ASTR/GEOL-2040: Search for life in the Universe: Lecture 26

- Europa
- Water & Cracks
- Life in Lake Vostok

Axel Brandenburg
(Office hours: Mondays 2:30 – 3:30 in X590 and Wednesdays 11-12 in D230)

Conversion of units: 2 examples

- Standard unit for density: kg/m^3
- Example 1: length in km, e.g. $10^{12}\ kg/km^3$ = ??

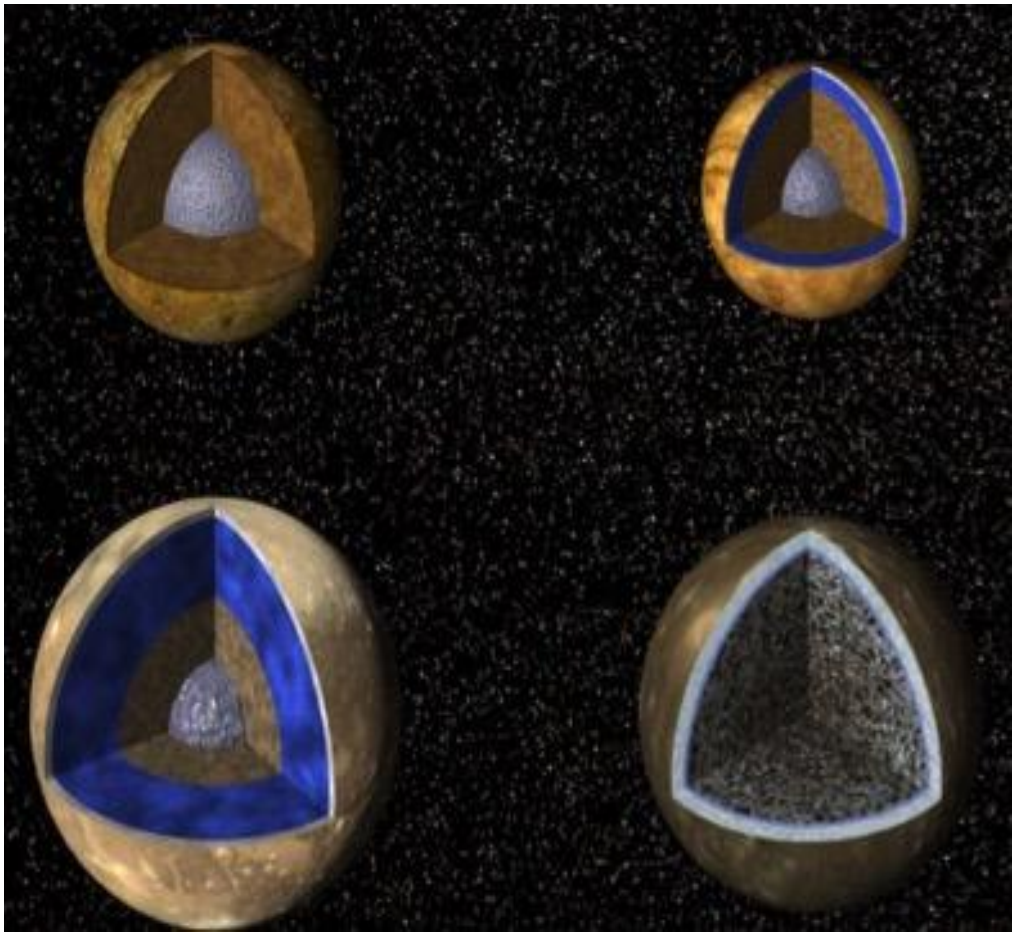
$$\frac{10^{12}\,\mathrm{kg}}{\mathrm{km}^3} = \frac{10^{12}\,\mathrm{kg}}{\left(10^3\,\mathrm{m}\right)^3} = \frac{10^{12}\,\mathrm{kg}}{10^9\,\mathrm{m}^3} = \frac{10^3\,\mathrm{kg}}{\mathrm{m}^3}$$

- Example 2: length in cm, mass in g

$$1\,\mathrm{g/cc} = \frac{1\,\mathrm{g}}{\mathrm{cm}^3} = \frac{10^{-3}\,\mathrm{kg}}{\left(10^{-2}\,\mathrm{m}\right)^3} = \frac{10^{-3}\,\mathrm{kg}}{10^{-6}\,\mathrm{m}^3} = \frac{10^3\,\mathrm{kg}}{\mathrm{m}^3}$$

Galilean moons: why this change in ρ?

Io
3.57 g/cc



Europa
2.97 g/cc

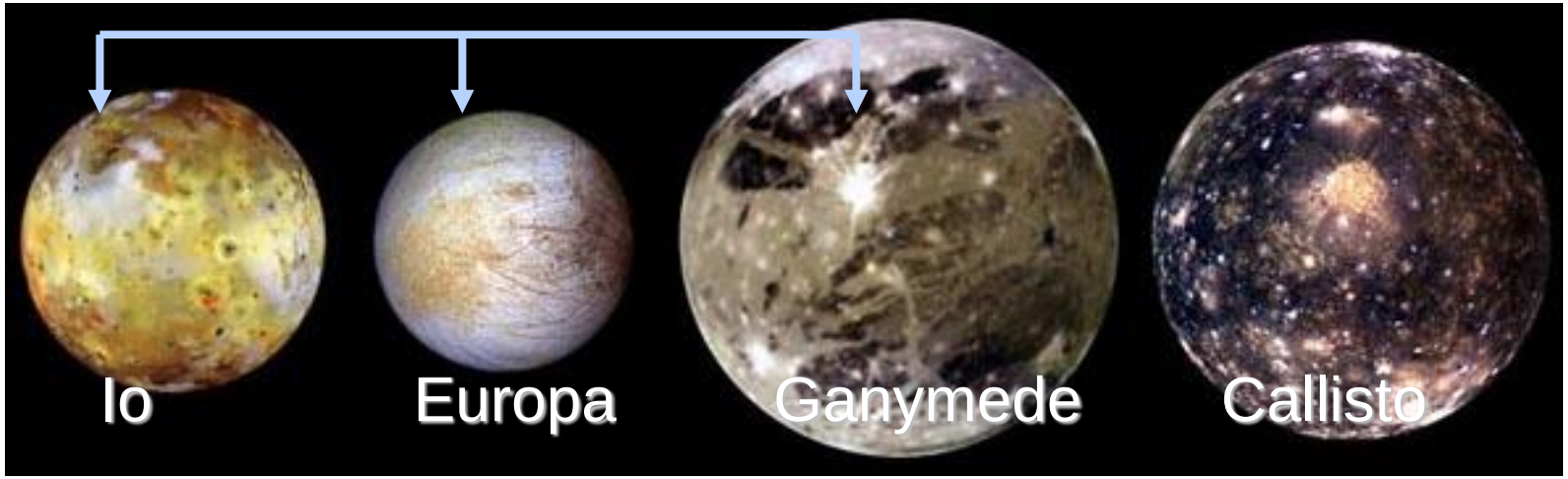
Ganymede
1.94 g/cc

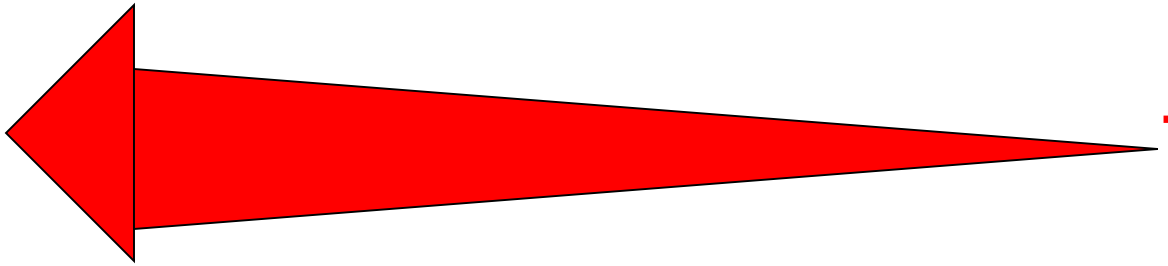
Callisto
1.86 g/cc

Outer moons less dense?

A. Accreted less material
B. Accreted lighter material
C. Suffered less heating
D. Outer moons are larger
E. Larger orbits

Orbital Resonance





Tidal Heating

Outer moons less dense?

