Supporting Information for:

Direct Observations of Colloid Retention in Granular Media in the Presence of Energy Barriers and Pitfalls of Inferring Mechanisms from Indirect Observations

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Time series images demonstrates that colloids immobilized on the collector surfaces remained immobilized with no discernable motion even over long periods of time (link to movie).

Slow moving colloids associated with surfaces were observed (link to movie), and it is possible that these colloids are effectively retained across the time and spatial scales of column experiments. In this movie it is observed that rear stagnation zones showed no accumulation of colloids, and surfaces associated with these zones showed lesser concentration of attached colloids relative to upstream surfaces and forward stagnation zones.

Negligible detachment from the glass beads was observed in response to reduction of colloid concentration, reduction of solution ionic strength, increase in fluid velocity up to a factor of 64 times or more, and mild disassembly of the pore structure (link to movie).

The observations described in the paper also applied to the experiments performed in Ottawa sand, which involved the 0.21, 1.1, and 9.0 μm microspheres (Figures 1, 2, and 3 below), demonstrating that the observations were general among the two porous media (smooth spherical and rough angular) for the large range of colloid sizes examined here.

Figure 1. Images of initial (top row) and later (bottom row) attachment of 0.21, 1.1, and 9.0 μm microspheres in Ottawa sand porous media using white light combined with fluorescence. Bright spots emanate from microspheres. Light from individual microspheres is observable for sizes greater than 1-μm in size; whereas, lighter areas indicate accumulation of microspheres for

