Depth of Enceladus craters: Implications of surface properties on the early differentiation of icy moons

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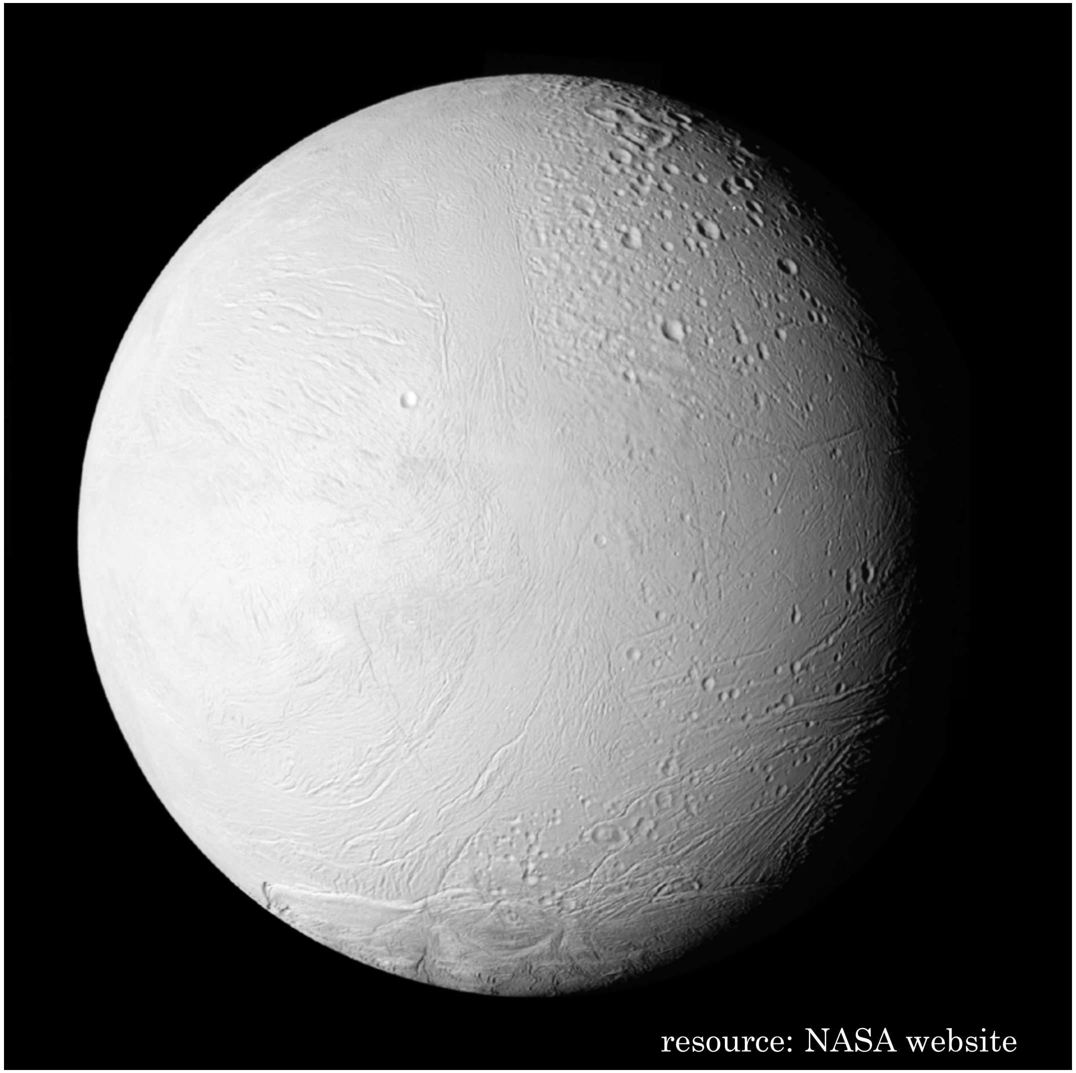
Outline

I. Scientific context
II. Model and Data
III. Results
IV. Discussion
V. Conclusion

I. Scientific Context

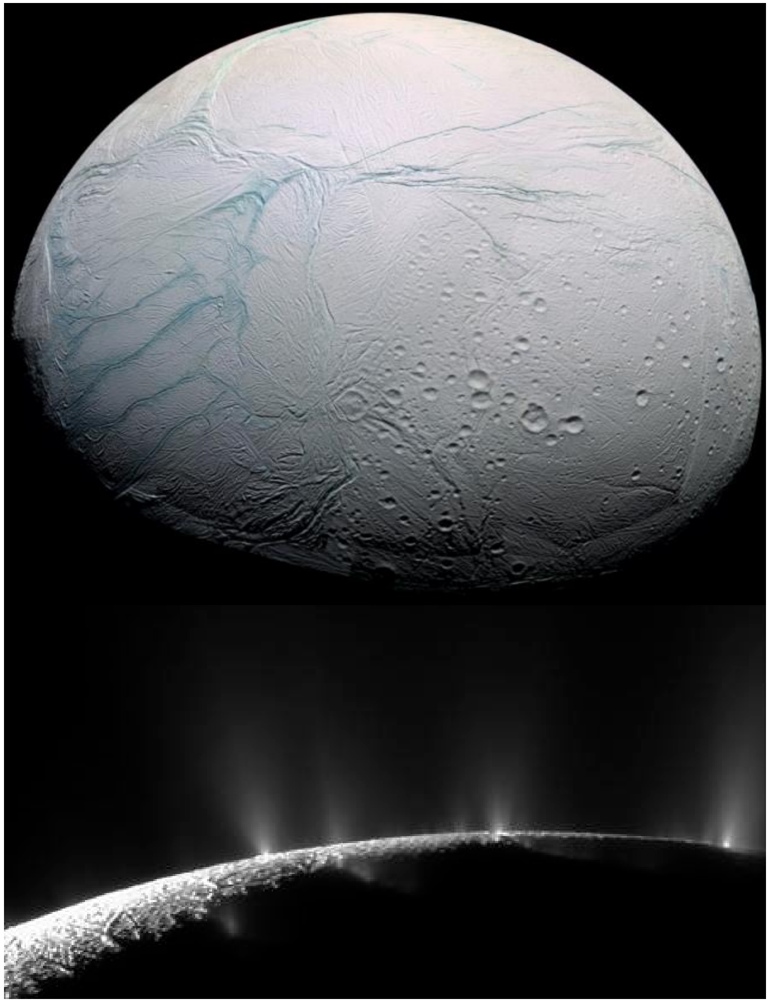


Why Enceladus?

- Interest:
  - High heterogeneity (Smith et al. 1982 Voyager probe)
  - South pole matter ejection (Porco et al. 2006 Cassini)

  → **Geological activity**!

