Surname	Centre Number	Candidate Number
First name(s)		2

GCE A LEVEL

A480U30-1

O21-A480U30-1

MONDAY, 18 OCTOBER 2021 – MORNING

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.	18		
	4.	8		
	5.	7		
	6.	12		
Section C option		12	10	
		12	14	
		6		
	Total	105		

ADDITIONAL MATERIALS

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

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 alongside 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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SECTION A

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

1. **Figure 1a** is a map of the Bristol Channel area showing an estimate of wave heights from a possible tsunami that caused a flood event in January 1607.

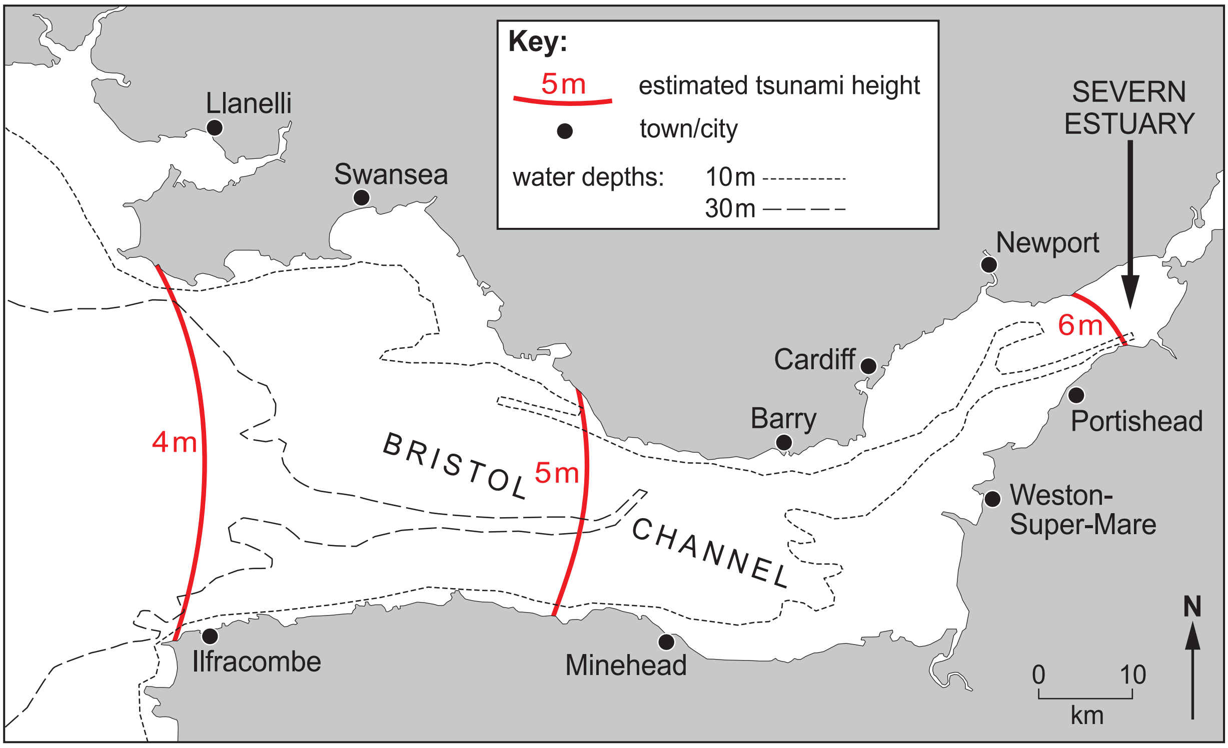

Figure 1a

Refer to **Figure 1a.**

(a) (i) Describe the change in the estimated height for this tsunami wave in the Bristol Channel area. [2]

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(ii) State **two** reasons why the estimated tsunami wave height changes along the Bristol Channel area. [2]

1. ....

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2. ....

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(b) Suggest **one** possible cause of a tsunami around the British coast in the recent geological past. [1]

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(c) **Figure 1b** shows the maximum height of storm waves in the Bristol Channel area and the predicted tsunami wave heights required to transport and align boulders found along the coast in this area.

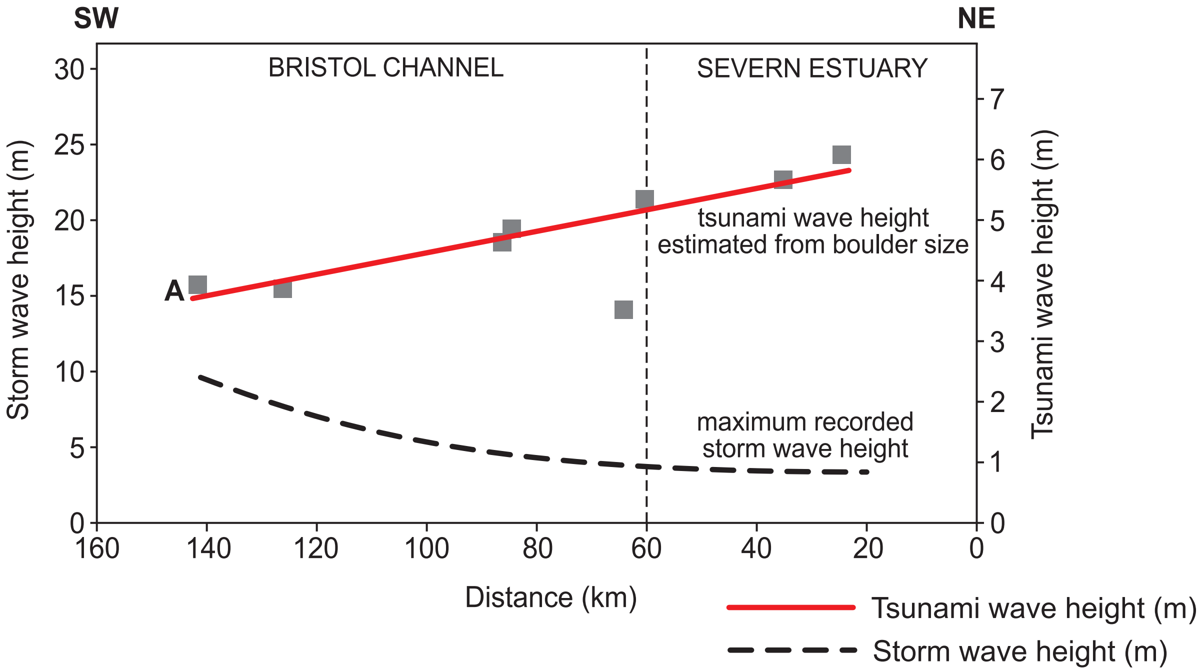

Figure 1b

Refer to **Figure 1b**.

(i) Boulder **A** could be transported and aligned by a tsunami wave 4 metres high. Determine how many times higher a storm wave would have to be in order to transport and align the same boulder. [1]

....

(ii) A boulder that was measured at 100 km would have required a storm wave height of 22 m to transport and align it.
Plot this data point onto **Figure 1b**. [1]

(iii) With reference to the point you have plotted on **Figure 1b**, explain how this boulder supports the theory that the 1607 flood event was caused by a tsunami rather than a storm. [2]

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Turn over.

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(iv) From your knowledge of tsunamis, suggest and explain **one** *other* piece of evidence that could be used to support the theory that the 1607 flood event was caused by a tsunami. [2]

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(d) Refer to **Figures 1a** and **1b**.

"The coastline of the Bristol Channel should be defended against future tsunamis." Evaluate this statement with reference to geohazard risk. [4]

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2. **Figure 2** is a cross-section through a cutting for a new route for the A465 road in South Wales.

