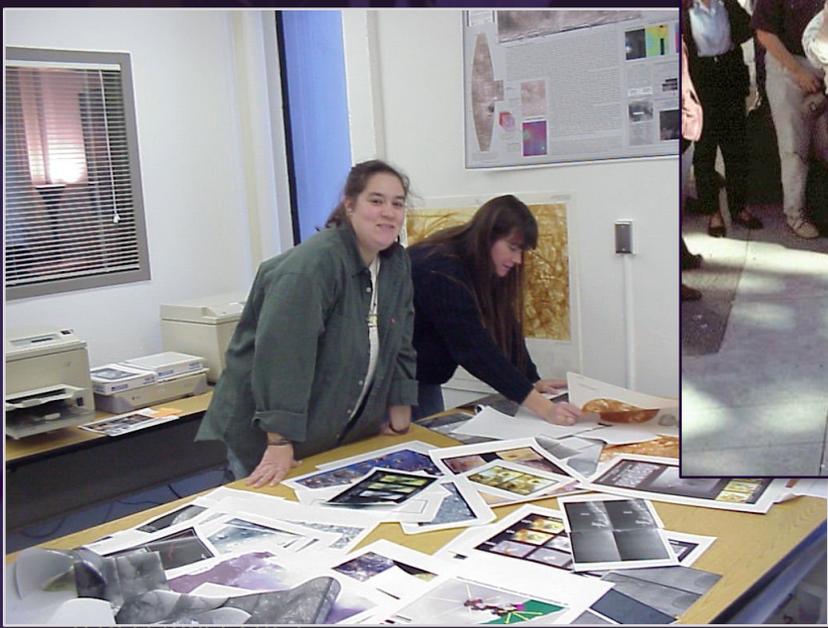


Learning about Europa from Galileo

Zibi Turtle, Johns Hopkins Applied Physics Laboratory
Galileo Solid State Imaging (SSI) Associate



Z Turtle – Galileo at 30 !

Pre-Galileo Exploration

- Pioneer 10, 3 Dec 1973
 - ~321,000 km
- Pioneer 11, 3 Dec 1974
 - ~587,000 km



Pre-Galileo Exploration

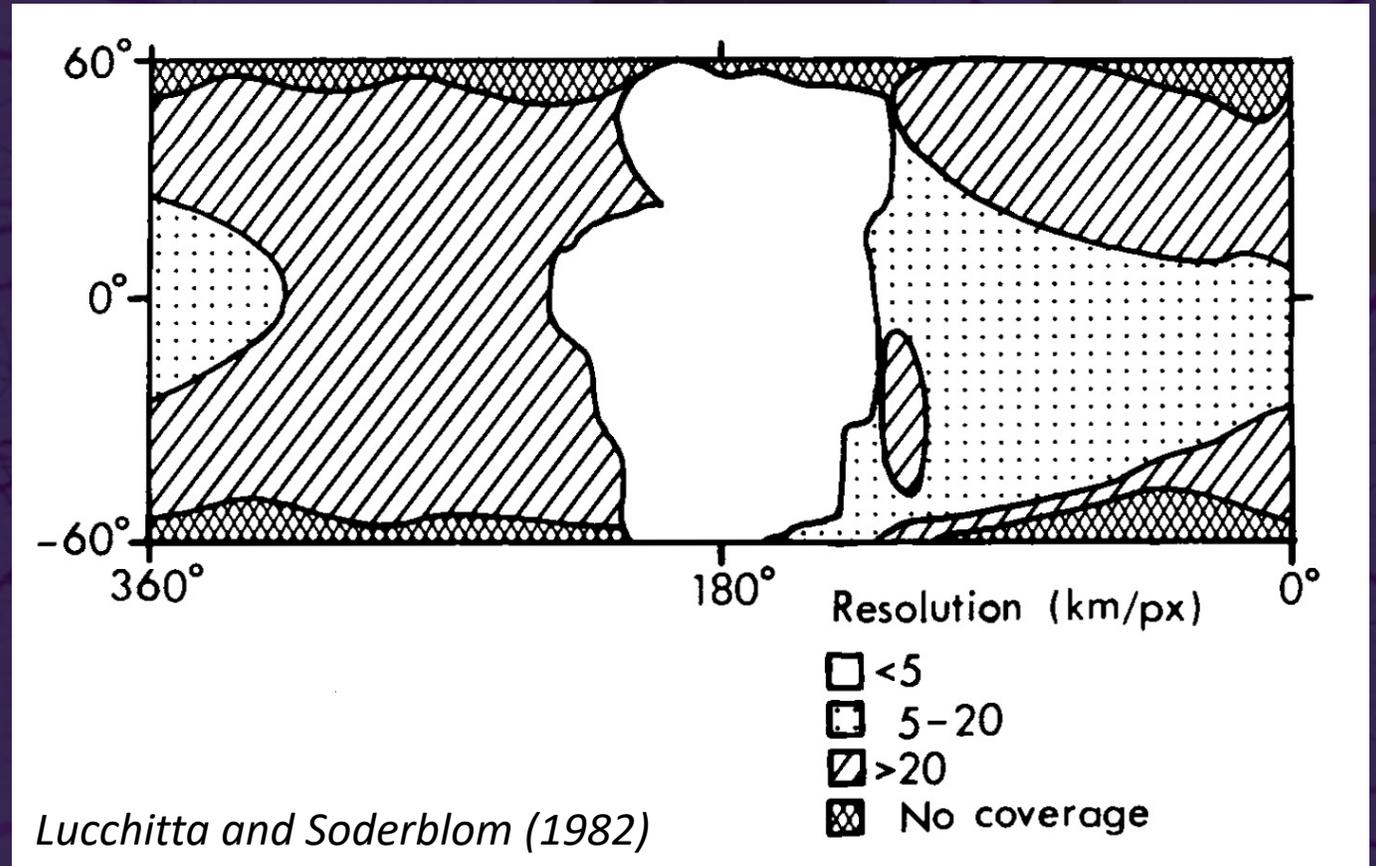
- Pioneer 10, 3 Dec 1973
 - ~321,000 km
- Pioneer 11, 3 Dec 1974
 - ~587,000 km
- Voyager 1, 5 March 1979
 - 2,870,000 km
 - 30-100 km/line pair



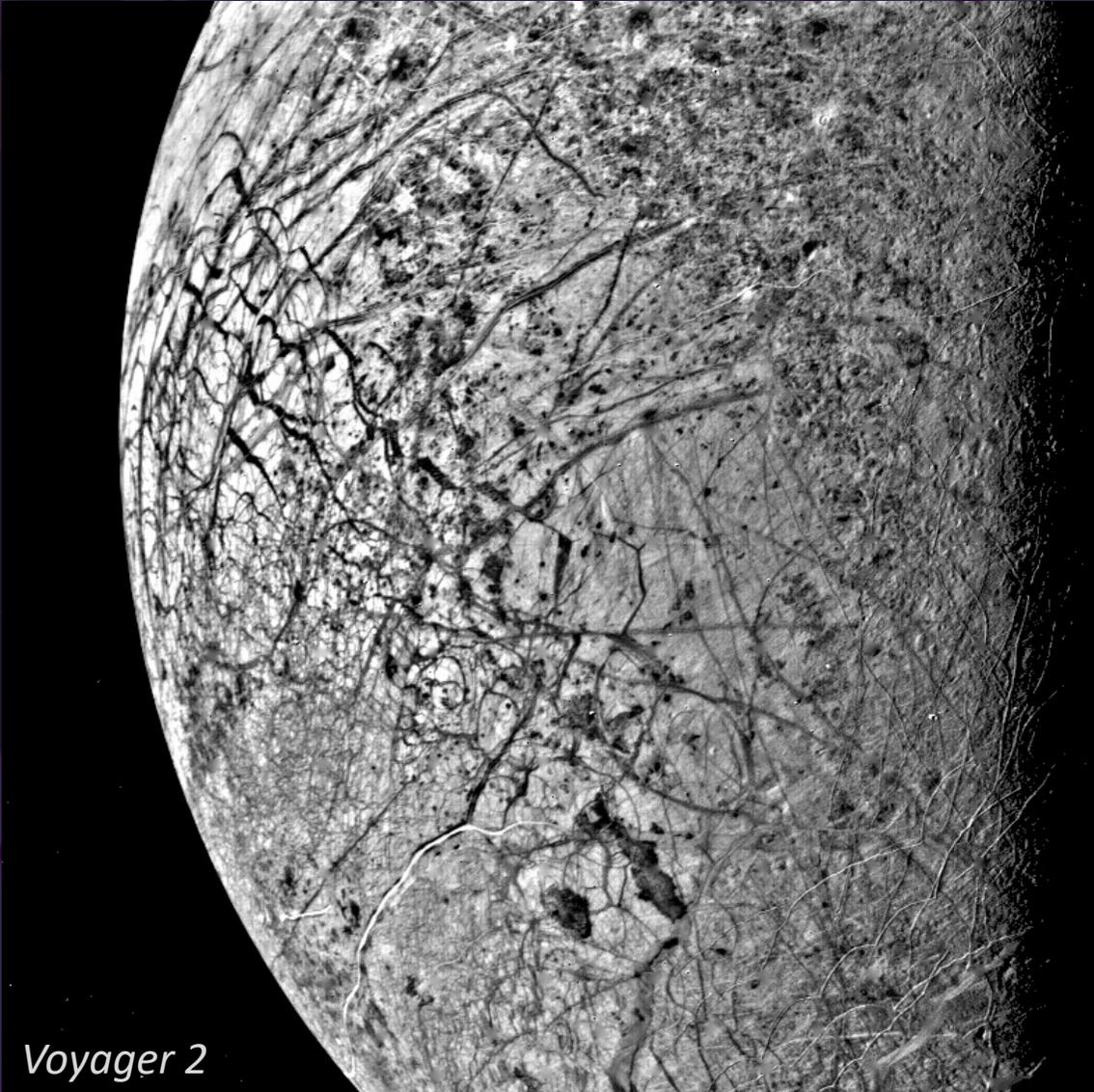
Europa as seen by Voyager 1

Pre-Galileo Exploration

- Pioneer 10, 3 Dec 1973
 - ~321,000 km
- Pioneer 11, 3 Dec 1974
 - ~587,000 km
- Voyager 1, 5 March 1979
 - 2,870,000 km
 - 30-100 km/line pair
- Voyager 2, 9 July 1979
 - C/A ~205,000 km
 - ~20% @ ≥ 4.5 km/line pair

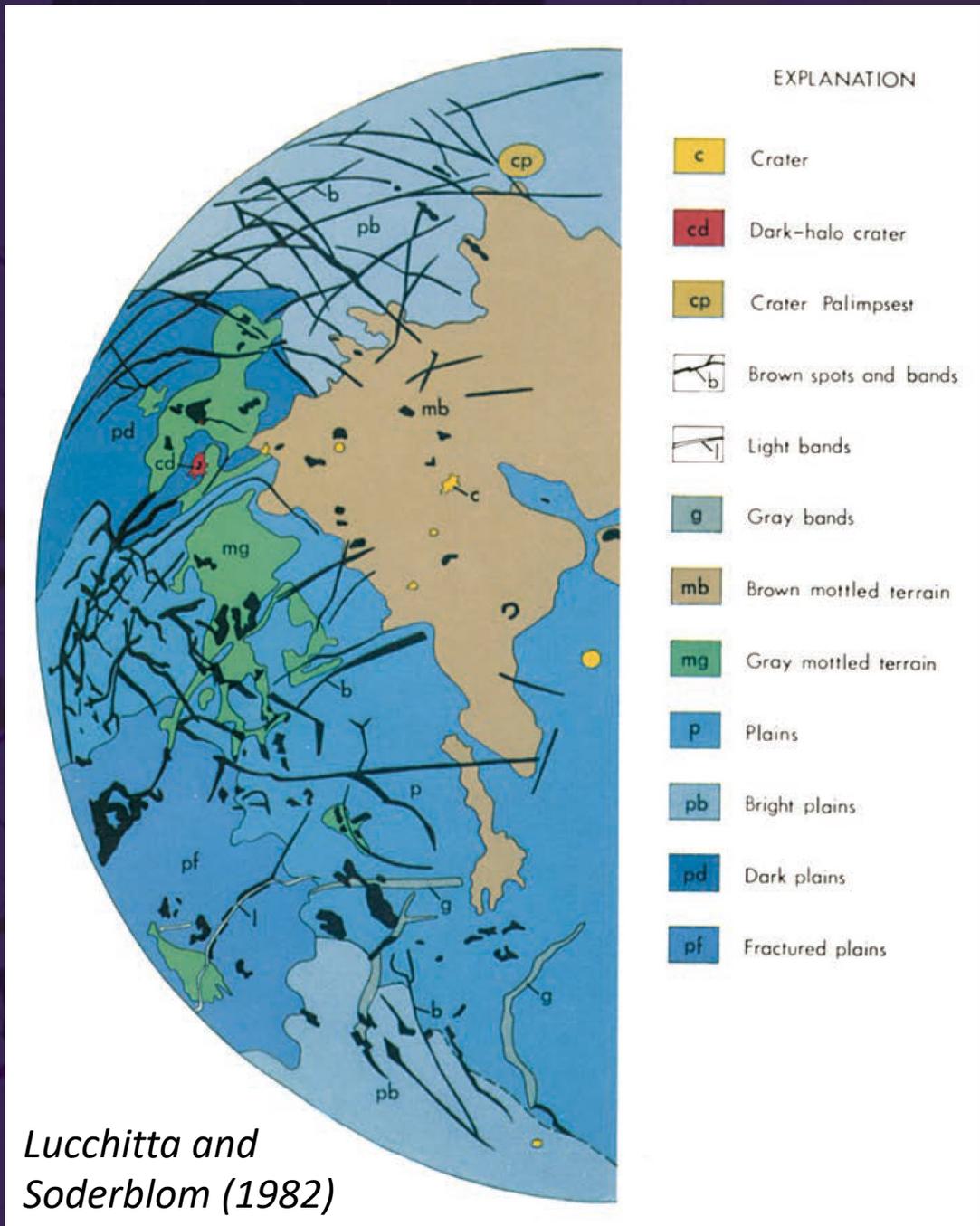


Voyager 2



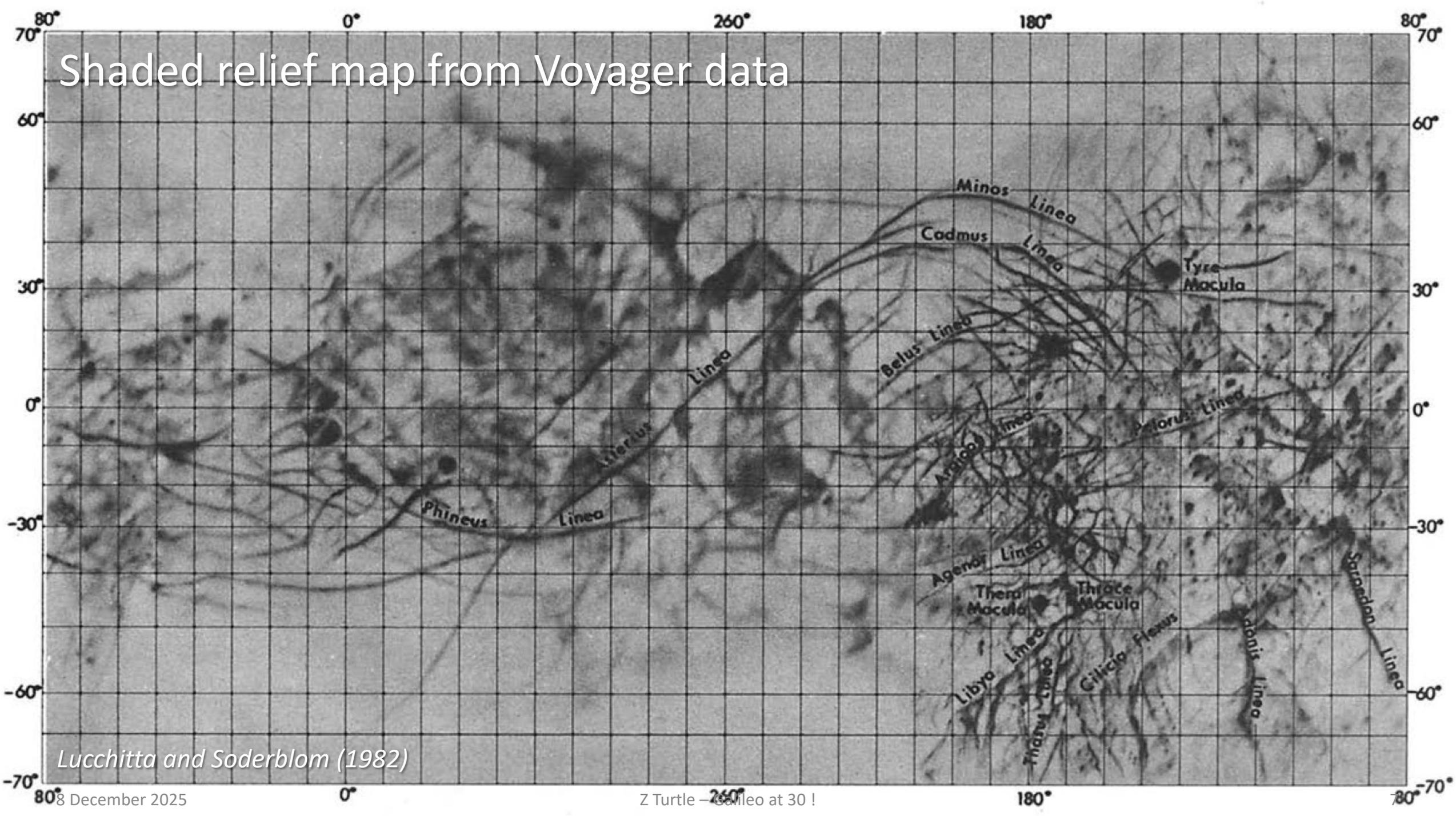
Voyager 2

8 December 2025



Z Turtle – Galileo at 30 !

