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A LEVEL

Examiners' report

GEOLOGY

H414

For first teaching in 2017

H414/02 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 2 series overview

This paper is synoptic and assesses content from across teaching modules 1-7. There is an emphasis on scientific literacy: the ability to comprehend a passage of text of A Level standard, to extract information from it and to use the information to answer the question posed.

Most candidates were well prepared and planned their time to answer all the questions. There was no evidence that any ran out of time. In the main, candidates confined their answers to the answer lines given in the examination booklet, which provide enough space to attain the maximum marks available for each question.

Answers to the two 6 marks Level of Response questions (LoR) were usually concise and it was clear that many candidates have a sound understanding of how to approach these questions. The list of indicative points given in the guidance column of the mark scheme for these questions are by no means exhaustive and candidates do not have to include all the points in order to attain the highest level.

The mathematical requirement of the paper continues to be a challenge for some. Those candidates who had been given opportunities to practise the required mathematical skills (Appendix 5e of the specification) over the two years of the course were able to demonstrate their proficiency and performed well on the mathematical skills questions.

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• read the questions carefully, taking note of all the information supplied and the command words used • used their knowledge and understanding from different areas of the specification when answering individual questions • had good command of correct geological terminology and knowledge and were able to apply what they had learnt to unfamiliar contexts • produced clear and concise answers to the Level of Response questions which included sufficient detail and addressed all the requirements of the questions • performed mathematical calculations with confidence, following the required rubric, e.g., clearly laid out working, use of correct units and significant figures • drew, labelled, and plotted graphs and diagrams carefully and accurately using a sharp HB pencil.	• wrote under-developed answers which either repeated the questions or did not clearly address what the questions asked • did not have the depth and breadth of geological understanding required to answer the mainly synoptic questions on this paper • did not have good command of correct geological terminology and knowledge and found it difficult to apply what they had learnt to unfamiliar contexts • produced unstructured responses to the Level of Response questions which were lacking in depth and explanation or contained incorrect and contradictory information • were unable to tackle the mathematical skills questions with any confidence, with some giving no response to all the calculation questions • were inaccurate when plotting graphs and drawing diagrams, which often gained little or no credit.

Question 1 (a)

1 Coal mining in the UK peaked in the 18th and 19th centuries with as many as 2000 mines operating in the UK. These abandoned mines have left spoil heaps, abandoned engineering, unstable land surfaces and brownfield sites.

(a) Describe and explain the term **brownfield site**.

....

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....

....

.... **[2]**

The definition of a brownfield site was well known, and most candidates gained marks for their answers.

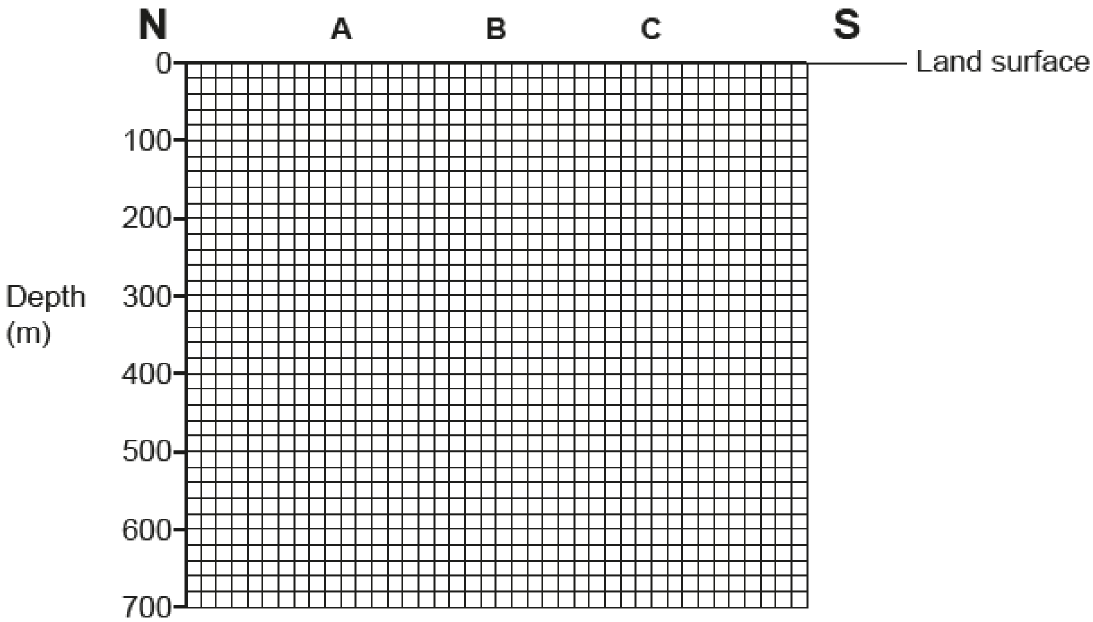
Less successful answers repeated the information given in the question and described abandoned mines, spoil heaps and unstable land or described waste disposal sites, both of which are excluded from the UK definition of a brownfield site.

Question 1 (b) (i)

(b) The table shows data about the position of coal seams and faults, collected from three boreholes (sites **A**, **B** and **C**) across an abandoned underground coal mine.

	Depth from surface (m)		
Feature	**Site A**	**Site B**	**Site C**
Fault	Not seen	650	450
Top of coal seam X	200	250	260
Bottom of coal seam X	210	340	390
Top of coal seam Y	500	520	485
Bottom of coal seam Y	565	585	550

(i) Plot the data on the grid below to show both coal seams and the fault.



[3]

A significant number of candidates did not gain any credit for their answers to this question as they did not understand or ignored the prompt to show the coal seams and the fault. Many just plotted and marked the data points with an x, rather than connecting them up to show the positions of coal seams **X** and **Y** and the fault.

Of those candidates who understood what to do, not all accessed all the marks. The most common omission was not showing coal seam **Y** displaced by the fault, while others made mistakes plotting the positions of the data points.

Question 1 (b) (ii)

(ii) An engineering company is assessing the abandoned coal mine as a potential repository for the storage of low-level nuclear waste. The coal was mined using a shaft system and stope mining. The shaft access is close to site **A**.

Assess the suitability of the abandoned coal mine as a potential repository for storing waste underground.

....

....

....

....

.... **[2]**

There were some well written and detailed assessments which described advantages such as 'easy access', 'ready-made hole in the ground' and 'rocks absorb radiation' and disadvantages such as the possibility of roof collapse, fault reactivation, leakage and groundwater contamination. However, overall, this was a low scoring question as many candidates did not use precise or correct geological terminology.

Candidates often only evaluated the shaft entrance at site **A** rather than the whole underground coal mine which made it difficult to attain full credit. Some candidates referred to leaching of waste when, in this context, they should have described leaking of waste products.

Misconception

Candidates frequently described contamination of the water table, rather than correctly referring to contamination of groundwater or aquifers. The water table is the surface separating unsaturated rock above from saturated rock below, whereas groundwater is the water in the pore space of rocks below the water table.

Question 1 (b) (iii)

(iii) Describe how stope mining was used in the removal of coal and explain **one** problem with this method of extraction.

....

....

....

....

.... **[2]**

The mechanics of how stope mining is carried out was not well understood but about half the candidates were able to access some credit usually for explaining a problem associated with this method of mineral extraction.

Candidates did not always distinguish between entry shafts, which are usually vertical, versus levels, roadways and trackways, which are usually horizontal. Some candidates referred to the use of explosives which would be appropriate for hard rock stope mining for metallic mineral ores, but not for coal extraction. In addition, others were confused with open cast mining.

Misconception

It was clear there was confusion between stope mining and longwall retreat mining. In longwall retreat mining the roof is deliberately allowed to collapse as mining takes place backwards towards the shaft, whereas in stope mining the mined-out areas, called stopes, are either left as voids or backfilled with waste.

