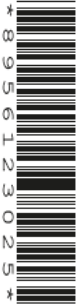


## Tuesday 5 October 2021 – Afternoon

### A Level Geology

#### H414/01 Fundamentals of geology

Time allowed: 2 hours 15 minutes



**You can use:**

- a ruler (cm/mm)
- an HB pencil
- a scientific or graph calculator
- A4 plain paper
- a protractor



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

Centre number

|  |  |  |  |  |
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|  |  |  |  |  |
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Candidate number

|  |  |  |  |
|--|--|--|--|
|  |  |  |  |
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First name(s)

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Last name

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### INSTRUCTIONS

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

### INFORMATION

- The total mark for this paper is **110**.
- The marks for each question are shown in brackets [ ].
- Quality of extended response will be assessed in questions marked with an asterisk (\*).
- This document has **36** pages.

### ADVICE

- Read each question carefully before you start your answer.

## SECTION A

You should spend a maximum of 35 minutes on this section.

Write your answer to each question in the box provided.

Answer **all** the questions.

- 1 Minerals are defined as naturally occurring elements and inorganic compounds whose composition can be expressed as a chemical formula.

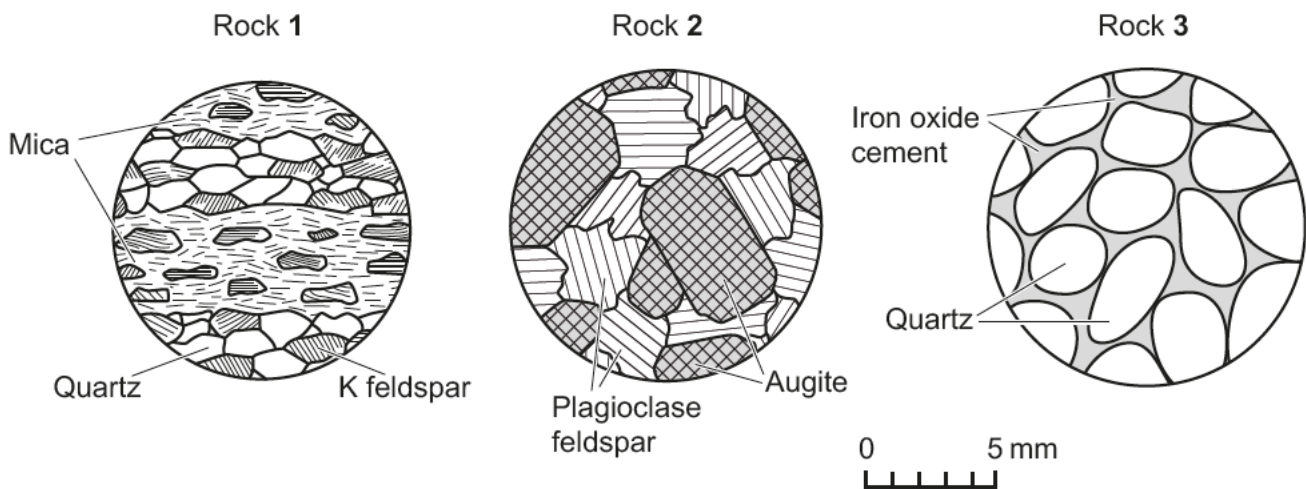
Which of the following does **not** fit this definition?

- A Arkose
- B Galena
- C Halite
- D Native sulfur

Your answer

[1]

- 2 The thin-section diagrams below show rocks from the three rock classes.



Which combinations correctly identify the rock classes for these rocks?

|   | Rock 1      | Rock 2      | Rock 3      |
|---|-------------|-------------|-------------|
| A | Sedimentary | Igneous     | Metamorphic |
| B | Igneous     | Metamorphic | Sedimentary |
| C | Metamorphic | Igneous     | Sedimentary |
| D | Sedimentary | Metamorphic | Igneous     |

Your answer

[1]

- 3 A rock was formed at 350 °C and 500 MPa.

Which is the most likely classification for this rock?

- A Igneous
- B Low grade metamorphic
- C Medium grade metamorphic
- D Sedimentary

Your answer

[1]

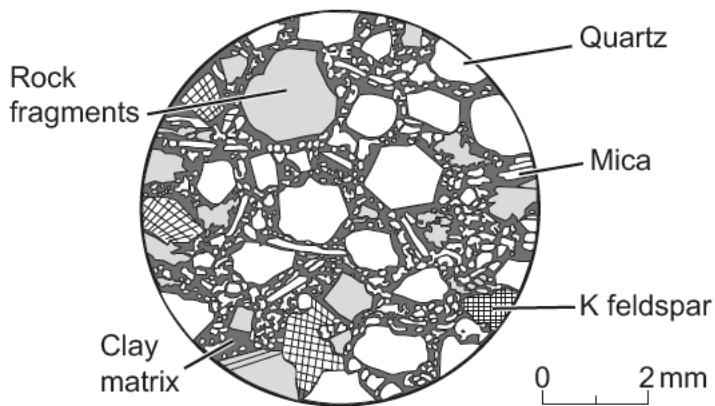
- 4 With increasing erosion, sediment usually becomes texturally **and** mineralogically more mature. Which sediment sample does **not** fit this trend?

|          | <b>Grain shape</b> | <b>Feldspar content (%)</b> | <b>Quartz content (%)</b> | <b>Mica content (%)</b> |
|----------|--------------------|-----------------------------|---------------------------|-------------------------|
| <b>A</b> | Very angular       | 50                          | 30                        | 20                      |
| <b>B</b> | Angular            | 45                          | 40                        | 15                      |
| <b>C</b> | Sub-angular        | 45                          | 35                        | 20                      |
| <b>D</b> | Sub-rounded        | 40                          | 60                        | 0                       |

Your answer

[1]

- 5 The diagram is a thin-section of a dark-coloured rock.



Which rock type is shown in the thin-section diagram?

- A Arkose
- B Greywacke
- C Orthoquartzite
- D Wackestone

Your answer

[1]

- 6 Iridium is a very scarce metal in the Earth's crust with an average crustal abundance of 0.001 ppm. This can be explained partly by reference to Goldschmidt's classification of elements.

Which statement does **not** provide evidence for iridium being classified as a siderophile element?

- A Density =  $22\,560\text{ kg m}^{-3}$
- B Tends to bond with iron
- C Melting point =  $2446^\circ\text{C}$
- D Tends to bond with sulfur

Your answer

[1]

- 7 The Earth has geochemically distinct layers possibly explained by partitioning of elements according to Goldschmidt's groups.