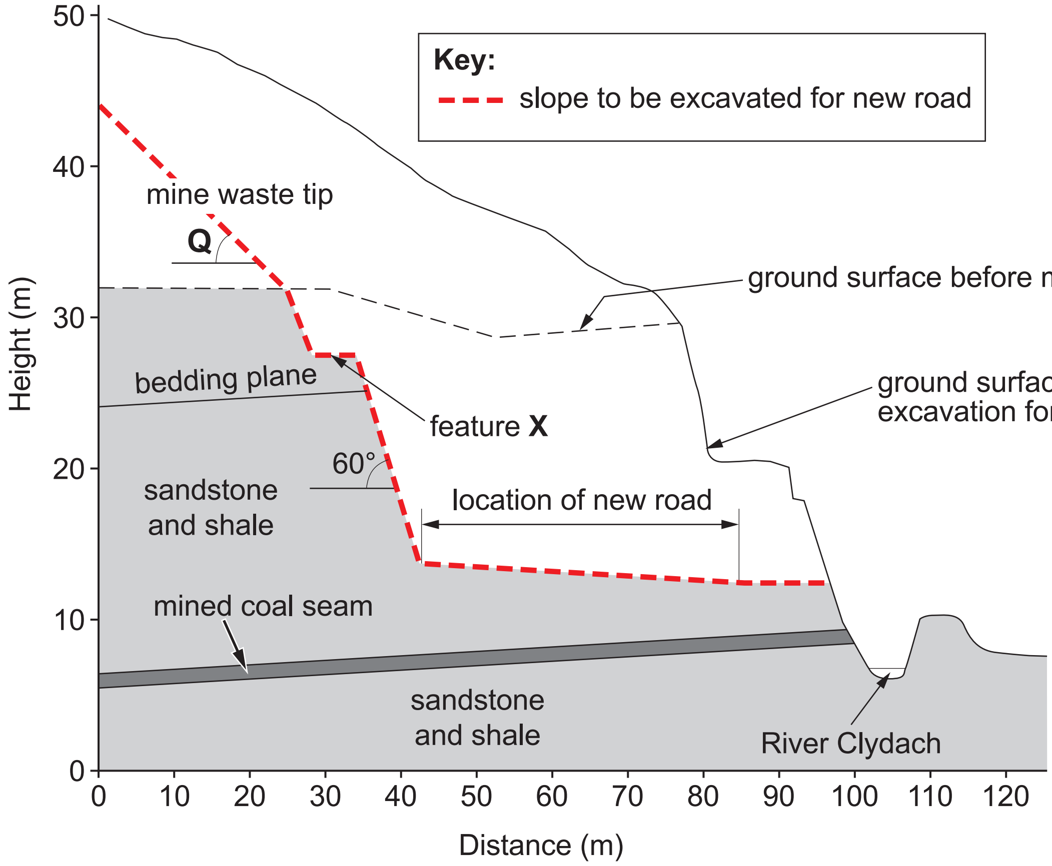

Figure 2

Refer to **Figure 2**.

(a) Describe **one** way in which the mined coal seam might affect the stability of the new road. [2]

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(b) (i) State **two** reasons for the inclusion of feature **X** in the design for the slope to be excavated for the new road. [2]

1. ....

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(ii) Describe how **one other** slope stabilisation technique might be suitable to stabilise the 60° slope of sandstone and shale. [2]

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(c) (i) Calculate, using trigonometry, the slope angle **Q** that is to be excavated in the mine waste. Show your working. [3]

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(ii) Explain why the slope angle in the mine waste must be excavated to be lower than that in the sandstone and shale. [3]

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(d) Explain **one** method that could be used to monitor the stability of these slopes once the new road has been built. [3]

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SECTION B

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

Questions ***3 – 6*** *relate to the* ***British Geological Survey 1:50 000 geological map*** *extract of Falmouth (352)*

3. *(a)* Refer to the key on the **geological map**. Complete **Table 1** to identify the features represented by the symbols at the following grid references. [2]

Grid reference	Feature
749380	•
737396	•

Table 1

(b) (i) Complete **Table 2** by inserting the following events from the **geological map** in order of their relative ages – oldest at the base. [2]

Pluton **P**   mineral veins   Mylor Slate Formation (**MrSl**)

Relative age	Events
Youngest	•
	•
Oldest	•

Table 2

(ii) State the evidence from the **geological map** that Pluton **Q** was intruded after the Dolerite (**D'**). [2]

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(iii) Explain the evidence from:
1. the **geological map**
2. the **Bouguer gravity anomaly map**

to suggest that, at depth, Pluton **P** is part of the larger Pluton **Q** to the south. [3]

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(c) The width of outcrop of the metamorphic aureole varies around the granite pluton.

(i) Calculate the width of outcrop of the metamorphic aureole along the line **X–Y** on the **geological map**. Show your working. [2]

width .... (km)

(ii) Draw an annotated diagram(s) to explain how the width of outcrop of the metamorphic aureole may reflect the dip of the contact between the pluton and the country rock. [2]

(iii) State and explain **one** *other* possible reason for the variation in outcrop width of the metamorphic aureole. [2]

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(d) **Figure 3** shows a student's field map of strike and dip orientations of cleavage within the Devonian slates on the **geological map**.

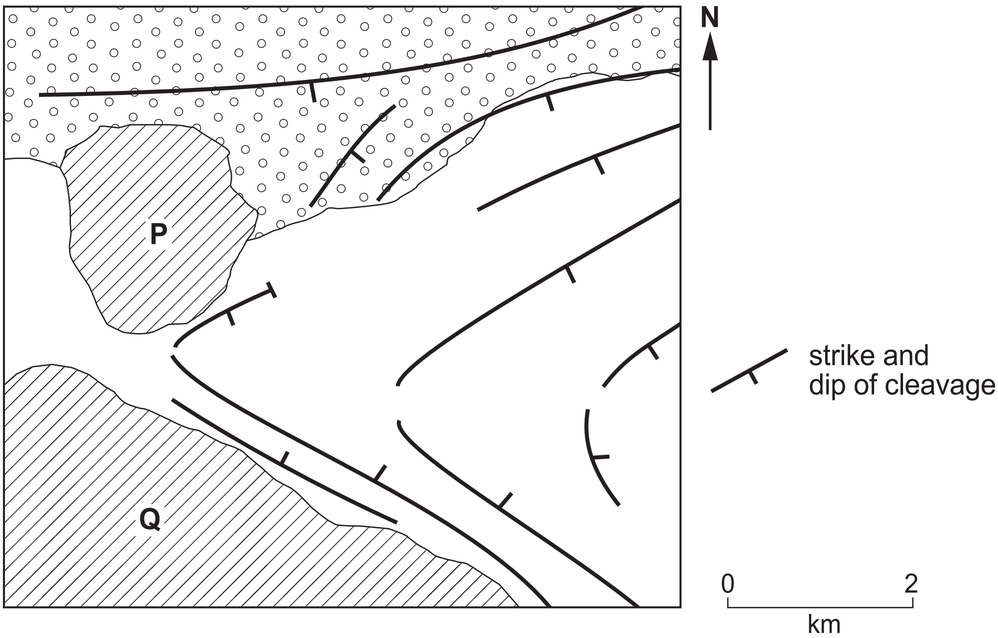

Figure 3

The student concluded that *'the intrusion of the granite pluton was unlikely to have been responsible for the development and orientation of the cleavage within the slates'.* Evaluate this statement. [3]

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4. A student undertook a field investigation into the alignment of the long axis of feldspar phenocrysts in Pluton **Q**. **Figure 4** is a rose diagram of data collected from a single rock surface.

Table 3 is a partly completed chi-squared test used to test the null hypothesis (H_0); *there is no alignment of the phenocrysts.*

