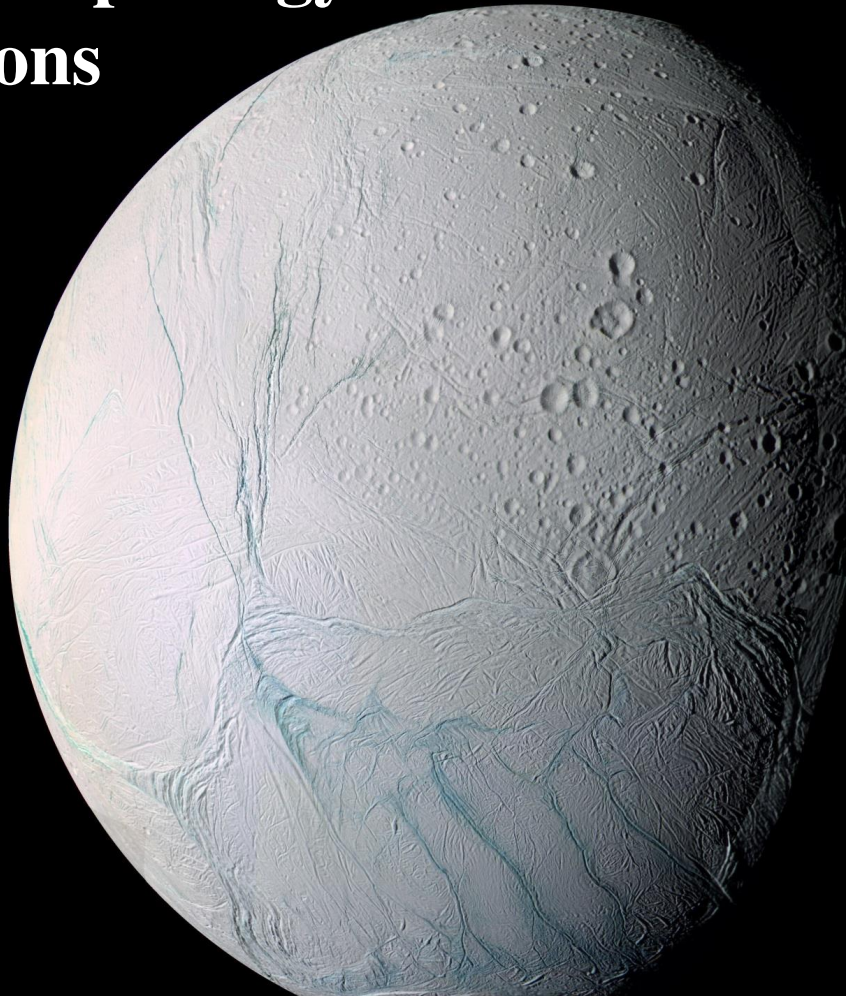
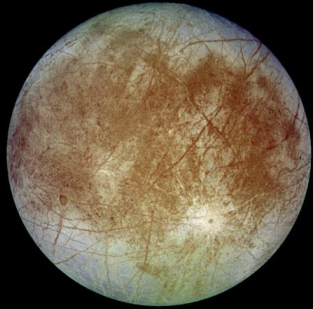


The Geomorphology of Icy Moons



Icy Moons in the Solar System



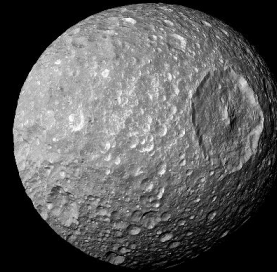
Europa



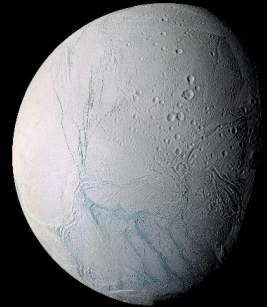
Ganymede



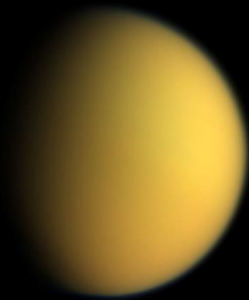
Callisto



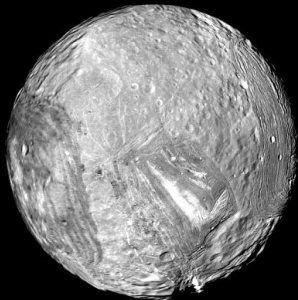
Mimas



Enceladus



Titan?



Miranda



Umbriel



Triton

Jupiter

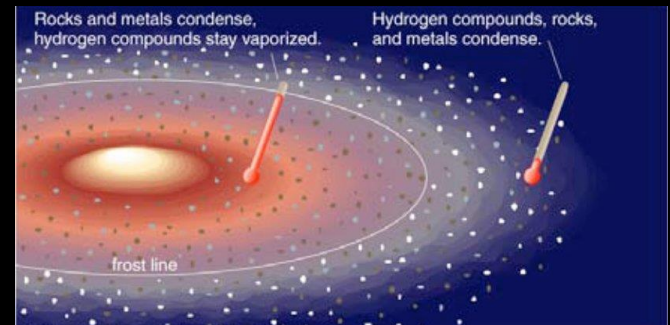
Saturn

Uranus

Neptune

What Makes A Moon Icy?

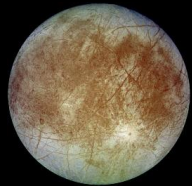
- Orbit A Giant Planet
 - Lie Beyond the Solar System's Frost Line
- Formed Outside of the Inner Region of a Proto-Satellite Disk
 - Lie Beyond the Planet's Frost Line



Characterizing Icy Moons

- Size
- Albedo
 - Geometric or Bond
- Surface Age
 - Cratering
- Surface Temperature

Relative Sizes of Icy Moons



Europa



Ganymede



Callisto



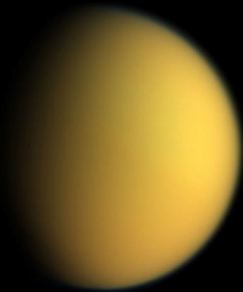
Luna



Mimas



Enceladus



Titan?



Miranda



Umbriel



Triton

Jupiter

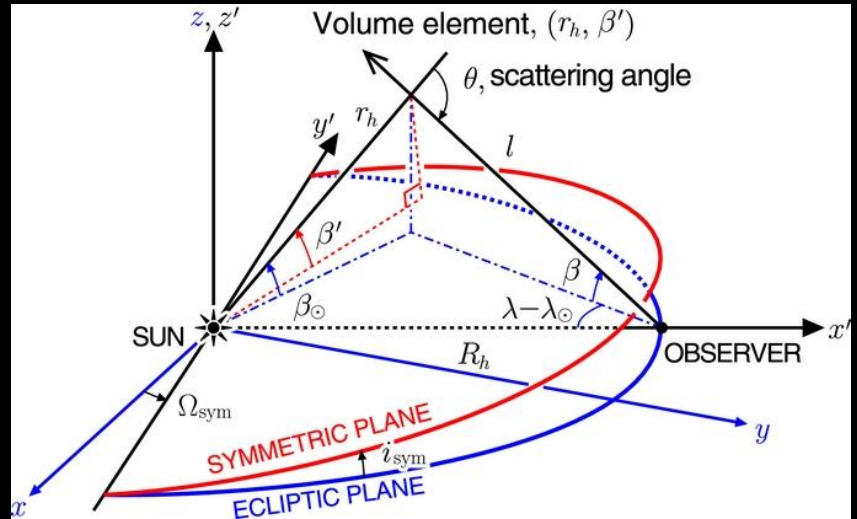
Saturn

Uranus

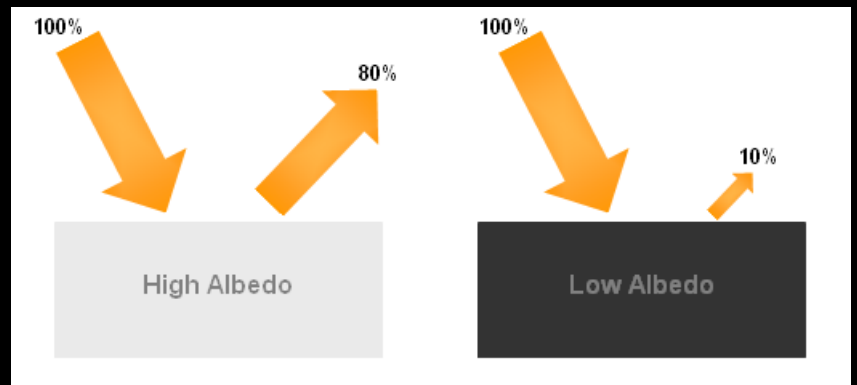
Neptune

Types of Albedo

- Bond
- Geometric



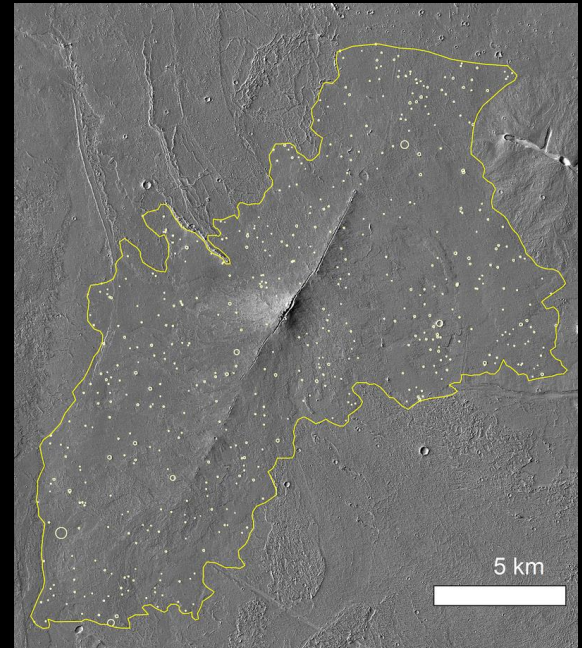
iopscience.iop.org



nc-climate.ncsu.edu

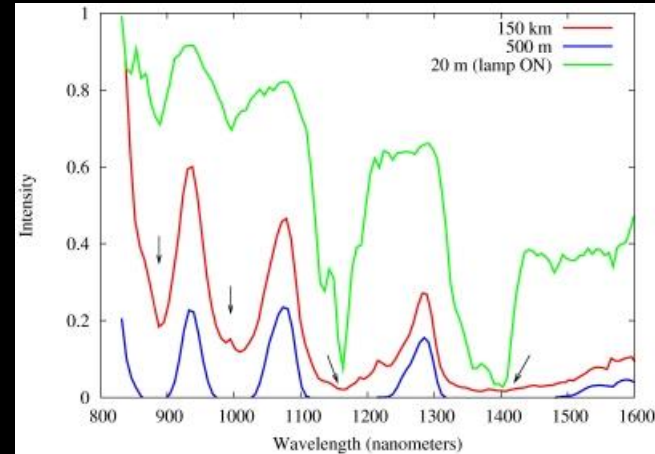
Determining Surface Age

- Crater Counting
 - Hard to Determine True Age
 - Determines Relative Ages

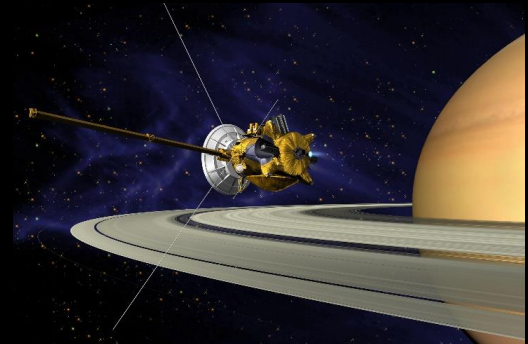


Surface Temperature

- Indirect Detection
 - Observed Emitted IR-Spectra
 - Fitting to Blackbody Curves
- Direct Detection
 - Orbiters
 - Thermal Radiation



