OCR
Oxford Cambridge and RSA

Tuesday 06 October 2020 – 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 | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

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

INFORMATION
- The total mark for this paper is **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.

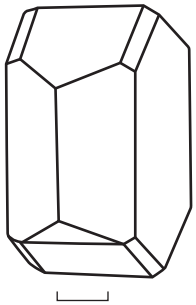
SECTION A

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 Crystal shape is strongly affected by cooling rates. Very slow cooling rates in plutonic intrusions produce crystals such as the one below.



Identify the crystal shape shown.

A anhedral

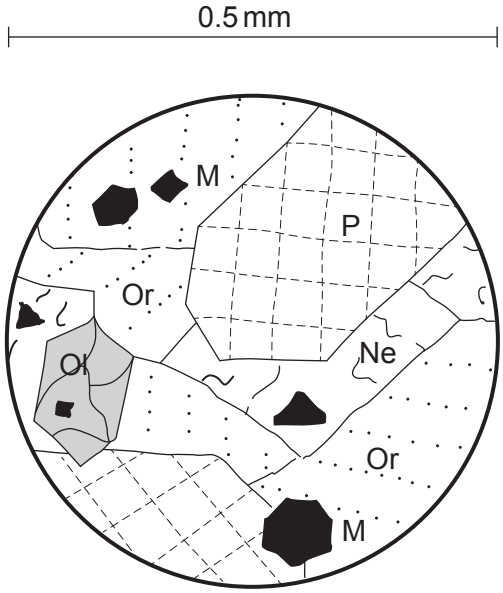
B euhedral

C equant

D platy

Your answer ☐ **[1]**

The thin-section diagram below is of an unusual igneous rock. Five of the minerals that make up the rock have been identified and labelled.



Questions **2** and **3** refer to this diagram.

2 Using your knowledge of igneous textures, identify the apparent order in which the minerals crystallised.

A first (P – Or – Ne – Ol – M) last

B first (M – Ol – P – Ne – Or) last

C first (M – Or – Ne – Ol – P) last

D first (Or – Ne – P – Ol – M) last

Your answer ☐ **[1]**

3 Which of the following best describes the texture of the igneous rock?

A fine, porphyritic

B medium, vesicular

C fine, equicrystalline

D medium, porphyritic

Your answer ☐ **[1]**

4 An igneous rock showing flow-banded texture was formed by which of the following processes?

A crystals settling at the base of the magma chamber

B gas bubbles forming as volatiles exsolve during cooling

C coarse crystals forming by slow cooling in the magma chamber

D separation of minerals in lava

Your answer ☐ **[1]**

5 A forward-looking infrared (thermal) camera produces an image using a colour spectrum that correlates to the detected temperature. A lava measured appears to be at 900 °C.

Which of the following terms is most likely to describe its chemistry?

A intermediate

B mafic

C silicic

D ultramafic

Your answer ☐ **[1]**

6 An infrared camera was used in preference to direct measurement with a thermocouple probe.

Which of the following reasons would explain that choice?

A greater accuracy

B greater safety

C greater resolution

D better penetration of ash clouds

Your answer ☐ **[1]**

7 Which of the following provides evidence for the rheid nature of the asthenosphere?

A the negative gravity anomaly over Cornwall

B the positive gravity anomaly over Cornwall

C the negative gravity anomaly over Scandinavia

D the positive gravity anomaly over Scandinavia

Your answer ☐ **[1]**

8 Which of the following statements describes advection?

A a process by which thermal energy is transferred through a substance with no overall movement of that substance

B a process by which thermal energy is transferred through a medium by a substance (fluids or rheids) due to buoyancy differences within the substance

C a process by which thermal energy is transferred through a medium by a fluid

D a process whereby electromagnetic radiation is generated by the thermal motion of particles in the substance

Your answer ☐ **[1]**

9 Approximately two thirds of the Earth's geothermal energy results from radioactive decay. The half-life of Uranium-238 is 4.47×10^9 years.

Approximately, what fraction still remains of the Uranium-238 that was present when the Earth was formed?

A $\frac{1}{4}$

B $\frac{1}{2}$

C $\frac{3}{4}$

D $\frac{7}{8}$

Your answer ☐ **[1]**

10 In an early attempt to classify the elements according to how they occur in the Earth, elements which combine readily with oxygen such as aluminium, calcium, potassium and titanium were classed by Goldschmidt as which of the following?

A atmophile

B chalcophile

C lithophile

D siderophile

Your answer ☐ **[1]**

11 The chemical properties of the elements determine the type of compounds and/or phases they form. This influences density and therefore where they occur in the layered Earth.

Which of the following statements would explain the existence of metals in the crust that were expected to be only found in the core?

A they have anomalous chemistry and form sulfides

B they are the result of deep weathering of granites

C they were in meteorites landing after the crust had solidified

D oxygen was not available in the Proto-Earth

Your answer ☐ **[1]**

12 The present understanding of plate tectonics rests upon the development of earlier models. The geosyncline model was developed in the nineteenth century based on the geology of the Appalachian and Caledonian mountains.

Which of the following ideas were used to explain orogeny at that time?

A continents are carried by convection of the mantle

B lateral compression is caused by the contraction of the Earth as it cools

C continents move towards the equator due to gravitational and centrifugal forces

D cold lithospheric plates sink into the mantle carrying continents as they are subducted

Your answer ☐ **[1]**

13 A student sampled fossils in three different beds, keeping a tally of the different types of fossils and their frequency.

Which of the following statistical tests should be used to see if these beds contain significantly different assemblages?

A Standard deviation

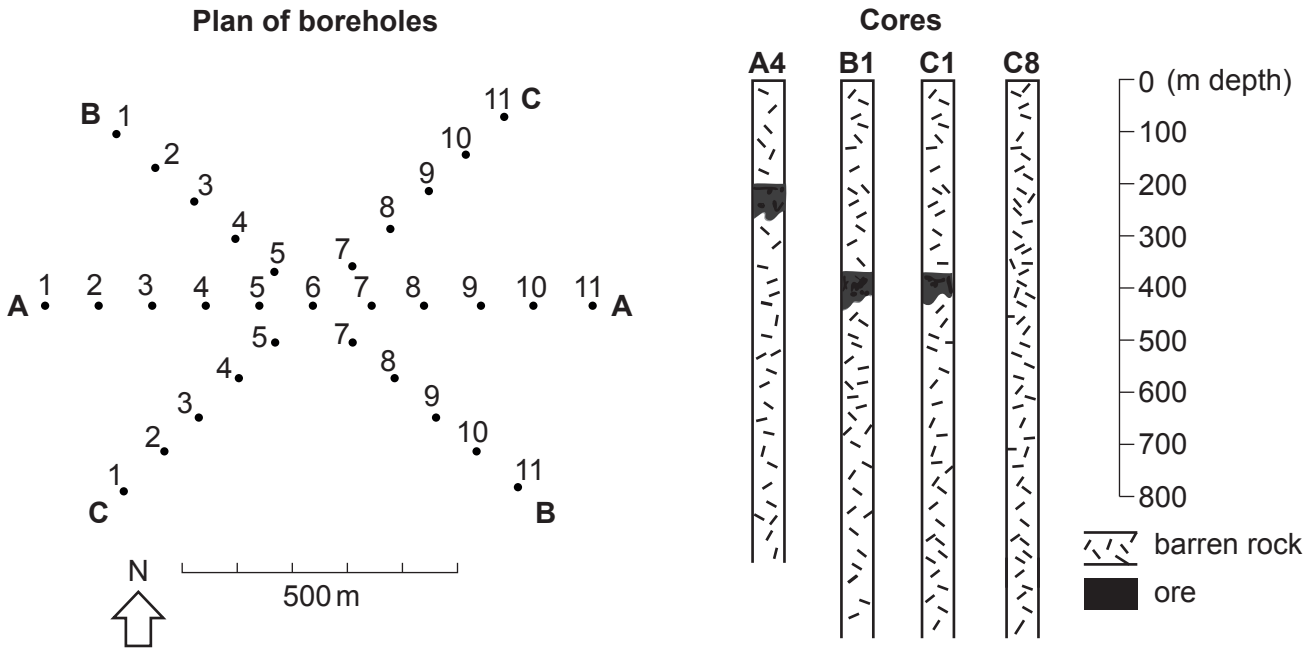
B Man-Whitney *U*-test

C Spearman's rank

D Chi squared

Your answer ☐ **[1]**

14 To assess the reserves prior to mining, a star-shaped pattern of exploratory boreholes was centred on an indication of the metal ore at the surface (gossan). The diagram shows the plan of boreholes and the core recovered for four of the boreholes.



Using this evidence, what is the most likely extent and structure of the ore body?

A a 200 m radius, vertical cylinder centred on A6

B a sheet-like body dipping shallowly (20°) to the south

C a sheet-like body dipping steeply (45°) to the west

D two horizontal sheets, each about 50 m thick

Your answer ☐ **[1]**

15 The geological conditions play an important part in establishing and maintaining a sustainable mining operation.

Which of the following conditions would **least** affect the viability of a deep coal mine using longwall retreat extraction?

A frequency of faulting

B dip of strata

C depth of overburden

D throw of faults

Your answer ☐ **[1]**

16 Earthquake forecasting is widely used and refers to the probability of an earthquake occurring, with reference to the frequency and magnitude of damaging events, in a given area over a period of years.

What is the main criticism of this method?

A it does not account for uncertainty in the geographical location

B there is a lack of physical and mathematical evidence

C there is uncertainty in the magnitude for previous earthquakes

D it does not account for the different ways in which waves propagate

Your answer ☐ **[1]**

17 An earthquake of magnitude 6.0 has an annual probability of 0.02.

Which of the following statements describes the risk of a seismic event?

A An earthquake of that magnitude will definitely happen within 50 years of the last one.

B There is a lower chance of an earthquake as one happened 2 years ago.

C There is a higher chance of an earthquake because it has been nearly 50 years since the last one.

D There is a 2% chance that an earthquake of that magnitude will occur this year.

Your answer ☐ **[1]**

18 The amniotic egg allowed dinosaurs to successfully adapt to life on land.

Which of the following components is also found in eggs laid in water?

A a hard shell

B a porous shell

C a yolk sac

D albumen

Your answer ☐ **[1]**

19 The Burgess Shale has become the best known Konservat-Lagerstätt in the fossil record and is located in the Canadian Rockies. Early ideas that the exceptional preservation involved an underwater avalanche have been replaced by an understanding of the unique chemistry of the sea-water and site of deposition.

Using your knowledge of preservation and early diagenesis, which of the following chemical environments resulted in the preservation of the fossils?

A decreased calcium carbonate concentrations and decreased oxygen and sulfate

B enhanced calcium carbonate concentrations and increased oxygen and sulfate

C decreased calcium carbonate concentrations and depletion of oxygen and high sulfate

D enhanced calcium carbonate concentrations and depletion of oxygen and sulfate

Your answer ☐ **[1]**

20 Which of the following microfossils is **least** likely to be useful in the biostratigraphic analysis of sediments when locating hydrocarbon reserves?

A coccolithophores – phytoplankton with calcareous skeletons, a major component of chalk

B conodonts – minute tooth-like fossils composed of apatite occurring in rocks of Palaeozoic age

C foraminifera – protists with an external shell, of which there are 40,000 species

D radiolaria – protozoa that produce intricate mineral skeletons, typically made of silica

Your answer ☐ **[1]**

21 Once an exploratory well has been drilled and the cuttings analysed for geology and biostratigraphy, more information on the solid rock can be gained by down-hole geophysics. Organic content can be measured by gamma ray logs. Resistivity and porosity are also routinely measured.

Which of the following combinations of outputs is most likely to show trapped oil?

A high porosity, high resistivity, high gamma ray count

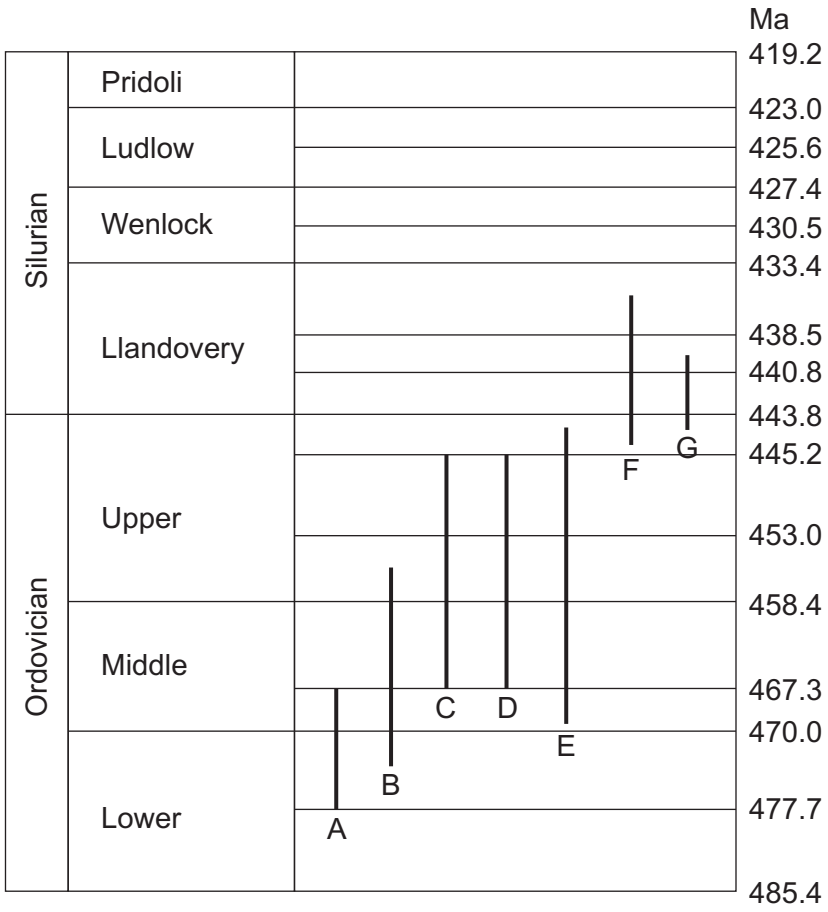
B high porosity, low resistivity, low gamma ray count

C low porosity, low resistivity, high gamma ray count

D low porosity, high resistivity, low gamma ray count

Your answer ☐ **[1]**

22 Graptolites are used to zone the Welsh Basin. There are graptolite biozones identified throughout the Ordovician and Silurian. The diagram shows a simplified evolution of graptolite genera. Solid lines show the fossil ranges, plotted to scale, based on absolute age dating.



Which combination of graptolite genera provides the most precise age range for the rock in which they are found?

A A, B and E

B B, C and E

C C, D and E

D E, F and G

Your answer ☐ **[1]**

23 The average crustal abundance of copper is 0.007%. The global average grade for copper ore extracted in 2016 was 0.62%.

Which of the following represents the concentration factor necessary for economic ore extraction in 2016?

A 0.0043

B 0.011

C 8.86

D 88.6

Your answer ☐ **[1]**

24 Chalcopyrite is one of the most common copper sulfide minerals.

Which of the following is the formula for the mineral?

A Cu_5FeS_4

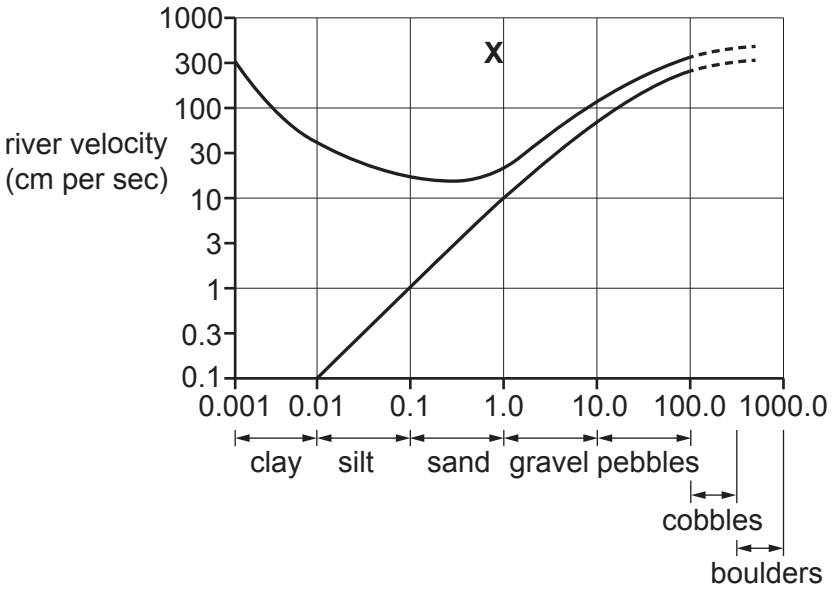
B CuS_2

C $CuFeS_2$

D CuS

Your answer ☐ **[1]**

25 The graph shows a Hjulstrom curve.



Which of the following processes best describes the area marked **X**?

A erosion

B deposition

C saltation

D transportation

Your answer [ ] **[1]**

SECTION B

Answer **all** the questions.

26 **(a)** Complete the paragraph by choosing the most appropriate terms from the list below.

burial **death assemblages** **traces** **soft parts**

life assemblages **morphology** **taphonomy**

A species of an extinct organism can only be classified using ..... .

Fossils are the remains of organisms which are preserved in rocks. The process of fossilisation is called ..... and this determines how well preservation has occurred.

Well-preserved fossils are often ..... .

[3]

(b) Explain why fossils that are preserved within most sedimentary rocks are not a true record of what lived in those environments.

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

(c) Fig. 26.1 shows diagrams of U-shaped and vertical trace fossils (burrows) from a shallow sea environment.

× 0.25

Fig. 26.1

Using Fig. 26.1, interpret the environment of deposition.

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(d)* Fig. 26.2 shows the external morphology of a fossil bivalve and a brachiopod, not to scale.

bivalve

brachiopod

Fig. 26.2

Using Fig. 26.2 and your own geological knowledge, describe and explain the differences between a brachiopod and a bivalve.

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Additional answer space if required.

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(e) Ornithischian and Saurischian are the names of two different orders of dinosaurs.

(i) Ornithischian and Saurischian dinosaurs show major differences in their skeletons.

Describe **one** difference which can be used to classify these dinosaurs **and** explain the advantage of that characteristic.

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

(ii) Complete the table by identifying the features characteristic of a Saurischian Sauropod dinosaur. Indicate your answers using a tick (✓).

Feature	Characteristic of Sauropod?
Large olfactory lobes	
Gastroliths	
Peg like teeth	
Thumb spike	
Short neck	
Laid amniotic eggs	

[3]

(iii) State one possible cause for the mass extinction of the dinosaurs.

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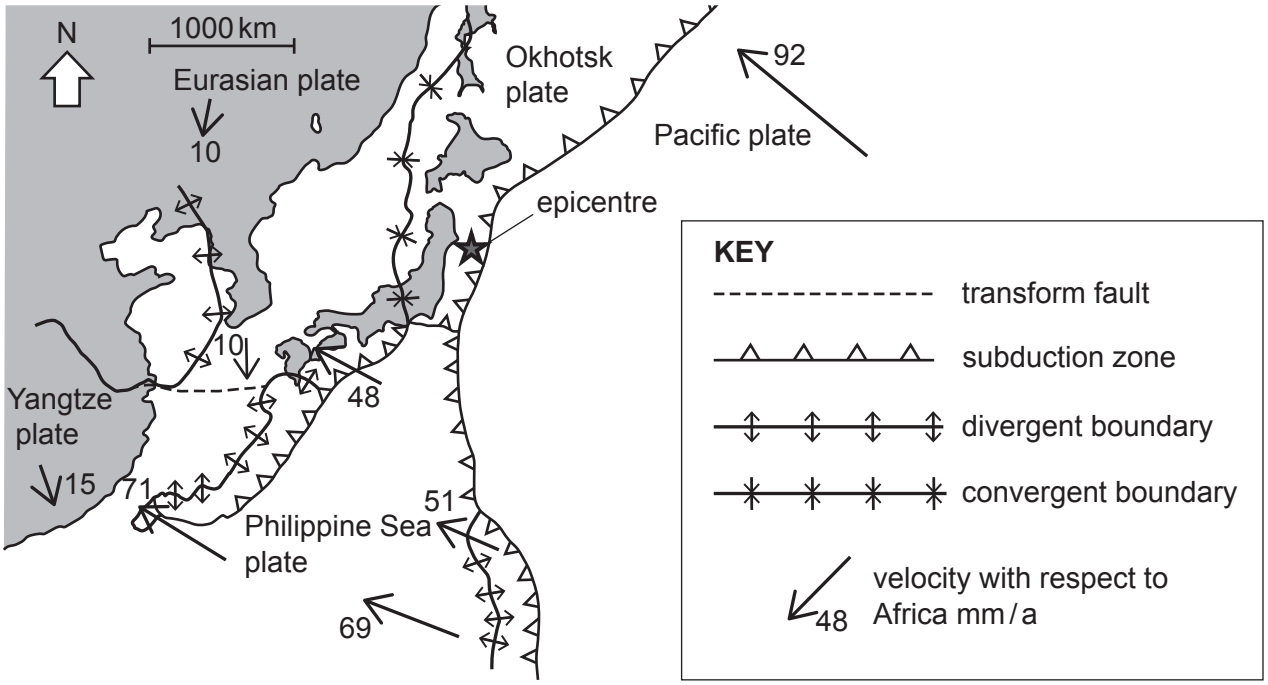
Turn over for the next question

27 The map shows the different plate margins in the region of Japan along with their relative plate motion.



(a) (i) What kind of stresses dominate at conservative margins such as the one to the south-west of Japan?

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

(ii) Conservative margins include transform faults, which are often the cause of earthquakes.

Explain the elastic rebound theory which accounts for many of the observed properties of earthquakes.

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

(b) (i) The map shows the epicentre of the 2011 Tohoku earthquake. It had a magnitude of 9.1 and resulted in a devastating tsunami.

Explain why earthquakes at convergent plate boundaries in the Japan region are the most likely cause of such devastating tsunami.

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(ii) Describe **two** ways by which the effects of a tsunami could be mitigated by the use of GIS.

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(iii) The Pacific plate is closing with the Okhotsk plate at a rate of 90 mm / a and the subduction zone dips at 30°.

Calculate how long it would take the subducting plate to reach a depth of 150 km.

number of years = ... Ma **[4]**

(iv) Describe how you would recognise geological evidence of past tsunami events.

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28 The diagram shows a bathymetric section across an ocean ridge.

Bathymetric section, Vine, F. J; Matthews, D. H. (1963). "Magnetic Anomalies Over Oceanic Ridges" Springer Nature. Item removed due to third party copyright restrictions. Link to material: https://www.nature.com/search?q=Vine%2C+F.+J%3B+Matthews%2C+D.+H.

(a) (i) Explain why this ocean ridge has a rift valley at its axis.

