OSIRIS Images Based Fragmentation Numerical Model

Admission to Second Year
22 September 2017

PhD student: **Pamela Cambianica**
Supervisor: **Giampiero Naletto**
Co-Supervisor: **Gabriele Cremonese**

Fragmentation

Process of breaking down a body into smaller parts

A complex phenomenon seen ubiquitously in nature

It manifests itself at different scales and the lower limit is the fundamental of matter itself

SOIL FRAGMENTATION MODEL

- ✖ INSTANTANEOUS fragmentation
- CONTINUOUS fragmentation

To investigate through the fragments pattern the rock breakage processes

To study the mechanical properties of the material

To understand the evolution and the erosion of a surface

Particle Size Distribution (PSD)

A basic descriptive element of the soil's origin and the processes that have formed and altered it through time

Fragmentation model

- Image Analysis
  - Selection of specific area
  - Size-frequency distribution
  - Fractal theory
  - Shape factors

  → Quantitative analysis of the image
  - Power-law exponent
  - Fractal dimension
  - Shape classification

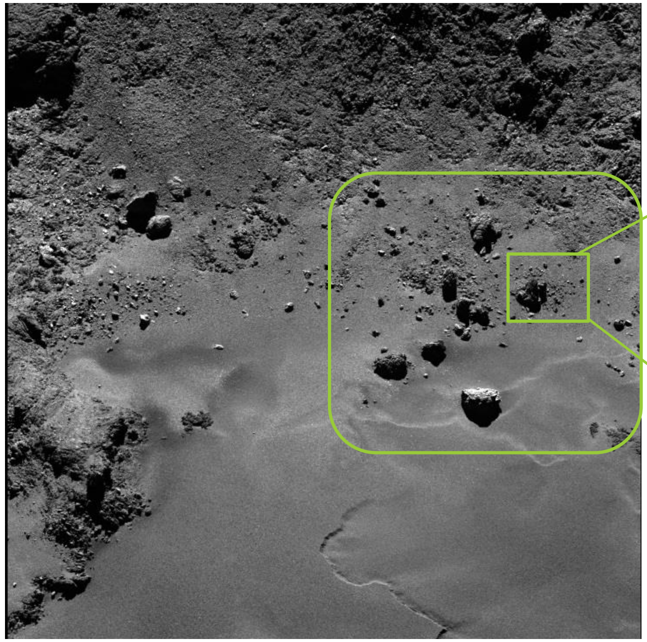
- Thermal and Sublimation model
  - Sublimation Rate
  - Illumination conditions
  - Solar irradiation
  - Heat flux density
  - Diurnal thermal cycle
  - Temperature gradients
  - Thermo-mechanical processes
  - Radiative heat exchange
  - Conductive heat transfer

- Fragmentation Model
  - Finite Element Method

IMAGE ANALYSIS

Selection of the specific area

- Far from landslides, niches …
- Evidence of thermal fatigue
- Selection of regions with a variation in composition (H_2O ice, CO_2 ice..)

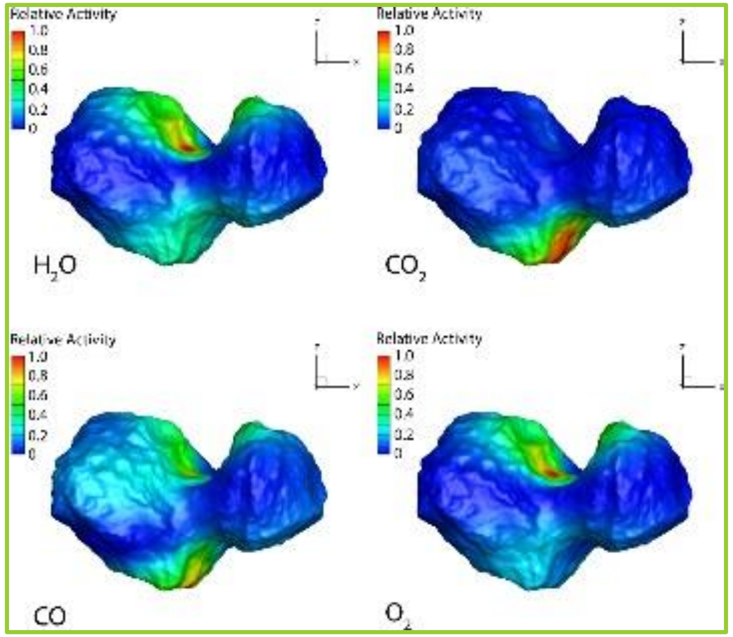


NAC_2014-09-29T13.29.30.598Z_ID30_1397549600_F22

Imhotep

NAC_2014-09-29T13.29.30.598Z_ID30_1397549600_F22

Imhotep detail

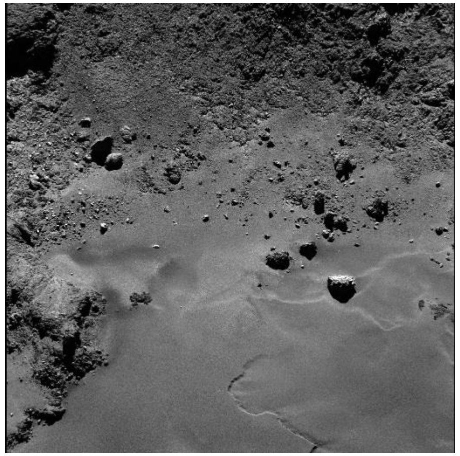


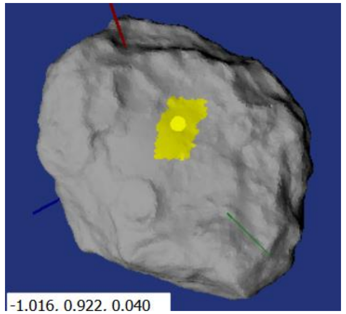
(Fougere at al., 2016 - ROSINA)

