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

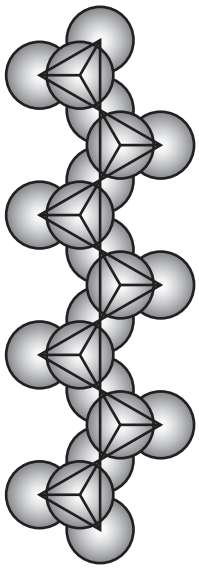
B A naturally occurring aggregate of elements and organic compounds whose composition varies

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

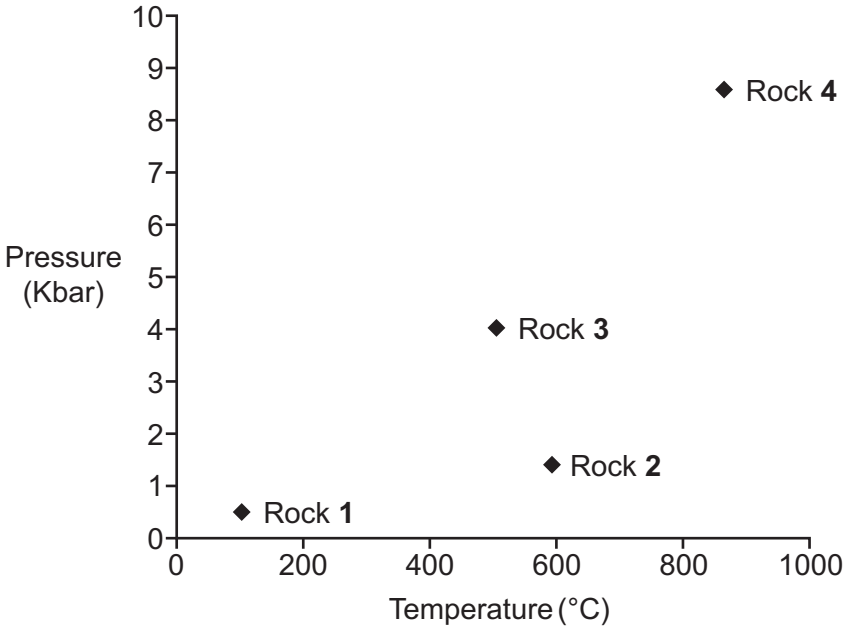
B Micas

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

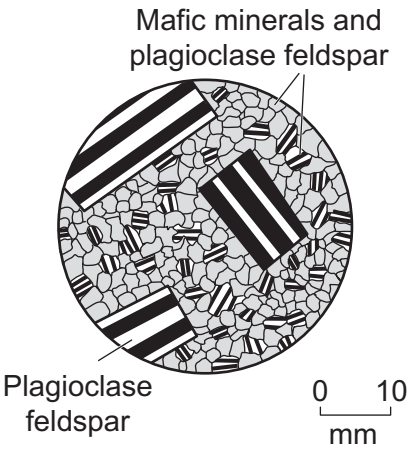
B Gypsum is most soluble and precipitates last