- Explanations:
  - Internal ocean (Shubert et al. 2007)
  - Viscosity heterogeneity (Tobie et al. 2008)



Resources: NASA website

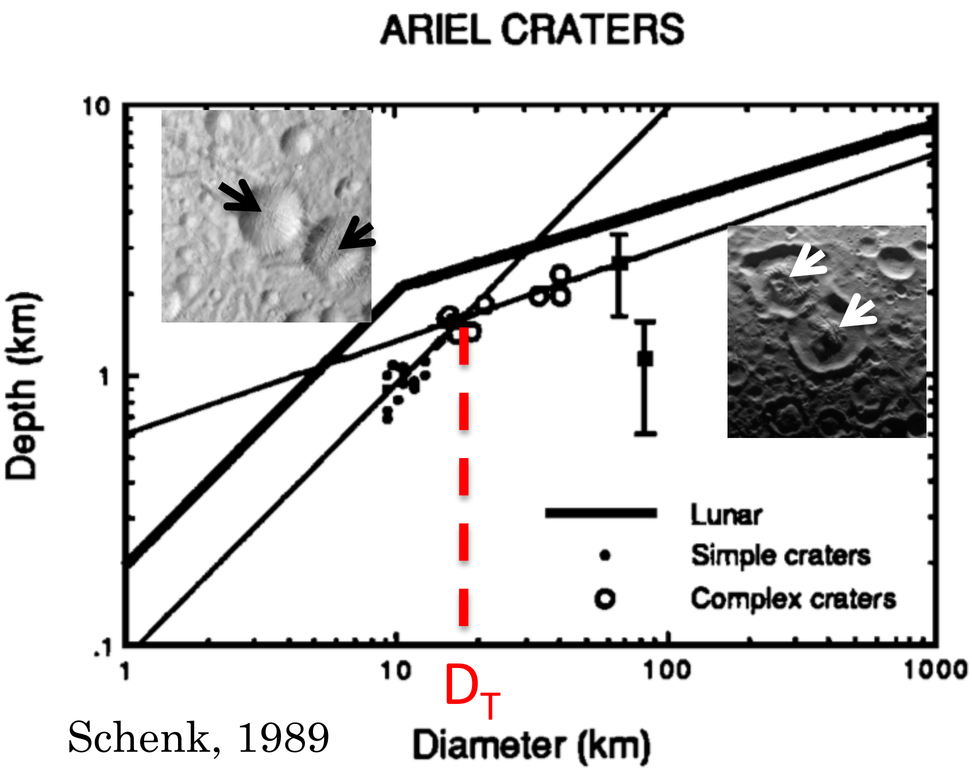
Scientific questions

- What are the rheological properties of Enceladus soil?

- What constraints can we put on formation models?

Craterisation

- Impact craters probe ground's mechanical properties
  (Melosh 1986, Chapman and McKinnon 1986, Schenk 1989, Giese et al. 2008)



Schenk, 1989

Simple craters, bowl-shaped, Hassan and Mustafa.

Complex craters Ali-Baba and Aladdin

Simple/Complex transition diameter

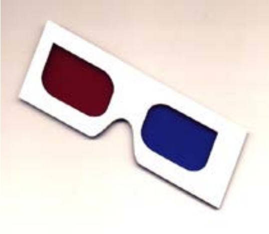
➔ Effective cohesion c

➔ Effective viscosity η_{eff}

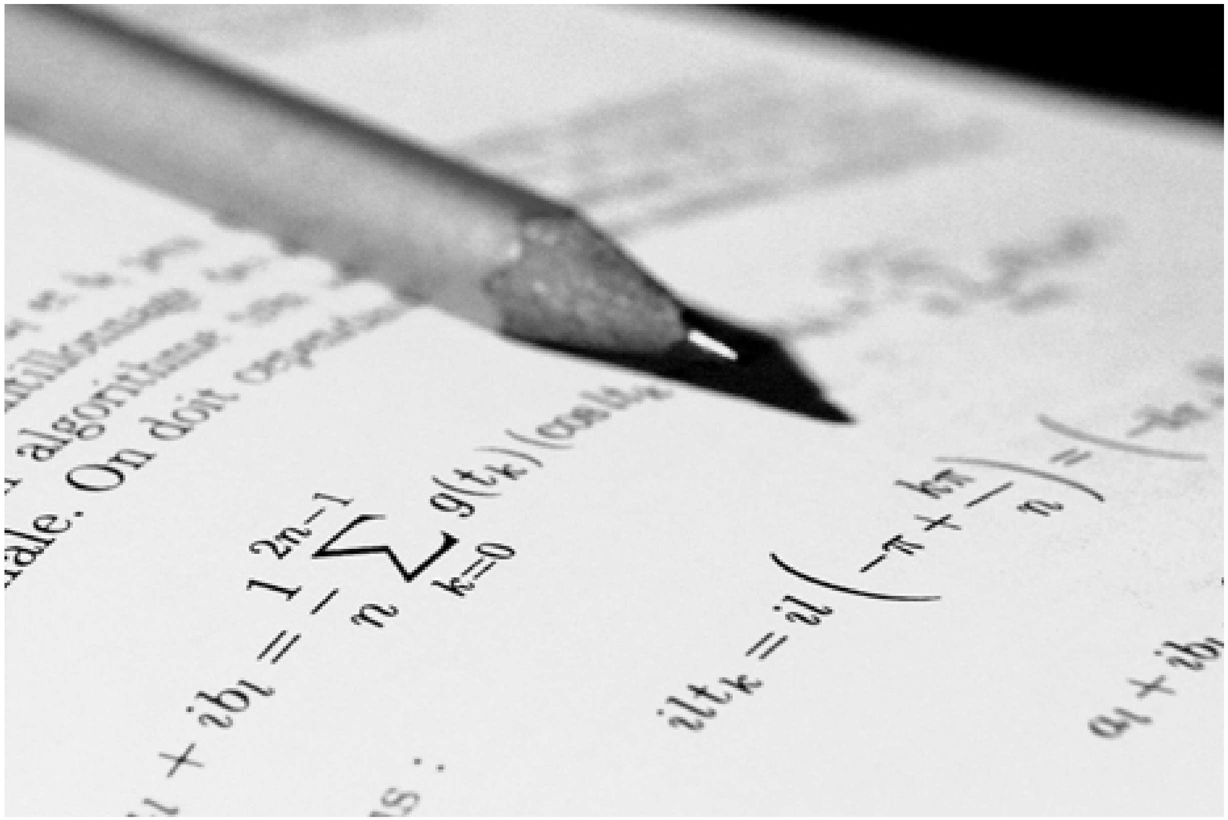
(Melosh 1980, 1986; Schenk 1989)