IMAGE ANALYSIS

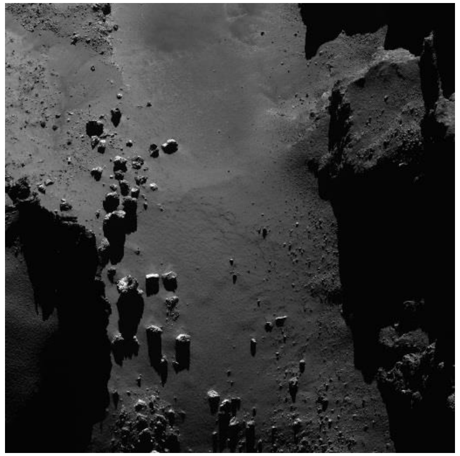
Selection of the specific area

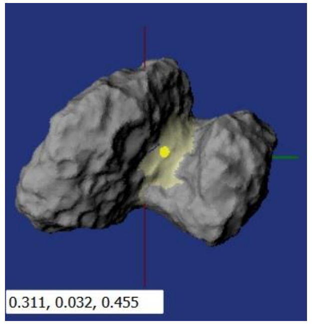
Imhotep



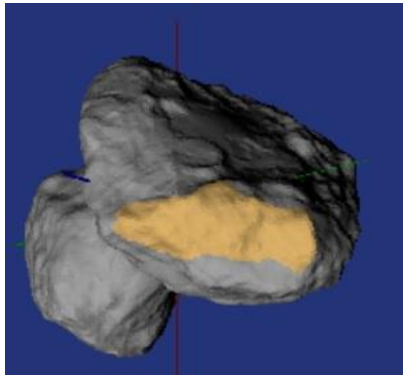


Hapi





Khonsu



Head

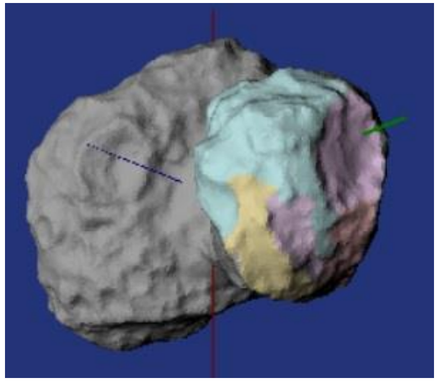
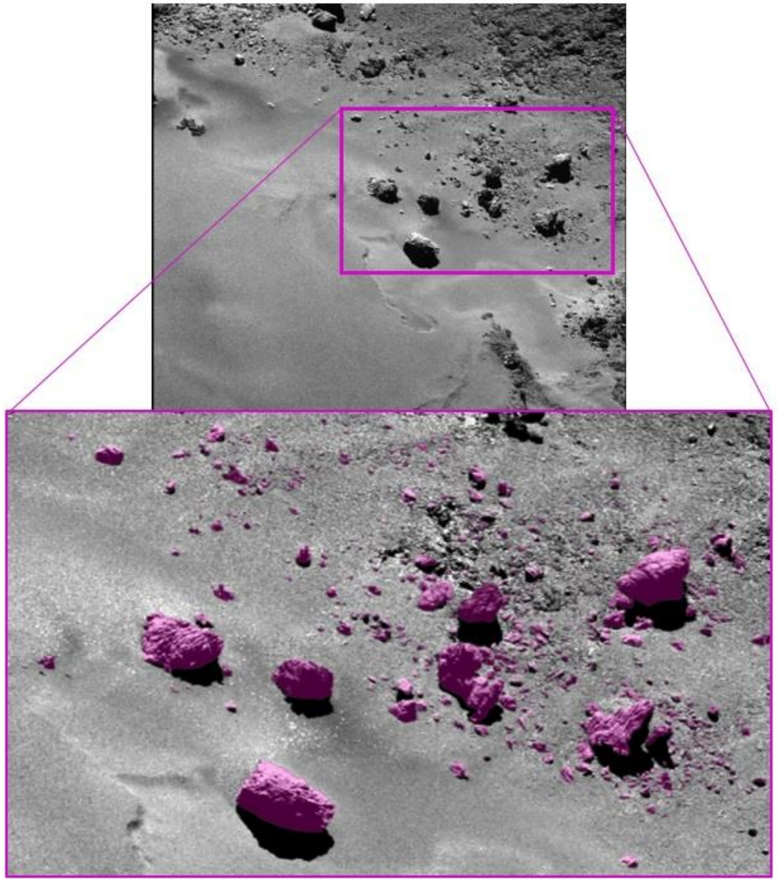


IMAGE ANALYSIS

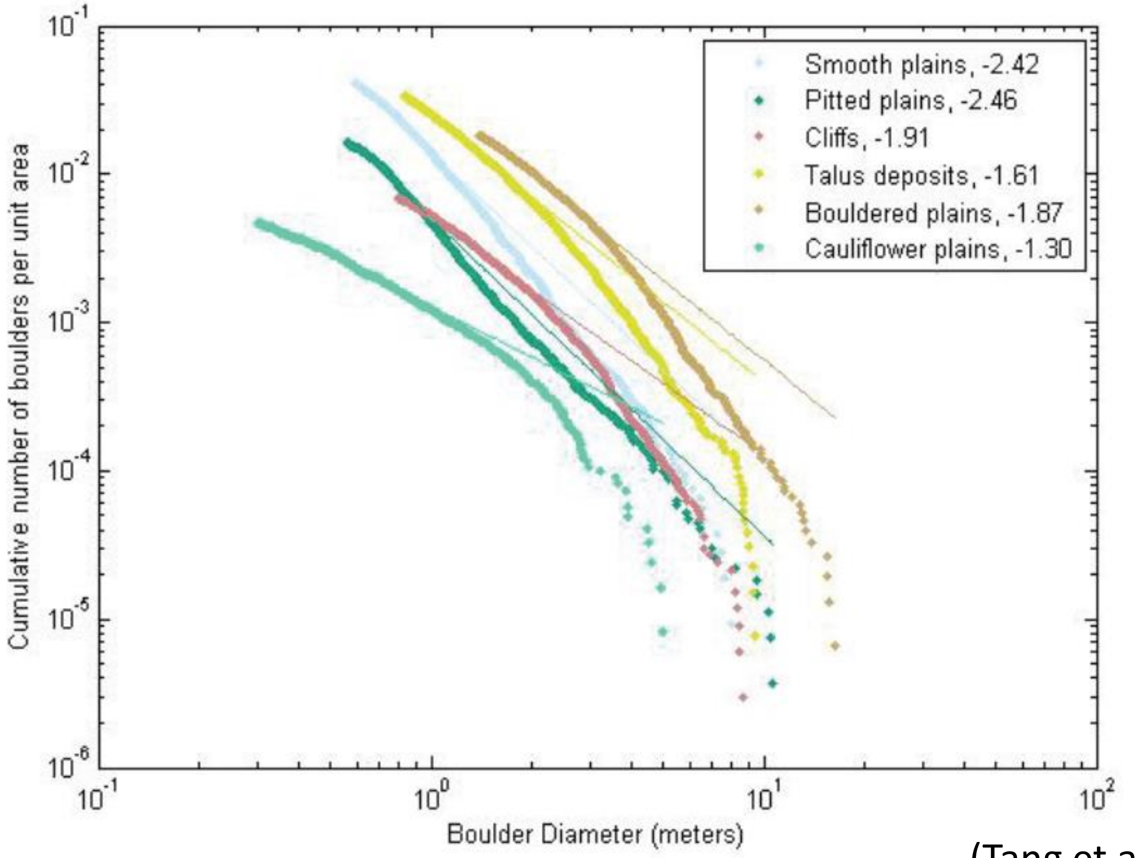
Size-Frequency Distribution and Power-Law Exponent



- Manually outlining each boulder with ArcGIS Software
- Calculating the area of each element
- Calculating the cumulative number of boulder / km^2
- Plotting the cumulative frequency *vs* the diameter
- Finding the trend line and extrapolating the power-law exponent

IMAGE ANALYSIS

Size-Frequency Distribution and Power-Law Exponent



(Tang et al., 2017, LPSC)

The different soil classes depict linear and power-law behavior in their respective textural class segments, suggesting that different processes have played a dominant role in their creation and formation over time

Larger power-law exponent means more fine material

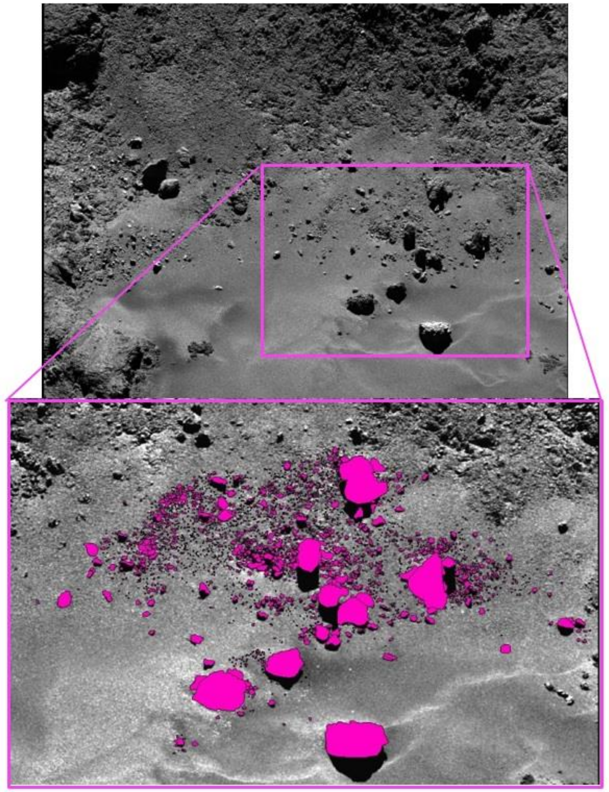
This power-law dependent segments may also be described as fractal implying a statistical self-similarity of the particles.

