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Examiners' report

GEOLOGY

H414

For first teaching in 2017

H414/01 Summer 2023 series

Version 1

Contents

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates.

The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. A selection of candidate answers is also provided. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.

A full copy of the question paper and the mark scheme can be downloaded from OCR.

Paper 1 series overview

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

This paper is one of three examination components for A Level geology. This component focuses on:

- the development of practical skills
- minerals, rocks and fossils
- global tectonics
- sedimentary environments and geochronology
- petrology and economic geology
- geohazards
- basin analysis.

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

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

Section A overview

This section provided candidates with a broad range of topics to be assessed. Many candidates showed a full range of geological knowledge, gaining at least 20/25 marks. This maintains the improvement on previous series and shows candidates are now familiar with the demands of these questions. This style of question clearly suits some candidates who find the questions requiring longer answers more challenging.

Question 1

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

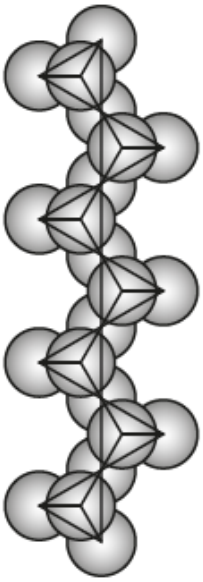
D A naturally occurring element or organic compound whose composition can be expressed as a chemical formula

Your answer ☐ **[1]**

Option C is the correct answer which is a standard definition of a mineral. The other 3 potential answers had distractors often with one word swapped for the opposite meaning. Therefore, candidates need to know a precise definition.

Question 2

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

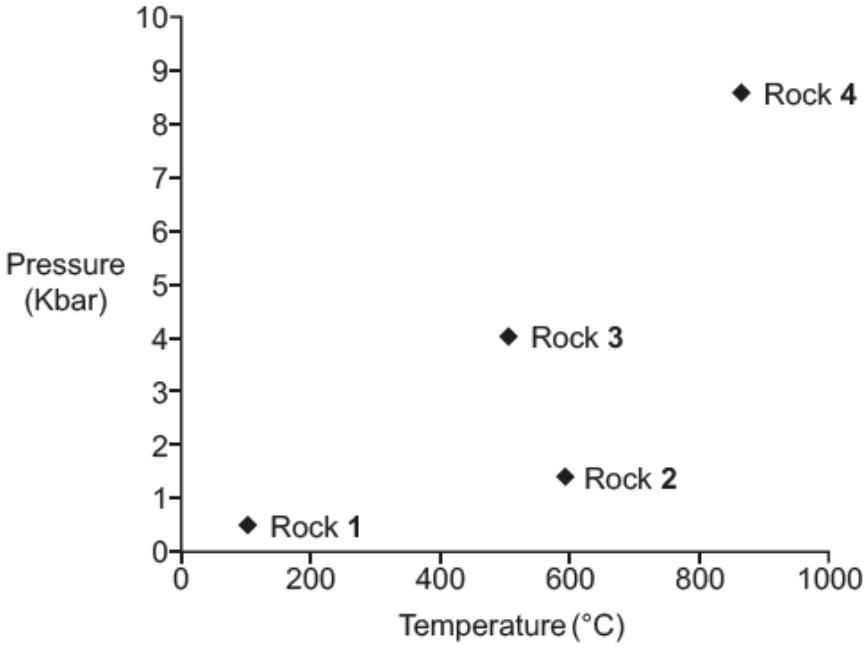
D Pyroxenes

Your answer ☐ **[1]**

Option D is the correct answer. Candidates should be familiar not only with the structure of the main silicate minerals but also how these structures affect the physical properties of the minerals. In this case candidates should recognise that this is a single chain silicate which is found in the pyroxene group of minerals which includes augite.

Question 3

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]**

The distribution of the main rock classes within a P/T diagram was well known by candidates.

Question 4

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

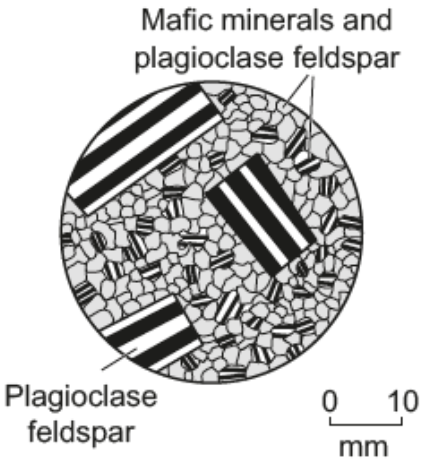
D K minerals are most soluble and precipitate first

Your answer ☐ **[1]**

Candidates need to be clear on the order of formation of evaporite minerals which links to their solubility. In this case answer A is correct as the least soluble mineral crystalises first which is calcite.

Question 5

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

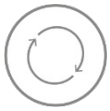
C Silicic composition with a glassy texture

D Ultramafic composition with an equicrystalline texture

Your answer ☐ **[1]**

Candidates are confident in identifying igneous textures in thin section, especially porphyritic texture. This helped most candidates identify answer B as being correct. Candidates are generally less confident when asked just to identify the composition from thin section.

Assessment for learning



Candidates need to practice not only recognising igneous textures in thin section but also the more difficult task of recognising the rock type. This will involve working out the mineral content which combined with the texture will identify the correct igneous rock. Recognition of texture and mineral content is more difficult in hand specimen but should be practised in the lab and in the field.

Question 6

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]**

Most candidates know how to recognise dykes, sills and lava flows in the field and were able to avoid the distractor answers to give the correct answer C.

Question 7

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]**

Most candidates knew that chlorite is the first index mineral to form but answer D proved to be a distractor as not all candidates were confident about which mineral formed at the highest grade. It should be sillimanite and so C was correct. Candidates need to know the sequence and also be able to link it to the appropriate metamorphic rock types.

Question 8

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]**

This question was by far the most difficult of the multiple-choice questions. Many candidates were not familiar with the term boudinage and so had no idea of how it formed. Boudinage only forms under tensional stress and requires stretching of a competent rock to create the typical "sausage shaped" boudins. Therefore, B is the correct answer.

Question 9

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]**

There is an expectation that candidates are familiar with analysis of the Jurassic and Welsh basins. Many candidates did know that the Jurassic basin involved cyclical sedimentation in shallow seas (answer D). Answer A was more typical of parts of the Welsh Basin.

Question 10

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

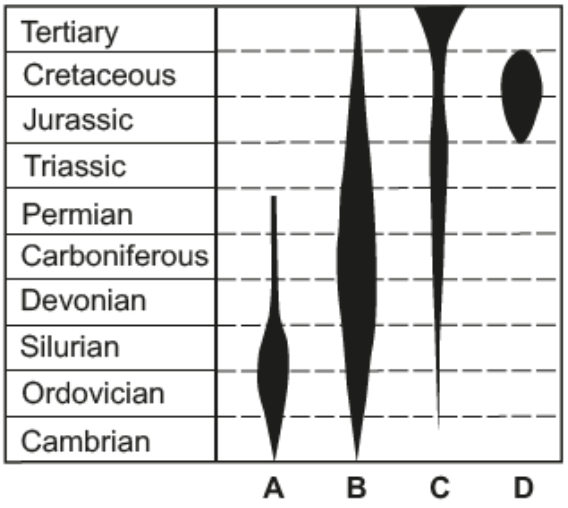
D Rapid evolutionary changes

Your answer ☐ **[1]**

Most candidates showed that they understood the key characteristics of a zone fossil; answer C had a characteristic that did not apply.

