

Sand Properties

understanding common tests

Douglas Cortes

Carlos Santamarina

School of Civil and Environmental Engineering
Particulate Media Research Laboratory

Particle size

Particle shape / crushing

e_{\min} e_{\max}

Friction angle

Flow test

Strength

P-wave velocity

Thermal properties

Particle size

Particle shape / crushing

e_{\min} e_{\max}

Friction angle

Flow test

Strength

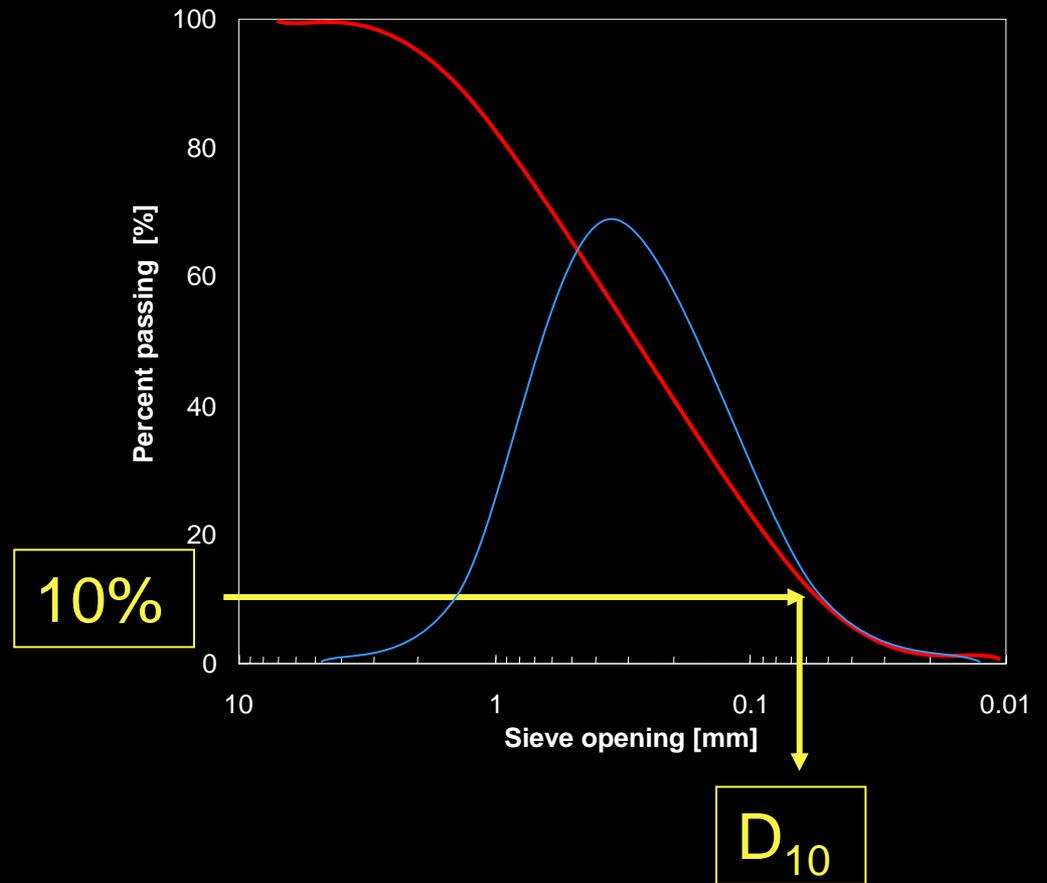
P-wave velocity

Thermal properties

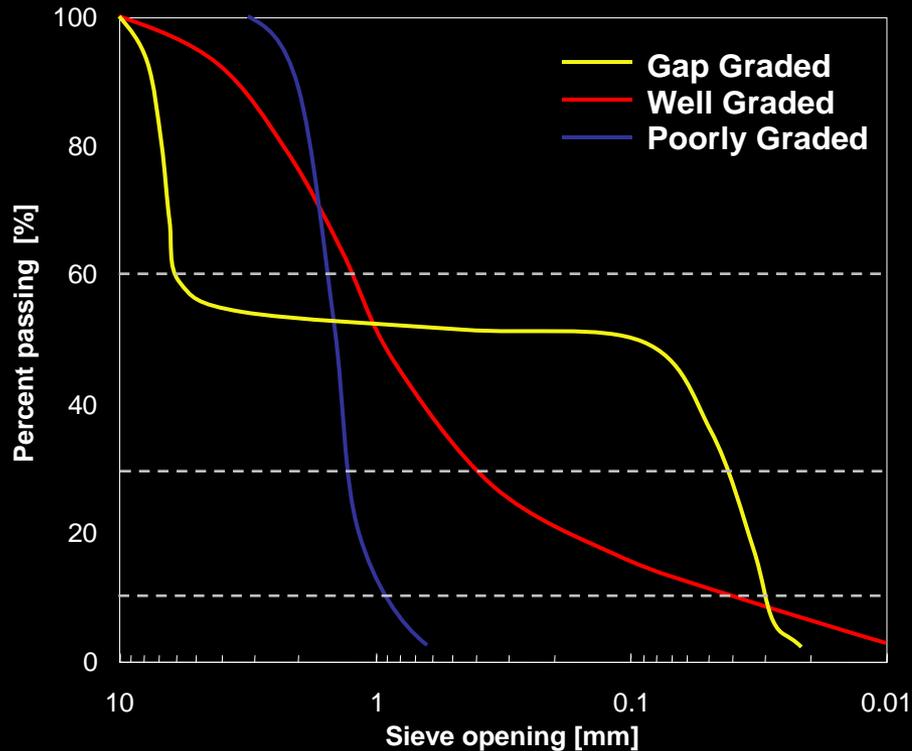
Sieve Analysis



Computing Particle Size Distribution



Important Particle Size Parameters



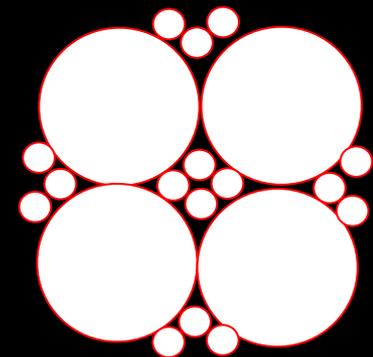
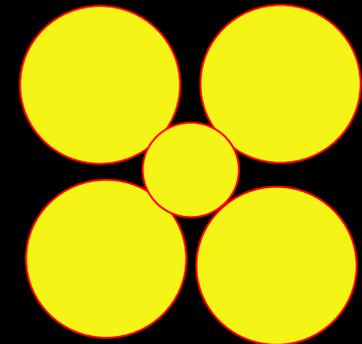
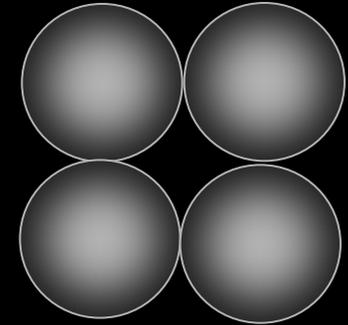
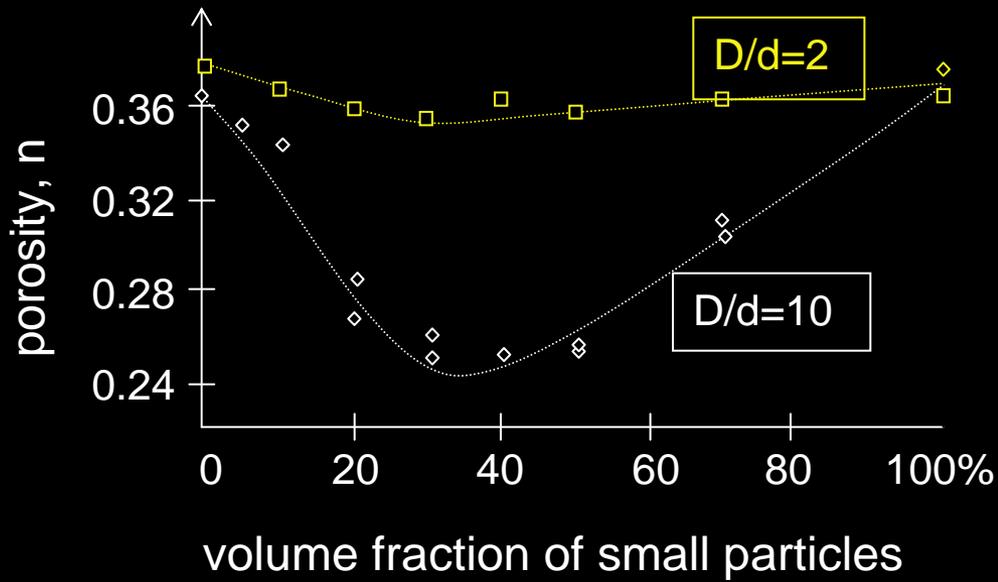
Coefficient of curvature

$$C_c = \frac{(D_{30})^2}{D_{10} \cdot D_{60}}$$

Uniformity coefficient

$$C_u = \frac{D_{60}}{D_{10}}$$

Size Distribution → Packing Density



Caution: Capillarity



Capillarity Holds!



Caution: Electrical Forces



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Particle shape / crushing

e_{\min} e_{\max}

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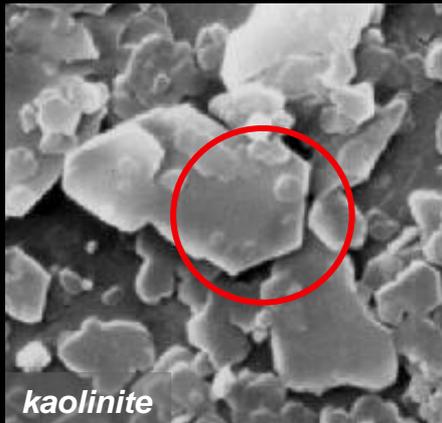
Thermal properties

mm



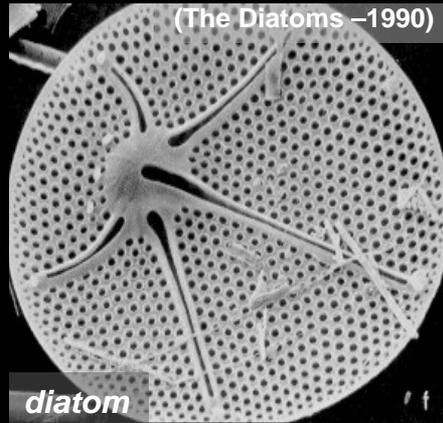
Ottawa sand

μm



kaolinite

μm



diatom

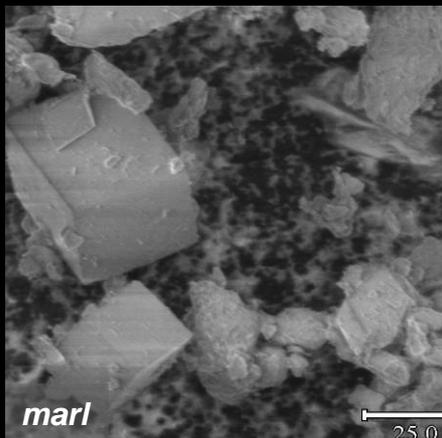
mm



table salt



crushed granite



marl



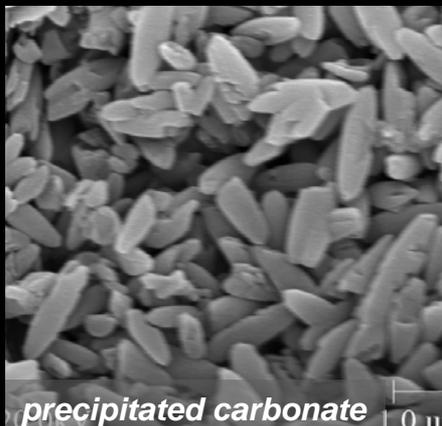
diatom



lentil



sintered lead



precipitated carbonate

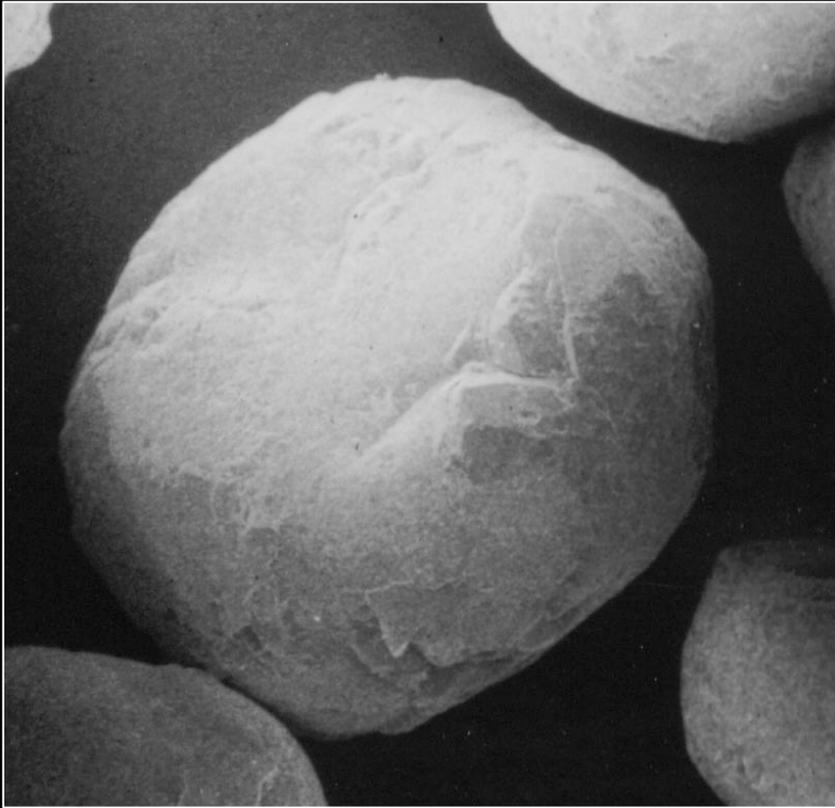


foraminiferan

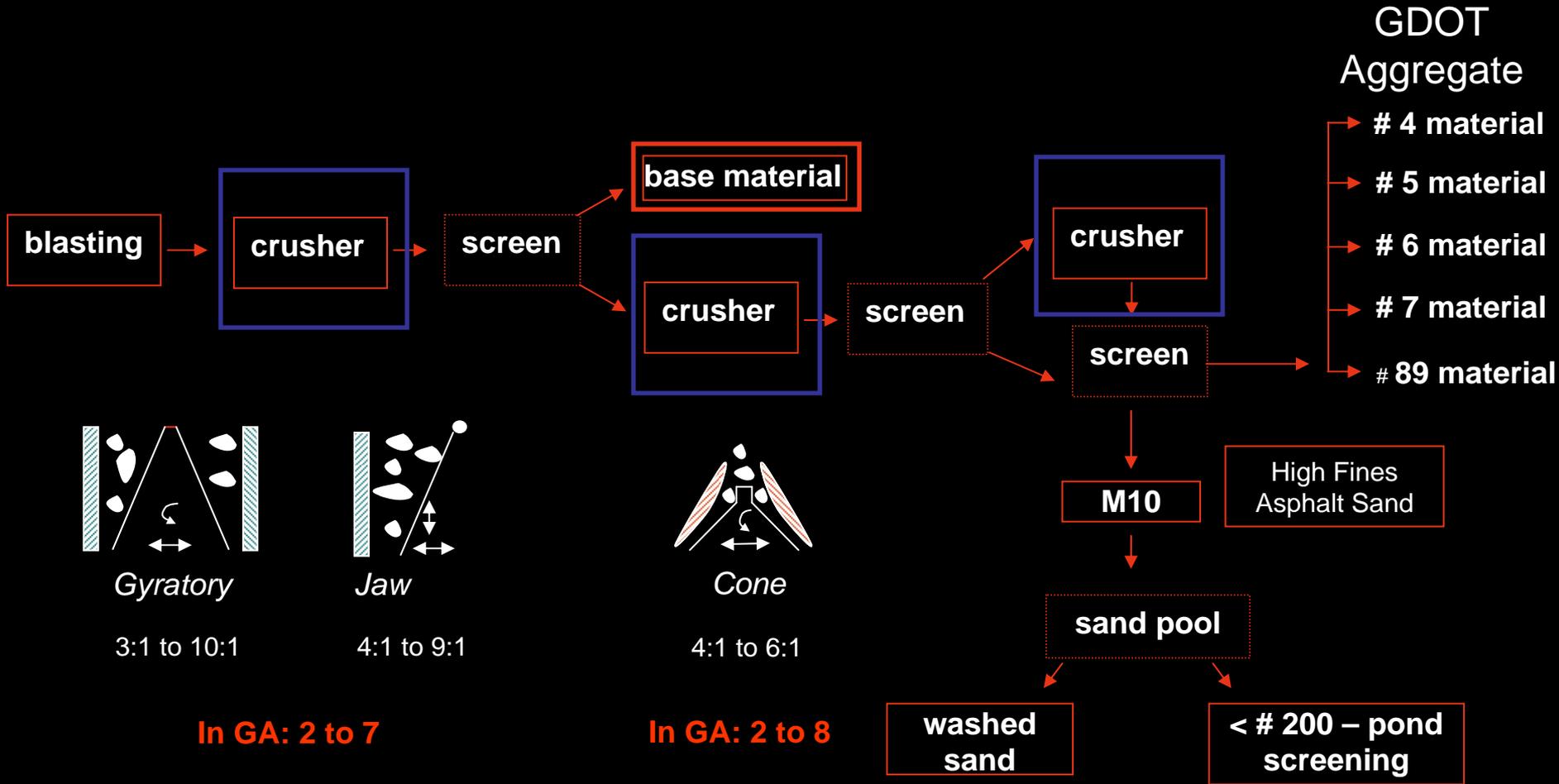


rice

Why Shape? Formation History



Crushers: Fines and Shape



Test Loading Configurations

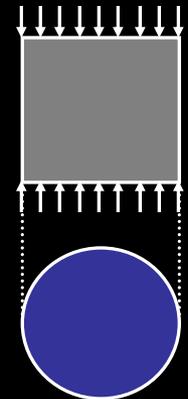
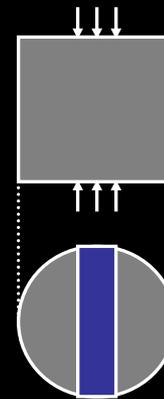
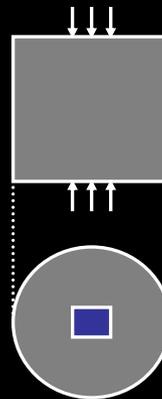
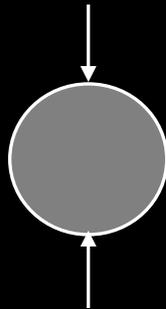
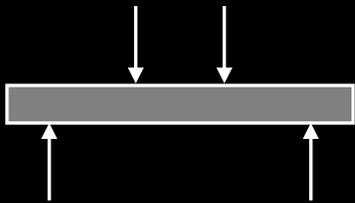
4-point load

