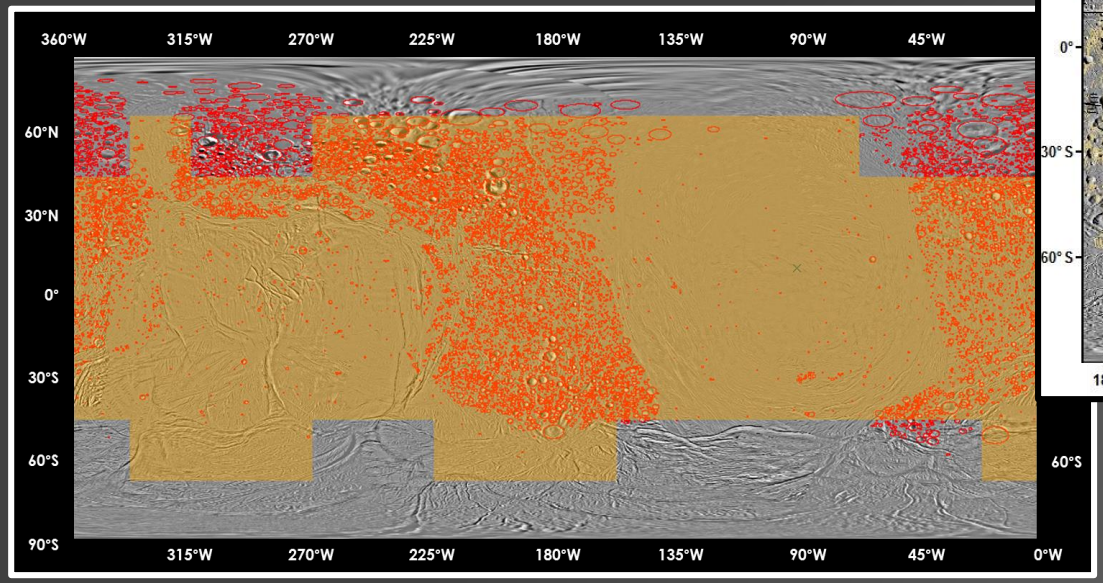
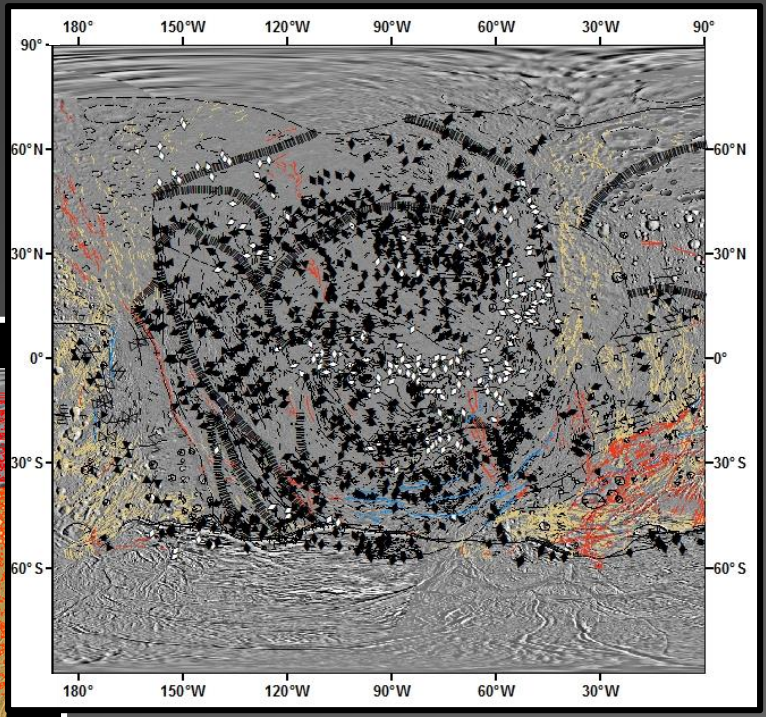
# Progress on a 1:2M Global Geologic Map of Enceladus

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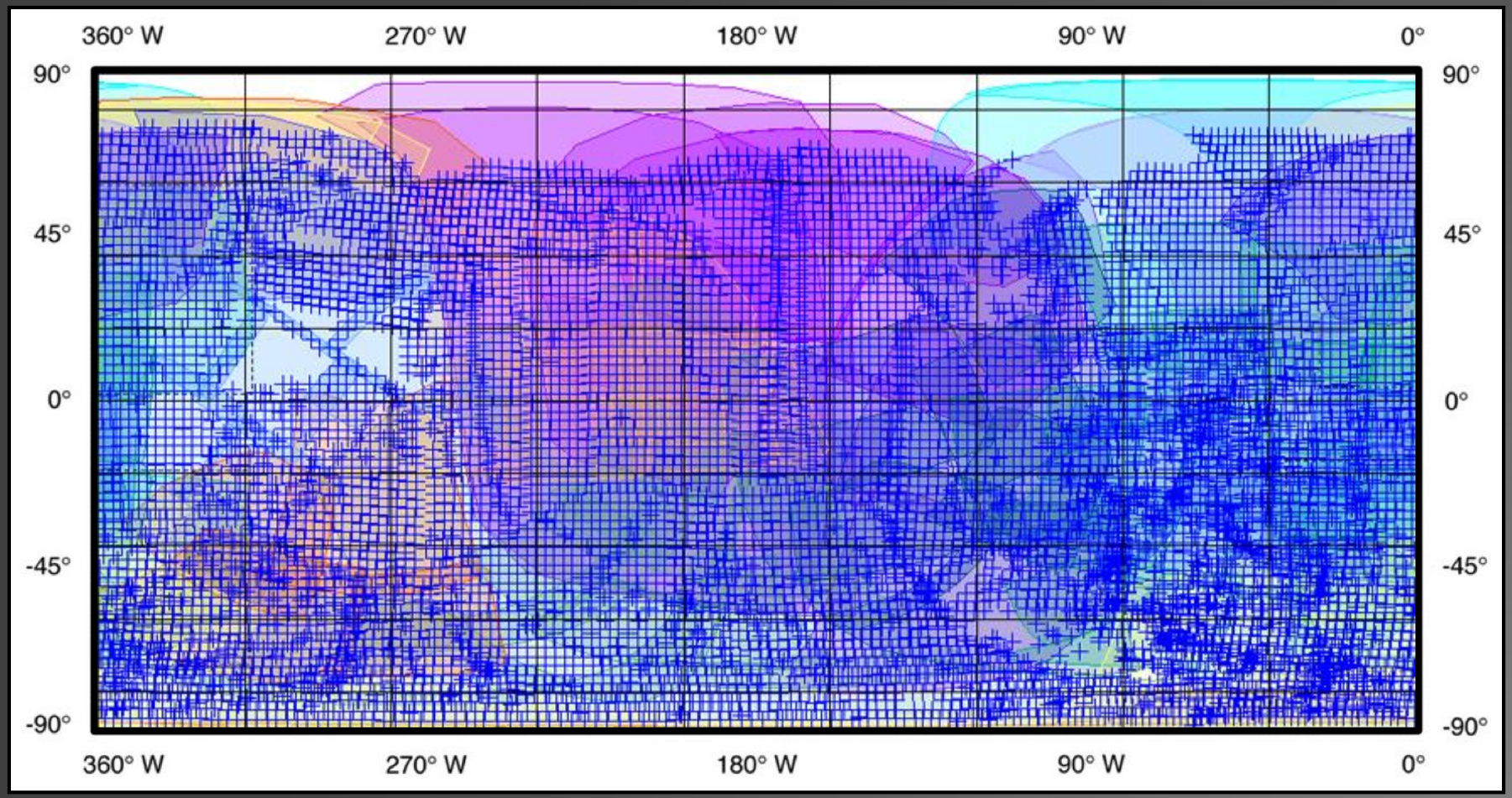
[2]Wheaton College, Norton, MA
[3]North Carolina State University, Raleigh, NC
[4]Planetary Science Institute, Tucson, AZ
[5]Jet Propulsion Laboratory, Pasadena CA
[6]USGS Astrogeology, Flagstaff AZ

# OUTLINE

- The map base
- Observation mosaics
- Crater statistics
- Structural mapping
- Where things stand

# The Map Base

We have produced a controlled photomosaic drawn from all Cassini ISS images with a resolution better than 500 m/px and a phase angle of less than 120º in the CLR, GRN, UV3, and IR3 filters (> 10,362 control points).



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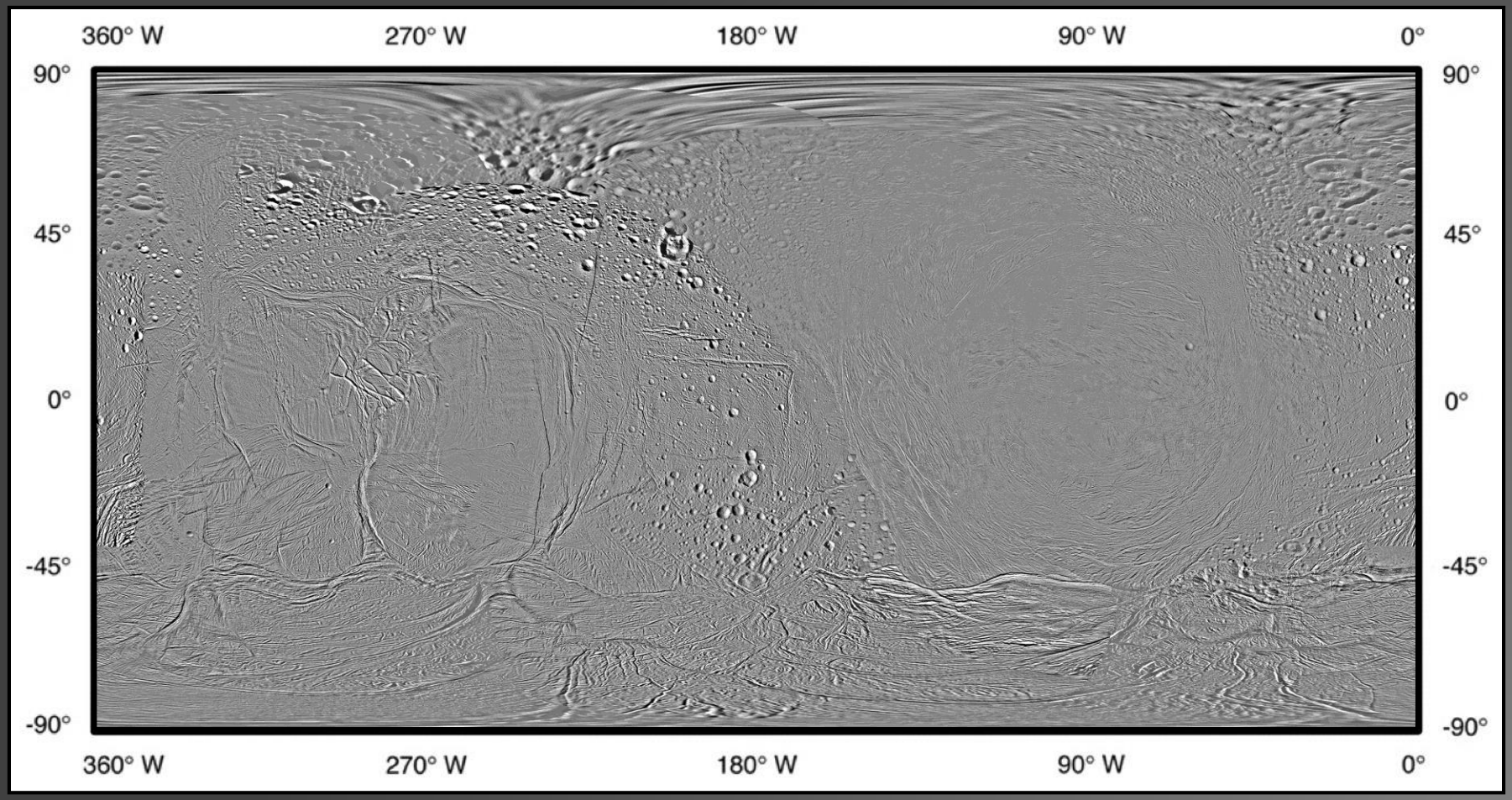
We have produced a controlled photomosaic drawn from all Cassini ISS images with a resolution better than 500 m/px and a phase angle of less than 120º in the CLR, GRN, UV3, and IR3 filters (586 images).



