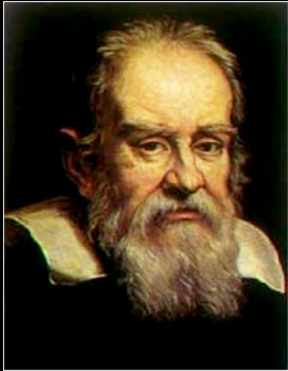




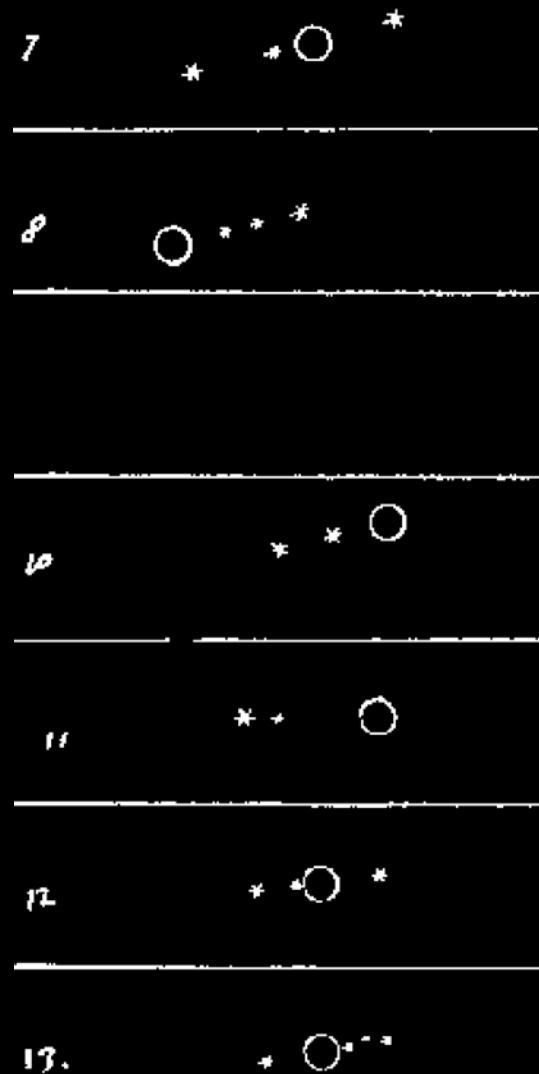
# Europa 101

Louise Prockter

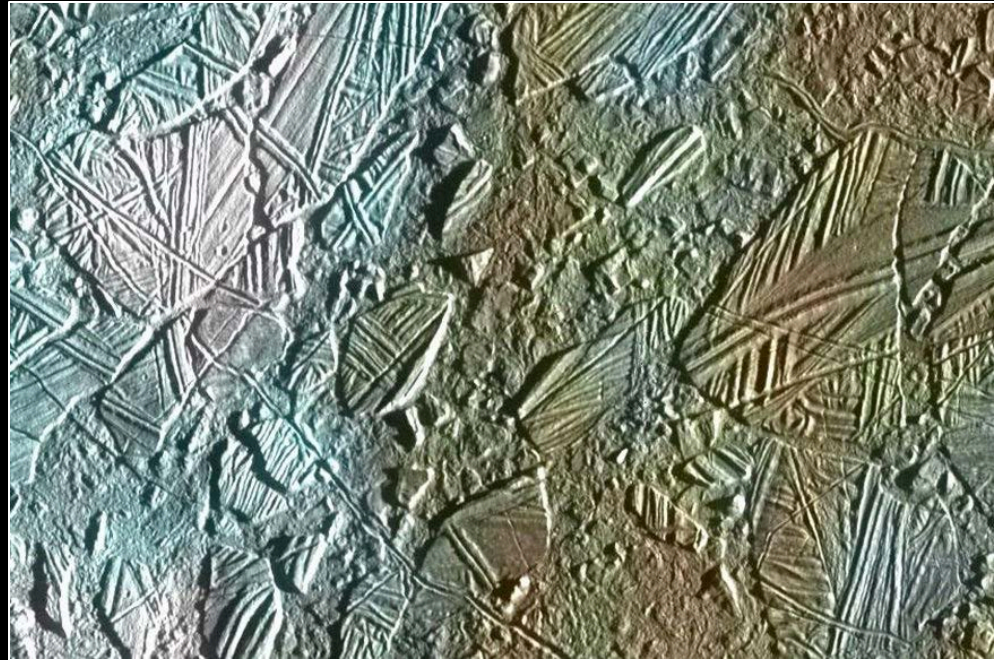
# Discovery of Jupiter's moons: January 1610



Galileo's sketches



# Galileo



Deployed from Space Shuttle Oct 1989

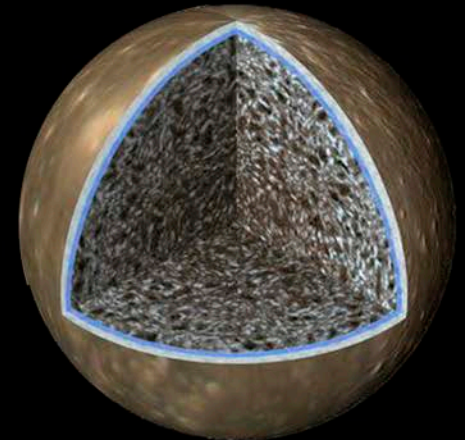
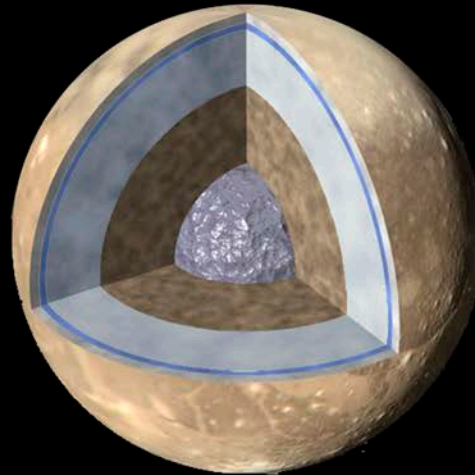
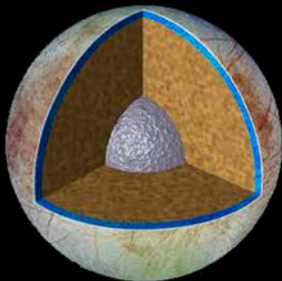
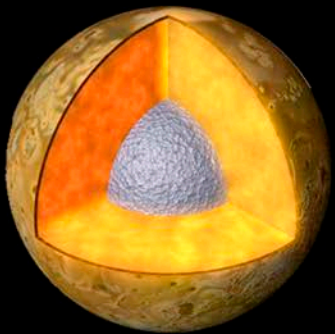
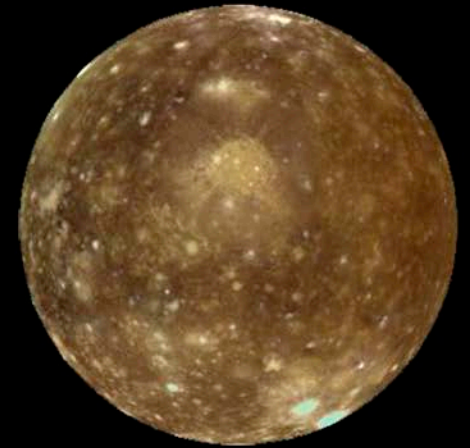
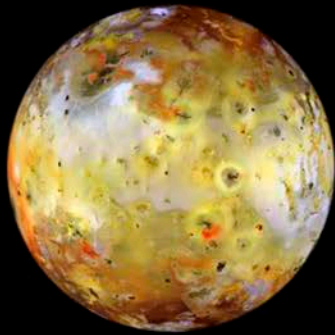
Probe deployed 7 Dec 1995

End of mission 21 Dec 2003

# The Galilean satellites



# The Galilean satellites



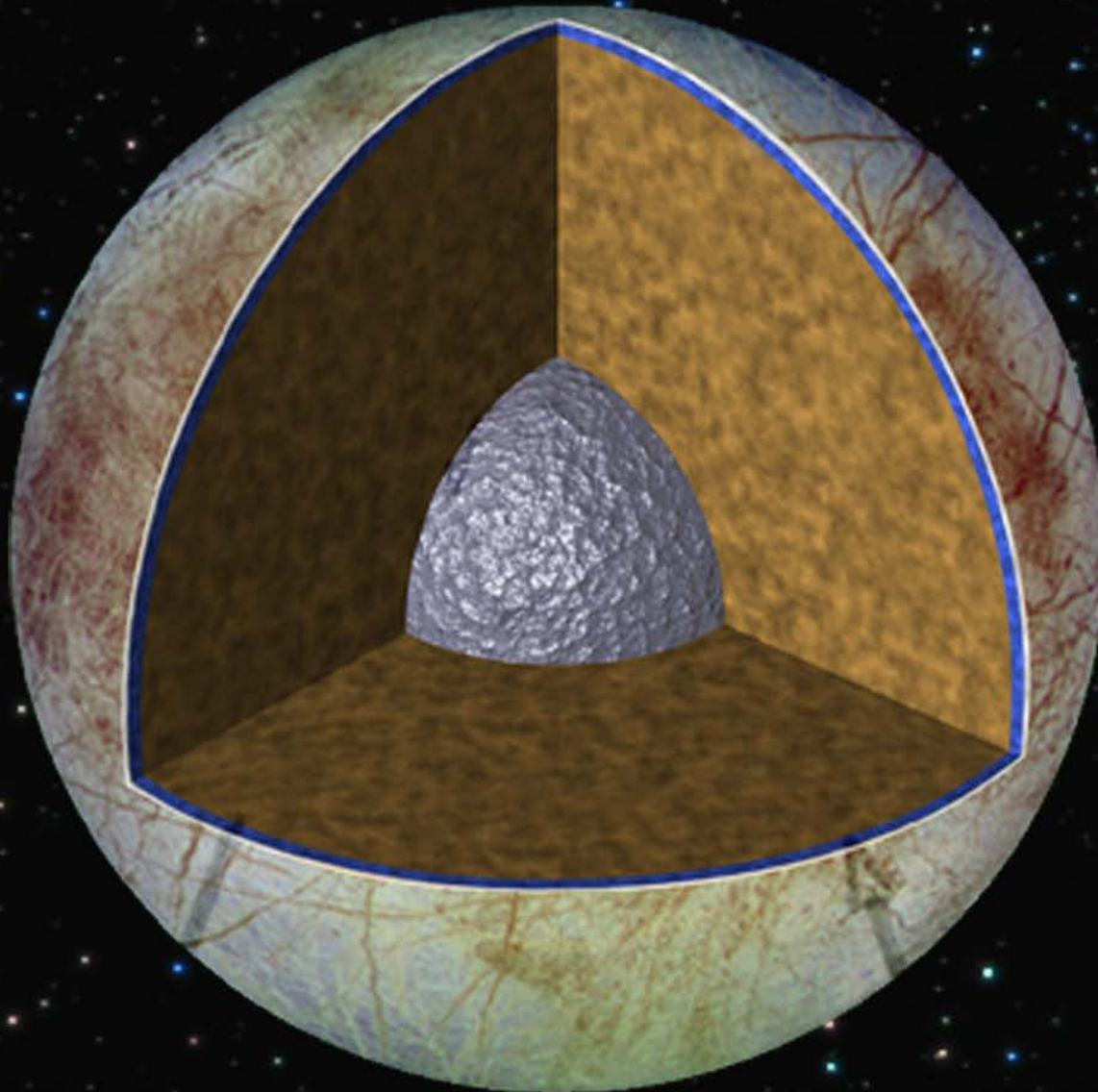
Io

Europa

Ganymede

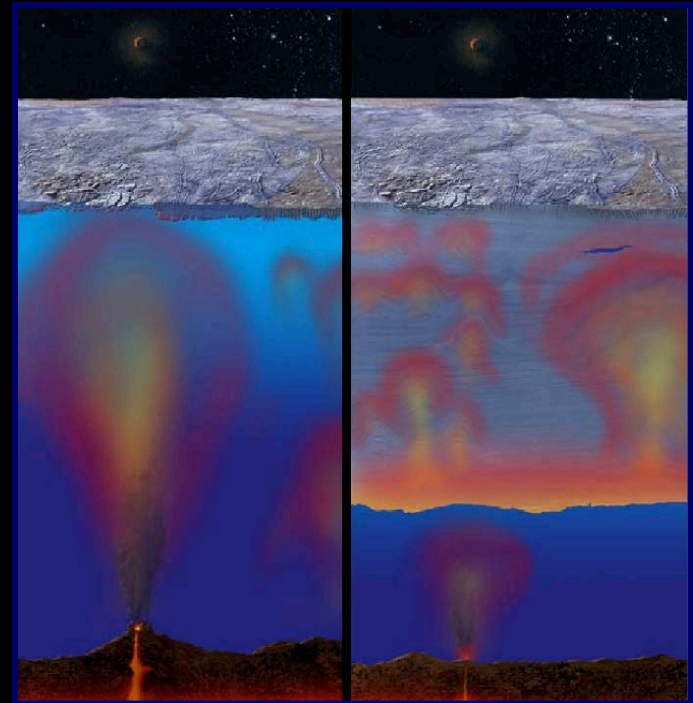
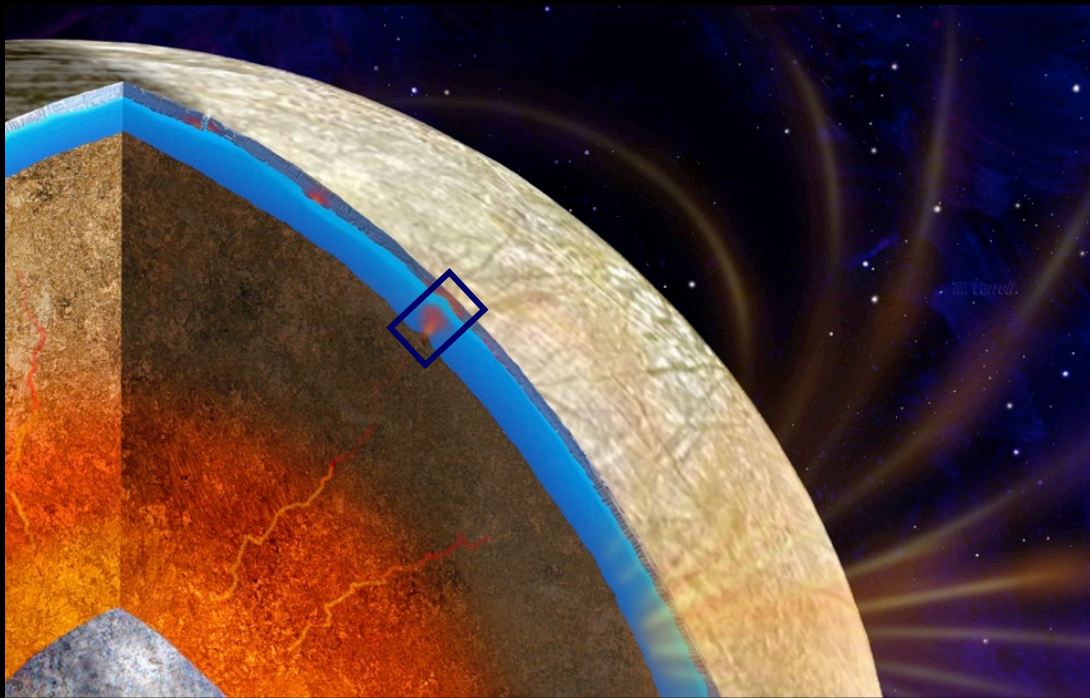
Callisto

