GCE

Geology

H414/01: Fundamentals of geology

A Level

Mark Scheme for June 2023

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

MARKING INSTRUCTIONS

PREPARATION FOR MARKING
RM ASSESSOR

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: *RM Assessor Assessor Online Training*; *OCR Essential Guide to Marking*.

2. Make sure that you have read and understood the mark scheme and the question paper for this unit. These are posted on the RM Cambridge Assessment Support Portal http://www.rm.com/support/ca

3. Log-in to RM Assessor and mark the **required number** of practice responses ("scripts") and the **number of required** standardisation responses.

   YOU MUST MARK 10 PRACTICE AND 10 STANDARDISATION RESPONSES BEFORE YOU CAN BE APPROVED TO MARK LIVE SCRIPTS.

MARKING

1. Mark strictly to the mark scheme.

2. Marks awarded must relate directly to the marking criteria.

3. The schedule of dates is very important. It is essential that you meet the RM Assessor 50% and 100% (traditional 40% Batch 1 and 100% Batch 2) deadlines. If you experience problems, you must contact your Team Leader (Supervisor) without delay.

4. If you are in any doubt about applying the mark scheme, consult your Team Leader by telephone or the RM Assessor messaging system, or by email.

5. **Crossed Out Responses**
   Where a candidate has crossed out a response and provided a clear alternative then the crossed out response is not marked. Where no alternative response has been provided, examiners may give candidates the benefit of the doubt and mark the crossed out response where legible.

   Rubric Error Responses – Optional Questions
   Where candidates have a choice of question across a whole paper or a whole section and have provided more answers than required, then all responses are marked and the highest mark allowable within the rubric is given. Enter a mark for each question answered into RM assessor, which will select the highest mark from those awarded. *(The underlying assumption is that the candidate has penalised themselves by attempting more questions than necessary in the time allowed.)*

Multiple Choice Question Responses

When a multiple choice question has only a single, correct response and a candidate provides two responses (even if one of these responses is correct), then no mark should be awarded (as it is not possible to determine which was the first response selected by the candidate).

When a question requires candidates to select more than one option/multiple options, then local marking arrangements need to ensure consistency of approach.

Contradictory Responses

When a candidate provides contradictory responses, then no mark should be awarded, even if one of the answers is correct.

Short Answer Questions (requiring only a list by way of a response, usually worth only **one mark per response**)

Where candidates are required to provide a set number of short answer responses then only the set number of responses should be marked. The response space should be marked from left to right on each line and then line by line until the required number of responses have been considered. The remaining responses should not then be marked. Examiners will have to apply judgement as to whether a 'second response' on a line is a development of the 'first response', rather than a separate, discrete response. *(The underlying assumption is that the candidate is attempting to hedge their bets and therefore getting undue benefit rather than engaging with the question and giving the most relevant/correct responses.)*

Short Answer Questions (requiring a more developed response, worth **two or more marks**)

If the candidates are required to provide a description of, say, three items or factors and four items or factors are provided, then mark on a similar basis – that is downwards (as it is unlikely in this situation that a candidate will provide more than one response in each section of the response space.)

Longer Answer Questions (requiring a developed response)

Where candidates have provided two (or more) responses to a medium or high tariff question which only required a single (developed) response and not crossed out the first response, then only the first response should be marked. Examiners will need to apply professional judgement as to whether the second (or a subsequent) response is a 'new start' or simply a poorly expressed continuation of the first response.

6. Always check the pages (and additional objects if present) at the end of the response in case any answers have been continued there. If the candidate has continued an answer there, then add a tick to confirm that the work has been seen.

7. Award No Response (NR) if:
   - there is nothing written in the answer space

   Award Zero '0' if:
   - anything is written in the answer space and is not worthy of credit (this includes text and symbols).

Team Leaders must confirm the correct use of the NR button with their markers before live marking commences and should check this when reviewing scripts.

8. The RM Assessor **comments box** is used by your team leader to explain the marking of the practice responses. Please refer to these comments when checking your practice responses. **Do not use the comments box for any other reason.**
If you have any questions or comments for your team leader, use the phone, the RM Assessor messaging system, or e-mail.

9. Assistant Examiners will send a brief report on the performance of candidates to their Team Leader (Supervisor) via email by the end of the marking period. The report should contain notes on particular strengths displayed as well as common errors or weaknesses. Constructive criticism of the question paper/mark scheme is also appreciated.

