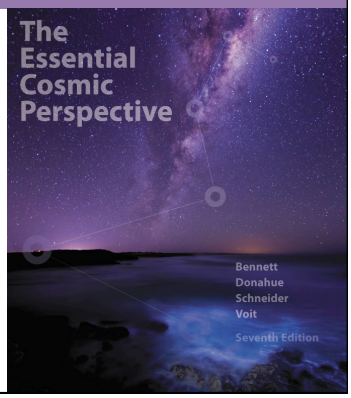
Lecture Outline

Chapter 7: Earth and the Terrestrial Worlds



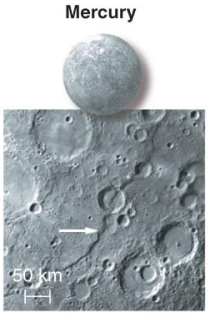
Earth as a model

All our understanding of geological features are from observations and experiments here on Earth.

How the Earth reshapes it's surface

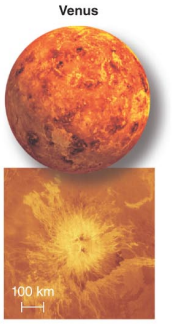
- Plate tectonics can change Earths outer layers.
  - Volcanoes can reshape ocean floors
  - Earthquakes can form mountains
  - Entire continents can move over a few hundred million years
- Erosion can gradually change the landscape.
  - Wind, rain and ice can cut down mountains
  - Rivers can carve out canyons
- Dramatic events can create changes instantly.
  - On rare occasions asteroids or comets slam into earth

Mercury



Craters
Smooth plains
Cliffs

Venus

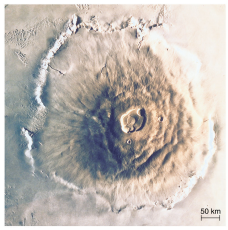


Volcanoes
Few craters

Radar view of a twin-peaked volcano

Mars

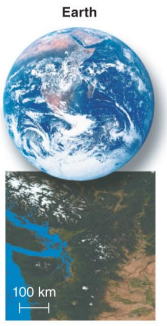
Some craters
Volcanoes
Riverbeds?



Moon

Craters
Smooth plains

Earth



Volcanoes
Craters
Mountains
Riverbeds

Why have the planets turned out so differently, even though they formed at the same time from the same materials?

7.1 Earth as a Planet

Our goals for learning:

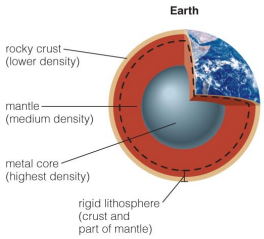
- Why is Earth geologically active?
- What processes shape Earth's surface?
- How does Earth's atmosphere affect the planet?

Why is Earth geologically active?

Interior Structure

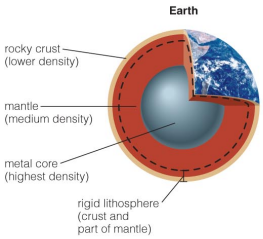
- We cannot see inside the Earth
  - Measure seismic vibrations after earthquakes
  - Comparison of density between surface rocks and overall
  - Measurements of gravity by spacecrafts gives mass
  - Magnetic fields tell us layers that generate those fields
  - Volcanic rocks tell us interior composition

Earth's Interior



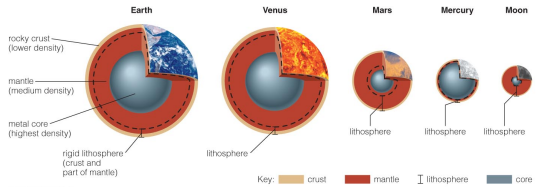
- **Core:** Highest density; nickel and iron
  - Solid inner
  - Molten liquid outer
- **Mantle:** Moderate density; minerals with silicon, oxygen, etc.
- **Crust:** Lowest density; granite, basalt, etc.

Lithosphere



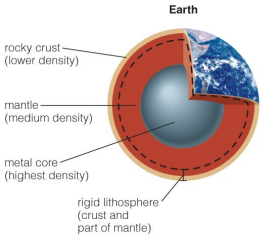
- A planet's outer layer of cool, rigid rock is called the lithosphere.
  - Encompasses the crust and part of the mantle of each world
- It "floats" on the warmer, softer rock that lies beneath.

Terrestrial Planet Interiors



- Applying what we have learned about Earth's interior to other planets tells us what their interiors are probably like.

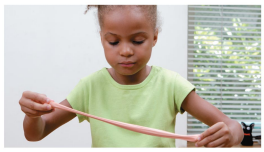
Differentiation



- Gravity pulls high-density material to center.
- Lower-density material rises to surface.
- Material ends up separated by density.

