OCR
Oxford Cambridge and RSA

Tuesday 13 October 2020 – Morning

A Level Geology

H414/02 Scientific literacy in geology

Time allowed: 2 hours 15 minutes

You can use:
- an HB pencil
- a ruler (cm/mm)
- a scientific or graphical calculator

8209865870

H414O2

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

INFORMATION
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **32** pages.

ADVICE
- Read each question carefully before you start your answer.

BLANK PAGE

PLEASE DO NOT WRITE ON THIS PAGE

Answer **all** the questions.

1 **(a)** **(i)** Explain the meaning of the term sedimentary basin.

.....

..... **[1]**

(ii) Describe how the geometry of an ancient sedimentary basin can be determined.

.....

.....

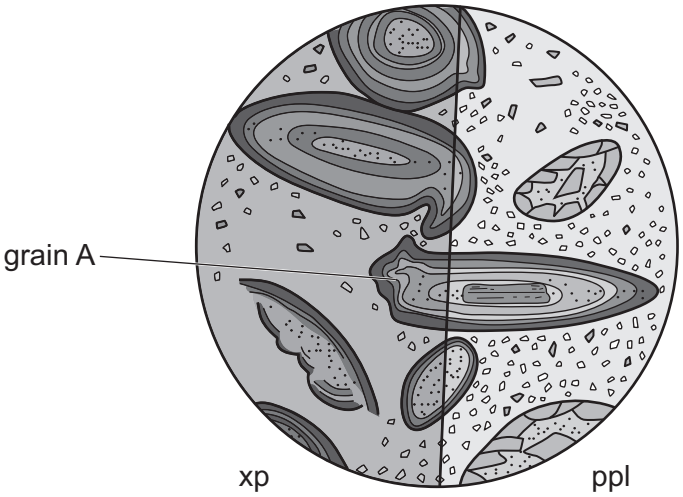
.....

.....

..... **[2]**

(b) The Jurassic Basin in England extended from North Yorkshire, across to the Mendip Hills and to Dorset in the South, encompassing large parts of South-East England. Other basins also existed at the same time, including the Hebrides Basin in Scotland.

The image below shows a thin-section diagram of a carbonate rock from the Middle Jurassic found in the Hebridean Basin in Raasay. Chamosite and siderite are iron minerals.



Key:

- concentric grains containing chamosite
- chamosite-rich mud with siderite rhombs
- deformed concentric grains
- large siderite rhombs
- xp — viewed in cross-polarised light
- ppl — viewed in plane-polarised light

(i) The size of grain A, indicated on the thin-section diagram, is 1.26 mm in maximum diameter.

Calculate the magnification shown in the thin-section diagram.

magnification = ... **[2]**

(ii) Classify the rock and describe how the rock was formed.

.....

.....

.....

.....

..... **[2]**

(c) (i) Upper Jurassic sediments from part of the Jurassic Basin in southern England have been studied. They are described as thin evaporites and interbedded limestones. No marine fossils have been found in the evaporites. Bivalves and ostracods are abundant in the limestones.

Describe the most likely interpretation of the palaeoenvironment, including an indication of water depths and energy levels.

.....

.....

.....

.....

..... **[2]**

(ii) Part of an Upper Jurassic cliff was investigated by students. They did not measure the thickness of the beds, but numbered them from the bottom to the top. They recorded the numbers of macrofossils found in each bed and they noted the presence of ichnofauna (trace fossils). Their descriptions are found in the table below.

Bed	Description of sediment	Macrofossils	Ichnofauna
6	Thick limestones with cross bedding	*Gryphaea* (×18) *Pecten* (×7)	*Rhizocorallium* *Arenicolites*
5	Clay	No fossils	*Thalassinoides*
4	Thin limestones	*Gryphaea* (×3) *Pecten* (×12)	*Rhizocorallium* *Arenicolites*
3	Coarse sandstone with ripples	Wood fragments (×25)	*Diplocraterion*
2	Clay	Shelly fragments at the base	*Thalassinoides*
1	Limestones showing some cross bedding in places	*Gryphaea* (×5) *Pecten* (×4)	*Rhizocorallium* *Arenicolites*

These beds show cyclical sedimentation. Describe **one** cycle and suggest a possible reason for the repetition.

.....

.....

.....

.....

..... **[2]**

(iii) Calculate the ratio of **one** of the macrofossils found in beds 1, 4 and 6.

ratio = ... **[2]**

2 **(a)*** Fig. 2.1 shows a simplified palaeogeographic map of part of the Upper Jurassic in Southern Germany, when the Solnhofen Limestone was being deposited in a basin.

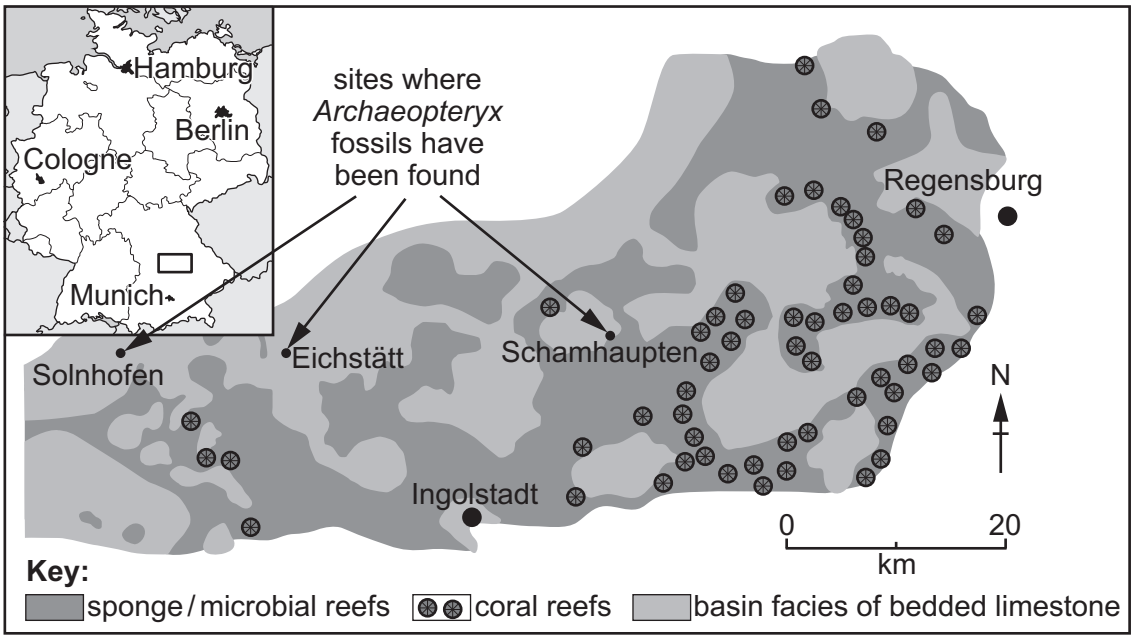


Fig. 2.1

Describe and explain how the geological setting and sedimentary conditions led to the exceptional preservation of organisms in the Solnhofen Limestone.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... **[6]**

Additional answer space if required.

.....

.....

.....

.....

.....

(b) The most famous fossil to be found in the Solnhofen Limestone is the exceptionally preserved *Archaeopteryx*.

There have only been 12 specimens of *Archaeopteryx* found to date. Most of these specimens have been found in the west of the Jurassic basin, around Solnhofen and Eichstätt. The most recent specimen, number 12, has been found in the east, near Schamhaupten.

Fig. 2.2 shows the geological units in which eleven of the twelve specimens have been found, which span about 7 million years of the Jurassic. Specimen 4 has been omitted due to uncertainty.

<table>
<tr><th>Ammonite horizon</th><th colspan="2">West of basin</th><th>East of basin</th></tr>
<tr><td>moernsheimensis</td><td colspan="2">Mörnsheim Formation
8</td><td rowspan="2"></td></tr>
<tr><td>rueppelianus</td><td colspan="2" rowspan="2">Altmühital Formation</td></tr>
<tr><td rowspan="2">riedlingensis</td><td>Upper Solnhofen Member
7
3 9
1</td><td rowspan="2"></td><td rowspan="3">Painten Formation

12</td></tr>
<tr><td rowspan="2">Lower Solnhofen Member</td><td rowspan="2">Upper Eichstätt Member
6 10 11
5</td></tr>
<tr><td>eigeltingense</td><td rowspan="2">Geisental Formation</td><td rowspan="2">Lower Eichstätt Member
2</td></tr>
</table>

Fig. 2.2

The oldest *Archaeopteryx* specimen, number 12, has several anatomical differences to the other specimens that have been found.

Discuss the likelihood that all 12 specimens belong to the same species.

.....

.....

.....

.....

.....

.....

.....

..... **[3]**

(c) Fig. 2.3 shows diagrams of *Archaeopteryx* and *Gallus* (chicken).

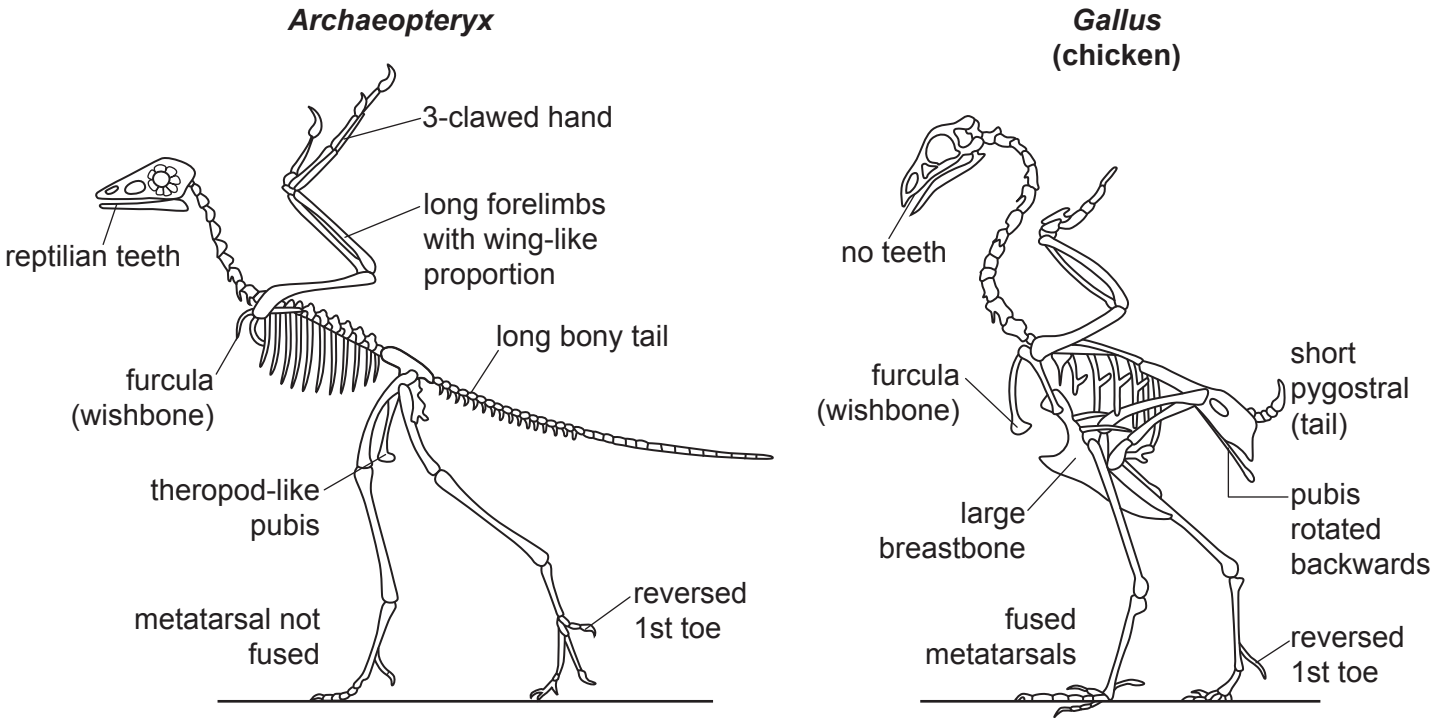


Fig. 2.3

Identify **two** similarities and **two** differences between *Archaeopteryx* and birds that can be seen on Fig. 2.3.

similarity 1 .....

.....

similarity 2.....

.....

difference 1 .....

.....

difference 2 .....

.....

[2]

(d) The Jurassic Period is zoned by ammonites. The species that allow zonation of the Tithonian stage of the Jurassic are shown in Fig. 2.2.

Describe and explain **two** reasons why ammonites make good zone fossils.

.....

.....

.....

.....

..... **[2]**

(e) The Tithonian is 95 m thick in some areas.

Calculate the rate of deposition in metres per year, if the time interval was 5.3 million years.

Give your answer in standard form.

rate of deposition = ... $m\,y^{-1}$ **[2]**

3 (a) (i) The process of metamorphism is often described as isochemical.

Describe the meaning of the term isochemical.

.....

..... **[1]**

(ii) Describe the mineralogical and textural changes that occur when a sandstone is metamorphosed in low pressure and high temperature conditions. Identify the metamorphic rock formed.

.....

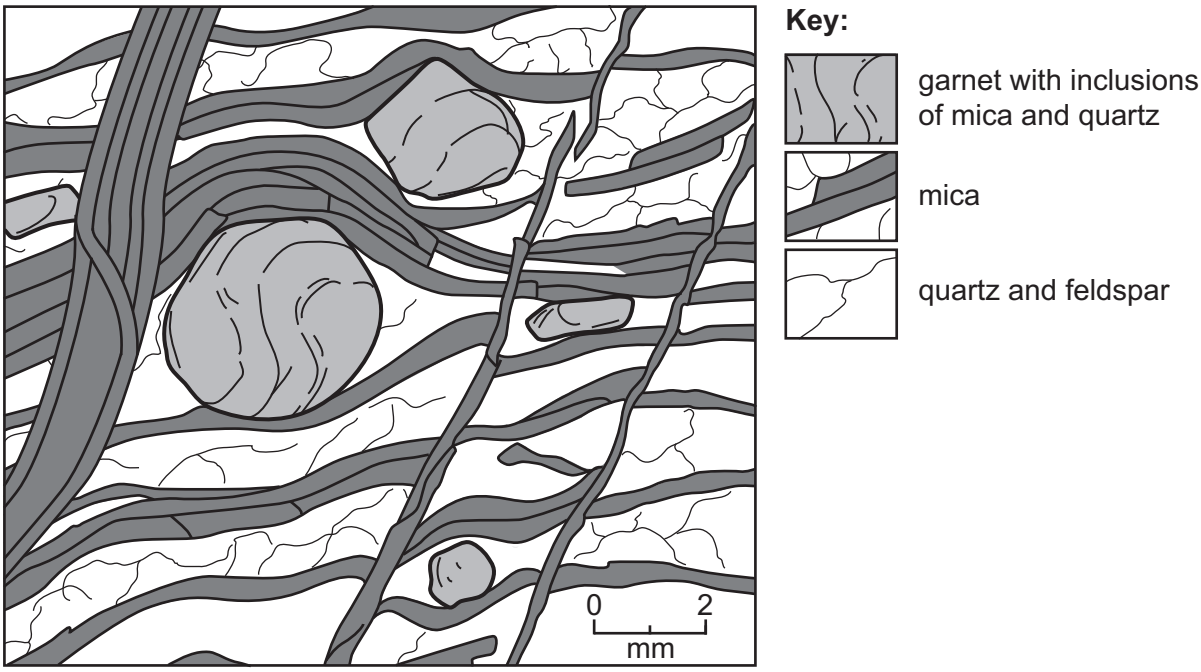
.....

.....

.....

..... **[2]**

(b)* The image shows a thin-section diagram from a metamorphic rock.



Use the information seen on the thin-section diagram to establish the metamorphic history of the rock. Include reference to the parent rock and details of the metamorphic grade and fabric.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... **[6]**

Additional answer space if required.

.....

.....

.....

.....

.....

(c) Metamorphic grade can be mapped over a large area by identifying the first appearance of key index minerals.

A geologist mapped an area looking for biotite (B), chlorite (C), garnet (G) and sillimanite (S). The results are shown on the map below.

C	C	C	C	B	B	G	G	S	S	N
C	C	C	C	B	B	B	G	S	S	
C	C	C	C	B	B	B	G	G	S	
C	C	C	B	B	B	B	G	G	G	
C	C	B	B	B	B	B	G	G	G	
C	C	B	B	B	B	G	G	G	G	
C	C	B	B	B	B	G	G	S	S	
C	C	C	C	B	B	G	G	S	S	
C	C	C	C	B	B	G	S	S	S	
C	C	C	B	B	G	S	S	S	S	

(i) Complete the map by drawing the isograds. **[2]**

(ii) Shade the area of the map where low-grade metamorphism has been identified. **[1]**

(iii) (Circle) the name given to these metamorphic zones.

Barrovian zones **contact zones** **index zones** **[1]**

(d) Metamorphism of limestone produces marble. However, impurities in the limestone can lead to the formation of minerals, such as wollastonite ($CaSiO_3$) and the evolution of volatiles.

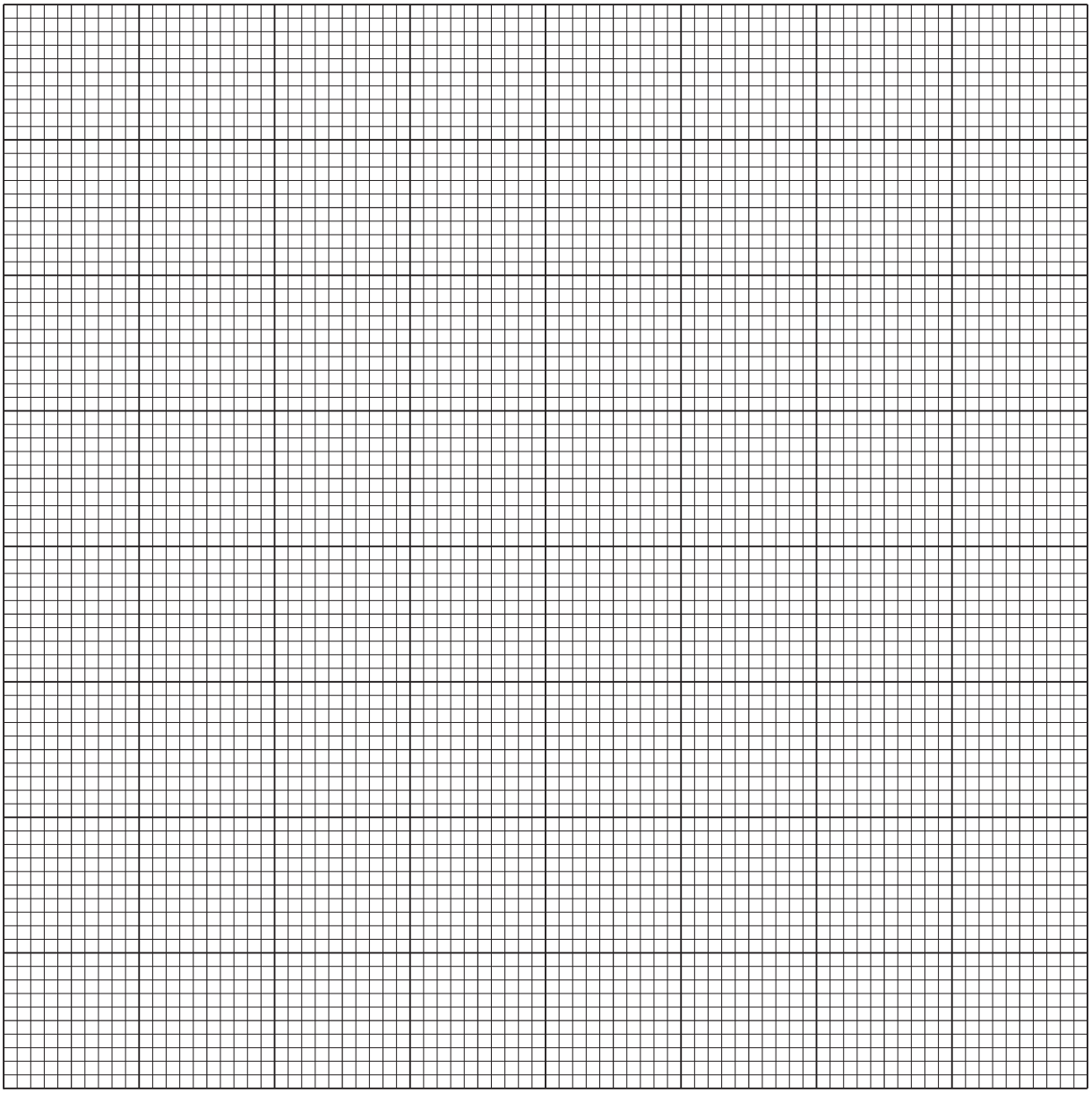
Write a balanced symbol chemical equation to show how wollastonite can form if the limestone contains quartz.

..... **[2]**

(e) The table shows the temperatures and pressures where two Al_2SiO_5 metamorphic polymorph minerals are stable (stability fields).

Temperature (°C)	230	250	300	375	450	500
Pressure (MPa)	60	80	130	225	310	360

(i) Draw a line graph of the data on the graph paper.



[3]

(ii) Label the **two** stable minerals found either side of the line you have drawn. **[2]**

4 An engineering company has been employed to construct a 3 km long tunnel passing through a hill. The rocks consist of Cretaceous sandstones and some interbedded clays. There is a dip of 5° to the East.

(a) (i) Explain why tunnelling through the rocks may cause stability problems. Suggest a method that could be used to increase the stability.

.....

.....

.....

.....

