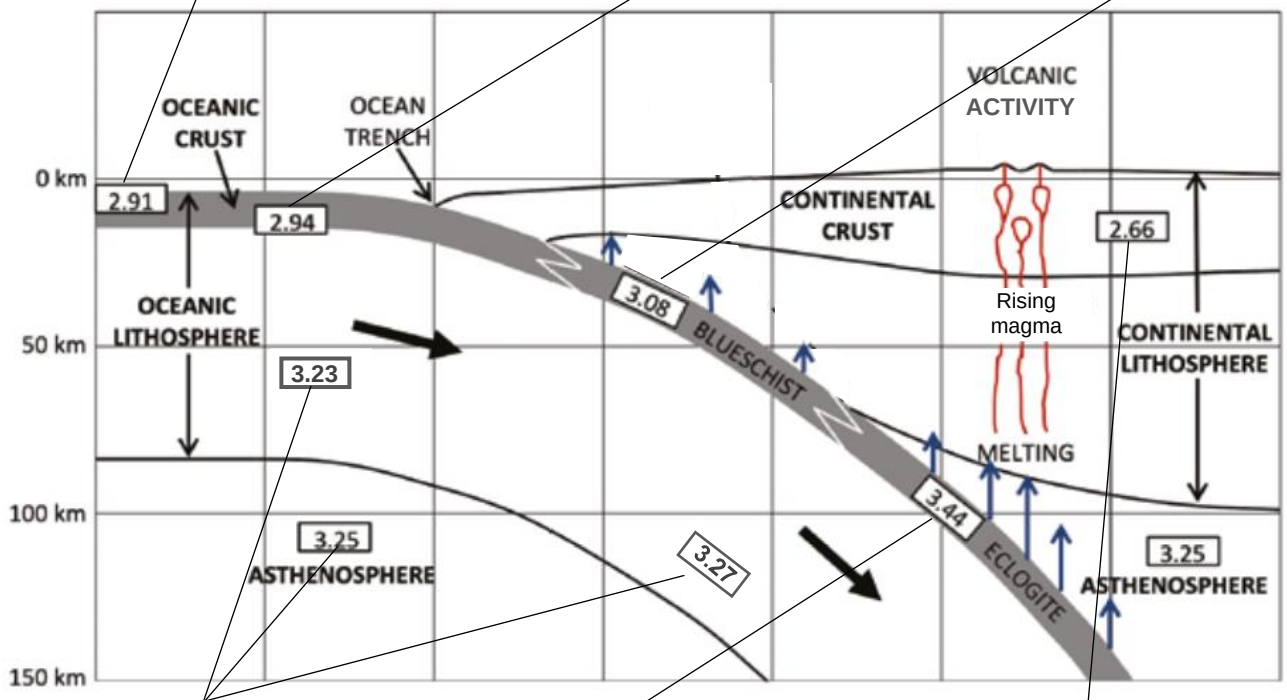
What drives the plates? In slab pull, what is it that pulls?
Understanding how slab pull works through examining the data

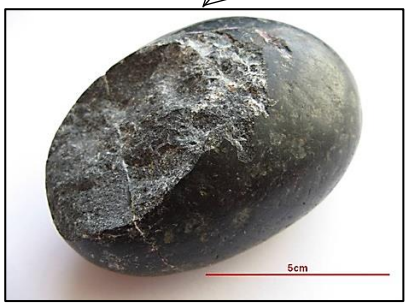
The diagram shows how the slab pull plate-driving mechanism works. As oceanic crust is subducted, the pressure of the overlying rocks increases, causing metamorphism. Basalt and gabbro are metamorphosed, first into blueschist, and then into eclogite. As this happens, water is released and rises into the rocks above (shown by blue arrows). Meanwhile the mantle part of the oceanic lithosphere also becomes denser as it cools and the overlying pressure increases.
Use the diagram to answer the questions below.

Basalt, density around 2.91gcm^{-3}

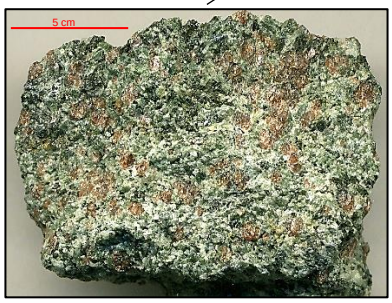
Gabbro, density around 2.94gcm^{-3}

Blue schist, density around 3.08gcm^{-3}





Peridotite of the asthenosphere, density of 3.23 – 3.27gcm^{-3}



Eclogite, density around 3.44gcm^{-3}

Granite, density around 2.66gcm^{-3}

- What happens to the density of the oceanic crust as it is subducted?
- What causes this density change?
- What happens to the density of the mantle part of the oceanic lithosphere as it is subducted?
- How do these changes in density cause the slab pull mechanism?
- How could you explain the slab pull plate-driving mechanism to someone who thinks that plates are moved mainly by heat-generated convection currents in the mantle (the mantle drag theory)?

