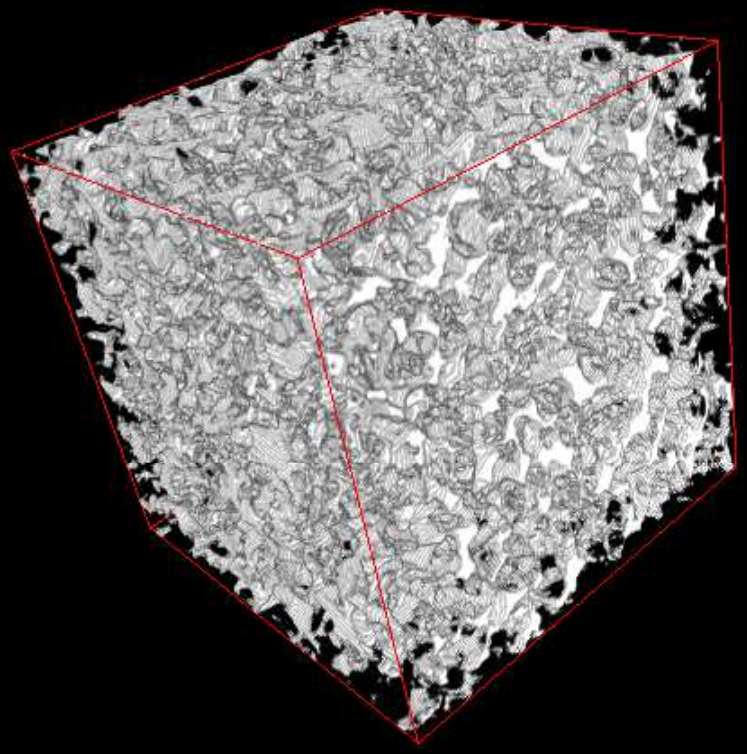
STUDY OF ROCK PORE SHAPE USING FOURIER DESCRIPTOR ANALYSIS



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FACULTY OF MATHEMATICS AND NATURAL SCIENCES
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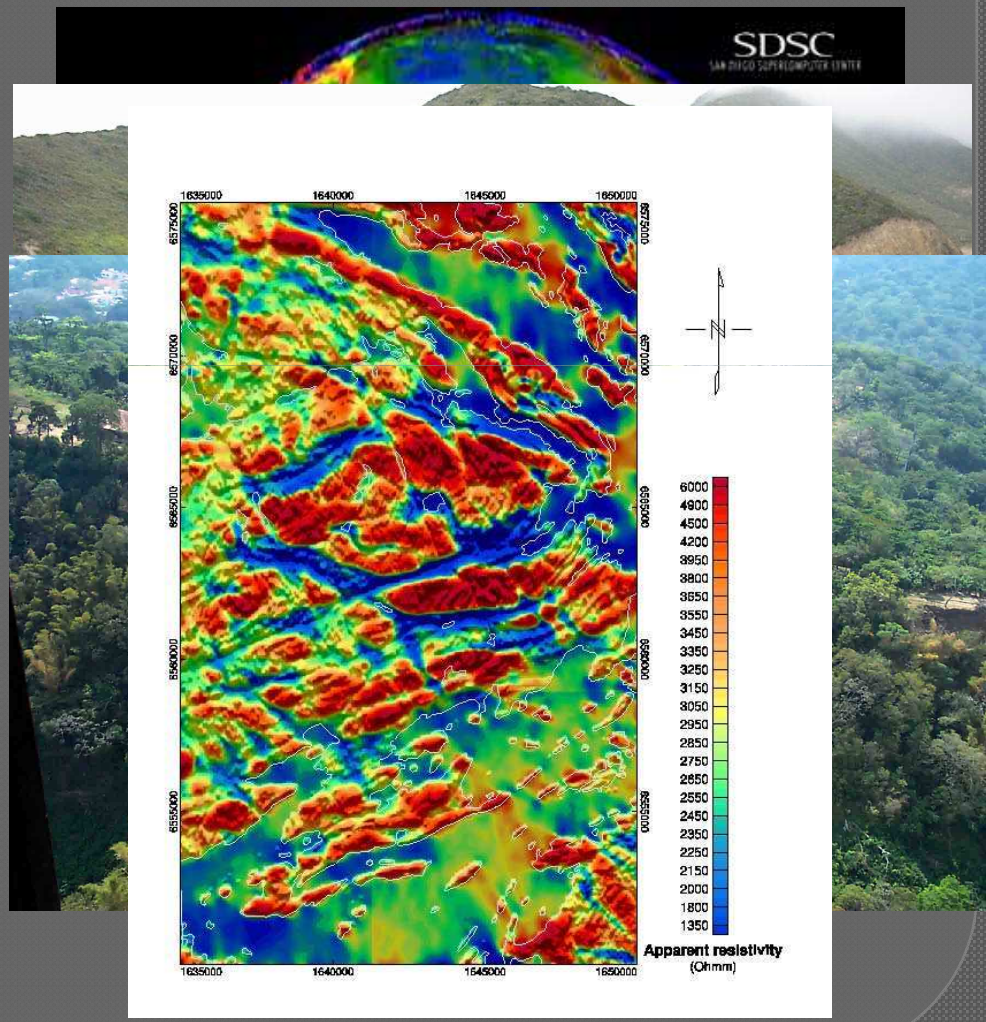
INTRODUCTION

Introduction: Background

- The importance of the knowledge of physical properties of rocks: porosity, permeability, conductivity, seismic velocity, etc.
  - Geosciences & geotechnical engineering
  - Applied geophysics
  - Environmental engineering & natural hazards

