SPOTLIGHT

QCE

UNITS 1 and 2

Earth and Environmental Science

• Rob Mahon • David Heffernan •

Science Press

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Words to Watch

account, account for State reasons for, report on, give an account of, narrate a series of events or transactions.

analyse Interpret data to reach conclusions.

annotate Add brief notes to a diagram or graph.

apply Put to use in a particular situation.

assess Make a judgement about the value of something.

calculate Find a numerical answer.

clarify Make clear or plain.

classify Arrange into classes, groups or categories.

comment Give a judgement based on a given statement or result of a calculation.

compare Estimate, measure or note how things are similar or different.

construct Represent or develop in graphical form.

contrast Show how things are different or opposite.

create Originate or bring into existence.

deduce Reach a conclusion from given information.

define Give the precise meaning of a word, phrase or physical quantity.

demonstrate Show by example.

derive Manipulate a mathematical relationship(s) to give a new equation or relationship.

describe Give a detailed account.

design Produce a plan, simulation or model.

determine Find the only possible answer.

discuss Talk or write about a topic, taking into account different issues or ideas.

distinguish Give differences between two or more different items.

draw Represent by means of pencil lines.

estimate Find an approximate value for an unknown quantity.

evaluate Assess the implications and limitations.

examine Inquire into.

explain Make something clear or easy to understand.

extract Choose relevant and/or appropriate details.

extrapolate Infer from what is known.

hypothesise Suggest an explanation for a group of facts or phenomena.

identify Recognise and name.

interpret Draw meaning from.

investigate Plan, inquire into and draw conclusions about.

justify Support an argument or conclusion.

label Add labels to a diagram.

list Give a sequence of names or other brief answers.

measure Find a value for a quantity.

outline Give a brief account or summary.

plan Use strategies to develop a series of steps or processes.

predict Give an expected result.

propose Put forward a plan or suggestion for consideration or action.

recall Present remembered ideas, facts or experiences.

relate Tell or report about happenings, events or circumstances.

represent Use words, images or symbols to convey meaning.

select Choose in preference to another or others.

sequence Arrange in order.

show Give the steps in a calculation or derivation.

sketch Make a quick, rough drawing of something.

solve Work out the answer to a problem.

state Give a specific name, value or other brief answer.

suggest Put forward an idea for consideration.

summarise Give a brief statement of the main points.

synthesise Combine various elements to make a whole.

Chapter 1
EARTH SYSTEMS AND MODELS

Figure 1.1 Change and interactions Takes place throughout the Universe.

Interactive vocabulary
https://quizlet.com/_6xcazh

'When we try to pick out anything by itself, we find it hitched to everything else in the Universe.'

John Muir: pioneering naturalist and preservationist.

The study of the Earth is the study of changes and of connections. At times throughout its long history the Earth has experienced many periods of stability in its geology, climate and life forms. Inevitably however, these times are always overturned by changes in one form or another; from the very gradual (such as continental drift) to the very sudden (such as the eruption of a volcano or the impact of a meteorite).

1.1 Introduction to Earth systems

We are all familiar with the concept of change. During your lifetime your body and mind change dramatically. The 'you' of today is very different from who you were ten years ago, or who you will be in another 10 years. Human society itself changes. Today's society seems to be changing at an ever increasing rate.

In your short life you may have noticed large changes in the way you have been taught at schools or how you communicate with others. The Earth itself has undergone drastic changes too, though usually over much longer time frames than humans live for (and so it can be hard for us to notice them happening).

At one time in the past the entire Earth was covered with thick ice from pole to pole, and at other times it has been a planet free of any ice, with warm temperatures and even lush forests at the South Pole.

With the convergence of social media and digital communications in the 21st century, most students have an understanding of the intricate network of connections between people. What science continues to reveal to us is that nature itself also contains a vast number of interconnections, ranging from the powerful to the miniscule to the downright strange.

The most astounding fact
http://qr.w69b.com/g/tpXhRXlBu

Introduction to Earth science
http://qr.w69b.com/g/s7bBx9dTi

Earth science
http://qr.w69b.com/g/q2SXXOPsI

Spheres of the Earth

Figure 1.2 Where does the atmosphere begin and end? The pilots of the experimental X-15 rocket plane were regarded as astronauts as they flew at a height of 85 kilometres.

Earth system interactions
http://qr.w69b.com/g/tCaPmhiMw

For easier reference, scientists refer to various **spheres** of the Earth, each of which is simply a zone in which a particular feature is found. The spheres of major interest to Earth scientists include the atmosphere, lithosphere, hydrosphere and biosphere.

The atmosphere. The zone of gases extends from the surface upward until gases are so thin that we have entered outer space. This gradual thinning means there is no clear boundary between the atmosphere and space. Air particles have been detected at a height of 1000 kilometres. To put this into perspective, the International Space Station orbits at a height of around 400 kilometres. NASA defines space as beginning at an altitude of 85 kilometres (Figure 1.2). Around 80 per cent of the atmosphere's mass is located in the bottom 12 kilometres.