IMAGE ANALYSIS

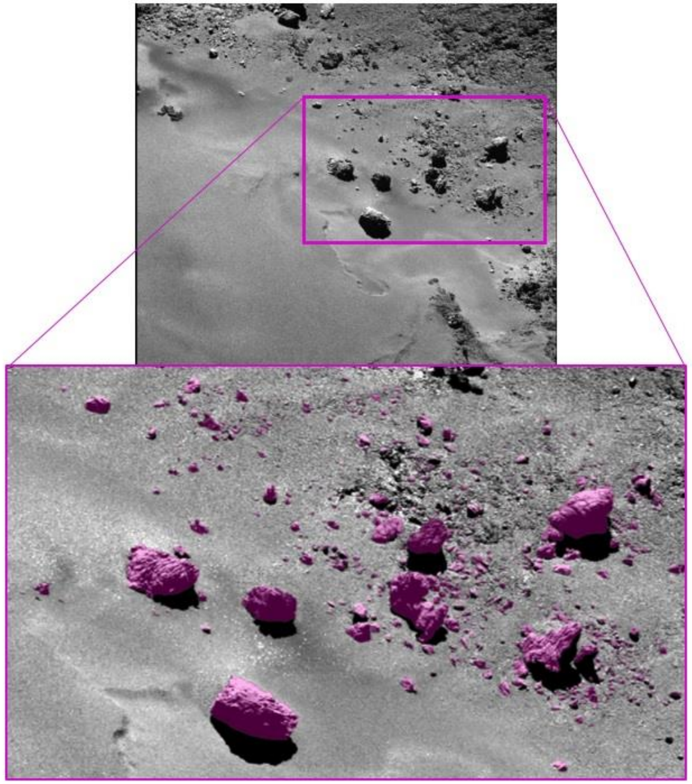
Pre-perihelion

IMHOTEP

Post-perihelion



NAC_2014-09-29T13.29.30.598Z_ID30_1397549600_F22



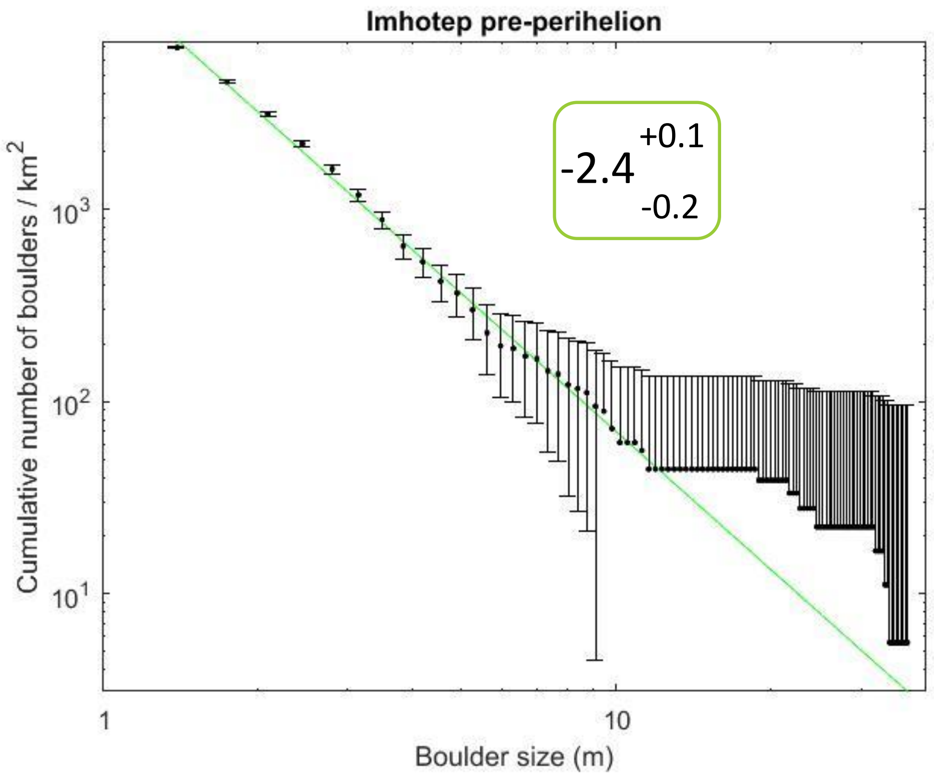
NAC_2016-07-09T11.25.15.786Z_ID30_1397549000_F41