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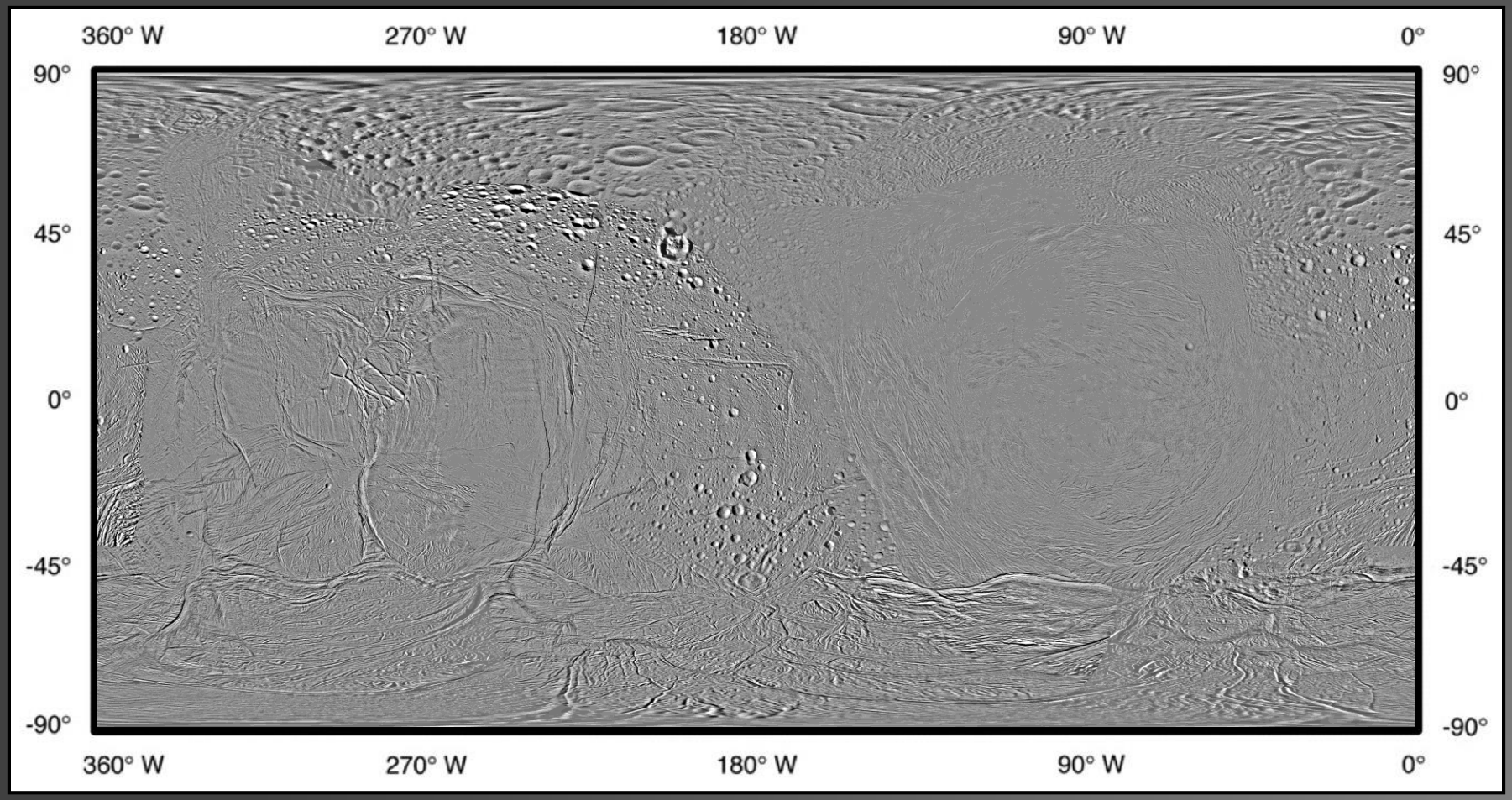
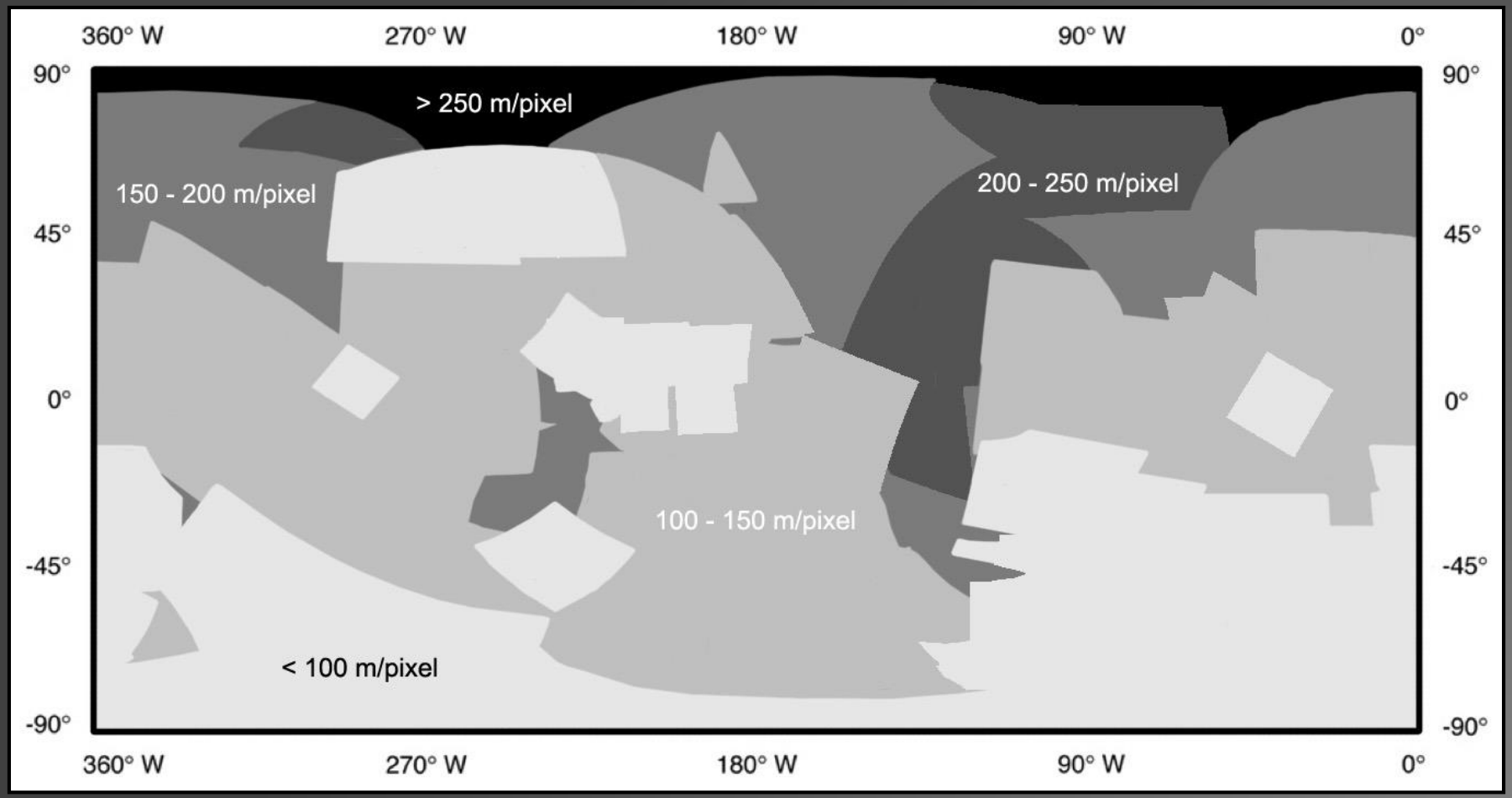


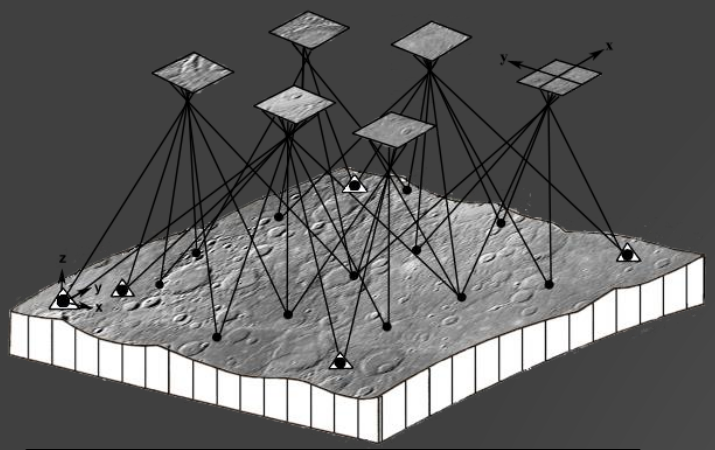
# THE MAP BASE

This is the first controlled photomosaic of an icy satellite produced with image data having global coverage at a consistent (and map-able) spatial resolution!



# The Map Base

## Bundle adjustment

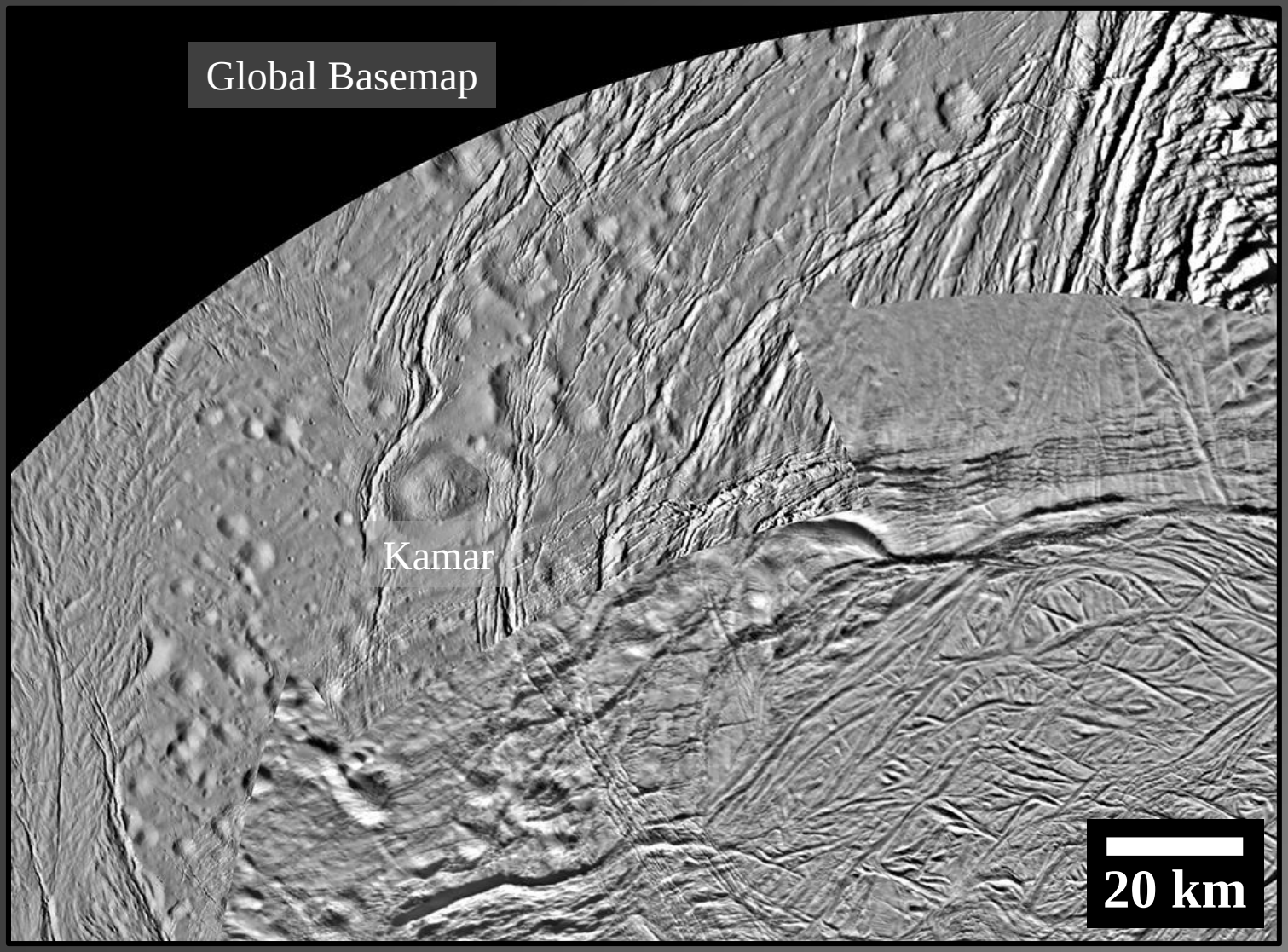


| Bundle Adjustment | |
|---|---|
| images | 586 |
| angle constraints | ±2° |
| ground points | 10,362 |
| all points constrained in radius | ±150 m |
| line/sample measurements | 173,704 |

