Further guidance

Contents

Speaker's notes for Presentation IP1.1 *Stories that rocks tell*

Slide	Image details	Slide label/caption	Notes/comment
1	The Earth in the Universe – module title	Stories that rocks tells	
2	Hells Mouths Grits at St Tudwal's Peninsula in North Wales.	From desert to ocean – evidence in the rocks	
3	*Top left:* A large fossilised coral in a limestone rock, Kenya. *Bottom right:* Corals in Fiji Reefs.	• Specimens of 160-million-year-old Jurassic limestone, like this one, are found in the UK. • A modern coral reef. The evidence in the specimen shows that parts of the UK were like this in Jurassic times.	Colonial corals like this are only found in tropical and sub-tropical shallow clear seas today. So, by applying the 'principle of uniformitarianism' that 'the present is the key to the past' it is likely that the ancient coral lived in similar warm, shallow, clear sea conditions.
4	*Top left:* Dune-bedded sandstone, De Chelley Sandstone - Permian, Cayon de Chelley, Arizona, USA. *Bottom right:* Dunes at the Sossuvlei Pan, Namib-Naukluft Park, Namibia.	• Sedimentary rocks like these were deposited 230 million years ago (Triassic Period) in the UK. • The evidence in the rock shows that parts of the UK were like this in Triassic times.	When ancient sand dunes were buried and 'fossilised' they preserved the large-scale cross-bedded structure of the sand dunes.
5	*Top left:* Exposed coal seam in old open-cut strip mine, Usibelli Coal Formation - Eocene, Healy Creek, Alaska, USA. *Bottom right:* Mangrove Swamp in Florida, USA.	• Coal seams like this were deposited 300 million years ago in the Late Carboniferous Period in the UK. • A modern tropical swamp. When the trees die, they fall into the swamp and eventually could become coal.	The conditions necessary to form coal are • fast growth (e.g. as in equatorial conditions) • fresh water for tree growth • stagnant water for the trees to fall into (so they don't rot away) • subsidence – so that the organic sediments are preserved Conditions like these are found on tropical deltas today, e.g. the Mekong Delta.

Further guidance

Slide	Image details	Slide label/caption	Notes/comment
6	*Top left:* Oligomictic Conglomerate Puddingstone (rounded pebbles of flint set in a fine grained groundmass) locally known as 'Hertfordshire Puddingstone', UK. *Bottom right:* A mountain stream flowing through stream bed of mostly graded gravel admixed with some cobbles and occasional boulders, Switzerland.	• An ancient gravel of the Tertiary Period deposited in the UK 55 million years ago. • A modern river. The ancient gravel was laid down like this.	Since most modern gravels are deposited in the high-energy conditions of a fast-flowing river or a stormy beach, ancient gravels must have been deposited in similar conditions.
7	*Top left:* Salt pseudomorph cubes in Triassic Mercian mudstone, Nottingham. *Bottom right:* A compression ridge caused by crystallising salt mars the surface of the Bonneville Salt Flats, Utah, USA. The Silver Island Mountains are in the distance.	• A 230-million-year-old Triassic mudstone preserving the shapes of salt crystals • A modern desert lake. The salt deposit crystallized when the lake water evaporated.	Salt crystals form today when desert lakes evaporate. Conditions must have been similar in the past when the salt pseudomorphs (casts of salt crystals) formed.
8	Ripple marks on a vertical bedding plane in Silurian sandstone at Marloes Bay, Pembrokeshire, Wales.	• This 425-million-year-old sandstone has ripple marks preserved on its surface. • What do you think the area was like when the sands were deposited?	Symmetrical ripples like these are only formed by waves. Waves affect lake margins, beaches, shallow seas, and the outer margins of tidal flats. So the area is likely to have been a lake/beach/shallow sea deposit when the ripples were formed.
9	Dinosaur footprints in Namibia, formed when a dinosaur left imprints in mud or sand, which was then baked dry by the Sun and filled with other material. As the overlying material was eroded, the prints were exposed again.	• Dinosaurs walked here 150 million years ago. • Similar footprints are found in the UK. • What does the evidence in the rock show the area was like when the dinosaurs walked here?	The reptiles, early relatives of the dinosaurs, lived on land, so this must have been land. But it was a muddy area, since the footprint is preserved in the mud. So it was likely to have been a lake/river margin, with vegetation nearby for the reptile to feed from.

Further guidance

Slide	Image details	Slide label/caption	Notes/comment
10	*Top left:* Dune-bedded sandstone, De Chelley Sandstone - Permian, Cayon de Chelley, Arizona, USA. *Top right:* Salt pseudomorph cubes in Triassic Mercian mudstone, Nottingham. *Bottom left:* Ripple marks on a vertical bedding plane in Silurian sandstone at Marloes Bay, Pembrokeshire, Wales. *Bottom right:* Dinosaur footprints in Namibia.	Rocks of similar age and type to these can be found in the same area of the UK. What was the area like when they were laid down?	Desert dunes, evaporating lakes with wave ripples, reptiles walking. A desert margin area from Triassic times.
11	Sand dunes in a desert.	How could the UK have had desert conditions 230 million years ago?	The area we now call the UK has moved north over time through plate tectonic movement. During Triassic times, it had the same latitude as the present-day Sahara.
12	Coral reef table.	During Jurassic times, the UK was at the latitude of Florida. Corals flourished in the shallow seas off the coast whilst swamps formed on the deltas in coastal areas.	How could the UK have had tropical shallow sea conditions 160 million years ago?
13	A climbers' camp on Kahiltna Glacier, Mount McKinley, Denali National Park, Alaska, USA.	How could southern Africa have had freezing conditions 350 million years ago?	The area we now call Africa was near the south pole during Carboniferous times, and covered by an ice cap, as Antarctica is today.