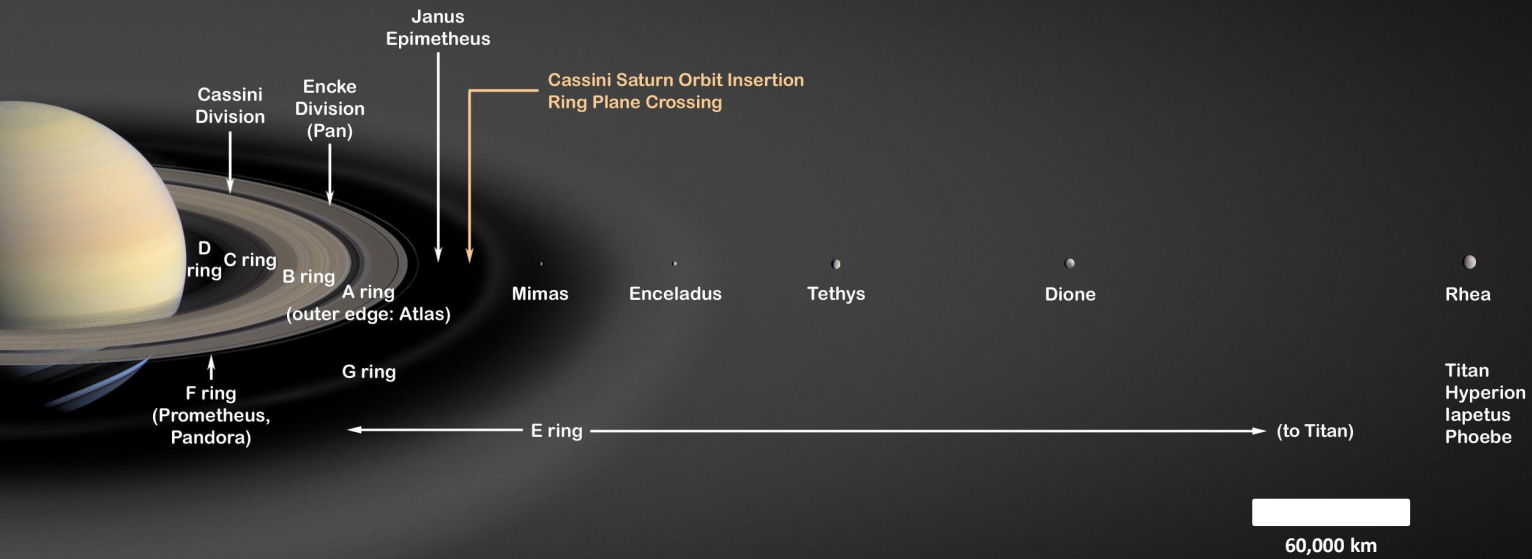
sci.esa.int

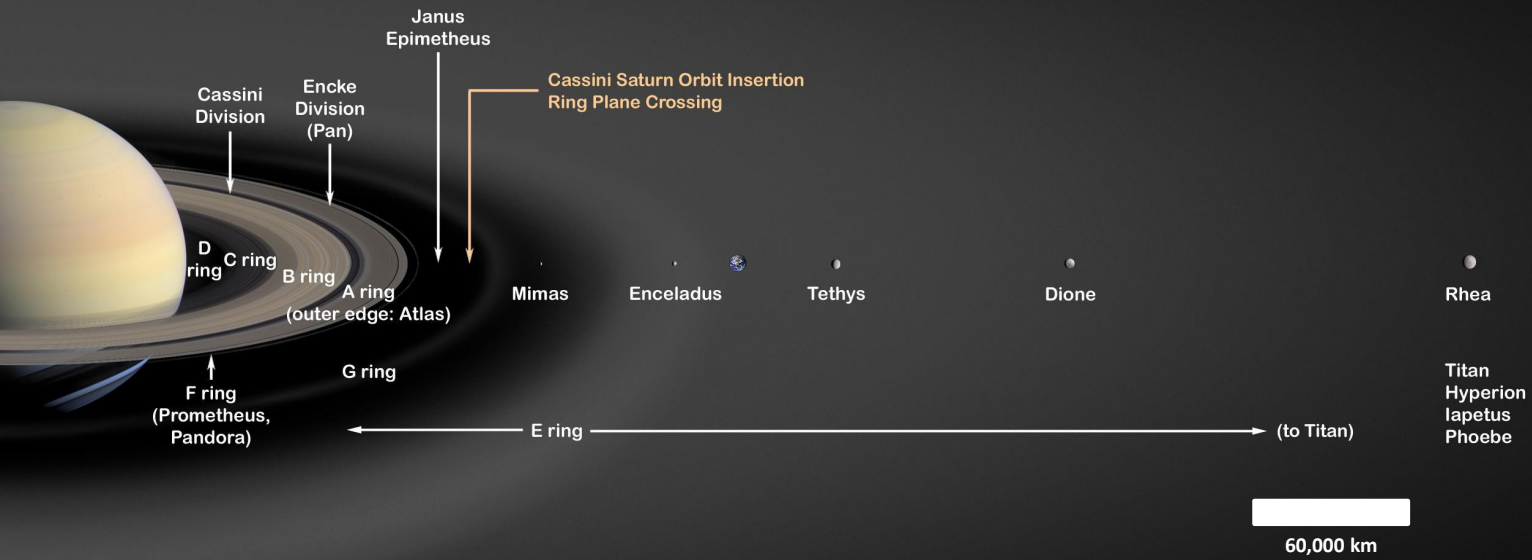


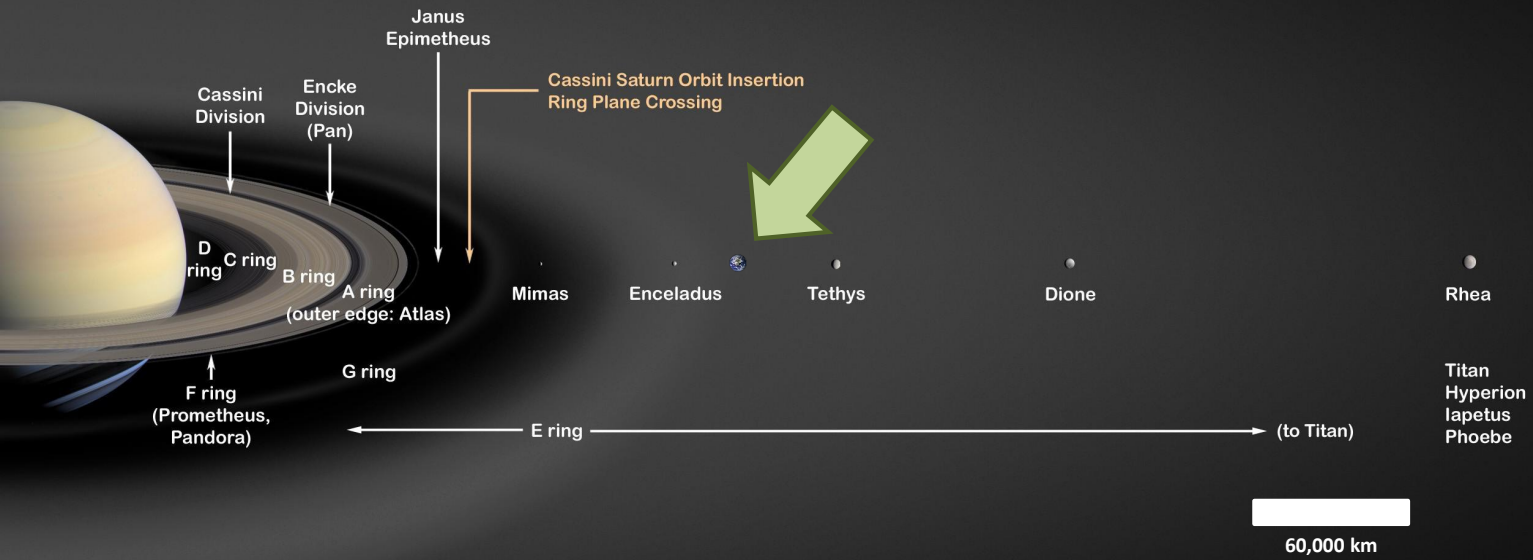
jpl.nasa.gov

Saturnian System

- Extensive Ring System
 - A-, B-, C-, D-, and E-Ring
 - 6,630 – 120,700 km Above Equator
 - 20 km Thick
- 150 Satellites
 - Moons or Moonlets
 - At least 1 (Rhea) Has Its Own Ring System

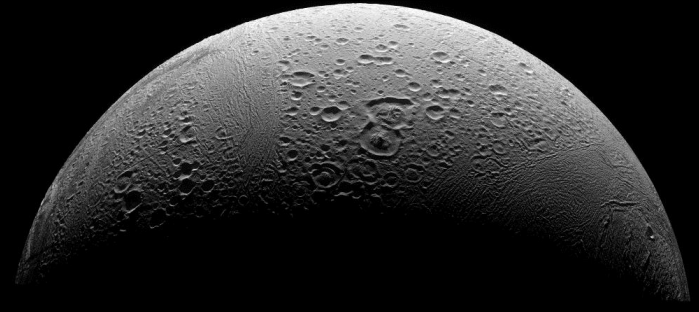






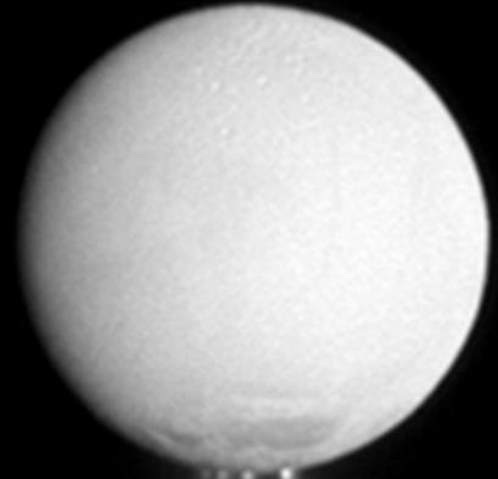
Enceladus

- 6th Largest Moon of Saturn
- Located in the E-Ring
- Only 500km in Diameter
(1/13th of Earth)
- Albedo of 0.99 (Bore)



