

Hot Science Cool Talks

UT Environmental Science Institute

78

Life on Europa? Exploring Jupiter's Icy Moon

Dr. Britney Schmidt

April 13, 2012

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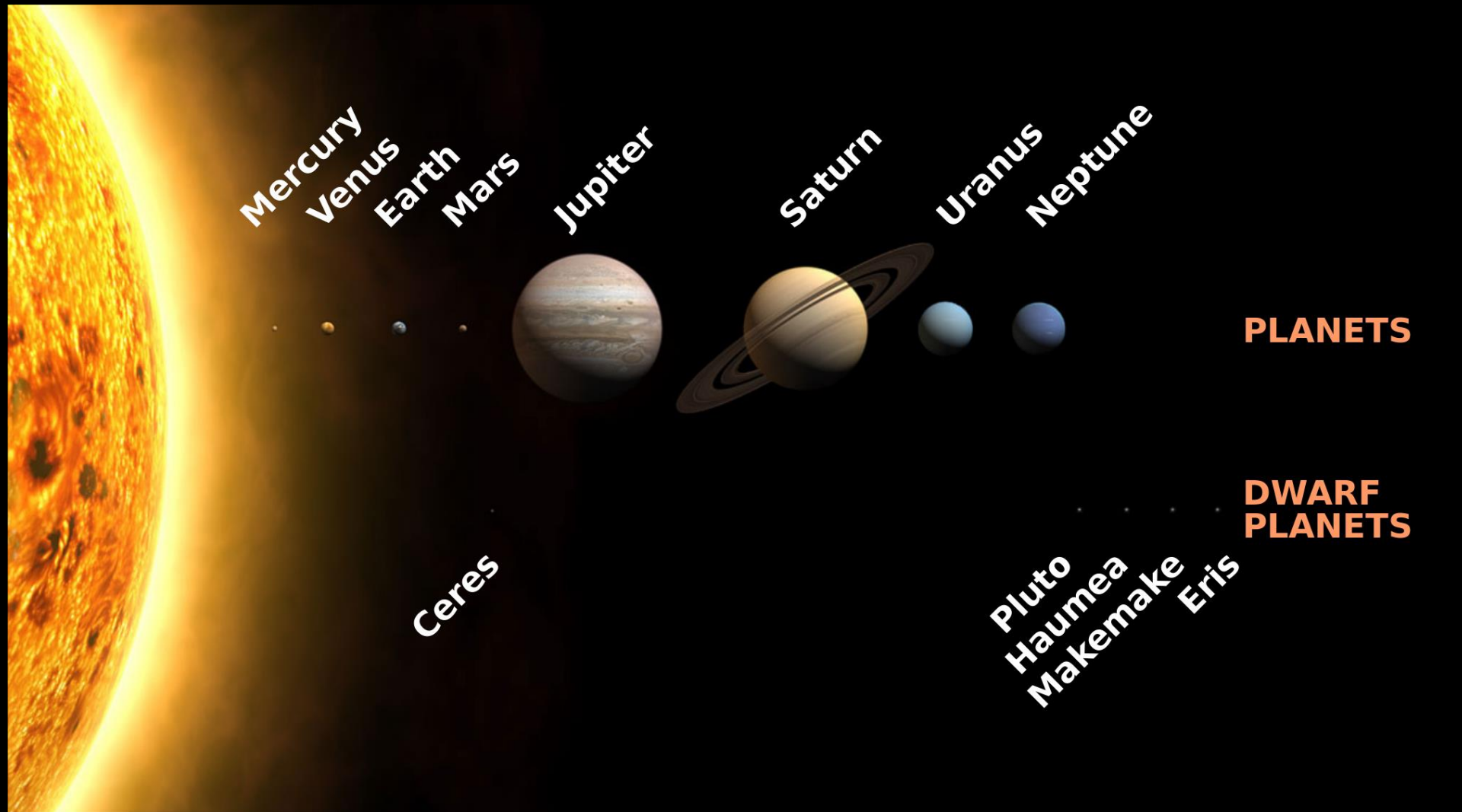
Life on Europa? Exploring Jupiter's Icy Moon

Britney E. Schmidt

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April 13, 2012

Thanks: Don Blankenship, Krista Soderlund, Jamin Greenbaum, Duncan Young, Wes Patterson, Paul Schenk, Peter Doran, Stacy Kim



Mercury
Venus
Earth
Mars

Jupiter

Saturn

Uranus

Neptune

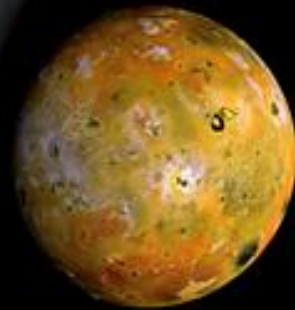
PLANETS

Ceres

Pluto
Haumea
Makemake
Eris

**DWARF
PLANETS**

The Galilean Satellites:



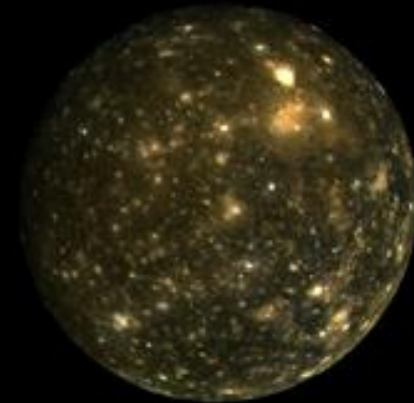
Io



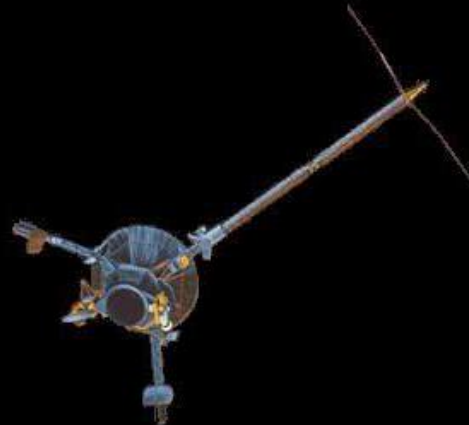
Europa



Ganymede



Callisto



Galileo, 1995-2003

Callisto

Ganymede



Europa

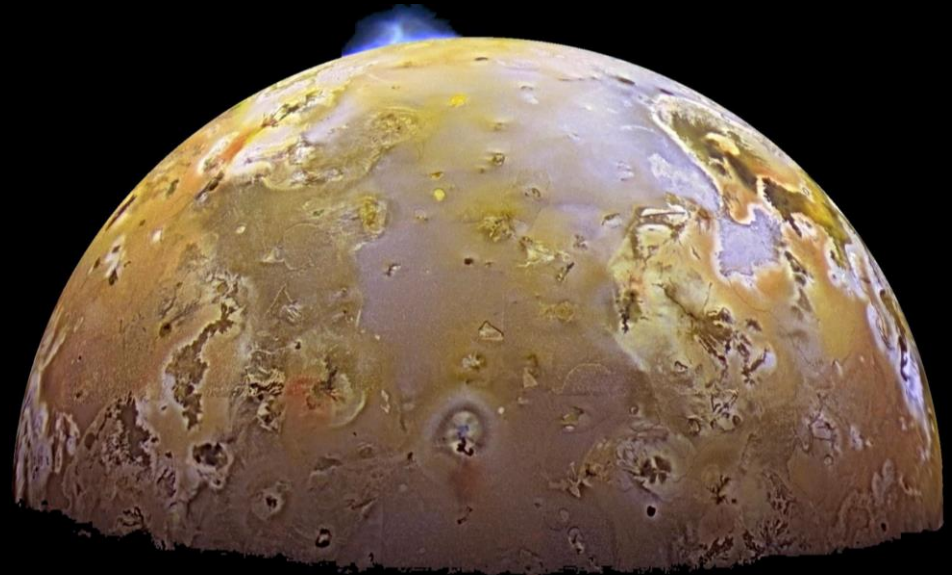
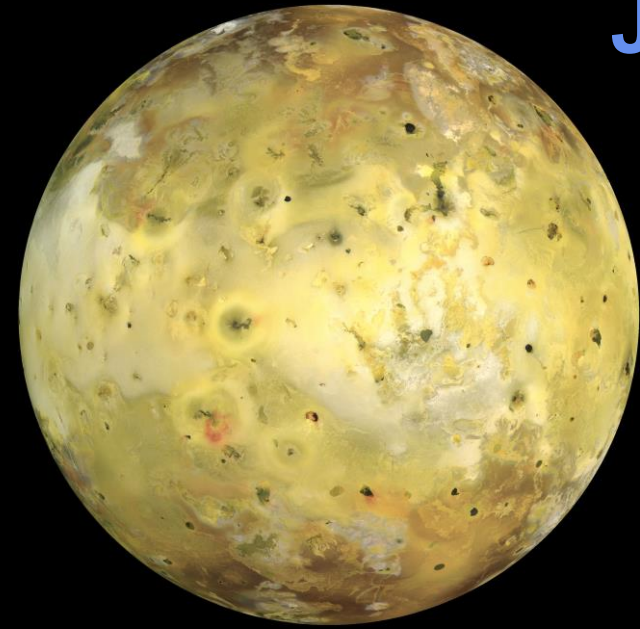
JUPITER'S VOLCANIC MOON: IO

-- 4th largest moon

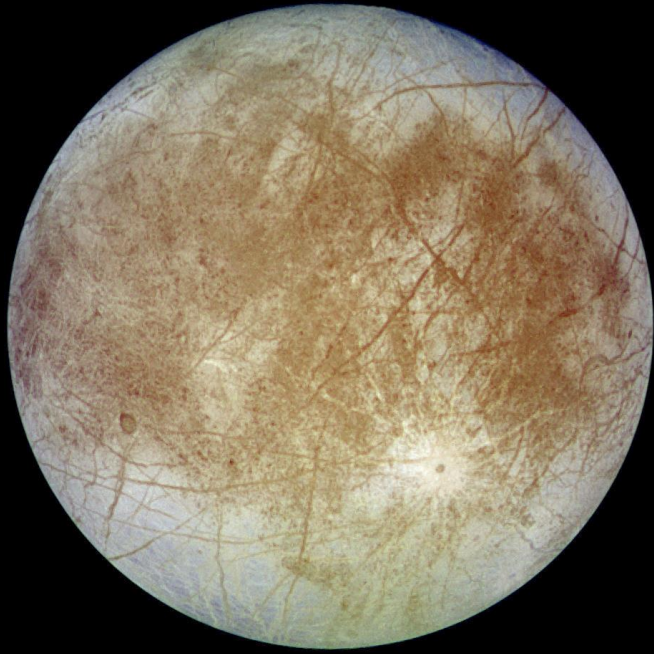
-- Over 400 active volcanoes

→ most active object in the solar system

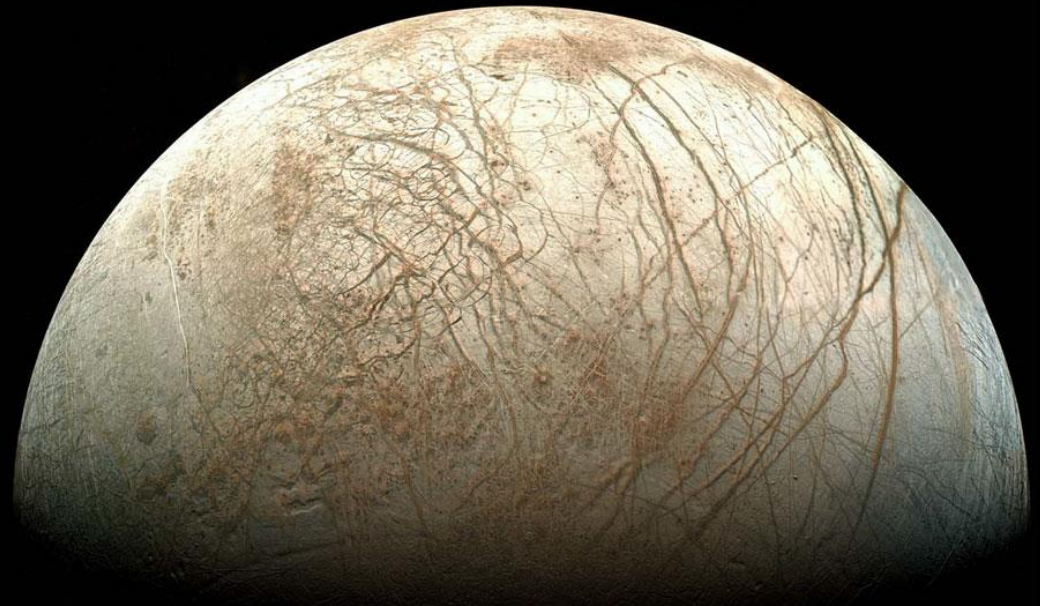
-- Energy from tidal heating



JUPITER'S OCEAN MOON: EUROPA



- 6th largest moon (~size of our moon!)
- Very young surface
- Internal energy from tides



JUPITER'S ICY MOON: GANYMEDE

- Largest moon, larger than Mercury!!
- Liquid iron core and its own magnetosphere
→ even has its own aurora!
- Perched ocean



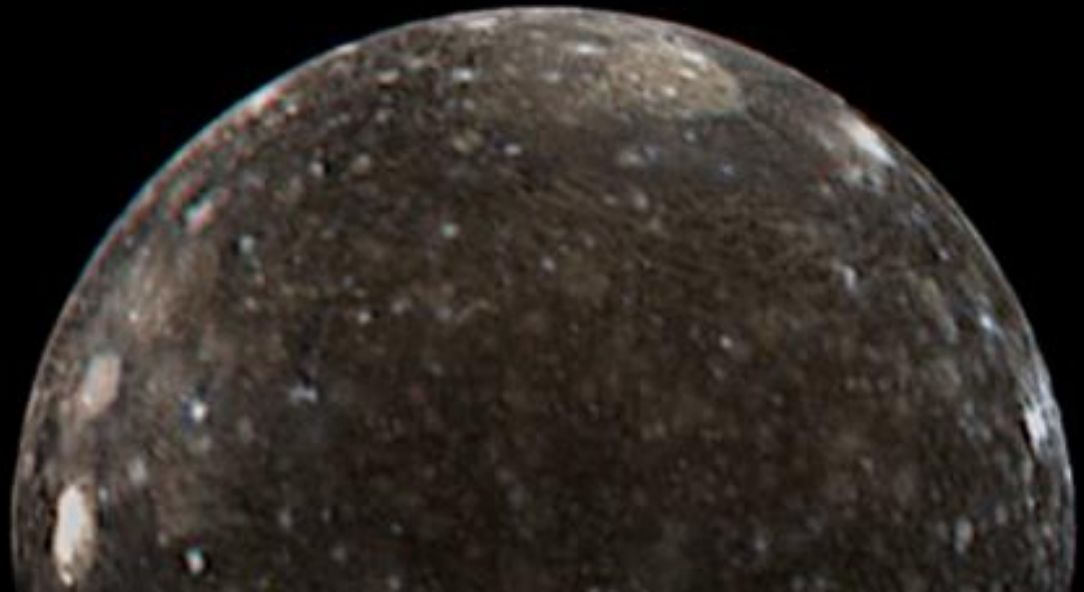
JUPITER'S DIRTY MOON: CALLISTO

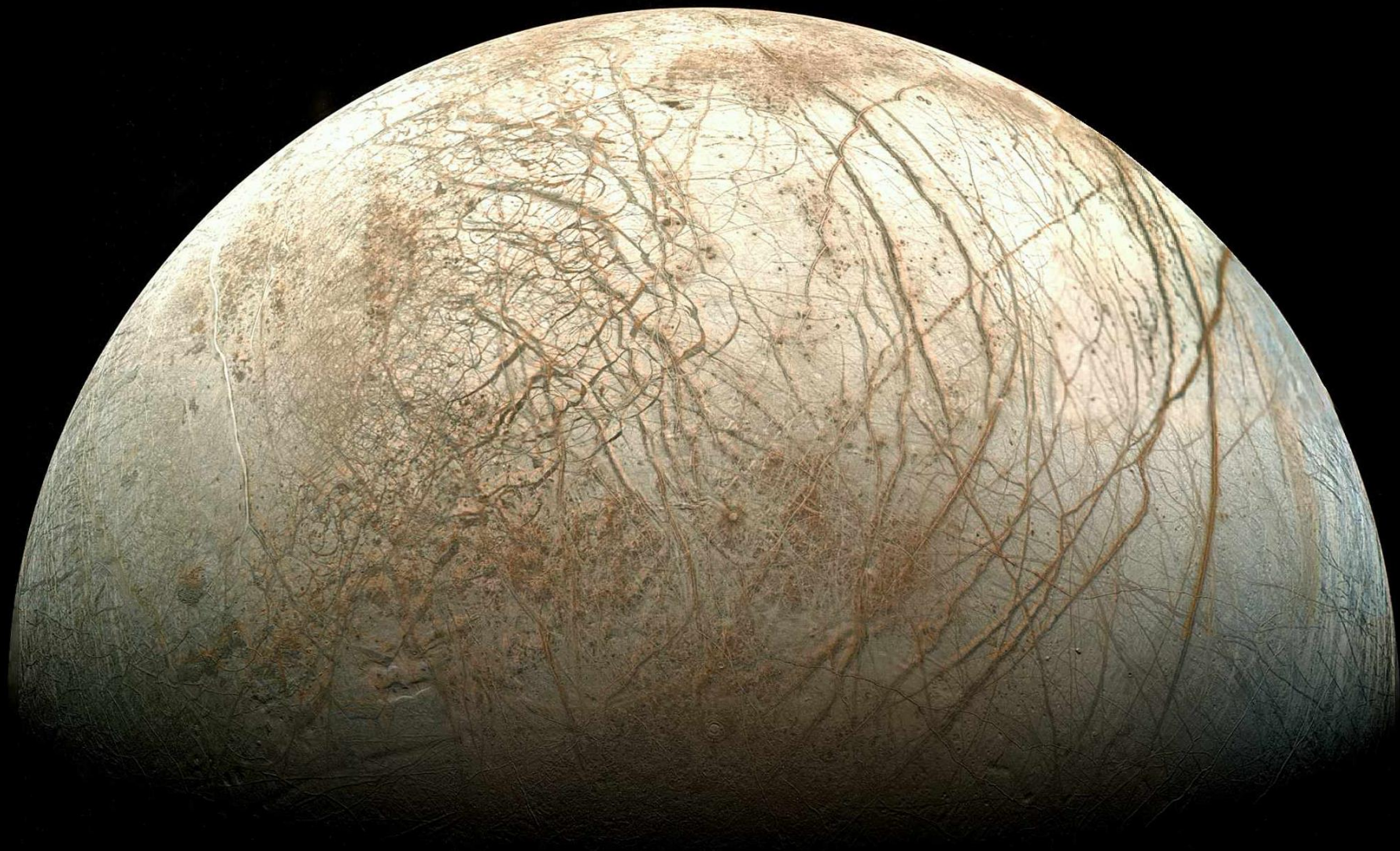
-- 3rd largest moon

-- Very old surface

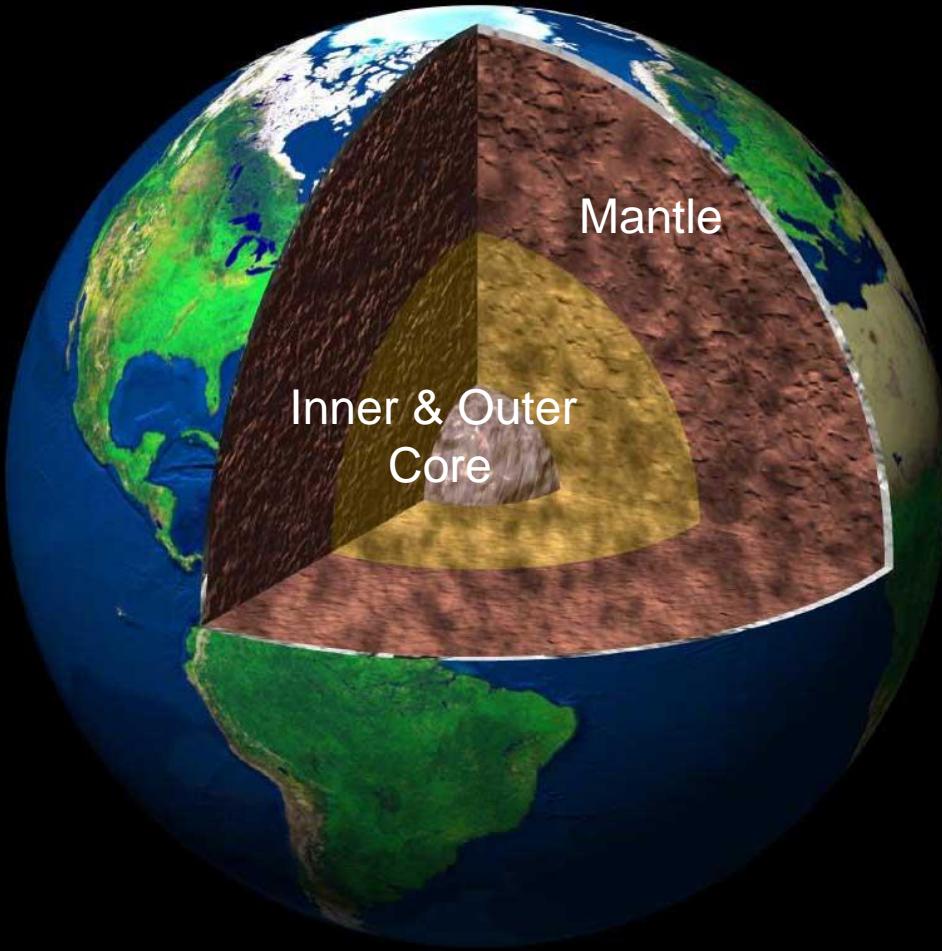
-- No tidal heating

-- Perched ocean

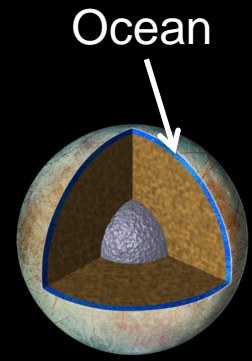




Energy on Europa?



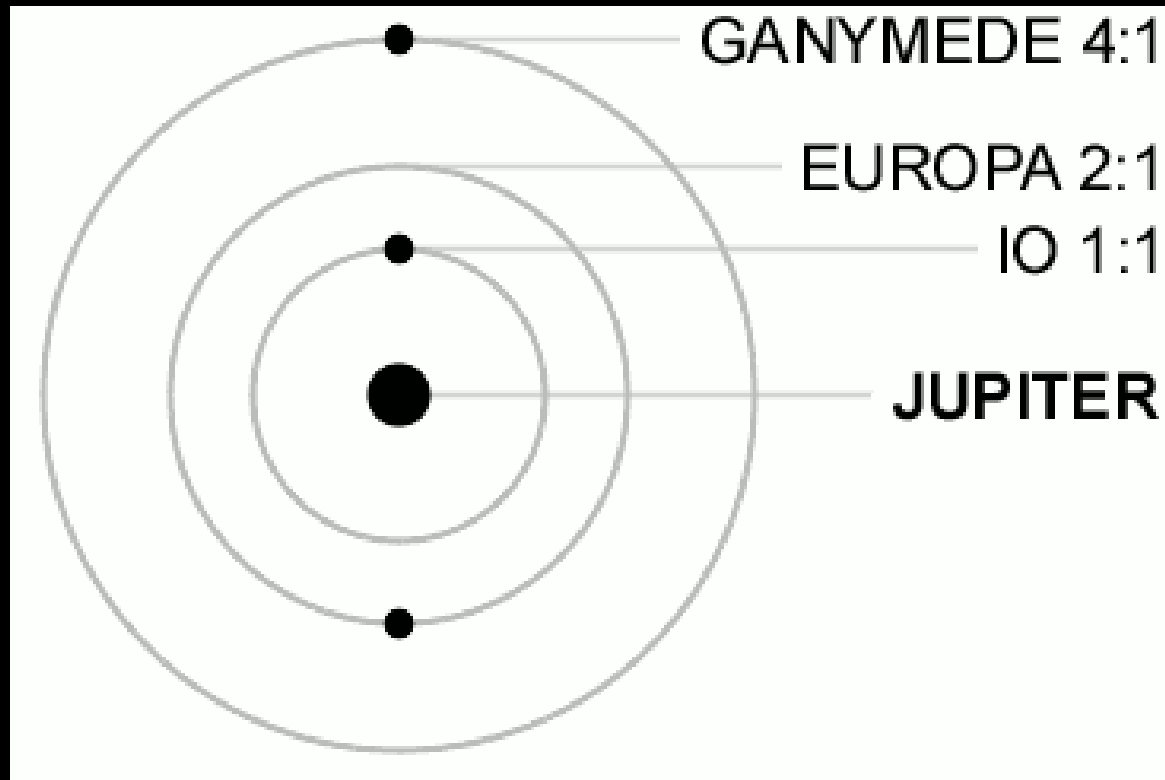
Earth:
*warm salty H₂O, mantle
contact,
Energy: Sun + Accretion + Interior*



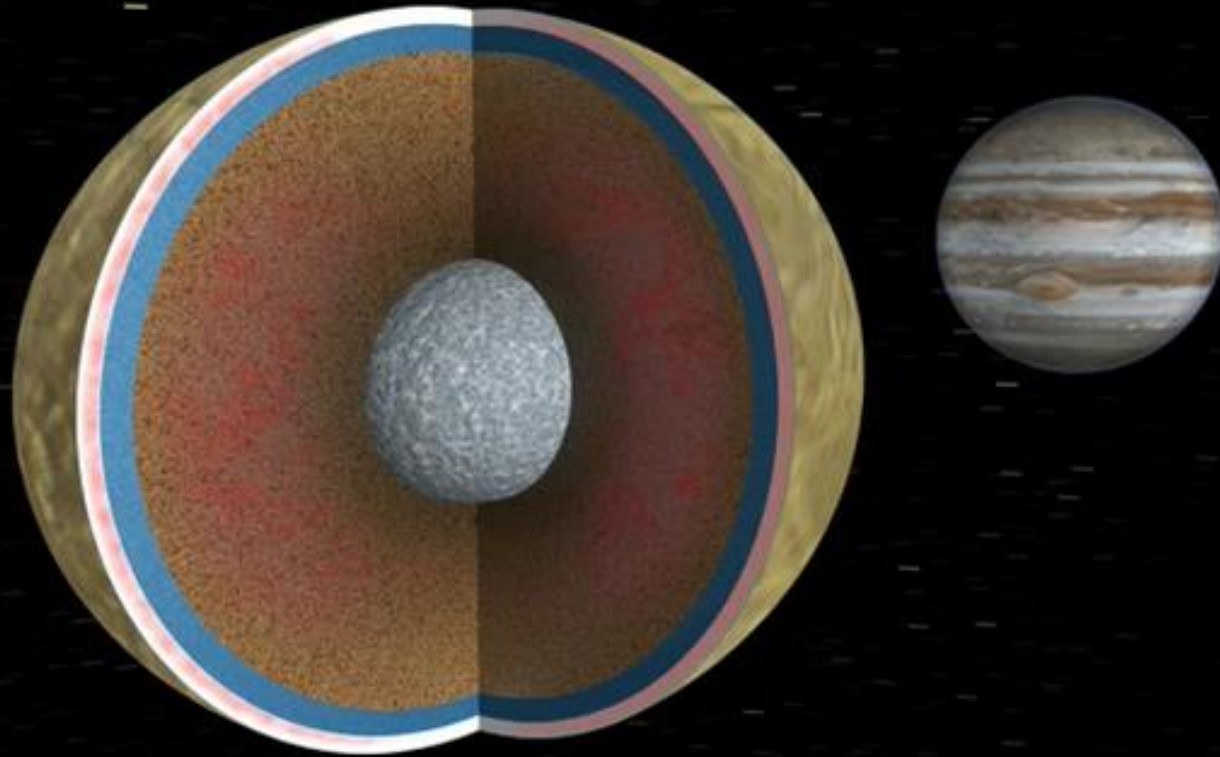
Europa:
*warm salty H₂O,
mantle contact,
Energy: Orbital*

Energy From Orbits!