Question 11

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]**

It is important for candidates to know the stratigraphic ranges of key fossil groups. Most candidates knew that trilobites started in the Cambrian and became extinct at the end of the Permian (answer A).

Question 12

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

A Carboniferous

B Jurassic

C Permian

D Triassic

Your answer ☐ **[1]**

In a similar way to Question 11, candidates are expected to know the stratigraphic ranges of key fossil groups including dinosaurs. Many candidates did know that dinosaurs first evolved in the Triassic (answer D).

Question 13

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

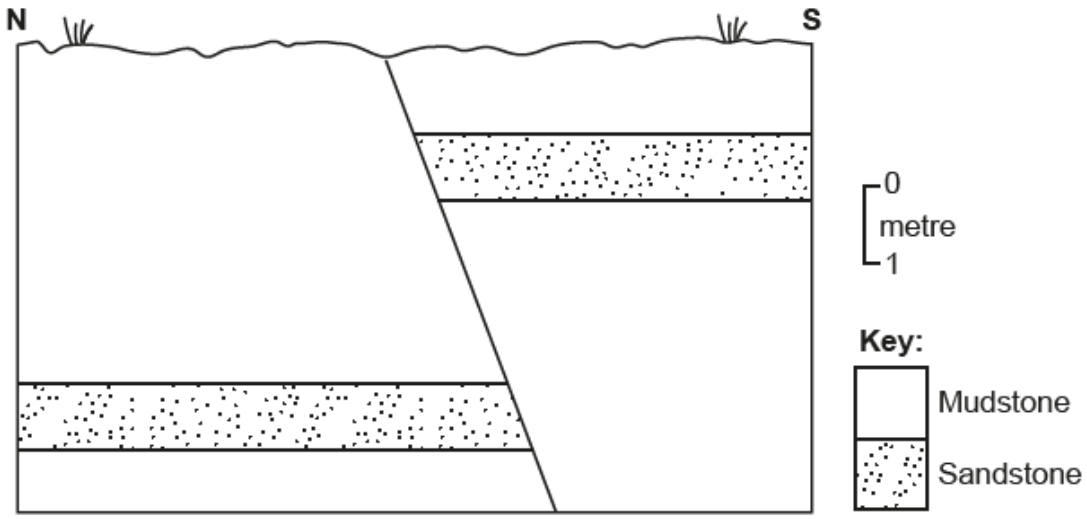
D Saurischia Theropoda

Your answer ☐ **[1]**

Candidates generally have a good understanding of the key features of Ornithischia, Saurischia and Pterosauria. Therefore, many candidates knew that Diplodocus is a Saurischian Sauropod (answer C).

Question 14

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

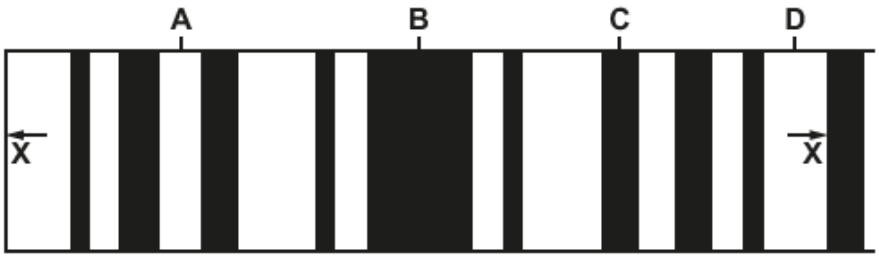
D Only 1

Your answer ☐ **[1]**

Candidates need to be able to identify fault types in cross section and on a geological map. Many candidates recognised that this is a dip-slip fault with an upthrown hanging wall and so answer B is correct.

Question 15

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]**

Candidates had no difficulty recognising the centre of the mid-ocean ridge which is also the line of symmetry (answer B).

Question 16

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]**

It is important that candidates can use scales and measure distances on graphs, and in this case convert distance and age differences into a velocity. Answer B was the correct answer.

Assessment for learning

Candidates need to practice using scales and taking measurements on maps and then converting results from one form to another. This can occur in different scenarios and so candidates need to practice and be confident with these conversions

Question 17

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]**

Candidates struggled to recognise the features of a slow spreading mid-ocean ridge which includes a discontinuous magma chamber and an axial rift valley (answer C). Answer B is a distractor and describes a fast spreading mid-ocean ridge.

Question 18

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]**

Candidates are still not confident in their understanding of seismic tomography but are improving. A subducted slab is cold and dense and so P waves increase in velocity and so answer A is correct.

Question 19

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]**

Candidates need to know the key features found at the different plate boundaries. Many candidates knew that grabens and horsts are tensional features and so found at divergent plate boundaries (answer B).

Assessment for learning

Candidates need to be familiar with all of the processes, landforms and hazards associated with each plate boundary. It is also useful for candidates to be able to locate the different plate boundaries on a world map so that they are also familiar with the location of the main tectonic hazards.

Question 20

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

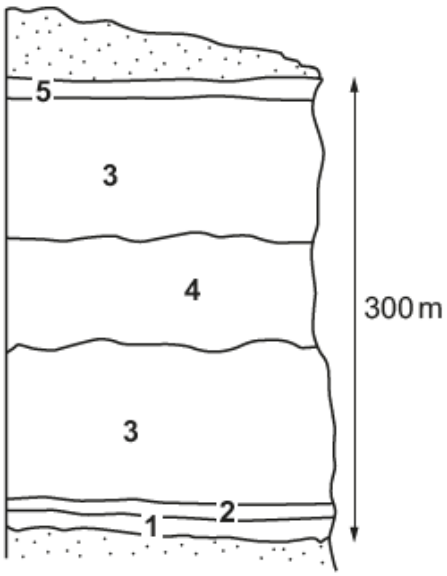
D Radioactive particles resulting from nuclear tests in the 1950s found worldwide in deep ocean sediments

Your answer ☐ **[1]**

Recognising the Anthropocene was introduced in this specification and so candidates are still uncertain of the detail. It is the radioactive particles from nuclear tests that are most likely to be used as the start of the Anthropocene. These are easy to identify chemically in strata and can be dated. Therefore, answer D is correct. The other answers will either not show up well in the strata or are not as widespread as the nuclear fallout.

Question 21

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]**

Candidates did find this question difficult with the incorrect answers being close enough to distract from the correct answer C. Answer A said gravity settling formed layer 1 while it was the layer 2 above. Answer B was incorrect because Layer 4 has the most changed chemistry from the original magma.

