Surname	Centre Number	Candidate Number
First name(s)		2

GCE A LEVEL

A480U30-1

S23-A480U30-1

TUESDAY, 20 JUNE 2023 – AFTERNOON

GEOLOGY – A level component 3
Geological Applications

2 hours

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1.**	**15**	
	2.	**15**	
Section B	**3.**	**10**	
	4.	**16**	
	5.	**9**	
	6.	**10**	
Section C option		**11** / **12**	
		13 / **12**	
		6	
	Total	**105**	

ADDITIONAL MATERIALS

In addition to this examination paper, you will need:
- a calculator
- a ruler
- the Geological Map Extract

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen or correction fluid.

You may use a pencil for graphs and diagrams only.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions in sections **A** and **B**.

Answer all questions in **one** option only in section **C**.

Write your answers in the spaces provided in this booklet. If you run out of space, use the additional page(s) at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

This paper is in 3 Sections, **A**, **B** and **C**.

Section A: 30 marks. Answer **both** questions. You are advised to spend about 35 minutes on this section.
Section B: 45 marks. Answer **all** questions. You are advised to spend about 50 minutes on this section.
Section C: 30 marks. Answer all the questions in **one** option only. You are advised to spend about 35 minutes on this section.

The number of marks is given in brackets at the end of each question or part-question.

The assessment of the quality of extended response (QER) will take place in questions **9**, **12** and **15**.

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PJ/DJ*(X23-A480U30-1)

SECTION A

Answer **all** questions in the spaces provided.

1. **Figure 1a** is a map of the North Pacific Ocean showing the epicentre of the 2006 Kuril earthquake (M_w8.3), the location of a tsunami monitoring buoy and Arena Cove, California.
Figure 1b shows the sea level record from the tsunami monitoring buoy.
Figure 1c shows the tide gauge record for Arena Cove, California.

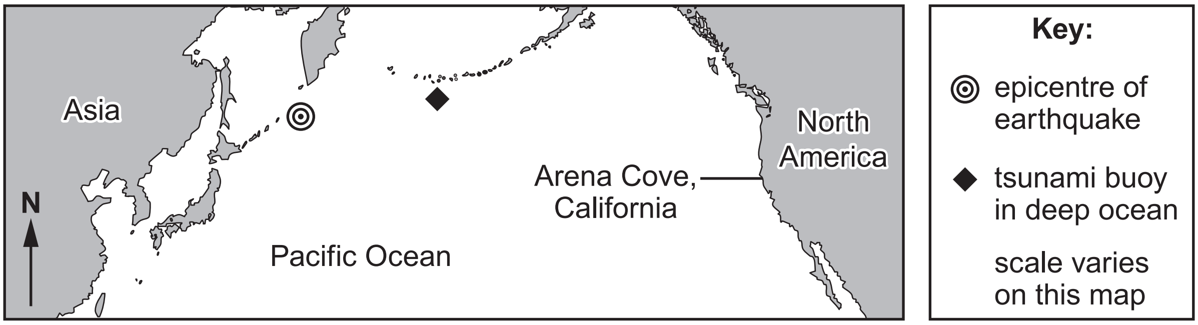

Figure 1a

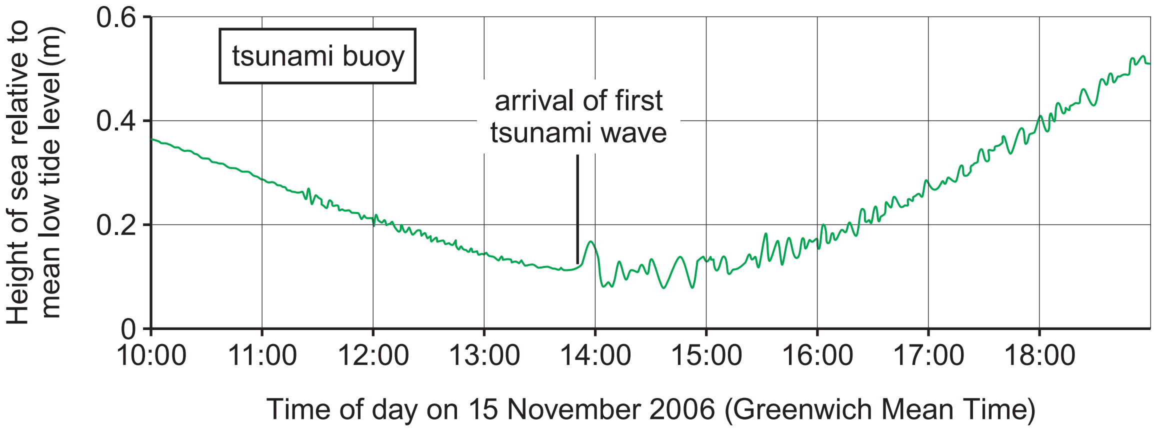

Figure 1b

Examiner only

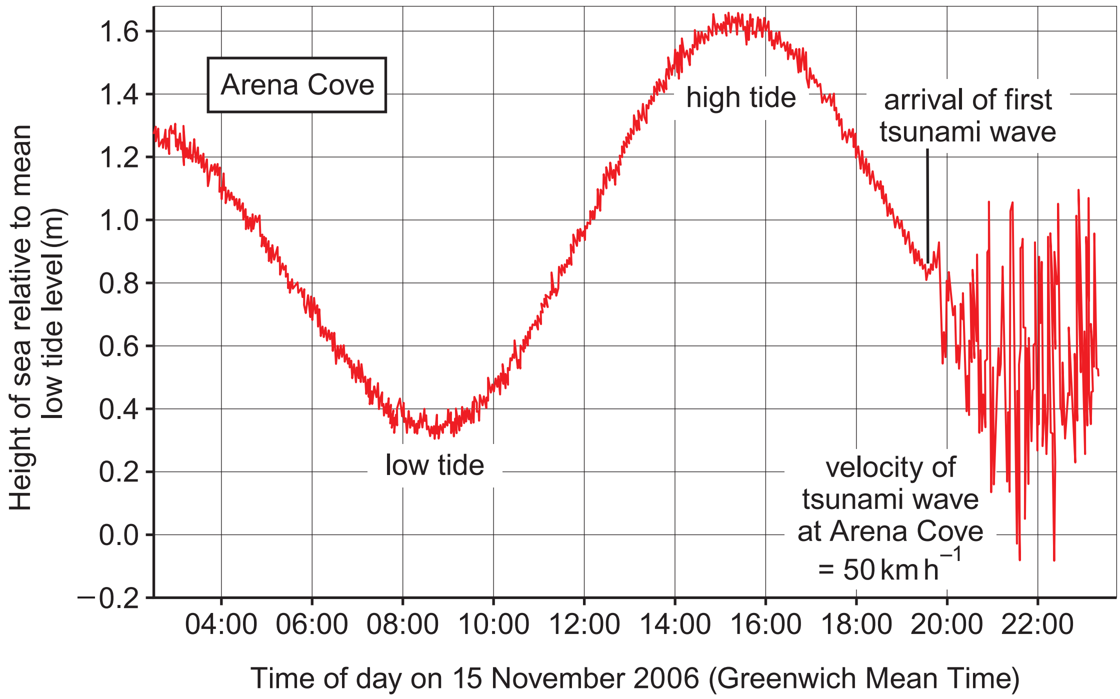

Figure 1c

(a) Suggest how an earthquake at the location shown on **Figure 1a** could generate a tsunami. [2]

....

....

....

Refer to **Figures 1b** and **1c**.

(b) Arena Cove is 4174 km from the tsunami buoy. Calculate the mean velocity of the tsunami wave between these two locations. Show your working. [3]

.... km h^{-1}

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Turn over.

Examiner only

(c) (i) Explain why people at sea, around where the tsunami buoy is located, would be unaware of tsunami waves passing. [3]

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(ii) State the maximum height of the sea caused by the tsunami wave measured at Arena Cove. [1]

.... m

(iii) Describe how the tsunami waves changed between the tsunami buoy and when they reached Arena Cove. [2]

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(d) Evaluate the risk posed by the 2006 Kuril tsunami on Arena Cove. [4]

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2. **Figure 2a** is a graph to show how the lead concentration in mine water varies with pH. **Figure 2b** is a model of Cwmrheidol Mine, an abandoned metal mine in Wales, which discharges up to 8 tonnes of metal pollution per year into the River Rheidol.