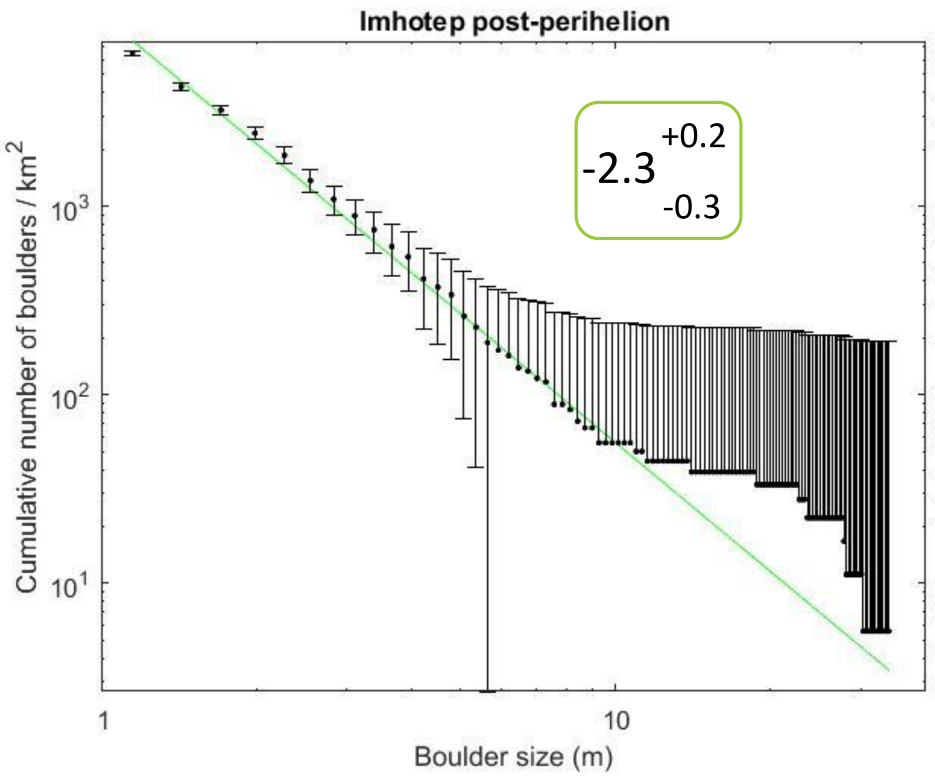
IMAGE ANALYSIS

Pre-perihelion

IMHOTEP

Post-perihelion





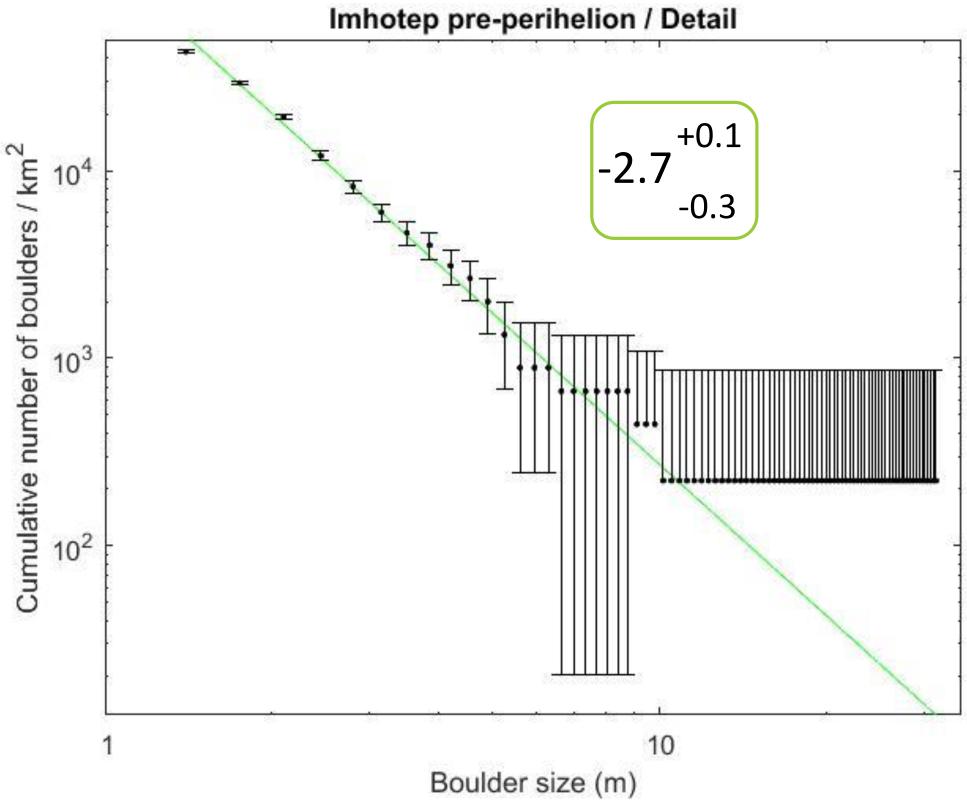
Size-frequency distribution and power-law exponent

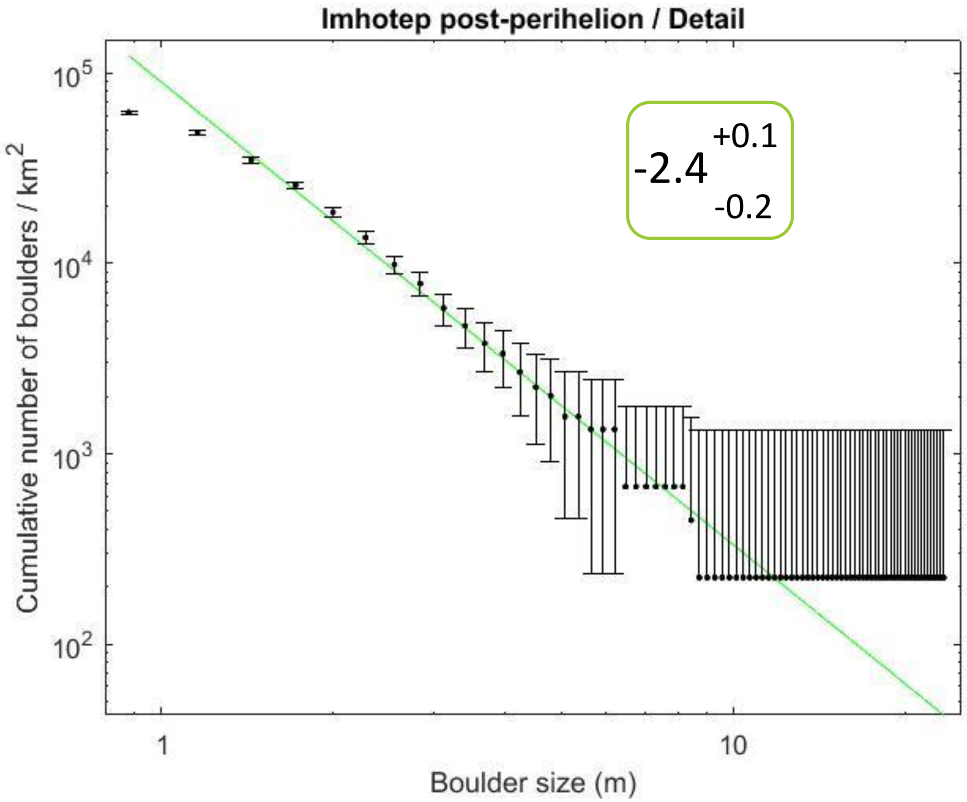
IMAGE ANALYSIS

Pre-perihelion

IMHOTEP DETAIL

Post-perihelion





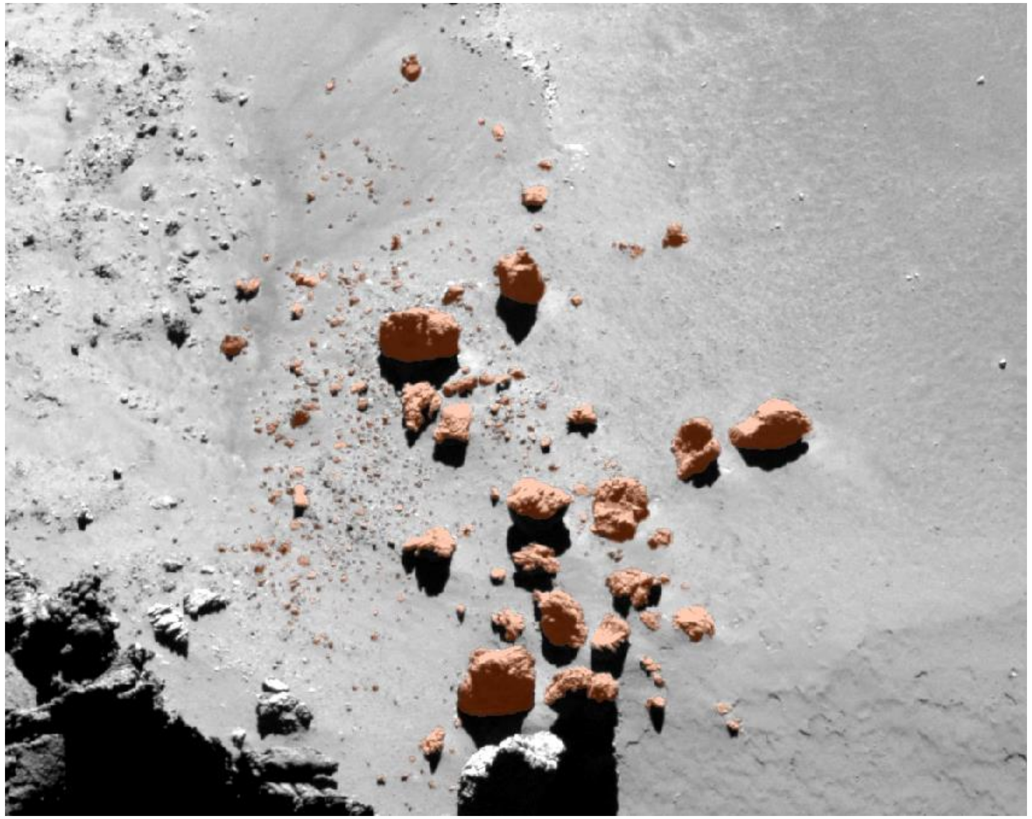
Size-frequency distribution and power-law exponent