Brazilian

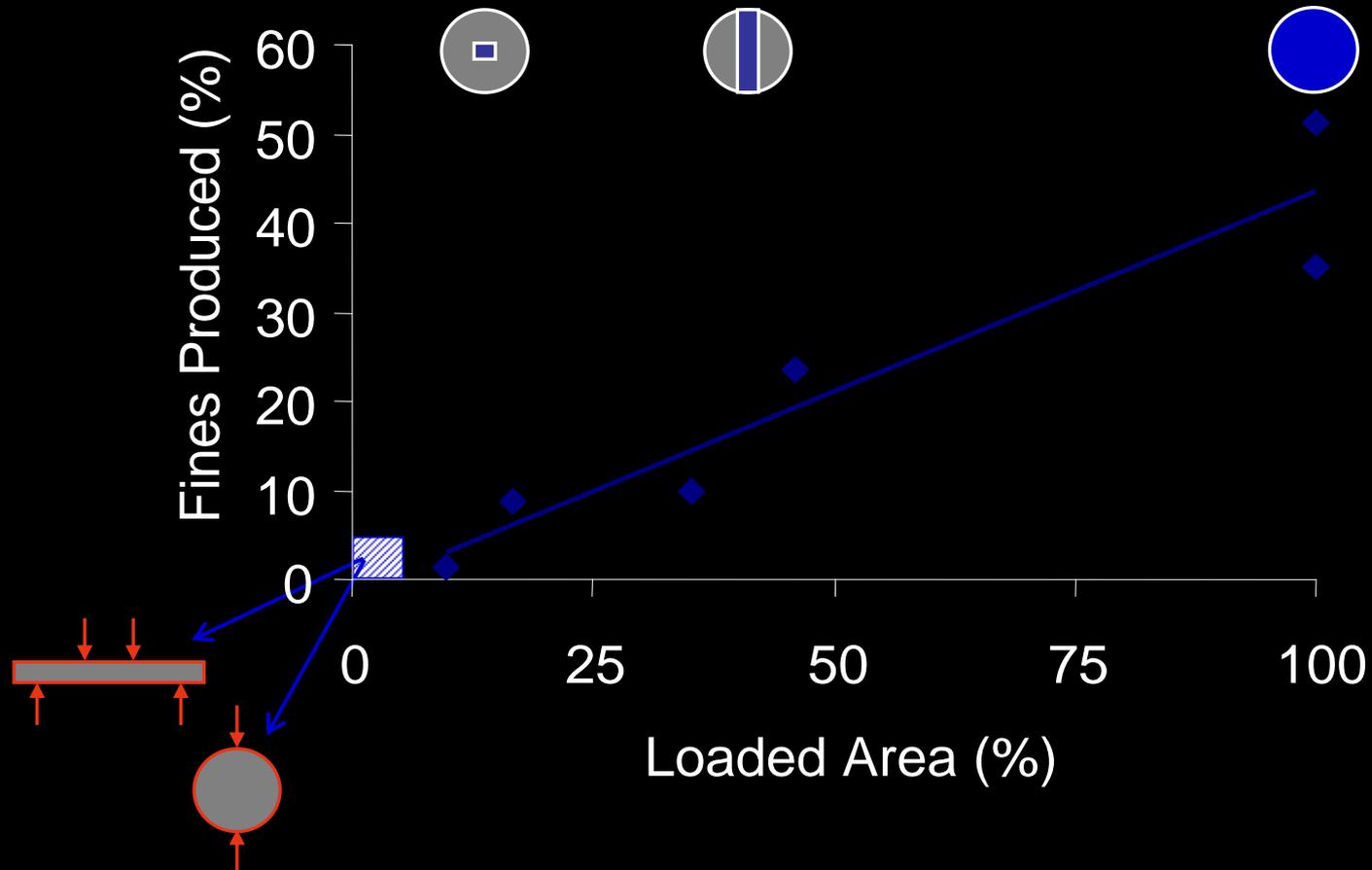
point load

long load

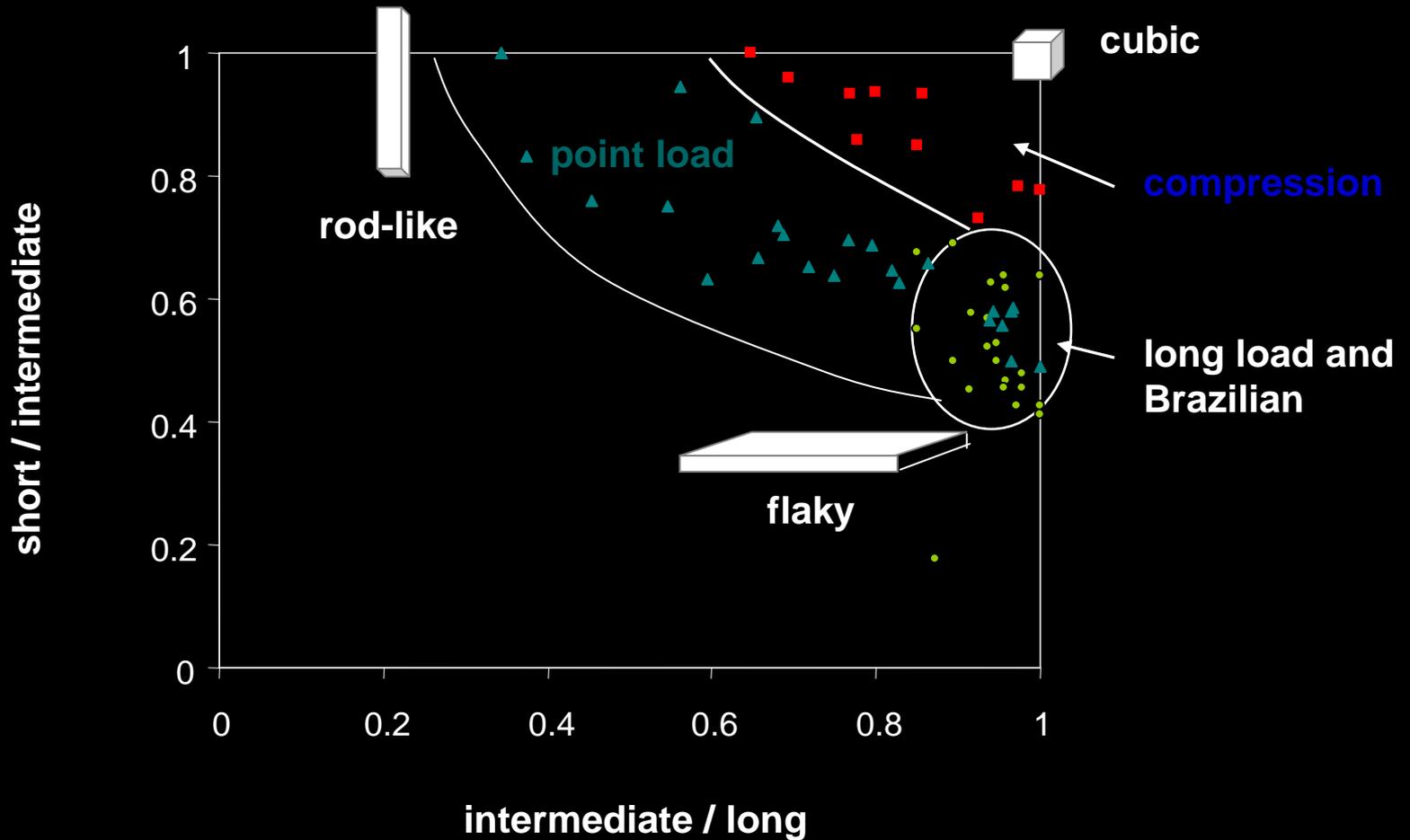
compression



Fines Generation



Shape: Cubicity



Crushing Mode: Shape and Fines

point load



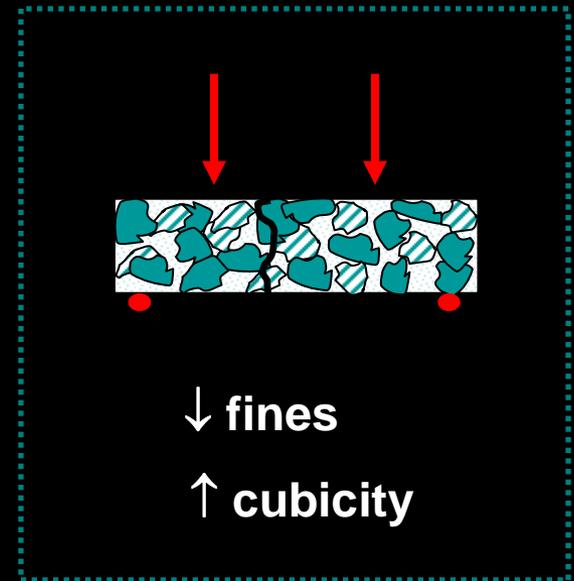
↓ fines
↓ cubicity

compression



↑ fines
↑ cubicity

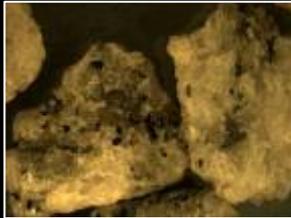
4-point load



↓ fines
↑ cubicity

Particle Shape - Microphotographs

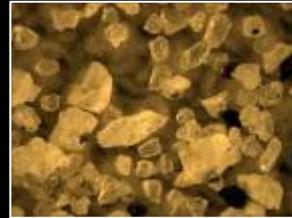
**Crushed
Granite**



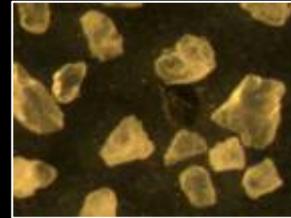
Sieve 4



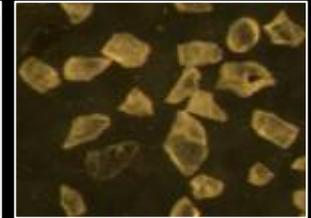
Sieve 16



Sieve 50



Sieve 100



Sieve 200

**Crushed
Limestone**



Sieve 4



Sieve 16



Sieve 50



Sieve 100



Sieve 200

**GDOT
Standard
Natural
Sand**



Sieve 4



Sieve 16



Sieve 50

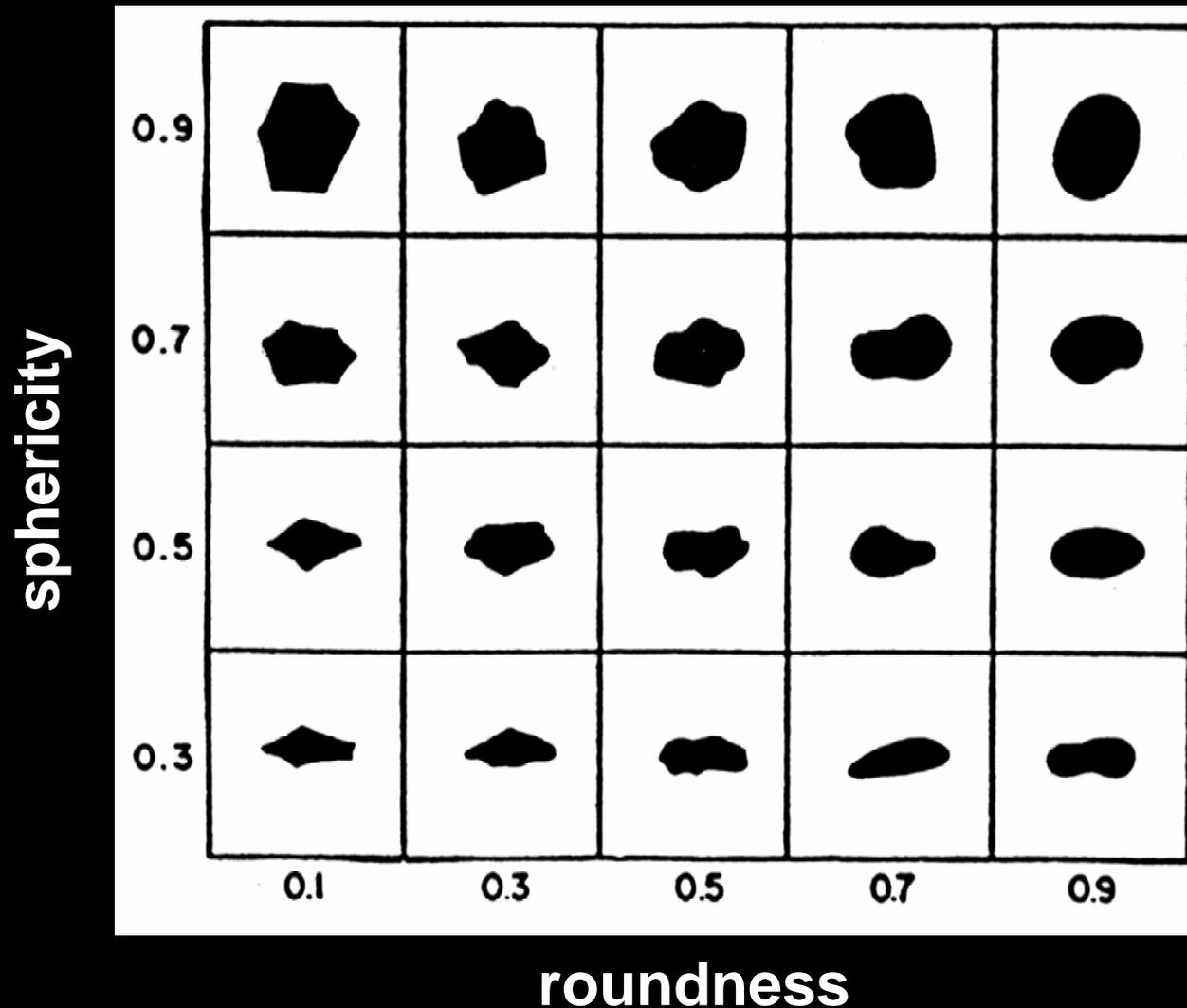


Sieve 100

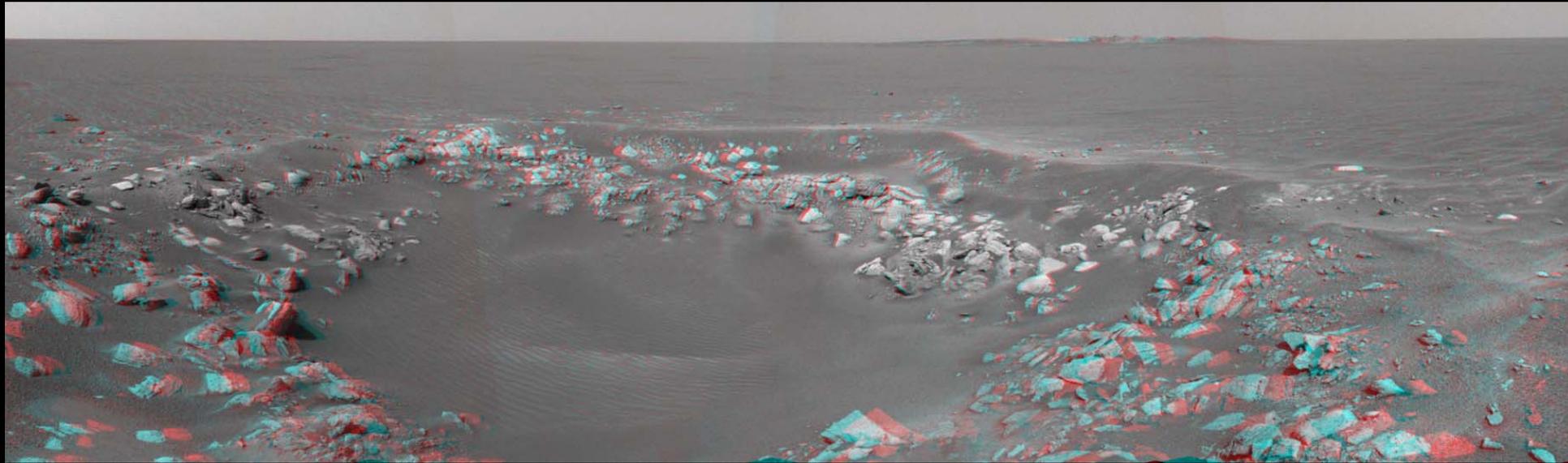


Sieve 200

Particle Shape: See & Match



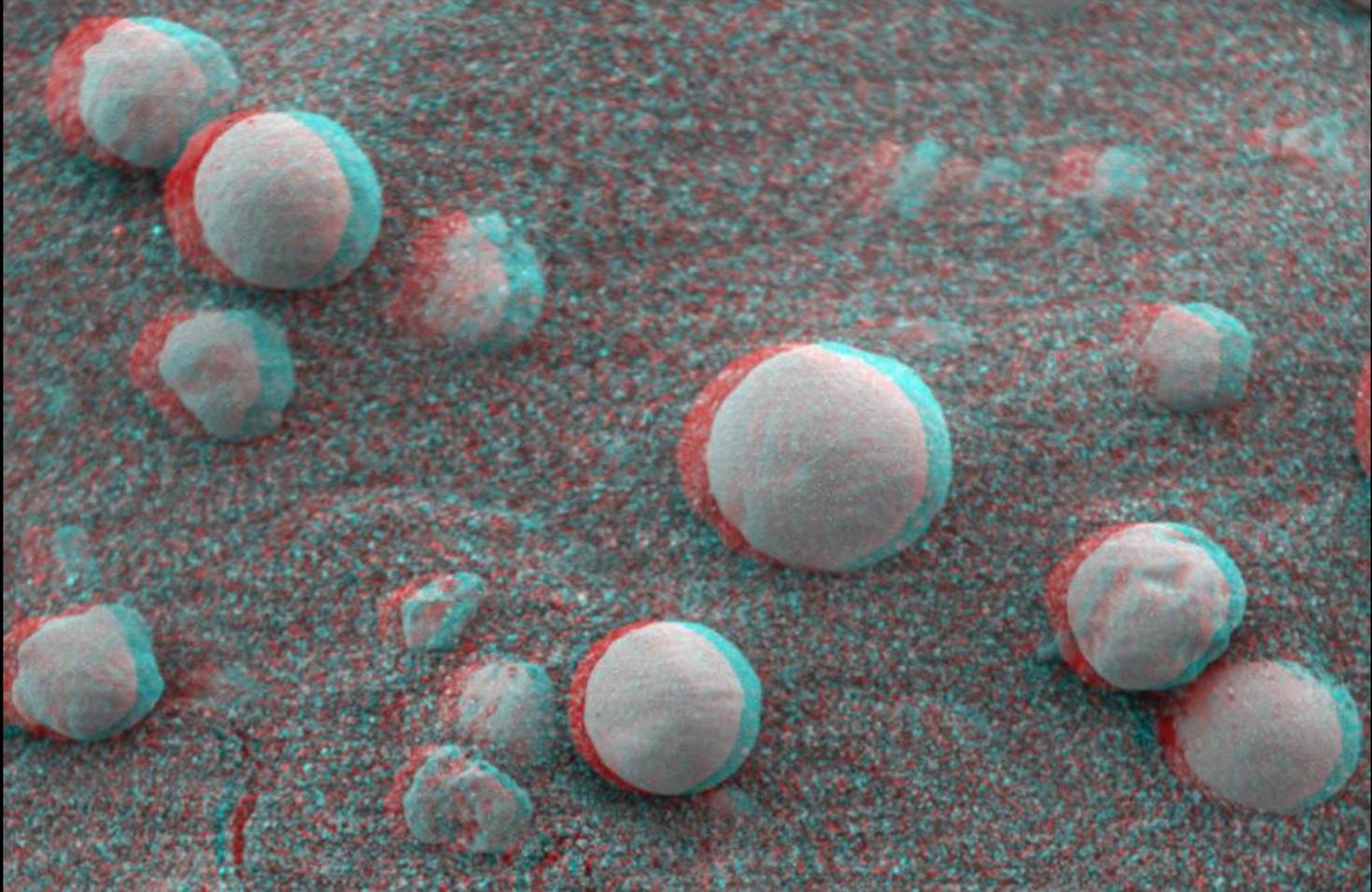
Crater on Mars (April 21, 2004)



red on left

NASA/JPL

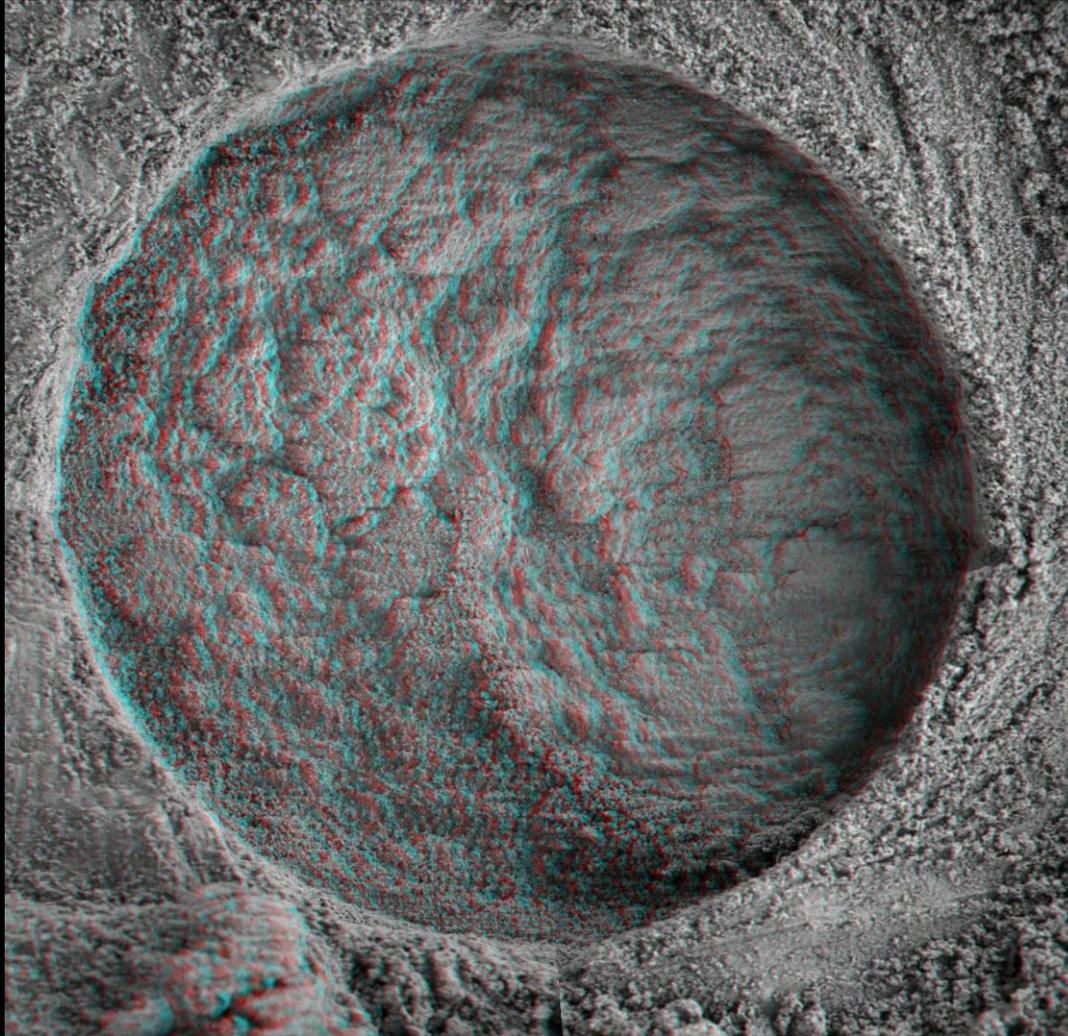
"Berries" on Mars (February 12, 2004)



red on left

NASA/JPL

Core – Martian Rock (August 18, 2004)



