STRUCTURAL ANALYSIS OF THE VICTORIA QUADRANGLE (H2) OF MERCURY BASED ON NASA MESSENGER DATA

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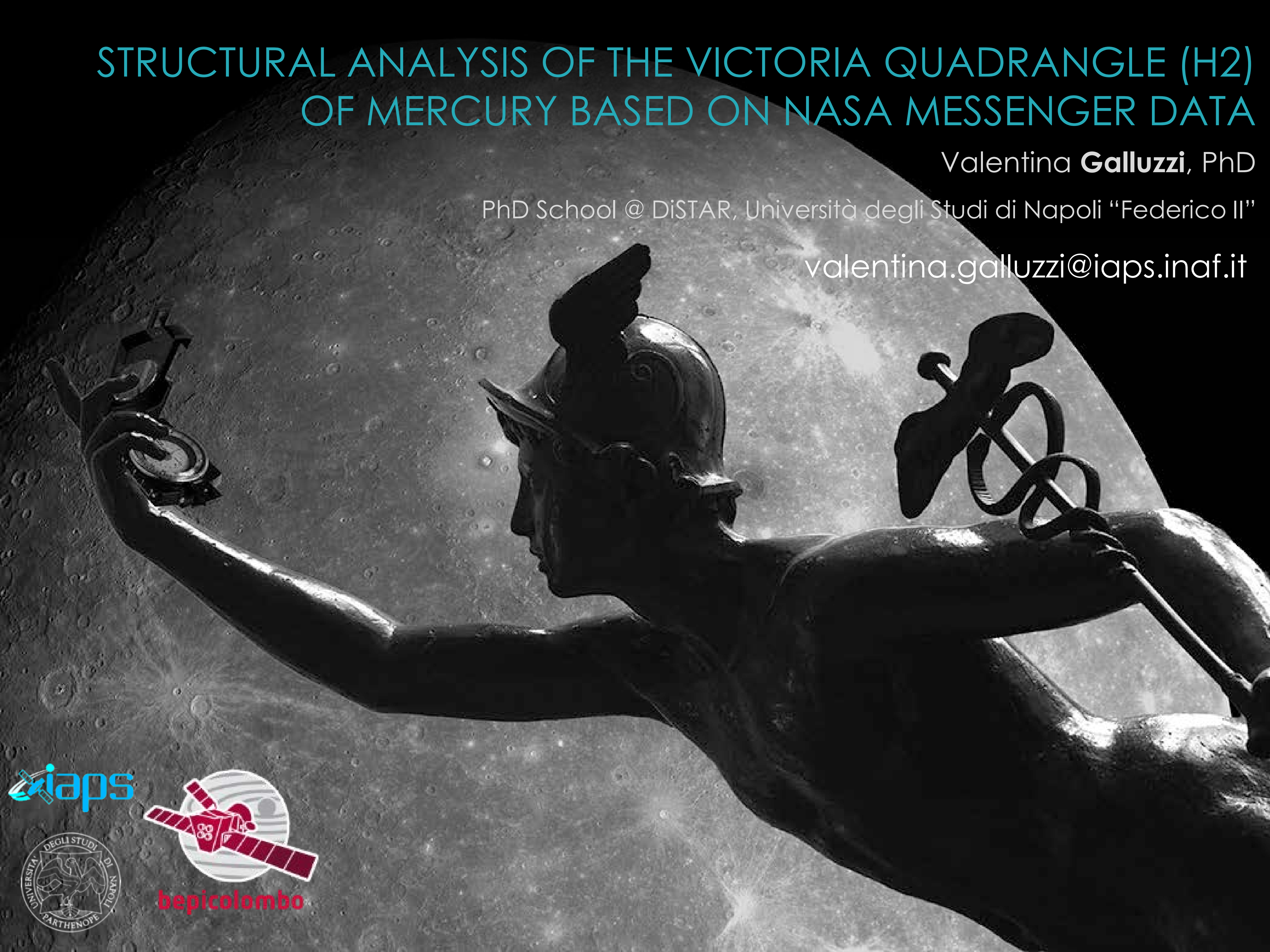
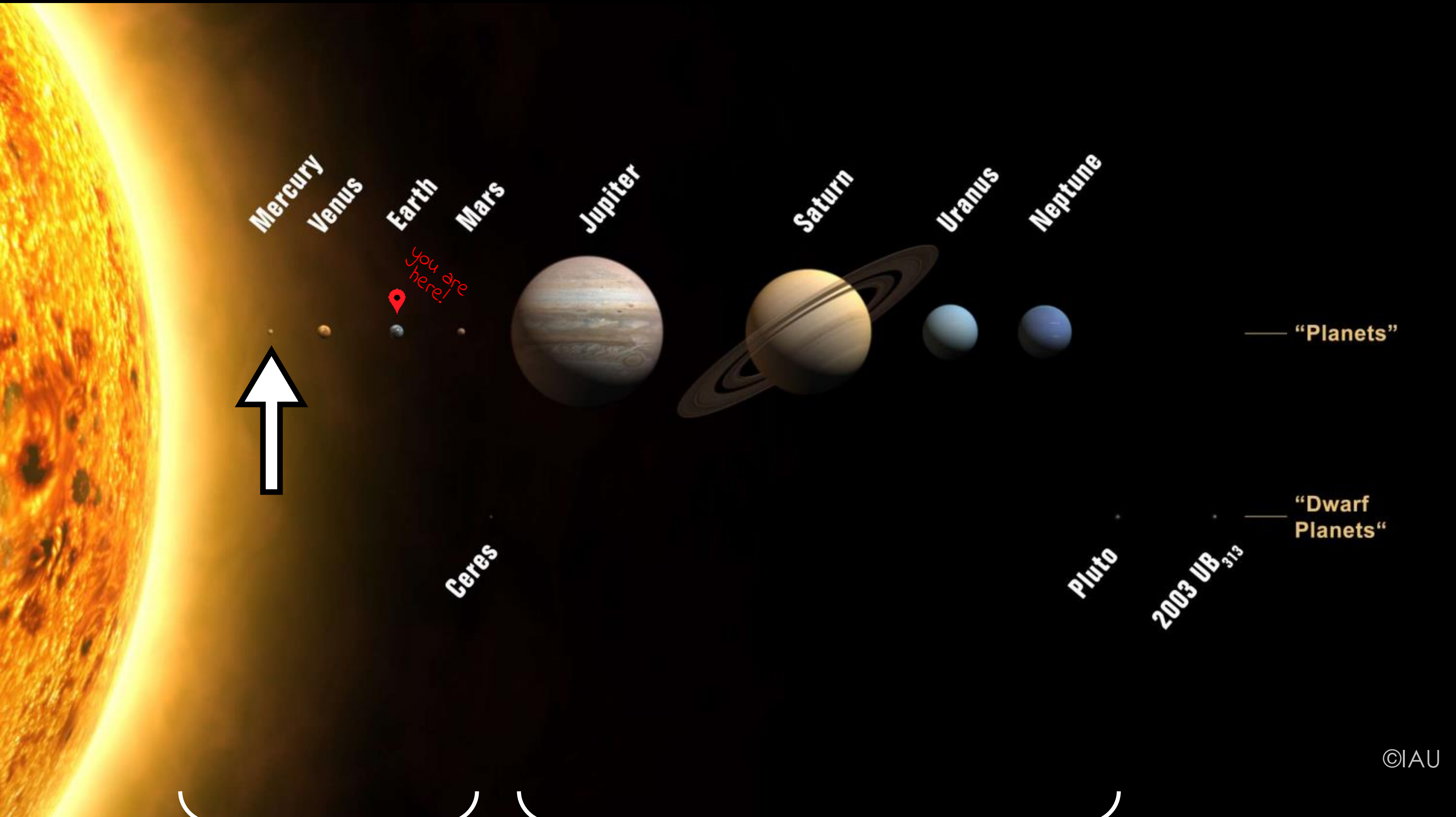


Objective of this work is the **mapping** *and* **structural analysis** *of the* Victoria quadrangle *and a reconnaissance study of the* **geometry** *and* **kinematics** *of lobate scarps on* **Mercury.**



INNER Solar System
Terrestrial planets

OUTER Solar System
Gas-giant planets

	MOON	MERCURY	EARTH
Radius	**1738** Km	**2440** Km	**6378** Km
Density	**3.35** g/cm^3	**5.42** g/cm^3	**5.52** g/cm^3
Gravity	**0.17** g	**0.38** g	**1.00** g

1973 – 1975 – Mariner 10 (NASA)
(Mariner Venus/Mercury 73 – Mariner-J)

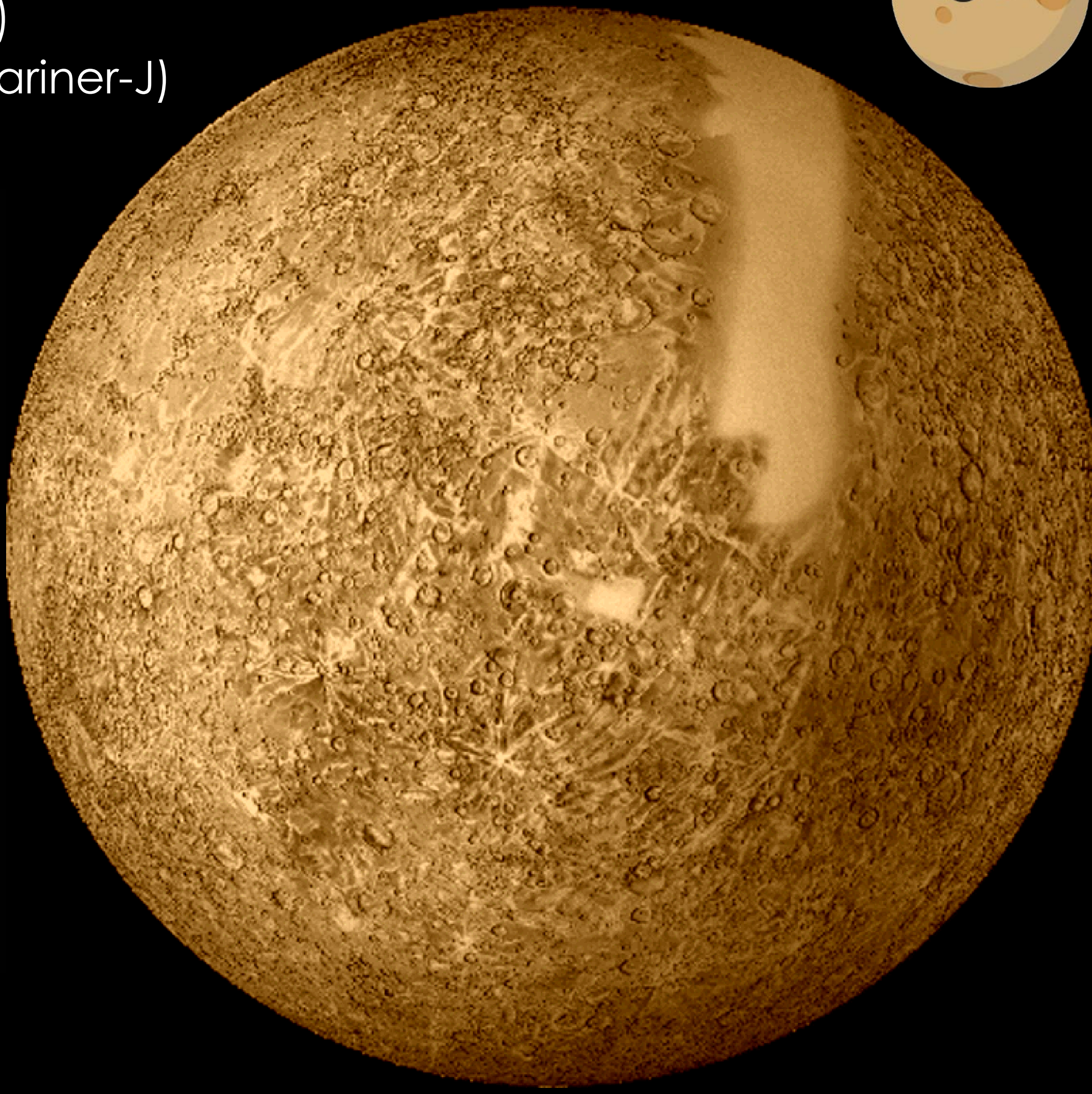
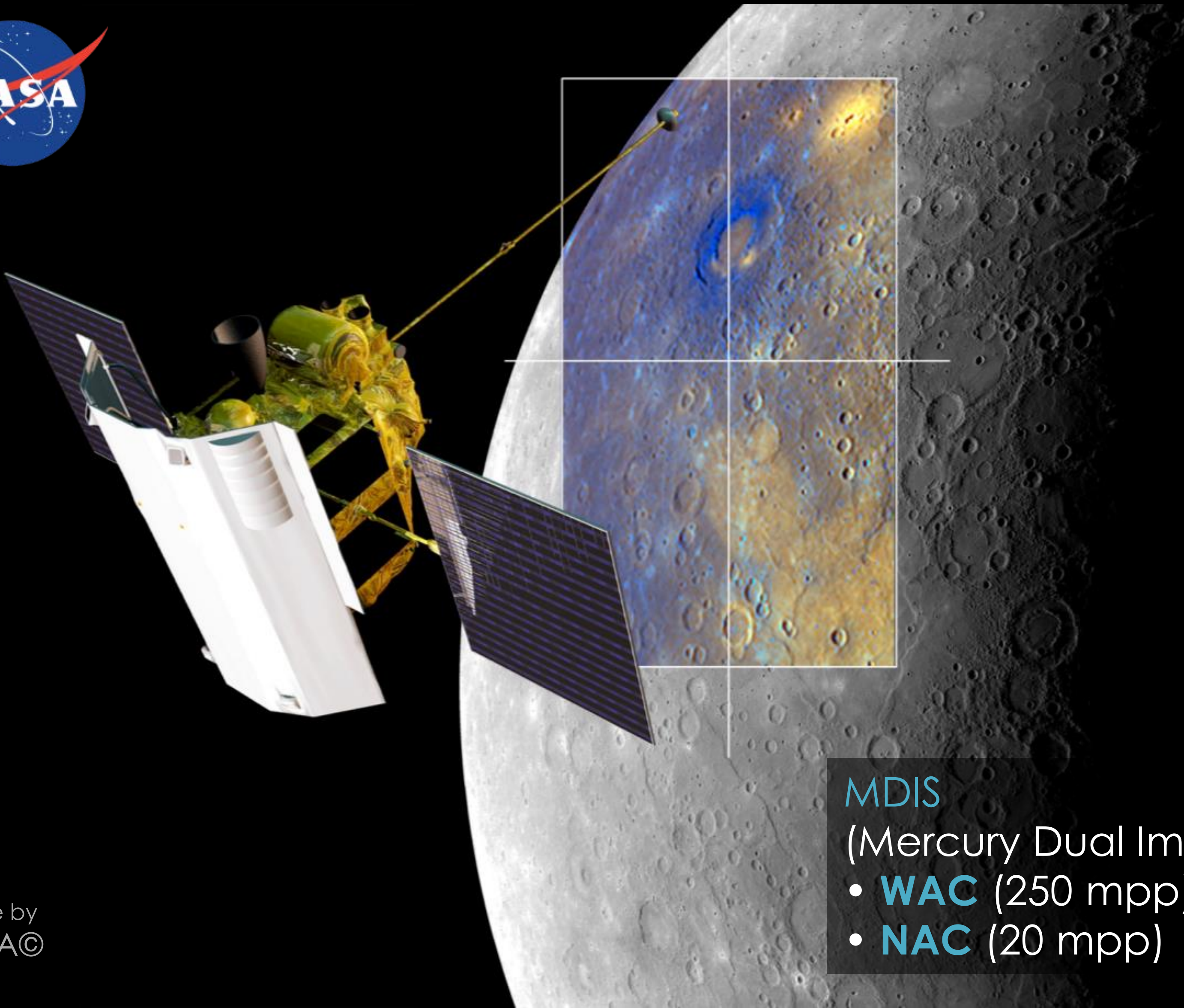


Image by
NASA©

2004 – 2015 – MESSENGER (NASA)

(MErcury Surface ENvironment, GEochemistry and Ranging)

