**Mantle**

References:
*Encyclopedia of Volcanoes*, pp. 41-54

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**Structure of the Earth**

Core
Mantle
Crust
Lithosphere
Aesthenosphere

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**Layer Compositions**

<table>
<thead>
<tr>
<th>name</th>
<th>thickness</th>
<th>composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>crust</td>
<td>6-75 km</td>
<td>Si, Al, Ca, Na</td>
</tr>
<tr>
<td>mantle</td>
<td>2900 km</td>
<td>Si, Al, Fe, Mg</td>
</tr>
<tr>
<td>core</td>
<td>6370 km</td>
<td>Fe, S, Ni</td>
</tr>
</tbody>
</table>

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**Behavior**

<table>
<thead>
<tr>
<th>name</th>
<th>thickness</th>
<th>behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithosphere</td>
<td>10-300 km</td>
<td>Brittle</td>
</tr>
<tr>
<td>Asthenosphere</td>
<td>100-200 km</td>
<td>Ductile &amp; weak</td>
</tr>
<tr>
<td>Mesosphere</td>
<td>2800 km</td>
<td>Ductile and strong</td>
</tr>
<tr>
<td>Outer core</td>
<td>2270 km</td>
<td>Ductile and weak</td>
</tr>
<tr>
<td>Inner core</td>
<td>2400 km</td>
<td>Strong</td>
</tr>
</tbody>
</table>

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**Earth’s Heat Source**

- Original accretion
- Radioactive decay
- Geotherm
  - Temperature increases 20-40°/km
  - T at 100 km depth ~ 1100°C

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*Fig. 1.5 Decline of the Earth's surface heat flow through geological time*
The value of radioactive heat production relative to heat loss from the core has increased with time.

Core

- During Earth’s formation metallic iron separated into the core releasing a tremendous amount of energy.
- The core is a source of heat, but otherwise does not play an obvious role in volcanism.

Mantle

- Composition
  - Peridotite (olivine, pyroxene)
- Physical characteristics
  - Moho (seismic discontinuity)
  - Creep deformation (flows)
- Significance for volcanism
  - Source of primary magmas

Mantle Composition

- Bulk Earth composition is similar to chondritic meteorites.
- Subtract the core and crust composition to get the mantle.
- The theoretical mantle composition is lherzolite (olivine/2-pyroxene rock).
- Actual lherzolite xenoliths have been erupted from volcanoes with deep roots!

Mantle Minerals

- Olivine: \( \text{Mg}_2\text{SiO}_4 \)
- Orthopyroxene: \( \text{MgSiO}_3 \)
- Clinopyroxene: \( \text{Ca(Mg,Fe)}\text{Si}_2\text{O}_6 \)
- Pyrope: \( \text{(Mg,Fe)}_3\text{Al}_2\text{(SiO}_4\text{)}_3 \)
- Phlogopite: \( \text{K}_2\text{Mg}_3\text{Al}_5\text{Si}_3\text{O}_{10}(\text{OH})_2 \)
- Spinel: \( \text{MgAl}_2\text{O}_4 \)
- Perovskite: \( \text{CaTiO}_3 \)

**Table 1.5** Composition of the Orgueil C1 chondrite meteorite, spinel lherzolite and "undepleted" mantle

<table>
<thead>
<tr>
<th>Component</th>
<th>Orgueil meteorite</th>
<th>Orgueil water-free</th>
<th>Spinel lherzolite</th>
<th>Undepleted mantle</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO(_2)</td>
<td>21.7</td>
<td>26.8</td>
<td>45.1</td>
<td>45.1</td>
</tr>
<tr>
<td>TiO(_2)</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Al(_2)O(_3)</td>
<td>1.6</td>
<td>1.9</td>
<td>2.2</td>
<td>3.3</td>
</tr>
<tr>
<td>Cr(_2)O(_3)</td>
<td>0.4</td>
<td>0.4</td>
<td>0.5</td>
<td>0.4</td>
</tr>
<tr>
<td>MnO</td>
<td>0.2</td>
<td>0.2</td>
<td>0.1</td>
<td>0.14</td>
</tr>
<tr>
<td>FeO</td>
<td>22.9</td>
<td>28.3</td>
<td>8.3</td>
<td>8.0</td>
</tr>
<tr>
<td>NiO</td>
<td>1.2</td>
<td>1.4</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>MgO</td>
<td>15.2</td>
<td>18.8</td>
<td>41.5</td>
<td>38.1</td>
</tr>
<tr>
<td>CaO</td>
<td>1.2</td>
<td>1.5</td>
<td>2.0</td>
<td>3.1</td>
</tr>
<tr>
<td>Na(_2)O</td>
<td>0.7</td>
<td>0.8</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>K(_2)O</td>
<td>0.07</td>
<td>0.08</td>
<td>0.1</td>
<td>0.03</td>
</tr>
<tr>
<td>P(_2)O(_5)</td>
<td>0.3</td>
<td>0.4</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>H(_2)O</td>
<td>19.2</td>
<td>0</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>Organics</td>
<td>9.7</td>
<td>11.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>5.7</td>
<td>7.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td>100.17</td>
<td>100.0</td>
<td>100.9</td>
<td>98.77</td>
</tr>
</tbody>
</table>
The seismic velocity of S-waves increases with depth in the Earth. Discontinuities are due to mineralogical phase changes.

**Depleted Mantle**
- Lherzolite is considered “enriched”
- Depleted mantle consists of hartzburgites – Olivine + orthopyroxene
- They formed as a residual by removal of basalt composition melts
- Depleted mantle is considered the source for MORB, the most common volcanic rock

**Crust**
- **Compositional types**
  - Continental (granitic)
  - Oceanic (basaltic)
- **Physical characteristics**
  - 10-60 km thick
  - Rigid (fractures)
  - Evolved composition

**Significance of Crust for Volcanism**
- Controls Migration to the surface
- Contamination of primary magmas
- Hosts magma chambers
- Plate margins are key features

**Lithosphere**
- Contains crust and mantle
- Defined by brittle behavior
- Upper temp. of about 1350 °C
- 100 to 150 km thick

**Aesthenosphere**
- Essential mantle material
- Moves by convection
- Source for most primary magmas