OCR
Oxford Cambridge and RSA

Accredited

A Level Geology

H414/02 Scientific literacy in geology

Sample Question Paper

Date – Morning/Afternoon

Version 2.2

Time allowed: 2 hours 15 minutes

You must have:
- a protractor
- a ruler (cm/mm)
- a pencil

You may use:
- a scientific or graphical calculator

First name									
Last name									
Centre number						**Candidate number**				

INSTRUCTIONS
- Use black ink. HB pencil may be used for graphs and diagrams.
- Complete the boxes above with your name, centre number and candidate number.
- Answer **all** the questions.
- Where appropriate, your answers should be supported with working. Marks may be given for a correct method even if the answer is incorrect.
- Write your answer to each question in the space provided.
- Additional paper may be used if necessary, but you must clearly show your candidate number, centre number and question number(s).
- Do **not** write in the bar codes.

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

Answer **all** the questions.

1 **Fig. 1.1** shows a length of beach backed by a section of coastal cliffs.

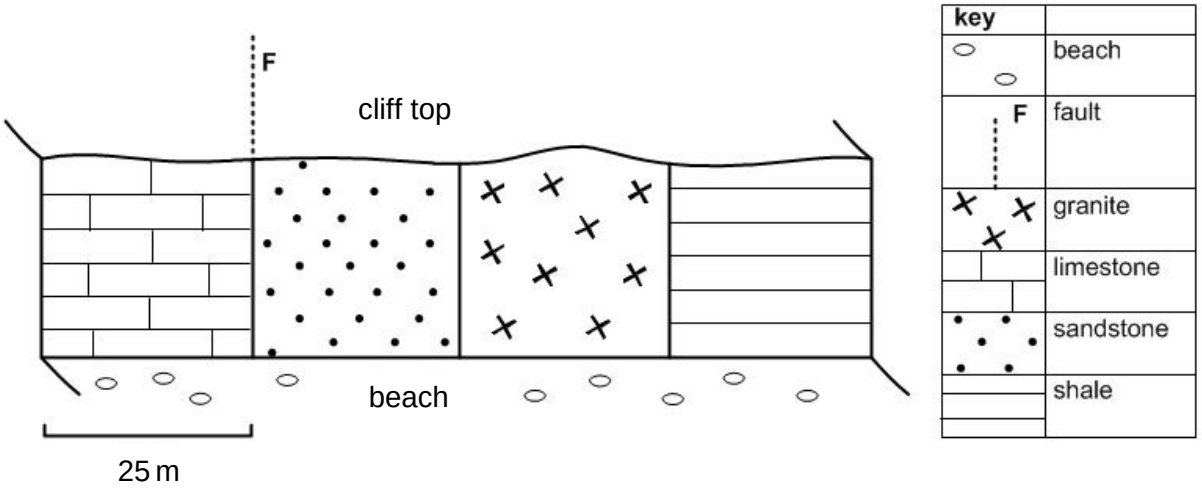

Fig. 1.1

A student collects a random sample of 800 clasts from the beach.

Table 1.1 shows the numbers of each type of clast collected.

Type of clast	Number in sample
limestone	193
sandstone	188
granite	237
shale	182
Total	**800**

Table 1.1

(a) The student decides to use a chi squared test to determine whether there is a significant difference between the numbers of different types of clast.

The student uses the following null hypothesis (H_0):

> There is no significant difference between the number of limestone, sandstone, granite and shale clasts on the beach.

Table 1.2 lists critical values for chi squared at a range of confidence levels.

Degrees of freedom	Probability				
	0.1	**0.05**	**0.01**	**0.005**	**0.001**
1	2.71	3.84	6.64	7.88	10.83
2	4.60	5.99	9.21	10.60	13.82
3	6.25	7.82	11.34	12.84	16.27
4	7.78	9.49	13.28	14.86	18.46
5	9.24	11.07	15.09	16.75	20.52
6	10.64	12.59	16.81	18.55	22.46
7	12.02	14.07	18.48	20.28	24.32
8	13.36	15.51	20.09	21.96	26.12
9	14.68	16.92	21.67	23.59	27.88
10	15.99	18.31	23.21	25.19	29.59

Table 1.2

(i) Calculate chi squared (χ^2). (You may wish to use **Table 1.3** to write figures for steps in your calculation process.)

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

Type of clast	**% of cliff length**	***O***	***E***	***O – E***	$(O-E)^2$	$\frac{(O-E)^2}{E}$
limestone	25	193				
sandstone	25	188				
granite	25	237				
shale	25	182				

Table 1.3

χ^2 = …… **[4]**

(ii) Show whether H_0 is rejected or accepted at a probability value of 0.05.

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……**[2]**

(b) **(i)** The student uses random sampling to collect the clasts. Outline the steps in this technique.

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…….. **[3]**

(ii) Is random sampling the best approach in this environment? Explain your answer.

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……**[1]**

(c) **(i)** Suggest why the proportion of granite clasts in the sample is higher than that of the other types of clast.

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…….. **[3]**

(ii) The sandstone was an orthoquartzite and the size distribution of the clasts was negatively skewed. The smaller clasts were very well rounded and easily broken.

Name the most likely cement in the sandstone.

……**[1]**

(d)* **Fig. 1.2** shows a sketch of a sequence found in a borehole 2 km inland from a low-lying coast.

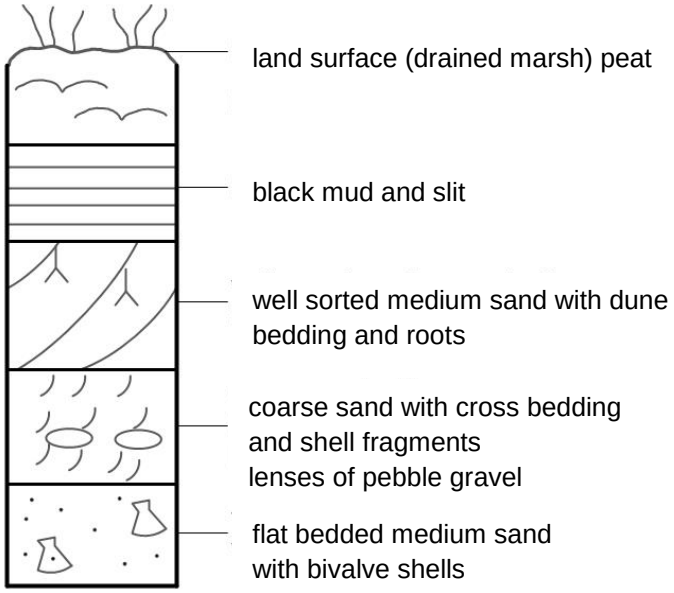

Fig. 1.2

Critically apply Walther's Law to interpret the facies observed in the borehole and draw conclusions about the geology of the area. **[6]**

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Additional answer space if required.

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(e) A geologist investigates the mud size fraction of a sediment sample using a settling tube as shown in **Fig. 1.3**. This is known as the pipette or hydrometer method.

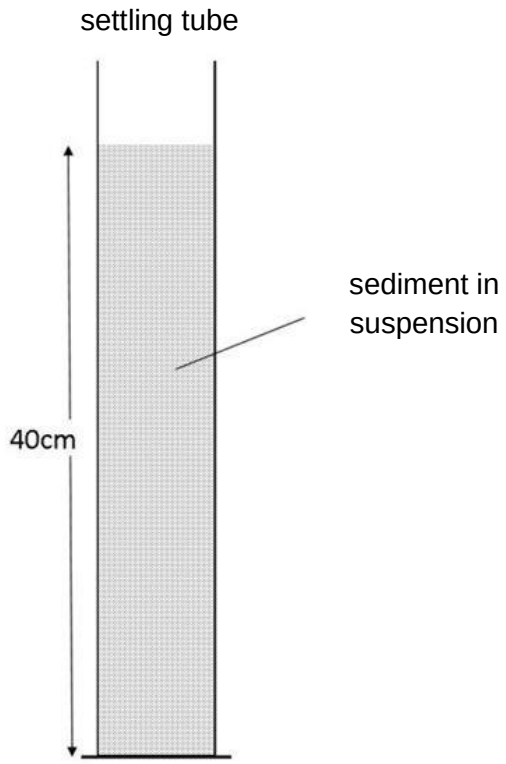


Fig. 1.3

The geologist agitates the sample to produce a fully dispersed homogeneous suspension. After 1 hour, 6 minutes and 40 seconds all the sediment has settled out of the suspension.