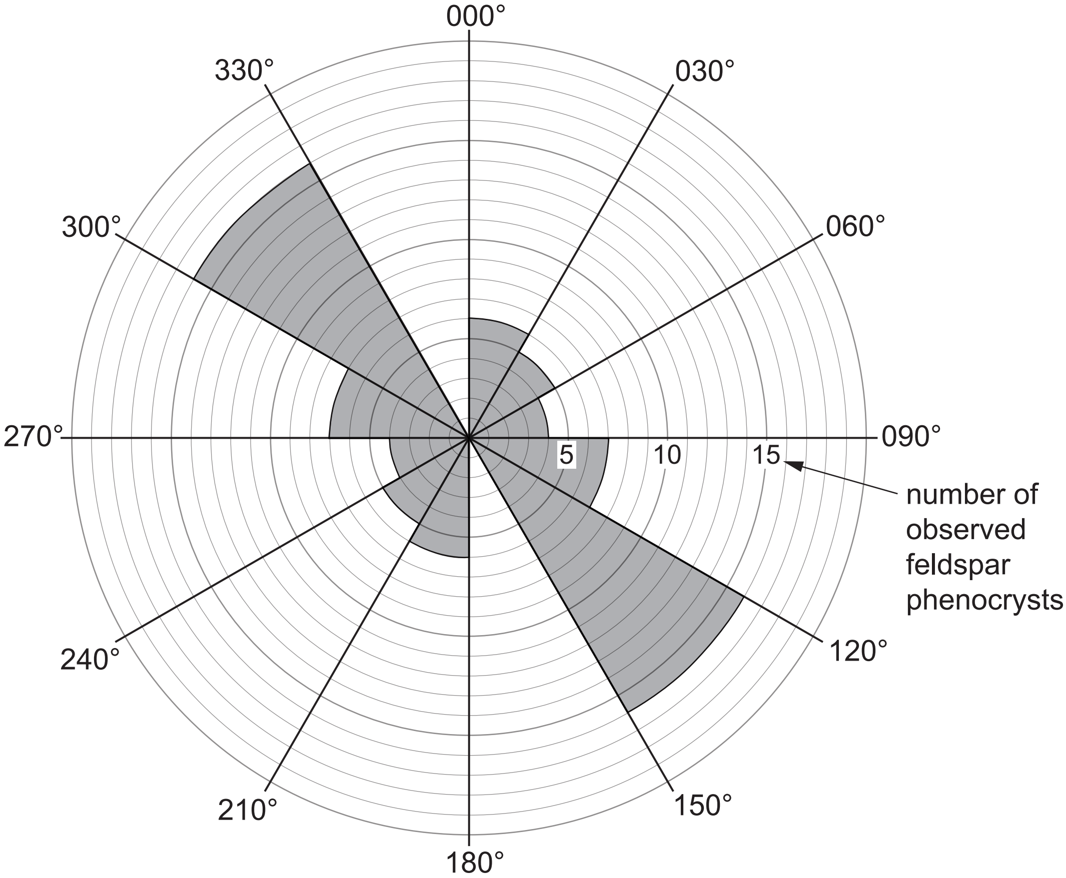

Figure 4

Phenocryst alignment in degrees (class)	Observed frequency (O)	Expected frequency (E)	(O – E)	$(O - E)^2$	$\frac{(O-E)^2}{E}$
000 – 029	•	8	•	•	•
030 – 059	5	8	–3	9	1.125
060 – 089	4	8	–4	16	2
090 – 119	7	8	–1	1	0.125
120 – 149	16	8	8	64	8
150 – 179	10	8	2	4	0.5
Total	48	48	chi-squared value		12.25

Table 3

Examiner only

(a) (i) Complete **Figure 4** by using the observed frequency (O) for phenocryst alignment in the 150° – 179° class in **Table 3**. [1]

(ii) Using data from **Figure 4**, complete **Table 3** for phenocryst alignment in the 000°– 029° class. [2]

(iii) The critical value for chi-squared in this case is **11.07** at the 0.05 confidence level. State, with reasons, whether the null hypothesis (H_0) is accepted or rejected. [2]

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(b) Suggest why the data collected from the single rock surface in this investigation may have resulted in a false conclusion. [3]

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5. **Figure 5** shows the area within **box A** on the **geological map**. It provides details of the Porthtowan Fault Zone (**PTF**) in the vicinity of the planned United Downs Deep Geothermal Power Project.

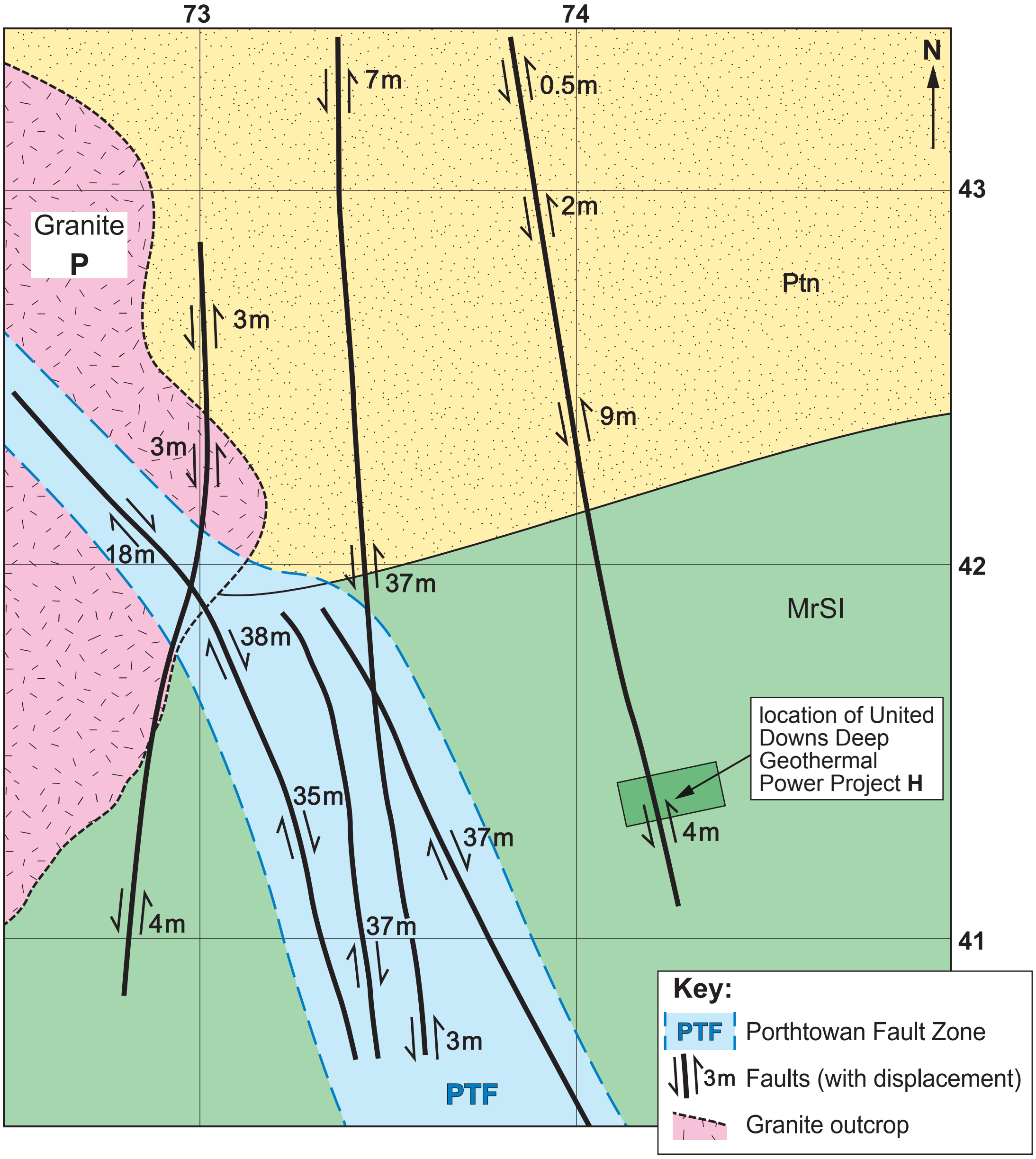

Figure 5

Examiner only

Refer to **Figure 5**

(a) (i) Complete **Table 4** to identify the fault characteristics **within** the Porthtowan Fault Zone (**PTF**). [2]

Porthtowan Fault Zone (**PTF**) characteristics	
Range of fault displacements	•
Fault type	•

Table 4

(ii) Explain how you might confirm the direction and amount of fault displacements in the field. [3]

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(b) Explain why the permeability of the granite is likely to be significantly higher in the Porthtowan Fault Zone (**PTF**) than in other areas of granite underlying this region. [2]

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6. **Figure 6** is a cross-section through the planned United Downs Deep Geothermal Power Project shown in **Figure 5** and on the **geological map**. **Table 5** shows geotechnical data relevant to this project.