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

(ii) State whether this ocean ridge is fast-spreading or slow-spreading **and** give a reason for your choice.

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(iii) Describe the mechanisms that form ocean core complexes at ocean ridges.

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(b) Explain why there is a negative Bouguer gravity anomaly over the axial rift.

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(c) As new oceanic lithosphere is created at the ridge and spreads away from the axis, it cools as it ages. As it cools, it sinks and there is a straightforward relationship between its age and the depth of sea water above it.

The relationship is defined by the equation: $w = k\,t^x$

where w is the depth, t is the age, k is a constant and x is a power.

The table shows age and depth measurements from the Mid Atlantic Ridge.

t (Ma)	w (m)
5	726.7
10	1027.7
15	1258.7
20	1453.4
25	1625.0
30	1780.1
35	1922.7
40	2055.5
45	2180.2

(i) The constant k for this part of the ocean is 325. Rearrange the equation and use logarithms on any pair of the data.

Calculate the power x.

x = ... **[3]**

(ii) State how you would use a graphical method to find the constant of proportionality k.

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

(iii) How would a fast-spreading rate affect the topography of the ocean ridge, given that the relationship between cooling and water depth remains the same?

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(d) (i) How does the topography of the ocean ridge contribute to sea-floor spreading?

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

(ii) It is estimated that slab pull provides twice the force on the lithosphere as ridge push.

Suggest why this is **and** why plate velocities in the Pacific and Atlantic oceans support this comparison.

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(e)* Explain how magma is generated at divergent margins **and** why it has mafic chemistry.

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Additional answer space if required.

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29 The global demand for copper has increased dramatically in recent years. From 1991 to 2015 the world's copper extraction has doubled from 9.3 to 18.7 million tonnes. The average grade of copper extracted in 2016 was 0.62%. There is realistic concern over the future of available copper, as reserves are finite.

(a) (i) Identify and describe **one** geological process that results in an increased concentration of copper in an ore deposit.

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

(ii) The table shows changes in the estimated copper ore grade, as it was extracted, from 1900 to 2000.

Year	Average grade of copper %
1900	4.00
1920	1.98
1940	1.78
1960	1.75
1980	1.50
2000	1.10

Explain why the grade of mined copper has decreased throughout the twentieth century.

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

(iii) Calculate the percentage change in the grade of extracted copper ore between 1920 and 2000.

percentage change = ... % **[2]**

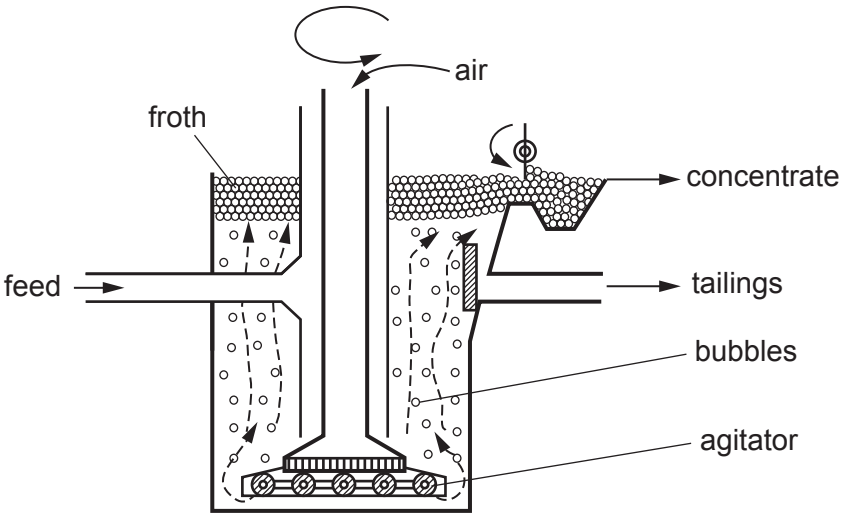
(iv) Complete the table to indicate how copper deposits can be located in the field.

Method of exploration	**How method is used to locate copper deposits**
Geochemical	....
Geophysical	....

[2]

(b) Escondida is the largest copper mine in the world.

At Escondida, 77% of the copper is found as sulfide ore which can be concentrated by froth flotation. The diagram shows a generalised froth flotation cell.



Describe and explain how froth flotation can be used to process the copper ore extracted from Escondida mine.

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

(c) While mines are operational, the water used in the mineral extraction process is treated before being discharged into rivers. Once mines are no longer useful for mineral extraction, they are abandoned.

The formation of acidic waters is a major issue in abandoned mines and is known as acid mine drainage (AMD).

(i) Describe the chemical changes that enable mine water to become acidic.

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

(ii) Water from closed mines can be treated by passive methods.

State **and** explain how one passive treatment method is used to reduce the impact of AMD.

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

30 The North Sea oil and gas basin has been successfully exploited since the early 1970s. Due to diminishing reserves, the location of the remaining oil and gas now requires sophisticated geophysics and geological knowledge.

(a) The basic requirements are a source rock, maturation, a reservoir rock, a caprock and some form of trap to achieve economic exploitation of the hydrocarbons.

(i) State what makes a good source rock and name the depositional environment in which it formed.

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

(ii) Explain the process **and** results of maturation.

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

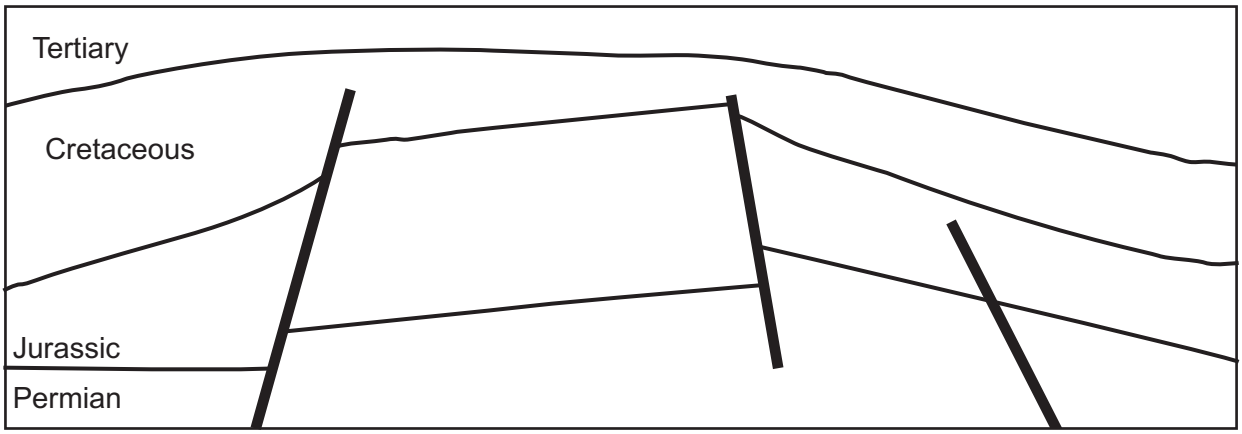
(iii) Once formed, the fluid hydrocarbons will rise with the water that is squeezed out of the rock. They would eventually escape at the surface unless prevented by the geology.

Complete the table by identifying one property and giving one example for caprocks and reservoir rocks.

	Property	**Example**
Caprock	.....	.....
Reservoir rock	.....	.....

[2]

(iv) The diagram shows a simplified cross section of the Piper Field in the northern North Sea.



Label the diagram to show the source, reservoir and caprocks. Shade where you might expect oil to be trapped. **[5]**

(b) To locate suitable traps, it is necessary to conduct geophysical surveys over the area being investigated.

Explain the role of gravity surveys in locating oil fields.

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

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).

OCR
Oxford Cambridge and RSA

Tuesday 5 October 2021 – Afternoon

A Level Geology

H414/01 Fundamentals of geology

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- a protractor

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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 Minerals are defined as naturally occurring elements and inorganic compounds whose composition can be expressed as a chemical formula.

Which of the following does **not** fit this definition?

A Arkose

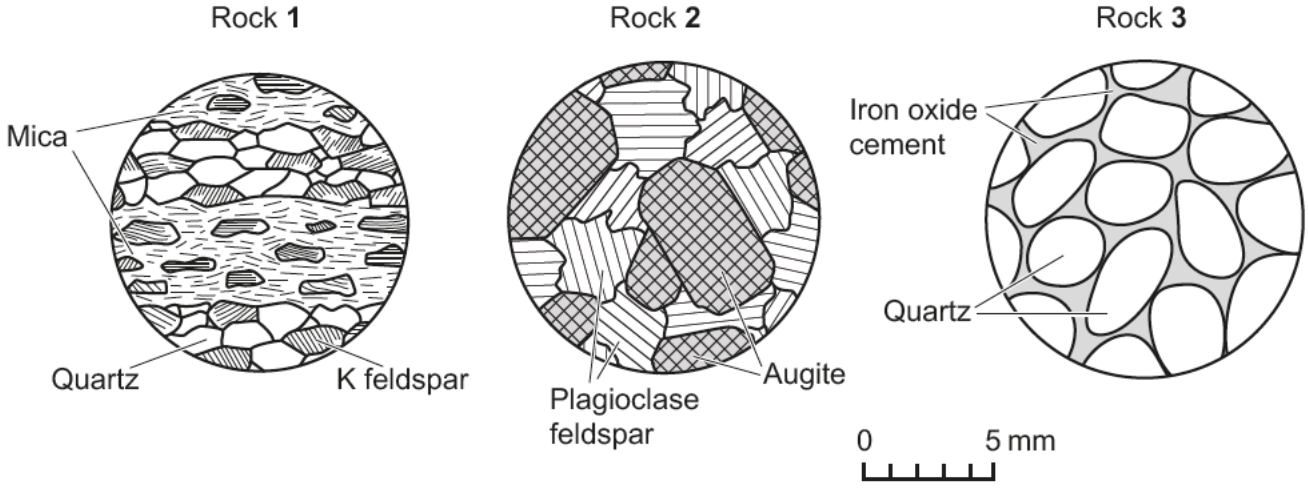
B Galena

C Halite

D Native sulfur

Your answer ☐ **[1]**

2 The thin-section diagrams below show rocks from the three rock classes.



Which combinations correctly identify the rock classes for these rocks?

	Rock **1**	Rock **2**	Rock **3**
A	Sedimentary	Igneous	Metamorphic
B	Igneous	Metamorphic	Sedimentary
C	Metamorphic	Igneous	Sedimentary
D	Sedimentary	Metamorphic	Igneous

Your answer ☐ **[1]**

3 A rock was formed at 350 °C and 500 MPa.

Which is the most likely classification for this rock?

A Igneous

B Low grade metamorphic

C Medium grade metamorphic

D Sedimentary

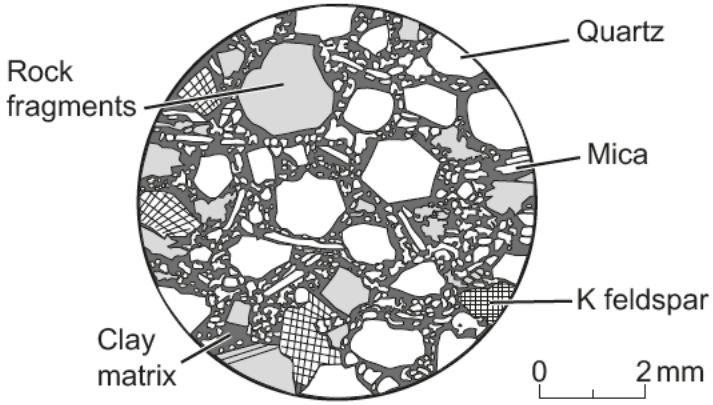
Your answer ☐ **[1]**

4 With increasing erosion, sediment usually becomes texturally **and** mineralogically more mature. Which sediment sample does **not** fit this trend?

	Grain shape	**Feldspar content (%)**	**Quartz content (%)**	**Mica content (%)**
A	Very angular	50	30	20
B	Angular	45	40	15
C	Sub-angular	45	35	20
D	Sub-rounded	40	60	0

Your answer ☐ **[1]**

5 The diagram is a thin-section of a dark-coloured rock.



Which rock type is shown in the thin-section diagram?

A Arkose

B Greywacke

C Orthoquartzite

D Wackestone

Your answer ☐ **[1]**

6 Iridium is a very scarce metal in the Earth's crust with an average crustal abundance of 0.001 ppm. This can be explained partly by reference to Goldschmidt's classification of elements.

Which statement does **not** provide evidence for iridium being classified as a siderophile element?

A Density = 22 560 kg m ^{3}

B Tends to bond with iron

C Melting point = 2446 °C

D Tends to bond with sulfur

Your answer ☐ **[1]**

7 The Earth has geochemically distinct layers possibly explained by partitioning of elements according to Goldschmidt's groups.

What provides evidence for the composition of the core?

A Kimberlite pipes

B Mantle xenoliths

C The density of the Earth

D The S-wave shadow zone

Your answer ☐ **[1]**

8 The geomagnetic field is thought to be generated by a self-exciting dynamo operating in the outer core.

Which statement provides evidence for this mechanism rather than permanent magnetism?

A The magnetic field is geocentric – it appears to originate at the Earth's centre

B The magnetic field is axial – aligned with the spin axis of the Earth

C The magnetic inclination is vertical at the Earth's magnetic poles

D The Earth's magnetic field is bipolar – it has a North and a South pole

Your answer ☐ **[1]**

9 The deposition of banded iron-formations (BIFs) in the Palaeoproterozoic Era provides evidence for which change during Earth history?

A The breakup of Pangaea

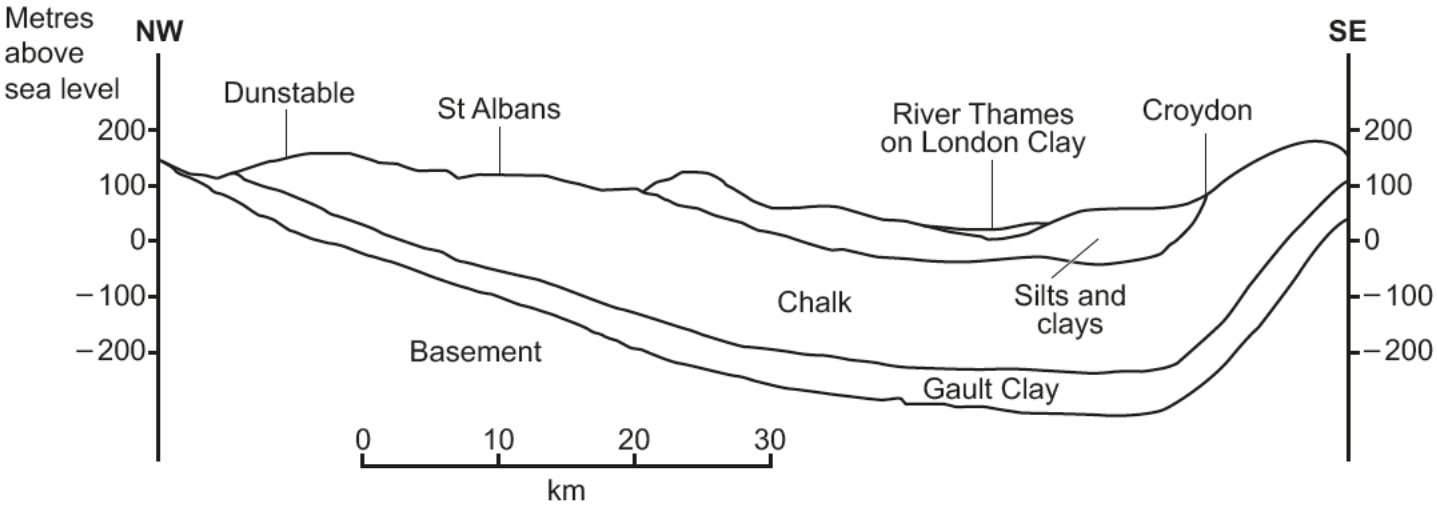
B The Great Oxidation Event

C The Vail sea level curves

D The Wilson cycle

Your answer ☐ **[1]**

The diagram shows a cross-section through the London Basin.



Use the cross-section diagram to answer questions **10** and **11**.

10 Use your knowledge of the permeability of rocks to decide which combination is correct.

	Chalk	Gault Clay	Silts and clays
A	Aquifer	Aquiclude	Aquitard
B	Aquiclude	Aquifer	Aquitard
C	Aquitard	Aquifer	Aquiclude
D	Aquifer	Aquitard	Aquiclude

Your answer ☐ **[1]**

11 What would the height of the piezometric surface be if the confined aquifer shown on the cross-section above was filled at the recharge zones to maximum capacity?

A +180 m

B +100 m

C +35 m

D −10 m

Your answer ☐ **[1]**

12 Long-term changes in sea level have been identified which can be grouped by the frequency at which the oscillations occur.

What has been linked to first order cycles with a period of hundreds of millions of years?

A Formation and break-up of major continents

B Major episodes of volcanism

C Astronomical cycles

D Major asteroid impacts

Your answer ☐ **[1]**

13 The mean mass of a selection of pebbles from a beach was calculated to be 344 g with a standard deviation of ± 56.8.

What can be deduced from the standard deviation?

A The difference between the upper and lower quartiles of the data.

B A measure of how symmetrical the data is about the mean.

C A measure of the spread of the data about the mean.

D The degree to which the data shows a normal distribution.

Your answer ☐ **[1]**

14 Which statement applies to the **deterministic** prediction of earthquakes?

A It only gives the probability of an earthquake occurring within a given time period.

B It takes the full range of possible earthquake magnitudes into account.

C It calculates the ground motion close to a fault at a given site.

D It has been criticised for lacking a physical and mathematical basis.

Your answer ☐ **[1]**

15 It is estimated that there are 8.7 million species, excluding bacteria, living on Earth. Extinction rates are currently between 1000 and 50 000 species per year. A major extinction event is defined as the loss of at least 75% of species within a geologically short period.

What is the **maximum** time before the present day extinction becomes a mass extinction on the scale of the P-T and K-Pg events?

A 130 years

B 174 years

C 6525 years

D 8700 years

Your answer ☐ **[1]**

16 Which value best represents the lithostatic pressure in a tunnel 150 m below the surface? All the rock above is orthoquartzite.

You may assume $g = 10\,m\,s^{2}$, the density of quartz is $2650\,kg\,m^{3}$ and the rock has zero porosity.

A 3.58 MPa

B 3.73 MPa

C 3.98 MPa

D 4.80 MPa

Your answer ☐ **[1]**

17 Which mechanism is currently thought to provide the greatest force in driving the movement of tectonic plates?

A Convection currents in the mantle

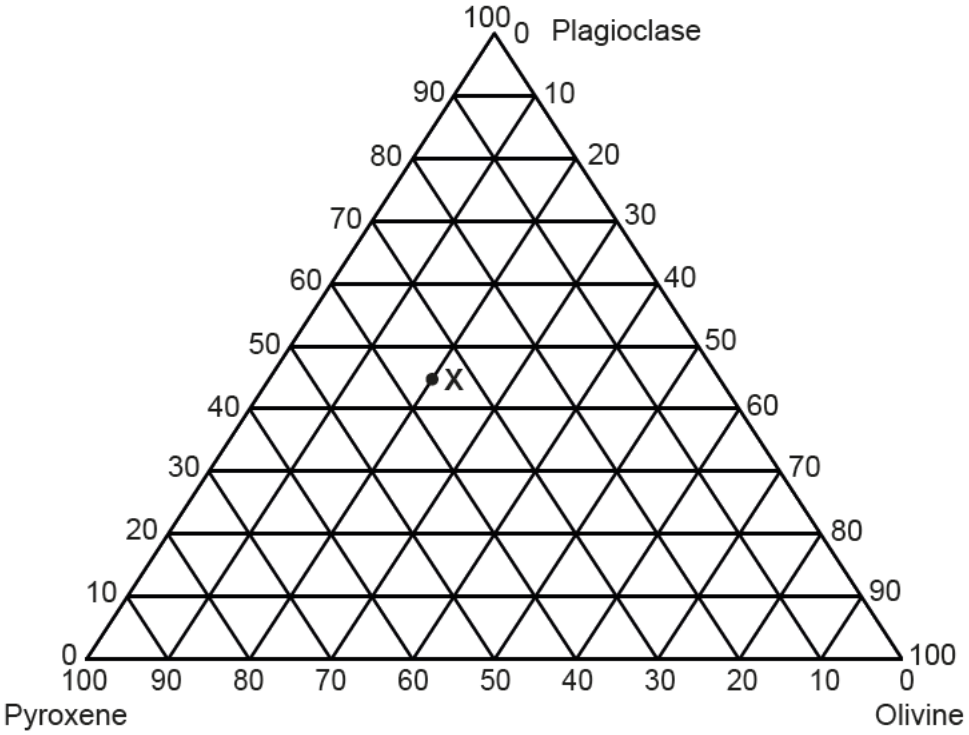
B Convection currents in the outer core

C Ridge push at mid-ocean ridges

D Slab pull at subduction zones

Your answer ☐ **[1]**

18 The triangular diagram below is used to plot the mineral composition of rocks in a layered intrusion.



What is the composition at point **X**?

	Plagioclase %	Pyroxene %	Olivine %
A	55	20	25
B	20	45	35
C	45	20	35
D	45	35	20

Your answer ☐ **[1]**

19 Which will most affect buoyancy forces to allow magma to rise to the surface to produce a volcanic eruption?

A Magma > dense than the surrounding rock

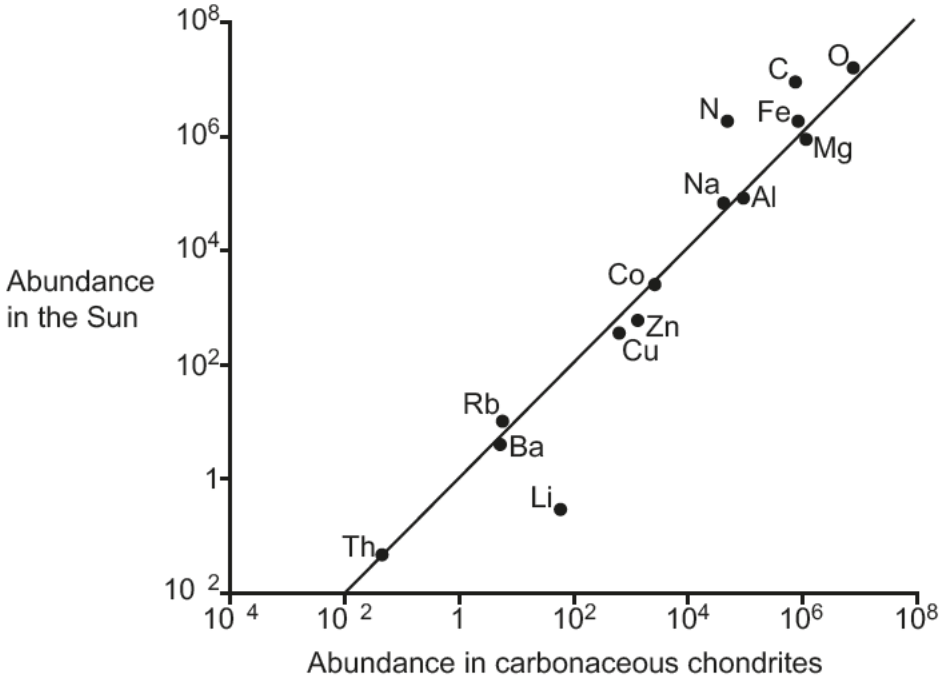
B Magma >> dense than the surrounding rock

C Magma < dense than the surrounding rock

D Magma << dense than the surrounding rock

Your answer ☐ **[1]**

20 The graph compares the composition of chondrite meteorites with that of the Sun.



Which statement can be deduced by analysing this graph?

