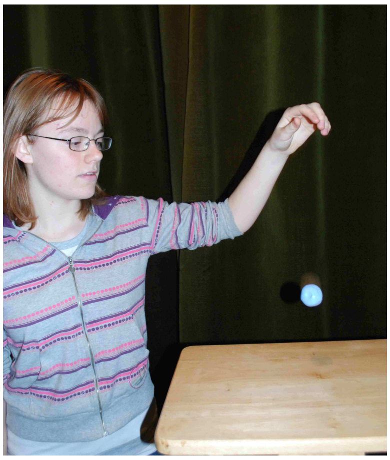
Bouncing, bending, breaking
Modelling the properties of the Earth's mantle with Potty Putty™ from a toy shop

Pupils (and some writers of textbooks) often find difficulty in understanding how the rocks of the mantle can have different properties in different circumstances. The mantle transmits earthquake waves by elastic deformation; although solid, it can flow; it can also fracture dramatically. How can this be?
The physical properties of the mantle can be modelled using a silicone putty, known as Potty Putty™. This can be bought in toyshops or made in a school lab (See Resources).

Give each pupil a small piece of Potty Putty™ (about 1 cm across) and ask them to roll it into a ball.
Ask the pupils to drop the ball onto the bench from a height of only four centimetres or so and watch it bounce (elastic deformation).

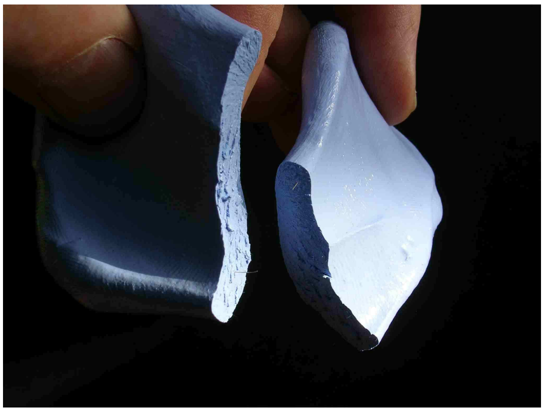


Elastic deformation (with a full class, start from a lower height!)

Ask them to stretch out their piece of putty and hold it up so that it droops under its own weight (plastic or ductile deformation, or flow).

Plastic deformation under its own weight

Invite them to roll it up again and pull it apart sharply to see if it breaks (brittle deformation).



Brittle deformation when pulled apart

Collect up all the pieces, roll them up into a ball and place the ball on the desk or table. Show pupils by how much it has spread out by the end of the lesson (by flowing under the influence of gravity).

(You may also wish to demonstrate that the putty will shatter into small pieces when hit by a hammer, but don't do this if the room is carpeted or if pupils are wearing their best clothes – extracting bits of putty from textiles takes a lot of "dabbing" with a larger piece!).

Brittle deformation when hit by a hammer
(*Photos: Peter Kennett*)

This activity demonstrates that it is essential to consider the time factor when studying the effects of stress: short sharp stresses cause brittle failure; stresses imposed over longer times cause elastic deformation; stresses over even longer time spans cause plastic/ductile flow.

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The back up

Title: Bouncing, bending, breaking

Subtitle: Modelling the properties of the Earth's mantle with Potty Putty™ from a toy shop

Topic: Pupils work with Potty Putty™ to discover how one single material can respond elastically, plastically or by brittle failure, depending on the scale and duration of the applied stress.

Age range of pupils: 14 – 18 years

Time needed to complete activity: 5 minutes

Pupil learning outcomes: Pupils can explain that, under different scales and duration of stress a solid material can behave:

- in an elastic way, (and therefore transmit earthquake waves)
- in a plastic/ductile way (and can therefore flow or creep, whilst still being a solid)
- in a brittle way (and can therefore fracture, which could create an earthquake).

Context: Understanding how the rocks of the mantle can behave in a brittle way is not difficult – pupils will know that when a rock is hit with a hammer, it will break! Seismic evidence shows that the Earth's mantle may also transmit earthquake waves, by the elastic deformation of the mantle rocks, showing they must be solid. However, mantle rocks may also "flow" or creep, given enough time and under the conditions of higher temperatures and pressures existing within the Earth. Some textbook writers assume that pupils will not be able to understand that flow can happen in a solid material and therefore state that the mantle is largely liquid, even though seismic evidence contradicts this.

Following up the activity:
Study seismic data which demonstrate that:

- earthquake waves can pass through the mantle (by elastic deformation), as shown in the graph below of P and S wave velocities through the Earth;

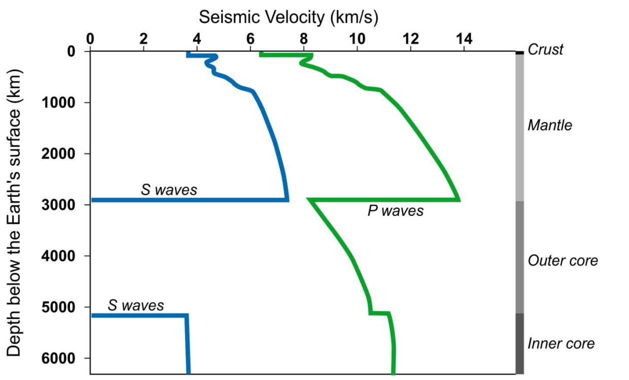

Diagram by permission of the Earth Science Education Unit

- the mantle is almost completely solid (apart from very localised magma chambers, only a few kilometres across);
- the upper mantle is capable of brittle failure, which generates earthquakes. Discuss the rate of movement of the plates of the Earth's outer layers, demonstrating plastic deformation of the mantle beneath.

Underlying principles:

- One single substance may demonstrate the properties of elastic, plastic and brittle deformation depending on the stress conditions.
- Earthquake waves are transmitted by the elastic deformation of the rocks of the solid mantle, i.e. the rock particles oscillate forwards and backwards and from side to side but return to their original positions.
- Earthquakes are generated within the top 700 km or so of the mantle by brittle failure of rock masses.
- The various tectonic plates are moving in relation to each other at a few centimetres per year, as a result of plastic flow in the largely solid mantle beneath. (The mantle can be up to about 5% liquid, held between the crystals of its rocks, in the relatively weak zone known as the asthenosphere, approximately 150 km below the Earth's surface. P and S wave velocities decrease here, as shown in the graph opposite).

Thinking skill development:
Understanding how one substance can exhibit three types of deformation involves cognitive conflict. Applying the Potty Putty™ investigation to the Earth's mantle involves a major effort at bridging.

Resource list:
Potty Putty™ (also known as Silly Putty™) from toy shops, or laboratory suppliers, or made from PVA glue and borax (See http://www.esta-uk.net/jesei/index2.htm, 'Solid mantle in full flow: the DIY potty putty simulation' for recipe).

Useful links: See how mantle convection and plate movement can be simulated using syrup at: http://www.esta-uk.net/jesei/index2.htm' Mantle convection moving plates: the golden syrup / hobnob teacher demonstration' (but be wary of allowing students to think that the mantle IS liquid)

Source: Based on the workshop titled "The Earth and plate tectonics", Earth Science Education Unit. http://www.earthscienceeducation.com