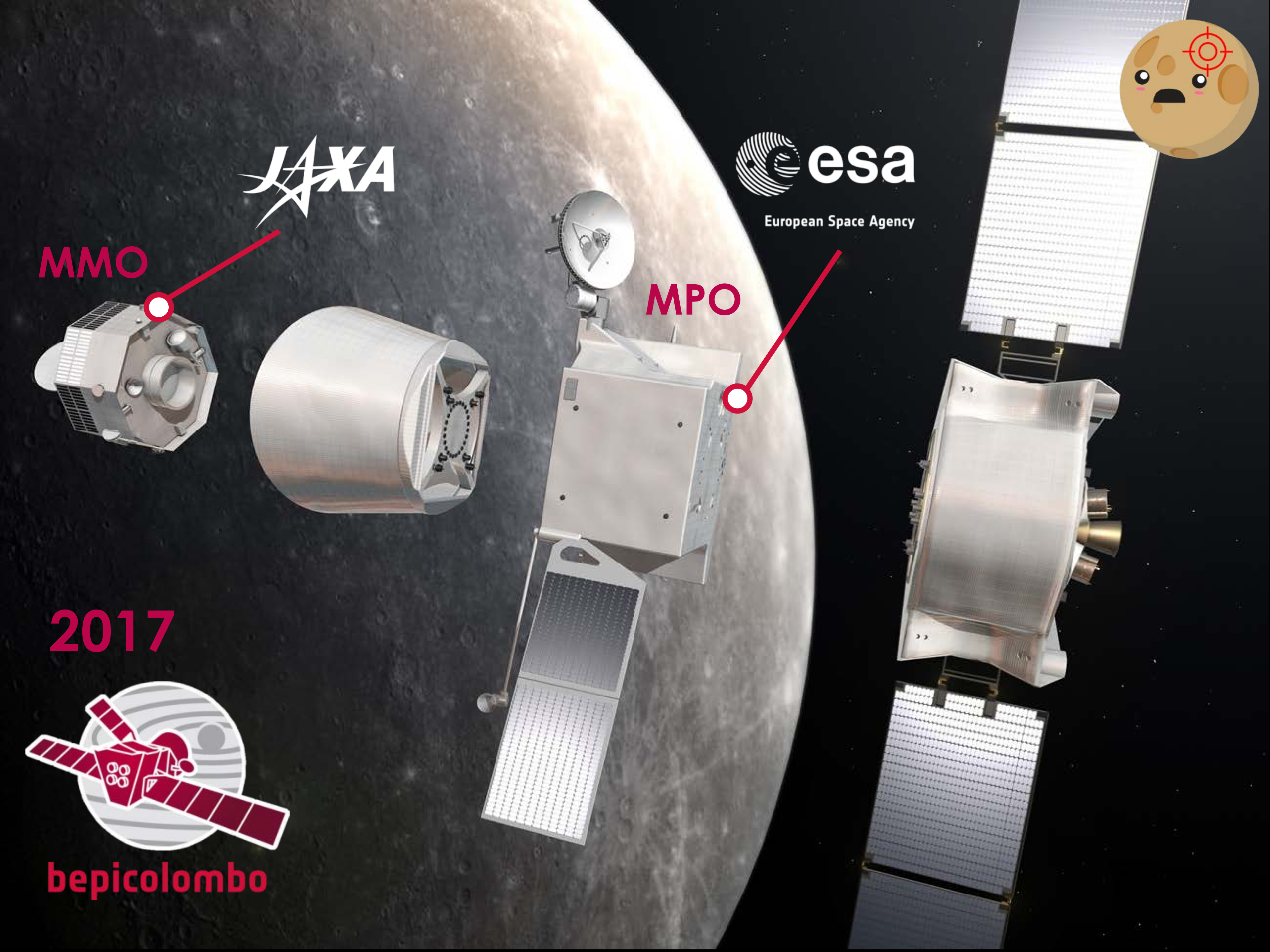


MDIS

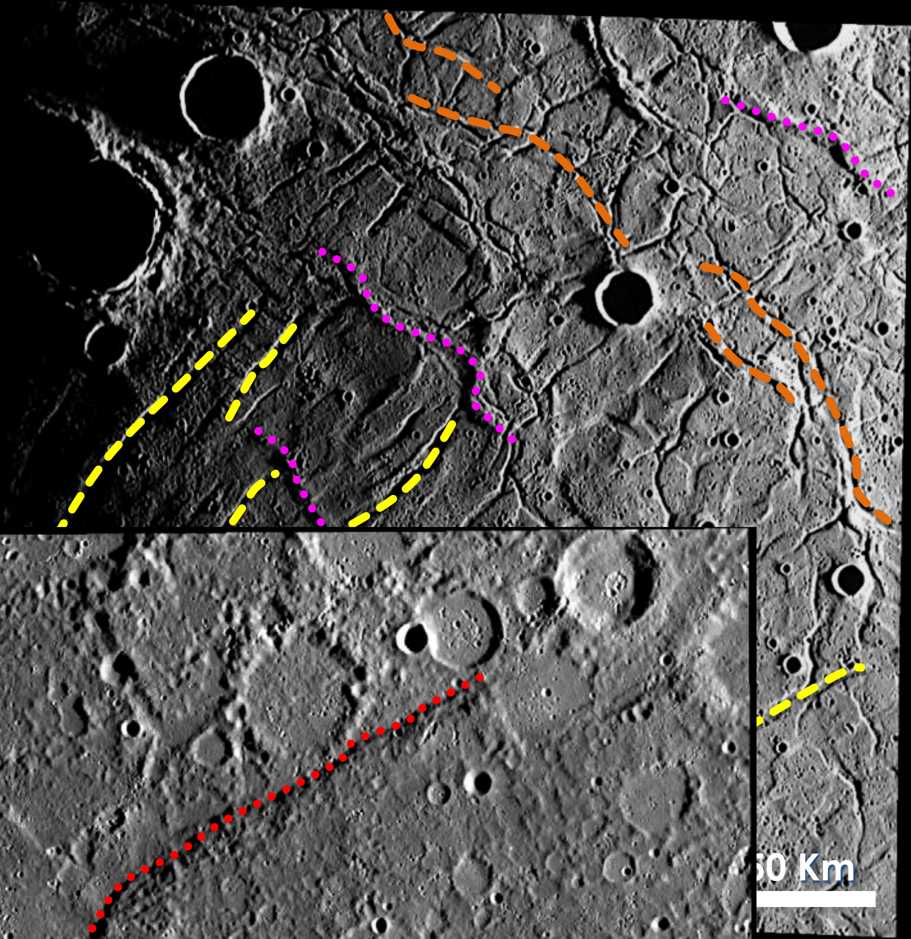
(Mercury Dual Imaging System)

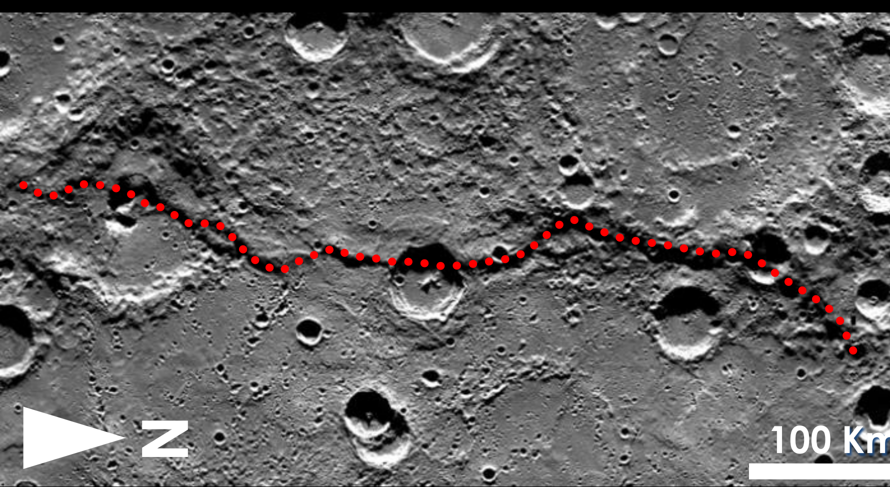
- **WAC** (250 mpp)
- **NAC** (20 mpp)

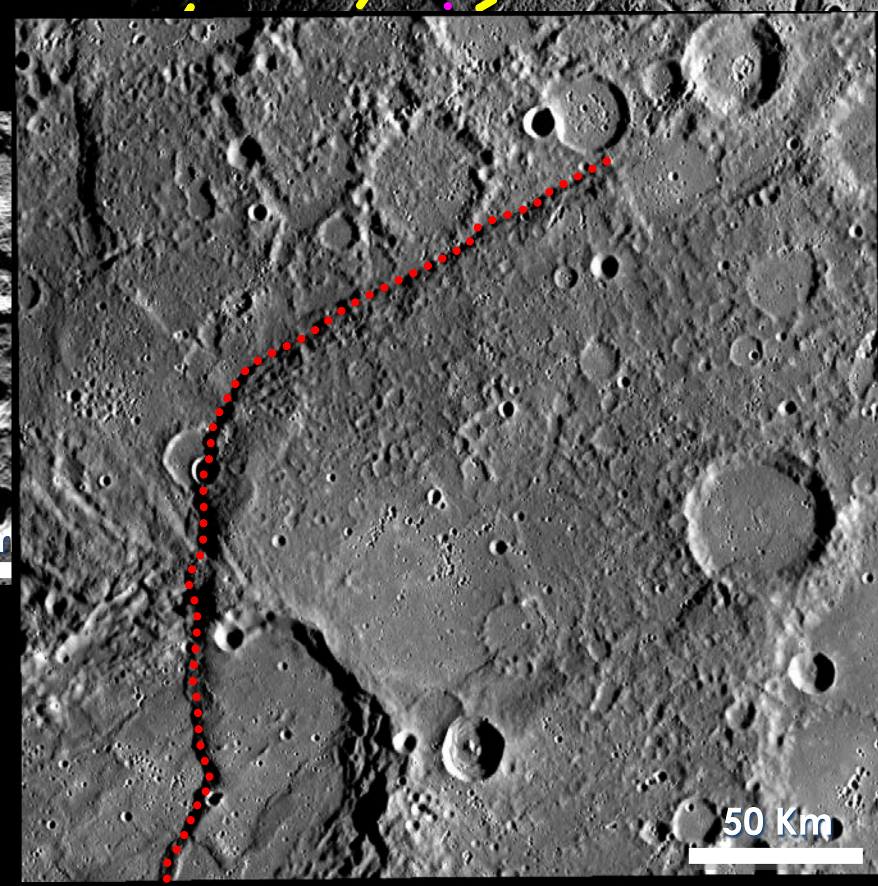
Image by NASA©


JAXA
MMO
esa
European Space Agency
MPO
2017
bepicolombo

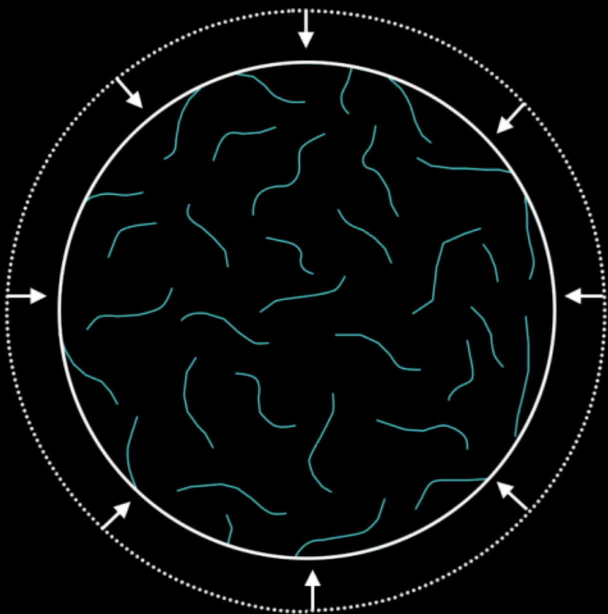
- EXTENSION structures
  - radial GRABEN
  - concentric GRABEN
- COMPRESSION structures
  - *WRINKLE RIDGES (thrusts?)*
- COMPRESSION structures (outside craters)
  - *LOBATE SCARPS (thrusts)*







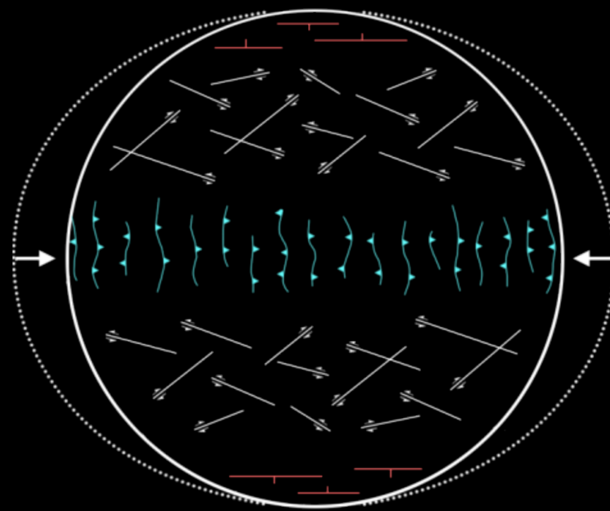
Strom et al., 1975



global contraction

(Strom, 1975)

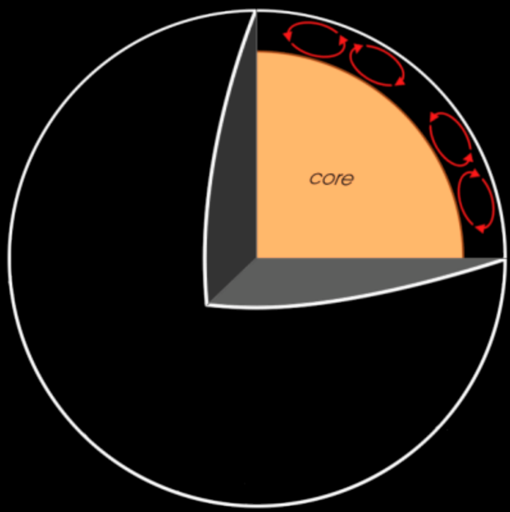
- ↓ core solidification
- ↓ surface shrinking
- ubiquitous thrusts
- random orientations



tidal despinning

(Melosh & Dzurisin, 1978)

- ↓ rotation despinning
- ↓ inversion tectonics
- all kind of faults
- latitudinal variations

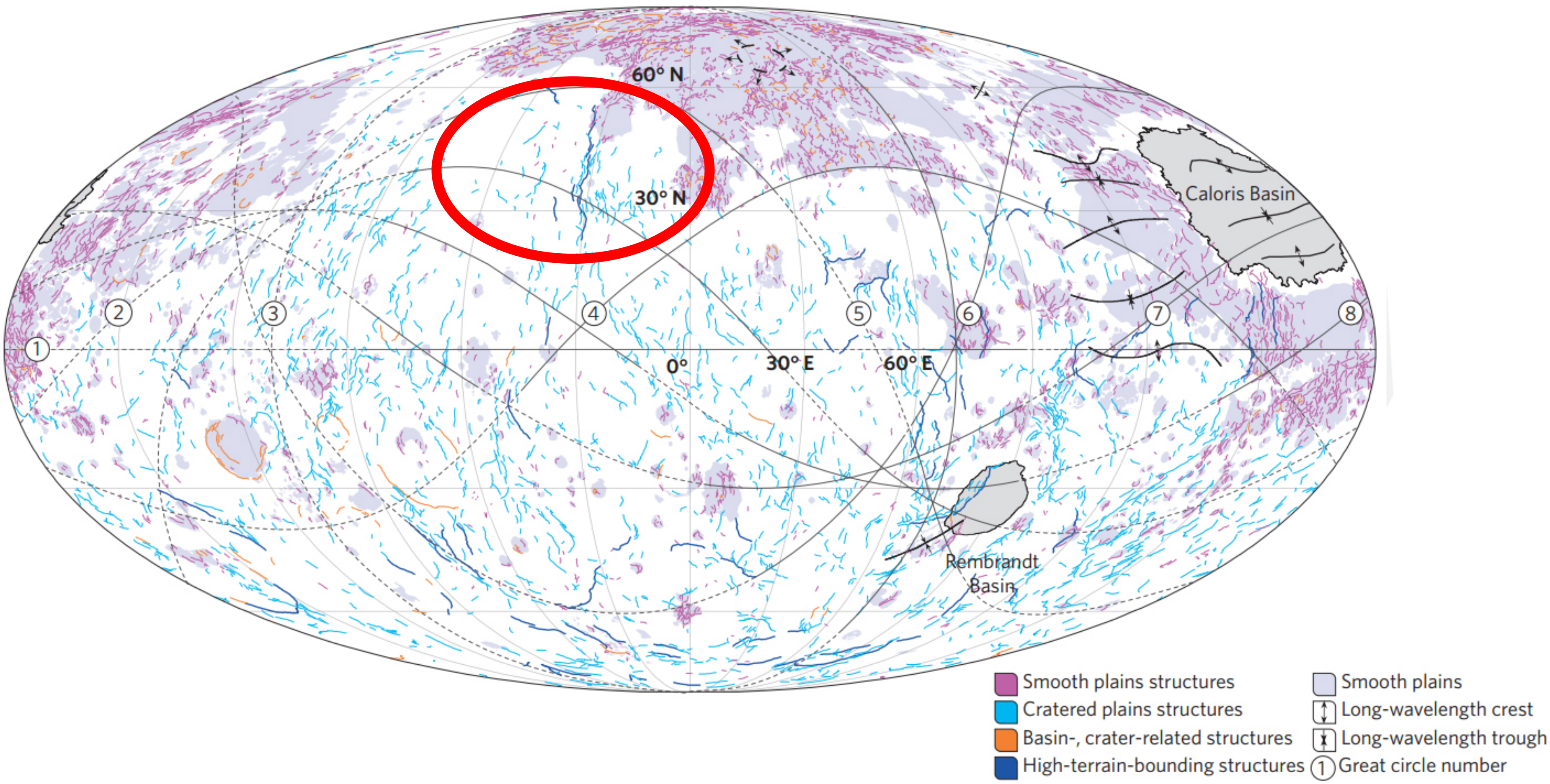


mantle convection

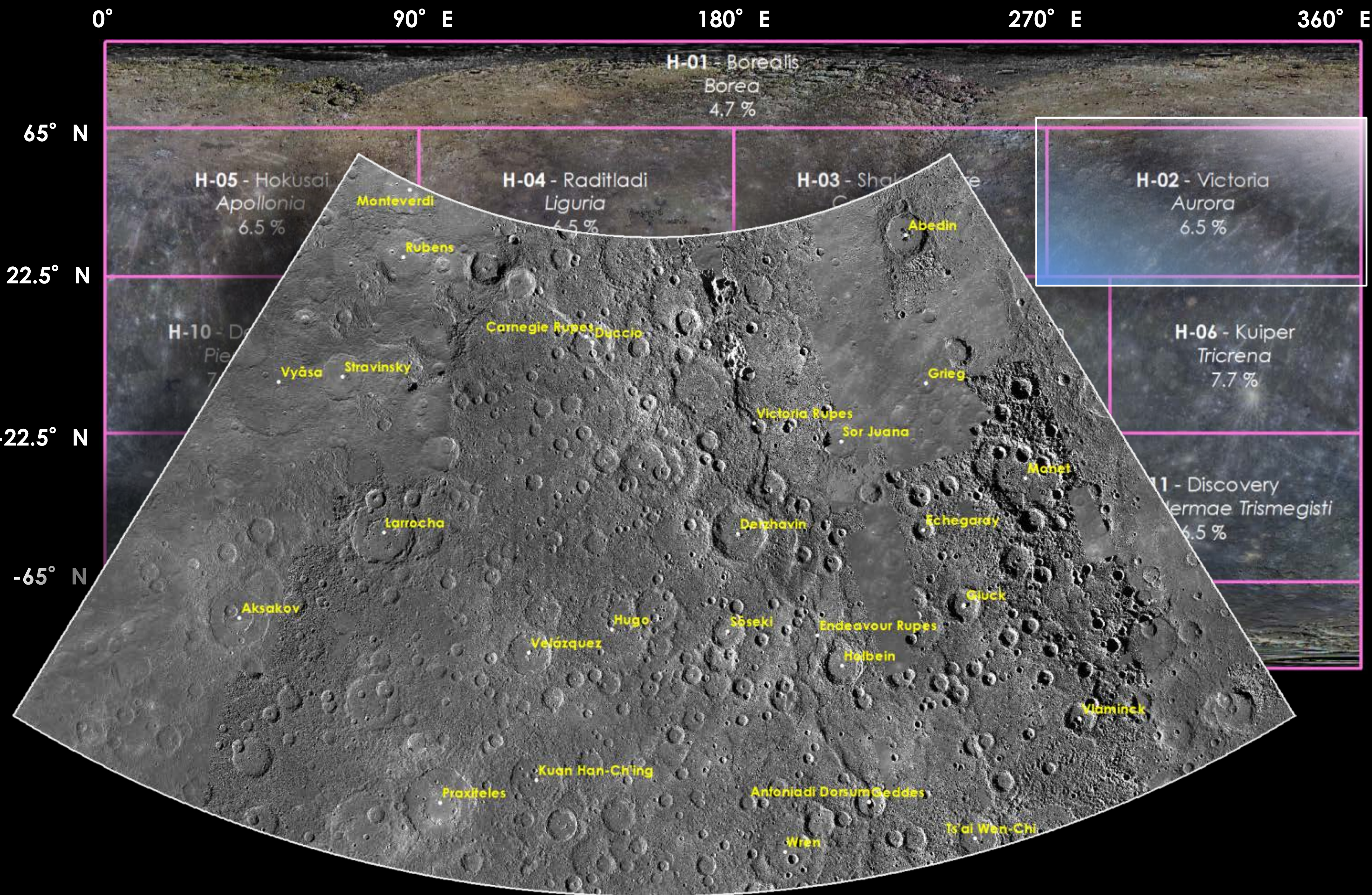
(King, 2008)