..... **[2]**

(ii) There is the possibility that swelling clays could form part of the sequence.

Identify a type of swelling clay that could be present in the Cretaceous clay.

..... **[1]**

(b) The engineering company is concerned about the tunnel flooding. Engineering geologists are employed to calculate the rate of flow through part of the sandstone. They drill two boreholes 1000 m apart along a fairly flat ridge at the top of the hill. They measure the height of the water in the two boreholes, 55 m and 50 m respectively.

Darcy's law is given by the simplified formula: $Q = KA((h2 - h1)/L)$

Where: Q = rate of flow; K = coefficient of permeability and A = cross-sectional area in m^2.

The value for Q has been calculated as 45.4 m^3 per day and the A value has been calculated as (20 m × 500 m).

Determine the value for K.

Give your answer to **3** significant figures.

K = ... **[3]**

5 Fig. 5.1 shows a hypothetical cross-section diagram (not to scale) through several igneous features within a volcanically active region.

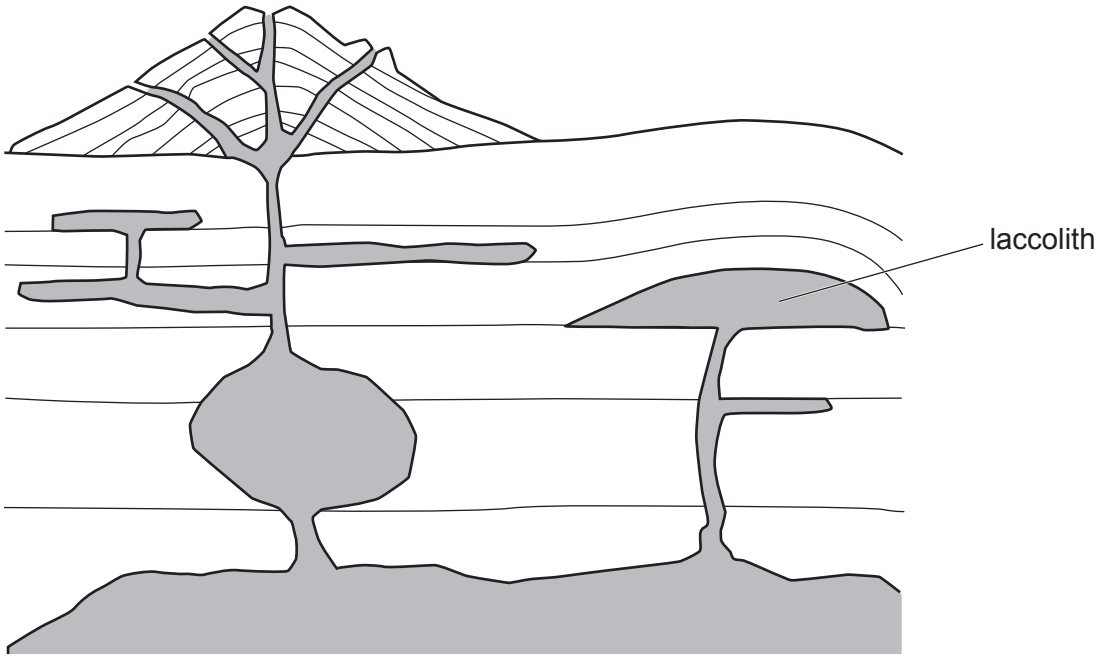


Fig. 5.1

(a) (i) **On Fig. 5.1**, clearly label the igneous intrusions listed below.

batholith **dyke** **pluton** **sill** **[2]**

(ii) Explain how geodetic surveying might be used to identify the location of a laccolith.

.....

..... **[1]**

(iii) Describe how geologists classify igneous intrusions by depth.

.....

.....

..... **[1]**

(b) Iceland is located over a section of the mid-ocean ridge known as the Reykjanes Ridge. The magma should be entirely mafic, yet Icelandic volcanoes have produced a range of compositions from eruptions in the past, ranging from mafic to silicic.

Describe and explain how the composition of erupted material affects the volcanic hazard and controls the shape of the landscape.

.....

.....

.....

.....

.....

.....

.....

..... **[3]**

(c) Fig. 5.2 shows part of Bowen's Reaction Series.

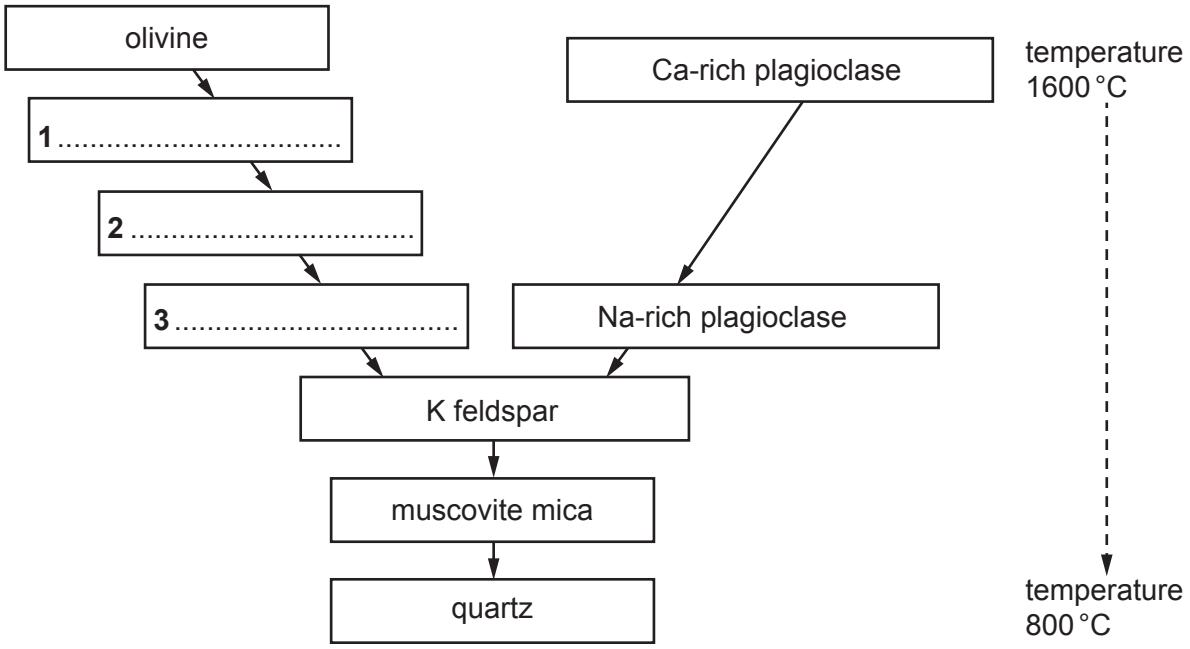


Fig. 5.2

(i) **On Fig. 5.2**, complete boxes **1** to **3** to indicate the correct mineral within the series. **[3]**

(ii) **On Fig. 5.2**, circle the minerals that form the Discontinuous Reaction Series. **[1]**

(iii) Describe and explain how reaction rims form.

.....

.....

.....

.....

..... **[2]**

(iv) Chromite can be concentrated by fractional crystallisation, gravity settling and filter pressing.

Describe how these three processes result in concentrated deposits.

.....

.....

.....

.....

.....

.....

.....

..... **[3]**

(d) The phase diagram in Fig. 5.3 shows the solid solution series for olivine end members forsterite and fayalite.

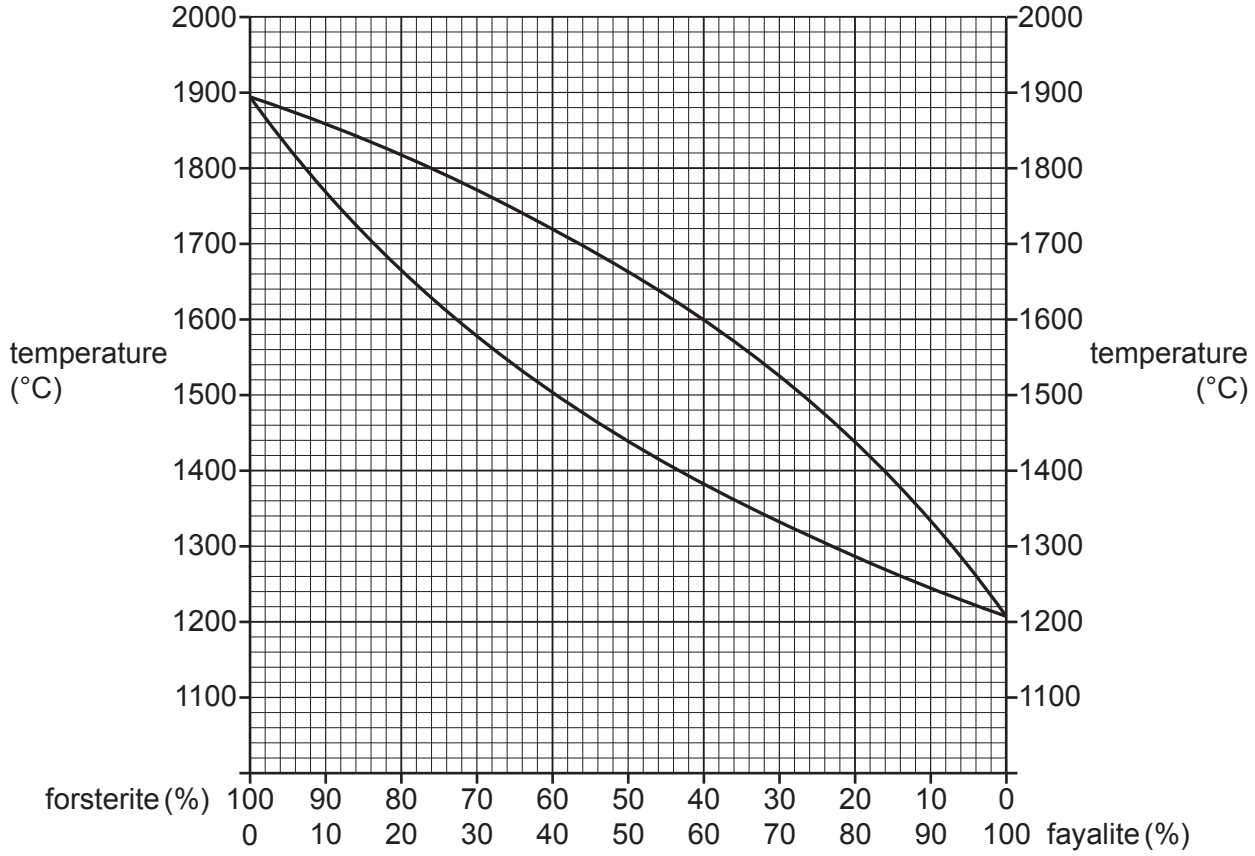


Fig. 5.3

(i) **On Fig. 5.3** clearly label the **liquidus** and **solidus**. **[1]**

(ii) If the composition of the original magma is 40% forsterite (60% fayalite), what will be the temperature **and** composition of the first formed crystals?

.....

.....

.....

..... **[2]**

(iii) When this melt (magma) has cooled to 1500 °C, what will be the composition of the newly formed crystals?

..... **[1]**

(iv) At what temperature will the last liquid of this melt crystallise?

..... **[1]**

BLANK PAGE

PLEASE DO NOT WRITE ON THIS PAGE

6 The Earth's climate, atmospheric composition and ocean chemistry have all changed over geological time.

(a) Between 2.5 and 1.8 billion years ago, during the Archean and Palaeoproterozoic eras, an important commercial source of iron ore was deposited. These units of sedimentary rock are known as the Banded Iron Formations (BIFs).

Describe how BIFs formed.

.....

.....

.....

.....

..... **[2]**

(b) Explain how the Wilson Cycle model can help scientists understand the long-term changes in palaeoenvironment that result in the formation and extinction of coral reefs.

.....

.....

.....

.....

..... **[2]**

(c) Explain how $\partial^{18}O$ and $\partial^{13}C$ isotope analysis of fossil coral skeletons can be used to help determine the palaeoclimate and sea level at the time the corals were alive.

.....

.....

.....

.....

..... **[2]**

(d) A student looking for evidence of palaeoclimate change on New Zealand's North Island made a qualitative observation that the limestone deposits increase in purity over time. The student decided to perform a quantitative test on samples of the limestones of different ages using the following procedure.

A beaker containing 50 ml of 1 M HC*l* mass was measured using an electronic balance and then a 2 g sample of crushed limestone **A** was poured into the beaker. The student allowed 6 minutes for the reaction to reach completion and then reweighed the beaker recording its mass. The experiment was repeated for samples **B**, **C** and **D**, with fresh HC*l*. Their results are shown in the table below.

	Mass in g			
	A	**B**	**C**	**D**
Mass of beaker & HC*l*	114.00	114.00	114.00	114.00
Mass of sample	2.00	2.00	2.00	2.00
Total mass of beaker & sample at 0 minutes	116.00	116.00	116.00	116.00
Total mass of beaker & sample at 6 minutes	115.12	115.26	115.41	115.19
Loss of mass	0.88		0.59	
Mass of $CaCO_3$ in sample	2.00		1.34	
% $CaCO_3$ in sample	100%		67%	

Pure limestone (100% $CaCO_3$) loses 44% of its mass by the evolution of CO_2. The student was able to calculate the mass of $CaCO_3$ in each sample and, from that, calculate the percentage of $CaCO_3$ in samples **A**, **B**, **C** and **D**.

(i) Using the data in the table, calculate the mass of $CaCO_3$ and percentage of $CaCO_3$ for samples **B** and **D**.

[Record your results **in the table**.] **[2]**

(ii) Suggest why this method may not yield accurate results.

.....

.....

..... **[1]**

(iii) Sample **D** came from Permian, **C** from Cretaceous, **B** from Palaeogene and **A** from Neogene beds. The student has now concluded that the limestones on North Island increase in purity over time.

Evaluate the student's conclusion.

.....

.....

.....

.....

..... **[2]**

7 Read the information below, then answer the questions that follow.

Coral reefs (ancient and modern)

Tropical coral reefs occupy less than one percent of the Earth's marine environment, but they are home to more than a quarter of all known marine fish species and tens of thousands of other species found nowhere else on Earth. Coral reefs form a natural and self-repairing barrier that protects the coasts by absorbing the violent wave impacts of ocean storms and hurricanes.

In principle, there are three broad categories of tropical reef: 'fringing reefs', 'barrier reefs' and 'atolls'. Fringing reefs are mostly close to coastlines, barrier reefs are offshore, and atolls are typically a wall of reefs surrounding a central lagoon built on top of a subsiding island. Charles Darwin was the first to identify that fringing reefs surrounding an island, developed into barrier reefs as the island subsided and subsequently became an atoll when the island vanished below the sea.

Many ancient reefs, especially those of the Palaeozoic, were not built just by corals, but by a wide array of organisms including algae, sponges and molluscs, with microbial carbonates (carbonate mud) contributing to the construction of the framework. Some modern reefs are still formed in a similar manner, built predominantly by vermetid 'worms' (molluscs) or coralline algae. However, most modern reefs are dominated by scleractinian corals, in shallow, turbulent well-lit environments. There is no correlation between coral diversity and reef formation but there is a clear correlation between temperature and zooxanthellate coral distribution and also between temperature and the formation of highly consolidated reefs.

The bulk of any modern coral reef colony is composed of non-living matter; only the upper layer is living coral. With carbonate mud being largely absent from the reef crest and upper slope, it is coralline algae that cement various corals together with compounds of calcium, consolidating the reef. Reef limestones are typically unbedded because reefs form by growing upwards, however the reef slope, fore reef and basin can all be bedded and contain intraclasts (irregularly shaped grains). Zonation patterns (distribution of corals of the same morphological type) on the reef slope are common but highly variable, even between adjacent reefs of the same type.

An increase in hurricanes and storms in the Caribbean led to scientists performing a quantitative study of coral communities growing on the Tobago Cays reef slope, between St. Vincent and Grenada. This study produced the results shown in the table, for three different types of coral, at increasing depths.

		Colonies per 10 m^2		
Coral type	**Name**	Upper slope	Mid slope	Lower slope
Domed	*Orbicella annalaris*	2	5	8
Branching	*Acropora palmata*	16	4	0
Dish	*Helioseris cucallata*	0	0	16

(a) (i) Using the information, describe the distribution of coral types **and** suggest **one** potential reason for the distribution of the plate-like dish corals.

.....

.....

.....

.....

.....

.....

.....

..... **[3]**

(ii) Suggest **one** potential reason why the growth rate and consolidation levels of coral reefs might be controlled by temperature.

.....

..... **[1]**

(b) Fig. 7.1 shows a cross-section diagram through a modern fringing reef and carbonate platform.

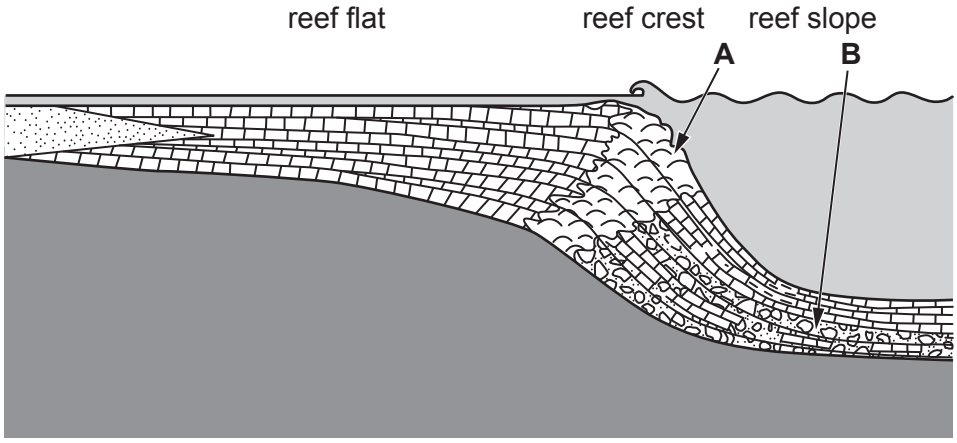


Fig. 7.1

(i) Using the Dunham classification, identify a likely rock that will form at **A**.

..... **[1]**

(ii) The rock that forms at **B** has a variable composition.

Describe the characteristics of the rock **and** the geological processes involved in its formation.

.....

.....

.....

..... **[2]**

(iii) Fig. 7.2 shows a thin-section diagram from a rock **C** found on Fig. 7.1.

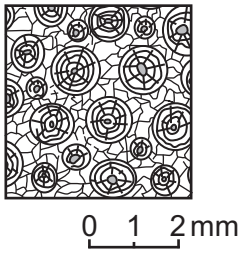


Fig. 7.2

On Fig. 7.1, use the letter **C** to indicate where rock **C** is most likely to have formed. **[1]**

(iv) A borehole is drilled just behind the reef crest and shows a succession of facies.

Explain the term facies association.

.....

..... **[1]**

(c) (i) Describe and explain how calcium enters carbonate seas as part of the rock cycle.

.....

.....

.....

.....

..... **[2]**

(ii) Only around 5% of modern carbonate deposits are of coral reef origin; most (90–95%) are deep sea sediments.

Describe the deposition in **deep water** carbonate seas above and below 4.5 km water depth.

.....

.....

.....

.....

.....

.....

.....

..... **[3]**

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).

OCR
Oxford Cambridge and RSA

Tuesday 12 October 2021 – Morning

A Level Geology

H414/02 Scientific literacy in geology

Time allowed: 2 hours 15 minutes

You can use:
- an HB pencil
- a pair of compasses
- a ruler (cm/mm)
- a scientific or graphical calculator

8956351529

H414O2

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. You can use extra paper if you need to, but you must clearly show your candidate number, the centre number and the question numbers.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

INFORMATION
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **32** pages.

ADVICE
- Read each question carefully before you start your answer.

BLANK PAGE

PLEASE DO NOT WRITE ON THIS PAGE

Answer **all** the questions.

1 **(a)** **(i)** Explain the term erosion.

.....

..... **[1]**

(ii) Describe how the process of erosion can result in the formation of mature sediments.

.....

.....

.....

.....

..... **[2]**

(b) Sediments and organic materials are transformed into rock during diagenesis. Part of this process involves cementation of the grains.

(i) Describe and explain how sandstones may be cemented by other minerals such as hematite or clay.

.....

.....

.....

.....

..... **[2]**

(ii) Other than hematite, state the name of another cement.

..... **[1]**

(iii) Peat is largely composed of the elements carbon, hydrogen, oxygen, nitrogen and sulfur.

Describe the chemical changes that occur during diagenesis which allow coal to form from peat.

.....

.....

.....

.....

..... **[2]**

(c) Stylolites are structures that look like serrated surfaces. They are formed by pressure dissolution in sedimentary rocks.

Stylolites are found commonly in limestone or chalk, but are found less commonly in some other rocks, such as mudstone. The serrated surfaces can only be seen at right angles to the bedding, usually in cliff sections.

Fig. 1.1 shows stylolites found in two different types of rock which formed early during diagenesis. It also shows some detail of fluid movement in the limestone.

