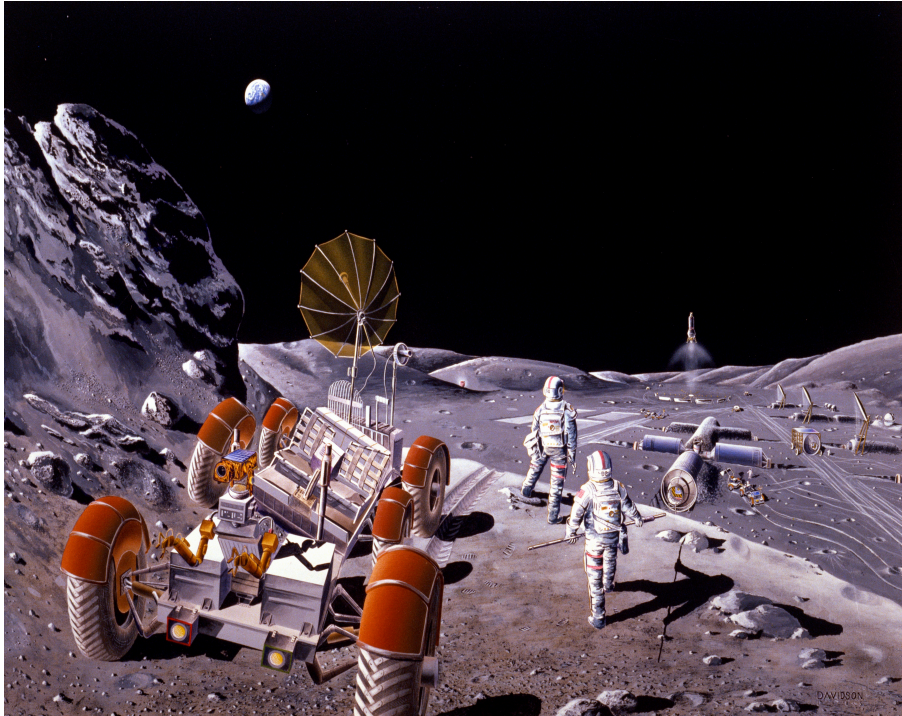
Avalanche on Earth



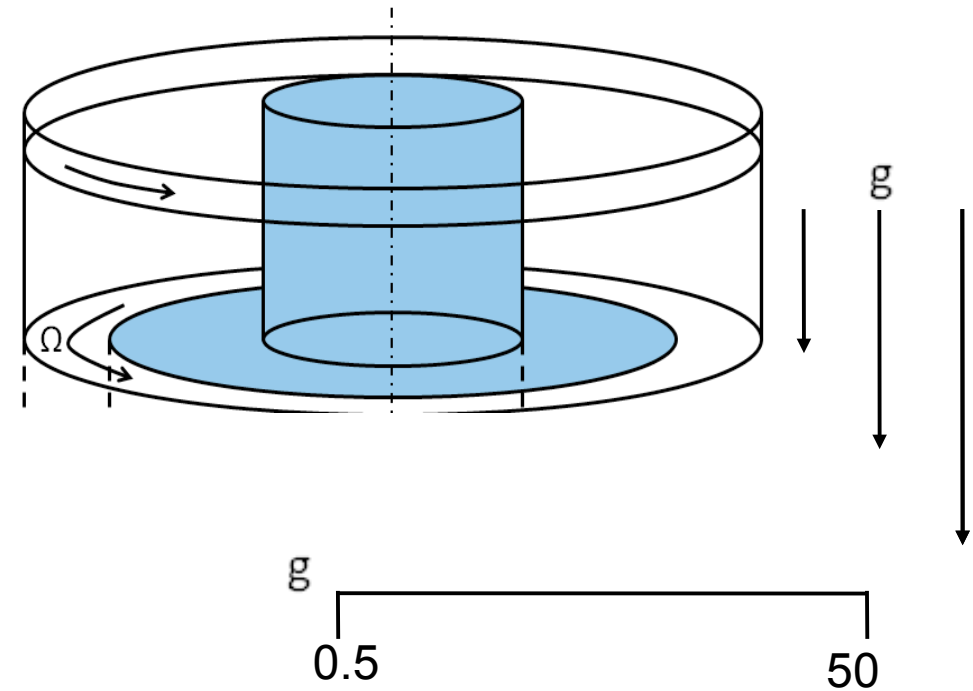
Avalanche on Moon?

