



RPUG 2018 CONFERENCE - SOUTH DAKOTA

30 Years On The Road To Progressively Better Data

Rapid City September 18-21

Aggregate Micro-Texture Analysis based on Morphometric Parameters

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Sponsored by TxDOT and US DOT

Overview

- Introduction
- Research Motivation
- Research Goal
- Research Methodology
- Experiments & Results
- Conclusions & Future Work

Introduction



- Safety of Road Users
- Accidents

- ~ 20 – 30 % Wet Accidents
- Skid Resistance

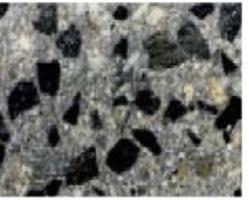
SKID RESISTANCE IS AFFECTED BY SEVERAL FACTORS



Road Condition
(Wet or Dry)



Pavement
Texture



Tire Condition



Ride Quality

Skid Resistance

Pavement Surface Profile Characteristic

Wavelength

Scale

Roughness

$0.5 \text{ m} < \text{Wavelength} < 50 \text{ m}$

Short Segment of Road

Mega-texture

$50 \text{ mm} < \text{Wavelength} < 500 \text{ mm}$

Tire

Macro-texture

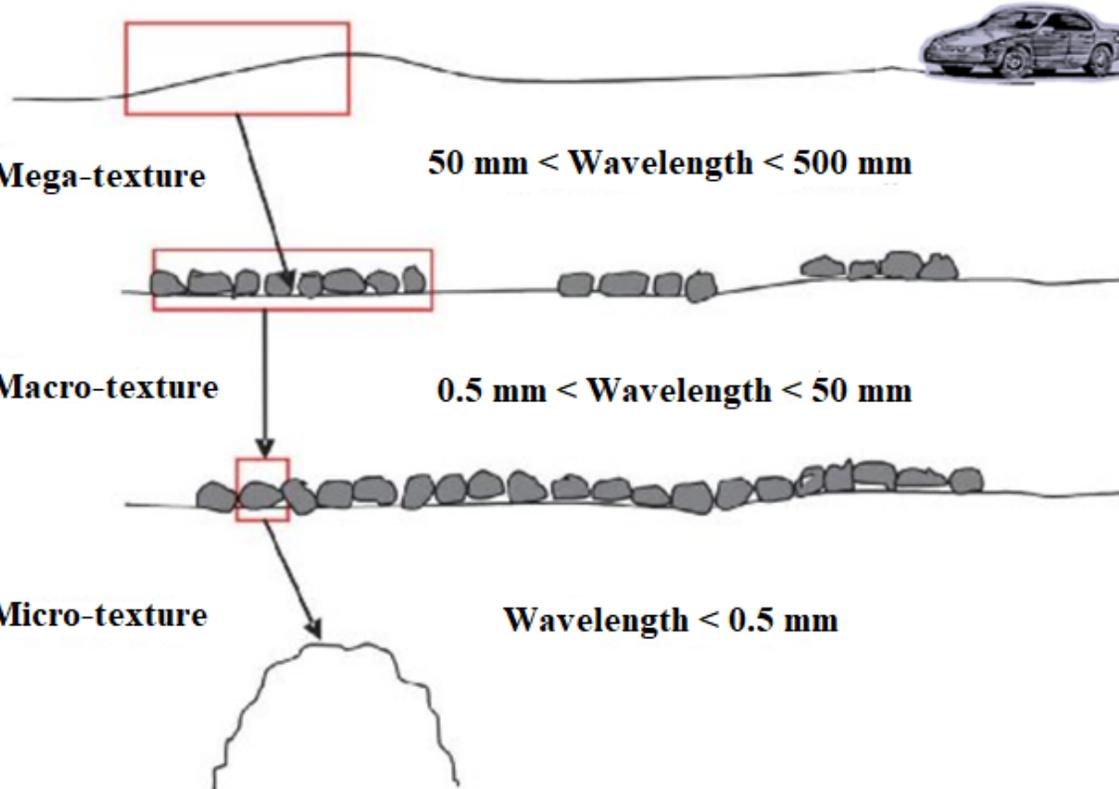
$0.5 \text{ mm} < \text{Wavelength} < 50 \text{ mm}$

Tire - Road Contact Patch

Micro-texture

$\text{Wavelength} < 0.5 \text{ mm}$

Single Aggregate



Research by Pedro A. Serigos et al. 2016

- ❖ 28 flexible pavement surfaces
 - ❖ Skid Resistance → Under wet condition & using BPT
 - ❖ Pavement Macro-Texture → CTM & MPD
 - ❖ Pavement Micro-Texture → LTS & Texture profile parameters*
- *Texture Profile Parameters: Spectral, Amplitude and Slope Parameters
- ❖ A linear model between the skid resistance and the macro-texture

Incorporating the micro-texture parameters into the skid resistance prediction model is significant.

Research Motivation

Connection Between Pavement Micro-Texture and Skid Resistance

Need to Improve Pavement Micro-Texture

Need for Aggregate Particles with Rougher Texture in the Mixture

Need for an Objective Measuring Method

Goal and Objectives

□ Goal:

Improving **Aggregate Texture Characterization** Using a High-Resolution Digital Microscope.

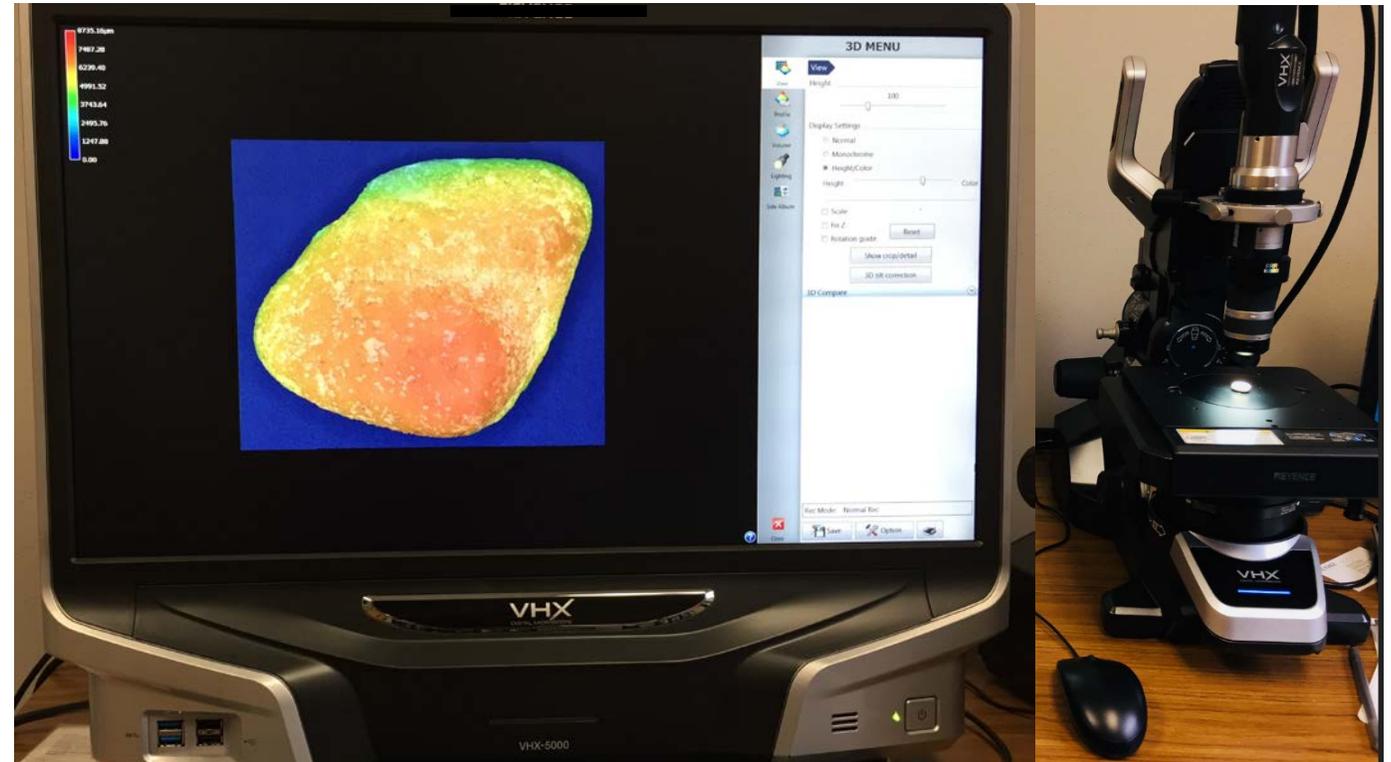
□ Objectives:

- Collecting Three – Dimensional Surface Texture Data.
- Developing an Algorithm to Quantify Aggregate Surface Micro-Texture.
- Comparing the Surface Texture of Different Aggregate Particles.

