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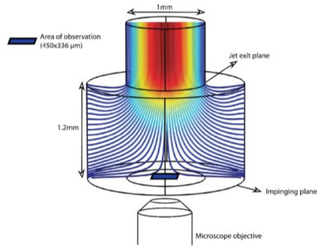
The Rise and Fall … and Expansion and Contraction … of Colloid-Surface Interactions

William P. Johnson
University of Utah Geology & Geophysics

Observation:

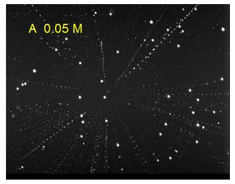
Colloid attachment occurs on like-charged surfaces (unfavorable attachment conditions, typical of environmental transport).



Ron C., Johnson W.P., 2020, Complementary Colloid and Collector Nanoscale Heterogeneity Explains Microparticle Retention Under Unfavorable Conditions, Environ. Sci. Nano, 7, 4010– 4021.

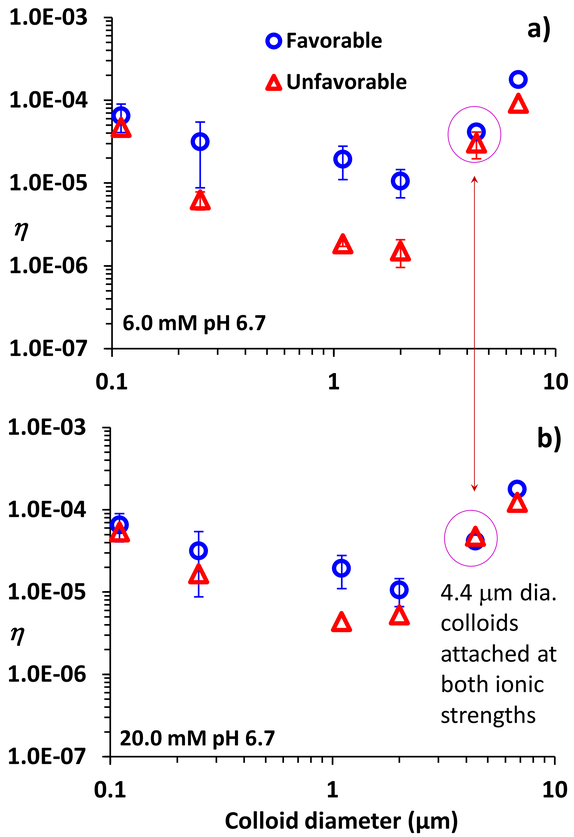
Colloid transport in impinging jet flow cell atop an epifluorescence microscope (left).

Image from microscope of fluorescent colloids with trajectories shown for mobile near-surface colloids distinct from immobilized attached colloids (right)



Collector efficiencies (η) below quantify attachment of carboxylate-modified polystyrene latex microspheres interacting with SC1-cleaned silica (glass slide) (both surfaces negatively charged).

Attachment increased with increased ionic strength from 6 mM panel a) to 20 mM (panel b).