# Interior ocean



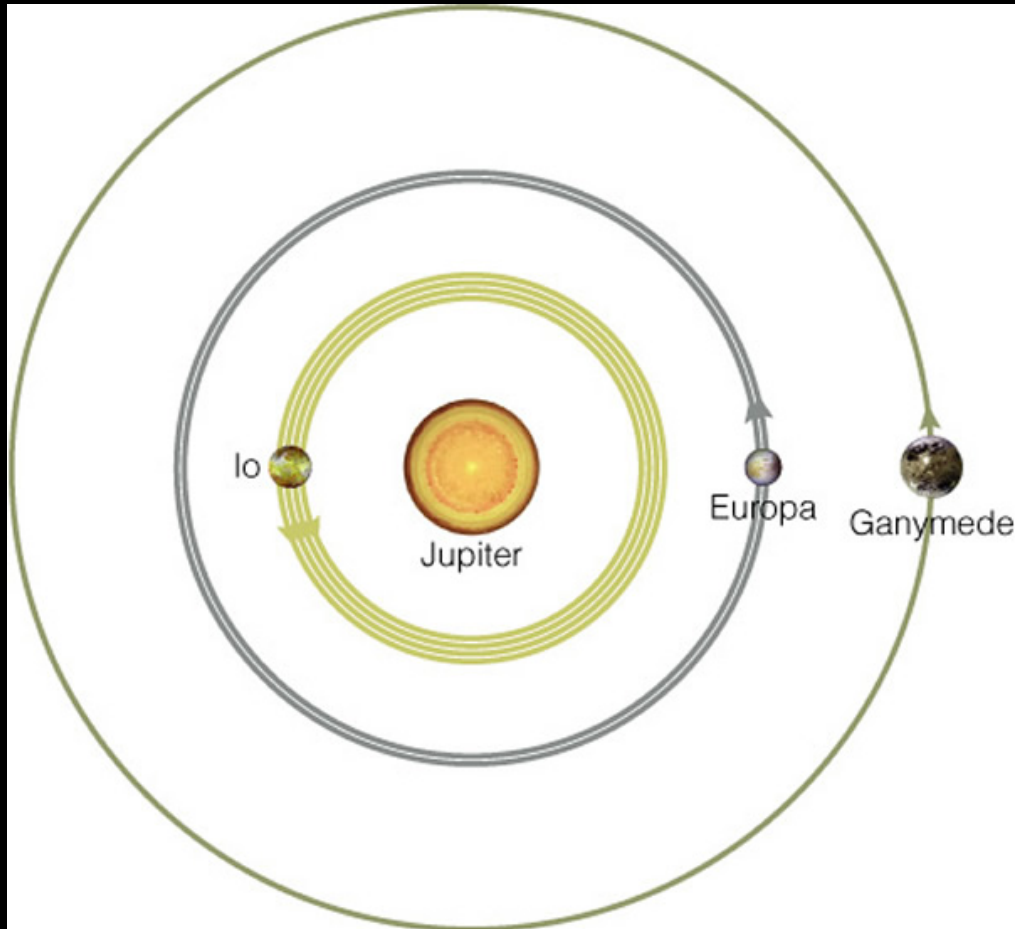
*Europa is as conductive as seawater!*

# Magnetometer evidence indicates the presence of a ~100 km thick subsurface liquid water ocean at Europa



Thickness of the overlying ice shell is the subject of intense debate  
– estimates range from a few km to ~30 km