Crater's depth

- Diameter well known (USGS)
- Crater depth determination:
  - ~~RADAR or LASER Altimetry:~~
    - ~~+ High spatial resolution~~
    - ~~- Not available for Enceladus~~
  - ~~Photoclinometry (Passey 1982):~~
    - ~~+ 2D topographic profile~~
    - ~~- Depends on resolution~~
    - ~~- Not valid for high albedo (Enceladus)~~
  - ~~Stereometry (Schenk 2002, Giese et al. 2008):~~
    - ~~+ 3D profile~~
    - ~~- Computer time consuming~~

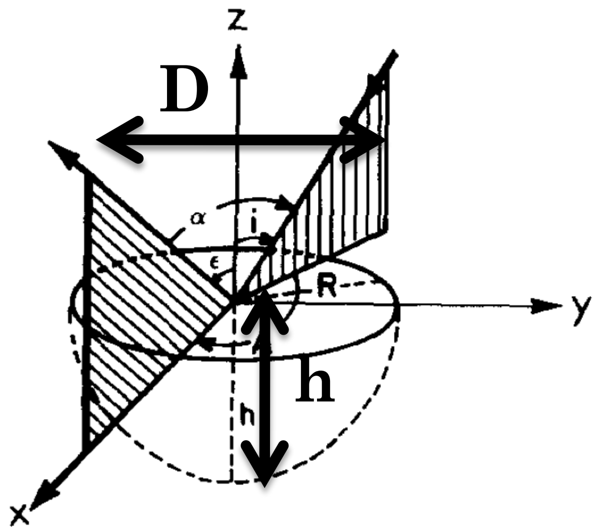


II. Model and Data



Crater Roughness Model

- Macroscopic:



Buratti & Veverka ,1985

- One morphological parameter: q=h/D

- Microscopic (regolith):

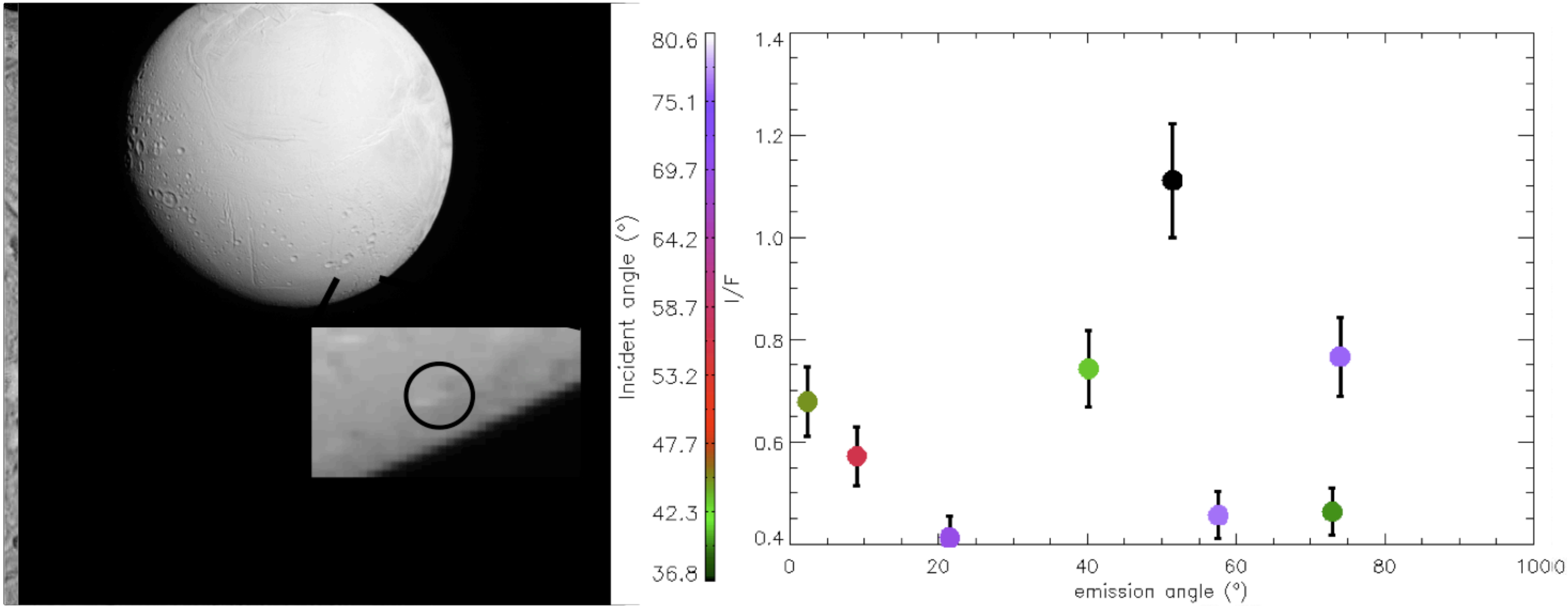
Hapke Modelling 2002

- Anisotropic scattering
- Multiple scattering
- SHOE

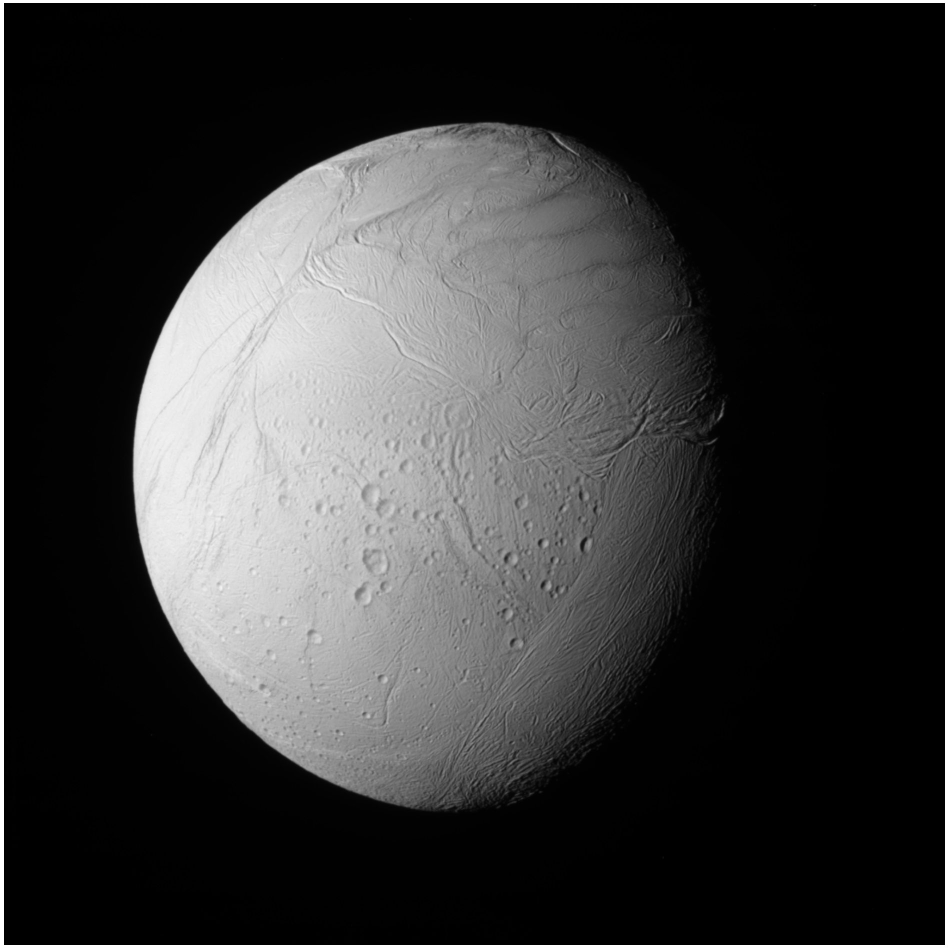
- 4 physical parameters of the regolith.