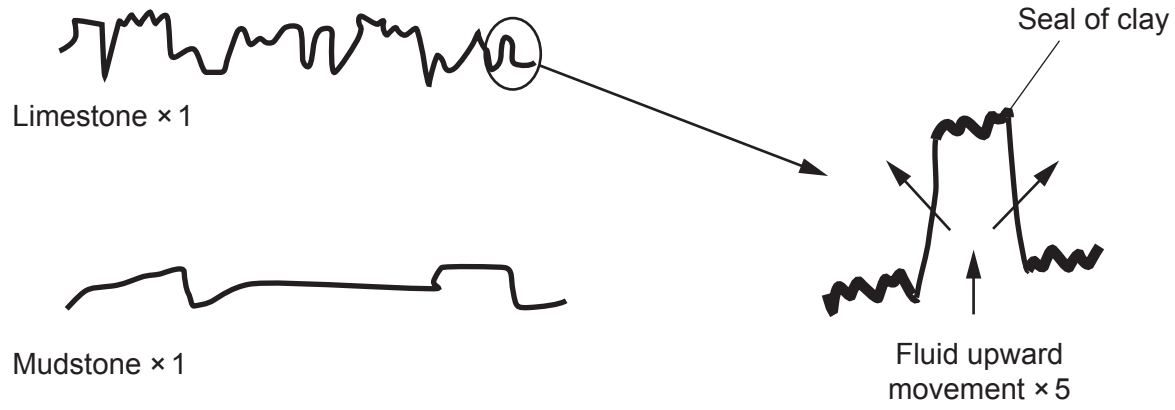


Fig. 1.1

(i) Explain how stylolites form in limestone.

Use the information provided and your knowledge of pressure solution in your answer.

.....

.....

.....

.....

..... **[2]**

(ii) Explain the effect of the formation of stylolites on the porosity and permeability of limestone.

.....

..... **[1]**

(iii) Explain the source of the **clay** labelled in **Fig. 1.1**.

.....

..... **[1]**

(iv) Give **one** geological reason why stylolitic limestone is used for flooring.

.....

..... **[1]**

(d) (i) Identify the sedimentary structures shown in **Fig. 1.2**.

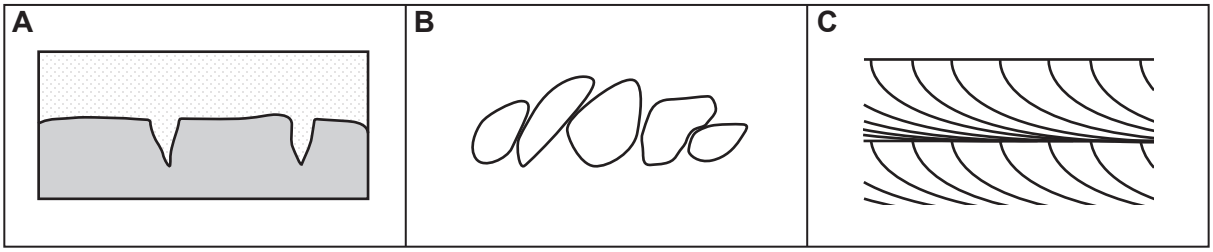


Fig. 1.2

A .....

B .....

C .....

[3]

(ii) Which of the structures, **A**, **B** or **C**, can be used to determine the 'way-up' of a bed?

Tick (✓) **two** boxes.

A ☐

B ☐

C ☐

[1]

(e) Describe how the composition and characteristics of sediments change from the littoral zone (beach), to below the wave base, in a shallow siliciclastic sea.

You may use an annotated diagram to illustrate your answer.

.....

.....

.....

.....

.....

..... **[3]**

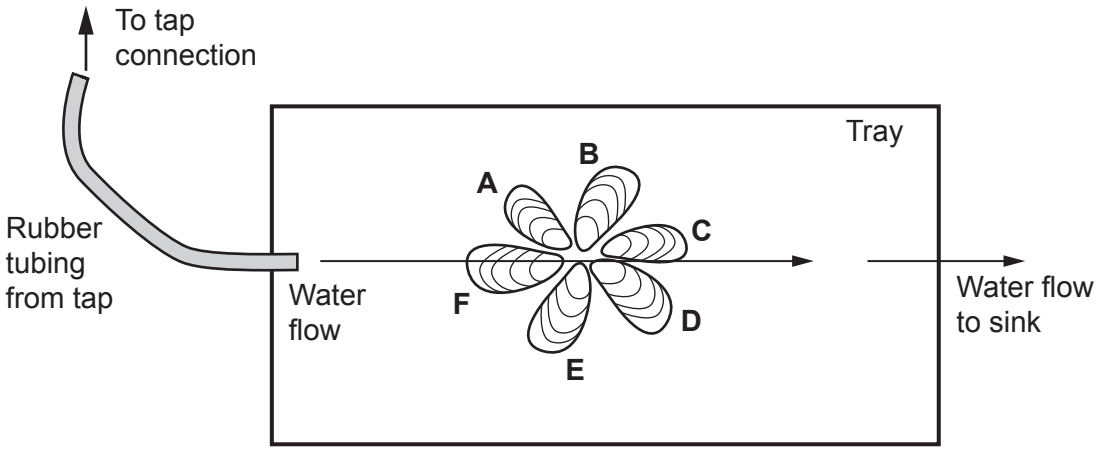
BLANK PAGE

PLEASE DO NOT WRITE ON THIS PAGE

2 **(a)** A student investigates how modern shells are transported by a current of water. This is the method they follow:

- Put a shallow tray at an incline of 15°, with the lower part of the tray overhanging a sink.
- Place six mussel shells in the centre of the tray, in the pattern shown in **Fig. 2.1**. The mussels should be laid concave-side down and with the umbones pointing to the centre.
- Connect rubber tubing to a tap and place the end at the top of the tray in the middle.
- Turn the tap on and allow water to overflow into the sink.
- Turn the tap off when one of the shells reaches the bottom of the tray.
- Use a compass clinometer to record the orientations of the six mussel shells, at the long axis.
- Repeat this method.

The student's results were recorded in **Table 2.1**.



Plan view

Fig. 2.1

Shell	Orientation of shell in degrees (°)			
	First experiment		Second experiment	
	Raw data	Data after correction	Raw data	Data after correction
A	259	**079**	260	.....
B	095	**095**	222	.....
C	016	**016**	012	.....
D	249	**069**	328	.....
E	268	**088**	055	.....
F	070	**070**	355	.....
Average		.....		.....

Table 2.1

(i) Correct the data for the second experiment in **Table 2.1** so that all values lie between 0 and 180°. Record these values in **Table 2.1**. **[2]**

(ii) Calculate the average values for both experiments. Record these values in **Table 2.1**. **[1]**

(iii) Give **two** reasons to explain the differences between the two averages in **Table 2.1**.

1 .....

.....

2 .....

.....

[2]

(iv) Suggest **one** improvement that could be made to the method.

.....

..... **[1]**

(v) Evaluate if this experiment could be used as a model to explain the distribution of shells in some sedimentary rocks.

.....

.....

.....

.....

.....

.....

.....

..... **[3]**

(b) The student wanted to see if they could conduct a different experiment to look at the effect of attrition on the preservation of shells.

Suggest a method they could follow in a school laboratory to investigate the effect of attrition on the preservation of modern shells.

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... **[4]**

3 **(a)** Information from seismograms can be used by seismologists to locate the epicentre of an earthquake.

Fig. 3.1 shows simplified seismograms from three seismometers from the same earthquake.

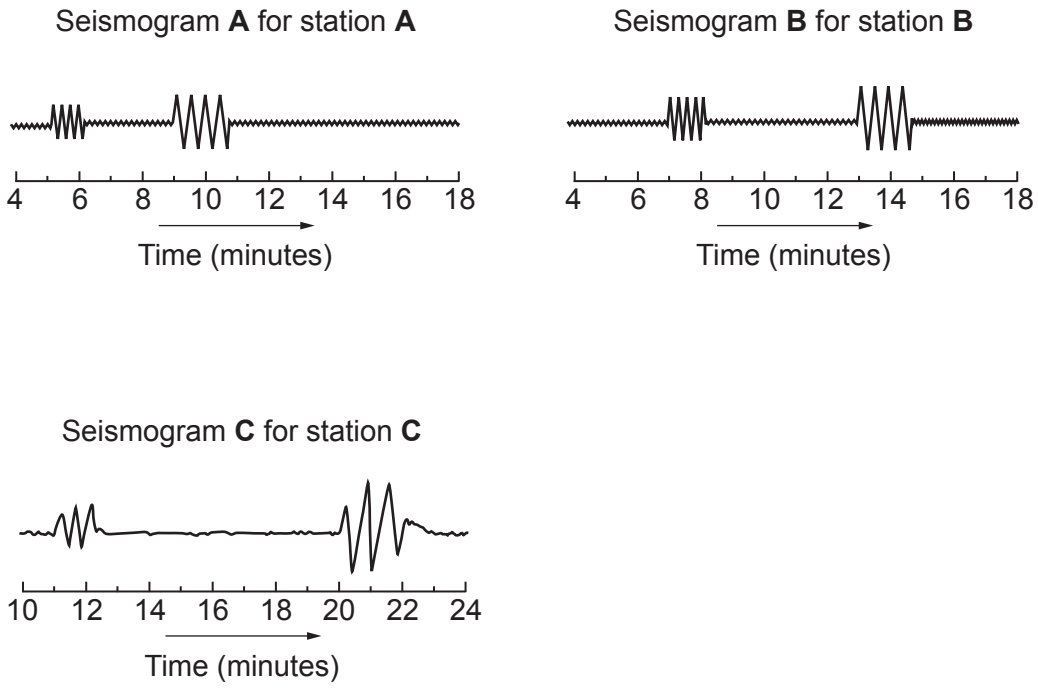


Fig. 3.1

(i) Using the seismograms in **Fig. 3.1**, measure the difference in the first P and S wave arrival times for seismograms **B** and **C**.

Seismogram **A** has been completed for you.

	P and S wave arrival time difference (min)
Seismogram **A**	4
Seismogram **B**	
Seismogram **C**	

[2]

(ii) **Fig. 3.2** shows time–distance curves for P and S waves.

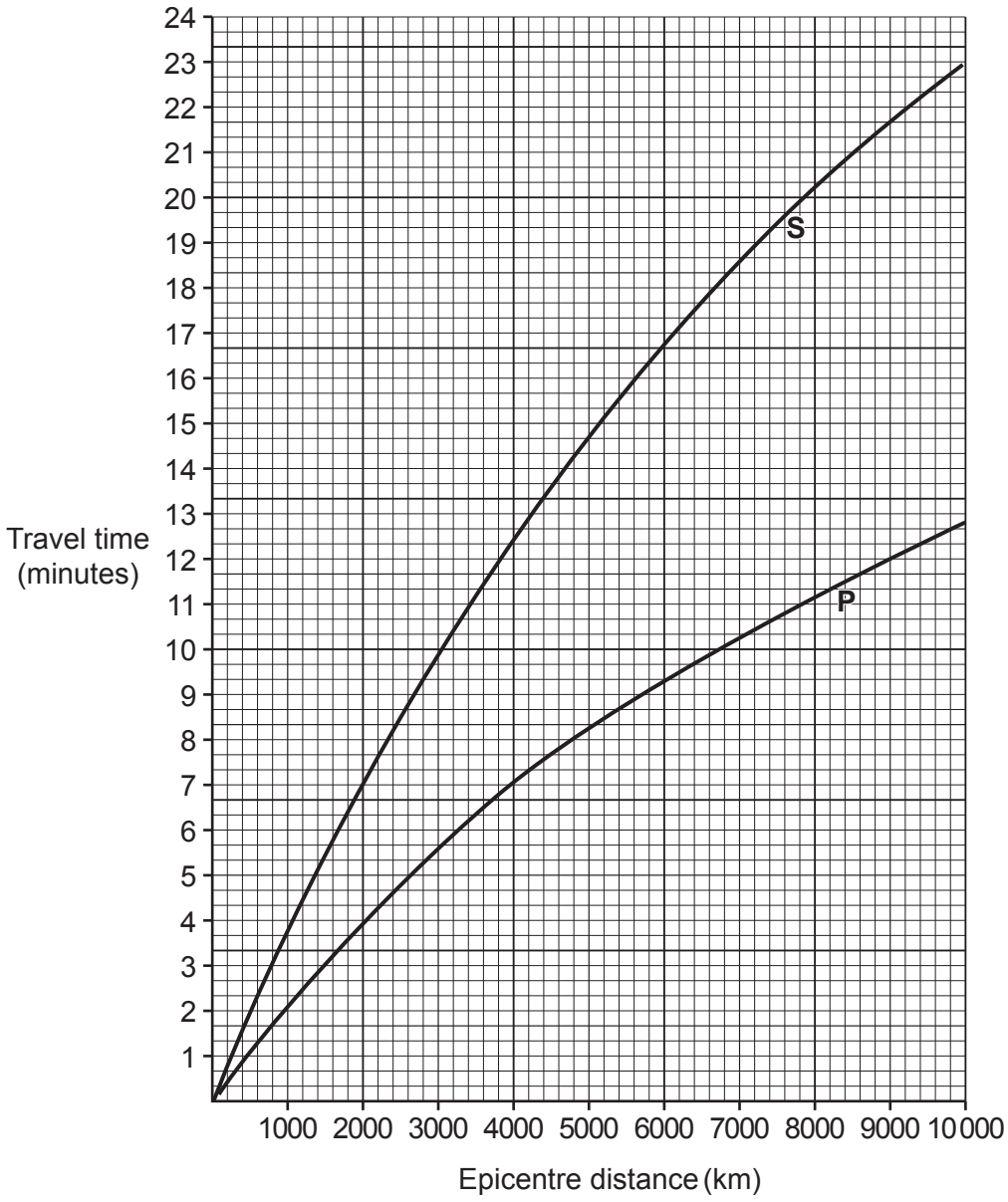


Fig. 3.2

Using your answers from **3(a)(i)** and the time–distance curves in **Fig. 3.2**, determine the distance from the epicentre for stations **B** and **C**.

Station **A** has been determined for you.

Station **A** distance .....2800..... km

Station **B** distance ..... km

Station **C** distance ..... km

[2]

(iii) The geographical locations for seismometer stations **A**, **B** and **C** are shown on the map in **Fig. 3.3**.

Using the distance from epicentre data for all three stations, locate and label the epicentre of the earthquake on the map.

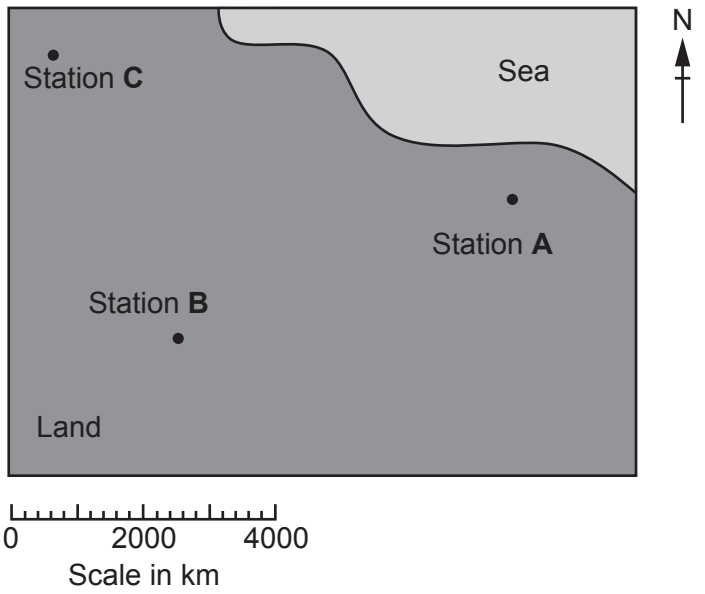


Fig. 3.3

[Answer on Fig. 3.3]

[3]

(b) Seismic tomography is a technique that allows the creation of 2D or 3D virtual images from an analysis of the behaviour of seismic waves as they pass through a section of the Earth.

Fig. 3.4 shows a cross-section through Fiji and Tonga with slower than average and faster than average P-wave velocities highlighted.

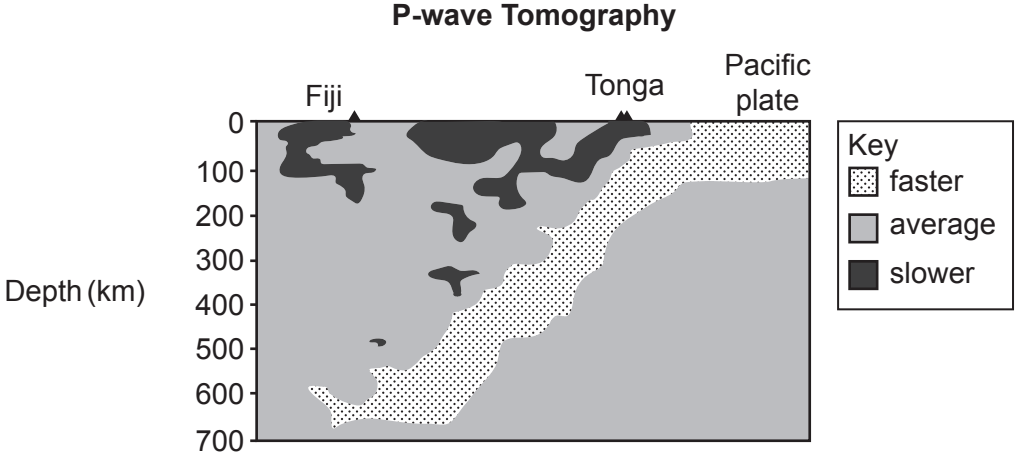


Fig. 3.4

(i) Identify the geological feature shown in **Fig. 3.4**.

.....

..... **[1]**

(ii) Explain the reasons for the positive **and** negative P-wave velocity anomalies.

.....

.....

.....

.....

..... **[2]**

(iii) Describe how seismic tomography can be used to determine the position of the asthenosphere.

.....

..... **[1]**

(iv) Explain why there are only shallow focus earthquakes at mid-ocean ridges.

.....

..... **[1]**

BLANK PAGE

PLEASE DO NOT WRITE ON THIS PAGE

4 Archbishop James Usher, a 17th Century biblical scholar, calculated the age of the Earth as 5650 years. Early geoscientists accepting this age, needed to explain how all of the geology that they could see could have formed in such a short space of time. This led to the development of the theory of catastrophism, in part supported by the work of the 18th Century French naturalist and zoologist Georges Cuvier.

James Hutton, an 18th Century Scottish geologist, considered the Earth to be much older than this and he proposed an alternate theory to that of catastrophism.

Fig. 4.1 shows a field sketch of the geology observed by James Hutton at Siccar Point on the East coast of Scotland.

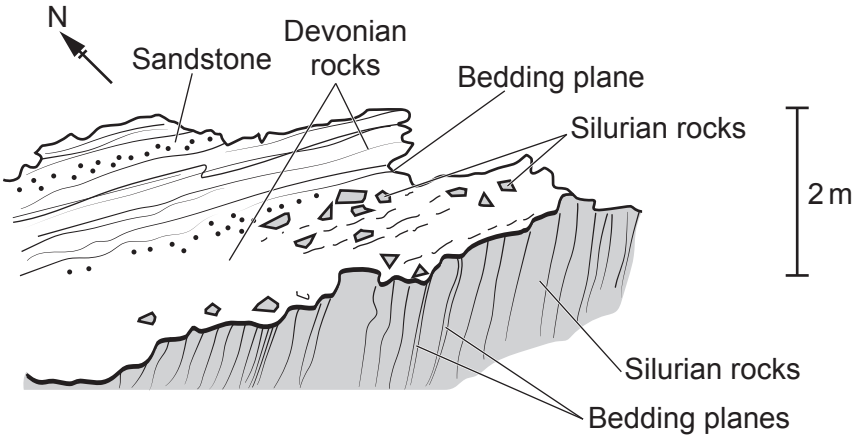


Fig. 4.1

(a) (i) Describe **one** piece of evidence that supports the theory of catastrophism.

.....

..... **[1]**

(ii) Name the alternative theory **and** the physical process proposed by James Hutton.

Alternative theory .....

Physical process .....

[2]

(iii) Explain what is meant by the statement 'The present is the key to the past'.

.....

.....

..... **[1]**

(iv) State **two** relative dating principles that can be seen in **Fig. 4.1**.

1 .....

2 .....
[2]

(v) Explain how one of the named methods in **4(a)(iv)** can be used to establish the sequence of geological events.

.....

.....

..... **[1]**

(vi) Explain how biostratigraphy could be used to correlate the sequence of rocks at Siccar Point with those elsewhere in Scotland.

.....

..... **[1]**

(vii) What are included fragments **and** how might they affect the process of relative dating?

.....

.....

.....

.....

..... **[2]**

(viii) Explain how the work of William Smith supports the theory proposed by James Hutton.

.....

.....

..... **[1]**

(b) (i) Sedimentation rates have been used to calculate the age of the Earth.

Describe **two** limitations of using this method.

1 .....

.....

2 .....

.....

[2]

(ii) A core through Devonian rock shows that 141 metres of sediment was deposited over a period of 7.2 million years.

Calculate the average rate of sedimentation in mm per year.

Give your answer to **3** significant figures.

Rate of sedimentation = ... mm per year **[2]**

BLANK PAGE

PLEASE DO NOT WRITE ON THIS PAGE

(c) The geological map shown in **Fig. 4.2** can be used to identify a series of sedimentary and structural events. Some have been listed and numbered (not in chronological sequence).