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

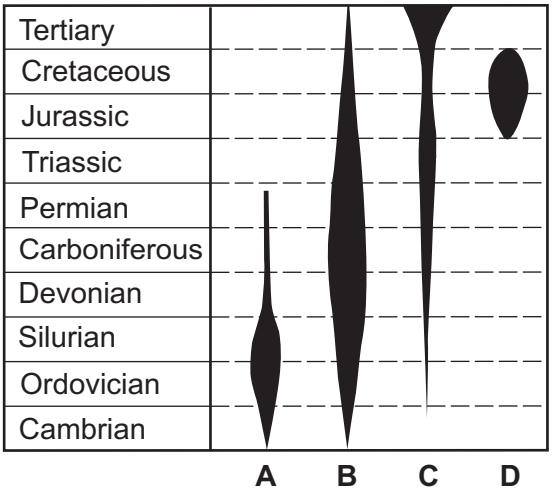
B Numerous with widespread distribution

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

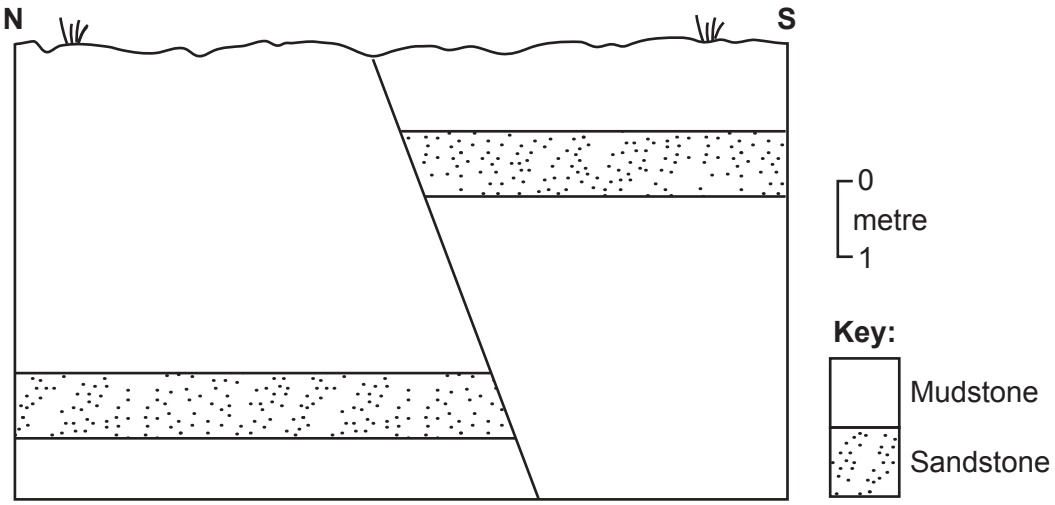
B Pterosauria

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

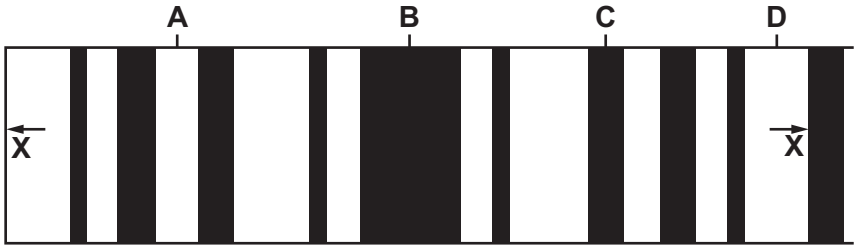
B Only 1 and 2

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

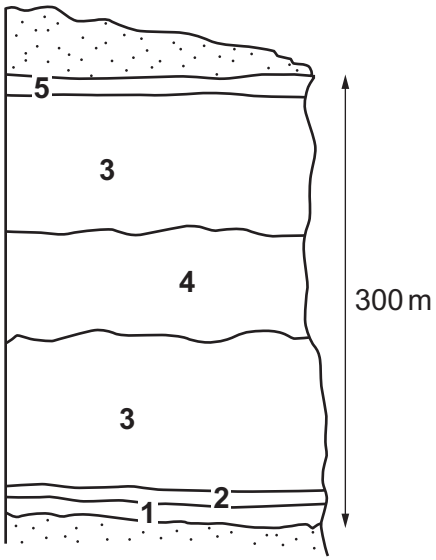
B The 1750 Industrial Revolution of Europe and North America

