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.

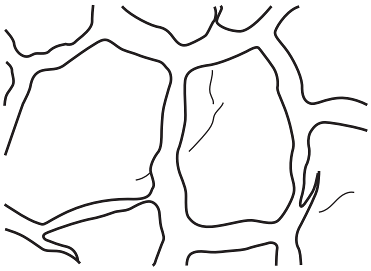
INFORMATION
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **24** pages.

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

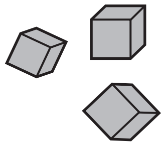


View from above ×0.2

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.

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.... **[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.

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.... **[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 → $(O-E)^2$				
$\frac{(O-E)^2}{E}$				

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

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.... **[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.

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.... **[6]**

Additional answer lines if required.

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(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.

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[2]

(iii) The thickness of each bed was estimated.

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

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.... **[1]**

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

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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.

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.... **[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.

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.... **[2]**

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

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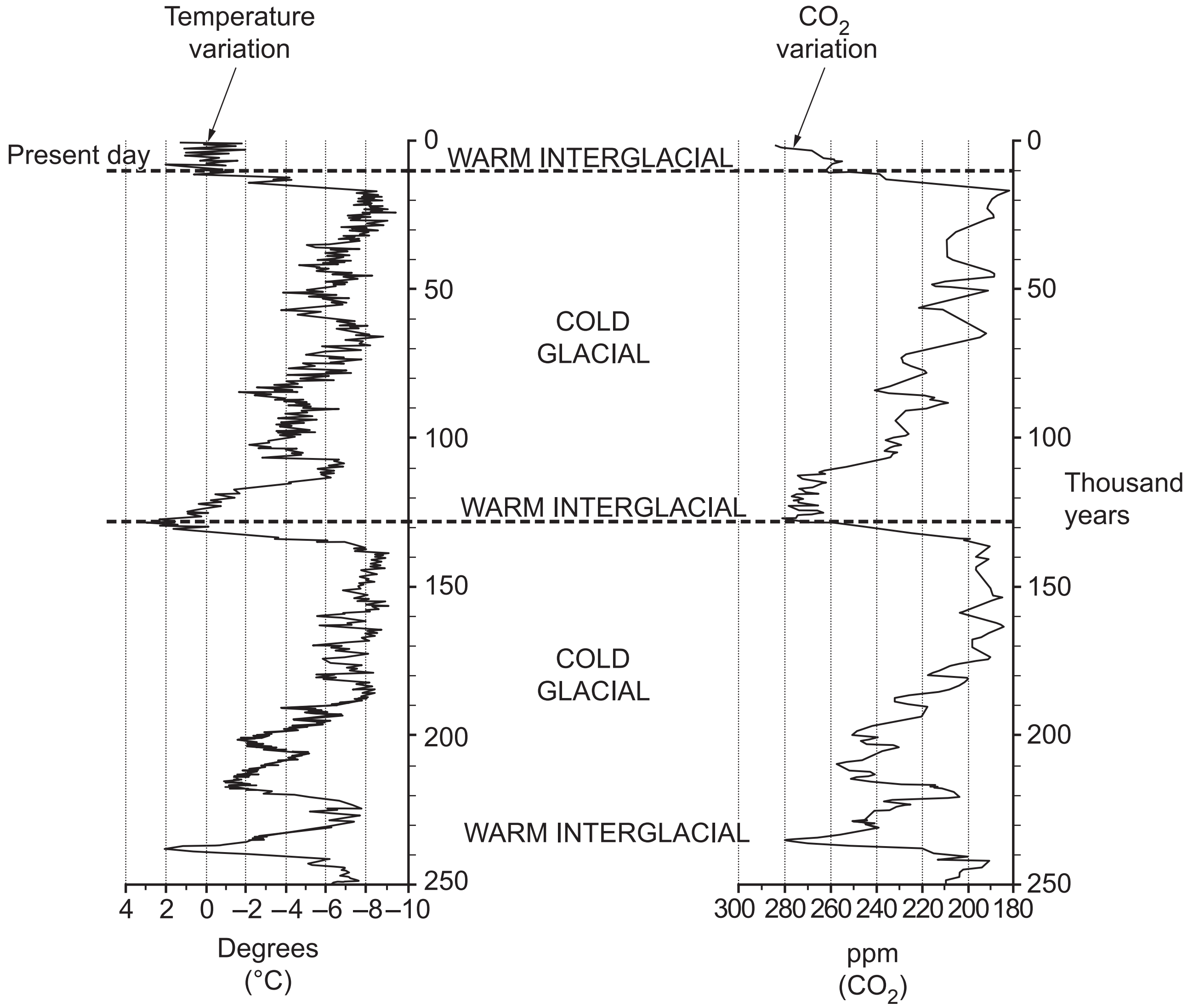
.... **[2]**