The geosphere. This is the zone of all rock on Earth, including all of the interior layers (Figure 1.3). Two subsections of this that are of particular importance when studying plate tectonics are the **lithosphere** and the **asthenosphere**. The lithosphere is the zone of rigid rock, including the crust and uppermost mantle. It ranges from 5 km thick below oceanic crust up to 100 km thick below continental crust. The asthenosphere is the zone of partially molten (plastic) upper mantle rocks. It can flow slowly due to convection and sits directly below the lithosphere and above the solid lower mantle.

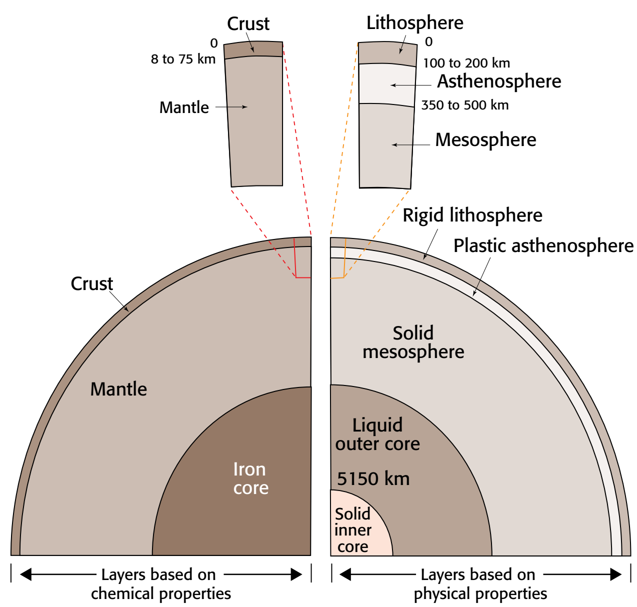

Figure 1.3 Geosphere This is the region extending from the surface down into the mantle until the rocks become partly molten.

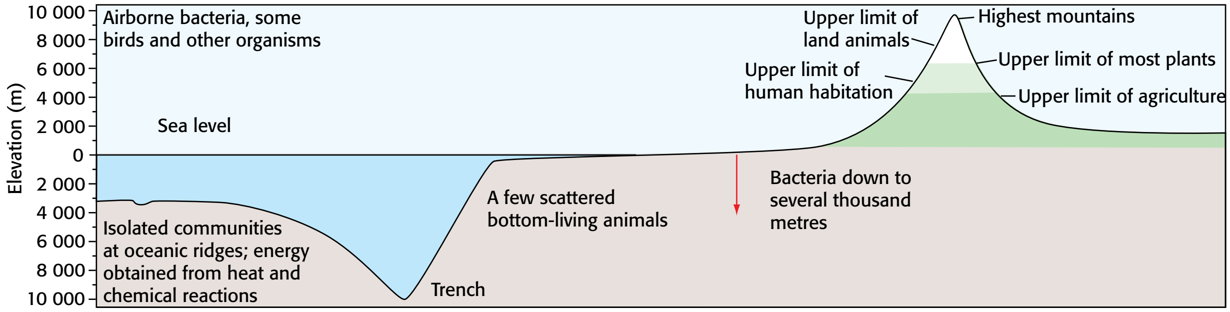

Figure 1.4 Biosphere The biosphere's upper limit is about 12 kilometres above the Earth's surface.

The hydrosphere. The zone of water extends from within the lithosphere and possibly the mantle to about 12 kilometres into the lower atmosphere. Water in the hydrosphere occurs as ice, vapour and liquid, most of which is contained in the oceans.

The biosphere. The zone of life, the biosphere's upper limit is about 12 kilometres above the surface, where air currents can carry airborne spores and pollen (Figure 1.4).

One place where all these spheres interact is on a rock platform (Figure 1.5 (a)). For example, the rocky shore allows us to see adaptations to various aspects of the environment. Although many rocks appear to lack life, you will notice small blue snails (*Littorina*) and flat limpets. They move about to feed on algae covering wet rocks and have a muscular foot that allows them to cling tightly and not be washed off by waves. They are also able to cling to the rocks when they are hot and dry.

Also, they have adaptations to stop water loss when conditions are dry. The blue snails fill their shell with water and then close off the end with a protective lid called an **operculum**. Limpets use their larger muscular foot to pull themselves tight against the surface to retain moisture. However, look in the crevices and you will see a myriad of other types of shellfish waiting in moist places for the tide to return: they cannot survive the drying effects of the Sun. When the tide comes in, they move out to feed.

The Sydney rock oyster is found on rock platforms and is also common in coastal estuaries (Figure 1.5 (b)). It lives only in a narrow band along the part of the shore that becomes exposed at low tide. The oyster is adapted to life on a rock platform in that it is cemented to the rock and cannot be washed off. It is also able to close its shell and survive some drying. However, as much as it has adapted to life on the rock platform, the oyster is at its mercy as well. It cannot withstand high temperatures and to being exposed to the Sun for too long. Furthermore, it can fall victim to various worms and crabs and be overgrown by algae and other marine life. Nonetheless, by working with its environment, such as tolerating some daily exposure to the drying air, the oyster can keep the predators and choking growth at bay.

