Chapter 14

Earth’s Interior

Interior Terms

- **Crust**
  - Oceanic
  - Continental
- **Mantle**
  - Upper
  - Transition
  - Lower
- **Core**
  - Outer
  - Inner
- **Peridotite**
- **Eclogite**
- **Spinel**
- **Perovskite**
- **Xenolith**
- **Discontinuity**
- **Phase Change**
- **Tomography**
- **Kimberlite**

Interior Terms

- **Basalt**
- **Chondrule**
- **Multi-anvil press**
- **Diamond anvil cell**
- **Convection**
- **Magnetic reversal**
- **Dynamo**
- **Magnetic field**
- **Asthenosphere**
- **Lithosphere**

How do we know what is inside the Earth?

- **Seismology:** Earthquake waves
- **Cosmochemistry:** Meteorites
- **Experiments:** Laboratory synthesis

Earthquakes

- **Earthquake Monitor**
  - http://www.iris.edu/seismon/bitmap/index.phtml
**Major Parts**

- Ocean water 0.025% of mass
- Crust (Above the Moho) 0.5% of mass
  - Oceanic (7 to 10 km of basalt & gabbro)
  - Continental (30 to 60 km of granite)
- Mantle - Moho to 2900 km - Solid Rock
  - 65% of total mass
  - Upper (Moho to 410 km) (Olivine + pyroxene)
  - Transition Zone (410 - 670 km) (Silicate Spinel)
  - Lower 670 to 2900 km (Perovskite + periclase)
- Core (2900 to 6367 km) 35% of mass
  - Outer Core (Liquid Metal)
  - Inner Core (Solid Metal)

**Crust**

- Oceanic Crust (Basalt and Gabbro)
  - Thin (7 - 10 km)
  - Dense (2.9 - 3.1 g/cm³)
  - Young (< 250 my)
- Continental Crust (Granite + Diorite + Seds)
  - Thick (30 - 60 km)
  - Light (2.7 - 2.8 g/cm³)
  - Old (250 - 4000 my)

**Mantle**

- Upper Mantle (Moho to 410 km)
  - Peridotite (Olivine + pyroxene)
  - Eclogite (Pyroxene + Garnet)
- Transition Zone (410 - 670 km)
  - Spinel and Spinelloids
- Lower Mantle (670 - 2900 km)
  - MgSiO₃ - Perovskite
  - MgO - Periclase

**Core**

- Outer Core (2900 to 5150 km)
  - Molten iron metal (+ ~10% lighter element)
  - No S-wave transmission
- Inner Core (5150 - 6378 km)
  - Solid Iron Metal
  - May slowly rotate relative to mantle

**Seismology**

- S-wave shadow
  - No S-waves opposite-side earthquakes
- P and S reflections and conversions
- Meteorites:
  - Earth formed from primitive meteorites
- Xenoliths from kimberlites & basalts
- Experiments

- How do we know what’s there?
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**Seismology**

**P-waves**  **S-waves**

![Seismology Diagram](image)

**Velocity Structure and Earthquakes at N. Tonga**


*Red = slow = hot  green = fast = cold*

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**Clicker Question**

What observation led to the conclusion that the Earth has a liquid outer core?

- A) Earth’s gravity field
- B) P-wave shadow
- C) S-wave shadow
- D) Seismic reflection from 660km
- E) Polar wandering

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**Clicker Question**

Why does the P-wave shadow exist?

- A) Seismic refraction into the slower outer core
- B) P-waves cannot pass the liquid outer core
- C) Seismic reflection at the core-mantle boundary
- D) Seismic reflection from 660km
- E) No earthquakes large enough
**Xenoliths**

- Xenoliths are ‘strange rocks’
- Xenoliths are inclusions in kimberlites and basalts
- Xenoliths provide natural high pressure rocks.
  - Kimberlites bring diamonds and other rock samples from as deep as 670 km.
  - Basalts are derived from the lithospheric mantle

**Meteorites**

- Meteorites tell us of Earth’s bulk composition
  - Chondrites are primitive meteorites
  - Earth is “chondritic”
- Composition is similar to sun minus H, He and other volatiles.
Meteorites

Clicker Question
• How do we know that the core is made of iron?
  • A) Earth has a permanent magnetic field and iron is ferromagnetic.
  • B) Iron metal is abundant in meteorites and has about the right density for the core.
  • C) Iron metal is abundant in volcanic rocks and has about the right density for the core.
  • D) Iron metal is an electrical conductor
  • E) Iron is highly compressible.

Experiments
• Multi-Anvil Press
  – Synthesis experiments to 1000 km depth
  – Samples 1-5 mm³
• Diamond Anvil Cell
  – Spectroscopy
  – Ultrasound
  – X-ray diffraction

Multi-anvil Press
5000 ton
(Bayerisches Geoinstitut)
Carbide cubes retain a lot of strain

Multi-anvil Press Octahedral Assembly: After and Before

Multi-Anvil Press Octahedron

Diamond-anvil Cell
Mica Crystal with Quartz @ 5GPa

Clicker Question
• The diamond anvil cell can create pressure greater than the center of the Earth in the laboratory
  • A) True
  • B) False
410 km:

- **Olivine**
  - Density: 3.2 g/cm³

- **Wadsleyite**
  - Density: 3.5 g/cm³

525 km

- **Olivine**
- **Wadsleyite**
- **Ringwoodite**

660 km

- **Ringwoodite Crystal with Quartz**
  - Density: 3.6 g/cm³

- **Perovskite + MgO**
  - Density: 4.2 g/cm³
Clicker Question

The Earth’s mantle is made of:

- A) Solid silicate rock
- B) Molten silicate magma
- C) Solid iron metal
- D) Molten iron metal
- E) Olivine

Clicker Question

The seismic discontinuity at 660 km is thought to be caused by:

- A) A change in crystal structure
- B) A compositional change to metal
- C) Melting of silicates.
- D) Magnetic reversal
- E) A change to a gas phase
Convection in solid mantle

- Driven by U, Th, K decay (internal engine)
- Moves about 2 cm/yr
- Causes earthquakes
- Moves plates
- Splits and rejoins continents
- One Cell or two?

Clicker Question

- The Earth’s outer core is made of:
  - A) Solid silicate rock
  - B) Molten silicate magma
  - C) Solid iron metal
  - D) Molten iron metal
  - E) Olivine

Magnetic Field

- Due to electrical currents from Earth’s dynamo.
- Convection in liquid metal outer core.
- Convection is coupled to Earth’s rotation.
- Field is subject to sporadic reversals.
  - Last reversal was 30,000 years ago.
- Field holds ozone layer (UV shield) in place.
**Magnetic Field Reversals**

**Clicker Question**
- The Earth’s magnetic field is caused by:
  - A) Permanent magnet in the inner core.
  - B) Magnetic minerals in the rocks
  - C) Convection currents in the upper mantle
  - D) Convection in the liquid metal outer core
  - E) Solar wind dynamo

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