Comparison of pore fabric based on high-resolution X-ray computed tomography and magnetic pore fabric in sedimentary rocks

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1. Introduction

- The pore size and geometry, as well as their connectivity determine the permeability and preferred permeability direction.
- X-ray micro-tomography (XRCT) is a widely used technique to generate digital rock models, visualize and quantify pore shape and size distributions, and the connectivity of pores with a spatial resolution on the order of 10 microns.
- Magnetic pore fabrics (MPF), obtained by impregnating ferrofluid prior to measuring anisotropy of magnetic susceptibility could be complementary to existing techniques and capture smaller pores.
- This study is aimed at quantitatively analyzing relationships between pore fabric or permeability anisotropy and MPF.
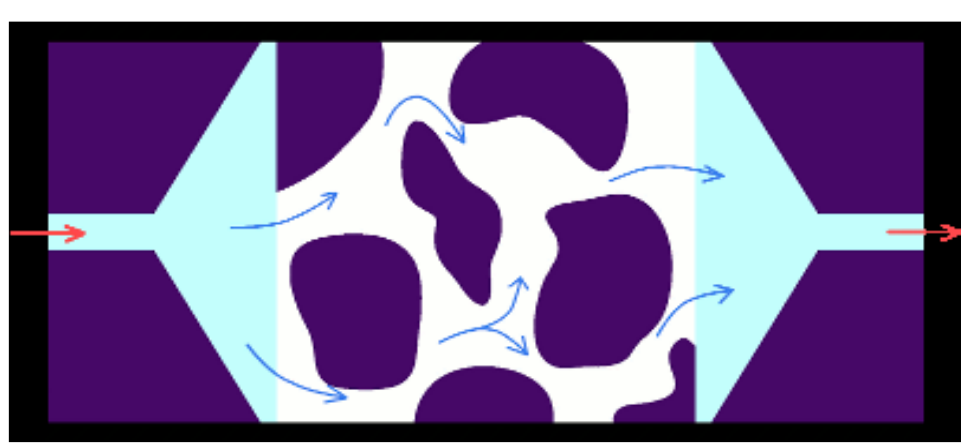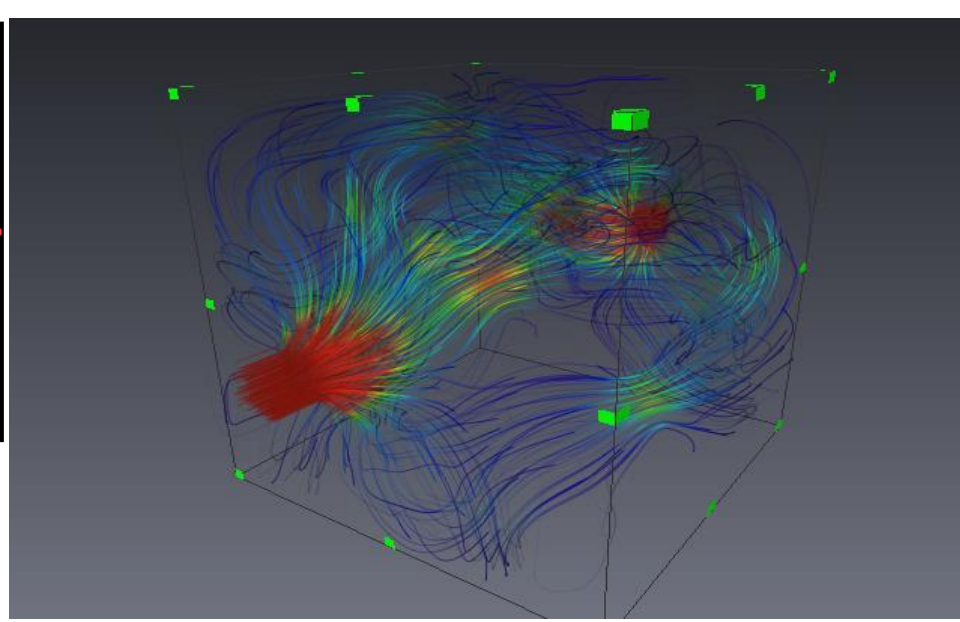
2. Methods