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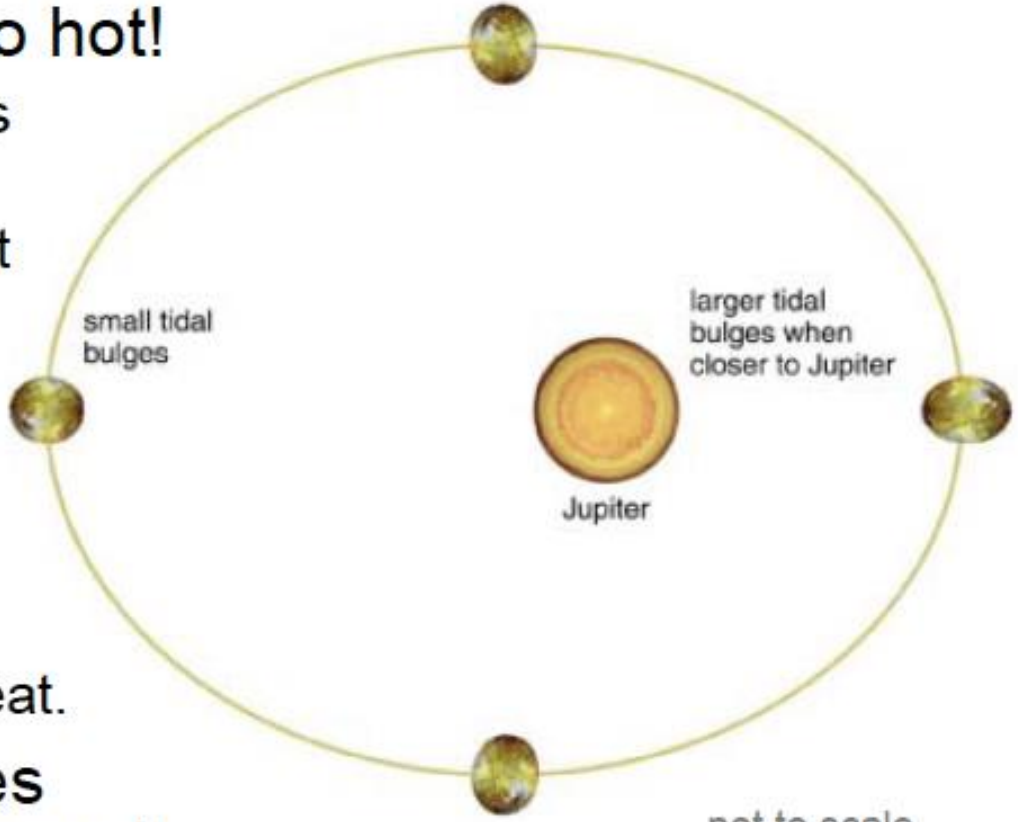
Why tidal heating?

A. Because of tidal locking
B. Close proximity to Jupiter
C. Orbit is elliptical
D. Water bulges

Why So Hot? Tidal Heating!

- **Tidal heating** keeps Io hot!
  - Jupiter's gravity stretches Io, creating *tidal bulges*.
  - During Io's eccentric orbit about Jupiter, the tidal bulges grow when Io is closer, and shrink when Io is farther.
  - Tidal bulges also "nod" from side-to-side.
  - This flexing generates heat.
- Tidal heating generates enough heat energy to melt rock and power Io's volcanoes.



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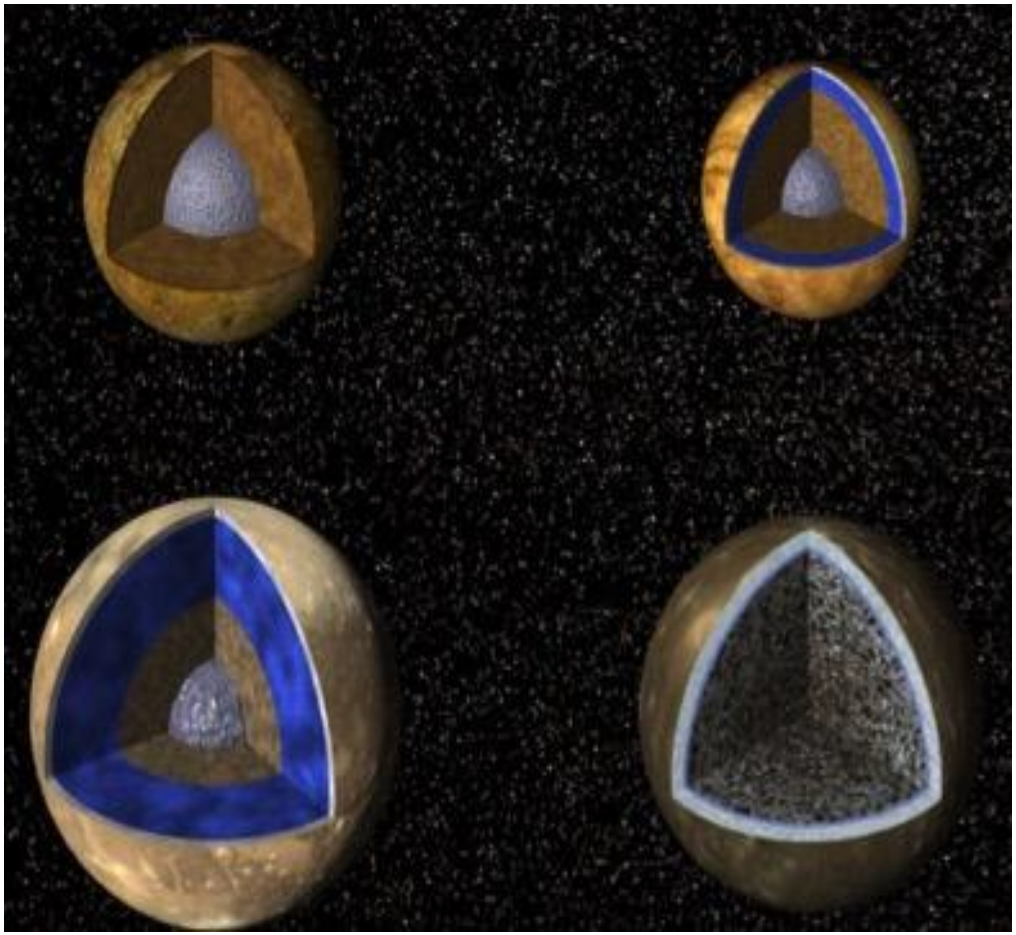

