Geotechnical Innovations: From Research to Practice

Purdue Geotechnical Society Workshop

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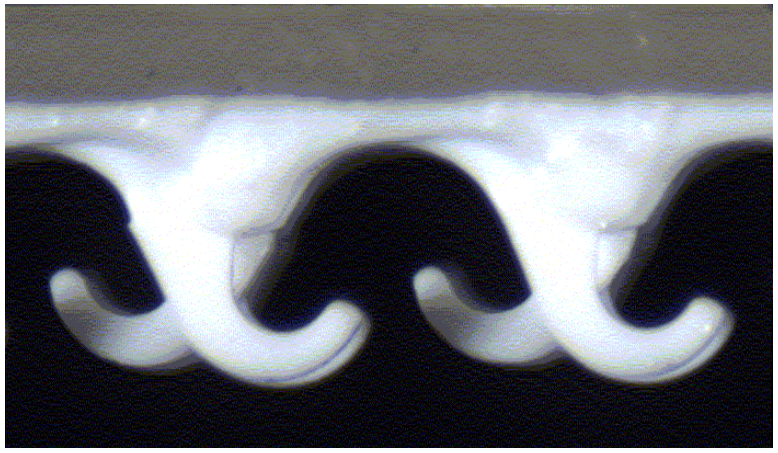
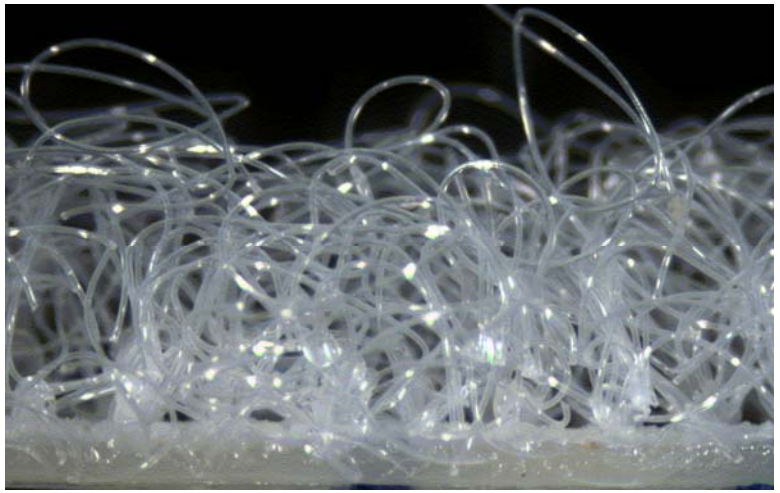
Professor & Vice Provost
Georgia Institute of Technology

Who knows what this is …..





Outline of presentation

- A few comments about innovation
- In-situ penetration tests
- Laboratory tests
- Geosynthetics
- Digital soils
- Non-disruptive technologies
- Full-scale tests
- Insight inspired innovation
- Emerging opportunities

A Definition of Innovation:

The successful exploitation of a new idea, method, device or system that creates a new dimension of performance…..

Innovation Path (iPath)

Applied Research

System Realization

Basic Research

Translational Research

Commercialization

Innovation Path (can be long and tortuous)

Academia tends to focus on this end…

Practice tends to focus on this end…

Innovation can begin/occur anywhere along the path

Invention not same as Innovation!

Innovation Characteristics

TYPES

- Transformational
- Incremental
- Device
- System
- Project specific
- Method

METRICS

- Relative to what base
- Cost to develop
- Revenue generated
- Return on investment
- Simplicity

Characteristics of Innovators

WHO

- Individual
- Group of individuals
- Team
- Owner
- Thread of above

TRAITS

- Inquisitive mind
- Willingness to explore
- Not afraid to fail
- Pioneer spirit
- Enjoys working at interfaces

Innovation Enablers/Detractors

SUPPORT FACTORS

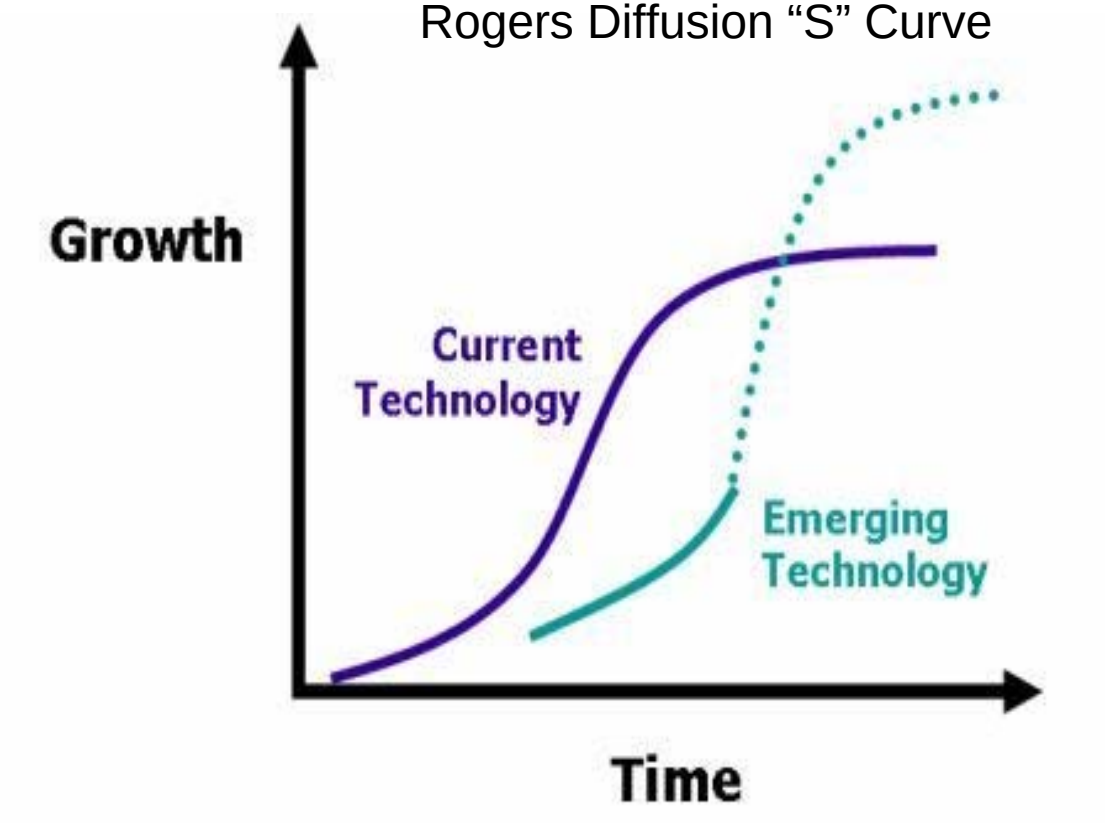
- Situational
- Constraint motivated
- Insight inspired
- Accidental
- Environment driven

IMPEDIMENTS

- Resources
- Ethics
- Environment
- Competitors
- Constructability
- Sustainability

Cycle of Innovation

Rogers Diffusion “S” Curve



SURVIVABILITY

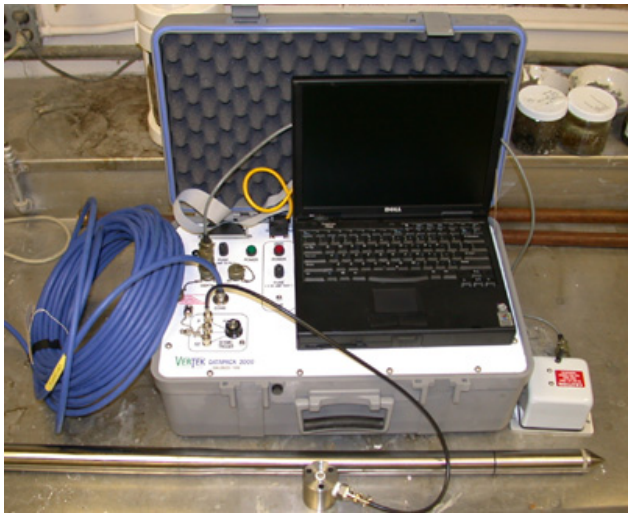
- One time event
- Short life
- Long life
- Multiple incarnations

Identified Geo-Innovations

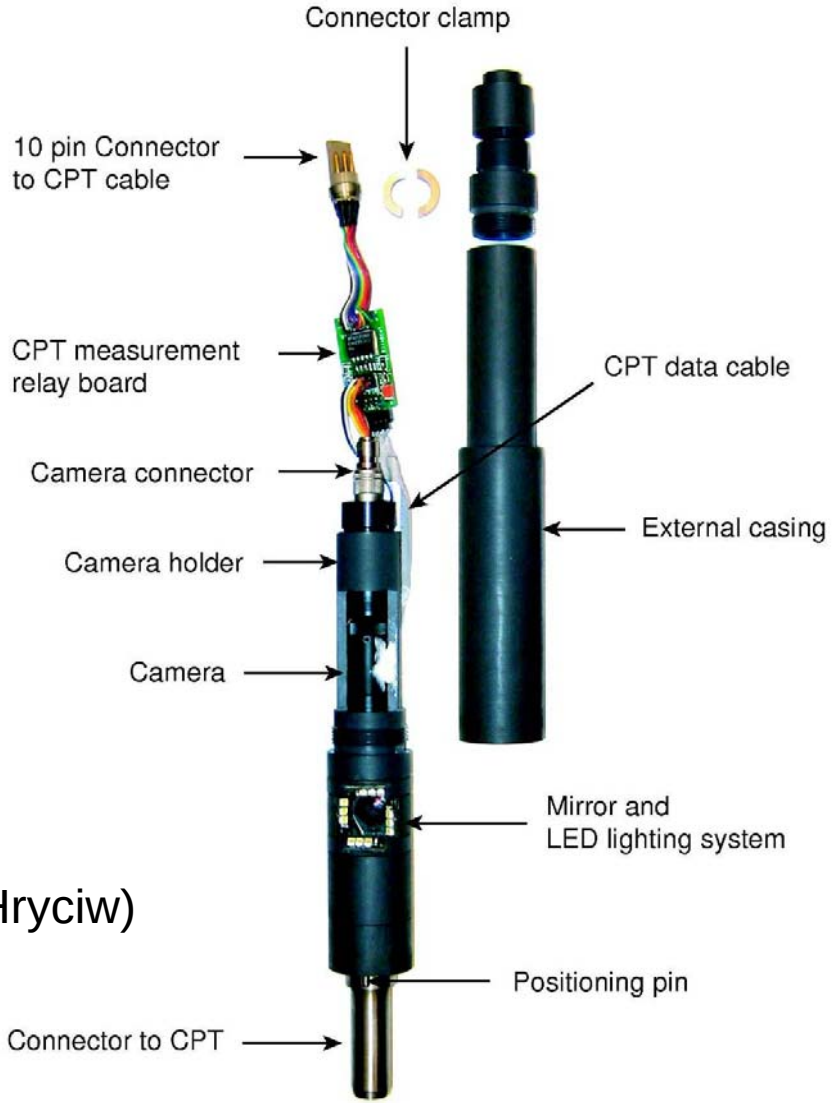
- Electronic data acq.
- Data visualization
- Numerical analysis
- DEM
- Osterberg Load Cell
- System analysis
- Geosynthetics
- Ground improvement
- Suction piles
- Real-time monitoring
- Wave based char.
- Probabilistic methods
- Soil nailing
- Penetration testing
- Small strain
- New materials
- Higher resolution tools
- Tomography

In-Situ Penetration Tests

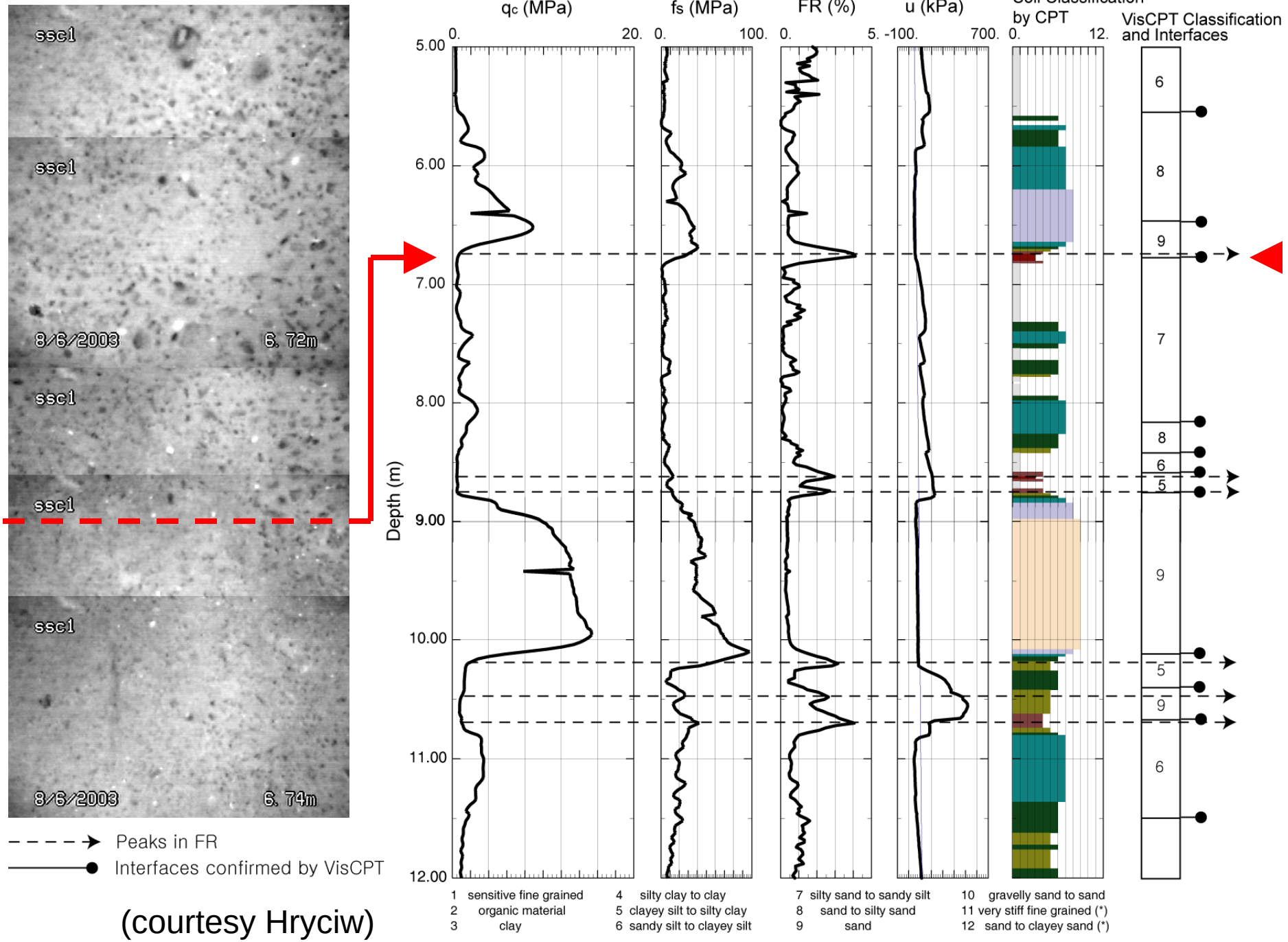
Penetration Testing



Vision Cone Penetrometer

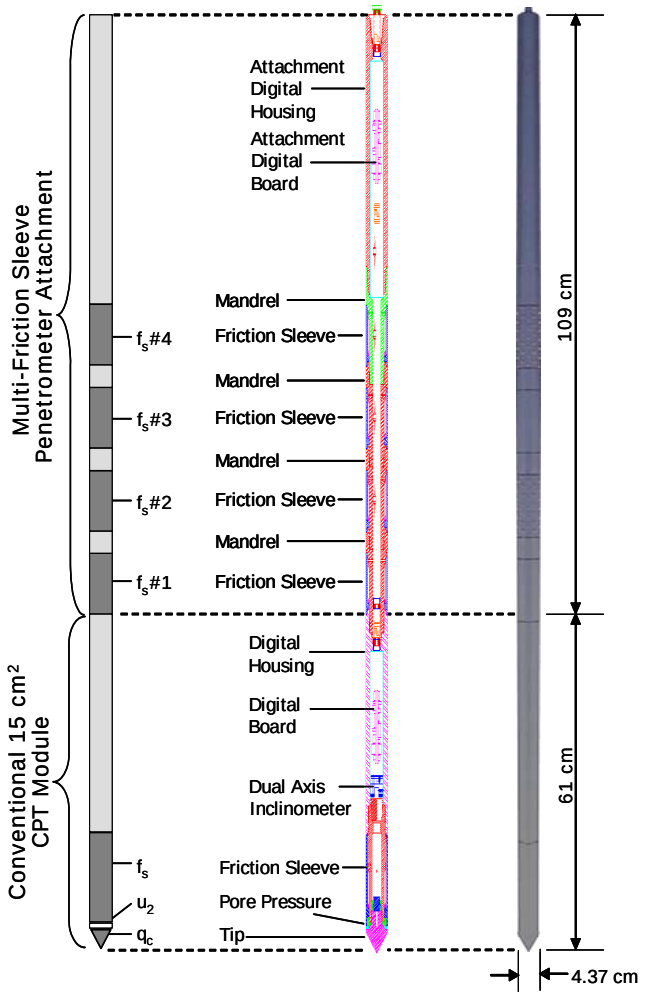


(courtesy Hryciw)



(courtesy Hryciw)