What provides evidence for the composition of the core?

- A Kimberlite pipes
- B Mantle xenoliths
- C The density of the Earth
- D The S-wave shadow zone

Your answer

[1]

- 8 The geomagnetic field is thought to be generated by a self-exciting dynamo operating in the outer core.

Which statement provides evidence for this mechanism rather than permanent magnetism?

- A The magnetic field is geocentric – it appears to originate at the Earth's centre
- B The magnetic field is axial – aligned with the spin axis of the Earth
- C The magnetic inclination is vertical at the Earth's magnetic poles
- D The Earth's magnetic field is bipolar – it has a North and a South pole

Your answer

[1]

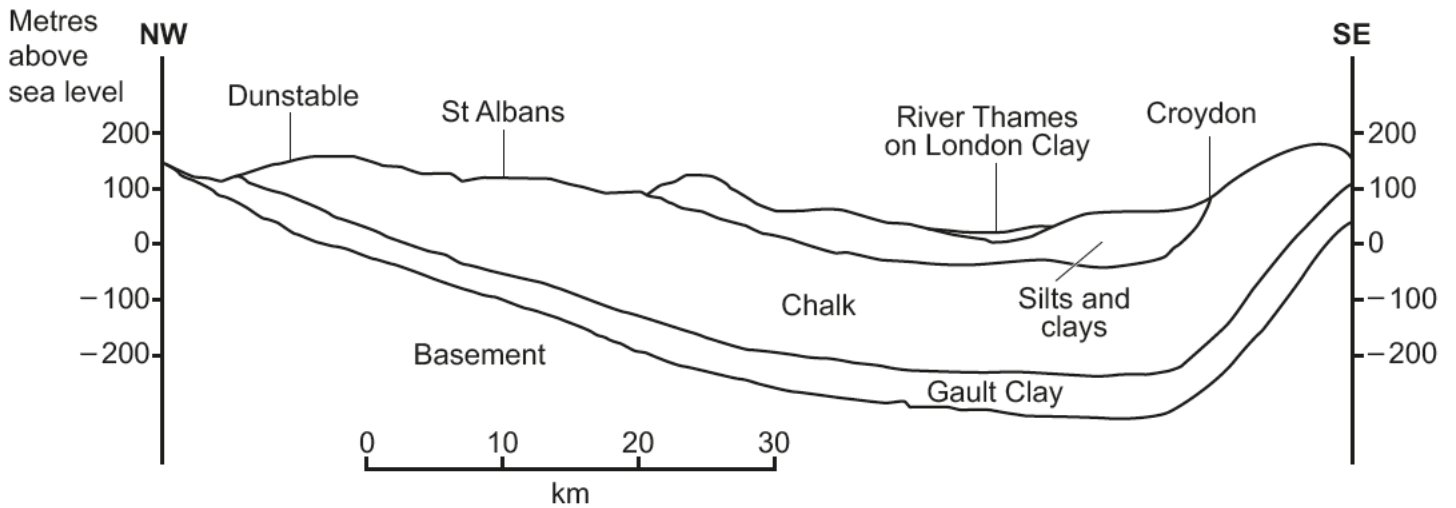
- 9 The deposition of banded iron-formations (BIFs) in the Palaeoproterozoic Era provides evidence for which change during Earth history?

- A The breakup of Pangaea
- B The Great Oxidation Event
- C The Vail sea level curves
- D The Wilson cycle

Your answer

[1]

The diagram shows a cross-section through the London Basin.



Use the cross-section diagram to answer questions 10 and 11.

10 Use your knowledge of the permeability of rocks to decide which combination is correct.

|   | Chalk     | Gault Clay | Silts and clays |
|---|-----------|------------|-----------------|
| A | Aquifer   | Aquiclude  | Aquitard        |
| B | Aquiclude | Aquifer    | Aquitard        |
| C | Aquitard  | Aquifer    | Aquiclude       |
| D | Aquifer   | Aquitard   | Aquiclude       |

Your answer

[1]

11 What would the height of the piezometric surface be if the confined aquifer shown on the cross-section above was filled at the recharge zones to maximum capacity?

- A +180 m
- B +100 m
- C +35 m
- D -10 m

Your answer

[1]

- 12 Long-term changes in sea level have been identified which can be grouped by the frequency at which the oscillations occur.

What has been linked to first order cycles with a period of hundreds of millions of years?

- A Formation and break-up of major continents
- B Major episodes of volcanism
- C Astronomical cycles
- D Major asteroid impacts

Your answer

[1]

- 13 The mean mass of a selection of pebbles from a beach was calculated to be 344 g with a standard deviation of  $\pm 56.8$ .

What can be deduced from the standard deviation?

- A The difference between the upper and lower quartiles of the data.
- B A measure of how symmetrical the data is about the mean.
- C A measure of the spread of the data about the mean.
- D The degree to which the data shows a normal distribution.

Your answer

[1]

- 14 Which statement applies to the **deterministic** prediction of earthquakes?

- A It only gives the probability of an earthquake occurring within a given time period.
- B It takes the full range of possible earthquake magnitudes into account.
- C It calculates the ground motion close to a fault at a given site.
- D It has been criticised for lacking a physical and mathematical basis.

Your answer

[1]

- 15 It is estimated that there are 8.7 million species, excluding bacteria, living on Earth. Extinction rates are currently between 1000 and 50 000 species per year. A major extinction event is defined as the loss of at least 75% of species within a geologically short period.

What is the **maximum** time before the present day extinction becomes a mass extinction on the scale of the P-T and K-Pg events?

- A 130 years
- B 174 years
- C 6525 years
- D 8700 years

Your answer

[1]

- 16 Which value best represents the lithostatic pressure in a tunnel 150 m below the surface? All the rock above is orthoquartzite.

You may assume  $g = 10 \text{ m s}^{-2}$ , the density of quartz is  $2650 \text{ kg m}^{-3}$  and the rock has zero porosity.

- A 3.58 MPa
- B 3.73 MPa
- C 3.98 MPa
- D 4.80 MPa

Your answer

[1]

- 17 Which mechanism is currently thought to provide the greatest force in driving the movement of tectonic plates?