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Avalanche on Moon?

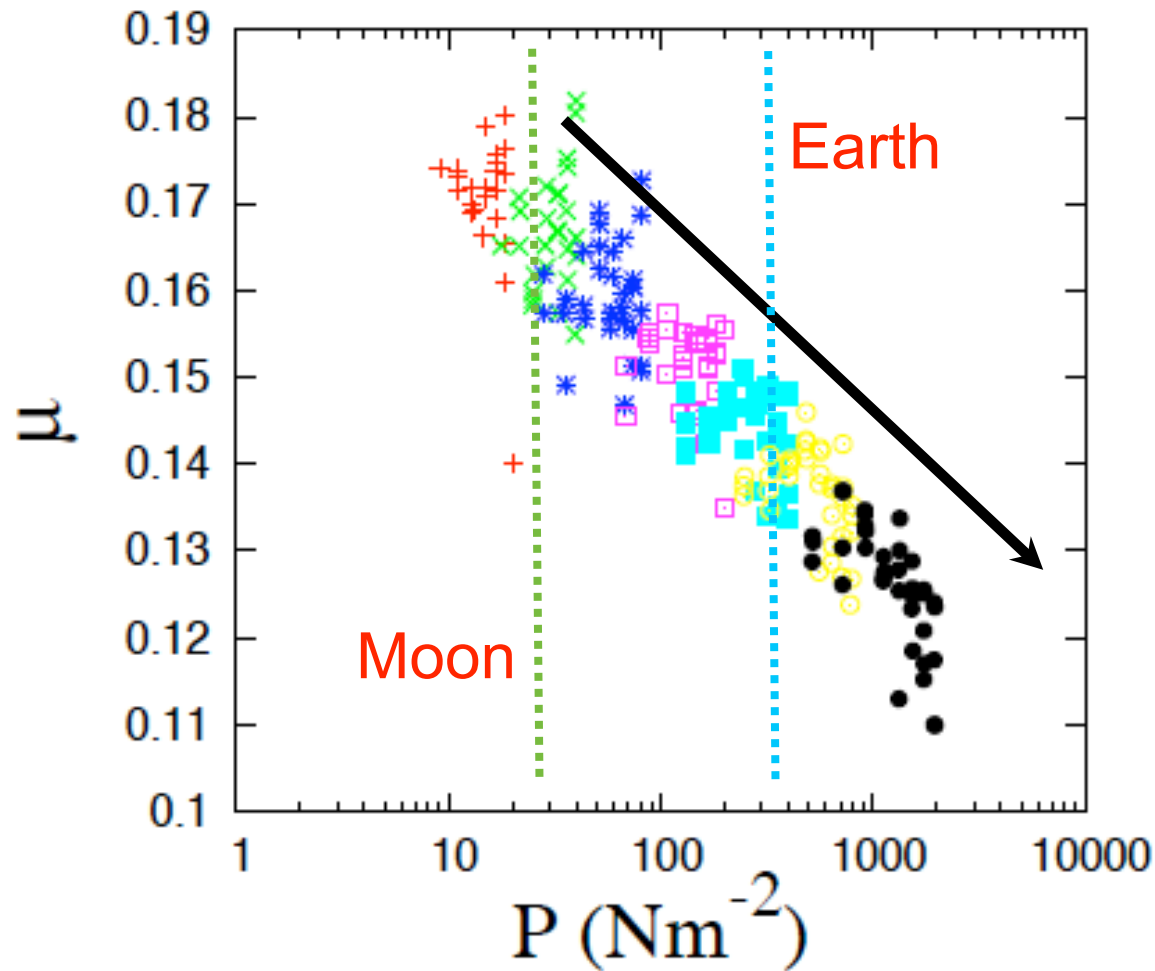


Avalanche on Moon?