Speaker's notes for Presentation IP1.3 *Wegener's clues*

Slide	Image details	Slide label/caption	Notes/comment
1	The Earth in the Universe – module title	Wegener's clues	
2	A. Wegener, 'Reconstruction of the map of the world according to drift theory for three epochs', The Origin of Continents and Oceans, translated by J. Biram (Dover, New York, 1966; translation of the 1962 printing of the fourth revised edition of Die Entsehung der Kontinente und Ozeane, Vieweg, 1929),	Late Carboniferous - around 300 million years ago Eocene - around 40 million years ago Quaternary - around 1 million years ago	Wegener was wounded by a bullet in the neck in 1914 during the First World War and was never fit for active service again. The first edition of his book The Origin of Continents and Oceans was published in German in 1915. Further editions, each a complete revision, were published in 1920, 1922, and 1929. The first English translation was from the third edition in 1924. The material in these slides is from the English translation of the fourth edition. Wegener died in 1930 while leading an expedition to the Greenland icecap. **Comment** The jigsaw fit. Did the continents really fit together once?
3	A. Wegener, 'Same as Fig. 4, in different projection', *The Origin of Continents and Oceans*, translated by J. Biram (Dover, New York, 1966)	Wegener's map of the Earth 40 million years ago.	The first words of Wegener's book (p. 1) are: 'The background to this book may not wholly be without interest. The first concept of continental drift came to me as far back as 1910, when considering the map of the world, under the direct impression produced by the congruence of the coastlines on either side of the Atlantic. At first I didn't pay attention to the idea because I regarded it as improbable.' **Comment** The 'picture on the jigsaw'. How does the 'picture' given by the rocks help?

Further guidance

Slide	Image details	Slide label/caption	Notes/comment
4	A. Wegener, ‘Former relative position of South America and Africa, according to du Toit’, *The Origin of Continents and Oceans*, translated by J. Biram (Dover, New York, 1966)	The geological match of South America and Africa shown by du Toit, from Wegener’s book.	Wegener wrote (p. 72): ‘I must admit that du Toit’s book made an extraordinary impression on me, since up till then, I had hardly dared to expect so close a geological correspondence between the two continents.’ **Comment** Matching fossils – and living species. If they couldn’t walk or float across – how did they get there?
5	A. Wegener, ‘More precise illustration of garden-snail distribution, according to Ökland’, *The Origin of Continents and Oceans*, translated by J. Biram (Dover, New York, 1966)	Shaded areas show garden snail distribution today, according to Ökland, from Wegener’s book.	Wegener wrote (p. 98): ‘Where ocean basins are involved, it is not a question of whether drift theory or the theory of sunken continents is to be preferred, because the latter just does not come into the picture…For the foregoing reasons, we are justified in counting as favourable all biological facts which imply that at one time unobstructed land connections lay across today’s oceans. The number of such facts is legion.’ He goes on to cite many examples including the fossil plant *Glossopteris,* the fossil reptile *Mesosaurus,* and the modern garden snail. **Comment** Climate clues. How can we make these clues fit together?

Further guidance

Slide	Image details	Slide label/caption	Notes/comment
6	A. Wegener, 'Traces of the Permo-Carbiniferous inland glaciation on present-day continents. The cross indicates the position of the South Pole most suitable for the explanation; the broad curve is the associated equator.', *The Origin of Continents and Oceans*, translated by J. Biram (Dover, New York, 1966).	Wegener's map of glaciated areas 300 million years ago.	Wegener wrote (p. 131): '…the Permo-Carboniferous glaciation of the southern continents is a genuine inland-ice phenomenon…Even if we place the south pole at the most favourable point…then inland ice traces…lie at a geographical latitude of not quite 10o '. He goes on to discuss the distribution of Carboniferous coal deposits indicating the position of the former equator and the Permo-Carboniferous red beds, indicating the distributions of sub-tropical desert conditions.

Speaker's notes for Presentation IP1.8 *Geohazards that might affect us*

Slide	Image details	Slide label/caption	Notes/comment
1	The Earth in the Universe – module title	Geohazards that might affect us	
2	Students studying in a Year 7 Maths class at Sheldon Comprehensive in Wiltshire.	**What Earth processes can affect us?** Geohazards that might affect us today are: • landslide • flood • the effects of a volcanic eruption • earthquake • tsunami	These geohazards could all affect your school or home in the UK. Landslides are most likely in areas of steep slope, e.g. coastal areas, but subsidence collapse can happen even in flat areas. Tsunamis only affect coastal regions.
3	Landslide in a mountain range near Zermatt, Switzerland.	**Landslide** Landslides are triggered where: • slopes are steep • rocks are weak or fractured • erosion undermines a slope • water builds up in the ground • earthquakes strike • human activities are poorly planned	Many landslides happen in the winter when the ground is more waterlogged. Landslide could be simulated in a jam-jar at this point – either as a teacher demonstration or as a brief pupil activity in groups.
4	A sign warning against the danger posed by subsidence caused by a disused tin mine and mine shafts, Cornwall.	**Collapse** But, even on flat ground: • Foundations on weak rock can subside. • Old mine workings can collapse. • Soluble rocks below ground can dissolve.	When buying a house, the 'searches' should discover if it is over old mine workings, on areas subject to subsidence or on reclaimed land.