Calculate the diameter of the smallest grains present in the sediment sample. Include units in your answer.

Stokes' law: $v = \dfrac{d^2 g\left(\rho_p - \rho_w\right)}{18\eta}$

Density of water = 1000 kg m^{-3}

Density of sediment = 2500 kg m^{-3}

Viscosity of suspension = 0.001 kg m^{-1} s^{-1}

grain size = …… units …… **[3]**

2 **Fig. 2.1** shows part of a volcanic island in the Mediterranean where a geologist is collecting data.

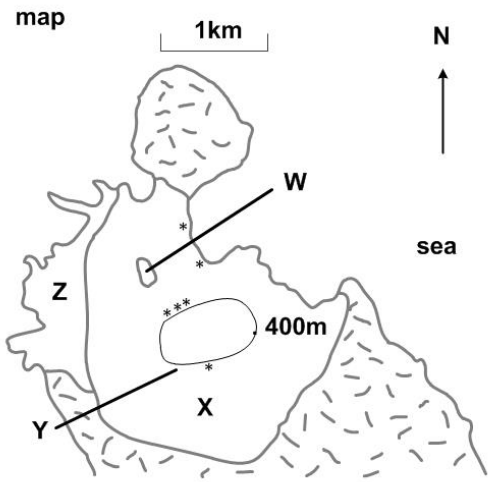
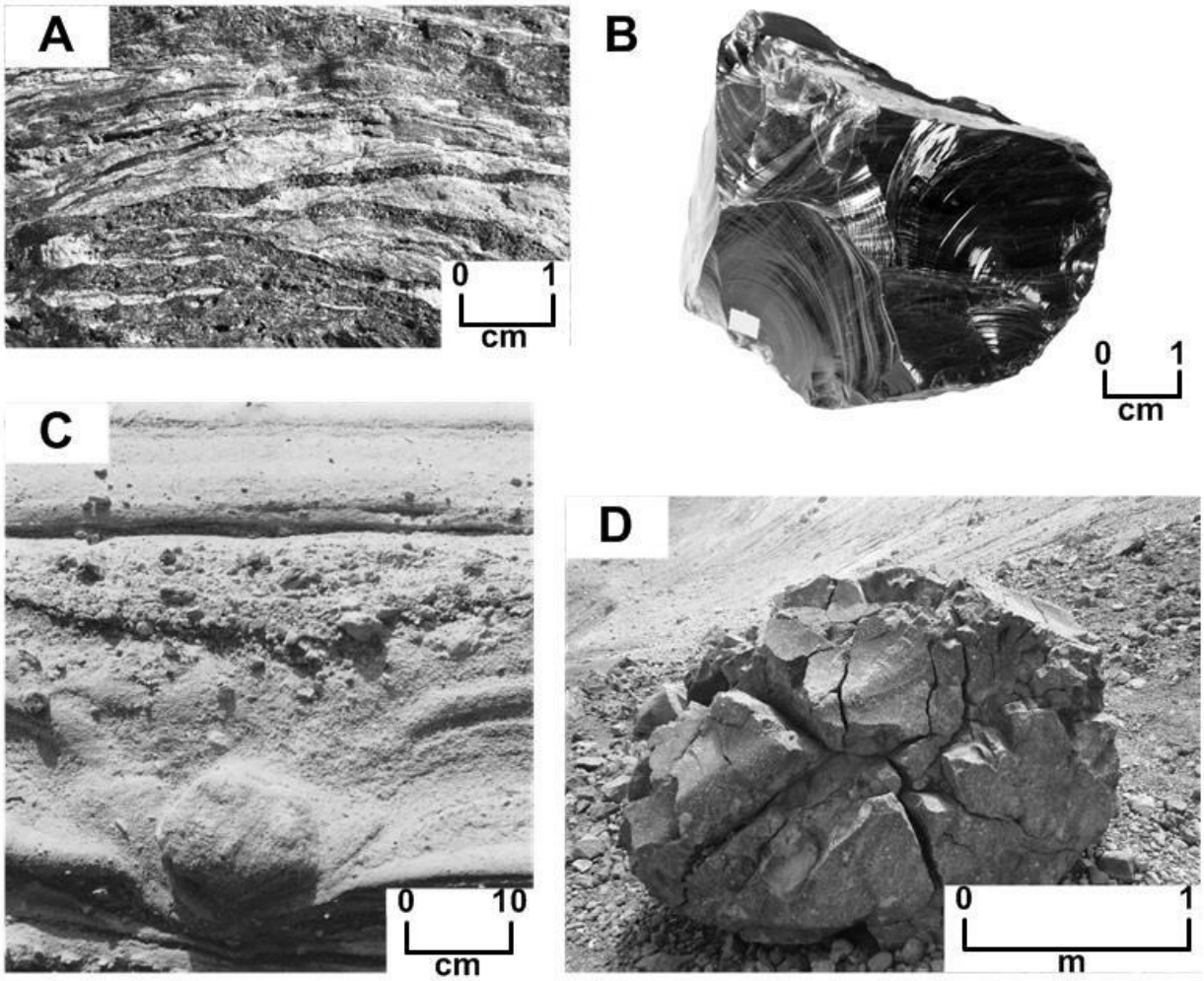


Fig. 2.1

Key	
	andesite
W	**B**
X	……
Y	……
Z	……
* *	fumeroles
400 m	height above sea level

The photographs (**A**, **B**, **C** and **D**) show some volcanic products which the geologist observed on the island.



(a) **(i)** Using **Fig. 2.1** identify the rocks **A**, **B** and **C**, and the object, **D**.

A ……

B ……..

C ……

D ……

[4]

(ii) Complete the key in **Fig. 2.1** by writing the letter from the correct photograph next to the letters **X**, **Y** and **Z**. **[1]**

(iii) Suggest what a geologist can learn from observations of samples **A** and **B** and which field and laboratory observations they should make.

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……... **[3]**

(b) **(i)** Using the data provided draw a fully labelled geological sketch cross-section in the space below to show the type of volcano you would expect to find on this island.

[2]

(ii) Explain how the composition and physical properties of the erupted material control the shape of this type of volcano.

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……**[3]**

(c) Based on the data collected the geologist has to produce a report on the risks from volcanic hazards to residents and visitors.

(i) What technique could the geologist use to synthesise and summarise the data set collected during this investigation to improve disaster planning?

……**[1]**

(ii) Evaluate the data set collected by the geologist and communicate the likely risks from volcanic hazards, for use by tour operators and tourists visiting the island.

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…… **[4]**

3 Records of earthquakes in California have been kept between 1812 and 2015.
Table 3.1 shows all recorded earthquakes of magnitude >7.
The probability of such an earthquake occurring again can be calculated.

Earthquakes of magnitude >7 in California	
Year	**Magnitude**
1812	7.1
1857	7.9
1872	7.6
1873	7.3
1892	7.8
1906	7.8
1922	7.3
1923	7.2
1927	7.1
1940	7.1
1952	7.3
1980	7.2
1991	7.1
1992	7.2
1992	7.3
1994	7.1
1999	7.2
2005	7.2

Table 3.1

(a) Using the information in **Table 3.1**, calculate:

(i) the return period to the nearest year for earthquakes with a magnitude >7 between 1812 and 2015.

return period =……..years **[2]**

(ii) the expected frequency of earthquakes with a magnitude >7. Include units in your answer.

expected frequency =…… units……. **[1]**

(b) **Fig. 3.1** shows the results of an experiment in which stress was applied to a block of granite so that microseisms could be observed. The granite had been saturated with water.

