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OCR
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A LEVEL

Examiners' report

GEOLOGY

H414

For first teaching in 2017

H414/02 Summer 2022 series

Version 1

Contents

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates.

The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. A selection of candidate answers is also provided. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.

A full copy of the question paper and the mark scheme can be downloaded from OCR.

Advance Information for Summer 2022 assessments

To support student revision, advance information was published about the focus of exams for Summer 2022 assessments. Advance information was available for most GCSE, AS and A Level subjects, Core Maths, FSMQ, and Cambridge Nationals Information Technologies. You can find more information on our website.

Paper 2 series overview

H414/02 is the second of the three examined components for this qualification. The paper is synoptic in nature and assesses content from across all the 1 to 7 teaching modules, with an emphasis on scientific literacy – the ability to comprehend a passage of text of A Level standard, to extract information from it and use this information to answer the question posed.

The quality of candidate responses has improved compared with the first sitting of the question paper in Summer 2019. It is evident that candidates are more familiar and confident about the structure of the paper and how best to approach it. Most candidates were able to plan their time to answer all questions and there was no evidence that any candidates ran out of time. Those who did not attempt the final question had also left other sections of the question paper blank. Most candidates confined their responses to the answer lines given in the examination booklet, which should be more than enough room to attain the maximum marks available for each question.

Answers to the two 6 marks Level of Response questions (LoR) were usually concise and stayed within the confines of the answer lines provided. It was clear that candidates now have a better understanding of how to approach these questions. The list of indicative points given in the guidance column of the mark scheme for these questions are by no means an exhaustive list and candidates do not have to include all the points in order to attain the highest level.

The mathematical requirement of the paper continues to be a challenge. Those candidates who had been given opportunities to practise the required mathematical skills (Appendix 5e of the specification) over the two years of the course were able to demonstrate their proficiency and performed well on the mathematical skills questions.

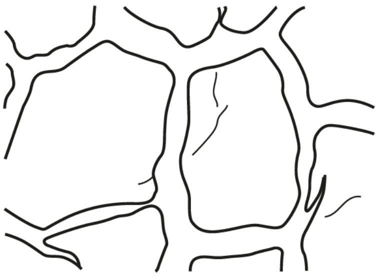
Handwriting was an issue for some candidates, making it difficult for examiners to read and decipher what they had written. If responses are illegible, candidates run the risk of losing credit worthy marks.

Candidates who did well on this paper generally did the following:	Candidates who did less well on this paper generally did the following:
• read the questions carefully, taking note of all the information supplied and the command words used • put together their knowledge and understanding from different areas of the specification when answering individual questions • had good command of correct geological terminology and knowledge and were able to apply what they had learnt to unfamiliar contexts • produced clear and concise responses to the Level of Response questions which included sufficient detail and addressed all the requirements of the questions • performed mathematical calculations with confidence, following the required rubric, e.g., clearly laid out working, use of correct units and significant figures. • drew clear, well-labelled and accurate diagrams when required.	• wrote under-developed responses which either repeated the questions or did not clearly address the questions asked • did not have the depth and breadth of geological understanding required to answer the mainly synoptic questions on the paper • did not have good command of correct geological terminology and knowledge and found it difficult to apply what they had learnt to unfamiliar contexts • produced unstructured responses to the Level of Response questions which were lacking in depth or explanation, or contained incorrect or contradictory information • were unable to tackle the mathematical skills questions with any confidence, with some giving 'No Response' to all the calculation questions • drew inaccurate, and unlabelled diagrams not worthy of any credit • in some cases, had almost illegible handwriting which was extremely difficult and time-consuming to decipher.

Question 1 (a) (i)

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

A

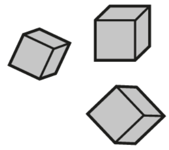


View from above ×0.2

B

View from side ×1

C



View from above ×0.4

A ....

B ....

C ....

[3]

Candidates were familiar with sedimentary structures, and many were able to correctly identify all of the sedimentary structures shown in the diagrams. Sedimentary structure **A**, desiccation cracks, were well known, but some were less familiar with the view from above, rather than a cross-section view. Not all candidates took account of the scale for sedimentary structure **B**, ripple marks, so the most common incorrect responses were cross-bedding or sand dunes. Some did not know the required technical term of pseudomorphs for sedimentary structure **C**, salt pseudomorphs.

Question 1 (a) (ii)

(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]

The application of sedimentary structures to determine way up and palaeocurrent direction was well known, so virtually all candidates achieved some credit. A small number of candidates did not read the question carefully enough and although they used a ✓ to indicate the structure could be used, some did not use a **X** to indicate the structure could not be used and left the boxes blank instead.

Question 1 (a) (iii)

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

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....

.... **[2]**

Few candidates gained both marks for this question.

Although correctly named rocks were accepted, the question asked for sediments, so unconsolidated material should have been described. Of those who did describe a correct sediment type, not all gained the mark as very few linked the sediment to its correct position in the sea, either near shore or offshore. Those who recognised the offshore transition from high energy beach to low energy below the wave base were in the minority.

Correct sedimentary structures were better known but many did not describe where or why the sedimentary structure would be formed.

Misconception

? The term siliciclastic was not understood by some candidates. This resulted in some suggesting various limestones as the likely sediment type. These would be expected in shallow carbonate seas rather than in shallow siliciclastic seas.