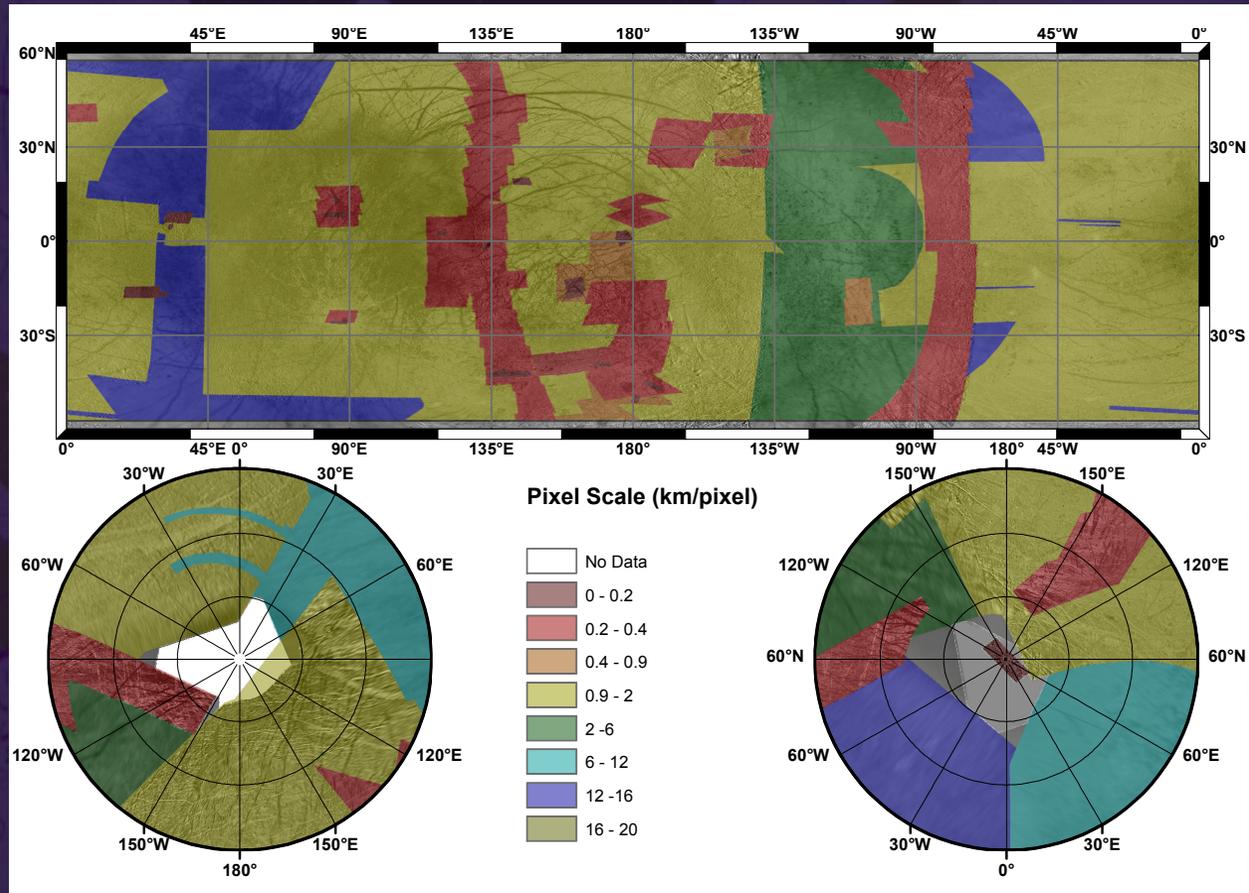
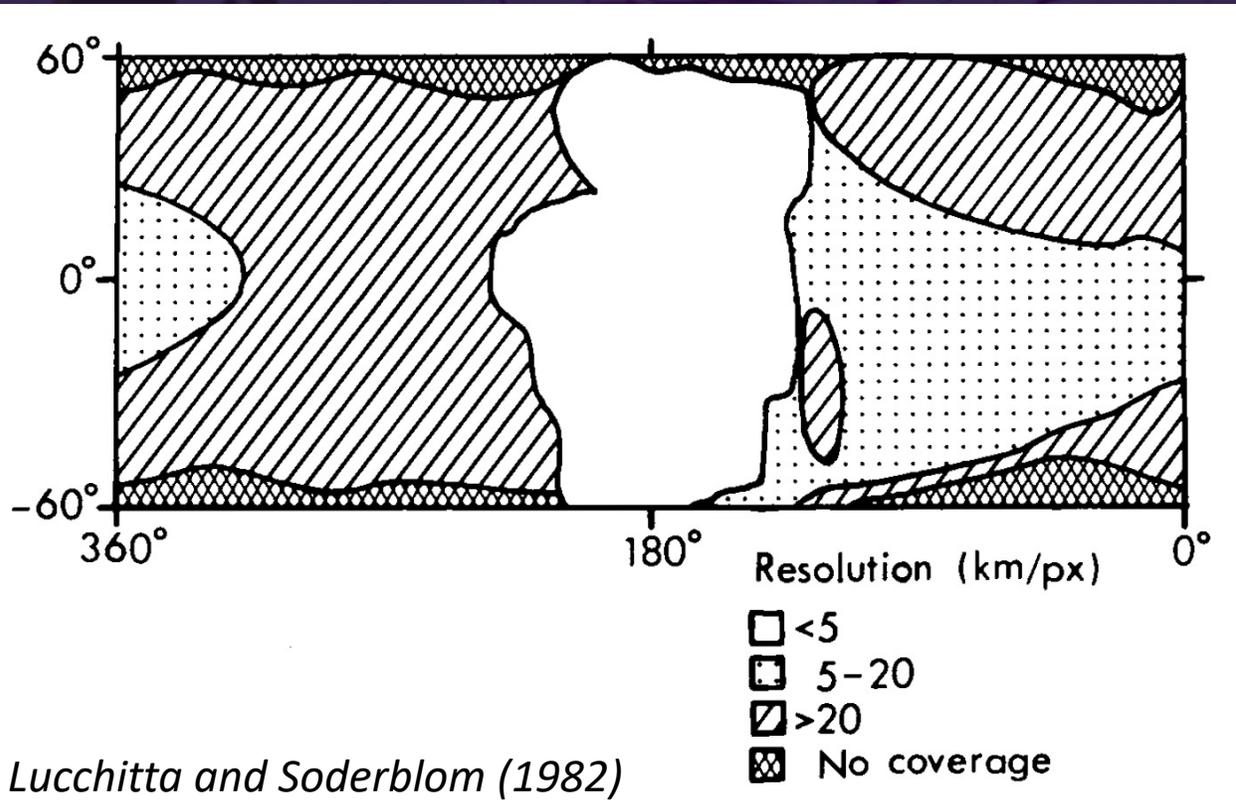
Shaded relief map from Voyager data



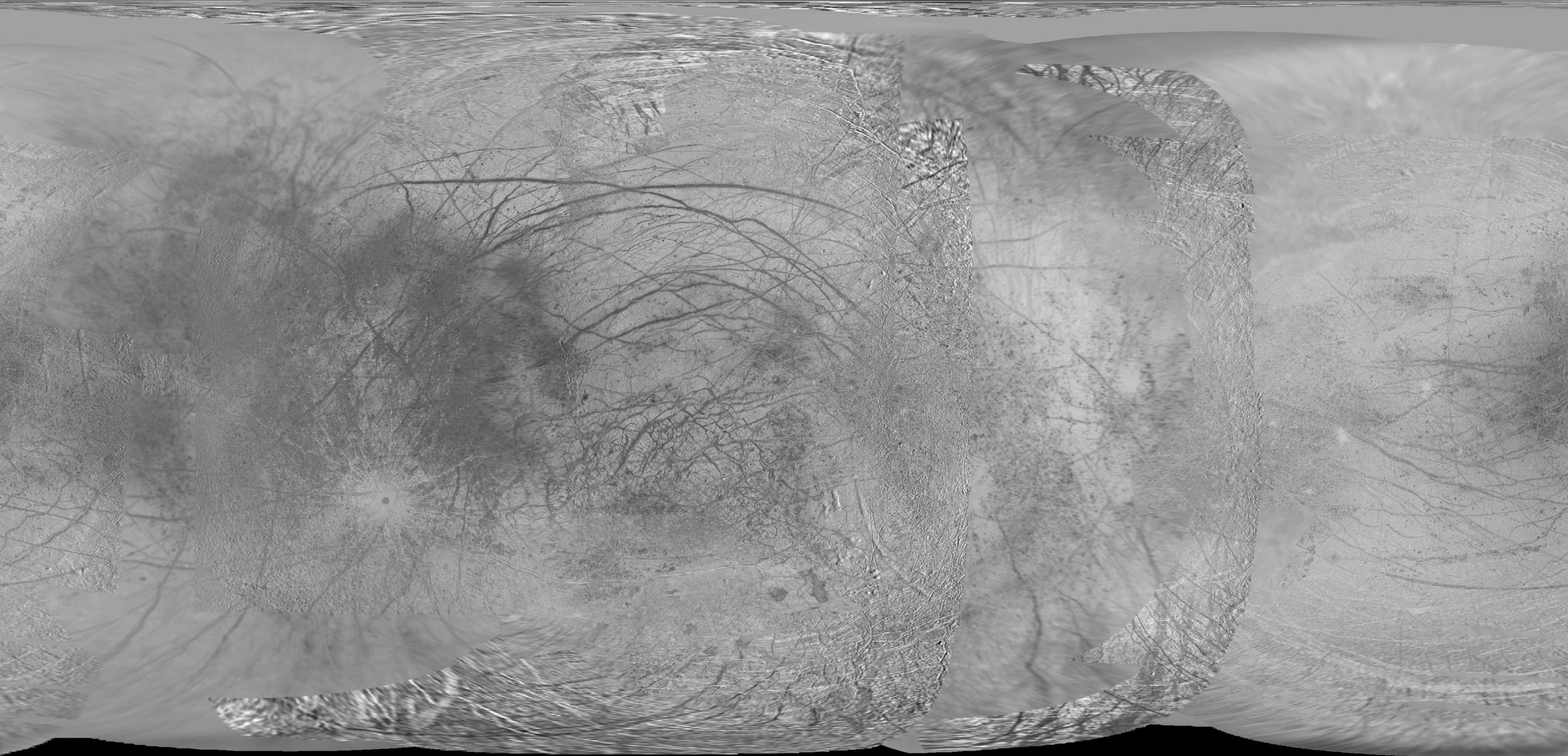
Lucchitta and Soderblom (1982)

Voyager imaging coverage of Europa

Galileo imaging coverage of Europa



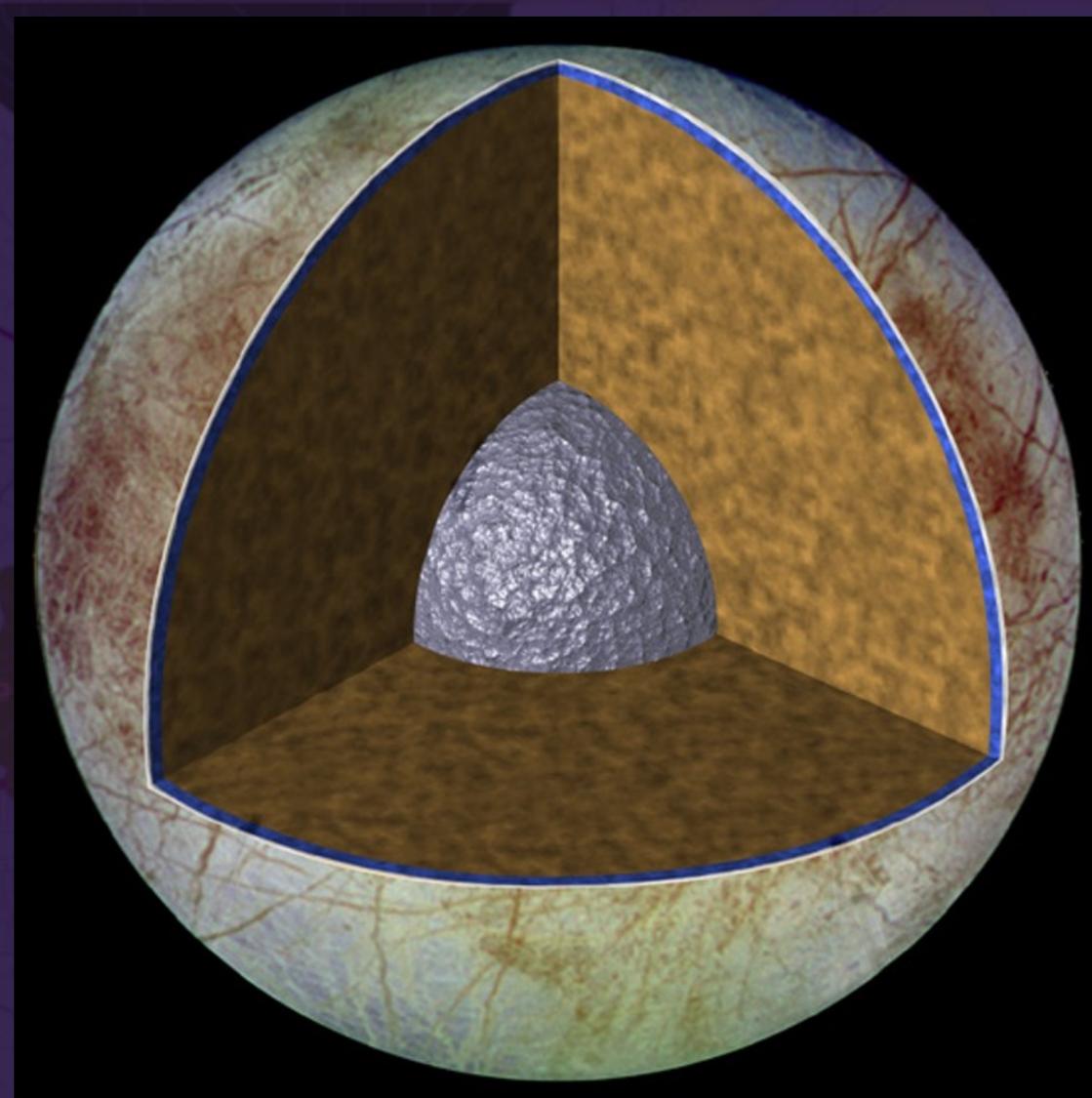
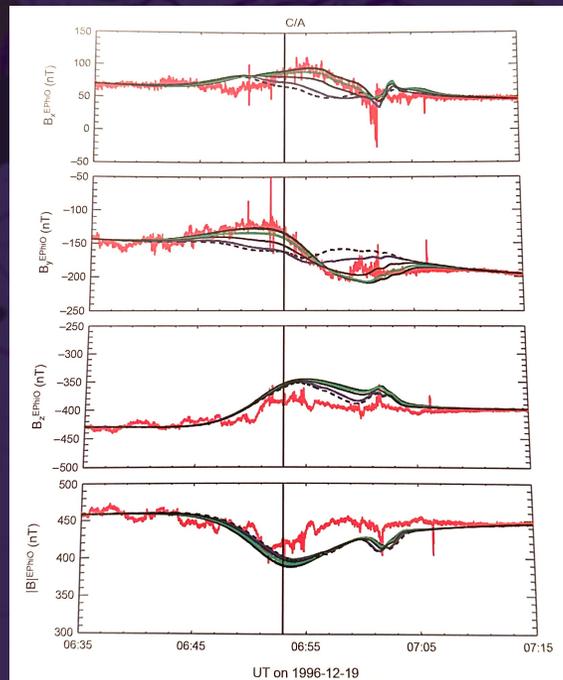
Pixel scale	Galileo coverage
≤6 km	82%
≤900 m	15.3%
≤200 m	0.54%
≤10 m	<10 images
≤1 m	none



