Isostasy and the dynamics of the Earth’s crust

Isostasy: the condition of equilibrium, comparable to floating, of the units of the lithosphere on the asthenosphere.
The physical state (solid / partially solid / liquid) of the different layers of the Earth depends on which is higher - the melting temperature or the actual temperature.

\[ A = M \quad A < M \quad A > M \]

The ocean floor sinks as it gets older because the rate of spreading decreases with age. This is due to the cooling and solidification of the oceanic crust as it moves away from the mid-ocean ridge, causing it to subduct into the mantle at subduction zones. The graph of age vs. depth of the ocean floor shows this relationship, with older ocean floors being deeper due to their reduced spreading rates.
\[ \rho_{\text{lithosphere}} = \rho_{\text{crust}} \times \%\text{thickness}_{\text{crust}} + \rho_{\text{mantle}} \times \%\text{thickness}_{\text{mantle}} \]

**Mid-ocean ridge**

**Oceanic crust** \( \rho = 3.0 \text{ g/cc} \)

**Rigid mantle** \( \rho = 3.3 \text{ g/cc} \)

**Asthenosphere mantle** \( \rho = 3.25 \text{ g/cc} \)

- **age = 0 my**
  \[
  \rho_{\text{lithosphere}} = 3.0 \text{ g/cc} \times 1.0 + 3.3 \text{ g/cc} \times 0 = 3.0 \\
  \rho_{\text{lithosphere}} \ll \rho_{\text{asthenosphere}}
  \]

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  \[
  \rho_{\text{lithosphere}} = 3.0 \text{ g/cc} \times 0.4 + 3.3 \text{ g/cc} \times 0.6 = 3.18 \\
  \rho_{\text{lithosphere}} < \rho_{\text{asthenosphere}}
  \]
Isostasy - equilibrium position of lithosphere “floating” on asthenosphere.
Other ways to change the isostatic equilibrium of the crust

- Heating / cooling of the lithosphere
  - Changes the density of the crust = buoyancy
  - Caused by passage of plates over mantle hot spots
- Heating / cooling of the mantle
  - Rising plumes of hot mantle displace the lithosphere upward
  - Sinking slabs of cold mantle pull the lithosphere downward

**Archimedes’ principle:**
\[ t_{\text{crust}} \times \rho_{\text{crust}} = t_{\text{mantle}} \times \rho_{\text{mantle}} \]

**Example**

How much mantle will be displaced by 45 km of crust?

\[ t_{\text{crust}} \times \rho_{\text{crust}} = t_{\text{mantle}} \times \rho_{\text{mantle}} \]

\[ 45 \times 2.65 = t_{\text{mantle}} \times 3.25 \]

\[ \frac{45 \times 2.65}{3.25} = t_{\text{mantle}} \]

\[ 36.7 = t_{\text{mantle}} \]
Example

Archimedes’ principle:
\[ t_{\text{crust}} \times \rho_{\text{crust}} = t_{\text{mantle}} \times \rho_{\text{mantle}} \]

How high above sea level will the crust be?

If \( d_{\text{mantle}} = 8.0 \text{ km} \)

\[ a_{\text{crust}} = t_{\text{crust}} - (d_{\text{mantle}} + t_{\text{mantle}}) \]
\[ a_{\text{crust}} = 45 - (8 + 36.7) \]
\[ a_{\text{crust}} = .3 \text{ km} \]

\[ 36.7 \text{ km} = t_{\text{mantle}} \]
\[ 45 \text{ km} = t_{\text{crust}} \]