Student Worksheet: Density of Lithosphere and Mantle Rocks Experiment

Aim: To determine the role of rock density and buoyancy in tectonic plate motion.

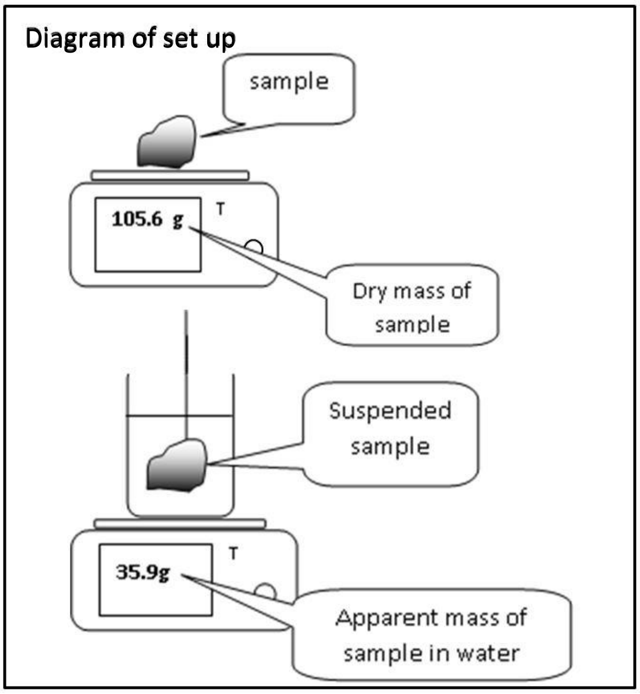
Materials: Rock samples (basalt, gabbro, blueschist, eclogite, andesite, granite, peridotite, serpentinite), scales (+/- 0.1 g), cotton thread, 500 mL beaker or plastic container, tap water, retort stand, boss head, clamp

Method:

1. A dry rock sample was placed on the scales and the mass recorded.
2. A length of cotton was securely tied to the rock.
3. The retort stand, boss head and clamp were set up so that the rock sample could be suspended from the clamp.
4. A half-full beaker of water was placed on the scales and the scales were zeroed.
5. The rock was suspended and wholly immersed in the water and the mass recorded (this mass will be equal to the volume of the displaced water in cm^3 because the density of fresh water = 1 g/cm^3).
6. The density was calculated using the formula:

Density (in g/cm^3) = $\dfrac{\textbf{mass}}{\textbf{volume}}$ = $\dfrac{\textbf{dry mass in air (g)}}{\textbf{volume of rock (cm}^3\textbf{)}}$

7. The rock densities were plotted on the cross-section of a subduction zone (following page).



Results: (TYPICAL)

Rock type	Location	Dry mass in air (g)	Mass in water (g) = volume (cm^3)	Density (g/cm^3)
basalt	oceanic crust (upper 0.5 km)	**188.0**	**64.5**	**2.91**
gabbro	oceanic crust (0.5-10 km)	**105.6**	**35.9**	**2.94**
blueschist	subducting oceanic crust	**182.1**	**59.1**	**3.08**
eclogite	subducting oceanic crust	**185.9**	**54.1**	**3.44**
andesite	continental crust (volcanic arc)	**117.1**	**43.0**	**2.72**
granite	continental crust	**154.3**	**58.0**	**2.66**
peridotite	upper mantle (lithosphere + asthenosphere)	**310.9**	**95.6**	**3.25**
serpentinite	hydrated mantle	**102.8**	**39.2**	**2.62**