- ↓ convective cells…
- …changing over time

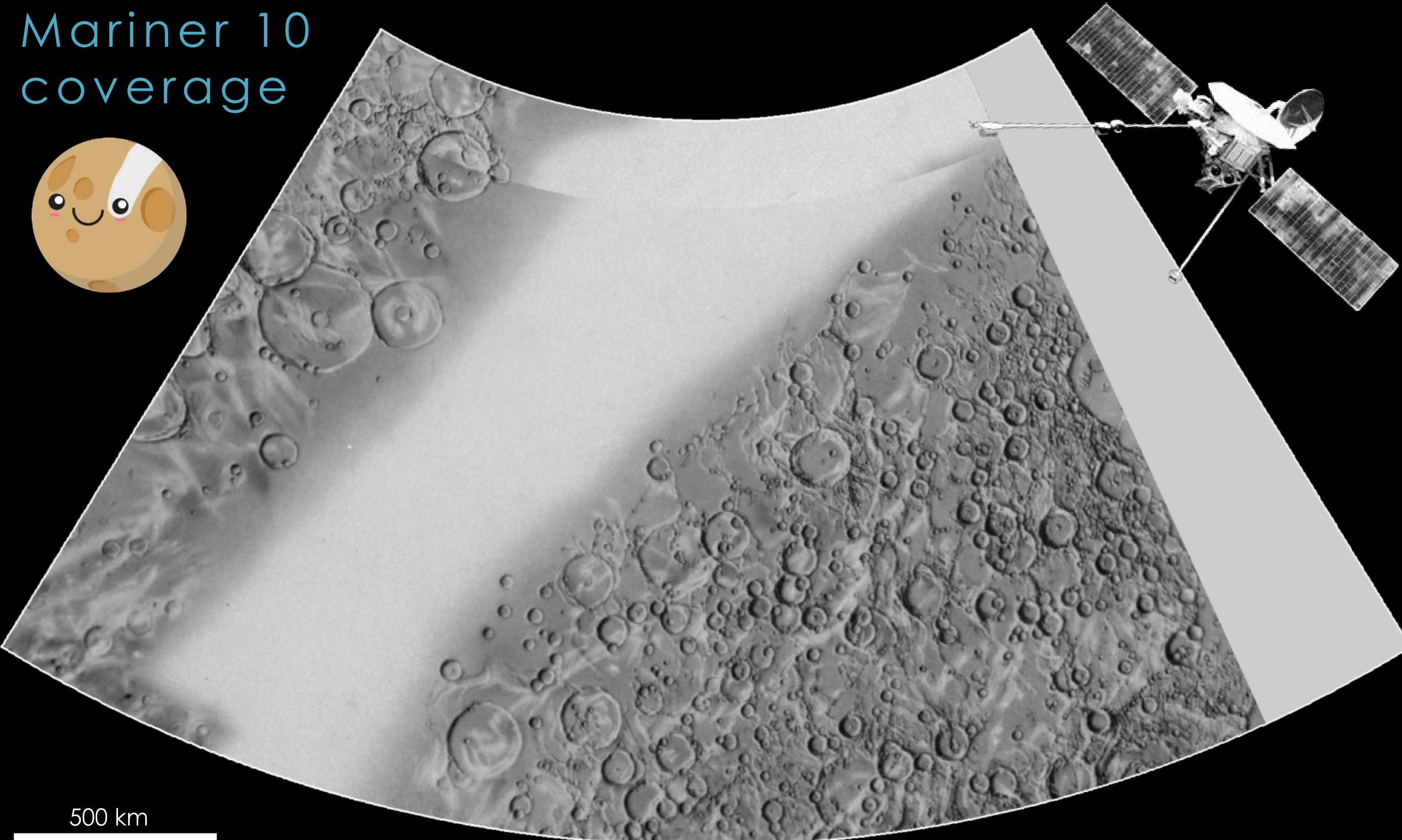
Global structural map



Byrne et al., 2014


0°
90° E
180° E
270° E
360° E
65° N
22.5° N
-22.5° N
-65° N
H-01 - Borealis
Borea
4.7 %
H-05 - Hokusai
Apollonia
6.5 %
H-04 - Raditladi
Liguria
H-02 - Victoria
Aurora
6.5 %
H-06 - Kuiper
Tricrena
7.7 %
Discovery
Monteverdi
Rubens
Abedin
Carnegie Rupes
Duccio
Vyāsa
Stravinsky
Grieg
Victoria Rupes
Sor Juana
Manet
Larrocha
Derzhavin
Echegaray
Aksakov
Hugo
Sōseki
Endeavour Rupes
Gluck
Velázquez
Holbein
Vlaminck
Kuan Han-Ch'ing
Praxiteles
Antoniadi Dorsum
Geddes
Ts'ai Wen-Chi
Wren