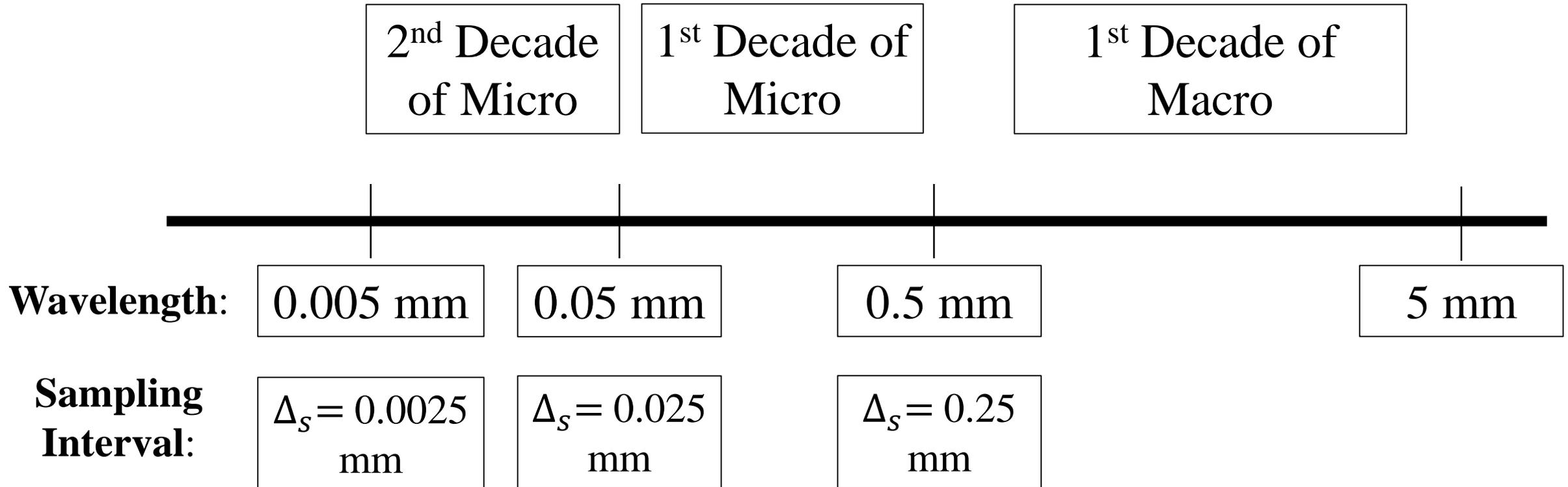
3D Surface Texture Measurement Approach

3D Approach vs. 2D Profile Measurement:

- Surface texture is 3D.
- Missing surface peaks and valleys in 2D.
- More data in 3D.
- Precise results in 3D.