| | | rms error pointing corrections (degrees) | | |
|---|---|---|---|---|
| sequence | # images | right ascension | declination | twist |
| ISS_003EN (N1487) | 14 | 0.01405 | 0.80253 | 0.00069 |
| ISS_004EN (N1489) | 60 | 0.01805 | 0.18419 | 0.00331 |
| ISS_011EN (N1500) | 92 | 0.24755 | 0.16474 | 0.07659 |
| ISS_028EN (N1536) | 3 | 0.42992 | 0.00256 | 0.08760 |
| ISS_061EN (N1584) | 8 | 0.14867 | 0.02227 | 0.03583 |
| ISS_080EN (N1597) | 40 | 0.03780 | 0.02085 | 0.00993 |
| ISS_088EN (N1602) | 24 | 0.06630 | 0.01961 | 0.03075 |
| ISS_091EN (N1604) | 35 | 0.06329 | 0.02946 | 0.00656 |
| ISS_121EN (N163746) | 29 | 0.02785 | 0.07692 | 0.01289 |
| ISS_121EN (N163747) | 7 | 0.01289 | 0.03852 | 0.00539 |
| ISS_131EN (N165285) | 32 | 0.02745 | 0.04840 | 0.02771 |
| ISS_131EN (N165286) | 17 | 0.01380 | 0.05263 | 0.01300 |
| ISS_136EN (N1660) | 36 | 0.05241 | 0.16927 | 0.00565 |
| ISS_141EN (N1669) | 15 | 0.00454 | 0.11912 | 0.00270 |
| ISS_142EN (N1671) | 25 | 0.01700 | 0.11131 | 0.00362 |
| ISS_144EN (N1675) | 10 | 0.00615 | 0.13104 | 0.00227 |
| ISS_153EN (N1694) | 33 | 0.00563 | 0.05850 | 0.00191 |
| ISS_154EN (N1696) | 4 | 0.01098 | 0.08338 | 0.00472 |
| ISS_155EN (N1697) | 40 | 0.22431 | 0.01667 | 0.22151 |
| ISS_156EN (N1699) | 10 | 0.03328 | 0.01130 | 0.03738 |
| ISS_158EN (N1702) | 30 | 0.08275 | 0.10141 | 0.05260 |
| ISS_163EN (N1711) | 17 | 0.01137 | 0.03883 | 0.00391 |
| ISS_165EN (N1714) | 5 | 0.00262 | 0.00674 | 0.00551 |
| All Images | 586 | 0.12451 | 0.11596 | 0.06784 |

# Observation Mosaics

What does this effort mean for Mapping the geology of Enceladus?



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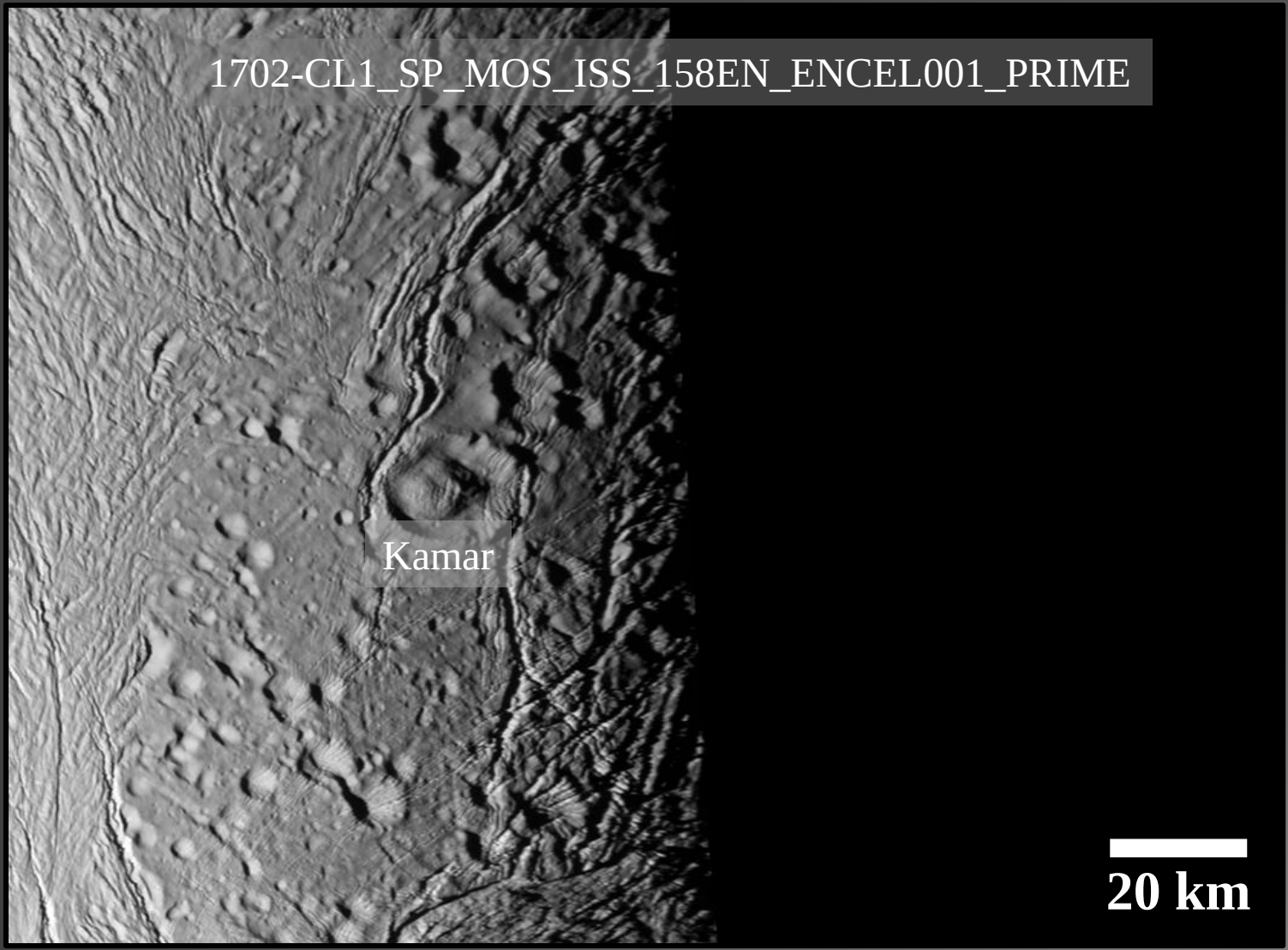

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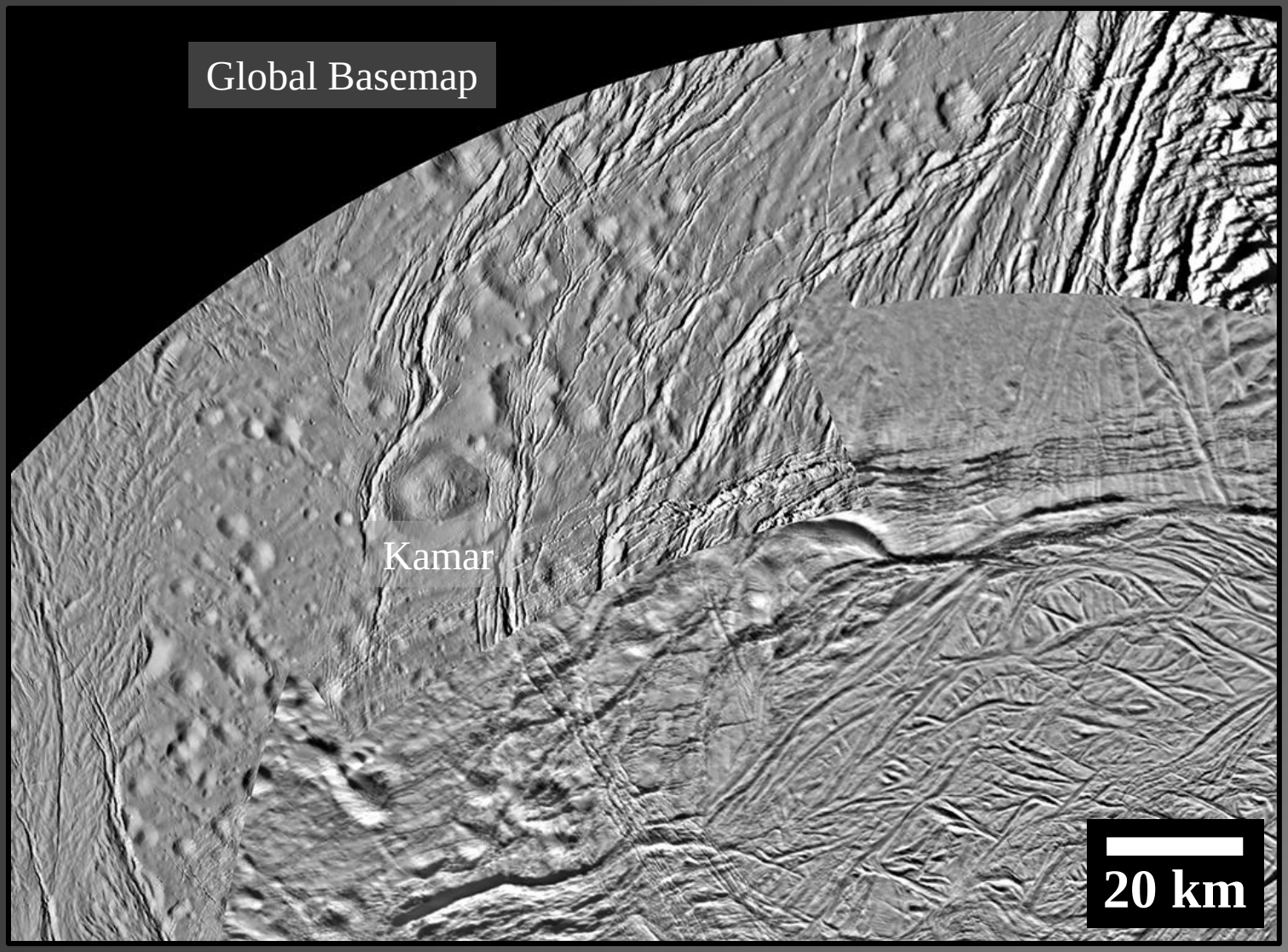

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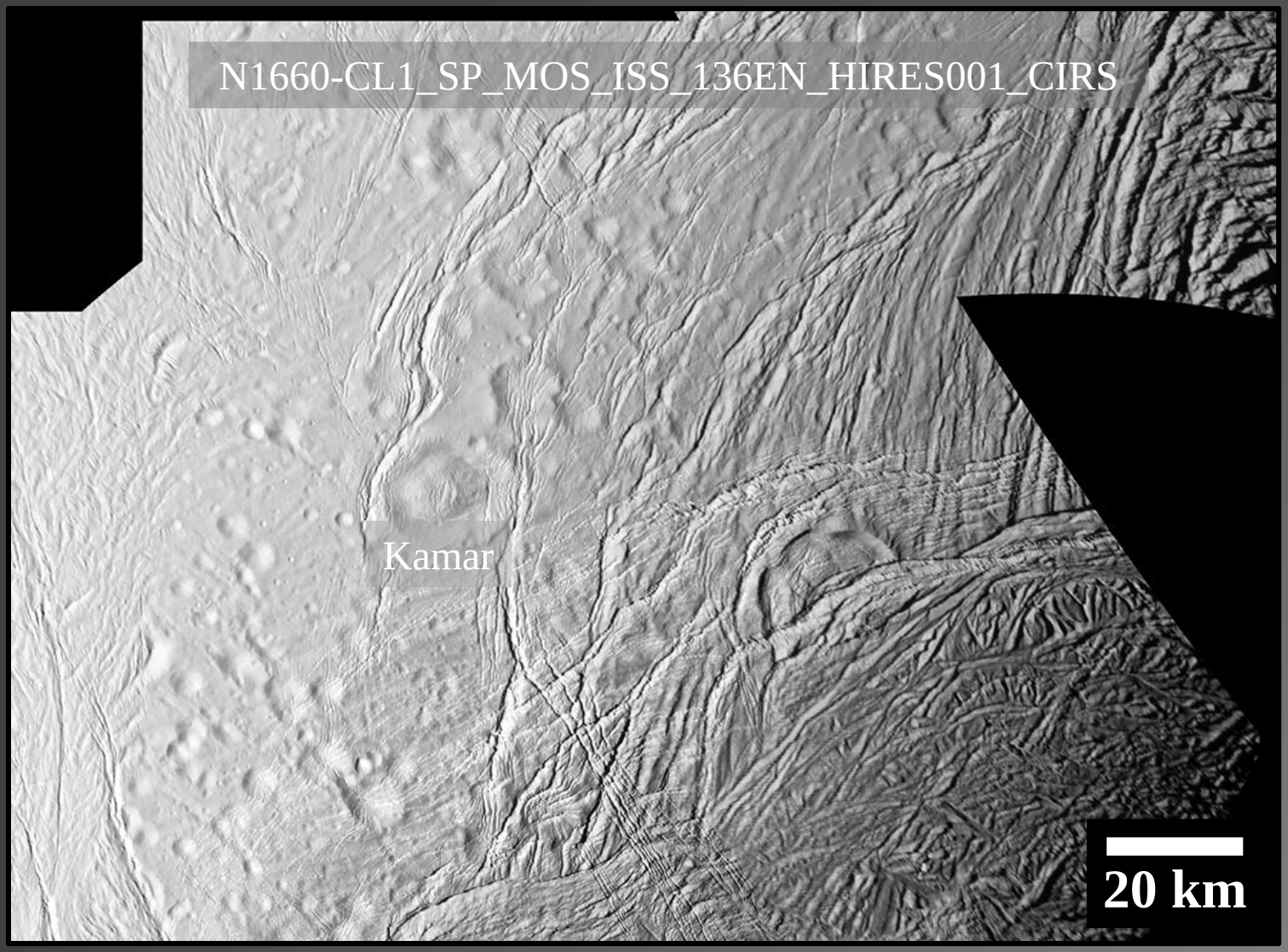

