Reconciling Micro and Macro through Mesoscience

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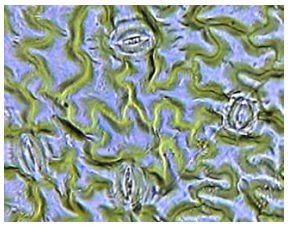
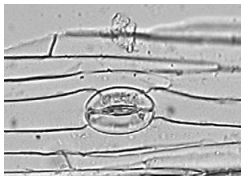
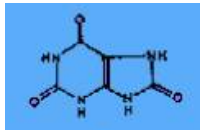
My vision of “Meso”: from Macro to Micro

(through various levels of organisation)



… and vice versa…

Scientists have been able to broken down, sectioned, analysed the matter; now they are challenging themselves to reassemble the various systems, to be able to explain the macro “appearance” in accordance with the micro elements

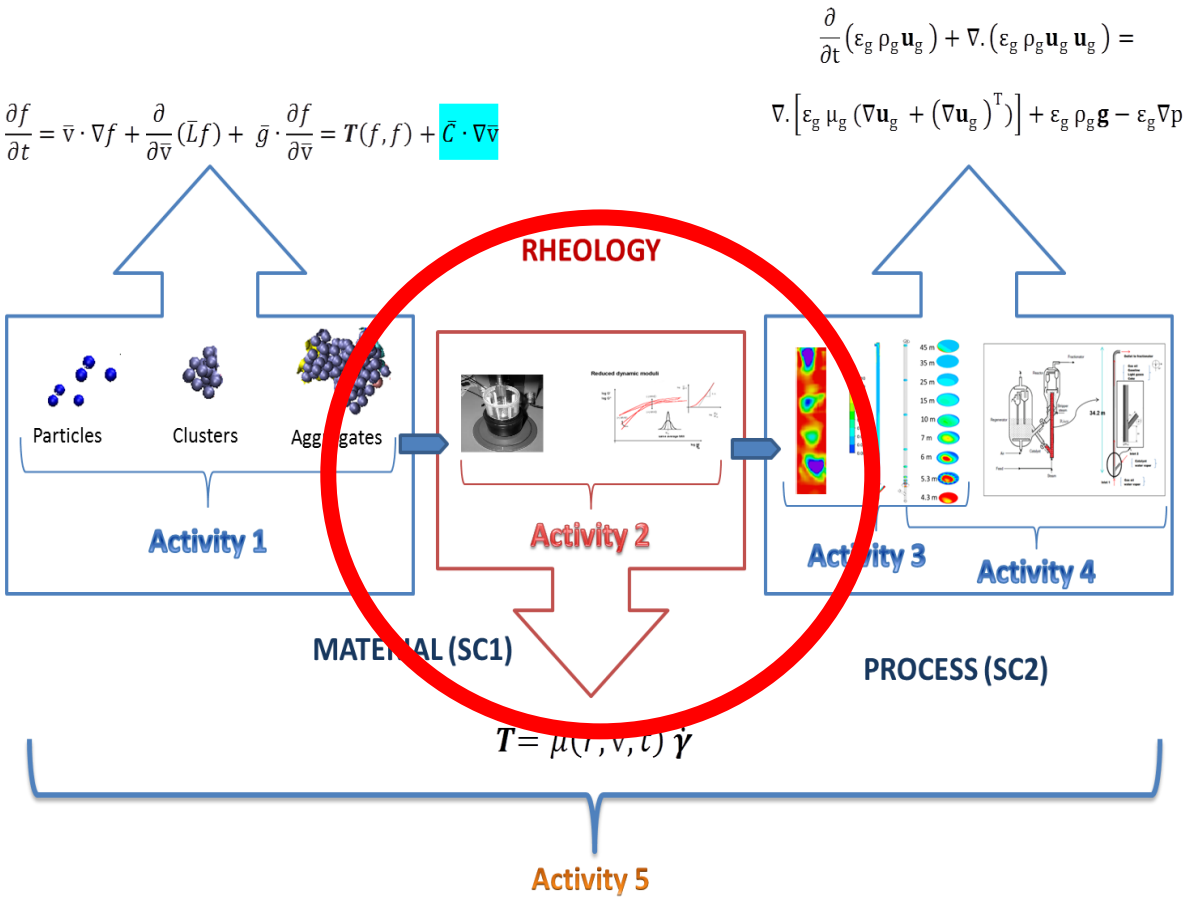
Mesoscience bridges **bottom-up** and **top-down** approaches through multi-objective optimisation under constraints

Solid, Liquid or …..?