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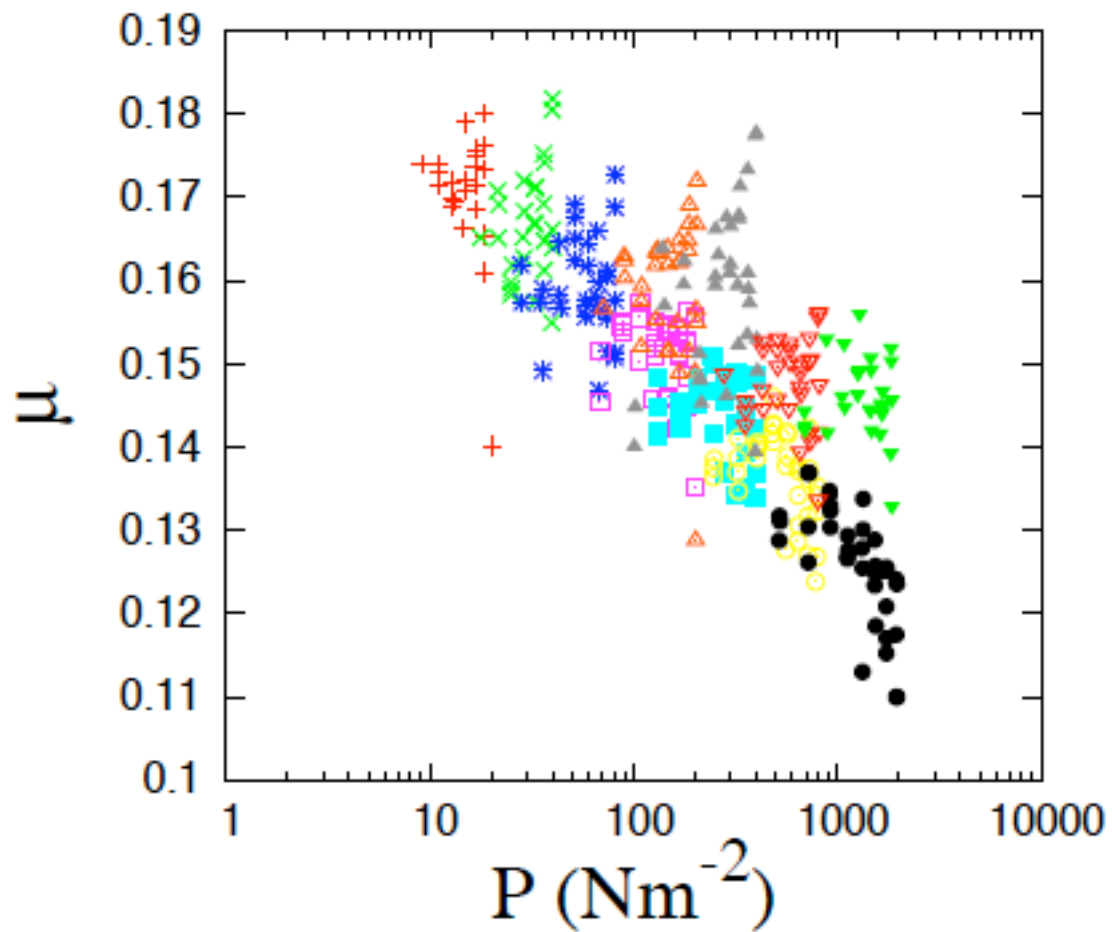
Compression at contact



Shear resistance of material **decreases** with increasing gravity.

