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Examiners' report

GEOLOGY

H414

For first teaching in 2017

H414/01 Summer 2022 series

Version 1

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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.

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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 and Section B which includes short answer questions and two 6 mark extended response questions. It covers A01, A02 and A03.

This paper is one of 3 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 did the following:	Candidates who did less well on this paper generally did the following:
• carried out familiar and unfamiliar calculations • could convert units and use the correct units • were familiar with and used scientific geological terminology • were able to identify and interpret thin section diagrams of igneous, sedimentary and metamorphic rocks • were able to structure extended responses which focused on the question and used technical terms.	• struggled with calculations • were not able to convert units • were not always secure in use and understanding of geological scientific terminology • were unable to confidently interpret thin section diagrams • struggled to organise extended responses or to provide significant detail.

Section A overview

This section provided candidates with a broad range of topics to be assessed. Many candidates demonstrated a full range of geological knowledge. It also seems that candidates spent the appropriate amount of time on this section as overall it does not appear that candidates ran out of time.

Question 1

1 What is the main factor that controls the flow of groundwater through rock or sediment?

A Hydrostatic pressure

B Permeability

C Porosity

D Temperature

Your answer ☐ **[1]**

Option C "Porosity" provided a distractor and a common incorrect response, which although a factor in groundwater flow is not the main factor which in this case is option B "Permeability".

Question 2

2 What characteristic of the depositional environment of the Jurassic Solnhofen Limestone did **not** lead to the exceptional preservation of *Archaeopteryx*?

A Deep water

B Fine-grained sediment

C Low energy

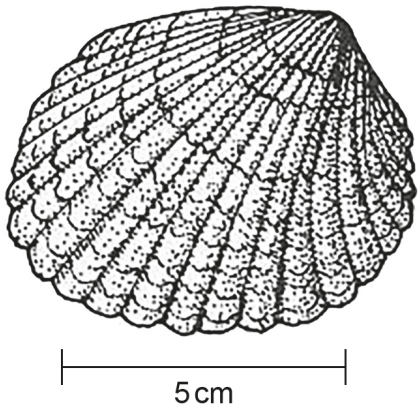
D Low oxygen

Your answer ☐ **[1]**

Most candidates were confident with the depositional environment for *Archaeopteryx* and very few were distracted by options B, C and D which are the key features of the Solnhofen Limestone depositional environment.

Question 3

3 The diagram shows a body fossil.



Which environment is the most likely habitat for the organism when it was living?

A Deep marine

B Delta top

C Lagoonal

D Shallow marine

Your answer [ ] **[1]**

Candidates were confident in recognising that the strong ribs on this bivalve provide added strength for a shallow marine environment (option D).

Question 4

4 In a solid solution series, there is progressive substitution of one element for another in the mineral crystal structure as the magma cools.

Which is the correct example of this process?

A Ca-rich plagioclase is replaced by Na-rich plagioclase

B Fe-rich olivine is replaced by Mg-rich olivine

C K feldspar is replaced by Na plagioclase

D Na-rich plagioclase is replaced by Ca-rich plagioclase

Your answer [ ] **[1]**

Although candidates often find aspects of solid solution series difficult, most candidates recognised that option A, Ca-rich plagioclase being replaced by Na-rich plagioclase was the only correct statement. The other 3 options were incorrect statements but option D was the distractor most likely to be chosen, the direct opposite of the correct answer.

Question 5

5 A student set out to test the hypothesis that the mean clast size in a river would get smaller downstream. At each of 10 sites along the river course, the student selected 5 clasts at random and calculated their mean diameter.

Which statistical technique should the student select to test their hypothesis?

A Calculate the standard deviation at each site

B Chi squared test

C Mann-Whitney *U* test

D Spearman's rank correlation coefficient

Your answer [ ] **[1]**

Candidates found identifying the correct statistical technique to choose very difficult and commonly gave all 3 of the other distractor options most commonly option B "Chi squared test". Option D "Spearman's rank correlation coefficient" is correct as this technique measures the association between the two sets of ranked data.

Question 6

6 Which of the Earth's layers has the greatest rate of change of temperature with depth (geothermal gradient)?

A Continental crust

B Inner core

C Lower mantle

D Outer core

Your answer [ ] **[1]**

This proved the most difficult question of Section A with all the distractors, options, B, C and D being chosen by many candidates. The greatest rate of change of temperature is within the continental crust, option A, and it would be useful for candidates to look at a graph or table showing how the geothermal gradient changes with depth within the Earth.

Question 7

7 Which statement is a true comparison of the Lehmann and Gutenberg discontinuities?

A Both show a sudden change in pressure

B Both show no change in density

C Only one is a change of phase

D Only one is a marked change in composition

Your answer [ ] **[1]**

This question takes time to think through as there are elements of truth in all four options but only option D is entirely correct "Only one is a marked change in composition" as the lower mantle to outer core (Gutenberg) is a marked compositional change (peridotite to mainly iron and nickel) while outer to inner core is still mainly iron and nickel.

Question 8

8 What combination leads to the formation of slaty cleavage?

A Competent rock subjected to compressional stress

B Competent rock subjected to tensional stress

C Incompetent rock subjected to compressional stress

D Incompetent rock subjected to tensional stress

Your answer [ ] **[1]**

Many candidates identified option C as being correct realising that shale/mudstone is an incompetent rock and that the alignment of the clays/micas to form slaty cleavage required compressional stress. The options most likely to distract were A and D where one aspect of the statement was true.

Question 9

9 Which type of geological structure will dominate at transform (conservative) plate boundaries?

A Antiformal folds

B Dip-slip faults

C Strike-slip faults

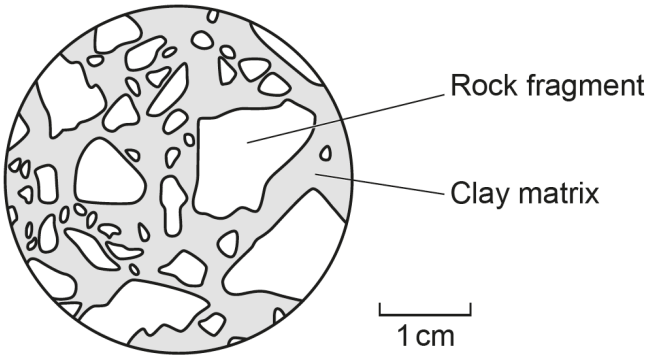
D Synformal folds

Your answer [ ] **[1]**

Most candidates linked transform plate boundaries to strike-slip/shear movements and so chose option C "Strike-slip faults" option B "Dip-slip faults" was the most likely distractor to be chosen.

Question 10

10 The thin section diagram is of a sedimentary rock.



Which method is most likely to have transported the sediment?

A Ice flow

B River flow

C Waves

D Wind

Your answer [ ] **[1]**

Candidates demonstrated skill in identifying the key features of the thin section diagram (boulder clay) and could link it to a glacial environment and therefore chose option A "Ice flow". Candidates could be distracted by option B in particular possibly thinking it was a wadi/river deposit.

Question 11

11 Economic deposits of china clay have formed on the weathered granites of SW England.

Which weathering process or processes is/are responsible for their formation?

A Biological and chemical

B Biological and mechanical

C Chemical only

D Mechanical only

Your answer [ ] **[1]**

Candidates were not confident regarding how china clay forms even though they were told it involves the weathering of granite. The granites weather in situ and the clay is a by-product of chemical weathering for example by hydrolysis of feldspars and so option C "Chemical only" is the correct answer.

Question 12

12 8100 years old sediments in the Shetland Islands contain diatoms, sand layers and rip-up clasts. They are 9 metres above current sea level.

Which depositional environment are they evidence of?

A Delta channels

B Glacial

C Playa lake

D Tsunami

Your answer [ ] **[1]**

Candidates were often distracted by options B Glacial" and A "Delta channels" as some characteristics of the Shetland sediments are to be found in these environments. However, all three features are peculiar to tsunami deposits especially being in young sediments 9 metres above sea level and so option D "Tsunami" is correct.

Question 13

13 A facies association contains red sandstones with large-scale cross-bedding, mudstones and an arkosic conglomerate.

Applying the principle of uniformitarianism, in which environment was this facies association deposited?