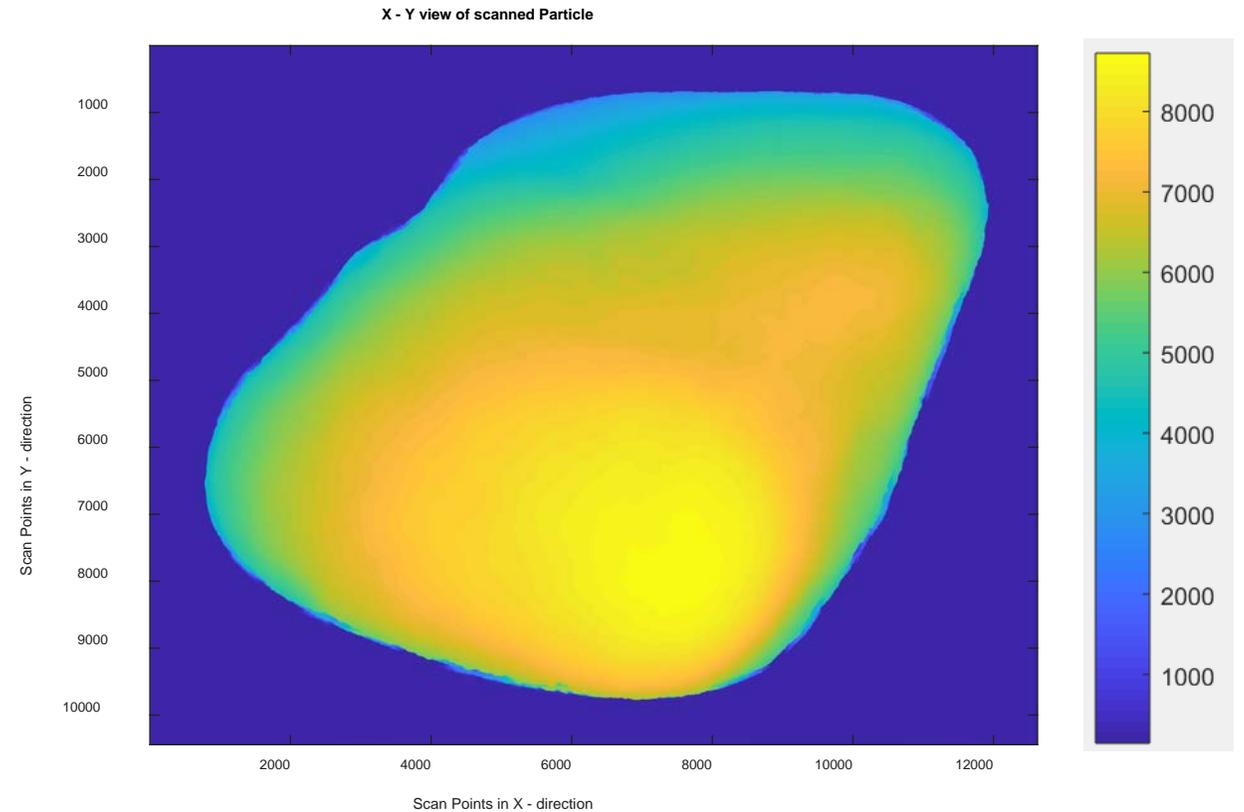
Scan-sampling Interval



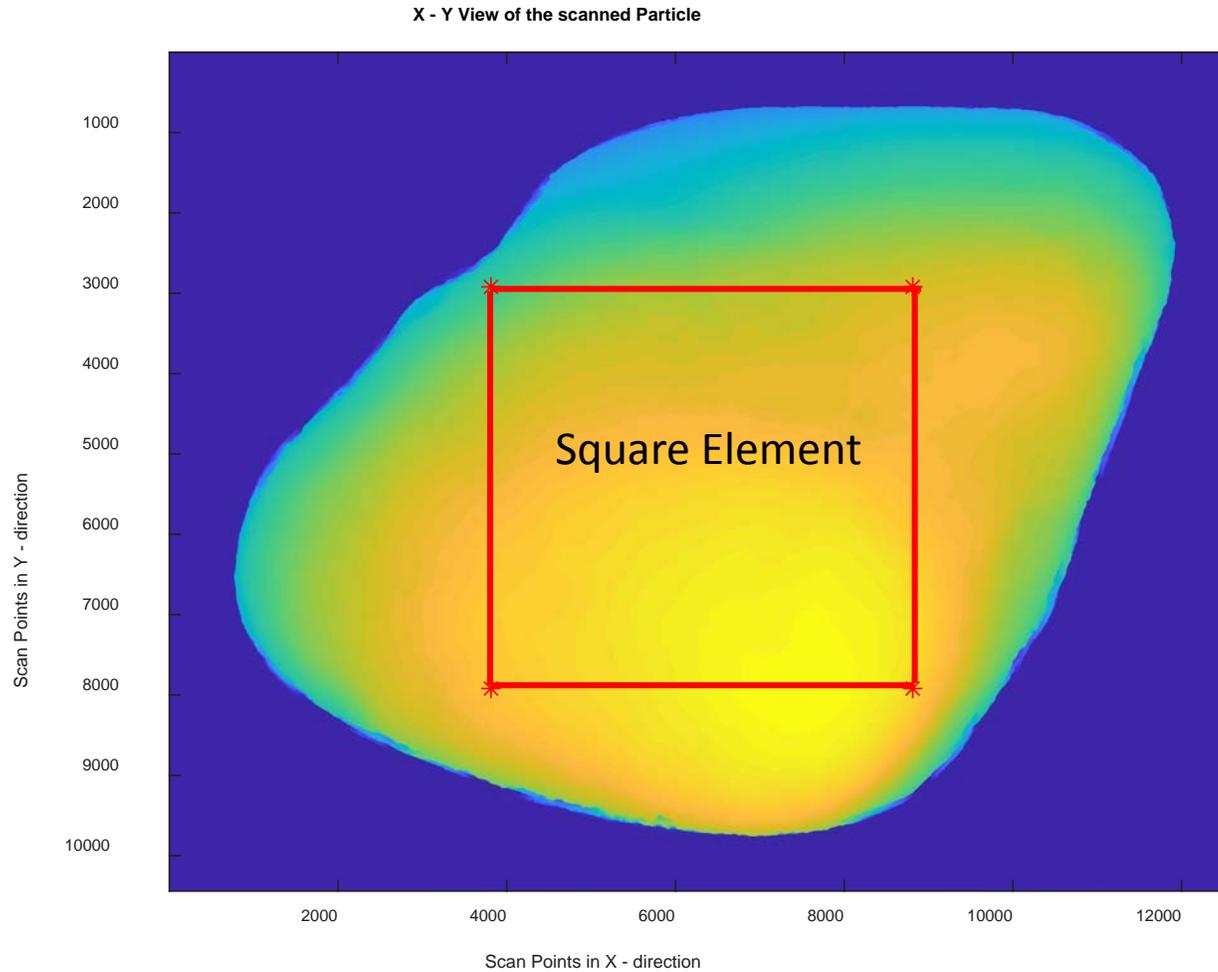
❖ Shannon Sampling Theorem

Micro-Texture Measurement Process

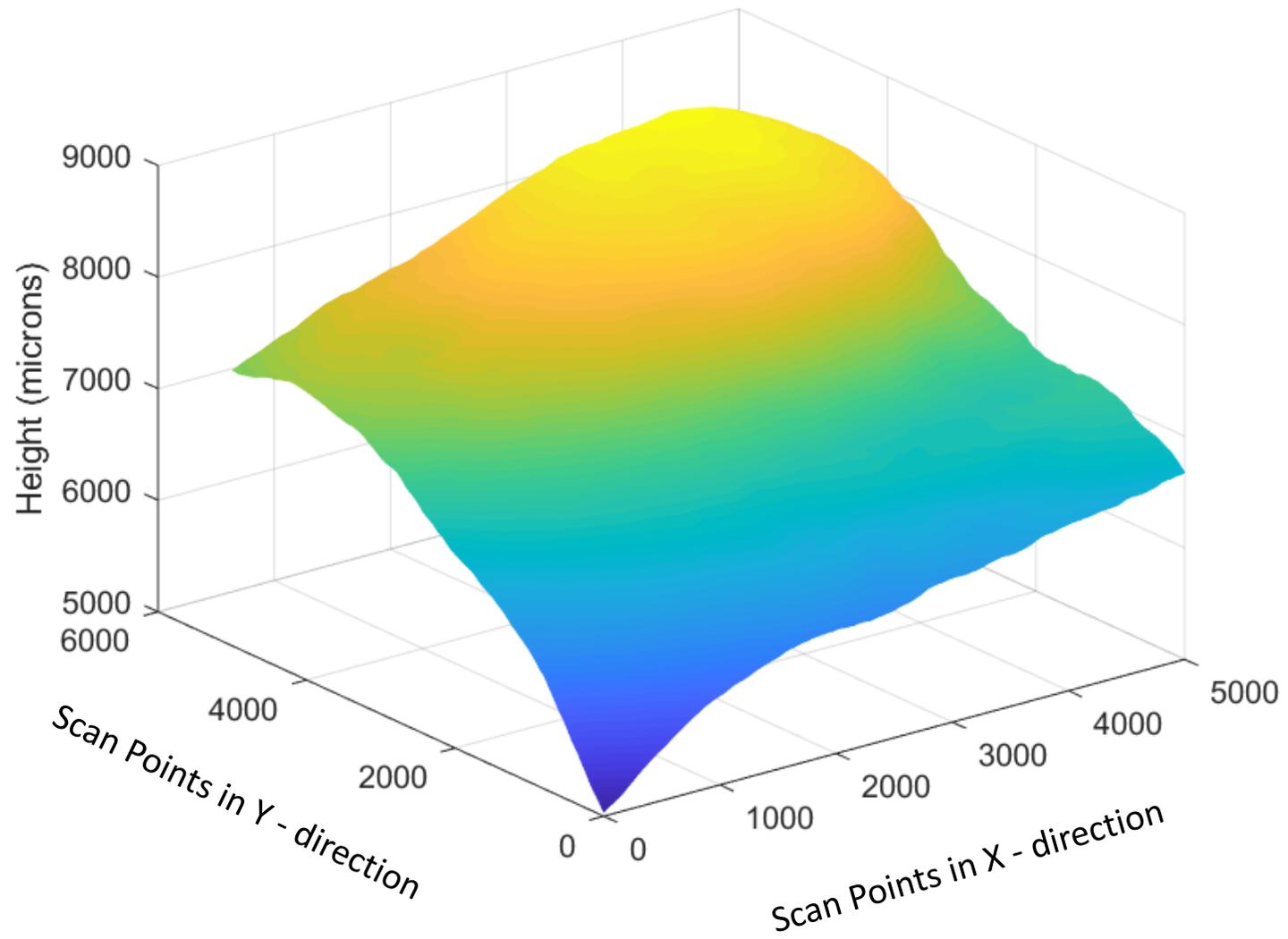
1- Scanning an Aggregate Particle



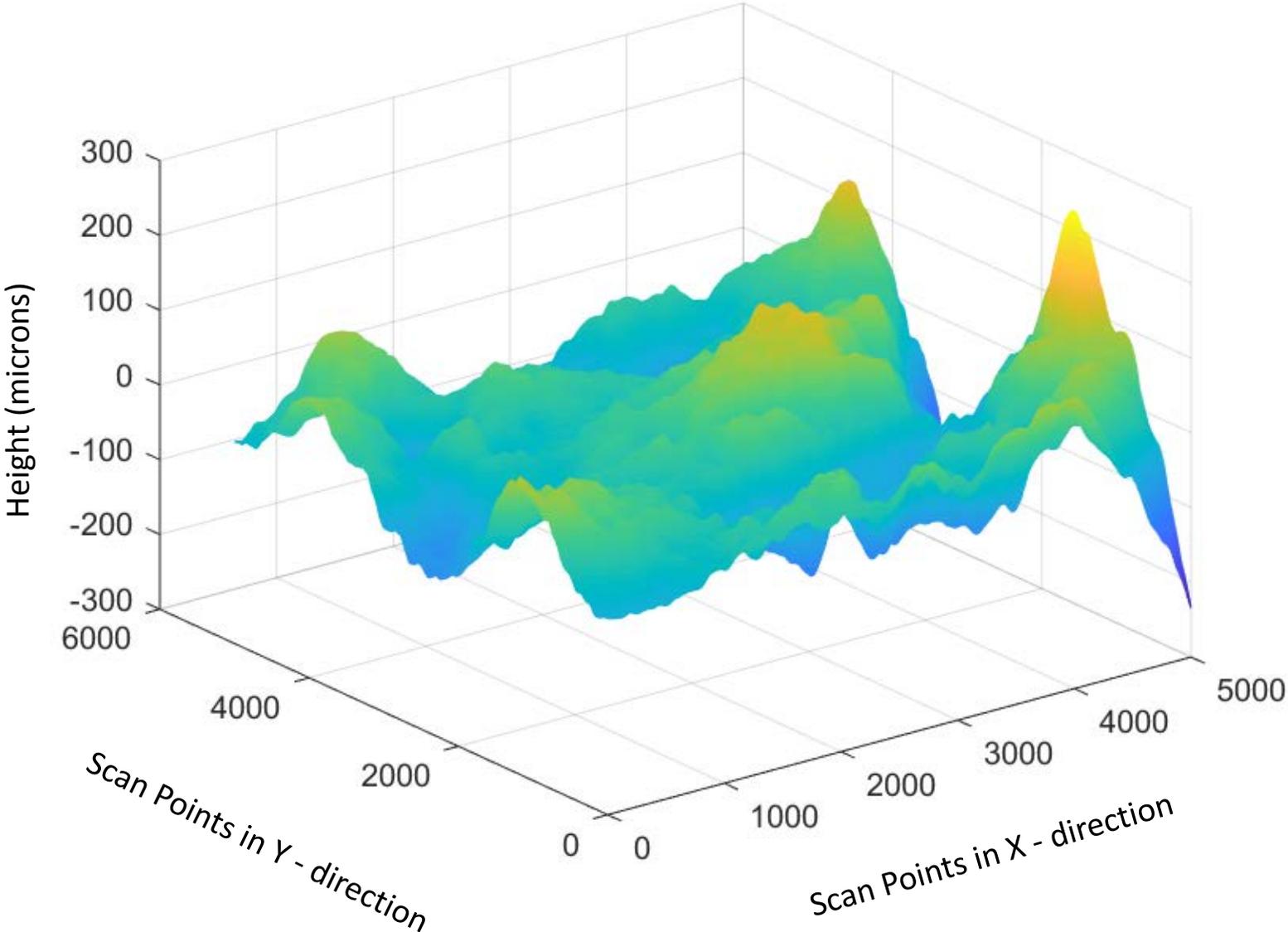
2- Selecting a Square Element



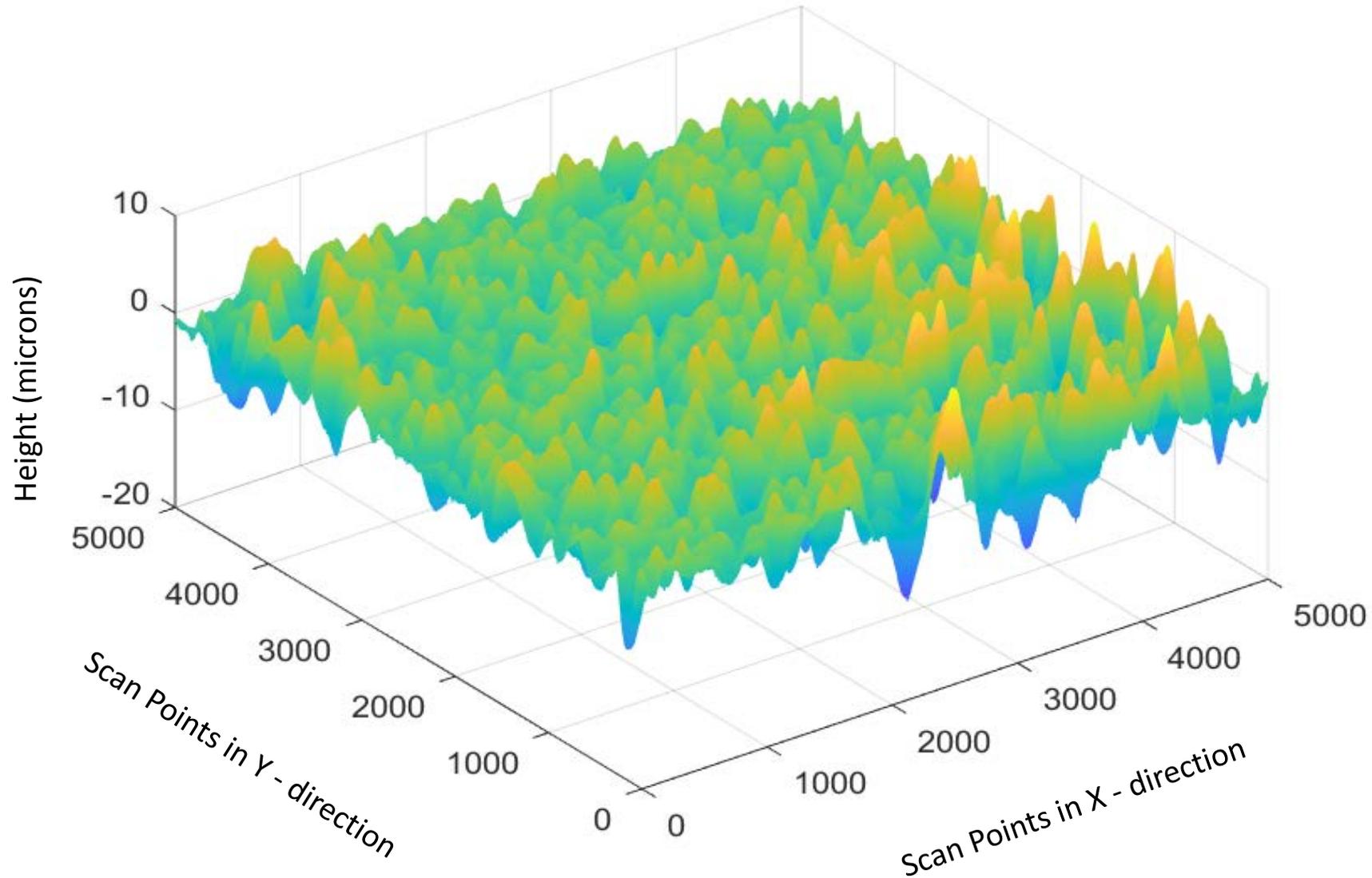
3- Extracting a Square Element



4- Detrending the Extracted Data



5- Filtering out the Macro-Texture Part



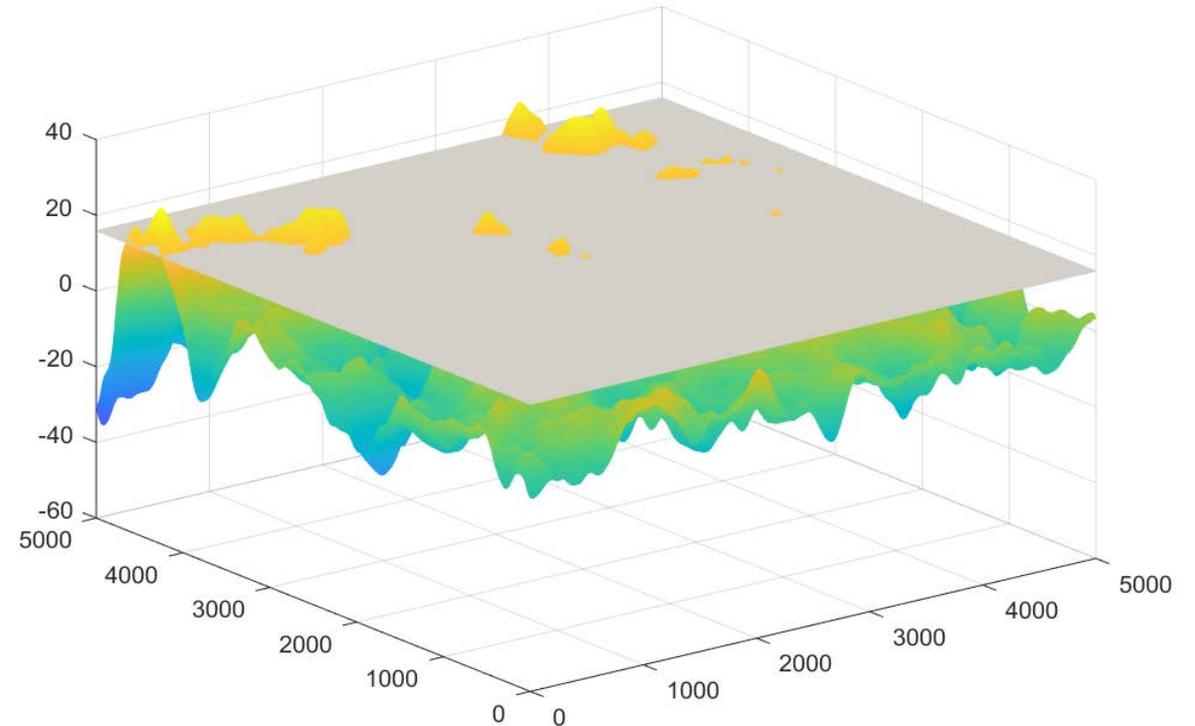
6- Calculating the Texture Parameters

- *Mean Deviation from the baseline surface (S_a)* = $\frac{\sum_{i=1}^m \sum_{j=1}^n |h_{i,j}|}{m*n} = 1.77 \mu\text{m}$