Diagram modified from Price, C. (2019) An evidence-based approach to teaching plate tectonics in high school. Teaching science*, 65.2. p35. Rock images from https://www.earthlearningidea.com/virtual_rock_kit/START.htm apart from blue schist image, by Graeme Churchyard under the Creative Commons Attribution 2.0 Generic license; granite, by Zimbres under the Creative Commons Attribution-Share Alike 2.0 Brazil license; eclogite, by James St. John under the Creative Commons Attribution 2.0 Generic license.*

The back up

Title: What drives the plates? In slab pull, what is it that pulls?

Subtitle: Understanding how slab pull works through examining the data.

Topic: Using a diagram showing rock densities to aid understanding of the slab pull plate-driving mechanism.

Age range of pupils: 14 years upwards

Time needed to complete activity: 15 minutes

Pupil learning outcomes: Pupils can:

- describe how the rock types and densities of oceanic crust change as a plate is subducted;
- explain how this change occurs due to metamorphic effects with pressure related to depth being particularly important;
- explain why, because the density of the oceanic crust as it is metamorphosed becomes greater than the underlying mantle, this causes sinking;
- explain that the sinking cold dense lithospheric plate pulls the surface portion of the plate across the surface as the primary plate-driving mechanism.

Context:

The responses that might be expected from the pupils are given below. Some might need to be guided to these answers.

- What happens to the density of the oceanic crust as it is subducted?
  A. The density increases, from the 2.91-2.94 gcm^{-3} densities of basalt and gabbro to the 3.08gcm^{-3} density of blueschist to the 3.44gcm^{-3} density of eclogite.
- What causes this density change?
  A. The basaltic rock of the oceanic crust becomes metamorphosed by the increase in temperature and the great increase in pressure first to blue schist and then to eclogite
- How do these changes in density cause the slab pull mechanism?
  A. The density of the metamorphosed oceanic crust eclogite, around 3.44gcm^{-3}, is denser than the peridotite of the underlying and surrounding mantle at around 3.25gcm^{-3}. Thus the lithospheric plate with the denser eclogite sinks. The cold dense sinking lithosphere pulls the surface part of the plate along, through the slab pull mechanism.

As part of this process it is worth noting that water lost during subduction and metamorphism is less dense than the surrounding materials and so rises; this rising water can reduce the melting point of the rocks in the plate above, causing them to partially melt and so generate the magma that results in the surface volcanism.

- What happens to the density of the mantle part of the oceanic lithosphere as it is subducted?
  A. The mantle peridotite which forms the base of the lithosphere, also becomes denser during plate cooling as it is moved from the warm divergent margin to the cool subduction zone, from around 3.23gcm^{-3} to around 3.27gcm^{-3}.
- How could you explain the slab pull plate-driving mechanism to someone who thinks that plates are moved mainly by heat-generated convection currents in the mantle (the mantle drag hypothesis)?
  A. Refer them to the 'What drives the plates? – the evidence' *Earthlearningidea activity which explains the evidence for the slab pull mechanism and the lack of evidence for the mantle drag theory.*

This is the second of four Earthlearningidea activities focussed on the mechanisms driving plates. The others are shown in the table on page 3.

Following up the activity:

Continue with the third and fourth activities, described above.

Underlying principles:

- As the oceanic crust part of an oceanic plate is moved towards and into a subduction zone, the metamorphism caused by increasing temperature and greatly increasing pressure, changes the basaltic (mafic) rocks first to blue schist and then to eclogite.
- The metamorphic changes and loss of water increase the density of the rock until it becomes more dense than the underlying and surrounding mantle peridotite in the asthenosphere, so the plate sinks.
- The sinking plate pulls the remaining surface part of the plate across the surface through the slab pull mechanism.
- This process is aided by the increasing density of the cooling mantle peridotite which forms the base of the plate, as it is moved from the divergent margin to the subduction zone.
- The water released by this process can cause partial melting of the plate above, and volcanicity.

Thinking skill development:

Understanding the pattern of densities is a construction activity. Linking this to the slab pull mechanism uses bridging. Cognitive conflict is caused by the unexpected finding that crustal material that is less dense than the underlying asthenosphere becomes so much more dense that it causes sinking.

Resource list:

- none

Useful links:
Access the other Earthlearningideas on plate tectonics at:
https://www.earthlearningidea.com/home/Teaching_strategies.html#platetectonics

Source: Modified by Chris King of the Earthlearningidea Team from work published by Colin Price in: Price, C. (2019) An evidence-based approach to teaching plate tectonics in high school. *Teaching science*, 65.2. 30-37. The advice of Pete Loader and Ian Stimpson in the preparation of this activity was crucial.

The Earthlearningidea "What drives the plates" activities	
What drives the plates? The evidence. Examine the evidence for the different plate tectonic driving mechanisms.	https:www.earthlearningidea.com/PDF/347_What_drives_plates1.pdf
What drives the plates? In slab pull, what is it that pulls? Understanding how slab pull works through examining the data.	http://www.earthlearningidea.com/PDF/348_What_drives_plates2.pdf
What drives the plates? Modelling slab pull. Modelling and discussing the slab pull plate-driving mechanism in the classroom.	http://www.earthlearningidea.com/PDF/349_What_drives_plates3.pdf
What drives the plates? Using a pupil model to demonstrate that slab pull is the main plate-driving force.	https://www.earthlearningidea.com/PDF/217_Slab_pull.pdf