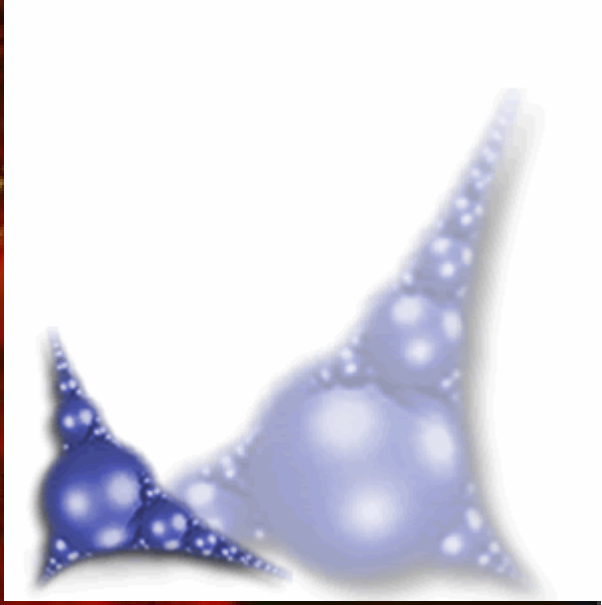
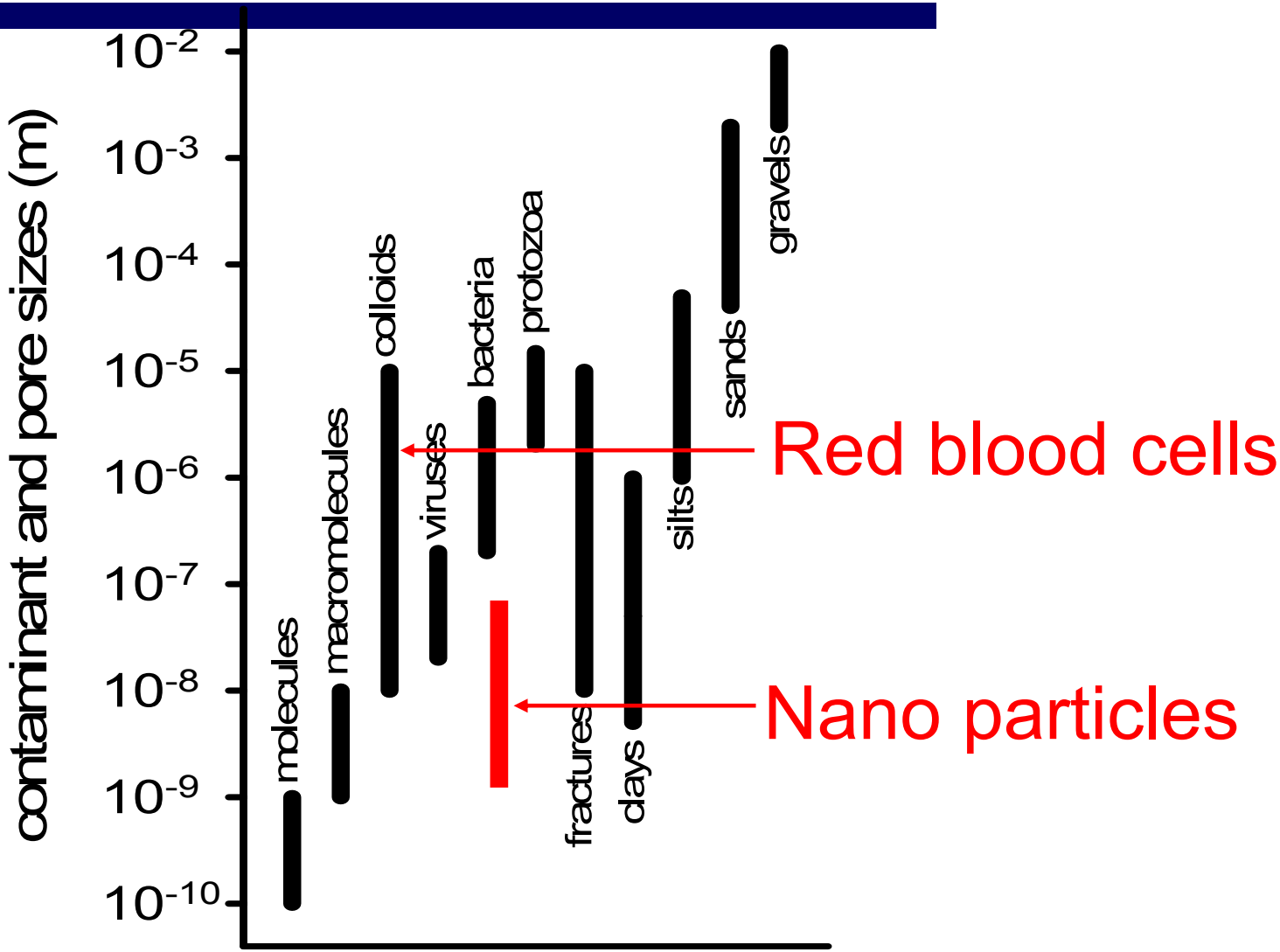
Flow Visualization and Quantification of Bacterial Transport in Sand Under Steady and Transient Conditions



This project was supported by National Research Initiative Competitive Grant from the USDA Cooperative State Research, Education, and Extension Service