- Io's orbit: $\sim 1 \frac{3}{4}$ days.
- Europa's orbit: $\sim 3 \frac{1}{2}$ days.
- Ganymede's orbit: ~ 7 days.
- Keeps the moons' orbits eccentric, so they gain energy from tides



Stressing Europa: Tidal Heating & Flexure



[Play Video Animation \(Apple Quicktime Required\)](#)

Help from the Magnetic Field



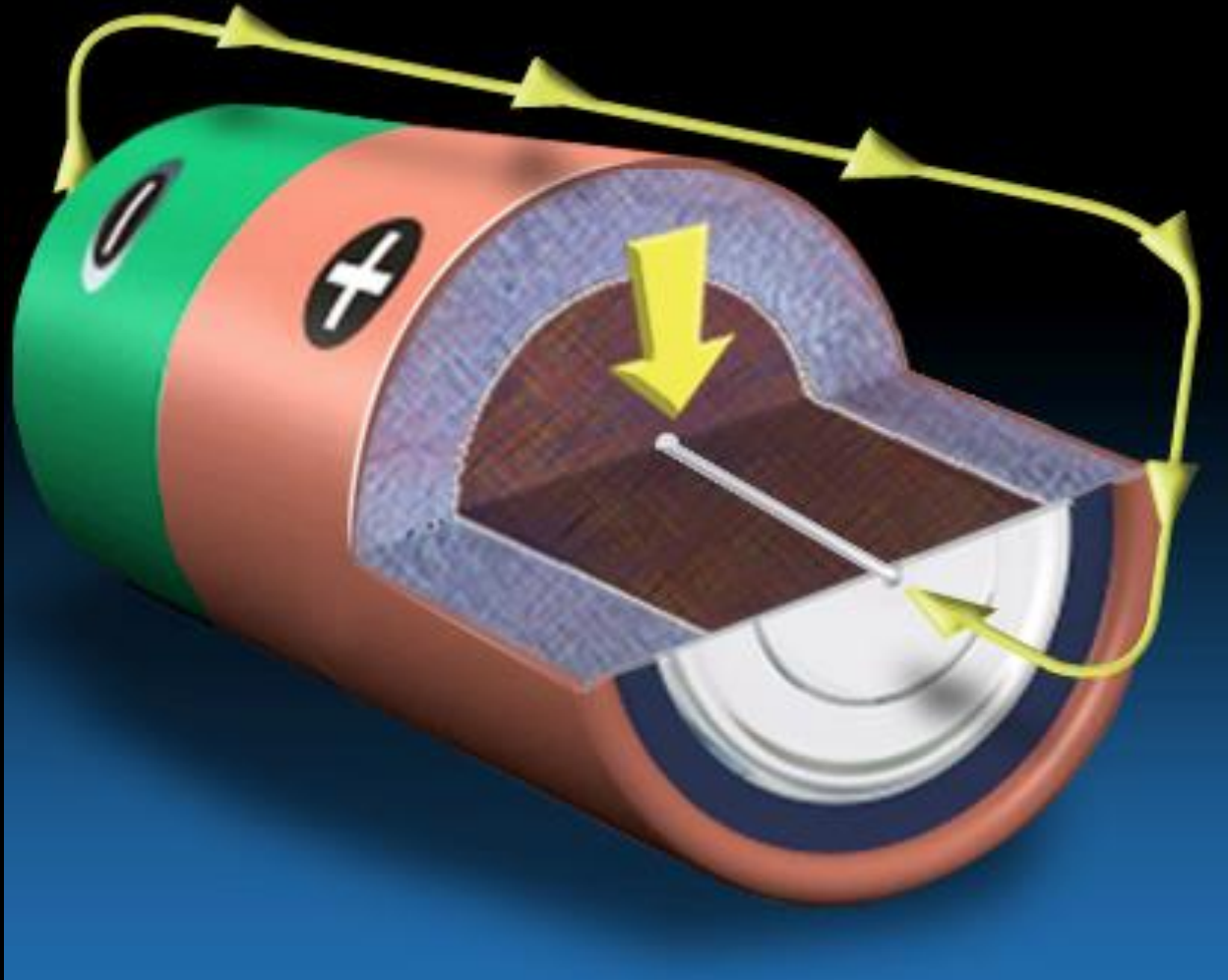
An Oxidized Surface

An Ocean on Europa??

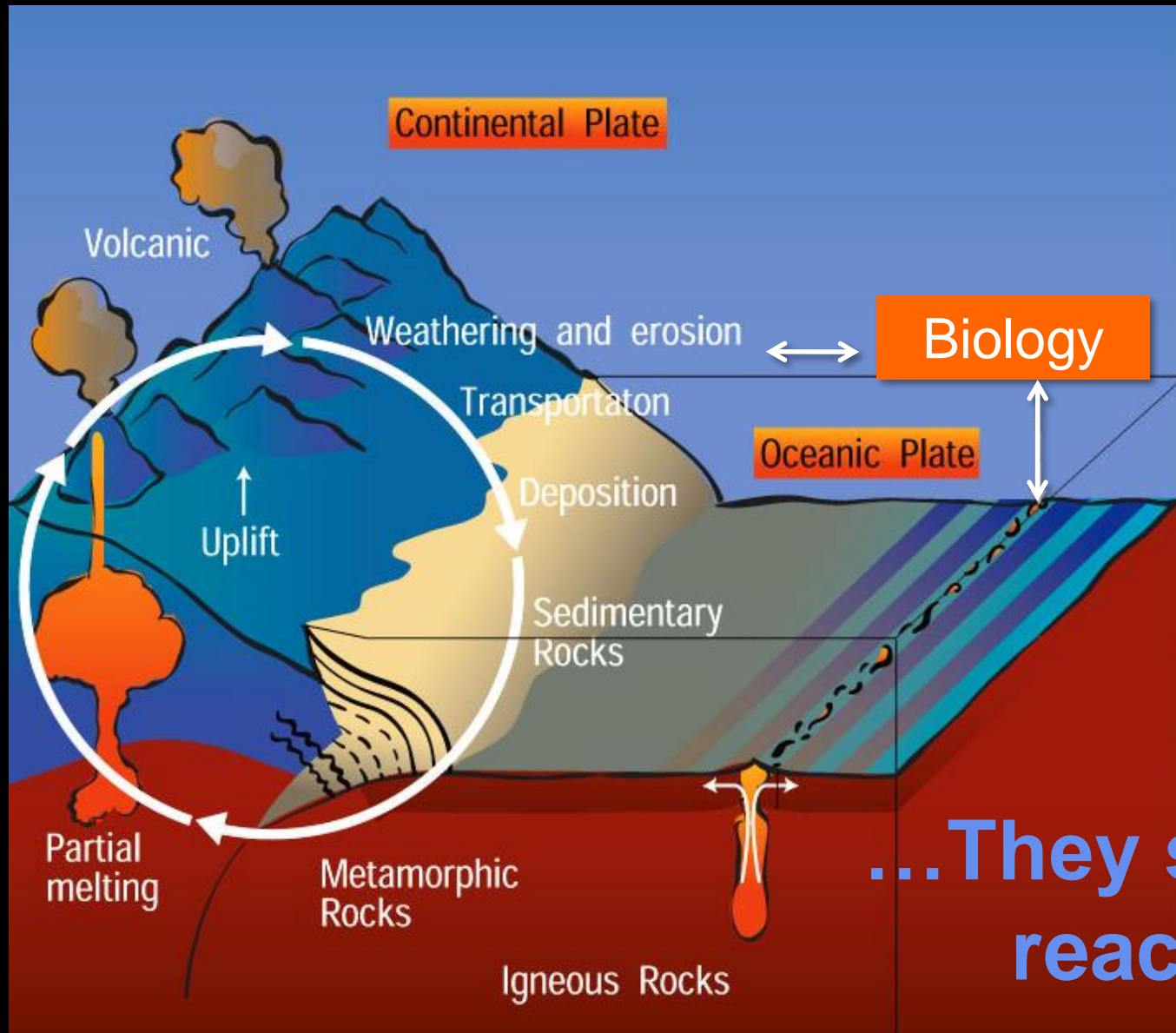
Why We Care About Energy:

Life in a Subsurface Ocean?

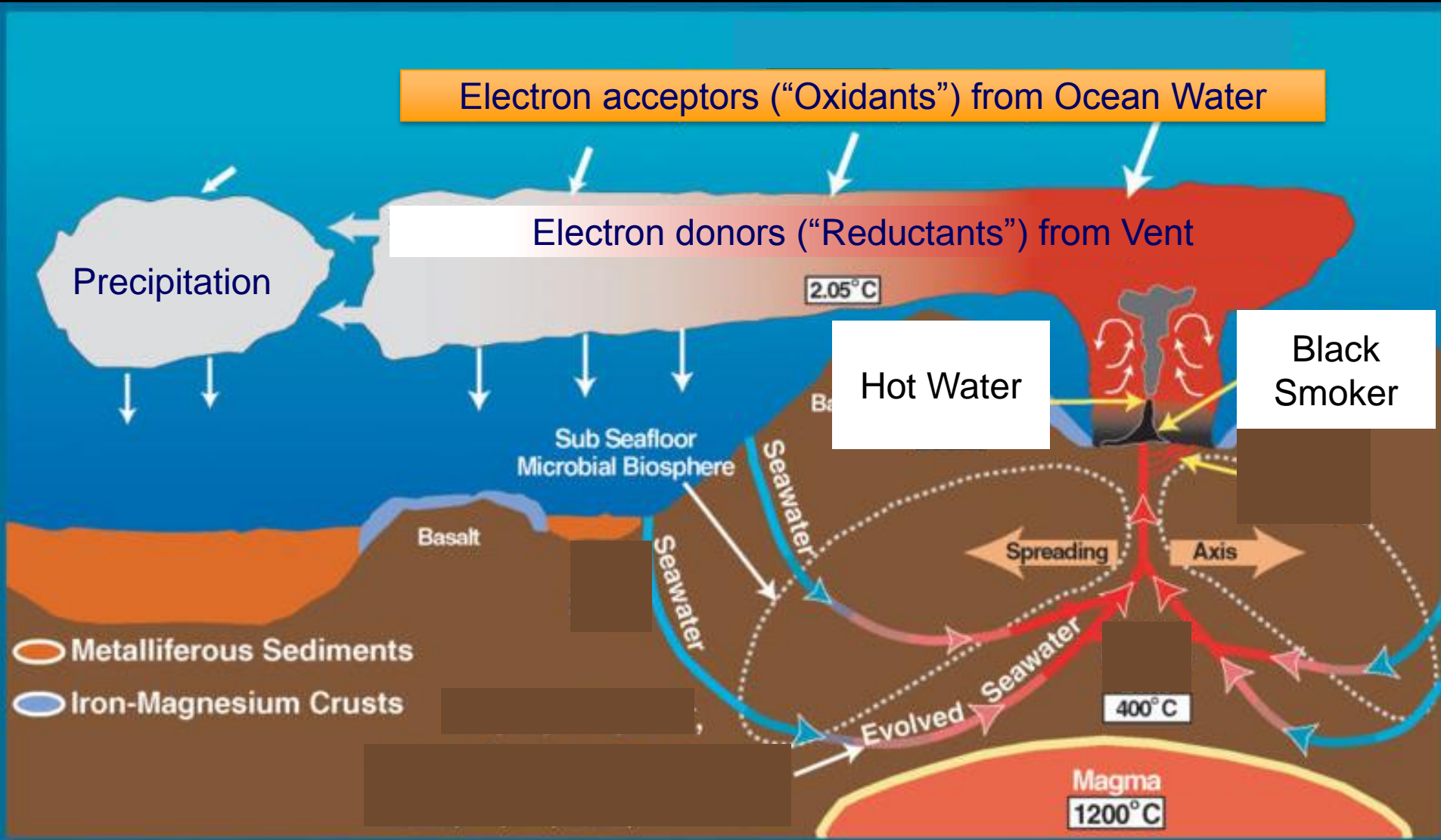
Life is like a battery...



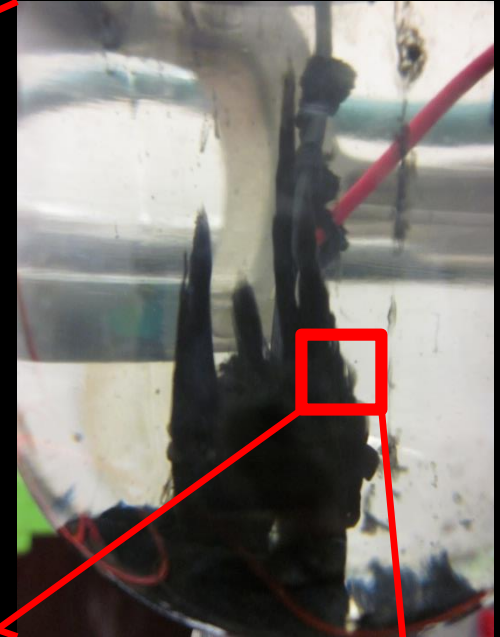
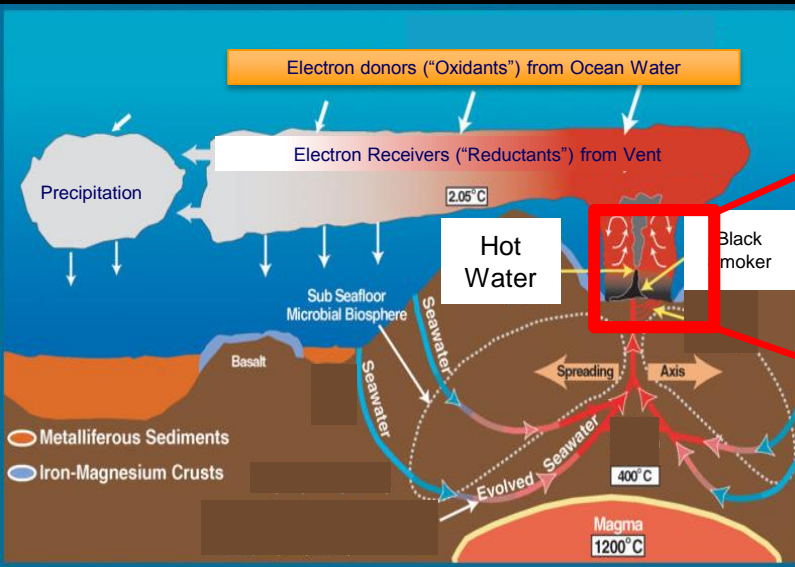
Earth's geologic cycles are also like batteries...



EUROPA ECOSYSTEM ANALOGUE: BLACK SMOKERS?

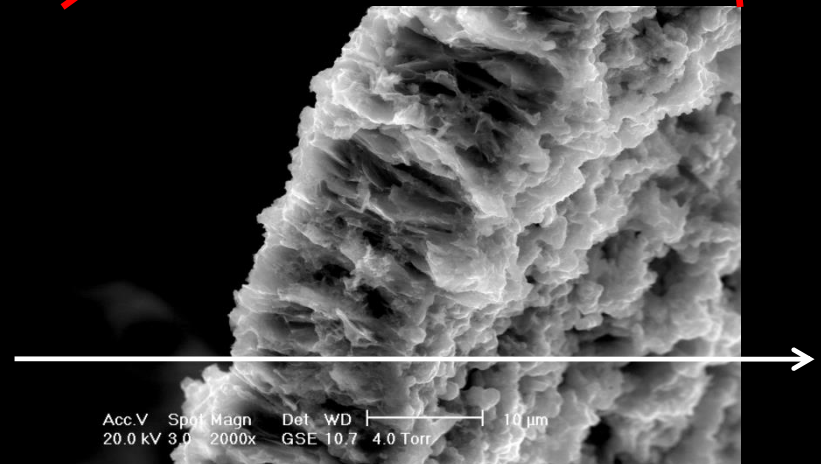


EUROPA ECOSYSTEM ANALOGUE: BLACK SMOKERS?



Redox Reactions form the basis of life...
And they get set up
by hydrothermal vents!

Electron
flow

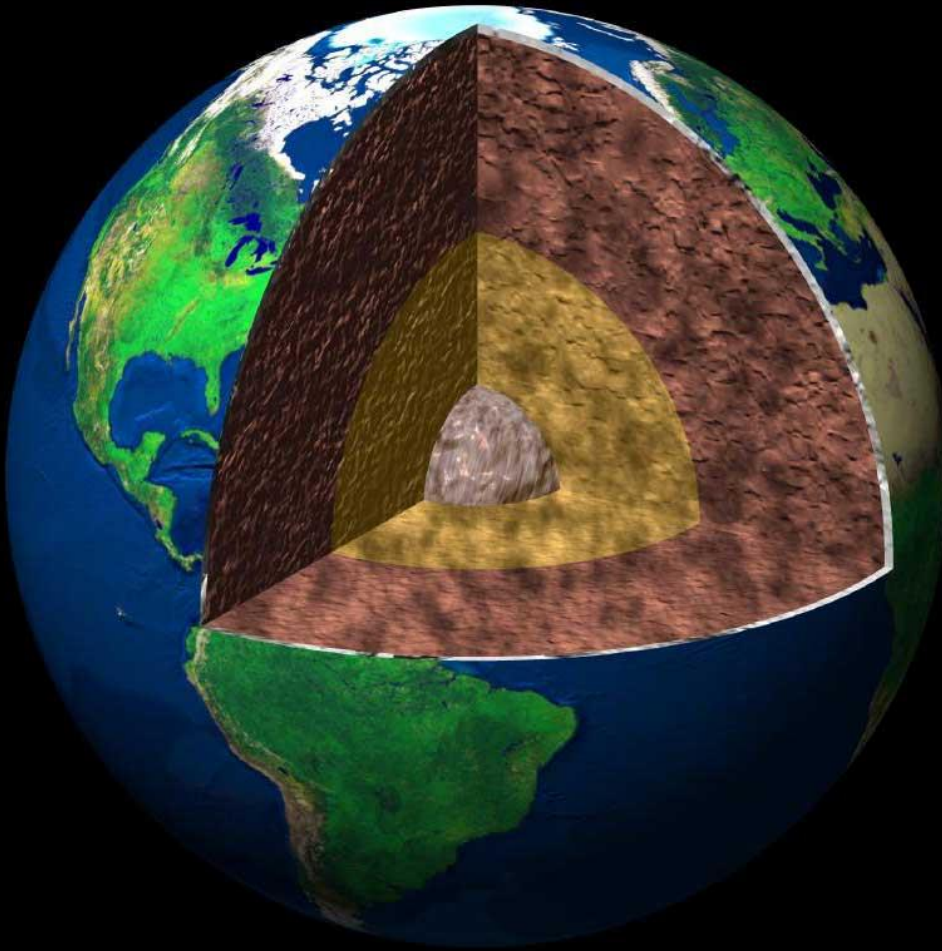


PRECIPITATE FORMATION EXAMPLES:

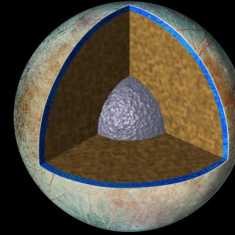
Windows Media Player

Apple Quicktime

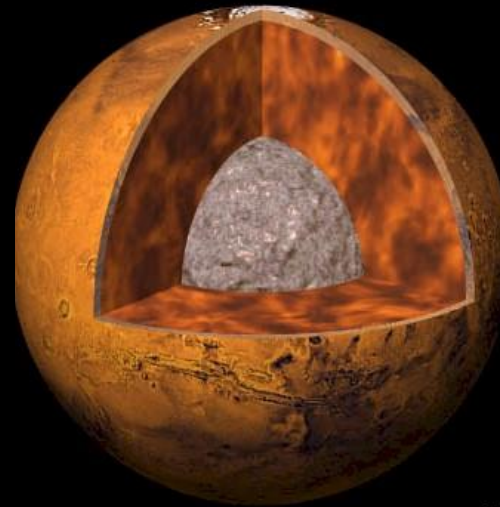
Why Europa?



Earth:
*warm salty H₂O, mantle
contact, high energy*



Europa:
*warm salty H₂O,
mantle contact,
high energy*

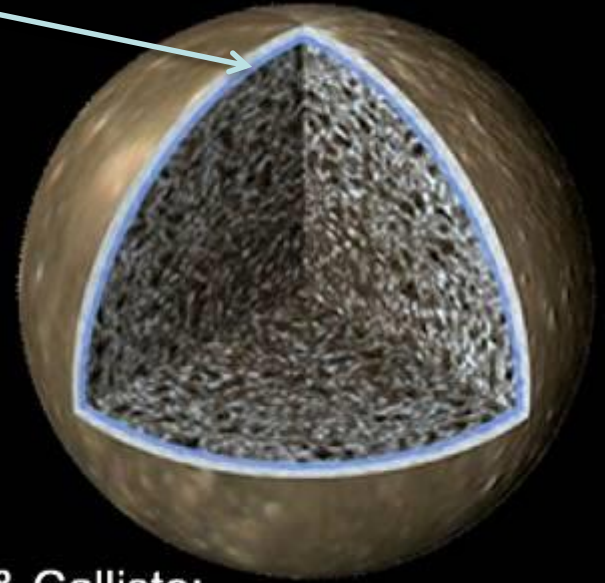
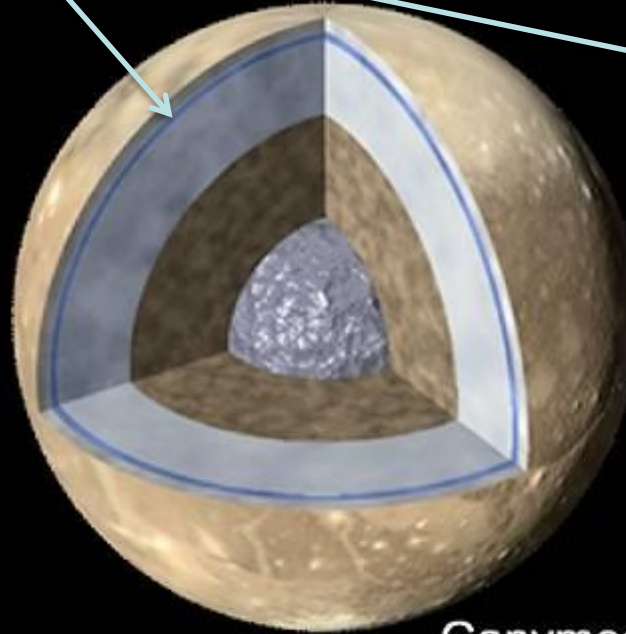
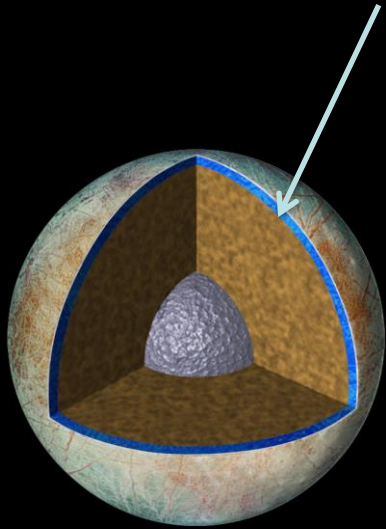


Mars:
*frozen polar caps,
subsurface activity?
Ocean 3.5 Ga?*

© Calvin J. Hamilton

Why Europa?

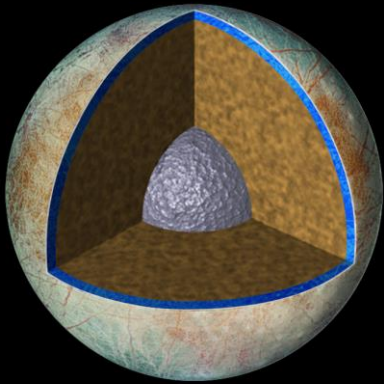
Where's the Ocean?



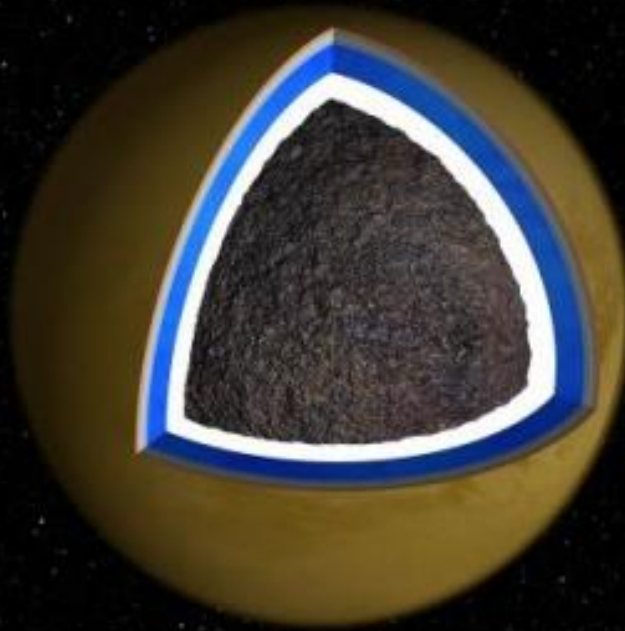
Europa:
*warm salty H_2O , mantle
contact, high energy*

Ganymede & Callisto:
perched salty $H_2O(-NH_3?)$

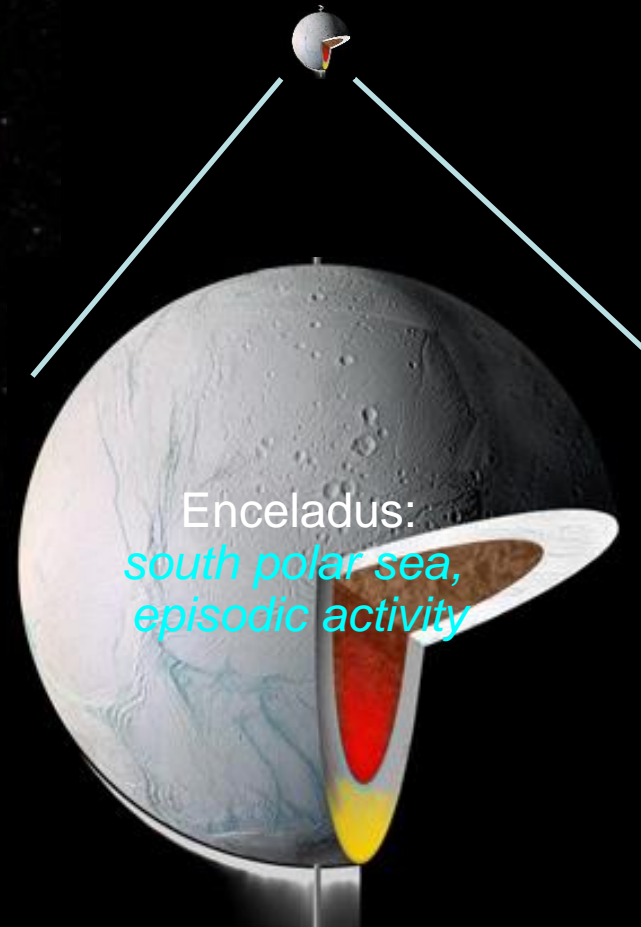
Why Europa?



Europa:
*warm salty H₂O, mantle
contact, high energy*



Titan:
*perched H₂O, high pressure
ices, undifferentiated core?*

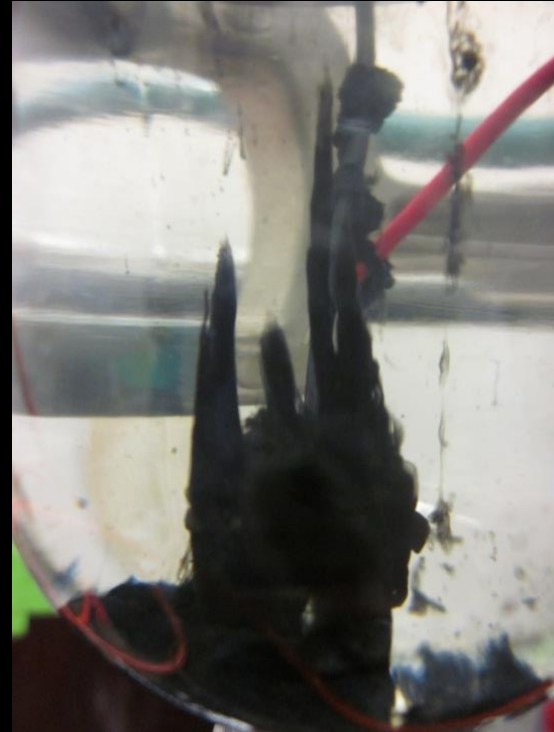
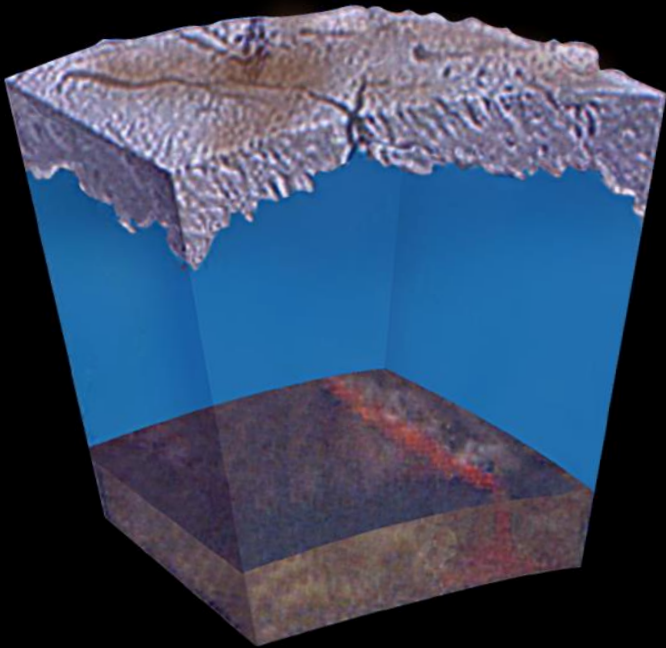


Enceladus:
*south polar sea,
episodic activity*

Europa's Ingredients for Life

- Water: much more than all of Earth's oceans
- Organic molecules: from accretion and comets
- Chemical energy: Oxidized material from above, reduced material from below
- But does the system recycle???