Question 22

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**

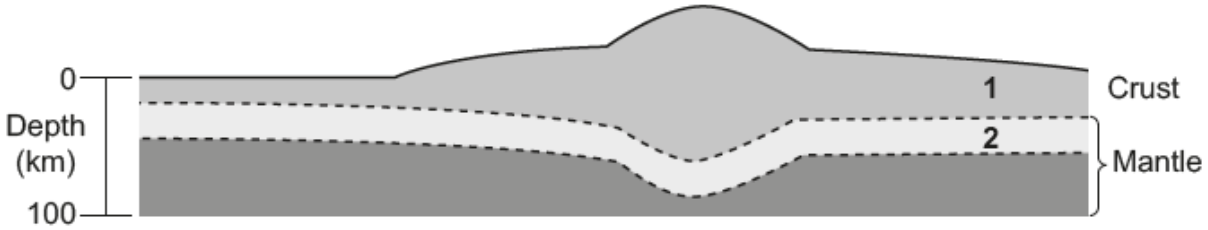
D Layer **4**

Your answer ☐ **[1]**

It was necessary for candidates to realise that the cumulate layer (layer 2) would be above the chilled margin (layer 1).

Question 23

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]**

Most candidates can locate the lithosphere and asthenosphere on a simple cross section.

Question 24

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]**

Candidates are expected to know which engineering techniques are best for stabilising slopes either on the slope surface or the slope toe. Gabions are best out of this selection for toe support.

Question 25

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]**

Candidates are becoming more confident in understanding the causes of subsidence linked to clays. Many candidates identified smectite (answer D) as the mineral with the highest shrinking and swelling capacity.

Section B overview

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

Question 26 focused on sedimentary petrology. Candidates are generally confident with identifying sedimentary rocks in thin section. In addition, candidates are also confident with identifying sedimentary textures along with the processes that formed them. Candidates are less certain of what controls the mineralogy in sedimentary rocks. Plotting triangular graphs is an expected skill but is not commonly practised. Candidates also understand the main diagenetic processes.

Question 27 focused on plotting earthquake data, the Benioff zone and calculating a Spearman's rank correlation. Candidates were confident in most aspects of this question being able to plot the data and calculate the statistical data. Some plotting errors occurred but mainly due to not following the instructions and guidance. Candidates are familiar with the Benioff zone and its significance.

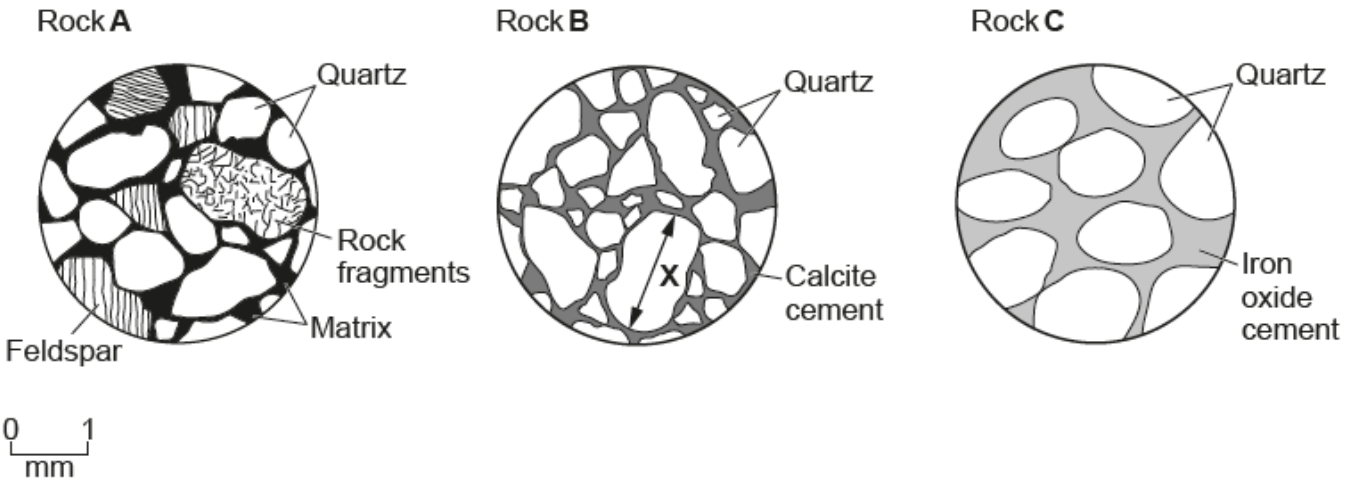
Question 28 had a 6 mark question on the Wilson cycle and the formation and use of palaeomagnetism. Another focus is on global temperature change which included a calculation of temperature change and questions on the formation of Snowball Earth, albedo and the role of volcanic activity in ending Snowball Earth.

Question 29 focused on tsunami events including their formation and the risks caused. A calculation of tsunami velocity was required which indicated that some candidates struggled converting kilometres and hours into ms^{-1}. There was a focus on the cause and evidence for the Storegga slide event that affected the coast of Scotland.

Question 30 used copper ore formation and extraction as a focus. Initially it asked candidates to describe the secondary enrichment of copper ores and then describe the extraction including heap leaching and smelting. The 6 mark question focused on an evaluation of the geophysical techniques used to locate copper ore minerals within different host rocks based on their contrasting geophysical properties.

Question 26 (a) (i)

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



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

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

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

Candidates are expected to be able to use a scale to determine the correct length of a feature, be it from a thin section or a map, cross section or sketch. Most candidates were able to carry out this task.

Assessment for learning

Candidates need to practice identifying sedimentary rocks in thin section and hand specimen. Hand specimen speed dating is a good exercise at the beginning or end of a lesson. Each table has a sedimentary rock specimen and the candidates have 1 minute to write down grain size, clast shape, sorting, mineralogy and any fossils as well as name the rock. This creates a hectic scene with usually a great deal of cooperation and quick thinking. The specimens are passed round each table and then the results are peer marked. This will lead to a great deal of discussion about what the correct answers are and will lead to greater confidence when describing and identifying sedimentary rocks in thin section or in the field. A similar exercise can take place with igneous and metamorphic rocks as well as minerals and fossils

Question 26 (a) (ii)

(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 .....

.....

[1]

Most candidates recognised that these rocks are all sandstones, siliclastic or arenaceous. Far fewer candidates could explain what defines a sandstone, siliclastic or arenaceous rock. Candidates do need to know these definitions which will help recognising thin sections, rock descriptions or observations in the field.

Question 26 (a) (iii)

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

1 .....

.....

2 .....

.....

[2]

Candidates had no difficulty describing the textural differences, most focusing on roundness and sorting. Alternative good answers included discussing textural maturity. Some candidates did not use the correct technical terms which limited the marks achieved. It is also important that when discussing differences that candidates' descriptions are comparative, mentioning both rocks rather than just one.

Question 26 (a) (iv)

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

.....

.....

