Oxford Cambridge and RSA

Thursday 6 June 2019 – Morning

A Level Geology

H414/02 Scientific literacy in geology

Time allowed: 2 hours 15 minutes

You may use:
- a scientific or graphical calculator
- a ruler (cm/mm)

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 may use an HB pencil for graphs and diagrams.
- Answer **all** the questions.
- Where appropriate, your answers should be supported with working. Marks may be given for a correct method even if the answer is incorrect.
- Write your answer to each question in the space provided. If additional space is required, use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.

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

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Answer **all** the questions.

1 The physical and chemical processes that act on sediments after they become buried are varied but can be grouped under the term diagenesis.

(a) Complete the table showing four diagenetic processes.

Name of diagenetic process	Explanation of process
Cementation	
	Sediment squeezed by weight of overlying sediment; porosity and permeability reduced.
	Crystals change in size and shape.
	Minerals dissolve where grains press into each other.

[4]

(b) Peat undergoes diagenesis that allows it to change into coal. Different types of coals are formed at different stages as shown in Fig. 1.1 below.

C King, 'Sedimentology: Processes and Analysis', p82, Fig. 5.6, Longman, 1991.
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Fig. 1.1

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Fig. 1.2 shows the geothermal gradient for an area in South Wales at the time of coal formation.

C King, 'Sedimentology: Processes and Analysis', p82, Fig. 5.6, Longman, 1991. Item removed due to third party copyright restrictions.

Fig. 1.2

(i) Using Fig. 1.2, calculate the average geothermal gradient in this area.

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

geothermal gradient = ... °C km^{-1} **[2]**

(ii) Using Fig. 1.2, state the depth range at which you might expect to find **anthracite** coal deposits.

depth range = ... km **[1]**

(c)* Sedimentary rocks are classified using a variety of diagnostic properties.

Explain, with named examples, how appropriate diagnostic properties are used to classify the different **siliciclastic** rocks.

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Additional answer space if required.

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2 Scientific knowledge of the physical structure of the Earth has advanced in the last 50 years.

The density of different parts of the Earth is one physical aspect that it has been possible to calculate. For example:

- density of surface rocks – 2.8 g cm^{-3}
- mean density of mantle – 4.5 g cm^{-3}
- mean density of the Earth – 5.5 g cm^{-3}

(a) **(i)** Describe and explain what can be inferred about the Earth's structure and processes of formation using the density evidence above.

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(ii) The global distribution of seismic activity is shown in Fig. 2.1. Each black dot represents a recorded earthquake epicentre.

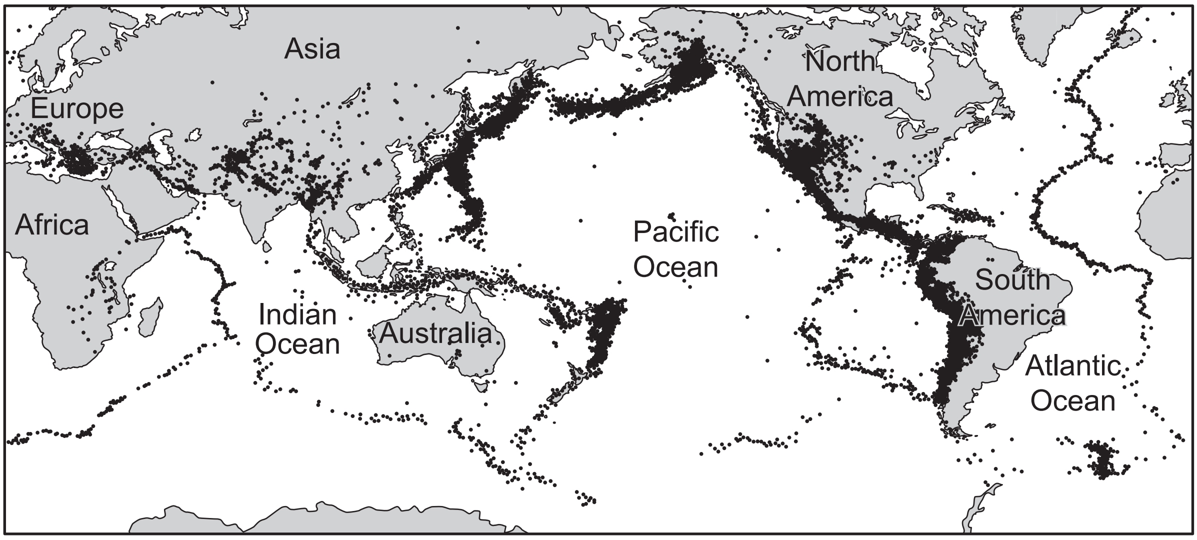

Fig. 2.1

Describe and explain what can be inferred about the Earth's structure and internal processes using the seismic evidence from Fig. 2.1.

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(b) A variety of volcanic landforms have formed across the Earth's surface. One factor controlling these landforms is the nature of surface igneous activity at plate boundaries.

Describe the landforms of The Andes and Indonesia by completing the table below.

Location	**Type of plate boundary**	**Type of volcanic activity**	**Composition of magma**	**Example of rock type**
The Andes in South America				
Indonesia				

[4]

(c) There is evidence that a 'supercontinent' called Pangaea existed in the Permian which gradually broke up to give the present day distribution of the continents.

Palaeomagnetism in rocks can be used as evidence that the continents have moved apart.

(i) Describe how palaeomagnetism forms in rocks.

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(ii) Polar wandering curves use palaeomagnetism as evidence for the movement of continents.