Just like oil floats on water because it is less dense.

Strength of Rock

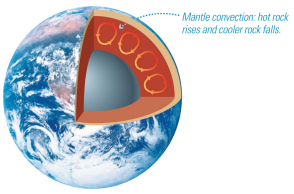


- Rock stretches when pulled slowly but breaks when pulled rapidly.
- The gravity of a large world pulls slowly on its rocky content, shaping the world into a sphere.

Heat Drives Geological Activity

Convection: Hot rock rises, cool rock falls.

One convection cycle takes 100 million years on Earth.



Sources of Internal Heat

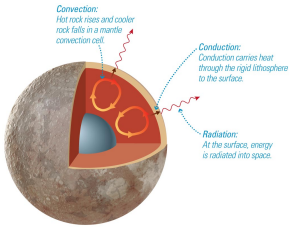
1. Gravitational potential energy
   - accreting of planetesimals
2. Differentiation
   - gravity pulls denser material downward
3. Radioactivity
   - isotopes decay, $E=mc^2$

All three convert into thermal energy

Heating of Interior over Time

- Accretion and differentiation when planets were young
- Radioactive decay is most important heat source today.

Cooling of Interior



- **Convection** transports heat as hot material rises and cool material falls.
- **Conduction** transfers heat from hot material to cool material.
- **Radiation** sends energy into space.

Thought Question

What cools off faster?

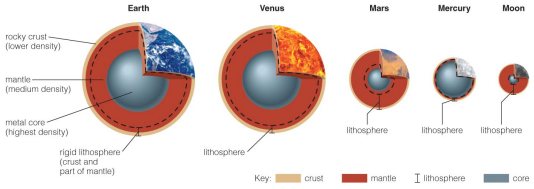
A. A grande-size cup of Starbucks coffee
B. A teaspoon of cappuccino in the same cup

Thought Question

What cools off faster?

A. A big terrestrial planet
B. A tiny terrestrial planet

Role of Size



- Smaller worlds cool off faster and harden earlier.
- The Moon and Mercury are now geologically "dead."

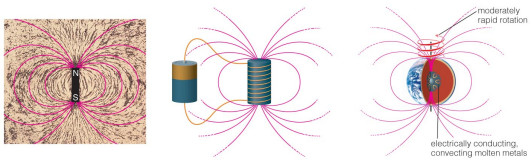
Surface Area-to-Volume Ratio

- Heat content depends on volume.
- Loss of heat through radiation depends on surface area.
- Time to cool depends on surface area divided by volume:

$$\text{Surface area-to-volume ratio} = \frac{4\pi r^2}{\frac{4}{3}\pi r^3} = \frac{3}{r}$$

- Larger objects have a smaller ratio and cool more slowly.

Planetary Magnetic Fields

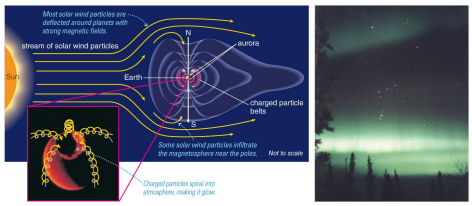


Moving charged particles create magnetic fields.

A planet's interior can create magnetic fields if its core is electrically conducting, convecting, and rotating.

Earth's Magnetosphere

- Earth's magnetic field protects us from charged particles from the Sun.
- The charged particles can create aurorae ("Northern lights").



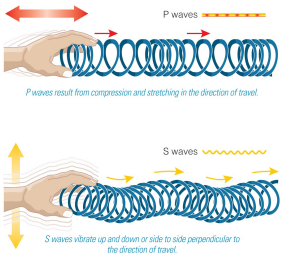
Thought Question

If the planet core is cold, do you expect it to have magnetic fields?

A. Yes. Refrigerator magnets are cold, and they have magnetic fields.

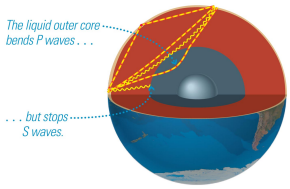
B. No. Planetary magnetic fields are generated by moving charges around, and if the core is cold, nothing is moving.

Special Topic: How do we know what's inside a planet?



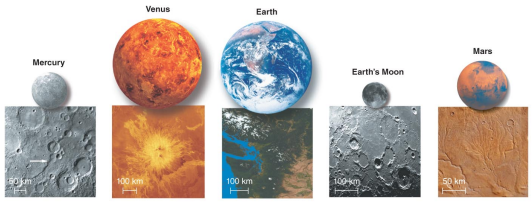
- Earthquakes!
- P waves push matter back and forth.
- S waves shake matter side to side.

Special Topic: How do we know what's inside a planet?