A Deep sea

B Fluvial

C Hot desert

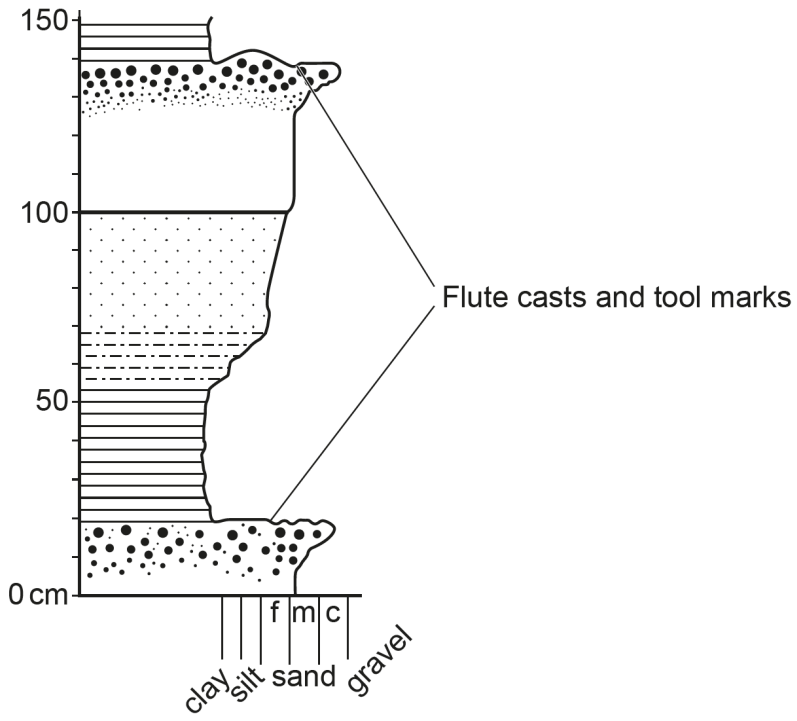
D Shallow siliciclastic sea

Your answer [ ] **[1]**

Most candidates are confident in identifying the characteristics of a hot desert facies and so very few were distracted; option B being the most likely incorrect distractor, chosen possibly because of the cross-bedding and mudstones.

Question 14

14 The diagram shows a graphic log.



What is the correct interpretation of this graphic log?

A Inverted and formed by turbidity currents

B Inverted and formed in a deltaic environment

C Right way-up and formed by turbidity currents

D Right way-up and formed in a deltaic environment

Your answer [ ] **[1]**

Firstly, candidates needed to use the graded bedding and eroded bases to realise that the sequence is the wrong way up/inverted and then to realise that the graded bedding and greywacke are typically formed from turbidity currents. Therefore, option A is correct. Distracter options A and C are partly correct and so tended to be the most chosen incorrect answer.

Question 15

15 Which geophysical survey method could be used to detect higher conductivity of magma at shallow depths below ocean ridges?

A Downhole logging of gamma rays

B Electromagnetic survey

C Gravity survey

D Seismic survey

Your answer ☐ **[1]**

Most candidates chose the correct option which is B, "Electromagnetic survey" probably noticing that the method is detecting conductivity and so linking it to "electrical" conductivity.

Question 16

16 A lava with high viscosity would have which property?

A High crystal content

B High temperature

C Low silicate polymerisation

D Mafic composition

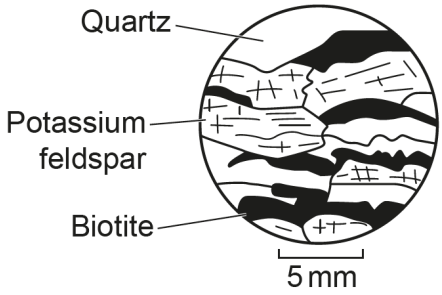
Your answer ☐ **[1]**

The distractor options B, C and D are all properties typical of low viscosity magmas while option A "High crystal content" and therefore with less magma will be more viscous.

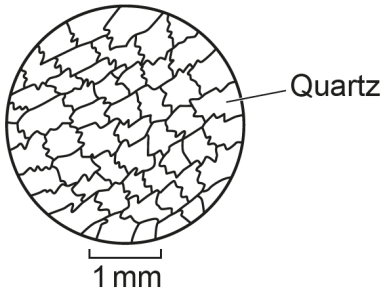
Question 17

17 The four thin section diagrams show metamorphic rocks.

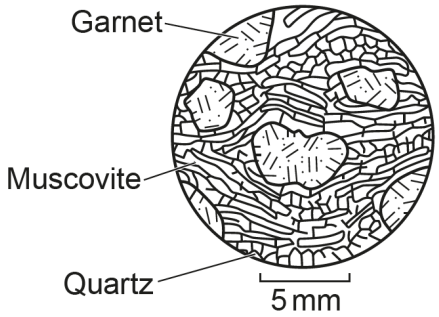
Rock **A**



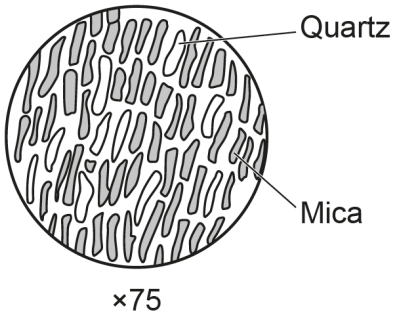
Rock **B**



Rock **C**



Rock **D**



Which metamorphic texture, **A**, **B**, **C** or **D**, would **not** result from a directed stress?

Your answer [ ] **[1]**

Most candidates recognised that the thin section diagrams of options A (gneiss), C (schist) and D (slate) all show aligned minerals and a foliation (linked to a directed stress) while the correct option B (metaquartzite) is granoblastic/equigranular with no preferred alignment.

Question 18

18 Which rock could develop gneissose banding during metamorphism?

A Dolerite

B Orthoquartzite

C Shale

D Wackestone

Your answer [ ] **[1]**

Option C "Shale" which is correct was chosen by about half the candidates realising that shale is linked to the sequence shale, slate, schist, and gneiss indicating increased grade of regional metamorphism. Option B "Orthoquartzite" and D "Wackestone" are monomineralic and so unlikely to form gneissose banding and option A "Dolerite" will be dominated by dark mafic minerals with low amounts of light coloured minerals so gneissose banding will not develop fully.

Question 19

19 Which order of index minerals encountered during field mapping shows that the metamorphic grade was **reducing** in the direction the geologist was walking?

A Biotite → garnet

B Biotite → kyanite

C Garnet → chlorite

D Kyanite → sillimanite

Your answer [ ] **[1]**

Candidates do tend to find prograde regional metamorphism and index minerals difficult and in this case candidates did struggle and many chose one of the 3 distractors. Candidates need to learn the prograde sequence of chlorite, biotite, garnet, kyanite and sillimanite so that they can recognise only option C indicates decreasing grade from garnet to chlorite.

Question 20

20 The top 5 metres of a large brownfield site is found to be contaminated with lead (Pb) from petrol.

Which remediation method would permanently remove the lead?

A Ion exchange treatment using clays

B Phytoremediation

C Solidification with cement

D Stabilisation with lime

Your answer ☐ **[1]**

Candidates are not confident with remediation strategies for contaminated land and only half the candidates recognised option B "Phytoremediation" as being the most appropriate method for removing lead from a brownfield site. The distracter options are all remediation techniques but for other contaminants and not lead.

Question 21

21 Which technique is most likely to be used to extract shale gas from onshore basins?

A Fracking

B Primary recovery

C Secondary recovery using bacteria

D Secondary recovery using carbon dioxide

Your answer ☐ **[1]**

Most candidates were familiar with the use of fracking (option A) for the extraction of onshore shale gas. The distractors (options B, C and D) are all extraction techniques for the more typical oil and gas scenarios.

Question 22

22 Use your knowledge of the extinction event at the end of the Cretaceous period to decide which statement could **not** explain the replacement of land dinosaurs by mammals.