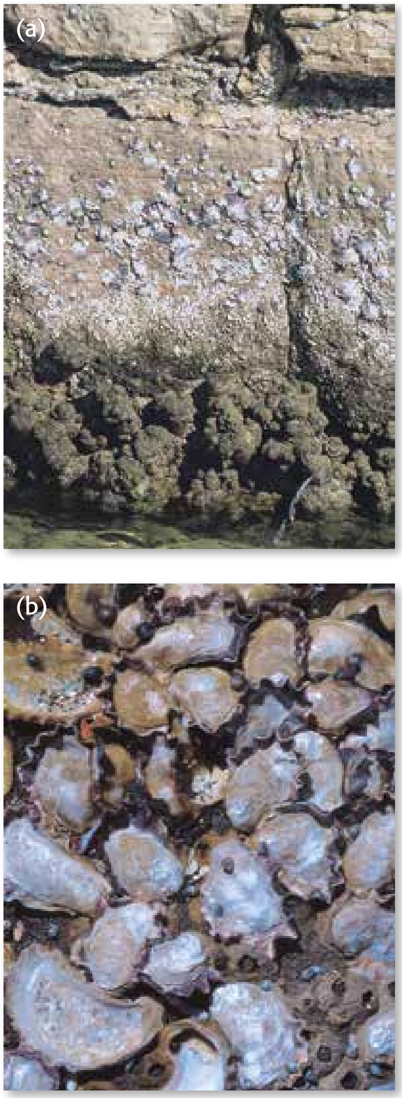

Figure 1.5 Rock platforms (a) Notice the zonation on this rock platform. (b) Rock oysters.

ACTIVITY 1.1 BRAINSTORMING INTERACTIONS

Aim: To share ideas about what we mean by the term ‘environment’ and to identify connections within it.

Apparatus: Butchers paper, coloured markers

Risk assessment: No hazards.

Method

1. Divide into groups of 4 and appoint a scribe to record notes for the group.
2. Go around the group one at a time and get each person to suggest a word that they associate with the term ‘environment’. The scribe is to record these on a piece of A4 paper. Each person needs to contribute at least 5 or 6 words.
3. Use a colour key to classify your group’s ideas as relating to rocks, water, air, humans or other life.
4. Write the following headings around the edge of the butchers paper (Figure 1.6) .
   - Humans
   - Atmosphere: zone of gas
   - Geosphere: zone of rock
   - Hydrosphere: zone of water
   - Biosphere: zone of life
5. Draw two parallel lines between ‘Humans’ and ‘Hydrosphere’. Make one of these an arrow towards ‘Humans’ and the other an arrow away from ‘Humans’. Repeat this process between ‘Humans’ and each other heading, then draw similar arrows to and from every other heading (Figure 1.6).

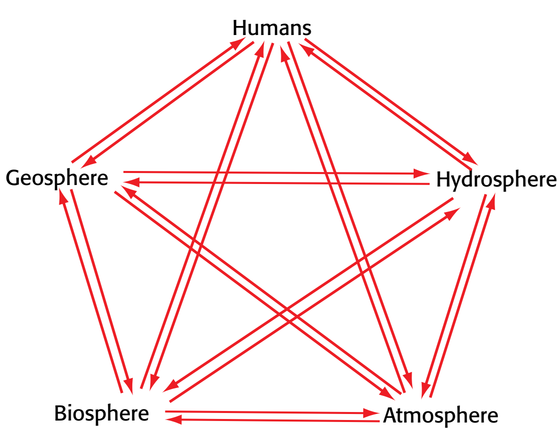

Figure 1.6 Interactions How does each component affect the others?

6. On each arrow add one or more words from your list that identifies how one of these things affects the other. For example, on the arrow from Geosphere to Humans, you could add words such as ‘soil’, ‘earthquakes’, ‘farmland’, ‘volcanoes’, ‘avalanche’. If any arrow does not have a label, discuss and decide on something appropriate.
7. Compare with other groups what labels you attached to specific arrows. Do others have ideas that your group did not think of or that you disagree with? Discuss similarities and differences. Are some things hard to put in one category? If so, why?
8. For homework start a vocabulary list with the definitions for each of the following terms: environment, atmosphere, geosphere, hydrosphere and biosphere.

SCIENCE SKILLS

Each of the verbs in bold type used in these questions has a very specific meaning in terms of what it is asking you to do. You are required to understand the specific meanings of the verbs that may be used in examination questions. Whenever you answer a question, always start by focusing on the meaning of the verb – it is telling you *how* to answer the question.

1. The verb **identify** means to recognise and name. You may need to recognise an image or a verbal statement. For example, **identify** the main band of stars in Figure 1.1.

   Answer:

   The main band of stars is known as the Milky Way.
2. **Compare** means to show how things are similar or different. For example, **compare** the way people communicated electronically in 1990 with how they communicate today.

   Answer:

   In 1990 both landline phone and mobile phones were in use. However, by 2015 both types of phone were much smaller and many people only have a mobile phone and not a landline phone.

TO THINK ABOUT

1. **Identify** a major technological change that has occurred in your lifetime.
2. **Identify** a slow geologic change taking place in your local environment.
3. **Compare** a fast and a slow geologic change taking place in Australia or nearby.
4. **Compare** a slow and a fast ecological change that has taken place in your local environment.
5. **Identify** an interaction taking place in your local environment.

Types of systems

The term 'system' refers to any group of objects, materials or processes that interact with each other to form an integrated 'whole'. For example, you will be familiar with the fact that the digestive system is made up of different organs such as the stomach, liver, small intestine and large intestine. Each of these has a different purpose to the other organs, but all work together to complete the vital role of digestion.