2.1 Samples

- Plio-Pleistocene calcarenite (Apulia, Italy) with ~50% porosity, ~300 μm average equivalent diameter of pores and complex pore structure.
- Upper Marine Molasse sandstone (OMM, Belpberg, Switzerland) with 5-20% porosity, ~150 μm average equivalent diameter of pores and relatively homogeneous pore structure.
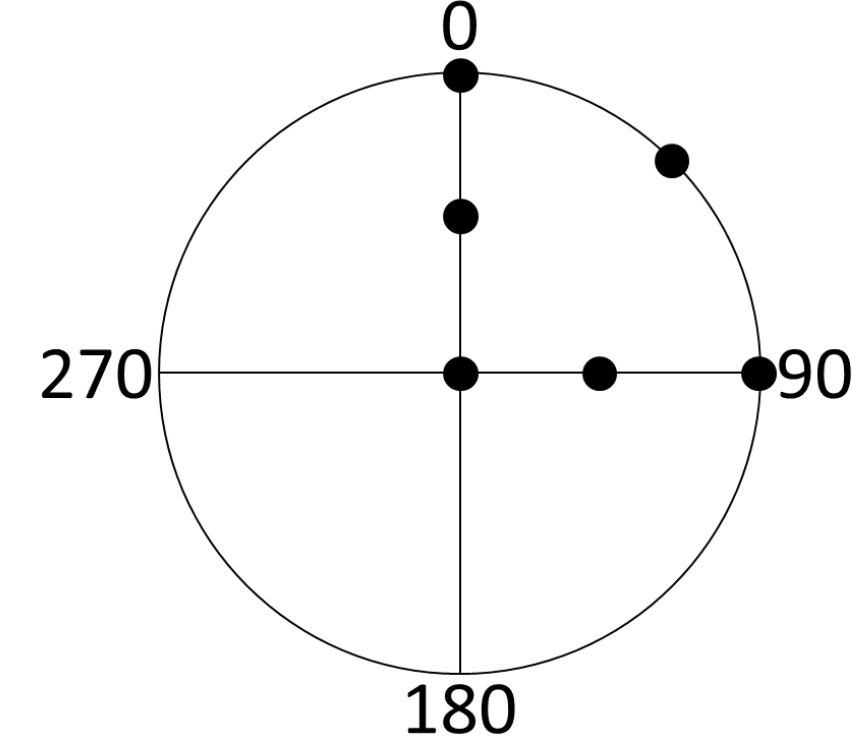
2.2 XRCT

- XRCT scanning and full-tensor permeability simulations in 6 directions

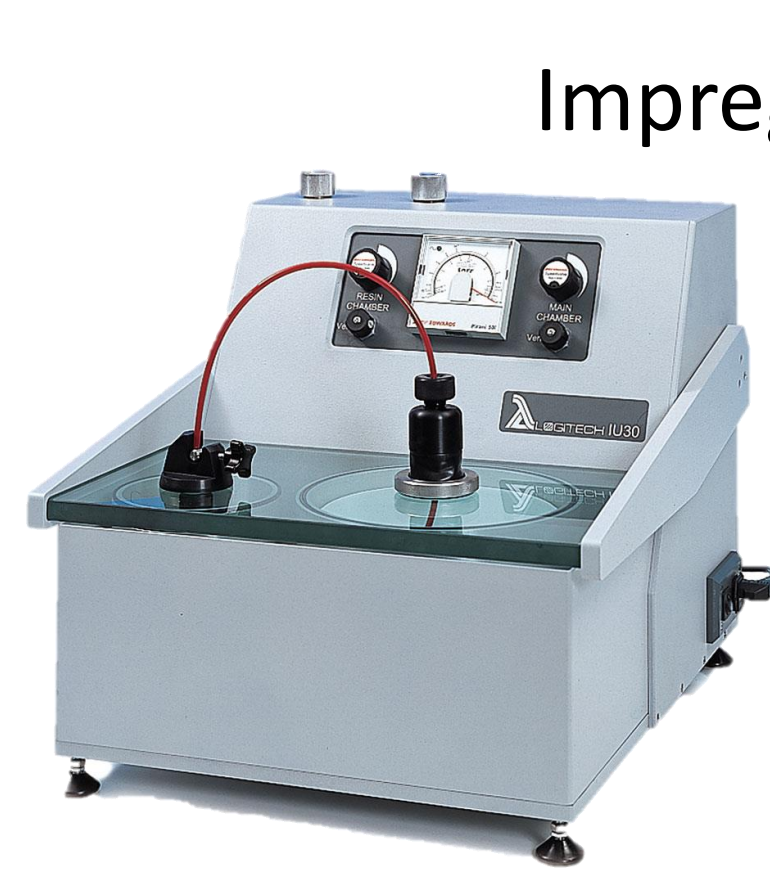Avizo 2019.4 pore network modelling User Guide from www.fei.com

