2.1 Earth surface jigsaw

Lesson outcomes

At the end of this activity students will be able to:

- describe the evidence for continental drift theory based on the shape of southern continents and the distribution of certain fossils.

Key vocabulary:

Gondwana, supercontinent, Alfred Wegener, continental drift.

Equipment list

Each STUDENT will require:

- scissors, glue
- coloured pencils or marker pens
- handout worksheet (pages 26 (Fossil Evidence) and 27 (Wegener's Puzzling Evidence) only from https://volcanoes.usgs.gov/vsc/file_mngr/file-139/This_Dynamic_Planet-Teaching_Companion_Packet.pdf)
- *Science by Doing* ***Notebook***

Things to consider:

Students may have the same reasons for disbelieving that the continents could drift that scientists had for the first half of the twentieth century. This is mainly that it simply sounds implausible and they, like the scientists, may not be aware of any mechanism that could account for it. In science a new theory without an appropriate mechanism will be unlikely to have wide acceptance, or at least will be seen as problematic. The doubts of the students will be perfectly reasonable at this stage. It is worth discussing with the class as a whole what they think of this idea, rather than regarding it as unproblematic at this early stage in this part of the unit.

This topic could be extended to include a greater SHE emphasis by including a discussion of how this scientific idea took so long, half century in fact, to be accepted by the wider scientific community.

Teacher content information

The development and final acceptance of continental drift theory is an interesting scientific story. Alfred Wegener was primarily a meteorologist and climatologist. In 1906 and 1913 he was involved in expeditions to Greenland and his observations there helped direct his attention to the origin of the continents. The fundamental aspect of his continental drift theory, and the one that was so contentious, was that the present position of the continents was the result of movement. He was the first to propose the existence of the supercontinent, Pangaea, which eventually broke into two smaller continents, Gondwana and Laurasia. This idea that all the land on Earth was at some stage confined within a single continent was indeed startling.

As his theory was presented to the broader scientific, and in particular the geological community, it met with fierce resistance. Reportedly the American Association of Petroleum Geologists organised a symposium during the 1920's, specifically to oppose his ideas. One of the main stumbling blocks was the lack of an accepted mechanism that could account for the movement of whole continents. How could they plough through sections of oceanic crust to get to where they are today? In science the existence of mechanisms to account for new theories is always important.

The fact that certain continents appear to fit together like a jigsaw has been recognised for a long time. Certain patterns in the geology and fossil distributions of some continents have also been known for a long time. Nearly 400 years ago Francis Bacon noticed that the outlines of the east coast of South America and the west coast of Africa matched, and these are still the most obvious match. Distributions of fossils, glacial deposits, and geological features also suggested previous links between continents that are far apart. The latter were such a problematic set of observations that some scientists suggested that long land bridges had previously existed spanning both the Atlantic Ocean.

One frequent problem with this activity is often that the continental outlines themselves don't match exactly. Wegener, as early as the 1920's realised that the shallow continental shelf regions should also be included, since they are part of the continent even though they happen to be underwater today. They are included in this activity. Page 25 from https://volcanoes.usgs.gov/vsc/file_mngr/file-139/This_Dynamic_Planet-Teaching_Companion_Packet.pdf shows the correct arrangement of the continents forming the supercontinent Gondwana. See also page 20 of the *Student Guide*.

Note – Glossopteris has long been considered a fern after its discovery in the 1820s but has lately been assigned to the gymnosperms.

Lesson plan

Step 1: Ask students to put names onto the centre of each continent – South America, Africa, India, Antarctica, and Australia.

Step 2: Direct students to read about each of the fossils. Choose a colour for each fossil and colour it in where it is located on the different continents.

Step 3: Cut out the five continents. Using the continent edges and fossil deposits arrange them to form the supercontinent Gondwana.

Step 4: Discuss as a whole class the significance of the evidence you have examined. Although Wegener first proposed the idea of continental drift early in the 20th Century, it was not widely accepted until the 1960's.

Why do you think this was the case?

Why did other scientists not believe that the continents could move in this way?

2.2 Ring of Fire

Lesson outcomes

At the end of this activity students will be able to:

- describe the pattern of volcanic and earthquake activity in the Pacific region and identify the patterns and relationships between these.

Key vocabulary:

Gondwana, supercontinent.

Equipment list

The CLASS will require:

- map of Pacific region printed on A3 paper

Each GROUP will require:

- internet access

Each STUDENT will require:

- map of Pacific region on A4 paper.

