DEEP EARTH EXPLORERS – SUGGESTED ANSWERS

These are some suggested answers to the worksheet. They are NOT the only right answers, and things not on here might also be valid answers to the questions; these have only been provided so you can see the kind of thing the questions were trying to get at.

Experiment 1 – Silly Putty

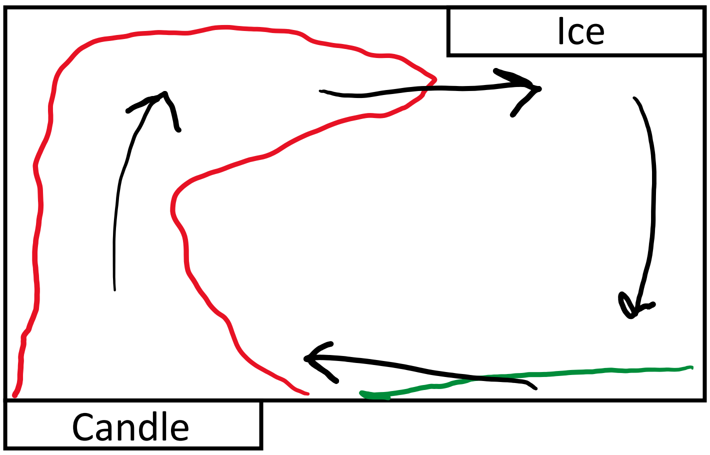
Follow at the instructions on the first page of 'Experiment Instructions' to do the experiment.

What are the material properties of silly putty? (hint: how does it behave differently over short timescales compared to long timescales e.g. seconds vs hours?)

On a short timescale, silly putty behaves like a solid – you can bounce it, and it holds its shape. Over a longer time, silly putty behaves like a fluid – it flows e.g. down a slope, or down out of your hands in a long snake.

Experiment 2 – Convection

Follow at the instructions on the second page of 'Experiment Instructions' to do the experiment. Then, complete the diagram to show what happened.



Why did you see this pattern? (hint: if you're stuck, try thinking about how hot air balloons work)

The candle heats up the water below it, and makes it rise up because it's less dense (because all the particles are moving faster and more spread-out in hot materials). The ice makes the water cold, and sink. Because the water is moving up on the candle side, water is pulled along the bottom from the ice side to replace it.

*What other examples of **convection** in real life can you think of?*

e.g. Hot air balloons.

Tubes that form in rice when you cook it, which are holes where the hot steam rises up from the bottom of the pan.

Farts rising to the top of the room.

In hot rooms at night, the floor is always the coolest place to sleep because the cold air sinks.

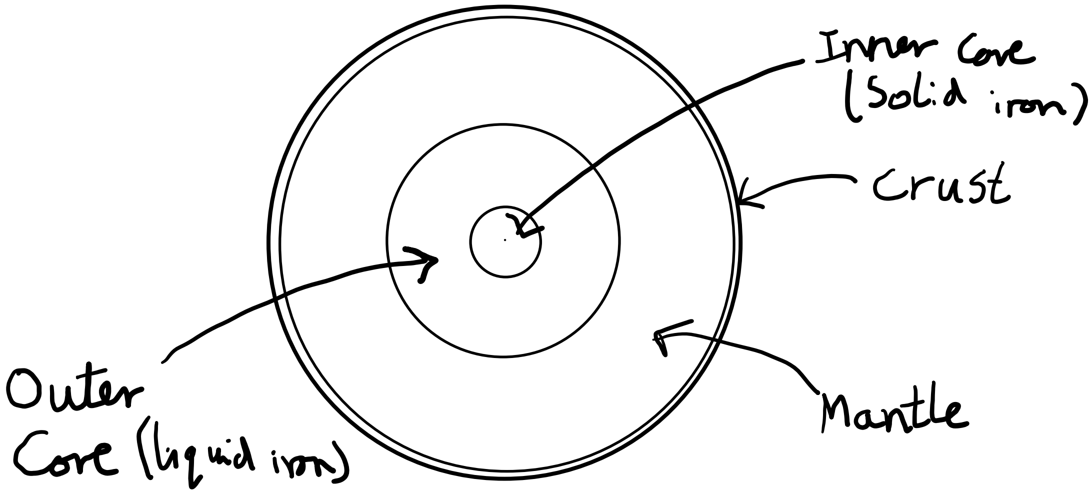
The Earth's inner core (where convection generates the Earth's magnetic field).

Which states of matter usually convect: solids, liquids, or gases?

Usually liquids and gases. Importantly, only **fluids**.

THE INSIDES OF THE EARTH

Complete and label this diagram with the structure of a cross-section(slice) through the Earth.



How do you think we know this? How might we 'look' inside the solid Earth? (hint: how do we look inside other solid things e.g. people?)

