

Monday 6 June 2022 – Afternoon

A Level Geology

H414/01 Fundamentals of geology

Time allowed: 2 hours 15 minutes



You can use:

- a ruler (cm/mm)
- an HB pencil
- a scientific or graphical calculator



Please write clearly in black ink. **Do not write in the barcodes.**

Centre number

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Candidate number

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First name(s)

Last name

INSTRUCTIONS

- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

INFORMATION

- The total mark for this paper is **110**.
- The marks for each question are shown in brackets [].
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **32** pages.

ADVICE

- Read each question carefully before you start your answer.

2
SECTION A

You should spend a maximum of 35 minutes on this section.

Write your answer to each question in the box provided.

Answer **all** the questions.

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]

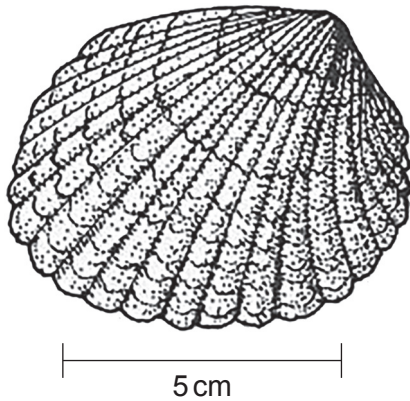
2 What characteristic of the depositional environment of the Jurassic Solnhofen Limestone did **not** lead to the exceptional preservation of *Archaeopteryx*?

- A Deep water
- B Fine-grained sediment
- C Low energy
- D Low oxygen

Your answer

[1]

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]

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]

- 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]

- 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]

- 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]

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]

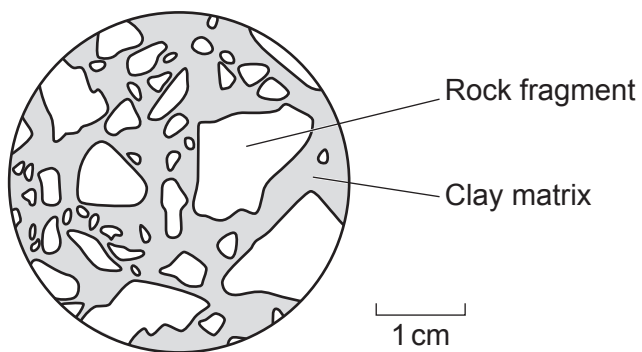
9 Which type of geological structure will dominate at transform (conservative) plate boundaries?

- A Antiformal folds
- B Dip-slip faults
- C Strike-slip faults
- D Synformal folds

Your answer

[1]

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]

- 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]

- 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]

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

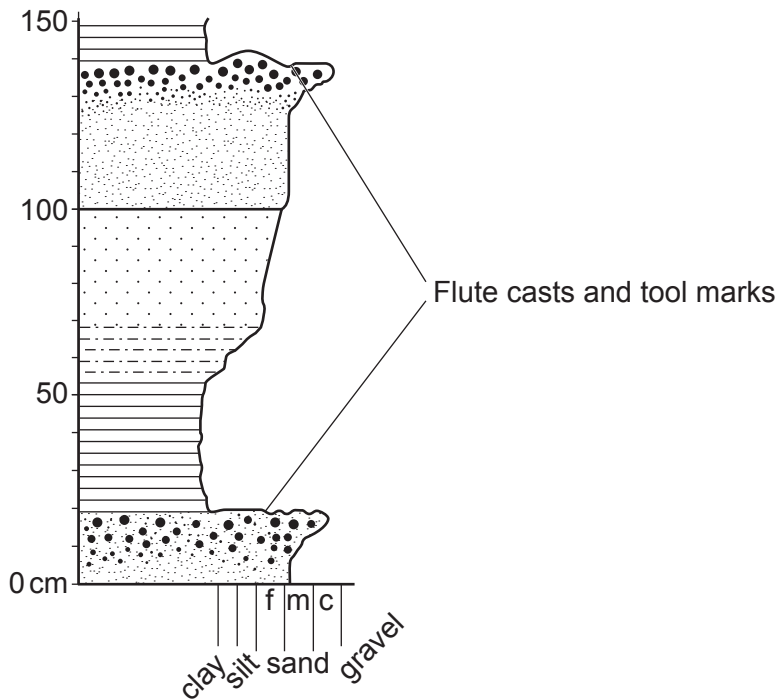
Applying the principle of uniformitarianism, in which environment was this facies association deposited?