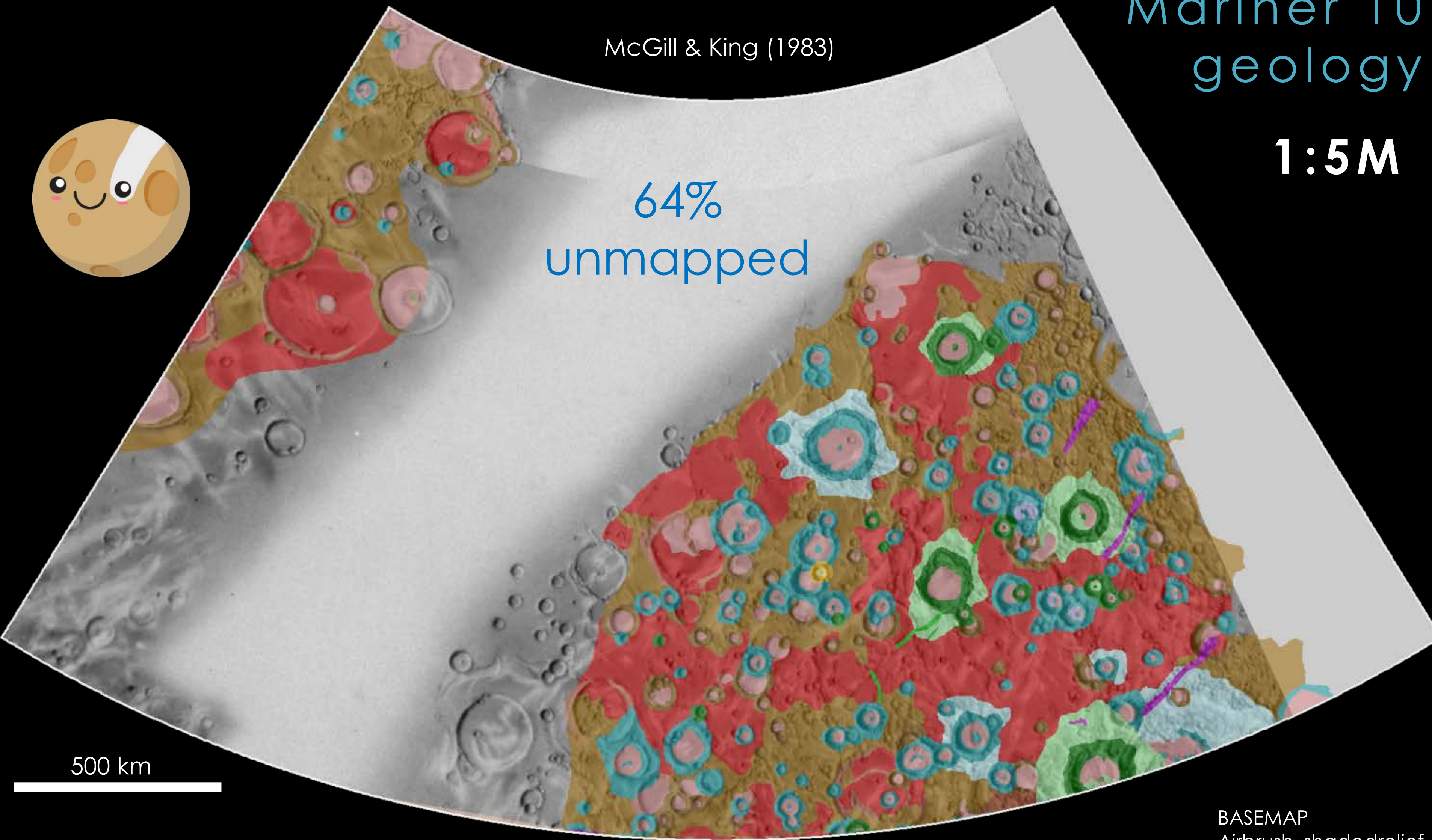
Mariner 10 coverage



BASEMAP
Airbrush_shadedrelief
© NASA

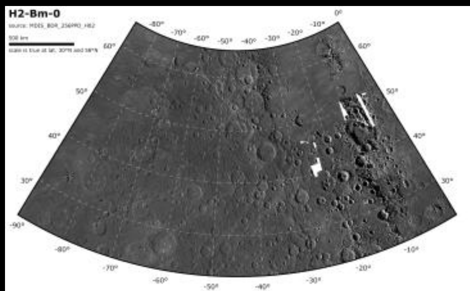
Mariner 10 geology

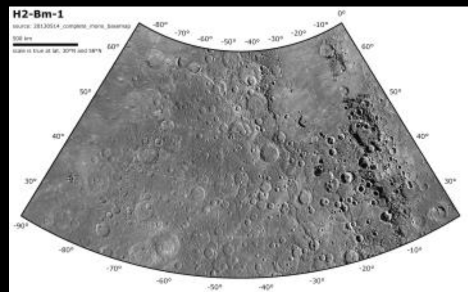
1:5M

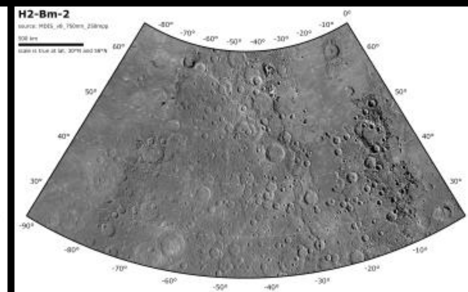


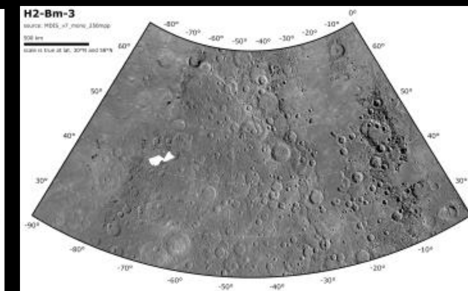
BASEMAP
Airbrush_shadedrelief
© NASA

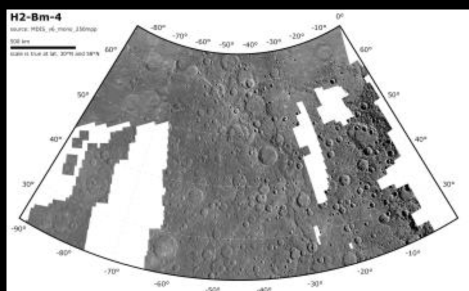
MESSENGER BASEMAPS

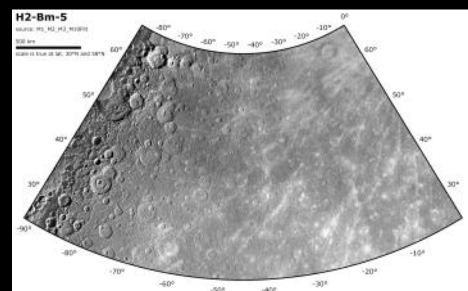


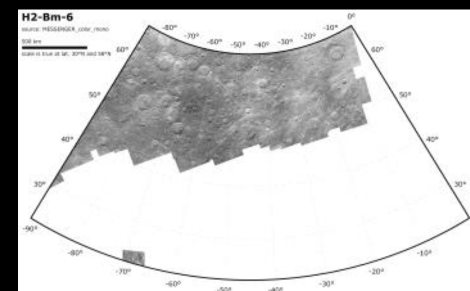


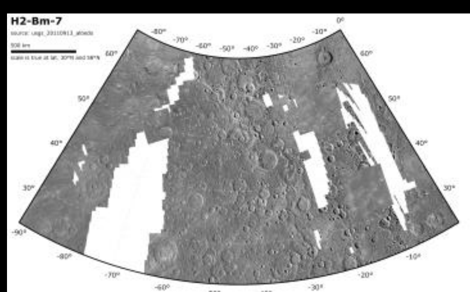


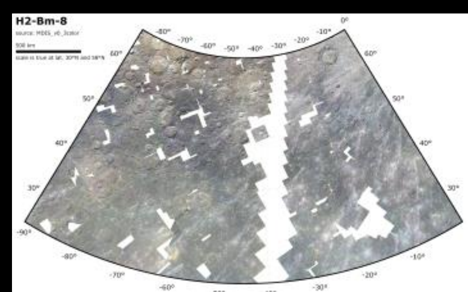


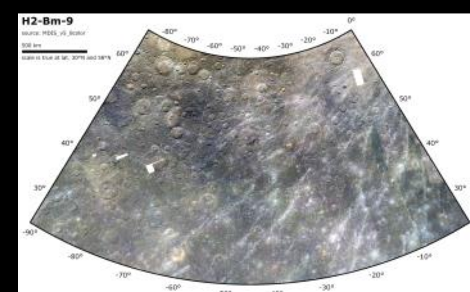












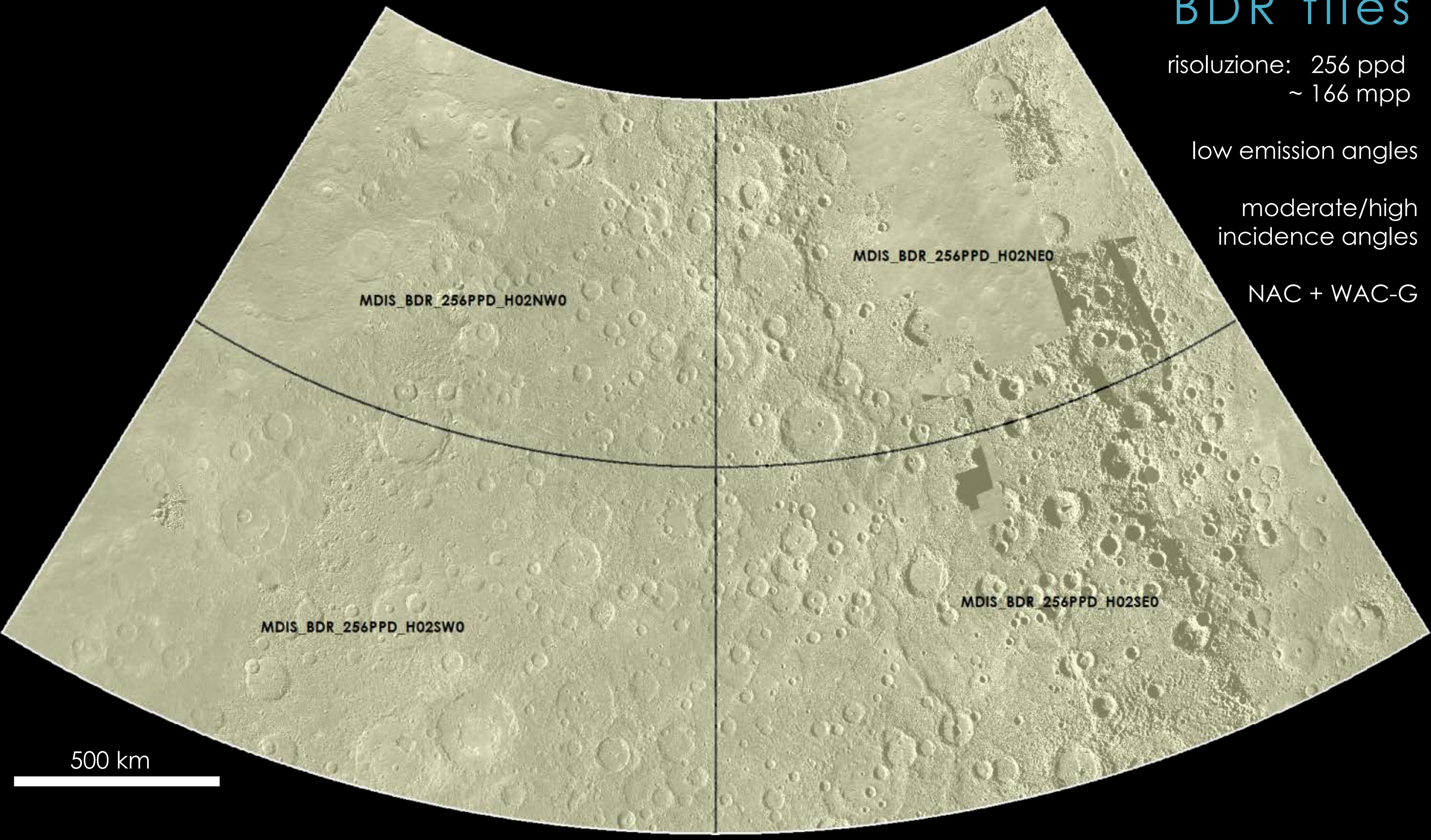
BDR tiles

risoluzione: 256 ppd
~ 166 mpp

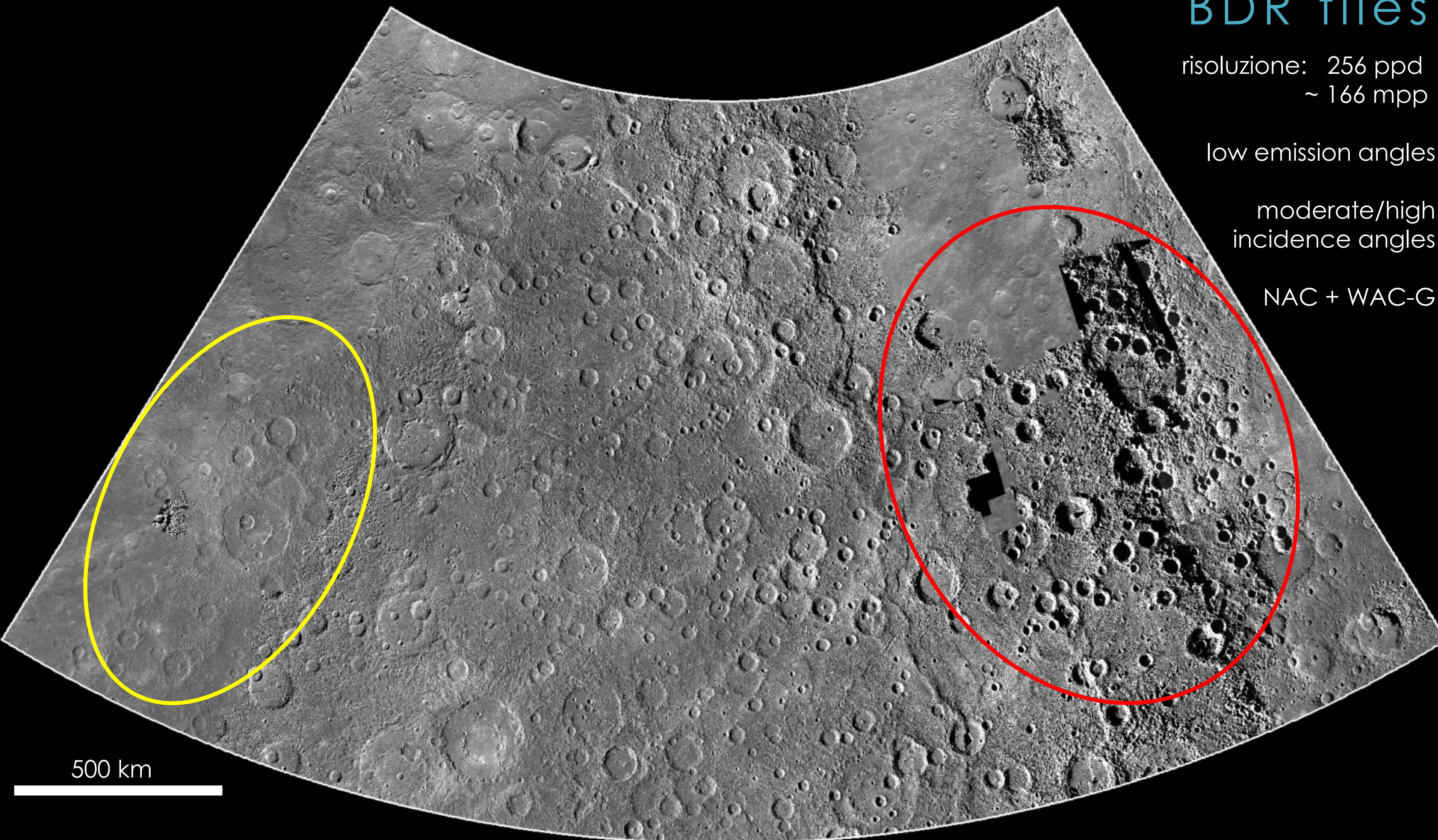
low emission angles

moderate/high
incidence angles

NAC + WAC-G



BASEMAP
mdis_bdr_256ppd_H02



BDR tiles

risoluzione: 256 ppd
~ 166 mpp

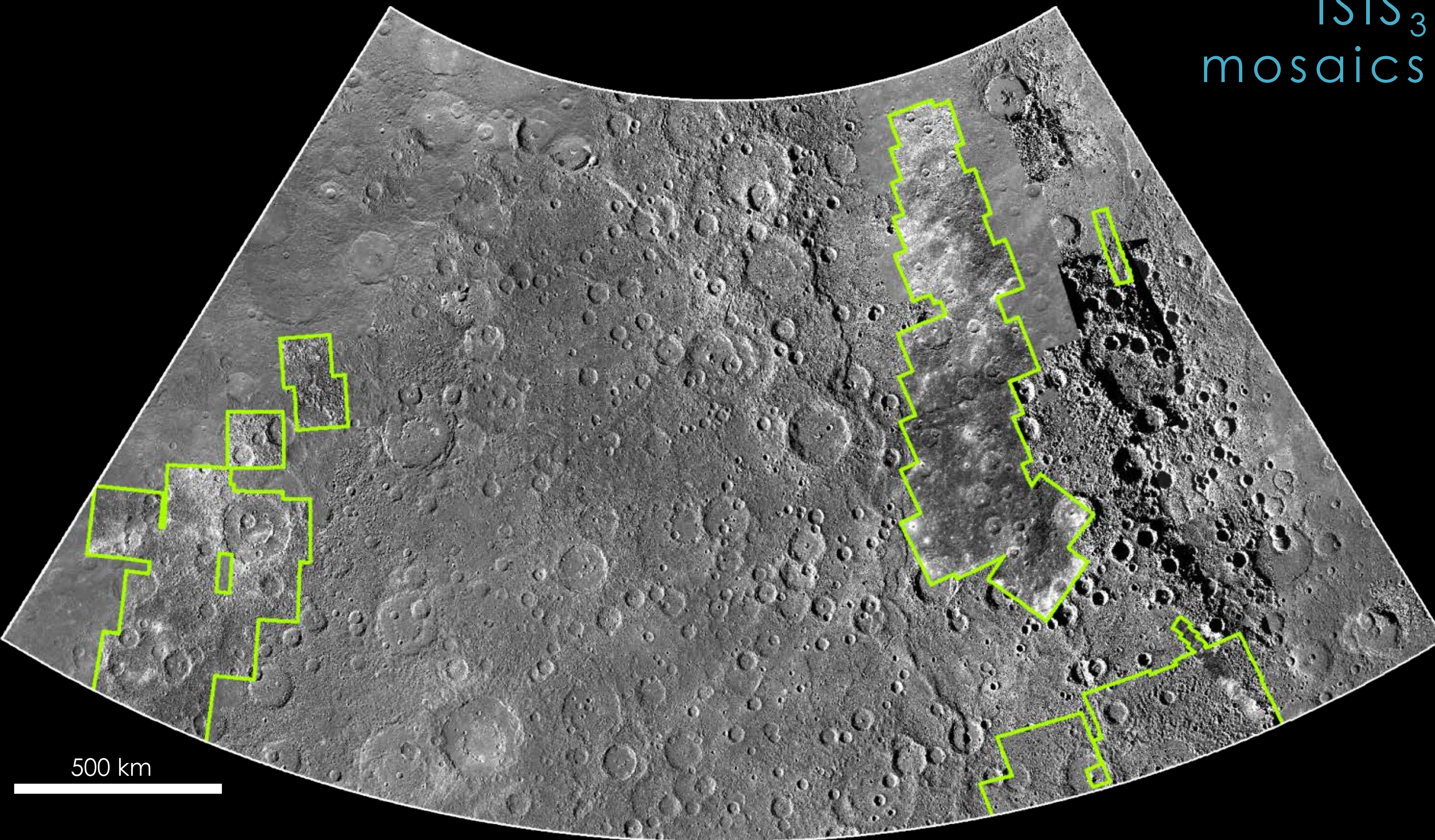
low emission angles

moderate/high
incidence angles

NAC + WAC-G

BASEMAP
mdis_bdr_256ppd_H02

ISIS$_3$ mosaics

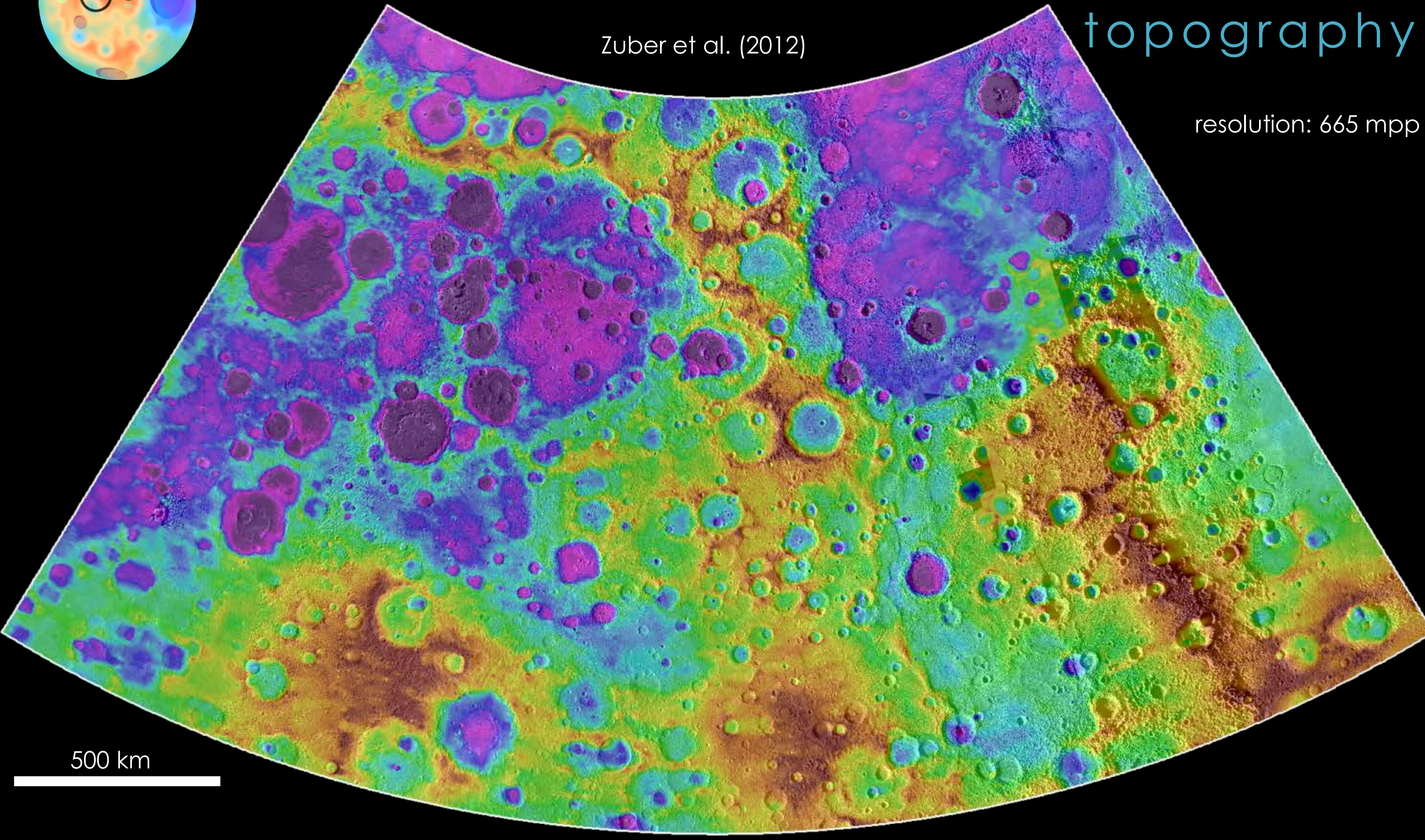


BASEMAP
mdis_bdr_256ppd_H02

MLA topography

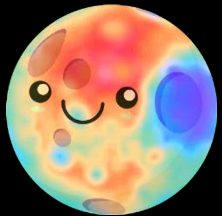
Zuber et al. (2012)

resolution: 665 mpp



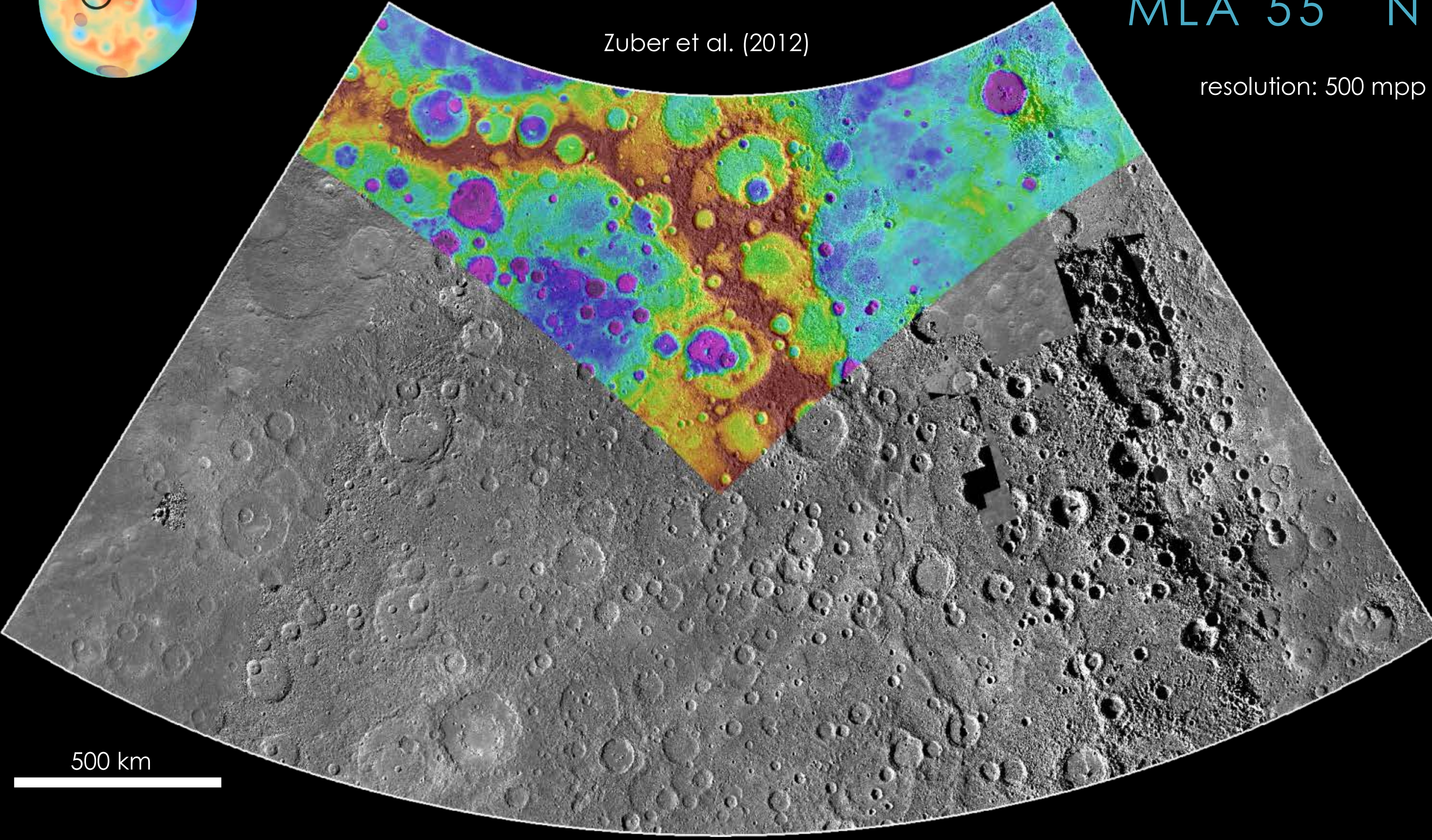
TOPOGRAPHY
hdem_64

BASEMAP
mdis_bdr_256ppd_H02



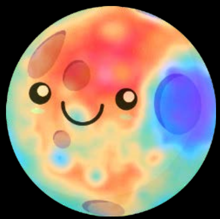
MLA 55° N

resolution: 500 mpp



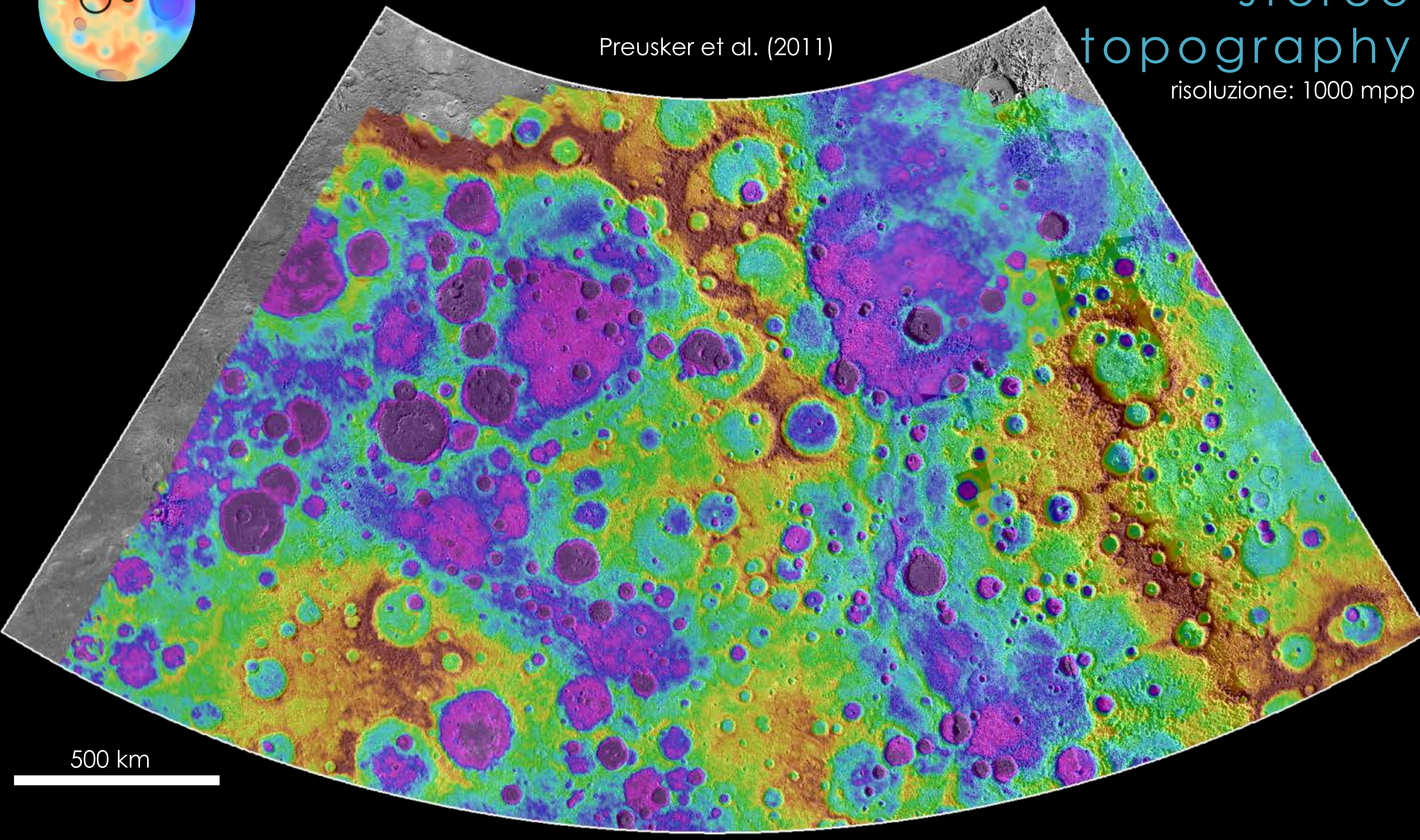
TOPOGRAPHY
hdem_55n_500m

BASEMAP
mdis_bdr_256ppd_H02



stereo topography

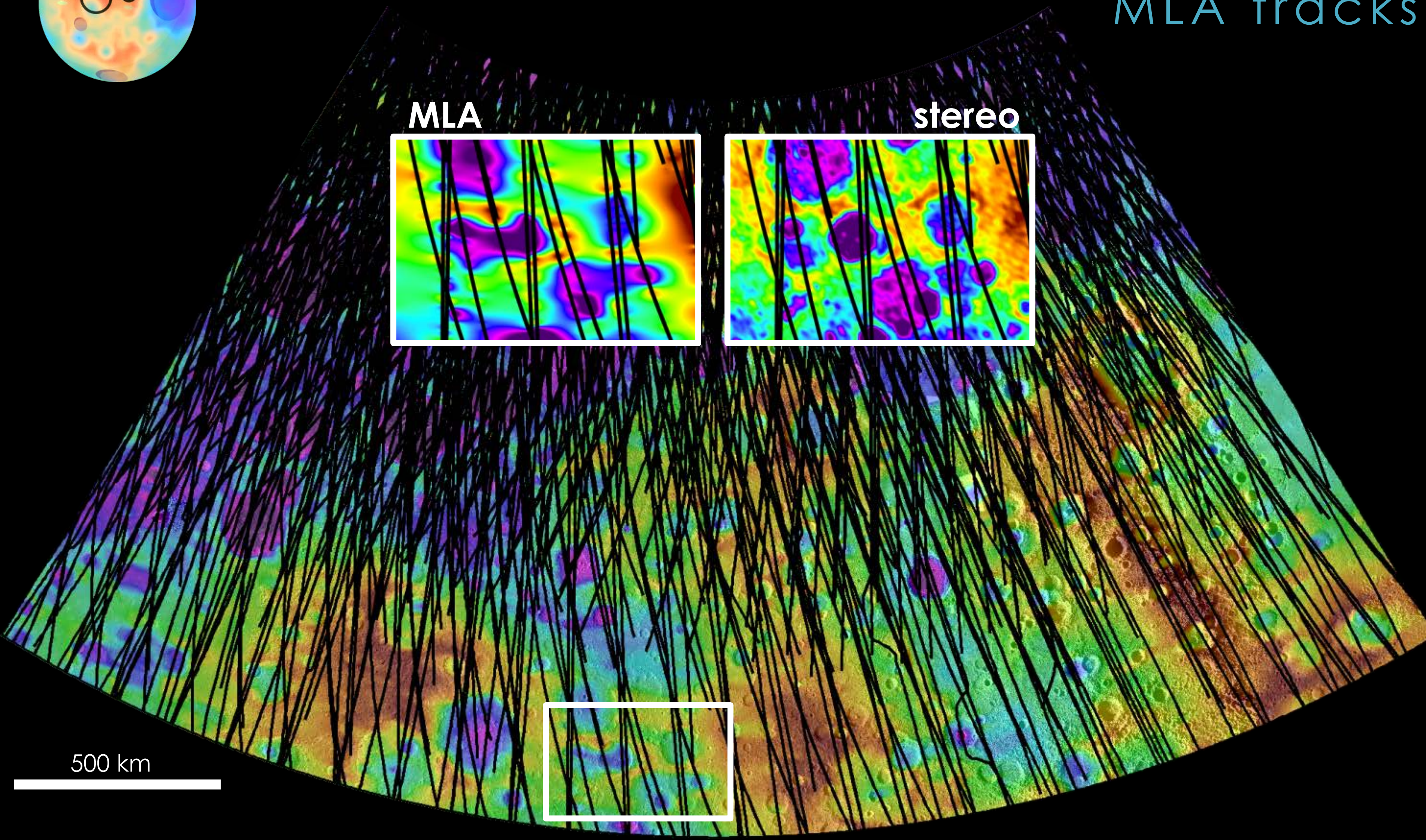
risoluzione: 1000 mpp



TOPOGRAPHY
M2_equi000_1km

BASEMAP
mdis_bdr_256ppd_H02

MLA tracks



TOPOGRAPHY
hdem_64

BASEMAP
mdis_bdr_256ppd_H02

METHODS

planetary geological mapping

planetary surface dating

fault slip data of remote sensed structures

☿ Past studies already considered **faulted craters** as an important **marker** to constrain the nature of **faults** on terrestrial planets … **QUALITATIVE approach**

e.g. Strom et al. (1975); Watters (1993); Watters et al. (1998)