IMAGE ANALYSIS

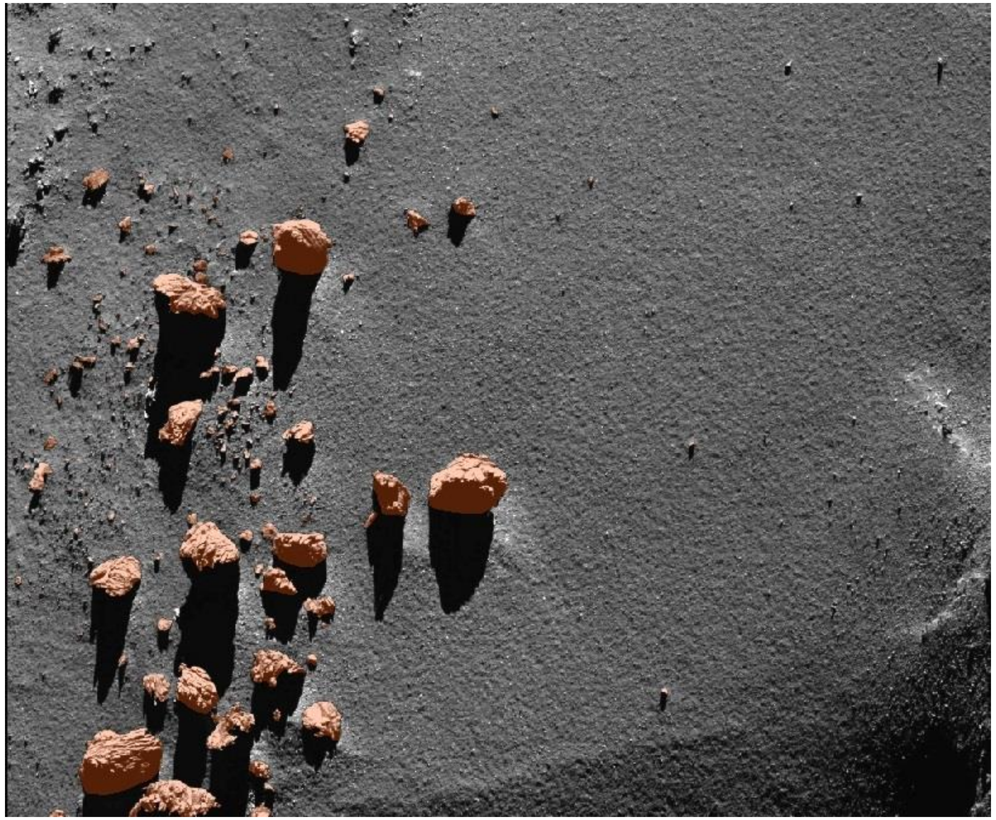
Pre-perihelion

HAPI

Post-perihelion



NAC_2014-12-10T06.29.11.447Z_ID10_1397549002_F24

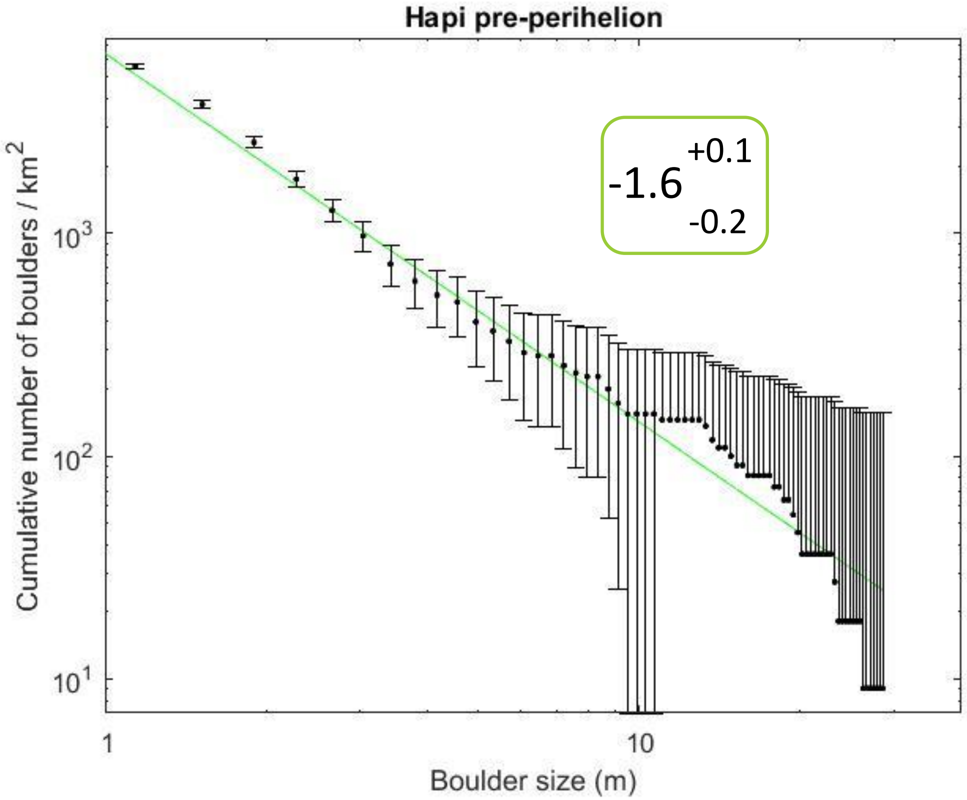


NAC_2016-07-20T08.02.48.392Z_ID30_1397549001_F22

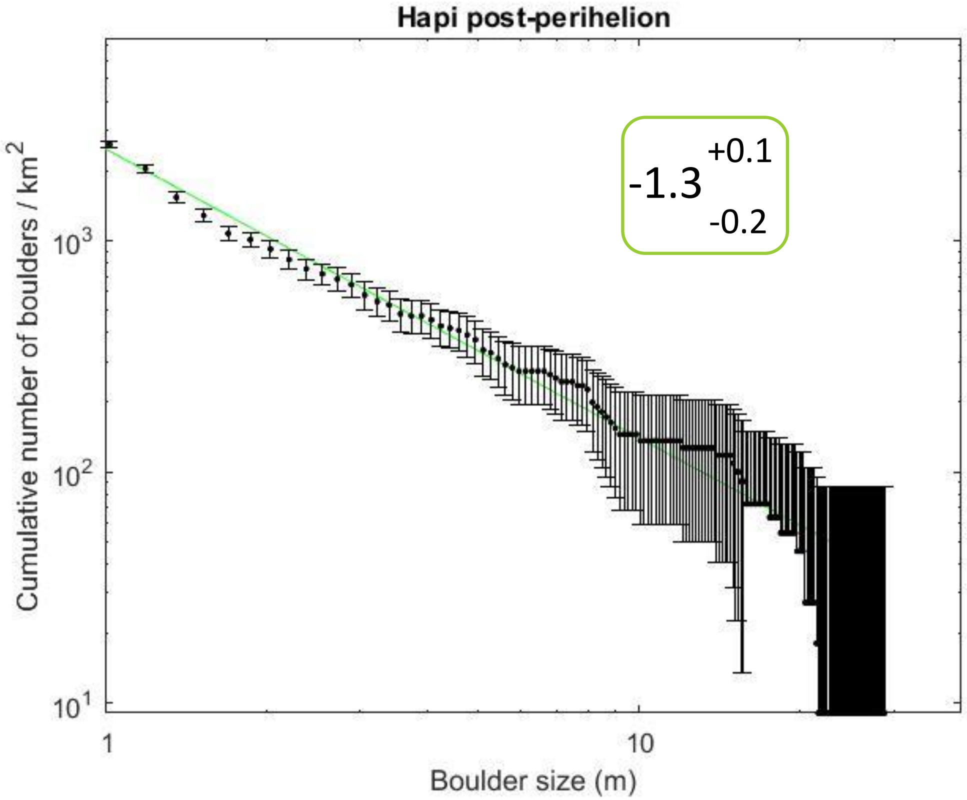
IMAGE ANALYSIS

HAPI

Pre-perihelion



Post-perihelion



Size-frequency distribution and power-law exponent

IMAGE ANALYSIS

Fractal Theory – Fractal dimension

"The exponents derived from power-laws explicitly characterize the fragmentation fractal dimension"

(Charalambous, 2015)

Relationship for a number-size distribution that follows a power-law
(Turcotte, 1986)

$$N(R > r) = Cr^{-D}$$

0 < D < 3

Total fragmented area
(Turcotte, 1986)