A Mammals had a varied diet

B Mammals were relatively small

C Some mammals could fly

D Some mammals lived in burrows

Your answer ☐ **[1]**

This question did need to be thought through carefully and about half the candidates realised that option C "Some mammals could fly" was not an explanation for the replacement of land dinosaurs by mammals while all three distractors have been given as explanations for this replacement.

Question 23

23 Facies changes are found in the cyclic sedimentation of Upper Jurassic rocks.

Which rock sequence would be evidence of a fall in sea level?

A Coarse sandstone → ironstone → shale

B Coarse sandstone → shale → oolitic limestone

C Oolitic limestone → coarse sandstone → shale

D Shale → oolitic limestone → coarse sandstone

Your answer ☐ **[1]**

Candidates found this question difficult and were generally unable to realise that option D going from shale (low energy and deeper water) to coarse sandstone (higher energy and shallower water) was the only option indicating a fall in sea level.

Question 24

24 Which of the options suggests that major volcanism contributed to the mass extinction event at the end of the Permian period?

A An enrichment of iridium at the boundary

B An increase in concentration of SO_2 in the atmosphere

C The presence of shocked quartz

D The presence of tektites

Your answer [ ] **[1]**

Most candidates realised that the distractor options A, C and D are all evidence of a meteorite impact and not volcanic activity and that option B is linked to SO_2 release from active volcanoes.

Question 25

25 Which isotopic change recorded in marine fossil shells would indicate the onset of a greenhouse Earth event?

A A decrease in the proportion of ^{13}C

B An increase in the proportion of ^{12}C

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

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

Your answer [ ] **[1]**

Remembering which of the O or C isotopes increases or decreases during a greenhouse Earth event is difficult and relies on the candidates fully understanding the preferential removal or storage of a particular isotope during such an event. It is no surprise that many candidates opted for one of the distractors. Option C is correct as the ^{16}O held in icecaps is released into the oceans and marine shells as the ice melts.

Section B overview

Candidate did seem to have enough time to complete all this section and did not spend too long on the Section A multiple choice questions.

Question 26 was primarily about igneous rocks the basics of which are usually understood well but the detail is often lacking. This was the case here although fractional crystallisation and magma control of eruptions was generally well understood.

Question 27 was primarily about palaeontology and this was a strong area for many candidates especially as graphical and measuring/scale skills were also being tested. Candidates did though find the question on taphonomic processes more challenging.

Question 28 was mainly about geohazard and engineering geology. Candidates do typically find aspects of engineering geology difficult. There were also 3 calculations to complete which varied in difficulty. Candidates were most confident in discussing the strength of rocks and least confident in definitions of earthquake forecasting and prediction as well as the formation of acid mine drainage and toxic metal leaching.

Question 29 is focused on engineering geology and in particular dams and slope stability. There were also two further calculations. Candidates found some of the more technical aspects of the questions difficult but were confident in their knowledge of geotechnical solutions to slope instability. Candidates also performed well in calculating lithostatic and hydrostatic pressure.

Question 30 focused on evidence for the nature of the core. The 3 mark question focused on the use of crustal and whole Earth density to estimate the density of the core and the 6 mark extended response looked at how P and S waves can provide evidence for the state and depth of the inner and outer core. Candidates are usual confident in these areas although the actual responses were very variable.

Question 26 (a) (i)

26 (a) **Fig. 26.1** is a drawing of a thin section of an igneous rock in plane polarised light (PPL). It contains three different minerals.

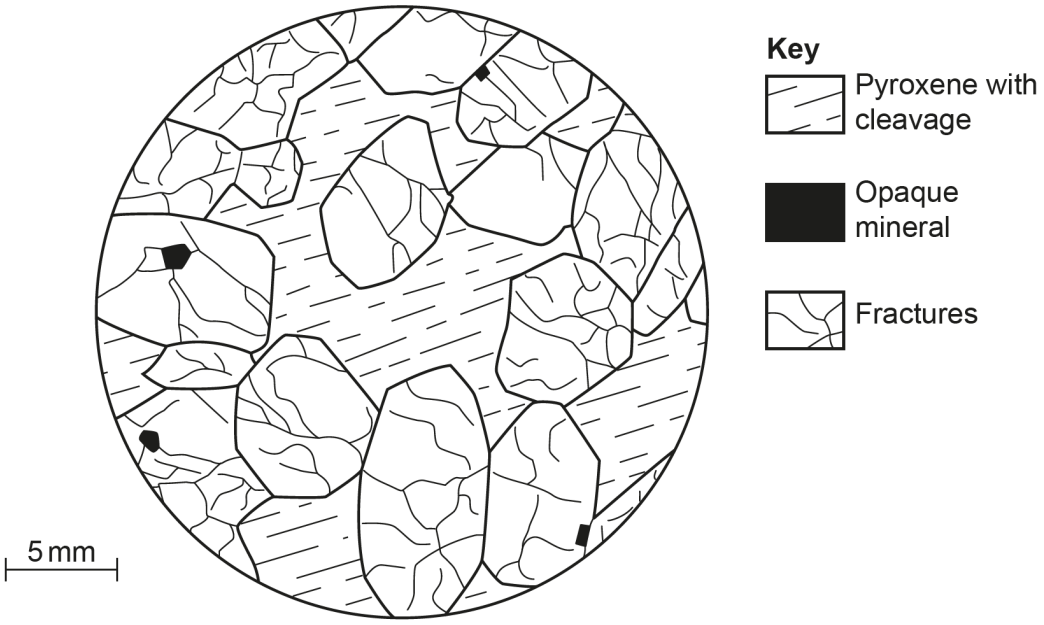


Fig. 26.1

The crystals with the fractures were hand-picked from a crushed sample of the rock. This was possible because they have a distinctive colour. Individually, these crystals were too small for accurate measurements but when a large number had been selected, the density of the mineral could be determined.

The total mass of the selected crystals was found using an electronic balance. The crystals were then added to a displacement can filled with water. The displaced water was used to determine their volume. The results are shown in the table.

Dry mass (g)	Volume of displaced water (cm^3)
14.92	4.52

(i) Calculate the mineral density.

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

Density = ... $kg\,m^{-3}$ **[2]**

Most candidates were able to work out the density in g cm^{-3} but were unable to convert this result into kg m^{-3}.

Assessment for learning

Candidates need to practice converting results from one form to another on a regular basis so that candidates are confident with these conversions.

Question 26 (a) (ii)

(ii) Describe and explain **one** geological factor and **one** experimental factor which could cause errors in the determination of the mineral's density.

Geological factor .....

.....

Experimental factor .....

.....

[2]

Most candidates could gain at least 1 mark either for a geological or experimental factor. Many candidates knew general experimental errors that could take place such as problems with the balance including errors in zeroing or the resolution being too low. Geological factors tended to be less well known with impurities within the mineral or additional minerals in the rock fragment being the most cited. General comments about impurities were not enough for the mark it needed to be specific. Fractures within the mineral needed to be linked to lowering the mass or density of the mineral.

Question 26 (a) (iii)

(iii) Use the table of mineral properties below to identify the mineral with fractures in **Fig. 26.1**. Remember that the apparent properties of the mineral will vary depending on its orientation to the thin section.

Mineral	Crystal form	Cleavage
Biotite mica	Sheets / flakes	One perfect
Hornblende	Often six-sided crystals	Two at 60°
Plagioclase feldspar	Approximately rectangular	Two good at right angles
Olivine	Sub-equant, subhedral	Poor
Quartz	Irregular	None

Mineral name ..... **[1]**

Half the candidates could recognise olivine from the description. Candidates should be able to recognise the main rock forming minerals from descriptions given especially when a table is given as a guide.

Question 26 (a) (iv)

(iv) Use your knowledge of Bowen's discontinuous reaction series and the texture of the rock shown in **Fig. 26.1** to determine the correct order of the crystallisation of the minerals in the rock.

(Circle) the correct answer for each mineral.