➔ Average radiance factor I/F

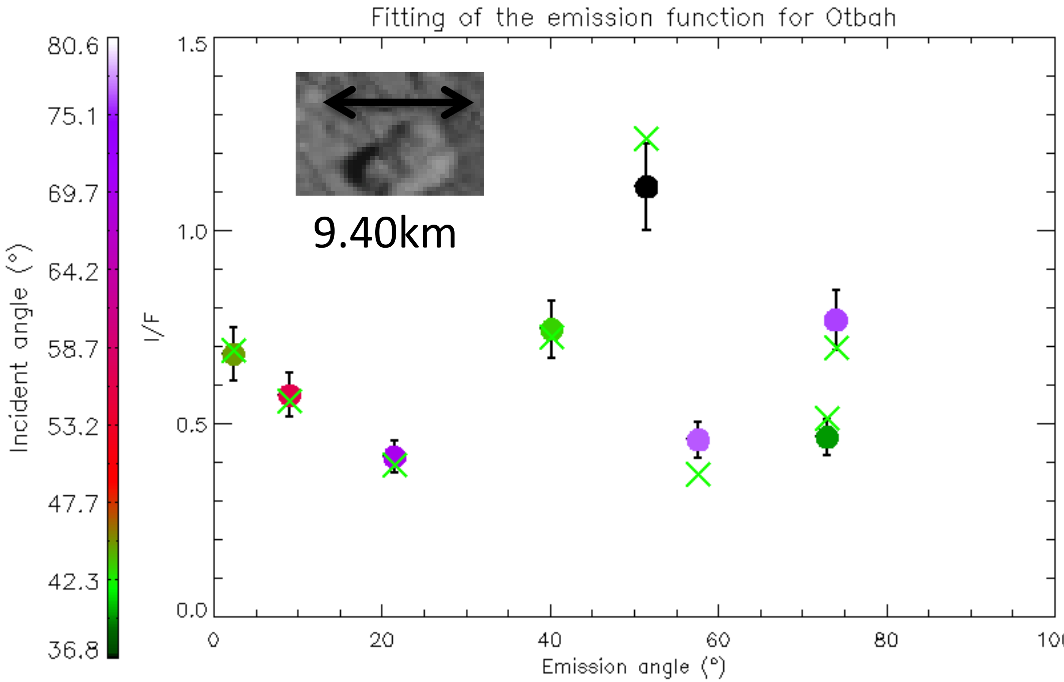
Data


80.6
75.1
69.7
64.2
58.7
53.2
47.7
42.3
36.8
Incident angle (°)
I/F
1.4
1.2
1.0
0.8
0.6
0.4
0
20
40
60
80
100
emission angle (°)