# The Laplace resonance



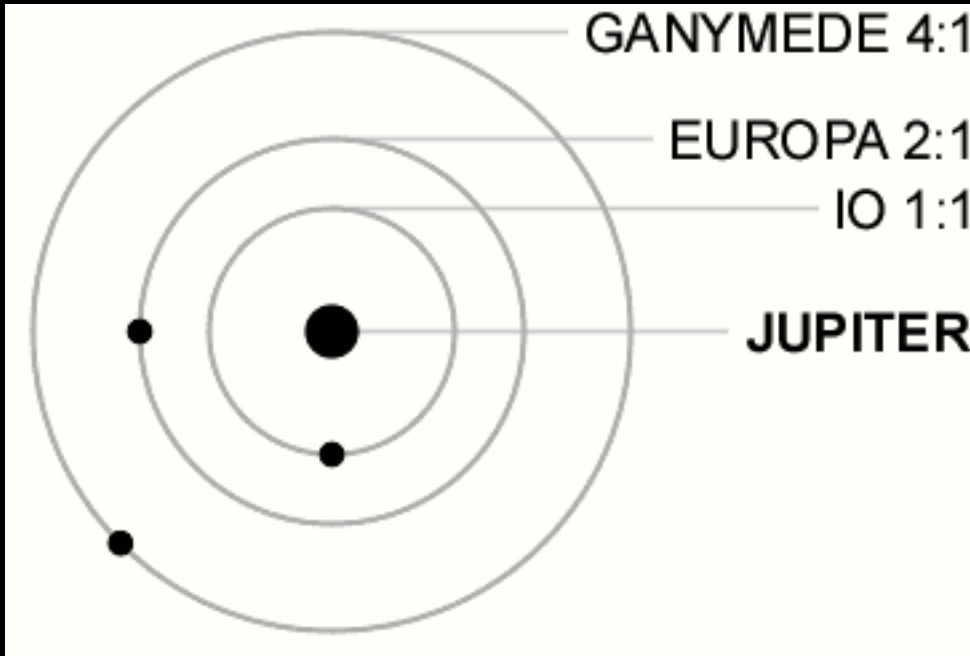
**Ganymede 7.2 days 4:1**

**Europa 3.6 days 2:1**

**Io 1.8 days 1:1**



# The Laplace resonance

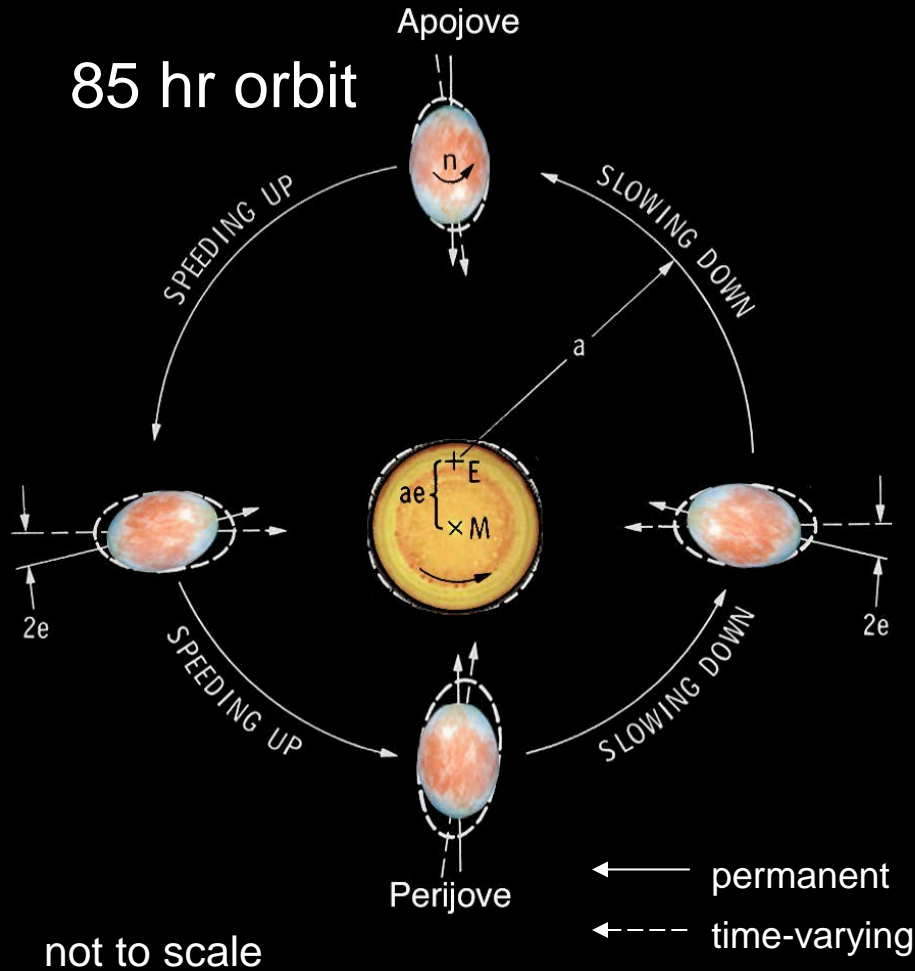


**Ganymede 7.2 days 4:1**

**Europa 3.6 days 2:1**

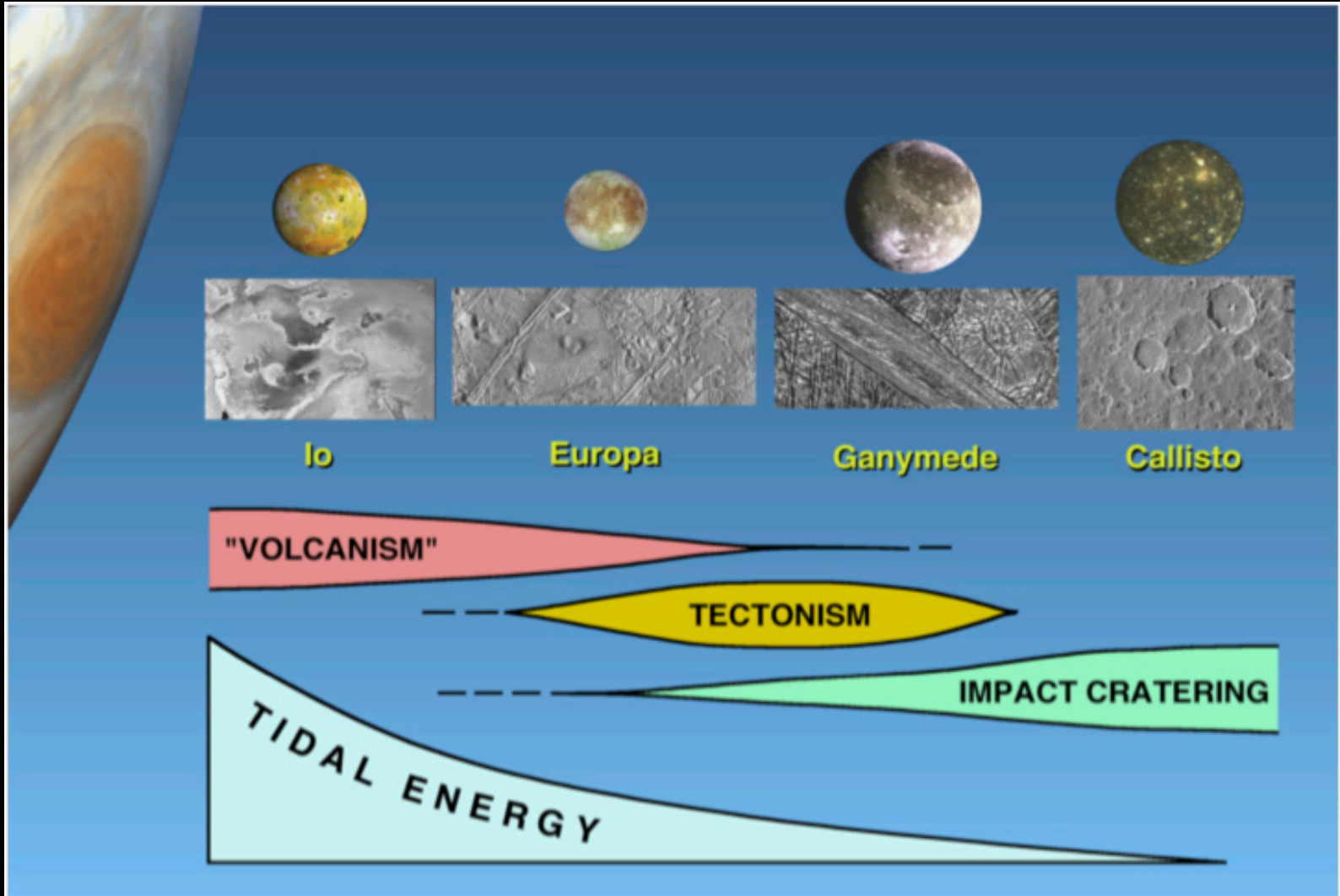
**Io 1.8 days 1:1**

# Eccentric orbit: Tidal heating



*Squeezing heats up warm ice (or rock): tidal heating!*

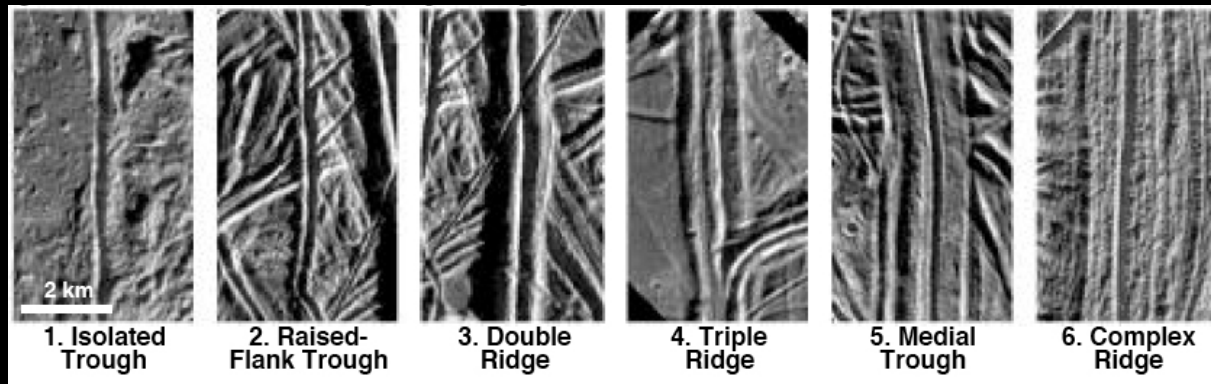
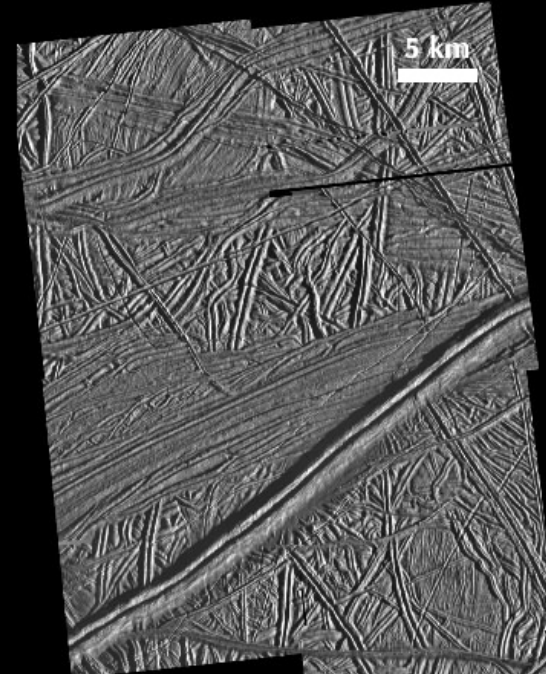
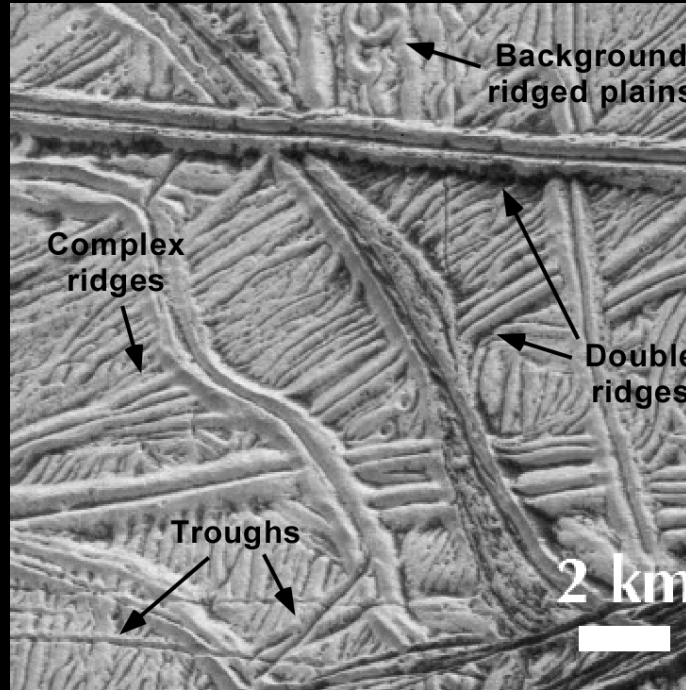
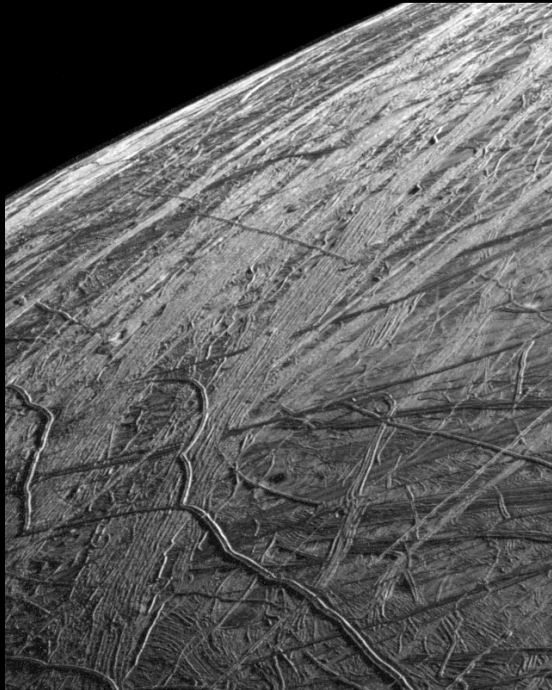
# The Galilean satellites



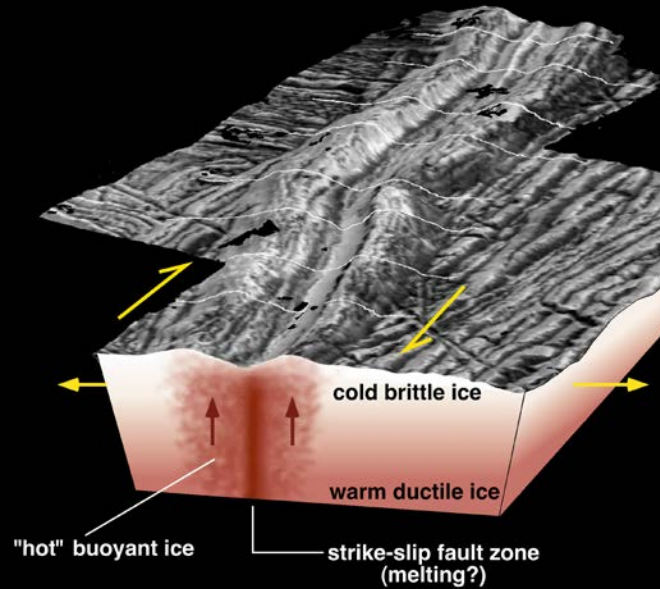
# Ridged plains



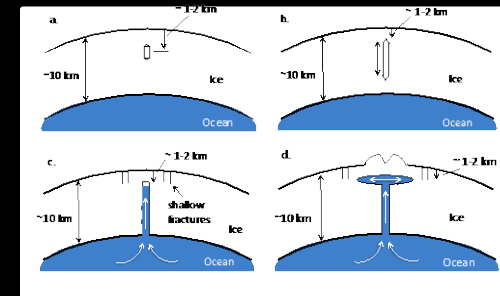
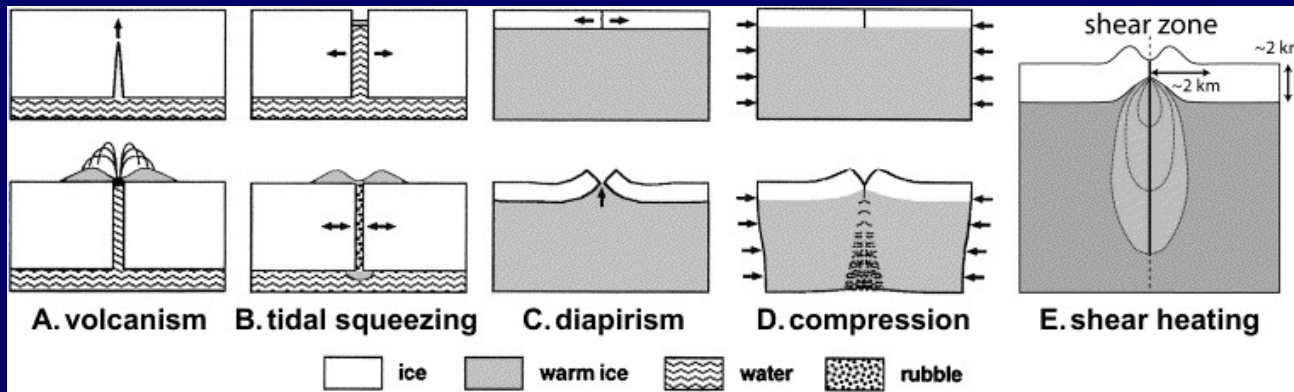
# Ridges



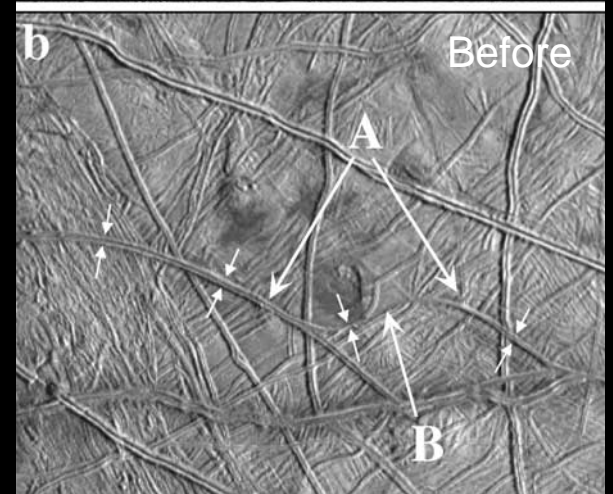
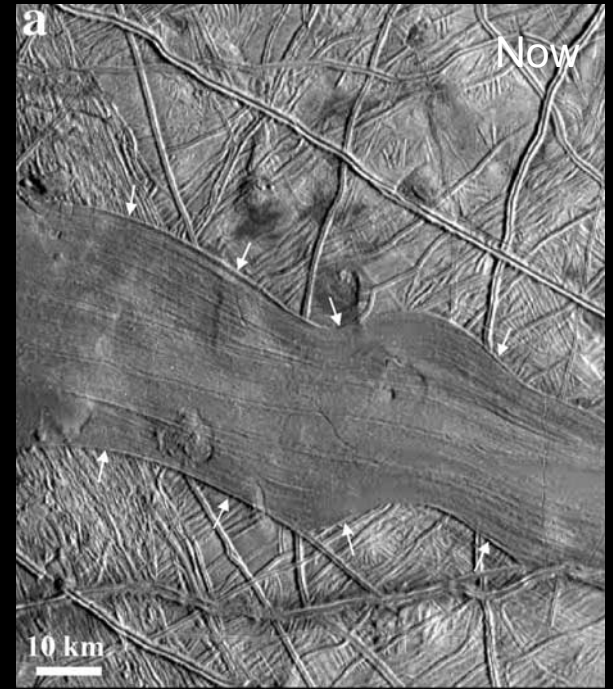
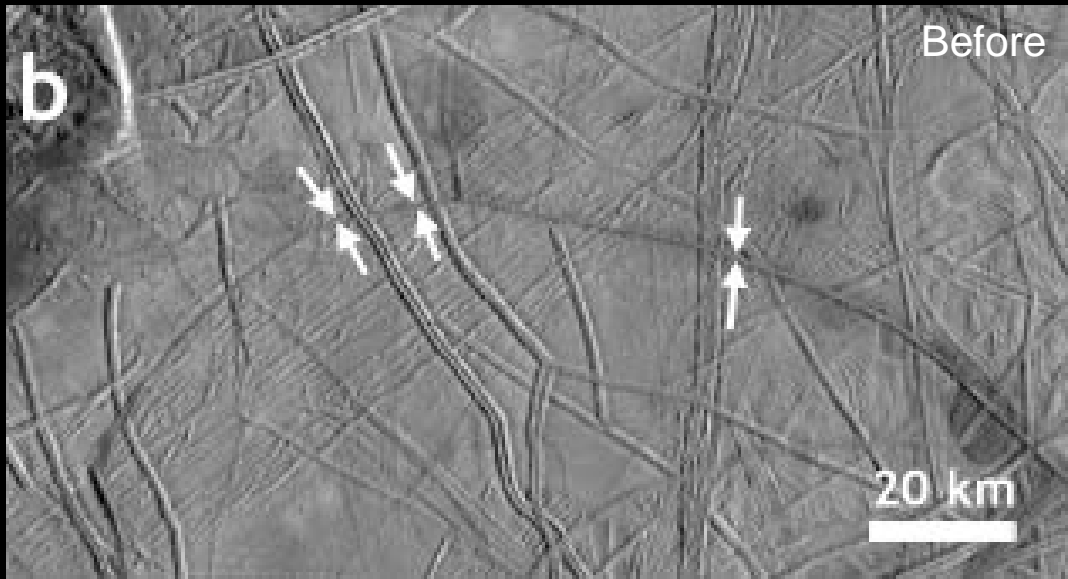
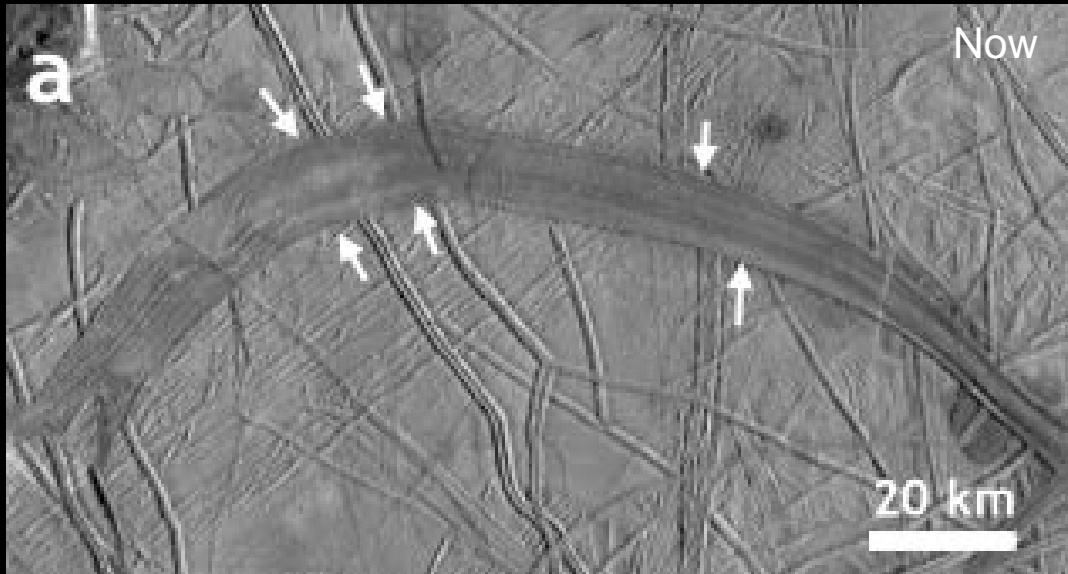
# Ridge formation models