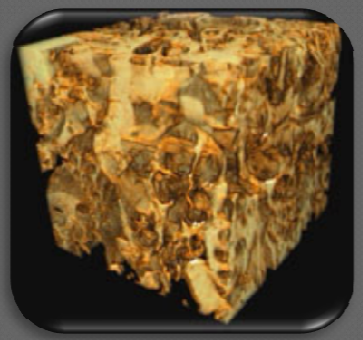


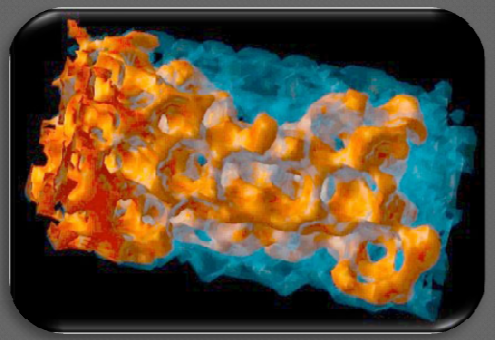
Introduction: Background

- In applied geophysics (hydrocarbon exploration & exploitation), the most important part is the reservoir rocks.
  - It is significant to understand both the petrophysical and mechanical properties of the reservoir rocks
  - There is a strong relationship between the mechanical properties and the petrophysical properties of a reservoir rock
  - Rock texture plays important role in sedimentary rocks.
  - Petrophysical properties of rocks (e.g. the porosity and permeability) are dependent on the pore-solid wall texture

Numerical/ Computational Approach:

+ Reasonably cheaper
+ High rate of techniques advancements due to fast development of computing technology
+ Easier methods of samples/data preservation
+ Some of the properties can only be analyzed using computational approach
- Sometimes requires idealization/assumption