"With a bucket of sand and a few careful observations, we will meet fields as diverse as ***elasticity****,* ***plasticity****,* ***statistical physics****,* ***fluid mechanics*** *and* ***geomorphology****. Often we will face unresolved issues that are still at the frontier of our knowledge. Here certainly lies, beyond the numerous applications, the profound attraction exerted by the physics of granular media*"

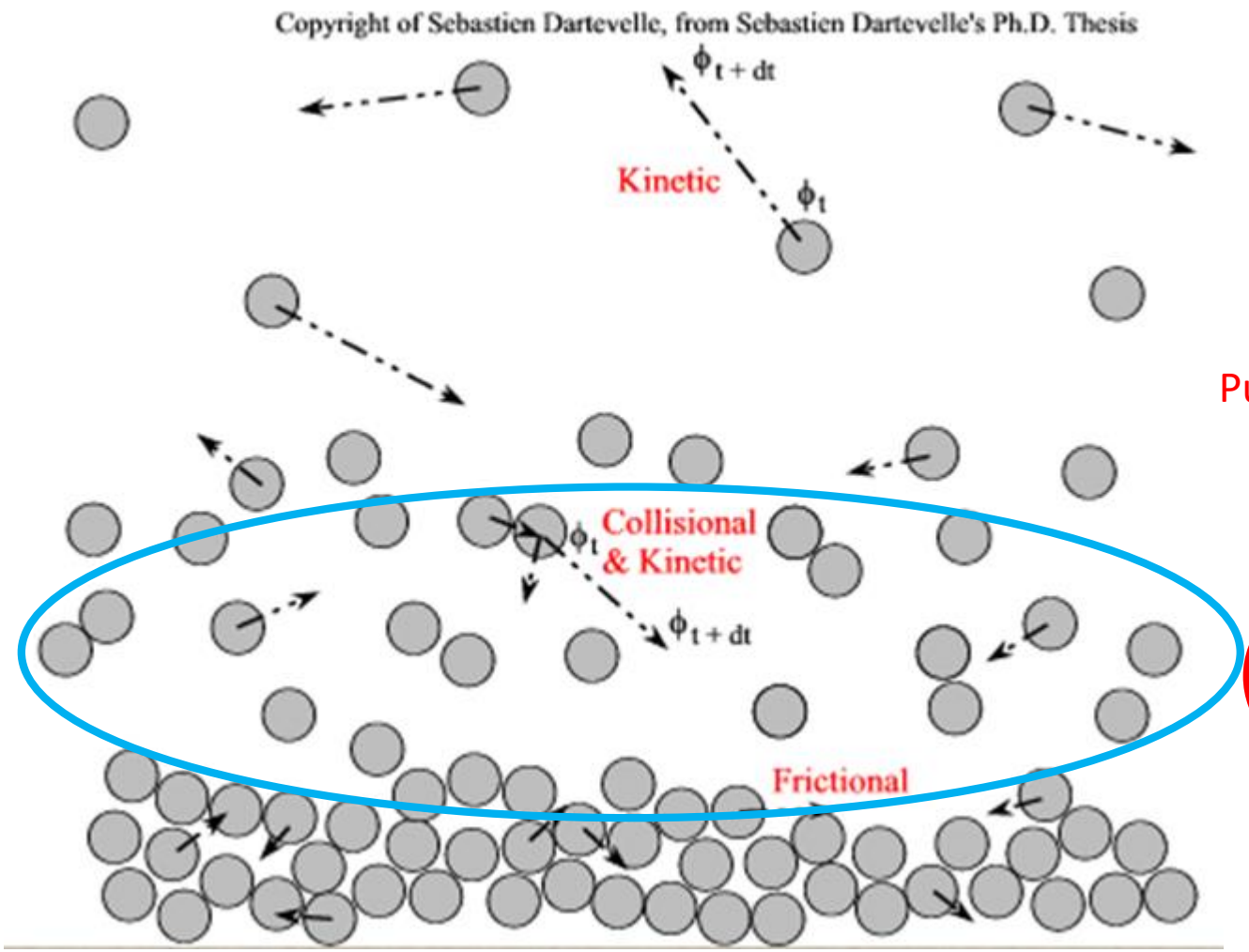
"Granular Media: between fluid and solid", B. Andreotti, Y. Forterre, O. Pouliquen, Cambridge University press (2013)