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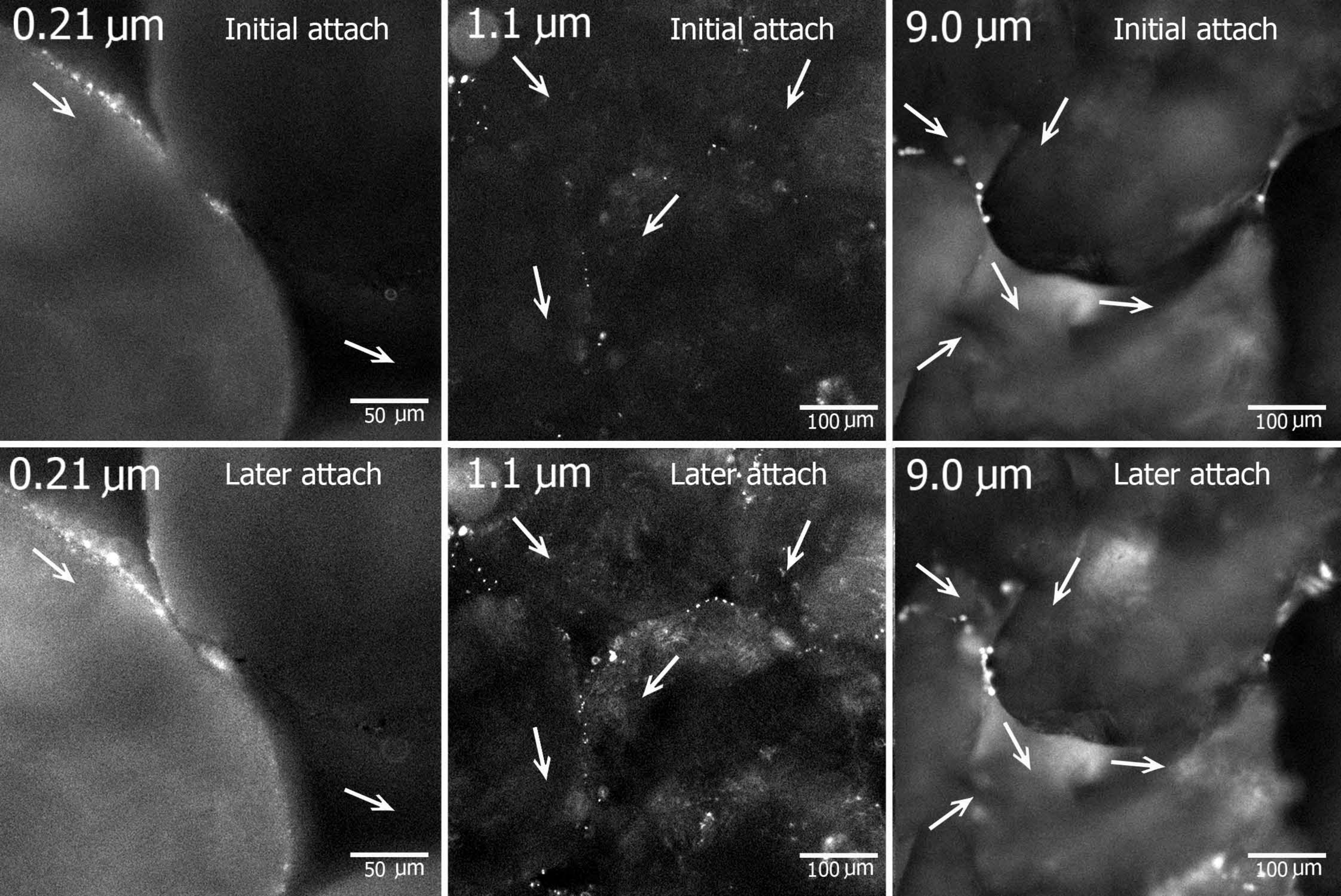
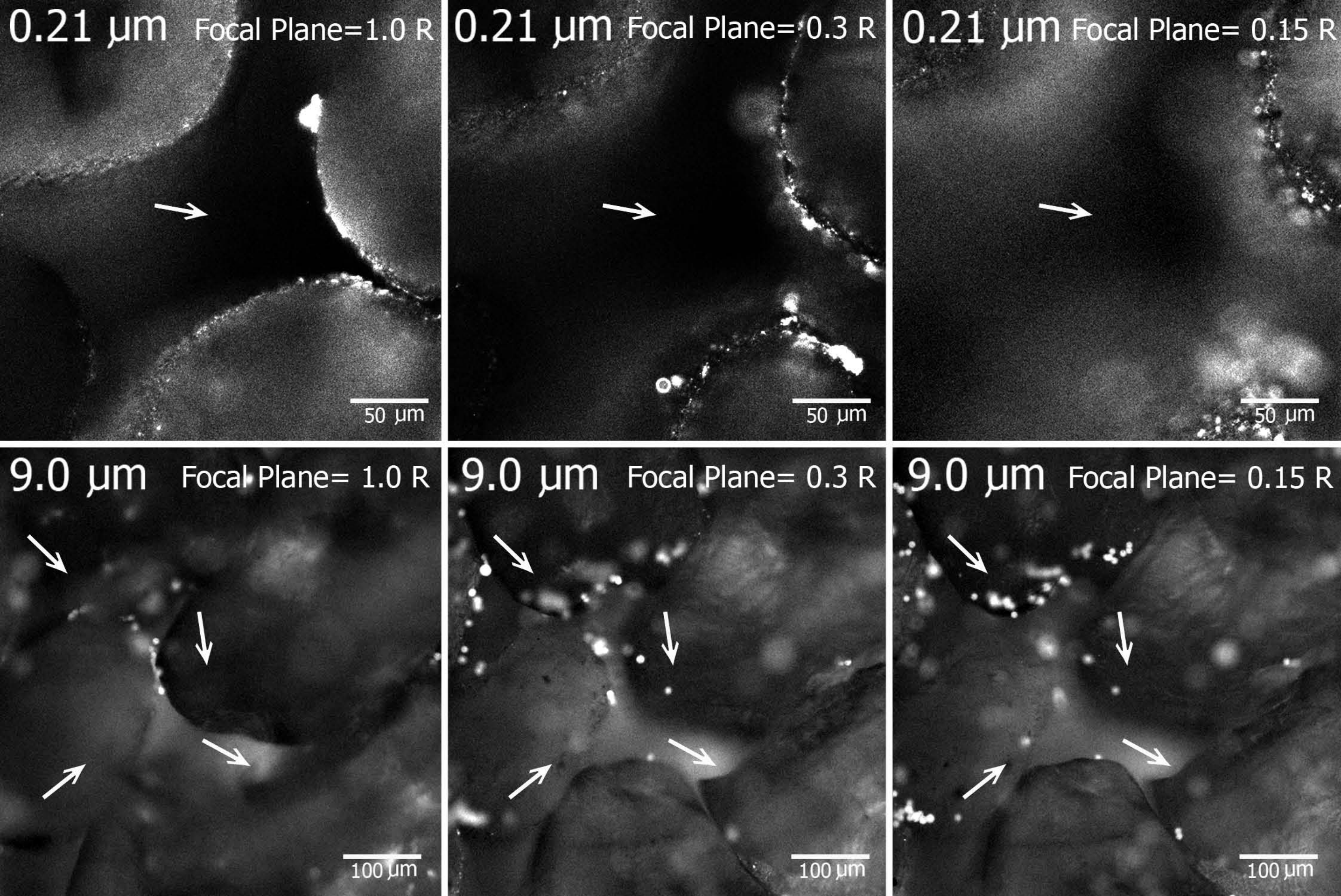
0.21-μm size. Focus planes in all panels are at the collector centers (grain to grain contacts). Arrows depict general directions of flow.

