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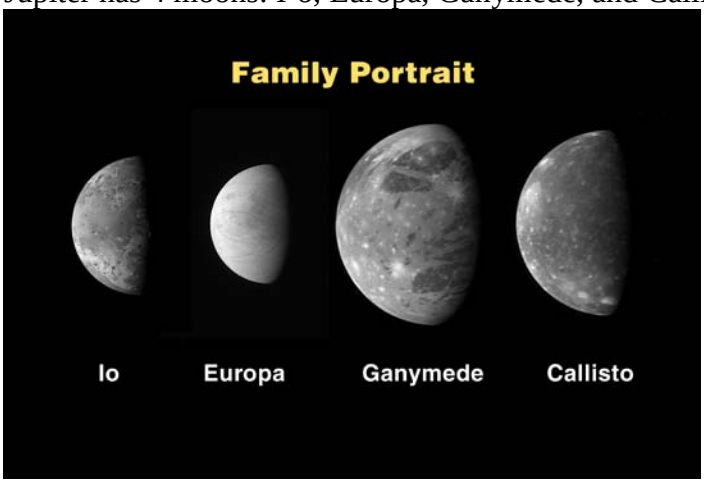
Jupiter has 4 moons: I'o, Europa, Ganymede, and Callisto.



http://www.nasa.gov/centers/ames/multimedia/images/2007/jupiterflyby.html

General info for moons of Jupiter:

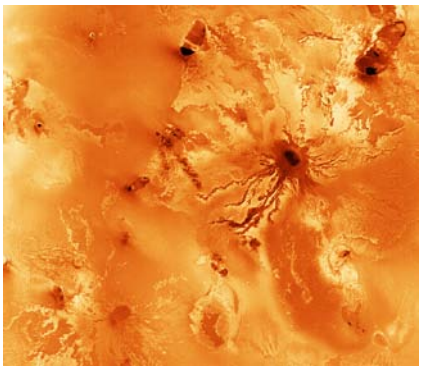
- The planets experience tidal heating, especially the inner planets.
- Impact craters tell us a lot about the orbit, surface age, surface material, etc.
- In terms of their orbit, planets have a trailing and leading hemisphere, as is confirmed by the ratio of impacts on each hemisphere (trailing = less, leading = more). Indicates that these moons are tidally locked to Jupiter.
- Orbital periods double for I'o, Europa, and Ganymede, which allows them to line up at predictable rates. 1:2:4
- Orbital resonances keep orbits elliptical

Io:

- The closest moon to Jupiter
- 2 day orbital period
- 3.57 g/cm^3 bulk density

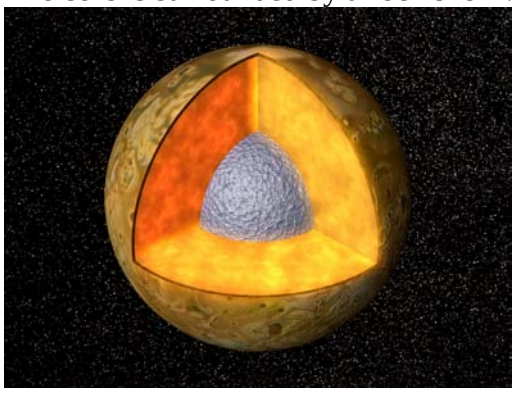
http://www.solarviews.com/raw/jup/io5.gif

- It is the most volcanic body known, with lava flows, lava lakes, and giant calderas covering its sulfurous landscape
- It has billowing volcanic geysers spewing sulfurous plumes to over 500 kilometers high
- Its mountains are much taller than those on Earth, reaching heights of 16 kilometers (52,000 feet).
- The extreme geologic activity is the result of tidal heating from friction generated within Io's interior as it is pulled between Jupiter and the other Galilean satellites



http://www.solarviews.com/raw/jup/io4.gif

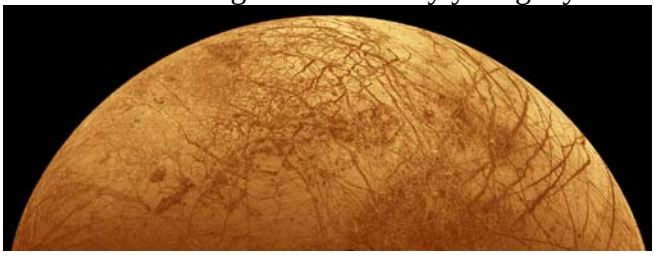
- Io has a metallic iron, nickel core
- The core is surrounded by a rock shell which extends to the surface



