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Examiners' report

A LEVEL

GEOLOGY

OCR Level 3 Advanced GCE in Geology

H414

For first teaching in 2017

H414/01 Summer 2025 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 responses 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 Teach Cambridge.

Paper 1 series overview

Paper H414/01 (Fundamentals of geology) assesses subject content from across modules 1 to 7. It contains 2 sections. Section A consists of 25 multiple-choice questions covering AO1 and AO2. Section B includes short answer questions, extended response questions, and two 6 mark extended response questions, covering AO1, AO2 and AO3.

This paper is one of three examination components for A level Geology. This component focuses on:

- The development of practical skills
- Minerals, rocks, and fossils
- Global tectonics
- Sedimentary environments and geochronology
- Petrology and economic geology
- Geohazards
- Basin analysis

The paper appeared to be accessible with most candidates attempting all the questions.

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• carried out familiar and unfamiliar calculations • could convert units and use the correct units • were familiar with and used scientific geological terminology • identified a sill and lava flow from a cross section • understood Bowen's reaction series and could interpret the order of crystallisation from an igneous texture • understood the magmatic differentiation processes of gravity settling and filter pressing • described and explained the diagenetic and metamorphic processes involved in the formation of mudstone, shale and slate from a mud sediment • described and explained metamorphic textures • interpreted a simple geological map and recognised fold and fault structures and an unconformity and knew how they formed • drew isolines on a gravity survey map and identified the salt dome oil trap • described the fracking process • understood the role of rock types and geological structures in the formation of springs in the Bristol-Bath basin.	• struggled with calculations • could not rearrange equations • were unable to convert units • we're not always secure in the use and understanding of geological scientific terminology • could not recognise the characteristic features of a sill and lava flow in a cross section • we're not confident in interpreting igneous textures, in particular the order of crystallisation and how it might link to Bowen's reaction series • did not understand magmatic differentiation • could not describe or explain the diagenetic and metamorphic processes involved in the formation of mudstone, shale and slate from a mud sediment • had difficulty structuring longer 6-mark questions • could not describe or explain metamorphic textures • could not recognise types of fold or fault on a simple geological map

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
	• could not identify an unconformity on a geological map or explain how an unconformity formed • could not draw accurate isolines on a gravity map • we're not sure about the fracking process • could not use many technical terms when describing the role of rock types and geological structures in the formation of springs in the Bristol-Bath basin.

Section A overview

This section provided candidates with a broad range of topics to be assessed. Many candidates showed a full range of geological knowledge gaining over 20 marks out of 25. This style of question clearly suits some candidates who find the questions requiring longer answers more challenging.

Question 1

1 What is the correct chemical formula for pyrite?

A FeS

B Fe_2S

C FeS_2

D $FeSO_4$

Your answer ☐ **[1]**

Candidates are expected to know the chemical formulae for calcite, quartz, pyrite and galena.

Question 2

2 Using Mohs hardness test, which of the following conclusions is correct for the hardness of calcite?

A > copper coin and < steel nail

B < fingernail

C > fingernail and < copper coin

D > steel nail

Your answer ☐ **[1]**

Candidates were confident in recognising the correct result for the hardness of calcite.

Assessment for learning

Candidates should practice applying Mohs hardness test both in the lab and the field. They should also learn the hardness scale so that they know the hardness of minerals such as quartz, calcite and feldspar.

Question 3

3 This is a description of an igneous rock:

- Light grey in colour
- Flow-banded
- Fine crystal size

What is the rock type?

A Basalt

B Microdiorite

C Obsidian

D Rhyolite

Your answer ☐ **[1]**

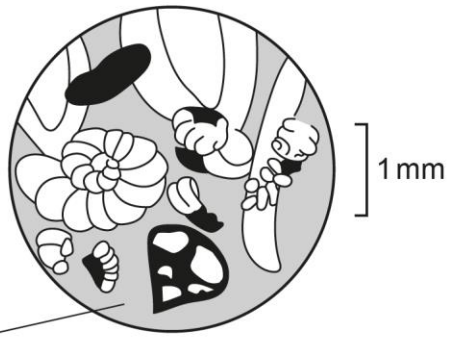
Candidates confidently identified rhyolite.

Assessment for learning

Candidates need to practice describing igneous rocks both in the lab and field. In addition, they should learn the igneous rock classification table so that this simple description will allow a candidate to identify (flow banded) rhyolite.

Question 4

4 The thin section diagram shows a carbonate rock.



Use the Dunham classification scheme to identify the rock type shown in the thin section.

A Grainstone

B Mudstone

C Packstone

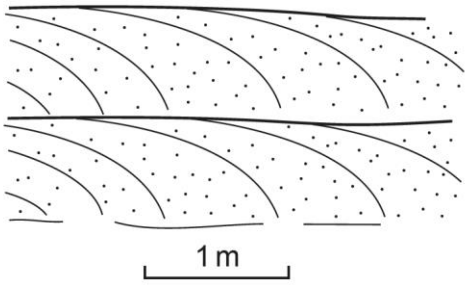
D Wackestone

Your answer [ ] **[1]**

It was evident that many candidates were uncertain in the use of the Dunham classification scheme which is used for limestones. In this question the main decision is whether the rock is a pack stone or grainstone. The mud matrix means that it is a packstone.

Question 5

5 The diagram shows a cross-section through a sedimentary structure.



Identify the sedimentary structure and the correct way-up.

A Inverted asymmetrical ripple marks

B Inverted cross-bedding

C Right way-up asymmetrical ripple marks

D Right way-up cross-bedding

Your answer [ ] **[1]**

Candidates were confident in firstly identifying that the sedimentary structure is cross-bedding, the 1 m scale helping to differentiate it from cross lamination and then realising that the cross-beds were convex upwards which indicates that the beds are upside down/inverted. Candidates need to be able to identify sedimentary structures from a simple diagram, photograph or in the field. They must also know how to use these structures as way up indicators.

Question 6

6 The table shows the grain sizes of 16 pebbles collected from a riverbed.

Pebble number	Grain size (mm)
1	24
2	13
3	16
4	12
5	25
6	22
7	9
8	15
9	13
10	18
11	24
12	10
13	13
14	23
15	15
16	16

What is the median of these pebble grain sizes?

A 13 mm

B 14 mm

C 15.5 mm

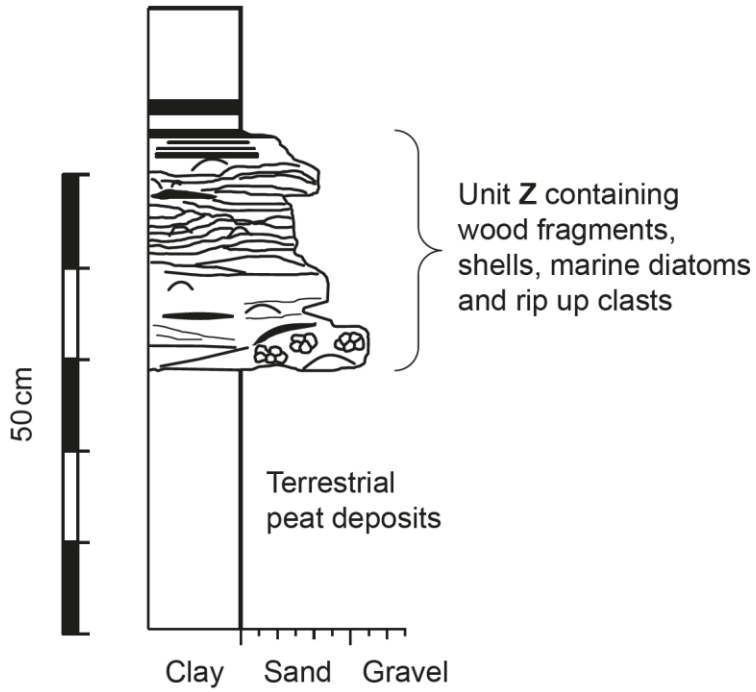
D 16.75 mm

Your answer ☐ **[1]**

Most candidates were able to calculate the median for this data set. Equally candidates should be able to calculate the mean and mode of a data set.

Question 7

7 The graphic log shows a sequence of recent sedimentary deposits in Scotland.



What type of deposit is unit **Z**?