Question 1 (b) (i)

(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]**

This was a low scoring question with a significant number of 'No Responses'. Many candidates appeared to be unfamiliar with Walther's Law of facies or the changes in sediment type in a braided river. A significant number described a meandering river rather than a braided river but could still attain up to 2 marks for correct descriptions.

Optional labelled diagrams showing a network of wide shallow channels separated by islands of sand and gravel were used to good effect by those familiar with braided river systems. Only the best responses gave a correct explanation of Walther's Law which relates vertical sequences in outcrop to the lateral facies changes within sedimentary environments.

Exemplar 1

as velocities increased and decreased bar deposits were formed and deposited conglomerates however as river velocity increased, these bar deposits were covered and eroded and new deposits on top were made over the top as velocity decreased again.
The river moves laterally as banks are eroded so over a large area these deposits are made and as new rivers come along, they deposit over old rivers deposits.

The law of facies is about how vertically formed facies ~~show~~ now, show us that the vertical ~~xx~~ succession shows us what environments were at one point next to each other, or happened laterally

Exemplar 1 is an example of a response that gained full marks. The diagram and accompanying text clearly describe a braided river system. Lateral channel migration is well understood and, although the wording could be more concise, a clear understanding of Walther's Law relating vertical sequences to lateral facies changes is demonstrated.

Question 1 (b) (ii) and (iii)

(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

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.... **[2]**

For Question 1 (b) (ii) not all candidates were acquainted with how to perform a chi squared test. Of those who understood the process, many attained 2 marks for correctly calculating the expected frequency as the sum of the observed frequencies divided by the number of categories of data, and then went on to calculate the ***O – E*** values correctly. A significant number of candidates then lost the remaining marks as they did not remove the negative sign when squaring negative values for the ***(O – E)²*** row.

For Question 1 (b) (iii) error carried forward from 1 (b) (ii) was allowed. It was clear there was a lack of understanding of how to calculate the degrees of freedom required to use the excerpt from the table of critical values provided. The degrees of freedom are one less than the number of categories, so in this case the degrees of freedom are 4-1 = 3.

As candidates were not required to use a particular significance level, correct comparison of their calculated chi squared value to any significance level was allowed, including for those who calculated the degrees of freedom incorrectly. However, there was confusion between probability, degrees of freedom and critical value – some candidates used them as if they are interchangeable.

Not all candidates understood that if the chi squared value is greater than the critical value, then the (null) hypothesis should be rejected and very few went on to state that the shape of the pebbles was not random (which was arguably the whole point of the exercise).

OCR support

The OCR Geology Mathematical Skills Handbook provides support for the mathematical skills required by the A Level Geology specification, including skill M2.12 select and use a statistical test. The content of the handbook follows the structure of the mathematical requirements table in Appendix 5e of the specification, with each skill (M1.1–M4.3) discussed in turn.

Question 1 (c) (i)*

(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

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.... **[6]**

There were some excellent responses to this Level of Response question which attained the maximum Level 3 marks with ease. Candidates secure in their knowledge and understanding of the characteristics of the different sedimentary environments listed in the specification were able to successfully identify the sequence as deltaic in origin and could correctly link the features of beds **A** to **G** to the different parts of a deltaic cyclothem.

Less successful responses did not look at the cliff section as a whole. These candidates tried to identify each bed as a separate depositional environment rather than linking them together as adjacent facies within one depositional environment. This led to incorrect interpretations. For example, some ascribed the large scale cross-bedding in bed **E** to a desert environment, ignoring the presence of plant fragments and the poor sorting of the sandstone.

Beds **A** and **B** both contained mudstone and bivalves. Candidates often lumped then together as representing one environment even though the other characteristics of the two beds did not match. The coal and rootlets in bed **A** indicated it was from a swampy, terrestrial delta top environment, while the bioturbation and laminations in bed **B** suggested the low energy, deeper water marine environment of the prodelta. There was confusion as to where thin-shelled bivalves can be found – these can exist in fresh water, brackish and fully marine conditions, so do not always indicate marine conditions.

Assessment for learning

Although they were not penalised for doing so, candidates often discussed the sequence from the top downwards which, for some, made it difficult to suggest a sensible progression from one environment to the next over time. When teaching recognition of ancient sedimentary environments in the geological record, it should be emphasised that sequences should be considered in age order from the oldest to the youngest event, which is from the bottom of the sequence upwards.

Exemplar 2

The environment of deposition is a ~~det~~ delta. This can be ~~se~~ identified as it is a coarsening-up sequence and contains coal. Bed G is the top of the cyclothem, in the topset environment which forms coal in swamps. Bed ~~E~~ C ~~4~~ to F show the foresets, where the rivers meet the sea and deposit all the material they were carrying. This forms coarse sandstone near the top that ~~fix~~ get finer the further from the river mouth. They often contain cross-bedding. Bed B shows the bottom set environment which in this case is mudstone formed from settling of mud grains which creates laminations. The bottom set often contain marine fossil, ~~bea~~ this bed contains bivalves, which haven't ~~beed~~ been specified as marine. ~~B~~ However, the sediment **[6]**

Additional answer lines if required.

is described as black which suggests deep marine. Bed A, looks to show the start of a new cyclothem (at the topset again). This is because it contains coal. However, it also contains mudstone and bivalves, but they aren't specified to be marine so could be forming similarly to floodplain clays in the topset swamps.