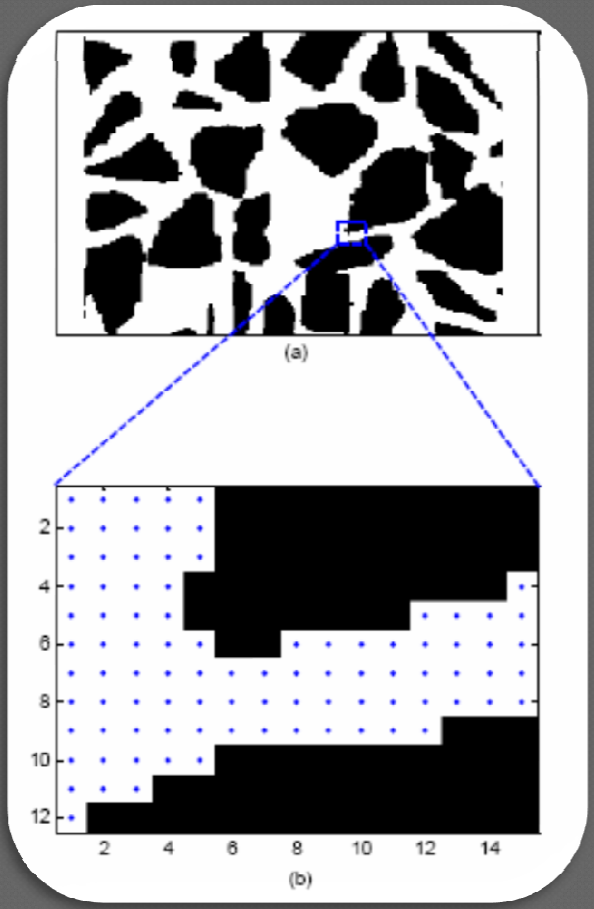


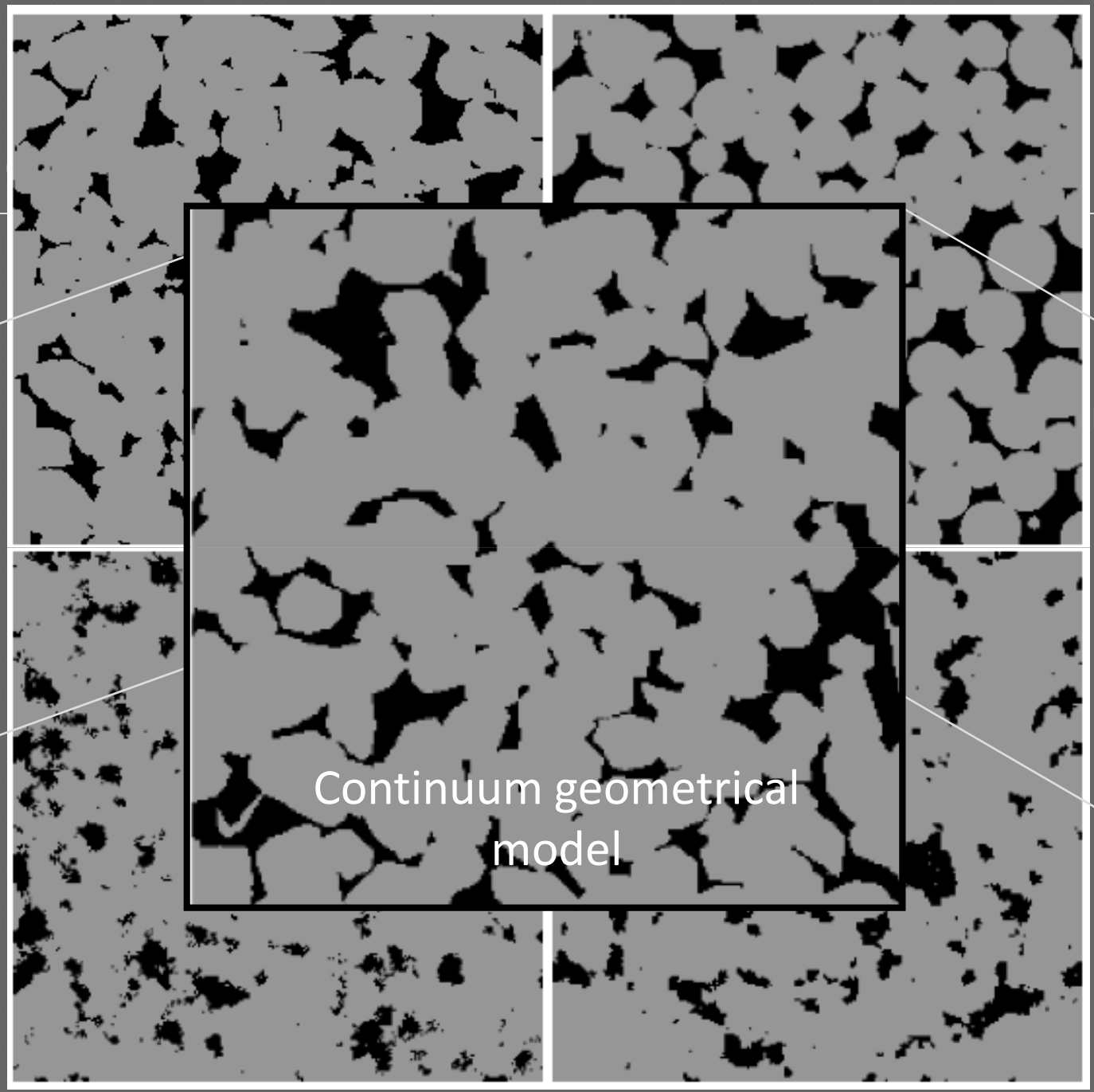


Digital Representation of Rock

Rock is represented as a collection of pixels in a set of images

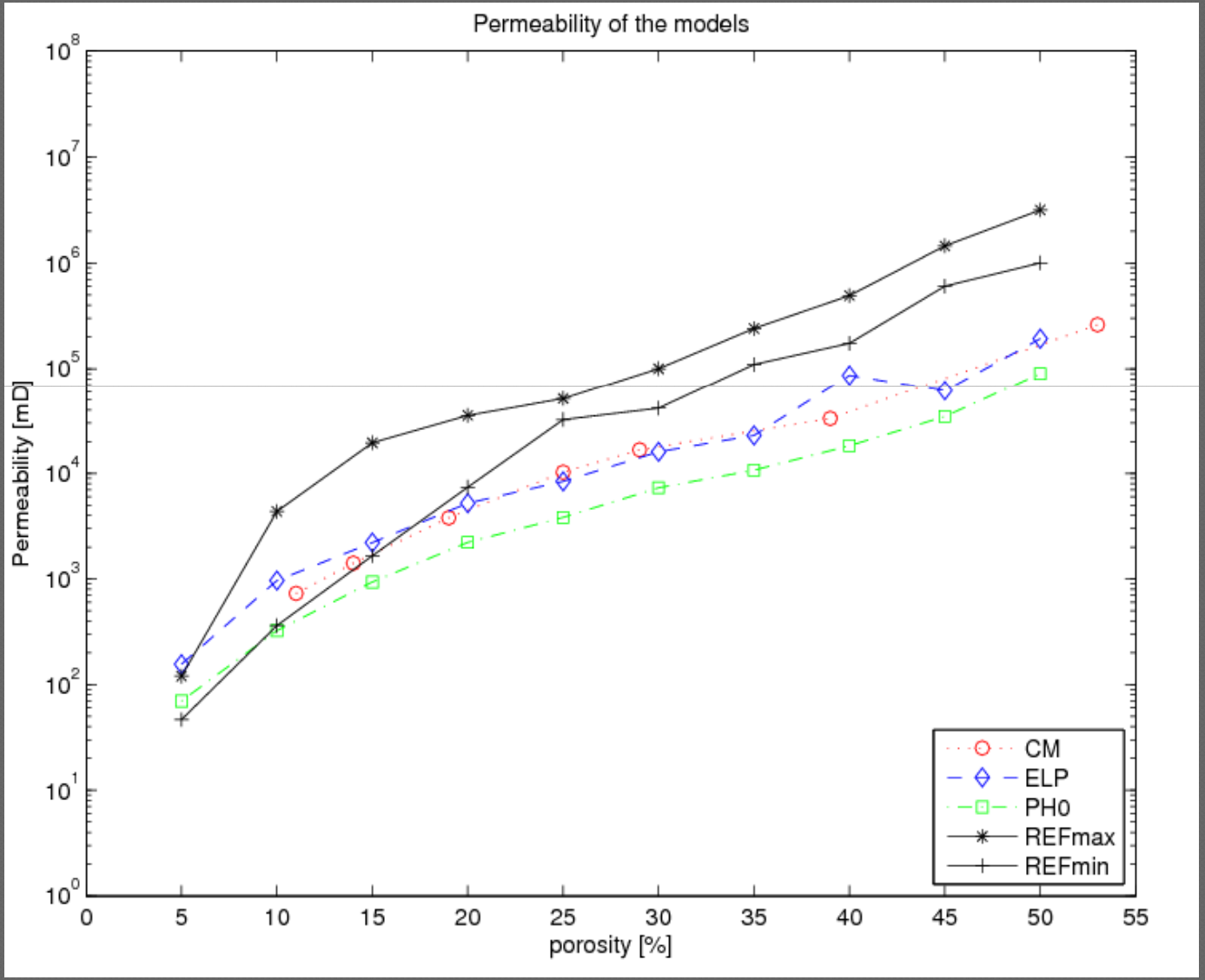
- Experiment based:
  - Acquisition using X-Ray micro-Computed Tomography (µCT)
  - Produced binarized series of images
  - Solid-pore phase represented as zeroes and ones
- Modelling based:
  - Producing synthetic micro-structure
  - Based on characteristics
  - Represented as zeroes and ones




Fontainebleau
Diagenesis model
Continuum geometrical model
Gaussian Field
Simulated Annealing