A Deltaic deposit

B Fluvial deposit

C Tsunami deposit

D Turbidite deposit

Your answer ☐ **[1]**

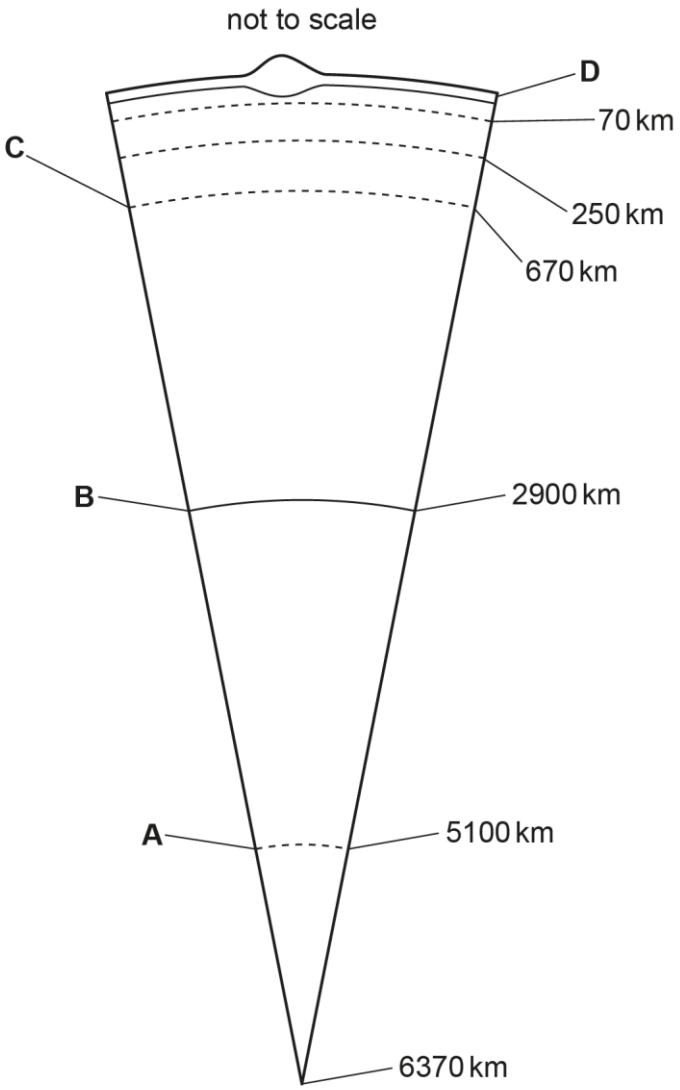
Candidates were able to ascertain that the graphic log represented a tsunami deposit. A common error was to indicate "A Deltaic deposit", probably because of the wood fragments. It is the rip up clasts and marine diatoms within an otherwise terrestrial sequence which indicates a tsunami deposit.

Assessment for learning

Candidates are expected to be able to identify the palaeoenvironment of sedimentary rock sequences as well as be able to construct their own graphic logs for unfamiliar sequences in the field. Therefore, practice in the field will give candidates greater confidence when interpreting a graphic log.

Question 8

8 The diagram shows a simplified cross-section through the Earth.



Which letter on the cross-section, **A**, **B**, **C** or **D**, marks the position of the Lehmann discontinuity?

Your answer [ ] **[1]**

Most candidates knew the location of the Lehmann discontinuity at A (5100km) between the outer and inner core. A common error was to place it at B which is the Gutenberg discontinuity between the mantle and outer core.

Question 9

9 The layers of the Earth are defined by their rheological properties.

What comprises the lithosphere?

A Ductile crust and ductile upper mantle

B Ductile crust and rigid upper mantle

C Rigid crust and ductile upper mantle

D Rigid crust and rigid upper mantle

Your answer ☐ **[1]**

Candidates found the rheological properties of the lithosphere difficult. The lithosphere makes up the plates and so is rigid and includes the (rigid) crust and the (rigid) upper mantle. Candidates need to be familiar with the rheological properties of all the layers of the Earth as well as their location and composition.

Question 10

10 Which value is the inferred average density of the Earth's outer core?

A $7.5\,g\,cm^{-3}$

B $11.5\,g\,cm^{-3}$

C $15.5\,g\,cm^{-3}$

D $17.5\,g\,cm^{-3}$

Your answer ☐ **[1]**

The average density of the mantle, outer and inner core should be known as well as the composition of each layer.

Question 11

11 What are the correct Goldschmidt classifications for the elements lead and oxygen?

	Lead	Oxygen
A	Chalcophile	Atmophile
B	Chalcophile	Lithophile
C	Siderophile	Atmophile
D	Siderophile	Lithophile

Your answer ☐ **[1]**

Candidates find Goldschmidt's classification difficult to remember and apply and so struggled with this question. Candidates are expected to be able to define terms such as chalcophile, atmophile, etc. and give examples of elements that fit in each classification.

Question 12

12 What are the orientations of the maximum and minimum principal stresses at transform (conservative) plate boundaries?

A Maximum and minimum principal stresses are both horizontal

B Maximum and minimum principal stresses are both vertical

C Maximum principal stress is horizontal and minimum principal stress is vertical

D Maximum principal stress is vertical and minimum principal stress is horizontal

Your answer ☐ **[1]**

Candidates found identifying the orientation of the maximum and minimum principal stresses at transform boundaries difficult. In this case plate movement is in a horizontal manner and so both maximum and minimum stresses are horizontal.

Question 13

13 Which geophysical survey method would **not** provide evidence for the internal structure and processes occurring at mid-ocean ridges?

A Electromagnetic survey

B Resistivity survey

C Seismic reflection survey

D Seismic tomography survey

Your answer [ ] **[1]**

Half the candidates knew that resistivity surveys will not be practical or effective in a mid-ocean ridge setting. The other three methods are commonly used when looking for evidence of processes and structure at ridges.

Question 14

14 Acid mine drainage can be mitigated using reed bed wetlands. These are an example of which type of remediation?

A Active treatment

B Barrier method

C Passive treatment

D Stabilisation / solidification

Your answer [ ] **[1]**

Most candidates knew that reed beds in wetlands are a passive treatment that, once established, can be effective in acid mine drainage remediation. Candidates should know examples of active and passive as well as source and migration control.

Question 15

15 Which combination is most likely to result in liquefaction of sediments during an earthquake?

A High pore fluid pressure and increased friction

B High pore fluid pressure and reduced friction

C Low pore fluid pressure and increased friction

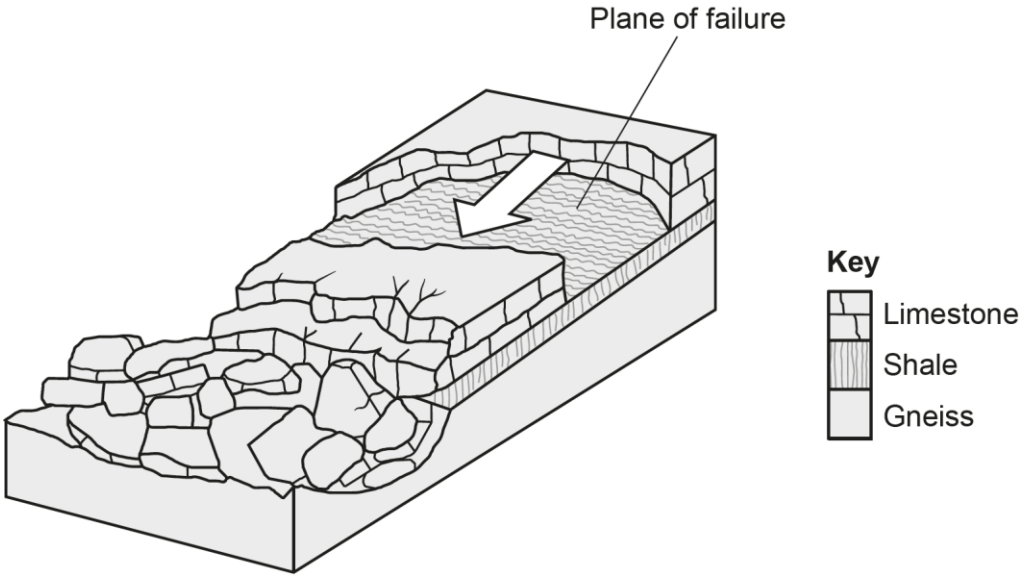
D Low pore fluid pressure and reduced friction

Your answer [ ] **[1]**

Many candidates understood the role of high pore fluid pressure with a reduced friction leading to liquefaction during an earthquake.

Question 16

16 The block diagram shows a recent landslide.



The landslide is the result of a slip plane developing along the bedding plane between two rock types.

Which statement is true regarding the competence of the two rock types?

A Competent rocks above and below

B Competent rock above and incompetent rock below

C Incompetent rock above and competent rock below

D Incompetent rocks above and below

Your answer [ ] **[1]**

The relative competency of rocks in a sequence of rocks has a large impact on stability of slopes. Just under half the candidates knew that dipping competent on top of incompetent rocks can lead to landslides.

Question 17

17 Which slope stabilisation method would be most suitable to support the sides of a road cutting through clay?

A Rock bolts

B Shotcrete

C Vegetation

D Wire netting

Your answer ☐ **[1]**

Candidates struggled to identify the appropriate stabilisation method for the sides of a road cutting in clay. Rock bolts, shotcrete and wire netting will not be effective, but vegetation can help. Candidates need to know about the range of slope stabilisation methods available and know in which geological situation they are best applied.

Question 18

The diagram shows a graptolite fossil collected from the Welsh Basin.

×4

Use the graptolite fossil diagram to answer questions **18** and **19**.

18 What is the actual length of this graptolite fossil?

A 1.1 mm

B 11 mm

C 44 mm

D 176 mm

Your answer ☐ **[1]**

Most candidates knew how to calculate the actual length of the graptolite by measuring the image on the paper and dividing by the multiplication factor (4).

