Exploring Geoscience Across the Globe

Activities and questions

Chris King

Approved by:
the International Geoscience Education Organisation
the International Union of Geological Sciences
the European Geosciences Union
for the teaching of the International Geoscience Syllabus

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Exploring Geoscience – activities and questions

In memory of Abigail Brown, an inspiring and innovative teacher of Earth Science.

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International Geoscience
Education Organisation

Contents

Purpose of the ‘activities and questions’ book

The ‘*Exploring Geoscience’* book published on the International Geoscience Education website at: http://www.igeoscied.org/teaching-resources/geoscience-text-books/ has been produced to support teachers across the world in teaching the International Geoscience Syllabus. The syllabus covers the geoscience that all 16-year-old pupils should know and understand, as recommended by the international geoscience education community. The structure of chapter headings in the book directly reflects the syllabus.

The *Exploring Geoscience – activities and questions* book has been developed to support the *Exploring Geoscience* textbook with activities for teachers to use in the classroom and pupil questions to promote and consolidate understanding. It uses the same chapter headings and subheadings as the *Exploring Geoscience* textbook to aid cross referencing.

The International Geoscience Syllabus is published at: http://www.igeoscied.org/?page_id=269.

Contributors and acknowledgements

We are grateful to Gillian Drennen (gillian.drennen@wits.ac.za) for first suggesting the writing of a textbook to address the international syllabus. The idea for this companion volume arose from a chance remark by Sykle Hlawatch. She said, in paraphrase, ‘The *Exploring Geoscience* textbook is different from the textbooks we are familiar with in today’s classrooms – which as well as information include practical activities and questions’. The result is this *Exploring Geoscience – activities and questions* book which, by being published separately from the original textbook, makes the original simpler to translate for other regions and languages.

The main sources of information used in the compilation of this ‘activities and questions’ book are as shown below. We are most grateful to all these sources for allowing their material to be referenced in this way.

- The Earthlearningidea website (ELI), which publishes geoscience teaching activities at: https://www.earthlearningidea.com/index.html; a new Earthlearningidea activity or question is added to the website every two weeks
- The Joint Earth Science Education Initiative (JESEI) website at: https://geohubliverpool.org.uk/jesei/contents.htm
- The Woodside Australian Science Project (WASP) at: https://www.wasp.edu.au/ as recommended by the Chief Executive Officer of Earth Science Western Australia (ESWA) at: http://www.earthsciencewa.com.au/;
- R. Valli Divya at the Centre for Earth Sciences and the Indian Institute for Science in Bangalore, India for recommending an activity from https://www.amnh.org/ology/paleontology

We are most grateful to Peter Craig, Elizabeth and Martin Devon, Peter Kennett, Pete Loader and Giulia Realdon for all their work in checking the accuracy of the script, in helping to make the text more accessible and in proof-reading. We are also most grateful to Anthony Tibbs for his formal proof-reading efforts. Any remaining errors remain mine and mine alone. Many thanks to Tanja Reinhardt for improving the final version through excellent formatting and well-designed covers.

The *Exploring Geoscience* textbook has been approved by the International Geoscience Education Organisation, the International Union of Geological Sciences through its Commission on Geoscience Education, and the European Geosciences Union, for the teaching of the international geoscience syllabus, and we are most grateful for their support and encouragement.

IGEO International Geoscience Education Organisation

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Chris King.

0 Why explore geoscience?

This companion volume to the *Exploring geoscience* textbook series includes interactive practical activities and ‘Question/Discussion’ sections to consolidate the understanding of pupils. There are more than 300 activities and more than 300 questions (including 50 ‘deep questions’). It available for free-of-charge download at: http://www.igeoscied.org/teaching-resources/geoscience-text-books/.

The headings and subheadings of this volume are the same as those in the *Exploring geoscience* textbook.

In most of the question sections, the first question can be answered by reference to the text in the textbook. Some of these are ‘Directed Activity Relating to Texts or DARTS questions (see: https://www.teachingenglish.org.uk/article/interacting-texts-directed-activities-related-texts-darts) which ask pupils to take text information and show it in a different way, such as through a list, table or diagram.

The later questions in each section of this volume are intended to extend understanding and classroom discussion, and some of them are ‘deep questions’ requiring thinking and discussion but with no fixed answers.

Some answers to the questions are included in the *Some answers* publication, which is only available to teachers, educators and other individuals who can justify their interest. The *Some answers* publication is free-of-charge to download from a restricted part of the IGEO website. To access this restricted webpage, send your CV showing your background and interest to chris@earthlearningidea.com to receive the link.

The activities and some of the questions are referenced in this companion volume, and can be found in detail on the internet. They are taken from:

- the Earthlearningidea website (ELI), which publishes geoscience teaching activities at: https://www.earthlearningidea.com/index.html; a new Earthlearningidea activity or question is added to the website every two weeks;
- the Joint Earth Science Education Initiative (JESEI) website at: https://geohubliverpool.org.uk/jesei/contents.htm;
- The Woodside Australian Science Project (WASP) at: https://www.wasp.edu.au/ as recommended by the Chief Executive Officer of Earth Science Western Australia (ESWA) at: http://www.earthsciencewa.com.au/ [Note that most of the WASP activities have both teacher notes and pupil activity sheets with adjacent file numbers – there was only space to include just one of these in the activities lists below];
- R. Valli Divya at the Centre for Earth Sciences and the Indian Institute for Science in Bangalore, India for recommending an activity from https://www.amnh.org/ology/paleontology

If anybody spots any errors or erroneous oversimplifications in either the textbook or this companion volume, please let the author know (chris@earthlearningidea.com), so that they can be corrected. One of the advantages of publication in electronic form, is that amendments are readily made.

1 Earth as a changing system

Questions/Discussions

1. What does the term ‘open system’ mean?
2. Apart from a washbasin, what is another example of an open system? Explain why it is an open system.
3. Apart from a vacuum flask, what is another example of a closed system? Explain why it is a closed system.

1.1 Attributes

Questions/Discussions

1. The Earth is a nearly closed system to matter today (little gain from or loss of matter from/to space) When, during Earth’s history, was Earth a much more open system to matter?
2. What, in the future, might make Earth no longer a nearly closed system to matter?

1.2 Interactions

Questions/Discussions

1. What geosphere, hydrosphere, atmosphere and biosphere interactions affect a potted plant?
2. What geosphere, hydrosphere, atmosphere and biosphere interactions are found in a coral reef exposed at low tide?

1.3 Feedback

Questions/Discussions

1. What do the terms ‘positive feedback’ and ‘negative feedback’ mean?
2. As the Earth becomes warmer, water from the land and oceans evaporates at a greater rate, as water vapour. Water vapour is a greenhouse gas. Explain whether this results in an example of positive or negative feedback.
3. As the Earth becomes warmer, it radiates more heat into space. Explain whether this is an example of positive or negative feedback.

1.4 Processes and products

1.4.1 Cycles

Questions/Discussions

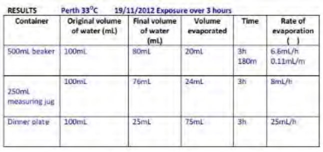
1. In a cycle, what is the difference between a process and a product?
2. In the Spring in temperate regions, leaves grow on deciduous trees and in the Autumn, the leaves fall. Explain how this is part of a cycle of nutrients.
3. We are often asked to recycle – what does this mean?

1.4.2 The water cycle

Activities

ELI title	**Topic**	**Images**	
Changing state – transforming water: practical activities to change the state of water; solid, liquid, gas	Investigating and discussing the change in state of water from solid to liquid to gas and *vice versa*		

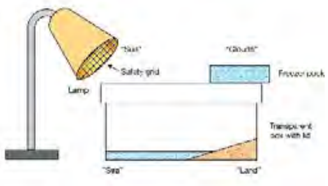
https://www.earthlearningidea.com/PDF/167_Water_1.pdf

ESWA title	**Topic**	**Images**	
Rate of evaporation	Pupils investigate the concept of evaporation through an experiment to measure its rate		

RESULTS Perth 33°C 19/11/2012 Exposure over 3 hours

Container	Original volume of water (mL)	Final volume of water (mL)	Volume evaporated	Time	Rate of evaporation ( )
500mL beaker	100mL	80mL	20mL	3h 180m	6.6mL/h 0.11mL/m
250mL measuring jug	100mL	76mL	24mL	3h	8mL/h
Dinner plate	100mL	25mL	75mL	3h	25mL/h

http://www.wasp.edu.au/mod/resource/view.php?id=41

ELI title	**Topic**	**Images**	
Mini-world water cycle: a water cycle demonstration model in a box	A demonstration water cycle in a transparent box, using materials readily available in the classroom		

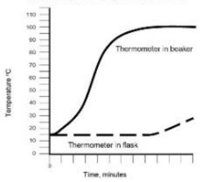
https://www.earthlearningidea.com/PDF/168_Water_2.pdf

ESWA title	**Topic**	**Images**	
Clouds	This teacher demonstration allows pupils to visualise the formation of clouds		

http://www.wasp.edu.au/mod/resource/view.php?id=44

Water Cycle animation	A fast-paced animation that takes viewers through the water cycle		

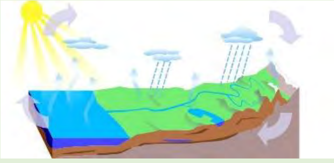
https://youtu.be/b6YrP47CbGk

ELI title	**Topic**	**Images**	
Cycling water and heat in the lab – and the globe: the water cycle, latent heat and global energy transfer	A lab demonstration of the water cycle used to develop understanding of latent heat transfer and its global effects		

https://www.earthlearningidea.com/PDF/174_Cycling_water_heat.pdf

Questions/Discussions

1. Explain the processes that link ice, liquid water and water vapour products in the water cycle.
2. What part do trees play in the water cycle?
3. How might increasing global temperatures affect the water cycle?

ELI Title	Topic	Images	
4. Water cycle world – a discussion activity on the natural water transformations on Earth	Pupils apply their understanding of the water cycle to the 'real world'		
https://www.earthlearningidea.com/PDF/171_Water_3.pdf			
5. 'Tagging' water molecules – to explore the water cycle: a thought experiment to investigate the water cycle	An activity to help pupils to visualise the movement of water through the water cycle		
https://www.earthlearningidea.com/PDF/173_Tagging.pdf			

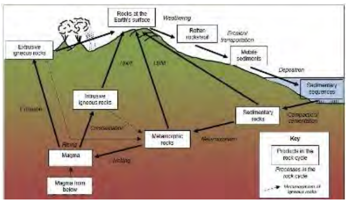
1.4.3 Fluxes, stores and residence times

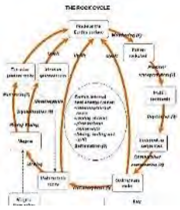
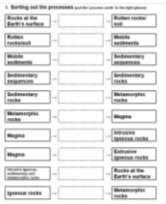
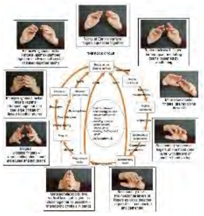
Questions/Discussions

1. What do the terms 'flux', 'store' and 'residence time' mean?
2. Rank the following in order of their residence times, from No. 1, the shortest to No. 6, the longest – the organic molecules in: a piece of coal, a tree trunk, a mosquito, a lizard, a leaf that falls in the Autumn, an insect fossilised in amber.

1.4.4 The rock cycle

Activities

ESWA title	Topic	Images	
Rocks and minerals animation	This animation takes viewers through the rock cycle – a fast paced way to introduce the rock cycle		
https://youtu.be/WYtF-ZdTr7s			
ELI title	**Topic**	**Images**	
The rock cycle in wax: using a candle to demonstrate the rock cycle processes	A candle is used to demonstrate several rock cycle processes, to consolidate understanding of the rock cycle		
https://www.earthlearningidea.com/PDF/Rock_cycle_in_wax_final_July.pdf			

From 'Rock detective' to 'Laying out the rock cycle': sort rocks into groups and add them to the rock cycle	Using sorting cards to link '*Rock detective*' and '*Laying out the rock cycle*' activities to observe, identify and name rocks		
https://www.earthlearningidea.com/PDF/316_Rock_detective_rock_cycle.pdf			
Laying out the rock cycle – product and process: sorting out the rock cycle products – and then adding the processes	Place rock cycle products in the correct places on a diagram of the rock cycle, then add the rock cycle processes		
https://www.earthlearningidea.com/PDF/253_Rock_cycle_product_process.pdf			
Not misunderstanding the rock cycle: addressing common misconceptions about the rock cycle	A sorting exercise directly focussed on common rock cycle misconceptions		
https://www.earthlearningidea.com/PDF/272_Rock_cycle_misconceptions.pdf			
The rock cycle at your fingertips: modelling the rock cycle with your fingers	A class activity to help the pupils to remember the products of the rock cycle through modelling with their fingers		
https://www.earthlearningidea.com/PDF/274_Rock_cycle_fingertips.pdf			

Questions/Discussions

1. Do rock cycle processes all act at the same rates? Explain your answer.

2. What is the likely range of residence times for rock cycle products?

3. Which are usually the hottest when they first form, sedimentary rocks, metamorphic rocks or magma?

4. Sand on a sill: What will happen to a sand grain left on a window sill? – a rock cycle discussion

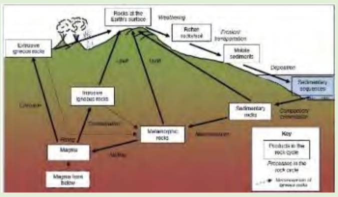
   A pupil group discussion activity based on what will happen to a sand grain left on a windowsill.

Rock cycle processes	Links to other Earth cycles
Weathering – physical break-up or chemical breakdown	Break-up or break down linked to biological cycles
Erosion of sand by wind or water Transportation of sand by wind or water Deposition of sand by wind or water	Wind as part of the atmospheric cycle Water as part of the water cycle
Erosion, transportation and deposition of sand by human activity	
Soil formation	Soil processes as part of biological cycles (water, carbon, nitrogen, etc. cycles)
Lithification by comp-action/ cementation	Lithification as part of the sedimentary cycle
Rock deformation Metamorphism Melting Igneous activity – intrusion or extrusion	Internal Earth cycles – linked to plate tectonic activity
Uplift	Plate tectonic mountain-building processes

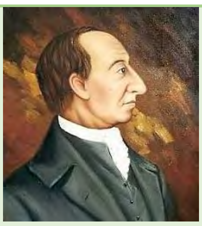
https://www.earthlearningidea.com/PDF/219_Sand_on_sill.pdf

5. Rock cycle through the window: the rock cycle processes you might be able to see - and those you can't

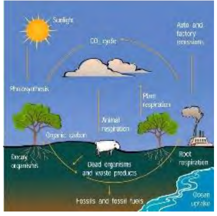
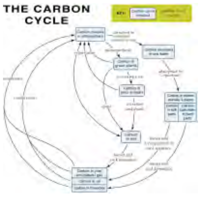
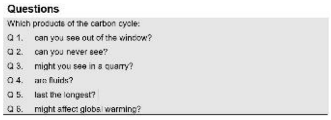
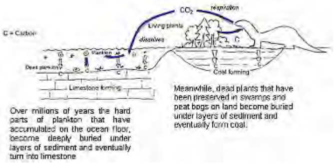
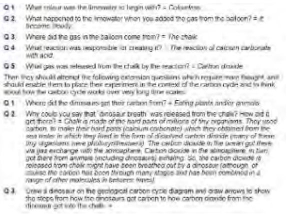
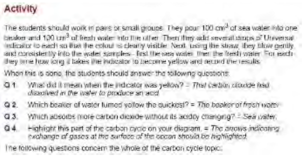
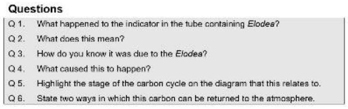
   Using the view through the window to gain deeper understanding of rock cycle processes and how they affect the local area

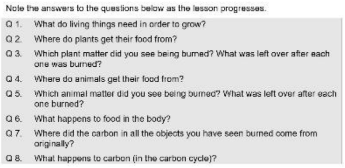
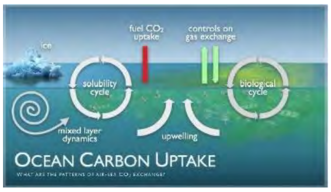
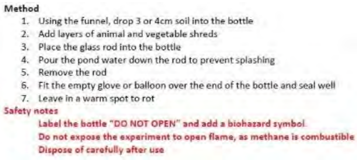


https://www.earthlearningidea.com/PDF/52_Rock_cycle.pdf

6.	James Hutton – or 'Mr. Rock Cycle'? – thinking towards the rock cycle, the Hutton way	Following the thoughts of James Hutton as he developed his ideas in the context of what we now call the rock cycle		
https://www.earthlearningidea.com/PDF/93_James_Hutton.pdf				

1.4.5 The carbon cycle

Activities			
ELI title	**Topic**	**Images**	
Carbon goes round and round and round: make your own carbon cycle	An introduction to the carbon cycle through placing carbon cycle products in the best positions on a diagram	 	
https://www.earthlearningidea.com/PDF/Carbon_goes_round.pdf			
JESEI title	**Topic**	**Images**	
Carbon cycle in the lab: carbon products and the processes that link them	The nature of carbon and the different compounds, reactions and processes linked together to form the carbon cycle	 	 **Questions** Which products of the carbon cycle: Q 1. can you see out of the window? Q 2. can you never see? Q 3. might you see in a quarry? Q 4. are fluids? Q 5. last the longest? Q 6. might affect global warming?
https://geohubliverpool.org.uk/jesei/carbon%20cycle%202.htm			
Carbon cycle: releasing dinosaur breath in the lab	CO_2 is released into the atmosphere during exhalation and eventually becomes chalk; the CO_2 can be released from chalk in the lab	 Over millions of years the hard parts of plankton that have accumulated on the ocean floor, become deeply buried under layers of sediment and eventually turn into limestone Meanwhile, dead plants that have been preserved in swamps and peat bogs on land become buried under layers of sediment and eventually form coal.	
https://geohubliverpool.org.uk/jesei/carbon%20cycle%203.htm			
Carbon cycle: exchanging carbon dioxide between the atmosphere and ocean	Testing whether sea water or fresh water absorbs more carbon dioxide		 **Activity** The students should work in pairs or small groups. They pour 100 cm^3 of sea water into one beaker and 100 cm^3 of fresh water into the other. Then they add several drops of Universal indicator to each so that the colour is clearly visible. Next, using the straw, they blow gently and consistently into the water samples – first the sea water, then the fresh water. For each they time how long it takes the indicator to become yellow and record the results. When this is done, the students should answer the following questions: Q 1. What did it mean when the indicator was yellow? = *That carbon dioxide had dissolved in the water to produce an acid* Q 2. Which beaker of water turned yellow the quickest? = *The beaker of fresh water* Q 3. Which absorbs more carbon dioxide without its acidity changing? = *Sea water.* Q 4. Highlight this part of the carbon cycle on your diagram. = *The arrows indicating exchange of gases at the surface of the ocean should be highlighted.* The following questions concern the whole of the carbon cycle topic:
https://geohubliverpool.org.uk/jesei/carbon%20cycle%201.htm			
Cycling carbon: seeing how plants use carbon dioxide in the lab	This activity demonstrates the uptake of carbon dioxide by plants, using the water plant *Elodea* as the example		 **Questions** Q 1. What happened to the indicator in the tube containing *Elodea*? Q 2. What does this mean? Q 3. How do you know it was due to the *Elodea*? Q 4. What caused this to happen? Q 5. Highlight the stage of the carbon cycle on the diagram that this relates to. Q 6. State two ways in which this carbon can be returned to the atmosphere.
https://geohubliverpool.org.uk/jesei/cycling%20carbon.htm			

Carbon cycle: where is this crucial carbon?	Discussion as teacher burns a variety of things over a Bunsen flame to carbonise them to show they contain carbon	  Note the answers to the questions below as the lesson progresses. Q 1. What do living things need in order to grow? Q 2. Where do plants get their food from? Q 3. Which plant matter did you see being burned? What was left over after each one was burned? Q 4. Where do animals get their food from? Q 5. Which animal matter did you see being burned? What was left over after each one burned? Q 6. What happens to food in the body? Q 7. Where did the carbon in all the objects you have seen burned come from originally? Q 8. What happens to carbon (in the carbon cycle)?
https://geohubliverpool.org.uk/jesei/carbon%20cycle%204.htm		
ESWA title	**Topic**	**Images**
Solution	Across two simple activities, examine the solubility of carbon dioxide in cold and warm water; then relate this to our oceans	 
http://www.wasp.edu.au/mod/resource/view.php?id=336		
Fermentation	In this teacher demonstration pupils can observe gases being produced through the process of fermentation	  **Method** 1. Using the funnel, drop 3 or 4cm soil into the bottle 2. Add layers of animal and vegetable shreds 3. Place the glass rod into the bottle 4. Pour the pond water down the rod to prevent splashing 5. Remove the rod 6. Fit the empty glove or balloon over the end of the bottle and seal well 7. Leave in a warm spot to rot **Safety notes** Label the bottle "DO NOT OPEN" and add a biohazard symbol. Do not expose the experiment to open flame, as methane is combustible Dispose of carefully after use
http://www.wasp.edu.au/mod/resource/view.php?id=333		

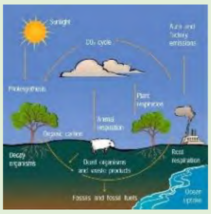
Questions/Discussions

1. How are you part of the carbon cycle?

2. What is the difference between the short- and longer-term carbon cycles?

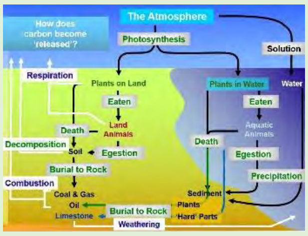
3. How are human activities affecting the longer carbon cycle?

4. The carbon cycle through the window: how much evidence of the carbon cycle can you see? — Using the view through the window to discuss the carbon cycle processes that can be seen in the products outside



https://www.earthlearningidea.com/PDF/55_Carbon_cycle2.pdf

5. Tag a carbon atom – and explore the carbon cycle: a thought experiment to investigate carbon cycle processes — An activity asking pupils to 'visualise' stages of the carbon cycle by 'following' a 'tagged' carbon atom



https://www.earthlearningidea.com/PDF/213_Tag_carbon.pdf

1.5 Energy sources

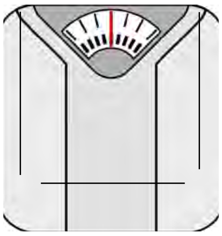
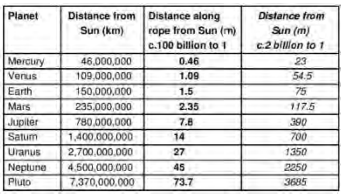
Questions/Discussions

1. Coal and other hydrocarbons release energy when they are burned, but where did that energy originally come from?

2. What are the energy sources that drive: (a) surface, and (b) deep Earth processes?

2 Earth is a system, within the solar system, within the universe

2.1.1 Origins

Activities			
ESWA title	**Topic**	**Images**	
Solar system static	Activities to assist pupils in understanding one of the key forces involved in the early formation of our solar system		
http://www.wasp.edu.au/mod/resource/view.php?id=455			
Solar system gravity	Activities to assist in explaining the impacts of gravity in our solar system		
http://www.wasp.edu.au/mod/resource/view.php?id=457			
ELI title	**Topic**	**Images**	
Playground planets – modelling the relative sizes of the planets and their distances from the Sun	An outdoor activity modelling the main parts of the solar system		
https://www.earthlearningidea.com/PDF/92_Playground_planets.pdf			

Planet	Distance from Sun (km)	Distance along rope from Sun (m) c.100 billion to 1	*Distance from Sun (m) c.2 billion to 1*
Mercury	46,000,000	**0.46**	*23*
Venus	109,000,000	**1.09**	*54.5*
Earth	150,000,000	**1.5**	*75*
Mars	235,000,000	**2.35**	*117.5*
Jupiter	780,000,000	**7.8**	*390*
Saturn	1,400,000,000	**14**	*700*
Uranus	2,700,000,000	**27**	*1350*
Neptune	4,500,000,000	**45**	*2250*
Pluto	7,370,000,000	**73.7**	*3685*

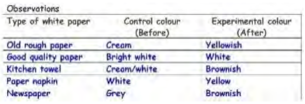
Questions/Discussions

1. Where in the universe did the elements on Earth heavier than hydrogen form?

2. If the asteroids in the asteroid belt between Mars and Jupiter collided together to form a new planet, what would that planet probably be like?

3. Draw graphs plotting the distance of the planets from the Sun against:
   (a) their diameter,
   (b) their mass,
   (c) their mean surface temperatures.
   On which of these graphs can a trend or pattern be seen (can a line of best fit be drawn?)? For graph(s) that show a pattern, which planet(s) are very different from the pattern?

2.2 The Sun

Activities			
ESWA title	**Topic**	**Images**	
Sun changed paper	Pupils explore the concept of a fair test and examine the impact of sunlight on a range of paper types in this fun activity		
http://www.palms.edu.au/mod/resource/view.php?id=532			
Sun and energy	This demonstration introduces pupils to Earth's magnetosphere and its importance to life		
http://www.wasp.edu.au/mod/resource/view.php?id=481			

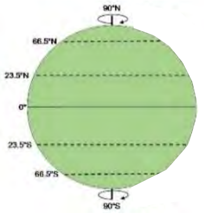
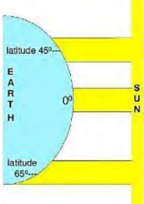
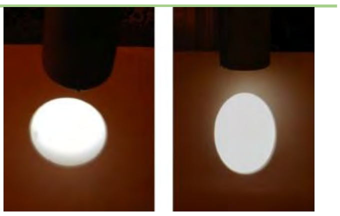
Observations

Type of white paper	Control colour (Before)	Experimental colour (After)
Old rough paper	Cream	Yellowish
Good quality paper	Bright white	White
Kitchen towel	Cream/white	Brownish
Paper napkin	White	Yellow
Newspaper	Grey	Brownish

Questions/Discussions
1. How does most of the energy from the Sun reach the Earth?
2. At what time during the day/night is the area where you live usually: (a) coldest, (b) warmest?

2.3 Sun, Earth and moon

2.3.1 Day/night

Activities			
ELI title	**Topic**	**Images**	
A screaming roller coaster: how fast am I travelling (due to Earth's spin and Earth's orbit)?	An introduction to the speed of the spinning and orbiting Earth		
https://www.earthlearningidea.com/PDF/169_Roller_coaster.pdf			
Hot or not?: investigating how latitude affects the amount of solar radiation received	An activity to show how the amount of energy the Earth receives from the Sun is different at different latitudes		
https://www.earthlearningidea.com/PDF/191_Hot_or_not.pdf			
Earth on Earth: using a globe in the sunshine to show how day/night and the seasons work	A model globe is fixed in the same position, relative to the Sun, as the real Earth, to see how day and night and the seasons work		
https://www.earthlearningidea.com/PDF/192_Earth_on_Earth.pdf			

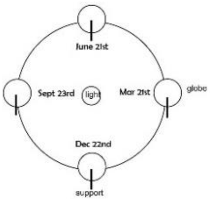
Questions/Discussions

1. When is the length of your shadow shortest during a sunny day?

2. What experiments could you set up in a classroom or lab to show:
   (a) how land heats up faster than water, and
   (b) how pale-coloured solid surfaces heat up more slowly than dark-coloured solid surfaces?

2.3.2 The seasons

Activities

ELI title	Topic	Images
Seasons – the effect of our tilted Earth: an indoor demonstration explaining the changing seasons	A globe is ‘walked’ round a circle of pupils, with a bright light at the centre, to show how the tilt of the Earth creates different seasons	 
https://www.earthlearningidea.com/PDF/193_Seasons.pdf		

ESWA title	Topic	Images
The seasons	Comparing European ideas about seasonal change with Australian aboriginal ideas about seasons	 
http://www.earthsciencewa.com.au/mod/resource/view.php?id=1323		

Questions/Discussions

1. Give two reasons, linked to the tilt of the Earth, to explain why regions of the Earth away from the tropics are warmer during the summer than the winter.

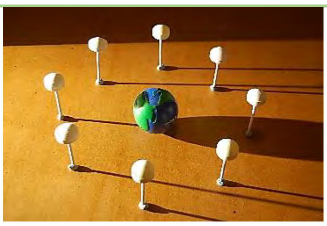
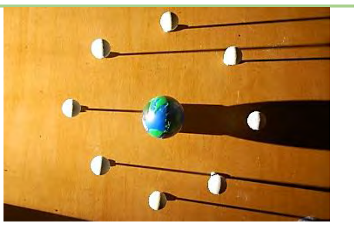
2. Why do the reasons given in the answer above have little effect in equatorial regions of the Earth, where the temperature stays around the same for the whole year?

3. Draw a circle to represent the Sun, of 2 millimetres diameter, on a piece of paper and stick it on a wall; on another piece of paper draw a very fine dot to represent the Earth; stick the second piece of paper on the wall so the Earth’s dot is 2 metres horizontally away from the Sun’s circle. Use this scale model of the Sun and the Earth to explain how the fact that the Earth’s equator is hotter than the Earth’s poles cannot be explained because the Equator is closer to the Sun than the poles, and so that there must be another reason to explain this temperature difference. (Note: the ‘other reason’ is that the Sun’s radiation hits the Earth at right angles near the Equator and so is intense; polar areas are curved away from the Sun and so the Sun’s radiation is more spread out and so is much less intense in those regions.)

2.3.3 The phases of the moon

Activities

ELI title	Topic	Images
Polystyrene moon – visualising the phases of the moon using a ball on a stick	Using a ball and stick to simulate the moon and a light beam to simulate the Sun to see Earth’s view of the phases of the moon	   
https://www.earthlearningidea.com/PDF/158_Polystyrene_moon.pdf		

Lollipop moon – modelling the phases of the moon with a ball, lollipops and a bright light	Pupils use a model to appreciate what the phases of the moon look like when viewed from outside the Earth		
https://www.earthlearningidea.com/PDF/160_Lollipop_moon.pdf			
Jaffa moon – modelling the phases of the moon using Jaffa Cakes™	Cutting Jaffa Cakes™ to model the waxing and waning moon.	 	 
https://www.earthlearningidea.com/PDF/154_Jaffa_moon.pdf			

Questions/Discussions

1. When the moon rises as the Sun sets, it is a full moon. How can this be explained?
2. We only ever see one side of the moon from Earth as the moon circles the Earth over about 27 days. Does the moon rotate? If so, how long does it take for one rotation?

2.3.4 Eclipses

Activities

ELI title	Topic	Images	
Why does the Sun disappear? Demonstrate what happens when the Moon hides the Sun	This activity helps in investigating the solar system; it compares the relative sizes of the moon and the Sun in relation to the Earth		
https://www.earthlearningidea.com/PDF/56_solar_eclipse_new.pdf			
Eclipse the lollipop – modelling eclipses of the moon and the Sun with a ball, lollipops and a bright light	Pupils use a model to appreciate what lunar and solar eclipses look like when viewed from outside the Earth		
https://www.earthlearningidea.com/PDF/162_Eclipse_lollipop.pdf			

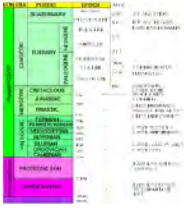
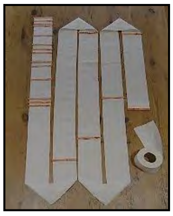
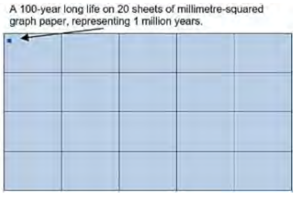
Questions/Discussions

1. During a full solar eclipse, birds stop singing. Why might this be so?
2. Why do lunar eclipses only occur at times of the full moon?
3. If you were on the Moon, what would the Earth look like:
   (a) during a solar eclipse,
   (b) during a lunar eclipse?
4. Seen from the Earth, which planets can pass in front of the Sun? Why do they not cause a solar eclipse?