- P waves go through Earth's core, but S waves do not.
- We conclude that Earth's core must have a liquid outer layer.

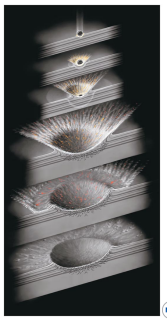
➢What processes shape Earth's surface?



Geological Processes

- Impact cratering
  - Impacts by asteroids or comets
- Volcanism
  - Eruption of molten rock onto surface
- Tectonics
  - Disruption of a planet's surface by internal stresses
- Erosion
  - Surface changes made by wind, water, or ice

Impact Cratering



- Most cratering happened soon after the solar system formed.
- Craters are about 10 times wider than the objects that made them.
- Small craters greatly outnumber large ones.

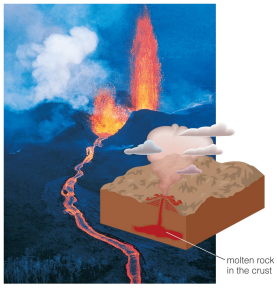
MA INTERACTIVE FIGURE

Impact Craters

Meteor Crater (Arizona)

Tycho (Moon)

Volcanism

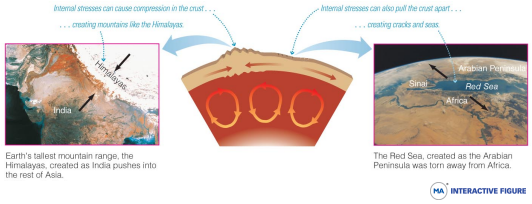


- Volcanism happens when molten rock (magma) finds a path through lithosphere to the surface.
- Molten rock is called *lava* after it reaches the surface.

Outgassing

- Volcanism also releases gases from Earth's interior into the atmosphere.

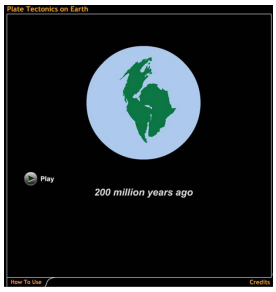
Tectonics



MA INTERACTIVE FIGURE

- Convection of the mantle creates stresses in the crust called tectonic forces.
- Compression forces make mountain ranges.
- A valley can form where the crust is pulled apart.

Plate Tectonics on Earth



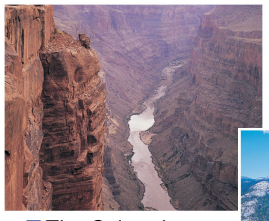
- Earth's continents slide around on separate plates of crust.

PLAY Plate Tectonics on Earth

Erosion

- Erosion is a blanket term for weather-driven processes that break down or transport rock.
- Processes that cause erosion include
  - Glaciers
  - Rivers
  - Wind

Erosion by Water



- The Colorado River continues to carve the Grand Canyon.

Erosion by Ice

- Glaciers carved the Yosemite Valley.

Erosion by Wind

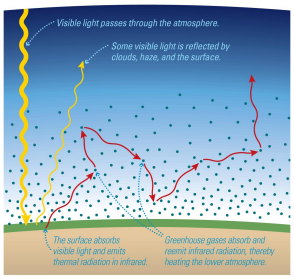
- Wind wears away rock and builds up sand dunes.

Erosional Debris

- Erosion can create new features by depositing debris.

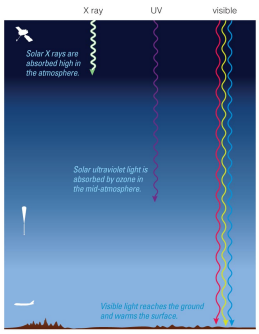
➢How does Earth's atmosphere affect the planet?

1. Radiation protection
2. Greenhouse effect
3. Makes the sky blue!

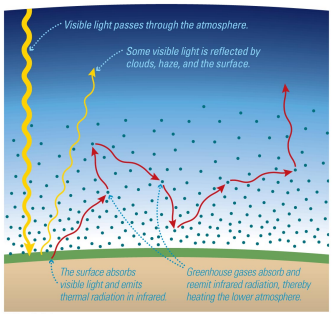


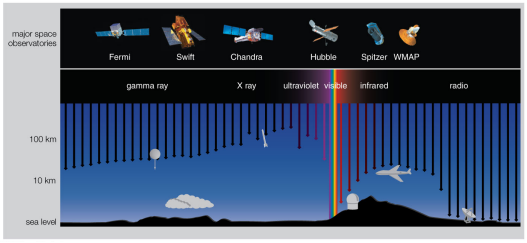
Radiation Protection

- All X-ray light is absorbed very high in the atmosphere.
- Ultraviolet light is absorbed by ozone (O_3).



