Multiscale characterization & modeling of geomaterials

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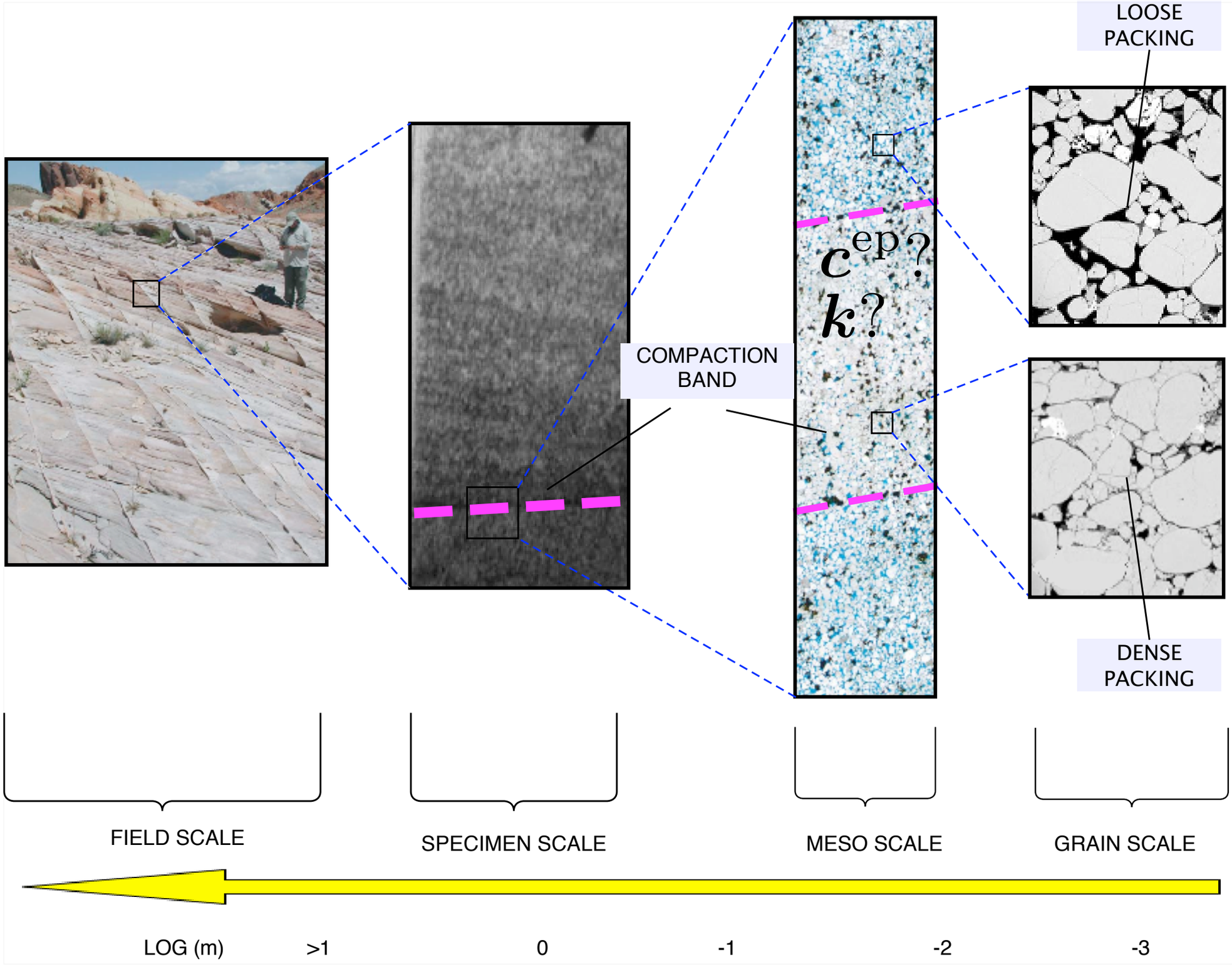
AGU fall meeting, December 2011

Today's Menu

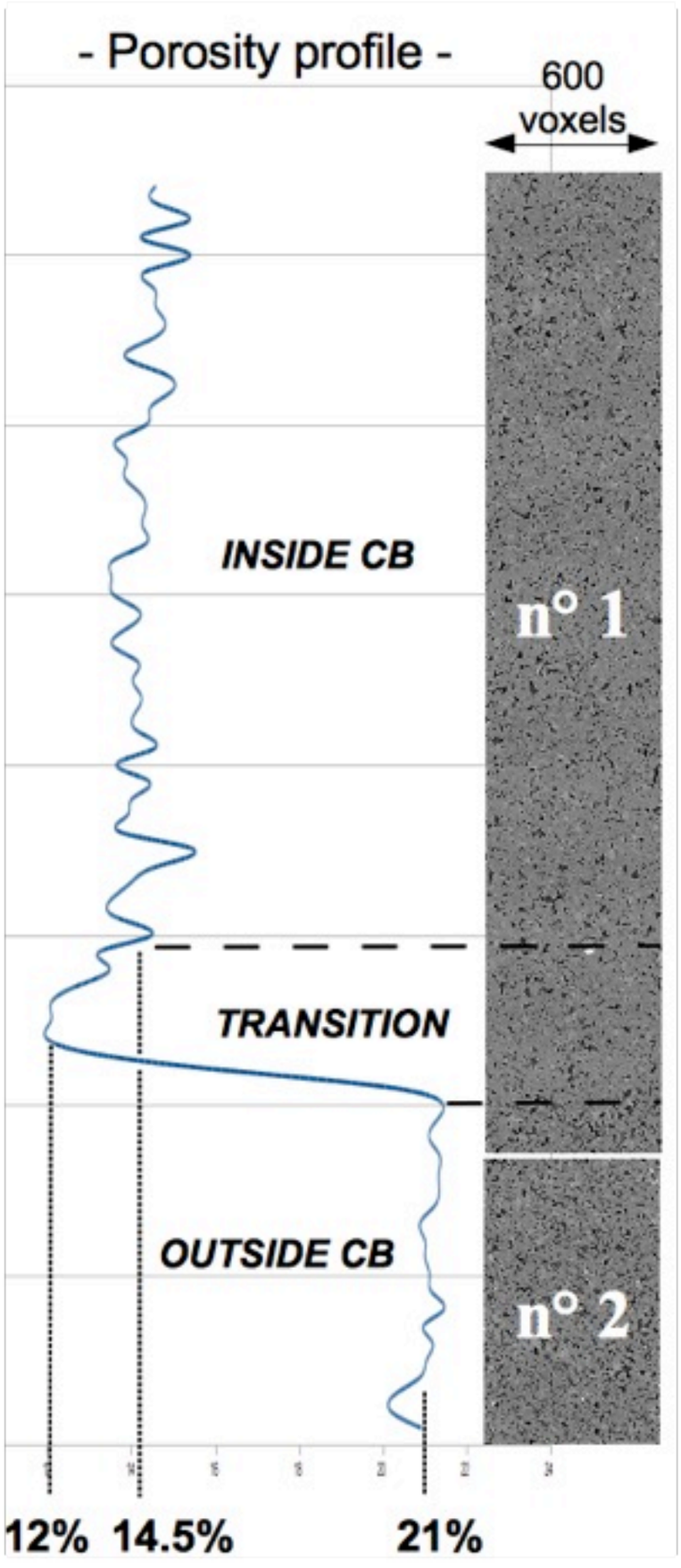
- Multiscale concept in porous rocks
- Multiscale flow in porous materials
- Multiscale deformation in porous materials
- Conclusion