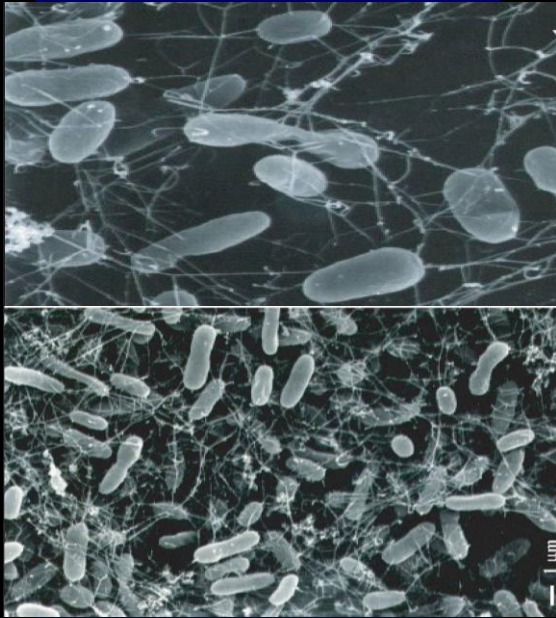
Credit: Laurie Barge



“Black Smoker” Grown in Europa-like Conditions

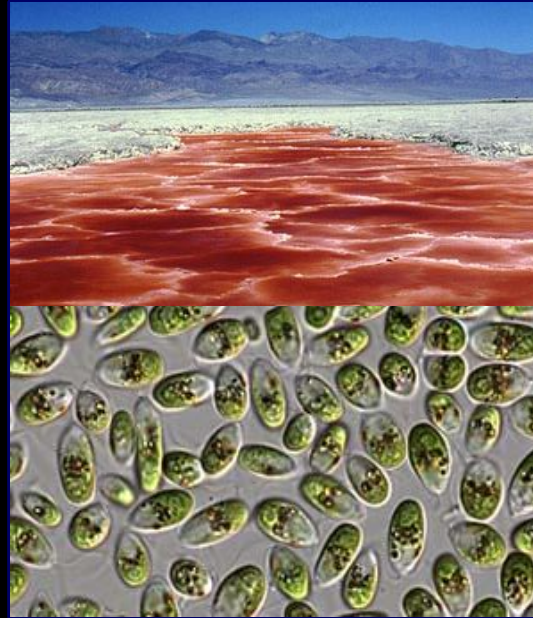
EUROPA-TYPE EXTREMOPHILES?

Thermophiles



- Chemical Energy
- Grow from 45-80 °C
- At hydrothermal systems
- Acid, metal tolerant
- May survive above 130°C!

Halophiles



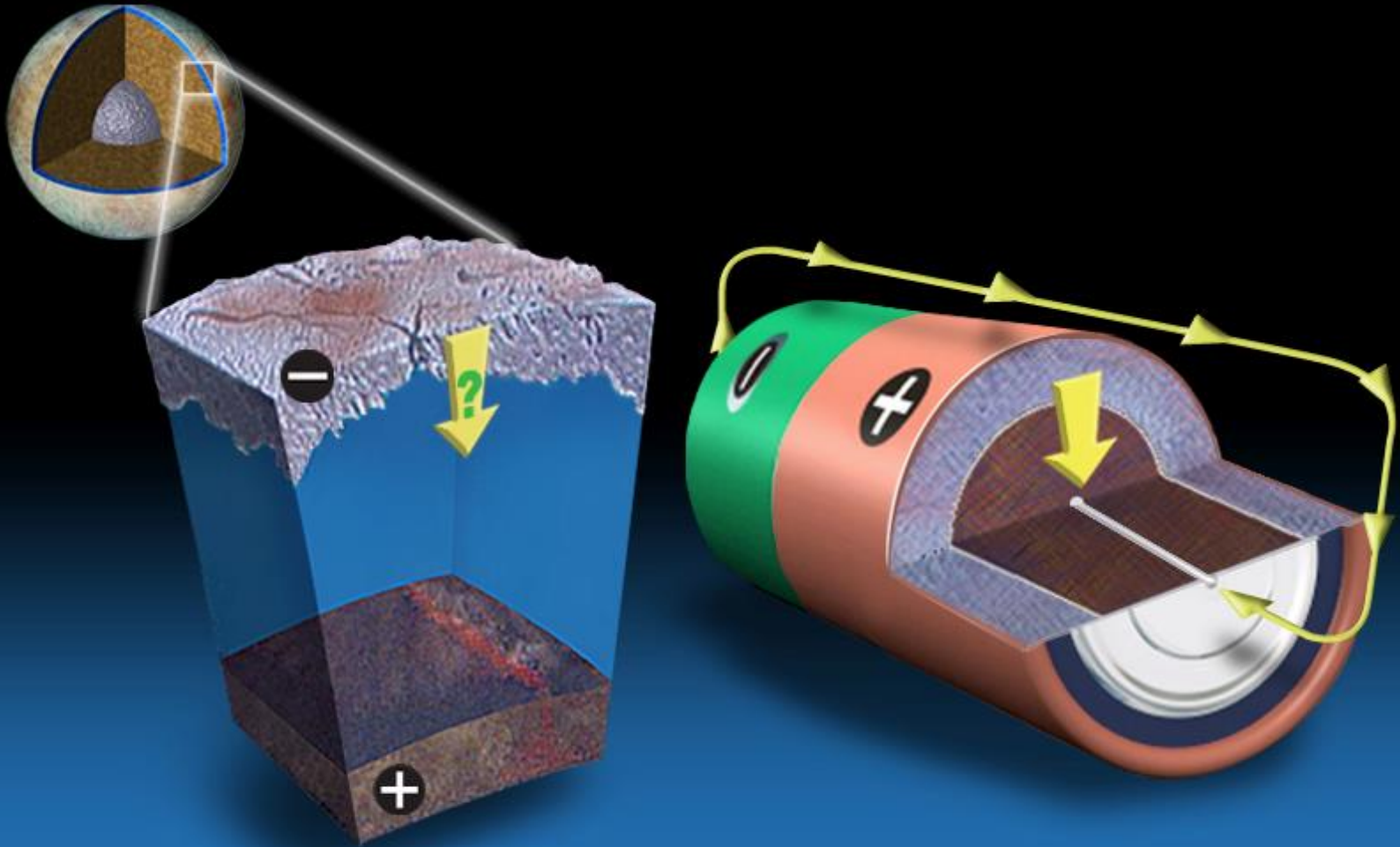
- Grow in 5-35 wt% salt
- Heat, Cold, alkali and acid tolerant.
- Can survive within salt crystals for long time periods
- Chemical Energy

Psychrophiles



- Grow at or below 10 °C
- Protective extracellular coat
- Aerobic or anaerobic
- Some may reproduce as low as -10 °C
- Chemical Energy

An Energetic System



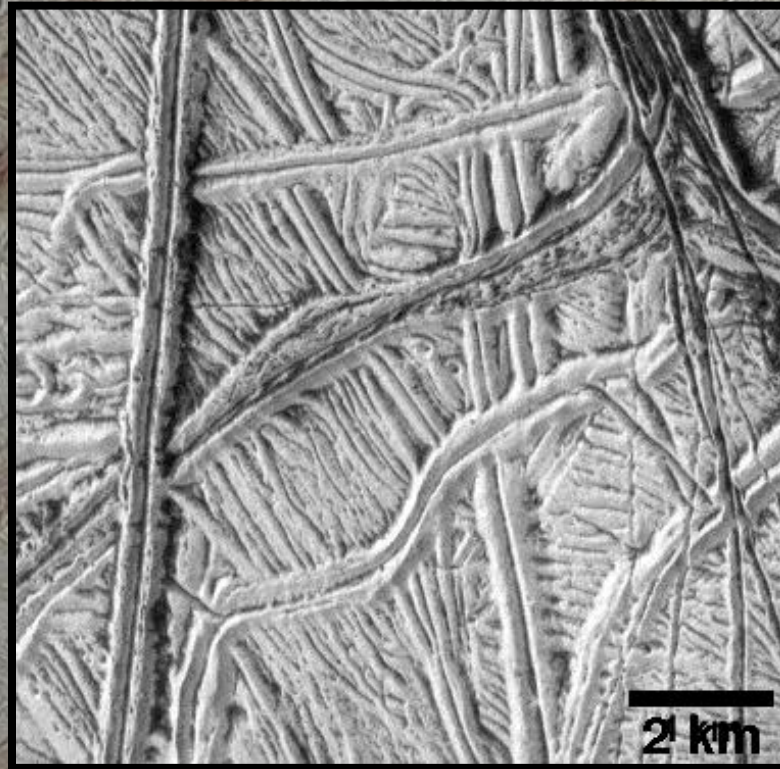
To Understand Europa's Habitability,

First We Must Understand the
System

A Dynamic, Young Surface



Ridged Plains

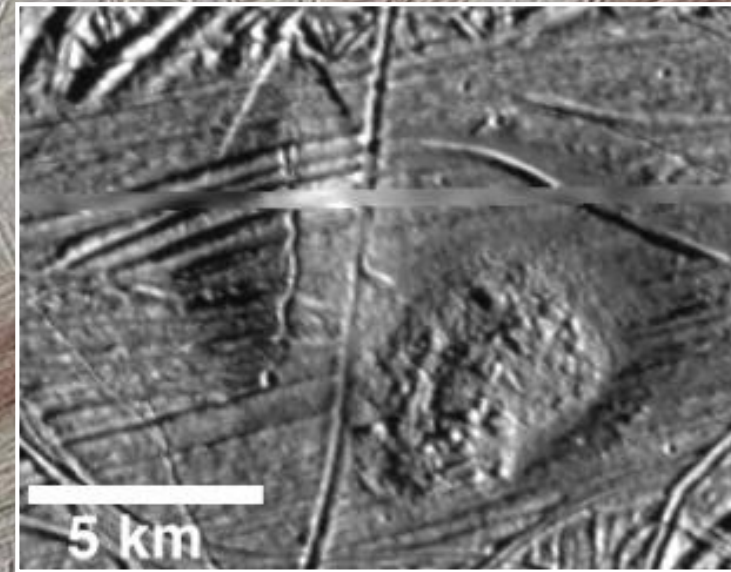
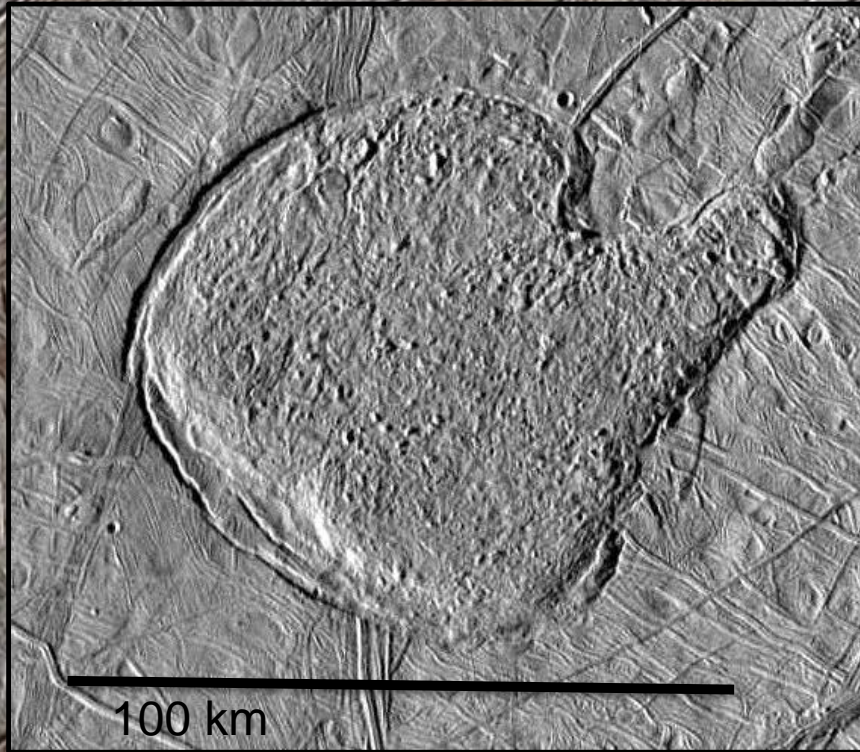


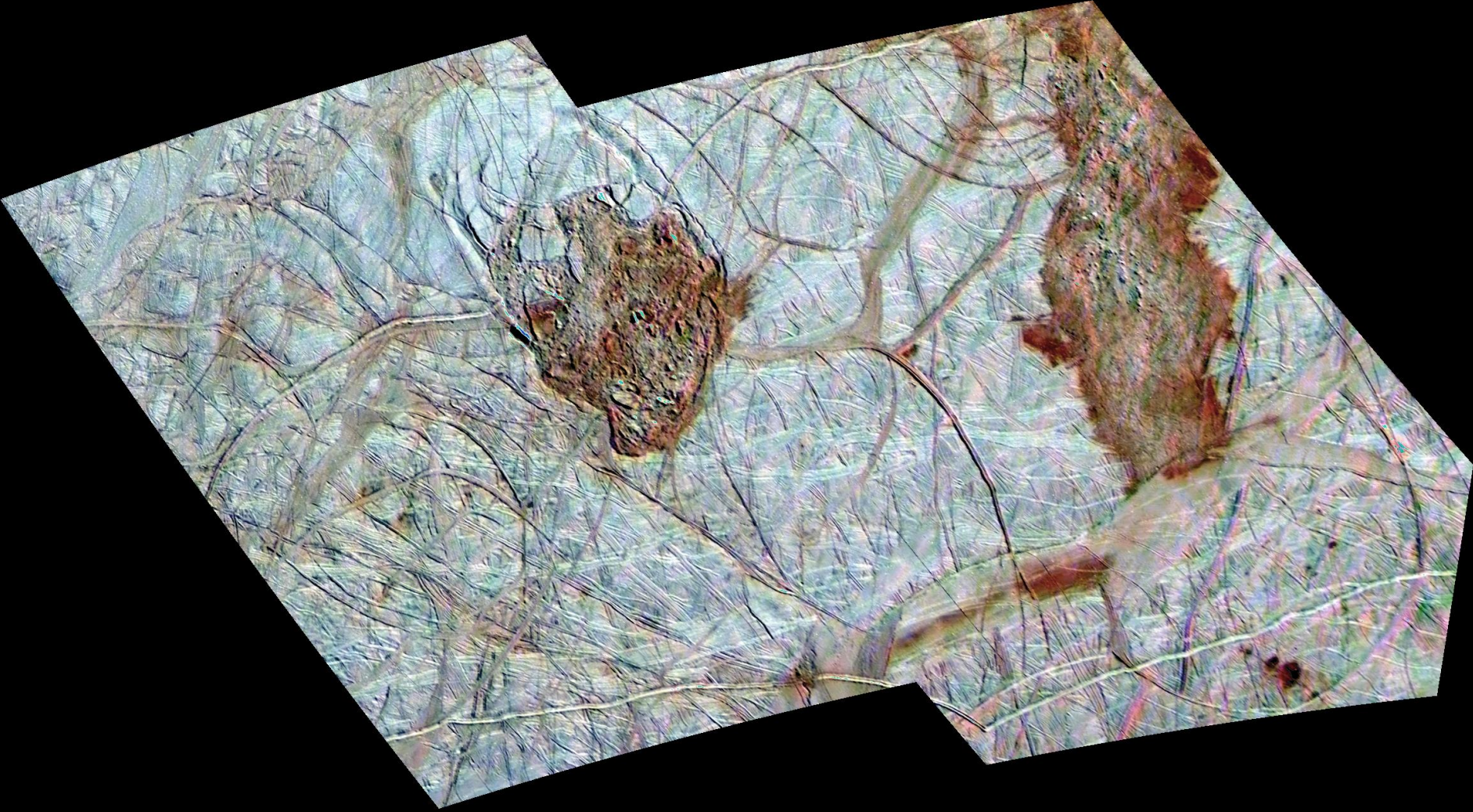
Bands



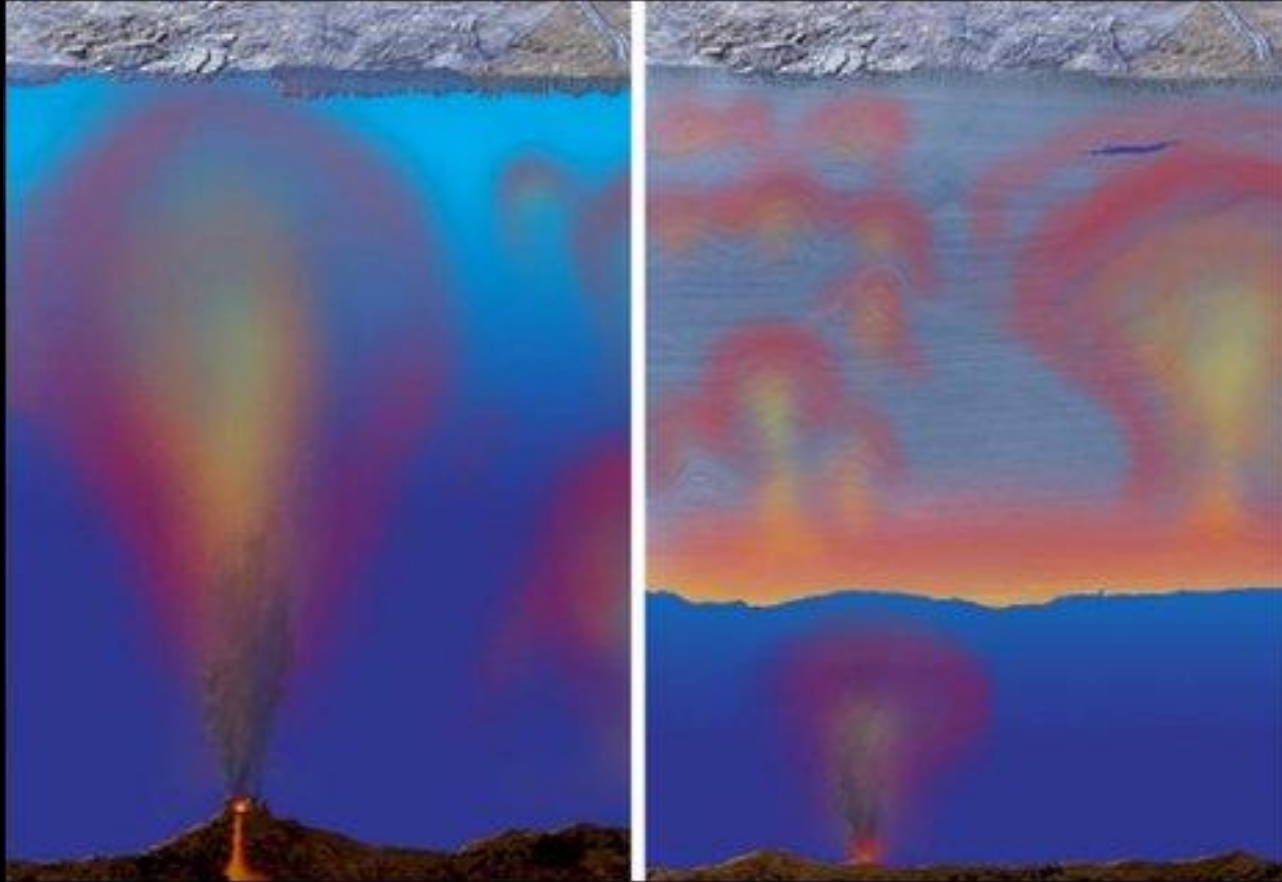
Separation and spreading of the icy crust

Europa's Mottled "Chaos" Terrains



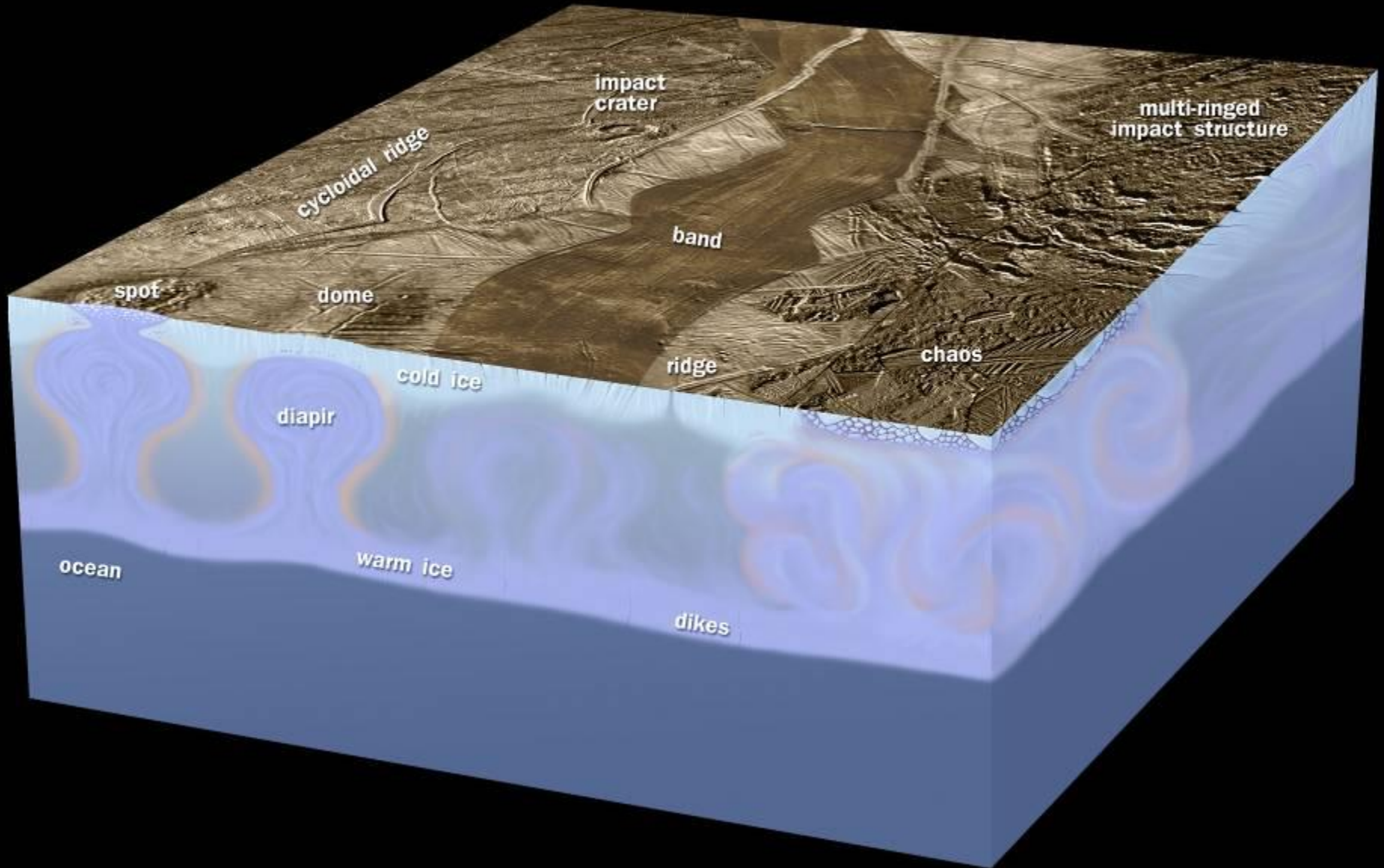


Thick vs Thin Ice



Two initial Hypotheses:
3-5 km or 15-30 km

Europa's Floating Ice Shell



Chaos Has...

Fractures

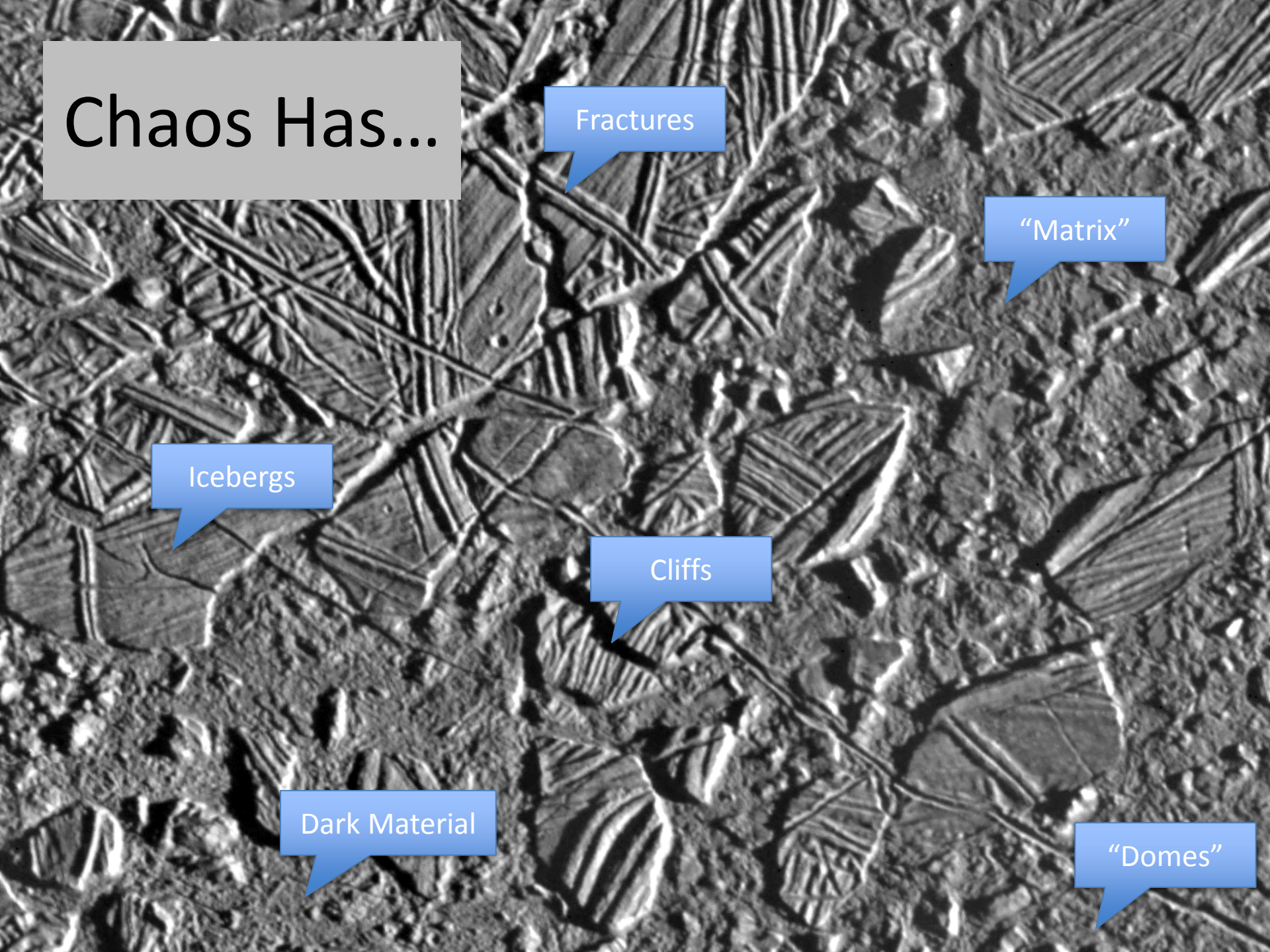
"Matrix"

Icebergs

Cliffs

Dark Material

"Domes"



Chaos Has...



