



**GCE A LEVEL**

**A480U30-1**

**TUESDAY, 20 JUNE 2023 – AFTERNOON**

**GEOLOGY – A LEVEL COMPONENT 3  
GEOLOGICAL APPLICATIONS**

**2 hours plus your additional time allowance**

**Surname**

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**First name(s)**

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**Centre Number**

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**Candidate Number**

**2**

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## **ADDITIONAL MATERIALS**

**In addition to this examination paper, you will need:**

- a calculator
- a ruler
- the Geological Map Extract

## **INSTRUCTIONS TO CANDIDATES**

**Use black ink, black ball-point pen or your usual method.**

**You may use a pencil for graphs and diagrams only.**

**Write your name, centre number and candidate number in the spaces on the previous 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.**

**(Turn over)**

## **INFORMATION FOR CANDIDATES**

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

**SECTION A: 30 marks. Answer BOTH questions. You are advised to spend about 35 minutes on this section.**

**SECTION B: 45 marks. Answer ALL questions. You are advised to spend about 50 minutes on this section.**

**SECTION C: 30 marks. Answer all the questions in ONE option only. You are advised to spend about 35 minutes on this section.**

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

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

**(Turn over)**

**SECTION A**

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

**1 FIGURE 1a opposite is a map of the North Pacific Ocean showing the epicentre of the 2006 Kuril earthquake ( $M_w$  8.3), the location of a tsunami monitoring buoy and Arena Cove, California.**

**FIGURE 1b opposite shows the sea level record from the tsunami monitoring buoy.**

**FIGURE 1c opposite the following page shows the tide gauge record for Arena Cove, California.**

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

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**(Turn over)**

Refer to FIGURES 1b and 1c.

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

[3 marks]

\_\_\_\_\_ km h<sup>-1</sup>

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

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(Turn over)

1 c (ii) State the maximum height of the sea caused by the tsunami wave measured at Arena cove.

[1 mark]

\_\_\_\_\_m

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

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(Turn over)



**2** FIGURE 2a opposite is a graph to show how the lead concentration in mine water varies with pH.

**FIGURE 2b** opposite the following page is a model of Cwmrheidol Mine, an abandoned metal mine in Wales, which discharges up to 8 tonnes of metal pollution per year into the River Rheidol.

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

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2 (b) Refer to FIGURES 2a and 2b.

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

[2 marks]

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

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(Turn over)

**2 (c) (i) One solution to the metal pollution problem at this mine has been to install a filter of limestone gravel between the outfall from the No.9 tunnel and the river.**

**Explain how this would reduce metal pollution into the river. [3 marks]**

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**2 (c) (ii) Suggest ONE OTHER potential solution to this metal pollution problem. Explain how this would reduce metal pollution from this mine.**

**[2 marks]**

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**SECTION B**

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

**Questions 3–6 relate to the BRITISH GEOLOGICAL SURVEY GEOLOGICAL MAP extract from the Harrogate Sheet 62 (Solid edition)**

**3 Refer to BOX A on the GEOLOGICAL MAP.**

- (a) Describe the evidence in BOX A on the GEOLOGICAL MAP to support the presence of an unconformity at the base of the Permian, as shown on the GENERALISED GEOLOGICAL COLUMN. [2 marks]**

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**(Turn over)**

**3 (b) (i) Using the GENERALISED GEOLOGICAL COLUMN, show that the Upper Magnesian Limestone (UML) has a maximum thickness of 30m.**

**Show your working. [2 marks]**

**3 (b) (ii) Explain the evidence from BOX A alone that the Upper Magnesian Limestone (UML) is dipping**

- **at a shallow angle**
- **to the East**

**along the line X – Y on the GEOLOGICAL MAP.**

**[3 marks]**

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

Angle of dip \_\_\_\_\_ degrees

10

(Turn over)

- 4 **FIGURE 4** opposite shows details of **BOX B**, part of the Harrogate Anticline on the **GEOLOGICAL MAP**, indicating the location of principal mineral springs in the Harrogate area.

**Refer to the GEOLOGICAL MAP, GEOLOGICAL SECTION and FIGURE 4.**

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

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**(Turn over)**

**4 (a) (ii) Using the GEOLOGICAL MAP, describe the plunge of the Harrogate Anticline. Explain the evidence for your answer.**

**[3 marks]**

**Description** \_\_\_\_\_

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**Evidence** \_\_\_\_\_

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**(iii) Describe ONE OTHER fold characteristic of the Harrogate Anticline. [2 marks]**

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**(Turn over)**

**4 (b) (i) Measure the vertical displacement along the Harrogate Fault using the GEOLOGICAL SECTION. [1 mark]**

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

**[2 marks]**

**Fault type** \_\_\_\_\_

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**Evidence** \_\_\_\_\_

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

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

TABLE 1

Ion	Spring S ion concentration (mg l <sup>-1</sup> )	Spring S (%)	Spring T (%)
Ca	10.7	•	29
Mg	9.8	•	31
Na	15.5	•	40
Total	36.0	100	100

Refer to FIGURE 5 and TABLE 1.

- (a) (i) Complete TABLE 1 by calculating the percentages of the three ions from the ion concentration data (mg l<sup>-1</sup>) for SPRING S, to two significant figures. [2 marks]
- (ii) Complete FIGURE 5 by plotting the percentage data for SPRING T. Label your plot SPRING T. [1 mark]
- (iii) Draw a line across FIGURE 5 to represent a Ca:Mg ion ratio of 1:1. [1 mark]

(Turn over)

**5 (a) (iv) Describe the variation in the RATIO of Ca to Mg ions in the sampled waters on FIGURE 5.**

**[2 marks]**

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**(Turn over)**



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

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

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

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**(Turn over)**

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

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**6 (c) With reference to the data from Ripon, describe the extent of the potential subsidence risk associated with Permian and Triassic strata in BOX A on the GEOLOGICAL MAP. [3 marks]**

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10

**SECTION C**

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

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

**OPTION 1:  
QUATERNARY GEOLOGY  
PAGE 30**

**OPTION 2:  
GEOLOGICAL  
EVOLUTION OF BRITAIN  
PAGE 42**

**OPTION 3:  
GEOLOGY OF THE  
LITHOSPHERE  
PAGE 55**

**(Turn over)**

**OPTION 1: QUATERNARY GEOLOGY**

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

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

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

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

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**(Turn over)**

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

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**FIGURE 7b opposite is a graphic log of a sequence of Quaternary sediments.**

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

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

**Environment of deposition: \_\_\_\_\_**

\_\_\_\_\_

**Reason 1: \_\_\_\_\_**

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**Reason 2: \_\_\_\_\_**

\_\_\_\_\_

\_\_\_\_\_

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**(Turn over)**

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

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11

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

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

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

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(Turn over)

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

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- 8 (b) FIGURE 8b opposite shows how the rate of uplift varies with distance from LOCATION A on FIGURE 8a.

Refer to FIGURE 8b.

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

\_\_\_\_\_ mm yr<sup>-1</sup> km<sup>-1</sup>

(Turn over)

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

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

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**OPTION 2: GEOLOGICAL EVOLUTION OF BRITAIN**

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

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

Refer to FIGURE 10a and FIGURE 10b opposite the following page.

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

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**(Turn over)**

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

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

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

\_\_\_\_\_ mGal km<sup>-1</sup>

(Turn over)

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

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

[3 marks]

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12

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

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

**(i)** State the type of fault to the east of the Mochras Borehole. Give ONE reason for your answer.

**[2 marks]**

Type of fault movement: \_\_\_\_\_  
\_\_\_\_\_

Reason: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**(Turn over)**

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

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

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

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

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

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**(Turn over)**

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

**[2 marks]**

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**(Turn over)**







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**OPTION 3: GEOLOGY OF THE LITHOSPHERE**

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

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

Refer to FIGURE 13a.