Amenthes Rupes (Mars)
from **Watters (1993)**

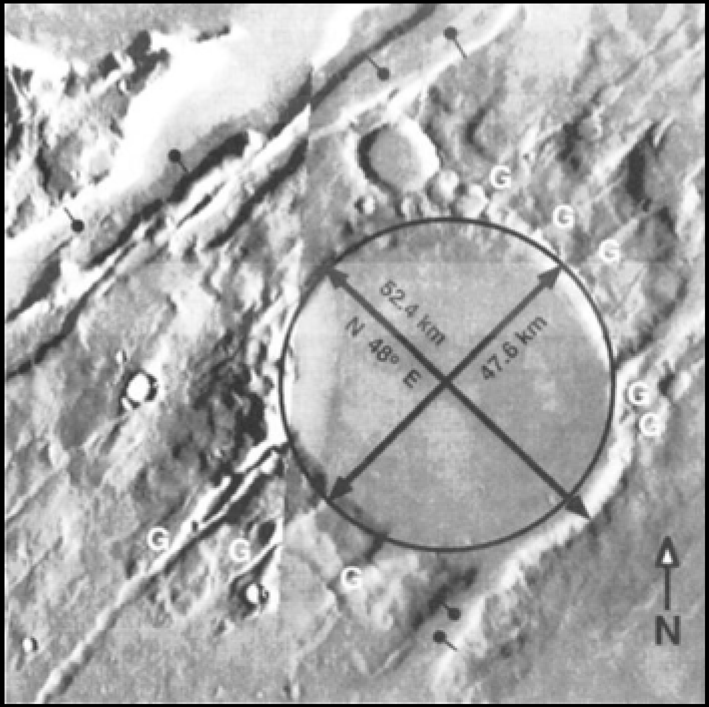
DIP-SLIP motion

unknown dip-angle

☿ … or even to perform **strain analysis**:

e.g. Thomas & Allemand (1993); Golombek *et al.* (1996); Pappalardo & Collins (2005)

QUANTITATIVE approach



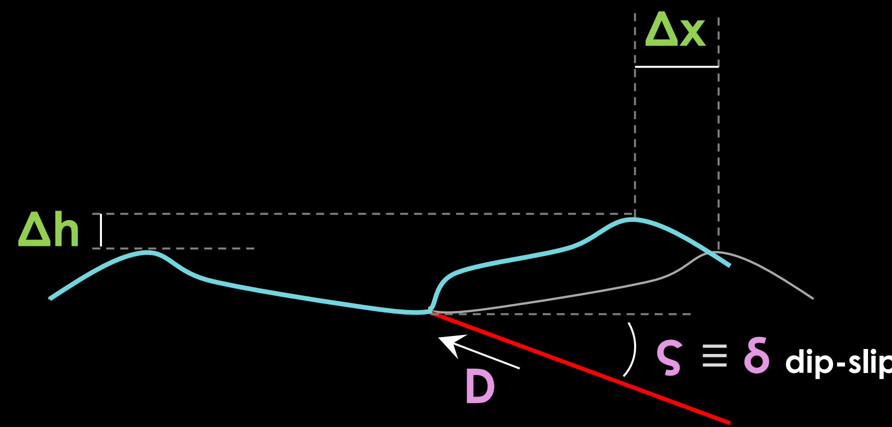
Gandzani Crater, Tempe Terra (Mars)
from **Golombek *et al.* (1996)**

Galluzzi et al., 2015

- The analysis of faulted craters leads to assess:

Δx slip **horizontal** component

Δh slip **vertical** component



- Thus these parameters can be calculated:

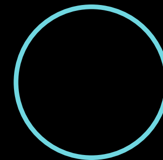
ς slip **plunge** **δ** fault **true dip** **λ** fault **rake** **D** fault **displacement**

$\varsigma = \tan^{-1}(\Delta h / \Delta x)$ $\delta = \tan^{-1}(\tan\varsigma / \sin\varphi)$ $\lambda = \cos^{-1}(\textit{strike} \cdot \textit{slip})$ $D = \Delta h / \sin\varsigma$

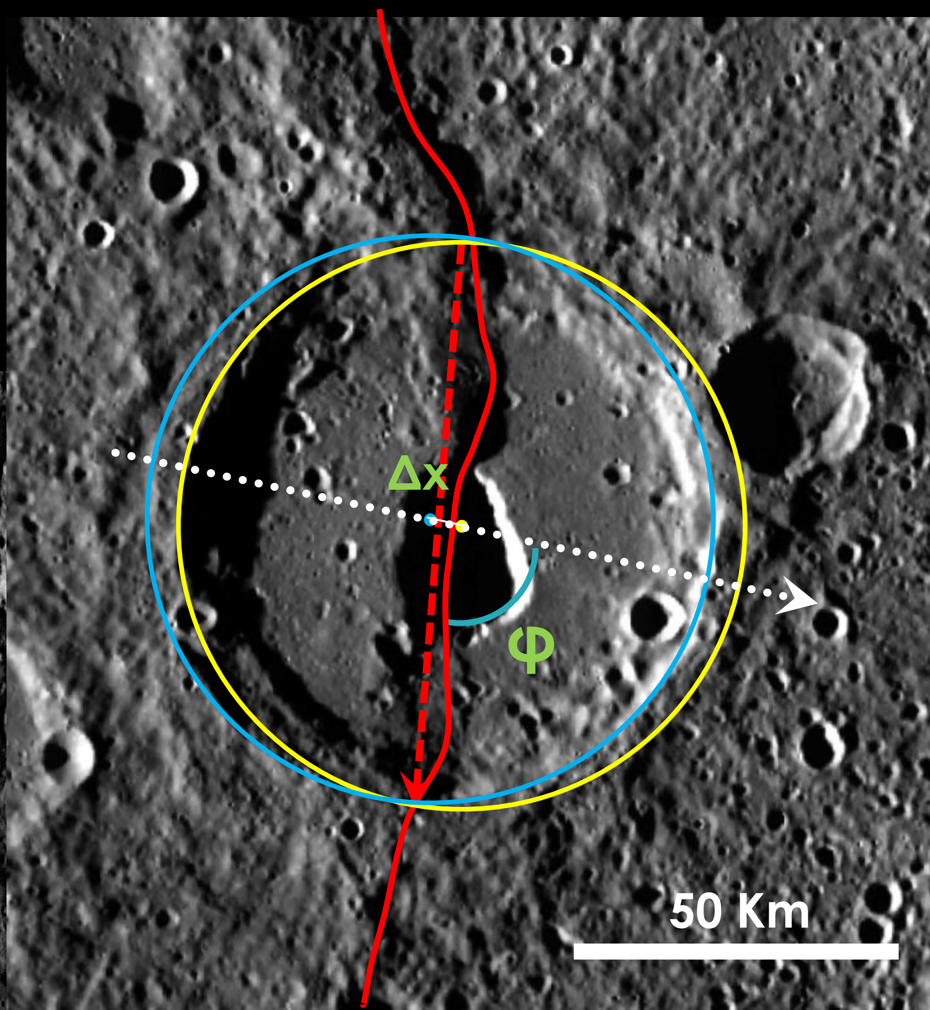
Galluzzi et al., 2015

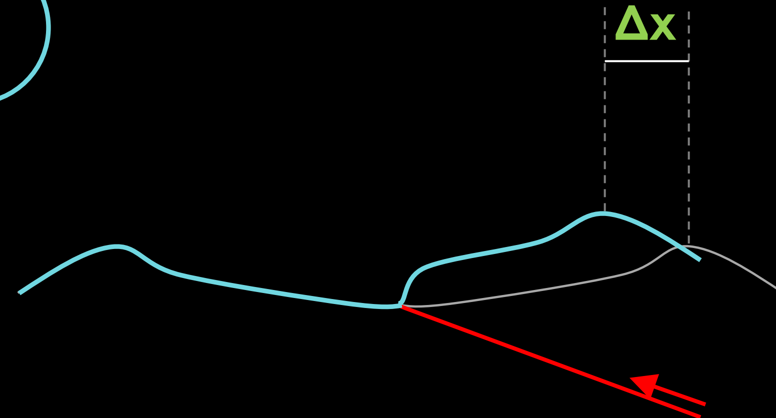
☿ ASSUMPTION:

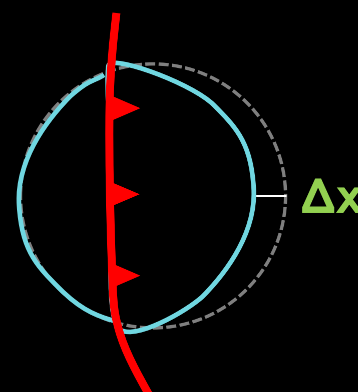
The crater was originally **circular** in shape



STEREOGRAPHIC PROJECTION !!







Δx segment also indicates the **slip's trend**

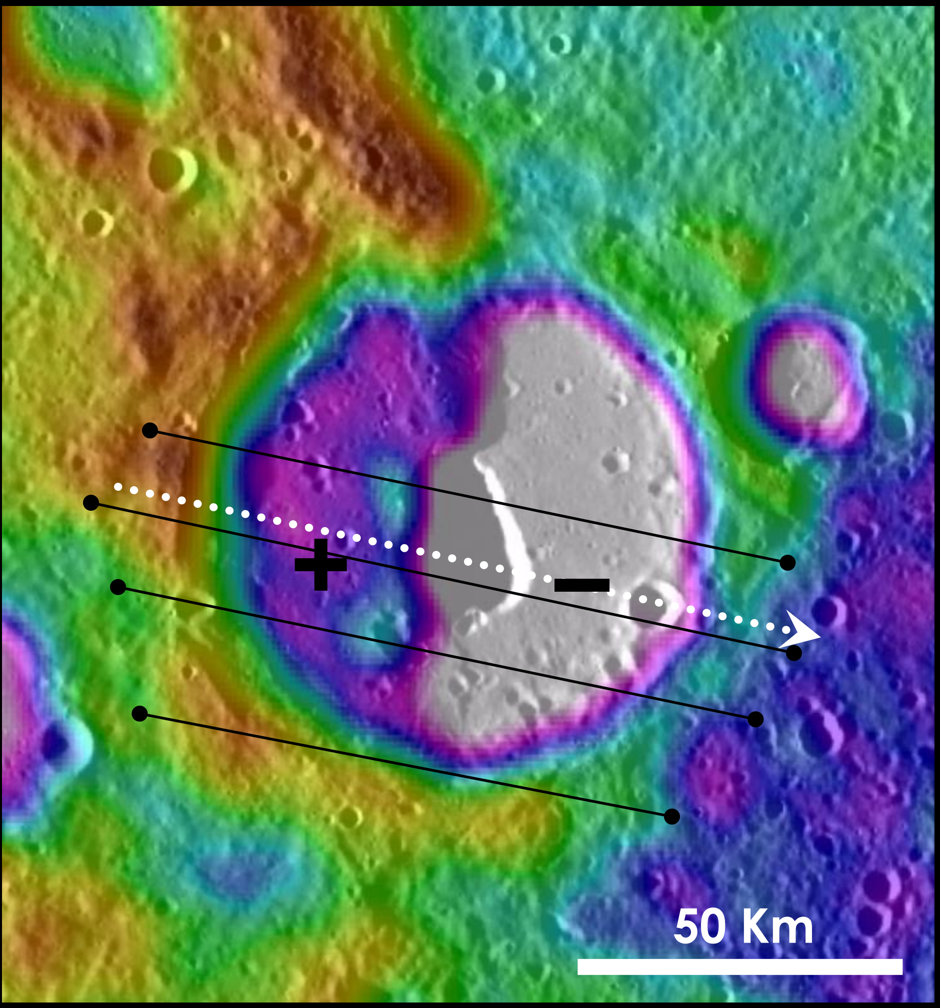
$\varphi = 90^\circ$ → **dip-slip**

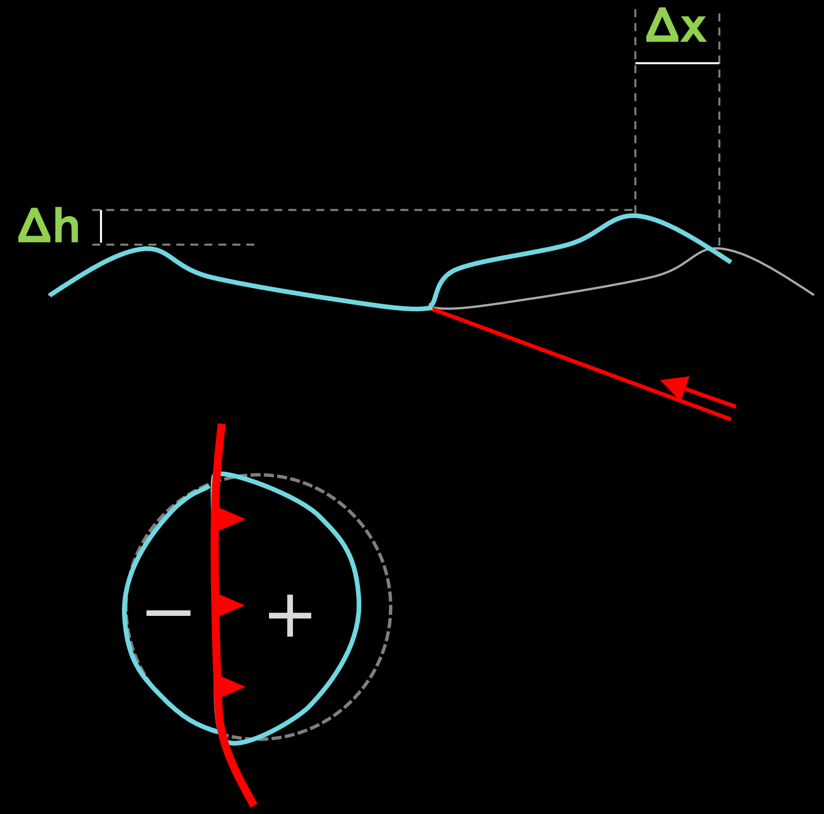
$\varphi \neq 90^\circ$ → **oblique-slip**

$\varphi = 0^\circ\ /180^\circ$ → **strike-slip**

Galluzzi et al., 2015

STEREOGRAPHIC PROJECTION !!