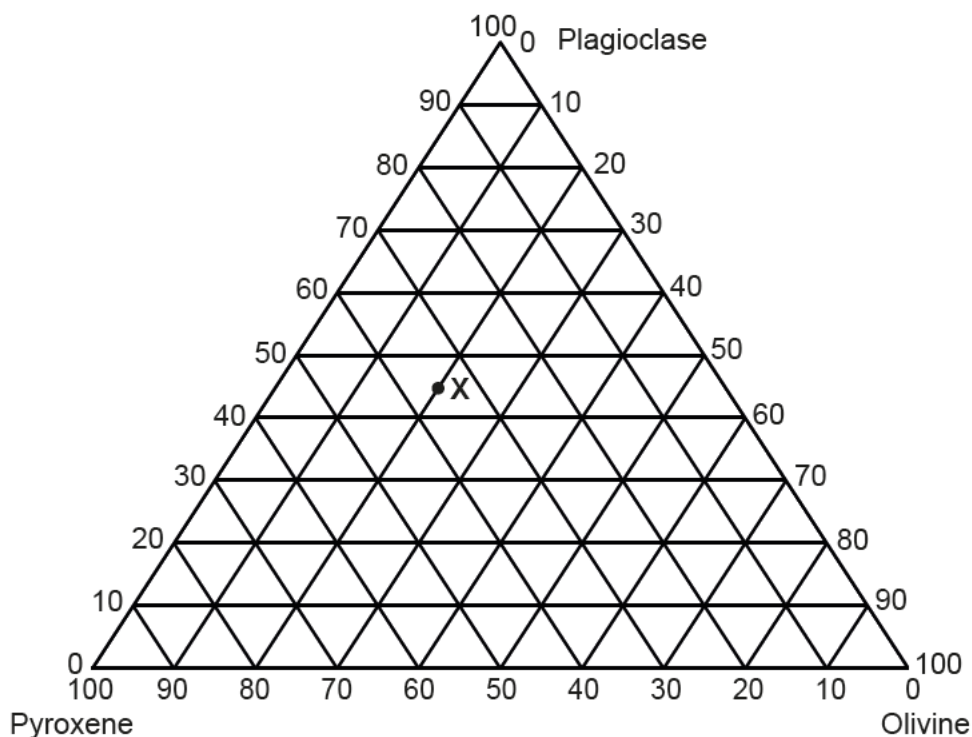
- A Convection currents in the mantle
- B Convection currents in the outer core
- C Ridge push at mid-ocean ridges
- D Slab pull at subduction zones

Your answer

[1]



18 The triangular diagram below is used to plot the mineral composition of rocks in a layered intrusion.



What is the composition at point X?

|   | Plagioclase % | Pyroxene % | Olivine % |
|---|---------------|------------|-----------|
| A | 55            | 20         | 25        |
| B | 20            | 45         | 35        |
| C | 45            | 20         | 35        |
| D | 45            | 35         | 20        |

Your answer

[1]

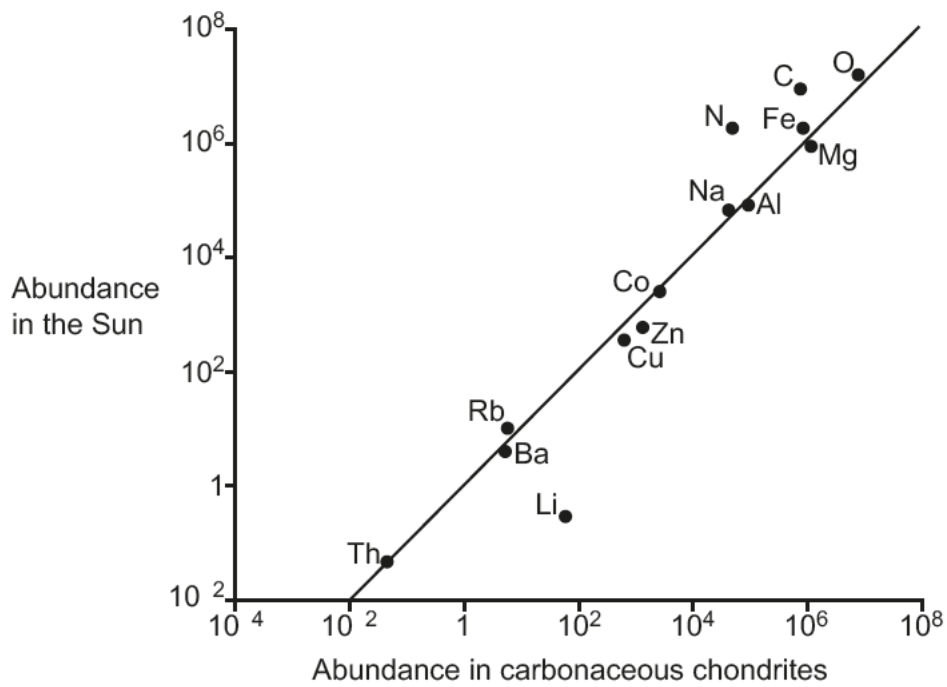
19 Which will most affect buoyancy forces to allow magma to rise to the surface to produce a volcanic eruption?

- A Magma > dense than the surrounding rock
- B Magma >> dense than the surrounding rock
- C Magma < dense than the surrounding rock
- D Magma << dense than the surrounding rock

Your answer

[1]