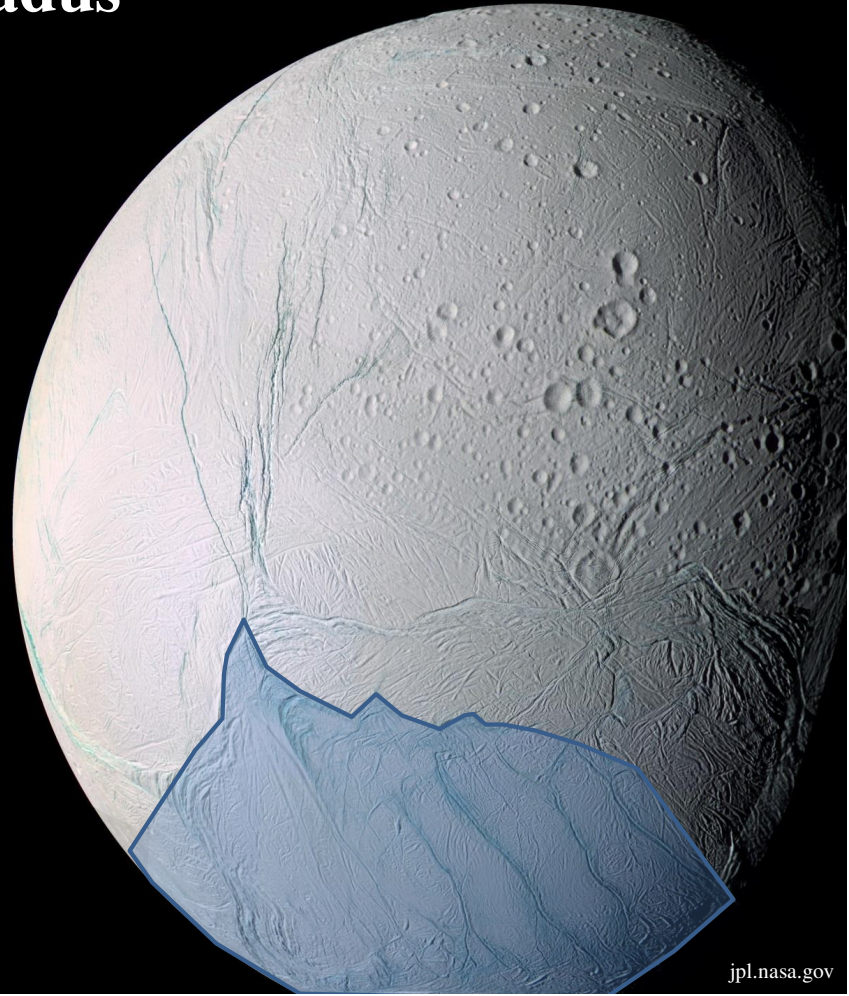
What is Special About Enceladus?

- Surface is Made Almost Entirely of Water Ice
- Over 100 Cryovolcanic Plumes on the South Pole
- Possible Location of Extraterrestrial Life



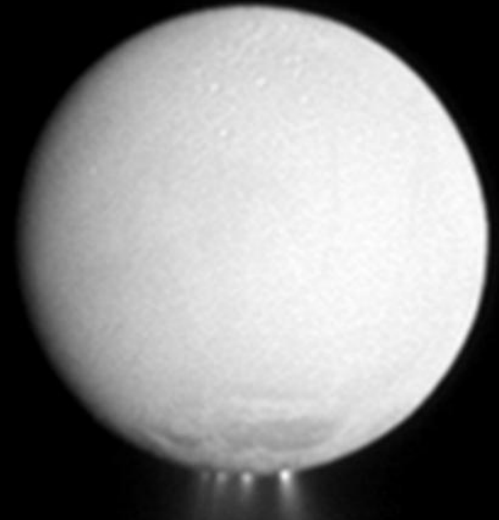
Geography of Enceladus

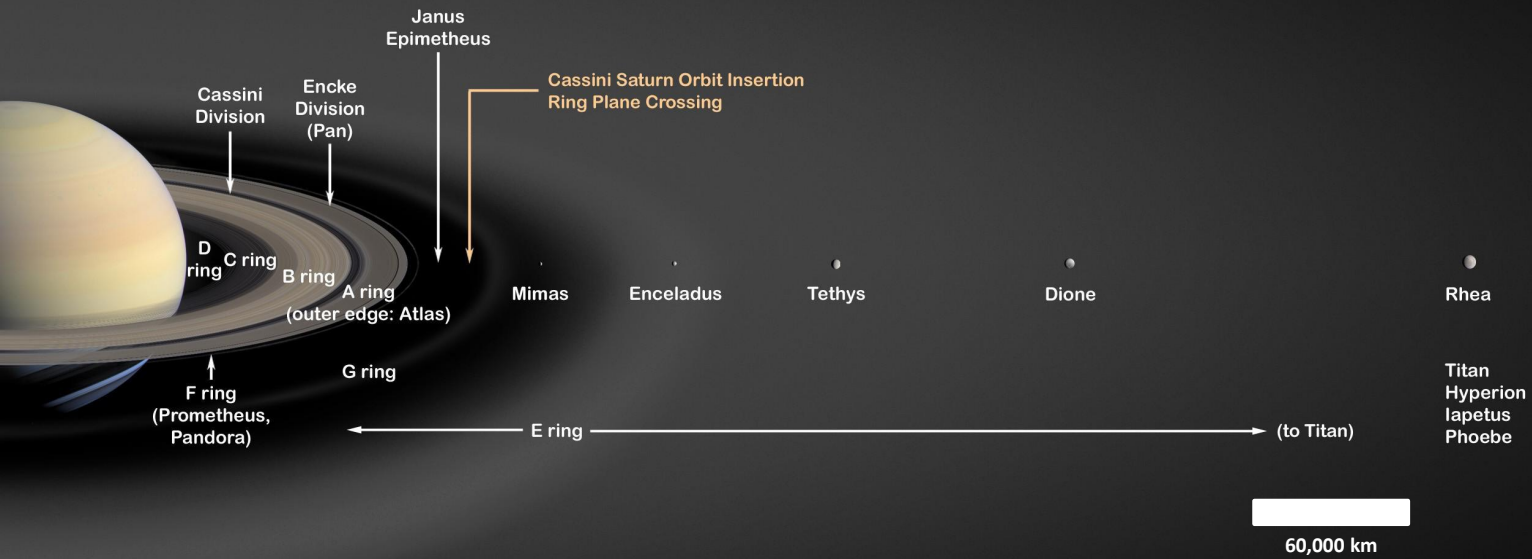
- 4 Regions
 - Southern Polar Terrain (SPT)



Southern Polar Terrain (SPT) - Plumes

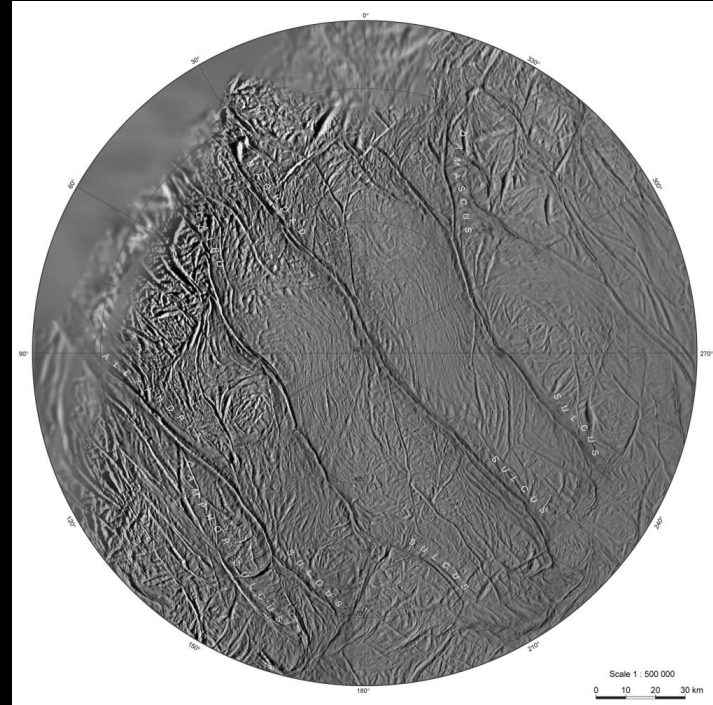
- Cryovolcanic
- Extend 100s of Kilometers into Space
- Consist of Water Ice, NH_3 , Na and K Salts, and Various Gases
- Contributing to Saturn's E-Ring