3 Earth is a system which has changed over time

3.1 Geological time span

Activities

ESWA title	**Topic**	**Images**	
Personal timescale	Pupils draw a human timescale and discuss significant divisions and breaks; they then relate this to the geological time scale		
http://www.earthsciencewa.com.au/mod/resource/view.php?id=1248			
ELI title	**Topic**	**Images**	
Toilet roll of time: make a geological timeline to take home	A pupil activity to make a geological timeline		
https://www.earthlearningidea.com/PDF/234_Toilet_roll_of_time.pdf			
How many for a million? How many sheets of graph paper for 1 million, or 100 million, or a 1000 million squares?	Calculations to help pupils to visualise the enormity of a million years, and then 1000 million years	 A 100-year long life on 20 sheets of millimetre-squared graph paper, representing 1 million years.	
https://www.earthlearningidea.com/PDF/149_Million.pdf			

Timeline markers

Event	Geological time (years ago)
Today – the future begins here	0 years
Oldest stone tools	3,300,000 years
India/Eurasia collision – Himalayan Mountains formed	50,000,000 years
K-Pg (K-T) mass extinction – dinosaurs became extinct	65,000,000 years
Early flowering plants	130,000,000 years
Early birds	160,000,000 years
Beginning of the opening of the Atlantic Ocean	190,000,000 years
Early mammals	220,000,000 years
The 'great dying' mass extinction	251,000,000 years
Supercontinent of Pangaea assembled	300,000,000 years
Early reptiles	315,000,000 years

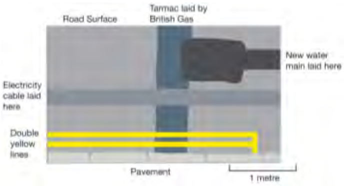
Questions/Discussions

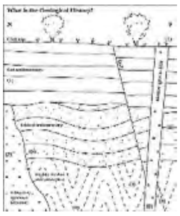
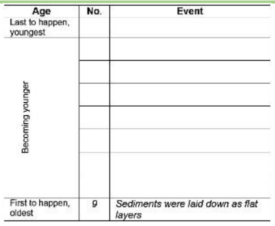
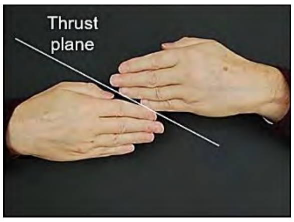
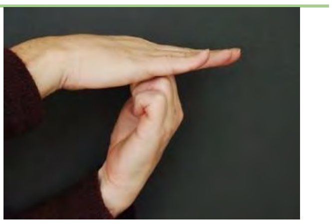
1. How old is the Earth in millions of years, as measured by radiometric dating, when the age is written in words?

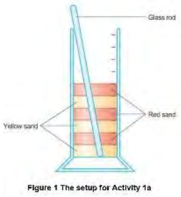
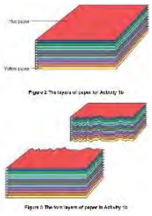
2. How old did scientists think the Earth was in the late 1700s/early 1800s?

3.2 Relative dating

Activities

ELI title	**Topic**	**Images**	
Laying down the principles: sequencing the events that form rocks through applying stratigraphic principles	The relative dating of the events that form rocks and rock sequences through applying stratigraphic and other principles		
https://www.earthlearningidea.com/PDF/Laying_down_the_principles.pdf			
What happened when? Sorting out sequences using stratigraphical concepts: are the concepts principles or laws?	Understanding and applying stratigraphical concepts, indoors and outdoors.		
https://www.earthlearningidea.com/PDF/307_What_happened_when.pdf			

What is the geological history?: sequencing events to reveal a history using simple stratigraphic principles	Using simple principles to unravel the geological history of a diagram of a cliff face		 Age | No. | Event Last to happen, youngest Becoming younger First to happen, oldest | 9 | *Sediments were laid down as flat layers*
https://www.earthlearningidea.com/PDF/40_What_is_the_geological_history.pdf			
Modelling by hand 'when the youngest rock is not on top': illustrating how rock sequences can have older rocks on top of younger ones	Helping pupils to visualise how older rocks can be found above younger ones, through modelling with their hands		
https://www.earthlearningidea.com/PDF/282_Oldest_youngest_rocks.pdf			
Modelling unconformity – by hand: using your hands to demonstrate how unconformities form	Pupils use their hands to model unconformity processes		
https://www.earthlearningidea.com/PDF/287_Unconformity_by_hand.pdf			

JESEI title	**Topic**	**Images**	
Sequencing of rocks: what was the order of events?	Pupils use layers of coloured sand and of coloured paper to simulate the sequencing involved in the formation of layers of rock		
https://geohubliverpool.org.uk/jesei/sequencing%20of%20rocks.htm			

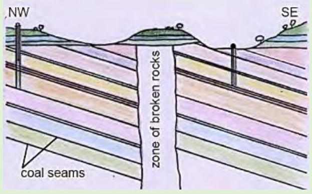
Questions/Discussions

1. William Smith published his 'Map that changed the world', the first geological map of a country, in 1815. As he was traveling around the UK on horseback, how was he able to work out which geological sequences were the same age as each other (correlated with one another) and which were younger or older?

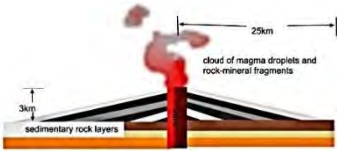
2. The map of Mars in Box 2.4 of the *Exploring Geoscience* book shows the geology of Mars and was prepared before any of the landers first arrived. How was it possible to work out the relative age relationships of the rocks shown?

3. In the cracked brick wall diagram above, how do the stratigraphic principles/laws help you to work out the order of events: the crack; the lower layer of bricks; the top layer of bricks; the making of the bricks?

4. In William Smith's cross section, shown in the box below, what is the order of the following events: the laying down of the horizontal beds; the laying down of the green dipping (tilted) bed; the laying down of the yellow dipping bed; the zone of broken rocks; the mine shafts (Note: the beds in this sequence have not been overturned). What principles/laws helped you to work out the sequence of these events?

5. William Smith – 'The Father of English Geology' – thinking like William Smith	Questions and answers that outline the possible thoughts of William Smith as he developed his ideas		
https://www.earthlearningidea.com/PDF/109_William_Smith.pdf			
6. Fieldwork: the 'All powerful' strategy: discussing geological histories in imaginative ways	A plenary activity to help pupils to imagine the geological history of a rock exposure or landscape		
https://www.earthlearningidea.com/PDF/203_All_powerful.pdf			
7. Filling the gap – picturing the unconformity '*abyss of time*'? What happened in unconformity time gaps?	A method of helping pupils to visualise the enormous time-spans between the upper and lower layers of unconformities		
https://www.earthlearningidea.com/PDF/261_Filling_the_gap.pdf			
8. Questions for any rock face 10: Questions about sequencing events to be asked at any rock exposure	Questions helping pupils to sequence events using 'relative dating' methods		
https://www.earthlearningidea.com/PDF/238_Questions_rock_face_sequencing.pdf			

3.3 Absolute dating

Activities			
ELI title	**Topic**	**Images**	
Dating the Earth – before the discovery of radioactivity: Charles Lyell and Mount Etna, 1828	Using simplified calculations to demonstrate the immense age of the Earth, before the discovery of radioactivity		
https://www.earthlearningidea.com/PDF/295_Lyell_on_Etna.pdf			

Questions/Discussions

1. If the radioactive atoms in a dark igneous rock were 25% parent to 75% daughter atoms and the half life was 200 million years – how old would the rock be?

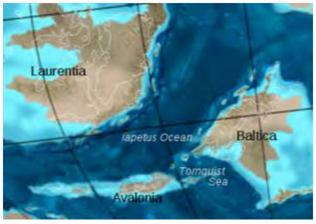
2. If one sixteenth of the radioactive atoms in a pink igneous rock were parent atoms and the other fifteen sixteenths were daughter atoms and the radioactivity in the rock had a half life of 180 million years – how old would it be?

3. If the waste material from a nuclear reactor would only be safe after five half-lives and it had a half-life of 600 years – how long would it be before it was safe?

4. Radioactive isotopes can have half lives of different lengths. Which of the following do you think might be possible?

- microseconds
- seconds
- hours
- days
- weeks
- years
- thousands of years
- millions of years
- billions of years

3.4 Rates of processes

Activities			
ELI title	**Topic**	**Images**	
Craters on the moon: Why are the moon's craters such different shapes and sizes?	Investigating the factors which affect the dimensions of craters produced by the impact of external bodies, such as meteorites		
https://www.earthlearningidea.com/PDF/68_Moon_craters.pdf			
How long does it take? – quick to very, very, very slow: sorting out Earth events according to the time they take	An activity discussing the rates of Earth processes		
https://www.earthlearningidea.com/PDF/150_Quick_slow.pdf			

Questions/Discussions

1. In the early 1800s there were two main theories about how rocks were formed:
The *Theory of Catastrophism* argued that the Earth had been shaped by sudden world-wide events.
The *Theory of Uniformitarianism* said that global rock sequences had been formed by slow processes like those seen today, such as erosion and deposition.
Which theory about rock-formation do scientists hold today?

2. If you wanted to demonstrate to a friend that:
(a) some processes that deposit the sediments that become sedimentary rocks are 'slow and steady' according to the *Theory of Uniformitarianism* where the *present is the key to the past*, and
(b) some sedimentary processes are catastrophic, as in the *Theory of Catastrophism*,
what sorts of rock exposures would you take them to (or what photographs of rock sequences would you show them)? What would you explain about them?

3. The Norber erratics are boulders of ancient sandstone deposited on top of limestones by a glacier around 12,000 years ago. Now they stand on platforms of limestone around 30cm high. How can this be used to work out the rate of chemical weathering of the limestone in the area?

An erratic boulder at Norber, Yorkshire, England.

4 Earth’s system comprises interacting spheres

4.1 Geosphere

Activities

JESEI title	Topic	Images	
Amazing Earth: facts that fascinate	Pupils build up a list of facts about Earth Science that fascinate them by searching the internet		 **Amazing Earth: facts that fascinate** **Website search** Try the following activities to build up a list of facts about Earth Science that fascinate you by searching the internet. One starting point is to use a search engine – ‘Google’ (www.google.com) is a popular one, but you may have your own particular favourite. An alternative is to visit some of the sites on the useful web sites link on the home page at www.jesei.org and follow links from there. If you use a search engine, think carefully about sensible terms to search for. Q 1. Find your own ‘top ten’ amazing facts about the Earth from a website search. Q 2. Note them down in order, from the ‘most amazing’ at the top Q 3. How many of your top ten amazing facts may cause death? Q 4. How many of your amazing facts were about the Earth’s future? Q 5. How many of your amazing facts were about the Earth’s past? Q 6. How many of your amazing facts might affect you tomorrow?

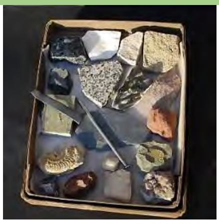
https://geohubliverpool.org.uk/jesei/amazing%20%20earth.htm

Questions/Discussions

1. What does the term ‘Geosphere’ mean?

4.1.1 Earth materials and properties

Activities

ELI title	Topic	Images	
Found in the ground - sorted! An introduction to classification using things ‘found in the ground’	An introduction to the classification of materials derived from the Earth		

https://www.earthlearningidea.com/PDF/155_Found_in_ground.pdf

Questions/Discussions

1. Natural history museums, as found in many of the world’s major cities, have collections of animals, plants, minerals, rocks and fossils. Which of these are thought of as ‘Earth materials’?

4.1.1.1 Minerals

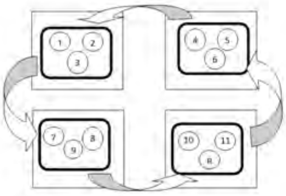
Activities

ELI title	Topic	Images	
Minerals form crystals	Pupils create their own crystals		

http://www.wasp.edu.au/mod/resource/view.php?id=200

ELI title	Topic	Images	
Mineral or not? Discussion about what is a mineral and what is not	Using pictures or samples to distinguish between a mineral in the Earth science sense and other uses of the term		

https://www.earthlearningidea.com/PDF/314_Mineral_or_not.pdf

Be a mineral expert – 1: beginning to identify minerals – introducing colour, habit, lustre, cleavage	Using simple visual tests to identify a set of ‘unknown’ minerals		
https://www.earthlearningidea.com/PDF/165_Minerals_1.pdf			
Be a mineral expert – 2: identifying minerals using ‘action’ tests – streak, density, hardness, acid test	Using simple practical tests for the identification of a set of ‘unknown’ minerals, previously only observed visually		
https://www.earthlearningidea.com/PDF/166_Minerals_2.pdf			
Identifying minerals – use your sense(s)! – Minerals in the dark: identifying minerals when the lights fail	Pupils use their senses other than sight to enable them to identify a range of different minerals		
https://www.earthlearningidea.com/PDF/131_Identifying_minerals.pdf			

Questions/Discussions

1. What is the definition of the term ‘mineral’ as used by geoscientists?

2. Quartz is a mineral made of silicon dioxide, with the formula SiO_2; metaquartzite is a metamorphic rock which is also almost entirely formed of SiO_2 but metaquartzite is not a mineral. Why is quartz a mineral but metaquartzite not?

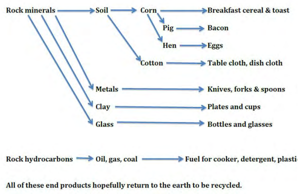
3. Mineral hardness can be measured using Mohs’ scale, which has ten levels of hardness from the softest mineral talc (1) to the hardest mineral diamond (10). Why are some minerals harder than others?

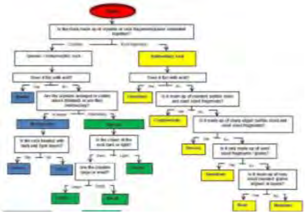
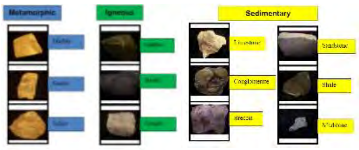
4. I’m pure calcium carbonate: the calcium carbonate question – common calcium carbonate misconceptions

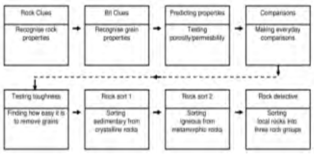
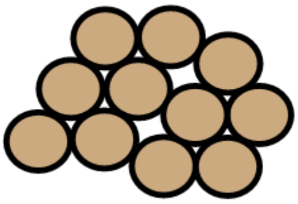
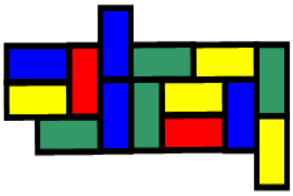
4. I’m pure calcium carbonate: the calcium carbonate question – common calcium carbonate misconceptions	Helping pupils to understand the likely purity of minerals and rocks		
https://www.earthlearningidea.com/PDF/248_Calcium_carbonate.pdf			

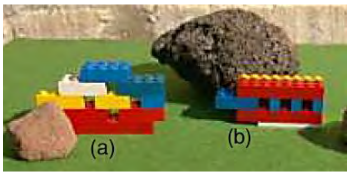
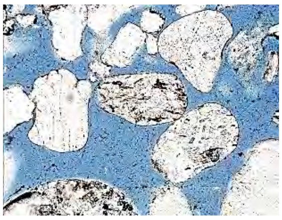
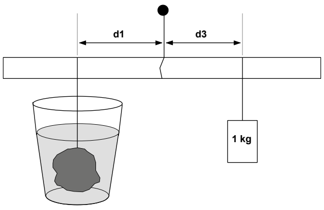
4.1.1.2 Rocks

Activities

ESWA title	Topic	Images	
We need rocks for breakfast	Pupils examine how their breakfast relates to rocks and the resources we gain from them		
http://www.wasp.edu.au/mod/resource/view.php?id=112			

Why study rocks 1? http://www.wasp.edu.au/mod/resource/view.php?id=114	Pupils consider some common questions and important considerations around the study of rocks	 
Why study rocks 2? http://www.wasp.edu.au/mod/resource/view.php?id=564	Pupils consider further common questions and considerations around rock study	 
Get to know your rock http://www.earthsciencewa.com.au/mod/resource/view.php?id=1417	Pupils carry out a series of short activities in a race to examine the properties of rocks	 
Rock types key http://www.earthsciencewa.com.au/mod/resource/view.php?id=1613	Pupils use a dichotomous key to identify common rock samples	 

ELI title	Topic	Images
Rock detective – rocky clues to the past: investigating your local rocks to find out how they formed https://www.earthlearningidea.com/PDF/Rock_detective.pdf	Sorting rocks according to their properties, which depend upon how they were formed	  
The space within – the porosity of rocks: investigating the amount of pore space between the 'grains' of a model 'rock' https://www.earthlearningidea.com/PDF/Space_within.pdf	The porosity of 'models' of sedimentary rocks tested by filling the gaps between the 'grains' with water	 
Modelling for rocks: What's hidden inside – and why? The permeability of rocks and how they let water, oil and gas flow through https://www.earthlearningidea.com/PDF/Modelling_for_rocks.pdf	An investigation of local rocks for their permeability; their potential for extracting water, oil or gas, or for sealing traps	 

Does my rock hold water and will water flow through it? Investigating the differences between porosity and permeability	Investigating chocolate and chocolate biscuits to discover which are porous and which are permeable – then modelling them	 
https://www.earthlearningidea.com/PDF/247_Porosity_permeability.pdf		
Rock grain cut out: how can you tell which grains come from which rock?	A scissors and paper activity to tell apart the grains from sedimentary, igneous and metamorphic rocks	 
https://www.earthlearningidea.com/PDF/303_Rock_grain_cut-out.pdf		
Eureka! – detecting ore the Archimedes way: measuring density using a stick, string, a ruler, a bucket and a bottle of water	Using very simple apparatus to measure density	 
https://www.earthlearningidea.com/PDF/Archimedes.pdf		

ESWA title	Topic	Images
Eggsamples of different rock types	This shows that the difference between rock types is not due to the chemistry of the rock but to what processes it has undergone	 
http://www.earthsciencewa.com.au/mod/resource/view.php?id=1428		
Chopping on rock	A STEM project to design a chopping board, examining many properties of materials	 
http://www.wasp.edu.au/course/view.php?id=47		

JESEI title	Topic	Images
The chemistry of limestone	The Pupils heat limestone to form lime and note the differences between the reactions of lime with water, acids and carbon dioxide	 
https://geohubliverpool.org.uk/jesei/chemistry%20of%20limestone.htm		
Limestone in your everyday life	Pupils fill in a timetable of their activities in the morning from waking up to leaving for school	 
https://geohubliverpool.org.uk/jesei/limestone%20everyday%20life.htm		

Questions/Discussions

1. What is the difference between porosity and permeability?

2. Based on permeability and scratch tests, which type of rock (igneous, sedimentary or metamorphic) would be the best to choose for each of the following: a statue; a kitchen worktop; a rock to store water in its pore spaces underground; a thin slab of facing stone on an important building; angular gravel used for railway ballast?

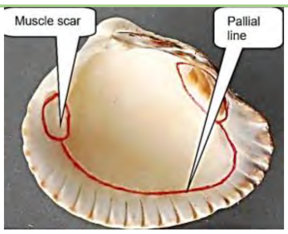
3. How could you set up an experiment in the classroom to compare the permeability of different types of loose sediment?

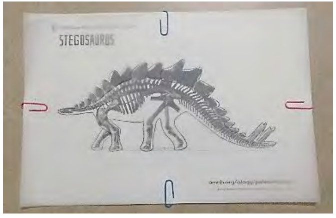
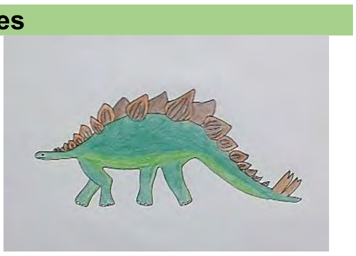
4. Questions for any rock face 4: rock group – What questions about rock type might be asked at an exposure? A field activity to help teachers to ask basic questions to help pupils to distinguish between sedimentary and igneous rocks

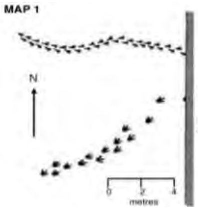
https://www.earthlearningidea.com/PDF/227_Questions_rock_face_rock_group.pdf

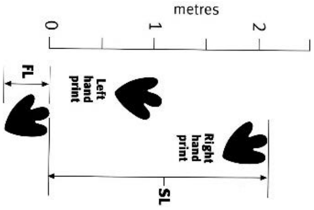
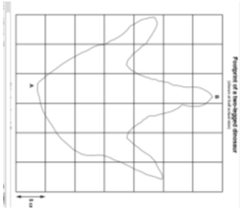
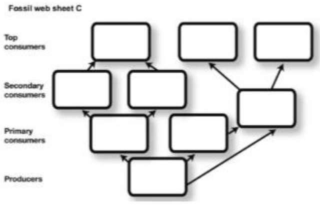
4.1.1.3 Fossils

Activities		
ELI title	**Topic**	**Images**
How could I become fossilised? Thinking through fossilisation in the context of me or you	Pupils are asked to think through what is likely to happen to a human body after it dies in an active environment	 
https://www.earthlearningidea.com/PDF/50_How_could_I_be_fossilised.pdf		
ESWA title	**Topic**	**Images**
Bodies in bogs	Pupils tan an egg then observe the effect of a mild acid on it to model the preservation of bodies in peat bogs	 
http://www.earthsciencewa.com.au/mod/resource/view.php?id=1305		
Moulds and casts	Activities looking at the formation of fossils, including moulds and casts	 
http://www.earthsciencewa.com.au/mod/resource/view.php?id=1239		
ELI title	**Topic**	**Images**
Fossilise!: a game showing how fossils form and survive	The game can be played in any science or geography lesson	 
https://www.earthlearningidea.com/PDF/202_Fossil_game.pdf		

Sea shell survival: how are common sea shells adapted to their habitats?	An introduction to the relationship between the features of shells of bivalves and their habitats		
https://www.earthlearningidea.com/PDF/183_Shell_survival.pdf			
Fossil or not? Discussion about what is a fossil and what is not	This activity fits well with lessons about the development of life on Earth and with sorting objects into groups	 Some hazelnuts Photo: P.Kennett	 Fossil shell Photo: P.Kennett
https://www.earthlearningidea.com/PDF/What_is_a_fossil.pdf			
Dig up the dinosaur: become a fossil hunter and dig up a dinosaur	Digging up buried 'bones' in a systematic manner and reconstructing the skeleton		
https://www.earthlearningidea.com/PDF/06_Dig_up_the_dinosaur.pdf			

Ology title	Topic	Images	
Drawing dinos: fossil bones used to reconstruct fossil animals as they were when alive	A simple method showing how a fossil animal can be reconstructed using a picture of its skeleton, tracing paper and crayons		
https://www.amnh.org/explore/ology/paleontology/drawing-dinos2			

ELI title	Topic	Images	
Trace fossils – burrows or borings: what evidence do living organisms leave behind in rocks?	Pupils are invited to apply previously learned observations about the features of modern bivalve shells to the fossil record		
https://www.earthlearningidea.com/PDF/186_Trace_fossils.pdf			
Trail-making: making your own "fossil" animal trails	Try thinking about how animals lived and moved before 'recreating' your own fossil trails on damp sand		
https://www.earthlearningidea.com/PDF/66_Trail-making.pdf			
The meeting of the dinosaurs – 100 million years ago: the evidence given by dinosaur footprints	Fossil tracks, such as footprints, provide evidence about the environment when they were made and how the animals lived and moved		
https://www.earthlearningidea.com/PDF/Dinosaur_Footprints.pdf			

A dinosaur in the yard: was *Iguanodon* strolling in the sun, or fleeing in fear?	How can the size of a dinosaur's footprints and the length of its stride be used to show how big it was and how fast it was moving?		
https://www.earthlearningidea.com/PDF/Dinosaur_in_the_yard.pdf			
How to weigh a dinosaur: using a dinosaur footprint impression to estimate how heavy the animal was	The relationship between pressure, force and area used to estimate the mass of a dinosaur from one of its fossilised footprints		
https://www.earthlearningidea.com/PDF/How_to_weigh_a_dinosaur.pdf			
Curious creatures: using fossil and modern evidence to work out the lifestyles of extinct animals	A snapshot of the history of life on Earth		
https://www.earthlearningidea.com/PDF/119_Curious_creatures.pdf			
Who ate the ammonite?: a Jurassic food web – from fossil evidence	Discussion about carnivore/herbivore, predator/prey relationships, building food chains/webs, producers/consumers and trophic levels		
https://www.earthlearningidea.com/PDF/142_Jurassic_menu.pdf			
Running the fossilisation film backwards: bringing a fossil 'back to life'	A re-enactment, to recreate the likely 'final moments' of an animal which later became a fossil		
https://www.earthlearningidea.com/PDF/176_Fossilisation_film.pdf			
Fifty million years into the future: investigating how animals become adapted to their environments	Evolution of life – adaptations to environment and natural selection	 Desert Shark	 Bardelot
https://www.earthlearningidea.com/PDF/146_Life_in_future.pdf			

Questions/Discussions

1. The image opposite shows a mould of the inside of a Jurassic brachiopod. How do such internal moulds form?

2. How could you make a 'dinosaur trail' in damp sand to show:
   (a) a small dinosaur running on two feet, dragging its tail behind it to give balance, and
   (b) the dinosaur walking into a lake until it is able to swim away.

3. Sometimes fossils are found at the end of a track or trail they have made. Why is a find like this very important to geoscientists?

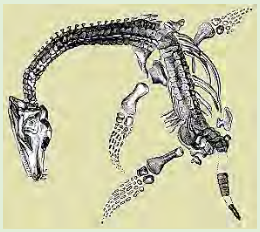
4. What was it like to be there? – bringing a fossil to life through a series of questions

Using a series of questions to bring fossils to life in the ancient environments in which they lived

https://www.earthlearningidea.com/PDF/37_What_like_be_there_fossil.pdf

5. Mary Anning – Mother of Palaeontology: "A woman in a man's world"

A series of questions to help pupils to think about Mary Anning and her times



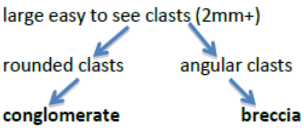
https://www.earthlearningidea.com/PDF/115_Mary_Anning.pdf

6. Questions for any rock face 6: fossils – questions about fossils to be asked at a rock exposure

Questions to ask at any rock face where fossils can be found

https://www.earthlearningidea.com/PDF/231_Questions_rock_face_fossils.pdf

4.1.1.4 Sedimentary rocks

Activities		
ESWA title	**Topic**	**Images**
Recognising sedimentary rocks	Pupils identify a series of photographs of sedimentary rocks using a dichotomous key	 
http://www.wasp.edu.au/mod/resource/view.php?id=185		
Grain size in sedimentary rocks	Pupils examine sedimentary rocks and compare their grain sizes with sandpaper	 
http://www.earthsciencewa.com.au/mod/resource/view.php?id=1439		

Questions/Discussions

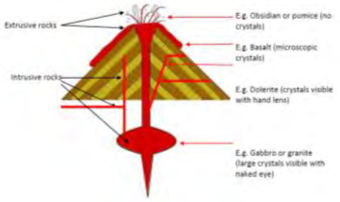
1. How can sands become cemented into sandstones, and yet remain permeable?

2. Which processes cause the compaction of sediments into sedimentary rocks?

3. Which sedimentary rocks are the most permeable; which are the least permeable?

4.	Questions for any rock face 5: sedimentary grains – questions for any rock exposure	Using questions about grain size and shape as clues to the way sediments were transported and deposited		
https://www.earthlearningidea.com/PDF/229_Questions_rock_face_grains.pdf				

4.1.1.5 Igneous rocks

Activities			
ESWA title	**Topic**	**Images**	
Recognising igneous rocks	Pupils research the terms intrusive and extrusive, mafic and felsic and then use these to classify igneous rock photos		
http://www.wasp.edu.au/mod/resource/view.php?id=187			

Questions/Discussions

1. How is chemical composition linked to the colour of igneous rocks?

2. Some igneous rocks have large crystals in a fine-grained groundmass. What does this tell us about the cooling history of the magma from which the rock formed?

3. Often when iron/magnesium-rich magmas erupt, they rise up vertical fissures and then flow out over the surface as lava flows. The molten rock cools and crystallises as vertical dykes and horizontal lava flows. How is the dyke rock likely to differ from the lava rock?

4.1.1.6 Metamorphic rocks

Activities			
ESWA title	**Topic**	**Images**	
Identifying metamorphic rocks	Contrasting metamorphic rocks and their parents to consider the temperatures and pressures involved in metamorphism		
http://www.wasp.edu.au/mod/resource/view.php?id=571			

Questions/Discussions

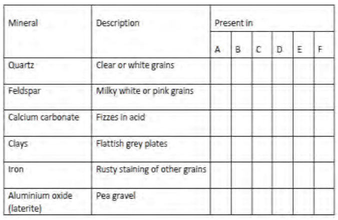
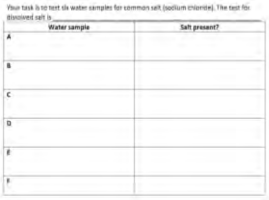
1. Both igneous rocks and metamorphic rocks are crystalline. How does the formation of the two rock types differ?

2. Both marble and metaquartzite are monomineralic rocks (containing only one main mineral) and are often pale in colour, so how could you tell hand specimens of these rocks apart?

3. When granite is metamorphosed it often forms gneiss. Gneiss and granite have similar colours and minerals, so how can you tell them apart?

4.	Questions for any rock face 9: metamorphic rock. – questions for any rock exposure	Questions to help pupils distinguish metamorphic rocks and understand the processes by which they formed		
https://www.earthlearningidea.com/PDF/237_Questions_rock_face_met.pdf				

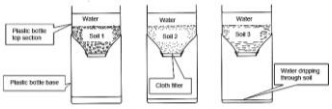
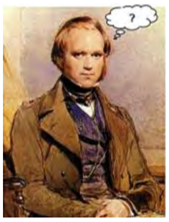
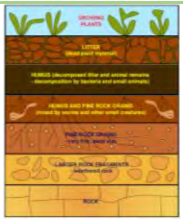
4.1.1.7 Soil

Activities			
ESWA title	**Topic**	**Images**	
Soil grain size	A simple tool to assist pupils to determine grain size		
http://www.wasp.edu.au/mod/resource/view.php?id=519			
Humus in soil	Pupils examine humus in soils to consider its origin and purpose		
http://www.wasp.edu.au/mod/resource/view.php?id=517			
CSI soils	This series of 'Crime Scene Investigation' activities will give pupils some insight into soil composition		
http://www.earthsciencewa.com.au/mod/resource/view.php?id=1291			
Soil compaction	Pupils measure the air within non-compacted soils and compacted soils and consider the consequences of soil compaction		
http://www.palms.edu.au/mod/resource/view.php?id=639			
Salt in water and soils	Soils acquire a variety of salts from groundwater passing through them; these activities examine this process		
http://www.earthsciencewa.com.au/mod/resource/view.php?id=1294			

Mineral	Description	Present in					
		A	B	C	D	E	F
Quartz	Clear or white grains						
Feldspar	Milky white or pink grains						
Calcium carbonate	Fizzes in acid						
Clays	Flattish grey plates						
Iron	Rusty staining of other grains						
Aluminium oxide (laterite)	Pea gravel						

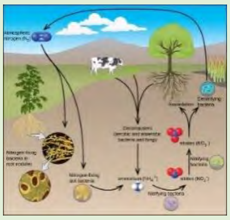
Your task is to test six water samples for common salt (sodium chloride). The test for dissolved salt is __________

Water sample	Salt present?
A	
B	
C	
D	
E	
F	

ELI title	Topic	Images	
Make your own soil: investigating the type and origin of the ingredients of soil	Use this activity in lessons about environment, rocks, landscape, agriculture, gardening or out of doors		
https://www.earthlearningidea.com/PDF/152_Make_own_soil.pdf			
Soil doughnuts: sorting out soils	A method used to sort out different types of soil		
https://www.earthlearningidea.com/PDF/153_Soil_doughnuts.pdf			
Permeability of soils – the great soil race: investigating the properties of different soils by pouring water on them	An investigation of local soils for their permeability		
https://www.earthlearningidea.com/PDF/Permeability_of_soils_Final.pdf			
Darwin's 'big soil idea': can you work out how Charles Darwin 'discovered' how soil formed?	Finding out how Charles Darwin 'discovered' soil by trying to think as he thought, including building a wormery		
https://www.earthlearningidea.com/PDF/58_Darwin_worms.pdf			
Soil layers puzzle – make your own soil profile and investigate others	A puzzle to work out how different soil layers form		
https://www.earthlearningidea.com/PDF/161_Soil_layers_puzzle.pdf			
ESWA title	**Topic**	**Images**	
Desertification and salinity in soil	A series of activities examining the issue of salinity in soils		
http://www.earthsciencewa.com.au/mod/resource/view.php?id=1361			

Questions/Discussions

1. What are the main constituents of soil?
2. What could be added to the soil in your local park to help the plants to grow?
3. How could you find out in the laboratory the percentage of organic material in a soil sample?