Particles in Soil

A sheet of paper is 100,000 nm thick



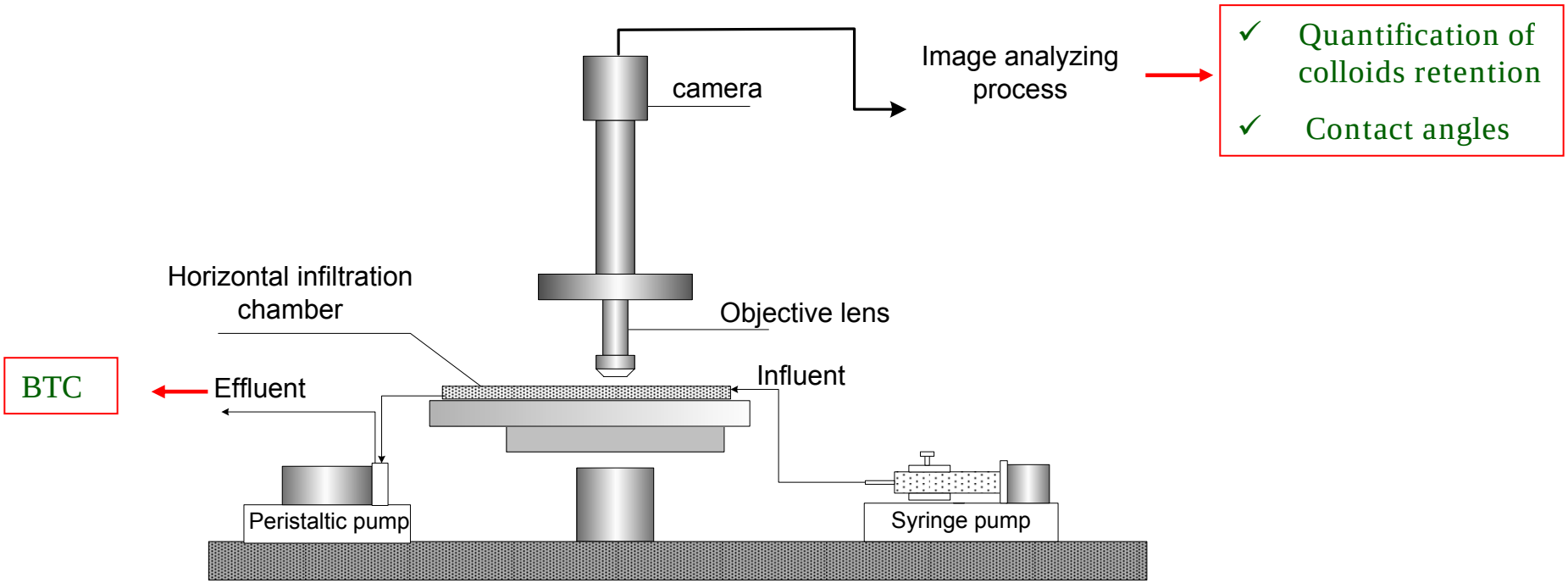
Visualization Techniques

Confocal microscope

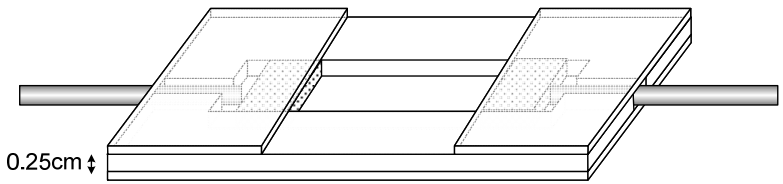
Fluorescent microspheres

Zevi, Y., A. Dathe, J.F. McCarthy, B.K. Richards, T.S. Steenhuis. 2005. Distribution of Colloid Particles onto Interfaces in Partially Saturated Sand. Environ. Sci. Technol. 39:7055-7064

