Chocolate Plates
Simulating the properties of a lithospheric plate

The surface of the Earth is broken up into large tectonic **plates**. It's easy to confuse these plates with the Earth's crust – the thin outermost layer of the Earth. But there is more to the structure of a plate than the 'crust' and a simple image of a 'cracked egg-shell'.

The Earth's layers can be defined in two different ways – based on either the **chemical** composition or the **mechanical** properties of rock (Figure1). To better understand what a plate is, it is important to understand these different models.

When the outer Earth is defined by its chemistry, it is divided into the **crust** and **mantle.** The crust is further chemically divided into the continental crust (typically of granitic composition) and the ocean crust (typically of basaltic composition). The upper mantle beneath is composed of peridotite (an olivine-rich igneous rock).

So, what exactly is a tectonic plate?

It is not only the chemistry of rocks that changes with depth - their mechanical properties also change, according to pressure and temperature. Both factors affect a rock's mechanical strength, whatever its chemical composition.

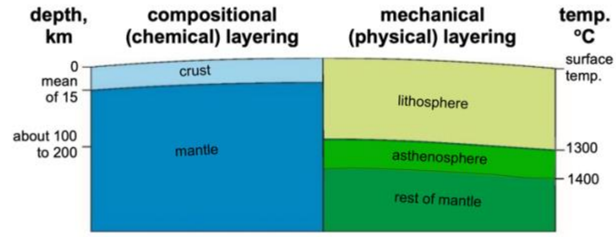

Figure 1: Two models for defining the outer layers of the Earth depending on composition or mechanical properties. *(ESEU)*

As temperature and pressures increase with depth, mantle peridotite will change from being a strong 'colder' rock near the surface to a weaker, hotter rock with depth. This occurs when peridotite reaches temperatures of around 1300°C and gives rise to a layer called the **asthenosphere** (weak sphere), where the rock is nearer its melting point than the mantle above. Although the asthenosphere is almost entirely **solid,** the immense forces cause the mantle to flow plastically (in a ductile manner) over geological time.

The rocks above the asthenosphere (**the uppermost mantle and the overlying crust**) are colder and more rigid and move as a single unit. This outer mechanical layer is called the **lithosphere** and represents the tectonic, or lithospheric plate (Figure 2).

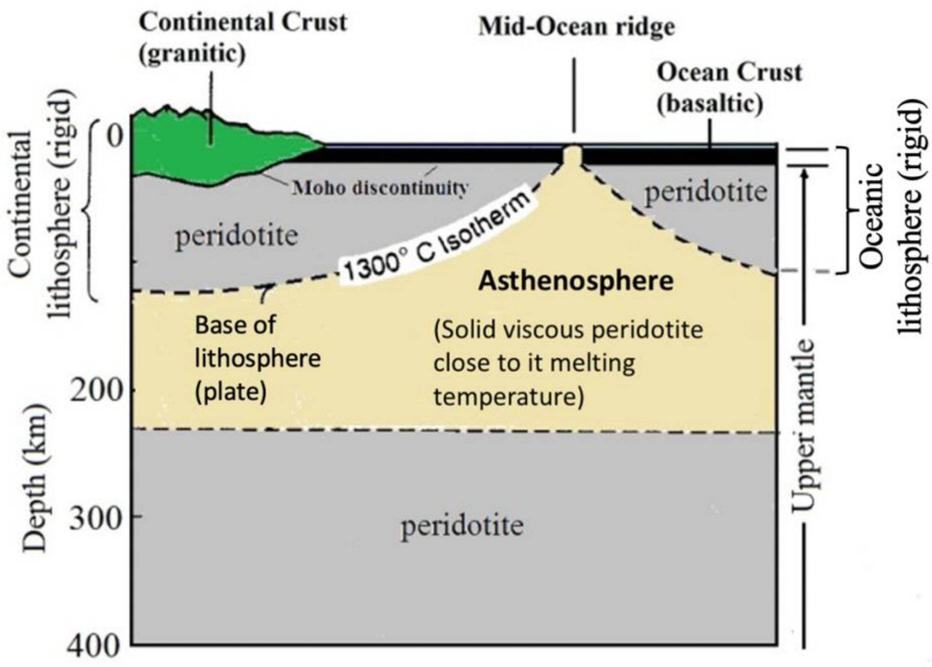

Figure 2: Continental and lithospheric (tectonic) plates consist of strong, rigid crust **and** upper mantle. Their thickness depends upon where rock temperatures are less than 1300°C. Plates are, on average, 125km thick, reaching maximum thickness below mountain ranges. Oceanic plates (50-100km) are thinner than the continental plates and even thinner at the ocean ridges where the temperatures are higher. *(Pete Loader)*