A New Multi-Scale Paradigm for Particulate Flows



To develop a *user-inspired* theory that help master the hydrodynamics of particulate media and improve the reliability of their industrial processing

Regime Map for Particle-Particle Interactions



❑ **Rapid flow regime**

Binary-collisions
Fluid-like behaviour
KTGF (kinetic theory of granular flow)

Purpose for **MESOSCIENCE**

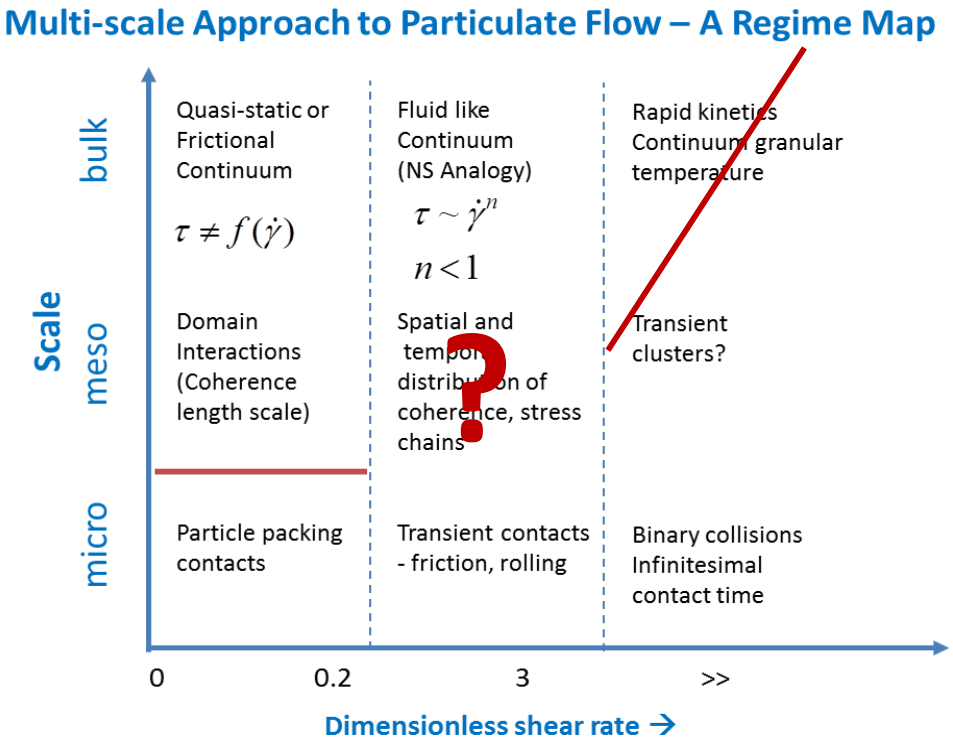
❑ **Intermediate regime**

Coexistence of **frictional** and **collisional** stress

❑ **Slow, friction regime**

Solid-like behaviour
Particle packing
Enduring contact
Coulomb frictional law

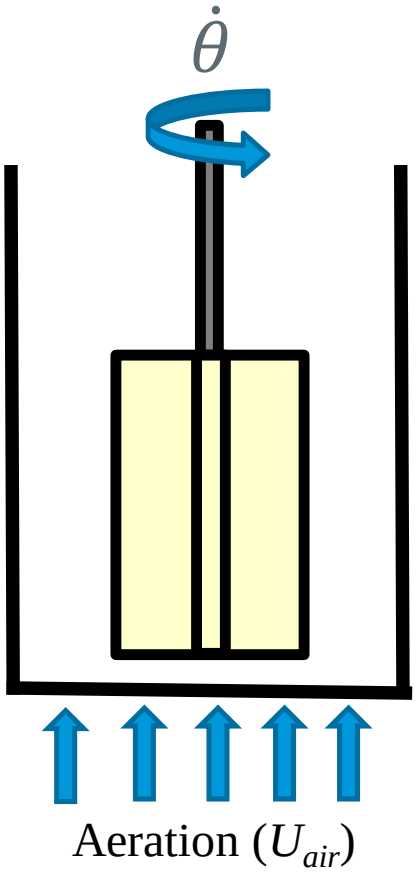
The Classification of Flow Regimes depends on the Applications