simulations in 6 directions

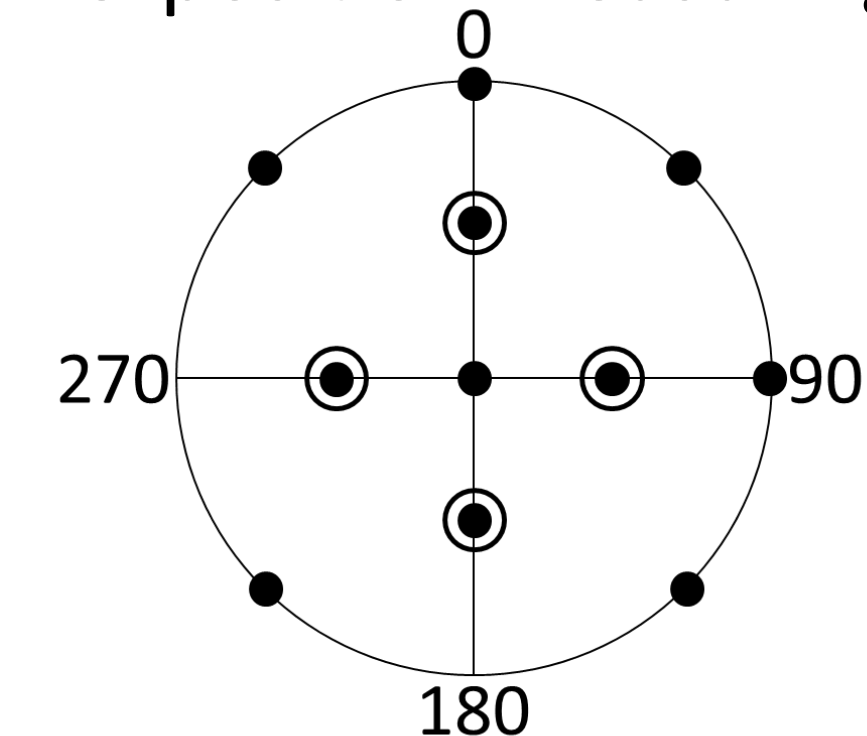### 2.3 Magnetic pore fabric method

- Impregnation by vacuum and fifteen-directions measurement scheme to determine the full susceptibility tensor.