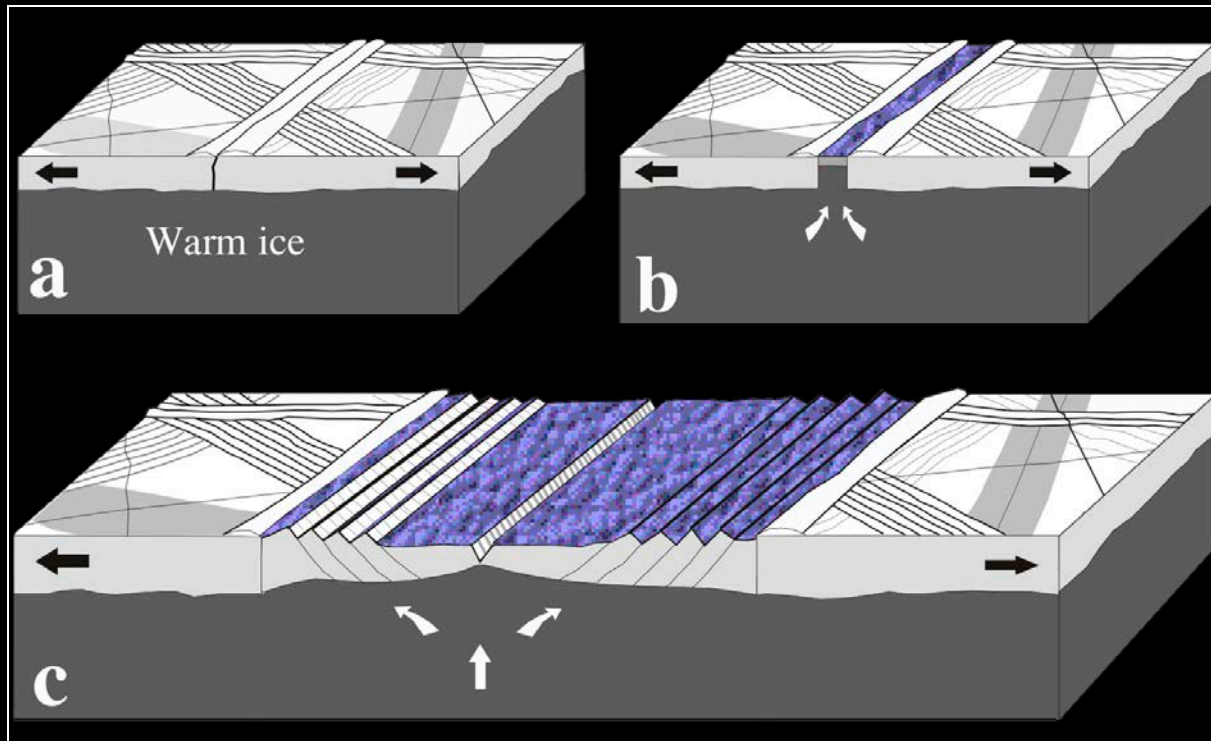
*Nimmo and Gaidos, 2002*



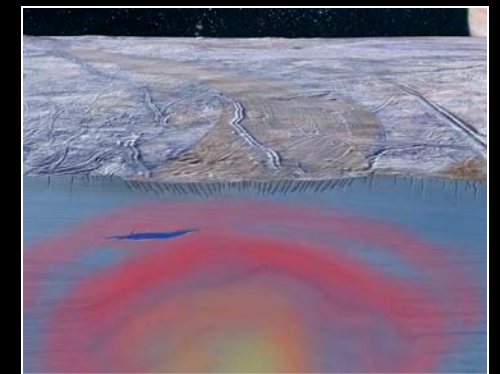
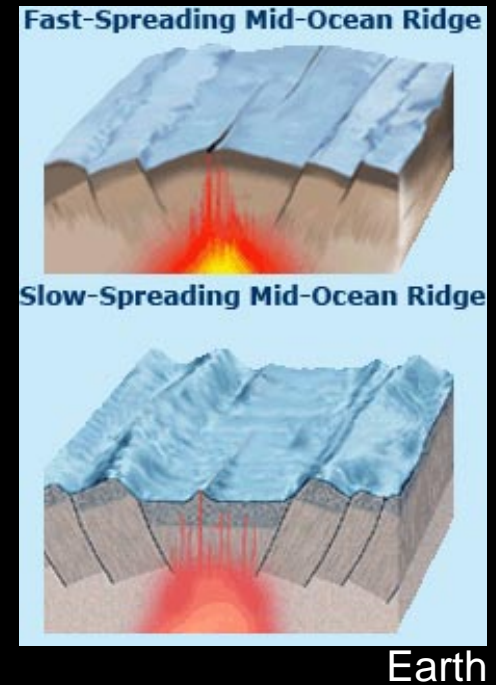
# Pull-apart bands