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

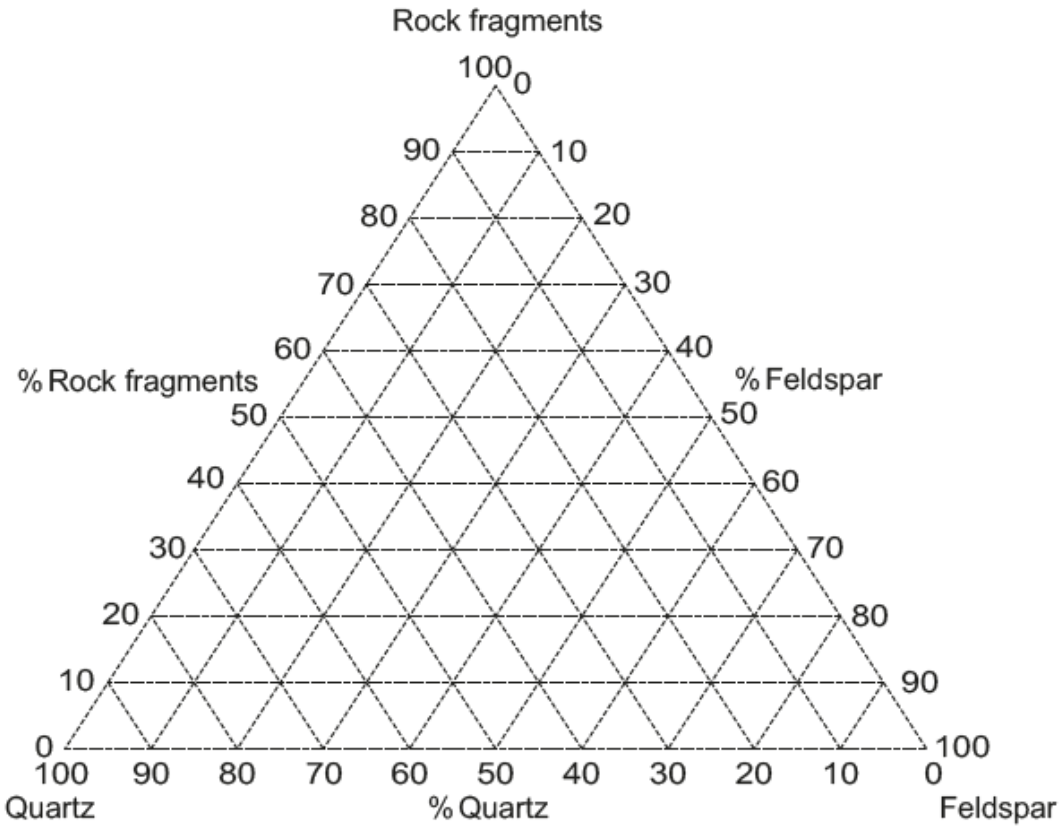
Many candidates recognised that differences of transport distance or amount of erosion were responsible for the differences between the rocks. Just naming different possible environments of deposition is not sufficient as that is not enough to explain how the texture forms.

Question 26 (b) (i)

(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]

Plotting triangular diagrams is an expected skill and many candidates plotted the point accurately. Using construction lines for the 3 compositions will help.

Question 26 (b) (ii)

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

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.....

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

Many candidates determined a correct environment for rock A. Many candidates also described the texture and composition but struggled to explain what the texture and composition indicate about how the sediment formed. Few candidates discussed the significance of abundant feldspar which, being relatively soft and with cleavages, would normally be destroyed if there is significant transport or erosion so will tend to be close to its source.

Question 26 (c)

(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]**

Many candidates recognised that the calcite cement is the main evidence that rock B has undergone diagenesis. A detailed explanation of how cementation occurs was expected and many did indicate that the calcite precipitates around the clasts. Extra detail could include pore fluids with dissolved minerals or pressure solution.

Question 27 (a) (i)

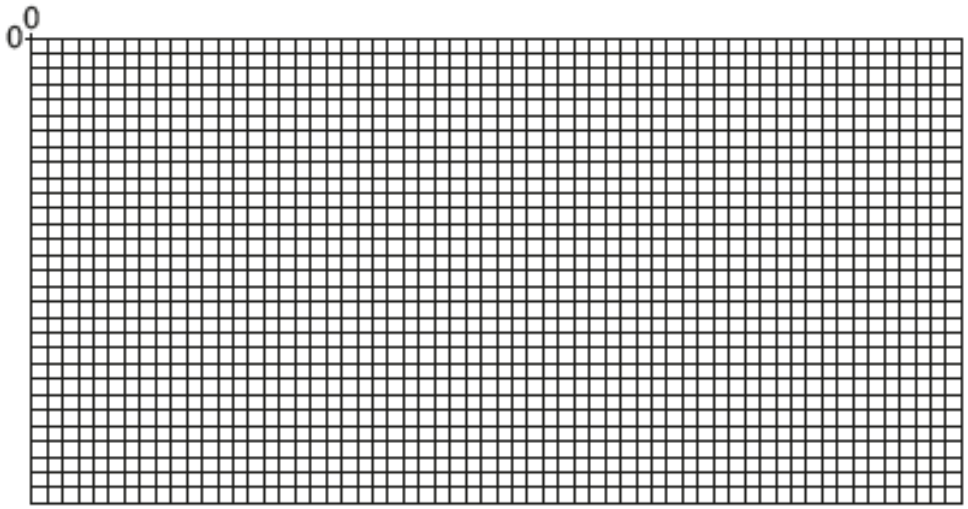
27 Earthquake data for the convergent plate boundary to the west of South America was collected from Google Earth™.

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

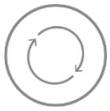
(a) (i) Use the data from the table to plot a scatter graph of depth of earthquake focus (y-axis) against distance from the plate boundary (x-axis).



[4]

Most candidates successfully plotted the scatter graph. The main error involved ignoring the 0,0 origin given on the graph and plotting the origin at the bottom left of the graph. Some candidates did not add units to the labelled axes. It is also good practice to choose scales that are easy to use.

Assessment for learning



Candidates must take note of the instructions given in a question. If axes are partly marked then they should not be ignored. In this question candidates were asked to plot depth of earthquake focus on the y axis and the distance from the plate boundary on the x axis, candidates must know the difference. The origin 0,0 was given on the graph for a good reason and this should not be ignored by the candidate. Therefore, candidates must practice plotting graphs with axis given or partially given as in this case.

Question 27 (a) (ii)

(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]**

Most candidates had no difficulty drawing an appropriate line to show the plate boundary. However, the line does need to reach the surface at or close to the origin.

Question 27 (a) (iii)

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

.....

.....

.....

.....

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

Candidates knew that the pattern is linked to the subduction of a plate. Many candidates also identified the pattern as the Benioff zone. Marks were lost because the extra detail was lacking, in particular that friction leads to strain energy building up at the plate boundary and is then released as seismic waves.

Question 27 (a) (iv)

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

Almost every candidate recognised and circled the correct point.

Question 27 (a) (v)

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

.....

.....

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

Many candidates knew to link earthquakes with fault movement. The best answers included reactivation of faults. Other good answers suggested rising magma triggering earthquakes.

Question 27 (b) (i)

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

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

where n is the number of pairs of values.

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

The calculation was carried out successfully by many candidates. Candidates are becoming more confident with the calculation and use of statistical data.

Question 27 (b) (ii)

(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.

.....

.....

.....

.....