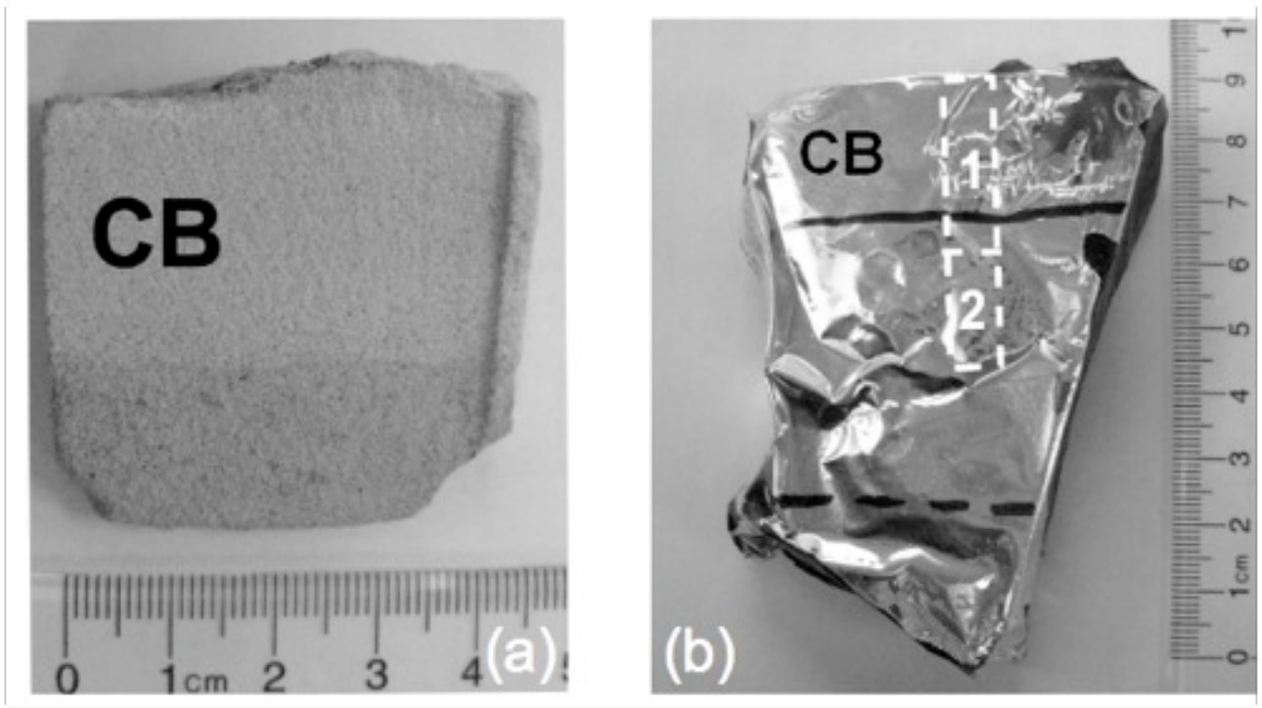


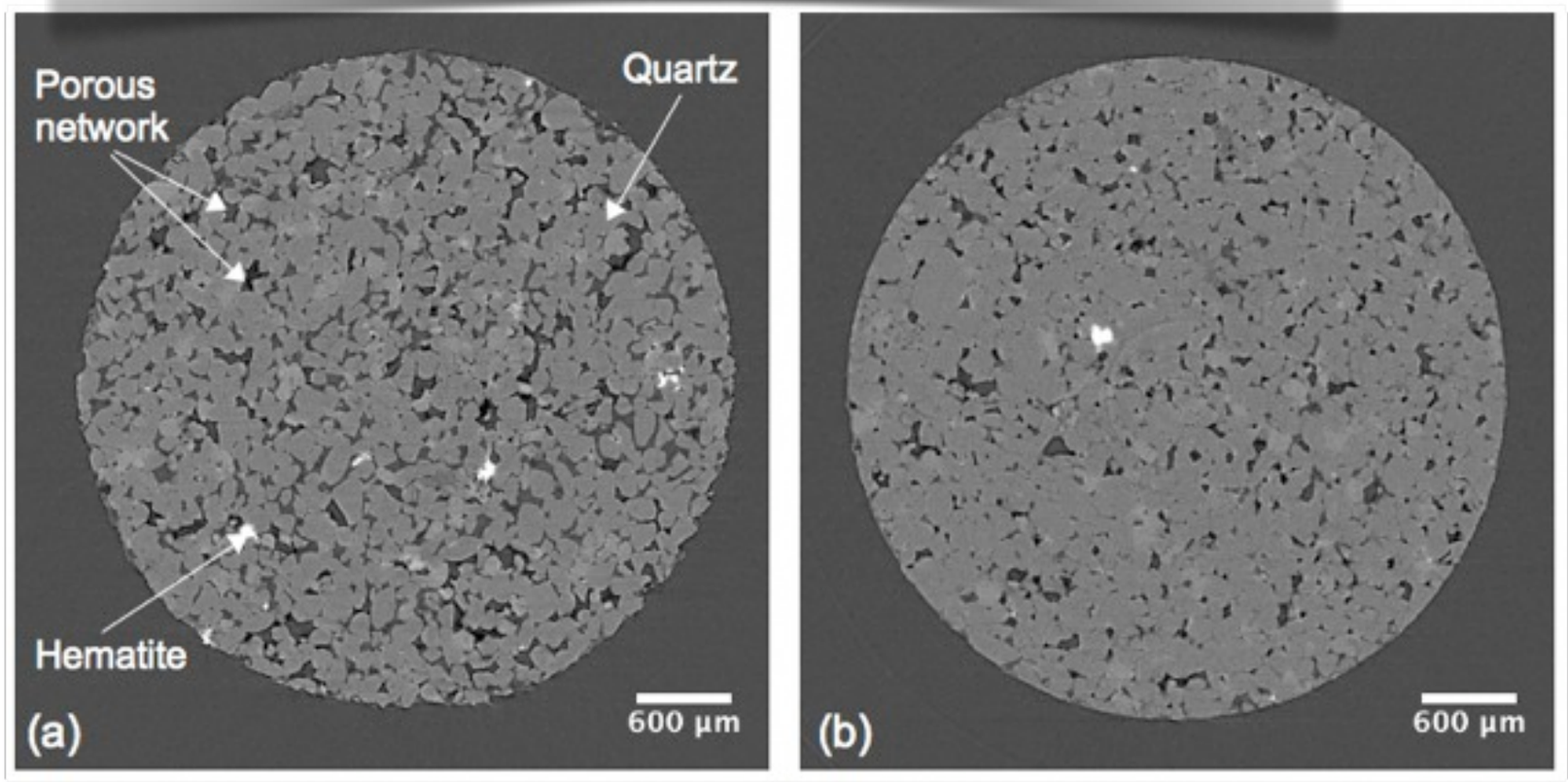
Multiple scales in sandstones: CO2 repositories