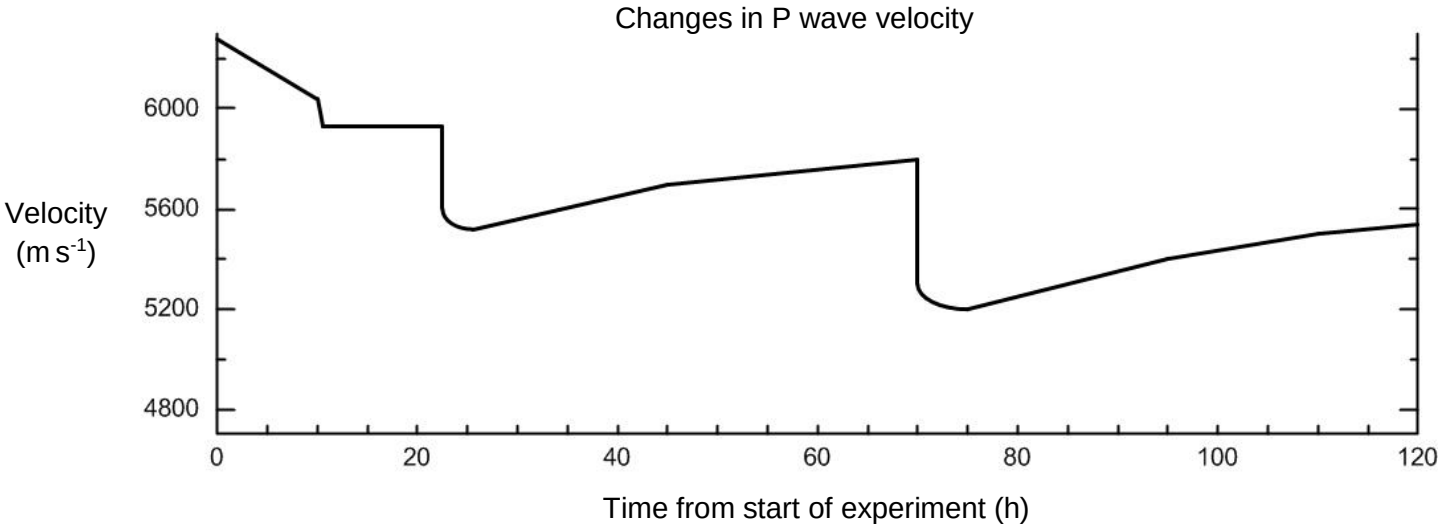

Fig.3.1

(i) Describe the changes in P wave velocity observed during the experiment.

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……**[3]**

(ii) Explain the changes in P wave velocity.

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……**[3]**

(c) **(i)** Describe how changes in P wave velocity can be used to predict earthquakes.

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……**[2]**

(ii) If we could predict earthquakes successfully, this could greatly reduce the impact of earthquakes. For example, at-risk areas can be evacuated and emergency services put on stand-by.

Given this information, a student decides that prediction is more effective than probability forecasting in reducing the impact of earthquakes.

Use your knowledge of geohazard risk analysis to evaluate the student's comment. Decide whether or not you agree with their conclusion.

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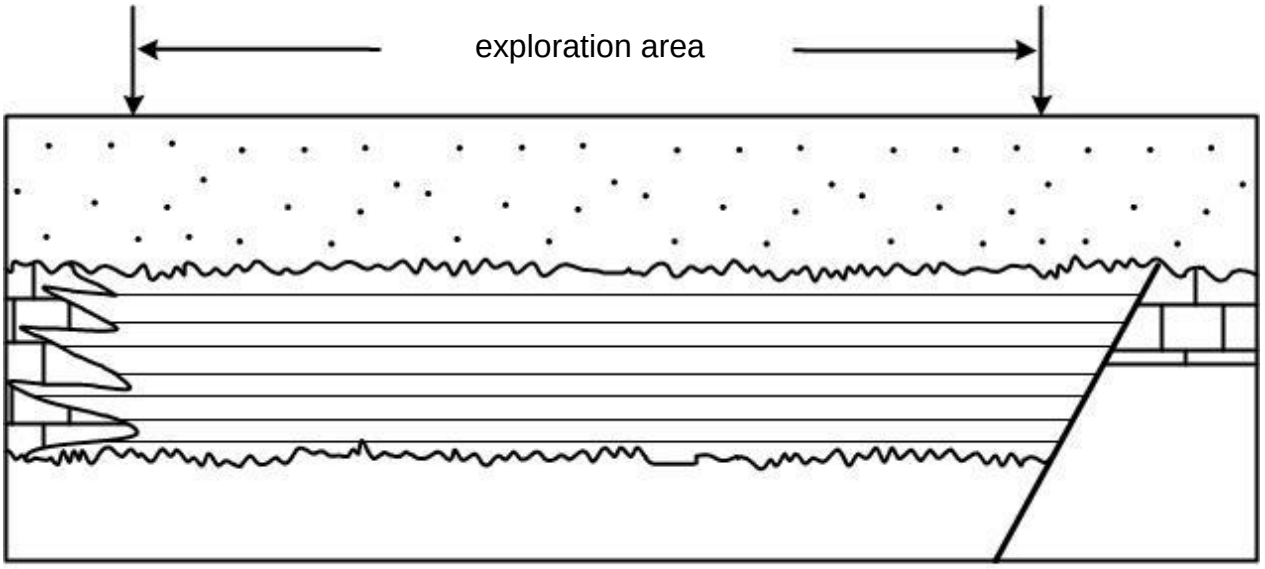
……**[4]**

4 **Fig 4.1** shows an onshore sedimentary basin that is being explored for gas extraction from shale in the UK. The exploration area is circular.



horizontal scale 1 cm: 5 km
vertical scale 1 cm: 1 km

Fig 4.1

(a) **(i)** Calculate the volume of shale in the exploration area to the nearest whole number.

volume = ……. km^3 **[2]**

(ii) The shale contains 2% gas by volume.
Calculate the volume of gas in the reservoir in m^3.

Give your answer in standard form.

volume of gas = ……..m^3 **[2]**

(b) **(i)** Describe **two** differences between North Sea gas reserves and the onshore gas reserve shown in **Fig 4.1**.

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……**[2]**

(ii) What implications do these differences have for development of the onshore gas reserve?

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……**[2]**

(c) **Fig. 4.2** shows the subsurface geology of an area where a seismic survey is being carried out to find offshore oil and gas deposits.