Question 1 (c) (i)

(c) Abandoned coal mines have significant impact as they discharge acidic water into the environment. Pyrite (FeS_2) in the rocks is exposed to water, oxygen and microorganisms producing acidified water.

This can be shown in the balanced equation.

$$2FeS_2 + 7O_2 + 2H_2O \rightarrow 2Fe^{3+} + 4H^+ + 4SO_4^{2-}$$

(i) Explain how the resultant waters from this chemical reaction can cause environmental problems.

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....

....

.... **[3]**

Most candidates gained some marks for their knowledge of how the acid mine drainage water described in the question can cause environmental problems. The most common correct responses were that acid mine drainage water contaminates surface or groundwater supplies and damages ecosystems by killing plants or poisoning wildlife. The harming of marine organisms was accepted as acid mine drainage water can flow out to sea.

Not all candidates were able to give sufficient detail to attain maximum marks and only the best answers referred to the presence of toxic heavy metals such as lead, mercury, and arsenic in the water. There was confusion with acid rain, carbon dioxide emissions and climate change which are not direct environmental consequences of acid mine drainage water.

Question 1 (c) (ii)

(ii) Suggest **one** method to mitigate the effects of the pollution outlined in **(i)**.

....

.... **[1]**

Fewer than half of candidates were able to suggest a suitable active or passive treatment method to mitigate the effects of acid mine drainage water. Some answers were too vague to gain the mark.

A minority of candidates wrote acid mine drainage as their answer which is the problem caused by the chemical reaction described in Question 1 (c) (i), rather than a mitigation method.

Question 2 (a) (i)

2 (a) (i) The table shows some morphological features that are found in brachiopods and bivalves.

For each morphological feature, use a (✓) or a cross (✗) to indicate if it is found in brachiopods, bivalves or both.

The first one has been done for you.

Morphological feature	**Brachiopod ✓ or ✗**	**Bivalve ✓ or ✗**
Composed of calcite	✓	✓
Pedicle foramen		
A line of symmetry along the hinge line		
Pallial line		

[3]

Most candidates attained at least 1 or 2 marks for correctly comparing the morphology of brachiopods and bivalves, but those who achieved maximum marks were in the minority. Most were familiar with the pedicle foramen as a brachiopod characteristic and the line of symmetry along the hinge line as a bivalve characteristic, but few knew the pallial line is exclusive to bivalves. A small number of candidates got all the features the wrong way round.

Question 2 (a) (ii)

(ii) Describe and explain **three** adaptations of a brachiopod which lived in a high-energy marine environment.

1 ....

....

2 ....

....

3 ....

....

[3]

This question was well answered, and most candidates were able to correctly describe and explain some brachiopod adaptations to a high energy environment. Only a few gave descriptions with no explanations.

As the question did not specify fossil, either referring to the pedicle foramen showing the existence of a pedicle or the pedicle itself allowing attachment to the substrate were acceptable answers. However, a common error was to suggest the brachiopod was attached by the pedicle foramen.

Some candidates referred to hard rather than robust or thick valves, which showed a lack of understanding of the difference between hard and strong. Calcite, which is the primary constituent of a brachiopod valve, is a soft mineral.

Spines to anchor the brachiopod in sediment were sometimes suggested, but this is an adaptation for stability in a low energy environment with a soft substrate.

Assessment for learning

When teaching morphology of brachiopods, a clear distinction should be made between the foramen as the opening through which the pedicle emerges, and the pedicle itself which is the fleshy stalk which attaches the brachiopod to the substrate. Only the foramen would be seen in a fossil brachiopod.

Question 2 (a) (iii)

(iii) Describe what other **fossil** evidence you would look for in the field to interpret an environment as high energy.

....

....

....

....

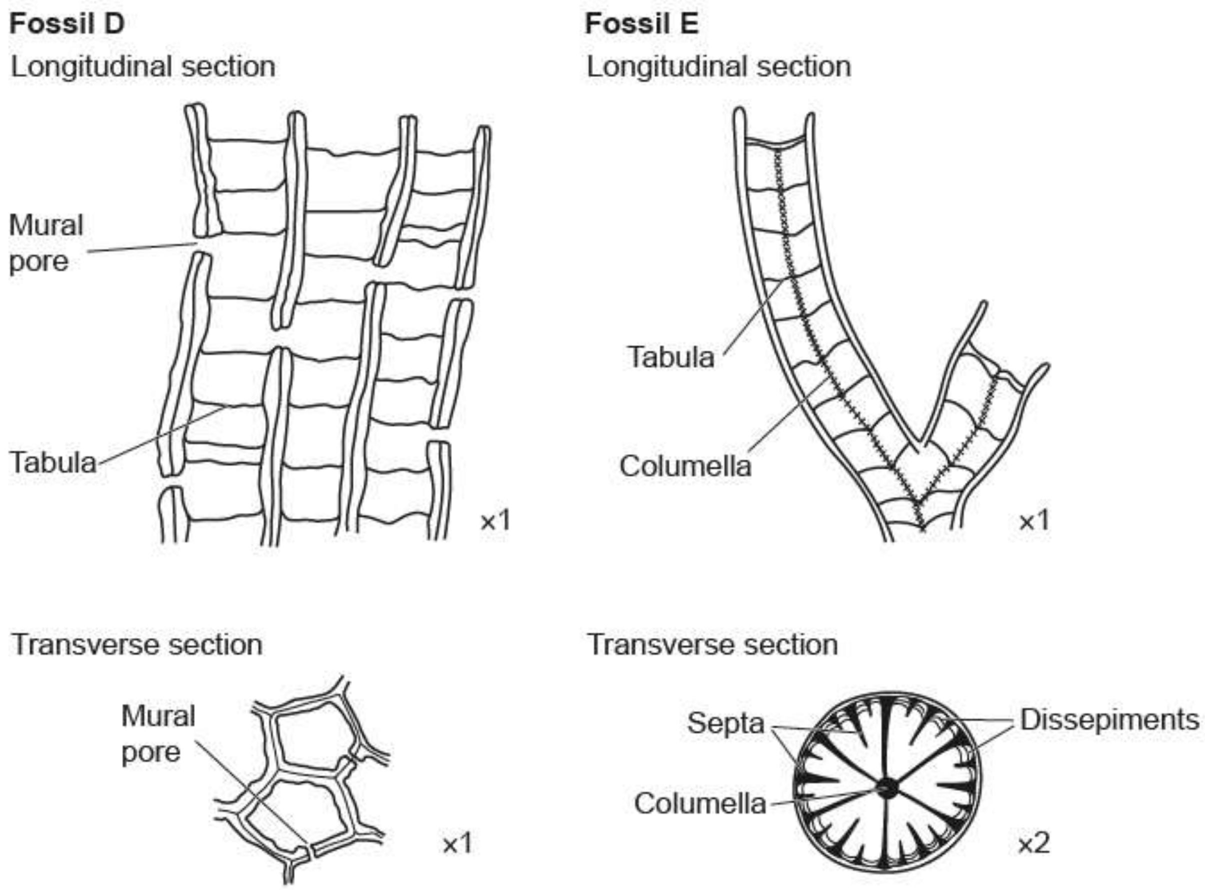
.... **[2]**

Most responses attained 1 mark for correctly describing fragmented/disarticulated fossils or a death assemblage. Few candidates were able to suggest anything more, such as sorting by size, alignment by current, or the presence of burrows as adaptations to high energy conditions.

A small number of candidates discussed the presence of sedimentary structures such as ripple marks indicating a current, but these were not relevant as the question asked for **fossil** evidence.

Question 2 (b) (i)

(b) Fossils **D** and **E** are from two different geological periods.



(i) Identify the fossil phylum or group to which these fossils both belong.

.... **[1]**

The majority of candidates correctly identified the fossil phylum as Cnidaria or the group as corals. A few also gave Anthozoa as a correct answer.

However, some candidates identified both fossils as either tabulate, rugose or scleractinian corals which is incorrect as fossil **D** is a tabulate coral, whereas fossil **E** is a scleractinian coral.