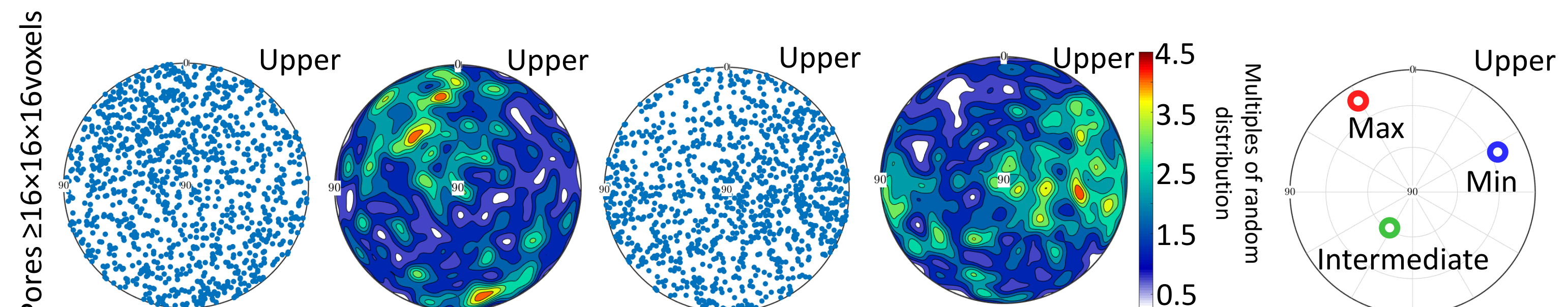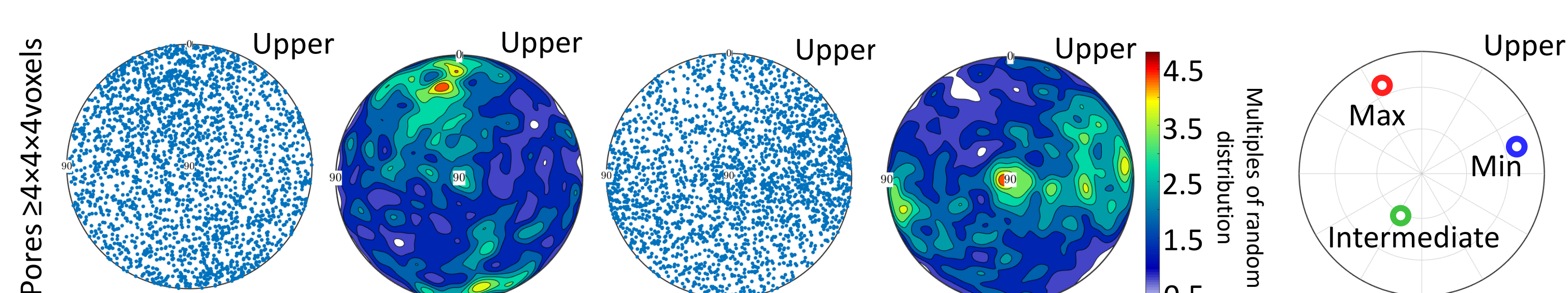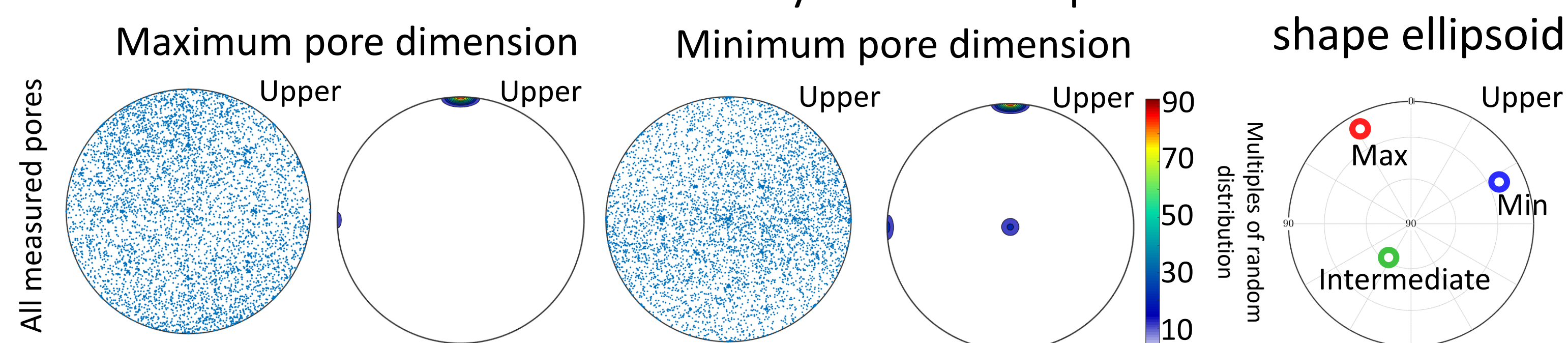
