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GeoBus supporters 2012 - 2018:

Plate Tectonics and their Hazards

These workshop notes are designed for use along with the accompanying slides which contain further notes

Year Group: S1 - S4 (11 - 15 years)

Length: approx. 1hr30 but easy to focus on specific hazards and expand or shorten as required

Set-up Time: 15-30mins depending on activities

Room requirements: A classroom space with desks, ideally in groups of 4-6, sink nearby is useful

Summary: Plate tectonics is the driving force behind some of the Earth's most devastating natural disasters. Pupils are first introduced to the theory of plate movements, tracking them through time to create the continents we see today and revealing the relationship to natural hazards. The workshop then takes a closer look at *volcanoes*, *earthquakes* and *tsunamis*, using practical activities including earthquake modelling, simulated volcanic eruptions and a tsunami evacuation race.

Equipment:

- Science putty[1]
- Large boxes filled with plain flour[2]
- Balloons
- Wooden skewers
- Film canisters (with lids)
- Effervescent vitamin tablets
- Jugs/bottles of water
- Coarse sandpaper (A5-size, per group)
- Masking tape
- Breeze block/brick (1 per group)[3]
- Newton Meter (1 per group)
- Thin pipe or spare marker pens
- String
- Rulers
- Bean bags (10 sets of 15-20 bags)
- Printed signs/flags for each country

[1]Also sold as 'bionic putty' or use oobleck (cornflour and water mixed in a 2:1 ratio)
[2]Not essential but helps if these have a lid for tiding up purposes!
[3]Alternatively, a fairly heavy object with sandpaper attached to it to provide a rough surface

EarthViewer - www.hhmi.org/biointeractive/earthviewer (also available as app) is a useful additional tool, as it provides an interactive display of the changing positions of the continents through time

History of plate tectonics:

Around 1912, German researcher Alfred Wegener looked at world map, felt is seemed like jigsaw puzzle and started to suggest that some continents would fit together (e.g. South America and Africa). His idea (which he called 'Continental Drift') was laughed at as he had no evidence to support his theory, but after his death his ideas were developed by others and the theory of Plate Tectonics was eventually accepted in the 1950's.

[For the rather tragic story of Alfred Wegner, see this song/video by Science Rock band The Amoeba People titled 'Continental Drift' - https://www.youtube.com/watch?v=T1-cES1Ekto]

Evidence for plate tectonics:

Geology – Plutons (large underground bodies of magma) of the same age and same chemistry are found on both sides of the Atlantic, suggesting the continents were once connected. Similarly, there is evidence of the same mountain-building event in Scotland and Greenland/North America.

Plate Tectonics and their Hazards

Fossils – Plants of the same species have been found on different continents – they couldn't pollenate across that kind of distance so must have spread when the continents were connected.

Climate – The rock record shows that in the past, the continents had very different climates from today. Not only does evidence of past climates show areas that must have once been joined, it also indicates that the continents must have been in different locations. For example, there is evidence of tropical swaps in Scotland!

Driving forces:

We now know that our planet is made up of different layers; an inner core, outer core (discovered by a German female scientist called Inge Lehmann), mantle and crust. The mantle is solid but can behave in a *plastic* way, meaning it can move and flow (a bit like ice can flow under certain conditions on the surface, forming glaciers).

Demonstration: Use putty – or oobleck – to demonstrate that solids can flow. Putty: roll into a short sausage, pinch with both hands in the middle and then pull sharply apart, the putty will snap (behaving like a brittle solid) – however if you make a teardrop shape and hold the narrow end, it will start to 'drip' downwards, flowing under its own weight (behaving in a ductile way). Oobleck: will move and flow if handled gently but breaks into shards if hit with a hammer or squeezed suddenly.

In the mantle, the bottom of the layer is warmed up (by the heat from the core – caused by radioactive decay of elements) and is then less dense. It rises up and spreads outwards underneath the crust layer. It then begins to cool, becoming more dense again and sinking down. This creates a convection current – these occur throughout the mantle and drives the movement of the tectonic plates.

As a result, the crust is split in to 7 large plates (and some smaller ones) that are constantly moving – some apart from each other, some together, some side by side … all at a rate of a few centimetres per year (or roughly the same speed finger nails grow).