Pyroxene	First	Second	Last
Opaque mineral	First	Second	Last
Mineral with fractures	First	Second	Last

[1]

Candidates struggled with interpreting the order of crystallisation of the minerals in this igneous texture. Candidates could not rely on using Bowens Reaction Series as the opaque mineral is not represented in the series. Candidates were expected to recognise that the opaque mineral is completely enclosed by the mineral with fractures (olivine) and so came before the olivine and that the pyroxene filled in the spaces between the mineral with fractures. Hence the opaque mineral crystalised first within a great deal of space within the magma, the mineral with fractures then grew freely and surrounded the opaque mineral and then the pyroxene formed last and filled in all the gaps with anhedral crystal edges.

Question 26 (a) (v)

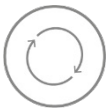
(v) Estimate the relative proportions of the **three** minerals in **Fig. 26.1**.

Pyroxene	.....%
Opaque mineral	.....%
Mineral with fractures	.....%

[1]

This can be difficult for candidates and is a skill required for many different rock types. A wide tolerance was given. It was the opaque mineral estimated percentage that caused the most difficulty being 0.5 to 2%. Candidates need to make sure that the total adds up to 100%.

Assessment for learning



This skill can be practiced in the lab or in the field with many grain size cards having a percentage coverage estimate included.

Question 26 (a) (vi)

(vi) Identify the igneous rock shown in **Fig. 26.1**. Explain your choice.

Rock name .....

Explanation .....

.....

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

If the candidate recognised olivine in the rock (Question 26 (a) (iii)) then they were more likely to identify the rock correctly as peridotite. Common misidentifications included gabbro but also fine grained rocks such as basalt. Many candidates did realise the rock is coarse grained with fewer describing it as being ultramafic or being dominated by mafic minerals.

Question 26 (b)*

(b)* The opaque minerals in **Fig. 26.1** represent only a small fraction of the rock. They are usually metal oxide or sulfide ore minerals.

Describe and explain how the igneous process of fractional crystallisation can lead to economically viable deposits of ore minerals.

Use named ore minerals in your answer.

.....

.....

.....

.....

.....

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

There was a range of responses to this question many of which were excellent in content, detail and structure. The most successful responses were well structured and outlined the main processes such as fractional crystallisation, gravity settling and filter pressing but also described the ores that formed. Particularly strong responses also referred to Platinum Group Elements and the unusual way in which they formed economic deposits. Candidates felt confident in structuring this response as many could describe fractional crystallisation as a linear story linked to Bowens Reaction Series, early mafic minerals, gravity settling, cumulates and filter pressing. It was the additional detail regarding ore minerals or scenarios which was often missing with many candidates not being able to name an ore mineral. The best responses were balanced in terms of process but also products with examples given.

Exemplar 1

fractional crystalisation means that minerals ~~exolve~~ solidify out of a melt at different times, depending on their cooling point. So, mafic minerals such as iron can be found at the bottom of an intrusion. Also when a magma melt becomes heavily concentrated in Sulfur (usually because of assimilation) the Sulfur starts to exsolve out of the melt, it will then sink. Platinum Group Elements (PGE) such as palladium and platinum act as chalcophiles (they are siderophiles) when theres no iron and so bonds reacts with the Sulfur in the melt rather than oxygen. So, ~~Sulfide~~ Solid parts of Sulfur accumulate PGE as it sinks, creating a deposit at the bottom before the rest Cools. [6]

This response includes a discussion of Platinum Group Elements (PGEs) linked to metal sulphides which can be used as an alternative example of how economic deposits can form by fractional crystalisation. To be a more balanced response it could also discuss the more typical formation of cumulate magnetite or chromite from a mafic magma.

Question 26 (c) (iii)

(iii) Explain why the volcanic activity was more explosive when the magma became andesitic in its chemistry.

.....

.....

.....

.....

.....

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

Candidates were generally confident enough to give at least two appropriate points but did struggle to give three explanations. The most common points made were the increased silica percentage, the increase in viscosity and the consequent difficulty for gases to escape. Particularly good responses discussed increased polymerisation and the temperature of the magma.

Question 26 (c) (i)

(c) **Fig. 26.2** shows a cross-section through an ocean–ocean convergent plate boundary.

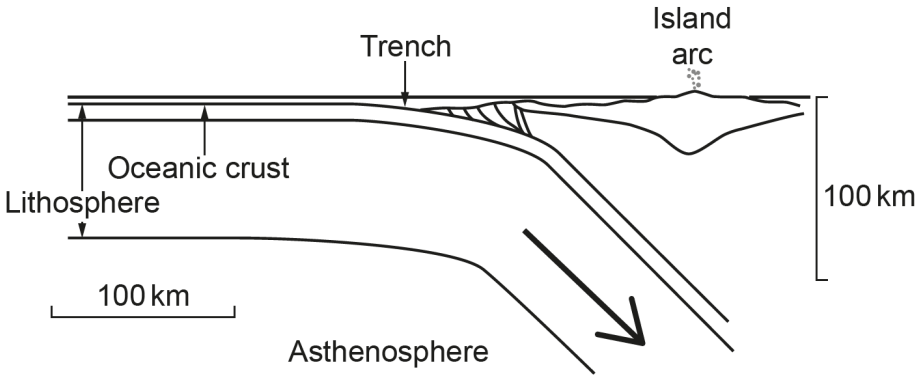


Fig. 26.2

(i) Explain why the island arc formed approximately 150 km from the trench.

.....

.....

.....

.....

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

Most candidates knew about the crust melting and the magma rising to the surface to create the island arc. However, few knew why the partial melting took place at 150 km from the trench as it was only at that distance from the trench that the subducting plate was deep and hot enough to begin to melt. This is linked to the angle (45° in this case) of subduction. Better responses also discussed the role of flux melting in the mantle wedge above the subducting plate.

Question 26 (c) (ii)

(ii) The first lavas to erupt at the island arc were mafic but became more intermediate in chemistry as the arc matured.

Name **one** process, **other than** fractional crystallisation, that would explain this change in chemistry.

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

Candidates showed an impressive knowledge of a range of alternative processes that could change magma composition most commonly giving assimilation/stoping/contamination while others mentioned magma mixing.

Question 27 (a)

27 (a) Describe how organisms are fossilised and become preserved as **body fossils** in rocks.

.....

.....

.....

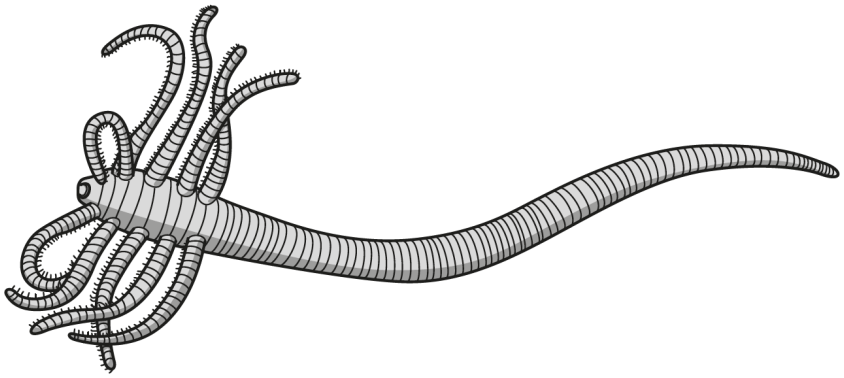
.....

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

Candidates generally have a good idea about fossilisation with many gaining a mark for the idea of initial burial within sediment. However, the detail of how the transformation takes place via replacement is sometimes lacking. The most successful responses discussed at least one named fossilisation method such as silicification, pyritisation or recrystallisation.

Question 27 (b) (i)

(b) **Fig. 27.1** shows the fossil *Facivermis sp.* of a soft-bodied organism from the Chengjiang Formation.



×1.5

Fig. 27.1

(i) Describe and explain **two** conclusions that can be made about the environment in which this fossil was preserved.

1 .....

.....

2 .....

.....

[2]

Although candidates will have studied the Chengjiang Formation they may not have encountered this fossil and so general principles about linking morphology and state of preservation to the environment were expected. Given this scenario candidates did well with most realising that such exceptional preservation of a soft bodied creature required and least one of: fine grained sediment, low energy, rapid burial, anoxic and/or hypersaline conditions.

Question 27 (b) (ii)

(ii) Use the morphology of the fossil shown in **Fig. 27.1** to state and justify **one** conclusion about the mode of life of the organism.