III. Results



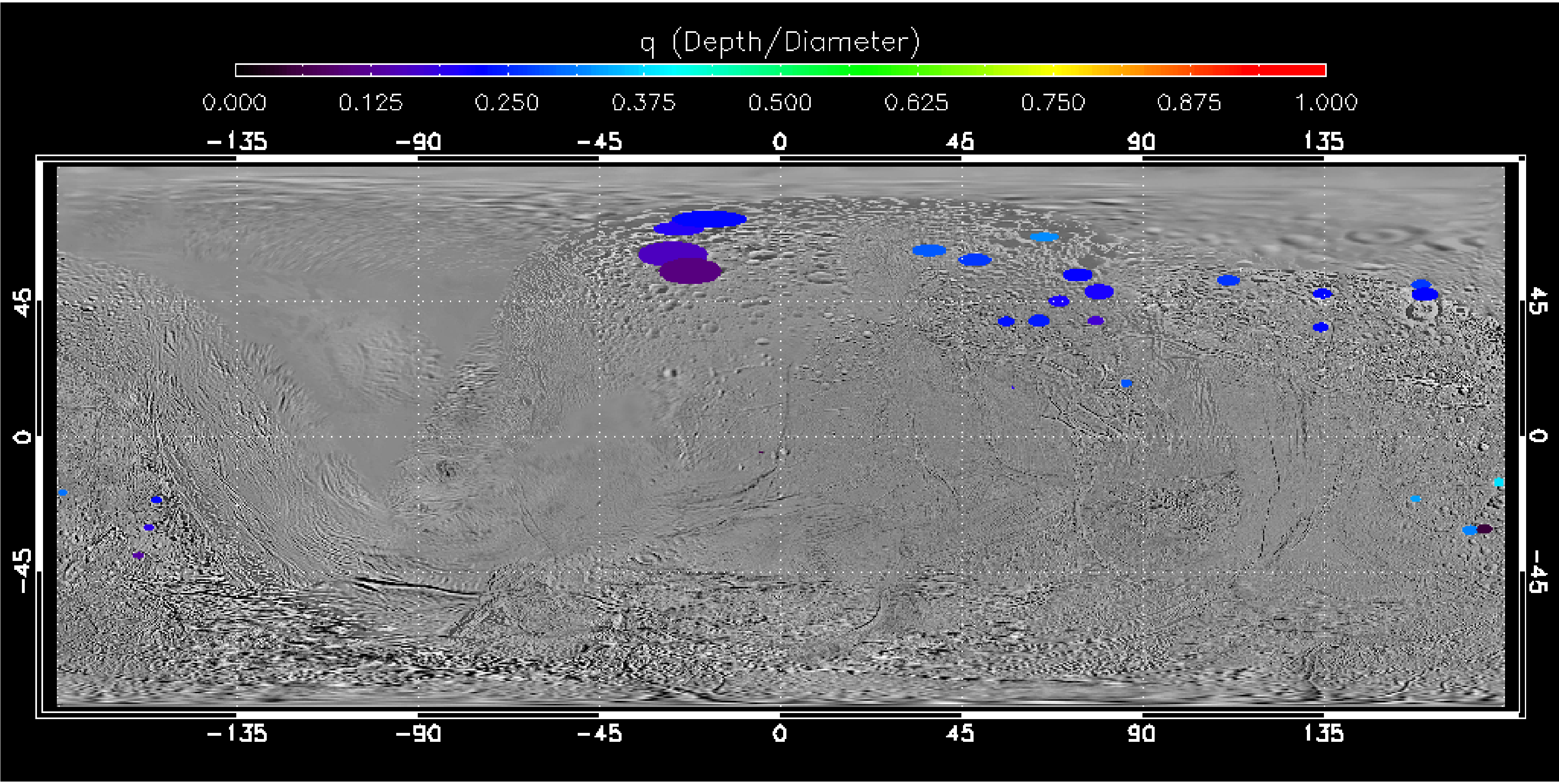
Fitting



- $q = h/D = 0.13^{+0.09}_{-0.04}$
- $g = -0.27^{+0.19}_{-0.24}$
- $\omega_0 = 0.998 \pm 0.002$
- $X^2 = 1.88$

- Depth = $1.2^{+0.9}_{-0.4}$ km

Maps



→No evidence of regional heterogeneity.