Question 19

19 This type of graptolite fossil is used to date and correlate rocks of which age?

A Cambrian

B Carboniferous

C Devonian

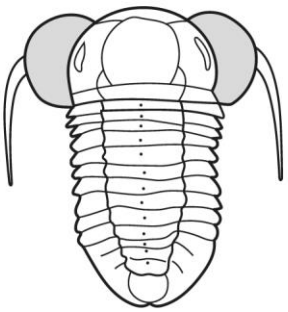
D Silurian

Your answer ☐ **[1]**

Candidates were generally unclear about the age of rocks that graptolites are most used for dating. Candidates should know that graptolites are commonly used in Silurian (and Ordovician) rocks. Candidates should also be familiar with the use of ammonoids (goniatites, Ceratite, ammonites) and the periods they are useful for dating.

Question 20

20 The diagram shows a fossil trilobite.



×2

What was the most likely mode of life of this trilobite?

A Epifaunal

B Infaunal

C Nektonic

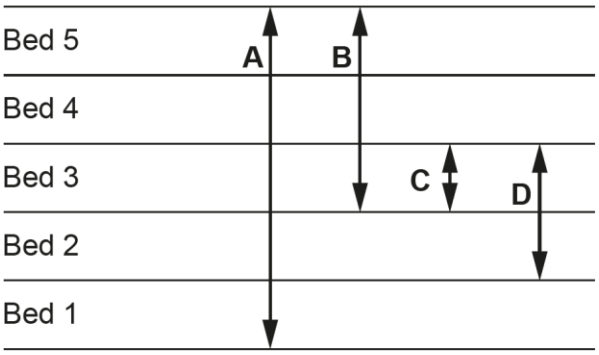
D Planktonic

Your answer ☐ **[1]**

Candidates had difficulty deciding on the likely mode of life of the trilobite illustrated. The large eyes indicated that it could see backwards, forwards, up and down which suggests that it lived in the water column. Its relatively large size suggests a nektonic (swimming) mode of life rather than planktonic. Candidates need to be able to identify the typical morphological features of benthonic (epifaunal and infaunal) and pelagic (planktonic and nektonic) trilobites.

Question 21

21 A sequence of Jurassic strata in Yorkshire has been logged and the ammonite fauna recorded as species **A** to **D**.



Which of the ammonite species **A**, **B**, **C** or **D** is the best zone fossil?

Your answer [ ] **[1]**

Candidates are very confident at recognising that the best zone fossils have the shortest stratigraphic range such as C in this case.

Question 22

22 The following statements about belemnites may be true or false.

1 Belemnites are cephalopods

2 Belemnites have an internal guard made of calcite

3 Belemnites became extinct at the start of the Cretaceous period

Which combination of statements is true?

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer [ ] **[1]**

About half the candidates knew that belemnites had an internal guard made of calcite (1) and are cephalopods (2) so that B is correct. They became extinct at the end of the Cretaceous period and not the start.

Question 23

23 Which isotopic change recorded in marine microfossils would indicate the onset of an icehouse Earth event?

A A decrease in the proportion of ^{12}C

B A decrease in the proportion of ^{18}O

C An increase in the proportion of ^{16}O

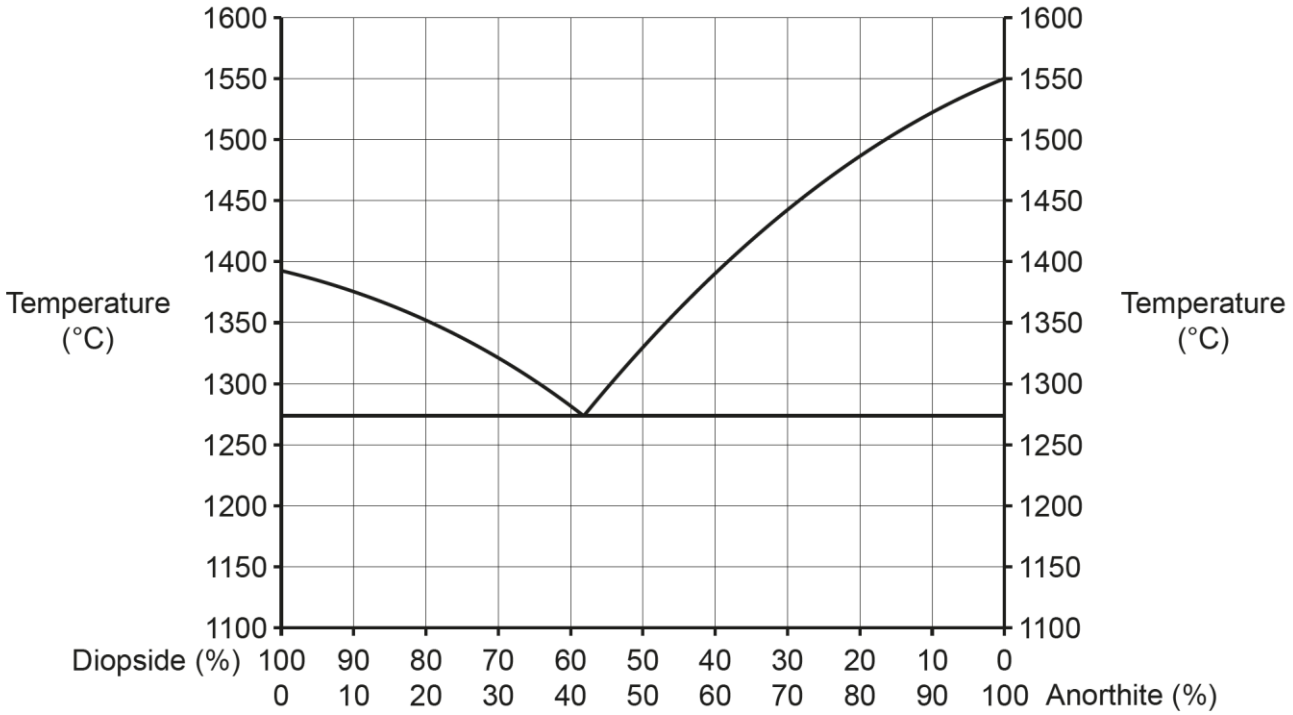
D An increase in the proportion of ^{18}O

Your answer ☐ **[1]**

About half the candidates knew that ^{18}O increases proportionally as an Icehouse Earth event starts as proportionally more ^{16}O is held up in glaciers, ice sheets and ice caps. Therefore, it is not released back into the ocean for marine organisms to use constructing their calcium carbonate shells.

Question 24

The binary phase diagram shows the diopside-anorthite system.



Use the phase diagram to answer questions **24** and **25**.

A cooling magma has a composition **80% anorthite** (An) and **20% diopside** (Di).

24 At which temperature will crystallisation begin?

A 1274 °C

B 1350 °C

C 1485 °C

D 1553 °C

Your answer [ ] **[1]**

Most candidates could work out that crystallisation would begin at 1485 °C by drawing a vertical line up from 80% anorthite on the x axis to reach the liquidus at 1485 °C.

Question 25

25 What will be the composition of the first formed crystals?

A 0% anorthite / 100% diopside

B 42% anorthite / 58% diopside

C 80% anorthite / 20% diopside

D 100% anorthite / 0% diopside

Your answer [ ] **[1]**

Candidates were not so sure about the composition of the first formed crystals. At 1485 °C it is anorthite + liquid in the field below and so pure (100%) anorthite would form. This is not a solid solution series and so only pure end members anorthite or diopside (or both simultaneously) can form.

Section B overview

Candidates appeared to have sufficient time to complete this section which indicates that candidates are familiar with the demands of the paper.

Question 26: Candidates were confident recognising and describing sills and lava flows but less certain about Bowen's reaction series and fractional crystallisation.

Question 27: Candidates found it challenging to explain aspects of fractional crystallisation/magmatic differentiation such as with gravity settling and filter pressing.

Question 28: Candidates had a sound understanding of key rock cycle processes such as diagenesis.