Internal structure

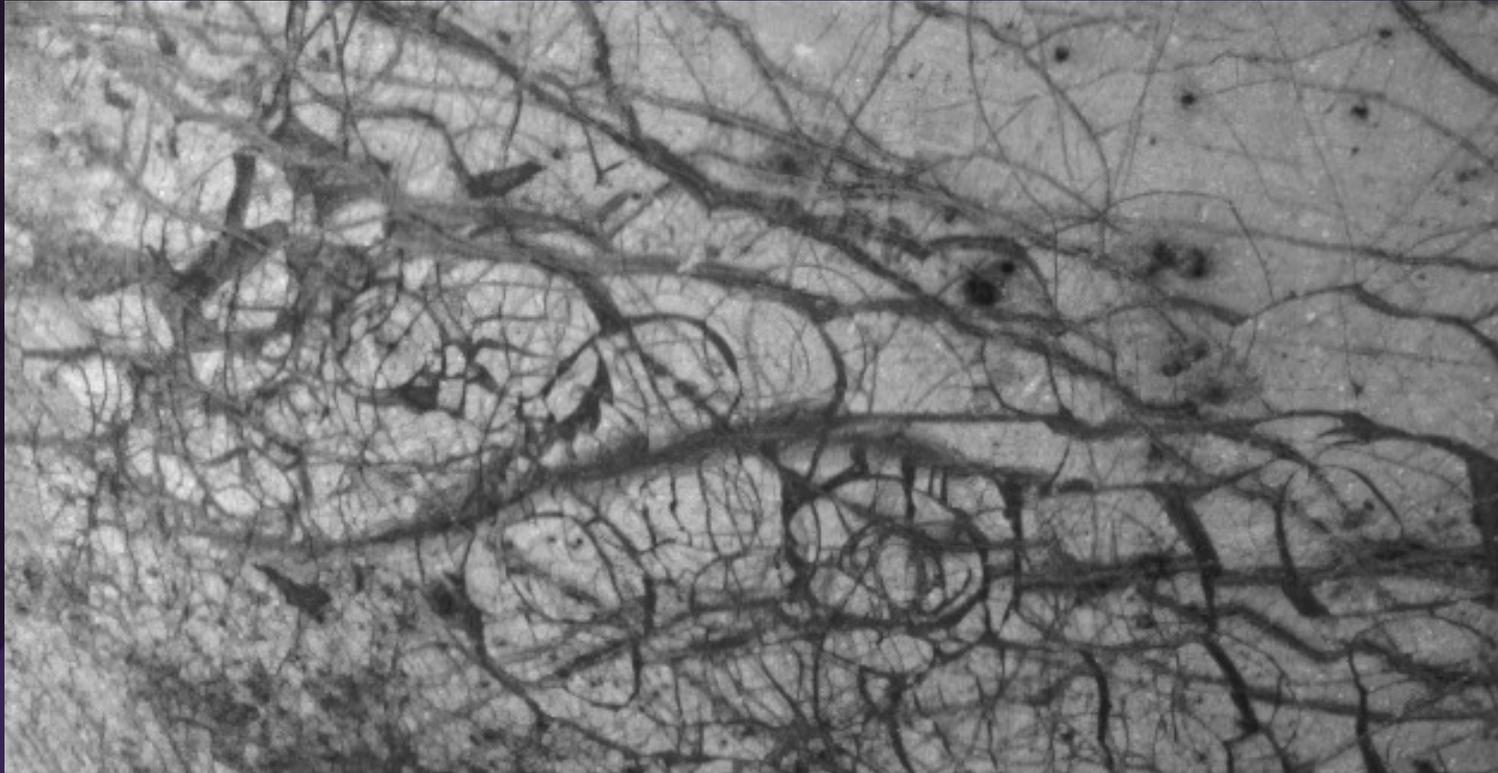
- Gravity measurements indicate differentiated interior: metallic core, rocky mantle, solid/liquid water layer ~80-170 km (Anderson et al. 1998)
- Magnetometer showed changes in magnetic field consistent with current-carrying outer shell, e.g., global-scale ocean (Kivelson et al. 2000)
- Geological features appear consistent with ice shell overlying liquid water ocean

Kivelson et al. 2009

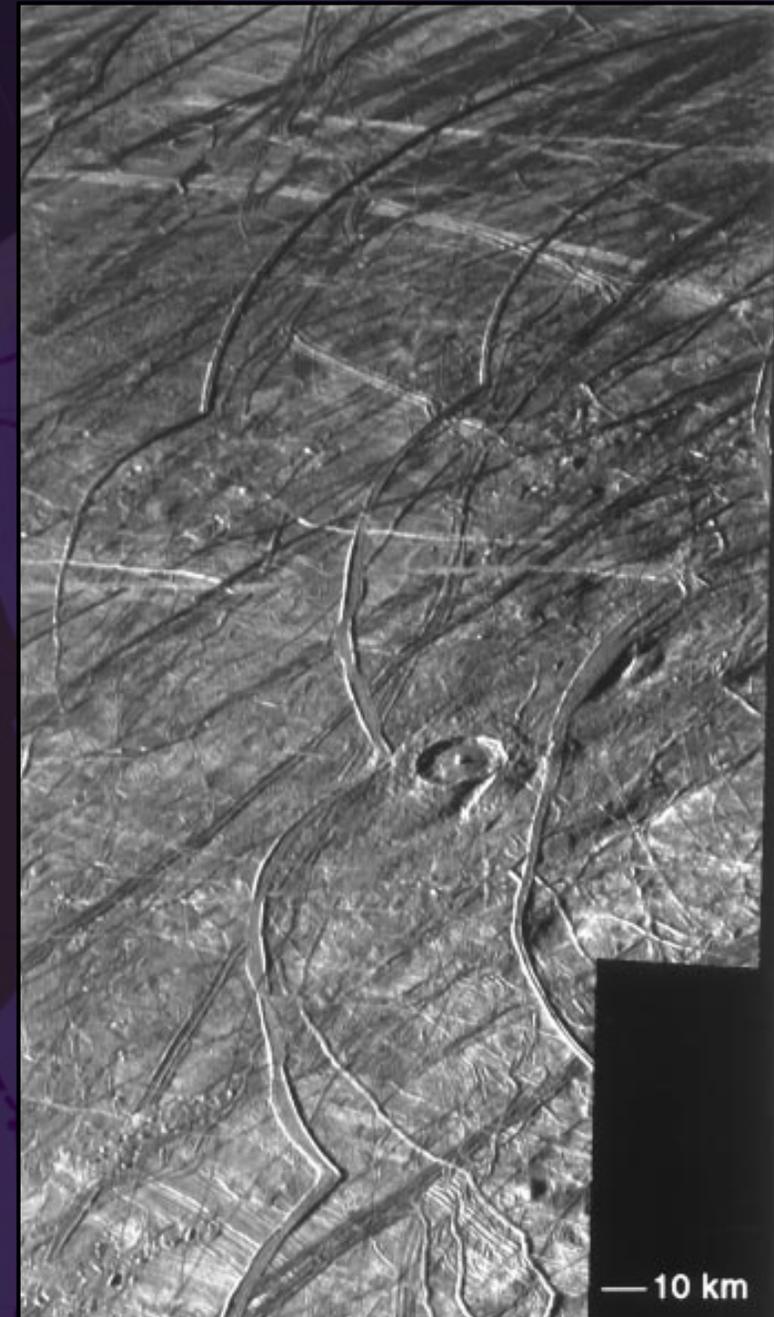


Schubert et al. 2009

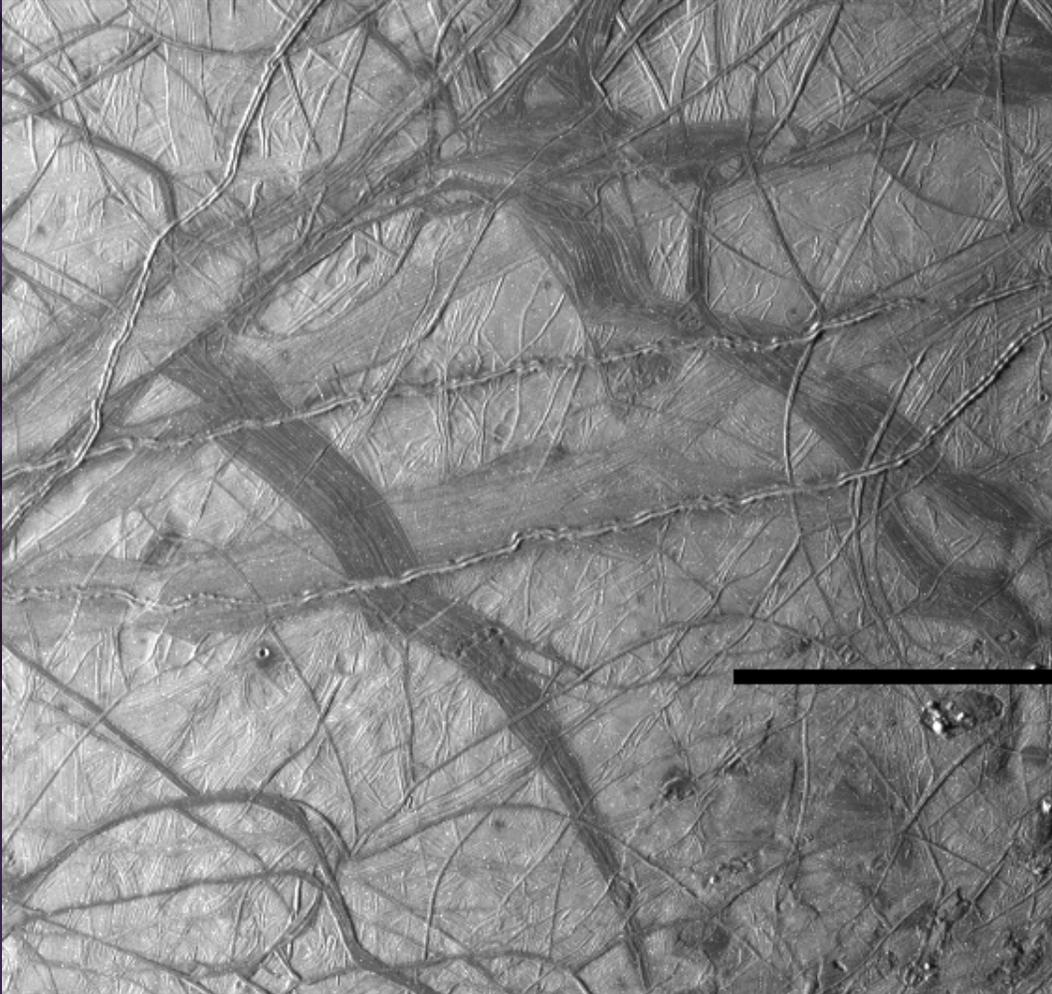
Europa's unique geology: Bands, tectonic ridges, fractures



■ *Argadnel Regio (1.6 km/pixel, 990 km x 510 km)*



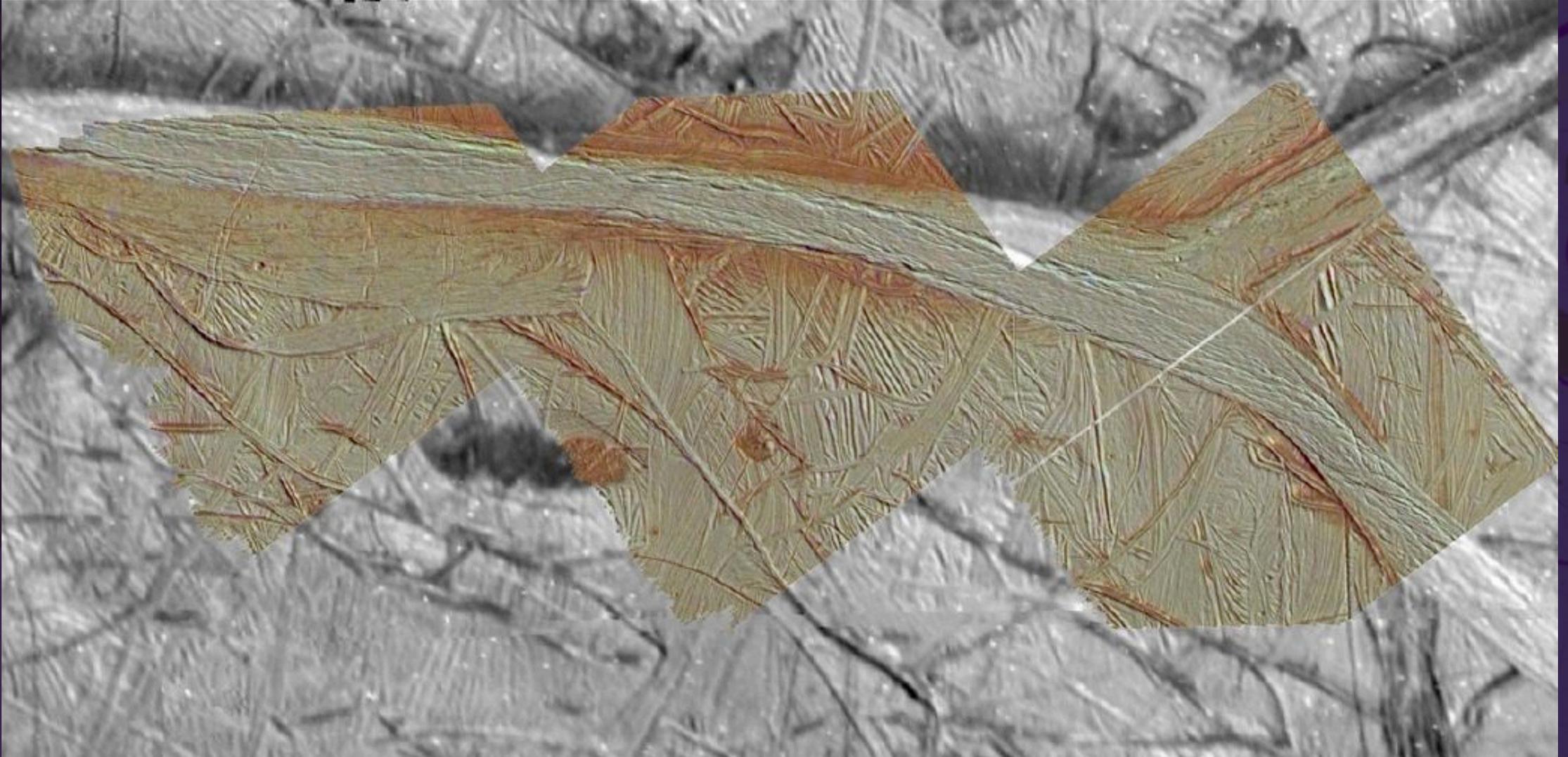
Europa's unique geology: Bands, tectonic ridges, fractures