Pore Shape Characteristic

Permeability Dependence on Pore Geometry



$$k = \frac{(\phi)^3}{c\tau^2 S_a^2}$$

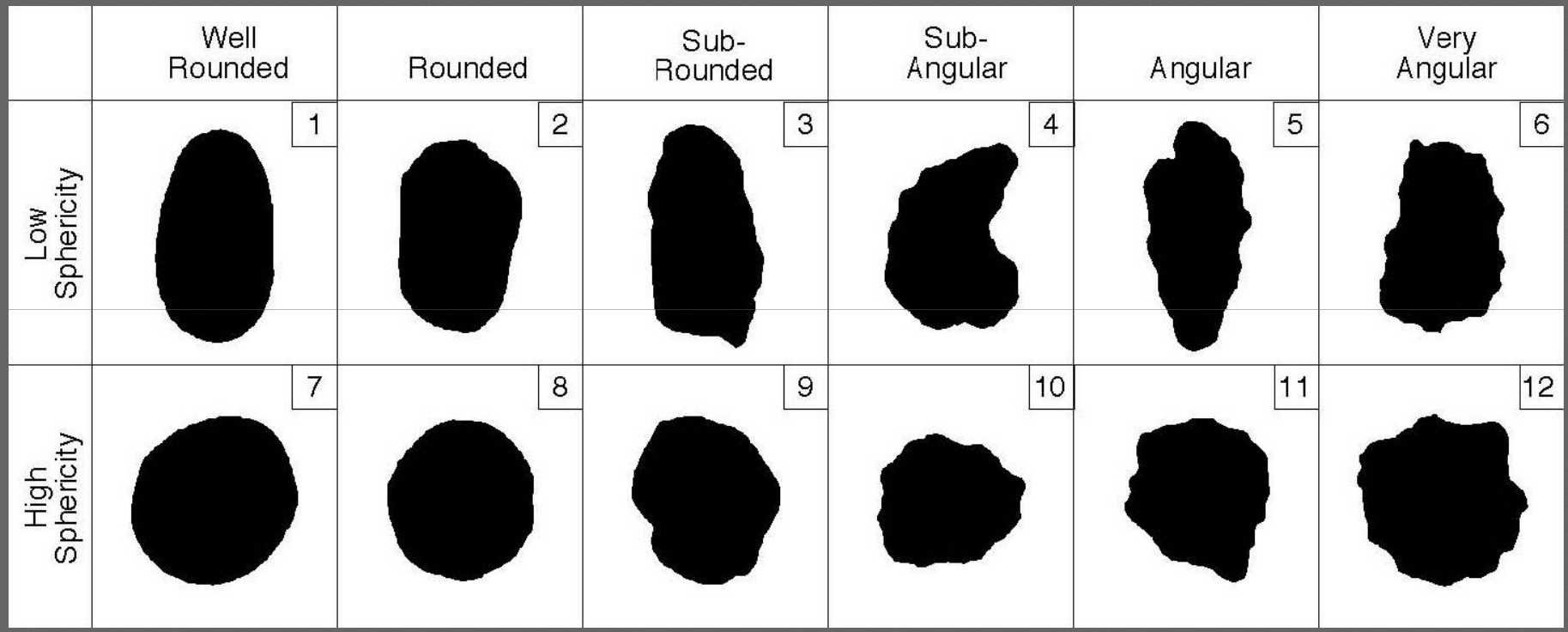
Geometrical factor

$c = 2$ for idealized cylindrical tube

Shape Characterization

Shape Characterization

- The three main features used to describe a shape are *form*, *roundness* and *surface texture* (Barrett, 1980).
  - *Form* is used to describe the gross shape, related to the three principal axes, usually quantified in terms of sphericity (Diepenbroek, et al, 1992)
  - *Roundness* and *angularity* reflect the variations in corners, edges and faces and are related to *surface texture*. *Roundness* was defined as the ratio of the curvature of corners and edges of the particle to that of the overall particle (Wadell, 1932).
  - *Surface texture* reflects the roughness along the particle surface and on corners (Sukumaran & Ashmawy, 2001).

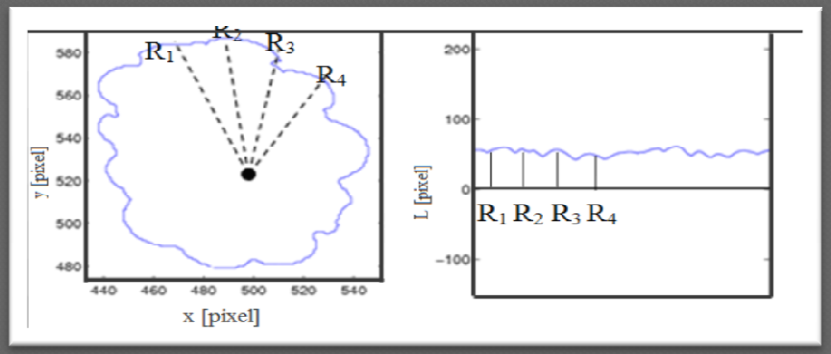

Well Rounded
Rounded
Sub-Rounded
Sub-Angular
Angular
Very Angular
Low Sphericity
High Sphericity
1
2
3
4
5
6
7
8
9
10
11
12

Quantitative Shape Description

A shape can be quantitatively described by a set of numbers which are often called descriptors

Shape Description – Fourier Analysis

- Analysis of roughness and textural features of granular soils: Clark (1981) proposed a quantitative shape analysis is the Fourier Descriptor (FD) method
- FD is using the Complex Fourier analysis, the boundary of the particle is circumnavigated in the complex plane, such as to obtain the shape boundary coordinates of an object