Fractures

Cliffs

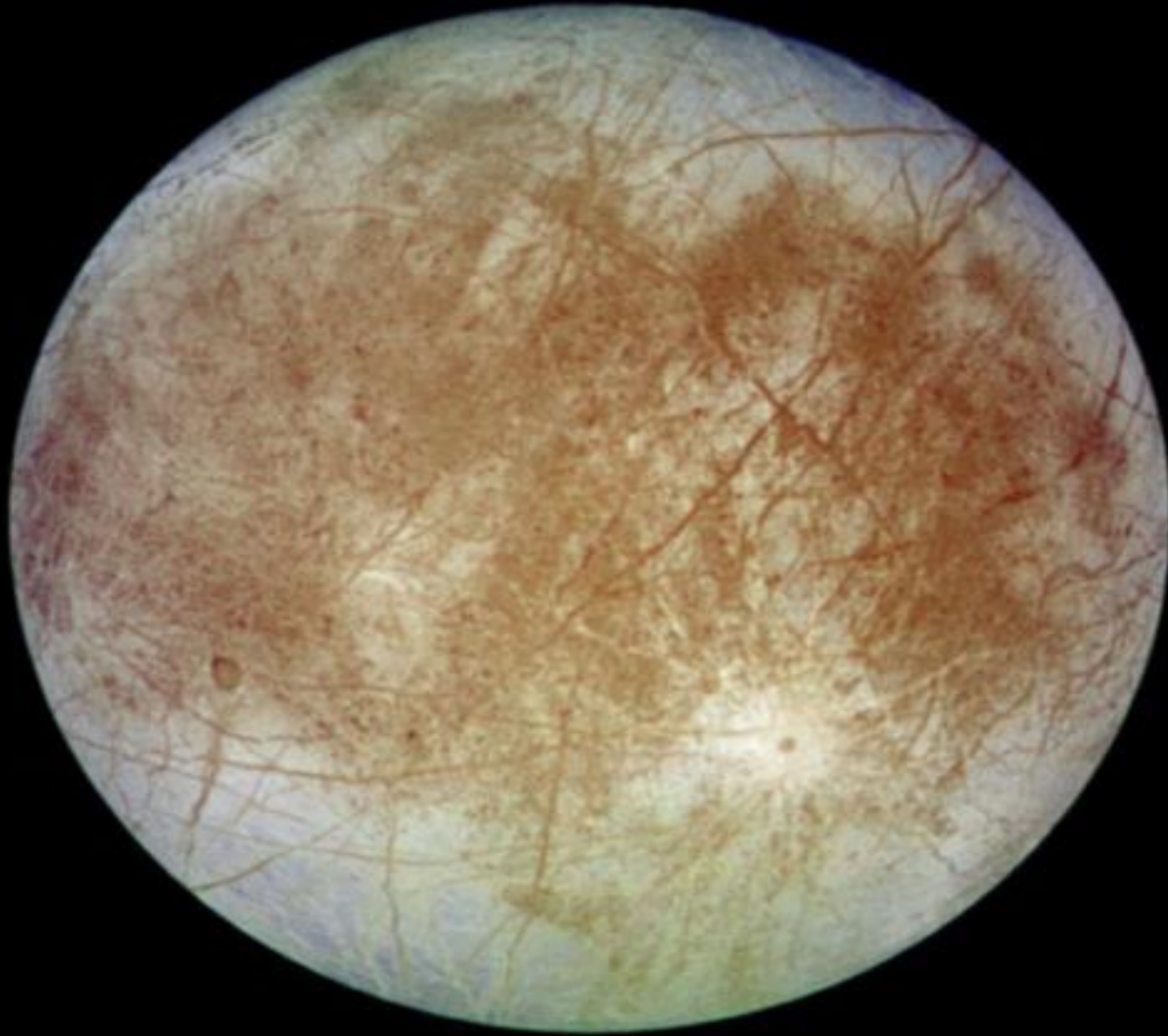
Icebergs

"Matrix"

Dark Material

"Domes"

Journey to Conamara Chaos



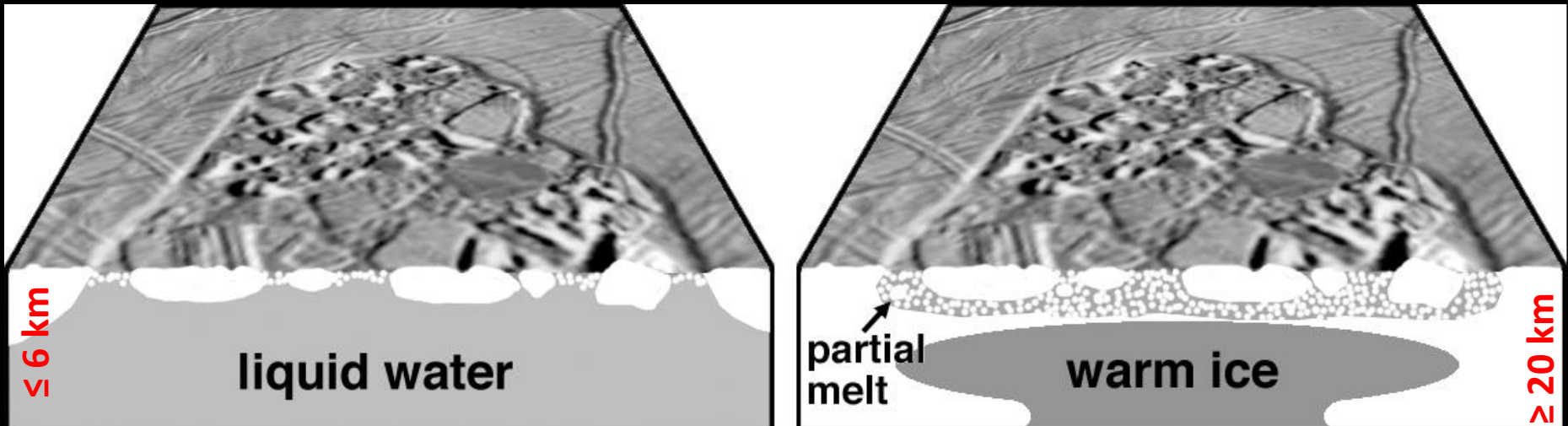
Chaos is unique to Europa...

What does that tell us?

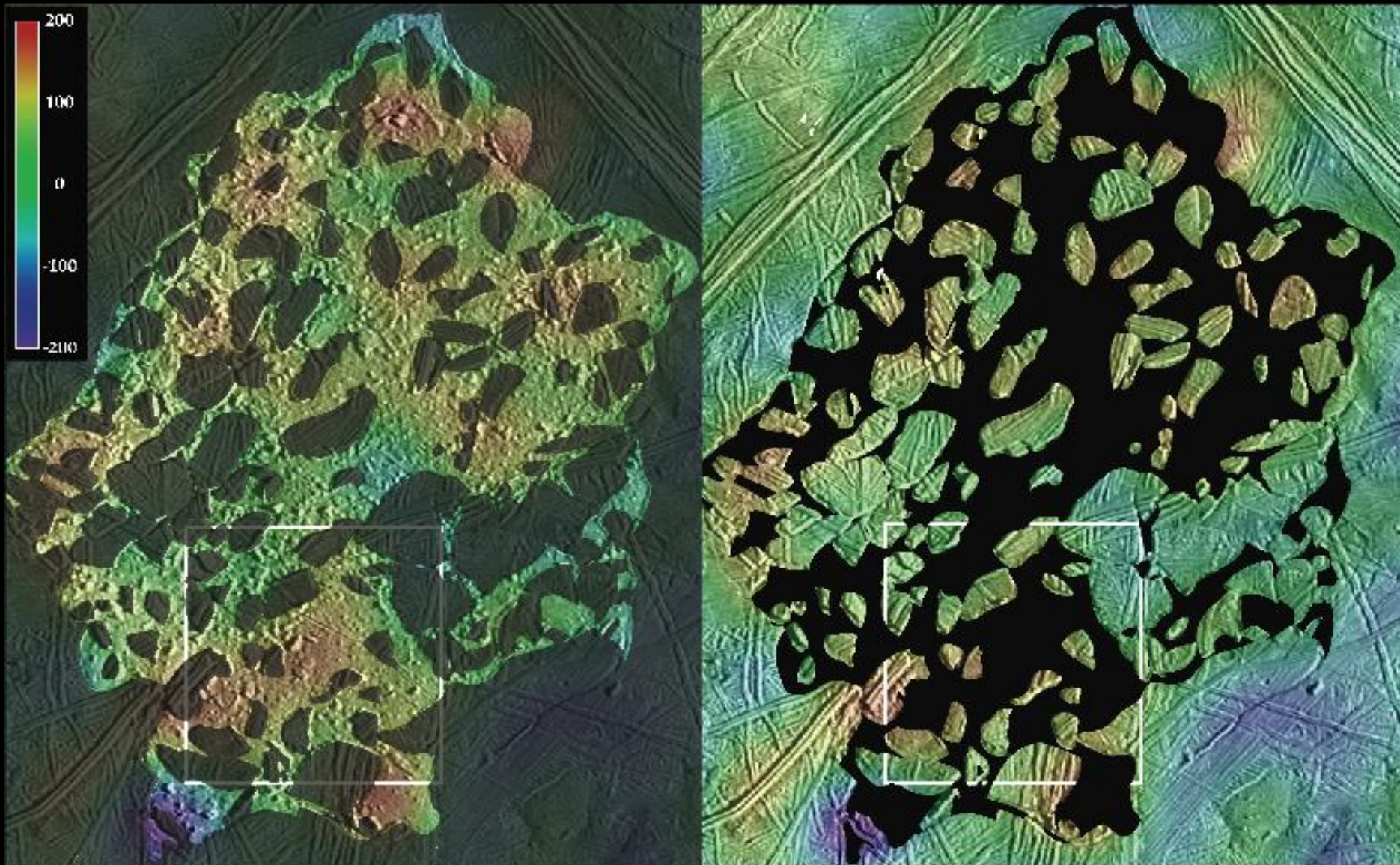
Chaos Models

- *Melting model:*
 - Ice shell thins and melts above oceanic megaplumes.
- *Diapiric*
 - Ice convection partially melts salty ice.

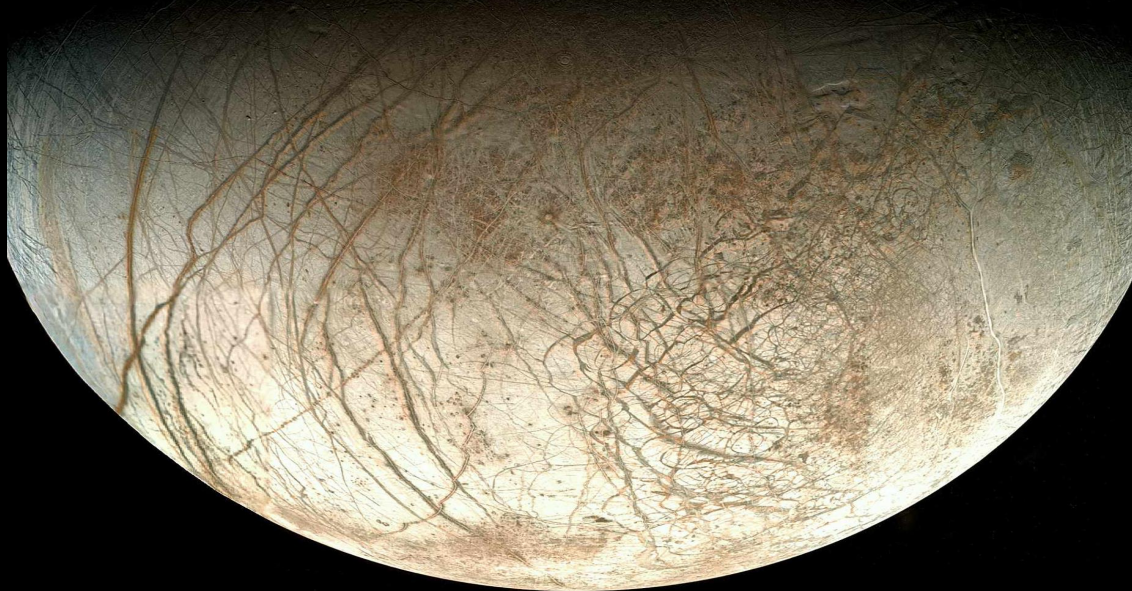
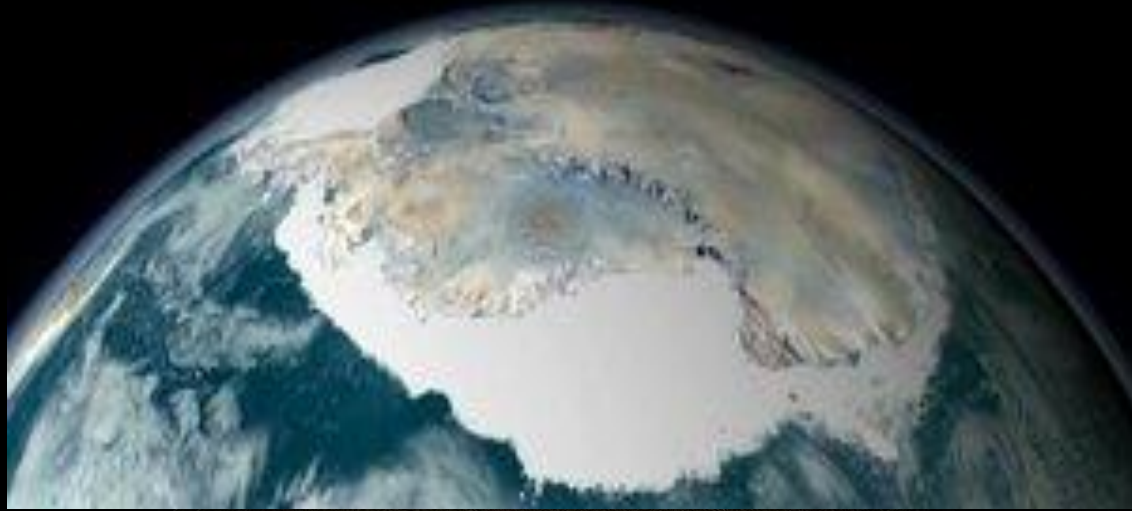
THE TOPOGRAPHY IS WRONG!

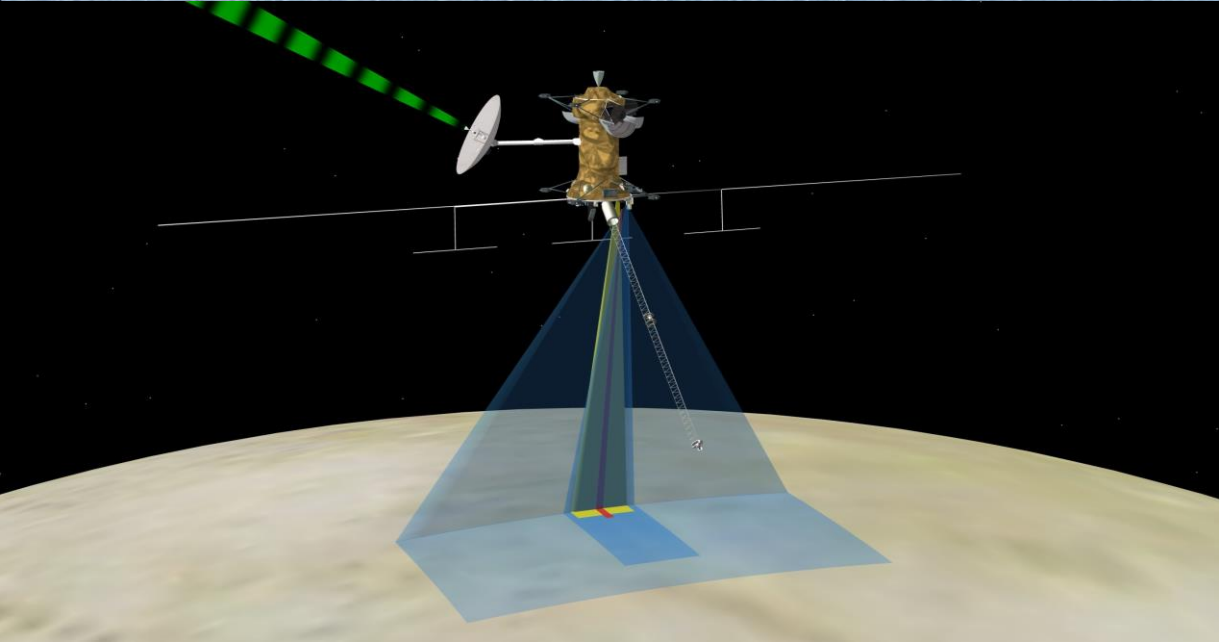


Icebergs No Longer Floating-Why?

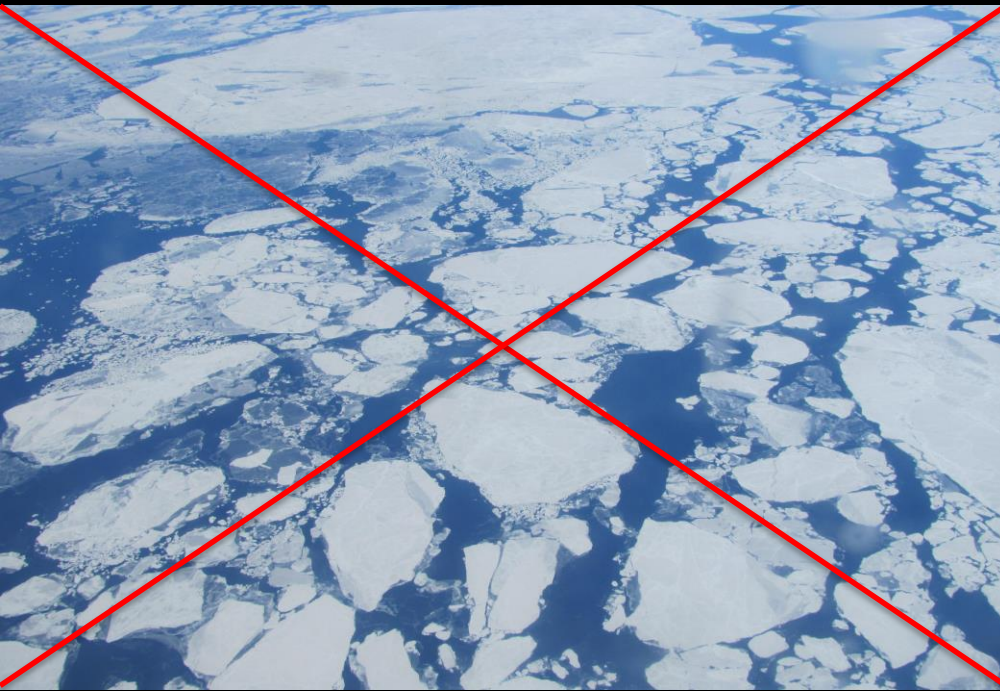
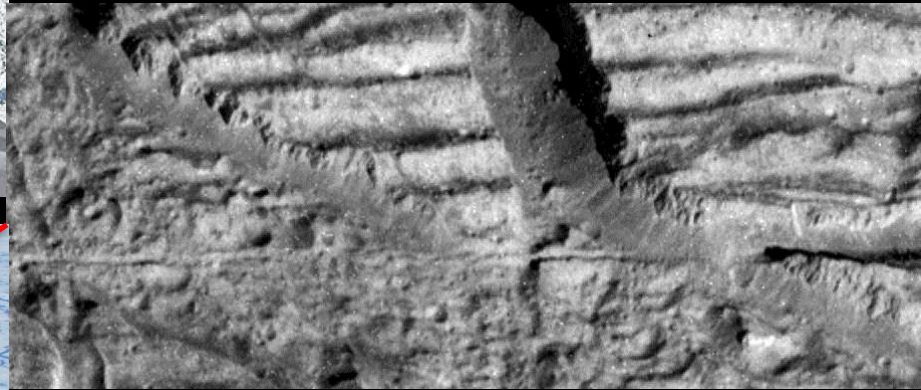


Time to look in our backyard





Observational Bias



Ice Shelves
VS
Sea Ice

≥ 20 km

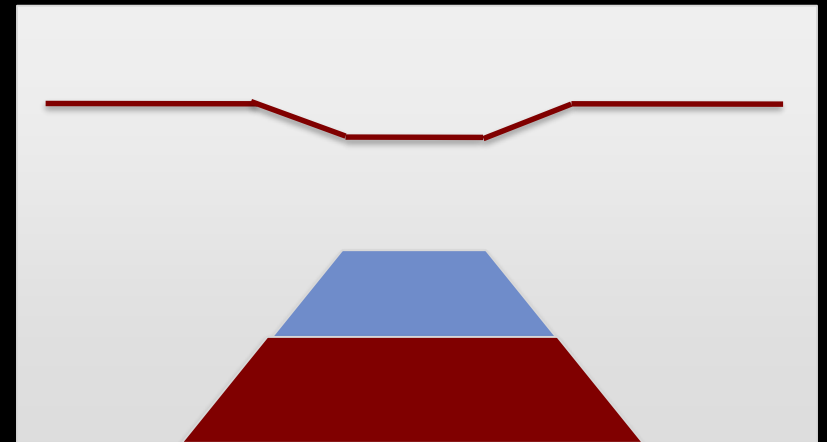
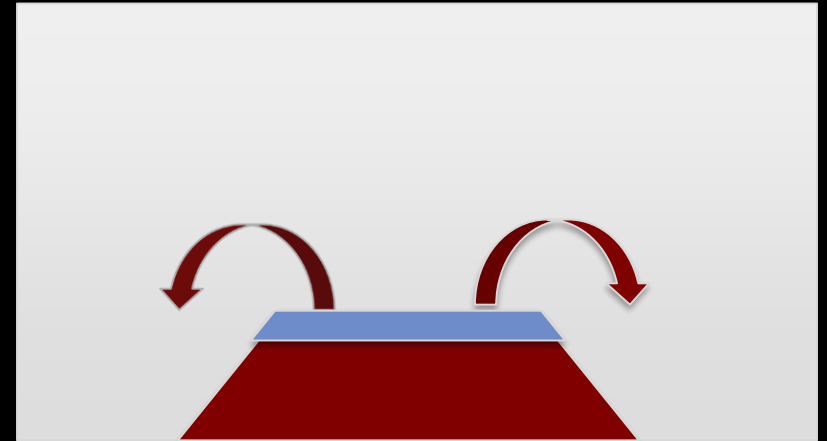
Analog: Subglacial Volcano Lakes

Grimsvotn, Iceland



Bjornsson 2002

Volcanoes



Subglacial Volcanoes

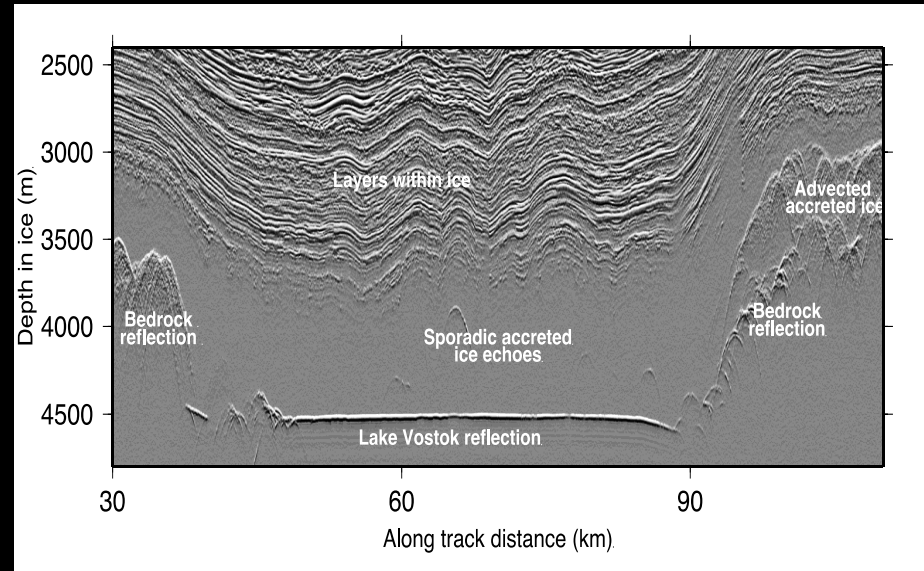
Analog: Subglacial Lakes

Grimsvotn, Iceland

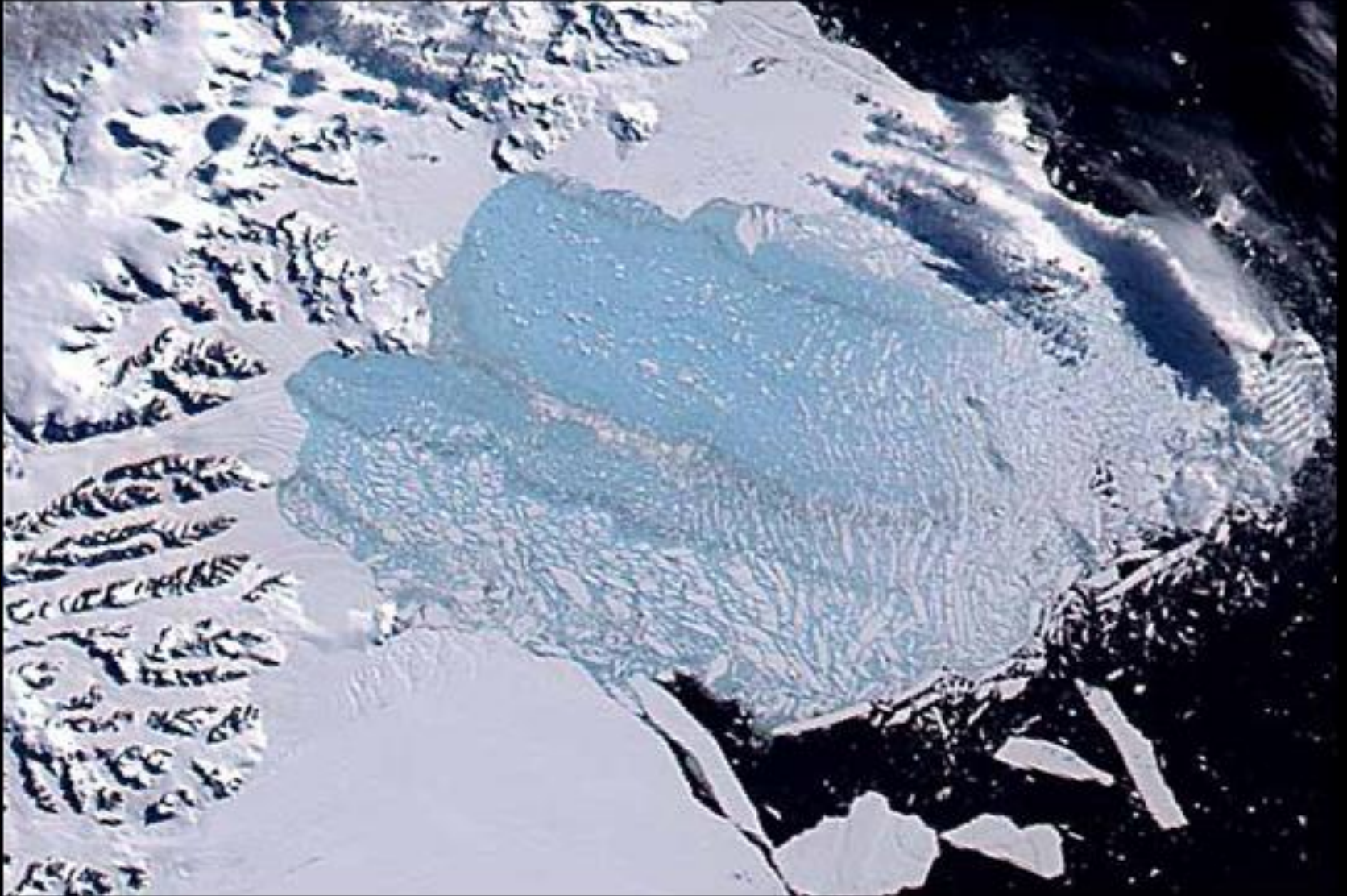


Bjornsson 2002

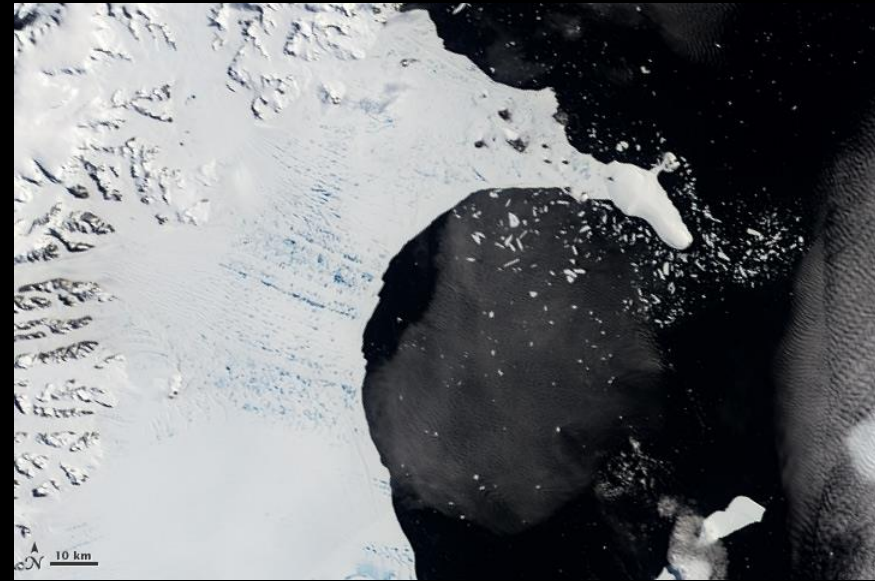
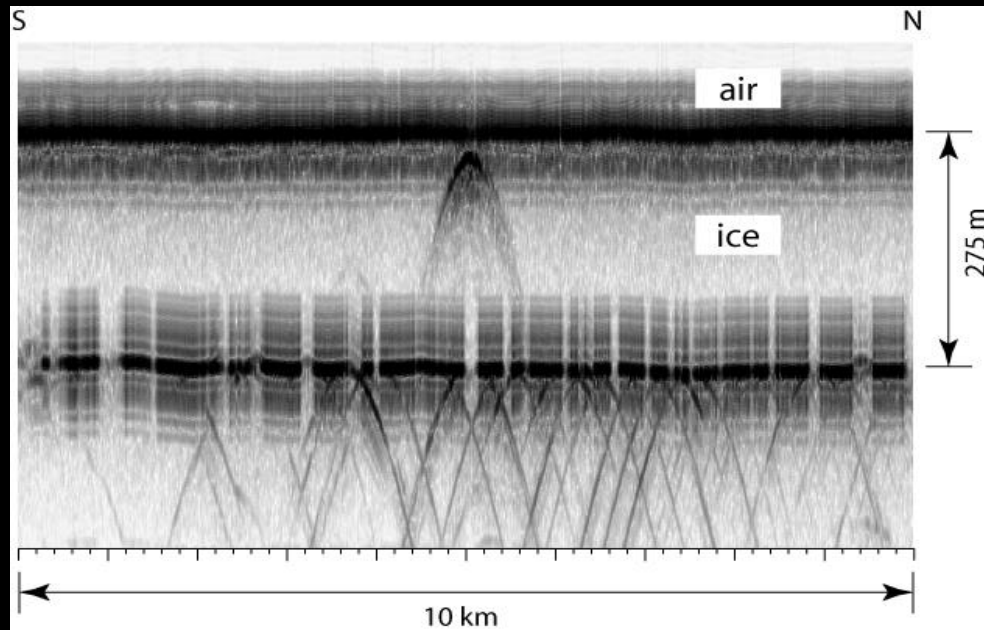
Vostok, Antarctica



Analog: Ice Shelf Collapse



Fractures Are Important!