Multi-sensor Technology



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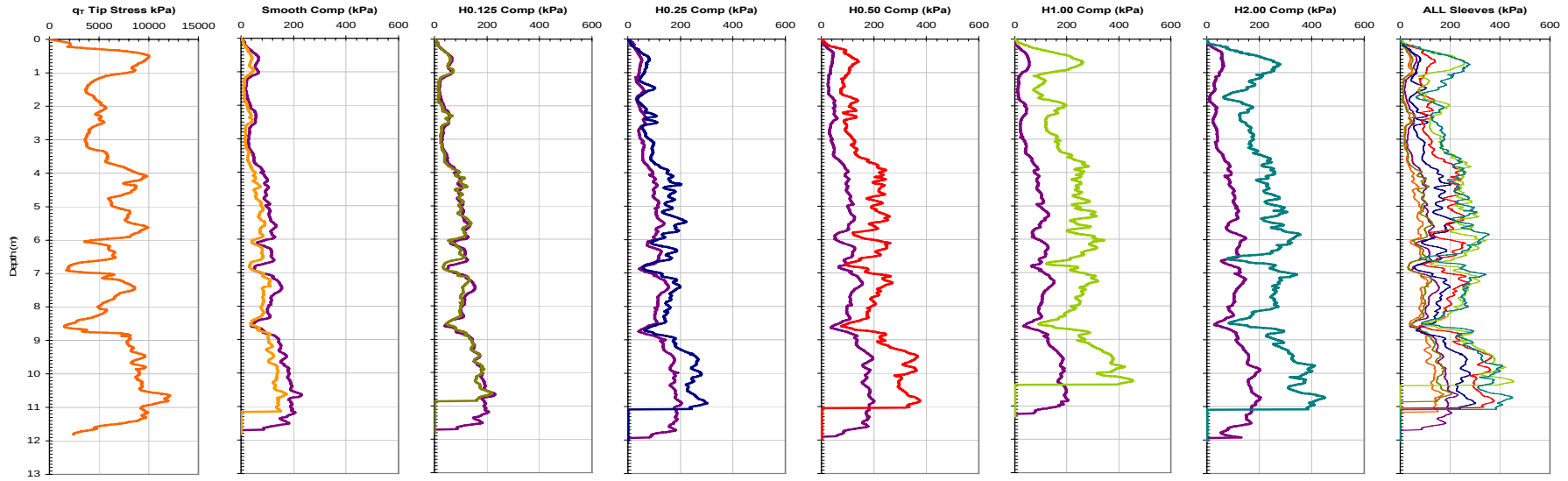
Multi Friction Sleeve CPT Attachment Data

Test Site:	Timian Yard - South Royalton, VT	**Oper:**	JD, GLH, DF	**MS #2:**	SM2
Date:	Variable	**Tip Conf:**	15cm2 CPT	**MS #3:**	Variable
Test ID:	Variable	**MS #1:**	SM1	**MS #4:**	SM4
Notes:	Response of Sleeve Texture to Silica Sand at the SRVT test site - APF Corrected				

MS #5:	N/A
Pen. Rate (cm/s):	2
Meas Rate (Sa/cm):	1

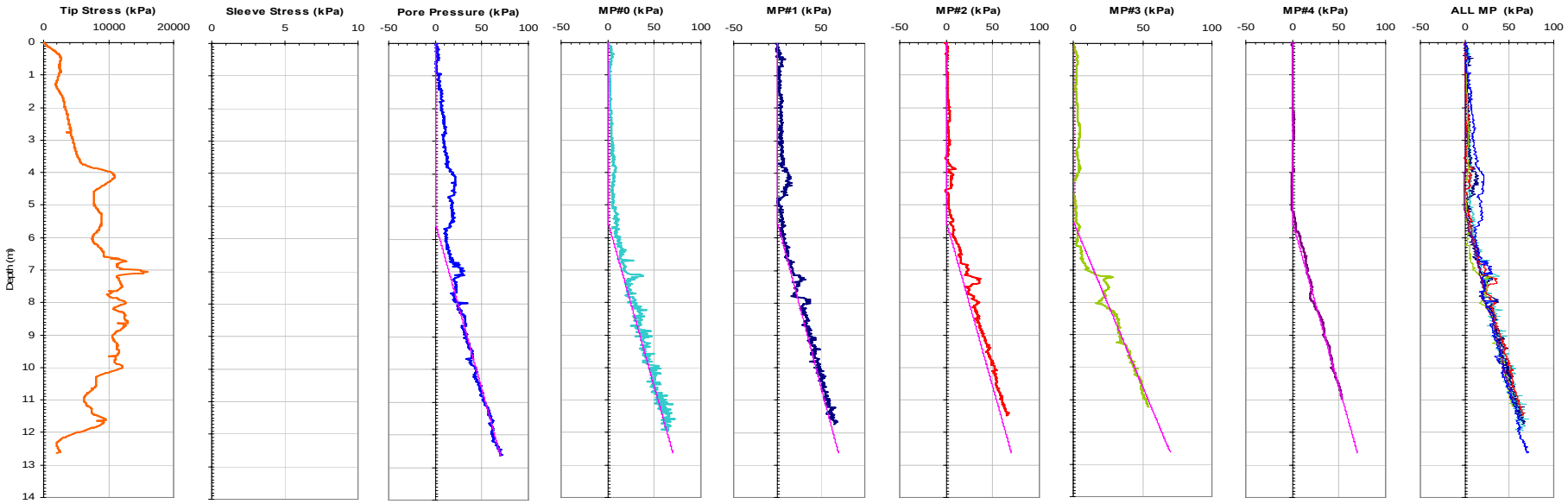


Georgia Institute of Technology - Geosystems Group

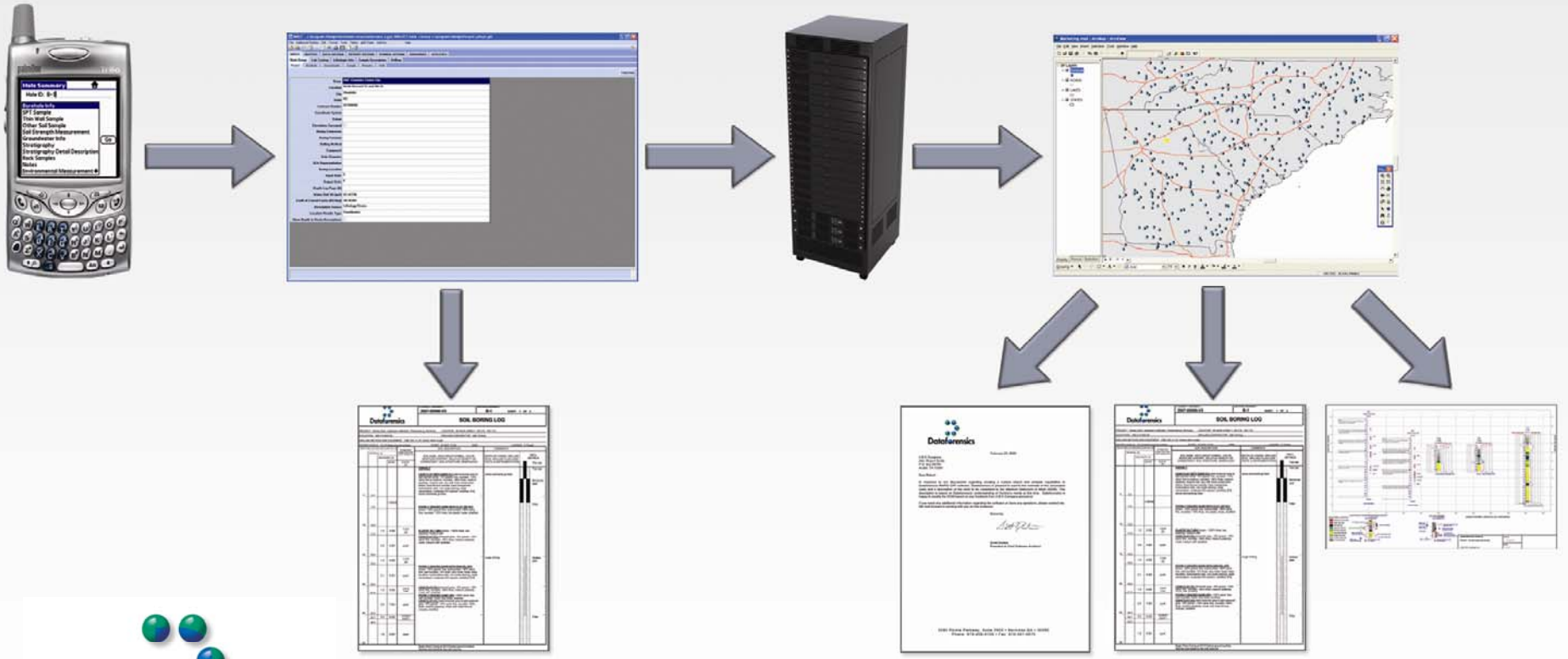
Multi Piezo Friction Sleeve CPT Attachment Data

Test Site:	Shenton Park Sand Site	**Oper:**	GLH, James, Andrew (Probedrill WA)	**MS #2:**	30H.5S3
Date:	7/30/2004	**Tip Conf:**	15cm2 CPT	**MS #3:**	30H1S3
Test ID:	MP30L0409C	**MS #1:**	30H.25S3	**MS #4:**	30H2S3
Notes:	MPFA - No fs, MS1				

MS #5:	N/A
Pen. Rate (cm/s):	2
Meas Rate (Sa/cm):	1
Page:	**2 of 2**



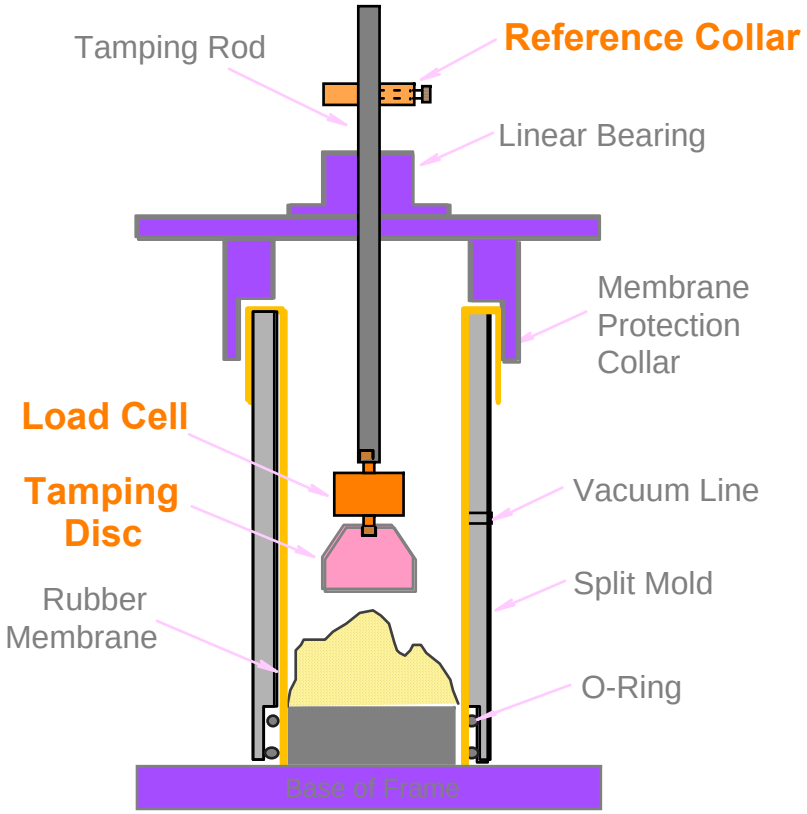
Integrated Digital Data Management



Dataforensics

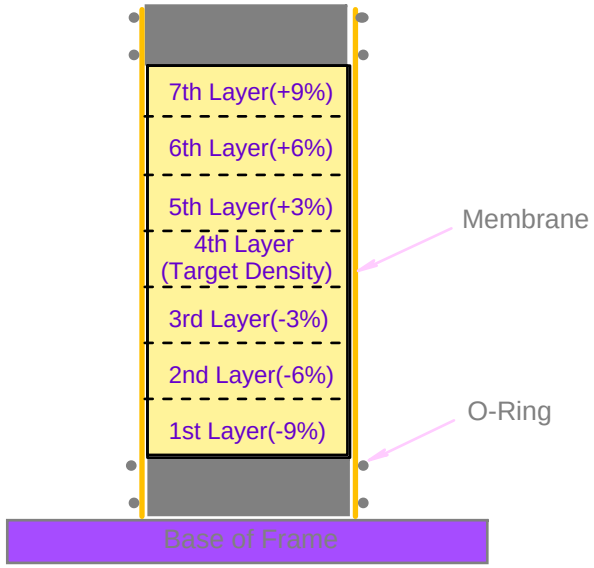
Laboratory Tests

Moist Tamping System



(a)

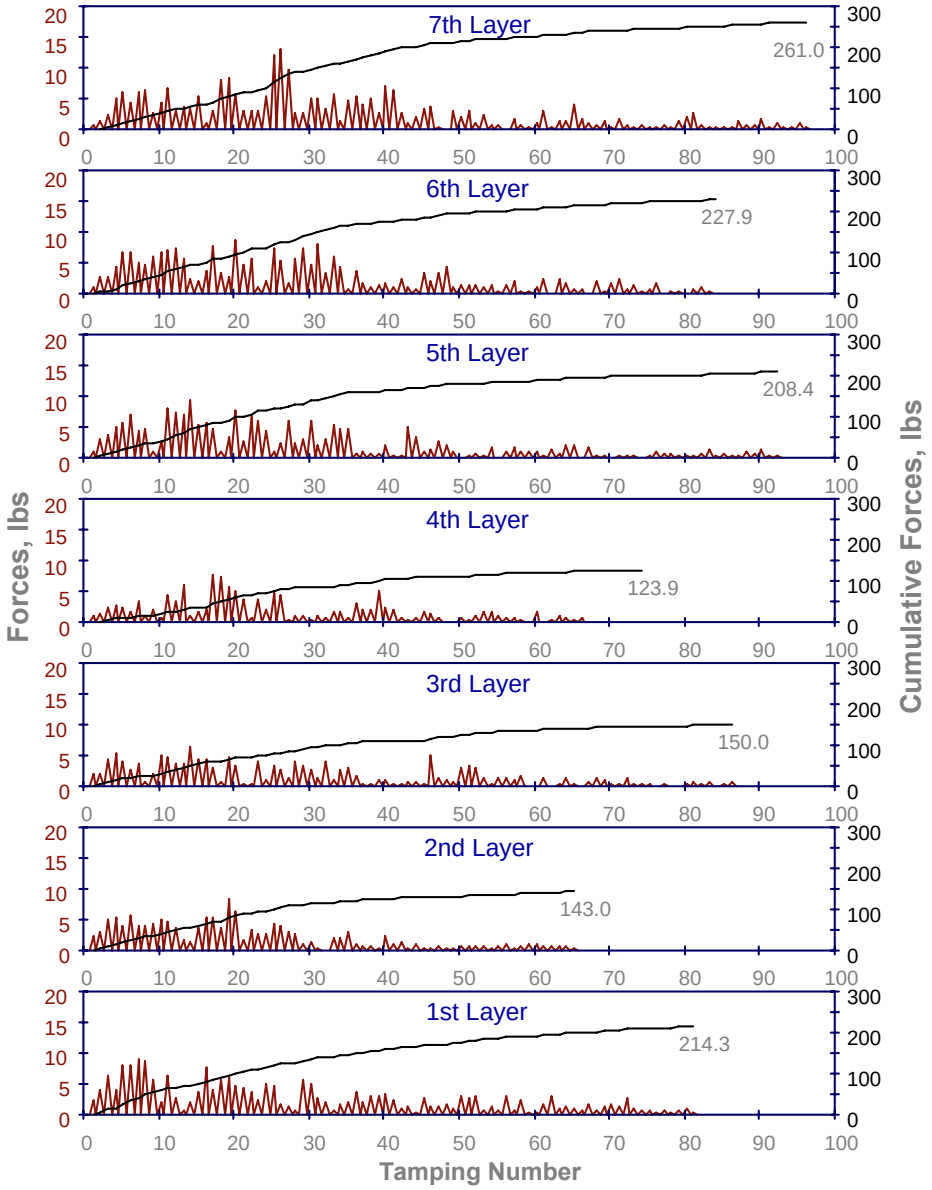
Schematic View of Moist Tamping System



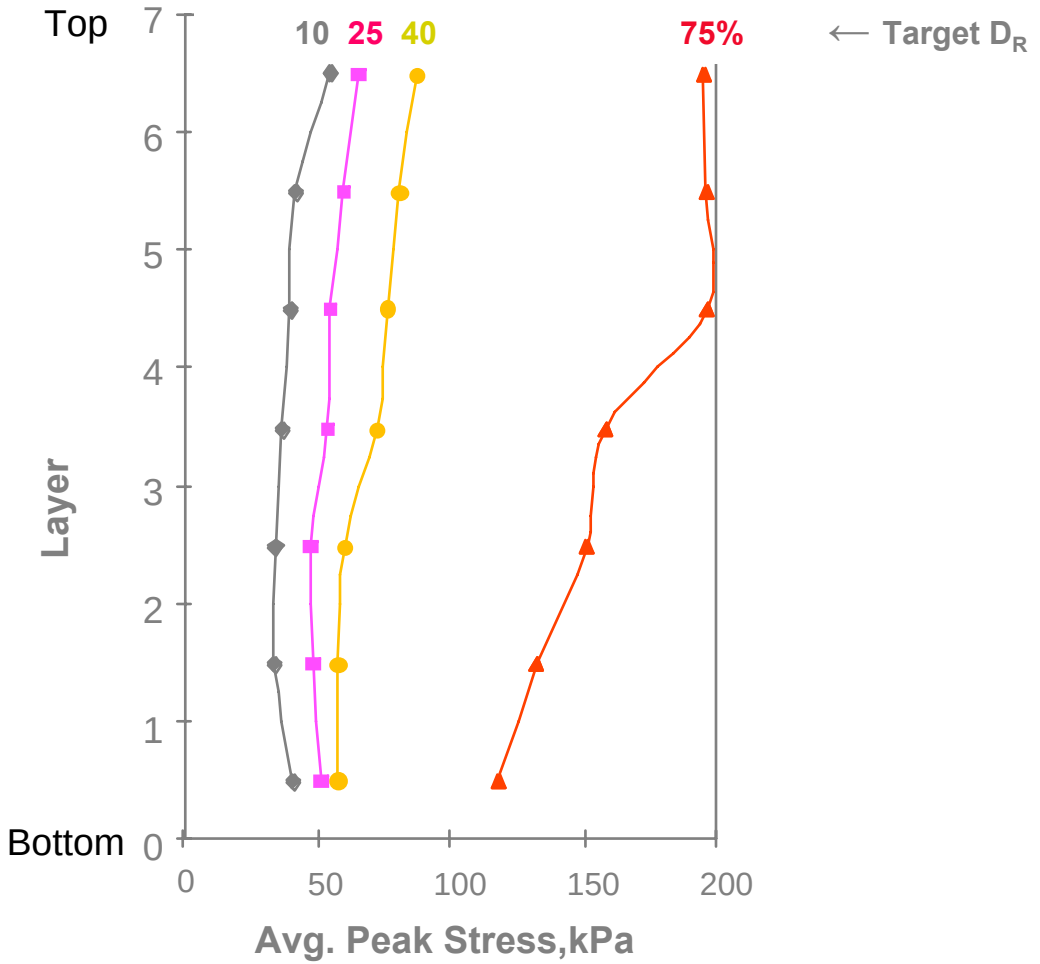
(b)