Question 2 (b) (ii)

(ii) Compare and contrast the morphology of fossils **D** and **E**.

....

....

....

....

....

.... **[3]**

Only the best answers to this question used all the information provided on the diagrams to make concise and explicit comparisons of the two fossils for maximum marks.

Common errors were suggesting fossil **E** was solitary or that fossil **D** had no symmetry. Some described the features of each but did not make comparisons between them. Others included explanations or interpretations in their answers which were not required. A minority got confused and contradicted themselves, for example, by stating fossil **D** had mural pores and fossil **D** did not.

Question 2 (b) (iii)

(iii) In which geological era did fossil **D** live?

Tick (✓) **one** box.

Cenozoic ☐

Mesozoic ☐

Palaeozoic ☐

[1]

Candidates found this question more challenging as it required them to identify fossil **D** as a tabulate coral and know tabulate corals were extant in the Palaeozoic era. Nearly half of answers were incorrect.

Question 2 (b) (iv)

(iv) Identify **one** other fossil that is likely to be found in a life assemblage with fossil **E**.

.... **[1]**

Just over half of candidates gained credit for suggesting a suitable reef-building or reef-dwelling organism with hard parts that would have the potential to be fossilised and found in a life assemblage with fossil **E**.

Question 2 (b) (v)

(v) Fossils **D** and **E** have relatives that are extant (alive at the present time). Geologists presume that they all had the same mode of life and ecology.

Describe the likely mode of life and ecology of this group of organisms.

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.... **[4]**

The mode of life and ecology of corals was well-known and there were some excellent answers to this question which scored maximum marks with ease. These candidates had good command of the subject matter, included good use of technical terminology, and quoted precise facts and figures of water depth, temperature and salinity. Less successful answers gave descriptions of warm, shallow water which were not specific enough to earn credit.

The most common correct marking point was knowledge that corals have a sessile/benthonic/epifaunal mode of life. However, some candidates used all the available answer lines by repeating every combination of this mode of life for just 1 mark, while others managed to contradict themselves by including pelagic or infaunal in their long list of alternatives.

Some candidates thought that corals are plants, while others thought polyps are not part of the coral but have a symbiotic relationship with the coral suggesting confusion with symbiotic algae.

Misconception

There is a common and recurring misconception that corals are plants and carry out photosynthesis. Coral polyps are animals and do not photosynthesise. It is the zooxanthellae algae, with which the corals have a symbiotic relationship, which do this. Hence the need for most corals to live in the photic zone with good light penetration.

Question 2 (c) (i)

(c) The Cretaceous–Tertiary (K/T) boundary marks a mass extinction event which saw the demise of many organisms, including dinosaurs.

(i) In addition to the dinosaurs, identify a terrestrial organism or group which became extinct at the Cretaceous–Tertiary boundary.

.... **[1]**

This was a low scoring question. Some candidates quoted a correct terrestrial organism or group which became extinct at the Cretaceous–Tertiary boundary. Pterosaurs was the most common correct answer. Incorrect answers included marine organisms such as ammonites and belemnites, also trilobites and graptolites which were extinct long before the end of the Cretaceous period.

Question 2 (c) (ii)

(ii) State the name of a replacement organism that filled the same ecological niche as dinosaurs **and** explain the reasons for your choice.

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....

.... **[2]**

Some candidates were able to name mammals or birds as the replacement organism, but fewer answers attained the explanation mark. Few used technical terms such as diversification or adaptive radiation. Those who understood the more varied diet of mammals or the fact some were burrowing/aquatic made them more able to survive the rapid environmental change brought on by an asteroid impact were in the minority. A few answers referred to the increase in size of mammals and even used technical terms such as megafauna to describe them.

Question 2 (c) (iii)

(iii) The Cretaceous–Tertiary mass extinction event was thought to have been triggered by an asteroid or meteorite.

Describe and explain **two** pieces of evidence which support this hypothesis.

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.... **[2]**

Most candidates gained credit for their knowledge of the evidence for the asteroid or meteorite impact that triggered the Cretaceous–Tertiary mass extinction. The impact site at Chicxulub, Mexico, was well-known, as were the iridium anomaly, shocked quartz grains, tektites and tsunami deposits.

Less successful answers were merely descriptive and did not provide linked explanations. Some candidates did not quote the site of the proposed impact and thus lost a mark, while others referred to ejecta from volcanic eruptions or described an unusual extraterrestrial metal without naming iridium.

Question 3 (a) (i)

3 **(a)** Early ideas about how the continents moved have been improved by new hypotheses using current evidence.

(i) Describe the theory of **continental drift**, as proposed by Wegener in 1915.

....

....

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....

.... **[2]**

Responses to this question were variable. Some candidates displayed a sound understanding of Wegener's theory of continental drift, including the existence of supercontinents in the past, the moving together or apart of continents, the 'jigsaw' fit of the continents and Wegener's other evidence. However, few conveyed the idea of continents moving <u>over time</u> in their answers.

Other candidates were less familiar with Wegener's theory and were unable to give creditworthy answers. These candidates were not aware that the theory of continental drift pre-dates knowledge of plate tectonics, sea floor spreading, ridge push and slab pull and that, at the time, there was no suggestion of a mechanism for the movement of continents.

Question 3 (a) (ii)

(ii) A later theory explained the movements of the plates using mantle convection, a theory which has now been rejected.

Describe why active mantle convection as a method to move plates has been discounted as a theory.

....

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....

....

.... **[2]**

Not many candidates gained one mark here and very few gained both marks. The idea that convection cells do not have enough energy to move the plates and the lack of any correlation between the movement of the mantle and the movement of the plates were most well-known, as was the idea that the asthenosphere is too plastic/flexible to produce enough friction to move the plates along. A small number also suggested the drag of the mantle may slow the movement of plates. Common misunderstandings were either the mantle is solid or a rheid so cannot undergo convection.

Question 3 (a) (iii)

(iii) Describe and explain **one** mechanism of the current theory of plate movement.

....

....

....

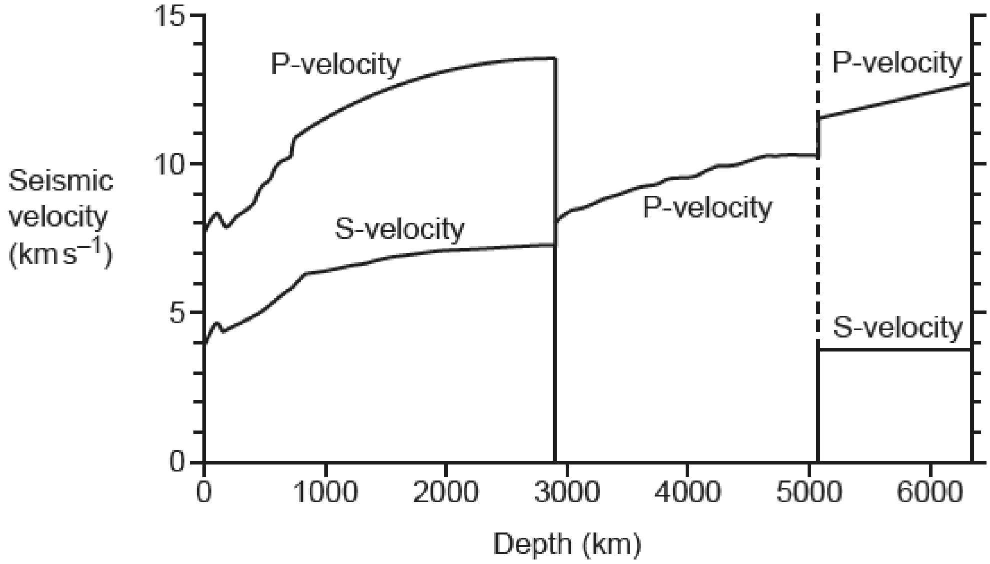
....