“Floating” Blocks



2.5 km



70 km



EUROPA'S "GREAT LAKES"

From the paper in Nature,
AOP November 16, 2011:

Active formation of 'chaos terrain' over shallow subsurface water on Europa

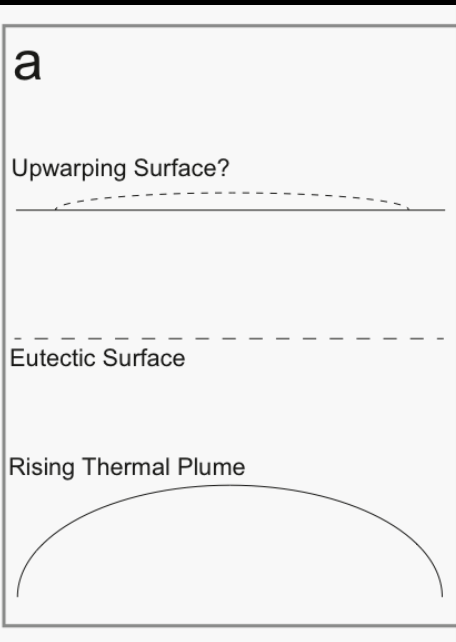
B. E Schmidt, D. D. Blankenship,
G. W. Patterson & P. M. Schenk
doi: 10.1038/nature10608

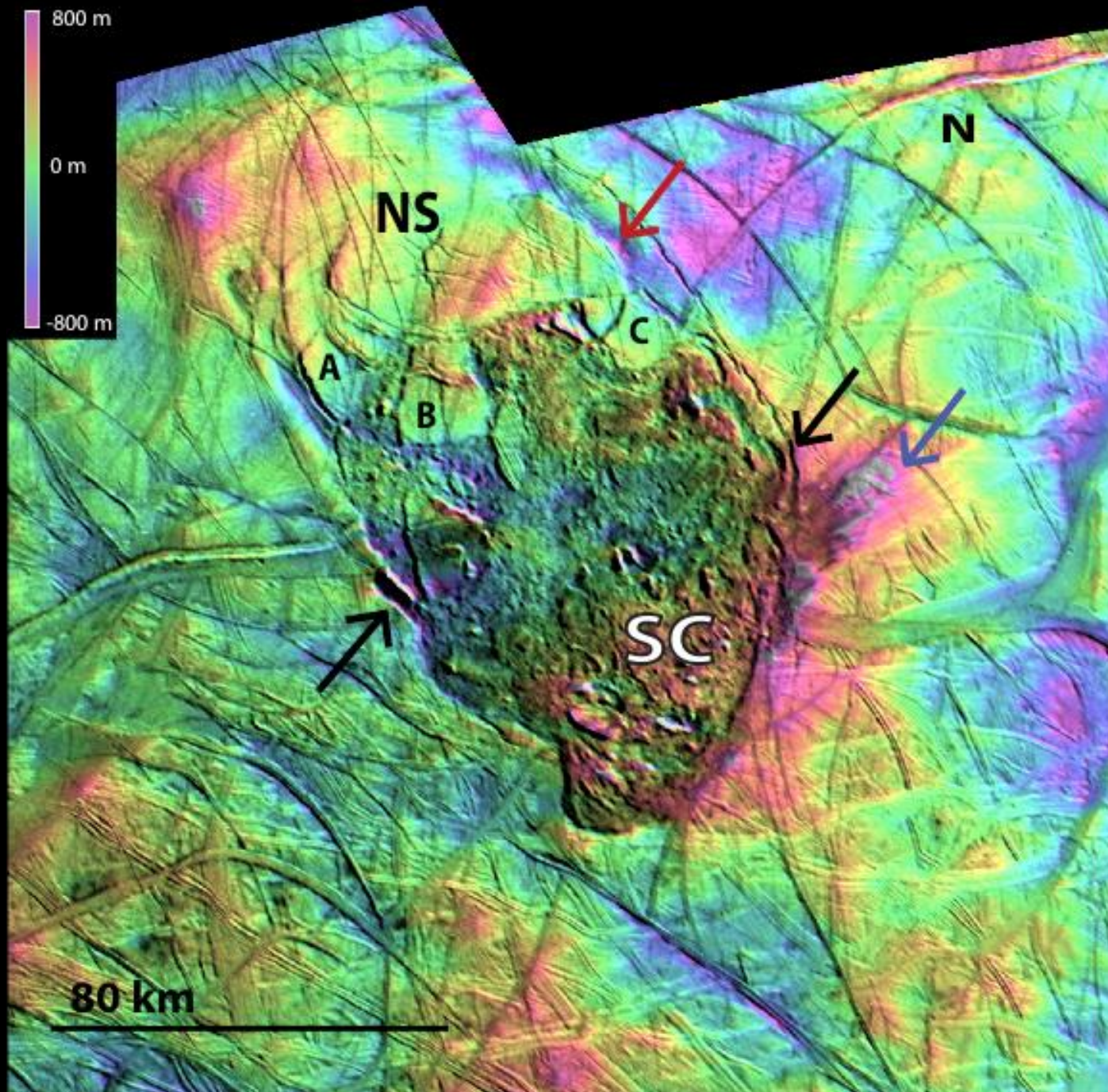
Video by: Deadpixel Visual Effects
© B.E. Schmidt & Deadpixel Visual Effects

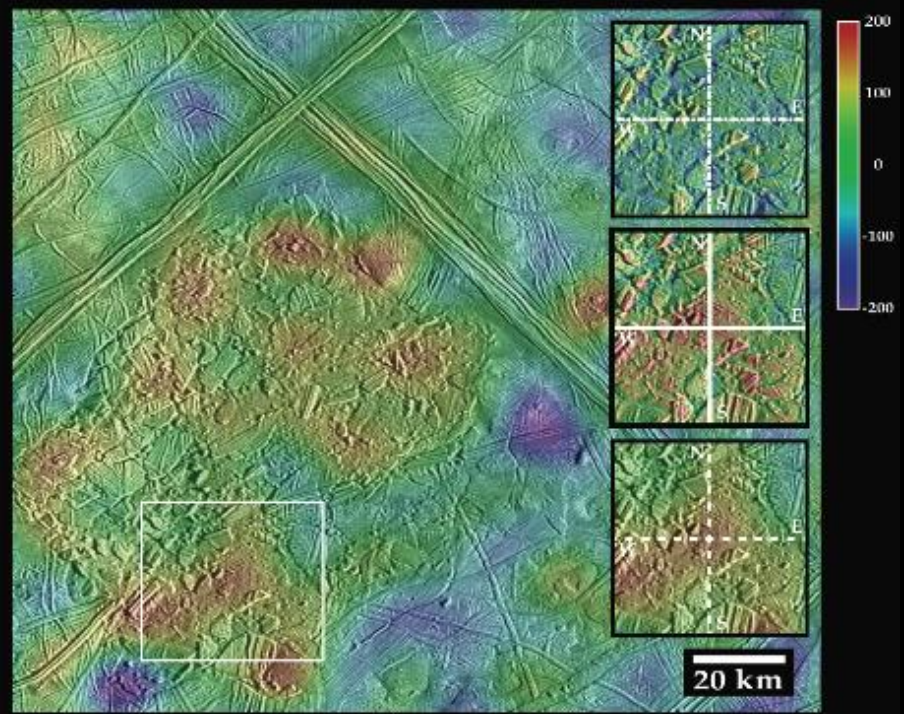
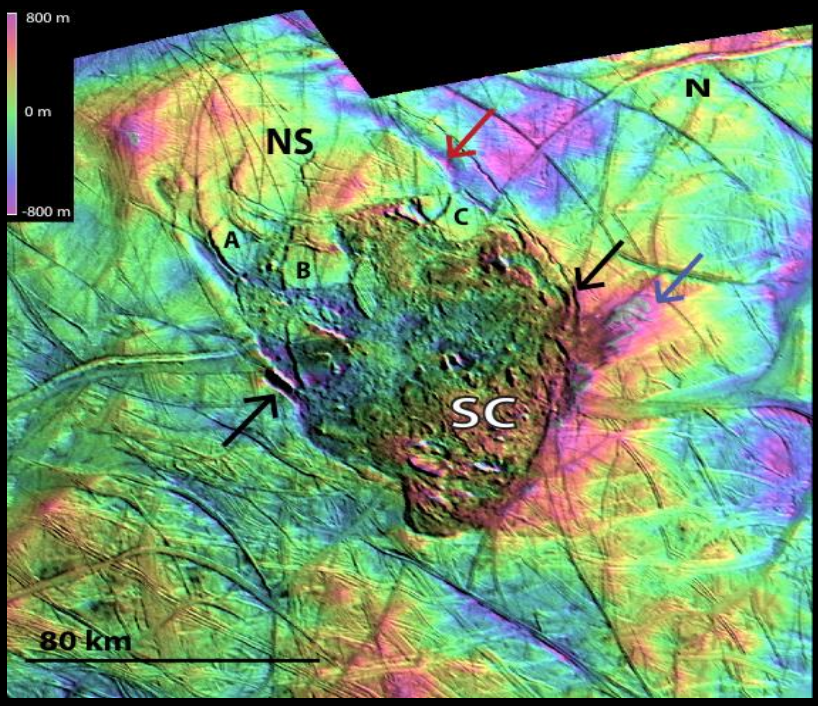
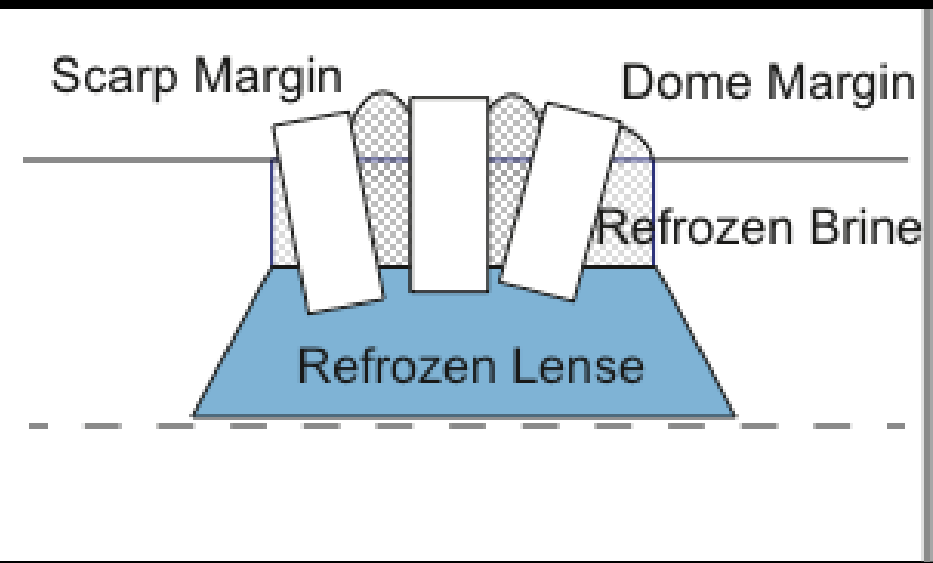
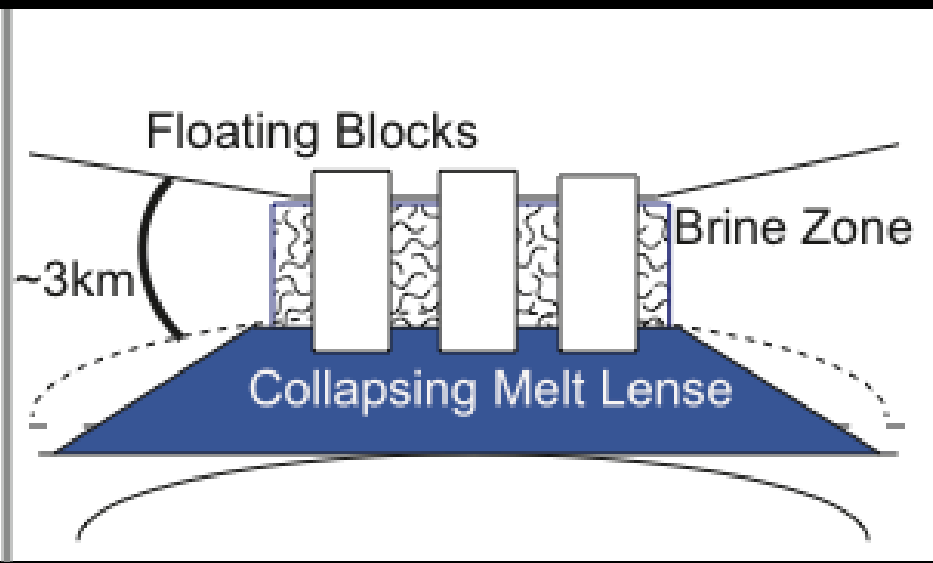


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The Lens-Collapse Model





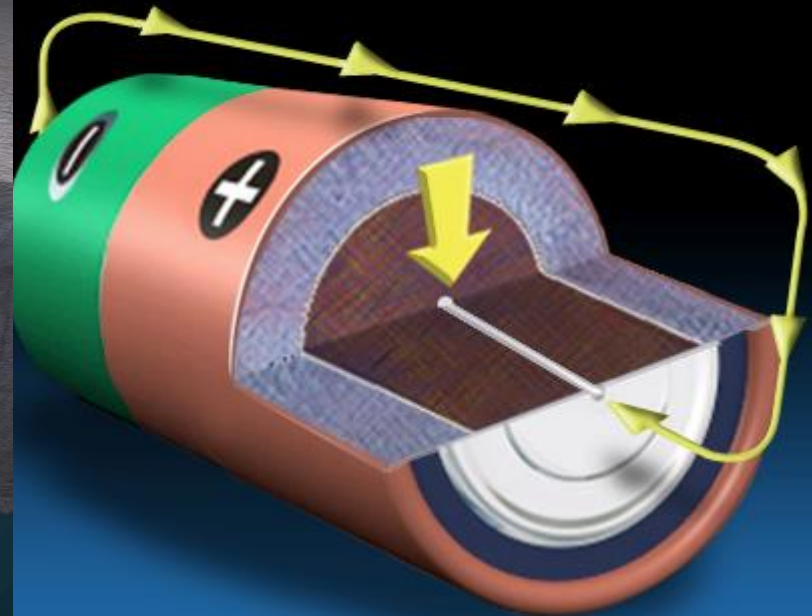
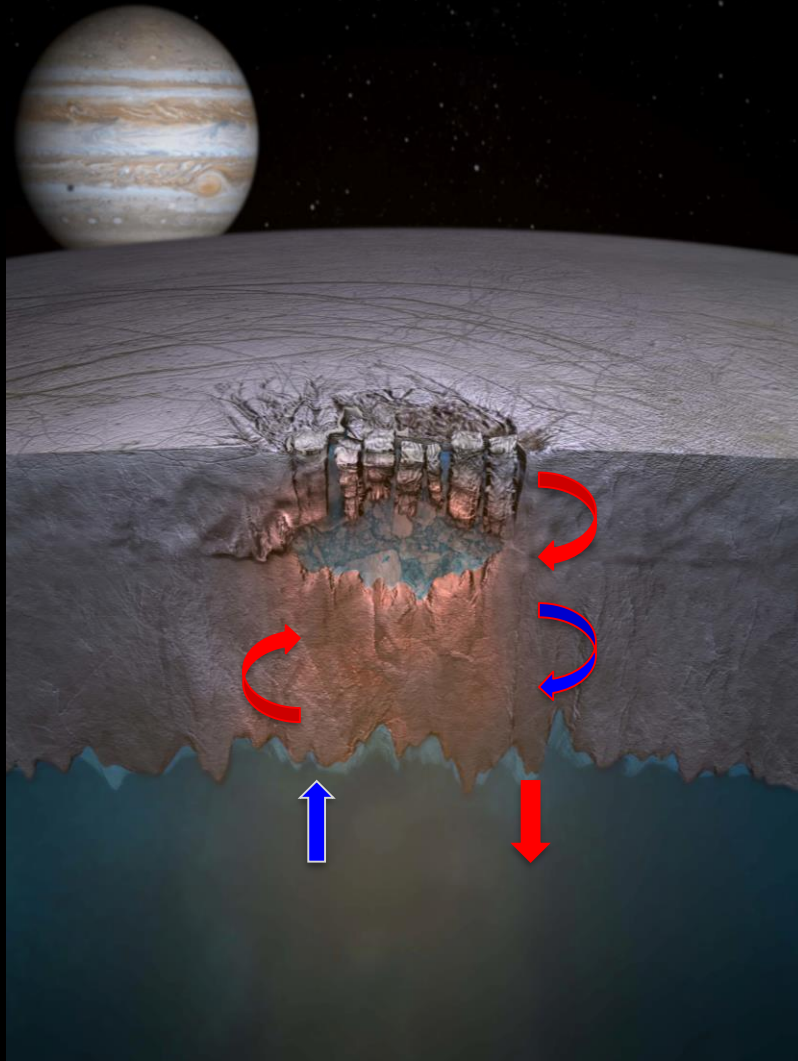




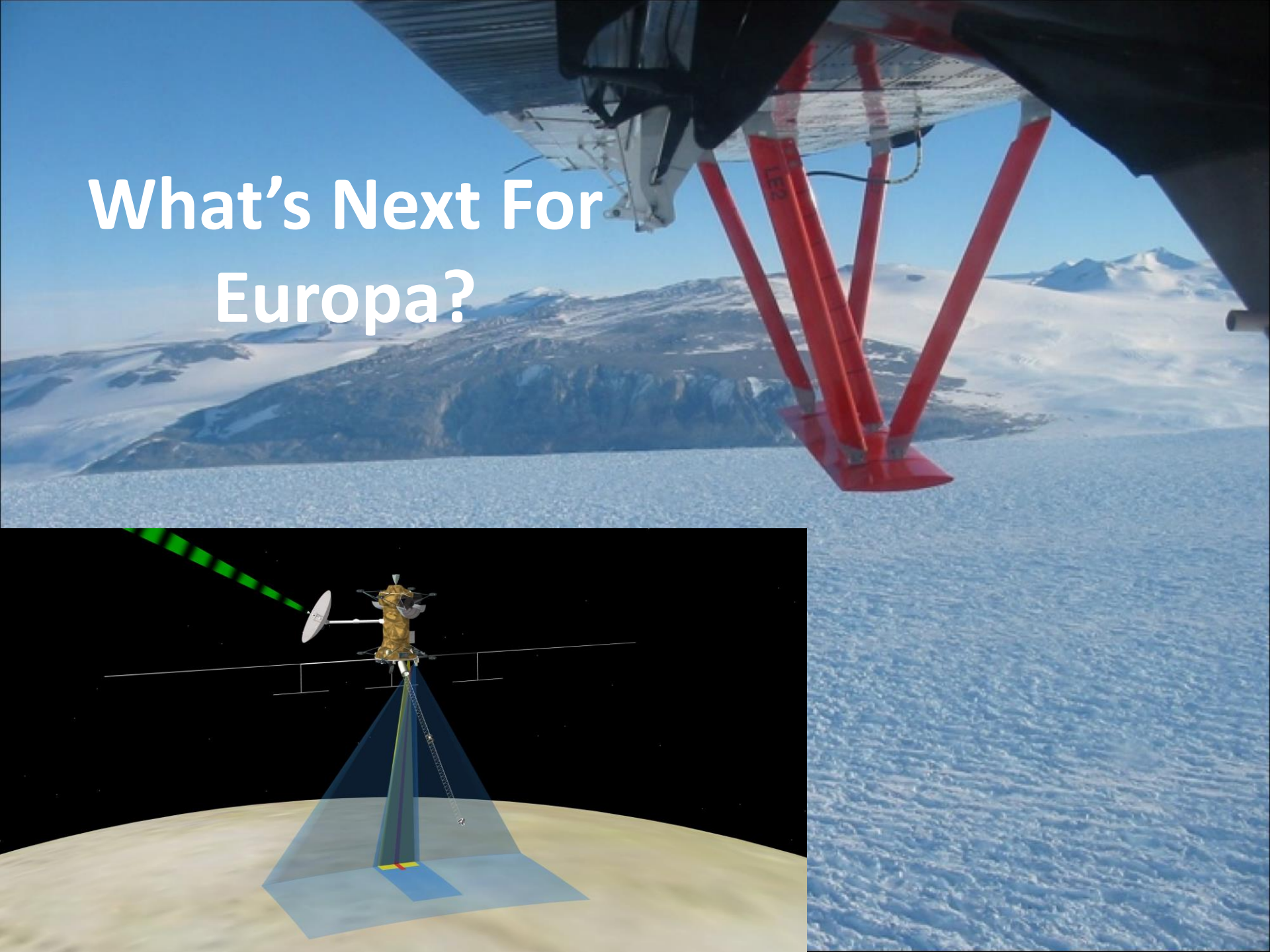
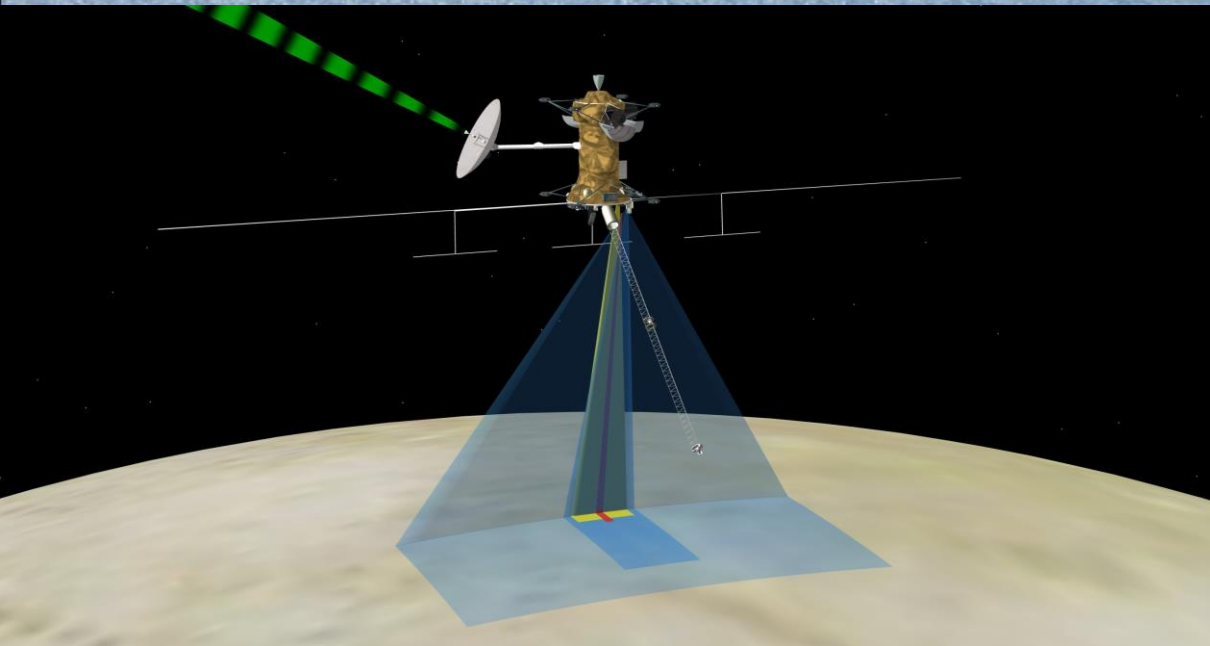
[Play MP4 Video File](#)

What does this mean for the search for
life on Europa?