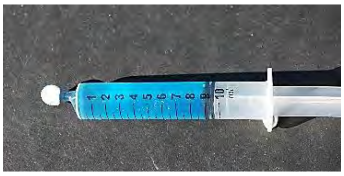
ELI title	Topic	Images
4. Is there life in this soil sample?: Questions to consolidate pupil understanding of soil-formation	Help pupils to build their understanding of soil through a question and answer exercise	 
https://www.earthlearningidea.com/PDF/271_Soil_life.pdf		
5. Where on Earth is no soil found? A 'deep question' discussion about soil-formation	A class discussion to consolidate learning about soil-forming processes	 
https://www.earthlearningidea.com/PDF/332_Where_no_soil.pdf		
6. 'Tagging' nitrogen atoms – to explore the nitrogen cycle: a thought experiment	Using the pretend 'tagging' of a nitrogen atom to trace its nitrogen cycle journey through a window or potted plant	 
https://www.earthlearningidea.com/PDF/334_Tag_nitrogen.pdf		
7. Questions for any rock face 3: soil – What questions about soil might be asked at any rock exposure?	Helping teachers to ask suitable investigative questions about soil-formation on top of rock exposures	 
https://www.earthlearningidea.com/PDF/226_Questions_rock_face_soil.pdf		

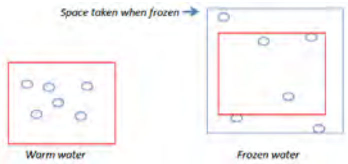
4.1.2 Earth's processes and observed characteristics

Questions/Discussions
1. How are parts of the rock cycle linked to water cycle processes?
2. Which parts of the rock cycle form the sedimentary cycle?

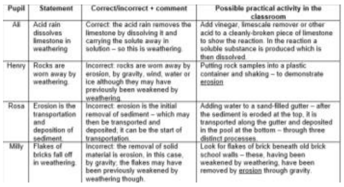
4.1.2.1 Surface processes

Activities		
ELI title	**Topic**	**Images**
Weathering limestone – with my own breath!: a classroom demonstration of how limestone is weathered	Blowing into neutral water to produce a weak acid then adding powdered limestone to neutralise the acid	 
https://www.earthlearningidea.com/PDF/214_Weathering_limestone.pdf		

Cracking apart: simulating the weathering of rocks in a desert environment	Chips of granite heated in a Bunsen flame and rapidly cooled in water to see the rate at which they break apart		
https://www.earthlearningidea.com/PDF/71_Cracking_apart.pdf			
Ice power: freezing water in a syringe to measure the expansion	A simple demonstration, using a 10 or 20 ml syringe, of the power of water to expand when it freezes		
https://www.earthlearningidea.com/PDF/180_Ice_power.pdf			

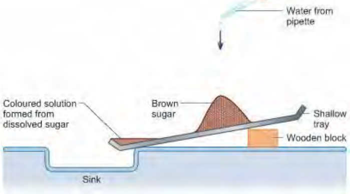
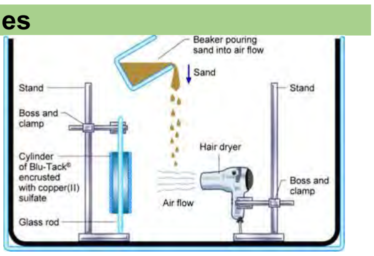
ESWA title	Topic	Images	
Physical weathering – freezing (plaster)	In this activity pupils simulate physical weathering by freezing		
http://www.wasp.edu.au/mod/resource/view.php?id=121			
Chemical weathering – salt and water	In this experiment pupils examine the role that water and salt play in the rate of weathering of materials		
http://www.wasp.edu.au/mod/resource/view.php?id=132			
Chemical weathering – acid rain	Pupils investigate the impact of acid rain on various rock types and materials		
http://www.palms.edu.au/mod/resource/view.php?id=613			

ELI title	Topic	Images	
Karstic scenery – in 60 seconds: modelling the chemical weathering of limestone	Using a block of sugar cubes to model the formation of limestone platforms and karstic scenery		
https://www.earthlearningidea.com/PDF/215_Karst.pdf			
Weathering – rocks breaking up and breaking down: matching pictures of weathered rocks with the processes that formed them	Studying the appearance of weathered rocks and understanding the processes which cause weathering		
https://www.earthlearningidea.com/PDF/46_Weathering_final_2.pdf			

Teacher – What's the difference between weathering and erosion?: addressing misconceptions	Using a 'contrasting ideas' approach to address weathering/erosion misconceptions		
https://www.earthlearningidea.com/PDF/207_Weathering_erosion.pdf			

Pupil	Statement	Correct/incorrect + comment	Possible practical activity in the classroom
Ali	Acid rain dissolves limestone in weathering	Correct: the acid rain removes the limestone by dissolving it and carrying the solute away in solution – so this is weathering.	Add vinegar, limescale remover or other acid to a cleanly-broken piece of limestone to show the reaction. In the reaction a soluble substance is produced which is then dissolved.
Henry	Rocks are worn away by weathering.	Incorrect: rocks are worn away by erosion, by gravity, wind, water or ice although they may have previously been weakened by weathering.	Putting rock samples into a plastic container and shaking – to demonstrate erosion
Rosa	Erosion is the transportation and deposition of sediment.	Incorrect: erosion is the initial removal of sediment – which may then be transported and deposited; it can be the start of transportation.	Adding water to a sand-filled gutter – after the sediment is eroded at the top, it is transported along the gutter and deposited in the pool at the bottom – through three distinct processes.
Milly	Flakes of bricks fall off in weathering.	Incorrect: the removal of solid material is erosion, in this case, by gravity; the flakes may have been previously weakened by weathering though.	Look for flakes of brick beneath old brick school walls – these, having been weakened by weathering, have been removed by erosion through gravity.

Rock, rattle and roll: investigating the resistance of rocks to erosion by shaking in a plastic container	Shake rock specimens in a plastic container to assess their resistance to erosion		
https://www.earthlearningidea.com/PDF/Rock_rattle_and_roll.pdf			
Shell shake – survival of the toughest: why is the fossil record incomplete?	Pupils smash a variety of seashells to see which ones are strong and which ones are so weak that they are unlikely to survive		
https://www.earthlearningidea.com/PDF/212_Shell_shake.pdf			
Grinding and gouging: how moving ice can grind away rocks	Activity for teaching the rock cycle; wearing away of rocks, erosion by ice		
https://www.earthlearningidea.com/PDF/60_Grinding_gouging.pdf			

JESEI title	**Topic**	**Images**	
Weathering and erosion: simulating rock attack in the lab	A circus of class activities that simulate some of the processes occurring in weathering and erosion		
https://geohubliverpool.org.uk/jesei/weathering.htm			

ELI title	**Topic**	**Images**	
Geological postcards 1: granite and chalk – picture postcard puzzles	Using 'postcards' of landscape features as clues to the nature of the underlying granite or chalk rocks		
https://www.earthlearningidea.com/PDF/97_Postcards_1.pdf			
Geological postcards 2: sandstone and limestone – picture postcard puzzles	'Postcards' of landscape features used as clues to the nature of the underlying sandstone or limestone rocks		
https://www.earthlearningidea.com/PDF/98_Postcards_2.pdf			

Evidence from the deep freeze: photographs of glacial and periglacial landscapes

Using photographs of landscapes formed by ice sheets or glaciers and those formed by periglacial processes

https://www.earthlearningidea.com/PDF/104_Evidence_from_deep_freeze.pdf

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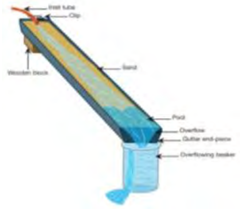
Mighty river in a small gutter: sediments on the move

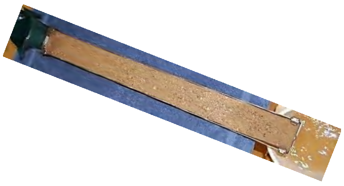
Investigating the effects of flowing water on loose sediment to see how it is eroded, transported and deposited



https://www.earthlearningidea.com/PDF/River_in_a_gutter.pdf

Investigating small-scale sedimentary processes AND modelling mighty rivers: the gutter activity used at different scales

Highlighting the differences in using the *Mighty river in a small gutter* Earthlearningidea activity at different scales



https://www.earthlearningidea.com/PDF/260_River_processes.pdf

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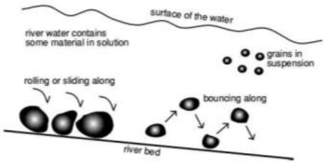
Rolling, hopping and floating and invisibly moving along: investigating how sediment is transported by water

Investigating different ways in which sediment is transported by water



https://www.earthlearningidea.com/PDF/230_Sediment_transport.pdf

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A bucket for a pothole – visualising past processes by calculation: river pothole-formation by calculation

How to simulate pothole formation in the field, involving calculation and the discussion of assumptions

https://www.earthlearningidea.com/PDF/259_Bucket_pothole.pdf

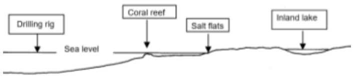
Why do coastlines change shape?: investigating wave erosion, transportation and deposition on a coastline

Investigating processes of coastal erosion, transportation and deposition and the problems they can cause

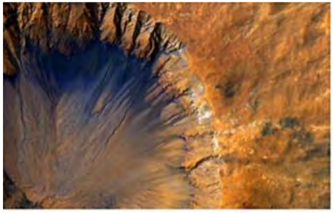
https://www.earthlearningidea.com/PDF/73_Coastal_crumble.pdf

Environmental detective: imagining how the evidence of modern environments could become preserved

Thinking about where different environments might occur on a tropical desert coast and the evidence preserved



https://www.earthlearningidea.com/PDF/53_Environmental_detective.pdf

EWSA title	Topic	Images	
How did that get there?	Pupils decide which of the landforms pictured were shaped by impact, volcanic, fluvial or aeolian processes		
http://www.palms.edu.au/mod/resource/view.php?id=720			

Questions/Discussions

1. What is the difference between weathering and erosion?

2. Most weathering processes depend on water; it has been found that even weathering by heating and cooling acts at a faster rate if the rock has some water in the cracks. How is water involved in other weathering processes?

3. Explain how storms can affect erosion rates.

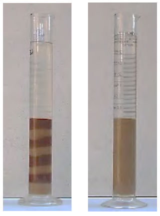
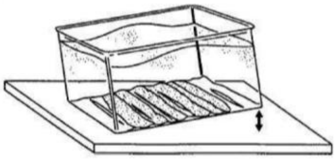
4. Explain how the processes of erosion and deposition have changed the shape of the land (the landscape) in the area where you live.

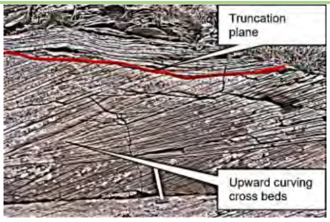
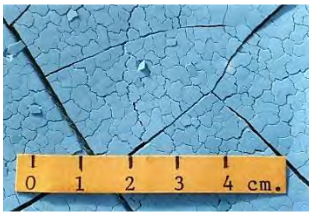
5. What would it feel like to wriggle your toes on an ancient bedding plane as the sediment was being deposited?

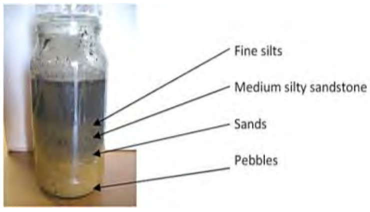
6. What was it like to be there – in the rocky world? Bringing solid rock to life – by imagining yourself there	Asking questions relating to all the senses to bring past environments of the formation of sedimentary rocks to life		
https://www.earthlearningidea.com/PDF/What_was_it_like_to_be_there_-_rock.pdf			
7. If a bed were laid down outside now – what would it be like? Catastrophic processes	A class discussion to develop the idea of a ‘bed’ of rock and how beds might be deposited catastrophically		
https://www.earthlearningidea.com/PDF/309_Catastrophic_processes_beds.pdf			
8. Questions for any rock face 1: weathering – questions on weathering for any rock exposure	Helping teachers to ask suitable investigative questions about weathering at rock exposures		
https://www.earthlearningidea.com/PDF/221_Questions_rock_face_weathering.pdf			
9. Questions for any rock face 2: erosion – questions about erosion for any rock exposure	Helping teachers to ask questions about erosion at rock exposures		
https://www.earthlearningidea.com/PDF/222_Questions_rock_face_erosion.pdf			

10. When are soft rocks tough, and hard rocks weak? Discussing rock toughness/ resistance	The simple idea, of tough rocks forming hills and headlands and weaker rocks, valleys and bays, does not always apply		
https://www.earthlearningidea.com/PDF/312_Hard_soft_rocks.pdf			

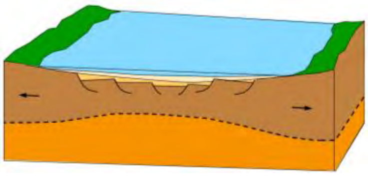
4.1.2.2 Sedimentary processes

Activities			
ELI title	**Topic**	**Images**	
How do sedimentary beds form? – and why can we see them?: the formation of beds in sedimentary rocks	Using a measuring cylinder to demonstrate how beds form and why bedding can be seen clearly in many rocks		
https://www.earthlearningidea.com/PDF/329_How_sedimentary_beds_form			
From river sediment to stripy rocks: modelling the build up of different layers of sediment as in sedimentary rocks	Classroom modelling of how sedimentary layers are formed in rivers		
https://www.earthlearningidea.com/PDF/283_Sediments_stripes.pdf			
Sand ripple marks in a tank: how symmetrical ripple marks form in sand	Ripple marks indicate wave flow conditions. This gives clues about how 'fossil' symmetrical ripple marks formed		
https://www.earthlearningidea.com/PDF/Symmetrical_Ripple_Marks.pdf			
Sand ripples in a washbowl: how asymmetrical ripple marks form in sand	Ripple marks can indicate the direction of flow of the water. Direction of flow can then be worked out from 'fossil' ripple marks		
https://www.earthlearningidea.com/PDF/Asymmetrical_Ripple_Marks.pdf			
Sedimentary structures – make your own cross-bedding: classroom activities to explain how cross-bedding forms	Classroom demonstrations of how sub-aqueous and eolian (wind-formed) cross-bedding form		
https://www.earthlearningidea.com/PDF/320_Make_own_cross_bedding			

Sedimentary structures – cross-bedding: cross-bedding used to find the directions of ancient currents	An introduction to the types of evidence which can be obtained from cross-bedding in sediments and in sedimentary rocks	 
https://www.earthlearningidea.com/PDF/195_Cross_bedding_2.pdf		
Cracking the clues: making your own cracking clues to the Earth's past	Reproducing shrinkage cracks in mud and contraction joints in lavas, using varieties of maize flour	 
https://www.earthlearningidea.com/PDF/47_Mudcracks.pdf		
Sedimentary structures – graded bedding: make your own graded bed – one event, but with coarse to fine sediment	A teacher demonstration (or a small group activity) showing the origins of graded bedding	 
https://www.earthlearningidea.com/PDF/177_Graded_bedding.pdf		
Make your own rock: investigating how loose sediment may be stuck together to form a “rock”	Compaction and cementation of sediments. Making, and testing, ‘rocks’ using sand and a range of ‘cements’	 
https://www.earthlearningidea.com/PDF/Make_your_own_rock.pdf		

ESWA title	Topic	Images
De-watering of sediments	This activity allows pupils to examine what happens to sediments as they are compacted and cemented	 
http://www.wasp.edu.au/mod/resource/view.php?id=169		
Sedimentation and sedimentary sandwiches	Pupils model the formation of sedimentary rocks through making a sandwich	 
http://www.earthsciencewa.com.au/mod/resource/view.php?id=1430		

ELI title	Topic	Images
Rock builder: simulating the formation of fossiliferous sedimentary rocks	Simulating the formation of fossiliferous sedimentary rocks using sediments and shells in a plastic bottle	 
https://www.earthlearningidea.com/PDF/241_Rock_builder.pdf		

The deep rock cycle explained by plate tectonics: lithification – modeling sediments to sedimentary rocks	As plates carrying continents are moved apart, the sediments in between sag into a basin giving quicker lithification		
https://www.earthlearningidea.com/PDF/317_Rock_cycle_plates_lithification.pdf			

Questions/Discussions

1. Which minerals commonly form sedimentary rocks?

2. Which sedimentary structures can show the direction of flow of the water or wind that deposited them?

3. Which sedimentary structures can be formed by both wind and water?

4. Complete the table below to show the answers to questions 2 and 3 above (where part of the table is blank, write 'X').

Sedimentary structures:	showing flow direction	not showing flow direction
formed by both wind and water		
formed by water only		
formed by wind only		

5. Which different sedimentary structures could you make in the classroom, with the right apparatus and materials?

6. What was it like to be there?: clues in sediment which bring an environment to life

   Asking 'deep questions' about sedimentary structures to help pupils to visualise the environment in which they formed

https://www.earthlearningidea.com/PDF/235_Sedimentary_structures.pdf

7. Beach, river, dune, mountain, plain – what layers might be preserved here?

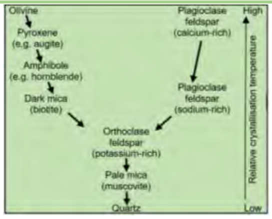
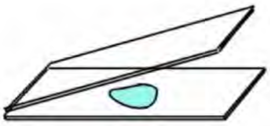
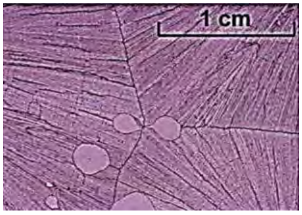
   A discussion about the layers and evidence that might be laid down and preserved in land and coastal environments

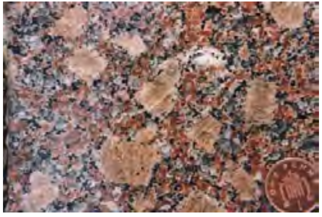
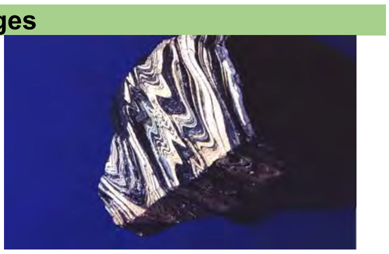
https://www.earthlearningidea.com/PDF/327_What_layers_are_preserved.pdf

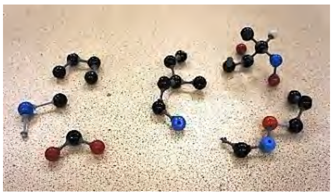
4.1.2.3 Igneous processes

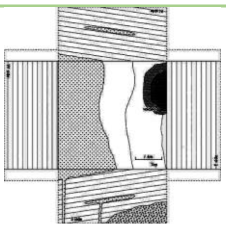
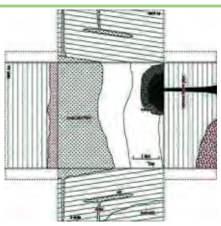
Activities

ELI title	Topic	Images	
Partial melting – simple process, huge global impact: how partial melting, has changed the chemistry of our planet	A demonstration of partial melting explaining how this affected the chemistry of the planet, igneous rocks/eruptions		
https://www.earthlearningidea.com/PDF/82_Partial_melting.pdf			

Partial melting model and real rock: comparing a model with the reality of the partial melting process	A consolidation exercise on partial melting, discussing how a model mirrors processes in real rocks		
https://www.earthlearningidea.com/PDF/262_Partial_melting.pdf			
Why do igneous rocks have different crystal sizes?: the relationships between crystal sizes and different rates of cooling	This activity models the cooling and crystallisation of magma to form igneous rocks		
https://www.earthlearningidea.com/PDF/94_Salol.pdf			

JESEI title	Topic	Images	
Crystal size and cooling rate: fast and slow cooling of lead iodide	Illustrating how the rate at which molten rock cools affects the size of the crystals that form		
https://geohubliverpool.org.uk/jesei/xtal%20size%20&%20cooling%20rate.htm			

ELI title	Topic	Images	
The unfair 'build your own crystal' race: a 'race' showing the greater the time available, the larger the crystals	A quick 'game' to show that the more time there is available to 'build' a crystal or model, the larger it will become		
https://www.earthlearningidea.com/PDF/99_Build_crystal_race.pdf			
'Crystallisation' in a pudding dish: simulating the formation and growth of crystal lattices	The formation of regular patterns with spherical objects, akin to the way in which crystal lattices may be produced		
https://www.earthlearningidea.com/PDF/100_Crystallisation_in_pudding_dish.pdf			
Volcano in the lab: modelling igneous processes in wax and sand	Modelling the rise of "magma" through the "crust" to show eruption, intrusions and a lava flow		
https://www.earthlearningidea.com/PDF/89_Volcano_in_the_lab.pdf			
Volcanoes and dykes/ jelly and cream – radial dykes: intruding cream radial 'dykes' into jelly 'volcanoes'	A simulation of the intrusion of magma into a volcano, usually forming radial dykes before erupting		
https://www.earthlearningidea.com/PDF/145_Jelly_cream_1.pdf			

JESEI title	Topic	Images	
Igneous processes: matching the evidence they leave behind https://geohubliverpool.org.uk/jesei/igneous%20processes.htm	Igneous rocks form by exciting processes; match the evidence from the rocks or photos to their origins		
Igneous rocks: completing the 3D picture https://geohubliverpool.org.uk/jesei/igneous%20rocks.htm	Pupils make a paper model showing igneous features; they use this to help them to answer questions		

Questions/Discussions

1. Add these words to this table: andesite, dolerite, volcanic ash (in two places), gabbro, microgranite, sill, pluton, pillow lava, magma chamber, volcanic pipe, lava flow, volcanic plug, extrusive.

Description	**Depth**	**Formation**	**Chemical composition**		
			iron/magnesium-rich	**intermediate**	**silicon-rich**
	Earth's surface		basalt		
intrusive	**Below surface**	dyke		unusual – add no terms here	
	Deep below surface	batholith		unusual – add no terms here	granite

2. What foods could you mix together in a saucepan and heat on the stove to show that some things melt before others – to model the melting of minerals at different temperatures and so the partial melting of rocks in the Earth?

3. Draw an east-west cross section diagram to show a dyke and a sill that have intruded an area of sedimentary rocks that dips (slopes downwards) at an angle of 30^{o} to the west.

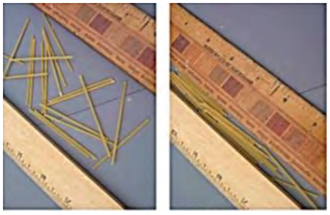
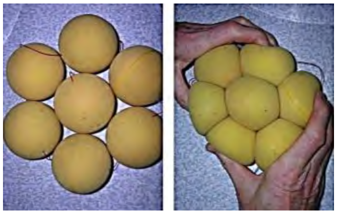
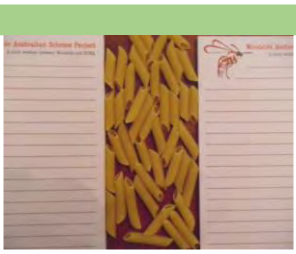
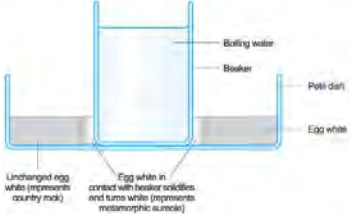
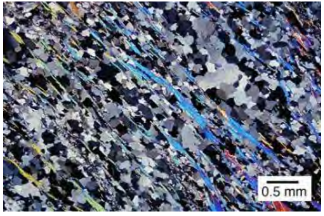
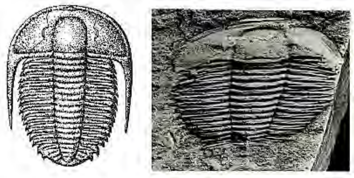
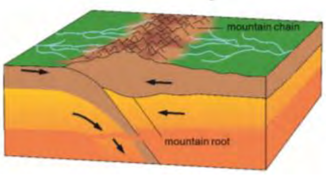
4. Put the following igneous rocks in order, from the quickest to form to the slowest: the rectangular feldspar crystals in the granite image shown opposite, the glassy obsidian shown in the images in Box 4.3 of the *Exploring geoscience* textbook, gabbro, andesite, dolerite.

5. What was it like to be there – in the rocky world? Bringing solid rock to life – by imagining yourself there

Asking questions relating to all the senses to bring the environments of igneous rock formation to life

https://www.earthlearningidea.com/PDF/What_was_it_like_to_be_there_-_rock.pdf

4.1.2.4. Metamorphic processes

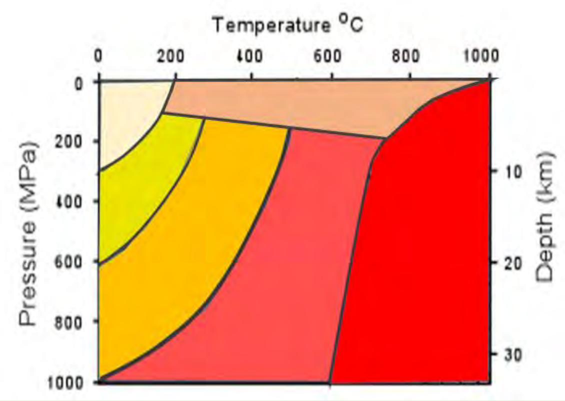
<table>
<tr><th colspan="3">Activities</th></tr>
<tr><th>ELI title</th><th>Topic</th><th>Images</th></tr>
<tr><td>Metamorphism – that's Greek for change of shape, isn't it?: when rocks are put under great pressure</td><td>A demonstration of the formation of two common textures seen in metamorphic rocks</td><td> </td></tr>
<tr><td colspan="3">https://www.earthlearningidea.com/PDF/43_Metamorphism.pdf</td></tr>
<tr><th>ESWA title</th><th>Topic</th><th>Images</th></tr>
<tr><td>Recognising metamorphic rocks</td><td>Pupils consider what metamorphism is and use simple models to examine the effect of pressure</td><td> </td></tr>
<tr><td colspan="3">http://www.wasp.edu.au/mod/resource/view.php?id=189</td></tr>
<tr><th>JESEI title</th><th>Topic</th><th>Images</th></tr>
<tr><td>Metamorphic modelling – simulating metamorphic processes</td><td>Simulate some of the ways in which metamorphic rocks are formed</td><td>  </td></tr>
<tr><td colspan="3">https://geohubliverpool.org.uk/jesei/metamorphics.htm</td></tr>
<tr><th>ELI title</th><th>Topic</th><th>Images</th></tr>
<tr><td>Squeezed out of shape: detecting the distortion after rocks have been affected by Earth movements</td><td>A carefully made mould of a shell is deliberately distorted before a plaster cast is made, producing an artificial 'fossil'</td><td> </td></tr>
<tr><td colspan="3">https://www.earthlearningidea.com/PDF/51_Squeezed_out_of_shape.pdf</td></tr>
<tr><td>Metamorphic aureole in a tin: what controls the changes in temperature around an intrusion?</td><td>Modelling with hot water and sand in a tin the factors affecting temperature changes around an igneous intrusion</td><td> </td></tr>
<tr><td colspan="3">https://www.earthlearningidea.com/PDF/252_Metamorphic_aureole.pdf</td></tr>
<tr><td>The deep rock cycle explained by plate tectonics: deformation and metamorphism: a model of mountains and roots</td><td>A model to show how, as continents move towards one another, the rocks are deformed into mountain chains with roots</td><td>  </td></tr>
<tr><td colspan="3">https://www.earthlearningidea.com/PDF/318_Rock_cycle_plates_def_met.pdf</td></tr>
</table>

Questions/Discussions

1. Which two rocks:
(a) can be formed by both regional and thermal metamorphism,
(b) can be the original rocks from which gneiss forms?

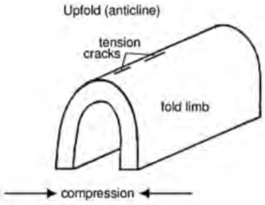
2. Label a diagram like the one shown opposite using the following terms: compaction and cementation into sedimentary rock, partial melting of wet rocks, low grade regional metamorphism, medium grade regional metamorphism, high grade regional metamorphism, thermal metamorphism.

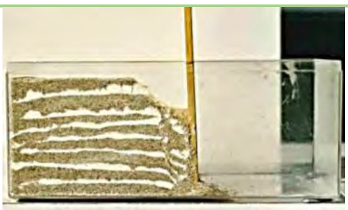
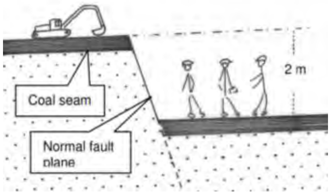
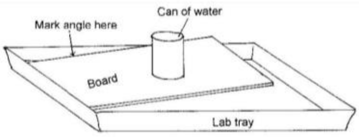
3. EITHER on an A4 sized version of this diagram, put specimens of sedimentary, igneous and metamorphic rocks in the right places OR, on a smaller version, write the names of common sedimentary, igneous and metamorphic rocks in the places on the diagram where they are likely to form.

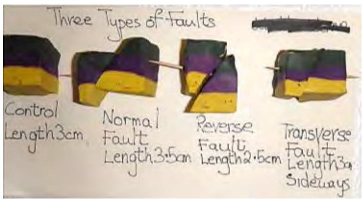


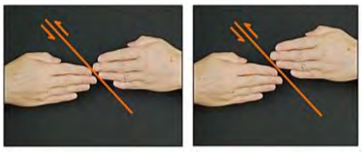
4.1.2.5. Deformation processes

Activities

ELI title	Topic	Images	
The Himalayas in 30 seconds! Making a miniature fold mountain range in an empty box	Modelling how lateral pressure can squeeze rocks into folds and faults, to show the way in which fold mountain ranges are formed		
https://www.earthlearningidea.com/PDF/Himalayas_in_30_seconds_final_071029.pdf			
Margarine mountain-building: making mountains every time you make a sandwich	A breakfast-time reminder of how rocks can become folded and mountain ranges are formed.		
https://www.earthlearningidea.com/PDF/118_Margarine_mountains.pdf			
Swiss roll surgery: investigating geological structures and their outcrops using sponge rolls	Demonstrating folded and faulted rock patterns, by slicing sponge rolls in different ways		
https://www.earthlearningidea.com/PDF/251_Swiss_roll_surgery.pdf			
Banana benders: using a banana to simulate geological structures	Simulation of the deformation of materials – in small-scale exposures or large-scale mountain building		
https://www.earthlearningidea.com/PDF/120_Banana_benders.pdf			

A valley in 30 seconds: pulling rocks apart: investigating faulting in an empty box	Modelling how tensional forces can cause fractures in rocks, sometimes creating rift valleys		
https://www.earthlearningidea.com/PDF/Valley_in_30s.pdf			
Fluids, friction and failure: How can unseen fluids affect the movement along faults and glacier beds?	A test of the angle at which friction is overcome as a drinks can begins to slide down an inclined board with or without water		
https://www.earthlearningidea.com/PDF/122_Fluids_friction.pdf			
From folds to crustal shortening – visualising past processes by calculation: modelling folding by calculation	Calculating approximate crustal shortening in the field (or a diagram or photograph) then discussing the assumptions		
https://www.earthlearningidea.com/PDF/256_Crustal_shortening.pdf			
Modelling folding – by hand: using your hands to demonstrate different fold features	Pupils use their hands to demonstrate different elements of folding in rocks		
https://www.earthlearningidea.com/PDF/291_Folding_hands.pdf			

ESWA title	**Topic**	**Images**	
Three types of fault	Pupils model the three major types of fault and examine their features (using playdough or similar)		
http://www.wasp.edu.au/mod/resource/view.php?id=261			

ELI title	**Topic**	**Images**	
Modelling faulting – by hand: using your hands to demonstrate different fault features	Using your hands to illustrate the different types of faulting		
https://www.earthlearningidea.com/PDF/298_Hands_faults.pdf			
Modelling Earth stresses with your hands: hand modelling of compression, tension and shear in the Earth	A class activity to help pupils to visualise types of stress in the Earth through modelling with their hands		
https://www.earthlearningidea.com/PDF/289_Model_Earth_stresses.pdf			

Questions/Discussions

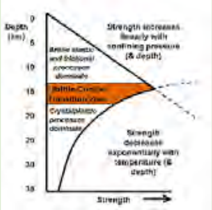
1. How can you tell the difference between a joint and a fault in a rock exposure?