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

\_\_\_\_\_ km

(Turn over)

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

South Pacific spreading rate

\_\_\_\_\_  $\text{cm yr}^{-1}$

(Turn over)

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

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**13 (b) (ii) Briefly explain ONE other method that can be used to calculate ocean spreading rates.**

**[2 marks]**

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**(Turn over)**

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

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

**State which ocean (Pacific or Atlantic) shows the most advanced stage in ocean basin evolution. Give THREE reasons for your choice. [4 marks]**

**Ocean:** \_\_\_\_\_

\_\_\_\_\_

**Reasons** \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**(Turn over)**

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12

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

**Refer to FIGURE 14a.**

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

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

**(Turn over)**

**14 (b) FIGURE 14b opposite is a geological map of Pembrokeshire showing the regional structural setting.**

**FIGURE 14c opposite the following page is a photograph of a true dip section showing minor geological structures associated with the regional structures in FIGURE 14b. These minor structures formed under the stress conditions in FIGURE 14a.**

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

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**(Turn over)**

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

**[2 marks]**

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**(Turn over)**







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6

**END OF PAPER**

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<b>QUESTION NUMBER</b>	<b>ADDITIONAL PAGE, IF REQUIRED. WRITE THE QUESTION NUMBER(S) IN THE LEFT-HAND MARGIN.</b>

<b>QUESTION NUMBER</b>	<b>ADDITIONAL PAGE, IF REQUIRED. WRITE THE QUESTION NUMBER(S) IN THE LEFT-HAND MARGIN.</b>

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## ACKNOWLEDGEMENTS

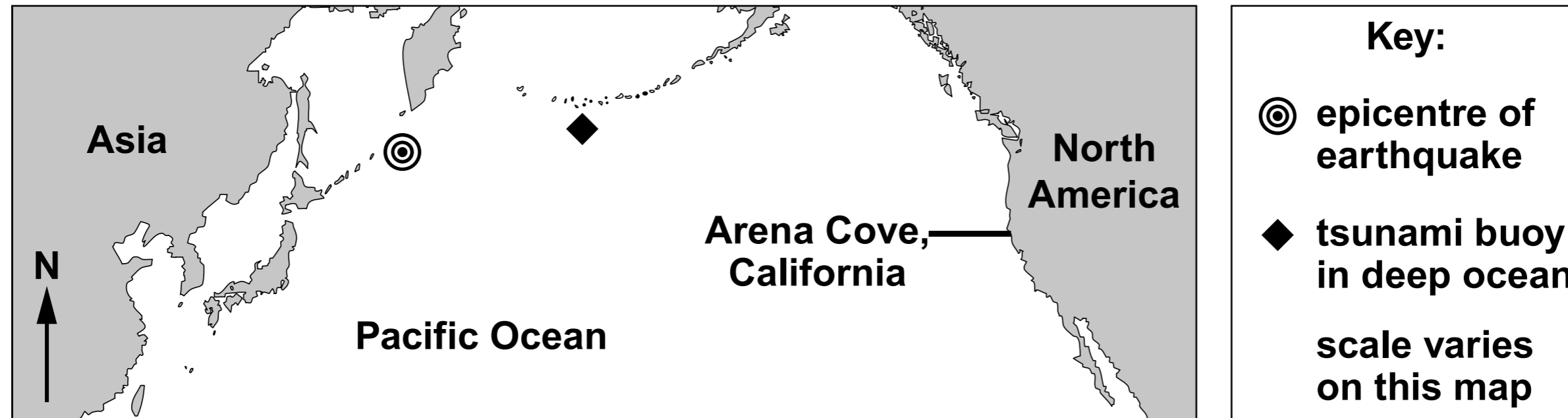
**FIGURE 7a:** <http://earthwise.bgs.ac.uk/>. Photograph  
British Geological Survey

**FIGURE 14b:** [https://sp.lyellcollection.org/  
content/487/1/105](https://sp.lyellcollection.org/content/487/1/105). Acknowledgement not  
found

**FIGURE 14c:** P. Loader

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

**FIGURE 1a**



**Height of sea relative to mean low tide level (m)**

**FIGURE 1b**

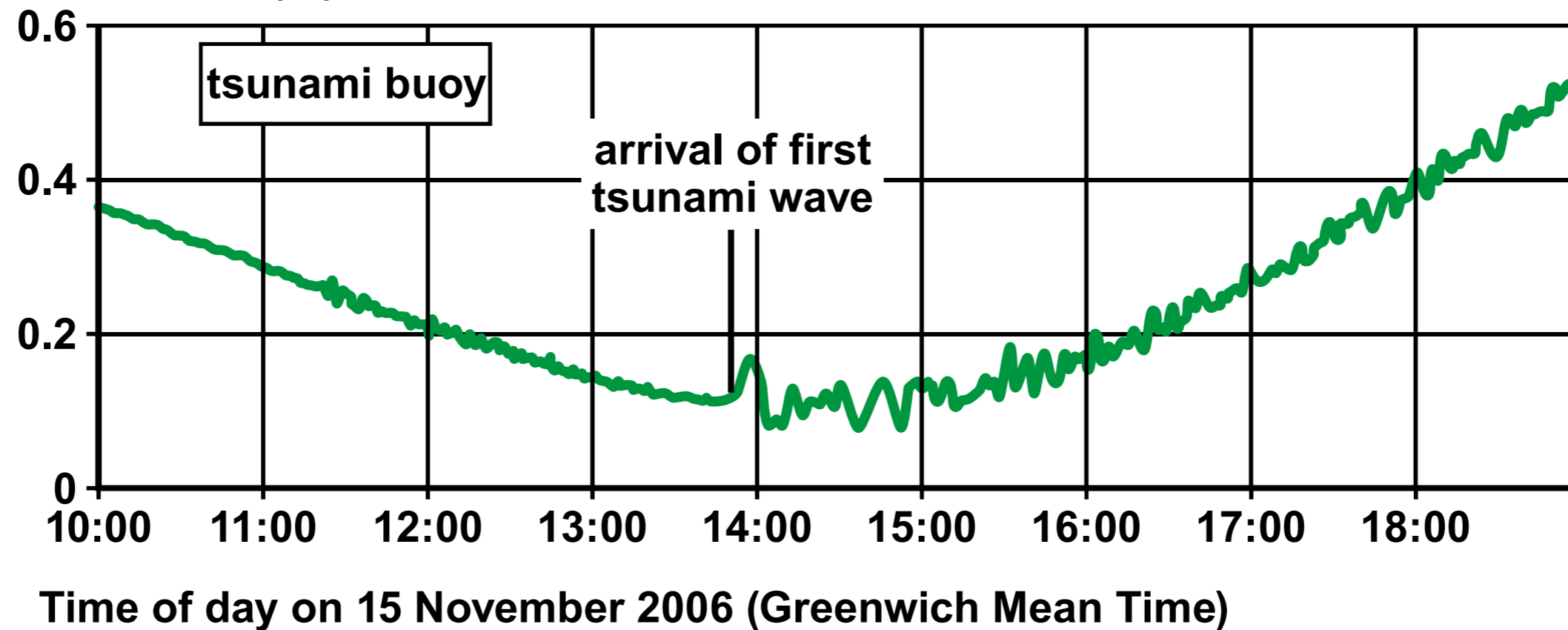




FIGURE 2a

Lead concentration (mg l<sup>-1</sup>)

