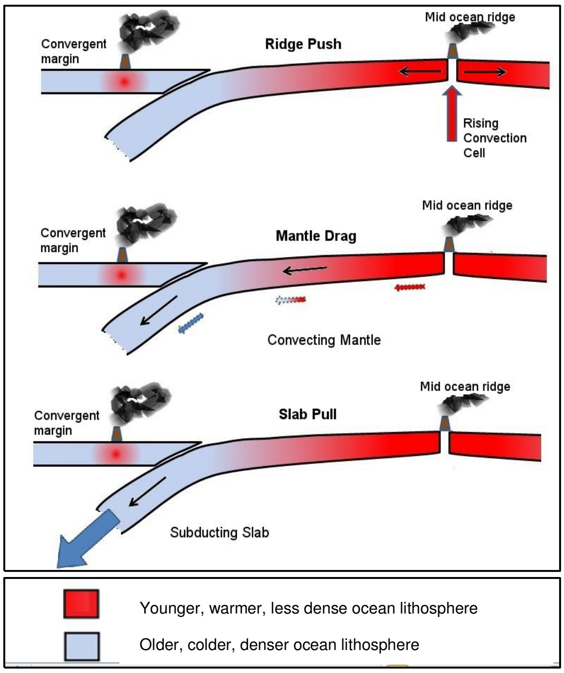
What drives the plates?
Using a pupil model to demonstrate that slab pull is the main plate-driving force

The Earth's tectonic plates move, but what processes cause this movement?



(*Pete Loader*)

Three of the forces that have been proposed as the main drivers of plate movement are:

- **mantle convection currents** – mantle currents carrying plates of lithosphere along on top, like shopping on a supermarket conveyor belt;
- **ridge push** – newly-formed plates at oceanic ridges are warm, and so have a higher elevation at the oceanic ridge than the colder, more dense plate material further away; gravity causes the higher plate at the ridge to push away the lithosphere that lies further from the ridge;
- **slab pull** – older, colder plates sink at subduction zones because as they cool, they become more dense than the underlying mantle – so the sinking plate pulls the rest of the plate along behind it.

Recent research has shown that the major driving force for most plate movement is **slab pull**, because the plates with more of their edges being subducted are the faster-moving ones.

Meanwhile, if there are **mantle convection currents**, as traditionally pictured (and they have not been detected by geophysics), they seem to have a small or no effect on plate movement. **Ridge push** only seems to be effective where there are no slab pull forces. Demonstrate this by asking two pupils to stand together at the front of the room, representing two plates together at an oceanic ridge. Then ask around five pupils to stand beside one of these 'plate margins', and link arms to form a 'pupil tectonic plate' of lithosphere, as in the photo.

- Simulate a **mantle convection current** force by walking along behind the linked line of pupils, from the oceanic ridge plate margin, nudging the students in the back as you do so – showing that a mantle convection current has little effect on plate movement.
- Simulate **ridge push** by pushing between the two 'plate margins', as in the photo, showing that this has only a small impact on the 'pupil tectonic plate'.

(*David Bailey*)

- Simulate slab pull by going to the end of the line and pulling the last pupil, and so pull the whole 'pupil tectonic plate' (photo) – showing that this is the force which has the greatest effect.

(*David Bailey*)

Convection – but not as we know it
Slab pull, which appears to be the main driving force of lithospheric plate movement, is convection in the solid state. Movement is caused when the solid lithospheric plate cools, becomes more dense than the underlying mantle, and so sinks – this causes the **slab pull** process to take place in the solid state as plates sink into the mantle at subduction zones. If **ridge push** also contributes to plate movement, this too is an example of convection in the solid state, where higher, less dense material pushes downwards and outwards.

Note that geophysical evidence shows that the mantle is a solid, not a liquid (S-waves travel through the mantle and they only travel through solids). Between around 100 and 250 km depth is the asthenosphere (or weak-sphere), where seismic waves slow down slightly, which is evidence of a tiny amount of liquid (~1%). The small amount of liquid softens the solid mantle and forms the weak layer over which the rigid lithospheric plates can slide. So plate movement is a convecting solid (rheid) phenomenon – the mantle is not molten.

……

The back up

Title: What drives the plates?

Subtitle: Using a pupil model to demonstrate that slab pull is the main plate-driving force

Topic: Considering the different processes likely to be driving plate movement by use of a pupil model.