Further guidance

Slide	Image details	Slide label/caption	Notes/comment
5	Flooded buildings in York. The River Ouse flooded York in November 2000 following prolonged heavy rainfall. A rise of over 5 metres in water level exceeded the record of 1625.	**Flood** Floods occur: • in low-lying areas • after a storm upstream • after many wet days upstream • if snow melts quickly • when rivers overflow • on stormy coasts at high tide • if dams burst	Buildings constructed on floodplains are likely to flood at some time in the future, even if flood defences effectively deal with most flood events. Erosion and deposition could be demonstrated here, using guttering.
6	Santa Barbara residents survey the damage caused by a flood.	**Flood mayhem** It's not just the amount of water in a flood: • There are thick mud and silt deposits. • Sewers overflow. • Large objects are swept away: bridges, houses, embankments, cars. • There is electrical danger.	
7	Aerial view of a huge ash plume erupting from the summit of the Sakurajima Volcano, Japan.	**Eruption afar** There are no active volcanoes in the UK, but a major eruption elsewhere may cause: • a volcanic winter – from ash and sulphur dioxide in the atmosphere • drought over great regions • widespread crop failure in summer, bitter cold in winter • the whole Earth cooled • fantastic sunsets	It may well be thought that volcanic eruptions could not affect the UK, since the nearest plate margins with associated volcanoes are in Iceland and the Mediterranean. However, the Laki eruption in Iceland in 1783 caused a dry fog to hang over much of Europe and North America for months causing crop failure and a bitterly cold winter.

Further guidance

Slide	Image details	Slide label/caption	Notes/comment
8	The eruption of Mount Vesuvius, Italy.	**Eruption on your doorstep** Catastrophic effects include: • blast: 30km+ - everything is destroyed • glowing cloud - a red-hot current of ash - travelling with speeds of 100 km/h+ • lahar - waterlogged volcanic ash flooding down valleys • tsunami - a great wave in coastal areas • lava flow - rarely kills because you can get out of the way	Dangers from an eruption on your doorstep are much more immediate, however, many people are surprised that lava causes very few deaths in comparison with other volcanic phenomena.
9	Damage caused by a falling chimney in Clarendon Street, Bloxwich after the 'Dudley earthquake' on 23 September 2002.	**Earthquakes in the UK** • They are not big enough to make surface waves, so little damage occurs. • We can feel seismic waves. • Recent UK earthquakes: www.quakes.bgs.ac.uk/recent_events/recent_events.html • Earthquakes are plotted from eyewitness accounts. • If you feel an earthquake, send in your evidence: www.quakes.bgs.ac.uk/questionnaire/EqQuestIntroB.html	Death or injury from UK earthquakes is minimal.

Further guidance

Slide	Image details	Slide label/caption	Notes/comment
10	Buildings demolished by an earthquake in Kobe, Japan, in 1995.	**Earthquake** In a catastrophic earthquake: • The ground rises and falls in waves. • There is total destruction of non-flexible structures. • People are killed by falling buildings – outside is safest. • There is risk from falling glass and fire storms. • There may be a tsunami – a huge wave in coastal areas. • Many die afterwards from disease. • The most recent big earthquake: earthquake.usgs.gov/eqcenter/recenteqsww/index.php?old=world.html	
11	*Top:* Artwork of a tsunami destroying a small harbour. *Bottom:* Small fishing boat is washed aground on a breakwater as a roof sits on what was once a wharf of a port on Okushiri Island, Japan, on 14 July 1993, one day after a major earthquake shook the island and a tsunami flattened the seaside area.	**Tsunami** These huge waves produced by volcanic eruptions, earthquakes, or submarine landslides: • can form waves over 40 m high • can reach speeds of 1000 km/h • can travel 10 000 km across oceans, killing thousands in coastal areas • can trick you, because water first draws back from the coast – and then thunders back in	A tsunami triggered by a submarine slide in the North Atlantic near Iceland nearly 8000 years ago appears to have produced waves 10 metres high which devastated coastal areas of Norway and of eastern Scotland and England.
12	Squad car with siren blaring.	**Worry? – Us?** • Major eruptions and earthquakes affect only the active zones of the Earth. • They don't happen in the Uk. • But – could a geohazard happen here? • What might its effects be?	

Further guidance

Speaker's notes for Presentation IP1.17 *The Sun and other stars*

Slide	Image details	Slide label/caption	Notes/comment
1	The Earth in the Universe – module title	The Sun and other stars	
2	Sun setting over St Michael's Mount, Cornwall. (Adam Woolfitt/Science Photo Library)	-	The Sun is our star; we see it glowing steadily in the sky. It's difficult to relate it to the stars we see at night.
3	Solar loop prominence, recorded by the Skylab space station on 19 December 1973. (NASA/Science Photo Library)	The speckled Sun	This photo of the Sun Sun was taken by astronauts aboard the Skylab spacecraft in 1973. To see details, you must use filters that reduce the intensity of the light. A giant 'solar flare' like this lasts for several hours. The flare of hot gas is over 500 000 km long.

Further guidance

Slide	Image details	Slide label/caption	Notes/comment
4	photo of sunspots	Using a computer model, scientists can now predict the appearance of sunspots years into the future.	Sunspots are dark areas on the surface of the Sun, associated with intense magnetic storms in the Sun's hot atmosphere. Although they are blindingly bright, at temperatures of roughly 4000 - 4500 K, the contrast with the surrounding material at some 5700 K leaves them clearly visible as dark spots. When intense magnetic fields at the Sun's surface 'snap', they throw huge amounts of energy and matter into Space as solar flares. The science of sunspots is still an area of active research. In 2006 scientists at The National Center for Atmospheric Research, USA announced that they had developed a computer model of solar dynamics. They built their model using data gathered during previous solar cycles, combined with helioseismology - a technique for tracking pressure waves inside the Sun. Using this model, they can now forecast sunspot activity for the next 20 years.
5	Orion constellation. (John Chumack/Science Photo Library)	Distant Suns	These stars are similar to the Sun, but much further away. They are also a long way from each other, but from where we look they make a pattern (or constellation). This is the constellation Orion, visible in the northern hemisphere during the winter months.
6	Hubble Space telescope	The Hubble Space telescope	The Hubble Space Telescope is in orbit high above the Earth’s atmosphere.