Impregnation   15-position measuring
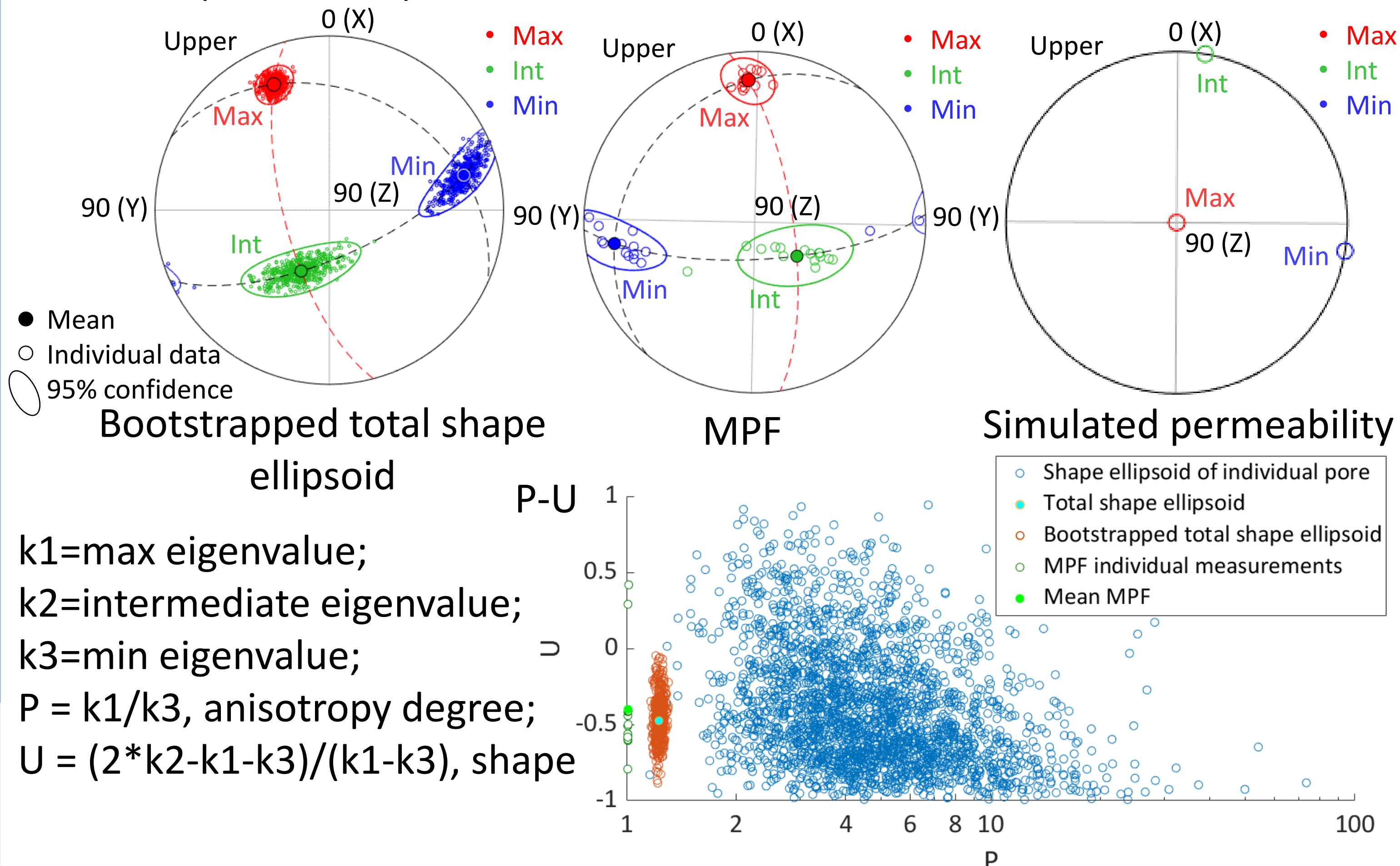
3. Results