Whatever occurs to you – this is mostly a question about getting you to think. We image people using x-rays and 3D CAT scans, so perhaps we could look inside the Earth in a similar way?

Theoretically, it might be an idea to cut open/drill into the Earth to have a look. However, this is very difficult because of the pressure and heat. The deepest ever borehole (the Kola Superdeep borehole) is only 12km deep. That's less than half the thickness of the crust there, and only 0.2% of Earth's radius.

Use the images on sheet 1 to answer the following questions.

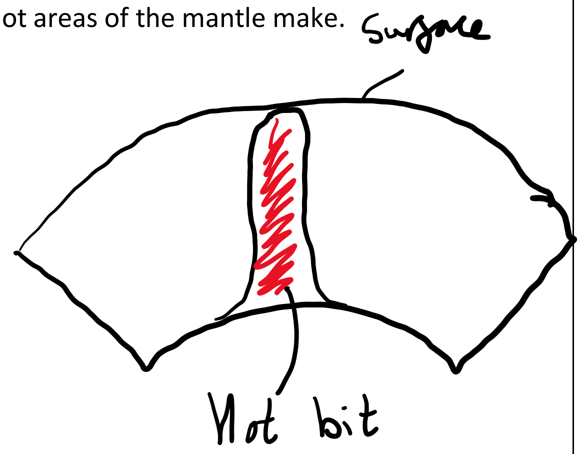
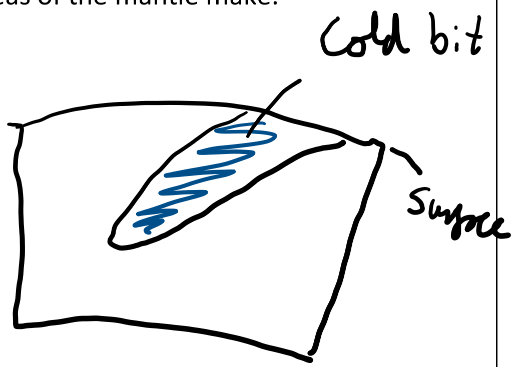
In the ***tomographic images****, are red areas hotter or colder than the surrounding mantle?*

Red areas have a lower seismic wave speed than the surrounding mantle. Lower seismic wave speed means higher temperature, because the particles are spaced further apart and vibrating more. Therefore, red areas are hotter than the surrounding mantle.

What about blue areas?

Blue areas are colder than the surrounding mantle.

Sketch and label the important patterns in the images.

For the images in A, sketch the shapes that the hot areas of the mantle make.	For the images in B, sketch the shapes that the cold areas of the mantle make.
	

Which direction do you think the hotter patches in mantle are moving?

The hot patches are less dense and so are probably moving up.

What about the colder patches?

The cold patches are denser and so are probably moving down.

What might this mean for what is going on in the ***mantle****? (hint: think back to experiment 2)*

The Earth's mantle is convecting! There are hotter bits moving up, and colder bits moving down, just like in our convection tank.

EXPERIMENT 3 – MAKING HOTSPOT TRACKS

Follow the instructions on the fourth page of 'Experiment Instructions' to make your own hotspot track! Hotspot tracks usually result in a series of discrete volcanoes rather than one long volcano.

The Hawaiian hotspot track bends because the Pacific plate changes direction in the past. We can use hotspot tracks in a useful way to work out how the Earth's plates have moved in the past.

MEETING THE MANTLE

*How can you reconcile the **mantle** being **solid Peridotite** and also convecting (i.e. flowing like a **fluid**)? (hint: think back to experiment 1)*

The mantle is like the silly putty – on short timescales (like, the kind of timescales we can see) it is a solid, and acts like one. However, on very long timescales (longer than the couple of minutes for silly putty) the mantle can flow like a fluid, and so convect. This doesn't mean that the mantle is ever not a solid, just that solids (like silly putty and the mantle) can behave like fluids on long timescales.

FLOWING SOLIDS

*Can you think of any other examples of **solids** which behave as **fluids** on a long timescale?*

e.g. Glass does! However, this isn't the reason why old windows are thicker at the bottom – it happens far too slowly for that. It was just hard to make flat glass in the past, and when you put in the pane of glass it's safer and stronger to put the thick bit at the bottom.

Bitumen or 'pitch' is the most famous example (There's a famous experiment with pitch: https://youtu.be/BZvsrOciU_Q).

Ice also does e.g. in glaciers.