Further guidance

Slide	Image details	Slide label/caption	Notes/comment
7	Starbirth in the Eagle Nebula, photographed by the Hubble Space Telescope. (NASA/Zooid Pictures)	Starbirth	New stars are forming from huge clouds of gas in this part of Orion. Look for the hot, bright stars lighting up the dust clouds.
8	'Time lapse' picture of the evolution of a low-mass star. (David Melzer/National Geographic Image Collection)	The life-cycle of a star	This shows the stages in the life of a star like a Sun. The interval between images of this star is a few million years. The Sun will spend most of its lifetime as a yellow dwarf. It has enough fuel to last for thousands of millions more years.

P1 The Earth in the Universe – Foundation Workbook answers

1	**a**	From the inside: core – solid, core – liquid, mantle, crust
	b	Planet, solar system, galaxy, Universe
	c	Universe, Sun, Earth
	d	Milky Way, Sun, Earth
	e	The Solar System was formed about 5000 million years ago, when a great swirl of dust and gas came together over a period of a few 100 million years. Most of that material became the Sun. Gravity pulled the remains into clumps, which joined together to become the planets.
	f	Known: B, C, D, E Unknown: A
2	**a**	• Data: new mountains, erosion; Rivers carry sediment…(whole sentence); In some places, layers of sedimentary rocks are tilted and folded. • Explanations: erosion would wear the continents flat; Sediments are compressed…(whole sentence).
	b	For example: There are six sedimentary layers, each containing typical fossils. The layers have not been folded, so the deeper the layer the older it is. A rock has fallen from the cliff; it contains a fossil showing that it came from the second layer from the top. (Scientists would be able to date the rocks by measuring their radioactivity.)
	c	One example, e.g.: Magnetic data from rocks either side of oceanic ridges can show a pattern that provides evidence of seafloor spreading. Sedimentary rock, once at the seafloor, is found at the tops of very high mountains. Metamorphic rock shows recycling of sedimentary rock, heated deep inside the Earth's crust. Folding of sedimentary layers indicates that the Earth's surface has been 'wrinkled', by enormous forces. Some craters have been eroded so much that they are invisible from the Earth's surface.
3	**a**	From left to right: South, Africa, India
	b	Missing words: The Origins of Continents and Oceans, peer review
	c	1, 2, 4, 6, 5, 3
	d	Missing words: data, explanation, measure, simpler, geologist, big
	e	The correct ending is: accounts for all observations
4	**a**	Convection currents in the solid mantle push oceanic plate outwards from an oceanic ridge, uniformly on each side, at a rate of about 10 cm a year. Some of the mantle melts to form magma, where it erupts through the seafloor. The magma cools here and becomes new rock, forming a ridge.

Further guidance

	b	• Correct ending: the direction of magnetism on the rocky seafloor • Correct explanation: hot magma erupts from oceanic ridges, equally on both sides of the ridge; as the magma cools to become solid rock, it records the direction of the Earth's magnetic field
5	**a**	Missing words: tectonic plates, convection currents, mantle, radioactive decay
	b	M – mountain chains – best examples are along the western edges of North and South America; also where the Africa plate meets the Indo-Australian plate (e.g. Himalayas) R – oceanic ridges – where plates are moving apart in the oceans; best example is the mid-Atlantic ridge C – oceanic crust – a good example is the Pacific plate E – earthquakes – where plates are moving against each other, e.g. western edge of the Americas, western edge of Asia, where Africa and Eurasian plates meet V – volcanoes – where plates are moving towards each other, e.g. Mt St Helens (west coast of North America), Vesuvius/Etna (Italian coast), Krakatoa (Indonesia)
	c	Missing words: solid, flow, atoms, radioactive, decay, hot, spreading, oceanic
	d	M M E
6	**a**	Clockwise from top left: volcano; coastal areas destroyed; land, roads, and buildings buried; earthquake
	b	To minimize harm to people by being able to give early warning of imminent danger.
	c	1 Educate people, so they will know what to do 2 Enforce building regulations, which can reduce the chance of buildings collapsing 3 Prepare emergency plans, so trained staff can then respond quickly
7	**a**	Correctly labelled diagram
	b	• A comet is a rocky lump, held together by frozen gases and water, that orbits the Sun in a path which brings it close to the Sun sometimes, but has it beyond Pluto much of the time. • An asteroid is rocky lump much smaller than a planet, generally orbiting the Sun between the orbits of Mars and Jupiter.
	c	Missing words: Arizona, volcano, iron, meteor, support, pressures, reverse order, violent impact
8	**a**	A mass extinction is when many species of plant and animal die out at the same time.
	b	

A E	F
B C	D

Further guidance

	c	• An asteroid strike: the ground and asteroid were partly vaporized, making huge amounts of dust and poisonous gases that were carried round the world by winds, blocking out sunlight. This cooled the Earth's surface and prevented photosynthesis, killing plants and so starving to death animals which depended on them. • Massive eruptions of lava: making huge amounts of dust and poisonous gases that were carried round the world by winds, blocking out sunlight. This cooled the Earth's surface and prevented photosynthesis, killing plants and so starving to death animals starved which depended on them.
	d	You cannot wind the clock backwards and watch what happened. The best that can be done is to use available evidence to create a likely explanation.
9	**a**	…their light reaches Earth
	b	Missing words: spectrum, more, blue and green, less, red and yellow, lines, elements, fusion, hydrogen
	c	O E E E E
	d	• Evidence: ticks in the 1st, 2nd and 4th boxes • Correct conclusions: ticks in all the boxes
10	**a**	• Sun: 8 light minutes • Proxima Centauri: 4.2 light years
	b	By looking at distant objects, they look back in time. The most distant galaxies are seen as they were over 10 000 million years ago.
	c	1 measuring the amount of parallax 2 comparing the brightness of (similar) stars
	d	• Parallax: diagram as on textbook page 74, with annotation saying that nearer star shows a larger parallax (compare angles). • Brightness: diagram showing Earth and two identical stars, at different distances from Earth, with annotation saying that nearer star looks brighter.
	e	Example: There are millions and millions of planets in the Universe. Many stars have planets. Chances are that some stars have planets with the right conditions for life (temperature, water, etc.), where some form of life has evolved.
	f	Example: Life occurs because of a very complex combination of circumstances and developments – the chances of these being repeated are remote. SETI has so far (since 1992) detected no sign of intelligent life elsewhere.
11	**a**	Streetlights and car parks…direct light upwards into the night sky. Upward-travelling light scatters off particles in the atmosphere to…make the night sky glow brightly. Faint, deep sky objects such as galaxies and nebula…become impossible to see.
	b	Mountaintops, far away from cities
	c	A huge number of distant galaxies, typical of a very small part of the night sky
	d	Missing words: faster, expanding, explanation, 14 000 million, big bang