Simplified polar wandering curves for two present day continents, **A** and **B**, are shown in Fig. 2.2. The ages of the rocks on each continent are given in millions of years (Ma), from the late Precambrian to the present day.

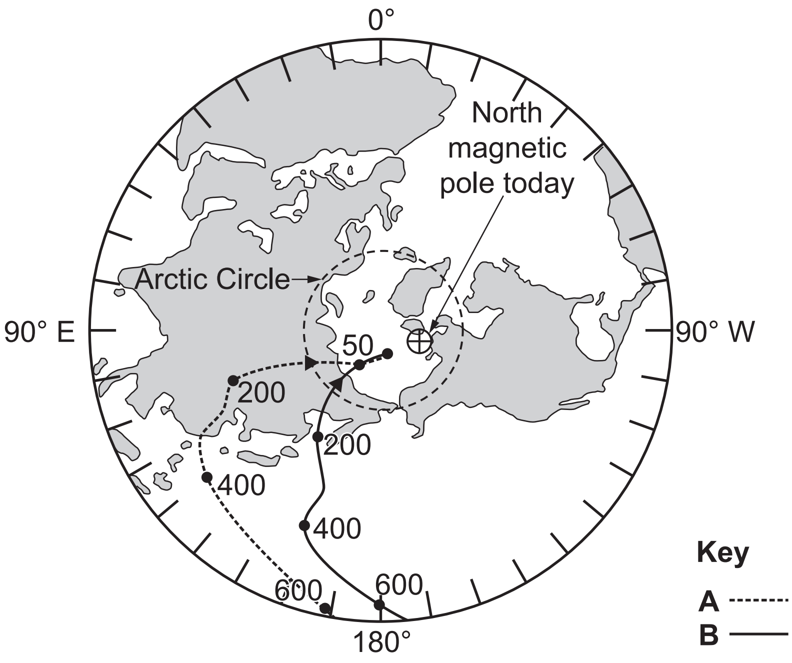

Fig. 2.2

Explain how the two polar wandering curves provide evidence for plate tectonic movement.

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3 In the late 1800s the iron industry in the town of Merthyr Tydfil in South Wales was expanding rapidly. In order to supply the increasing demand for water, a new dam (the Pentwyn Dam) was developed at a site north of Merthyr Tydfil, in order to create a reservoir.

The maps in Fig. 3.1 show the area around the dam as well as the local geology.

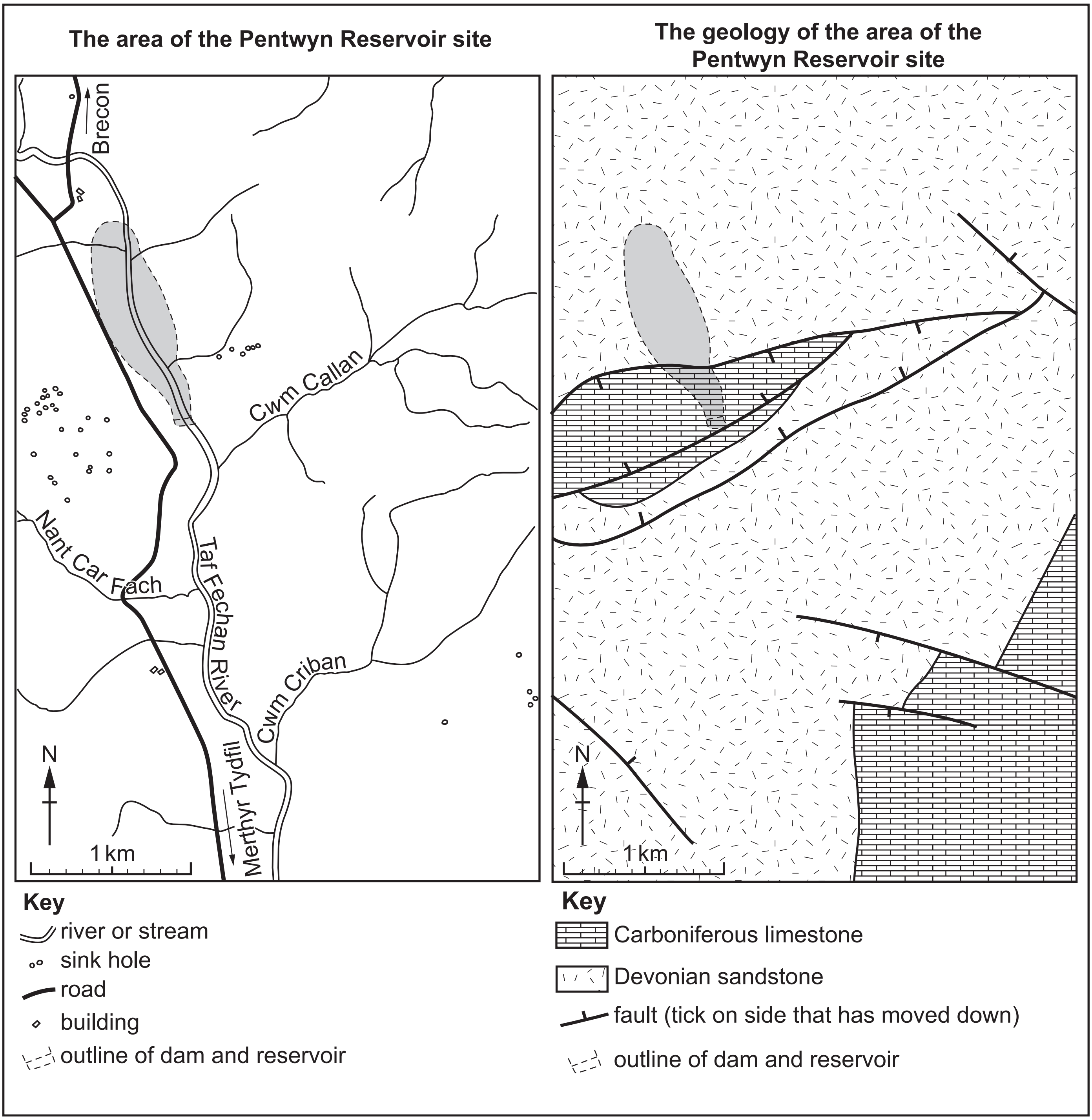

Fig. 3.1

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(a) Large scale leakage occurred as soon as the Pentwyn Dam was completed.

