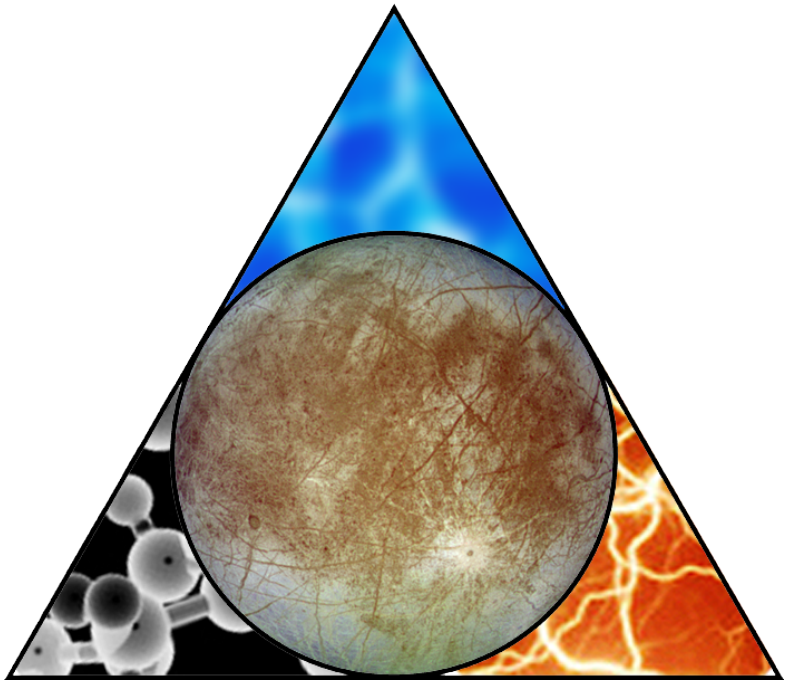


Preliminary Lander Science Overview

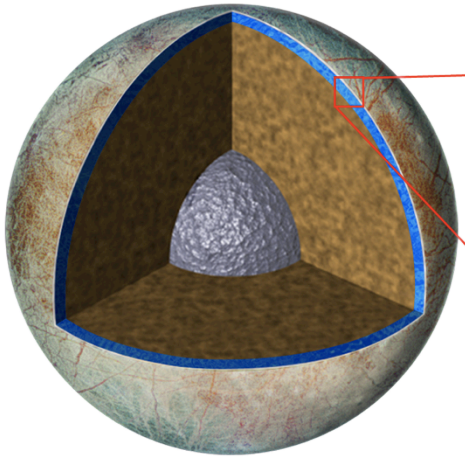
Bob Pappalardo

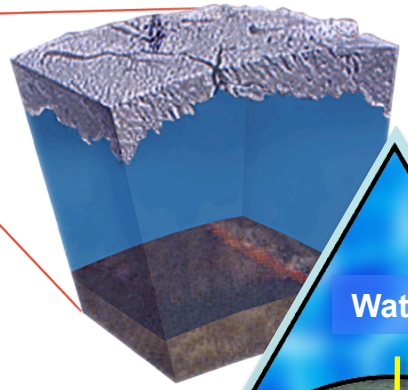
Europa Study Scientist

Jet Propulsion Laboratory, California Institute of Technology

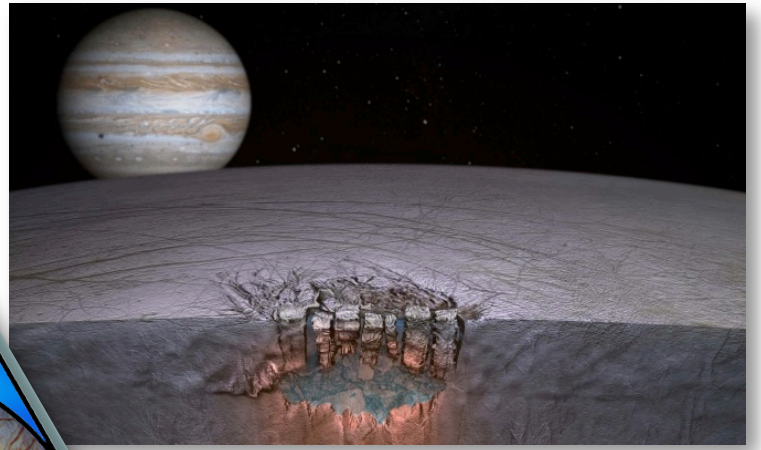
ISEFG, Feb. 29, 2012

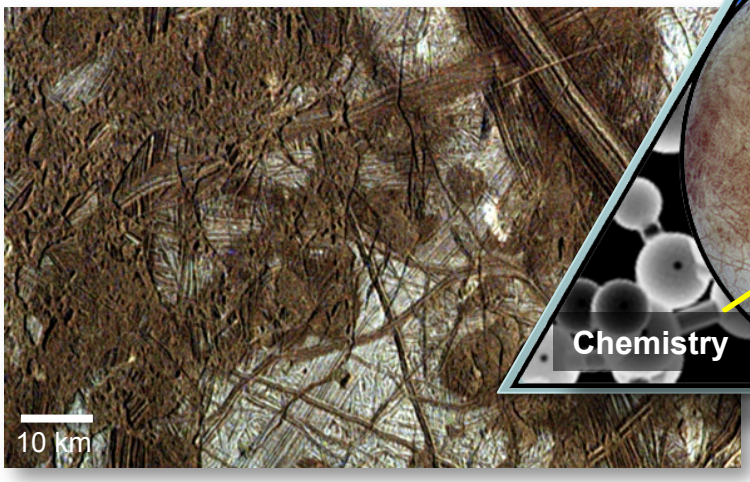
Europa: Ingredients for Life?

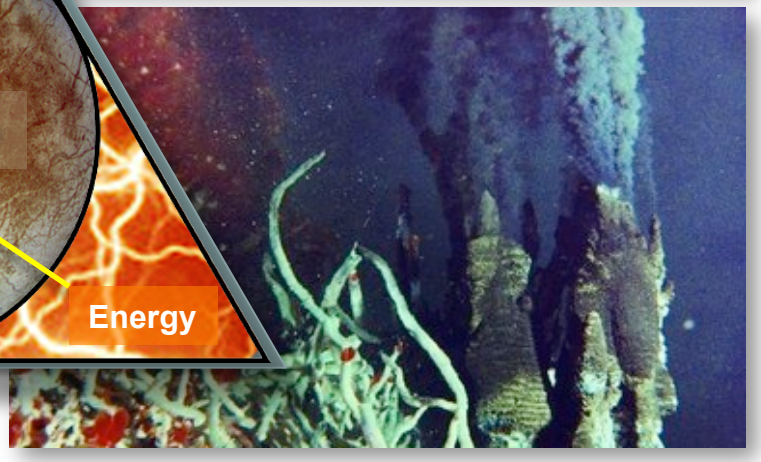




Water: A global ocean and lakes hidden within the ice?