Exemplar 2 is typical of the well-written, comprehensive responses that attained Level 3 for this question. Although the candidate has worked from the top downwards, they have given concise descriptions and explanations linking the evidence in each bed of the table to a specific part of a delta. They recognise that the sequence is coarsening upwards as a result of the increase in energy from the prodelta bottomset beds to the delta front foreset beds. They have suggested that deposition is cyclical, understanding that beds **A** and **G** are the topset beds of their respective cyclothems.

Question 1(c) (ii)

(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]

Well answered. Most candidates scored both marks with the textural observations of grain size, grain shape and sorting being the most common correct responses cited. A small number of candidates lost marks as they stated size and shape without referring to grain or an equivalent, while others stated texture which was not specific enough. Testing the rock with acid was not accepted as this is not an observation.

Question 1(c) (iii)

(iii) The thickness of each bed was estimated.

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

....

.... **[1]**

Many candidates correctly suggested some variation on measuring the bottom, accessible beds and then using a suitable scale to estimate the thicknesses of the remaining beds. Some suggested using a person or object but had to make it clear they were of known size to gain the mark. Some of the more inventive suggestions, such as hanging a tape measure down from the top of the cliff, were rejected on the grounds of safety.

Question 1(c) (iv)

(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]**

Well known with most candidates attaining credit. Unreasonable safety implications such as 'falling off a cliff and hurting yourself when climbing' were not accepted as unsafe activities should never need to be mitigated against when logging a sedimentary sequence or doing any other field-based activities.

Question 2 (a) (i)

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]**

Wegener's evidence for the theory of continental drift was well known and most candidates attained some credit for their responses. However, very few gained maximum marks as much of the evidence described was too vague to score marks.

For example, many stated the 'continents fit together' which is not really precise enough, as it is the coastlines or edges of the continental shelves that fit together. Others described 'similar fossils or similar rock types across different continents'. The correct evidence is land-based or shallow water fossils of the same species found on different continents or rocks of the same age and same type that match across different continents.

Discussion of radiometric dating and palaeomagnetic evidence did not attain credit as these are more recent lines of evidence that have been developed since Wegener's time.

Question 2 (a) (ii)

(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]**

Mantle convection currents, ridge push and slab pull were well known mechanisms but not all candidates could give credit worthy descriptions and explanations of these processes.

Question 2 (a) (iii)

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

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.... **[2]**

This recall question was answered well, and most candidates attained some credit. However, a minority got the density the wrong way round and stated continental crust is denser, while others confused the composition and rock types that would be found in the two types of crust.

Question 2 (b) (i)

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

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

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

Very few candidates attained both marks for this question as many misunderstood what they were supposed to do. Instead of reading off the maximum value (280 ppm) and the minimum value (190 ppm) between 250 and 230 thousand years, they read off the values at 250 thousand years (210 ppm) and at 230 thousand years (240 ppm) so lost the marks. Others did not understand how to calculate a percentage change and forgot to subtract the minimum number from the maximum number, forgot to divide by the minimum number, or forgot to multiple by 100 to convert their response to a percentage.

Question 2 (b) (ii)

(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]**

Most candidates attained at least 1 mark for either recognising that CO_2 concentrations were high due to volcanic activity or because few organisms existed that were able to photosynthesise during this time in Earth history. Some candidates lost marks as they did not specify the term photosynthesis. Although a few candidates cited the Great Oxygenation Event, some did not make it clear that the high levels of CO_2 in the Precambrian were before this event.

Question 2 (b) (iii)

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

....

.... **[1]**

This question proved challenging. Many candidates did not include the idea of periodicity in their responses, and few were familiar with Icehouse / Greenhouse Earth cycles. Many stated there was more or less CO_2 in the atmosphere or there were glacial and non-glacial periods which did not attain credit.

Question 2 (c) (i)

(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]**

The Anthropocene epoch was well known. Not all could spell the word correctly, but candidates were given credit if their meaning was clear. Homocene, which doesn't exist, was a common incorrect response.

Question 2 (c) (ii)

(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]**

There were some excellent responses to this question. Many candidates seemed to relish having the opportunity to debate the global impact human activities are having on the planet and the evidence this is leaving in the geological record. Correct descriptions included man-made materials such as plastics, widespread radionuclides from nuclear testing in the 1950s and the vast accumulation of chicken bones in landfills. However, very few were able to correctly describe the requirement of finding a global standard stratotype-section and point (GSSP) – a so-called 'golden spike' which is an internationally agreed global marker horizon.

Question 3 (a) (i)

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

Explain the meaning of this statement.

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.... **[2]**

Well understood with most candidates attaining credit for explaining that isochemical means the composition stays the same. Some mistakenly stated that the minerals stay the same, which is not correct as during recrystallisation new minerals form, but the bulk composition remains the same. The explanation of solid state was not done as well with many repeating the question it is sold state rather than explaining that this means no melting occurs or the rock stays solid.

Question 3 (a) (ii)

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

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.... **[2]**

Retrograde metamorphism was not as well known and there were a significant number of 'No Responses'. Many candidates did not explain this occurs as temperatures and pressures reduce when rocks are uplifted towards the surface. However, at the top end there were some superb examples of hydration, carbonation and oxidation reactions described, including the serpentinisation of olivine when it reacts with water.

Question 3 (b)

(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.