Hazards associated with tectonics:

Earthquakes – occur when friction prevents the plates moving past (or towards) each other and energy builds up which is then released as ground vibrations when the plates eventually move. Most occur at plate boundaries as forces are concentrated.

Volcanoes – occur where part of the mantle is able to melt, forming magma, and rise through the crust to the earth's surface. Where plates are moving apart (spreading margins/divergent boundaries) the crust is thin so magma can easily rise through (decompression melting) and where they are coming together with one plate being subducted below another (destructive margins/convergent boundaries) the down-going slab releases water which makes the mantle easier to melt. Volcanoes can also form at 'hot spots' – areas of the mantle with a temperature anomaly which causes melting (e.g. Hawaii).

Tsunamis – can originate from earthquakes that either occur underwater (directly displacing water) or occur near the coast (material falls in and displaces water). Can also be caused by landslides and other processes that result in quick displacement of large amounts of water.

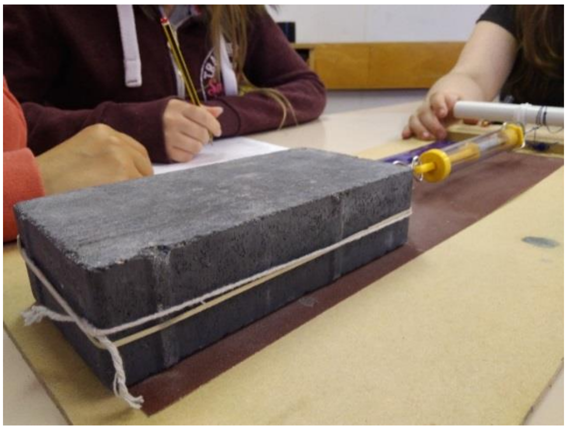
The following pages provide a series of demonstrations/discussions about each of the hazards which can be combined to give the 'full' workshop, or any individual hazard can be studied in more detail.

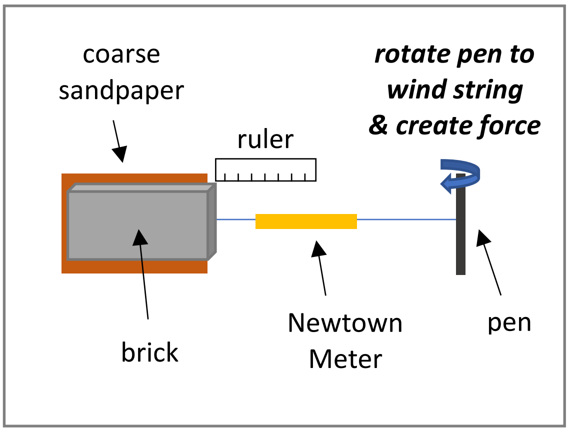
Plate Tectonic Hazards: Earthquakes

Demonstration to show the build-up of forces and release of energy as a result of plate tectonic motions – causing earthquakes to occur at plate boundaries.

Set-up:

1. Securely attach a piece of sandpaper to the table using tape (alternatively, if this will be repeated multiple times, the sandpaper can be glued to wooden board as shown below). This represents one of the tectonic plates.
2. Place the brick (or heavy block with sandpaper face down) on top. This represents a second tectonic plate.
3. Tie a piece of string in a loop around the brick/block as shown below.
4. Take another piece of string and tie one end to the Newton Meter. Attach the other end to the length of thin pipe/pen using tape, and wrap around a few times to secure.
5. Hook the other end of the Newton Meter in to the loop of string around the brick/block.
6. Place a ruler alongside the set up so that '0' is at the front edge of the brick.





Activity:

Pupils gently but continuously turn the pipe/pen to represent motion in the mantle – while holding it in the same place at the end of the board (not moving the pen towards the brick). The spring in the newton meter will stretch and the force can be seen to increase as friction prevents the brick from moving on the coarse sandpaper.

When the forces become too great, the brick will suddenly move. Pupils can record the amount of movement by marking where the brick has moved to along the ruler (recorded as a tally on the handout sheet). Pupils can then continue to wind in the string and record further movements (every so often the brick will need to be 'reset' by unwinding the string and putting it back on top of the sandpaper).