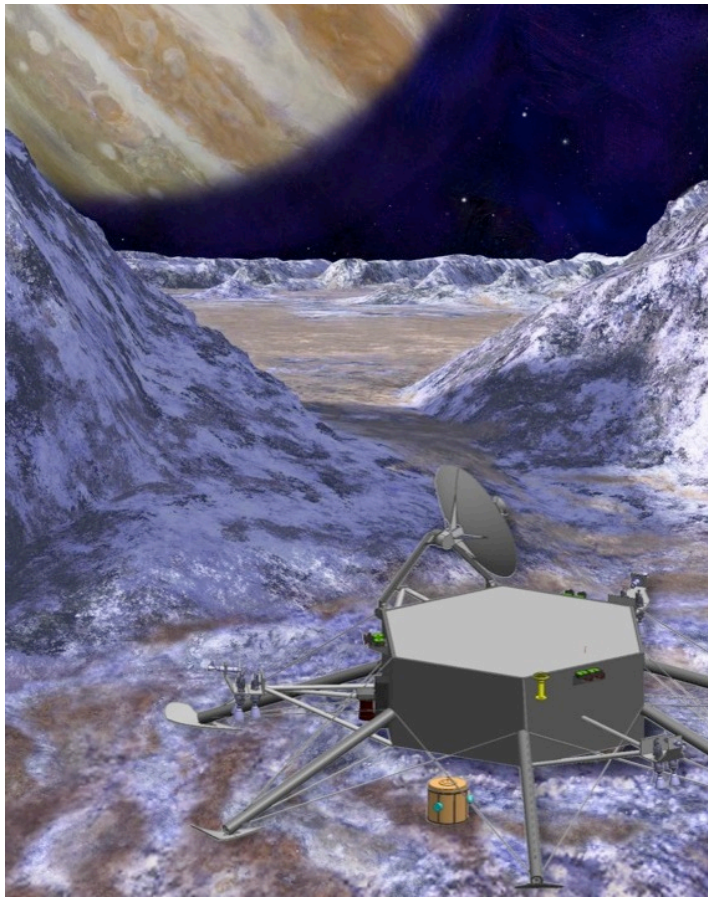


Chemistry: Do red surface deposits contain salts and organics from below?

Energy: Can chemical disequilibrium provide energy for metabolism?

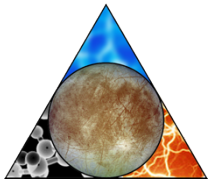
Science from Europa's Surface

- For key habitability science, Europa surface materials must be sampled and analyzed *in situ*
- Geophysical and geological observations *in situ* would greatly advance Europa science
- The Europa Science Definition Team defined the highest priority science objectives, investigations, and measurements to be achieved from a landed platform on Europa's surface
- Aim for great science at low cost



Art by Michael Carroll

Europa Science Definition Team
2011-2012



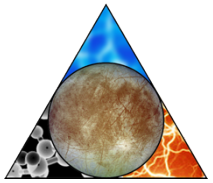
• Fran Bagenal	Univ. Colorado	Plasma
• Amy Barr	Brown Univ.	Geophysics
• Bruce Bills	JPL	Geophysics
• Diana Blaney	JPL	Composition
• Don Blankenship	Univ. Texas	Ice shell
• Will Brinckerhoff*	GSFC	Astrobiology
• Jack Connerney	GSFC	Magnetometry
• Kevin Hand*	JPL	Astrobiology
• Tori Hoehler*	Ames	Astrobiology
• Bill Kurth	Univ. Iowa	Plasma
• Melissa McGrath	MSFC	Atmosphere
• Mike Mellon*	SWRI	Ice Physics
• Jeff Moore	Ames	Geology
• Bob Pappalardo	JPL	Chair / Study Scientist
• Louise Prockter	APL	Deputy / Geology
• Dave Senske	JPL	Deputy / Geology
• Everett Shock*	ASU	Geochemistry
• David Smith	MIT	Geophysics

*SDT augmentations for lander study

Europa SDT: Lander-Focused Meetings

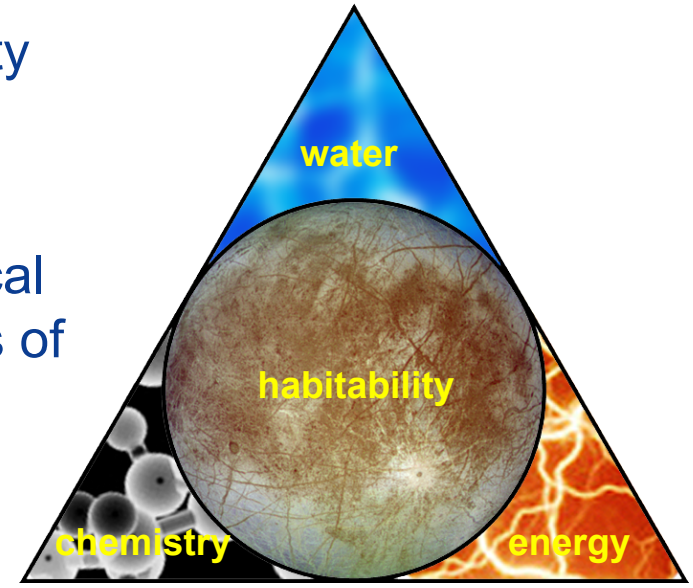
- Oct. 17–18, 2011, JPL
  - Developed initial objectives and investigations for a landed mission
- Nov. 29–30, 2011, Boulder, Colo.
  - Derived preliminary lander model payload and science mission requirements
- Jan. 31–Feb. 2, 2012, JPL
  - Determined baseline vs. floor science and finalized lander model payload and mission requirements

Science Goal, Objectives, and Themes



- *Goal:* Explore Europa to investigate its habitability
- *Objectives:*
  - *Composition:* Understand the habitability of Europa's ocean through composition and chemistry
  - *Ocean & Ice Shell:* Characterize the local thickness, heterogeneity, and dynamics of any ice and water layers
  - *Geology:* Characterize a locality of high scientific interest to understand the formation and evolution of the surface at local scales

Themes:

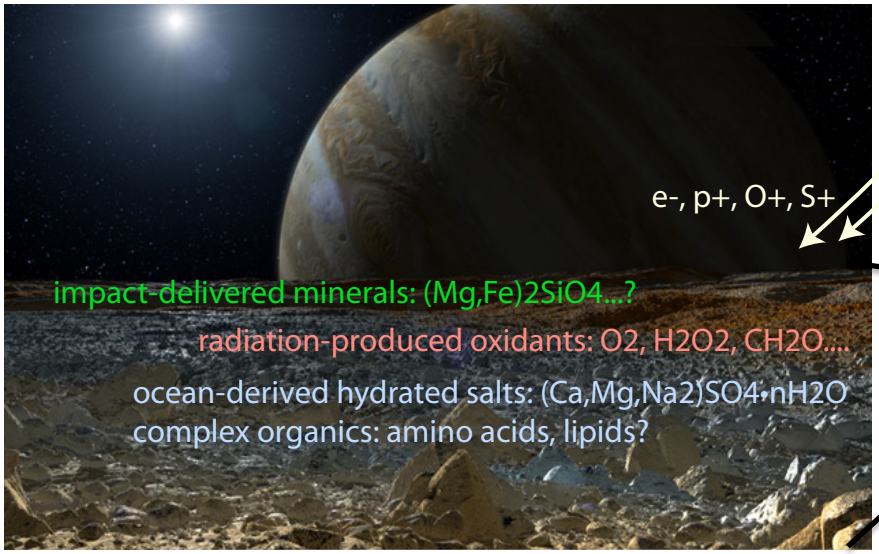


Traceability Example

Goal	Objective	Investigation	Measurement	Model Instrument(s)	Mission constraints/ requirements
Explore Europa to investigate its habitability	C.1. Understand the habitability of Europa's ocean through composition and chemistry	C.1a Characterize surface and near-surface chemistry, including complex organic chemistry to constrain ocean composition and understand the endogenic processes from which it evolves	Measure organic content of surface (0-2 cm depth) and near-surface (5-10 cm depth) materials to as low as 1 ppb concentrations.	Mass Spectrometer (with filtration and thermally evolved gas analysis); Raman Spectrometer	(1) Maintain the sample at a temperature to prevent melting (<198K); to preserve O2, CO and CO2, the sample needs to be maintained at a temperature lower than 150K; (2) *Baseline:* Mass Spectrometer and Raman measurements of each of samples two depths; Raman and Mass Spectrometer to look at same sample. *Floor:* Mass Spectrometer measurements of samples acquired from two depths. (3) *Sample handling:* ~1 cc each, sufficient to obtain a minimum of one sample from 0.5–2 cm depth, and one from 5–10 cm depth. Samples are not required to be from the same location. Contamination control of spacecraft organics in the sample analysis chain of < 1 ppb.

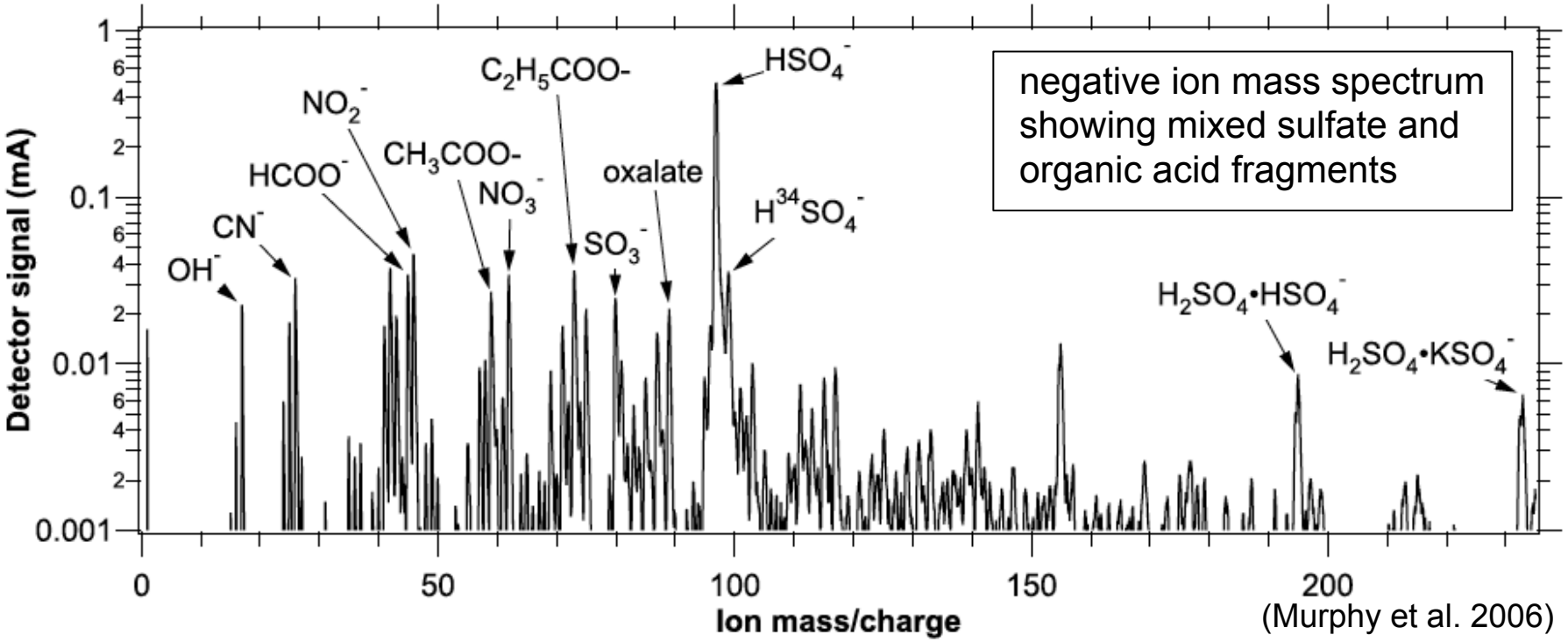
Composition: Objective and Investigations

- *Objective:* Understand the habitability of Europa's ocean through composition and chemistry
- *Investigations:*
  - Ocean composition and endogenic processes
  - Exogenic processes and material fluxes
  - Context of compositional measurements



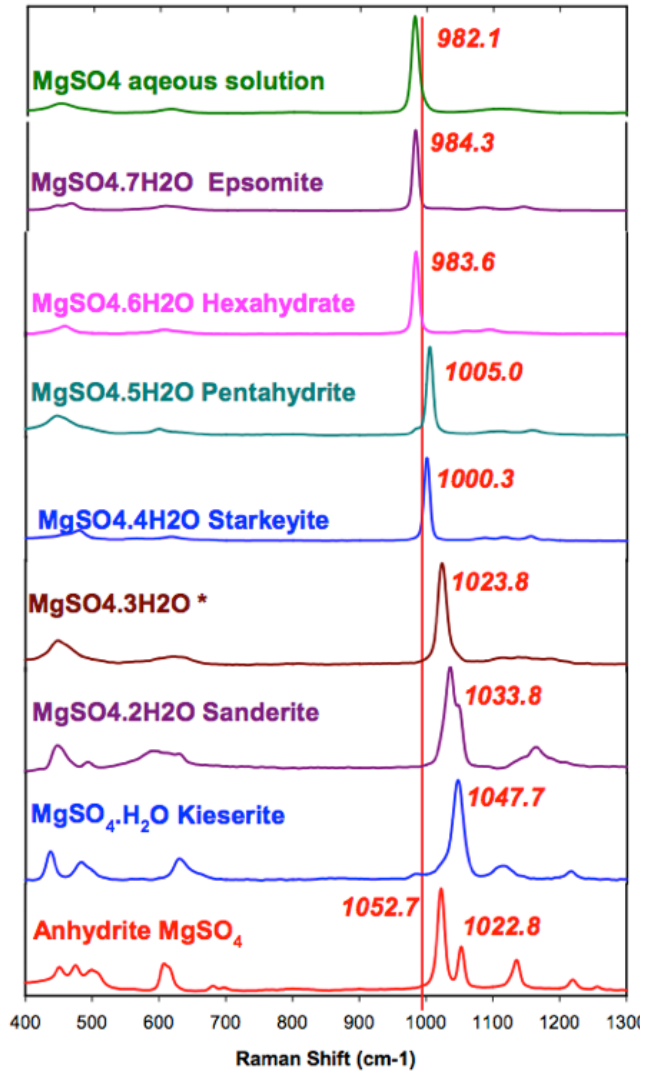
Composition: Techniques

- Mass Spectrometry
  - Characterize surface and near-surface organic composition to search for signs of habitability from the ocean, and determine the influx of exogenous organics and effect of Jupiter's high-radiation environment.