Time for 'chocolate'!
To demonstrate this distinction between chemical and mechanical properties, take two chocolate bars with a chewy, caramel centre (e.g. Chomp bar®). Place one in a freezer overnight and leave one at room temperature.

- Unwrap the frozen bar and discuss with the class that it is made of chocolate around a chewy caramel centre. Ask them to predict what they think will happen if you deform the bar by pushing down whilst holding both ends between your fingers. *Usually they will say the bar will bend though the chocolate may crack*.

- When the bar snaps (to their surprise) suggest that to make this a fair scientific test the experiment should be done again. This time the bar at room temperature will bend as they originally predicted.

- Ask what the chemical difference is between the two bars. *Nothing!*

- Explain that the snapped bar was in the freezer overnight and has mechanically behaved differently because of the difference in temperature.

- Ask if either of the bars is liquid or molten. *No! But the bar at room temperature is nearer its melting point.*

Figure 3: Chomp bars after same force was applied to them. *(Pete Loader)*

- Ask how this simulation might help to answer the question, 'What is a tectonic plate'? *The colder, outer, mechanical layer of the Earth (less than1300ºC) represents a strong, brittle lithospheric plate whilst the weaker asthenosphere is hotter (nearer its melting point, but not molten) and is able to flow (it is more ductile).*

- Share the chocolate bars! (Warning – frostbitten tongue!)

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The back up

Title: Chocolate plates

Subtitle: Simulating the properties of a lithospheric plate

Topic: A simulation of the mechanical properties of a lithospheric plate using chocolate bars.

Age range of pupils: 15 years +

Time needed to complete activity: 10 minutes

Pupil learning outcomes: Pupils can:
- describe two methods of defining Earth's outer layers (chemical & mechanical);
- explain that temperature influences the way in which rock behaves (deforms) mechanically;
- describe the composition of a lithospheric plate in terms of its chemistry (crust and upper mantle);
- describe the structure of a lithospheric plate in terms of its mechanical properties (strong, rigid);
- explain the reason for the variation in thickness of lithospheric plates.

Context: This simulation helps answer the question "What is a tectonic plate"? It explains that materials of the same composition can mechanically behave differently when at different temperatures – analogous to the lithosphere and asthenosphere. This is to counter a common misconception that refers to tectonic plates as features of the Earth's surface only associated with the crust.

Following up the activity: Students can progress to any of the Earthlearningidea activities on plate tectonics by typing '*plate*' into the Earthlearningidea search engine.

Underlying principles:
- A tectonic plate is composed of both crust (continental, oceanic or both) **and** the upper part of the mantle.
- A plate is of varying thickness which is controlled by the depth at which mantle rock reaches 1300ºC.
- Below 1300ºC the mantle behaves as a strong, rigid, brittle unit which moves as one to form the lithosphere.

- Where the mantle is above 1300ºC (the asthenosphere) it is closer to its melting temperature (but almost entirely solid) and behaves as a ductile solid which can flow over geological time.
- Lithospheric plates are thinner at divergent plate boundaries (e.g. mid-oceanic ridge) where the 1300ºC isotherm is nearer the surface.
- The lithospheric plate gets thicker (the base deeper) as it becomes older and colder on moving from a divergent plate margin.

Thinking skill development: Students need to construct a model of a tectonic plate in their minds based on the simulation. Cognitive conflict comes from the different behaviours of the two identical chocolate bars. Metacognition through discussion requires the development of bridging skills between the simulation and reality.

Resource list:
- chocolate bars with chewy, caramel centre (e.g. Chomp bar®)
- access to a freezer

Useful links:
https://www.geolsoc.org.uk/Plate-Tectonics/Chap2-What-is-a-Plate
https://www.earthlearningidea.com/PDF/334_Top_bottom_plates.pdf

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