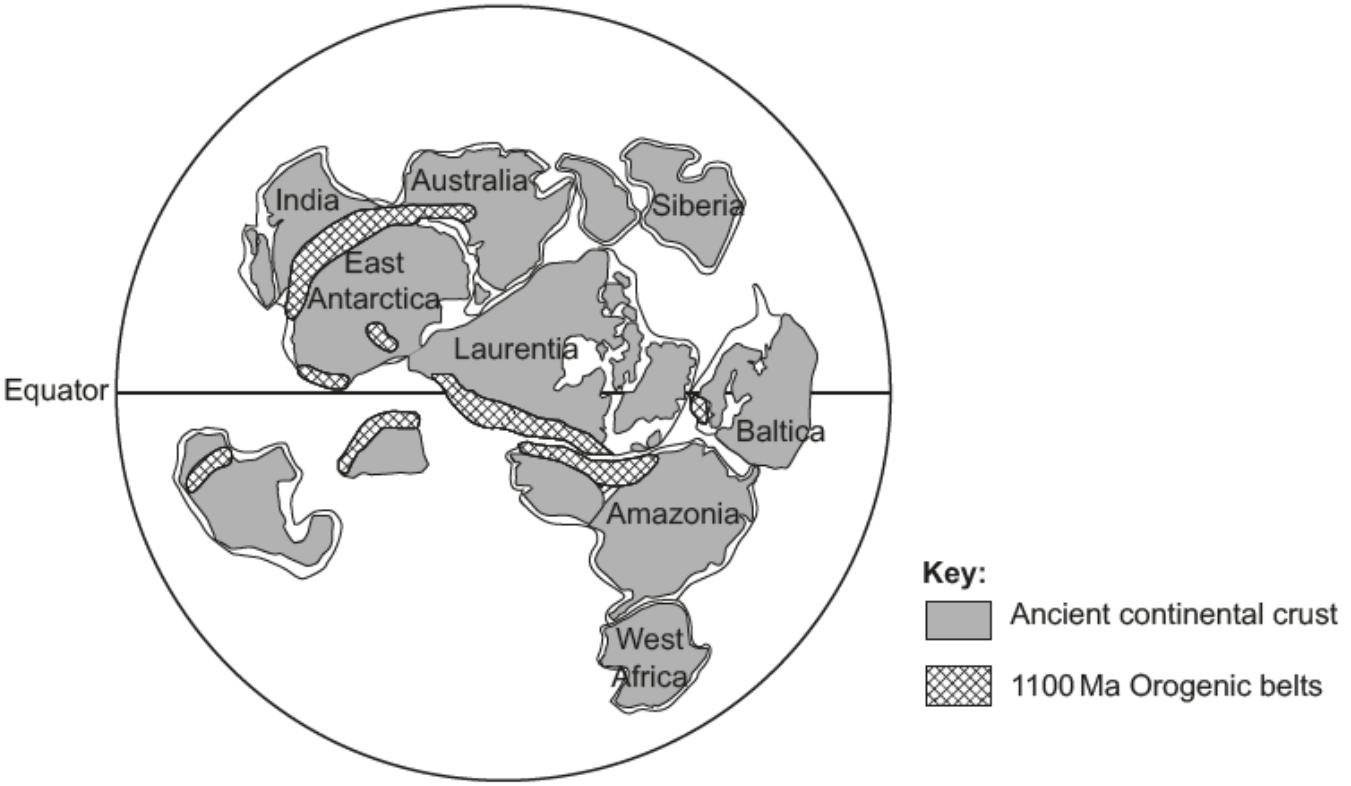
..... **[2]**

There is evidence that candidates are increasingly familiar with analysing statistical data. Most candidates could work out the degrees of freedom, the significance and knew to reject the null hypothesis.

Question 28 (a)*

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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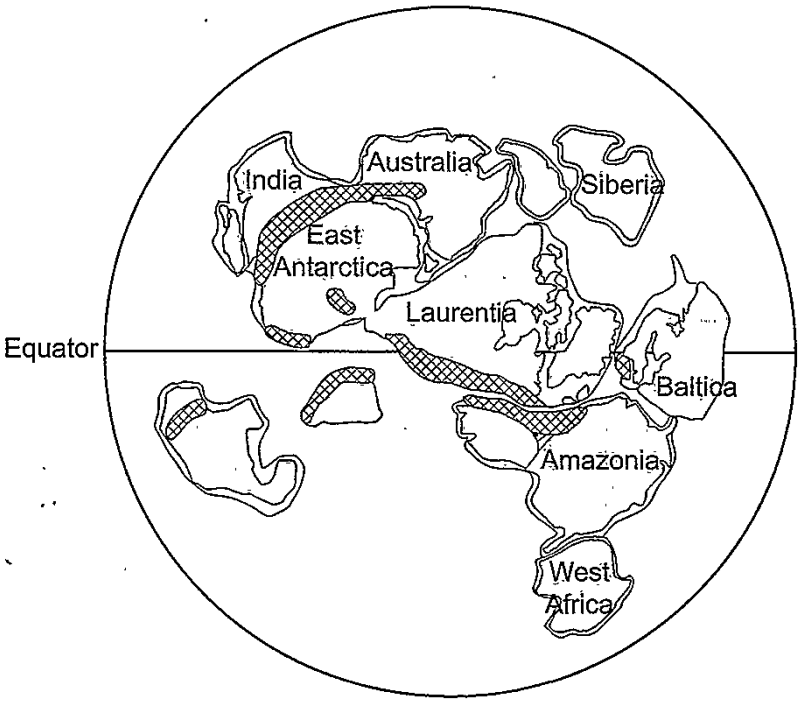
.....

Most candidates were able to describe the main processes involved in the Wilson cycle but were less certain of the stages of the cycle. Most candidates mentioned slab pull, ridge push and subduction; however, these were not always linked to the opening and closing of oceans. Rather, candidates focused on the movement of the continental plates. The best answers were well structured, discussing the rifting of the continent, the opening of an ocean and its eventual closure and collision. Candidates generally made good use of technical terms and most answers had a logical structure. The better answers also referred to the map of Rodinia. Weaker answers focused on ridge push and slab pull with little or no link to the Wilson cycle of ocean development.

Exemplar 1

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



Super C
start mant plume
hotspot (SE)
bouyncy, splitting
rifting (eg EARV)
~~subd~~
2nd grav sliding
1st subduct
both move
ocean open
conton
even reform
repeat