.....

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

Even though candidates had probably not encountered this fossil before many were able to deduce a sensible mode of life with some justification given. The exact mode of life is not known for certain and so any reasonably justified mode of life was accepted.

Question 27 (b) (iii)

(iii) Explain how fossils such as *Facivermis sp.* provide evidence for the Cambrian Explosion.

.....

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

Most candidates struggled to provide an explanation of how this fossil provides evidence for the Cambrian Explosion. Answers could include ideas about experimental body plans which are particularly evident if soft tissues are preserved (as in this case). Also the idea that this soft bodied creature is preserved which is not usually the case so a more complete representation of the organisms present is provided.

Question 27 (c) (i)

(c) **Fig. 27.2** is a simplified diagram of the trace fossil *Asteriacites sp.* made by a starfish found in rocks of the Lower Palaeozoic Welsh Basin.

It shows a bedding plane view and a cross-section view.

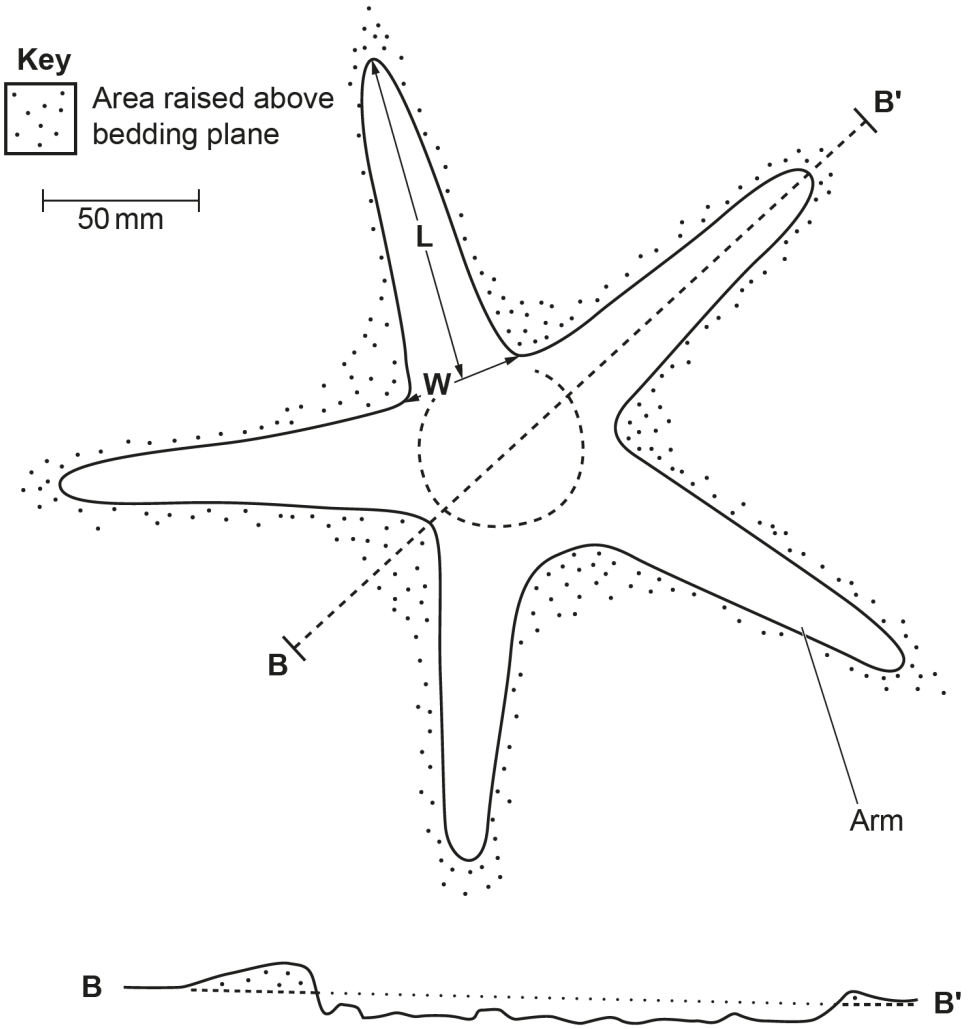


Fig. 27.2

(i) Measure and use the scale to calculate the actual width (**W**) and length (**L**) of the arm impression labelled on **Fig. 27.2**.

Record your results to an appropriate number of significant figures.

Width = ...

Length = ...

[2]

Candidates were generally good at measuring and making the appropriate scale adjustments to gain the correct width and length of the trace fossil.

Assessment for learning

Measuring dimensions of fossils, minerals etc from a diagram does need practice so that actual sizes can be worked out by using scales.

Question 27 (c) (ii)

(ii) Give **one** reason why the trace fossil shown in **Fig. 27.2** is **unlikely** to have resulted from feeding activity.

.....

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

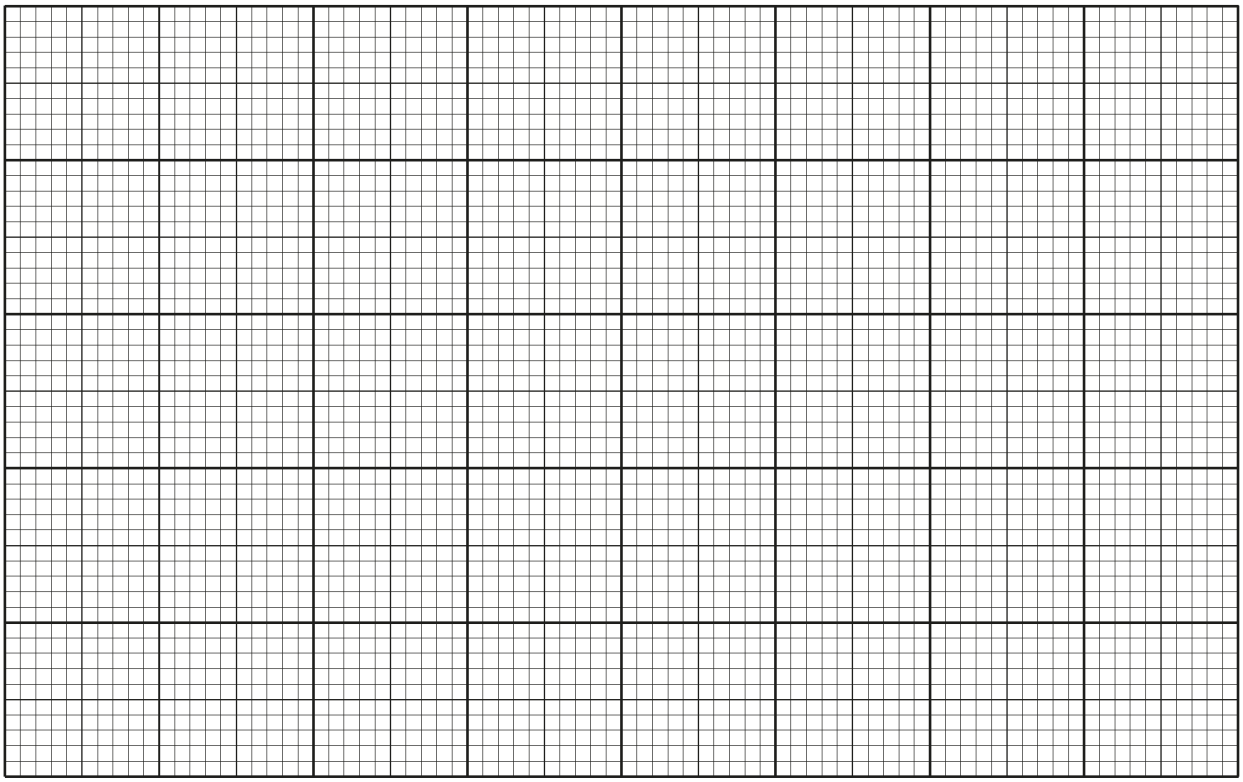
Many candidates realised that a feeding trace should show evidence of movement and that in this case no movement is evident. Many recognised this as a resting trace.

Question 27 (d) (i)

(d) (i) The table shows a series of measurements of the maximum arm width versus the maximum arm length from similar trace fossils within Jurassic rocks in the British Isles.