3.1 Sample: calcarenite

- MI-1-Z3 (calcarenite)

Orientations and orientation density functions of pore axes

Maximum pore dimension   Minimum pore dimension   Total pore shape ellipsoid

All measured pores

Pores ≥4x4x4voxels

Pores ≥16x16x16voxels

- MI-1-Z3 (calcarenite)

Bootstrapped total shape ellipsoid   MPF   Simulated permeability

k1=max eigenvalue;
k2=intermediate eigenvalue;
k3=min eigenvalue;
P = k1/k3, anisotropy degree;
U = (2*k2-k1-k3)/(k1-k3), shape

P-U

Shape ellipsoid of individual pore
Total shape ellipsoid
Bootstrapped total shape ellipsoid
MPF individual measurements
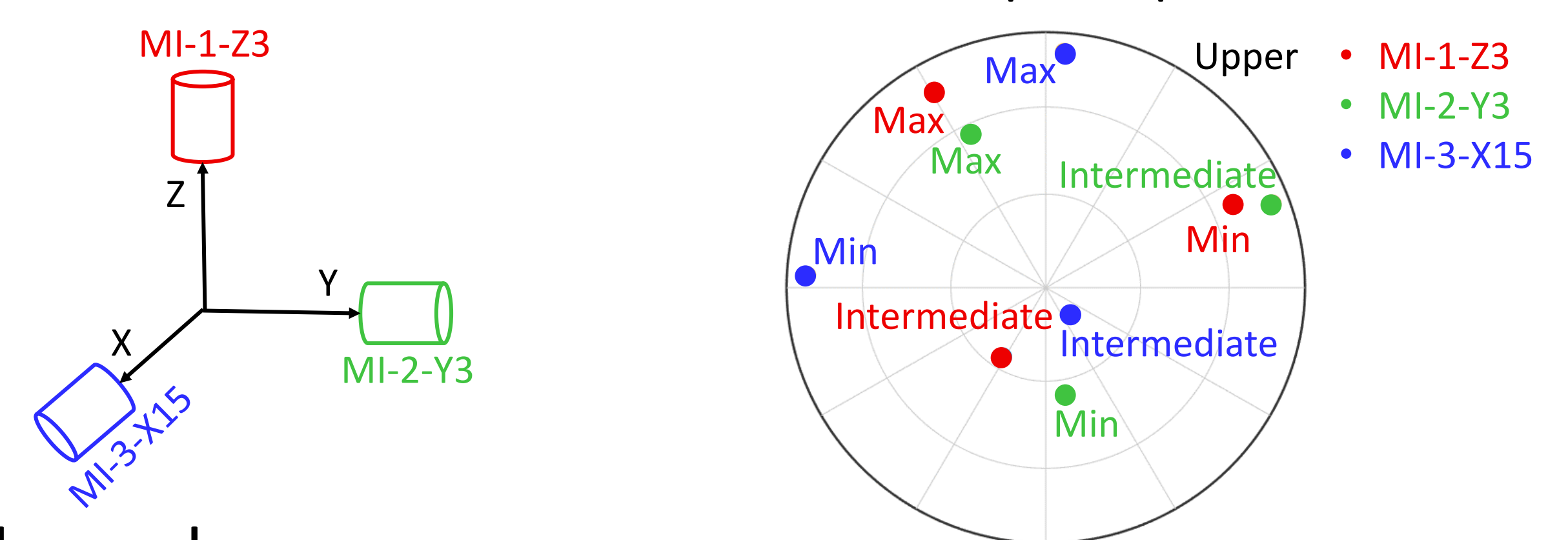Mean MPF