Describe and explain **two** engineering strategies that could have been used to improve the site prior to the construction of the dam.

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[2]

(b) Table 3.1 lists data relevant to the strength of various rock types.

Rock type	**Uniaxial compressive strength (MPa)**	**Uniaxial tensile strength (MPa)**	**Shear strength (MPa)**
Basalt	100–300	10–30	20–60
Granite	100–250	7–25	14–50
Limestone	30–250	5–25	10–50
Sandstone	20–170	4–25	8–40
Shale	5–100	2–10	3–30

Table 3.1

(i) Explain why basalt and granite have the highest values for the different types of strength.

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(ii) State the difference between the terms compressive strength and tensile strength.

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(iii) Explain why the compressive strength of the underlying rock is important when considering the site for a new dam.

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(iv) Using the data in Table 3.1, calculate the percentage difference between the compressive strength of the limestone and sandstone.

difference = ... % **[2]**

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(c)* The Pentwyn Dam was constructed from limestone blocks, broken limestone and sandstone over a waterproof core.

Evaluate the information and evidence given in Fig. 3.1 and Table 3.1 to determine whether the chosen site was appropriate for constructing a dam.

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4 Bowen's Reaction Series, shown in Fig. 4.1, charts the formation of different minerals as a magma cools.

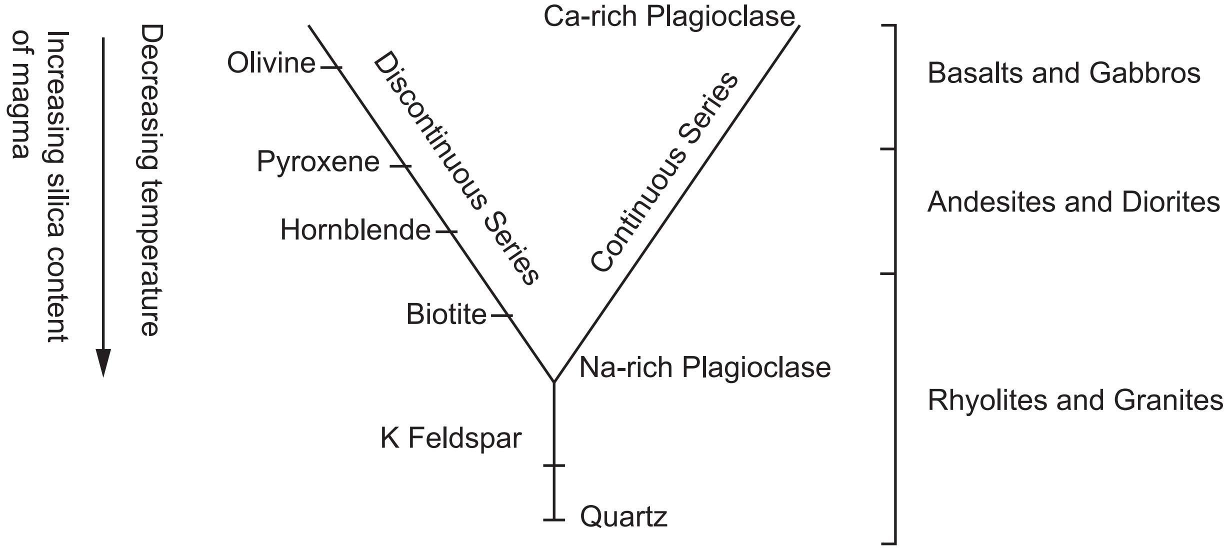

Fig. 4.1

(a) The reaction series indicates increasing silica content of magma as it cools.

(i) Explain why the silica content of magma increases as it cools.

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(ii) Changing silica content affects the properties of magma.

Explain how the differing silica content of extruded magma at divergent and convergent plate boundaries affects the properties of the magma and the resulting landforms.

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(b) The viscosity of lava erupted by volcanos at convergent plate margins is dependent on both the composition of the lava and the temperature.

A group of students decided to investigate the effect of temperature on the viscosity of liquids. They dropped ball bearings through golden syrup, as shown in Fig. 4.2 below.

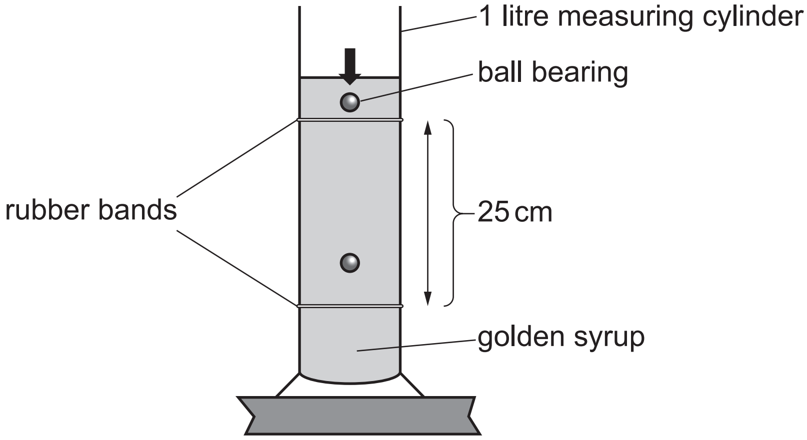

Fig. 4.2

The students recorded the time taken for the ball bearing to drop through the golden syrup from the top rubber band to the bottom rubber band. They repeated the experiment four times at two different temperatures. Their results are shown in Table 4.1.