Moist Tamped Specimen with Undercompation Ratio of 3 %

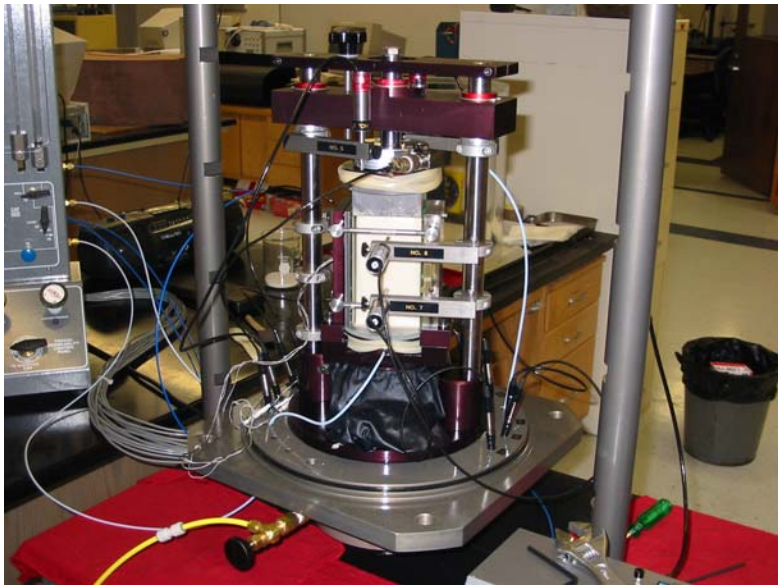
Forces Applied to MT Specimen



Peak Stress Measurement




AUTOCON-II
GEOCOMP
LAB SYSTEMS

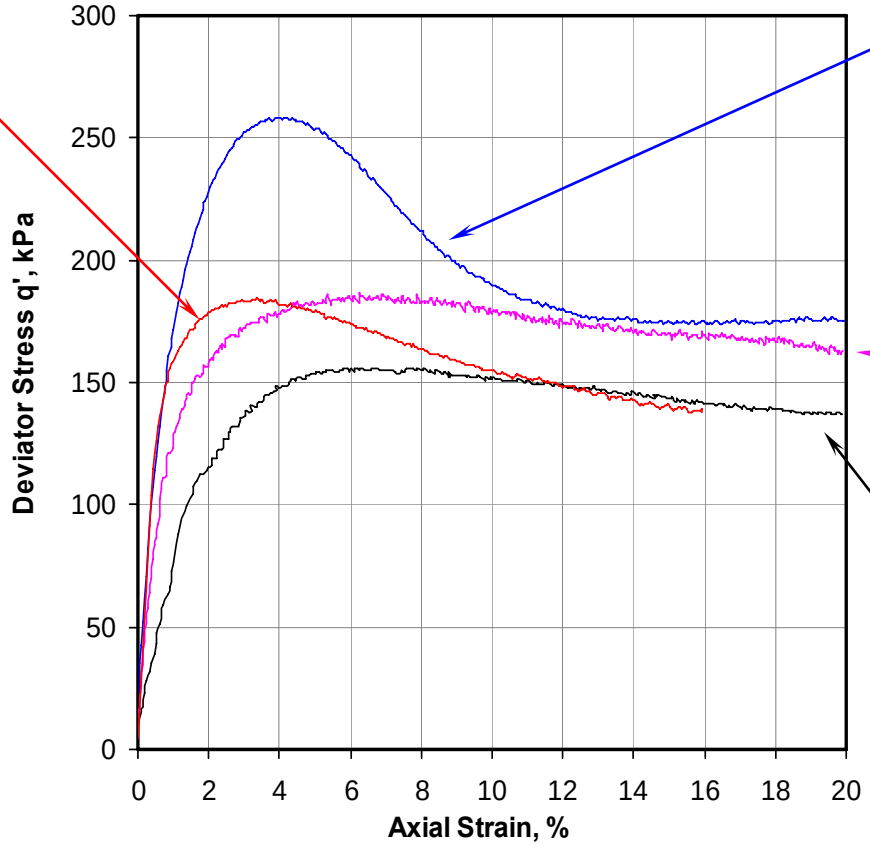



Sigma-1
Automated Load
Test System
GEOTAC


VERTICAL
Shear Trac II
HORIZONTAL

Global Response of Dilatant Specimens

H/D=2, Non-lubricated



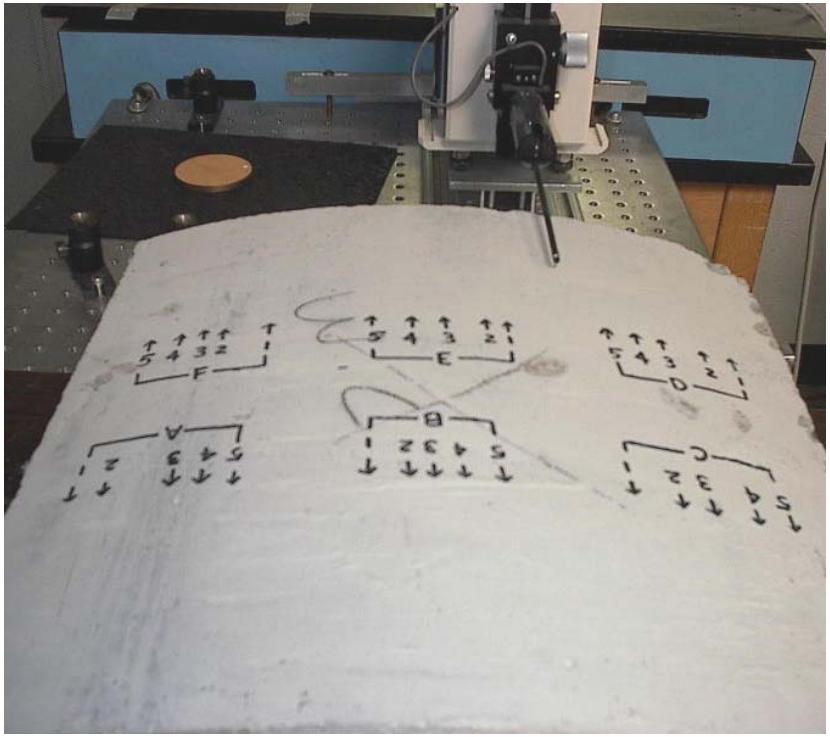
H/D=1, Non-lubricated

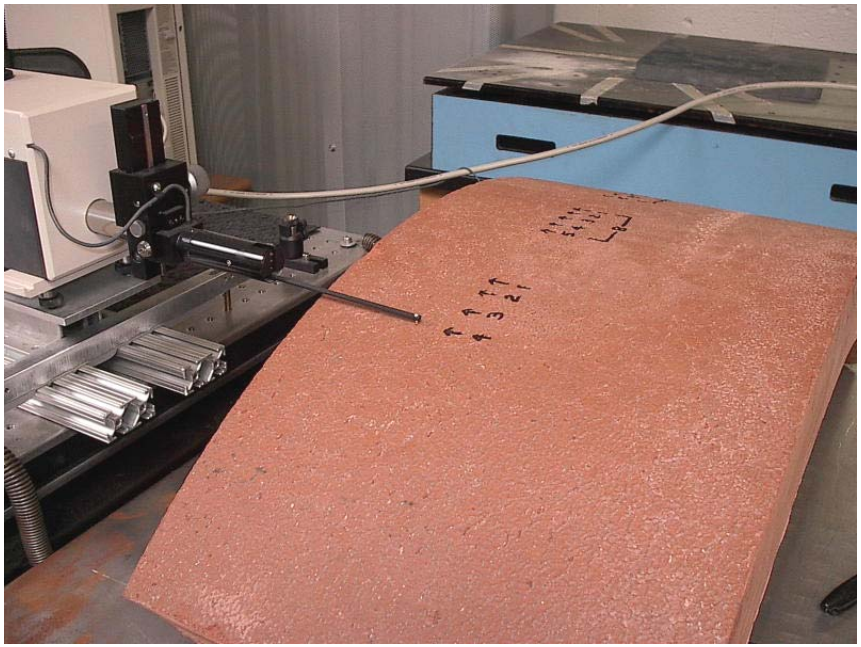
H/D=1, Thin Lubricated

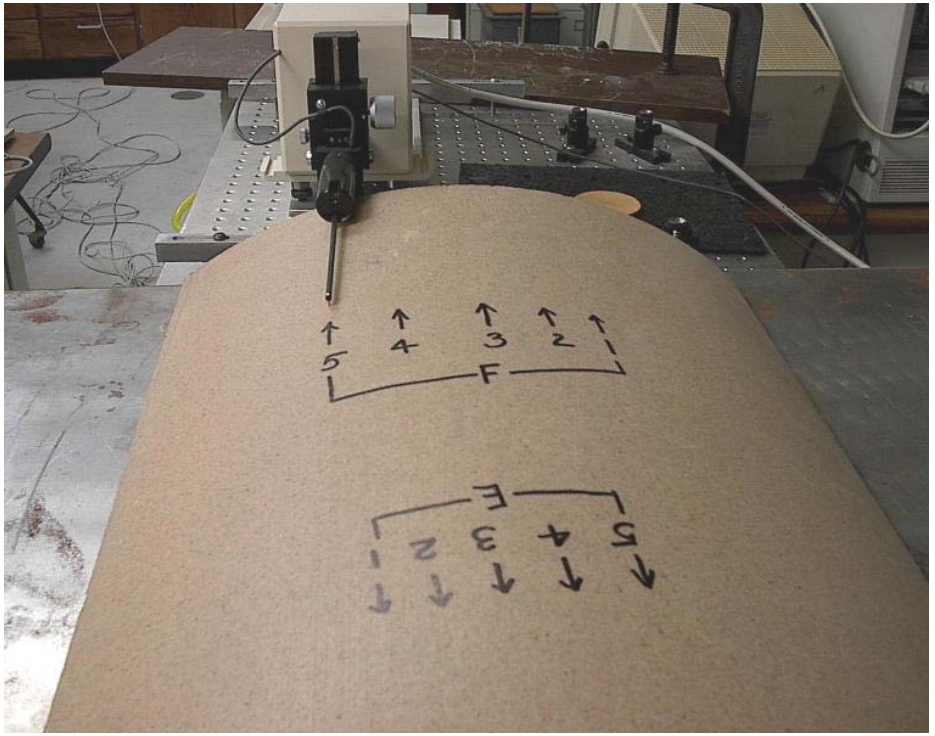
H/D=1, Thick Lubricated

50 kPa confining pressure

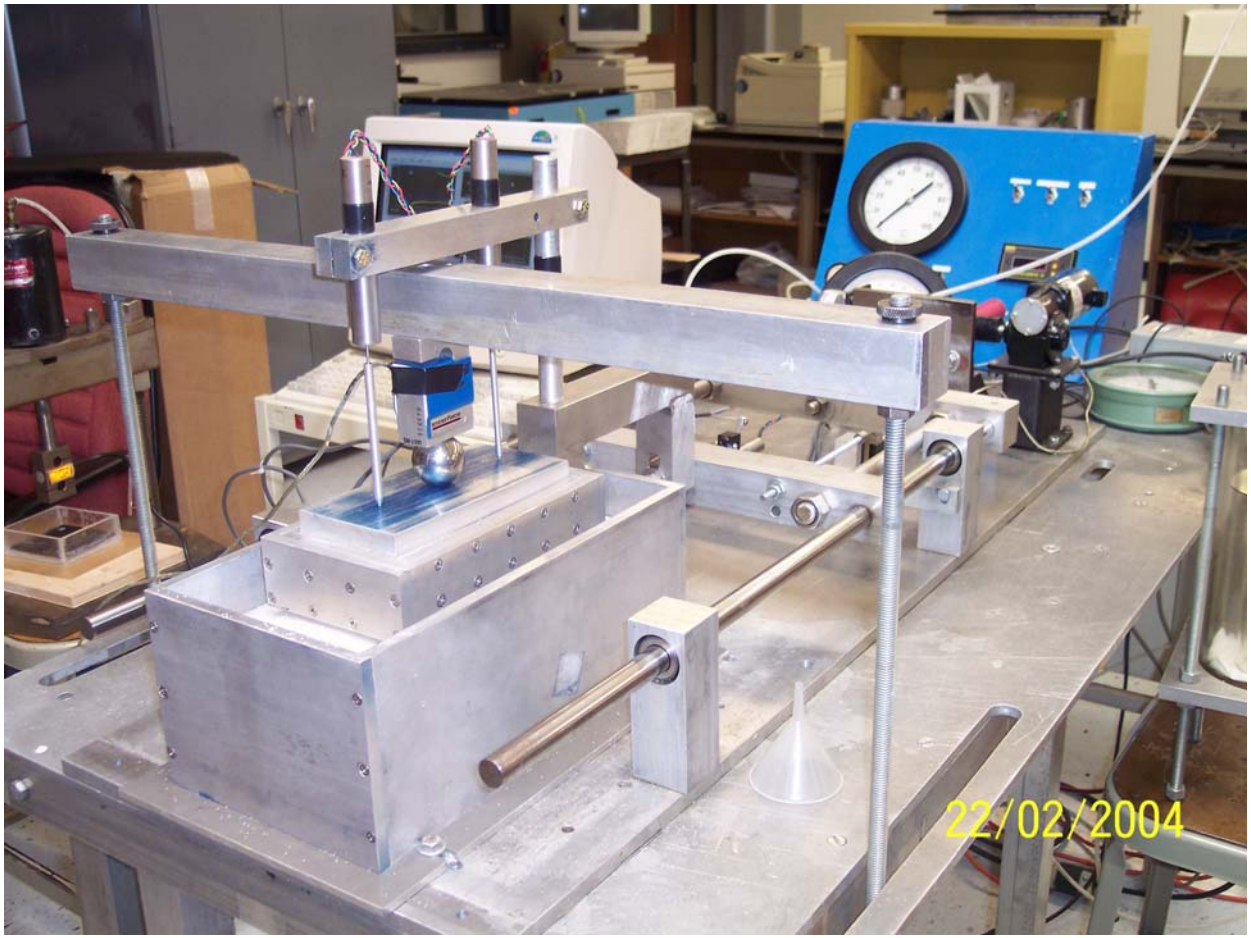
Typical Geomaterials







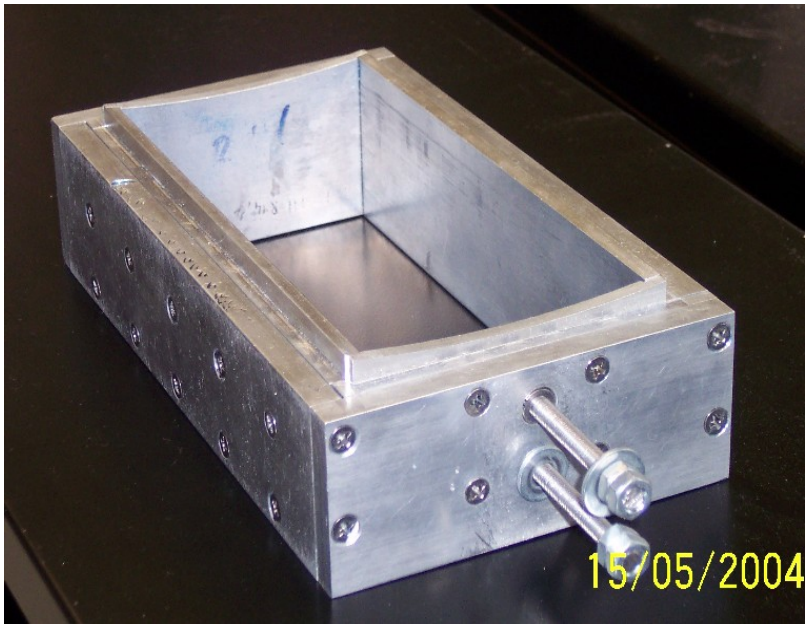
Interface Shear Device (End View)



Curved Shear Box

Shear Box on Top of Pipe Coupon

Photograph of the Underside of the Shear Box



Geosynthetics

Geosynthetics

(courtesy Hebeler)

Geosynthetics

Geosynthetics

(courtesy Hebeler)

Geosynthetics

(courtesy Hebeler)