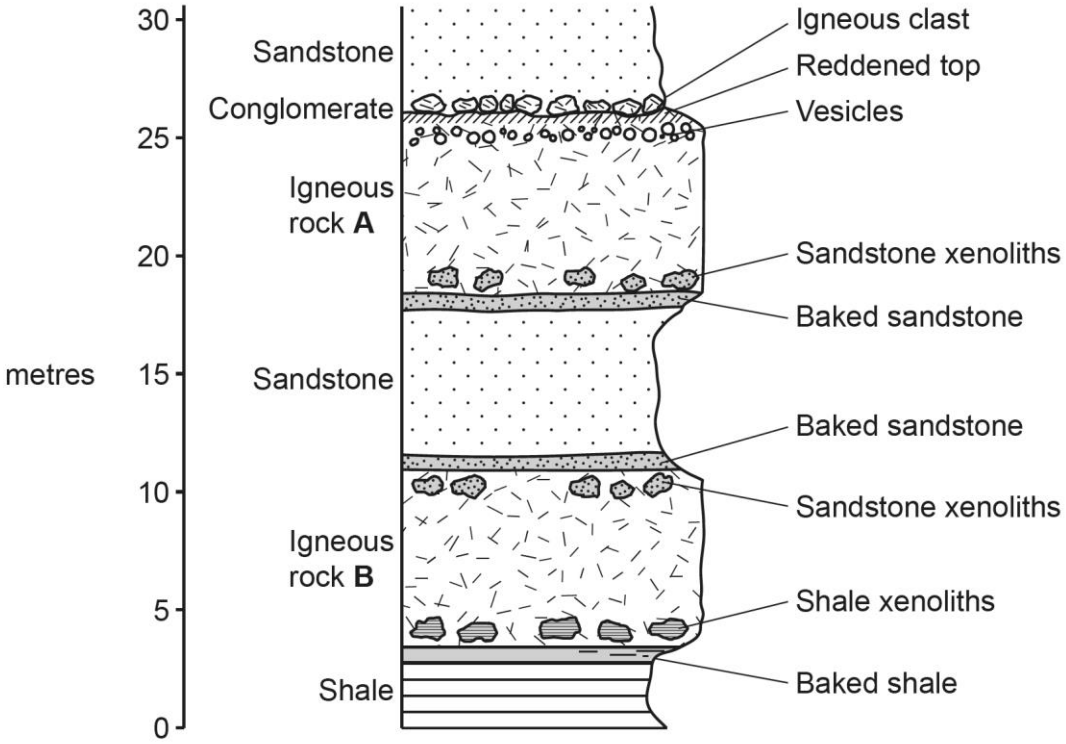
Question 29: Candidates were confident at interpreting the geological map and identifying the fold structure and unconformity. Candidates found describing how a horst structure formed more difficult. They also had difficulty recognising the strike slip fault and then indicating the correct stress regime.

Question 30: Overall candidates struggled with understanding the use of isolines, describing the use of microfossils and fracking.

Question 31: In general candidates are confident when discussing aquifers and groundwater.

Question 26 (a)

26 The diagram shows a sequence of igneous and sedimentary rocks exposed in a cliff face.



(a) Identify the types of igneous body formed by rock **A** and rock **B**.

A .....

B .....

[2]

Candidates were very confident in identifying these two igneous features as a lava flow and sill.

Question 26 (b)

(b) Describe **three** characteristics shown on the diagram that allowed you to identify the type of igneous body formed by rock **A**.

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

Candidates were able to extract the characteristics from the diagram that are associated with lava flows.

Question 26 (c)

(c) Describe **two** characteristics shown on the diagram that allowed you to identify the type of igneous body formed by rock **B**.

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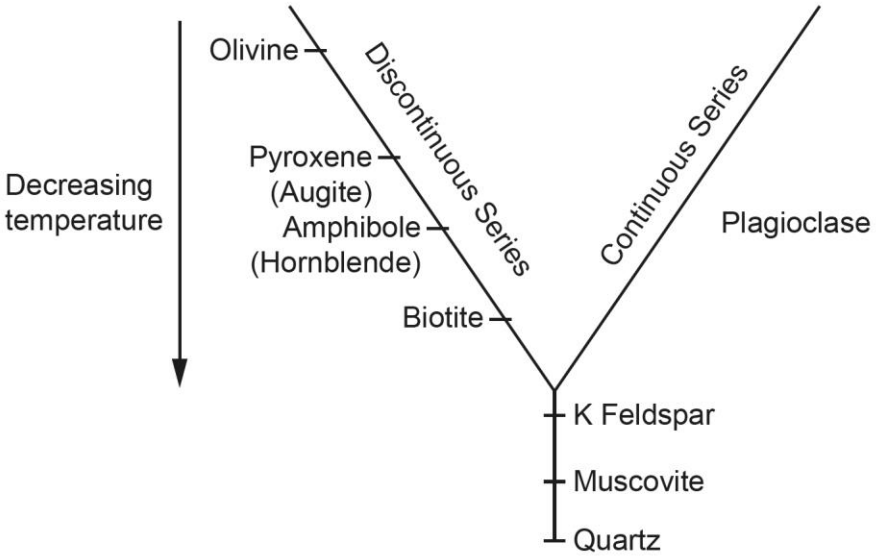
..... **[2]**

Candidates were also able to extract the characteristics from the diagram that are associated with sills.

Question 27 (a)

27 Norman L Bowen carried out laboratory experiments to investigate the order of crystallisation of different minerals as magma cools.

The diagram of Bowen's reaction series shows the results of his investigations.



(a) Observations and chemical analyses of zoned plagioclase feldspar crystals provide supporting evidence for the plagioclase continuous solid solution series.

Draw a sketch of a zoned plagioclase crystal.

Label the crystal to show the difference in composition of the centre and the rim of the crystal.

[2]

Many candidates knew that the centre of the crystal was Ca rich and the edge Na rich. Exemplary answers used terms such as anorthite and albite.

Question 27 (b)

(b) Explain why plagioclase feldspars form a continuous solid solution series.

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

Candidates had difficulty with understanding how and why Ca and Na substitute within the plagioclase feldspar mineral lattice.

Question 27 (c) (i)

(c) Olivine crystals can undergo gravity settling through mafic magma to form a cumulate layer at the bottom of a magma chamber.

(i) Explain how the process of gravity settling of olivine crystals results in changes to magma composition.

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

The formation of cumulate layers of olivine and the effect it has on magma composition was generally well understood. Good answers linked early/high temperature crystallisation of olivine with its density leading to it sinking. Many candidates understood that removing Fe and Mg from the magma as olivine formed made the magma more silicic.

Question 27 (c) (ii)

(ii) Stokes' Law can be used to calculate the velocity at which crystals settle out of magma.

Calculate the velocity at which a 2 mm diameter olivine crystal will settle through mafic magma.

Use the formula: $\text{Velocity (v)} = \frac{g \times d^2 \times (\rho_p - \rho_w)}{18\eta}$

Where:

g = the acceleration due to gravity = $9.8\,m\,s^{-2}$

d = the diameter of the olivine crystal = $2\,mm = 2 \times 10^{-3}\,m$

ρ_p = the density of the solid crystal of olivine = $3800\,kg\,m^{-3}$

ρ_w = the density of the liquid mafic magma = $2900\,kg\,m^{-3}$

η = the viscosity of the magma = $30\,kg.m^{-1}.s^{-1}$

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

Velocity = ... $m\,s^{-1}$ **[3]**

Most candidates were confident in applying the data to the formula and working out the velocity of settling. Most candidates used the correct significant figures.

Question 27 (d)

(d) Describe the process of filter pressing.

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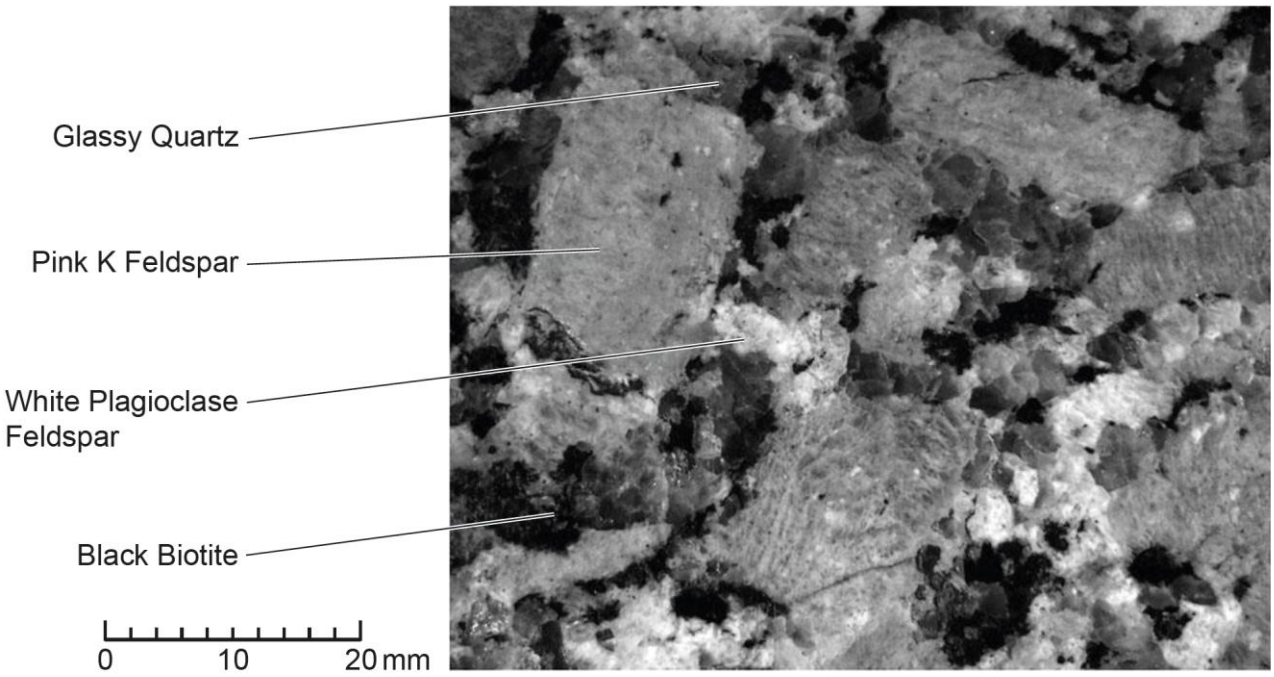
..... **[2]**

Candidates were not confident in describing filter pressing. Many candidates did link the process to a mixture of magma and crystals but were not always clear in their description. Most candidates did not realise that the result was a layer of crystals at the bottom of the magma chamber and magma squeezed out and upwards with a more silicic composition.