red on left

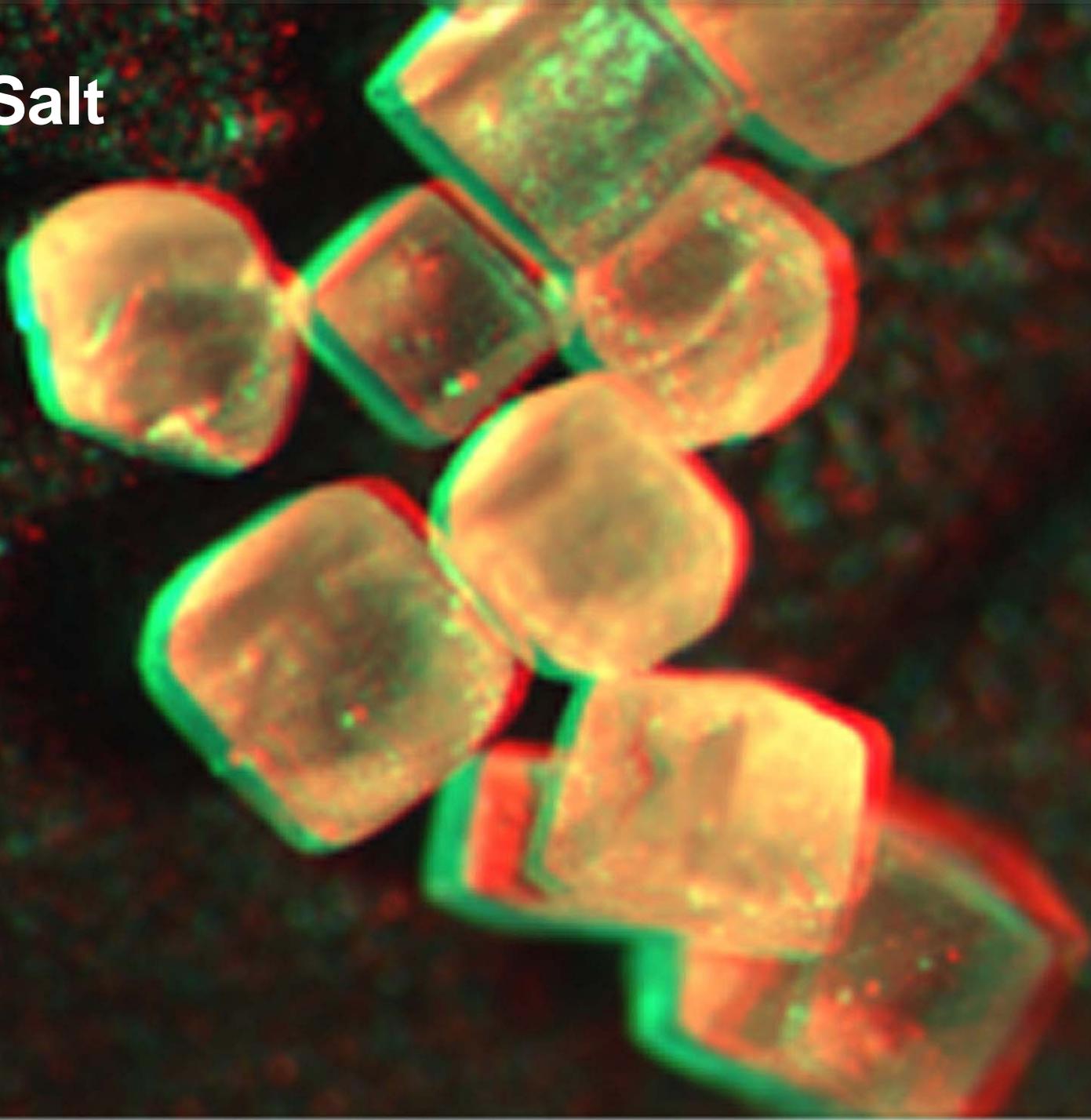
Rice



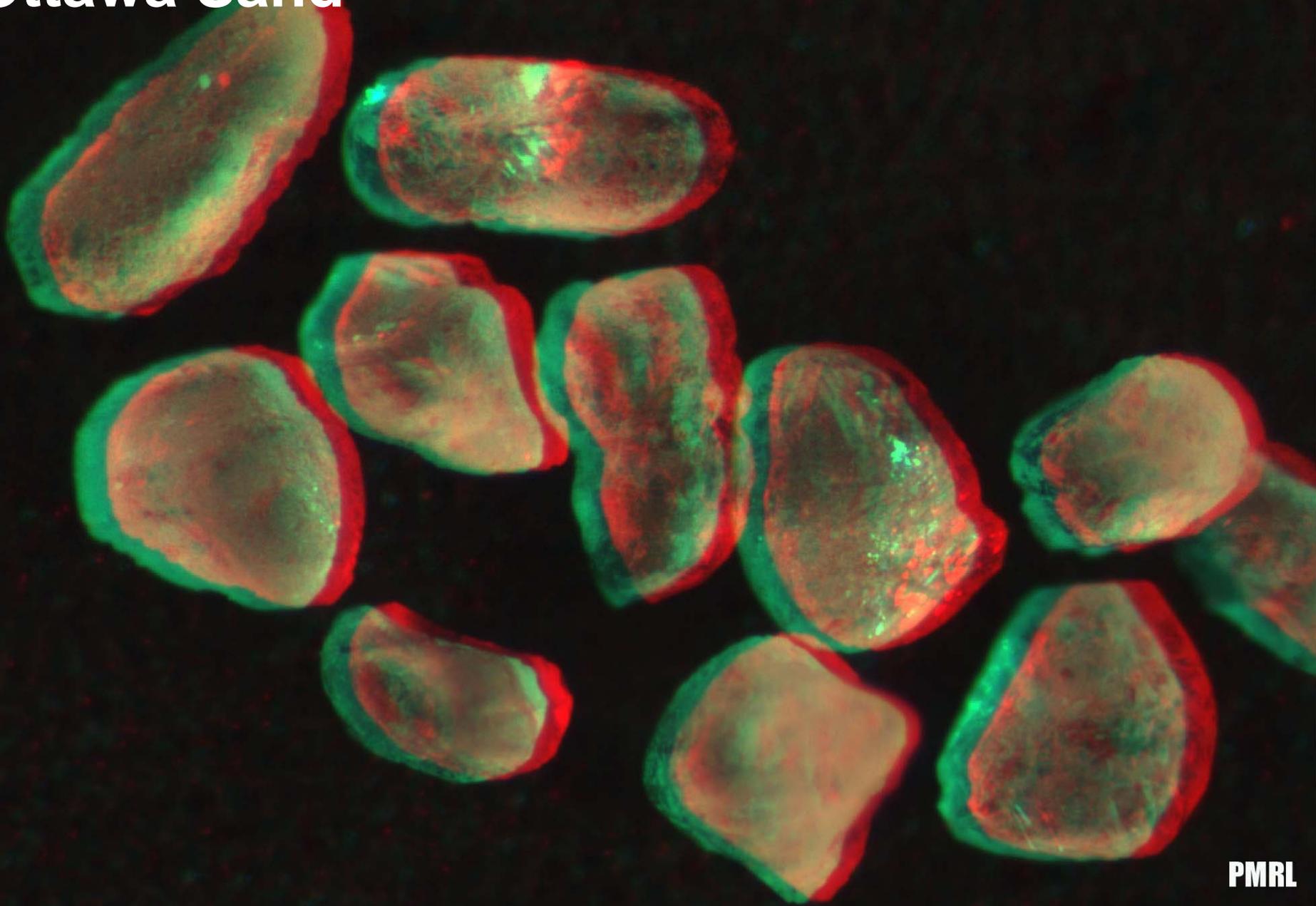
red on right

PMRL

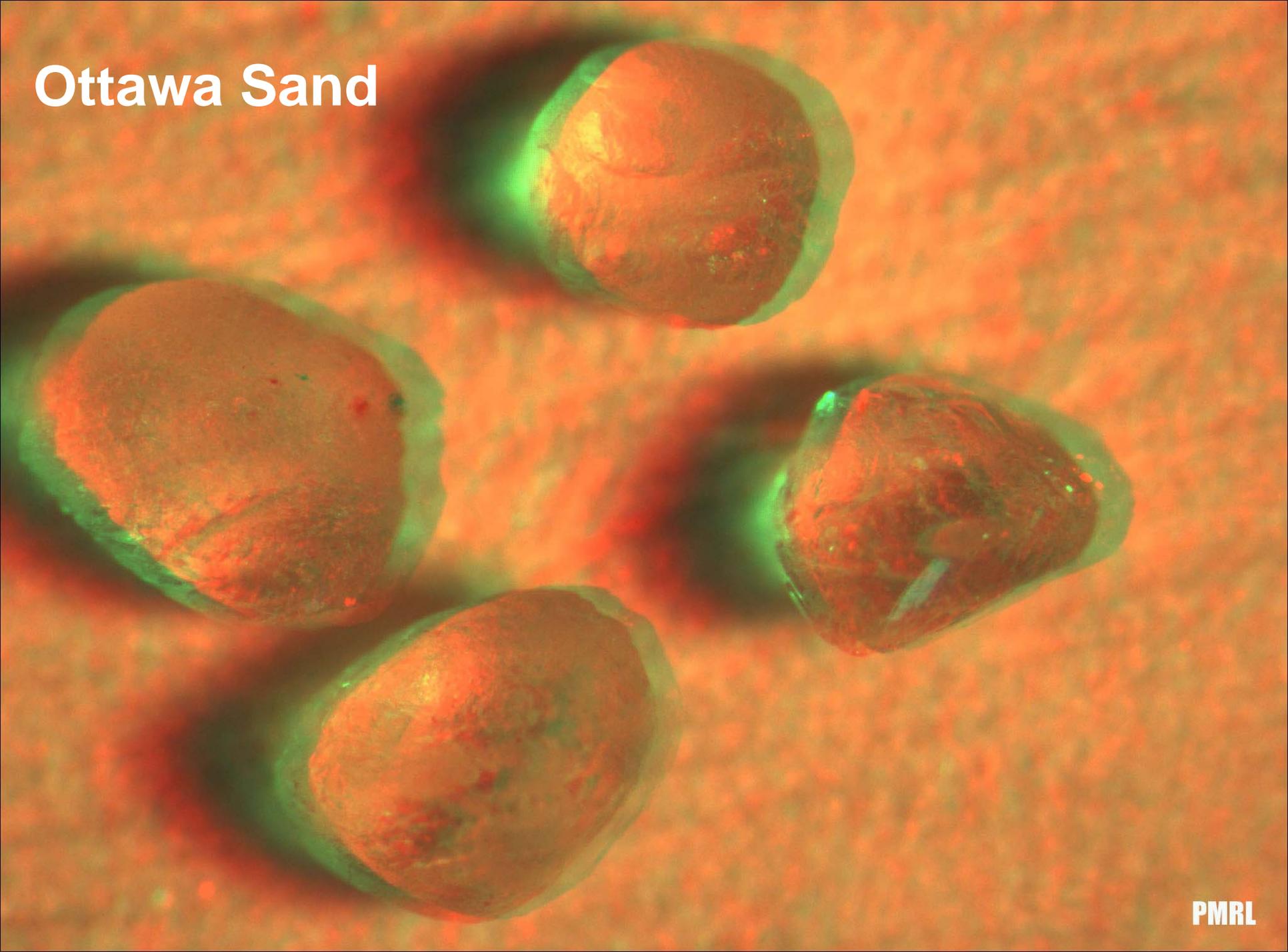
Table Salt



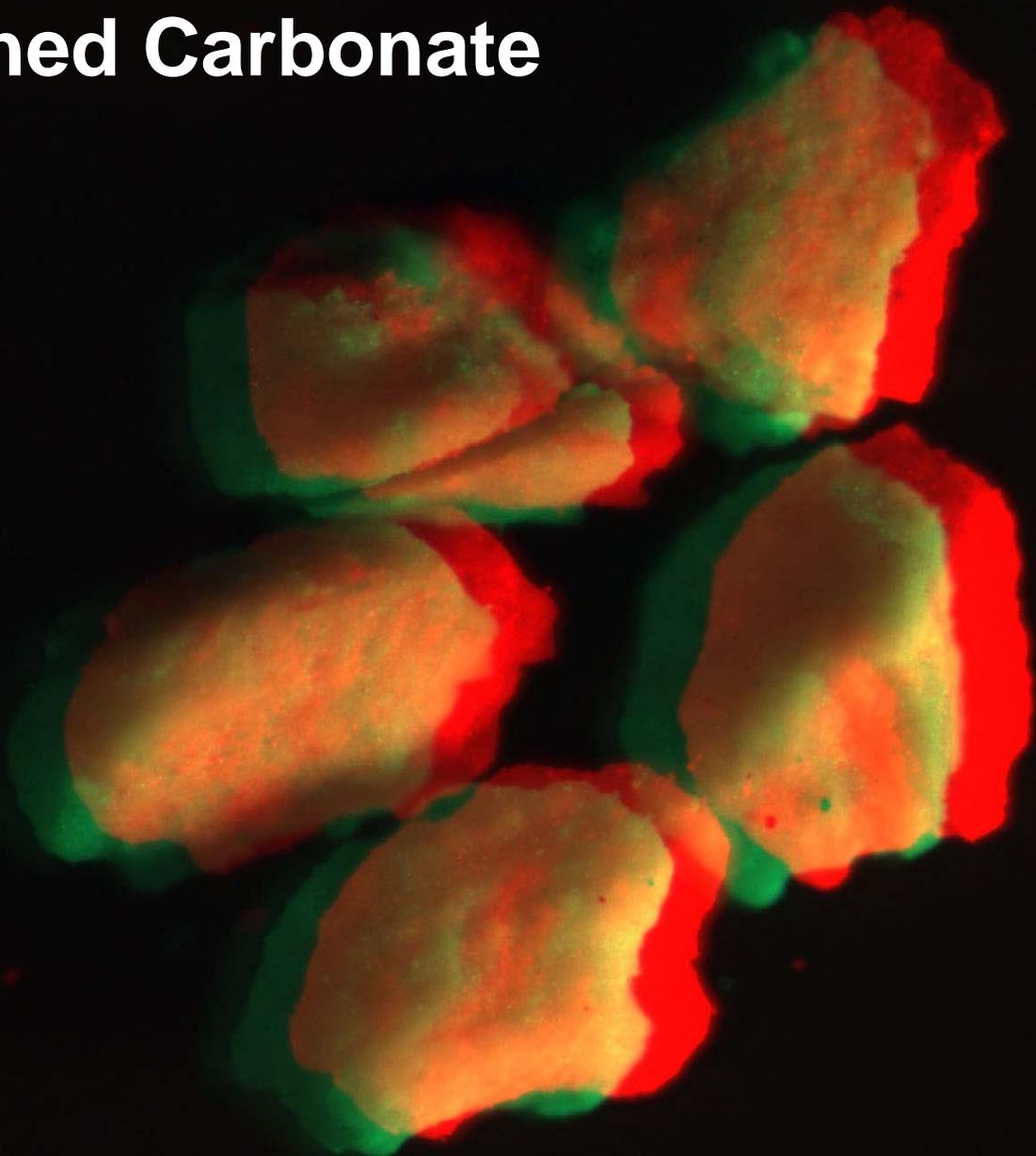
Ottawa Sand



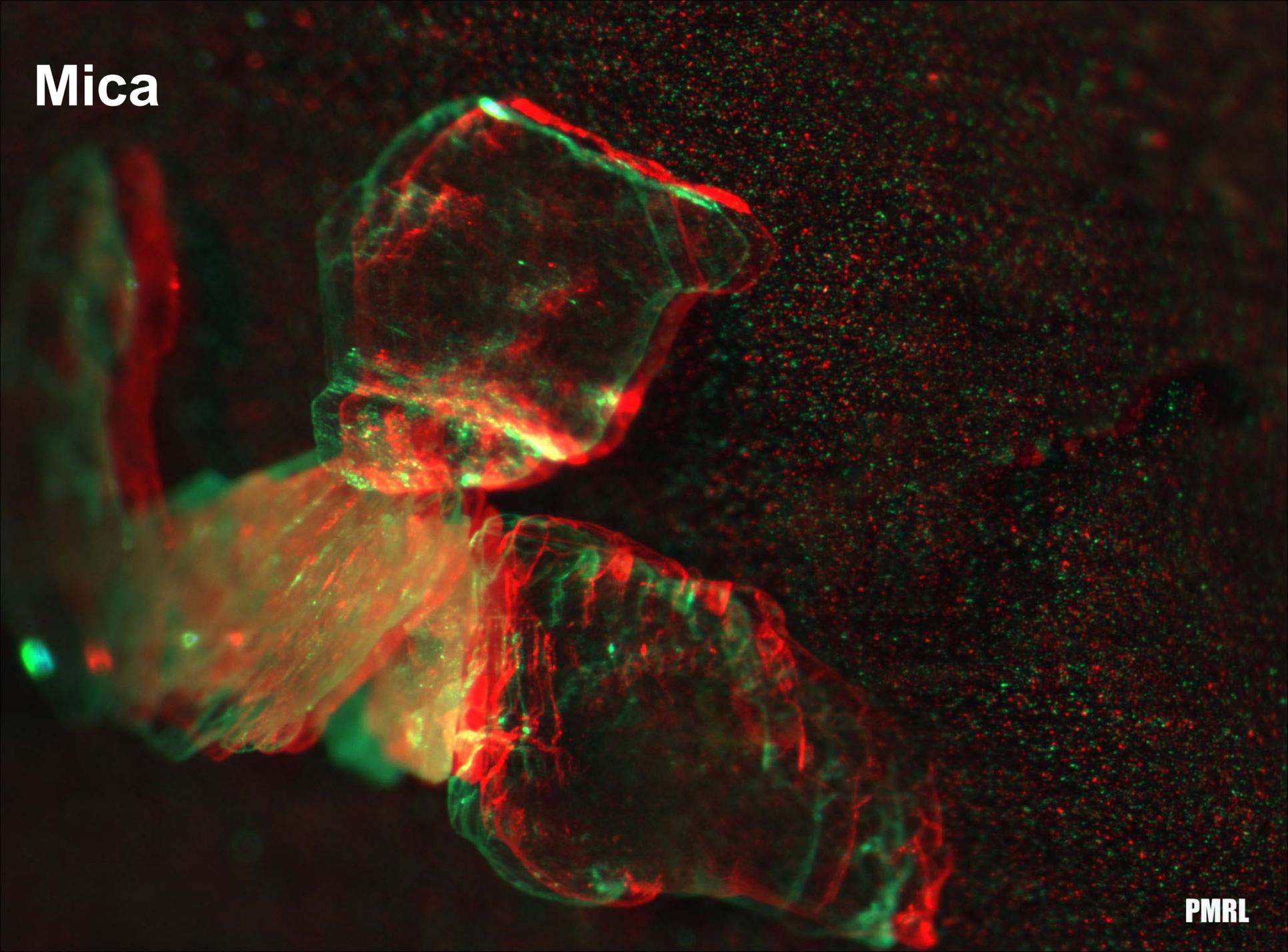
Ottawa Sand



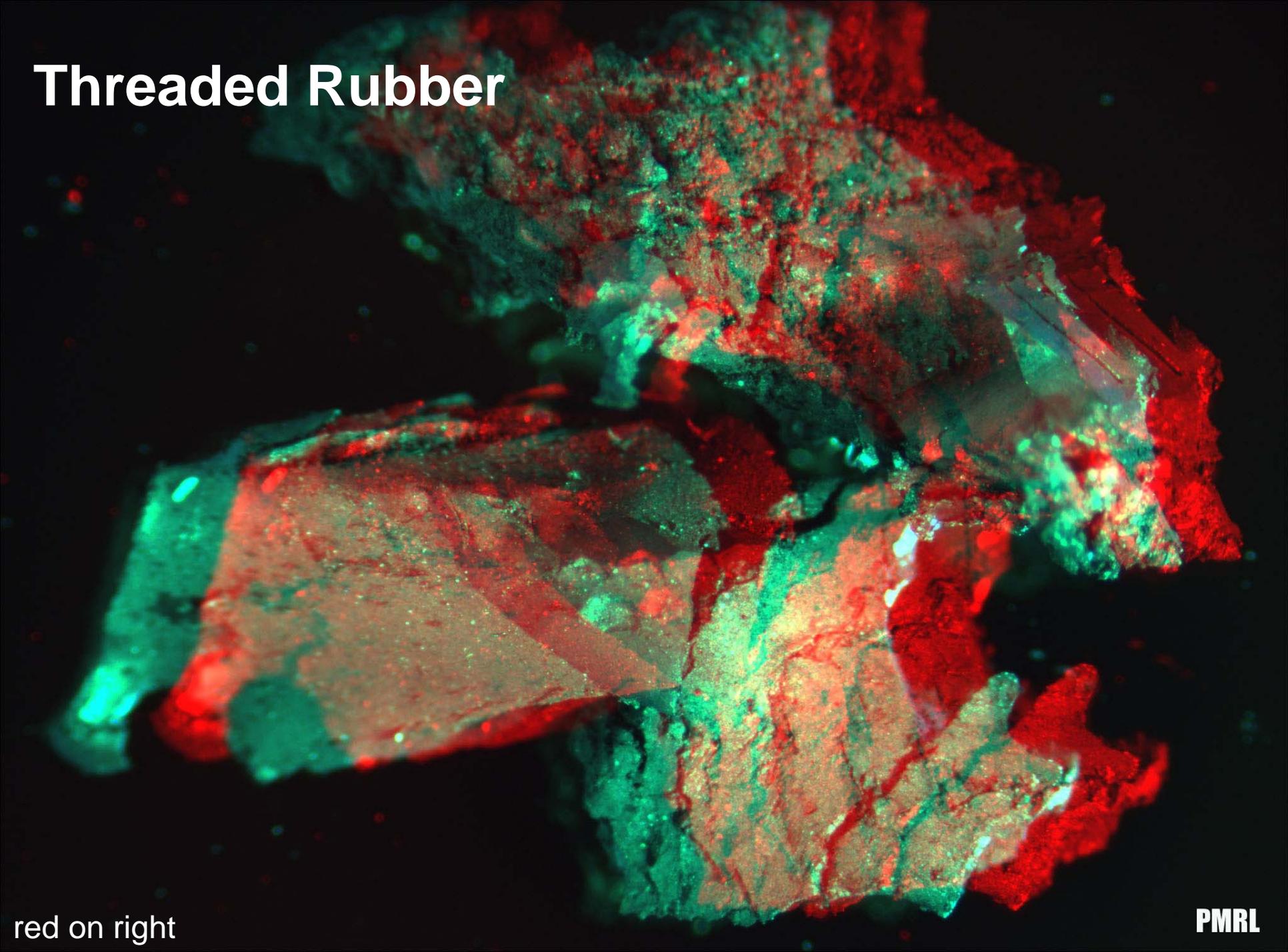
Crushed Carbonate



Mica



Threaded Rubber



red on right

Particle size

Particle shape / crushing

e_{\min} e_{\max}

Friction angle

Flow test

Strength

P-wave velocity

Thermal properties

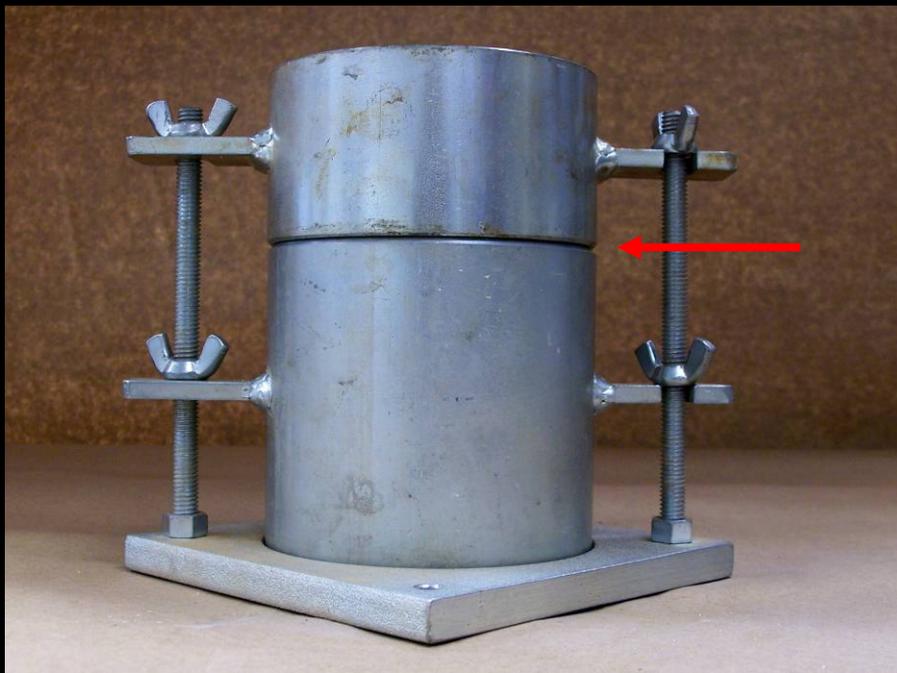
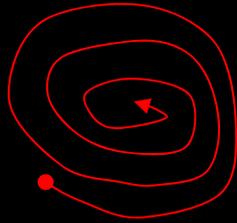
Volumetric – Gravimetric Relations

