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

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.

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Answer **all** the questions.

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

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.... **[1]**

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

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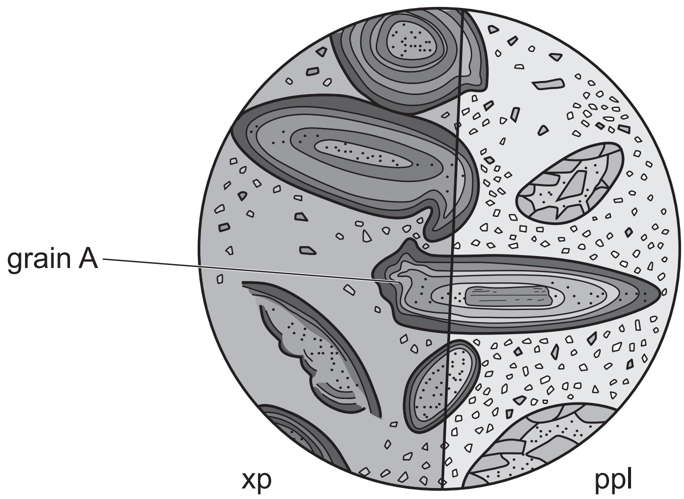
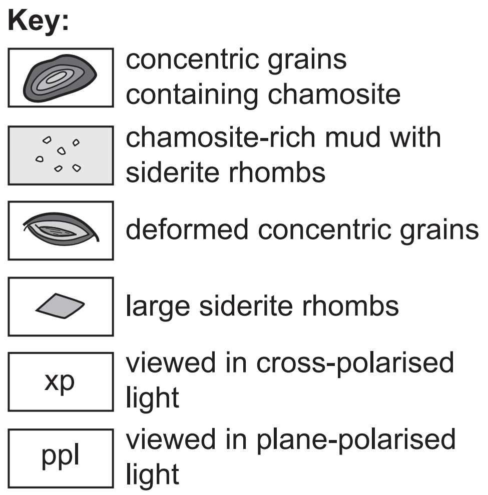
(b) The Jurassic Basin in England extended from North Yorkshire, across to the Mendip Hills and to Dorset in the South, encompassing large parts of South-East England. Other basins also existed at the same time, including the Hebrides Basin in Scotland.

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.





(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.

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(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.

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.... **[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.

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.... **[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.

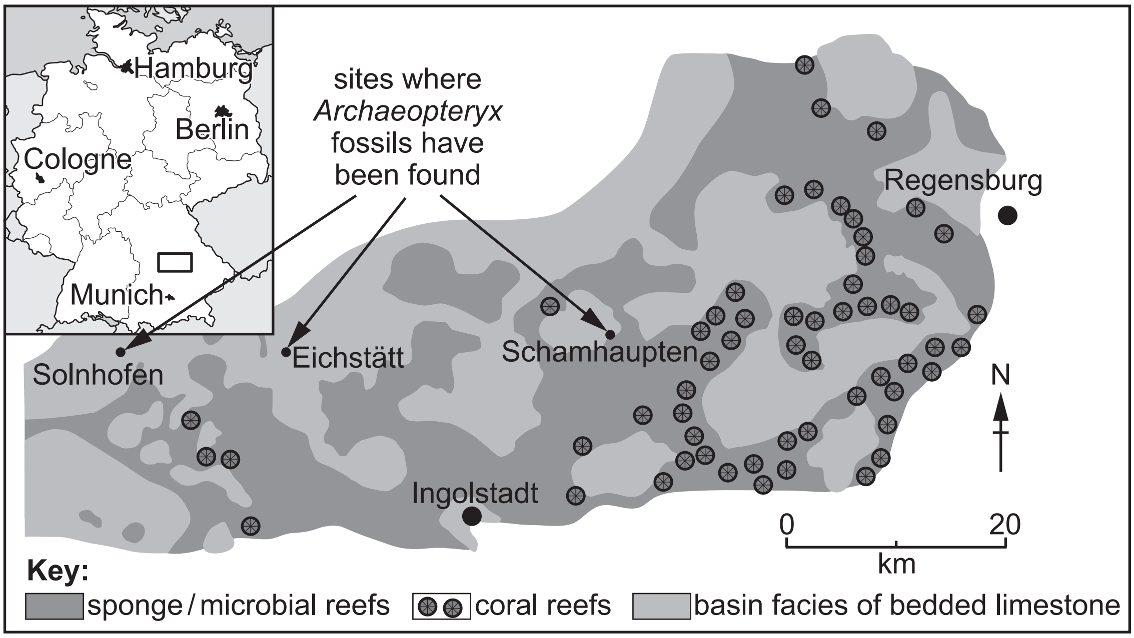

Fig. 2.1

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

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Additional answer space if required.