	Time taken (s)	
Test	**20 °C**	**40 °C**
1	70	61
2	69	57
3	73	71
4	72	62

Table 4.1

(i) The students calculated a mean value of 60 seconds at 40 °C.

Explain how they arrived at this value.

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(ii) The students needed a modification of Stokes' Law in order to calculate the viscosity of the golden syrup.

Calculate the viscosity of the golden syrup at 40 °C.

Use the formula: $\text{Viscosity}(\eta) = \dfrac{2g \times (\rho_b - \rho_l) \times a^2}{9v}$

where: **g** is the acceleration due to gravity = $9.8\,\text{ms}^{-2}$
$\boldsymbol{\rho_b}$ is the density of the steel ball bearing = $8.0 \times 10^3\,\text{kg}\,\text{m}^{-3}$
$\boldsymbol{\rho_l}$ is the density of the liquid golden syrup = $1.4 \times 10^3\,\text{kg}\,\text{m}^{-3}$
a is the diameter of the ball bearing = $5.0 \times 10^{-3}\,\text{m}$
v is the velocity of the ball between the two rubber bands (ms^{-1})

Give your answer to an appropriate number of significant figures.

viscosity = ... Pa.s **[3]**

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(c) Earthquake activity occurs at convergent plate boundaries.
The table below shows data for a series of earthquakes giving depth of focus and distance from the plate boundaries off the coast of Japan.

Distance from plate boundary (km)	1600	1100	900	390	180	100	420	1200	1000	260
Depth of focus (km)	350	310	200	30	35	20	100	300	230	45

(i) Plot a graph of the data and draw a line of best fit.

[3]

(ii) Define the term focus.

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(iii) Use a **labelled diagram** to explain the pattern shown by your graph.

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5 Analysis of sediments can give a valuable insight into the sedimentary processes and conditions operating at the time the sediment was deposited.

(a) The Welsh Basin, a sedimentary basin formed during the Lower Palaeozoic, is located across Central Wales and the Welsh borders.

Turbidite deposits are found within Ordovician rocks in the area. The diagram shown in Fig. 5.1 represents an idealised Bouma turbidite model of deposition.

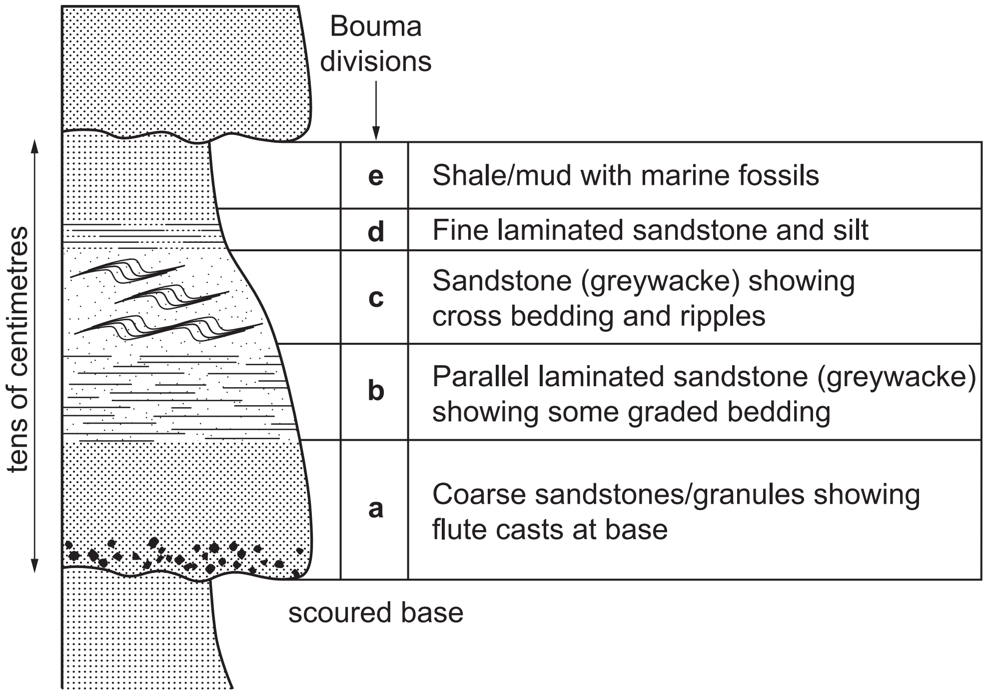

Fig. 5.1

(i) Explain how the idealised Bouma sequence shown in Fig. 5.1 was formed.