$$\rho = \frac{M}{V}$$

$$e = \frac{V_v}{V_s} = \frac{n}{1-n}$$

$$\rho_{dry} = \frac{M_s}{V_T} = \frac{G_s \cdot \rho_w}{1+e}$$

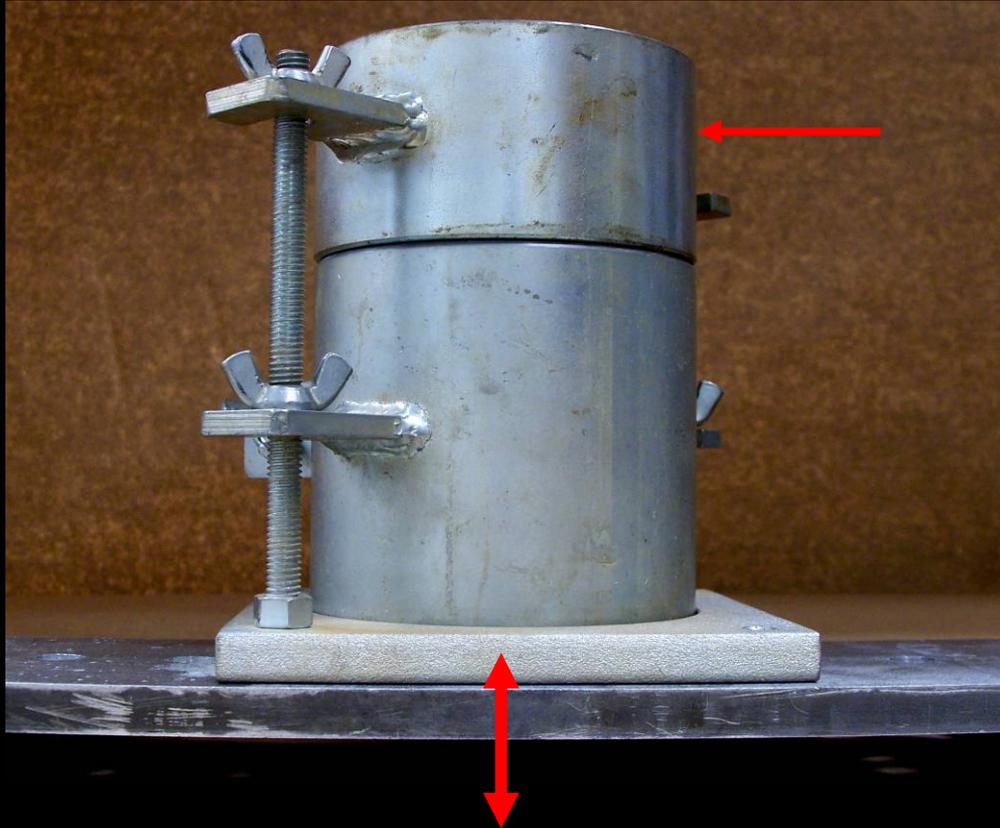
e_{\max}



$$\rho_{d \min} = \frac{M_s}{V}$$

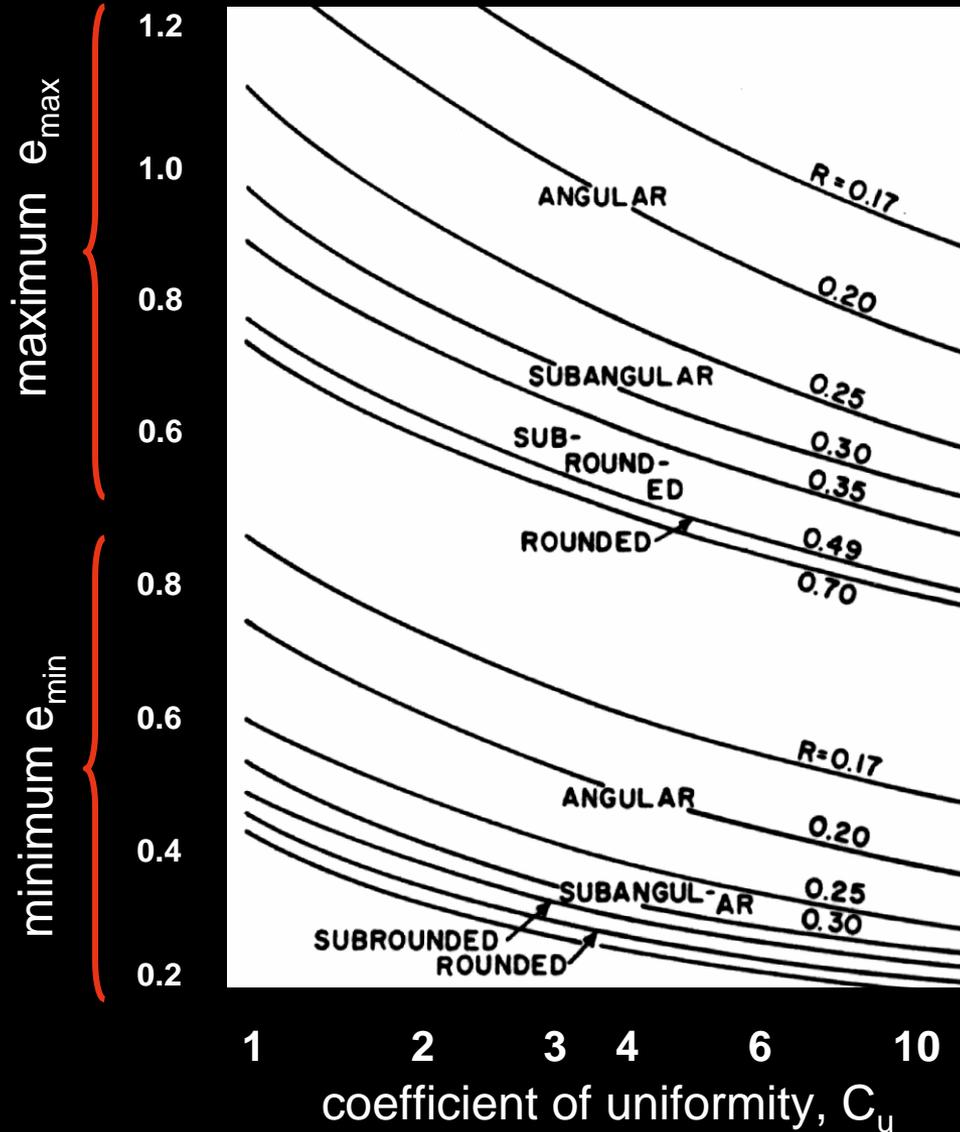
$$e_{\max} = \frac{\rho_w G_s}{\rho_{d \min}} - 1$$

e_{\min}



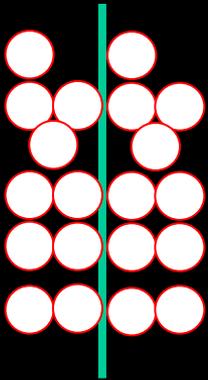
$$\rho_{d \max} = \frac{M_s}{V}$$
$$e_{\min} = \frac{\rho_w G_s}{\rho_{d \max}} - 1$$

Size and Shape → Packing Density

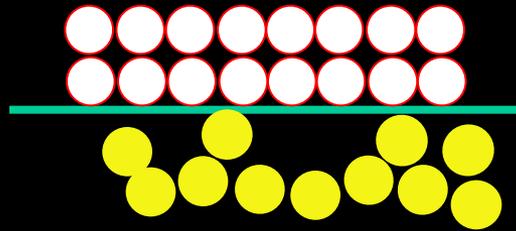


Mica: bridging & ordering

ordering

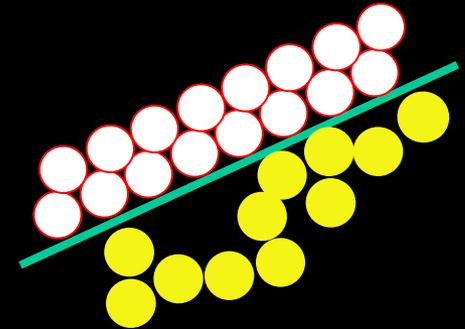


ordering



bridging

ordering



bridging

Particle size

Particle shape / crushing

e_{\min} , e_{\max}

Friction angle

Flow test

Strength

P-wave velocity

Thermal properties

Slope Stability



Slope Stability

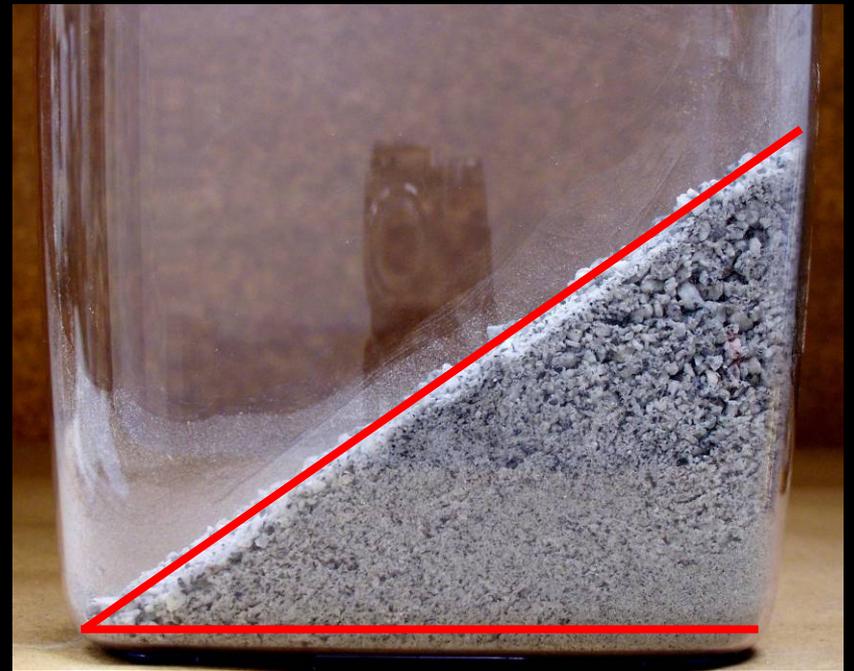


Boullanger

Friction Angle in Sands: Simple !

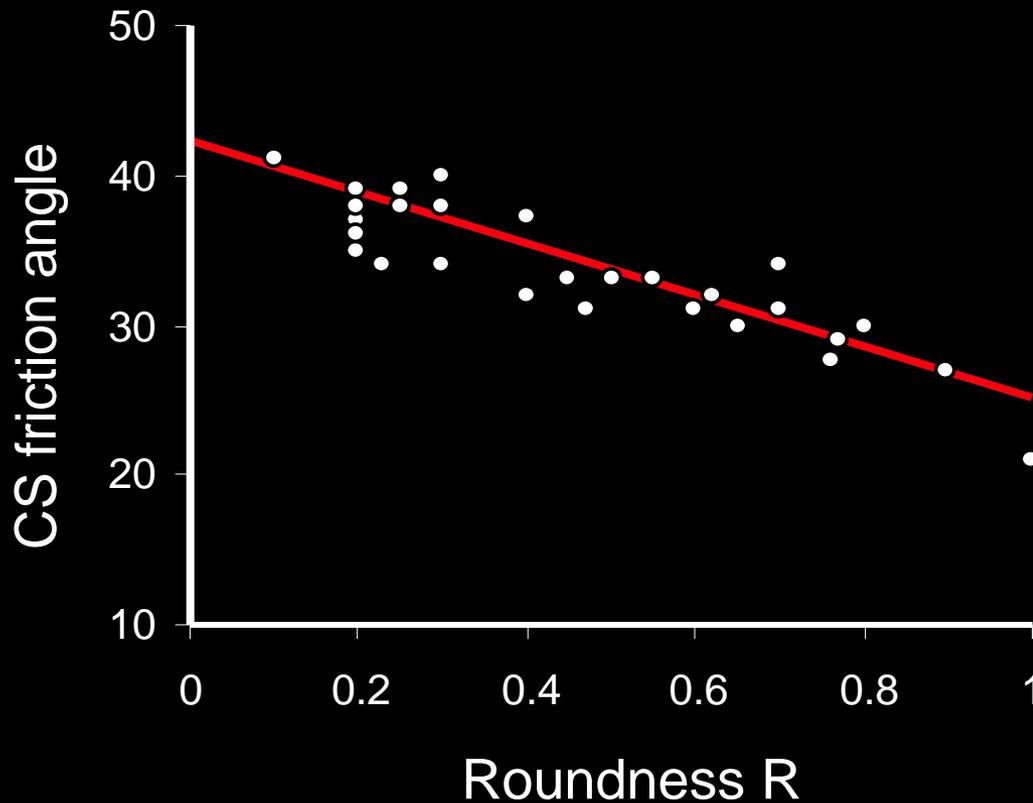
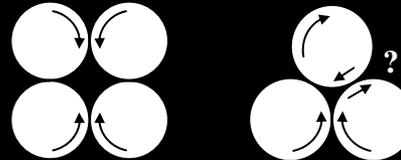


Measure the Angle of Repose



Why Friction Angle?