Either allow the pupils to collect a significant data set (15 'slips') or combine the data from the whole class to show that the frequency of small slips is much higher than large ones. This is the case in real earthquake situations (see frequency graph in slides) – luckily very large, destructive earthquakes are not as common as smaller ones.

See also the GeoBus 'Earthquakes' workshop which looks in more detail at the energy released by earthquakes and considers the importance of building safe-structures in earthquake-prone areas.

Plate Tectonic Hazards: Volcanoes

Activities to show the formation of a volcanic caldera and to demonstrate the driving force of explosive volcanic eruptions.

[1] Caldera Collapse

Set-up:

1. Each group needs a box of flour, a balloon, and several wooden skewers (or sharp pencils)
2. Blow up the balloon until it is just a little bigger than a tennis ball in size, and carefully burry in the flour, creating a volcano shape with the balloon as the 'magma chamber' hidden inside *(this can also be done in advance if you want to give pupils the surprise/minimise mess!)*
3. Pop the balloon by stabbing the skewers/pencil through the flour, creating a small eruption and a huge crater shape due to the collapsed flour in the middle of the box

During large explosive volcanic eruptions, a process similar to this occurs and the top of the volcano will collapse in on itself, creating a volcanic crater that is known as a caldera. This occurred at Glencoe around 420 million years ago, due to a huge eruption - Glencoe is world famous not just as a stunning landscape that attracts thousands of tourists, but also because it was the first ancient caldera to be recognized in the geological record.

[2] Driving force of explosive eruptions

Set-up:

1. Each group needs three film canisters + lids, a jug of water and 3 half effervescent tablets (some paper towel on hand is also useful!)
2. Fill one canister ¼ full of water
3. Fill a second canister ½ full of water
4. Fill the final canister ¾ full of water

*** the next step should be completed for all three canisters at the same time ***

5. Quickly drop one of the half tablets in to the canister and replace the lid (allowing it to seal completely with a 'click'), then turn the canister upside down
6. Stand back and wait …

Pupils should be warned not to lean over the pressurized canisters, and everyone in the room should be made aware that the experiment is taking place – care should also be taken not to place the canisters under any delicate light fittings or near items of work that would be ruined by getting wet!

After a period of time, each of the canisters should pop open due to the build-up of pressure from the gas released by the effervescent tablet. Ask pupils to observe which order the canisters popped (¾ full, less space for gas to fill, so pops faster) and which went highest (¼ full, more space to build pressure, therefore force of explosion is greater when it does pop).

The expansion of gas (dissolved from the magma, usually H_2O and CO_2) drives large, explosive, volcanic eruptions. Similarly, if there is lots of gas build up (often due to more viscous, sticky magma which prevents the gas from escaping easily) the eruption will be more violent.

An active demonstration of the importance of early-warning systems in tsunami-prone areas

Set-up:

1. Lay out the flags representing the 10 countries with a pile of beanbags by each, and mark a 'safe' area a couple of meters away
2. Pupils should arrange themselves in small groups so that there is the same number of people allocated to each country, and stand between the pile of beanbags and the safe area
3. On the word 'go' the warning system sounds and pupils can start moving the bean bags – representing local people – to safety
4. As the tsunami wave hits each country (in the order noted below), anyone not evacuated is in danger and the pupils allocated to that country must stop and sit down
5. Bean bags cannot be thrown (transport people safely) and only one may be in transit at a time
6. After the wave has hit the last country, count how many bean bags have been saved

Country order:

- Indonesia — give approximately 10 seconds
- Thailand
- India
- Sri Lanka
- Myanmar
- Malaysia
- Maldives
- Seychelles
- Somalia
- Kenya — give approximately 2 minutes

The time given should be varied depending on the number of bean bags/distance/number of pupils – Indonesia should only be able to move 1-2 and Kenya should be able to move them all.

This represents the order in which the countries were hit by the wave (i.e. how much warning they had) but the death toll was relatively higher in some countries than would be expected based on this. Part of the reason is the specific shape of the landscape and how many people live in exposed areas, but it is also true that countries that can't afford early warning systems, lack communication or education about tsunamis may have a higher death toll.

The activity can be repeated with handicaps on some of the countries to reflect preparedness and economic ability of the country. For example; Thailand can transfer 2 bags at a time, Somalia can only transfer using their elbows.