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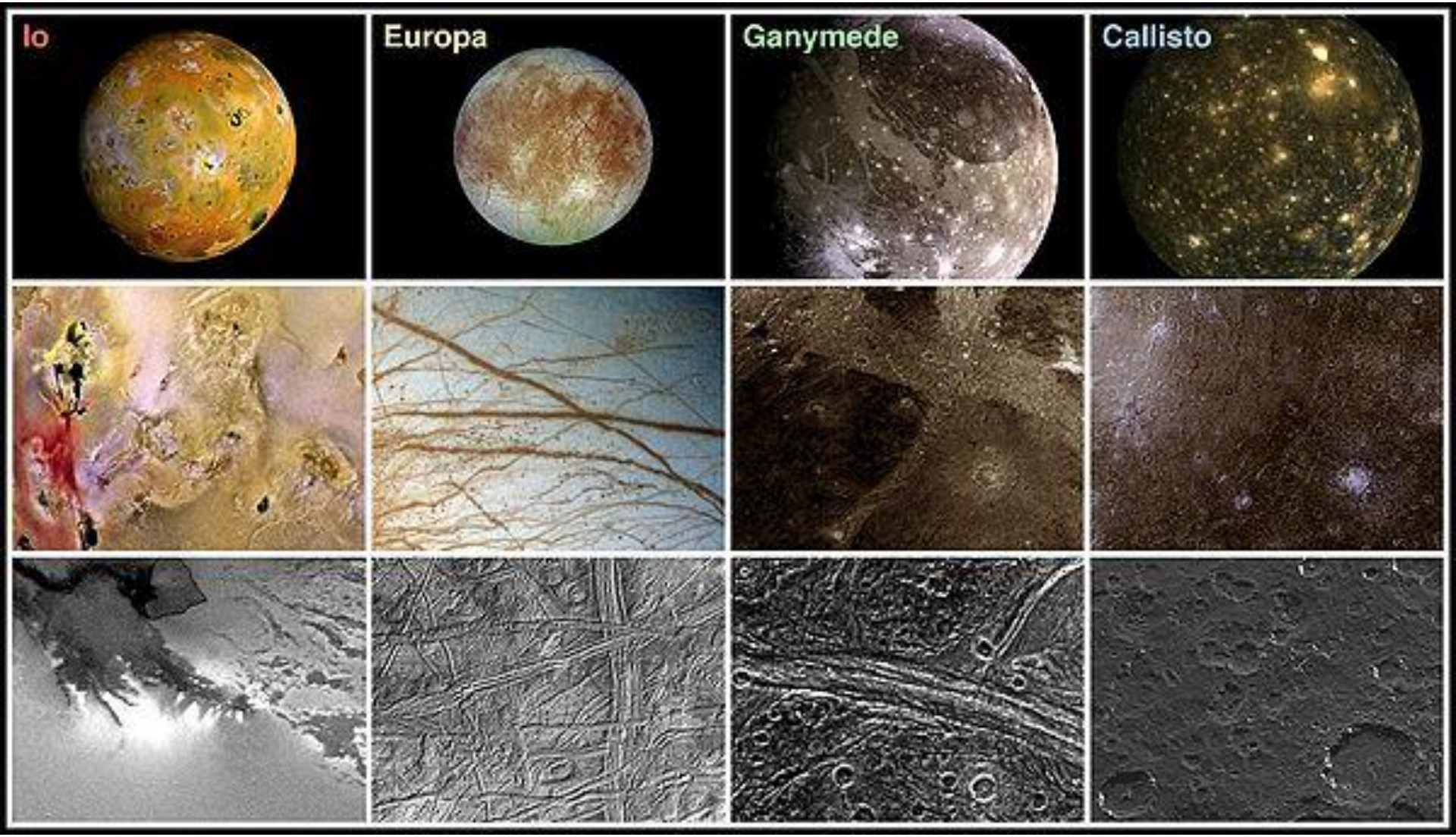
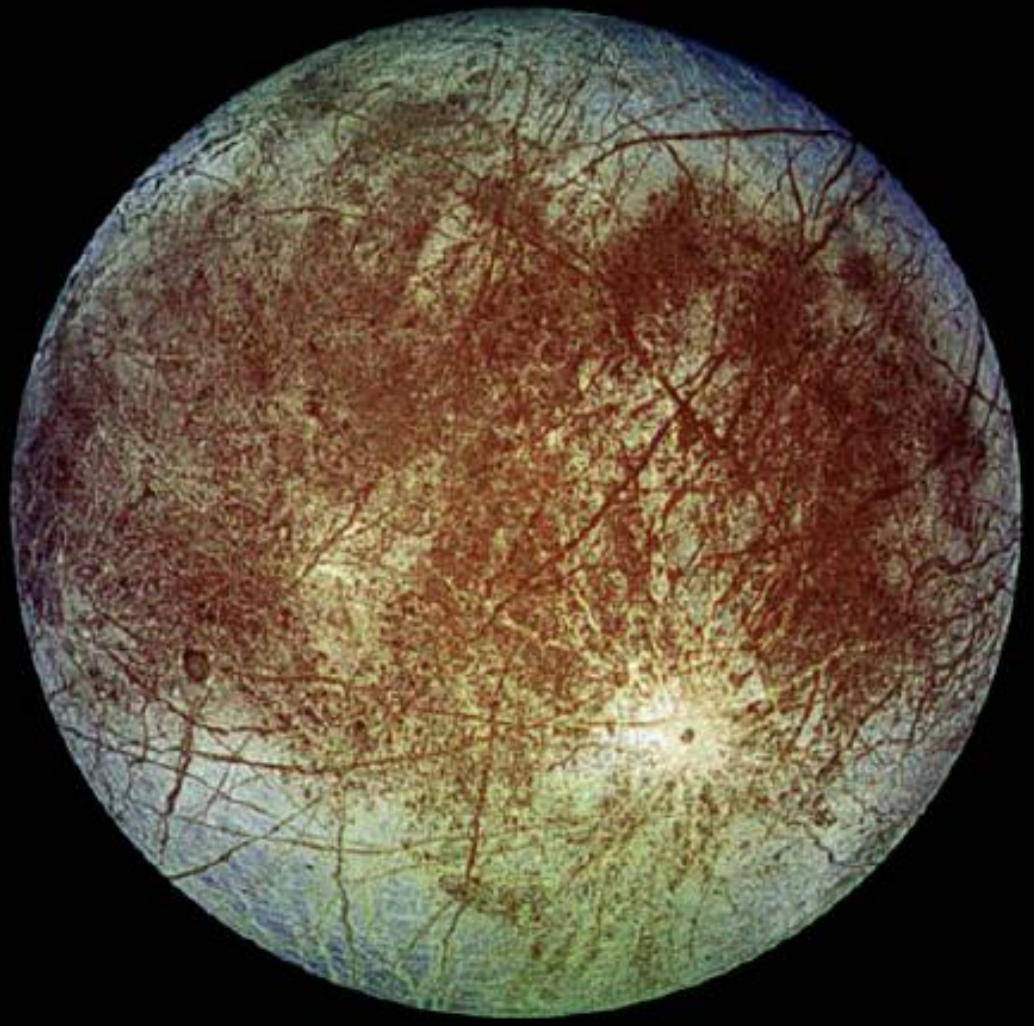
Comparison

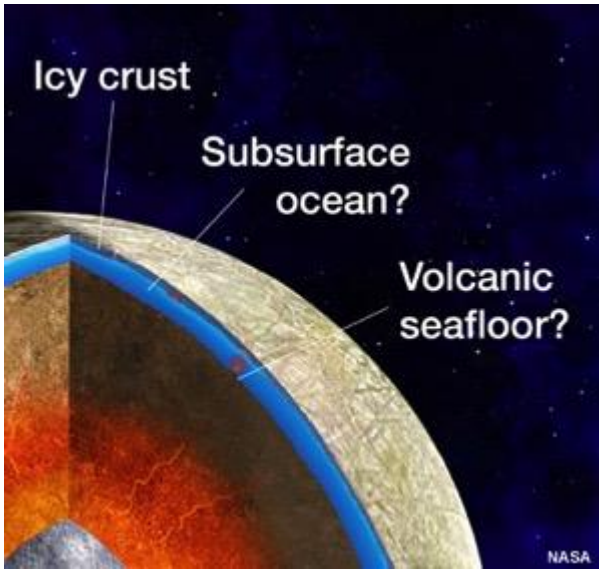


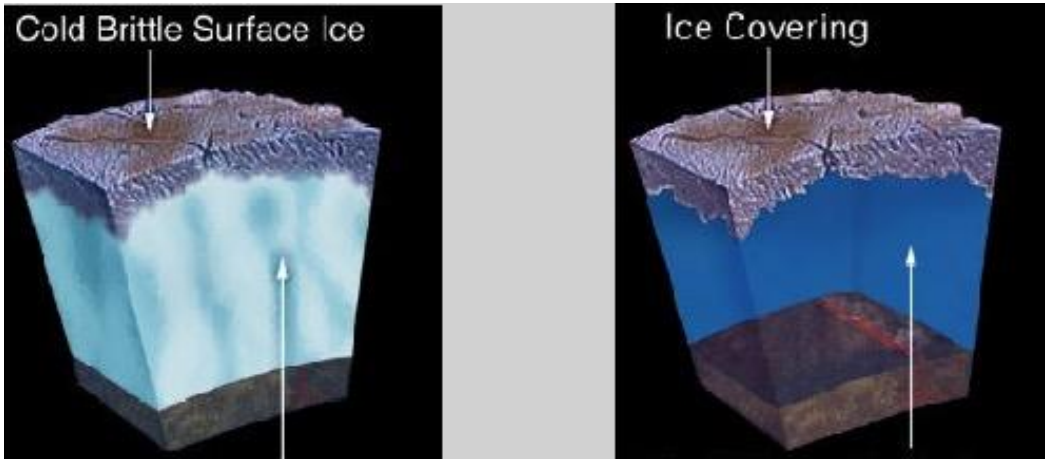
Europa: Water World

- Impact craters:
  - Very few!
  - "Young" surface (50 million yr).
- Tectonics:
  - Surface is squeezed, pulled, cracked by tides.
  - Cracks and ridges on many scales!
- Convection:
  - Floating ice shell probably convects.



Europa: interior

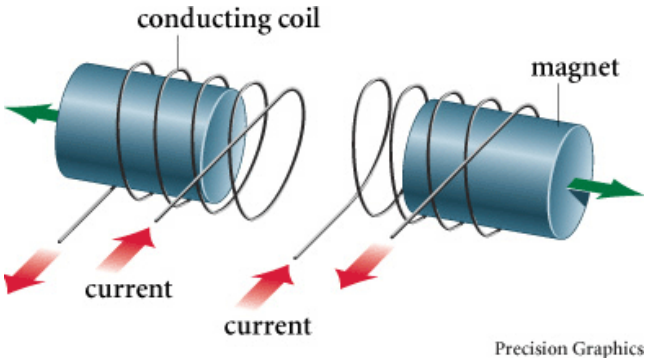




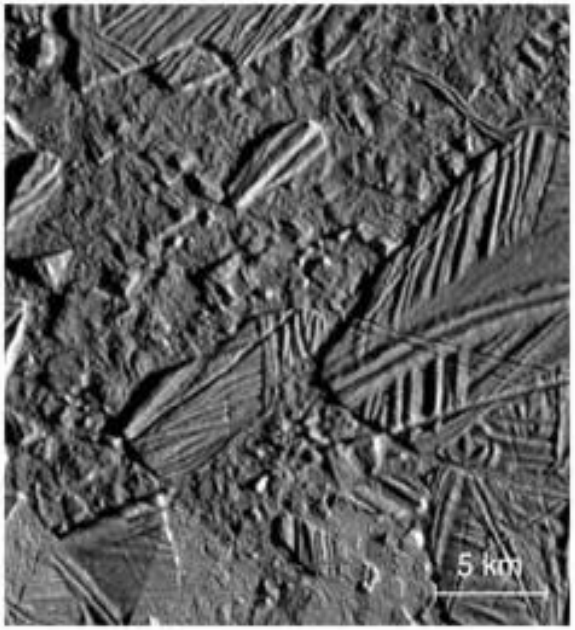
Warm ice..or..liquid water?
or some combination?

