Characterization of lunar crater wall slumping -method & some early results.

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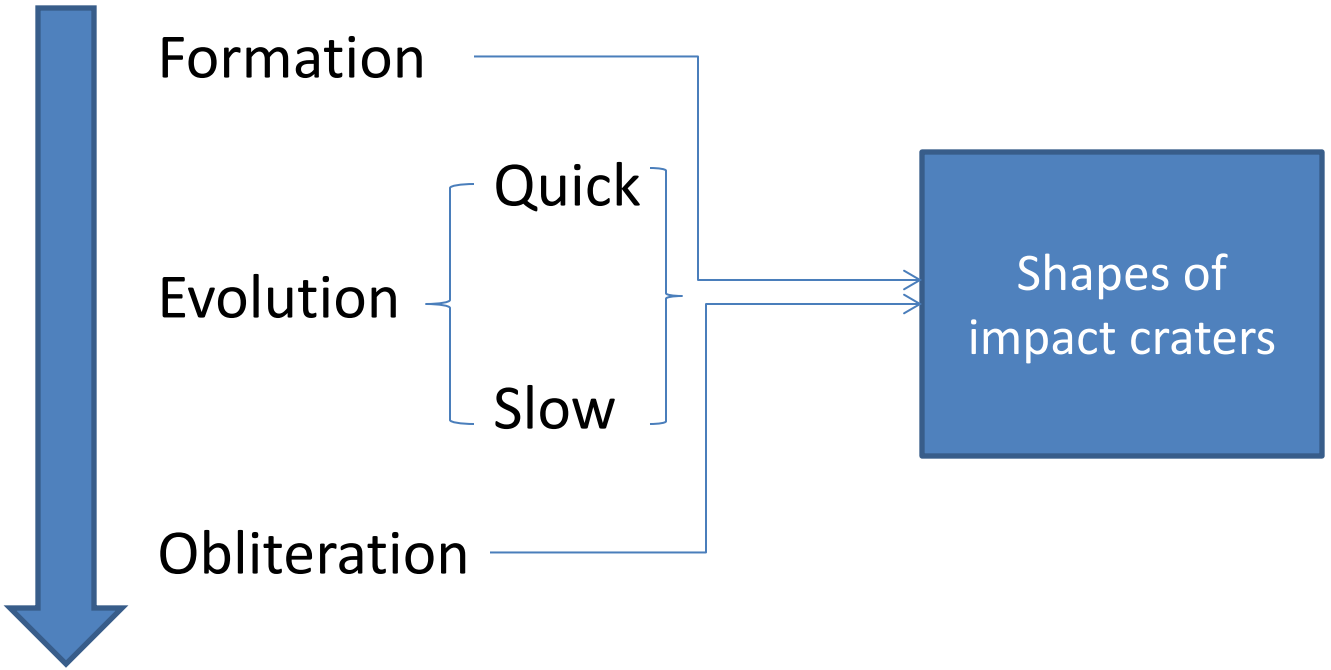
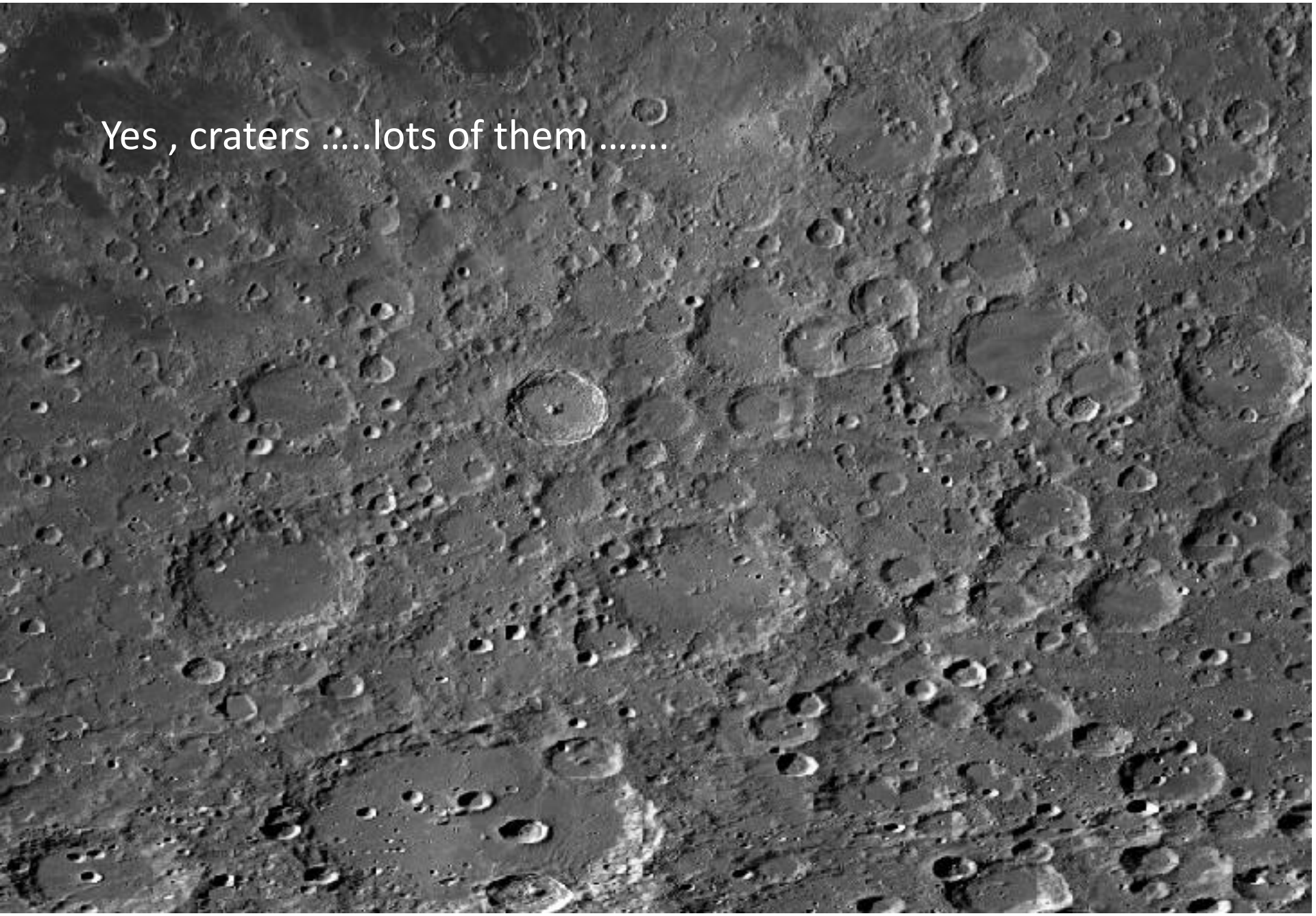
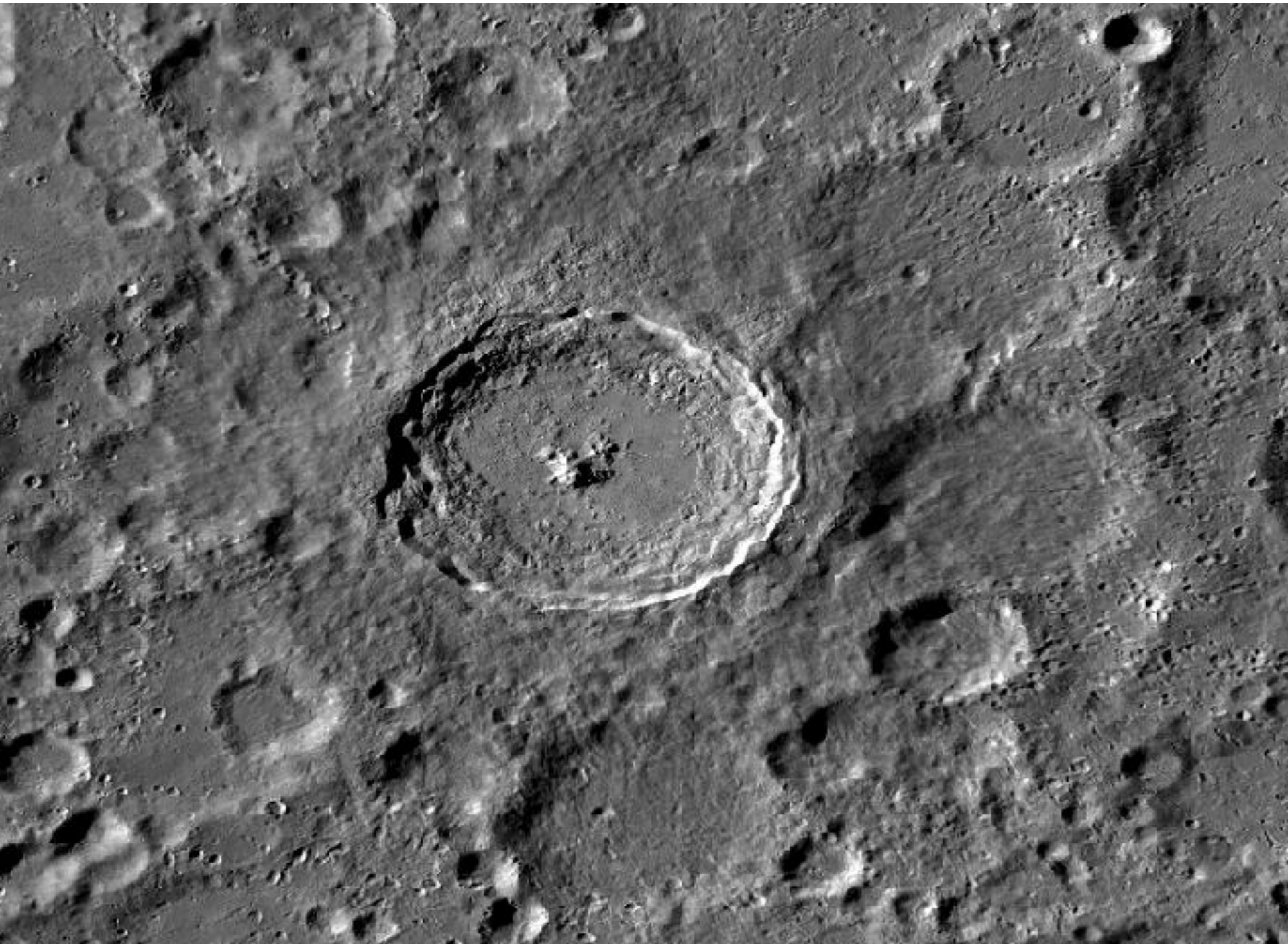
Mark Robinson
Tyler Thompson
LROC Team

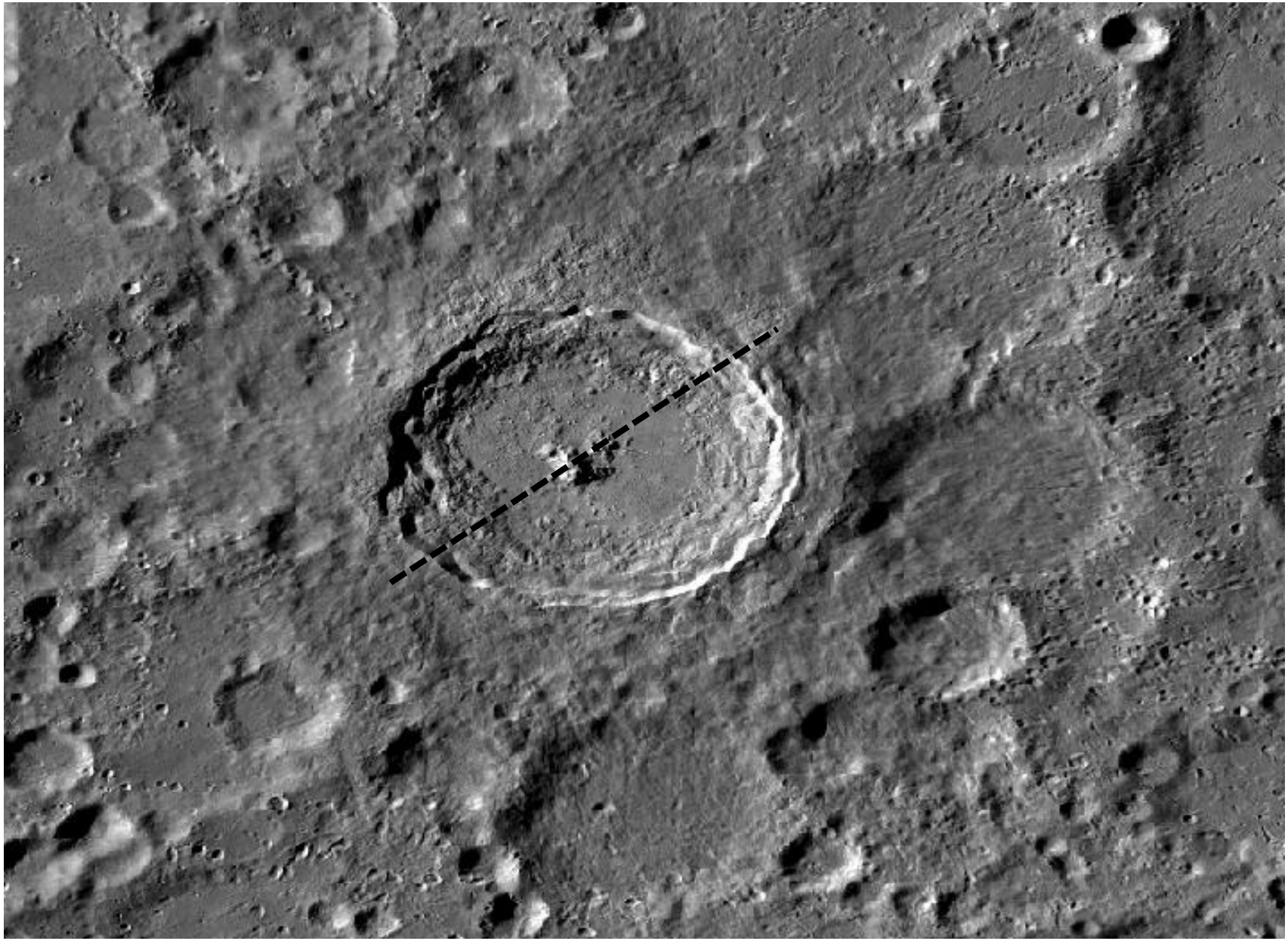
- Impact events continue to reshape the lunar landscape; shapes of impact craters evolve over time as a result of both slow (e.g. micrometeorite impacts) and instantaneous (e.g. impact events occurring on existing craters) processes.