[courtesy of P Mort]

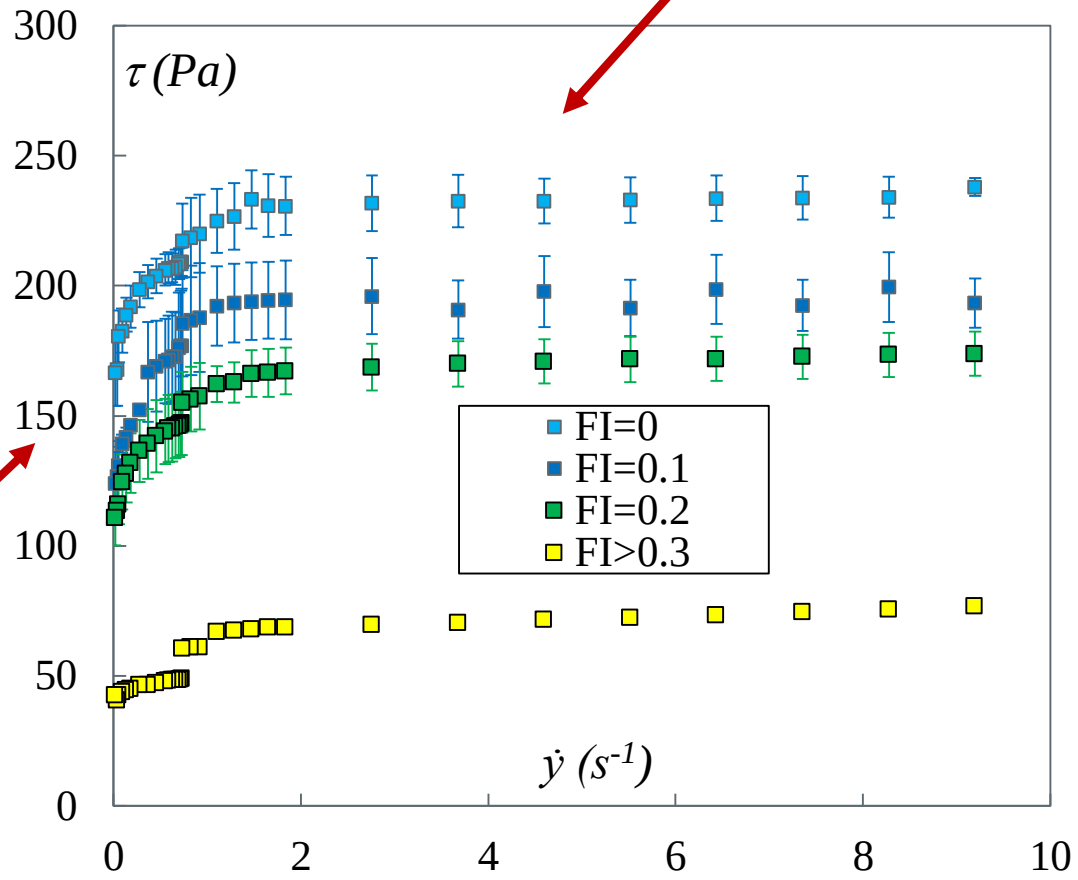
We need to understand the bulk properties (at the meso-scale)