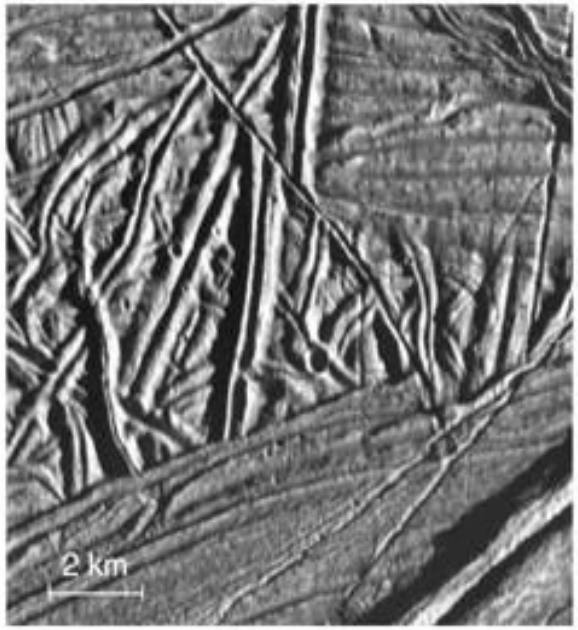
Ocean in Europa?

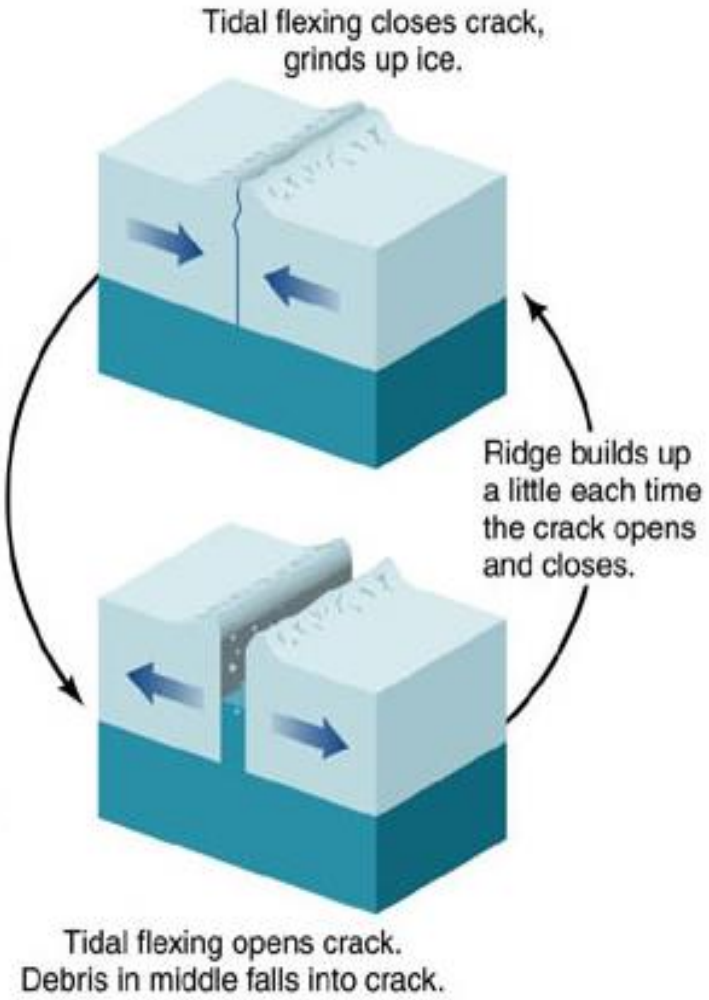
- Europa has no magnetic field of its own
- Galileo probe saw: induced magnetic field
- Time-varying magnetic field from Jupiter
- 11 hours period



- Continuous conducting layer
- Brine (salty) ocean
- Range of values of conductivity