- The shapes of craters = key indicators of the nature of past and present surface processes + target property

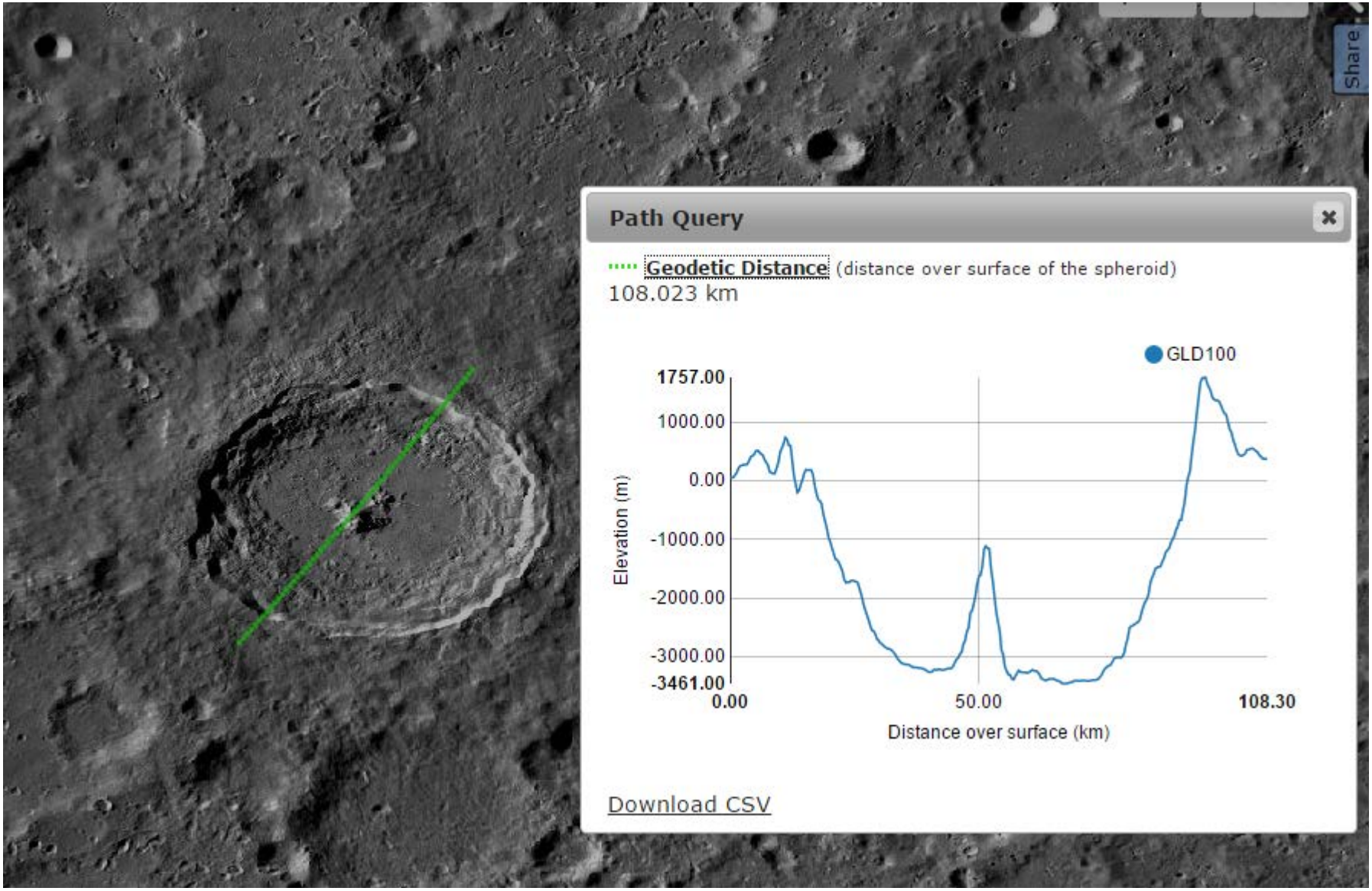



Yes , craters …..lots of them …….