Further guidance

	e	Missing words: peer review
	f	Example: Find out what it is that she has observed, and how she observed it. More important, find out if her ideas were published in a place where other scientists can read and critically analyse them. What do other scientists say about her work? What is her track record as a scientist? (Previous publications, reputation as a scientist in this area of work, etc.)
	g	Tick in the 1st, 2nd and 4th boxes
	h	Scientists can't agree on the evidence (whether the rate of expansion of the Universe is increasing) or how to explain it. Also, they can cannot estimate its mass accurately and so cannot estimate the gravitational force slowing its expansion.

P1 The Earth in the Universe – Higher Workbook answers

1	a	From the inside: core – solid, core – liquid, mantle, crust
	b	Planet, solar system, galaxy, Universe
	c	Universe, Sun, Earth
	d	Milky Way, Sun, Earth
	e	The Solar System was formed about 5000 million years ago, when a great swirl of dust and gas came together over a period of a few 100 million years. Most of that material became the Sun. Gravity pulled the remains into clumps, which joined together to become the planets.
	f	Known: B, C, D, E Unknown: A
2	a	• Data: new mountains, erosion; Rivers carry sediment…(whole sentence); In some places, layers of sedimentary rocks are tilted and folded. • Explanations: erosion would wear the continents flat; Sediments are compressed…(whole sentence).
	b	For example: There are six sedimentary layers, each containing typical fossils. The layers have not been folded, so the deeper the layer the older it is. A rock has fallen from the cliff; it contains a fossil showing that it came from the second layer from the top. (Scientists would be able to date the rocks by measuring their radioactivity.)
	c	Two examples, e.g.: Magnetic data from rocks either side of oceanic ridges can show a pattern that provides evidence of seafloor spreading. Sedimentary rock, once at the seafloor, is found at the tops of very high mountains. Metamorphic rock shows recycling of sedimentary rock, heated deep inside the Earth's crust. Folding of sedimentary layers indicates that the Earth's surface has been 'wrinkled', by enormous forces. Some craters have been eroded so much that they are invisible from the Earth's surface.
3	a	From left to right: South, Africa, India
	b	Missing words: The Origins of Continents and Oceans, peer review
	c	1, 2, 4, 6, 5, 3
	d	Missing words: data, explanation, measure, simpler, geologist, big
	e	Ticks for: accounts for all observations; links things that were previously thought unrelated; leads to predictions that are later confirmed
4	a	Convection currents in the solid mantle push oceanic plate outwards from an oceanic ridge, uniformly on each side, at a rate of about 10 cm a year. Some of the mantle melts to form magma, where it erupts through the seafloor. The magma cools here and becomes new rock, forming a ridge.

Further guidance

	b	**i** Like zebra stripes, symmetrical on either side of the ridge. **ii** As hot magma rises in the gap between plates, it spills out to both sides and solidifies, recording the Earth's magnetic field at that time.
5	**a**	Missing words: tectonic plates, convection currents, mantle, radioactive decay
	b	M – mountain chains – best examples are along the western edges of North and South America; also where the Africa plate meets the Indo-Australian plate (e.g. Himalayas) R – oceanic ridges – where plates are moving apart in the oceans; best example is the mid-Atlantic ridge C – oceanic crust – a good example is the Pacific plate E – earthquakes – where plates are moving against each other, e.g. western edge of the Americas, western edge of Asia, where Africa and Eurasian plates meet V – volcanoes – where plates are moving towards each other, e.g. Mt St Helens (west coast of North America), Vesuvius/Etna (Italian coast), Krakatoa (Indonesia)
	c	Missing words: solid, flow, atoms, radioactive, decay, hot, spreading, oceanic
	d	M M E
	e	Clockwise from top: lava flows, sediment, oceanic plate, rock carried into subduction zone
	f	• Earthquakes: Plates push and rub against each other. Forces build up along these fault lines. When chunks of rock along the edge of a fault break, the plates move suddenly, causing the ground to shake. • Volcanoes: Heating of an oceanic plate, as it moves under continental plate at a destructive margin, melts rock and causes vents to appear, through which lava escapes. • Mountain building: Plates push against each other, forcing the crust to buckle and fold. • Parts of the rock cycle: One plate moving under another takes with it sedimentary rock, which melts (igneous rock) and changes (metamorphic rock). Folding and faulting causes the rock to rise to the Earth's surface, where it is worn and washed away again (sedimentary rock).
6	**a**	Clockwise from top left: volcano; coastal areas destroyed; land, roads, and buildings buried; earthquake
	b	To minimize harm to people by being able to give early warning of imminent danger.
	c	1 Educate people, so they will know what to do 2 Organize public drills, so everyone can practise what to do. 3 Enforce building regulations, which can reduce the chance of buildings collapsing 4 Prepare emergency plans, so trained staff can then respond quickly
7	**a**	Correctly labelled diagram
	b	• A comet is a rocky lump, held together by frozen gases and water, that orbits the Sun. • An asteroid is dwarf rocky planet, generally orbiting the Sun between the orbits of Mars and Jupiter. • A moon is a natural rocky satellite that orbits a planet. • Typically, a moon is larger than an asteroid, which is larger than a comet.