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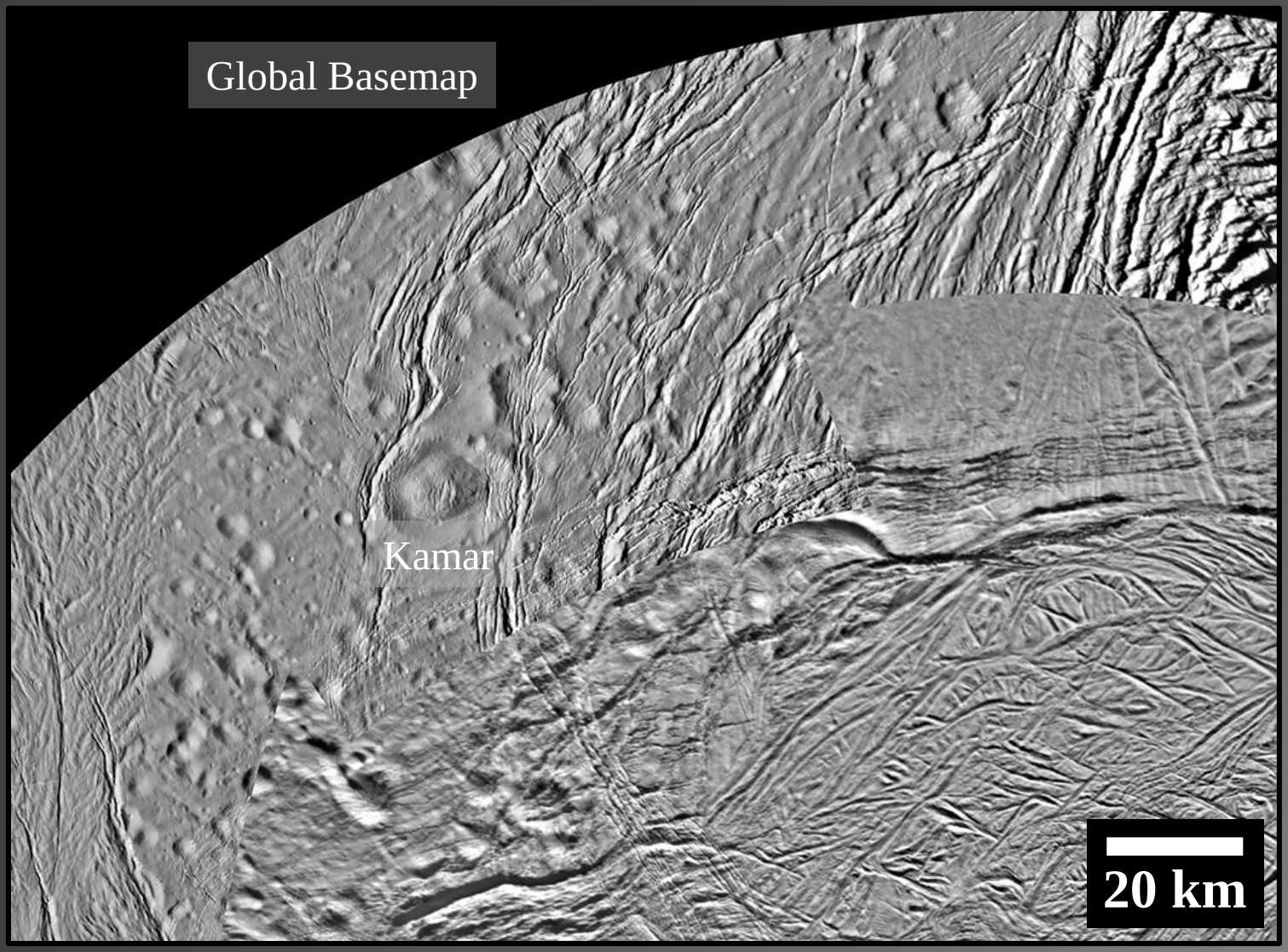

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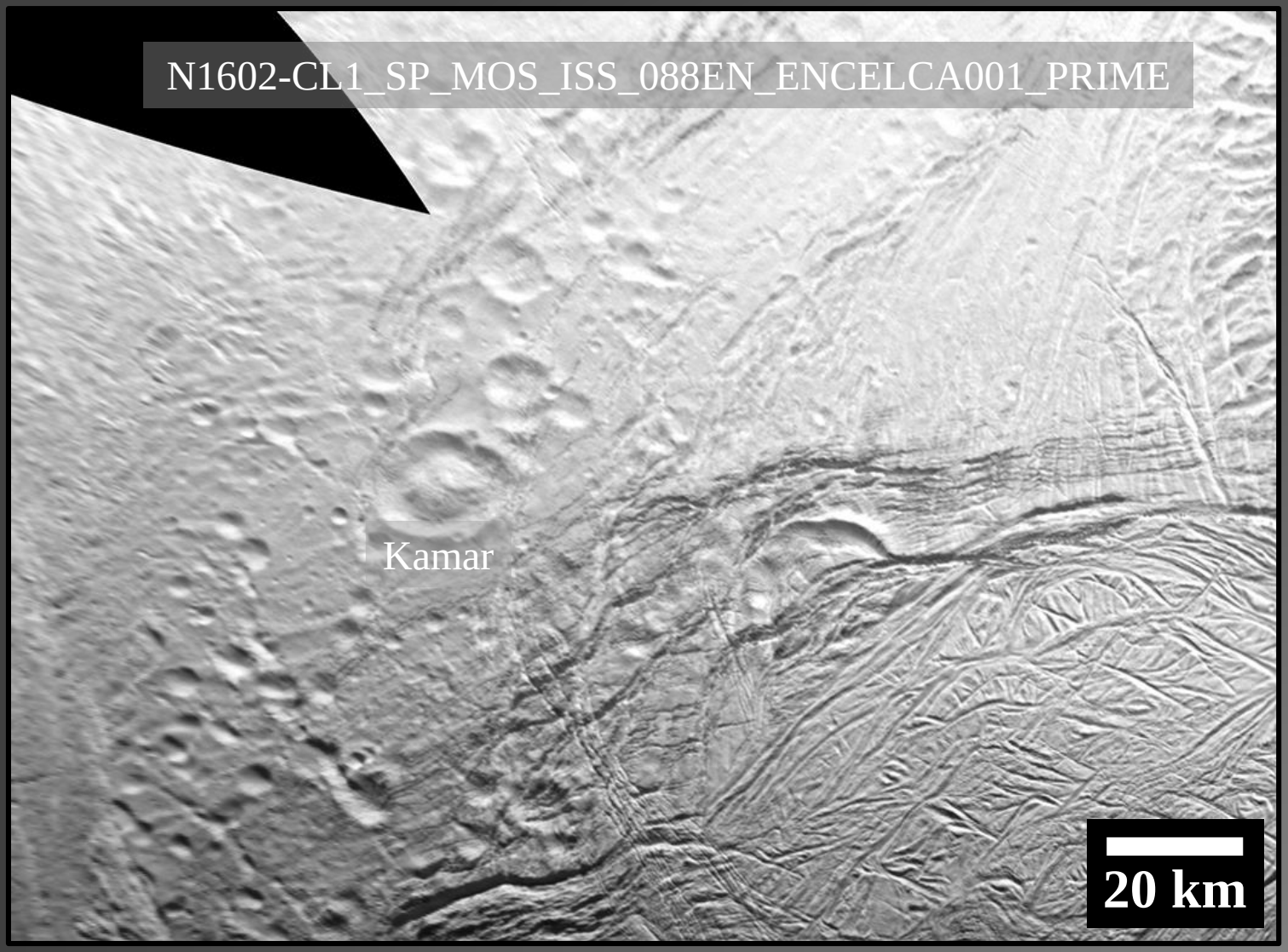
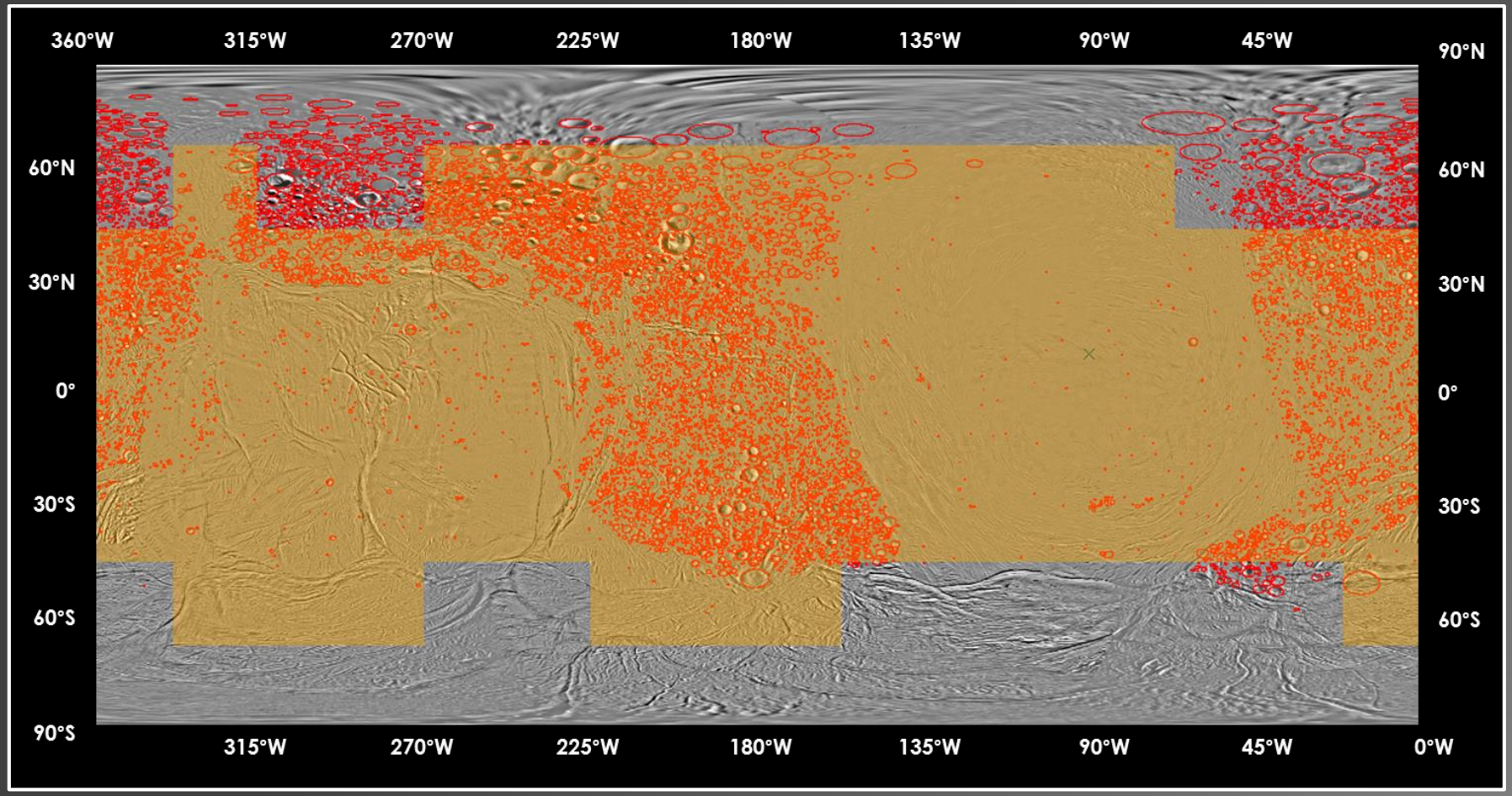