.... **[2]**

Ridge push and slab pull were well-known mechanisms but not all were able to give convincing explanations. When explaining slab pull a common omission was forgetting to include the key point that oceanic lithosphere is dense or cold or that gravity is the main driving force. However, those who chose to explain slab pull were generally more successful in their explanations than those who chose ridge push. Few were able to give a sound explanation of the process of gravity sliding acting on the MOR as the main mechanism for ridge push.

Question 3 (b) (i)

(b) The graph shows the changes in seismic velocities of P and S waves as they pass through the Earth.



(i) On the graph, clearly label:

- Low velocity zone
- Gutenberg discontinuity
- Outer core.

[3]

Most candidate gained some marks on this question, but many did not achieve all the available marks.

The correct positions of the Gutenberg discontinuity and the outer core were most often recognised. However, some lost marks as they labelled the outer core as a point on either the Gutenberg or Lehmann discontinuity or, in some cases, within the inner core. Others labelled the Gutenberg discontinuity as the boundary between the outer and inner core (the Lehmann discontinuity).

The position of the low velocity zone was most often incorrect, with many candidates labelling it within the outer or inner core. Of those who knew it is where the seismic velocities dip as they travel through the rheid asthenosphere within the mantle, some were not accurate enough in their labelling to be given the mark.

Question 3 (b) (ii)

(ii) Describe and explain the changes in S wave velocities shown on the graph.

....

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....

....

.... **[2]**

The descriptive part of this question was done well, the explanation less so. Although most candidates were able to use the graph and their own knowledge to describe the general increase in S wave velocity with depth in the mantle or no transmission through the outer core or their reappearance in the inner core, few could give a satisfactory explanation. While some mentioned that S waves are generated by P waves in the inner core, few referred to changes in rigidity in their answers.

Question 3 (b) (iii)

(iii) Calculate the percentage increase in P wave velocity between 1000 km and 2900 km.

Increase in P wave velocity = ... % **[2]**

This question tested mathematical skill M1.4, use of ratios, fractions and percentages, and required recall of the formula for calculating a percentage change. Over half knew the correct formula and this question was done well.

However, some made errors reading the P wave velocities from the graph and their values were out of tolerance, while others read the initial velocity at 0 km rather than 1000 km depth and a few read off the S wave velocities instead. These candidates could still attain 1 mark for error carried forward if their calculation was correct.

The most common calculation errors were forgetting to subtract the original value or dividing by the final value.

Question 3 (c)*

(c)* Describe how the structure and composition of the Earth has been inferred from both direct and indirect evidence.

You should include evidence from density, gravity and magnetism in your answer.

Do **not** include evidence from seismic waves in your answer.

....

....

....

....

....

.... **[6]**

Most candidates attained some credit for their answers to this wide-ranging Level of Response question about the direct and indirect evidence for the structure and composition of the Earth. Candidates who took careful note of the prompt to include density, gravity and magnetism evidence generally performed better than those who didn't.

At the top end there were some excellent, detailed and yet concise answers that gave a good account of the density evidence, along with either the gravity or magnetic evidence, often corroborated with discussion of evidence from other sources such as boreholes, ophiolites, mantle xenoliths and meteorites. These responses touched on many of the different lines of evidence suggested in the guidance column of the mark scheme.

While there was some very good discussion of the density evidence by some candidates, others gave lengthy descriptions of the Goldschmidt classification of elements without correctly linking it to the evidence for the high density of the core. Some of the density values quoted for the crust, mantle and core were incorrect, while others used kg m^{-3} units for quoted values that were clearly in g cm^{-3}. There was also a misconception that density is controlled by state rather than by composition. Some thought that because the metallic outer core is liquid, its density is lower than the solid rock of the mantle.

For magnetism, many provided sound analysis of the evidence provided by the existence of the Earth's magnetic field. Despite there being some confusion as to whether the magnetic field is generated in the outer or inner core, many gave sufficient correct discussion of the evidence for liquid, iron or convection in the core to attain credit for their answers.

Description of the evidence from gravity proved most challenging. Only the highest level responses gave correct accounts of how negative gravity anomalies provide evidence for the roots of mountains made of less dense continental crust or that parts of the mantle flow as a rheid. Many got muddled and tried to link density and gravity evidence, suggesting that gravity evidence shows the Earth gets denser towards the centre.

Issues that limited some candidates' attainment included:

- giving lengthy descriptions of how the evidence is obtained from density, gravity, meteorites, boreholes, ophiolites and mantle xenoliths, but without describing what information about the Earth they provide
- describing the composition and structure of the layers of the Earth, without describing the evidence for them
- digressing into evidence for the formation of the Earth which was not asked for in this question
- Not addressing any correct evidence from density, magnetism and gravity which limited the answer to Level 1
- describing the use of density, magnetism and gravity evidence in the context of geophysical exploration for metallic mineral deposits
- ignoring the prompt not to include evidence from seismic waves.

Exemplar 1

the direct evidence for the structure and composition of the earth comes from the crust, bore holes and volcanic magma. continental and oceanic crust show densities of 2.3 and 2.9 g/cm³. ~~which allows us to know the~~ These can be physically measured to know their composition. Volcanic magma shows the composition of the mantle with the magma released. Boreholes show composition and structure through physical identification. kimberlite pipes can be used as direct evidence as they show the pressure within the mantle through the diamonds and bring mantle xenoliths of peridotite which allow for the composition to be known. the indirect evidence includes the density of the earth, gravity surveys, and EM surveys. the density of the earth is known and the mean density is 5.5 g/cm³ meaning the core must be very dense to make up for the light crust (2.3 → 2.9 g/cm³). meteorites can be used along with this from failed planets to show the earth could have an iron core as when under that pressure iron could be the mineral present. Gravity surveys show the density of different areas of rock through giving gravity anomalies. **[6]**

Exemplar 1 is a concise response that includes more than enough correct content to attain Level 3. Although there a few inaccuracies in the discussion of the magnetic/electromagnetic evidence and one of the density values is incorrect, the candidate has included a good balance of correct evidence, including sufficient detail of density and magnetism, plus mention of gravity, to satisfy the criteria for a Level 3 answer.

Question 4 (a)

4 Distinguishing between dykes, sills and lava flows in the field requires the identification of key characteristics relating to their formation.

(a) Describe and explain the difference between sills and lava flows with reference to crystal size and xenoliths.

Crystal size ....

....

....

Xenoliths ....

....

....

[4]

Most candidates gained some marks for their answers. The fact that crystals in sills are coarser than those in lava flows was well-known and the majority were able to give a correct explanation linked to the differing rates of magma cooling. However, some included irrelevant discussion of chilled and/or baked margins and, in some cases, then forgot to do the comparison and explanation asked for in the question. A significant minority got their descriptions and explanations the wrong way round.

Candidates were less successful when it came to the distribution of xenoliths within sills and lava flows. It was clear that some did not know what xenoliths are, while others did not know where they would be found within the two types of igneous bodies. A common misconception was that xenoliths would only be found in one and not the other, equally split between sills and lava flows. Candidates also struggled to give correct explanations.

Assessment for learning

Candidates should be encouraged to use the correct technical terms of fine, medium and coarse, rather than small or large, when referring to crystal or grain sizes. These terms are not only descriptive, but have an exact size meaning – for igneous rocks fine crystals are < 1mm; medium crystals 1–5mm; and coarse crystals are > 5 mm.

Question 4 (b)

(b) Define the term **discordant**.

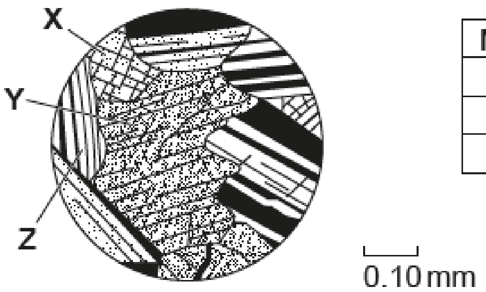
....