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(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="3"></td></tr>
<tr><td rowspan="2">rueppelianus</td><td colspan="2">Altmühital Formation</td></tr>
<tr><td rowspan="2">Upper Solnhofen Member
7
3 9
1</td><td rowspan="3"></td></tr>
<tr><td rowspan="3">riedlingensis</td><td rowspan="6">Painten Formation

12</td></tr>
<tr><td rowspan="3">Lower Solnhofen Member</td></tr>
<tr><td rowspan="2">Upper Eichstätt Member
6 10 11
5</td></tr>
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<tr><td rowspan="2">Geisental Formation</td><td>Lower Eichstätt Member
2</td></tr>
<tr><td></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.

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

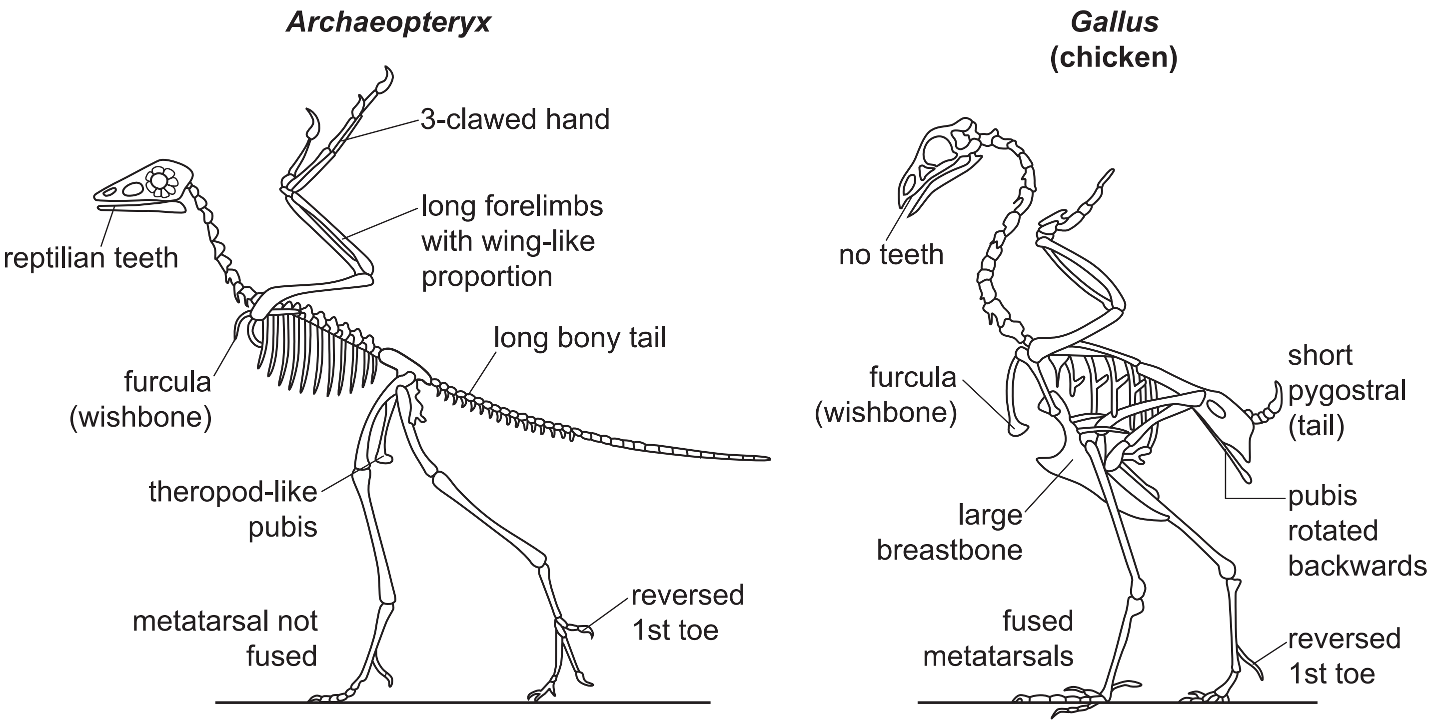

Fig. 2.3

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

similarity 1 ....

....

similarity 2..

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difference 1 ....

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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.

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.... **[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.

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.... **[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.