10. For answers marked by levels of response:
Read through the whole answer from start to finish, using the Level descriptors to help you decide whether it is a strong or weak answer. The indicative scientific content in the Guidance column indicates the expected parameters for candidates' answers, but be prepared to recognise and credit unexpected approaches where they show relevance. Using a 'best-fit' approach based on the skills and science content evidenced within the answer, first decide which set of level descriptors, Level 1, Level 2 or Level 3, best describes the overall quality of the answer.

Once the level is located, award the higher or lower mark:

The higher mark should be awarded where the level descriptor has been evidenced and all aspects of the communication statement (in italics) have been met.

The lower mark should be awarded where the level descriptor has been evidenced but aspects of the communication statement (in italics) are missing.

In summary:

The skills and science content determines the level.

The communication statement determines the mark within a level.

Level of response questions on this paper are **28(a)** and **30(b).**

11. **Annotations**

Annotation	Meaning
	Correct response
	Incorrect response
	Omission mark
BOD	Benefit of doubt given
CON	Contradiction
RE	Rounding error
SF	Error in number of significant figures
ECF	Error carried forward
L1	Level 1
L2	Level 2
L3	Level 3
NBOD	Benefit of doubt not given
SEEN	Noted but no credit given

Annotation	Meaning
I	Ignore
BP	Blank page

12. **Subject Specific Marking Instructions**

Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

Annotation	Meaning
I	alternative and acceptable answers for the same marking point
✓	Separates marking points
DO NOT ALLOW	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

13. **Subject-specific Marking Instructions**

INTRODUCTION

Your first task as an Examiner is to become thoroughly familiar with the material on which the examination depends. This material includes:

- the specification, especially the assessment objectives
- the question paper
- the mark scheme.

You should ensure that you have copies of these materials.

You should ensure also that you are familiar with the administrative procedures related to the marking process. These are set out in the OCR booklet **Instructions for Examiners**. If you are examining for the first time, please read carefully **Appendix 5 Introduction to Script Marking: Notes for New Examiners**.

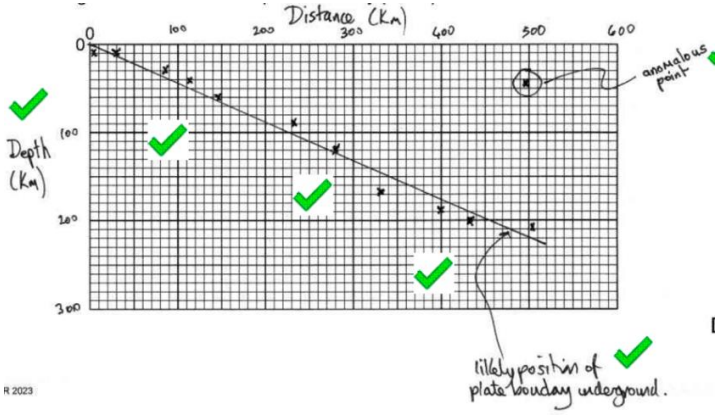
Please ask for help or guidance whenever you need it. Your first point of contact is your Team Leader.

Question			Answer	Marks	AO Element	Guidance
1			C	1	1.1a	**C –** A naturally occurring element or inorganic compound whose composition can be expressed as a chemical formula
2			D	1	2.1a	**D** – Pyroxenes
3			B	1	2.1a	**B** – Rock **1** = Sedimentary; Rock **2** = Contact Metamorphic; Rock **3** = Regional Metamorphic; Rock **4** = Igneous
4			A	1	1.1c	**A** – Calcite is least soluble and precipitates first
5			B	1	2.1a	**B** - Mafic composition with a porphyritic texture
6			C	1	2.1b	**C** – Lava flows and sills are concordant but only sills have two baked margins
7			C	1	2.1a	**C** – Chlorite → Biotite → Garnet → Kyanite → Sillimanite
8			B	1	2.1a	**B** – Competent rock subjected to tensional stress
9			D	1	2.1a	**D** – Cyclical sedimentation in shallow seas with deposition of shales, limestones, sandstones and ironstones
10			C	1	2.1a	**C** – Only found in high energy marine facies
11			A	1	2.1b	**A** – Cambrian to end Permian
12			D	1	1.1a	**D** – Triassic
13			C	1	2.1a	**C** – Saurischia Sauropoda
14			B	1	2.1a	**B** – Only **1** and **2**
15			B	1	2.1b	**B** – Magnetic anomalies are symmetrical on either side
16			B	1	2.1b	**B** – 2 cm a^{-1}
17			C	1	1.1a	**C** – Has a discontinuous magma chamber and has an axial rift valley
18			A	1	2.1b	**A** – A high velocity zone caused by P-waves travelling through colder and denser material
19			B	1	1.1c	**B** – At divergent plate boundaries
20			D	1	1.1c	**D** – Radioactive particles resulting from nuclear tests in the 1950s found worldwide in deep ocean sediments
21			C	1	2.1a	**C** – Some of the layers 1 to 5 have the same chemistry
22			B	1	2.1a	**B** – Layer **2**
23			C	1	2.1a	**C** – Lithosphere