20 The graph compares the composition of chondrite meteorites with that of the Sun.



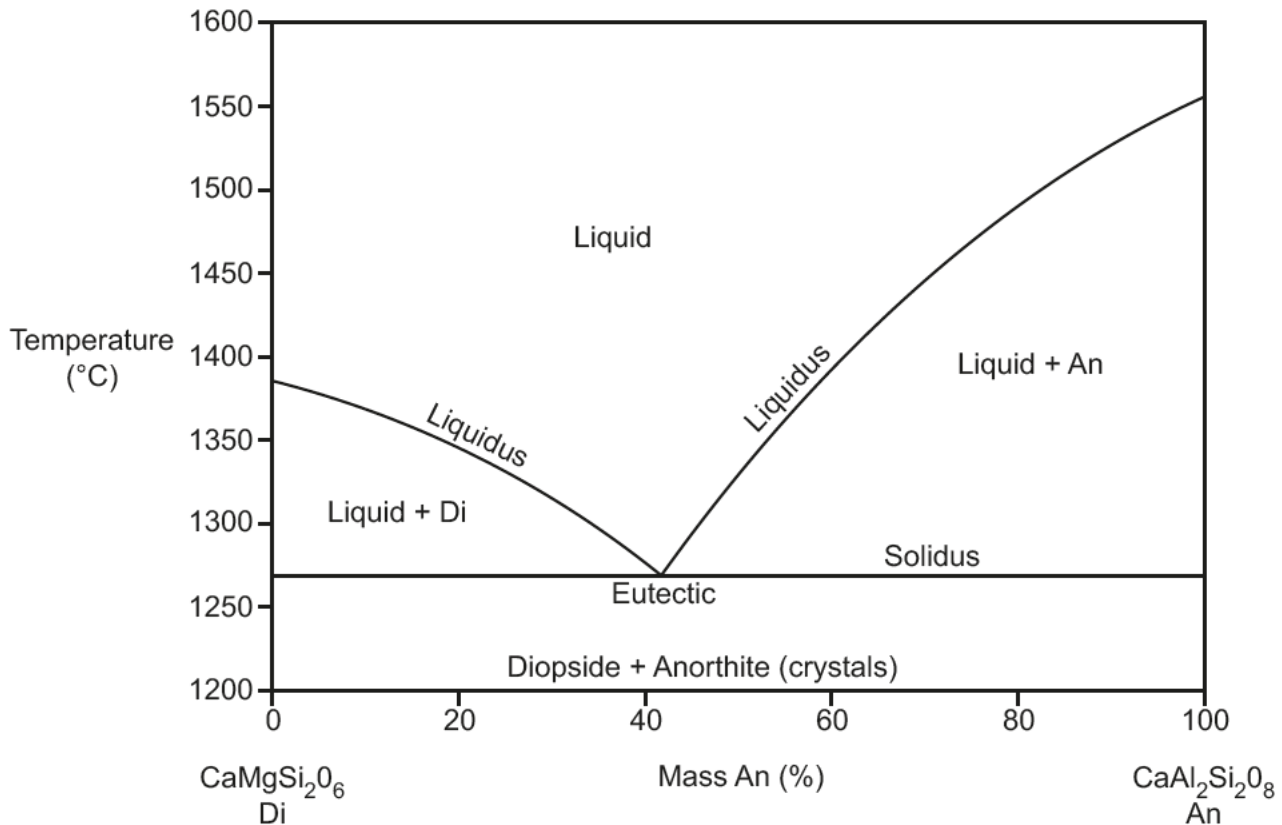
Which statement can be deduced by analysing this graph?

- A Iron meteorites represent the composition of the Earth's core.
- B The Sun and chondrites are made from the same original material.
- C There is no comparison as the Sun is 99.9% hydrogen and helium.
- D The apparent correlation is a result of the logarithmic scales.

Your answer

[1]

The graph shows a discontinuous binary phase diagram which can be used to model the crystallisation of the immiscible minerals anorthite (An) and diopside (Di).



Use the graph to answer questions 21 and 22.

**21** If a melt has a composition of 70% anorthite (An) and 30% diopside (Di), at which temperature will the first crystals form?

- A 1445 °C
- B 1391 °C
- C 1315 °C
- D 1274 °C

Your answer

[1]

**22** What is the correct description of the bulk composition of the solid when crystallisation is complete?

- A 100% An 0% Di
- B 70% An 30% Di
- C 60% An 40% Di
- D 30% An 70% Di

Your answer

[1]

23 Which statement about the formation, movement and crystallisation of magma is **incorrect**?

- A Partial melting of those minerals with higher melting points produces magma.
- B Stopping is a process that allows magma to move up by fracturing of the country rock.
- C Country rock broken up by stopping is assimilated into the magma.
- D Xenoliths are fragments of country rock preserved in the magma.

Your answer

[1]

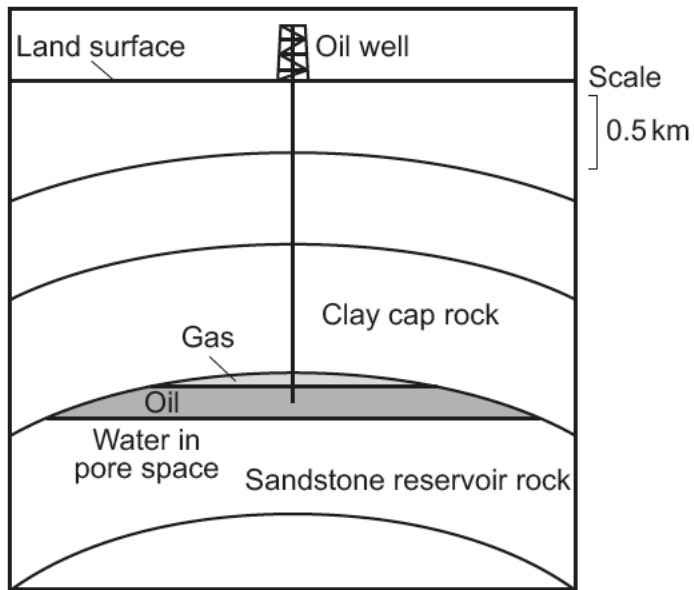
24 Which tectonic process allowed oil and natural gas traps to form in the North Sea Basin?

- A Isoclinal folding
- B Nappe formation
- C Strike-slip faulting
- D Synsedimentary faulting

Your answer

[1]

25 The cross-section shows an accumulation of oil and gas in a trap structure under a cap rock.



Identify the type of trap structure from which the oil is being extracted.

- A Anticline
- B Lithological
- C Salt dome
- D Unconformity

Your answer

[1]

SECTION B

Answer **all** the questions.

26 The properties and compositions of the rock-forming minerals are largely controlled by the way in which their silicon-oxygen tetrahedra are bonded together.

(a) (i) Describe the arrangement of the silicon-oxygen tetrahedra in micas.

..... [1]

(ii) Explain how this arrangement of tetrahedra affects **one** physical property of micas.

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

(b) (i) Name a mineral that has the silicon-oxygen tetrahedra arranged in a chain structure.

..... [1]

(ii) Describe how the **chain** structure controls the cleavage in the mineral named in (b)(i).

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

(c) (i) Describe the arrangement of the silicon-oxygen tetrahedra in quartz.