Systems are classified as either open, closed or isolated (Figure 1.7). **Open systems** are any system that freely exchanges both matter and energy with its surroundings, for example a jar of water sitting outdoors. It can have gases dissolve into or out of the water, it can lose water by evaporation or gain water when it rains, and the water can be heated or cooled by the conditions around it. A natural example of an open system would be an aquatic ecosystem. It can be altered by external energy changes and by introduced matter such as nutrients.

Closed systems are any system that exchanges only energy with its surroundings, not matter. For example, the jar of water in the example above with a lid screwed on. The contents inside the jar are sealed and cannot be added to or subtracted from, but the sealed contents can be heated by the Sun or cooled by the air. All of the systems on Earth are classified as open systems. However, the Earth system as a whole is considered a closed system because there is a limit to how much matter is exchanged.

Isolated systems are any system where neither energy nor matter are exchanged with its surroundings. For example, if the sealed jar mentioned above was encased by insulation so that no energy could enter or leave. This is what a Thermos flask tries to do in order to keep drinks hot or cold. However, because its insulation is imperfect, heat energy is gradually either gained or lost. Our Universe is an example of an isolated system where no matter or energy can enter or escape.

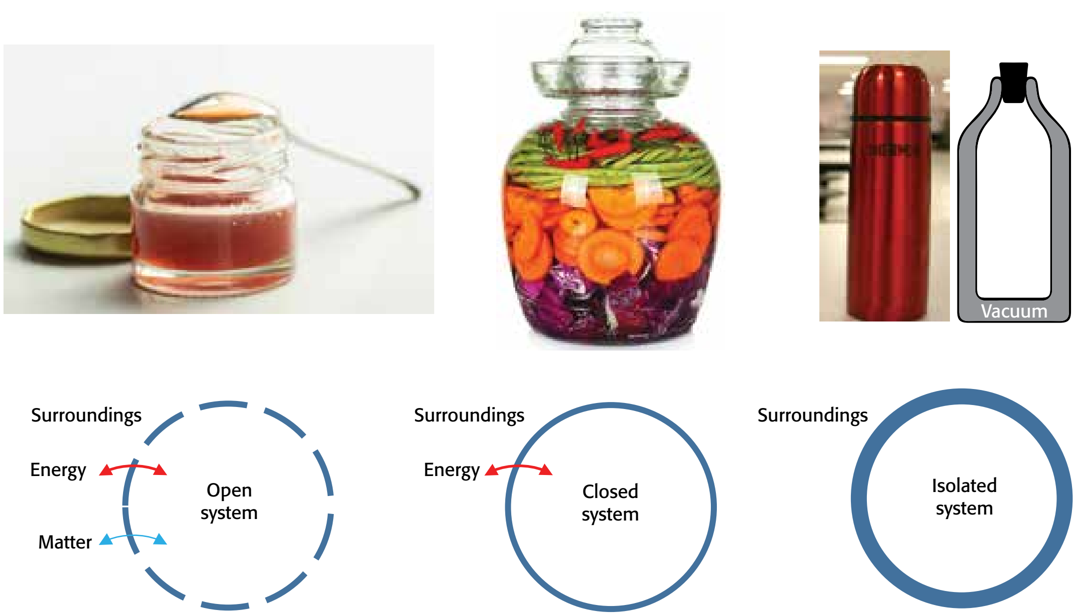

Figure 1.7 Systems These can be classified as either open, closed or isolated.

Scientific models

In science, a model is any type of representation that describes how something works, behaves or is constructed. Models are particularly useful when the thing you are describing is difficult to observe directly. Models can be a physical representation (e.g. the DNA double helix, a plastic skeleton), a set of coherent ideas (germ theory, plate tectonic theory), a diagram (the heliocentric solar system, atomic structure), a graph (a Hertzsprung-Russell diagram) or an equation ($E = mc^2$).

Models are used in every field of science to explain observations and to make predictions that can then be tested. The entire scientific method is really about testing our scientific models. If new information shows that our model is incorrect, we must go back and redesign our model so that it can account for this new data. It is by rigorously testing models and deliberately setting out to disprove them that science eliminates weak models and replaces them with more robust ones that can account for real world observations more accurately.

What is a scientific model?
http://qr.w69b.com/g/uiWfrmhxu

Scientific laws, theories and hypotheses

The terms 'law' and 'theory' are two of the most misunderstood words in all of science. People who do not have a scientific background commonly confuse 'theory' with 'hypothesis' or 'opinion' and may think that their different opinion is equally as valid as an accepted scientific theory (e.g. climate change denial opinions versus climate change theory). Many people also believe that a theory will become a law if it is 'proven correct' over time. These ideas are both widespread and incorrect.

A **scientific law** is a *description* of a general set of observations. Laws are descriptions (often mathematical) of naturally occurring phenomena. They do not have anything to say about how or why they occur. Contrary to popular belief, laws are able to be modified as new evidence is discovered. An example of a scientific law is Isaac Newton's law of universal gravitation (a formula that describes the relationship between the masses of two objects, their distance apart and the gravitational pull they will exert on each other). Another is Edwin Hubble's law of cosmic expansion (a formula describing the relationship between the distance to other galaxies and how fast they are moving away from us).