2. Describe, by adding labels to the photographs above:
   (a) the folds formed in the plastic box in *The Himalayas in 30 seconds!* activity,
   (b) the fault in the *A valley in 30 seconds* activity.

3. Sometimes rocks both fold and fracture as they deform; which type of faulting is most likely to be formed at the same time as folds?

4. The view from above – living tectonism: to be there – on a mountain-building collision?

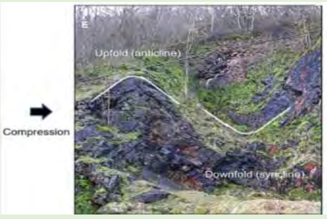
   A thought experiment – pupils imagine what it would have been like on top of a mountain range as it was being formed

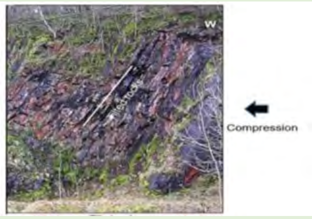


https://www.earthlearningidea.com/PDF/255_View_from_above.pdf

5. Questions for any rock face 7: tilted or folded rocks – questions for any rock exposure

   Questions to aid pupil understanding of tilted and folded rocks

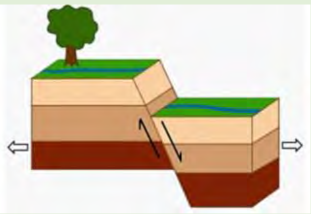




https://www.earthlearningidea.com/PDF/232_Questions_rock_face_tilted_folded.pdf

6. Questions for any rock face 8: faults – questions about faults for any rock exposure

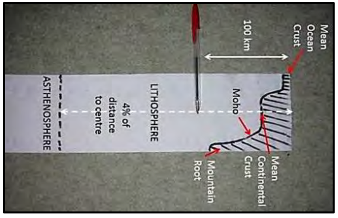
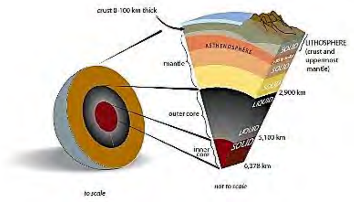
   Questions to help pupils to understand faults seen in field exposures, and the forces that caused them



https://www.earthlearningidea.com/PDF/233_Questions_rock_face_faults.pdf

4.1.3. Structure of the Earth and evidence

Activities

ELI title	Topic	Images	
Journey to the centre of the Earth – on a toilet roll: just how thin is the crust we live on?	A scale model of the size of the Earth, emphasising the thinness of the crust and other uppermost layers		

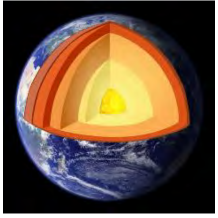
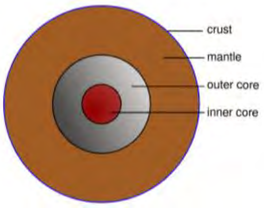
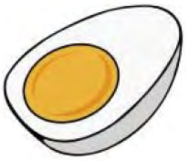
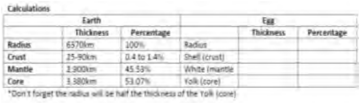
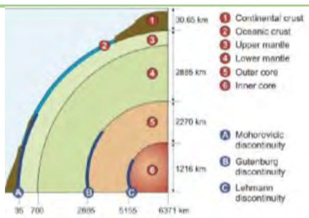
https://www.earthlearningidea.com/PDF/196_Journey_centre_E.pdf

Questions/Discussions

1. If the distance to the centre of the Earth was the length of your arm and hand from your elbow to the tips of your fingers, about how thick would the Earth's crust be (mean crustal thickness = 15 km)?

2. Draw a table to summarise the properties of the different Earth layers; leave plenty of space so you can add more information as you read more about the deep Earth. [Note: you will be asked later to draw a similar table for the layers of the outer Earth in oceanic areas, the atmosphere and the ocean].

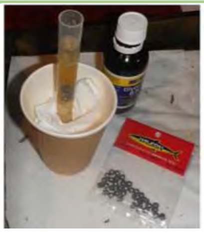
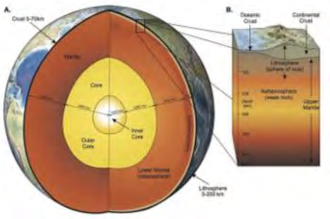
4.1.3.1. Evidence

Activities			
ELI title	**Topic**	**Images**	
From clay balls to the structure of the Earth – a discussion of how physics can be used to probe Earth’s structure	A series of questions provokes pupil discussion of the structure of the Earth		
https://www.earthlearningidea.com/PDF/74_Clay_balls.pdf			
From an orange to the whole Earth: using an orange to model different densities of the Earth's layers	This activity can form part of a lesson about density and the structure of the Earth		
https://www.earthlearningidea.com/PDF/59_Oranges_and_Earth.pdf			
ESWA title	**Topic**	**Images**	
Layers of the Earth (density)	In activity one pupils calculate the relative proportions of the layers of the Earth. Activity two asks them to produce models		
http://www.wasp.edu.au/mod/resource/view.php?id=403			
Earth egg model	Activity one uses a hard-boiled egg to simulate the layers of the Earth while activity two examines tectonic plates		
http://www.wasp.edu.au/mod/resource/view.php?id=401			
Denser down	This activity examines density and its role in the internal differentiation of our Earth		
http://www.wasp.edu.au/mod/resource/view.php?id=399			
The Great Iron Catastrophe and rock density	Pupils investigate rock density and how this relates to the structure of our Earth and the types of crust		
http://www.wasp.edu.au/mod/resource/view.php?id=296			

Calculations

Earth			Egg		
	Thickness	Percentage		Thickness	Percentage
Radius	6370km	100%	Radius		
Crust	25-90km	0.4 to 1.4%	Shell (crust)		
Mantle	2,900km	45.53%	White (mantle		
Core	3,380km	53.07%	Yolk (core)		

*Don’t forget the radius will be half the thickness of the Yolk (core)

Planetary differentiation	Through a series of activities pupils examine the 'Great Iron Catastrophe' and planetary differentiation		
http://www.wasp.edu.au/mod/resource/view.php?id=294			

Questions/Discussions

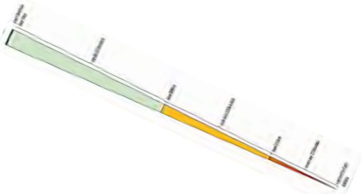
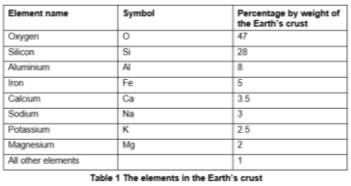
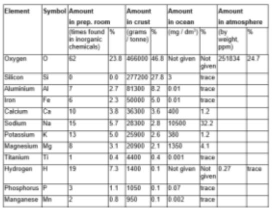
1. The Greek word for earthquake is ‘*seismos*’; how is this related to the study of earthquakes?

2. Because of the pressure of the layers above, the Earth generally becomes more and more incompressible with depth; it also becomes more and more rigid with depth (except where it is molten or near-molten); how is this likely to affect the speed of earthquake shock waves as they travel through the Earth?

3. What would the layers of the Earth below the crust be like, if you could visit them?

4.1.3.2. Crust

Activities

JESEI title	Topic	Images	
Earth’s crust: thinner than you think	Use the radius of the Earth and the thickness of the crust to work out the thickness of a postage stamp		
https://geohubliverpool.org.uk/jesei/earths%20crust%201.htm			
Minerals, elements and the Earth’s crust	Questions about the composition of minerals and ores linked to elements, compounds, symbols and formulae		
https://geohubliverpool.org.uk/jesei/minerals%20&%20elements.htm			
Earth’s crust versus the prep. room – why the differences?	This ‘starter’ activity introduces pupils to the common elements found in the Earth		
https://geohubliverpool.org.uk/jesei/earths%20crust%202.htm			

Element name	Symbol	Percentage by weight of the Earth’s crust
Oxygen	O	47
Silicon	Si	28
Aluminium	Al	8
Iron	Fe	5
Calcium	Ca	3.5
Sodium	Na	3
Potassium	K	2.5
Magnesium	Mg	2
All other elements		1

Table 1 The elements in the Earth’s crust

Element	Symbol	Amount in prep. room		Amount in crust		Amount in ocean		Amount in atmosphere	
		(times found in inorganic chemicals)	%	(grams / tonne)	%	(mg / dm^3)	%	(by weight, ppm)	%
Oxygen	O	62	23.8	466000	46.8	Not given	Not given	251834	24.7
Silicon	Si	0	0.0	277200	27.8	3	trace		
Aluminium	Al	7	2.7	81300	8.2	0.01	trace		
Iron	Fe	6	2.3	50000	5.0	0.01	trace		
Calcium	Ca	10	3.8	36300	3.6	400	1.2		
Sodium	Na	15	5.7	28300	2.8	10500	32.2		
Potassium	K	13	5.0	25900	2.6	380	1.2		
Magnesium	Mg	8	3.1	20900	2.1	1350	4.1		
Titanium	Ti	1	0.4	4400	0.4	0.001	trace		
Hydrogen	H	19	7.3	1400	0.1	Not given	Not given	0.27	trace
Phosphorus	P	3	1.1	1050	0.1	0.07	trace		
Manganese	Mn	2	0.8	950	0.1	0.002	trace		

Questions/Discussions

1. Why is the oceanic crust at a lower level (an average of 3.7 km below sea level) than the continental crust (an average of 0.8 km above sea level)?

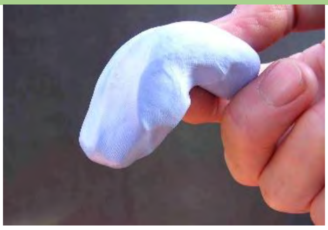
2. Why is the Earth’s crust called the crust?

3. How have geoscientists found out what the continental crust is made of in the area where you live?

4. How do geoscientists find out what the oceanic crust is like?

4.1.3.3. Mantle

Activities

ELI title	Topic	Images	
Bouncing, bending, breaking – modelling the properties of the Earth's mantle with Potty Putty™ from a toy shop	Using Potty Putty™ to discover how one single material can respond elastically, plastically or by brittle failure.		
https://www.earthlearningidea.com/PDF/78_Bouncing_bending_breaking.pdf			

Questions/Discussions

1. The boundary between the crust and the mantle was discovered by the Croatian scientist Mohorovičić in 1909; the boundary is now called the Mohorovičić Discontinuity or Moho for short. What method did he use to discover this boundary?

2. Ice and the mantle have similar mechanical properties. What are these properties?

4.1.3.4. Core

Activities

JESEI title	Topic	Images	
Structure of the Earth: teacher demonstrating seismic evidence for the core	Demonstrating the nature of the Earth's interior, from which we hypothesise that the Earth has a liquid outer core		
https://geohubliverpool.org.uk/jesei/structure%20of%20earth%203.htm			

ELI title	Topic	Images	
A core activity: piecing together evidence for the composition of the Earth's core	An activity asking pupils to examine and discuss the evidence for the composition of the Earth's core		
https://www.earthlearningidea.com/PDF/147_Core.pdf			

Questions/Discussions

1. The boundary between the mantle and the core was discovered by the German-American scientist Gutenberg and is now called the Gutenberg Discontinuity. What method did he use to discover this boundary?

2. Over time the Earth's core loses heat. What is likely to happen to the liquid outer core as it slowly cools?

4.1.3.5. Lithosphere

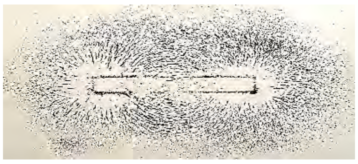
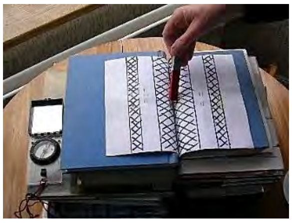
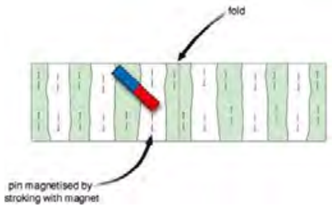
Questions/Discussions

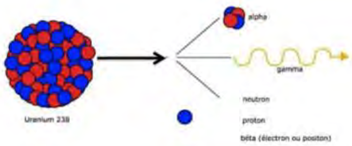
1. The base of the crust and the base of the lithosphere are at different depths. What other difference is there between these two boundaries?

2. The early Earth is thought to have been mostly molten. Explain whether it is likely to have had a lithosphere at this time.

4.1.4. Plate tectonics and evidence

Activities

ELI title	Topic	Images	
Frozen magnetism – preserving evidence of a past magnetic field in wax	How the evidence for the magnetic field around a bar magnet may be preserved, even after the magnet has been removed		
https://www.earthlearningidea.com/PDF/80_Frozen_magnetism.pdf			
Magnetic stripes – modelling the symmetrical magnetic pattern of the rocks of the sea floor	Demonstrating the origin of the symmetrical magnetic anomalies which occur at oceanic spreading centres		
https://www.earthlearningidea.com/PDF/81_Magnetic_stripes.pdf			

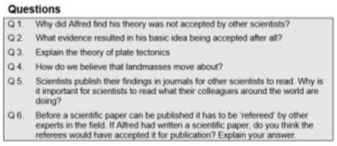
ESWA title	Topic	Images	
Rock age data	Pupils consider how we 'age' rocks and interpret data to find answers in this exercise		
http://www.wasp.edu.au/mod/resource/view.php?id=249			

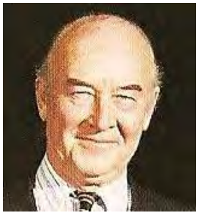
Questions/Discussions

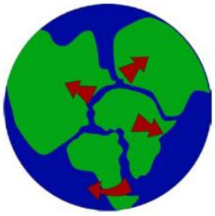
1. How could you measure the directions of the Earth’s magnetic flux lines (directions of magnetic force) in the room where you are sitting?
2. Why were we unable to detect ocean floor magnetism before the 1950s?

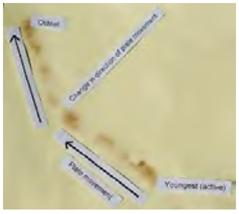
4.1.4.1. Unifying theory

Activities

JESEI title	Topic	Images	
The plate tectonic story: a scientific jigsaw puzzle	A page of description about the evolution of the theory of plate tectonics is followed by pupil questions	The plate tectonic story: a scientific jigsaw	**Questions** Q 1. Why did Alfred find his theory was not accepted by other scientists? Q 2. What evidence resulted in his basic idea being accepted after all? Q 3. Explain the theory of plate tectonics Q 4. How do we believe that landmasses move about? Q 5. Scientists publish their findings in journals for other scientists to read. Why is it important for scientists to read what their colleagues around the world are doing? Q 6. Before a scientific paper can be published it has to be 'refereed' by other experts in the field. If Alfred had written a scientific paper, do you think the referees would have accepted it for publication? Explain your answer.
https://geohubliverpool.org.uk/jesei/plate%20tectonic%20story.htm			

ELI title	Topic	Images	
Wegener’s ‘Continental drift’ meets Wilson’s ‘Plate tectonics’ – how the evidence matches up	Sorting out which parts of the evidence we now have for plate tectonics that Alfred Wegener knew about in the 1920s		
https://www.earthlearningidea.com/PDF/91_Wegener.pdf			

ESWA title	Topic	Images	
Tectonics history	Pupils explore the history of the development of the theory of plate tectonics; they then complete a cloze exercise		
http://www.wasp.edu.au/mod/resource/view.php?id=588			
Plate jigsaw	In this activity pupils create their own version of our tectonic plates as a jigsaw puzzle, using bread and paints		
http://www.wasp.edu.au/mod/resource/view.php?id=235			
Seafloor model	Pupils create their own model to demonstrate seafloor spreading, using simple materials		
http://www.wasp.edu.au/mod/resource/view.php?id=247			

ELI title	Topic	Images	
Model a spreading ocean floor offset by transform faults – the transform fault ‘steps’ in oceanic ridges and magnetic stripes	Making a working model showing how sea floors spread, offset by transform faults		
https://www.earthlearningidea.com/PDF/84_Transform_faults.pdf			
Hotspots: modelling the movement of a plate across the globe	A candle and a piece of card used to model the movement of a tectonic plate over a heat source in the Earth’s mantle		
https://www.earthlearningidea.com/PDF/208_Hotspots.pdf			

ESWA title	Topic	Images	
Supercontinents	Pupils research supercontinents and explore Australia's continental history		Cratons What is a craton? A craton is a thick part of the Earth's Continental Crust that has been stable over long periods of geological time. Where would you find cratons in WA? Please locate them on the map. Kimberley Craton Pilbara Craton Yilgarn Craton
http://www.wasp.edu.au/mod/resource/view.php?id=592			

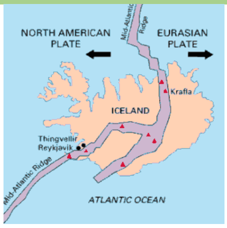
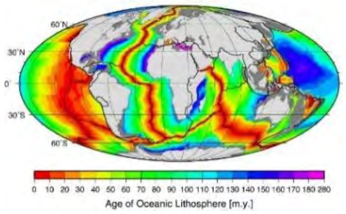
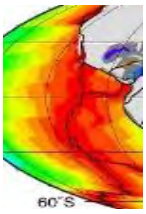
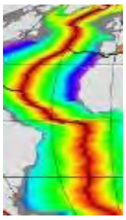
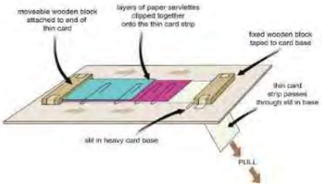
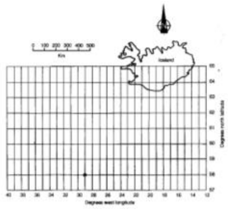
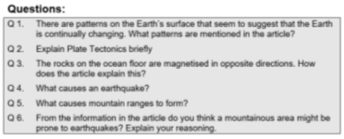
Questions/Discussions

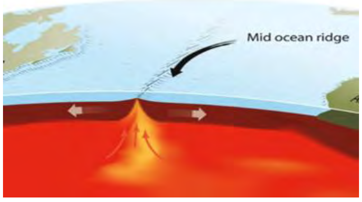
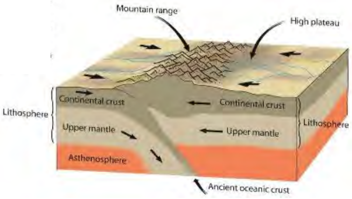
1. Why is the theory proposed by J. Tuzo Wilson to explain plate tectonics called a ‘unifying theory’?
2. Why do the magnetic stripes on the ocean floor not form straight lines but instead, the edges of each stripe are very irregular?
3. The sonar method of depth sounding (measuring ocean depths) depends on the speed of sound waves in water. Explain how this works.

4.1.4.2. Plate construction and subduction

Questions/Discussions	
1. The three types of plate margin are divergent, conservative and convergent. What is the meaning of each of these names? 2. What are the similarities between a tectonic plate and a china plate?	

4.1.4.3. Characteristics of plate margins

Activities		
ELI title	**Topic**	**Images**
Faults in a Mars™ Bar; pulling apart a Mars™ Bar to model a divergent plate margin	A demonstration of the forces involved in the creation of a rift valley at a divergent margin, using a Mars™ Bar	 
https://www.earthlearningidea.com/PDF/302_Mars_bars.pdf		
Which is the fastest spreading oceanic ridge?: a map-based activity to find the most active oceanic spreading ridge	A measurement and calculation activity – which of the ridges is spreading fastest, based on the ages of the ocean floors?	  
https://www.earthlearningidea.com/PDF/328_Fastest_spreading_ocean.pdf		
Continents in collision: modelling processes at a destructive (convergent) plate margin	Cardboard model of the features of a destructive (convergent) continent v continent plate margin	 
https://www.earthlearningidea.com/PDF/83_Continents_in_collision.pdf		
JESEI title	**Topic**	**Images**
Magnetic patterns: ocean floor pattern plotting	Plotting magnetic field data on a map of the ocean floor shows how the magnetisation of the ocean floor varies	 
https://geohubliverpool.org.uk/jesei/magnetic%20patterns%201.htm		
Dangerous Earth: a plate tectonic story	Pupils read a written description of plate tectonics before answering a series of questions	  **Questions:** Q 1. There are patterns on the Earth's surface that seem to suggest that the Earth is continually changing. What patterns are mentioned in the article? Q 2. Explain Plate Tectonics briefly Q 3. The rocks on the ocean floor are magnetised in opposite directions. How does the article explain this? Q 4. What causes an earthquake? Q 5. What causes mountain ranges to form? Q 6. From the information in the article do you think a mountainous area might be prone to earthquakes? Explain your reasoning.
https://geohubliverpool.org.uk/jesei/dangerous%20earth.htm		

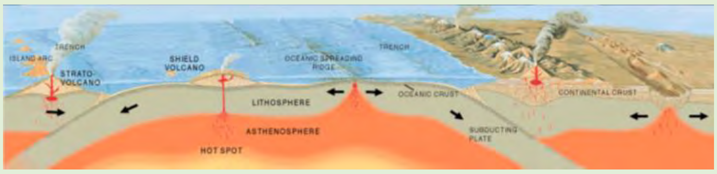
ELI title	Topic	Images	
Plate margins by hand: modelling plate margins and plate movement with your hands	A class activity to help pupils to visualise plate margins and movements through modelling with their hands		
https://www.earthlearningidea.com/PDF/278_Plate_margins_movement.pdf			
Plate tectonics through the window: What might you see through a window or porthole at a plate margin?	Imagining the scenery and plate activity at different plate margins		
https://www.earthlearningidea.com/PDF/88_PT_thru_window.pdf			

Questions/Discussions

1. How do the earthquakes at convergent plate margins differ from those at divergent and conservative margins?

2. Explain which type of convergent plate margin forms mountains with the deepest roots.

3. Explain which types of rocks from those shown in Tables 4.3 and 4.4. (sedimentary rocks), 4.6 and 4.7. (igneous rocks), 4.8 and 4.9. (metamorphic rocks) and which types of structures from Tables 4.17 (fractures) and 4.18. (folds) in the *Exploring geoscience* textbook are most likely to be formed in mountain root zones.

4. Questions for any rock face 11: tectonic plates – questions about tectonic plates	Questions asking pupils to relate their observations from a rock exposure to the 'bigger picture' of plate tectonics	
https://www.earthlearningidea.com/PDF/240_Questions_rock_face_plates.pdf		

4.1.4.4. Mechanism and rates of movement

Activities

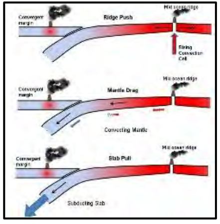
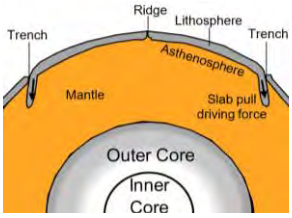
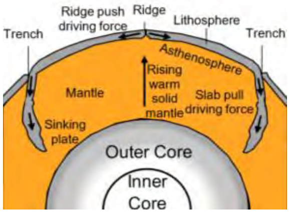
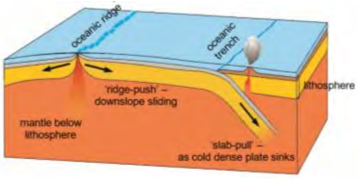
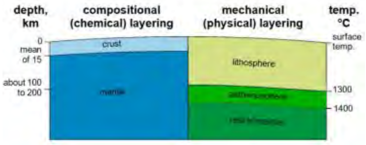
ELI title	Topic	Images	
What drives the plates?: using a pupil model to demonstrate that slab pull is the main driving force	Considering the different processes likely to be driving plate movement, using a pupil model		
https://www.earthlearningidea.com/PDF/217_Slab_pull.pdf			
All models are wrong – but some are really wrong: plate-driving mechanisms: many diagrams have wrong arrows	All models are simplifications, and these can be seen to be wrong when superseded by better evidence-based models		
https://www.earthlearningidea.com/PDF/326_Plate_driving_mechanisms.pdf			

Plate-riding – role-play plate-surfing to ask: 'How is the plate you live on moving now?'	Helping pupils relate to the movement of the plate that they live on		
https://www.earthlearningidea.com/PDF/87_Plate_riding.pdf			
What do the top and bottom of a tectonic plate look like?: questions to test understanding of plate tectonic processes	A deep question discussion on the properties of tectonic plates		
https://www.earthlearningidea.com/PDF/ 333_Top_bottom_plates			

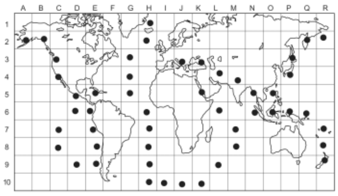
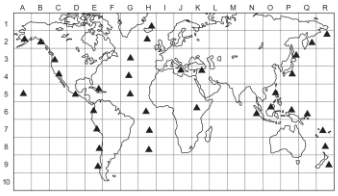
Questions/Discussions

1. Which plates are the fastest-moving ones?

2. A classroom model to show the ridge-push plate-driving mechanism could be made by putting an open book with a shiny cover face-downwards on the table, placing a cloth or piece of paper on either side, and then lifting the centre of the book to show the cloths/papers sliding off either side. However, this might cause some misunderstandings. What misunderstandings might this produce?

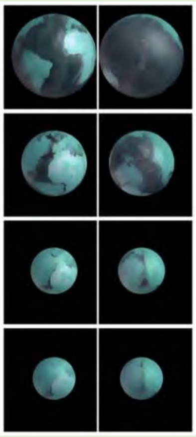
4.1.4.5. Evidence

Activities

ELI title	Topic	Images	
The continental jigsaw puzzle: Can you reassemble a super-continent from a 'jigsaw puzzle'?	Using a series of prepared maps of the modern day continents to reconstruct the supercontinents of the past		
https://www.earthlearningidea.com/PDF/85_Continental_jigsaw_puzzle.pdf			
Geobattleships – do earthquakes and volcanoes coincide?	Using a children's game to match the distribution of volcanoes and earthquakes on the Earth's surface		
https://www.earthlearningidea.com/PDF/79_Geobattleships.pdf			

Questions/Discussions

1. Which of the pieces of evidence for plate tectonic theory come from:
   (a) oceanic areas alone,
   (b) the continental areas alone,
   (c) come from both oceans and continents?



2. One theory used to explain the geology of the outer Earth was the 'expanding Earth' theory, which assumed that the Earth's surface was once mostly or completely covered by a continent, and that the continents were moved apart as the Earth expanded (see image). Which of the pieces of evidence supporting plate tectonic theory could also be used to support the 'expanding Earth' theory?

3. An alternative theory used to explain the Earth's geology was the 'shrinking Earth' theory. This explained that mountain chains were formed by the Earth shrinking in size (as it cooled), like the wrinkles on an old shrinking apple (see photo). Which of the pieces of evidence supporting plate tectonic theory could also be used to support the 'shrinking Earth' theory as well?

4. What is the evidence for plate tectonic theory in your region?

4.2. Hydrosphere

Questions/Discussions

1. What does the term 'hydrosphere' mean?

2. Draw a table for the layers of the outer Earth in oceanic areas, the atmosphere and the ocean, similar to the table you drew for the solid Earth for section 4.1.3.

4.2.1. Continental water

4.2.1.1. Continental water sources

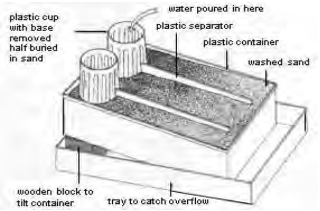
Questions/Discussions

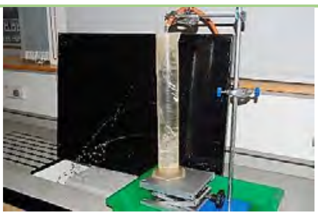
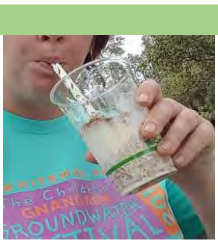
1. Using system terms, list the main stores of water on Earth.

2. Explain which major store of water on Earth has:
   (a) the longest residence time,
   (b) the shortest residence time.

3. In which of the continental water sources can water flow upwards? Explain how this can happen.

4.2.1.2. Water supplies

Activities			
ELI title	**Topic**	**Images**	
Groundwater – from rain to spring: water from the ground: how water flows through the ground – and can be polluted	A demonstration of groundwater flow, springs, wells and problems of toxic waste disposal		
https://www.earthlearningidea.com/PDF/54_Groundwater.pdf			

Well, well, well! Making a working model of a well	Use a model to show how water percolates through the grain spaces of a sediment or rock to accumulate at the bottom of a well		
https://www.earthlearningidea.com/PDF/139_Wells.pdf			
Water pressure – underground: demonstrating how hydrostatic pressure increases with depth	A lab demonstration of increased hydrostatic pressure with depth		
https://www.earthlearningidea.com/PDF/190_Pressure_water.pdf			
ESWA title	**Topic**	**Images**	
Groundwater spiders	Pupils construct a groundwater aquifer from yummy ingredients and relate it to the Perth basin in Australia		
http://www.earthsciencewa.com.au/mod/resource/view.php?id=1053			

Questions/Discussions

1. Use a table to show the sources of world water supply and the uses of water, given as percentages.

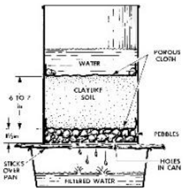
2. The area of drawdown of the water table around a pumping well is called a 'cone of depression'. Why is this term used?

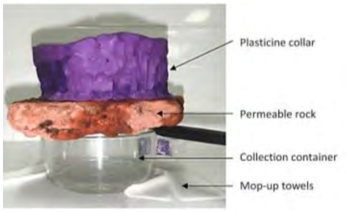
3. Wells (boreholes) drilled when prospecting for water are usually 150 – 300 mm in diameter. Why would wells narrower than this not be so effective?

4. Describe the likely path of water from water vapour in the atmosphere until it flows as treated water from your tap at home. [Note: in a few countries, tap water did not originate as atmospheric water vapour but is desalinated ocean water (i.e. with the salt removed)].

4.2.1.3. Water contamination

Activities

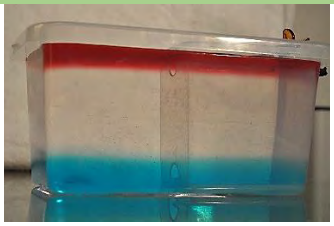
ELI title	Topic	Images	
Water: a matter of taste or a taste of matter – Does all water taste the same?	How water can dissolve solids and comparing the chemical composition of rain water with bottled mineral water	 	
https://www.earthlearningidea.com/PDF/144_Water.pdf			
'Water, water everywhere but not a drop to drink': investigating how to get clean water from dirty water	A water supply activity; people need to find clean water to drink – a vital factor in where people can live		
https://www.earthlearningidea.com/PDF/67_Cleaning_pond_water.pdf			

ESWA title	Topic	Images	
Filtering with sand	Pupils begin their exploration of filtration by simulating filtration in nature, through sand		
http://www.wasp.edu.au/mod/resource/view.php?id=32			
Filtering with a sari	Pupils continue their exploration of filtration through following guidelines from the World Health Organisation (WHO)	 Contaminated water kills one child every 20 seconds. A sari is a simple women’s garment made from one long strip of cotton or silk. The World Health Organisation (WHO) advises that under these conditions filtering water through a sari folded four times is the best answer for people forced to use contaminated water. It is an acceptable simple technique that can continue to be used after the catastrophe. Just employing this technique has reduced the number of cholera bacteria (V cholera) victims by over 90%.	
http://www.wasp.edu.au/mod/resource/view.php?id=33			
Filtering with rock	Pupils discover that rock can be permeable and a great way to filter water		
http://www.wasp.edu.au/mod/resource/view.php?id=34			

Questions/Discussions

1. List the common sources of non-natural water pollutants.
2. Why are feathers and contaminated areas of water or atmosphere often both called plumes?
3. Explain which types of water pollutants, low density, moderate density (similar density to water), or high density, usually travel most quickly to places where groundwater is extracted.