Question 27 (e) (i)

(e) The photograph shows a specimen of granite.



(i) Explain why this rock is correctly identified as granite.

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

Most candidates knew that a granite is coarse grained, silicic, and so described the coarse crystal grain size in the photograph and recognised the felsic quartz and K feldspar. Lower scoring answers mentioned a "fine grained" groundmass and could not identify the minerals.

Question 27 (e) (ii)

(ii) Use evidence from the photograph to explain what can be deduced about the cooling history of this granite rock.

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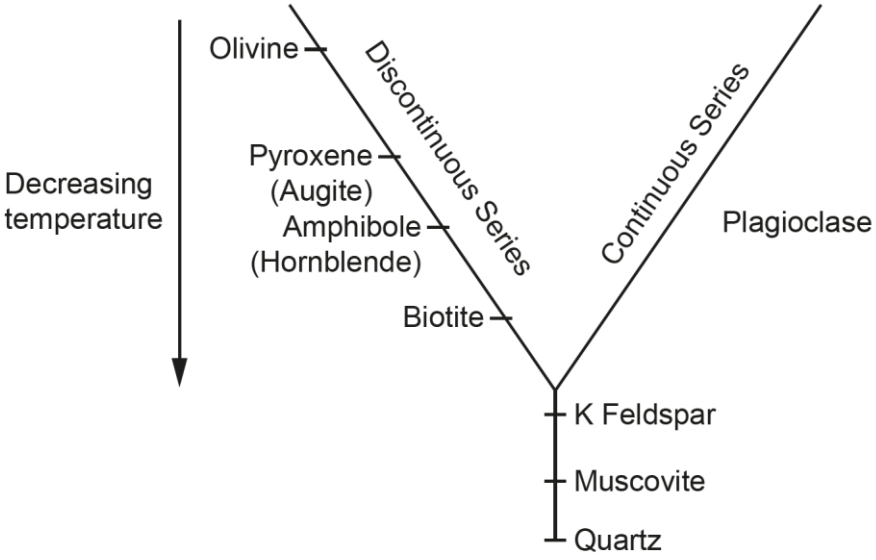
..... **[3]**

Most candidates identified the porphyritic texture and knew that this texture implies two stages of cooling. It was the detail of these two stages that was lacking in some answers. The best answers indicated the correct mineral (e.g. K feldspar), when (first, early, high temperatures) and where (deep, plutonic) it crystalises and at what rate (slow). Low scoring answers were too simplistic, for example stating that feldspar formed first followed by quartz.

Question 27 (f)

(f) Bowen's reaction series is shown again for reference.



Evaluate whether evidence from the granite specimen shown in the photograph supports the order of crystallisation of minerals shown in Bowen's reaction series.

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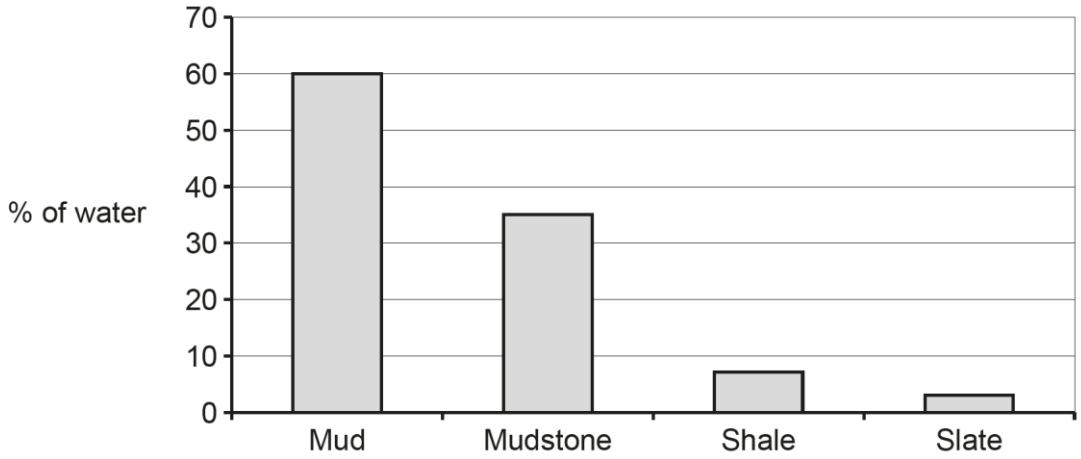
..... **[3]**

Candidates found this question more challenging as they needed to be able to interpret the porphyritic texture in terms of the order of mineral crystallisation and then compare this to the recognised order of crystallisation shown in Bowen's reaction series. The best answers recognised that the K feldspar phenocrysts were the first minerals to form but should form after plagioclase and biotite and so did not support Bowen's reaction series. However, quartz is part of the finer groundmass and so formed later which agrees with Bowen's reaction series. Therefore, the best answers concluded that there was only partial support.

Question 28 (a)*

28 Rock cycle processes transform sediments into sedimentary rocks and then into metamorphic rocks.

(a)* The chart shows the change in water content of mud as it undergoes diagenesis and then metamorphism.



Describe and explain the diagenetic and metamorphic processes that change mud into the sequence of rocks shown on the chart.

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

This topic was generally well understood by candidates especially the main diagenetic processes of compaction involved with changing mud to mudstone. Candidates also understood the conversion to slate via the alignment of crystals during regional metamorphism to form slate. However, many candidates were uncertain of the position of shale in the sequence thinking that it was a low grade regional metamorphic rock which then progressed to slate. Better answers described the clay minerals in mudstone becoming further compacted and aligned to create fissile laminations, a key feature of shales. Most candidates wrote a well-structured answer helped by the logic of progressing from mudstone to shale and then slate. Very few candidates used annotated diagrams to support their answer but were used they often elevated the response. Candidates should be encouraged to make full use of the technical terms such as diagenesis, compaction, porosity, recrystallisation, alignment and clay minerals which will help elevate the answer to Level 3.

Exemplar 1

Mud Mudstone Shale Slate

The diagenenc changes to mud occur at depths no greater than 200 km.

Describe and explain the diagenetic and metamorphic processes that change mud into the sequence of rocks shown on the chart.

mud is an fine grained unconsolidated hydrous sediment or deposit formed at the surface after deposition. To turn any mud and therefore form mudstone, compaction burial and compaction must take place. This is where sediment is deposited on top of the mud burying the mud allowing it to compact due to the increased load pressure from sediment above it, this enables the grains to become more compacted/closer together and causes water volumes and water between grains (pore spaces) to be expelled - shown through the decrease in the % of water from mud to mudstone. In order for mud to be limited into mudstone, cementation must also occur, in which percolating groundwater containing dissolved ions precipitates minerals between grains, cementing them together. To turn mudstone to shale, increased burial must take place in and so increased load pressure from overburden rocks, this causes shale [6]