A Iron meteorites represent the composition of the Earth's core.

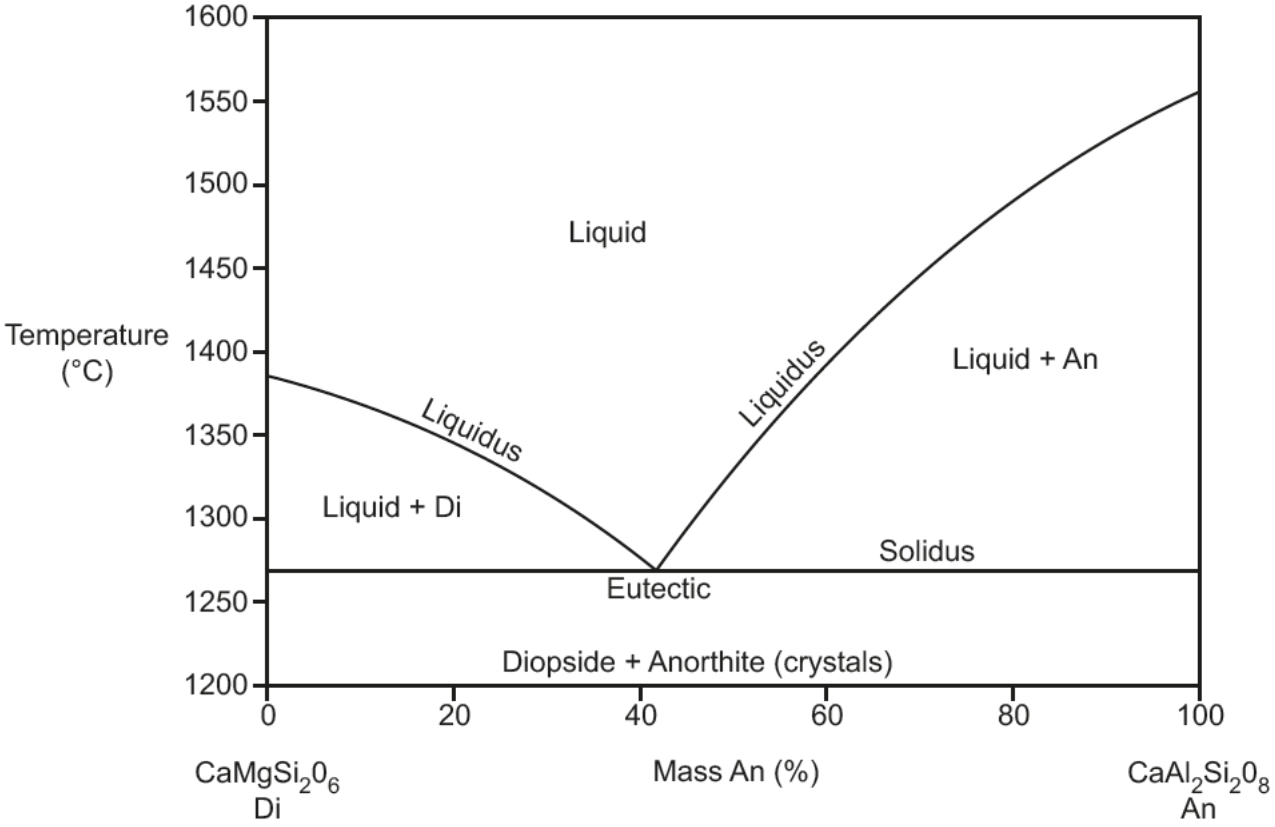
B The Sun and chondrites are made from the same original material.

C There is no comparison as the Sun is 99.9% hydrogen and helium.

D The apparent correlation is a result of the logarithmic scales.

Your answer ☐ **[1]**

The graph shows a discontinuous binary phase diagram which can be used to model the crystallisation of the immiscible minerals anorthite (An) and diopside (Di).



Use the graph to answer questions **21** and **22**.

21 If a melt has a composition of 70% anorthite (An) and 30% diopside (Di), at which temperature will the first crystals form?

A 1445 °C

B 1391 °C

C 1315 °C

D 1274 °C

Your answer ☐ **[1]**

22 What is the correct description of the bulk composition of the solid when crystallisation is complete?

A 100% An 0% Di

B 70% An 30% Di

C 60% An 40% Di

D 30% An 70% Di

Your answer ☐ **[1]**

23 Which statement about the formation, movement and crystallisation of magma is **incorrect**?

A Partial melting of those minerals with higher melting points produces magma.

B Stoping is a process that allows magma to move up by fracturing of the country rock.

C Country rock broken up by stoping is assimilated into the magma.

D Xenoliths are fragments of country rock preserved in the magma.

Your answer ☐ **[1]**

24 Which tectonic process allowed oil and natural gas traps to form in the North Sea Basin?

A Isoclinal folding

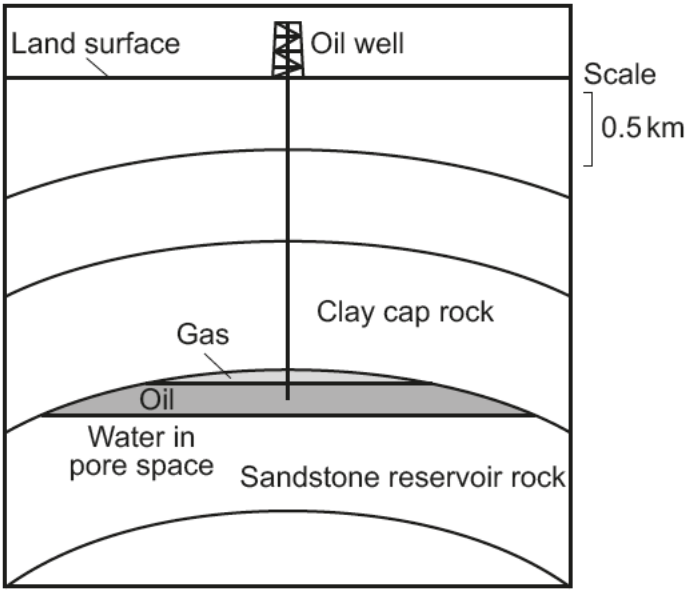
B Nappe formation

C Strike-slip faulting

D Synsedimentary faulting

Your answer ☐ **[1]**

25 The cross-section shows an accumulation of oil and gas in a trap structure under a cap rock.



Identify the type of trap structure from which the oil is being extracted.

A Anticline

B Lithological

C Salt dome

D Unconformity

Your answer ☐ **[1]**

SECTION B

Answer **all** the questions.

26 The properties and compositions of the rock-forming minerals are largely controlled by the way in which their silicon-oxygen tetrahedra are bonded together.

(a) (i) Describe the arrangement of the silicon-oxygen tetrahedra in micas.

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

(ii) Explain how this arrangement of tetrahedra affects **one** physical property of micas.

.....

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

(b) (i) Name a mineral that has the silicon-oxygen tetrahedra arranged in a chain structure.

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

(ii) Describe how the **chain** structure controls the cleavage in the mineral named in **(b)(i)**.

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

(c) (i) Describe the arrangement of the silicon-oxygen tetrahedra in quartz.

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

(ii) Explain how this arrangement of tetrahedra affects **one** physical property of quartz.

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

(iii) Explain why the arrangement of the silicon-oxygen tetrahedra in quartz results in the chemical formula SiO_2.

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

27 Henri Darcy published the results of his careful experiments on flow rates of water through sands in 1856. The apparatus he used is shown in **Fig. 27.1**.

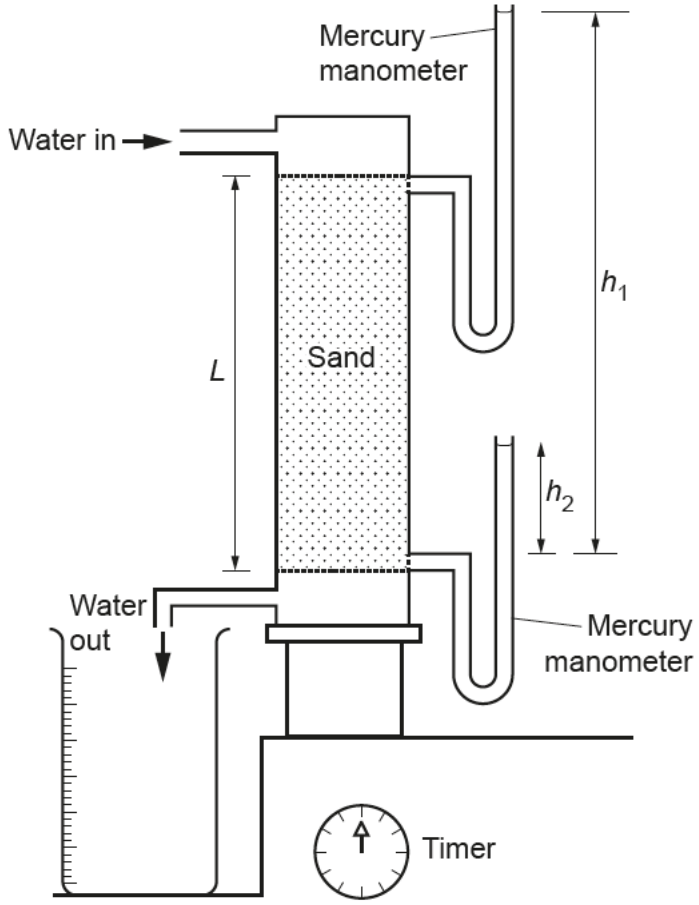


Fig. 27.1

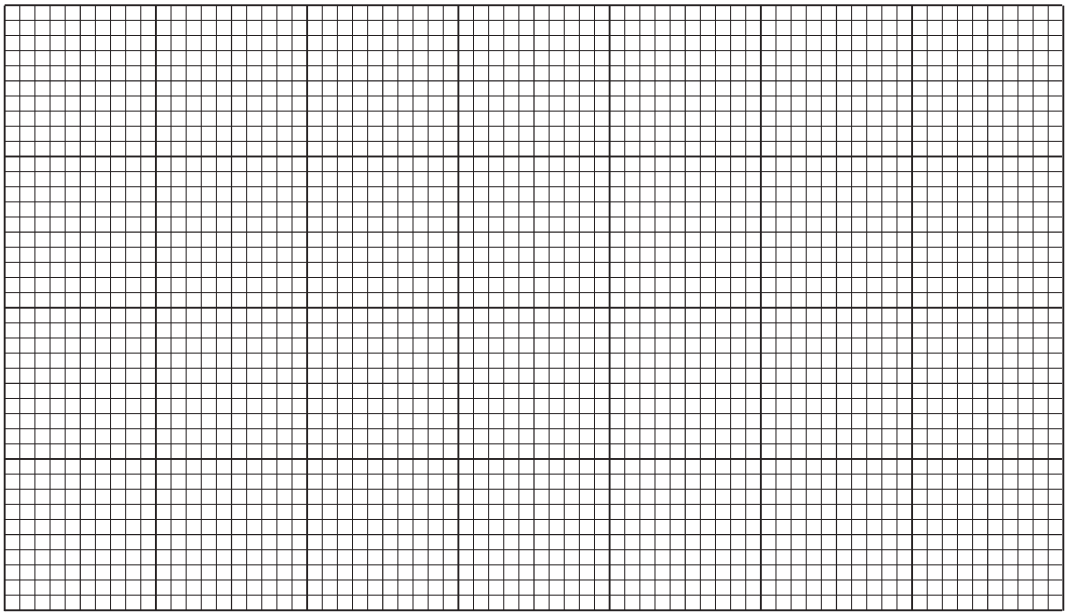
Table 27.1 shows some of the results from the experiment.

Experiment	Sand length L (m)	Head $h_2 - h_1$ (m)	Hydraulic gradient	Flow rate Q ($m^3 s^{-1} \times 10^{-3}$)
1	0.58	1.11	1.9	0.60
2	0.58	2.36	.....	1.28
3	0.58	4.00	6.9	2.00
4	0.58	4.90	.....	2.38
5	0.58	5.02	8.7	2.53
6	0.58	7.63	13.2	3.63

Table 27.1

(a) (i) Calculate the hydraulic gradients for experiments **2** and **4** and write your answers in **Table 27.1**. **[1]**

(ii) Plot a graph of flow rate **Q** against the hydraulic gradient and draw a line of best fit.



[3]

(iii) Describe the relationship between flow rate **Q** and the hydraulic gradient.

.....

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

(iv) Darcy used these results to formulate his law:

$$Q = -\kappa A \left(\frac{h_2 - h_1}{L} \right)$$

where:
Q is the rate of flow
κ is a constant
A is the cross-sectional area of $0.1\,m^2$ through which the water passes
$h_2 - h_1$ is the difference in pressure from the start to the end of the column
L is the distance between the start and end points.

Use your graph to find a numerical value for the constant κ.

κ = ... (units not required) **[1]**

(v) In the original experiment the water inlet was connected directly to the building's water supply.

Explain how this set-up may have affected the accuracy of Darcy's measurements.

.....

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

(vi) Suggest how the apparatus set up in **Fig. 27.1** could be improved to better establish Darcy's Law.

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

(b) Darcy used unwashed sand containing fine clay to obtain his data.

Explain how the results would change if better sorted, well-washed sand from the same source was used.

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

(c) **(i)** Explain why lower permeability rock could improve drinking water quality.

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

(ii) Long residence times of dissolved ions can result in chemical changes to groundwater.

State **two** ions commonly found in solution in groundwater. For each ion suggest how it could affect water quality.

1 .....

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2 .....

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[2]

28 Early seismic refraction and reflection studies showed that the ocean floor had a simple layered structure. It was only explained once the process of sea-floor spreading was understood.

Fig. 28.1 shows the seismic layering of the oceanic lithosphere compared to the geology of the Semail ophiolite complex, Oman.

Typical P-wave velocities ($km\,s^{-1}$)

Water	1.50
Layer 1	1.77
Layer 2	5.24 – 6.20
Layer 3	6.93

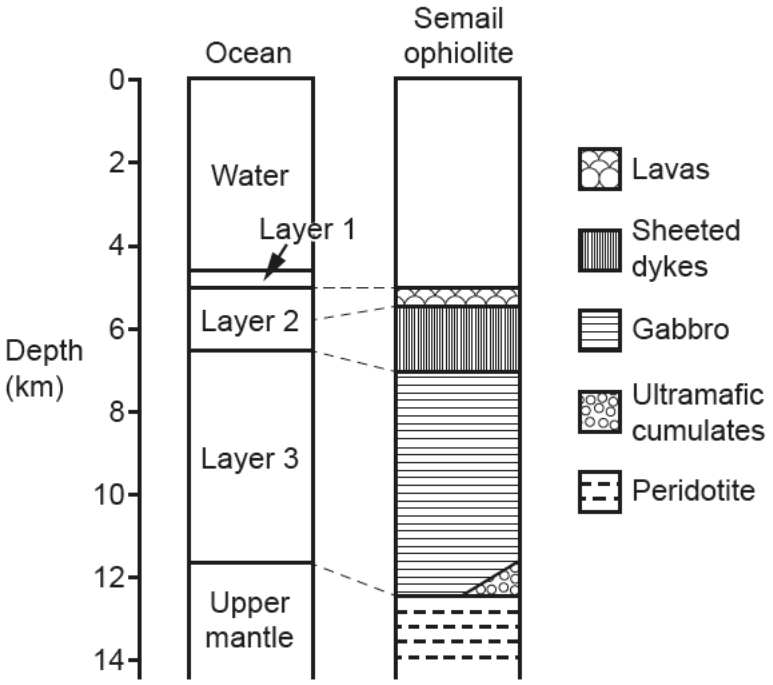

Fig. 28.1

(a) (i) Identify the composition of layer **1** shown in **Fig. 28.1**.

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

(ii) Explain why the layer identified in **(a)(i)** has a much lower P-wave velocity compared to the other layers.

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

(iii) Explain why the seismic data shows layer **1** increases in thickness the further away it is from the axis of the ocean ridge.

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

(iv) Explain how sheeted dykes form in the oceanic crust and how their chilled margins provide evidence for this process of formation.

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

(b) **Fig. 28.2** shows pillow lavas exposed in Anglesey, North Wales.

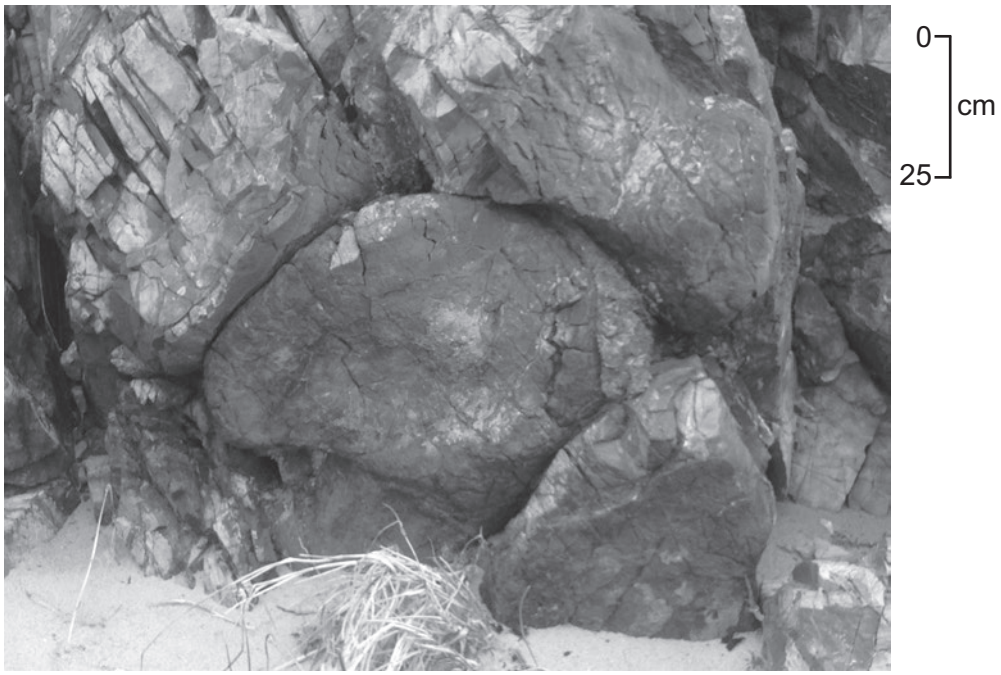

Fig. 28.2

(i) Draw an arrow **on Fig. 28.2** to show the right way-up and younging direction of the pillow lavas. **[1]**

(ii) Describe how pillow lavas form and explain how you deduced the way-up direction you have indicated on **Fig. 28.2**.

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

(c) Describe the **two** sources of geothermal energy from within the Earth for igneous processes such as those that occur at mid-ocean ridges.

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[2]

(d)* Describe and explain how hydrothermal processes at mid-ocean ridges can result in the formation of massive sulfide ores.

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

Additional answer space if required.

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29 **Fig. 29.1** shows maps of the geology and zones of land use of the same area.

Location ☆ marks the epicentre of an earthquake which had a Moment magnitude (M_w) of 6 and a depth of focus of 15 km.

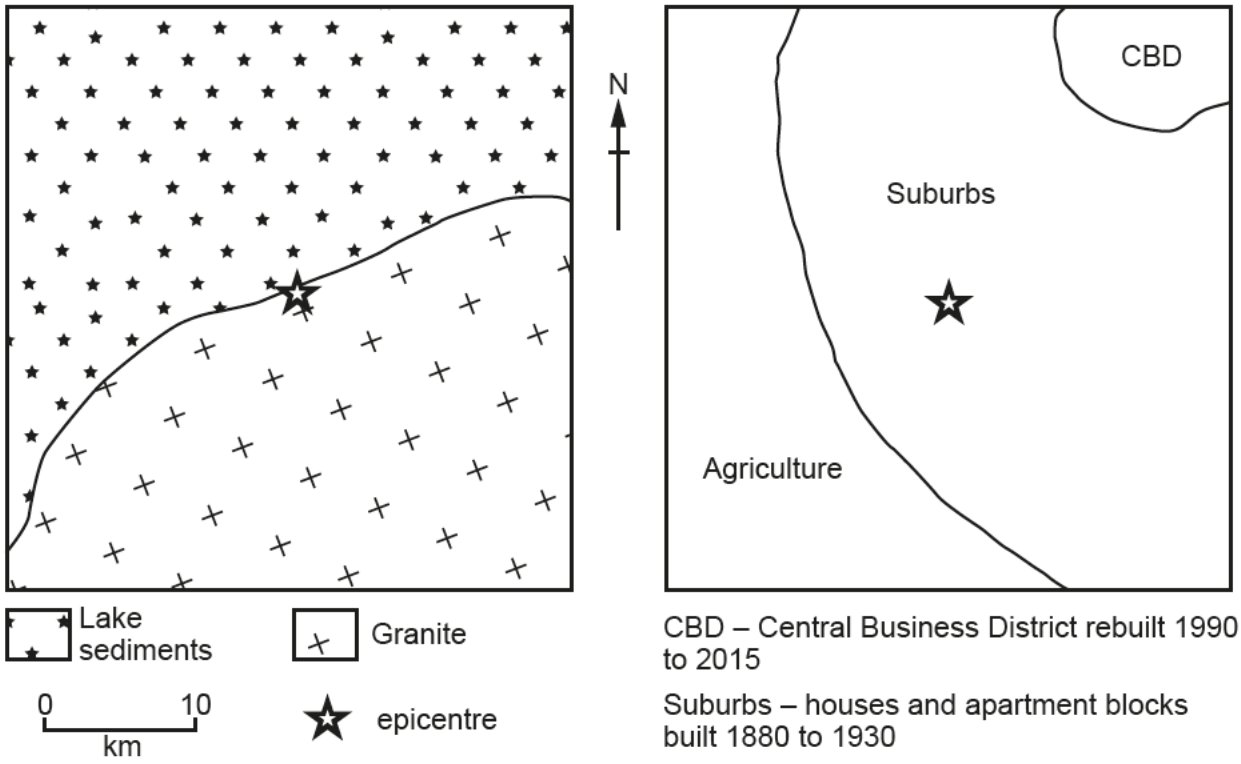

Fig. 29.1

(a) **(i)** The modern structures in the Central Business District of the city showed little damage after the earthquake.