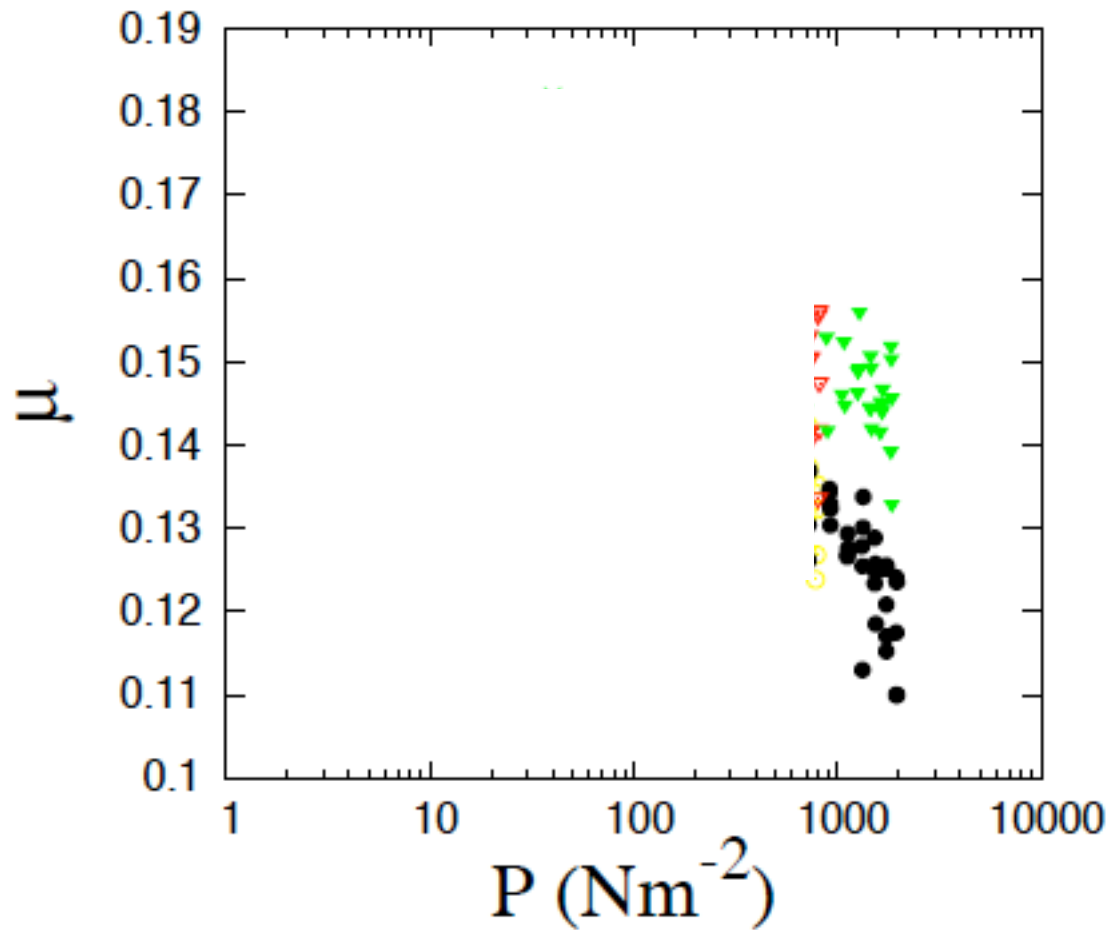
What if we make particles **stiffer for a
given gravity?**

Compression/stiffness at contact



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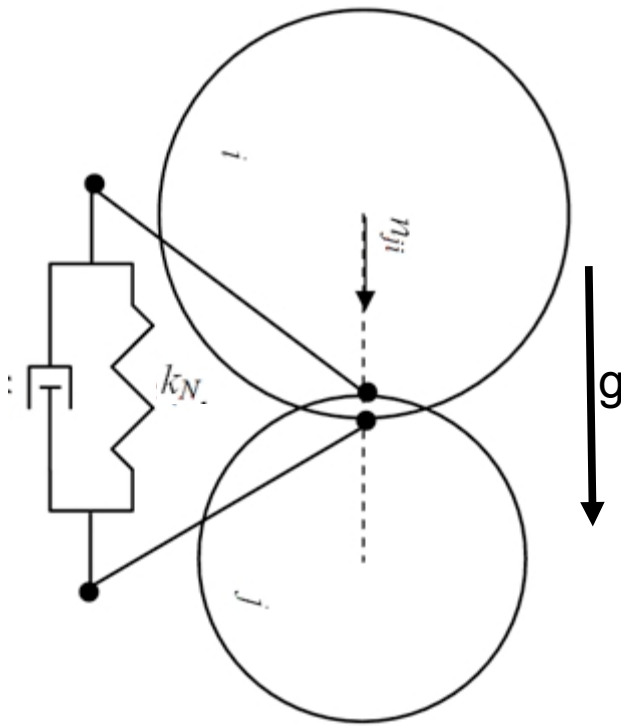
Compression/stiffness at contact



Shear resistance of material **increases** with increasing stiffness.