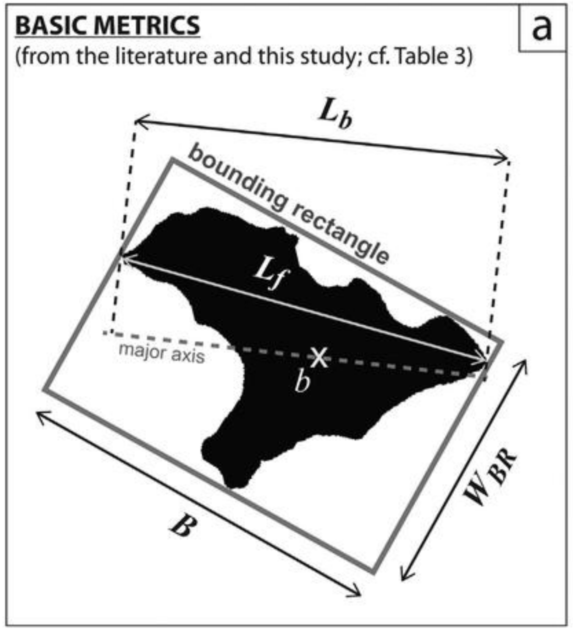
$$A = \int_{d_{min}}^{d_{max}} N_p(4\pi r^2)p(r)dr$$

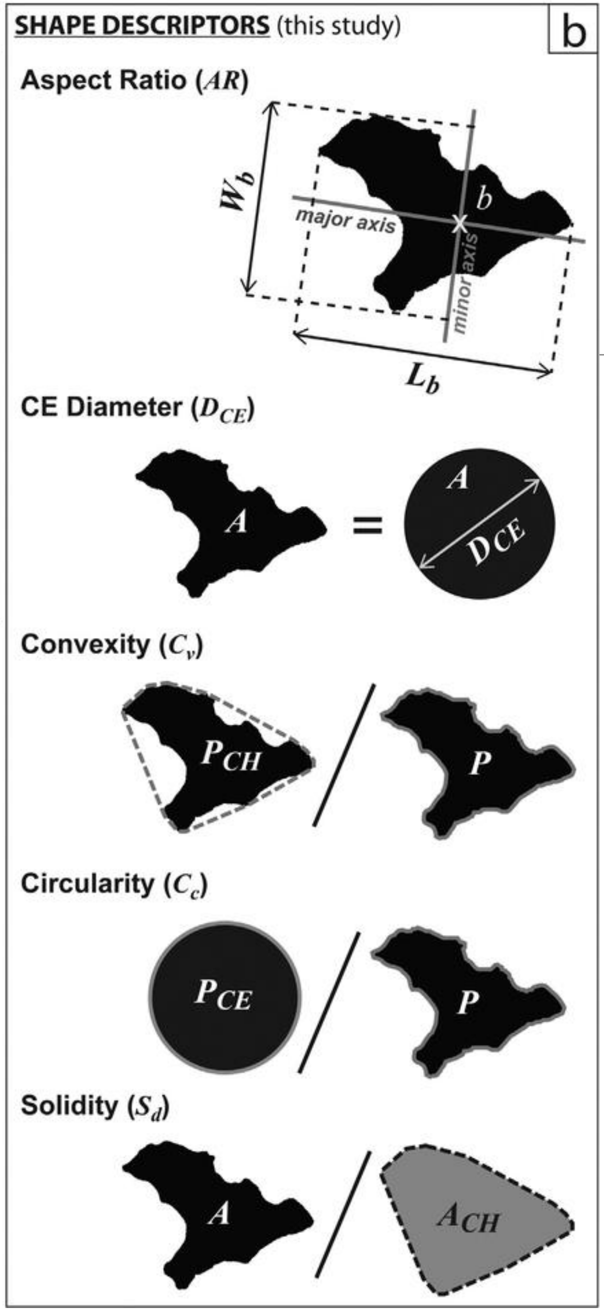
$$A = 4\pi N_p \frac{D}{D-2} d^D{}_{min}\left(\frac{1}{d_{min}{}^{D-2}} - \frac{1}{d_{max}{}^{D-2}}\right)$$

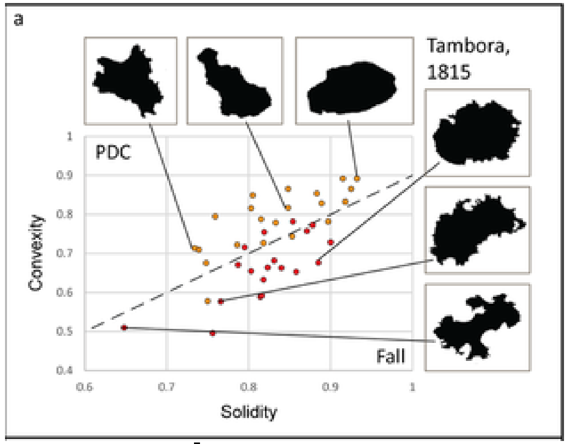
Total volume of fragments
(Turcotte, 1986)

$$V = \int_{d_{min}}^{d_{max}} N_p\left(\frac{4}{3}\pi r^3\right)p(r)dr$$

$$V = \frac{4}{3}\pi N_p \frac{D}{3-D} d^D{}_{min}(d_{max}{}^{3-D} - d_{min}{}^{3-D})$$