Question			Answer	Marks	AO Element	Guidance
24			**A**	**1**	2.1a	**A** – Gabions
25			**D**	**1**	1.1a	**D** – Smectite

Question			Answer	Mark	AO Element	Guidance
26	(a)	(i)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer =** 1.6 **award 2 marks** 16 mm /10 mm ✓ 1.6 (mm) ✓✓	**2**	2.1b	**ALLOW** +/- 0.1 mm **ALLOW** 1 mark for correct answer not to 2 significant figures
		(ii)	Sandstones / arenaceous **AND** average grain sizes are between 0.0625 / $^{1}/_{16}$ and 2 mm / made of sand grains/ medium grained **OR** siliciclastic **AND** made of quartz / feldspar rich grains / sediment ✓	**1**	1.1a	**MUST** have correct rock group name **AND** matching reason for **1** mark
		(iii)	grains in **B** are angular / subangular / subrounded **AND** grains in **C** are rounded / well rounded ✓ grains in **B** are poorly sorted **AND** grains in **C** are well sorted **OR** grains in **B** have a more varied grain size compared to grains in **C** ✓ **B** is (texturally) immature **AND C** is (texturally) mature ✓	**Max 2**	1.1b	**ALLOW** implicit comparisons, e.g., grains in **C** are **more** rounded
		(iv)	grains in **C** have undergone more / further / longer transport than in **B** ✓ grains in **C** have undergone more erosion / abrasion / attrition than in **B** ✓	**Max 1**	3.1b	**ORA**
	(b)	(i)	correct plotting of composition of **A** on triangular diagram at 65% quartz, 25% feldspar and 10% rock fragments ✓	**1**	1.1d	

Question			Answer	Mark	AO Element	Guidance
		(ii)	**Any one** environment of deposition from: river / alluvial fan / wadi / turbidity flow ✓ Analysis of **Any one** textural characteristic from: immature **OR** poorly sorted **OR** angular / subangular grains **OR** muddy matrix **AND** deposited close to source **OR** transport was of short duration **OR** lack of erosion / abrasion / attrition **OR** rapid deposition **OR** clay settled from suspension **OR** low energy ✓ Analysis of **Any one** composition characteristic from: immature **OR** quartz and feldspar-rich **OR** contains feldspar / rock fragments **AND** softer minerals / minerals with cleavage have not been destroyed by erosion / abrasion / attrition ✓	**3**	3.1d 3.1a 3.1a	
	(c)		evidence from thin section diagram: has a (calcite) cement / has undergone cementation ✓ **Any two** explanations from: • groundwater / pore fluid contains dissolved minerals / calcite ✓ • dissolved calcite / minerals may be products of pressure solution ✓ • solution passes through sediment / pore space ✓ • minerals are precipitated / crystallise in the pore space ✓	**3**	2.1b 1.1a 1.1c	

Question			Answer	Mark	AO Element	Guidance
27	(a)	(i)	axes with correct linear scales, labels and units ✓ Points plotted correctly ✓✓✓	4	1.1d	1 to 5 points plotted correctly = 1 mark 6 to 9 points plotted correctly = 2 marks 10 to 12 points plotted correct = 3 marks 
		(ii)	smooth line through the plotted points **OR** just above the plotted points ✓	1	3.1b	**ALLOW** straight **OR** curved line
		(iii)	subduction **OR** earthquakes occur along the top of the subducted plate **OR** earthquakes mark the Benioff Zone ✓ the plates are prevented from moving by friction and <u>strain energy</u> builds up **OR** stored <u>strain energy</u> is released as seismic waves when the plates move ✓	max 2	2.1b	