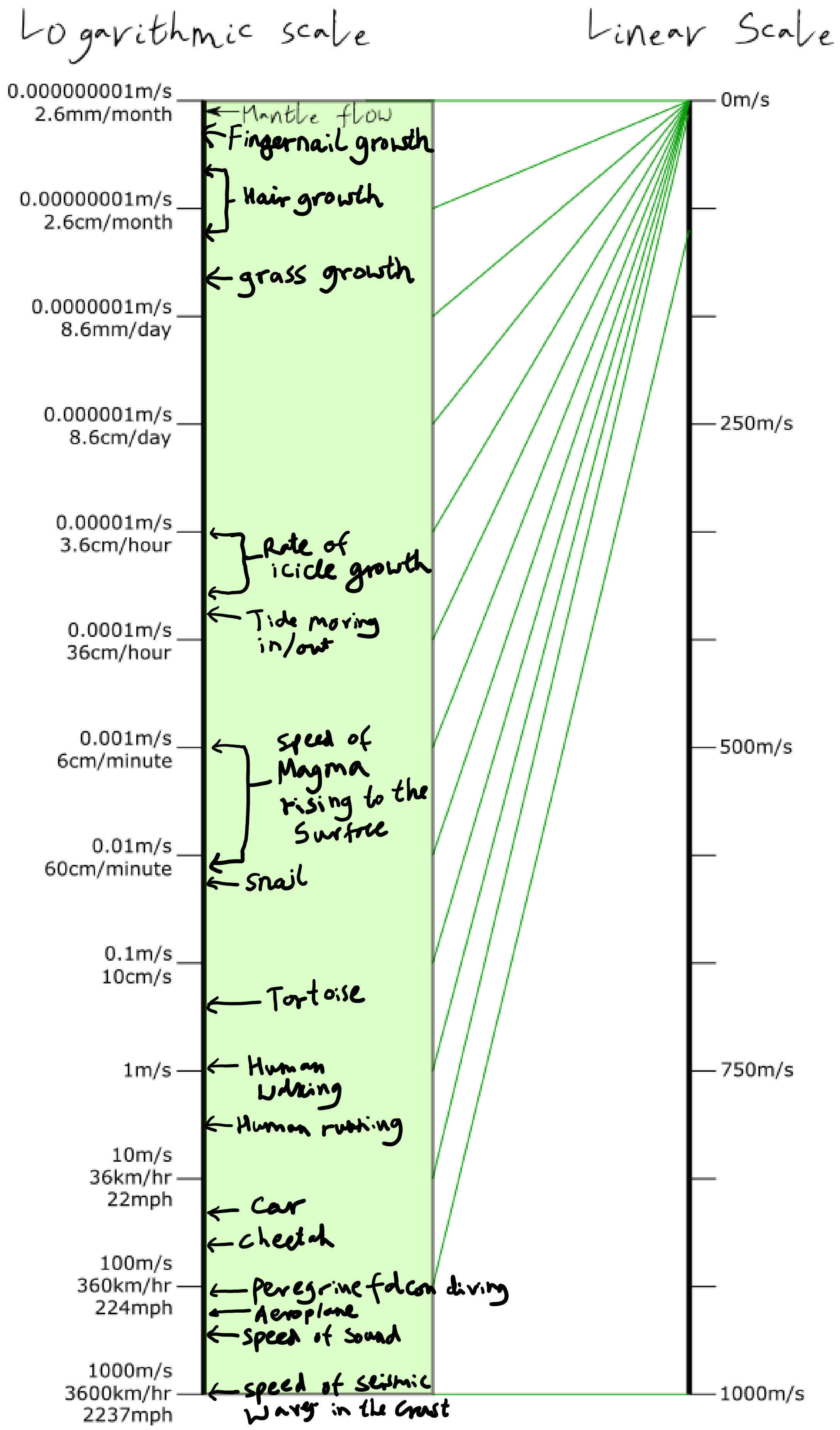
EXPERIMENT 4 – CREEP

In the images to the left, these stripes and bands can be seen in a glacier.

Which direction do you think the glacier is moving?

Like in experiment 4, and with the silly putty, creep makes lines parallel to the direction of flow, so in a) the glacier is flowing out of/into the page.