# “Seafloor spreading” model of band formation



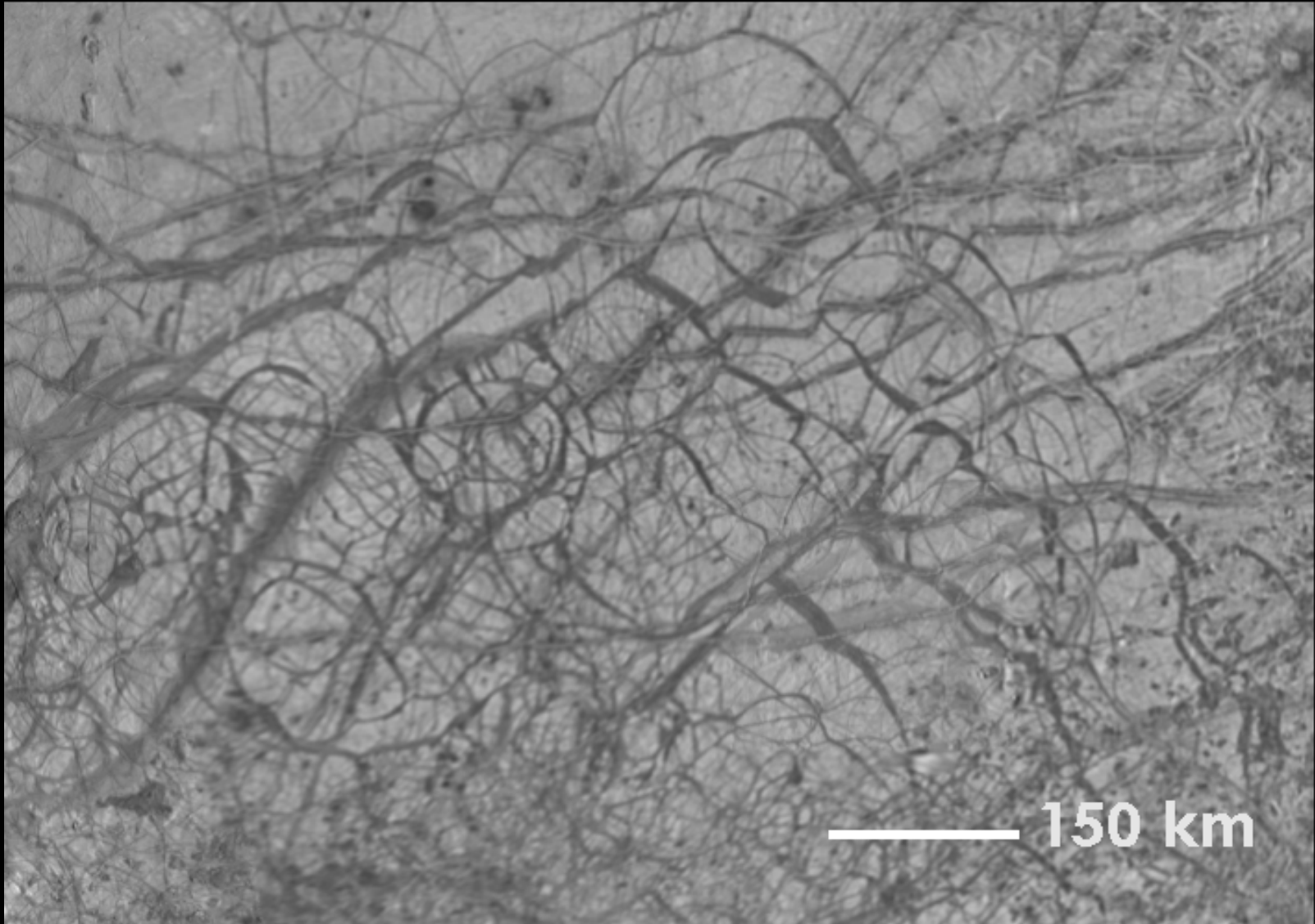
Prockter et al., 2002



*Similar mechanism to terrestrial mid-ocean ridges*

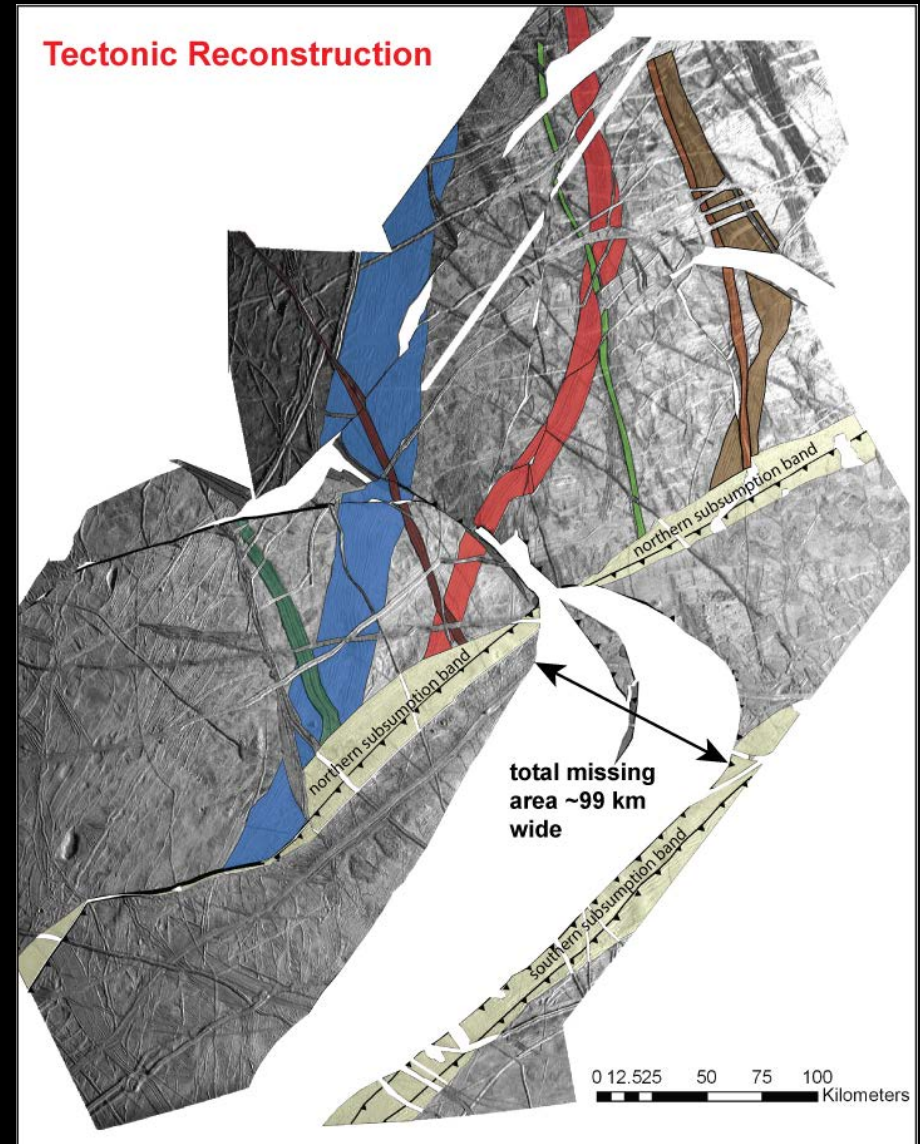
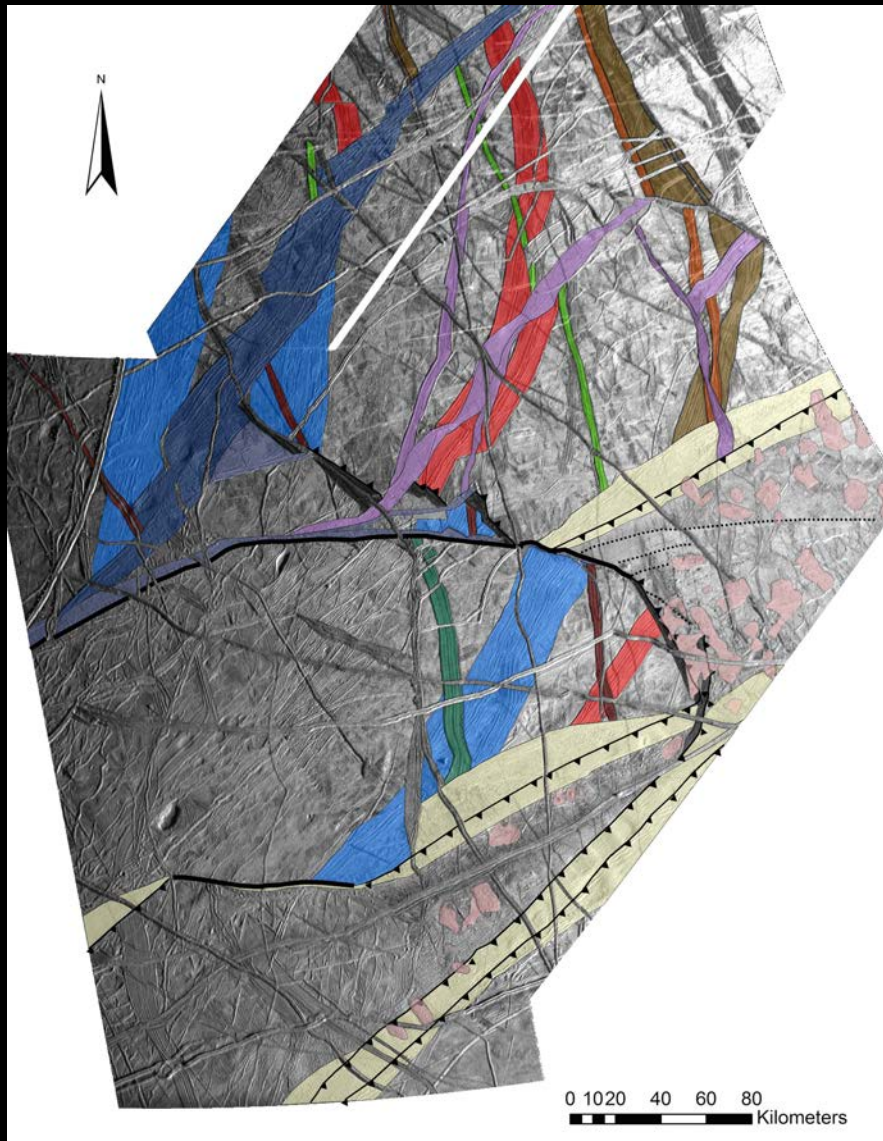


Lots of extension – where's the contraction?

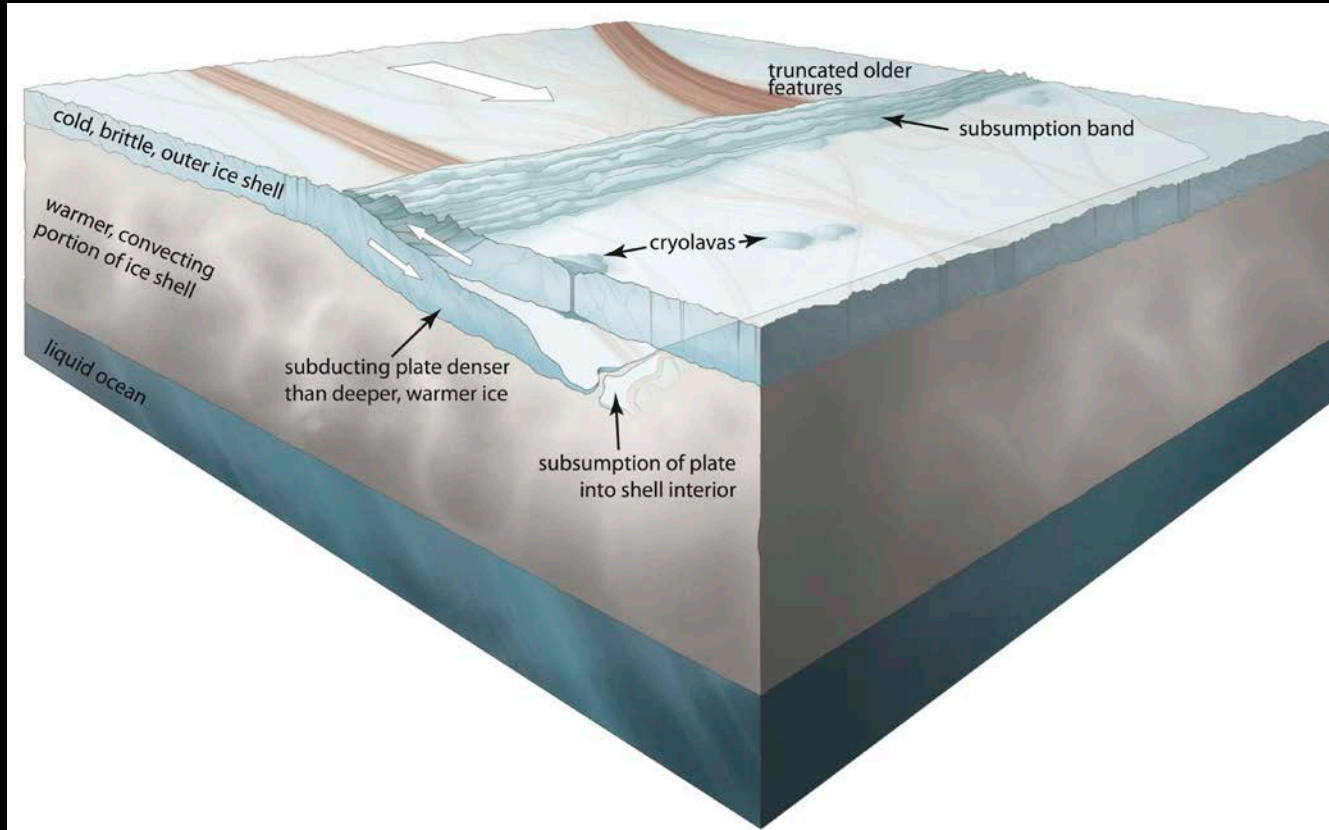


anti-jovian

# Subduction on Europa



# Subduction on Europa

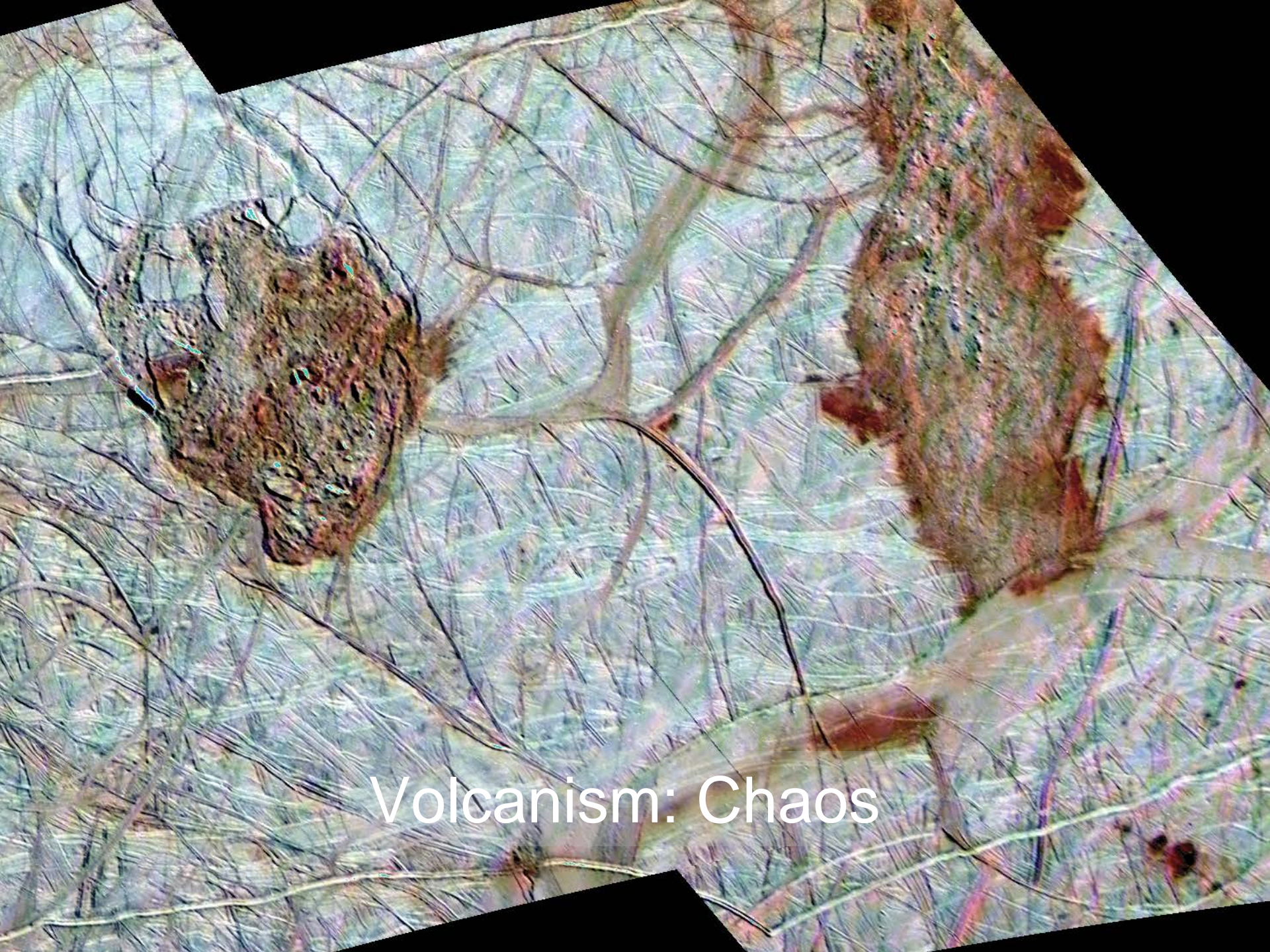


Kattenhorn and Prockter, 2014

*If Europa's surface is undergoing spreading and subduction, it is the only other body in the Solar System beside Earth which has plate tectonics*