Question			Answer	Mark	AO Element	Guidance
		(iv)	anomalous point circled on graph at distance 492 km, depth 45 km ✓	**1**	3.1d	
		(v)	there is movement along a fault ✓ earthquake was triggered by rising magma ✓ an old fault has been reactivated ✓ earthquakes can occur anywhere where sufficient strain has built up ✓	**Max 1**	2.1a	

Question			Answer	Mark	AO Element	Guidance
	(b)	**(i)**	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer =** 0.85(13986) **award 2 marks** Correct substitution of values into equation: $r_s = 1 - ((6\sum d^2) / (n^3-n)) = 1 - ((6 \times 42.5) / (12^3 - 12))$ ✓ $= 0.85$ ✓	**2**	2.1b	
		(ii)	the critical value is less than the calculated correlation coefficient (r_s) value (0.8514) ✓ the critical value is 0.6485 at the 0.05 / 95% significance level **OR** 0.7939 at the 0.01 / 99% significance level ✓ can be 95% confident that the null hypothesis can be rejected as the Spearman's rank correlation coefficient (r_s) value is above 0.6485 ✓ (can be 99% confident that) the null hypothesis can be rejected as the Spearman's rank correlation coefficient (r_s) value is above 0.7939 ✓ can be 99% confident that the result did not occur by chance / there is correlation ✓ there is a statistically significant correlation between the distance from the plate boundary and the depth of foci of the earthquakes ✓	**max 2**	3.1d 3.1e	**ALLOW ECF** for Spearman's rank correlation coefficient from **28(b)(i)** E.g., • If **ECF** r_s value lower than 0.5636 there is no statistically significant correlation / null hypothesis cannot be rejected • If **ECF** r_s value between 0.5636 and 0.6485 can only be 95% confident that the null hypothesis can be rejected • If **ECF** r_s value above 0.7939 can be 99% confident that the null hypothesis can be rejected **ORA**

Question			Answer	Mark	AO Element	Guidance
28	(a)*		Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question. **Level 3 (5–6 marks)** Describes all stages of the Wilson cycle model for ocean basin evolution **AND** Fully explains the plate tectonic processes involved. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Describes an outline of the Wilson cycle model **AND** Explains some of the plate tectonic processes involved. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Attempts to give some stages of the Wilson cycle **OR** Attempts to explain some of the plate tectonic processes involved. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.*	**6**	3 x 1.1a 3 x 2.1a	**Indicative points may include:** **AO1.1a Demonstrates knowledge of the Wilson cycle:** • occurs on a 300 - 500 Ma year cycle. • starts with rifting / rift valleys / graben / embryonic oceans forming in continental areas • continents then drift / move apart to form a new / young ocean basin • passive margins on either side • ocean basin becomes mature • ocean basin then begins to close / decline • terminal stage / collision of continents and final closure / suturing of ocean basin occurs • may give present day examples, e.g., East Africa for rifting **OR** Red Sea / Atlantic Ocean for drifting apart **OR** Pacific Ocean for closure **OR** Himalayas for final closure / suturing **AO2.1a Applies knowledge and understanding of plate tectonic processes:** • continents rift apart due to tensional stresses / crustal extension / continental hot spots / mantle plumes • driven by convection currents in the mantle • ocean widens / new oceanic lithosphere is created by seafloor spreading at divergent plate margin / mid-ocean ridge • ridge push occurs

Question			Answer	Mark	AO Element	Guidance
			0 marks *No response or no response worthy of credit.*			• ocean starts to close due to subduction of ocean lithosphere at convergent plate margins / trenches / island arcs • slab pull occurs • compressional stress results in collision of continents / formation of orogenic belts • obduction may occur / ophiolites may be preserved in continental areas • idea that oceans open and close due to balance between formation by seafloor spreading and destruction by subduction
	(b)	**(i)**	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer =** 9 **award 2 marks** temperature change = -50 - +40 = 90 °C time = 720 - 710 = 10 Ma working showing temperature change ÷ time period ✓ = 90 / 10 = <u>9</u> +/- 0.5 (°C Ma^{-1}) ✓	**2**	2.1b	1 mark for correct working 1 mark for correct answer **ACCEPT** 8.5 – 9.5 (°C Ma^{-1})
		(ii)	arrow at 710Ma – rapid increase in temperature ✓	**1**	3.1a	
	(c)	**(i)**	lava / magma / rock contains magnetic minerals / iron minerals / magnetite ✓ iron minerals align with the Earth's magnetic field (at the time) **OR** iron minerals align in direction of the	**max 2**	1.1b 2.1a	**ALLOW** correct named rock containing iron minerals, e.g. mafic rock / basalt