.... **[1]**

Most candidates correctly defined discordant as meaning cross-cutting. However, a number of candidates used the descriptors vertical or perpendicular which are insufficient as discordant igneous bodies can be at angle to the beds or layers in the country rock.

Question 4 (c) (i)

(c) The diagram shows a sketch of a thin section from a lava flow, produced at a mid-ocean ridge (MOR), showing three common rock-forming minerals **X**, **Y** and **Z**.



Mineral	Colour in hand specimen
X	Green
Y	Dark greenish black
Z	Whitish grey

(i) Identify the minerals **X**, **Y** and **Z** shown in the thin-section diagram.

X ....

Y ....

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

Many candidates were able to correctly name at least one of the minerals shown in the thin-section diagram. Olivine was most often recognised and plagioclase least often. Some got **X** and **Y** the wrong way round, while others named hornblende or biotite mica as one of the mafic minerals. Plagioclase was often misidentified as either orthoclase feldspar or quartz and some wrote rock names rather than mineral names as their answers. Although the plagioclase would be Ca-rich plagioclase, candidates were not penalised for identifying mineral **Z** as Na-rich plagioclase.

Assessment for learning

The information given in the question that the lava flow was produced at a mid-ocean ridge should have helped candidates realise the rock is mafic and, hence, augite and plagioclase would be expected to make up the bulk of the rock. The distinctive multiple twinning (black and white stripes) should have been a give-away for mineral **Z**, as this is only seen in plagioclase feldspar.

Question 4 (c) (ii)

(ii) Identify the rock shown in the thin-section diagram.

.... **[1]**

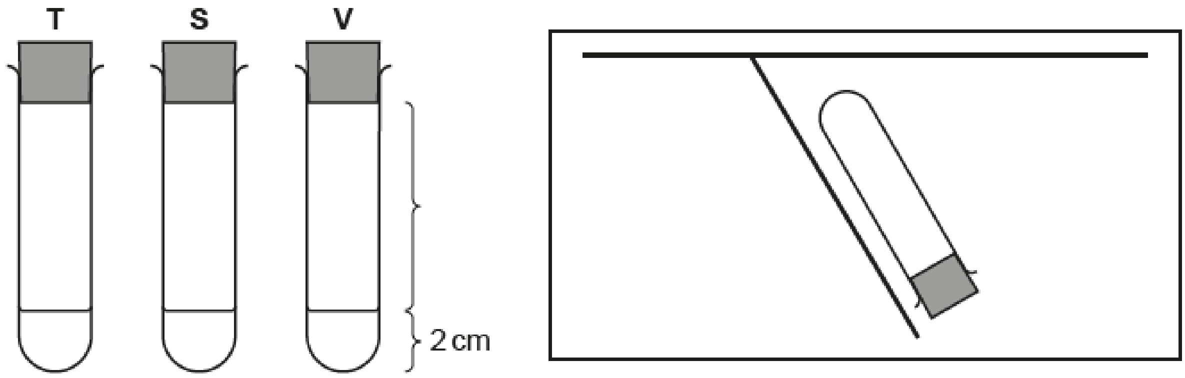
Not many candidates correctly named the rock as basalt. Some did interpret the composition as mafic from the minerals present or from the fact it was produced at a mid-ocean ridge. However, of these, a significant number ignored the scale bar and the description of the rock as a lava flow and misidentified the rock as dolerite or gabbro. The scale bar clearly shows the average crystal size is < 1 mm. Others suggested other igneous rocks such as peridotite, granite or obsidian, and a few gave any random rock name they could think. There were also some 'no responses'.

Question 4 (d) (i)

(d) Measuring the velocity of moving lava can help indicate the composition of the lava.

A group of students decided to investigate the effect of temperature on the velocity of liquids.

They selected three liquids, treacle (**T**), syrup (**S**) and vegetable oil (**V**). They marked a 2 cm line at the bottom of each boiling tube, as shown in the diagram. They then added each liquid to a boiling tube to the 2 cm level and sealed it with a rubber bung.



Boiling tubes Template card

The students recorded the distance between the top of each liquid and the base of the rubber bung. They then tilted each tube to a 60° angle, using a template card for consistency, and measured the time taken for the first part of the liquid to flow down the tube and touch the rubber bung.

The experiment was performed at room temperature (20 °C) and then repeated at 50 °C after immersing the boiling tubes in a hot water bath.

The results are shown in the table.

	Boiling tube T		**Boiling tube S**		**Boiling tube V**	
	20 °C	**50 °C**	**20 °C**	**50 °C**	**20 °C**	**50 °C**
Distance (cm)	10.5	10.5	10.1	10.1	10.1	10.1
Time (s)	29.64	3.69	11.54	1.45	0.40	No reading
Velocity (mm s^{-1})	3.54	....	8.75	....	252.50	No value

(i) Calculate the velocity of the contents for boiling tubes **T** and **S**.

Velocity **T** = ... mm s^{-1}

Velocity **S** = ... mm s^{-1}

[2]

This maths skills question was well answered. Most candidates spotted that they had to convert the distances given in the results table into millimetres before doing the calculations. Many also gave their answer to two decimal places to match the data in the table. However, a few made rounding errors which lost them a mark.

Question 4 (d) (ii)

(ii) Describe the relationship between velocity and temperature.

....

.... **[1]**

This question was well understood with most candidates attaining the mark. A few suggested velocity and temperature are directly proportional which is not the case, while a small number wrote about viscosity rather than velocity.

Question 4 (d) (iii)

(iii) Which of these simulations (**T**, **S** or **V**) best fits the flow from a shield volcano? Give a reason for your answer.

....

....

.... **[1]**

Many candidates knew shield volcanoes erupt fast flowing, low viscosity or mafic lava, but a sizeable number then incorrectly matched this up with liquid **S** or **T**, rather than the lowest viscosity liquid, **V**.

Question 4 (d) (iv)

(iv) Describe **two** health and safety hazards that must be considered for this experiment.

1 ....

....

2 ....

.... **[1]**

Most candidates correctly recognised a scald/burn hazard from hot liquids, hot test tubes or the hot water bath, but some lost the mark as they then went on to repeat another version of the same scald/burn hazard for their second hazard.

General laboratory safety precautions such as wearing safety goggles, tying back hair, placing bags out of the way were not credited as these are not hazards and nor are they specific to this experiment.

Question 4 (d) (v)

(v) Suggest **one** potential reason why the students were unable to take a reading for boiling tube **V** at 50 °C.

.... **[1]**

This question was answered well with most realising that at 50°C liquid **V** flowed too fast to measure the time taken. However, there were a few incorrect suggestions that liquid **V** (vegetable oil) had boiled or evaporated which would not happen at 50°C.

Question 5 (a) (i)

5 Geological surveys involve a systematic examination of an area to determine the character, relations, distribution and origin or mode of formation of its rocks and mineral resources.

Surveying of ophiolite suites around the world has added greatly to our knowledge and understanding of the origin of rock masses.

(a) **(i)** Define the term **ophiolite**.

....

.... **[1]**

Fewer than half of the candidates gave a correct definition of an ophiolite. Some forgot to state that the crust/lithosphere is oceanic, while others did not convey the idea of obduction as forcible emplacement onto continental crust.

Although ophitic texture is not on the specification a number of candidates mistakenly gave descriptions of smaller crystals enclosed within bigger crystals which seemed to be a definition of this texture.

Question 5 (a) (ii)

(ii) Draw a fully labelled diagram of a section through an ophiolite.