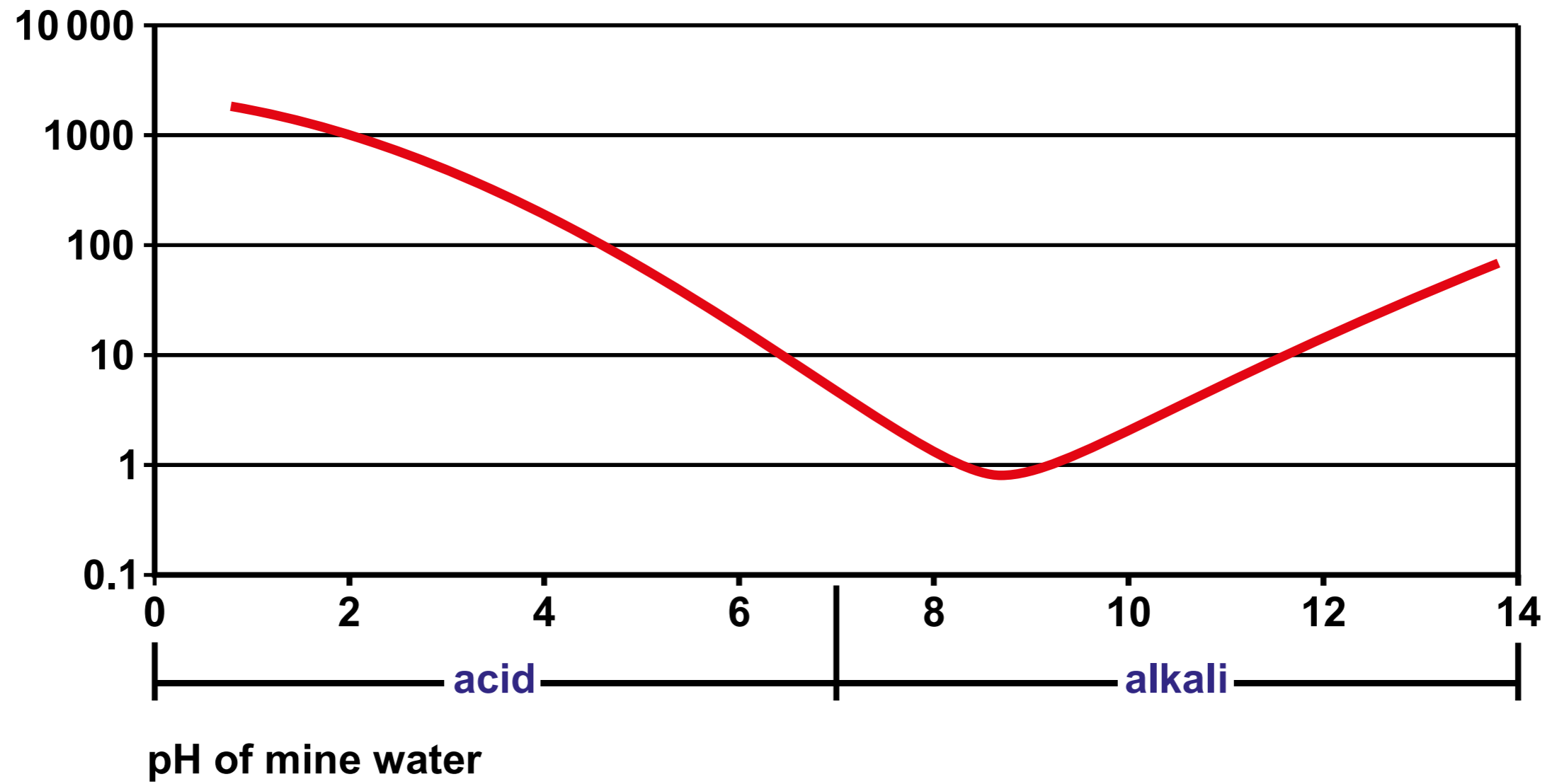


FIGURE 2b

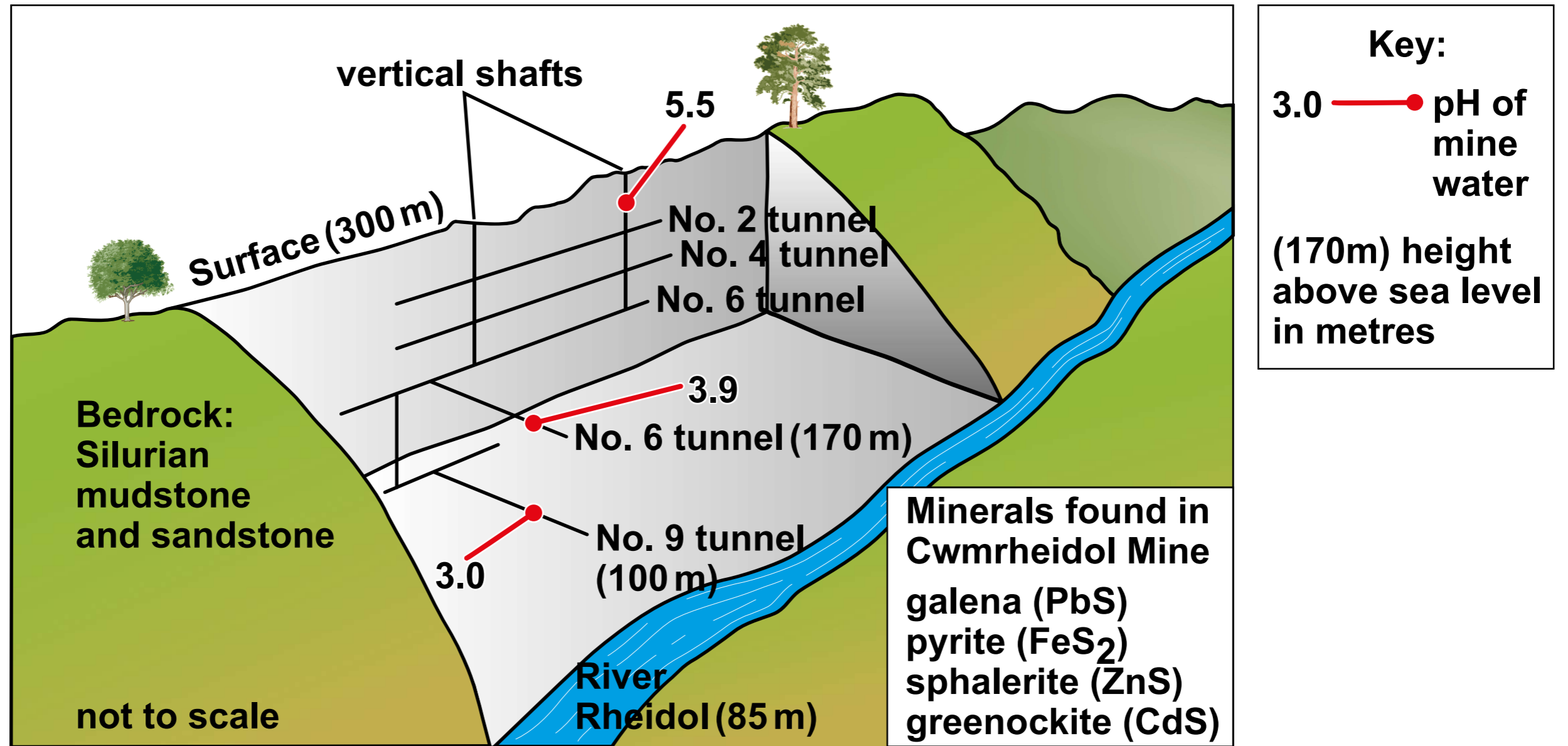
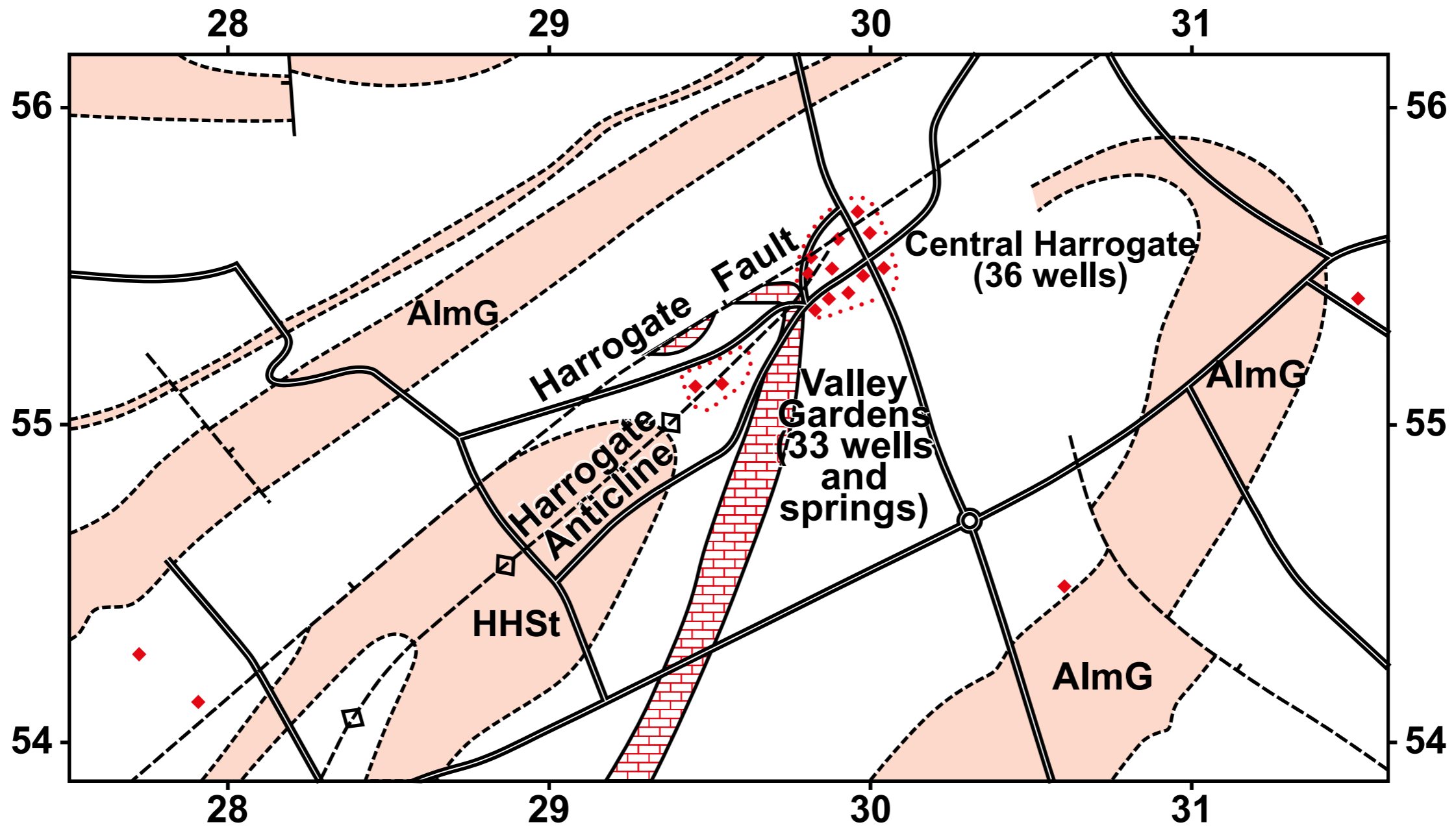
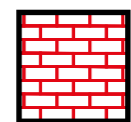