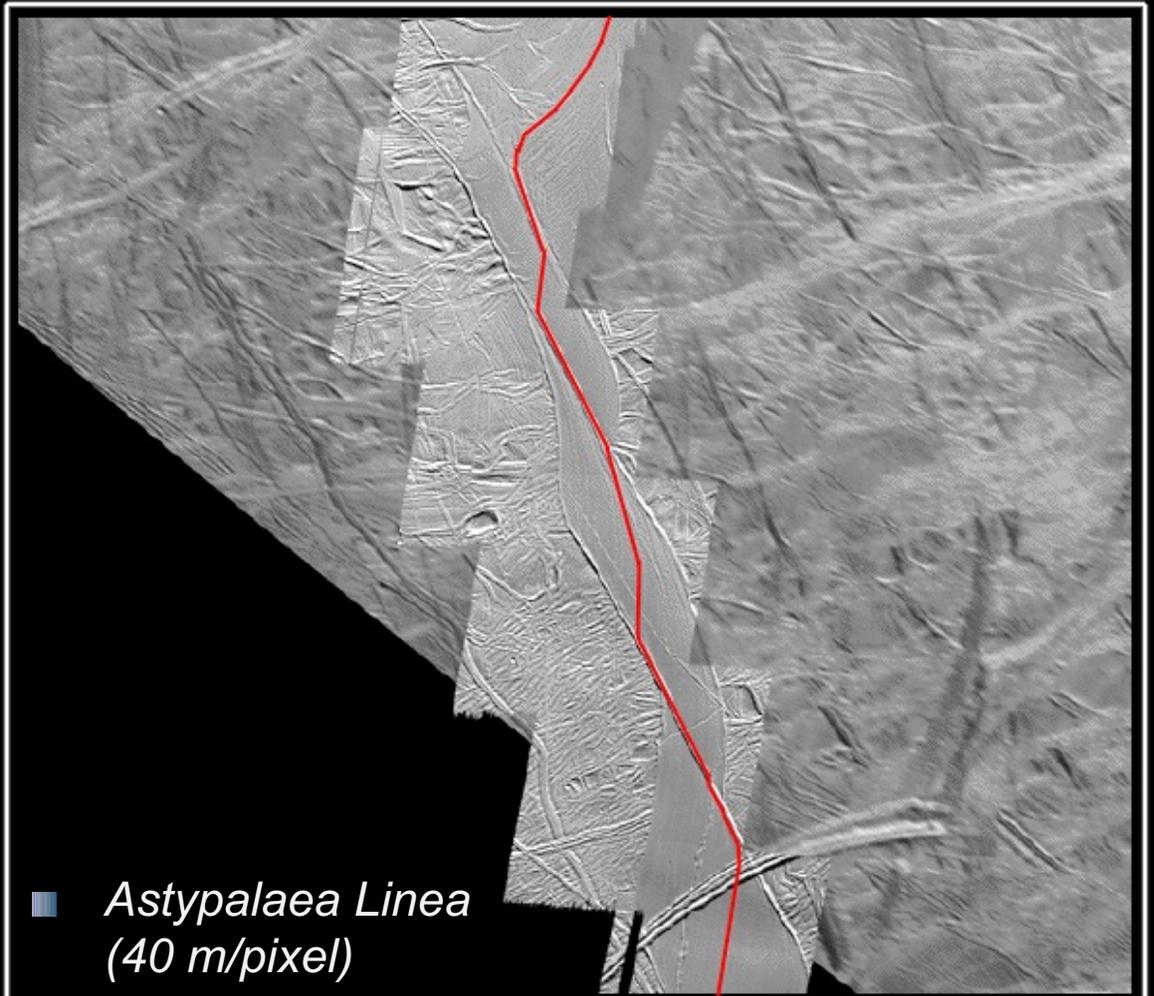
- *Yelland and Ino Lineae*
(420 m/pixel, 238 km x 225 km)

Europa's unique geology: Bands, tectonic ridges, fractures

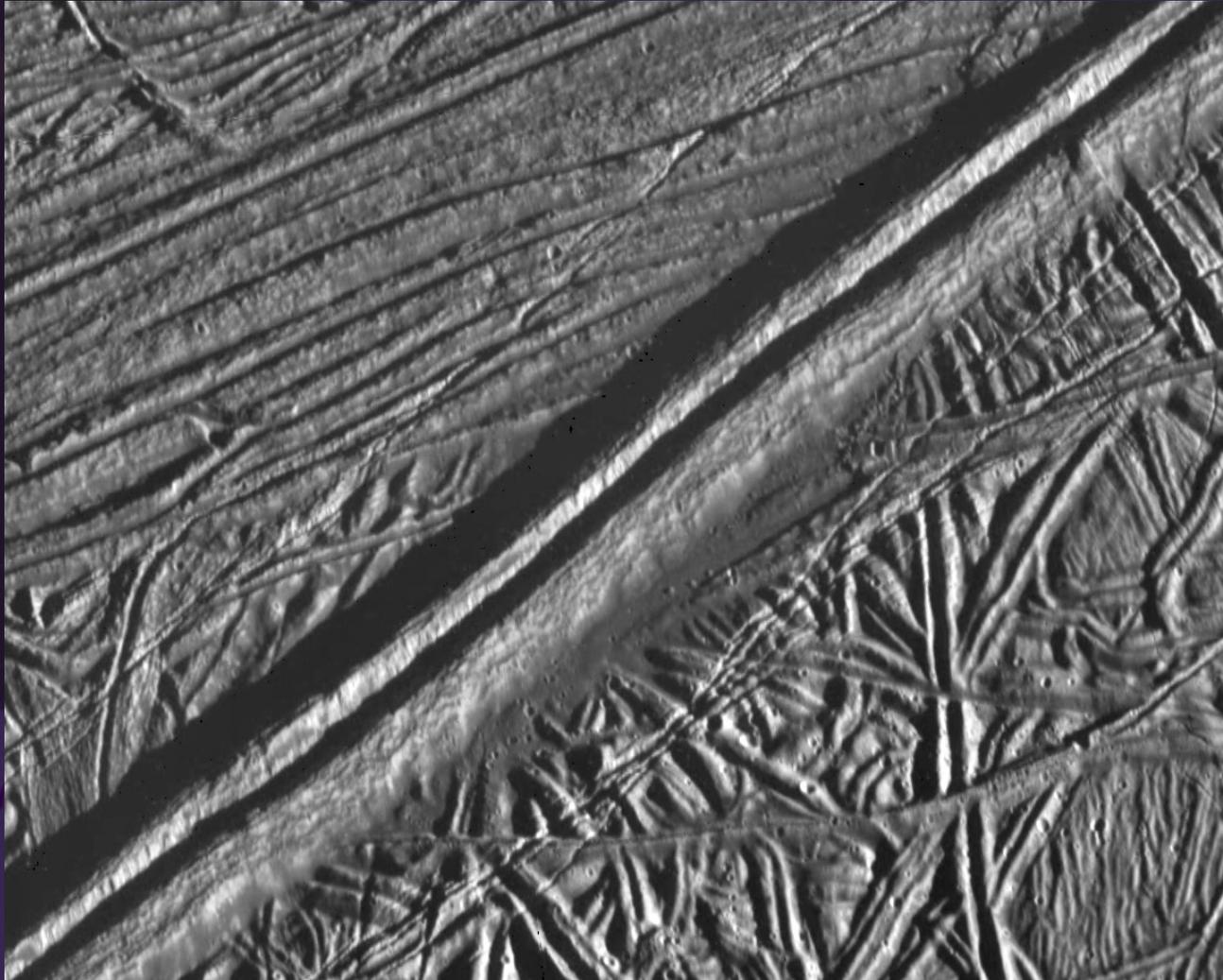
- *Agenor Linea (50 and 220 m/pixel, 135 km x 60 km)*



Europa's unique geology: Bands, tectonic ridges, fractures



Europa's unique geology: Tectonic ridges and fractures

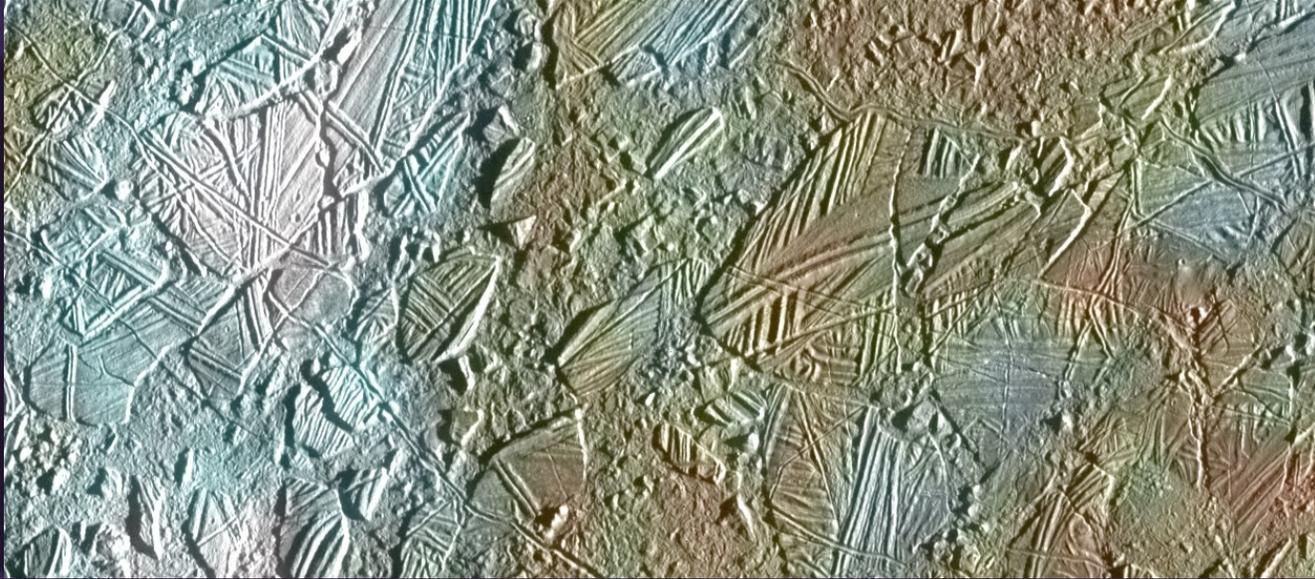


■ *Double ridge (20 m/pixel, ~17 km x 14 km)*



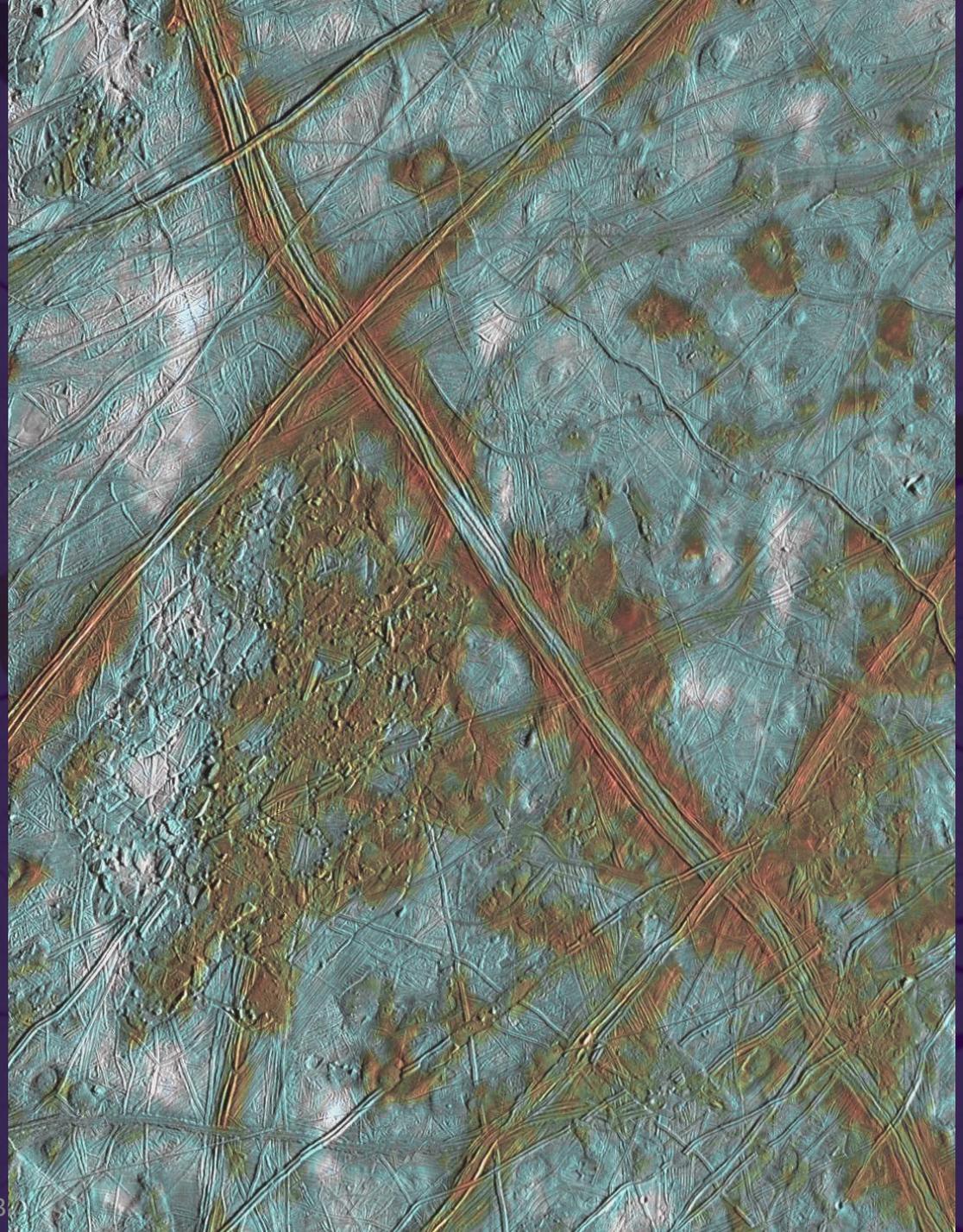
■ *6 m/pixel
(oblique view,
1.8 km across)*