Depth/diameter

- Appearance of slope break

  → Simple/Complex

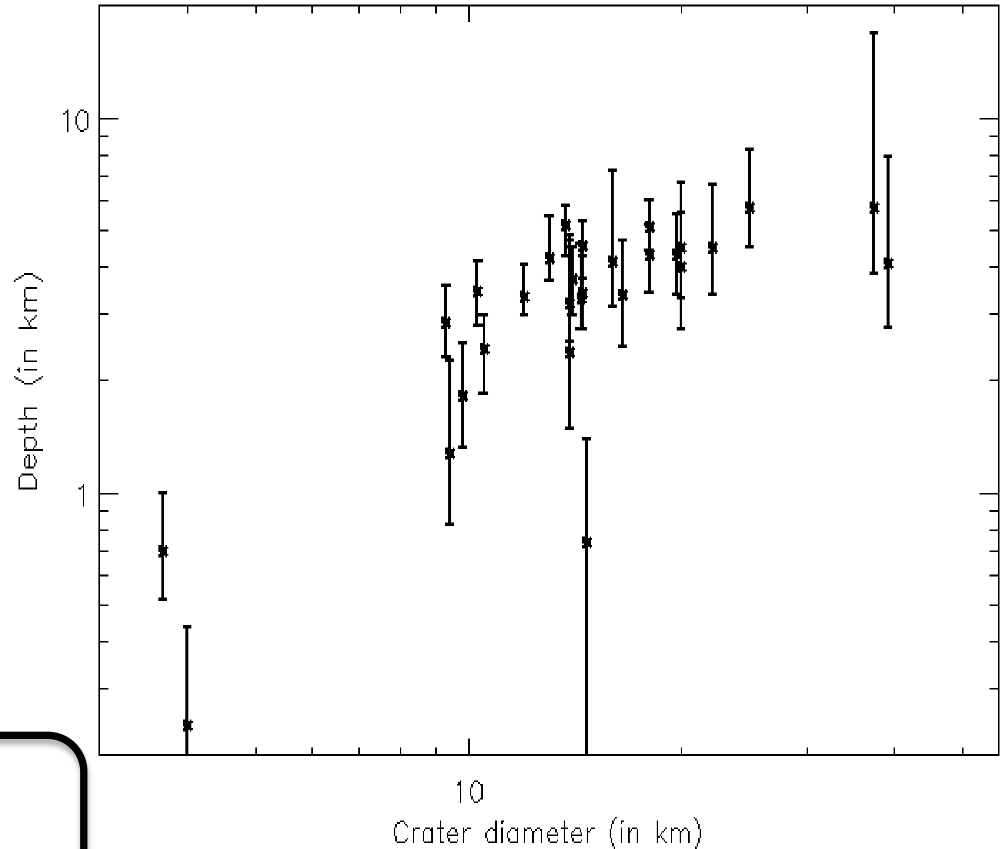
Define transition diameter

$D_T = 17.8 \pm 5.5$km

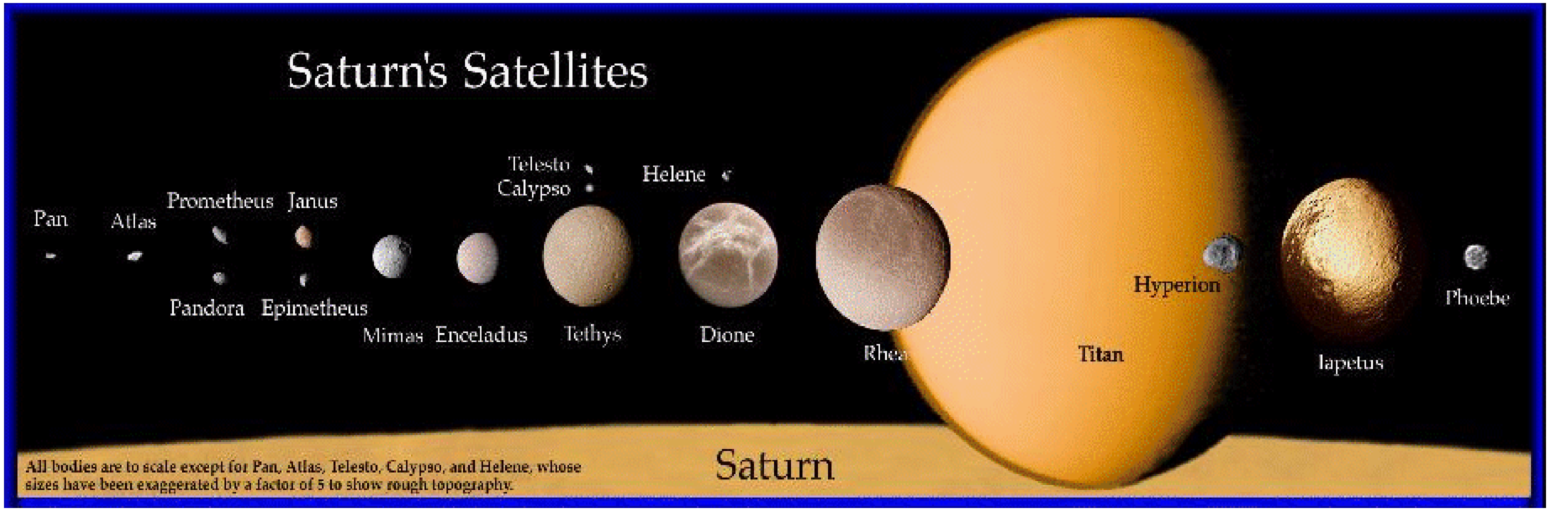
→ Access to soil properties

$c = 89 \pm 18$ kPa

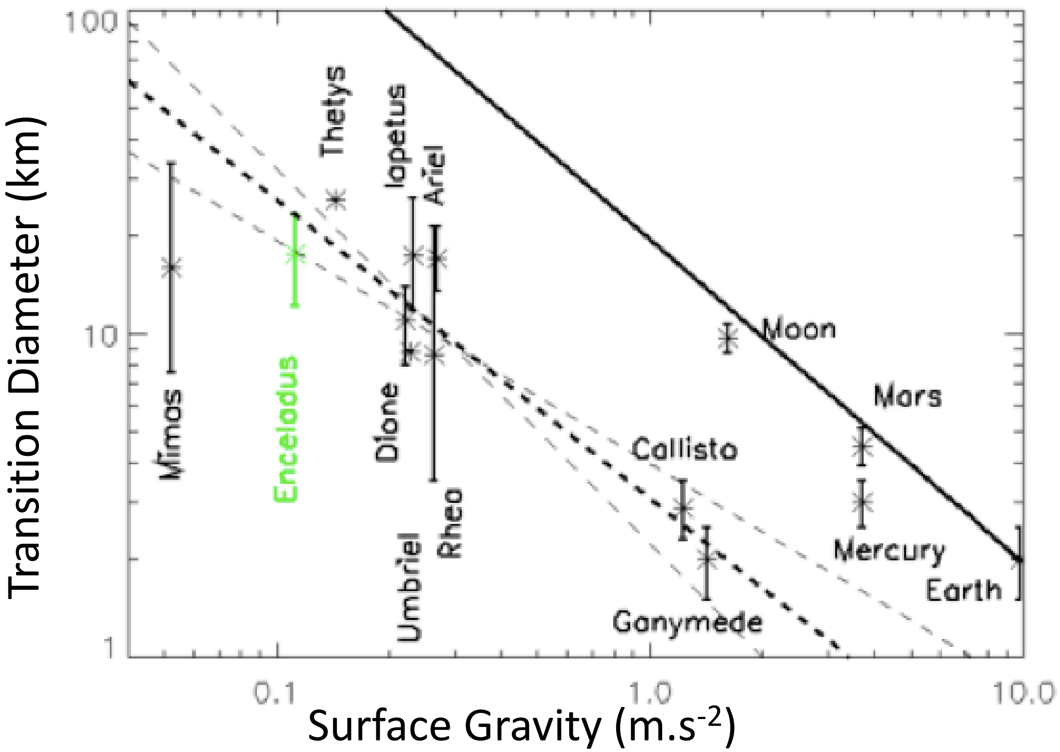
$\eta_{eff} = 1.2 \pm 0.5\ 10^8$ Pa.s



IV. Discussion



Transition Diameter



Transition diameter as a function of surface gravity for planets and satellites from Chapman & McKinnon . [1986], Schenk [1989]. (*) this paper. ([1]) Giese et al. [2008].

- -Inverse to gravity
- -≠ Rocky/Icy bodies
- -Enceladus follows semi-empirical law

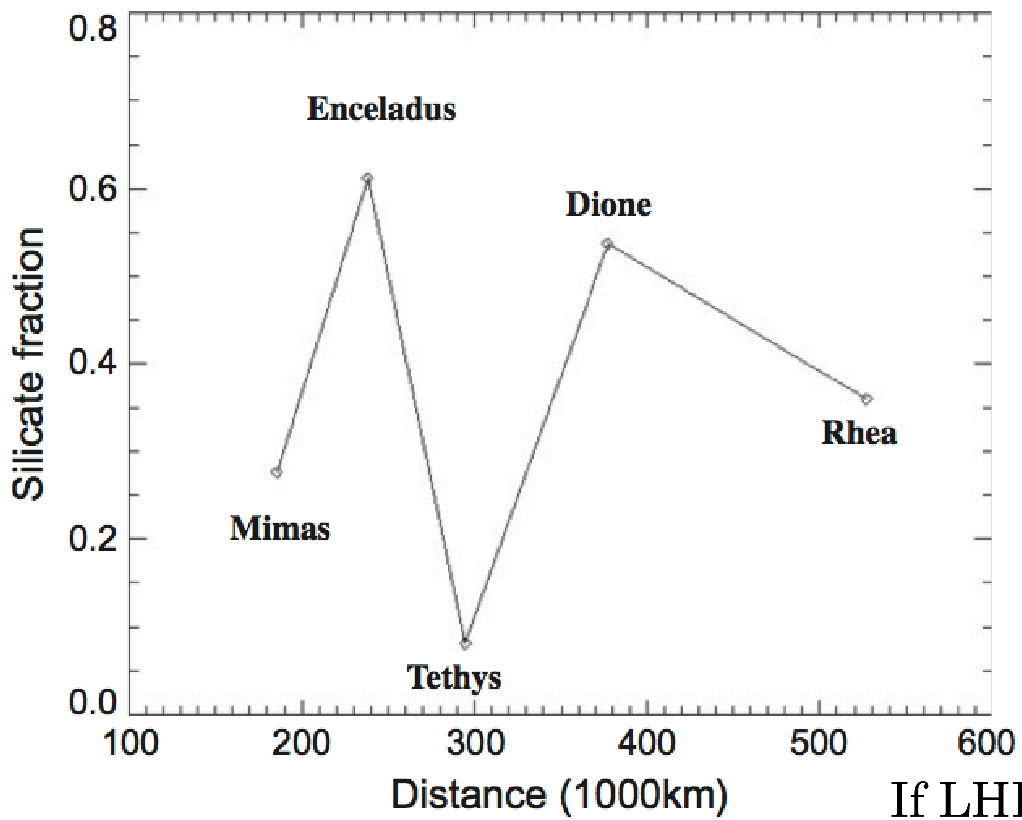
Rheological Properties

Planet	Surface Gravity (m.s^{-1})	Surface Density (10^3 kg.m-3)	d/D Transition diameter (km)	Effective Cohesion (kPa)	Effective Viscosity (10^7 Pa.s)
Earth	9,8	3			
Crystalline			1,9	2230	1,6
Sediments			1,9	2230	14
Moon	1,62	3			
Highlands			10,9	2120	15
Mare			8,6	1680	19
Mercury	3,69	3	4,7	2130	10
Mars	3,7	3	3,1	1380	14
Ganymede	1,43	0,93	2,9	<330	<7,8
Callisto	1,23	0,93	2	<290	
Iapetus ([1])	0,222	0,93	11	40	60
Rhea	0,263	0,93	8,6	60	6,3
Ariel	0,269	0,93	17	100	15
Dione	0,231	0,93	17,5	90	16
Tethys	0,144	0,93	26	110	27
Enceladus(*)	0,112	0,93	17,8	89	12
Mimas	0.052	0.93	16	30	59

Enceladus is not special!!