Experimental setup



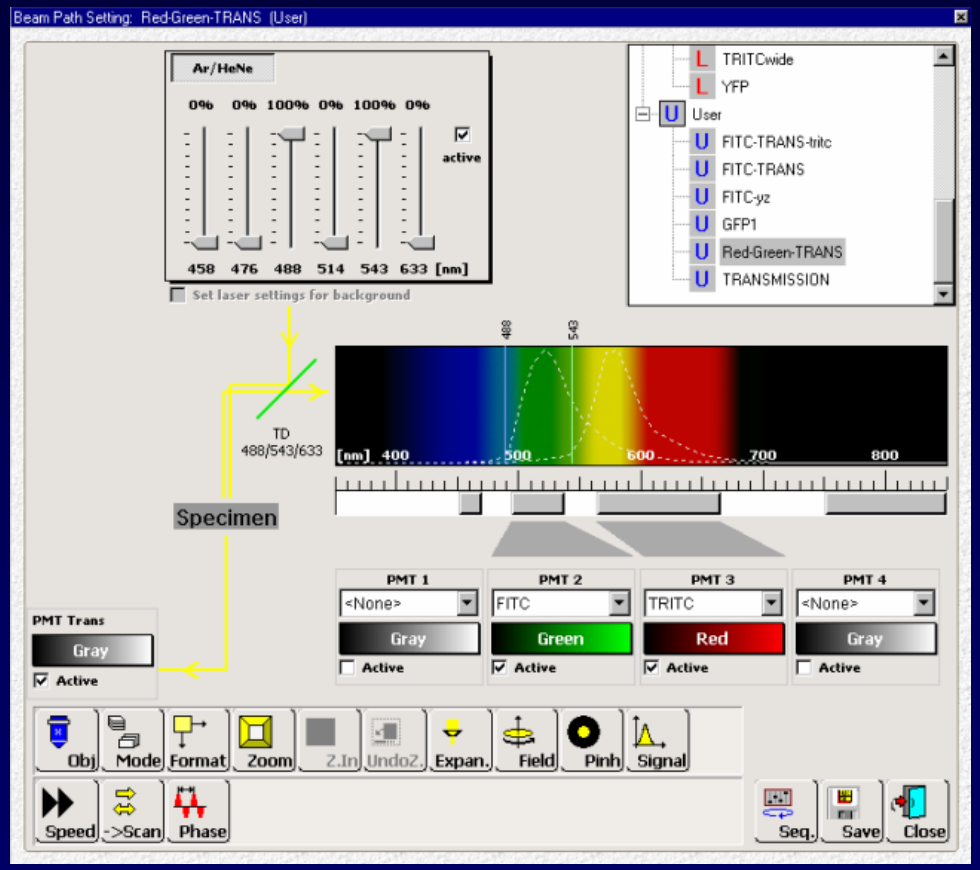
Infiltration chamber



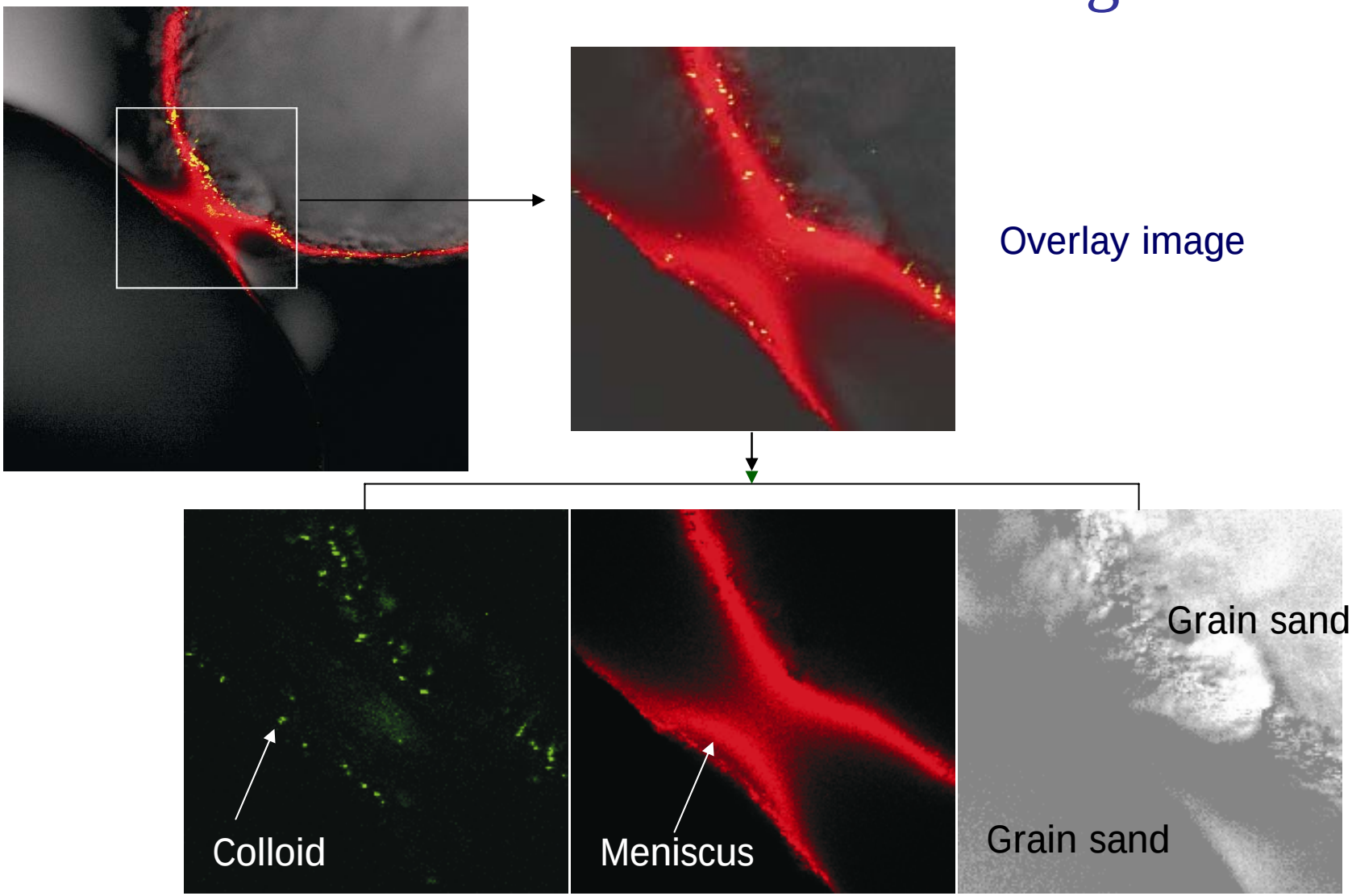
Confocal Laser Scanning Microscope

Leica TCS SP2 with a 10.0x0.40 UV objective

- **488 nm** (argon) line excites the **colloid** fluorescence
- **543 nm** green (HeNe) line excites **Rhodamine B** fluorescence
- Bright field channel detects the laser reflectance intensity of quartz grains



Confocal images



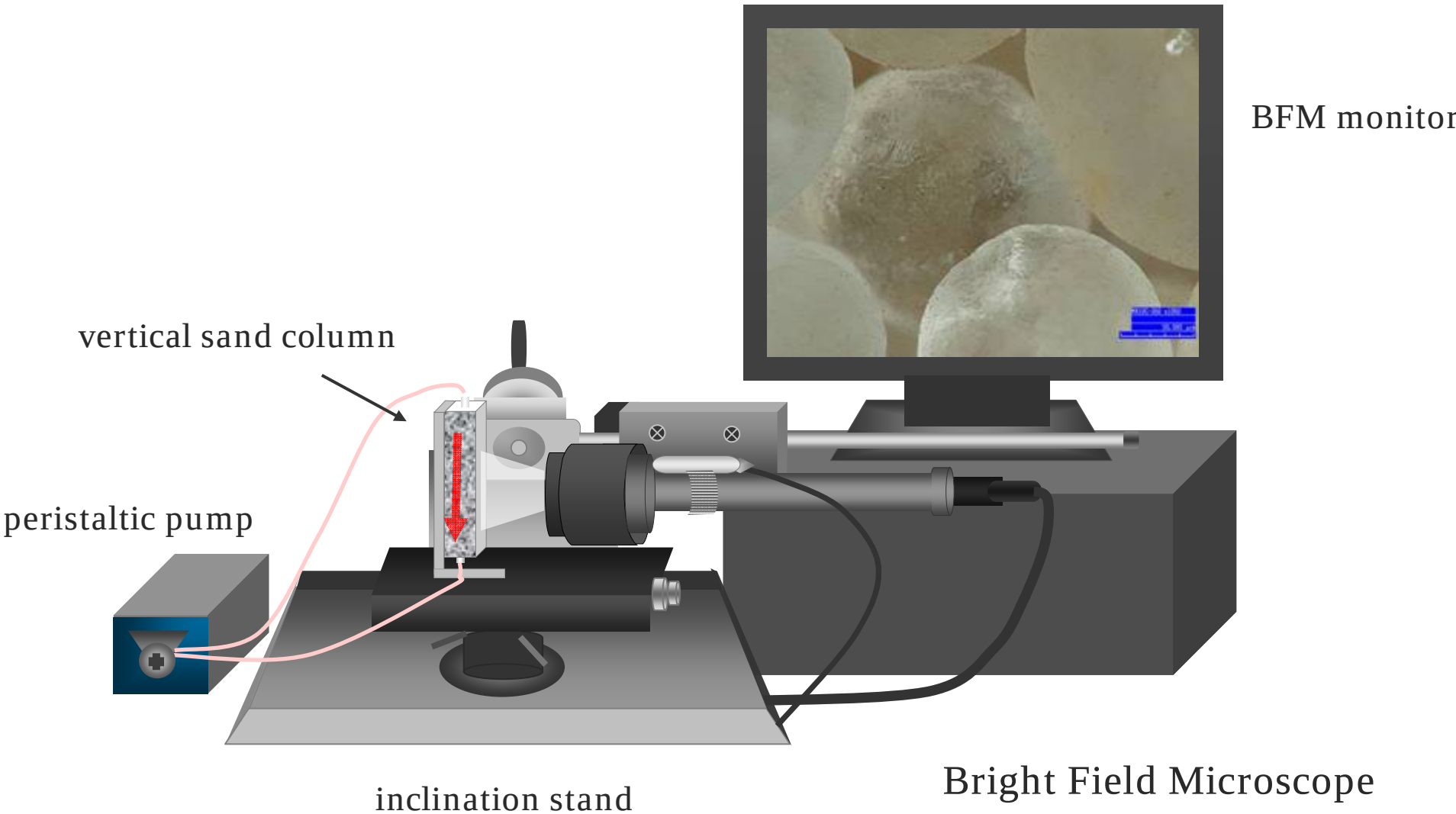
Video 1
Retention of hydrophilic colloids