- A Deep sea
- B Fluvial
- C Hot desert
- D Shallow siliciclastic sea

Your answer

[1]

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]

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]

16 A lava with high viscosity would have which property?

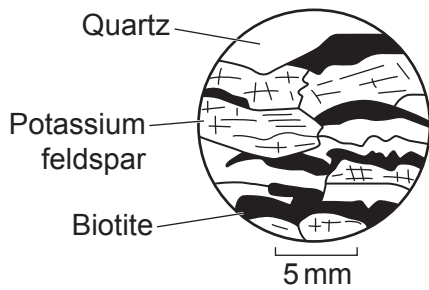
- A High crystal content
- B High temperature
- C Low silicate polymerisation
- D Mafic composition

Your answer

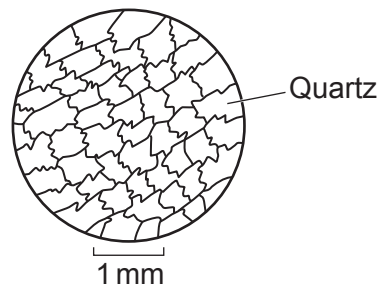
[1]

17 The four thin section diagrams show metamorphic rocks.

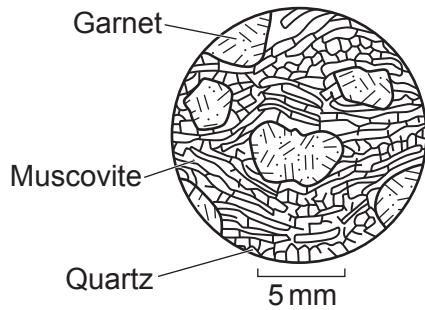
Rock A



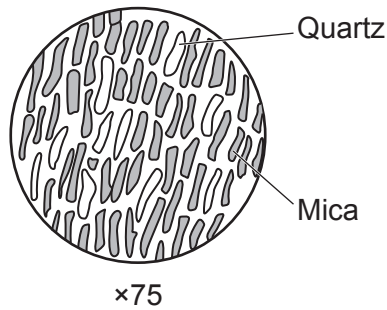
Rock B



Rock C



Rock D



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

Your answer

[1]

18 Which rock could develop gneissose banding during metamorphism?

- A Dolerite
- B Orthoquartzite
- C Shale
- D Wackestone

Your answer

[1]

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]

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]

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]

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]

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]

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]

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]

12
SECTION B

Answer **all** the questions.

- 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.

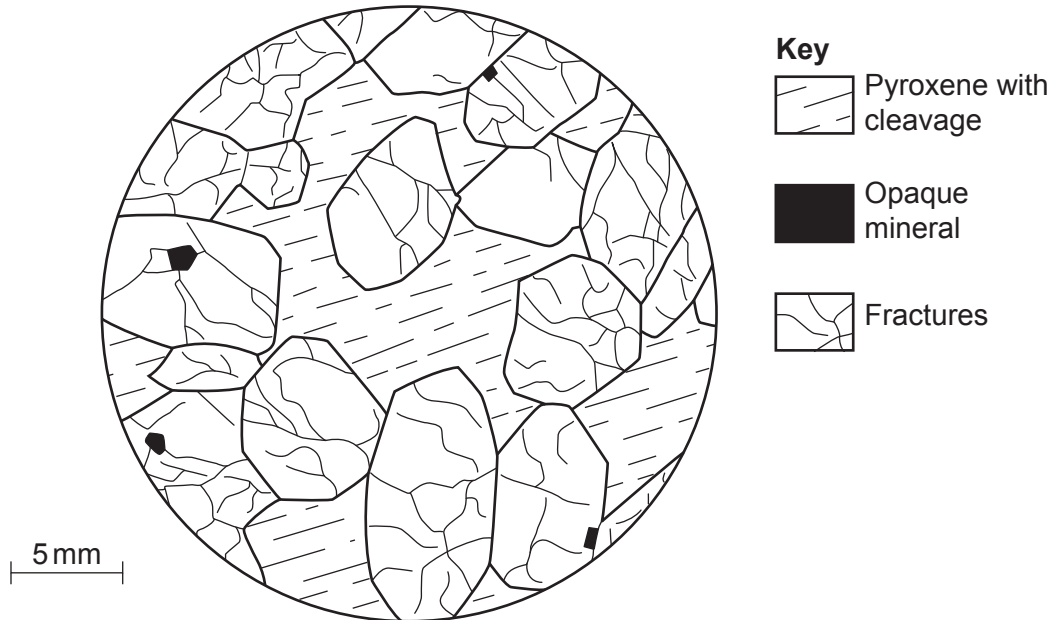


Fig. 26.1

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]

- (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]

- (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]

- (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]

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

Pyroxene%

Opaque mineral%

Mineral with fractures%

[1]

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

Rock name

Explanation

.....