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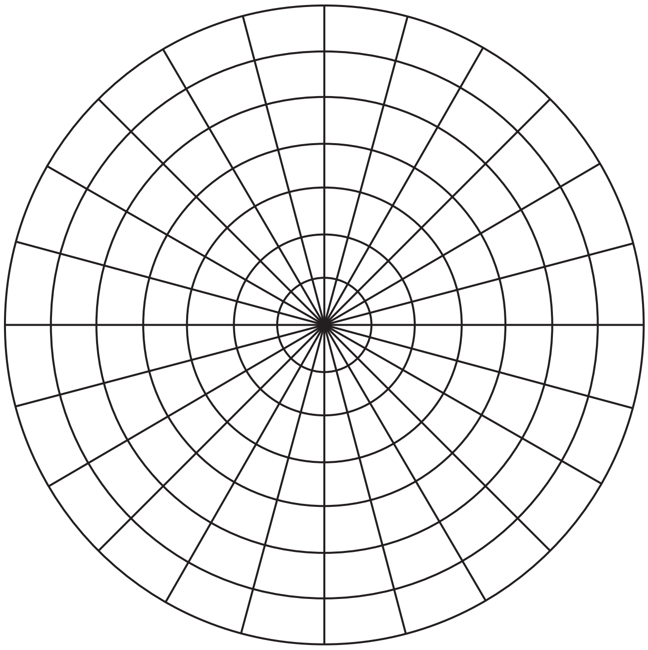
(ii) The orientation of flute casts at the base of a turbidite can be measured using a compass-clinometer.

A group of students took measurements from turbidite deposits found in the Welsh Basin. These are recorded in Table 5.1.

Orientation	Number of flute casts
0–180°	0
181–195°	0
196–210°	2
211–225°	3
226–240°	6
241–255°	14
256–270°	12
271–285°	8
286–300°	6
301–315°	2
316–330°	1
331–345°	2
346–360°	1

Table 5.1



Plot a rose diagram using the data in Table 5.1 and describe the pattern shown.

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(b) Two graphic logs were plotted of outcrops on the western and eastern sides of the Welsh Basin, shown in Fig. 5.2.

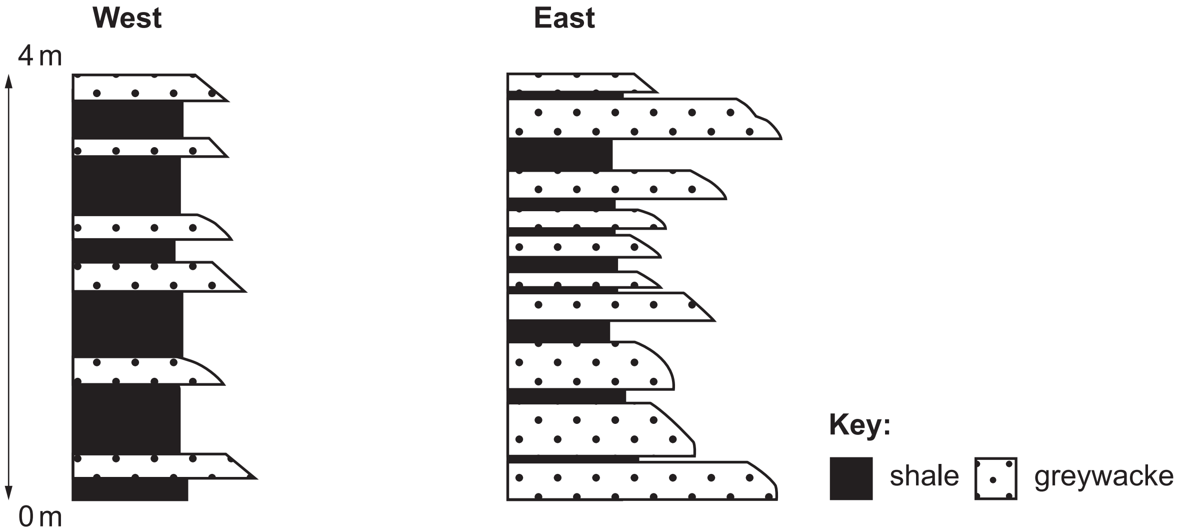

Fig. 5.2

Use the evidence provided by both the graphic logs and the rose diagram to describe and explain the geological setting and depositional environment of this area of the Welsh Basin.

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(c) The two graphic logs have been interpreted as being of the same age.

Describe and explain how geologists may have used additional evidence to reach this conclusion.

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Turn over for the next question

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

The Burgess Shale

This deposit is a Cambrian, Konservat-Lagerstätten, found at a locality in British Columbia, Canada.