Yuniati Zevi

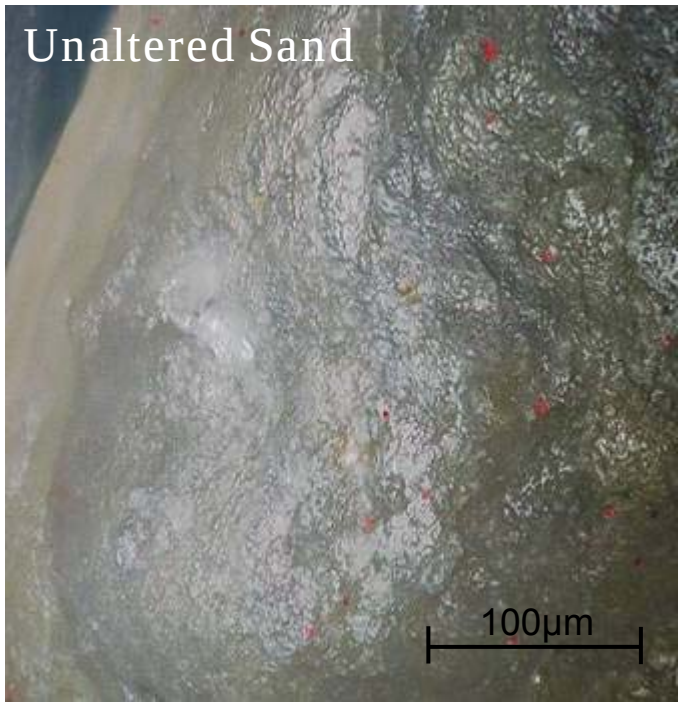
2006

V.L. Morales[1], B. Gao[2], L.W. Lion[3], T.S. Steenhuis[1] Grain Surface-Roughness Effect on Colloidal Retention in the Vadose Zone. Submitted

Experimental Setup

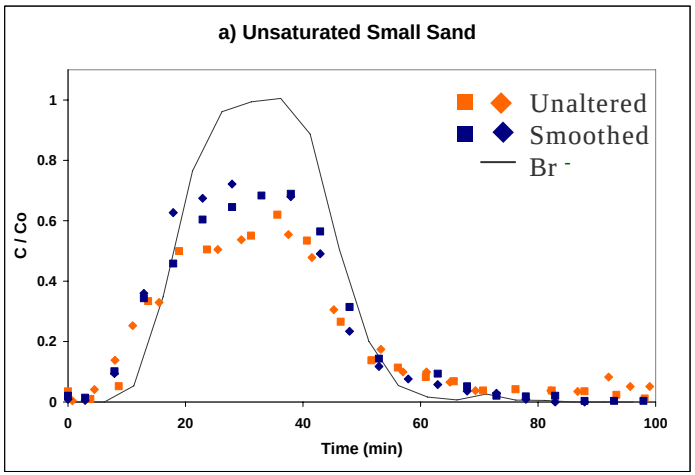


Surface-Roughness Alterations

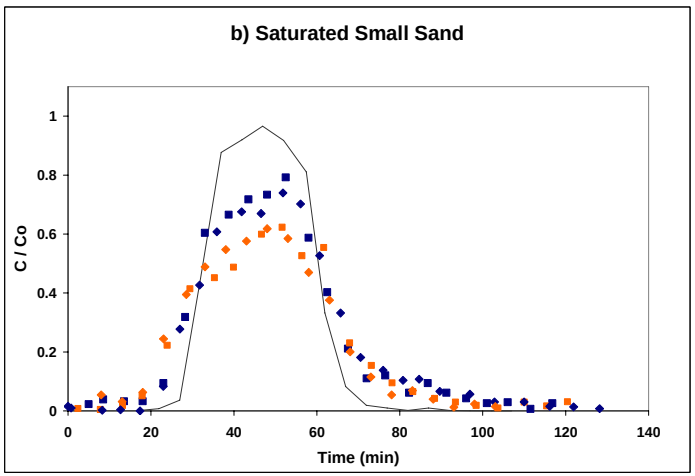


Surface roughness was altered by means of lapidary rotation.