..... [3]

(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.

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Additional answer space if required.

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

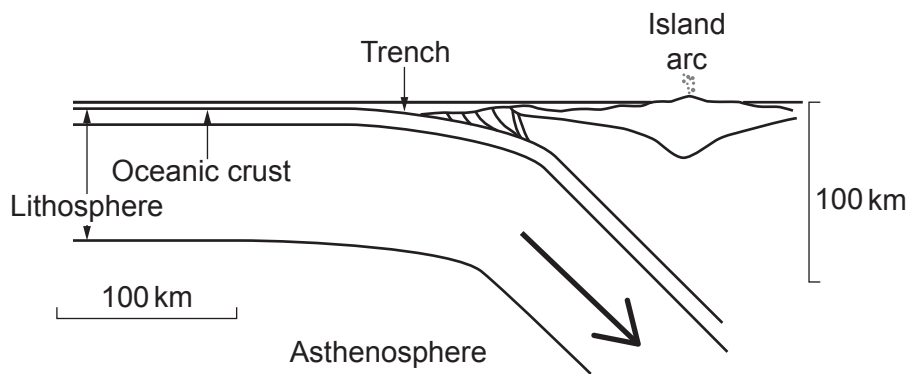


Fig. 26.2

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

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(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]

17
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27 (a) Describe how organisms are fossilised and become preserved as **body fossils** in rocks.

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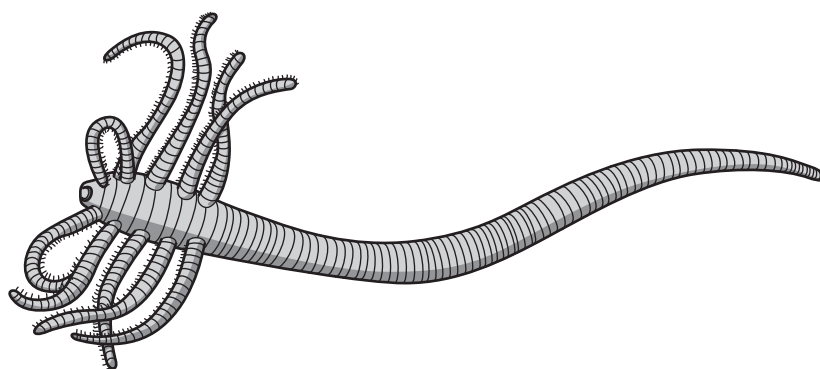
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(b) Fig. 27.1 shows the fossil *Facivermis sp.* of a soft-bodied organism from the Chengjiang Formation.



×1.5

Fig. 27.1

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

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[2]

(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.

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..... [1]

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

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..... [1]

- (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.