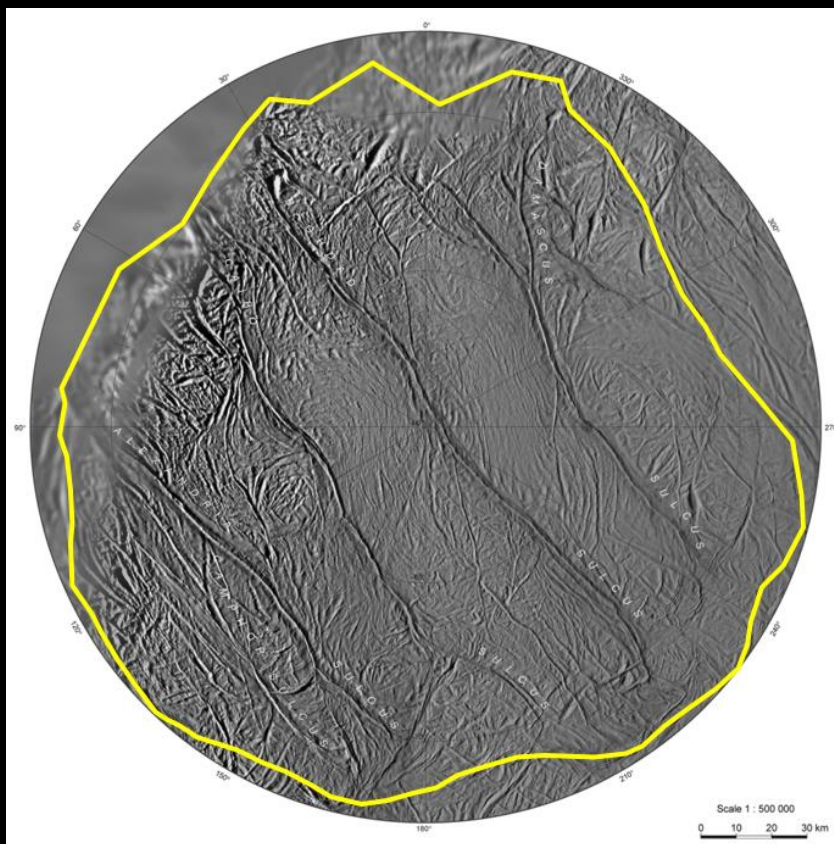


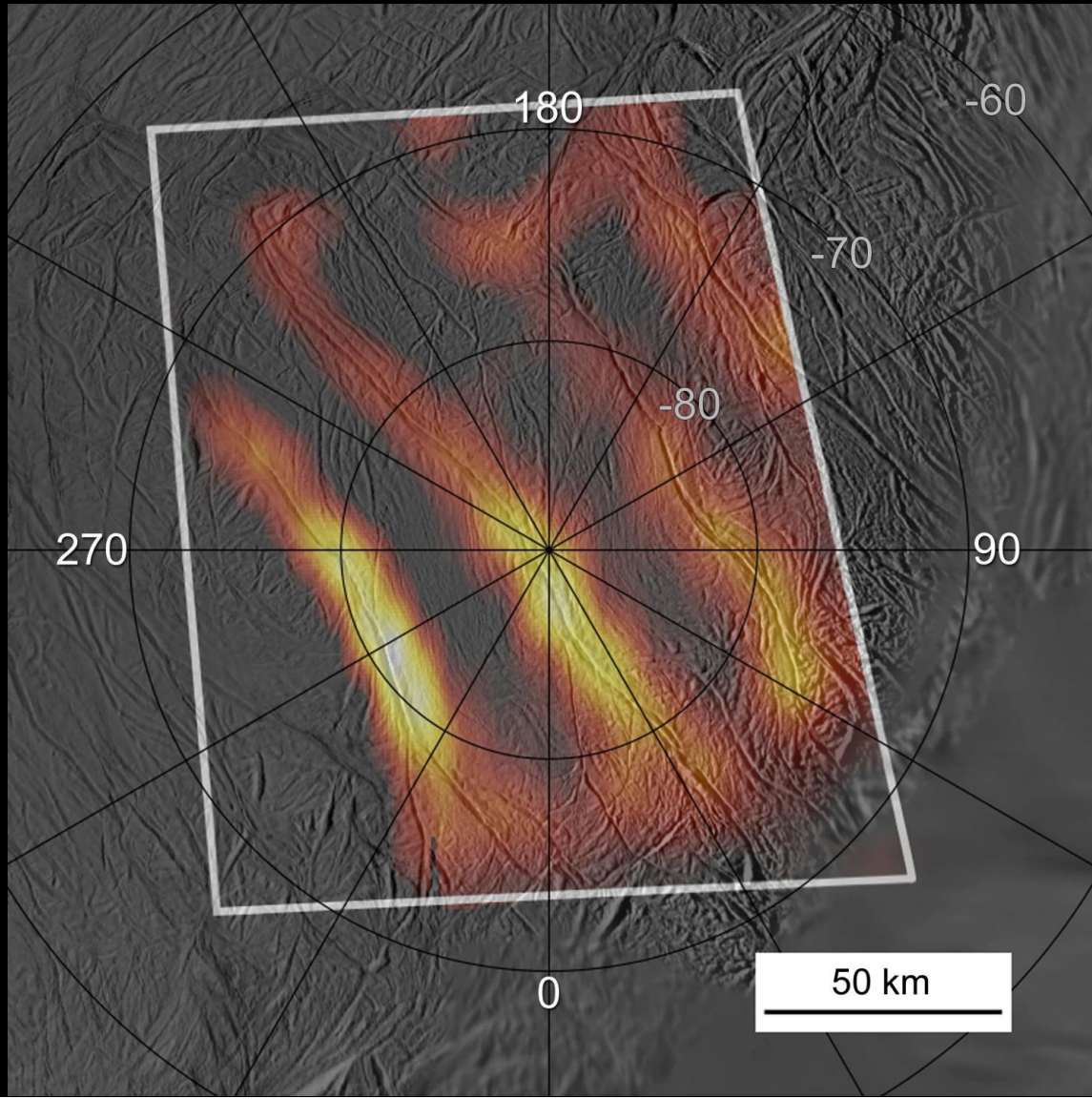
Southern Polar Terrain (SPT) – Tiger Stripes

- Curvilinear, Nearly Parallel Rifts
- Younger and Warmer than Adjacent Surfaces
- Sources of Plumes
- Located in a Basin

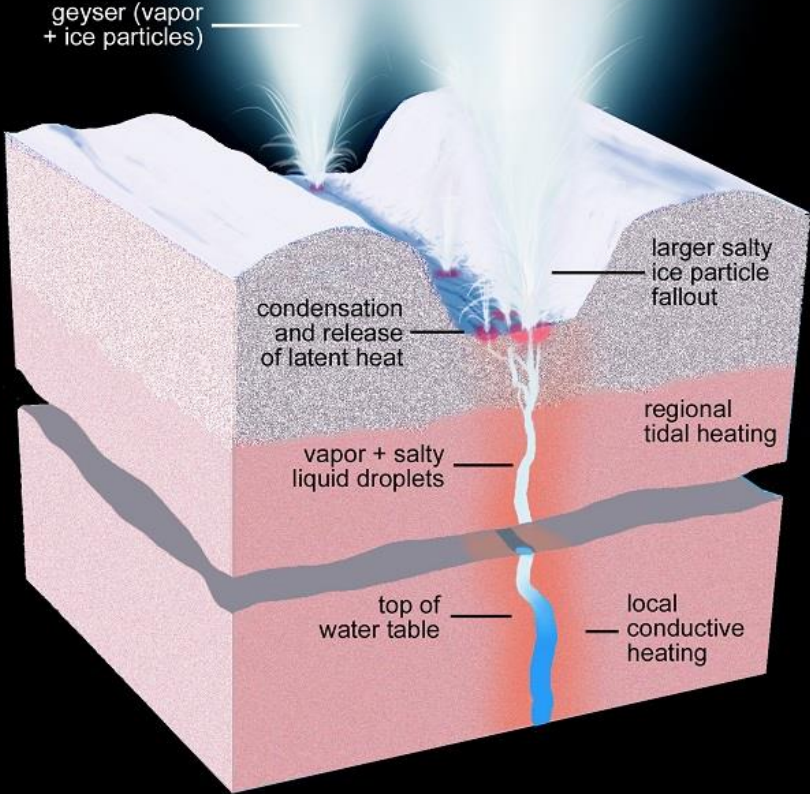


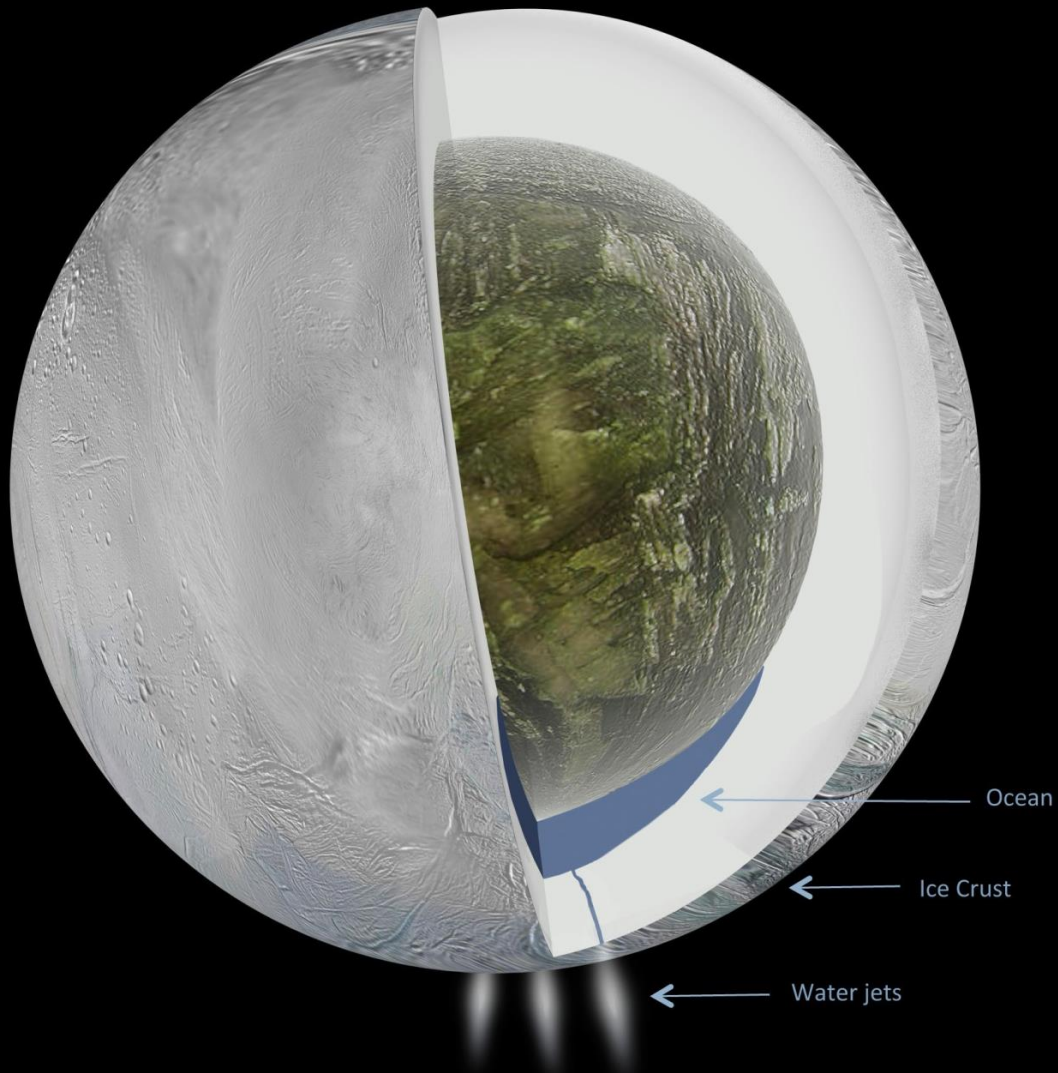
Southern Polar Terrain (SPT) – Tiger Stripes