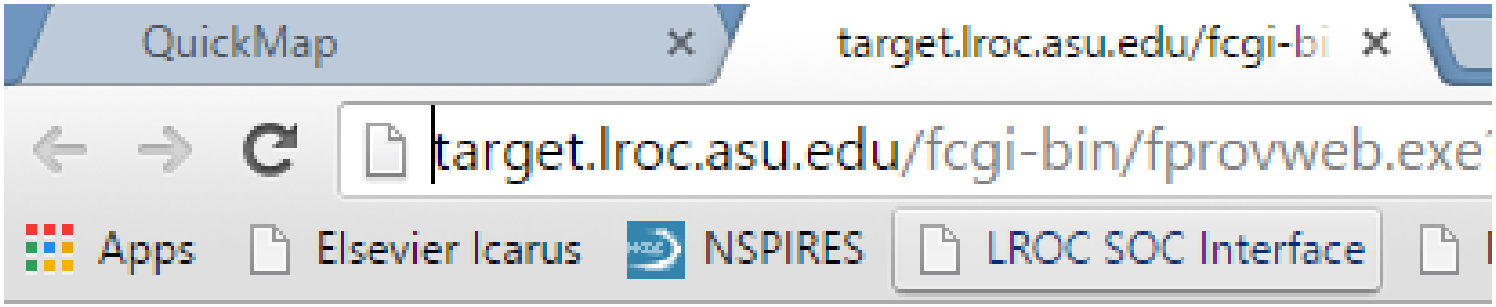




Use Quick Map



Use Quick Map

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       0.69721,    746.00000,     -9.69428,    -41.94382
       1.04582,    752.00000,     -9.70424,    -41.95261
       1.39443,    744.00000,     -9.71421,    -41.96140
       1.74304,    727.00000,     -9.72417,    -41.97019
       2.09164,    741.00000,     -9.73414,    -41.97898
       2.44025,    743.00000,     -9.74411,    -41.98776
       2.78886,    743.00000,     -9.75409,    -41.99655
       3.13746,    744.00000,     -9.76407,    -42.00534
       3.48607,    745.00000,     -9.77405,    -42.01412
       3.83468,    728.00000,     -9.78403,    -42.02290
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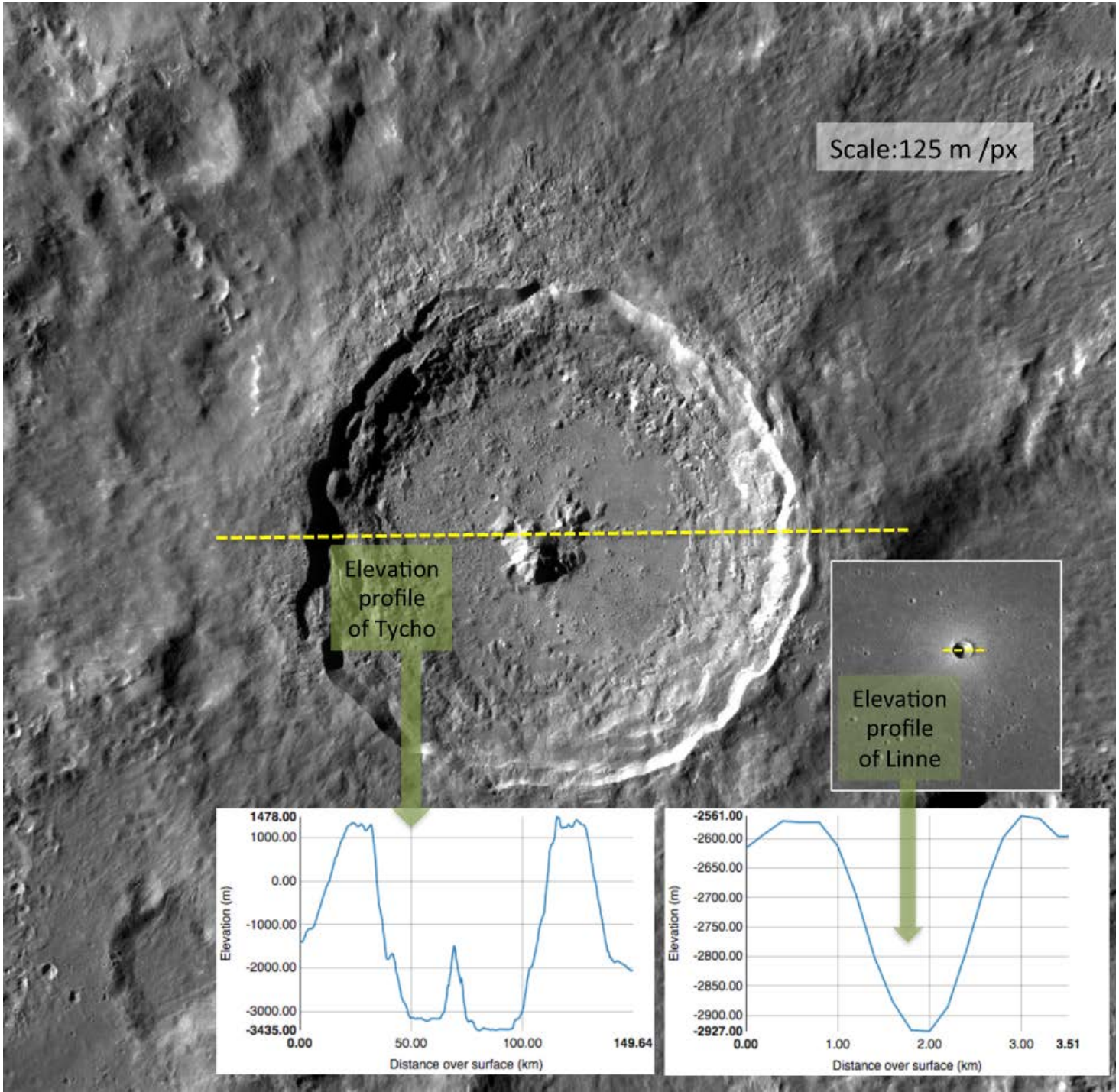
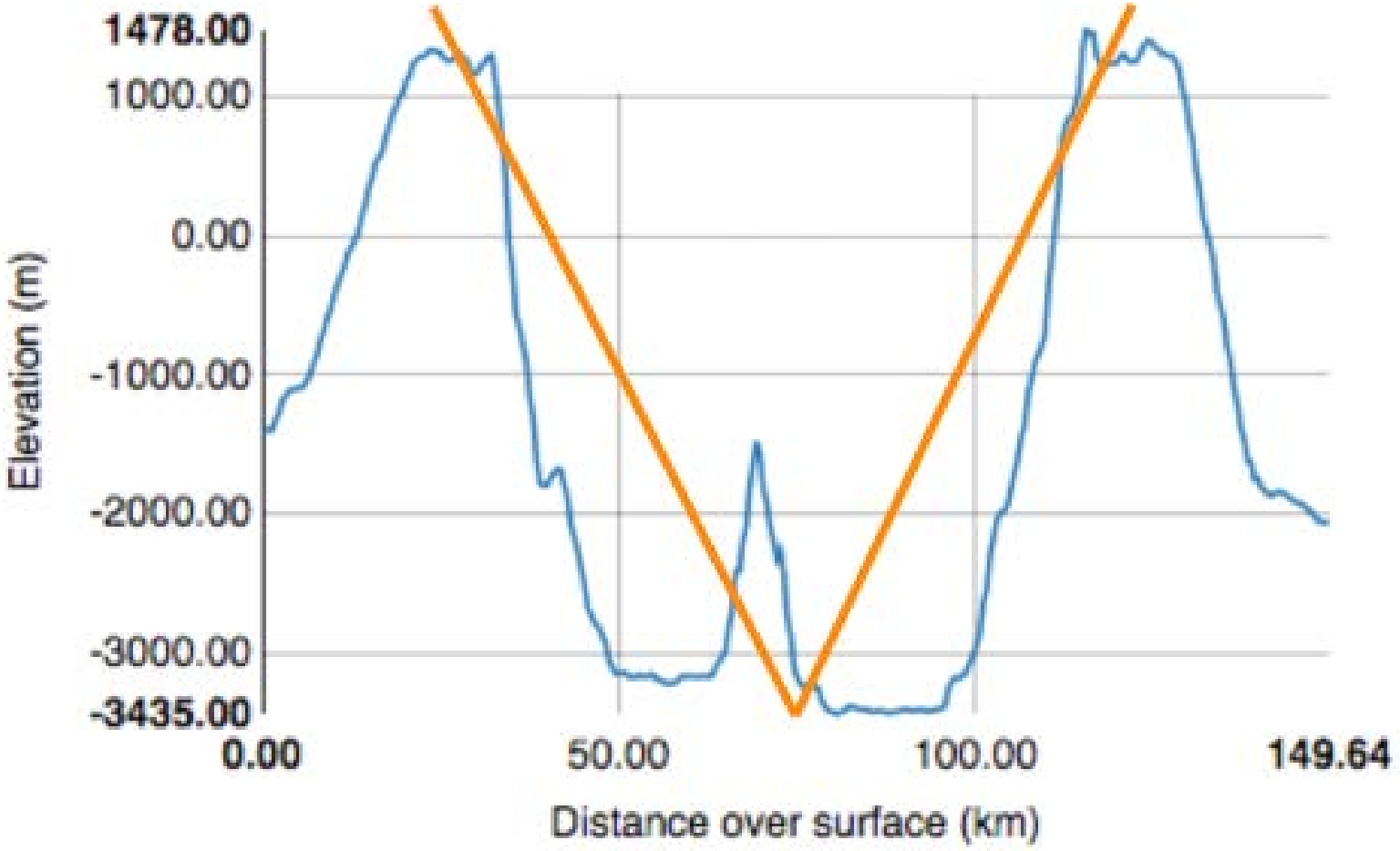
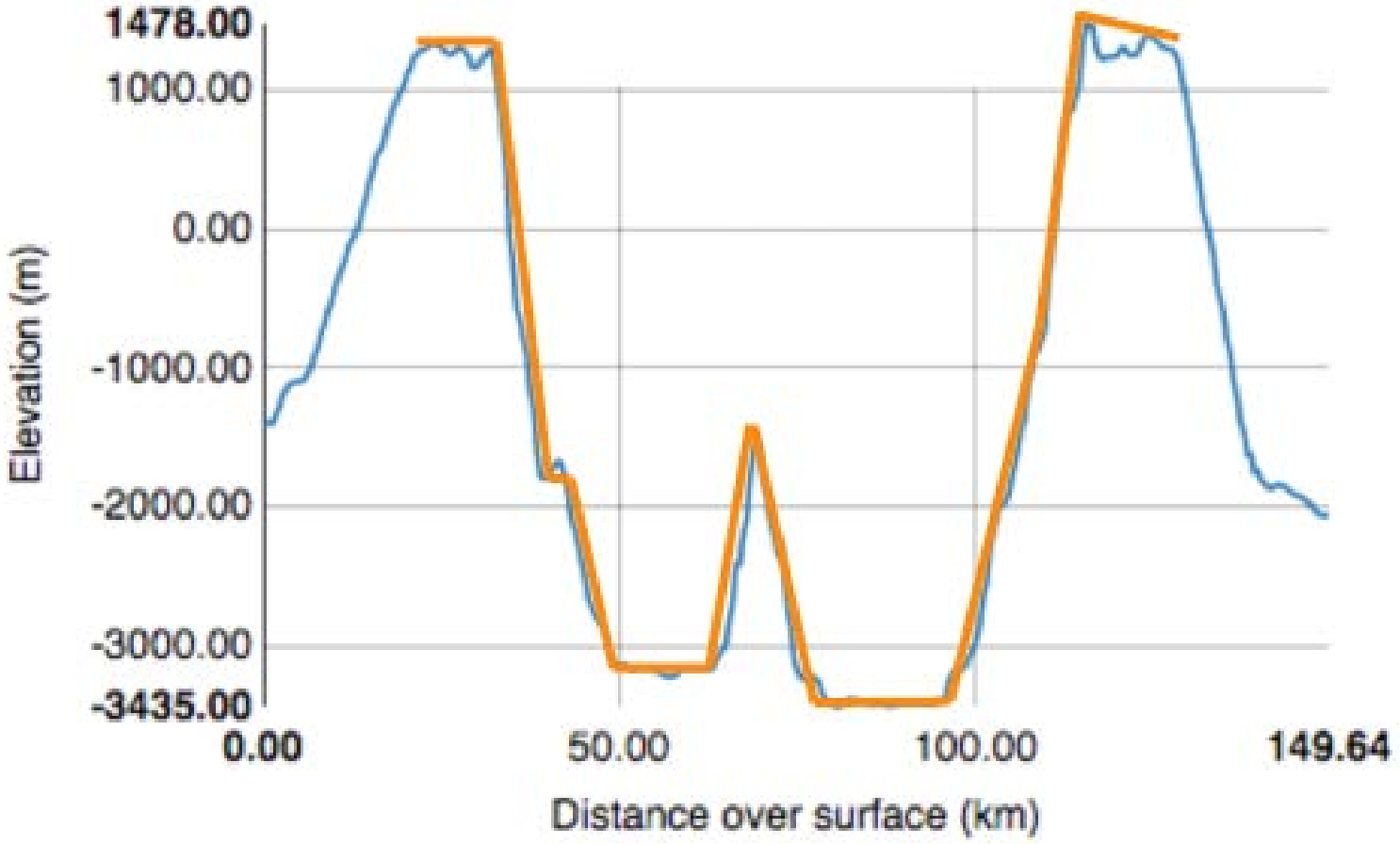
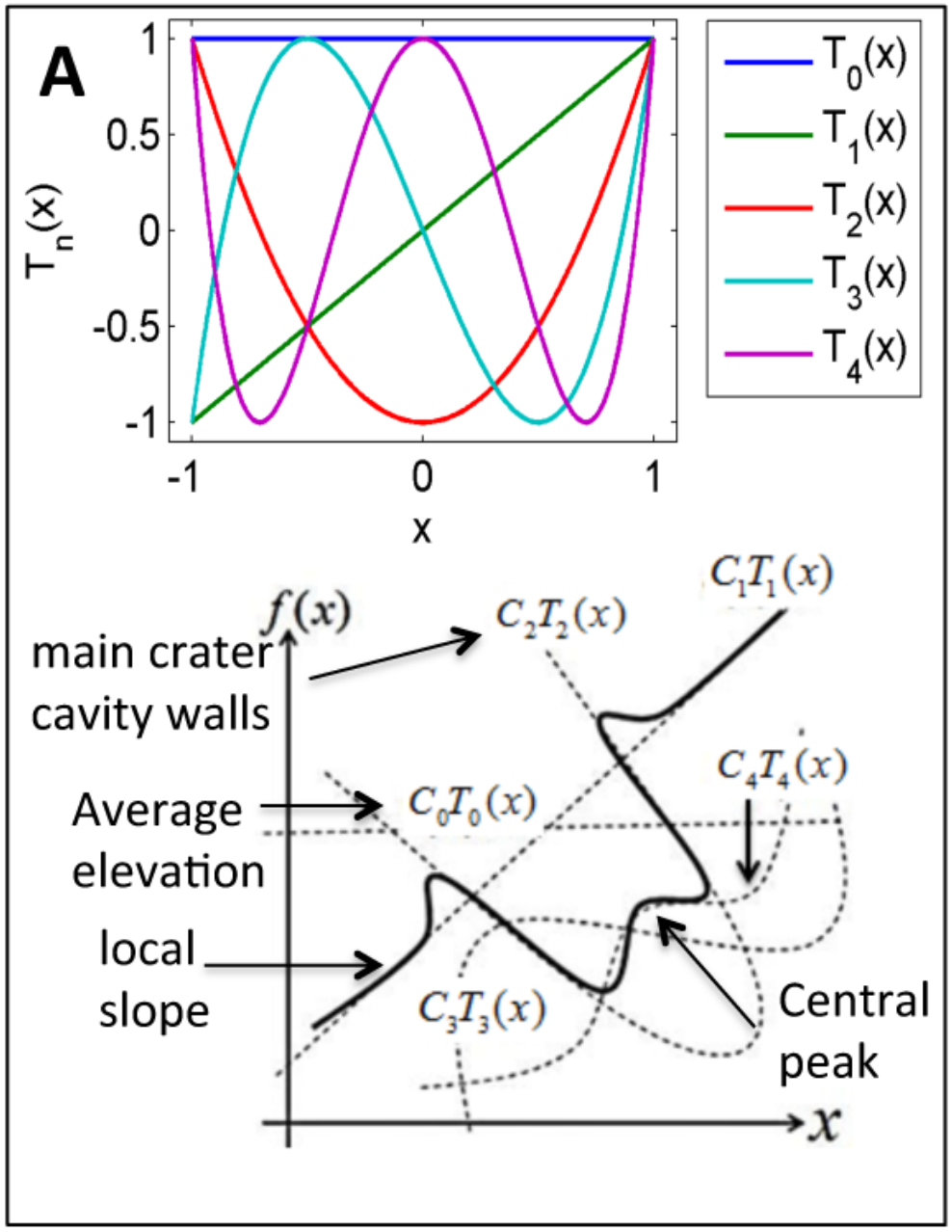
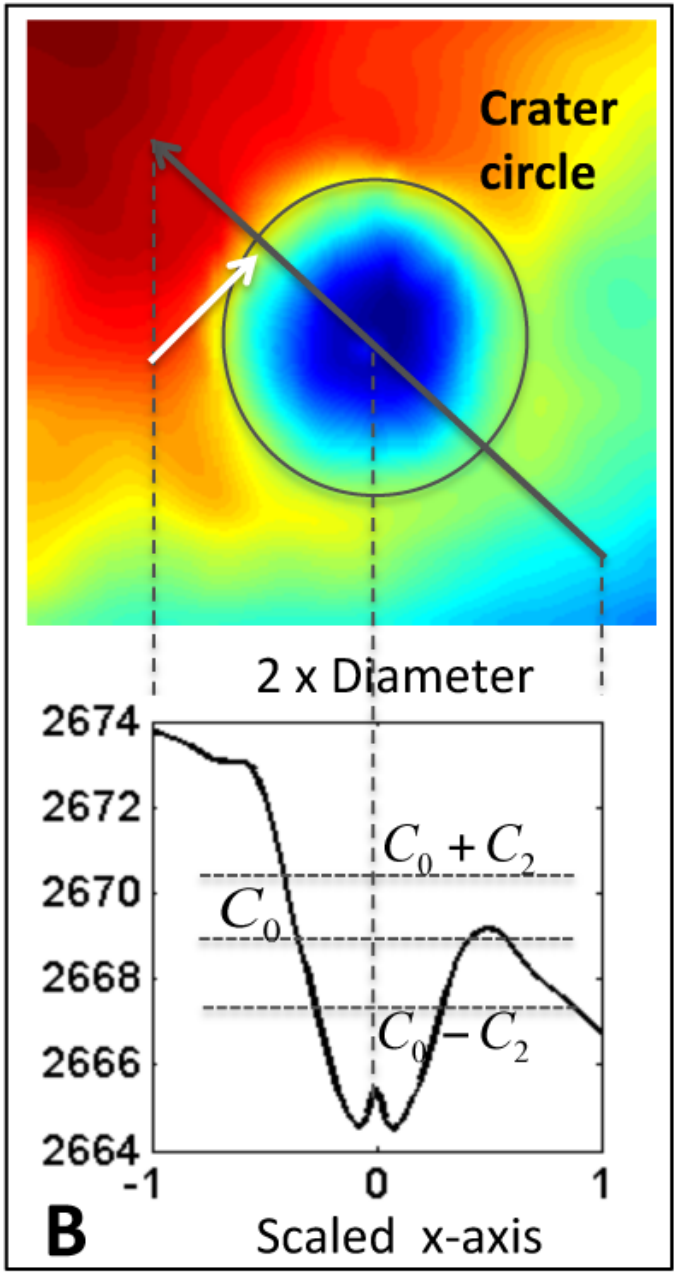
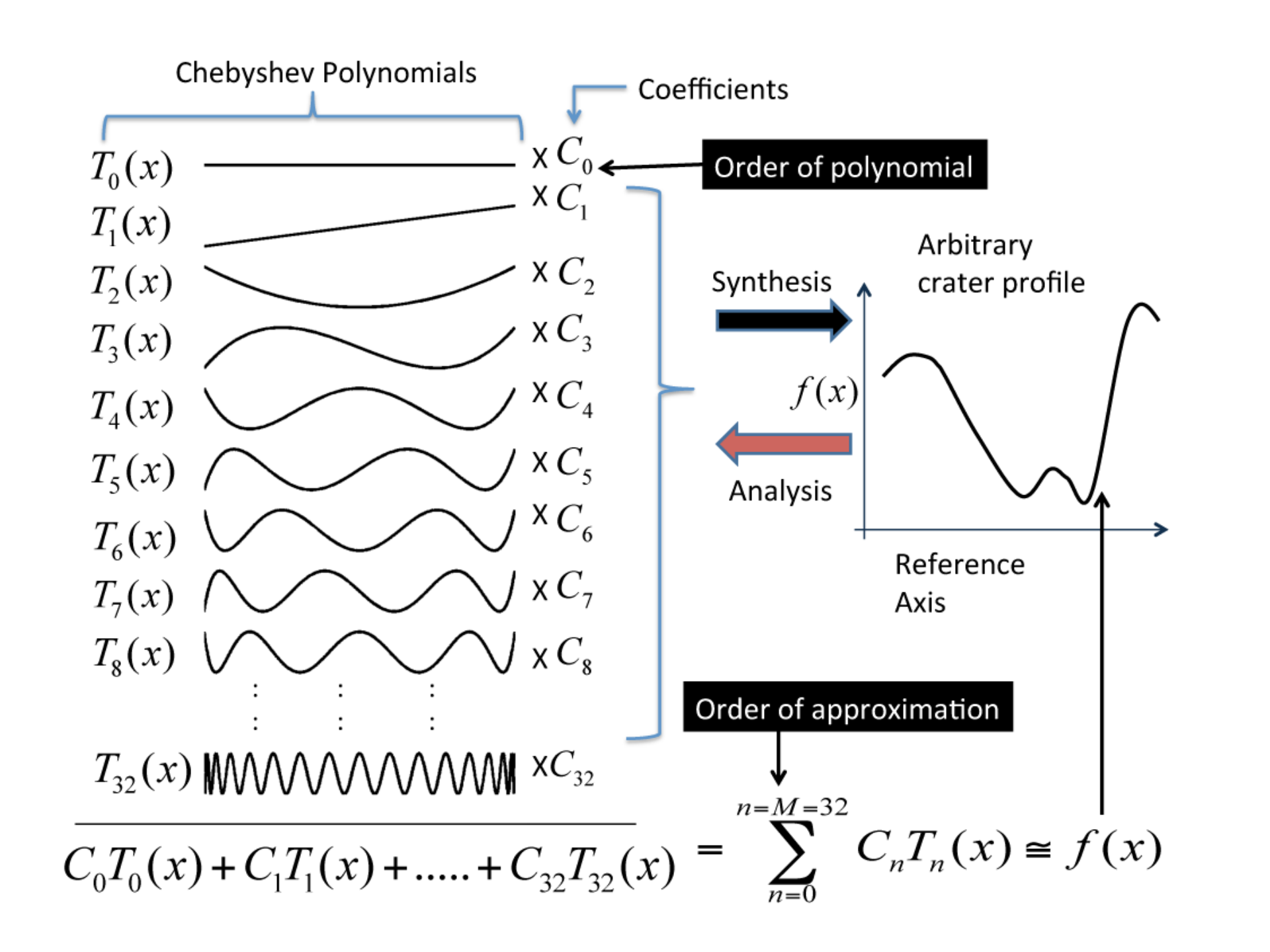