Flow: from Boltzmann to Darcy

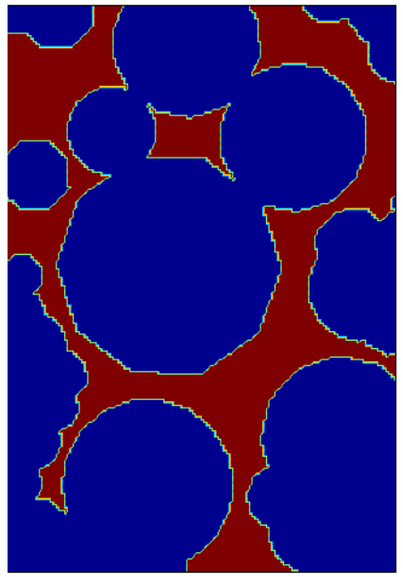
Based on synchrotron data from Argonne

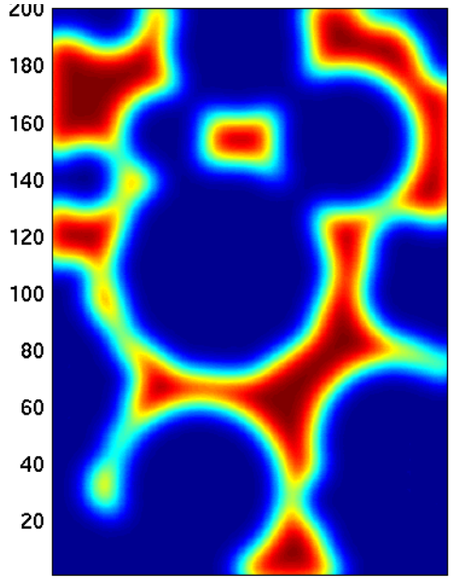


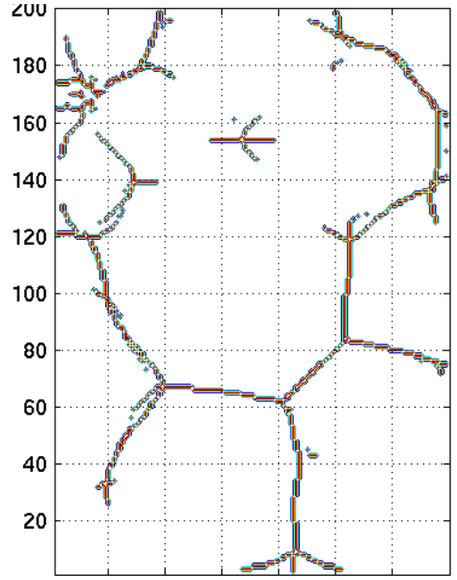




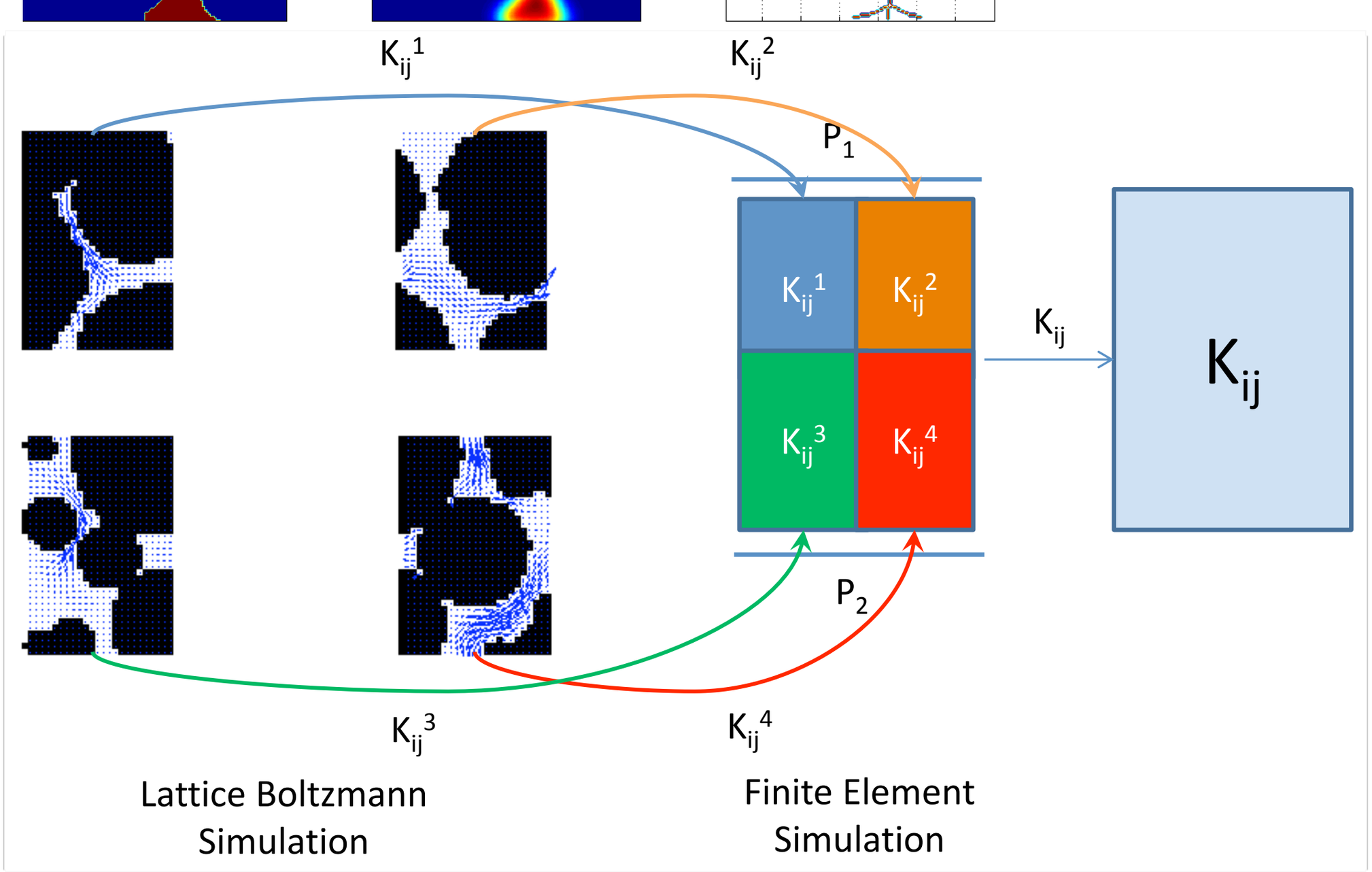
x-rays on Valley of Fire sandstone

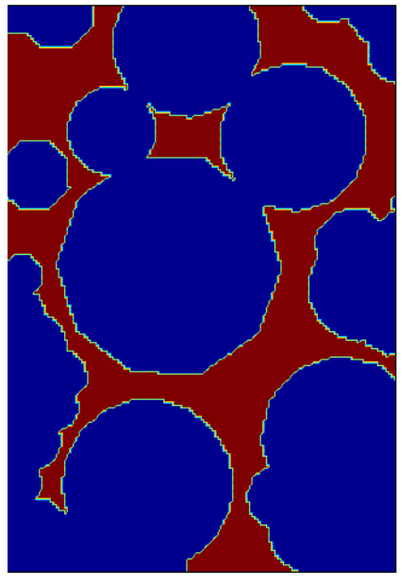


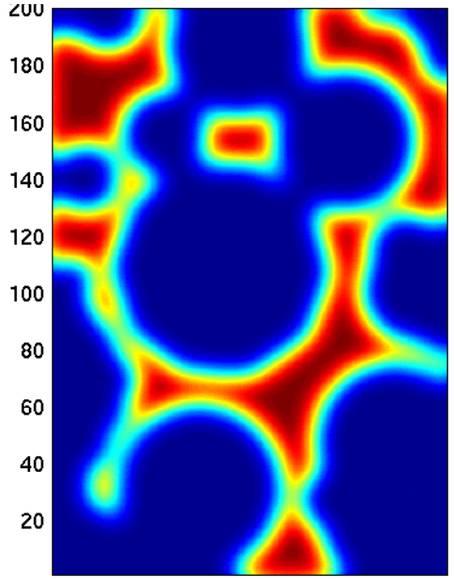


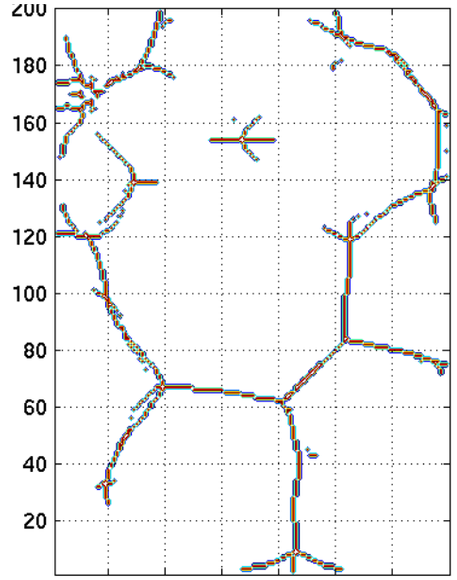


tools: X-R CT,
level sets,
graph theory



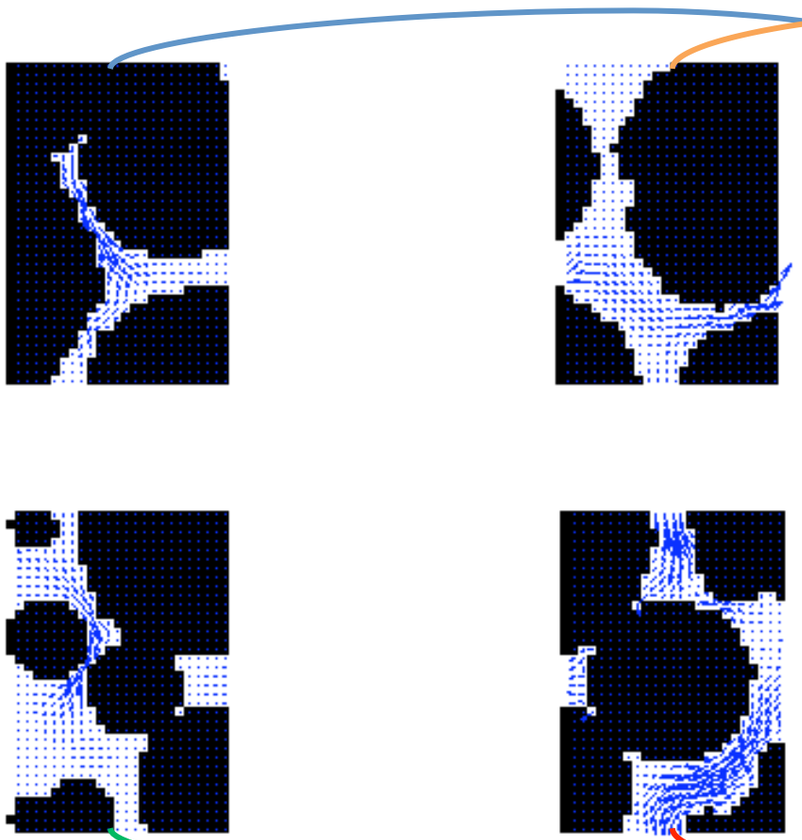




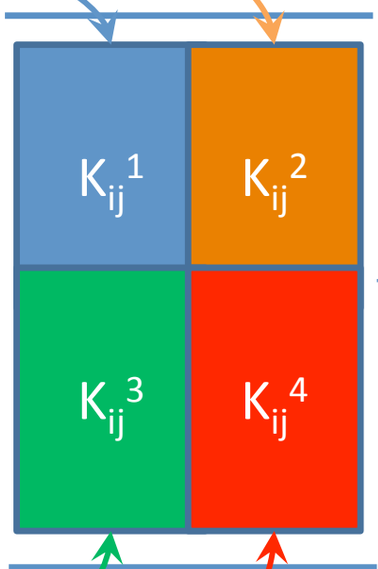


tools: X-R CT,
level sets,
graph theory

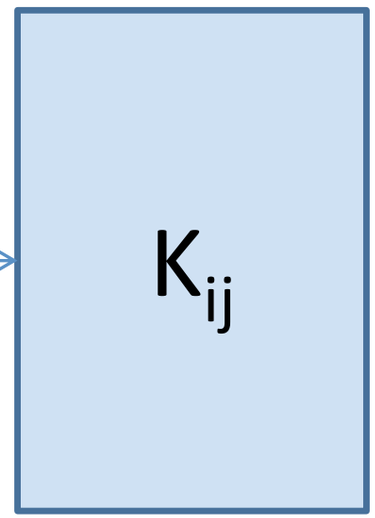
K_{ij}^1 K_{ij}^2



P_1



K_{ij}



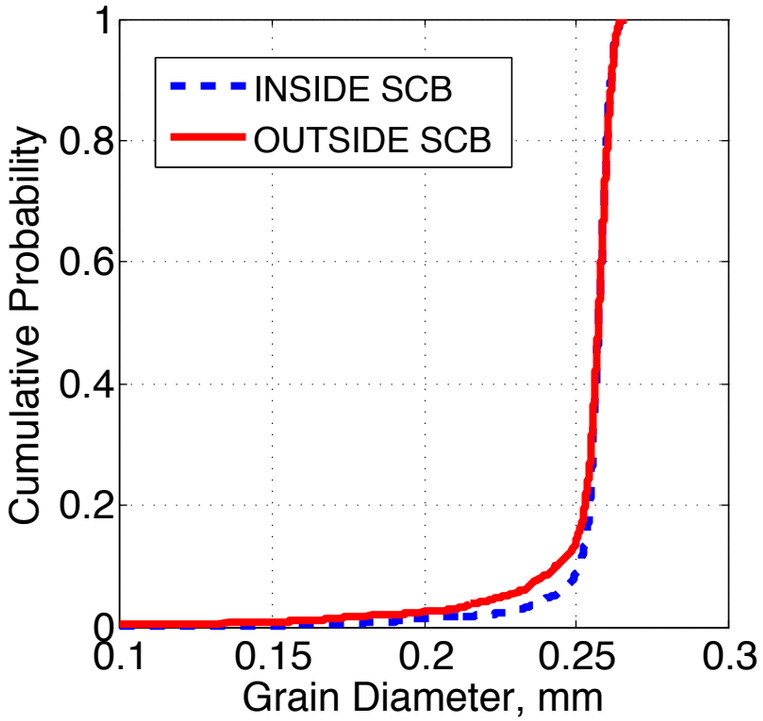
P_2

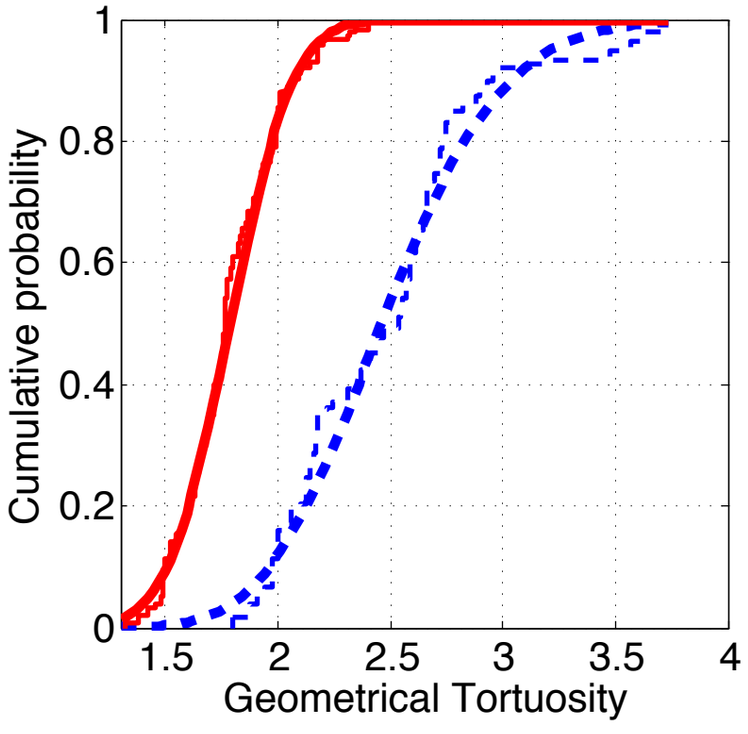
K_{ij}^3 K_{ij}^4

From Boltzmann
to Darcy...