(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]**

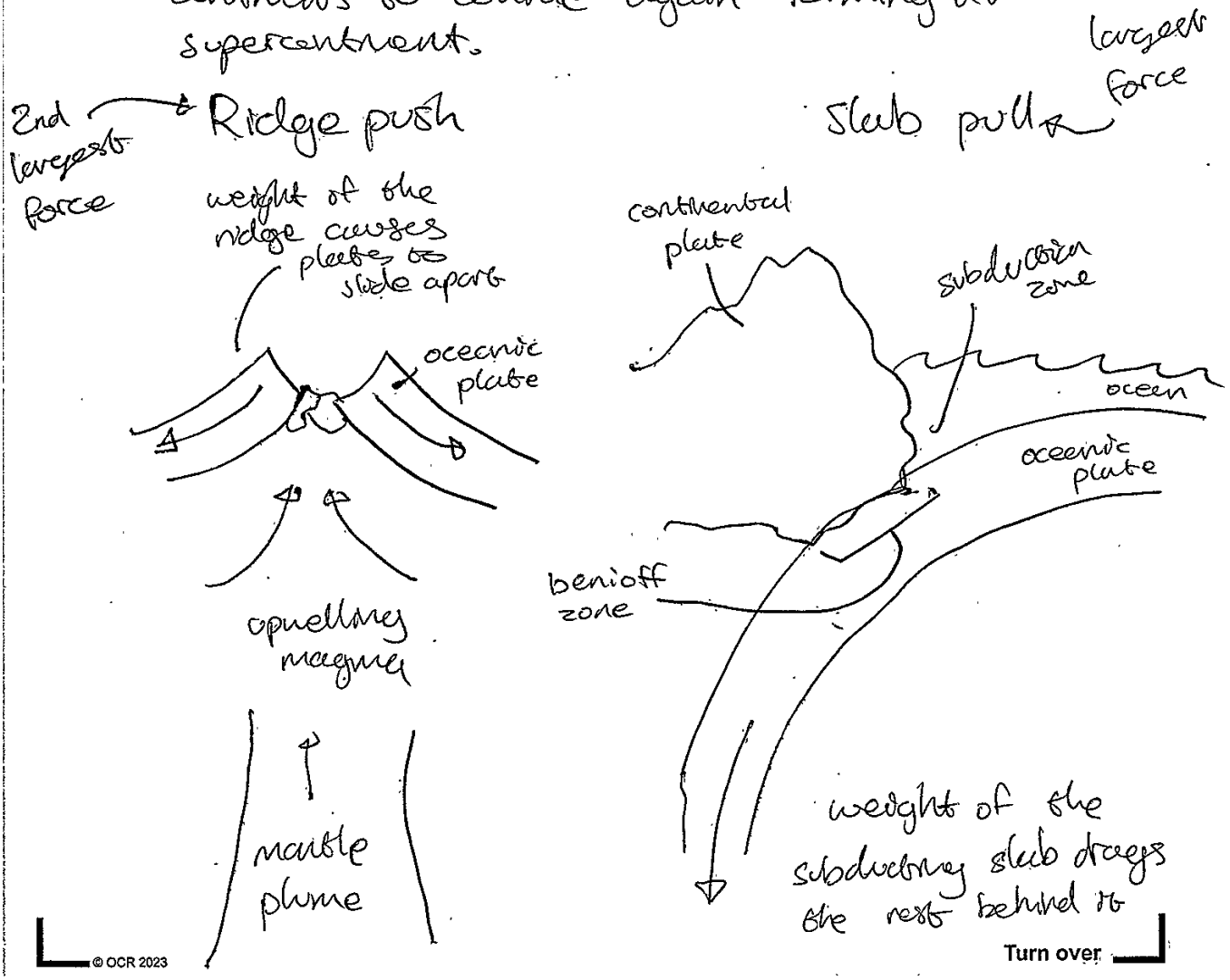
Initially, a supercontinent exists, however, its break up is initiated by stationary mantle plumes. These plumes rise from the outer core, and have the surface expression of hotspots. These hotspots (due to rising magma) bouy and split the crust of the supercontinent. This creates a rift valley, and the bouyncy of the crust induces gravity sliding - the process by which the weight of the mountainous sides forces the plate outwards. This, in turn, causes subduction at the other end of the tectonic

ridge + push

plate, and subsequently induces slab pull. the weight of the subducting plate drags the rest of the plate behind it. These are the two main forces inducing tectonic

Additional answer space if required.

movement. As the rift valley widens oceans flood in and oceanic crust is created. These new oceans in the supercontinent divide it into sub-continents. Eventually (≈ 50,000,000 yrs) these tectonic processes cause the new continents to collide again - forming a new supercontinent.

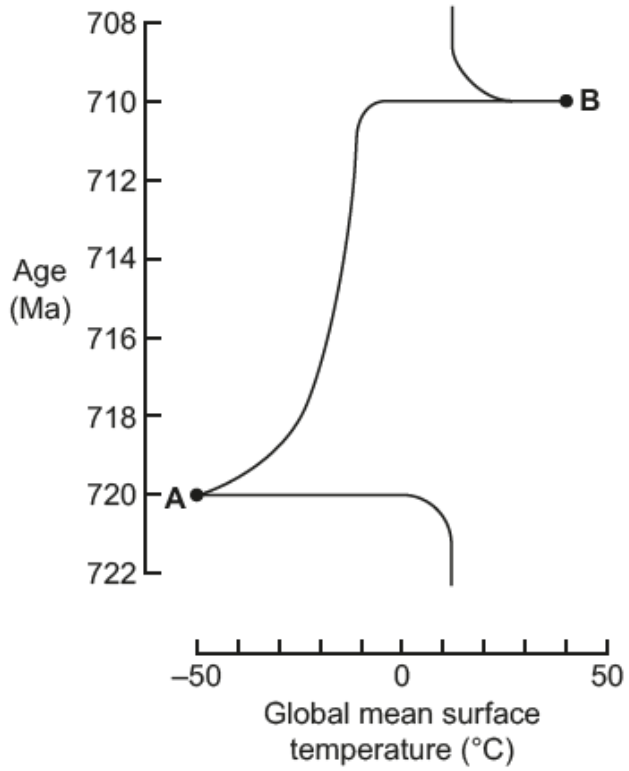


Turn over

This is a full 6 mark Level 3 response. It covers both the stages of the Wilson cycle but also all the processes in some detail. There is a simple plan which can help structure the response. There are diagrams at the bottom of the second page which are useful in helping to answer this question. Diagrams are perfectly valid in this type of question if they are annotated. The response did not need to be this long to gain full marks as you will see in the exemplar for Question 30 (b), which is more concise.

Question 28 (b) (i)

(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]**

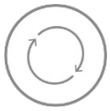
The mean was generally well calculated. Some errors occurred because candidates did not use a ruler/straight edge to draw vertical lines or read off the values from A and B to the x axis.

Question 28 (b) (ii)

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

There was a wide range of points offered with half the candidates correctly identifying the horizontal line at B. Candidates must be precise when drawing arrow to a specific point or line. The end of the arrow should be touching the point or line and not some distance away as it is can be difficult to be certain where the candidate intended to indicate.

Assessment for learning



Candidates will lose marks if labels are not located in a precise manner. Candidates must practice placing all arrows and other labels such that there is no ambiguity about what is being labelled and where. The end of the arrow or label line should touch the feature being indicated or labelled and not left some distance away as the mark may not be given.

Question 28 (c) (i)

(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]**

Most candidates had a general idea of how rocks preserve magnetism. The best answers mentioned specific minerals such as magnetite and their alignment with the Erath's magnetic field at that time. They also discussed the magnetism being "locked" once the rock's temperature fell below the Curie point.

Question 28 (c) (ii)

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

.....

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.....

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

Very few candidates understood the significance of magnetic inclination preserved in rocks and its link to palaeolatitude. Some candidates did indicate that the magnetism would be parallel to the Earth's surface or horizontal. Many candidates just indicated that the magnetism would point to the poles or was weaker. Candidates should be familiar with magnetic inclination and palaeolatitude which also links to an understanding of polar wandering curves and evidence for plate movement.

