OCR
Oxford Cambridge and RSA

Tuesday 13 June 2023 – Afternoon

A Level Geology

H414/02 Scientific literacy in geology

Time allowed: 2 hours 15 minutes

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

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

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

First name(s) _____

Last name _____

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

INFORMATION
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **28** pages.

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

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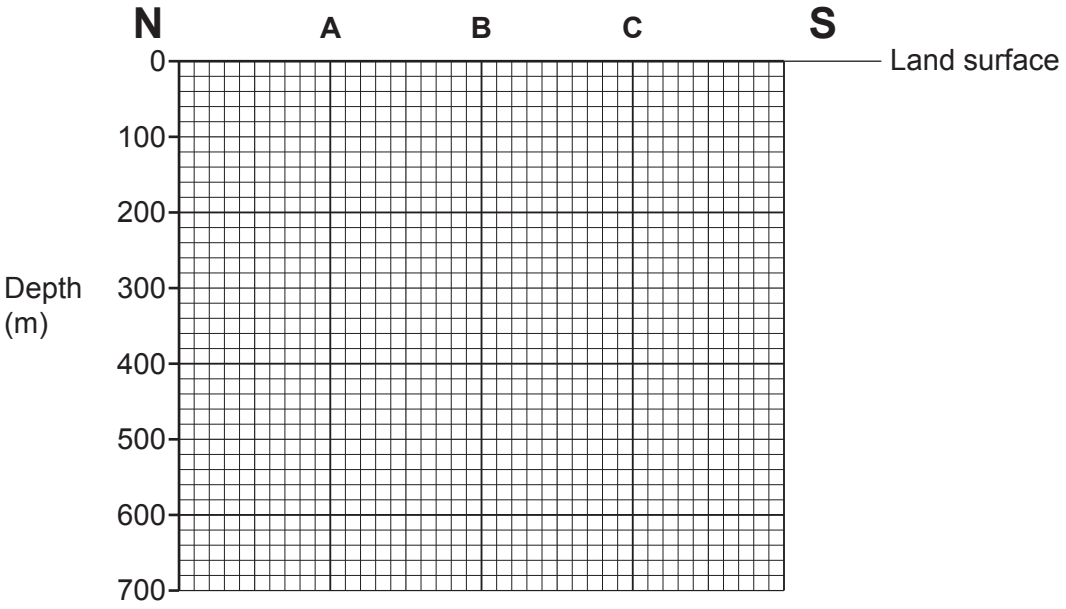
(b) The table shows data about the position of coal seams and faults, collected from three boreholes (sites **A**, **B** and **C**) across an abandoned underground coal mine.

	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]

(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.

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

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(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.

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

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

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

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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]

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

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[3]

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

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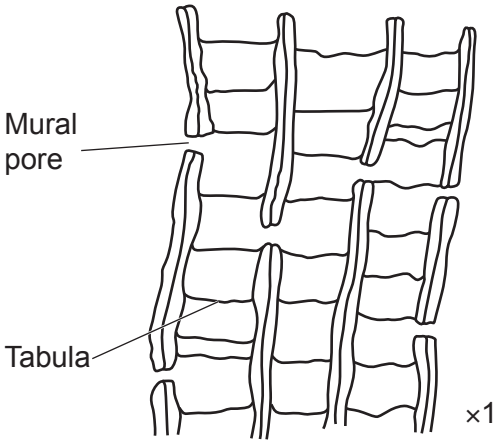
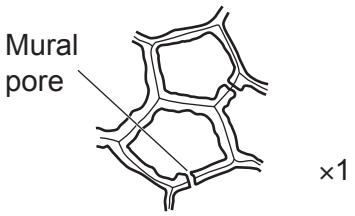
(b) Fossils **D** and **E** are from two different geological periods.

Fossil D

Longitudinal section

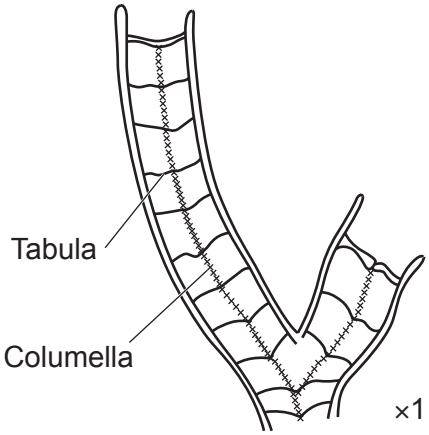


Transverse section



Fossil E

Longitudinal section



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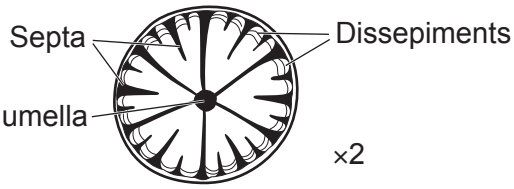

(i) Identify the fossil phylum or group to which these fossils both belong.