Scale:125 m /px
Elevation profile of Tycho
Elevation profile of Linne
1478.00
1000.00
0.00
-1000.00
-2000.00
-3000.00
-3435.00
Elevation (m)
0.00
50.00
100.00
149.64
Distance over surface (km)
-2561.00
-2600.00
-2650.00
-2700.00
-2750.00
-2800.00
-2850.00
-2900.00
-2927.00
Elevation (m)
0.00
1.00
2.00
3.00
3.51
Distance over surface (km)

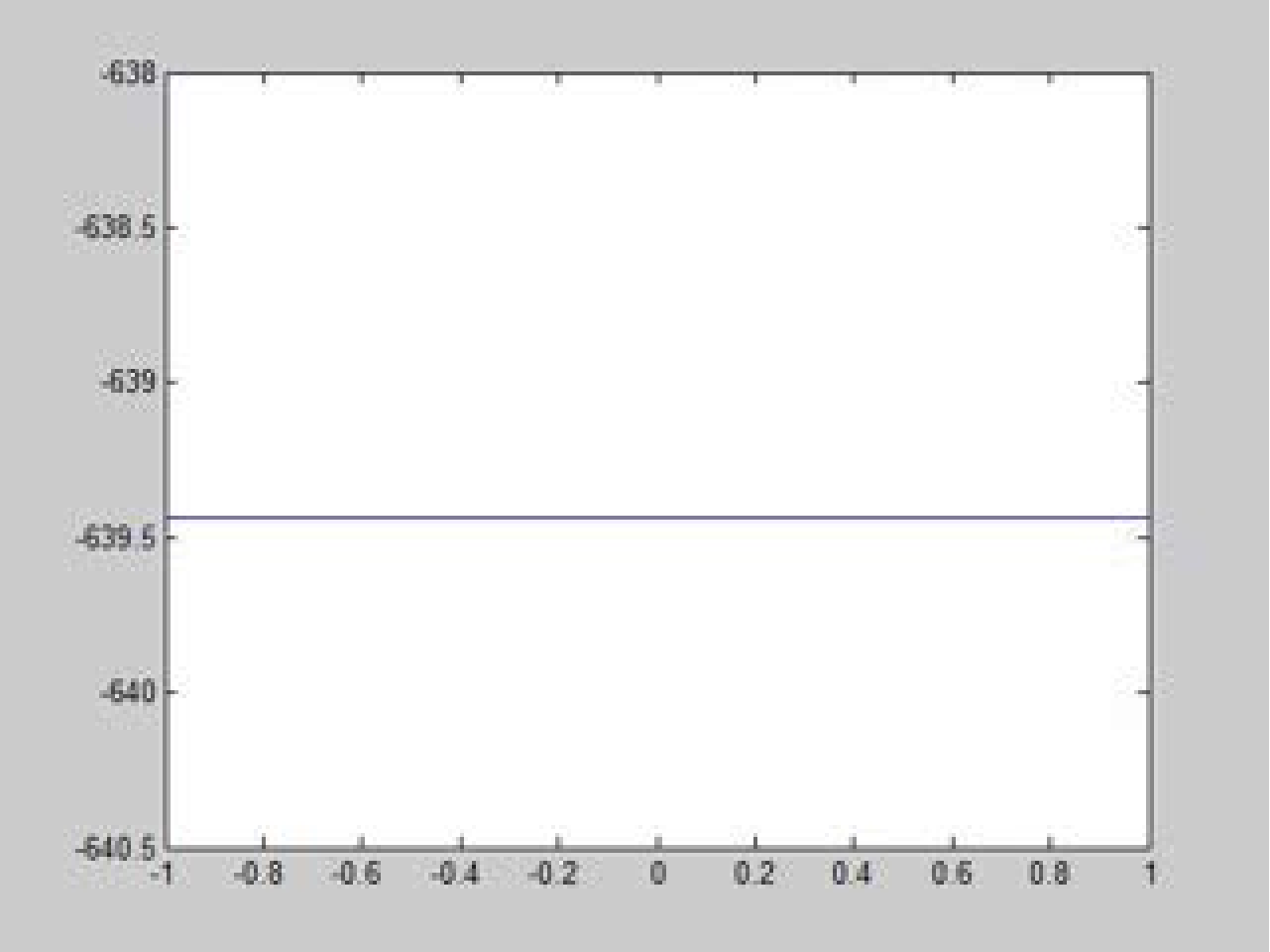

1478.00
1000.00
0.00
-1000.00
-2000.00
-3000.00
-3435.00
Elevation (m)
0.00
50.00
100.00
149.64
Distance over surface (km)

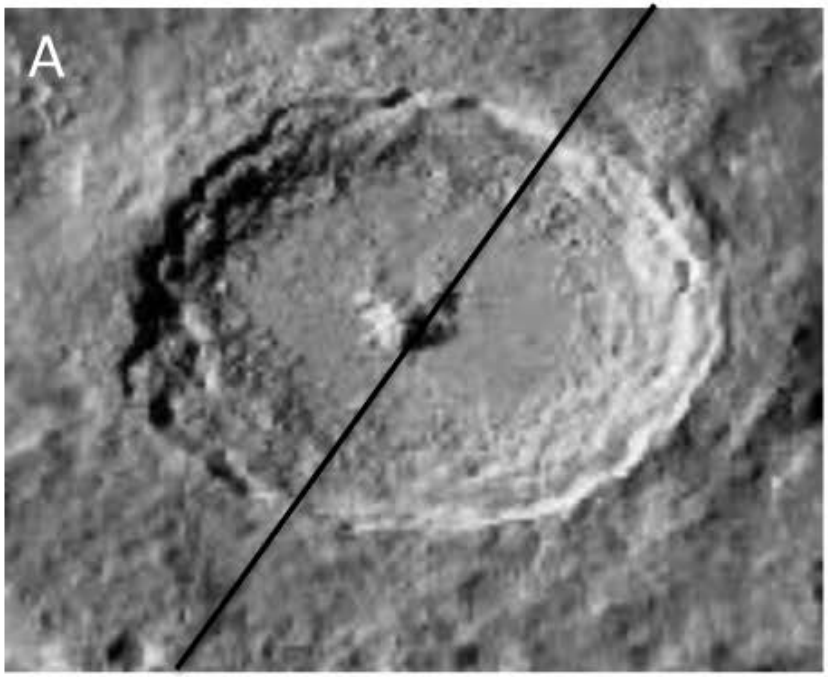

1478.00
1000.00
0.00
-1000.00
-2000.00
-3000.00
-3435.00
Elevation (m)
0.00
50.00
100.00
149.64
Distance over surface (km)


A
$T_n(x)$
x
$T_0(x)$
$T_1(x)$
$T_2(x)$
$T_3(x)$
$T_4(x)$
$f(x)$
$C_1T_1(x)$
$C_2T_2(x)$
$C_4T_4(x)$
$C_0T_0(x)$
$C_3T_3(x)$
main crater cavity walls
Average elevation
local slope
Central peak
x


Crater circle
2 x Diameter
2674
2672
2670
2668
2666
2664
$C_0 + C_2$
C_0
$C_0 - C_2$
-1
0
1
B
Scaled x-axis


Chebyshev Polynomials
Coefficients
$T_0(x)$ x C_0
$T_1(x)$ x C_1
$T_2(x)$ x C_2
$T_3(x)$ x C_3
$T_4(x)$ x C_4
$T_5(x)$ x C_5
$T_6(x)$ x C_6
$T_7(x)$ x C_7
$T_8(x)$ x C_8
$T_{32}(x)$ xC_{32}
Order of polynomial
Synthesis
Analysis
$f(x)$
Arbitrary crater profile
Reference Axis
Order of approximation
$C_0T_0(x)+C_1T_1(x)+.....+C_{32}T_{32}(x) = \sum_{n=0}^{n=M=32} C_nT_n(x) \cong f(x)$


-638
-638.5
-639
-639.5
-640
-640.5
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1



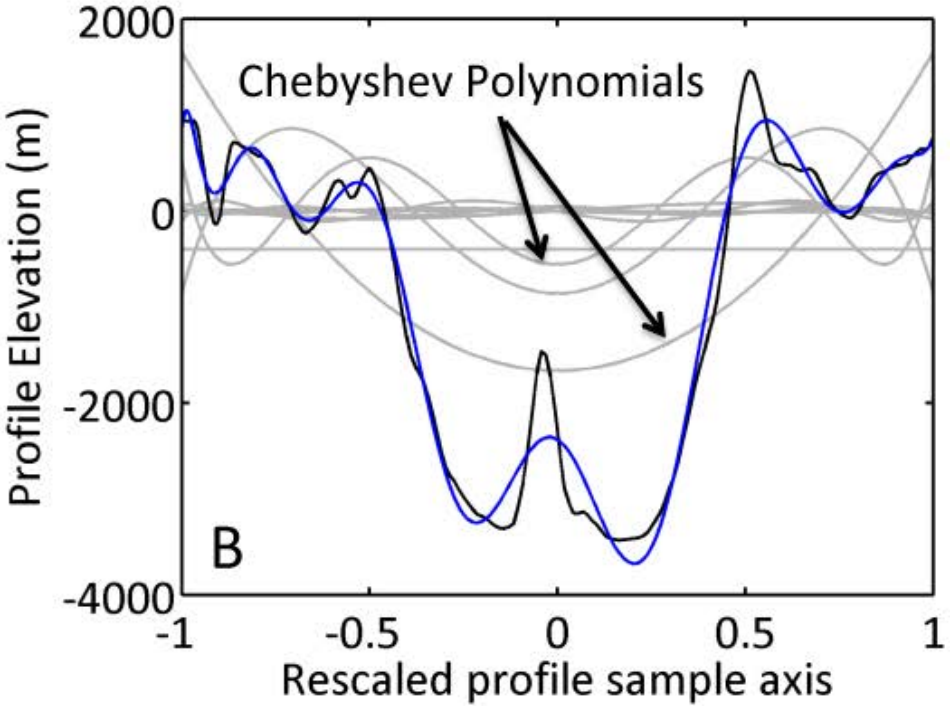


Table of first 9 Chebyshev coefficients

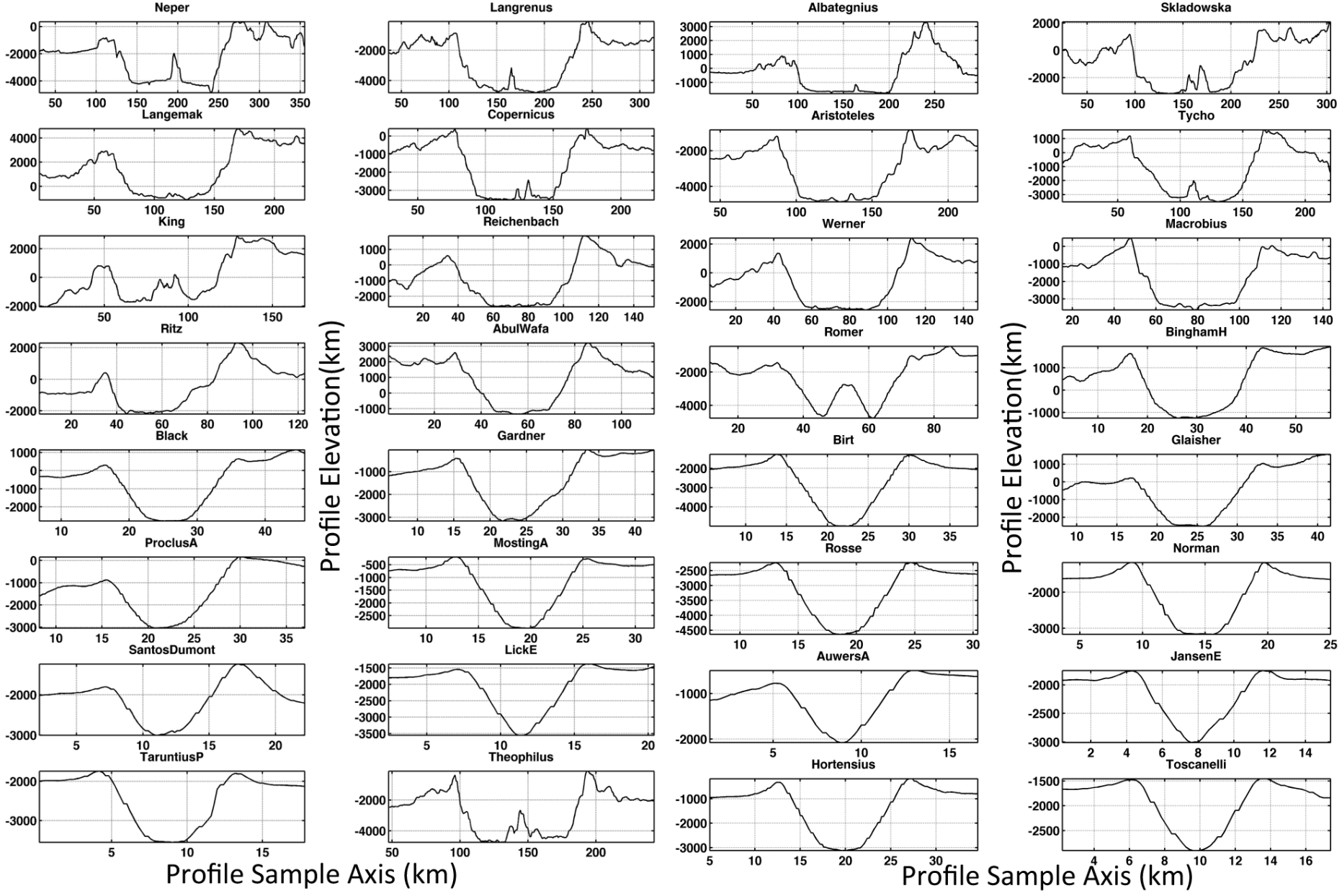
	C0	C1	C2	C3	C4	C5	C6	C7	C8
Tycho	-400	-9	1177	-57	-609	-21	395	76	32
Linne	-2660	3	49	4	-56	-6	49	8	-33