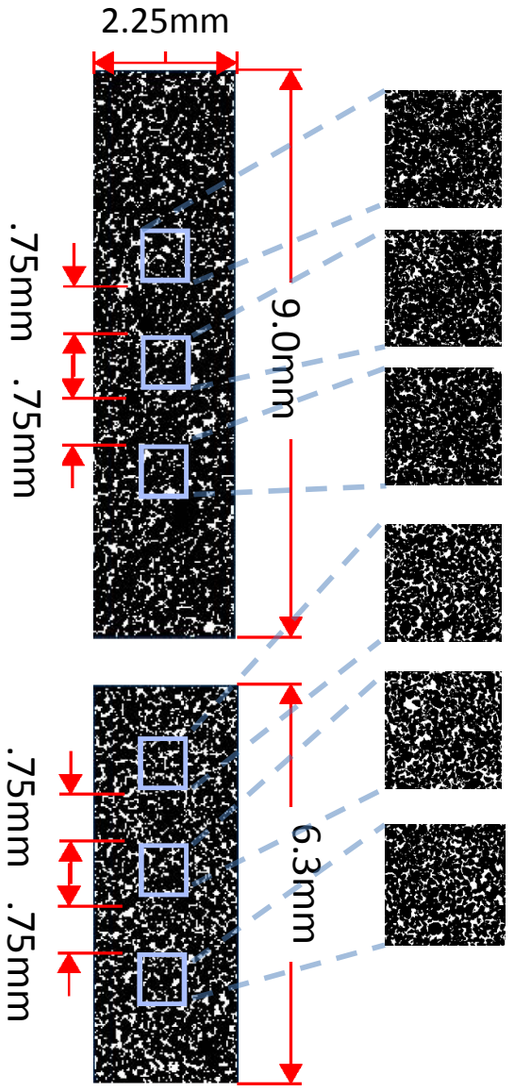
Lattice Boltzmann
Simulation

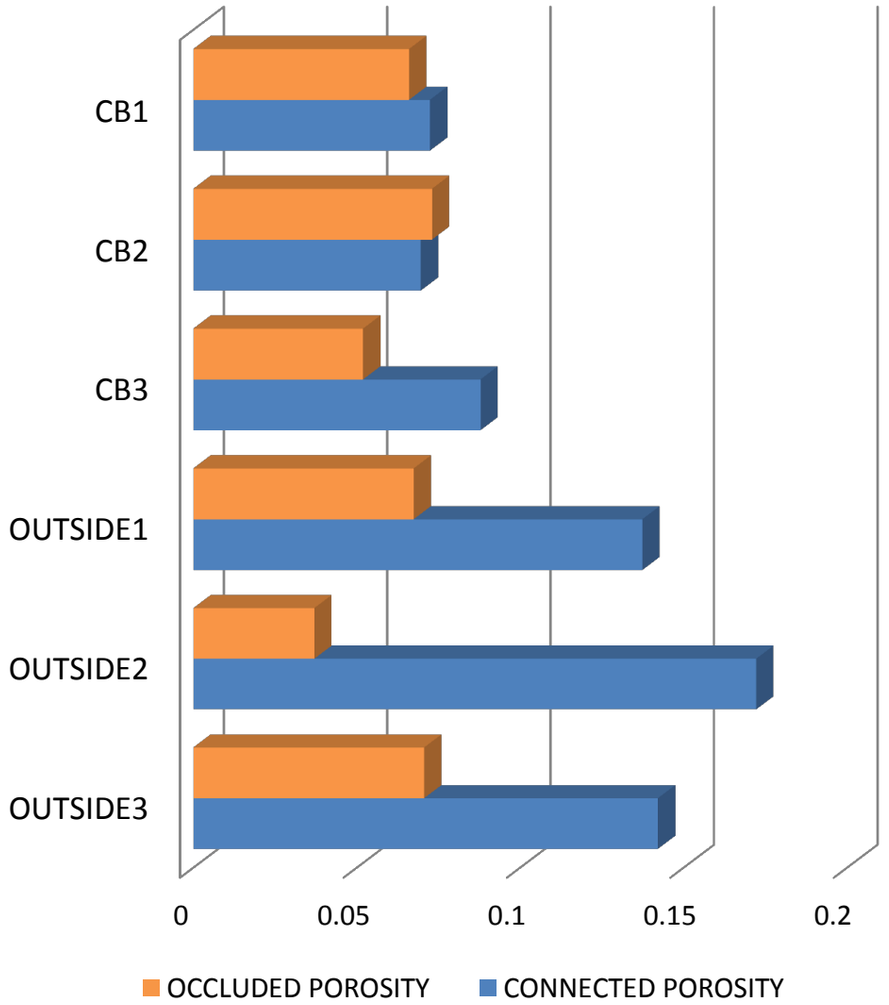
Finite Element
Simulation

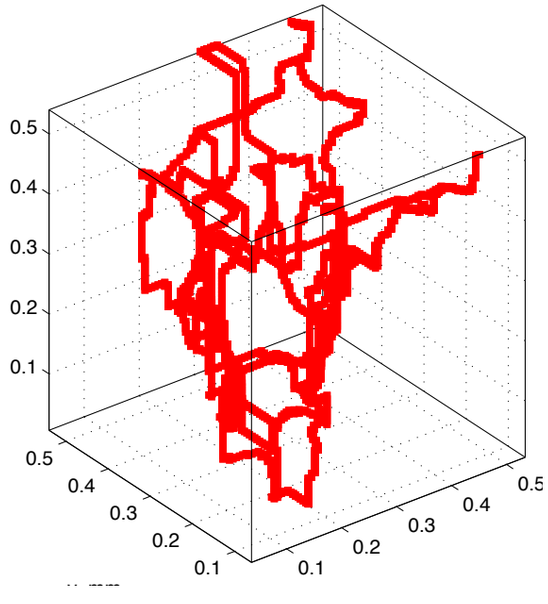


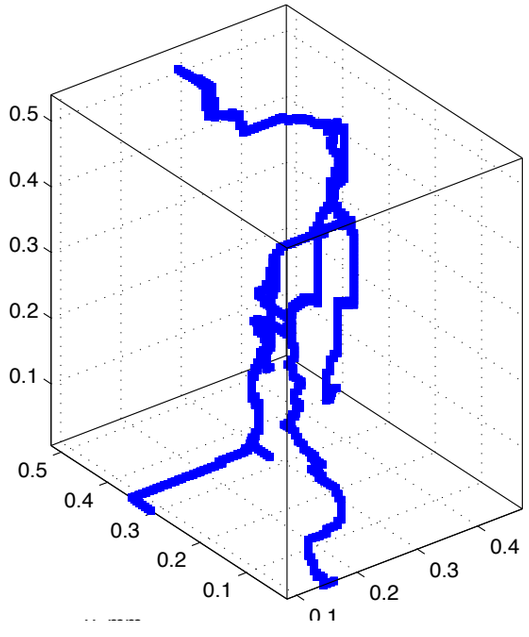


Micromechanical features



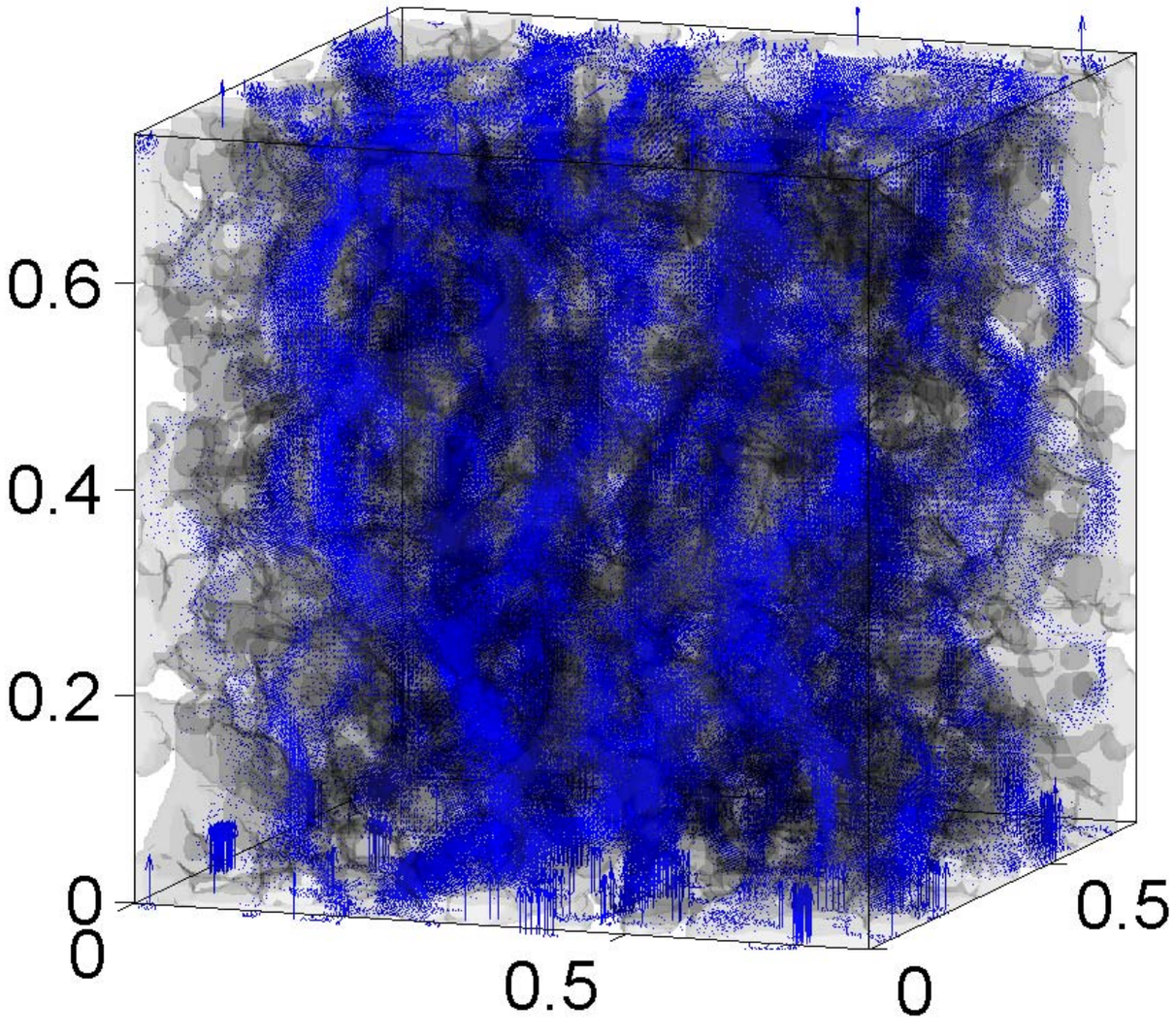






$k_{11} \approx 10^{-12}$

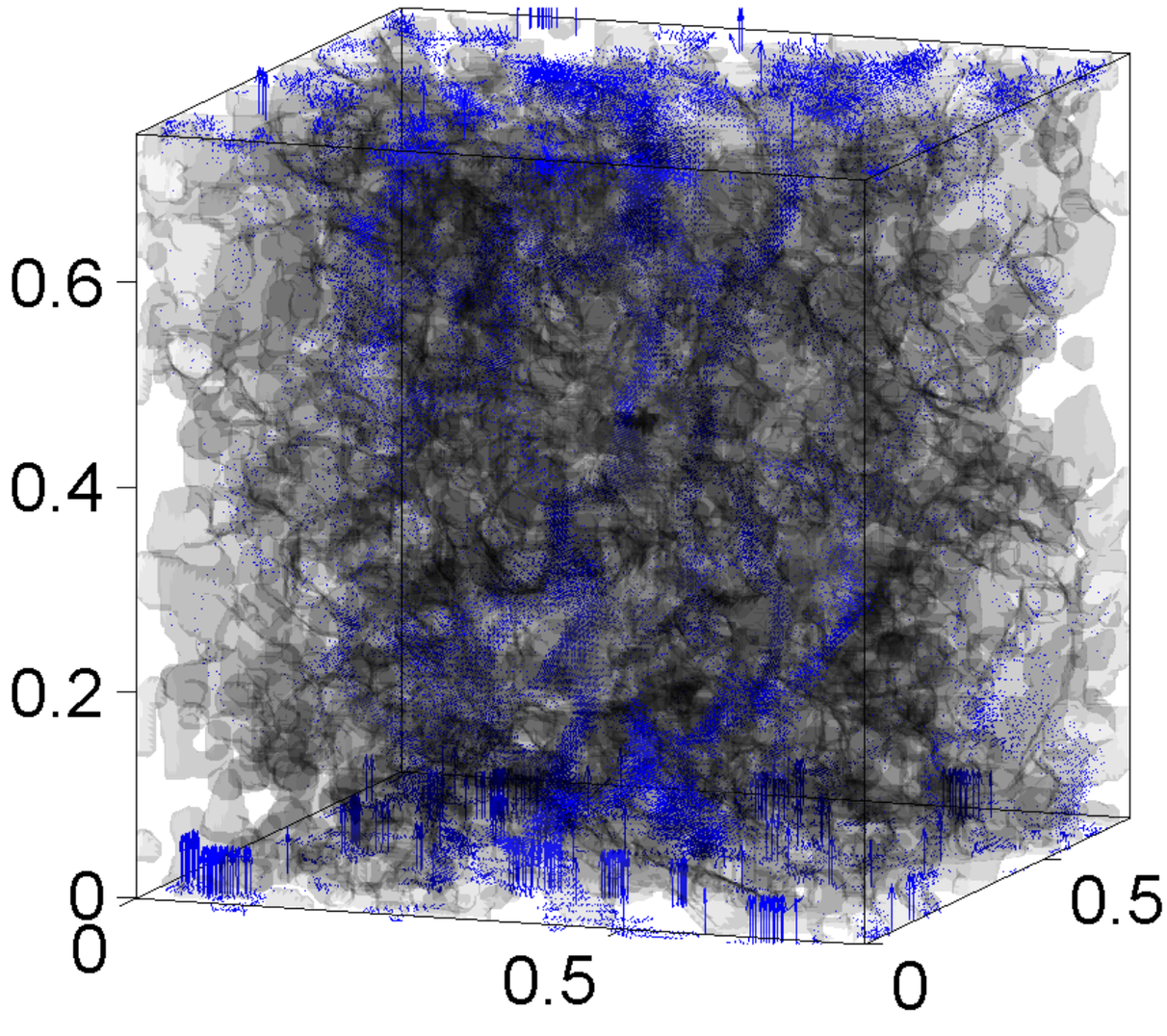
$\phi \approx 0.2$