http://upload.wikimedia.org/wikipedia/commons/2/2d/PIA01129_Interior_of_Io.jpg

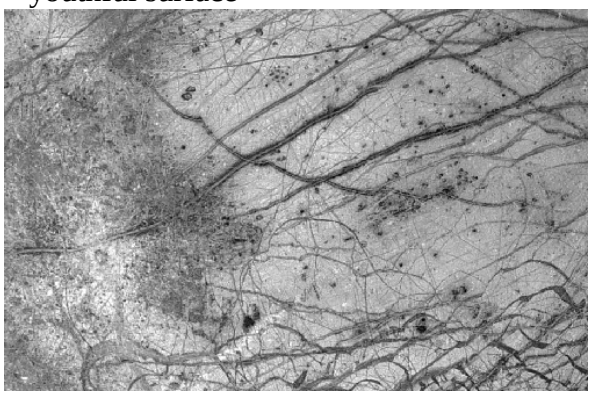
Europa:

- 2nd moon from Jupiter
- 4 day orbital period
- 2.97 g/cm^3
- Its surface is among the brightest in the solar system, a consequence of sunlight reflecting off a relatively young icy crust



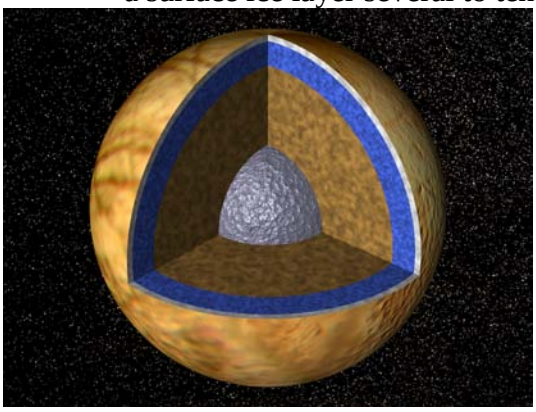
http://www.solarviews.com/raw/jup/europa.gif

- Its face is also among the smoothest, lacking the heavily cratered appearance characteristic of Callisto and Ganymede
- Symmetric ridges in the dark bands suggest that the surface crust was separated and filled with darker material, somewhat analogous to spreading centers in the ocean basins of Earth
- Although some impact craters are visible, their general absence indicates a youthful surface



http://apod.nasa.gov/apod/image/europa11_gal.gif

- Europa may be internally active, and its crust may have, or had in the past, liquid water which can harbor life.
- Europa has a metallic iron, nickel core
- The core is surrounded by a rock shell which is surrounded by a shell of water in ice or liquid form
- Galileo images of Europa suggest that a liquid water ocean might now underlie a surface ice layer several to ten kilometers thick

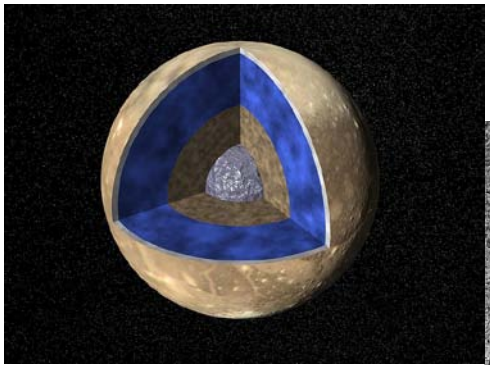
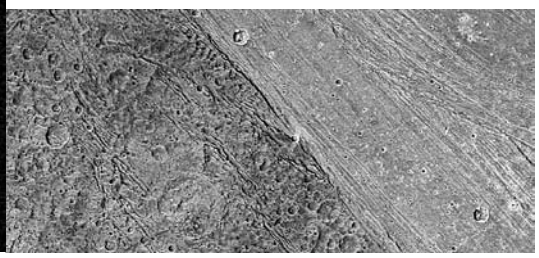


http://upload.wikimedia.org/wikipedia/commons/7/7b/PIA01130_Interior_of_Europa.jpg

- heat energy from tidal flexing causes the ocean to remain liquid and drives geological activity similar to plate tectonics
- Europa has an induced magnetic field through interaction with Jupiter's, which suggests the presence of a subsurface conductive layer. The layer is likely a salty liquid water ocean
- The primary ingredients for life are water, heat, and organic compounds obtained from comets and meteorites. Europa has had all three.