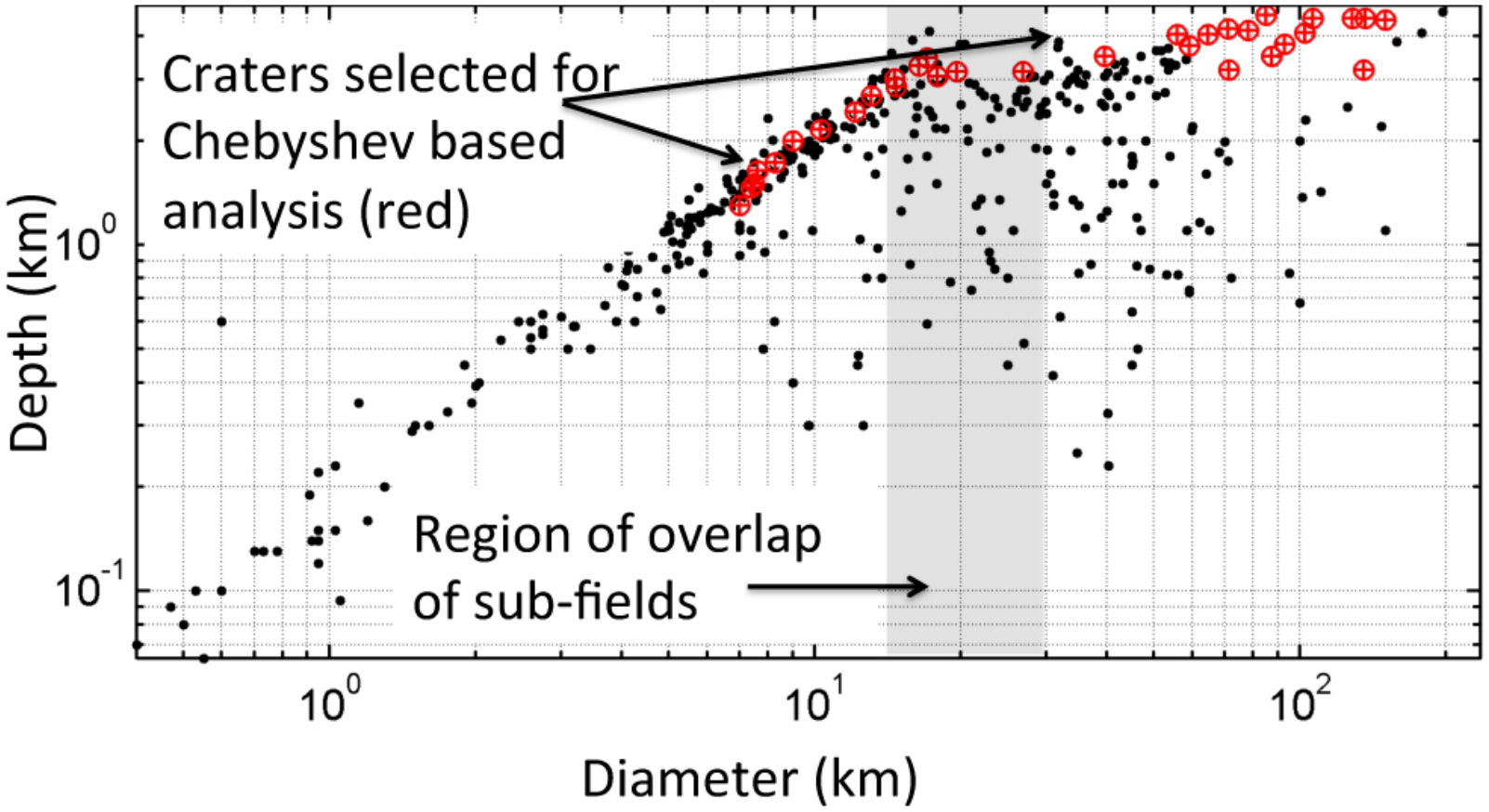
Tycho mean elevation closer to zero

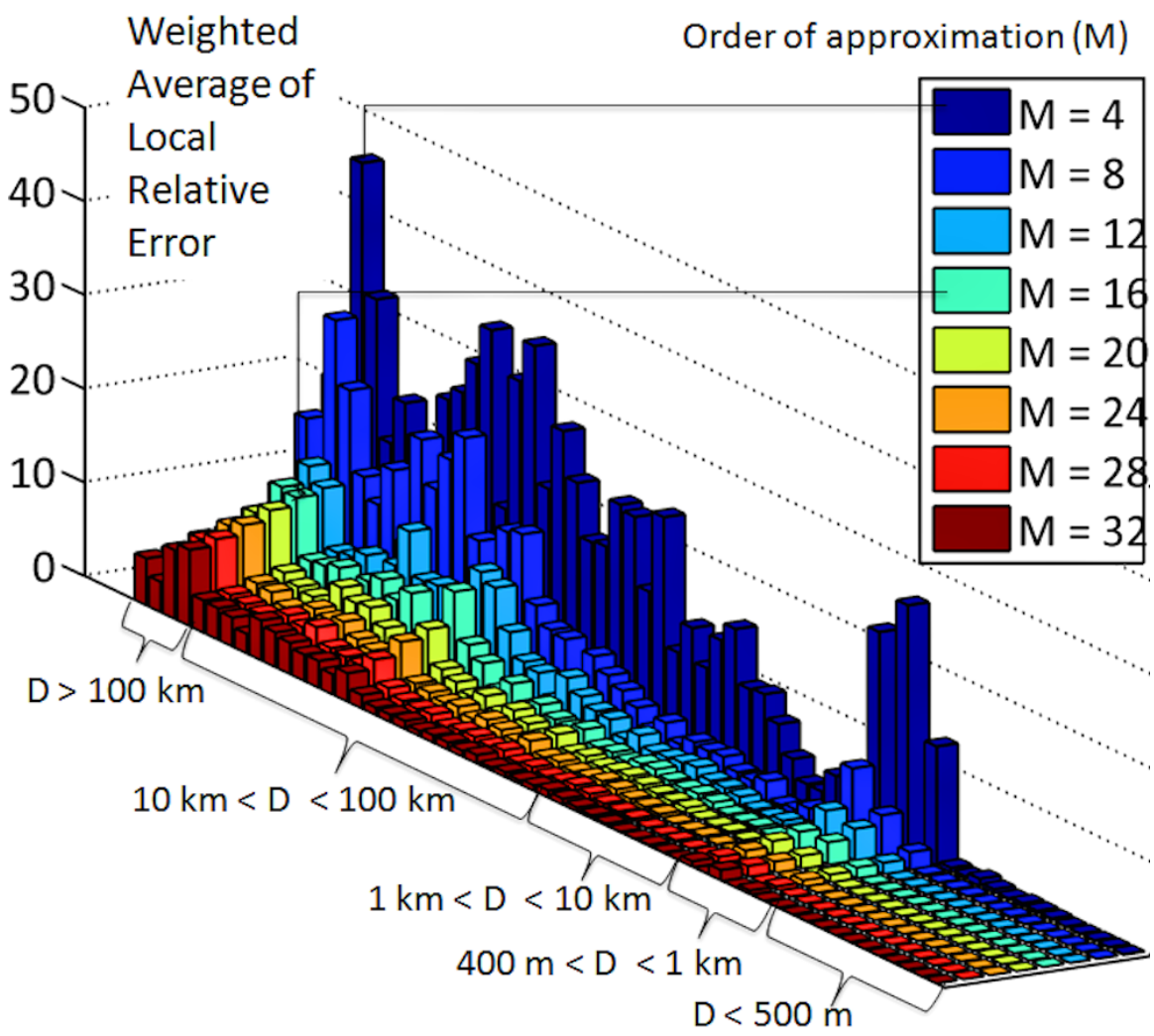
Tycho is deeper

Linne is more symmetric

Tycho has stronger central peak activity


Neper
Langrenus
Albategnius
Skladowska
Langemak
Copernicus
Aristoteles
Tycho
King
Reichenbach
Werner
Macrobius
Ritz
AbulWafa
Romer
BinghamH
Black
Gardner
Birt
Glaisher
ProclusA
MostingA
Rosse
Norman
SantosDumont
LickE
AuwersA
JansenE
TaruntiusP
Theophilus
Hortensius
Toscanelli
Profile Elevation(km)
Profile Elevation(km)
Profile Sample Axis (km)
Profile Sample Axis (km)


Craters selected for
Chebyshev based
analysis (red)
Region of overlap
of sub-fields
Depth (km)
Diameter (km)
10^0
10^{-1}
10^0
10^1
10^2

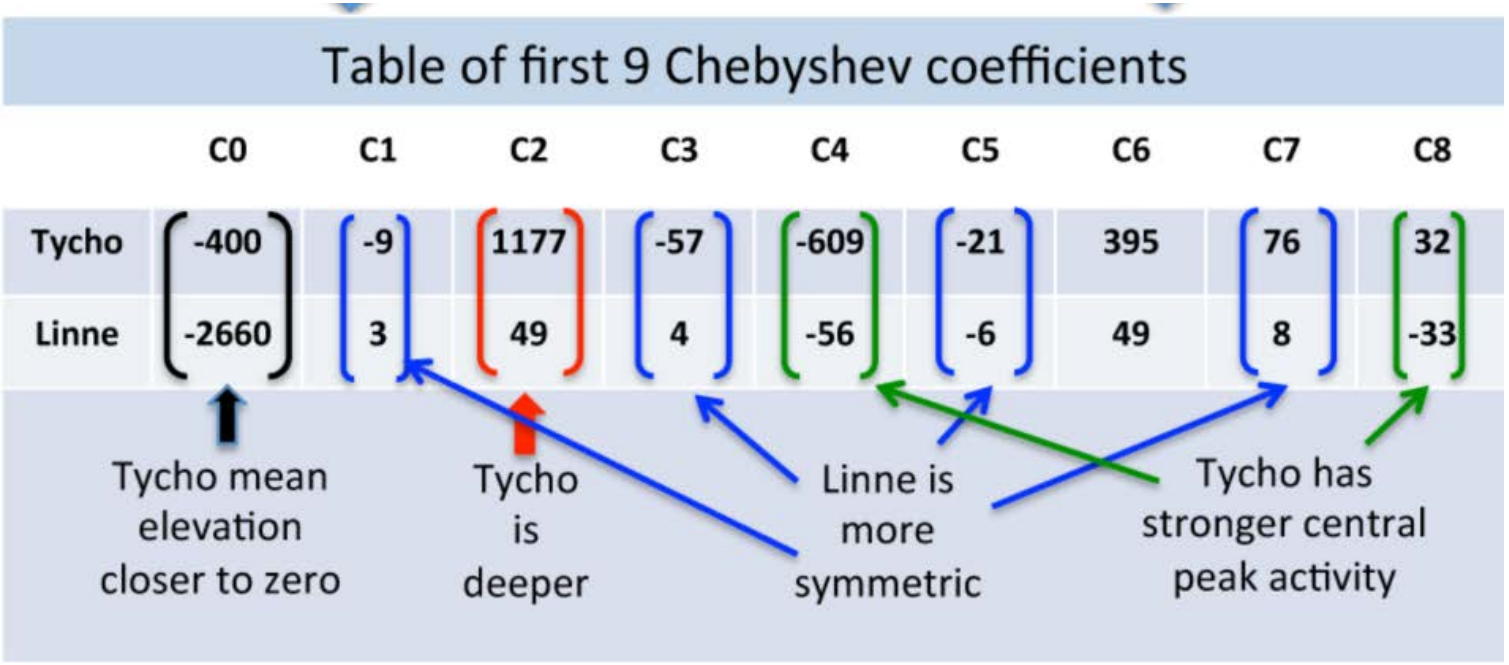


Almost any lunar crater can be well-represented (10% error or less) by < 20 numbers.

A 128 x 128 raster can store information of 768 craters

A standardized approach for quantitative characterization of impact crater topography

P. Mahanti [a,*], M.S. Robinson [a], D.C. Humm [b], J.D. Stopar [a]



How can we use the symmetry property ?