rotational frustration



$$\phi_{cv} = 42 - 17 \cdot R$$

Particle size

Particle shape / crushing

e_{\min} , e_{\max}

Friction angle

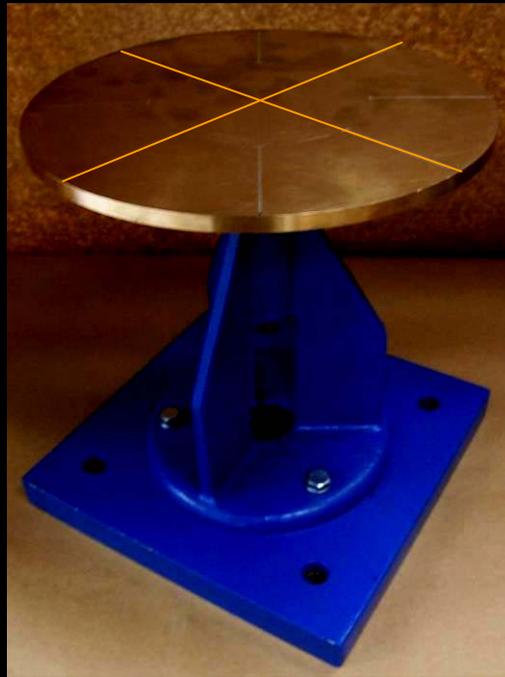
Flow test

Strength

P-wave velocity

Thermal properties

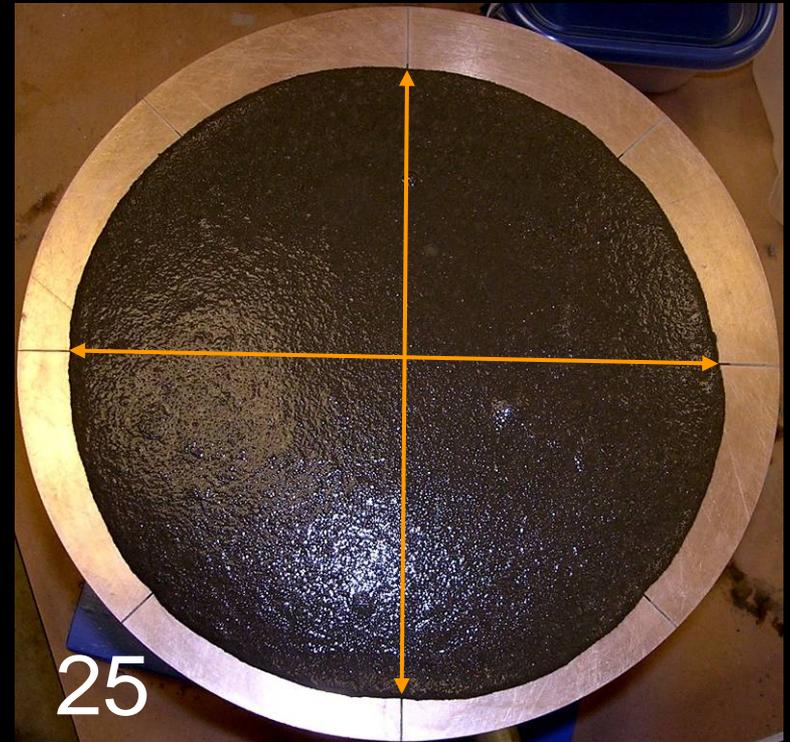
Flow Test: Devices



Flow Test: Procedure



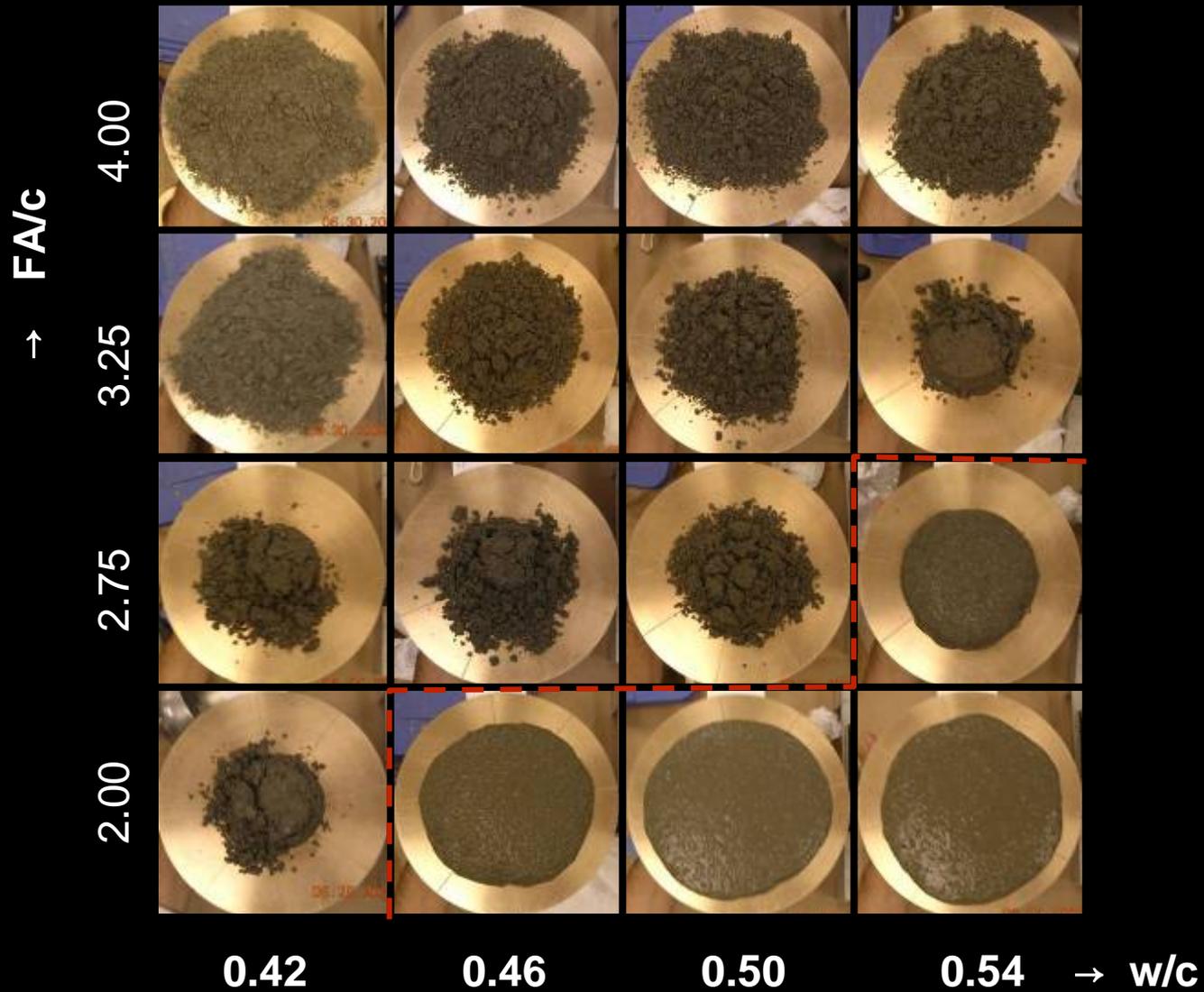
Flow Test: Evolution and Analysis



$$F = \frac{D - D_0}{D_0} \times 100[\%]$$

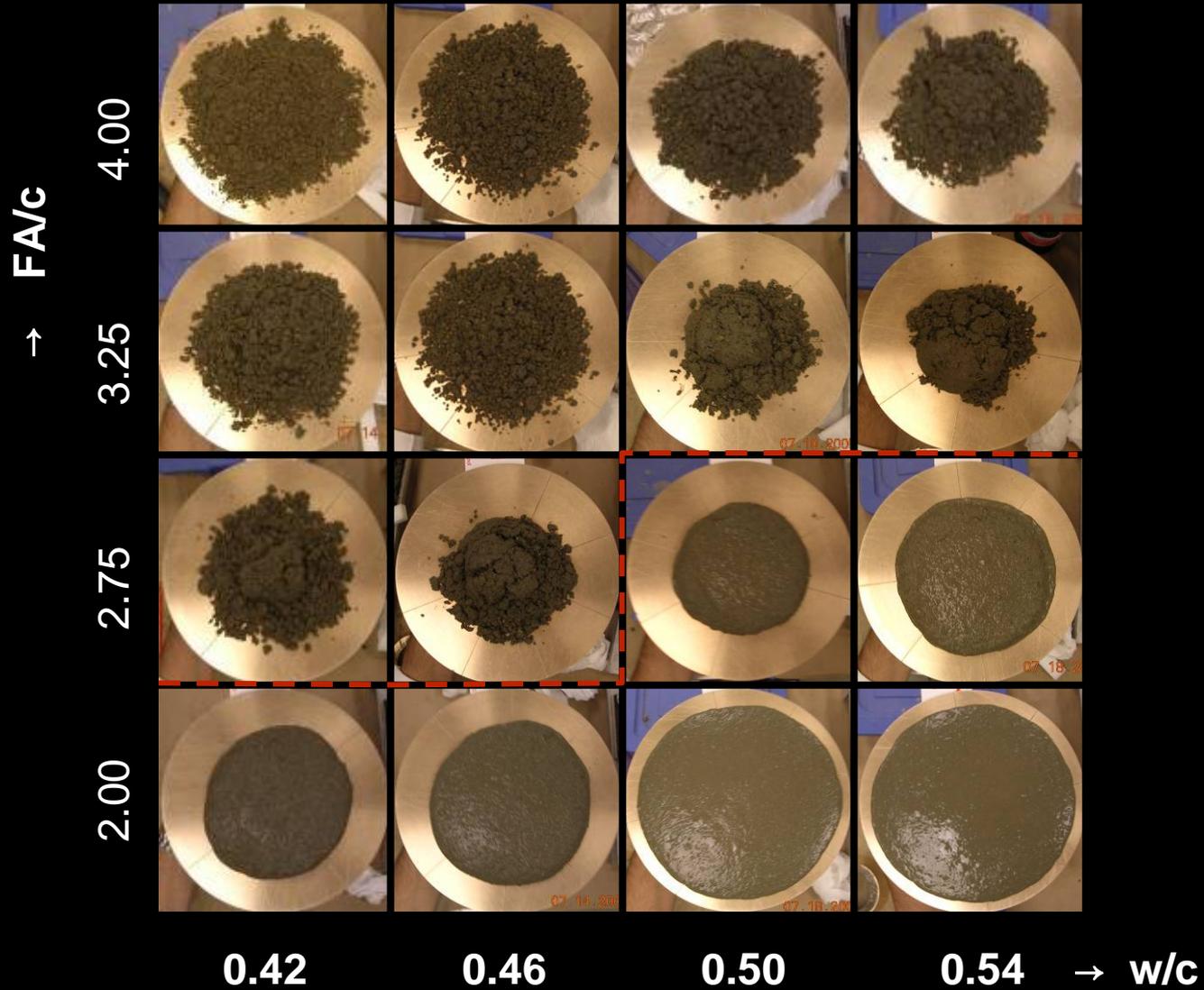
"Wetness"

Crushed granite type III

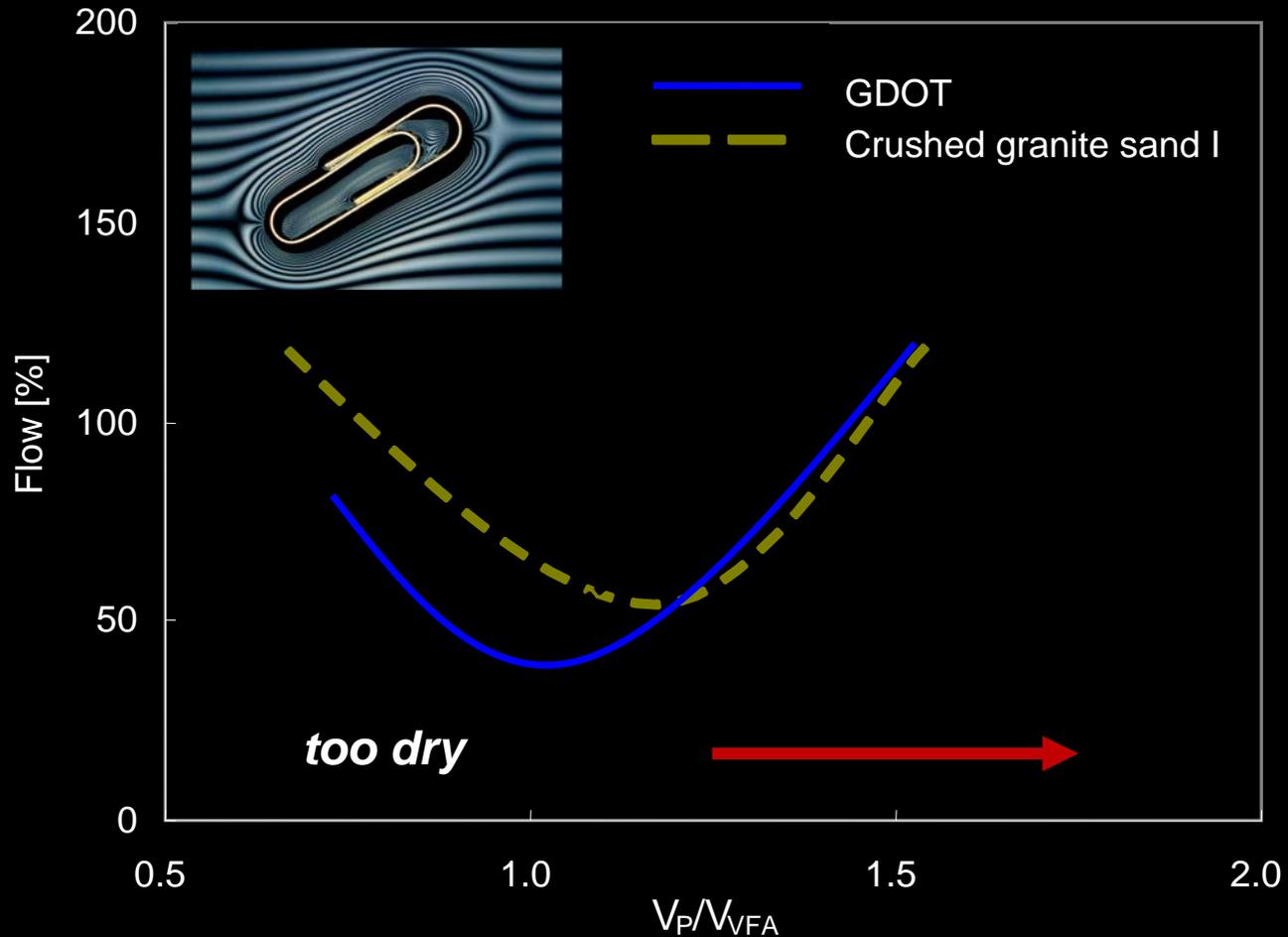


"Wetness"

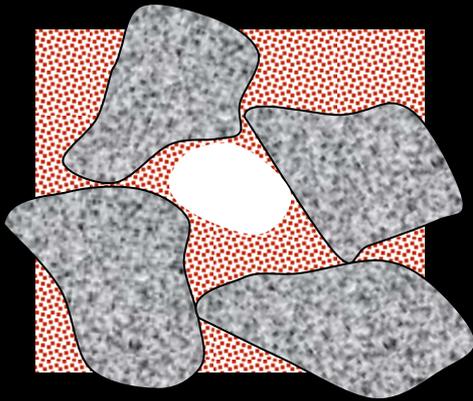
GDOT standard natural sand



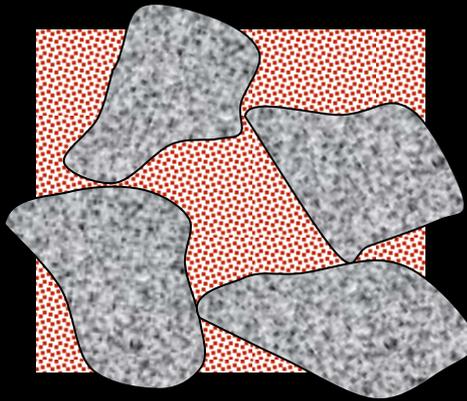
Increase Flow? **Add More Paste**



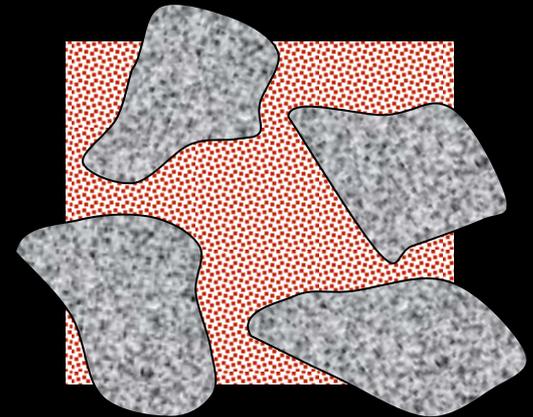