Digital Soils

Tomography & Imaging Technologies

Serial Sectioning and Image Capture

Polishing Off 8µ ⇄ Capturing Images

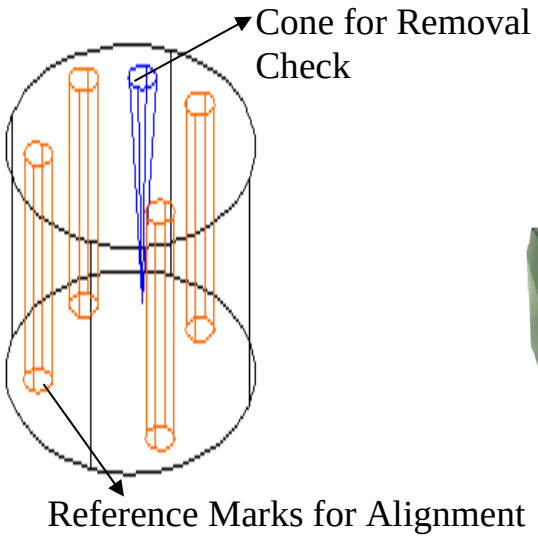
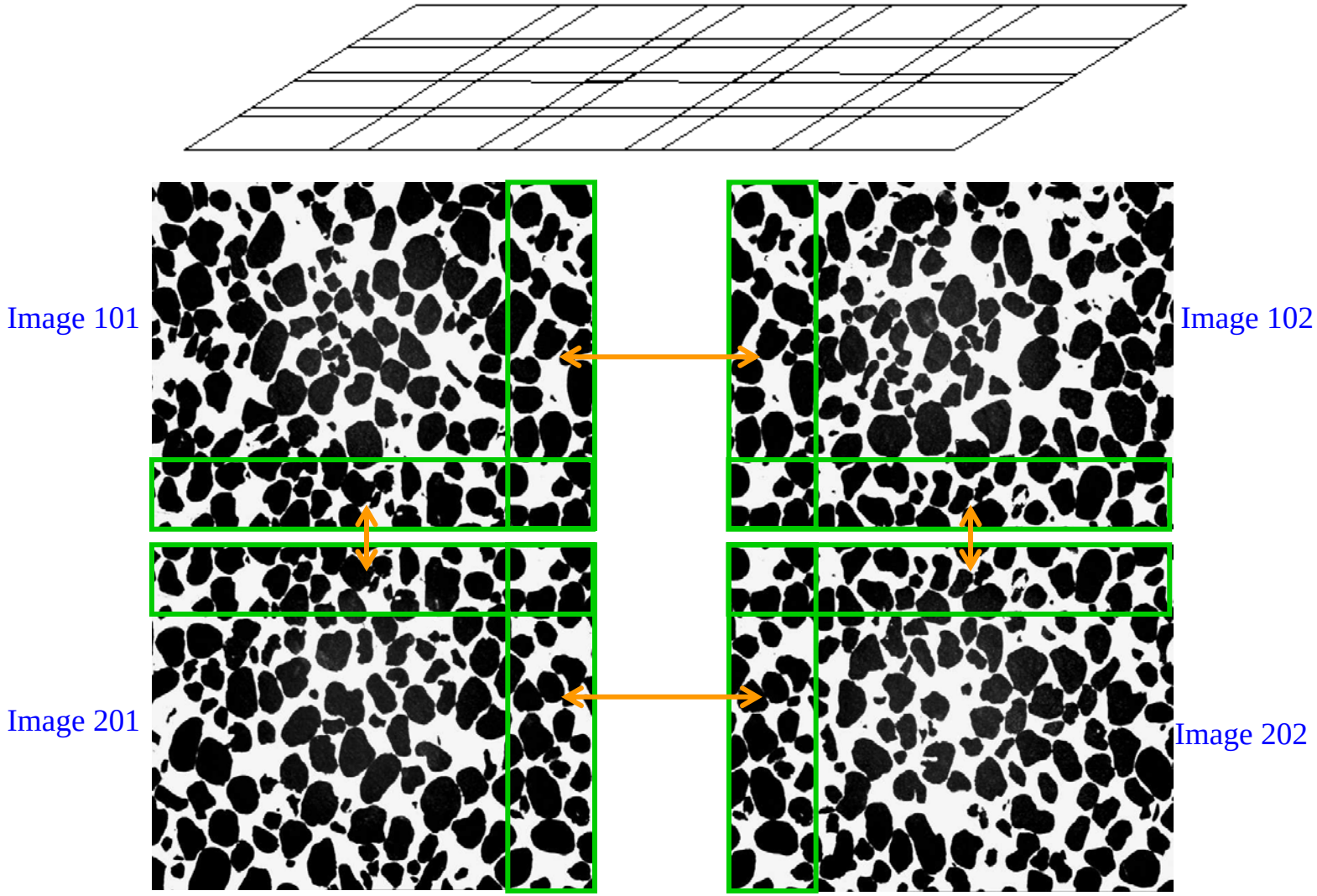


Illustration of Reference Marks

MultiPrep System

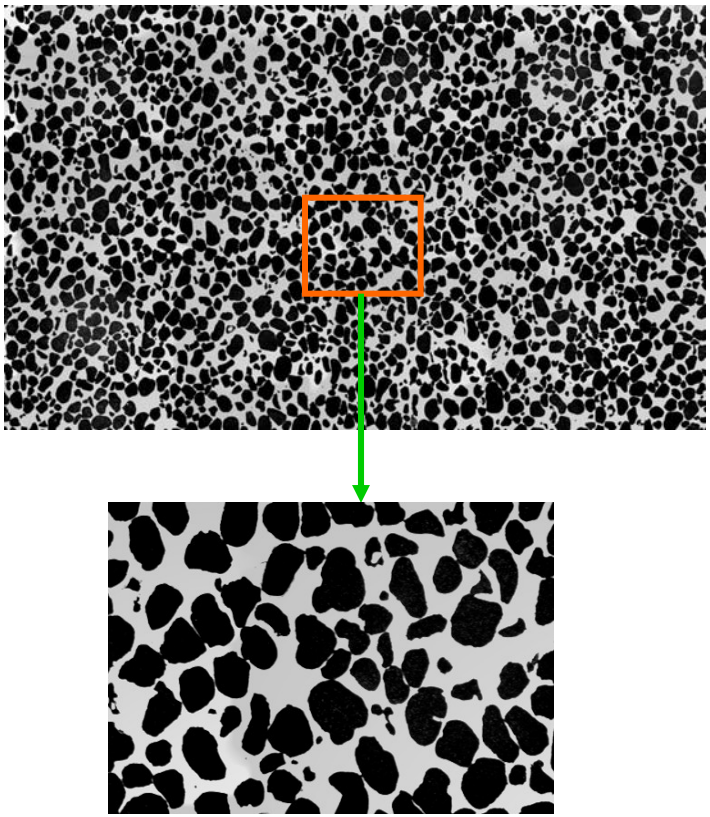
Leica DM 4000

Mosaic Generation

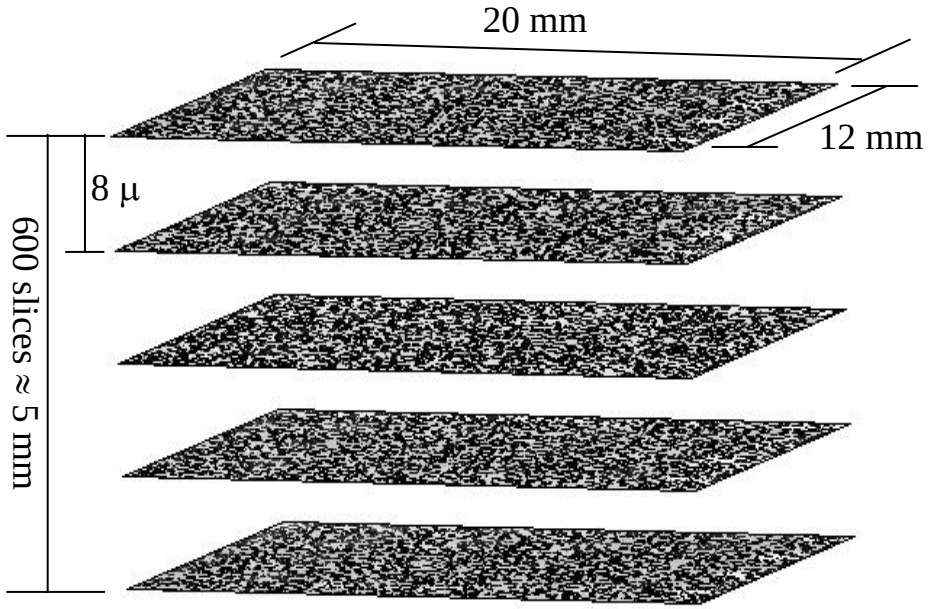


Four Neighboring Images with 20% Overlap

3-D Reconstruction

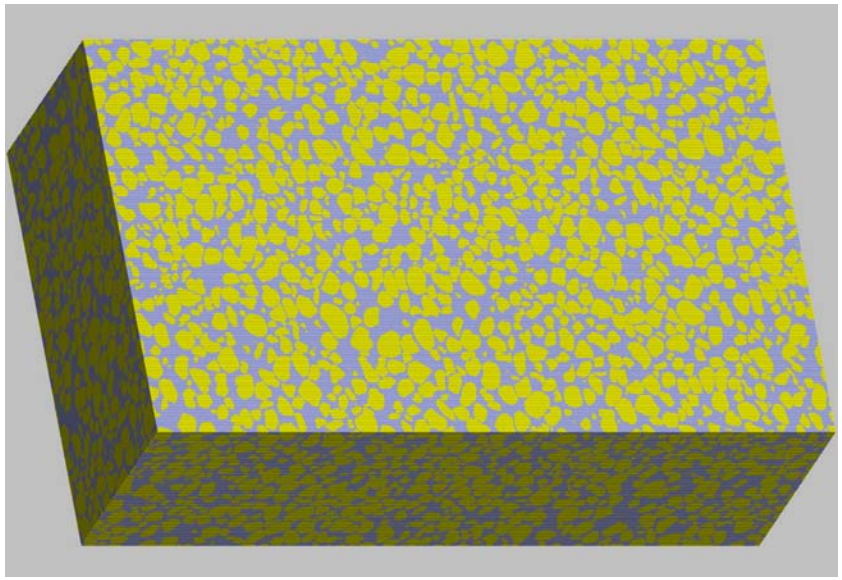


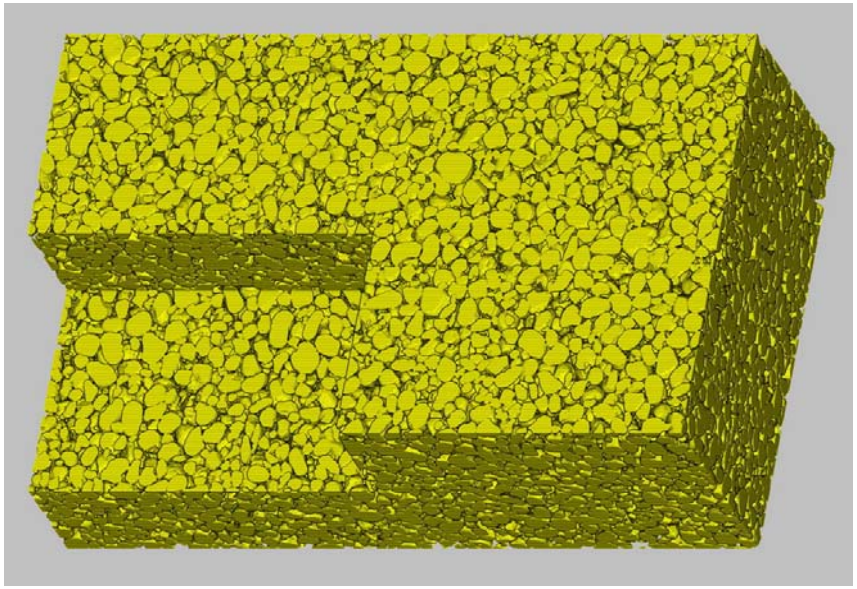
Slice used in 3D reconstruction



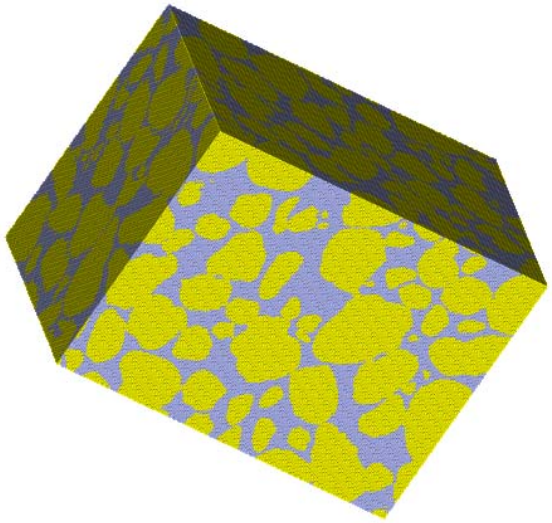
Dimensions of the Reconstructed Volume

Reconstructed Ottawa 50-70 Block

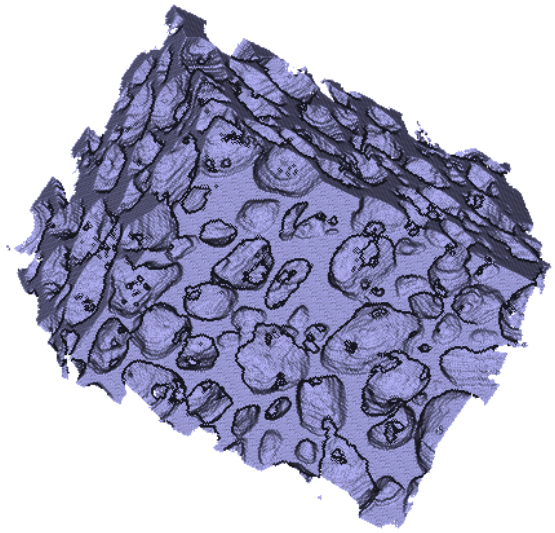




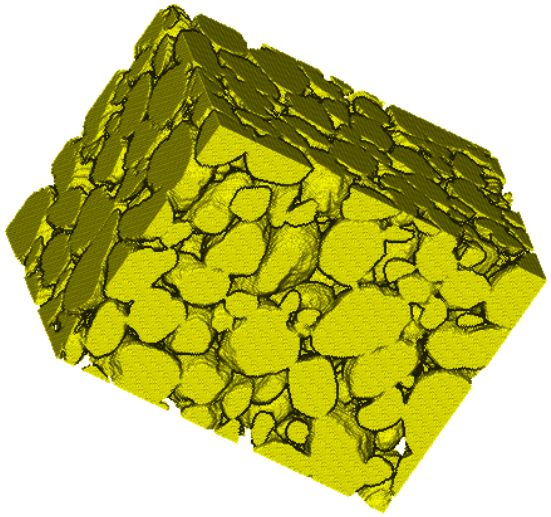
3-D Reconstructed Specimens



Sub-volume of a specimen

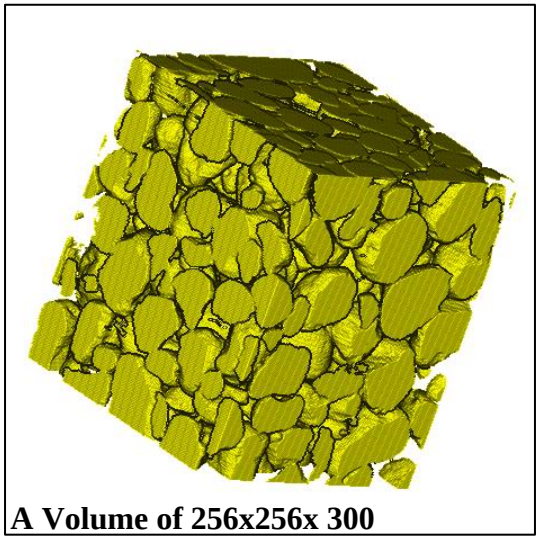


Extracted Pore Structure

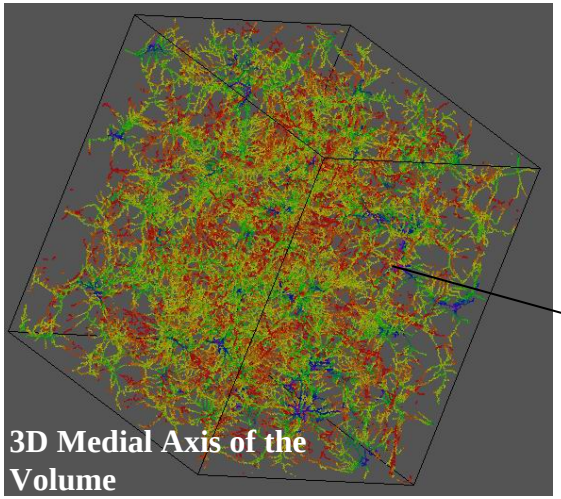


Extracted Particles

3-D Analysis: Pore Structure



A Volume of 256x256x 300

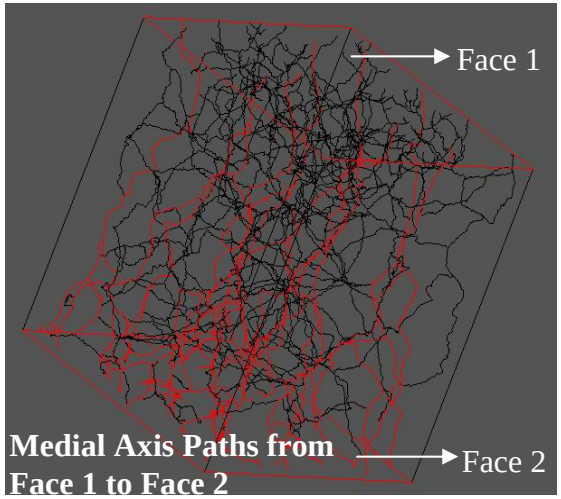


3D Medial Axis of the Volume

Medial Axis Analysis:

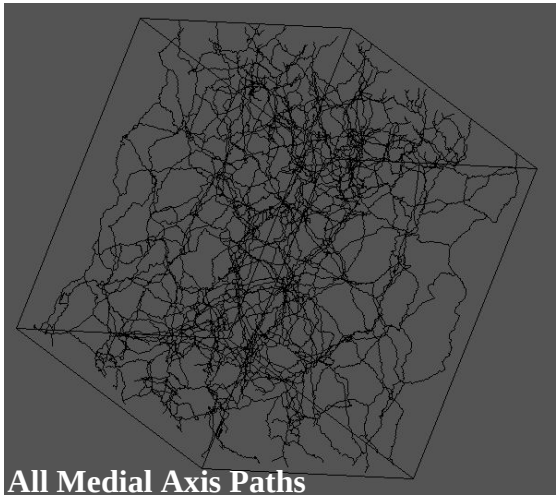
- Shortest Paths
- Tortuosities

Colors represent relative distance (red - close, blue - far) to the nearest particle surface. (Particles are not shown)



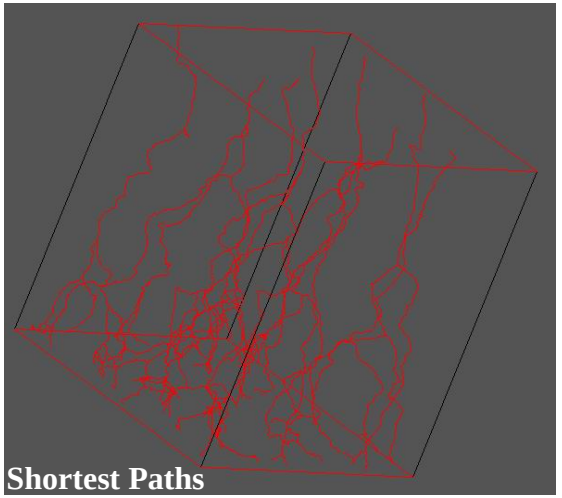
Medial Axis Paths from Face 1 to Face 2

=



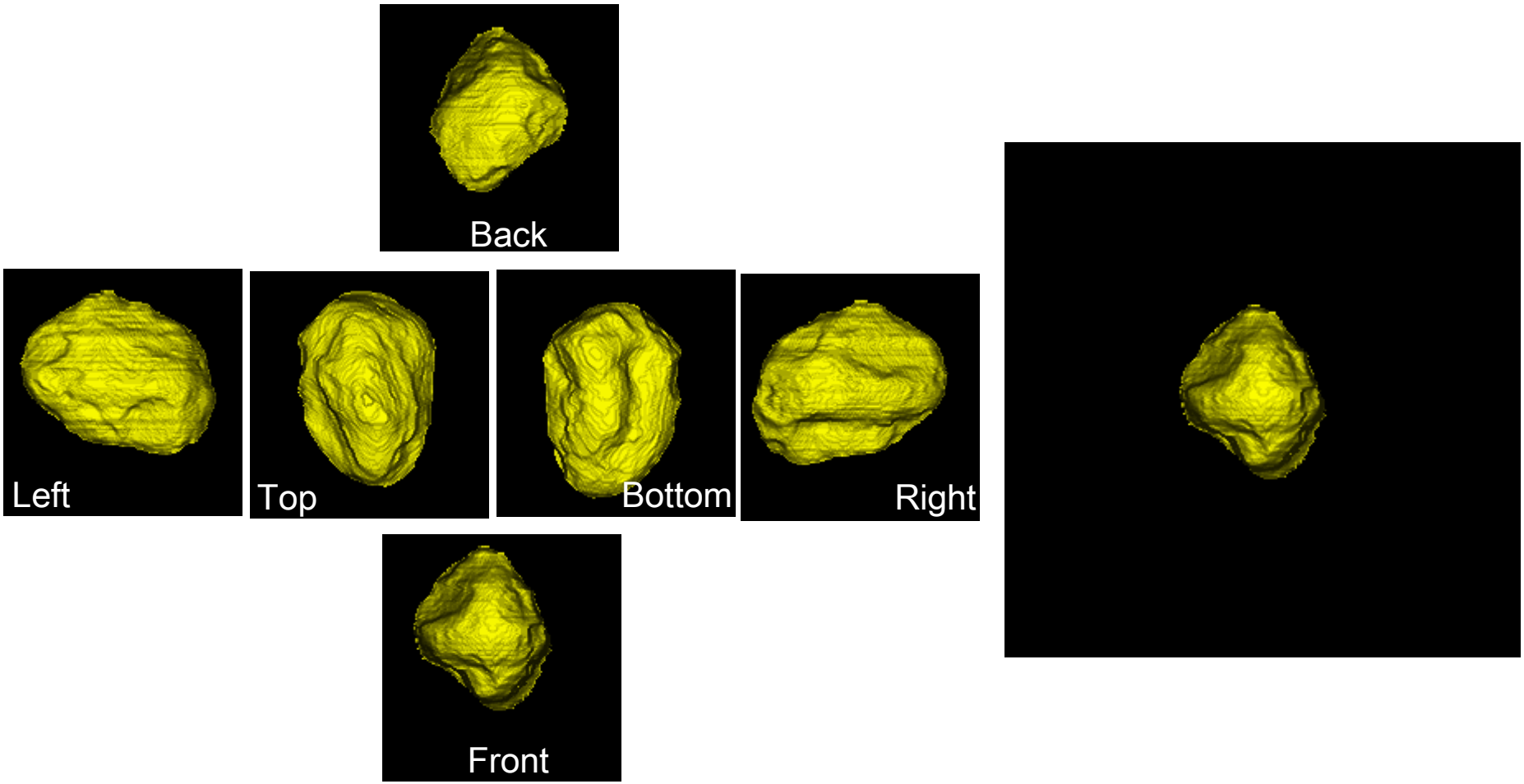
All Medial Axis Paths

+

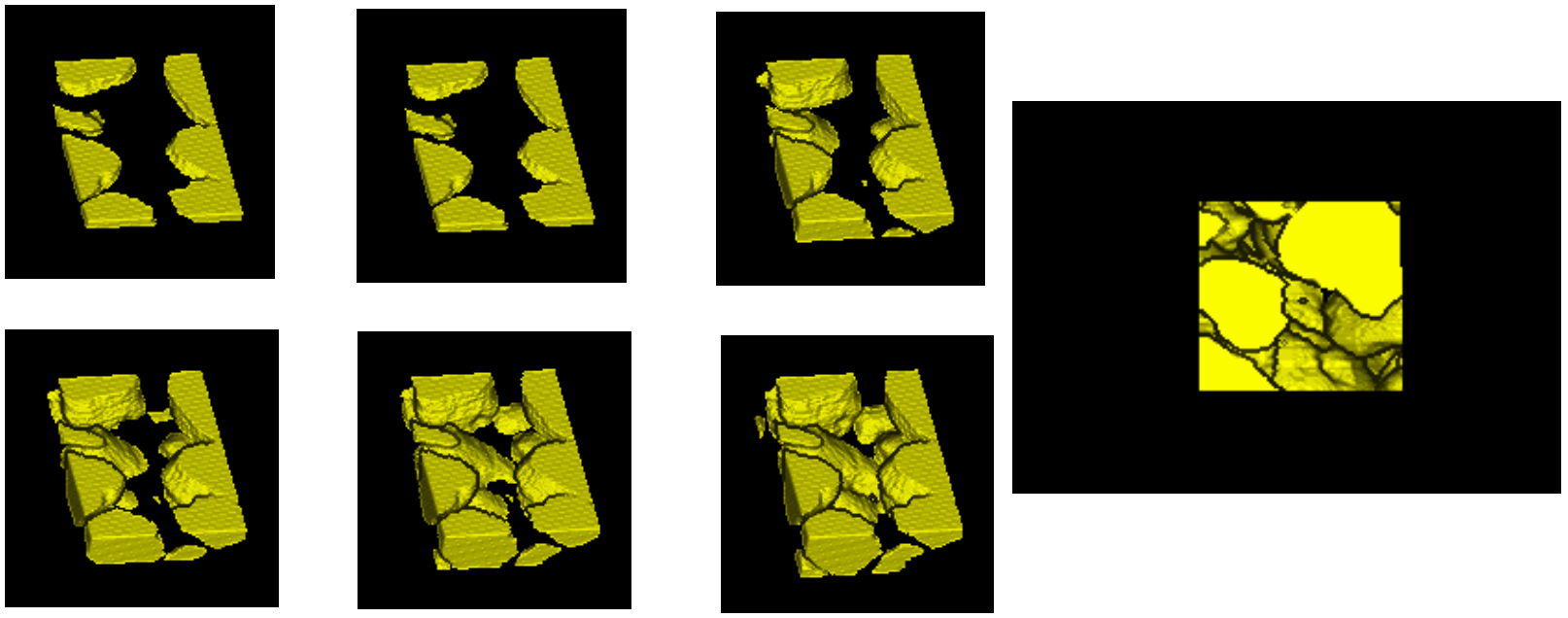


Shortest Paths

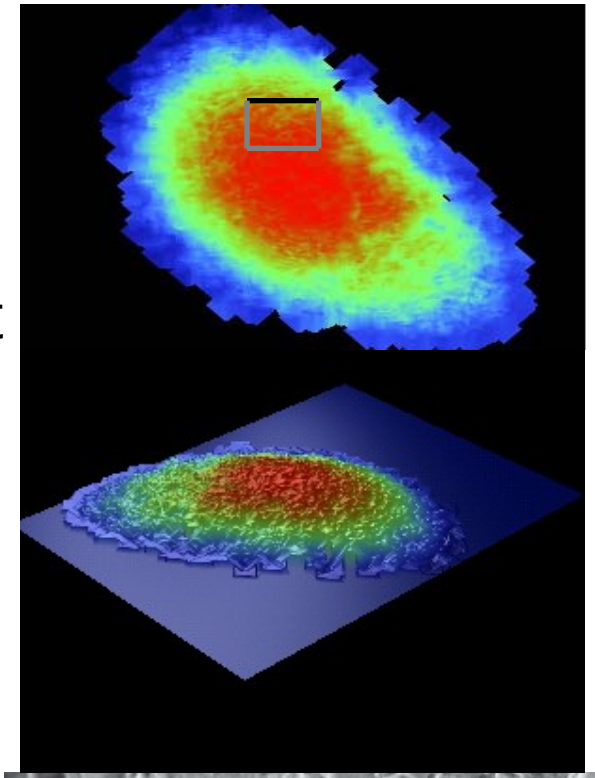
3-D Particle Visualization



3-D Pore Visualization

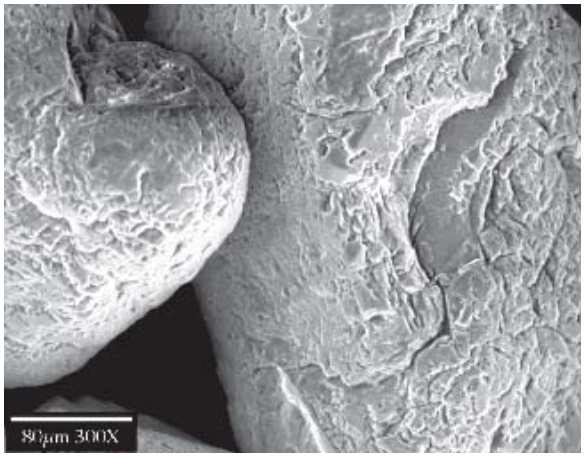


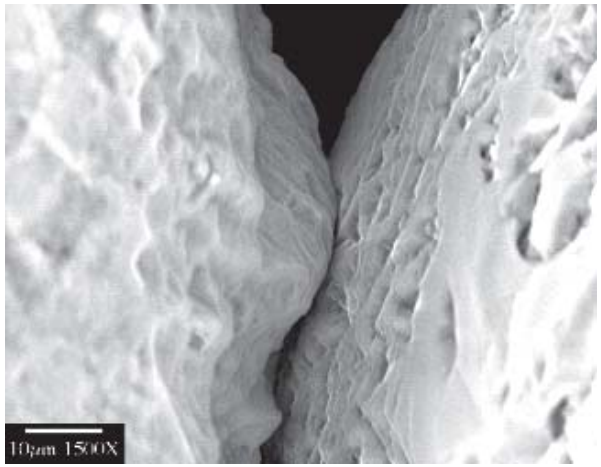
- Surface Texture, roundness and sphericity influence strength properties and deformation characteristics of granular materials.
- There are few experimental studies that link strength properties and instability phenomena of unbound granular materials to their micro-properties.

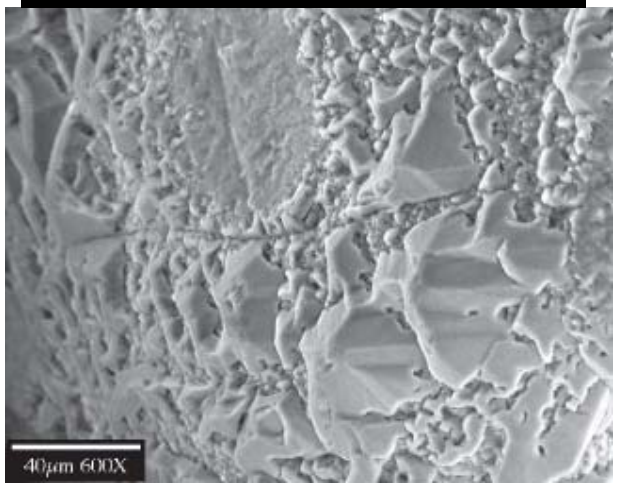


Influence of particle surface toughness on friction and dilatancy angle under Plane strain Loading

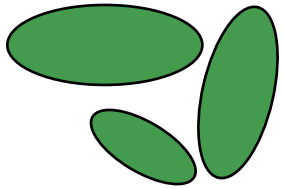
(courtesy Al-Shibli)



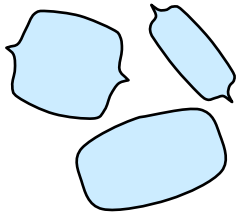




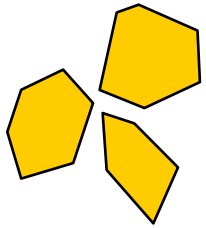
Particle Shape Modeling in DEM



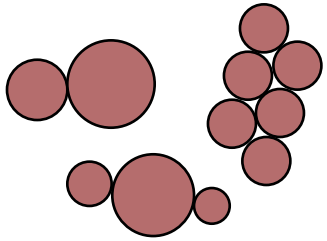
Ellipses/Ellipsoids
Ting, Ng, Lin, others



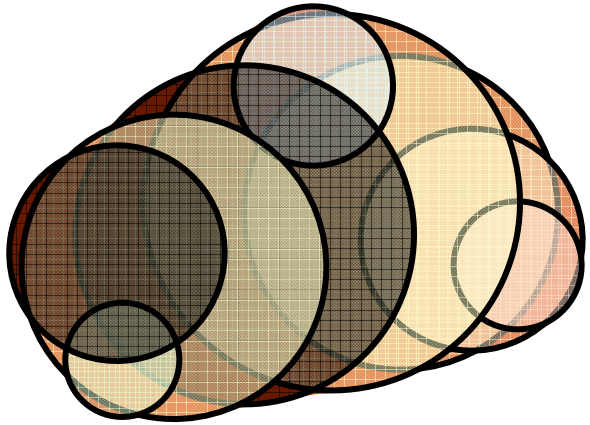
Superquadratics
Williams et al.