(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.

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.... **[2]**

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

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.... **[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.

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

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

Explain the meaning of this statement.

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.... **[2]**

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

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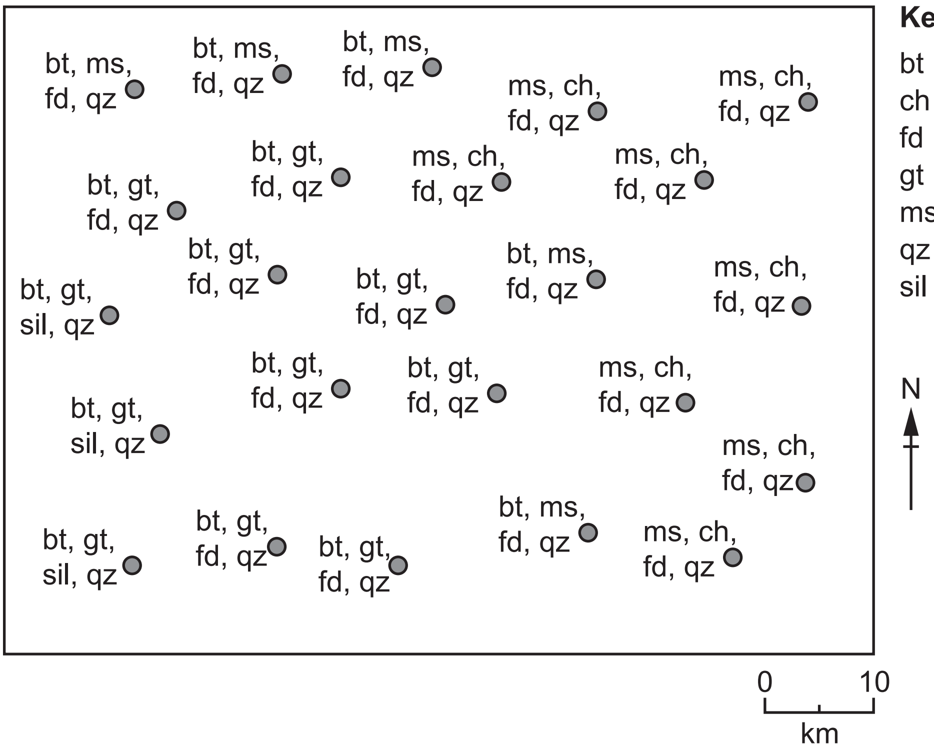
.... **[2]**

(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.



Key:

bt biotite mica
ch chlorite
fd feldspar
gt garnet
ms muscovite mica
qz quartz
sil sillimanite

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.