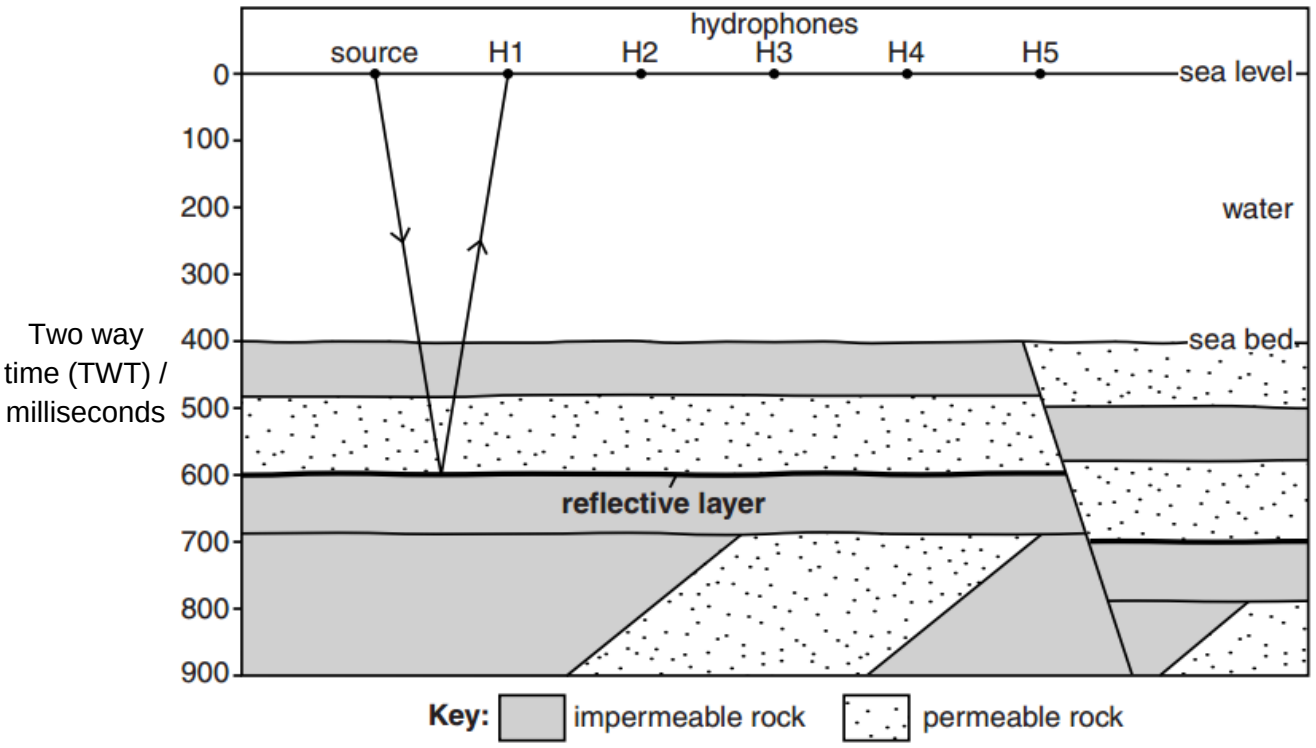

Fig. 4.2

(i) Calculate the total depth to the reflective layer.

Use the following typical seismic velocity values:

water 1500 m s^{-1}

rock 5000 m s^{-1}

total depth to reflective layer = ……. m **[3]**

(ii) Explain why the fault shown in **Fig. 4.2** is not a suitable trap for hydrocarbons.

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……**[1]**

5 **Fig. 5.1** shows sea levels and the number of families of organisms over time.

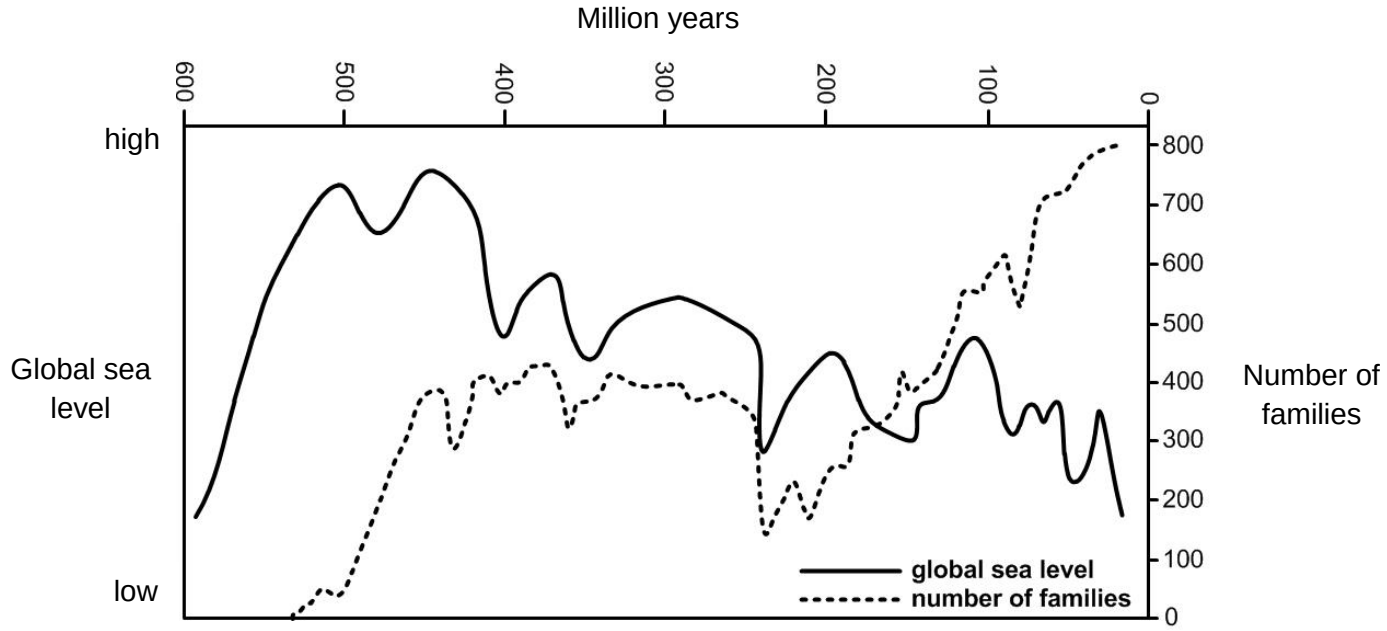

Fig. 5.1

(a) **(i)** A student says that the graph shows a relationship between mass extinctions and changing sea levels.

Do you agree with the student's statement? Use information from the graph to support your answer.

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……**[3]**

(ii) Suggest how a fall in sea level might directly contribute to mass extinction.

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……**[1]**

(b) Geologists think that the Siberian Traps major volcanic event contributed to the mass extinction at the end of the Permian. Both the Earth's atmosphere and hydrosphere were affected by the eruption.

(i) Describe how sulfur dioxide in volcanic emissions can directly affect plant growth on land and in water.

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……**[2]**

(ii) Describe the longer term global effects of major volcanic activity on the atmosphere and hydrosphere.

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……**[2]**

(iii) What evidence is there in the rocks for a major catastrophic event at this time?

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……**[2]**

(c) Isotope studies of fossils can provide information about changes in the Earth's climate.

Table 5.1 shows the concentration of ^{18}O isotope data for three bivalve shells from three consecutive beds.

Bed identification number	**^{18}O / ppm**
1	0.10
2	3.00
3	2.50

Table 5.1

Which bed is likely to have been deposited during the period with lowest sea water temperatures? Explain your answer.

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……..……**[3]**

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

The North African country Morocco is located at a plate boundary. Outcrops range from Precambrian to Cenozoic and from sedimentary basins to fold belts. At present, there is active exploration for oil and gas fields offshore.

In the north, the Rif Range extends along the Mediterranean coast. South of this a domain of plateaux and intermontane basins occurs. Then the NE–SW trending Atlas (early Cenozoic) and Anti-Atlas (Caledonian) fold mountains rise up, providing a northern boundary to the extended and generally low elevation Saharan platform domain. **Fig 6.1** was taken in this domain.

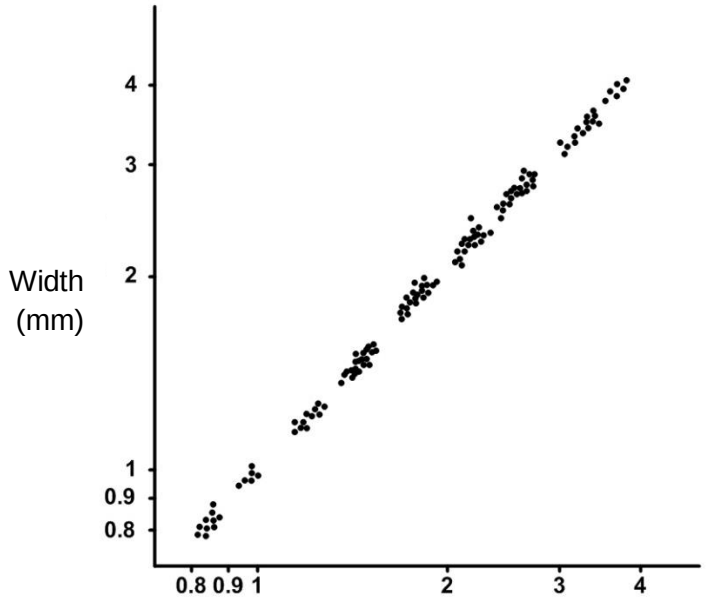
Geophysical data confirm that the elevated topography is related to a hot mantle anomaly. The anomaly is also outlined by the pattern of recent alkaline volcanoes.

The Upper and Lower Fezouata formations in the Saharan platform domain fill an important preservational window between the Cambrian and late Ordovician. In the Fezouata Lagerstätten the fossilized fauna contain numerous forms thought to have become extinct by the mid Cambrian.