1. Deposition of coal
2. Uplift & Tilting 15º W
3. Deposition of siltstone
4. Strike Slip Fault
5. Deposition of sandstone
6. Uplift & Tilting 5º E
7. Deposition of conglomerate
8. Folding E-W

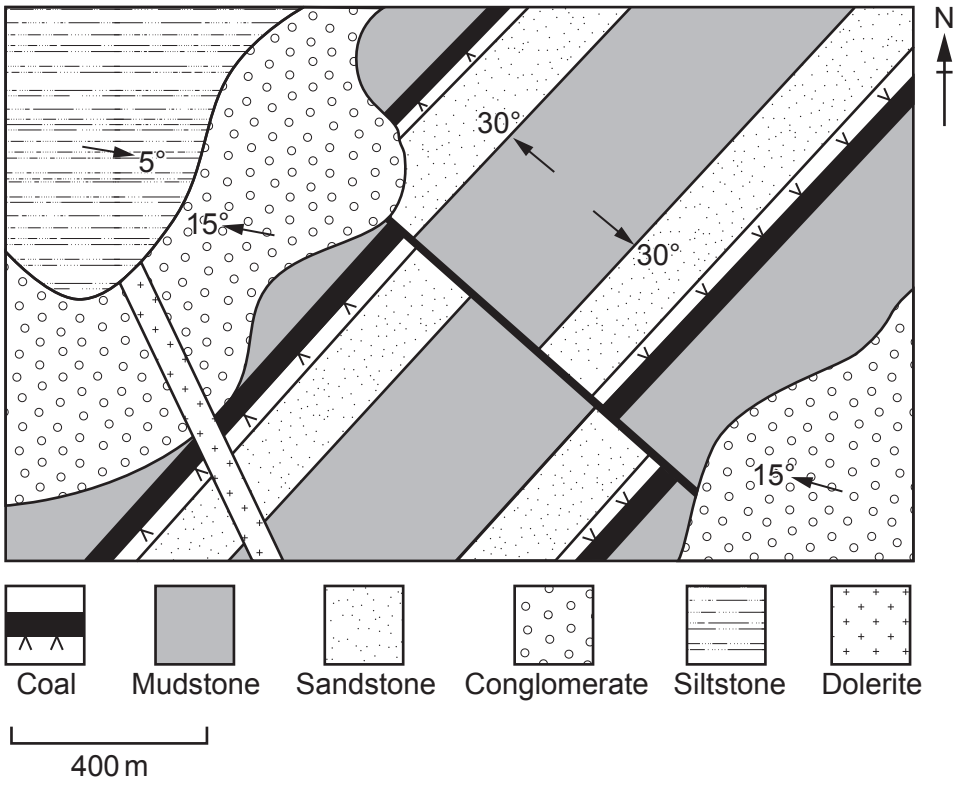


Fig. 4.2

(i) Complete the table of structural events from youngest to oldest by writing the correct number from the list of events shown in **Fig. 4.2**.

Structural Events	Number
Youngest	
Oldest	

[1]

(ii) Complete the table of sedimentary events from youngest to oldest by writing the correct number from the list of events shown in **Fig. 4.2**.

Sedimentary Events	Number
Youngest	
Oldest	

[1]

5 **(a)** Pressure due to the mass of overlying rocks interacts with pore pressure from fluids within any void spaces and can be significant when considering slope stability. **Fig. 5.1** shows a number of rock layers, their thicknesses and their unit weights, and the position of the water table.

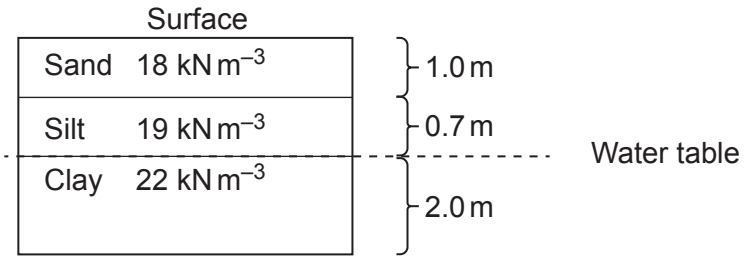


Fig. 5.1

Pore pressure $\mu = g_w h_w$

$g_w = 9.81\,kN\,m^{-3}$

h_w = depth below water table

Total normal stress σ = sum of the unit weight of all of the layers

Effective stress $\sigma^1 = \sigma - \mu$

(i) Calculate the effective stress at the base of the clay layer shown in **Fig. 5.1**.

Effective stress = ... $kN\,m^{-2}$ **[3]**

(ii) Addition of water is a common cause of slope failure.

Describe **one** method of slope stabilisation that could mitigate against water.

.....

..... **[1]**

(b) In 1999 a landslide, composed of 45 000 km^3 of mud, rock and concrete, struck a city in the Philippines. Heavy rainfall due to tropical cyclone Olga intensified the normal monsoon rainfall and a total of 565 mm of rainwater fell in 3 days, the equivalent of 120 days' normal rainfall. Developers claimed that this unusually high rainfall was the only reason for the landslide. However, geologists examining the scene considered that other factors may have been in play. The landslide destroyed 379 houses in the area.

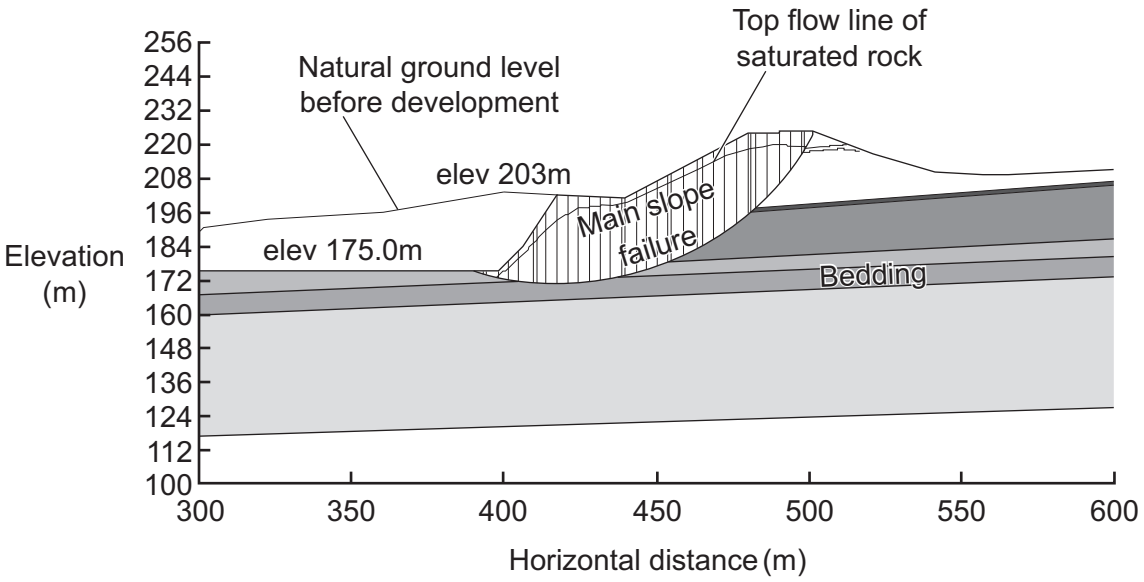


Fig. 5.2

The underlying geology of the affected area was comprised of heavily fractured interbedded siltstones, sandstones and clays with varying degrees of permeability and shear strength. X-ray phase analysis of clay samples taken from under the houses showed high levels of smectite, up to 58%, whilst in the wider area illite dominates the clay composition with smectite as low as 7%. Bedding planes in the mountains to the North and East of the area varied from horizontal to having an 8° South West dip. See **Fig. 5.2**.

Development of the area began in 1991. Excavation into the hill sides led to the construction of low-cost concrete housing units with shallow foundations on slopes of up to 25°. Due to the known flash-flood risk, trenches were dug between houses to divert run-off. However, these retained water which seeped into the foundations.

Prior to this, over-quarrying of the mountain ranges around the city and rainforest clearing in the vicinity of the area had been allowed to continue unchecked.

In 1994, 5 years before the landslide, hairline fissures began to open up in the walls and pavements around the area.

(i)* Evaluate the developers' claim that heavy rainfall alone could have been the cause of the landslide.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... **[6]**

Additional answer space if required.

.....

.....

.....

.....

.....

.....

(ii) Describe and explain **one** chemical ground improvement strategy that could have been used to improve the area prior to the housing development.

.....

.....

.....

.....

..... **[2]**

(iii) Geotechnical site investigations were not completed prior to the housing development and building commenced before planning was approved.

Describe **two** techniques that would have been included in a geotechnical site investigation.

1 .....

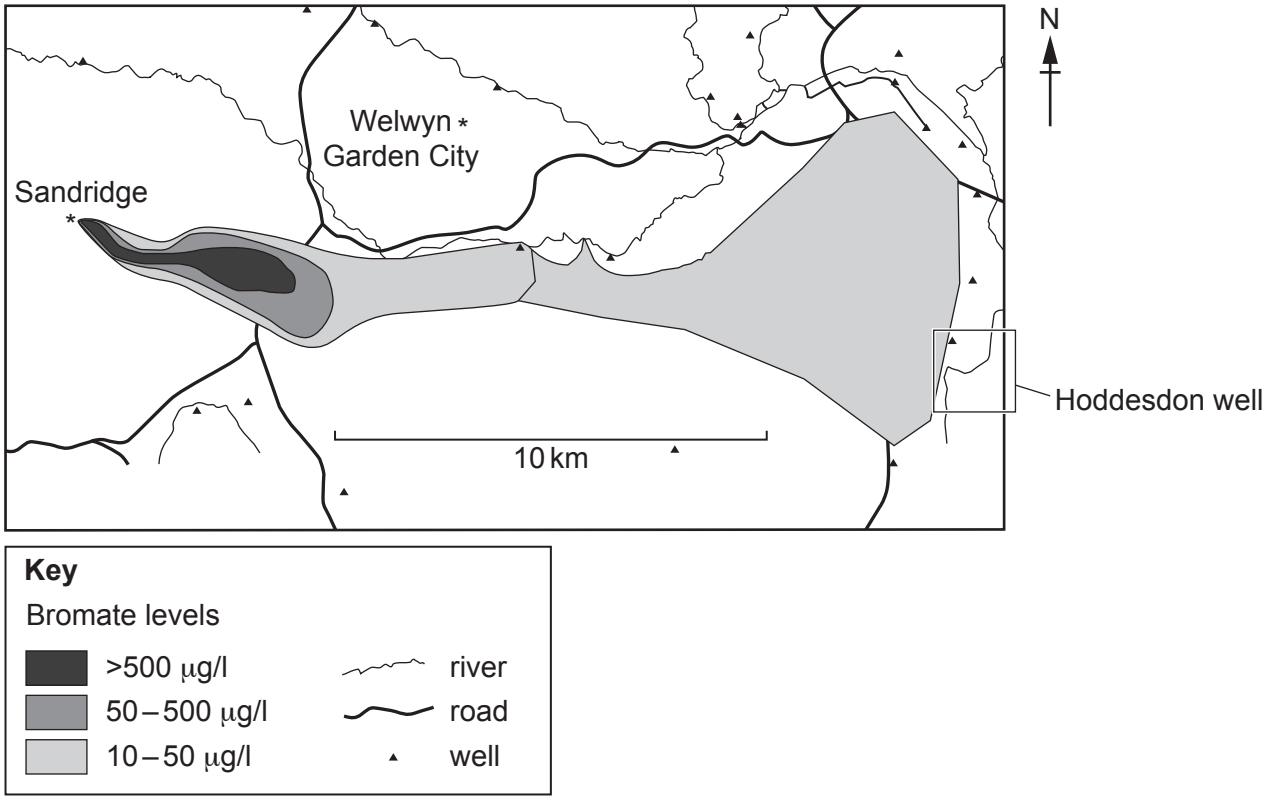
.....

2 .....

.....

[2]

6 A bromate pollution plume, in the Hertfordshire chalk, was discovered in the mid 2000s. The plume, shown in the map below, stretched 20 km to the East from Sandridge. The source of the contamination was a former chemical factory in the village of Sandridge. The brownfield site was redeveloped for housing but not all contaminated subsurface material was removed.



(a) Data from Hoddesdon well shows fluctuations in bromate levels. Safe levels for drinking water are 10 μg/l.

(i) Explain why the water authority consider that bromate levels in the groundwater will increase in drought years.

.....

..... **[1]**

(ii) Diluting water from the Hoddesdon well with clean water from elsewhere will lower the overall concentration of bromate.

The Hoddesdon well produces 1200 m^3 of water per day.

Clean water is available from a well in Hertfordshire at 1820 m^3 per day. This well does not contain any bromate.

Calculate the highest acceptable concentration of bromate in the Hoddesdon well to achieve a diluted concentration of 10 μg/l once mixed.

Bromate concentration = ... μg/l **[2]**

(iii) Describe **two** steps that could be taken to reduce the bromate pollution.

1 .....

.....

2 .....

.....

[2]

(b) Engineering works were required on the chalk bedrock near Welwyn Garden City to mitigate localised subsidence.

Explain the likely cause of this subsidence.

.....

.....

..... **[1]**

7 Read the information below, then answer the questions that follow.

Who were the Archosaurs?

Archosauria ('ruling reptiles') are a group of animals known as diapsid amniotes, generally classed as reptiles. They belong to the phylum Chordata and many are also tetrapods due to the evolution of fin bones into limb bones.

Diapsids ('two arches') is a name given to the two temporal openings, or holes, in each side of their skulls which are close to the eyes. This evolutionary change is believed to have occurred in early representatives of the group, as far back as the Permian, well before the age of the true dinosaurs. This reduction in the skull bone content is thought to have allowed the skull to be lighter providing more space for muscles and tissues, and may have increased the flexibility of the skull when the animal was feeding. This reduction in skull bone content continued in later tetrapods and was coupled with fusion of multiple bones in the skull, presumably to increase skull strength.

All extant forms of the Archosaurs are amniotes and they lay fertilised eggs on land. It is believed that this was also the case for the extinct forms. These are distinguished from anamniotes, such as fish and amphibians, who lay eggs in water.

Archosaurs have both living and extinct representatives. Extant forms include birds and crocodilians. Extinct forms include pterosaurs and dinosaurs. The classification can be simplified into two major groups, as shown in **Fig. 7.1**.

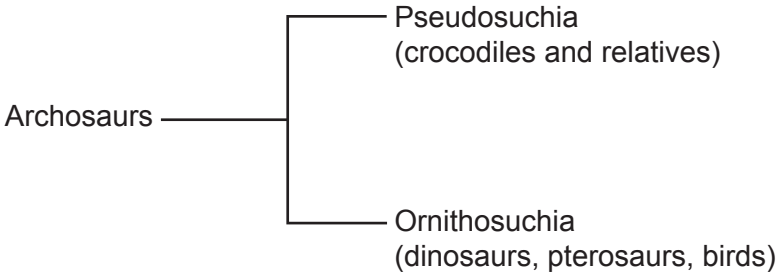


Fig. 7.1

These two groups of Archosaurs show differences in their arrangement of bones, especially in the ankle joint, as shown in **Fig. 7.2**. There were also other evolutionary skeletal changes in teeth, leg bones, and toes.

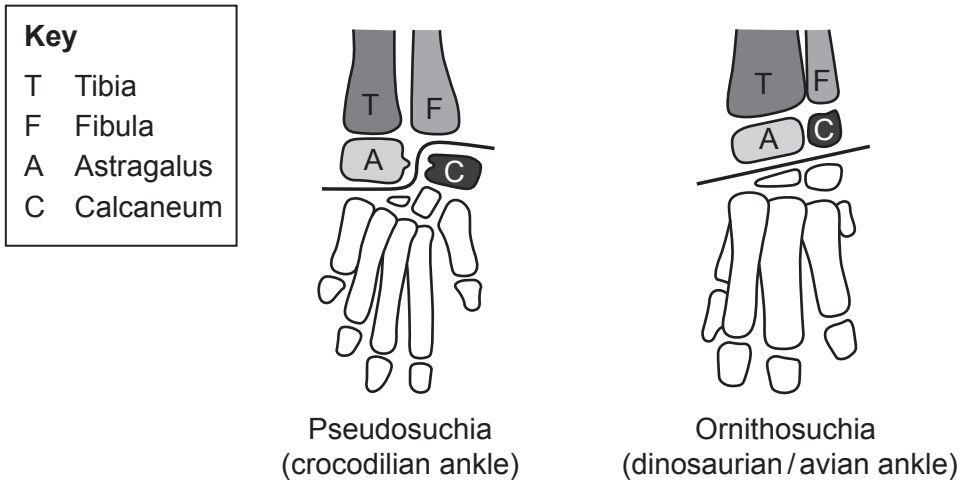


Fig. 7.2

Archosaurs in the fossil record are diverse and the living representatives of the Archosaurs (birds and crocodiles) are not typical. This group includes tiny animals of only a few centimetres, such as hummingbirds, to giant dinosaurs around the size of a bus. It includes animals that walked on two legs, and those who walked on four. Fliers and swimmers. Nectar feeders, herbivores and carnivores.

(a) (i) Using the information, describe the characteristics of a tetrapod.

.....

..... **[1]**

(ii) Give **two** advantages of reptiles being diapsid amniotes.

1 .....

.....

2 .....

.....

[2]

(iii) Describe **one** morphological difference between the eggs laid by amniotes and those laid by anamniotes (amphibians).

.....

..... **[1]**

(iv)* The evolution of locomotion in the Archosaurs followed different paths, resulting in morphological differences between Pseudosuchia (crocodilians) and Ornithosuchia (dinosaurs, pterosaurs and birds).

Use information from the article provided as well as your knowledge of reptile, dinosaur and bird evolution to evaluate the suitability of morphology to mode of life.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... **[6]**

Additional answer space if required.

.....

.....

.....

.....

.....

.....

(b) Several features of dinosaurs are described in the table.

Complete the table to classify the features as belonging to Saurischian sauropods (SS), Saurischian therapods (ST), or Ornithischian (O) dinosaurs. Each feature may belong to one or more than one dinosaur group.

Description of dinosaur feature	**Dinosaur classification (SS, ST and/or O)**
Short and flattened peg shaped teeth	
Large olfactory lobes	
Hinged jaw containing teeth suitable for grinding	
Primitive hips with pubis bone which points forward	

[4]

(c) Several groups of reptiles evolved flight in the Mesozoic, including the pterosaurs, which were not dinosaurs. A fossil of one of these pterosaurs, *Wukongopterus*, was found in China in 2009. It has been dated to the late Jurassic. It has been described as a carnivore and was around the size of a pigeon. The skeleton was incomplete.

The skeletal outline of a *Wukongopterus* is shown in **Fig. 7.3**.

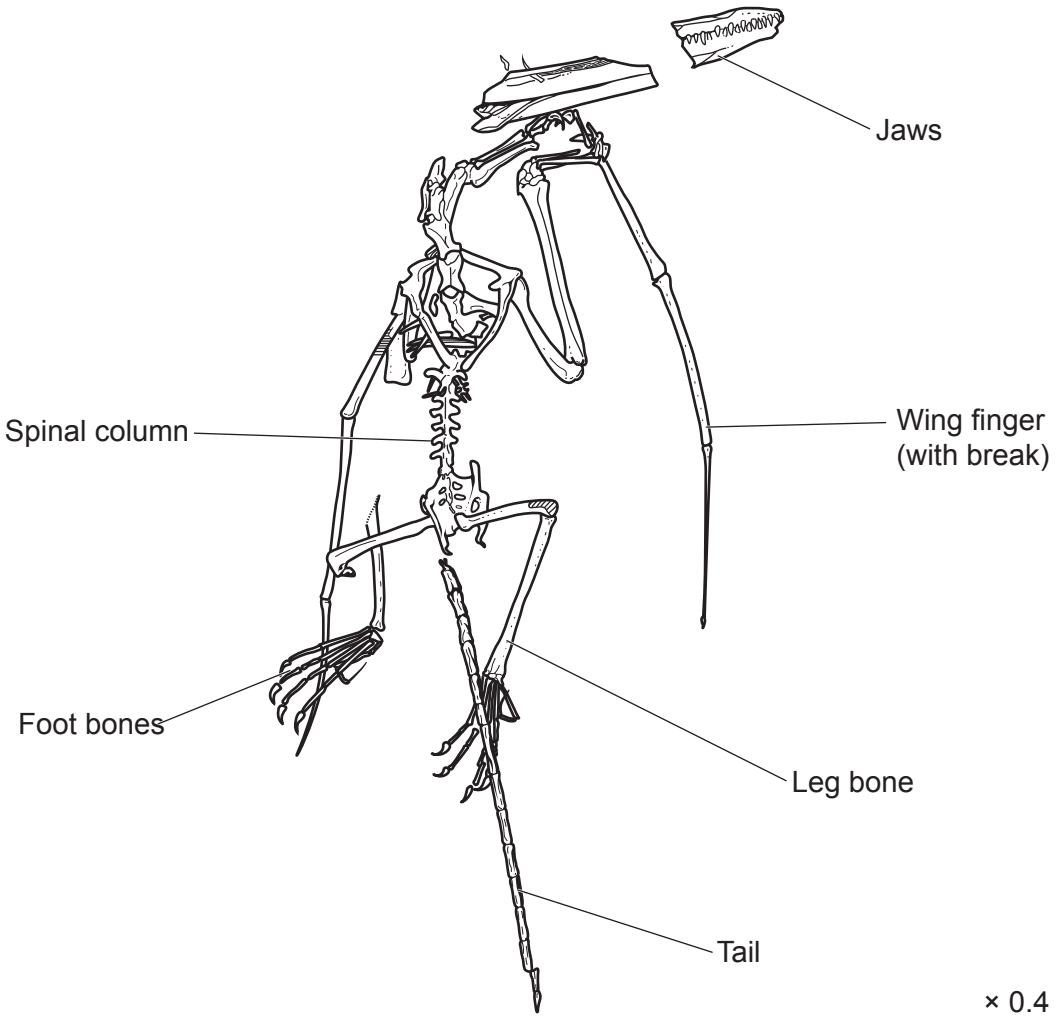


Fig. 7.3

Describe how pterosaurs and bird evolution could be described as convergent. Use the information provided about *Wukongopterus* and your knowledge of the evolution of birds in your answer.