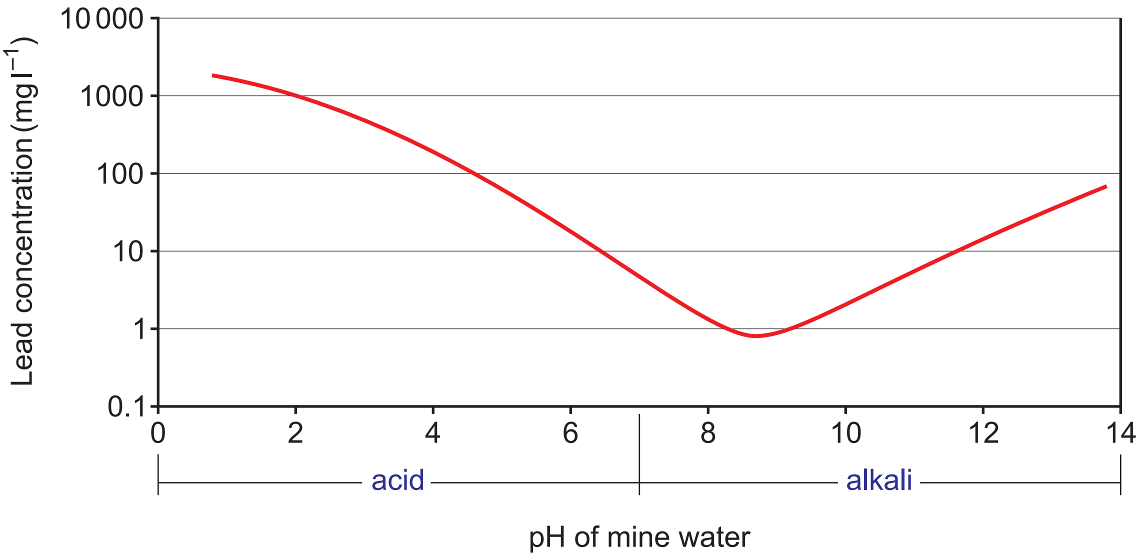

Figure 2a

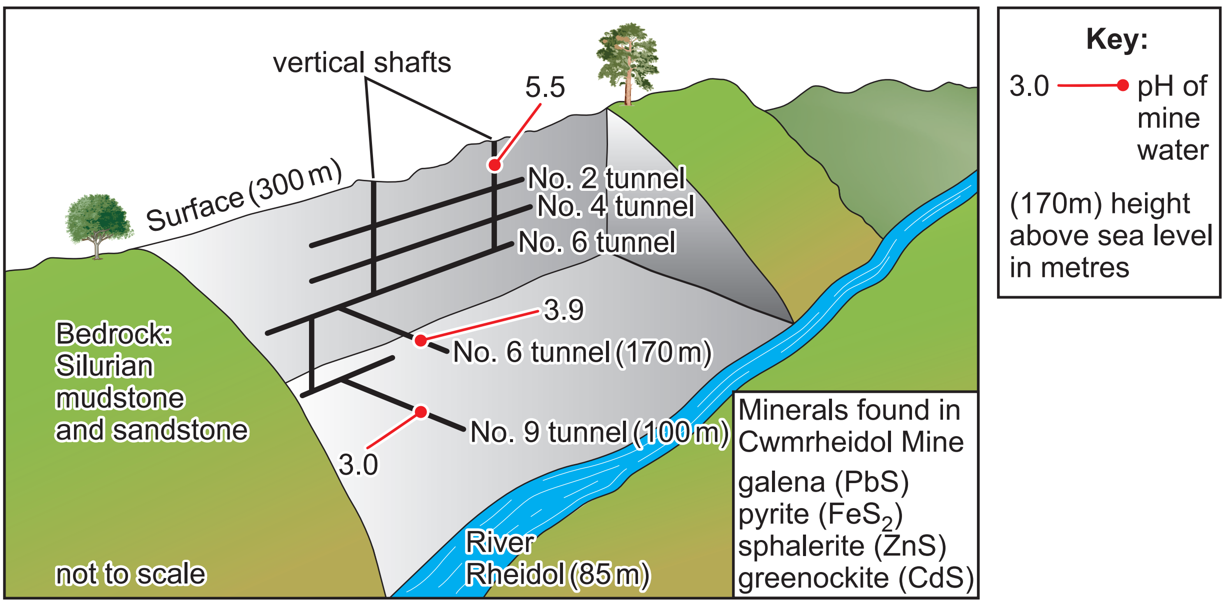

Figure 2b

Examiner only

(a) Refer to **Figure 2a**. Describe how the concentration of lead in mine water varies with pH. [2]

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....

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(b) Refer to **Figures 2a** and **2b**.

(i) Describe how the pH of mine water changes as water passes through the shafts and tunnels of the mine. [2]

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....

(ii) Explain how changes in the pH of mine water can affect how much lead is discharged into the River Rheidol. [2]

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(c) (i) One solution to the metal pollution problem at this mine has been to install a filter of limestone gravel between the outfall from the No.9 tunnel and the river. Explain how this would reduce metal pollution into the river. [3]

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(ii) Suggest **one other** potential solution to this metal pollution problem. Explain how this would reduce metal pollution from this mine. [2]

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(d) The **loose** waste rock fragments from this mine were dumped on the valley side from the No.6 tunnel down to the river. Explain **two** ways in which the slope of loose waste rock may be stabilised. [4]

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SECTION B

Answer **all** questions in the spaces provided.

Questions **3–6** relate to the **British Geological Survey geological map** extract from the Harrogate Sheet 62 (Solid edition)

3. Refer to **box A** on the **geological map**.

(a) Describe the evidence in **box A** on the **geological map** to support the presence of an unconformity at the base of the Permian, as shown on the **generalised geological column**. [2]

....

....

....

(b) (i) Using the **generalised geological column**, show that the Upper Magnesian Limestone (**UML**) has a maximum thickness of 30 m.
Show your working. [2]

(ii) Explain the evidence from **box A** alone that the Upper Magnesian Limestone (**UML**) is dipping
- at a shallow angle
- to the East

along the line **X – Y** on the **geological map**. [3]

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Examiner only

(iii) Calculate the angle of dip of the Upper Magnesian Limestone (**UML**) along the line **X – Y** on the **geological map**. Assume the surface topography along the line **X – Y** is horizontal and the Upper Magnesian Limestone (**UML**) is 30 m thick. Show your working and write your answer to the nearest whole degree. [3]

Angle of dip .... degrees

10

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Turn over.

Examiner only

4. **Figure 4** shows details of **box B**, part of the Harrogate Anticline on the **geological map**, indicating the location of principal mineral springs in the Harrogate area.