- *Root Mean Square (S_q)* = $\sqrt{\frac{\sum_{i=1}^m \sum_{j=1}^n |h_{i,j}|^2}{m*n}} = 2.66 \mu\text{m}$
 - ❖ $h_{i,j}$: height value of a Surface point
 - ❖ m: number of scan points in X – direction
 - ❖ n: number of scan points in Y - direction
- *Mean Texture Depth (MTD)*
- *Peak Density*

Mean Texture Depth (MTD)

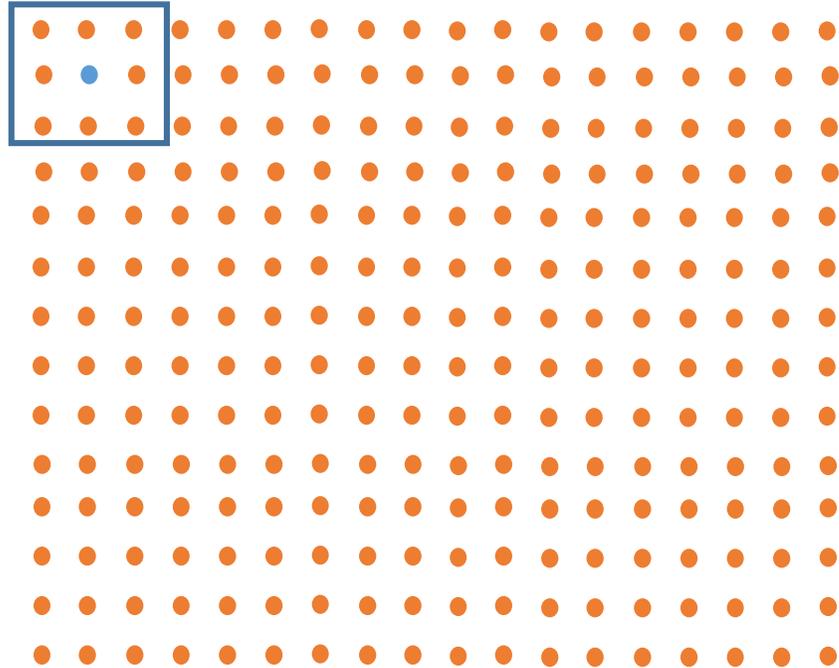
Digitalized Sand Patch Test

- Creating a reference plane at the 97th percentile value of the surface data
- Locating the surface points below the reference plane.
- Numerically integrating the volume between the measured surface and the reference plane.



$$MTD = 4.44 \mu m$$

Peak Density



Scan Points

Peak: any point, above all 8 nearest neighbors.