Europa's unique geology: Chaos, pits, spots, domes



- *Conamara Chaos, enhanced color
(54 m/pixel)*

- *Conamara Chaos, enhanced color
(~200 m/pixel, 250 km x 200 km)*

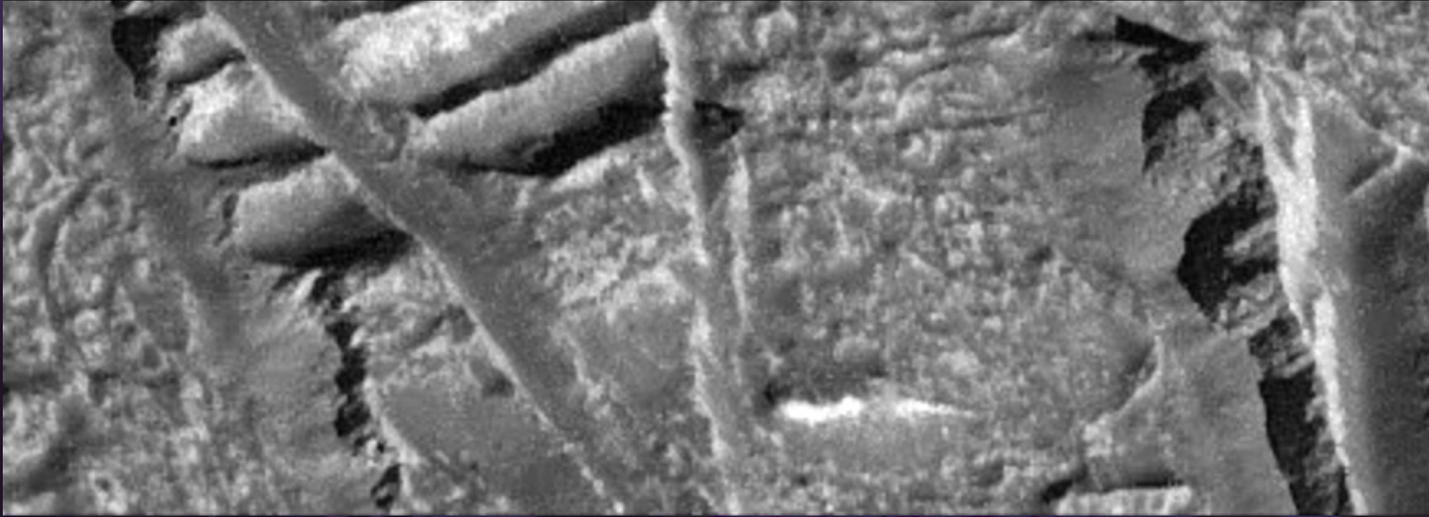


Europa's unique geology: Chaos, pits, spots, domes

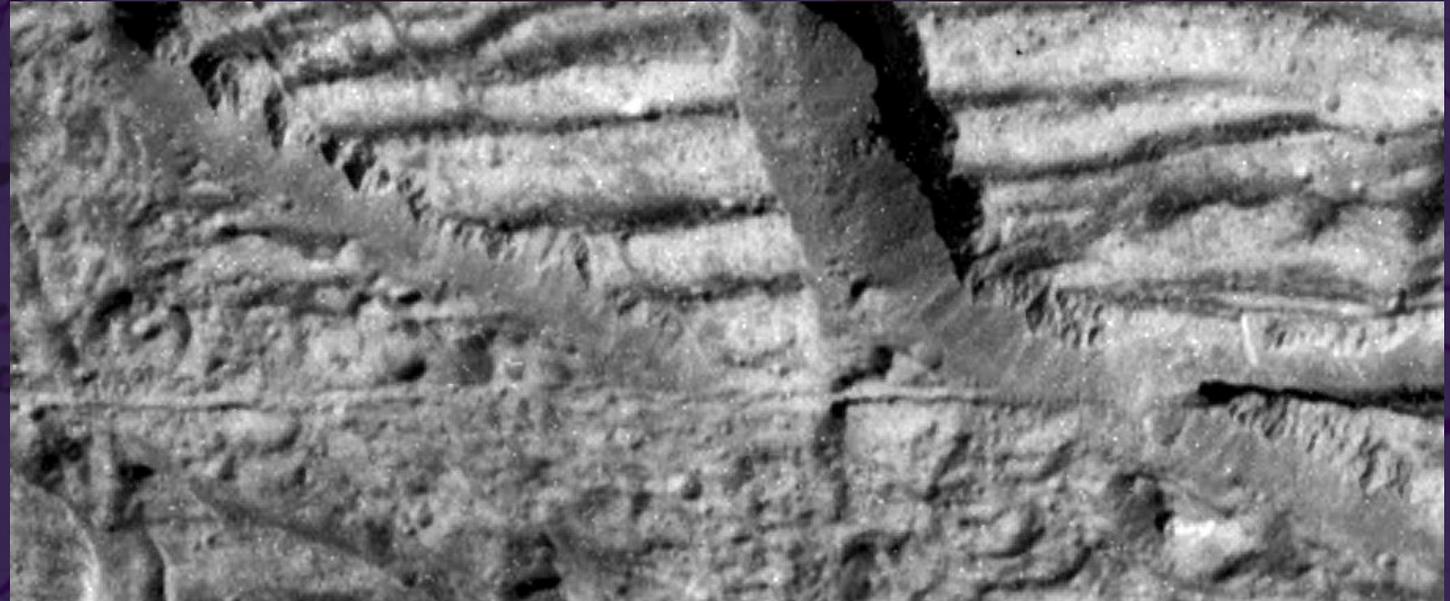
■ *Conamara Chaos (54 m/pixel, 42 km x 22 km)*



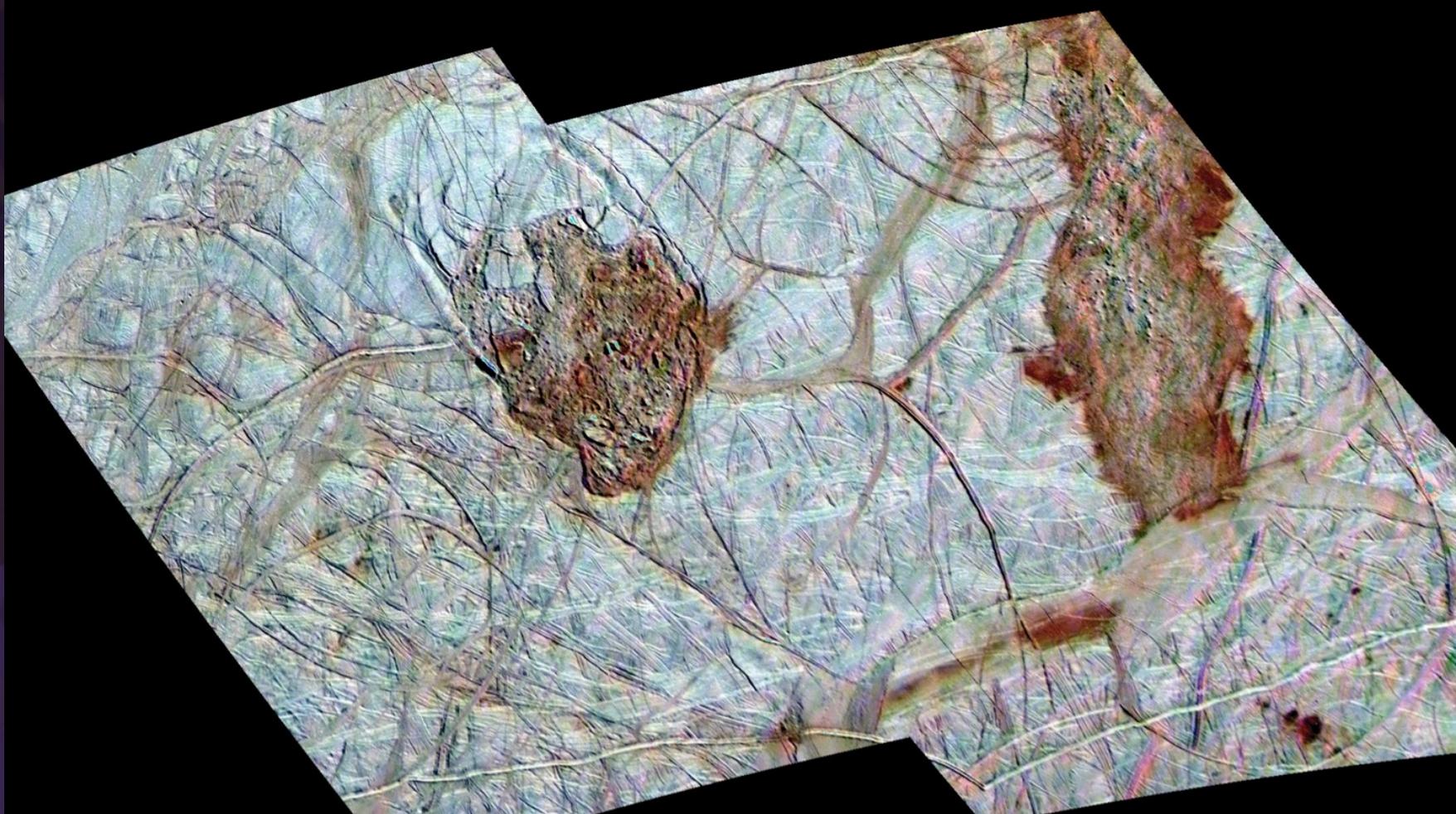
Europa's unique geology: Chaos, pits, spots, domes



- *Conamara Chaos*,
(9 m/pixel, 4 km across)

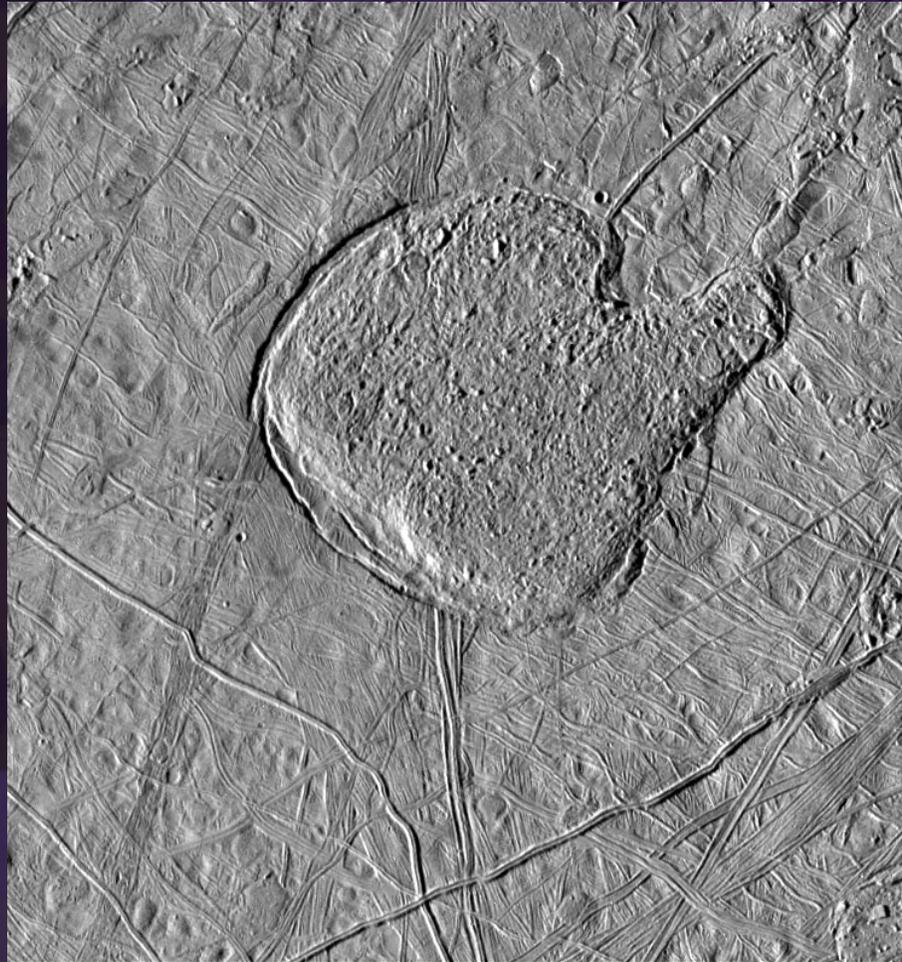


Europa's unique geology: Chaos, pits, spots, domes

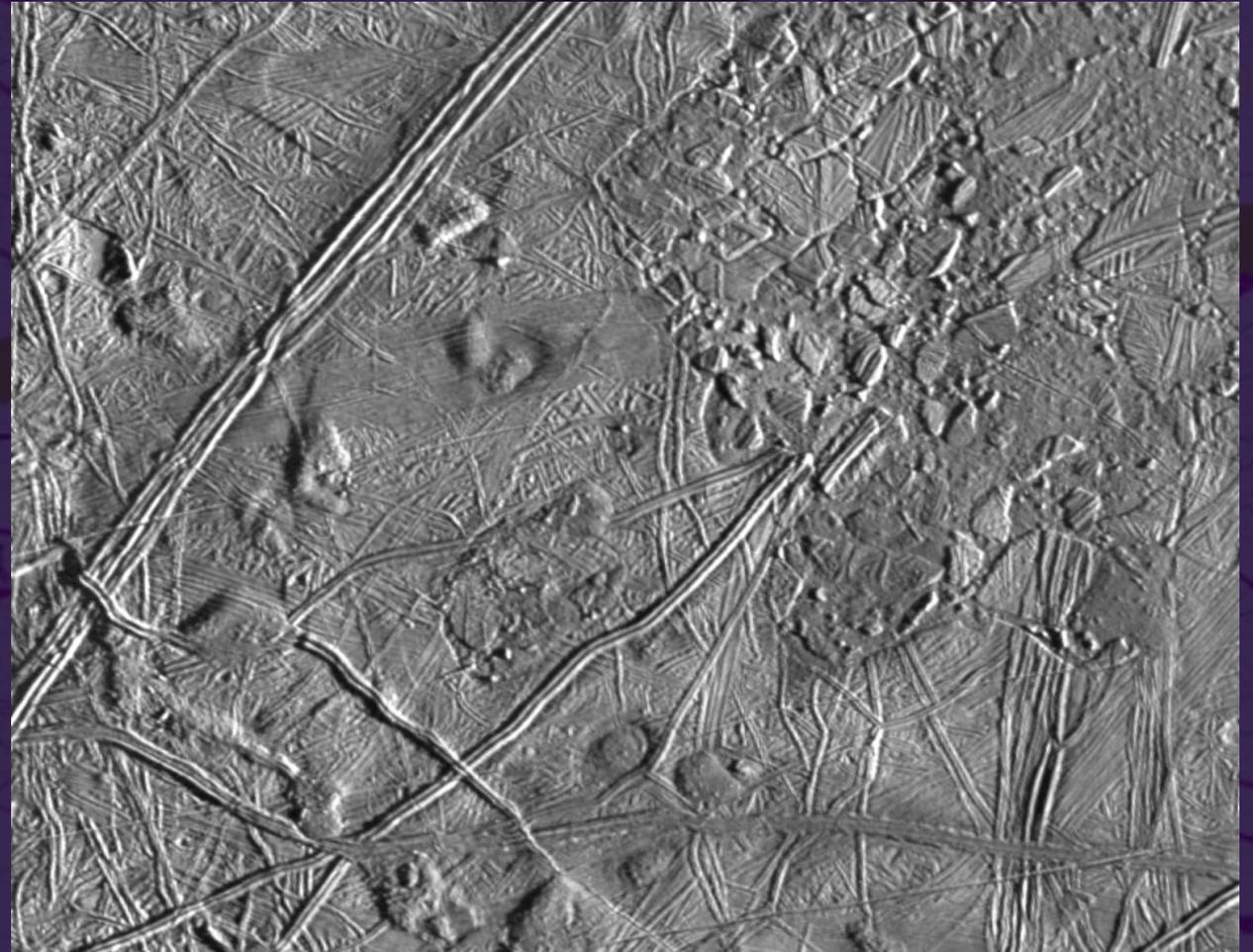


- *Thera and Thrace Maculae*
(220 m/pixel, 525 km x 300 km)

