Resolving Flow Heterogeneity as a Graph-Theory Problem

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AUTHORS

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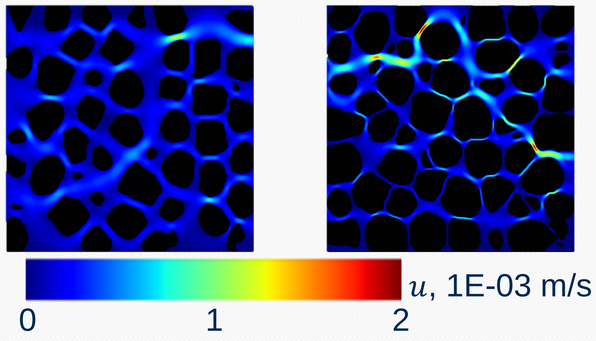
BACKGROUND

- The spatial distribution of channelized flow is difficult to predict.
- Flow becomes channelized as the underlying pore structure grows in complexity.
- We aim to understand how the pore structure constrains flow partitioning.

Uniform Flow Field | Channelized Flow Field



FUNDING SOURCES

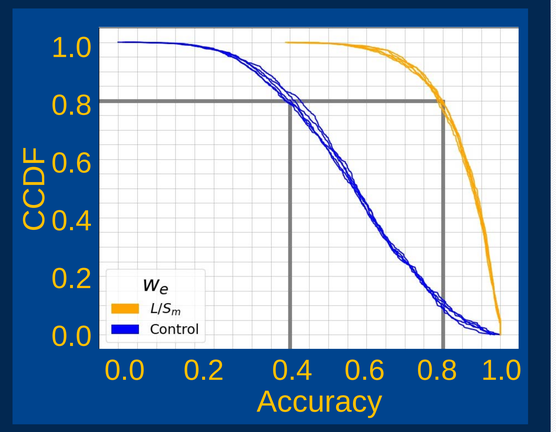
AXA ACS PRF NSF

MAIN FINDINGS

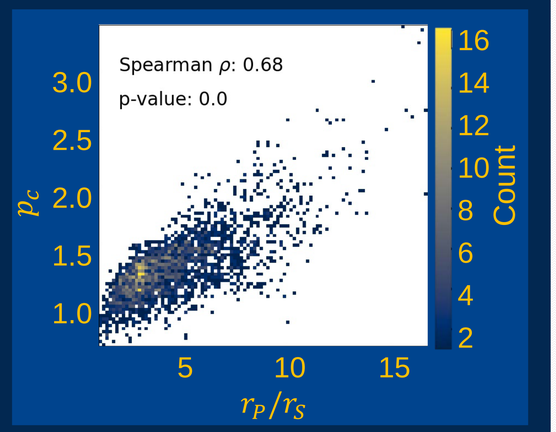
1. A metric is proposed to quantify flow channelization and physically defined mobile and immobile flow regions.

Immobile Flow Region
$u/\langle u \rangle < p_c$
Mobile Flow Region
$u/\langle u \rangle \geq p_c$
- Percolating path
- Disconnected High Velocity Regions

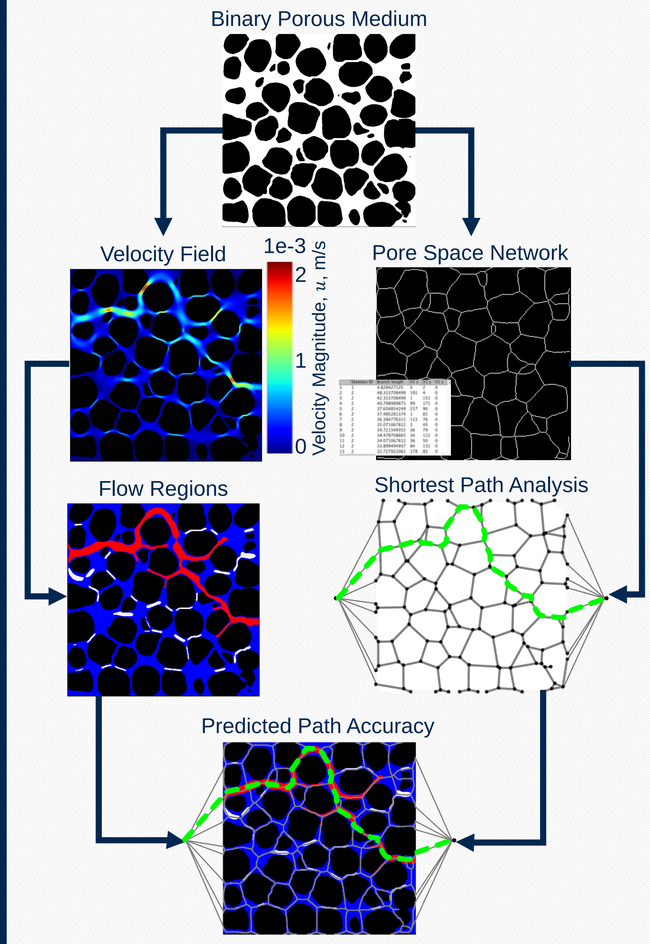
2. Path of least resistance through the pore network describes accurately the percolating flow path in all structures.



3. Local structural similarity of pore networks provides constraints for flow separation into mobile and immobile regions.



EXTRACT FLOW & STRUCTURE



PATH OF LEAST RESISTANCE

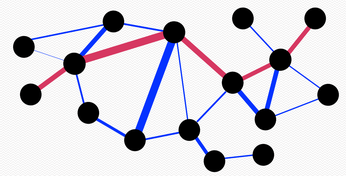
$$\mathcal{R} = \min_{\Gamma \in \mathcal{P}_s^t} \sum_{e \in \Gamma} w_e$$

The path, Γ, of least resistance, $\mathcal{R}$, has the minimum the sum of edge weights, w_e (here, the ratio of arc length to pore throat, L/S_m) of all possible paths, $\mathcal{P}_s^t$.

GRAPH THEORY ANALYSIS

Mobile flow subnetwork, r_P

Immobile flow subnetwork, r_S



Line thickness ∝ Pore Throat

Assortativity, r, measures the pore throat similarity between edges in each flow region.