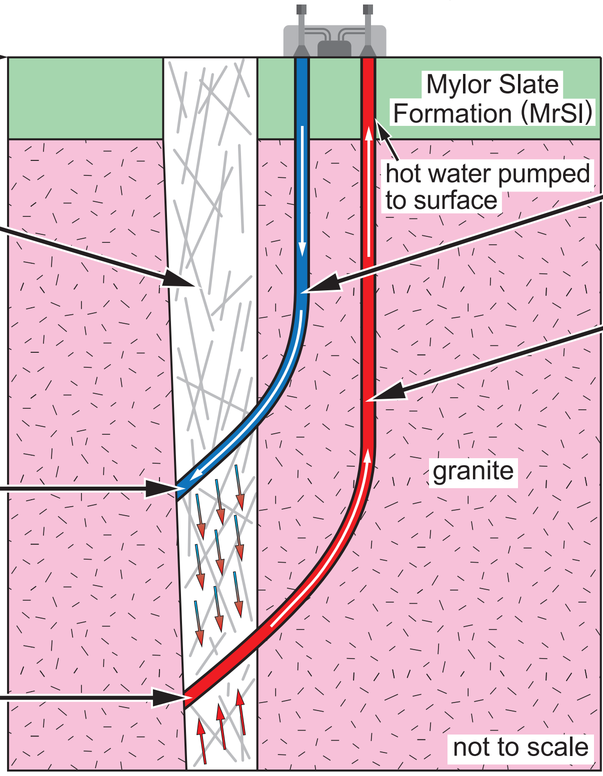

Figure 6

United Downs Deep Geothermal Power Project – geotechnical data	
temperature of surface rock	12°C
geothermal gradient	$0.040\,°C\,m^{-1}$
estimated permeability of granite in the Porthtowan Fault Zone (**PTF**)	$9.9 \times 10^{-16}\,m^2$

Table 5

Refer to the **geological map, Figure 6** and **Table 5**.

(a) (i) Suggest **two** reasons why this region has such a high heat flow. [2]

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Examiner only

(ii) Calculate the predicted temperature of the rock at the bottom of the production well. Show your working. [2]

temperature .... °C

(b) In order to achieve the required flow rate in the Porthtowan Fault Zone (**PTF**) between the injection and production wells, the permeability of the granite needs to be **19 times** greater than the estimated value of $9.9 \times 10^{-16}\,m^2$.

(i) Calculate the permeability needed in the granite to achieve the required flow rate between the two wells. Give your answer in standard form. [1]

permeability .... m^2

(ii) Suggest how the permeability of the granite might be artificially increased between the two wells to achieve the required flow rate. [2]

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(c) Assess the possible impact of **two** of the following environmental issues that might be associated with developing this site for geothermal energy production:

- radon gas emissions
- interference with the hydrological system
- seismic activity [5]

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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.*

☐ Quaternary Geology ☐ Geological Evolution of Britain ☐ Geology of the Lithosphere

Option 1: Quaternary Geology

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

7. **Figure 7a** is a reconstruction of a species of fossil mammoth found at Condover, Shropshire.

Figure 7a

(a) Explain how the mammoth shown in **Figure 7a** may provide evidence for climatic change in the Quaternary. [2]

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(b) **Figure 7b** is a cross-section through Quaternary sediments at Condover. **Table 6** lists part of two beetle fossil assemblages (**C** from sediment **C** and **M** from the skull of the fossil mammoth in sediment **C**).

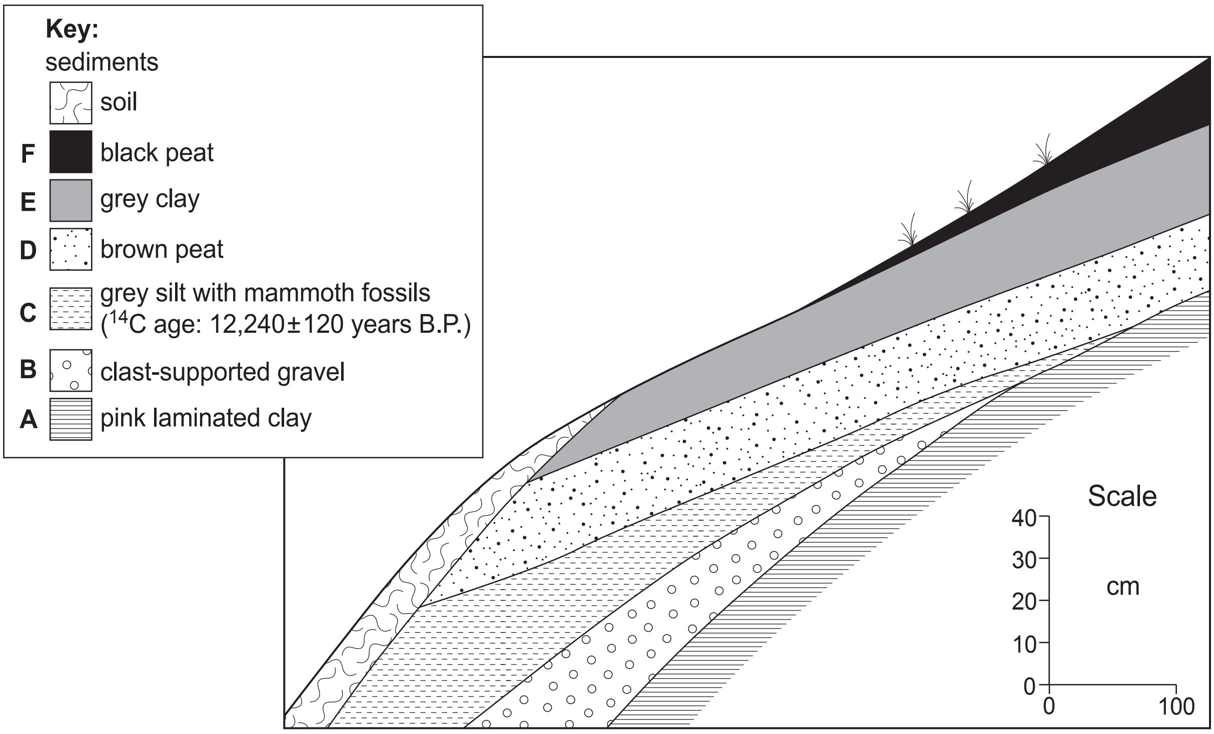

Figure 7b

assemblage	representative species	present-day habitat
M (2 species)	*Necrobia violacea* *Aphodius*	corpse beetle – feeds on larvae of flies in decomposed carcasses lives on dung
C (75 species)	*Agabus bipustulatus* *Agabus congener* *Rhantus notatus* *Colymbetes dolobratus* *Coelostoma orbiculare* *Blethia multipunctata* *Aphodius*	ponds and puddles cold water ponds ponds with silty sediments very cold water in Norwegian mountains marshy edges of ponds marshy bogs lives on dung

Table 6

Examiner only

Refer to **Figure 7b** and **Table 6**.

(i) Describe the environment in which the grey silt (sediment **C**) was likely to have been deposited. [2]

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(ii) Explain the origin of the fossil assemblage (**M**) found in the mammoth skull. [2]

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(c) Explain **one** reason why ^{14}C dates might not be obtained from sediment **B**. [2]

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(d) Refer to **Figures 7a**, **7b** and **Table 6**.

"Invertebrate fossils, such as beetles, give better evidence for Quaternary climatic fluctuations than vertebrate fossils, such as mammoths."

Evaluate this statement with reference to the evidence from Condover. [4]

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8. **Figure 8a** is a map showing glacial corries in Snowdonia, North Wales. **Figure 8b** is a graph showing the orientation and altitude of the corries in **Figure 8a**. **Figure 8c** is a graph showing the altitude of the floor of the corries in **Figure 8a**.