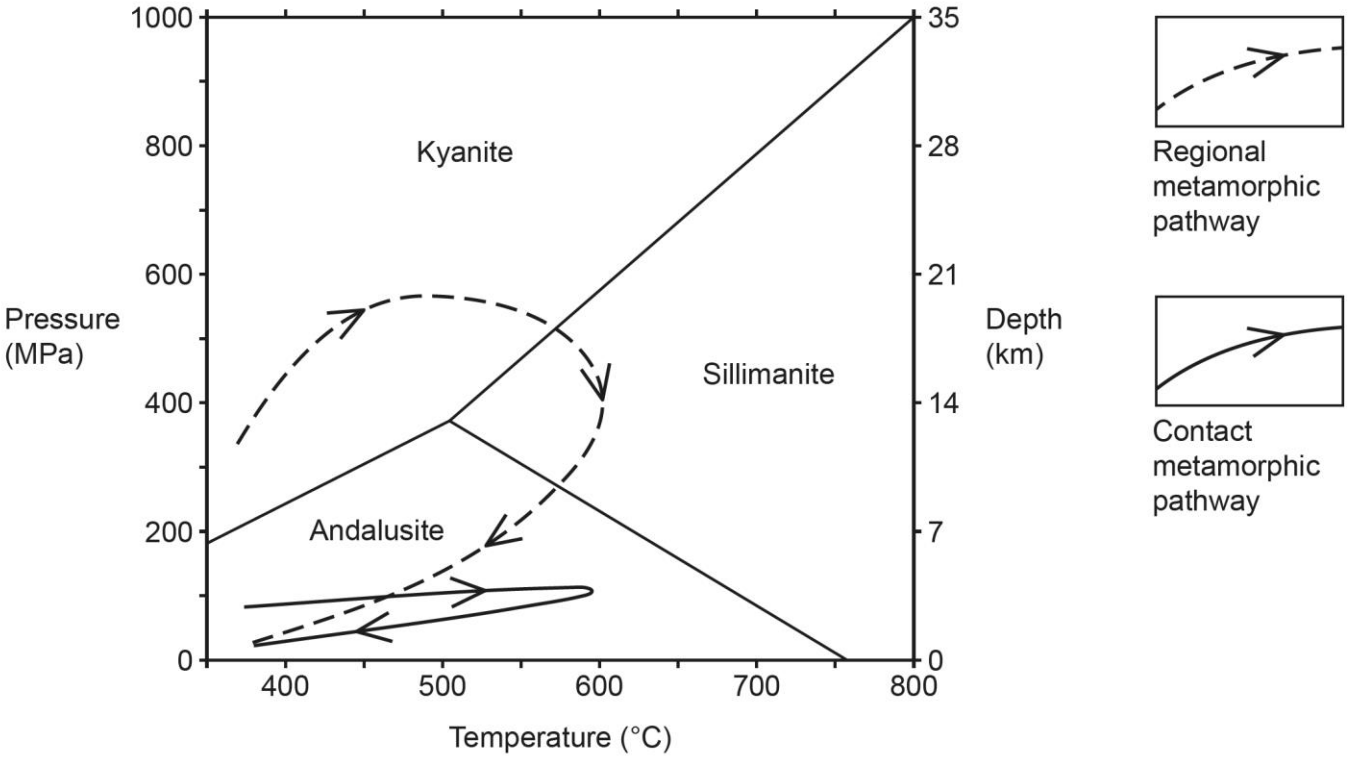
there is no preferred alignment of platy minerals in mudstone

to be fissile as the increased load pressure caused the compaction alignment of platy minerals within the shale aswell as the removal of more water during the transition from mudstone to shale. To turn shale to ~~metastone~~ slate however metamorphic processes must occur, this is because the pressure has increased, potentially due to mae burial and compaction (and temperature to a certain extent due to depth-however is not a major component of regional metamorphism). ~~low grade~~ Regional metamorphism occurs on the shale turning it to slate, which exhibits slaty cleavage from the alignment of platy minerals at 90° to the principle stress direction and aswell as having the index minerals of chlorite and biotite. This causes ~~shale~~ slate to have the lowest % of water as the ~~high~~ heat and high pressure have driven it off.

This exemplar is slightly more detailed than required but shows a very clear structure, excellent use of technical terms.

Question 28 (b) (i)

(b) The pressure-temperature graph shows the stability fields of the metamorphic minerals andalusite, kyanite and sillimanite.



(i) Describe the relationship between the minerals andalusite, kyanite and sillimanite.

.....

.....

.....

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

Most candidates wrote about the pressure/temperature relationship as shown by the graph. The best answers showed knowledge that the minerals are aluminosilicate/Al_2SiO_5 polymorphs (have the same composition but different physical properties)

Question 28 (b) (ii)

(ii) Complete the table to show:

- The maximum pressure reached along the regional metamorphic pathway
- The maximum temperature reached along the contact metamorphic pathway.

Metamorphic pathway	Maximum temperature (°C)	Maximum pressure (MPa)
Regional	605	.....
Contact	.....	110

[1]

Most candidates successfully extracted the correct temperature and pressure from the graph.

Question 28 (b) (iii)

(iii) Describe and explain how the texture of the metamorphic rocks produced during prograde metamorphism along each pathway would differ.

.....

.....

.....

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

Most candidates knew that regional metamorphic rocks typically have a foliation of some kind but had difficulty describing and explaining the texture of contact metamorphic rocks. There was also confusion about the use of the terms granoblastic and porphyroblastic.

Question 28 (c)

(c) Describe and explain the rock cycle processes that result in retrograde metamorphism.

.....

.....

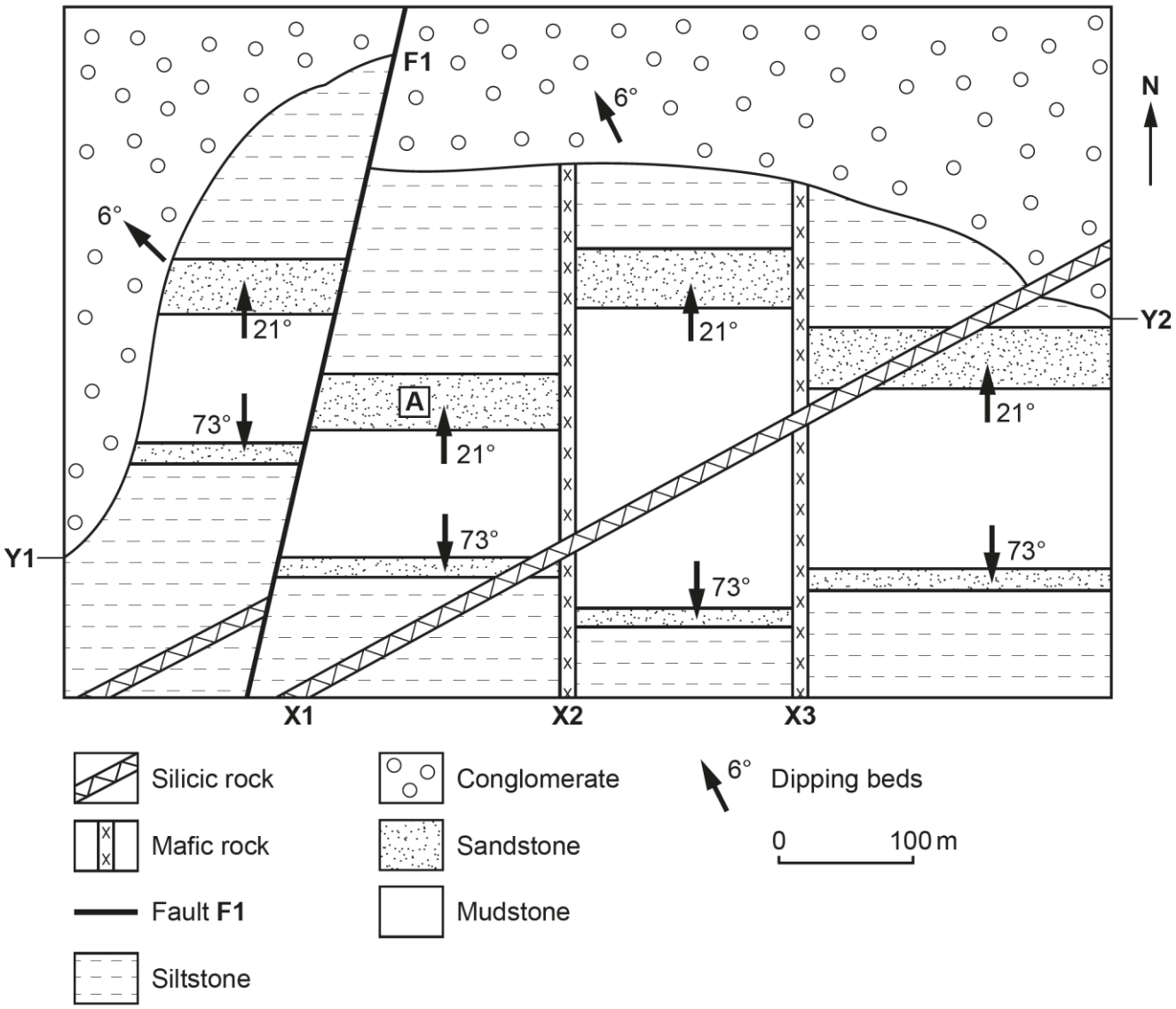
.....

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

The strongest answers stated that contact metamorphic rocks lacked a foliation as there was no directed stress and that the typical texture is granoblastic. The question asked for differences in texture and so a discussion of porphyroblastic textures was not appropriate as both regional and contact metamorphic rock can be porphyroblastic.

Question 29 (a) (i)

29 The geological map is of an area where erosion has produced a flat land surface.



(a)
(i) Draw the axial plane trace of the fold to the west of mafic rock **X2** on the map. **[2]**

Many candidates gained one mark for correctly drawing the axial plane trace in the mudstone between X2 and F1. However, relatively few candidates realised that the axial plane trace had been offset by F1 and so it should also be drawn between F1 and the unconformity. A common error was to extend the trace beyond the fault or the unconformity. The strongest answers had the trace at the southern end of the mudstone reflecting the asymmetric nature of the antiform.

Question 29 (a) (ii)

(ii) Fully describe the fold structure using technical terms.

.....

.....

.....

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

Candidates confidently described the fold as an asymmetric antiform/anticline.

Question 29 (b)

(b) Complete the table to summarise the characteristics of fault **F1** shown on the map.

Type of movement	.....
Amount of displacement	..... metres
Type of tectonic stress	.....