Palaeoenvironmental Setting

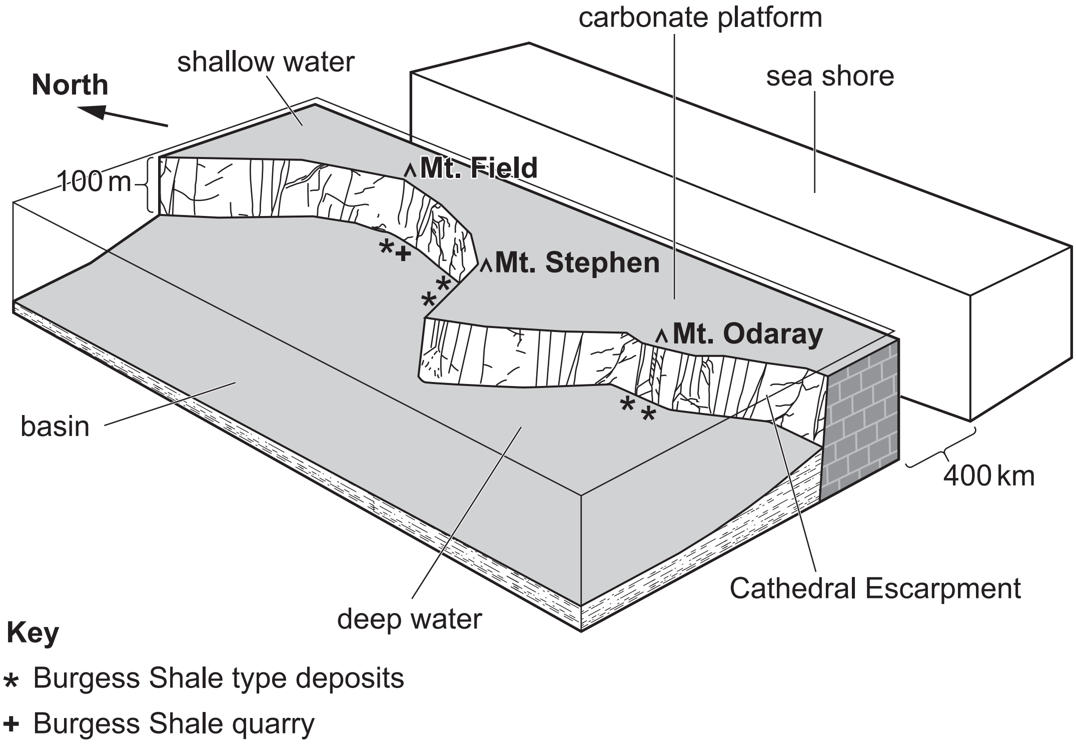

Fig. 6.1

Environment

Most animals lived at the base of a large submarine cliff known as the Cathedral Escarpment. This formed at the outer edge of a wide, tropical platform of carbonate rock that may have extended as far as 400 kilometres from the shoreline.

The Escarpment itself was about 200 metres high before mud and other sediments began to fill in the basin.

Burgess Shale fossils

The Burgess Shale deposits exhibit a wide variety of organisms, including Cnidaria, annelid and priapulid worms, primitive molluscs and chordates, as well as the arthropods. More than 80% of these are soft bodied. It is exceptional to find complete animals preserved, especially ones that had only soft tissues and no mineralised structures.

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This is a fossil rich locality, indeed 65 000 Burgess Shale specimens were collected from one particular site in the locality, and more are being found today. The pie chart shows the diverse nature of the biota discovered.

The overwhelming majority of species (64%) were epifaunal, followed by the infaunal sediment dwellers (13%), low-level swimming nektobenthonics (12%) and swimming nektonics (11%).

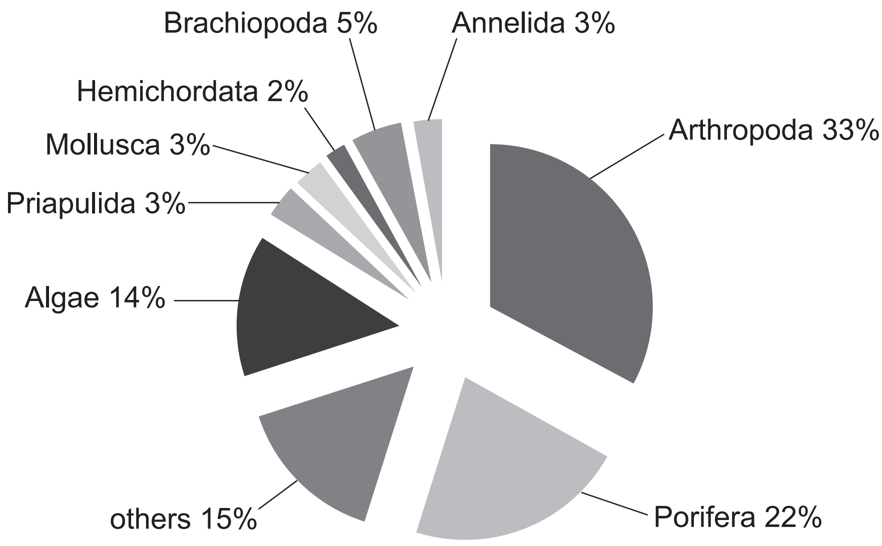

Fig. 6.2

(a) **(i)** State the names of the fossil groups shown in the pie chart in Fig. 6.2 that could be found in sediments of a similar age that were **not** exceptionally preserved.

.... **[1]**

(ii) Soft tissue preservation is extremely rare, but the palaeoenvironmental setting and conditions where the Burgess Shale deposits were being formed were ideal for preservation.

Suggest and explain why both the setting and probable conditions allowed for preservation of soft bodied animals.

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(iii) The majority of soft bodied fossils in the Burgess Shale are preserved as carbon films.

Explain the mechanism of preservation resulting in carbon films.

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(b) Trilobites are a relatively common arthropod fossil found in the Burgess Shale and include *Olenoides*, shown below.

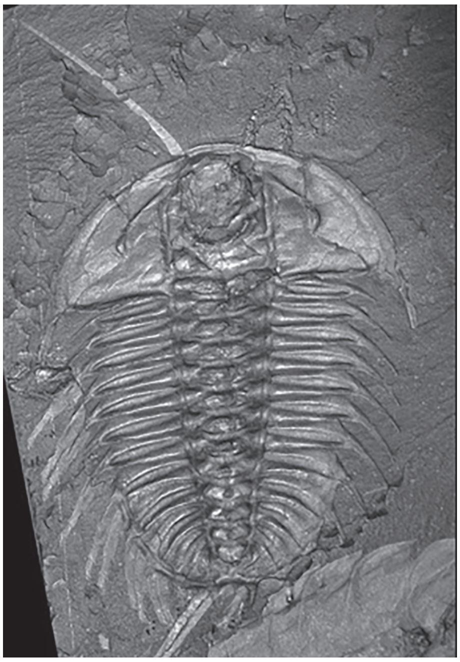

Fig. 6.3

(i) The actual length of the *Olenoides* in Fig. 6.3 is 7.6 cm.