Hypothesis: Most craters when formed are symmetric (radially)
Axiom : Local activity causes loss of symmetry

1. **Impact (near and far)**
2. **Gravity controlled / structural stability**
3. **Seismic shaking**

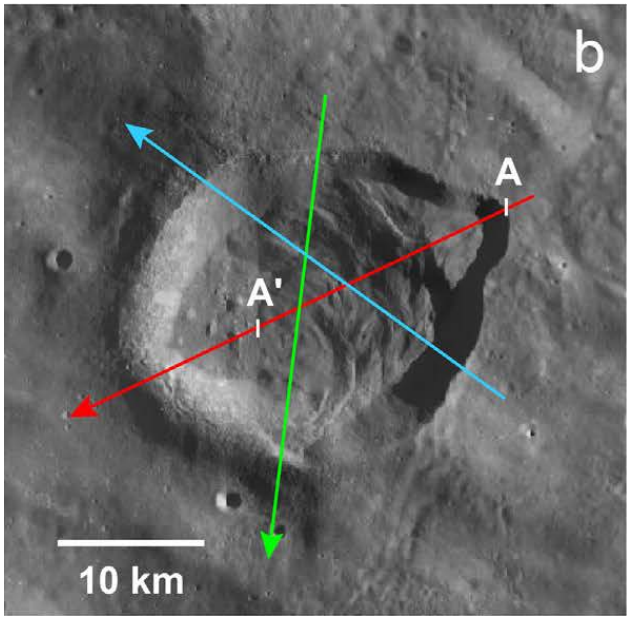
SLUMPING : Dislodging from rim + wall → collection via gravity + friction

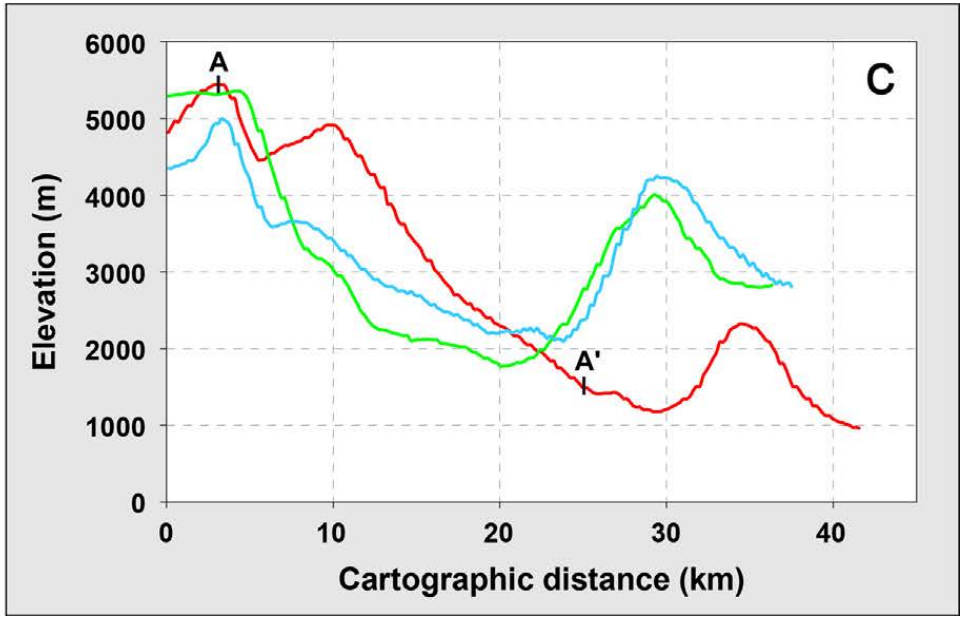
The slump formed can be identified and characterized from the topographic profile of the crater, only the measurements of the observed depth and diameter of the crater is not sufficient.

Further, if **the slumping is locally constrained (e.g. present in the north-east but not elsewhere) then this results in an asymmetric topographic profile** (when drawn northeast to south-west) which can be compared with other parts of the crater to analyze the slumping.

If slumping happened close to formation event, quantitative study leads to understanding the morphometric transition in shape, change in cavity volume

If slumping is recent, characterization leads to understanding of recent events.





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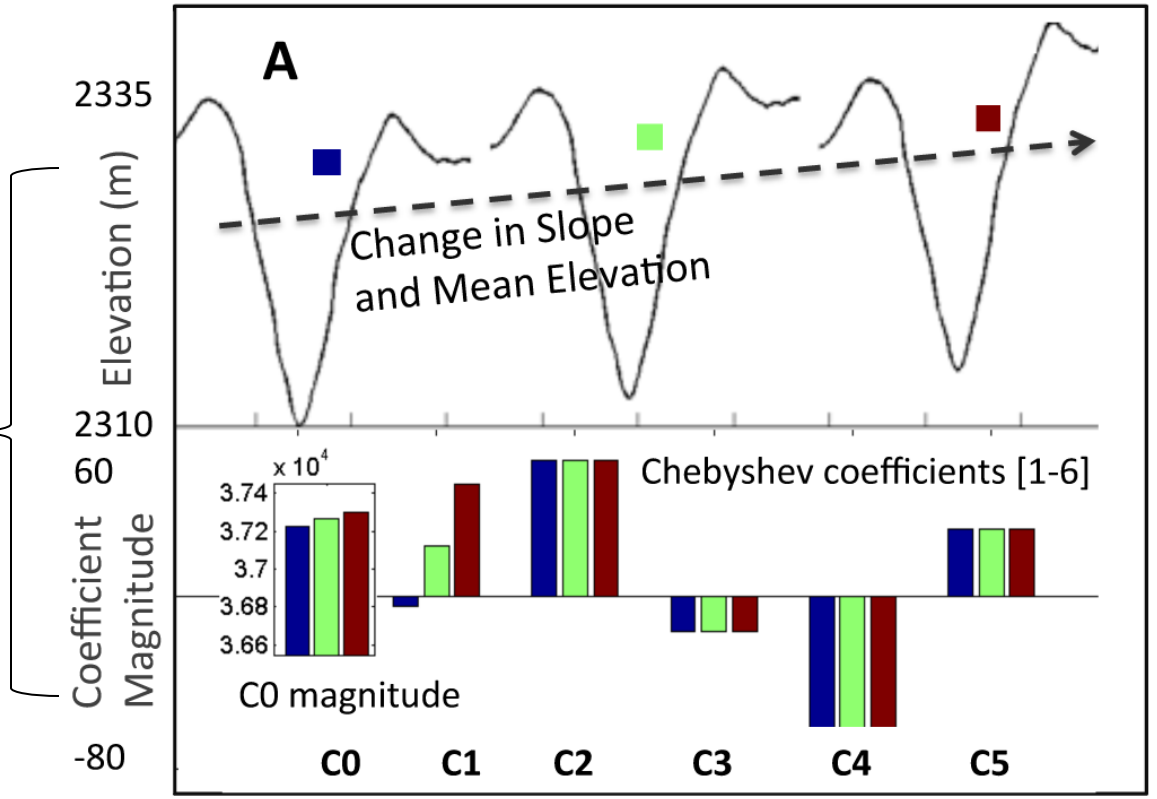
Large rock slides in impact craters on the Moon and Mercury

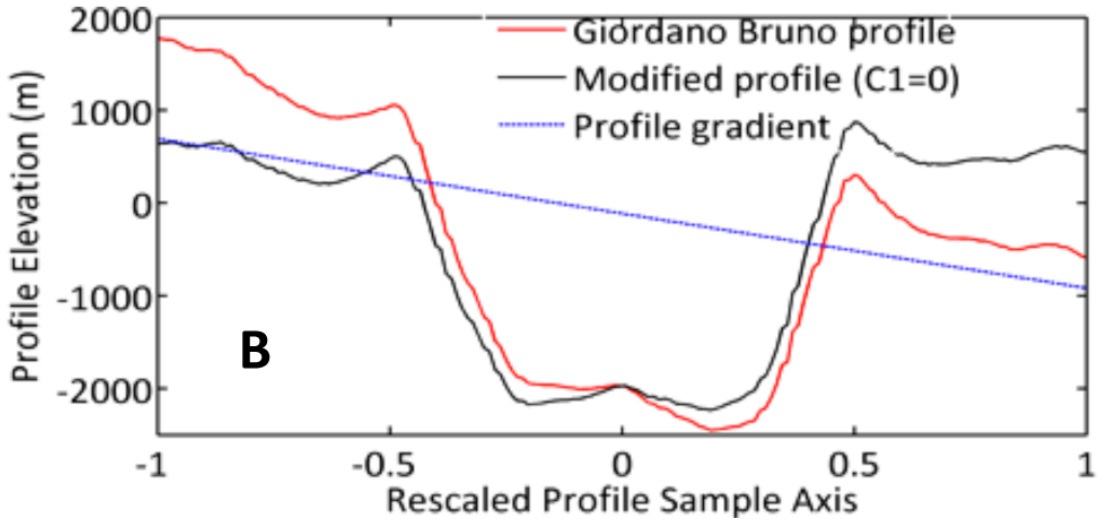
Maria Teresa Brunetti [a,b,*], Zhiyong Xiao [c,d], Goro Komatsu [e], Silvia Peruccacci [a], Fausto Guzzetti [a]

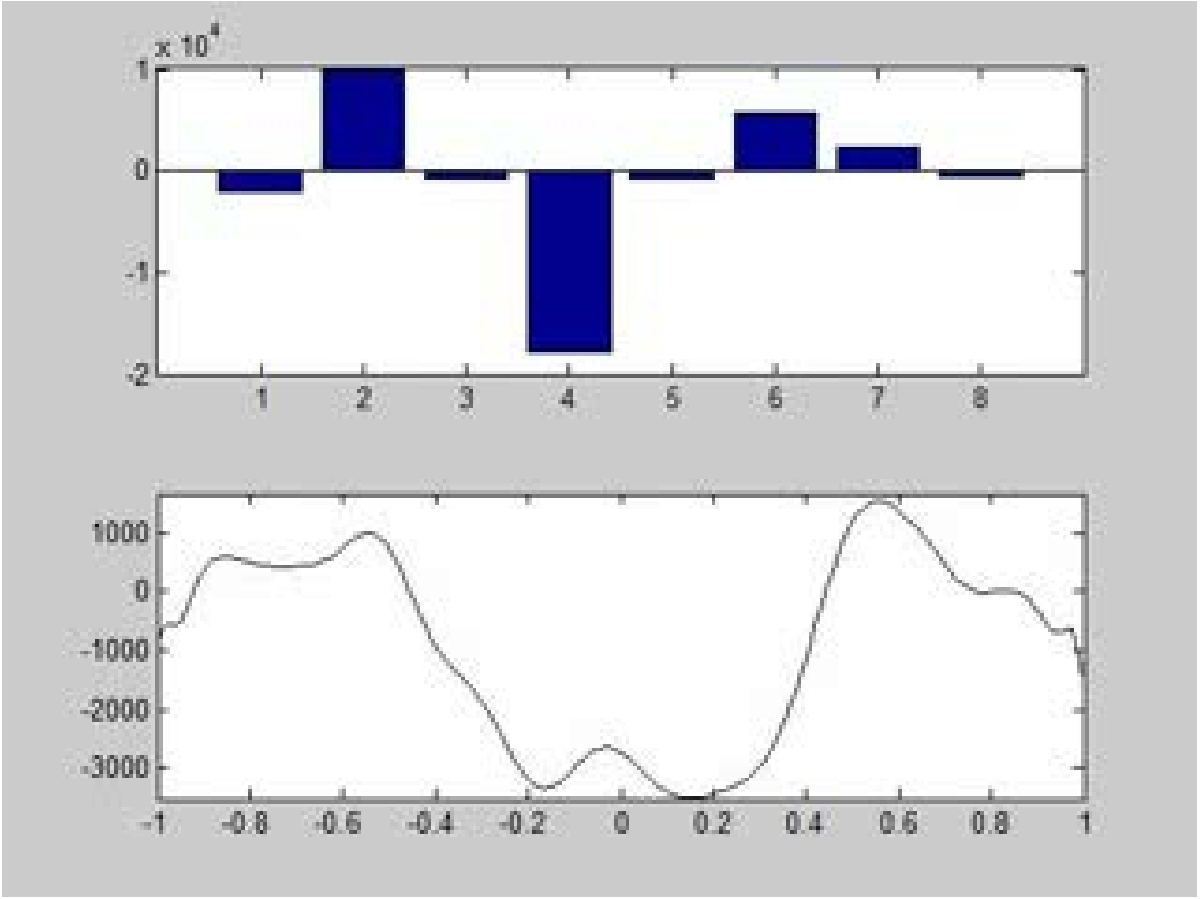
Using the symmetry property

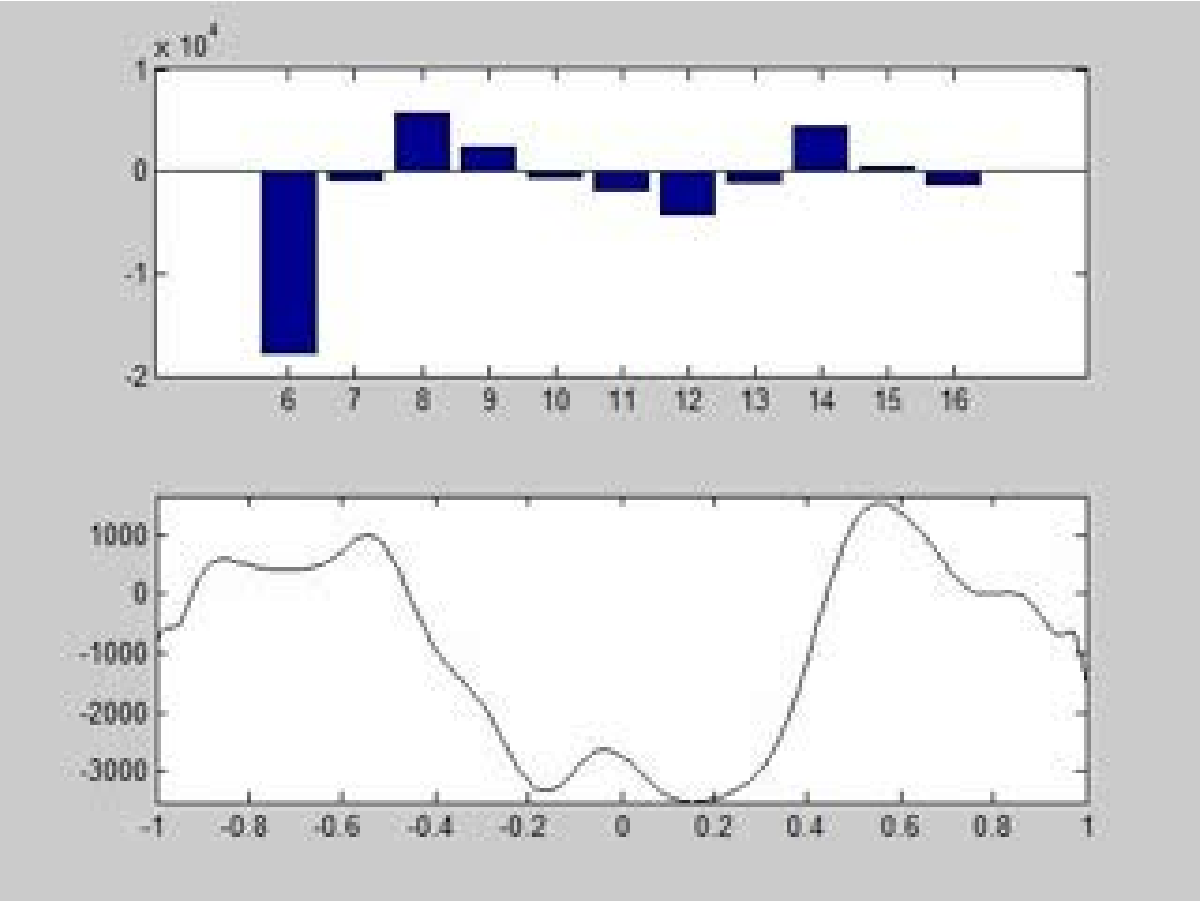
Forward application effect



Reverse usage Effect (Symmetry correction)