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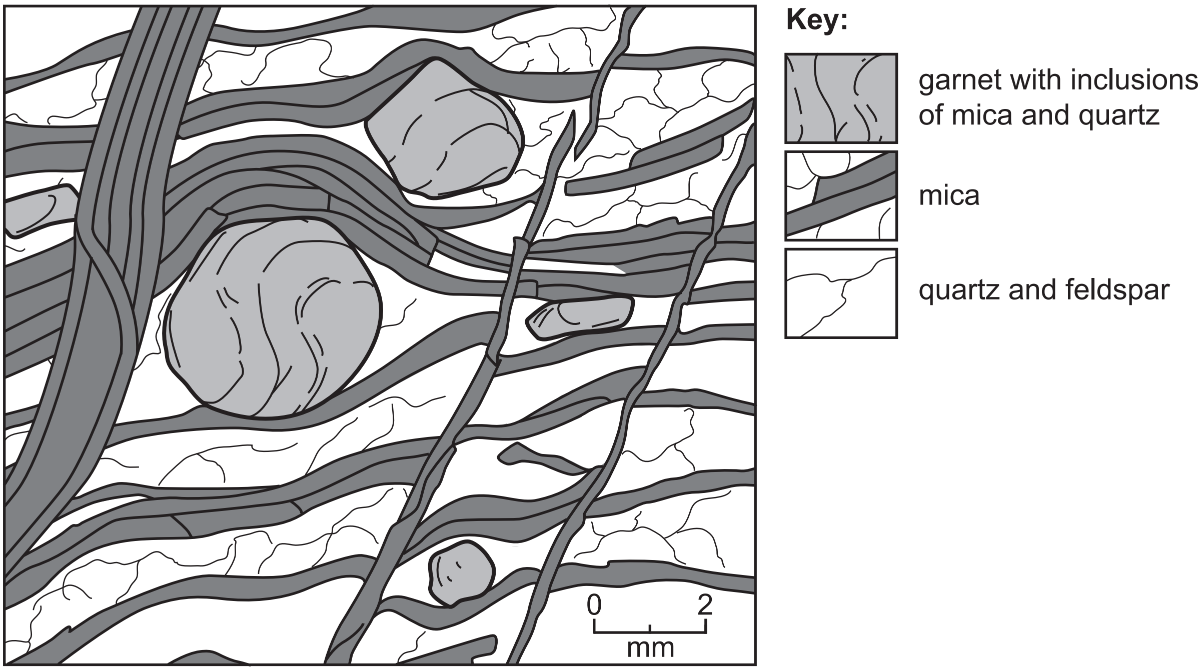
(b)* The image shows a thin-section diagram from a metamorphic rock.



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.

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Additional answer space if required.

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(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.

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.... **[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.

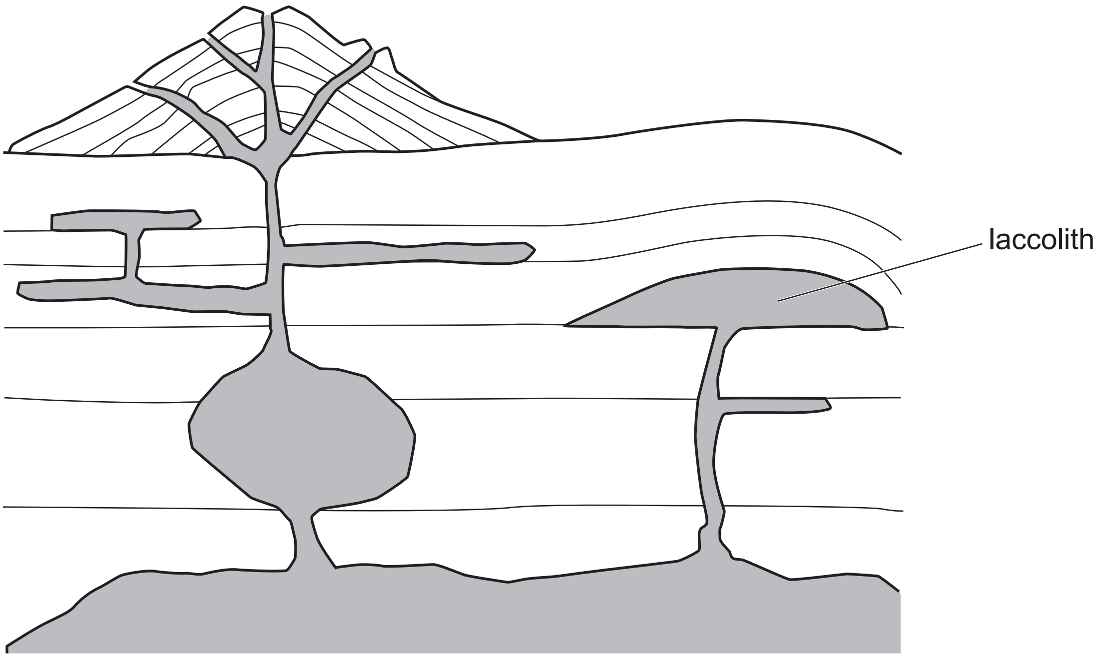

Fig. 5.1

(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.