Outline **three** civil engineering strategies that can reduce the impact of seismic events on the built environment.

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[3]

(ii) During the earthquake, some apartment blocks in the northern suburbs sank and tilted. The water table was close to the surface in that area.

Name the process that caused this problem and explain the mechanisms involved.

Name of process .....

Explanation .....

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

(iii) Sketch the probable pattern of **three** isolines of equal earthquake intensity (isoseismals) onto the land use map in **Fig. 29.1**.

Label each isoline with a number to suggest the earthquake intensity on the modified Mercalli scale.

Use the information on the maps and your knowledge of the effects of the underlying geology, types of land use and buildings on earthquake intensity in your answer.

Answer on the land use map in Fig. 29.1. **[5]**

(b) The Moment magnitude (M_w) of an earthquake can be converted into an equivalent of the energy released using the equation:

$$M_w = \frac{2}{3}\log E - 6.1$$

Where M_w is the Moment magnitude and E is the energy released.

Calculate the energy released by a Moment magnitude (M_w) 6 earthquake.

Give your answer to an **appropriate number** of significant figures.

Energy released = ... J **[3]**

(c) (i) In seismic risk analysis it is generally understood that increasing distance from an active fault will lower the impact of an earthquake.

Use your knowledge of the mechanisms of seismic wave propagation through rocks to explain this assumption.

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

(ii) Give **two** geological explanations why this simplistic correlation of distance from faults with seismic risk can be misleading.

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2 .....

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[2]

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30 (a) Tectonic plate movement can be measured using accurate daily positions recorded by permanent GPS stations.

Fig. 30.1 shows eastward and northward motion data from a GPS station located in the west of Iceland.

Fig. 30.1

(i) The average precision of the GPS data shown in **Fig. 30.1** was determined to be ±10 mm.

Explain the meaning of the term **precision**.

.....

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

(ii) Use **Fig. 30.1** to determine the **annual** rate of eastward and northward movement of the GPS station.

Give your answers in mm y^{1}.

Eastward = ... mm y^{1}

Northward = ... mm y^{1} **[2]**

(iii) Explain the direction of movement of the GPS station in **Fig. 30.1**.

In your answer use your knowledge of the plate tectonic situation of Iceland.

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

(b) Historical plate movements can be reconstructed using the global distribution of geological features within the continents.

Using named example(s), describe and explain how palaeoecology (fossils) can be used as evidence for plate movements.

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

31 A government is considering constructing a road tunnel beneath a major river to improve the economy of the area. **Fig. 31.1** shows a map of the geology of the area. The maximum depth of the river is 10 metres and maximum depth of the fluvio-glacial drift deposits is above the profile of the tunnel.

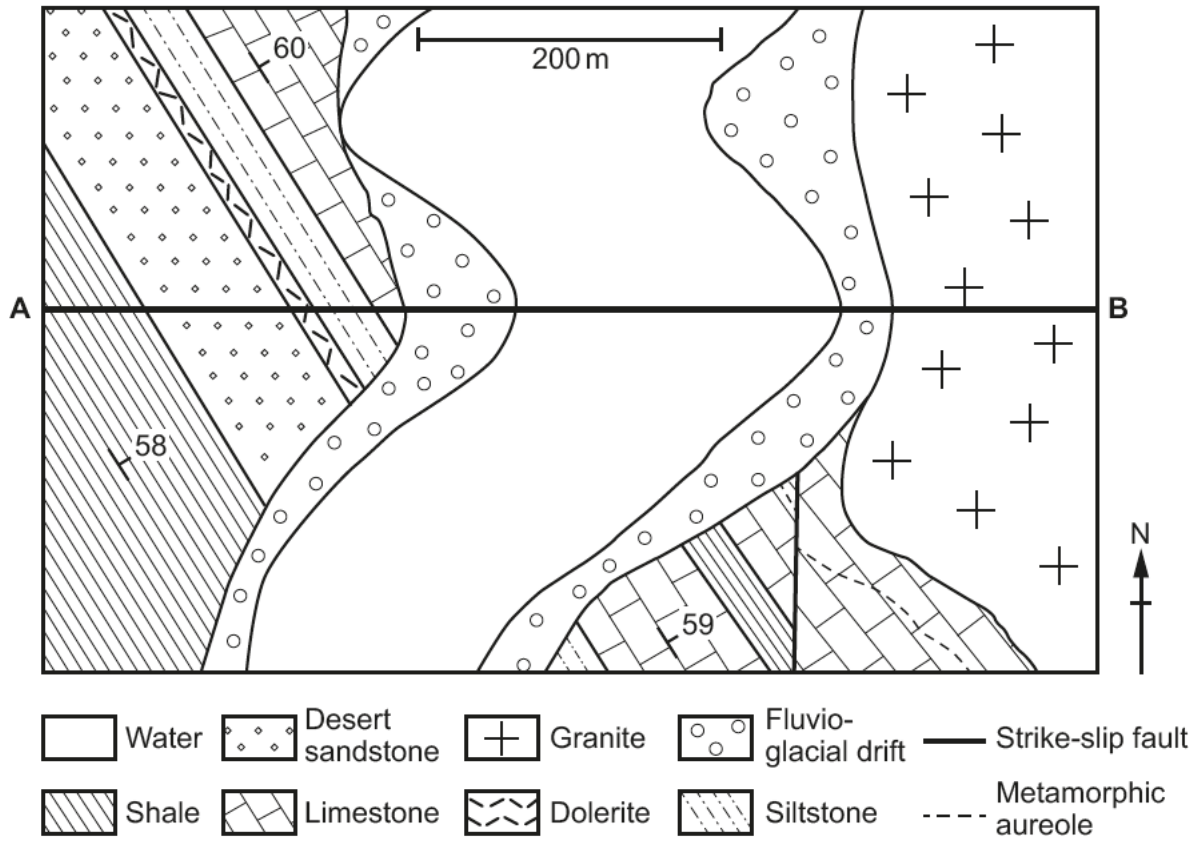

Fig. 31.1

(a) Construct a geological cross-section along the line of the tunnel A–B from the map onto **Fig. 31.2**, which shows the surface topography and the tunnel profile. There is no vertical exaggeration.

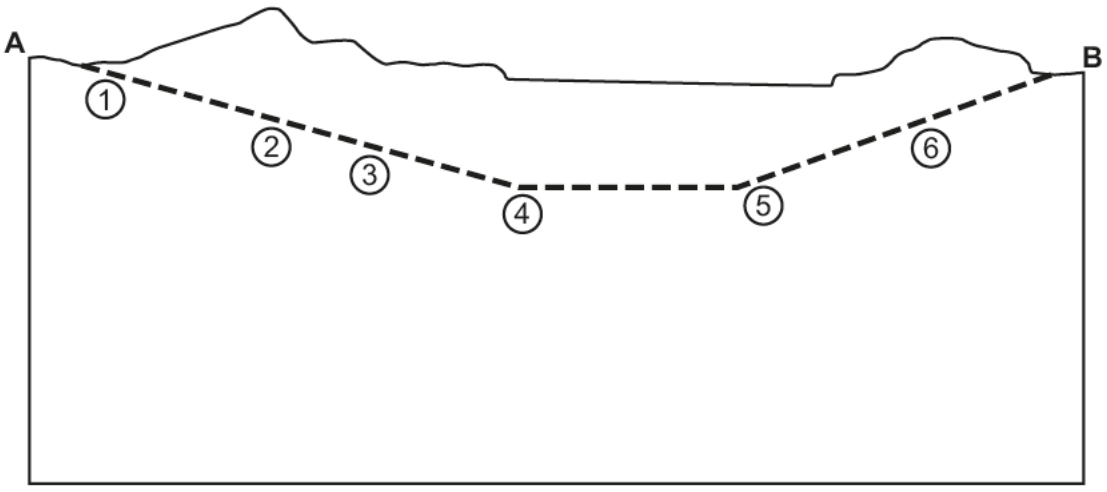

Fig. 31.2

[5]

(b)* Describe and explain the effects that the geology shown in **Fig. 31.1** and **Fig. 31.2** could have on the construction of the tunnel.

You should use information from locations **1** to **6** in **Fig. 31.2** to structure your answer.

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

Additional answer space if required.

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(c) Old records suggest that there may have been small-scale mining for metal ores in the area around location **5** shown on **Fig. 31.2**.

Suggest the processes by which this mineralisation could have formed.

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

(d) To decide whether to construct the tunnel, the environmental impacts will be considered as part of a cost–benefit analysis.

(i) **Fig. 31.3** shows a cross-section through the proposed 660 metres-long road tunnel. The excavation can be approximated as a circle of radius 5.7 m.

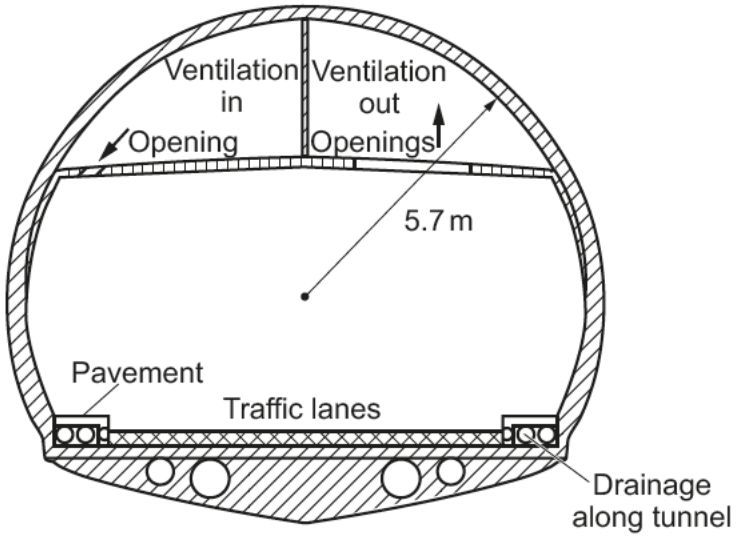

Fig. 31.3

Calculate the volume of spoil that will need to be removed during the excavation of the tunnel.

Volume of spoil = ... m^3 **[2]**

(ii) Suggest how this quantity of spoil could be disposed of **and** describe one possible impact of spoil disposal on the environment.

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

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).

OCR
Oxford Cambridge and RSA

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 | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

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

INFORMATION
- The total mark for this paper is **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.

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

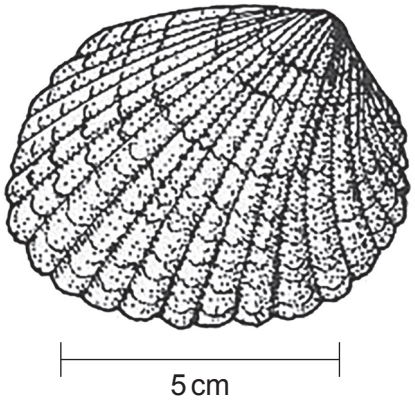
B Fine-grained sediment

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

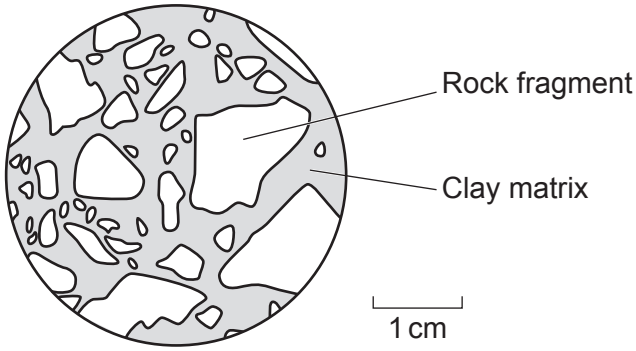
B Dip-slip faults

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

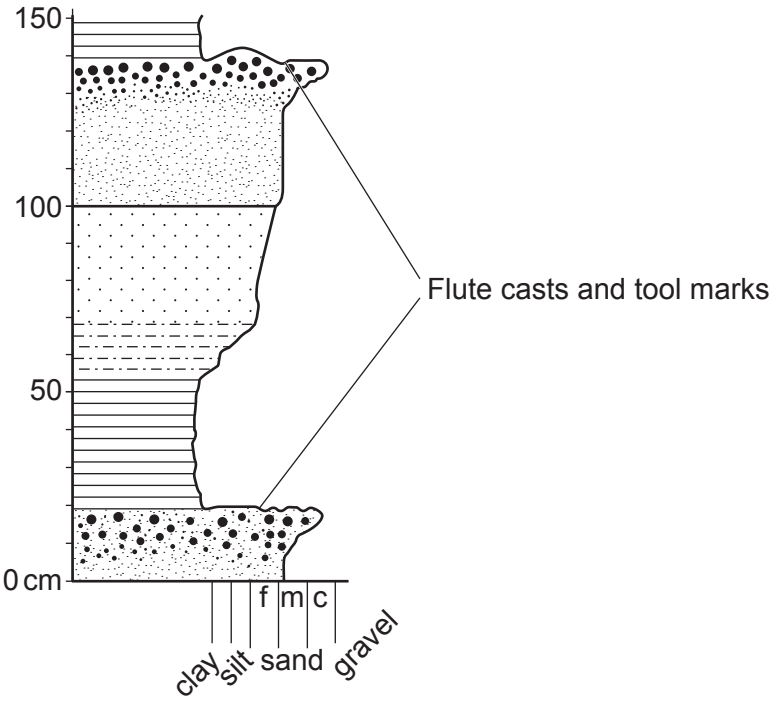
B Fluvial

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

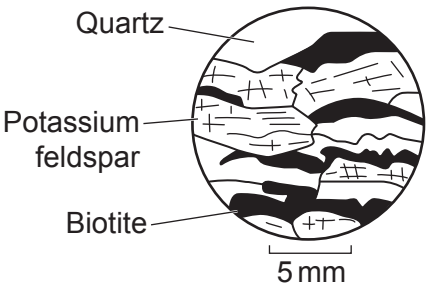
C Low silicate polymerisation

D Mafic composition

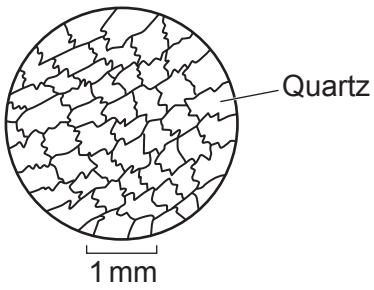
Your answer ☐ **[1]**

17 The four thin section diagrams show metamorphic rocks.

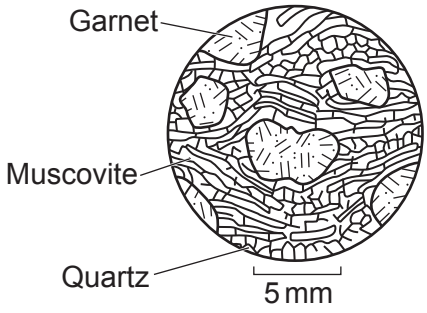
Rock **A**



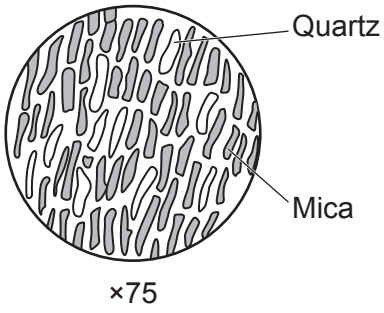
Rock **B**



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]**

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.

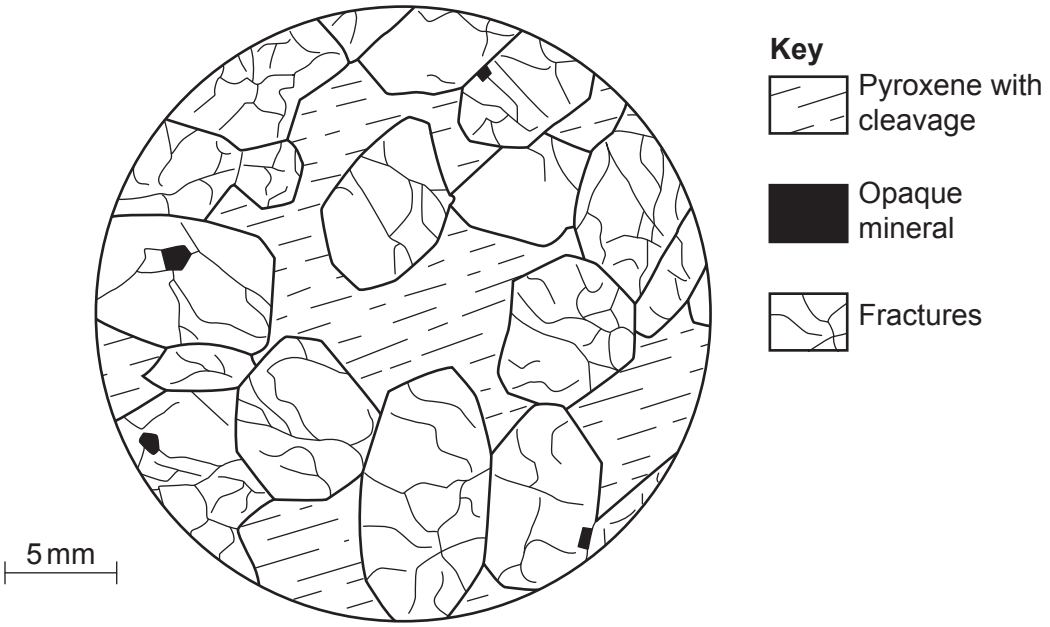


Fig. 26.1

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

Additional answer space if required.

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

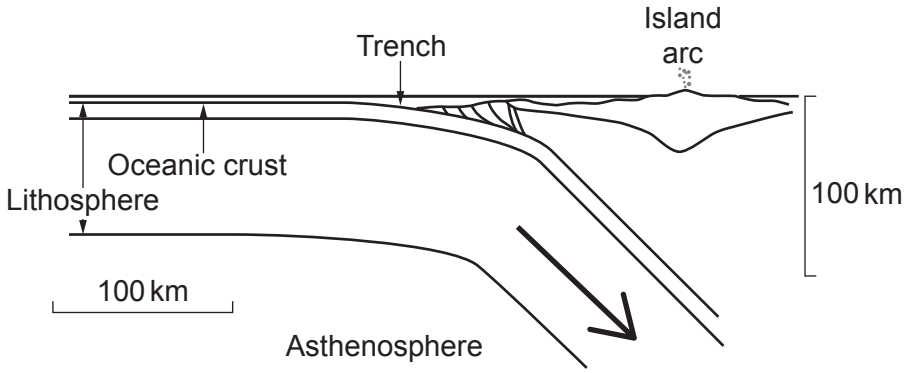

Fig. 26.2

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

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

(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]**

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

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

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

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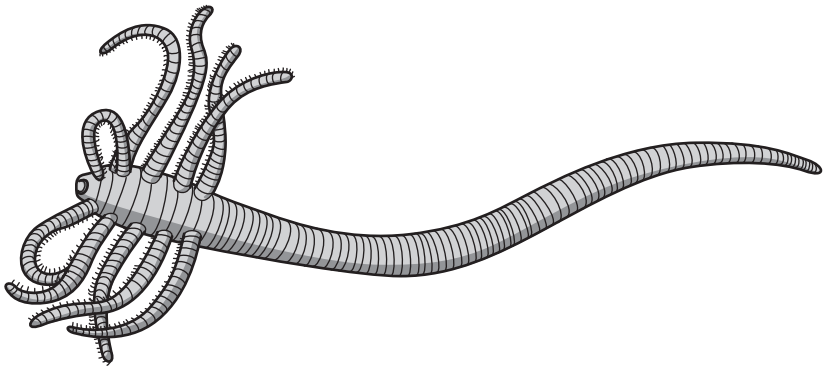
..... **[2]**

(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 .....

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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.

.....

..... **[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.

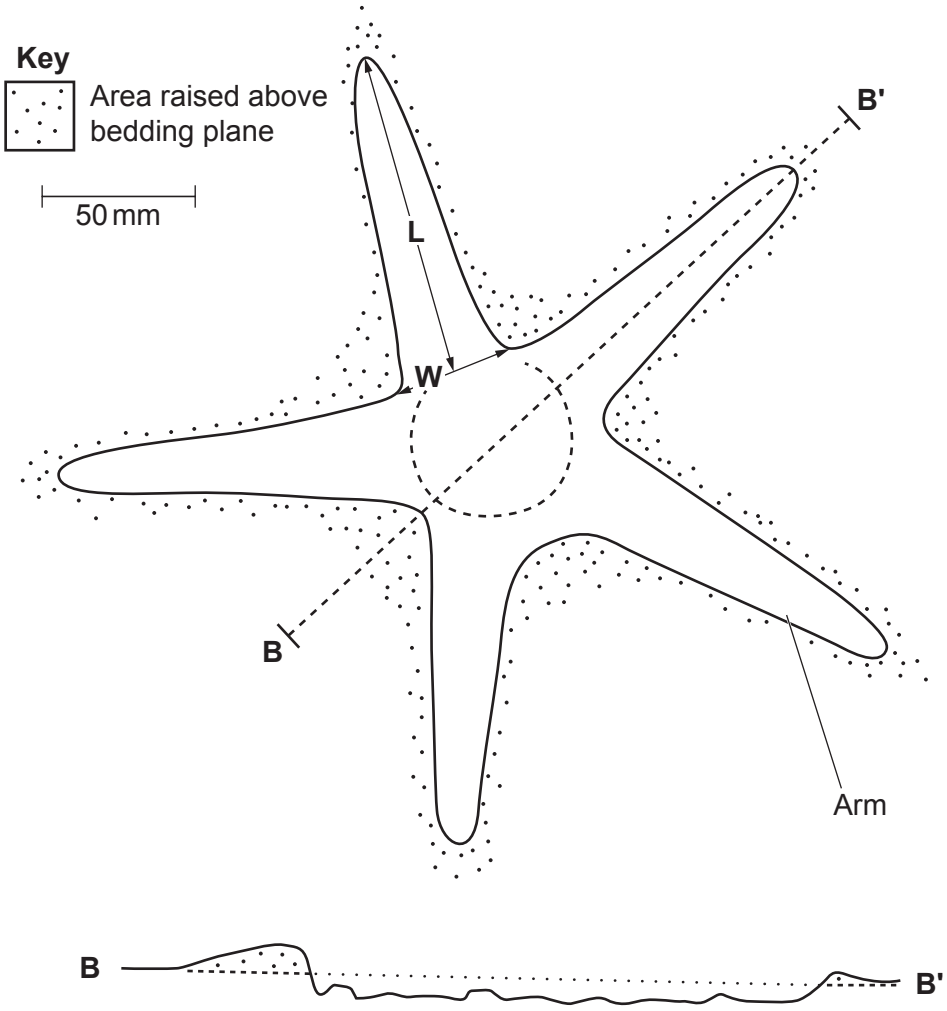


Fig. 27.2

(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.