Polygons
Ghaboussi, Williams



Bonded Clusters
Jensen, Bray, O'Sullivan



Overlapping Clusters
Ashmawy, Sukumaran

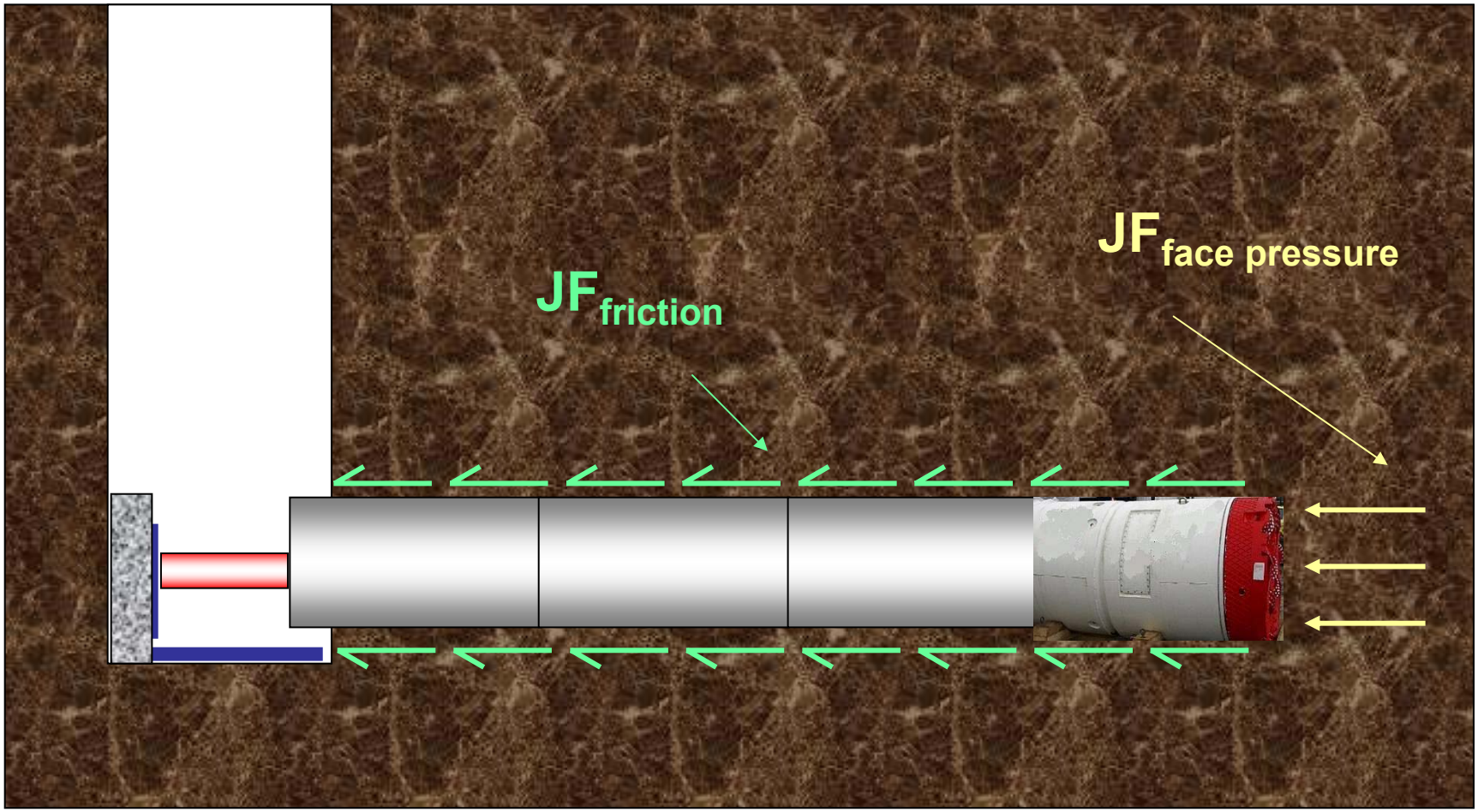
(courtesy Sukumaran)

Non-disruptive Technologies

Machines

Jacking Forces

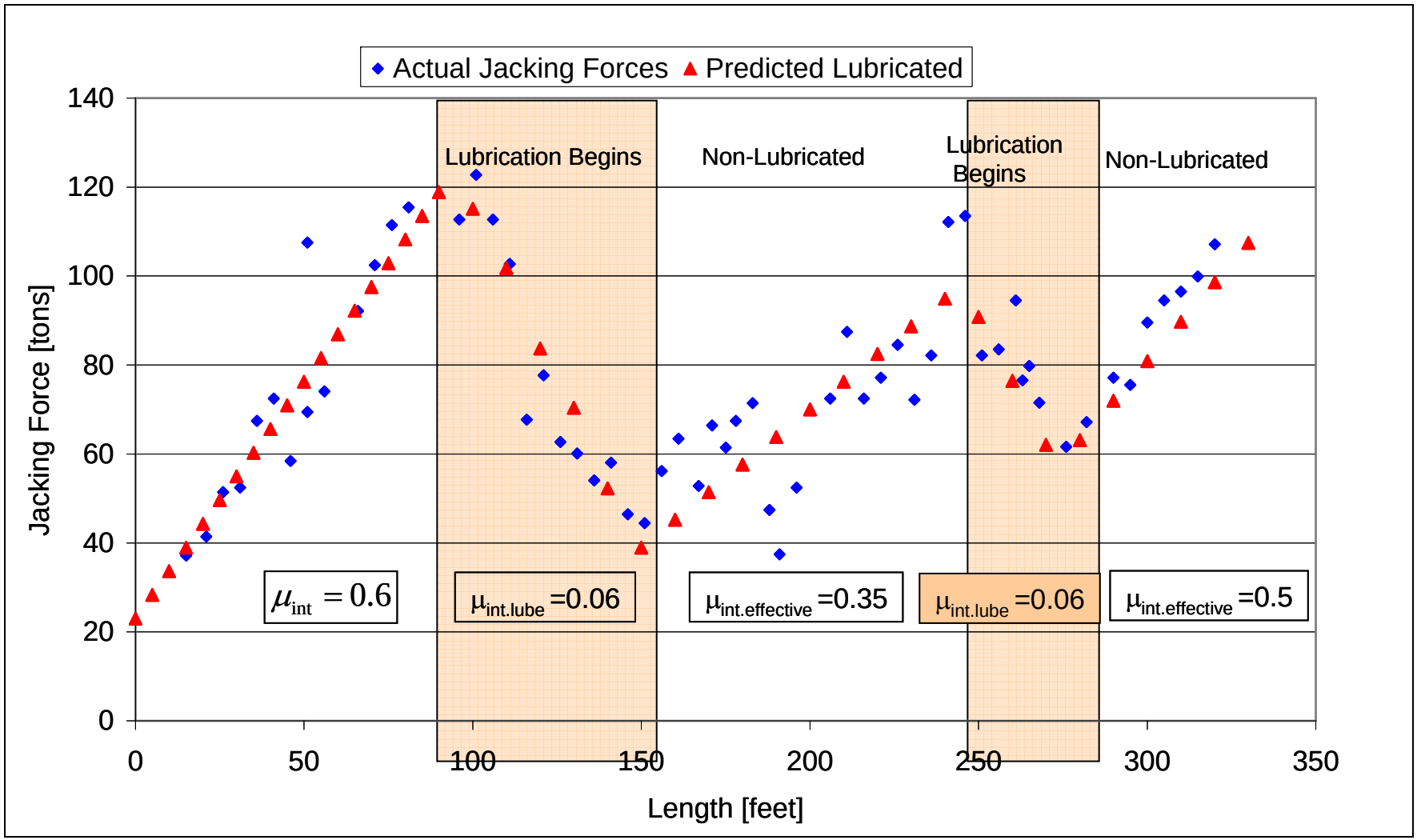
$$JF_{total} = JF_{face\ pressure} + JF_{friction}$$



Intermediate Jacking Stations

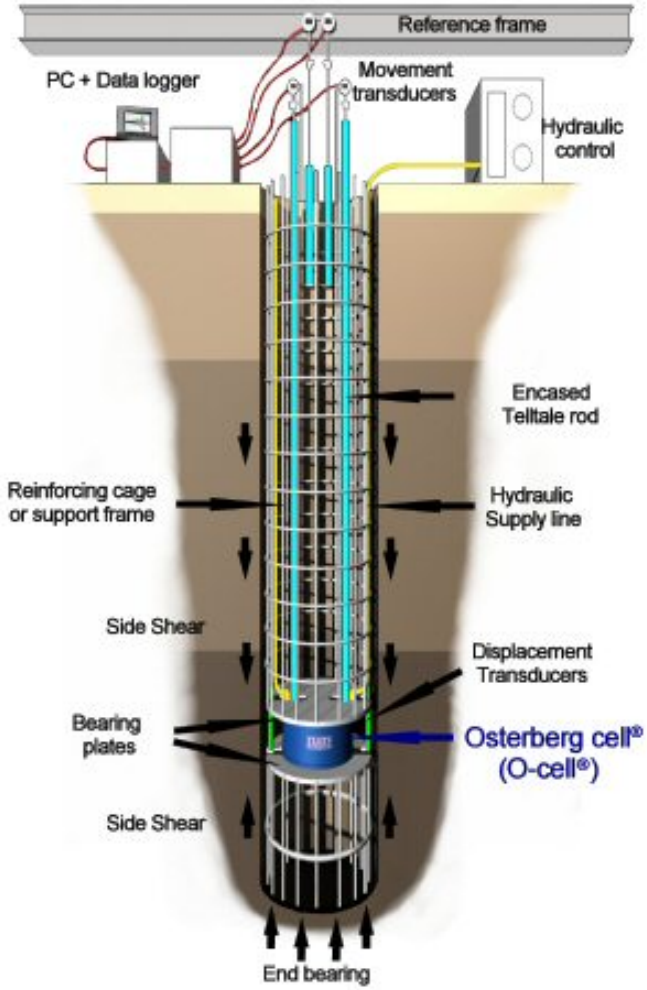
- For Pipelines 36-inch and Larger
- Long Lead Time Items
- Must be inserted at Proper Location or they are useless

No Lube – Lube – No Lube – Lube – No Lube



Full-scale Man-induced and Natural Tests

Osterberg Load Cell

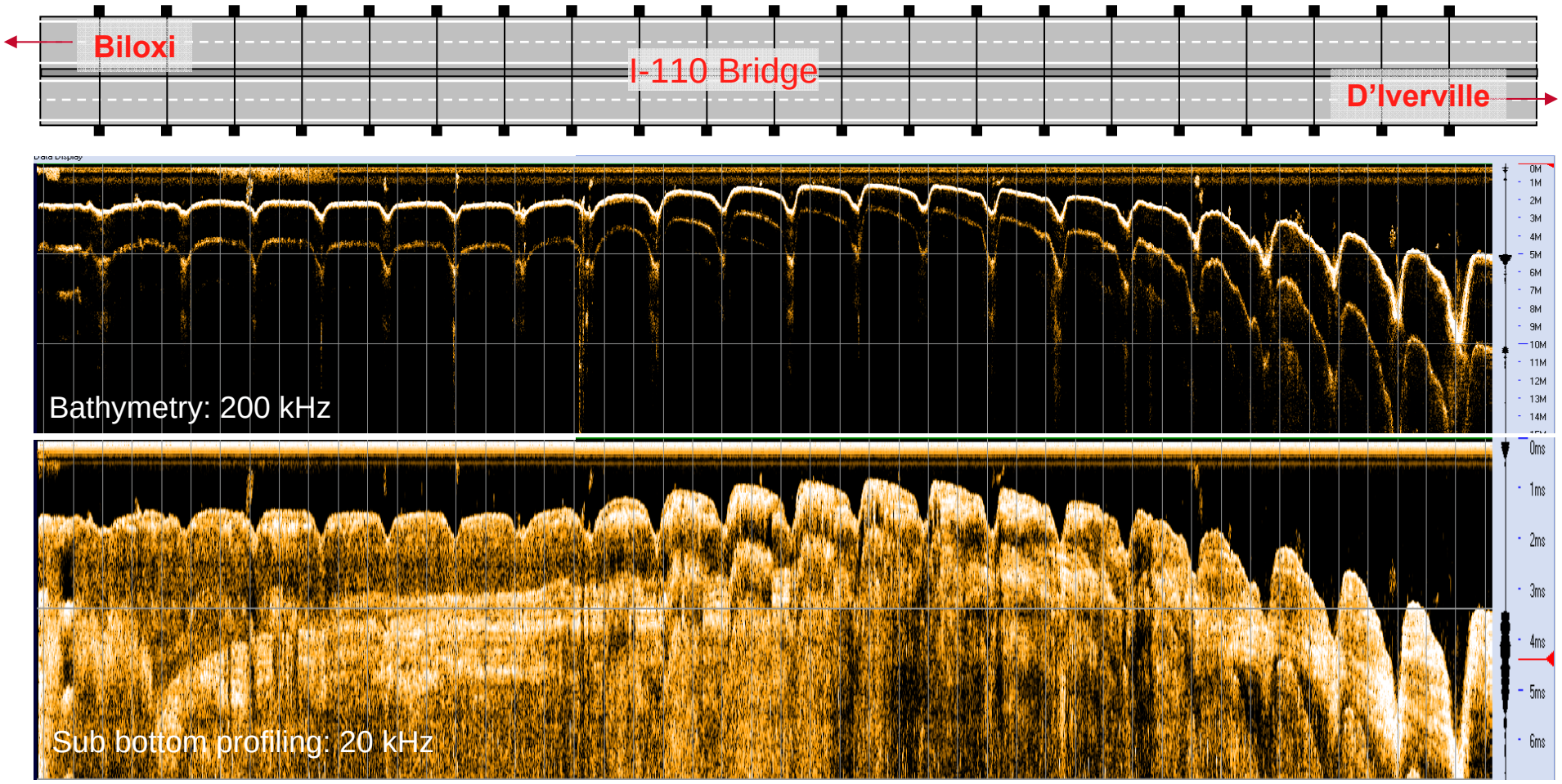


(courtesy LoadTest)

Hurricane Storm Surge

(courtesy Santamarina)

Hurricane Storm Surge



(courtesy Santamarina)

Insight Inspired

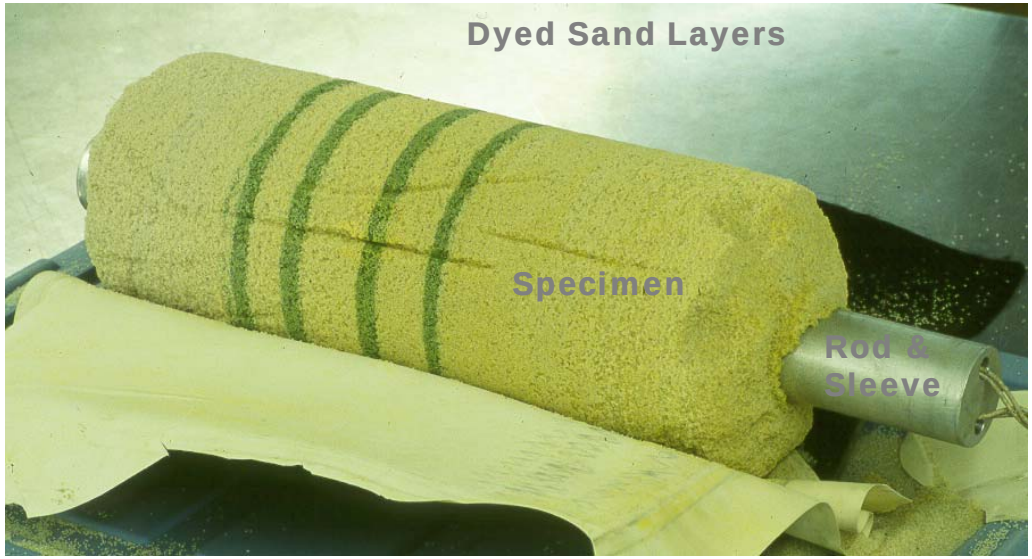
Shearing Mechanisms

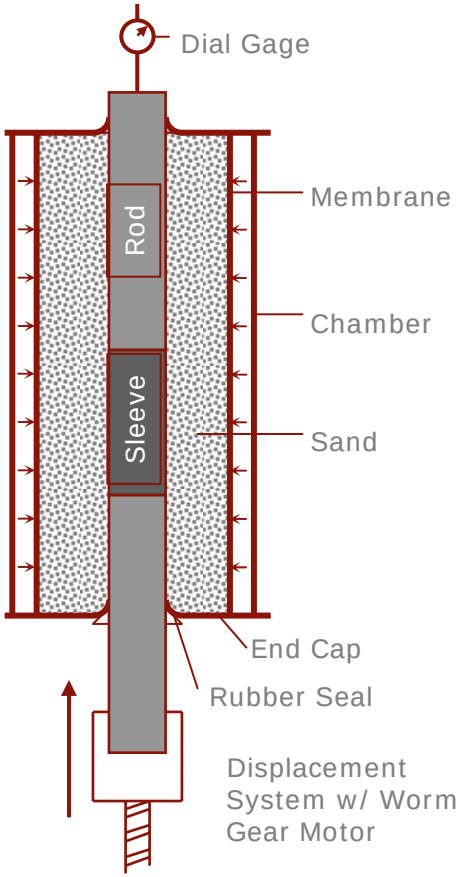
Ottawa 20-30 Sand Specimen with Dyed Sand Layers

Structure Preservation After Shearing: Phenolic Resin (1% by weight)