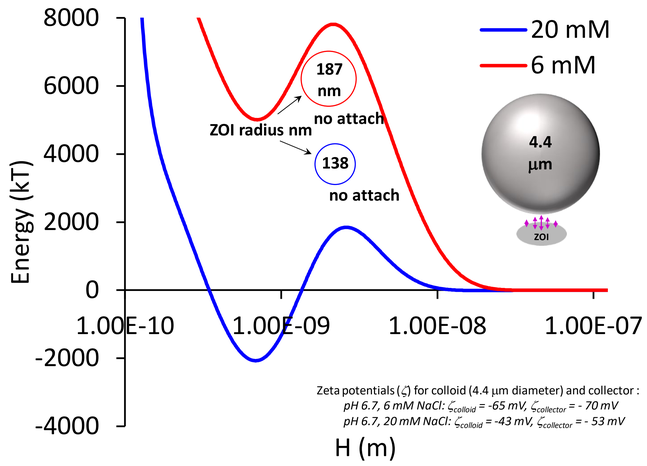


4.4 µm dia. colloids attached at both ionic strengths

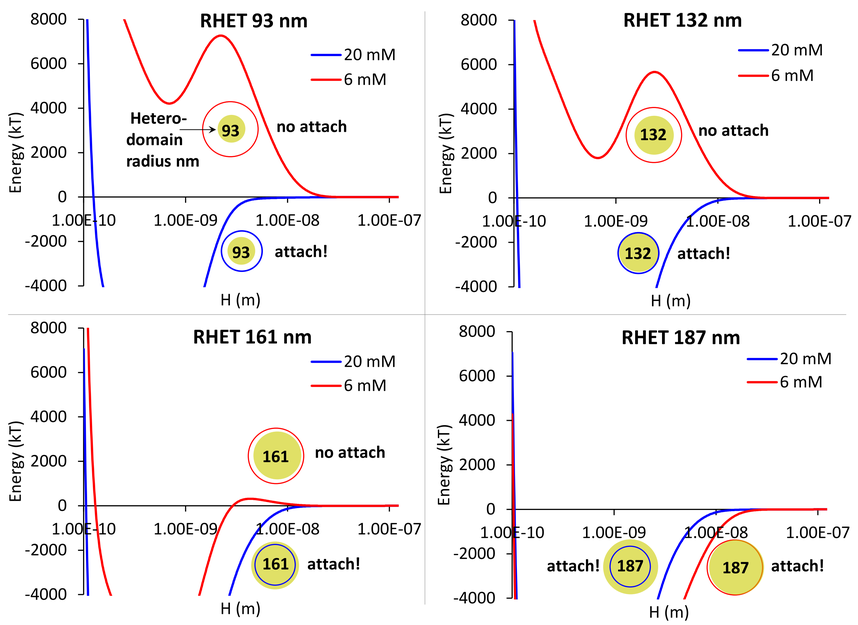
Theory:

(Parti-Suite https://wpjohnsongroup.utah.edu/trajectoryCodes.html)

Height of barriers to attachment decreased with increasing ionic strength, but remained far greater than the ~ 10 kT limit for attachment, contradicting experiments



Secondary minimum interactions do not produce attachment (ask me why!). Nanoscale heterogeneity locally eliminates the repulsive barrier by partly filling the finite zone of colloid-surface interaction (ZOI) **RZOI = $2\sqrt{\kappa a_p}$, κ is the inverse Debye length and a_p is the colloid radius)**



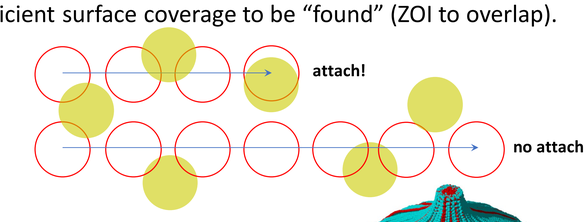
Outcome & Implications:

Attachment depends on the ZOI being occupied sufficiently by a heterodomain(s) or contracting around a heterdomain(s) in response to ionic strength increase. The corollary is that detachment is driven by expansion of ZOI (ionic strength reduction).

Pazmino E., J. Trauscht, and W.P. Johnson, 2014, Release of Colloids from Primary Minimum Contact Under Unfavorable Conditions by Perturbations in Ionic Strength and Flow Rate, Environ. Sci. Technol., 48(16), 9227–9235

xDLVO required heterodomain with radii > ~ 170 nm to match experiments (middle bottom).

Attachment depends on heterodomains of sufficient size, and also on sufficient surface coverage to be “found” (ZOI to overlap).

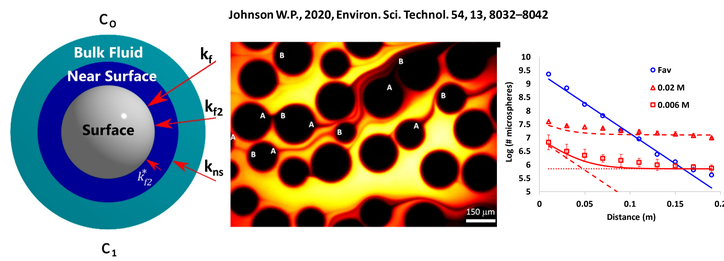


At grain scale, colloids may enter the near surface fluid domain where surface interactions are significant) (aqua trajectories in figure right)

They may “find” and attach to heterodomains (red trajectories in figure right).

In porous media, the probabilities of interception (entering near surface fluid domain) and attachment upon interception, along with incomplete pore scale mixing produces fast-and slow-attaching subsets from a population of identical individuals.

Johnson W.P., 2020, Environ. Sci. Technol. 54, 13, 8032–8042



See the posters of **Sabrina Volponi, Luis Ullauri, and Bashar Al Zghoul** in this session, as well as the following book for more.
https://gw-project.org/books/colloid-nano-and-micro-particle-transport-and-surface-interaction-in-groundwater/

Or just google “GW Project Colloids”