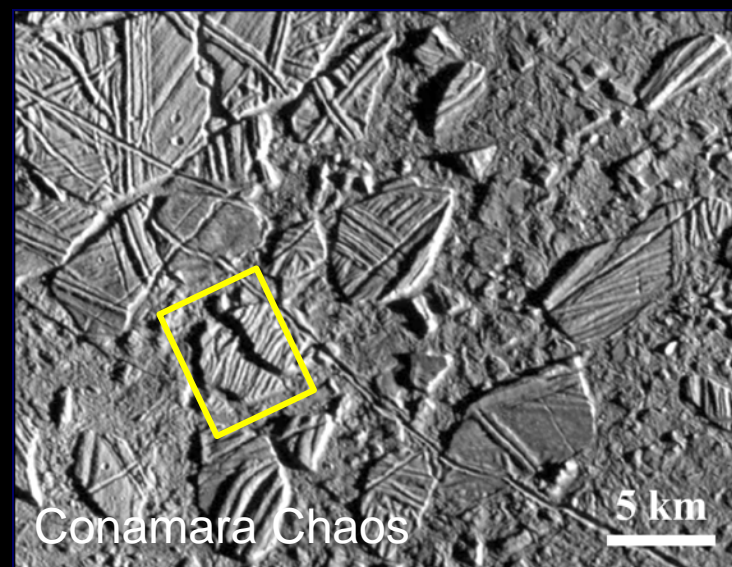
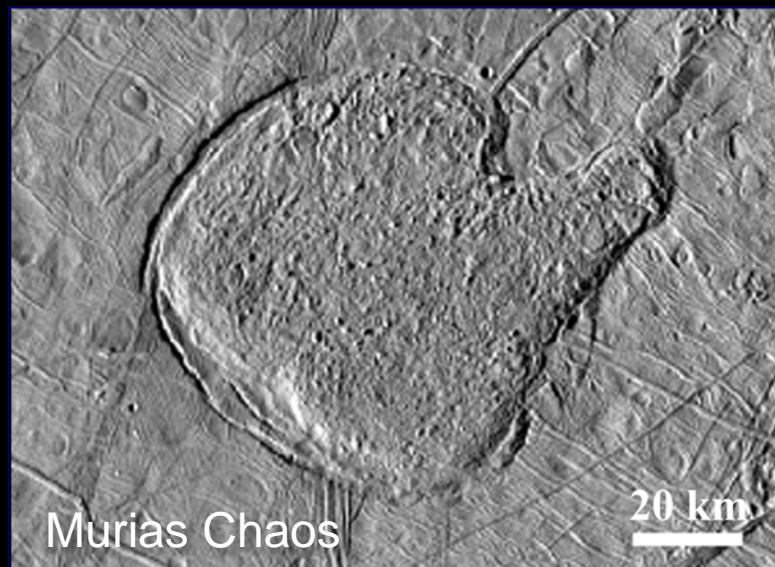
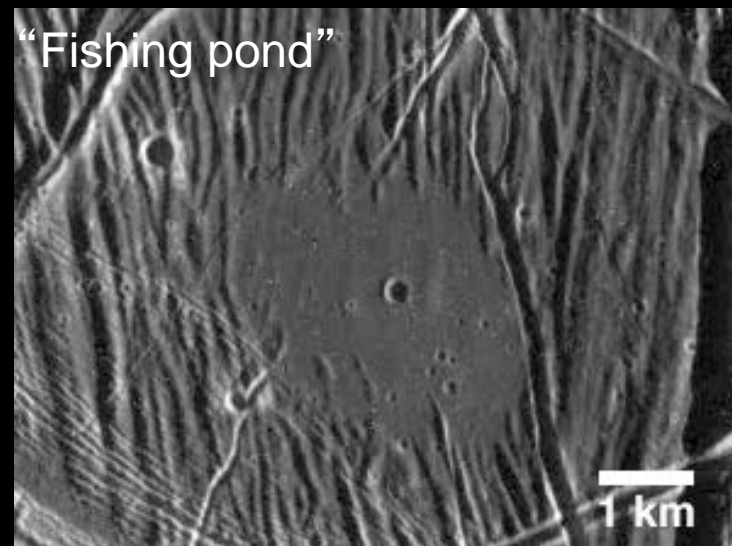
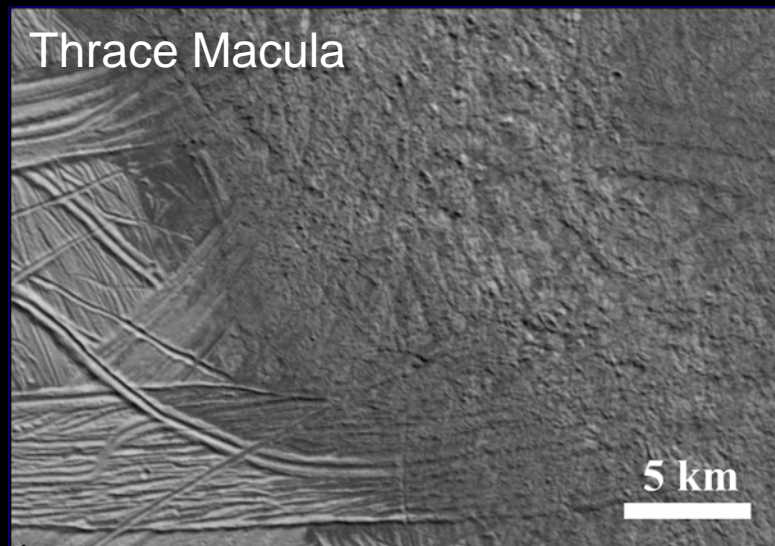
# Volcanism: Lenticulae





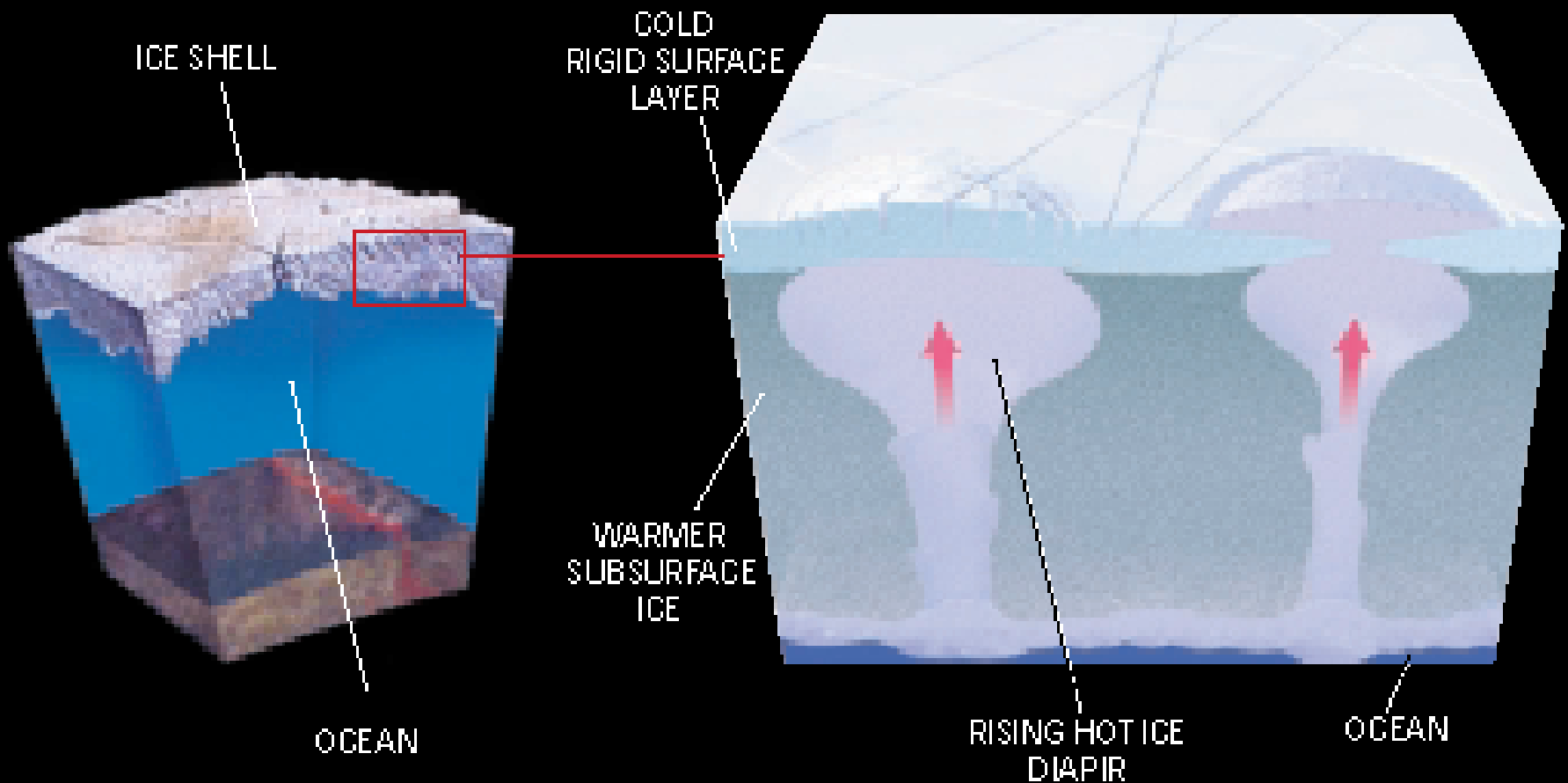
Volcanism: Chaos

# Chaos morphology



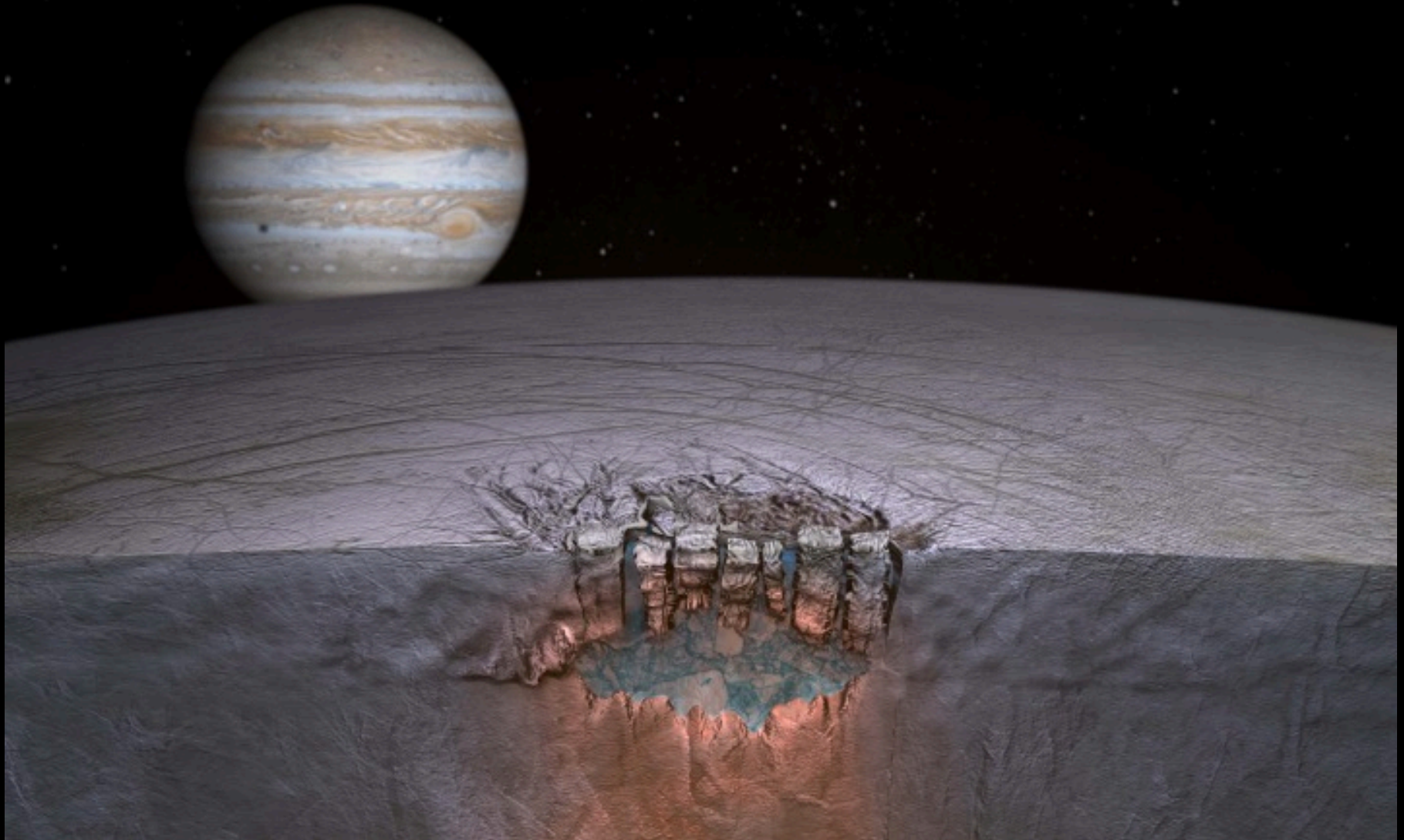


# Convection in the ice shell leads to volcanism



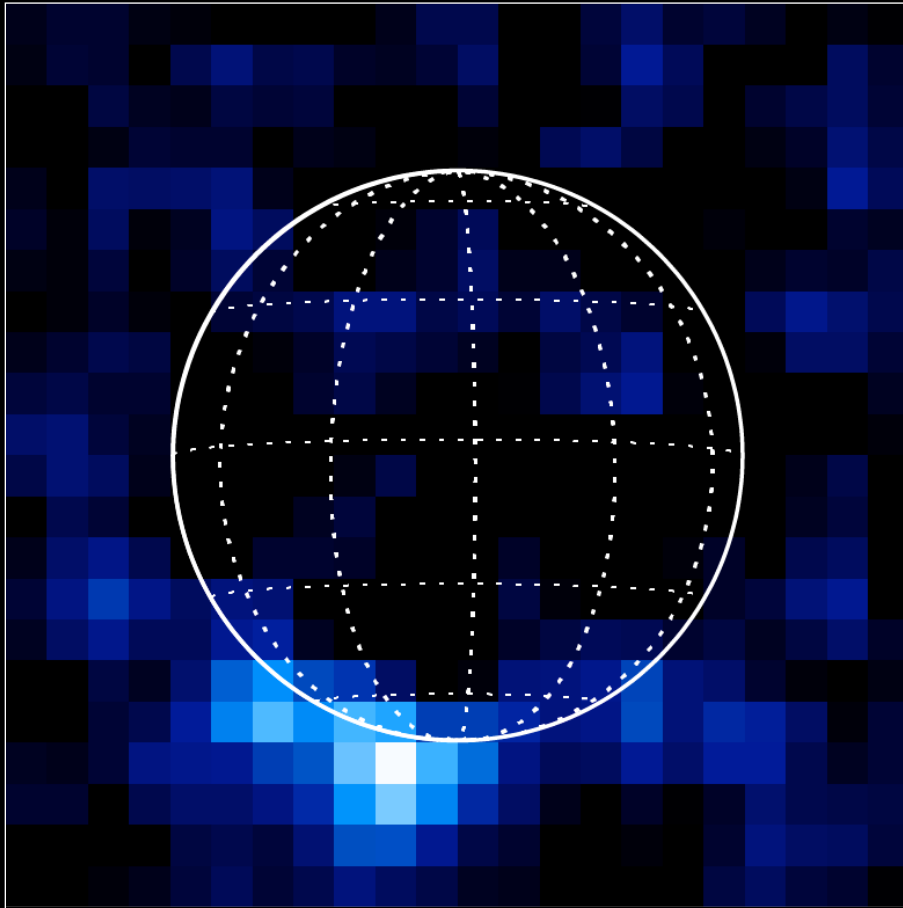


# Brine-mobilization model

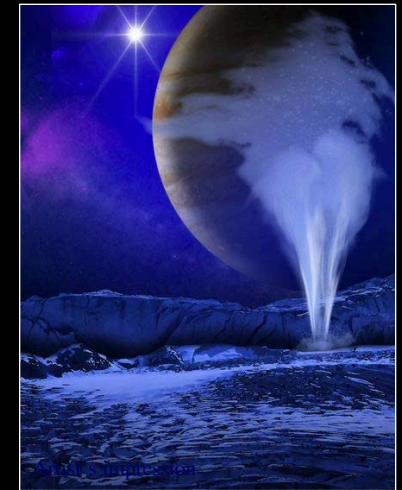


# Volcanism: Possible plumes of water

- Recent Hubble observations of Hydrogen and Oxygen ions concentrated near Europa's south pole (Roth et al., 2014)
- Interpreted as plumes of water vapor ~200 km high