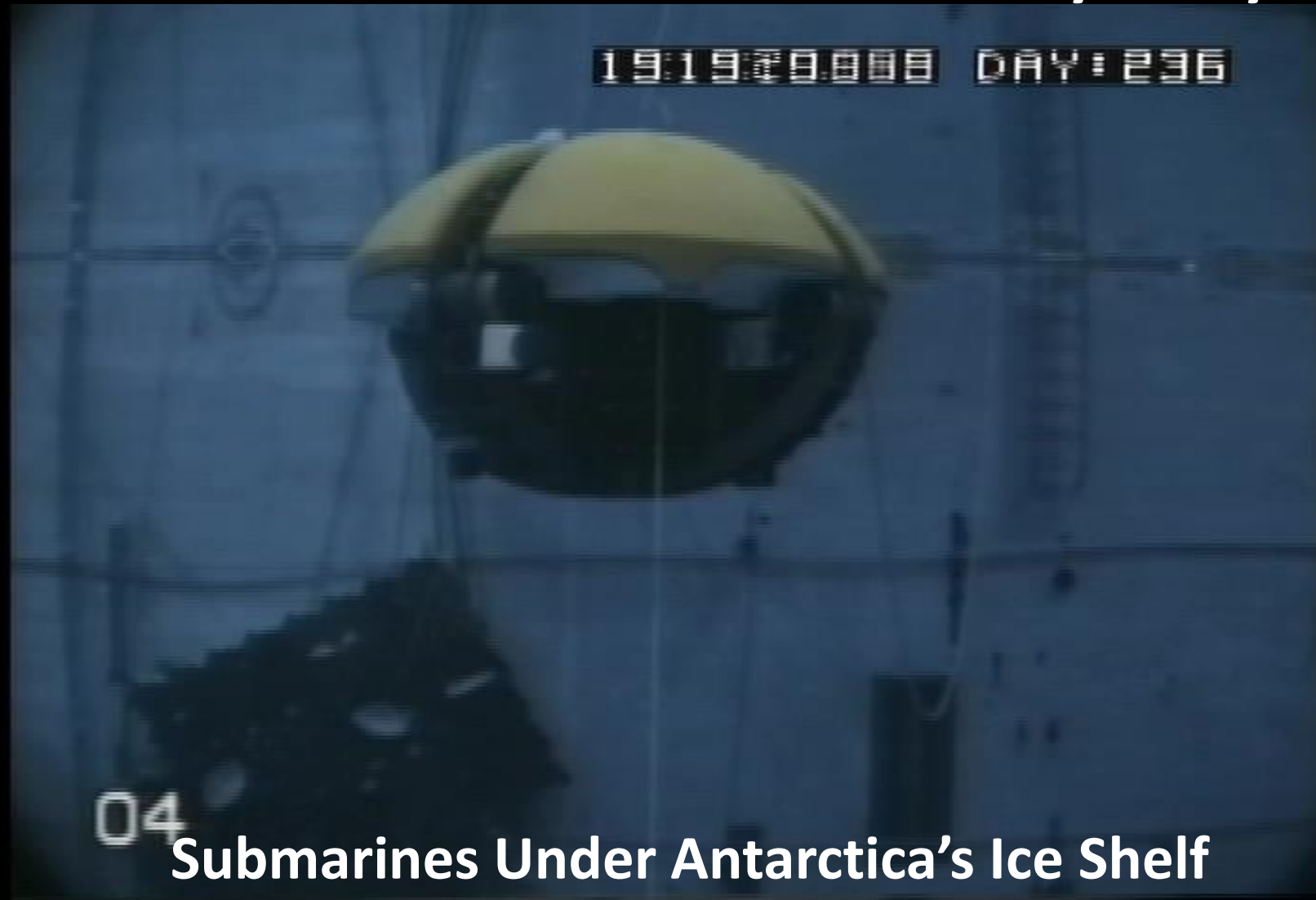
An Energetic System



What's Next For Europa?



SIMPLE: Sub Ice Marine and PLanetary Ecosystems



Submarines Under Antarctica's Ice Shelf
to Get Ready for Europa! [Play Apple Quicktime Video](#)

SIMPLE: Sub Ice Marine and PLanetary Ecosystems

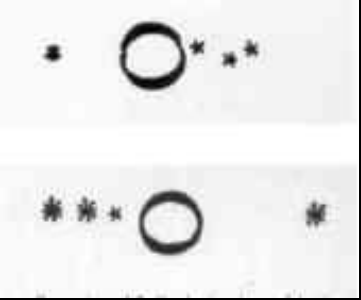


Endurance-L and SCINI

[Play Apple Quicktime Video](#)



Europa: Then and Now



Sec^{mo} Principio.

Galileo Galilei, Humiliss^{imo} Servo della Ser^{enissima} V.^{ra} Inuigilant^{issima}
Ho studiato et ho ogni spirito di essere ho solo satisfare
alquanto che nera della stessa Sr. Mathematica nella Scu-
ola di Padova,

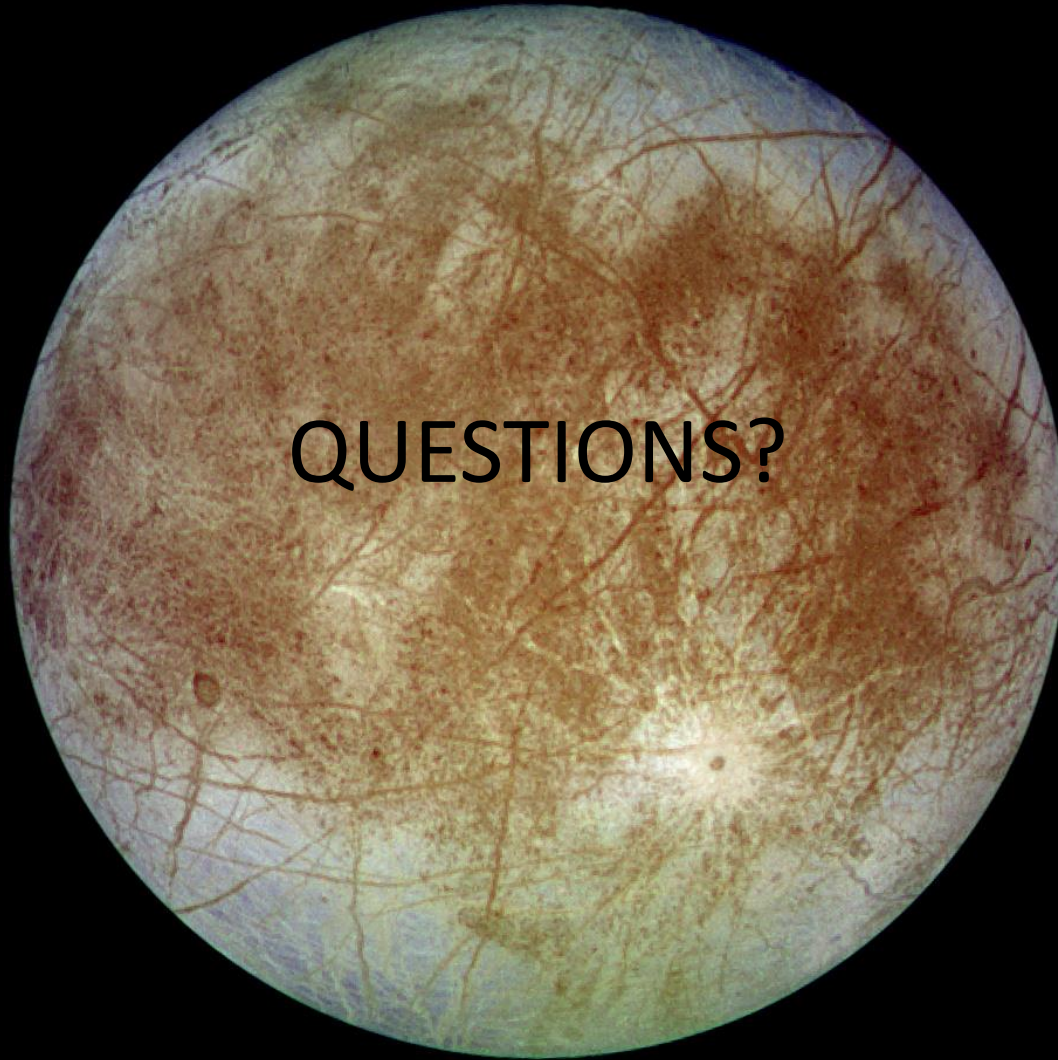
Impero diuote determinate di presentare al Sec^{mo} Principe
l'Orchiale et a p^{re} essere di firmamento inestimabile p^{er} ogni
negotio et in terra marittima o terrestre stimo di tenere qual-
che nuovo artificio nel maggior partito et usare a disposizione
di l'or^o l'Orchiale cauato dalle piu^{re} di dite speculationi di
pro^o bestina na^o l'vantaggio di scoprire Legni et Vele dell' inimico
p^{er} due hore et piu^{re} di tempo prima di egli pensara^o et distinguendo
il numero et la qualita^o de i Vasselli, giudicare li sue forze
p^{er} ballottarsi alla caccia al combattimento o alla fuga, o pure mass
nella campagna aperta di esse et particolar^{mente} Distinguerne ogni suo
moto et propriamento.

Adi 7. di gennaio
Gioue si vede 4^{te} * * * * *
Adi 8. usi * * * * *
Adi 10. si vede in tale costituzione * * * * *
Adi 13. si vedono minimi^o a Gioue 4 stelle * * * * *
Adi 14. è angelo * * * * *
Adi 15. la prest^o a 7^o ora in me^o la 4^{ta} ora di^o
sparte della 9^{ta} il doppio la 1^{ra}
La spatio delle 3. au^o di^o ad ora
maggiore del diametro de 7. et e^o
sono in linea retta.

Hand-drawn diagrams of star patterns corresponding to the text. The diagrams show various constellations and star arrangements, including a cluster of stars and a line of stars, with some stars marked with circles and others with dots.



Let's Go NOW!



QUESTIONS?

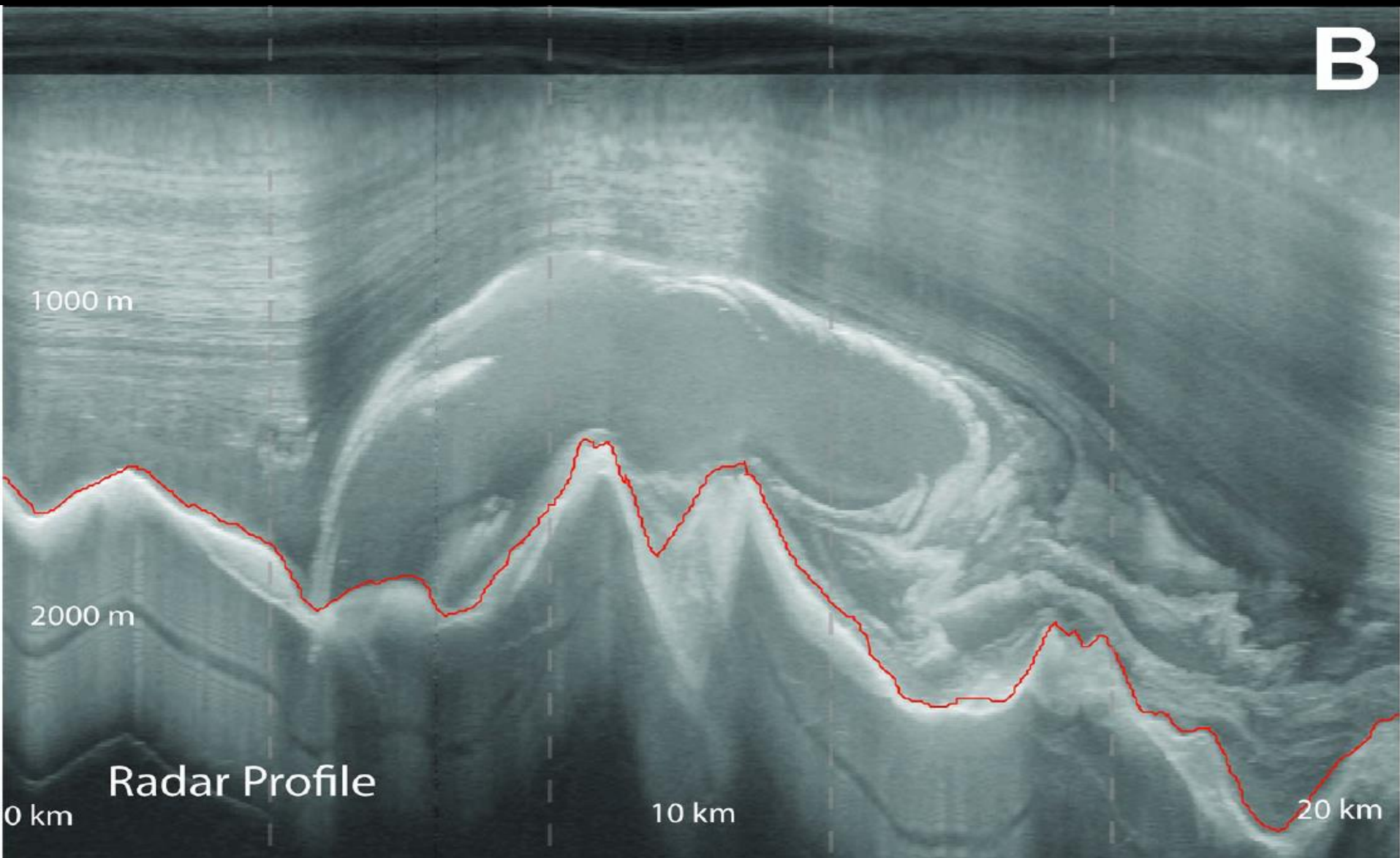
Exploration of Europa

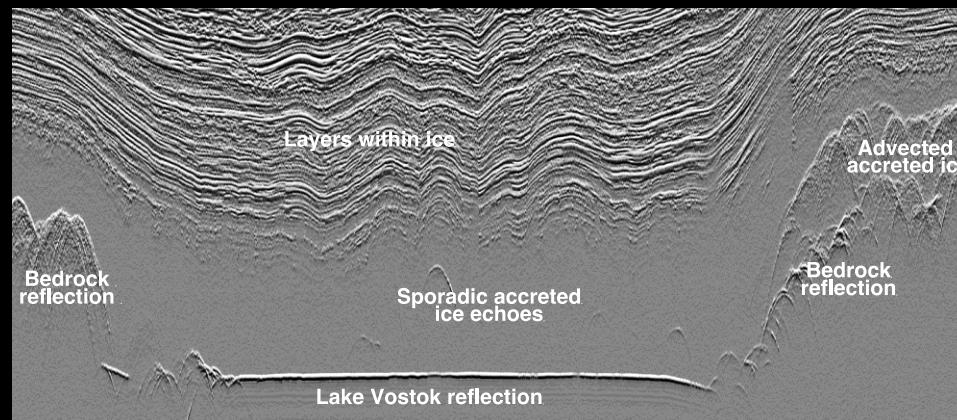
Radar Opportunities



David Glacier, Antarctica

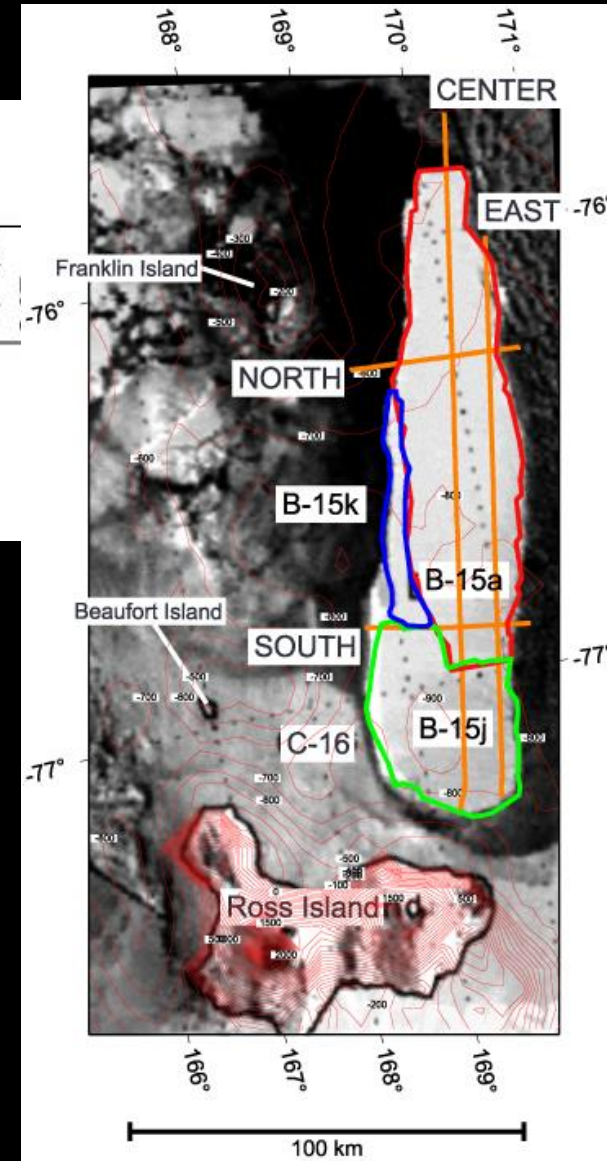
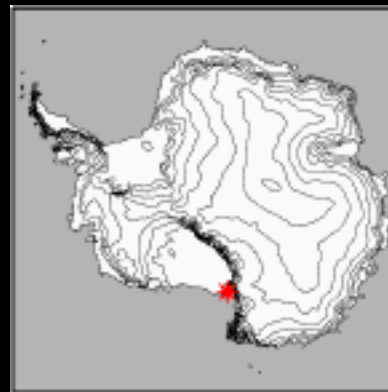
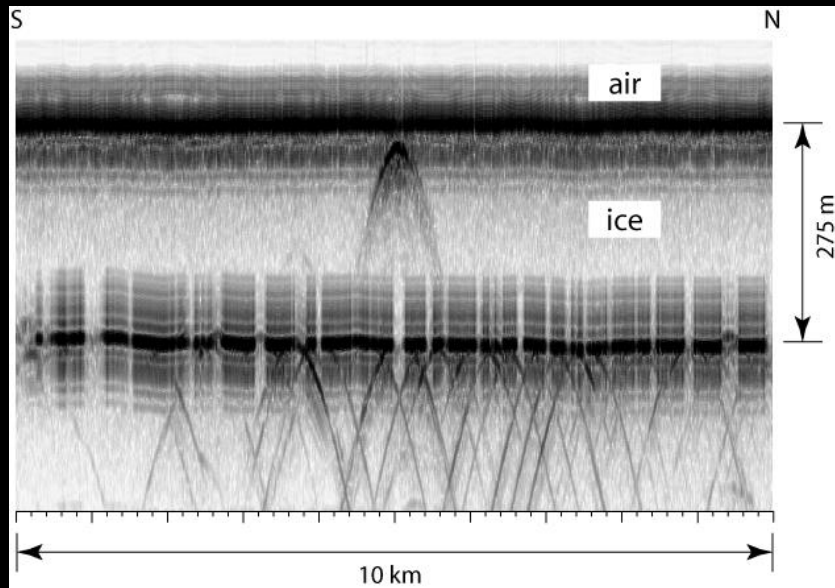
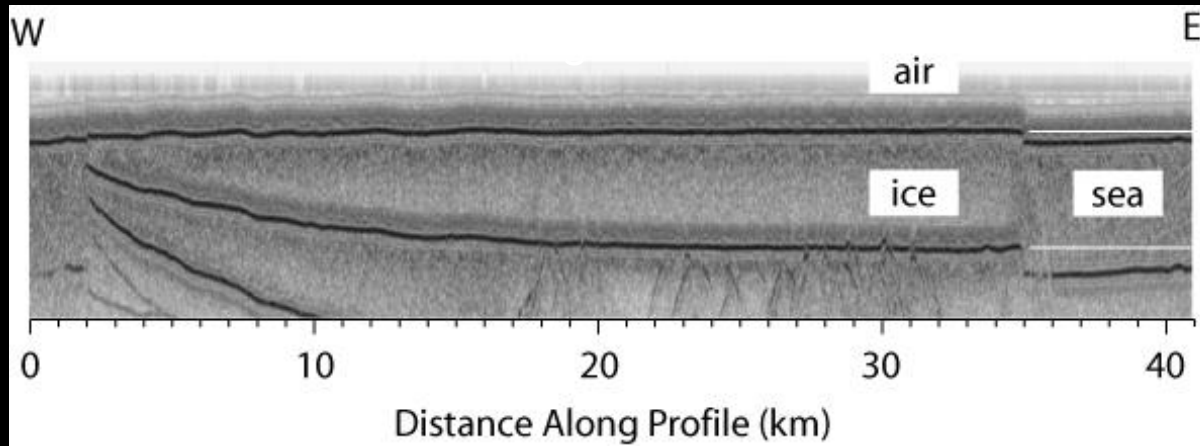
Can we see chaos forming?





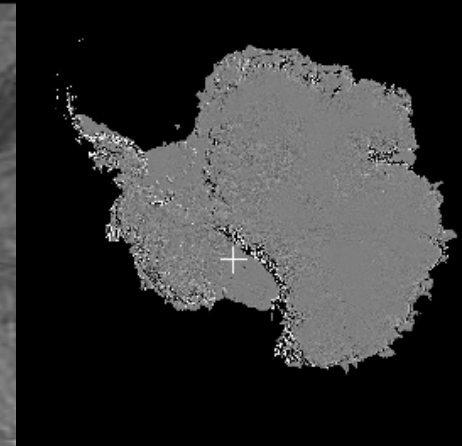
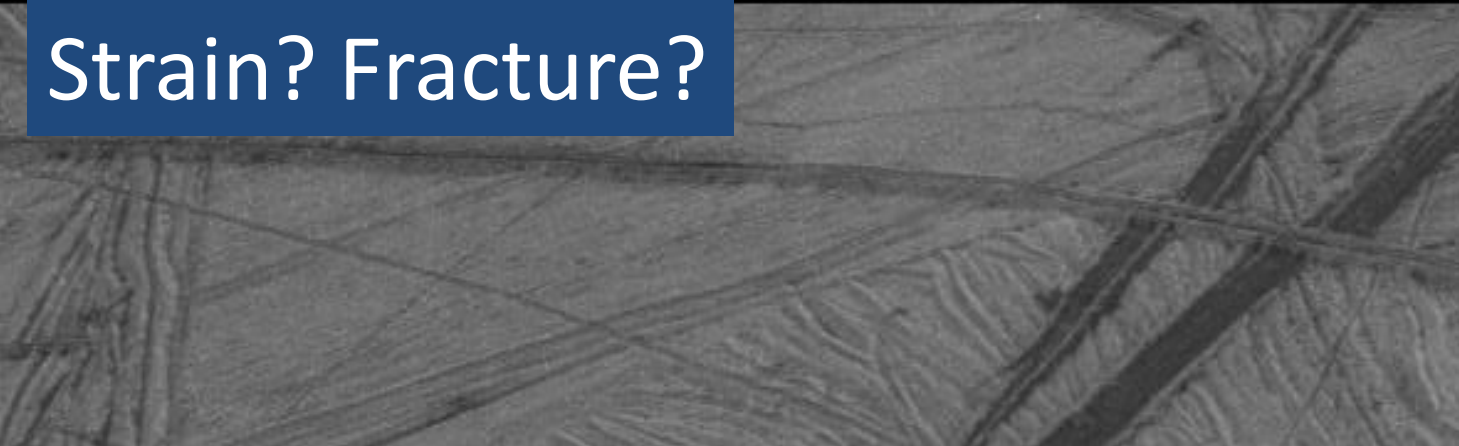
Lake Vostok was validated by floatation inferred from coupled surface/subsurface geometry (Blankenship et al 2009)

Fracture and Brine Infiltration

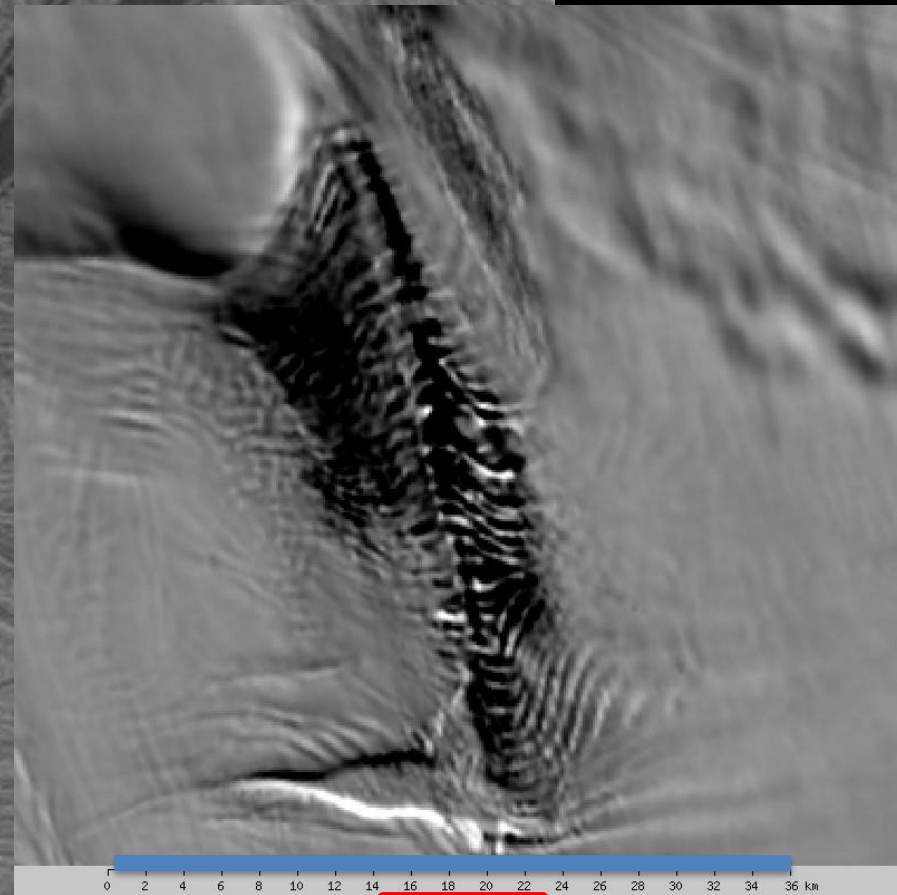


(Peters et al., 2007).

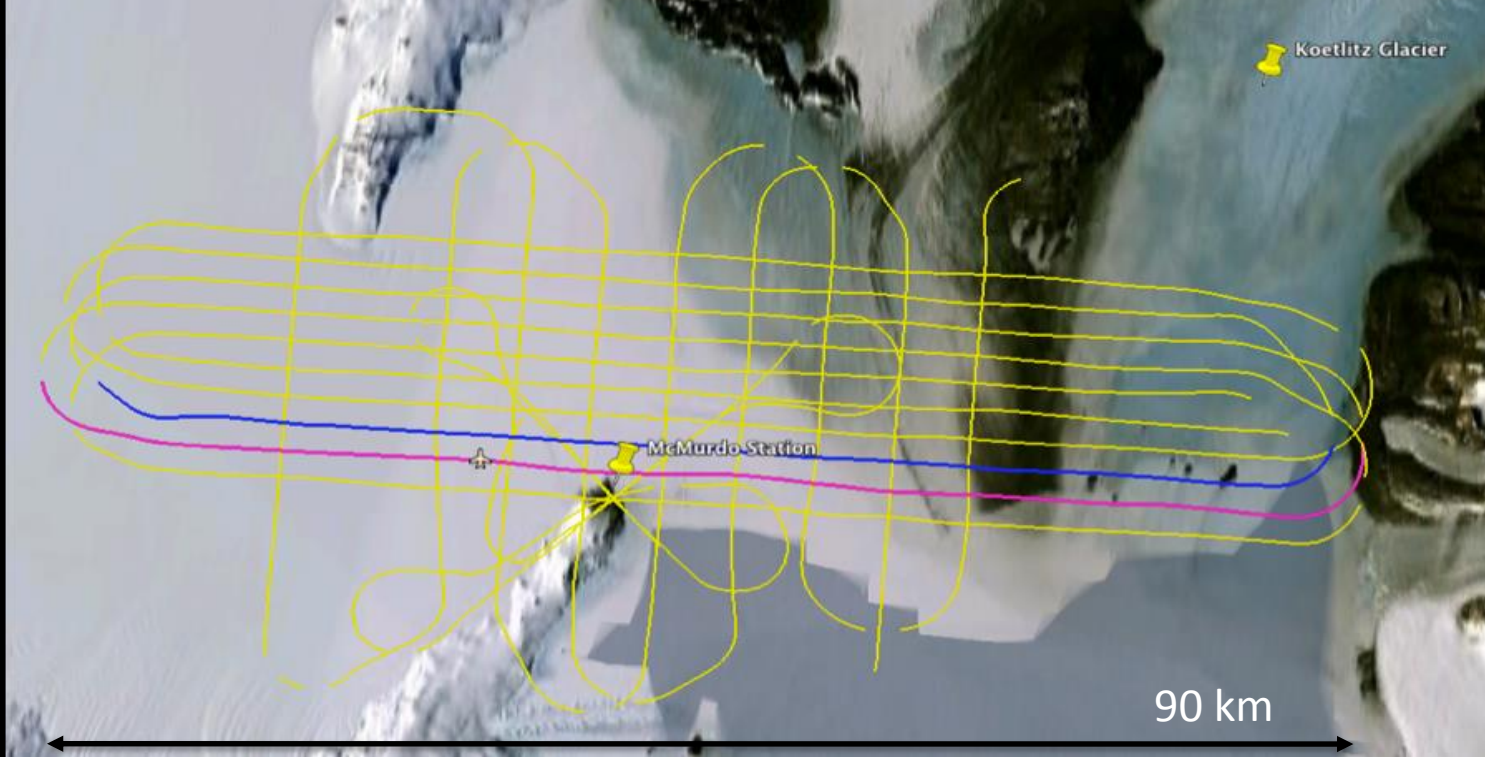
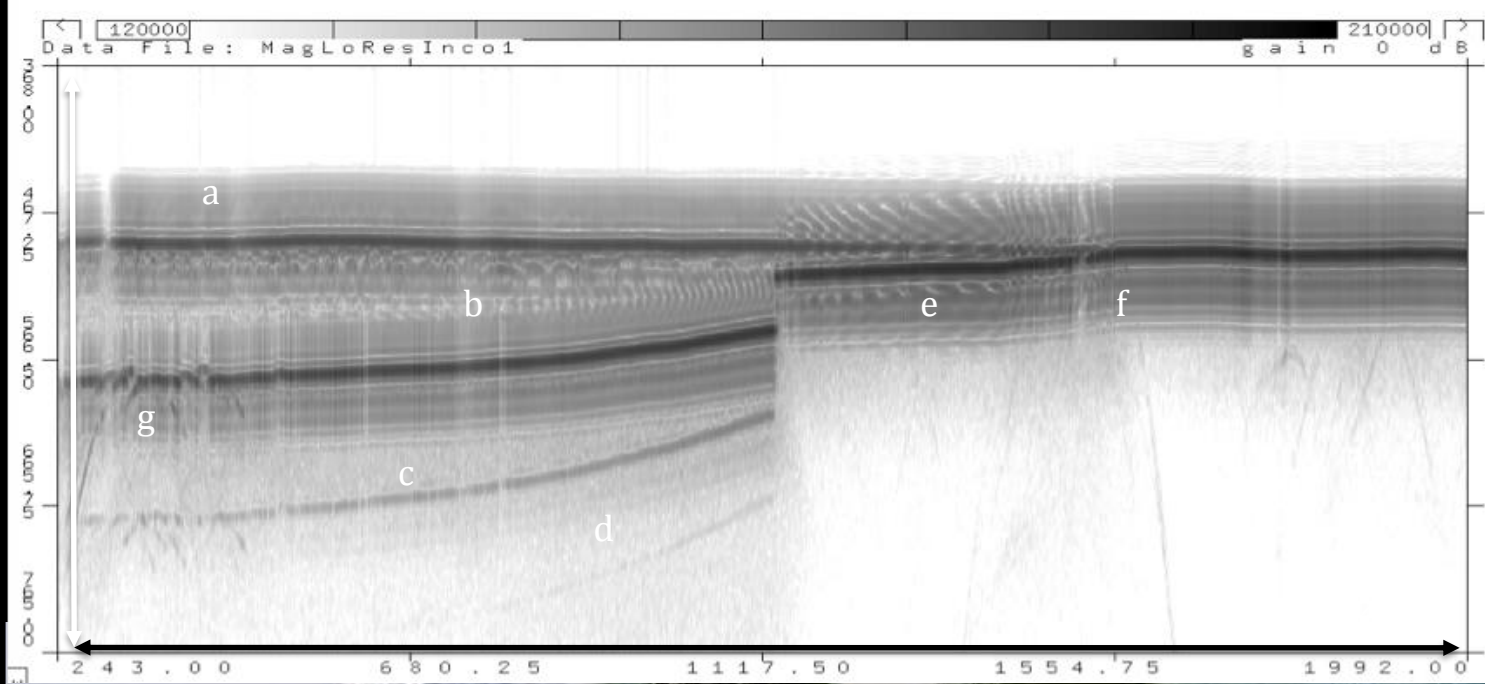
Strain? Fracture?