Further guidance

	c	Radioactive dating of rock samples from Earth, the Moon, Mars, and meteorites show that none is older than 5000 million years.
	d	Missing words: Arizona, volcano, iron, meteor, support, pressures, reverse order, violent impact
8	**a**	A mass extinction is when many species of plant and animal die out at the same time.
	b	<table><tr><td>A E</td><td>F</td></tr><tr><td>B C</td><td>D</td></tr></table>
	c	• An asteroid strike: the ground and asteroid were partly vaporized, making huge amounts of dust and poisonous gases that were carried round the world by winds, blocking out sunlight. This cooled the Earth's surface and prevented photosynthesis, killing plants and so starving to death animals which depended on them. • Massive eruptions of lava: making huge amounts of dust and poisonous gases that were carried round the world by winds, blocking out sunlight. This cooled the Earth's surface and prevented photosynthesis, killing plants and so starving to death animals starved which depended on them.
	d	You cannot wind the clock backwards and watch what happened. The best that can be done is to use available evidence to create a likely explanation.
9	**a**	…their light reaches Earth
	b	A C B E D
10	**a**	Missing number: 300 000 • Sun: 8 light minutes • Proxima Centauri: 4.2 light years • Arcturus: 36.7 light years
	b	The more distant an object is, the older it is. Because light travels at a finite speed, looking out into space is looking back in time.
	c	A light year is the distance travelled by light in one year.
	d	1 measuring the amount of parallax 2 comparing the brightness of (similar) stars
	e	• Parallax method: It is very difficult to measure very small angles. • Brightness method: it is difficult to be sure that distant stars are identical in the amount of light they give out.
	f	Example: There are millions and millions of planets in the Universe. Many stars have planets. Chances are that some stars have planets with the right conditions for life (temperature, water, etc.), where some form of life has evolved.
	g	Example: Life occurs because of a very complex combination of circumstances and developments – the chances of these being repeated are remote. SETI has so far (since 1992) detected no sign of intelligent life elsewhere.

Further guidance

11	**a**	Streetlights and car parks…direct light upwards into the night sky. Upward-travelling light scatters off particles in the atmosphere to…make the night sky glow brightly. Faint, deep sky objects such as galaxies and nebula…become impossible to see.
	b	Outside the Milky Way / within the Milky Way
	c	Hubble's telescope enabled him to make a better measurement of the distance to Andromeda.
	d	From the top: galaxies, Milky Way, light years, Sun, stars
12	**a**	• Missing words: red, faster, expanding • Caption, e.g.: Imagine yourself on the surface of a very big balloon looking along a line of galaxies at 1-metre intervals. If the balloon is expanding, every metre is growing larger. If the distance between you and the first galaxy moves by half a metre, then the distance between you and the second galaxy will appear to move by a metre, and the third galaxy will appear to move away by one and a half metres. The further away a galaxy, the faster it will appear to move. • Missing words: explanation, 13 7000 million, big bang
	b	Any 3 of following: Expansion of the Universe Discovery of cosmic microwave backed radiation, an afterglow of the big bang Explains why the early Universe was about 24% helium by mass Oldest stars are younger than the calculated age of the Universe
	c	Peer review is when experts review a scientific paper before it is published, to make sure that what is published is correct, and has something new and useful to say.
	d	Through peer review, scientists describe their ideas in detail. Any data/observations will be severely challenged and may be tested. Those that survive this process are more likely to be reliable.
	e	Scientists can't agree on the evidence (whether the rate of expansion of the Universe is increasing) or how to explain it. Also, they can cannot estimate its mass accurately and so cannot estimate the gravitational force slowing its expansion.
	f	Hawking suffers from motor neuron disease. He has been in a wheelchair most of his adult life, dependent on others for his basic physical needs. What does work is his remarkable mind: he has been able study the Universe and theorise about it, and is one of the world's leading cosmologists.

Ideas about Creation

Background notes for teachers

Beliefs about God – or the absence of God – underlie any discussions of origins. They might arise at two points in this module: the discussion of fossils and the age of the Earth; the 'big bang' theory of the originals of the Universe. Your students may hold a variety of religious views so the issue is likely to be controversial. Are scientific accounts the only (or the best) accounts? Can science explain everything? The Students' Book is deliberately brief on these matters but does allow for explanation of creation from religious perspectives.

We suggest that you let students air their views, but at the same time prevent this becoming a major distraction from the module content. There are two possible approaches. You could either wait sensitively until the issue arises, or deliberately bring it out at the first opportunity. There is no need for a conflict between science and religion. But be prepared for extreme views, held by a small minority of fundamentalists (for instance, fossils are the work of the Devil, or were created by God to test the faith of believeres).

Try not to let the discussion broaden to encompass the theory of evolution by natural selection. This will be explored fully in module C7 *Life on Earth*.

Some students (and their families) may be athiests, who deny the existence of God; some agnostics, who are not sure; some believers with different faiths, each with their own account of a deity. It is important that respect is shown towards every person's beliefs.

Discussion could draw out the following:

- the creation stories of more than one religion
- the viewpoint of people who find these scientific explanations compatible with their religious belief (perhaps a God who created physical laws but does not intervene in the development of the Universe or in human affairs)
- the viewpoint of people who find these scientific explanations incompatible with their religious belief (believing in a God who actively guides everything and everyone)
- that science answers 'how' question; religion answers 'why' questions, such as 'why is there a Universe?'
- that the formation of the Universe, Sun, or Earth refers to a physical *process*; Creation refers to the *act* of a Creator
- that scientific theory cannot confirm or disconfirm the existence of a Creator; faith cannot be tested by evidence
- a few scientists (e.g. Richard Dawkins or Peter Atkins) are radical materialists, who believe there is no *need* for a God
- some people are inclined to a 'God of the gaps' – one whose actions explain what science cannot: this view leads to a God who shrinks, as the scope of phenomena explained by science grows; these people feel threatened by the advance of science.