Specimen	Maximum arm width (mm)	Maximum arm length (mm)	Ratio length /width
1	20	34	1.70
2	20	36	1.80
3	21	47	2.24
4	18	30	1.67
5	19	53	2.79
6	21	30	1.43
7	23	48	2.09
8	13	24	1.85
9	17	31	1.82
10	20	49	2.45

Plot a graph of the maximum arm width (y-axis) against the maximum arm length (x-axis).



[3]

Candidates generally showed accuracy and precision when plotting the graph including using the correct axes. The main error was not labelling the axes correctly. Candidates need to practice plotting graphs as they should be expected in an examination and having a standard and practiced approach to graph plotting should gain full marks.

Question 27 (d) (ii)

(ii) Circle specimen numbers **2**, **8** and **9** on your graph.

Describe the relationship between these three specimens **and** suggest an explanation for the relationship.

.....

.....

.....

.....

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

Many candidates drew a line of best fit for the three selected points which helped them to identify a positive linear correlation. Many candidates gained this first mark but struggled to explain the pattern. The most likely explanation being that the three samples represent growth stages of the same species.

Question 27 (d) (iii)

(iii) Evaluate the theory that the data on the graph shows evidence of **two** separate species.

.....

.....

.....

.....

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

Many candidates spotted that there were two distinct data clusters on the graph which gained a mark. However, candidates then needed to add further evaluation and detail which proved more difficult. The most successful responses discussed the different ratios shown by the two clusters.

Question 27 (e)

(e) Fossilisation could be described as a rare or unlikely process. Scientists have estimated that < 0.01% of all animal species that have ever lived have become fossils.

Describe the taphonomic processes that make fossilisation an unlikely event.

.....

.....

.....

.....

.....

..... **[4]**

Many candidates misunderstood the question and described how fossilisation occurs and the processes involved rather than the taphonomic processes that stop fossilisation from occurring. Although there was sometimes enough to gain 1 or 2 marks it was only the candidates who focused on what stopped fossilisation from occurring that gained top marks. Processes such as disarticulation, bacterial decay, scavenging, diagenetic processes, replacement, and mechanical action could have been discussed.

Question 28 (a) (i)

28 Our understanding of the mechanisms causing geohazards has allowed their impact to be reduced by probabilistic forecasting.

(a) (i) Explain the difference between seismic forecasting and seismic prediction.

.....

.....

.....

.....

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

It is clear that not many candidates knew the difference between seismic forecasting and seismic prediction which led to responses that were not precise enough to gain the marks. Forecasting involves a probability of an earthquake occurring while prediction tries to state when and where an earthquake will occur.

Question 28 (a) (ii)

(ii) A search of the British Geological Survey seismic database revealed that 13 earthquakes of magnitude 4 or higher occurred between 1937 and 2015 within a 200 km radius of Greenwich in London.

Calculate the return period for a magnitude 4 or higher earthquake for this area.

Return period = ... **[2]**

Most candidates were able to calculate the return period although some lost a mark for not giving the units, in this case years or months.

Question 28 (a) (iii)

(iii) Calculate the probability of an earthquake with magnitude 4 or higher occurring in this area in any one year.

Probability = ... **[1]**

Candidates were equally good at calculating the probability giving the answer as a fraction or a percentage.

Question 28 (a) (iv)

(iv) Explain whether the probability you have calculated would change in the year **following** a magnitude 4.3 event in this area.

.....

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

Many candidates were not sure about how probability worked and concluded that a similar event was either more or less likely depending on the logic that they used. However, just because an event had just happened the probability of it happening again is unchanged.

Question 28 (b) (i)

(b) Underground coal mine workings can have significant impacts on the surface and subsurface environments.

(i) Suggest a reason why abandoned underground coal mine workings may collapse.

.....

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

Many candidates understood that the supports in old mine working were likely to disintegrate over time and lose their structural integrity and so lead to collapse.

Question 28 (b) (ii)

(ii) Describe the effect a collapse underground may have at the surface.

.....

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

Many candidates knew that subsidence was the most likely effect, however some were more specific mentioning crown holes. Candidates should be aware that sinkholes are linked to natural processes of dissolution in limestone areas leading to the collapse of cave systems.

Question 28 (b) (iii)

(iii) Explain how this effect at the surface can cause damage to built structures **and** suggest an appropriate engineering geology mitigation technique.

.....

.....

.....

.....

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

Many candidates were too vague in their explanation of how surface damage is caused and the engineering mitigation techniques. Most damage is caused if there is differential subsidence. The best responses discussed engineering solutions such as raft type foundations or isolating foundations. In addition backfilling of the mine was also a frequent correct suggestion.

Question 28 (b) (iv)

(iv) Explain how the chemistry of minerals associated with the formation of coal can cause mine water to be contaminated.

.....

.....

.....

.....

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

Most candidates did not know about the formation of pyrite/sulphides during coal formation. However, some did discuss the formation of acids which they often linked to acid mine drainage and so could gain a mark. A few candidates also discussed the water taking up toxic/heavy metals.

Question 28 (b) (v)

(v) Explain why contaminated mine water from abandoned underground coal mine workings poses a threat to the environments of rivers and lakes.

.....

.....

.....

.....

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

Candidates struggled to gain full marks as candidates needed to discuss the effect of acid mine drainage or the toxic/heavy metals which needed to be identified in Question 26 (b) (iv). However, there were some good responses regarding acid mine drainage affecting ecosystems. Fewer candidates discussed the impact of toxic/heavy metals. Candidates do need to understand the chemical reactions that take place in abandoned coal and metal mines and how it can lead to acid mine drainage (AMD) and the leaching of toxic/heavy metals.

Question 28 (c)

(c) The table shows the strengths of three rocks.

Rock	Uniaxial compressive strength (MPa)	Uniaxial tensile strength (MPa)	Shear strength (MPa)
Dolerite	300	30	50
Shale	80	7	24
Metaquartzite	250	24	42

Compare and explain the differences in strengths of these rocks.

.....

.....

.....

.....

.....

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

There were some excellent responses to this question about relative strengths of three different rock types. The best responses were well structured stating the relative strengths of the three rock types and then explaining the relative strengths of each rock type. Even better responses also discussed the relative significance of each of the three types of strength (compressive, tensile and shear). Many candidates realised that the interlocking crystalline nature of both dolerite and metaquartzite were key to their strength in contrast to the relatively weakly cemented shale which had fundamental weakness being fissile.

Exemplar 2

Shale has the lowest strengths of all the rocks, this is because clay minerals are layered, which means shale is less resistant to tensile and compressive stresses. Dolerite is the strongest in all three strengths because it contains interlocking crystals, similarly, metaquartzite is stronger than shale but slightly weaker than ~~metaqtz~~ dolerite because it has interlocking ~~lotting~~ crystal structure. [3]

Dolerite is igneous so it is strongest.
Metaquartzite is metamorphic so it is strong, but weaker than dolerite.

~~Metaquartzite~~
Shale is sedimentary with no crystals ~~structure~~ so it is the weakest.

The response is well structured and logical. It states the relative strengths of the 3 rocks and gives a reasoned explanation for the relative strengths. This is only part of the response so it could be a bit more concise.

Question 28 (d) (i)

(d) The length of time an unsupported roof in an underground mine will last before it collapses is called the stand-up time.

The stand-up time is affected by the strength of the rock and the **frequency** of discontinuities such as fractures, bedding planes and foliation within the rock.

(i) State **one other** characteristic of discontinuities within a rock that will affect the stand-up time.

.....

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

Candidates were not very confident in their knowledge of the characteristics of rocks affecting stand-up time. Some candidates were also not sure what discontinuity meant. The best responses discussed the openness, permeability, or asperity of the discontinuity. Other considerations were the angle of the discontinuity and the presence or absence of water.