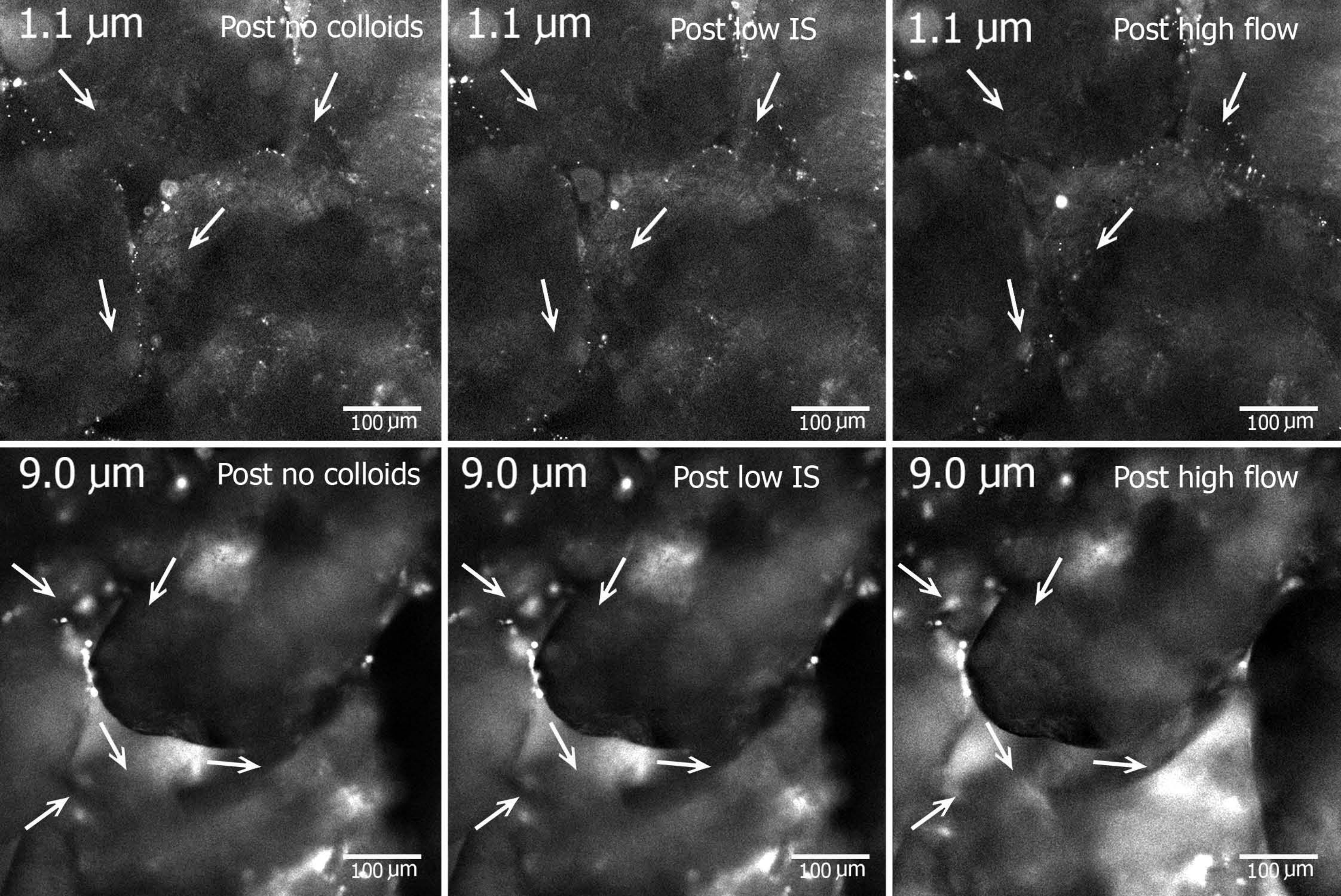
Figure 2. Images for two different experiments (0.21-μm and 9.0-μm) at different distances from the glass coverslip (chamber bottom). R = collector radius.   Colloid deposition is observed across the open surface of the collectors at different focal planes. The 9.0-μm colloids shown for focal plane at 0.15R are attached to the glass cover slip rather than the collector. Arrows depict general directions of flow.

Figure 3. Images following cessation of colloid injection, reduction of ionic strength, and increase in flow (factor of 64 for 1.1-μm, factor of 10 for 9.0-μm). Rotation and vibration of the collectors during high flow resulted in the change of 9.0-μm colloid distribution on the collector surfaces between the post-high-flow and post-low-ionic-strength (IS) conditions. Arrows depict general directions of flow.


0.21 μm
Initial attach
50 μm
1.1 μm
Initial attach
100 μm
9.0 μm
Initial attach
100 μm
0.21 μm
Later attach
50 μm
1.1 μm
Later attach
100 μm
9.0 μm
Later attach
100 μm



0.21 µm Focal Plane=1.0 R
50 µm
0.21 µm Focal Plane= 0.3 R
50 µm
0.21 µm Focal Plane= 0.15 R
50 µm
9.0 µm Focal Plane= 1.0 R
100 µm
9.0 µm Focal Plane= 0.3 R
100 µm
9.0 µm Focal Plane= 0.15 R
100 µm


1.1 µm
Post no colloids
1.1 µm
Post low IS
1.1 µm
Post high flow
100 µm
100 µm
100 µm
9.0 µm
Post no colloids
9.0 µm
Post low IS
9.0 µm
Post high flow
100 µm
100 µm
100 µm