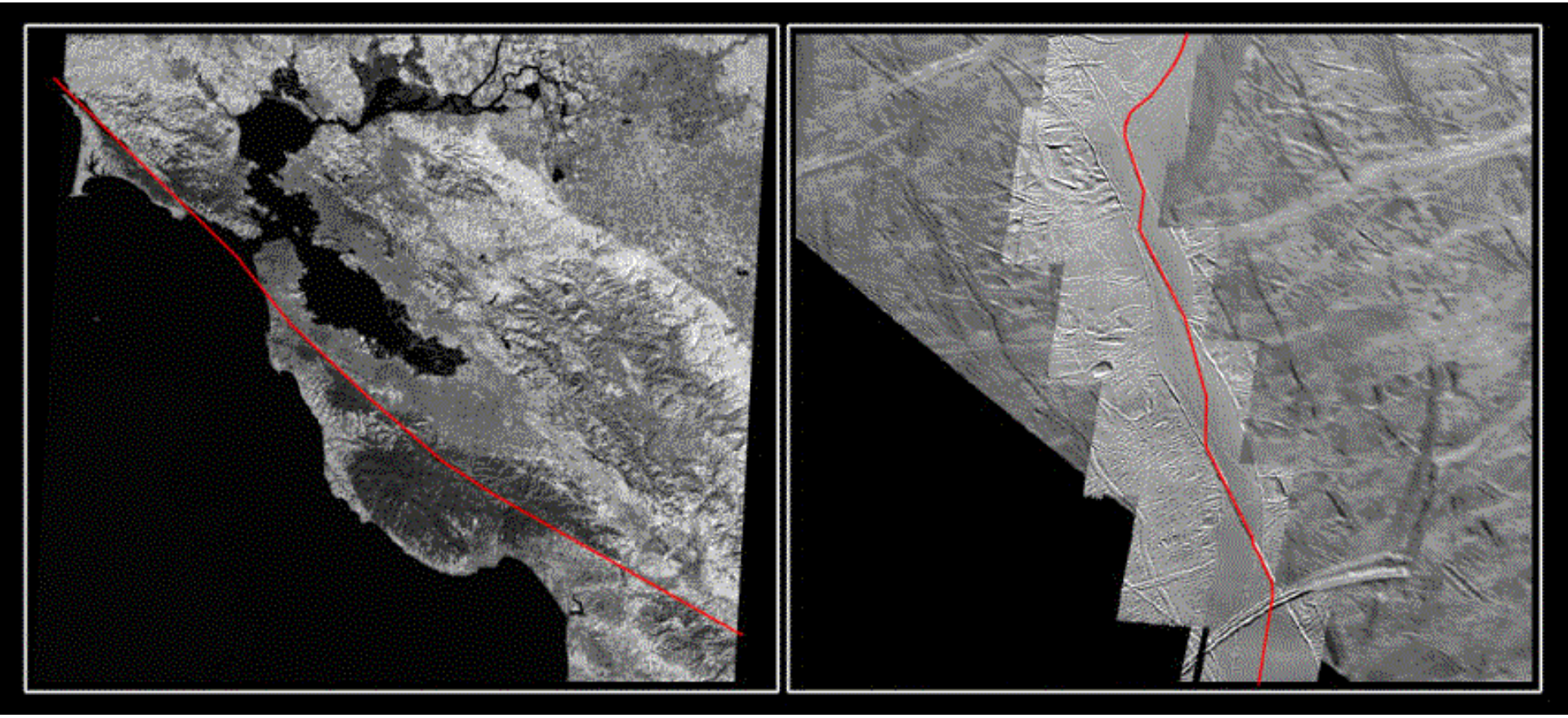






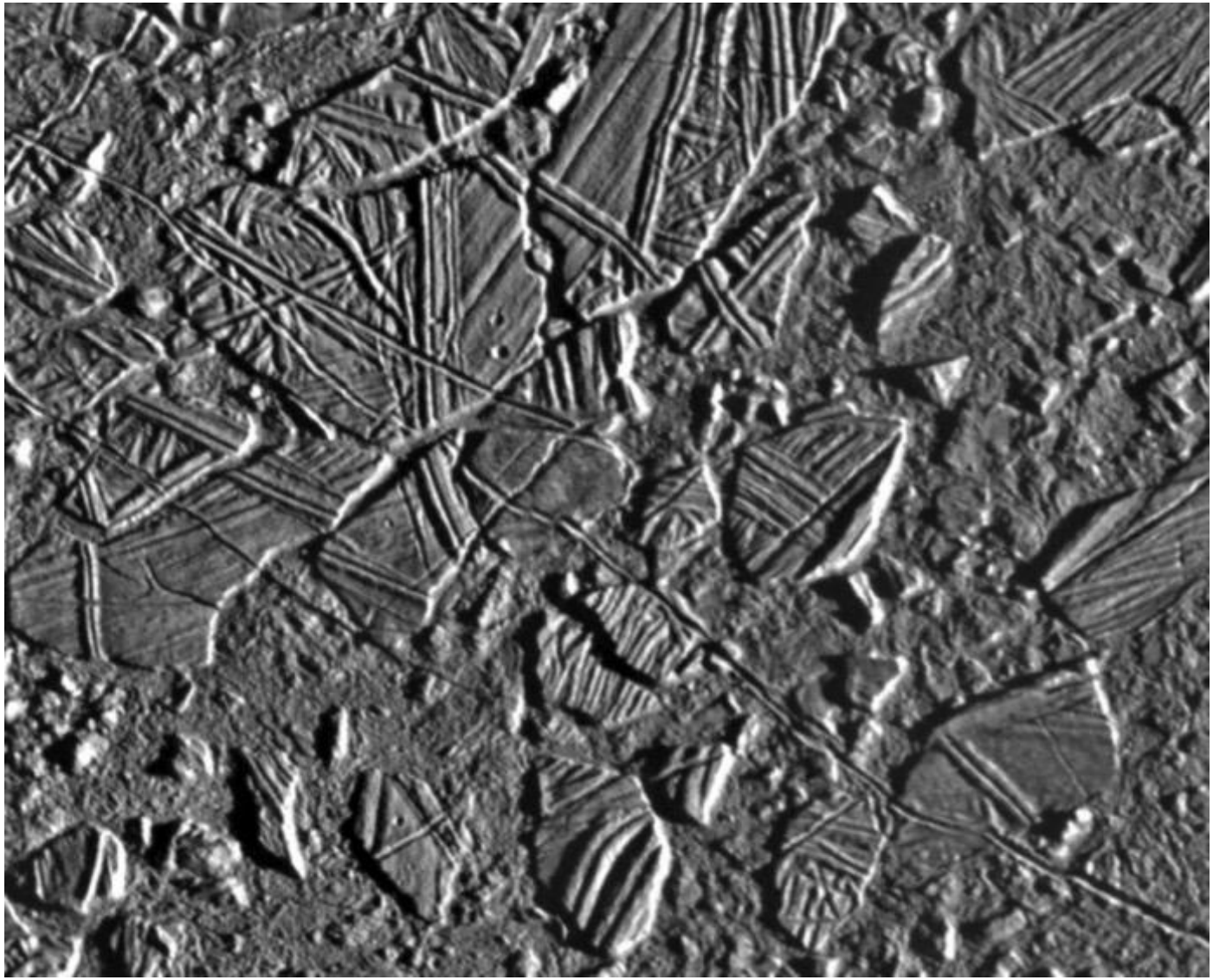
California's San Andreas Fault

Europa



San Andreas Fault

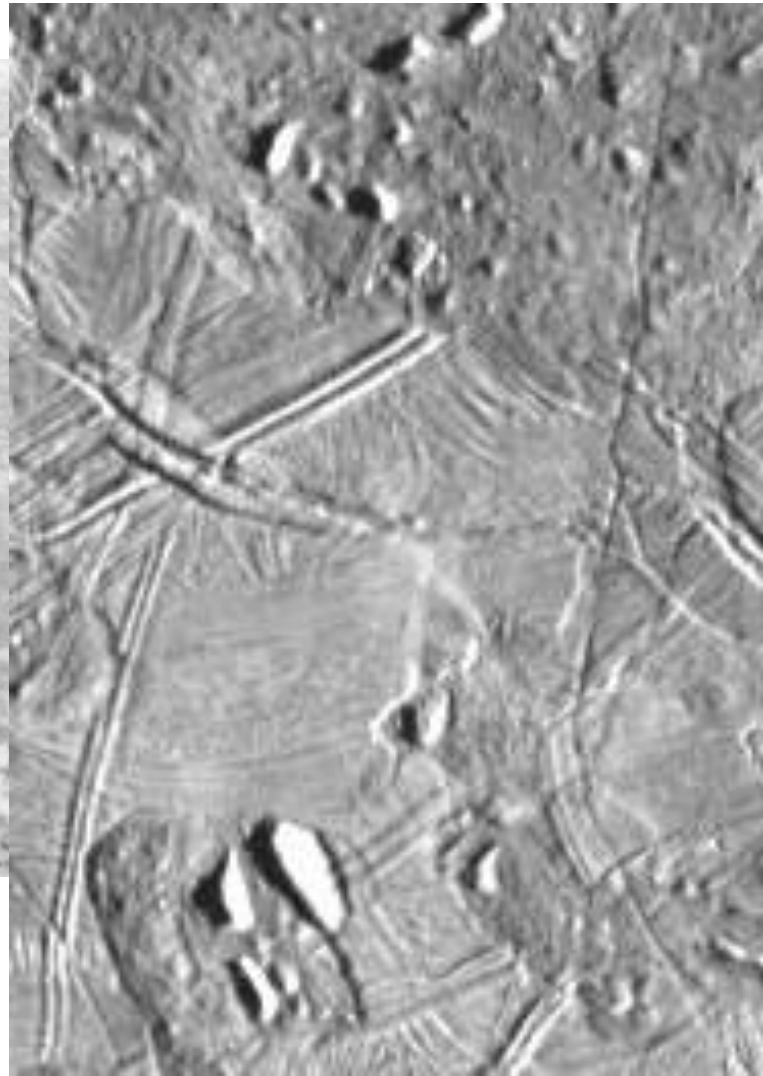
Astypalaea Linea

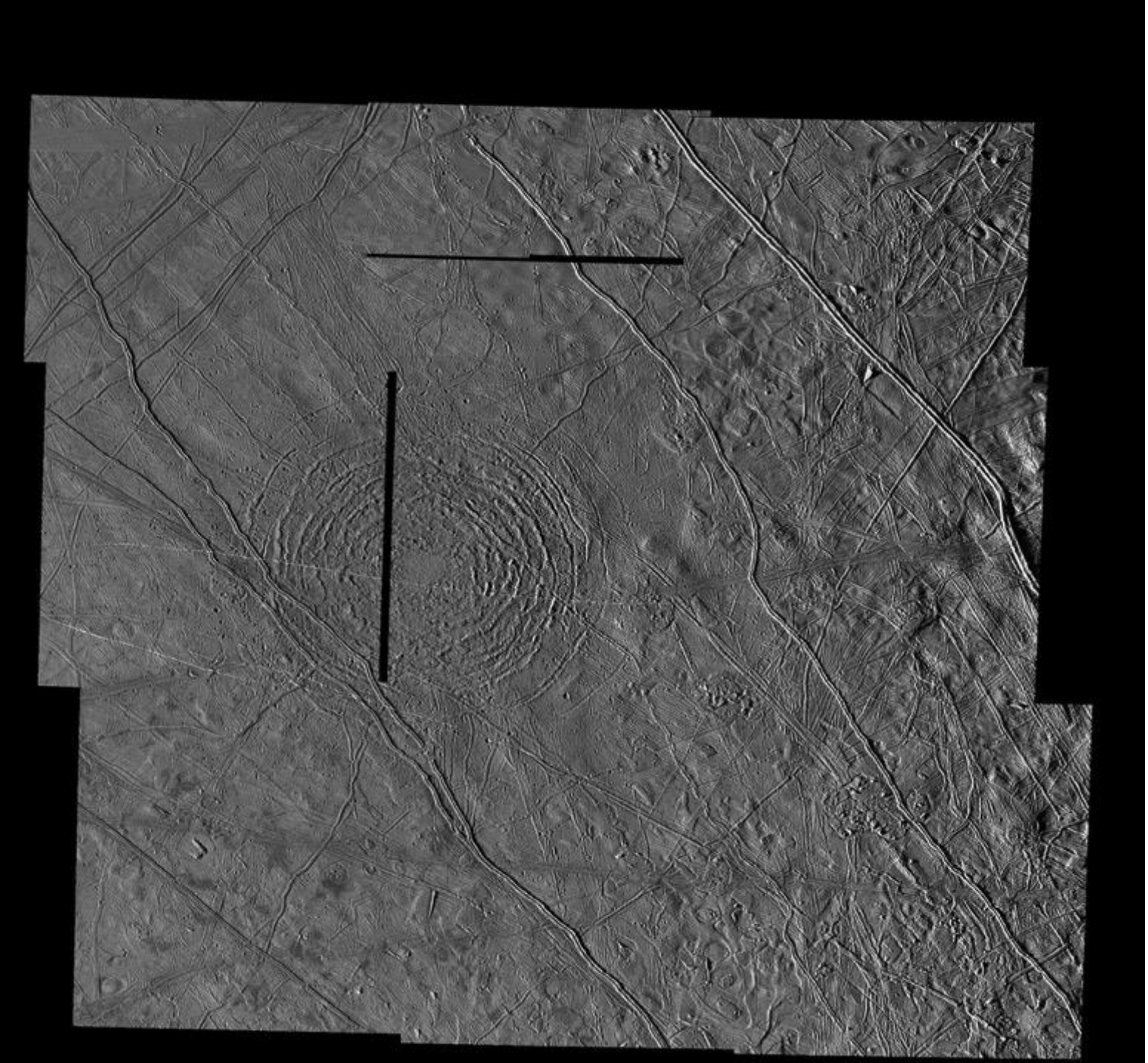


Icebergs?