..... [1]

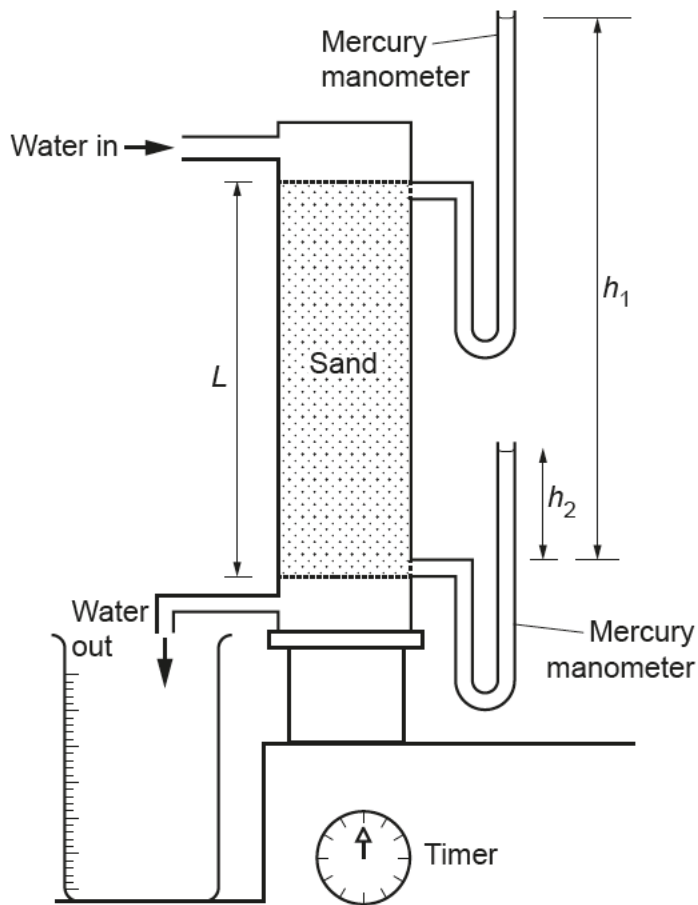
(ii) Explain how this arrangement of tetrahedra affects **one** physical property of quartz.

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

(iii) Explain why the arrangement of the silicon-oxygen tetrahedra in quartz results in the chemical formula  $\text{SiO}_2$ .

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

- 27 Henri Darcy published the results of his careful experiments on flow rates of water through sands in 1856. The apparatus he used is shown in **Fig. 27.1**.



**Fig. 27.1**

**Table 27.1** shows some of the results from the experiment.

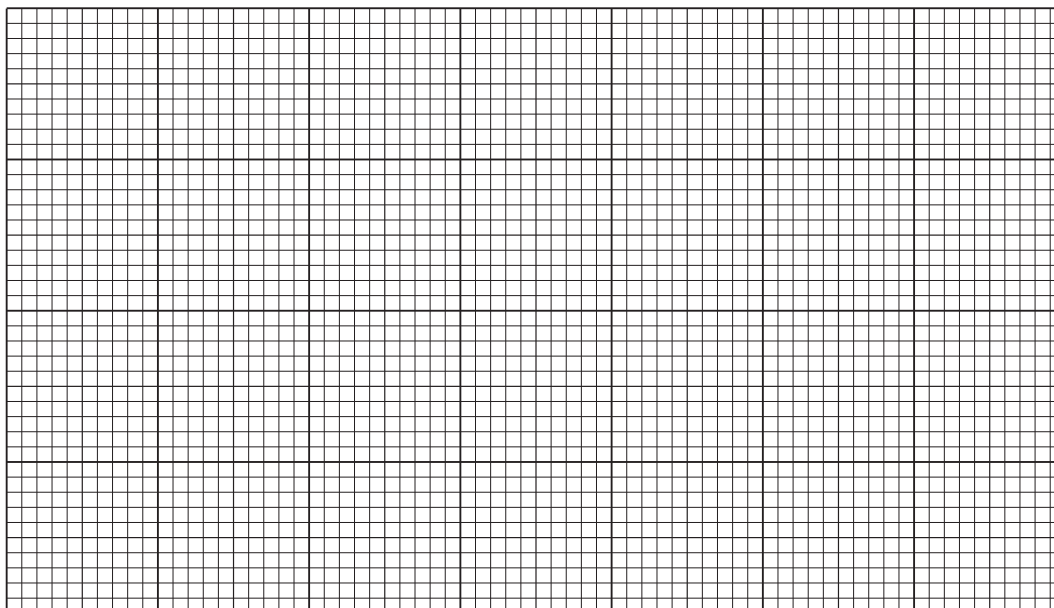
| Experiment | Sand length $L$ (m) | Head $h_2 - h_1$ (m) | Hydraulic gradient | Flow rate $Q$ ( $\text{m}^3 \text{s}^{-1} \times 10^3$ ) |
|------------|---------------------|----------------------|--------------------|--|
| 1          | 0.58                | 1.11                 | 1.9                | 0.60   |
| 2          | 0.58                | 2.36                 | .....              | 1.28   |
| 3          | 0.58                | 4.00                 | 6.9                | 2.00   |
| 4          | 0.58                | 4.90                 | .....              | 2.38   |
| 5          | 0.58                | 5.02                 | 8.7                | 2.53   |
| 6          | 0.58                | 7.63                 | 13.2               | 3.63   |

**Table 27.1**

- (a) (i) Calculate the hydraulic gradients for experiments 2 and 4 and write your answers in **Table 27.1**. [1]



(ii) Plot a graph of flow rate **Q** against the hydraulic gradient and draw a line of best fit.



[3]

(iii) Describe the relationship between flow rate **Q** and the hydraulic gradient.

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

(iv) Darcy used these results to formulate his law:

$$Q = -\kappa A \left( \frac{h_2 - h_1}{L} \right)$$

where:

**Q** is the rate of flow

$\kappa$  is a constant

**A** is the cross-sectional area of 0.1 m<sup>2</sup> through which the water passes

$h_2 - h_1$  is the difference in pressure from the start to the end of the column

**L** is the distance between the start and end points.

Use your graph to find a numerical value for the constant  $\kappa$ .

$\kappa =$  ..... (units not required) [1]

(v) In the original experiment the water inlet was connected directly to the building's water supply.

Explain how this set-up may have affected the accuracy of Darcy's measurements.

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

(vi) Suggest how the apparatus set up in **Fig. 27.1** could be improved to better establish Darcy's Law.

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

(b) Darcy used unwashed sand containing fine clay to obtain his data.

Explain how the results would change if better sorted, well-washed sand from the same source was used.

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

(c) (i) Explain why lower permeability rock could improve drinking water quality.

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

(ii) Long residence times of dissolved ions can result in chemical changes to groundwater.

State **two** ions commonly found in solution in groundwater. For each ion suggest how it could affect water quality.

1 .....  
.....  
2 .....  
.....

[2]

28 Early seismic refraction and reflection studies showed that the ocean floor had a simple layered structure. It was only explained once the process of sea-floor spreading was understood.

Fig. 28.1 shows the seismic layering of the oceanic lithosphere compared to the geology of the Semail ophiolite complex, Oman.