# Crater Statistics

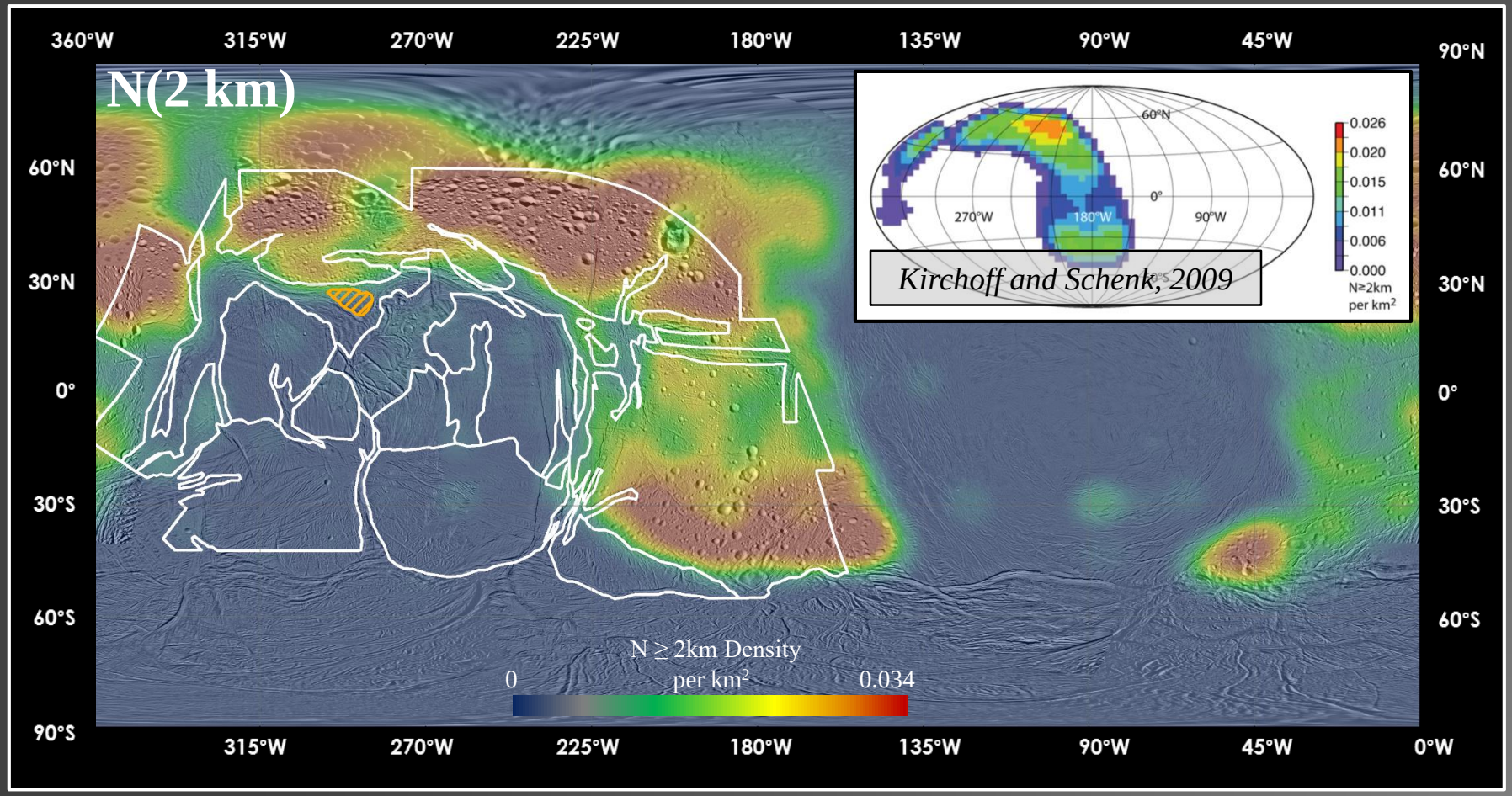
A global basemap with consistent image resolution, and image geometry, provides an ideal dataset for compiling crater statistics of Enceladus.

- We have mapped craters to diameters < 1 km across the surface.



# Crater Statistics

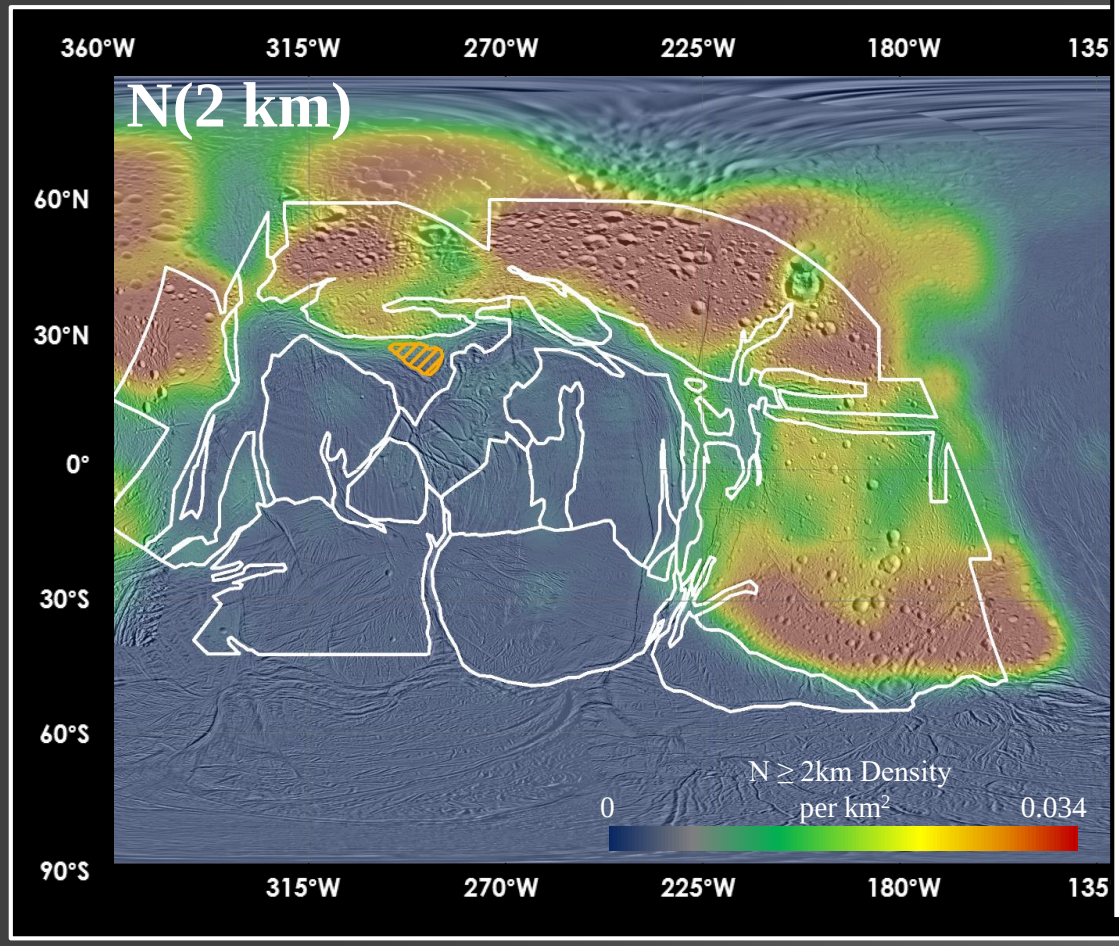
We have used those data to generate areal crater density maps using *N*(*D*) measurements, where *D* is crater diameter (similar to Kirchoff and Schenk, 2009).

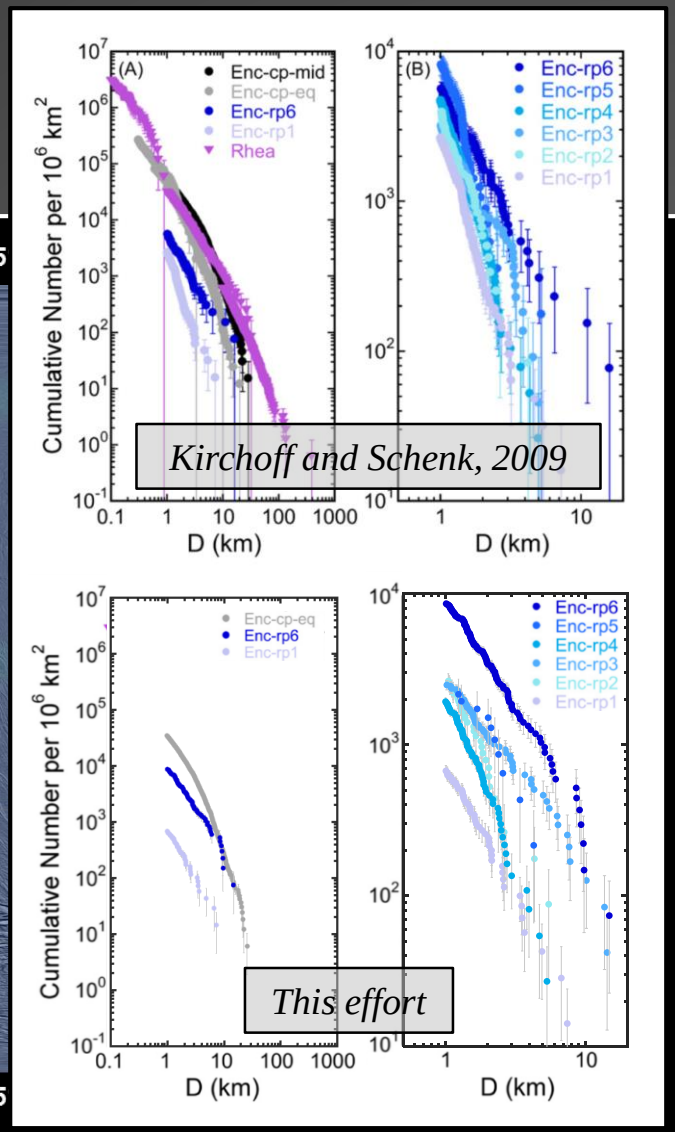


# Crater Statistics

We have used those data to generate areal crater density maps.

- Comparison suggests general agreement.



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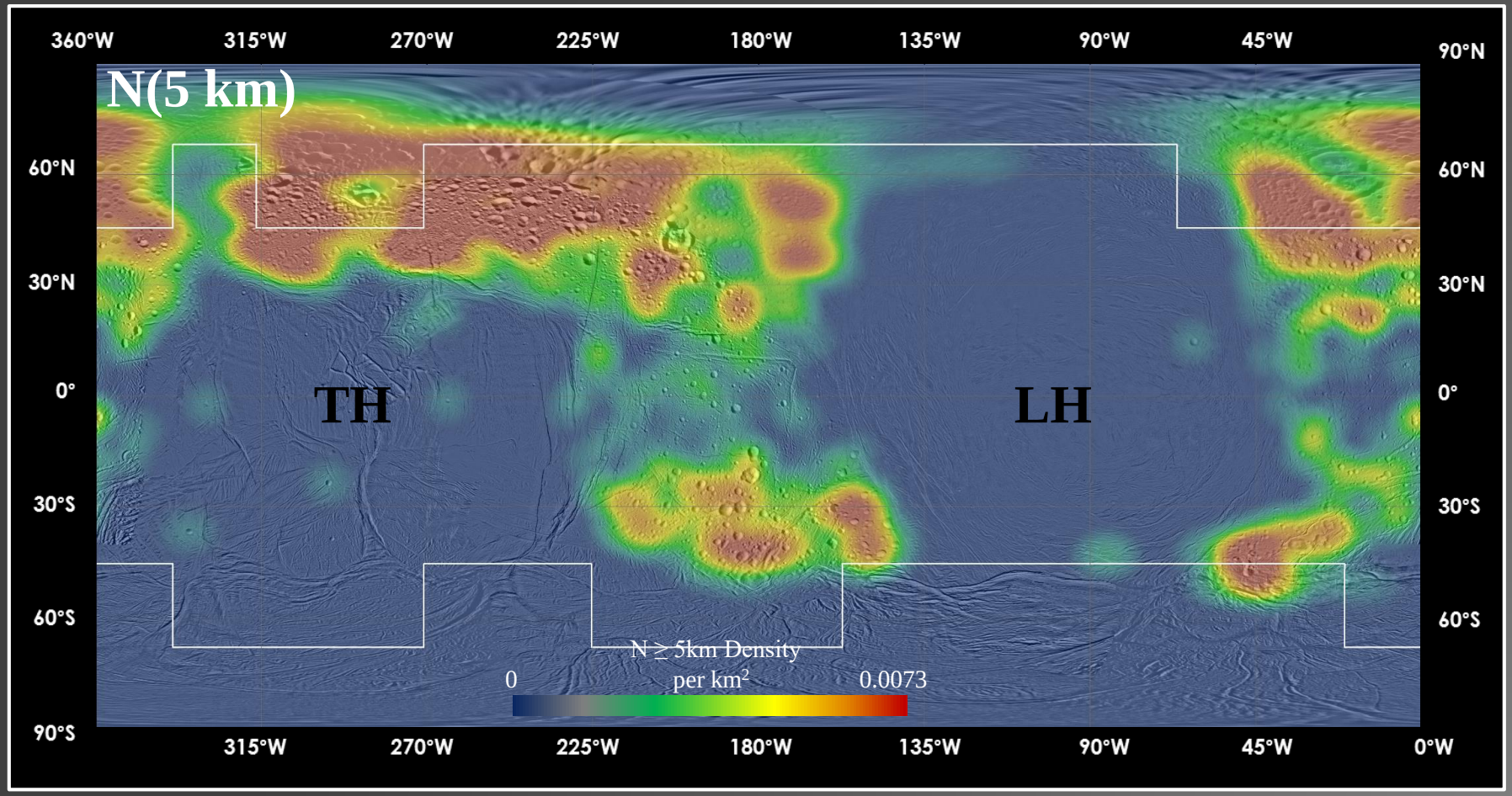