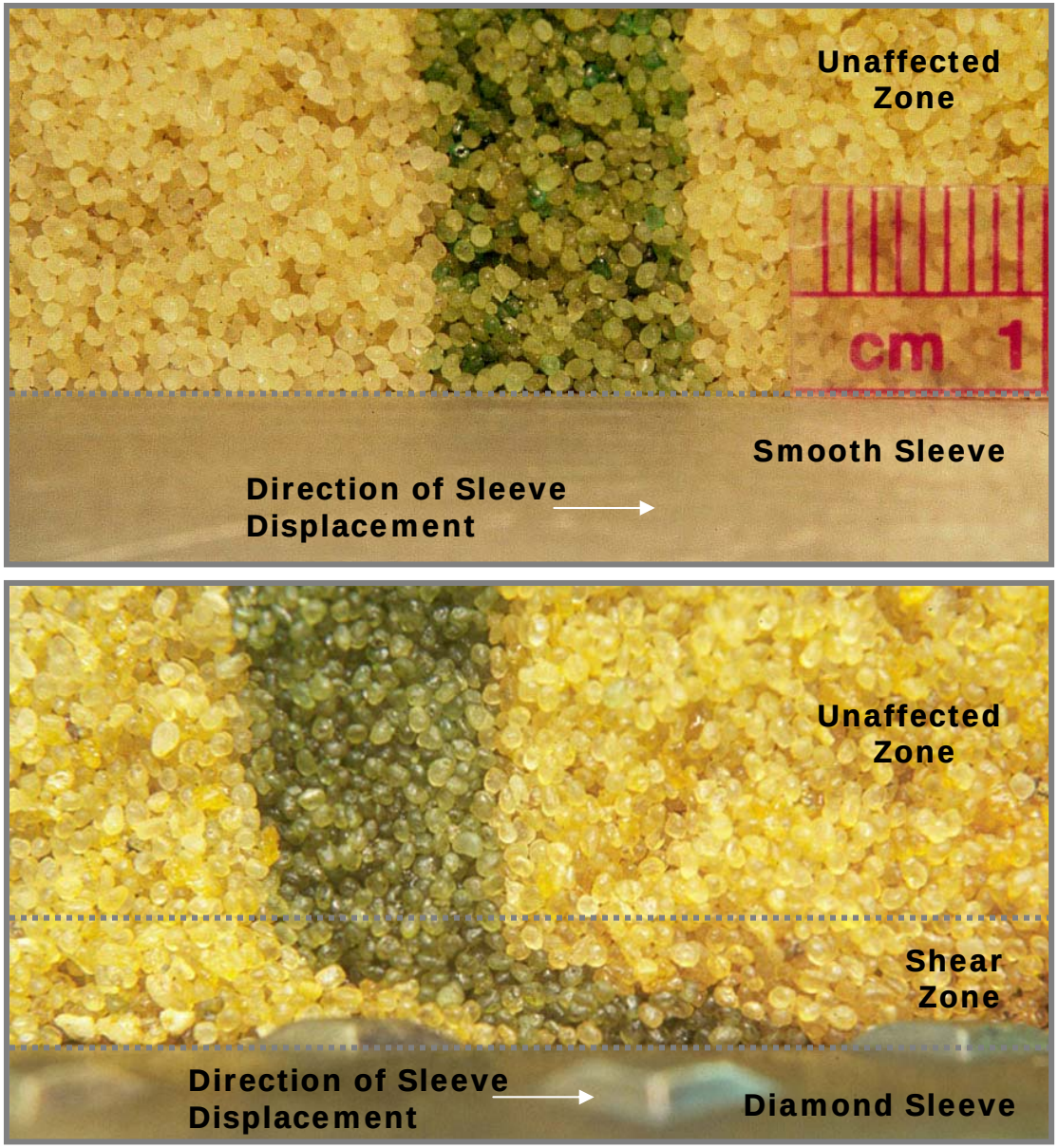
Confining Stress = 50 kPa

Rod/Sleeve Displacement = 67.5 mm

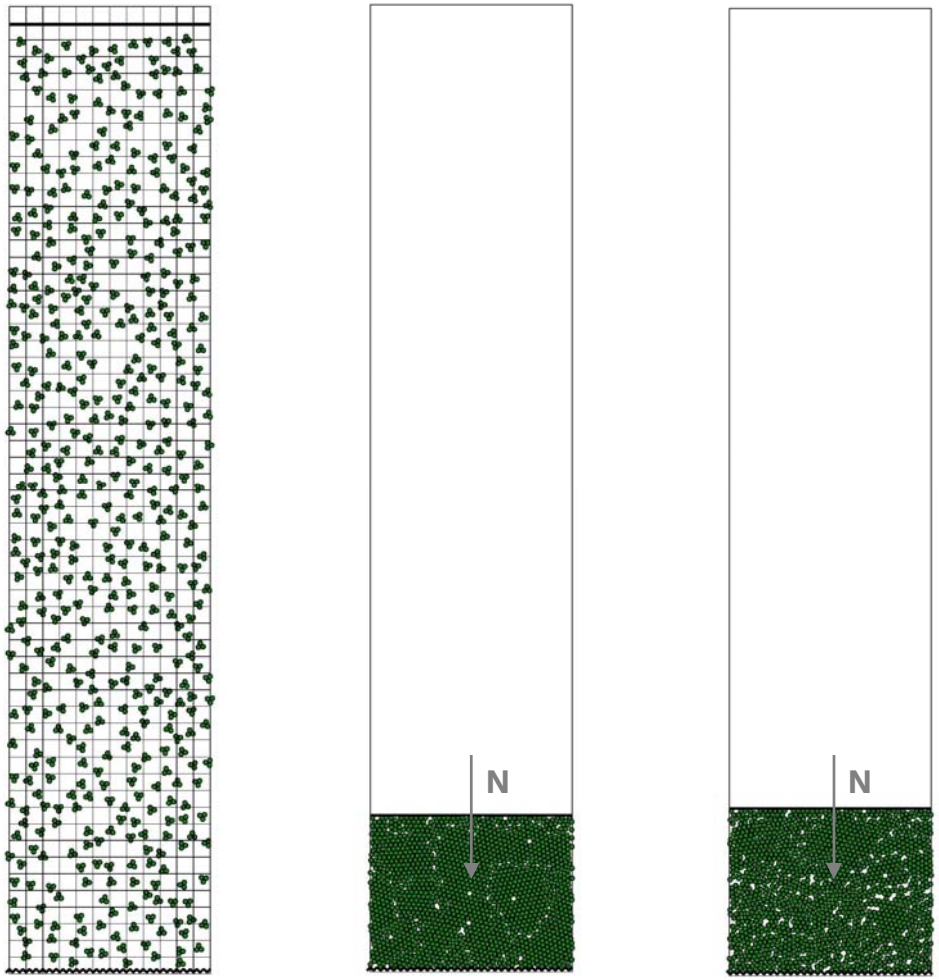




Shearing Mechanisms



Discrete Element Modeling



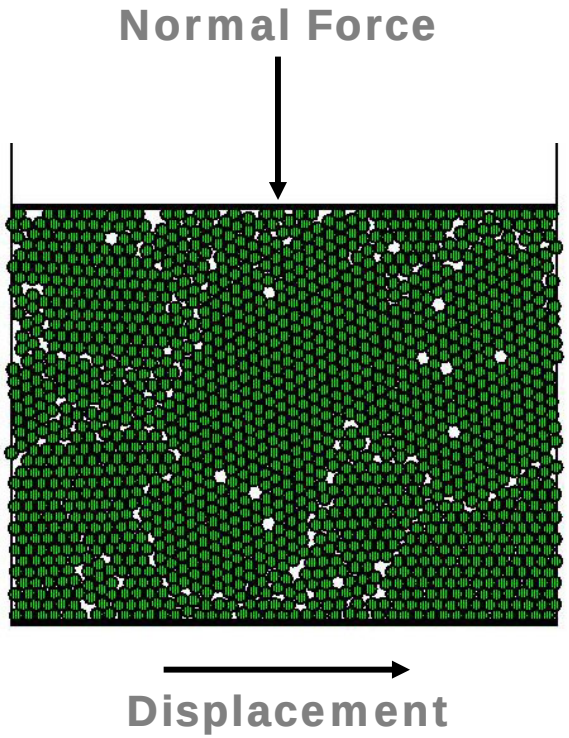
Random Cluster Generation

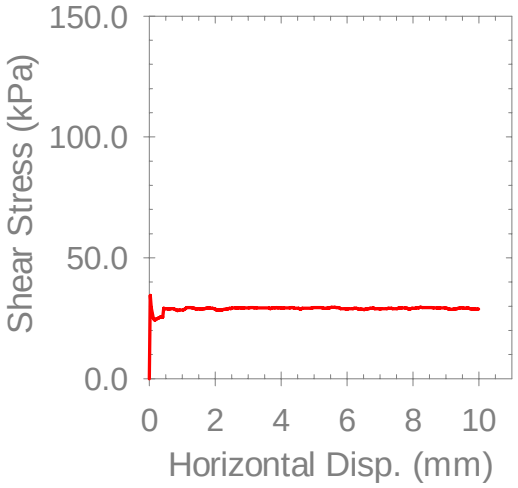
Consolidation

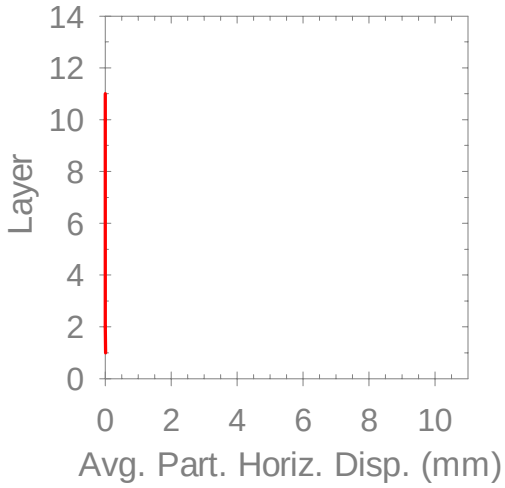
Shearing

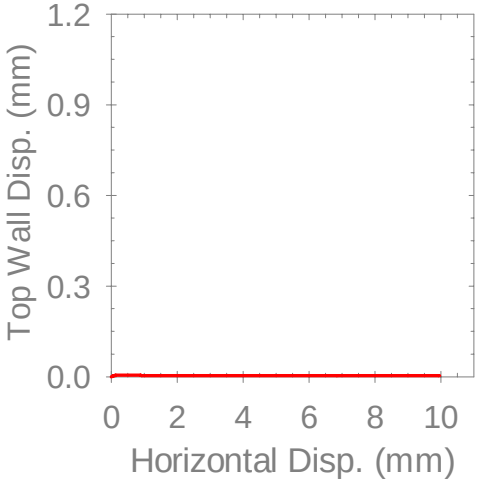
Discrete Element Modeling

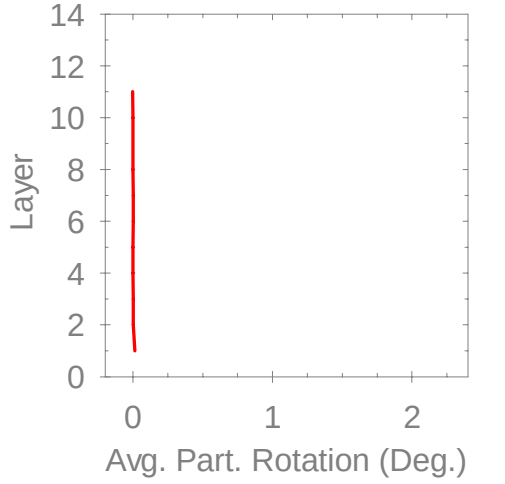
- Smooth Surface
  $\mu_{p\text{-}p}$ = 0.4
  $\mu_{p\text{-}c}$ = 0.3





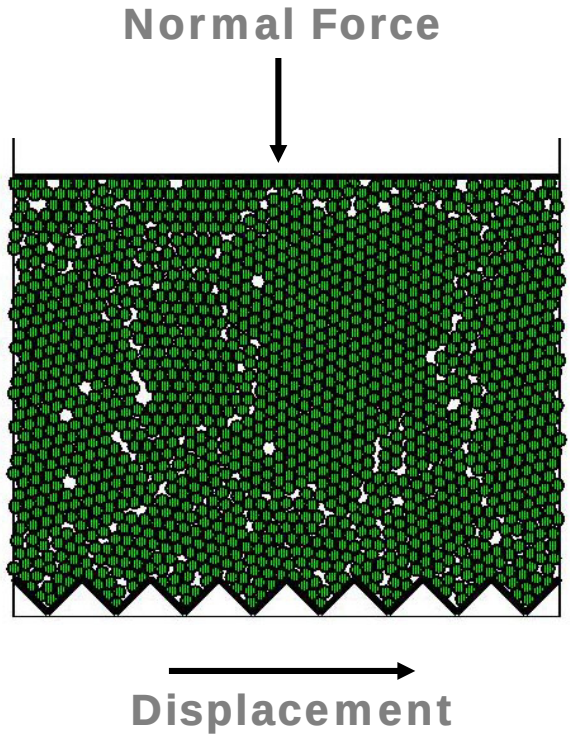


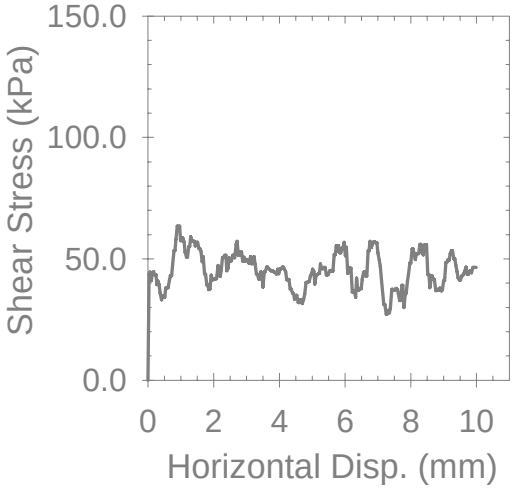


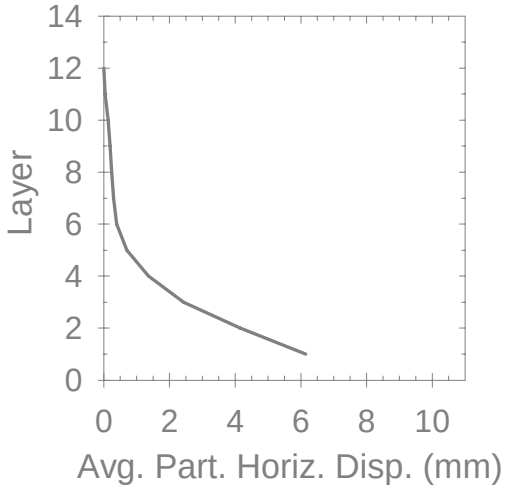


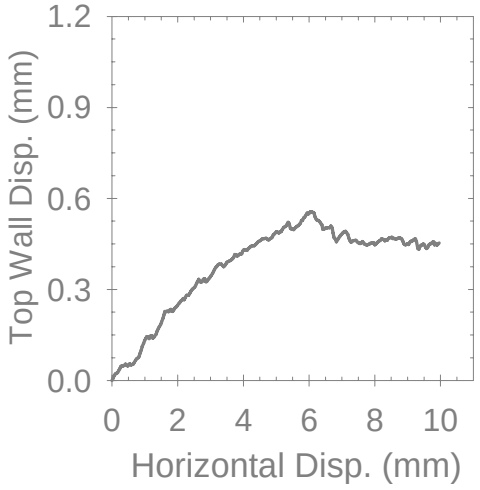
Discrete Element Modeling

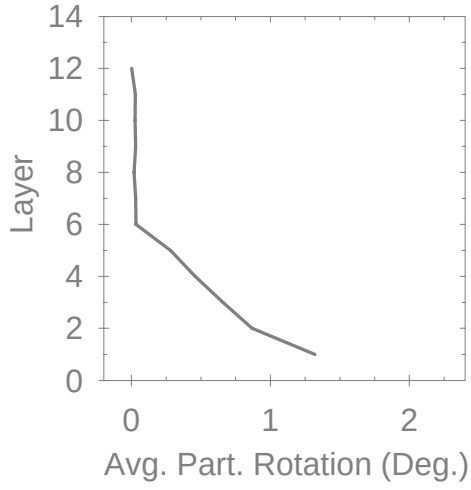
- Textured Surface
  $\mu_{p\text{-}p}$ = 0.4
  $\mu_{p\text{-}c}$ = 0.3