Composition: Techniques

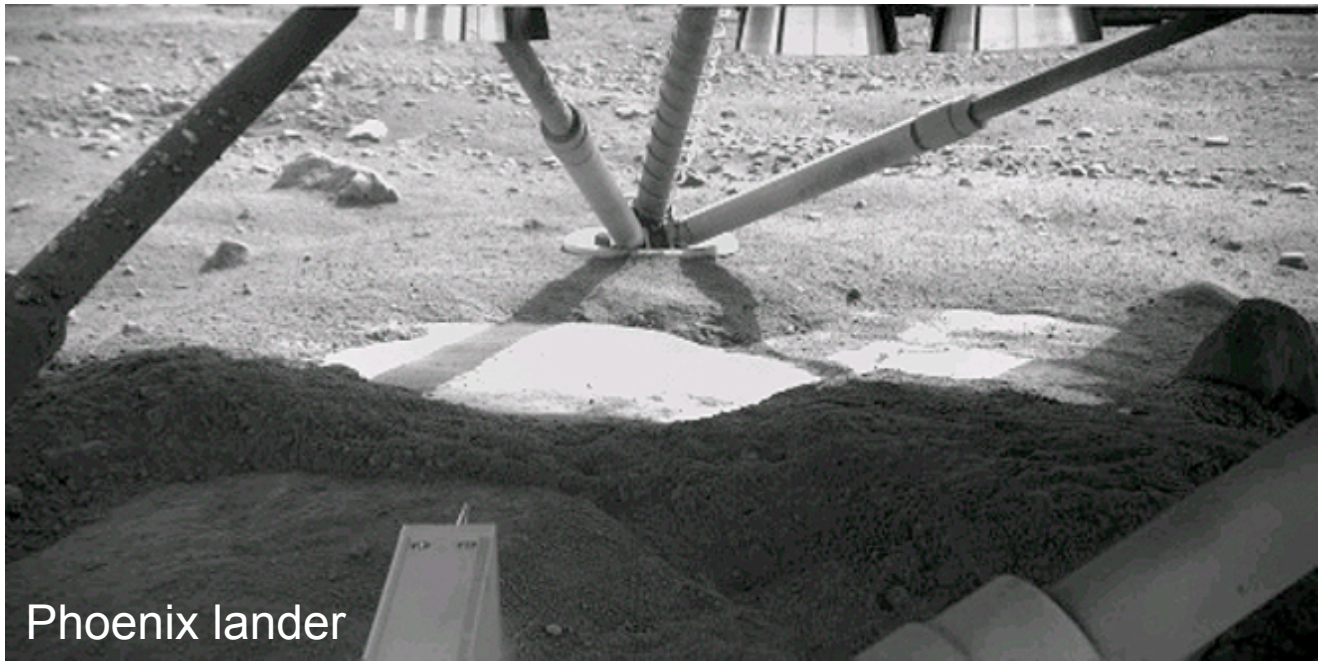
- Raman Spectroscopy
  - Characterize surface and near-surface inorganic chemistry to constrain ocean composition and influx of material from space
  - Measure the inventory of hydrated salts and other minerals in samples
  - Search for exogenous materials (e.g. Io silicates)
  - Supplements the mass spectrometer in characterizing organics



(B. Jolliff)

Composition: Techniques

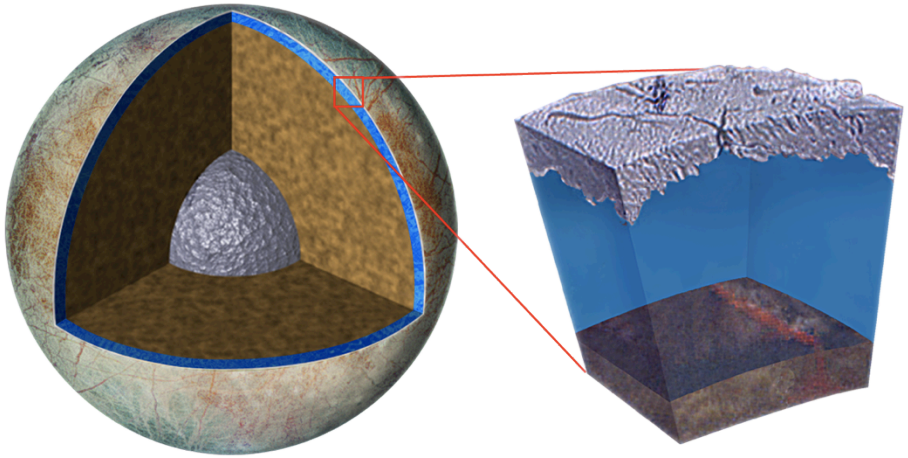
- Imaging
  - Constrain the context of compositional measurements
  - For any remote compositional measurements of the surface, obtain context imaging of the target area.

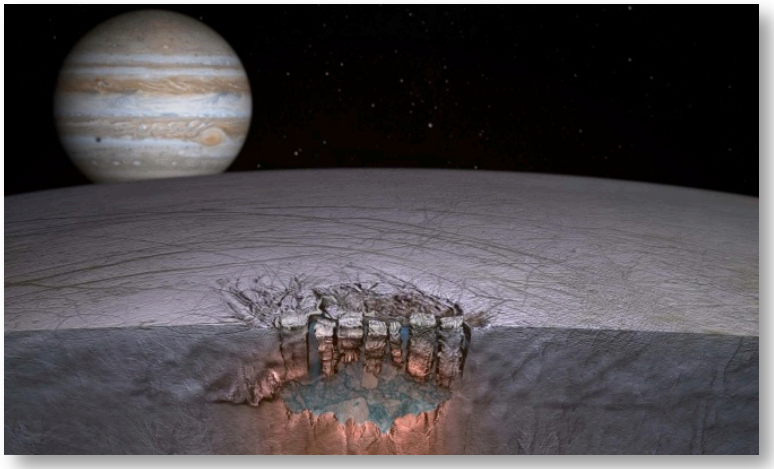

Phoenix lander


Antarctic ice core
(Reuters)

