Internal Heating: Planets and Moons (Moon, Io, Europa, Titan)

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Text

Heat Sources of Planetary Bodies

- Gravitational potential energy (differentiation)
- Decay of radioactive elements
- Tidal friction
- Accretion or collision energy (external source)

Abundant Isotopes (G = billion, M = million, K = thousand)

	decay chain	half life
Extinct:	$^{26}Al \Rightarrow {}^{26}Mg$	720 K yrs.
Present time:		
	$^{40}K \Rightarrow {}^{40}Ar, {}^{40}Ca$	1.27 G yrs.
	^{238}U ... ^{208}Pb	4.47 G yrs.
	^{235}U ... ^{207}Pb	704 M yrs.
	^{232}Th ... ^{208}Pb	14.0 G yrs.

Voyager missions (1979 flybys) showed that each of Jupiter's moons is a different world

The moons are all 'tidally locked', rotate in the same direction in nearly circular orbits in Jupiter's equatorial plane. They likely formed as a 'subnebula' in the solar disk.

Moon	orbit	density
Io	5.9	3.5
Europa	9.4	3.0
Ganymede	15.0	1.9
Callisto	26.4	1.8

(orbits in Jupiter radii)

Deformation of Europa: Four possible processes

- Upwarping
- Surface fractures (compression
- Upwelling of fluid and fluid flow
- Collpse (tension) to chaotic terrain

The Moon

Galileo Galilei (1564-1642) - observed the moon through a telescope and called the dark smooth areas *maria* (latin for seas) and the lighter colored, rugged terrain he called *terrae* (latin for lands).

Aside from the Earth the moon is the best understood planetary body in the solar system.

Many of our current theories and hypotheses of how the Earth and other planets formed were developed and tested by studying the moon.

Moon Formation Theories

1) Co-accretion in orbit while Earth formed.
2) Capture - Moon formed elsewhere in the nebula but was captured by Earth's gravity.
3) Giant impact.

Observation sthat need to be explained by successful theory:

Chemically, the moon is similar to the Earth's mantle.
The moon is deficient in volatile elements (K, Na, Cl) relative to Earth.
Moon's metal core, if any, is relatively small.
Oxygen isotope ratios of Moon are the same as Earth, unlike Mars & meteorites.

Radiometric Dates for the Moon

Absolute ages determined by radiometric dating of lunar samples.
Basaltic lavas are 3.65 to 4.0 billion years old
Lunar highlands are more than 4.5 billion years old
Some ray material from Copernicus crater is less than 1 billion years old
Integrating these ages into the relative scale (from craters) allows development of an absolute scale

Rate of Cratering and Volcanism with Time

Rate of cratering was much more intense early in lunar history
The decline in the amount of impact events was rapid after about 3 G years ago
The lunar record is assumed to represent impact history of all planets, esp. Earth
Radiometric ages show volcanism lasted ~1 G yrs. between 4.0 and 3.2 G yrs. ago
Some lavas are 2.5 billion years old, but may be melt generated by later impacts

References and Links[i]

Texts:

Mathez, E. and J. Webster (2004) *The Earth Machine*, Columbia U. Press. Hardcover, 334 pages

Beatty, K., C.C. Petersen and A. Chaikin (1999) *The New Solar System*, Cambridge U. Press (4th edition).

Chart of the Nuclides (1996) distrib. by GE Nuclear Energy, 175 Curtner Ave. M/C 948, San Jose CA 95125 (800-668-7379, or nuclides@sjcpo2.ne.ge.com)

Links:

Missions: See NASA web space for *Galileo* and *Cassini* missions.
Water ice phase diagrams and discussion of physics/chemistry:
http://www.physics.brocku.ca/courses/1p23/Heat/ice.html
http://snobear.colorado.edu/Markw/SnowHydro/Phases/phases.html
http://www.lsbu.ac.uk/water/phase.html
details of ice III and a new metastable phase:
http://www.cmmp.ucl.ac.uk/people/finney/soi.html
CO_2-H_2O and Clathrate phase diagrams and discussion
easy: http://users.bigpond.net.au/Nick/Mars/NH1.htm (applied to Mars)
moderate: http://www.isis.rl.ac.uk/isis2000/highlights/titanH3.htm (on Titan)
difficult:
http://www.unileoben.ac.at/~buero62/minpet/ronald/Publications/IMA1994/IMA.html

http://www.unileoben.ac.at/~buero62/minpet/ronald/Publications/CG1997/CG.html
http://www.lpi.usra.edu/meetings/lpsc2001/pdf/1780.pdf (on Mars)

Titan
- Internal Structure: http://www.lpi.usra.edu/meetings/lpsc2002/pdf/1989.pdf
- Surface processes:
  http://www.es.ucl.ac.uk/research/planetaryweb/undergraduate/dom/weathering_titan/tocf.htm
- Orbit calculation exercise (for advanced HS students)
  http://nfsi-server.yerkes.uchicago.edu/FTProot/titan/mainpage.htm
  http://www.redshift.com/~vikweb/The_Mass_of_Saturn.html

Europa
- Internal Structure:
  http://lasp.colorado.edu/icymoons/europaclass/Anderson_Europa2.pdf
- Possible microbial life: http://www.ucolick.org/~laura/microbio/europa.htm

Methods: Remote Sensing
- http://earthobservatory.nasa.gov/Library/RemoteSensing/remote_08.html
  (types; how they are used for planetary science)
- http://rst.gsfc.nasa.gov/Homepage/Homepage.html (complete text)
  (very rich site! history; development; use to understand Earth & cosmos)

Earth-moon system
- Tides http://www.astronomynotes.com/gravappl/s10.htm
- Moon: http://www4.geology.utoronto.ca/glg130/moon.html (college course)

Saturn
- Moon/Ring motion http://www.astro.indiana.edu/~durisen/saturn//
- Voyager 2 images http://ringmaster.arc.nasa.gov/saturn/vgr2_iss/

Isotope Decay
- http://chemed.chem.purdue.edu/genchem/topicreview/bp/ch23/modes.html
- http://www.chartofthenuclides.com/ (where to get Nuclide Chart)
- http://wwwndc.tokai.jaeri.go.jp/CN04/ (web-based version)

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[i] *This list does not constitute a blanket endorsement of all content over all time for all the sites listed. There are many worthy sites that are not listed here.*