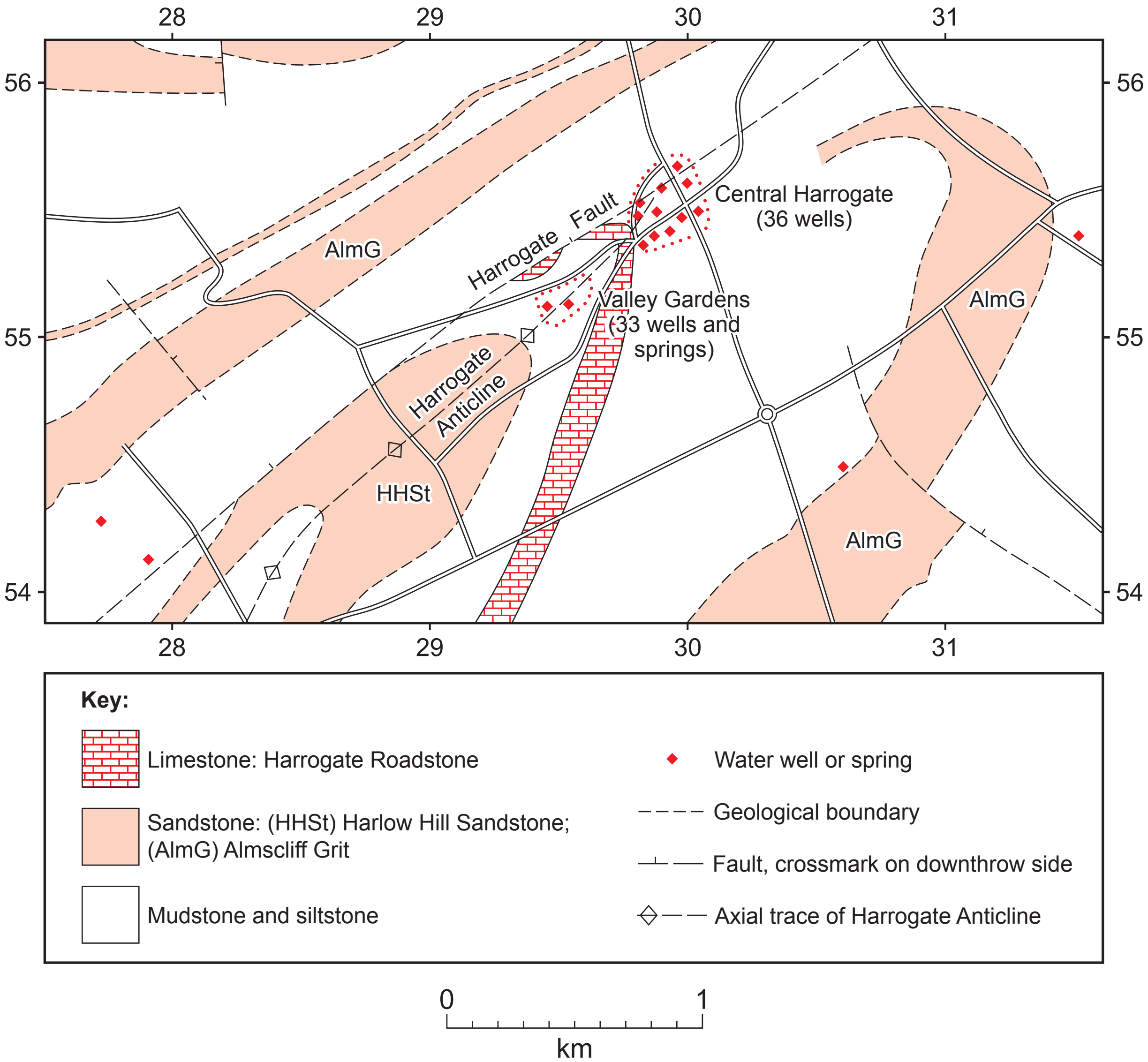

Figure 4

Refer to the **geological map**, **geological section** and **Figure 4**.

(a) (i) Explain why the Harrogate Anticline is classified as an anticline. [1]

....

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(ii) Using the **geological map**, describe the plunge of the Harrogate Anticline. Explain the evidence for your answer. [3]

Description ....

....

Evidence ....

....

(iii) Describe **one other** fold characteristic of the Harrogate Anticline. [2]

....

....

....

(b) (i) Measure the vertical displacement along the Harrogate Fault using the **geological section**. [1]

....

(ii) State the type of fault represented by the Harrogate Fault. Explain the evidence for your answer. [2]

Fault type ....

Evidence ....

....

(c) A student suggested that the Harrogate Fault and Anticline were probably formed during the same period of deformation. Evaluate this statement with reference to the evidence from the **geological map** and the **geological section**. [3]

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(d) Explain how the geological structure may have influenced the distribution of the springs on **Figure 4**. [4]

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5. Water samples, obtained from a selection of springs and wells in the Harrogate area, were analysed for three main ions (Na, Ca and Mg). **Figure 5** is a triangular graph showing the variation in the chemistry of these samples. **Table 1** shows the chemistry of water samples from two springs (**S** and **T**).

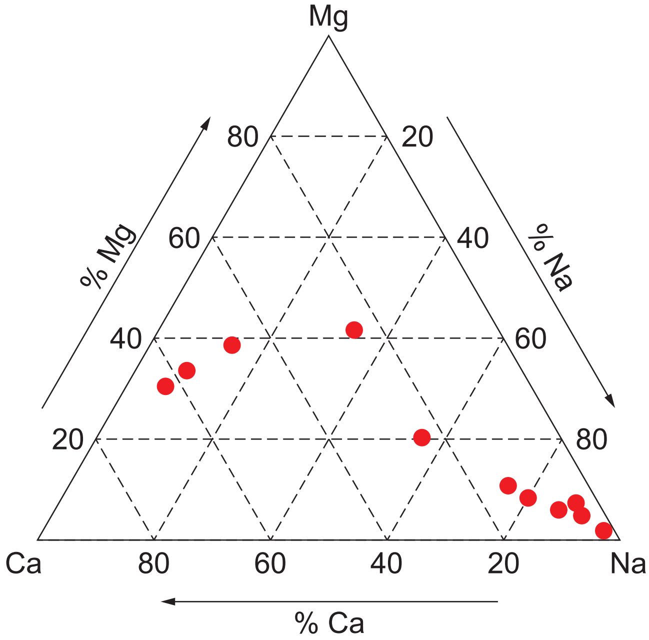

Figure 5

Ion	Spring S ion concentration (mg l^{-1})	Spring S (%)	Spring T (%)
Ca	10.7	•	29
Mg	9.8	•	31
Na	15.5	•	40
Total	36.0	100	100

Table 1

Refer to **Figure 5** and **Table 1**.

(a) (i) Complete **Table 1** by calculating the percentages of the three ions from the ion concentration data (mg l^{-1}) for **Spring S**, to two significant figures. [2]

(ii) Complete **Figure 5** by plotting the percentage data for **Spring T**. Label your plot **Spring T**. [1]

(iii) Draw a line across **Figure 5** to represent a Ca:Mg ion ratio of 1:1. [1]

Examiner only

(iv) Describe the variation in the **ratio** of Ca to Mg ions in the sampled waters on **Figure 5**. [2]

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(b) The variation in the chemistry of the spring waters is thought to be associated with groundwater circulation. Suggest possible **geological** reasons for the variation in the chemistry of the spring waters despite the close proximity of the springs to each other. [3]

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Turn over.

6. **Figure 6a** is a geological section (and enlargements) of subsurface conditions that result in subsidence of Permian and Triassic strata in the area around Ripon, just to the north of the **geological map**.

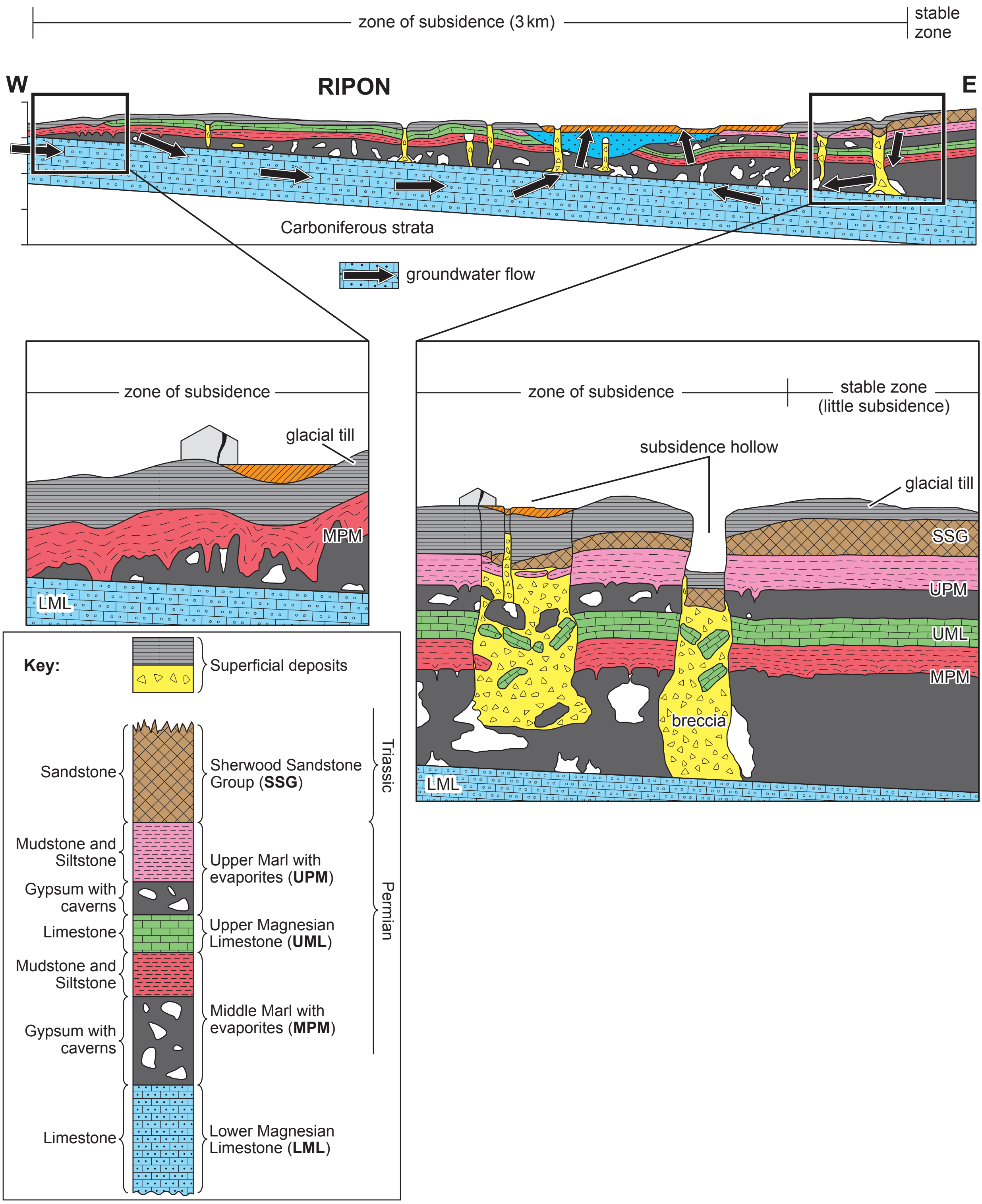
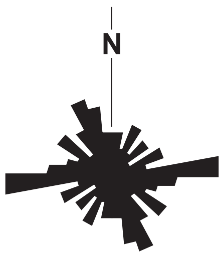