Age range of pupils: 11 – 18 years

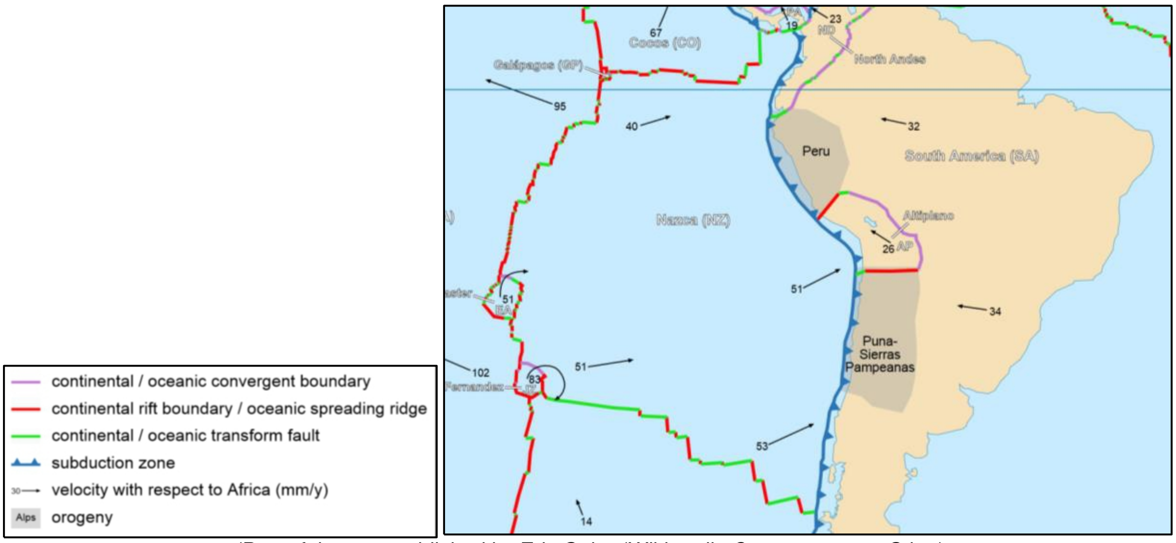
Time needed to complete activity: 10 minutes

Pupil learning outcomes: Pupils can:
- describe three forces that could cause plate movement;
- identify slab pull as the main driving force;
- explain that this is an example of convection in the solid state.

Context:
Recent evidence has shown that the traditional view of mantle convection being the main driving force in lithospheric plate movement is probably incorrect. If it were the main driving force, then plates with the largest surface area would move fastest because they would have the largest area on which the mantle convection forces would act – this is not the case. However, those plates that have the longest subducting margins, with geophysical evidence of the deepest subduction slabs, do seem to be moving fastest – which is why this is now considered to be the main driving force.

A fourth force that might be important is **subduction suction** where the old, cold oceanic plate subduction trench migrates towards the oceanic ridge pulling the over-riding plate behind it. Some geophysicists argue that this is an important driver of plate movement.

Following up the activity:
Ask the pupils to test the idea that the fastest moving plates have the greatest proportion of subducting margin (and therefore the greatest slab pull effect) as follows:
- ask them to identify three plates on a plate map: the Pacific plate, the Nazca plate and the South American plate;
- for each if these plates, ask them to approximately measure the total length of the plate margin (all parts of the margin, including the ridges/rifts, transform faults, and subduction zones);
- then they should measure the length of that plate margin which is subducting (in the direction of the triangular 'teeth' shown on most maps (e.g. at the Nazca/South American plate boundary, it is the Nazca plate which is subducting, not the South American plate), see the map on the next page;



(Part of the map published by Eric Gaba (Wikimedia Commons user: Sting) under the Creative Commons Attribution-Share Alike 2.5 Generic license)

- they should then compare the two figures to work out the percentage of margin which is subduction zone;
- finally, they should compare these results with the fact that the Pacific is the fastest-moving plate, the Nazca plate is moving at an intermediate rate, whilst the South American plate is slow-moving.

A. *The Pacific plate has about a third down-going subduction margin (at the Aleutian, Kurile, Japan, Philippine and Fiji-Tongan trenches) and is an old, cold plate = fastest rates.*
The Nazca plate has about a quarter subduction margin (Chile-Peru trench) and is a young, warm plate = intermediate velocities.
The South American plate has no down-going subduction margin = slow velocities (probably caused by ridge push from South Atlantic oceanic ridge).

Underlying principles:
- The three main processes proposed to drive the movement of plates are **mantle convection currents, ridge push** and **slab pull**.
- **Mantle convection** involves currents in the outer mantle carrying plates along on top.
- **Ridge push** is caused by the higher elevation new plate material at constructive plate margins pushing downwards and outwards.
- **Slab pull** is caused by old cold subducting plate sinking beneath subduction zones, pulling the rest of the plate behind it.
- Current research indicates that slab pull is the main plate-driving force, and that, where slap pull is not effective, ridge push may then be important.
- There is little geophysical evidence for mantle convection being an important mechanism.

Thinking skill development:
Picturing the different potential processes of plate movement involves discussion. Thinking about the possible mechanisms involves cognitive conflict. Applying these to the potential evidence uses bridging skills.

Resource list:
- several willing participants

Useful links:
A global plate map is available for free download from:
http://en.wikipedia.org/wiki/Plate_tectonics#mediaviewer/File:Tectonic_plates_boundaries_detailed-en.svg

Source: Activity devised by Pete Loader, with helpful contributions from Ian Stimpson.

© **Earthlearningidea team.** The Earthlearningidea team seeks to produce a teaching idea regularly, at minimal cost, with minimal resources, for teacher educators and teachers of Earth science through school-level geography or science, with an online discussion around every idea in order to develop a global support network. 'Earthlearningidea' has little funding and is produced largely by voluntary effort.
Copyright is waived for original material contained in this activity if it is required for use within the laboratory or classroom. Copyright material contained herein from other publishers rests with them. Any organisation wishing to use this material should contact the Earthlearningidea team.
Every effort has been made to locate and contact copyright holders of materials included in this activity in order to obtain their permission. Please contact us if, however, you believe your copyright is being infringed: we welcome any information that will help us to update our records.
If you have any difficulty with the readability of these documents, please contact the Earthlearningidea team for further help. Contact the Earthlearningidea team at: info@earthlearningidea.com