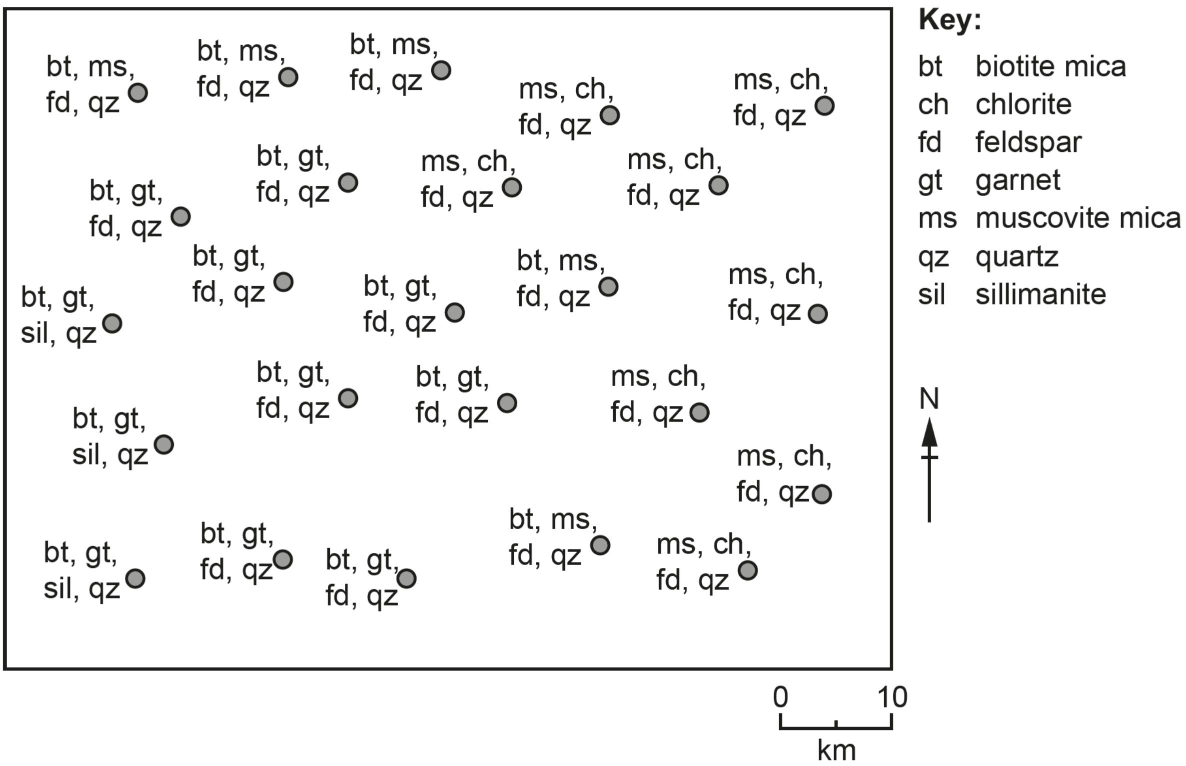

Fig. 3.1

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]**

The construction of isograds was quite well understood with many candidates attaining 1 mark for the isograd between garnet and sillimanite. However, attaining the second mark proved more challenging. A number of candidates did not recognise they needed to draw two more isograds and only drew one. The isograd between chlorite and biotite was tricky to draw and the chlorite-biotite and biotite-garnet isograds were quite close to each other in places leading to some candidates overlapping them. Others had no idea and tried a random 'join the dots' method or left the map blank.

Question 3 (c) (i)

(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]

This question was answered well. Most candidates were able to interpret the rock descriptions to correctly identify metamorphic rocks **A** and **B**. This was coupled with a good knowledge of the respective parent rocks leading to many scoring maximum marks. The most common incorrect response was marble with the parent rock of limestone for **A**. These candidates had not taken account of the mineralogy of predominantly quartz. Some penalised themselves as they did not use the prefixes ortho and meta when referring to quartzites. Gneiss was well known as metamorphic rock **B**, but not all correctly suggested a suitable parent rock, with granite given as a common incorrect response. Some gave mineral rather than rock names so could not attain credit.

Question 3 (c) (ii)

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

Include a scale on your diagram.

[3]

Generally done well but the small amount of biotite mica in the rock proved to be a distractor for some. Taking account of the granoblastic texture, most candidates correctly drew the quartz crystals all the same size and usually included a suitable labelled scale bar to match the 3 mm average crystal size. The most common mistake was to draw the quartz as rounded grains rather than interlocking crystals. The question stated 'metamorphic fabric' so candidates should have been clear they needed to draw metamorphic rock **A** rather than its sedimentary parent rock.

OCR support

The OCR Geology Drawing Skills Handbook provides support for the essential drawing skills required by the A Level Geology specification. As well as providing advice on producing field sketches of geological features in outcrop, the handbook also provides guidance on how to approach the drawing of rocks in hand specimen and thin-sections under the microscope.