A **scientific theory** is an attempt to explain *how* or *why* natural phenomena occur. They are the explanation of a law. For example, Albert Einstein's theory of general relativity is an explanation of why Newton's law of universal gravitation works. Similarly, the steady state theory and the Big Bang theory were both attempts to explain why Hubble's law of cosmic expansion works. As evidence mounted, the steady state theory was disproved and discarded while the Big Bang theory became more firmly accepted as the preferred scientific model.

Hypotheses (plural of hypothesis) are simply ideas that can be tested scientifically. They occur after observations/laws in the scientific method, but due to the cyclic nature of the scientific method they can also lead to the development of laws. With wider testing and investigation, they can potentially lead to new theories.

One famous and long held hypothesis was first proposed by Aristotle in the 4th century BC. He proposed that an object falls with a speed proportional to its weight (i.e. the heavier the object, the faster it falls). This view was regarded as fact for hundreds of years until Galileo in 1638 investigated an alternative hypothesis: that the rate of fall caused by gravity is the same for all objects. He tested his hypothesis using metal balls of different mass that would overcome the effects of air, and also by using ramps to slow down the fall of these balls to assist with comparing the time each took. Galileo's hypothesis disproved Aristotle's idea and was used as part of the basis for Newton's law of universal gravitation in 1687. The mathematical description offered by Newton's law was what allows humans to put satellites in space and land vehicles on other planets. An explanation of the reasons why gravity behaves the way that it does had to wait until Einstein published his theory of general relativity in 1915. General relativity works very well (i.e. allows for accurate predictions) at some scales, but it fails when applied to the very small (quantum physics) and the very large (galactic scales). Are corrections to this model required to enable it to account for these so far unexplained phenomena, or do different forces/ theories dominate at different size scales?

Scientific theories, laws, hypotheses
http://qr.w69b.com/g/nmNZnLPzy

1.2 Geologic time

'It has not been easy for man to face time. Some, in recoiling from the fearsome prospect of time's abyss, have toppled backward into the abyss of ignorance.'

Claude C Albritton, *The Abyss of Time* (1980).

It would be pointless to study history without also considering the order and time in which historical events occurred. Likewise, when studying the history of our planet, we must first understand the concept of **geologic time –** the vast period of time over which Earth's rocks have formed.

For centuries the question of 'How old is the Earth?' proved to be a challenging problem for scientists. Finding an answer to this puzzle would profoundly change the way in which humans would view their home planet and their place on it.

How old is the Earth?

In the year 1510 Florentine artist, inventor and genius Leonardo da Vinci (1452-1519) concluded that the sediments deposited by the River Po in Italy must have taken 200 000 years or more to accumulate and that the Earth itself must be much older than this. However, his conclusion was not made widely known. Typically for da Vinci, he was far ahead of his time in using evidence and observations (i.e. science) to inform his theories.

Figure 1.8 Creation James Ussher calculated that the Earth was created in 4004 BCE.

In 1654, the Irish Bishop James Ussher calculated that the Earth was created in 4004 BCE (Figure 1.8). He arrived at this date by starting with the birth of Jesus Christ (the start of year zero on our calendars), adding together all of the generations described in the Bible back to Adam (listed there as the first human) and then multiplying this by his estimated average generation gap.

Many scientists thought that Ussher's estimate of 6000 years was far too short a time span to explain such features as cliffs showing accumulated sediments hundreds of metres thick (Figure 1.9 (a)). However, due to the lack of any other credible theories, Ussher's estimate became widespread in European religious and scientific circles. Given the Bible's description of a catastrophic flood, the idea that the world had been shaped in the past by sudden, short-lived catastrophic events took hold. This idea is called **catastrophism**, and was used to explain a number of things seen in the rocks, including the following.

- Layers of sedimentary rocks were due to a worldwide flood where huge tides deposited massive loads of sediment that over a short period of time formed rocks (Figure 1.9 (a)).
- Fossils found in such rocks were buried during The Flood (Figure 1.9 (b)).
- Rocks such as basalt and granite had been crystallised from the waters of The Flood (Figure 1.9 (c)).

In 1778 French mathematician and naturalist Georges de Buffon (1707-1788) estimated Earth's age based on experimental observation. Correctly inferring that the interior of the Earth must be like iron, he heated iron cannonballs of various sizes and studied the rate at which they cooled. He applied the observed cooling rates to the Earth's diameter and concluded a much older age of 75 000 years.