$$\text{Peak Density} = \frac{\text{Number of Peaks}}{\text{Area}} =$$

$$14.8 \text{ per } 100 \text{ mm}^2$$

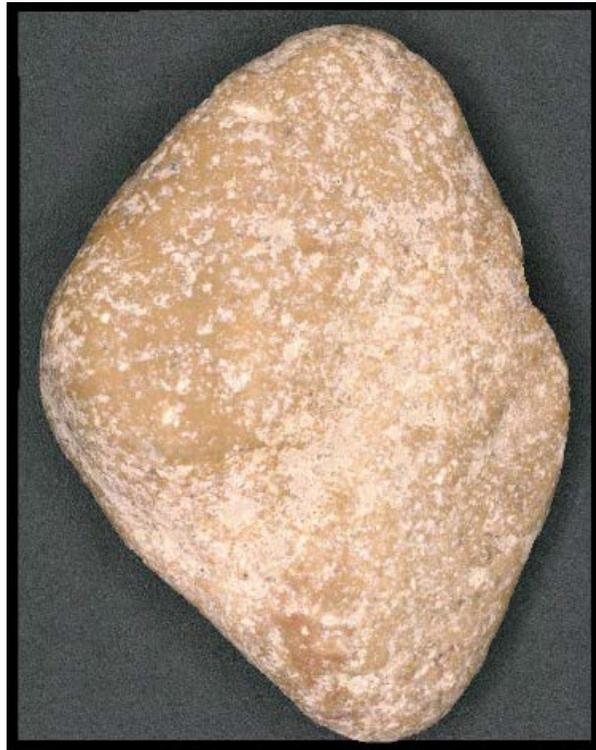
Scans at Different Orientations



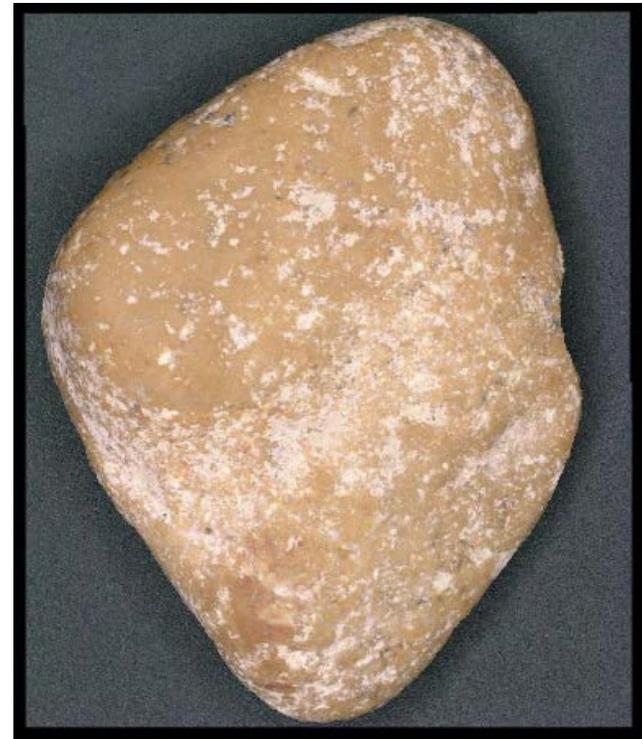
1



2



3

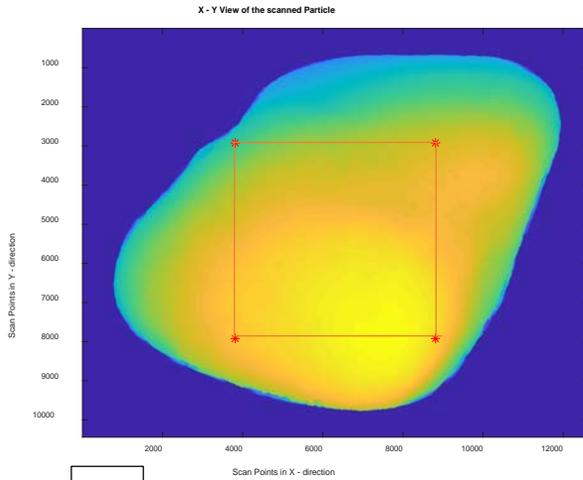


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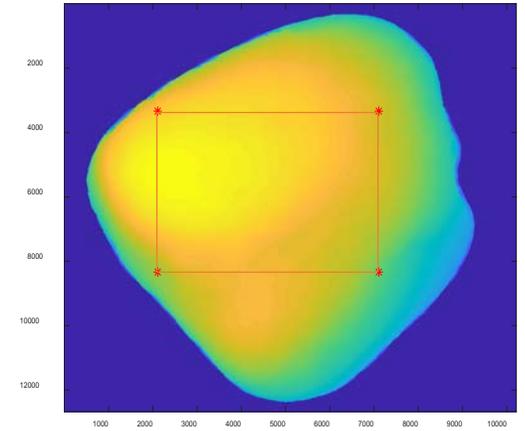


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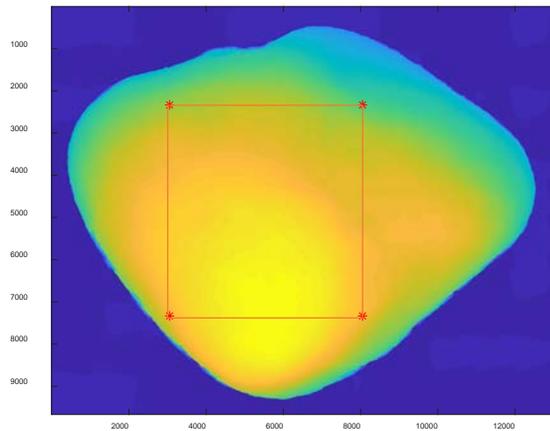
X-Y View of Scans and the Selected Square Element



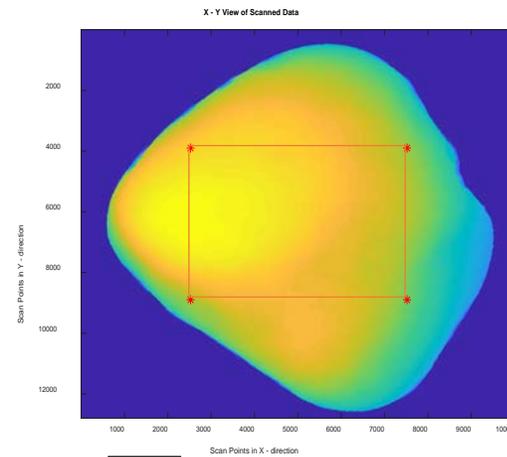
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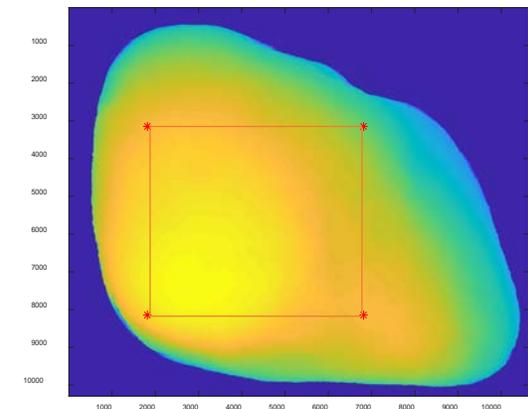
5



2



3



4

Variability of Texture Parameters

Scan Orientation	Peak Density	MTD (μm)	Sa (μm)	Sq (μm)
1	16.8	4	1.62	2.53
2	14.39	3.88	1.59	2.4
3	17.03	4.18	1.73	2.61
4	19.05	5.03	2.02	2.99
5	14.8	4.44	1.77	2.66
Mean	16.41	4.31	1.75	2.64
STD	1.88	0.46	0.17	0.22
COV	11%	11%	10%	8%

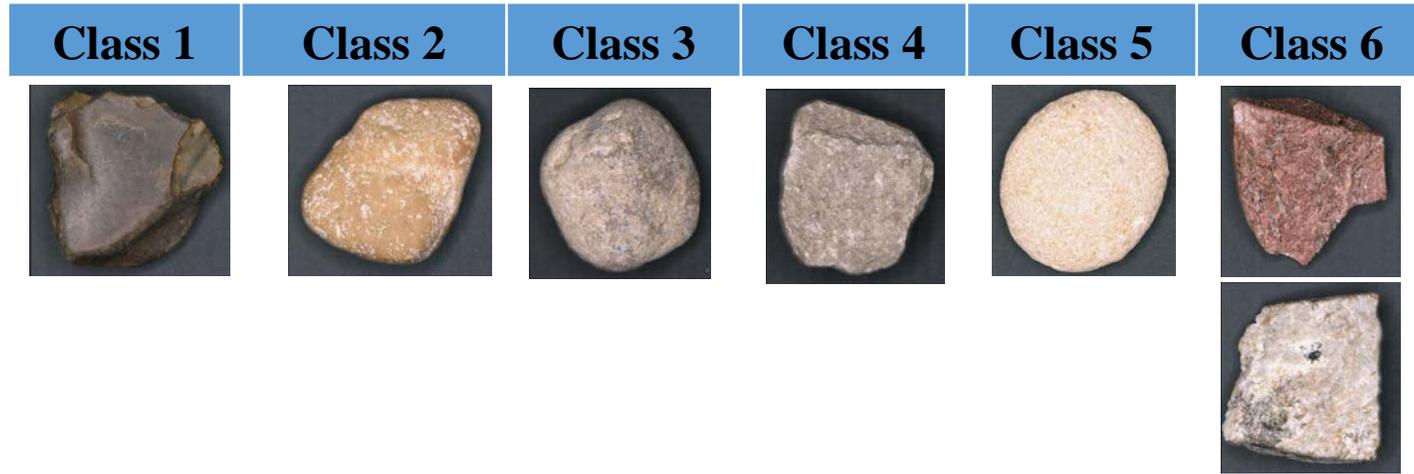
Ordering the Aggregate Samples by Touching