(25 miles across)

Tilted ice blocks look like the Arctic Ocean too…



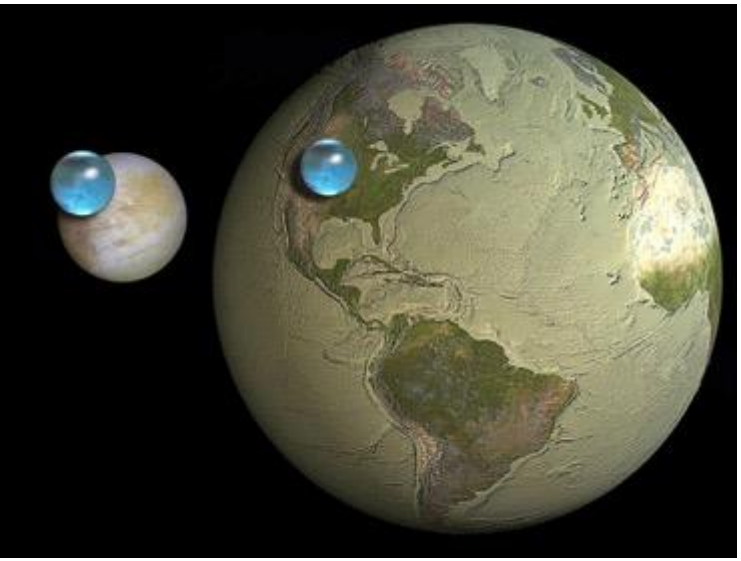


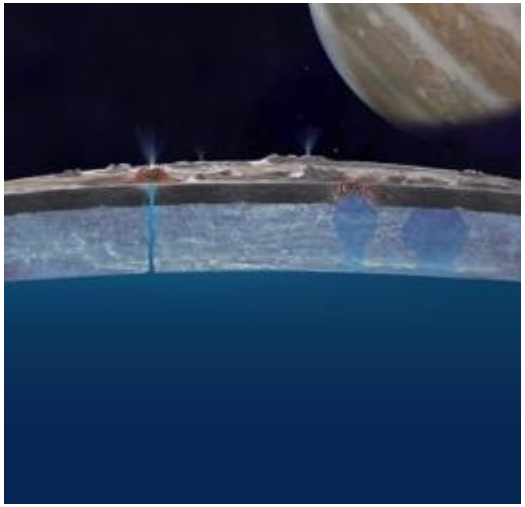
Tyre multi-ring
impact structu

Few large
impact craters
>
Suggests 60
Myr surface
age.

A couple of
multi-ringed
impacts: ->
Penetrated 20
km thick ice!

Europa: ocean and atmosphere

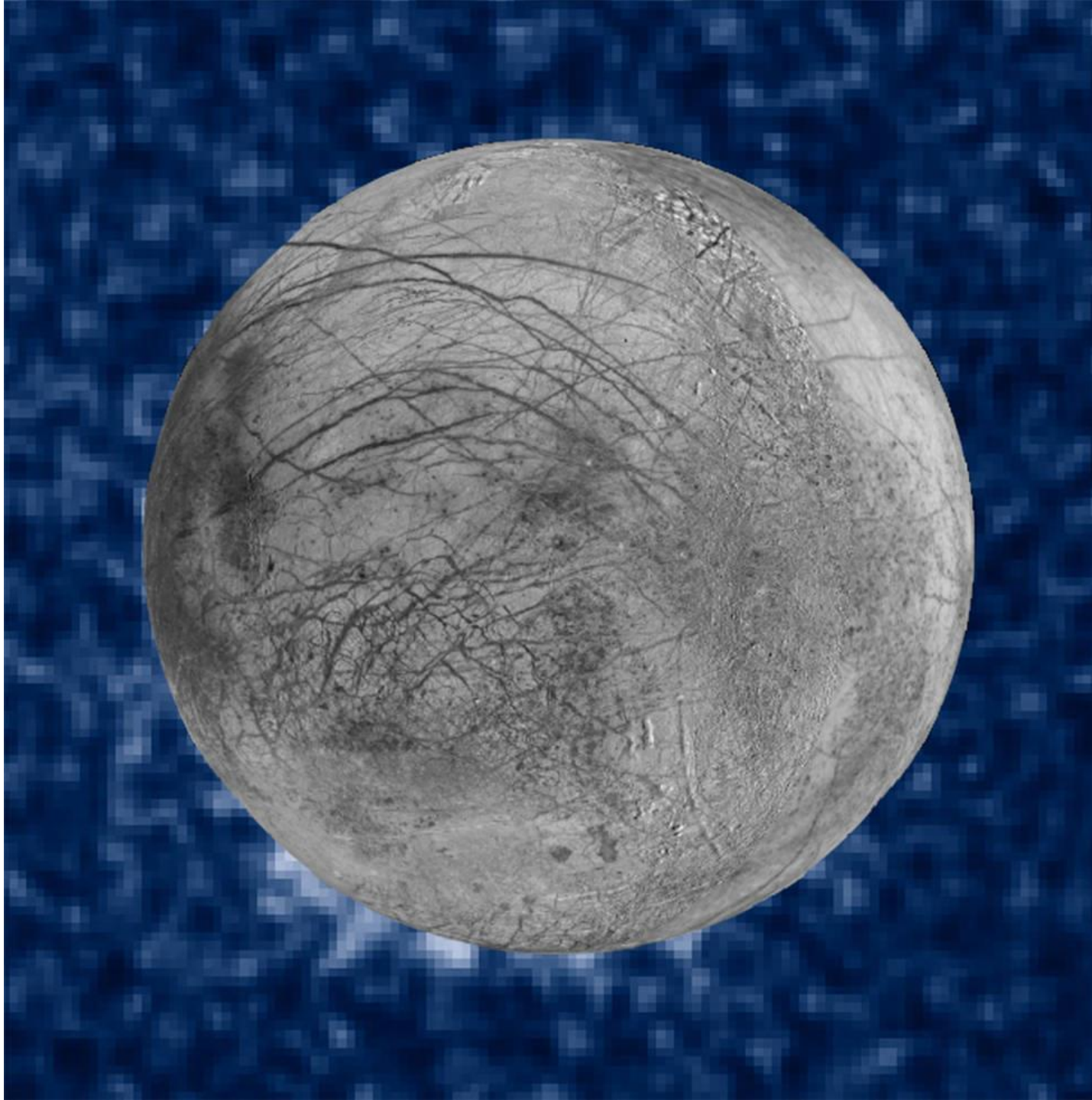




- surface pressure of Europa's atmosphere is 10^{-12} atm
- tenuous ionosphere
- H2, O2, O that escapes Europa's gravity form a gas torus in the vicinity of Europa's orbit around Jupiter -> feeds Jupiter’s magnetospheric plasma
- A lot of water
- periodically occurring plumes of water 200 km high