Most importantly, publicly recognize that there are *types* of explanation other than scientific ones.

References

Michael Poole, *Beliefs and Values in Science Education* (Open University Press, 1995)

Sedimentation and folding

Sedimentation rates very enormously. Early attemps to find a minimum age for the Earth, based on assumed sedimentation rates, ranged from 3 million years (Winchell 1883) to 1526 million years (Haughton 1871).

It is estimated that on the deep ocean floor, remote from underwater currents, sediment accumulates as slowly as 1mm per thousand years. However, where an underwater current sweeps material off the continental shelf, a metre or more of sediment may be deposited in a matter of minutes. The existence of such currents was first discovered by timing the sequential breaking of transatlantic cables by a current flowing at more than 70 km/h, after an earthquake in 1929 off the Grand Banks of Newfoundland. Subsequent exploration of the sea floor revealed several thick sets of sediment deposited by these currents.

Folding: dating of the rocks of fold mountain ranges, such as the Alps, shows that the ranges took millions of years to form, and indeed are still forming. Folding usually takes place deep underground, where the rocks are in a more plastic state than at the surface, but there are occasional examples where the effects of recent folding can actually be seen. For example, there is a canal in the Middle East, built by the Babylonians, which presumably held water along the whole of its length. Now, over 2500 years later, the central parts are some 10 m higher than the ends, indicating that folding has been taking place in the area.

In the Alps, many strata have been compressed so much that they have at first been folded, and then fractured, creating a low-angle fault. The strata above the fault have then continued travelling for many kilometres. Considerations of mineral stability of the rocks along one such fault (the Glarus Thrust) have led to the conclusion that it moved at an average rate of 3.5 mm pe ryear.

Then Demonstration experiment SEDIMENTATION.

Further guidance

Remanent magnetism found in rocks

In practice, the magnetisation of a sequence of real lavas is measured, using a delicate magnetometer. The age of each lava is determined by radiometric means such as a potassium-40 to argon-40 decay series. This enables periods of normal and reversed magnetisation to be dated.

By definition, the magnetisation of a rock is regarded as 'normal' when it is in the same direction as the Earth's field of today, and 'reversed' when it is compeletely opposite.

The main value of our knowledge of reversals in the magnetic field comes from its application to the rocks underlying the ocean floors. These are predominantly iron-rich igneous rocks, which readily acquire a permanent magnetisation as they cool. Where they are normally magnetised, they add a few per cent to the Earth's field: where magnetisation is reversed, the values are correspondingly lower than the Earth's field. A magnetometer towed deep behind a ship above these rocks will record alternately high and low magnetic field values. These are then correlated with theoretical figures, calculated from the land-based knowlege of reversals and their dates as described above. This enables dates to be assigned to sections of the ocean floor, which are virtually inaccessible to most Earth scientists.

It seems that the Earth's magnetic poles have bene in the general vicinity of the geographic poles for most of geological time, and have 'wandered' very little, in contrast to the belief of some scientists in the 1950s and 1960s when the pioneer work was being done.

Plate tectonics (1)

Most students will have no difficulty understanding the following information, which contributed to the theory of plate tectonics:

- The idea that convection currents in the solid mantle are a driving force for 'continental drift'
- oceanic ridges and deep ocean trenches (ridges rise 4 km or so off the deep ocean floor and trenches plunge to 11 km below sea level)
- The oceanic crust is thin (about 6 km) relative to the continental crust (which averages 35 km in thickness)
- The top of the oceanic crust is made of only one material – basalt.
- The oceanic crust is 'young' in terms of geological time (the oldest parts are usually no more than 200 million years old) compared with continents, parts of which can be thousands of millions of years old.
- symmetrical 'magnetic stripes' at oceanic ridges
- the distributions of earthquakes and volcanoes that outline the plate margins
- Modern global positioning systems (GPS) show that the plates are moving, through observations made at intervals.

There is additional evidence supporting the theory of plate tectonics, which students are certainly not expected to know. For example:

- Oceanic ridges (constructive margins) have rift valleys at their centres (down to 2 km deep) – produced as they are pulled apart, allowing the central block of rock to slide down on steep faults either side. This is evidence for tension as the plate are moved apart.
- The composition of (iron-rich) volcanic magmas at constructive plate margins indicates partial melting of the mantle.
- At trenches (destructive margins) there are earthquake zones sloping downwards from the trench, indicating where a plate is being carried down (subducted) – first recognised by Benioff, and now called the Benioff zone. The angle of subduction can vary from a few degrees to nearly 90 degrees.
- The composition of some volcanic magmas in continental areas (silica-rich) indicates partial melting of the subducting plate and the continental crust above.
- Plate margins, particularly constructive margins, are offset by enormous faults called transform faults, which offset ridges by tens of kilometres. These are conservative, or sliding margins and the most famous one on land is the San Andreas Fault through California, USA.
- The remanent magnetisation retained by some rocks records the positions of the north and south magnetic poles (which have always been near the north and south geographic poles) backwards into geological time. A plot of these over the past 600 million years plus shows that the poles appear to have 'wandered'. This 'polar wandering' is now attributed to movement of the continents, rather than the poles. When 'polar wandering' curves from different continents are compared, they show how continents moved together when they were joined, but moved separately after they split up.
- Ocean floor sediments are very thin over oceanic ridges, but generally thicken steadily away from the ridges, reflecting the increased time available for sedimentation to occur in areas away from the ridges.
- Undersea volcanoes that were once at the surface near oceanic ridges become steadily deeper and older away from the ridges – as they are carried away and the oceanic plate cools, becomes denser, and sinks.
- In some parts of the world, plates are carried over areas where 'plumes' of magma have been rising through the mantle in the same place for millions of years (areas called 'hot spots'). Where this has happened near Hawaii, a line of volcanic islands has been produced more than 4000 km long. The youngest volcano is active on Hawaii today. Towards the north and west, the volcanoes become steadily older and deeper as they are carried away from teh hot spot and the oceanic plate cools and sinks.
- Modern global positioning systems (GPS) show that the plates are moving, through observations made at intervals. Similar information was previously given by laser ranging technology. The plates are moving at rates of centimetres per year – faster in some places than others.