Figure 6a

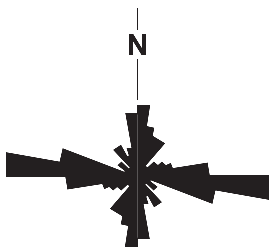
Examiner only

Figure 6b and **Figure 6c** are rose diagrams showing the relationship between the orientation of subsidence hollows and the pattern of joints associated with Permian strata in the Ripon area.



Orientation of 100 subsidence hollows

Figure 6b



Orientation of 110 joints

Figure 6c

(a) (i) Describe the pattern formed by the orientation of subsidence hollows on **Figure 6b**. [2]

....

....

....

(ii) 'The pattern of subsidence reflects the underlying joint pattern of the Permian strata.'
Evaluate this statement with reference to **Figure 6b** and **Figure 6c**. [2]

....

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(b) Explain why subsidence in the Ripon area (**Figure 6a**)
- is confined to a zone three kilometres wide
- increases in depth to the east. [3]

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Turn over.

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(c) With reference to the data from Ripon, describe the extent of the potential subsidence risk associated with Permian and Triassic strata in **box A** on the **geological map**. [3]

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SECTION C

Answer the questions from only **one** option.

Tick (✓) **one** of the boxes below to indicate which **one** option you have selected.

☐	**Option 1: Quaternary Geology**	page 22
☐	**Option 2: Geological Evolution of Britain**	page 28
☐	**Option 3: Geology of the Lithosphere**	page 36

Examiner only

Option 1: Quaternary Geology

If you have chosen this option, answer **all** the questions within this option.

7. **Figure 7a** is a photograph of part of Unit **A** on **Figure 7b**.

Figure 7a

(a) Refer to **Figure 7a**.

(i) Describe the texture of Unit **A**. [2]

....

....

....

(ii) A student stated that 'the texture of Unit **A** indicates that it is a glacial deposit'. Evaluate this statement with reference to geological processes. [3]

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Figure 7b is a graphic log of a sequence of Quaternary sediments.

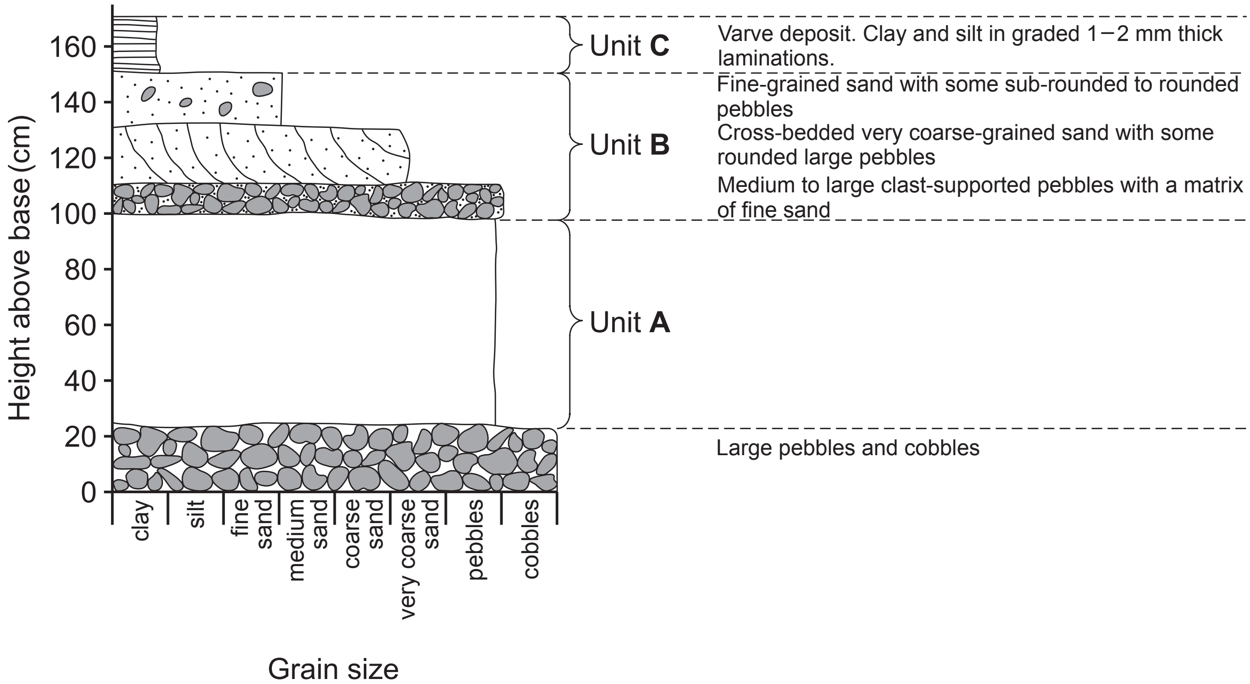

Figure 7b

(b) Refer to **Figure 7b**.

Suggest the environment of deposition of Unit **B**. Give **two** reasons for your answer. [3]

Environment of deposition: ....

Reason 1: ....

....

Reason 2: ....

....

(c) ‘The amount of time taken for Unit **C** in **Figure 7b** to be deposited can be determined.’ Evaluate this statement with reference to the processes that resulted in its deposition. [3]

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 (A480U30-1) **Turn over.**

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8. **Figure 8a** is a map showing the present-day rate of annual crustal uplift.