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**

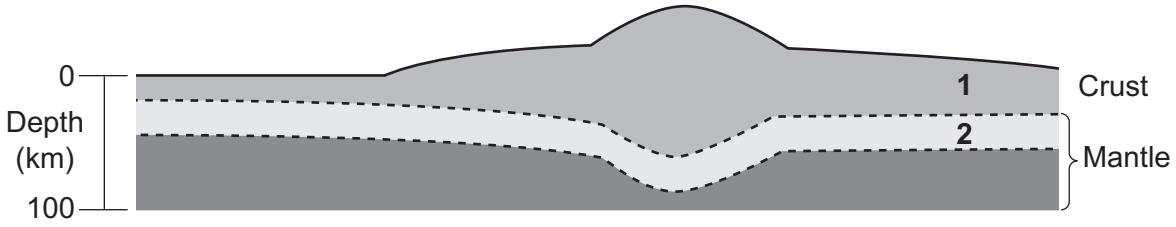
B Layer **2**

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

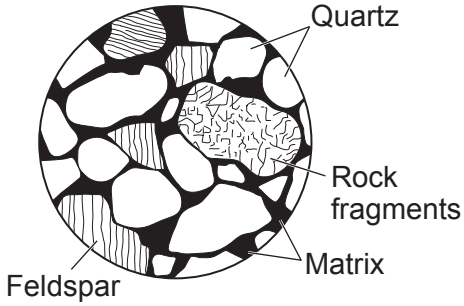
D Smectite

Your answer ☐ **[1]**

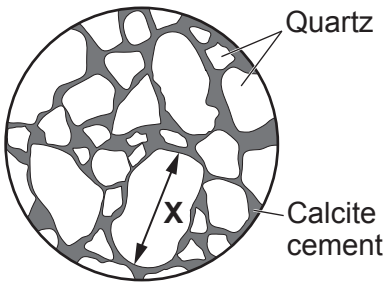
Section B

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

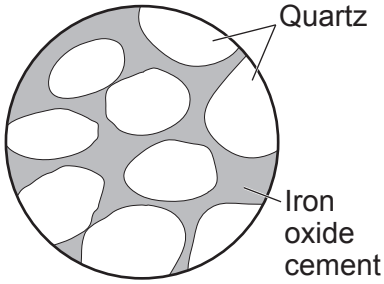
Rock **A**



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**.

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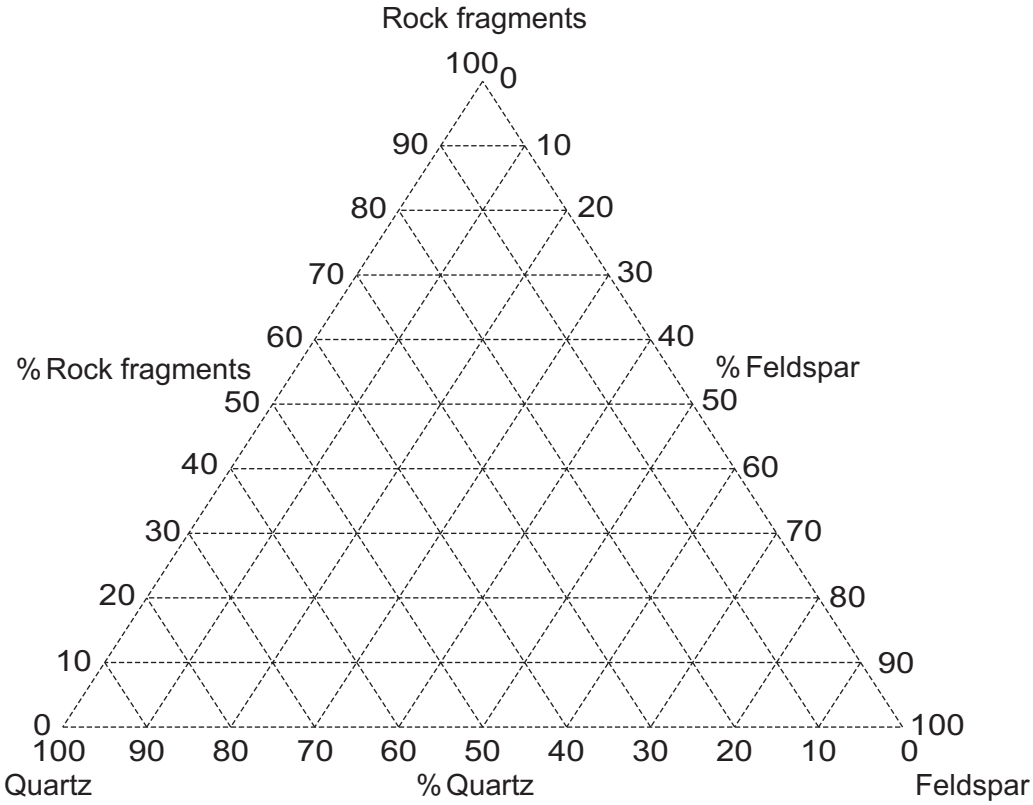
..... **[1]**