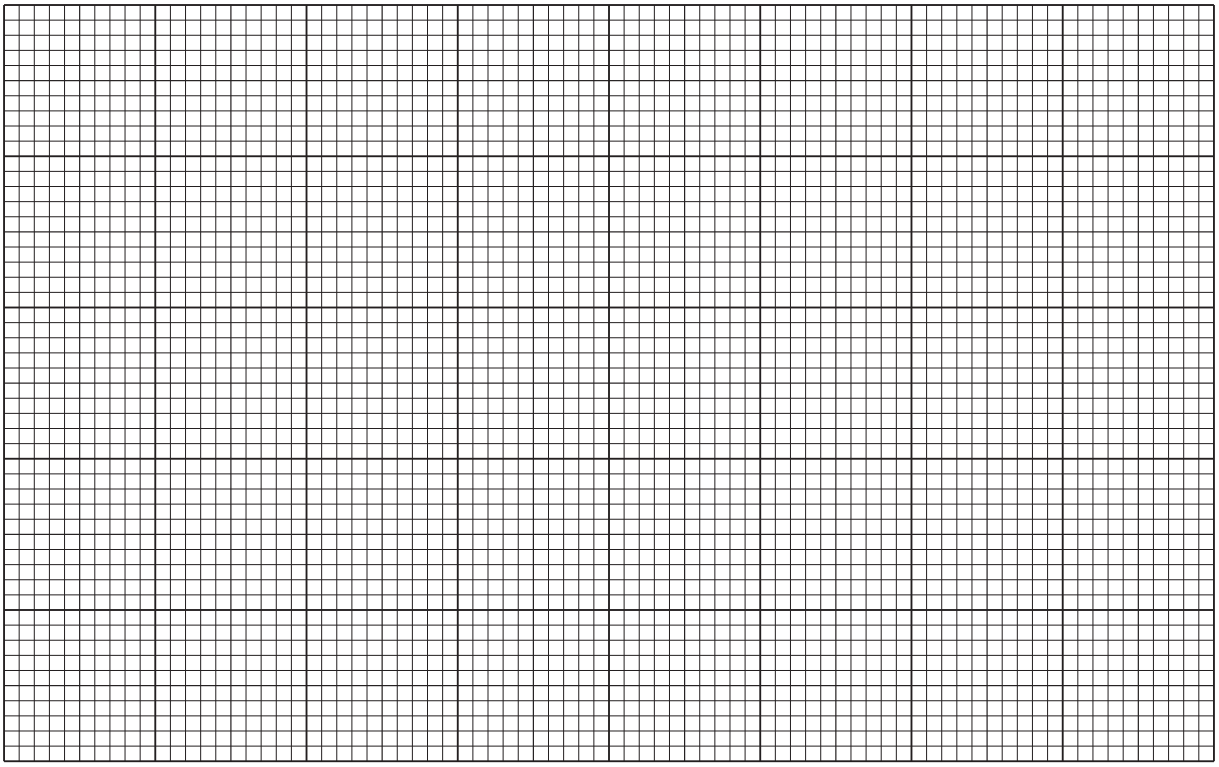
.....

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

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

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

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

(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.

.....

..... **[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.

.....

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

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

.....

..... **[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]**

(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.

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

(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.

.....

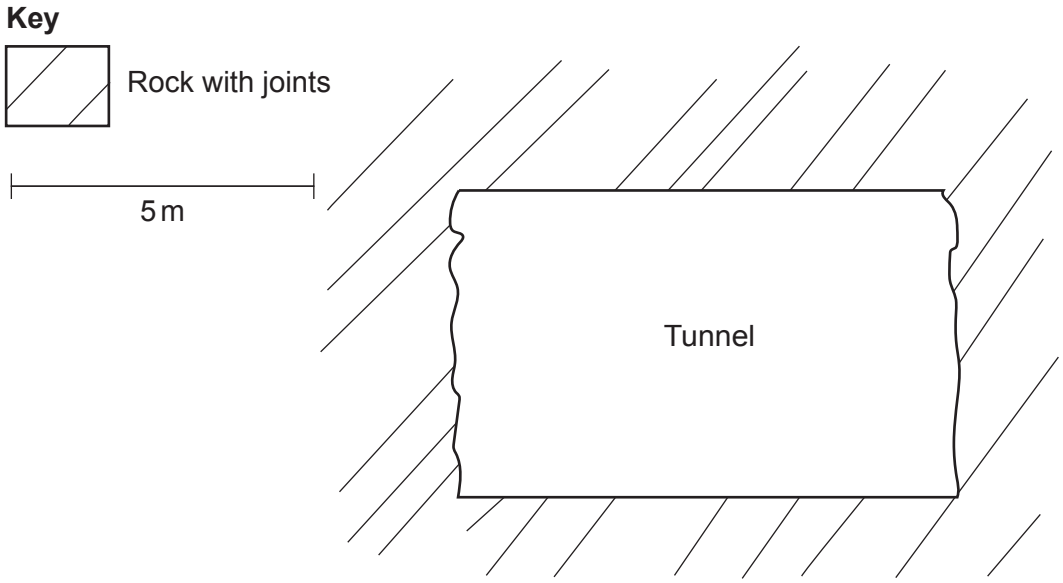
..... **[1]**

(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]**

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]**

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

.....

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

(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.

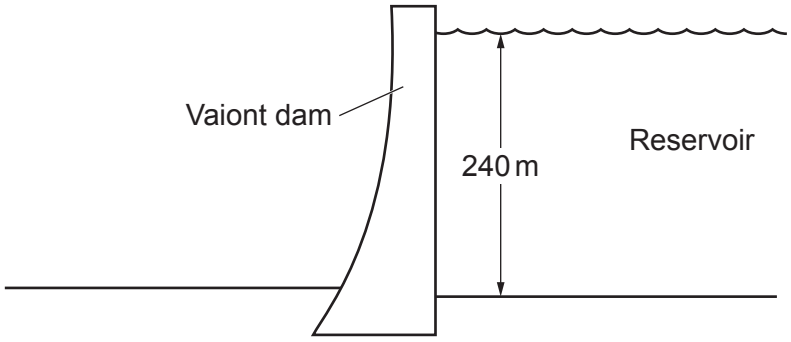


Fig. 29.1

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]**

(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]**

(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]**

(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.

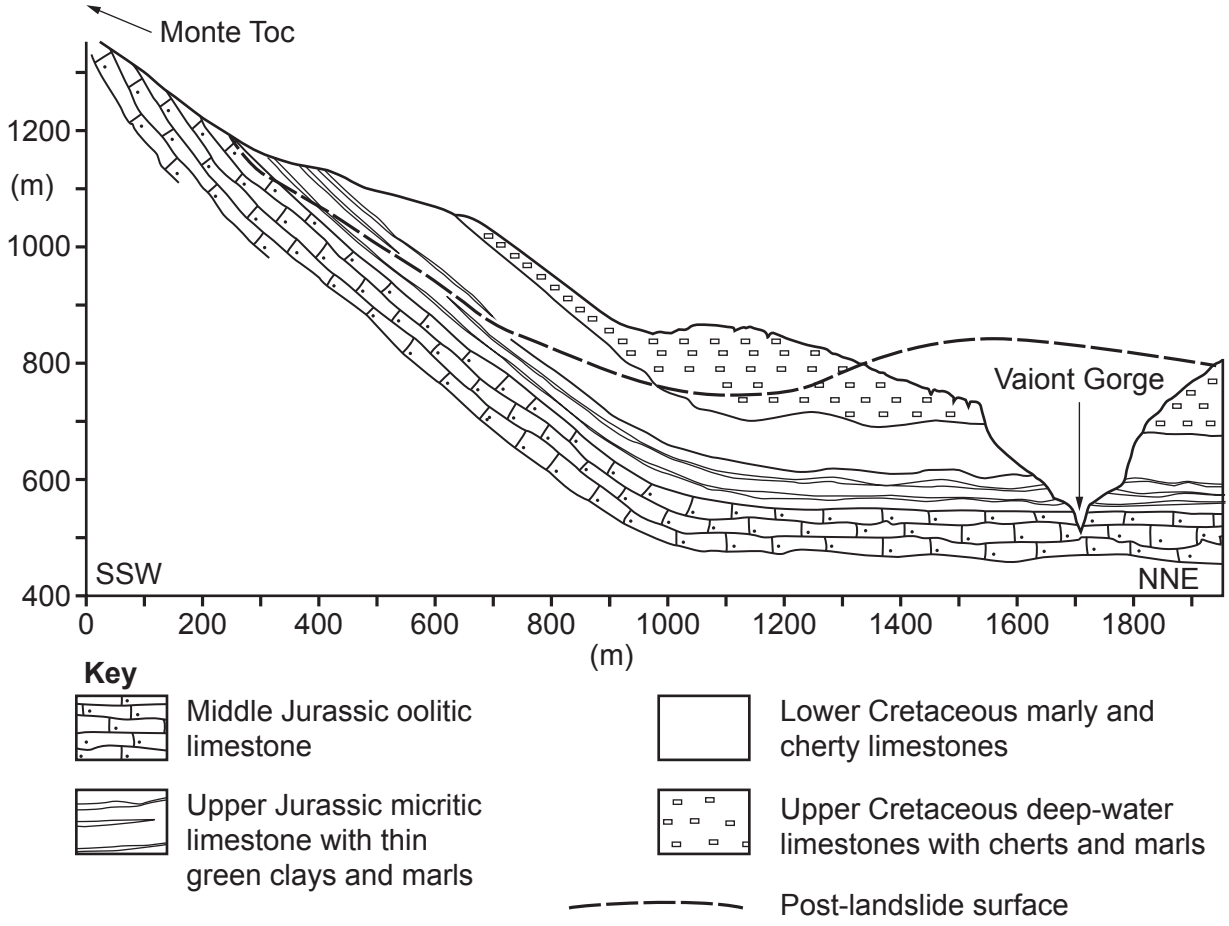

Fig. 29.2

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

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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.

1 .....

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2 .....

.....

[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]**

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.

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

(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.

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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).

OCR
Oxford Cambridge and RSA

Monday 5 June 2023 – Morning

A Level Geology

H414/01 Fundamentals of geology

Time allowed: 2 hours 15 minutes

You can use:
- a scientific or graphical calculator
- a ruler (cm/mm)
- an HB pencil

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

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

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

INFORMATION
- The total mark for this paper is **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.

Section A

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

Write your answer to each question in the box provided.

1 What is the correct definition of a mineral?

A A naturally occurring aggregate of elements and inorganic compounds whose composition varies

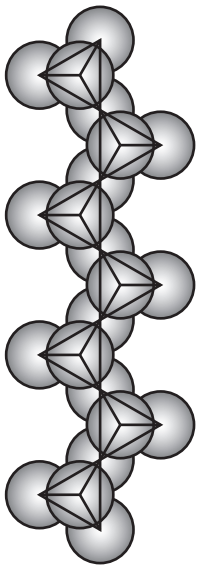
B A naturally occurring aggregate of elements and organic compounds whose composition varies

C A naturally occurring element or inorganic compound whose composition can be expressed as a chemical formula

D A naturally occurring element or organic compound whose composition can be expressed as a chemical formula

Your answer [ ] **[1]**

2 The diagram shows the arrangement of the silicon-oxygen tetrahedra in a group of rock-forming silicate minerals.



Which group of silicate minerals has this structure?

A Feldspars

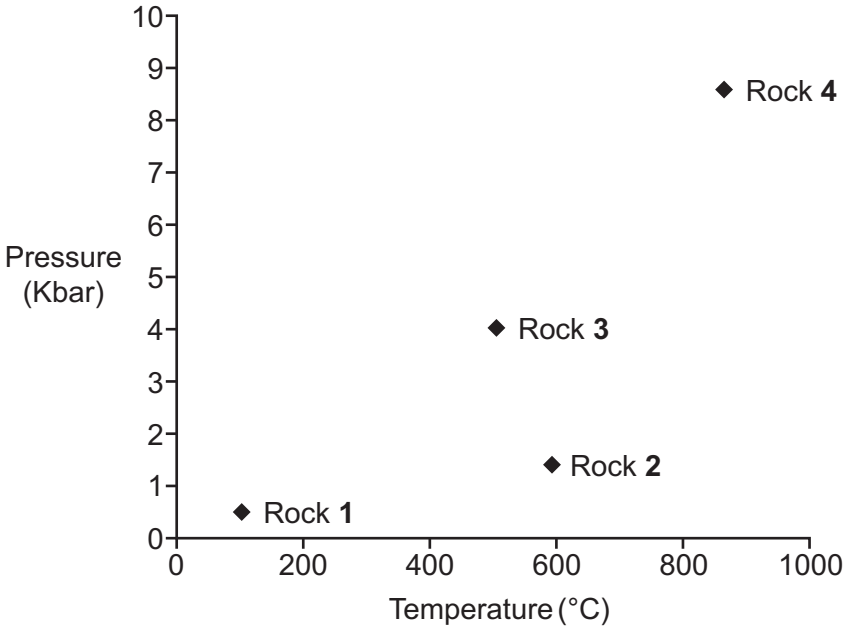
B Micas

C Olivines

D Pyroxenes

Your answer ☐ **[1]**

3 The diagram shows the temperature and pressure conditions under which four rocks formed in the rock cycle.



Which combination correctly identifies the rock classes of rocks **1**, **2**, **3** and **4**?

	Rock **1**	Rock **2**	Rock **3**	Rock **4**
A	Igneous	Sedimentary	Contact Metamorphic	Regional Metamorphic
B	Sedimentary	Contact Metamorphic	Regional Metamorphic	Igneous
C	Contact Metamorphic	Regional Metamorphic	Igneous	Sedimentary
D	Regional Metamorphic	Igneous	Sedimentary	Contact Metamorphic

Your answer ☐ **[1]**

4 Which statement about the formation of evaporites in hot desert environments is correct?

A Calcite is least soluble and precipitates first

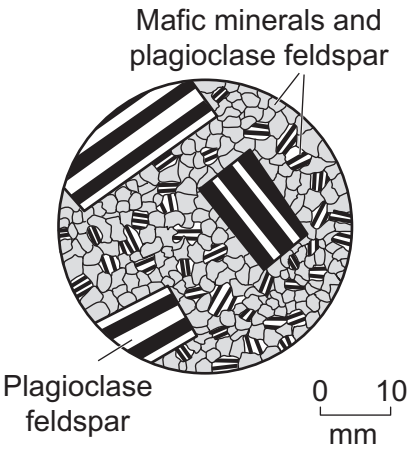
B Gypsum is most soluble and precipitates last

C Halite is least soluble and precipitates last

D K minerals are most soluble and precipitate first

Your answer ☐ **[1]**

5 The labelled thin-section diagram shows an igneous rock.



Which description of this rock is correct?

A Intermediate composition with an amygdaloidal texture

B Mafic composition with a porphyritic texture

C Silicic composition with a glassy texture

D Ultramafic composition with an equicrystalline texture

Your answer ☐ **[1]**

6 Igneous rocks can form dykes, sills and lava flows.

Which statement correctly describes these igneous structures when examining them in the field?

A Dykes and sills are concordant but only sills have two baked margins

B Dykes and sills are discordant and both have two baked margins

C Lava flows and sills are concordant but only sills have two baked margins

D Lava flows and sills are discordant and both have two baked margins

Your answer ☐ **[1]**

7 Which combination shows the correct sequence of formation of index minerals during prograde regional metamorphism?

A Biotite → Chlorite → Garnet → Kyanite → Sillimanite

B Biotite → Chlorite → Garnet → Sillimanite → Kyanite

C Chlorite → Biotite → Garnet → Kyanite → Sillimanite

D Chlorite → Biotite → Garnet → Sillimanite → Kyanite

Your answer ☐ **[1]**

8 The composition of the parent rock and the conditions at the time determine the nature of rock deformation during metamorphism.

What combination could produce **boudinage** in a metamorphic rock?

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 What is the correct geological setting for most Jurassic rocks which are exposed in the British Isles?

A Cyclical sedimentation in deep seas with deposition of turbidites, calcareous and siliceous oozes

B Cyclical sedimentation in deltaic environments with deposition of shales, sandstones, coal and seat earth

C Cyclical sedimentation in fluvial environments with deposition of conglomerates, sandstones and clays

D Cyclical sedimentation in shallow seas with deposition of shales, limestones, sandstones and ironstones

Your answer ☐ **[1]**

10 Ammonites are used as zone fossils for the Jurassic period.

Which characteristic of zone fossils does **not** apply to ammonites?

A Good preservation potential

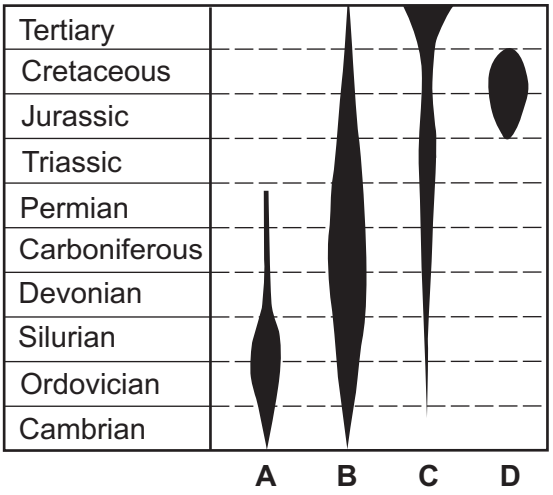
B Numerous with widespread distribution

C Only found in high energy marine facies

D Rapid evolutionary changes

Your answer ☐ **[1]**

11 The diagram shows part of the geological timescale and the stratigraphic ranges of four fossil groups.



Which letter, **A**, **B**, **C** or **D**, shows the stratigraphic range of the trilobites?

Your answer ☐ **[1]**

12 During which period did dinosaurs first appear in the geological record?

A Carboniferous

B Jurassic

C Permian

D Triassic

Your answer ☐ **[1]**

13 *Diplodocus* was a large dinosaur with a long flexible S-shaped neck, peg-like teeth at the front of the jaw and a pubis that pointed forwards.

In which group of dinosaurs is *Diplodocus* classified?

A Ornithischia

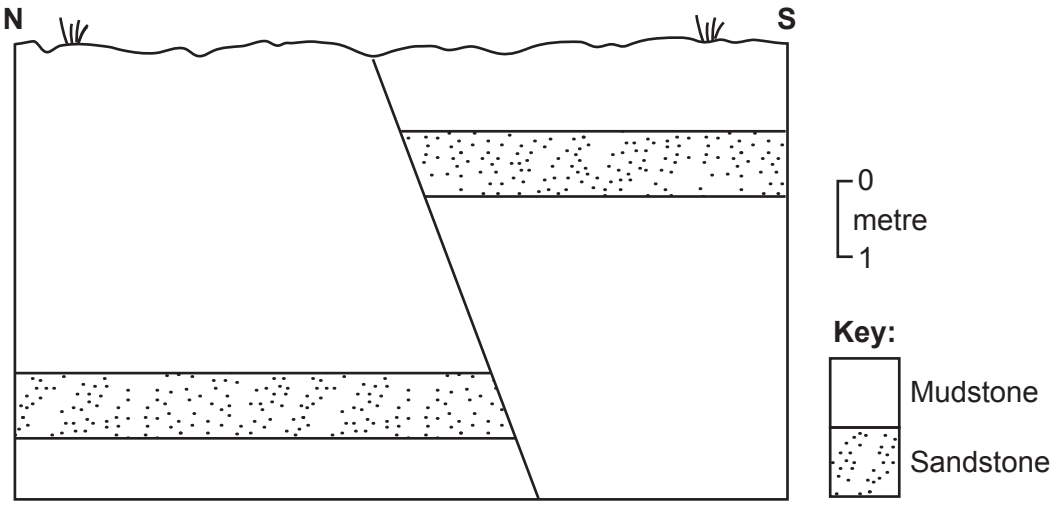
B Pterosauria

C Saurischia Sauropoda

D Saurischia Theropoda

Your answer ☐ **[1]**

14 The cross-section diagram shows a fault in a cliff.



The following statements about the fault may be true or false:

1 The fault has a dip-slip component

2 The hanging wall is the upthrow side

3 The fault was formed by tensional forces

Which combination of statements is true?

A 1, 2 and 3

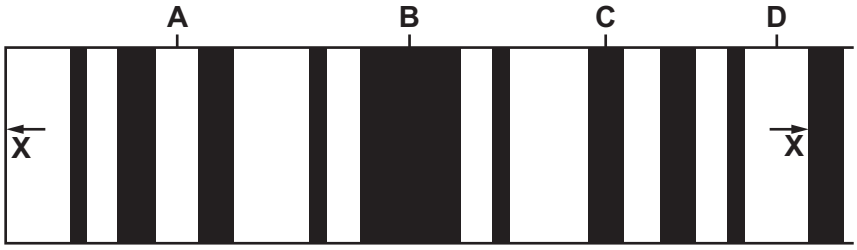
B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐ **[1]**

The map shows the pattern of magnetic anomalies recorded along a transect across a mid-ocean ridge.



Scale 1 cm = 100 km

Negative magnetic anomaly Positive magnetic anomaly

Use the map to answer questions **15** and **16**.

15 Which letter on the map, **A**, **B**, **C** or **D**, marks the centre of this mid-ocean ridge?

Your answer [ ] **[1]**

16 The ocean floor rocks between points **X** and **X** on the map formed over 53 million years.

What is the average rate of plate movement for this part of the ocean floor?

A $0.2\,cm\,a^{-1}$

B $2\,cm\,a^{-1}$

C $4\,cm\,a^{-1}$

D $20\,cm\,a^{-1}$

Your answer [ ] **[1]**

17 Which statement describes features typical of a slow spreading mid-ocean ridge?

A Has a continuous magma chamber and has an axial rift valley

B Has a continuous magma chamber and does not have an axial rift valley

C Has a discontinuous magma chamber and has an axial rift valley

D Has a discontinuous magma chamber and does not have an axial rift valley

Your answer [ ] **[1]**

18 Seismic tomography generates 2D and 3D virtual images from the analysis of the behaviour of seismic waves as they pass through the Earth.

What evidence from seismic tomography could indicate the position of a subducted slab within the mantle?