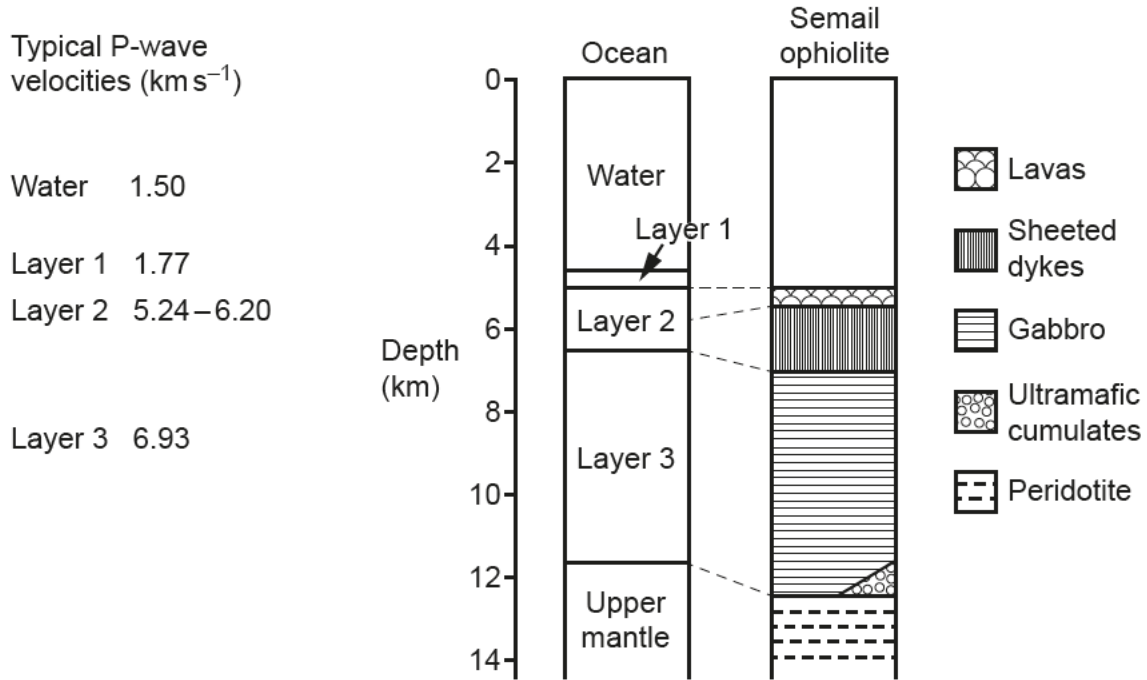


Fig. 28.1

(a) (i) Identify the composition of layer 1 shown in Fig. 28.1.

..... [1]

(ii) Explain why the layer identified in (a)(i) has a much lower P-wave velocity compared to the other layers.

..... [1]

(iii) Explain why the seismic data shows layer 1 increases in thickness the further away it is from the axis of the ocean ridge.

..... [2]

(iv) Explain how sheeted dykes form in the oceanic crust and how their chilled margins provide evidence for this process of formation.

.....

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..... [3]

(b) Fig. 28.2 shows pillow lavas exposed in Anglesey, North Wales.

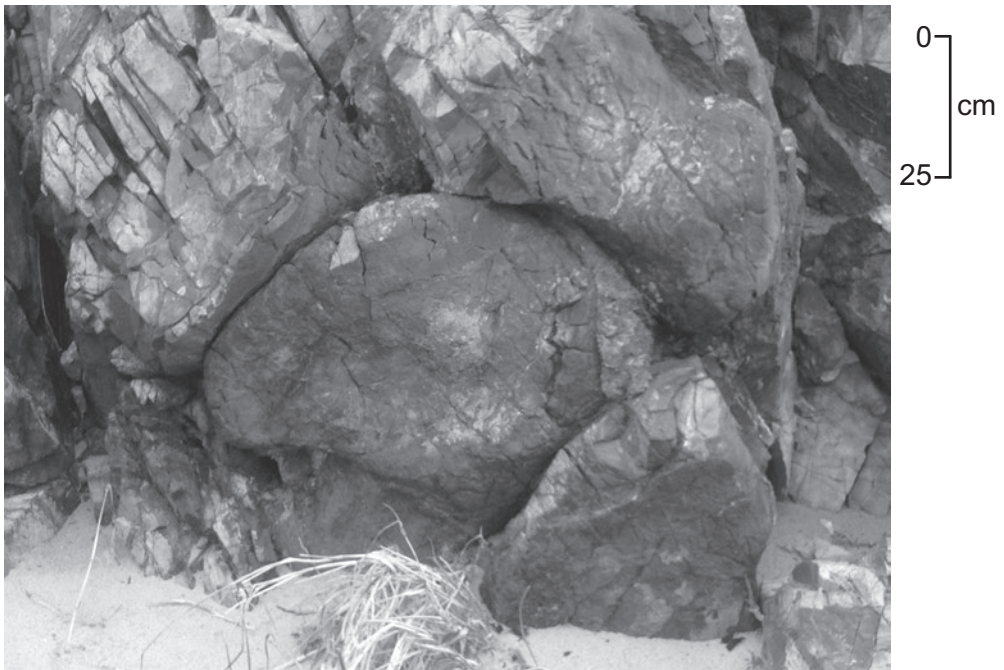


Fig. 28.2

(i) Draw an arrow on Fig. 28.2 to show the right way-up and younging direction of the pillow lavas. [1]





23  
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29 Fig. 29.1 shows maps of the geology and zones of land use of the same area.

Location ★ marks the epicentre of an earthquake which had a Moment magnitude ( $M_w$ ) of 6 and a depth of focus of 15 km.