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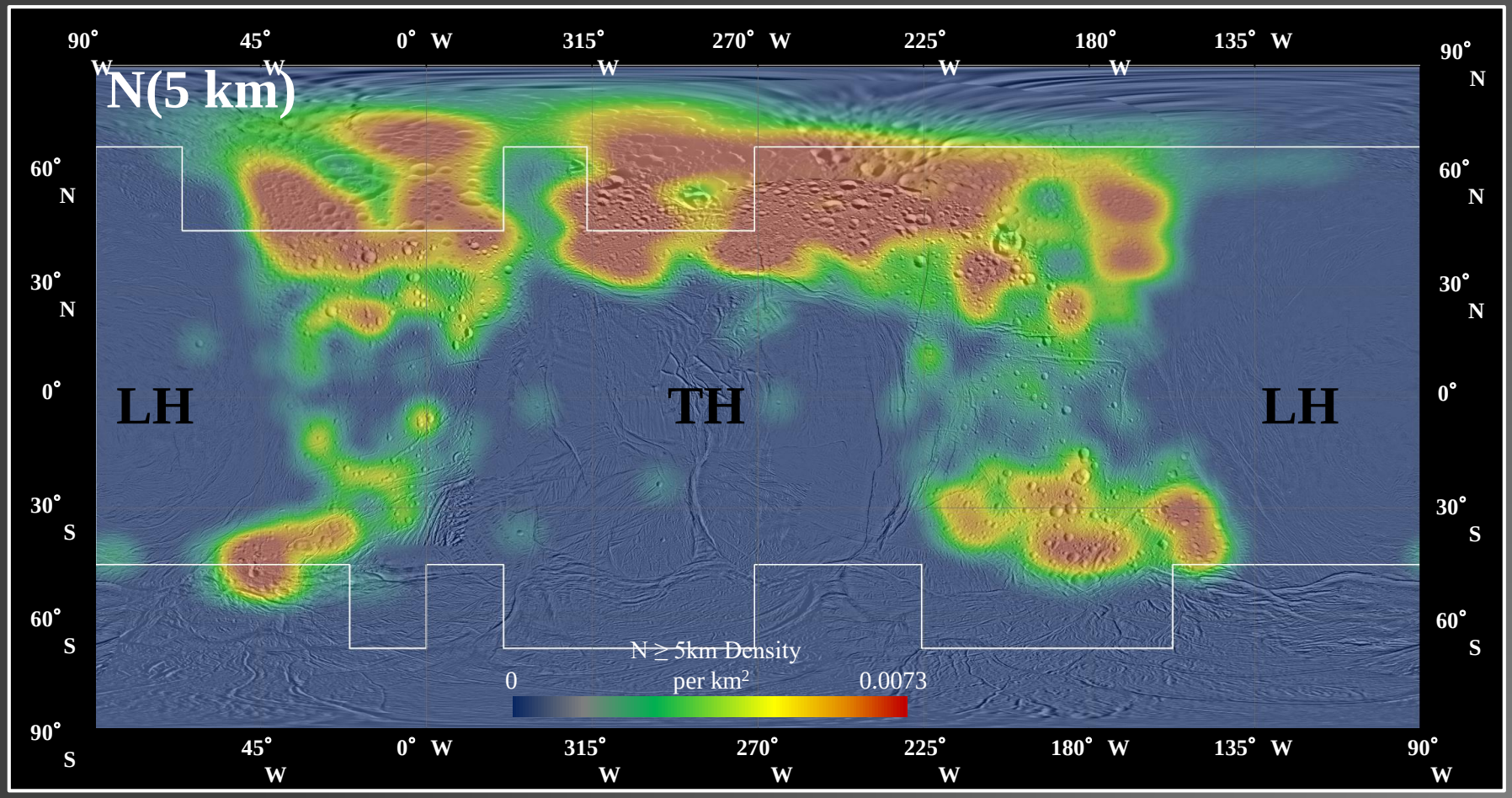

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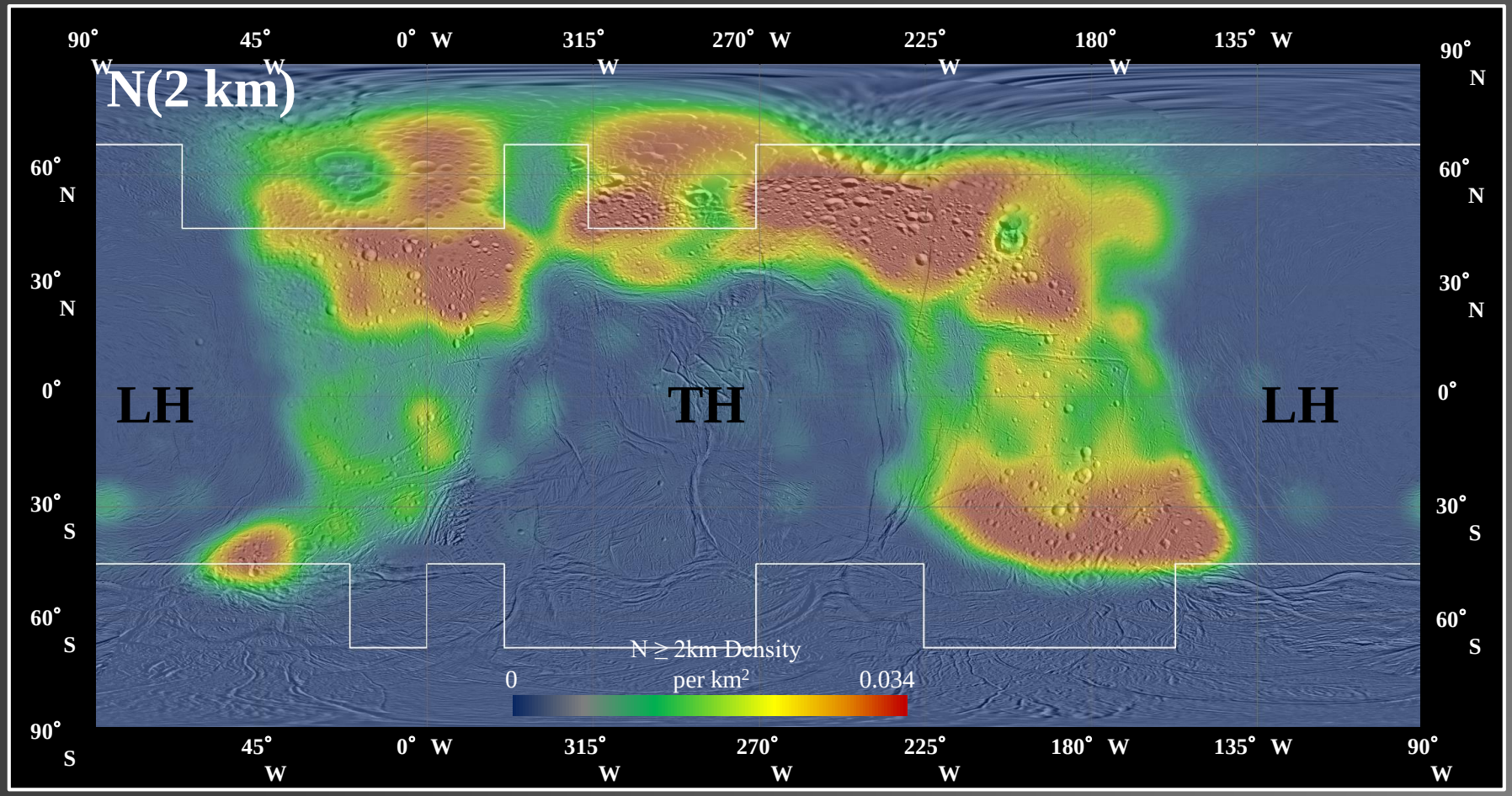

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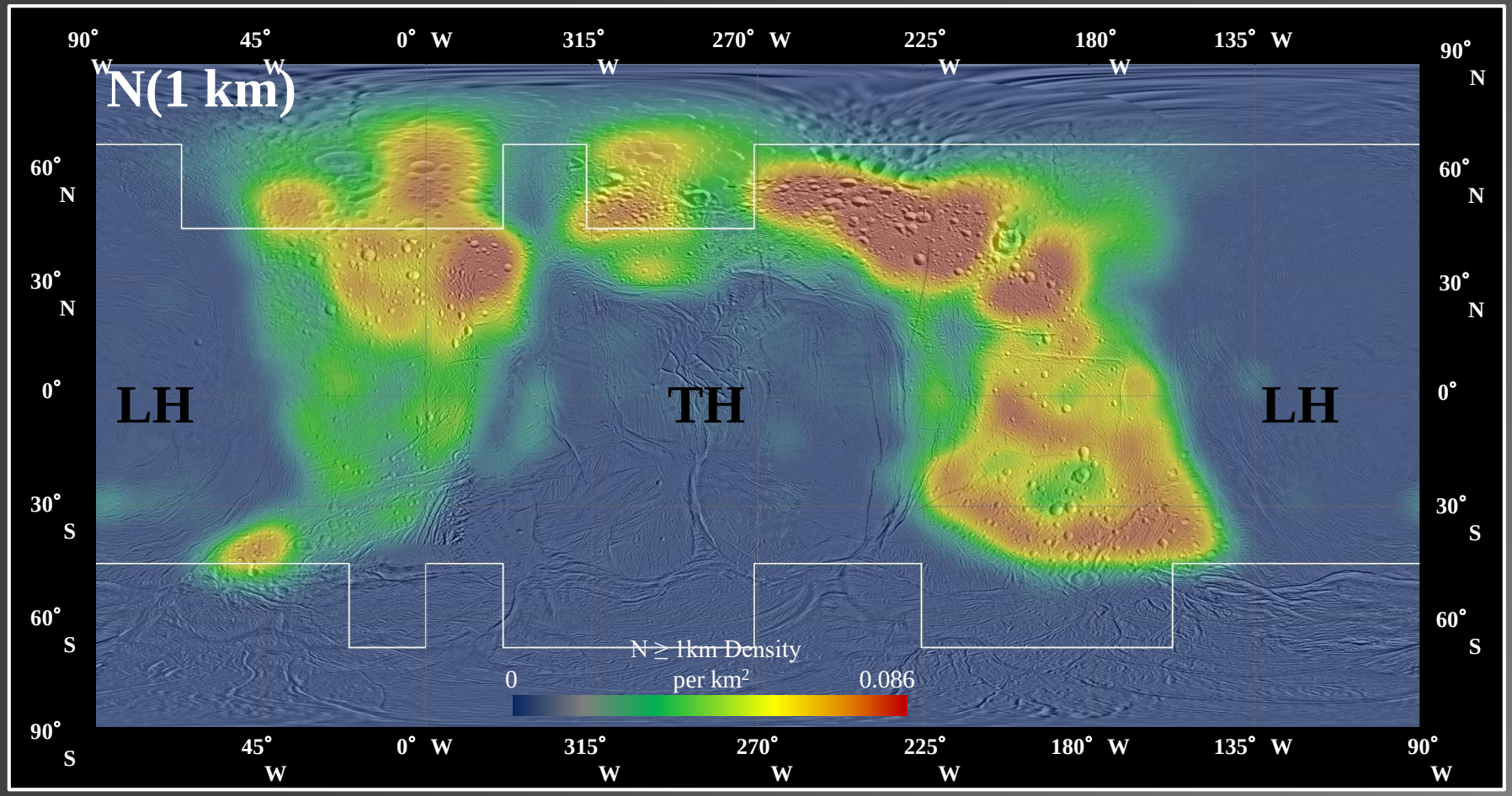

