Supplementary Materials:

S.1. Imaging and Image Analysis

Top row: Comparison between an image without ring artifacts (left) and one with ring artifacts (right). Ring artifacts reduce the contrast between various materials, and produce false high intensity rings within all phases. In corrected image, red circle shows location inside which quantification were performed (i.e. masked region). A ring with thickness of ca. 2 mm was cut out to avoid the wall effects.

Middle row: Left: Smoothed image with total variation filter. Right: Histograms of original and smoothed images, enhancement is visible through higher peaks. Dashed lines show the thresholds found by Kapur et al. method. Shaded areas show fuzzy regions where voxel allocation was conducted considering phase neighboring (i.e. conditional dilation).

Bottom row: Left: Magnified image to present fuzzy regions. Dark, gray, and white colors represent air, water, and beads determined by Kapur et al. method, respectively. Yellow and Pink zones are fuzzy region between air/water and water/beads, respectively, in which voxels are allocated to either dark, gray, or white phase if they have direct neighbors to said phases. Right: Segmented image in which air is dark, water is gray, and glass beads are white. Quantification was only conducted inside red circle.
## S.2. Details of experimental results

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<th>Rising velocity</th>
<th>Measured porosity</th>
<th>Imaging porosity</th>
<th>Relative error</th>
<th>Gas Content</th>
<th>Gas Saturation</th>
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S.3. Variation of porosity with height

The quality of packing was checked by analyzing variation in porosity versus height. As one can see, a slight increase is observed in all cases, with is due to changes in overburden with height. Otherwise, the variations are in acceptable range.