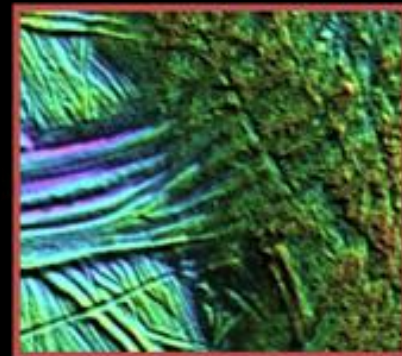
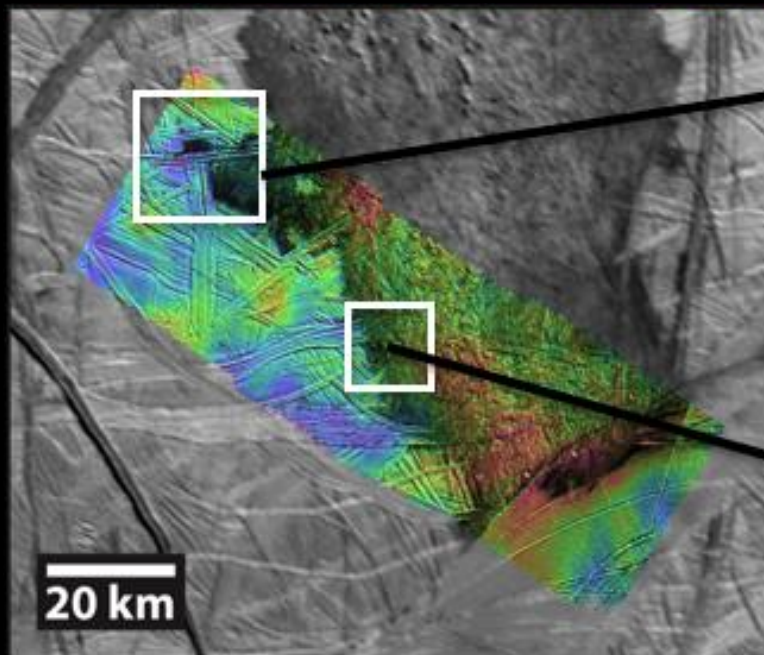
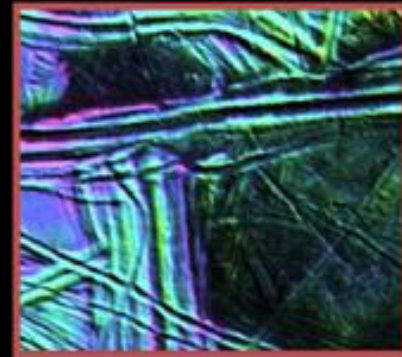
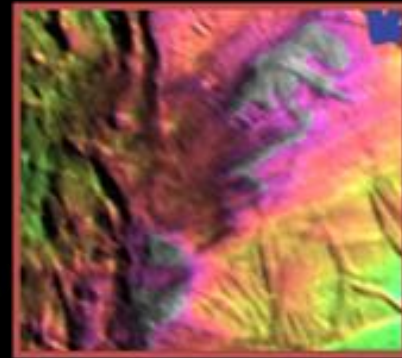
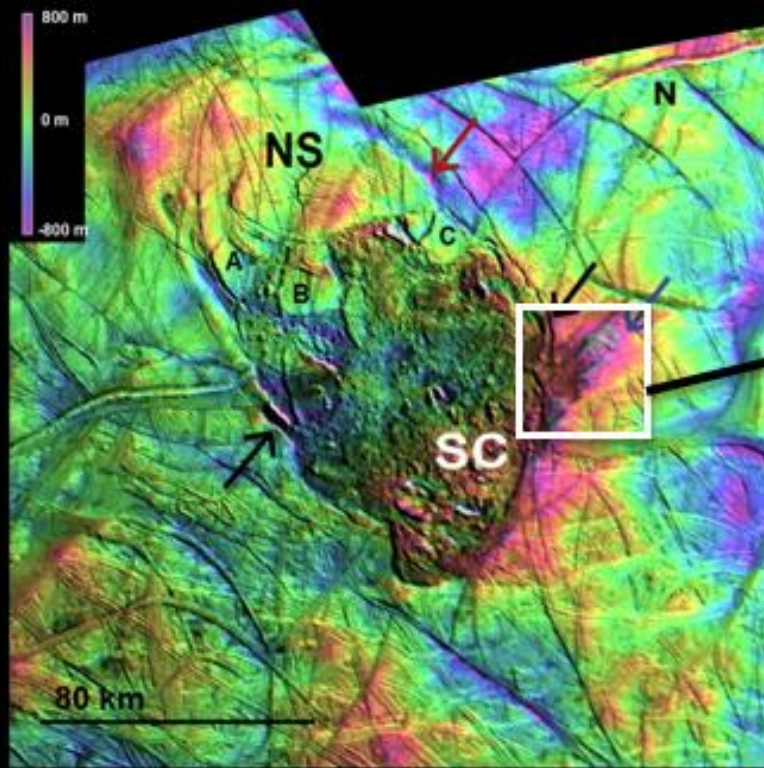


~7km

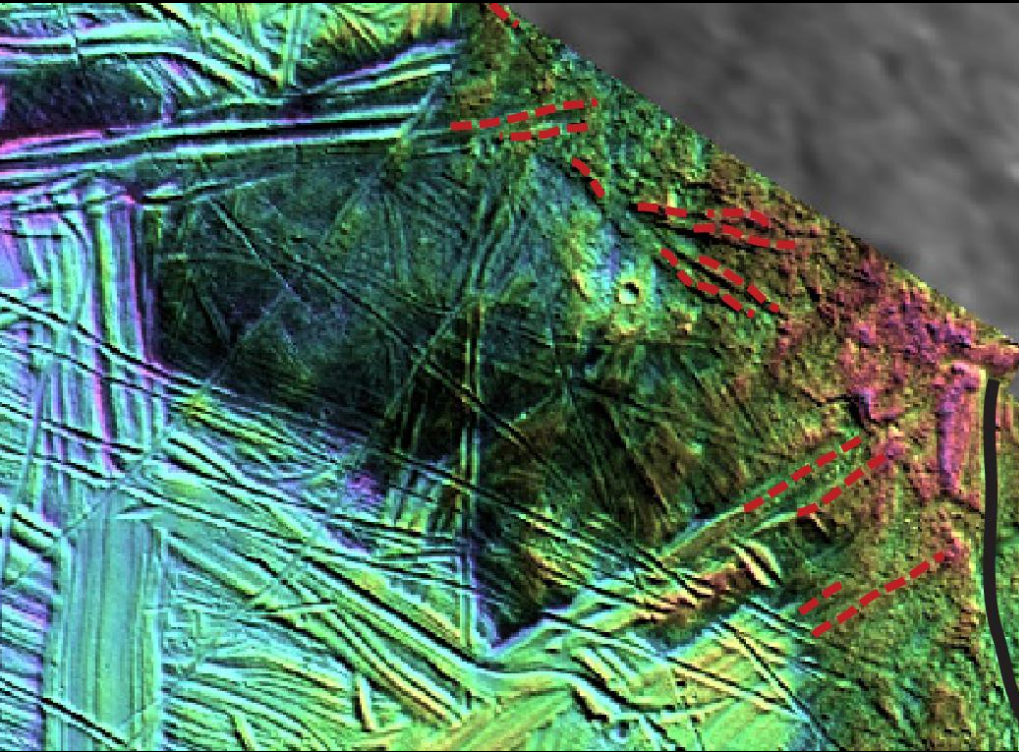


36 km





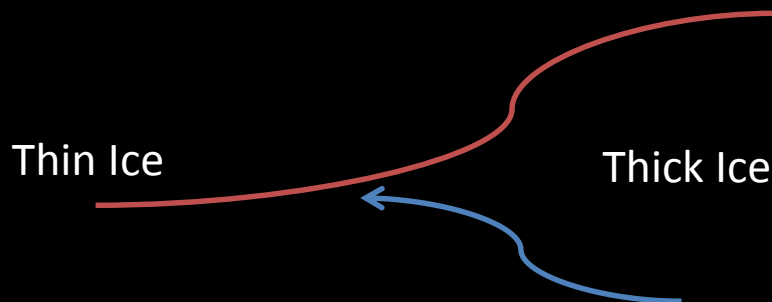
Hydraulic Forcing → Embayment

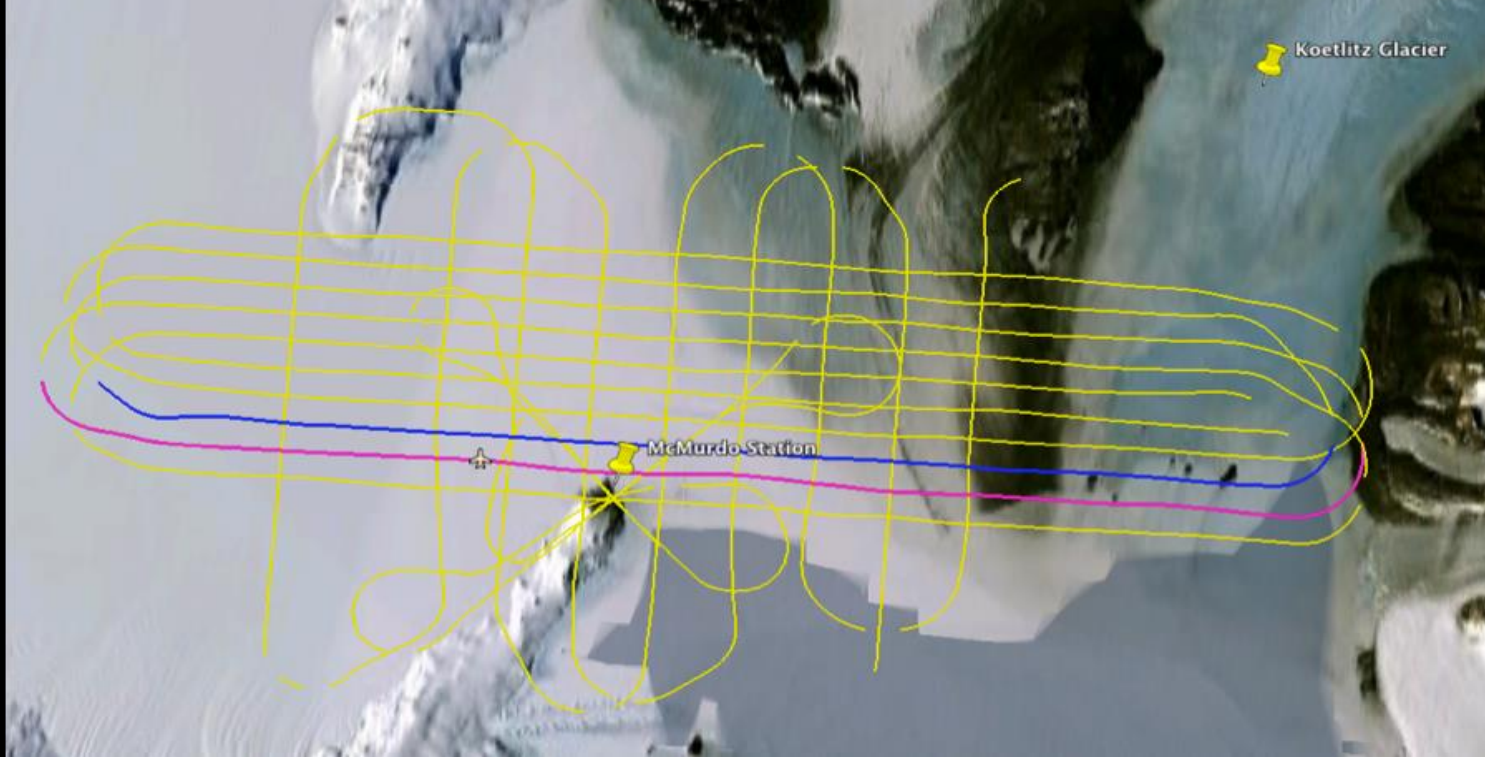
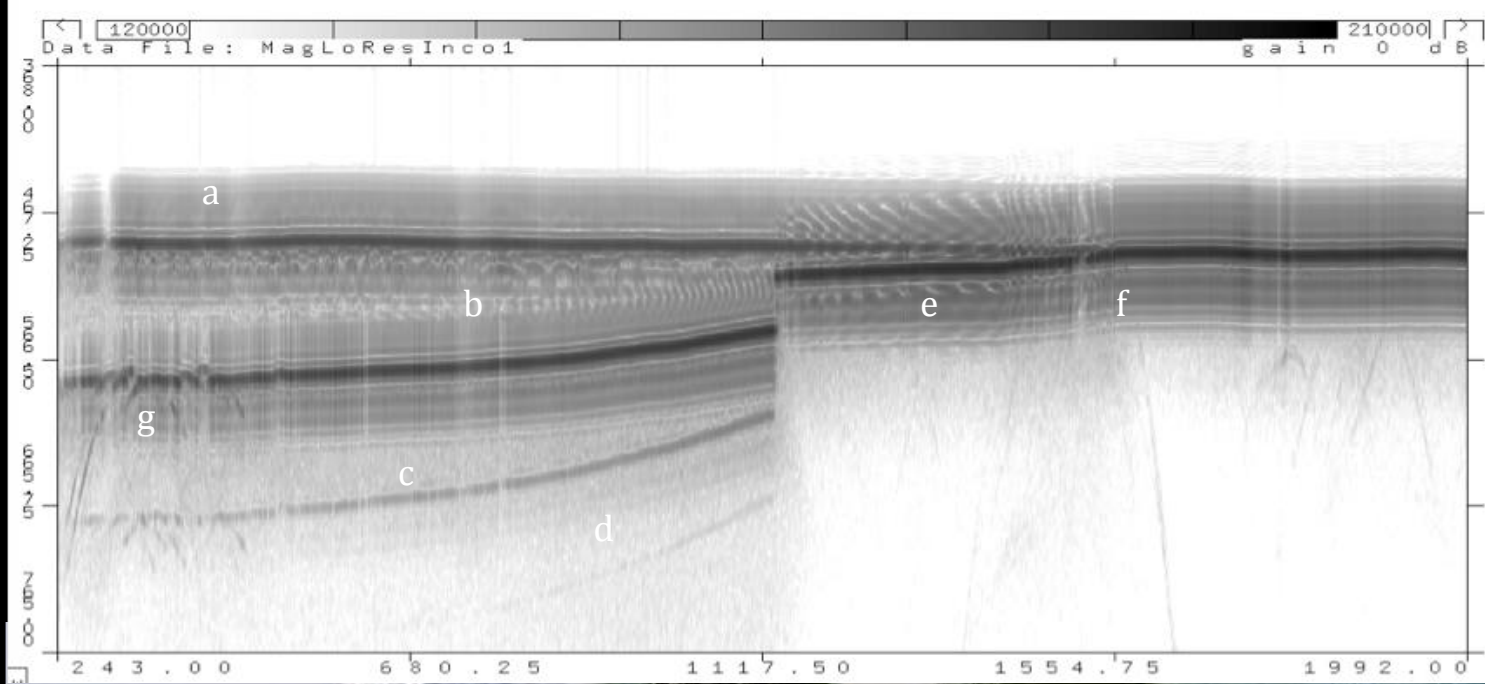


- Water flows according to the balance of overburden pressure and gravity:

$$\nabla \phi_b = (\rho_w - \rho_i)g \nabla z_b + g\rho_i \nabla z_s$$

- Surface slope is the strongest control on the flow
- Any subsurface water will move AWAY (and possibly up) from thick ice and towards thinner ice
- Embayment features should be topographically controlled
- Deep discontinuous boundaries?







2008/07/15 08:00:04



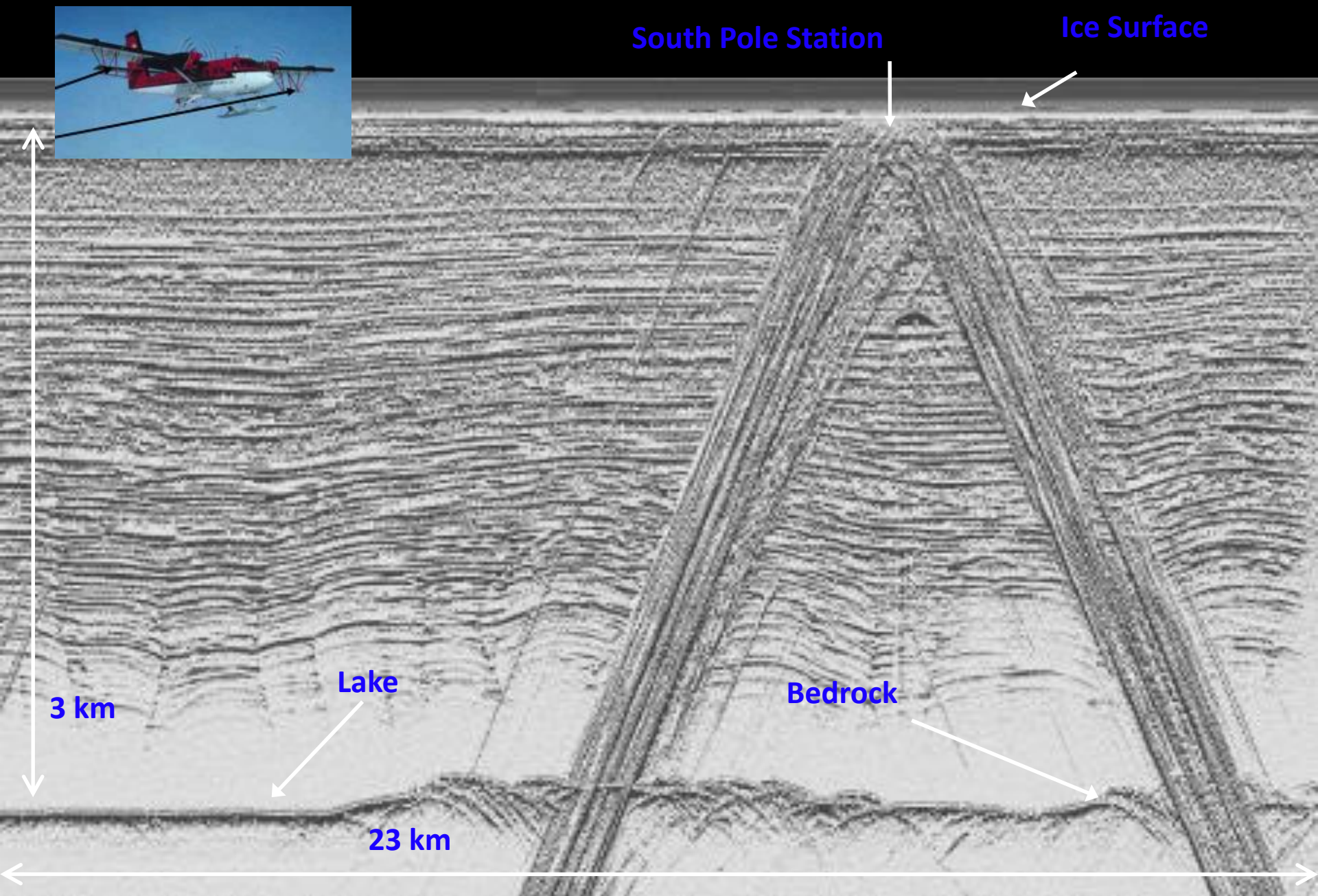
2009/08/21 06:27:41

U T Austin Instrumentation: HiCARS & DC-3

- Phase-coherent radar
 - 60 MHz center frequency
 - 15 MHz bandwidth
 - 8 MW peak power
 - 6.4 kHz PRF



Radar sounding of Earth's ice sheets is routine...



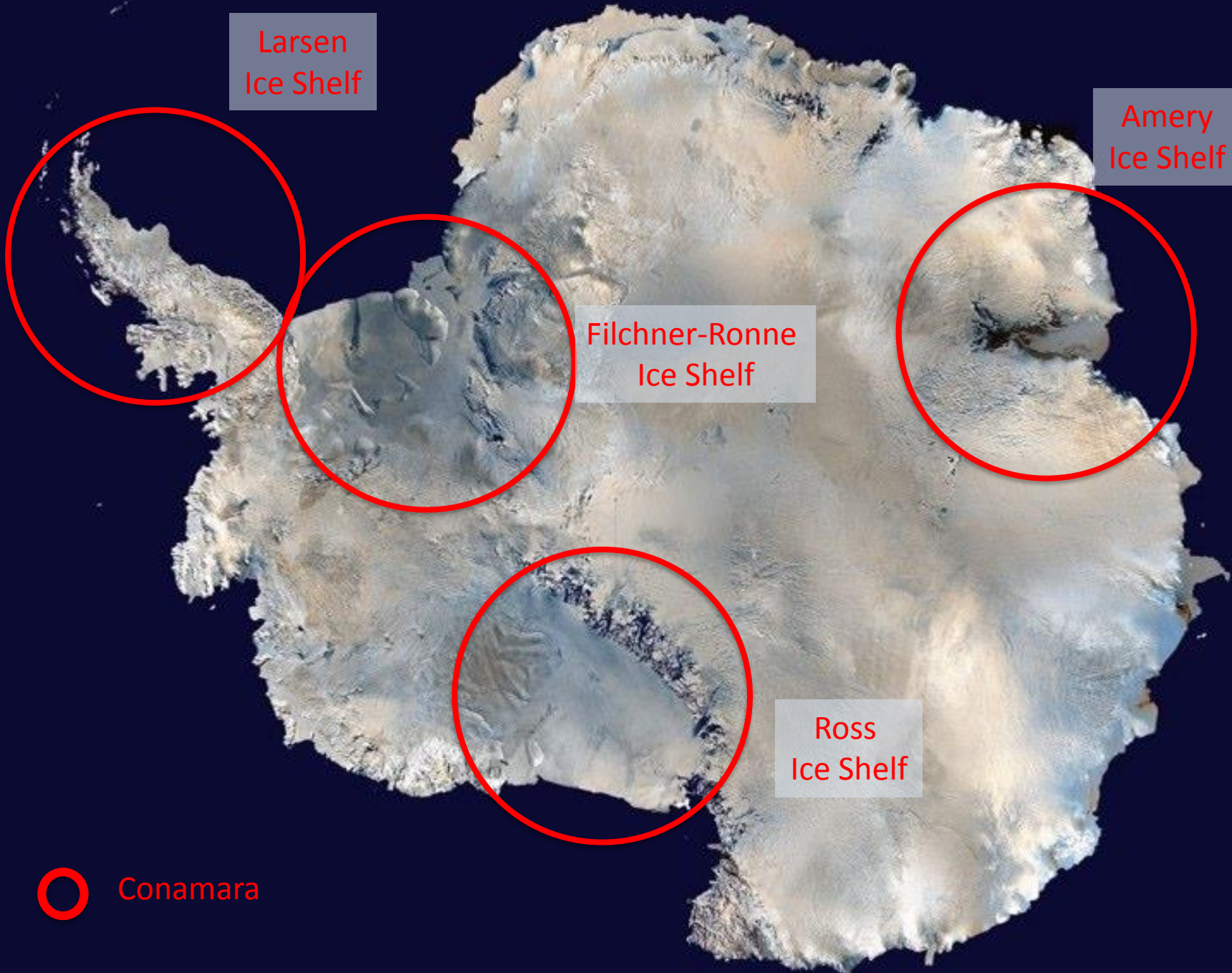
Larsen
Ice Shelf

Amery
Ice Shelf

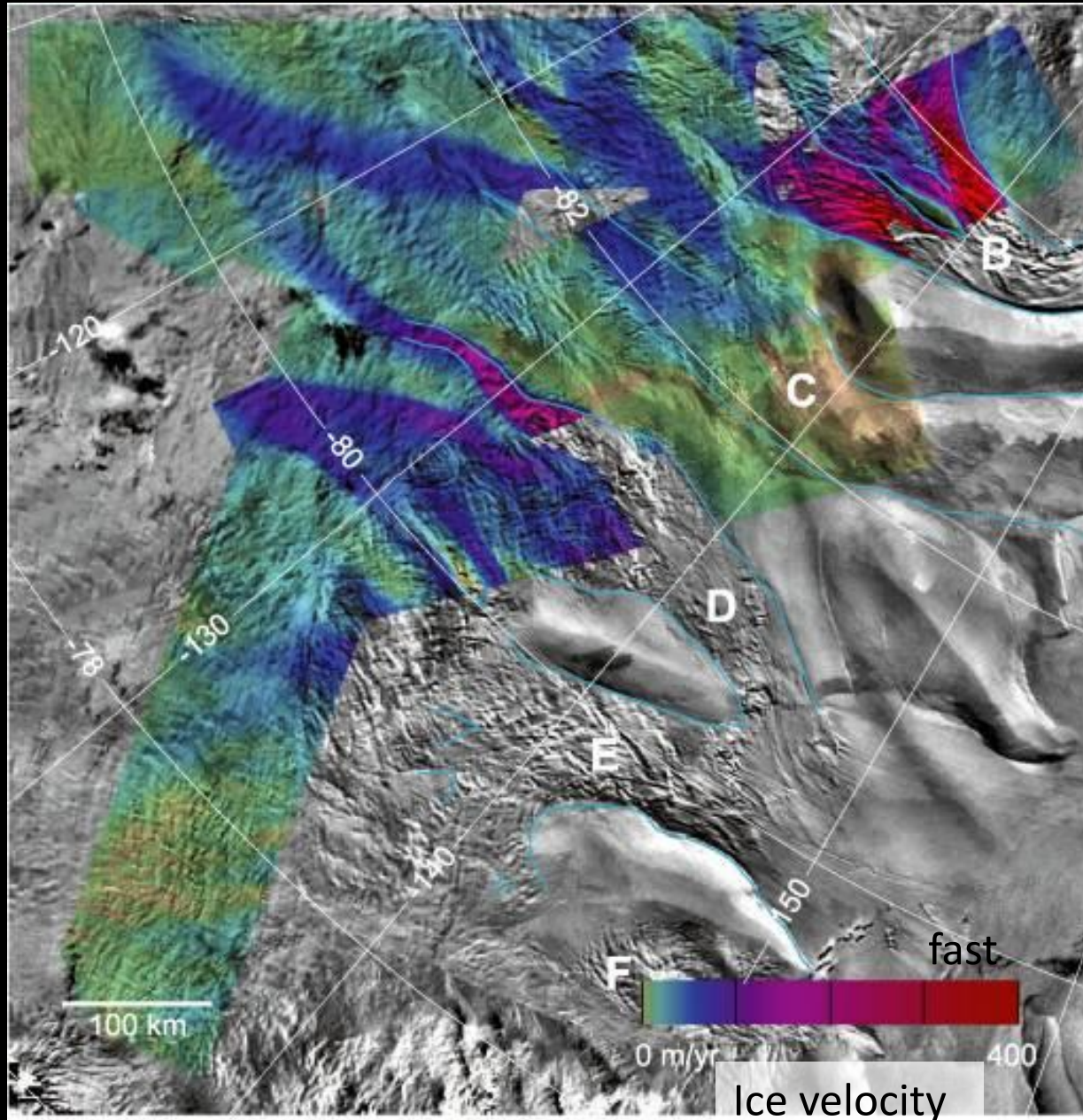
Filchner-Ronne
Ice Shelf

Ross
Ice Shelf

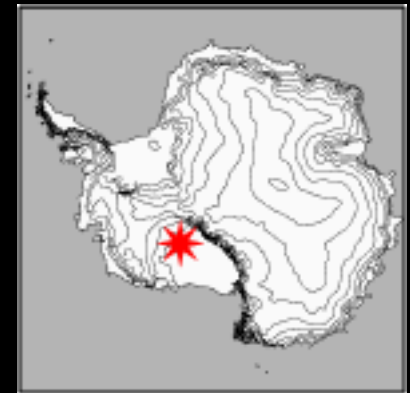
Conamara



Earth Analogs: Antarctic Ice Sheet and Ice Streams

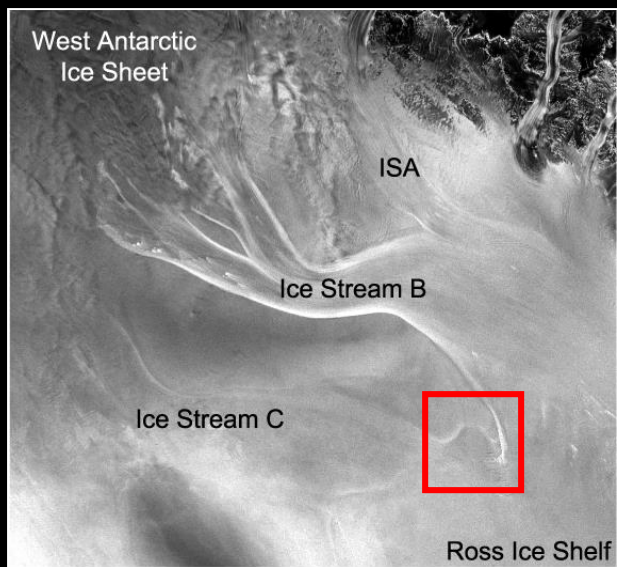


Europa's ice is under tension and compression.
So is Antarctica's!

