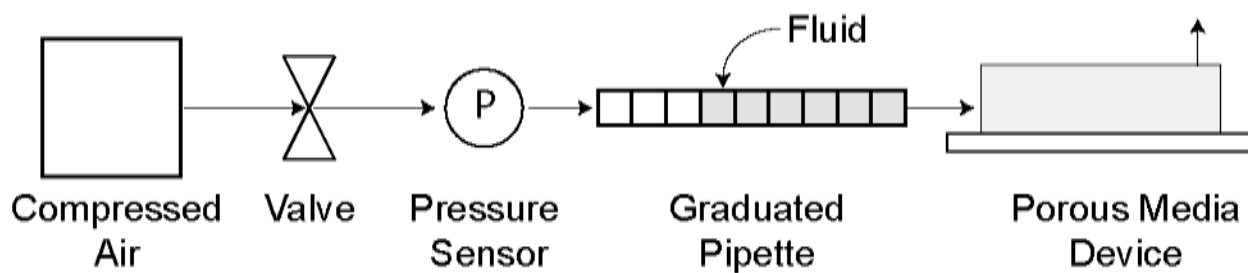
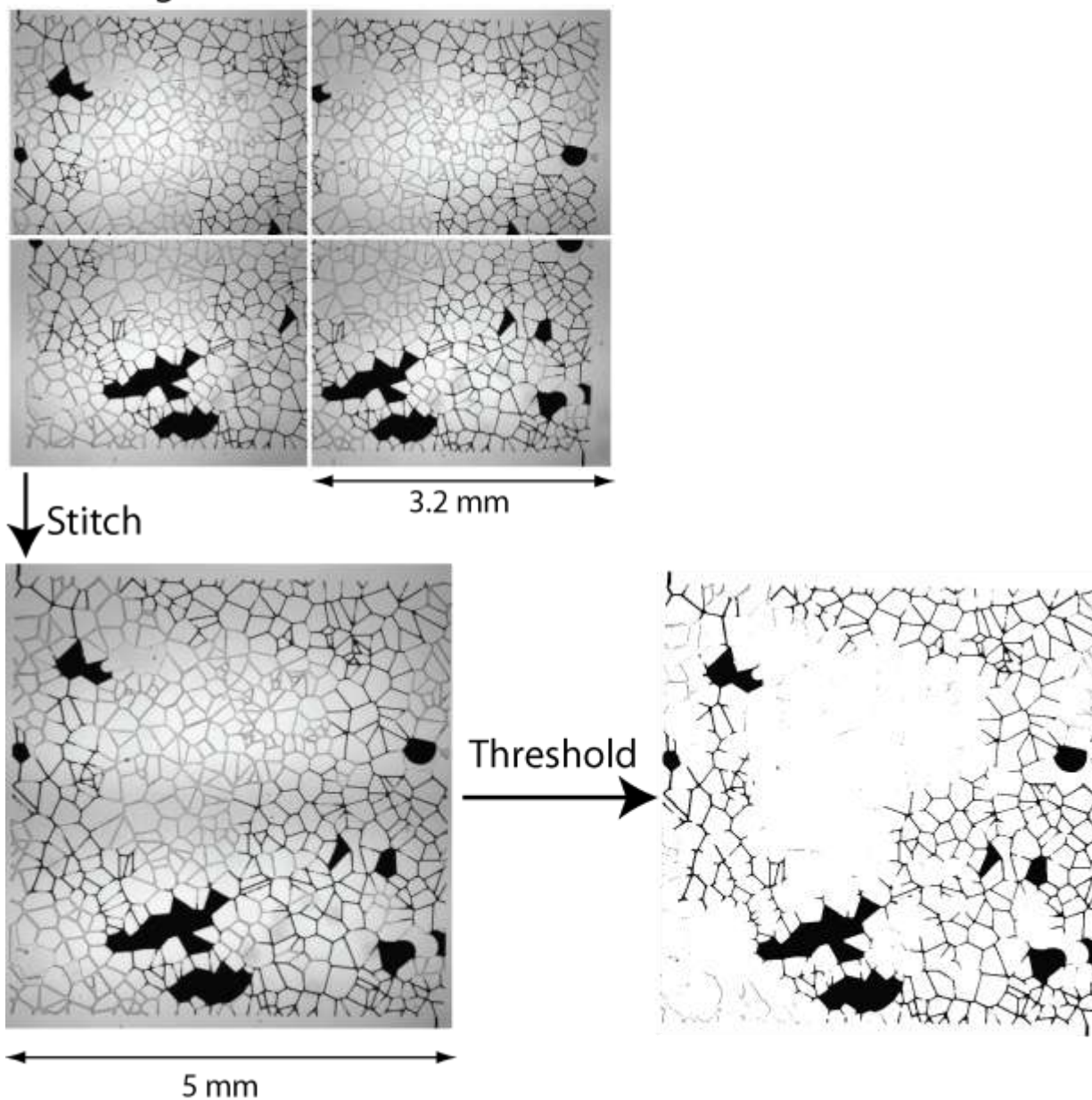