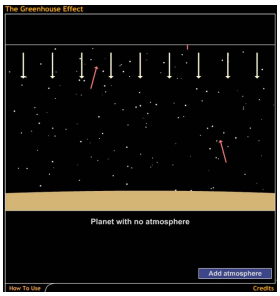
The Greenhouse Effect





Earth's atmosphere absorbs light at most wavelengths.

Greenhouse effect:



Certain molecules let sunlight through but trap escaping infrared photons.

(H_2O, CO_2, CH_4)

PLAY The Greenhouse Effect

A Greenhouse Gas

- Any gas that absorbs infrared
- Greenhouse gas: molecules with two different types of elements (CO_2, H_2O, CH_4)
- Not a greenhouse gas: molecules with one or two atoms of the same element (O_2, N_2)

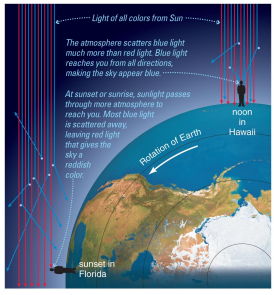
Because of the greenhouse effect, Earth is much warmer than it would be without an atmosphere…but so is Venus.

Thought Question

Why is the sky blue?

A. The sky reflects light from the oceans.
B. Oxygen atoms are blue.
C. Nitrogen atoms are blue.
D. Air molecules scatter blue light more than red light.
E. Air molecules absorb red light.

Why the sky is blue



- Atmosphere scatters blue light from the Sun, making it appear to come from different directions.
- At sunset sunlight passes through more atmosphere and most blue light is scattered leaving red light.

What have we learned?

- Why is Earth geologically active?
  - Earth retains plenty of internal heat because it is large for a terrestrial planet.
  - That heat drives geological activity, keeping the core molten and driving geological activity.
  - The circulation of molten metal in the core generates Earth's magnetic field.

What have we learned?

- What geological processes shape Earth's surface?
  - Impact cratering, volcanism, tectonics, and erosion
- How does Earth's atmosphere affect the planet?
  - Protection from radiation
  - Greenhouse effect

7.2 Mercury and the Moon: Geologically Dead

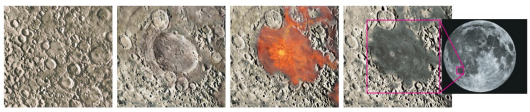
Our goals for learning:

- Was there ever geological activity on the Moon or Mercury?

Was there ever geological activity on the Moon or Mercury?

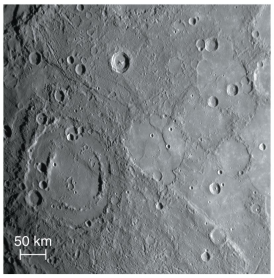
Moon Mercury

Moon



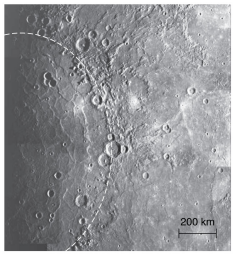
- Some volcanic activity 3 billion years ago must have flooded lunar craters, creating *lunar maria*.
- The Moon is now geologically dead.

Cratering of Mercury

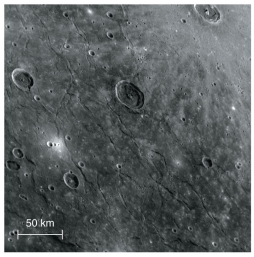


- Mercury has a mixture of heavily cratered and smooth regions like the Moon.
- The smooth regions are likely ancient lava flows.

Cratering of Mercury

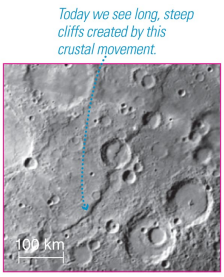


The Caloris Basin is the largest impact crater on Mercury.



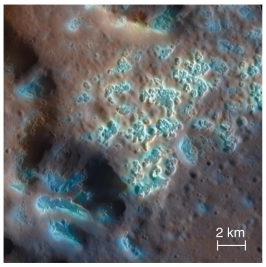
Region opposite the Caloris Basin is jumbled from seismic energy of impact.

Tectonics on Mercury



- Long cliffs indicate that Mercury shrank early in its history.
- Due to it's large iron core, Mercury retained heat more than the moon causing it to swell.

Recent Geology on Mercury



- Lighter areas (color enhanced) are thought to be "hollows" formed as easily vaporized minerals escape.

What have we learned?

- Was there ever geological activity on the Moon or Mercury?
  - Early cratering on the Moon and Mercury is still present, indicating that activity ceased long ago.
  - Lunar maria resulted from early volcanism.
  - Tectonic features on Mercury indicate early shrinkage.