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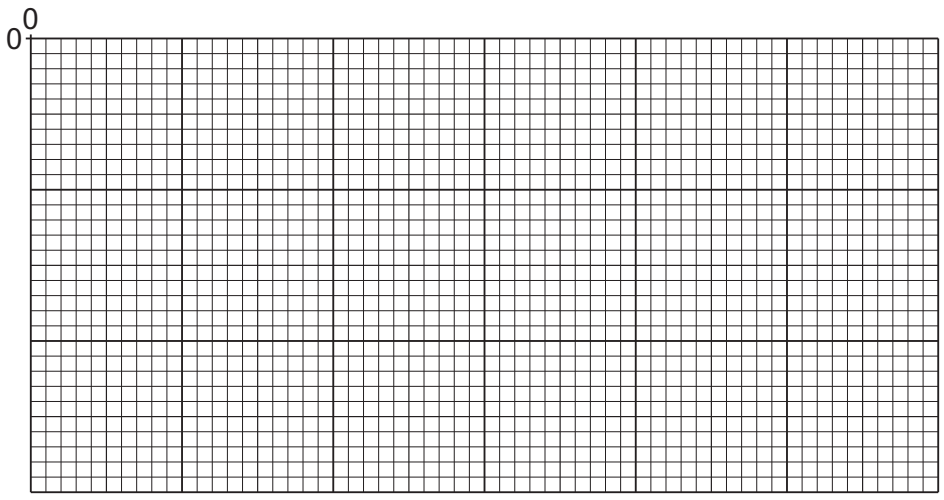
27 Earthquake data for the convergent plate boundary to the west of South America was collected from Google Earth™.

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

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

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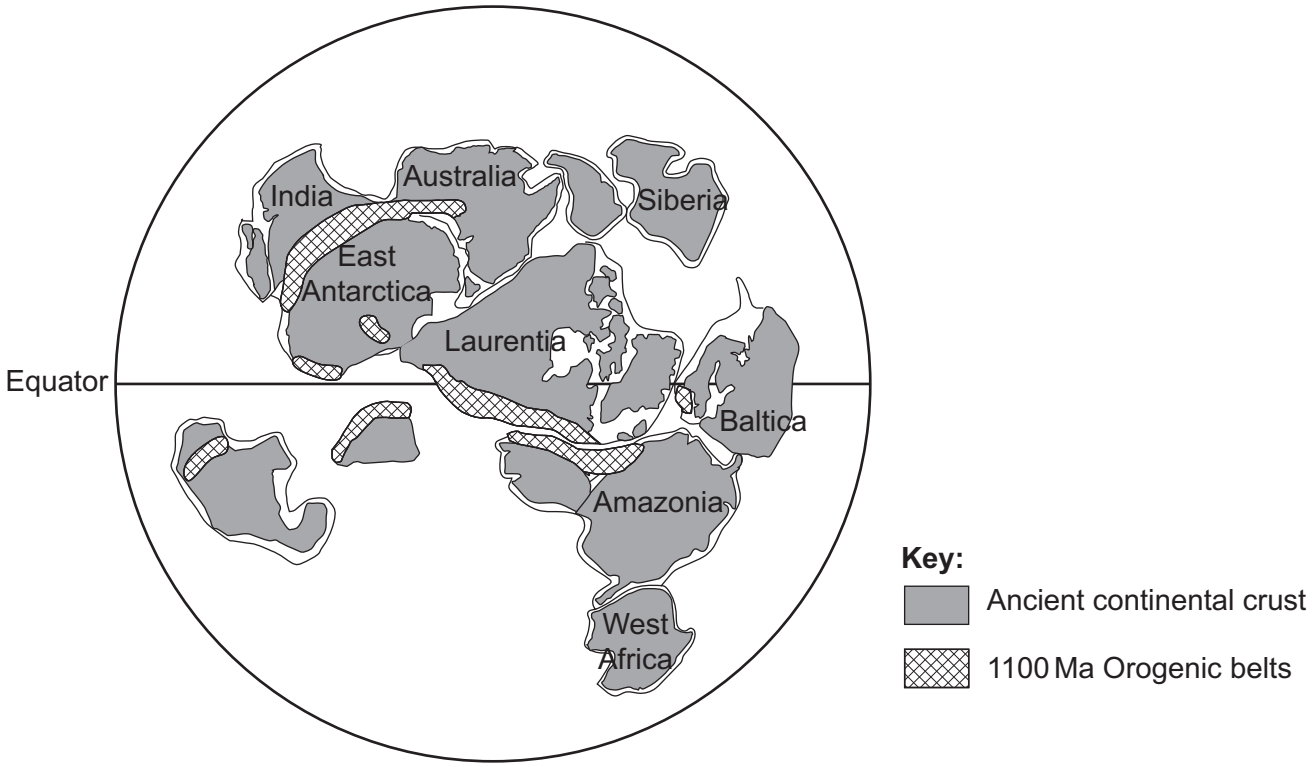
28 The Neoproterozoic Era (1000 to 542 Ma) was marked by the assembly and break-up of the supercontinents Rodinia and Pannotia and at least two global scale glaciations referred to as 'Snowball Earth' events.