Teacher content information

The fact that certain continents appear to fit together like a jigsaw has been recognised for a long time. Certain patterns in the geology and fossil distributions of some continents have also been known for a long time. Nearly 400 years ago Francis Bacon noticed that the outlines of the east coast of South America and the west coast of Africa matched, and these are still the most obvious match. Distributions of fossils, glacial deposits, and geological features also suggested previous links between continents that are far apart. The latter were such a problematic set of observations that some scientists suggested that long land bridges had previously existed spanning the oceans.

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Lesson plan

Step 1: Form students into small groups and divide the 16 volcanoes between the groups. Allow students' time to research the locations and details of each volcano.

Step 2: Let each group mark the locations of their volcanoes on the A3 map and recount an interesting fact about each one. All students should copy the volcano locations to their own A4 maps.

Step 3: Explore the digital activities about geological activity around the Pacific Ocean and complete the ***Notebook*** tasks. Discuss and compare student answers.

2.3 Plates on the move

Lesson outcomes

At the end of this activity students will be able to:

- describe the theory of plate tectonics
- explain how the theory of plate tectonics accounts for the shapes of continents and the pattern of fossils found in different continents.

Key vocabulary:

Convergent boundary, divergent boundary, transform boundary (conservative boundary), mid-ocean ridge, continental rift boundary, mantle.

Equipment list

Each STUDENT will require:

- internet access
- ***Notebook.***

Things to consider

- You might consider projecting the video on to a screen for a class viewing.
- Ensure each student has their own device for the digital interactive activities.

Teacher content information

- This activity provides the substantial details of tectonic plate theory. Students learn about the current pattern of tectonic plates on Earth, as well as their current relative motions.

Lesson plan

Step 1: Use the **Student Guide** to introduce the theory of plate tectonics and the various tectonic plate boundaries.

Step 2: Show the video to the class before inviting students to explore the digital activities.

Class discussion

How does the modern theory of plate tectonics account for the shapes and patterns of current continents, the pattern of fossils found on different continents, and the concentration of geological activity around the rim of the Pacific Ocean?

2.4 Ocean floor conveyers

Lesson outcomes

At the end of this activity students will be able to:

- describe how new crust is formed at divergent boundaries
- provide evidence for the creation of new crust at mid-ocean ridges in the Atlantic and Pacific Oceans.

Key vocabulary:

Mid-ocean ridge, oceanic crust, continental crust, hydrothermal vents (smokers), sea floor spreading, magnetic striping, craton.

Equipment list

Each STUDENT will require:

- internet access
- ***Notebook.***

Things to consider

- You might consider projecting the videos on to a screen for a class viewing.
- Ensure each student has their own device for the sea floor spreading simulation and plate boundary quiz.

Teacher content information

The mid-oceanic ridges appear to be the place where new crust is formed. Most of this is oceanic crust. There is one place where new crustal material is being produced within a continent; in the rift valley of Eastern Africa, as was briefly alluded to in **Activity 2.3**.

As you teach:

Step 1: Look back at **Activity 2.3** and highlight the divergent boundaries shown on the map and diagram. Use **Student Guide Activity 2.4** to develop the idea of sea floor spreading from mid-ocean ridges.

Step 2: Show the videos of hydrothermal vents and the multitude of life forms that have evolved to colonise the pitch-black darkness on the ocean floor. The producers in this food web do not use sunlight and photosynthesis. Instead, they are chemosynthetic microbes that create energy by mediating chemical reactions from the chemicals in the superheated fluids gushing from the hydrothermal vents.

Step 3: Allow students time to explore the sea floor spreading simulation and complete the plate boundary quiz.

Step 4: You might like to set the ***Notebook*** activity as a homework activity. The video is 16.5 minutes and comprehensively covers the evidence for the theory of plate tectonics.

Discussion:

How and where is new crust created on Earth?

2.5 Movement beneath the surface

Lesson outcomes

At the end of this activity students will be able to:

- describe the processes that drive the movement of tectonic plates.
- apply their understanding of heat and heat transfer to the behaviour of the mantle.
- explain how a model can be used to describe and understand processes that occur deep within the Earth.

Key vocabulary:

Mantle plume, convection.

Equipment list

Each GROUP will require:

- 200 mL beaker
- tea candle, matches
- dark ink
- 1 mL plastic syringe or pipette
- Tripod
- camera (optional)

Each STUDENT will require:

- ***Notebook***

Things to consider

- It may be useful to help students revise their understanding of heat transfer, and particularly convection, before doing this activity.
- Watch the video (*Teacher Content Information*) that describes the experiment.
- You may consider setting the ***Notebook*** activity as homework. The video is 14 minutes.