smaller escaping
salt-free ice particles





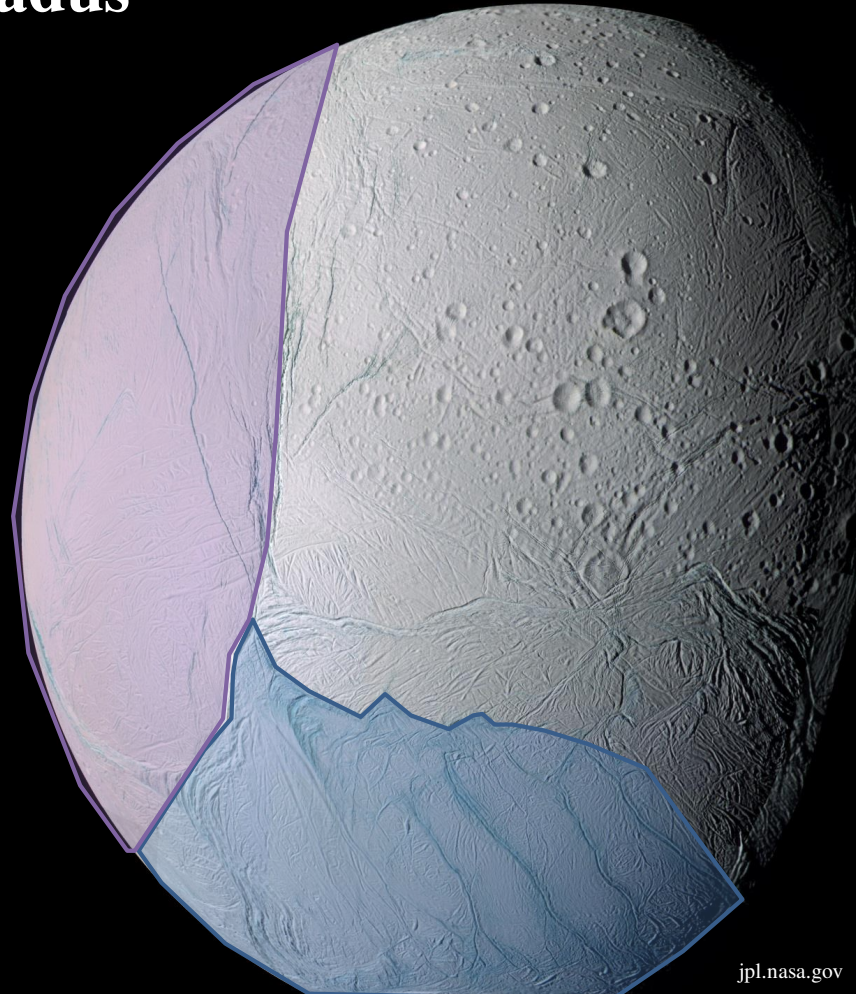
Ocean

Ice Crust

Water jets

Geography of Enceladus

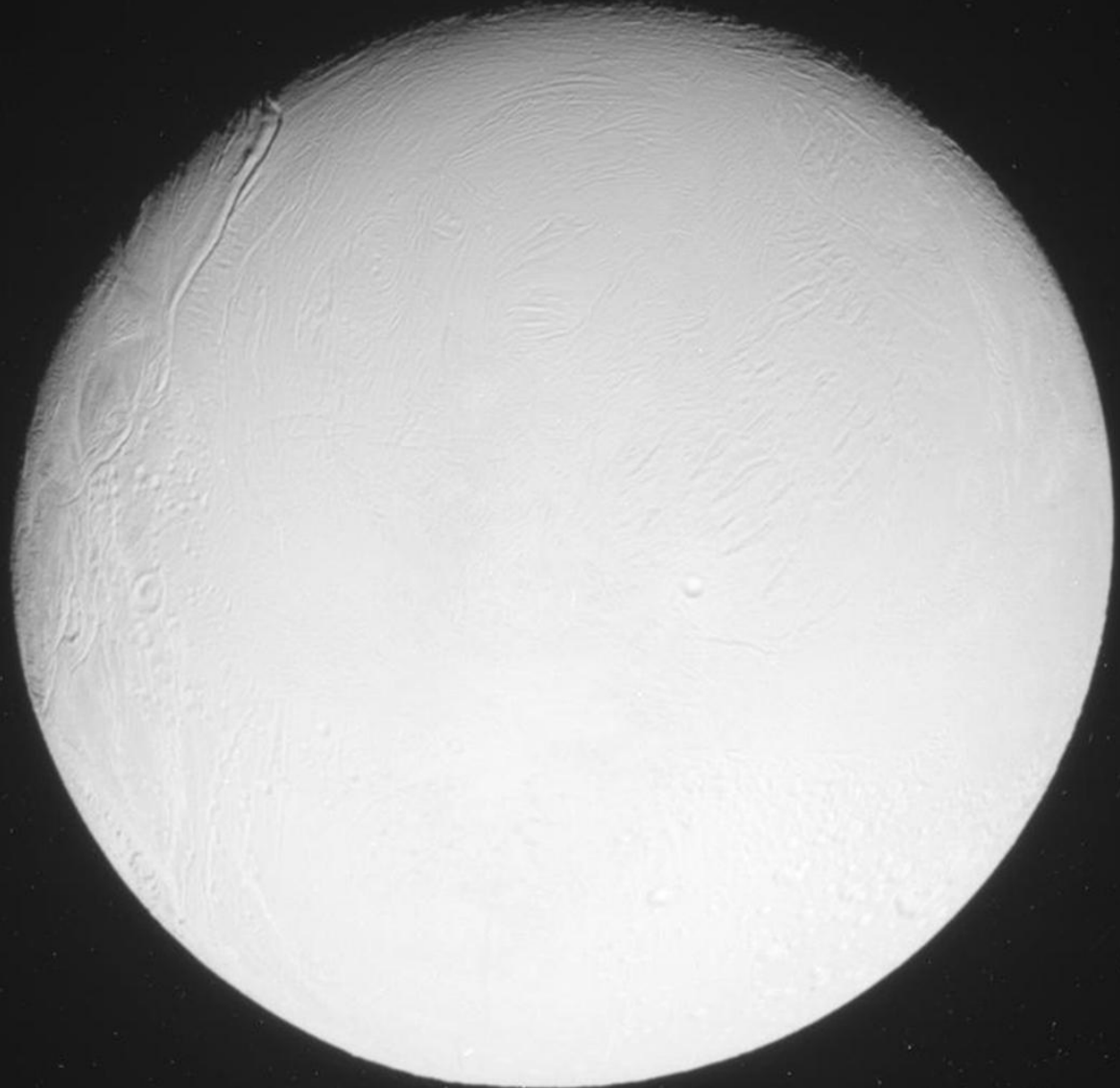
- 4 Regions
 - South Polar Terrain (SPT)
 - Leading Hemisphere



Resurfacing of Hemisphere

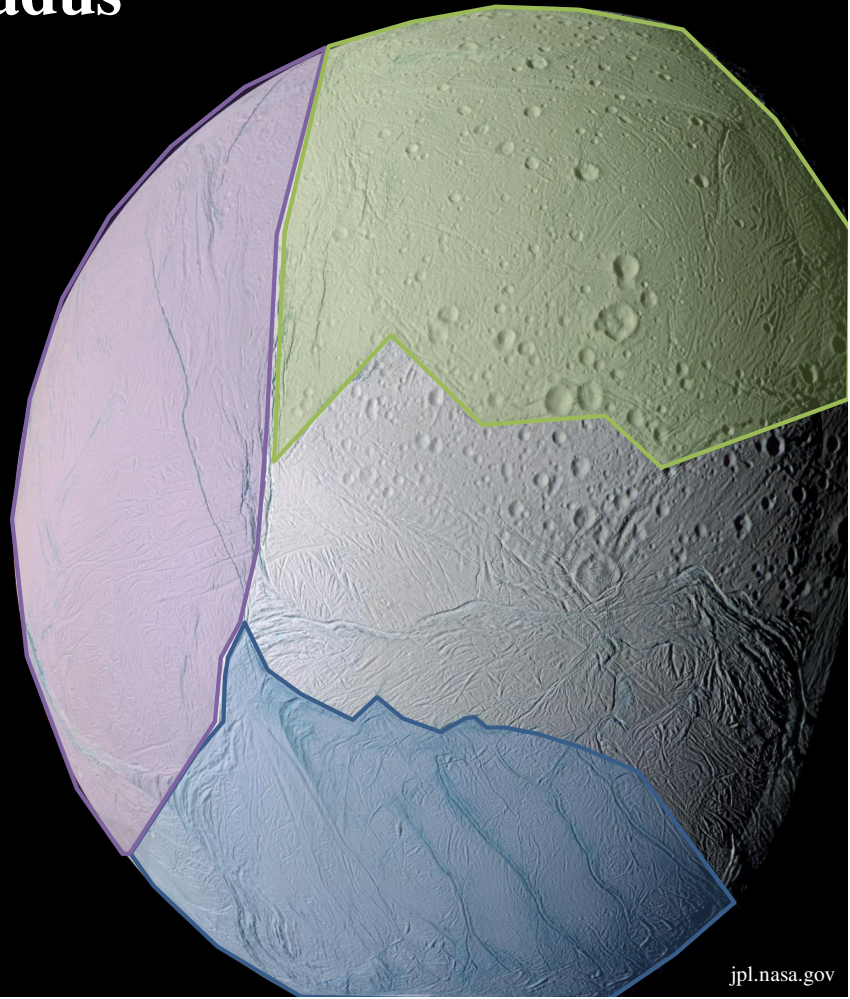
- Tidally-Locked with Saturn
- The E-Ring





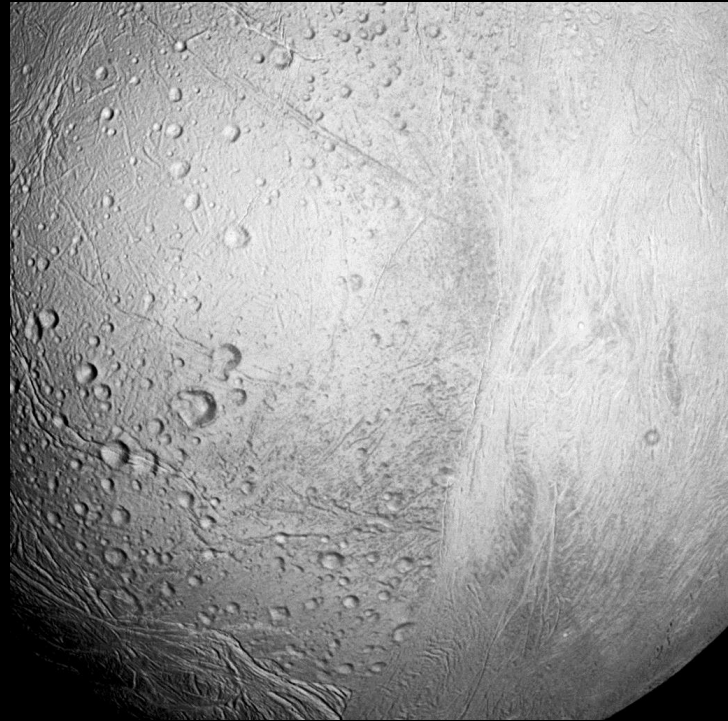
Geography of Enceladus

- 4 Regions
 - South Polar Terrain (SPT)
 - Leading Hemisphere
 - Northern Hemisphere



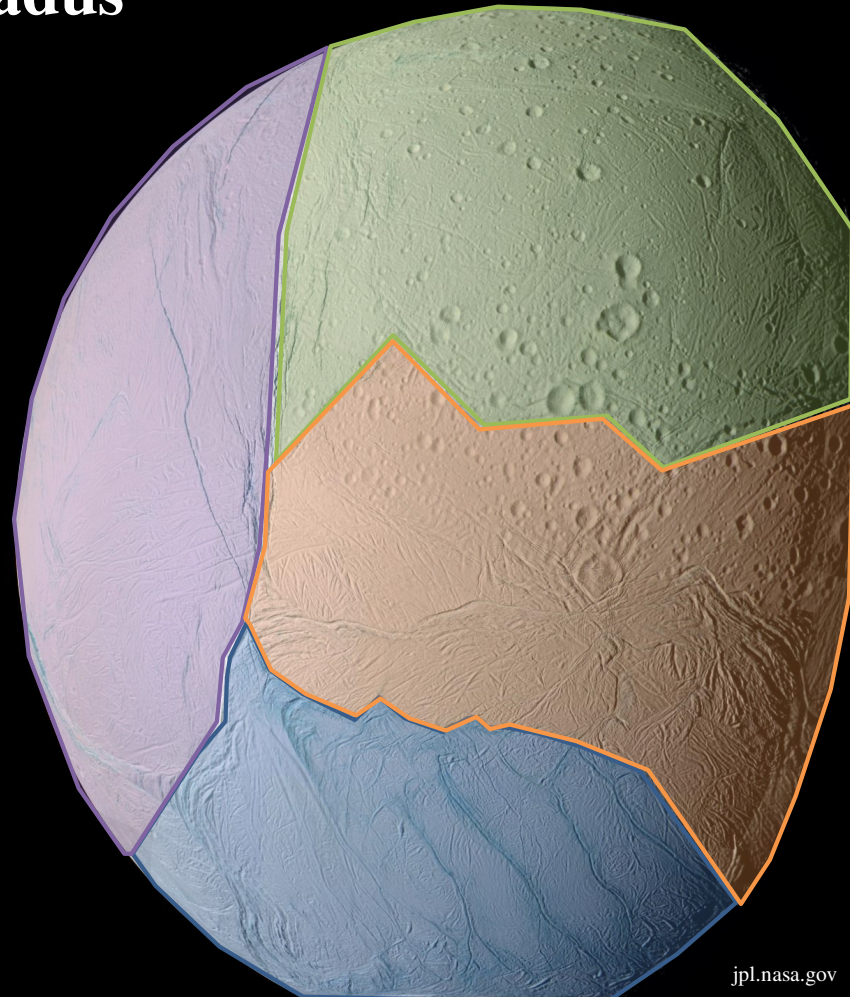
Northern Hemisphere

- Cratered Terrain
- Some of the Oldest Features on Enceladus
- Particularly Densely Cratered on the Trailing Hemisphere
- Least Geologically Active Region