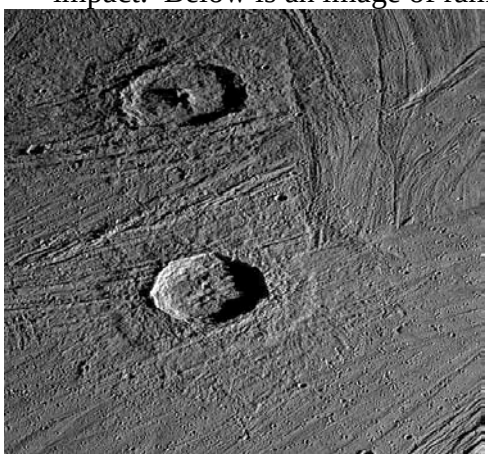
Ganymede:

- The largest moon in solar system, bigger than Mercury.
- 3rd moon from Jupiter
- ~7 day orbital period
- No substantial atmosphere
- 1.94 g/cm^3 bulk density
    - Because our models tell us it has a metal core, this tells us that there is probably a lot of water ice.
- Fully differentiated body, with an iron-rich liquid core. Outer layer of water ice, outer mantle of liquid water, inner mantle of silicates, and inner core of metal.

http://en.wikipedia.org/wiki/Ganymede_(moon)

- Surface mineralogy = primarily water and silicates.
- Magnetic field thought to be from conducting liquid in interior (molten metal)
- Complex surface: polar ice caps at the poles, and some parts more recently active than others. Dark parts are thought to be older, with light-colored impacts. Light terrain is slightly younger and has grooved and smooth parts, thought to be caused by ice flows and/or surface tension from tidal heating.
- Quantity and physical characteristics of impacts indicate surface age.
- Surface ice behaves plastically. Evident in the way surface craters become rounded and almost disappear (ghost craters)
- The shape of the crater tells you what type of material the impact hit: rampart ejecta = fluid and rayed crater = ice. Fluid can occur when ice melts upon impact. Below is an image of rampart craters on Ganymede.



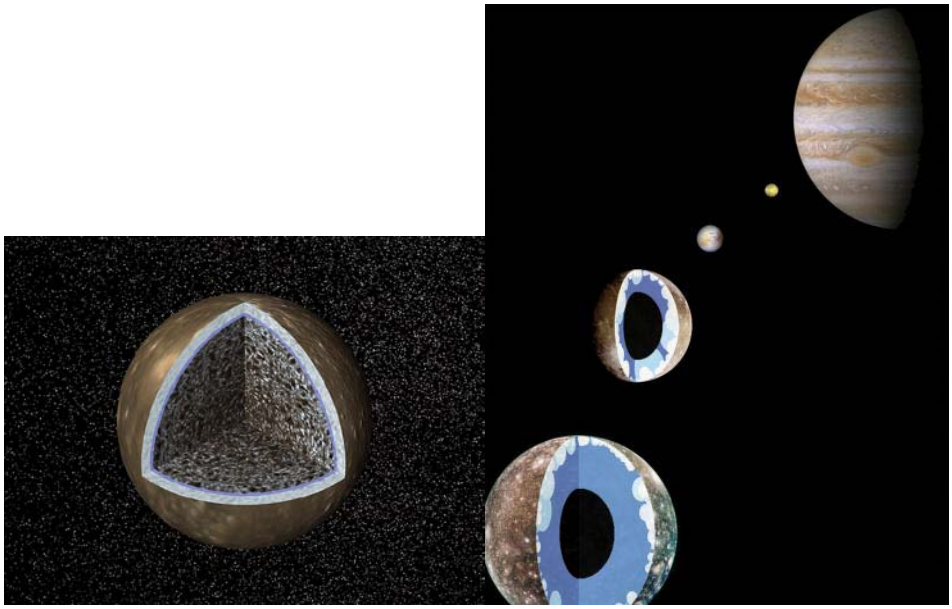
http://en.wikipedia.org/wiki/Ganymede_(moon)