Results for Small Sand



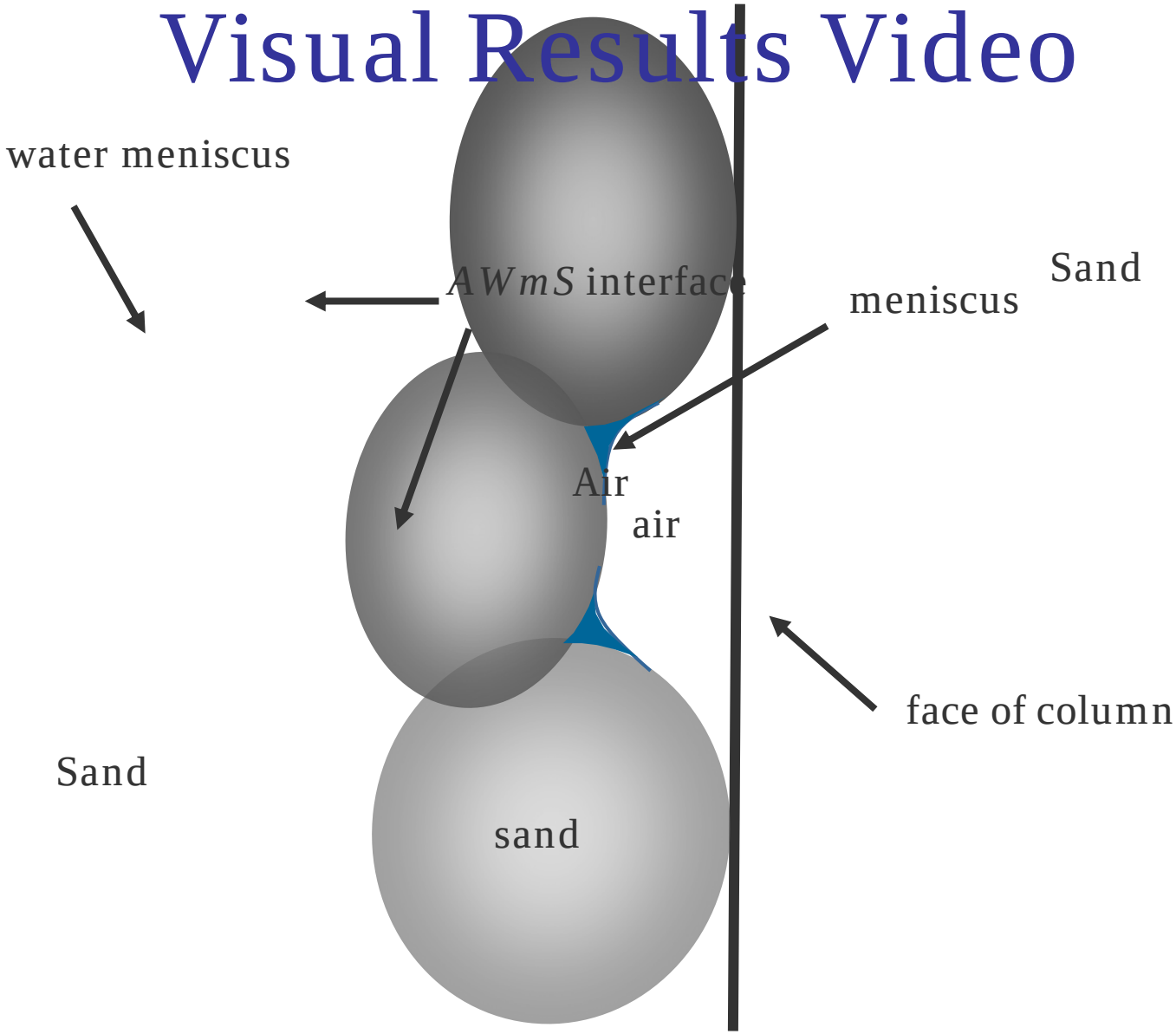
0.3-0.42 Unsaturated Sand	Unaltered	Smoothed	Fraction difference
mean Volumetric Water Content	0.30	0.28	**0.054**
mean percent Mass Recovery	75	91	**0.21**
Student t-test p value (two-tail)			0.001

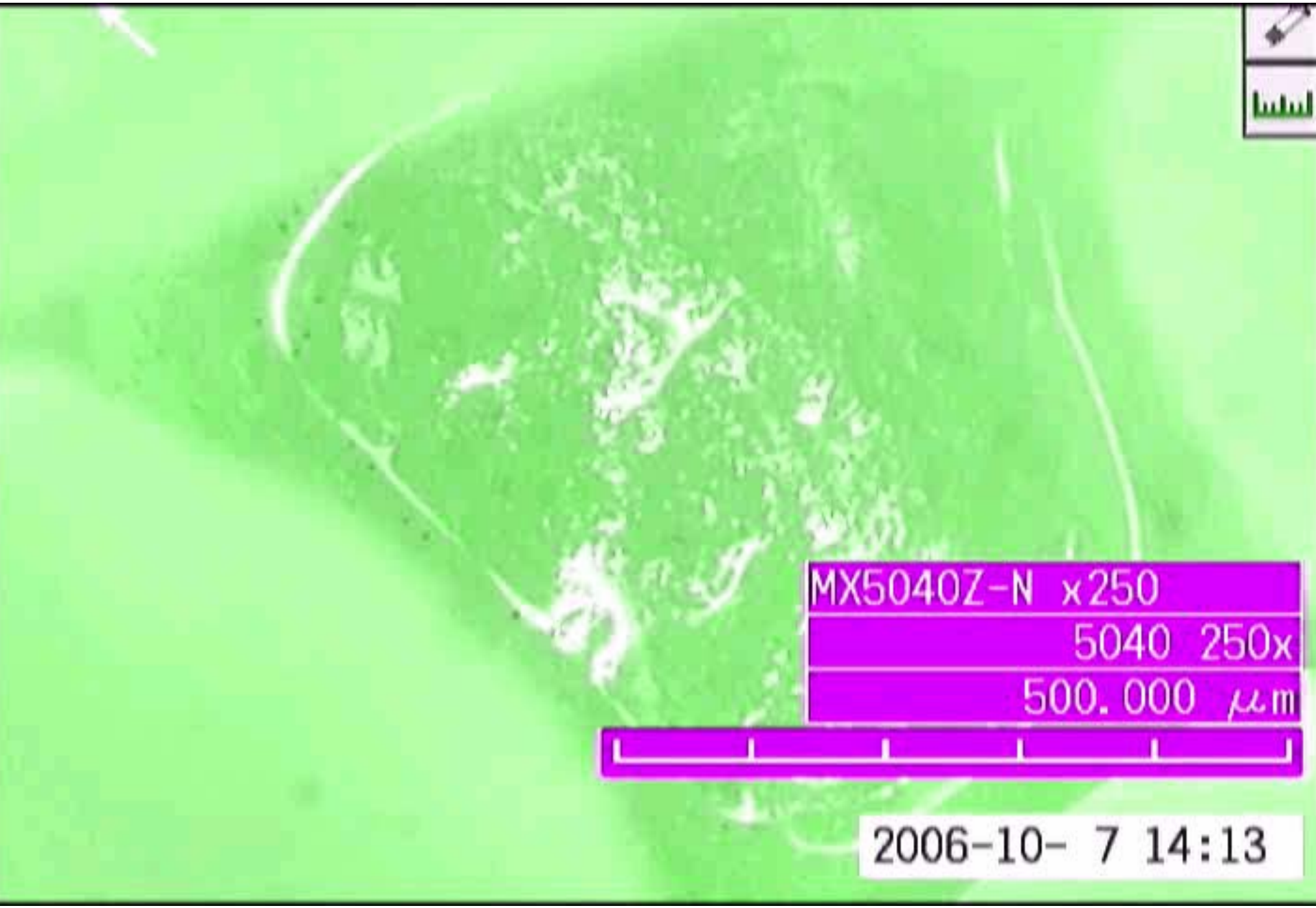


0.3-0.42 Saturated Sand	Unaltered	Smoothed	Fraction difference
mean Volumetric Water Content	0.44	0.43	**0.019**
mean percent Mass Recovery	86	96	**0.12**
Student t-test p value (two-tail)			0.036

Mass balance of breakthrough of colloid concentration demonstrates that more particles are retained at lower water contents and rougher sand medium