Rheology of Powders



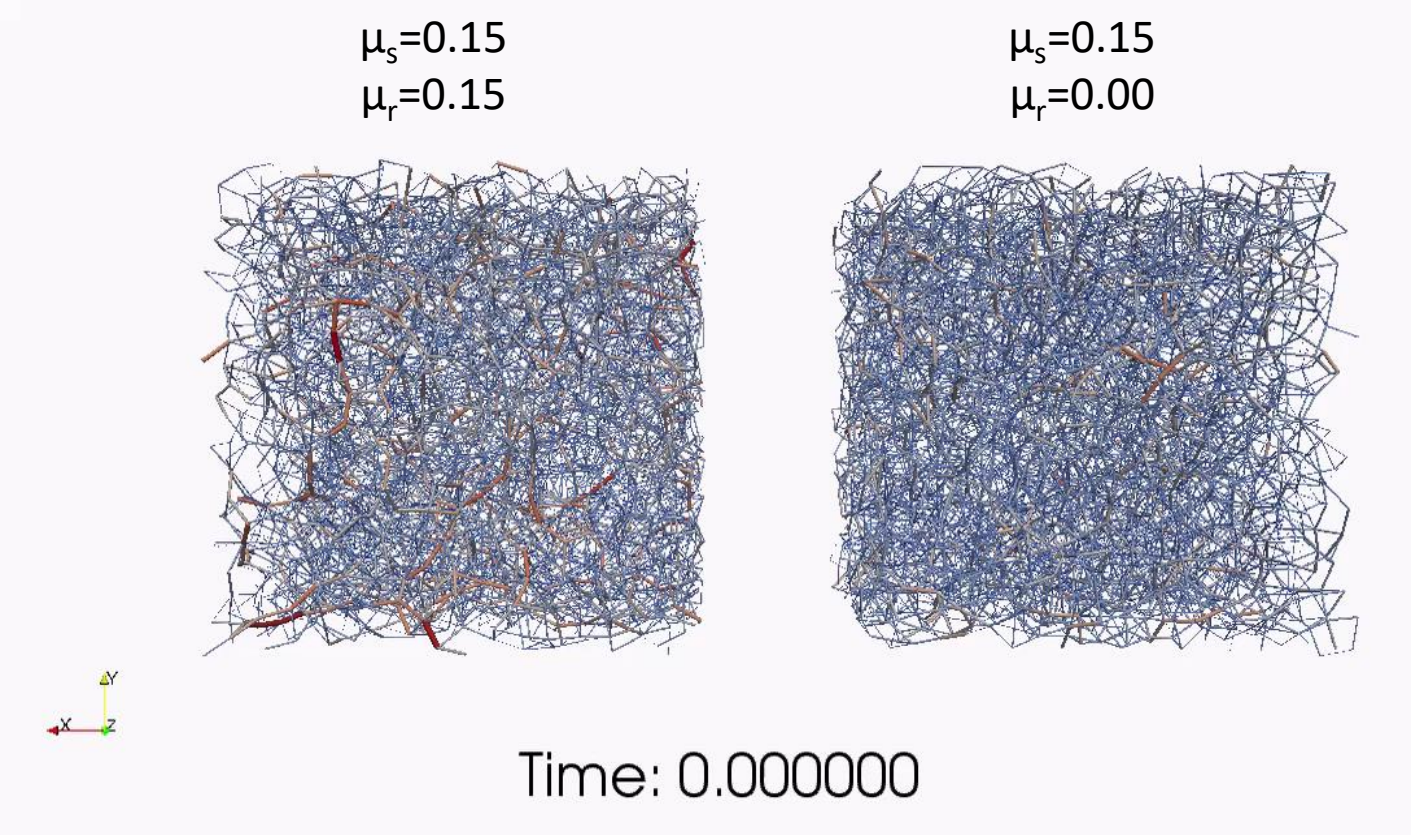
Coulomb

Bingham



Network of Forces –the Role of Friction

r = 0.25 mm
ρ = 2500 kg/m^3
γ = 0.0252 s^{-1}



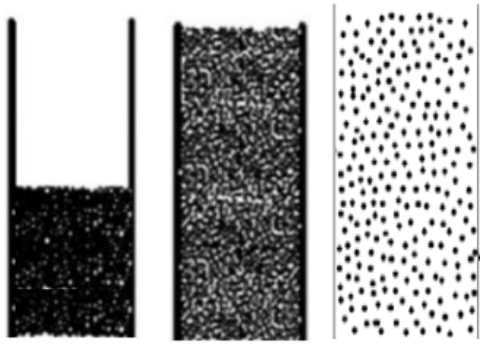
How Mesoscale Influences the Macroscale

Inter-phase drag model

Wen-Yu/Ergun model:

$$\beta_0 = \begin{cases} \beta_{\text{Wen-yu}} & \varepsilon_p < 0.75\varepsilon_{cp} \\ \dfrac{\varepsilon_p - 0.75\varepsilon_{cp}}{0.85\varepsilon_{cp} - 0.75\varepsilon_{cp}}\left(\beta_{\text{Ergun}} - \beta_{\text{Wen-yu}}\right) + \beta_{\text{Wen-yu}} & 0.75\varepsilon_{cp} \le \varepsilon_p \le 0.85\varepsilon_{cp} \\ \beta_{\text{Ergun}} & \varepsilon_p > 0.85\varepsilon_{cp} \end{cases}$$

$$\beta_{\text{Wen-yu}} = \frac{3}{4} C_d \frac{\varepsilon_g \varepsilon_p \rho_g \left|\boldsymbol{u}_g - \boldsymbol{u}_p\right|}{d_p} \varepsilon_g^{-2.65} \qquad \beta_{\text{Ergun}} = \frac{180\varepsilon_p \boldsymbol{u}_g}{\left(1-\varepsilon_p\right) d_p^2} + \frac{2\rho_g \left|\boldsymbol{u}_g - \boldsymbol{u}_p\right|}{d_p}$$