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.... **[1]**

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

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.... **[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.

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

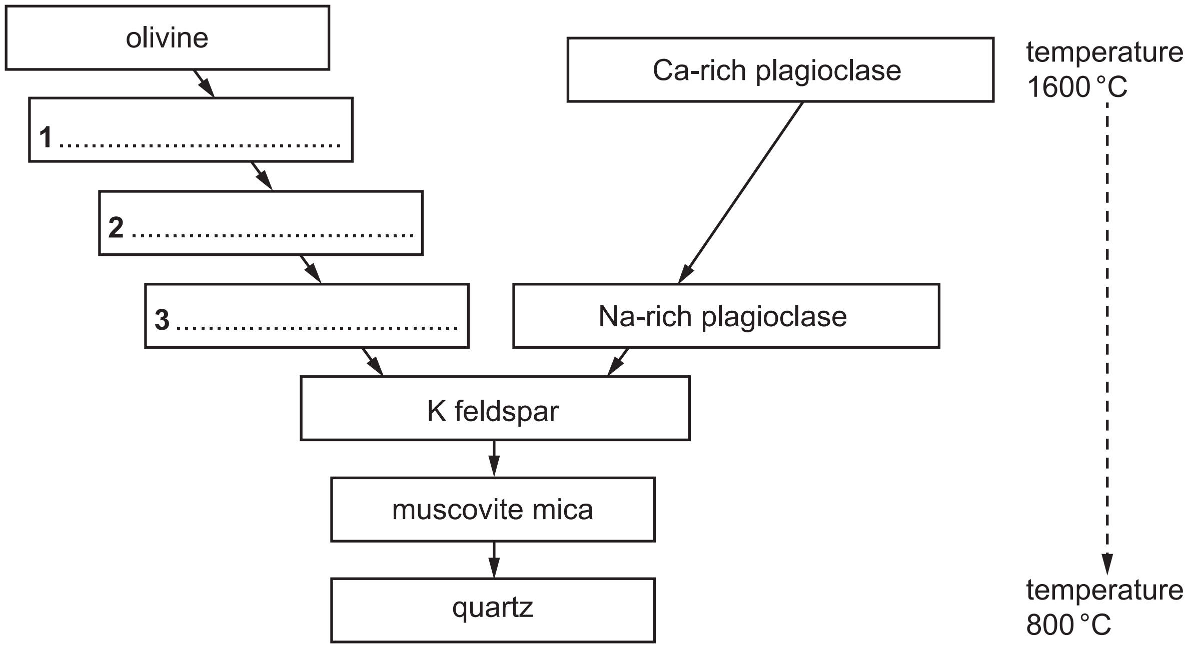

Fig. 5.2

(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.

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.... **[2]**

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

Describe how these three processes result in concentrated deposits.