Height is measured preferably **on rims** to avoid floor's morphological complications

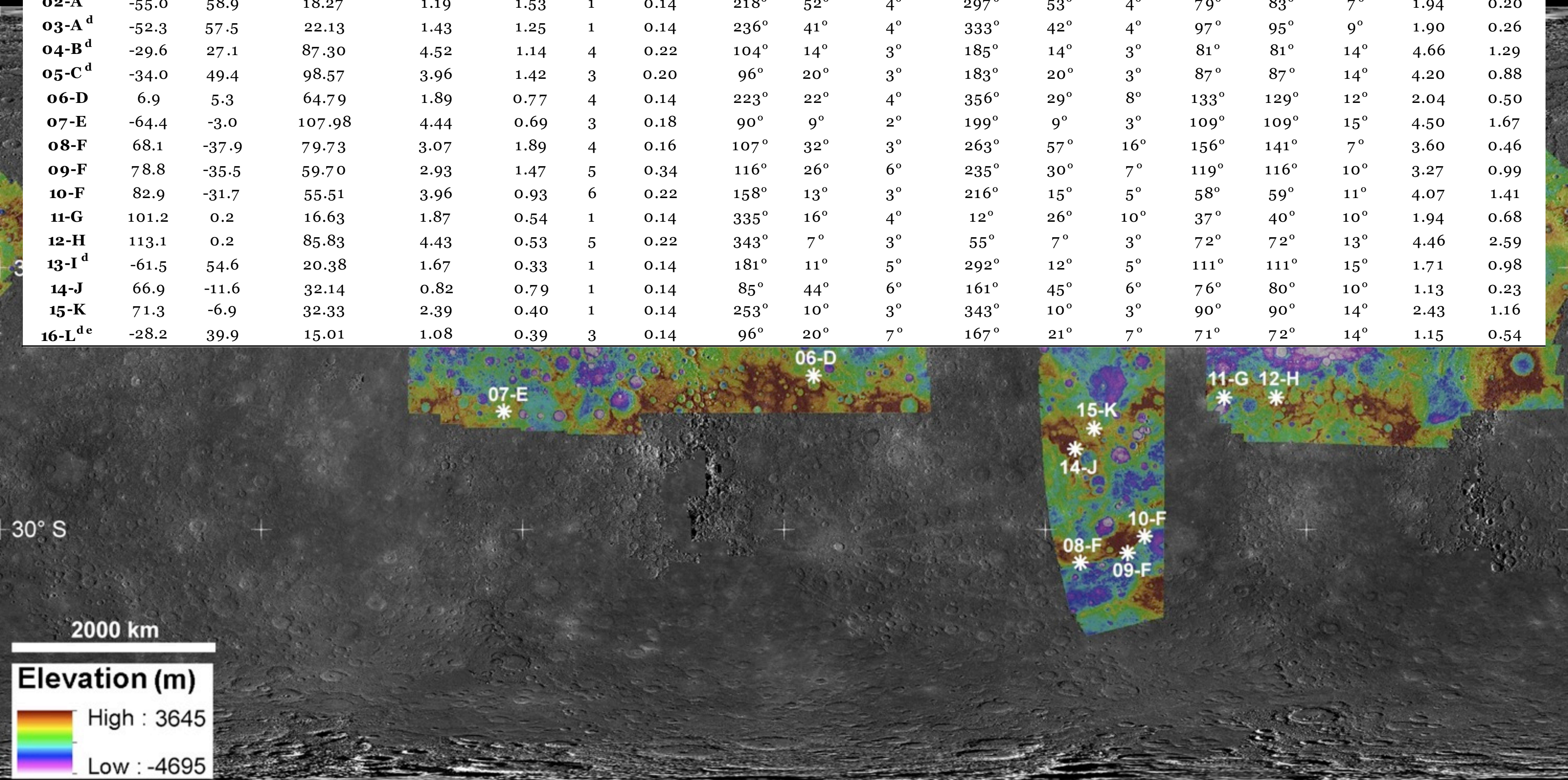
e.g. central peaks, peak ring …

Δh = **h**max – **h**min

RESULTS
[fault slip data]

Galluzzi et al., 2015

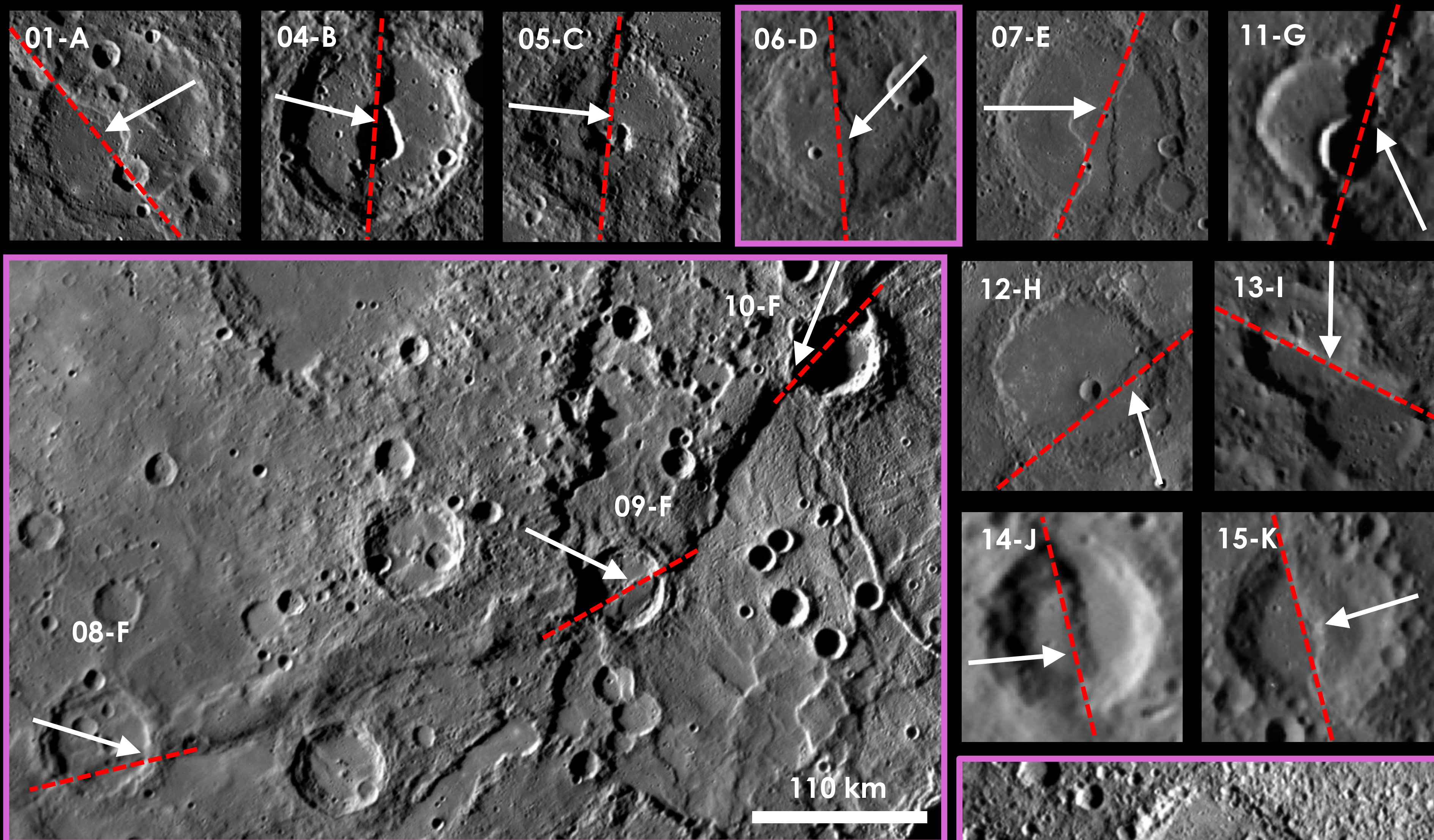
Crater	Lon. (dd)	Lat. (dd)	Diameter (km)	Δx [a] (km)	Δh (km)	n	$\sigma\,\Delta h$ (km)	trend [b]	plunge	σ plunge	strike [c]	δ	$\sigma\,\delta$	φ [b]	λ	$\sigma\,\lambda$	D (km)	$\sigma\,D$ (km)
01-A [d]	-52.5	58.2	109.90	4.14	2.43	6	0.25	241°	30°	4°	323°	31°	4°	82°	83°	10°	4.80	0.70
02-A [d]	-55.0	58.9	18.27	1.19	1.53	1	0.14	218°	52°	4°	297°	53°	4°	79°	83°	7°	1.94	0.20
03-A [d]	-52.3	57.5	22.13	1.43	1.25	1	0.14	236°	41°	4°	333°	42°	4°	97°	95°	9°	1.90	0.26
04-B [d]	-29.6	27.1	87.30	4.52	1.14	4	0.22	104°	14°	3°	185°	14°	3°	81°	81°	14°	4.66	1.29
05-C [d]	-34.0	49.4	98.57	3.96	1.42	3	0.20	96°	20°	3°	183°	20°	3°	87°	87°	14°	4.20	0.88
06-D	6.9	5.3	64.79	1.89	0.77	4	0.14	223°	22°	4°	356°	29°	8°	133°	129°	12°	2.04	0.50
07-E	-64.4	-3.0	107.98	4.44	0.69	3	0.18	90°	9°	2°	199°	9°	3°	109°	109°	15°	4.50	1.67
08-F	68.1	-37.9	79.73	3.07	1.89	4	0.16	107°	32°	3°	263°	57°	16°	156°	141°	7°	3.60	0.46
09-F	78.8	-35.5	59.70	2.93	1.47	5	0.34	116°	26°	6°	235°	30°	7°	119°	116°	10°	3.27	0.99
10-F	82.9	-31.7	55.51	3.96	0.93	6	0.22	158°	13°	3°	216°	15°	5°	58°	59°	11°	4.07	1.41
11-G	101.2	0.2	16.63	1.87	0.54	1	0.14	335°	16°	4°	12°	26°	10°	37°	40°	10°	1.94	0.68
12-H	113.1	0.2	85.83	4.43	0.53	5	0.22	343°	7°	3°	55°	7°	3°	72°	72°	13°	4.46	2.59
13-I [d]	-61.5	54.6	20.38	1.67	0.33	1	0.14	181°	11°	5°	292°	12°	5°	111°	111°	15°	1.71	0.98
14-J	66.9	-11.6	32.14	0.82	0.79	1	0.14	85°	44°	6°	161°	45°	6°	76°	80°	10°	1.13	0.23
15-K	71.3	-6.9	32.33	2.39	0.40	1	0.14	253°	10°	3°	343°	10°	3°	90°	90°	14°	2.43	1.16
16-L [d e]	-28.2	39.9	15.01	1.08	0.39	3	0.14	96°	20°	7°	167°	21°	7°	71°	72°	14°	1.15	0.54

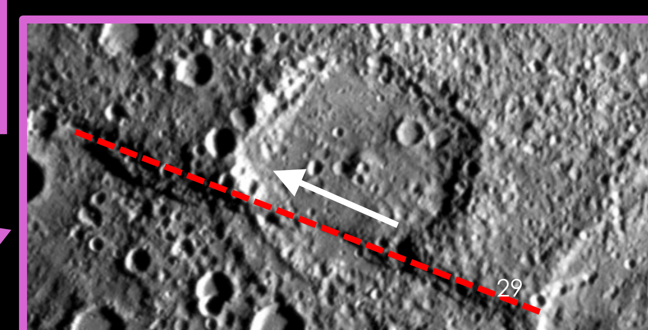


Stereo DTM Preusker et al. (2011)

Global mosaic v9 © NASA/JHUAPL/CIW

Galluzzi et al., 2015

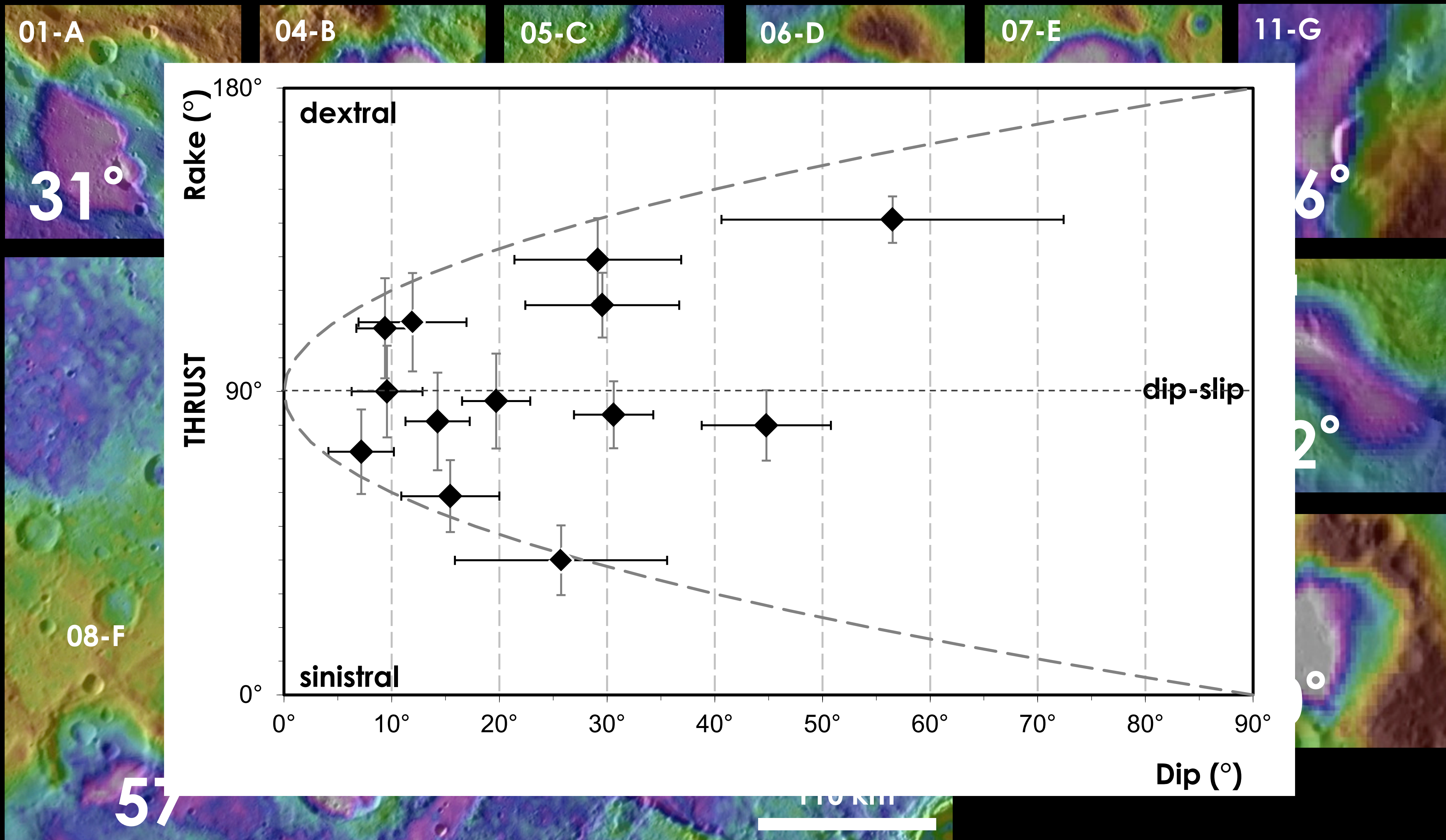




Most of the craters are cross-cut by oblique faults

Massironi et al., 2015

Galluzzi et al., 2015



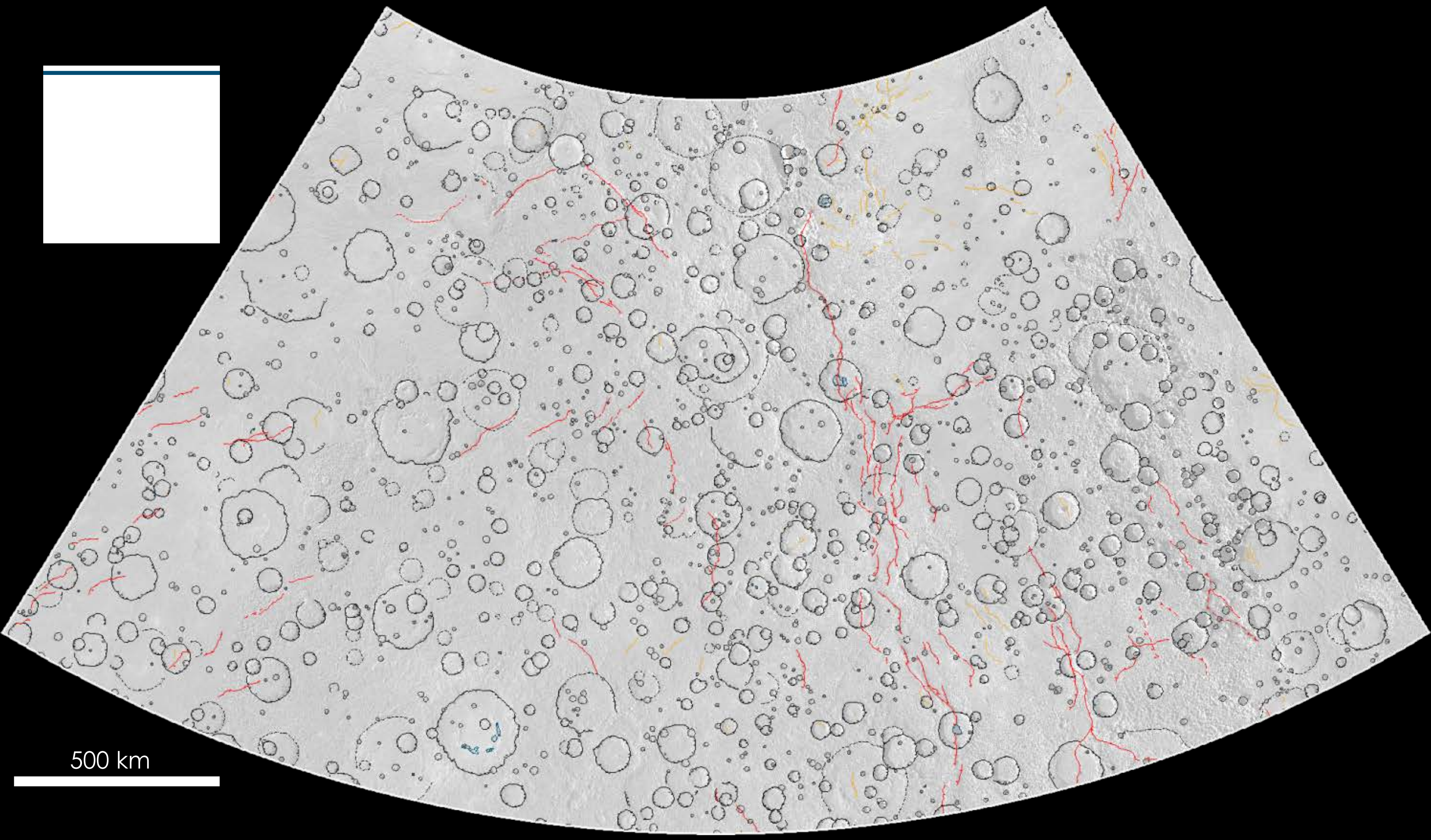
True dip angles:
7° < ∂ < 57° wide range