Visual Results Video




MX5040Z-N x250
5040 250x
500.000 μm
2006-10- 7 14:13

COUNTING COLLOIDS

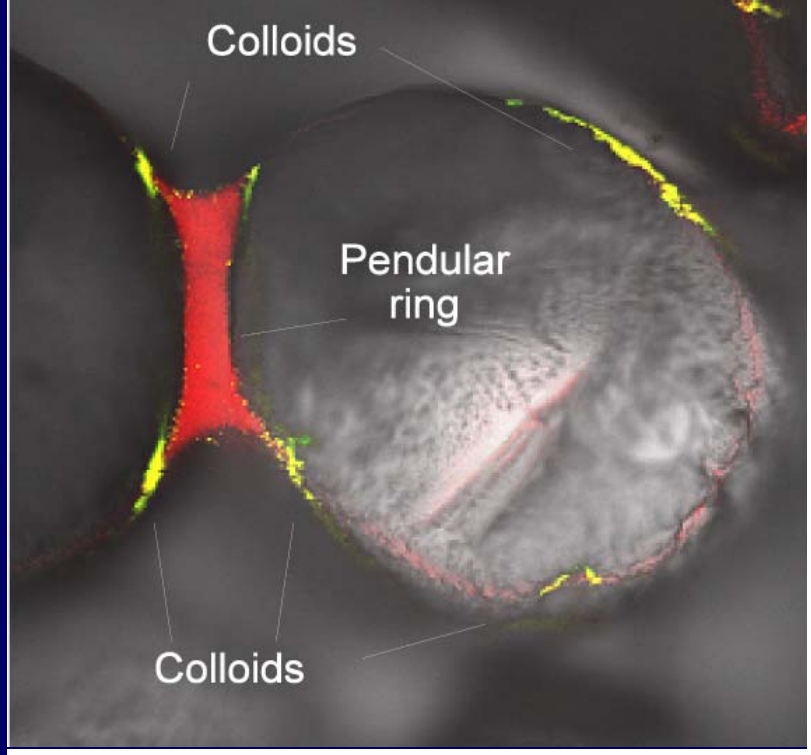
Movies are nice but not sufficient

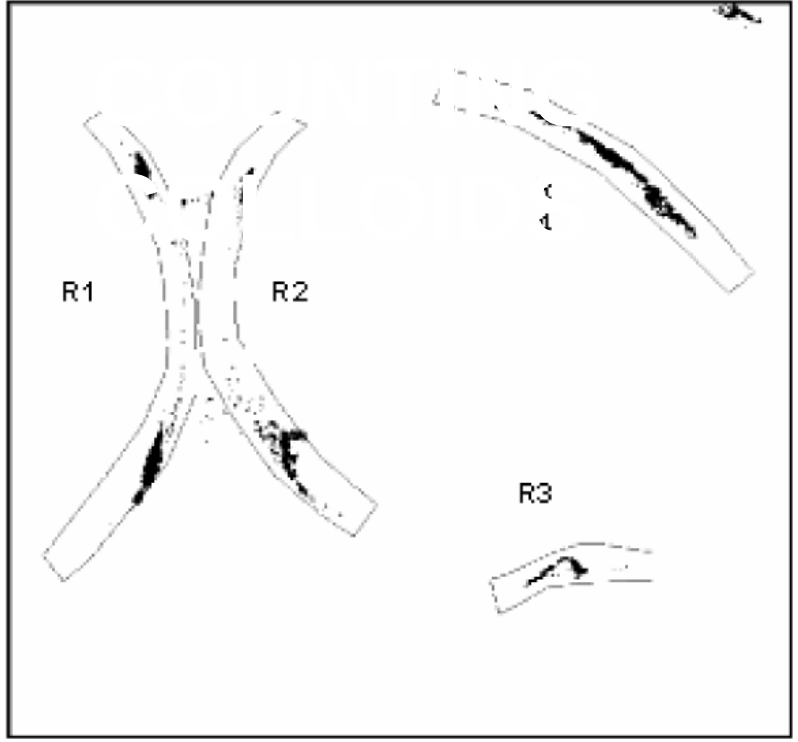
NEED

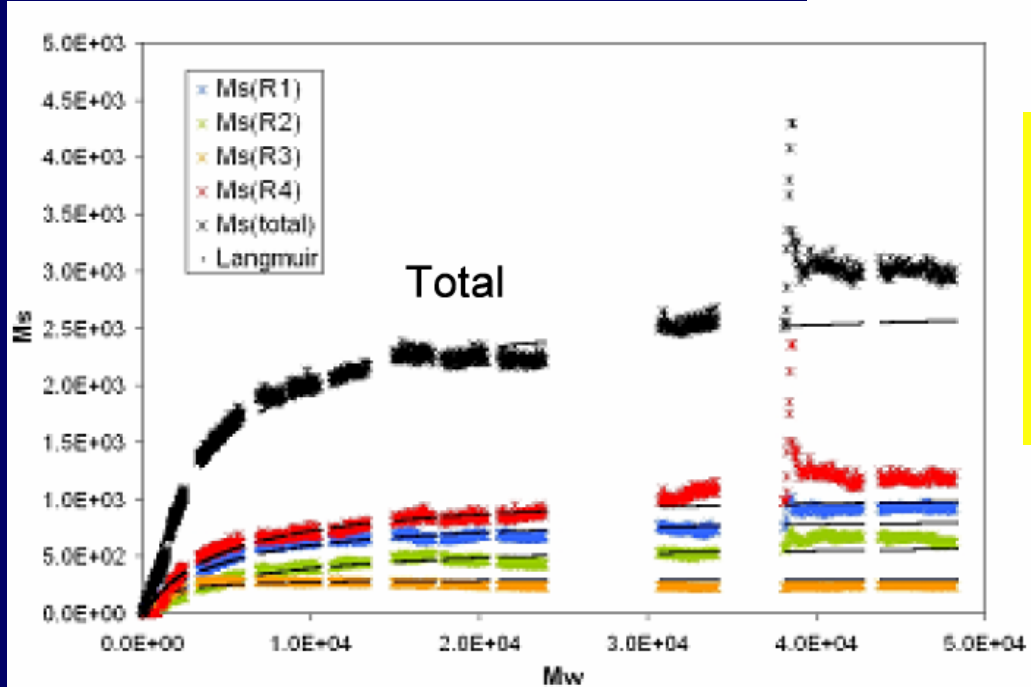
quantification of colloids

at air water solid interface

Zevi, Y., A. Dathe, B. Gao, B.K. Richards, T.S. Steenhuis. 2006. Quantifying colloid retention in partially daturated porous media. Water Resources Research, 42, W12S03, doi:10.1029/2006WR004929