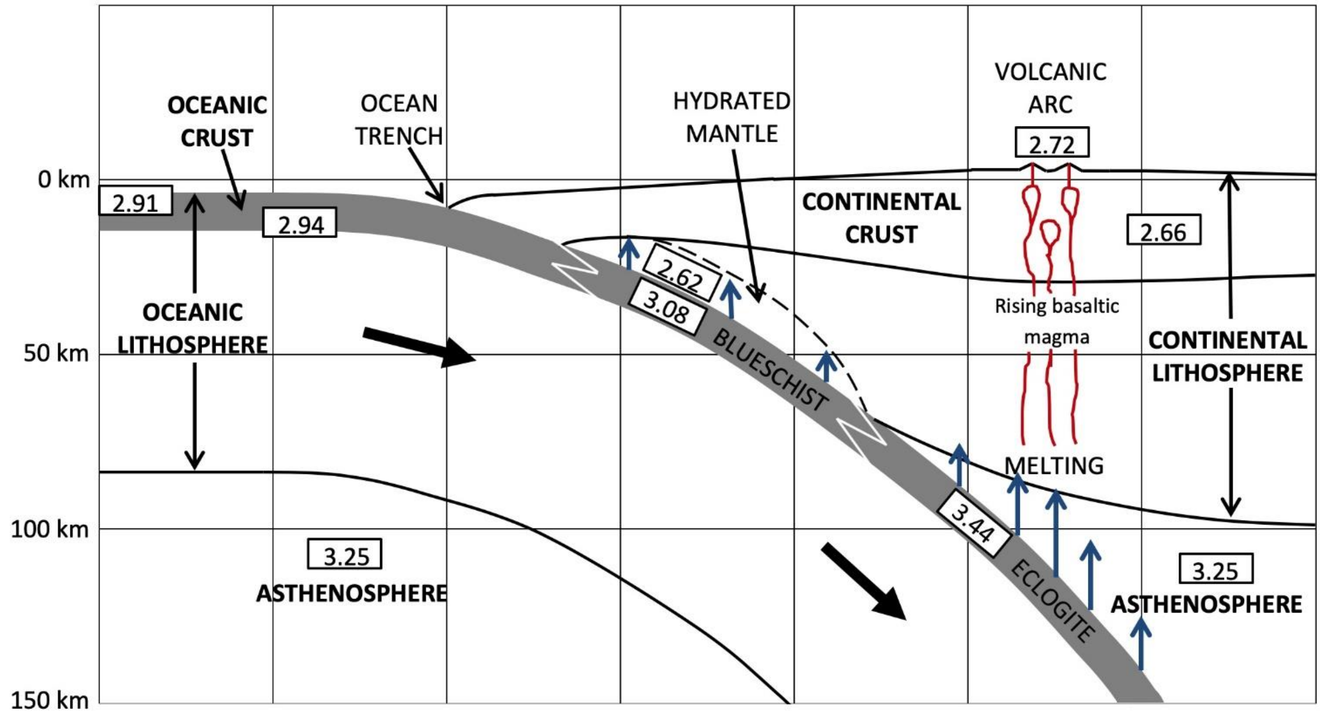


Figure 7: Cross section of a subduction zone with measured rock densities in g/cm³

Questions:

1. Classify the eight rocks in this experiment as:

Volcanic igneous — basalt, andesite

Plutonic igneous — gabbro, granite, peridotite

Metamorphic — blueschist, eclogite, serpentinite

2. Why does continental lithosphere float higher on the asthenosphere that oceanic lithosphere?

Because continental lithosphere is less dense, due to the low density continental crust (2.6-2.8 g/cm³) also being much thicker (30km) than the oceanic crust (2.9-3.0 g/cm³, 7-10km). So continental lithosphere has stronger positive buoyancy than the oceanic lithosphere. (The rigid upper mantle in the lower part of the continental and oceanic lithosphere is similar density.)

3. Explain why the metamorphism of basalt and gabbro to blueschist and then to eclogite is a possible cause for subducted plates being pulled down into the mantle (slab pull).

The metamorphism of basalt and gabbro to blueschist and then to eclogite causes its density to increase from 2.9 g/cm³ to 3.1 g/cm³ and then to 3.4 g/cm³. This causes the descending plate to be denser than the asthenosphere (3.2-3.3 g/cm³), so that it has negative buoyancy. So the subducting plate sinks into the asthenosphere pulling the rest of the plate along with it.

4. The metamorphism of blueschist to eclogite as the oceanic plate descends also releases a large amount of water. This water lowers the melting point of mantle peridotite causing the generation of mafic or basaltic magma (called flux melting). Why are volcanic arc eruptions often immense explosions of ash and pumice?

The lower pressure near the surface causes the water in the magma to become a gas and expand rapidly.

Conclusion:

The metamorphism of oceanic crust to eclogite causes its density to become greater than the peridotite of the asthenosphere, causing the oceanic lithosphere to be negatively buoyant and to pull the whole plate towards the subduction zone and down into the mantle (the slab pull mechanism).