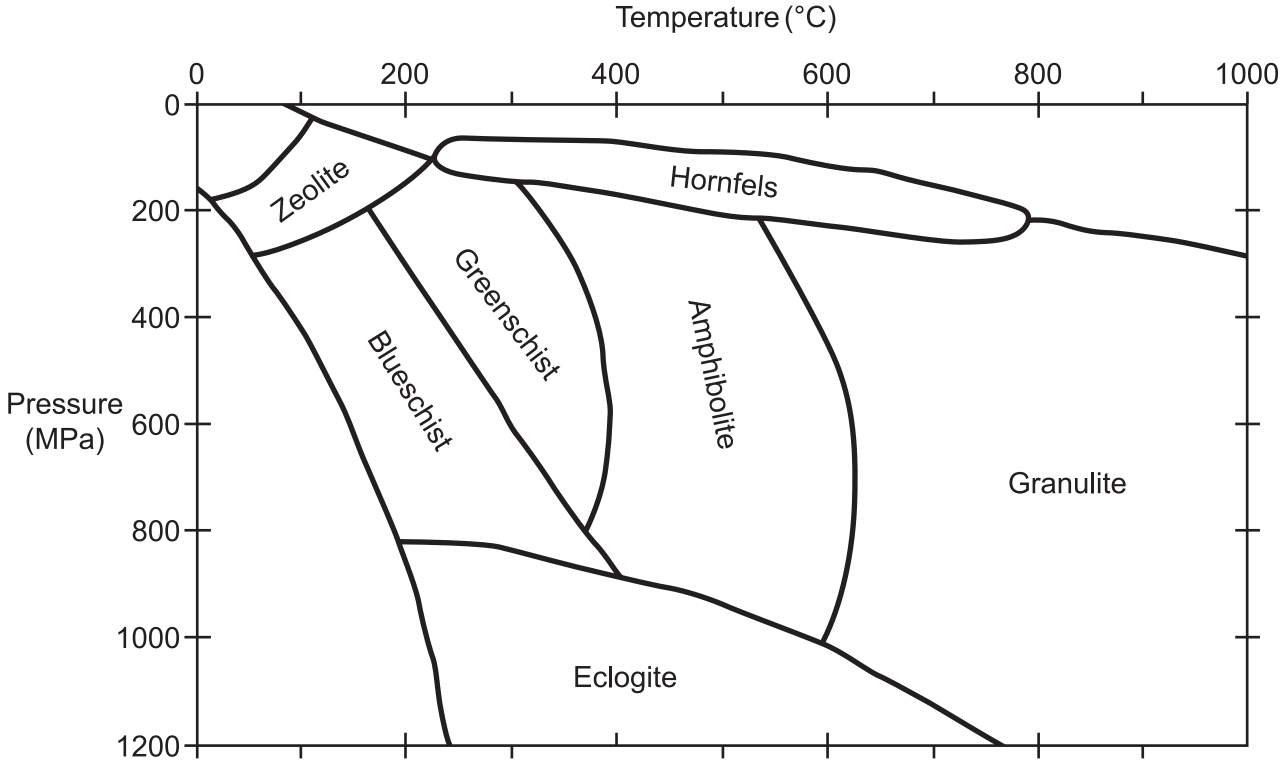


Fig. 3.2

(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.

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.... **[6]**

Additional answer lines if required.

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

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.... **[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.