SHEET 2 – TIMESCALES TIMELINE

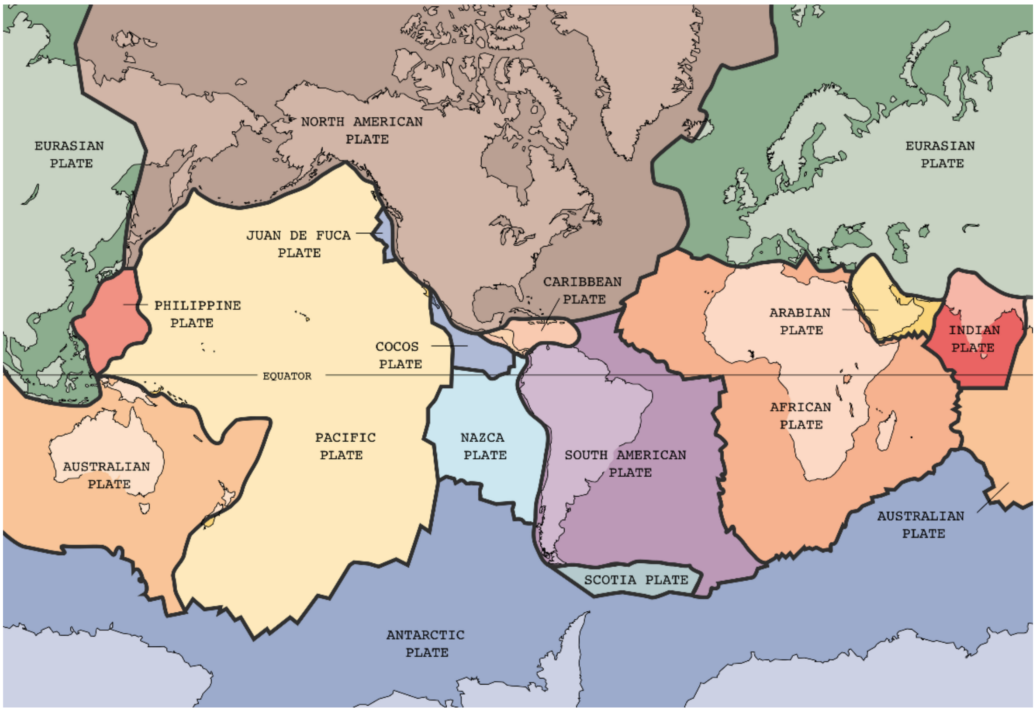


EXTENSIONS/QUESTIONS TO THINK ABOUT AND RESEARCH

WARNING: A lot of websites and people will tell you that the mantle is made from molten rock or magma – we know this is wrong, and the mantle is actually solid!!

1) Kimberlite pipes are famous for being a source of diamonds in the Earth's crust. Because diamonds only form under immense pressure (at the surface carbon naturally forms coal or graphite), on Earth diamonds are only formed in the mantle. Since kimberlite pipes bring up bits of the mantle, sometimes this includes diamonds! See more here: https://simple.wikipedia.org/wiki/Kimberlite

2) Plate tectonics is the idea that the hard, brittle, crust and upper mantle of the Earth is broken into plates. This is rather like a cracked eggshell on a boiled egg. These plates move around the surface of the Earth very slowly (between 1mm and 17cm a year). Here is a map of the tectonic plates:

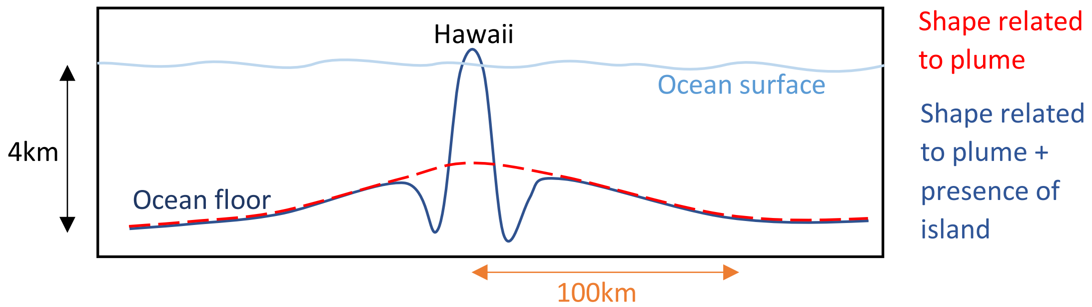


See here for more: http://eqseis.geosc.psu.edu/cammon/HTML/Classes/IntroQuakes/Notes/plate_tecto

1.html or https://www.nationalgeographic.org/topics/resource-library-plate-tectonics/?q=&page=1&per_page=25

3) Subduction something that happens at a boundary between two tectonic plates which are moving towards one another. One tectonic plate dives down under the other one, down into the mantle. Famous earthquakes/tsunamis related to subduction include the 2004 boxing day tsunami, and the 2010 Tohoku earthquake and tsunami. They are famous because subduction zone earthquakes tend to be very big compared to other types, and because subduction zones are usually under the sea and therefore produce tsunamis. See more here: https://youtu.be/oWzdgBNfhQU

4) The plumes are rising up and hit the bottom of the plate with an upwards motion, which pushes up the sea floor. We can see this around Hawaii:



Because plumes usually have a roughly circular cross-section, in 3D these shapes are usually domes. For more about how we use the shape of the sea floor "bathymetry", see here:
https://www.nationalgeographic.org/encyclopedia/bathymetry/ or
https://oceantracks.org/library/oceanographic-factors/bathymetry