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

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

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

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

Tick (✓) **one** box.

Cenozoic ☐

Mesozoic ☐

Palaeozoic ☐

[1]

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

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

(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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(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.

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

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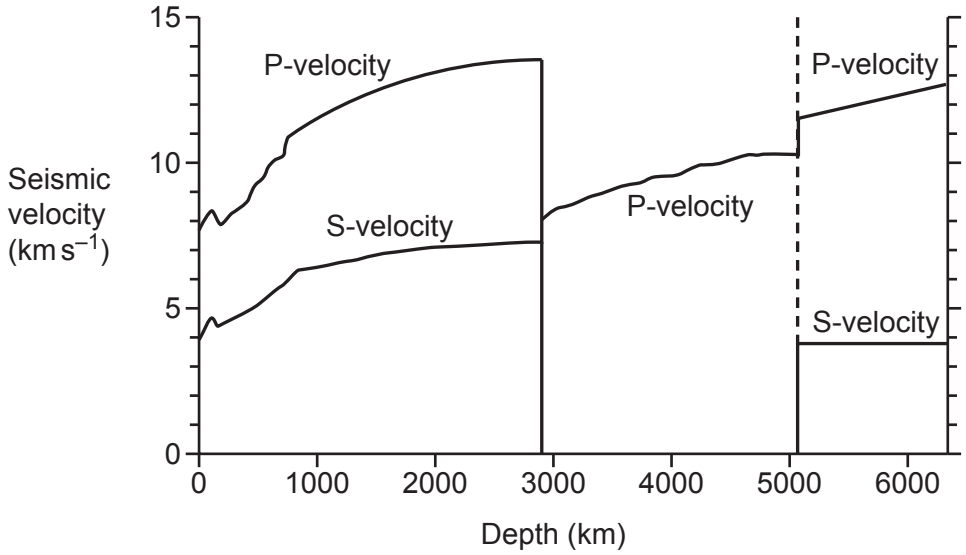
(b) The graph shows the changes in seismic velocities of P and S waves as they pass through the Earth.



(i) On the graph, clearly label:

- Low velocity zone
- Gutenberg discontinuity
- Outer core.

[3]

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

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

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

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

(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.

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Additional answer space if required.

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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 .....

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Xenoliths .....

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[4]

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

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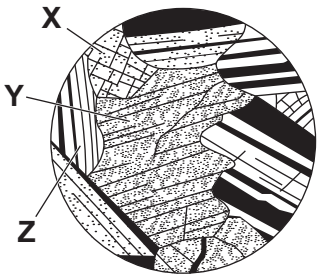
..... **[1]**

(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]**

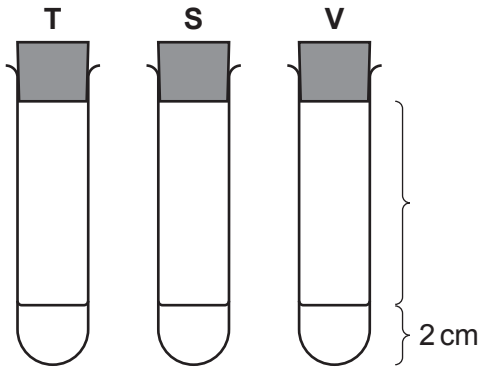
(ii) Identify the rock shown in the thin-section diagram.

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

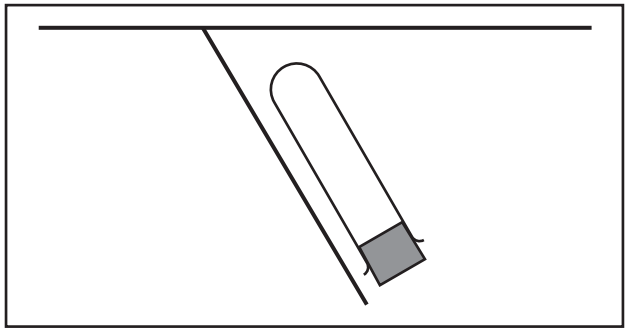
(d) Measuring the velocity of moving lava can help indicate the composition of the lava.

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]

(ii) Describe the relationship between velocity and temperature.

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

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

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

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

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**.