Ocean & Ice Shell: Objective and Investigations

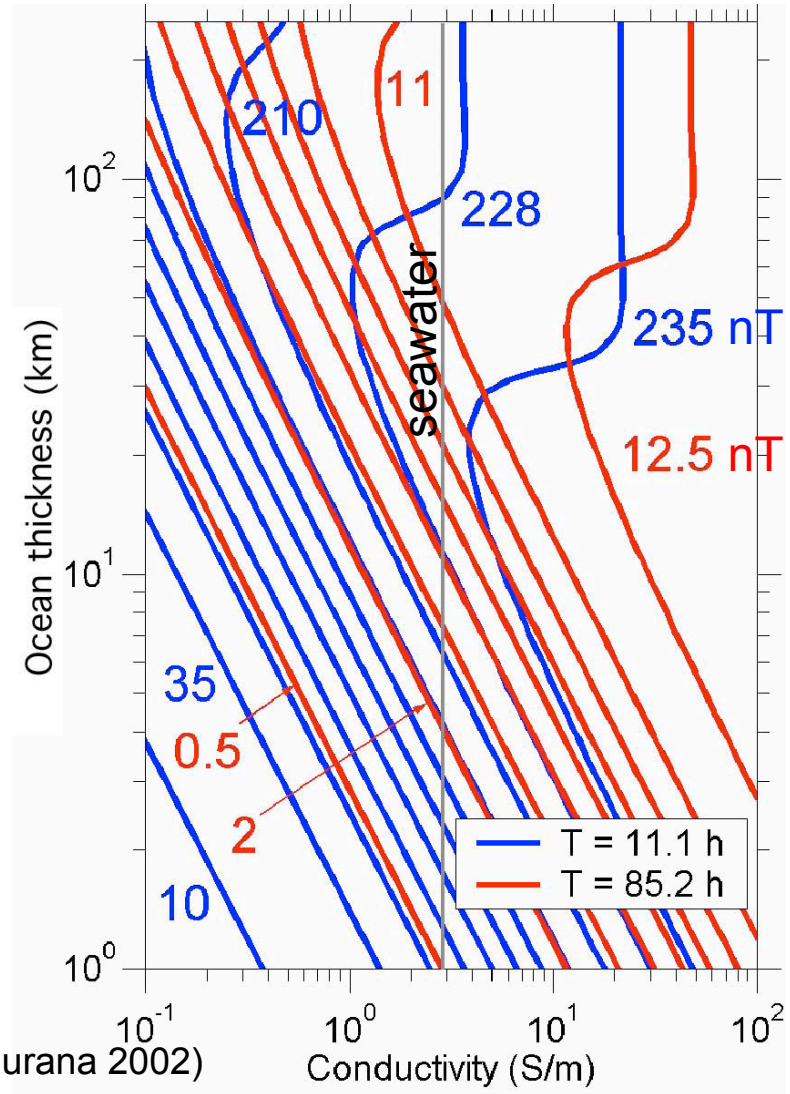
- *Objective:* Characterize the local thickness, heterogeneity, and dynamics of any ice and water layers
- *Investigations:*
  - Thickness and salinity of Europa's ocean
  - Regional ice and water layer thickness
  - Local ice heterogeneity and subsurface water
  - Seismic activity and its variation over the tidal cycle





Ocean & Ice Shell: Techniques

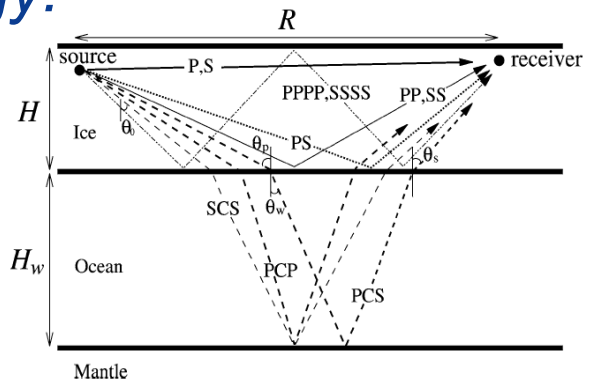
- Ocean characterization from magnetometry:
  - Measure induction field (nT) at Jupiter rotation period (11 h), Europa orbital period (85 h), and other natural periods
  - Ocean thickness and salinity can be uniquely derived over much of the likely parameter space
  - Plasma effects may be an issue

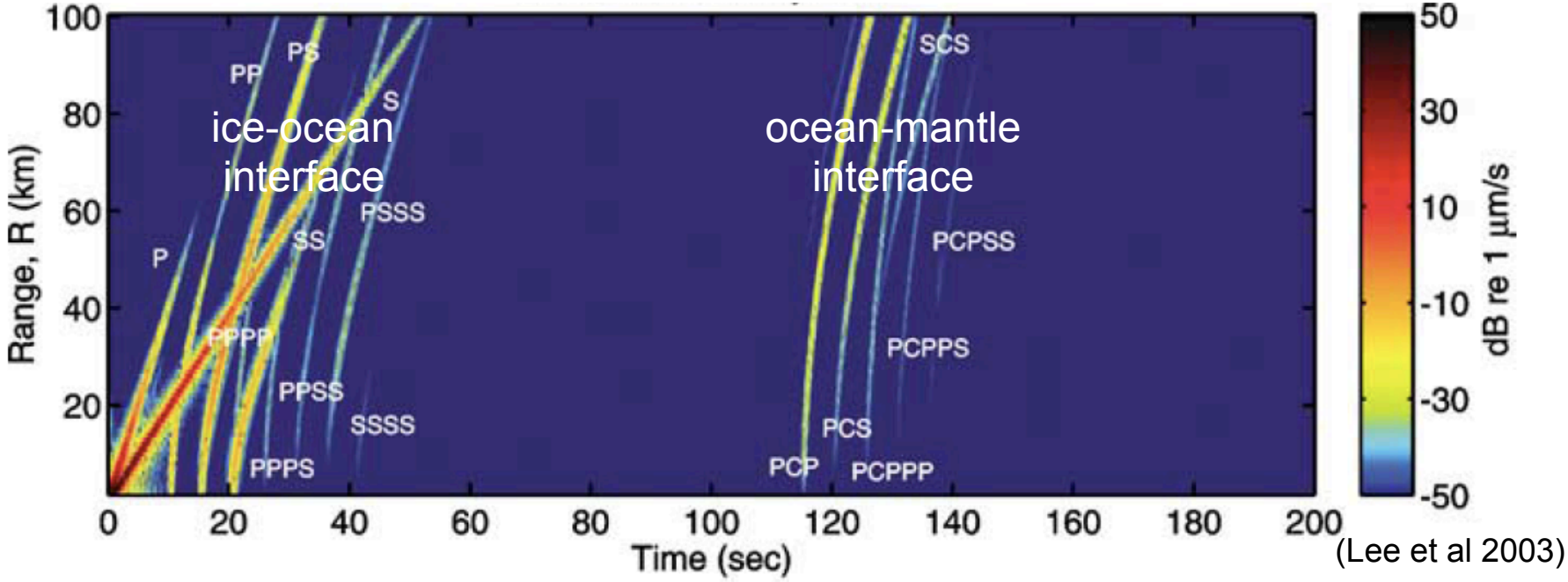


(Khurana 2002)

Ocean & Ice Shell: Techniques

- *Ice-ocean characterization from seismology:*
  - Determine ice shell and ocean thickness from reflected body waves
  - Locate cracks, characterize the ice shell, and determine the frequency of energy release by observing reflected and refracted body waves