$$M_s = \frac{KNM_w}{1 + KM_w}$$

K, N Constants

M_s Colloids at AWS interface

M_w Cumulative colloids in water

Colloid Retention

Colloid Retention

Surface tension

or

capillary forces

1000 times as large as DVLO forces

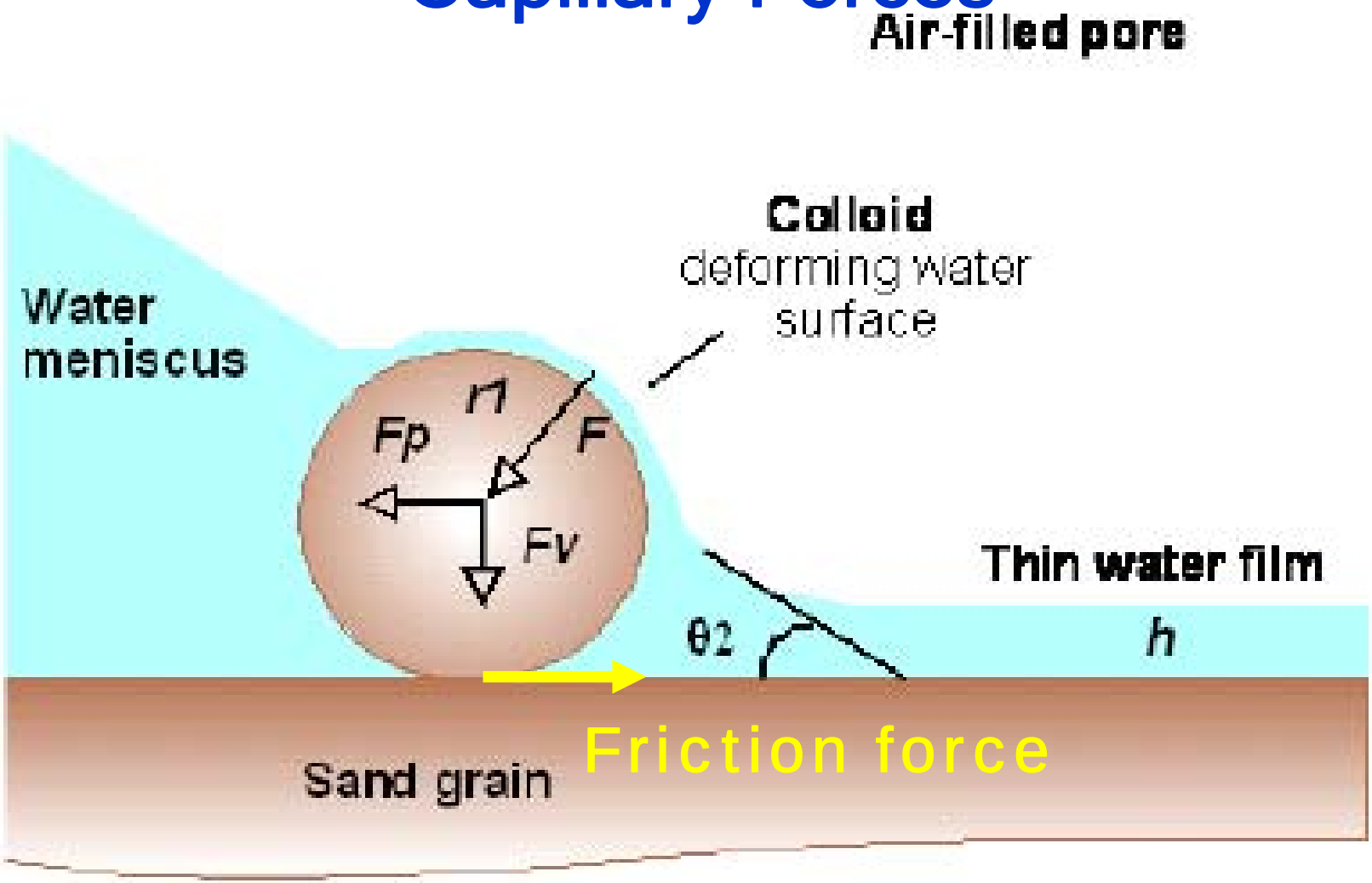
Colloid Retention

Laminar flow with zero velocity near grain

Colloid Retention

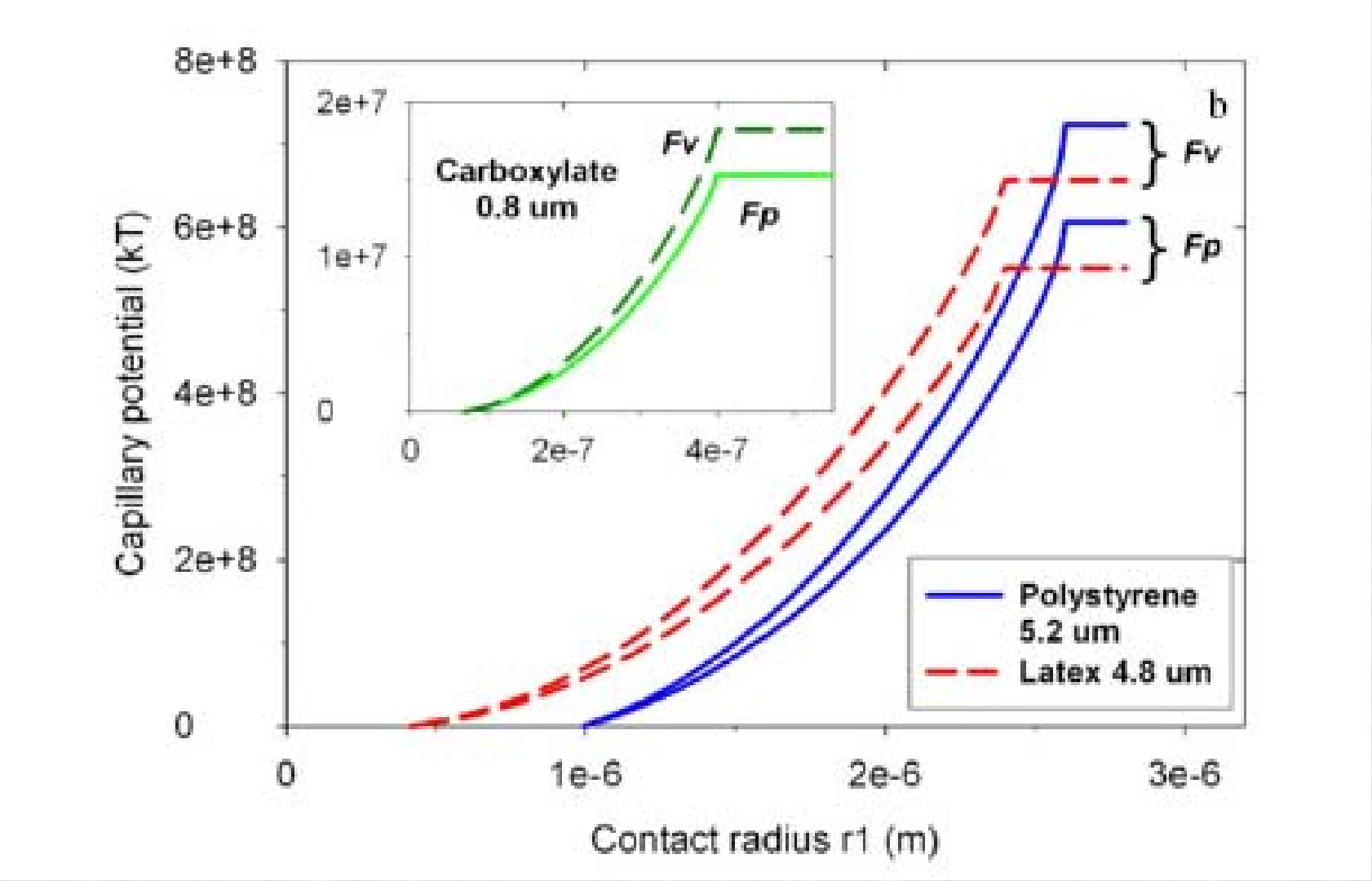
Interfacial Interaction energies or DVLO forces