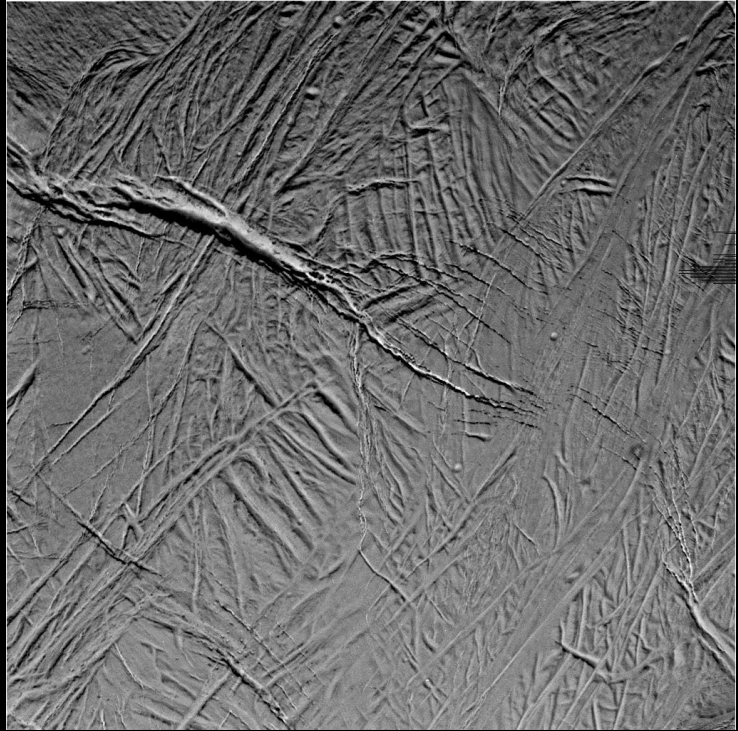
Geography of Enceladus

- 4 Regions
 - South Polar Terrain (SPT)
 - Leading Hemisphere
 - Northern Hemisphere
 - Equatorial Region



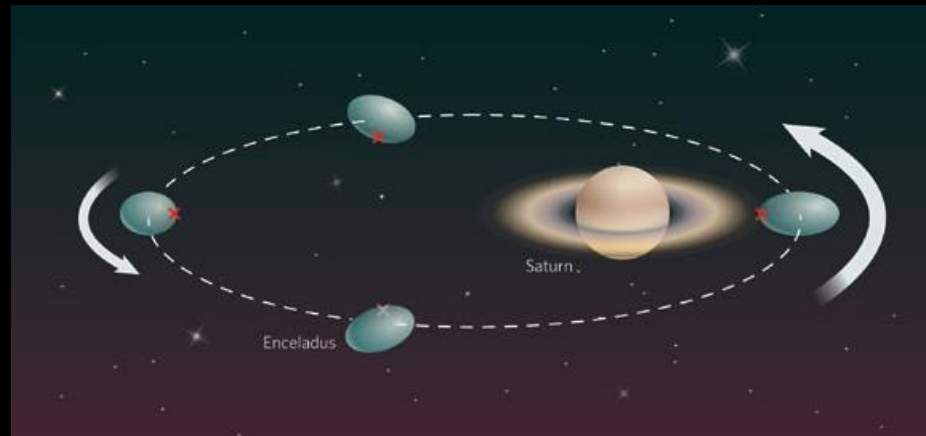
Equatorial Region - Icy Rifts

- 100 to 400 Meters Wide
- Formed by the Tidal Morphing of the Moon



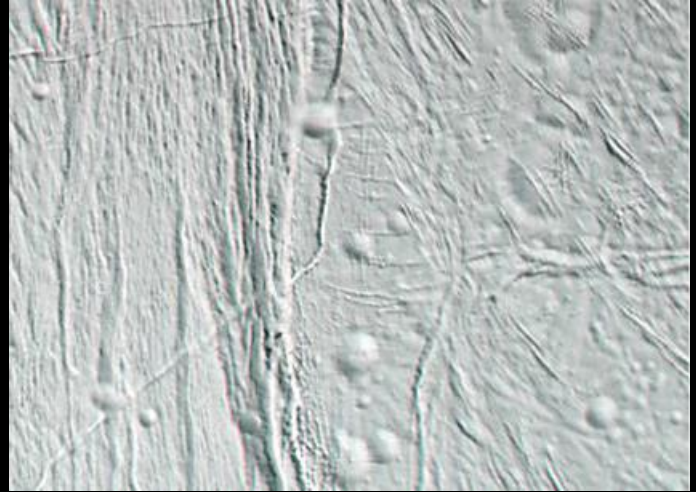
Tidal Morphing

- Enceladus's Eccentric Orbit: $e = 0.0047$
 - $\Delta F_g \sim 10^{17} \text{ N}$
- Similar to Earth's Tides



Equatorial Region – Transitional Terrain

- Located near Icy Rifts
- Fractures Form Boundaries between Cratered Surfaces and Folded Surfaces
- May be Evidence of Subduction Zones



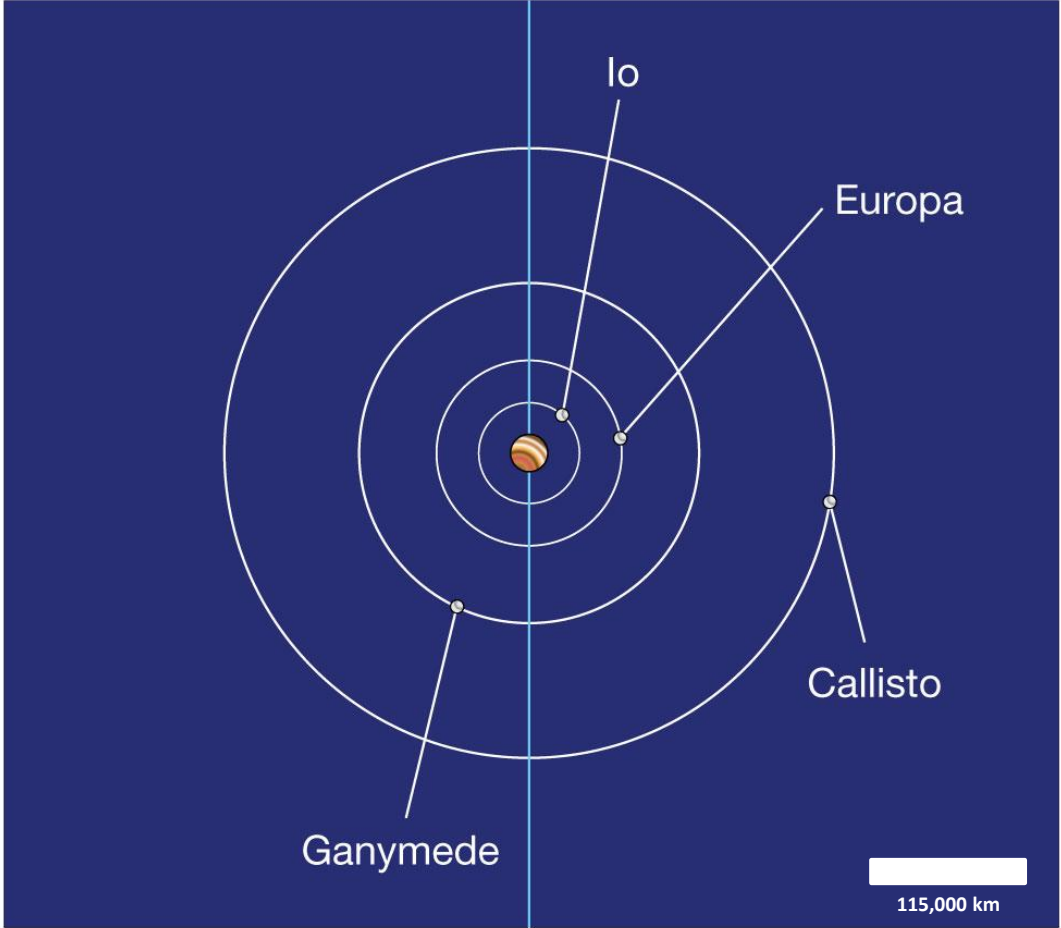
Equatorial Region – Modified Craters

- Further Evidence of Tectonic Forces
- Craters Show Signs of Crosscutting



Jovian System

- Slighter Ring System
 - Made of Dust
- Strong Magnetosphere
 - 14x the Strength of Earth's
- ≥ 67 Moons
 - Galilean Moons: Ganymede, Callisto, Io, and Europa



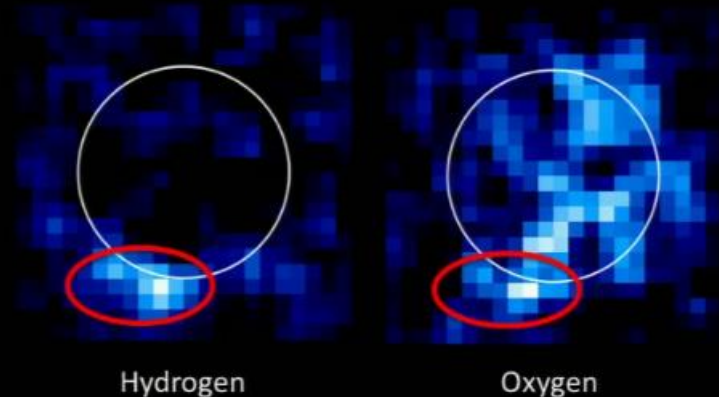
Europa

- 4th Largest Moon of Jupiter
 - Smallest Galilean Moon
- 3120 km in Diameter (1/4 of Earth)
- Albedo of 0.67 (Bore)



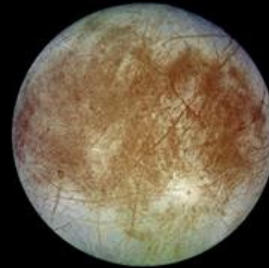
Similarities with Enceladus

- Water Ice Crust
- Liquid Subsurface Ocean
- Cryovolcanism
- Tidal Morphing/Heating
- NSR