A A high velocity zone caused by P-waves travelling through colder and denser material

B A high velocity zone caused by P-waves travelling through hotter and less dense material

C A low velocity zone caused by P-waves travelling through colder and denser material

D A low velocity zone caused by P-waves travelling through hotter and less dense material

Your answer ☐ **[1]**

19 In what plate tectonic setting do graben and horst form?

A At convergent plate boundaries

B At divergent plate boundaries

C At intraplate hot spots

D At transform plate boundaries

Your answer ☐ **[1]**

20 A new geological epoch called the Anthropocene has been proposed because the current rate and scale of environmental and biological changes are of the same order of magnitude as major events in the geological past.

Which marker is most likely to be accepted by geoscientists as the start of the Anthropocene epoch?

A The start of agriculture in the Middle East 12 000 years ago

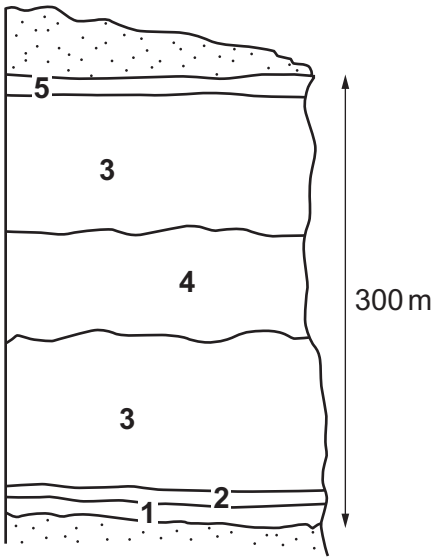
B The 1750 Industrial Revolution of Europe and North America

C The 1815 eruption of Mount Tambora, Indonesia – the largest volcanic eruption in recorded history and thought to be responsible for the deaths of more than 100 000 people worldwide

D Radioactive particles resulting from nuclear tests in the 1950s found worldwide in deep ocean sediments

Your answer ☐ **[1]**

The diagram shows a cross-section through a major layered intrusion which has associated chalcophile cumulates and platinum group elements.



Use the cross-section diagram to answer questions **21** and **22**.

21 Which statement about layers **1** to **5** shown on the cross-section diagram is true?

A Gravity settling is responsible for layer **1**

B Layer **4** has the same chemistry as the magma that formed the intrusion

C Some of layers **1** to **5** have the same chemistry

D The most mafic chemistry is found in layer **3**

Your answer ☐ **[1]**

22 In which layer, **1** to **4**, shown on the cross-section diagram, are economic deposits of chalcophile cumulates and platinum group elements most likely to be found?

A Layer **1**

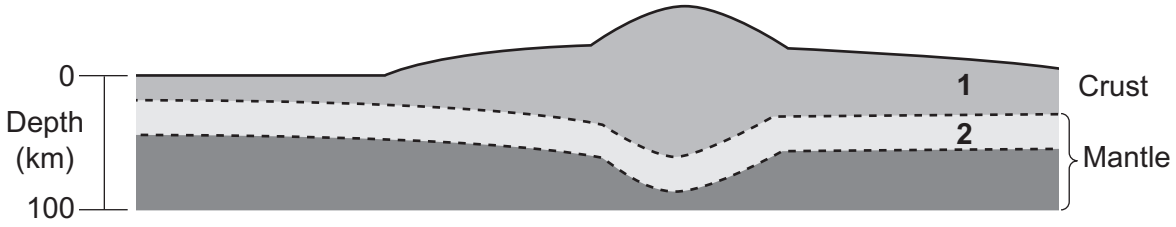
B Layer **2**

C Layer **3**

D Layer **4**

Your answer ☐ **[1]**

23 The diagram shows a simplified cross-section through the Earth's crust and part of the mantle.



Which part of the Earth is comprised of layers **1** and **2**?

A Asthenosphere

B Hydrosphere

C Lithosphere

D Mesosphere

Your answer ☐ **[1]**

24 Which engineering geology technique would be most suitable to give toe support to the sides of a road cutting through shale?

A Gabions

B Rock bolts

C Slope modification

D Wire netting

Your answer ☐ **[1]**

25 Structures built on shrinking and swelling clays can be liable to subsidence.

Which silicate mineral has high shrinking and swelling capacity?

A Biotite

B Chlorite

C Kaolinite

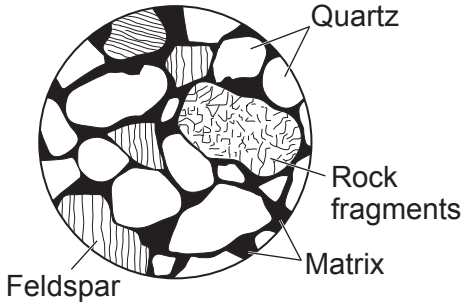
D Smectite

Your answer ☐ **[1]**

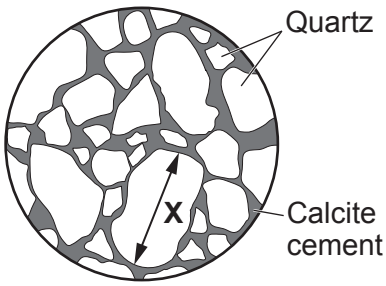
Section B

26 Different sedimentary rocks are shown in the three thin-section diagrams.

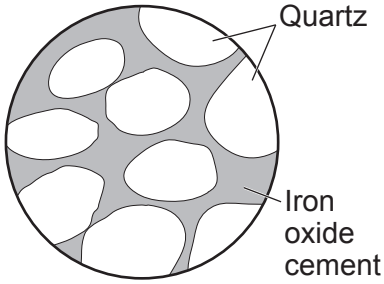
Rock **A**



Rock **B**



Rock **C**



(a) (i) Determine the actual length of grain **X** in rock **B**.

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

Length = ... mm **[2]**

(ii) State the name of the sedimentary rock group to which rocks **A**, **B** and **C** all belong. Give a reason for your answer.

Rock group name .....

Reason .....

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[1]

(iii) Describe **two** differences in texture between rocks **B** and **C**.

1 .....

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2 .....

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[2]

(iv) Explain the difference in formation of the textures shown in rocks **B** and **C**.

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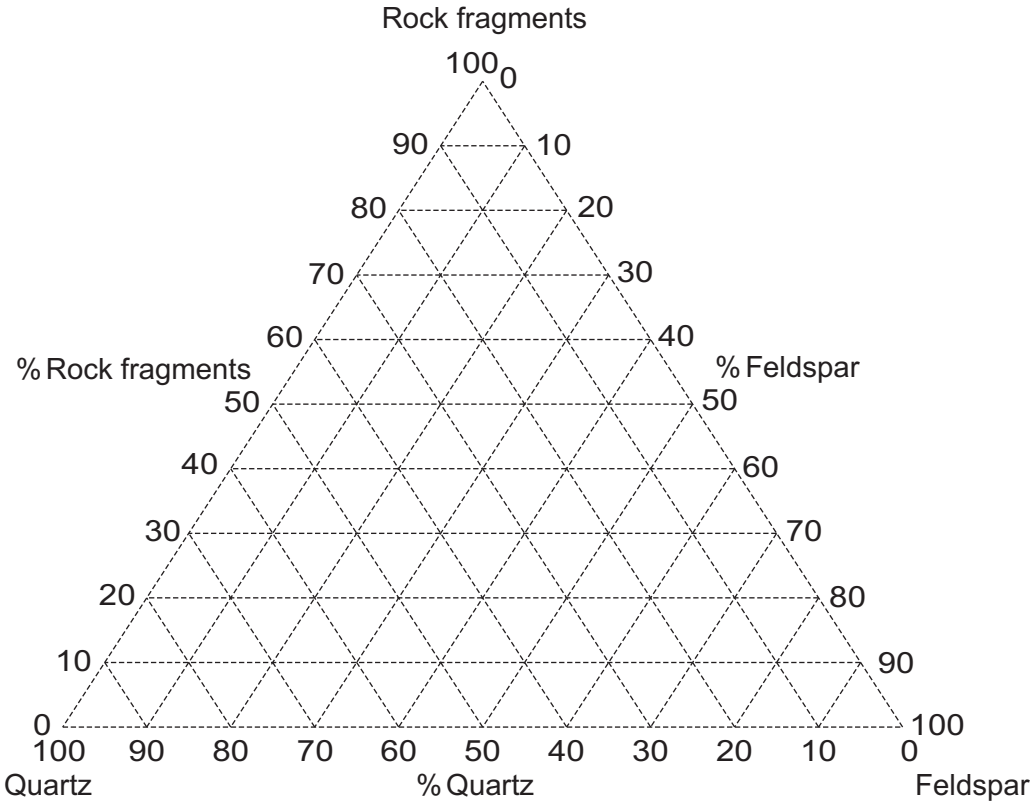
..... **[1]**

(b) The table below gives the composition of the grains in rock **A**.

Grain composition	Quartz	Feldspar	Rock fragments
%	65	25	10

(i) Plot the composition of rock **A** on the triangular diagram below.



[1]

(ii) Analyse the textural and compositional characteristics of rock **A** to determine the environment in which the rock was deposited.

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(c) Describe the evidence from the thin-section diagram of rock **B** that indicates the rock has undergone diagenesis **and** explain how this process of diagenesis occurred.

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

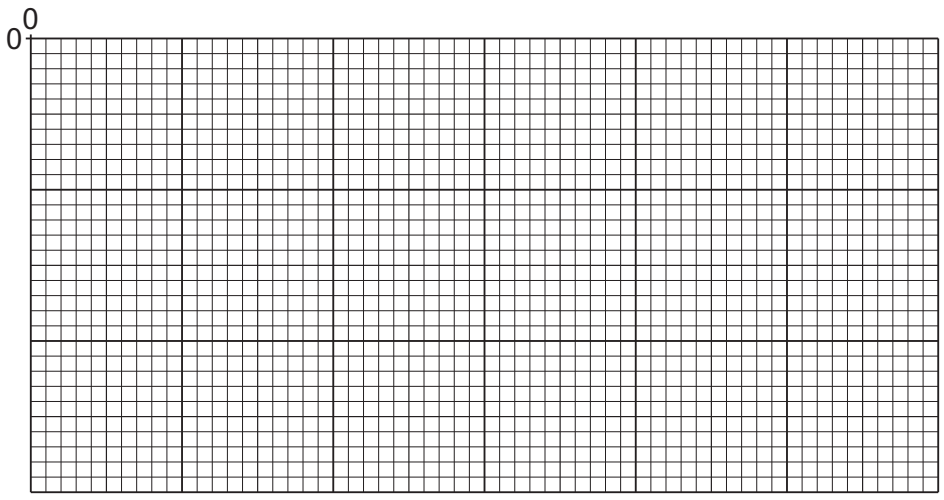
27 Earthquake data for the convergent plate boundary to the west of South America was collected from Google Earth™.

The table shows a Spearman's rank correlation coefficient test to investigate the relationship between the distance from the plate boundary and the depth of foci of earthquakes.

The null hypothesis (H_0) is that 'there is no significant relationship between the depth of foci of the earthquakes and their distance from the plate boundary'.

Distance from plate boundary (km)	Rank 1	Depth of earthquake focus (km)	Rank 2	d	d^2
87	10	30	10	0	0
112	9	41	9	0	0
5	12	10	11.5	0.5	0.25
492	2	45	8	–6	36
431	3	201	2	1	1
503	1	209	1	0	0
280	6	119	5	1	1
147	8	61	7	1	1
30	11	10	11.5	–0.5	0.25
231	7	89	6	1	1
400	4	189	3	1	1
331	5	168	4	1	1
				$\sum d^2$	42.5

(a) (i) Use the data from the table to plot a scatter graph of depth of earthquake focus (*y*-axis) against distance from the plate boundary (*x*-axis).



[4]

(ii) Draw a line **on your graph** to show the likely position of the plate boundary beneath the Earth's surface at this location. **[1]**

(iii) Explain why this pattern of earthquake foci occurs.

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

(iv) Circle the anomalous point **on your graph**. **[1]**

(v) Suggest a geological reason for an earthquake at this location.

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

(b) (i) Calculate the Spearman's rank correlation coefficient (r_s) for the earthquake data.

Use the formula: $r_s = 1 - \dfrac{6\sum d^2}{n(n^2 - 1)}$

where n is the number of pairs of values.

r_s = ... **[2]**

(ii) The table below is an excerpt of critical values for the Spearman's rank correlation coefficient.

	10%	**5%**	**2%**	**1%**
n				
9	0.6000	0.7000	0.7833	0.8330
10	0.5636	0.6485	0.7455	0.7939
11	0.5364	0.6182	0.7091	0.7545
12	0.5305	0.5874	0.6783	0.7273

Use information from this table and the degrees of freedom of $n-2$, where n is the number of pairs of values, to comment on the statistical significance of the r_s value you have calculated.

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

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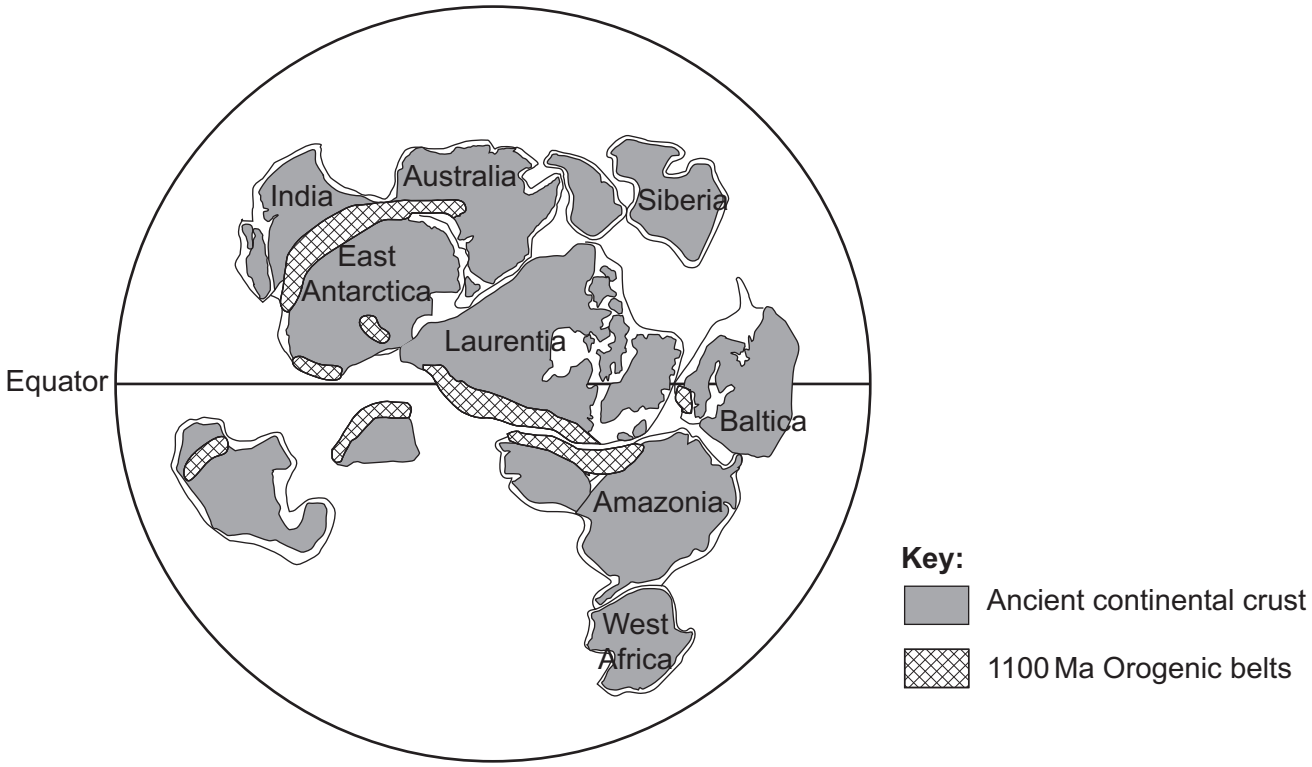
28 The Neoproterozoic Era (1000 to 542 Ma) was marked by the assembly and break-up of the supercontinents Rodinia and Pannotia and at least two global scale glaciations referred to as 'Snowball Earth' events.

The map of the Earth shows a plate tectonic reconstruction of the position of the supercontinent Rodinia 750 Ma.



(a)* Describe and explain the plate tectonic processes in the Wilson cycle that result in the formation and break-up of supercontinents such as Rodinia and Pannotia. **[6]**

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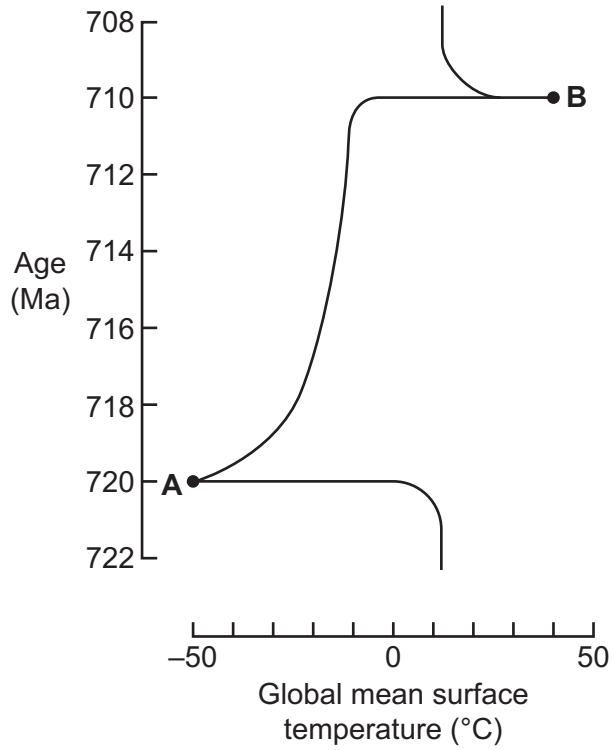
(b) The graph shows the changes in global mean surface temperature of the Earth during one Neoproterozoic Snowball Earth event.



(i) Calculate the mean rate of global surface temperature change between points **A** and **B** on the graph. Give your answer in $°C\,Ma^{-1}$.

Mean rate of global surface temperature change = ... $°C\,Ma^{-1}$ **[2]**

(ii) Draw an arrow **on the graph** above to mark a time of probable rapid sea level rise. **[1]**

(c) Polar wandering curves and lithological evidence show that ice extended from the poles to the Equator during this Neoproterozoic Snowball Earth event.

(i) Describe and explain how a record of the Earth's magnetic field can be preserved in rocks at the time of their formation.

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

(ii) Describe how the geomagnetic evidence (palaeomagnetism) preserved in rocks would show they formed at the Equator.

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(iii) State what lithological evidence might be found in the geological record to support the theory that ice caps extended to the Equator at this time.

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

(d) One theory that has been used to explain the onset of this Snowball Earth event is that intense tropical weathering of rocks occurred during the breakup of Rodinia.

(i) Describe how silicate rocks undergo chemical weathering.

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

(ii) Explain how chemical weathering of silicate rocks could change the composition of the atmosphere **and** why this would lead to global cooling.

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

(iii) State the lithological evidence that might be found in the geological record to support the theory that chemical weathering of silicate rocks changed the composition of the atmosphere at this time.

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

(iv) Explain how the development of ice cover on land could cause further global cooling.

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(e) Describe and explain how volcanic activity may have ended this Snowball Earth event.

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29 Tsunamis have the potential to cause widespread damage and destruction to coastal areas.

(a) Explain why the risk of tsunamis is considered to be higher in the Pacific Ocean in comparison to the Atlantic Ocean.

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

(b) The 2004 Sumatra-Andaman and the 2011 Tōhoku earthquakes both generated large tsunamis.

The table below compares these two events.

Location of earthquake	Moment magnitude (M_w)	Depth of focus (km)	Maximum height of tsunami wave generated (m)	Damage caused by tsunami
Sumatra-Andaman, Indonesia **Indian Ocean**	9.1	30	33.0	More than 227 000 people killed, widespread damage
Tōhoku, Japan **Pacific Ocean**	9.1	32	38.9	18 550 people killed, widespread damage

Suggest and explain reasons why the loss of life for these two similar magnitude tsunami events was so different.

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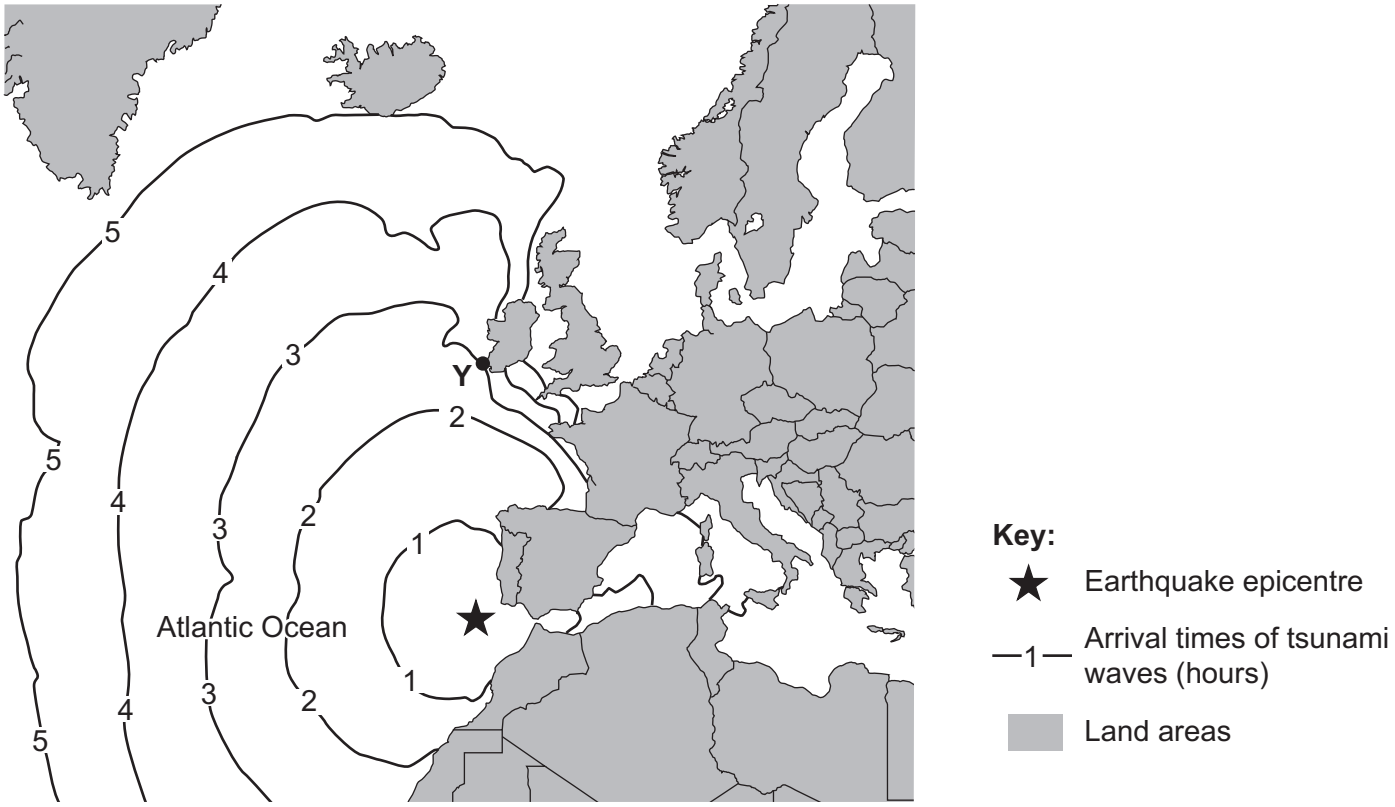
(c) Although considered to be at low risk, tsunamis have occurred in the Atlantic Ocean in the past.