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

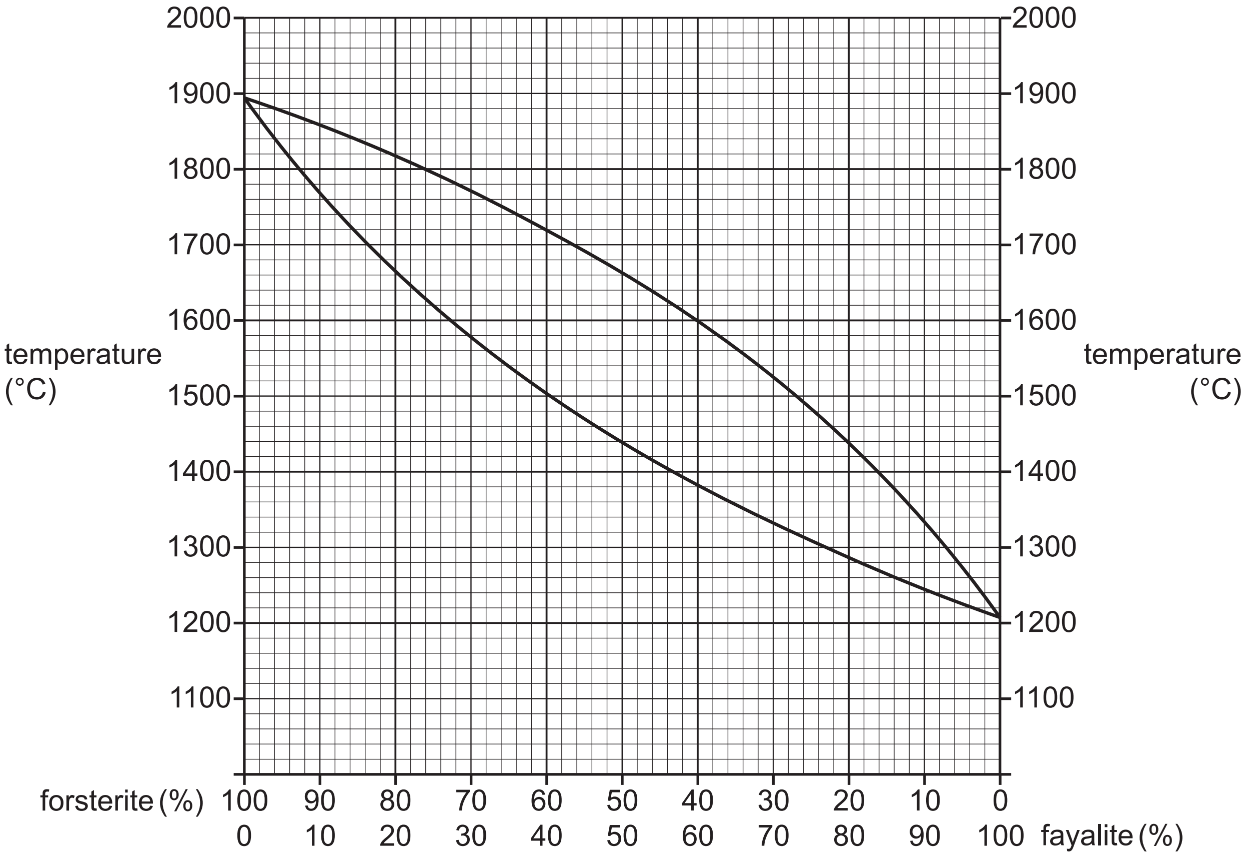

Fig. 5.3

(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?

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.... **[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]**

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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.

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.... **[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.

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.... **[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.

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.... **[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 HCl 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 HCl. Their results are shown in the table below.

	Mass in g			
	A	**B**	**C**	**D**
Mass of beaker & HCl	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.

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.... **[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.

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.... **[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.

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.... **[3]**

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

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.... **[1]**

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

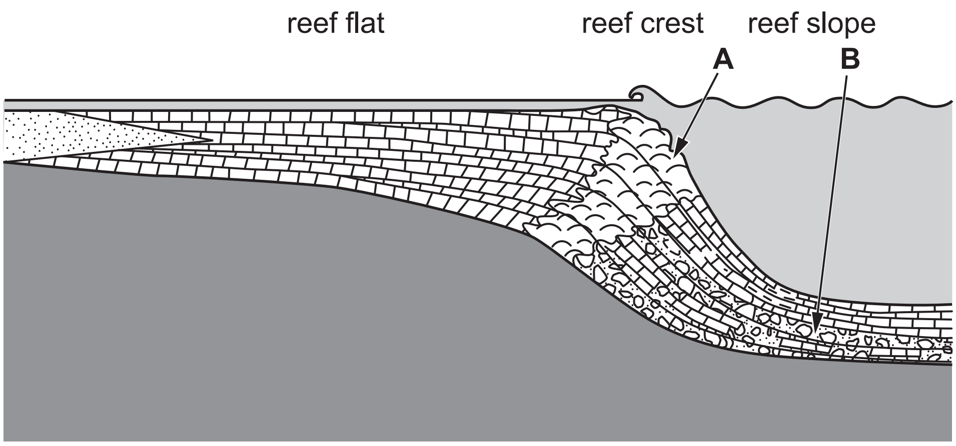

Fig. 7.1

(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.

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.... **[2]**

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

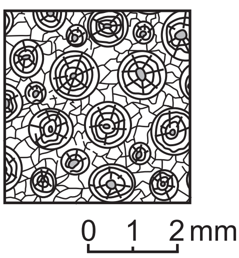

Fig. 7.2

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.

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.... [1]

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

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.... [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.

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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).