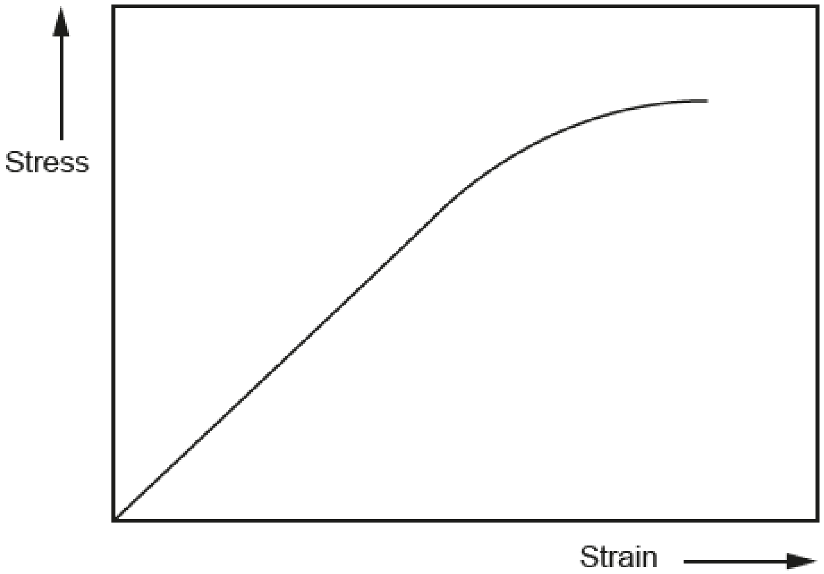
[3]

Many candidates also found this question challenging and number of candidates omitting to write any response was high. However, those who knew they needed to draw a cross-section to show and label the layers within obducted oceanic lithosphere often produced detailed, accurate diagrams that scored highly. Some candidates misunderstood the question and drew a recognisable, labelled cross-section showing the emplacement of an ophiolite complex at a convergent plate boundary but could still achieve 1 mark.

Question 5 (b) (i)

(b) Within the Earth, rocks are constantly subjected to forces that tend to bend, twist or fracture them. Site surveys can identify evidence of deformation that has occurred in the past. This requires an understanding of stress and strain.

The graph shows stress against strain in a rock.



(i) On the stress-strain graph clearly label:

- Elastic deformation
- Failure
- Plastic deformation.

[3]

Most candidates were familiar with stress-strain graphs and the majority accessed some credit for their labelling. A common error was to label the elastic limit (change from elastic to plastic deformation) as the point of failure. A significant minority got their elastic and plastic deformation labels the wrong way round and some hedged their bets by labelling one or the other at the point of elastic limit.

Question 5 (b) (ii)

(ii) Explain how earthquakes occur when stress stored in rocks is released.

....

....

....

....

.... **[2]**

Candidates often showed an understanding that when stress becomes too much, rocks break and release energy in the form of seismic waves, but only a minority attained both marks for their response. Some did not distinguish between stress and strain, and there were incorrect references to tension. Few explained that failure occurs when accumulated strain overcomes the strength of the rock or that, afterwards, elastic rebound occurs, and the rocks return to their undeformed state. Some referred to movement along plates when they should have described movement along faults.

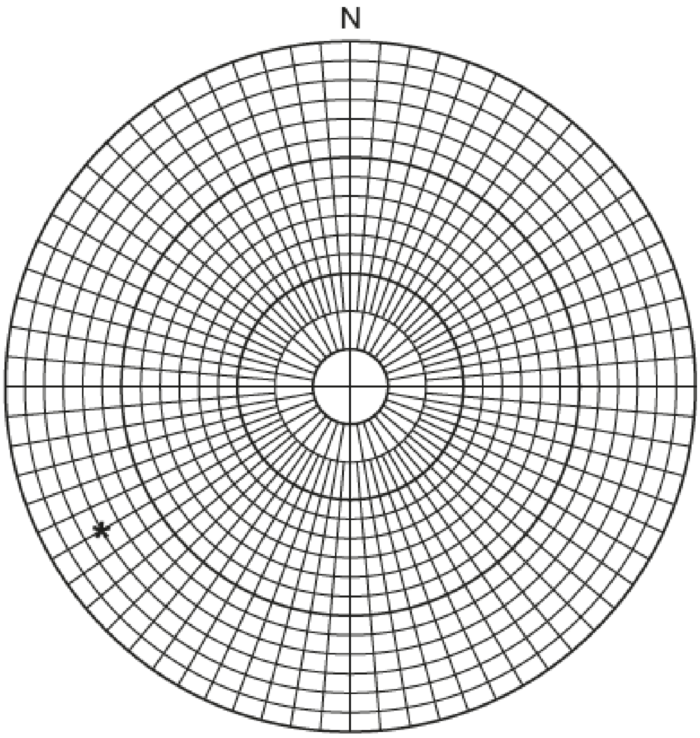
Question 5 (c) (i)

(c) When rocks experience compressional stress, this can result in folding.

Dip and strike measurements of fold limbs, when plotted on a stereonet, can enable the orientation of the principal compressional stress to be determined.

The table shows strike and dip measurements taken from both limbs of a fold.

Strike	Dip
240°	75°
055°	75°
065°	40°
230°	40°
050°	45°



(i) Plot the strike and dip data on the stereonet.

The first measurement has been plotted for you. **[3]**

This question tested mathematical skill M2.11 – the requirement to plot variables from circular data, including use of a polar equal area stereonet. The specification clearly states that only knowledge of polar plots and not projections or great circles is required.

Candidates who took the time to label strike values around the outside of the stereonet and dip values outwards from the centre, before plotting the data points, generally performed better than those who merely counted round from zero, as these candidates often made mistakes plotting the strike information.

OCR support

The OCR Geology Mathematical Skills Handbook provides support for the mathematical skills required by the A Level Geology specification, including skill M2.11 – plot variables from experimental or other circular data.

The content of the handbook follows the sequence of the mathematical requirements table in Appendix 5e of the specification, with each skill (M1.1–M4.3) discussed in turn. Appendix D at the back of the handbook contains useful blank templates that can be used for plotting circular data, including a polar equal area stereonet, the same as the one used in this question paper.

Question 5 (c) (ii)

(ii) State the orientation of the maximum compressional stress shown on your stereonet.

.... **[1]**

Candidates found this question challenging and most incorrectly stated that the maximum compressional stress would be orientated northeast – southwest.

The data table and stereonet show the strike measurements for the fold limbs are between 050-065 and 230-240, that is northeast – southwest. Only a few candidates comprehended that fold limbs are parallel to the fold axial plane and as folds result from compressional stress, the maximum compressional stress will usually be perpendicular to the fold axis, so in this case northwest – southeast.

Question 5 (c) (iii)

(iii) Explain if the type of fold (antiform or synform) can be determined from your stereonet plot.

....

.... **[1]**

This was a low scoring question. Many candidates did not understand that to identity the type of fold, the direction of dip of the limbs must be known, along with which limb each set of dip measurements came from so it is possible to work out if the limbs are dipping inwards or outwards. If the limbs are dipping towards each other the fold is a synform, and if dipping away an antiform. As the dip directions are not provided in the table it is not possible to determine the type of fold, only the orientation of the fold axis.

Question 6 (a)*

6 Read the text, then answer the questions that follow.

On 18th March 2020, a 5.7 magnitude earthquake hit Salt Lake City, Utah, when the Wasatch Fault ruptured. This caused buildings to sway which resulted in significant structural damage.