[3]

Very few candidates gained full marks. Many, however, worked out the displacement. Candidates need to know the type of movement, type of tectonic stress and the likely plate margin setting for each type of fault. In this case the candidates needed to recognise that as the bed widths of the folded rock did not change either side of the fault unlike X2 and X3 it meant there was no vertical movement, just horizontal.

Question 29 (c)

(c) Explain why igneous features **X1**, **X2** and **X3** have been identified as dykes.

.....

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

Almost all candidates recognised that the features were cross cutting and so correctly identified as dykes.

Question 29 (d)

(d) Describe the sequence of events that formed the horst structure and dykes between **X2** and **X3** on the map.

.....

.....

.....

.....

.....

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

Candidates found the description of the events difficult. They needed to recognise that two normal faults (X2 and X3) formed first which created the horst which is an upthrown block and lastly the dykes X2 and X3 intruded along the faults. Many candidates spent too much time writing about the geological history of the whole map.

Question 29 (e) (i)

(e)
(i) Identify the geological feature along the line from **Y1** to **Y2** on the map.

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

Most candidates identified the unconformity.

Question 29 (e) (ii)

(ii) Explain how this feature formed.

.....

.....

.....

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

Not many candidates gained full marks for the explanation of how an unconformity forms. Some answers gained a mark for mentioning younger rock was deposited. The best answers described the uplift and erosion of an older sequence of rocks followed by the deposition of the younger rock/conglomerate onto the eroded land surface.

Question 29 (f)

(f) The outcrop width of the sandstone unit at location **A** is 40.0 metres.

Calculate the true thickness of the sandstone unit at this location.

= ..... metres **[2]**

Very few candidates knew how to work out the true thickness of the bed from the apparent thickness using the sin of the angle of dip (20°) x the apparent thickness (40 m).

Assessment for learning

Candidates should practice working out the true thickness of a bed from the apparent thickness and dip of the bed.

Question 30 (a) (i)

30 Geophysical and exploration drilling techniques can be used to explore for oil and gas in sedimentary basins.

(a) The map shows the results of a gravity survey.

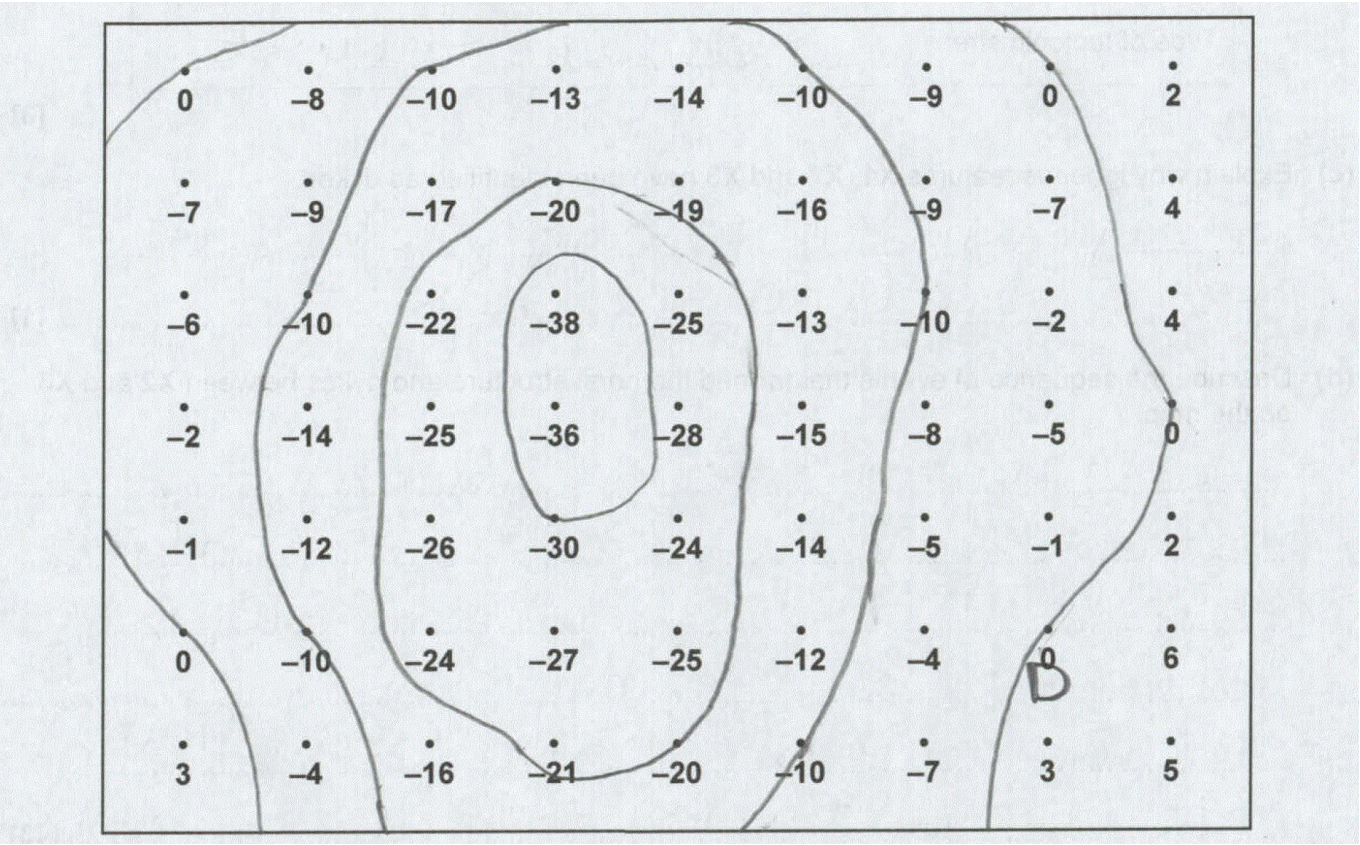
The readings are shown in milligals.

0	–8	–10	–13	–14	–10	–9	0	2
–7	–9	–17	–20	–19	–16	–9	–7	4
–6	–10	–22	–38	–25	–13	–10	–2	4
–2	–14	–25	–36	–28	–15	–8	–5	0
–1	–12	–26	–30	–24	–14	–5	–1	2
0	–10	–24	–27	–25	–12	–4	0	6
3	–4	–16	–21	–20	–10	–7	3	5

(i) Draw 0, –10, –20 and –30 milligal isolines on the map. **[3]**

Candidates struggled to construct accurate isolines. Many had the general concentric pattern but not in the correct place on the map. Candidates as a starting point should plot the isoline through any 0, -10, --20 and -30 values on the map and carry on from there. It is also good practice to label the isolines.

Exemplar 2



This exemplar shows correctly plotted isolines running through 0, -10, -20 and -30 milligal values and then continuing. The isolines should not cross. This could be improved by labelling the appropriate isolines as -10, etc. This exemplar also shows the correct location of a possible exploration drillhole close to the 0 milligal isoline and therefore at the edge of the salt dome.

Question 30 (a) (ii)

(ii) Identify the type of potential oil and gas trap shown on your completed map.

Explain your answer.

.....

.....

.....

.....

.....

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

Most candidates recognised the salt dome trap but could not adequately explain why the negative gravity anomaly forms. This is mainly because the salt/halite has a lower density (2.2 g cm^{-1}) compared to the surrounding rock (2.5-3.0 g cm^{-1})

Question 30 (a) (iii)

(iii) Label a **D** on the map where you would drill an exploration borehole to find oil and gas.

[1]

The oil is normally trapped at the edge of a salt dome and so should be at the edge of the negative anomaly. Candidates were given credit for labelling D in the centre of the anomaly if they had mentioned an antiform trap.

Question 30 (b)

(b) Explain how microfossils recovered from boreholes are used in oil and gas exploration.

.....

.....

.....

.....

.....

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

Many candidates knew that microfossils could be used to date the rocks. Only the strongest answers discussed why they are good zone fossils and that they are likely to be abundant and undamaged in drill cores/chips. Many candidates mistakenly discussed these microfossils forming the sapropel as a precursor to oil and gas formation which does not answer the question.

Question 30 (c)

(c) Fracking can be used to extract natural gas from rocks in onshore oil and gas basins.

Describe how fracking is carried out.

.....

.....

.....

.....

.....