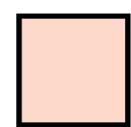
FIGURE 4



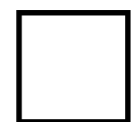
Key:



Limestone: Harrogate Roadstone



Sandstone: (HHSt) Harlow Hill Sandstone;  
(AlmG) Almscliff Grit



Mudstone and siltstone



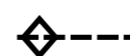
Water well or spring



Geological boundary



Fault, crossmark on downthrow side



Axial trace of Harrogate Anticline

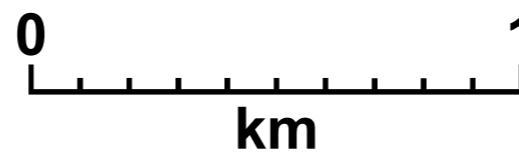


FIGURE 5

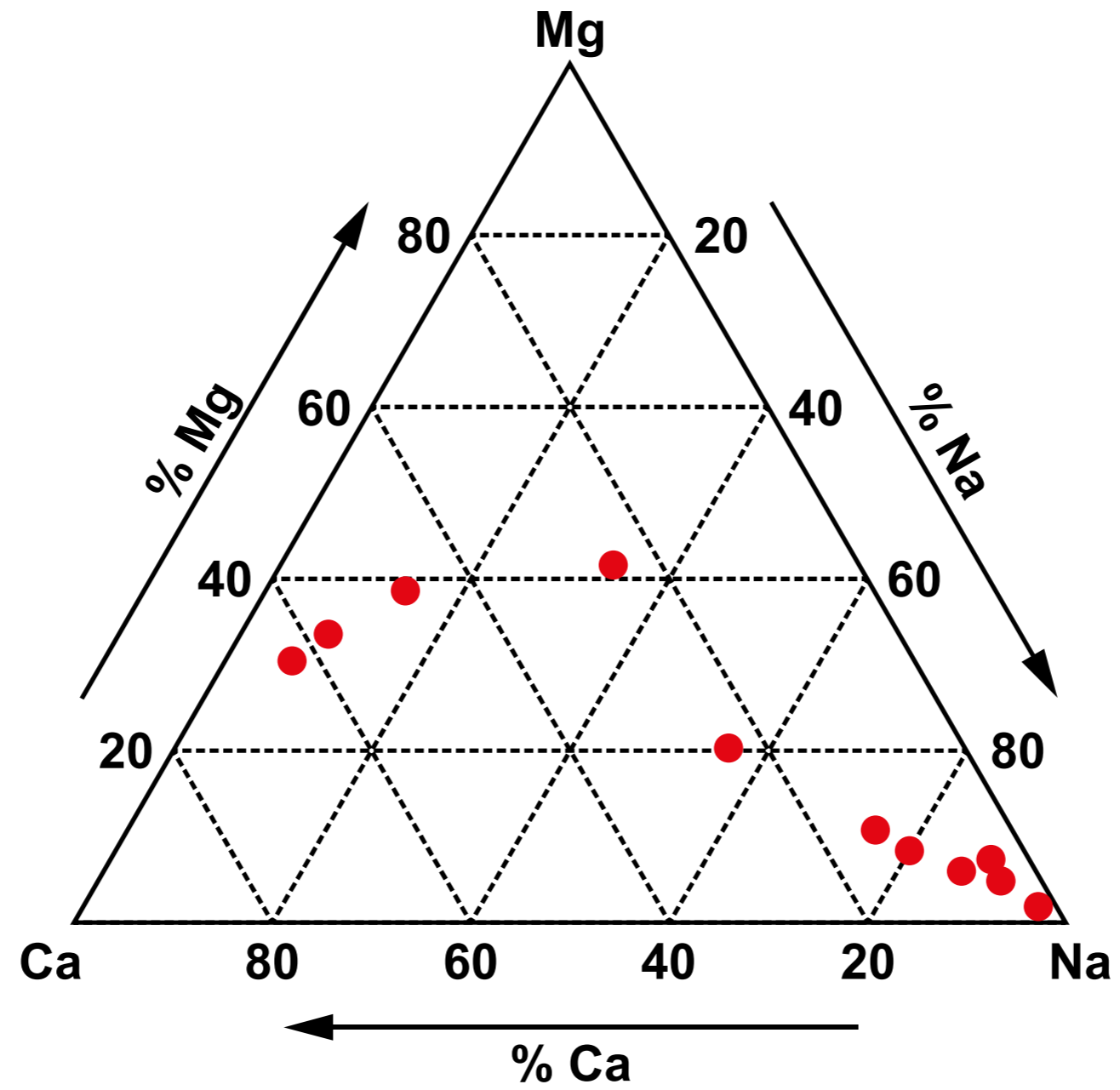
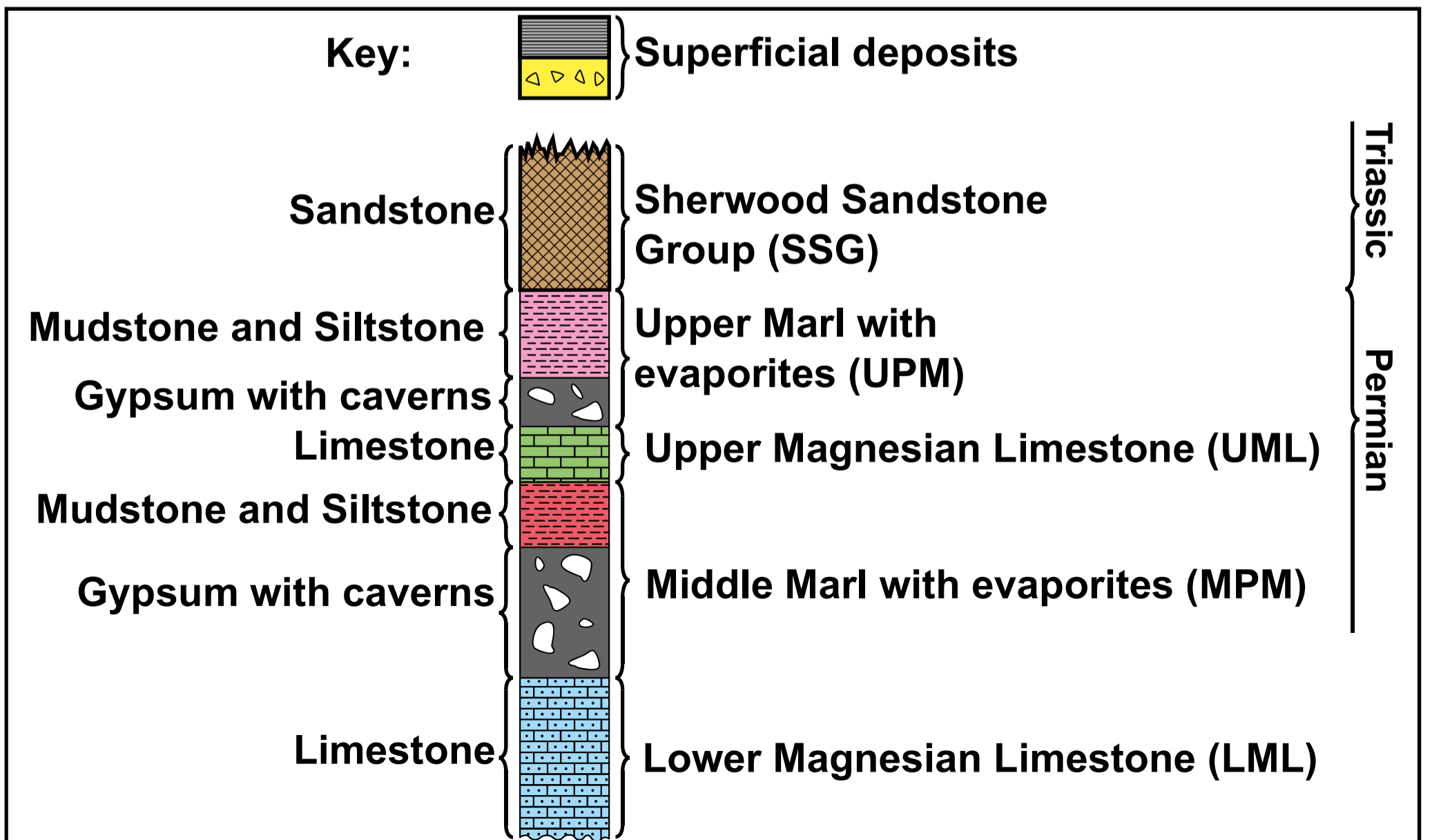
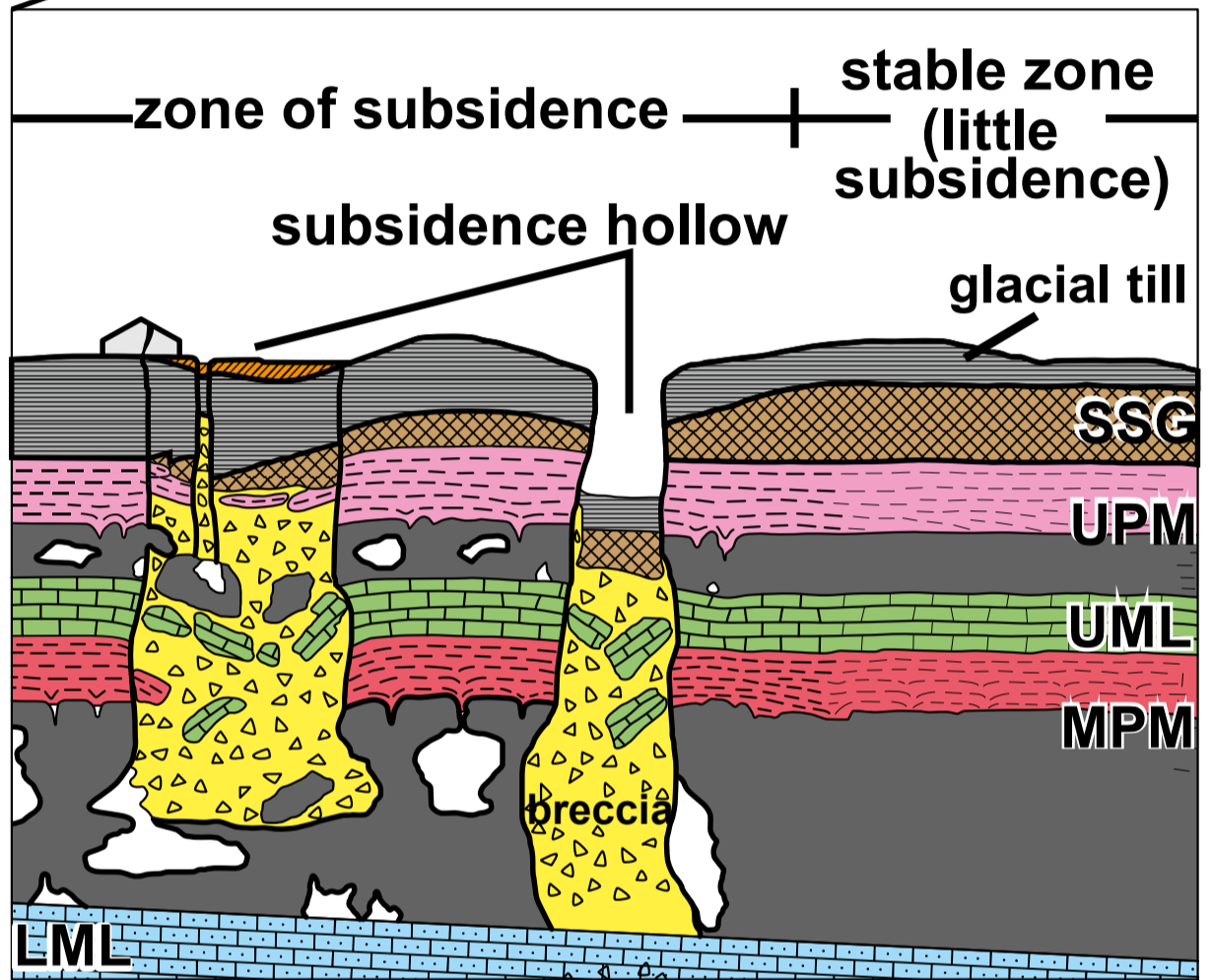
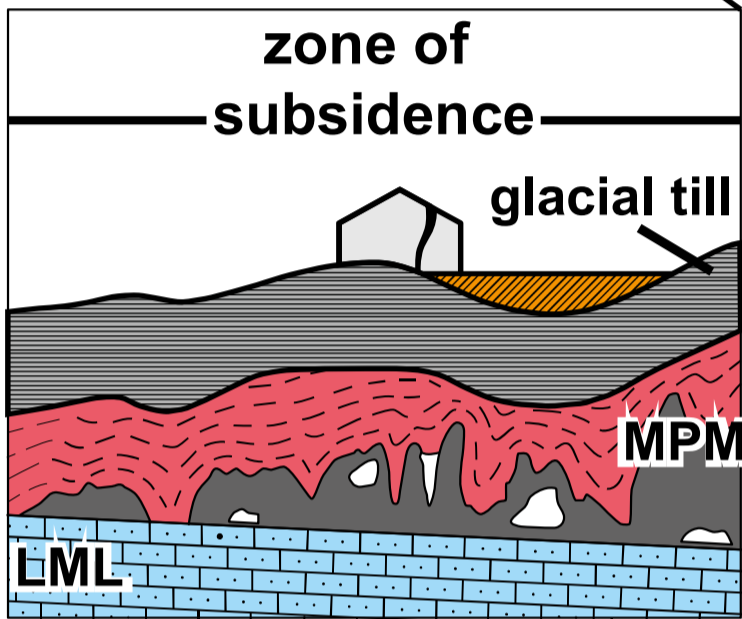
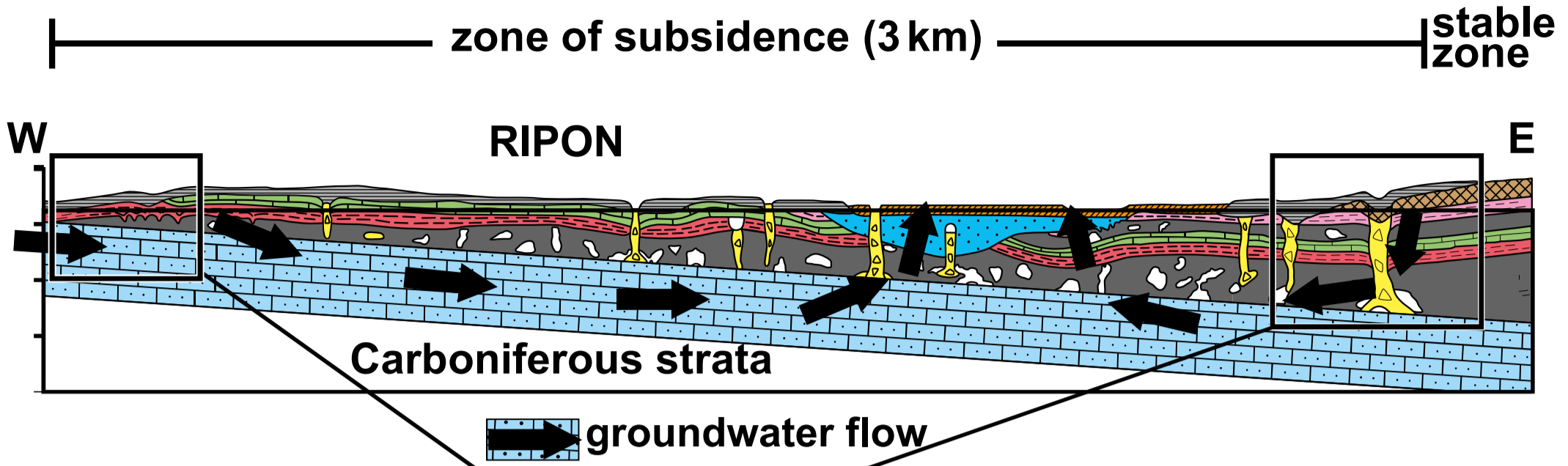
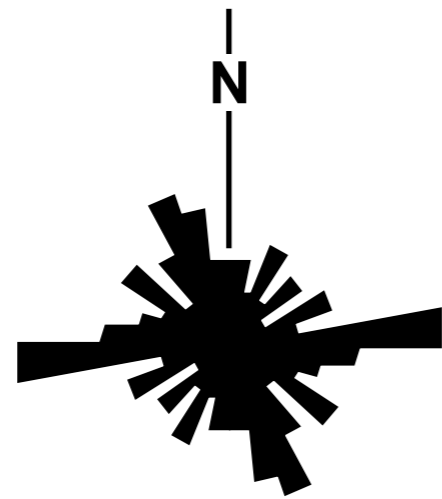