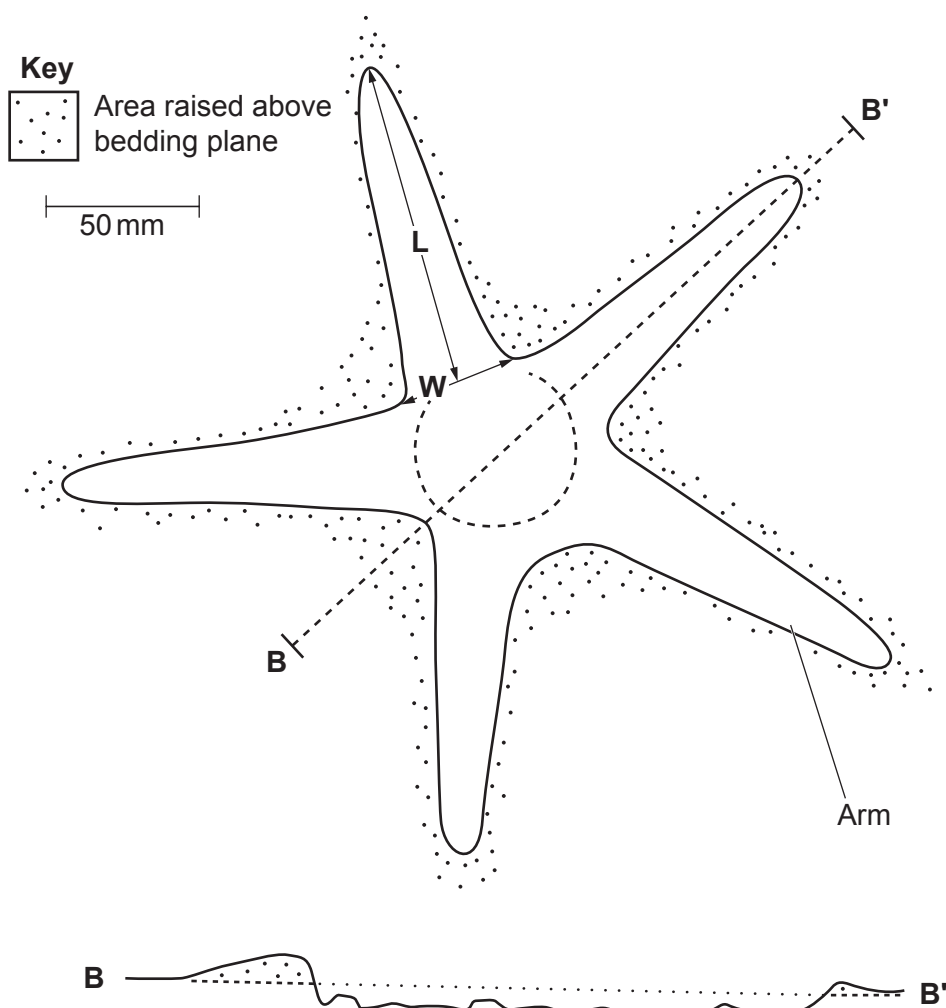


Fig. 27.2

- (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]

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

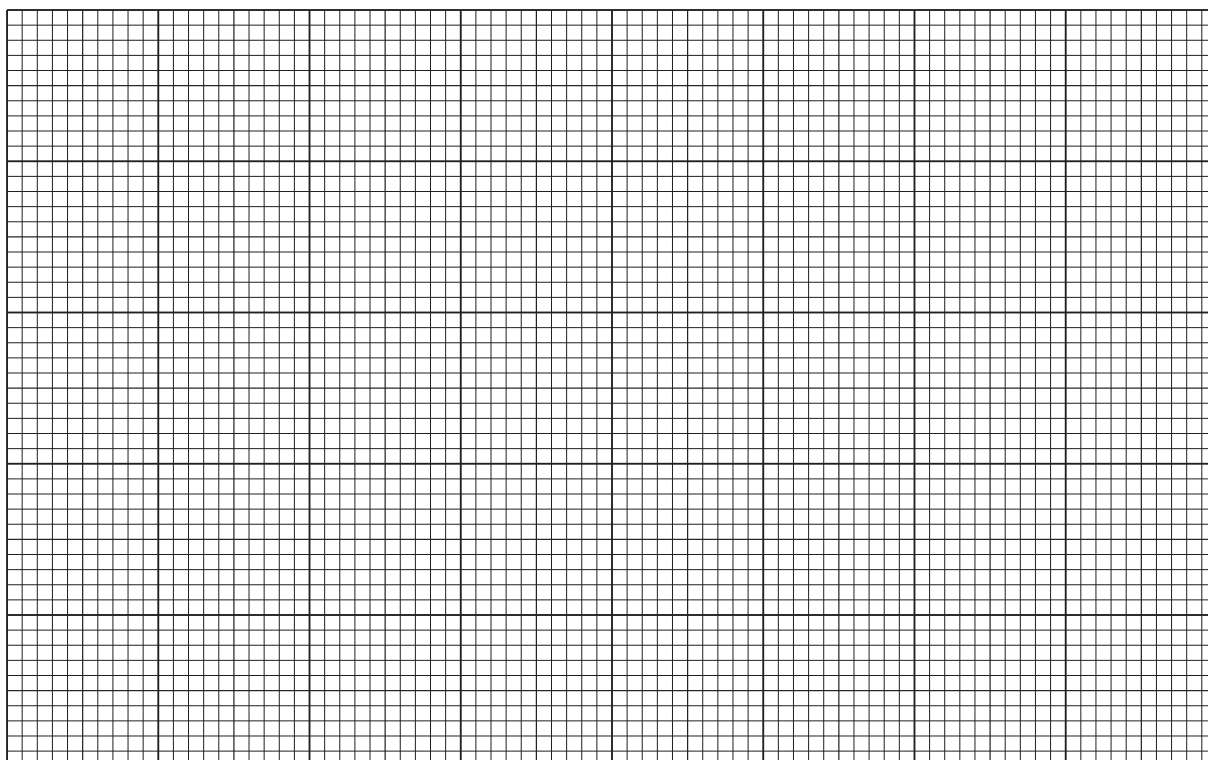
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- (d) (i) The table shows a series of measurements of the maximum arm width versus the maximum arm length from similar trace fossils within Jurassic rocks in the British Isles.