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Compression/stiffness at contact



Compression
(macro)

$$F_g = mg$$

Normal Resistance
(micro)

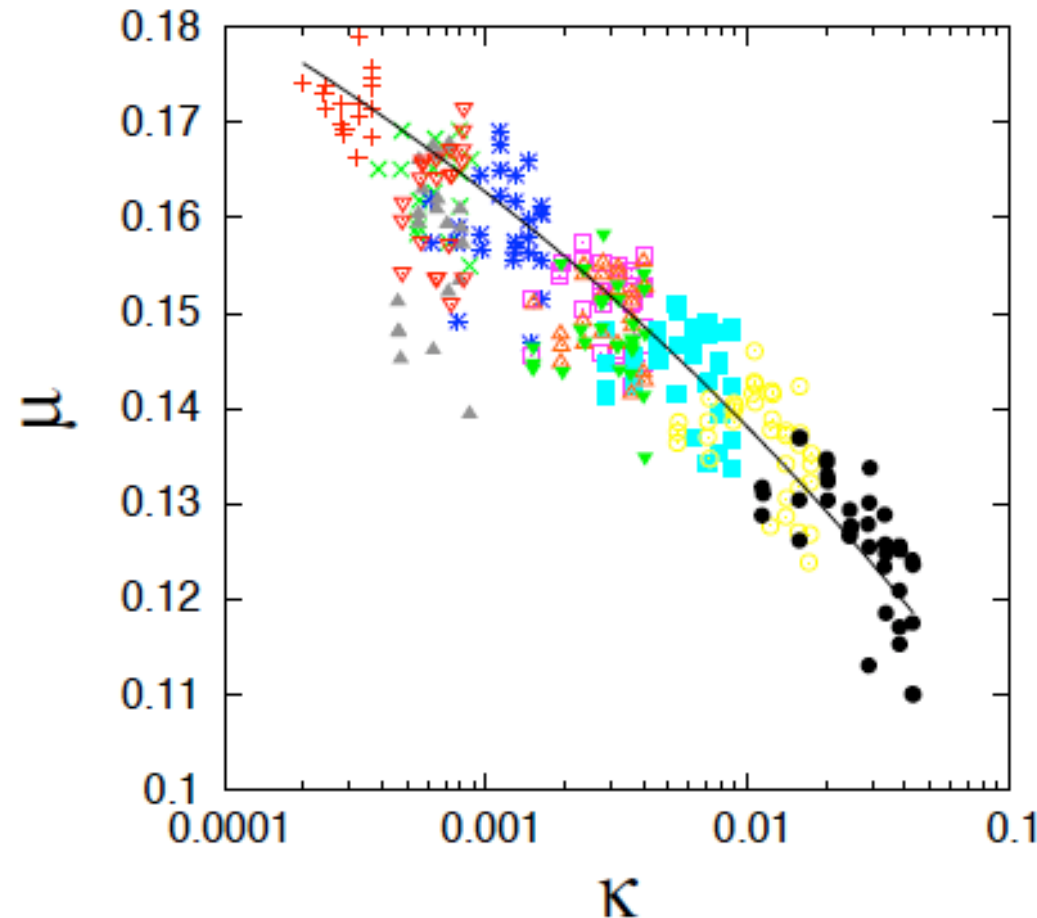
$$F_k = k_n d$$

$$\kappa = \frac{mg}{k_n d}$$

κ denotes softness/hardness of the particles.

Compression/stiffness at contact

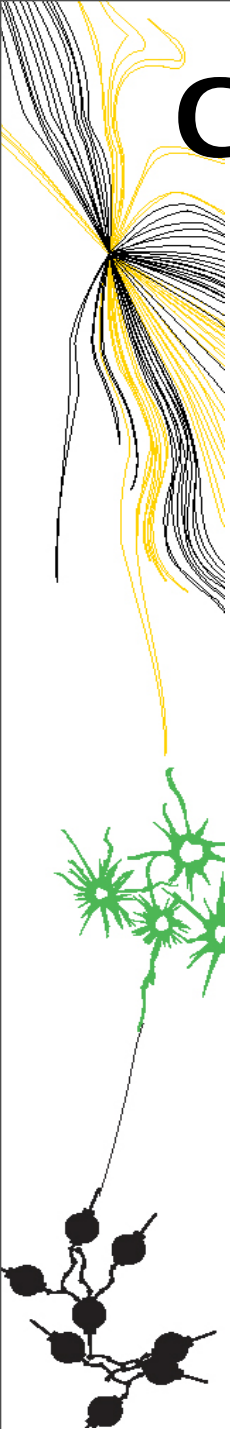
Hard Particles



Soft Particles

Data with different stiffness and gravity **collapse**.
Shear resistance **decreases** with softness.