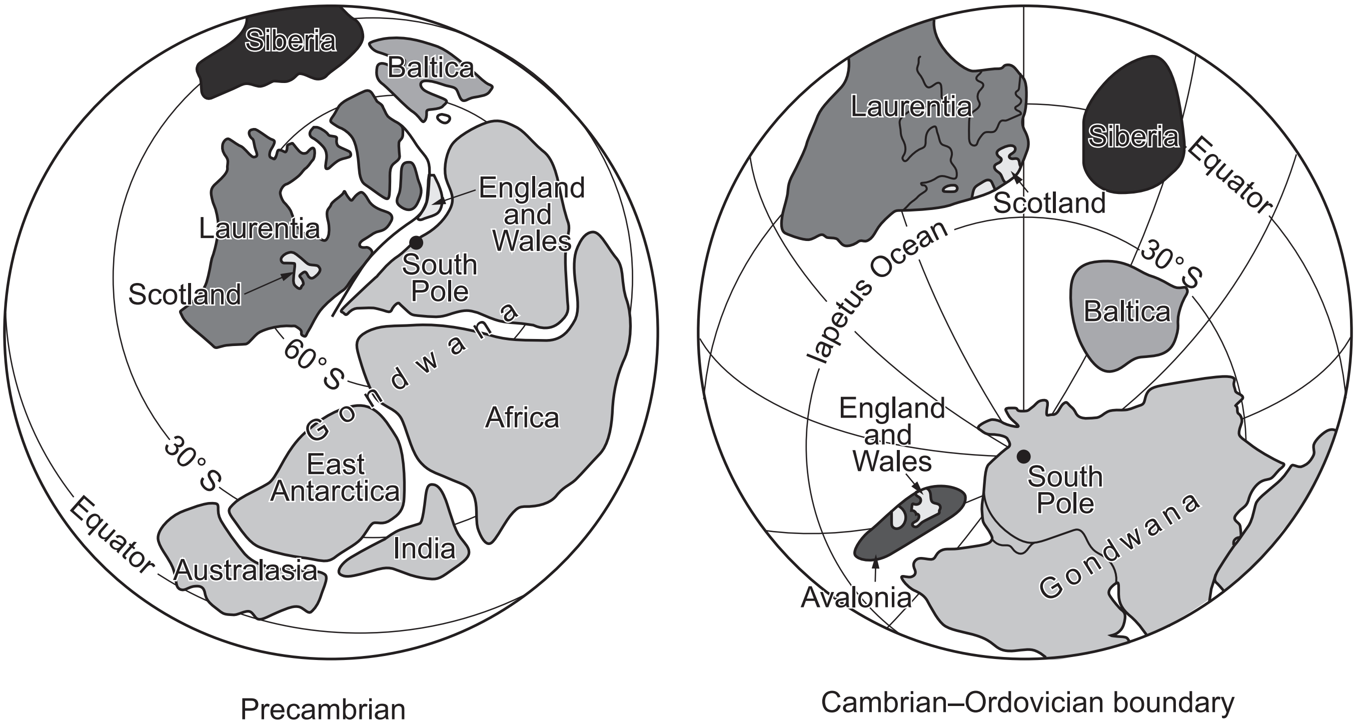

Fig. 4.1

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

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.... **[3]**

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

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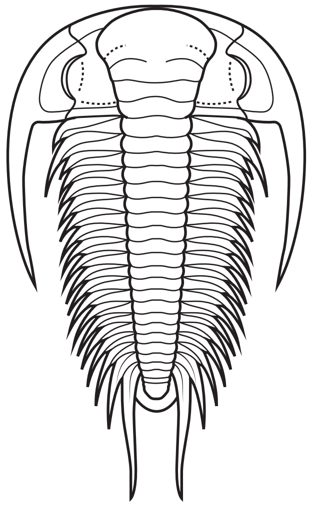
.... **[2]**

(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.

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.... **[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**.