Low

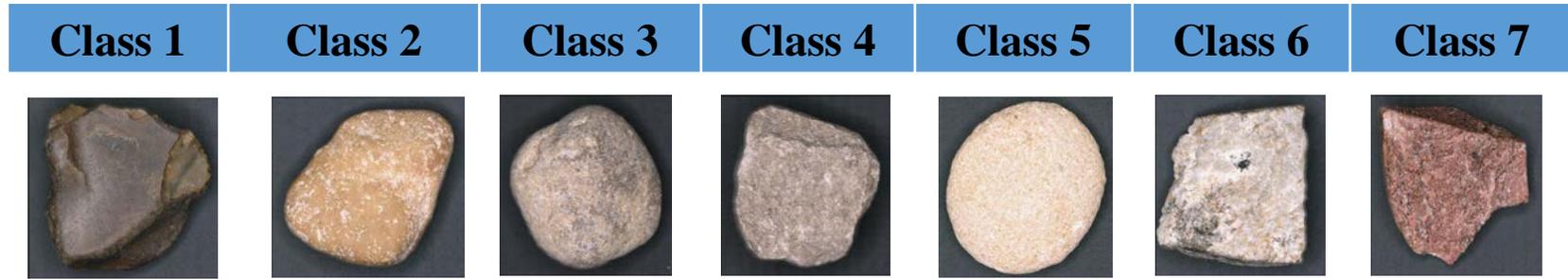
Roughness Level

High

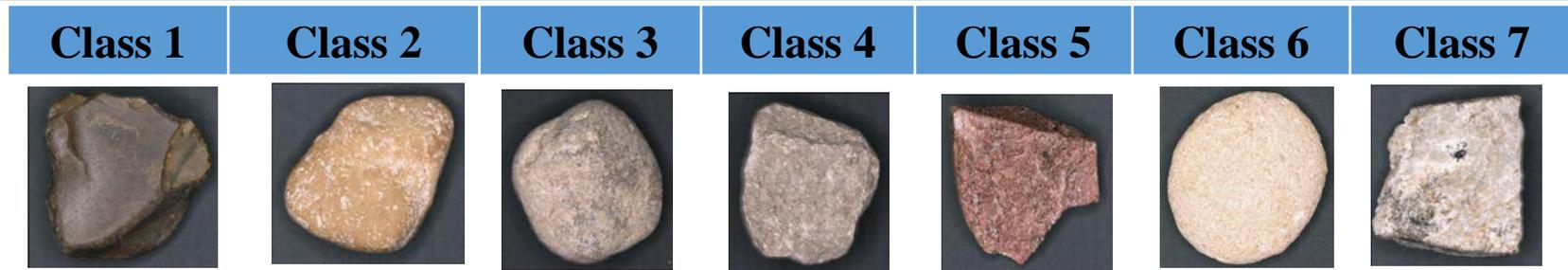
Person #1



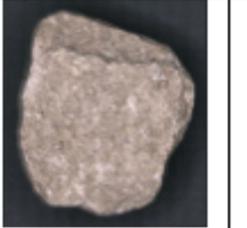
Person #2



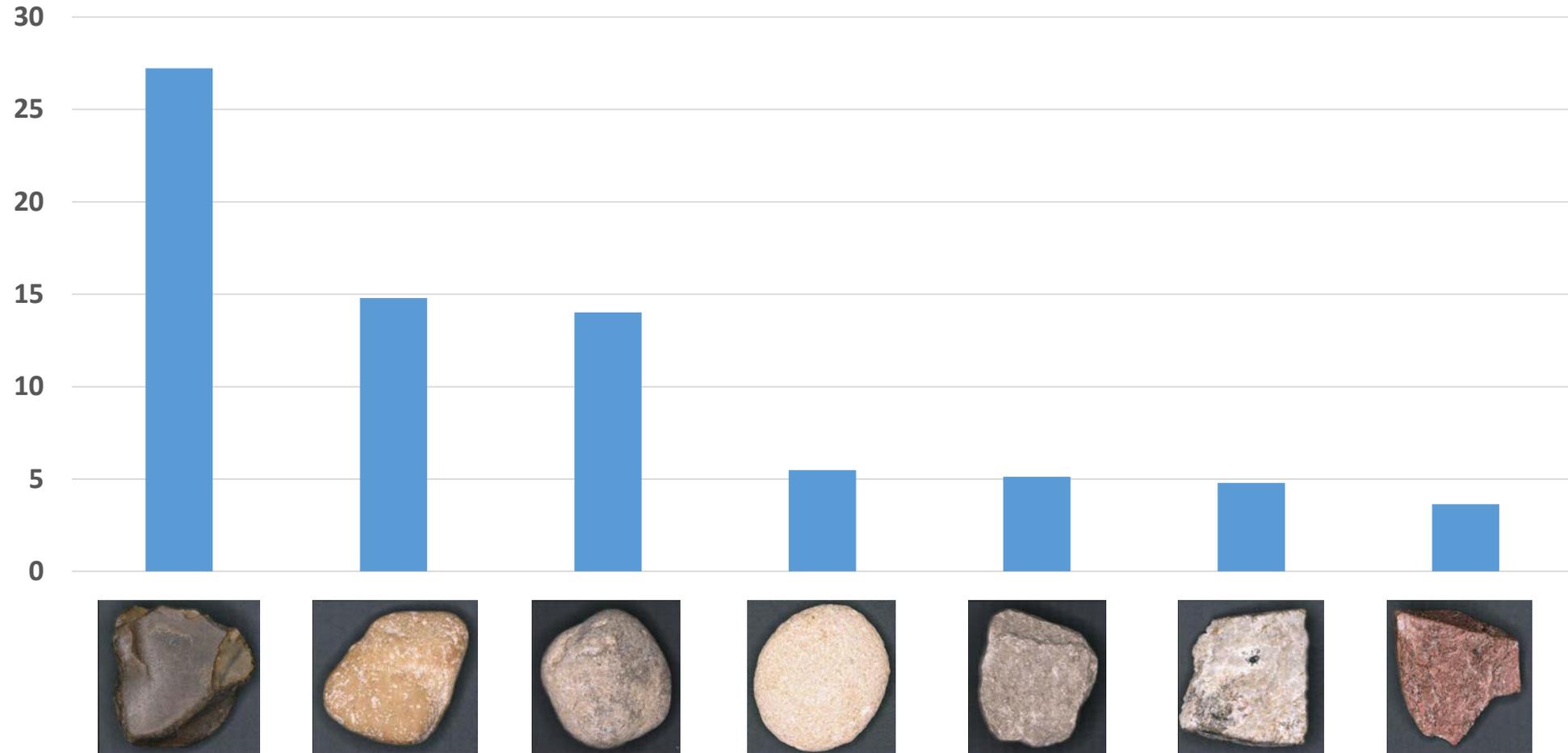
Person #3



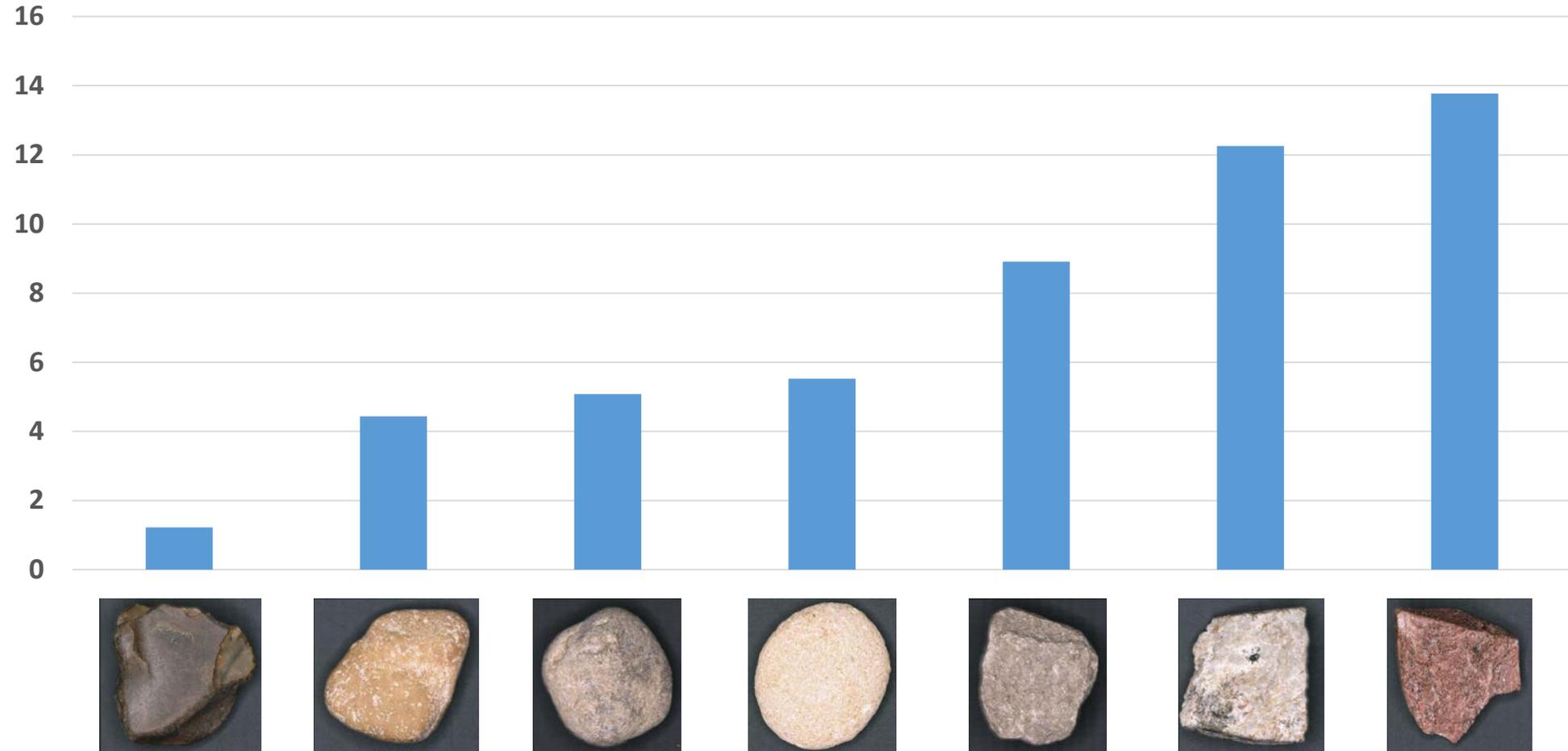
Ordering the Aggregate Samples Using the Developed Algorithm