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Conclusions

Slow granular flow: Yield stress depends on pressure and contact properties

Friction at contact: the shear resistance increases.

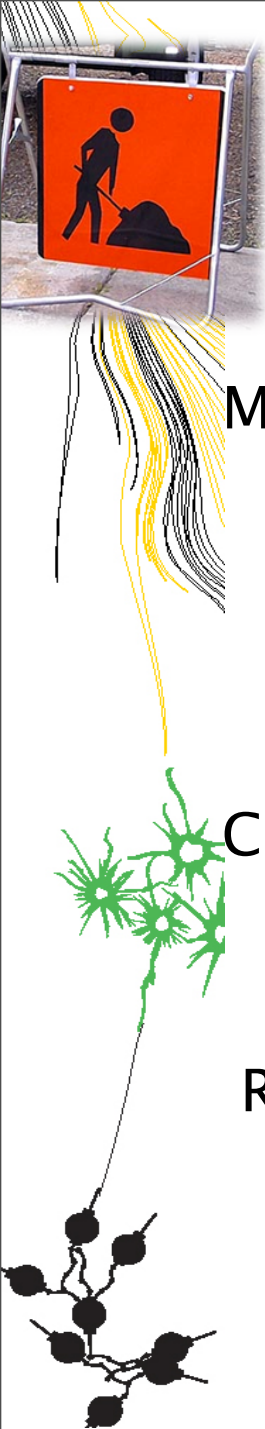
Compression at contact: the shear resistance depends on softness.

Hard particles have higher shear resistance.

Granular matter with the same softness will yield **easier** on Earth compared to moon.

Steeper mountains on Moon?