Europa's unique geology: Chaos, pits, spots, domes

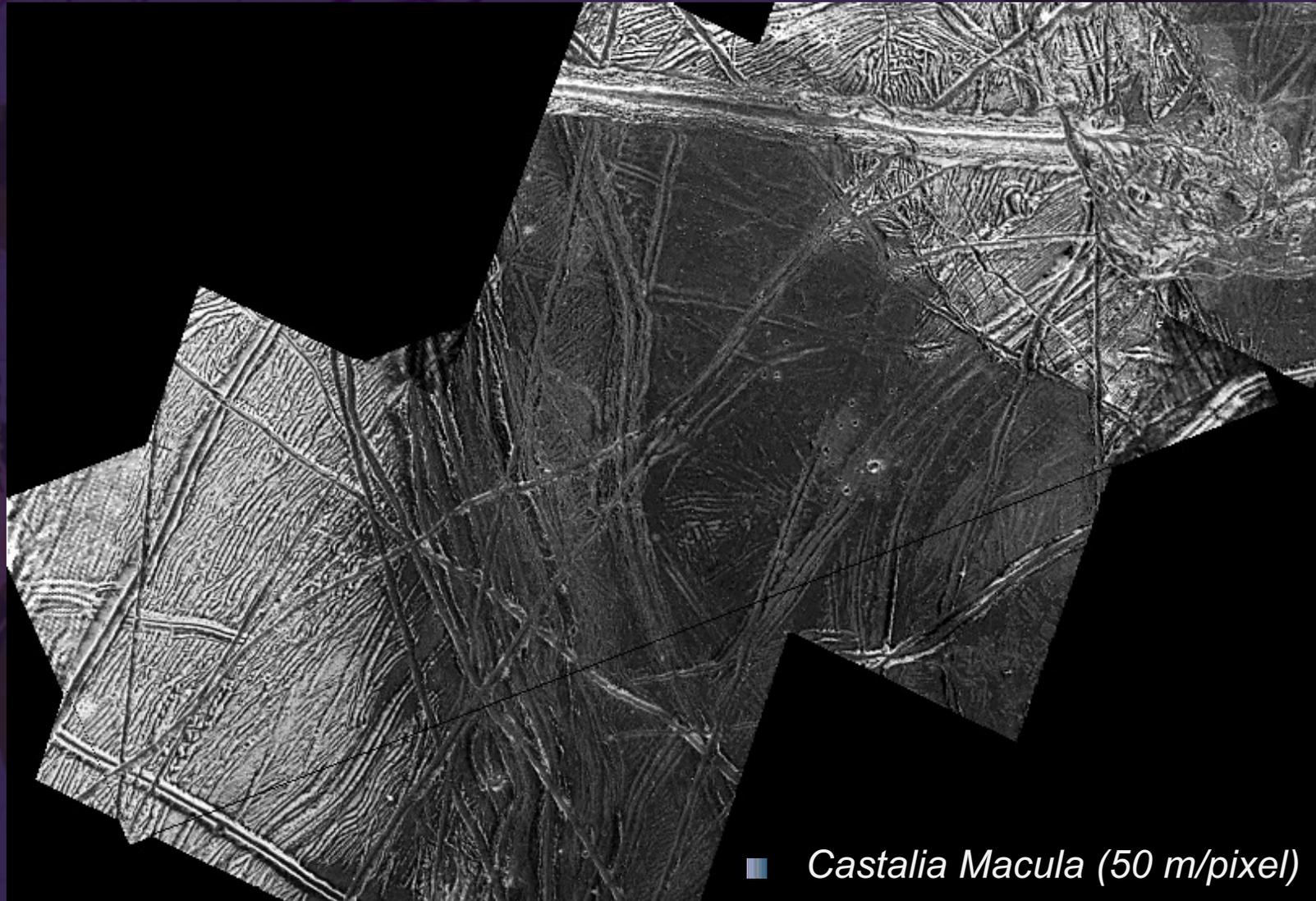


■ *Murias Chaos (235 m/pixel, 175 km x 180 km)*

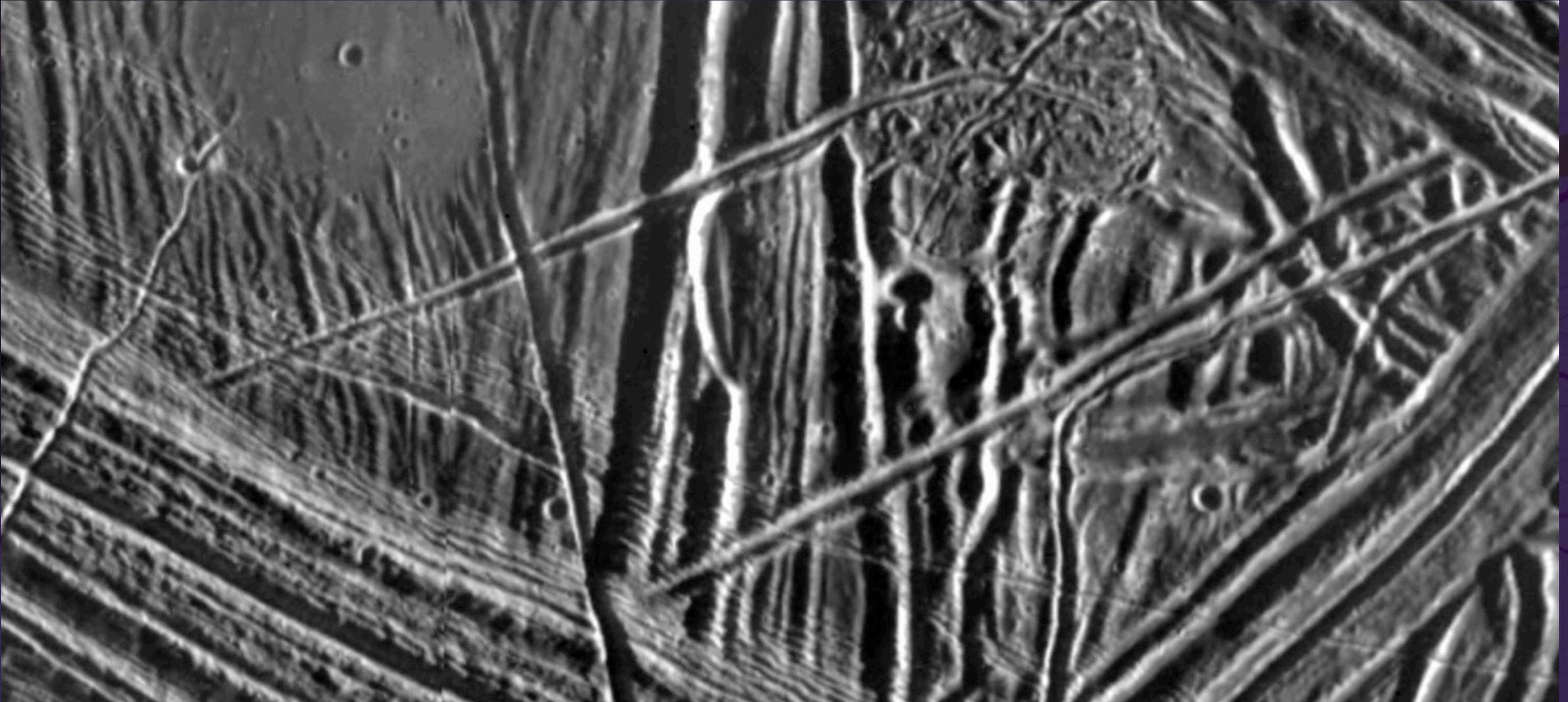


■ *Pits, spots and domes (180 m/pixel, 140 km x 100 km)*

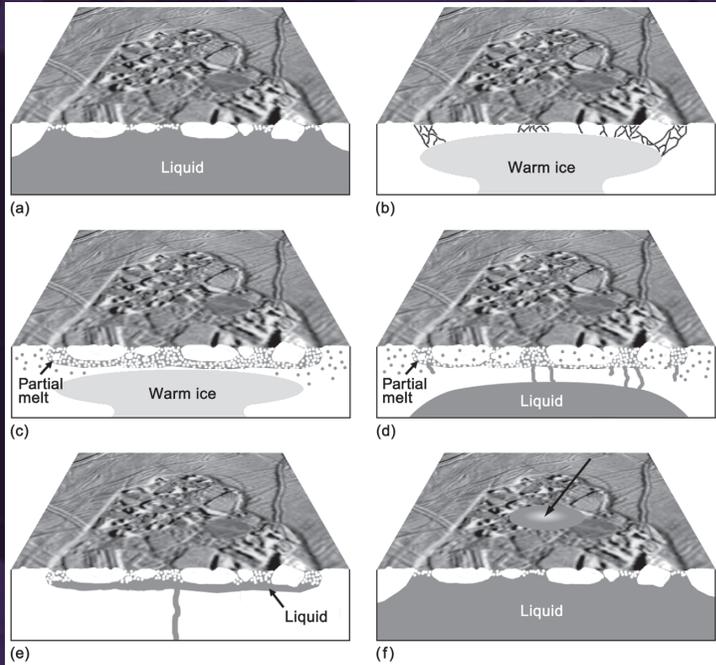
Europa's unique geology: Complex cross-cutting relationships



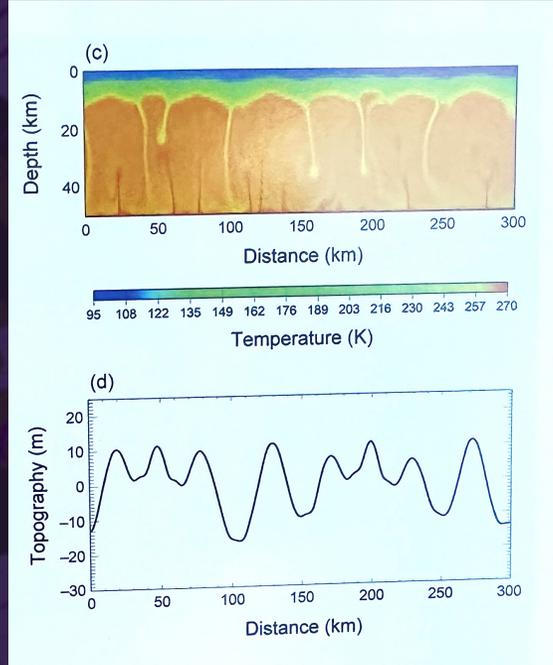
Europa's unique geology: Complex cross-cutting relationships



Europa's unique geology: Formation processes

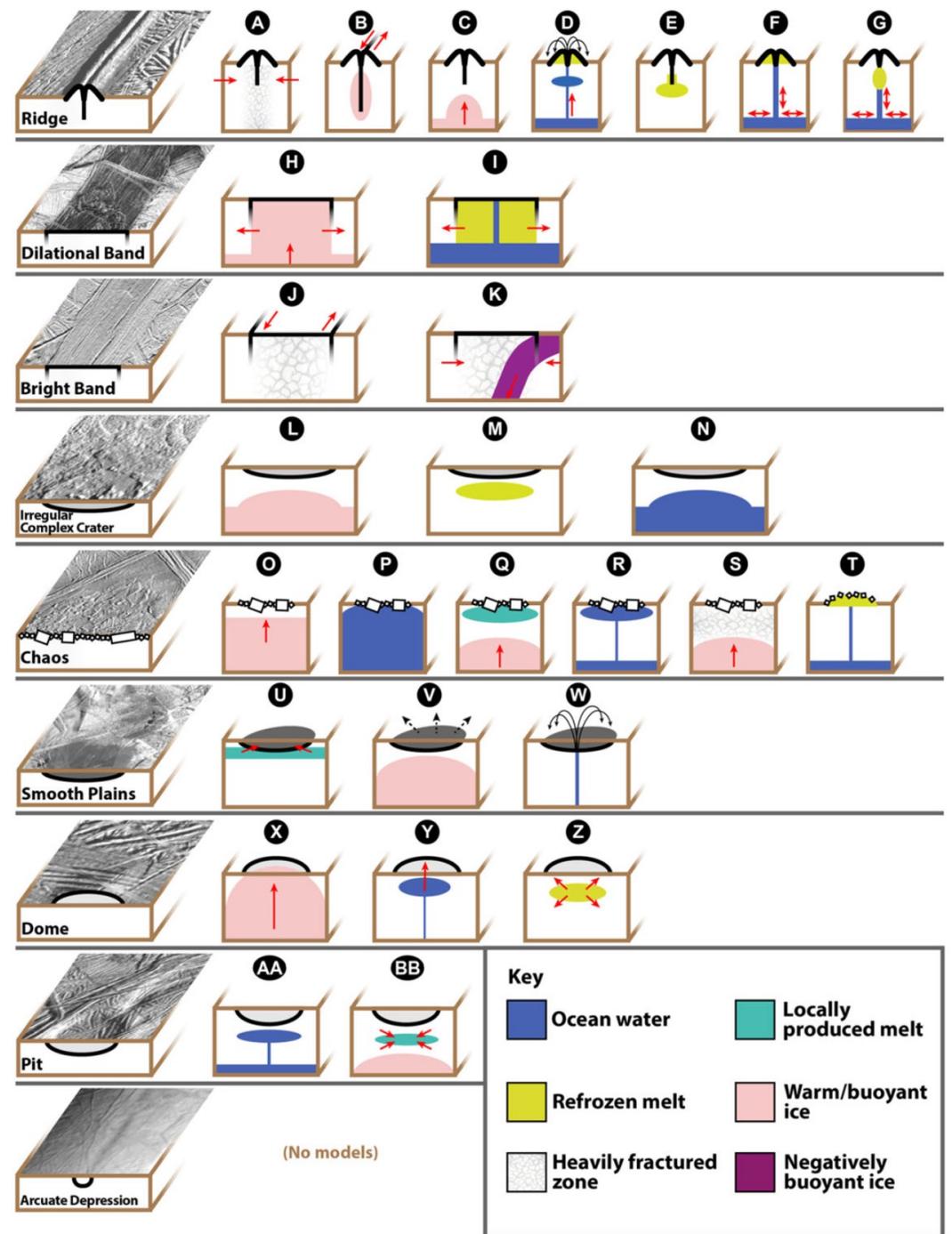


Collins and Nimmo 2009

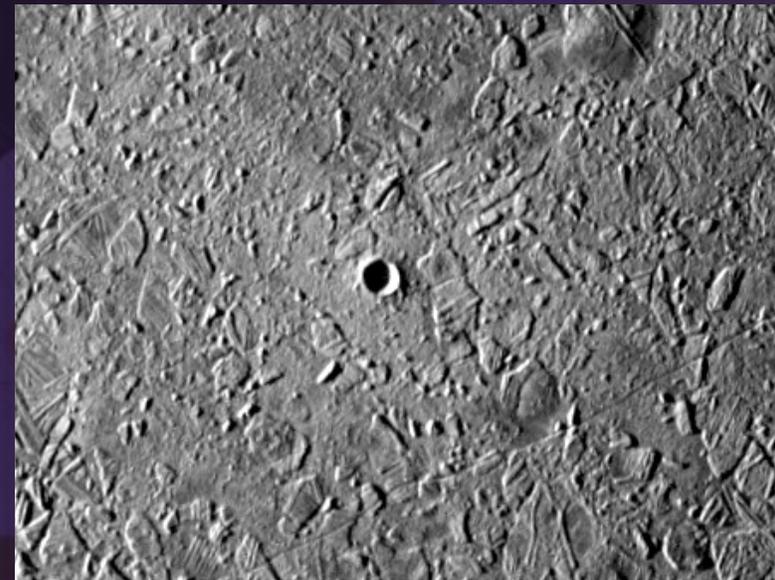
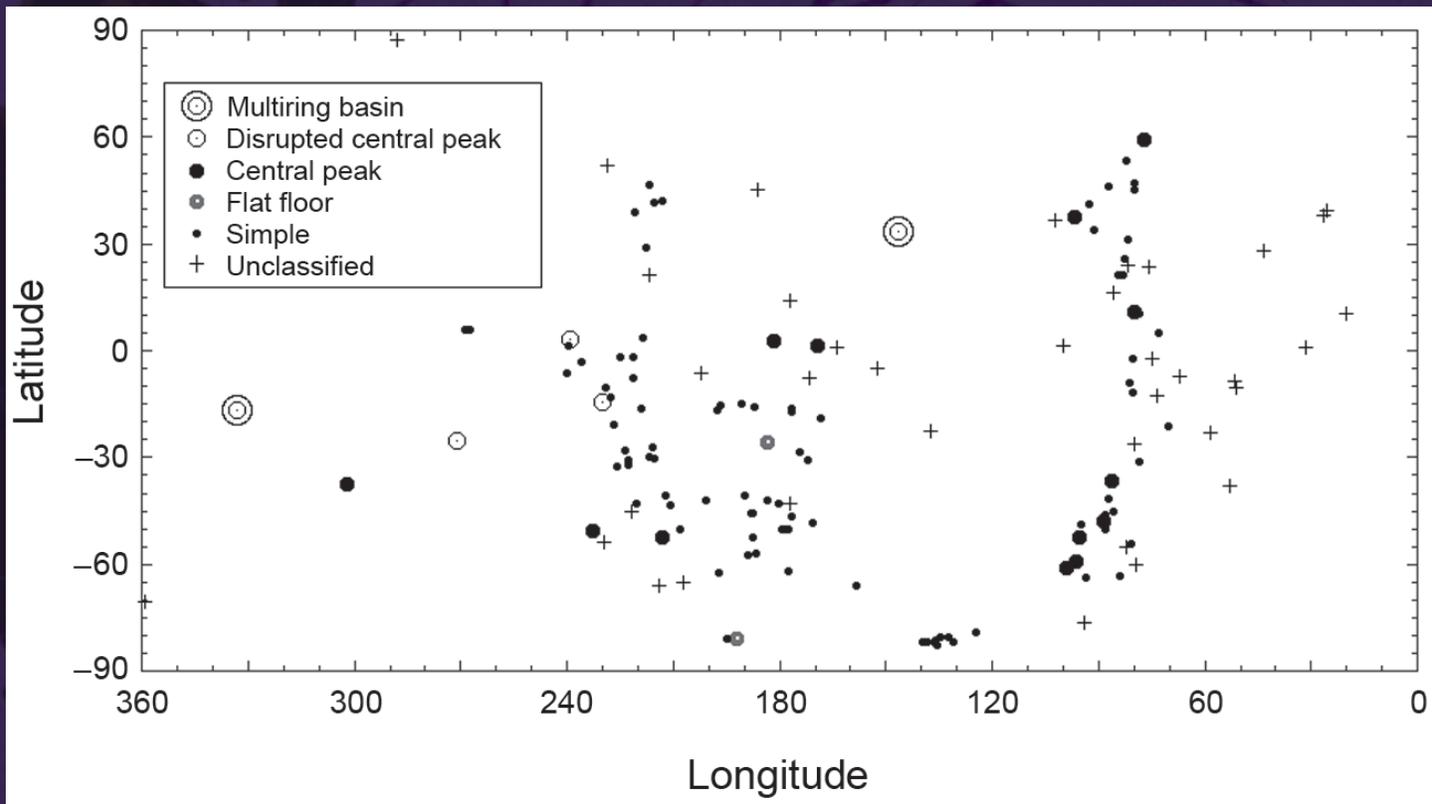