Teacher content information

This activity provides students with the opportunity to experiment with a simple experimental model that was actually used by scientists attempting to model the behaviour of processes in the mantle that drive plate tectonics. The original experiments utilised quite viscous liquids such as glucose syrup. The activity described in the **Student Guide** simply uses water and ink. It would be possible to experiment with different fluids, including glucose syrup, if time permits.

Video showing how the experiment is done - https://www.youtube.com/watch?v=nhrbtnIt-Hk

Reference: Griffiths, R. W. & Campbell, I. H. (1990) Stirring and structure in mantle starting plumes, Earth and Planetary Science Letters, 99, 66-78.

Lesson plan

Step 1: Follow the instructions in the **Student Guide** to create mantle plumes using ink in water. Encourage students to record their observations in their ***Notebooks***. Discuss the discussion questions.

Step 2: Invite students to apply their understanding about convection currents and explore the digital activities. Emphasise that actual mantle plumes in the Earth's mantle move incredibly slowly.

Step 3: Conclude with the ***Notebook*** activity. Show the video to the class and discuss answers to the questions.

2.6 From tectonics to landforms

Lesson outcomes

At the end of this activity students will be able to:

- relate the process of plate tectonics to the formation of anticlines and synclines
- relate the process of plate tectonics to the formation of normal faults, reverse faults and strike slip faults.

Key vocabulary:

Folding, faulting, tension, compression, normal fault, reverse (thrust) fault, strike slip fault, anticline, syncline, ammonite.

Equipment list

Each STUDENT will require:

- ***Notebook***
- Internet access

Things to consider

If your school has models showing folding and faulting, they would be useful here in demonstrating these sedimentary rock formations.

Teacher content information

The uplift of the Himalayas is one of the most spectacular examples of a major landform that is still being formed today. India began its northward movement, at around 9 cm per year, around 225 million years ago, as a small island continent. It finally collided with Asia 40-50 million years ago. Since then the Himalayas have been rising by 1 cm per year. This is one of the few examples of a converging boundary between two continental plates. Some maps show quite clearly the rippled effect of the mountain ranges that have formed as a result of this collision, much like a table cloth gets wrinkled as you scrunch it up. A Google Earth view of this region shows this quite clearly.

Lesson plan

Step 1: Introduce the sedimentary rock formations shown in the **Student Guide**. Ask students to copy the diagrams illustrating folding and faulting into their ***Notebook***.

Step 2: As a class, watch the two videos showing faulting under Parliament House and the folding of the Himalayas.

Step 3: Conclude with the ***Notebook*** activities providing formative assessment.

2.7 A dynamic Earth

Lesson outcomes

At the end of this activity students will be able to:

- select appropriate materials to communicate a scientific understanding of the Earth's geological structure and history
- present scientific ideas to a specific audience, using appropriate scientific language, conventions and visual aids.

What ideas might your students already have?

Students have a background in Earth Science from their studies of science in Years 7-9.

Key vocabulary:

Lithosphere, tectonic plates, geology, eco-tourism, geo-tourism

Equipment list

Each GROUP will require:

- computer, internet access and printer access
- sheet of paper /card for poster
- drawing materials

Things to consider

This activity is more interesting and interactive for the class if each group (three-four students) sets up a small geo-tourism travel company and establishes a stall in a class Geo-tourism Expo. They can try to sell holidays to classmates, or members of other classes. They might do a digital presentation and/or have a paper brochure. Emphasise that this is a short and enjoyable activity. The more flair they use the better in terms of selling a product. The materials could be finished for homework and the Expo held in a later lesson.

Lesson plan

Step 1: Give students an overview of the task. Divide them into groups and allow them time to revise the Earth's structure, plate tectonics etc. Alternatively, this could be set as pre-task homework.

Step 2: Show the suggested videos to establish that surface observations and structures are related to geological processes.

Step 3: Students now work in travel agency groups to find a destination and prepare some resources to sell it. They should follow the guidelines in the Notebook section. This can be finished as homework if necessary.

Step 4: Organise the expo and allow half the class at one time to visit the other stalls, so there is always a travel agent at each stall.

Step 5: Finish with a discussion session, in which students decide on the best presentation.

Suggested questions:

1. What will attract people to your holiday destination?
2. How will you make your destination look the most appealing to geo-tourists?
3. Which presentation won the most customers? Why?

Follow up:

If you have time, the episode *Dead or Alive*, in Brian Cox's *Wonders of the Solar System* is worth showing. It explores how scientists have found information on conditions on other planets by comparing geological formations to those on Earth.