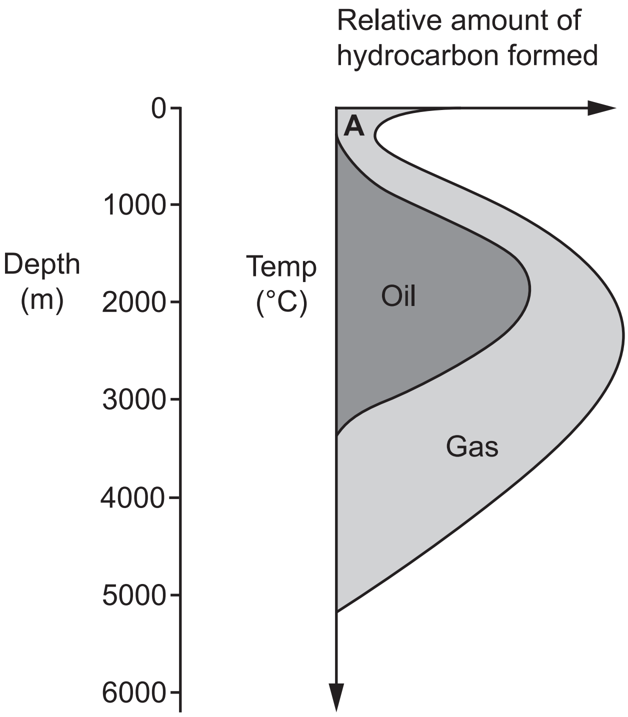

Fig. 5.1

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.

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.... **[2]**

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

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(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.

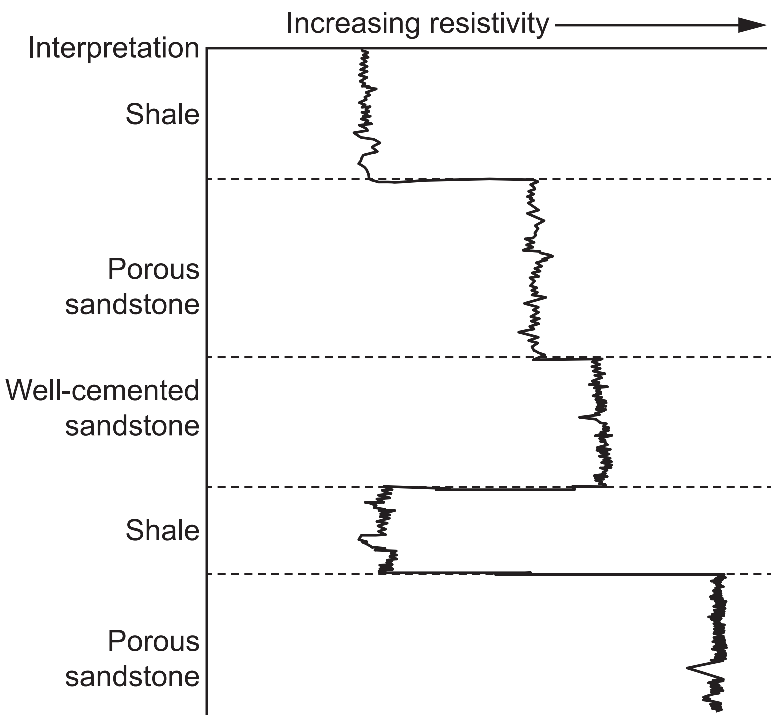

Fig. 5.2

(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.

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.... **[1]**

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

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.... **[1]**

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

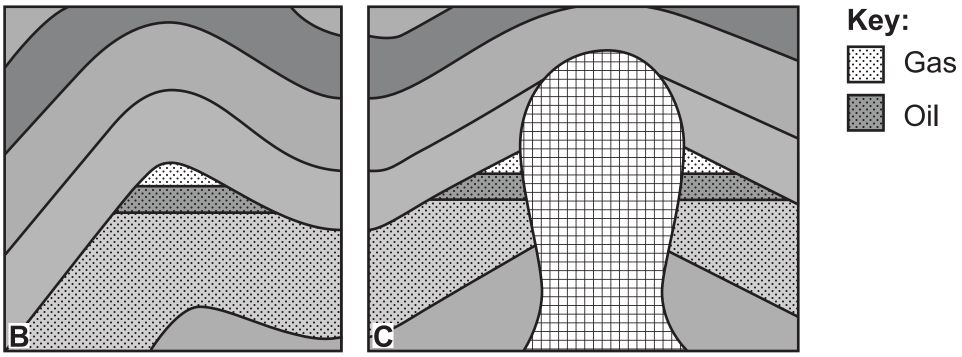

Fig. 5.3

(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.

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.... **[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).