FIGURE 6a

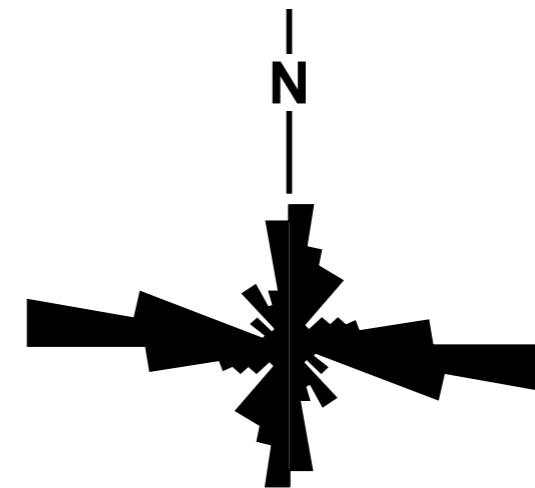


**FIGURE 6b**



**Orientation of 100 subsidence hollows**

**FIGURE 6c**



**Orientation of 110 joints**

**FIGURE 7a**



0 10  
cm

FIGURE 7b

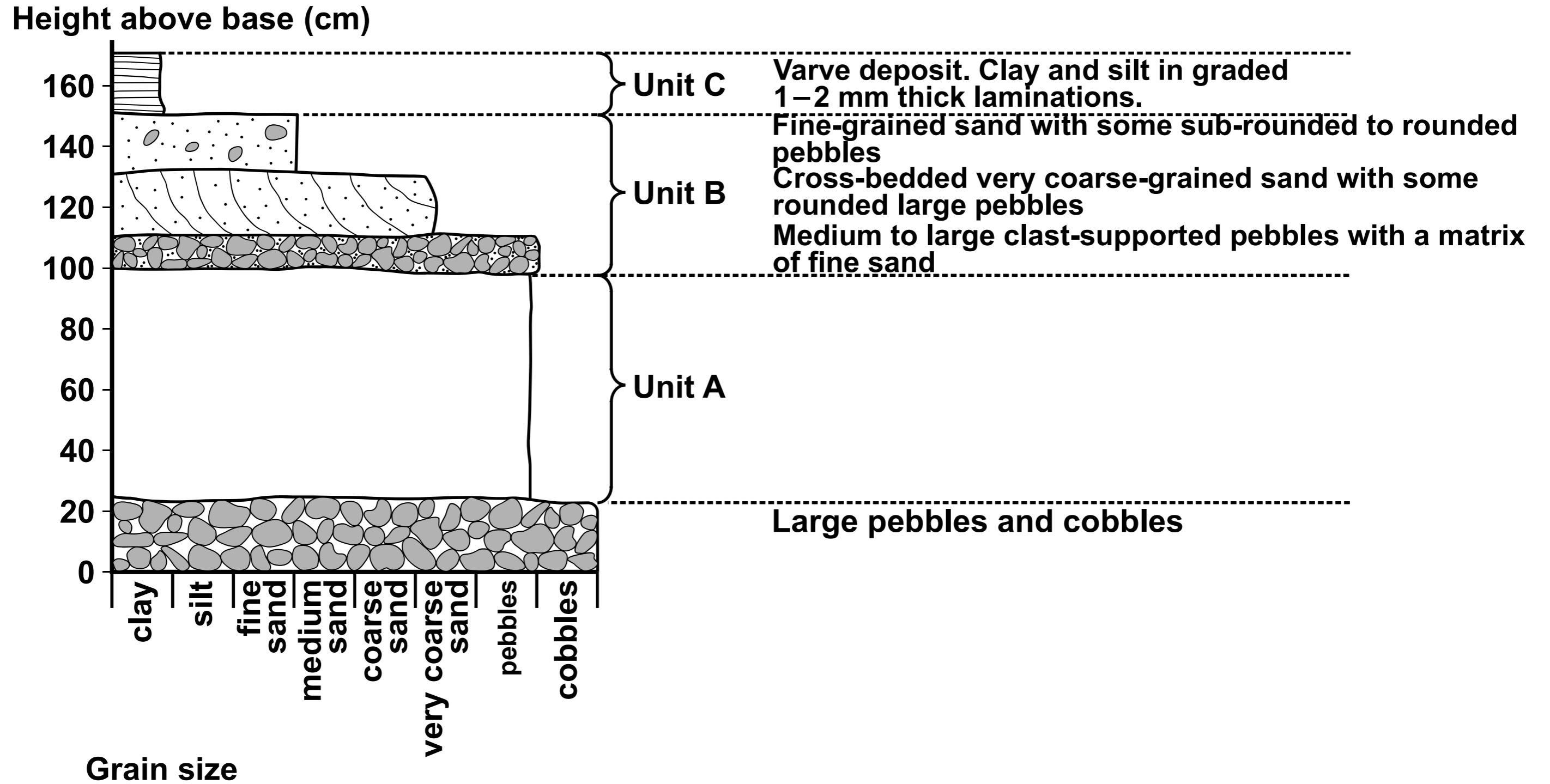
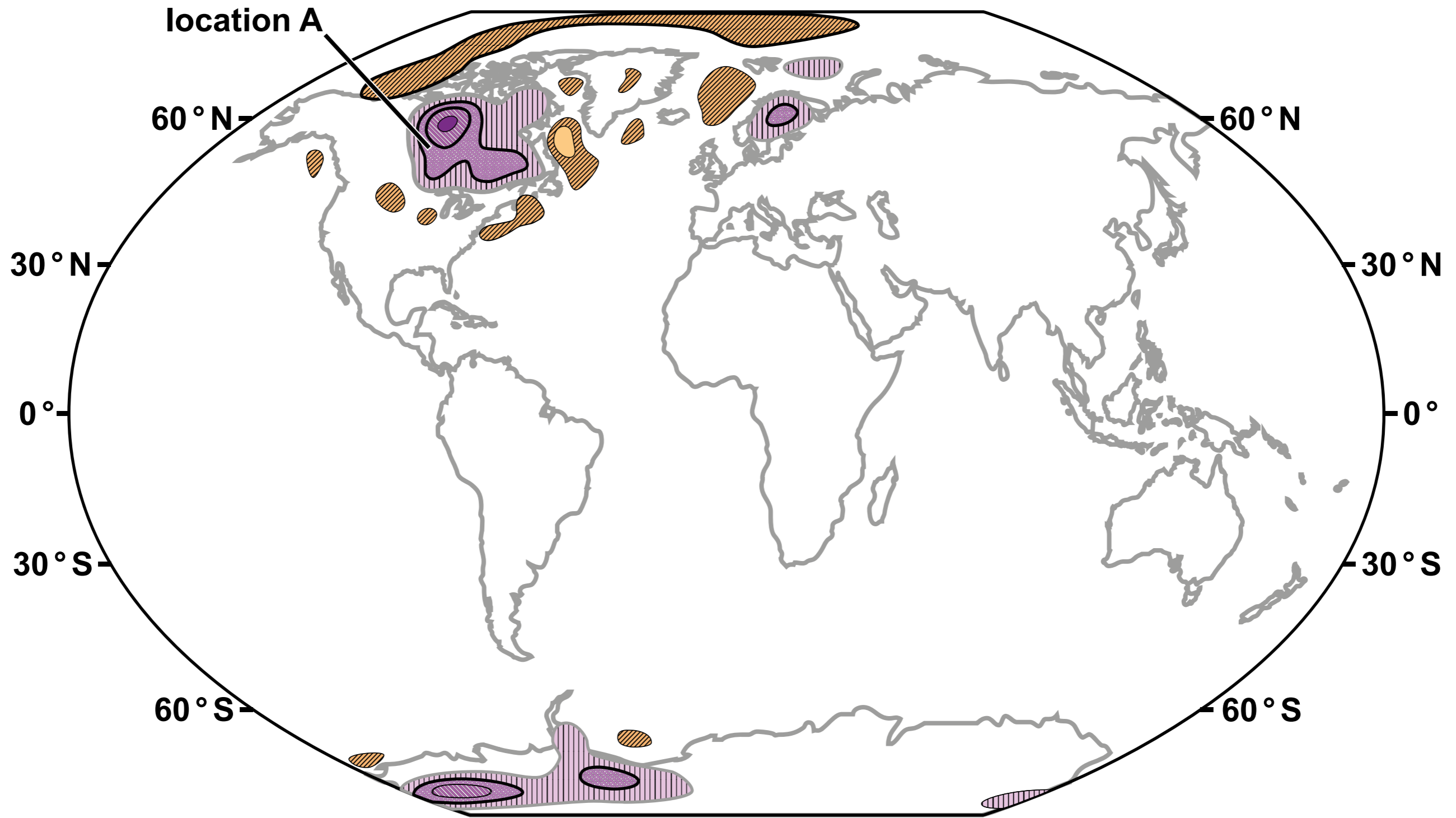