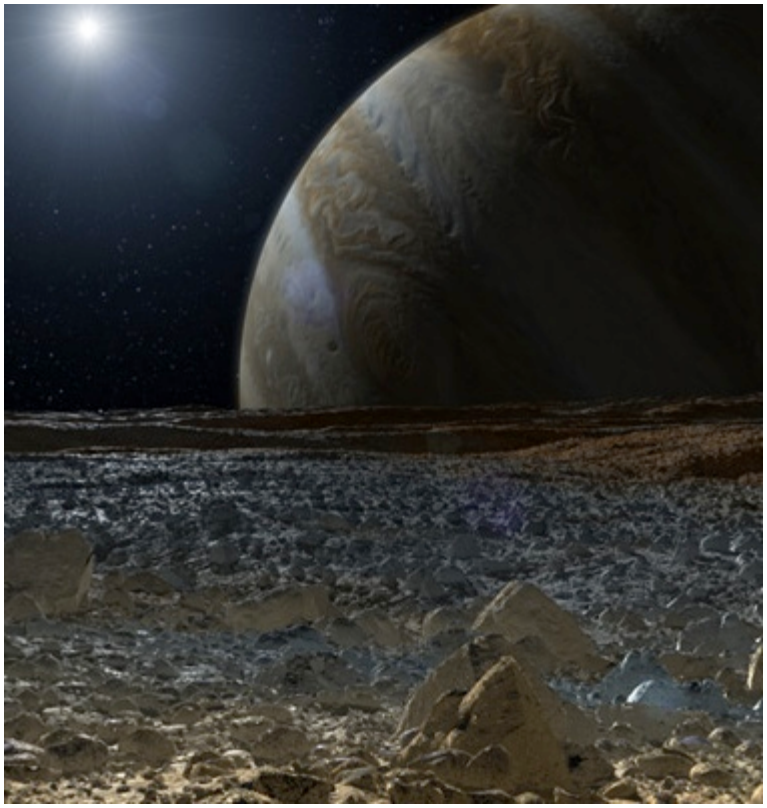




(Lee et al 2003)

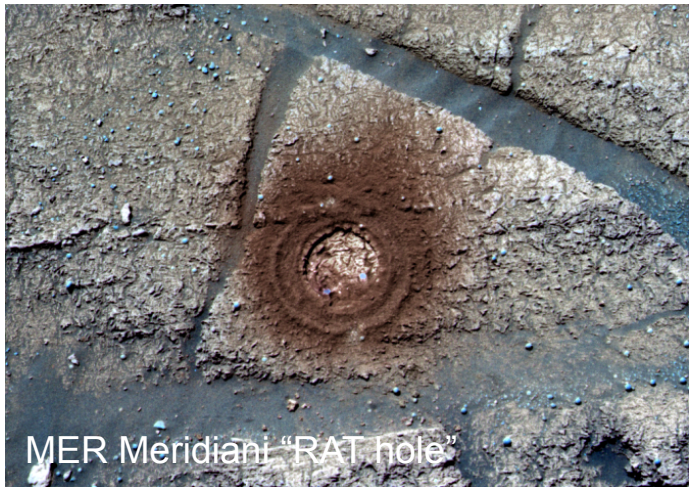
Geology: Objective and Investigations

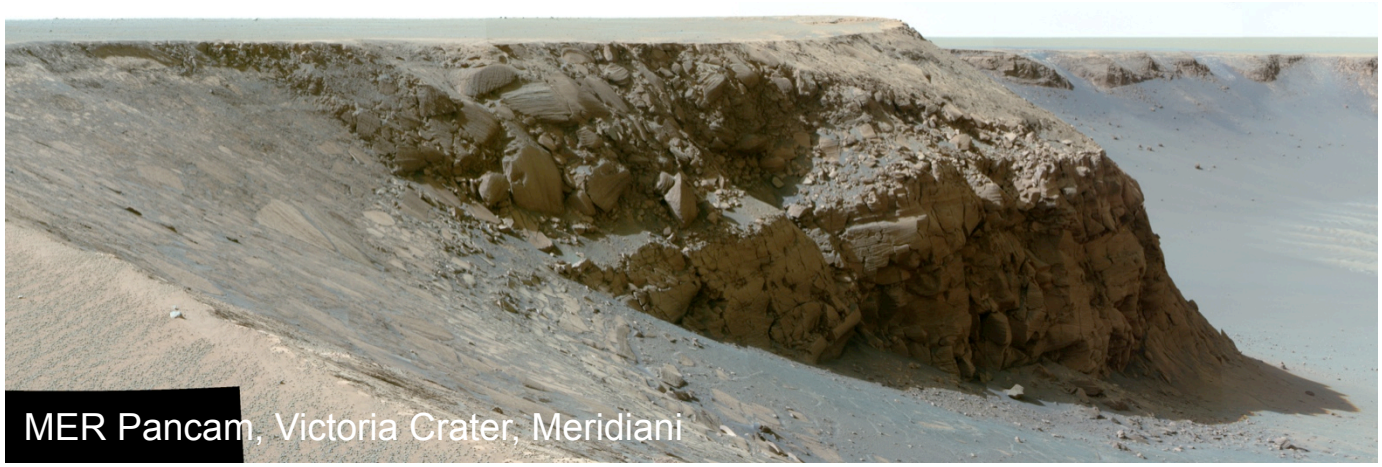
- *Objective:* Characterize a locality of high scientific interest to understand the formation and evolution of the surface at local scales
- *Investigations:*
  - Processes that exchange material among surface, near-surface, and subsurface
  - Formation and evolution of surface materials
  - Regional and local context of landing site
  - Physical properties of surface and near-surface as sample context



Geology: Techniques

- Site Imaging
  - Characterize lander scale geologic processes and link to processes observed at regional and global scales
  - Constrain rates by which surface materials (regolith and bedrock) form and evolve over time
  - Provide context for sample site

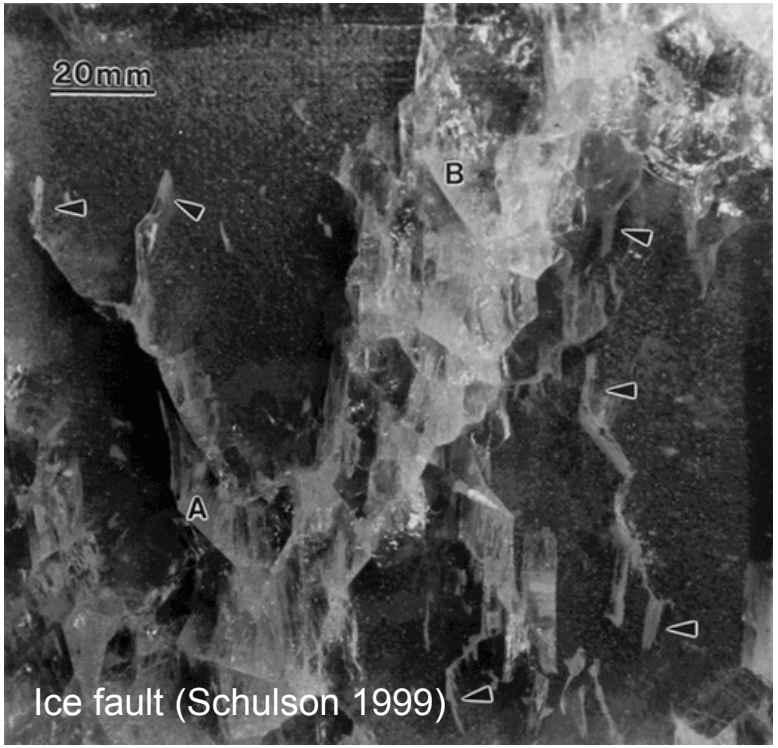

MER Meridiani "RAT hole"


MER Pancam, Victoria Crater, Meridiani


HiRISE, Victoria Crater

Geology: Techniques

- Microscopic Imaging
  - Characterize ice grains and non-ice materials within the sample to understand sample heterogeneity, ice history (ice morphology, inclusions), and context of non-ice materials.