Fig.6.1 5 cm

Over 1500 non-mineralised specimens have been recovered together with some shelly fauna. The sediment contains burrows that are between 1 and 3 cm wide, but it is not extensively bioturbated. High biodiversity of echinoids indicates normal salinity. The fossils are often coated with a small amount of pyrite and their preservation is similar in many ways to those found at Chenjiang. Non-mineralised soft appendages are often preserved. **Fig. 6.2** shows the length : width ratios of trilobite cephalons.

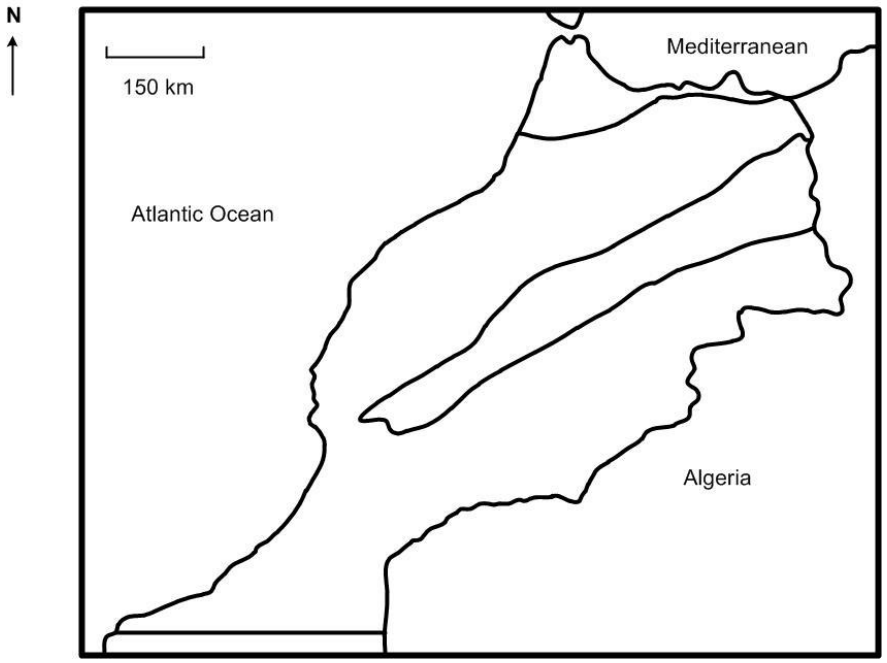
Fig. 6.2



Measurements of the cephalons of trilobite fossils

(a) **(i)** Below is a map of Morocco.

Label the map to show the positions of the **four** tectonic domains described in the text.



[2]

(ii) Using your knowledge of isostasy shade the area under which you would expect to find the hot mantle anomaly. **[1]**

(iii)* Suggest in what type of environment the Fezouata formations were deposited, and evaluate the significance of these formations to geological understanding.

Use evidence from the text to support your answer. **[6]**

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Additional answer space if required.

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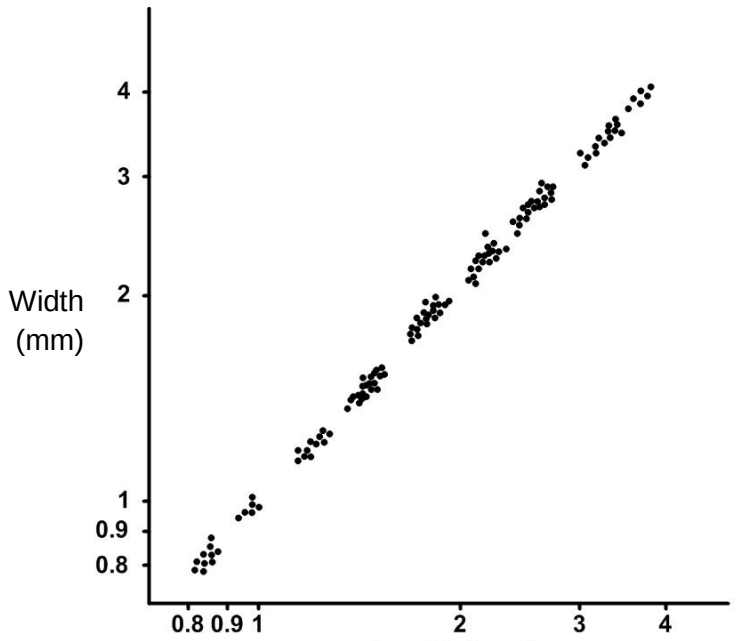
(b) Study **Fig. 6.2** which shows the length : width ratios of trilobite cephalons from a bed in the Upper Fezouata formation.



Measurements of the cephalons of trilobite fossils

Fig. 6.2

Explain the significance of the clusters and gaps in the points plotted on the graph.

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……**[3]**

(c) Identify the Cenezoic sedimentary deposit shown in **Fig. 6.1** and describe its deposition in the Saharan platform domain.

Fig. 6.1

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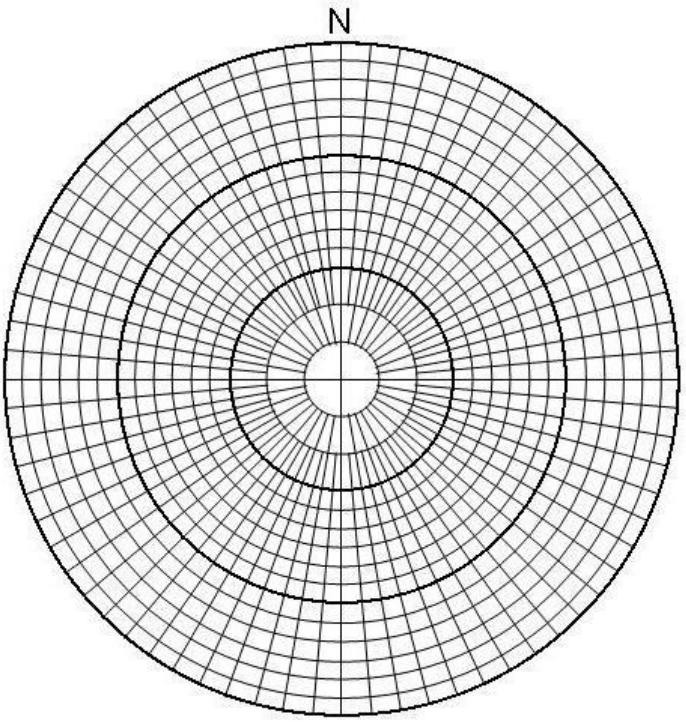
……**[3]**

(d) **Table 6.1** shows measurements of b-axis orientation and up dip angle of imbricated clasts, taken to determine the palaeoflow direction for the sedimentary deposit shown in **Fig. 6.1**.

B-axis orientation	B-axis angle
052°	45°
307°	20°
343°	55°
019°	40°
355°	45°

Table 6.1

(i) Plot the orientation and up-dip angle data on the stereonet.



[3]

(ii) Using the stereonet calculate the median palaeoflow direction.

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END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

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

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Oxford Cambridge and RSA

…day June 20XX – Morning/Afternoon

A Level Geology

H414/02 Scientific literacy in geology

SAMPLE MARK SCHEME

Duration: 2 hours 15 minutes

MAXIMUM MARK **100**

This document consists of 24 pages

MARKING INSTRUCTIONS

PREPARATION FOR MARKING
RM ASSESSOR

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

2. Make sure that you have read and understood the mark scheme and the question paper for this unit.

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

MARKING

1. Mark strictly to the mark scheme.

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

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

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

5. Work crossed out:
   a. where a candidate crosses out an answer and provides an alternative response, the crossed out response is not marked and gains no marks
   b. if a candidate crosses out an answer to a whole question and makes no second attempt, and if the inclusion of the answer does not cause a rubric infringement, the assessor should attempt to mark the crossed out answer and award marks appropriately.

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

7. There is a NR (No Response) option. Award NR (No Response)
   - if there is nothing written at all in the answer space
   - OR if there is a comment which does not in any way relate to the question (e.g. 'can't do', 'don't know')
   - OR if there is a mark (e.g. a dash, a question mark) which isn't an attempt at the question.

   Note: Award 0 marks – for an attempt that earns no credit (including copying out the question).