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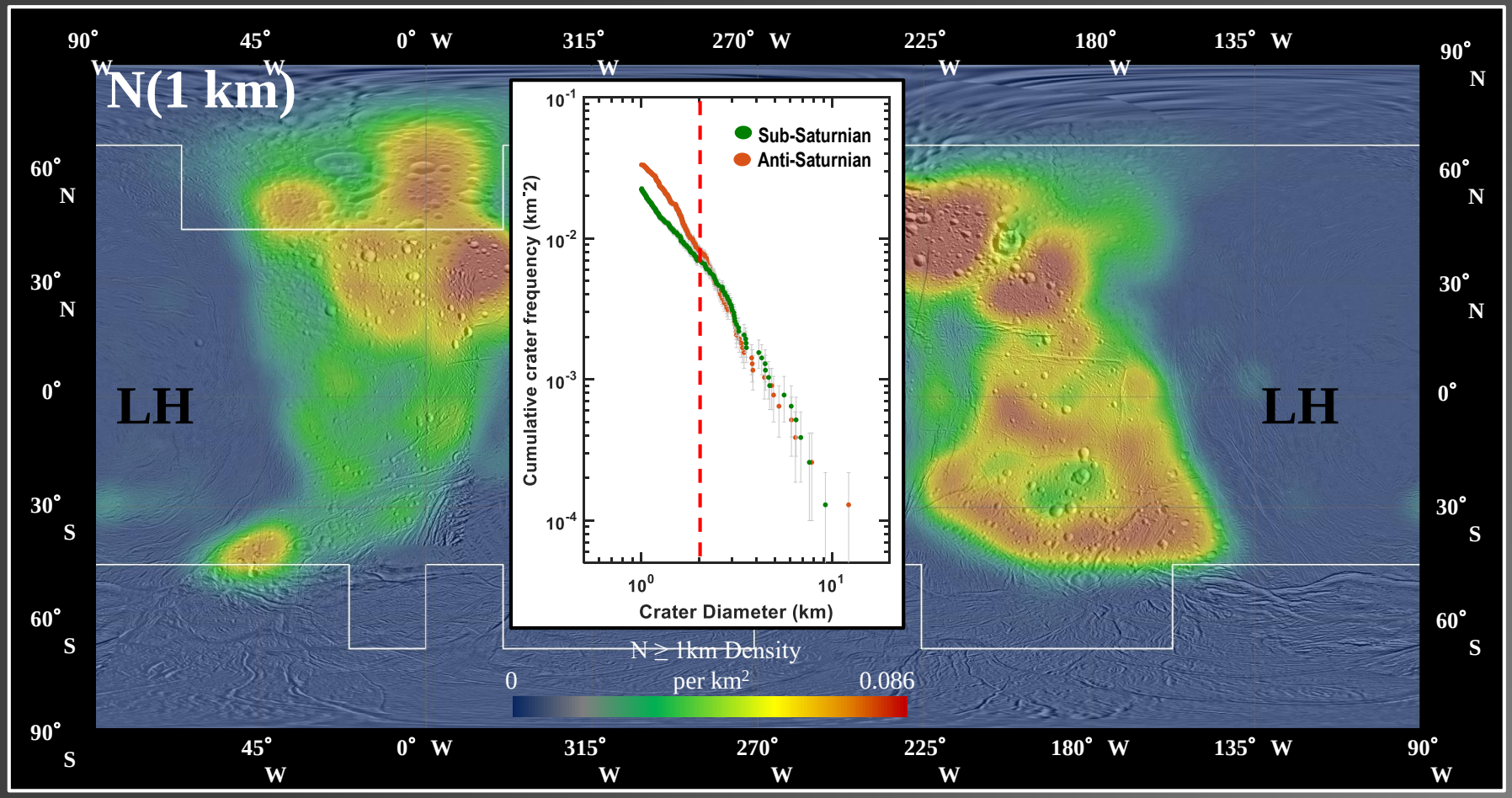
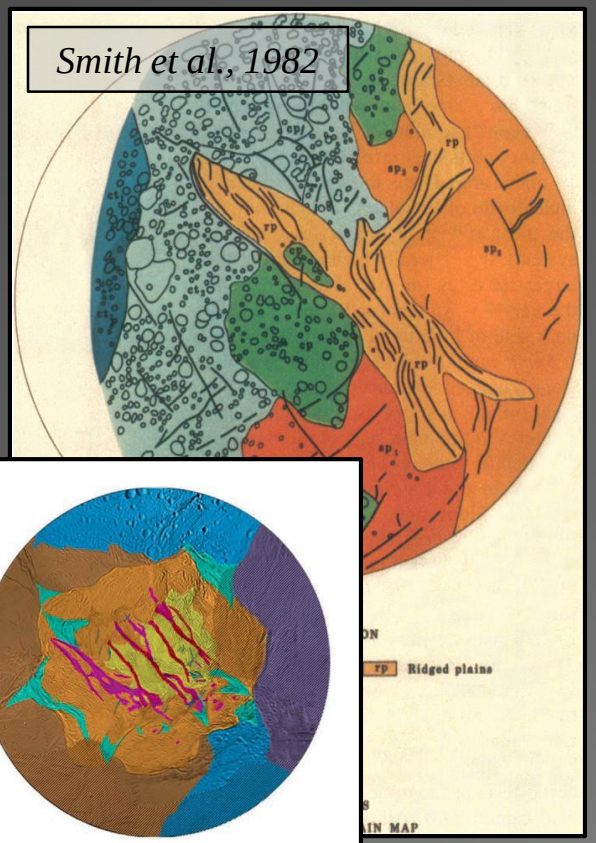
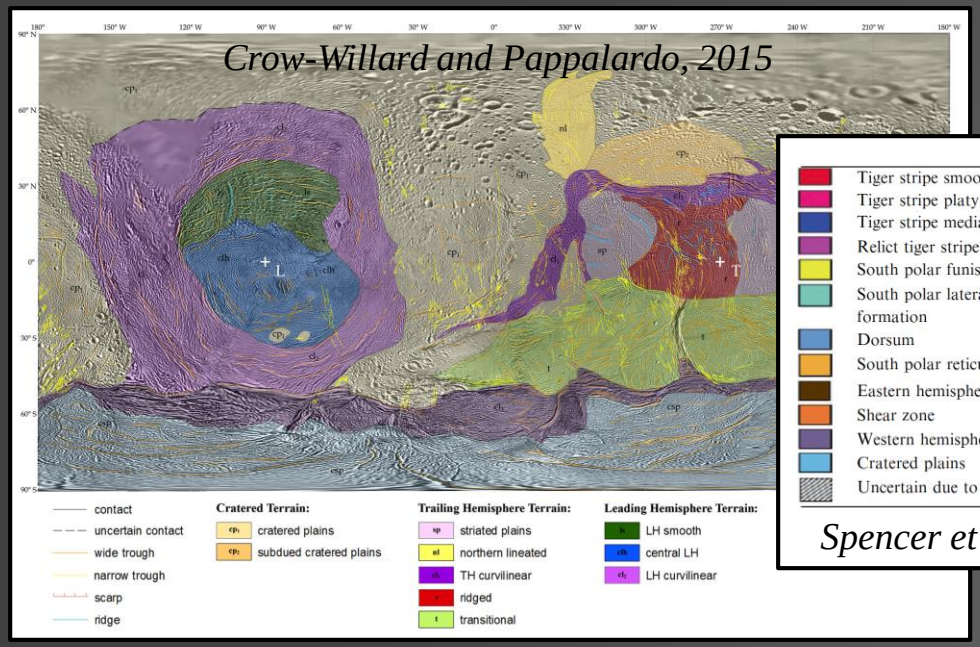


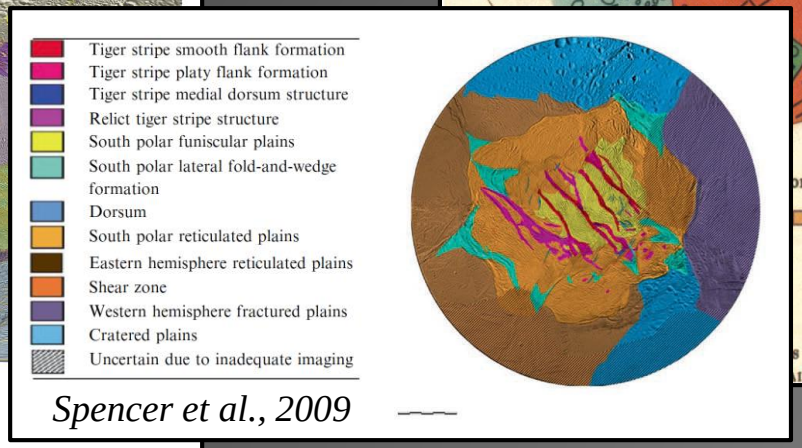
# Structural Mapping

Broadly speaking, the surface of Enceladus can be (and has been – Smith et al., 1982; Spencer et al., 2009; Crow-Willard and Pappalardo, 2015) divided into 4 primary terrains, differentiated by observed tectonic fabric(s):

- Ancient cratered terrain
- Leading hemisphere terrain
- Trailing hemisphere terrain
- South-polar terrain