Callisto:

- Farthest moon from Jupiter
- Darkest in color: makes it hard to see. Space weathering reddens the surface material and also sprinkles it with silicate space dust (determined by spectral signature).
- Impacts are white on a dark surface: tells us that water ice sits under a dark, dusty layer. Ie impacts excavate water ice.

http://en.wikipedia.org/wiki/Callisto_(moon)

- Surface is uniformly cratered, indicating very old surface. Larger proportion of impacts on leading hemisphere.
- Dust and impacts on surface indicate that the planet has not been active in a long time.
- Tidal heating not significant
- No evidence of plate tectonics or volcanism
- 17 day orbital period: not totally in sync with other 3 planets.
- 1.86 g/cm^3. we know there is metal and rock in core so this means a large proportion of water (as ice)
- Models based on gravity and magnetic data tell us that Callisto did not differentiate entirely. Some models say the core is differentiated into rock and metal, and some say there is a gradation of densities but not completely differentiated. Below are examples of the two models. The undiff model seems to be favored.



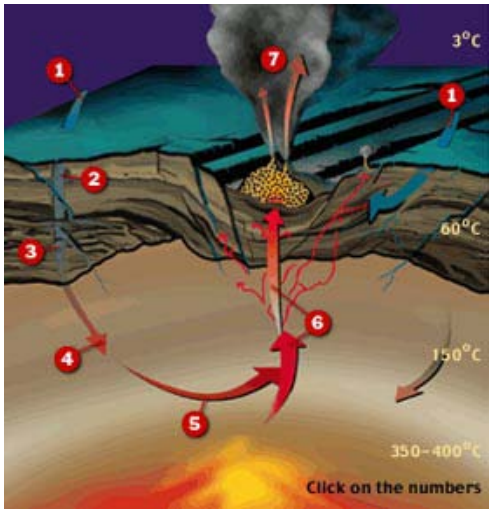
http://en.wikipedia.org/wiki/Callisto_(moon)
http://www.astronomy-blog.com/blogs/archives/Astronomy-blog/Sep-23-2010.html

What are we looking for?

Features on moons that have important elements of life that we see on Earth (remember from prior lecture things like magnetic field, hydrothermal vents, climate, liquid water, heating, etc. were crucial for life to evolve on Earth)

Hydrothermal vents

- Europa's unlit interior is now considered to be the most likely location for extant extraterrestrial life in the Solar System
- Life could exist in its under-ice ocean, perhaps subsisting in an environment similar to Earth's deep-ocean hydrothermal vents or the Antarctic Lake Vostok
- overview: water goes down towards the hot core, and comes back up as hot water at the bottom of ocean. The hot water hits the cold water and precipitates minerals in chimneys. In the image below, label 7 is a Chimney.



http://www.divediscover.whoi.edu/vents/vent-chemistry.html

- Chemosynthetic bacteria thrive on Earth's hydrothermal vents, and it is hypothesized that this may have been a place for the origin of life, which is why we look for hydrothermal vents on other planets.
- Chimneys can be up to 1000 ft high. Cross sections of these chimneys reveal pyrite and other precipitates. Archea and bacteria are the bottom of the food chain, and support tube worms and other organisms that don't need light to survive.
- Chemosynthetic bacteria = use inorganic substances (sulfer, methane, etc.) as a source of energy (compared to photosynthetic bacteria, which use sunlight as a source of energy). Chemosynethtic bacteria also use inorganic Carbon is a Carbon source for building organic molecules.

Magnetic fields:

- Intrinsic: requires rapid rotation and conducting fluid in interior such as liquid metal or briny water
- Induced: Because Jupiter has such a strong mag field, it generates 1 in close-by satellites.
  - Io = has a mag field. Maybe induced.
  - Ganymede = has 1. large dipoles is thought to be intrinsic due to a metal conducting fluid.
  - Europa = has a weak 1. small and farther away from Jupiter
  - Callisto = far away. Doesn't have 1