x 10^4
1
0
-1
-2
1
2
3
4
5
6
7
8
1000
0
-1000
-2000
-3000
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1


x 10^4
1
0
-1
-2
6
7
8
9
10
11
12
13
14
15
16
1000
0
-1000
-2000
-3000
-1
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0.6
0.8
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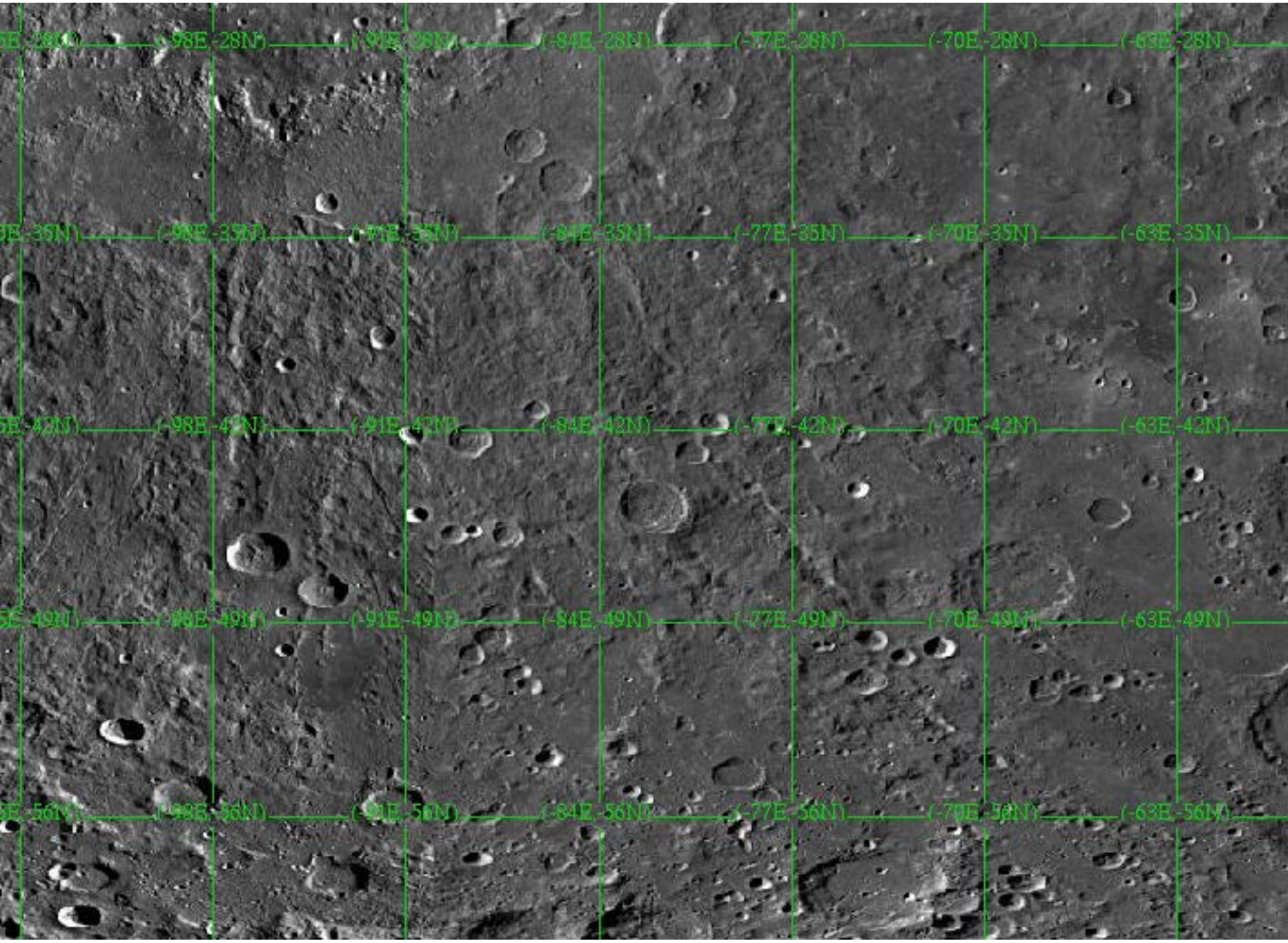
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(-84E,-28N)
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(-91E,-35N)
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(-70E,-49N)
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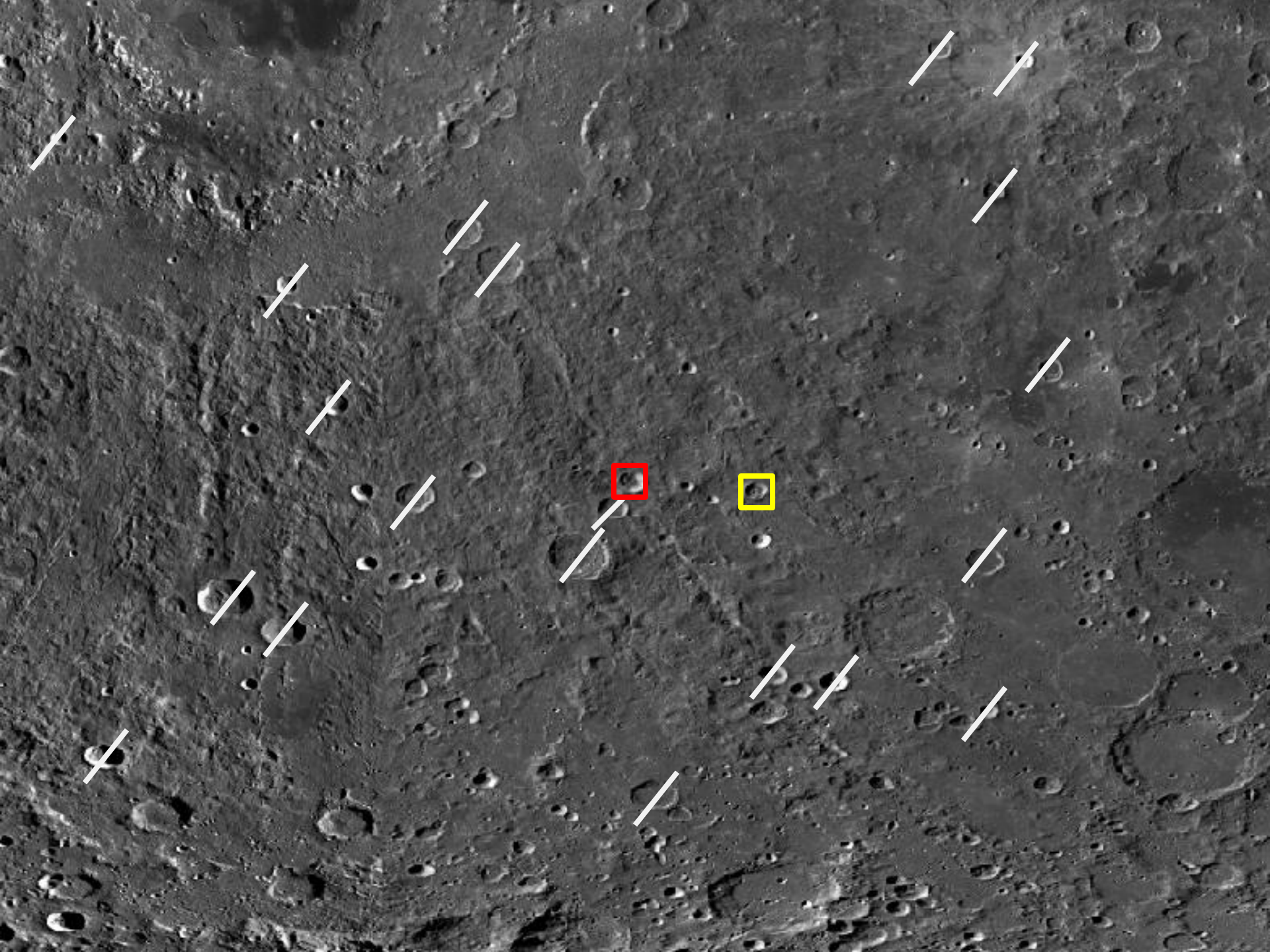
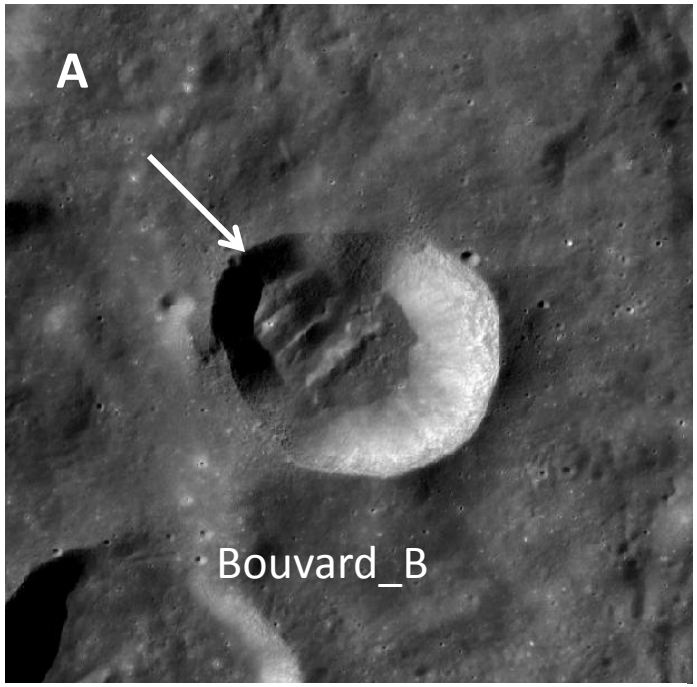
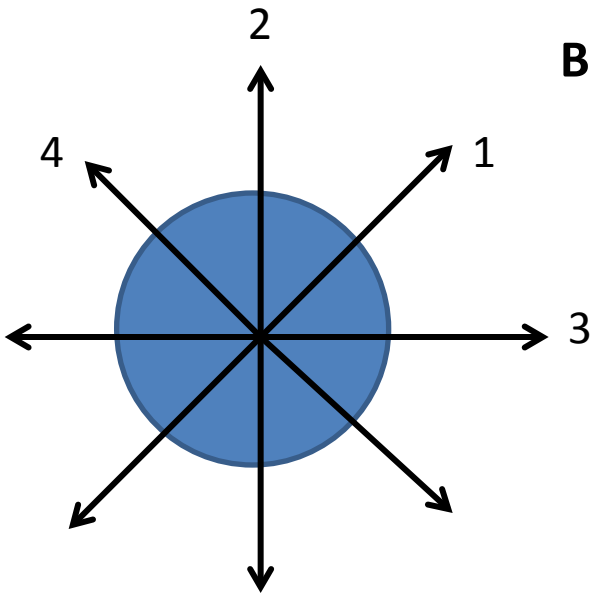
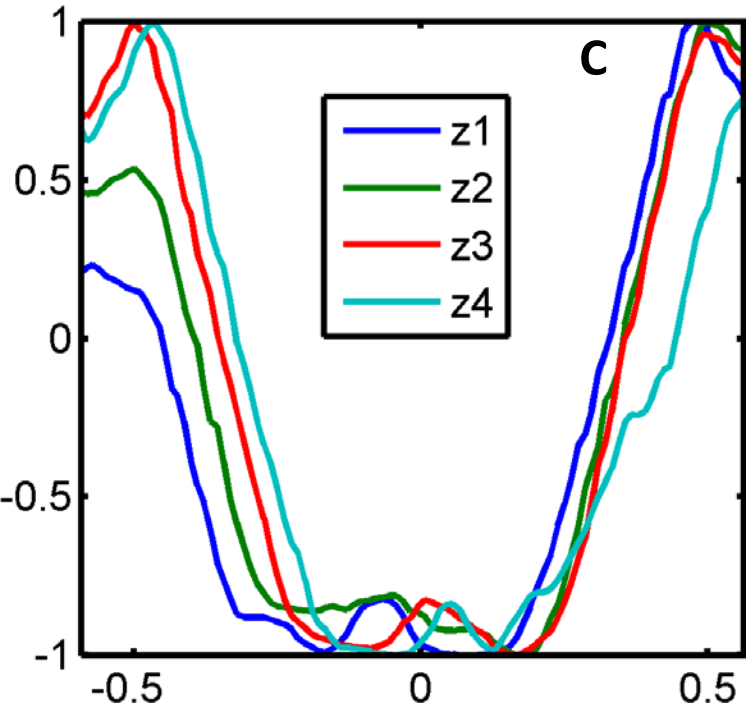
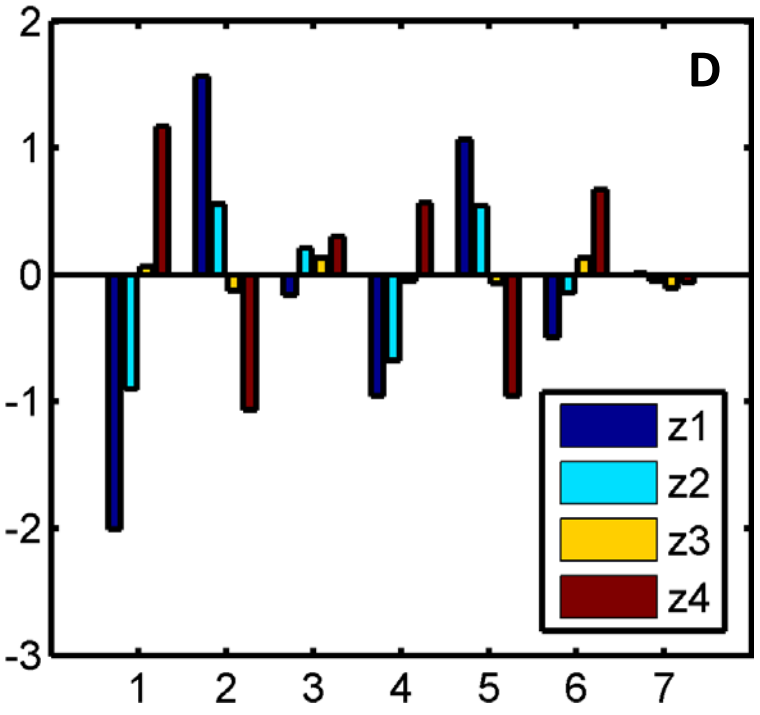
(-63E,-56N)