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

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

10. For answers marked by levels of response:
Read through the whole answer from start to finish, using the Level descriptors to help you decide whether it is a strong or weak answer. The indicative geological content in the Guidance column indicates the expected parameters for candidates' answers, but be prepared to recognise and credit unexpected approaches where they show relevance. Using a 'best-fit' approach based on the skills and geological content evidenced within the answer, first decide which set of level descriptors, Level 1, Level 2 or Level 3, best describes the overall quality of the answer.
Once the level is located, award the higher or lower mark:
The higher mark should be awarded where the level descriptor has been evidenced and all aspects of the communication statement (in italics) have been met.
The lower mark should be awarded where the level descriptor has been evidenced but aspects of the communication statement (in italics) are missing.
In summary:
The skills and geological content determine the level.
The communication statement determines the mark within a level.

Level of response questions on this paper are **1d** and **6a(iii)**

11. **Annotations**

Annotation	Meaning
DO NOT ALLOW	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

12. **Subject-specific Marking Instructions**

INTRODUCTION

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

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

You should ensure that you have copies of these materials.

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

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

The breakdown of Assessment Objectives for GCE Geology:

	Assessment Objective
AO1	**Demonstrate knowledge and understanding of geological ideas, skills and techniques**
AO1.1a	Demonstrate knowledge of geological ideas
AO1.1b	Demonstrate knowledge of geological skills and techniques
AO1.1c	Demonstrate understanding of geological ideas
AO1.1d	Demonstrate understanding of geological skills and techniques
AO2	**Apply knowledge and understanding of geological ideas, skills and techniques**
AO2.1a	Apply knowledge and understanding of geological ideas
AO2.1b	Apply knowledge and understanding of geological skills and techniques
AO3	**Analyse, interpret and evaluate geological information, ideas and evidence to make judgements, draw conclusions, and develop and refine practical design and procedures**
AO3.1a	Analyse geological information, ideas and evidence
AO3.1b	Interpret geological information, ideas and evidence
AO3.1c	Evaluate geological information, ideas and evidence
AO3.1d	Make judgements
AO3.1e	Draw conclusions
AO3.1f	Develop and refine practical design and procedures

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>AO element</th><th>Guidance</th></tr>
<tr><td>1</td><td>(a)</td><td>(i)</td><td>FIRST CHECK THE ANSWER ON ANSWER LINE
If answer = 9.43 award 4 marks

<table>
<tr><th>E</th><th>O – E</th><th>(O – E)^2</th><th>$\frac{(O-E)^2}{E}$</th></tr>
<tr><td>200</td><td>–7</td><td>49</td><td>0.245</td></tr>
<tr><td>200</td><td>–12</td><td>144</td><td>0.720</td></tr>
<tr><td>200</td><td>37</td><td>1369</td><td>6.845</td></tr>
<tr><td>200</td><td>–18</td><td>324</td><td>1.620</td></tr>
</table>

$O - E$ all correct ✓
$(O - E)^2$ all correct ✓
$\frac{(O-E)^2}{E}$ all correct ✓
χ^2 calculated using $\sum \frac{(O-E)^2}{E}$ ✓</td><td>4</td><td>2.1b × 4</td><td>Trailing zeroes for $\frac{(O-E)^2}{E}$ values not required

ECF from incorrect values for $\frac{(O-E)^2}{E}$</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>there are three degrees of freedom for this test / df 4 – 1 = 3 ✓

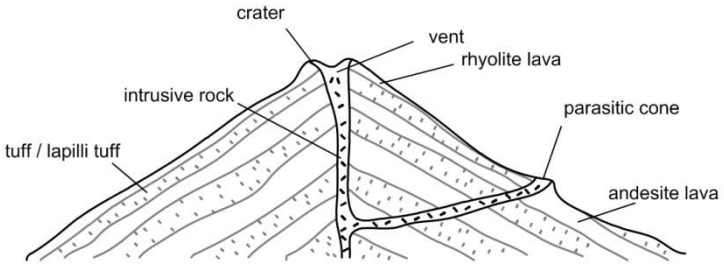
H_0 is rejected because $\chi^2 > 7.82$ ✓</td><td>2</td><td>3.1a

3.1d</td><td>

DO NOT ALLOW responses that merely identify appropriate value from the table</td></tr>
<tr><td></td><td>(b)</td><td>(i)</td><td>draw grid over plan of study area ✓
use random number generator / table to select grid coordinates ✓
collect fixed number of clasts closest to each spot / from within quadrat laid at each spot (AW) ✓</td><td>3</td><td>1.1d × 3</td><td></td></tr>
</table>

Question			Answer	Marks	AO element	Guidance
		(ii)	*No, because* study area is not the same throughout / different nature of cliffs affects study area / stratified sampling would be better (**AW**) ✓	1	3.1f	
	(c)	(i)	(more granite clasts because) granite is formed of interlocking crystals but sandstone is formed from sediment grains held together by cement ✓ interlocking crystals in granite are resistant to mechanical weathering ✓ granite clasts break down more slowly, so more clasts remain / clasts are larger so less likely to be transported from beach (by currents) ✓	3	1.1c × 1 2.1a × 2	
		(ii)	haematite ✓	1	2.1a	
	(d)*		<u>Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question</u>. **Level 3 (5–6 marks)** Clear recognition of situations where Walther's Law applies. Correctly interprets all facies / environments in the section and draws appropriate conclusions. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.*	6	2.1a × 1 3.1b × 3 3.1e × 2	**Indicative points include:** **AO 2.1a Applies knowledge and understanding of Walther's Law** • Walther's Law applies to facies that are superimposed without a break • There are no unconformities in the sequence so Walther's Law can be applied **AO 3.1b Interprets geological information, ideas and evidence** • bottom layer was shallow marine environment /facies • cross bedded layer was beach facies • gravels in cross bedded layer are storm beach

Question			Answer	Marks	AO element	Guidance
			Level 2 (3–4 marks) Sound interpretation of the majority of the layers in the section. Concludes, with reference to Walther's law, that there is a horizontal as well as vertical component involved. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Attempt at interpretation of the section. Walther's Law is mentioned, but not linked to evidence and no conclusion drawn. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*			environment • dune bedded layer with roots was coastal dunes • black mud and silt from marsh (fresh or salt water) • peat shows land environment with woody plants **AO3.1e Draws conclusions** • Walther's Law states that such facies once existed beside one another • the strata in the borehole represent environments that exist side by side now • Walther's Law enables diachronism to be explained • the beach /coast is now 2 km further away so this is a depositional / prograding coast
	(e)		**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 0.011 mm OR 11 μm award 3 marks** Settling velocity of the smallest grain (v) = 0.40 / 4000 = 0.0001 m s^{-1} ✓ $d = \sqrt{\frac{v18\eta}{g(\rho_p - \rho_w)}} = \sqrt{\frac{0.0001 \times 18 \times 0.001}{9.81 \times (2500 - 1000)}}$ ✓ d = 0.011 mm **OR** 11 μm ✓	**3**	**2.1b × 3**	**ALLOW** 1.1 × 10^{-5} m **OR** 6.5 φ
			Total	**23**		

Question			Answer	Marks	AO element	Guidance
2	(a)	(i)	**A** = rhyolite ✓ **B** = obsidian ✓ **C** = tuff / lapilli tuff ✓ **D** = (bread crust) bomb ✓	**4**	**2.1a × 4**	
		(ii)	**X** = **C**; **Y** = **D; Z** = **A** all boxes in key correctly completed ✓	**1**	**2.1a**	
		(iii)	crystal grain size – to determine cooling rate ✓ minerals in rock / mineralogy – to determine type of rock ✓ variations in texture – to determine cooling history / behavior of the molten rock ✓	**3**	**1.1a × 1** **2.1b × 2**	type of observation **MUST** be linked to what can be learned
	(b)	**(i)**	 cross section showing layered structure ✓ any three features labelled ✓	**2**	**2.1a** **1.1a**	