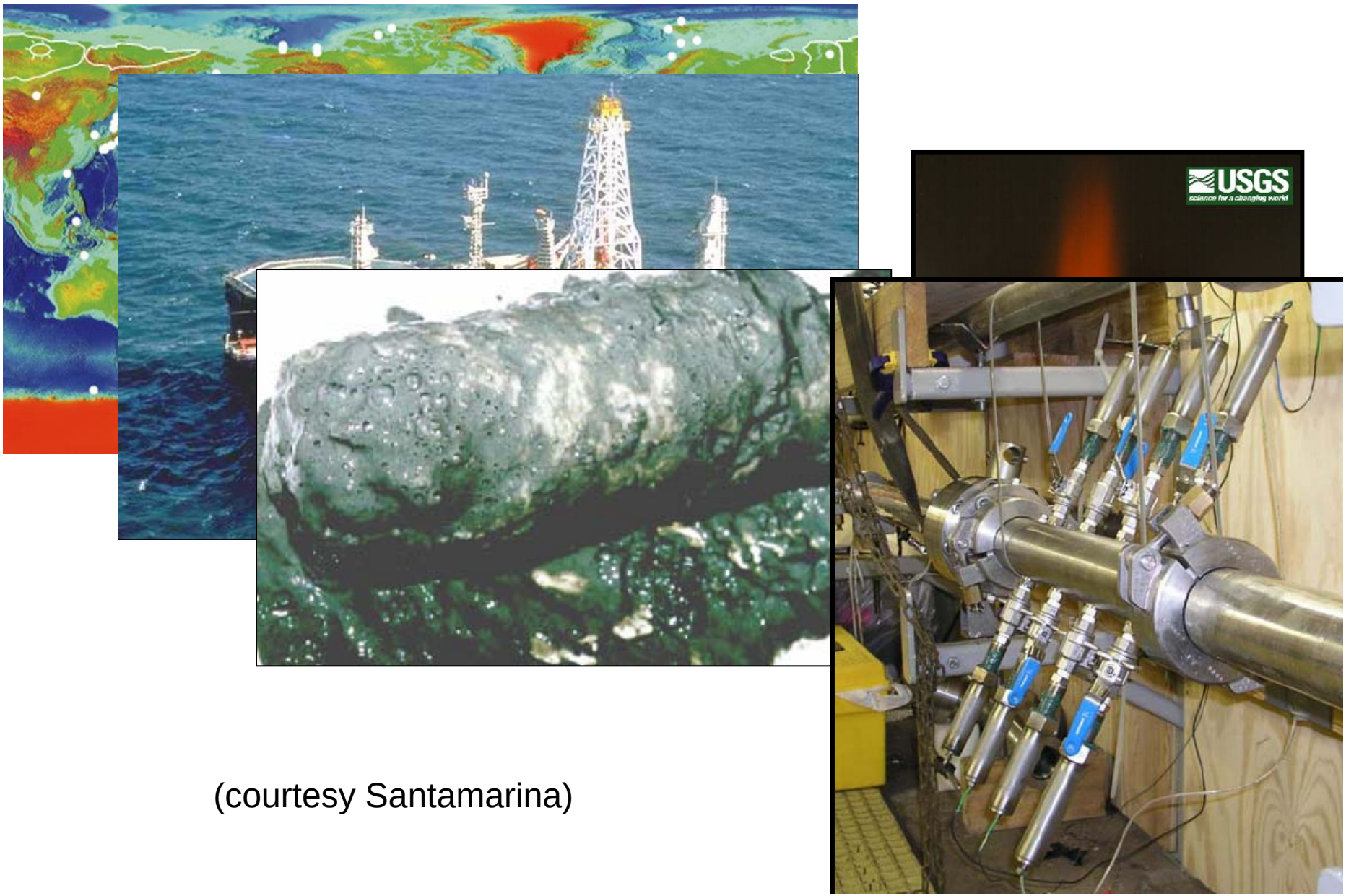






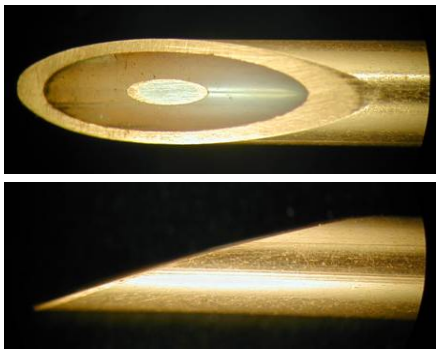


Emerging Opportunities



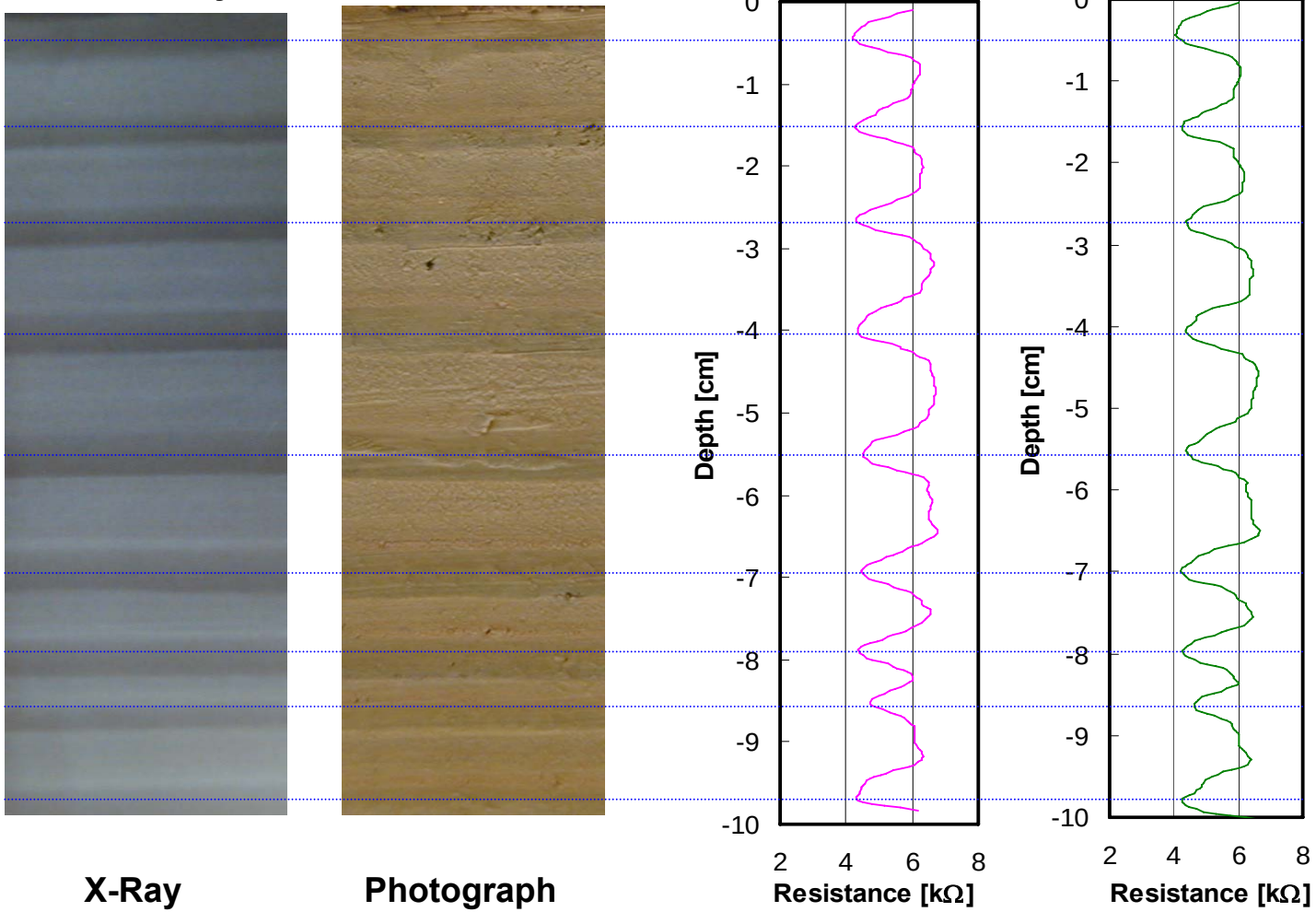
(courtesy Santamarina)

Spatial Variability: Electrical Needle Probe



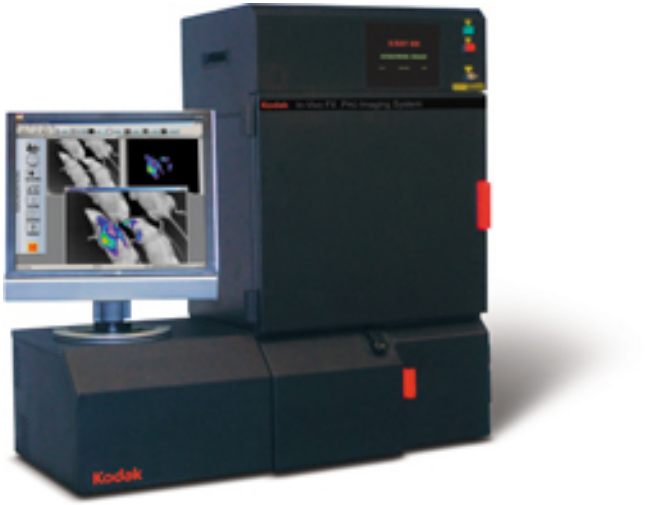
(courtesy Santamarina)

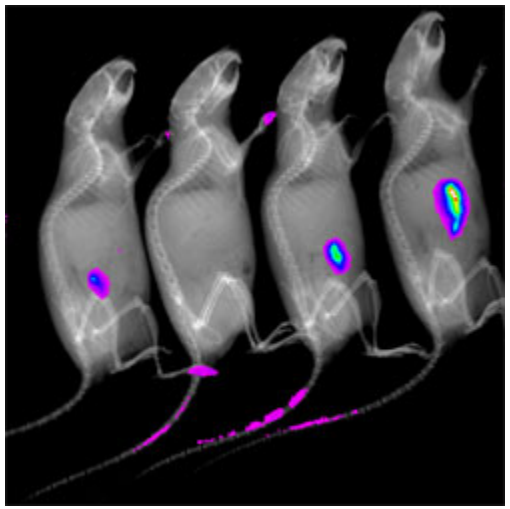
Varved Clay



X-Ray **Photograph**

In-Vivo Optical Molecular Imaging



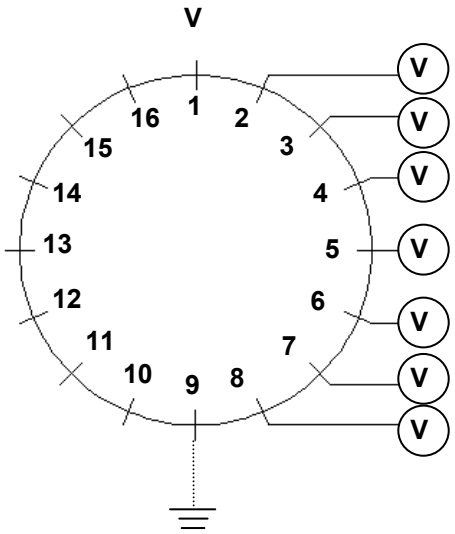


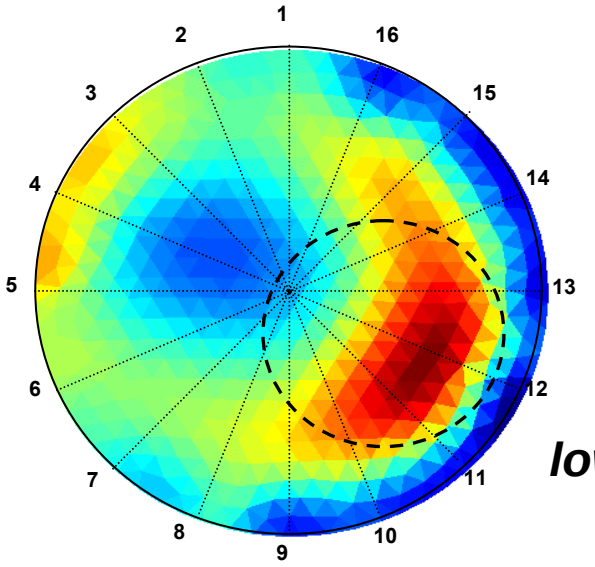
The Kodak In-Vivo Multispectral Imaging System FX locates and monitors changes in molecular activity of specific cells and organs long before morphological changes can be detected…….

Editors Choice – Bioscience Technology March Innovations.

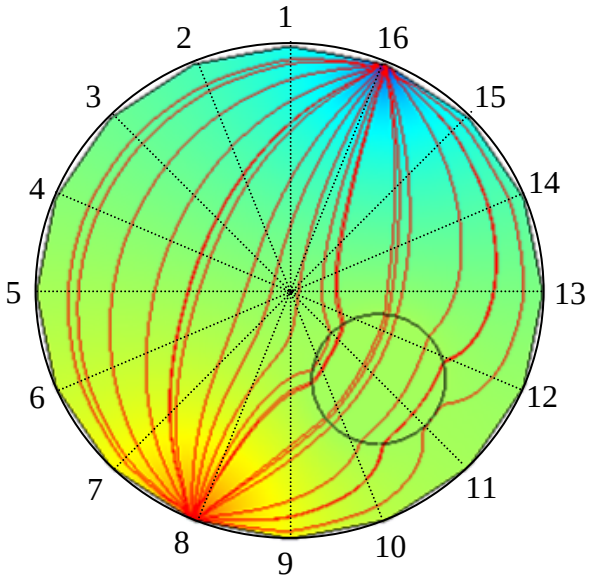
(courtesy Kodak)

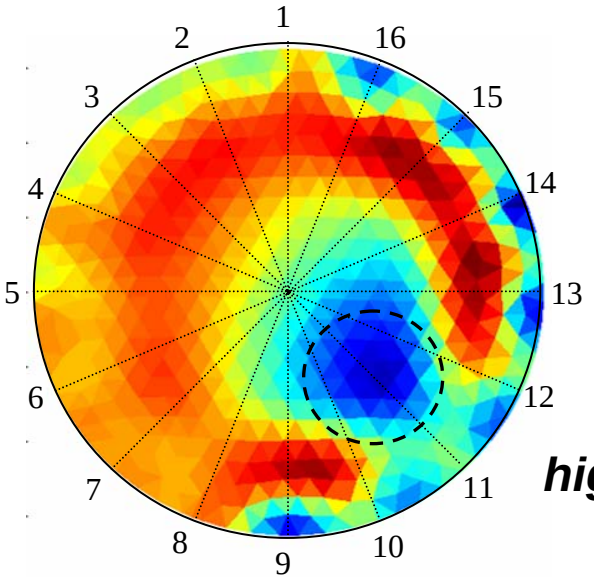
Resistivity Tomography ERT (courtesy Santamarina)





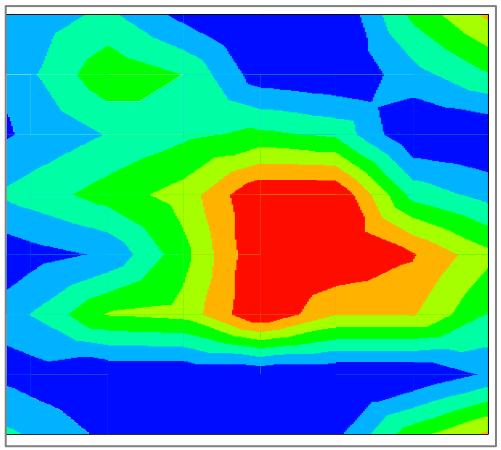
low σ

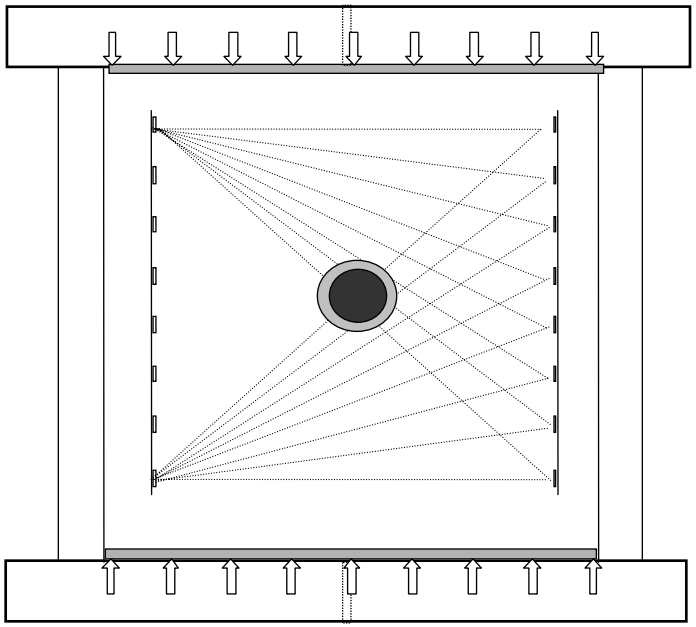


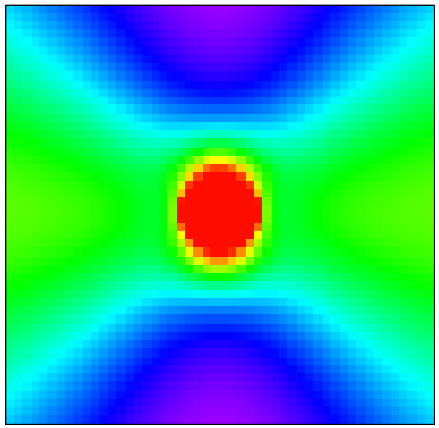


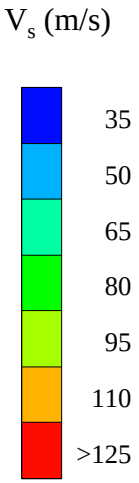
high σ

Shear Wave Imaging – Stress around tunnels



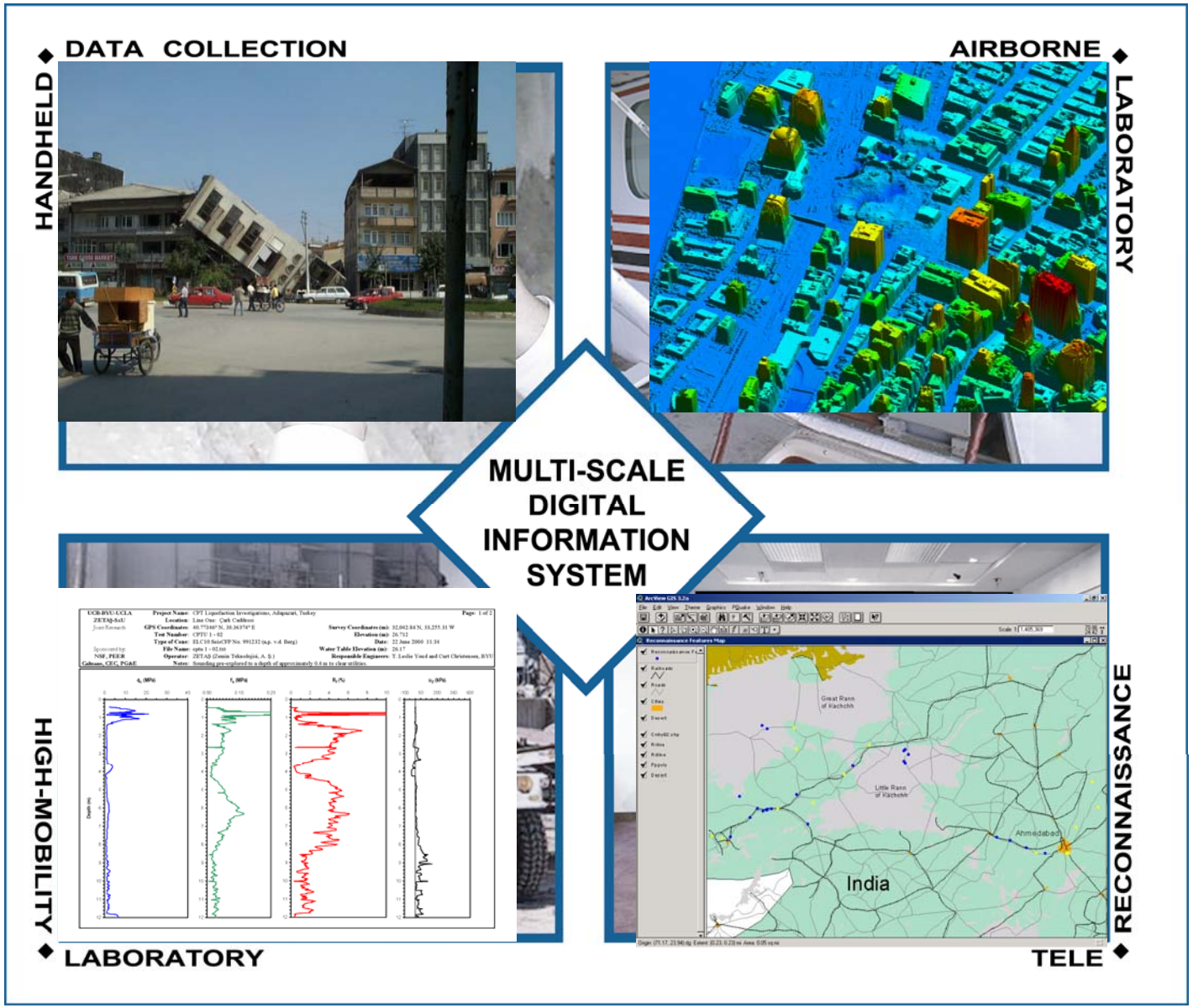






(courtesy Santamarina)

Next Generation...



Thank You.

(courtesy Hebeler)