outside cb

$k_{11} \approx 10^{-13}$

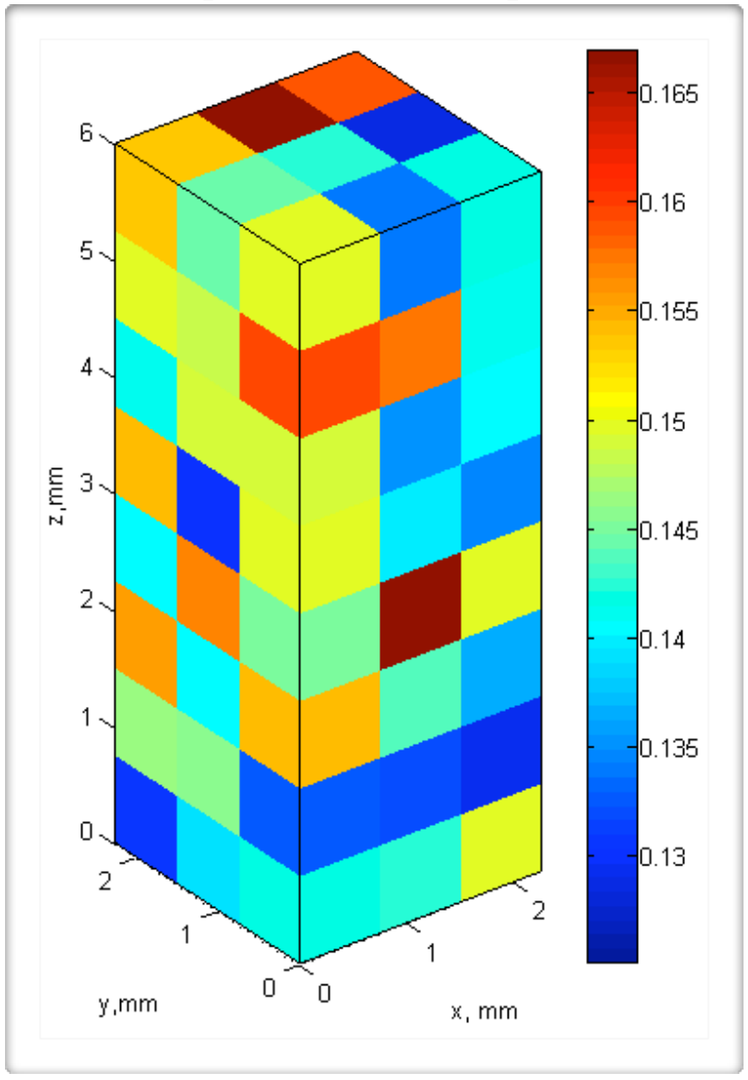
$\phi \approx 0.15$



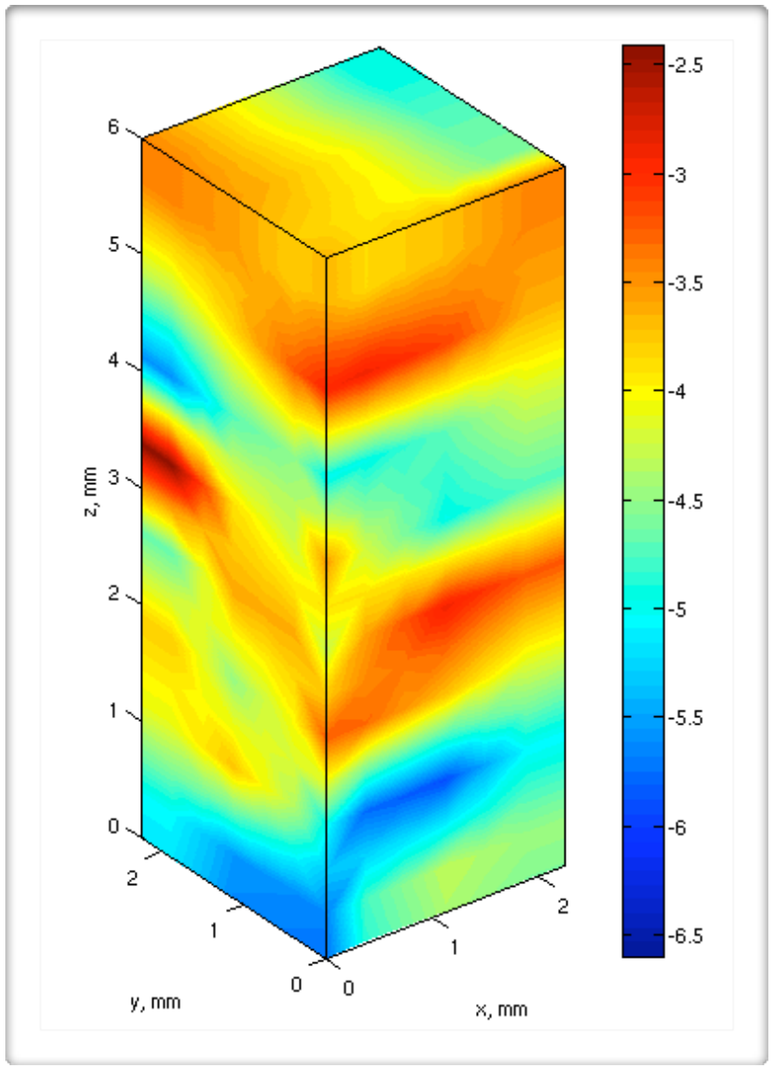
inside cb

in-situ permeability calculations with LB (m^2)

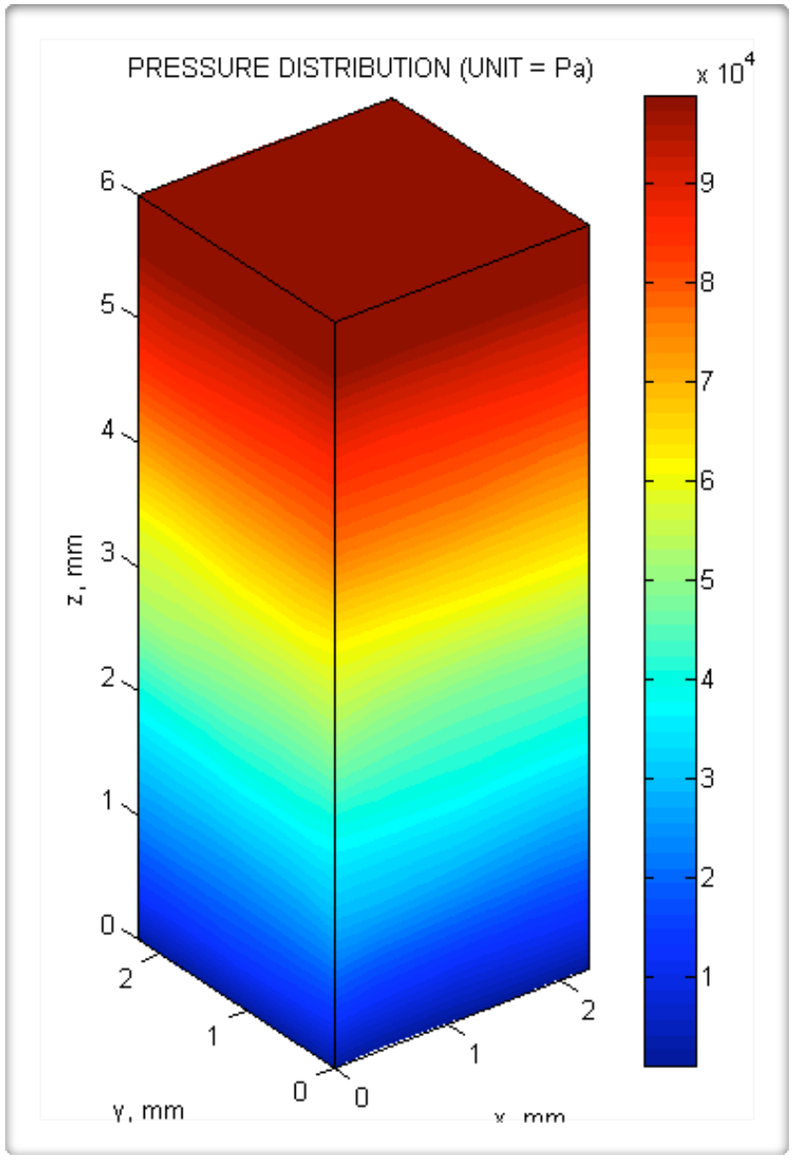
porosity



vertical velocity



pressure



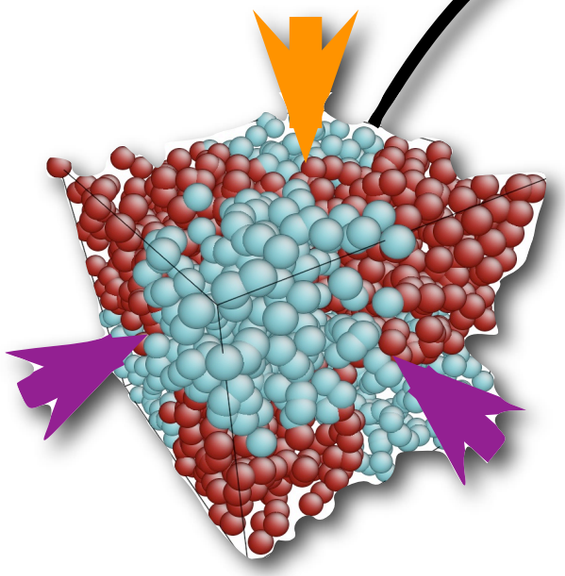
Homogenization using finite elements: specimen scale