Calculate the magnification of the image.

magnification = ... × **[2]**

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(ii) Identify **one** piece of evidence from the photograph in Fig. 6.3 which suggests that *Olenoides* was both an epifaunal organism **and** that it remained roughly 'in-situ' after death.

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(iii) Explain how trilobites grew.

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(c) Another Konservat-Lagerstätten deposit is the Chengjiang Formation in China. The chart in Fig. 6.4 shows the species diversity and evolution of various types of organisms, as well as an extinction event.

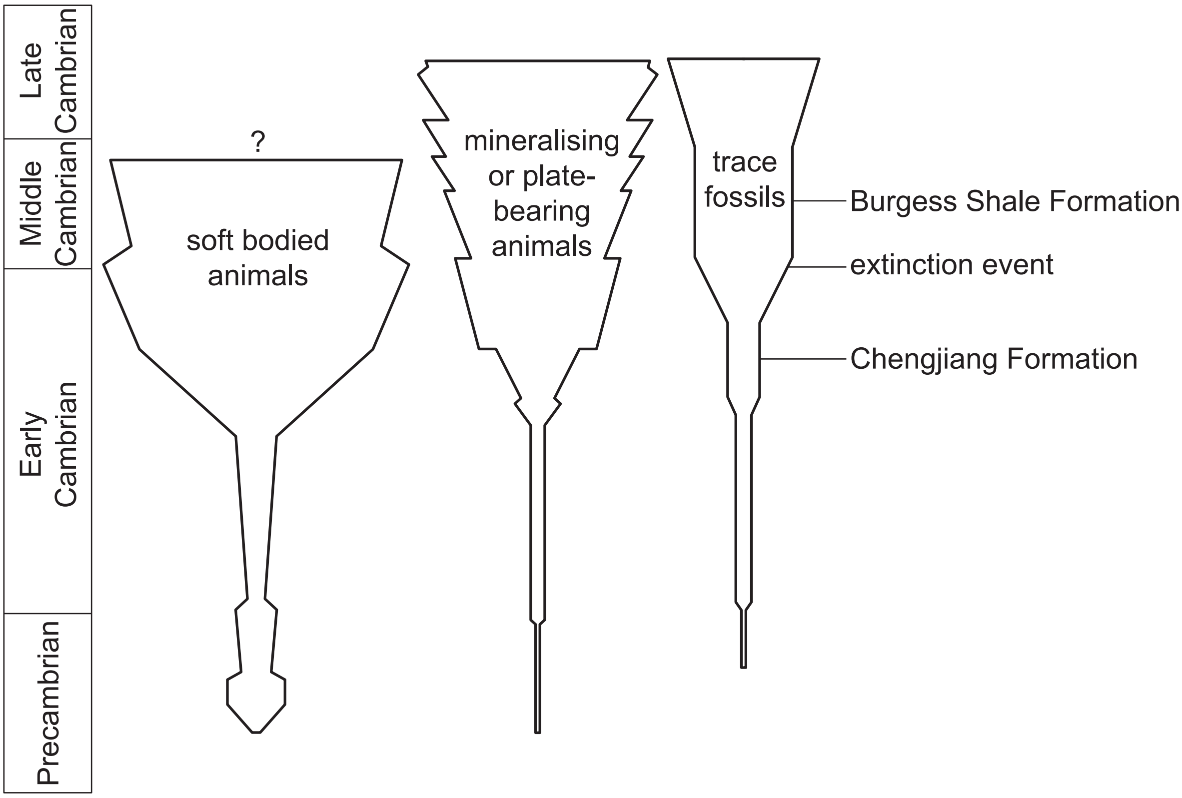

Fig. 6.4

(i) Explain how the information in Fig. 6.4 gives evidence for the 'Cambrian Explosion'.

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(ii) Fig. 6.5 shows the variation in number of types of organism across the whole of the Phanerozoic.