Parameter							
Peak Density	27.23	14.80	14.01	5.49	5.12	4.79	3.64
MTD (μm)	1.22	4.44	5.08	5.52	8.91	12.25	13.77
Sa (μm)	0.52	1.78	2.22	2.49	3.72	4.93	5.41
Sq (μm)	1.00	2.66	3.81	3.61	5.06	6.76	7.32

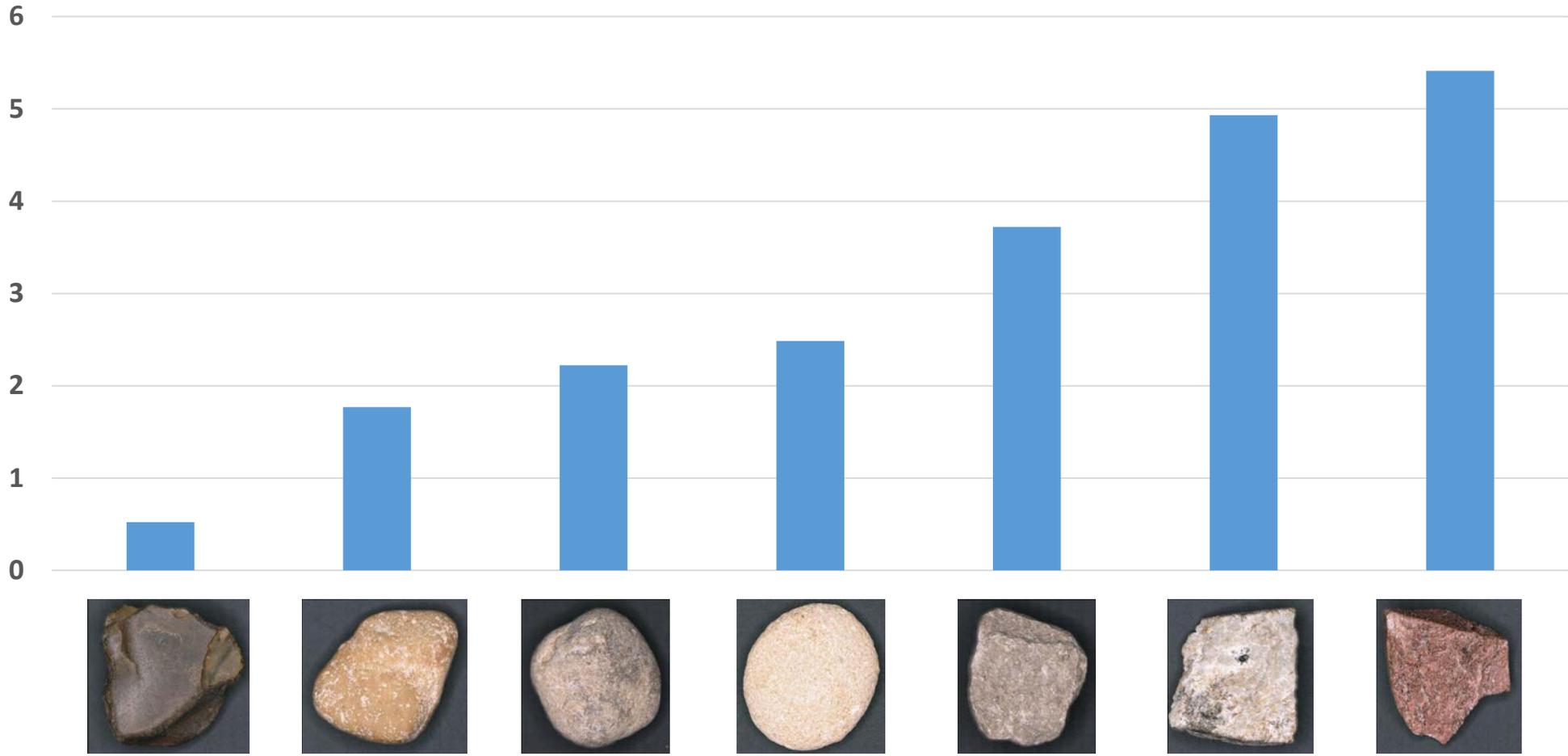
Peak Density



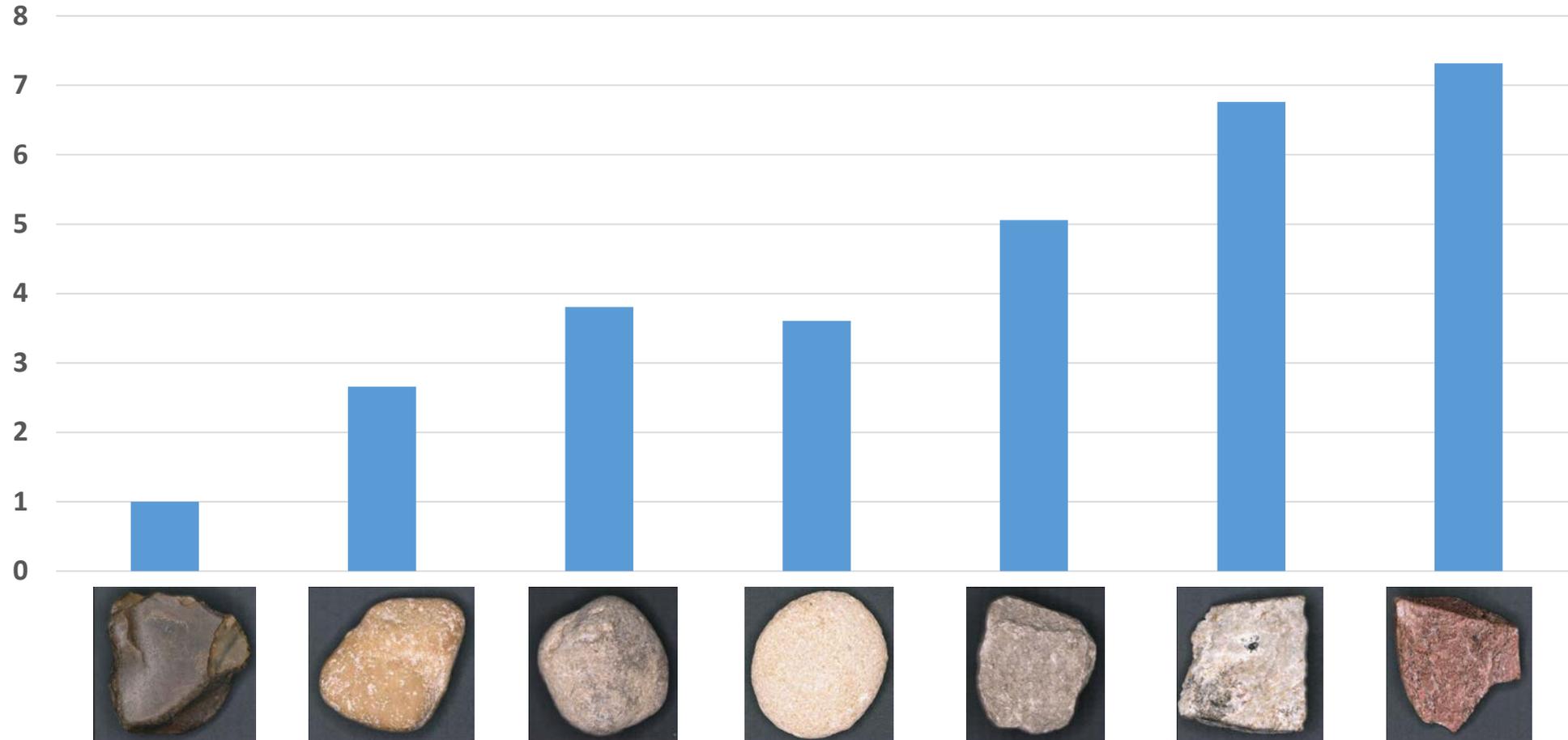
MTD (μm)