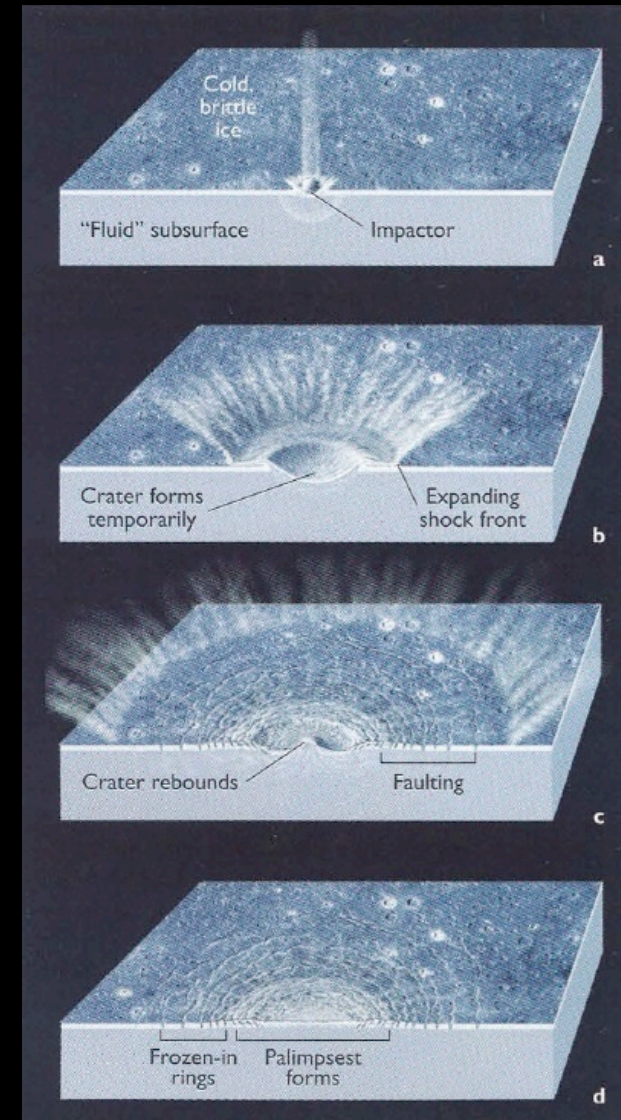


NASA/L. Roth



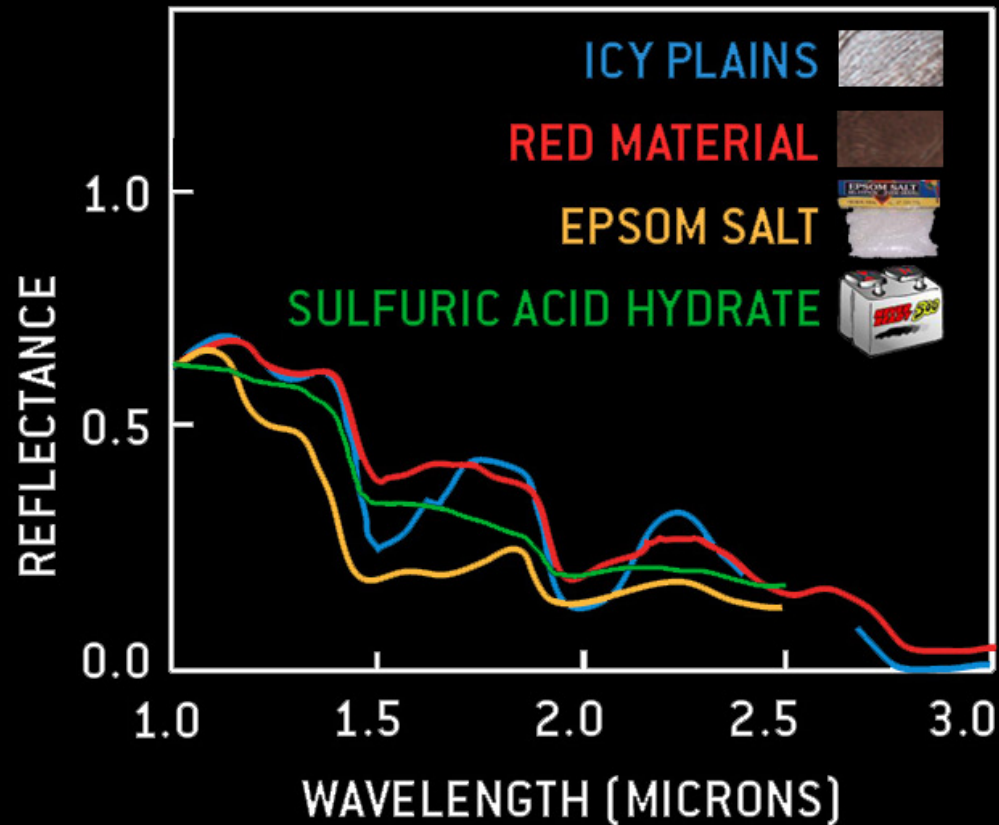
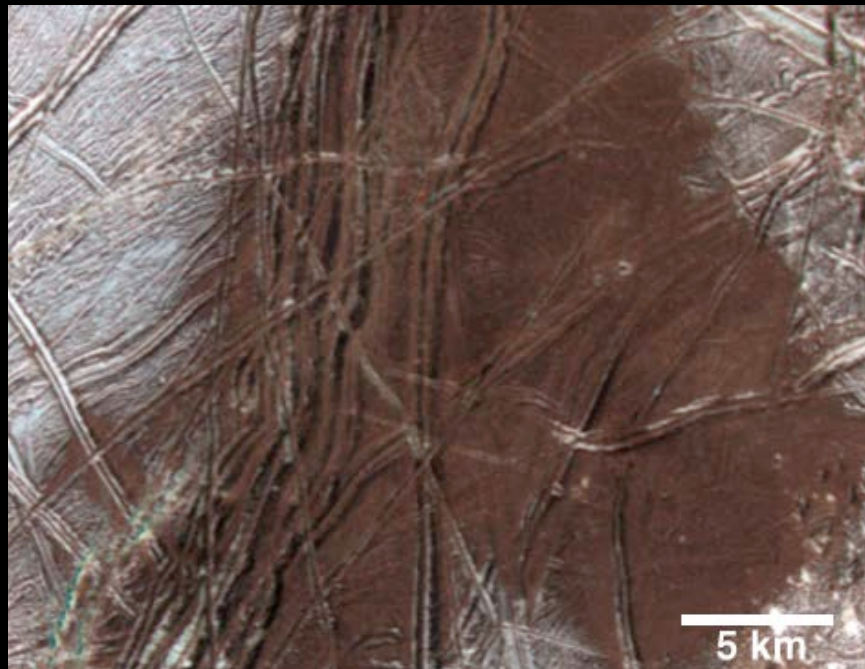
Enceladus plumes NASA/ESA/K. Retherford/SWRI

# Large impacts



*Few large impact craters: Suggests 40 - 90 Myr surface age  
A couple of multi-ringed impacts penetrated 20 km thick ice*

# Surface composition



*Infrared spectral fingerprint suggests sulfur-containing hydrates  
Sulfur might explain Europa's ruddy visible color*

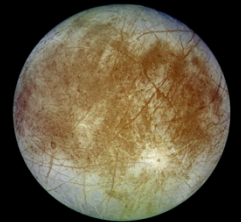
# Why is Europa of astrobiological interest?



Earth: Known life



Mars:  
Past conditions  
for life



Europa:  
Present conditions  
for life?

# Europa: Ingredients for Life?



Water: *More than 2x all of Earth's oceans*



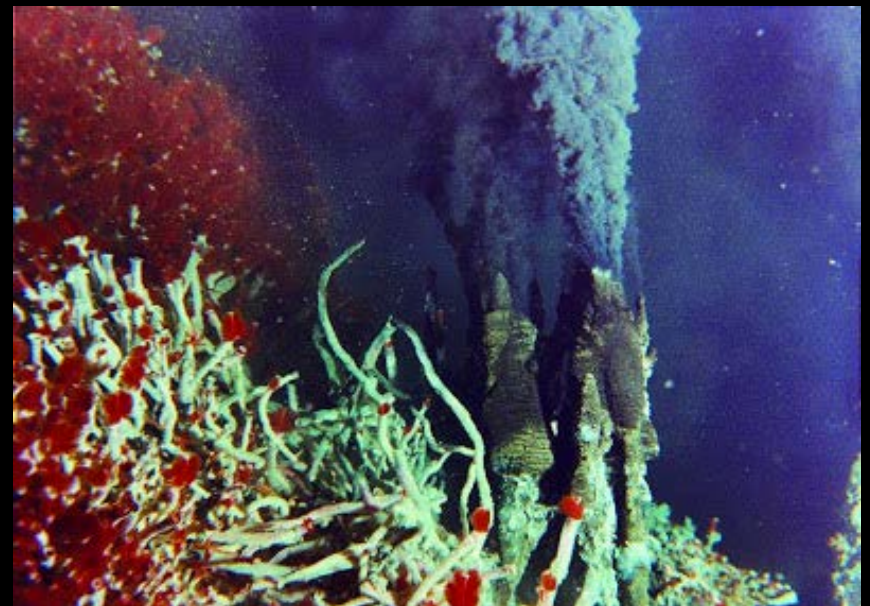
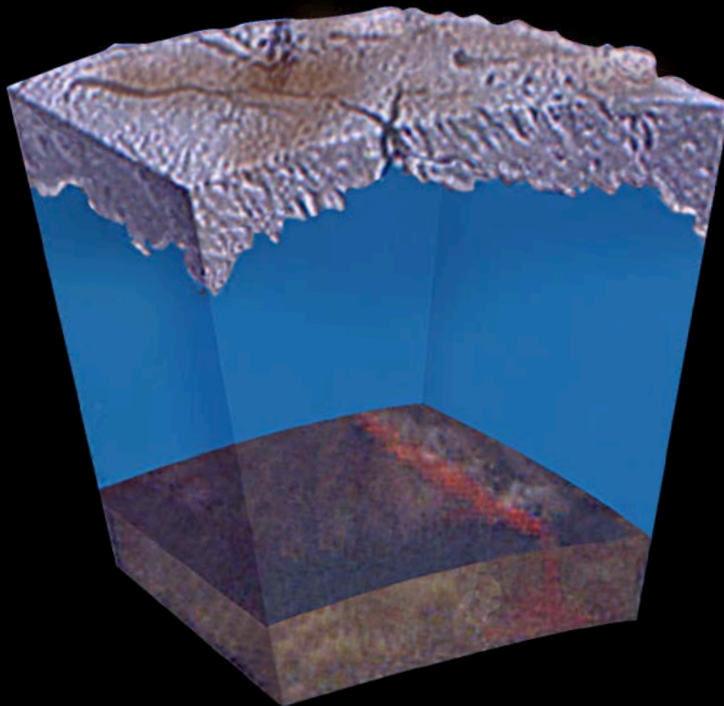
Essential elements: *From formation and impacts*



Chemical energy: *Potentially from above and below*



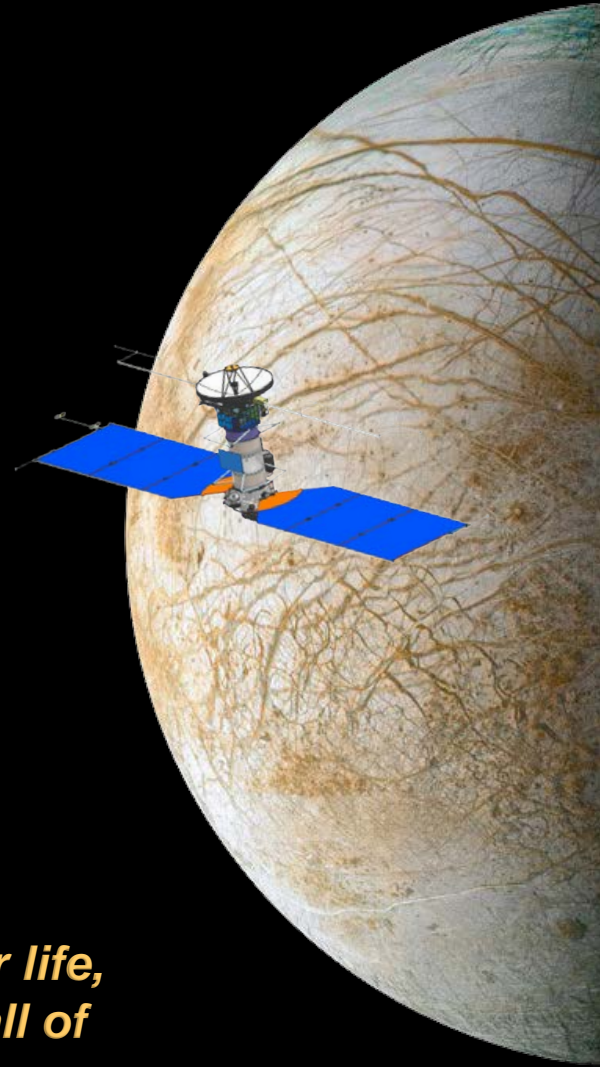
Stability: *Variable, but "simmering" for 4 billion years*