- Earthquake (seismic) wave evidence shows that the plates are solid, rigid sheets around 100 km thick (a layer called the lithosphere).

Further guidance

The mantle beneath, although solid, is able to flow through convection – the part of the mantle directly below the lithosphere (the approximately 150 km-thick asthenosphere) is 1–10% molten, allowing it to flow more easily; however, the solid mantle beneath also flows. The 100 km-thick rafts of lithosphere are much thicker and cover much larger areas than Wegener ever imagined when he was proposing drifiting continents.

Plate tectonics (2)

Like all good revolutionary scientific theories, plate tectonics explained a great deal of what puzzled geologists at the time (that is, in the 1960s). Since then, it has provided the basis for the prediction of, and explanation for, many other geological phenomena. Nevertheless, as with other scientific theories, it has posed new questions, which are still being investigated and discussed.

Explaining existing evidence

At first, plate tectonic theory explained the following evidence, already in existence, most of which came from the continents:

- the match of the continental margins (at or near the edges of the continental shelves)
- the amtch of the geology (The rocks and their structures formed before the continental splitting matched well, but the rocks formed later showed significant differences)
- the match of the distributions of fossils
- the patterns of ancient climatic changes recorded in rock sequences
- continental topography (large plateau areas – shields – bounded by mountains in chains)
- mountains made of intensely deformed sedimentary rocks of both shallow- and deep-sea origin
- deformation on enormous scales (e.g. faulting and folding that had moved materials for tens of kilometres)
- regional metamorphism and igneous intrusion
- the linear distribution of most groups of volcanoes
- the concentration of the most frequency earthquakes in linear belts, and their rarity elsewhere
- the distribution of shallow, intermediate and deep focus earthquakes.
- apparant polar wandering

Explaining new evidence

The theory provided explanations for the following phenomena, as they were discovered or investigated more fully:

- ocean floor topography (ridges with central rifts, transforms – faults offsetting rifts, trenches, abyssal i.e. broad-ocean plains etc.)
- ocean floro magnetic strips
- the age of the ocean floors
- the thickness of oceanic sediments
- submerged volcanotes (seamounts and guyots) – increasing in age away from where they formed.
- the distributions of many economic minerals (ores or copper, gold iron, etc. associated with subduction zones; copper, silver, zinc sulfide deposits associated with spreading margins)
- the distributions of many evaporite (salt) deposits – in evaporating young oceans as plates are splitting
- the distributions of many hydrocarbon deposits (oil and natural gas) – in young oceans as plate are splitting
- the distribution of diamonds – in areas of thick continental crust over deeply subducted plates
- extremes of past climates (Climates were most extreme at times of supercontinents when amelioration of climates by oceans influences had reduced effects)
- the 'growth' of continents from ancient cores (They grew as mountain chains were grafted onto the margins of the ancient cores by earlier plate collision activity or by the collision of the ancient cores.)
- the distributions of vast outpourings of basalt lavas on land e.g. Deccan lavas of India
- origins of magmas of different chemical composition, depending upon their plate setting.
- distribution of heat-flow values over the ocean floors
- a possible relationshiop between the distribution of continents and the causes of ice ages.

Questions currently being discussed and investigated

- the driving force(s) of plate movement (convection currents, pull of the sinking slab, or sliding of plate off oceanic ridges)
- details of convection current movement in the solid mantle
- how mantle plumes could survive in one place for millions of years
- evidence that fragments of subducted plates can be found at the base of the mantle
- the transfer of heat energy between the outer core and the mantle

Further guidance

- plate and continent movements pre-Pangaea
- whether or not plate tectonic processes operated on the earth Earth, and if so, how
- applications of plate tectonic theory to the understanding of planetary geology

Further guidance

The fusion of hydrogen

In explaining fusion, it is important that you do not give a false impression that atoms exist in stars. Collisions in stars are so energetic that atoms cannot stay together. A star such as the Sun therefore consists of colliding atomic nuclei and electrons – a plasma. In the most common fusion (also called 'thermonuclear') reactions, hydrogen nuclei combine to form helium nuclei.

Begin by describing fusion: hydrogen fuses to form a new element, helium, in a process which produces energy. How? It is helpful to students if they understand a few more things.

- Fusion is not an everyday process on Earth, as it requires collisions at enormous speeds (attained in the gravitational collapse which formed the star)
- Reactions take place between pairs of colliding particles
- Fusion is not a chemical reaction (it involves nuclear reactions.
- The probability of interactions and the amount of energy created per reaction are both very small, but the Sun is so massive (2×10^{30} kg) that the total energy radiated is enormous.

Now go on to give a fuller story. Atoms are made up of nuclei (which have positive charge) surrounded by sufficient electronic (which have negative charge) that the total charge is zero. Normally held together by (electrostatic) attraction due to their opposite charges, atoms do not survive in stars because collisions keep knocking electrons off. Fusion describes the process whereby hydrogen nuclei collide and combine to form (larger) helium nuclei. For them to come sufficiently close to fuse, the collision needs to be at high speed because the two particles have like charges and there is a strong electrostatic force of repulsion between them.

Your most able students might enjoy calculating how long the Sun will last, knowing that 65 million tonnes of hydrogen nuclei are used up every second. It will continue to shine until 10% of its hydrogen is used up (approx. 2×10^{29} kg).

(At A level, physics students need to know about protons, neutrons, and $E = mc^2$. They may learn that making helium nuclei from hydrogen nuclei involves a series of three events, one of them highly unlikely. This is what slows down the rate of hydrogen being used up and makes it possible for the Sun to last some 10 billion years.