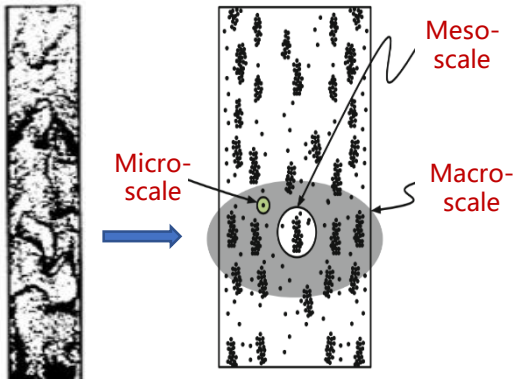


Homogeneous gas-solid flow

EMMS model:

$$\overrightarrow{X} = (\varepsilon_{sc}, \varepsilon_{sf}, U_c, U_f, U_{pc}, U_{pf}, d_{cl}, f)$$

$$N_{st} = \frac{W_{st}}{(1-\varepsilon)\rho_p} = \min \Rightarrow \boxed{H_d = \frac{\beta_{\text{EMMS}}}{\beta_{\text{Wen-yu}}}} \qquad H_d = a\,\text{Re}_p^b$$

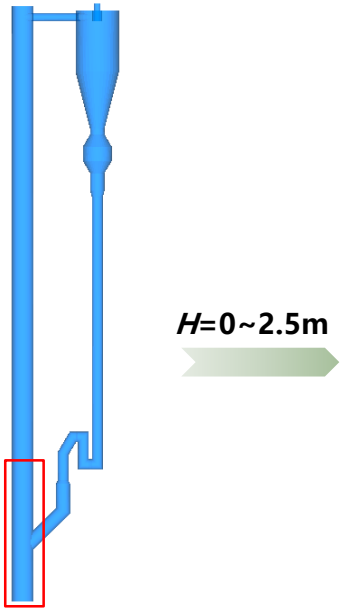


Heterogeneous gas-solid flow

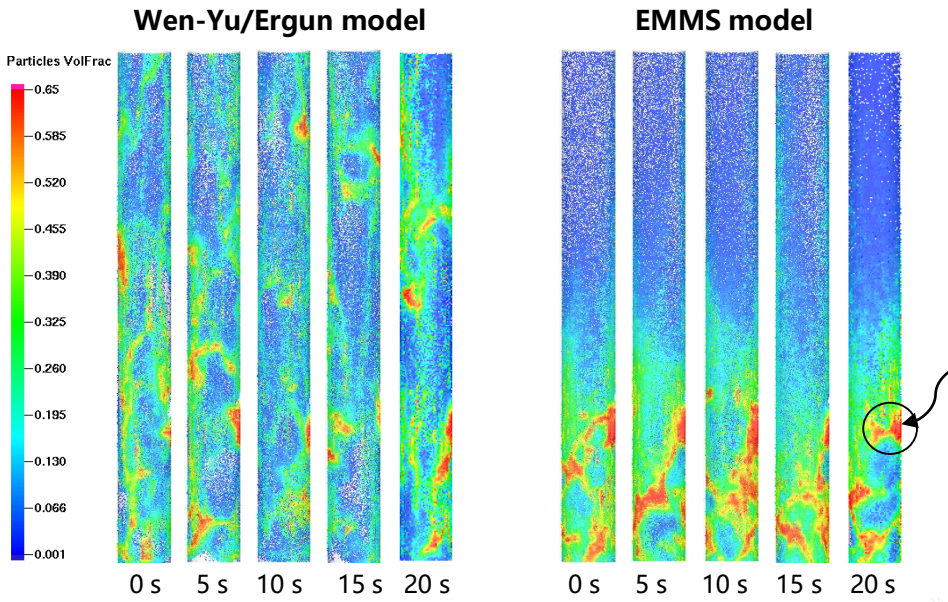
Work supported by NSFC, CAS and Newton Fund (X Zhu, H Wang)