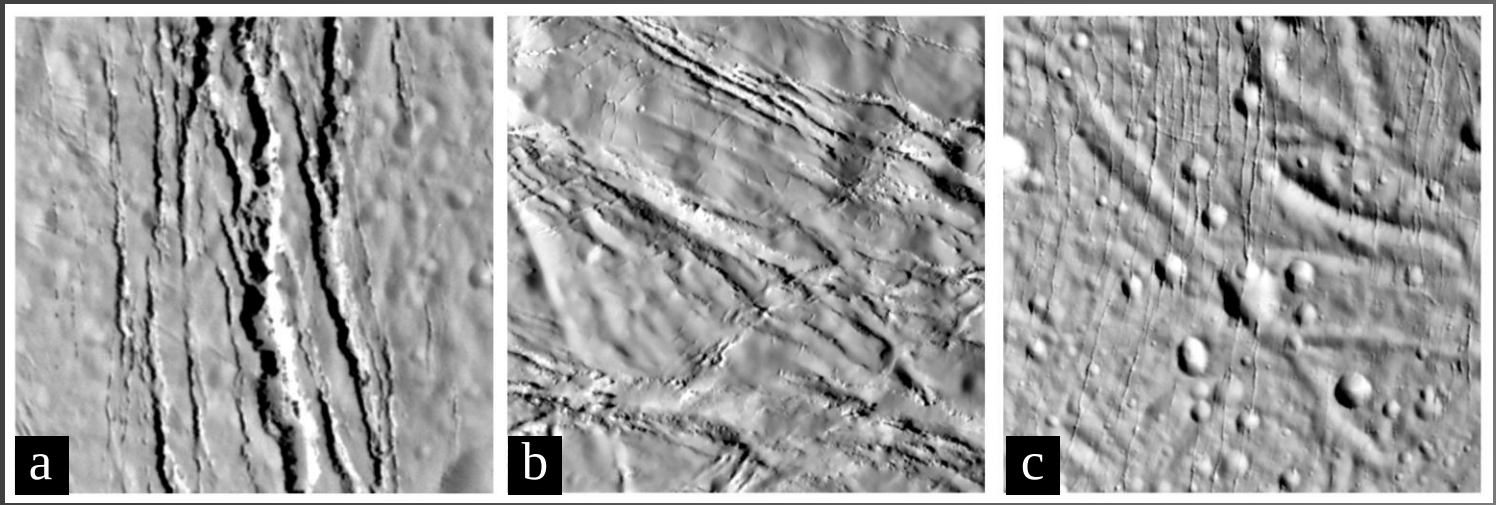



# Structural Mapping

Cratered plains

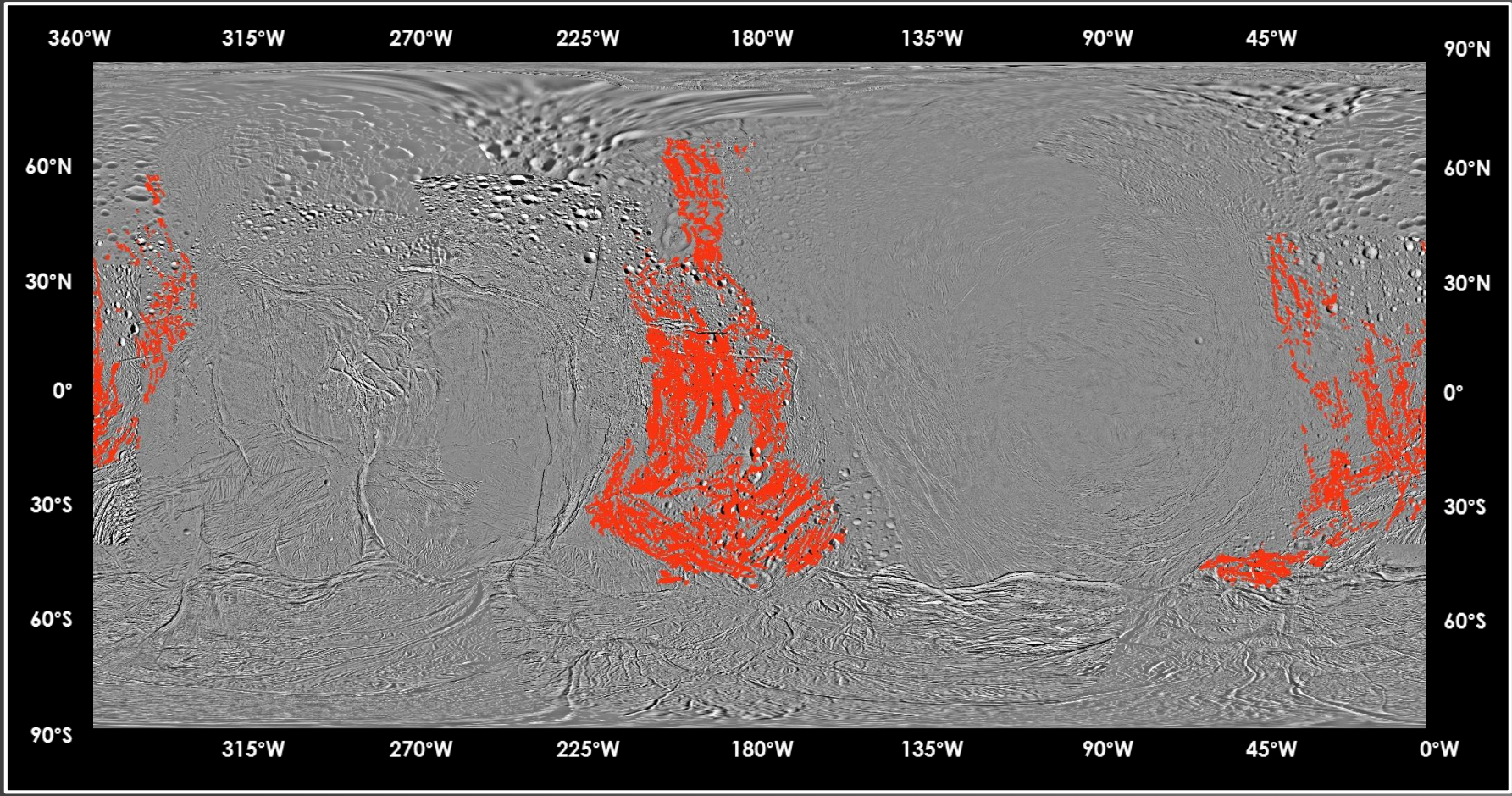
- Extends from the sub-Saturn hemisphere, over the north pole, to the anti-Saturn hemisphere
- At least three generations of tectonic features cross-cut the ancient terrain:
  a. The most recent are open fractures and parallel, linear chains of pits that appear to be associated with deformation of the south polar terrain.
  b. The next oldest are apparent normal faults and graben-like structures that are perhaps associated with deformation of terrain in the leading and trailing hemispheres.
  c. The oldest tectonic features are subdued, widely-spaced ridges and troughs of unknown origin.



# Structural Mapping

Cratered plains

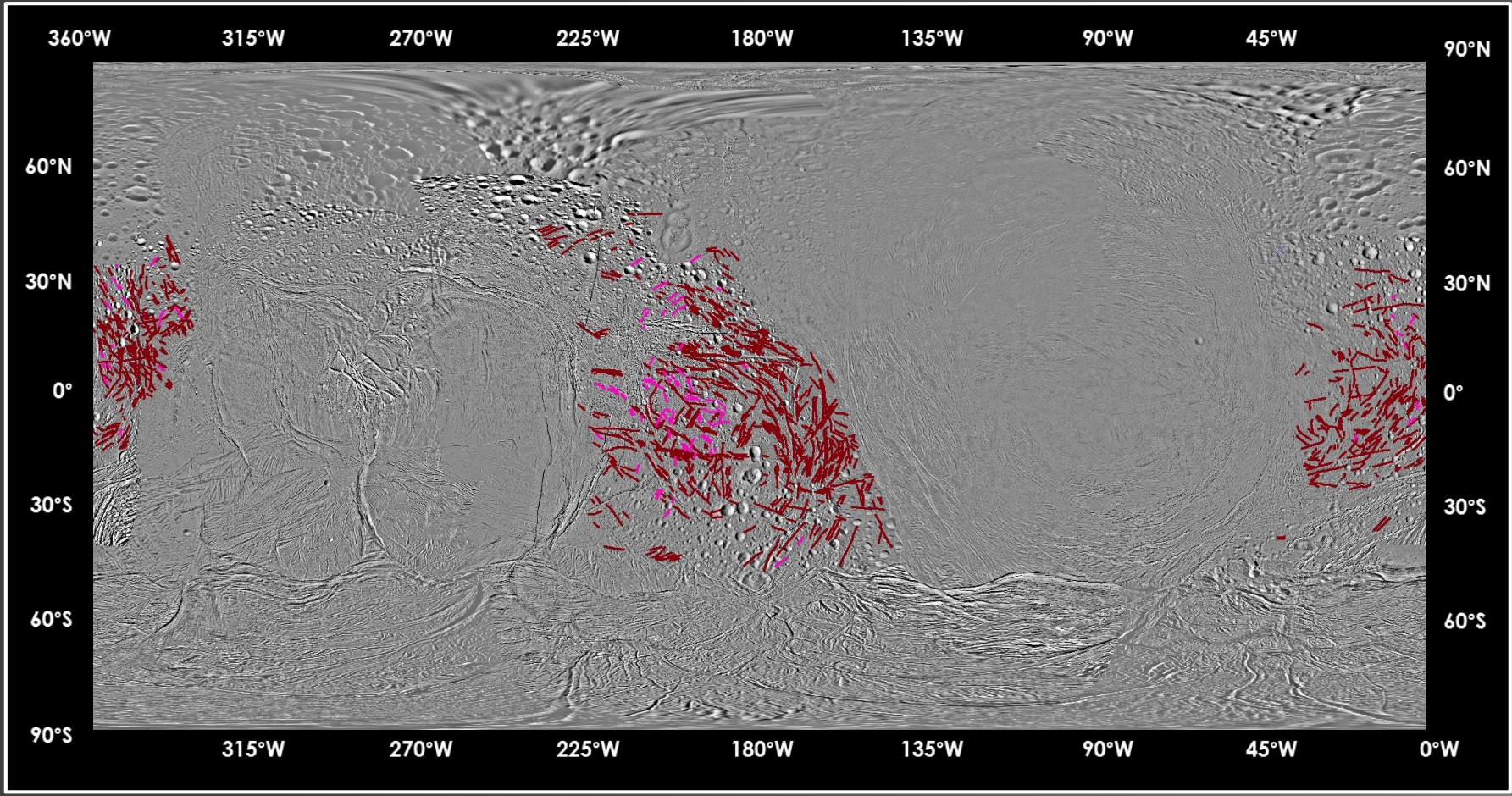
- Open fractures and pit chains



# Structural Mapping

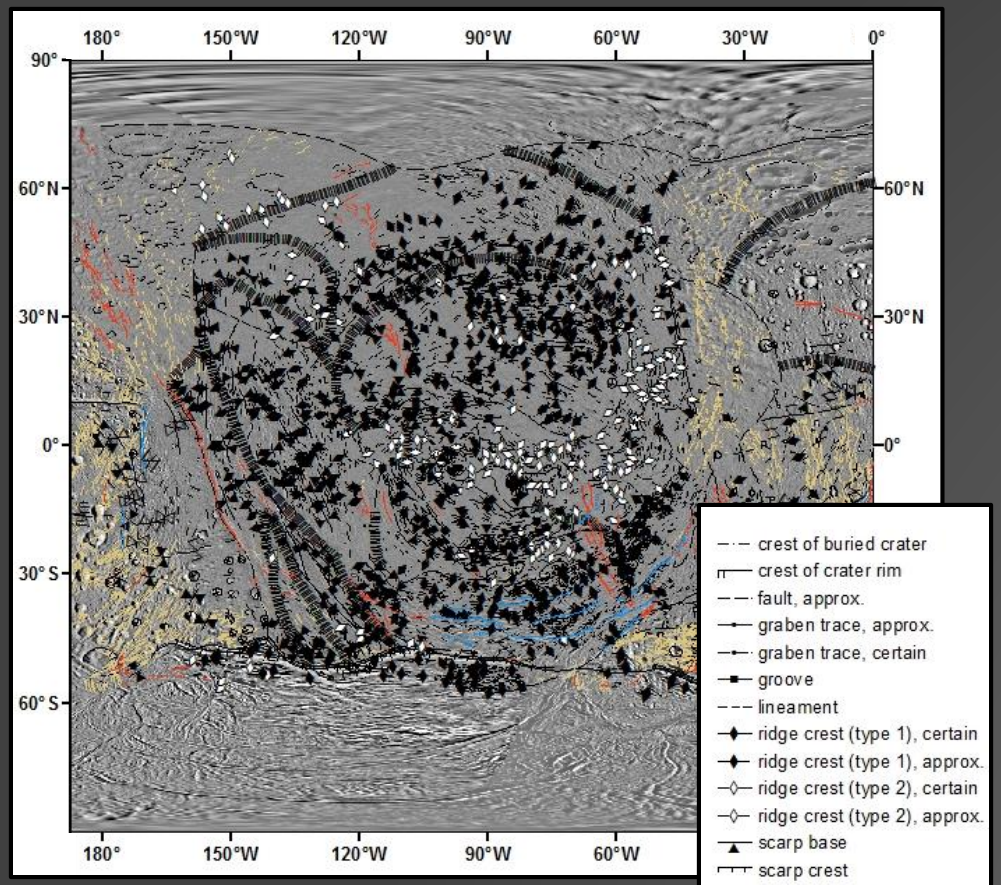
Cratered plains

- Subdued ridges (pink) and troughs (maroon)

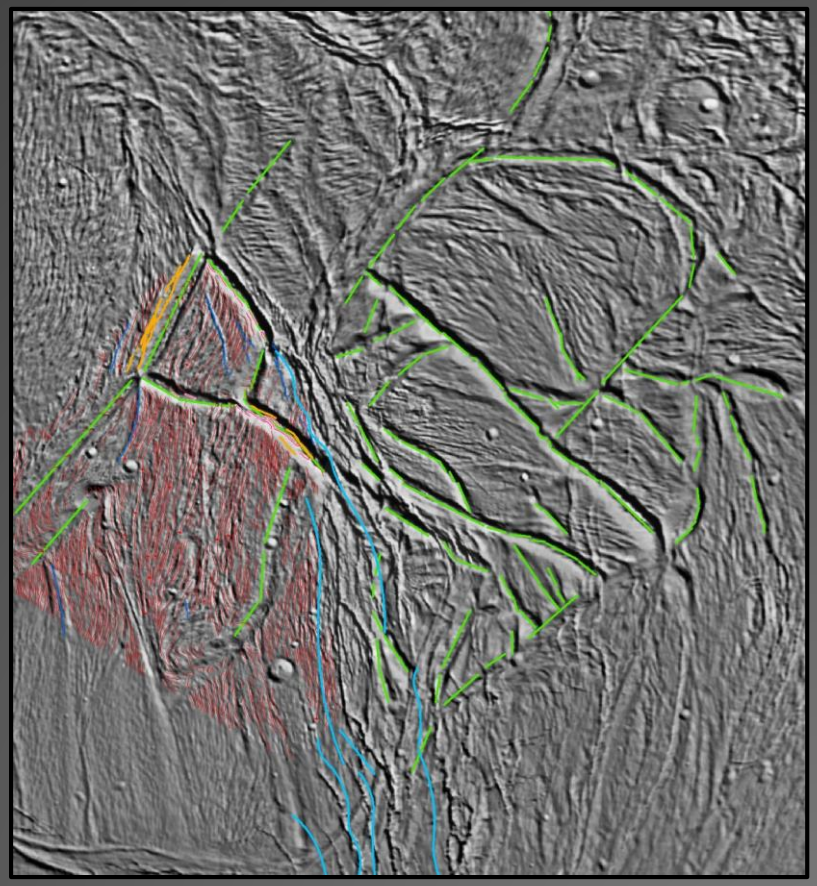


# Structural Mapping

Leading hemisphere terrain and Trailing hemisphere terrain (Dorsa region)




- crest of buried crater
- crest of crater rim
- fault, approx.
- graben trace, approx.
- graben trace, certain
- groove
- lineament
- ridge crest (type 1), certain
- ridge crest (type 1), approx.
- ridge crest (type 2), certain
- ridge crest (type 2), approx.
- scarp base
- scarp crest
- small crater rim
- trough (type 1)
- trough (type 2)
- generic linear 1
- generic linear 2
- generic linear 3



# Where Things Stand

We have made significant progress toward completing a 1:2M global geologic map of Enceladus!

- We have generated a controlled photomosaic for use as our basemap and a collection of controlled observation mosaics.
- We have nearly completed a global catalog of craters at diameters < 1 km.
- We have mapped structural features associated with the oldest surfaces of Enceladus.
- We are in the process of mapping structural features associated with the leading and trailing hemisphere terrains.

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A fair amount remains to be done, though.

- Structural mapping of the South-Polar terrain remains.
- Geologic units need to be defined and boundaries need to be drawn.
- A correlation of map units needs to be developed.
- There is that review process too….