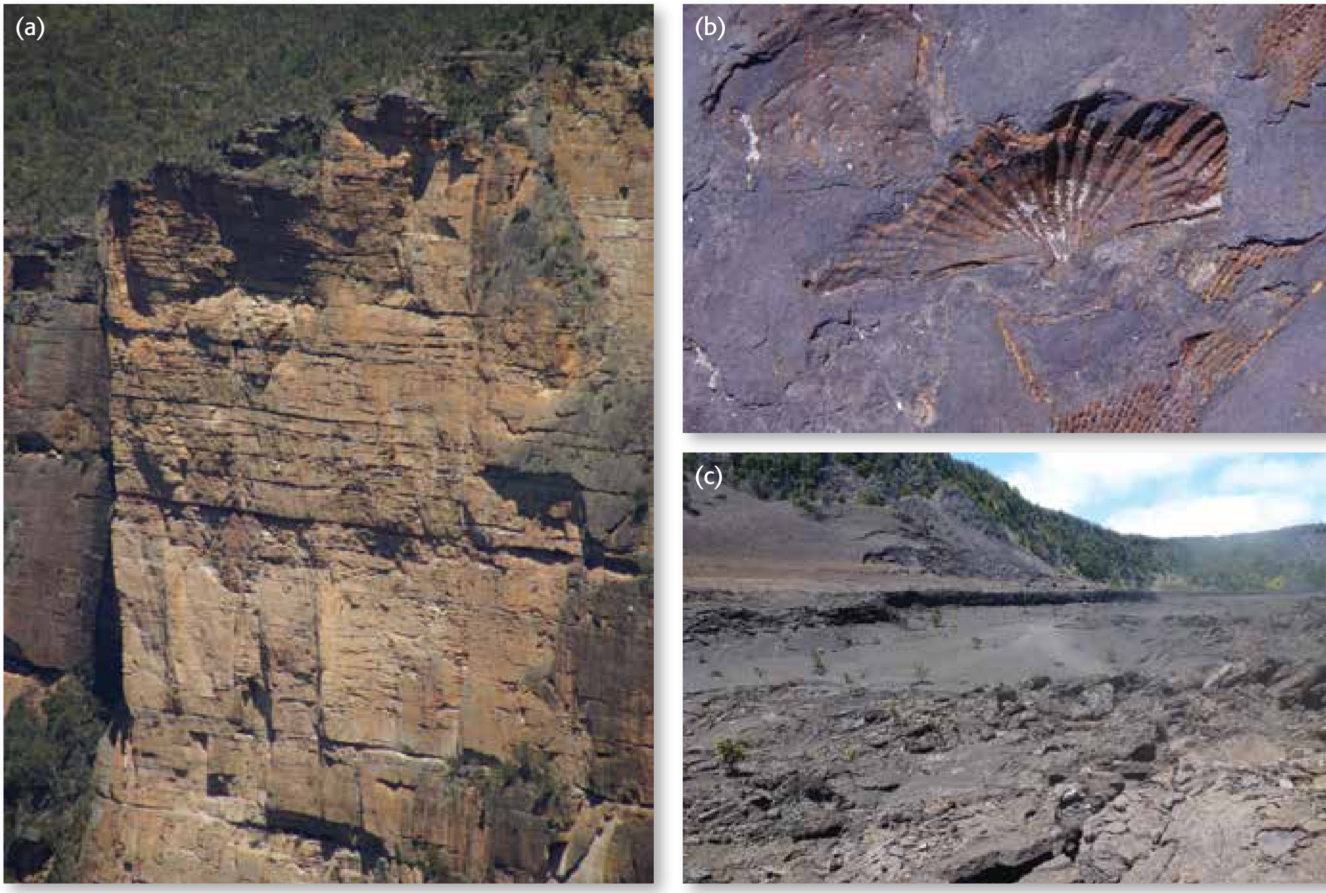

Figure 1.9 How did these form? (a) Beds of rock. (b) Fossils in sedimentary rock. (c) Layers of basalt.

Figure 1.10 Evidence (a) Unconformity showing rocks at different angles. The bottom rocks were deposited first before being tilted to a near vertical position. After being eroded, another layer of rocks was deposited horizontally and the whole formation tilted again. (b) Granite penetrating other rock showing that it must have been molten at the time.

Uniformitarianism

James Hutton (1726-1797) had been a gentleman farmer where he noticed how the soil on his farm was continually eroded away. He realised that the same thing happened to rocks, but much more slowly. Rocks slowly disintegrated before the particles formed were eroded away. How were the rocks and soil replaced?

Hutton went searching for evidence to try and solve his problem. Hutton examined **unconformities**, where layers of rock are at an angle to each other (Figure 1.10 (a)). It showed that after the original rock layers had been formed they were tilted and then partly eroded as solid rock. Then further sediment was deposited and gradually converted into rock. This would have taken a long period of time by normal geologic processes and would not have occurred in a single catastrophe.

He also found examples of granite penetrating other rocks including both metamorphic and sedimentary rocks (Figure 1.10 (b)). The idea that granite was formed by precipitation from water could not explain the patterns found. The only way this could have happened was if the granite was molten when the penetration took place.

Natural processes could explain the evidence he found – there was no need for a catastrophe. This lead to the principle of **uniformitarianism**: that the rate of processes such as evolution, erosion and the deposition of sediments has been fairly constant throughout Earth's history. This means we can use present day geologic processes to explain the geology from the past. It is often popularised as 'the present is the key to the past.'

This is an example of a change from one scientific model (catastrophism) to another that was better supported by the available data (uniformitarianism). This model has since been further altered to produce our current model, which is a hybrid of both of these. Current thinking is that the Earth goes through long periods of gradual change (i.e. uniformitarianism) interrupted occasionally by natural catastrophic events (i.e. catastrophism). Some agents of gradual change include the rock cycle and plate tectonics. Some examples of catastrophic events include meteorite impacts and large volcanic eruptions.