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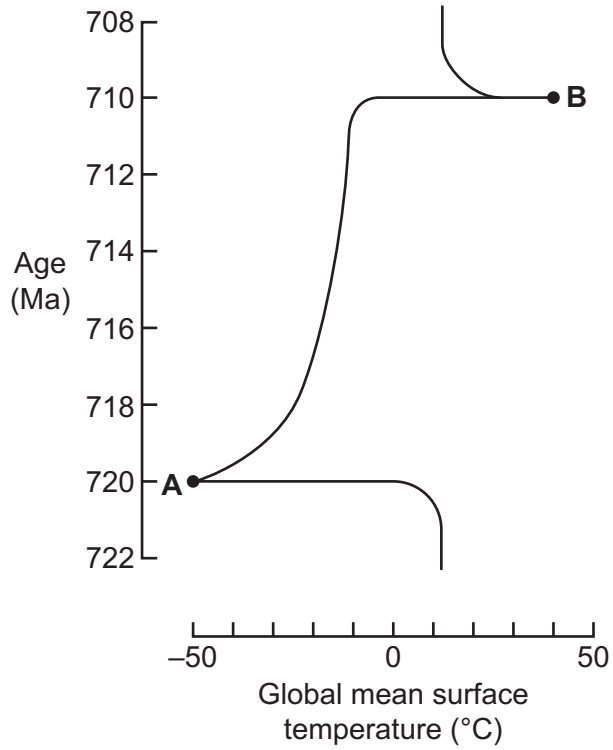
(b) The graph shows the changes in global mean surface temperature of the Earth during one Neoproterozoic Snowball Earth event.