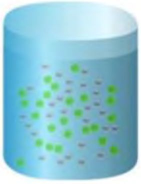
4.2.2. Oceanic water

Activities			
ELI title	Topic	Images	
Exploring current flows through straits: testing the L. F. Marsili model of Bosphorus currents (1680)	Model the flow of seawater of different densities through straits		
https://www.earthlearningidea.com/PDF/315_Marsilis_tank.pdf			

Questions/Discussions

1. What is the difference between an ocean and a sea?
2. When ocean water meets freshwater, one usually floats on top of the other; which is likely to be on top, and why?

4.2.2.1. Water composition

Activities			
ESWA title	**Topic**	**Images**	
Salinity and density	Over two experiments pupils examine whether sea ice includes salt and whether salinity impacts the density of water		
http://www.wasp.edu.au/mod/resource/view.php?id=389			
ELI title	**Topic**	**Images**	
Why is the Dead Sea dead?: measuring salinity	A classroom activity to measure the density of water of different salinities		
https://www.earthlearningidea.com/PDF/199_Dead_Sea.pdf			

Questions/Discussions

1. Water salinity is often described in parts per thousand (with this symbol ‰). What is the salinity of normal sea water in parts per thousand?

2. In what different ways could you make brackish water in the lab or classroom?

4.2.2.2. Tides

Questions/Discussions

1. Why do most coastal areas experience two high tides and two low tides each day?

2. The lowland areas beside the tidal mud flats in coastal areas and wide river mouths are called salt marshes. Why is this so?

3. Bores run up some rivers when tidal water is funnelled into the river mouths, as in the photo opposite. When would you expect bores to occur?

4.2.2.3. Waves

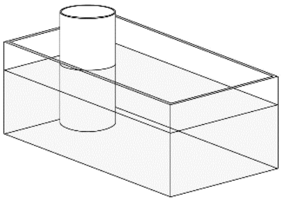
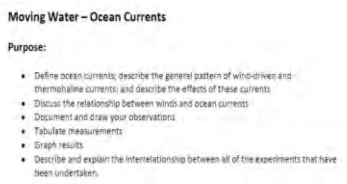
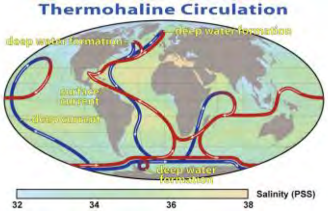
Questions/Discussions

1. How does the frequency of tides and waves differ?

2. How are the biggest wind-formed waves produced?

3. Both waves and tides produce steady currents of water:
   (a) How?
   (b) What sedimentary structures can be produced in the sediments they flow over (see Table 4.14 in the *Exploring geoscience* textbook)?

4.2.2.4. Large-scale circulations of fluids on Earth

Activities		
ELI title	**Topic**	**Images**
High flow. Low flow? – atmosphere and ocean in a tank: hot, cold and particle-filled flows in the atmosphere and ocean	A demonstration of how density currents flow in a tank of water – used as an analogy to the oceans and atmosphere	 
https://www.earthlearningidea.com/PDF/Atmosphere_ocean_tank.pdf		
Atmosphere and ocean in a lunchbox: a model for all pupils of hot, cold and cloudy density currents	An investigation of density currents in a small-scale model for pupil group use	 
https://www.earthlearningidea.com/PDF/288_Atmosphere_ocean_lunchbox.pdf		
ESWA title	**Topic**	**Images**
Oceanic currents	Pupils investigate different currents using simple materials	 **Moving Water – Ocean Currents** **Purpose:** • Define ocean currents; describe the general pattern of wind-driven and thermohaline currents; and describe the effects of these currents • Discuss the relationship between winds and ocean currents • Document and draw your observations • Tabulate measurements • Graph results • Describe and explain the interrelationship between all of the experiments that have been undertaken. 
http://www.earthsciencewa.com.au/mod/resource/view.php?id=1055		
Global conveyer belt	In this experiment pupils investigate how cold impacts the movement of water	 
http://www.wasp.edu.au/mod/resource/view.php?id=387		

Questions/Discussions

1. What is the name given to the flow of air across the Earth's surface from high pressure to low pressure areas?

2. Why do hurricanes rotate anticlockwise in the northern hemisphere and in the opposite clockwise direction in the southern hemisphere?

3. In coastal areas in quiet atmospheric conditions, when the land becomes warmer than the sea during the day and cooler than the sea at night, gentle winds blow from the sea to the land during the day, and from the land towards the sea at night. Why? (Note that the surfaces of solids heat up and cool down more quickly than liquids).

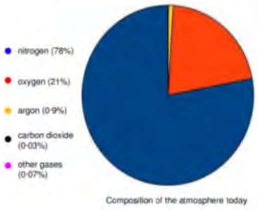
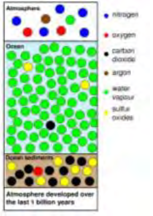
4. How is the global wind circulation pattern linked to the best marine fishing grounds in the oceans?

4.3. Atmosphere

Activities			
ELI title	**Topic**	**Images**	
Space survival: how could we survive a year in a dome? Pupils plan to survive for a year in a sealed dome in a desert	How can people survive in a closed environment? – the carbon, water and nitrogen cycles and the composition of the atmosphere		
https://www.earthlearningidea.com/PDF/Year_in_dome.pdf			

Questions/Discussions
1. The lower part of the atmosphere, the troposphere, is critical to life on Earth; but the layer above the troposphere is also critical to life. Why is this layer so important? 2. Explain what is the most important factor influencing the climate of the Earth. 3. Which of Earth's atmospheric gases are critical to life on Earth?

4.3.1. Atmospheric composition

Activities			
ELI title	**Topic**	**Images**	
Earth's atmosphere – step by step evolution: modelling the development of our current atmosphere	Activity to provoke discussions about the atmosphere or climate change and greenhouse gases		
https://www.earthlearningidea.com/PDF/103_Evolution_atmosphere.pdf			
ESWA title	**Topic**	**Images**	
Earth's early atmosphere and oxygen	Pupils collect oxygen produced by a water plant whilst considering the evolution of Earth's atmosphere		
http://www.earthsciencewa.com.au/mod/resource/view.php?id=1261			
Atmospheric evolution – BIF	Investigating Banded Iron Formation (BIF) rocks, thought to have been part of atmospheric evolution		
http://www.earthsciencewa.com.au/mod/resource/view.php?id=1259			

Questions/Discussions

1. Which do you prefer, humid or dry atmospheric conditions? Why?

2. Draw a table like the one below – then add the likely reasons for the variations in oxygen pressures, beginning at the bottom of the table.

Age Ma	Pressure of oxygen in the atmosphere, %	Likely reasons
850 – present	increasing from 3 – 20	
1850 – 850	3	
2500 – 1850	increasing from 0 – 3	
4000 – 2500	0	

4.3.2. Atmospheric flow

Questions/Discussions

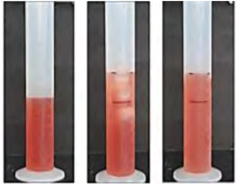
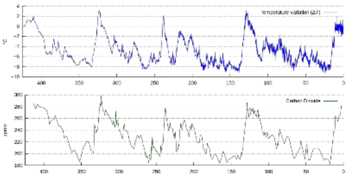
1. (a) Why does warm air rise?
   (b) Why does cool air sink?

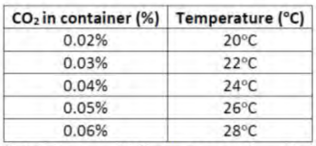
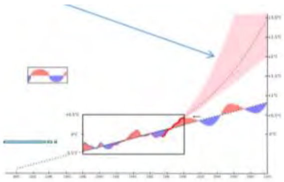
2. What can large scale cloud patterns tell us about how air masses are moving?

3. Explain why rain is much more likely during times of low pressure than of high pressure.

4.3.3. Atmospheric change

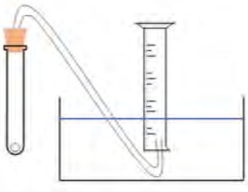
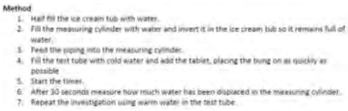
Activities

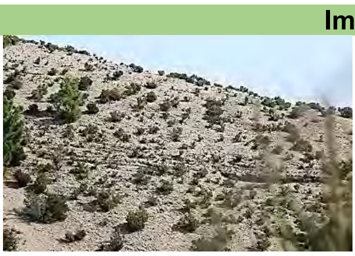
ELI title	Topic	Images
Melting ice and sea level change 1 – sea ice: does sea level change when floating sea ice melts?	Investigate the impact on water levels of allowing floating ice to melt	 
https://www.earthlearningidea.com/PDF/322_Melting_ice_sea_level_1.pdf		
Melting ice and sea level change 2 – ice caps: does sea level change when ice caps melt?	Investigate the impact on water levels when 'ice caps' melt	 
https://www.earthlearningidea.com/PDF/323_Melting_ice_sea_level_2.pdf		
How can the ice core evidence for climate change be explained? – evidence and hypotheses	How science depends upon evidence and interpretation using a complex scientific topic	 
https://www.earthlearningidea.com/PDF/285_Ice_core_evidence.pdf		

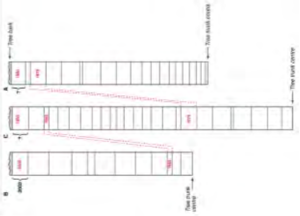
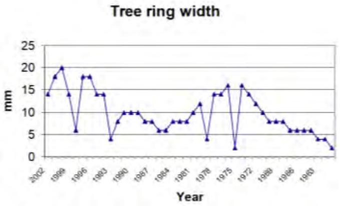
ELI title	Topic	Images
Carbon dioxide and temperature	Experimental data on the impact of carbon dioxide on temperature is examined and linked to climate change	 
http://www.wasp.edu.au/mod/resource/view.php?id=594		

CO_2 in container (%)	Temperature (°C)
0.02%	20°C
0.03%	22°C
0.04%	24°C
0.05%	26°C
0.06%	28°C

(fabricated results for purposes of exercise)

Carbon dioxide solubility	Pupil conduct an investigation to explore the link between water temperature and solubility of carbon dioxide		 Method 1. Half fill the ice cream tub with water. 2. Fill the measuring cylinder with water and invert it in the ice cream tub so it remains full of water. 3. Feed the piping into the measuring cylinder. 4. Fill the test tube with cold water and add the tablet, placing the bung on as quickly as possible 5. Start the timer. 6. After 30 seconds measure how much water has been displaced in the measuring cylinder. 7. Repeat the investigation using warm water in the test tube.
http://www.wasp.edu.au/mod/resource/view.php?id=706			
Methane clathrates	Pupils examine whether pressure can make a gas more dense and apply this to methane clathrates (methane hydrates)		
http://www.wasp.edu.au/mod/resource/view.php?id=382			
Sea ice thickness	An experiment to see the impact of ice thickness on its rate of melting		
http://www.wasp.edu.au/mod/resource/view.php?id=373			
Permafrost melting	An experiment to simulate the impact of melting permafrost on infrastructure		
http://www.wasp.edu.au/mod/resource/view.php?id=380			
Fossils and climate	Pupils examine the evidence that fossils provide us about past climates and then investigate leaf types		
http://www.wasp.edu.au/mod/resource/view.php?id=610			

ELI title	**Topic**	**Images**	
Climate on arrival: if you suddenly arrived somewhere – what would tell you what the climate was like?	Looking for features with a class that might be indicators of the current climate		
https://www.earthlearningidea.com/PDF/324_Climate_on_arrival.pdf			

JESEI title	**Topic**	**Images**	
Tree rings: a climate record of the past	Pupils learn about how tree rings provide a record of past growing conditions and, by inference, climate		
https://geohubliverpool.org.uk/jesei/tree%20rings.htm			

Questions/Discussions

1. (a) What is the difference between 'greenhouse' and 'icehouse' conditions on Earth?
   (b) Are we experiencing either of these now, if so, which?

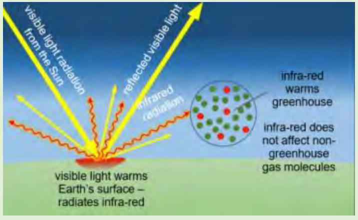
2. How can you demonstrate how the greenhouse effect works using your hands or fingers?

3. What can be done to reduce the release of greenhouse gases and the amounts of greenhouse gases in the atmosphere?
4. Use Table 4.25 in the *Exploring geoscience* textbook to work out how a warming Earth might change the region where you live.

5. If sea level in your region rose by 2m, what would the effects be?

6. If, due to climate change, the temperature in your area rose by 5^{o}C, what would the likely impact be
   (a) in the summer and
   (b) in the winter?

7. What might Equatorial areas have been like during a 'slushball Earth' (when there was no life on land)?

8. Is the greenhouse effect happening outside today? – discussion	A discussion to reinforce learning and to counter misconceptions about the greenhouse effect		

https://www.earthlearningidea.com/PDF/310_Greenhouse_effect.pdf

9. What could we measure to find out if climate change is happening here? – signs outside	A class discussion on the likely local impact of climate change			

https://www.earthlearningidea.com/PDF/305_Climate_change.pdf

4.4. Biosphere

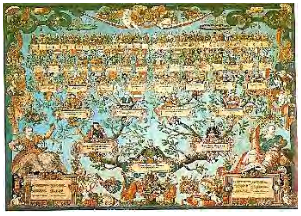
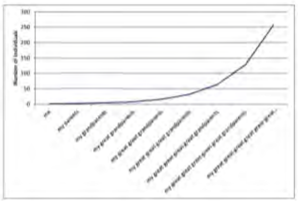
Questions/Discussions

1. Approximately how thick is the biosphere?

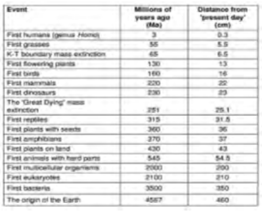
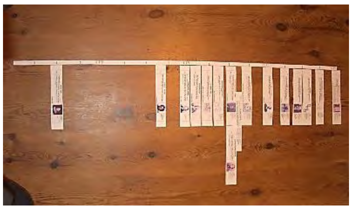
2. What colours does the biosphere have?

4.4.1. Evolution

Activities

ELI title	Topic	Images	
How many Great Great Great Great Grandparents? Finding out how we inherit our characteristics	A class discussion about numbers of ancestors and how these affect our make-up		

https://www.earthlearningidea.com/PDF/200_Inheritance.pdf

How many Beany Beetles?: the evolution game investigating evolution by adaptation and natural selection	A game providing an introduction to the theory of evolution and natural selection		
https://www.earthlearningidea.com/PDF/201_Evolution_game.pdf			
A time-line in your own backyard: hang pictures of the important events in the history of life on a string time-line	An activity to be used in teaching about the history of life on Earth or when discussing the fossil record or geological time		
https://www.earthlearningidea.com/PDF/Washing_line_time.pdf			
Sorting out the evolution of evolution headlines – lay out your own timeline of how the theory of evolution developed	Pupils put cards of 'milestones' in the evolution of evolutionary thought into a timeline		
https://www.earthlearningidea.com/PDF/132_Evolution_of_evolution.pdf			

Event	Millions of years ago (Ma)	Distance from 'present day' (cm)
First humans (genus *Homo*)	3	0.3
First grasses	55	5.5
K-T boundary mass extinction	65	6.5
First flowering plants	130	13
First birds	160	16
First mammals	220	22
First dinosaurs	230	23
The 'Great Dying' mass extinction	251	25.1
First reptiles	315	31.5
First plants with seeds	360	36
First amphibians	370	37
First plants on land	430	43
First animals with hard parts	545	54.5
First multicellular organisms	2000	200
First eukaryotes	2100	210
First bacteria	3500	350
The origin of the Earth	4567	460

Questions/Discussions

1. What percentage of life died out during each of the five major mass extinctions?

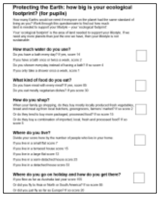
2. Can these be described as evolution:
   (a) the breeding of different types of dogs or flowers, and
   (b) genetic engineering (leading to genetic modification or GM)?
   Explain your answer.

3. Is the distribution of continents on Earth today likely to lead to fast or slow evolution? Why?

4. How could climate change cause a mass extinction?

4.4.2. Impact on other systems

Activities

JESEI title	Topic	Images	
Protecting the Earth: how big is your ecological footprint?	A sustainability questionnaire considering the impact that pupil actions have on the environment		
https://geohubliverpool.org.uk/jesei/protecting%20the%20earth.htm			

Questions/Discussions

1. What do the formation of coal and limestone have in common?
2. Why are limestone, peat and coal described as carbon sinks?
3. How do swampy or marshy areas provide good examples of the interactions between the biosphere and the lithosphere, hydrosphere and atmosphere?
4. What effects is life having on exposed rocks, building stones and other building materials in your area?

5 Earth's system produces resources

Questions/Discussions

1. Does the moon have natural resources?

5.1. Raw materials and fossil fuels

Activities

ELI title	Topic	Images
Finding the Earth in the UN Sustainable Development Goals: mapping the areas where Earth studies are linked to the UN SDGs	A mapping exercise to work out where geoscience is an important part of meeting the UN SDGs by 2030	 
https://www.earthlearningidea.com/PDF/319_Sustainable_development.pdf		

Questions/Discussions

1. In which two ways can natural materials be concentrated?
2. How can a forest be used to supply timber sustainably?
3. (a) How could the abandoned limestone quarry in the image opposite be remediated?
   (b) What factors should be considered before a decision is taken to remediate the quarry?
4. (a) What raw materials have been taken from your area in the past?
   (b) Are they likely to be taken in the future? Why?

5.1.1. Bulk raw materials for construction

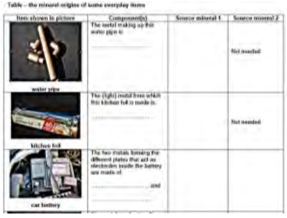
Questions/Discussions

1. Concrete is made of gravel or crushed aggregate mixed with sand and cement. What are the similarities and differences between concrete (shown in the image below) and conglomerate (see Table 4.5 in the Exploring Geoscience textbook)?
2. How were the bulk raw materials used to build the building where you are sitting, likely to have been brought to the site?
3. Is the diameter of a superquarry likely to be: 10s of metres across, 100s of metres across, kilometres or 10s of kilometres across (see aerial image of a superquarry image below)?

Concrete

Glensanda superquarry in Scotland

5.1.2. Bulk raw materials for industry

Activities			
ELI title	**Topic**	**Images**	
Be a mineral expert – 3: the mineral foundations of everyday life	Matching photographs of everyday objects with photographs of the minerals from which they are manufactured		
https://www.earthlearningidea.com/PDF/170_Minerals_3.pdf			
Rocks to eat? How we get the elements we need to stay healthy	Nutrition – why we need to eat a range of foods to stay healthy		
https://www.earthlearningidea.com/PDF/Minerals_into_me.pdf			
Salt of the Earth: who can make the biggest salt crystal?	Growing crystals of salt by evaporation of salty water under controlled conditions		
https://www.earthlearningidea.com/PDF/Salt_of_Earth.pdf			

Questions/Discussions

1. Which bulk industrial raw materials are used:
   (a) in the chemical industry,
   (b) for agriculture?

2. Which bulk industrial raw materials have been used in the building where you are now sitting?

5.1.3. Metal ores

Activities			
ELI title	**Topic**	**Images**	
Riches in the river: investigating how valuable ores may become concentrated on river beds	How differences in the density of sand and ore result in concentration by the action of moving water		
https://www.earthlearningidea.com/PDF/69_Riches_in_the_river.pdf			
Jigging – using density to separate different materials	A simple practical activity used to separate minerals of different density from each other		
https://www.earthlearningidea.com/PDF/133_Jigging.pdf			

JESEI title	Topic	Images
Separating mixtures: how we concentrate natural materials	Pupils devise ways of separating some simple mixtures and then see how some of the same methods are used for minerals	 
https://geohubliverpool.org.uk/jesei/separating%20mixtures.htm		

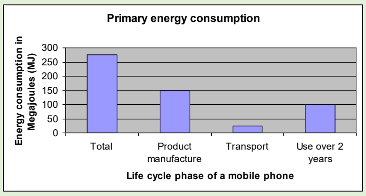
Questions/Discussions

1. What is the difference between a metal mineral and an ore?
2. Many common ores are oxides or sulphides. How is this shown in their chemical formulae?

5.1.4. Industrial minerals

Questions/Discussions

1. Why are diamonds used as gemstones and for industrial cutting and grinding?
2. Rare earth minerals contain one or more of the seventeen rare earth elements in the periodic table but despite the ‘rare earth’ name (meaning uncommon on Earth), some are fairly abundant in the Earth’s crust. Why might they nevertheless be called ‘rare earths’?
3. Be a mineral expert – 4: recycle your mobile phone – Why should I do this? Pupils think about the materials and energy used for a mobile phone, and why they should consider recycling it



https://www.earthlearningidea.com/PDF/172_Minerals_4.pdf

5.1.5. Fossil fuels

Questions/Discussions

1. Why is oxygen not wanted during the formation of fossil fuels?
2. Data about common fuels is shown in the table. The fuels are: natural gas (methane), petrol (gasoline), wood, peat, bituminous coal (normal black coal). Write the fuels in the correct positions in the table.

(C = carbon; kg = kilogram; kWh = kilowatt hours of energy)

Fuel	Carbon content of fuel, C kg/fuel kg	Carbon dioxide emitted on energy release by burning, CO_2 kg/kWh
	0.5	0.41
	0.52	0.4
	0.65	0.28
	0.75	0.18
	0.9	0.26

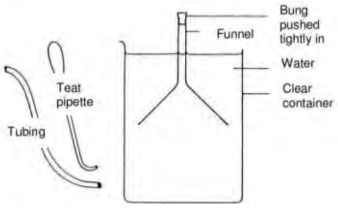
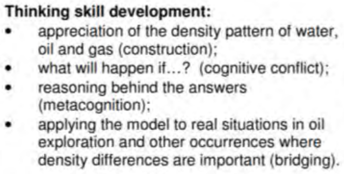
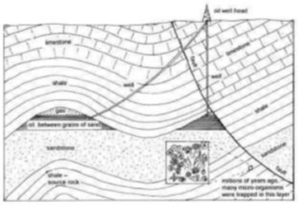
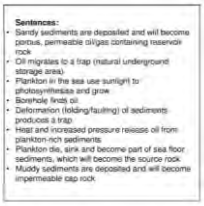
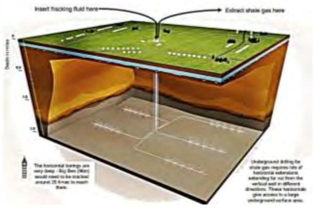
5.1.5.1. Peat and coal

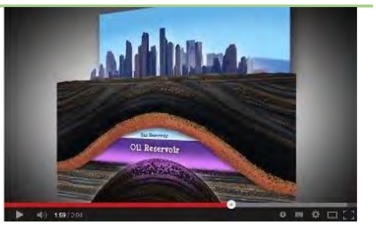
Questions/Discussions

1. The peat in the image opposite was cut out of a peat bed for burning. How was this peat first formed?
2. Coal seams often contain plant fossils and also often have fossil soils directly underneath them. Explain how the soils and the coal seams first formed.
3. The more deeply buried a coal seam has been, the greater the percentage of carbon contained by the coal. Why is this so?
4. Coal is sometimes called black sunshine. Why?

5.1.5.2. Oil and natural gas

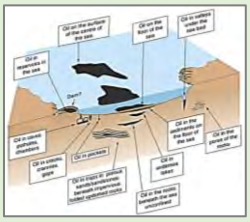
Activities

ELI title	Topic	Images	
Trapped! Why can't the oil and gas escape from their prison? How oil and gas can be trapped in reservoir rocks under the surface	The principle of how a natural underground trap for oil and natural gas works		
https://www.earthlearningidea.com/PDF/Trapped_why_cant_oil_gas_escape.pdf			
Make your own oil and gas reservoir: demonstrating how oil and water flow through permeable rocks	A teacher-led demonstration of the migration of oil and water in underground reservoirs		 **Thinking skill development:** • appreciation of the density pattern of water, oil and gas (construction); • what will happen if…? (cognitive conflict); • reasoning behind the answers (metacognition); • applying the model to real situations in oil exploration and other occurrences where density differences are important (bridging).
https://www.earthlearningidea.com/PDF/64_Oil_gas_reservoir.pdf			
Where shall we drill for oil? Sorting out the sequence – oil prospect	Oil and gas formation, storage underground and exploration		 **Sentences:** • Sandy sediments are deposited and will become porous, permeable oil/gas containing reservoir rock • Oil migrates to a trap (natural underground storage area) • Plankton in the sea use sunlight to photosynthesise and grow • Borehole finds oil • Deformation (folding/faulting) of sediments produces a trap • Heat and increased pressure release oil from plankton-rich sediments • Plankton die, sink and become part of sea floor sediments, which will become the source rock • Muddy sediments are deposited and will become impermeable cap rock
https://www.earthlearningidea.com/PDF/Sorting_Sequence.pdf			
Recipe for the perfect fracking fluid: make your own fluid to frack (hydraulic fracture) methane-bearing shale	Thinking through the purpose of the constituents of the fluid used for fracking, and the whole fracking concept	 **Recipe for the perfect fracking fluid** **Ingredients** • 10 litres of water • handful of sand • squirt of washing up liquid • squirt of lemon juice • several drops of vinegar • 10 x jelly babies **Instructions** • Take a suitable container, such as a bucket • Fill with water • Sprinkle in a handful of sand • Add a portion of washing up liquid • Squirt in some lemon juice • Add a dash of vinegar • Drop in ten jelly babies • Stir well • Pump under pressure into a borehole at least 1 km deep into methane-containing shale • Extract the methane (**Note**: it may not be possible to complete the last two stages of the recipe in the classroom!)	
https://www.earthlearningidea.com/PDF/269_Fracking.pdf			

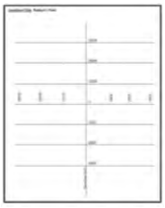
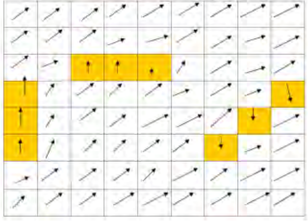
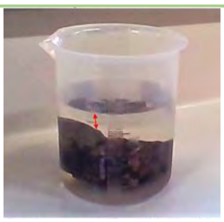
ESWA title	Topic	Images	
It's a gas!	Pupils investigate the formation of oil and gas		
http://www.wasp.edu.au/mod/resource/view.php?id=63			
Structural seal	A teacher demonstration which allows pupils to visualise the formation of a structural seal (for a reservoir)		
http://www.wasp.edu.au/mod/resource/view.php?id=71			
Viscosity raising raisins	Investigations to examine the important concept of viscosity and examine the role of gas in reducing the viscosity of oil		
http://www.wasp.edu.au/mod/resource/view.php?id=75			
Pressure lift	A demonstration of the reasoning behind pumping water and gas into a reservoir to increase pressure and therefore flow		
http://www.wasp.edu.au/mod/resource/view.php?id=73			
Oil and gas formation animation	A fast-paced explanation of how many oil and gas deposits form and how we explore for them		
https://youtu.be/8YHsxXEVB1M			

Questions/Discussions

1. What is the role of sand in fracking fluids?
2. Put the following into the correct time sequence for an oil or natural gas deposit to form, from the oldest to the youngest: laying down of cap rock; laying down of reservoir rock; burial heat and pressure; laying down of source rock; formation of trap.
3. It has been said that it is water pressure that drives oil and natural gas out of the ground. Why is this so?
4. (a) Explain why oil prospectors are more likely to drill rock structures that have older rocks surrounded by younger rocks, rather than the opposite.
   (b) Is it better if these structures contain faults, or not?
   Why?

5. Oil is sometimes called black gold. Why?			
6. Where does offshore oil come from? Addressing oil source misconceptions	Pupils are asked to highlight the misconceptions they may have about where offshore oil is found		
https://www.earthlearningidea.com/PDF/228_Offshore_oil.pdf			

5.1.6. Prospecting

Activities			
ESWA title	**Topic**	**Images**	
A typical exploration sequence	Pupils are guided by a fact sheet through the ten steps in a typical exploration process through class discussion		
http://www.earthsciencewa.com.au/mod/resource/view.php?id=1154			
Geochemical soil sampling	A mapping activity using the results of geochemical soil sampling		
http://www.earthsciencewa.com.au/mod/resource/view.php?id=1149			
Magnetic survey	Pupils explore for magnetic resources in a simulated exploration activity		
http://www.earthsciencewa.com.au/mod/resource/view.php?id=1157			
Searching for iron ore	A STEM project with a series of activities looking at the search for and extraction of iron ore		
http://www.wasp.edu.au/mod/resource/view.php?id=653			
Going for gold	A STEM project involving activities involved in the search for and extraction of gold		
http://www.wasp.edu.au/mod/resource/view.php?id=645			

ELI title	Topic	Images	
Gold prospectors – panning for 'gold' in river sediment	Investigating how prospectors use the property of density to search for gold in river sediments		

https://www.earthlearningidea.com/PDF/164_Gold_panning.pdf

Questions/Discussions

1. What part does remote sensing (collecting data remotely using instruments) play in prospecting today?
2. The Geological Survey of Northern Ireland (GSNI) has published a document describing the different exploration methods used in prospecting (at: https://www.economy-ni.gov.uk/sites/default/files/publications/economy/Common-Exploration-Methods-2017-Update.pdf), as listed below. How does each of these work?
   - Desk study
   - Field-based data acquisition:
     - field mapping
     - field prospecting
     - geochemistry methods
     - geophysical methods
     - drilling
     - trenching
   - Airborne surveys
   - Marine acquisition
3. The Chicxulub crater is the site of the meteorite impact linked to the extinctions of the dinosaurs and many other groups. It is in the Caribbean Sea just north of southern Mexico and is buried by younger sediments. It was first found by companies prospecting for oil (although they did not realise that it was an impact crater at the time). What methods might they have used in this prospecting?

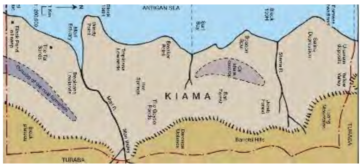
5.1.7. Environmental protection and remediation

Questions/Discussions

1. If a new quarry was planned in your area, what environmental protection and remediation requirements should be included in the plan?
2. If there was a working mine or quarry in your area with excellent environmental controls, how could you find out it was there?
3. The image opposite is an aerial view of Kokubu Tokugawa working quarry in central Japan. It quarries rock for aggregate used in building and road-making. If plans had been submitted to extend this quarry towards the top of the image and this was being debated at a public meeting, what might the following groups say:
   - the quarry owners;
   - the owners of the golf course at the bottom of the image;
   - the owners of the nearby houses, including those at the top and left-hand side of the image;
   - the quarry workers' unions;
   - groups interested in nature conservation;
   - the water authority interested in the river and underground water supplies;
   - the local government?

   [This question can be used in a classroom debate, with different groups giving different points of view].