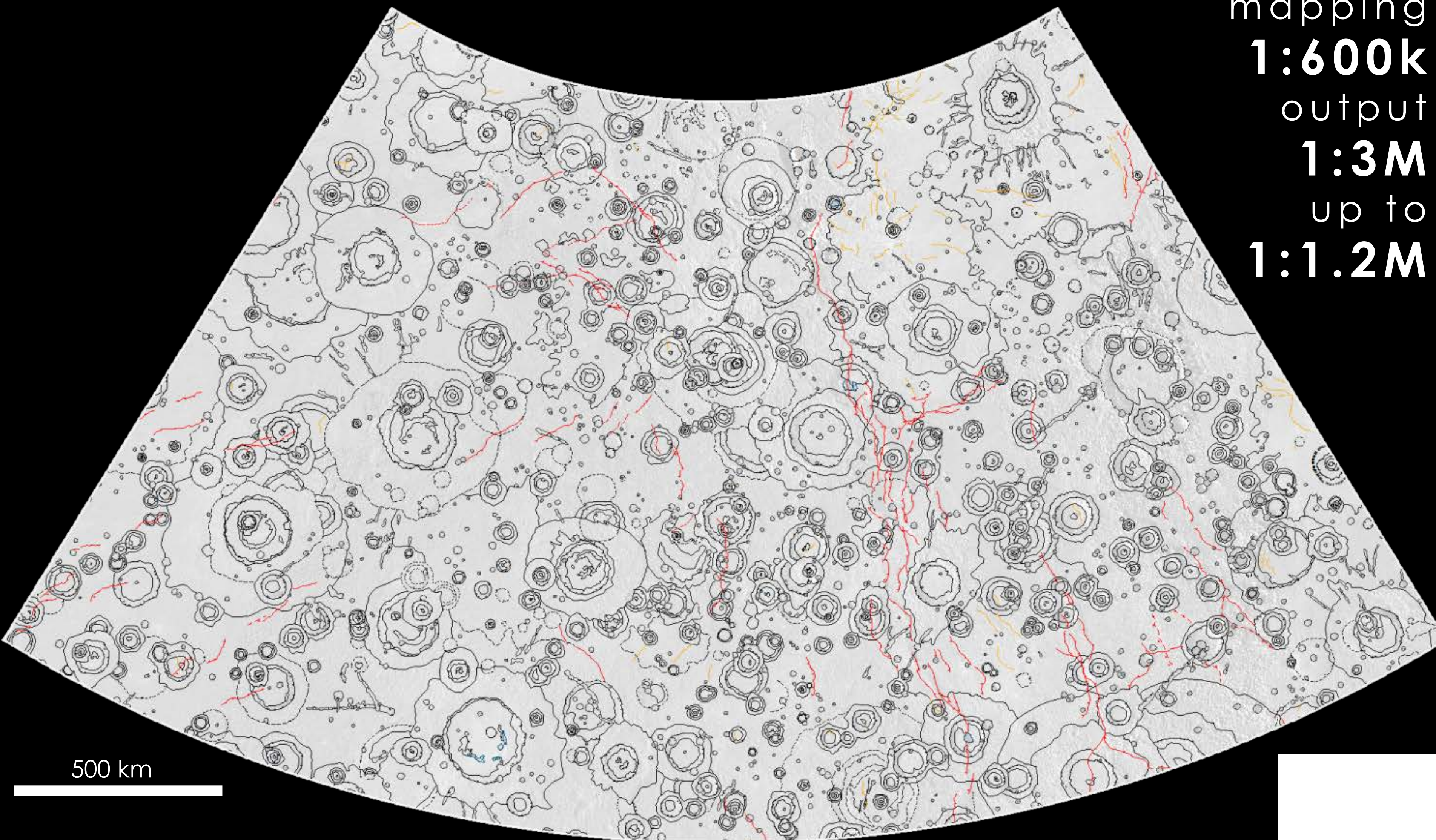
hypothetical dips:
25° < θ < 35°

+ strike-slip comp.
+ high dip

RESULTS

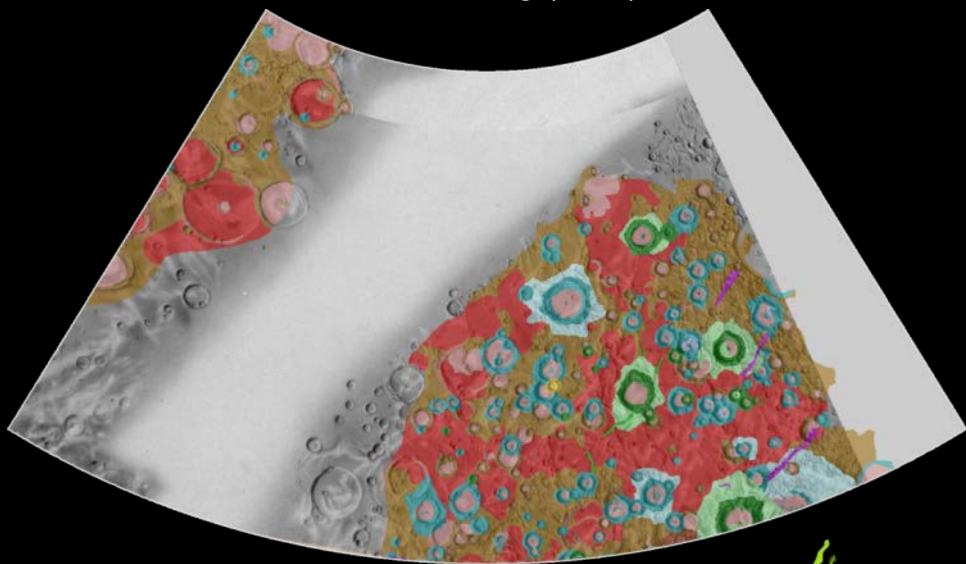
[geology]

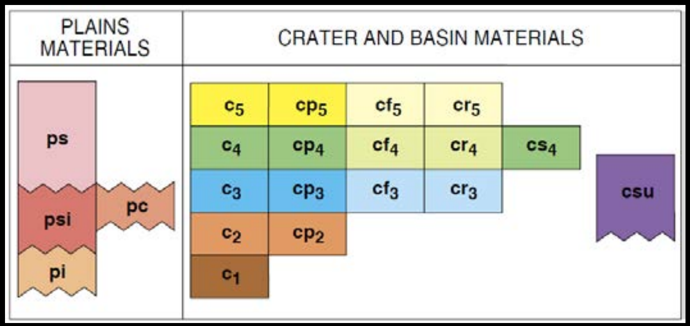

500 km

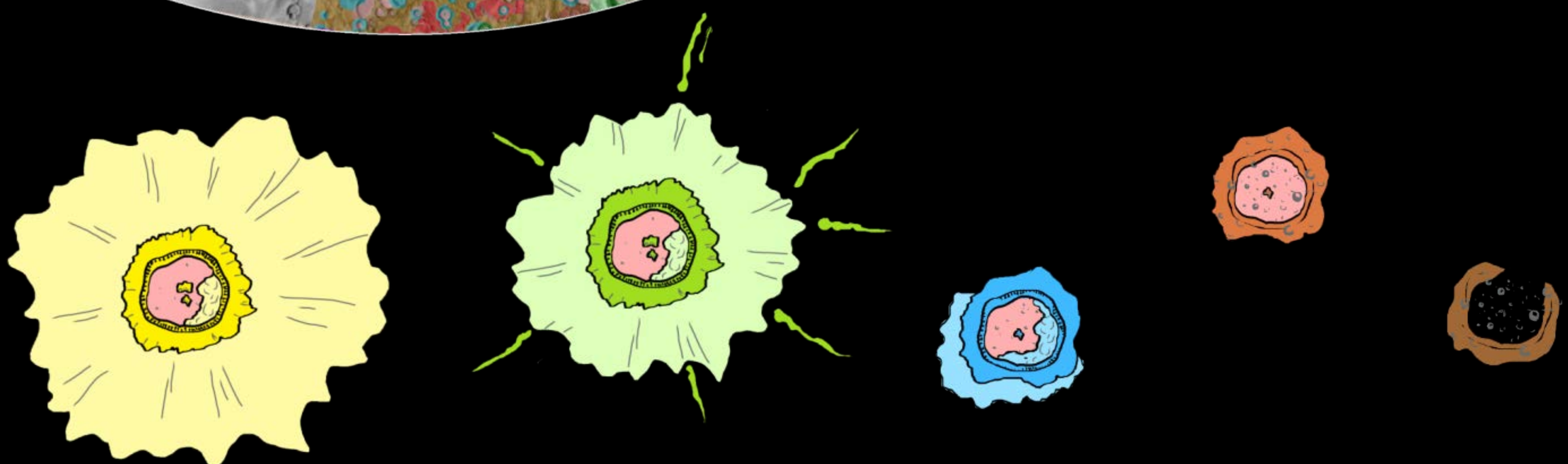


mapping
1:600k
output
1:3M
up to
1:1.2M

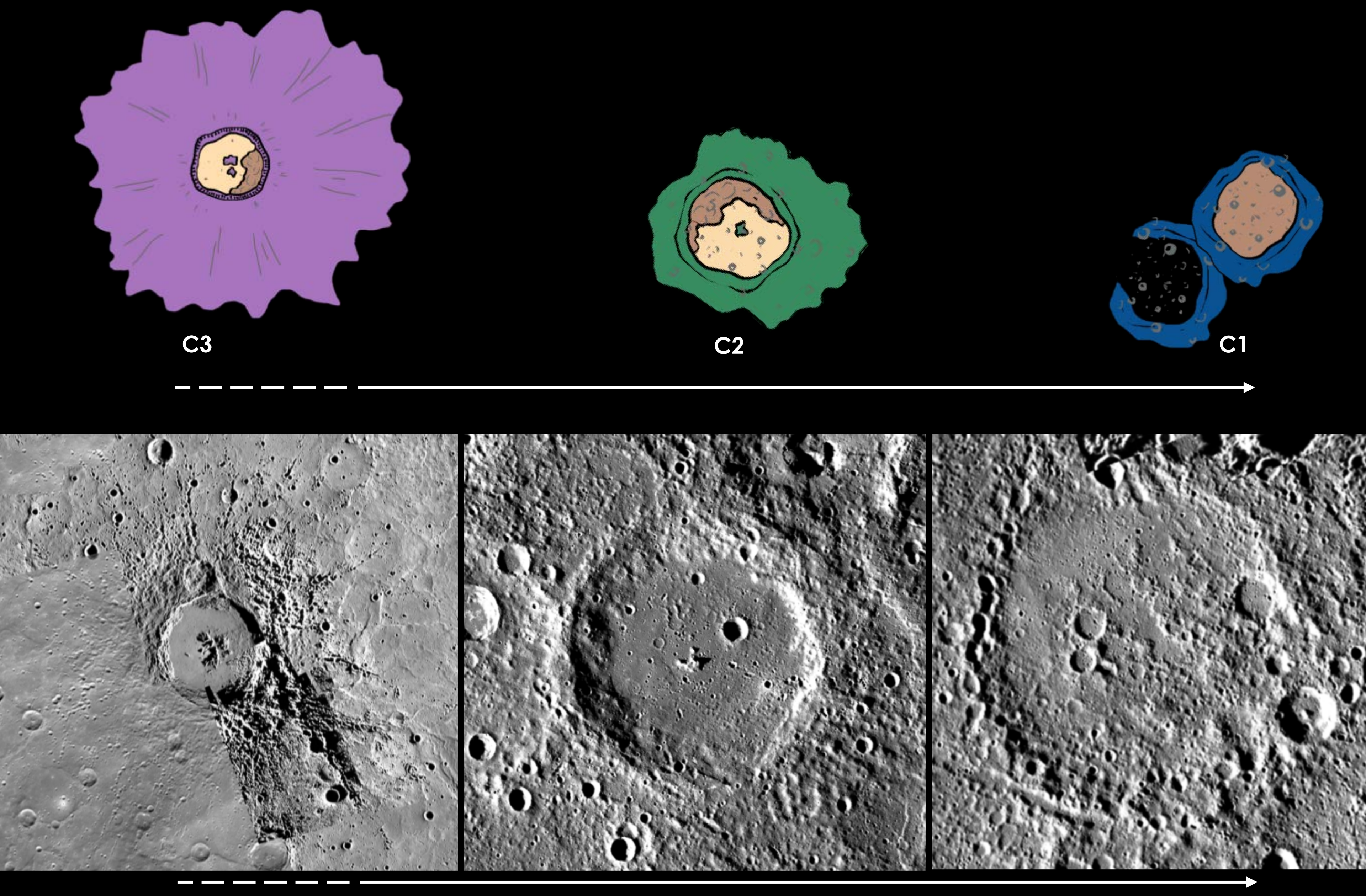
McGill & King (1983)