Compilation of rheologic parameters for planets and satellites from Schenk [1989]. (*) this paper. ([1]) Giese et al. [2008].

Silicate Fraction



Silicate Mass Fraction for Mimas, Enceladus, Thetys, Dione and Rhea. From Charnoz et al. 2011

-If ice/silicate mixed composition
→Different rheological properties.

-Same rheological properties

→Icy crust (≈30km for Enceladus) at caterisation time.

If LHB impactors →
Constraints on differentiation timescale
→ Consistent Charnoz et al. 2011 model.

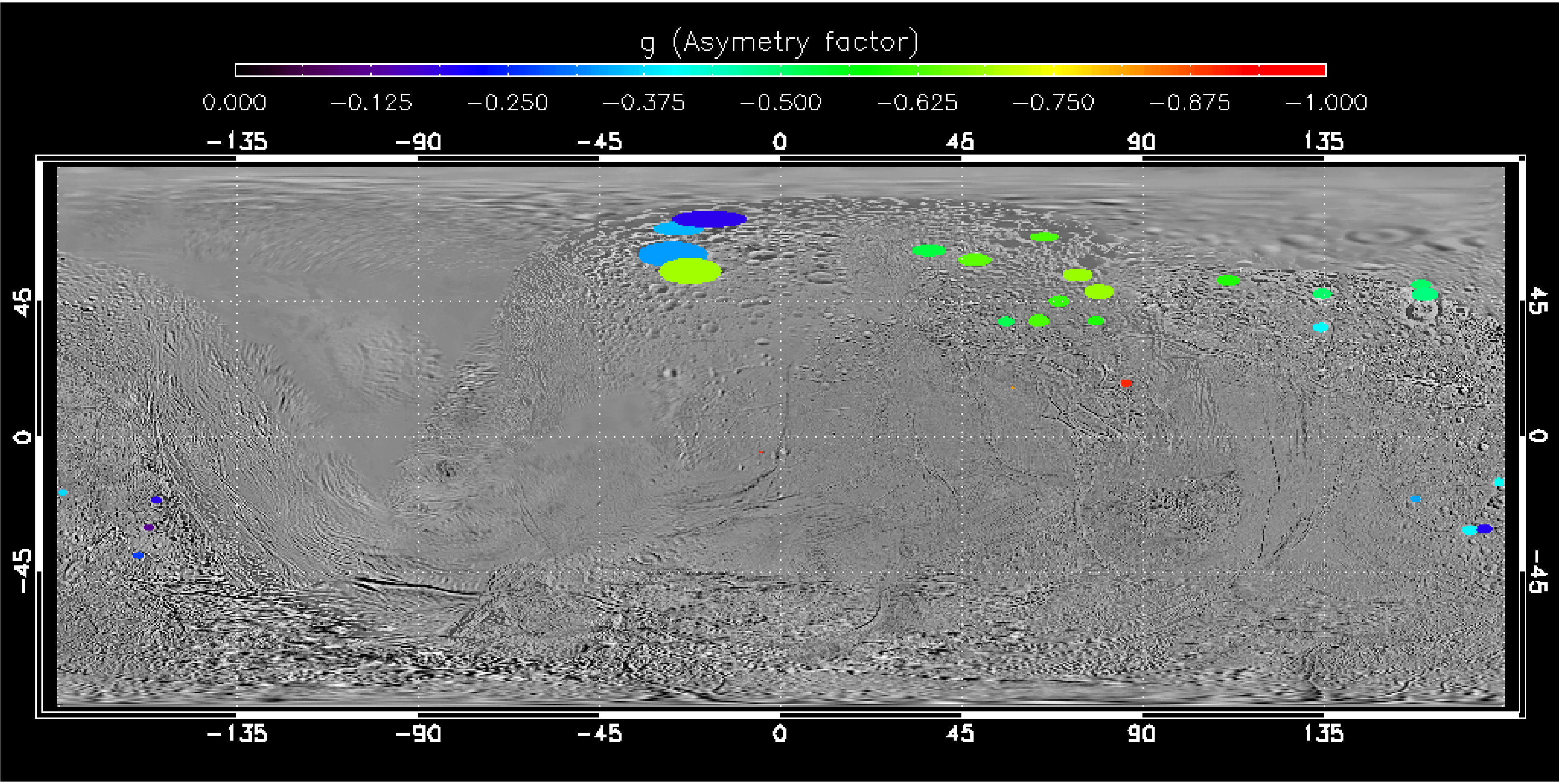
Conclusion

- Determination of rheological properties of Enceladus soil.
- All icy satellites, but Mimas, had same crust material at craterisation time
- If LHB impactors → Constraints on differentiation timescale

  → Consistent with Charnoz et al. 2011 model.