How Much Paste? $V_{\text{Paste}} / V_{\text{VFA}}$



$$V_{\text{Paste}} / V_{\text{VFA}} < 1.0$$



$$V_{\text{Paste}} / V_{\text{VFA}} \sim 1.0$$



$$V_{\text{Paste}} / V_{\text{VFA}} > 1.0$$

controlled by e_{max}

$$\frac{V_P}{V_{\text{VFA}}} = \frac{G_{\text{FA}} \left(\frac{1}{G_C} + \frac{W}{C} \right)}{e_{\text{max}} \left(\frac{\text{FA}}{C} \right)}$$

Particle size

Particle shape / crushing

e_{\min} , e_{\max}

Friction angle

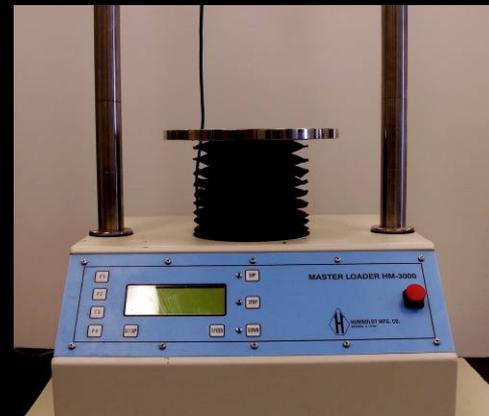
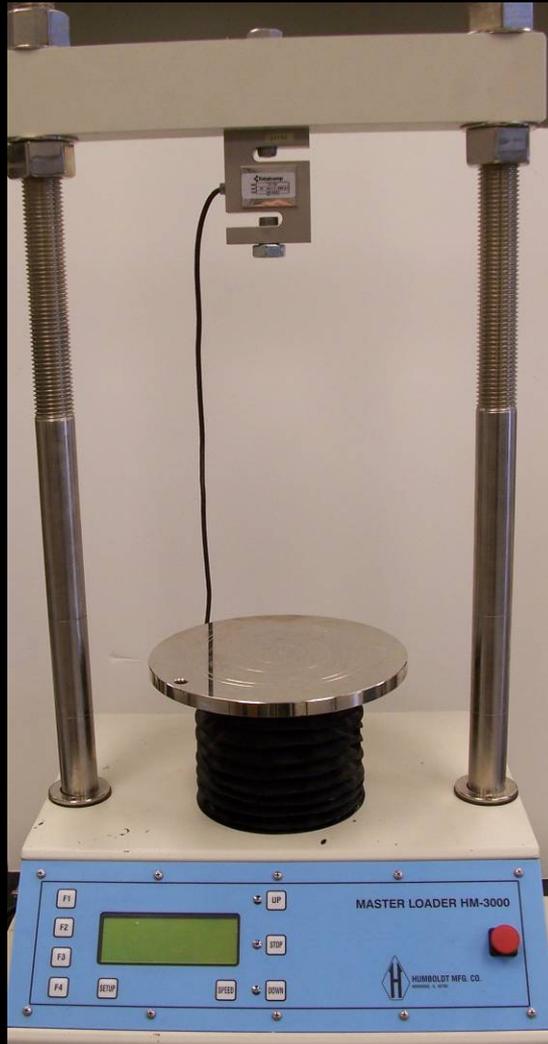
Flow test

Strength

P-wave velocity

Thermal properties

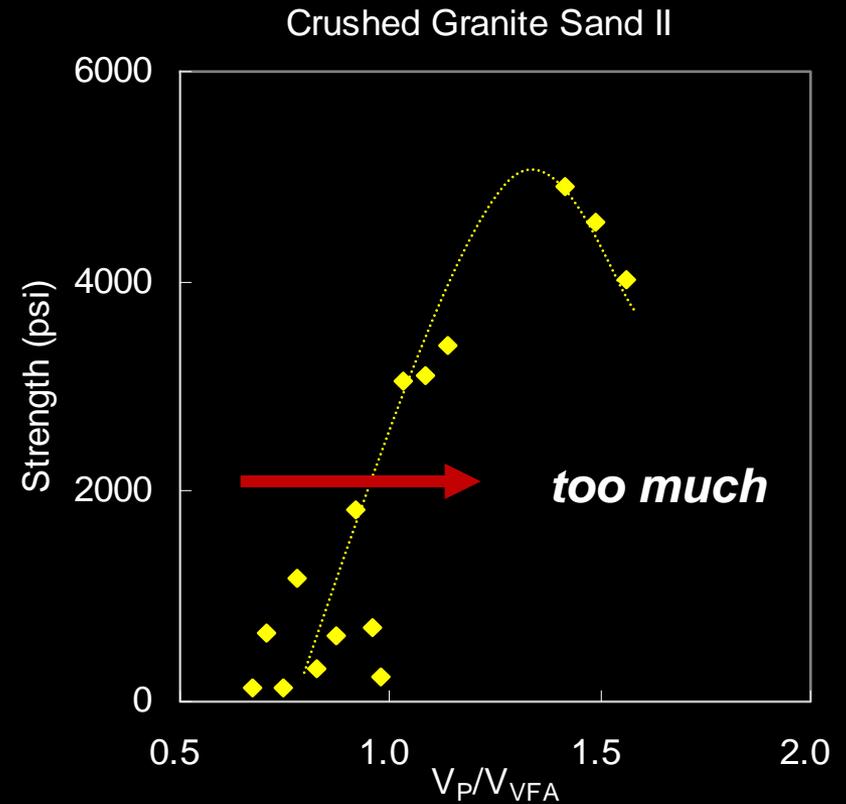
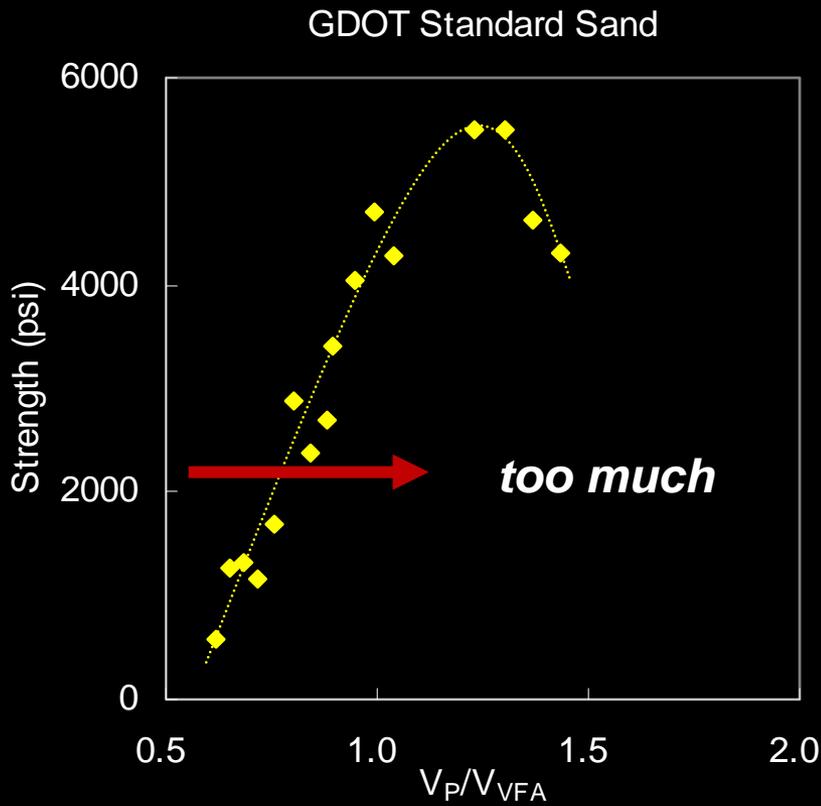
Strength – Compression Loading



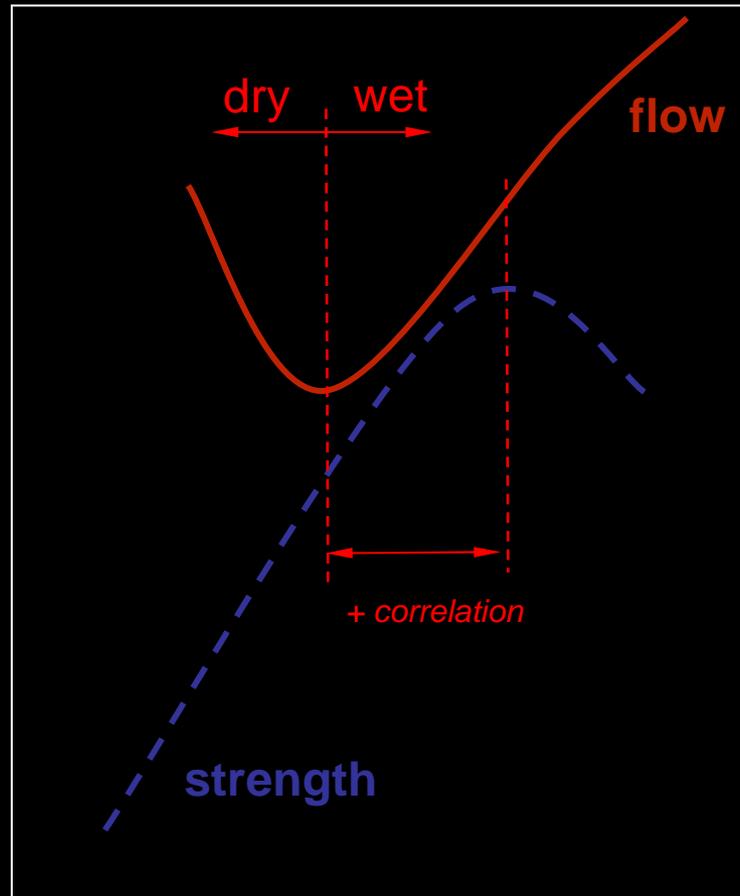
Before and After Crushing



Strength: Add Paste ... but not too much !