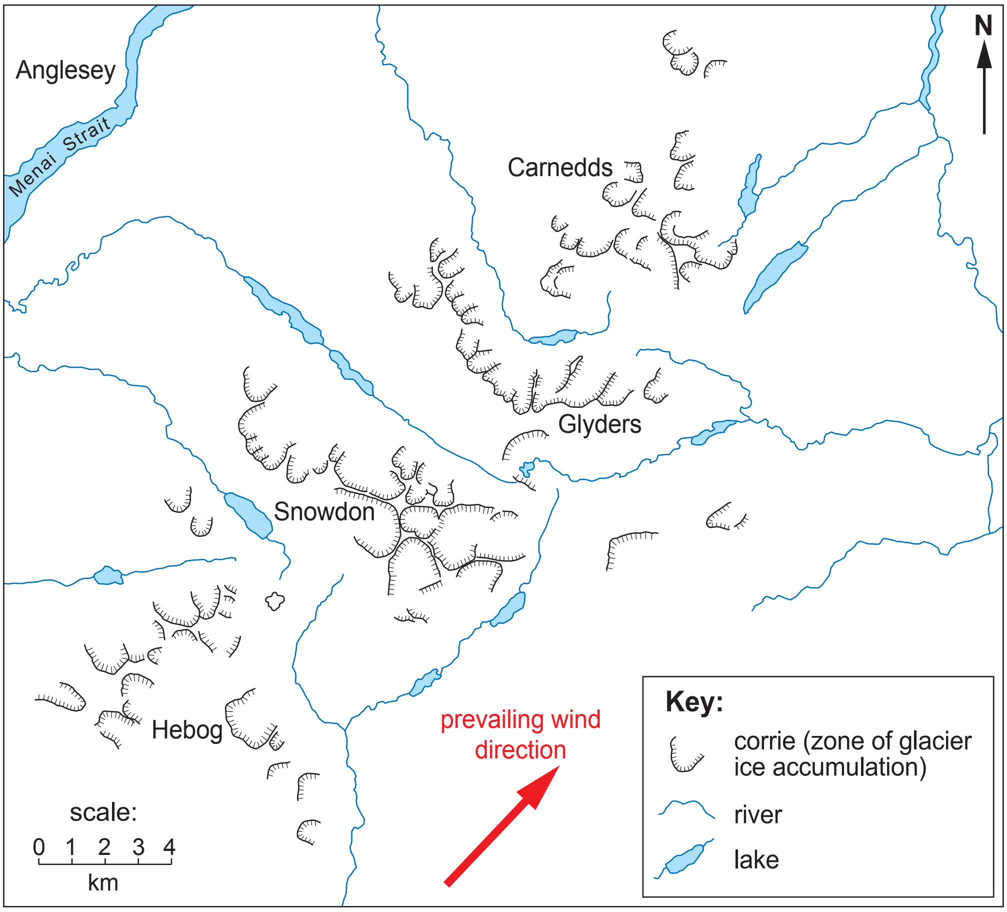

Figure 8a

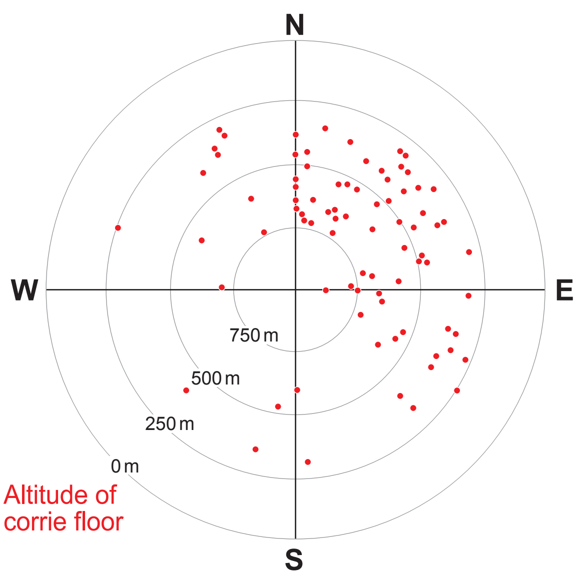

Figure 8b

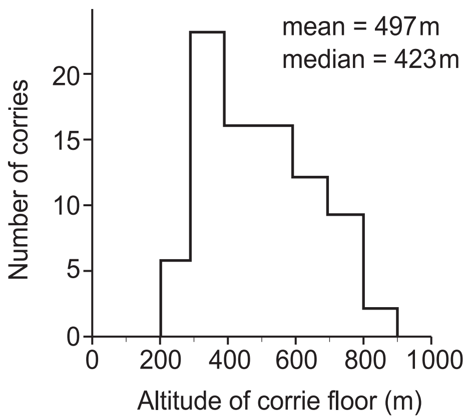

Figure 8c

Examiner only

(a) (i) Describe the range of corrie floor altitudes shown on **Figure 8b**. [2]

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(ii) State whether the graph in **Figure 8c** shows a positive or negative skew. Give a reason for your choice. [2]

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(b) Refer to **Figures 8a**, **8b** and **8c**. Explain why the corries in Snowdonia have this orientation and altitude. [3]

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Examiner only

Figure 8d is a map showing some of the Quaternary features of the glacial corrie Cwm Idwal in Snowdonia.

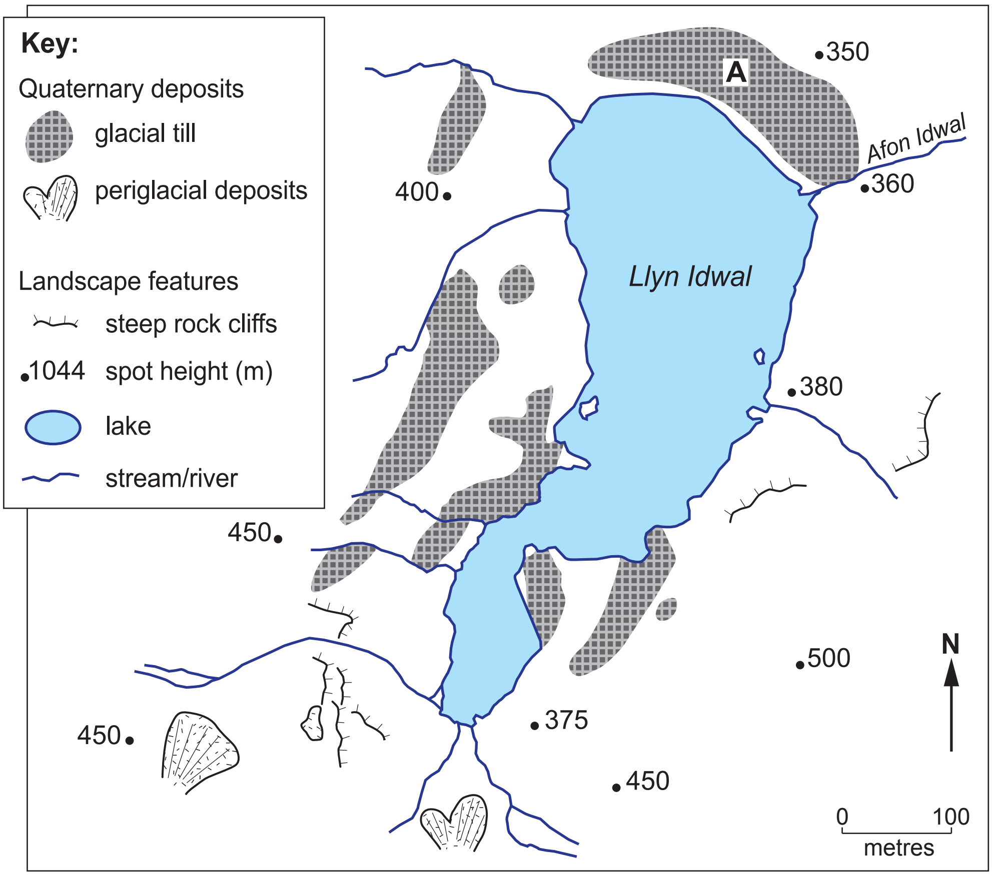

Figure 8d

Refer to **Figure 8d**.

(c) Explain the origin of the glacial till deposit **A**. [2]

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(d) *"The glacial till deposits found in Cwm Idwal allow the dimensions of the ice sheet that formed this valley to be deduced."*
Evaluate this statement with reference to the Quaternary geology of Cwm Idwal. [3]

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9. Explain why oceanic sediments give a more complete record of evidence for glacial and interglacial climatic cycles during the Quaternary than terrestrial sediments. [6 QER]

6

Option 2: Geological Evolution of Britain

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

10. **Figure 10** is a geological map of Great Britain.