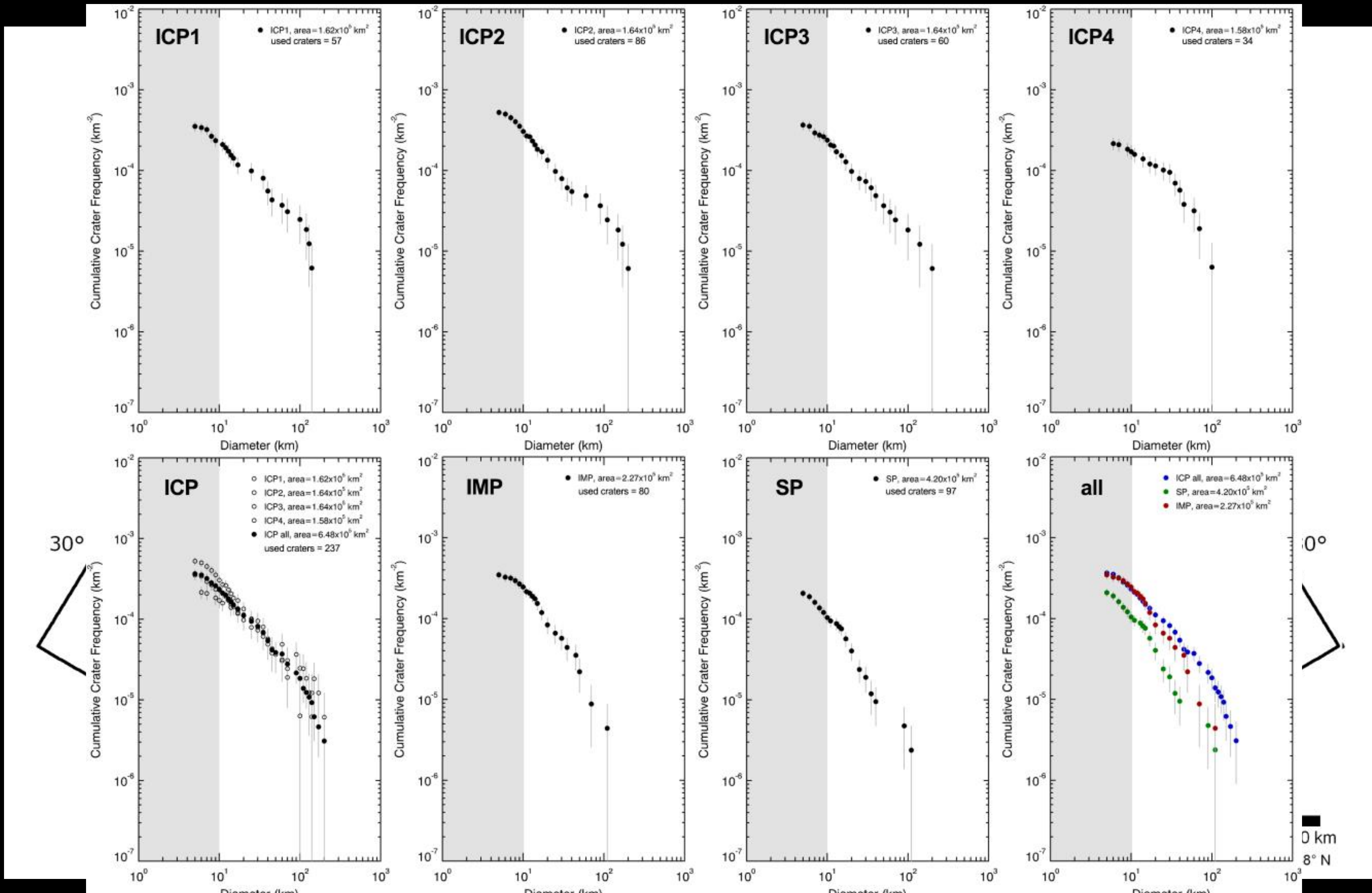




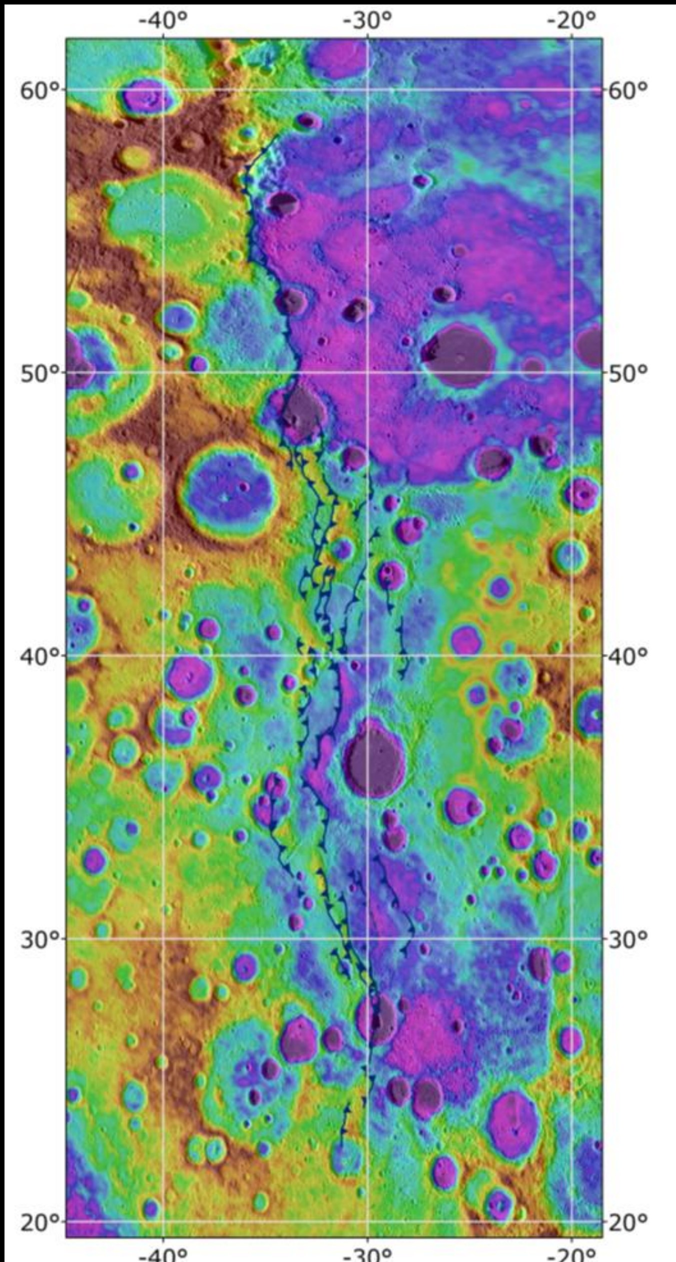


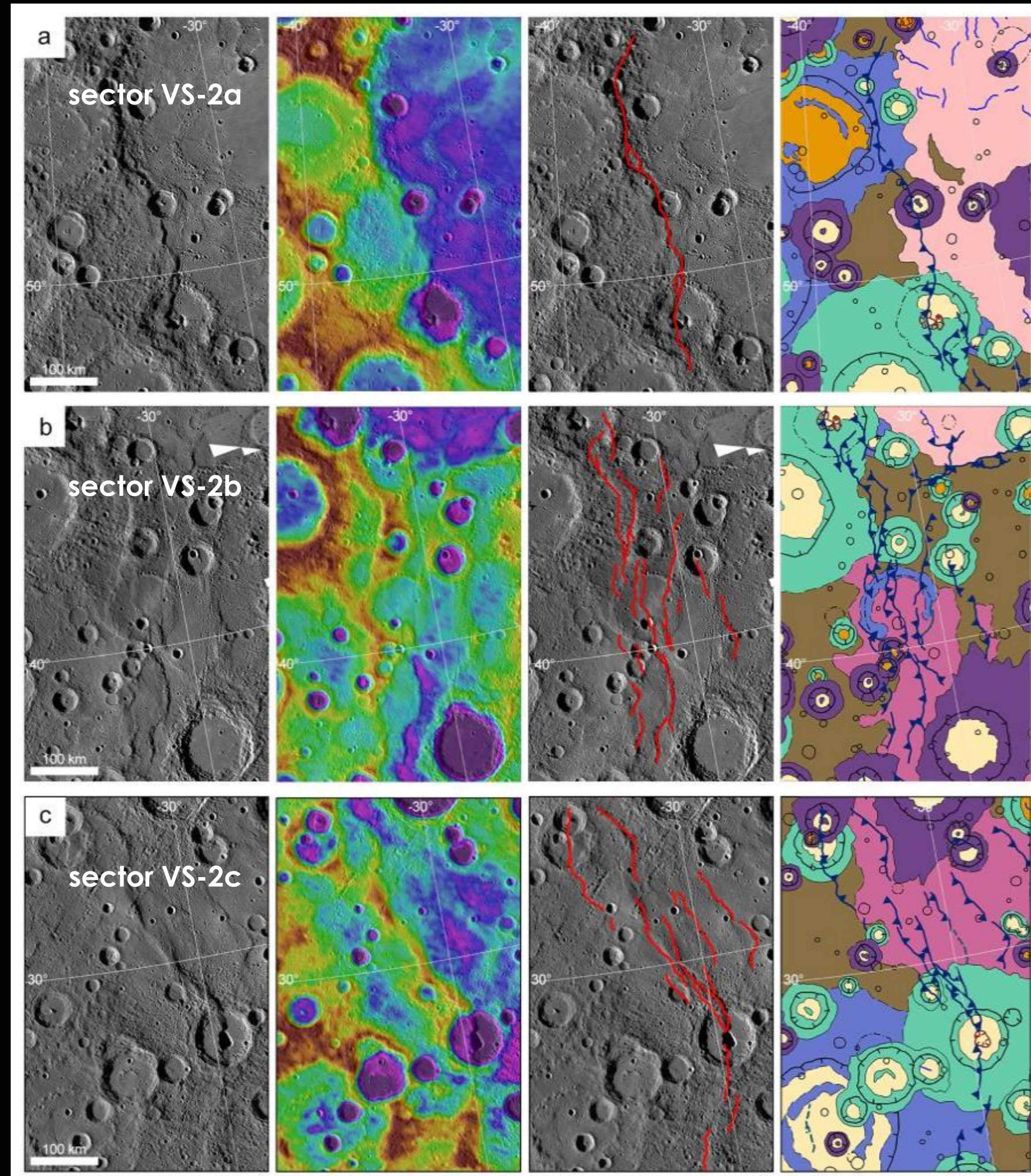
C5 C4 C3 C2 C1

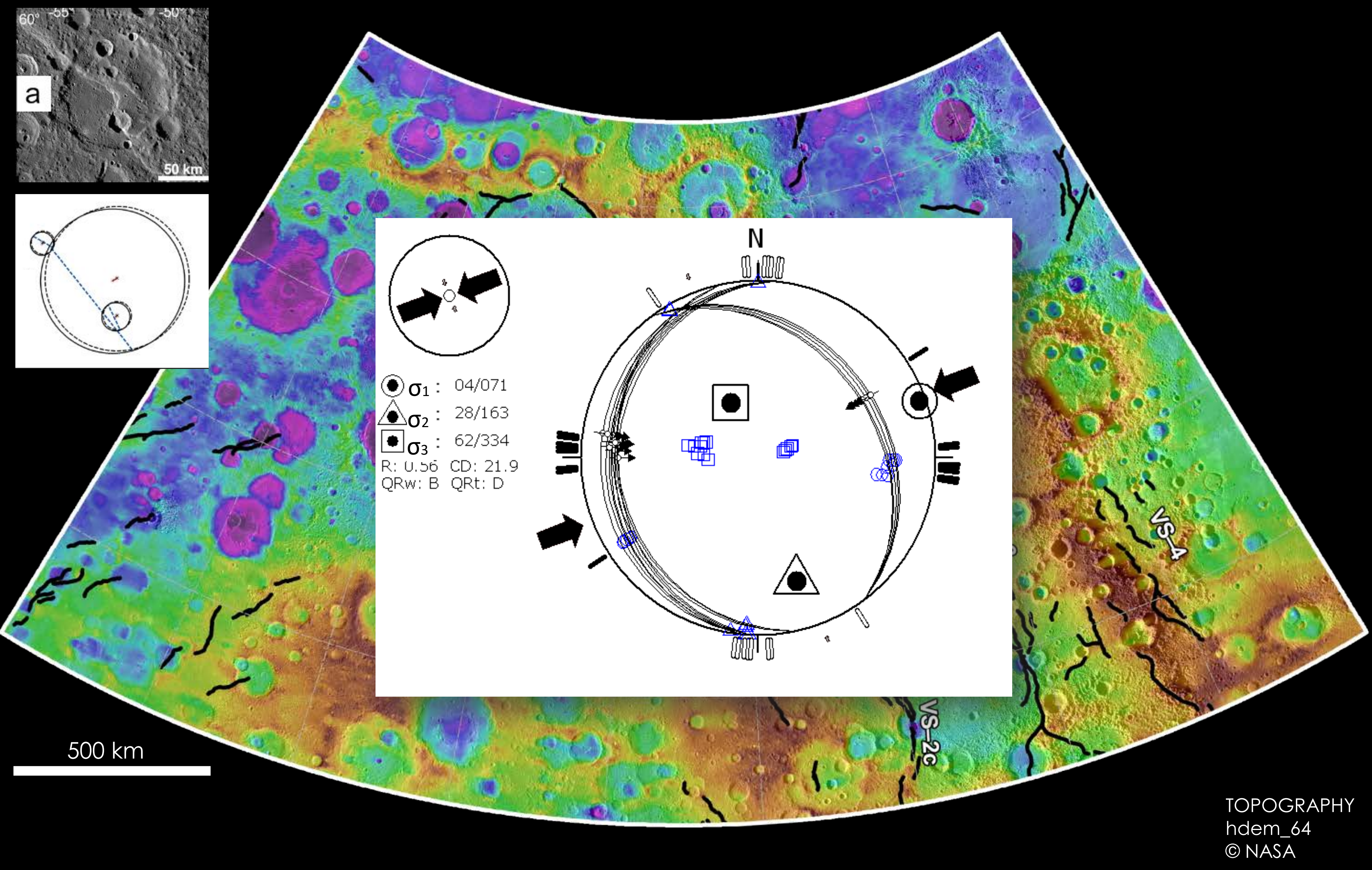

C3
C2
C1


ICP1
ICP1, area=1.62x10^5 km^2
used craters = 57
ICP2
ICP2, area=1.64x10^5 km^2
used craters = 86
ICP3
ICP3, area=1.64x10^5 km^2
used craters = 60
ICP4
ICP4, area=1.58x10^5 km^2
used craters = 34
ICP
ICP1, area=1.62x10^5 km^2
ICP2, area=1.64x10^5 km^2
ICP3, area=1.64x10^5 km^2
ICP4, area=1.58x10^5 km^2
ICP all, area=6.48x10^5 km^2
used craters = 237
IMP
IMP, area=2.27x10^5 km^2
used craters = 80
SP
SP, area=4.20x10^5 km^2
used craters = 97
all
ICP all, area=6.48x10^5 km^2
SP, area=4.20x10^5 km^2
IMP, area=2.27x10^5 km^2
Cumulative Crater Frequency (km^-2)
Diameter (km)
30°

RESULTS
[structural framework]

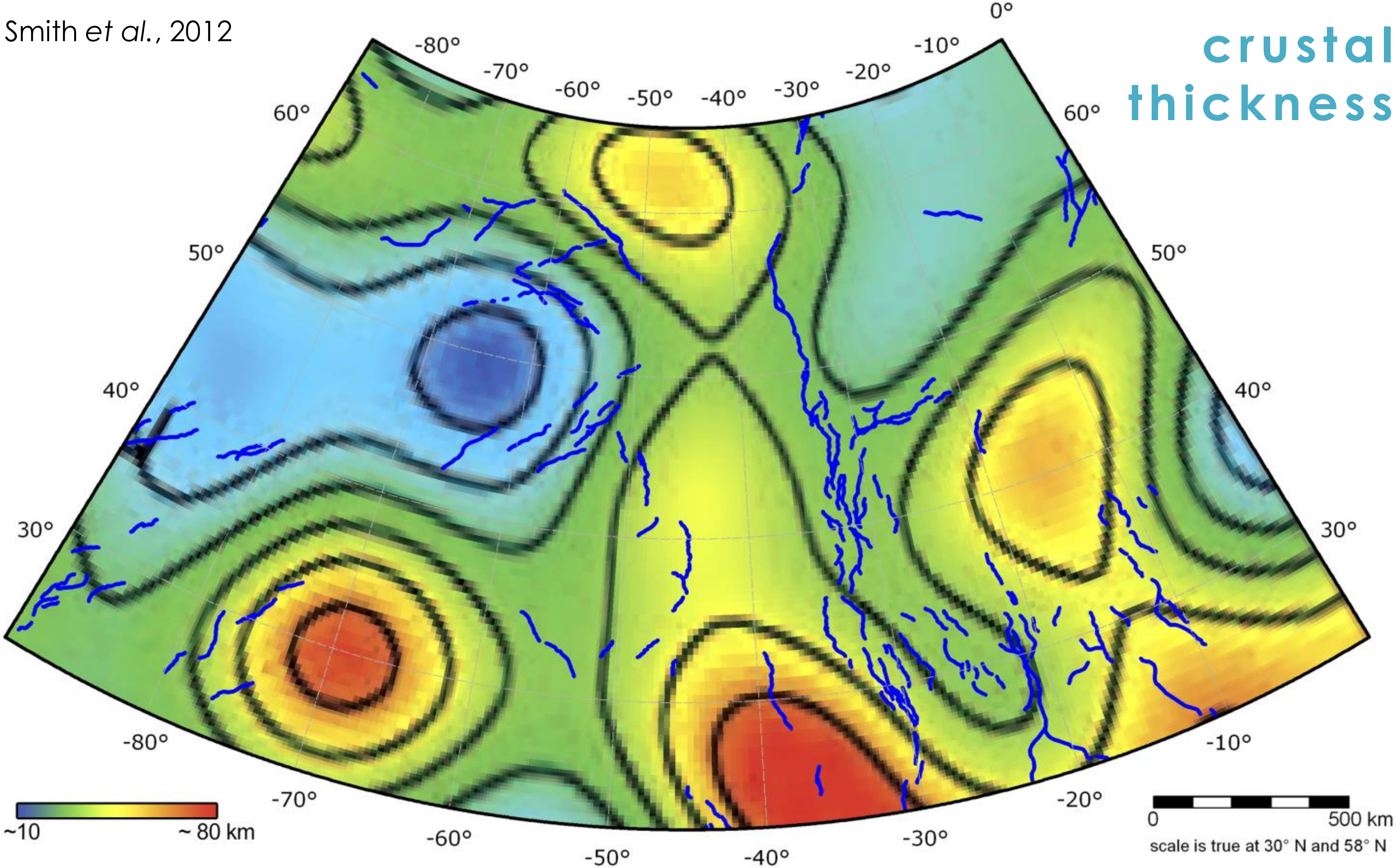

-40°
-30°
-20°
60°
50°
40°
30°
20°


a
sector VS-2a
b
sector VS-2b
c
sector VS-2c
100 km
-30°
-40°
50°
40°
30°


60°
-55°
-50°
a
50 km
N
σ1 : 04/071
σ2 : 28/163
σ3 : 62/334
R: 0.56 CD: 21.9
QRw: B QRt: D
VS-4
VS-2c
500 km
TOPOGRAPHY
hdem_64
© NASA

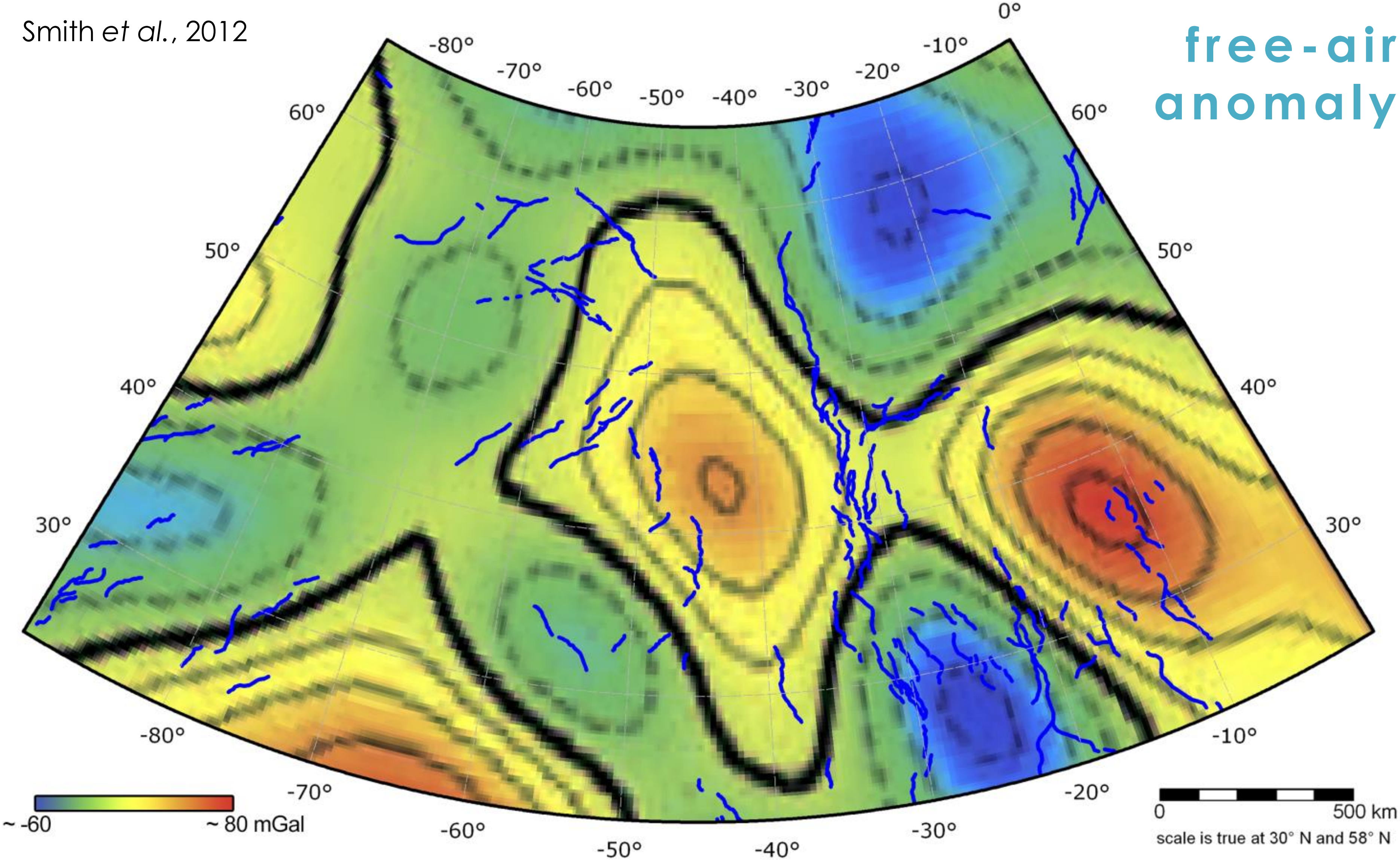
Smith *et al.*, 2012

crustal thickness

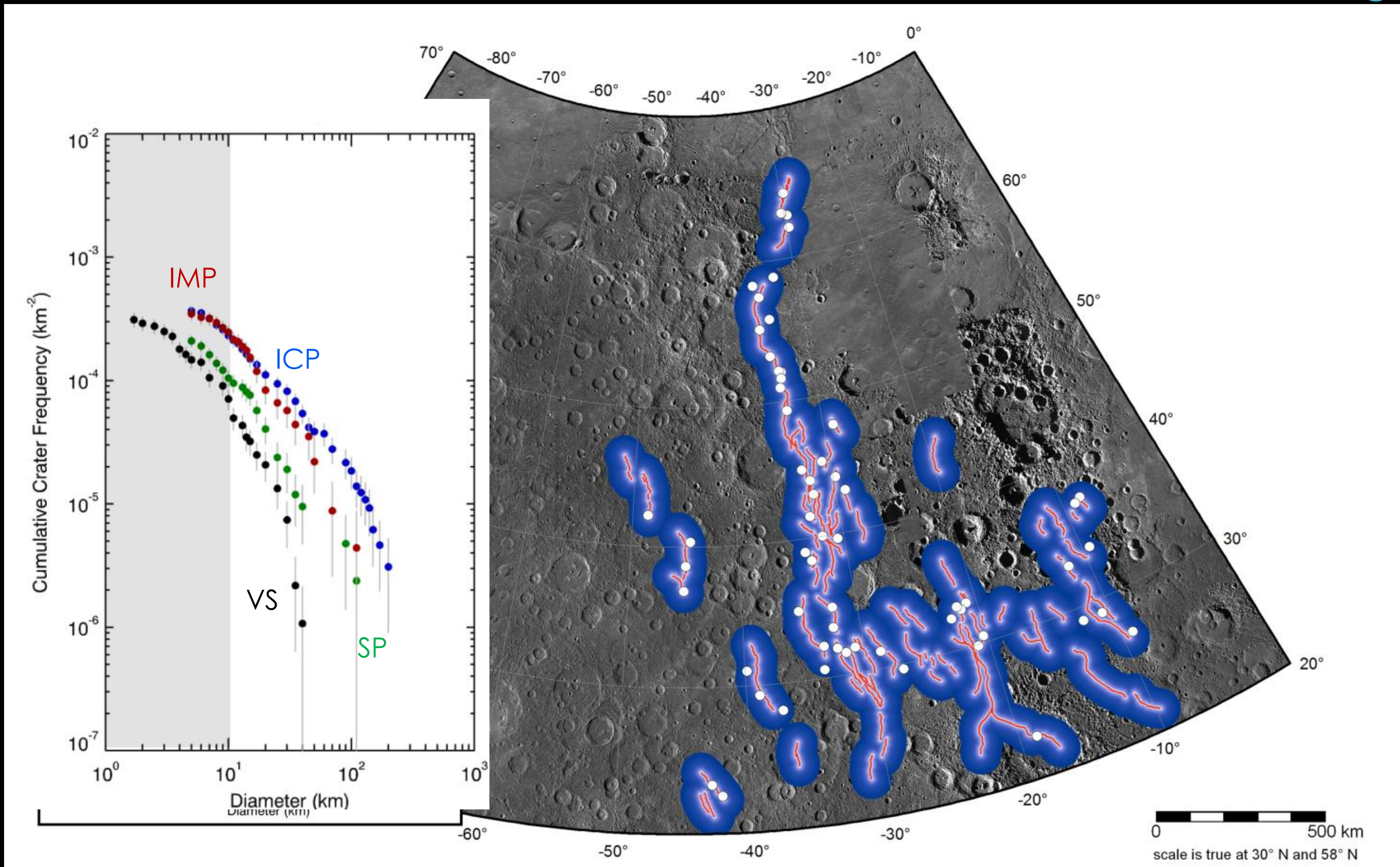


Smith *et al.*, 2012

free-air anomaly



buffered crater counting



CONCLUSIONS

- the **Victoria quadrangle** has now a **complete geologic map**
- a **tectonic fault-free pop-up** is present between the V-E-A array and the antithetic Carnegie thrust
- probable **mantle discontinuities** could explain the V-E-A bulge **N-S alignment**
- it is possible that **two stages of deformation** acted on this area
- **tectonics** and **fault segmentation** are most probably related to **volcanic activity**
- first time that **fault slip data** and **strain inversion** are estimated on **remote-sensed faults**!

OPEN ISSUES & FUTURE WORK

- what is the cause of Hermean thrust **shallow angles** ? → **overthrusts** ?

- which targets will be chosen for the future ESA/JAXA BepiColombo mission ?
  → **GEOLOGIC GLOBAL COVERAGE CAN HELP !!**

bepicolombo

THANK YOU

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