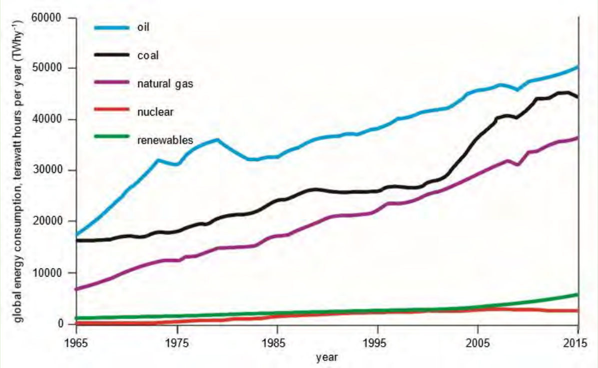
5.2. Power supplies

Activities			
ELI title	**Topic**	**Images**	
Which power source? – solving the crisis in Kiama: the power sources that could be developed in a mythical country	Pupils study a map to find clues to the different energy sources that could be exploited in a country		
https://www.earthlearningidea.com/PDF/175_Power_sources.pdf			
Power through the window: which power source might be built in the view you can see from your window?	Which sorts of power source could be built in the view through your window – then which of them should be built		
https://www.earthlearningidea.com/PDF/57_Power_thru_window.pdf			

Questions/Discussions

1. What are the major sources of power used for global energy consumption today, in rank order?
2. Figure 5.5. in the *Exploring Geoscience* textbook, reproduced here, shows how power source data has changed in the past 50 years (from 1965 to 2015). Use the graph to calculate approximately:
   (a) the total global energy consumption in 1965 in terawatt hours per year (TWhy^{-1}) and
   (b) the total global energy consumption in 2015.
   (c) How do these two figures compare?
3. Sketch an extension to the graph in Figure 5.5 in the '*Exploring Geoscience'* textbook (seen opposite) to show how the contributions of different energy sources to total power consumption might change in the next 50 years (to 2065). The total amount of energy consumption should relate to the figures you calculated in Question 2 above. What effects might your prediction have on the Earth?

Figure 5.5. Global energy consumption; data from BP statistical review of world energy



4. Around 20% of global energy consumption is used to make electricity while the other 80% is used mostly for heating and transportation. On which of these figures is the growth of renewable energy sources likely to make the most impact? Why?

5.2.1. Energy from fossil fuels

Questions/Discussions

1. Why is the global use of coal as an energy source reducing at a time when the use of the other fossil fuels, oil and natural gas, is increasing?
2. If carbon capture technology is successfully and commercially developed, allowing carbon dioxide from power stations to be captured and sequestered (stored underground rather than being allowed to reach the atmosphere), how is this likely to affect the burning of fossil fuels for power? (A pilot carbon capture plant is shown in the image opposite).

3. The term 'unconventional fossil fuels' is used to include the extraction of oil from oil sands and oil shale, the extraction of natural gas as coal bed methane, and by the fracking of shales and 'tight sandstones'. How does the relative amount of carbon dioxide produced by these energy sources compare with the amount of carbon dioxide produced by conventional sources?

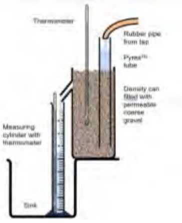
4. What is/are the least bad option(s) for plugging the future global energy gap? Most predictions show that we will not be able to provide all the world's energy from renewable resources for many tens of years to come (without badly damaging global economic growth), so which of the following are the least bad options for filling this energy gap?
   (a) coal – there are abundant coal reserves worldwide, but burning coal releases much more greenhouse gas and pollutants than other fuels;
   (b) oil from oilfields – there are reasonable global oil reserves, but energy from oil releases more greenhouse gas and pollutants than natural gas whilst oil often has to be imported using tankers or pipelines;
   (c) oil from oil sands and oil shale – extraction needs large volumes of water and damages the surface environment;
   (d) natural gas from gasfields – natural gas often has to be imported using pipelines or tankers;
   (e) natural gas from fracking – this may be available locally, but there is often resistance to fracking from local people;
   (f) coal, oil or natural gas with carbon capture – carbon capture will remove the greenhouse gases from power stations so that they can be permanently stored underground (sequestered);
   (g) nuclear power – this releases no greenhouse gas (apart from in the use of concrete during building), but nuclear waste has to be permanently and safely disposed of and there is risk of disasterous radiation leaks.

   [This question can be used in a classroom debate, with different groups defending different points of view].

5. If you were 'Ruler of the World' what realistic laws would you make to reduce the impact of climate change?

5.2.2. Renewable energy

Activities

ELI title	Topic	Images
Rock power: geothermal power simulations: showing they are not renewable	Using a density can filled with gravel to model different forms of geothermal power sources	 

https://www.earthlearningidea.com/PDF/95_Rock_power.pdf

Questions/Discussions

1. Renewable power sources have the advantages over fossil and nuclear fuels that they can be replaced as they are used, and produce no pollutants during use, including greenhouse gases. However, they do have disadvantages. Draw a table summarising the disadvantages of the different renewable sources.

2. (a) Which large-scale renewable energy source is most likely to be developed in your area?
   (b) What are local people most likely to say about this development?

3. Hydrogen can be used as a zero-emission fuel, which just produces water vapour when used. It is made by the electrolysis of water (separating the hydrogen from the oxygen in water) and is used to power some buses and cars today. What are the advantages and disadvantages of hydrogen fuel?

6 Human/Earth's system interactions

6.1. Natural hazards

Activities

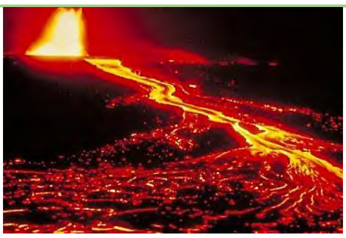
ELI title	Topic	Images
Fire and biodiversity	Pupils examine the impact of bushfires on biodiversity through a simulation activity	 
http://www.earthsciencewa.com.au/mod/resource/view.php?id=1330		

Questions/Discussions

1. When is a catastrophic natural process not a hazard?
2. Which natural hazards could affect the area where you live?
3. What catastrophic natural processes affected your region in the geological past?

6.1.1. Eruption

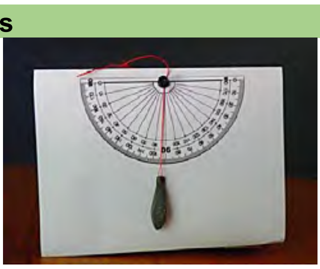
Activities

ELI title	Topic	Images
Blow up your own volcano! Demonstrate the importance of gases in volcanic eruptions	Simulating the role of gases in volcanic activity	 
https://www.earthlearningidea.com/PDF/Blow_up_your_own_volcano_1.pdf		
See how they run: investigate why some lavas flow further and more quickly than others	An investigation, using suggestions from the class, into some of the factors which can affect the viscosity of lavas	 
https://www.earthlearningidea.com/PDF/See_how_they_run.pdf		
Bubble-mania: the bubbling clues to lava viscosity and eruptions	A simple test of the viscosity of two similar-looking liquids, linked to volcanic eruption style	 
https://www.earthlearningidea.com/PDF/126_Bubblemania.pdf		

ESWA title	Topic	Images
Volcano variations	Pupils investigate the difference between a shield volcano and a stratovolcano using common household items	 
http://www.wasp.edu.au/mod/resource/view.php?id=408		
Pompeii bodies	Pupils simulate the preservation of bodies by volcanic ash	 
http://www.wasp.edu.au/mod/resource/view.php?id=413		

ELI title	Topic	Images
Best classroom eruption: Which type of classroom eruption best shows how volcanoes erupt?	Evaluating different types of classroom eruptions to gauge which best shows how eruptions are triggered	 
https://www.earthlearningidea.com/PDF/284_Best_eruption.pdf		
The balloon goes up at Krakatoa: simulating the huge tsunamis caused by the eruption of Krakatoa	A simulation, using a balloon in a tank of water, of one of the theories thought to have caused the devastating Krakatoan tsunamis	 
https://www.earthlearningidea.com/PDF/114_Krakatoa.pdf		
An eruption through the window: how could an eruption transform your view? – lava, ash, lahar or something worse	Pupils are asked to try to picture how the view through the window might be changed by different types of volcanic eruption.	 
https://www.earthlearningidea.com/PDF/Eruption_thru_window.pdf		
Party time for volcanoes! How much force does it take to set off a party popper "volcano"?	Measuring the force required to burst a party popper and relating the results obtained to the prediction of volcanic eruptions	 
https://www.earthlearningidea.com/PDF/90_Party_time_for_volcanoes.pdf		
Take a 'Chance' on the volcano erupting: how hazardous is the volcano?	Bursting a party popper; a series of possible events in the build up of a volcanic eruption is given on 'Chance' cards.	 
https://www.earthlearningidea.com/PDF/110_Party_poppers_card_game.pdf		

When will it blow? – predicting eruptions: how a tiltmeter shows the bulging of a volcano before eruption	How a simple 'tiltmeter' can demonstrate the bulging of a volcano before eruption – using a balloon		
https://www.earthlearningidea.com/PDF/When_will_it_blow.pdf			

ESWA title	Topic	Images	
Making a tilt-o-meter and clinometer	Pupils make their own tiltmeter and clinometer and compare their value in earthquake measurement to predict eruptions		
http://www.wasp.edu.au/mod/resource/view.php?id=415			

Questions/Discussions

1. (a) What is the main geological factor controlling whether an eruption is catastrophic or relatively safe?
(b) What changes this factor?

2. What signs of active eruption might be seen in satellite images of different types?

3. How might eruptions affect wildlife in the local area?

4. Are volcanic eruptions useful?

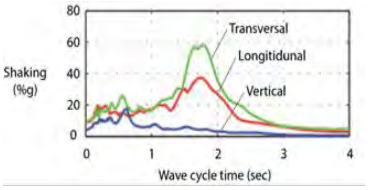
5. Draw a table of written advice for local people for eruptions ranging from Volcanic Explosivity Index (VEI) 0 (non-explosive) to VEI 6 (colossal).

6. (a) If you were to make a realistic painting of a volcanic eruption, which colours would you mostly use?
(b) Might the colours you choose be different if you wanted to show the eruption through modern art?

6.1.2. Earthquake

Activities

ELI title	Topic	Images	
Earthquake prediction – when will the earthquake strike? Modelling earthquake build-up of stress and sudden release	Bricks are used to show the build-up of stress before 'brittle failure' takes place; repeats show variability in time and stress		
https://www.earthlearningidea.com/PDF/49_Earthquake_prediction.pdf			
Spaghetti quakes: why are big earthquakes so much more destructive than small ones?	Spaghetti used to show how logarithmic increase in earthquakes is related to a 30-fold increase in energy		
https://www.earthlearningidea.com/PDF/300_Spaghetti_quake.pdf			

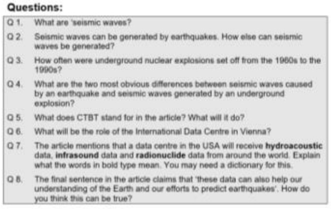
Shaken but not stirred? How earthquakes affect buildings	The relationship between the frequency of the shaking of the 'ground' and the movement of model 'buildings'		
https://www.earthlearningidea.com/PDF/112_Shaken_not_stirred.pdf			
Quake shake – will my home collapse? When an earthquake strikes –why do some buildings survive and others do not	A demonstration of how buildings with different foundations respond to earthquakes		
https://www.earthlearningidea.com/PDF/Quake_Shake.pdf			
Jelly/biscuit modelling of how earthquake waves amplify and devastate: how shaking depends on local geology	Modelling the effect of earthquake seismic waves on buildings		
https://www.earthlearningidea.com/PDF/273_Seismic_site_amplification.pdf			
An earthquake in your classroom: a classroom earthquake intensity scale	A strategy to help pupils to visualise what experiencing an earthquake of different intensities might be like		
https://www.earthlearningidea.com/PDF/266_Earthquake_in_classroom.pdf			
Earthquake through the window – what would you see, what would you feel? – picturing an earthquake through the window	Asking pupils to picture for themselves what an earthquake through the window might look like		
https://www.earthlearningidea.com/PDF/Earthquake_thro_window.pdf			
Surviving an earthquake – learn the earthquake drill and increase your chances of survival	Prepare your pupils by teaching them an earthquake drill, to minimise the risks of getting hurt if an earthquake should strike		
https://www.earthlearningidea.com/PDF/Surviving_an_earthquake_1.pdf			
Earthquakes in art: developing a scientific report based on evidence in historic paintings	Pupils prepare a scientific report about earthquakes as shown in historical paintings		
https://www.earthlearningidea.com/PDF/281_Earthquakes_art.pdf			

ESWA title	Topic	Images
Earthquake data	Pupils examine earthquake-prone areas and then look at real time data	 

https://www.wasp.edu.au/mod/resource/view.php?id=420

Shaky science	Pupils discuss scales by which earthquakes are measured and simulate seismic waves	 

http://www.wasp.edu.au/mod/resource/view.php?id=422

JESEI title	Topic	Images
Earthquakes or nuclear explosions: seismic clues to dirty deeds	A comprehension exercise on using seismic data to locate underground nuclear arms testing	  **Questions:** Q 1. What are 'seismic waves? Q 2. Seismic waves can be generated by earthquakes. How else can seismic waves be generated? Q 3. How often were underground nuclear explosions set off from the 1960s to the 1990s? Q 4. What are the two most obvious differences between seismic waves caused by an earthquake and seismic waves generated by an underground explosion? Q 5. What does CTBT stand for in the article? What will it do? Q 6. What will be the role of the International Data Centre in Vienna? Q 7. The article mentions that a data centre in the USA will receive **hydroacoustic** data, **infrasound** data and **radionuclide** data from around the world. Explain what the words in bold type mean. You may need a dictionary for this. Q 8. The final sentence in the article claims that 'these data can also help our understanding of the Earth and our efforts to predict earthquakes'. How do you think this can be true?

https://geohubliverpool.org.uk/jesei/earthquakea%20&%20nuclear%20xplos.htm

Questions/Discussions

1. What does the statement, 'It is not earthquakes that kill people, but buildings', mean?
2. Pumping water under pressure into rocks (to produce steam in hydrothermal areas, or in fracking) can produce small earth tremors even in areas where earthquakes are uncommon. How might this happen?
3. Would you expect there to be quakes on other planets? If so, why?
4. Is there a pattern in the map of the world's most dangerous earthquakes, shown in Table 6.5 in the *Exploring geoscience* textbook? If so, what is the pattern?
5. If a major earthquake struck the area where you live, make a list on one side of a page of what the major dangers would be; then, on the opposite side, add notes of the best ways of reducing these dangers.
6. What extra training is needed by members of emergency services in earthquake areas?
7. How might technology improve safety in earthquake areas in future?

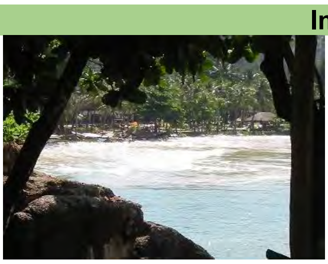
6.1.3. Tsunami

Activities

ELI title	Topic	Images
Tsunami: what controls the speed of a tsunami wave?	Investigating the relationship between the depth of water in a tank and the velocity of a water wave	 

https://www.earthlearningidea.com/PDF/45_Tsunami_demo_final.pdf

Tsunami alert! Run for the hills or stay by the sea? Why do some earthquakes produce tsunamis and not others?	Displacing water in a tank to find out why one type of movement can produce a tsunami wave and another may not		
https://www.earthlearningidea.com/PDF/254_Tsunami_alert.pdf			
A tsunami through the window – what would you see, what would you feel? Picturing a tsunami through the window	A 'thought experiment' imagining how a tsunami would affect the view through the window		
https://www.earthlearningidea.com/PDF/Tsunami_thro_the_window.pdf			

ESWA title	Topic	Images	
Tsunamis and shorelines	Demonstration of the effect of seafloor slope on tsunami development		
http://www.earthsciencewa.com.au/mod/resource/view.php?id=1397			
Tsunami	A demonstration of tsunami formation using simple equipment		
http://www.wasp.edu.au/mod/resource/view.php?id=431			

Questions/Discussions

1. What would a tsunami be like if you were in a ship on an open ocean?

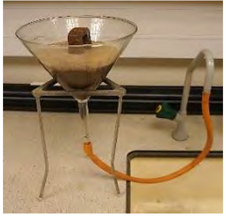
2. If you have a bowl of water, there are three different ways of making waves on the surface.
   (a) What are they?
   (b) Which are tsunami-like waves?

3. How could you measure the height of a tsunami wave as it hits the coast (tsunami waves up to 40m high are known)?

4. If the famous picture below is showing a tsunami wave, what is wrong with it?

5. If you saw a sign like the one below, what should you do if there is an earthquake? Why?

6.1.4. Landslide

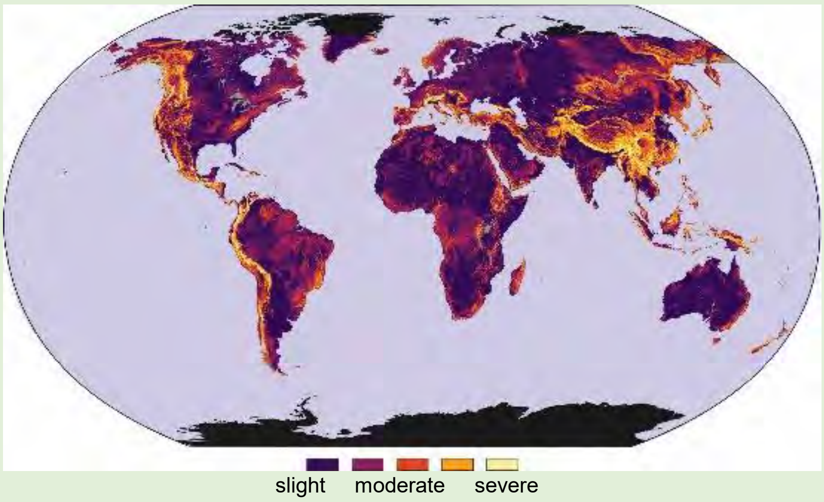
Activities			
ELI title	**Topic**	**Images**	
Danger – quicksands! Why do some rocks give way when it rains hard?	Demonstrating how raised pore water pressure can weaken apparently strong sediments, causing subsidence or landslides		
https://www.earthlearningidea.com/PDF/117_Quicksands.pdf			
Sandcastles and slopes: what makes sandcastles and slopes collapse?	Investigating the factors which affect the angle at which loose materials rest before they begin to slide		
https://www.earthlearningidea.com/PDF/66_Sandcastles.pdf			
Failing slopes: modelling how rock cliffs and slopes can collapse	Investigating the factors which affect the angle of slope at which materials fail and slip		
https://www.earthlearningidea.com/PDF/210_Slope_failure.pdf			
A landslide through the window – what would you see, what would you feel? Pupils picture a landslide for themselves	A ‘thought experiment’ imagining how different landslides might affect the view through the window		
https://www.earthlearningidea.com/PDF/Landslide_through_window.pdf			
ESWA title	**Topic**	**Images**	
Landslide engineering	A STEM project with a series of activities looking at landslides		
https://www.wasp.edu.au/course/view.php?id=51			

Questions/Discussions

1. Soil creep on very shallow slopes is common in permafrost areas of frozen sub-soil at the margins of arctic areas. Why is this so?
2. Why are some 30^{o} slopes stable, but others are unstable?
3. What different factors might have contributed to the devastating landslide in El Salvador shown below?
4. How is climate change likely to affect landslide risk?

5. How can the severe risk areas of the global landslide hazard map below be explained? The map is taken from Table 6.12 in the *Exploring geoscience* textbook.

Landslide in El Salvador, 2001.



Landslide potential.

6.2. Environmental issues

Activities

ELI title	Topic	Images	
Fieldwork – environmental evaluation: developing a strategy for evaluating the environment	A method to help pupils to evaluate and appreciate environments		

https://www.earthlearningidea.com/PDF/188_Environment_evaluation.pdf

Questions/Discussions

1. What would the vegetation be like in your area if there were no human activity and so vegetation reclaimed the area?

2. Which would you prefer and why – what your area is like today, or what it would be like if it were reclaimed by vegetation?

3. Questions for any rock face 12: What questions about the site potential might be asked?	Questions helping pupils to assess the future uses and prospects of a quarry/cutting site		

https://www.earthlearningidea.com/PDF/242_Questions_rock_face_potential.pdf

6.2.1. Erosion

Activities			
ELI title	**Topic**	**Images**	
Why does soil get washed away? Investigating why some farmers lose their soil through erosion whilst others do not	Investigating the effect of vegetation cover in protecting soil from erosion in heavy rainfall		
https://www.earthlearningidea.com/PDF/Soil_erosion_final.pdf			
Dust bowl: investigating wind erosion	Investigating the effects of different wind strengths and particle sizes on wind erosion, transportation and deposition		
https://www.earthlearningidea.com/PDF/61_Dust_bowl.pdf			

Questions/Discussions

1. Make a table of good farming practices to preserve soils, then find photographs of these on the internet to add to your table.

2. How could the footpaths in the images below on hilltops in the UK be preserved?

3. (a) How could the erosion of this house by the sea in Valiyathura, Kerala, India be prevented?
   (b) Should it be prevented?

6.2.2. Drainage-changes

Activities			
ELI title	**Topic**	**Images**	
Flood through the window: pupils picture for themselves what a major flood seen through the window might look like	Using your window as a teaching aid – what could a flood outside be like?		
https://www.earthlearningidea.com/PDF/Flood_through_the_window_2.pdf			

Dam burst danger: modelling the collapse of a natural dam in the mountains – and the disaster that might follow	Making a model of the collapse of a natural ice dam in the mountains – causing probable disaster		
https://www.earthlearningidea.com/PDF/62_Dam_burst.pdf			

Questions/Discussions

1. What is a storm drain?
2. Write a list of things that you and your family should do if there is a sudden flood warning and you live in a house or a ground floor apartment.
3. Why is flood water not clear water?

6.2.3. Waste disposal

Questions/Discussions

1. What does the term 'reduce, reuse, recycle' mean?
2. What happens to the waste you throw away in your bin?
3. Draw a sketch cross section of a toxic waste disposal site, showing all the safeguards that would be put in place.
4. Why has it been so difficult for most countries with nuclear power to build long-term high-level radioactive waste disposal sites?

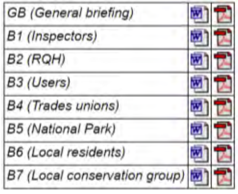
6.2.4. Pollution

Questions/Discussions

1. Why can 'the polluter pays' principle not always be applied?
2. Why is plastic pollution such a problem?
3. What sources of pollution can you see from your window?
4. Brownfield sites are old industrial sites that have often been heavily polluted, but are now needed for new uses like housing. How could these sites be remediated?
5. Use the internet to find out about and make a list of the different organisations that are trying to reduce the problems of plastic pollution and what they are trying to do – search for 'cleaning the ocean', 'plastic pollution' or similar terms.

6.2.5. Mining/quarrying

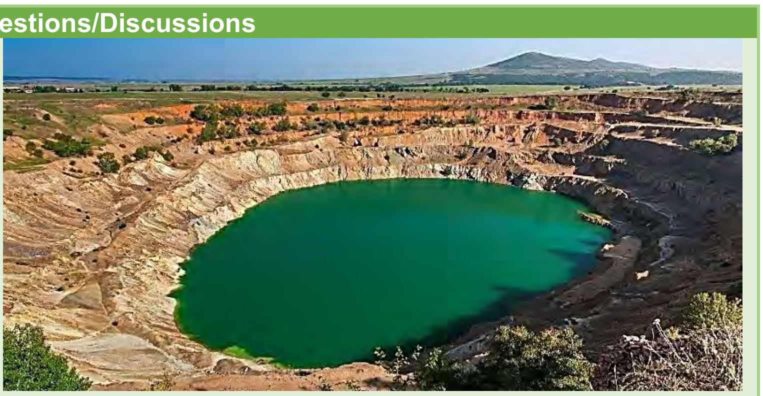
Activities

JESEI title	Topic	Images	
The limestone inquiry, 21st Century	A role-play exercise examining issues related to the quarrying of limestone in an area of outstanding natural beauty		General briefing sheets:  GB (General briefing) B1 (Inspectors) B2 (RQH) B3 (Users) B4 (Trades unions) B5 (National Park) B6 (Local residents) B7 (Local conservation group)
https://geohubliverpool.org.uk/jesei/limestone%20inquiry.htm			

ELI title	Topic	Images
Quarry through the window: asking pupils to 'picture' what a 'quarry through the window' might look like	What might a quarry through the window look like if you could see it, if it were screened, or if it had been landscaped?	 
https://www.earthlearningidea.com/PDF/Quarry_thro_window.pdf		

Questions/Discussions

1. Why might an abandoned quarry make a nature reserve with more variety of life than the landscape that was previously there?
2. How has this old copper mine in Bulgaria changed since it was abandoned? Why have these changes happened?



3. Questions for any rock face 13: quarry economics. Potential for quarry re-opening — Questions to enable pupils to begin to understand the economic viability of quarrying raw materials

https://www.earthlearningidea.com/PDF/244_Questions_rock_face_economics.pdf

6.2.6. Burning fossil fuels and the greenhouse effect

Questions/Discussions

1. If carbon capture technology becomes economically viable, where will carbon capture plants be sited?
2. What are the advantages of pumping captured carbon into old oil or gas fields?

6.3. Impact on human history

Questions/Discussions

1. The Native American Duwamish people live on the US Pacific coast and have a legend that large boulders found along the shores are haunted by A'yahos. If hunters approached the boulders the A'yaho spirits would shake the earth and then send large waves to kill them.
   (a) What might the origin of this legend be?
   (b) How might it have impacted on human history in the area?
2. The Maldives is a group of low-lying islands in the Indian Ocean where, according to the World Bank, the entire country could be submerged by rising sea levels by 2100. The capital city Malé is especially threatened because it is on a small flat island which is densely populated (see photos) and surrounded by sea walls. What should the people living in Malé and on other Maldive islands do about this?

3. The photographs below show Plymouth, the capital city of the island of Montserrat in the Caribbean region. Plymouth was abandoned in July 1995 when the Soufriere Hills volcano became active. In the first photo the city is being covered in ash, soon afterwards parts were buried by series of lahar flows shown in the second photo. If you had been one of the residents at the time, who had been evacuated to a safe area in the north of the island:
   (a) What would you have taken with you?
   (b) What would you have lost?
   (c) What would have felt about this?

4. If you were 'Ruler of the World', what realistic laws would you make to help the world to meet the United Nations Sustainable Development Goals (STGs), shown below, by 2030?

6.3.1. Resource wars

Questions/Discussions

1. The I-Disi aquifer is a deep sandstone aquifer 320 km long in the Arabian Peninsula which is not being recharged by rainfall. Most of it lies underneath Saudi Arabia but part also lies underneath Jordan. A dispute over the use of the aquifer has been taken to the United Nations. What might be the causes of this dispute?

2. UNITA, a rebel group in Angola was accused in the 1990s by the United Nations Security Council of using the funds from the sale of diamonds to fund the civil war there, and economic sanctions were applied; the diamonds are called 'blood diamonds' or 'conflict diamonds'. The UN Security Council is being pressurised to extend the sanctions to the Democratic Republic of Congo where similar trade seems to be happening. Why is this generally not good for the local people and region?

3. What natural resources in your region might have caused wars in the past, and why?

6.3.2. Migration due to climate change

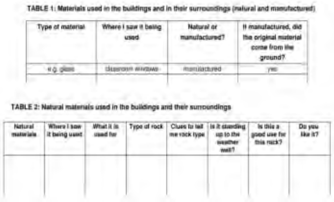
Questions/Discussions

1. How did climate change open the path to human migration:
   (a) to Australia around 50,000 years ago (allowing the migration of the people who eventually became aboriginal Australians),
   (b) to North America around 15,000 years ago (allowing the migration of the people who were to become native Americans)?

2. Recent evidence suggests that the earliest fully human people (*Homo sapiens sapiens*) evolved in the wetland of the Okavango swamps in Northern Botswana in southern Africa when it was surrounded by desert areas, but some of them migrated out of the area around 130,000 years ago. What might have caused this migration?

3. How might climate change cause human migration in the future?

7 Earth’s system is explored through fieldwork and practical work

<table>
<tr><th colspan="4">Activities</th></tr>
<tr><th>ELI title</th><th>Topic</th><th colspan="2">Images</th></tr>
<tr><td>The ‘What makes a good educational experience’ approach to fieldwork: fieldwork strategies to inform and inspire</td><td>Using the question to generate a checklist for evaluating pupil fieldwork experiences</td><td></td><td></td></tr>
<tr><td colspan="4">https://www.earthlearningidea.com/PDF/257_Educational_experience.pdf</td></tr>
<tr><td>Rock around your school: investigating the building materials around your school and in your area</td><td>This activity illustrates Earth science principles out of doors, often without a natural rock in sight</td><td> </td><td>
TABLE 1: Materials used in the buildings and in their surroundings (natural and manufactured)
<table><tr><th>Type of material</th><th>Where I saw it being used</th><th>Natural or manufactured?</th><th>If manufactured, did the original material come from the ground?</th></tr><tr><td>e.g. glass</td><td>classroom windows</td><td>manufactured</td><td>yes</td></tr><tr><td></td><td></td><td></td><td></td></tr></table>
TABLE 2: Natural materials used in the buildings and their surroundings
<table><tr><th>Natural materials</th><th>Where I saw it being used</th><th>What it is used for</th><th>Type of rock</th><th>Clues to tell me rock type</th><th>Is it standing up to the weather well?</th><th>Is this a good use for this rock?</th><th>Do you like it?</th></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr></table></td></tr>
<tr><td colspan="4">https://www.earthlearningidea.com/PDF/249_Rock_around_school.pdf</td></tr>
<tr><td>Urban fieldwork – the stories from materials, colours, lines and shapes: materials used in building and for decoration</td><td>Using the colours, lines and shapes of building stones and other natural decorative materials to help to tell their stories</td><td></td><td></td></tr>
<tr><td colspan="4">https://www.earthlearningidea.com/PDF/306_Urban_fieldwork.pdf</td></tr>
<tr><td>Fieldwork: Applying ‘the present is the key to the past’: an outdoor activity using Earth science -thinking in reverse</td><td>An outdoor-based thought experiment to show how Earth scientists use evidence from rocks to understand past environments</td><td></td><td>
<table><tr><td>• Erosion</td><td>Our footprints are eroding the ground</td></tr><tr><td>• Ground being compacted</td><td>We are compacting the ground – second-hand</td></tr><tr><td>• Sun radiating visible light</td><td>We can see</td></tr><tr><td>• Sun radiating heat</td><td>We can feel the warmth</td></tr><tr><td>• Cars driving</td><td>We can see them</td></tr><tr><td>• We are receiving chemical pollution</td><td>We can smell/taste it</td></tr><tr><td>• We are receiving sound pollution</td><td>We can hear it</td></tr></table></td></tr>
<tr><td colspan="4">https://www.earthlearningidea.com/PDF/187_Present_key_past.pdf</td></tr>
<tr><td>Fieldwork: interactive re-creation: activities using simple apparatus to simulate features in the field</td><td>A series of interactive demonstrations in the field to simulate geological features in front of the rock that contain them</td><td></td><td></td></tr>
<tr><td colspan="4">https://www.earthlearningidea.com/PDF/223_Interactive_re-creation.pdf</td></tr>
<tr><td>View to the future – and the past: using a viewpoint or overview educationally</td><td>A strategy for helping pupils to interact with the outdoor environment they are viewing</td><td></td><td></td></tr>
<tr><td colspan="4">https://www.earthlearningidea.com/PDF/297_View_future_past.pdf</td></tr>
</table>

Questions/Discussions

1. Draw a table to show, for each of the geoscience specialists in Table 7.1. of the *Exploring geoscience* textbook:
   (a) one measurement or observation that might be made in the field, and
   (b) one activity that might be carried out indoors.

2. What rocks are naturally available in your area and how might you study them?

3. How would the Geoethical Promise, shown opposite, affect:
   a) a geologist working for the quarrying industry,
   b) a geotechnical engineer investigating the ground conditions for the building of a city skyscraper,
   c) a volcanologist monitoring volcanoes for catastrophic eruptions,
   d) your work as a geology pupil?

The Geoethical Promise (simplified version)

I promise …

- *I will work in geoscience to best protect the people of Earth and all Earth systems.*
- *I understand that it is my job to help to protect the Earth for the future, through sustainable development.*
- *I will put the interest of all people first in my work.*
- *I will never misuse my geoscience knowledge, whatever other people may say or do.*
- *I will always be ready to use my knowledge of geoscience helpfully, and will try to provide a balanced view to people making decisions.*
- *I will develop my geoscience knowledge throughout my life.*
- *I will always be as honest as I can be.*
- *I will try to move the study of geoscience forward, to share geoscience knowledge, and to help everyone to behave geoethically.*
- *I will always respect Earth processes in my geoscience* studies.

I promise!