FIGURE 8a



Key:

Present-day rate of crustal uplift (mm yr<sup>-1</sup>)

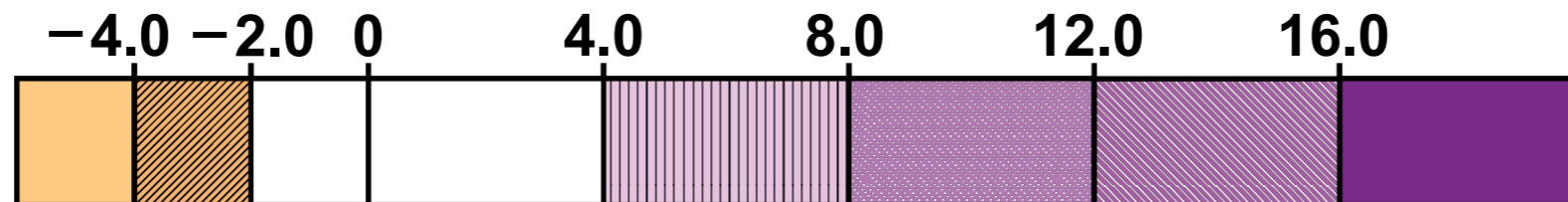


FIGURE 8b

Rate of crustal uplift  
(mm yr<sup>-1</sup>)