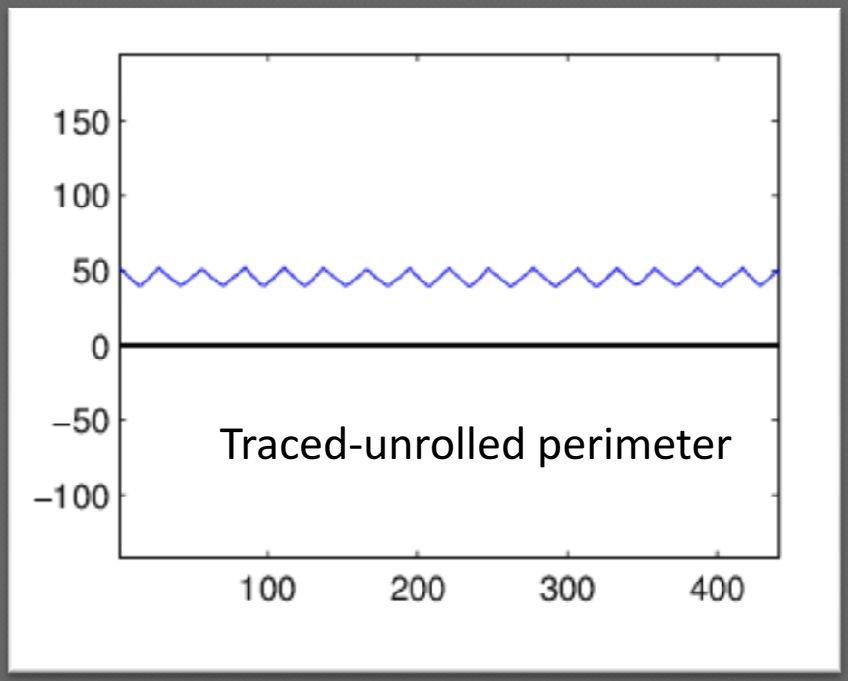


$$\{x(t), y(t), t = 0,1,\ldots, L_b - 1\}$$

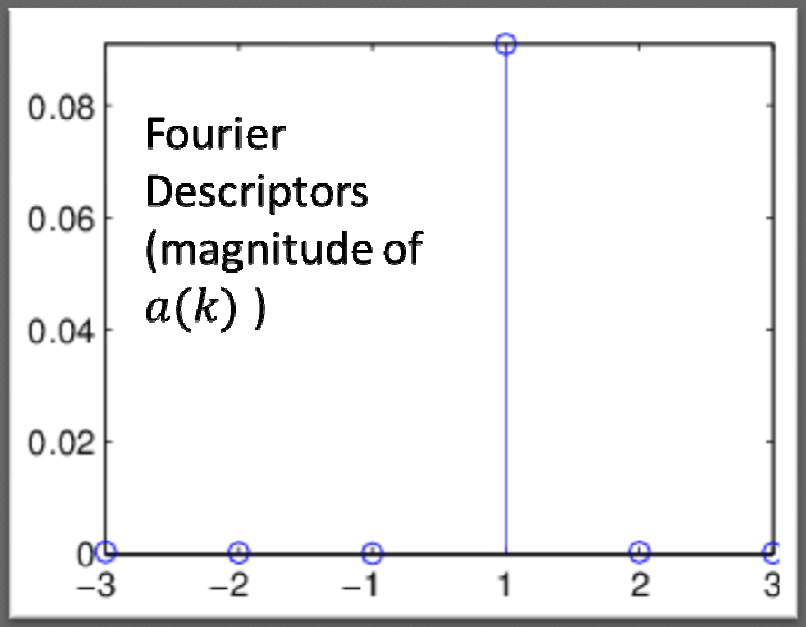
$$z(t) = [x(t) - x_c] + j[y(t) - y_c]$$

$$a(k) = \frac{1}{L_b} \sum_{t=1}^{L_b} z(t) \exp[-j2\pi(k-1)(t-1)/L_b]$$

object

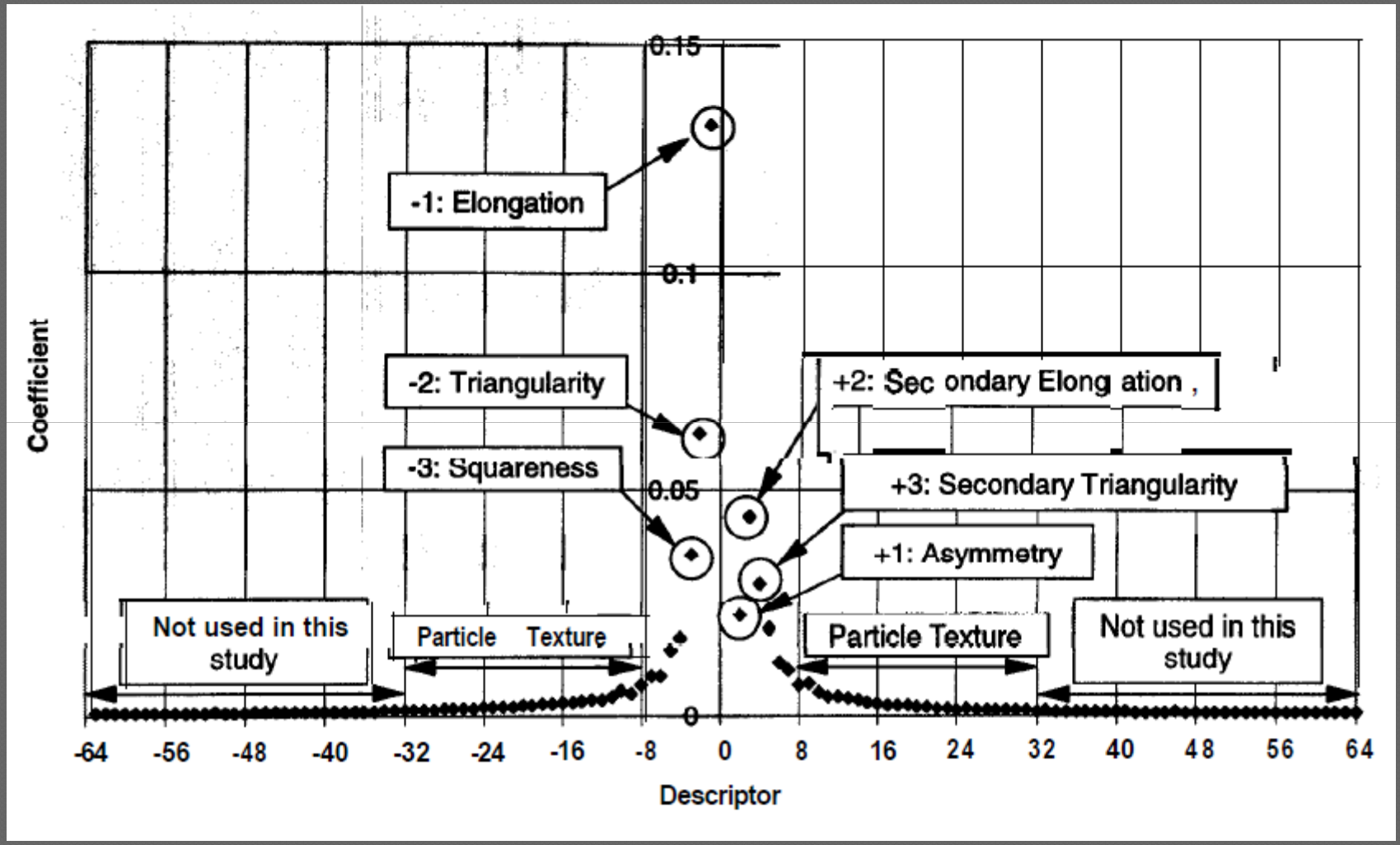


resembles the shape of a periodic function which can be reconstructed using Fourier series