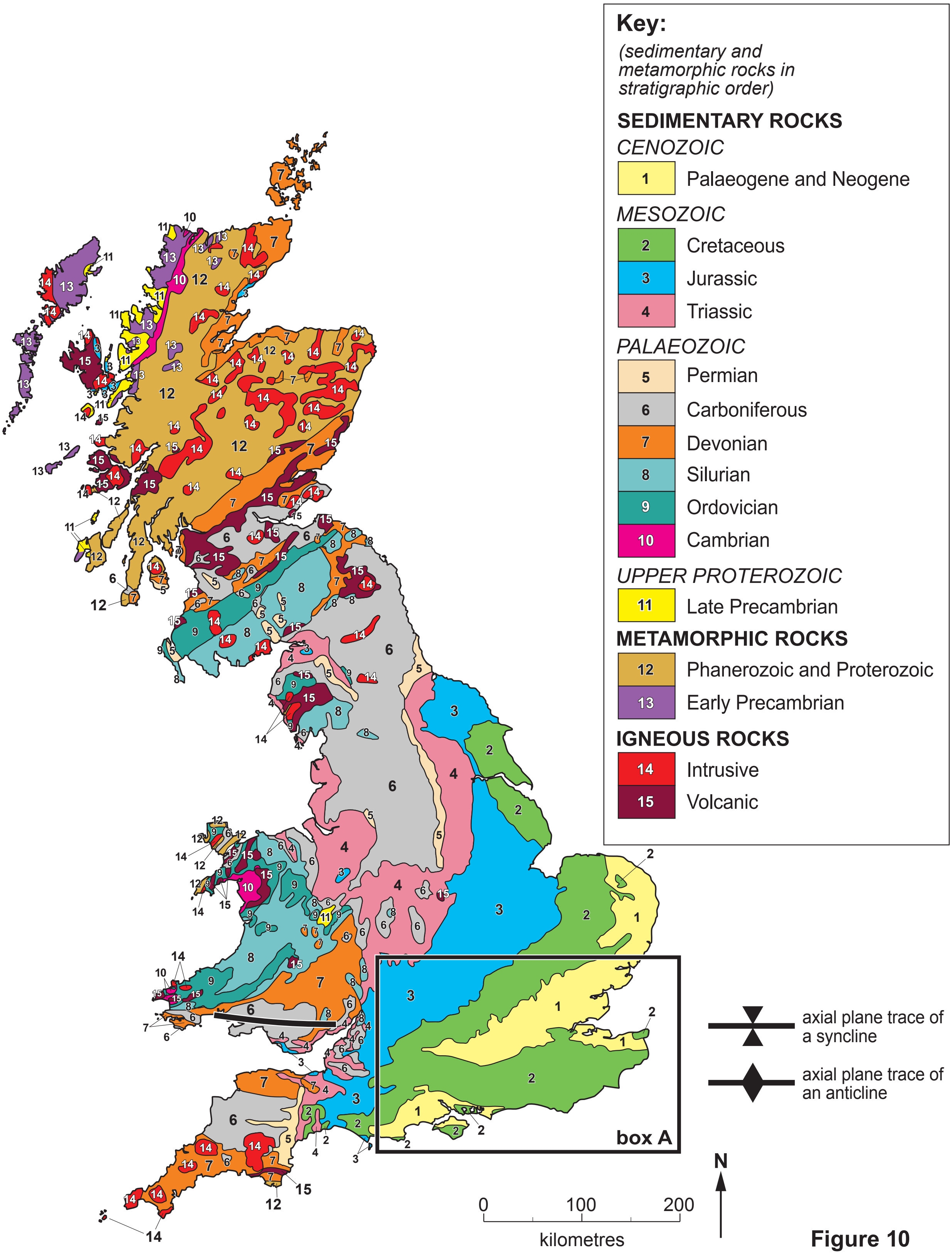

Figure 10

Examiner only

Refer to **Figure 10**.

(a) Describe the age range and general distribution of rock ages across Great Britain. [2]

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(b) (i) The axial plane trace of a major fold in South Wales is marked on **Figure 10**. Add the appropriate symbol to show the type of fold. Give **one** reason for your answer. [2]

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(ii) Using the appropriate symbols, draw the axial plane traces of **two** major folds in **box A** on **Figure 10**. [2]

(iii) A student suggested that *"the folds in South Wales and **box A** are thought to have been formed during the same orogenic event"*.
Evaluate this statement with reference to the evidence on **Figure 10**. [4]

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11. **Figure 11a** is a graph showing the mean production of oceanic crust through time. **Figure 11b** is a map showing the North Atlantic area in the Cretaceous period.