How Mesoscale Influences the Macroscale

Particle distribution in dense region

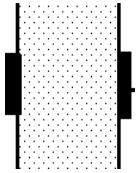


H=0~2.5m

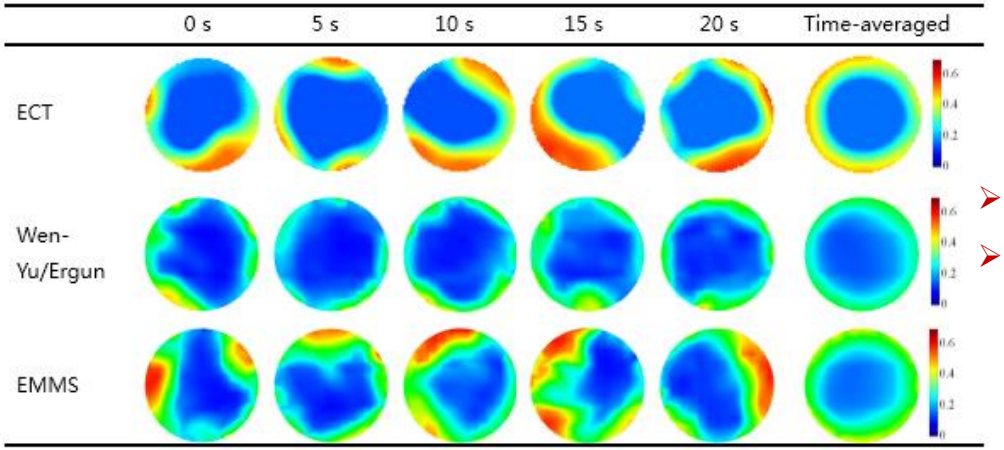


Cluster/agglomeration

ECT



H =0.5m



- Core-annular distribution
- EMMS>Wen-Yu/Ergun

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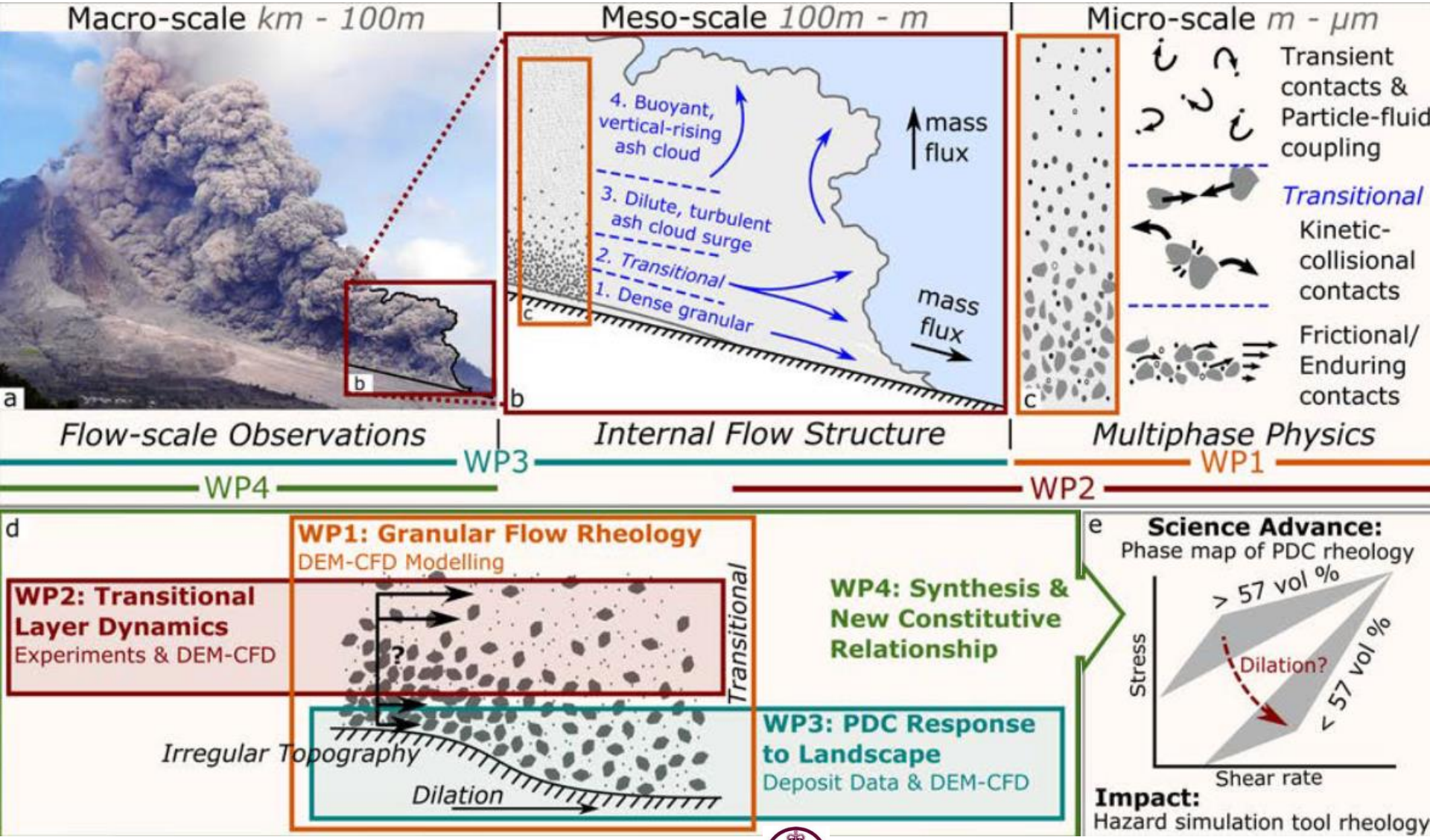
What's next?