Barr and Nimmo 2029

Daubar et al. 2024
Figure by G Collins



Europa's unique geology: Impact structures



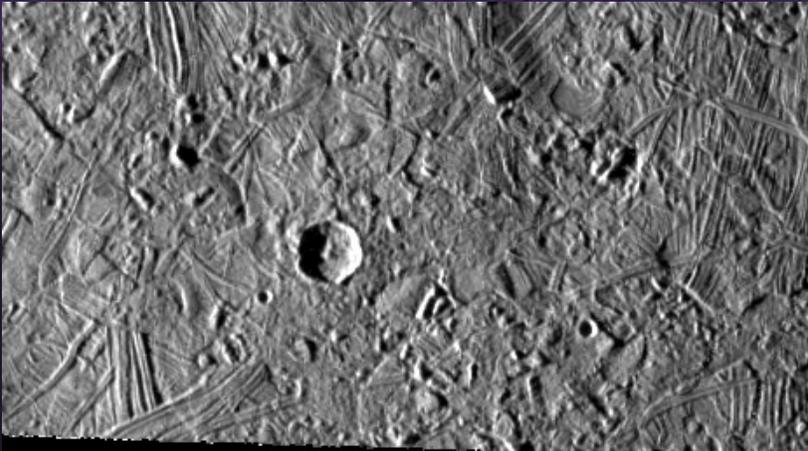
■ *Camulus (4.8 km diameter)*



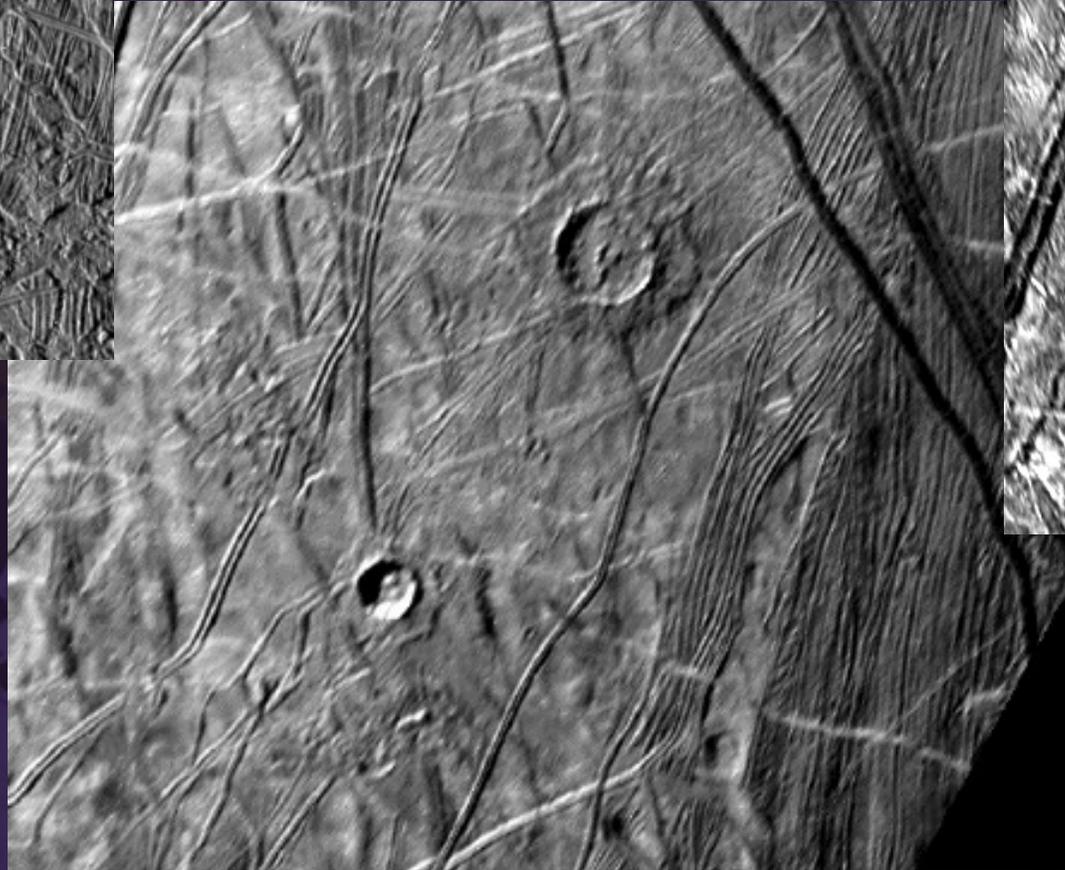
■ *Dylan (5.1 km diameter)*

- *Craters >1 km diameter (Schenk and Turtle 2009)*
- *Distribution reflects wide resolution range of imaging coverage*

Europa's unique geology: Impact structures

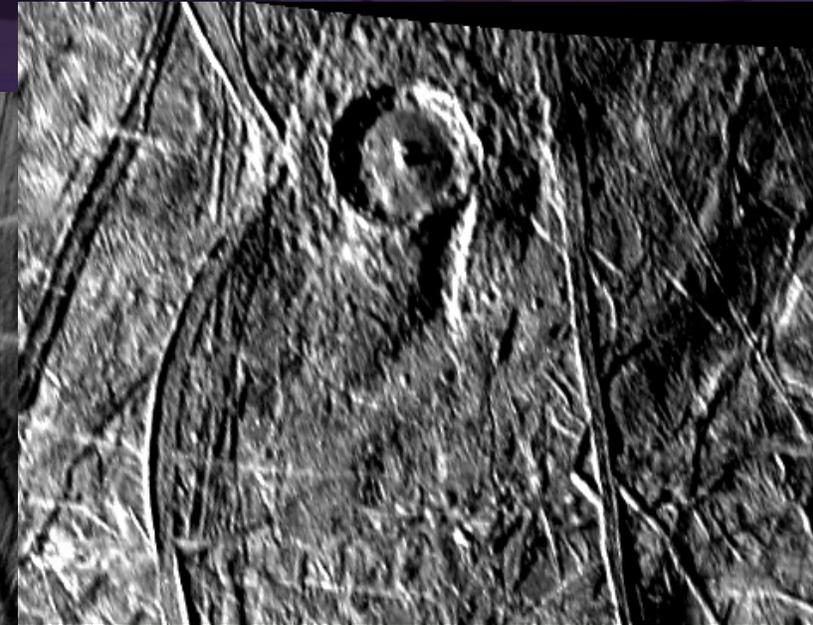


■ *Brigid (8.5 km diameter)*



■ *Grainne (13.5 km diameter)*

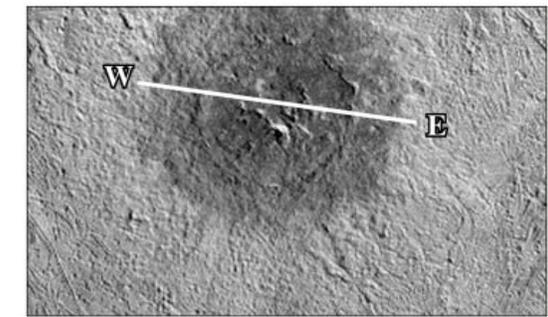
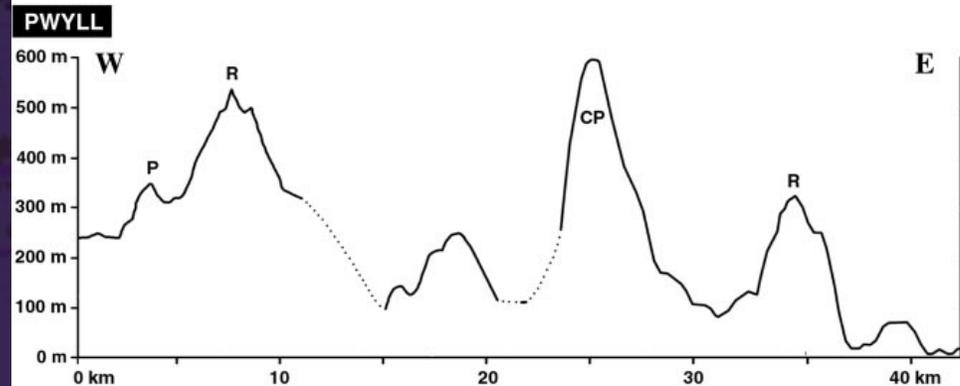
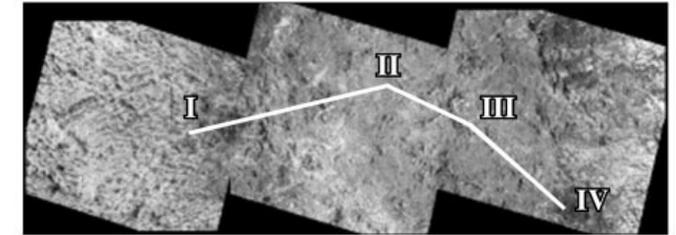
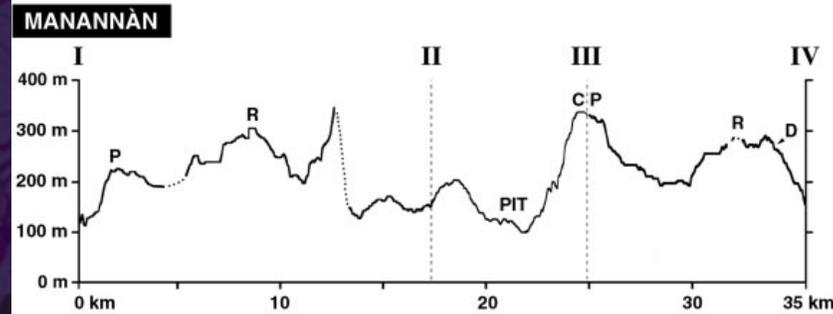
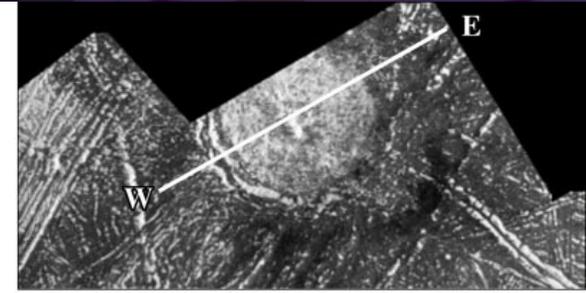
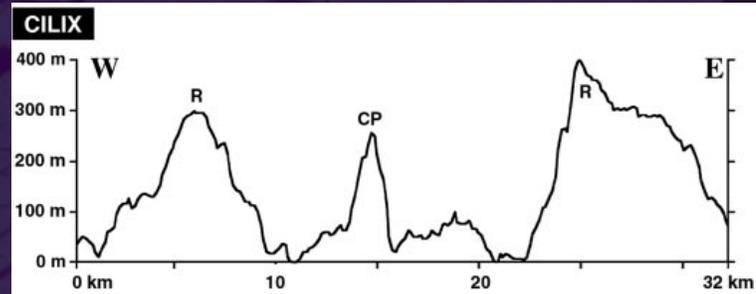
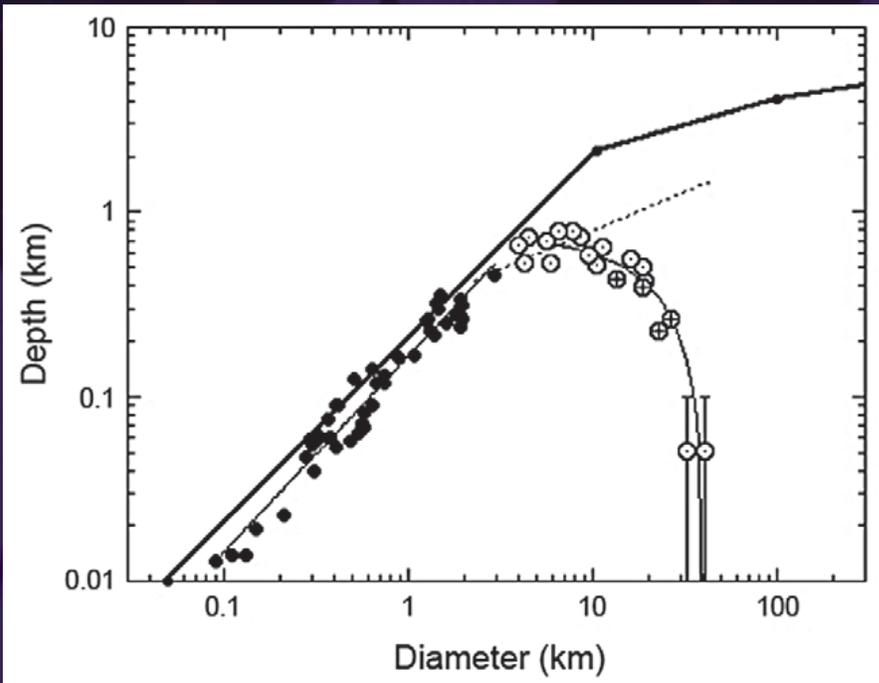
■ *Diarmuid (7.8 km diameter)*



■ *Maeve (20.4 km diameter)*

Europa's unique geology: Impact structures

- Large craters are shallower than for other icy satellites, interpreted as reflecting weak rheology in the lower crust during crater collapse

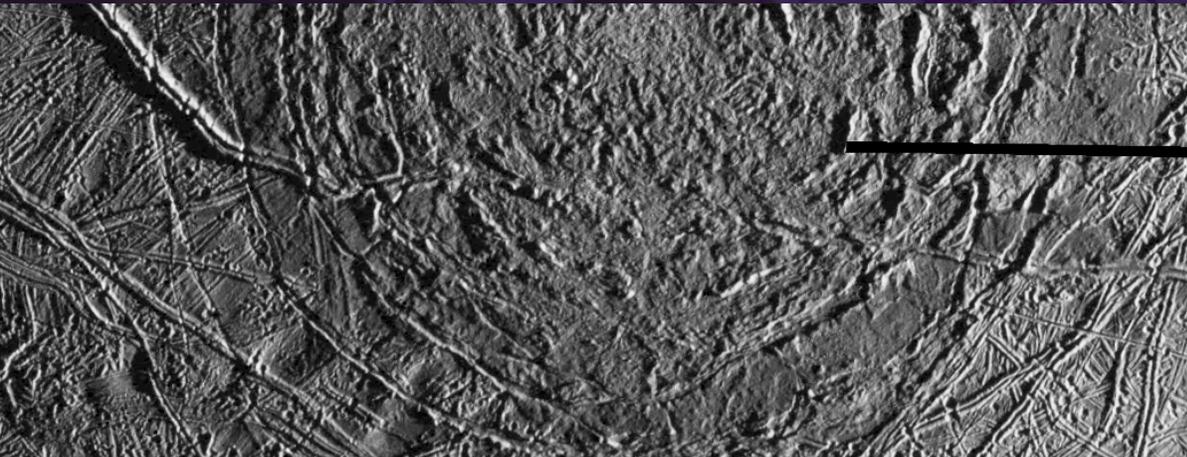


Europa's unique geology

Impact structures



■ Tegid (~28 km diam., Moore et al. 2001)