4. Fieldwork: Now and then – spotting the difference: How the conditions differed from today

A thought experiment, comparing the environment when the rock was formed, with conditions today

https://www.earthlearningidea.com/PDF/263_Now_and_then.pdf

5. So you want to conserve a geodiversity site?: What could you do?

A planning activity focussed on conserving a site of geoscientific importance

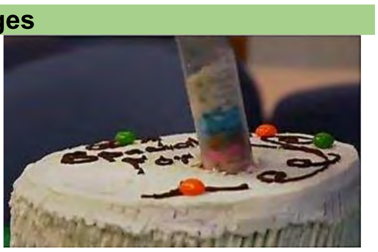
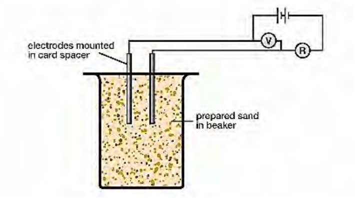
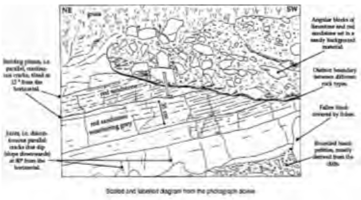
https://www.earthlearningidea.com/PDF/218_Conserving_geodiversity_site.pdf

6. Take it or leave it? geo-conservation debate: when is collecting wrong, and when is it right?

Asking pupils to discuss which minerals/ rocks/ fossils could be collected and which should be left for others

https://www.earthlearningidea.com/PDF/127_Geoconservation.pdf

7.1. Observation, measurement and recording

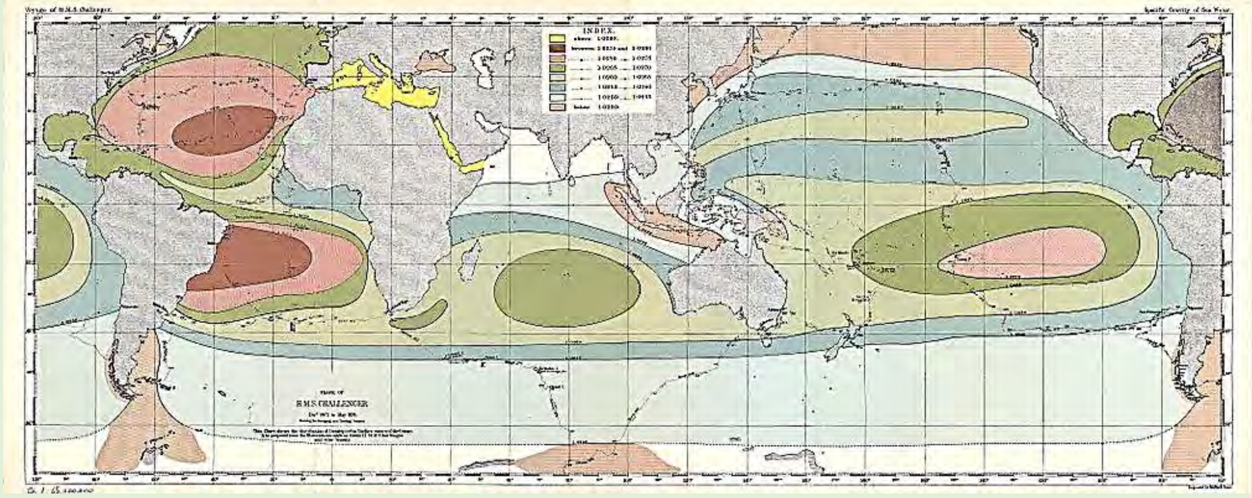
Activities		
JESEI title	**Topic**	**Images**
Investigating the Earth: the 'find the Mars™ Bar' challenge	Work out which bar is which. You cannot cut or bite through any part of the bars; the answer is found by probing with straws	 
https://geohubliverpool.org.uk/jesei/investigate%20earth.htm		
ELI title	**Topic**	**Images**
Boring chocolate!: what can boreholes tell us about the Earth?	An activity about finding what is beneath the Earth's surface, using chocolate and cake	 
https://www.earthlearningidea.com/PDF/243_Boreholes.pdf		
Electrical ground probing: measuring the electrical resistance of the ground to find buried objects	A laboratory demonstration of the principle of 'remote sensing', using the electrical properties of Earth materials	 
https://www.earthlearningidea.com/PDF/96_Electrical_ground_probing.pdf		
Planning for fieldwork: preparing your pupils before setting out to "ask questions for any rock face"	Indoor preparation for pupils before setting off to examine a local exposure of rocks and soil	 
https://www.earthlearningidea.com/PDF/220_Questions_rock_face_planning.pdf		
Rocks from the big screen: indoor preparation for outdoor field work, using a picture and specimens	An activity involving careful observation and recording of geological features, carried out indoors, using an image of a suitable site.	 
https://www.earthlearningidea.com/PDF/163_Rocks_from_big_screen.pdf		
Will my gravestone last?: testing scientific ideas in a graveyard	Using a local graveyard for pupils to see a wide range of rock types and to investigate different scientific hypotheses	 
https://www.earthlearningidea.com/PDF/135_Gravestones.pdf		

Questions/Discussions

1. If you were an early scientist who decided to make weather measurements everyday at 8.00 am in a nearby open space, but had no instruments. What could you measure and record?

2. Draw a table to show the electronic methods that the geoscientists shown in Table 7.1 of the *Exploring geoscience* textbook might use to record data.

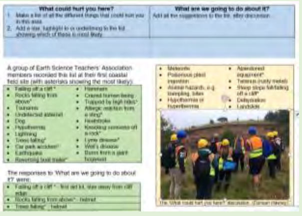
3. The first full oceanographic expedition was the Challenger expedition. *HMS Challenger* sailed around the world between 1872 and 1876, on the route shown on the map below. It carried compasses, barometers, thermometers, chemical apparatus, lines to measure the water depth (sounding lines), nets, trawls and dredges. What measurements, observations and collections is the expedition likely to have made?



The track of *HMS Challenger*; the colours show the density of the surface ocean water.

4. The 'What could hurt you here?' approach: teaching how to keep safe during fieldwork

How to introduce fieldwork safety in ways that the group is likely to remember



https://www.earthlearningidea.com/PDF/292_Fieldwork_safety.pdf

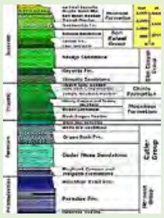
5. Fieldwork: the view from the site. Using the view of the local area to tune yourself into the local geology

Questions asking pupils to use the local landscape features as evidence for the underlying geology

https://www.earthlearningidea.com/PDF/246_View_from_site.pdf

6. Questions for any rock face 14: recording – What questions about recording data might be asked?

Questions to encourage pupils to think about the best ways of recording geological data at an exposure



https://www.earthlearningidea.com/PDF/245_Questions_rock_face_recording.pdf

7.2. Synthesis of observations

Activities		
ELI title	**Topic**	**Images**
Recreating the rocks – step by step: simulating a sedimentary rock sequence through a sequence of Earthlearningideas	Using a series of Earthlearningideas to show the steps by which a tilted sequence of sedimentary rocks was formed	 
https://www.earthlearningidea.com/PDF/321_Recreating_rocks.pdf		

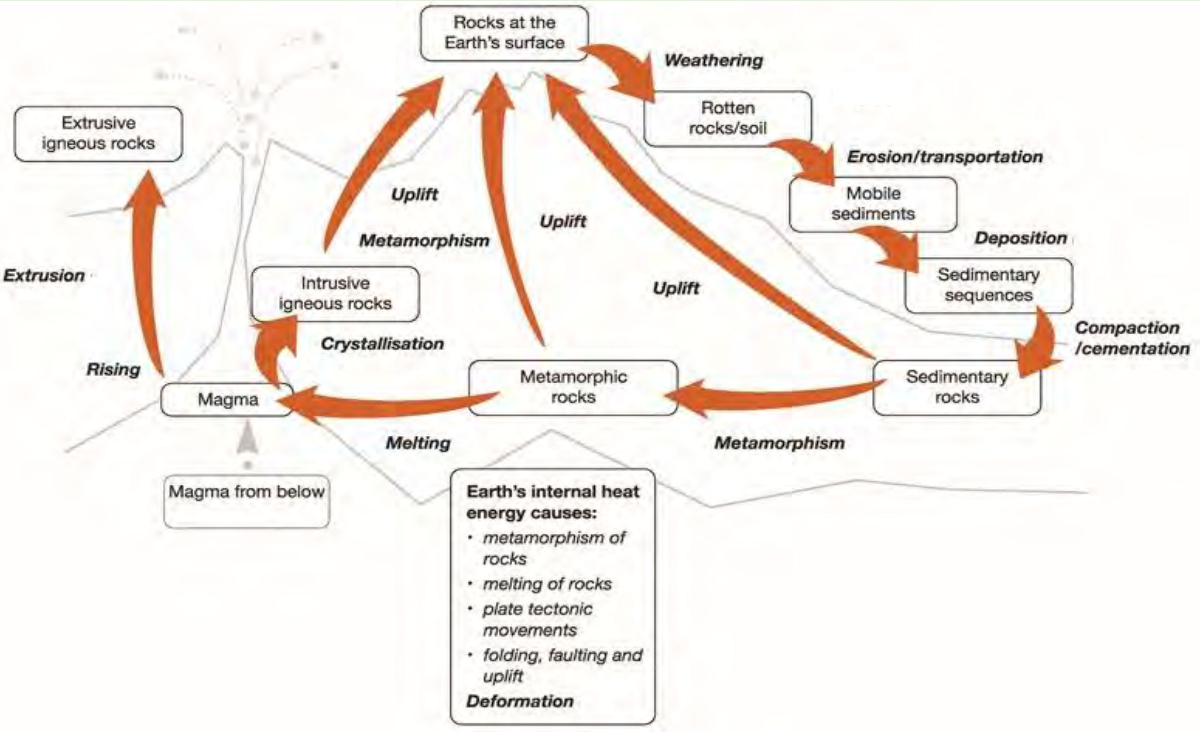
Questions/Discussions

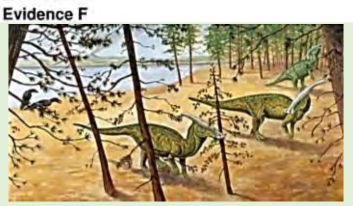
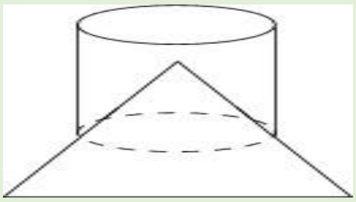
1. What is the geological history of the rock exposure shown below left? What information helped you sort out this history?

2. The bedding plane in the photograph below right is a preserved Silurian sea floor. What can you tell from the evidence in the rock about what the environment was like (the palaeoenvironment) at the time the sediment was being deposited?

3. What synthesis of observations contributed to the development of the model of plate tectonics?

4. The Scottish geoscientist James Hutton in the late 1700s made observations that helped him become the first person to describe key parts of the rock cycle. Write his observations in the correct places on the rock cycle diagram below:
   - molten granitic magma had forced its way into cracks in rocks and cooled to form dykes;
   - sediments became hardened into sedimentary rock;
   - soil and weathered rock were removed by surface processes;
   - some rock layers are tilted upwards, so there must be processes that bend and tilt rocks;
   - soil is formed from the weathering of rocks;
   - sedimentary rocks were originally deposited as sediment;
   - mountains do not get worn down to sea level, so there must be some process which pushes rock upwards.



5. Dinosaur death – did it die or was it killed? Cretaceous rock and fossil forensic evidence	Used for studying predator/prey relationships and food webs or a detective story to build up scientific investigation skills		
https://www.earthlearningidea.com/PDF/Crime_scene.pdf			
6. Darwin's 'big coral atoll idea': try thinking like Darwin did to solve the coral atoll mystery	A paper-folding activity to help pupils to visualise how Darwin developed his theory of how coral atolls formed		
https://www.earthlearningidea.com/PDF/63_Darwin_atoll.pdf			
7. What colour was the world in the past?: colouring the past geological world	A discussion, using '*the present is the key to the past'* to give a coloured picture of past geological worlds		
https://www.earthlearningidea.com/PDF/325_Colour_past_world.pdf			
8. Earth science out of doors: what evidence of the present times might be preserved in a million years?	Pupils go outdoors to consider what evidence of today's processes might be preserved in the rocks of the future		
https://www.earthlearningidea.com/PDF/Earth_science_out_of_doors.pdf			

7.3. Investigation and hypothesis-testing

Activities			
ELI title	**Topic**	**Images**	
Innocent until proven guilty: using forensic geoscience to solve the crime	Activity using problem-solving skills; adaptable to local conditions – local samples of soil, sand or rocks can be used		
https://www.earthlearningidea.com/PDF/72_Forensic_geology.pdf			

Questions/Discussions

1. When you have examined a rock exposure, then you need to decide what to investigate next. So, imagine you are a field geoscientist who has finished examining and recording all the key features of a rock exposure and then decide:
   (a) where you would go next in the field,
   (b) what you would do next in the field,
   (c) how you would follow up your investigations in the lab or office.

2. How might your answer to Question 1 above be different if you were: an exploration geologist looking for copper; a diamond prospector; a hydrogeologist; an engineering geologist investigating the building of a new dam?

3. Several attempts have been made to estimate the age of the Earth:
   (a) Lord Kelvin estimated in 1892 that the Earth's age was 100 million years, as this was the length of time it would take a molten ball of iron the size of the Earth to cool to its present temperature.
   (b) in 1899, James Joly calculated that the age of the Earth was 80 to 100 million years from the rate that the world's rivers were bringing salt into the ocean, and the current saltiness (salinity) of the ocean.
   In each case, what caused these brilliant scientists to make estimates that are much less than in current thinking (the age of the Earth from radioactive dating is 4.6 billion years old)?

4. Imagine that the Earth has gone past a climate change tipping point and so is several degrees warmer than today but that the human species has survived.
   (a) Describe what the warm Earth is likely to be like.
   (b) Devise a recovery plan to move the Earth back towards today's conditions, whilst preserving humans.

5. If the change described in Question 4 above had happened, what evidence might be preserved in the geological record?

Images and image credits

Key

CCA-SA	Creative Commons Attribution-Share Alike
ELI	Earthlearningidea
ESEU	Earth Science Education Unit
GNUFDL	GNU Free Documentation License (Version 1.2)
ipd	in/into the public domain
ISAL	Image Science and Analysis Laboratory
JESEI	Joint Earth Science Education Initiative
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
STEM	Science, Technology, Engineering and Maths
USGS	United States Geological Survey

1.4.2. The water cycle

- Changing state – transforming water: images, Peter Kennett
- Rate of evaporation: image and table from http://www.wasp.edu.au/mod/resource/view.php?id=41
- Mini-world water cycle: diagram ESEU; image, Peter Kennett
- Clouds: image from http://www.wasp.edu.au/mod/resource/view.php?id=44; plastic bottle image by Eastmain under the Creative Commons Attribution-Share Alike 4.0 International license
- Water cycle animation: images from https://youtu.be/b6YrP47CbGk
- Cycling water and heat in the lab – and the globe: apparatus drawing from, *Earth science for secondary teachers – an INSET handbook*, published by the National Curriculum Council, York, 1993. This was based on an activity described in *Coordinated Science: Earth Science* by P. Whitehead, Oxford University Press, 1993; graph Chris King
- Water cycle world: laundry image: by russavia under the Creative Commons Attribution 2.0 Generic license; diagram by Wasserkreislauf.png. and Moyogo under the Creative Commons Attribution-Share Alike 3.0 Unported license.
- 'Tagging' water molecules: ice image by Ivar Leidusunder the Creative Commons Attribution-Share Alike 3.0 Unported license; diagram http://ga.water.usgs.gov/edu/watercycleprint.html

1.4.4. The rock cycle

- Rocks and minerals animation: images from https://youtu.be/WYtF-ZdTr7s
- The rock cycle in wax: images, Chris King
- From *Rock detective* to *Laying out the rock cycle*: images, Chris King
- Laying out the rock cycle – product and process: images, Chris King
- Not misunderstanding the rock cycle: rock cycle image, ESEU with permission; page image, Chris King
- The rock cycle at your fingertips: images, Peter Kennett
- Sand on a sill: images, Chris King
- Rock cycle through the window: rock cycle image, Chris King; gutter image by permission of Infrogmation under the terms of the GNU Free Documentation license
- James Hutton – or 'Mr. Rock Cycle'?: painting of James Hutton by Abner Lowe in the public domain because its copyright has expired; unconformity image by Anne Burgess under the Creative Commons Attribution-ShareAlike 2.0 license.

1.4.5. The carbon cycle

- Carbon goes round and round and round: diagram, University Corporation for Atmospheric Research (UCAR) with the permission of the ESEU; image, Peter Kennett
- Carbon cycle in the lab: diagram and questions from https://geohubliverpool.org.uk/jesei/carbon%20cycle%202.htm
- Carbon cycle: releasing dinosaur breath in the lab: diagram and questions from https://geohubliverpool.org.uk/jesei/carbon%20cycle%203.htm
- Carbon cycle: exchanging carbon dioxide between the atmosphere and ocean: image from ESEU; questions from, https://geohubliverpool.org.uk/jesei/carbon%20cycle%201.htm

- Cycling carbon: seeing how plants use carbon dioxide in the lab: image by Christian Fischer under the Creative Commons Attribution-Share Alike 3.0 Unported license; questions https://geohubliverpool.org.uk/jesei/cycling%20carbon.htm
- Carbon cycle: where is this crucial carbon?: image of burning walnut by Adel Zhaneken under the Creative Commons Attribution-Share Alike 4.0 International license; questions https://geohubliverpool.org.uk/jesei/carbon%20cycle%204.htm
- The carbon cycle through the window: diagram, University Corporation for Atmospheric Research (UCAR) with the permission of the ESEU; image, Elizabeth Devon
- Tag a carbon atom – and explore the carbon cycle: diagram, Paul Grant; image, published by Nihiltres under the terms of the GNU Free Documentation License, Version 1.2
- Solution: images from http://www.wasp.edu.au/mod/resource/view.php?id=336
- Fermentation: images from http://www.wasp.edu.au/mod/resource/view.php?id=333

2.1. Origins

- Solar system static: images from http://www.wasp.edu.au/mod/resource/view.php?id=455
- Solar system gravity: images from http://www.wasp.edu.au/mod/resource/view.php?id=457
- Playground planets: image, Steve Blakesley; table, Elizabeth Devon

2.2. The Sun

- Sun change paper: images from http://www.palms.edu.au/mod/resource/view.php?id=532
- Sun and energy: http://www.wasp.edu.au/mod/resource/view.php?id=481

2.3.1. Day/night

- A screaming roller coaster: image, published by Boris23 in the public domain; diagram, Chris King
- Hot or not?: images, Elizabeth Devon
- Earth on Earth: images, Chris King

2.3.2 The seasons

- Seasons – the effect of our tilted Earth: diagram and image, Peter Kennett
- The seasons: images from http://www.earthsciencewa.com.au/mod/resource/view.php?id=1323

2.3.3. The phases of the moon

- Polystyrene moon: images, Peter Kennett
- Lollipop moon: images, Chris King
- Jaffa moon: moon diagram, released by Mond_Phasen.jpg and Gregors. under the Creative Commons Attribution-Share Alike 3.0 Unported license; image, Chris King.

2.3.4. Eclipses

- Why does the Sun disappear?: solar eclipse image, https://eclipse.gsfc.nasa.gov/eclipse.html; image, Peter Kennett
- Eclipse the lollipop: images, Chris King

3. Earth is system which has changed over time

3.1. Geological time span

- Personal timescale: images from http://www.earthsciencewa.com.au/mod/resource/view.php?id=1248
- Toilet roll of time: images, Chris King.
- How many for a million?: table, Chris King; image in the public domain from the USGS

3.2. Relative dating

- Laying down the principles: images, Peter Kennett
- What happened when?: diagrams, ESEU
- What is the geological history?: diagrams, Chris King
- Modelling by hand 'when the youngest rock is not on top': images, Peter Kennett
- Modelling unconformity – by hand: unconformity image, Alan Holiday; hands image, Peter Kennett
- Sequencing of rocks: what was the order of events?: diagrams from, https://geohubliverpool.org.uk/jesei/sequencing%20of%20rocks.htm
- William Smith map: in the public domain because the copyright term has expired

- William Smith – 'The Father of English Geology': cross section sketch from John Strachey's 1719 drawing in the public domain because the copyright term has expired; detail from Smith map in the public domain because the copyright term has expired
- Fieldwork: the 'All powerful' strategy: Coombs Quarry image, Nikki Edwards; Deccan Traps image, Chris King
- Filling the gap – picturing the unconformity '*abyss of time'*?: Hand image, David Bailey; Precambrian image, Peter Kennett
- Questions for any rock face 10: sequencing: Old Red Sandstone image by Rodney Harris under the Creative Commons Attribution-Share Alike 2.0 Generic licence as part of the Geograph project; dykes image Thomas Eliasson of the Geological Survey of Sweden http://www.flickr.com/people/geologicalsurveyofsweden/ under the Creative Commons Attribution 2.0 Generic license

3.3. Absolute dating

- Dating the Earth – before the discovery of radioactivity: Etna image released under the Creative Commons Attribution-Share Alike 4.0 International,3.0 Unported, 2.5 Generic, 2.0 Generic and 1.0 Generic licenses, diagram, Peter Williams

3.4. Rates of processes

- Craters on the moon: moon crater, NASA copyright and in the public domain; craters in a sand tray, Peter Kennett
- How long does it take? – quick to very, very, very slow: paleogeographic map by Dr Ron Blakey under the Creative Commons Attribution-Share Alike 3.0 Unported license; lava image, Stephanie Flude
- Norber erratic: image by Bryan Pready taken as part of the Geograph project under the Creative Commons Attribution-Share Alike 2.0 Generic license

4.1. Geosphere

- Amazing Earth: facts that fascinate: Earth image in the public domain by NASA; questions, https://geohubliverpool.org.uk/jesei/amazing%20%20earth.htm

4.1.1. Earth materials and properties

- Found in the ground – sorted!: images, Peter Kennett

4.1.1.1. Minerals

- Minerals form crystals: images from http://www.wasp.edu.au/mod/resource/view.php?id=200
- Mineral or not?: images, Peter Kennett
- Be a mineral expert – 1: images, Peter Kennett
- Be a mineral expert – 2: images, Peter Kennett
- Identifying minerals – use your sense(s)!: image, Peter Kennett; diagram Daniel Reis
- I'm pure calcium carbonate – the calcium carbonate question: aragonite image by Didier Descouens under the Creative Commons Attribution 4.0 International license; calcite and marble images, Peter Kennett; chalk and limestone images, Chris King; stalagmite image by Hannes Grobe under the Creative Commons Attribution-Share Alike 3.0 Unported licence

4.1.1.2. Rocks

- We need rocks for breakfast: images from http://www.wasp.edu.au/mod/resource/view.php?id=112
- Why study rocks 1?: images from http://www.wasp.edu.au/mod/resource/view.php?id=114 and http://www.wasp.edu.au/mod/resource/view.php?id=564
- Why study rocks 2?: images from http://www.wasp.edu.au/mod/resource/view.php?id=564
- Get to know your rock: images from http://www.earthsciencewa.com.au/mod/resource/view.php?id=1417
- Rock types key: images from http://www.earthsciencewa.com.au/mod/resource/view.php?id=1613
- Rock detective – rocky clues to the past: diagram, Chris King; image, Peter Kennett
- The space within – the porosity of rocks: images, Peter Kennett
- Modelling for rocks: What's hidden inside – and why?: images, Chris King
- Does my rock hold water and will water flow through it?: images, Elizabeth Devon
- Rock grain cut out: sedimentary rock, Jurassic lithic-arenite by Michael C. Rygel under the Creative Commons Attribution-Share Alike 3.0 Unported Licence; igneous rock, tonalite – by Chiara Groppo in

Atlante di petrografia and published under the Creative Commons Attribution-Share Alike 2.5 Generic license

- Eureka! – detecting ore the Archimedes way: diagram, John Perry; image, Peter Kennett
- Eggsamples of different rock types: images from http://www.earthsciencewa.com.au/mod/resource/view.php?id=1428
- Chopping on rock: images from http://www.wasp.edu.au/course/view.php?id=47
- The chemistry of limestone: image and instructions from, https://geohubliverpool.org.uk/jesei/chemistry%20of%20limestone.htm
- Limestone in your everyday life: brushing teeth image by Poppy Thomas-Hill under the Creative Commons Attribution 2.0 Generic license; table from, https://geohubliverpool.org.uk/jesei/limestone%20everyday%20life.htm
- Questions for any rock face 4: rock group (sedimentary or igneous): images, Peter Kennett

4.1.1.3. Fossils

- How could I become fossilised?: human image, by Bernhard Ungerer under the Creative Commons Attribution 3.0; tooth image, released into the public domain by Werneuchen
- Bodies in bogs: egg image from http://www.earthsciencewa.com.au/mod/resource/view.php?id=1305; bog hand image by Sven Rosborn and released into the public domain
- Moulds and casts: images from http://www.earthsciencewa.com.au/mod/resource/view.php?id=1239
- Fossilise!: image and diagram, Elizabeth Devon
- Sea shell survival: images, Peter Kennett
- Fossil or not?: images, Peter Kennett
- Dig up the dinosaur: images, Peter Kennett
- Drawing dinos: images from R. Valli Divya at Centre for Earth Sciences and the Indian Institute for Science in Bangalore, India
- Trace fossils – burrows or borings: images, Peter Kennett
- Trail-making: trilobite image released by Ghedoghedo under the terms of the GNU Free Documentation License; image of ‘trail-maker’, Nikki Edwards
- The meeting of the dinosaurs – 100 million years ago: diagram, copyright, 1964, American Geological Institute; adapted, with permission, from Investigation 19-2, Earth Science Curriculum Project Laboratory Manual, Johnson Publishing Company, Boulder, Colorado, USA; footprint image with permission from Dr. Oliver Wings, http://dinosaurhunter.org
- A dinosaur in the yard: image and diagram, Pete Loader
- How to weigh a dinosaur: image and diagram, Peter Kennett
- Curious creatures: animal images reproduced with kind permission of The Burgess Shale Geoscience Foundation http://www.burgess-shale.bc.ca; scene image, ESEU
- Who ate the ammonite?: images, ESEU
- Running the fossilisation film backwards: trilobite image, Dee Edwards; dinosaur image by Thomas Ihle under the terms of the GNU Free Documentation License, Version 1.2
- Fifty million years into the future: images, the ESEU adapted from the book *After man: a zoology of the future* (1981) by Dougal Dixon, Granada Publishing
- Brachiopod internal mould image, released by Dwergenpaartje under the Creative Commons Attribution-Share Alike 3.0 Unported license
- What was it like to be there?: trilobite image released by DanielCD under the terms of the GNU Free Documentation License; coral image released by Dlloyd under the terms of the GNU Free Documentation License
- Mary Anning – Mother of Palaeontology: images in the public domain because their copyright has expired
- Questions for any rock face 6: fossils: crinoid image by Gary Rogers under the Creative Commons Attribution-Share Alike 2.0 Generic licence; Silurian sea floor image by Mike Peel under the Creative Commons Attribution-Share Alike 2.0 UK licence

4.1.1.4. Sedimentary rocks

- Recognising sedimentary rocks: images from http://www.wasp.edu.au/mod/resource/view.php?id=185
- Grain size in sedimentary rocks: images from http://www.earthsciencewa.com.au/mod/resource/view.php?id=1439
- Questions for any rock face 5: sedimentary grains: Conglomerate image by Michael C. Rygel under the Creative Commons Attribution-Share Alike 3.0 Unported license; mudstone image, by Ducky under the terms of the GNU Free Documentation License, Version 1.2

4.1.1.5. Igneous rocks

- Recognising igneous rocks: images from http://www.wasp.edu.au/mod/resource/view.php?id=187

4.1.1.6. Metamorphic rocks

- Identifying metamorphic rocks: images from http://www.wasp.edu.au/mod/resource/view.php?id=571
- Questions for any rock face 9: metamorphic rock: slate image, Earth Science Image Bank h2eehf, © Bruce Molnia, Terra Photographics; gneiss image, Peter Kennett

4.1.1.7. Soil

- Soil grain size: images from http://www.wasp.edu.au/mod/resource/view.php?id=519
- Humus in soil: images from http://www.wasp.edu.au/mod/resource/view.php?id=517
- CSI soils: images from http://www.earthsciencewa.com.au/mod/resource/view.php?id=1291
- Soil compaction: images from http://www.palms.edu.au/mod/resource/view.php?id=639
- Salt in water and soils: images from http://www.earthsciencewa.com.au/mod/resource/view.php?id=1294
- Make your own soil: image, Elizabeth Devon; soil image from www.geo.msu.edu/SoilProfiles
- Soil doughnuts: images, Elizabeth Devon
- Permeability of soils – the great soil race: diagram, Earth Science Teachers' Association, (1993) *Teaching Primary Earth Science, No.3, Soil*, forming part of *Teaching Earth Sciences* Vol. 18; image, Peter Kennett
- Darwin's 'big soil idea': Darwin portrait, in the public domain because its copyright has expired; wormery image, Peter Kennett
- Soil layers puzzle: diagram, Elizabeth Devon; image from www.geo.msu.edu/SoilProfiles
- Desertification and salinity in soil: images from http://www.earthsciencewa.com.au/mod/resource/view.php?id=1361
- Is there life in this soil sample?: bagged soil image by, https://finds.org.uk/database/ajax/download/id/421891 under the Creative Commons Attribution-Share Alike 2.0 Generic license; soil image by Megan Mallen under the Creative Commons Attribution 2.0 Generic license
- Where on Earth is no soil found?: rocky desert image by Jacobo Suárez Domínguez under the Creative Commons Attribution-Share Alike 3.0 Unported license; Saunders Island image in the public domain because it came from NASA
- 'Tagging' nitrogen atoms – to explore the nitrogen cycle: diagram, from: https://cnx.org/contents/havxkyvS by OpenStax under the Creative Commons Attribution 4.0 International license; plant image, Chris King
- Questions for any rock face 3: soil: image and diagram in the public domain by the U.S. federal government

4.1.2.1. Surface processes

- Weathering limestone – with my own breath!: images, Peter Kennett
- Cracking apart: lab image, Peter Kennett; broken rock image, Prince Roy, Taipei, Flicr.com. under the Creative Commons Attribution 2.0 Licence
- Ice power: images, Peter Kennett
- Physical weathering – freezing (plaster): images from http://www.wasp.edu.au/mod/resource/view.php?id=121
- Chemical weathering – salt and water: images from http://www.wasp.edu.au/mod/resource/view.php?id=132
- Chemical weathering – acid rain: images from http://www.palms.edu.au/mod/resource/view.php?id=613
- Karstic scenery – in 60 seconds: sugar image, Elizabeth Devon; limestone image, Peter Kennett
- Weathering – rocks breaking up and breaking down: images, Peter Kennett
- Teacher – What's the difference between weathering and erosion?: image released by the National Cancer Institute, an agency part of the National Institutes of Health, with the ID 2200 (image) – released into the public domain by Michael Anderson; table, Chris King
- Rock, rattle and roll: images, Peter Kennett
- Shell shake – survival of the toughest: shell image, Peter Kennett, shaking image, Elizabeth Devon
- Grinding and gouging: striated rock by USGS
- Weathering and erosion: simulating rock attack in the lab: diagrams from, https://geohubliverpool.org.uk/jesei/weathering.htm
- Geological postcards 1: granite and chalk: photographs with a P number with the permission of the British Geological Survey, for non-commercial use; other images, Peter Kennett