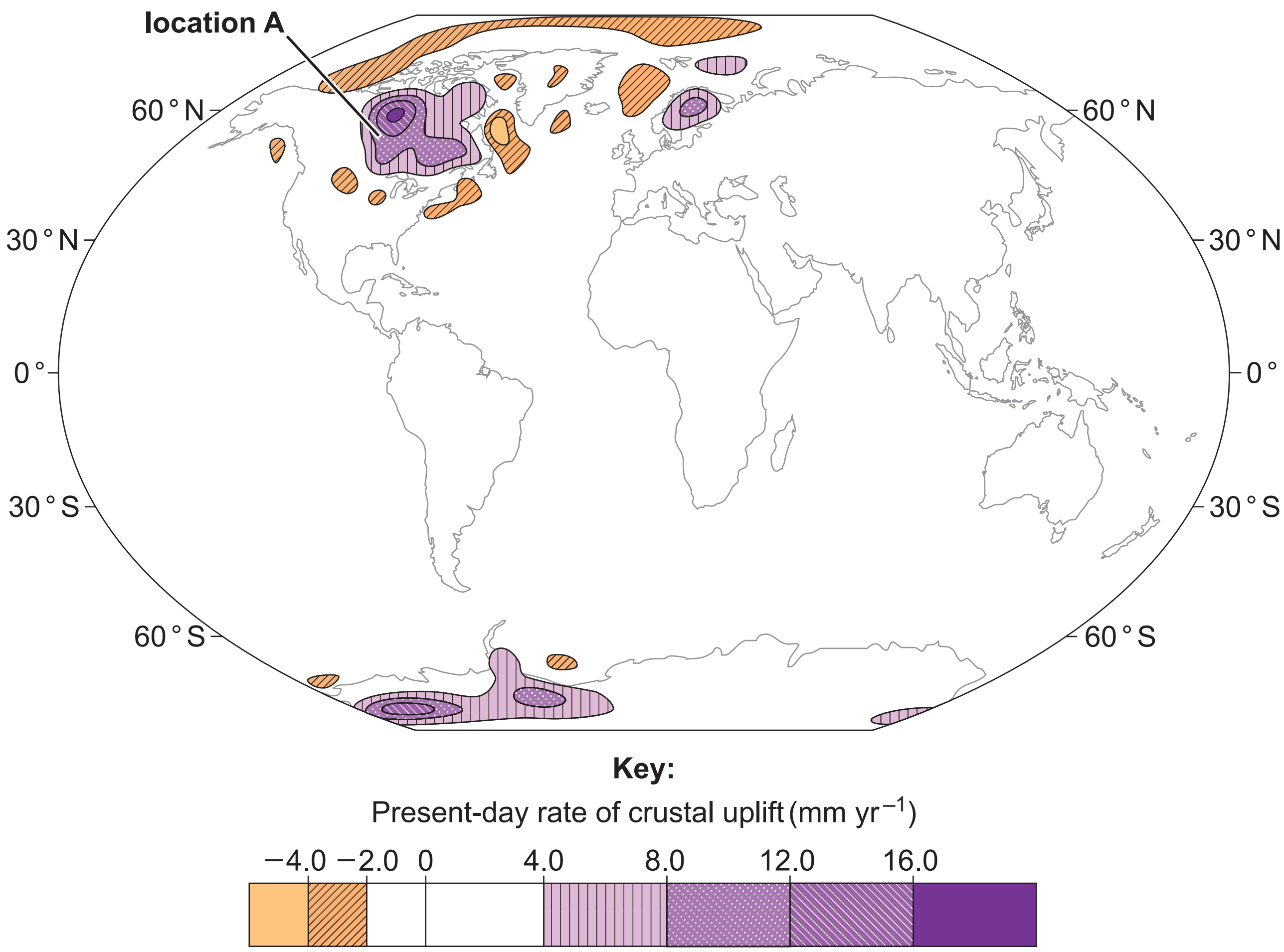

Figure 8a

(a) Refer to **Figure 8a**.

(i) Describe the distribution of areas that are being uplifted at a rate greater than 8 mm yr^{-1}. [2]

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Examiner only

(ii) Explain why these areas are experiencing crustal uplift. [3]

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(b) **Figure 8b** shows how the rate of uplift varies with distance from **location A** on **Figure 8a**.

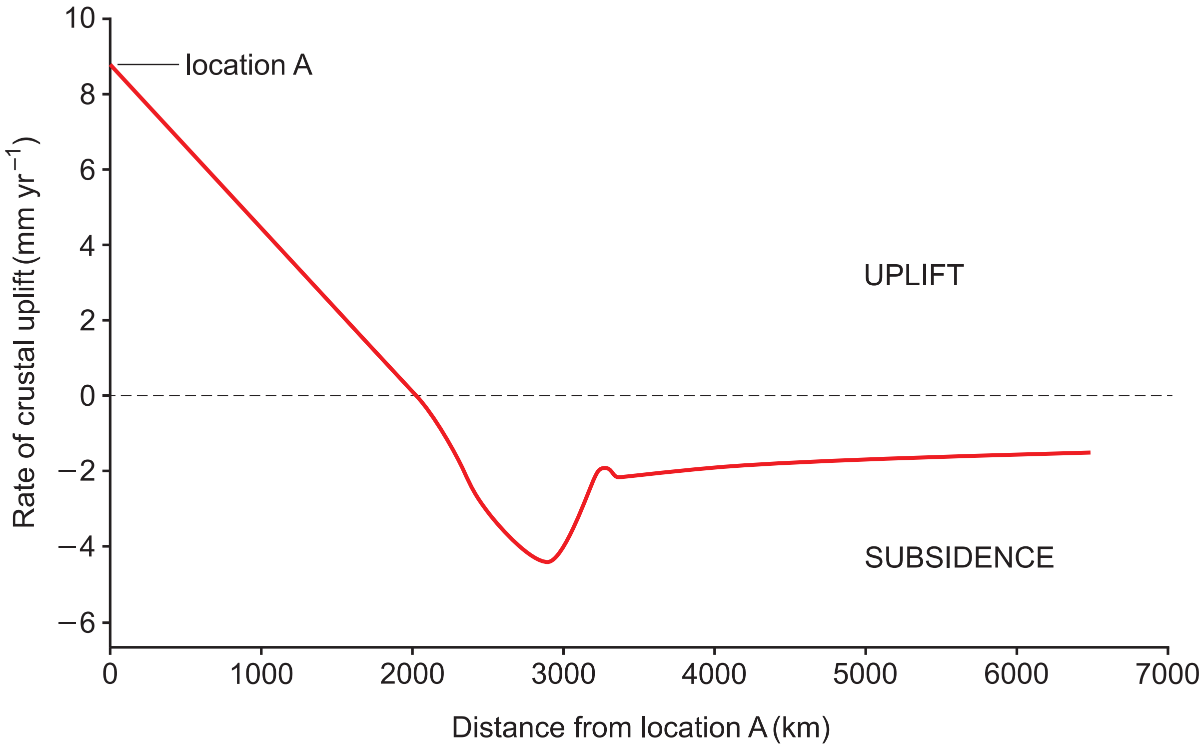

Figure 8b

Refer to **Figure 8b**.

(i) Calculate the change in the rate of crustal uplift per km from location **A** to 2000 km. Show your working. [2]

.... $mm\,yr^{-1}\,km^{-1}$

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Examiner only

(ii) Explain why the area beyond 2000 km from location **A** on **Figure 8b** is undergoing crustal subsidence. [3]

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(c) Suggest the geological evidence that could be used to measure the rate at which areas undergo crustal uplift. [3]

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13

Examiner only

9. Explain how data from ice cores can be used to provide evidence of the climatic fluctuations caused by Milankovitch cycles. [6 QER]

6

Examiner only

Option 2: Geological Evolution of Britain

If you have chosen this option, answer **all** the questions within this option.

10. **Figure 10a** is a Bouguer gravity anomaly map of the Isle of Skye, Scotland.