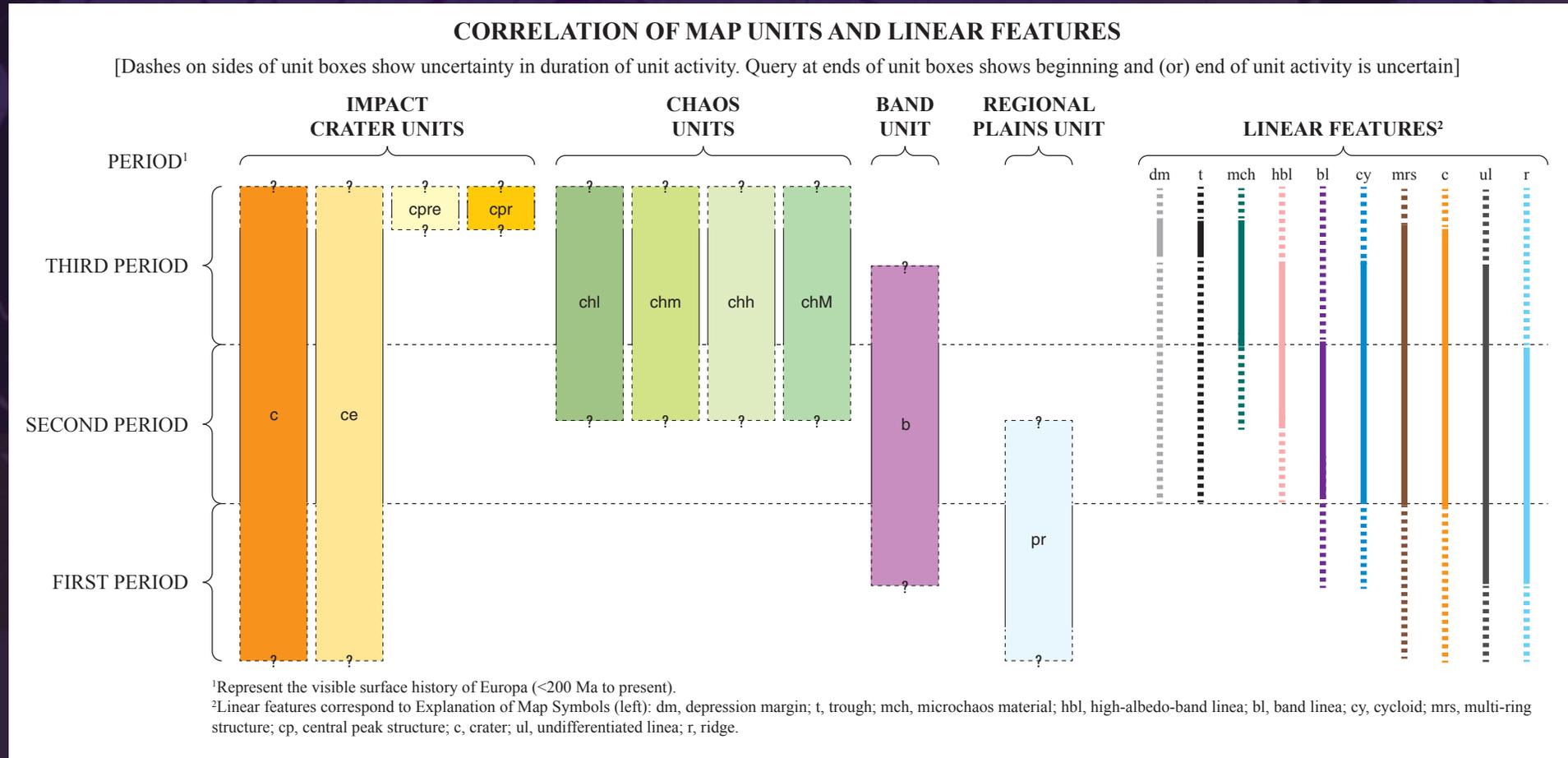


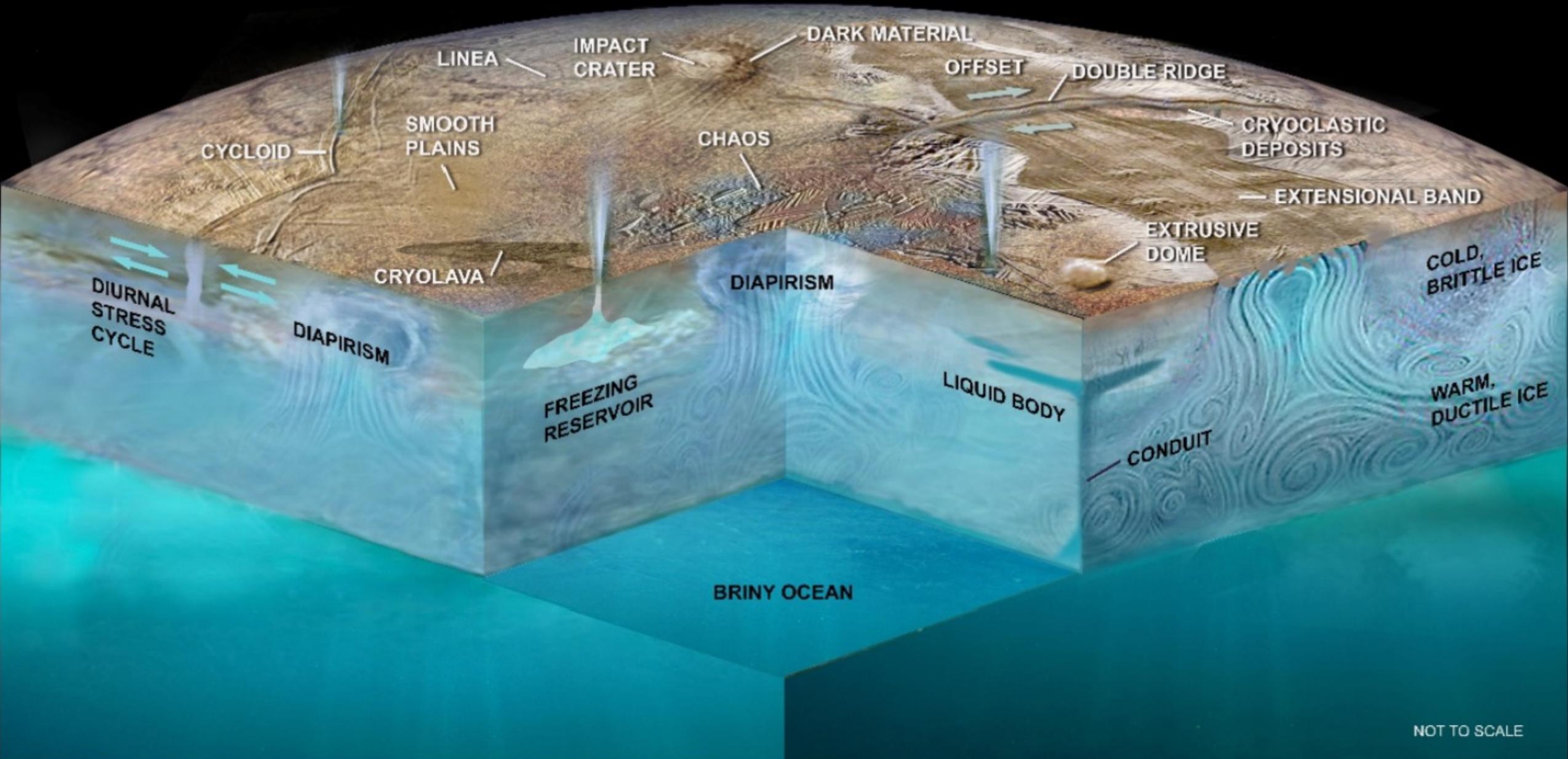
■ Callanish (~29-47 km estimated equivalent final rim diameter, Moore et al. 2001)



■ Tyre (~44 km estimated equivalent final rim diameter, Moore et al. 2001)

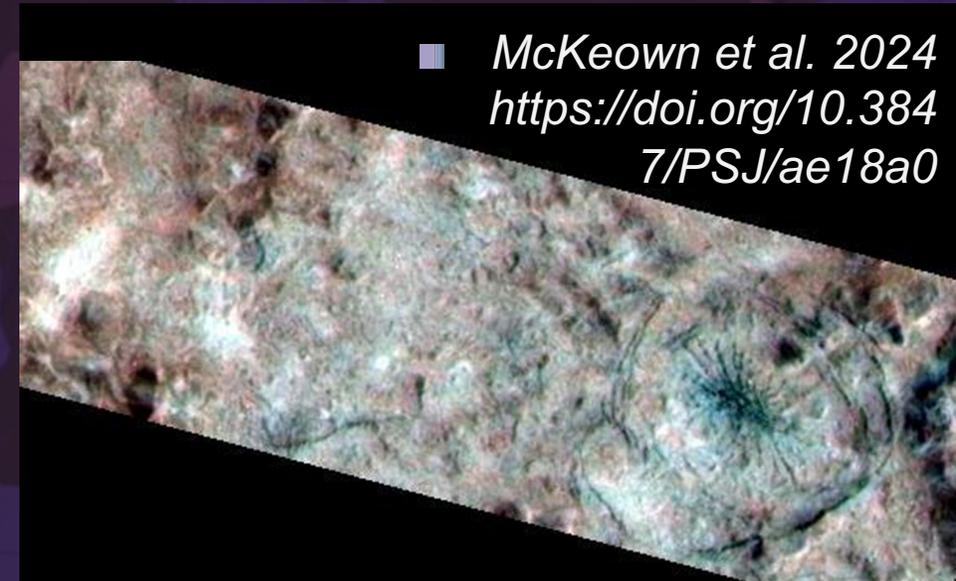
Relative geologic timeline (Leonard et al. 2024)

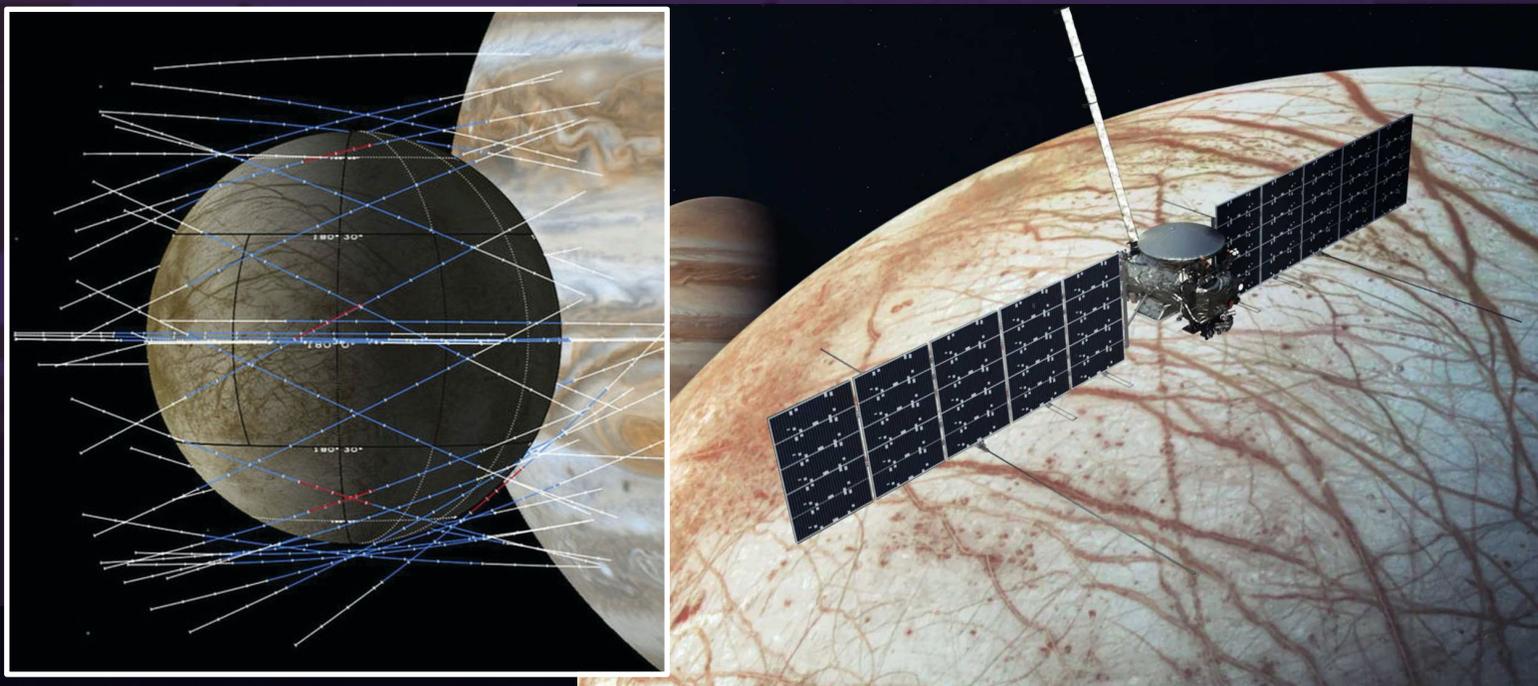




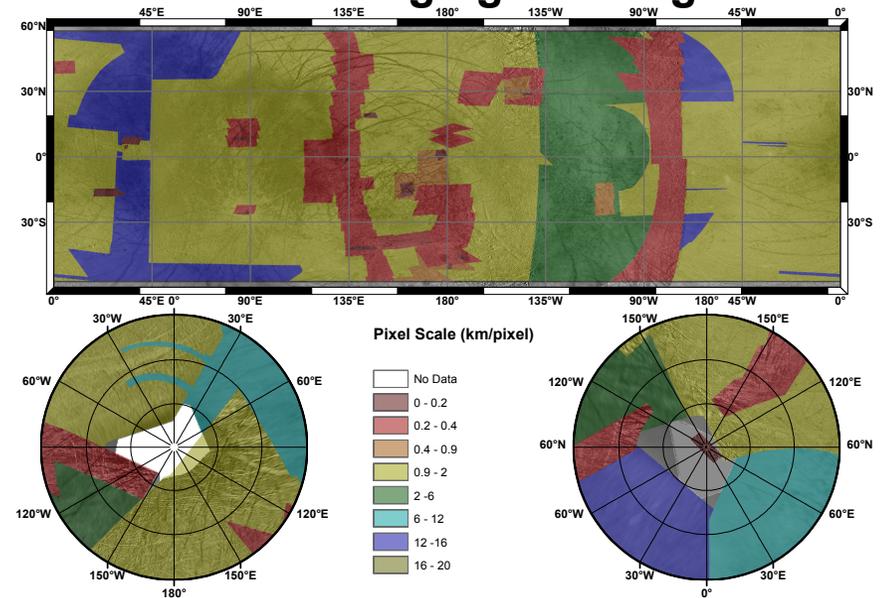
Many outstanding questions

- Nature of the ice shell and ocean?
 - Thickness, structure, thermal profile, and internal dynamics of ice shell
 - Potential for transfer of material between the ocean and the surface
 - Composition and habitability of ocean
- Formation processes for geological features?
 - Role(s) of convection, intrusive, and/or extrusive cryovolcanism
 - Global tectonics and relationships
 - Balance of extensional and compressional tectonics
- Recent or current activity?
 - Potential plume eruptions
- Nature of silicate mantle and deeper interior





Galileo Imaging Coverage



Europa-UVS

UV Spectrograph:
Surface, plume & atmosphere
composition

EIS

Narrow & wide angle
camera: Mapping
alien landscape in
3D & color

MISE

IR Spectrometer:
Surface chemical
fingerprints

E-THEMIS

Thermal Imager:
Searching for hot
spots

REASON

Ice-Penetrating
Radar: Plumbing
the ice shell

REMOTE SENSING

MASPEX

Mass Spectrometer:
Sniffing atmospheric
composition

SUDA

Dust analyzer:
Surface and plume
composition

ECM

Magnetometer:
Sensing ocean
properties

PIMS

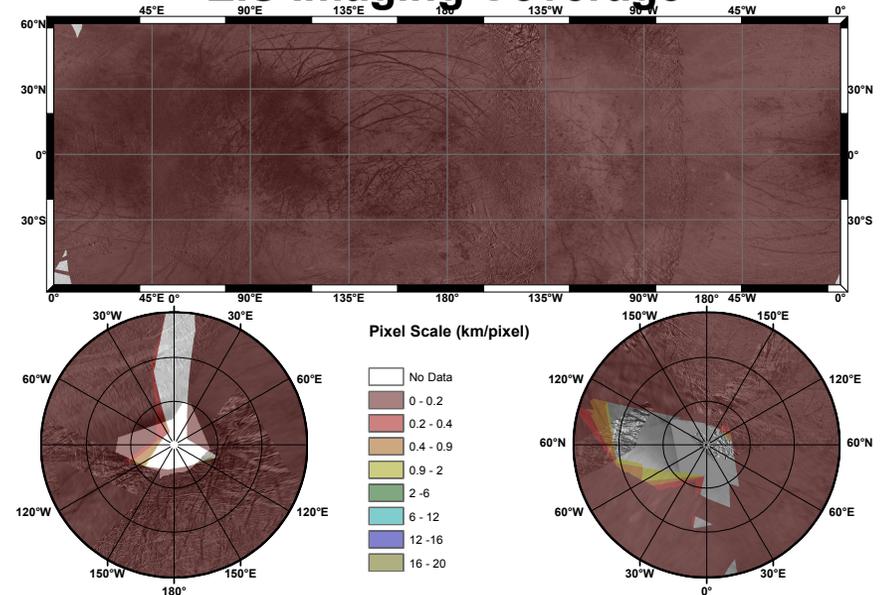
Faraday Cups:
Plasma
environment

Gravity/Radio Science

Measuring tidal
flexing, ice shell &
ocean depth

IN SITU

EIS Imaging Coverage





With deep gratitude to the
entire team who designed,
built, and operated the
Galileo Mission!!!