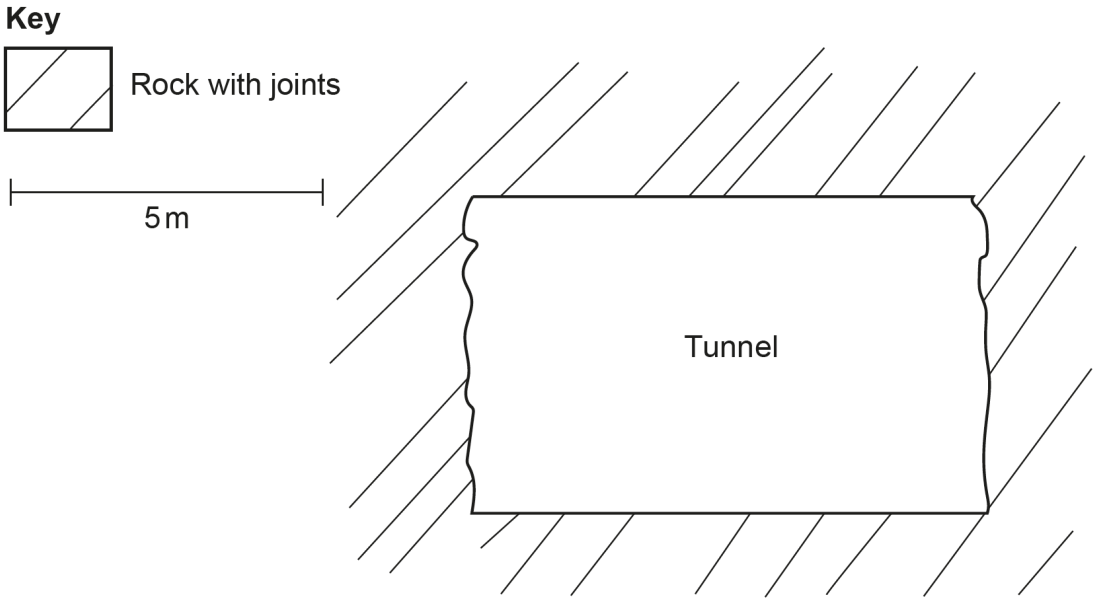
Question 28 (d) (ii)

(ii) When calculating stand-up time, the frequency of discontinuities is included as the Rock Quality Designation (RQD). The formula is:

$$RQD = 100\ (0.1\ \lambda + 1)\ e^{-0.1\lambda}$$

where λ is the number of joints per metre.

The diagram shows a scaled cross-section through a mine tunnel.



Use the scaled cross-section diagram to calculate the RQD for the **roof span** of this mine tunnel.

Give your answer to **4** significant figures.

RQD = ... **[2]**

Calculating the RQD proved one of the more difficult tasks for the candidates. Candidates were given the equation and so the key skill was in being able to use the equation as well as observing that there are 6 discontinuities over the 8 metres of the roof and so λ = 0.75. to this question.

Assessment for learning

Candidates do need to practice using standard and unexpected equations so that they can be confident in their use.

Question 29 (a) (i)

29 In 1961, a 262 m high concrete arch dam was built in the Vaiont Gorge in northern Italy for water supply.

(a) In April and May 1962, when the reservoir behind the dam had filled to a depth of 215 m, five earthquakes were reported in surrounding towns. These were intensity V on the Mercalli Scale – not strong enough to cause structural damage but alarming to nearby residents.

(i) Explain how filling of the reservoir could have caused this seismic activity.

.....

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

The best responses linked increasing pore fluid pressure to reactivating faults. Many responses were too vague and did not mention the role of water.

Question 29 (a) (ii)

(ii) Explain how reservoir-induced seismicity could be mitigated.

.....

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

Candidates were generally knowledgeable about the various mitigation methods that could be used. The best responses discussed using grout in the faults or filling the reservoir more slowly or to a lower level.

Question 29 (b) (i)

(b) In October 1963, when the reservoir was filled to near capacity, a large landslide of more than 260 million m^3 of rock slid into the reservoir and caused a water wave 250 m high to overtop the dam. The resultant downstream flooding caused the destruction of towns and villages and the loss of over 2000 lives.

(i) **Fig. 29.1** is a simplified cross-section through the Vaiont dam and reservoir showing the water level immediately before the 1963 landslide.

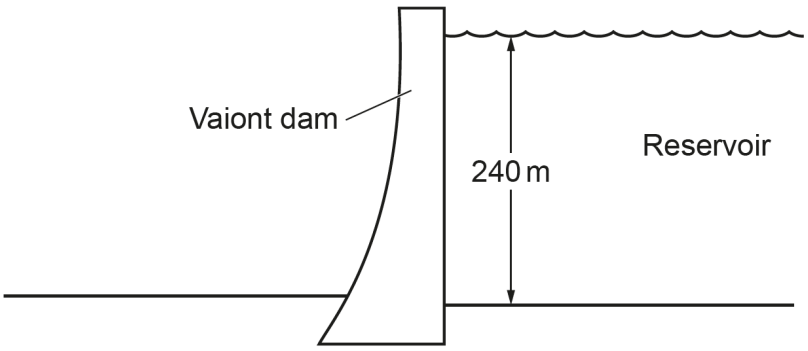


Fig. 29.1

Calculate the hydrostatic pressure in the rock at the base of the reservoir.

Use the formula $p = \rho gh$

Assume the density of water = 1000 kg m^{-3} and g = 10 m s^{-2}.

Hydrostatic pressure = ... MPa **[3]**

Candidates were generally very confident in working out the hydrostatic pressure using the given formula. Many had a correct answer in pascals (Pa) but were unable to convert into MPa, this lost a mark.

Assessment for learning

Candidates need to practice changing from Pa into MPa and in carrying out other similar unit conversions.

Question 29 (b) (ii)

(ii) A 250 m thick block of mostly limestone (density = 2400 kg m^{-3}) failed along a surface at the base to form the landslide.

Calculate the lithostatic pressure at the failure surface.

Use the formula $p = \rho gh$

Assume $g = 10\,m\,s^{-2}$.

Lithostatic pressure = ... MPa **[1]**

Most candidates were able to carry out this calculation and convert the Pa into MPa.

Question 29 (b) (iii)

(iii) Compare the relative sizes of the hydrostatic and lithostatic pressures you have calculated in parts **(i)** and **(ii)** to evaluate how much of an effect the hydrostatic pressure had on the stability of the slope.

.....

.....

.....

.....

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

The most successful responses gave a clear comparison of the relative sizes of the hydrostatic and lithostatic pressures such as hydrostatic is 40% of the lithostatic pressure. Then some qualitative evaluation about the relative importance such as hydrostatic pressure is less important than lithostatic in slope stability.

Question 29 (c) (i)

(c) The cross-section shown in **Fig. 29.2** illustrates the geology and structure of the south side of the Vaiont reservoir before the 1963 landslide. Marls are calcareous mudstones.