Question			Answer	Mark	AO Element	Guidance
			Earth's magnetic field **OR** iron minerals show alignment with respect to the poles (at the time) ✓ magnetism is preserved (as remnant magnetism) when minerals cool below Curie point ✓			
		(ii)	magnetic inclination / dip of the Earth's magnetic field (from the horizontal) **AND** varies with latitude **OR** gives palaeolatitude ✓ (magnetic inclination / dip of the Earth's magnetic field preserved in rock) would be horizontal / 0° / parallel to the Earth's surface ✓	**1** **1**	1.1b 1.1c	
		(iii)	(rocks formed at the Equator at this time) would contain glacial deposits / tillite / boulder clay / glacial striations ✓	**1**	2.1a	**ALLOW** any correct named glacially formed deposit, e.g., varves / dropstones / glacial till
	(d)	**(i)**	hydrolysis **OR** carbonation **OR** oxidation occur ✓ water and carbon dioxide react to form carbonic acid ✓ soluble ions are formed ✓ residue of clay minerals / unreactive minerals / quartz is left behind ✓	**max 3**	1.1a 1.1c	**ACCEPT** hydrolysed **ALLOW** any correct named ion, e.g., K^+ / Na^+ / Ca^{2+} / HCO^{3-}
		(ii)	chemical weathering removes carbon dioxide from the atmosphere **AND** stored as carbonate ions / hydrogen carbonate ions in solution / in rivers / the sea / carbonate sediments / carbonate rocks ✓	**2**	2.1a	**ALLOW AW**

Question			Answer	Mark	AO Element	Guidance
			carbon dioxide is a greenhouse gas so its removal from the atmosphere leads to global cooling ✓			
		(iii)	deposition of carbonate rocks / limestone / chalk (in marine areas) ✓	**1**	2.1a	**ALLOW** any correct named carbonate rock / limestone
		(iv)	snow / ice cover has a high albedo / albedo is 80-95% **OR** has high reflectivity ✓ high albedo reflects solar energy / heat back into space making it colder ✓ as it gets colder, more precipitation falls as snow / ice **AND** causes it to become even colder ✓ causes a positive feedback loop **OR** runaway global cooling effect ✓	**max 2**	1.1c	
	(e)		heat from volcanic eruptions (under the snow / ice cap) caused melting of the ice ✓ volcanic eruptions release carbon dioxide / greenhouse gases into the atmosphere causing global warming ✓ melting of methane hydrates / methane gas locked in frozen sediment releases methane into the atmosphere which is another powerful greenhouse gas / causes more global warming ✓ volcanic ash / lava/ basalt covers the ice / snow and absorbs more solar energy ✓	**max 2**	1.1a 1.1c	

Question			Answer	Mark	AO Element	Guidance
29	(a)		there are many convergent plate boundaries around the Pacific Ocean which have the potential to generate large submarine earthquakes / underwater slides of volcanic debris ✓ there are no / few convergent plate boundaries around the Atlantic Ocean **OR** most of the Atlantic Ocean is aseismic **OR** Atlantic Ocean has divergent plate margins with smaller earthquakes **OR** the Atlantic Ocean has many passive plate margins with no earthquakes ✓	**2**	1.1c	
	(b)		tsunamis occur more often in the Pacific Ocean so expected **OR** tsunamis in the Indian Ocean are rare so was not expected ✓ the Pacific Ocean had a tsunami warning system in place at the time, the Indian Ocean did not ✓ many people live in low-lying coastal areas / islands around the Indian Ocean ✓ Japan had tsunami defences / tsunami evacuation routes / raised buildings / development-free coastal zones / better emergency planning / preparation / building construction ✓	**max 3**	2 x 1.1c 2.1b	**ALLOW AW** **ALLOW** specific detail of Pacific Ocean tsunami warning system **ORA** **ALLOW** any correctly described tsunami defence, e.g., sea walls / embankments **ALLOW** impact of deforestation in Indian Ocean
	(c)	**(i)**	seismometers / seismographs had not been invented ✓	**1**	3.1b	