Question			Answer	Marks	AO element	Guidance
		(ii)	***Any three from*** • viscosity of the magma is high / silica content is high / rhyolite and andesite are high viscosity and this produces conical shape • rate of extrusion is slow / lavas move slowly and this means that angle of sides is steep / about 30° gradient • gas content is high / high viscosity prevents gas from escaping / explosive eruptions occur which cause damage to cone • pyroclastics can be unstable / slope failure produces irregular shape • during interval between eruptions may be caldera collapse / large depression / entire cone may collapse ✓✓✓	**3**	**1.1a × 3**	
	(c)	**(i)**	GIS / Geographical Information System	**1**	**1.1b × 1**	
		(ii)	**Evaluation** fumerole gases present a moderate risk ✓ ***Any one from*** • very low risk – high viscous lava is slow flowing and is only a hazard to fixed infrastructure • very low risk – viscous magma in the conduit traps gases/gas pressure becomes sufficient to explode solidified material/crust/older rocks in the crater • low risk – ash clouds and solid fragments ejected over time • very low risk / very low frequency – possible caldera collapse inferred from structure of volcano and likely	**4**	**3.1c × 2**	

Question			Answer	Marks	AO element	Guidance
			composition of magma (based on partial data set) ✓ **Judgement & communication** this is a safe island to visit ✓ • the day to day risk is from volcanic gas vents / do not walk through the gas vents **OR** • there is an infrequent low risk from falling debris during an eruption. ✓		**3.1d × 2**	Judgement **must** be supported by evaluative statements using technical vocabulary. **Must** be written in appropriate language for non-geologists Second judgement mark is for exception to safety of island at specific places (fumeroles) / under exceptional circumstances.
			Total	**18**		

Question			Answer	Marks	AO element	Guidance
3	(a)	(i)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 11 (years) award 2 marks** $\frac{n+1}{m}$ where *n* is number of years on record and *m* is number of recorded occurrences ✓ return period is 204 + 1 / 18 = (11.39) 11 to nearest year ✓	**2**	**1.1b × 2**	**ALLOW** mark for correct method even if formula not stated
		(ii)	expected frequency is 1/11 = 0.091 year^{-1} ✓	**1**	**2.1b**	mark for value **AND** unit
	(b)	**(i)**	initial velocity approx. 6300 m s^{-1} fallen to 5200 m s^{-1} at 75 h final velocity / at 120 h about 5500 m s^{-1} ✓ velocity declines abruptly at 23 h and 70 h ✓ after each decline the velocity increases slowly / velocity increases at a slower rate than it declines ✓	**3**	**2.1b × 3**	**ALLOW** correct quantified description from the graph
		(ii)	***Any three from*** • velocity of P waves depends on density of the medium • microcracks produced under stress are filled with gases/vapour which reduces P wave velocity • water percolates into microcracks and P wave velocity increases • initial velocity is not regained because the granite contains microcracks ✓✓✓	**3**	**2.1a × 3**	
	(c)	**(i)**	microseismic events occur before main earthquake / P waves can be detected before earthquakes occur ✓ P wave velocities decrease and then increase again before the main	**2**	**1.1c × 2**	

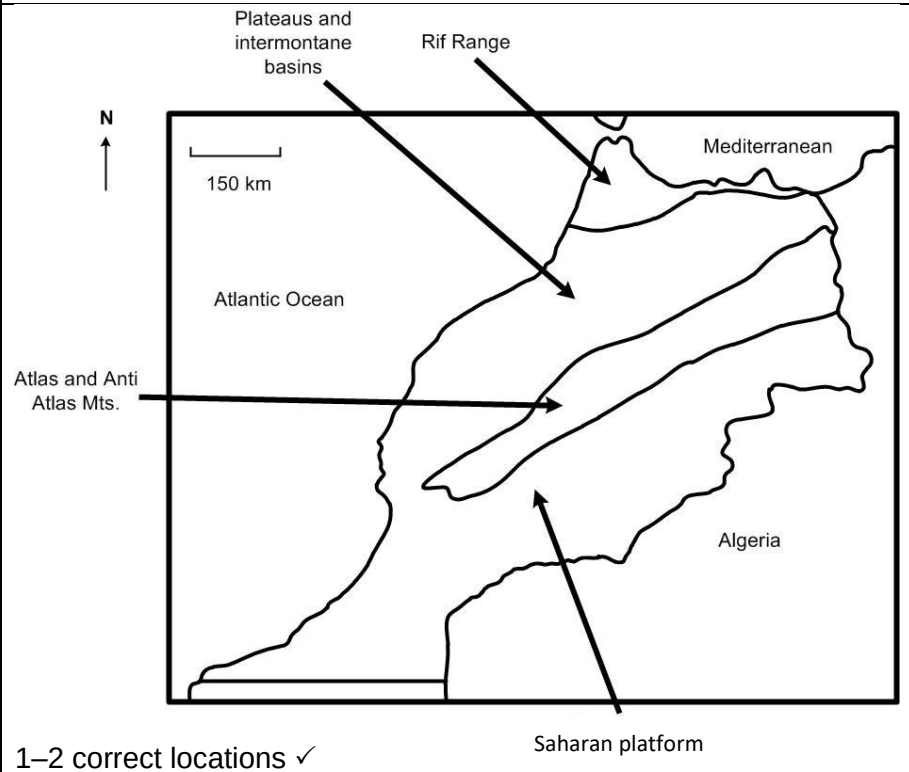
Question			Answer	Marks	AO element	Guidance
			earthquake ✓			
		(ii)	prediction is difficult / imprecise **OR** prediction only gives short notice ✓ forecasting provides basis for preparedness ✓ data used for forecasting may not be accurate **OR** past data do not guarantee future patterns of events ✓ reasoned judgement based on discussion ✓	**4**	**3.1c × 3** **3.1d**	**ALLOW** reference to negative effect of false predictions, e.g. damage to economy, public confidence **ALLOW** reference to specific preparations, e.g. earthquake-proof buildings **ALLOW** agree, disagree **OR** 'both required' as long as based on sound reasoning
			Total	**15**		

Question			Answer	Marks	AO element	Guidance
4	(a)	(i)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 7069 (km^3) award 2 marks** area = $\pi r^2 = \pi \times (30 \times 30) = 2827.43\ km^2$ ✓ thickness of shale reservoir beneath survey area is 2.5 km volume = area × 2.5 = 7069 (km^3) ✓	2	1.1d × 2	**ALLOW** thickness 2.5 km +/– 0.2 km
		(ii)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 1.41×10^{11} (m^3) award 2 marks** volume of gas = $\frac{7069}{100} \times 2 = 141\ km^3$ ✓ conversion of unit: $141 \times 10^9 = 1.41 \times 10^{11}$ (m^3) ✓	2	2.1b × 2	**ECF** based on calculation in **(a) (i)**
	(b)	(i)	***Any two from*** North Sea reservoirs composed of porous / permeable rocks / sandstone / limestone **BUT** reservoir in this basin is impermeable shale / shale normally the cap rock ✓ in North Sea accumulations the source rock is different from the reservoir rock **BUT** in this basin source rock is also the reservoir rock ✓ in North Sea setting gas often migrates to the top of a structure / anticlinal/salt dome/fault/stratigraphic trap **BUT** in this basin the reservoir does not have any structural highs ✓ North Sea reservoirs are normally found around the edge of	2	2.1a × 2	1 mark for each statement about North Sea **AND** corresponding difference **ALLOW** 1 mark for any 2 points that are not contrasting pairs

Question			Answer	Marks	AO element	Guidance
			a basin **BUT** this reservoir is in the middle of the basin ✓			
		(ii)	(unlike the North Sea) the onshore gas reserve could not be developed using the traditional recovery methods ✓ the onshore gas reserve could only be developed using novel extraction techniques such as directional drilling and fracking / hydro fracturing / foam fracturing ✓	**2**	**3.1b × 1** **3.1d × 1**	 **ALLOW AW** but must include ideas of horizontal drilling **AND** fracturing the shale to release the gas
	(c)	**(i)**	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 800 (m) award 3 marks** two-way times from diagram: through water = 400 ms through rock = 200 ms ✓ correct use of distance = velocity × time ✓ depth of water = 1500 × (400 / 1000) / 2 = 300 m depth of rock = 5000 × (200 / 1000) / 2 = 500 m total depth = 800 (m) ✓	**3**	**2.1b ×3**	 May be inferred from working **ALLOW ECF** from MP1
		(ii)	layers of permeable rock (either side of fault) are in contact / hydrocarbon could escape through permeable rock ✓	**1**	**2.1a**	
			Total	**12**		