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... **[4]**

END OF QUESTION PAPER

OCR
Oxford Cambridge and RSA

Tuesday 14 June 2022 – Morning

A Level Geology

H414/02 Scientific literacy in geology

Time allowed: 2 hours 15 minutes

You can use:
- an HB pencil
- a protractor
- a ruler (cm/mm)
- a scientific or graphical calculator

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

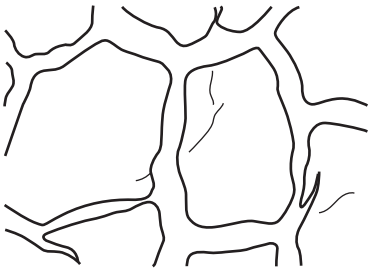
INFORMATION
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **24** pages.

ADVICE
- Read each question carefully before you start your answer.

Answer **all** the questions.

1 (a) (i) Identify the sedimentary structures **A**, **B** and **C**.

A

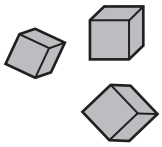


View from above ×0.2

B

View from side ×1

C



View from above ×0.4

A .....

B .....

C .....

[3]

(ii) Sedimentary structures can be used to determine the way up of a sequence and the direction of flow of a palaeocurrent.

Fill in the table with a ✓ **or** ✗ to indicate if each sedimentary structure can be used to determine the way up or palaeocurrent direction.

Sedimentary structure	Way up ✓ or ✗	Palaeocurrent direction ✓ or ✗
A		
B		
C		

[3]

(iii) Describe the characteristic sediments and sedimentary structures found in a shallow siliciclastic sea.

.....

.....

.....

.....

..... **[2]**

(b) Walther's Law of facies was first described by the geologist Johannes Walther in 1894.

Both the terms facies and Walther's Law are well known and have been used extensively in sedimentology ever since.

(i) Using ideas of Walther's Law of facies, describe the changes in sediment type in a braided river. You may use a labelled diagram to illustrate your answer.

.....

.....

.....

.....

.....

..... **[3]**

(ii) The pebbles in a braided river were investigated to see if the upper part of the river had an effect on the roundness of pebbles.

A student wanted to test the hypothesis that the shape of the pebbles is random and so decided to perform a chi squared test.

Forty pebbles were collected from the river bed, using random sampling and categorised as angular, sub-angular, sub-rounded or rounded.

The results are shown in the table.

	Angular	**Sub-angular**	**Sub-rounded**	**Rounded**
Observed frequency (*O*)	20	10	7	3
Expected frequency (*E*)				
$O - E$				
$(O - E)^2$				
$\frac{(O - E)^2}{E}$				

Calculate chi squared, χ^2.

Use the formula: $\chi^2 = \sum \frac{(O - E)^2}{E}$

You can fill in the table to help.

χ^2 = ... **[4]**

(iii) Using the probability table, comment on the significance of the results you have calculated.

State whether you accept or reject the hypothesis and at what significance level.

p%	10	5	2.5	1	0.5
df =					
1	2.706	3.841	5.024	6.635	7.879
2	4.605	5.991	7.378	9.210	10.60
3	6.251	7.815	9.348	11.34	12.84
4	7.779	9.488	11.14	13.28	14.86
5	9.236	11.07	12.83	15.09	16.75

df = degrees of freedom

.....

.....

.....

.....

..... **[2]**

(c) A student made some geological observations on a cliff face where the beds were dipping at 15 degrees.

Their observations are shown in the table.

Bed	Lithology	Structures and fossils	Description	Thickness (m)
G	Coal Mudstone	Rootlets	Youngest, top of the sequence Dark layers with coal material in organic rich mudstones	1.10
F	Sandstone	Plant fragments Erosional base Unidirectional ripples Cross-bedding	Coarse grained sandstone This bed cuts down through the previous bed (erosional base)	5.00
E	Sandstone	Cross-bedding Plant fragments	Poorly sorted medium to coarse grained sandstone Some large scale cross-bedding	6.60
D	Sandstone Mudstone	Cross-bedding (medium and small scale) Bioturbation	Interbedded yellow sandstones and thin bedded mudstones Sandstone becomes coarser upwards and forms an overhang above unit C	7.10
C	Fine grained sandstone	Intensely burrowed Cross-bedding	Very fine grained yellowish sandstone with large scale cross-bedding (hummocky) Some organic (carbon) dark layers a few cm thick are present throughout	7.40
B	Mudstone	Bioturbation Laminated bivalves	Dark grey to black colour, containing occasional thin layers of silt Quite loose fragments, not very stable	5.40
A	Coal Mudstone	Rootlets Thin shelled bivalves	Oldest, bottom of the sequence Dark layers with coal material Some layers more muddy with bivalves	1.50

(i)* Using the information in the table, evaluate the sedimentary environment of deposition.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... **[6]**

Additional answer lines if required.

.....

.....

.....

.....

.....

(ii) In addition to colour, sediment composition and sedimentary structures, describe **two** other observations that could be made when describing a sedimentary rock in hand specimen while in the field.

1 .....

2 .....

[2]

(iii) The thickness of each bed was estimated.

Explain how the student estimated these thicknesses in a vertical cliff face.

.....

..... **[1]**

(iv) Consider **two** health and safety implications **and** suggest a way of mitigating each issue when logging a sedimentary sequence in the field.

.....

.....

.....

.....

..... **[2]**

2 **(a)** Early ideas about the Earth included the theory of continental drift, first proposed by Wegener in 1915.

(i) Describe the evidence that Wegener used to propose the theory of continental drift.

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... **[4]**

(ii) Wegener's theory has been further developed and has led to our current understanding of plate tectonics.

Describe and explain the mechanisms that allow the tectonic plates to move.

.....

.....

.....

.....

..... **[2]**

(iii) Describe the density **and** compositional differences between an oceanic and a continental plate.

.....

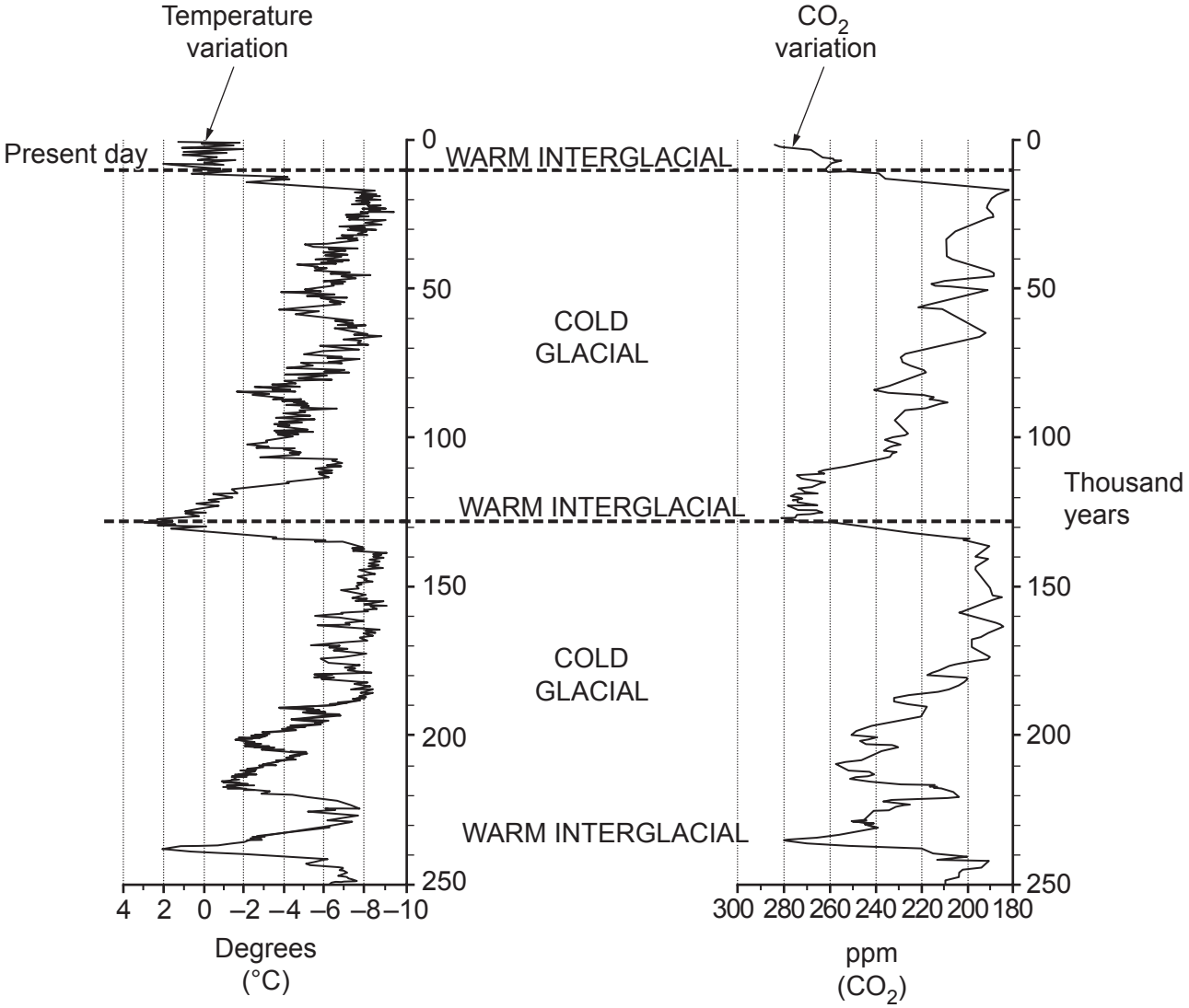
.....

.....

.....

..... **[2]**

(b) The graph shows the CO_2 concentration and global temperature in the last 250 thousand years.



(i) Calculate the maximum increase in CO_2 concentration between 250 and 230 thousand years as a percentage change.

Percentage change = ... **[2]**

(ii) CO_2 concentrations have been much higher in the past. For example, during the Precambrian, the concentration has been calculated as above 6000 ppm.

Explain why the CO_2 concentration was so high during the Precambrian.

.....

.....

.....

.....

..... **[2]**

(iii) Suggest **one** reason for the presence of cycles identified in the graph.

.....

..... **[1]**

(c) (i) The present day is technically part of the Holocene, the uppermost division of the Quaternary Period.

Scientists have recently debated and identified that the present day is part of a new geological epoch, which follows the Holocene.

Identify this new geological epoch.

..... **[1]**

(ii) Describe the evidence that scientists have used to propose that the present is no longer part of the Holocene.

.....

.....

.....

.....

.....

.....

.....

..... **[3]**

3 **(a)** **(i)** Metamorphism can be described as a solid state isochemical process.

Explain the meaning of this statement.

.....

.....

.....

.....

..... **[2]**

(ii) Using examples, explain the term **retrograde metamorphism**.

.....

.....

.....

.....

..... **[2]**

(b) A geologist surveyed an area which had undergone regional metamorphism. **Fig. 3.1** shows a sketch map of the minerals found at each location.

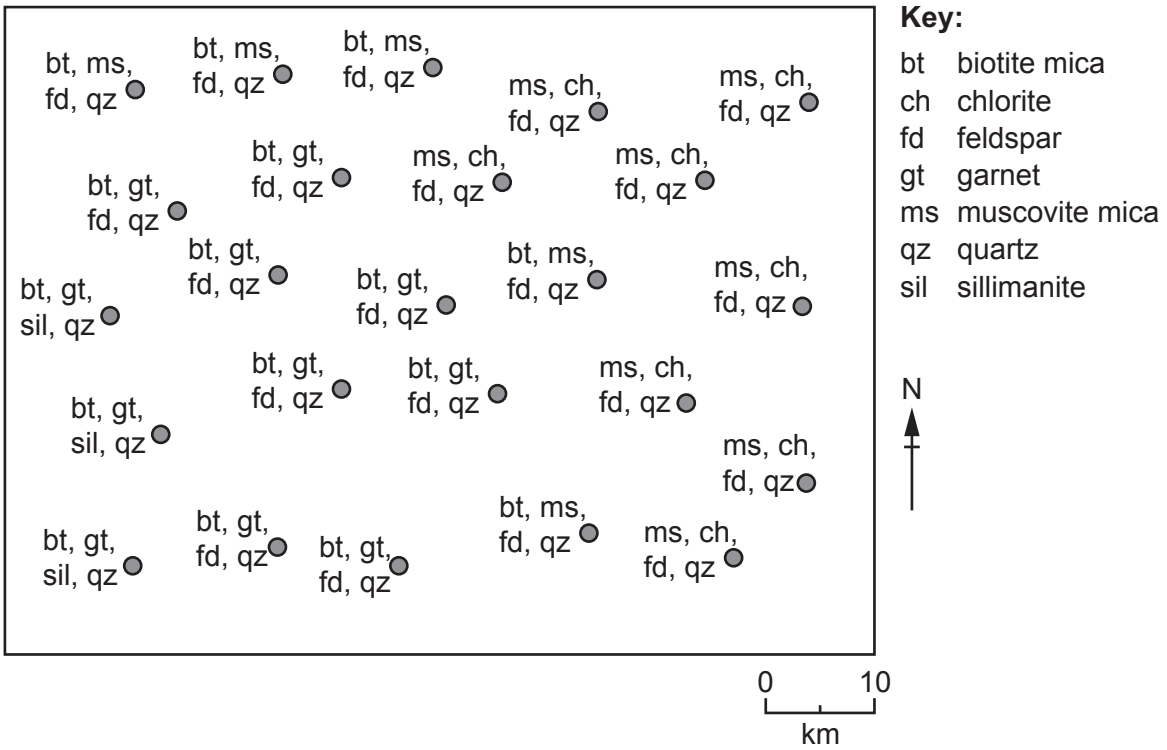


Fig. 3.1

Use your knowledge of metamorphic index minerals to complete the map by drawing on the isograds **on Fig. 3.1** to identify each metamorphic grade. **[2]**

(c) (i) **Table 3.1** shows the descriptions of two different metamorphic rocks, **A** and **B**.

Rock	Colour	Texture	Mineral composition	Foliated
A	White or grey	Granoblastic Medium-sized crystals Average size – 3 mm	Quartz Small amount of biotite mica	No
B	Grey/black and white bands	Very coarse crystals Average size >5 mm	Biotite mica Hornblende Sillimanite K feldspar Quartz	Yes

Table 3.1

Using **Table 3.1**, fill in the table below by identifying the likely parent and resultant metamorphic rock for **A** and **B**.

Rock identification	Parent rock	Metamorphic rock
A		
B		

[4]

(ii) Draw a labelled thin-section sketch of the metamorphic fabric of rock **A**.

Include a scale on your diagram.

[3]

(d) **Fig. 3.2** shows the metamorphic facies at different temperatures and pressures.

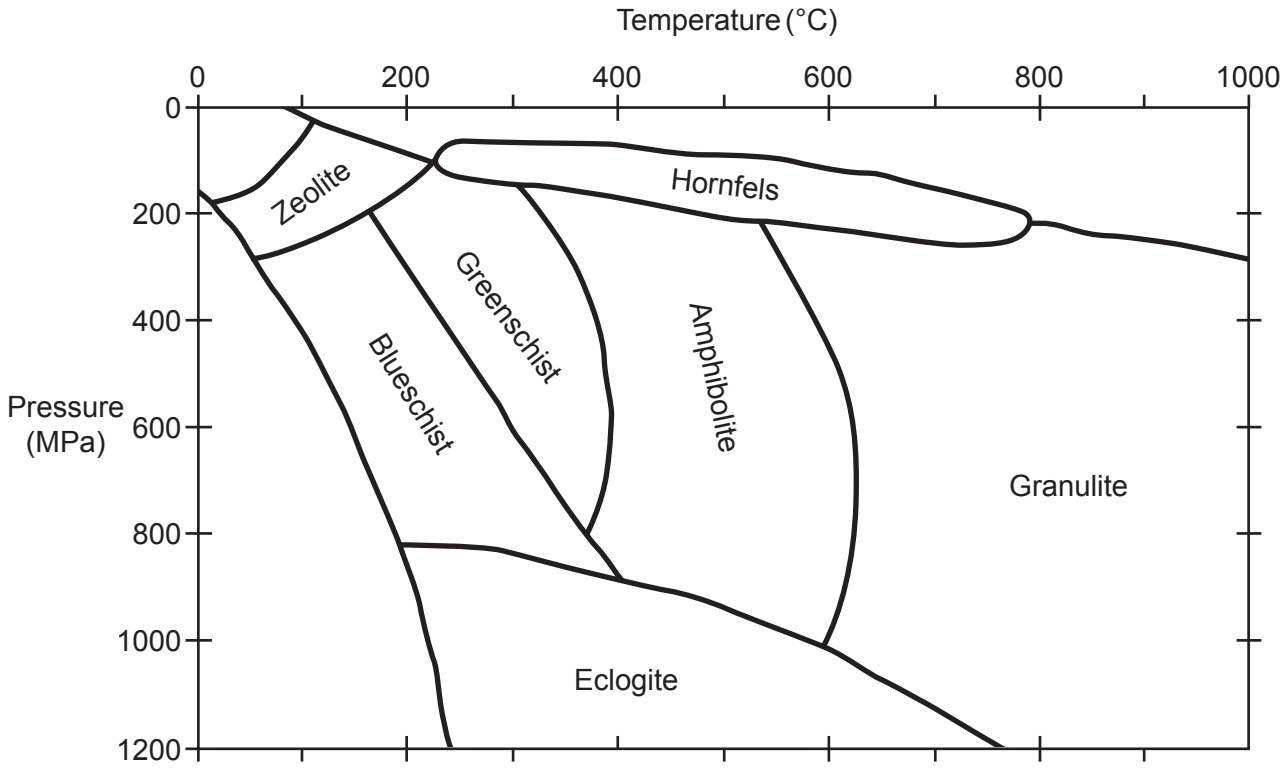


Fig. 3.2

(i) Draw and label the path that indicates contact metamorphism **on Fig. 3.2**. **[1]**

(ii) In which facies would all of the three Al_2SiO_5 polymorphs be stable?

..... **[1]**

(iii) State the range of pressures for blueschist facies.

..... **[1]**

(e)* Describe and explain how the mineralogy and texture of a mudstone is changed to produce new textures and minerals when it undergoes increasing regional metamorphism.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... **[6]**

Additional answer lines if required.

.....

.....

.....

.....

.....

(f) Explain how the composition of the parent rock affects the resultant deformation when a rock is folded.

.....

.....

.....

.....

..... **[2]**

4 The Lower Palaeozoic saw major tectonic activity in the Welsh Basin. One major event was the opening of the Iapetus Ocean during the Cambrian Period.

Fig. 4.1 shows the palaeogeography during the Precambrian and at the Cambrian–Ordovician boundary.

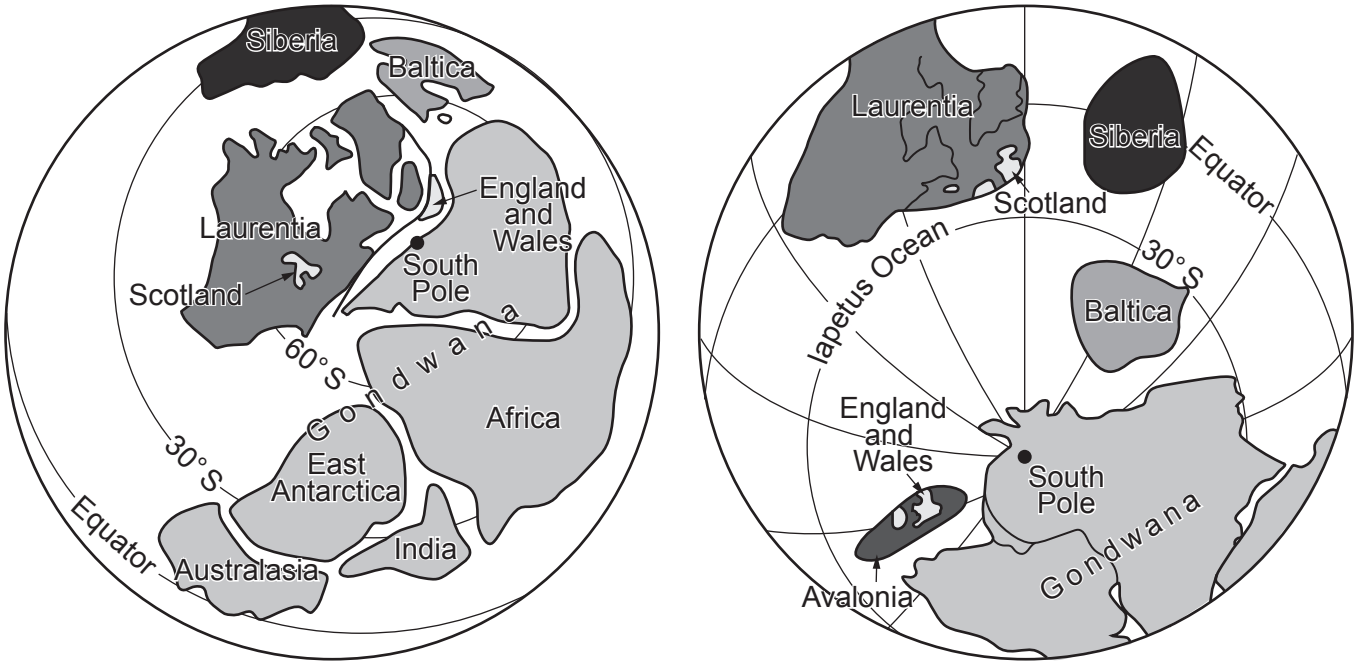


Fig. 4.1

(a) (i) Describe the events that led to the opening of the Iapetus Ocean during the Cambrian Period.

.....