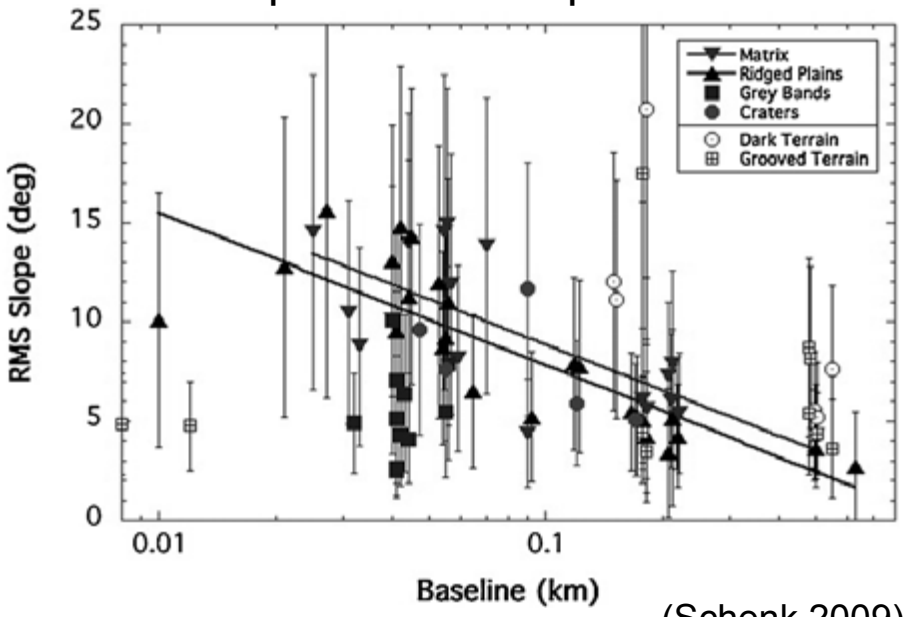
Ice fault (Schulson 1999)

MER Meridiani “blueberries”

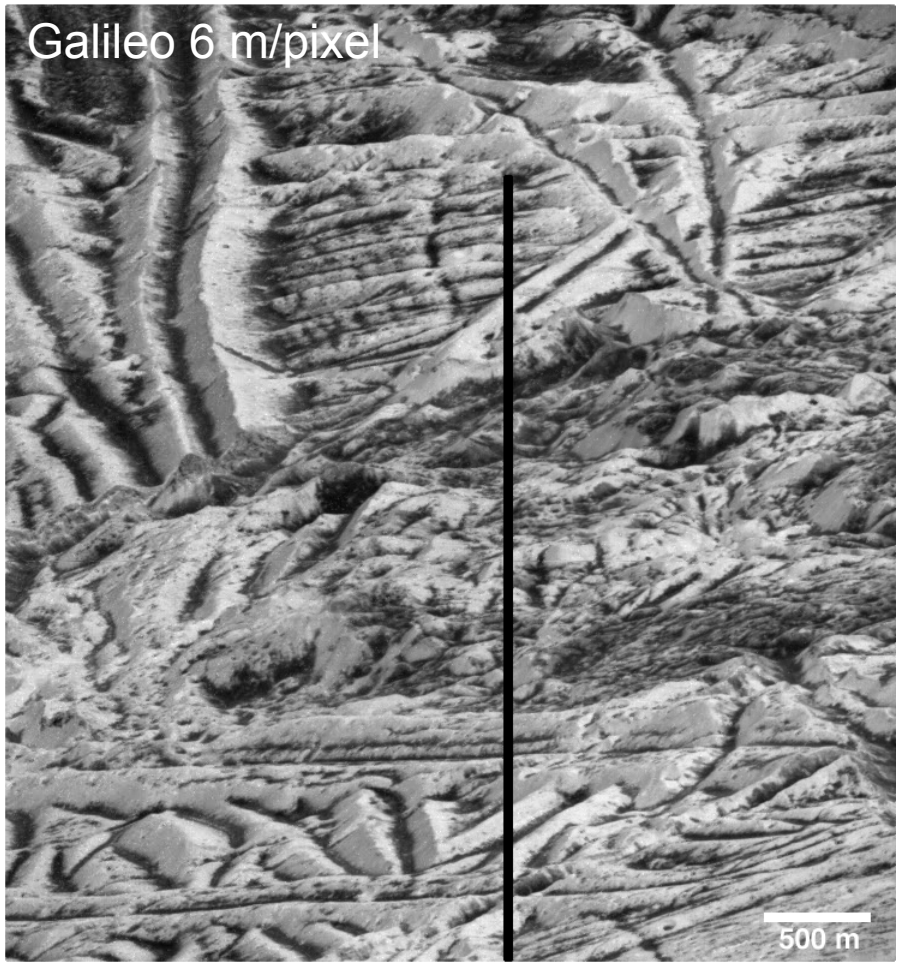
Landing Sites: Europa at a Small Scale

- Very limited information exists about surface at small scale from Galileo
  - 15 images at 9-12 m/pixel
  - 1 oblique image at 6 m/pixel

Europa surface slopes vs. scale



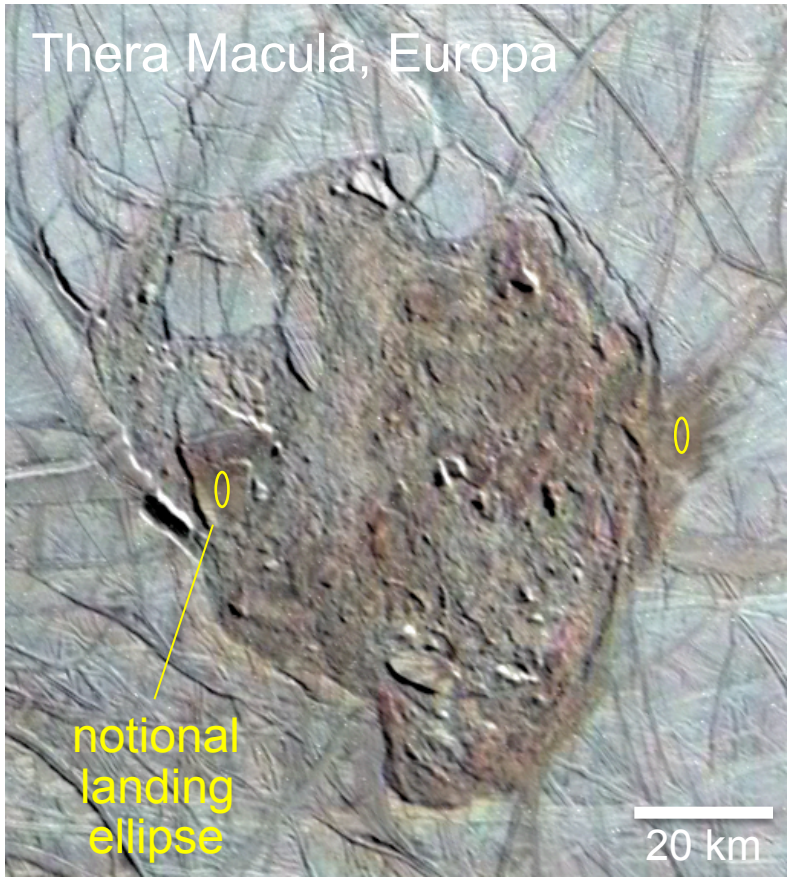
(Schenk 2009)