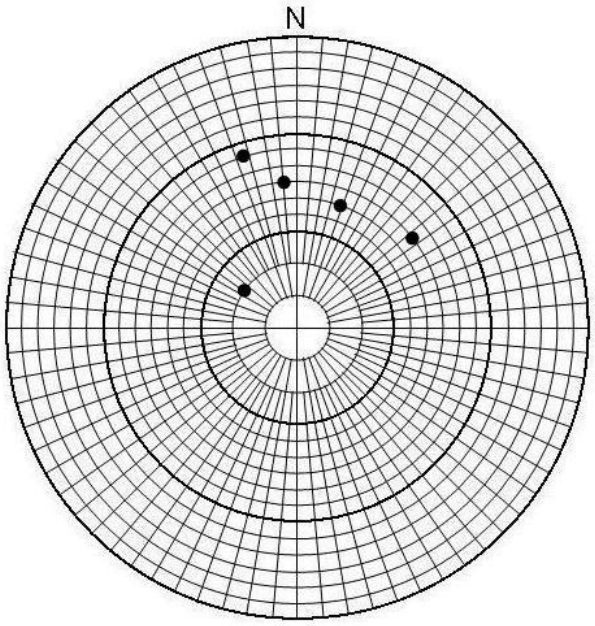
Question			Answer	Marks	AO element	Guidance
	(a)	(i)	2 **OR** 3 mass extinctions on graph preceded by / coincide with (sharp) fall in sea levels ✓ other mass extinctions no clear relationship with big change in sea levels (e.g. at 440 Ma) **OR** other big changes in sea level no relationship to mass extinction (e.g. at 480 Ma) ✓ relationship may exist, but other factors also contribute / mass extinctions sometimes related to sea level falls and sometimes other factors (**AW**) ✓	**3**	**3.1a ×2** **3.1e**	At 250 Ma and ~80 Ma and (possibly) 360 Ma **ALLOW** other reasonable conclusion <u>only if</u> related to balanced analysis
		(ii)	loss of shallow sea habitat leading to lower diversity ✓	**1**	**2.1a**	**ALLOW** fall of sea level related to glaciation, therefore lower temperatures / habitat destruction
	(b)	(i)	sulfur dioxide molecules block sunlight / absorb solar radiation casing global fall in temperatures ✓ sulfur dioxide dissolves in atmospheric water / rain and lead to acid rain / lakes and seas acidified ✓	**2**	**1.1a × 2**	
		(ii)	***Any two from*** • CO_2 from eruptions led to greenhouse effect / global warming in longer term / oceans warmed by 4 to 5 °C ✓ • oceans warmed enough to release methane hydrates from sea floor sediments / release of methane hydrates would increase global temperatures by a further 5 °C ✓ • burning coal deposits / release of methane would produce a decrease in the $^{13}C/^{12}C$ isotope ratio ✓	**2**	**1.1a × 2**	

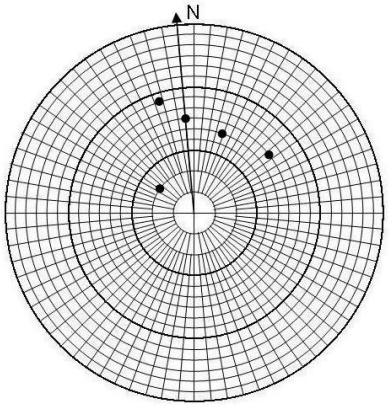
Question			Answer	Marks	AO element	Guidance
		(iii)	***Any two from*** • an increase in ^{12}C in carbonate rocks from the end of the Permian / decrease of about 1% in the $^{13}C/^{12}C$ isotope ratio ✓ • sea floor sediments from the late Permian / early Triassic contain pyrite / evidence of green sulfur bacteria which require both sunlight and hydrogen sulfide / anoxic conditions to survive ✓ • any named example of an extinction visible in fossil record e.g. trilobites, rugose, tabulate corals ✓	**2**	**1.1a × 2**	
	(c)		**Bed 2** because bivalve contains largest concentration of ^{18}O ✓ in colder temperatures more ^{16}O trapped in ice / more ^{18}O present in sea water ✓ therefore more ^{18}O incorporated into bivalve shells / contained in $CaCO_3$ ✓	**3**	**3.1a** **2.1a × 2**	**DO NOT ALLOW** just '**Bed 2**', justification required
			Total	**13**		

Question			Answer	Marks	AO element	Guidance
6	(a)	(i)	 1–2 correct locations ✓ 3–4 correct locations ✓	2	3.1a × 2	
		(ii)	shaded area corresponds with Atlas / Anti-Atlas Mountains ✓	1	1.1c	**ECF** from part **(a) (i)**

Question	Answer	Marks	AO element	Guidance
(iii)*	Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question. **Level 3 (5–6 marks)** Provides evidence, based on analysis of information from the text and the course, and makes environmental interpretation and detailed evaluation of the value of the Fezouata Lagerstätten. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** **EITHER** Detailed environmental interpretation **OR** detailed evaluation of significance, in either case using evidence from the text **OR** Limited environmental interpretation **AND** limited evaluation of significance with some evidence from the text. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Some relevant information lifted from the article, with an attempt at environmental interpretation **OR** evaluation of significance. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*	**6**	**3.1a × 1** **3.1b × 2** **3.1c × 3**	**Indicative points include:** **AO 3.1a Analyses information from the article for evidence** • Fezouata Formation (Fm) is part of a sedimentary basin • has some similarities with Chenjiang and with the Burgess Shale • soft parts that are normally destroyed by mineralisation / petrifaction are preserved **AO 3.1b Interprets evidence for environmental interpretation and nature of the Fezouata Fm** • marine with normal salinity water • lack of burrowing suggests environment unsuitable for benthonic fauna • small burrows may suggest benthonic infauna stunted • presence of pyrite suggests sea floor conditions may have been anoxic **AO 3.1c Evaluates the significance of Fezouata Fm** • Lagerstätten relatively uncommon in Ordovician • both Chenjiang and Burgess shales are from an earlier period than Fezouata Fm • extends range of some Cambrian faunas • there are no other deposits of this type from this period • Lagerstätten have produced landmark

Question			Answer	Marks	AO element	Guidance
						discoveries (e.g. *Archaeopteryx*) • study of soft parts may reveal unknown features.
	(b)		clusters show periods of growth / growth series of the trilobite / cephalon ✓ gaps are where there were no cephalons of those dimensions ✓ due to ecdysis / moulting exoskeletons of cephalon soft following moulting / ecdysis so not preserved ✓	**3**	**3.1b × 2** **2.1a**	
	(c)		(wadi) conglomerate ✓ ***Any two from*** rapid deposition / flow that dried up / occasional flow / ephemeral / flash flood ✓ sub rounded grains transported on several occasions ✓ angular grains briefly transported ✓	**3**	**2.1a** **1.1c × 2**	**ALLOW** sediment deposited at foot of mountains / form alluvial fans for one of the marks **IGNORE** references to red colour due to iron oxide references to box canyon / steep-sided channel

Question			Answer	Marks	AO element	Guidance
	(d)	(i)	 5 points accurate ✓✓✓ 3–4 points accurate ✓✓ all orientations **OR** up-dip angles plotted correctly ✓	**3**	**2.1b × 3**	**ALLOW** ±half a division on stereonet **DO NOT ALLOW** kite plots / rose diagrams / circular bar graph

Question			Answer	Marks	AO element	Guidance
		(ii)	 355° paleoflow ✓	1	2.1b	**DO NOT ALLOW** 307° for palaeoflow
			Total	19		

Summary of updates

Date	Version	Change
January 2019	2.1	Minor accessibility changes to the paper: i) Additional answer lines linked to Level of Response questions ii) One addition to the rubric clarifying the general rule that working should be shown for any calculation questions
February 2022	2.2	Updated copyright acknowledgements in SAM.