Charles Lyell (1797-1875) was a British lawyer with an intense interest in geology. Such was his interest that he spent his honeymoon in Switzerland and Italy on a geologic tour! Lyell worked as a lawyer for a time and as a professor of geology. He is most famous for his textbook *Principles of Geology* (Figure 1.11). He helped establish geology as a scientific discipline and also popularised James Hutton's principle of uniformitarianism.

In 1898 Irish chemist John Joly (1857-1933) devised another method for calculating the Earth's age. He determined the total amount of salt in the oceans and divided this by the estimated annual rate at which salt is added by erosion from land. He concluded that 100 million years were required to produce the current salinity. Had Joly used modern measurements of different added chemicals in the oceans, he would have arrived at these figures: 260 million years if using sea salt, 45 million years if using magnesium or only 8000 years if using silica. There is obviously a problem with this method. The problem lies in the incorrect assumption that nothing leaves the ocean.

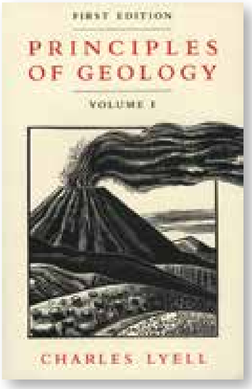

Figure 1.11 Principles of Geology First published in 1830 this was the first modern geology textbook.

In 1855 eminent British physicist William Thomson (1824-1907) – also known as Lord Kelvin – waded into this debate. Using de Buffon's principle of rate of heat loss, he announced that the Earth was 20 to 30 million years old. Most geologists did not challenge this estimate, even though it was not enough time to explain the variety of landscapes and life forms we observe around us. This was partly because of the high esteem in which physics generally (and Lord Kelvin particularly) was held, and partly because they could not show that Kelvin was wrong.

One of the few scientists willing to challenge Kelvin was American geologist Thomas Chamberlin (1843-1928). In 1899 he boldly declared that if physics determined Earth's age to be only 30 million years, physics must be wrong! He argued that another source of energy other than heat left over from its formation must exist to have driven Earth's geologic processes for much longer than this. Luckily for Chamberlin, breakthroughs to support his theory were just around the corner.

Radiometric dating

In 1896 French scientist Henri Becquerel (1852-1908) placed some uranium salts in a drawer along with sealed photographic plates. Normally photographic plates are only exposed (altered) by visible light. However these plates produced images of uranium salt crystals even though they were in the dark (Figure 1.12). The outline of a metal Maltese cross that sat between some of the salts and the photographic plate is clearly visible. Becquerel had accidently discovered nuclear radiation; a 'new' form of energy.

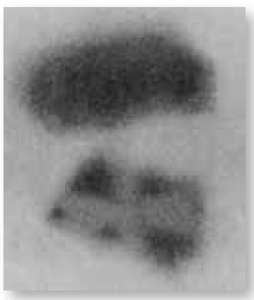

Figure 1.12 Effects of radiation Radioactive particles from uranium salts produced this image.

In 1902 Nobel Prize-winning New Zealand-born physicist Ernest Rutherford (1871-1937) outlined his hypothesis of how **radioactive decay** occurs. Certain atoms such as uranium have nuclei that are unstable, and give off high energy particles. As a result of giving off particles, the nuclei become stable and cease to be radioactive. In 1904 Rutherford suggested that radioactive decay of elements within the Earth acts as an additional source of internal heat, thus supporting Chamberlin over Kelvin.

When radioactive substances decay, they do so in a random manner that can only be studied statistically. The **half-life** measures the time needed for half the original number of atoms present to decay away (Figure 1.13). If we had 20 grams of a radioactive isotope with a half-life of 2 minutes, then after 2 minutes only 10 grams is left. After 4 minutes only 5 grams is left (half the 10 grams). After 6 minutes, only half the 5 grams is left, or 2.5 grams, and so on. Half-life is independent of environmental effects such as pressure and temperature, and whether it is joined to other chemicals. Some examples important in radiometric dating are listed in Table 1.1.

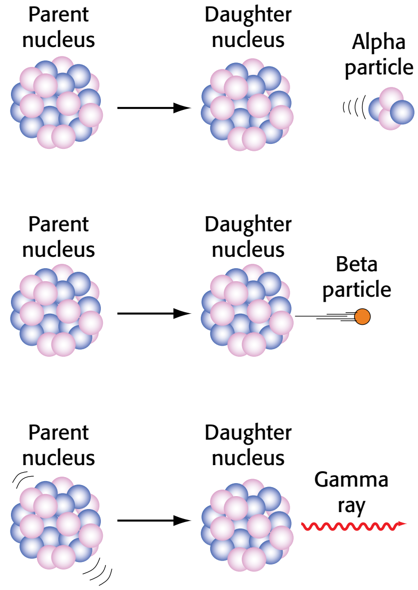

Figure 1.13 Radioactive decay Radioactive particles are emitted by the nucleus.

Table 1.1 Half-lives.

Element	Symbol of isotope	Half-life
Uranium-238	$^{238}_{92}U$	4.5×10^9 years
Carbon-14	$^{14}_{6}C$	5730 years
Potassium-40	$^{40}_{19}K$	1.3×10^9 years
Rubidium-87	$^{87}_{37}Rb$	48.8×10^9 years

In 1905 American chemist Bertram Boltwood (1870-1927) and British mathematician and physicist JWS Rayleigh (1842-1919) developed a relatively simple radioactive dating technique to determine the age of certain minerals commonly present in suitable rocks.