Question 3 (d) (i)

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

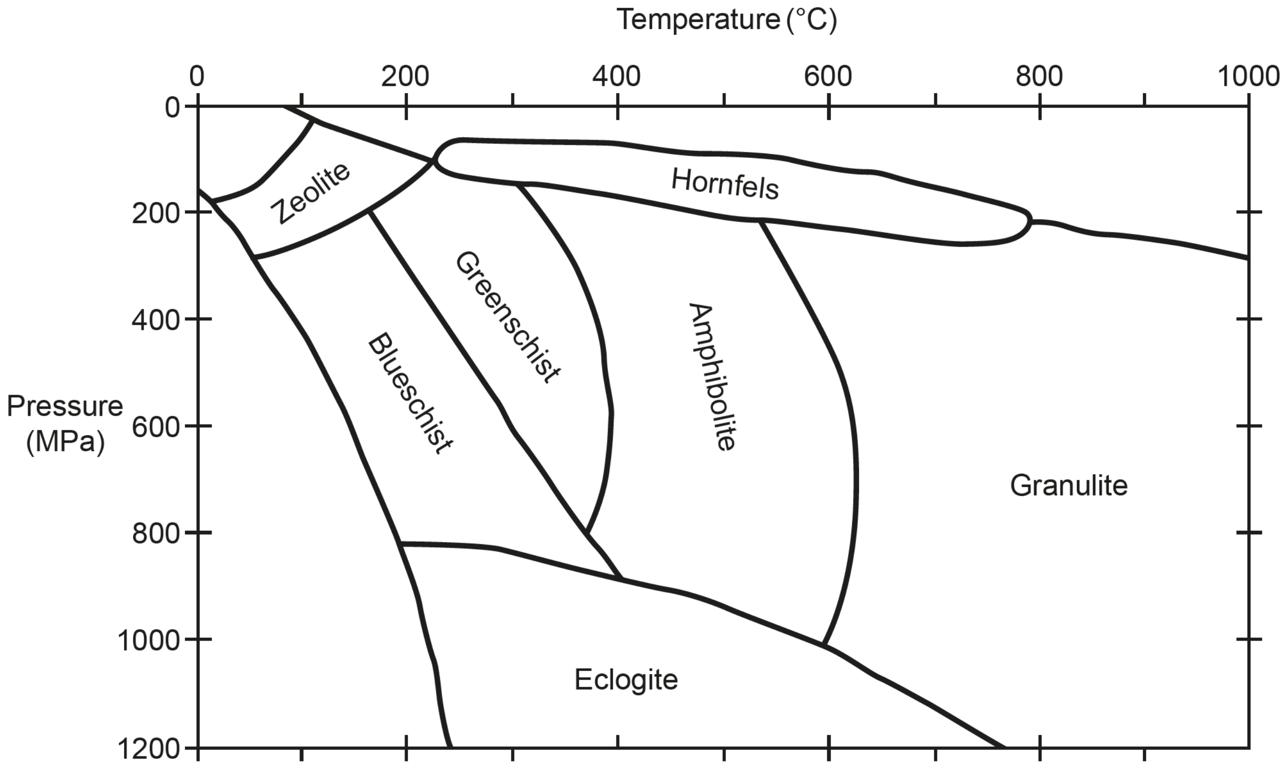

Fig. 3.2

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

Answered well as the majority of candidates knew contact metamorphism would be within the hornfels facies on the graph. Common errors included drawing the line above or below the hornfels facies or labelling a zone rather than a path.

Question 3 (d) (ii)

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

.... **[1]**

Many candidates knew the triple point is at about 525°C and 385 MPa so were able to correctly state this would be within the amphibolite facies.

Question 3 (d) (iii)

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

.... **[1]**

Well answered. Most candidates read the two numbers off the graph accurately and remembered to include the units of MPa.

Question 3 (e)*

(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]**

Most successful responses (Level 3 marks) gave succinct descriptions and explanations of the formation of new textures and minerals that develop during prograde regional metamorphism. These responses gave logical descriptions of the progression of metamorphic rocks from slate to phyllite to schist to gneiss with increasing grade and had good command of correct textural terms such as crenulation cleavage and porphyroblasts.

Few candidates made the mistake of describing contact metamorphic rocks, although some incorrectly used the term granoblastic lifted from Question 3 (c) (i). Other errors included describing shale as a low grade metamorphic rock or using the term porphyritic instead of porphyroblastic.

Less successful responses did not use correct metamorphic terminology. Level 1 standard responses frequently gave a basic description of the development of a foliation or stated a correct regional metamorphic rock name or index mineral, often with omissions, errors, and contradictions.

Misconception

The terms porphyritic and porphyroblastic are often transposed by candidates. Porphyritic is an igneous textural term referring to a rock with two distinct crystal sizes formed from magma that cooled at two depths. Coarse phenocrysts crystallise first at depth and then the magma rises to a higher level and cools more rapidly forming the finer groundmass. Whereas porphyroblastic is a metamorphic textural term referring to large new crystals that grow during recrystallisation. Porphyroblasts can form at any time during the metamorphic event so may be pre-, syn- or post-kinematic.

Exemplar 3

At low grade metamorphism, with low temperatures and pressures, it will become slate. It will have an index mineral of chlorite and possibly biotite. It will contain slaty cleavage, with alignment of platy mineral grains 90° to maximum pressure. At medium grade metamorphism, with medium temperatures and pressures, it will become schist. It will have index minerals garnet and possibly biotite and kyanite. It will contain schistosity, where the platy minerals, like micas will align 90° to maximum pressure. However, alignment may be interupted by ~~granoblasts~~ porphroblasts of garnet. At high grade metamorphism, with high temperatures and pressures, it will become gneiss. It will have index minerals of kyanite **[6]**

Additional answer lines if required.

and sillimanite. It's texture will be gneissose banding were melanocratic (dark coloured) and leucocratic (light coloured) minerals form in layers due to segregation of minerals.

Exemplar 3 shows a succinct response that was more than enough to attain Level 3. The candidate has described rocks, textures and minerals formed during prograde regional metamorphism in a logical order from low grade to high grade. The candidate has not included information about phyllite, but this did not preclude them attaining Level 3 as it is not necessary to include every indicative point in the mark scheme. All the terminology used is correct with good explanations of how the various types of foliation develop.