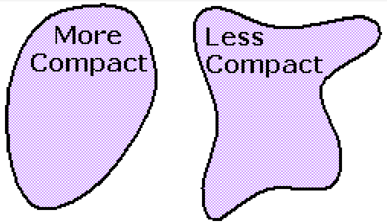


IMAGE ANALYSIS

Shape Factors

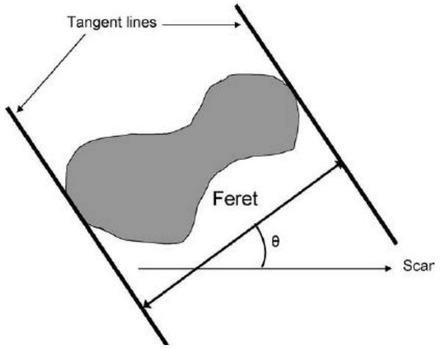
CIRCULARITY

$4 \pi \text{ Area}/\text{Per}^2$

ELONGATION

minor/major

FERET'S DIAMETER



SOLIDITY

Area/Convex Hull

ROUNDNESS

$4\text{Area}/ \pi a$

COMPACTNESS

$2(\text{Area } \pi)^{1/2}/\text{Per}$

COMPLEXITY

$\text{Per}/2(\text{Area } \pi)^{1/2}$

SPHERICITY

$Sph_A=A_s/A_{circ}$

$Sph_D=D_c/D_{circ}$

$Sph_c=D_{ins}/D_{circ}$

$Sph_p=P_c/P_s$

$Sph=b/a$

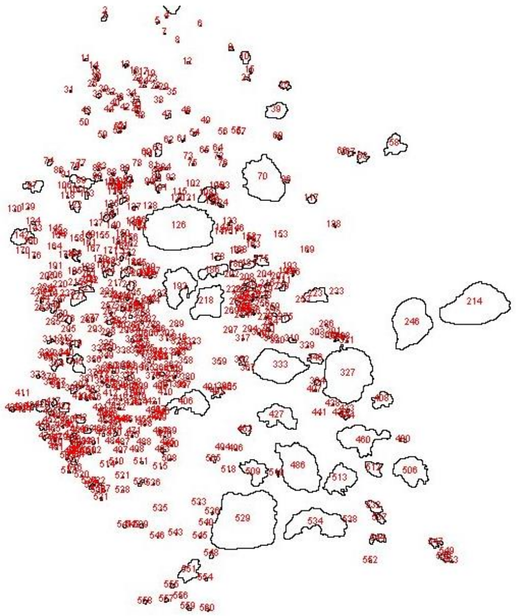
ASPECT RATIO

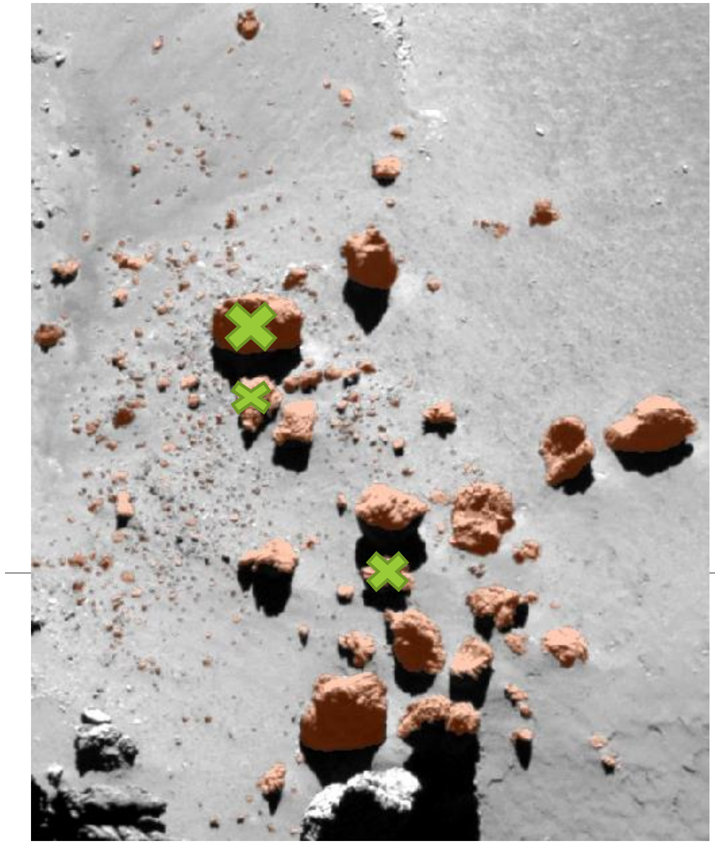
major/minor

IMAGE ANALYSIS

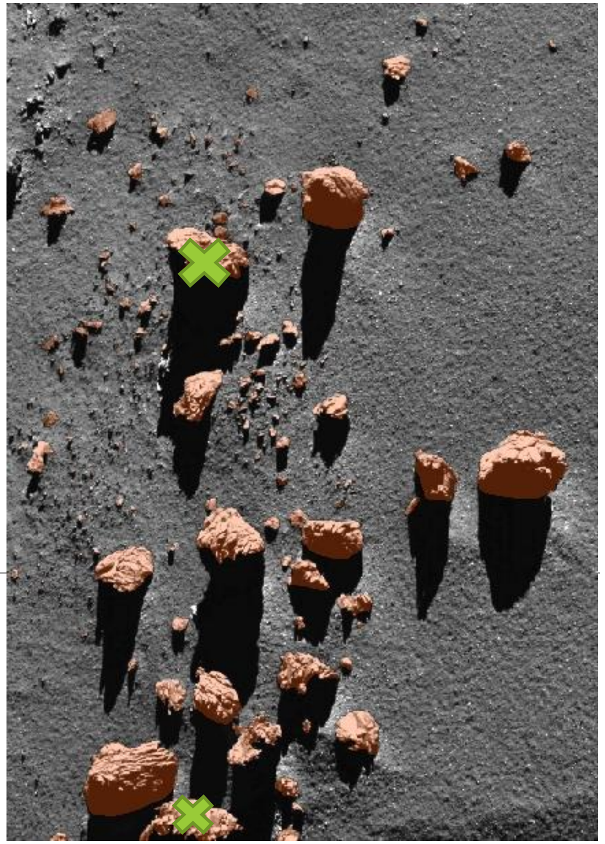
Shape Factors

HAPI

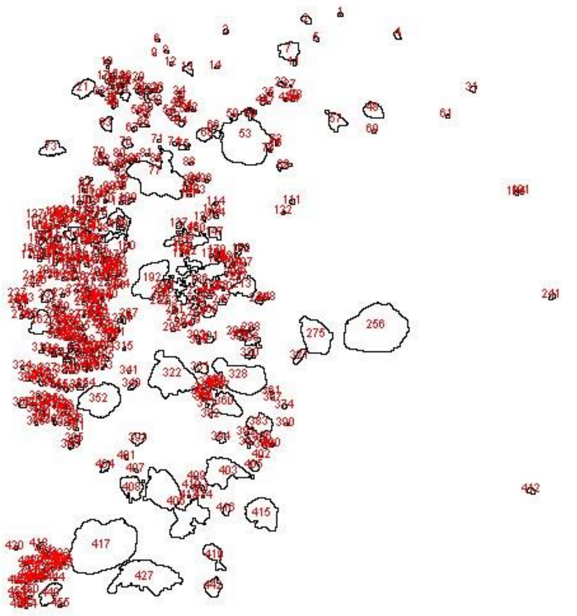




Phase angle: 91.79 deg
Resolution: 0.38 m/px

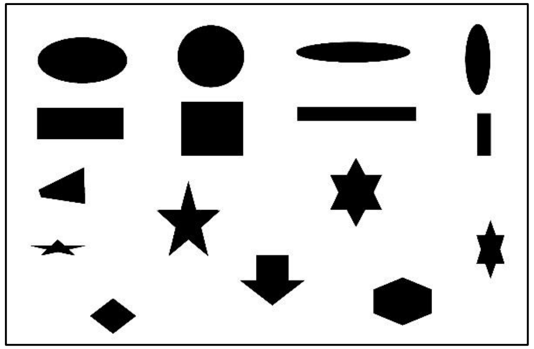


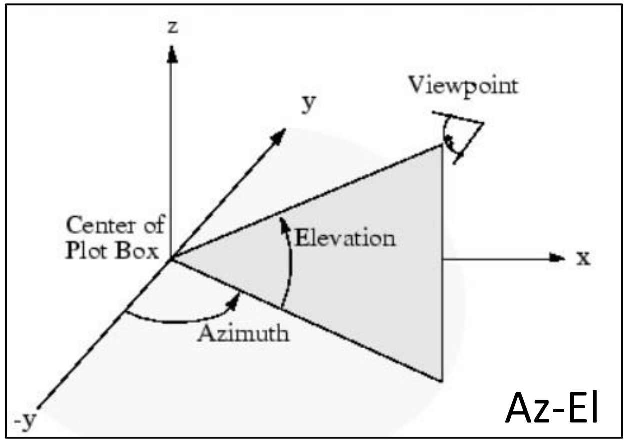
Phase angle: 89.11 deg
Resolution: 0.17 m/px