The map shows travel times in the Atlantic Ocean for a tsunami produced by the 1755 Lisbon earthquake.



(i) The moment magnitude of the earthquake that caused the 1755 tsunami is estimated to have been in the range of 8.5 to 9.0.

Explain why the magnitude of this earthquake is only an estimate.

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

(ii) State how long it took the tsunami waves to reach point **Y** on the southwest coast of Ireland.

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

(iii) Point **Y** is 1500 km from the earthquake epicentre.

Calculate the speed of the tsunami waves reaching this point. Give your answer in $m\,s^{-1}$.

Speed of the tsunami waves = ... $m\,s^{-1}$ **[2]**

(d) Describe the geological evidence that suggests significant tsunamis have affected the coast of the British Isles in the recent past.

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

(e) About 8100 years ago the Storegga Slide caused a tsunami up to 25 metres high that swept across the Scottish coast and islands.

Describe the Storegga Slide event and explain how it generated a tsunami.

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(f) Outline the difficulties of communicating seismic hazard risk analysis information to non-specialists.

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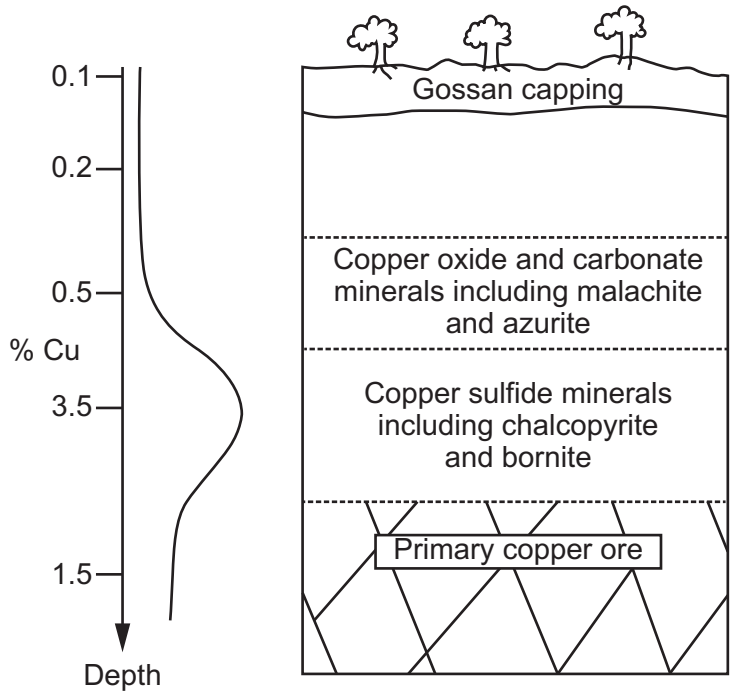
30 Porphyry copper ore deposits are an important source of copper.

(a) The diagram is a simplified cross-section through part of a porphyry copper deposit located in the Atacama Desert of Chile. The ore deposit has undergone secondary enrichment.

The sketch graph on the left side shows the change in copper content with depth.



(i) Draw and label a line **on the cross-section diagram** to show the likely position of the water table when secondary enrichment occurred. **[1]**

(ii) Describe and explain the processes that occur above **and** below the water table during secondary enrichment of copper.

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(iii) Explain why secondary enrichment processes are no longer occurring at this location.

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(b)* The table shows density, electrical resistivity and magnetic susceptibility data for some common porphyry copper ore deposit host rocks and copper ore minerals.

	Density ($kg\,m^{-3}$)	**Electrical resistivity ($\Omega\,m$)**	**Magnetic susceptibility ($10^{-8}\,m^3\,kg^{-1}$)**
Host rocks			
Diorite	2720 – 2990	10^3 – 10^4	22 – 4400
Granite	2500 – 2810	10^4 – 10^6	0 – 1900
Granodiorite	2670 – 2790	10^4 – 10^5	2 – 3100
Copper ore minerals			
Bornite	5090	10^{-5}	0 – 13
Chalcopyrite	4200	10^{-4}	0 – 10

Compare the data in the table for host rocks and copper ore minerals to suggest and evaluate which geophysical exploration techniques are likely to be most successful in locating porphyry copper ore deposits.

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Additional answer space if required.

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(c) The first stage in the life cycle of a mining operation is planning.

Describe this stage of mine development.

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

(d) Heap leaching followed by solvent extraction and electrowinning (SX/EW) is becoming a common method of extracting copper from copper ore.

SX/EW uses an organic solvent to purify the leach solution followed by electrolysis to produce the copper metal.

(i) Describe how heap leaching is carried out.

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

(ii) Suggest and explain the advantages of using heap leaching, solvent extraction and electrowinning to extract copper compared to the traditional method of smelting the ore.

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

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).

OCR
Oxford Cambridge and RSA

Tuesday 4 June 2024 – Morning

A Level Geology

H414/01 Fundamentals of geology

Time allowed: 2 hours 15 minutes

You can use:
- an HB pencil
- a protractor
- a ruler (cm/mm)
- a scientific or graphical calculator

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

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

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

INFORMATION
- The total mark for this paper is **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 **28** pages.

ADVICE
- Read each question carefully before you start your answer.

Section A

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

For each question write the letter in the box.

The diagram shows a thin section of a rock made of one mineral.

×10

Use the thin section diagram to answer questions **1** and **2**.

1 The mineral in the rock has rhombohedral cleavage and is scratched by a copper coin but not by a fingernail.

Which mineral is the rock composed of?

A Calcite

B Orthoclase feldspar

C Plagioclase feldspar

D Quartz

Your answer ☐ **[1]**

2 What is the rock type?

A Marble

B Metaquartzite

C Orthoquartzite

D Phyllite

Your answer ☐ **[1]**

3 The table shows the bulk composition of a sample from a chondritic meteorite that fell to Earth in 1934.

Oxide	Weight (%)
SiO_2	39.1
Al_2O_3	1.9
FeO	31.5
MgO	20.7
CaO	1.5
Others	5.3

Which layer of the Earth has a composition most similar to this meteorite?

A Continental crust

B Mantle

C Oceanic crust

D Outer core

Your answer ☐ **[1]**

4 The nebular hypothesis explains the formation of the Solar System.

What is the correct order of the formation of the Solar System according to this hypothesis?

	Earliest event	→	Latest event
A	Giant nebula collapses	Rotation **decreases** and protoplanetary disc forms	Formation of planetesimals
B	Giant nebula collapses	Rotation **increases** and protoplanetary disc forms	Formation of planetesimals
C	Rotation **decreases** and protoplanetary disc forms	Formation of planetesimals	Giant nebula collapses
D	Rotation **increases** and protoplanetary disc forms	Formation of planetesimals	Giant nebula collapses

Your answer ☐ **[1]**

5 The mineral composition of the layers of the Earth have been inferred using both direct and indirect evidence.

Pyroxene (augite) and plagioclase feldspar are the main minerals in which layer of the Earth?

A Continental crust

B Lower mantle

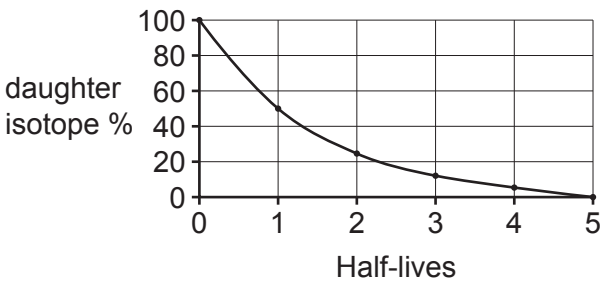
C Oceanic crust

D Upper mantle

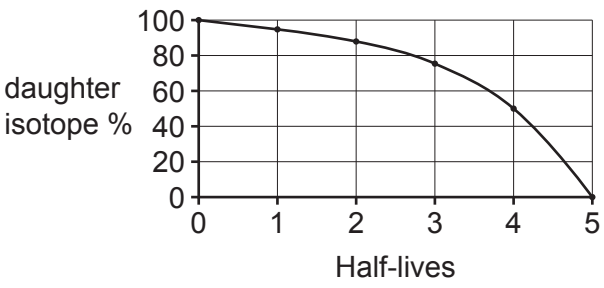
Your answer ☐ **[1]**

6 Which graph, **A**, **B**, **C** or **D**, shows the correct shape for the formation of a daughter isotope during radioactive decay?

A

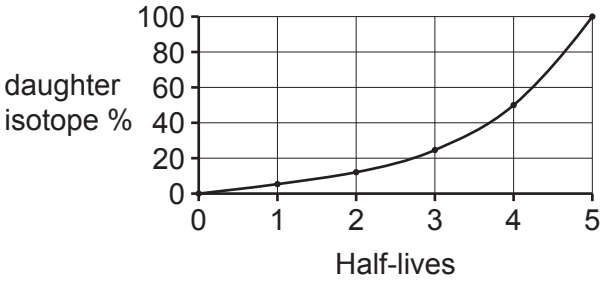


B



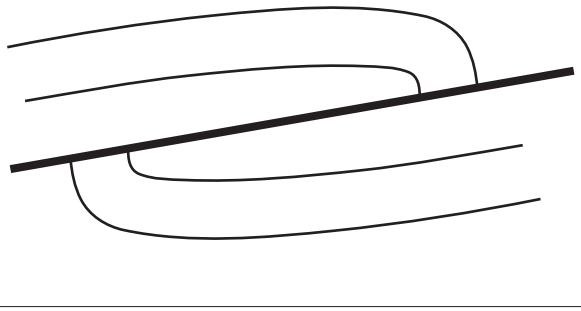
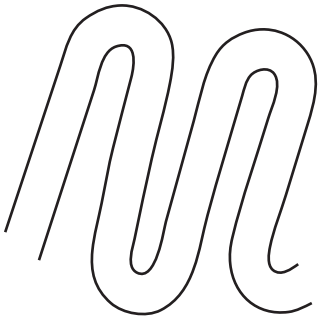
C

D



Your answer ☐ **[1]**

7 The cross-section diagrams show fold structures formed at convergent plate margins.

	
Fold **1** 1 cm = 200 m	Fold **2** 1 cm = 100 m

Identify these fold structures.

	Fold 1	**Fold 2**
A	Isoclinal	Nappe
B	Isoclinal	Overfold
C	Nappe	Isoclinal
D	Overfold	Isoclinal

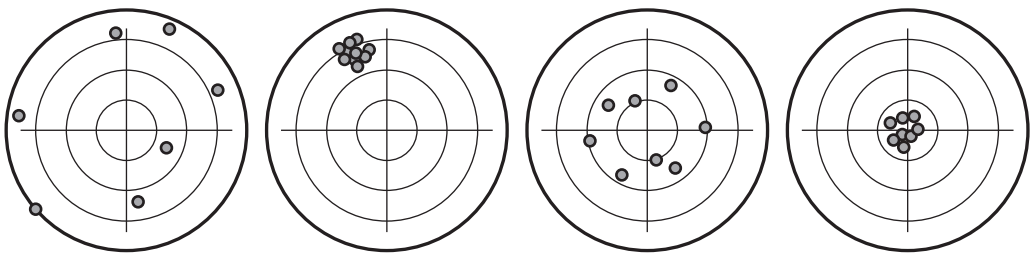
Your answer ☐ **[1]**

8 Global positioning systems (GPS) allow accurate and precise measurement of the relative movement of lithospheric plates.

For the repeat GPS measurements in the diagrams below the true value is at the centre of each chart.

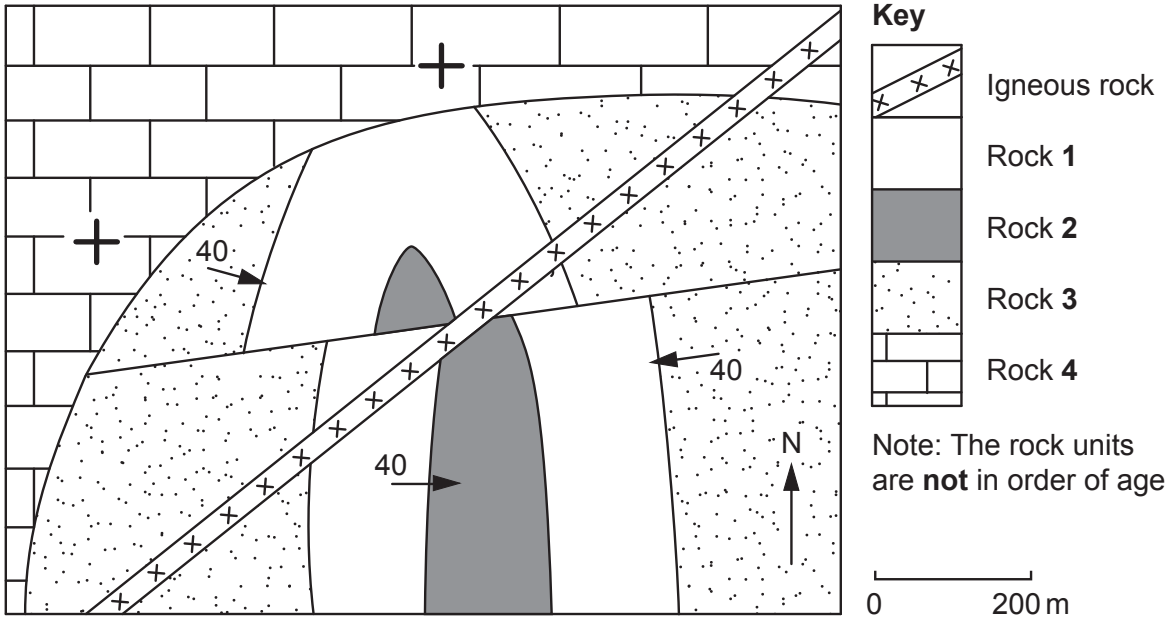
Which diagram, **A**, **B**, **C** or **D**, shows repeat measurements that are accurate but imprecise?

A **B** **C** **D**



Your answer ☐ **[1]**

The geological map shows a flat area. The sedimentary rocks are the right way up.



Use the geological map to answer questions **9**, **10** and **11**.

9 Apply relative dating techniques to determine the youngest feature on the geological map.

A Dyke

B Fault

C Fold

D Unconformity

Your answer ☐ **[1]**

10 Apply relative dating techniques to determine the oldest rock on the geological map.

A Rock **1**

B Rock **2**

C Rock **3**

D Rock **4**

Your answer ☐ **[1]**

11 Identify the fold structure shown on the geological map.

A Antiform plunging north

B Antiform plunging south

C Synform plunging north

D Synform plunging south

Your answer ☐ **[1]**

12 The Al_2SiO_5 polymorphs are useful metamorphic index minerals.

What would be the correct order of formation of the Al_2SiO_5 polymorphs during retrograde metamorphism?

A Andalusite to garnet

B Andalusite to sillimanite

C Kyanite to sillimanite

D Sillimanite to andalusite

Your answer ☐ **[1]**

13 The transmission of seismic energy depends on the competence of the rock.

Through which rock type would the velocity of P waves be lowest?

A Gabbro

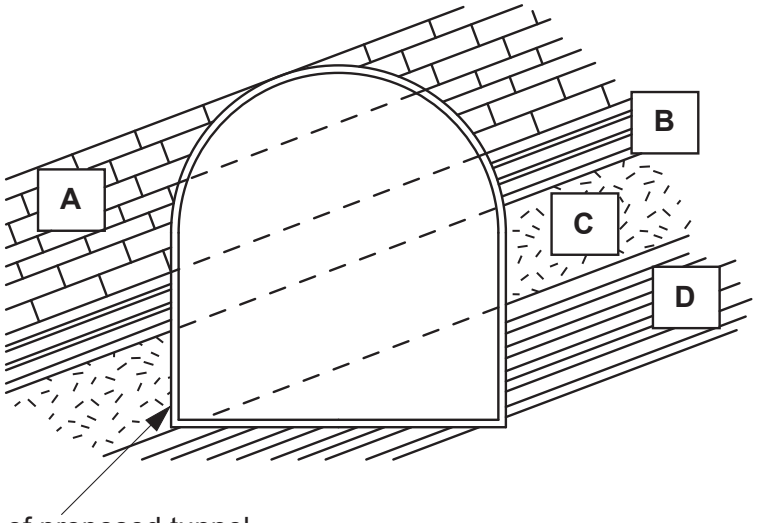
B Limestone

C Mudstone

D Schist

Your answer ☐ **[1]**

The geological cross-section shows an area where a tunnel is due to be constructed.



A Massive beds of well jointed, fissured limestone

B Thin beds of alternating mudstones and sandstones

C Dolerite sill

D Very thin beds of fissile, crumbly shale

Use the cross-section diagram to answer questions **14** and **15**.

14 The tunnel will be constructed using drilling and blasting techniques.

In which rock unit, **A**, **B**, **C** or **D**, is the engineering geology problem of underbreak, where not enough material is removed, most likely to occur?

Your answer ☐ **[1]**

15 There are concerns that the proposed tunnel may flood.

Through which rock unit, **A**, **B**, **C** or **D**, is high water flow most likely?

Your answer ☐ **[1]**

16 A dam and reservoir are planned for water supply. The dam is to be constructed in a broad, shallow valley on clay bedrock.

Which type of dam would be most suitable for this purpose?

A Arch dam

B Buttress dam

C Earth dam

D Gravity dam

Your answer ☐ **[1]**

17 In groundwater supplies, which term would describe a rock unit with a coefficient of permeability of $10^{-6}\,ms^{-1}$ (very low)?

A Aquiclude

B Aquitard

C Confined aquifer

D Unconfined aquifer

Your answer ☐ **[1]**

18 The minerals in rocks that groundwater has flowed through can affect drinking water quality.

The presence of which mineral is most likely to affect the quality of drinking water to toxic levels?

A Calcite

B Galena

C Pyrite

D Quartz

Your answer ☐ **[1]**

19 During which geological time period since the start of the Permian was global sea level at its highest?

A Cretaceous

B Jurassic

C Permian

D Triassic

Your answer ☐ **[1]**

20 The study of the ecology of modern reef-building corals and their comparison with fossil corals allow fossil corals to be used as palaeoenvironmental indicators.

Which combination in the table are the best conditions for good coral growth?

	Water temperature (°C)	Water depth (m)	Salinity (‰)
A	21	60	65
B	23	45	55
C	25	30	45
D	27	15	35

Your answer ☐ **[1]**

21 Which combination of sedimentary conditions led to the exceptional preservation of a range of organisms, including *Archaeopteryx*, in the Jurassic Solnhofen Limestone?

A High salinity and anoxic conditions

B High salinity and oxic conditions

C Low salinity and anoxic conditions

D Low salinity and oxic conditions

Your answer ☐ **[1]**

22 Carboniferous rocks are the main source rocks for natural gas in the Southern Basin of the North Sea.

In which palaeoenvironment were these source rocks deposited?

A Deltaic bottomset beds

B Deltaic foreset beds

C Deltaic topset beds

D Shallow marine platform carbonates

Your answer ☐ **[1]**

23 Which of these is unlikely to result in the loss of oil or natural gas from a trap structure?

A Erosion

B Faulting

C Lateral spill point

D Subsidence

Your answer ☐ **[1]**

24 Cephalopod fossils can be used to zone and correlate rocks in sedimentary basin analysis.

Which cephalopods are used to zone the Jurassic Period?

A Ammonites and belemnites

B Ammonites and ceratites

C Belemnites and nautiloids

D Ceratites and goniatites

Your answer ☐ **[1]**

25 What is the geological time range for trilobites?

A Cambrian to Carboniferous

B Cambrian to Permian

C Ordovician to Permian

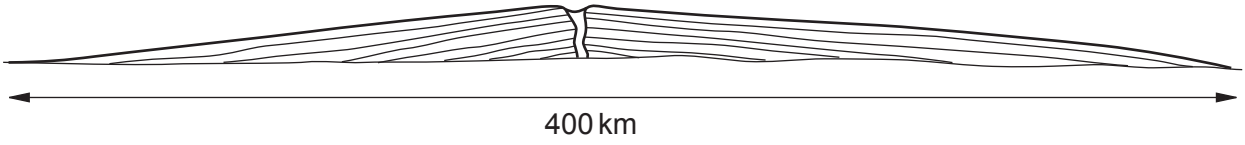
D Ordovician to Triassic

Your answer ☐ **[1]**

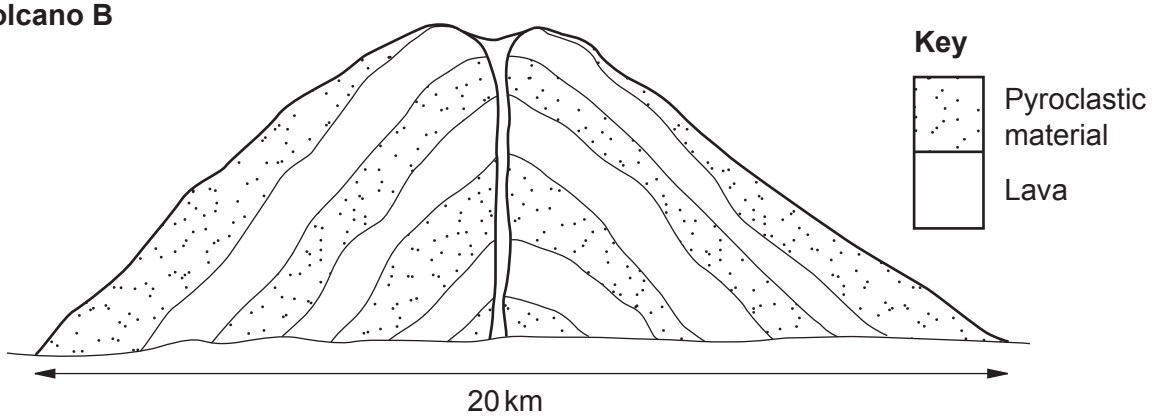
Section B

26 The diagrams show cross-section forms of **two** volcanoes, **A** and **B**.

Volcano A



Volcano B



(a)

(i) Identify the type of volcano shown in each cross-section diagram.

Volcano **A** .....

Volcano **B** .....

[2]

(ii) State the most likely plate tectonic settings for the locations of volcanoes **A** and **B**.