Question 3 (f)

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

....

....

....

....

.... **[2]**

Candidates who knew the terms competent and incompetent and were able to link these to the composition or mineralogy of parent rocks scored highly on this question. However, some used terms such as bend and snap rather than technical terms such as fold and fault, while others did not relate the brittle or ductile behaviour of rocks to their compositions.

Question 4 (a) (i)

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.

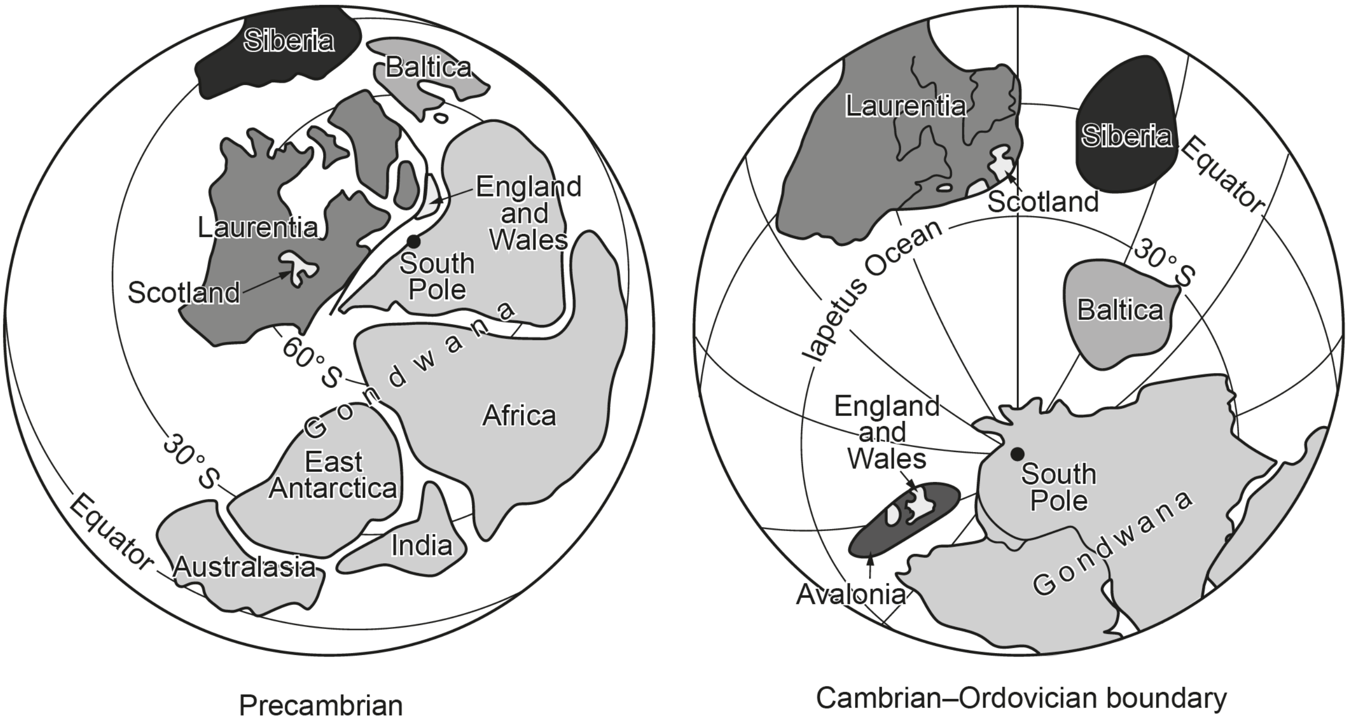


Fig. 4.1

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

....

....

....

....

....

....

....

.... **[3]**

Many candidates were able to attain some credit for the descriptive elements of this question. Rifting was the correct tectonic event most often described and many used the diagrams to state that the Iapetus ocean opened between Laurentia and Gondwana. However, the supercontinent Pannotia, that existed during the Precambrian, was named by only a small minority of candidates and the separation of Laurentia, Baltica and Siberia was not quoted very often.

A small number of candidates mistakenly referred to the South Pole as if it was a continent and stated that it had moved.

Question 4 (a) (ii)

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

....

....

....

....

.... **[2]**

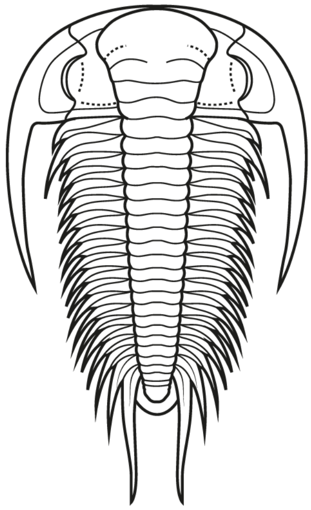
This was a low scoring question. Many candidates did not appear to be familiar with the palaeogeography of the Welsh Basin with some not realising it was a marine sedimentary basin. In consequence, some candidates wrongly described glacial as the palaeoenvironment.

Those who knew the basin was marine often did not distinguish between the shallow margins versus the deeper central part of the basin, so the palaeoenvironment and sediment type they described did not match. Many just guessed common sedimentary rock types such as sandstone and limestone which were not specific enough to attain the mark.