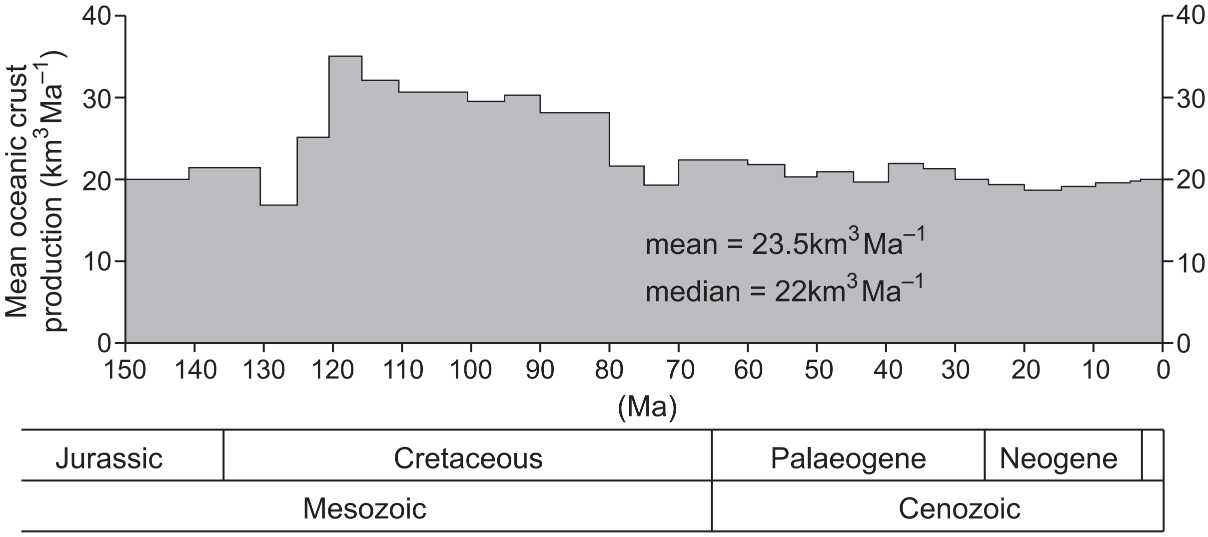

Figure 11a

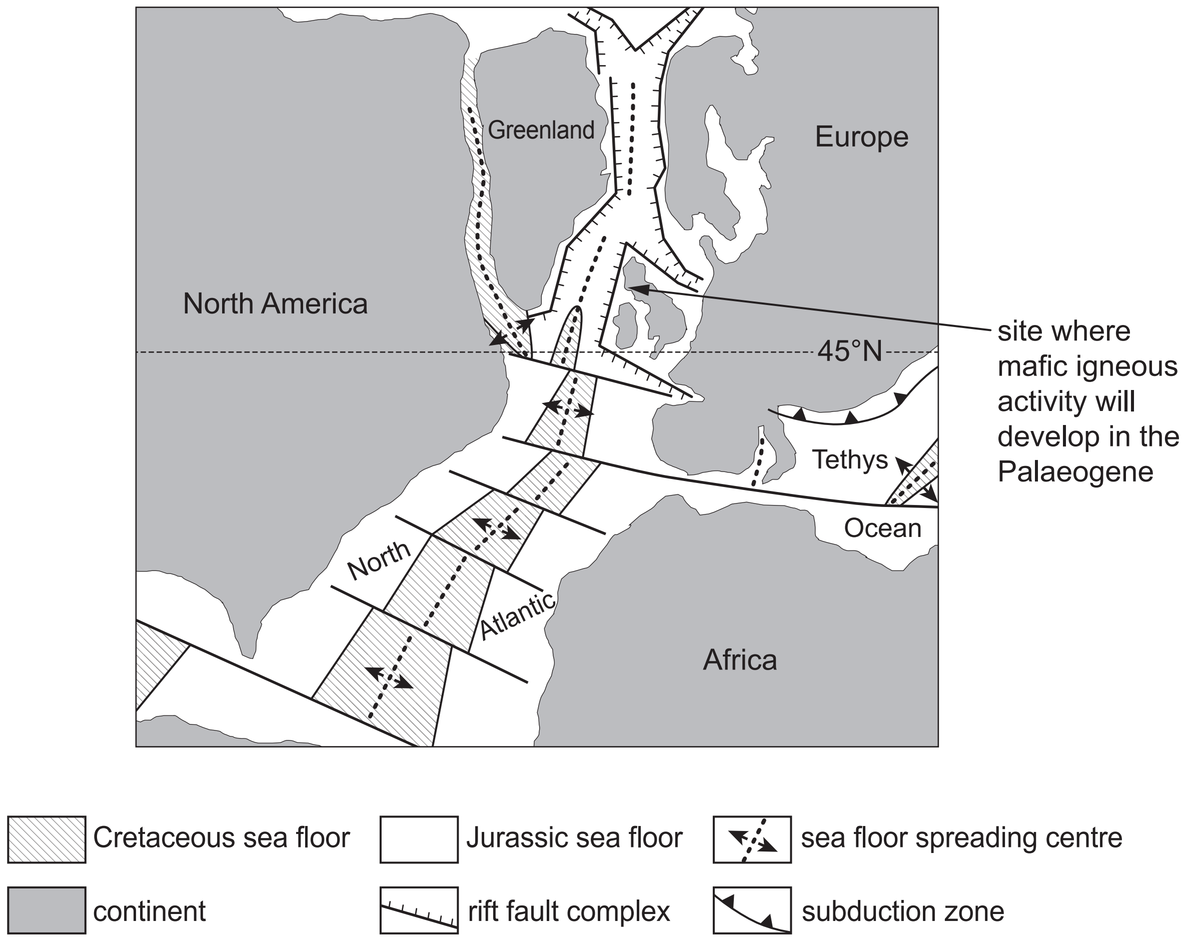

Figure 11b

Examiner only

Refer to **Figure 11a**.

(a) (i) Describe the range of mean oceanic crust production through the Cretaceous period. [2]

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(ii) State whether the graph shows a positive or negative skew. Give a reason for your choice. [2]

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Refer to **Figure 11b**.

(b) Explain the effects of the higher rate of production of oceanic crust in the Cretaceous compared to the Cenozoic. [2]

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(c) Explain why mafic igneous activity developed in the Palaeogene at the location shown on **Figure 11b**. [3]

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Question continues overleaf

Examiner only

(d) **Figure 11c** shows the sequence of Cretaceous sedimentary rocks found in Norfolk, eastern England.

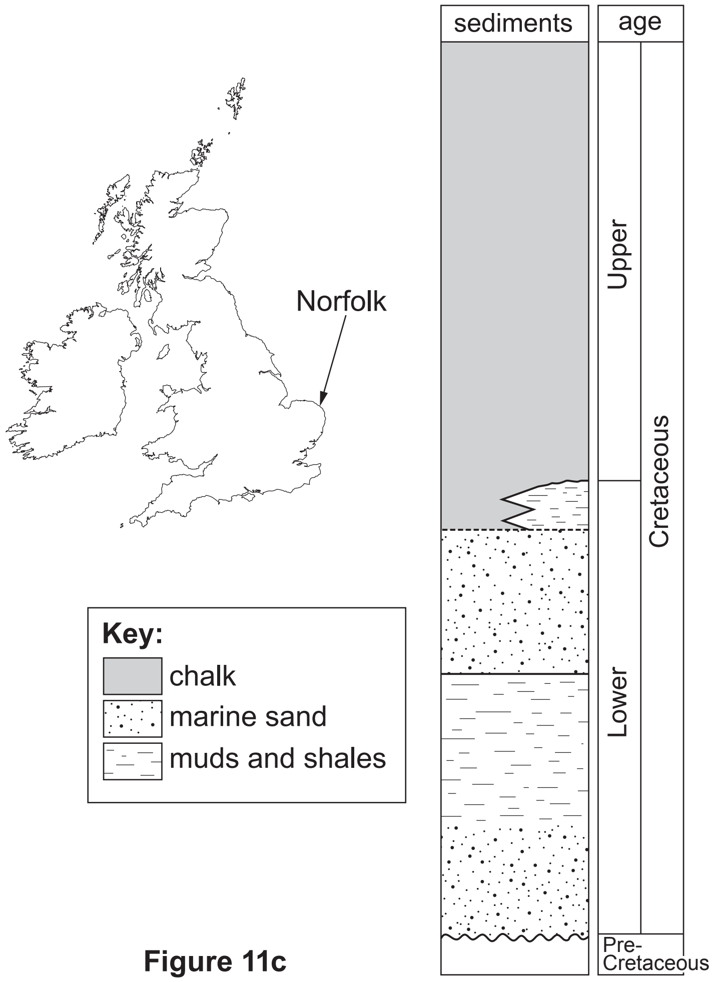

Figure 11c

Refer to **Figures 11b** and **11c**.

(i) Describe the changes in sedimentary rocks in Norfolk, in **Figure 11c**, through the Cretaceous period. [2]

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(ii) *"The Cretaceous sediments in Norfolk represent a deepening of the sea through this time."*
Evaluate this statement with reference to the geological evidence. [3]

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14

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12. Discuss how the geological evidence found in Britain suggests that the Iapetus Ocean closed in the Mid-Palaeozoic. [6 QER]

6

Examiner only

Option 3: Geology of the Lithosphere

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

13. **Figure 13** shows heat flow data for an ocean basin system, together with a cross-section through the oceanic lithosphere showing isotherms.

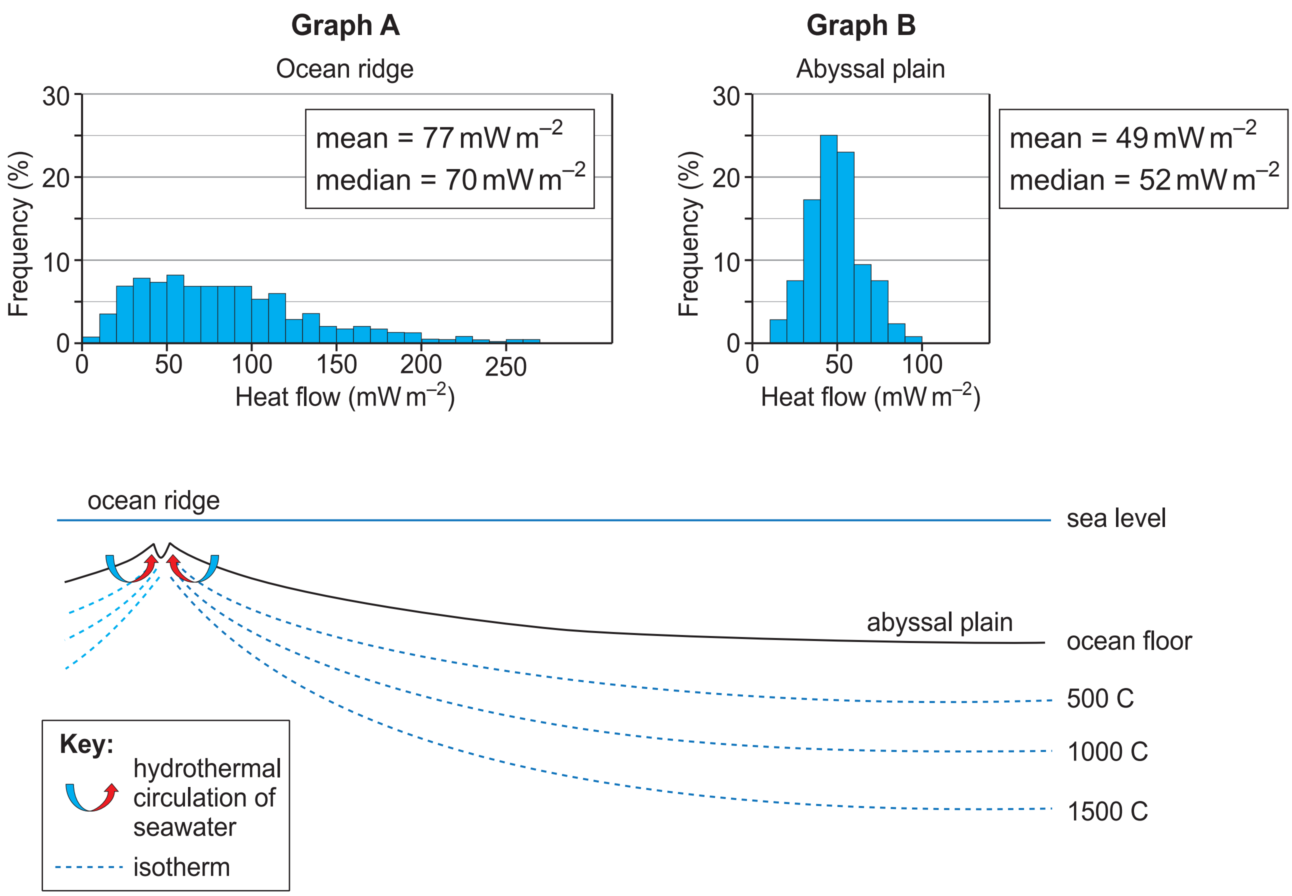

Figure 13

Refer to **Figure 13**.