### Electronic Supplementary Information

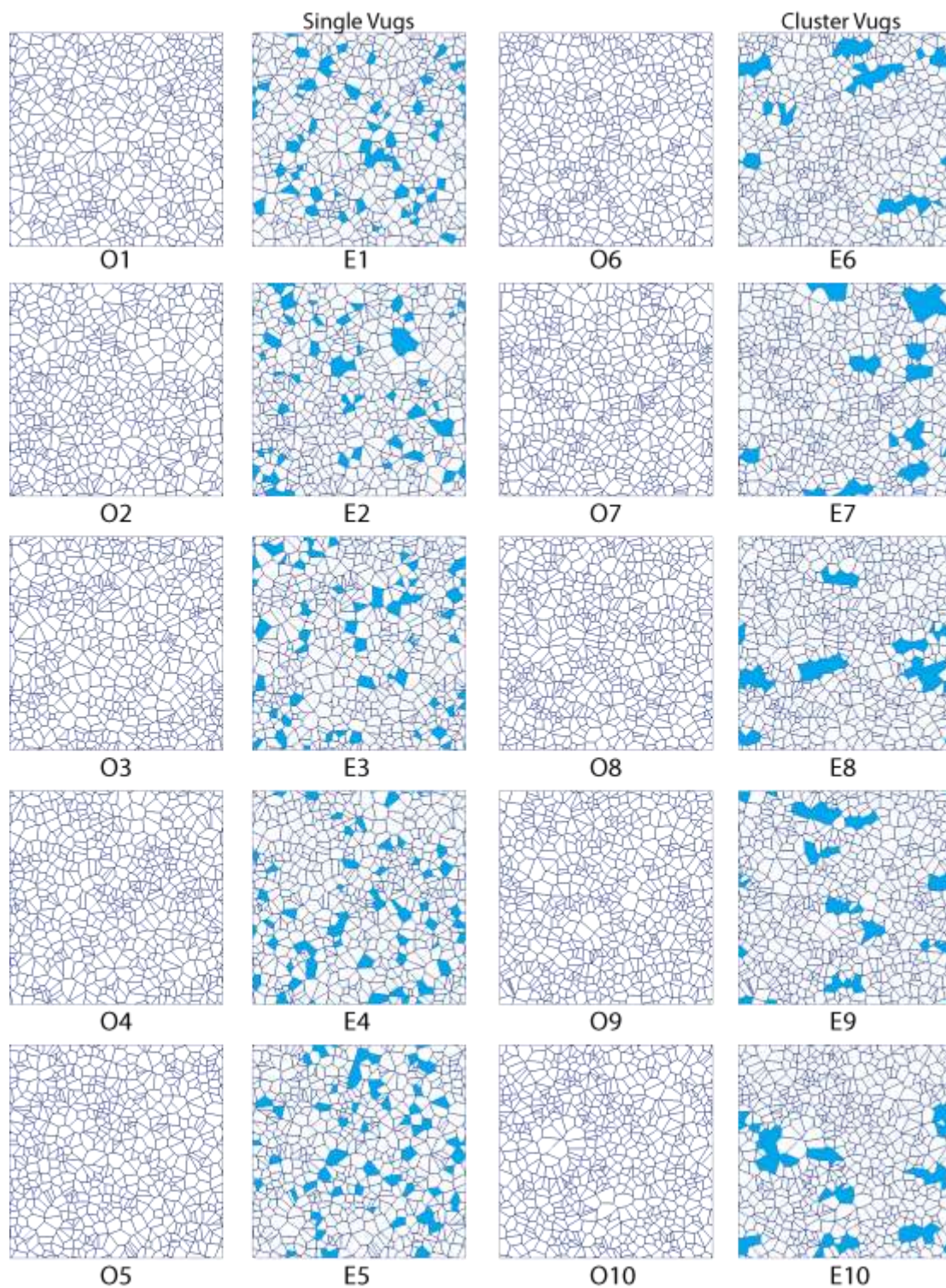


Supplementary Figure 1. Schematic of experimental apparatus. Compressed air was used to achieve a constant pressure gradient across the device. The pressure was modulated with a needle valve and monitored with a piezoelectric pressure sensor upstream from a graduated pipette filled with the infused fluid. The distance between gradations on the pipette was 5 mm and was used to calculate the velocity of fluid through the device in permeability experiments. The pipette was connected to the PDMS device with Tygon® tubing. The outlet of the device was open to the atmosphere.

## Raw Images



Supplementary Figure 2. Image analysis of two-phase flow experiments. At each time point for images are captured in the four corners of the porous media. These four images are stitched together into a single image and then converted to a binary image as described in Section 2.5. The dark fluid is water and the transparent fluid is mineral oil. The area of the black pixels in the binary image is used to calculate the water saturation.



Supplementary Figure 3. The twenty stochastic geometries generated from the Voronoi-based algorithm developed for this study. Homogeneous geometries are labeled O1 to O10, heterogeneous geometries consisting of single vugs are labeled E1 to E5, and heterogeneous geometries consisting of cluster vugs are labeled E6 to E10.