Strength: from Newton to Cauchy

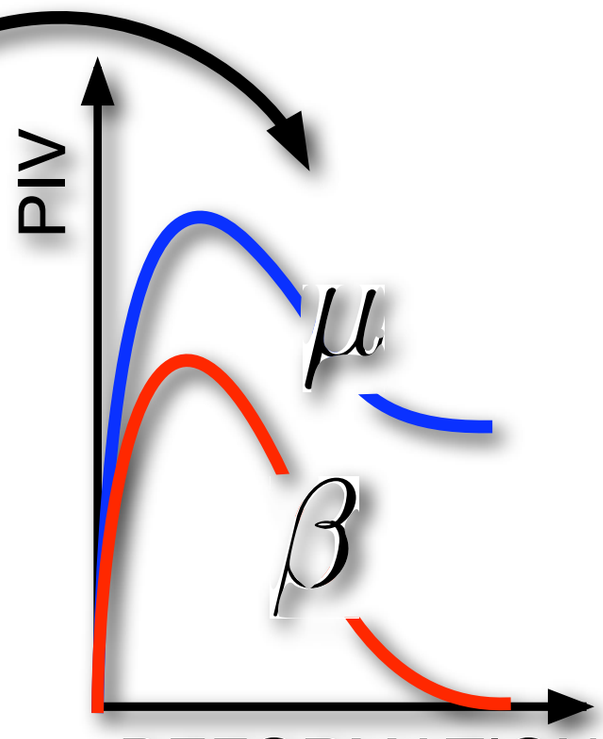
based on data from ESRF, Grenoble France