(a) State which of the graphs (**A** or **B**) shows a **positive** skew.
Give a reason for your choice. [2]

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Examiner only

(b) With reference to the cross-section in **Figure 13**, explain the differences in
- the mean
- the range

of heat flow data shown in graph **A** and graph **B**. [3]

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(c) (i) Draw in the base of the oceanic lithosphere on the cross-section in **Figure 13**. Give a reason for your answer. [2]

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(ii) Explain how the thickness of the oceanic lithosphere is related to its **age**. [3]

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14. **Figure 14a** shows the calculated effect of the supercontinent cycle on sea levels during the last 600Ma. **Figure 14b** is a model of the predicted effect of the supercontinent and break-up stage on global sea level.

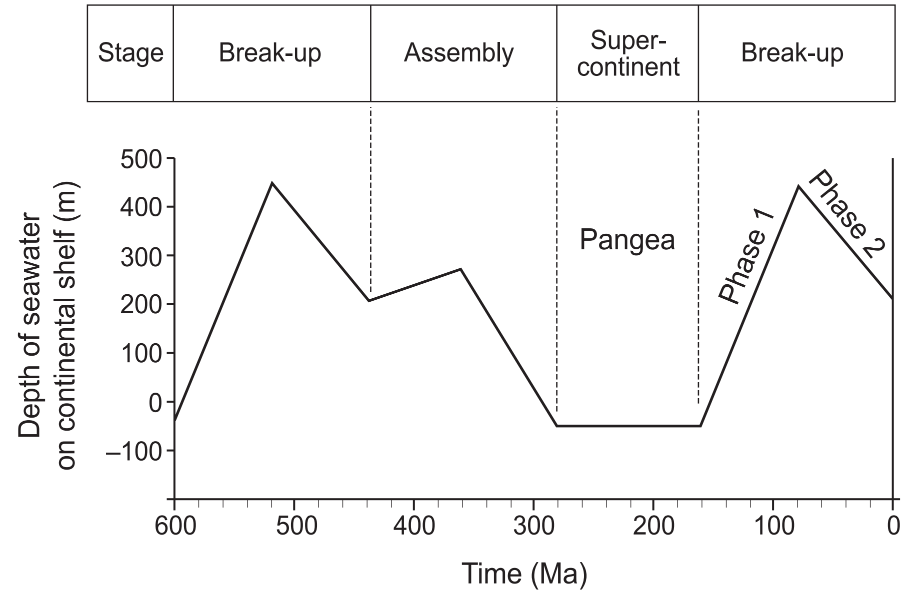

Figure 14a

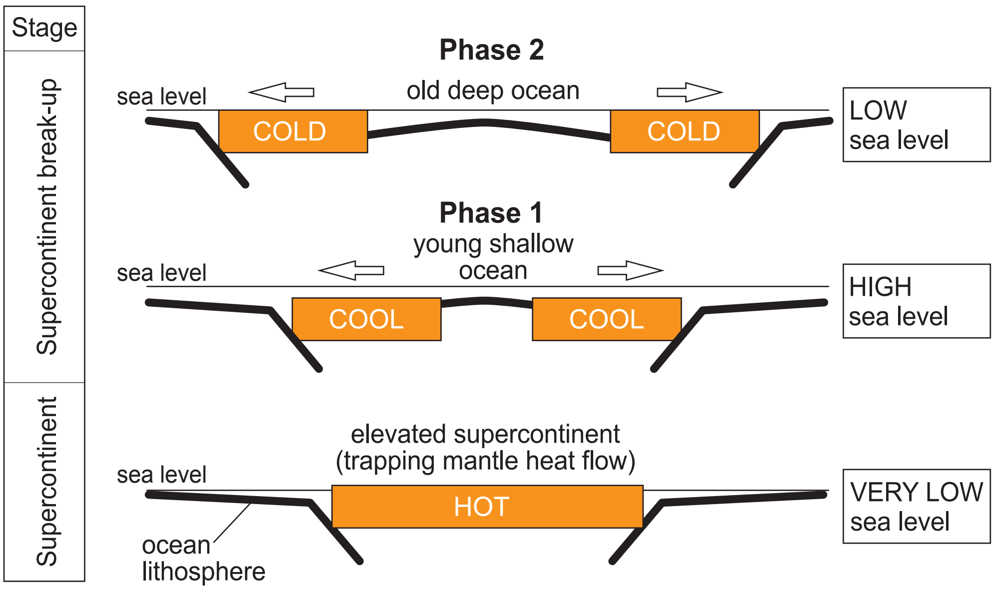

Figure 14b

Refer to **Figure 14a** and **Figure 14b**.

(a) Using the evidence from **Figure 14a**, complete **Table 7** by stating;
- the approximate length of a supercontinent cycle
- the future date at which the next supercontinent is predicted to form. [2]

the approximate length of a supercontinent cycle	• Ma
the future date of the formation of the next supercontinent	• Ma

Table 7

Examiner only

(b) State the stage of the supercontinent cycle in **Figure 14a** during which the following events are likely to be most active. Explain your answer in each case. [3]

1. *Continent-continent collision* ....

Explanation ....

....

2. *Mafic dyke intrusion* ....

Explanation ....

....

(c) (i) Refer to **Figure 14a**. Describe the sea level changes predicted during the **break-up** stage of a supercontinent. [2]

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(ii) With reference to **Figure 14b**, explain how isostasy may account for the sea level changes predicted during the break-up stage of a supercontinent. [3]

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(d) Describe the extent to which **Figure 14b** represents a J. Tuzo Wilson cycle. [4]

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14

Examiner only

15. Explain the extent to which ophiolite complexes provide evidence for the composition and structure of the oceanic crust and upper mantle. [6 QER]

6

END OF PAPER

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

Examiner only

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

Examiner only

Acknowledgements

Figures 1a and **1b:** adapted from: Bryant, E.A. and Haslett, S.K. (2007) Catastrophic Wave Erosion, Bristol Channel, United Kingdom: Impact of Tsunami? *The Journal of Geology*, ***115**, pp. 253–269*

Figure 2: adapted from: L. Campton (2004) Geoengineering along the A465 Heads of the Valleys Road. In: D. Nichol *et al* (eds) Urban Geology in Wales, *National Museums and Galleries of Wales*

Figure 6: adapted from: L. Cotton et al. An overview of the United Downs Deep Geothermal Power (UDDGP) Project. *Geothermal Engineering Limited*

Figure 7a: Source=http://www.uky.edu/OtherOrgs/KPS/poky/pages/pokych10.htm |Date=1922| Author=Charles R. Knight |Permission= |other_versions= }} Category:Charles R. Knight

Figure 7b: adapted from: Allen, J.R.M. *et al.* (2009) Palaeoenvironmental context of the Late-glacial woolly mammoth (Mammuthus primigenius) discoveries at Condover, Shropshire, UK. *Geol. J.* **44**: 414–446

Figures 8a and **8b:** adapted from: Unwin, D.J. (1973) The distribution and orientation of corries in northern Snowdonia, Wales. *Transactions of the Institute of British Geographers* **58**: 85–97

Figure 8c: adapted from Campbell, S. & Bowen, D.Q (1990) The Quaternary of Wales, Geological Conservation Review. *Nature Conservancy Council.*

Figure 10: British Geological Survey

Figure 11b: Skelton, P. (ed) (2006) The Cretaceous World, *Cambridge University Press, Cambridge.*

Figure 11a: Doyle et al (2001) Key to Earth History: An Introduction to Stratigraphy, *J. Wiley & Sons.*

Figure 11c: adapted from: Anderton, R. *et al.* (1979) A Dynamic Stratigraphy of the British Isles, *George Allen & Unwin, London*

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