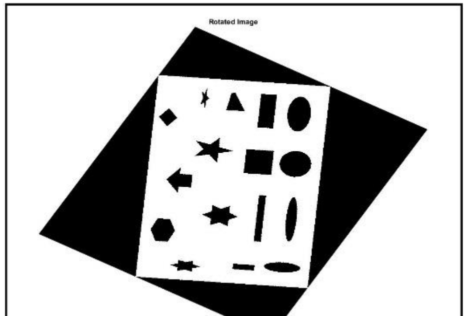
SHAPE FACTORS

Synthetic Image – Test 1

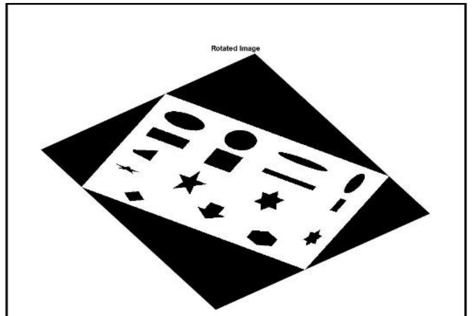




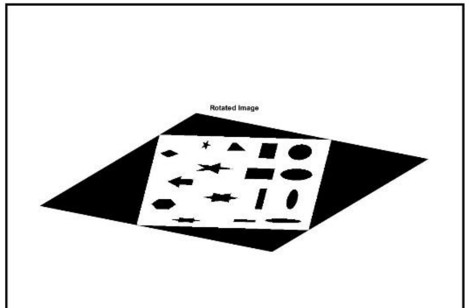
Az-El



120-50



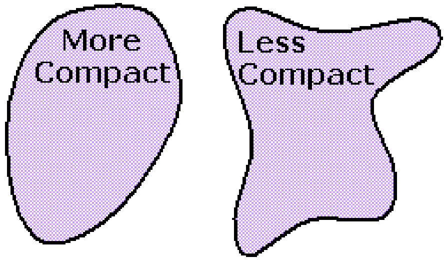
55-40



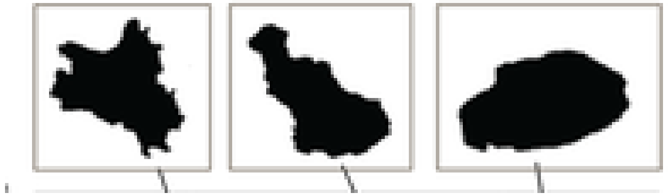
120-20

Random

Circularity

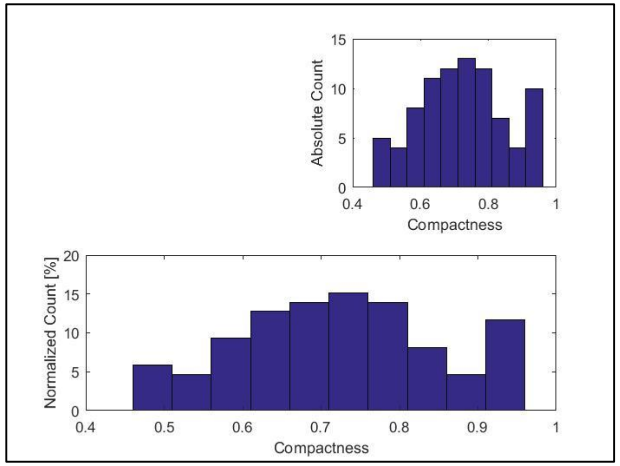


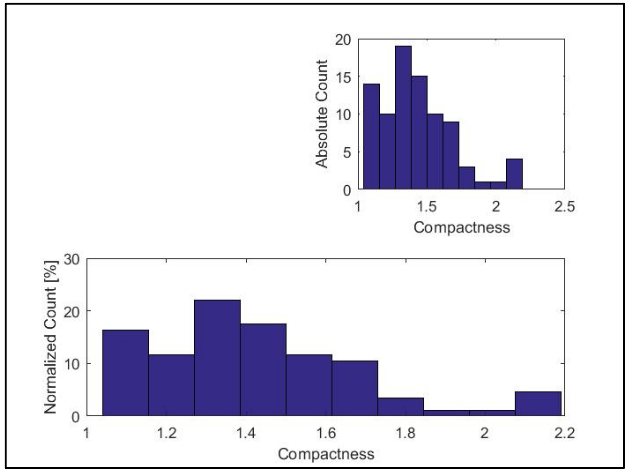
Compactness

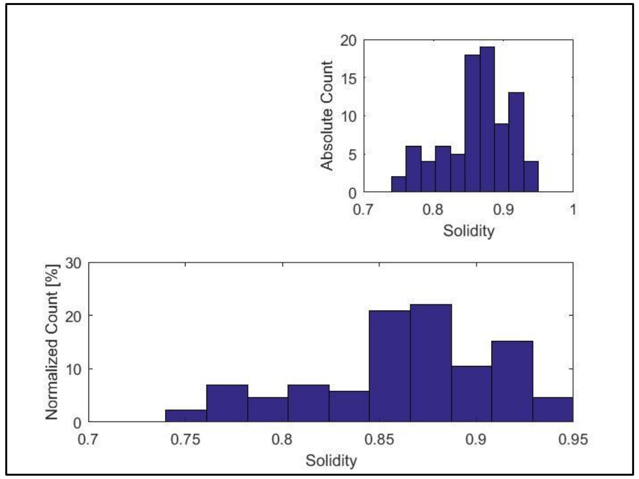


Solidity

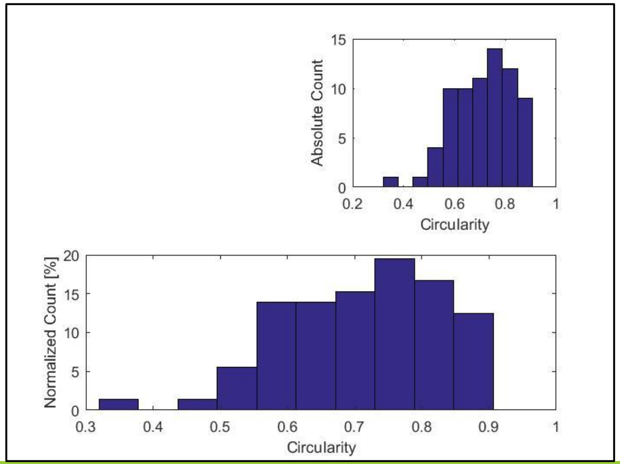
Pre

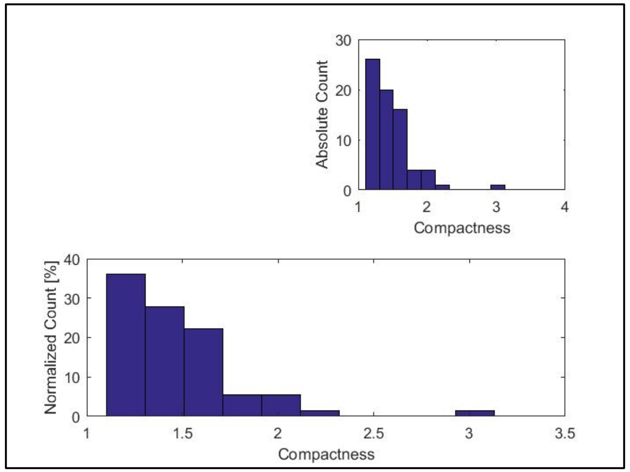


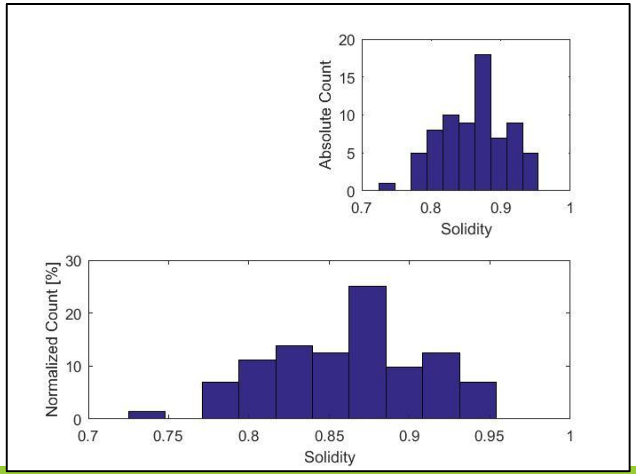




Post







SHAPE FACTORS

Average	IMHOTEP PRE	IMHOTEP POST	IMHOTEP DET PRE	IMHOTEP DET POST	HAPI PRE	HAPI POST
Circularity	0.76	0.75	0.81	0.78	0.73	0.71
Solidity	0.86	0.87	0.89	0.89	0.86	0.86
Compactness	1.35	1.36	2.53	2.58	1.42	1.46

- Extending this method to the other regions
- Comparing these results with Earth's classification

Future Work

Thermal and Sublimation model

Fragmentation model

Finite Element Method

To calculate macroscopic properties from images of real or simulated microstructures.

INPUT PARAMETERS

Density
Tensile strength
Shear strength
Compressive strength
Heat flux density
Thermal inertia
Thermal conductivity
Porosity
Thermal conductivity range
Water production rate
CO_2/H_2O ratio
SFD
Fractal dimension
…

- To read an image

To assign material properties to features in the image
To conduct virtual experiments to determine the macroscopic properties of the microstructure.

- To simulate the breakage of a mass

Pre-fractured
Variation of temperature
Variation of composition
It utilizes the time-dependent heat flux density as boundary conditions to calculate stresses over a period of time