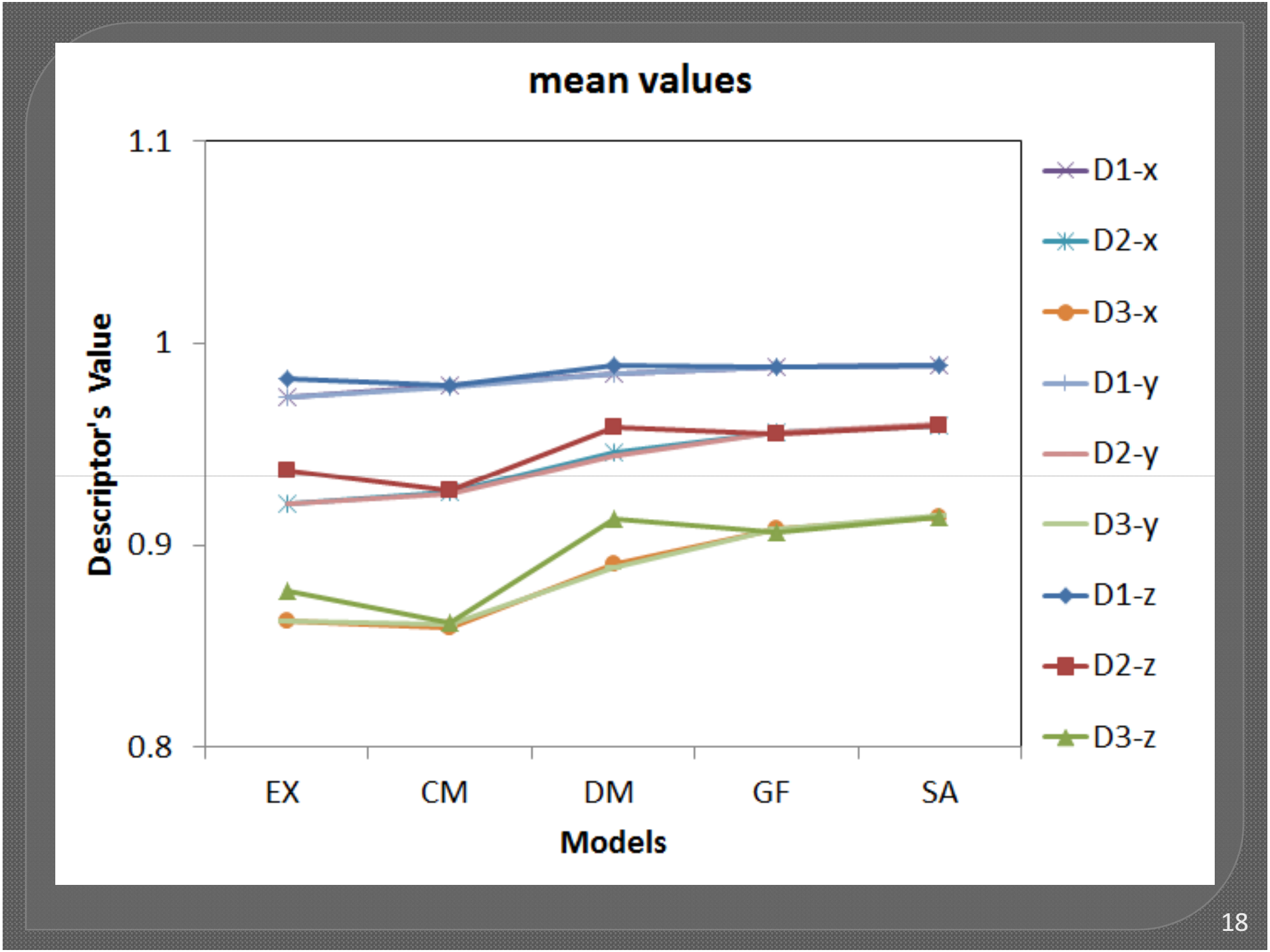
Fourier descriptors can be interpreted as the projection of the shape onto shape harmonics

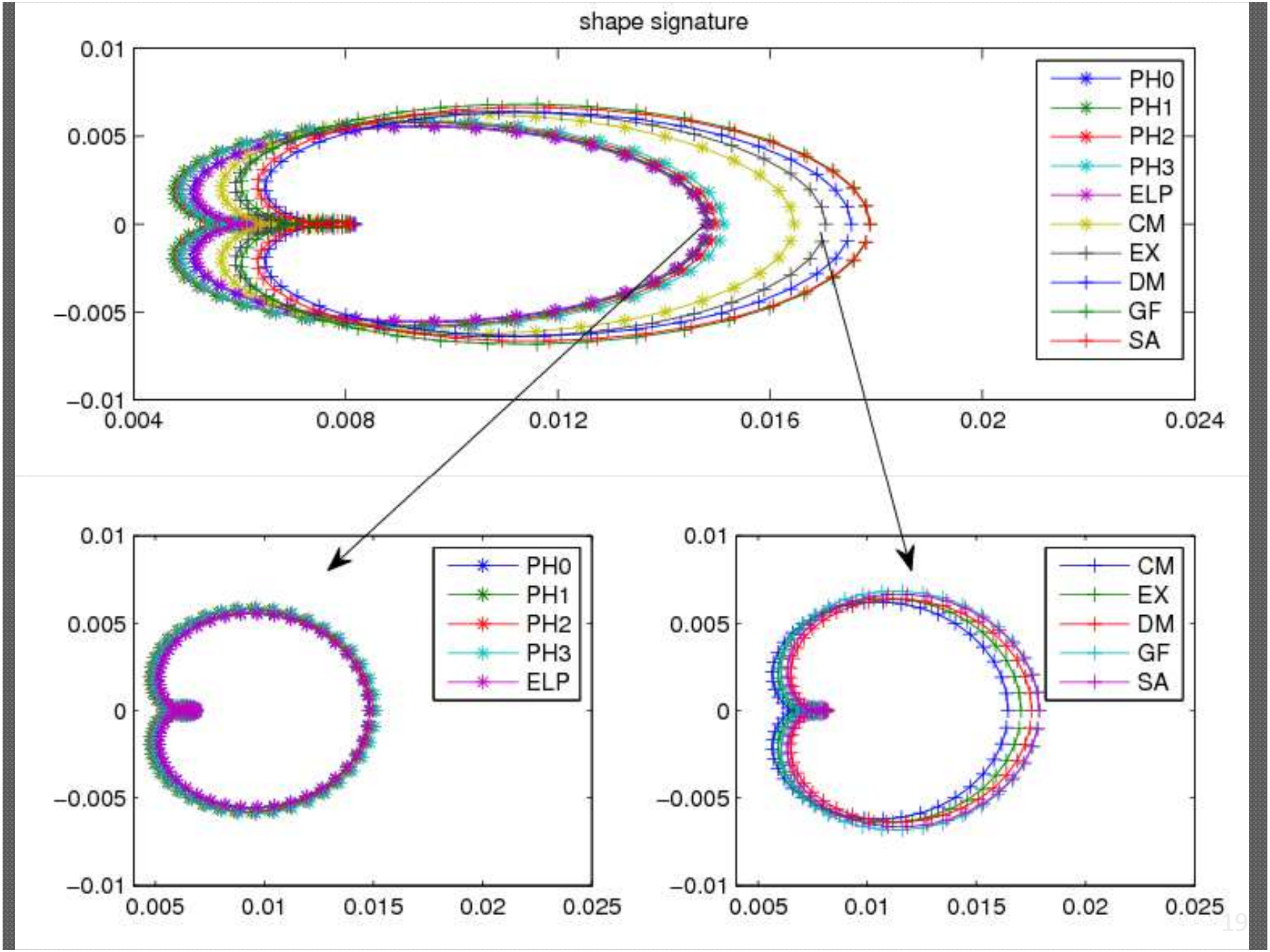
Magnitude of $a(k)$ refers to the influence of the shape harmonic at frequency $(2\pi n/N)$ in the original shape