Differences from Enceladus

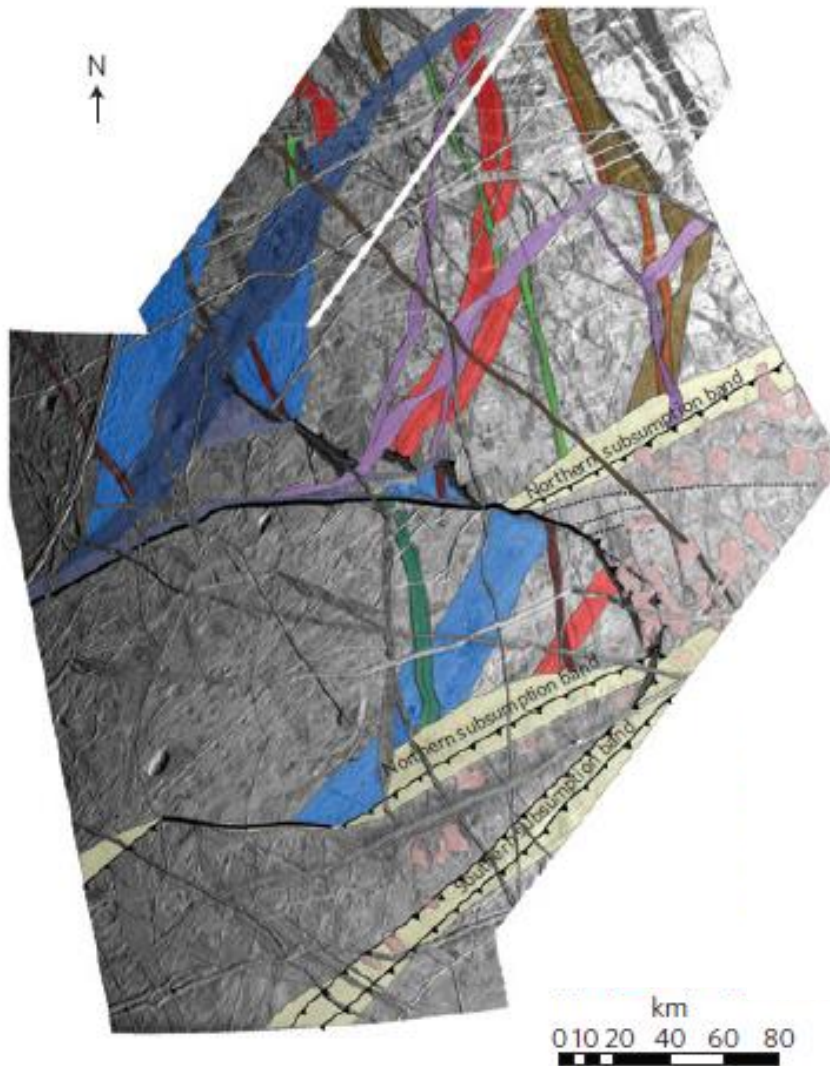
- Lower Albedo
- 6x in Diameter
 - 500x More Massive

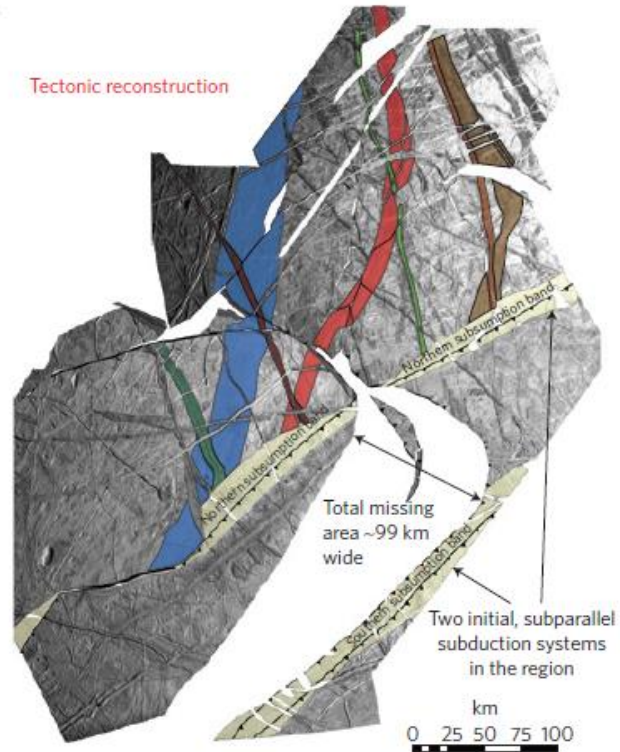
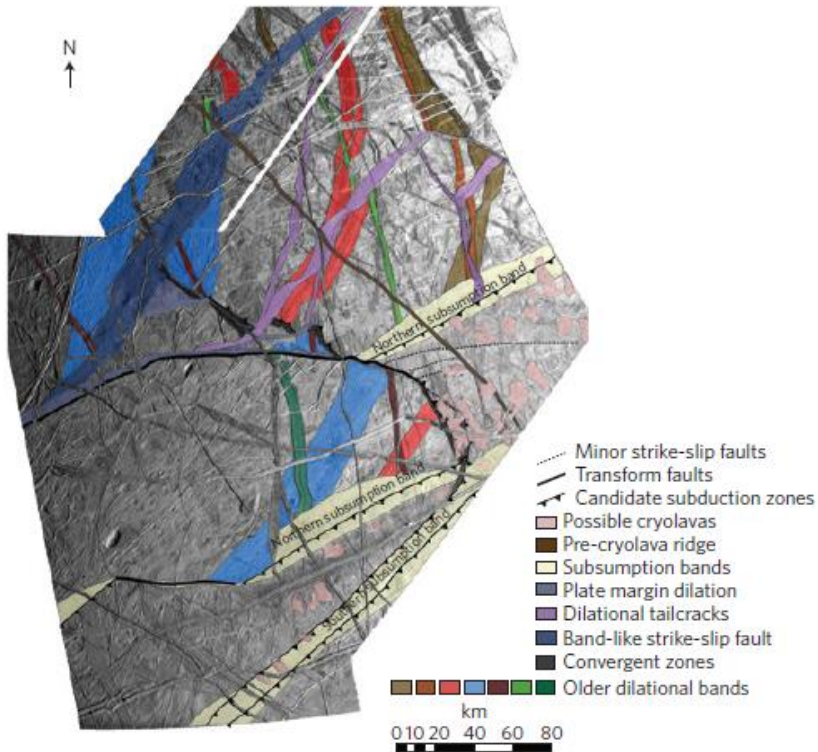