*"Black smoker" on Earth's ocean floor*

# Future exploration of Europa

- Europa mission concepts have been studied by NASA for more than a decade
- Europa is one of the highest priority targets identified in the 2011 National Research Council's Planetary Decadal Survey
- In June 2015 NASA selected a \$2B Europa multiple-flyby mission – the Europa Clipper - as its next outer planet flagship mission
- A comprehensive instrument payload was also selected around this time



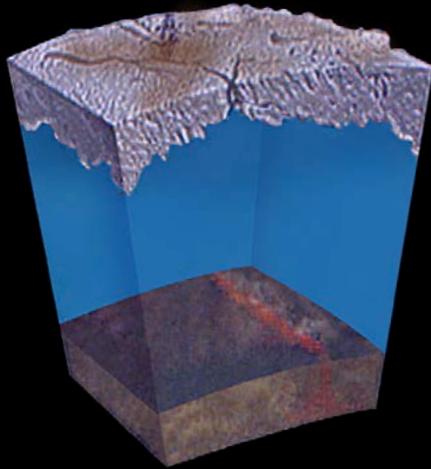
***“Because of (its) ocean’s potential suitability for life, Europa is one of the most important targets in all of planetary science.”***

**–2011 Planetary Decadal Survey**

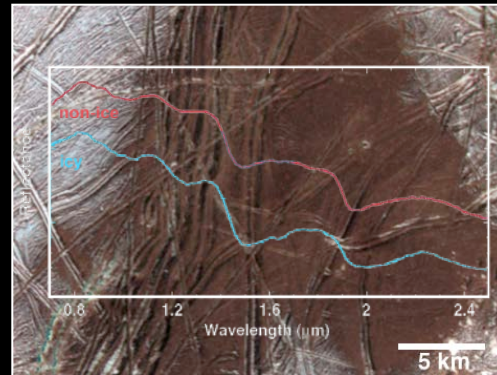
# Europa Clipper science

*Goal: Explore Europa to investigate its habitability*

## Ocean and Ice Shell



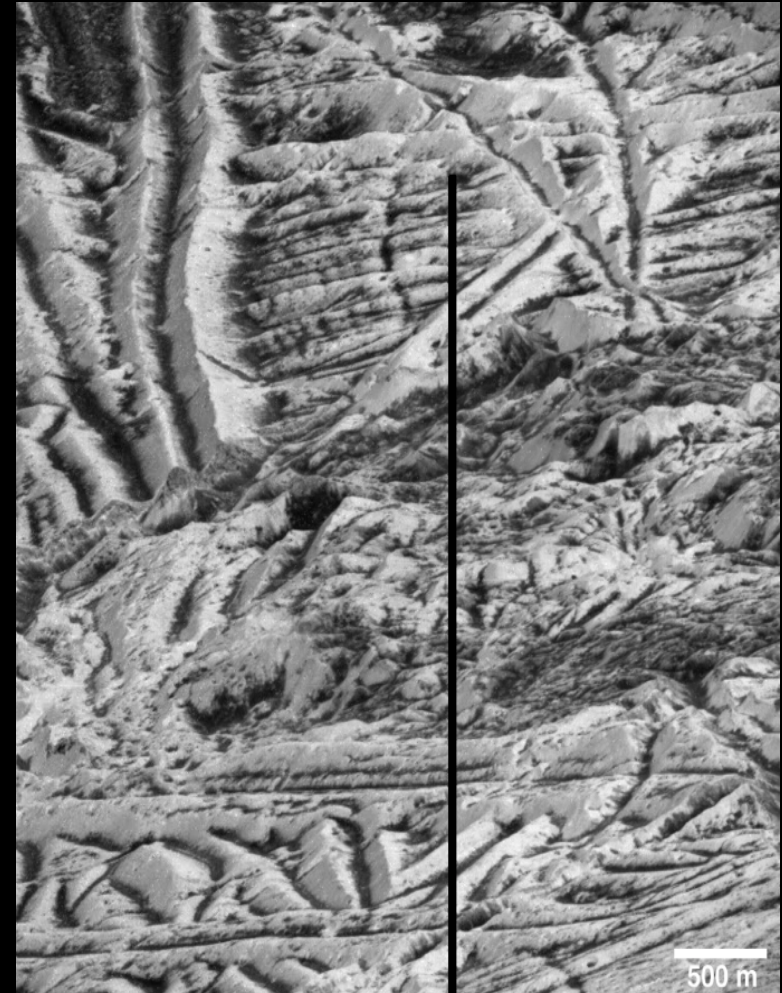
## Composition



## Geology



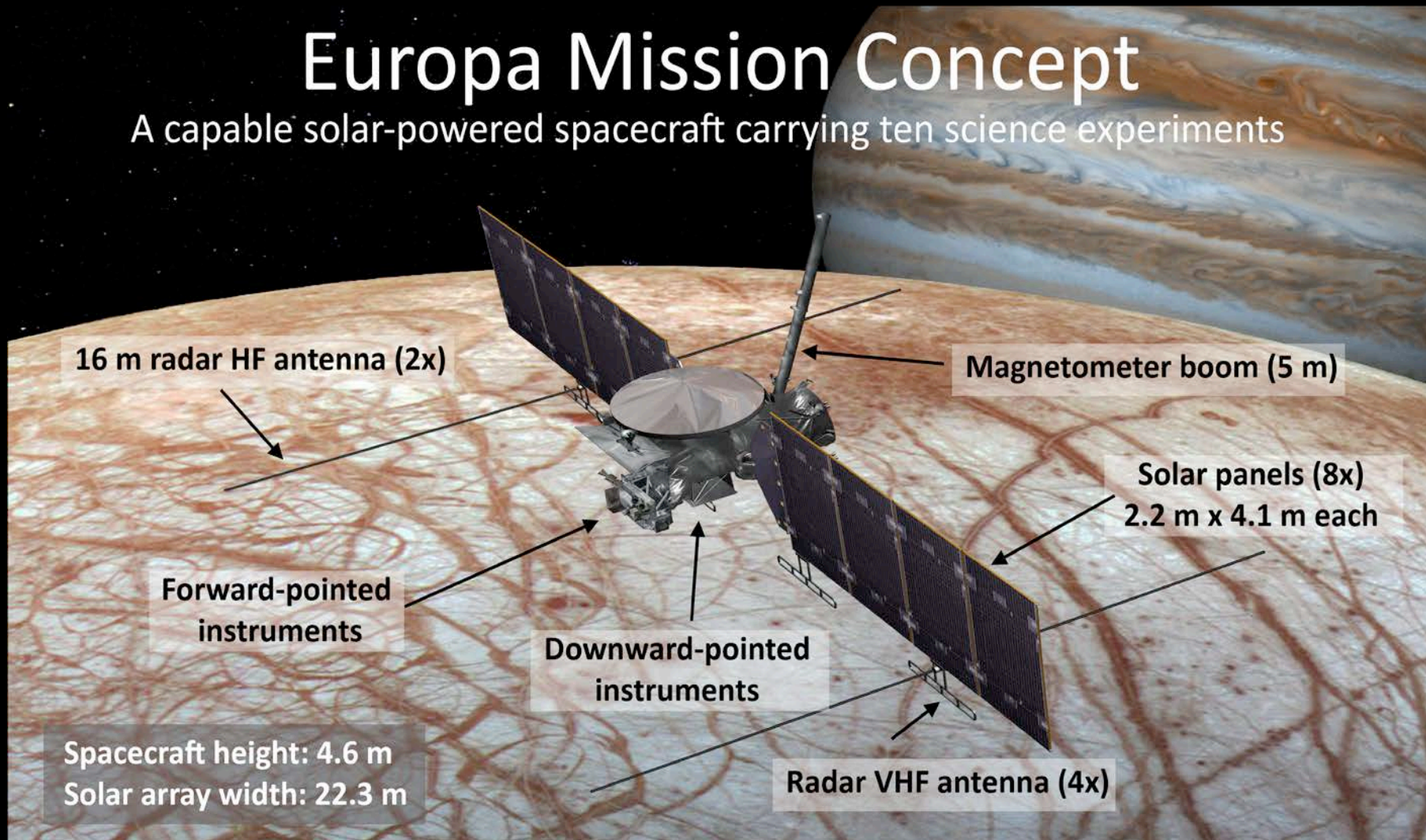
## Reconnaissance for a future lander





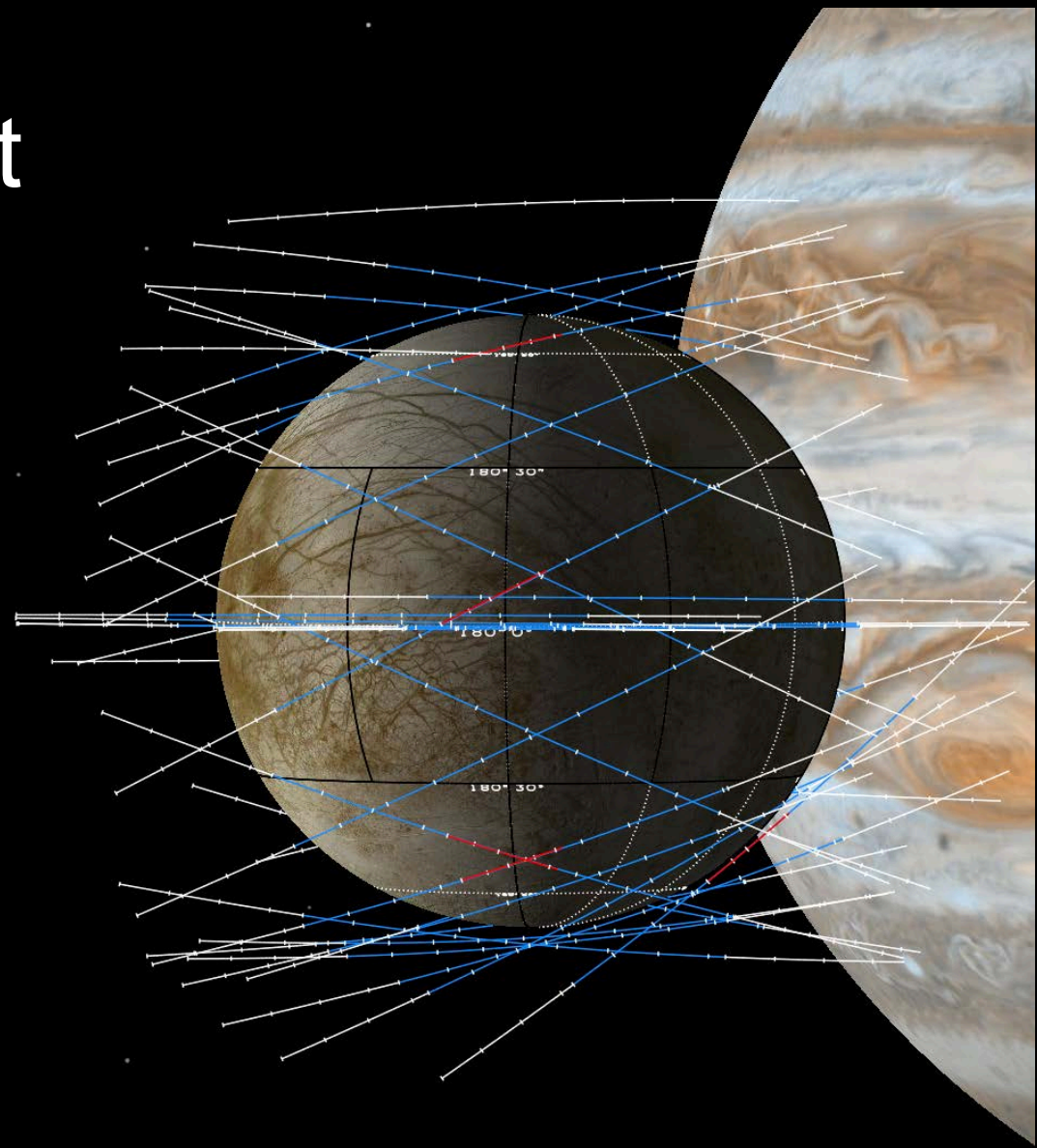
# Europa Mission Concept

A capable solar-powered spacecraft carrying ten science experiments



# Mission concept

- Launch 2022, arrive as early as 2025
- 3-year primary mission, includes >42 encounters with Europa
- Multiple flybys of Europa build up global-regional coverage while minimizing radiation dose



# Summary

- Europa is a recently or currently active moon, of high significance as a potentially habitable world
- NASA has selected a multiple-flyby solar-powered mission to study Europa's habitability; earliest launch is 2022
  - The spacecraft will orbit Jupiter and will carry out >40 globally distributed flybys of Europa to build up near-global coverage
- A lander is also being studied by NASA as a follow-on to the multiple-flyby mission – this will look for signs of life
- We are very close to the next phase of Europa exploration!