Question 28 (c) (iii)

(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.

.....

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

Many candidates indicated that glacial deposits such as glacial tills, tillites and boulder clay would indicate past ice caps at the Equator. Credit was given for stating glacial striations were found at the Equator.

Question 28 (d) (i)

(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]**

Most candidates could name one type of weathering, usually carbonation or hydrolysis but also oxidation. Many candidates also discussed the processes such as CO_2 combining with water to form carbonic acid. The best answers also mentioned the products such as the formation of clays and ions in solution along with insoluble residues such as quartz. A significant number of candidates did not focus on silicate minerals as required but discussed calcite reacting with acid rain.

Question 28 (d) (ii)

(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]**

Very few candidates could make the link between chemical weathering, the composition of the atmosphere and global cooling. The best answers linked removal of CO_2 from the atmosphere into seawater or sediments. Many candidates did make a link to CO_2 but in the opposite sense, saying it was released which changed the climate. It is the removal/sequestration of CO_2 that reduces the greenhouse effect and so can lead to global cooling.

Question 28 (d) (iii)

(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.

.....

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

Because so few candidates could link weathering to sequestration of CO_2 in seawater/sediments it was therefore difficult for candidates to realise that the effect of this process was an increase in the formation of limestones/carbonates.

Question 28 (d) (iv)

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

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.....

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

Many candidates understood the link between ice cover and the albedo effect. Many candidates did not make the link to an increase in albedo or reflectivity. The stronger answers discussed the positive feedback that is created which leads inevitably to further global cooling.

Question 28 (e)

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

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.....

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

Many candidates described the emission of greenhouse gases from the volcanoes as helping to end the Snowball Earth event. More complete answers also mentioned the eruption of large volumes of ash which blanketed the ice and so lowered the albedo, leading to a warming.

Misconception

Some candidates linked ash eruption into the atmosphere to blocking the solar energy from reaching the surface but this would lead to initial cooling and not warming. Candidates do also sometimes confuse the role of CO_2 and ozone in global temperature changes.

Question 29 (a)

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]**

Most candidates found it difficult to provide an accurate answer to this question. Many answers were too vague indicating that the Pacific has convergent plate margins and the Atlantic has divergent. The Pacific and Atlantic have both types of margin and it is the relative abundances that are important. The Pacific has a far greater area of convergent plate margins and it is these margins that produce the largest earthquakes with the greatest potential for seafloor movement and displacement of large volumes of seawater. The Atlantic has a much smaller area of convergent plate margins and a large divergent margin with smaller earthquakes. Many of the Atlantic margins are also passive. The best answers had an accurate comparison between the two oceans linked to the abundance and large underwater earthquakes.

Question 29 (b)

(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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.....

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.....

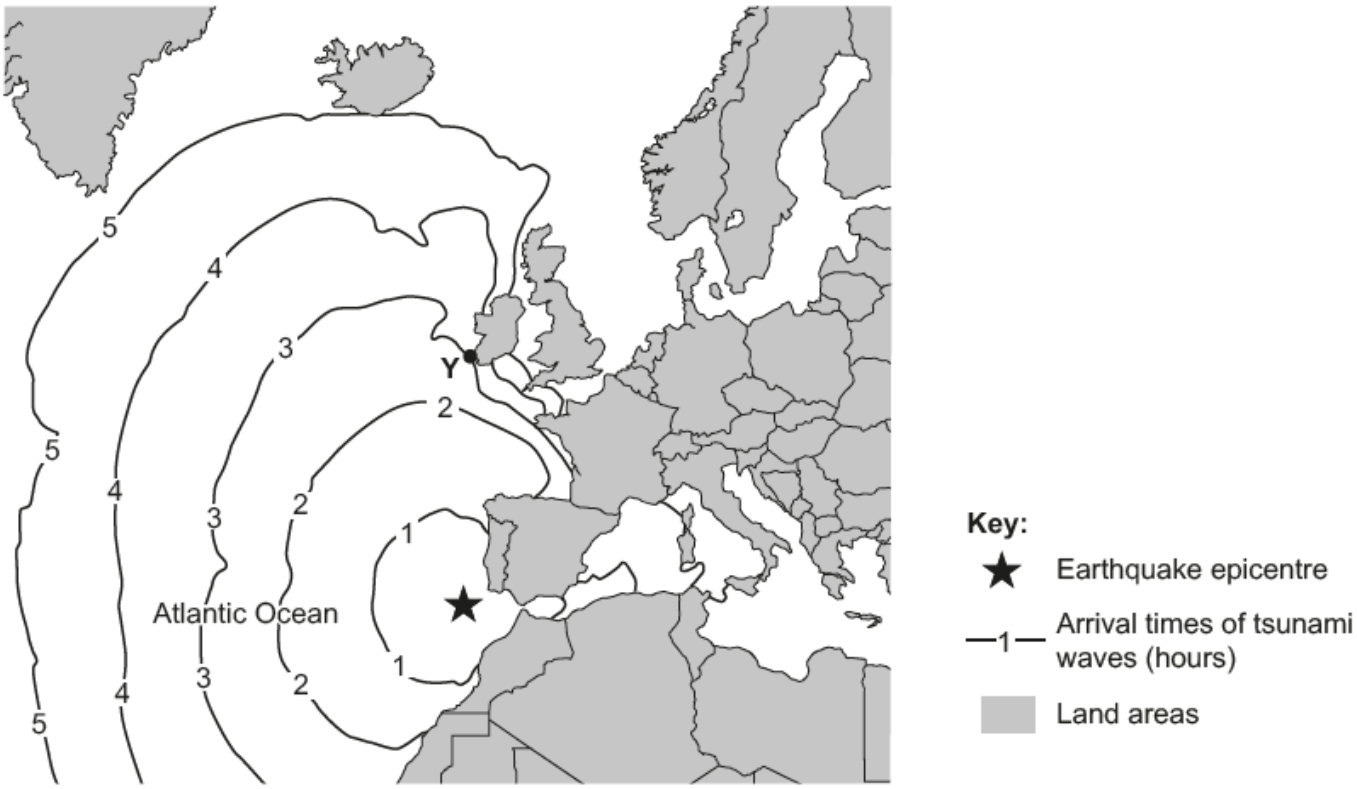
..... **[3]**

Most candidates gained 1 or 2 marks but very few gained 3. The most common answers linked to the relative preparedness of Japan compared to Indonesia, many giving examples such as tsunami defences and evacuation drills. Better answers discussed the early warning systems in the Pacific which are less developed in the Indian Ocean. The best answers also outlined that Japan has more frequent tsunamis and so the population is more aware of them and therefore more prepared. Other good answers indicated that much of Indonesia has low lying areas which are more prone to tsunami.

Question 29 (c) (i)

(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.

.....

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

Most candidates knew that seismometers/seismograms had not been invented at this time and so an accurate magnitude could not be given.

Question 29 (c) (ii)

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

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

Almost every candidate answered this correctly.