- Geological postcards 2: sandstone and limestone: photographs with a P number with the permission of the British Geological Survey, for non-commercial use; other images, Peter Kennett
- Evidence from the deep freeze – under or near the ice sheets: images, Peter Kennett
- Mighty river in a small gutter: image, Peter Kennett; diagram ESEU
- Investigating small-scale sedimentary processes AND modelling mighty rivers: images, Chris King
- Rolling, hopping and floating and invisibly moving along: image and diagram, Elizabeth Devon
- A bucket for a pothole – visualising past processes by calculation: image, Maggie Williams; bedrock potholes image by Kreuzschnabel under the Creative Commons Attribution-Share Alike 3.0 Unported licence
- Why do coastlines change shape?: images, Peter Kennett
- Environmental detective: diagram and image, Peter Kennett
- How did that get there?: images from http://www.palms.edu.au/mod/resource/view.php?id=720
- What was it like to be there – in the rocky world?: coral reef image by Clark Anderson/Aquaimages, under the Creative Commons Attribution ShareAlike License version 2.5: http://creativecommons.org/licenses/by-sa/2.5/; dune image by Horizon, http://www.flickr.com/photos/horizon/ under the licence http://creativecommons.org/licences/by-nc-nd/2.0/deed.en_GB
- If a sedimentary bed were laid down outside now – what would it be like?: landslide image, by Trocaire under the Creative Commons Attribution 2.0 Generic license; flood image by Love Krittaya in the public domain
- Questions for any rock face 1: weathering: Apes Tor image, Chris King; Giant's Causeway image, Peter Kennett
- Questions for any rock face 2: erosion: fan image, Peter Kennett; volcanic cone image by Dr. Dwayne Meadows, NOAA/NMFS/OPR. under the Creative Commons Attribution 2.0 Generic license
- When are soft rocks tough, and hard rocks weak?: chalk cliff image by Philippe Alès under the Creative Commons Attribution-Share Alike 4.0 International license; eroded anticline image, Rick Ramsdale

4.1.1.2. Sedimentary processes

- How do sedimentary beds form? – and why can we see them?: bedding image by Miguel Vera León under the Creative Commons Attribution 2.0 Generic license; measuring cylinder images, Chris King
- From river sediment to stripy rocks: jar and rock images, Elizabeth Devon; River Tweed, image Ian Kille, Northumbrian Earth
- Sand ripple marks in a tank: diagram, Chris King; image, Peter Kennett
- Sand ripples in a washbowl: images, Peter Kennett
- Sedimentary structures – make your own cross-bedding: gutter image, Chris King; jar image, Peter Kennett
- Sedimentary structures – cross-bedding and ancient currents: estuary image, Chris King; cross-bedding image, Peter Kennett
- Cracking the clues: images, Peter Kennett
- Sedimentary structures – graded bedding: images, Peter Kennett
- Make your own rock: images, Peter Kennett
- De-watering of sediments: images from http://www.wasp.edu.au/mod/resource/view.php?id=169
- Sedimentation and sedimentary sandwiches: images from http://www.earthsciencewa.com.au/mod/resource/view.php?id=1430
- Rock builder: diagram, ESEU; image, Elizabeth Devon
- The deep rock cycle explained by plate tectonics: lithification: image and diagram, Chris King
- What was it like to be there?: clues in sediment which bring an environment to life: cross-bedding image by Roy Luck (roy.luck on Flickr) http://www.flickr.com/people/royluck/ under the Creative Commons Attribution 2.0 Generic licence; ripple image, Peter Kennett
- Beach, river, dune, mountain, plain – what layers might be preserved here?: bedding image, released into the public domain by Bamyers99; fan satellite image in the public domain from NASA

4.1.2.3. Igneous processes

- Partial melting – simple process, huge global impact: beaker image, Chris King; lava image, in the public domain from the USGS
- Partial melting model and real rock: image, Peter Kennett; diagram, Chris King
- Why do igneous rocks have different crystal sizes?: diagram, Peter Kennett; Salol crystals from the JESEI website: https://geohubliverpool.org.uk/jesei/xtal%20size%20&%20cooling%20rate.htm

- Crystal size and cooling rate: fast and slow cooling of lead iodide: images from: https://geohubliverpool.org.uk/jesei/xtal%20size%20&%20cooling%20rate.htm
- The unfair 'build your own crystal' race: atomic model image, Chris King: rock image, Peter Kennett
- 'Crystallisation' in a pudding dish: images, Peter Kennett
- Volcano in the lab: images, Peter Kennett
- Volcanoes and dykes/jelly and cream – radial dykes: diagram, Chris King; image, Peter Kennett
- Rectangular feldspar crystals in granite released into the public domain by Wilson44691
- Igneous processes: matching the evidence they leave behind: images from: https://geohubliverpool.org.uk/jesei/igneous%20processes.htm
- Igneous rocks: completing the 3D picture: images from: https://geohubliverpool.org.uk/jesei/igneous%20rocks.htm
- What was it like to be there – in the rocky world?: volcanic image ID: h6iw7b courtesy USGS; image source: Earth Science World Image Bank http://www.earthscienceworld.org/images; granite image, Peter Kennett

4.1.2.4. Metamorphic processes

- Metamorphism – that's Greek for change of shape, isn't it?: images, Peter Kennett
- Recognising metamorphic rocks: images from, http://www.wasp.edu.au/mod/resource/view.php?id=189
- Metamorphic modelling – simulating metamorphic processes: images from: https://geohubliverpool.org.uk/jesei/metamorphics.htm
- Squeezed out of shape: image, Peter Kennett; trilobite image, Dr. M. Romano, Sheffield University
- Metamorphic aureole in a tin: datalogging image, Chris King; thermometer image, Peter Kennett
- The deep rock cycle explained by plate tectonics: deformation and metamorphism: image and diagram, Chris King
- Metamorphism diagram amended from diagram by Tamtawan.p under the Creative Commons Attribution-Share Alike 3.0 Unported licence

4.1.2.5. Deformation processes

- The Himalayas in 30 seconds!: images, Peter Kennett
- Margarine mountain-building: images, Peter Kennett
- Swiss roll surgery: images, Elizabeth Devon
- Banana benders: images, Martin and Elizabeth Devon
- A valley in 30 seconds – pulling rocks apart: image and diagram, Peter Kennett
- Fluids, friction and failure: image and diagram, Peter Kennett
- From folds to crustal shortening – visualising past processes by calculation: measuring image, Chris King; folded rocks image, Pete Loader
- Modelling folding – by hand: images, Peter Kennett
- Three types of fault: images from http://www.wasp.edu.au/mod/resource/view.php?id=261
- Modelling faulting – by hand: hand images, Peter Kennett; reverse fault image by Mikenorton under the Creative Commons Attribution-Share Alike 4.0 International license
- Modelling Earth stresses with your hands: images, Peter Kennett
- The view from above – living tectonism: squashed ball image, Chris King; graph image from: https://en.wikipedia.org/wiki/Brittle%E2%80%93ductile_transition_zone
- Questions for any rock face 7: tilted or folded rocks: images, Peter Kennett
- Questions for any rock face 8: faults: modified diagram in the public domain from the USGS; image, Peter Kennett

4.1.3 Structure of the Earth and evidence

- Journey to the centre of the Earth – on a toilet roll: Diagram, ESEU; image, Pete Loader

4.1.3.1. Evidence

- From clay balls to the structure of the Earth: diagram, Chris King; globe image by Charles C. under the Creative Commons Attribution-ShareAlike 3.0 license
- From an orange to the whole Earth: diagram and image, Elizabeth Devon
- Layers of the Earth (density): images from http://www.wasp.edu.au/mod/resource/view.php?id=403
- Earth egg model: images from http://www.wasp.edu.au/mod/resource/view.php?id=401
- Denser down: images from http://www.wasp.edu.au/mod/resource/view.php?id=399

- The Great Iron Catastrophe and rock density: images from http://www.wasp.edu.au/mod/resource/view.php?id=296
- Planetary differentiation: images from http://www.wasp.edu.au/mod/resource/view.php?id=294

4.1.3.2. Crust

- Earth's crust: thinner than you think: diagram, *Exploring Geoscience*; postage stamp image, Russia Post – work not an object of copyright
- Minerals, elements and the Earth's crust: tables from: https://geohubliverpool.org.uk/jesei/minerals%20&%20elements.htm
- Earth's crust versus the prep. room – why the differences?: image by Максим Фомич under the Creative Commons Attribution 2.0 Generic license; table from: https://geohubliverpool.org.uk/jesei/earths%20crust%202.htm

4.1.3.3. Mantle

- Bouncing, bending, breaking: images, Peter Kennett.

4.1.3.4. Core

- Structure of the Earth: teacher demonstrating seismic evidence for the core: overhead projector image by Bomas13 under the Creative Commons Attribution-Share Alike 3.0 Unported license; bowl image by Donovan Govan under the terms of the GNU Free Documentation License, Version 1.2
- A core activity: diagram by SoylentGreen under the GNU Free Documentation License, Version 1.2; cards, Chris King

4.1.4 Plate tectonics and evidence

- Frozen magnetism: images, Peter Kennett
- Magnetic stripes: image, Peter Kennett; diagram, ESEU
- Rock age data: images from http://www.wasp.edu.au/mod/resource/view.php?id=249

4.1.4.1. Unifying theory

- The plate tectonic story: a scientific jigsaw: questions and page from: https://geohubliverpool.org.uk/jesei/plate%20tectonic%20story.htm
- Wegener's 'Continental drift' meets Wilson's 'Plate tectonics': Alfred Wegener image, copyright expired; J. Tuzo Wilson image, in the public domain from the USGS
- Tectonics history: images from http://www.wasp.edu.au/mod/resource/view.php?id=588
- Plate jigsaw: images from http://www.wasp.edu.au/mod/resource/view.php?id=235
- Seafloor model: images from http://www.wasp.edu.au/mod/resource/view.php?id=247
- Model a spreading ocean floor offset by transform faults: images, Chris King
- Hotspots: images, Peter Kennett
- Supercontinents: images from http://www.wasp.edu.au/mod/resource/view.php?id=592

4.1.4.2. Plate construction and subduction

- Plate: image in the public domain because the copyright has expired

4.1.4.3. Characteristics of plate margins

- Faults in a Mars™ Bar; Mars™ Bar image, ESEU; Iceland map, USGS
- Which is the fastest spreading oceanic ridge?: map from http://www.ngdc.noaa.gov/mgg/ocean_age/ocean_age_2008.html; National Geophysical Data Center, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, http://www.ngdc.noaa.gov under the Creative Commons Attribution-Share Alike 3.0 Unported license
- Continents in collision: diagram, ESEU; image, Peter Kennett
- Magnetic patterns: table and diagram from: https://geohubliverpool.org.uk/jesei/magnetic%20patterns%201.htm
- Dangerous Earth: a plate tectonic story: page and questions from: https://geohubliverpool.org.uk/jesei/dangerous%20earth.htm
- Plate margins by hand: images, Peter Kennett
- Plate tectonics through the window: diagrams, ESEU

- Questions for any rock face 11: tectonic plates: diagram in the public domain from the USGS

4.1.4.4. Mechanisms and rates of movement

- What drives the plates?: diagram, Pete Loader; image, David Bailey
- All models are wrong – but some are really wrong: plate-driving mechanisms: diagrams, Chris King modified from USGS
- Plate-riding – role-play plate-surfing to ask: 'How is the plate you live on moving now?' surfing image, in the public domain from the United States Marine Corps; globe picture, published under the terms of the GNU Free Documentation License; plate map, USGS.
- What do the top and bottom of a tectonic plate look like?: diagrams, Chris King

4.1.4.5. Evidence

- The continental jigsaw puzzle: maps, ESEU
- Geobattleships – do earthquakes and volcanoes coincide? maps, Dave Turner
- 'Expanding Earth' images by MichaelNetzer under the Creative Commons Attribution-Share Alike 3.0 Unported license.
- Wrinkled apple image by DKrieger under the Creative Commons Attribution-Share Alike 4.0 International license.

4.2.1.2. Water supplies

- Groundwater – from rain to spring: diagram, Chris King; image, Earth Science World Image Bank – image ID: h4uu4k © Marli Miller, University of Oregon
- Well, well, well! Making a working model of a well: images, Peter Kennett
- Water pressure – underground: images, Chris King
- Groundwater spiders: images, Jo Watkins

4.2.1.3. Water contamination

- Water: a matter of taste or a taste of matter: images, Peter Kennett; label from a bottle of mineral water
- 'Water, water everywhere but not a drop to drink': image, Peter Kennett; diagram, a work of the U.S. federal government in the public domain
- Filtering with sand: images from http://www.wasp.edu.au/mod/resource/view.php?id=32
- Filtering with sari: text from http://www.wasp.edu.au/mod/resource/view.php?id=33; image Jo Watkins
- Filtering with rock: images from http://www.wasp.edu.au/mod/resource/view.php?id=34

4.2.2. Oceanic water

- Exploring current flows through straits; images, Giulia Realdon

4.2.2.1. Water composition

- Salinity and density: images from http://www.wasp.edu.au/mod/resource/view.php?id=389
- Why is the Dead Sea dead?: Dead Sea image by Pete under the terms of the GNU Free Documentation License, Version 1.2; test tube image, S. Allen and G. Jones

4.2.2.2. Tides

- The bore of the River Severn, UK: by Ruth Sharville as part of the Geograph project under the Creative Commons Attribution-Share Alike 2.0 Generic license

4.2.2.4. Large scale circulations of fluids on Earth

- High flow. Low flow? – atmosphere and ocean in a tank: diagram, Chris King; image, Peter Kennett
- Atmosphere and ocean in a lunchbox: images, Chris King
- Oceanic circulation: text from http://www.earthsciencewa.com.au/mod/resource/view.php?id=1055; diagram by Robert Simmon of the NASA Earth Observatory and released into the public domain
- Global conveyor belt: images from http://www.wasp.edu.au/mod/resource/view.php?id=387

4.3 Atmosphere

- Space survival: how could we survive a year in a dome?: dome image, CDO Ranching and Development, LP, Arizona, USA; pyramidal dome image, by Qygen under the Creative Commons Attribution-Share Alike 3.0 Unported license

- Explain what is the most important factor influencing the climate of the Earth? – question from Rahul Chopra, Coordinator of the Climate Education project (TROP-ICSU) of the International Council of Science

4.3.1. Atmospheric composition

- Earth's atmosphere – step by step evolution: images, ESEU
- Earth's early atmosphere and oxygen: http://www.earthsciencewa.com.au/mod/resource/view.php?id=1261
- Atmospheric evolution – BIF: http://www.earthsciencewa.com.au/mod/resource/view.php?id=1259

4.3.3. Atmospheric change

- Melting ice and sea level change 1 – sea ice: images, Peter Kennett
- Melting ice and sea level change 2 – ice caps: images, Peter Kennett
- How can the ice core evidence for climate change be explained?: graphs by Vostok Petit data.svg under the Creative Commons Attribution-Share Alike 3.0 Unported licence; image from http://www.ncdc.noaa.gov/paleo/slides/slideset /15/15_305slide.html Todd Sowers, LDEO, Columbia University and in the public domain from the U.S. NOAA
- Carbon dioxide and temperature: images from http://www.wasp.edu.au/mod/resource/view.php?id=594
- Carbon dioxide solubility: images from http://www.wasp.edu.au/mod/resource/view.php?id=706
- Methane clathrates: images from http://www.wasp.edu.au/mod/resource/view.php?id=382
- Sea ice thickness: images from http://www.wasp.edu.au/mod/resource/view.php?id=373
- Permafrost melting: images from http://www.wasp.edu.au/mod/resource/view.php?id=380
- Fossils and climate: images from: http://www.wasp.edu.au/mod/resource/view.php?id=610
- Climate on arrival: desert image Licensed by GerritR under the Creative Commons Attribution-Share Alike 4.0 International license; palm tree image, released into the public domain by BenSherman
- Tree rings: a climate record of the past: diagram and graph from, https://geohubliverpool.org.uk/jesei/tree%20rings.htm
- Is the greenhouse effect happening outside today?: classroom window image released into the public domain by Gorkaazk; diagram, Chris King redrawn by Tanja Reinhardt
- What could we measure to find out if climate change is happening here?: Stevenson's screen image by Bidgee under the Creative Commons Attribution-Share Alike 3.0 Australia license; rain gauge image by Kolling under the terms of the GNU Free Documentation License, Version 1.2; butterfly image by Ragnar1904 under the Creative Commons Attribution-Share Alike 4.0 International license

4.4.1. Evolution

- How many Great Great Great Great Grandparents?: the family tree of Ahnentafel von Herzog Ludwig (1568-1593), (Württembergisches Landesmuseum, Stuttgart) in the public domain because its copyright has expired; graph, Chris King.
- How many Beany Beetles?: image and table, Elizabeth Devon
- A time-line in your own backyard: image and table, Peter Kennett
- Sorting out the evolution of evolution headlines: diagram released into the public domain by Jerome Walker, Dennis Myts; image, Chris King

4.4.2. Impact on other systems

- Protecting the Earth: how big is your ecological footprint?: questionnaire adapted from one published in the *New Scientist* global environment supplement on the 28th April 2001; questionnaire and scoring matrix from: https://geohubliverpool.org.uk/jesei/protecting%20the%20earth.htm

5.1. Raw materials and fossil fuels

- Finding the Earth in the UN Sustainable Development Goals: diagram by the United Nations in the public domain; table, Chris King, based on a table in *Geology and the sustainable development goals* by Joel Gill (2017) *Episodes* 40(1), 70-76
- Abandoned quarry image published as part of the Geograph project by Alan Murray-Rust under the Creative Commons Attribution-Share Alike 2.0 Generic license

5.1.1. Bulk raw materials for construction

- Concrete image: concrete with obsidian aggregate in the complex around the Swartnoz Cathedral, Armenia, released by GerritR under the Creative Commons Attribution-Share Alike 4.0 International license
- Superquarry image: Glensanda superquarry in Scotland, Google Maps™ image.

5.1.2. Bulk raw materials for industry

- Be a mineral expert – 3: images, Peter Kennett
- Rocks to eat?: images, Elizabeth Devon
- Salt of the Earth: images, Peter Kennett

5.1.3. Metal ores

- Riches in the river: images, Peter Kennett
- Jigging: diagram, Earth Science Teachers' Association; image, Peter Kennett
- Separating mixtures: how we concentrate natural materials: image modified from an original image by the Utah State Office of Education; both image and table from: https://geohubliverpool.org.uk/jesei/separating%20mixtures.htm

5.1.4. Industrial minerals

- Be a mineral expert – 4: recycle your mobile phone: image, Peter Kennett; graph from http://ec.europa.eu/environment/ipp/pdf/nokia_mobile_05_04.pdf page 59

5.1.5. Fossil fuels

- Data about common fuels in the table taken from: https://www.engineeringtoolbox.com/co2-emission-fuels-d_1085.html

5.1.5.1. Peat and coal

- Peat image: by Jeffdelonge under the Creative Commons Attribution-Share Alike 3.0 Unported license

5.1.5.2 Oil and natural gas

- Trapped! Why can't the oil and gas escape from their prison?: diagram ESEU; image, Peter Kennett
- Make your own oil and gas reservoir: image, Peter Kennett; text, Earthlearningidea
- Where shall we drill for oil?: diagram, Chris King; text, Earthlearningidea
- Recipe for the perfect fracking fluid: text, Peter Styles; image licensed under the Creative Commons Attribution 4.0 International license
- It's a gas: images from http://www.wasp.edu.au/mod/resource/view.php?id=63
- Structural seal: images from http://www.wasp.edu.au/mod/resource/view.php?id=71
- Viscosity raising raisins: images from http://www.wasp.edu.au/mod/resource/view.php?id=75
- Pressure lift: images from http://www.wasp.edu.au/mod/resource/view.php?id=73
- Oil and gas formation animation: images from https://youtu.be/8YHsxXEVB1M

5.1.6. Prospecting

- A typical exploration sequence: images from http://www.earthsciencewa.com.au/mod/resource/view.php?id=1154
- Geochemical soil sampling: images from http://www.earthsciencewa.com.au/mod/resource/view.php?id=1149
- Magnetic survey: images from http://www.earthsciencewa.com.au/mod/resource/view.php?id=1157
- Searching for iron ore: images from http://www.wasp.edu.au/mod/resource/view.php?id=653
- Going for gold; images from http://www.wasp.edu.au/mod/resource/view.php?id=645
- Gold prospectors: pupil image, Peter Kennett; panning image Lebelot, GNU Free Documentation License, Version 1.2

5.1.7. Environmental protection and remediation

- Kokubu Tokugawa quarry: image by the 国土地理院 (Geospatial Information Authority of Japan) under the Creative Commons Attribution 4.0 International license

5.2. Power supplies

- Figure 5.5. Global energy consumption graph by Martinburo from Bp_world_energy_consumption_2016.gif under CCA-SA 4.0 International licence

5.2.1. Energy from fossil fuels

- Pilot carbon capture plant: image by Peabody Energy Inc. under the Creative Commons Attribution 3.0 Unported license

5.2.2. Renewable energy

- Rock power: geothermal power simulations: diagram, ESEU; image, Chris King.

6.1. Natural hazards

- Fire and biodiversity: fire image from http://www.earthsciencewa.com.au/mod/resource/view.php?id=1331; toothpick image, Jo Watkins

6.1.1. Eruption

- Blow up your own volcano!: soapsud volcano image, Elizabeth Devon; coke volcano image, Peter Kennett
- See how they run: lava image image no: h57sxr, from www.agiweb.org, courtesy of the USGS; treacle bottle image, Peter Kennett
- Bubble-mania: apparatus image, Chris King; magma fountain image by Jonathan Lewis under the Creative Commons Attribution-Share Alike 2.0 Generic license.
- Volcano variations: images from http://www.wasp.edu.au/mod/resource/view.php?id=408
- Pompei bodies: images from, http://www.wasp.edu.au/mod/resource/view.php?id=413
- Best classroom eruption: erupting cone image, Chris King; champagne image by Михајло Анђелковић under the Creative Commons Attribution-Share Alike 3.0 Unported licence
- The balloon goes up at Krakatoa: Krakatoa painting in the public domain because its copyright has expired; tank images, Lucy Greenwood
- An eruption through the window: bus image and pyroclastic flow image, both by the USGS
- Party time for volcanoes!: Stromboli image by de:Benutzer Wolfgangbeyer and Gralo.under the terms of the GNU Free Documentation License, Version 1.2; party popper image, Peter Kennett
- Take a 'Chance' on the volcano erupting: image and cards, Peter Kennett
- When will it blow?: classroom tiltmeter image, Peter Kennett; Moana Loa tiltmeter image in the public domain from the USGS
- Making a tilt-o-meter and clinometer: images from http://www.wasp.edu.au/mod/resource/view.php?id=415

6.1.2. Earthquake

- Earthquake prediction – when will the earthquake strike?: images, Peter Kennett
- Spaghetti quakes: images, Peter Kennett
- Shaken but not stirred?: straws image, Peter Kennett; Port-au-Prince building, Haiti image by Marcello Casal Jr/AB under the Creative Commons Attribution 2.5 Brazil licence
- Quake shake – will my home collapse?: tray image, Peter Kennett; building image in the public domain by the Earthquake Engineering Research Center Library, University of California at Berkeley
- Jelly/biscuit modelling of how earthquake waves amplify and devastate: model image and graph, Paul Denton
- An earthquake in your classroom: school image by Owngchu1 under the Creative Commons Attribution-Share Alike 4.0 International licence; table developed from: the Wikipedia article on the European Macroseismic Scale at: https://en.wikipedia.org/wiki/European_macroseismic_scale
  and the British Geological Survey synopsis at: http://earthquakes.bgs.ac.uk/education/education/ems synopsis.htm
- Earthquake through the window: tilted building image, from the USGS photographic library at: http://libraryphoto.cr.usgs.gov/ Slide I-5, U.S. Geological Survey Open-File Report 90-547; devastated school image from the American Geological Institute Earth Science World Image Bank at: http://www.earthscienceworld.org/images/ Photo ID: hfyysg, courtesy USGS
- Surviving an earthquake: building debris image from the USGS photographic library at: http://libraryphoto.cr.usgs.gov Slide 1-1 USGS Open File Report 90-547; fallen bookcases image from the USGS photographic library at: http://libraryphoto.cr.usgs.gov Slide VI-1 USGS Open File Report 90-547
- Earthquakes in art: both pieces of art in the public domain

- Earthquake date: images from http://www.wasp.edu.au/mod/resource/view.php?id=420
- Shaky science: images from http://www.wasp.edu.au/mod/resource/view.php?id=422
- Earthquakes or nuclear explosions: table and questions taken from: https://geohubliverpool.org.uk/jesei/earthquakea%20&%20nuclear%20xplos.htm

6.1.3. Tsunami

- Tsunami: what controls the speed of a tsunami wave?: tank image, Peter Kennett; Malé tsunami image in the Maldives released by Sofwathulla Mohamed into the public domain
- Tsunami alert! Run for the hills or stay by the sea?: images, Peter Kennett
- A tsunami through the window – what would you see, what would you feel?: palm tree tsunami image, released into the public domain by David Rydevik, skylark292@gmail.com; tsunami debris image by Ministry of Land, Infrastructure, Transport and Tourism (MLIT) (Japan) under the Creative Commons Attribution 3.0 IGO license
- Japanese wave picture is in the public domain because its copyright has expired
- Tsunami sign modified from image by Maksym Kozlenko under the Creative Commons Attribution-Share Alike 4.0 International licence
- Tsunamis and shorelines: tsunami image from Kata Noi beach by PHG in the public domain; sign image, by Harriv under the terms of the GNU Free Documentation License, Version 1.2
- Tsunami: images from http://www.wasp.edu.au/mod/resource/view.php?id=431

6.1.4. Landslide

- Danger – quicksands!: funnel image, Chris King; apparatus image, Peter Kennett
- Sandcastles and slopes: images, Peter Kennett
- Failing slopes: images, Hazel Clark
- A landslide through the window – what would you see, what would you feel?: Loma Prieta landslide cone image, USGS photo archive at: http://libraryphoto.cr.usgs.gov/ Slide IV - U.S. Geological Survey Open-File Report 90-547; buildings carried by landslide image, American Geological Institute Earth science World Image Bank (http://www.earthscienceworld.org/images/index.html), photo ID: hfyyxn. National Geophysical Data Center, courtesy NGDC
- Landslide engineering: images from https://www.wasp.edu.au/course/view.php?id=51
- Global landslide hazard map compiled by NASA, taken from https://earthobservatory.nasa.gov/images /89937/a-global-view-of-landslide-susceptibility
- El Salvador landslide image in the public domain from USGS

6.2. Environmental issues

- Fieldwork – environmental evaluation: tornado damage image, released into the public domain by Federal Emergency Management Agency employee, Adam Dubrowa; table, Chris King; Loch Lomond image released under the Creative Commons Attribution-Share Alike 2.5 Generic license
- Questions for any rock face 12: What questions about the site potential might be asked?: image, Peter Kennett; table, Chris King

6.2.1. Erosion

- Why does soil get washed away?: images, Peter Kennett
- Dust bowl: blowing sand image, Peter Kennett; dust cloud image NASA 01_theb1365 NOAA Photo Library, Historic NWS Collection
- Left image, Welsh footpath, Pen y Fan via Cwm Llwch: released by Sharon Loxton under the Creative Commons Attribution-Share Alike 2.0 Generic license; right image, Lyke Wake walk, released by Mick Garratt under the Creative Commons Attribution-Share Alike 2.0 Generic license, both part of the Geograph project; eroded house released by BHAVAPRIYA J U under the Creative Commons Attribution-Share Alike 4.0 International license

6.2.2. Drainage changes

- Flood through the window: left image, public domain image by Krittaya; right image by Jenik under GNU Free Documentation license
- Dam burst danger: Artesancocha, Cordillera Blanca, Peru, image © RGSL 2009; model image, Peter Kennett

6.2.5. Mining/quarrying

- The limestone inquiry, 21st Century: image by Dr Peter Tzeferis under the Creative Commons Attribution-Share Alike 4.0 International license
- Quarry through the window: images provided by Tim Parry, Quarry Products Association (http://www.qpa.org/)
- Bulgarian mine: image by Неси Арнауд under the Creative Commons Attribution-Share Alike 4.0 International license
- Questions for any rock face 13: quarry economics: image by Jan Kameníček under the Creative Commons Attribution-Share Alike 3.0 Unported license

6.3. Impact on human history

- Maldives: Maldive island image by Nevit Dilmen under the Creative Commons Attribution-Share Alike 3.0 Unported license; Malé image by Shahee Ilyas under the Creative Commons CC0 1.0 Universal Public Domain Dedication
- Plymouth, Montserrat: left image released by R.P. Hoblitt into public domain by the USGS; right image by Wailunip at English Wikipedia under the Creative Commons Attribution-Share Alike 2.5 Generic license
- Sustainable Development Goals by the United Nations in the public domain in order to disseminate "as widely as possible the ideas (contained) in the United Nations Publications"

7. Earth's system is explored through fieldwork and practical work

- The 'What makes a good educational experience' approach to fieldwork: Canadian image, Chris King; Anglesey image, Pete Loader
- Rock around your school: school image and table, Elizabeth Devon
- Urban fieldwork – the stories from materials, colours, lines and shapes: Nice image, Google Maps™ street view; other images, Chris King, apart from marble decoration by Illustratedjc – Creative Commons Attribution-Share Alike 4.0 International licence and pink granite and volcanic ash images, Peter Kennett
- Fieldwork: Applying 'the present is the key to the past': tree image by RNBC under the Creative Commons Attribution-Share Alike 3.0 Unported license; table, Chris King
- Fieldwork: interactive re-creation: images, Peter Kennett
- View to the future – and the past: arch image by Manfred Heyde under the terms of the GNU Free Documentation Licence, Version 1.2.; mountain image by Ximonic (Simo Räsänen) under the Creative Commons Attribution-Share Alike 3.0 Unported license
- Fieldwork: Now and then – spotting the difference: limestone image by Wilson44691 under the Creative Commons CC0 1.0 Universal Public Domain Dedication; Virgin Islands image by Sean Linehan NOAA Photo Library – Creative Commons Attribution 2.0 Generic licence
- So you want to conserve a geodiversity site?: the Sgurr of Eigg image © Brian Jackson, from: Scotland's Geodiversity Charter, www.scottishgeodiversityforum.org, Staithes Harbour image © Kevin Lowe, from: Geodiversity Charter for England, www.englishgeodiversityforum.org
- Take it or leave it? geoconservation debate: *Stigmaria* image, Peter Kennett; pebble image by Stan Zurek Creative Commons Attribution-Share Alike 3.0 Unported license

7.1. Observation, measurement and recording

- Investigating the Earth: the 'find the Mars™ Bar' challenge: Mars™ Bar image released into the public domain by Matthew Paul Argall; Milky Way™ image released by Evan-Amos under the Creative Commons CC0 1.0 Universal Public Domain Dedication
- Electrical ground probing: diagram and image, ESEU
- Planning for fieldwork: images, Peter Kennett
- Rocks from the big screen: image and diagram, Peter Kennett
- Will my gravestone last?: images, Peter Kennett
- Challenger track map: from the Special Collections of the University of Amsterdam and in the public domain because its copyright has expired
- The 'What could hurt you here?' approach to field safety: image, Duncan Hawley; page, Chris King
- Fieldwork: the view from the site: plateau image by Michaelphillipr under the Creative Commons Attribution-Share Alike 3.0 Unported license; ridge image by Ximonic (Simo Räsänen) under the Creative Commons Attribution-Share Alike 4.0 International licence
- Questions for any rock face 14: recording: field diagram, Quarterly Journal of the Geological Society of London (1850), v6, p131; stratigraphic log, released into the public domain by Rudolf Pohl

7.2. Synthesis of observations

- Recreating the rocks – step by step: shaking image, Elizabeth Devon; outdoor image, Amber Avery
- Cross-cutting dykes: image by Thomas Eliasson of Geological Survey of Sweden under the Creative Commons Attribution 2.0 Generic license
- Fossil sea floor: Fossil seabed (Wenlock limestone); specimen from Dudley, near Birmingham with trilobites (mostly tail and heads), brachiopods (the shells), bryozoa (look like seaweed), sponges and gastropods. Image by Mike Peel under the Creative Commons Attribution-Share Alike 2.0 UK: England & Wales license
- Rock cycle diagram: ESEU
- Dinosaur death – did it die or was it killed?: fossil image, Susannah Lydon; diorama drawing by Brian Regal, reproduced with permission from the artist
- Darwin’s ‘big coral atoll idea’: atoll image in the public domain because it was created by the Image Science & Analysis Laboratory, of the Johnson Space Center, NASA; diagram, Chris King
- What colour was the world in the past?: Uluru image by http://www.scienceimage. csiro.au/pages/about/ under the Creative Commons Attribution 3.0 Unported license; feathered dinosaur drawing by Lucas-Attwell under the Creative Commons Attribution-Share Alike 4.0 International license
- Earth science out of doors: tree image, Adam Slade, www.ituna.net; mud crack image, Peter Kennett

7.3. Investigation and hypothesis-testing

- Innocent until proven guilty: images, Elizabeth Devon