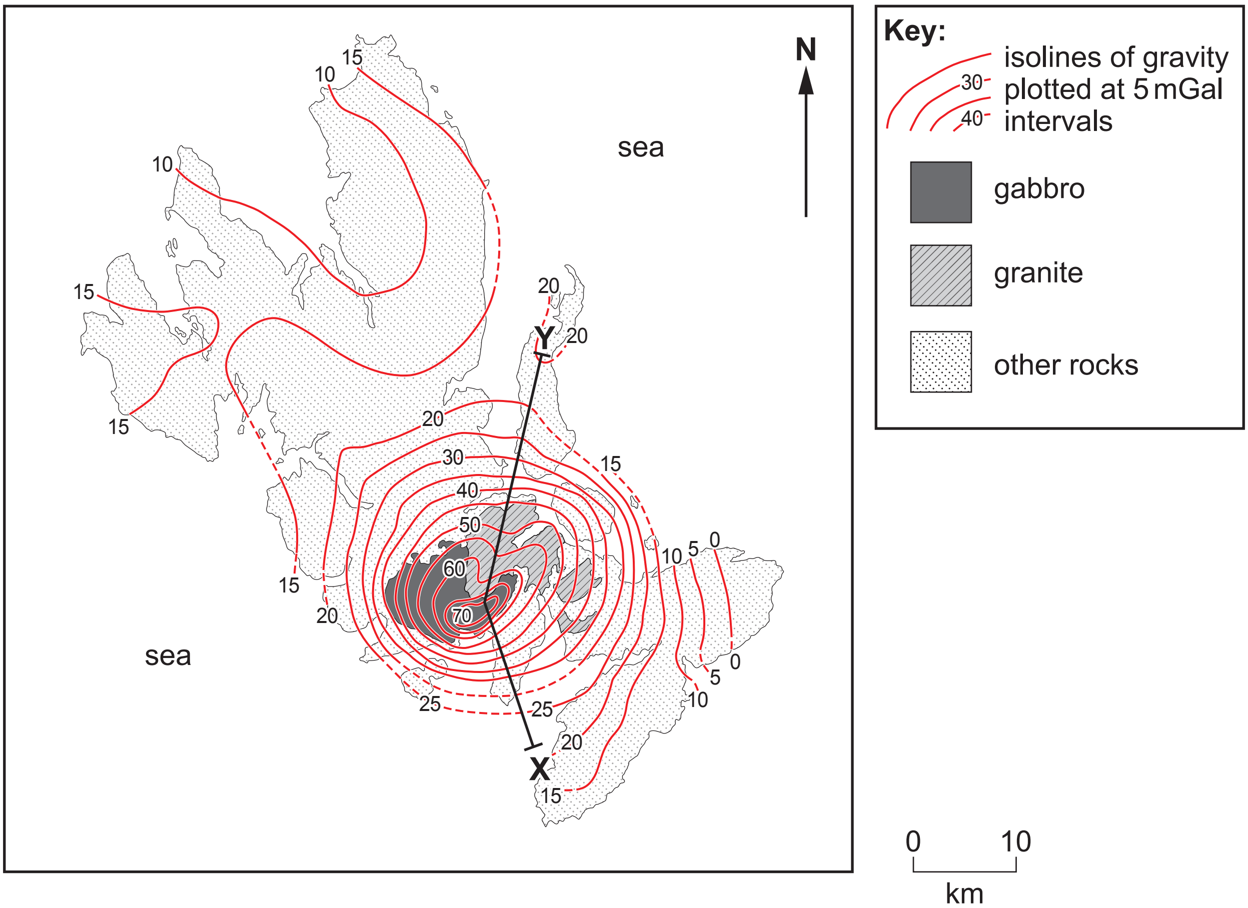

Figure 10a

Refer to **Figure 10a** and **Figure 10b**.

(a) Describe the size and shape of the 25 mGal gravity anomaly on **Figure 10a**. [2]

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Examiner only

Figure 10b shows the changing gravity anomaly, geology and relative density of rock types, along the line **X – Y** on **Figure 10a**.

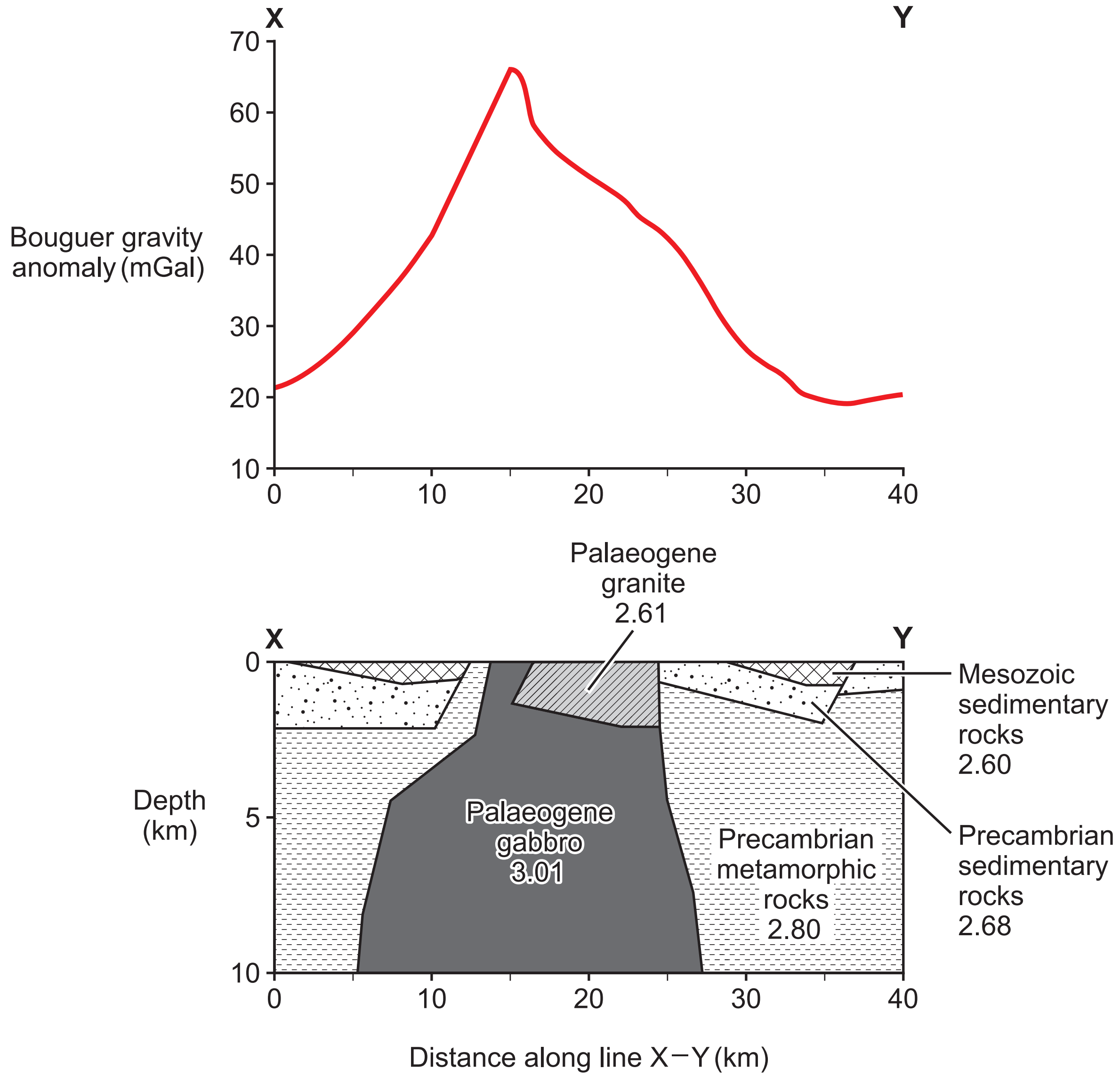

Figure 10b

(b) Explain why there is a positive gravity anomaly on the Isle of Skye. [2]

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Turn over.

Examiner only

(c) (i) Calculate the gradient of the gravity anomaly between 10 and 15 km from location **X** on **Figure 10b**. Show your working. [2]

.... mGal km^{-1}

(ii) The gradient of the gravity anomaly between 20 and 25 km from point **X** on **Figure 10b** is less than that between 10 and 15 km. Explain this difference. [3]

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(d) A student suggested that the igneous rocks in this location were intruded during the Variscan orogenic event. Evaluate this interpretation. [3]

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12

Examiner only

11. **Figure 11a** is a cross-section of the geology in the area around the Mochras Borehole in Wales.

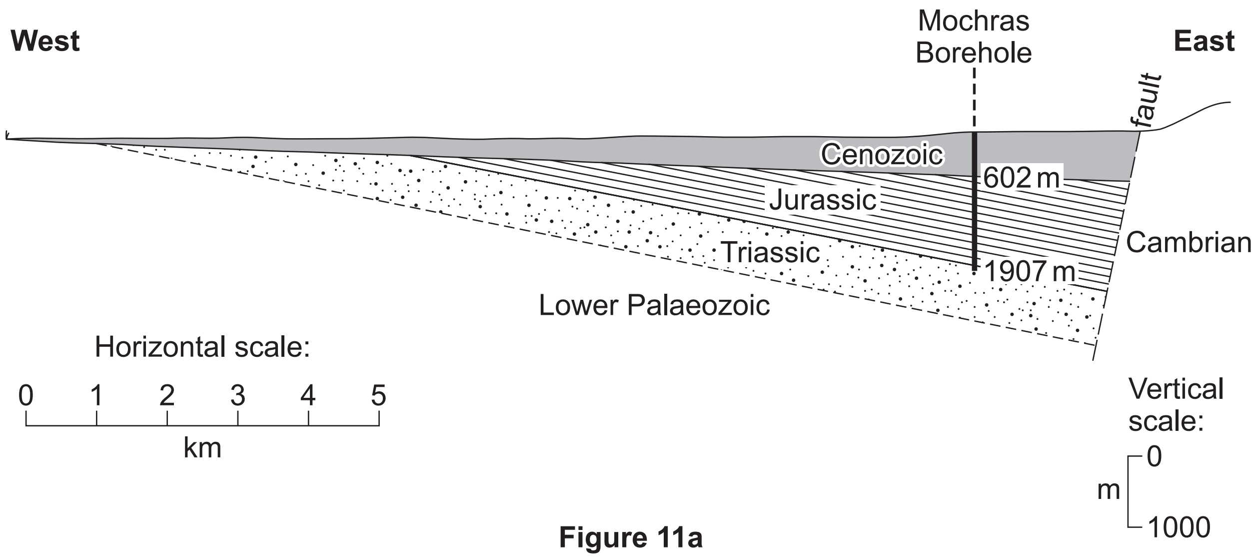

Figure 11a

(a) Refer to **Figure 11a**.