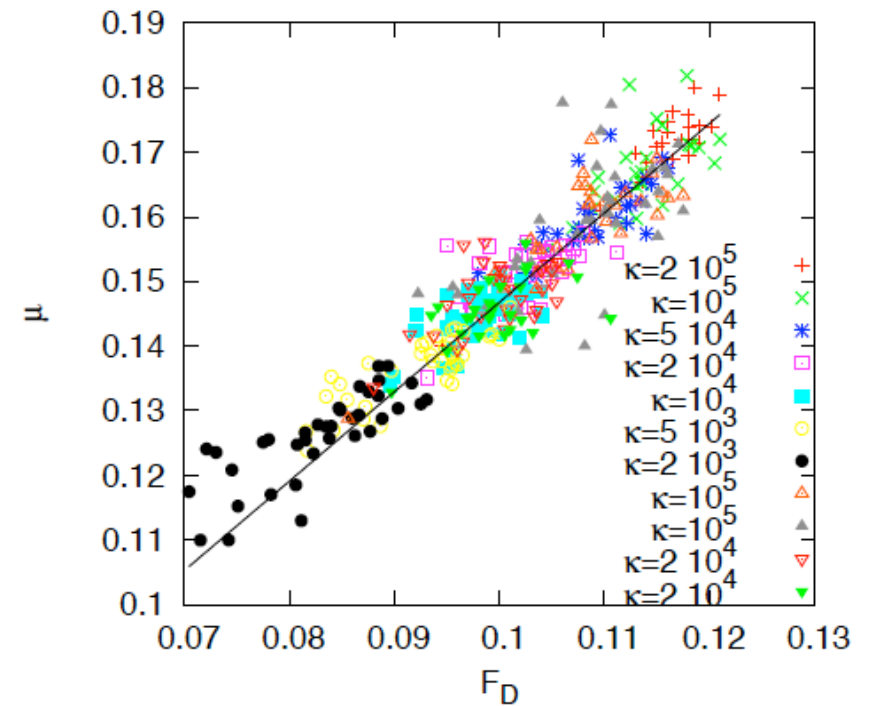
Work in progress



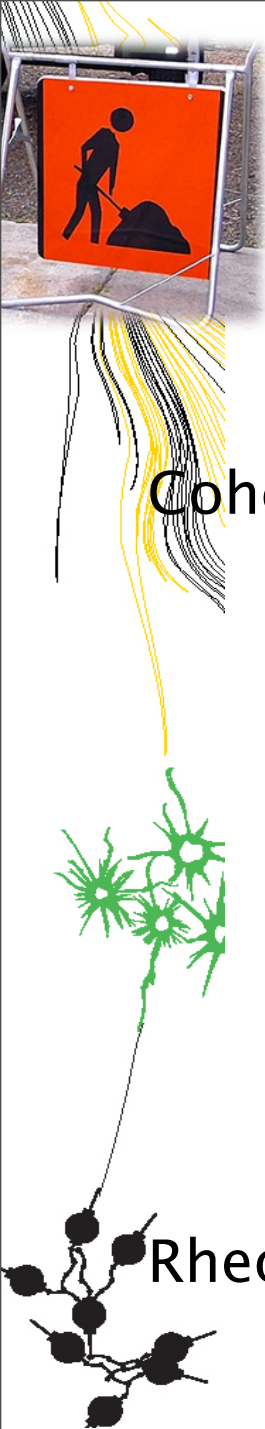
Microstructure?

Cohesion?

Rheology?

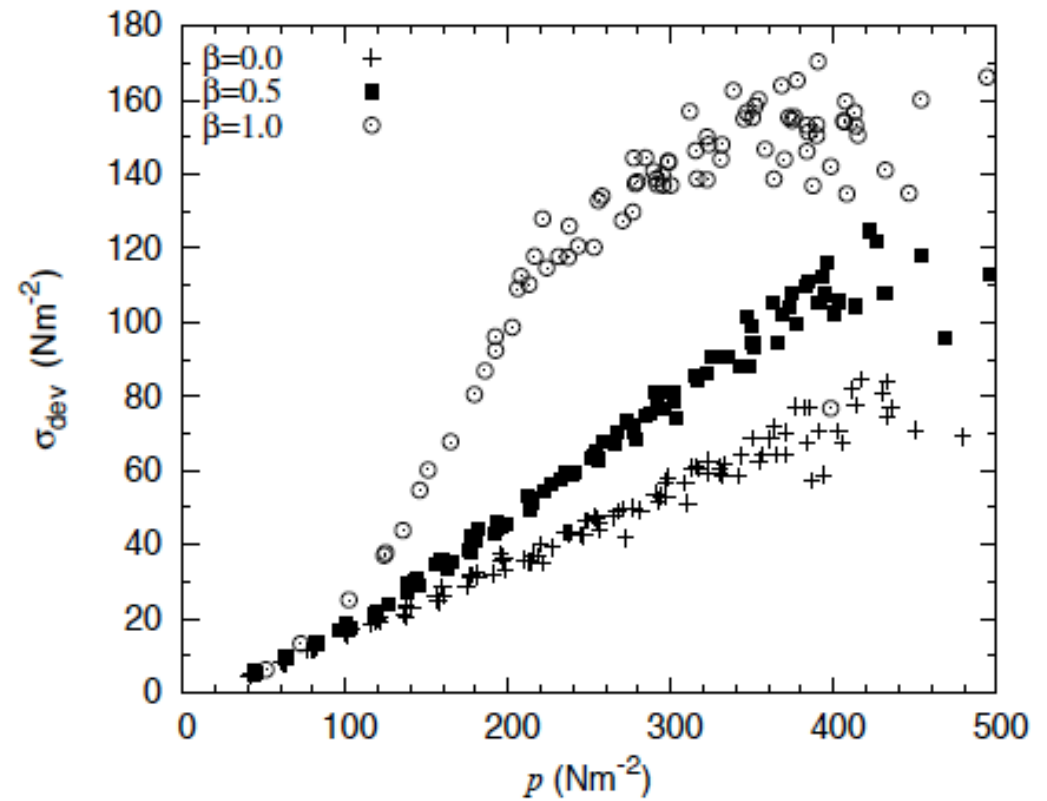


Work in progress



Cohesion?

Rheology?



Work in progress