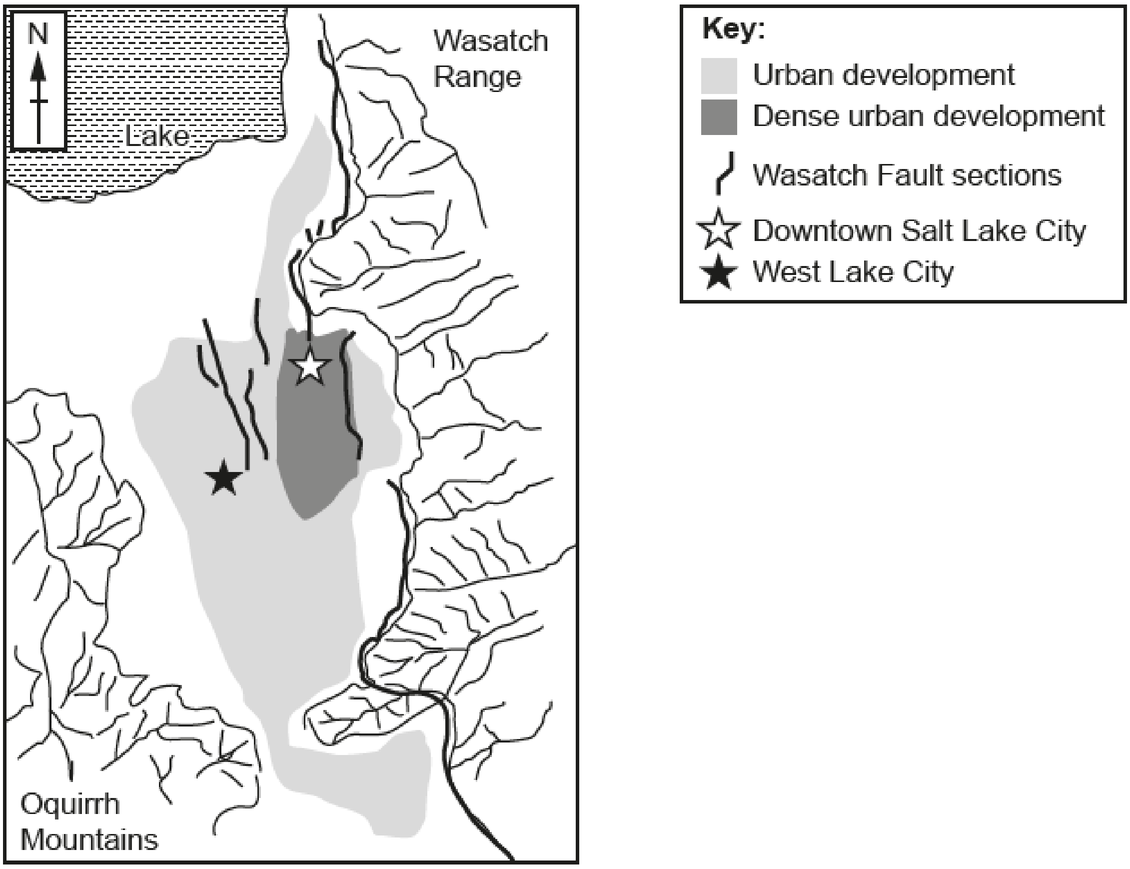
Geological studies show that over the last 7000 years a magnitude 6.5 to 7.5 earthquake has occurred somewhere along the central section of this fault every 270 years.

Seven earthquakes of magnitude 5.0 or above have occurred in the last 100 years.

Salt Lake City sits within a fault zone in a structural basin, bounded by two uplifted blocks, with the Oquirrh Mountains to the west and the Wasatch Mountains to the east. Alluvial fan, recessional delta, marsh and lakebed deposits of gravel, sand, silt and clay form the shallow subsurface of the basin. These sediments are of Cenozoic age, with units as young as 30000 years.

Downtown Salt Lake City is the oldest and most developed part of the urbanised area. West Lake City is younger and more recently developed.

This is shown on the map.



Unreinforced masonry (brick and block) was a common building material throughout Utah until building codes began requiring reinforcement. There are an estimated 140000 unreinforced masonry structures in Utah, including homes, businesses, schools and houses of worship.

The table shows the average damage with increasing Mercalli intensities.

Construction type	Average damage (%) at intensity		
	VIII	IX	X
Unreinforced masonry (non-seismic design)	40	80	100
Reinforced concrete frames (non-seismic design)	33	70	100
Reinforced masonry (non-seismic design)	16	38	66
Reinforced concrete frames (aseismic design)	13	33	58
Reinforced masonry (aseismic design)	5	13	25

Building codes are sets of regulations governing the design, construction, alteration and maintenance of structures. They specify the **minimum** requirements to adequately safeguard the health, safety and welfare of building occupants. These include seismic codes to ensure that structures can resist seismic forces during an earthquake.

Examples of seismic building codes include:
- Structural configuration ensures a direct and smooth flow of inertia forces to the ground
- Lateral strength sufficient to resist the maximum horizontal force without collapsing
- Adequate stiffness to resist deformation induced by low to moderate shaking
- Exterior walls should be supported on continuous solid concrete or masonry.

Except in certain circumstances, such as when a structure is significantly renovated or altered or there is a change in its use, the building code requirements for existing structures are those that were in effect when the structure was designed and constructed. Seismic retrofitting programmes are not state mandated in Utah.

(a)* Evaluate the statement that the seismic retrofitting of existing buildings should be mandatory in the Salt Lake City structural basin.

In your answer you should include a consideration of seismic hazard risk, civil engineering and the factors which affect the impact of earthquakes. **[6]**

Overall, candidates dealt well with the complex and varied data presented to them in this question. Most were able to successfully extract and consider some pertinent information to support their evaluation as to whether seismic retrofitting of existing buildings within the Salt Lake City structural basin should be mandatory.

Lower-attaining responses got bogged down with the table of data showing the average damage to different construction types with increasing Mercalli intensities or the frequency of earthquakes of differing magnitudes and didn't really consider anything else so attained Level 1. Better responses included a good balance of discussion of seismic hazards and risks and/or civil engineering and building code factors to arrive at an explicit decision as to whether retrofitting existing buildings should be mandatory or not.

When assessing seismic hazards, some picked out the presence of underlying faults, unconsolidated sediments and mountains on either side of the basin, but not all went on to link these to hazards such as ground shaking, liquefaction or landslides. Only the highest level attaining candidates recognised that, although frequent, magnitude 5 earthquake are unlikely to cause much damage, or that very a destructive 6.5 to 7.5 M_W earthquake may not occur for over 100 years but could occur tomorrow.

For civil engineering and building code factors, successful responses often made good comparisons between the older, densely packed, unreinforced buildings in Downtown Salt Lake City and the newer buildings in West Lake City, with some concluding that seismic retrofitting may only be needed for old buildings in Downtown Salt Lake City.

Issues that limited some candidates' attainment included:

- giving general descriptions of seismic hazards, risks and aseismic buildings without using or assessing any of the information supplied in the question
- confusing earthquake magnitude and intensity
- not providing an explicit conclusion as to whether seismic retrofitting of existing buildings should be mandatory.

Exemplar 2

Due to factors that affect the impact of earthquakes, salt lake city has high seismic risk. Due to it lying between two mountainous areas, Oquirrh mountains to the west and Wasatch mountains to the east, earthquakes may make salt lake city more prone to landslides, increasing seismic risk. Also, it is underlain by deposits of gravel, sand and silt, this makes earthquakes pose a higher seismic risk as seismic waves are more destructive when passing through looser sediments such as these. It also poses the risk of. Downtown salt lake city and West salt lake city are both in close proximity to Wasatch fault sections, earthquakes could therefore occur in close proximity to urban development posing high seismic risk. The table shows unreinforced masonry at intensity X causes 100% damage, whereas reinforced masonry at intensity X causes only 25% damage. This means civil engineering at salt lake city has a huge impact on the damage that occurs in high intensity earthquakes and therefore seismic retrofitting of existing buildings should be mandatory as it mitigates the damage of earthquakes by up to 75%, and as salt lake city has suffered 7 earthquakes of magnitude 5 or above in the last 100 years, this is a seismically active area with high risk so retrofitting would greatly reduce damage.

Exemplar 2 is typical of the responses that fulfilled the criteria for Level 3. The candidate has made use of the information provided to identify seismic hazards including the presence of numerous faults sections, loose unconsolidated sediments, and the risk of landslides. Although not as convincing, they have also touched on earthquake return periods. The candidate has discussed civil engineering factors by using the data given in the table to compare damage for different construction types. They have concluded with an explicit recommendation that seismic retrofitting should be mandatory.