Question			Answer	Mark	AO Element	Guidance
		(ii)	3 (hours) ✓	1	3.1a	
		(iii)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer =** 139 **OR** 138.9 **OR** 138.$\dot{8}$ **award 2 marks** distance = 1500 x 1000 m = 1500000 m time = 3 x 60 x 60 s = 10800 s working showing speed = distance ÷ time ✓ 139 **OR** 138.9 (m s^{-1}) ✓	2	1.1b	**ALLOW ECF** **Max 1** mark if correct but more than 1 decimal place
	(d)		tsunamites / tsunami deposits have been found in land areas / onshore ✓ marine diatoms / fossils found in terrestrial sediments ✓ rip-up clasts in finer sediments ✓ marine sediments within terrestrial deposits ✓ marine deposits found (9 m) above current sea level / coastline ✓ anomalous high energy / coarse sediments in finer sediments✓	max 2	1.1a	

Question			Answer	Mark	AO Element	Guidance
	(e)		**Any one** description of the Storegga Slide from: • submarine / underwater slide (off the coast of Norway) ✓ • sudden collapse of the continental shelf near Norway ✓ • submarine slide displaced about 3,000 km^3 of sediment ✓ • submarine slide may have been triggered by an earthquake **OR** by deposition of a large volume of sediment from melting glaciers on the continental shelf ✓ **Any one** explanation of how a tsunami was generated from: • large volume of sediment displaced a large volume of water (upwards) ✓ • sudden movement of seafloor sets up a large wave ✓ • forms a broad swell out to sea, height increases in coastal waters when the wave slows down and breaks ✓	**2**	1.1a 1.1c	**MUST** include idea submarine event **OR AW** for submarine

Question			Answer	Mark	AO Element	Guidance
	(f)		non-specialists lack technical / scientific knowledge **AND** understanding of probability / return periods / degree of ground shaking ✓ geologists are unable to predict exact time / location / magnitude of future earthquakes ✓ difficult to decide if a public warning is appropriate ✓ earthquakes of the same magnitude can have very different consequences ✓ public perception of risk **OR** what a person believes the risk to be **AND** is different to the actual / true risk established by collecting and analysing data ✓ geoscientists may be sued / prosecuted for attempting predictions **OR** for giving false alarms ✓	**max 2**	1.1c	**DO NOT ALLOW** general discussion of risk as given in question **ALLOW** reference to the 2009 L'Aquila earthquake, Italy, after which seismologists were prosecuted / jailed for manslaughter for giving 'falsely reassuring statements' before the earthquake

Question			Answer	Mark	AO Element	Guidance
30	**(a)**	**(i)**	labelled arrow at the boundary between the copper oxide and carbonate minerals and the copper sulfide minerals ✓	**1**	2.1b	

Question			Answer	Mark	AO Element	Guidance
		(ii)	**Any two** processes above the water table from: • above the water table conditions are oxidising / oxidation occurs ✓ • chemical weathering / chemical reactions convert insoluble copper sulfides into soluble copper sulfates / carbonates / oxides ✓ • correct example of a chemical reaction, e.g., chalcopyrite + water + oxygen → copper sulfate + iron (III) hydroxide ✓ • infiltrating / percolating (rain)water dissolves copper / takes copper into solution / copper is leached downwards ✓ **Any two** processes below the water table from: • below the water table conditions are reducing / anoxic / reduction occurs **OR** the water table is the redox boundary ✓ • chemical reactions convert (soluble) copper sulfates / carbonates / oxides into (insoluble) copper sulfides ✓ • copper / ore is (re)precipitated immediately below the water table ✓ • copper is concentrated into a smaller volume, so the grade is higher ✓	**4**	1.1a 2.1a 1.1a 2.1a	**ALLOW** use of correct named copper ore minerals in explanations **ALLOW** spelling sulphide / sulphate **ALLOW** the gossan capping is a barren / leached zone of insoluble iron oxides **DO NOT ALLOW** use of the term deposition
		(iii)	the area is now hot and arid **OR** a desert so there is no water available for chemical reactions / chemical weathering	**1**	2.1a	