Jurassic Kimmeridge Clay was cited as the sediment by some, even though the question was about the Welsh Basin in the Cambrian Period which is much older than the Jurassic Period.

Question 4 (b) (i)

(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]**

This question relating the trilobite's morphology to its mode of life and marine niche was not done very well and only a small number of candidates attained full marks. Basic morphological terms used to describe trilobites were not known by the majority. Many simplistically referred to eyes rather than compound eyes, or legs (which could not be seen on the diagram) rather than thoracic segments or pleurae. Those who did describe the features and adaptations correctly, didn't always go on to link them to the correct postulated mode of life for this trilobite.

Many candidates suggested the trilobite was infaunal rather than epifaunal. Some went as far as to describe it as having a 'shovel-shaped cephalon for burrowing' which would be best reserved for a description of the infaunal trilobite Trinucleus. Some candidates invented features such as a pitted cephalic fringe, which was not present on the trilobite in the diagram.

Question 4 (b) (ii)

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

.... **[1]**

Many candidates did cite graptolites, corals or brachiopods as correct zone fossils for the Welsh Basin. However, there were also plenty of incorrect proposals, including ammonites and belemnites, suggesting confusion with Jurassic age basins.

Question 5 (a) (i) and (ii)

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**.

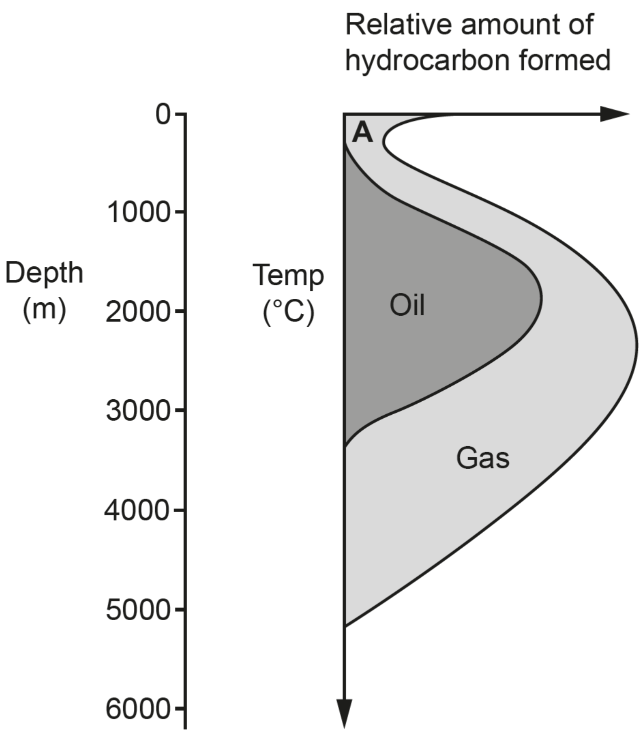


Fig. 5.1

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]**

For Question 5 (a) (i) about half of the candidates knew sapropel as the term for organic-rich unconsolidated sediment that is the precursor to a source rock. For Question 5 (a) (ii) kerogen was better known as the solid bituminous material that is the first product of maturation.

Unfortunately, some candidates got their responses for parts (i) and (ii) the wrong way round. Others gave the term kerosene (a type of paraffin) instead of kerogen and some picked up on the word bituminous and gave coal as their response for 5 (a) (ii).

Common incorrect responses for both part questions included Kimmeridge Clay and black shale – these candidates did not appreciate that these are not sediments but rocks that have undergone diagenesis. There was also confusion with oozes that form on the deep-sea floor.

Question 5 (a) (iii)

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

State the temperature range for the oil and gas window.

.... **[1]**

The temperature range for the oil and gas window was quite well known, but some responses were wildly out and ranged from 0°C to over 3000°C. Not all gave a range, and some lost the mark as they forgot to include the units.

Question 5 (a) (iv)

(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]**

Error carried forward from 5 (a) (iii) was allowed for. Most candidates attempted the calculations but there were some 'No Responses'. Some candidates lost a mark as they did not take account of the instruction to give their answers to 2 significant figures. Others lacked understanding of how to use recurring numbers, in this case $1.\dot{6}$ km and $7.\dot{6}$ km and either didn't round the numbers up or did not spot or include the 'dot above' symbol from their calculators.

Question 5 (a) (v)

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

Explain why biogenic gas is normally lost.

.... **[1]**

This question was poorly understood. Many candidates were unable to give a satisfactory explanation for the loss, when all they needed to do was show recognition that the shallow burial leads to the gas escaping to the surface. Answers suggesting biogenic gas seeped up faults or escaped as there was no cap rock could not be credited as this is the case for gas at any depth, not just close to the surface.

Question 5 (b) (i)

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

....

....

....

....

.... **[2]**

This was well answered with most candidates attaining some credit. Some candidates lost marks as they lumped the properties of porosity and permeability together and did not explicitly link porosity to storage and permeability to flow.

Question 5 (b) (ii)

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

....

....

....

....

.... **[2]**

Candidates found this question challenging. Although many had some understanding of the factors that control oil migration, few were able to give precise enough explanations to attain the marks. For example, many cited oil migrates in response to pressure and often stated it is squeezed out of the rock, but did not explain from areas of high pressure to low pressure. Others discussed the low density of oil but compared it to the density of the surrounding rock rather than to the density of the water in the pore spaces.