Question 6 (b)

(b) The table gives dates and the magnitude of earthquakes in the Salt Lake City area.

Date	**M_w**
Nov 1901	7.0
Sep 1921	6.3
Mar 1934	6.6
Aug 1962	5.9
Oct 1967	5.6
Jan 1989	5.2
Sep 1992	5.8
Mar 2020	5.7

Calculate the return period for earthquakes with a magnitude greater than 5.0, between the years 1901 and 2020.

Give your answer to the nearest year.

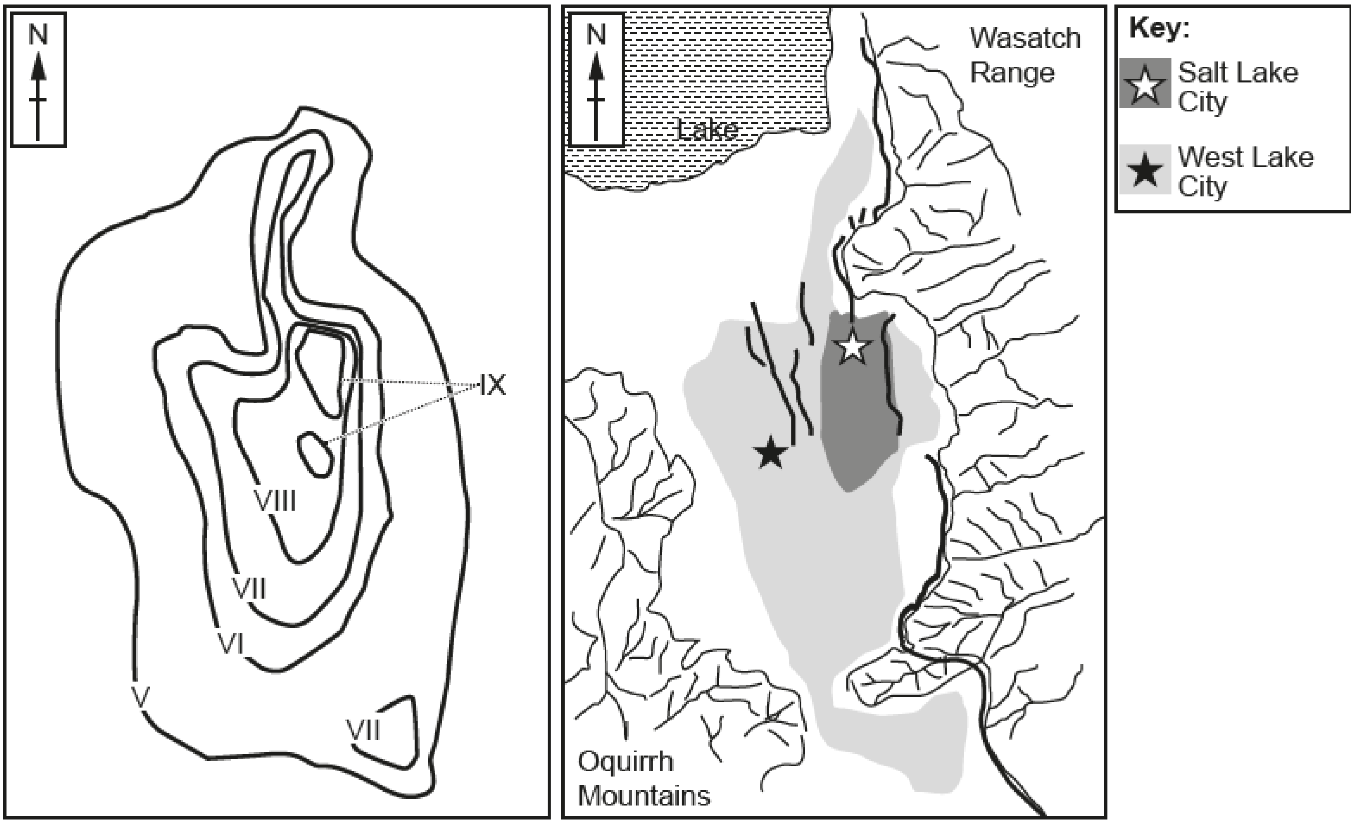
Return period = ... years **[2]**

Candidates either scored 0 or 2 marks for this question. Over half were able to correctly calculate the return period for earthquakes with a magnitude greater than 5.0 and virtually all of these gave their answer to the nearest year. However, few included the return period formula, which could have earned them 1 mark if they got their answer wrong, while others got the formula the wrong way round and divided n by m + 1.

Question 6 (c)

(c) The isoseismal map shows the projected earthquake intensity of the area around Salt Lake City forecast for a 7 M_w earthquake. The structural basin map is shown again for reference.

Isoseismal map for a 7 M_w earthquake | Map of structural basin



Suggest **three** reasons for the distribution of the isoseismal lines shown on the isoseismal map.

....

....

....

....

....

.... **[3]**

Many candidates struggled to formulate creditworthy answers using correct technical language, so this question was low scoring. Responses often described the distribution of the isoseismal lines as being concentrated, close together or spread out, or following the fault lines, but included nothing about high or low intensity areas or damage. Some wrote a list of factors that affect earthquake intensity but did not relate them to the information shown on the map. There was confusion between magnitude and intensity, and some used the term strongest when it should be highest for intensity.

Question 6 (d) (i)

(d) Civil engineering can reduce the impact of future seismic events. One method of achieving this is to mitigate for sway of buildings.

(i) Explain the relationship between sway and natural frequency.

....

.... **[1]**

Not many candidates were able to explain the relationship between sway and natural frequency correctly. Many stated that as natural frequency increases, sway either increases or decreases. Some thought natural frequency was the frequency of the earthquake, not the building. Many described sway and natural frequency aligning, rather than earthquake and natural frequency aligning. It was clear few understood the concept of resonant frequency, that if the natural frequency of a building coincides with the earthquake frequency, then sway increases.

Question 6 (d) (ii)

(ii) Natural frequency can be calculated using the equation:

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

where f = natural frequency (Hz)
m = mass (kg)
k = stiffness ($N\,m^{-1}$)

Rearrange the equation to make stiffness (k) the subject of the formula.

Stiffness (k) = ... **[1]**

This question tested mathematical skills M3.2 – change the subject of an equation and proved very demanding for most candidates. There was evidence that some candidates spent an inordinate amount of time trying every possible permutation of rearranging the equation they could think of, including using the extra answer space at the end of the question paper. Many struggled with the inclusion of a square root and often did not realise that any of the variables not included within the square root would need to be squared to arrive at the correct solution.

Question 6 (d) (iii)

(iii) The table shows data for three buildings, **A**, **B** and **C**. The buildings are of similar heights.

Building	Stiffness ($N\,m^{-1}$)	Mass (tonnes)	Natural frequency (Hz)
A	3462	27 952	1.52
B	1100	22 622	1.05
C	1217	37 956	1.11

Evaluate the structural integrity of these three buildings in a magnitude 6_{ML} earthquake that causes ground shaking at a frequency of 1.80 Hz.

....

....

....

....

.... **[2]**

Over half of candidates attained some credit for their responses to this question. The most common correct suggestion was that as the natural frequency of building A is closest to the ground shaking frequency it might have the lowest structural integrity of the three. Fewer candidates were able to make correct evaluations using the stiffness and mass data provided in the table.

Question 6 (d) (iv)

(iv) Explain why taller buildings tend to have lower natural frequencies than shorter buildings.

....

....

.... **[1]**

Candidates who used the equation given in Question 6 (d) (ii) to aid their answers were generally more successful but, overall, this was a low scoring question. The equation shows there is an inverse relationship between mass and natural frequency and a direct relationship between stiffness and natural frequency, so as tall buildings tend to have a higher mass or a lower stiffness than shorter buildings, they tend to have a lower natural frequency.

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