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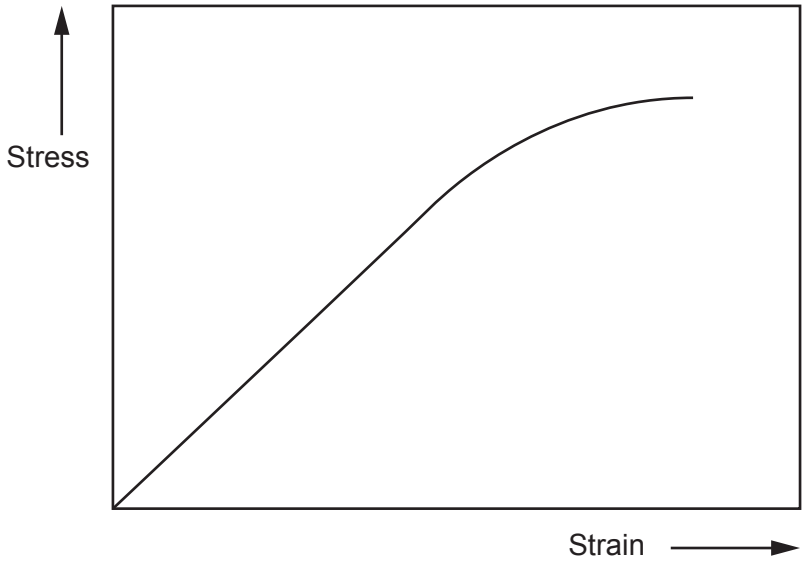
..... **[1]**

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

[3]

(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]

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

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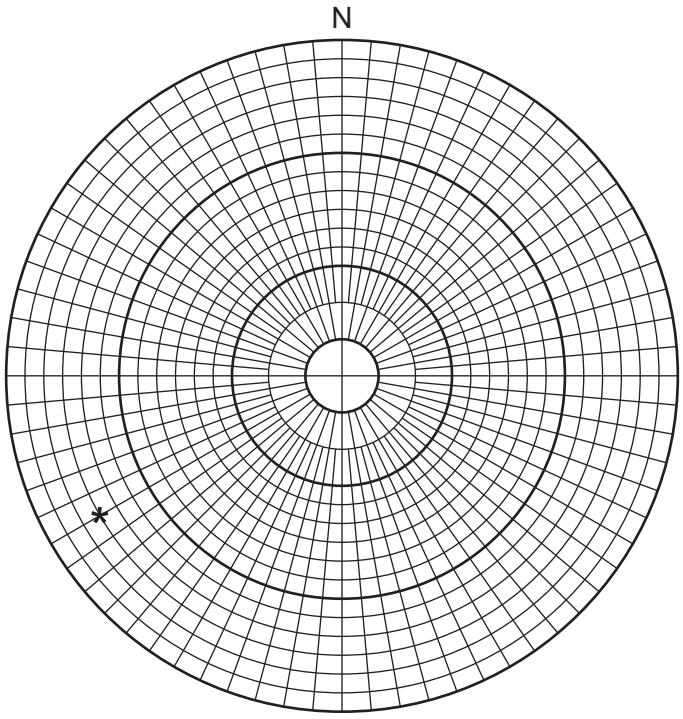
(c) When rocks experience compressional stress, this can result in folding.

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]**

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

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

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

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.

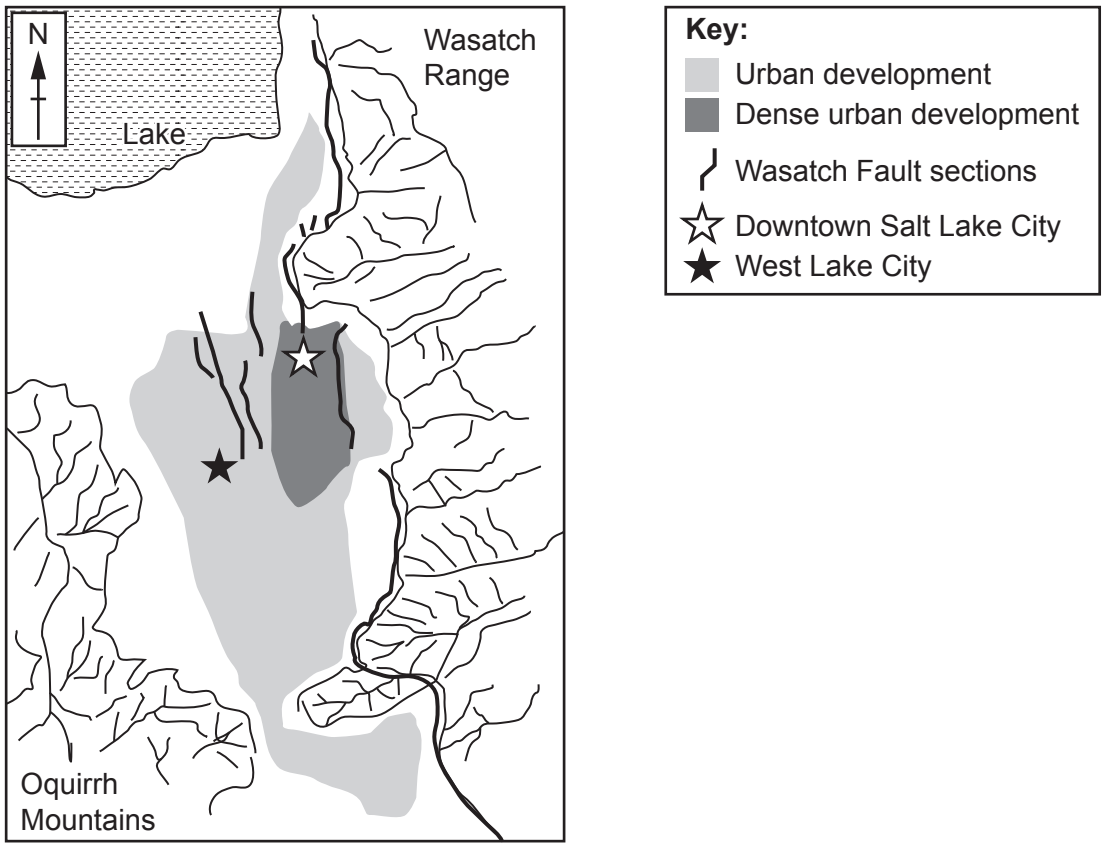
Geological studies show that over the last 7 000 years a magnitude 6.5 to 7.5 earthquake has occurred somewhere along the central section of this fault every 270 years.