EXTRACT MICRO-MECHANICAL STATE

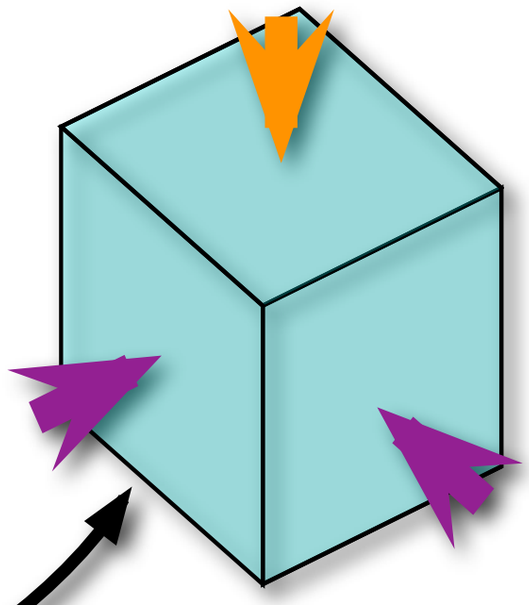
$\bar{\sigma}$ $\bar{\epsilon}$



DISCRETE MODEL



CONTINUUM MODEL

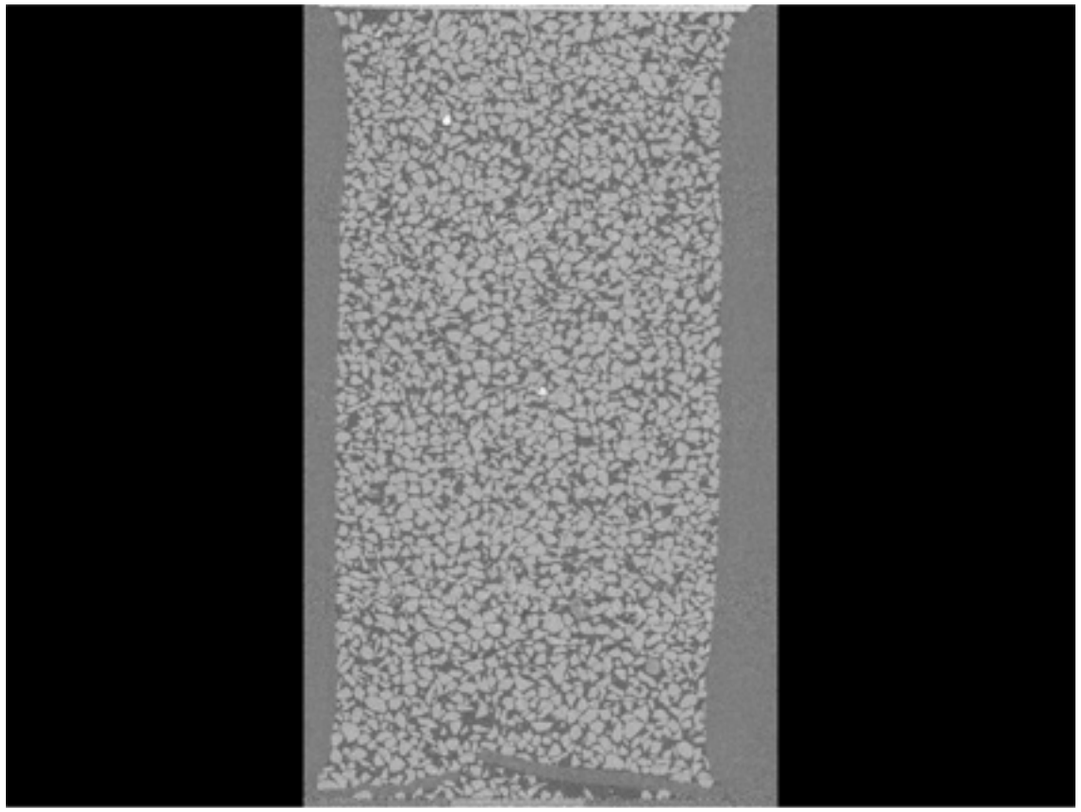


$F(.,\mu)\,Q(.,\beta)$

UPDATE CONTINUUM PLASTICITY

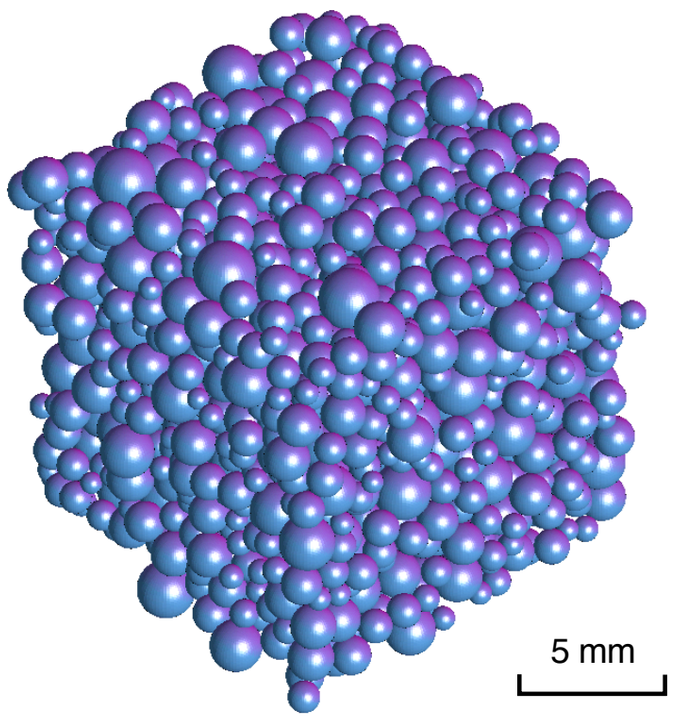
Hierarchical multiscale scheme

experiments



extract strains=>
dilatancy

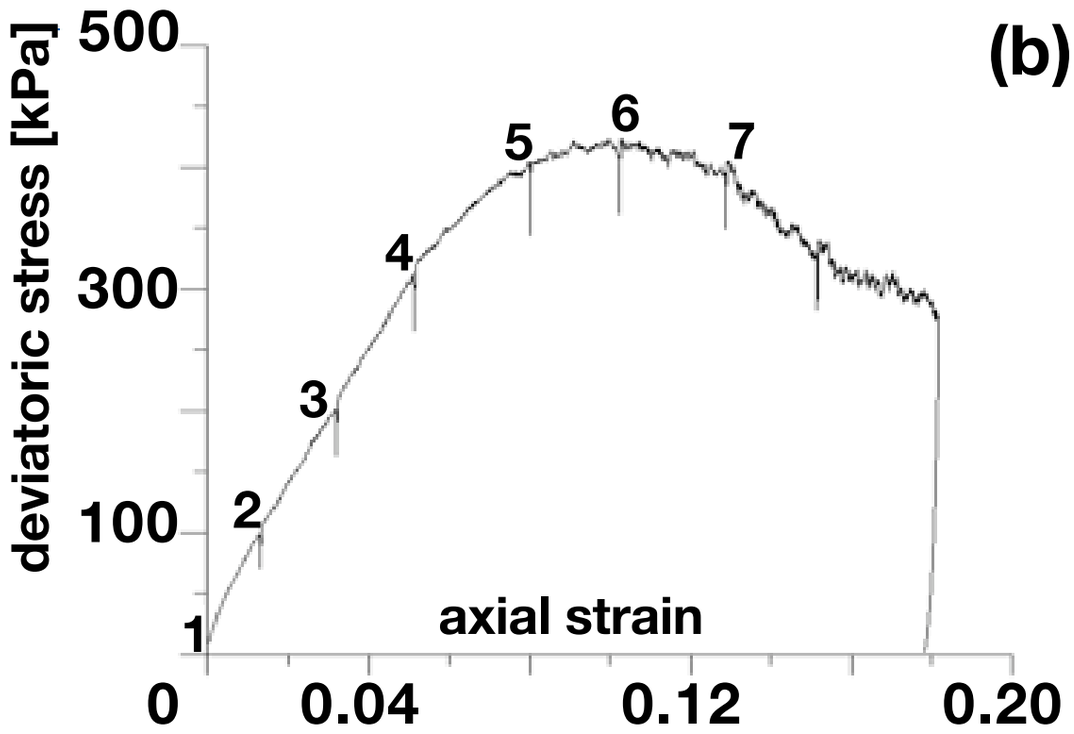
calculations



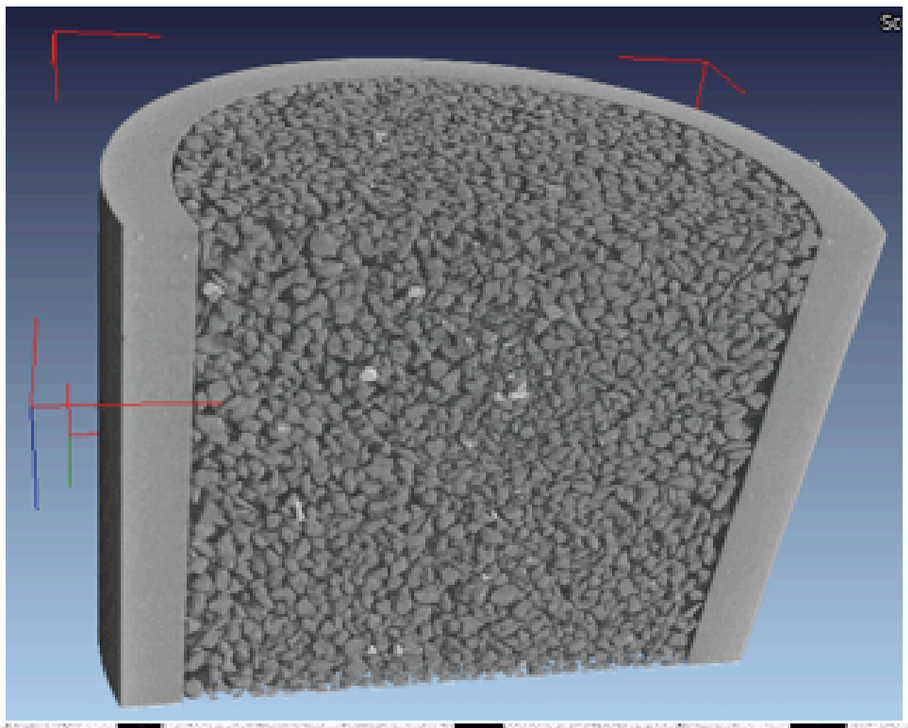
extract strains=>
dilatancy
AND
extract stress=>
friction

Unit cell concept: experiments
Vs. calculations

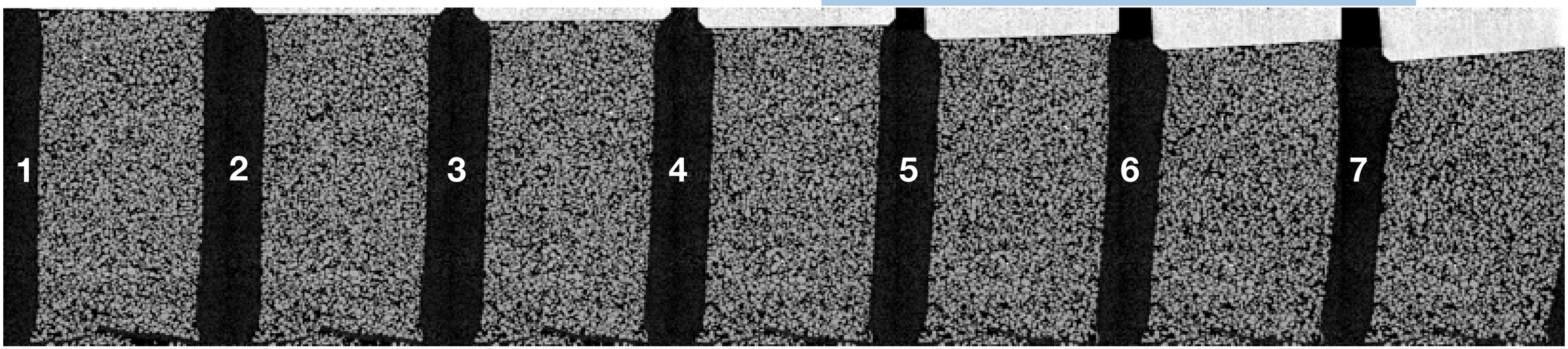
(a)



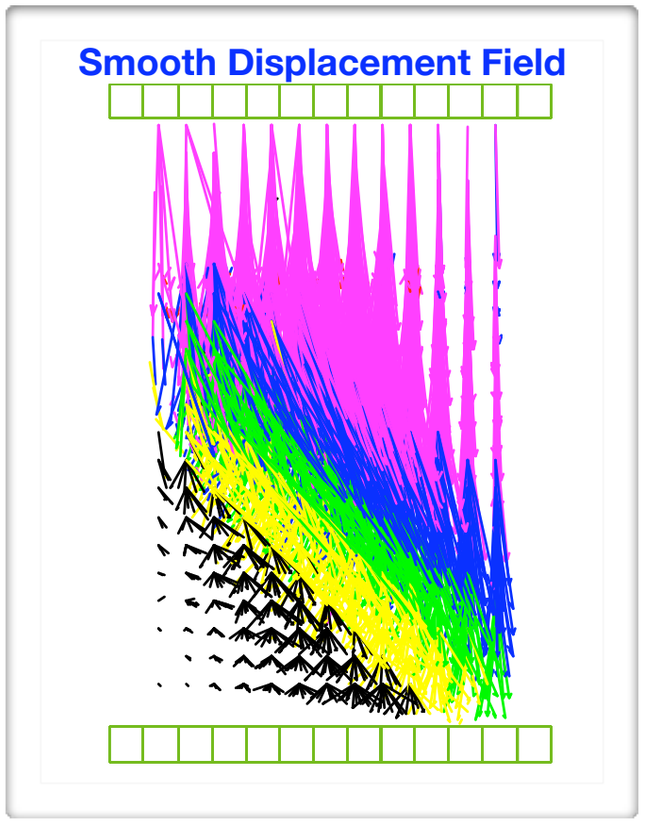
(b)

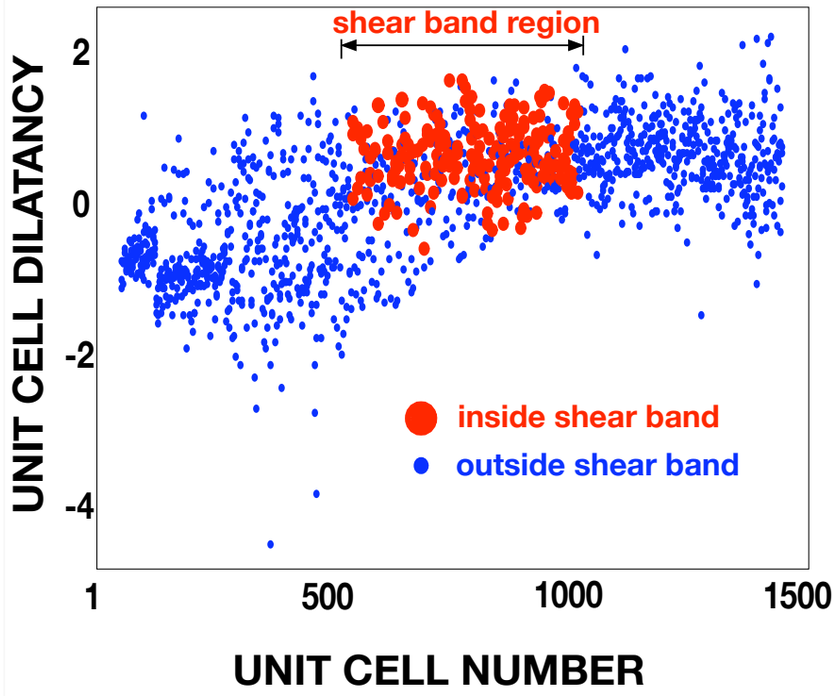


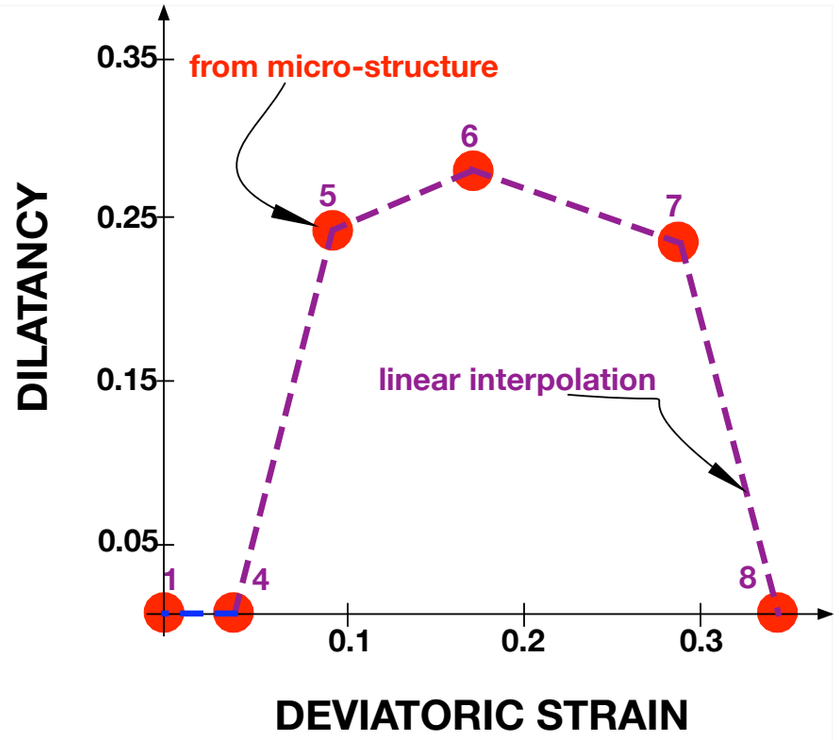
(c)