Landing Sites: Science Requirements

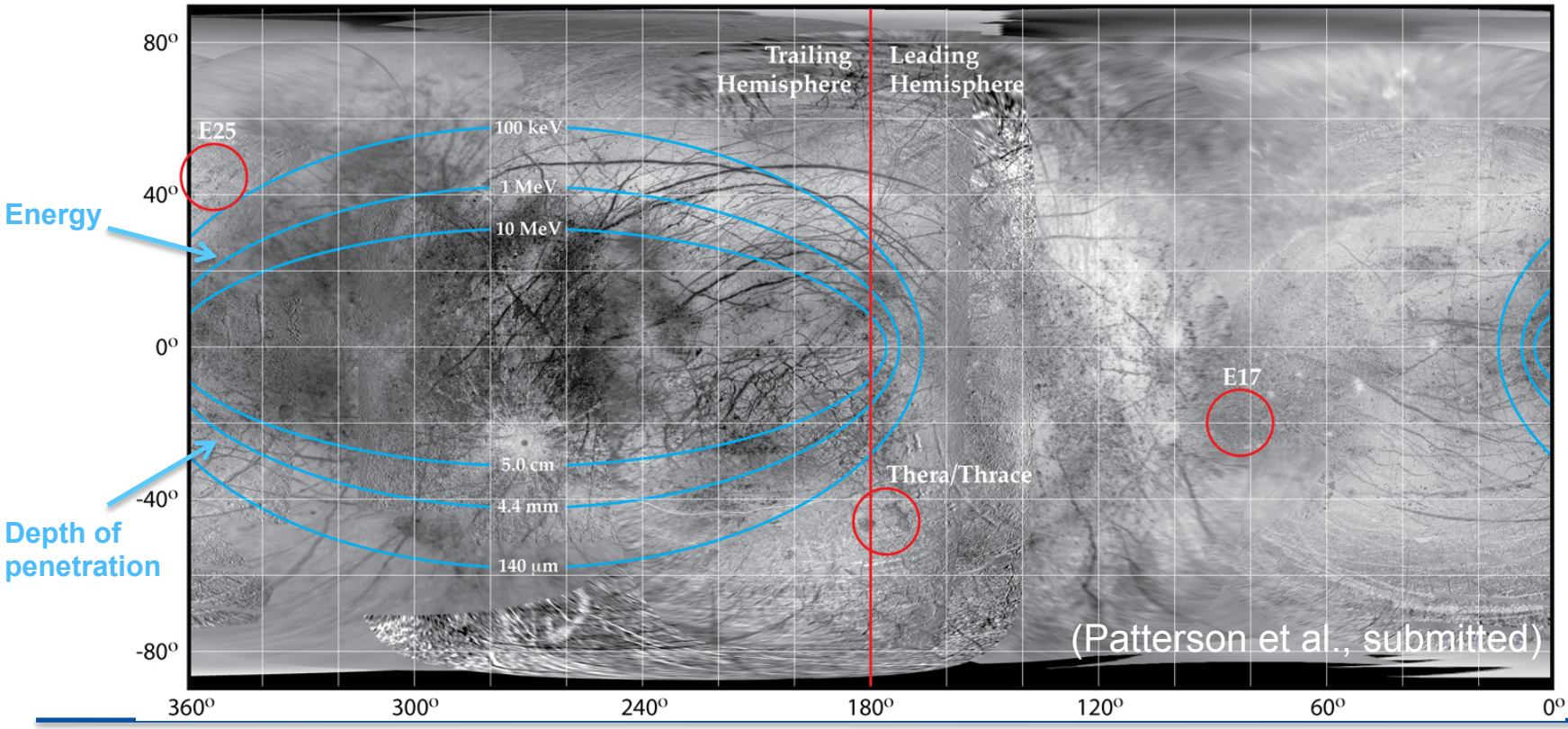
Primary landing site characteristics are derived from the science objectives and ideally satisfy the following:

- Relatively young surface
  - Less radiation processing
- Evidence of recent activity
  - May imply recent communication with subsurface ocean
- Evidence of impurities
  - Low albedo regions likely contain impurities which are of higher astrobiological interest
- Potential to sample ocean material
  - Search for evidence of fluid extrusion on surface
- Potential for tectonic activity
  - Characterize seismic sources
- Relatively safe to land
  - Relatively smooth, and lower radiation



Landing Sites: Recommendations

- Candidate landing sites that best meet the science requirements are adjacent to, or within, regions of chaos
  - Four candidate sites were chosen, which meet the science criteria and are outside the trailing hemisphere region of most intense radiation



Pre-Decisional — For Planning and Discussion Purposes Only

Key Science Drivers & Requirements

Model Instrument	Key Accommodation Requirements
Mass Spectrometer	Analysis of ~1 cm^3 samples from two depths, 0.5–2 cm and 5–10 cm; sample temperature maintained at < 198 K to prevent melting; sample at <150 K to preserve O_2, CO, and CO_2; contamination control in the sample analysis chain of of spacecraft organics to < 1 ppb; inorganics to < 1 ppm.
Raman Spectrometer	Spectra of samples from 0.5–2 cm and 5–10 cm; sample temperature maintained at < 198 K to prevent melting; sample at < 150 K to preserve O_2, CO, and CO_2; collect spectra of same samples collected for MS analyses.
Magnetometer	Continuous operations while on the surface for ≥ 3 Eurosols with a desire of ≥ 9 Eurosols; instrument isolated from the lander.
Multi-Band Seismometer Package	At least three, three-components sensors well coupled to the ground; continuous data monitoring for at least 3 Eurosols with a desire of 9 Eurosols; minimize lander noise at seismometer frequency range; knowledge of seismometer orientation.
Site Imaging System	Ability to survey landing site in stereo from near-field to horizon; unobstructed and lit view of sampling area. (Orbital context imaging required at 50 cm/pixel, with ability to resolve lander and correlate images with those from site imager.)
Microscopic Imager	Ability to access acquired samples; imager and target in close proximity for data taking; image same samples collected for MS and Raman analyses.

Europa Lander Science: Summary

- Europa lander enables unique *in situ* science opportunities
- The most definitive way to probe Europa's composition as relevant to habitability
  - Organics and salt chemistry
  - Exogenic vs. endogenic materials
- Would provide extremely valuable geophysical and geological science
  - Ocean salinity and thickness
  - Seismic activity and ocean-ice structure
  - Geological process at a human scale
- Though very limited information exists about surface at lander scales, promising targets can be identified