(i) State the type of fault to the east of the Mochras Borehole. Give **one** reason for your answer. [2]

Type of fault movement: ....

Reason: ....

....

(ii) The minimum throw of this fault is more than 3000 m. Explain why it is not possible to determine the exact throw of this fault from **Figure 11a**. [1]

....

....

(iii) The fault has moved on more than one occasion. State the evidence that suggests this. [2]

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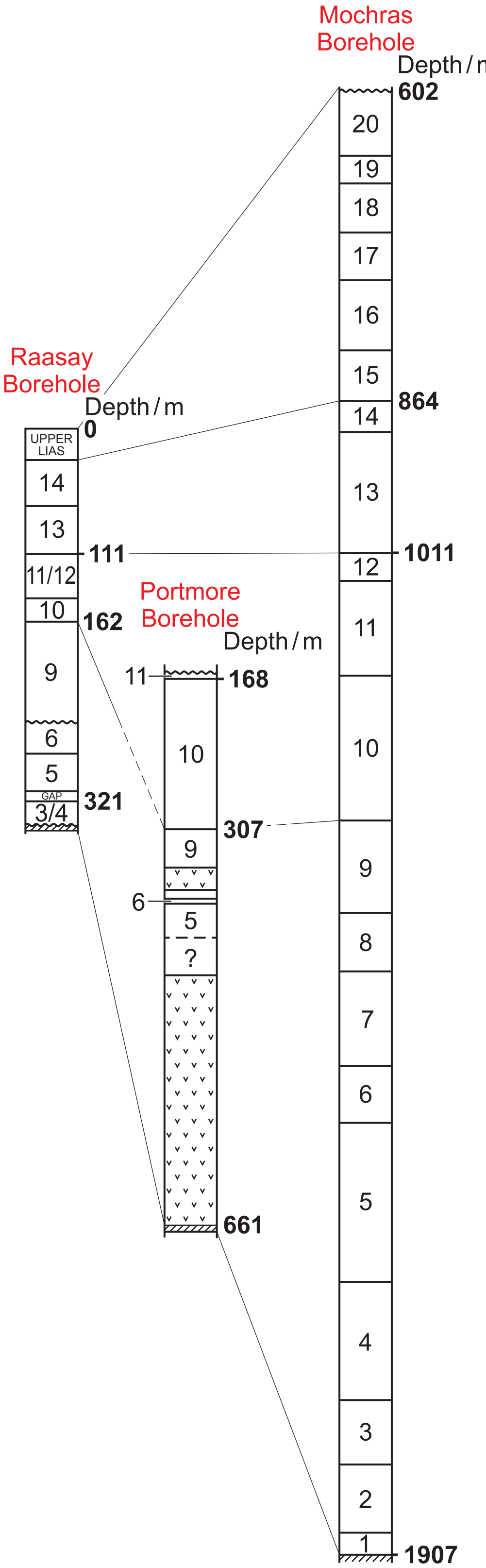
Figure 11b shows the ammonite zones of the Lower Jurassic rocks represented in three boreholes across the UK, including the Mochras Borehole.



Location of boreholes

Figure 11b

Examiner only

(b) Refer to **Figure 11b**.

Explain why boreholes, such as the ones in **Figure 11b**, are used to investigate the geological history of the British Isles. [2]

(c) Ammonites were used to correlate the Lower Jurassic rocks found in all three boreholes.
Explain, with reference to **Figure 11b**, why they were able to be used for these three boreholes. [2]

(d) Refer to **Figures 11a** and **11b**.

The Mochras Borehole has a more complete record of the geology of the Lower Jurassic than the other boreholes. Explain how the geology of the Mochras area has enabled this. [3]

12

Examiner only

12. Explain how palaeomagnetic data can be used to support the sedimentary evidence for Britain's northward drift during the Phanerozoic. [6 QER]

6

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Option 3: Geology of the Lithosphere

If you have chosen this option, answer **all** the questions within this option.

13. **Figure 13a** is a graph showing spreading rates for parts of the Atlantic and Pacific oceans. The ages are determined from the polarity reversal timescale for the last 4 Ma, obtained from continental lavas.

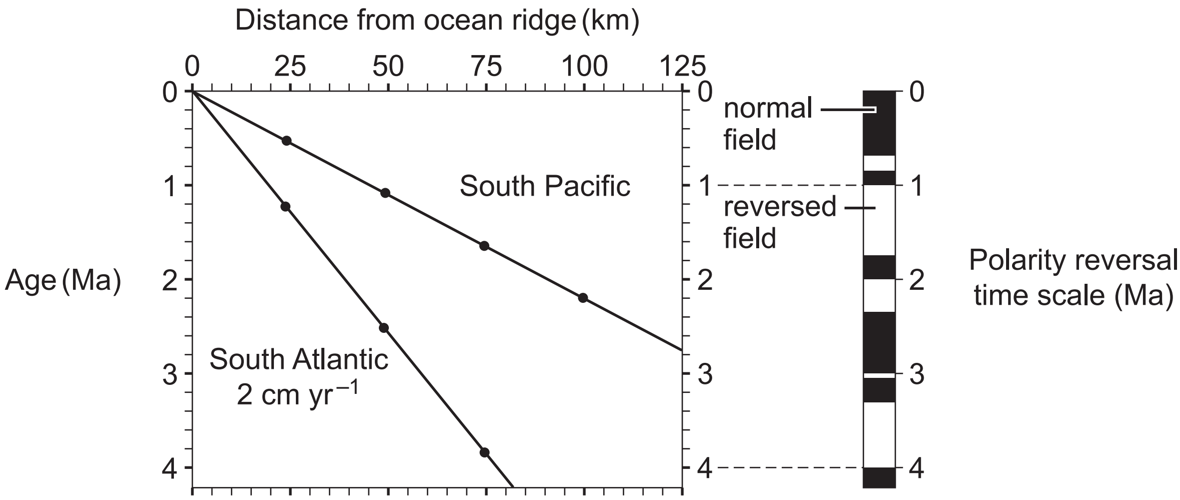

Figure 13a

Refer to **Figure 13a**.

(a) (i) State the distance from the **Pacific** ridge at which the 2 Ma boundary between the normal and reversed polarity would be located. [1]

.... km

(ii) Calculate the spreading rate (cm yr^{-1}) of the South Pacific Ocean. Show your working. [2]

South Pacific spreading rate .... cm yr^{-1}

(b) (i) Explain how the polarity reversal time scale, obtained from continental lavas, is used to calculate spreading rates of the **ocean** lithosphere. [3]

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Examiner only

(ii) Briefly explain **one** other method that can be used to calculate ocean spreading rates. [2]

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(c) **Figure 13b** is a map showing the main features of the Pacific and Atlantic ocean basins. The two oceans are considered to be at different stages in the J. Tuzo Wilson cycle of ocean basin evolution.