.....

.....

.....

.....

.....

.....

..... **[3]**

(ii) Describe **one** palaeoenvironment **and** the sediment type that deposited during the Cambrian Period in the Welsh Basin.

.....

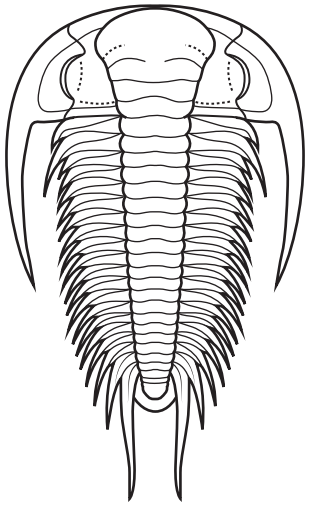
.....

.....

.....

..... **[2]**

(b) **Fig. 4.2** shows a Cambrian trilobite found in the Welsh Basin.



×1

Fig. 4.2

(i) Using **Fig. 4.2**, describe how this trilobite was suited to live in its marine niche. You may annotate the diagram to highlight the morphological features you discuss.

.....

.....

.....

.....

.....

.....

.....

..... **[3]**

(ii) In addition to trilobites, name **one** other fossil that can be used to zone the Welsh Basin.

..... **[1]**

5 Read the information, then answer the questions that follow.

Oil and gas formation and the Northern North Sea Basin

Oil and most gas, except coal gas, started life as microscopic plants and animals that lived in the ocean. When they died, they sank to the ocean floor, forming an organic-rich unconsolidated sediment with other fine particles that were washed or blown into the ocean basin. There was little or no oxygen in the water and the sediment contained more than 5% organic matter, allowing the formation of a black shale.

On burial, the sediment was compacted and heated due to the geothermal gradient. The organic matter was broken down to form a mixture of organic compounds in a process known as maturation. The first product of this process, the precursor to oil and gas, is a solid bituminous material. As maturation continues, oil and gas form within a specific temperature window, shown in **Fig. 5.1**.

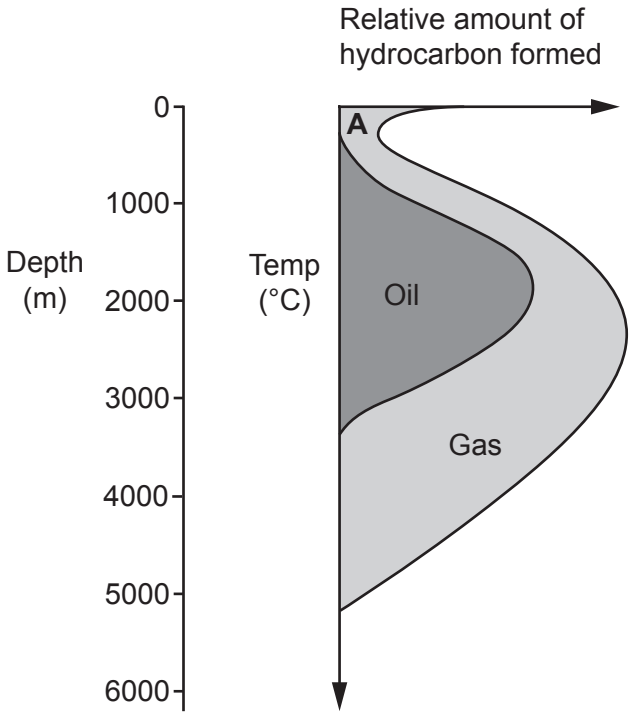


Fig. 5.1

A black shale, the Kimmeridge Clay, forms the source rock that underlies the Northern North Sea oil and gas fields. It was deposited during the Jurassic at a time of crustal extension when the Atlantic Ocean started to open. Synsedimentary faults formed at the same time as the deposition of sediments which ultimately controlled the sedimentation. The rocks that overlie the black shale are mainly marine sandstones and fractured chalk, and these are the reservoir rocks for the Northern North Sea oil and gas fields. There are also evaporites present within the sequence which had an effect on the migration of oil and gas to the reservoir rocks.

(a) (i) Identify the organic-rich unconsolidated sediment deposited on the ocean floor.

..... **[1]**

(ii) Identify the solid bituminous material that is the first product of maturation.

..... **[1]**

(iii) Oil and gas form within a specific temperature window.

State the temperature range for the oil and gas window.

..... **[1]**

(iv) The depth of the oil and gas window will vary depending upon the geothermal gradient.

Calculate the depths between which the oil and gas window will form given a geothermal gradient of 30 °C km^{-1}.

Assume the surface temperature is 0 °C.

Give your answers to **2** significant figures.

Depth = From ..... km to ..... km **[2]**

(v) Biogenic gas forms at **A** shown on **Fig. 5.1**.

Explain why biogenic gas is normally lost.

..... **[1]**

(b) (i) Describe and explain **two** properties of a marine sandstone that would make it a suitable reservoir rock for oil.

.....

.....

.....

.....

..... **[2]**

(ii) Explain why oil migrates from a source rock.

.....

.....

.....

.....

..... **[2]**

(iii) Draw fully labelled diagrams to show how synsedimentary faults trap oil.

[3]

(c) **Fig. 5.2** shows a down-hole electrical resistivity log from a borehole in the Northern North Sea Basin.

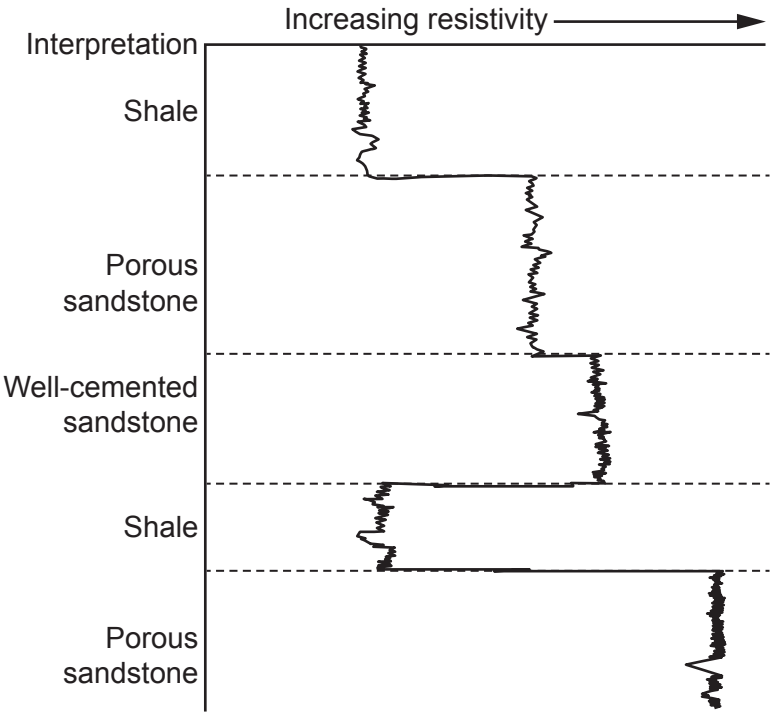


Fig. 5.2

(i) Label the bed **on Fig. 5.2** where oil is most likely to be found. **[1]**

(ii) Explain why the bed you labelled in part **(i)** is where oil is most likely to be found.

.....

..... **[1]**

(iii) Identify **one** other geophysical exploration technique and state how it could be used to identify the presence of oil.

.....

..... **[1]**

(d) **Fig. 5.3** shows two different types of oil trap, **B** and **C**, that exist within the Northern North Sea Basin.

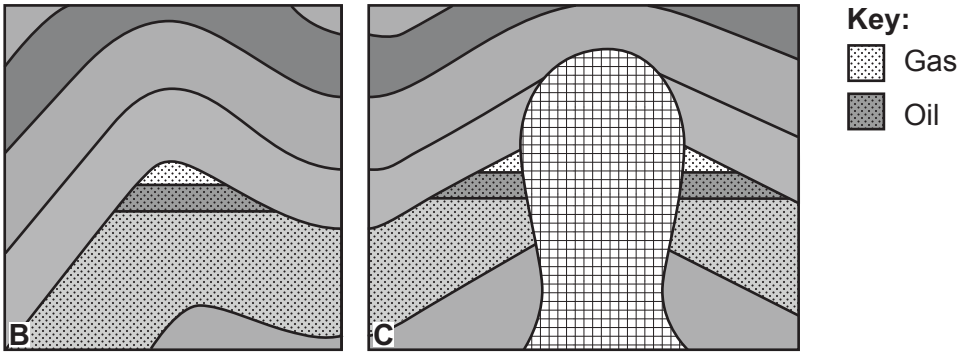


Fig. 5.3

(i) Identify the **two** different types of oil trap shown in **Fig. 5.3**.

B .....

C .....
[1]

(ii) Label **on Fig. 5.3** a potential place on the relevant oil trap where oil could be lost (spill point). **[1]**

(e) The Kimmeridge Clay represents a period of major sea level rise (transgression) that formed a deep basin with anoxic bottom waters. Sedimentation was cyclic.

Explain how palaeontologists locate the reservoir rocks that overlie the Kimmeridge Clay using microfossils. Include suitable example microfossil groups in your answer.

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... **[4]**

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).

OCR
Oxford Cambridge and RSA

Tuesday 13 June 2023 – Afternoon

A Level Geology

H414/02 Scientific literacy in geology

Time allowed: 2 hours 15 minutes

You can use:
- a scientific or graphical calculator
- a ruler (cm/mm)
- a protractor
- an HB pencil

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

INFORMATION
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **28** pages.

ADVICE
- Read each question carefully before you start your answer.

1 Coal mining in the UK peaked in the 18th and 19th centuries with as many as 2000 mines operating in the UK. These abandoned mines have left spoil heaps, abandoned engineering, unstable land surfaces and brownfield sites.

(a) Describe and explain the term **brownfield site**.

.....

.....

.....

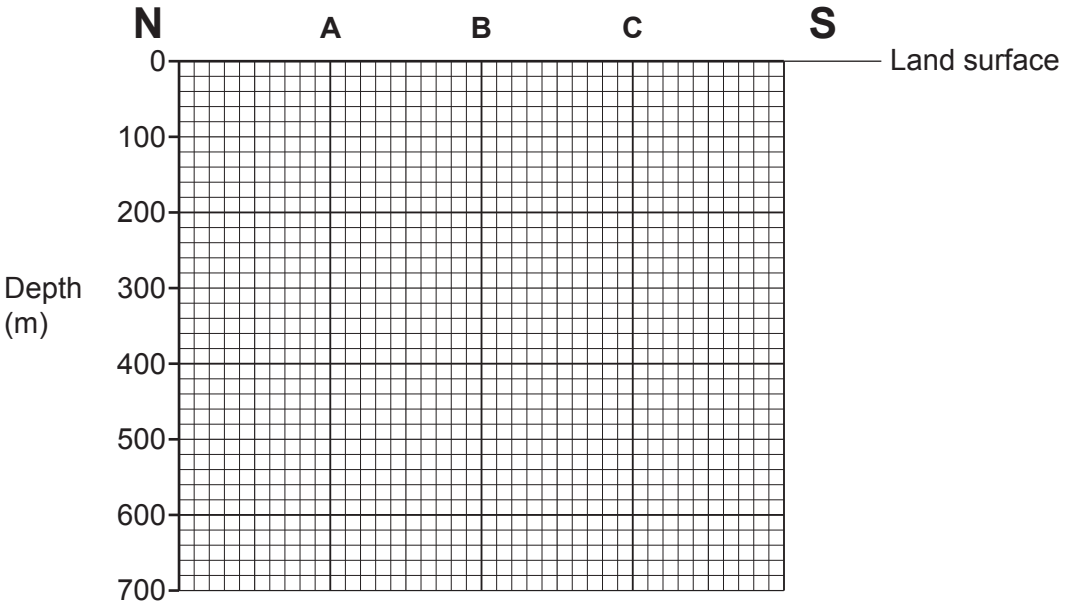
.....

..... **[2]**

(b) The table shows data about the position of coal seams and faults, collected from three boreholes (sites **A**, **B** and **C**) across an abandoned underground coal mine.

	Depth from surface (m)		
Feature	**Site A**	**Site B**	**Site C**
Fault	Not seen	650	450
Top of coal seam X	200	250	260
Bottom of coal seam X	210	340	390
Top of coal seam Y	500	520	485
Bottom of coal seam Y	565	585	550

(i) Plot the data on the grid below to show both coal seams and the fault.



[3]

(ii) An engineering company is assessing the abandoned coal mine as a potential repository for the storage of low-level nuclear waste. The coal was mined using a shaft system and stope mining. The shaft access is close to site **A**.

Assess the suitability of the abandoned coal mine as a potential repository for storing waste underground.

.....

.....

.....

.....

..... **[2]**

(iii) Describe how stope mining was used in the removal of coal and explain **one** problem with this method of extraction.

.....

.....

.....

.....

..... **[2]**

(c) Abandoned coal mines have significant impact as they discharge acidic water into the environment. Pyrite (FeS_2) in the rocks is exposed to water, oxygen and microorganisms producing acidified water.

This can be shown in the balanced equation.

$$2FeS_2 + 7O_2 + 2H_2O \longrightarrow 2Fe^{3+} + 4H^+ + 4SO_4^{2-}$$

(i) Explain how the resultant waters from this chemical reaction can cause environmental problems.

.....

.....

.....

.....

.....

.....

.....

..... **[3]**

(ii) Suggest **one** method to mitigate the effects of the pollution outlined in **(i)**.

.....

..... **[1]**

2 (a) (i) The table shows some morphological features that are found in brachiopods and bivalves.

For each morphological feature, use a (✓) or a cross (✗) to indicate if it is found in brachiopods, bivalves or both.

The first one has been done for you.

Morphological feature	**Brachiopod ✓ or ✗**	**Bivalve ✓ or ✗**
Composed of calcite	✓	✓
Pedicle foramen		
A line of symmetry along the hinge line		
Pallial line		

[3]

(ii) Describe and explain **three** adaptations of a brachiopod which lived in a high-energy marine environment.

1 .....

.....

2 .....

.....

3 .....

.....

[3]

(iii) Describe what other **fossil** evidence you would look for in the field to interpret an environment as high energy.

.....

.....

.....

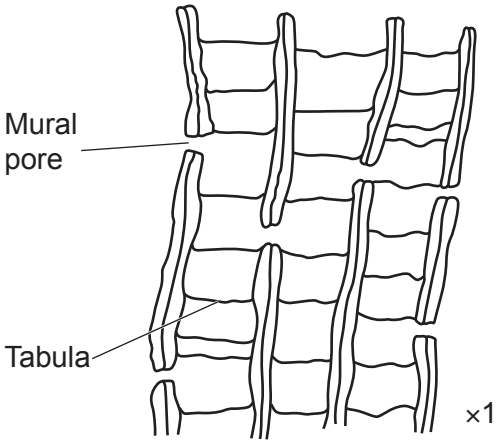
.....

..... **[2]**

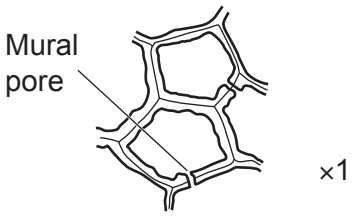
(b) Fossils **D** and **E** are from two different geological periods.

Fossil D

Longitudinal section

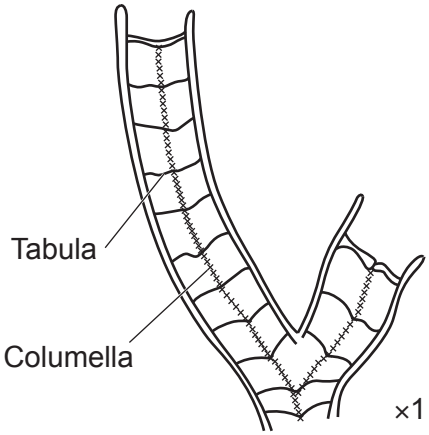


Transverse section

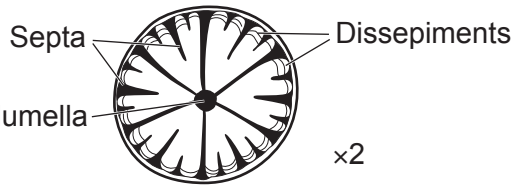


Fossil E

Longitudinal section



Transverse section



(i) Identify the fossil phylum or group to which these fossils both belong.

..... **[1]**

(ii) Compare and contrast the morphology of fossils **D** and **E**.

.....

.....

.....

.....

.....

.....

.....

..... **[3]**

(iii) In which geological era did fossil **D** live?

Tick (✓) **one** box.

Cenozoic ☐

Mesozoic ☐

Palaeozoic ☐

[1]

(iv) Identify **one** other fossil that is likely to be found in a life assemblage with fossil **E**.

..... **[1]**

(v) Fossils **D** and **E** have relatives that are extant (alive at the present time). Geologists presume that they all had the same mode of life and ecology.

Describe the likely mode of life and ecology of this group of organisms.

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... **[4]**

(c) The Cretaceous–Tertiary (K/T) boundary marks a mass extinction event which saw the demise of many organisms, including dinosaurs.

(i) In addition to the dinosaurs, identify a terrestrial organism or group which became extinct at the Cretaceous–Tertiary boundary.

..... **[1]**

(ii) State the name of a replacement organism that filled the same ecological niche as dinosaurs **and** explain the reasons for your choice.

.....

.....

.....

.....

..... **[2]**

(iii) The Cretaceous–Tertiary mass extinction event was thought to have been triggered by an asteroid or meteorite.

Describe and explain **two** pieces of evidence which support this hypothesis.

.....

.....

.....

.....

..... **[2]**

BLANK PAGE

PLEASE DO NOT WRITE ON THIS PAGE

3 **(a)** Early ideas about how the continents moved have been improved by new hypotheses using current evidence.

(i) Describe the theory of **continental drift**, as proposed by Wegener in 1915.

.....

.....

.....

.....

..... **[2]**

(ii) A later theory explained the movements of the plates using mantle convection, a theory which has now been rejected.

Describe why active mantle convection as a method to move plates has been discounted as a theory.

.....

.....

.....

.....

..... **[2]**

(iii) Describe and explain **one** mechanism of the current theory of plate movement.

.....

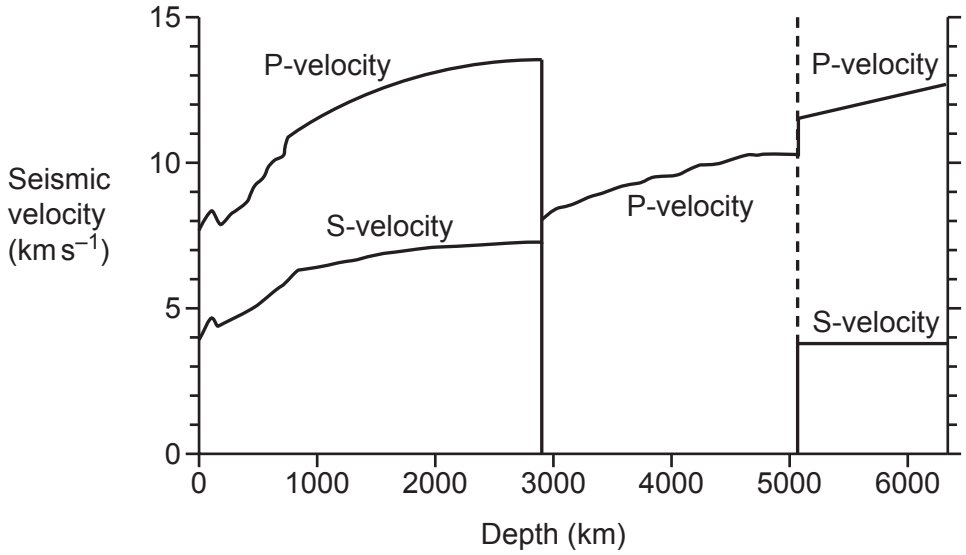
.....

.....

.....

..... **[2]**

(b) The graph shows the changes in seismic velocities of P and S waves as they pass through the Earth.



(i) On the graph, clearly label:

- Low velocity zone
- Gutenberg discontinuity
- Outer core.

[3]

(ii) Describe and explain the changes in S wave velocities shown on the graph.

.....

.....

.....

.....

..... **[2]**

(iii) Calculate the percentage increase in P wave velocity between 1000 km and 2900 km.

Increase in P wave velocity = ... % **[2]**

(c)* Describe how the structure and composition of the Earth has been inferred from both direct and indirect evidence.

You should include evidence from density, gravity and magnetism in your answer.

Do **not** include evidence from seismic waves in your answer.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... **[6]**

Additional answer space if required.

.....

.....

.....

.....

.....

4 Distinguishing between dykes, sills and lava flows in the field requires the identification of key characteristics relating to their formation.

(a) Describe and explain the difference between sills and lava flows with reference to crystal size and xenoliths.

Crystal size .....

.....

.....

.....

Xenoliths .....

.....

.....

.....

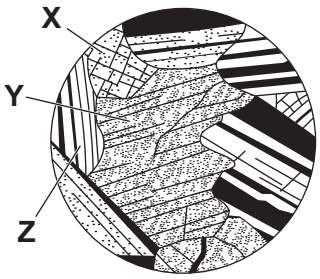
[4]

(b) Define the term **discordant**.

.....

..... **[1]**

(c) The diagram shows a sketch of a thin section from a lava flow, produced at a mid-ocean ridge (MOR), showing three common rock-forming minerals **X**, **Y** and **Z**.



Mineral	Colour in hand specimen
X	Green
Y	Dark greenish black
Z	Whitish grey

(i) Identify the minerals **X**, **Y** and **Z** shown in the thin-section diagram.