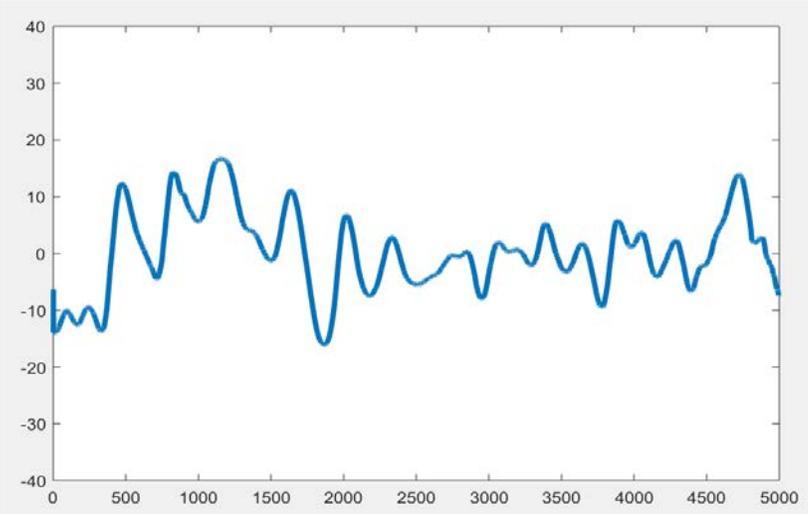
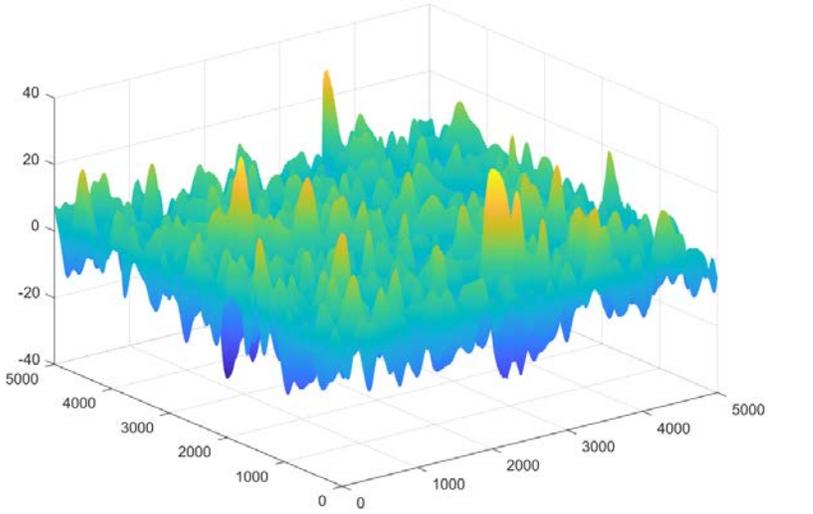
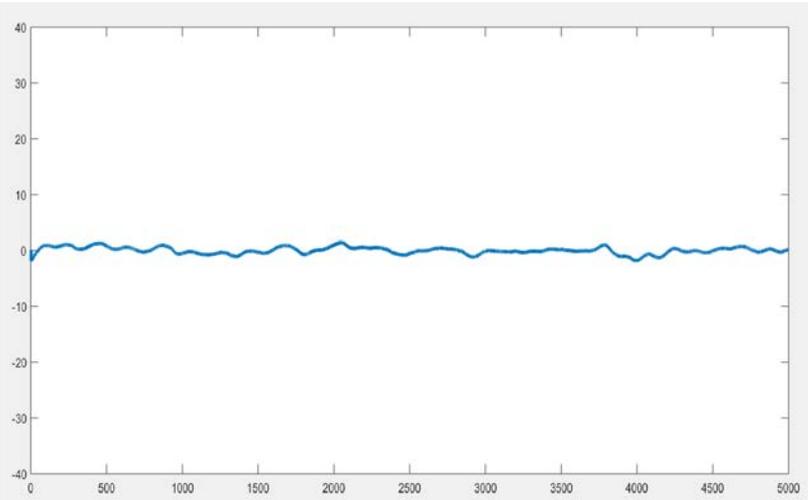
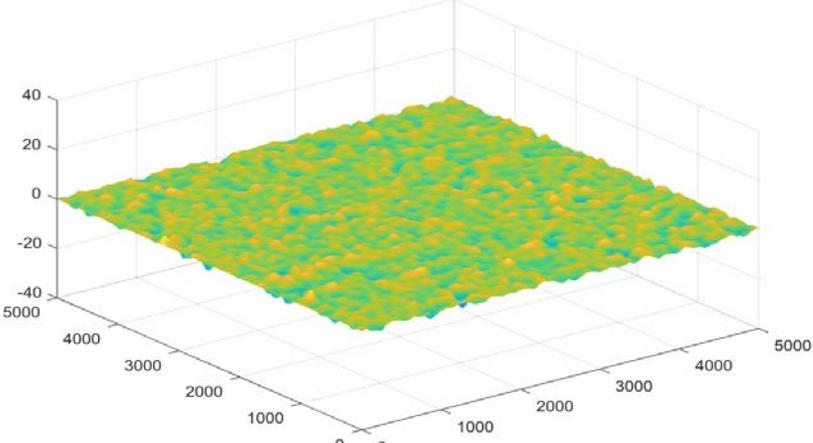
Sa (µm)



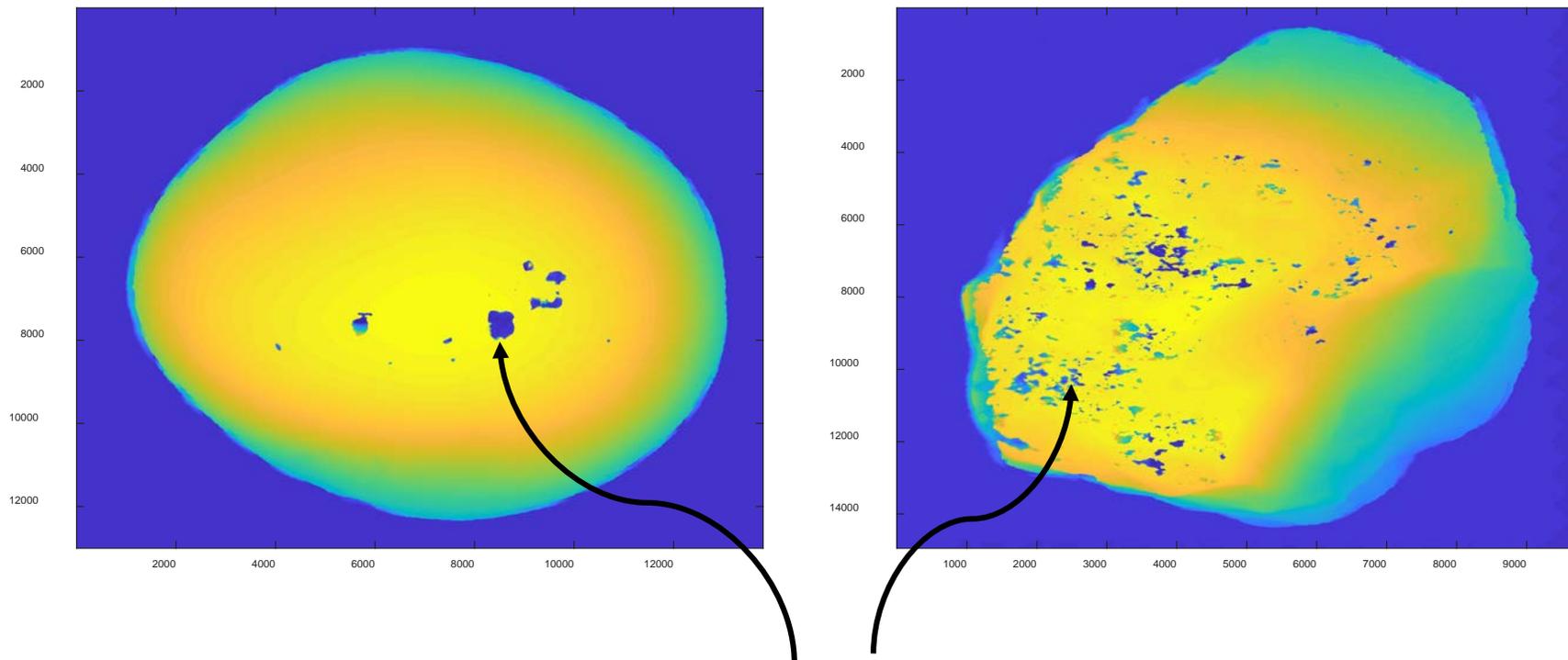
Sq (µm)



Two Different Particles



Microscope's Scanning Issue



Missing Data

Summary

- It is important to quantify the aggregates micro-texture to enhance the pavement skid resistance.
- A high resolution optical microscope was used to capture the 3D surface data from aggregate particles.
- An Algorithm was developed to quantify aggregates surface micro-texture.
- The developed Algorithm was capable of differentiating aggregate particles based on texture.

Future Work

- Studying on the lightening factor to mitigate the missing value issue.
- Generalizing the algorithm to measure aggregates of different sizes.

Thanks for Your Attention
Questions?