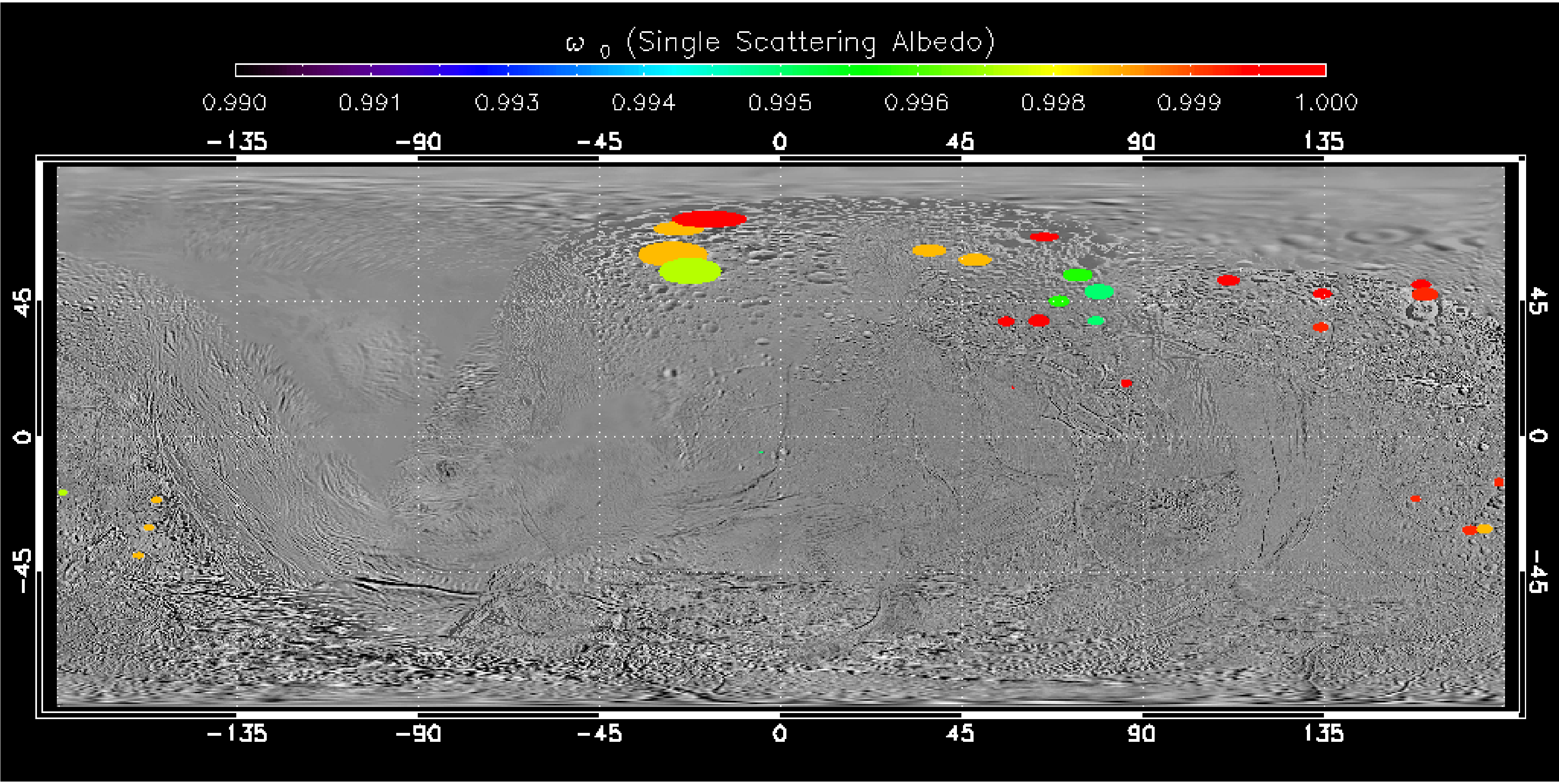
The End

Maps



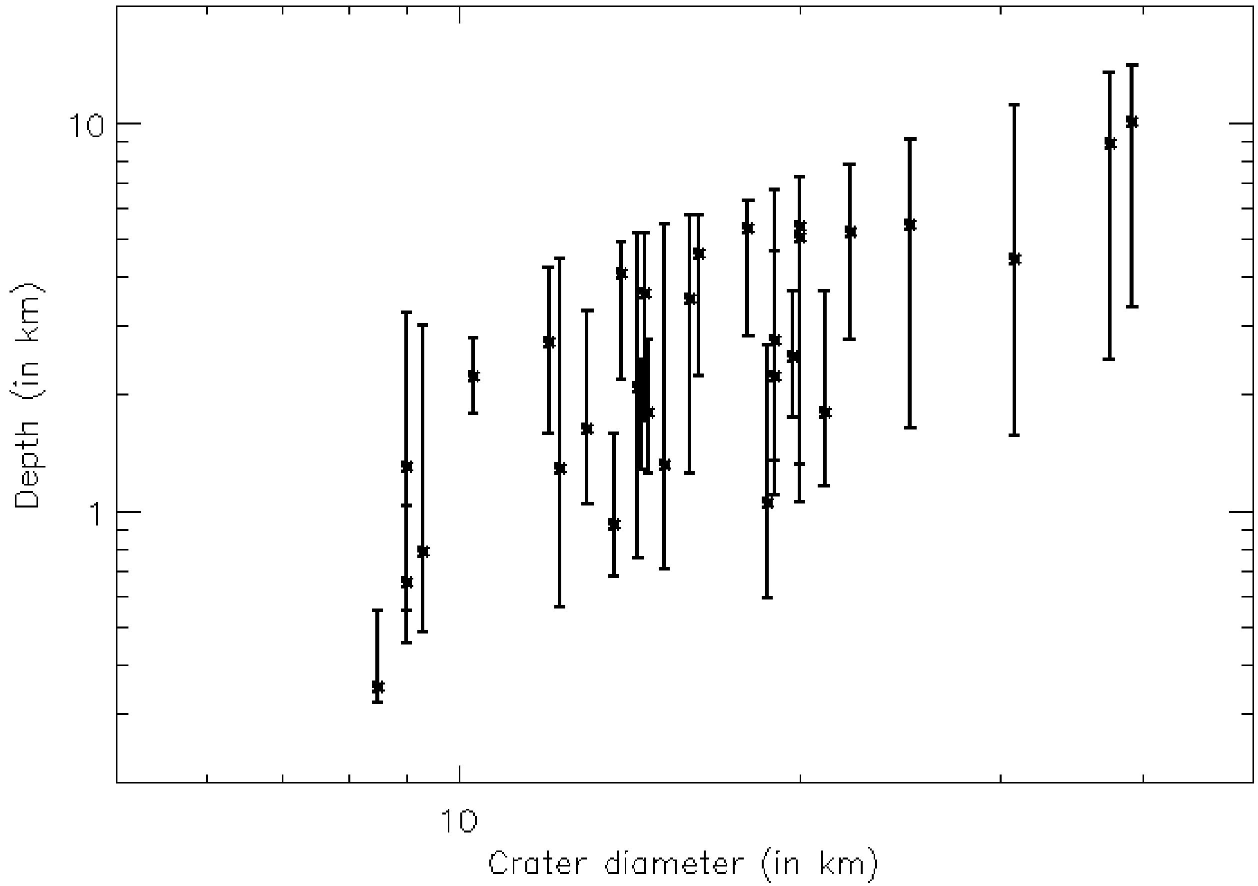
g (Asymetry factor)
0.000
−0.125
−0.250
−0.375
−0.500
−0.625
−0.750
−0.875
−1.000
−135
−90
−45
0
45
90
135
45
0
−45

Maps (2)



→Homogenate regolith properties

Relaxation



François Cloux, Master.