Question 29 (c) (iii)

(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]**

Only half the candidates could use the answer from Question 29 (c) (ii) and the distance in the question to convert to m s^{-1}. This is a common calculation; many candidates made an error converting hours into seconds and so were an order of magnitude out. Some candidates also made rounding errors.

Question 29 (d)

(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]**

It was clear that most candidates were familiar with this tsunami event. Most candidates struggled to clearly describe the evidence. Many candidates did talk about sediments being deposited but it was the fact that these were marine sediments/fossils/diatoms that were deposited inland. Good answers also referred to tsunamites.

Question 29 (e)

(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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.....

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

Many candidates could link the slide event to displacement of water triggering a tsunami. Many candidates incorrectly described the slide as starting above sea level and sliding, slumping or falling into the sea. The slide was entirely underwater. Candidates also need to indicate the large scale of the water displacement.

Question 29 (f)

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

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

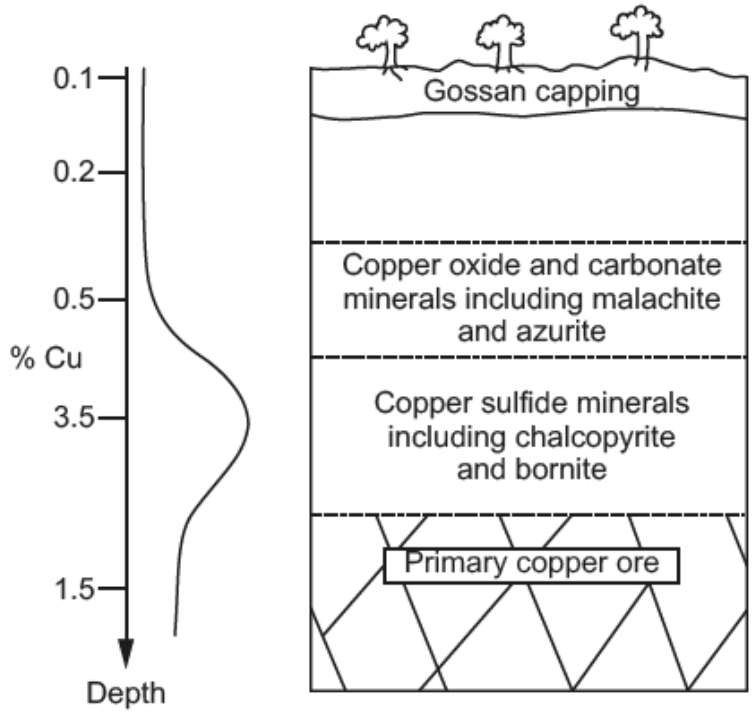
This proved difficult to answer with any detail. Most candidates rephrased the question. Many candidates correctly indicated that non-specialists lack the technical knowledge, but extra detail was required such as not understanding probability or the amount of ground shaking. Some good answers did discuss perceived risk being different from actual risk. Other good answers outlined the case that geologists cannot predict exact times, locations or magnitude.

Question 30 (a) (i)

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]**

Many candidates recognised that the water table is at the boundary between the azurite/malachite and chalcopyrite/bornite layers. Many were unsure. In a similar way to Question 28 (b) (ii) some candidates were not precise enough with the line and so a mark could not be given. One end of the line needs to touch the position of the water table so that the answer is unambiguous.

Question 30 (a) (ii)

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

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

Many candidates had an excellent understanding of secondary enrichment gaining full marks with balanced well-structured answers looking both above the water table and below it. Better answers indicated the change from oxidising to reducing conditions coupled with a change from soluble copper sulfate to insoluble copper sulfide. Some candidates had these conditions the wrong way round.

Question 30 (a) (iii)

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

.....

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

Candidates struggled with this question. Usually the main reason for secondary enrichment stopping is because all the copper above the water table has been removed/leached. An equally valid point was made by some candidates who realised that in the Atacama desert there may not be enough water available to leach the copper sulphate and the water table may drop.

Question 30 (b)*

(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 (Ωm)**	**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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.....

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

There were a wide range of responses to this question. The best answers involved a logical comparison of the data for the three host rocks and the two ore minerals. Then appropriate geophysical techniques were chosen and their suitability evaluated. Ideally candidates also gave a brief description of how the techniques work including whether a positive or negative anomaly was expected.

Common errors included thinking that the resistivity for the host rocks and ore minerals was similar, which was a misreading of the data as the hoist rocks had positive values while the ore minerals were negative. Therefore, a resistivity survey was often dismissed as of no use when in fact it would be an excellent method. Some candidates did not notice the overlap in magnetic susceptibility, the best responses indicating that a magnetic survey could work but not always. Most candidates knew that a gravity survey would show up density differences, though some answers talked about density surveys. Better answers were also more focused on which combinations of host rock and ore mineral would give the best contrast and so would be easiest to locate.

In general candidates made good use of terminology, except those who did not know the names of the geophysical techniques. Most candidates provided a logical structure, either focusing on one set of data and technique at a time or discussing all the data first followed by all the techniques.

Exemplar 2

Gravity Surveys; effective as ore mineral densities are noticeably higher than host rock densities, so will produce a positive anomaly once corrected for latitude/topography. Small range of potential values; reliable. May be used alone.

Resistivity surveys: Also effective as ore minerals have much lower resistivity than host rocks & will be very noticeably conductive & easily identifiable. Fairly reliable as there will always be a lot of difference, potentially, between host & ore values despite range.

Electro magnetic Surveys: ~~[illegible]~~ effective as disparity between magnetic Susceptibility of ~~[illegible]~~ ore minerals & host rocks may be large, but range of potential values of host rocks could either lead to no noticeable difference or a vast one. Best used alongside other methods.

This is a full 6 mark Level 3 response. This response is concise, well-structured and clear. The response focuses on each geophysical property and technique with clear comparisons of the host rock and ore mineral. There is a clear evaluation for each technique and excellent use of technical terms. This shows how a full mark response does not need to be very long if the response is focused, concise and well structured.

Question 30 (c)

(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]**

Most candidates knew at least one aspect of mine development planning, usually the economic viability. Better answers also included deciding on the best mining method and the equipment used. More detailed answers that gained 3 marks looked at environmental and safety planning as well as engagement with the local communities.

Question 30 (d) (i)

(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]**

Most candidates had a general idea about heap leaching but often the detail was lacking and so restricted the candidate to one mark. There was also some confusion between heap leaching and froth floatation. Candidates needed to indicate that the ore was broken up or crushed and placed on an impermeable layer/membrane. There needed to be an indication that the fluid added was a solvent which dissolved the copper. A common error was thinking that the solvent removed the gangue minerals leaving the copper behind.

Question 30 (d) (ii)

(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]**

Many candidates could explain correctly that smelting used fossil fuels which released harmful gases including greenhouse gases. The best answers also discussed the relative efficiency of heap leaching etc which allows for extraction of lower grade ores and working on a smaller scale.

Copyright information

Question 28 (b), Graph showing changes in global mean surface temperature during a Neoproterozoic Snowball Earth event, © snowballearth.org, Snowball Earth.

Question 29 (c), Map showing travel times for 1755 Lisbon earthquake tsunami, © NOAA National Centers for Environmental Information.

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