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]

(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.

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

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(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.

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..... [4]

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.

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..... [2]

(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]

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

Probability = [1]

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

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..... [1]

(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.

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..... [1]

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

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..... [1]

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

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..... [2]

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

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..... [2]

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

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..... [2]

- (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.

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 [1]

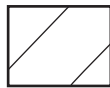
- (ii) When calculating stand-up time, the frequency of discontinuities is included as the Rock Quality Designation (RQD). The formula is:

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

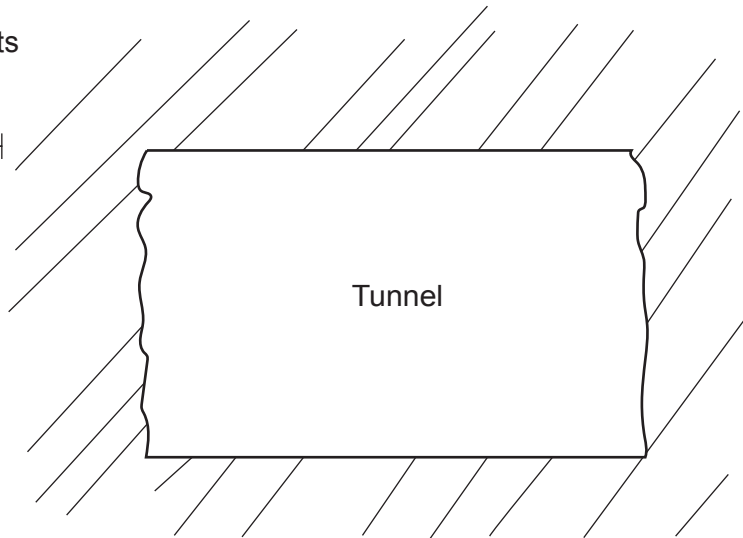
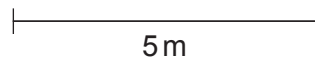
where λ is the number of joints per metre.

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

Key



Rock with joints



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]

29 In 1961, a 262m 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.

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 [1]

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

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 [1]

(b) In October 1963, when the reservoir was filled to near capacity, a large landslide of more than 260 million m³ 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.

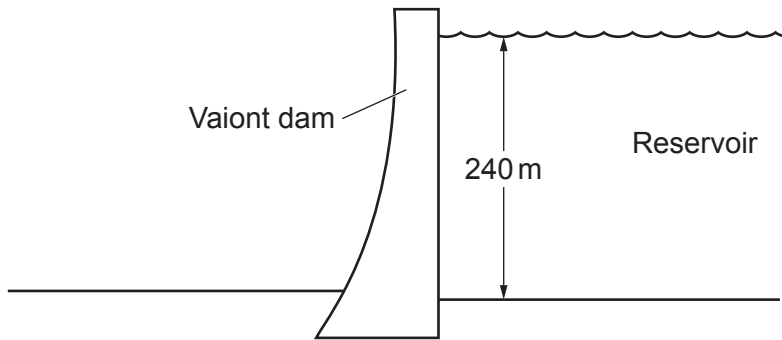


Fig. 29.1

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 $g = 10 \text{ ms}^{-2}$.

Hydrostatic pressure = MPa [3]

- (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 $g = 10 \text{ ms}^{-2}$.

Lithostatic pressure = MPa [1]

- (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.

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..... [2]

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

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

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[2]

(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.

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[2]

Additional answer space if required.

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END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).

A large rectangular area with a solid vertical line on the left side and horizontal dotted lines across the rest of the page, providing space for writing answers.



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