LEADERS IN IDEAS AND SOLUTIONS

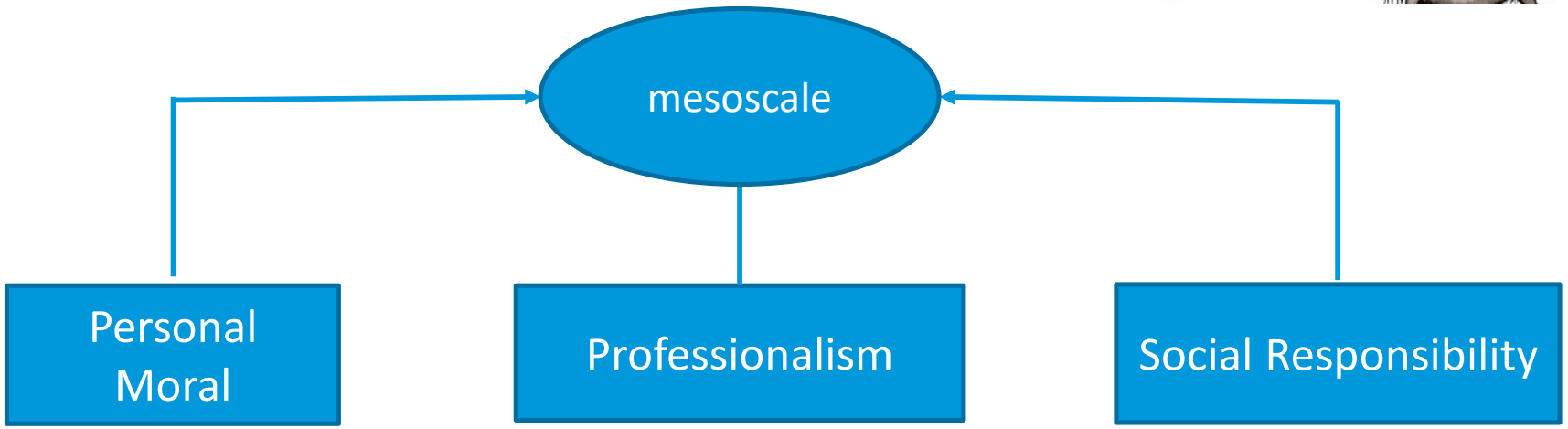
"Would you tell me please which way I ought to go from here?"
"That depends a good deal on where you want to go", said the cat.
Lewis Carroll

Regime Map for Particle-Particle Interactions



Work supported by NERC and in collaboration with BGS 1835

The Mesoscience of Engineering Ethics (?)



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LEADERS IN IDEAS AND SOLUTIONS

Thank you for your attention

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