X .....

Y .....

Z ..... **[3]**

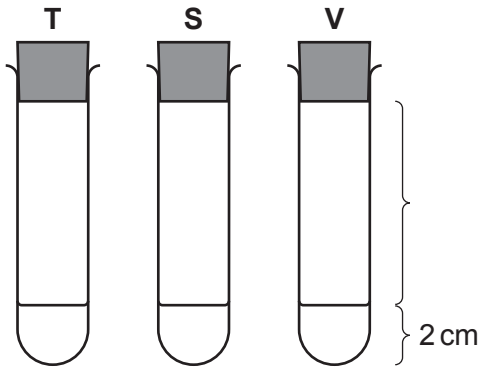
(ii) Identify the rock shown in the thin-section diagram.

..... **[1]**

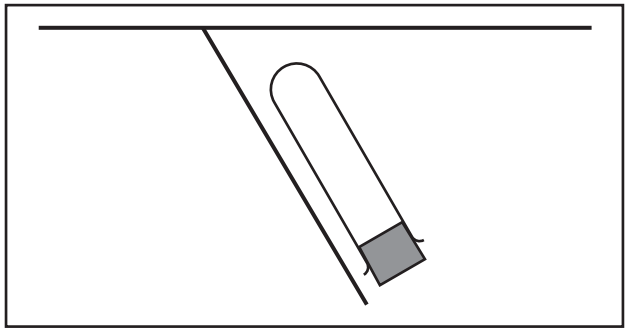
(d) Measuring the velocity of moving lava can help indicate the composition of the lava.

A group of students decided to investigate the effect of temperature on the velocity of liquids.

They selected three liquids, treacle (**T**), syrup (**S**) and vegetable oil (**V**). They marked a 2 cm line at the bottom of each boiling tube, as shown in the diagram. They then added each liquid to a boiling tube to the 2 cm level and sealed it with a rubber bung.



Boiling tubes



Template card

The students recorded the distance between the top of each liquid and the base of the rubber bung. They then tilted each tube to a 60° angle, using a template card for consistency, and measured the time taken for the first part of the liquid to flow down the tube and touch the rubber bung.

The experiment was performed at room temperature (20 °C) and then repeated at 50 °C after immersing the boiling tubes in a hot water bath.

The results are shown in the table.

	Boiling tube T		**Boiling tube S**		**Boiling tube V**	
	20 °C	**50 °C**	**20 °C**	**50 °C**	**20 °C**	**50 °C**
Distance (cm)	10.5	10.5	10.1	10.1	10.1	10.1
Time (s)	29.64	3.69	11.54	1.45	0.40	No reading
Velocity (mm s^{-1})	3.54	.....	8.75	.....	252.50	No value

(i) Calculate the velocity of the contents for boiling tubes **T** and **S**.

Velocity **T** = ... mm s^{-1}

Velocity **S** = ... mm s^{-1}

[2]

(ii) Describe the relationship between velocity and temperature.

.....

..... **[1]**

(iii) Which of these simulations (**T**, **S** or **V**) best fits the flow from a shield volcano? Give a reason for your answer.

.....

.....

..... **[1]**

(iv) Describe **two** health and safety hazards that must be considered for this experiment.

1 .....

.....

2 .....

..... **[1]**

(v) Suggest **one** potential reason why the students were unable to take a reading for boiling tube **V** at 50 °C.

..... **[1]**

5 Geological surveys involve a systematic examination of an area to determine the character, relations, distribution and origin or mode of formation of its rocks and mineral resources.

Surveying of ophiolite suites around the world has added greatly to our knowledge and understanding of the origin of rock masses.

(a) (i) Define the term **ophiolite**.

.....

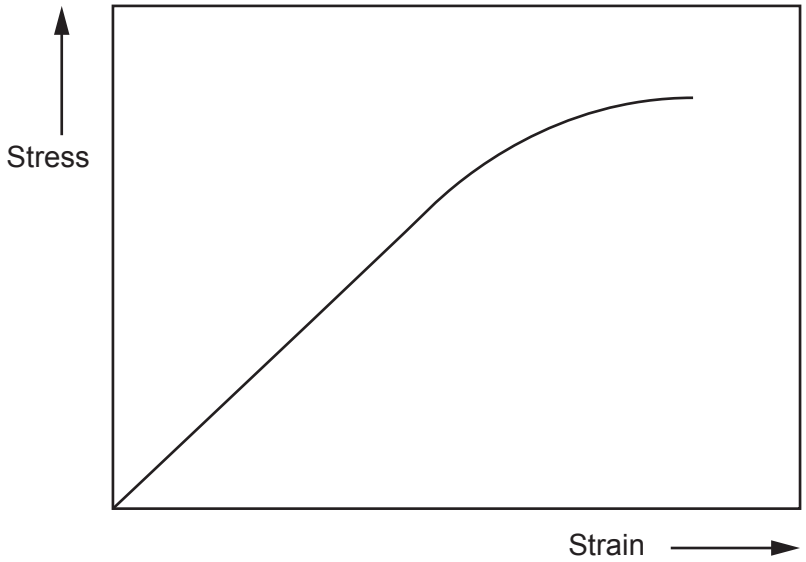
..... **[1]**

(ii) Draw a fully labelled diagram of a section through an ophiolite.

[3]

(b) Within the Earth, rocks are constantly subjected to forces that tend to bend, twist or fracture them. Site surveys can identify evidence of deformation that has occurred in the past. This requires an understanding of stress and strain.

The graph shows stress against strain in a rock.



(i) On the stress-strain graph clearly label:

- Elastic deformation
- Failure
- Plastic deformation.

[3]

(ii) Explain how earthquakes occur when stress stored in rocks is released.

.....

.....

.....

.....

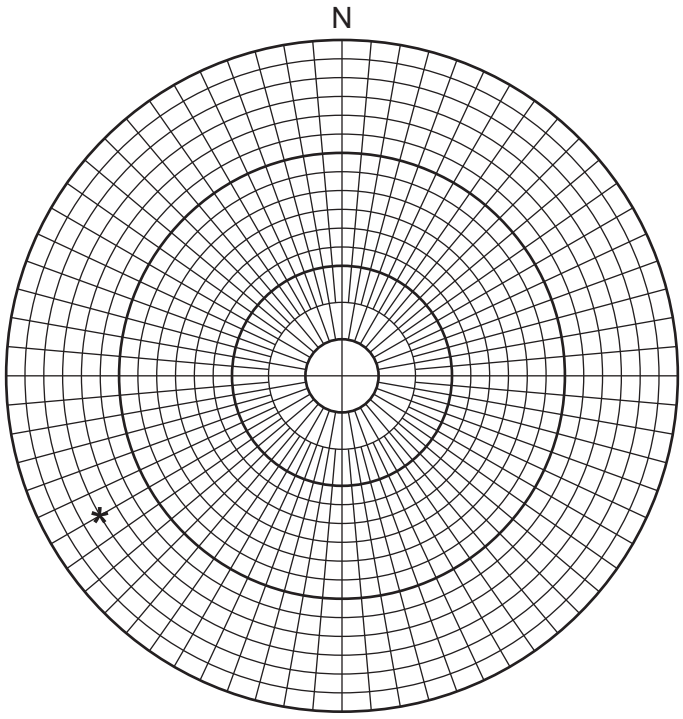
..... **[2]**

(c) When rocks experience compressional stress, this can result in folding.

Dip and strike measurements of fold limbs, when plotted on a stereonet, can enable the orientation of the principal compressional stress to be determined.

The table shows strike and dip measurements taken from both limbs of a fold.

Strike	Dip
240°	75°
055°	75°
065°	40°
230°	40°
050°	45°



(i) Plot the strike and dip data on the stereonet.

The first measurement has been plotted for you. **[3]**

(ii) State the orientation of the maximum compressional stress shown on your stereonet.

..... **[1]**

(iii) Explain if the type of fold (antiform or synform) can be determined from your stereonet plot.

.....

..... **[1]**

6 Read the text, then answer the questions that follow.

On 18th March 2020, a 5.7 magnitude earthquake hit Salt Lake City, Utah, when the Wasatch Fault ruptured. This caused buildings to sway which resulted in significant structural damage.

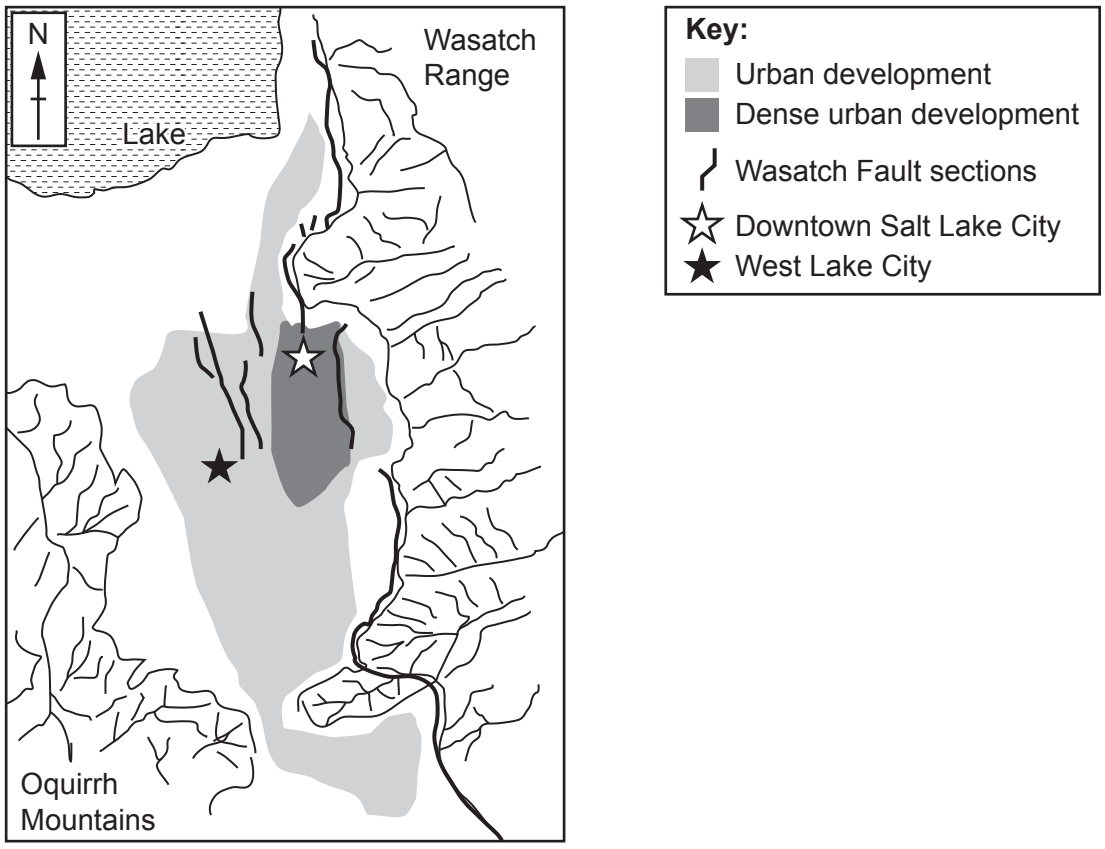
Geological studies show that over the last 7 000 years a magnitude 6.5 to 7.5 earthquake has occurred somewhere along the central section of this fault every 270 years.

Seven earthquakes of magnitude 5.0 or above have occurred in the last 100 years.

Salt Lake City sits within a fault zone in a structural basin, bounded by two uplifted blocks, with the Oquirrh Mountains to the west and the Wasatch Mountains to the east. Alluvial fan, recessional delta, marsh and lakebed deposits of gravel, sand, silt and clay form the shallow subsurface of the basin. These sediments are of Cenozoic age, with units as young as 30 000 years.

Downtown Salt Lake City is the oldest and most developed part of the urbanised area. West Lake City is younger and more recently developed.

This is shown on the map.



Unreinforced masonry (brick and block) was a common building material throughout Utah until building codes began requiring reinforcement. There are an estimated 140 000 unreinforced masonry structures in Utah, including homes, businesses, schools and houses of worship.

The table shows the average damage with increasing Mercalli intensities.

Construction type	Average damage (%) at intensity		
	VIII	IX	X
Unreinforced masonry (non-seismic design)	40	80	100
Reinforced concrete frames (non-seismic design)	33	70	100
Reinforced masonry (non-seismic design)	16	38	66
Reinforced concrete frames (aseismic design)	13	33	58
Reinforced masonry (aseismic design)	5	13	25

Building codes are sets of regulations governing the design, construction, alteration and maintenance of structures. They specify the **minimum** requirements to adequately safeguard the health, safety and welfare of building occupants. These include seismic codes to ensure that structures can resist seismic forces during an earthquake.

Examples of seismic building codes include:
- Structural configuration ensures a direct and smooth flow of inertia forces to the ground
- Lateral strength sufficient to resist the maximum horizontal force without collapsing
- Adequate stiffness to resist deformation induced by low to moderate shaking
- Exterior walls should be supported on continuous solid concrete or masonry.

Except in certain circumstances, such as when a structure is significantly renovated or altered or there is a change in its use, the building code requirements for existing structures are those that were in effect when the structure was designed and constructed. Seismic retrofitting programmes are not state mandated in Utah.

(a)* Evaluate the statement that the seismic retrofitting of existing buildings should be mandatory in the Salt Lake City structural basin.

In your answer you should include a consideration of seismic hazard risk, civil engineering and the factors which affect the impact of earthquakes. **[6]**

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

Additional answer space if required.

.....

.....

.....

.....

.....

(b) The table gives dates and the magnitude of earthquakes in the Salt Lake City area.

Date	**M_w**
Nov 1901	7.0
Sep 1921	6.3
Mar 1934	6.6
Aug 1962	5.9
Oct 1967	5.6
Jan 1989	5.2
Sep 1992	5.8
Mar 2020	5.7

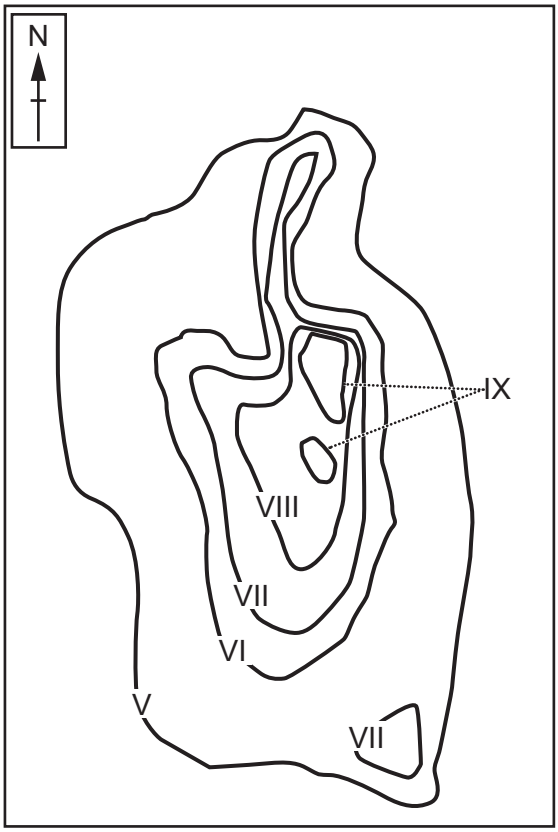
Calculate the return period for earthquakes with a magnitude greater than 5.0, between the years 1901 and 2020.

Give your answer to the nearest year.

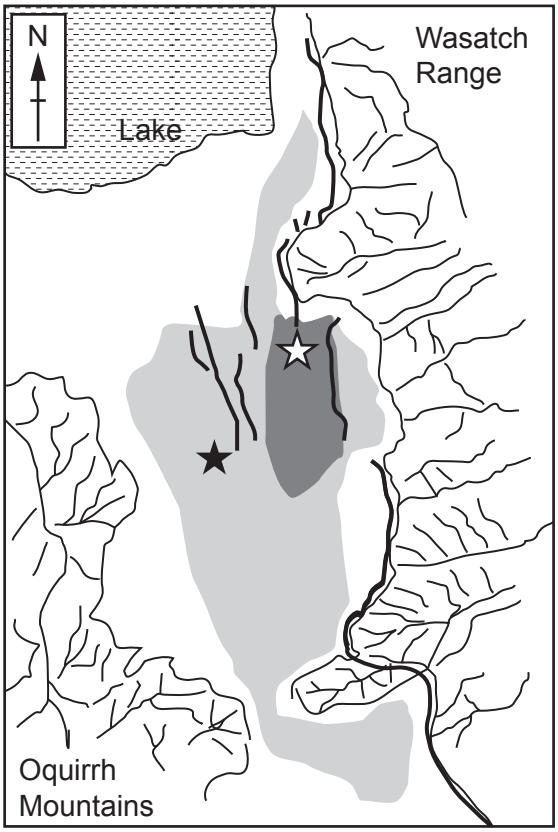
Return period = ... years **[2]**

(c) The isoseismal map shows the projected earthquake intensity of the area around Salt Lake City forecast for a 7 M_w earthquake. The structural basin map is shown again for reference.

Isoseismal map for a 7 M_w earthquake



Map of structural basin



Suggest **three** reasons for the distribution of the isoseismal lines shown on the isoseismal map.

.....

.....

.....

.....

.....

.....

.....

..... **[3]**

(d) Civil engineering can reduce the impact of future seismic events. One method of achieving this is to mitigate for sway of buildings.

(i) Explain the relationship between sway and natural frequency.

.....

..... **[1]**

(ii) Natural frequency can be calculated using the equation:

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

where f = natural frequency (Hz)
m = mass (kg)
k = stiffness ($N\,m^{-1}$)

Rearrange the equation to make stiffness (k) the subject of the formula.

Stiffness (k) = ... **[1]**

(iii) The table shows data for three buildings, **A**, **B** and **C**. The buildings are of similar heights.

Building	Stiffness ($N\,m^{-1}$)	Mass (tonnes)	Natural frequency (Hz)
A	3462	27 952	1.52
B	1100	22 622	1.05
C	1217	37 956	1.11

Evaluate the structural integrity of these three buildings in a magnitude 6_{ML} earthquake that causes ground shaking at a frequency of 1.80 Hz.

.....

.....

.....

.....

..... **[2]**

(iv) Explain why taller buildings tend to have lower natural frequencies than shorter buildings.

.....

.....

..... **[1]**

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).

OCR
Oxford Cambridge and RSA

Wednesday 12 June 2024 – Afternoon

A Level Geology

H414/02 Scientific literacy in geology

Time allowed: 2 hours 15 minutes

You can use:
- an HB pencil
- a protractor
- a ruler (cm/mm)
- a scientific or graphical calculator

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

INFORMATION
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **24** pages.

ADVICE
- Read each question carefully before you start your answer.

1

(a)

(i) Draw a fully labelled diagram to show the processes of saltation and traction along a river bed.

[2]

(ii) Given a constant flow velocity, explain how particles of the same grain size can be transported by saltation or suspension.

.....

..... **[1]**

(b) Describe the differences between sediments which are texturally mature and texturally immature. Explain how sediments become texturally mature.

.....

.....

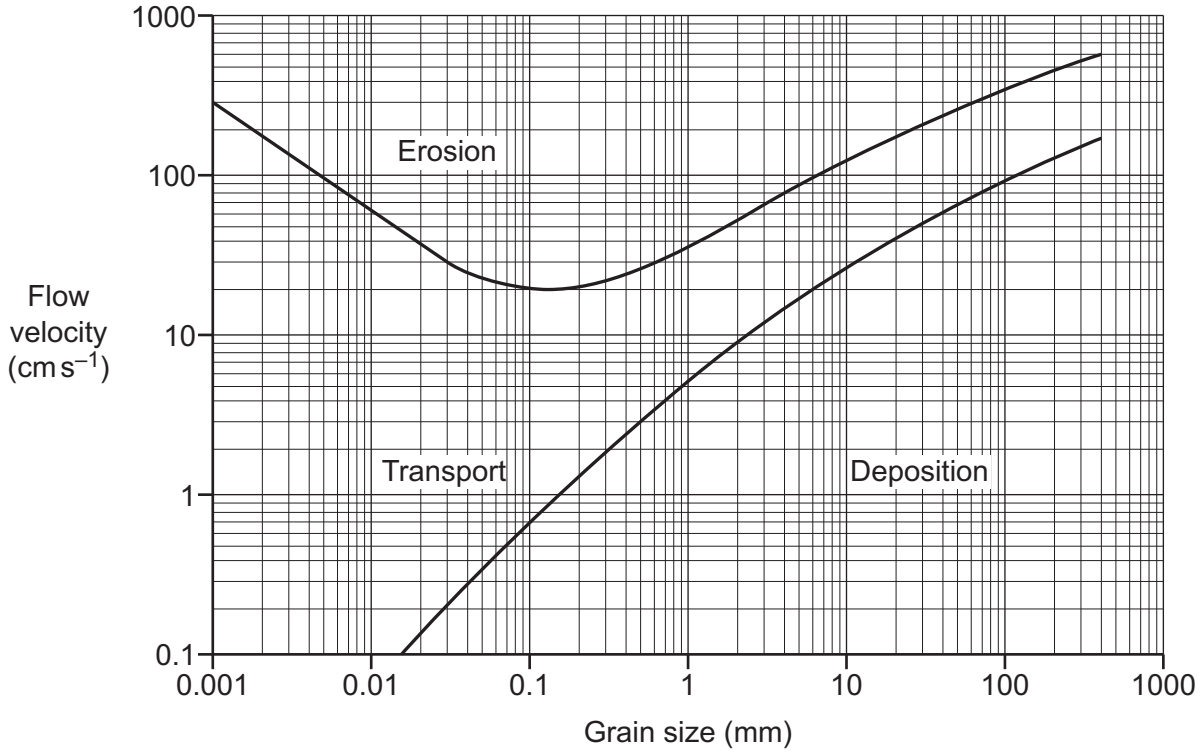
.....