Capillary Forces

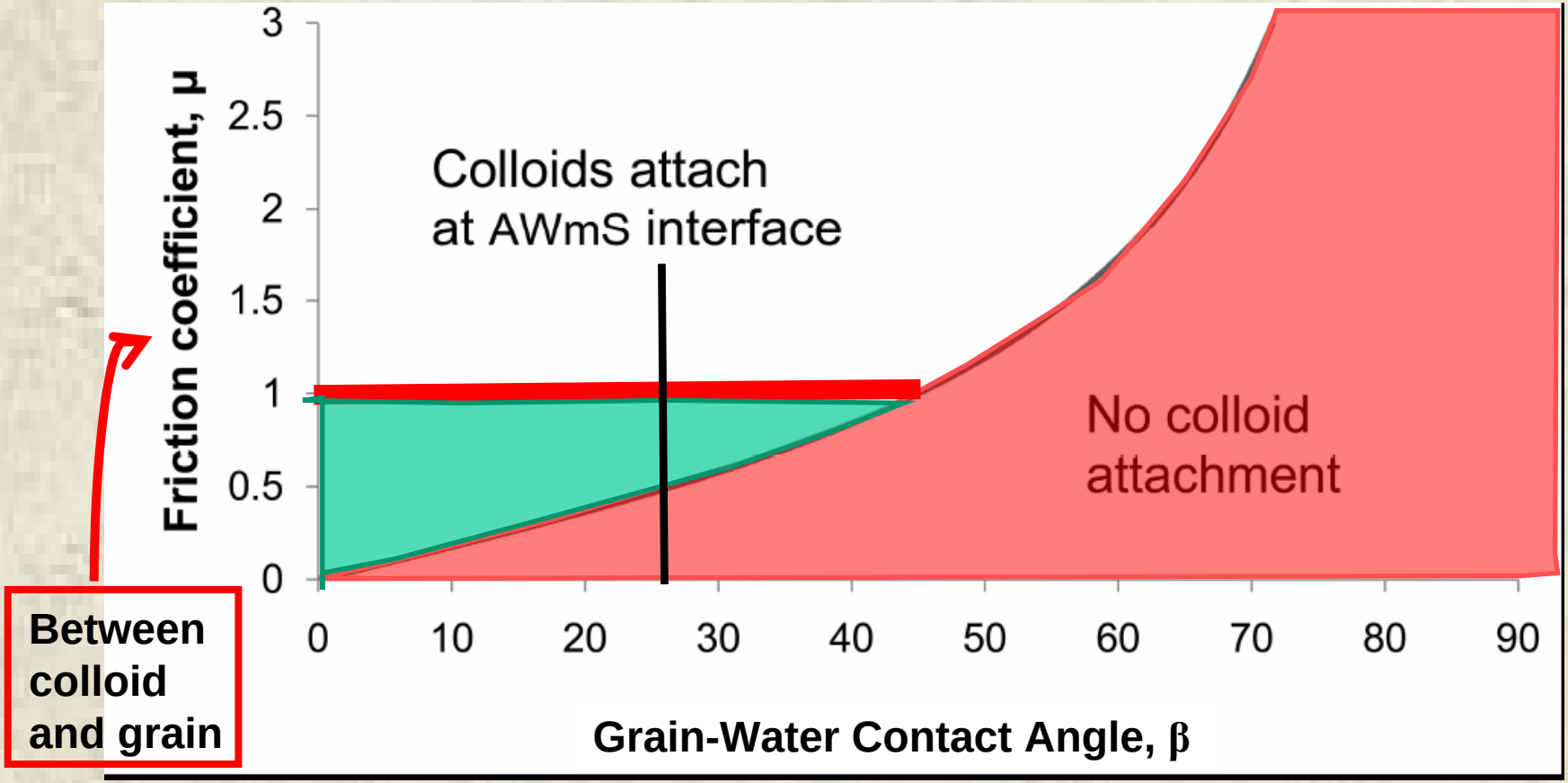


2 Schematic of capillary forces (F) on colloid trapped at AW_mS interface

Capillary Forces



Only friction and water grain contact angle play a role in retention of colloid at air-water-solid interface



Gao, B., T.S. Steenhuis*, [1], Y. Zevi[1], V.L. Morales[1], J. L. Nieber[2], B. K. Richards[1], J. F. McCarthy[3] and J.-Y. Parlange. Capillary Retention of Colloids in Unsaturated Porous Media. Water Resource Research. In Press

Other Results (and Movies)

Soil and Water Web Pages

http://soilandwater.bee.cornell.edu/

This project was supported by National Research Initiative Competitive Grant from the USDA Cooperative State Research, Education, and Extension Service