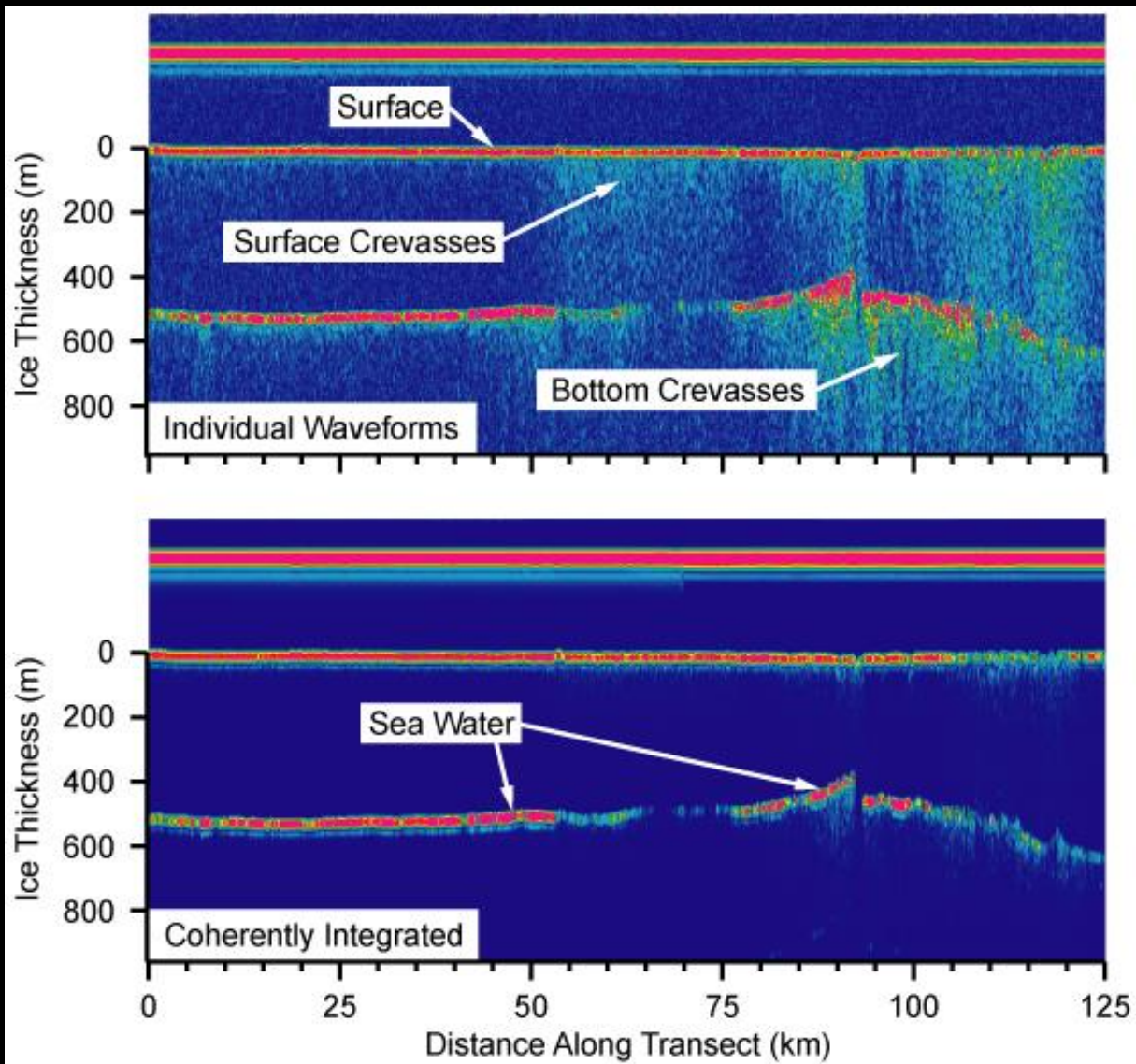
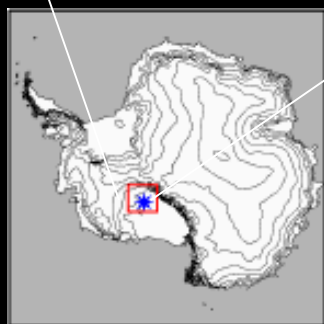


(Joughin, et al., 1999)

Radar can detect water-filled fractures beneath a thin ice shell: Idealized “Flat Europa” case



100 km

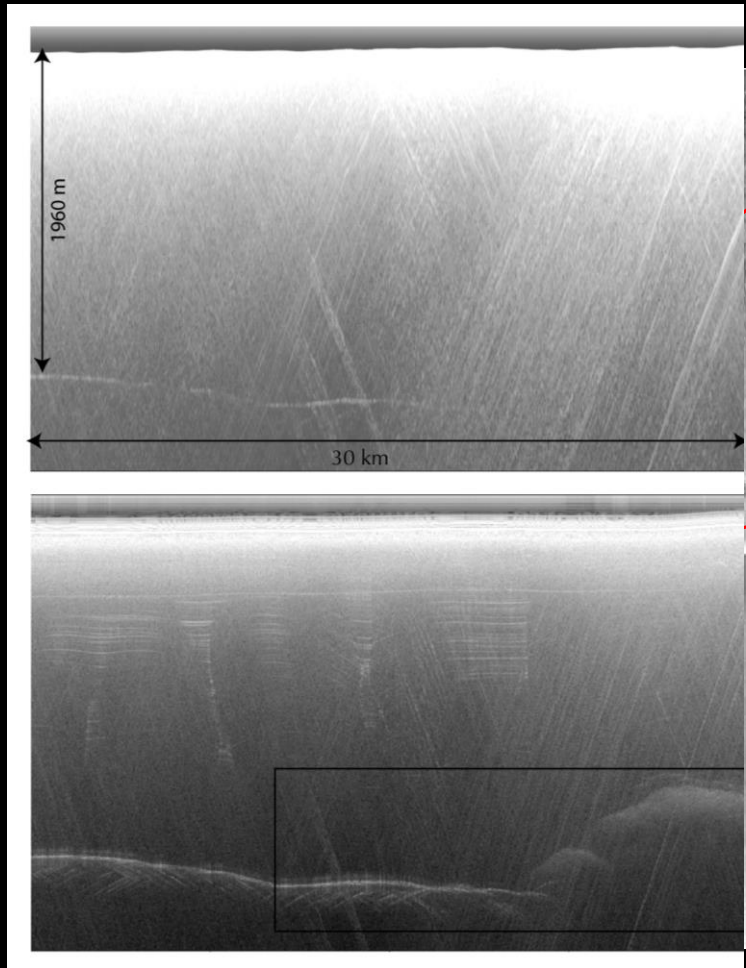


Earth: tidal cracking near ice shelf origin
Europa: ridge/band formation and transition

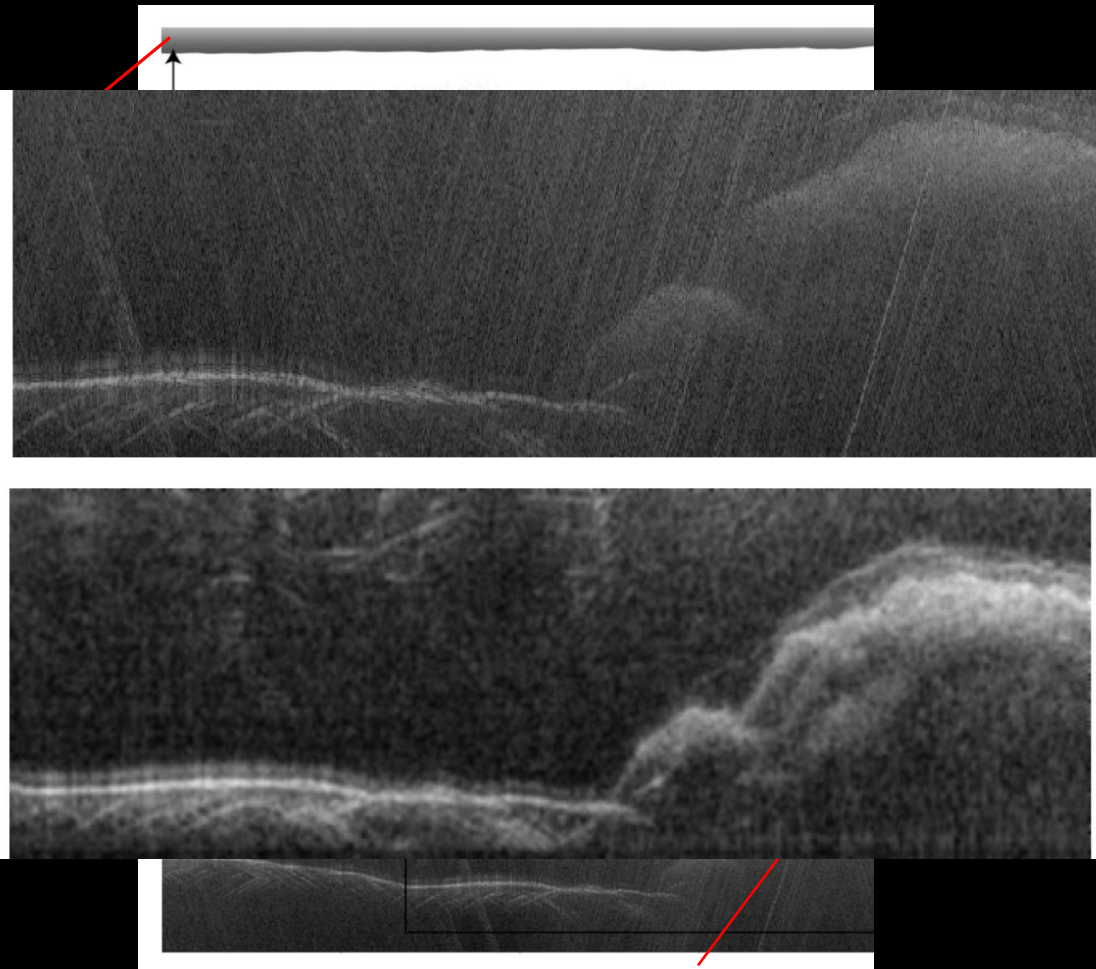
Peters et al., 2005, 2007

However, Europa has inspired development of new radar acquisition and imaging technologies....

Without these methods, we'll miss interesting and critical observations



(Peters et al. 2005, 2007)



New features seen with reduced scattering

Earth Analogs: Arctic Ice Caps



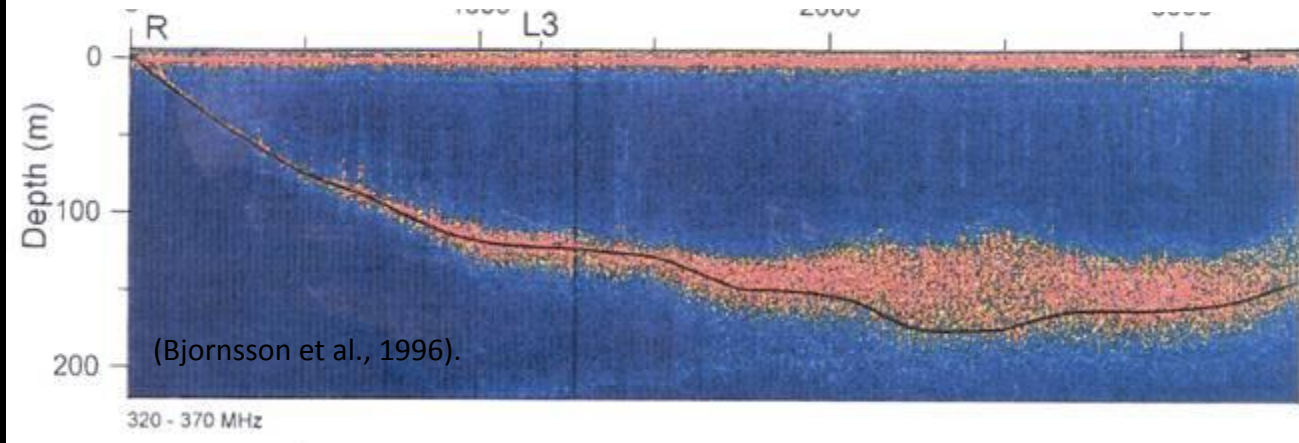
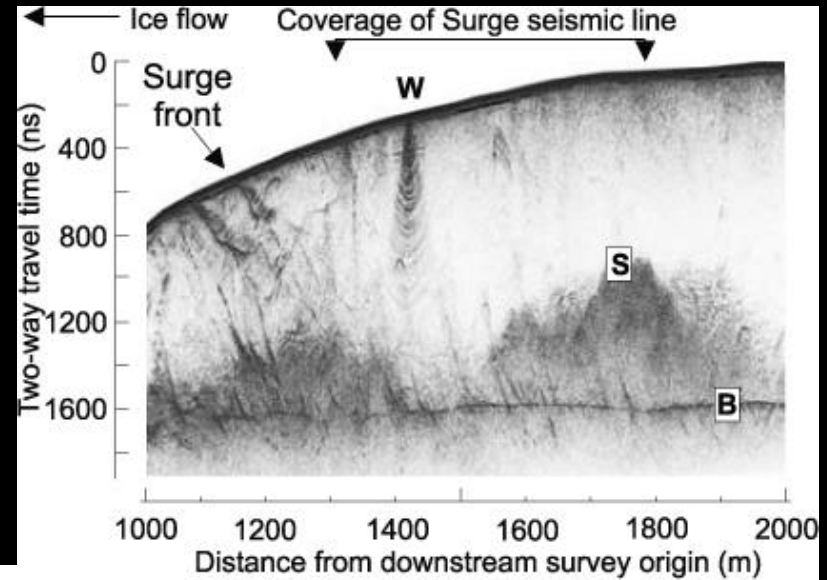
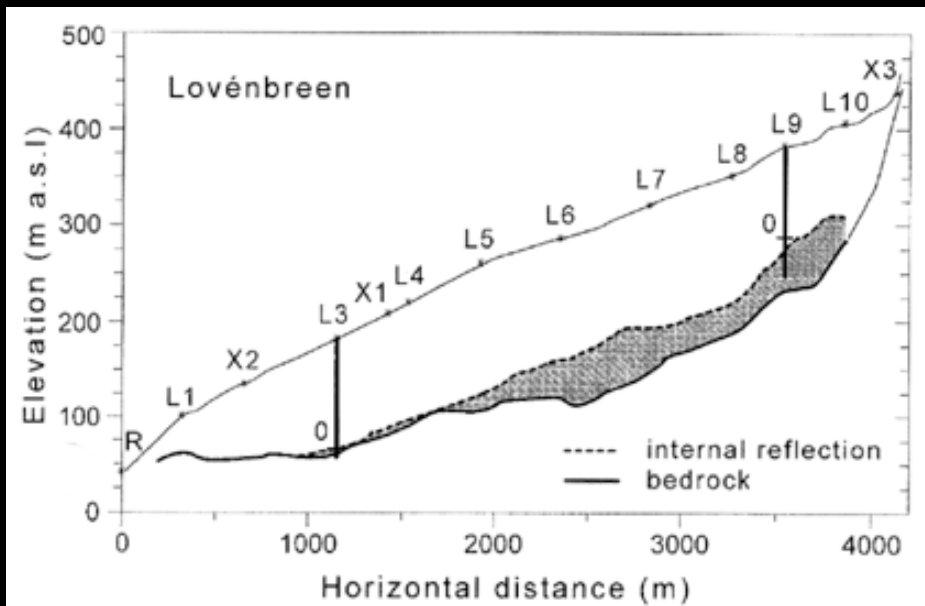
500 km

(Arctic Environmental Atlas, UNEP)

Europa has complex patterns of warm and cold ice.

Earth's arctic is also thermally complex.

Radar can detect water within an ice shell – Arctic Glaciers



- Earth: polythermal glaciers (melt drainage, mobile ice)
- Europa: ridged plains + mottled terrain (mobile ice/diapirism)

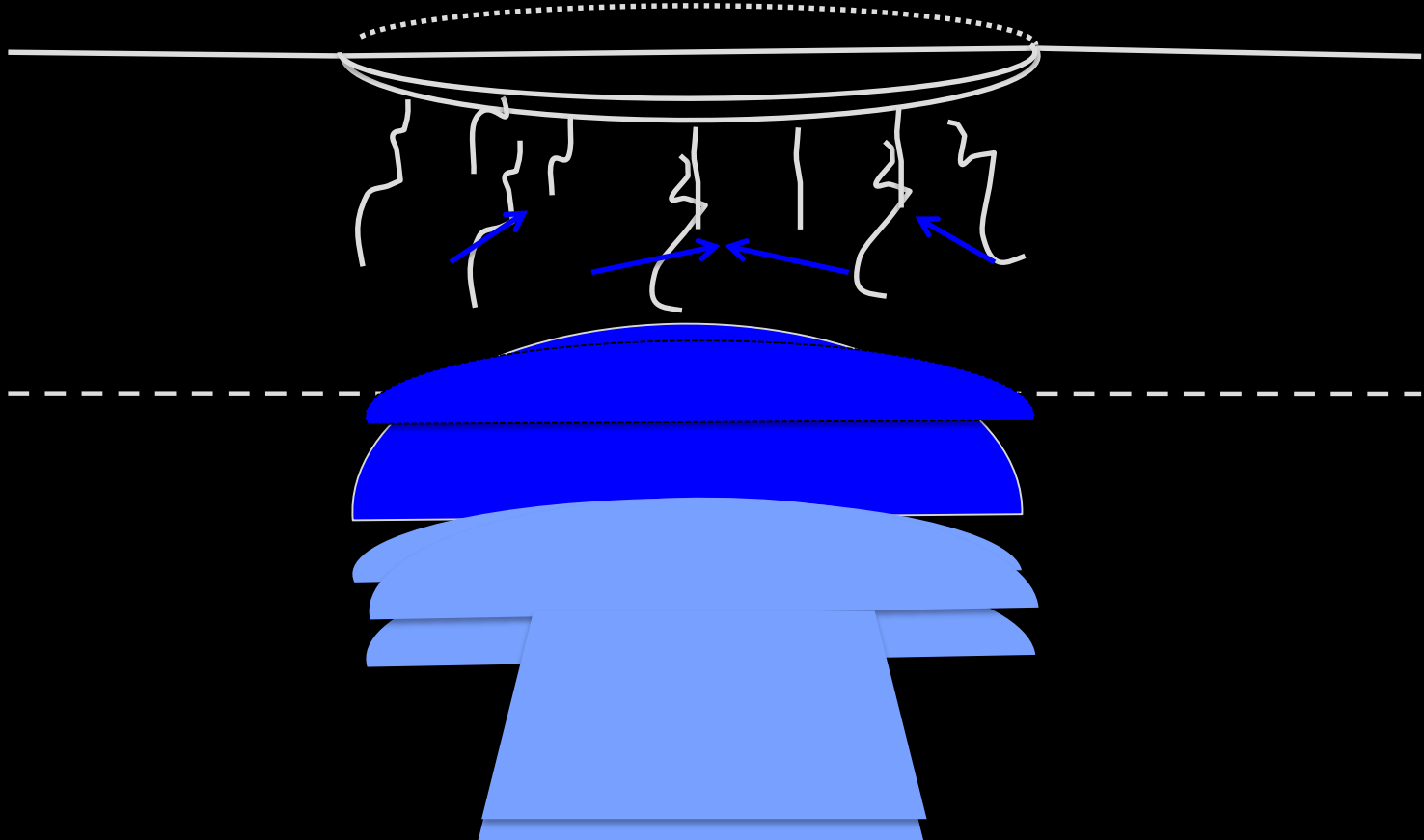
Implications

- A single, unified way to explain chaos & lenticulae formation
 - Europa is probably active TODAY
 - Pathway for ocean & surface ice to interact quickly
- Existence of PERVASIVE subsurface water within 2.5-3 km of the surface
 - 50% of Europa's surface!!
 - Toppling blocks of 2km imply depth of ~2.8 km
 - Brines may get as shallow as 30-100m of the surface
 - Brines 1000-1200 kg/m³

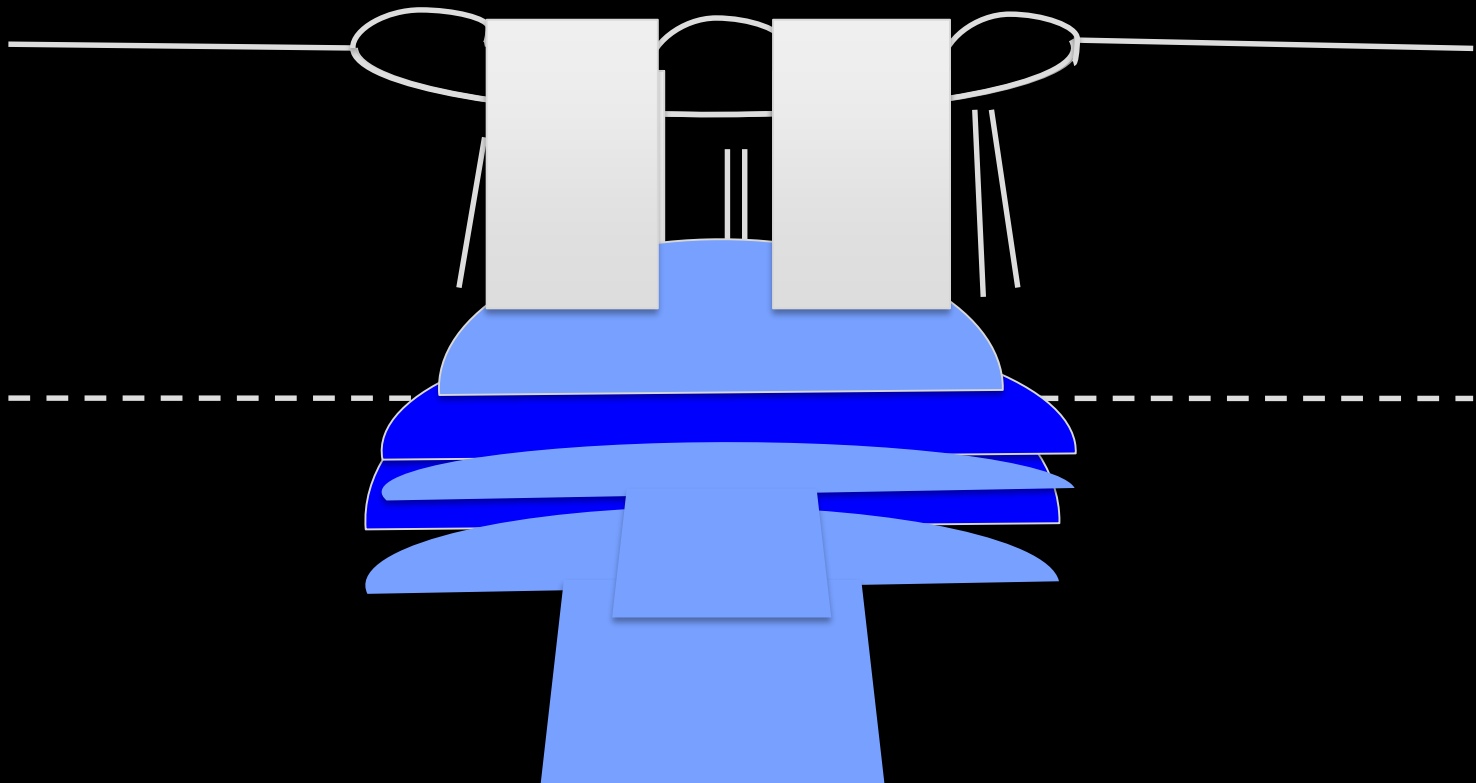
WE KNOW WHERE TO LOOK TO FIND SHALLOW WATER!

WE CAN IMAGE THESE PROCESSES IN ACTION WITH RADAR!

The Europa Case



The Europa Case



Dr. Britney Schmidt



Dr. Schmidt is a research scientist at The University of Texas Institute for Geophysics, working with Dr. Don Blankenship. She received her Ph.D. in Geophysics and Space Physics at The University of California at Los Angeles in 2010. Dr. Schmidt has published in premier scientific journals such as Nature and Science, and has won teaching awards as a graduate teaching assistant at UCLA. She is actively involved in academic service and public speaking, and served as Chair of the 2012 Astrobiology Research Focus Group conference. She also served as Acting EPO Science Team Liaison for the NASA Dawn Mission from August 2010 - February 2011.