Strength and Flow



$$V_{\text{Paste}} / V_{\text{VFA}}$$

Particle size

Particle shape / crushing

e_{\min} , e_{\max}

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Strength

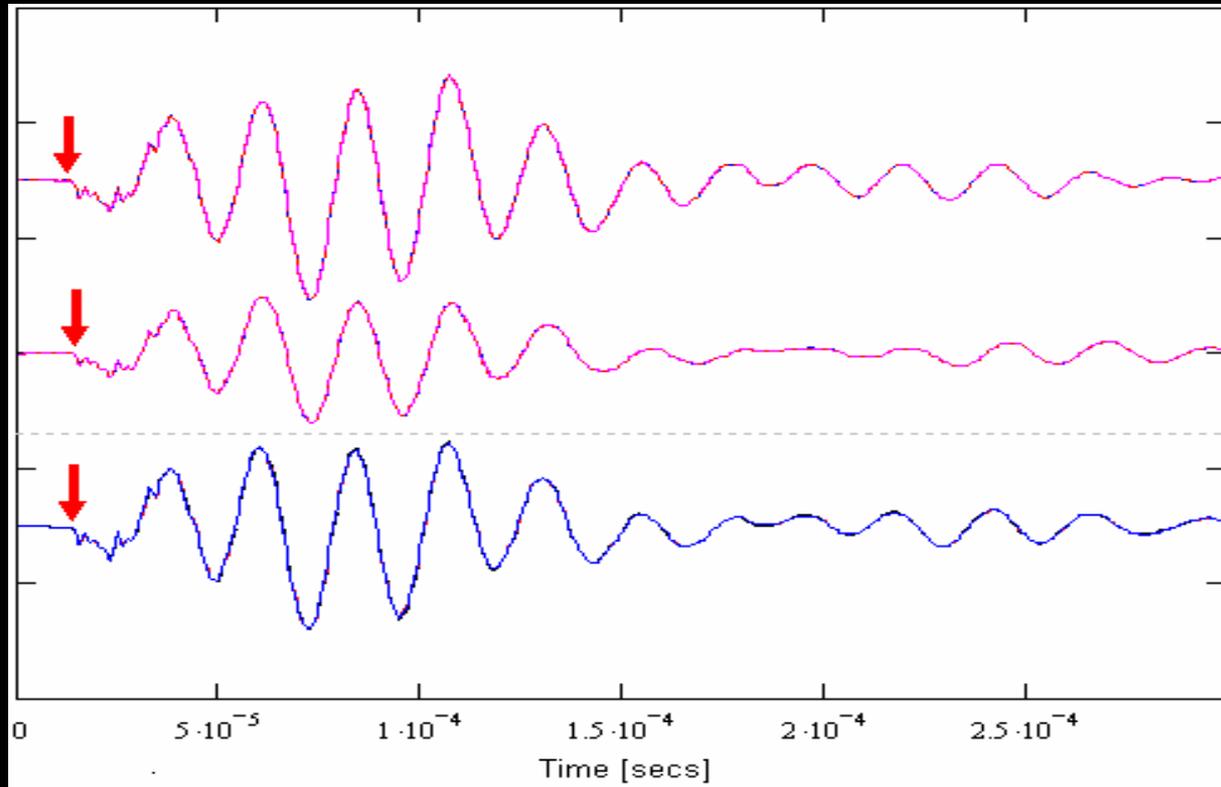
P-wave velocity

Thermal properties

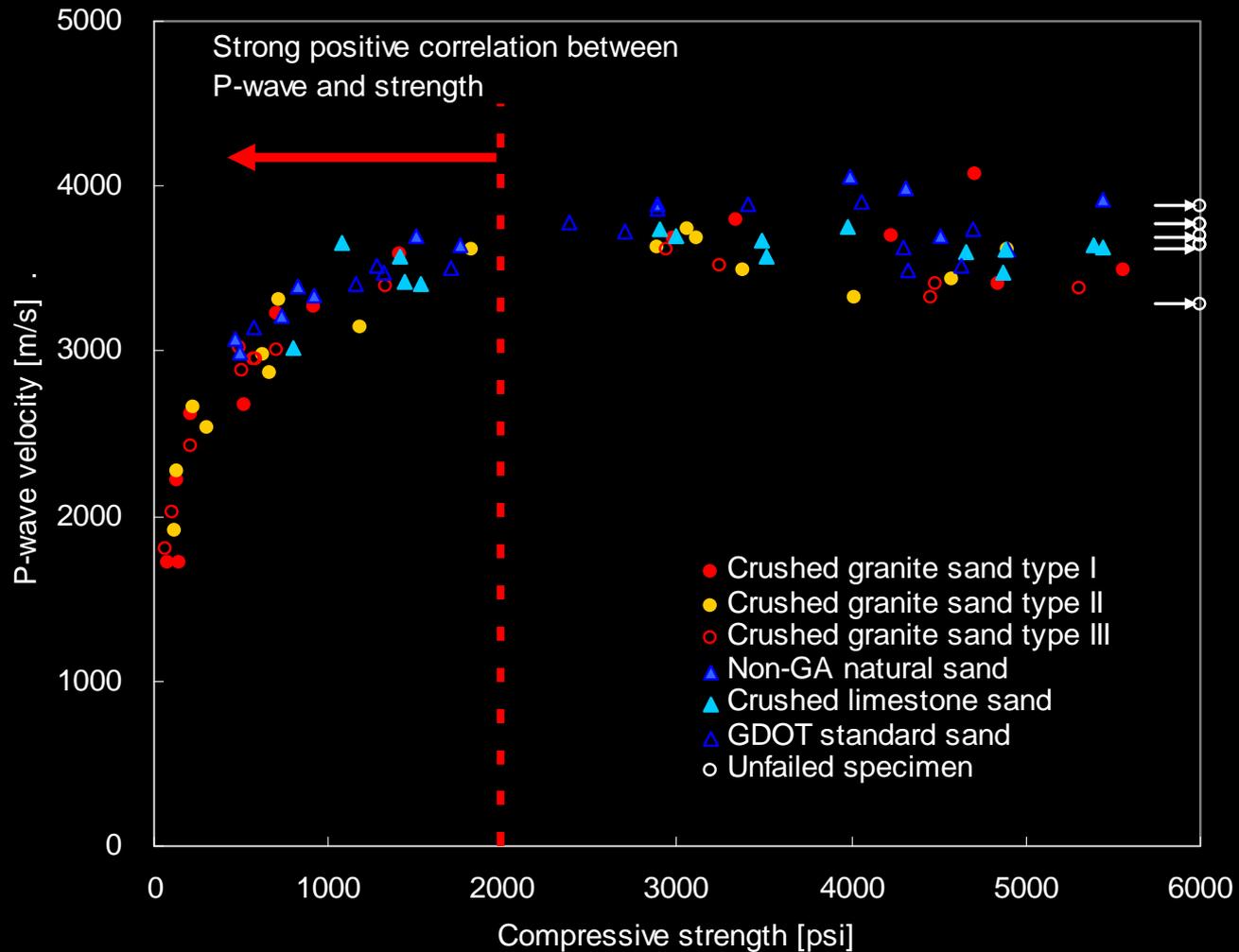
P-wave velocity



P-wave Signals



P-wave Velocity vs. Compressive Strength



Particle size

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Friction angle

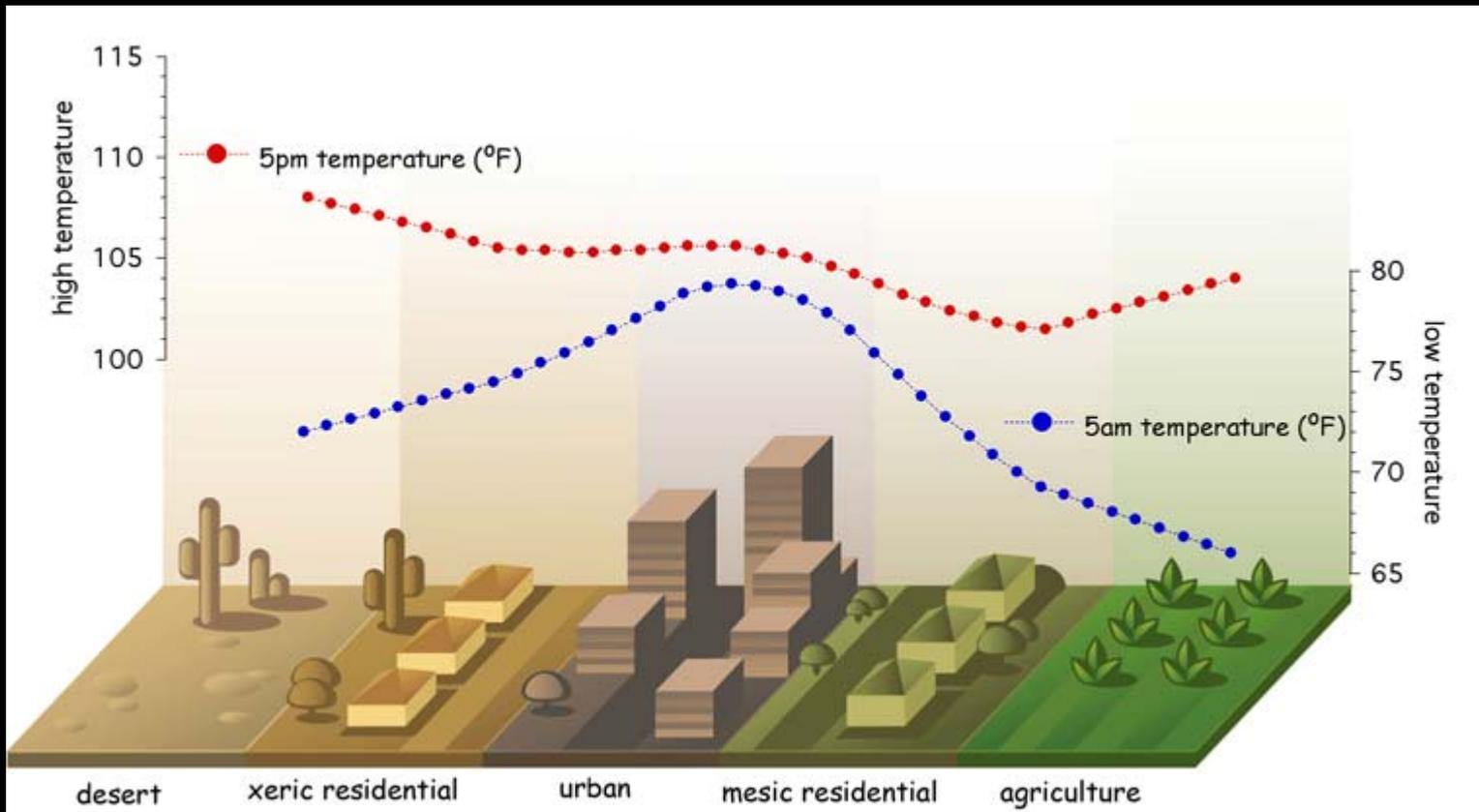
Flow test

Strength

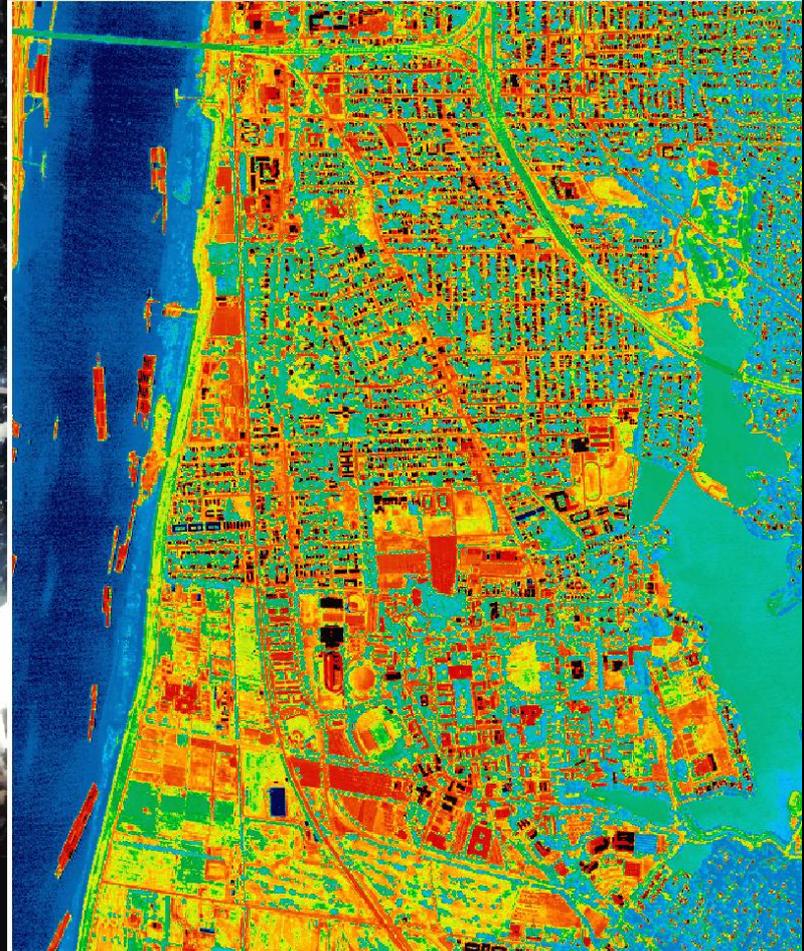
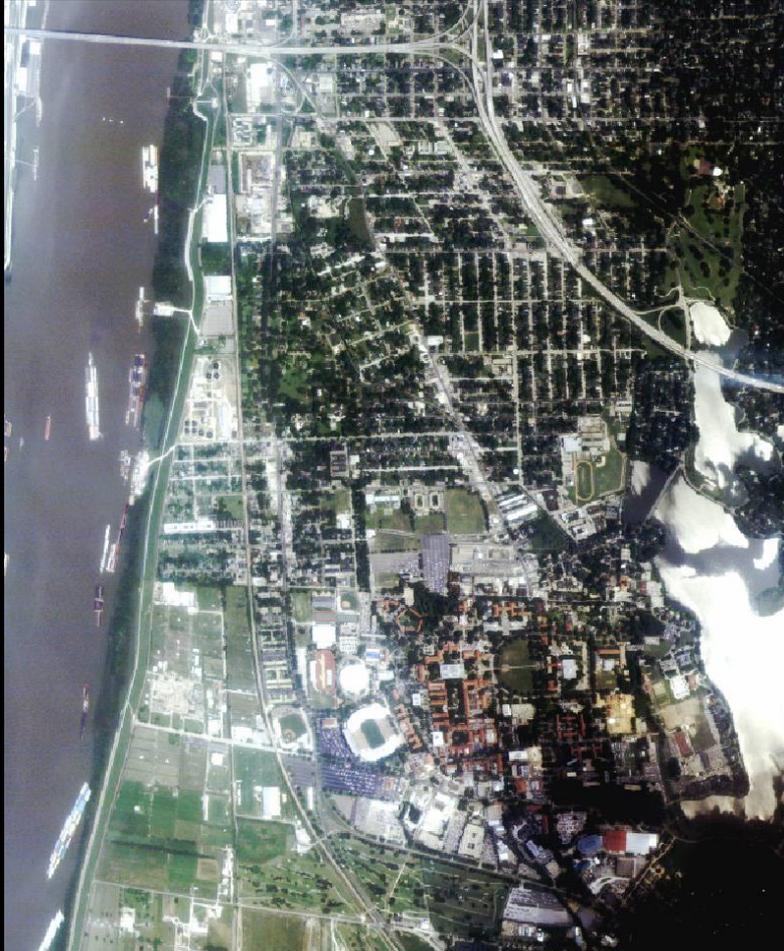
P-wave velocity