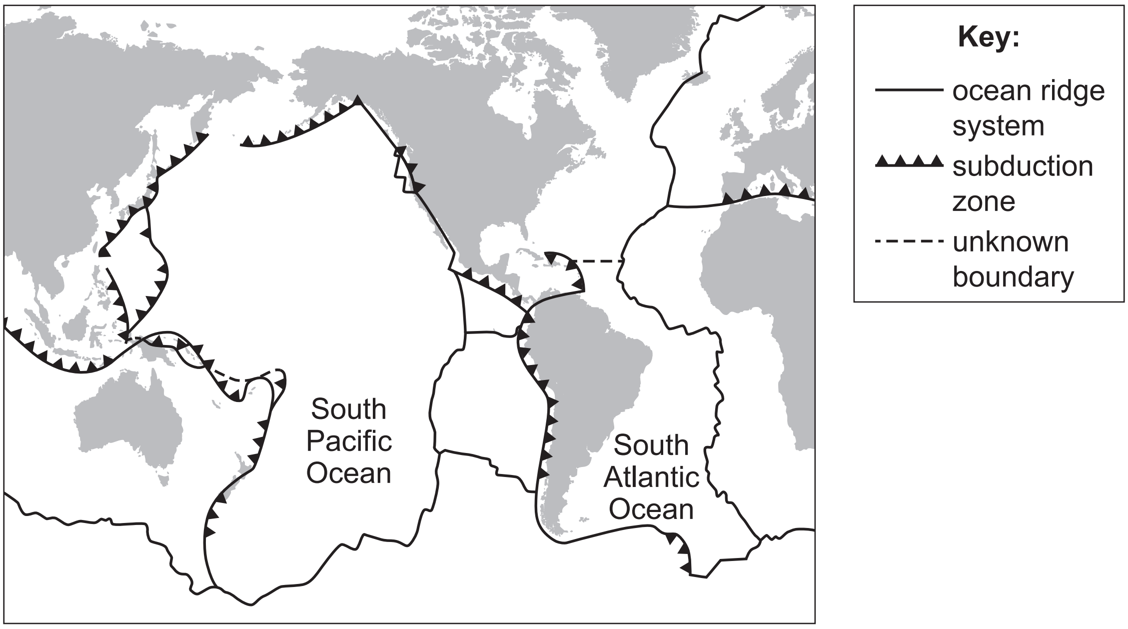

Figure 13b

Refer to **Figure 13a** and **Figure 13b**.

State which ocean (Pacific or Atlantic) shows the most advanced stage in ocean basin evolution. Give **three** reasons for your choice.

[4]

Ocean: ....

Reasons ....

....

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12

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Examiner only

14. **Figure 14a** shows the results of an experiment to compare the behaviour of two sandstone cores when compressed under different temperatures, at a confining pressure of 300 MPa.

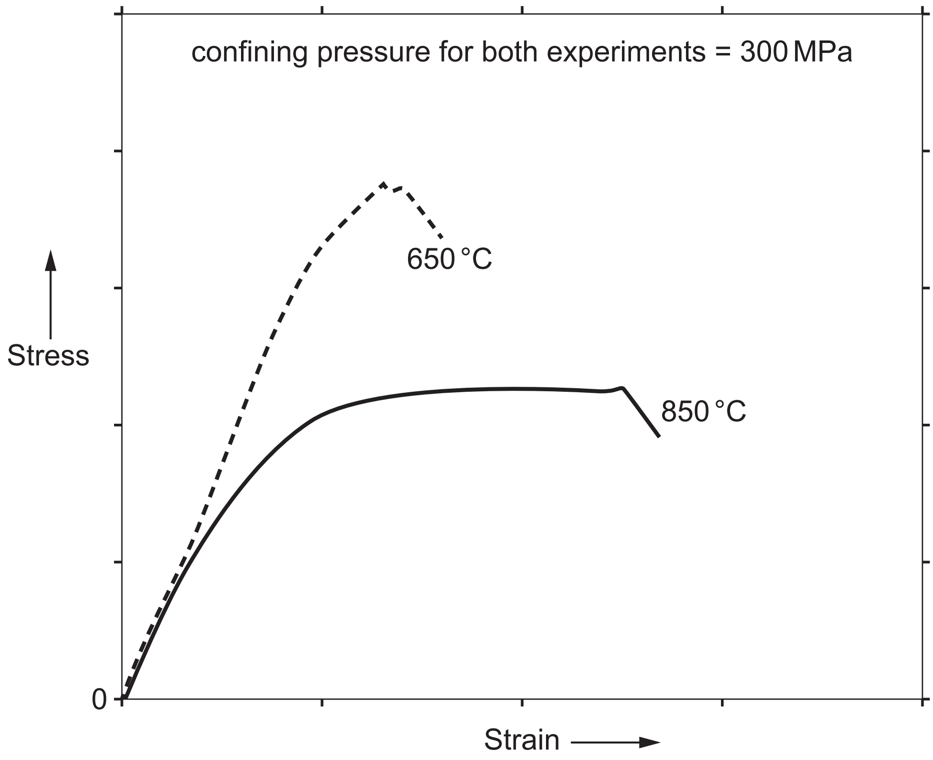

Figure 14a

Refer to **Figure 14a**.

(a) (i) Describe the difference in the behaviour of the sandstone cores when deformed at temperatures of 650 °C and 850 °C. [2]

....

....

....

(ii) Sketch a line on **Figure 14a** to illustrate the graph that might be predicted if the test was repeated at a temperature of 850 °C but with the confining pressure increased to 500 MPa. [2]

(b) **Figure 14b** is a geological map of Pembrokeshire showing the regional structural setting.
Figure 14c is a photograph of a true dip section showing minor geological structures associated with the regional structures in **Figure 14b**. These minor structures formed under the stress conditions in **Figure 14a**.

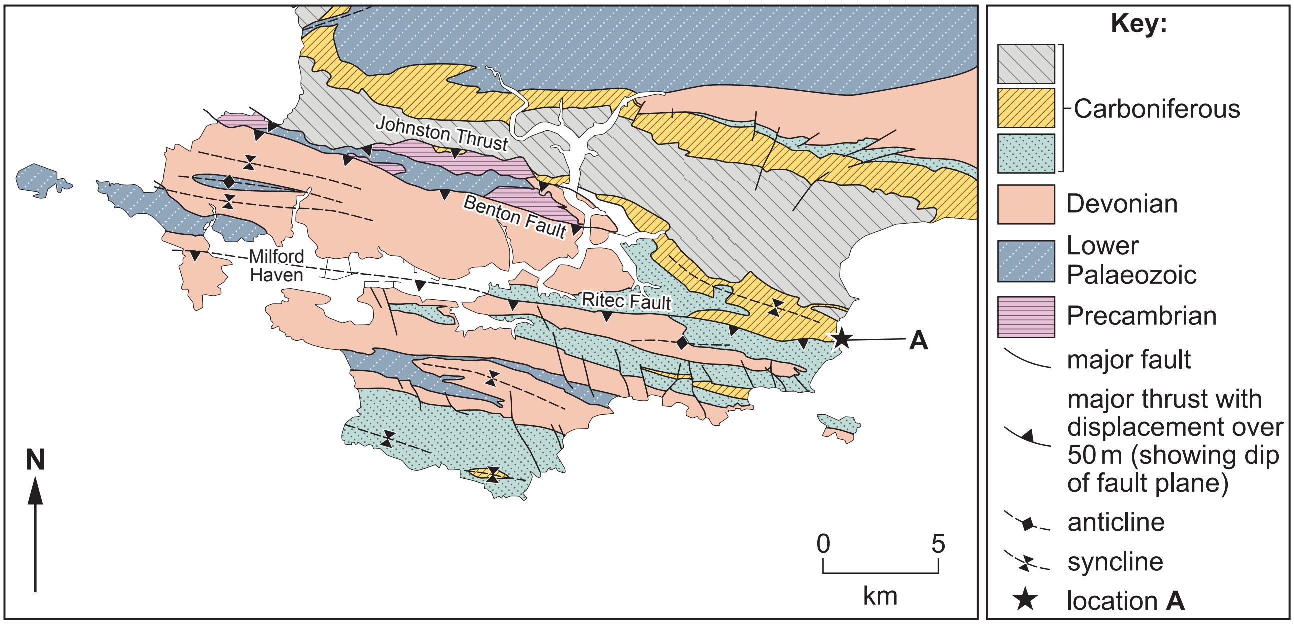

Figure 14b

Figure 14c

Examiner only

A student suggested the photograph (**Figure 14c**) was taken at **location A** on **Figure 14b** looking west. Evaluate this statement. [3]

.....

.....

.....

.....

(c) Explain why the principal stresses that formed the structures in **Figure 14c** are more likely to be associated with a convergent plate boundary rather than a divergent plate boundary. [2]

.....

.....

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(d) Suggest how the results of the tests in **Figure 14a** help to explain that the rock sequence in **Figure 14c** was deformed in the lower crust and then uplifted and further deformed during the formation of an orogenic belt. [3]

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12

Examiner only

15. Explain the seismic evidence for the distinction between the lithosphere and the asthenosphere. [6 QER]

6

END OF PAPER

Question number	Additional page, if required. Write the question number(s) in the left-hand margin.

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Turn over.

Question number	Additional page, if required. Write the question number(s) in the left-hand margin.

Examiner only

Acknowledgements

Figure 7a: http://earthwise.bgs.ac.uk/. Photograph British Geological Survey

Figure 14b: https://sp.lyellcollection.org/content/487/1/105. Acknowledgement not found

Figure 14c: P. Loader

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