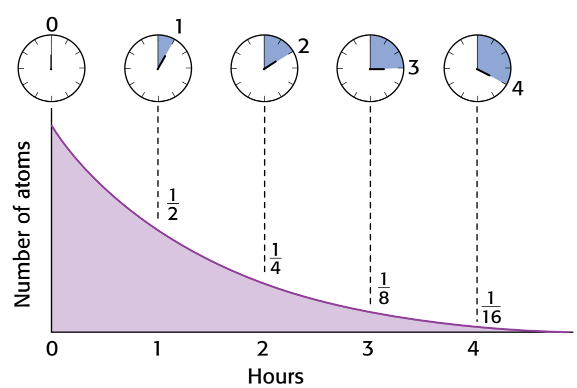

Figure 1.14 Radioactive decay Decay is at a constant rate.

Answers

Chapter 1 Earth Systems and Models

1.1 Introduction to Earth systems

1. Many answers: Smartphones; Facebook; watch phones.
2. Many answers: Weathering of rocks and buildings; soil erosion; movement of Australia towards New Guinea.
3. Many answers: Slow movement of New Zealand towards Australia; volcanic eruptions and earthquakes in New Zealand.
4. Many answers: Slow ecological change includes the invasion of cane toads; fast ecological change includes clearing of forests for housing.
5. Many answers: Interaction between trail bikes and the forest they ride through; interaction between a flowing stream and nearby forest or grassland.

1.2 Geologic time

1. A gap in layers of rock due to a period of non-deposition, weathering, or erosion. In particular, when rocks are at an angle to each other after tilting and erosion before new layers are deposited.
2. James Hutton.
3. Catastrophism seemed to explain the geologic strata around the world. It had the backing of the Church and there was no other viable theory at the time.
4. Radiometric dating.
5. Meteorites that fall to Earth give us access to rocks that formed at the same time as Earth and the rest of the Solar System. Radioactive dating of these rocks puts our current estimate for the age of the Earth at 4.54 (± 0.05) billion years.
6. Lord Kelvin was a physicist who was able to use mathematics to arrive at his date. He measured the rate of cooling of spherical metal balls, and then extrapolated to the known size of the Earth. He assumed that the only heat available came from the molten magma in the interior of the Earth.
7. Lord Kelvin was not aware of radioactivity and how this would generate extra energy to heat the interior of the Earth. Had he known of radioactivity he could have added the heat generated to that already present in the molten magma and thus come to a better estimate of the age of the Earth.
8. Scientific progress takes place all the time. Kelvin's estimate was the best available based on the knowledge at hand. Thus Kelvin was not stupid. When the new discovery of radioactivity took place, better age estimates could take place.
9. Sediment deposited = 1000 m/200 000 years = 5 mm per year.
10. (a) The layer of basalt was deposited before or during Noah's flood. During the flood the layers above were deposited. As the flood waters receded it eroded the valleys thus exposing the cliffs visible today.
    (b) Earth's history includes periods of volcanic activity that could have deposited the basalt as happens to this day. This was followed by periods of deposition to produce the layers above, some of which are hard enough to produce the small cliff. The region is then eroded to produce the valley that allows the cliffs to be exposed.

1.3 Stratigraphy

1. Eon (largest); era; period; epoch (smallest).
2. Too large to fit on a page. For example, even if we had 1 mm = 1 million years, the Precambrian would be 2400 mm = 2.5 m long.
3. While stratigraphy can tell you which strata is younger and which is older, it does not tell you the absolute age unless it can be dated radiometrically.
4. The law of superposition is most useful as nearly all studies of rock sections must use this technique. Law of cross-cutting relations and law of inclusions are used far less frequently.
5. A relative time scale can become an absolute time scale if rocks can be dated using radiometric methods.
6. For example: Geoscience Australia has a large poster that can be viewed.
   The National Geographic Time Scale allows you to click through a number of small screens that show you how the continents have moved and the flora and fauna for each period.
   The Smithsonian Museum of Natural History allows you the visit many pages from the Geologic Time Scale giving you much more detail.
7. A more detailed fossil record in recent geologic history such as the Quaternary allows for finer divisions in the geologic record. Periods such as the Cambrian are so old that a lot of their fossil content has been lost so we have less detail to allow for dating.
8. The Quaternary (1.6 million years) is about half the length as the Tertiary (65 million years) rather than around 2.5 per cent of the length.
9. Figure 1.30 gives a better idea of the length of geologic time while Table 1.4 allows more detail to be recorded.
10. Several examples exist. For example, the end of the Cretaceous is marked by a large asteroid striking the Earth near modern day Mexico. The tsunami that resulted, and the huge dust clouds generated helped to lead to a mass extinction. At about the same time there were massive lava flows in what we now call the Deccan plateau in southern India.

1.4 Origins of the Universe

1. The edge of the Universe is believed to be 13.7 billion light years from Earth.
2. 100 million = 10^5; 1 trillion = 1 million million = 10^{12}.
3. Hydrogen and helium.
4. The invention of powerful telescopes allowed astronomers to see objects such as the Andromeda Galaxy. Since this galaxy had a spiral structure, and was made up of individual points of light, and moved in a very different manner to the stars in our own galaxy, it must be a separate galaxy.