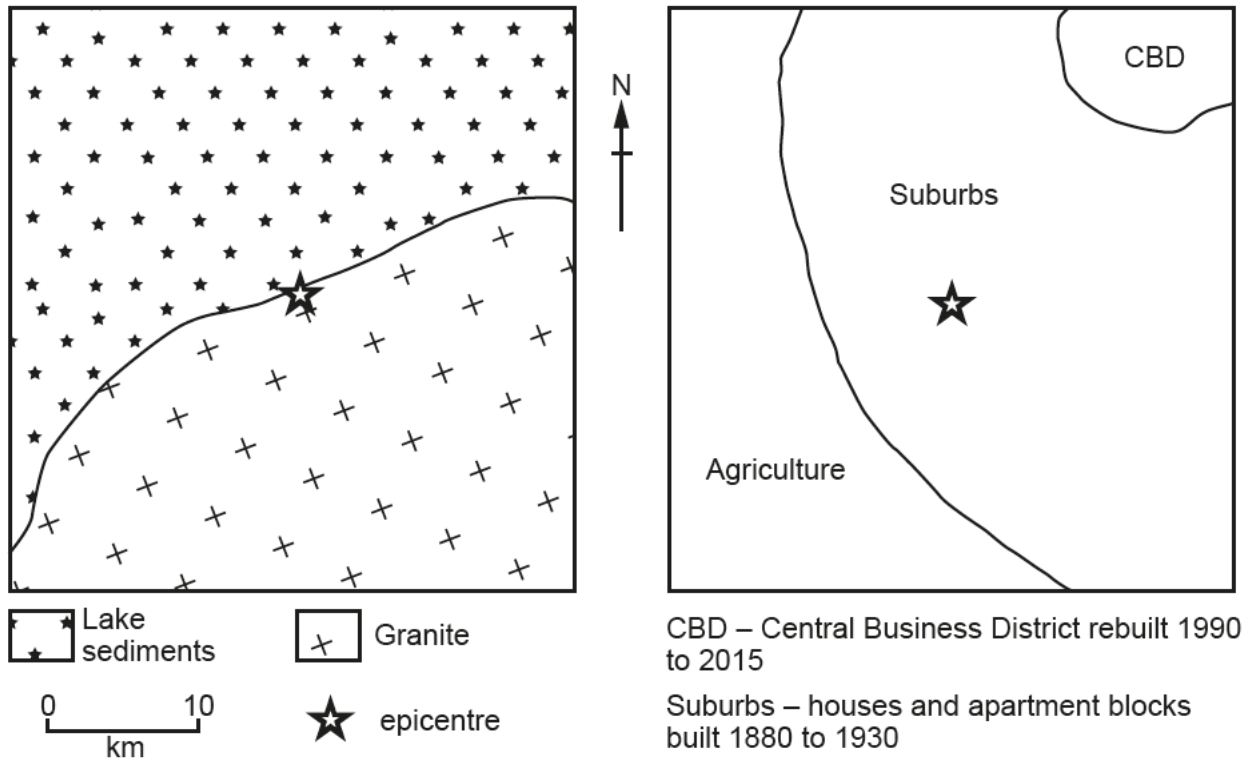


Fig. 29.1

(a) (i) The modern structures in the Central Business District of the city showed little damage after the earthquake.

Outline **three** civil engineering strategies that can reduce the impact of seismic events on the built environment.

- 1 .....
- 2 .....
- 3 .....

[3]



- (ii) During the earthquake, some apartment blocks in the northern suburbs sank and tilted. The water table was close to the surface in that area.

Name the process that caused this problem and explain the mechanisms involved.

Name of process .....

Explanation .....

.....

.....

.....

.....

..... [3]

- (iii) Sketch the probable pattern of **three** isolines of equal earthquake intensity (isoseismals) onto the land use map in **Fig. 29.1**.

Label each isoline with a number to suggest the earthquake intensity on the modified Mercalli scale.

Use the information on the maps and your knowledge of the effects of the underlying geology, types of land use and buildings on earthquake intensity in your answer.

**Answer on the land use map in Fig. 29.1.** [5]

- (b) The Moment magnitude ( $M_w$ ) of an earthquake can be converted into an equivalent of the energy released using the equation:

$$M_w = \frac{2}{3} \log E - 6.1$$

Where  $M_w$  is the Moment magnitude and  $E$  is the energy released.

Calculate the energy released by a Moment magnitude ( $M_w$ ) 6 earthquake.

Give your answer to an **appropriate number** of significant figures.

Energy released = ..... J [3]

- (c) (i) In seismic risk analysis it is generally understood that increasing distance from an active fault will lower the impact of an earthquake.

Use your knowledge of the mechanisms of seismic wave propagation through rocks to explain this assumption.

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

- (ii) Give **two** geological explanations why this simplistic correlation of distance from faults with seismic risk can be misleading.

1 .....  
.....  
2 .....  
..... [2]

27  
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- 30 (a) Tectonic plate movement can be measured using accurate daily positions recorded by permanent GPS stations.

**Fig. 30.1** shows eastward and northward motion data from a GPS station located in the west of Iceland.

Item removed due to third party copyright restrictions. Link to material: <https://www.unavco.org/education/resources/modules-and-activities/gps-measuring-plate-motion/module-materials/measuring-plate-motion-teacher-guide.pdf>

**Fig. 30.1**

- (i) The average precision of the GPS data shown in **Fig. 30.1** was determined to be  $\pm 10$  mm.

Explain the meaning of the term **precision**.

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

- (ii) Use **Fig. 30.1** to determine the **annual** rate of eastward and northward movement of the GPS station.

Give your answers in mm y<sup>-1</sup>.

Eastward = ..... mm y<sup>-1</sup>

Northward = ..... mm y<sup>-1</sup> [2]

- (iii) Explain the direction of movement of the GPS station in **Fig. 30.1**.

In your answer use your knowledge of the plate tectonic situation of Iceland.

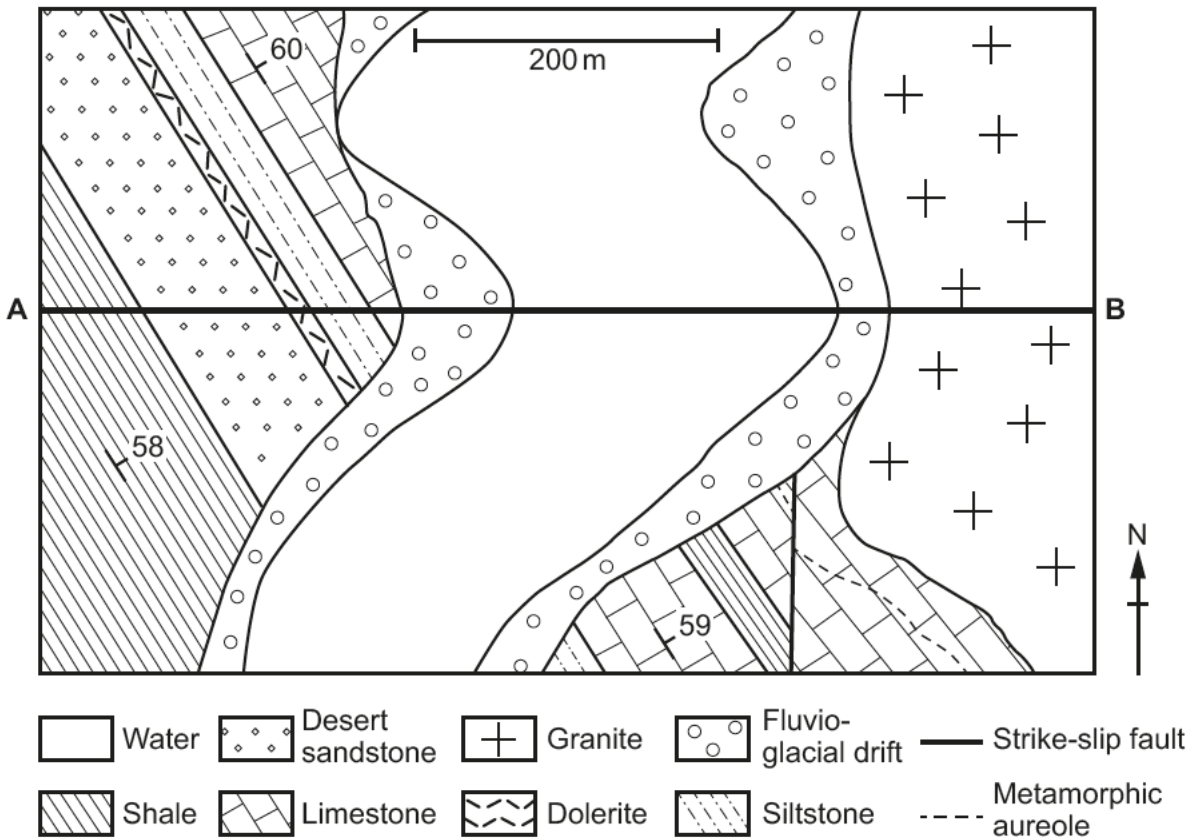
.....  
.....  
.....  
.....  
..... [2]