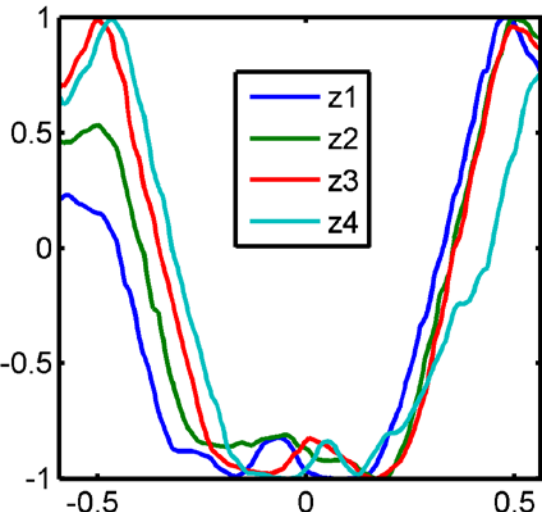



A
Bouvard_B


B
2
4
1
3

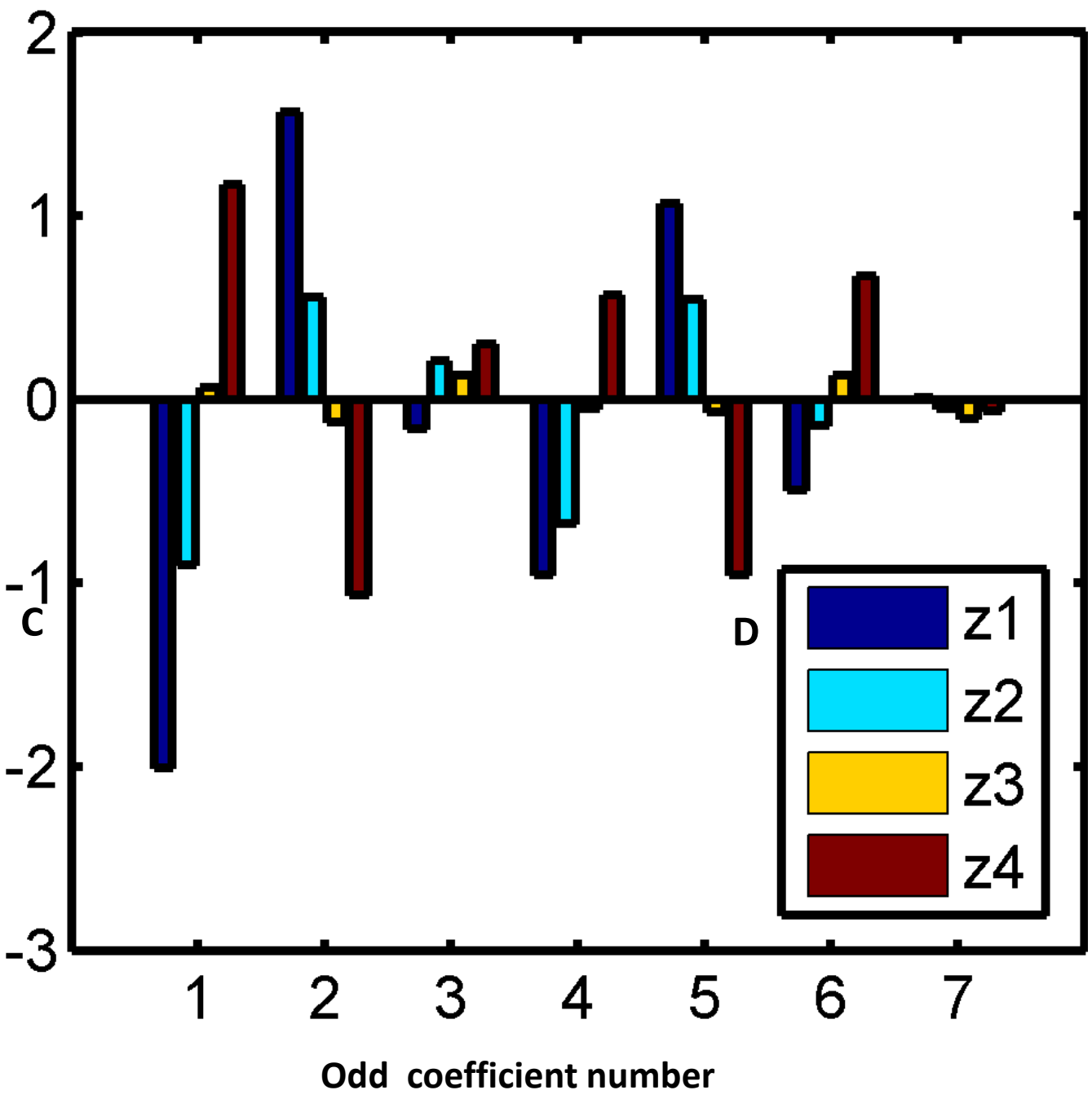

C
z1
z2
z3
z4
1
0.5
0
-0.5
-1
-0.5
0
0.5


D
z1
z2
z3
z4
2
1
0
-1
-2
-3
1
2
3
4
5
6
7

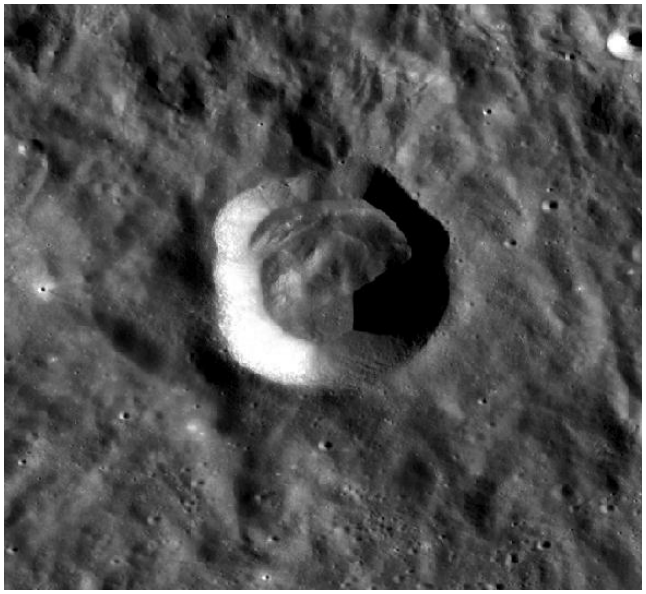

z1
z2
z3
z4
1
0.5
0
-0.5
-1
-0.5
0
0.5

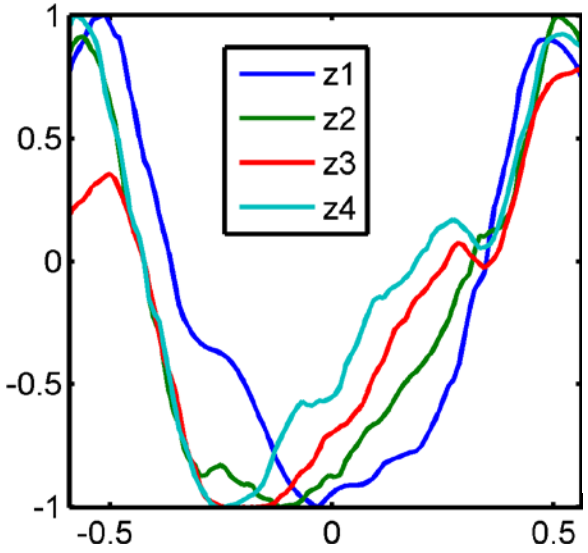
C

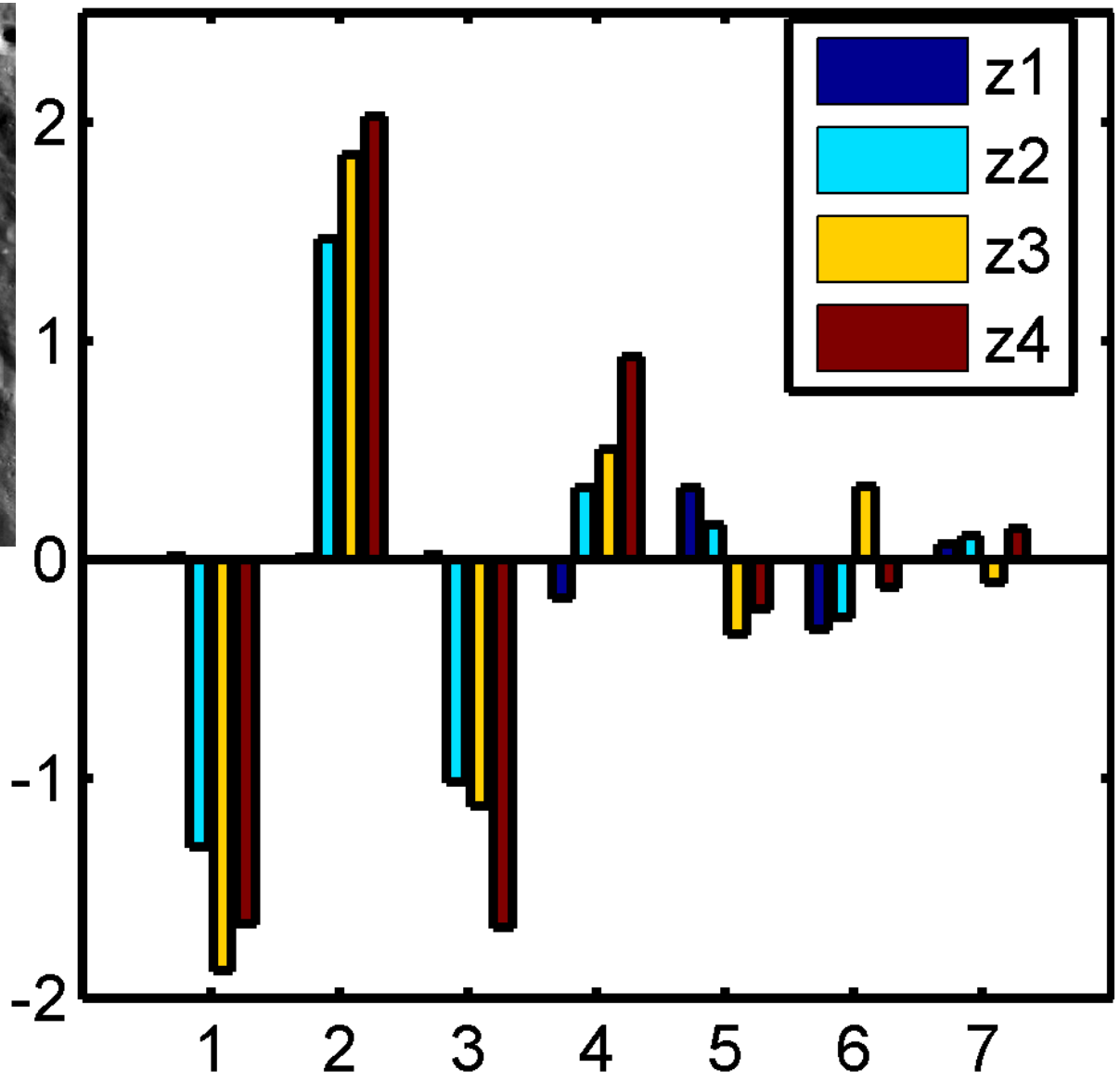
D


z1
z2
z3
z4
2
1
0
-1
-2
-3
1
2
3
4
5
6
7
Odd coefficient number

Drude Crater







Summary :

Asymmetry in topography

A: Large Asymmetry

a) Sign and magnitude
b) Which coefficients ?
c) Which direction

B: Small Asymmetry / Localized

a) Contribution to noise
b) Roughness in topography
c) Mostly large index odd coefficients

Use of Chebyshev Standardized representation

a) Compact, Collaborative, Accurate
b) Analyze asymmetry / symmetry as required.
c) Prediction and simulation of craters and cratered landscapes
d) Study of degradation (May be next LPSC)