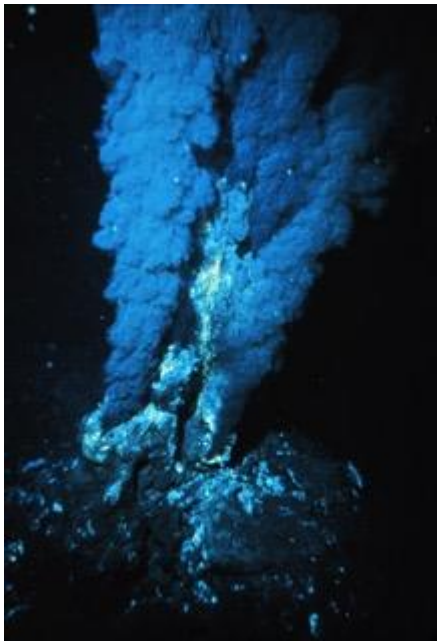
Plumes on Europa

Hubble Space Telescope



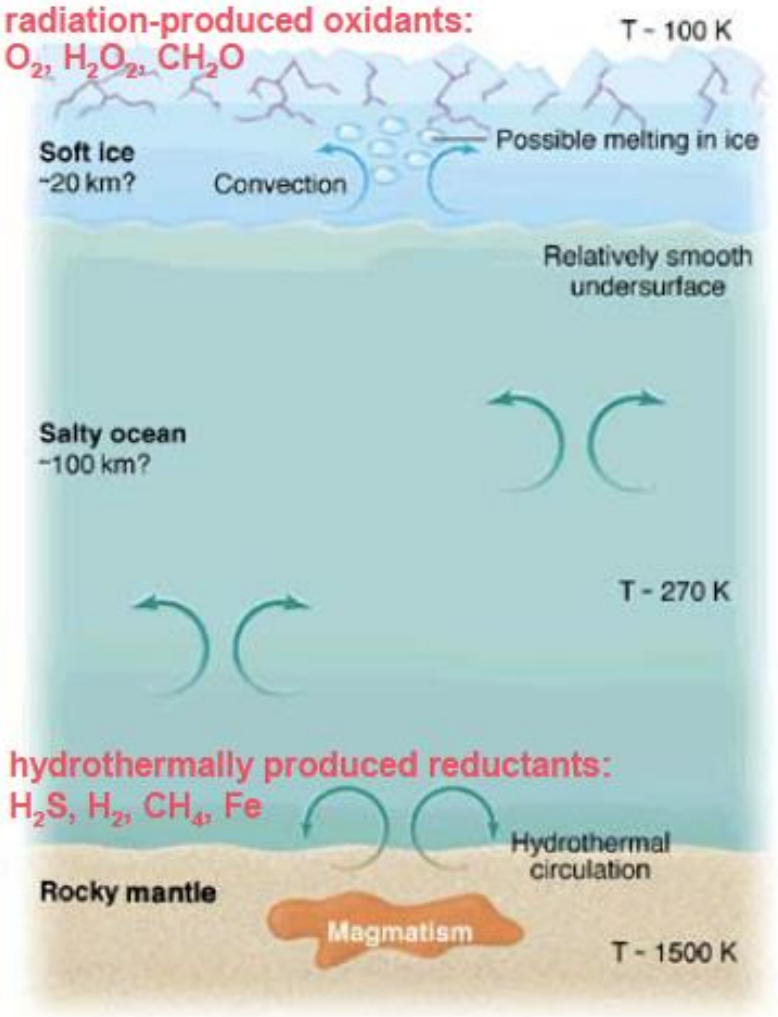
Europa: potential habitability

- one of the top locations in the Solar System in terms of potential habitability and the possibility of hosting life



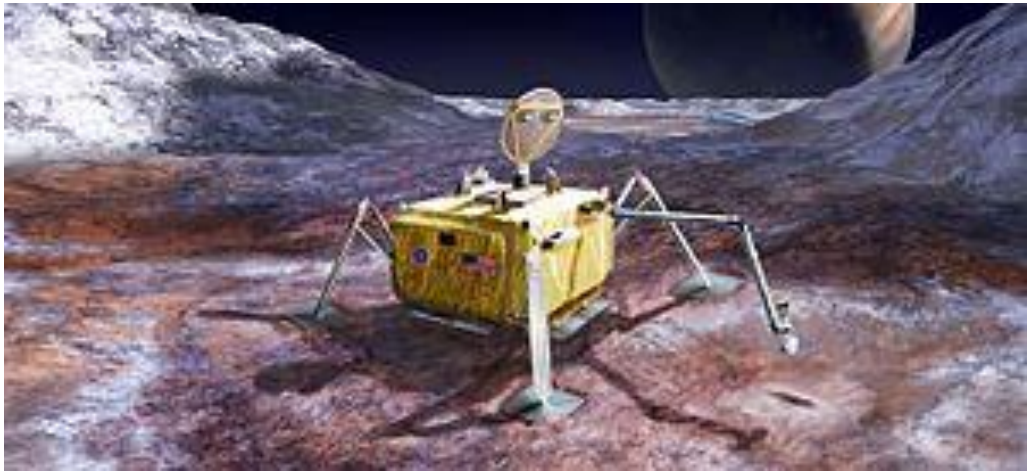
Possible Sources of Biogenic Elements & Chemical Energy

- Radiation chemistry on H_2O creates oxidants:
  - H_2O_2 (hydrogen peroxide) found.
  - HCOH (formaldehyde) predicted.
  - K^{40} decay $\Rightarrow$ O_2, H_2.
- Sources of biogenic elements:
  - CO_2 captured during accretion?
  - Carbon delivered by impactors (lots on Ganymede & Callisto).
- Hydrothermal vents on rocky mantle?
  - $\Rightarrow$ reductants?
  - organic synthesis?
- Better chances of life & detection improve if ocean & surface can communicate.



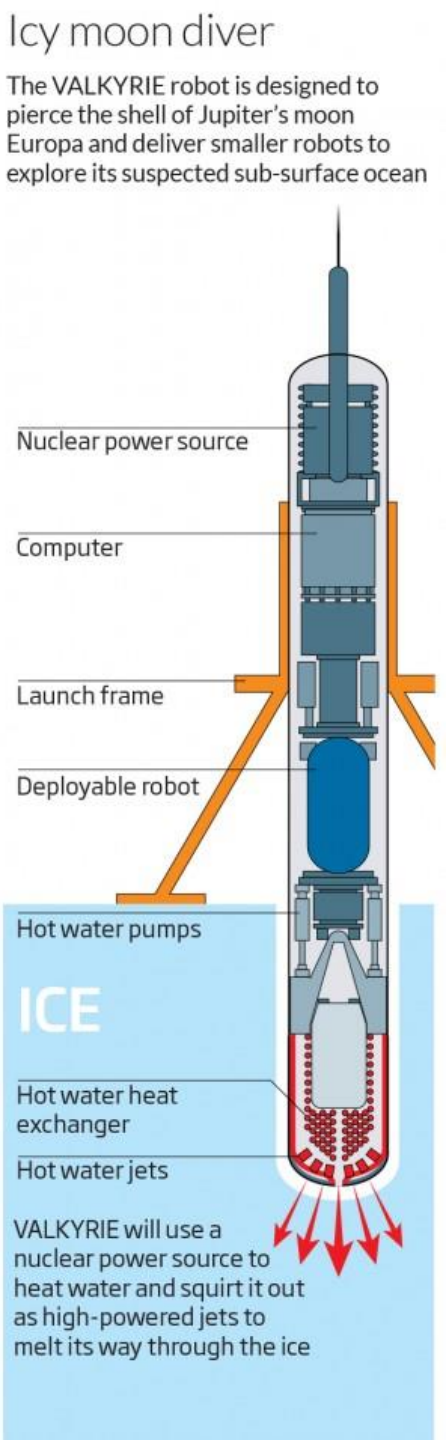
Future Europa missions

- ~ 2022 Europa Clipper, 50m res imaging
- ~ 2027 Europa Lander
- Hydrobots for the future



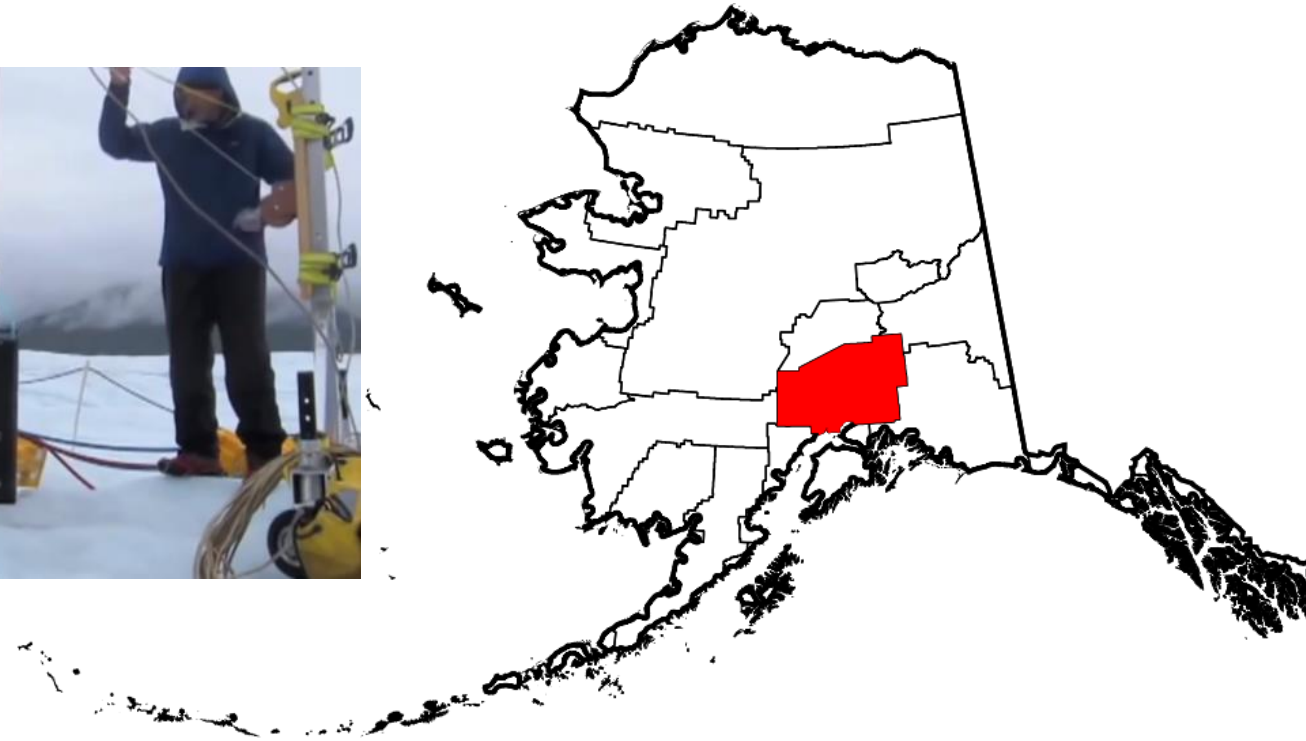
Robotic submarine

- Melt + gravity
- Self-sterilizing techniques
- Testing of hydrobots in Lake Vostok



NASA's Valkyrie cryobot

- First tests in 2014 in Manatuska Glacier
- Planned testing for Lake Voskok
  - Developed in 1960s to study glaciers
  - Lake Vostok discovered later (1973)



Liquid water in Lake Vostok?