.....

.....

..... **[3]**

(c) The Hjulström curve graph shows the relationship between the grain size of a sediment and the flow velocity required for erosion, transportation and deposition.



(i) State the minimum flow velocity required to erode a grain size of 1 mm.

Minimum flow velocity = ... Unit = ... **[1]**

(ii) State the maximum grain size that would be deposited if the flow velocity slowed to 2 cm s^{-1}.

Maximum grain size = ... Unit = ... **[1]**

(iii) Explain why both axes of the Hjulström curve graph use logarithmic scales.

.....

..... **[1]**

(d) Diagenesis refers to the physical and chemical processes that change unconsolidated sediments into sedimentary rock.

(i) Name and explain the physical processes that occur during diagenesis.

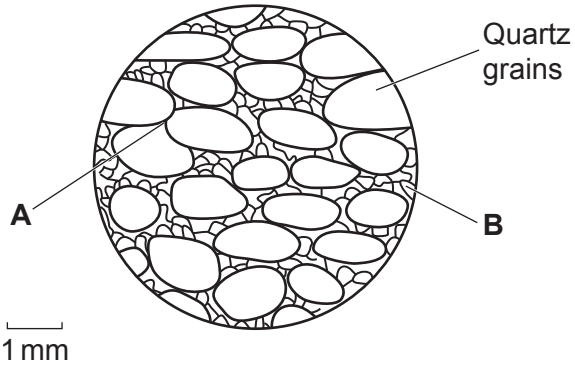
.....

.....

.....

..... **[2]**

The thin section diagram shows a sandstone.



(ii) During diagenesis, cement can form in a sedimentary rock by two separate chemical processes.

Name and explain the most likely diagenetic process that will occur at point **A** shown on the diagram.

.....

.....

.....

..... **[2]**

(iii) Name and explain the most likely process by which cement will form at point **B** shown on the diagram.

.....

.....

.....

..... **[2]**

(iv) Diagenesis may continue after the sediment has been converted into a rock, causing textural changes.

Describe and explain how continued diagenesis of a sandstone may affect its ability to act as an aquifer rock.

.....

.....

.....

.....

.....

..... **[3]**

2

(a) The upper part of the Earth consists of the lithosphere and the asthenosphere.

(i) Describe the physical properties of the lithosphere.

.....

..... **[1]**

(ii) What indirect evidence has been used to locate the base of the lithosphere?

..... **[1]**

(iii) Describe and explain the property of the asthenosphere that enables it to play a key role in plate tectonics.

.....

.....

.....

..... **[2]**

(b) Sir George Airy used gravity anomalies to explain the theory of isostasy.

(i) Explain what is meant by isostasy.

.....

.....

.....

..... **[2]**

(ii) Describe and explain how gravity anomalies can be used as indirect evidence for the theory of isostasy.

.....

.....

.....

..... **[2]**

(c)* Describe the geodynamo theory of the Earth's magnetic field **and** explain how it can provide indirect evidence for the processes operating within the Earth's core.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... **[6]**

Extra answer space if required.

.....

.....

.....

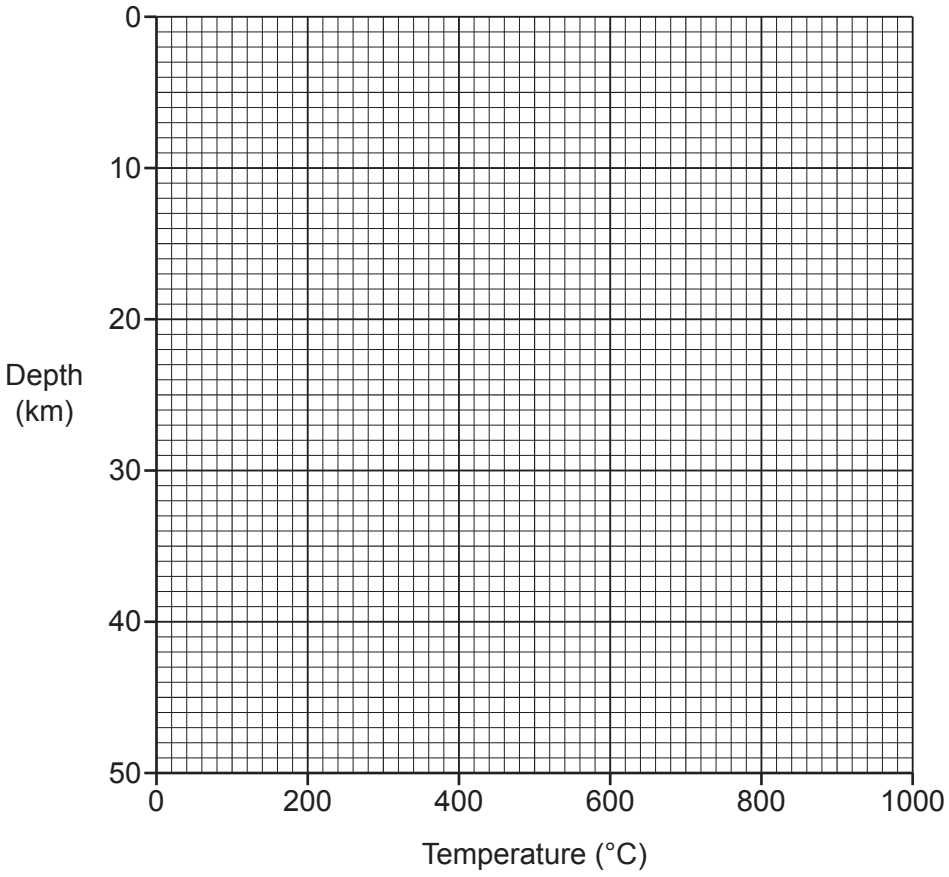
.....

.....

(d) The temperature change with depth (geothermal gradient) for **Region X** and **Region Y** in the Earth are shown in the table.

Region X		**Region Y**	
Depth (km)	**Temperature (°C)**	**Depth (km)**	**Temperature (°C)**
0	0	0	0
10	250	5	160
20	500	15	480
30	750	20	
40	1000	25	800

(i) Plot the data from the table for **Region X** and **Region Y** on the grid.



[3]

(ii) Determine the temperature at a depth of 20 km for **Region Y**. Write your answer in the table. **[1]**

(iii) Use the data from the table to calculate the geothermal gradient for **Region Y**.

Geothermal gradient = ... Unit = ... **[2]**

3

(a) Attenuation is an important factor to consider when compiling hazard maps used for seismic risk analysis.

(i) Define the term **attenuation** when applied to seismic waves.

.....

..... **[1]**

(ii) Explain why high-frequency seismic waves are more strongly attenuated than low-frequency seismic waves.

.....

..... **[1]**

(iii) The Mercalli Scale is used to measure earthquake intensity, rating earthquakes on the amount of damage produced in any given place.

Describe and explain why earthquake intensity depends on the nature of the underlying rock.

.....

.....

.....

..... **[2]**

(b) Seismic hazard risk analysis can be used to produce hazard maps that summarise geological data for use by government bodies (e.g. for purposes such as disaster planning and public education).

Describe **two** limitations and **two** strengths of hazard maps.

.....

.....

.....

.....

.....

.....

.....

..... **[4]**

(c) Probabilistic forecasting is a method used to determine the likelihood that an earthquake might occur in a certain area over a given period of time.

Critically analyse the statement 'the social consequences of probabilistic forecasting outweigh any benefit'.

.....

.....

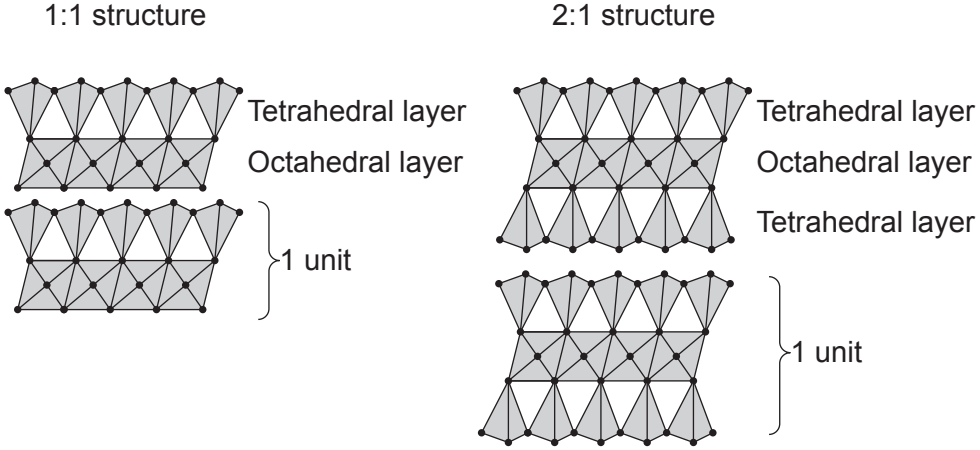
.....

.....

.....

..... **[3]**

(d) Most clays can be classified as 1:1 or 2:1. These ratios refer to the proportion of tetrahedral sheets to octahedral sheets. The arrangement of layers and the method of bonding between the layers affects the properties of different clay minerals.



(i) Complete the table by matching the correct clay mineral to its type and properties.

kaolinite **phyllite** **smectite**

Type	Clay mineral	Properties	
1:1		Non-expanding	Low shrink swell
2:1		Expanding	High shrink swell
2:1	Vermiculite	Limited expansion	Medium shrink swell
2:1	Illite	Non-expanding	Low shrink swell

[2]

(ii) A significant proportion of the UK land area is at risk of damage due to the shrinking and swelling of clays.

Describe and explain **one** chemical soil treatment that engineers can use to mitigate the problem of shrinking and swelling clays.

.....

.....

.....

..... **[2]**

4

(a) Amphibians evolved from more primitive tetrapods, the lobe-finned fish.

(i) Describe **one** similarity between a lobe-finned fish and an amphibian.

.....

..... **[1]**

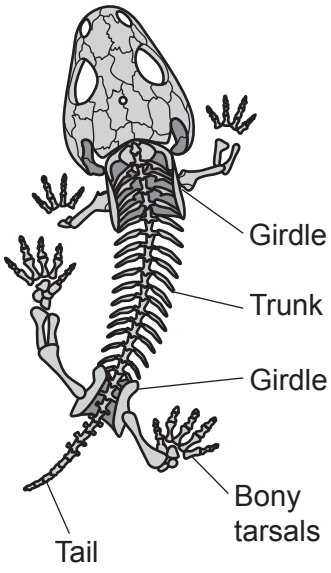
(ii) In which geological period did amphibians first evolve as aquatic organisms?

..... **[1]**

(b) The diagrams show **two** different amphibian skeletons, fossils **A** and **B**, that evolved to live in different environments.

Fossil A

Fossil B



Describe and explain the differences in the skeletons of fossils **A** and **B**. Indicate the likely environments that each of these organisms lived in.

.....

.....

.....

.....

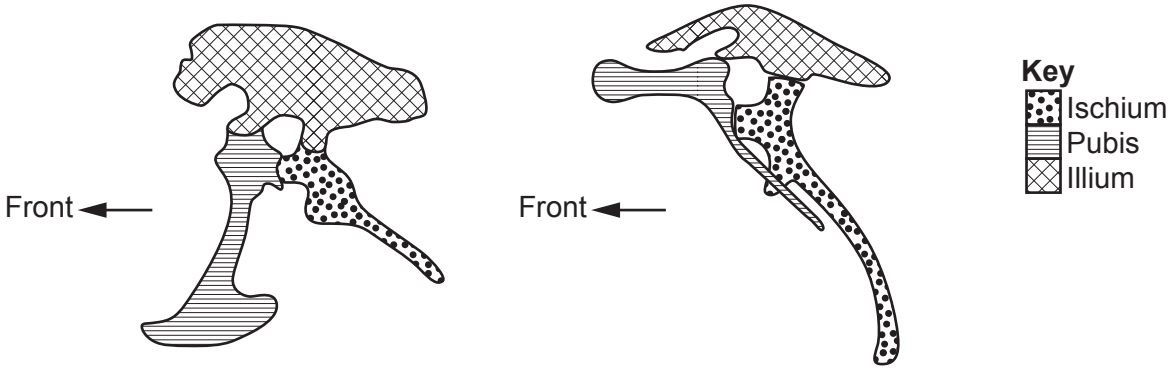
.....

.....

.....

..... **[4]**

(c) The diagrams show the hip-bone arrangements in **two** dinosaurs, *Tyrannosaurus* and *Iguanodon*.



Tyrannosaurus *Iguanodon*

(i) Compare the hip bones of *Tyrannosaurus* and *Iguanodon*.

.....

.....

.....

.....

.....

..... **[3]**

(ii) Using information shown in the hip-bone diagrams, describe and explain to which group of dinosaurs *Iguanodon* belongs.

.....

.....

.....

..... **[2]**

(iii) Describe and explain **one** morphological adaptation that suggests *Iguanodon* was a herbivore.

.....

.....

.....

..... **[2]**

(iv) Pterosaurs and birds independently evolved wings for flight at different times.

State the term used to describe this type of evolution.

..... **[1]**

(d) An important evolutionary change was the development of the amniotic egg.

(i) Draw lines to match each **characteristic** with its correct **function**.

Characteristic	Function
Yolk	Membrane containing fluid
Albumen	Fatty food store for developing embryo
Amnion	Separates internal from external environment
Shell	Embryo's water supply

[4]

(ii) Explain how the evolution of the amniotic egg enabled animals to colonise land.

.....

.....

.....

..... **[2]**

BLANK PAGE

PLEASE DO NOT WRITE ON THIS PAGE

5

(a) Measuring the settling rates of different sediments can help interpret the environment of deposition in ancient sediments.

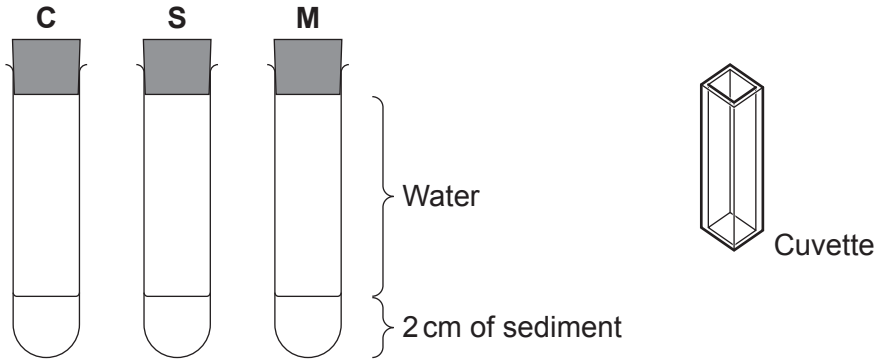
A group of students decided to investigate the effect of sediment type on the settling rate. They decided to use a colorimeter, a device which measures the amount of light that passes through a sample of liquid, where 100% transmission would be pure water with no particulates. Cuvettes are specialised tubes with a square cross section that can be inserted into a colorimeter.

Note the colorimeter must be calibrated to 100% transmission of light with a sample of pure water at the start of the experiment.

A 590 nm filter (amber) in the colorimeter was used for this experiment.

Method

- Select three types of dried sediment: clay (**C**); silt (**S**) and medium sand (**M**).
- Pour sediment up to a 2 cm line at the bottom of each boiling tube, as shown in the diagram.
- Using tube **C**, fill with water and put in a rubber bung.
- Shake the tube and place in a boiling tube rack.
- Using a pipette, remove some of the liquid from the centre of each boiling tube and transfer to a cuvette.
- Insert the cuvette into the colorimeter and record the % transmission value.
- Leave the cuvette in place and take readings every five minutes over the following twenty five minutes.
- Repeat with tubes **S** and **M** and record the % transmission values.



Boiling tubes before shaking

The results are shown in the table.

	% transmission		
Time (minutes)	**Tube C**	**Tube S**	**Tube M**
0	4.0	15.6	74.0
5	10.2	45.2	78.3
10	16.3	50.0	78.6
15	22.3	47.7	79.0
20	26.5	53.6	79.5
25	26.4	53.7	80.5

(i) Describe and explain the relationship between sediment type and % transmission.

Use the information given in the table.

.....

.....

.....

.....

.....

..... **[3]**

(ii) The percentage change in % transmission for tube **C** between 0 and 25 minutes has been calculated as 560%.

Calculate the percentage change in % transmission for tube **M** between 0 and 25 minutes.

Give your results to **3** significant figures.

Tube **M** = ... % **[3]**

(iii) Which experiment (**C**, **S** or **M**) would you choose to model sediment flow in a fast-flowing river? Give a reason for your answer.

.....

.....

..... **[1]**

(iv) Describe **one** health and safety hazard that must be considered for this experiment.

.....

.....

..... **[1]**

(v)* Analyse and evaluate the experimental procedure provided. Suggest improvements to the experiment to yield more accurate results.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... **[6]**

Extra answer space if required.

.....

.....

.....

.....

.....

(b) Describe an experiment that could be completed in the laboratory to investigate the deposition of cross-bedding in sediments.

You should include details of how you will collect data, any sampling methods that you would use and how you will process your data.

You may use an annotated diagram to illustrate your answer.

.....

.....

.....

.....

.....

.....

.....

..... **[4]**

6 Read the text below, then answer the questions that follow.

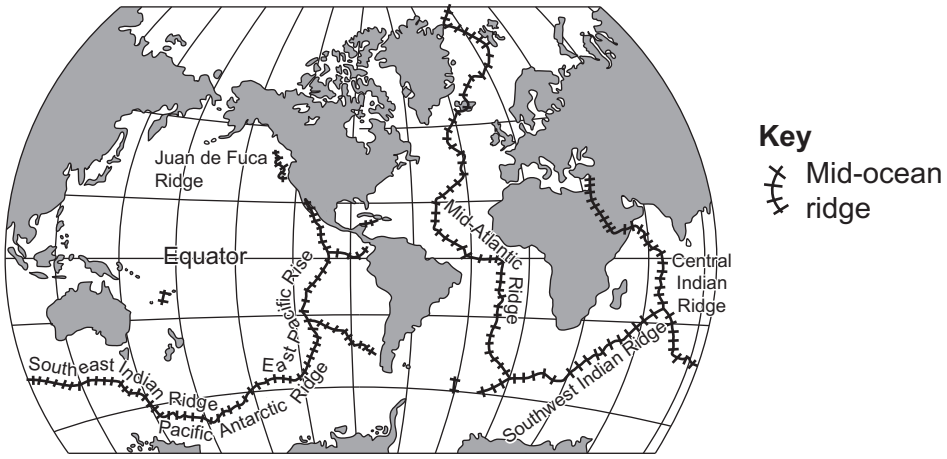
The Origins of the Plate Tectonics Paradigm?

The plate tectonic paradigm developed over a period of time, as new ideas, observations and models arose. The earliest model was called the geosynclinal model. This model used contraction theory to explain mountain building events, known as orogeny, to explain the existence of the Appalachian and Caledonian mountain ranges. This was followed by continental drift theory, proposed by Alfred Wegener in 1915. He proposed no mechanism, but noted that continents fitted together, rather like a jigsaw.

Mechanisms for the movement of plates evolved over time to explain earlier observations. In 1929 British geologist Arthur Holmes proposed that the Earth produces heat by radioactive decay. He also suggested that the Earth was losing heat through volcanic activity. He suggested that there could be mantle convection to enable dispersion of heat and linked this to continental drift with mantle convection driving this process. Holmes' textbook 'Principles of Physical Geology' became widely used and respected by academics.

Alex du Toit was a South African geologist who compared stratigraphy from different parts of the world – Africa, South America, Australia, India, Antarctica and Arabia. In 1937 he suggested the idea that these were all once joined in a supercontinent called Gondwanaland.

In 1962 the American geologist Harry Hess proposed the theory of seafloor spreading, based on ocean basin research during WWII and evidence from the global seismic network which was set up to monitor nuclear tests during the Cold War. He described new crust development at oceanic ridges.



Simplified map showing the positions of mid-ocean ridges, identified during and after WWII.

In 1954 the American geologist Hugo Benioff studied deep-focus earthquakes, up to around 700 km depth, and was the first to plot these earthquakes to identify island arcs as a narrow band. He linked this to the idea of subduction of the Earth's crust.

In 1965 J Tuzo Wilson wrote a paper entitled 'A New Class of Faults and Their Bearing on Continental Drift' where the offset nature of transform faults was noted.

In 1966 Lynn Sykes then noted that 95% of earthquakes occur in belts and identified about 12 major plates and described their relative motion.

In 2021 a group of researchers from Toronto, using supercomputer modelling, showed that the plates on which Earth's oceans sit are being torn apart by massive tectonic forces occurring away from plate boundaries. There may be a need to modify current ideas based on this evidence.

(a)

(i) Describe evidence for the geosynclinal model, which attempted to explain the presence of mountain ranges.

.....

.....

.....

..... **[2]**

(ii) Using evidence from the text and your own knowledge, evaluate the statement 'the plate tectonics paradigm has now been solved'.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... **[4]**

(iii) Harry Hess was the first person to describe hot spots. Describe **one** piece of evidence for the formation of hot spots.

.....

..... **[1]**

(b) Describe how uniformitarianism and the rock cycle models developed over time.

.....

.....

.....

..... **[2]**

END OF QUESTION PAPER

EXTRA ANSWER SPACE

If you need extra space use these lined pages. You must write the question numbers clearly in the margin.