Misconception

A common misconception is that oil migrates because it is less dense than the surrounding rock, whereas in reality it is because it is less dense than the water in the pore space of rocks. Oil migrates under hydrostatic, not lithostatic, pressure.

Question 5 (b) (iii)

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

[3]

The role of synsedimentary faulting in the accumulation of oil was poorly understood and the requirement to draw diagrams to illustrate this process made this question particularly challenging. Very few candidates were able to indicate the growth and displacement of faults occurring over time during deposition. The curved, listric nature of synsedimentary faults with increasing throw with depth was not evident on most diagrams. There were a number of 'No Responses' and most candidates just drew a fault trap with could attain a maximum of 2 marks if drawn accurately with correct labels. No credit could be given for diagrams that did not include a fault.

Question 5 (c) (i) and (ii)

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

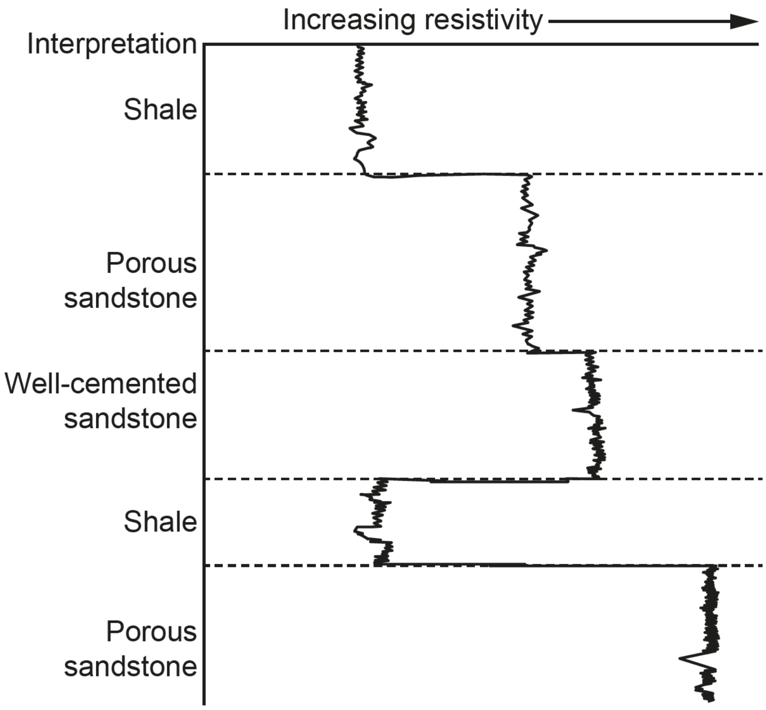


Fig. 5.2

(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]**

5 (c) (i) and 5 (c) (ii) were well answered by candidates. Most candidates correctly labelled the lower porous sandstone at the bottom of the electrical resistivity log as the bed where oil is most likely to be found. Many then went on to correctly ascribe this to the high resistivity.

Question 5 (c) (iii)

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

....

.... **[1]**

Although candidates often identified a seismic survey or a gravity survey as another geophysical exploration technique that could be used, not all could then give a correct statement as to how it could be used.

Some candidates incorrectly stated that seismic surveys find oil because it is liquid and the S-waves stop, not understanding that the rock in which the oil is stored is solid. Better responses showed understanding that the reflection of seismic waves at layer boundaries can identify traps containing oil.

Those candidates who chose gravity surveys often mistakenly referred to the low density of oil rather than to using gravity anomalies to identity the presence of traps.

Question 5 (d) (i)

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

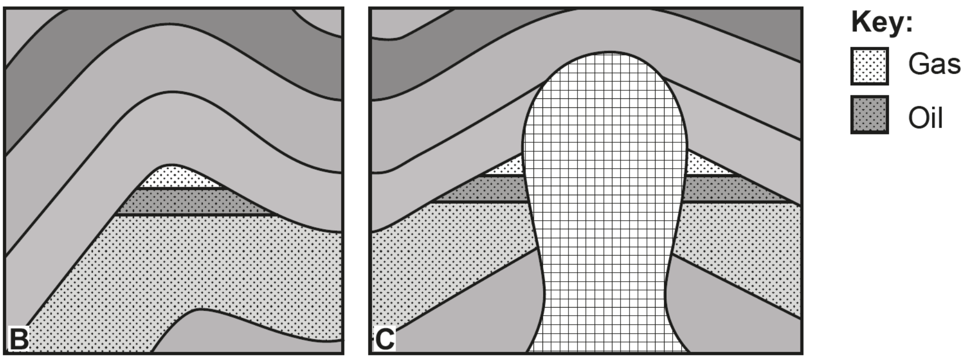


Fig. 5.3

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

B ....

C ....
[1]

This question was done well, and many candidates correctly identified the two types of oil trap. Some responses were not specific enough for **B** stating fold and others misidentified the anticline as a syncline. Some misidentified **C** as a salt pseudomorph rather than a salt dome trap.

Question 5 (d) (ii)

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

The position of the potential oil spill point was well known. Some candidates penalised themselves by labelling more than one place.

Question 5 (e)

(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]**

There were some very good responses to this question but overall, it was not done very well and there were a significant number of 'No Responses'. Those who scored highly had learnt the names of the various microfossil groups listed in the specification and knew of the role of exploration drilling and mud logging in locating oil reservoir rocks.

Some candidates named macrofossils such as bivalves and graptolites, while others found it difficult to explain the intricacies of how microfossils are used as zone fossils for dating and biostratigraphic correlation.

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