A. Because of high pressure
B. Because of insulation by the ice
C. Because of geothermal heat
D. Because of salt content
E. Because of tidal force

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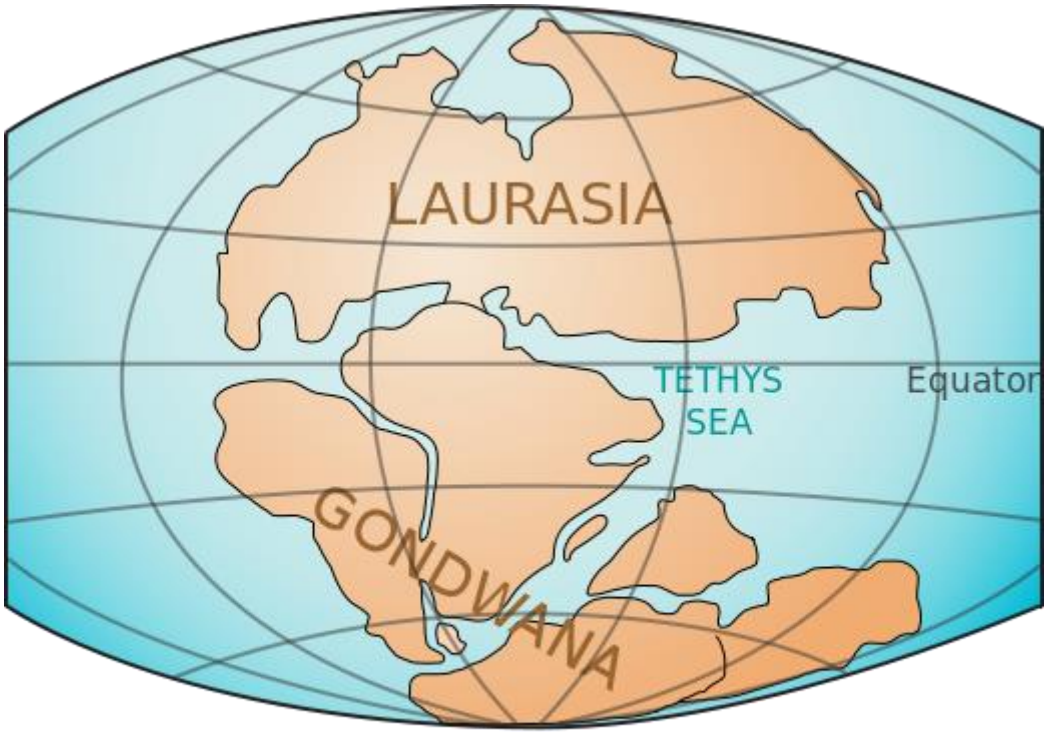
Why liquid water?

- Pressure helps (but very little)
- Insulation from the top is important
- Important: geothermal heat: 50 mW/m^2
  - basal melting 1mm/yr
  - 125 m / (1mm/yr) = 125,000 yr
- Lake is freshwater: no salts
- Tides detected in lake, but unimportant for melting

Gondwana → Antarctica

- Supercontinent 0.6 – 0.16 Gyr
- Gondwana split 160 Myr ago (0.16 Gyr)
- Antarctica still tropical 55 Myr
- 35 Myr → cooler
- Snow → ice



TRIASSIC
200 million years ago

Lake Vostok on Antarctica

- Lake 50 km size
- Existed the whole time
- Possibility of ancient lake sediments
- Unique record of life & climate
- Became sealed off 15 Myr ago
- Suggestion: constant supply of freshly molten water → frozen ice carried away

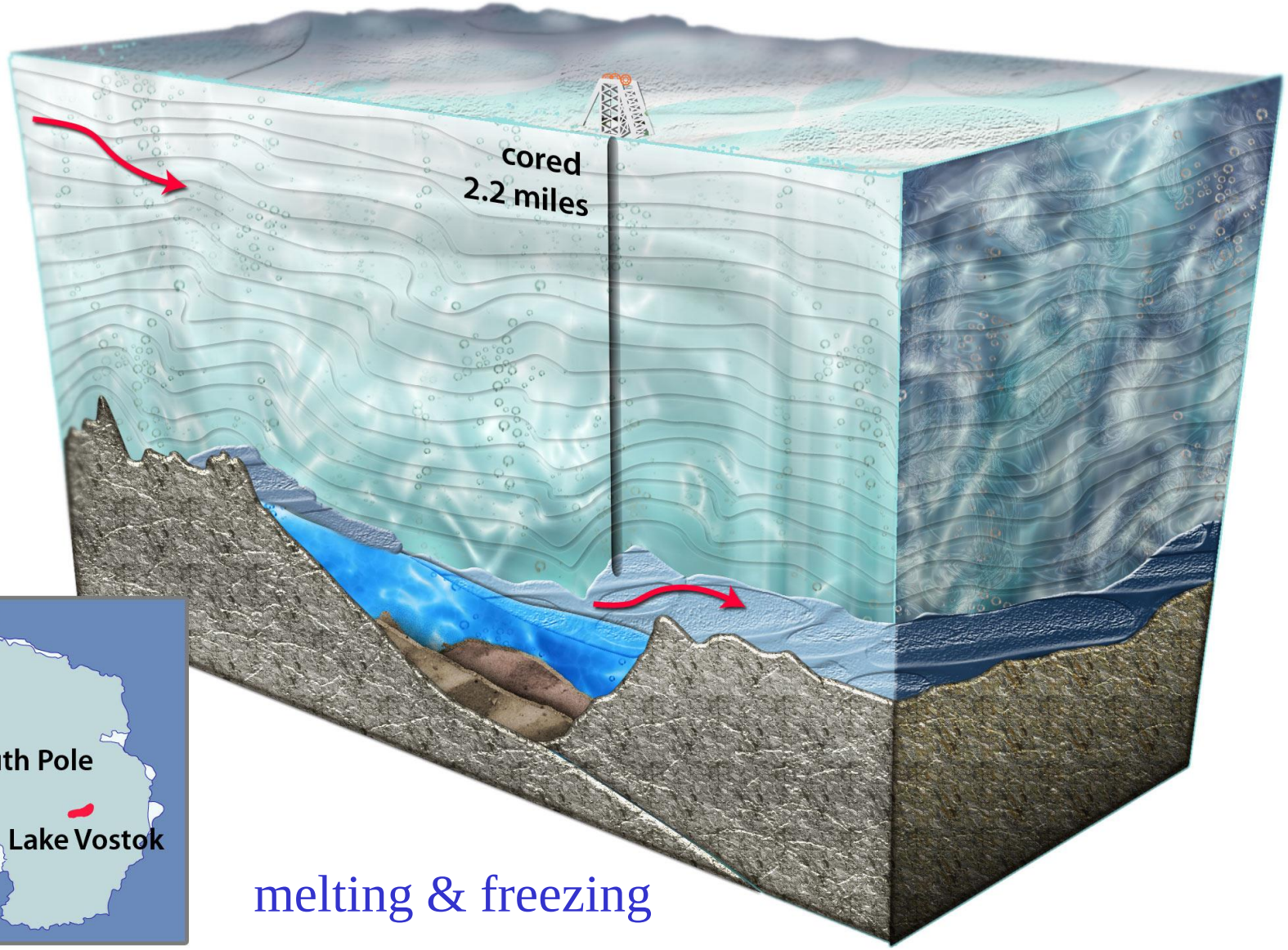
East

4/5000

Восточный

Vostochnyy

Lake Vostok



melting & freezing

Trapped gases

- Pressure 345 bars
  - Water supersaturated with N_2 and O_2 (2.5L/kg)
  - 50 times more than usual freshwater lake
- Are these polar or apolar?

  A. Polar

  B. Apolar

Trapped gases

- Pressure 345 bars
  - Water supersaturated with N_2 and O_2 (2.5L/kg)
  - 50 times more than usual freshwater lake
- Apolar → don't dissolve!
- Gases can be trapped in clathrates
  - Cages of hydrogen-bonded frozen water molecules
  - Unstable when brought to surface

Biology in Lake Vostok

- Oligotrophic: very few nutriens
- Complete darkness
- Ice core drillings:
  - *hydrogenophilus thermolutelus*
- But could be contamination

Lake Vostok

- Ice cores: age > 420,000 yr
- Halted 100m above lake: to avoid contamination
  - Kerosene, Freon (antifreeze)
  - Cleaned & continued in 2012
  - 94% bacteria, 6% eukaria
  - DNA sequencing: 255 know + 1 unknown
  - Contamination?
- May 2013: historic monument

Friday

- Titan
- Methane cycle (!)
- RGS pp. 171 – 178, 191 – 196
- Table 5.3