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Statistical Characterisation of Porous Media at the Pore Scale

Progress Report 3

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Report Outline

- **Current Status**
- **Next Steps**
- **Meeting Summaries**

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Current Status

- Parametric Models
  - Regular spaced ellipsoids now automated
    - » Computed Minkowski tensors as a function of second axis length
    - » Original model contained misplaced mesh elements leading to large anisotropy
    - » New models show strong anisotropy change as function of deviation from sphericity
    - » Key aspect of work: Sensitivity of the Minkowski Tensors to changes in geometry
      - E.g. Could indicate selective or directional cementation in samples
      - Requires mathematical understanding of how these anisotropies arise
- Evaluation of Micro-CT Images:
  - Computed Minkowski Tensors as function of expanding window (for 4 images, 500^3, Bentheimer results this week)
  - Results for 1st Translation Invariant Minkowski Tensor:
    - » Show strong anisotropy in Ketton when compared to Beadpack
    - » Possibly due to selective or directional cementation in Ketton
  - Results for 2nd Translation Invariant Minkowski Tensor:
    - » More expected order of anisotropy
      - Beadpack -> Ketton -> Estaillades -> Doddington
      - Doddington Angular -> Ketton/Beadpack Smooth surfaces i.e. constant curvature
      - 2nd Tensor interpretation as surface texture (preliminary)
- Evaluation of possible links to permeability
  - Micro-CT Images available where permeability in x,y,z has been computed
  - Computation of Minkowski Tensors on these images (next steps)
- Comparison of Minkowski Tensors to other “classical” measures
  - Covariance

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Next Steps

- Computation of Covariance on available images
  - 1D, 2D Radial Profile Plot?, 3D (FFT method)
- Compute regular spaced ellipsoid model for range of radii
- Computation of Minkowski tensor for more complex parametric models
  - Preferential cementation model
    - » Change deviation from sphericity as function of sample height
      - Should induce anisotropy in 1 preferential direction
  - Revisit ellipsoid model
- Investigate mathematical cause of strong anisotropy change
- Computation of Minkowski tensors on images with precomputed permeability
- Acquire computational resources to compute permeability on 1000^3 images
- Next Meeting:
  - TBA
  - Professor Olivier Dubrule away July, August
  - Dr. Branko Bijeljic at Imperial in July

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Meeting 6:

- Date: 24/06/2016
- Attendants: Prof. Martin Blunt, Prof. Olivier Dubrule, Lukas Mosser
- Discussed Topics:
  - Need for physical interpretation of Minkowski Tensors
    - » Translation Invariant Minkowski Tensors 1 and 2
  - Discussion of results based on parametric models:
    - » Bundle of tubes, regular spaced spheres, regular spaced ellipsoids
    - » Why are the eigenvalues for the cylindrical parametric model not the same?
  - Minkowski Tensors computed for 500^3 voxel images
    - » Ketton shows strongest anisotropy
    - » Beadpack as expected shows near isotropic behavior
  - Normalization necessary to better understand tensors

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Meeting 7:

- Date: 30/06/2016
- Attendants: Prof. Martin Blunt, Prof. Olivier Dubrule, Lukas Mosser
- Discussed Topics:
  - Physical Interpretation of Minkowski Tensors
    - » MT1: Second order moment (variance) of surface orientation
    - » MT2: Second order moment (variance) of surface orientation and curvatures
  - Normalization:
    - » Normalize by scalar Minkowski functionals of same order
    - » Normalization by surface area gives equivalent radius of curvature from MT2
  - Thesis structure:
    - » Classical Measures: What do they tell us? Compute
    - » Minkowski Tensors: What information do they contribute?
    - » Permeability: Evaluate permeability on 1000^3 images
    - » High Sensitivity to anisotropy possibly key feature of Minkowski tensors
    - » Requires mathematical treatment and modeling rather than computation
  - Computation of covariance on images

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Meeting 8:

- Date: 01/07/2016
- Attendants: Dr. Ali Raeini, Lukas Mosser
- Discussed Topics:
  - Available Permeability tensor data
  - For individual images permeability in x, y and z available
  - Possible to compute 1000^3 images but takes ~ 1 day per direction + 50 GB RAM

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Meeting 9:

- Date: 04/07/2016
- Attendants: Dr. Branko Bijeljic, Lukas Mosser
- Discussed Topics:
  - Discussion of previous work up to now
  - Selective cementation a possible reason for ketton deviation from isotropic behavior
  - Computational resources available for permeability and tensor computation
  - Branko will check with Ali Raeini which images need to be computed