Plate tectonic setting for volcano **A** .....

Plate tectonic setting for volcano **B** .....

[2]

(b) Explain how magma forms at convergent plate margins.

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

(c) Buoyancy and viscosity are two factors that affect the behaviour of magma.

(i) Explain the difference between buoyancy and viscosity.

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

(ii) Outline a simple experiment that could be carried out in a school science laboratory to model the viscosity of magma using a liquid such as golden syrup.

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(d) Describe the process of intrusion by which magma ascends through the crust.

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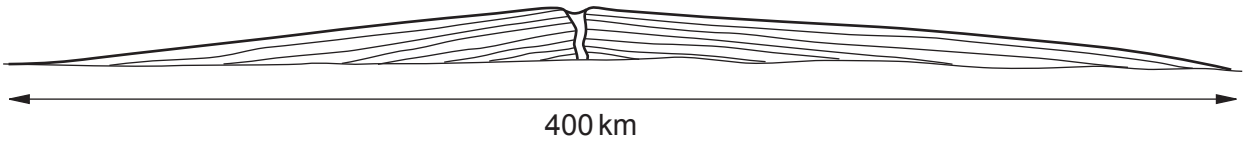
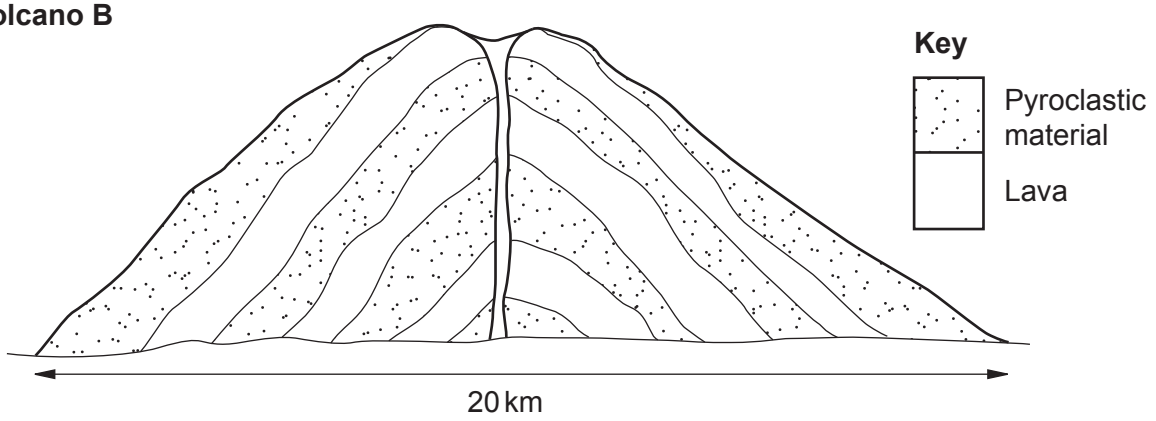
Cross-sections of volcanoes **A** and **B** are shown again for reference.

Volcano A



Volcano B



(e) The volume of material erupted from a volcanic vent each second is known as the discharge rate (Q). The discharge rate depends on:

- the depth of the magma chamber (d)
- the pressure within the magma chamber (P)
- the radius of the volcanic conduit (r)
- the viscosity of the magma (μ).

The table shows data for the start of an eruption from volcanoes **A** and **B**.

Volcano	d (m)	P (Pa)	r (m)	μ (Pa s)
A	5000	5.0×10^6	1.0	100
B	7000	3.0×10^7	50.0	450

The discharge rate for volcano **B** is $2.34 \times 10^7\ m^3\ s^{-1}$.

The formula for calculating the discharge rate is: $Q = \frac{\pi r^4 P}{8 \mu d}$

Use the formula and the data in the table to calculate the discharge rate for volcano **A**.

Give your answer to **3** significant figures.

Discharge rate for volcano **A** = ... $m^3\ s^{-1}$ **[3]**

(f)* Compare the nature of the eruption styles and volcanic hazards that would be associated with volcanoes **A** and **B**.

Use your knowledge of different magma compositions and characteristics to explain your answer.

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Extra answer space if required.

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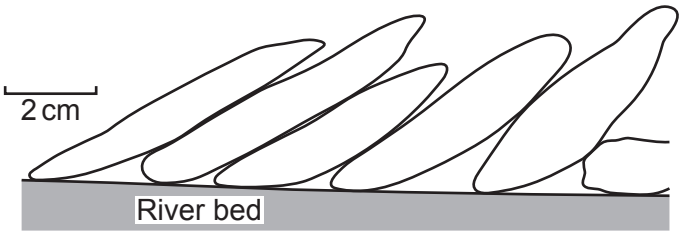
27

(a) The cross-section diagram shows an imbricate structure formed in river sediments.



(i) Draw an arrow above the diagram to show the current direction at the time of formation. **[1]**

(ii) Explain how an imbricate structure forms.

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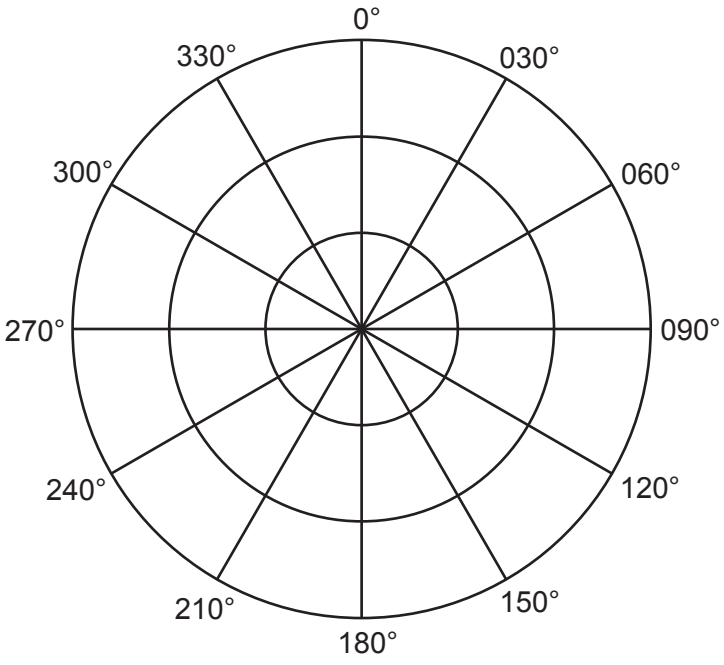
(b)

(i) The table shows measurements of dip direction of clasts in an ancient fluvial deposit showing imbrication.

Plot the data from the table on the rose diagram.

Dip direction (°)	Number of clasts measured
001–030	10
031–060	15
061–090	8
091–120	2
121–150	1
151–180	0
181–210	0
211–240	0
241–270	0
271–300	0
301–330	2
331–360	4

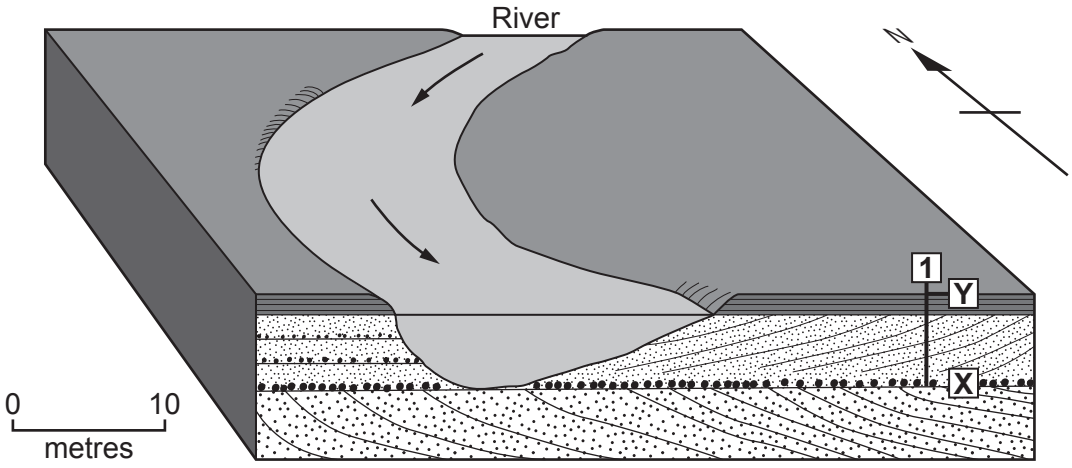


[2]

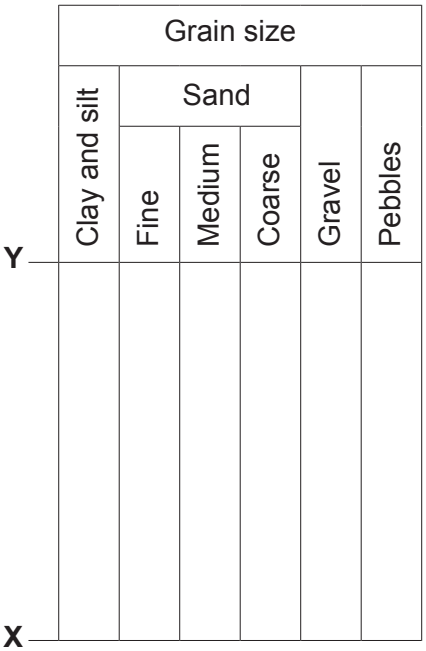
(ii) Interpret the palaeocurrent direction shown by the imbrication.

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

(c) The block diagram shows sediments deposited by a meandering river.



(i) Draw a sketch graphic log on the chart below to show the change in grain size from **X** to **Y** in the vertical sequence at location **1**.



[2]

(ii) Use Walther's Law to help explain how this vertical sequence of fluvial sediments formed.

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

(d) Evaporites can form in playa lakes and shallow marine environments.

(i) State the order of the **four** evaporite minerals that form when a playa lake dries up.

Last to form .....

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.....

First to form .....

[2]

(ii) Explain why the minerals form in this order.

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

(iii) An experiment showed that when a column of seawater 6 m deep was evaporated to dryness it produced an evaporite deposit 10 cm thick.

Based on the results of this experiment, calculate the depth of seawater needed to evaporate to produce an evaporite layer 150 m thick.

= ..... m **[2]**

(iv) Suggest how it is possible for thick sequences of evaporites to form in shallow marine environments.

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

(e)

(i) Describe how chalk forms in deep-water carbonate seas.

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

(ii) Chalk often contains nodules of flint.

Explain the most likely origin of flint nodules in chalk.

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

(iii) Explain why carbonate sediments do not form at depths greater than 5 km in modern marine environments.

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(f)* Describe and explain the differences in texture and mineralogy of sandstones deposited in desert and deep sea turbidite sedimentary environments.

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Extra answer space if required.

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28 Surface processes can be important in concentrating metal ore minerals to form economic deposits.

(a) The table shows properties of some common ore minerals.

Ore mineral	Chemical formula	Cleavage	Density ($g\,cm^{-3}$)	Hardness
Cassiterite	SnO_2	Poor	7.0	6–7
Chalcopyrite	$CuFeS_2$	None	4.2	3.5–4
Galena	PbS	3 at 90°	7.5	2.5
Gold	Au	None	19.3	3

(i) Use the data in the table to evaluate whether each ore mineral is likely to be found concentrated in placer deposits.

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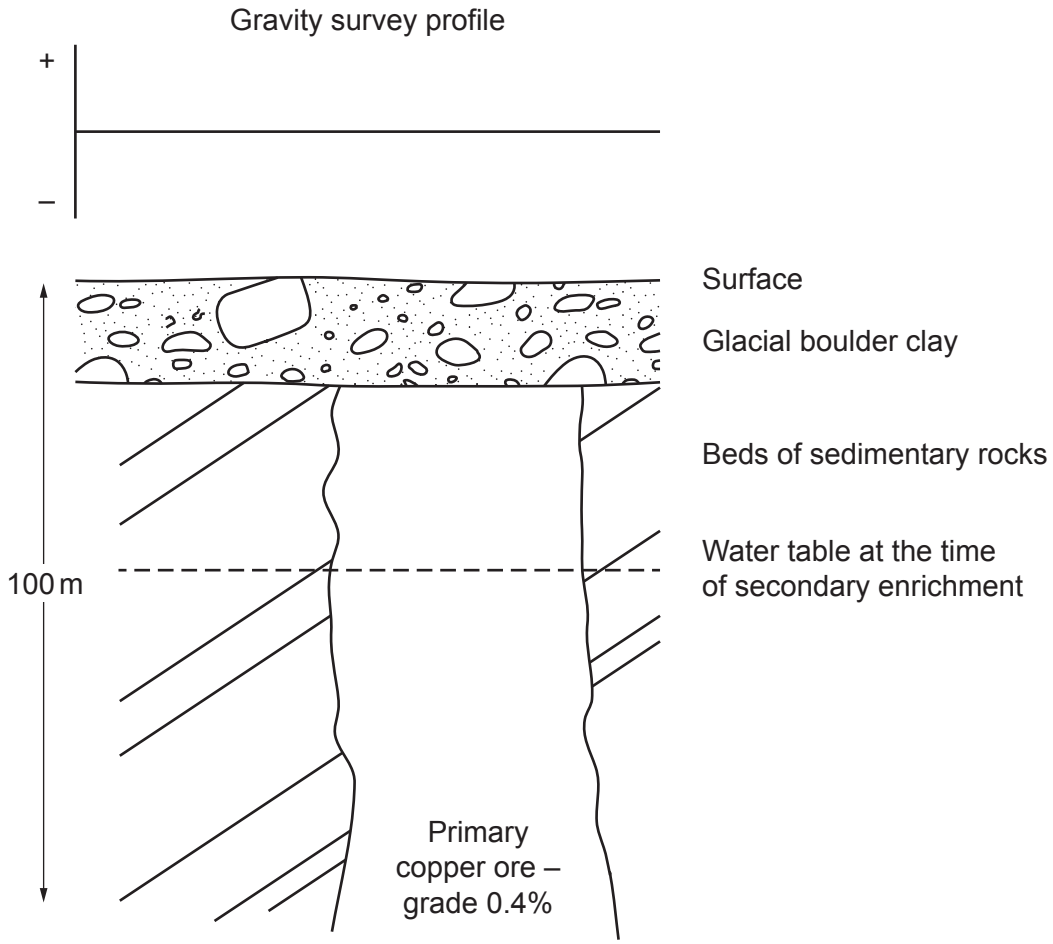
..... **[4]**

(ii) Draw **and** label a cross-section diagram to explain how placer deposits can form on beaches.

[2]

(b) The cross-section diagram shows the geometry of a vein of copper ore discovered using geophysical exploration techniques.

The copper ore has been concentrated by secondary enrichment.



(i) Shade on the cross-section an area where the percentage of copper will be >0.4%. **[1]**

(ii) Draw a sketch graph on the axes above the cross-section diagram to show the shape of the profile that would be produced by a transect gravity survey. **[1]**

(iii) Explain why geochemical exploration techniques may be unsuccessful in locating this vein of copper ore.

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(c) Prior to mining an ore deposit the reserves must be determined.

Describe the follow-up stages of mineral exploration and site investigation that allow reserves to be calculated.

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(d) A porphyry copper ore deposit has a circular cross-section area with a diameter of 800 m and is 500 m thick.

The average density of the ore is 3.2×10^3 kg m^{-3}.

(i) Calculate the mass of this copper ore deposit in tonnes.

Note: 1 tonne = 1000 kg

Mass = ... tonnes **[3]**

(ii) The average grade is 0.6% copper.

Calculate the reserves of copper in this copper ore deposit.

= ..... tonnes **[1]**

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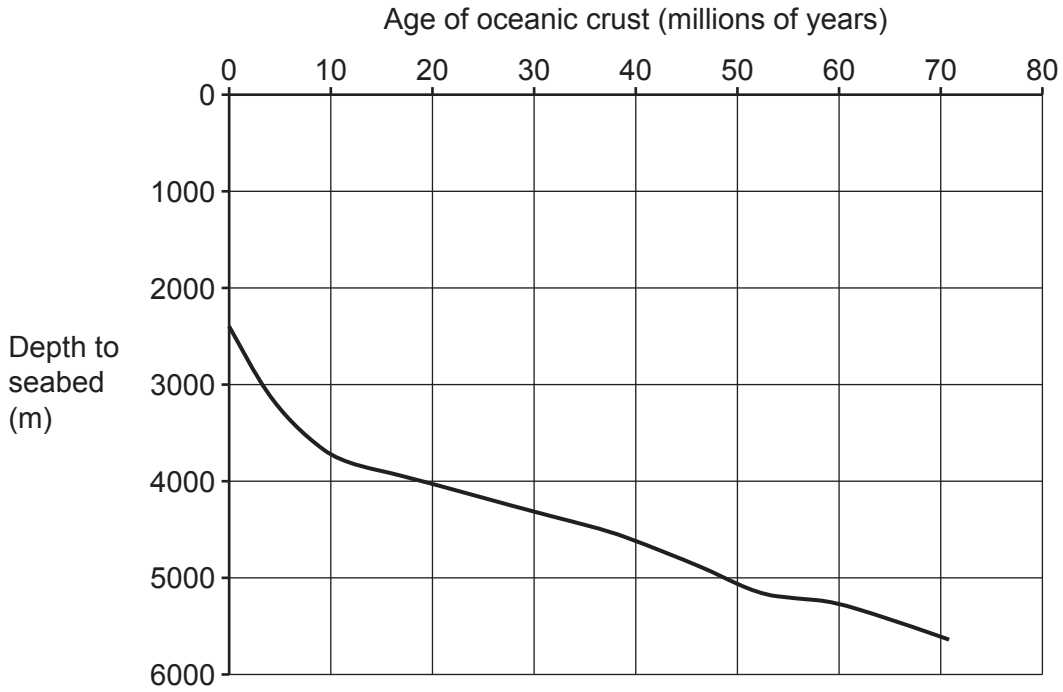
Turn over for the next question

29

(a) The graph shows the relationship between the depth to the seabed and the age of the oceanic crust in the eastern part of the Atlantic Ocean.



(i) Draw an arrow to show the position of the Mid-Atlantic Ridge on the graph. **[1]**

(ii) Explain the change in depth to the seabed shown on the graph.

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(b) A basalt sample obtained from the seabed by dredging was radiometrically dated using the potassium–argon (^{40}K–^{40}Ar) method.

95% of the parent ^{40}K isotope remained in the basalt sample.

The decay rate equation is: $N = N_0e^{-\lambda t}$

Where:

N = % of ^{40}K in the sample

N_0 = initial % of ^{40}K in the sample at the start of decay

λ = the decay constant = 0.693 / 1250 for the ^{40}K–^{40}Ar system

t = the age of the sample in millions of years

Rearrange the decay rate equation to make t the subject.

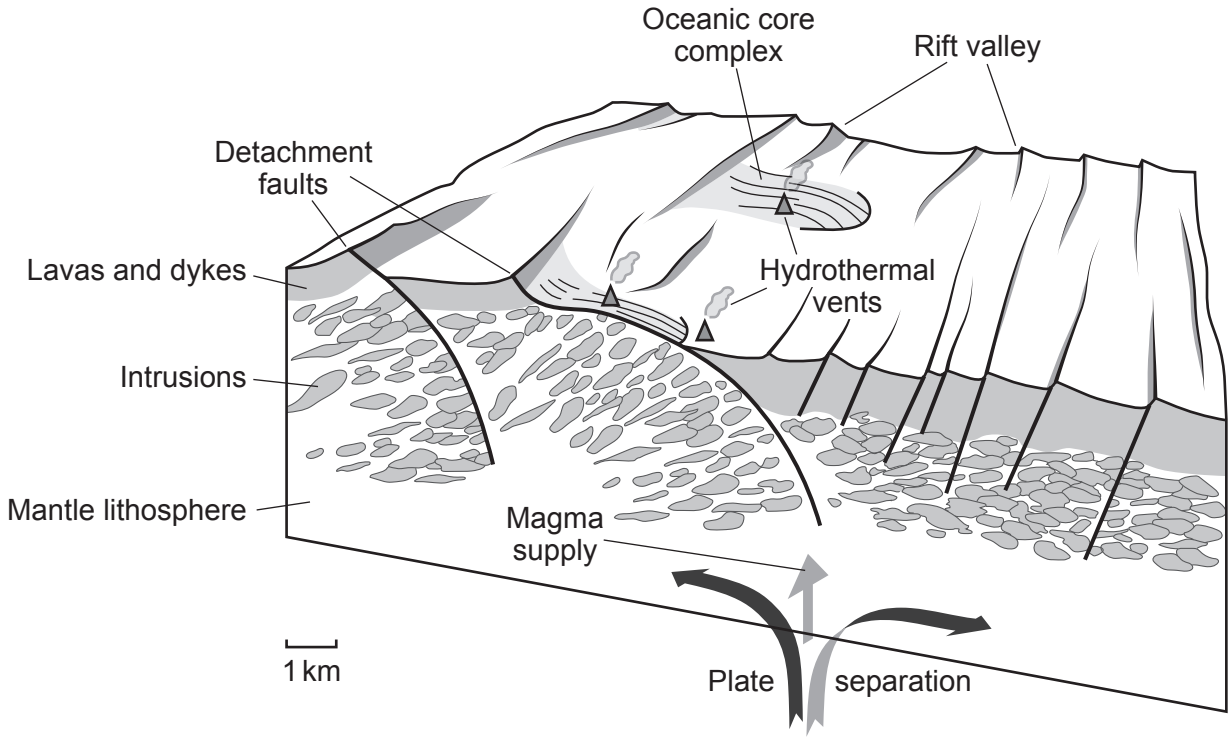
Calculate the age of the basalt sample (t) in millions of years (Ma).

Age of basalt sample (t) = ... Ma **[2]**

(c) The Mid-Atlantic Ridge is a slow-spreading ridge.

Recent research has shown that slow-spreading ridges have unusual features.

The simplified block diagram shows some of these features.



(i) Use information shown on the diagram to describe **one** characteristic of a detachment fault.

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

(ii) Gabbro and peridotite have been found at the surface of oceanic core complexes.

Explain the origin of the gabbro and peridotite and why they are now exposed at the surface.

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

(d) Hydrothermal vents are common along mid-ocean ridges.

(i) Explain how these hydrothermal vents form.

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

(ii) Describe **one** feature and **one** product of hydrothermal vents at mid-ocean ridges.

Feature .....

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Product .....

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[2]

(e) Ore deposits that originated from hydrothermal processes at mid-ocean ridges occur in sequences of oceanic lithosphere found in continental areas.

(i) What name is given to sequences of oceanic lithosphere found in continental areas?

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

(ii) Explain how these sequences become incorporated into continental crust.

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

END OF QUESTION PAPER

EXTRA ANSWER SPACE

If you need extra space use this lined page. You must write the question numbers clearly in the margin.