Thermal properties

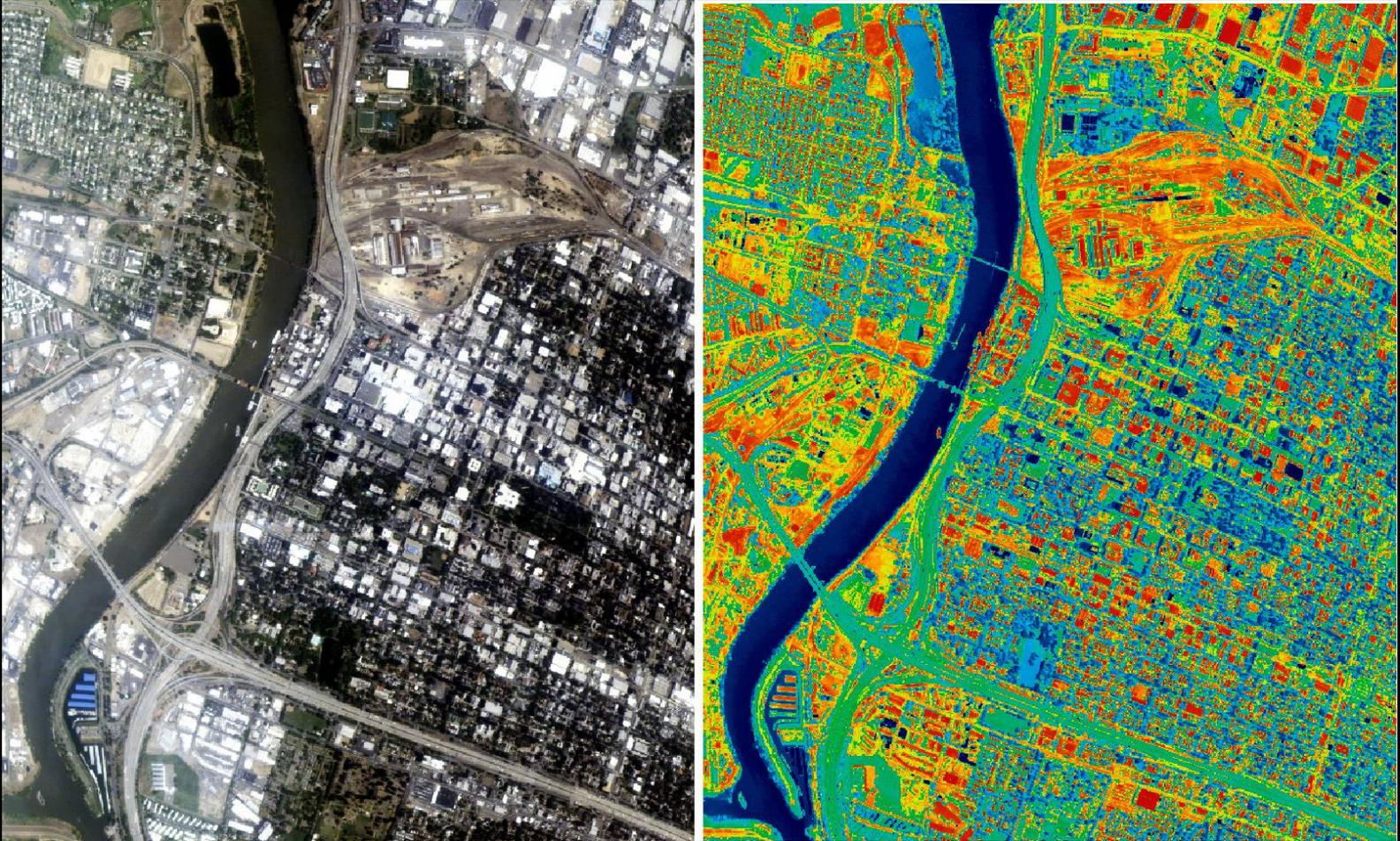
Cities = Thermal Islands



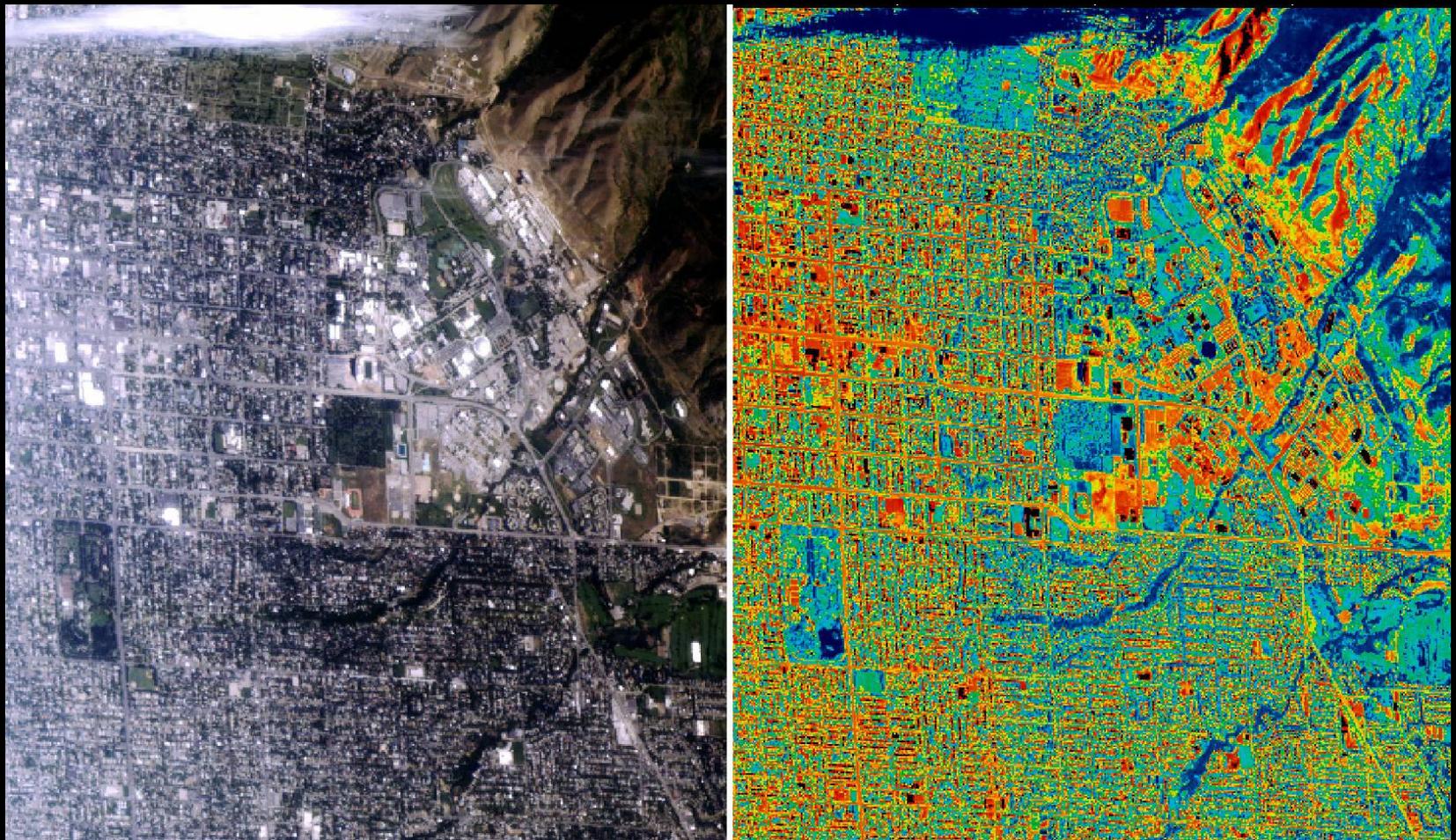
Baton Rouge, Louisiana



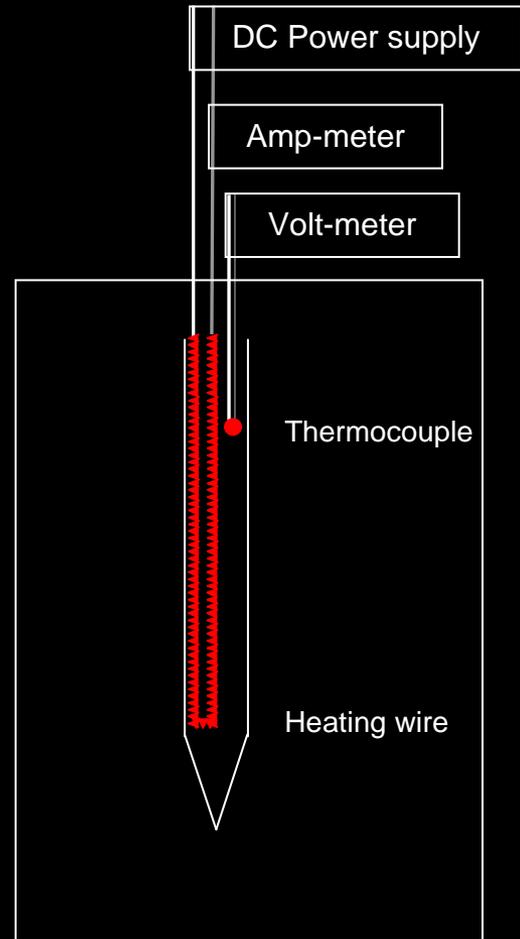
Sacramento, California



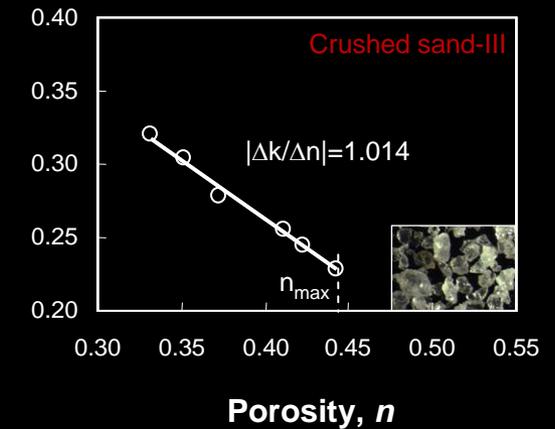
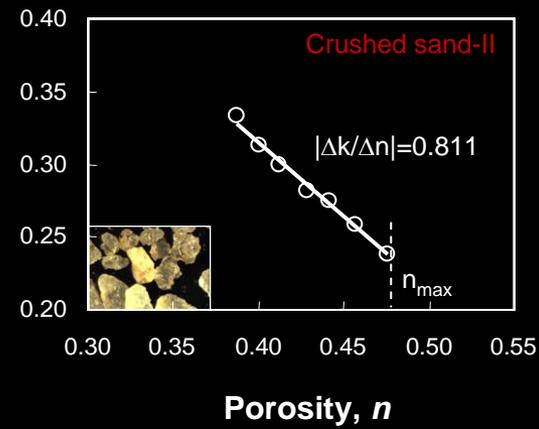
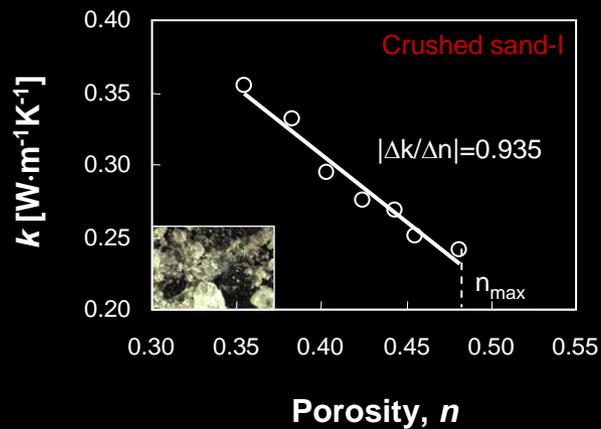
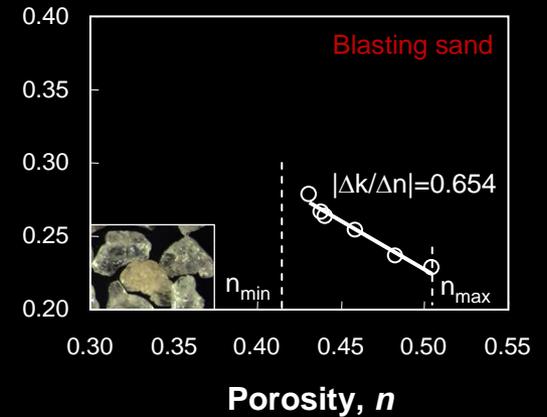
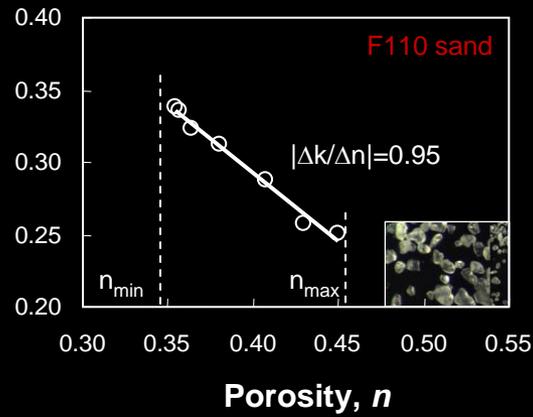
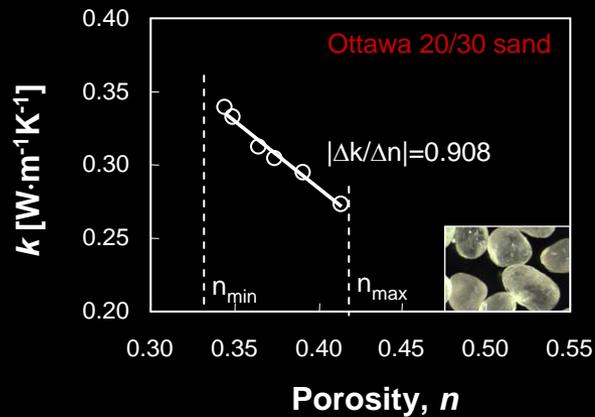
Salt lake City, Utah



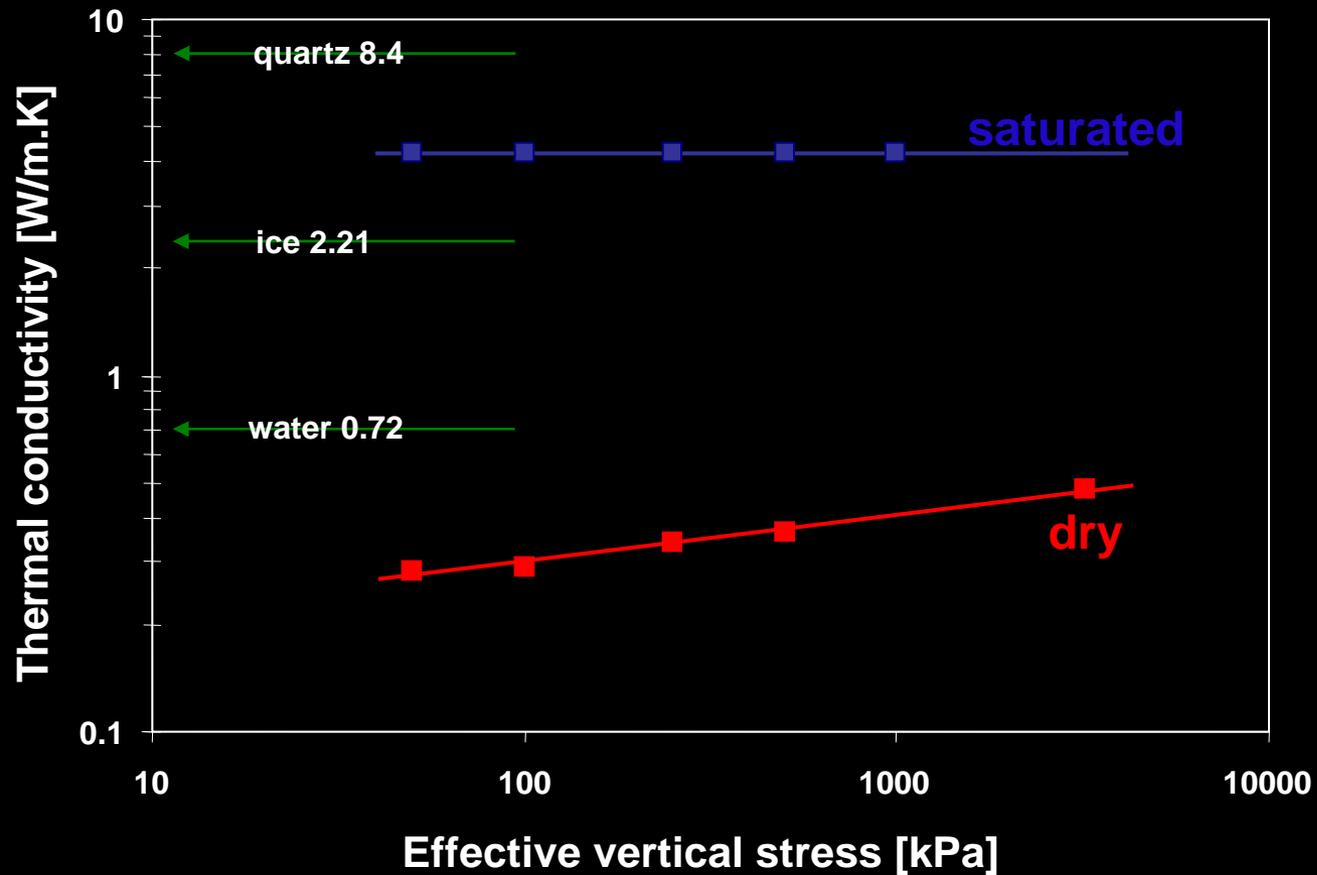
Thermal Conductivity: Determination



Thermal Conductivity: Dry Soils

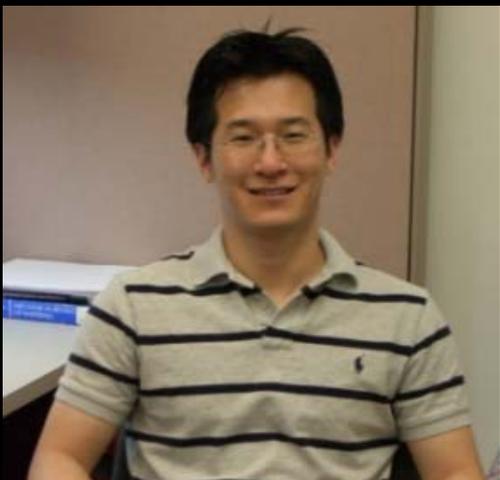


Thermal conductivity: Dry vs. Wet Soils



closing thoughts

Georgia Tech Research Team



Thank You