- (b) Historical plate movements can be reconstructed using the global distribution of geological features within the continents.

Using named example(s), describe and explain how palaeoecology (fossils) can be used as evidence for plate movements.

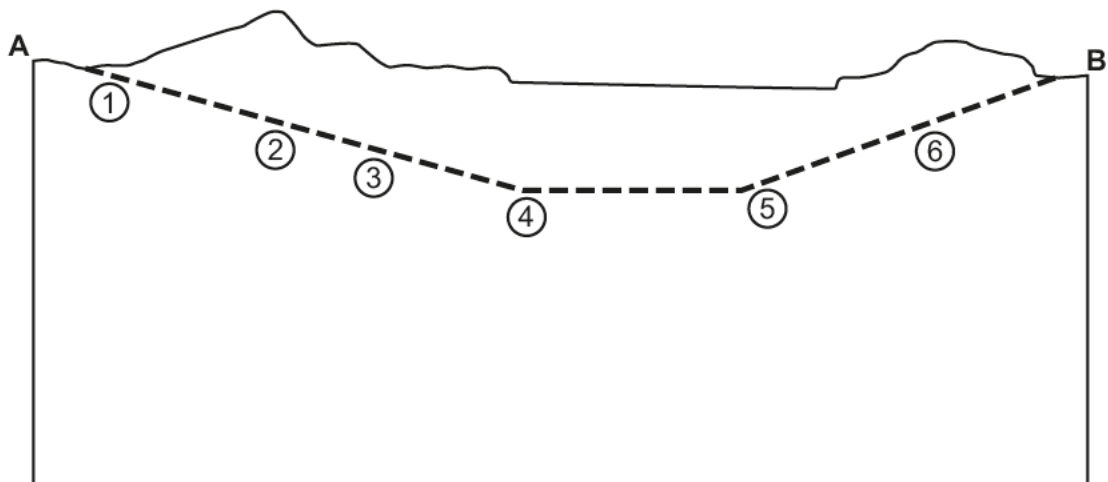
.....  
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.....  
.....  
.....  
..... [3]

- 31 A government is considering constructing a road tunnel beneath a major river to improve the economy of the area. **Fig. 31.1** shows a map of the geology of the area. The maximum depth of the river is 10 metres and maximum depth of the fluvio-glacial drift deposits is above the profile of the tunnel.



**Fig. 31.1**

- (a) Construct a geological cross-section along the line of the tunnel A–B from the map onto **Fig. 31.2**, which shows the surface topography and the tunnel profile. There is no vertical exaggeration.



**Fig. 31.2**

[5]



- (c) Old records suggest that there may have been small-scale mining for metal ores in the area around location 5 shown on Fig. 31.2.

Suggest the processes by which this mineralisation could have formed.

.....

.....

.....

.....

..... [2]

- (d) To decide whether to construct the tunnel, the environmental impacts will be considered as part of a cost–benefit analysis.

- (i) Fig. 31.3 shows a cross-section through the proposed 660 metres-long road tunnel. The excavation can be approximated as a circle of radius 5.7 m.

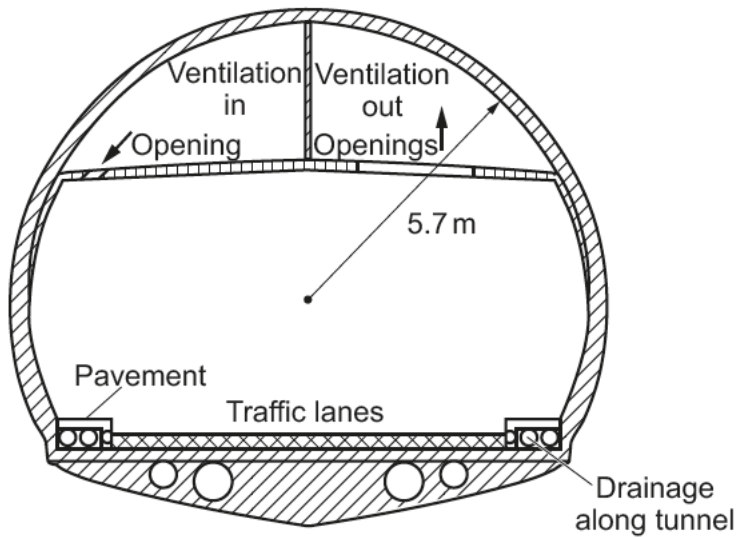


Fig. 31.3

Calculate the volume of spoil that will need to be removed during the excavation of the tunnel.

Volume of spoil = ..... m<sup>3</sup> [2]



- (ii) Suggest how this quantity of spoil could be disposed of **and** describe one possible impact of spoil disposal on the environment.

.....

.....

.....

.....

.....

..... [2]

**END OF QUESTION PAPER**

**ADDITIONAL ANSWER SPACE**

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

A large rectangular area with a solid vertical line on the left side and horizontal dotted lines extending across the page, providing space for writing answers.



A large rectangular area with a solid vertical line on the left side and horizontal dotted lines extending across the page, providing a space for writing answers.



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