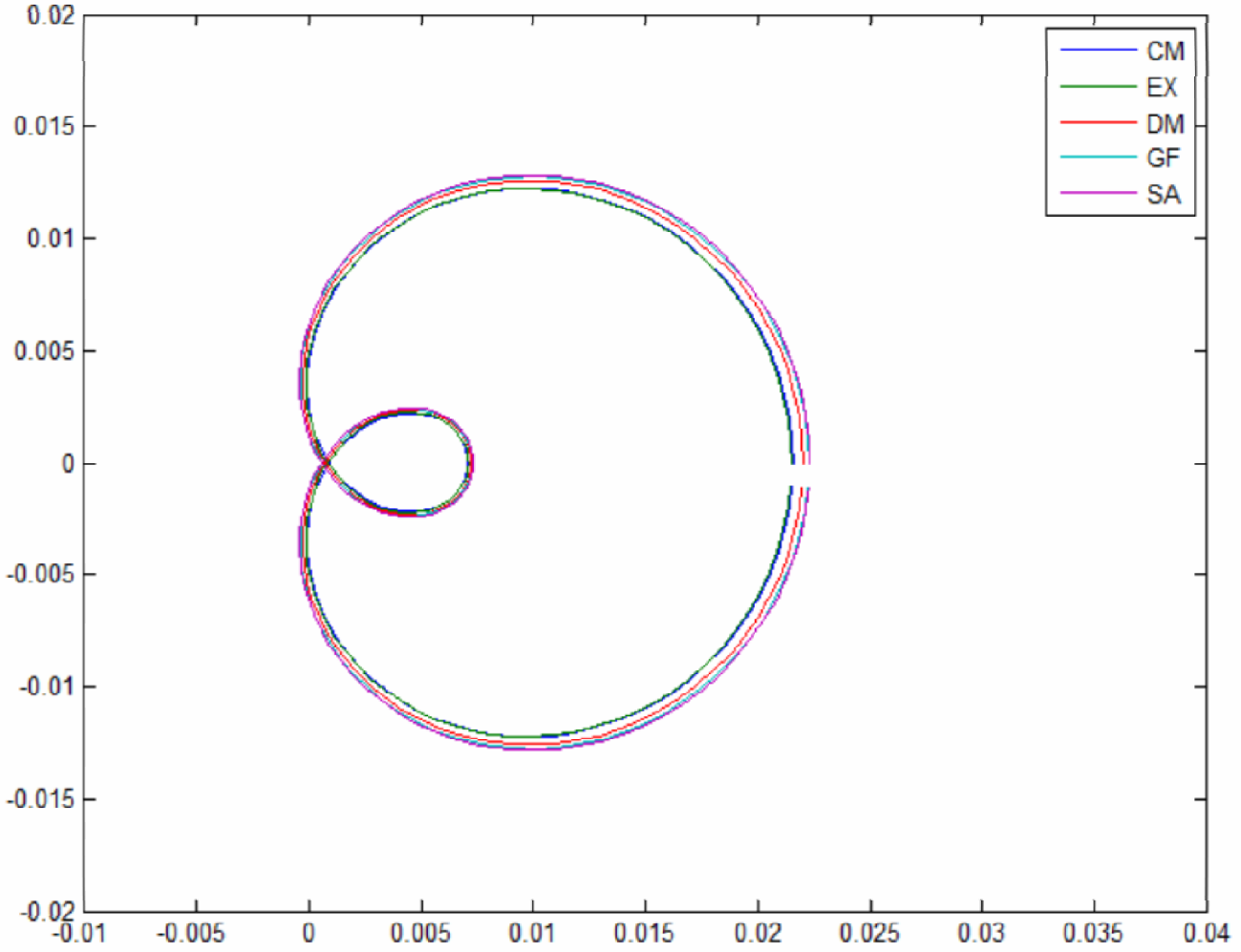


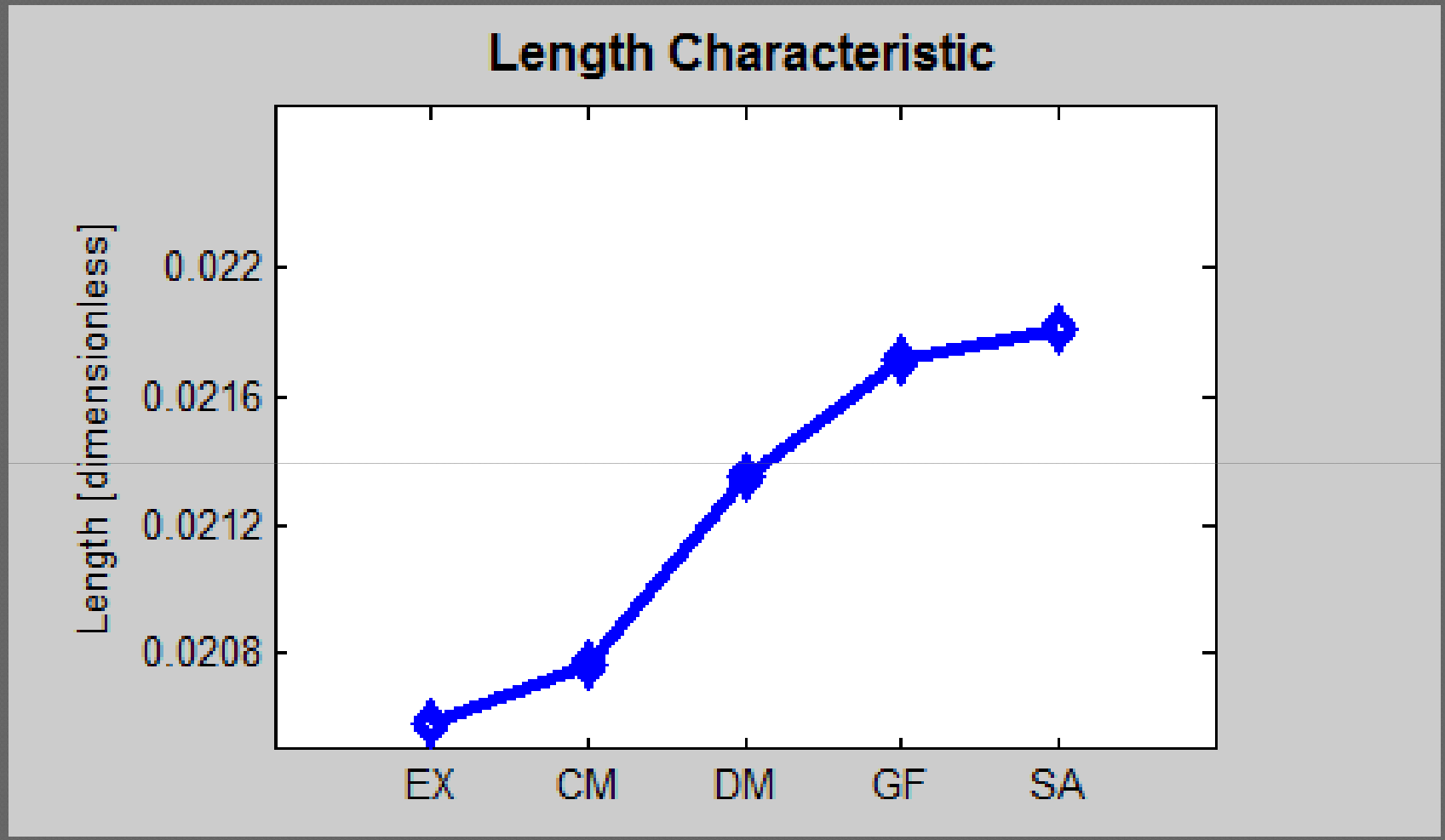
Elisabeth T. Bowman, Kenichi Saga & Tom W. Drummond, Particle Shape Characterization using Fourier Analysis, *CUED/D-SoWTR315 (2000)*

RESULTS


mean values
1.1
1
0.9
0.8
Descriptor's Value
EX
CM
DM
GF
SA
Models
D1-x
D2-x
D3-x
D1-y
D2-y
D3-y
D1-z
D2-z
D3-z


shape signature
PH0
PH1
PH2
PH3
ELP
CM
EX
DM
GF
SA
0.01
0.005
0
−0.005
−0.01
0.004
0.008
0.012
0.016
0.02
0.024
0.005
0.01
0.015
0.02
0.025


CM
EX
DM
GF
SA
0.02
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
-0.01
-0.005
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04


Length Characteristic
Length [dimensionless]
0.022
0.0216
0.0212
0.0208
EX
CM
DM
GF
SA

CONCLUSIONS

- The complexity level can be distinguished using Fourier Descriptors.
- Extracted characteristic length of the shape signature is used to define complexity level, i.e., the higher the level of complexity, the longer the length characteristic of shape signature.
- Continuum Geometrical model has the most similar pore geometry characteristics with the Fontainebleau sandstone.

List of Publications

Directly Related:

1. Fourier D. E. Latief, Umar Fauzi, Pore Shape Characterization of Fontainebleau Sandstone and Its Models Using Fourier Descriptor, The Fourth International Conference On Mathematics and Natural Sciences (ICMNS 2012), November 8-9, 2012, Bandung, Indonesia.

Closely Related:

1. Fourier D. E. Latief, Selly Feranie, Three-Dimensional Visualization and Characterization of Cracks in Geothermal Reservoir Rock Using Image Analysis of Reconstructed μCT Images: A Preliminary Study, The Fourth International Conference On Mathematics and Natural Sciences (ICMNS 2012), November 8-9, 2012, Bandung, Indonesia.
2. Fourier D. E. Latief, Tedy Muslim Haq, Digital Characterization and Preliminary Computer Modeling of Hydrocarbon Bearing Sandstone from Sumatra, The Fourth International Conference On Mathematics and Natural Sciences (ICMNS 2012), November 8-9, 2012 Bandung, Indonesia.
3. Z. Irayani, U. Fauzi, F.D.E. Latief, H. Atmoko, Microstucture Characterization of Reservoir Sandstone Using X-Ray Microtomography, PROCEEDINGS PIT HAGI 2012, 37th HAGI Annual Convention & Exhibition Palembang, 10-13 September 2012.
4. U. Fauzi, Annisa, F. D. E. Latief, Effective Permeability Of Layering Simple Grain Packings, PROCEEDINGS PIT HAGI 2012, 37th HAGI Annual Convention & Exhibition Palembang, 10-13 September 2012
5. F. D. E. Latief, Z. Irayani, U. Fauzi, Digital Characterization of Loose Sandstone Using Image Analysis and Simulation of Fluid Flow, PROCEEDINGS PIT HAGI 2012, 37th HAGI Annual Convention & Exhibition Palembang, 10-13 September 2012
6. Haq, T.M., Fatkhan, Latief, F.D.E., Digital Reconstruction and Simulation Method for Determining Physical Properties of Sandstone Reservoir, PROCEEDINGS PIT HAGI 2012 37th HAGI Annual Convention & Exhibition, Palembang, 10-13 September 2012

Thank you

Fourier D. E. Latief