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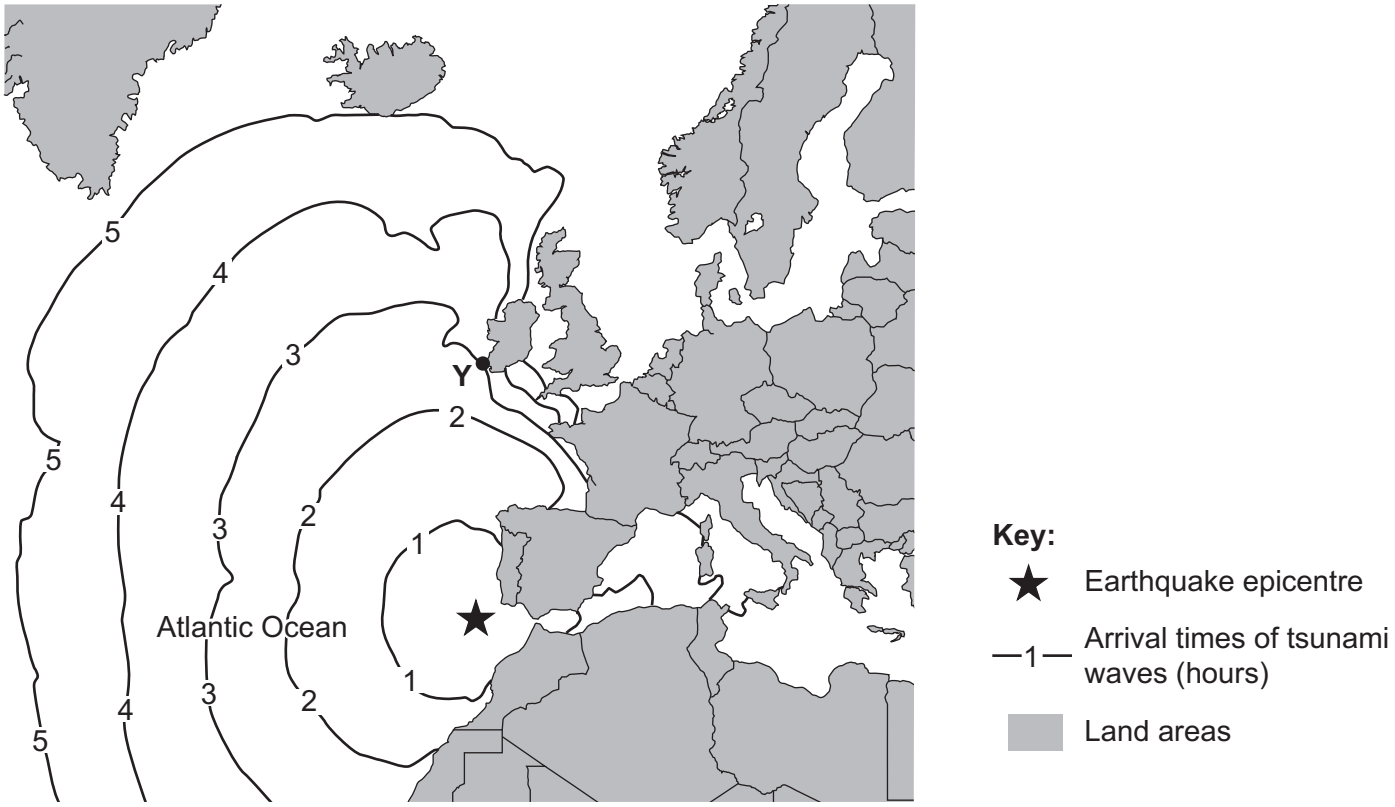
(c) Although considered to be at low risk, tsunamis have occurred in the Atlantic Ocean in the past.

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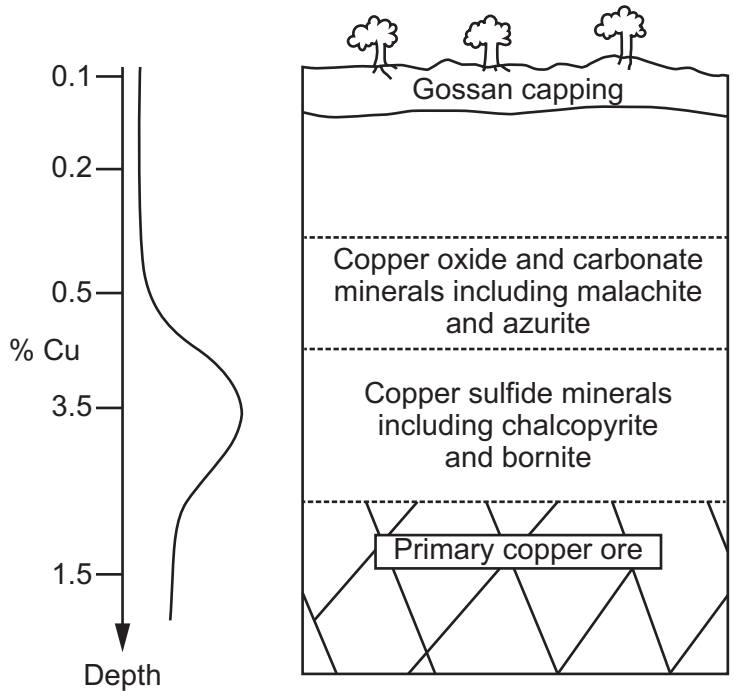
30 Porphyry copper ore deposits are an important source of copper.

(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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(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).