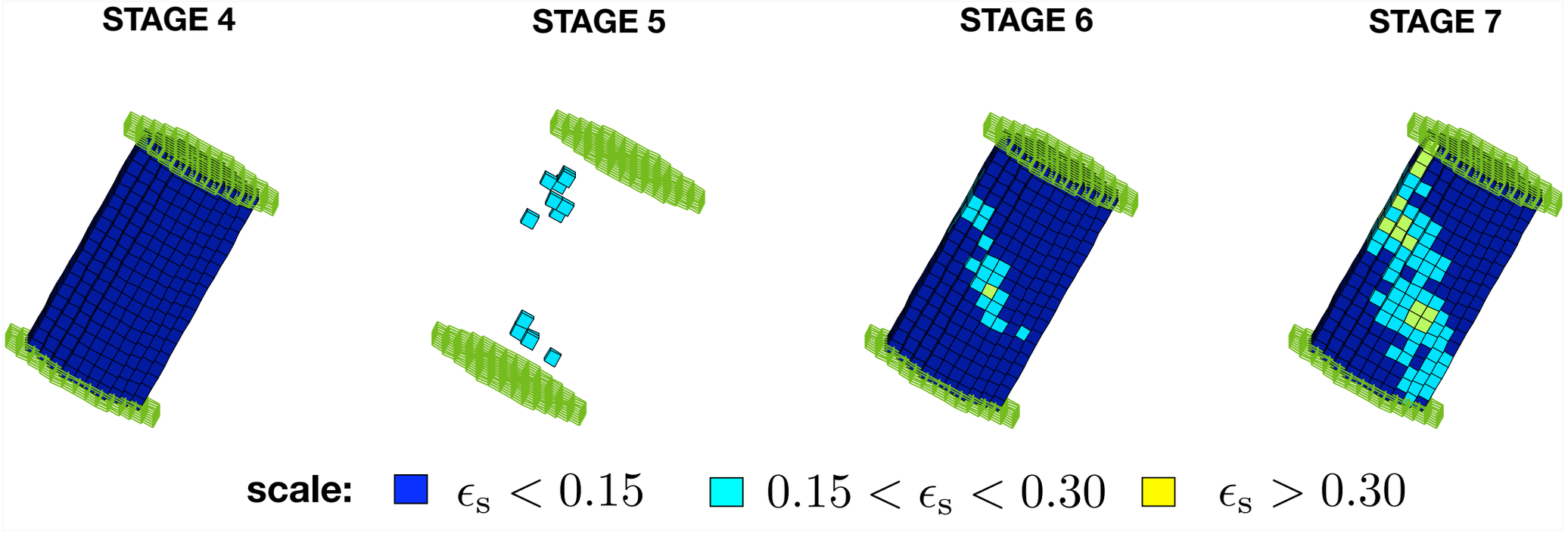


In-situ X-ray CT data from Grenoble

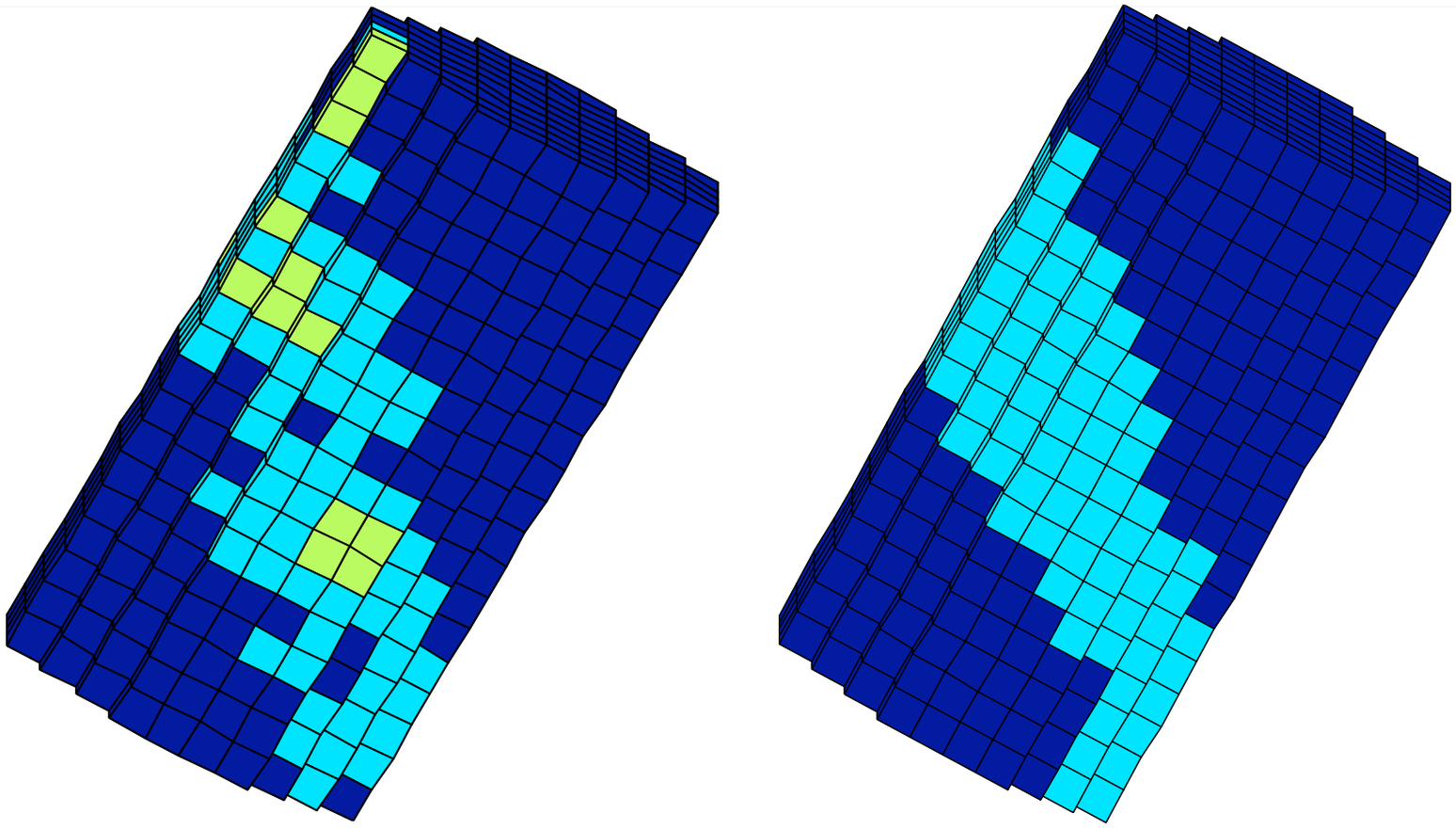




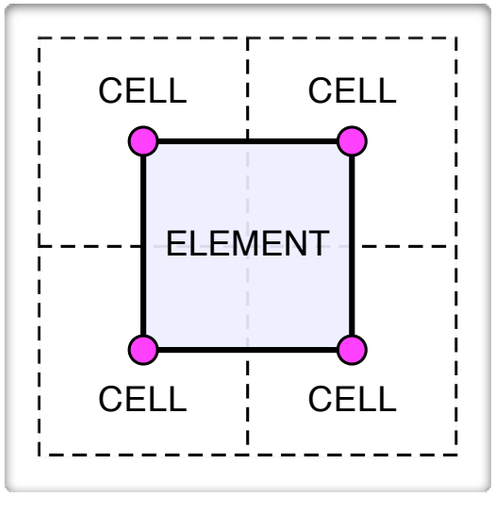




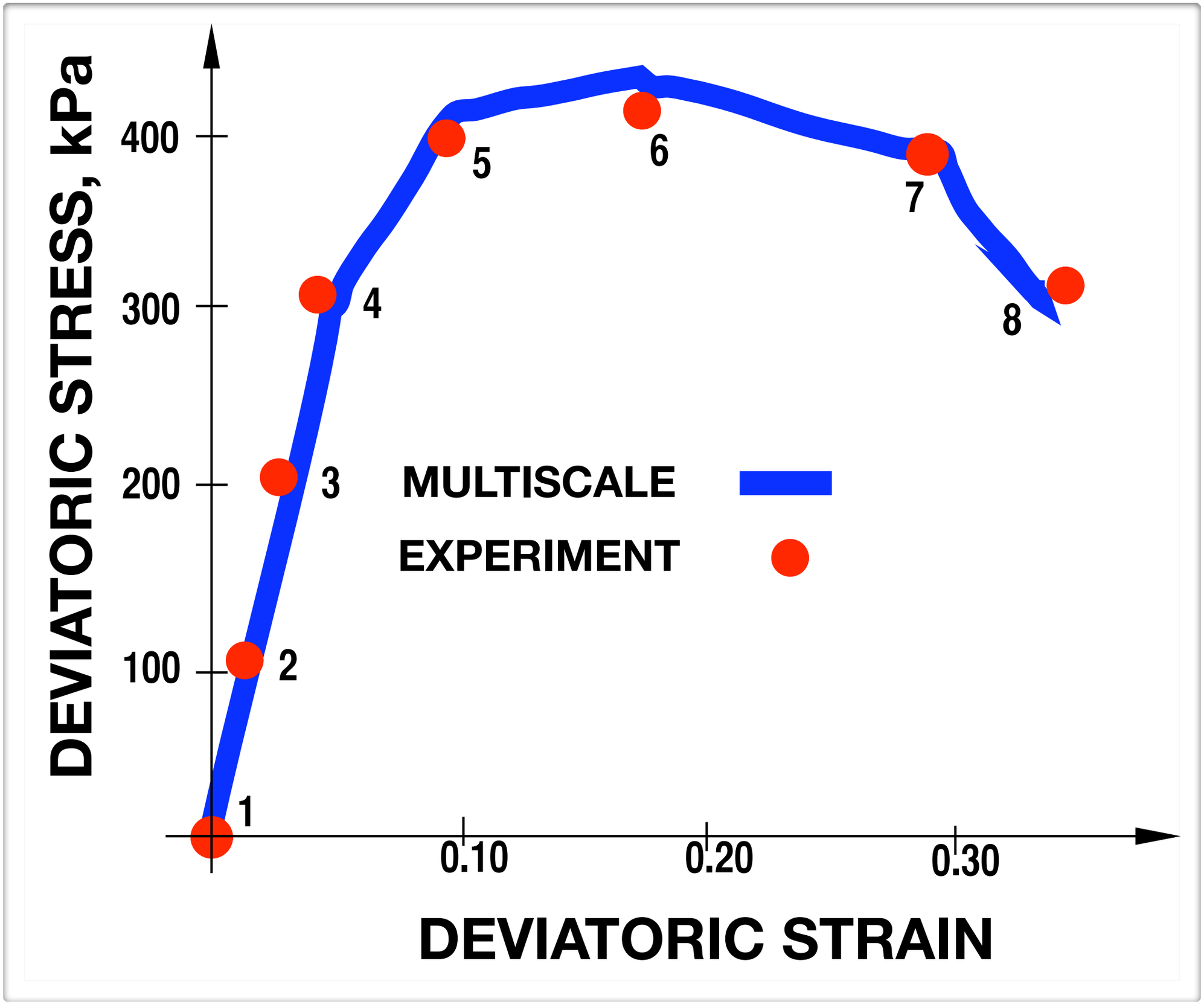
Strain fields and dilatancy



EXPERIMENT **MULTISCALE**



Strain prediction Vs. experiment


DEVIATORIC STRESS, kPa
400
300
200
100
1
2
3
4
5
6
7
8
0.10
0.20
0.30
DEVIATORIC STRAIN
MULTISCALE
EXPERIMENT

Conclusions

- New X-ray characterization can show microstructure & grain kinematics
- New models needed to harness powerful data for better prediction
- Modeling+characterization=prediction

References

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journal homepage: www.elsevier.com/locate/jmps

Multiscale modeling and characterization of granular matter: From grain kinematics to continuum mechanics

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Connecting microstructural attributes and permeability from 3D tomographic images of in situ shear-enhanced compaction bands using multiscale computations

WaiChing Sun,[1] José E. Andrade,[1] John W. Rudnicki,[2] and Peter Eichhubl[3]

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[1] Tomographic images taken inside and outside a compaction band in a field specimen of Aztec sandstone are analyzed. Using multiscale computations, they inferred that this band accommodated about equal amounts of shear displacement and band-perpendicular