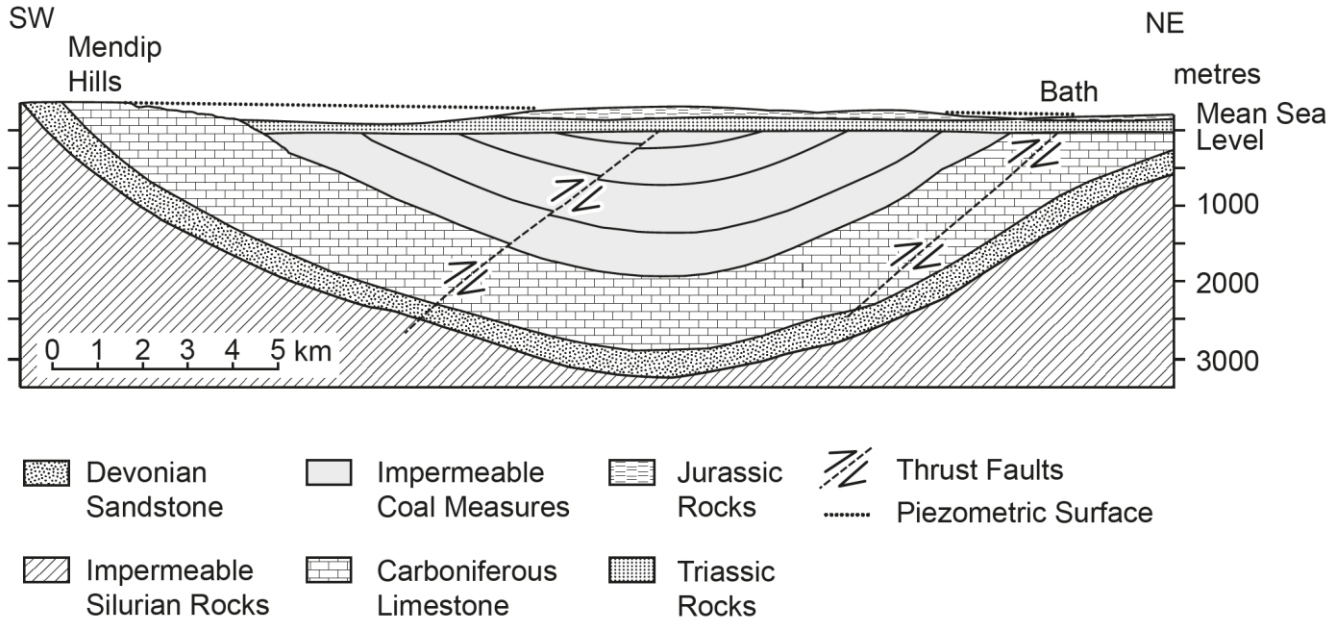
..... **[3]**

Many candidates had a vague idea of how fracking is carried out but very few could describe the process in detail. The best answers discussed directional/horizontal drilling and a drilling liquid that forcibly fractured the rocks and beads keeping the fractures open allowing gas to escape and be extracted from a borehole. A significant number of candidates discussed oil while the question was about natural gas.

Question 31 (a)

31 The cross-section shows the simplified subsurface geology of the Bristol-Bath basin in SW England.

Hot springs at average temperatures of 45 °C emerge from the basin at Bath.



(a) Geothermometry studies indicate that the water emerging from the hot springs has been heated to a maximum temperature of 86 °C.

The average geothermal gradient in the area is 25 °C km^{-1} and the surface temperature is 15 °C.

Calculate the depth at which groundwater with a temperature of 86 °C would be found.

= ..... metres **[2]**

Most candidates were able to calculate the depth at which groundwater would reach 86 °C.

Question 31 (b)

(b) State the likely source of the groundwater and explain how it entered the Bristol-Bath basin.

.....

.....

.....

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

Many candidates knew that the source of the groundwater is from rainfall in the Mendip Hills. Stronger answers described the Mendip Hills as a recharge zone where rainfall could infiltrate into the exposed unconfined Devonian sandstone or Carboniferous limestone. Some candidates mistakenly thought that the groundwater come from within the Earth and was brought upwards.

Question 31 (c)*

(c)* Describe and explain how the rock types and geological structures in the Bristol-Bath basin have resulted in the formation of springs at Bath.

.....

.....

.....

.....

.....

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

Most candidates had a sound understanding of how the rock types and geological structures resulted in springs in Bath. The Level 3 answers had a balance between discussing rock types and structures. They made good use of technical terms such as porosity, permeability, aquifers, aquicludes, aquitards, confined, unconfined, piezometric surface and hydrostatic pressure. Particularly good answers also explained that at 2840 metres this groundwater is at 86°C and could move up the thrust fault to Bath.

Exemplar 3

The impermeable silurian rocks below and the ~~car~~ impermeable impermeable coal measures show that there is an aquiclude present, which porosity and permeability is low. The carboniferous limestone is a permeable sedimentary rock, as well as porous. This means that it has a high volume capacity to store water, and it also has the ability for water to flow through it. The limestone is situated around 2000 - 2750 meters deep in range which shows that the geothermal gradient will be steepening. This means that the groundwater is heated to 45°C as shown in the spring from magma and intrusions below. The ~~the~~ surrounding [6]

Extra answer space if required.

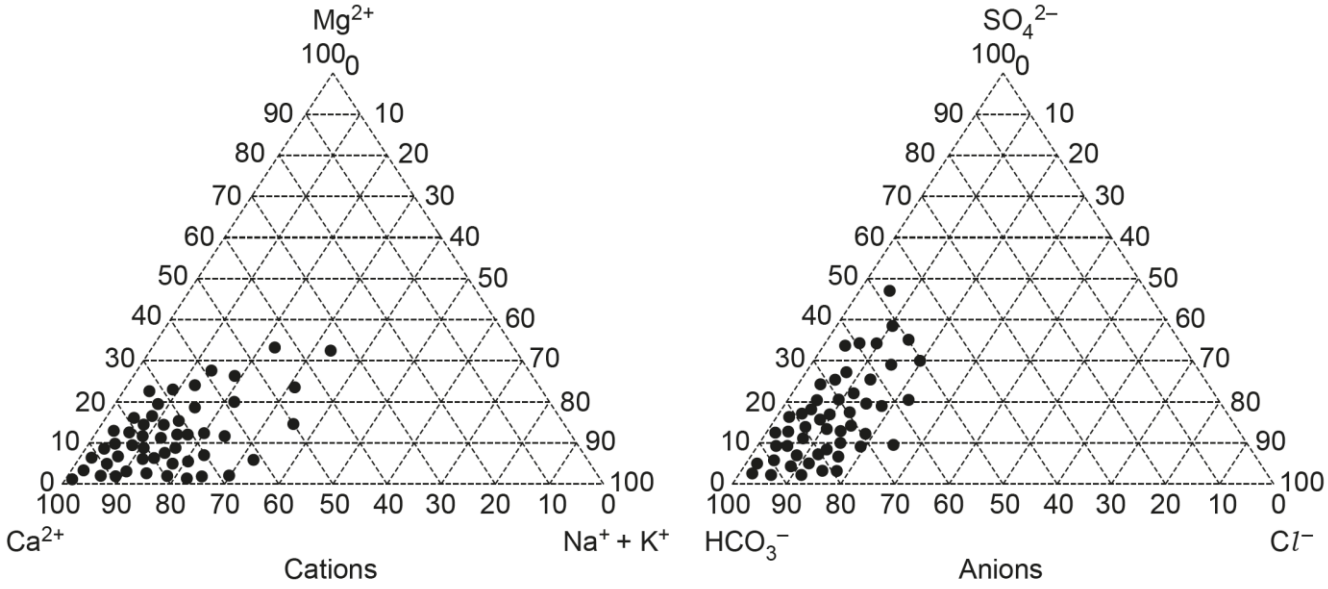
impermeable rock of the permeable limestone shows that a confined aquifer is present. The Bristol-Bath Basin is folded in a synclinal shape which forms an artesian basin. This means that the confined aquifer can be extracted with an artesian well.

The artesian basin shown shows a Thrust fault going through the country rock and aquifer which was caused from compressional stress. This means that the high hydrostatic pressure caused from the lithological map of the confined aquifer is relived as groundwater rises through fractured rock to Piezometric surface. The spring is formed when the groundwater intercepts the surface of ground, and therefore heated groundwater at the surface forms a hyperthermal spring.

This exemplar is well balanced between rock types and geological structures and makes excellent use of technical terms. The exemplar describes the Carboniferous limestone as an aquifer; the answer could be improved by also discussing the Devonian sandstone.

Question 31 (d) (i)

(d) The ternary plots show the relative concentrations of selected cations and anions in groundwater samples taken from the Bristol-Bath basin.



(i) Explain how these chemicals get into groundwater.

.....

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

Often candidates were too vague in explaining how the chemicals get into groundwater or discussed effluent and chemical spills. The best answers discussed solution/chemical weathering of rocks.

Question 31 (d) (ii)

(ii) State the term that is used to describe how long these chemicals remain in groundwater.

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

Relatively few candidates knew the technical term "residence time". A common incorrect answer was half-life.

Question 31 (d) (iii)

(iii) Analyse and describe what the ternary plots show about the cation and anion content of the groundwater in the Bristol-Bath basin.

.....

.....

.....

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

Most candidates could interpret the ternary plots correctly. This is an important skill for candidates to practice, not only interpreting them but also plotting them.

Question 31 (d) (iv)

(iv) Describe and explain the most likely water quality issues that will arise if this groundwater is used for water supply.

.....

.....

.....

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

If candidates correctly identified Ca^{2+} and HCO^{3-} as being in high concentration in the groundwater then they either mentioned "hard water" or limescale formation but often not both. Stronger answers also described the effects of hard water such as difficulty in lathering soap or blocking pipes.

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