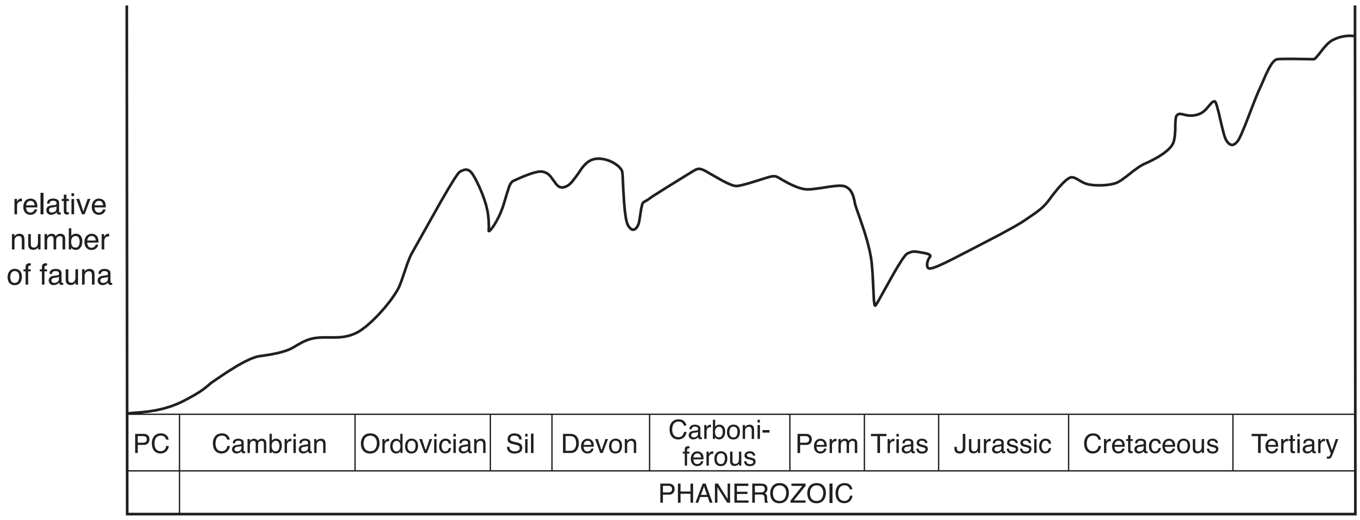

Fig. 6.5

Mark, **on Fig. 6.5**, with a vertical arrow (↓) the positions of **three** major extinction events. **[1]**

(iii) One of the extinction events occurred when the supercontinent Gondwanaland was situated over the South Pole.

Suggest why the formation of a supercontinent caused an extinction event.

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(d) Radiometric methods of dating provide absolute ages for rocks. They rely on the constant rate of breakdown of radioactive isotopes of elements found in some minerals in rocks.

Some minerals in Lower Palaeozoic rocks contain the radioactive potassium isotope, ^{40}K, which breaks down to argon, ^{40}Ar. The half-life of this radioactive decay is approximately 1250 million years.

The radioactive decay curve for ^{40}K to ^{40}Ar is shown in Fig. 6.6.

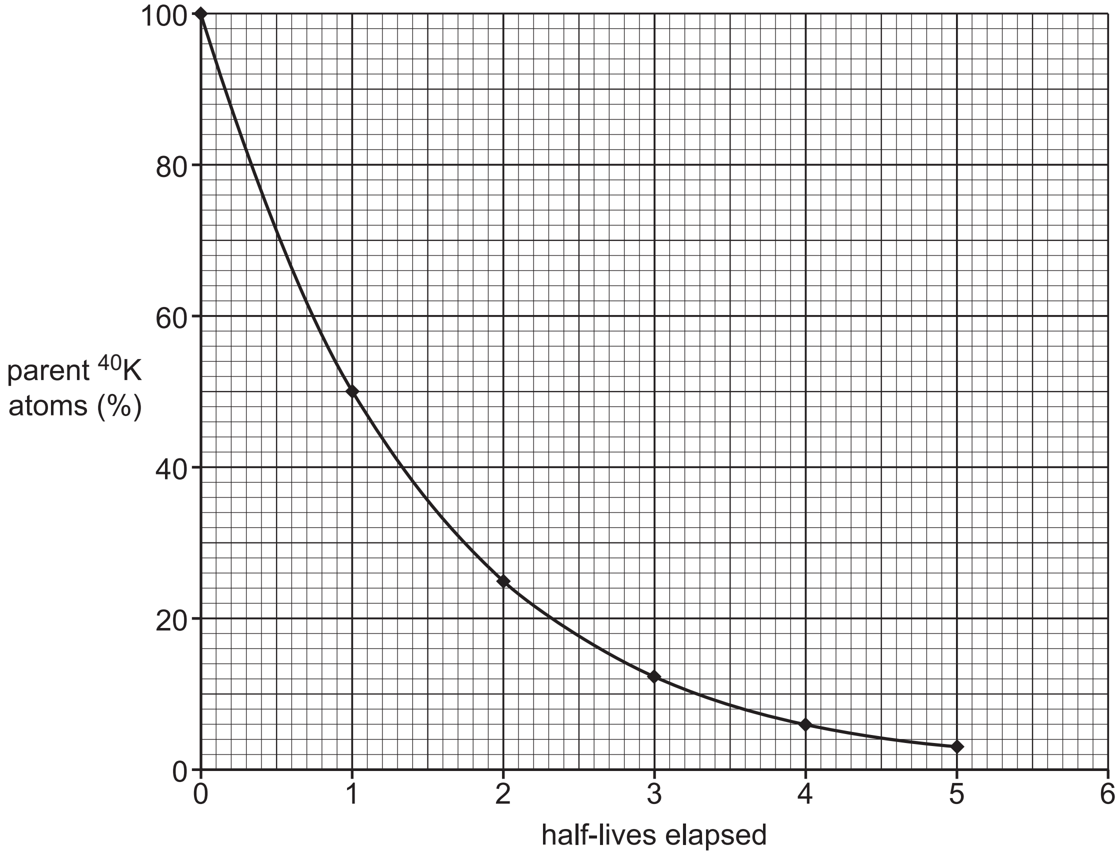

Fig. 6.6

(i) A sample of rock from the Lower Palaeozoic on analysis indicated that 76% of the original parent ^{40}K atoms were left.

Using Fig. 6.6, state the age of this rock.

age of rock sample = ... Ma **[2]**

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(ii) A second sample of rock indicated that only 70% of the original parent ^{40}K atoms were left. A more accurate way to date the rock is to calculate it using the formula for radioactive decay.

Calculate the age of this second sample of rock.

Use the formula: $N = N_0 e^{-\lambda t}$

age of rock sample = ... Ma **[2]**

(iii) The ratio of ^{40}K to ^{40}Ar atoms in the rock is used to determine the percentage of original parent ^{40}K atoms left in the rock.

Suggest why the final decay product of ^{40}Ar might cause a problem with the potassium dating method and explain how this problem would affect the calculated age of the rock.

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END OF QUESTION PAPER

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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).

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