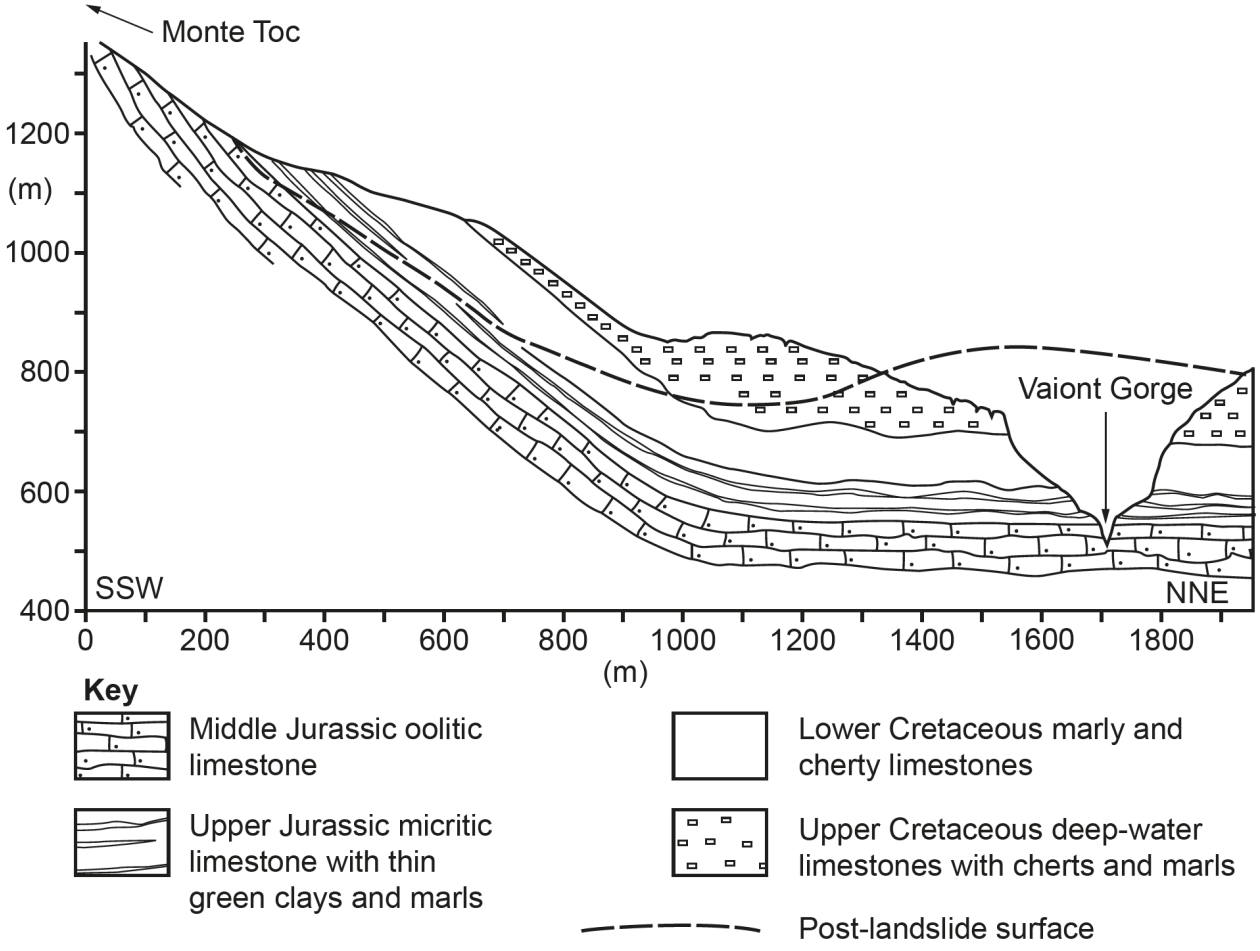


Fig. 29.2

(i) Use **Fig. 29.2** to explain why the geology and structure of the south side of the reservoir were likely to be unstable.

.....

.....

.....

.....

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

Candidates had some idea about why the south side of the reservoir was more unstable the most common correct response being about the weak/lubricated clay layers. Other common responses were about the beds dipping into the valley. Sometimes candidates did mention the dipping beds but did not clarify that it is the fact they dip into the valley which is the problem. Other good responses discussed the permeability of the limestone and impermeability of the clay.

Question 29 (c) (ii)

(ii) Recent research suggests that unusually heavy rains may have triggered the landslide.

Outline **two** ways in which rainwater could destabilise the slope.

1 .....

.....

2 .....

.....

[2]

Most candidates could outline at least one way that rainwater could destabilise the slope. The most common response was linked to causing the clay to act as a lubricant or cause a loss of friction. Other good responses discussed increasing pore fluid pressure and an increased load.

Question 29 (c) (iii)

(iii) Wherever possible, dams are not built where reservoir slopes are unstable.

Describe **two** engineering geology methods that can be used to help stabilise slopes.

.....

.....

.....

.....

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

Candidates are clearly confident in their knowledge of the various engineering solutions linked to slope stability with most giving at least one appropriate technique and many giving two. The most common correct responses were the use of rock bolts and shotcrete. Candidates must make sure that they use the correct technical terms rather than a vague description such as "metal rods are drilled into the rock" or just saying "they use concrete".

Question 30 (a)

30 (a) Explain how a knowledge of the density of the whole Earth and rocks exposed at the surface provide indirect evidence for the density of the core and mantle.

.....

.....

.....

.....

.....

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

Most candidates had at least a general knowledge of the relatively low density of the crustal rocks compared to the Earth's overall density although often the detail was lacking. The best responses used the correct densities for the crust and whole Earth and made logical assumptions about the density of the core. In the weaker responses the logic was lacking and a long response may only gain 1 mark.

Question 30 (b)*

(b)* Explain how P and S seismic waves recorded at the Earth's surface provide indirect evidence for the states and depths of the inner and outer core of the Earth.

.....

.....

.....

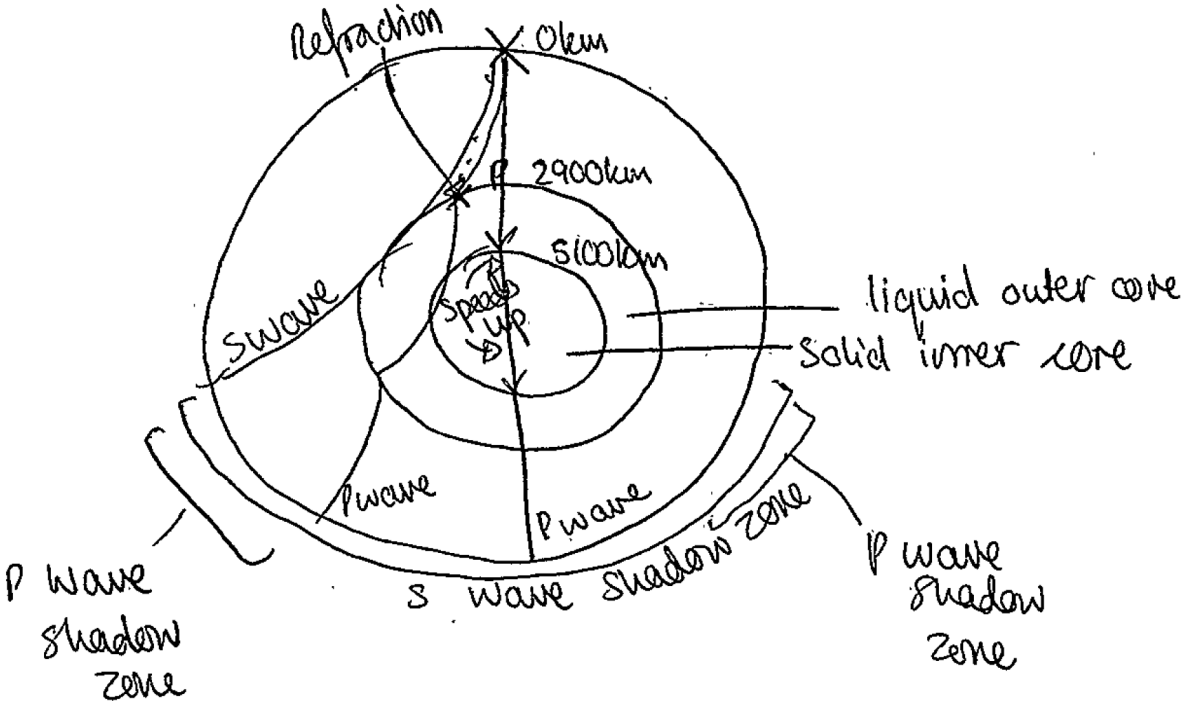
.....

.....

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

Candidates normally have a secure understanding of how P and S waves help in our understanding of the state and depth of the inner and outer cores. Some candidates had muddled responses mixing up the states of the inner and outer core or not making it clear what the state is. The best responses described the P and S wave shadow zones and indicated how the state of the rock affected the travel of the P and S waves. Both the inner core and outer core were considered equally. Less successful responses often were more focused on the outer core and the inner core was ignored. Particularly good responses gave the depths of the discontinuities and gave detail about what controls the velocity of P and S waves. Candidates should be encouraged to make more use of fully annotated diagrams as these will add to the clarity and structure of the response. The best responses were also logical in their structure and made full use of technical terminology.

Exemplar 3



This annotated diagram helps with the written explanation of how P and S waves can be used. It is well annotated and clear. It could be improved by adding the epicentral angles for the shadow zones. Annotated diagrams can be used to help answer most questions especially the longer questions.

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