Question			Answer	Mark	AO Element	Guidance
			OR all the available copper has already been leached from the rocks above the water table ✓			
	(b)*		Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question. **Level 3 (5–6 marks)** Uses numerical data from the table to compare the geophysical signatures of the host rocks and copper ore minerals to evaluate which geophysical techniques are likely to be most successful in locating copper ore deposits. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Attempts to evaluate which geophysical techniques are likely to be successful in locating copper ore deposits. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** May list or give a basic outline of one or more geophysical exploration techniques **AND / OR**	**6**	3 x 1.1b 3 x 3.1c	**Indicative points may include:** **AO1.1b Demonstrates knowledge of geophysical techniques** **general points** • can be land or air-based (except resistivity surveys) • may be done as a grid or transect survey • looking for geophysical anomalies **OR** departures from normal values • results are plotted on anomaly / isoline maps **gravity survey** • use of a gravimeter **OR** detecting variations in Earth's gravitational field strength • gravity survey gives information about density of underlying rocks / minerals • data is corrected for latitude **OR** altitude **OR** topography **electrical resistivity survey** • electrical resistivity is measured using metal electrodes / probes • an electric current is passed through rock **magnetic survey** • use of a magnetometer **OR** detects variations in Earth's magnetic field strength **electromagnetic (EM) survey**

Question			Answer	Mark	AO Element	Guidance
			Some relevant information is lifted from the table in an attempt to evaluate the use of geophysical techniques in locating copper ore deposits. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*			• measures ground conductivity • uses the process of electromagnetic induction **OR** may use VLF transmitters • values are given as percentage of the induced secondary field relative to the primary field **AO3.1c Evaluates which geophysical techniques are likely to be successful in locating copper ore deposits** **general points** • finding a geophysical anomaly does not guarantee the presence of an economic copper ore deposit • geophysical surveys do not give precise information about mineral content / grade / depth • only one part of an exploration programme / geochemical surveys / exploration drilling will also be needed **gravity survey** • copper ore minerals will give positive gravity anomaly • likely to be successful **AND** copper ore minerals have a much higher density than host rocks **OR** density of ore minerals 5090 – 4200 kg m^{-1} compared to 2500 – 2990 kg m^{-1} for host rocks • most successful if host rock is granite

Question			Answer	Mark	AO Element	Guidance
						electrical resistivity survey • copper ore minerals are good conductors **OR** copper ore minerals will give negative resistivity anomaly • likely to be successful **AND** copper ore minerals have a much lower resistivity / higher conductivity than host rocks **OR** resistivity of ore minerals 10^{-5} – 10^{-4} compared to 10^{3} – 10^{6} for host rocks • most successful if host rock is granite **magnetic survey** • not likely / may be successful **AND** magnetic susceptibility of copper ore minerals overlaps with that of the host rocks **OR** magnetic susceptibility of copper ore minerals 0-13 compared to 0-4400 for host rocks • most successful if host rock is diorite **electromagnetic (EM) survey** • copper ore minerals are good conductors **OR** copper ore minerals will give positive EM anomaly • likely to be successful **AND** copper ore minerals have a much higher conductivity than host rocks • most successful if host rock is granite
	(c)		decision needs to be made about the type and design of the mine, e.g., open cast or underground ✓	**max 3**	1.1a	**ALLOW** any correct named mining method

Question			Answer	Mark	AO Element	Guidance
			planning for / design of infrastructure **OR** access roads **OR** extraction facilities **OR** processing facilities **OR** ventilation ✓ checking that the mine is economically viable ✓ planning for environmental management **OR** environmental impact assessment must be done **OR** plans for restoration / reclamation must be made in advance ✓ involving the local community in decisions and plans ✓ planning must include health / safety considerations ✓ phased development may be planned to mine highest grade ore first to offset costs of exploration / development ✓			
	(d)	**(i)**	ore is broken / crushed / reworked mine waste is piled up on an impermeable liner ✓ a solvent is applied to the ore by spraying / pumping / using a drip system ✓ copper is <u>dissolved / taken into solution</u> and the leach solution is collected (in a pond) ✓ only 60-70% of the copper can be recovered **OR** the process takes two months to two years to complete ✓	**max 2**	1.1b	**ALLOW AW**
		(ii)	the electricity used for electrolysis can be generated using renewable methods **OR** no requirement to use coal as the fuel **OR** lower energy requirements **OR** lower energy costs ✓	**max 3**	3.1d	

Question			Answer	Mark	AO Element	Guidance
			smelting causes atmospheric pollution / acid rain / releases sulphur dioxide / releases carbon dioxide / releases greenhouse gases ✓ can be used to extract copper from very low-grade ore / reworked mine waste ✓ can be operated economically on a small scale ✓ copper produced by smelting has to be further purified by electrolysis ✓ other precious metals / valuable metals / gold / silver can be recovered as by-products from electrolysis ✓			**ORA**

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