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 30 000 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 140 000 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]**

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Additional answer space if required.

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(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

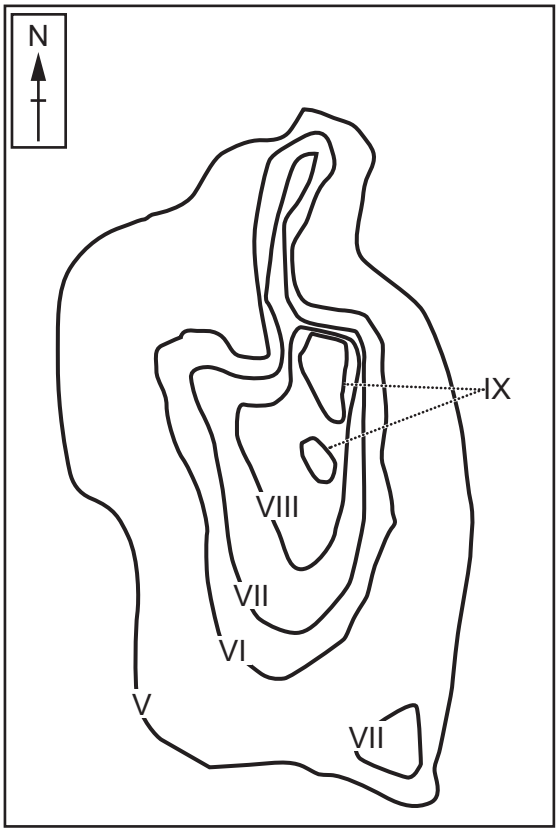
Calculate the return period for earthquakes with a magnitude greater than 5.0, between the years 1901 and 2020.

Give your answer to the nearest year.

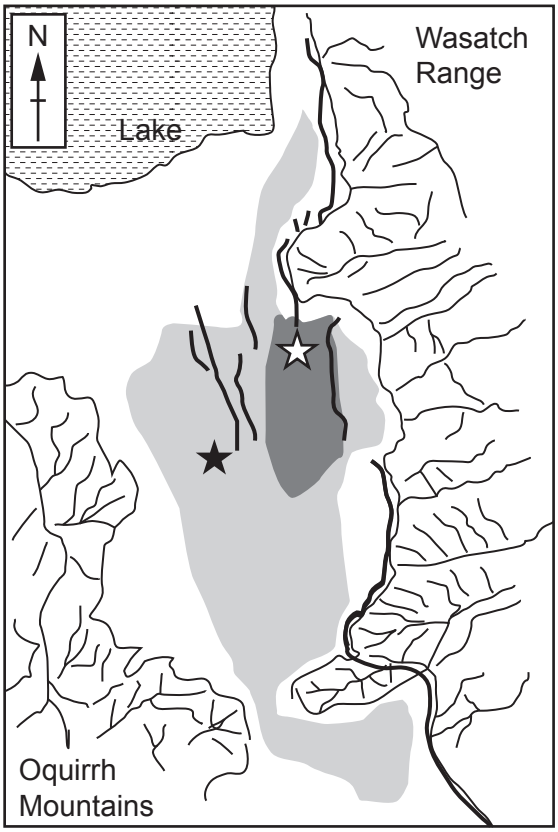
Return period = ... years **[2]**

(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.

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(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.

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(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]**

(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.

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

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END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).