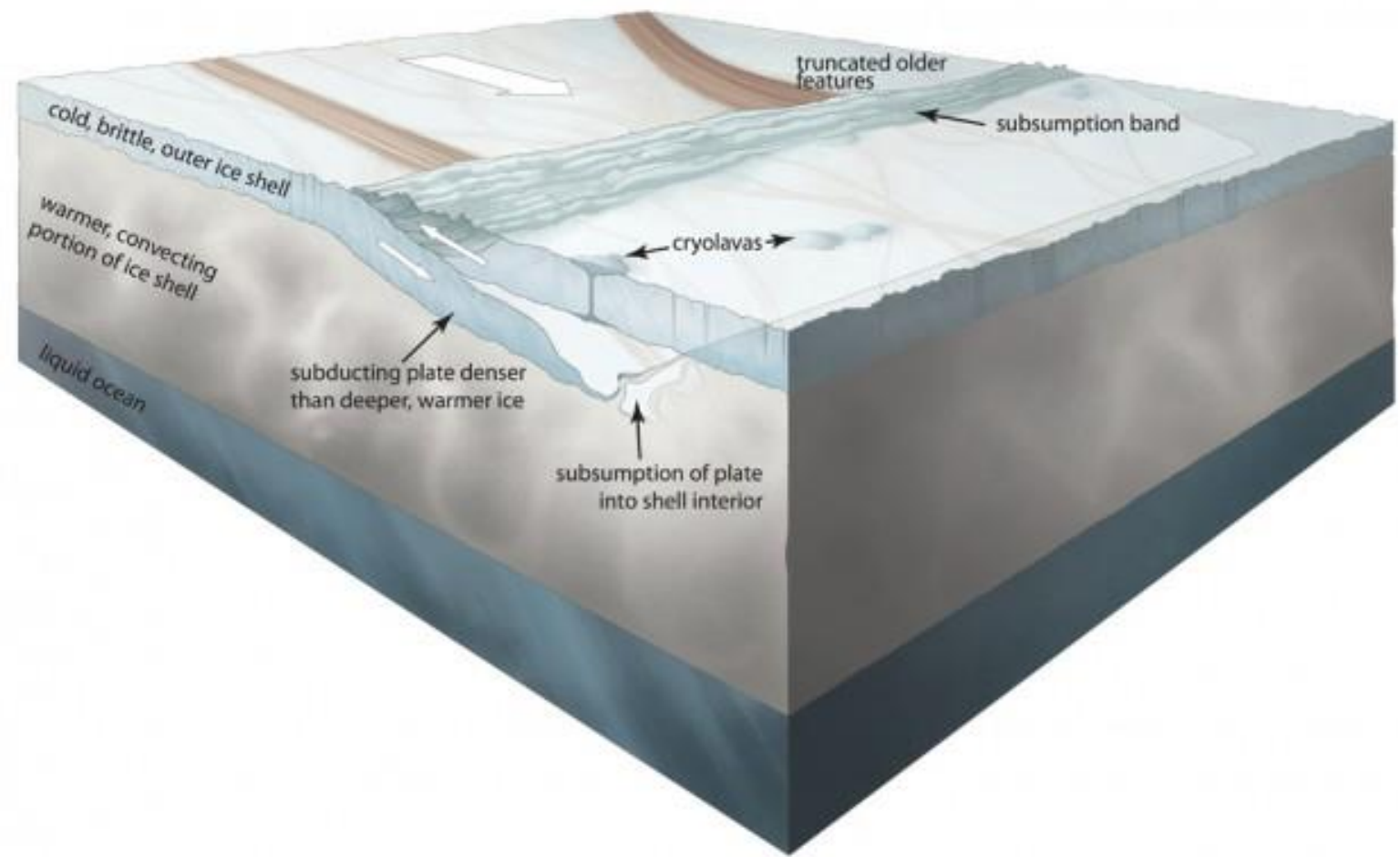
Europa



Enceladus



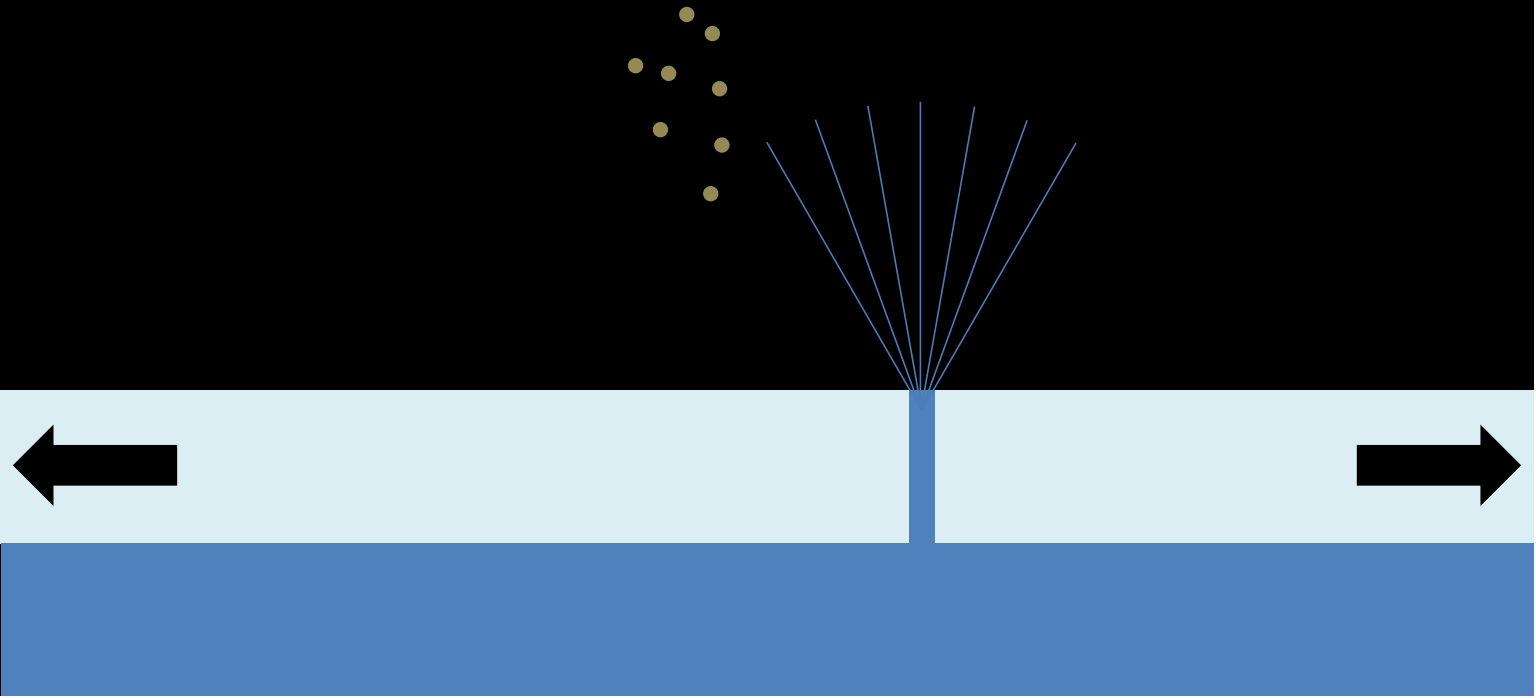




Hydrological Cycle on Europa



Hydrological Cycle on Europa



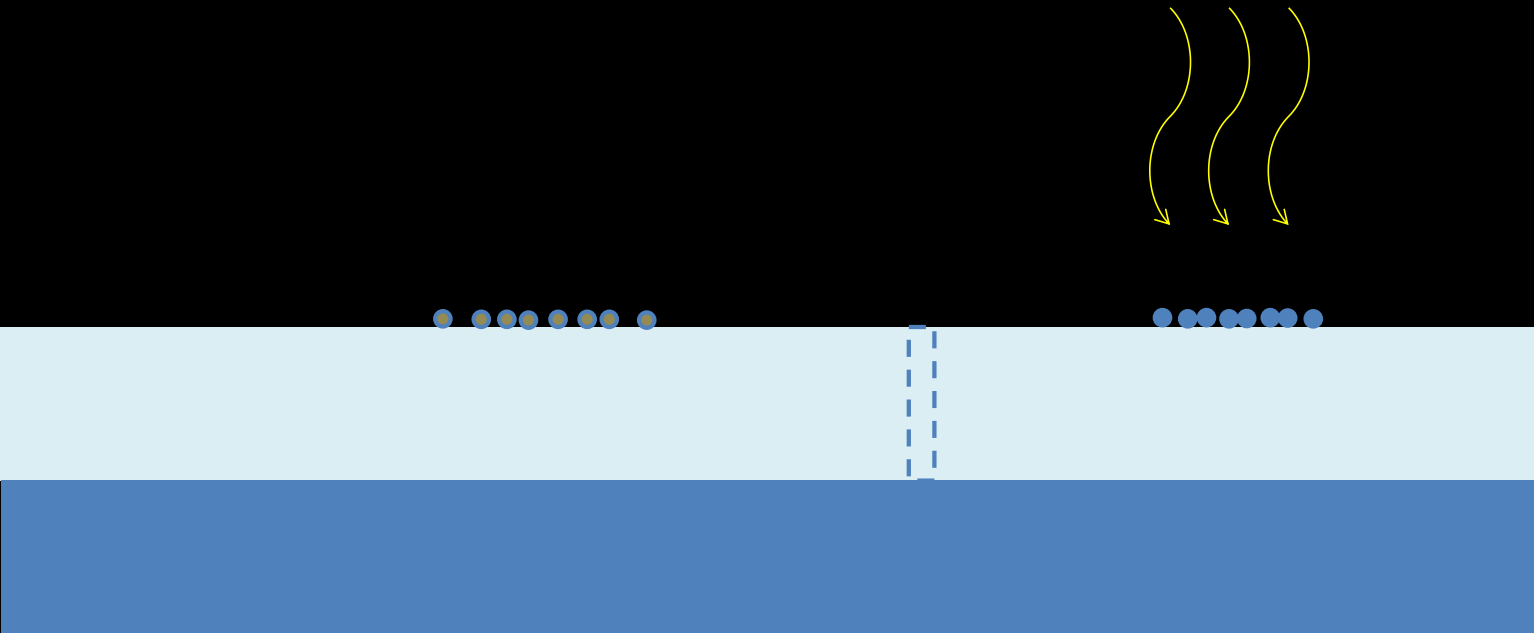
Hydrological Cycle on Europa



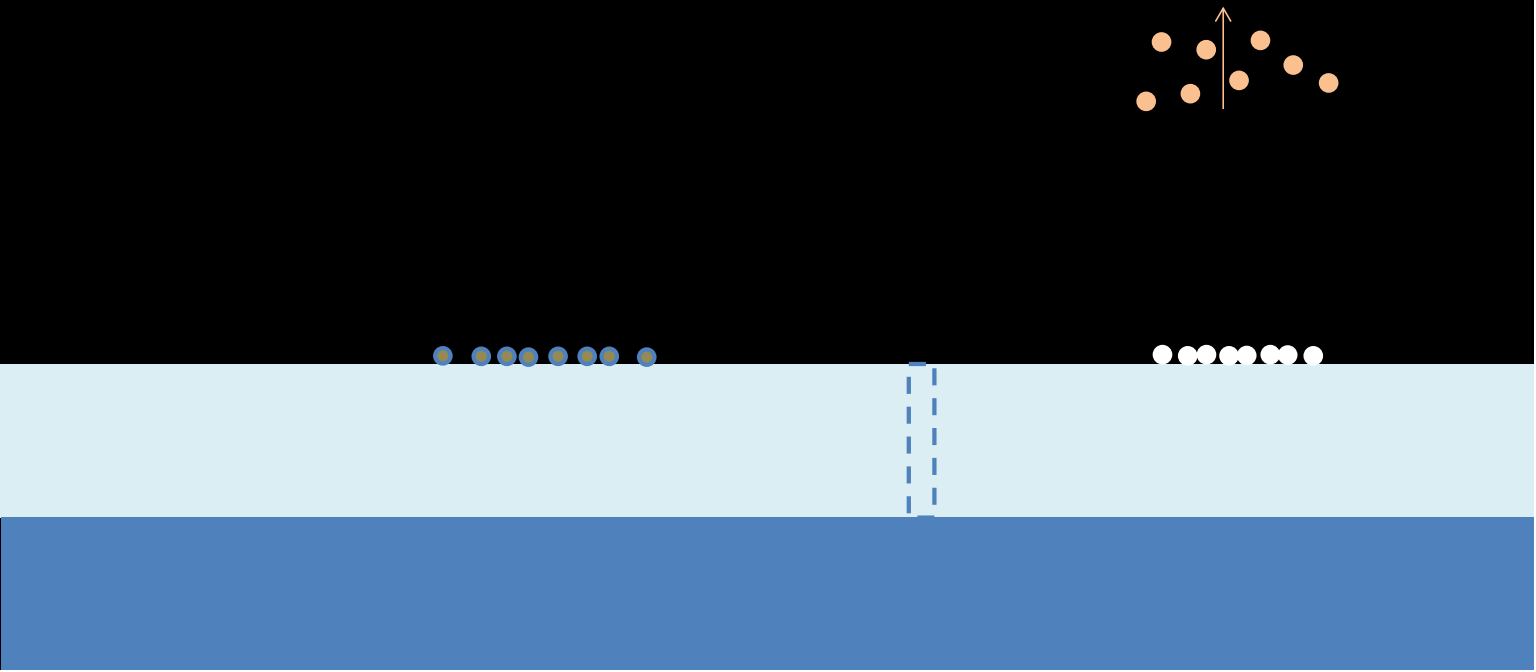
Hydrological Cycle on Europa



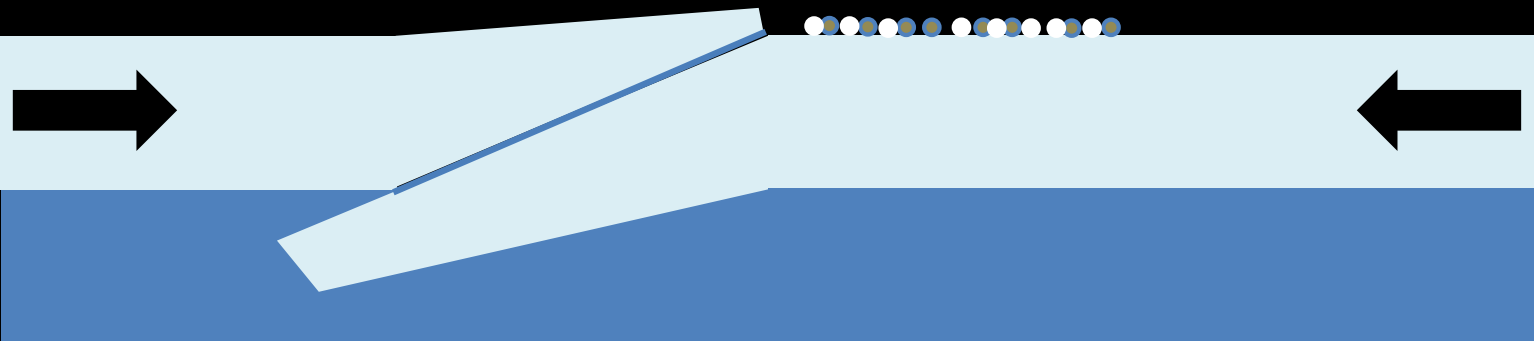
Hydrological Cycle on Europa



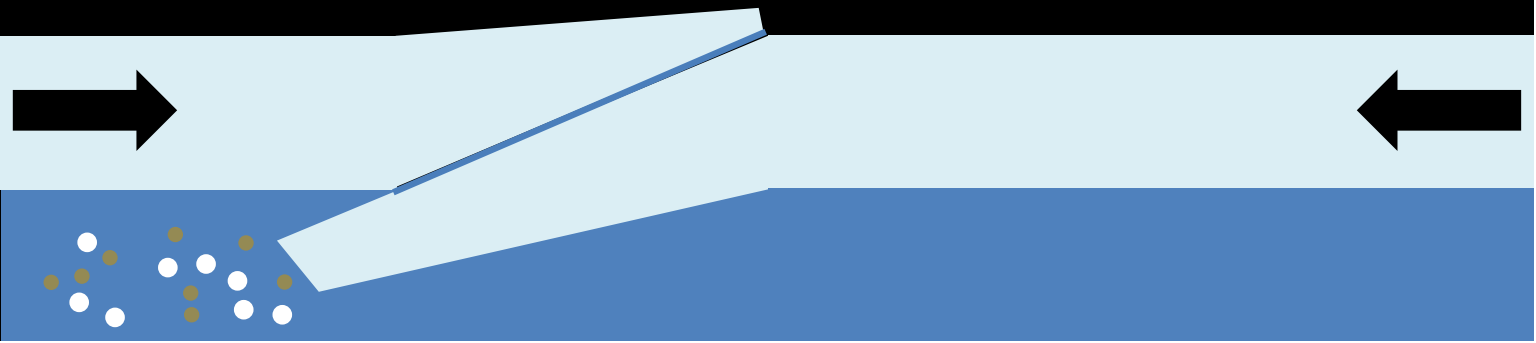
Hydrological Cycle on Europa



Hydrological Cycle on Europa



Hydrological Cycle on Europa



Hydrological Cycle on Europa

- Cryovolcanic Emissions
- Cosmic Dust Capture
- Refreezing
- Radiolysis
- Subduction

Astrobiological Implications

- Some Cosmic Dust Contains Organic Molecules
- Oxygenation of the Subsurface Ocean
- Similar to Enceladus
- More Access to Non-Indigenous Molecules



Any Questions?