- Checking for consistency of pore shape in three perpendicular cores

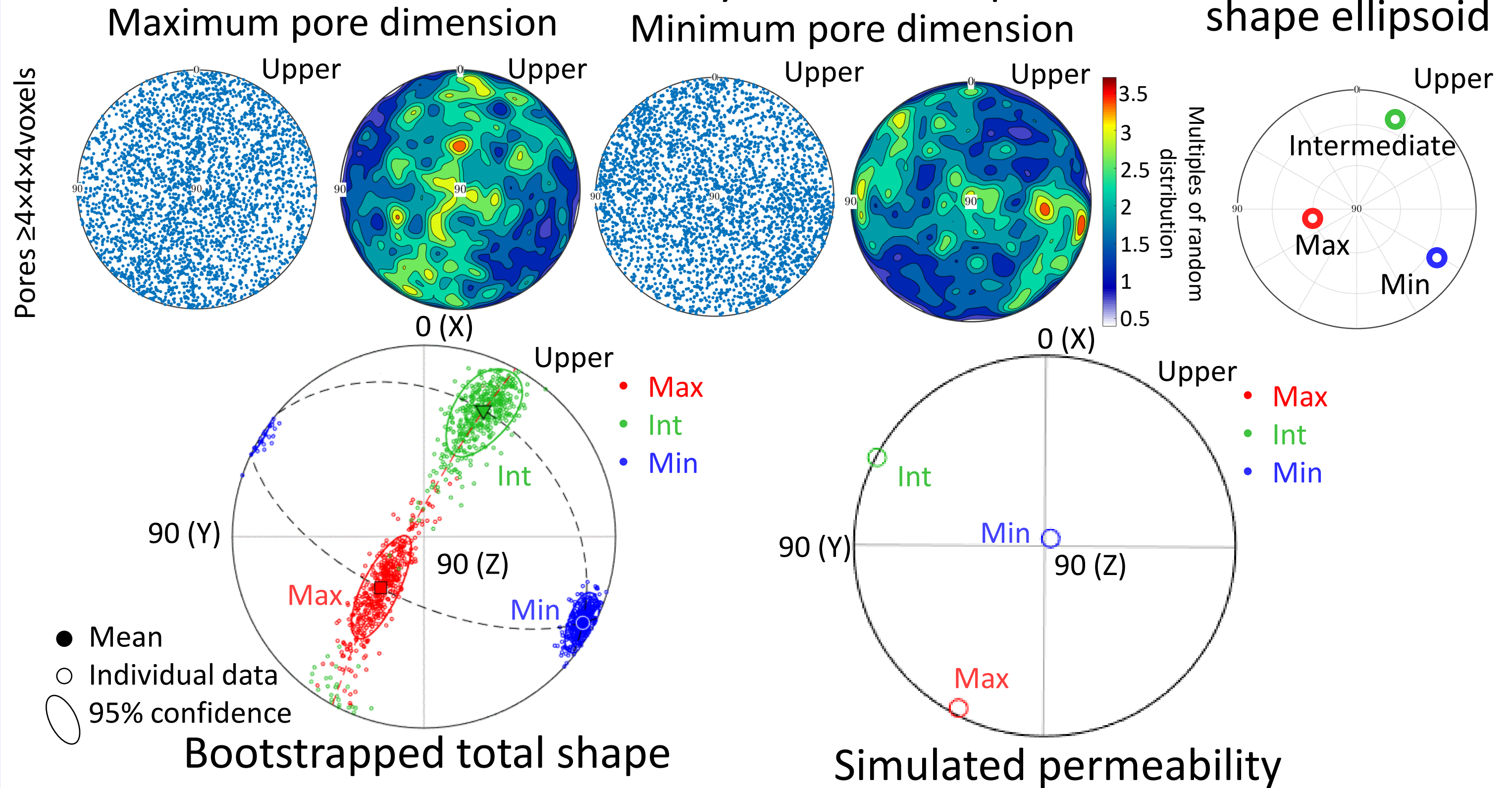Samples drilled in different directions

Comparison on total shape ellipsoid

MI-1-Z3
MI-2-Y3
MI-3-X15

3.2 Sample: molasse

- D1112Y (molasse)

Orientations and orientation density functions of pore axes

Maximum pore dimension   Minimum pore dimension   Total pore shape ellipsoid

Pores ≥4x4x4voxels

Bootstrapped total shape ellipsoid   Simulated permeability

P-U

Shape ellipsoid of individual pore
Total shape ellipsoid
Bootstrapped total shape ellipsoid

4. Summary

- Orientation density functions of maximum and minimum pore axes are affected by resolution artefacts unless smaller pores are filtered out.
- Total shape ellipsoid reflects preferred orientation of pore shape, and is largely unaffected by artefacts related to unresolved pores.
- Permeabilities can be simulated from the XRCT data, but can be still improved in accuracy and need verification against measurements.
- The orientation of the MPF maximum axis correlates with the maximum dimension of the mean shape ellipsoid at 95% confidence.
- The MPF anisotropy degree is generally smaller than that of the total shape ellipsoid.