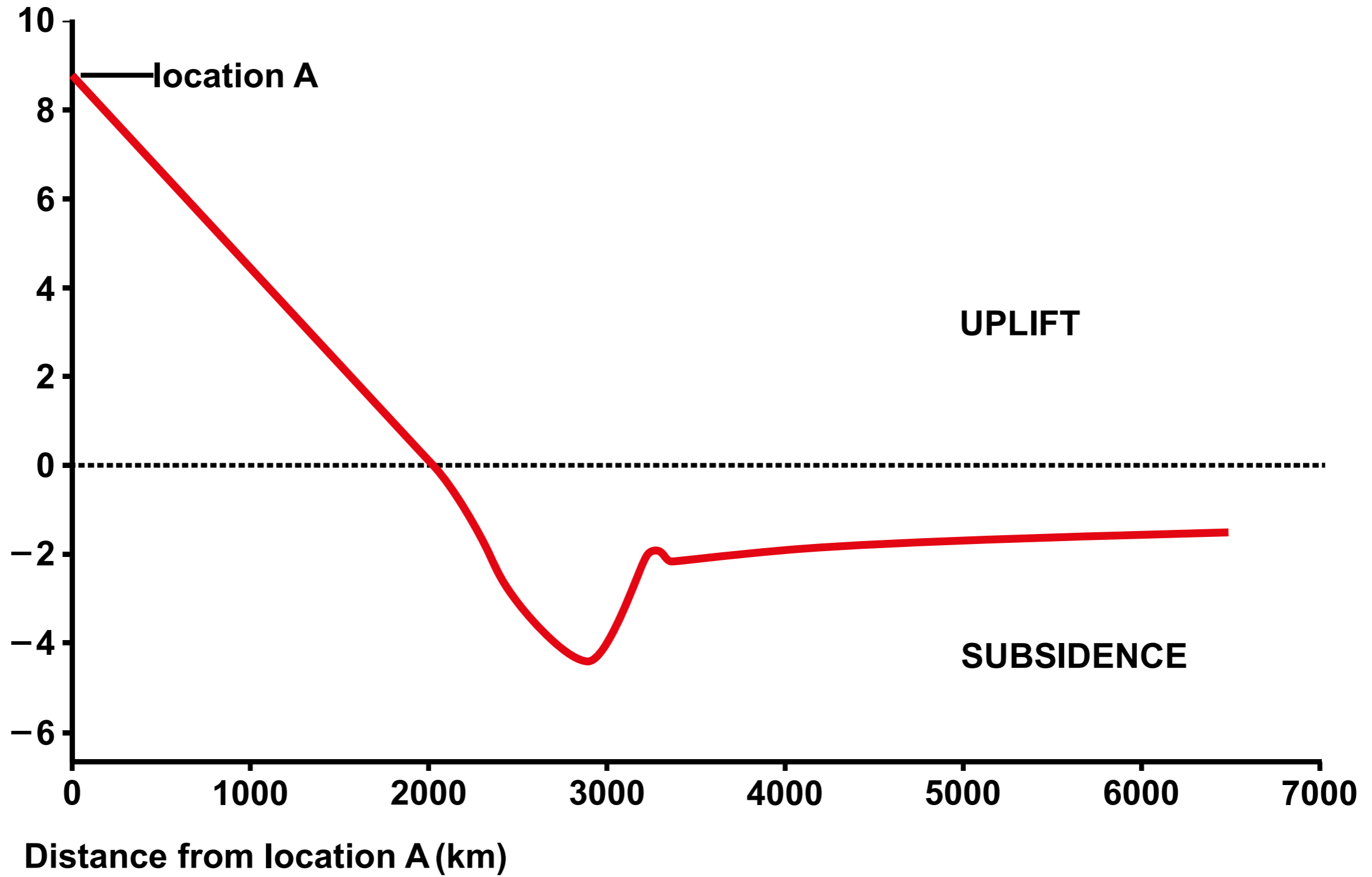
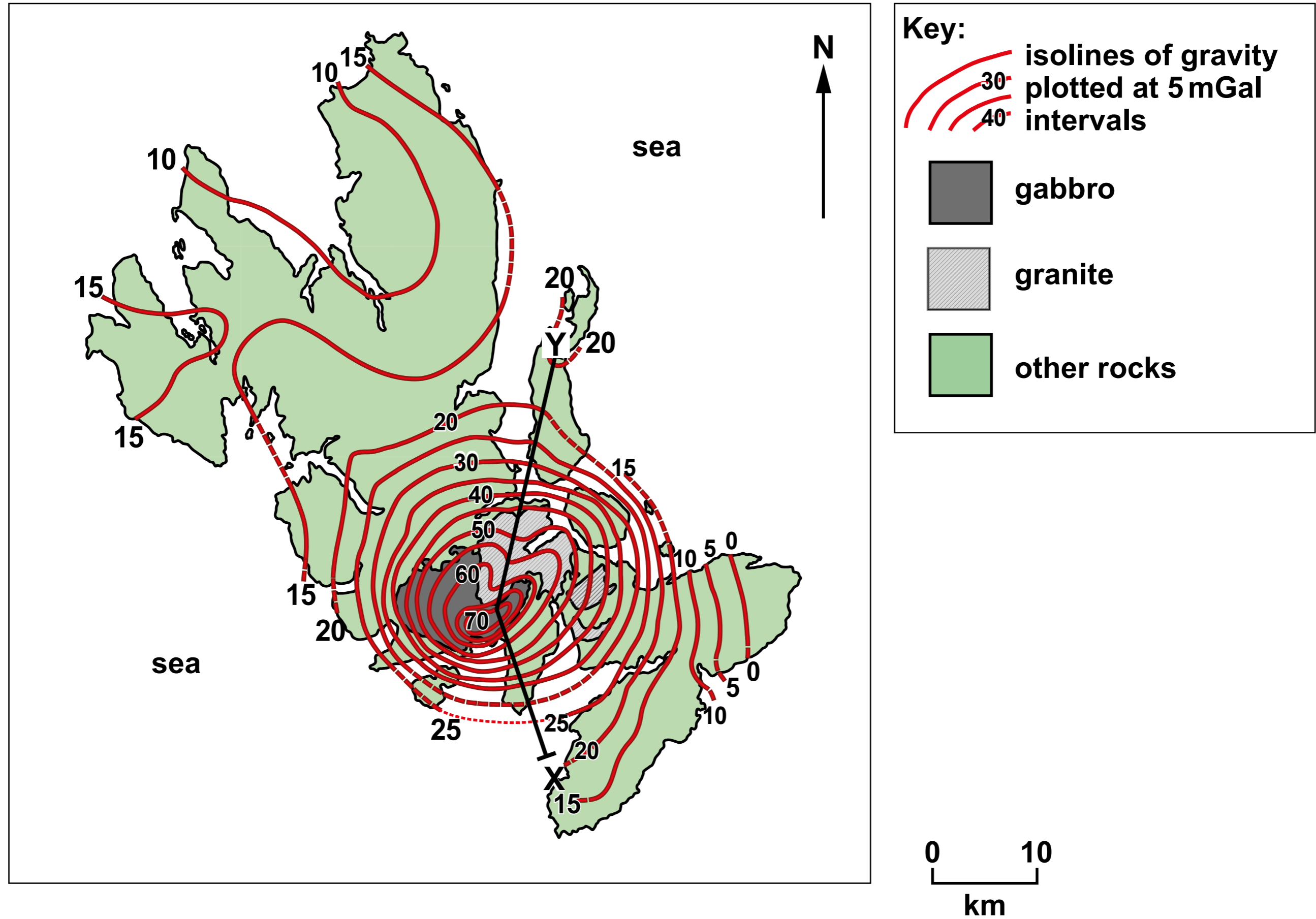


FIGURE 10a



**FIGURE 10b**

**Bouguer gravity anomaly (mGal)**

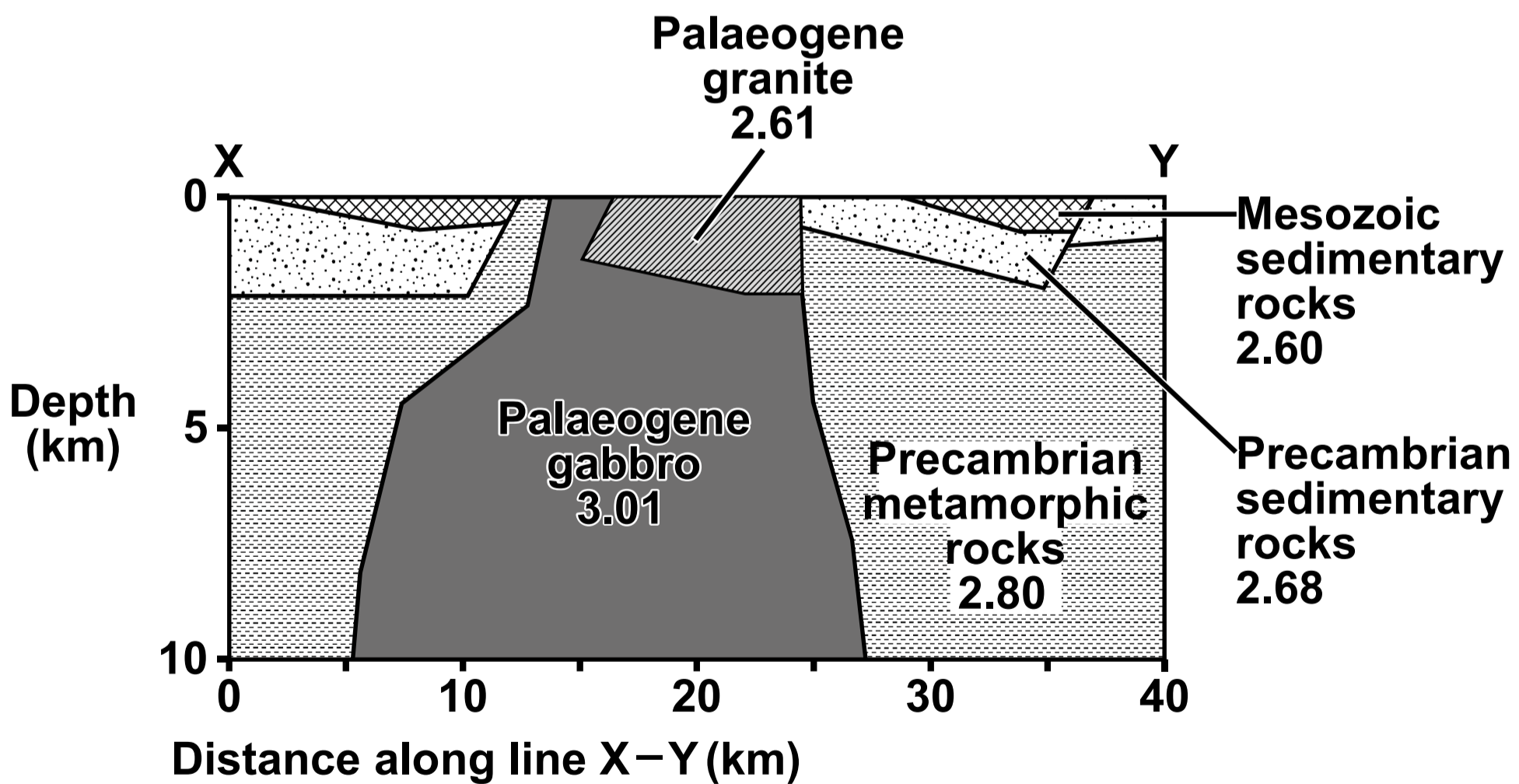
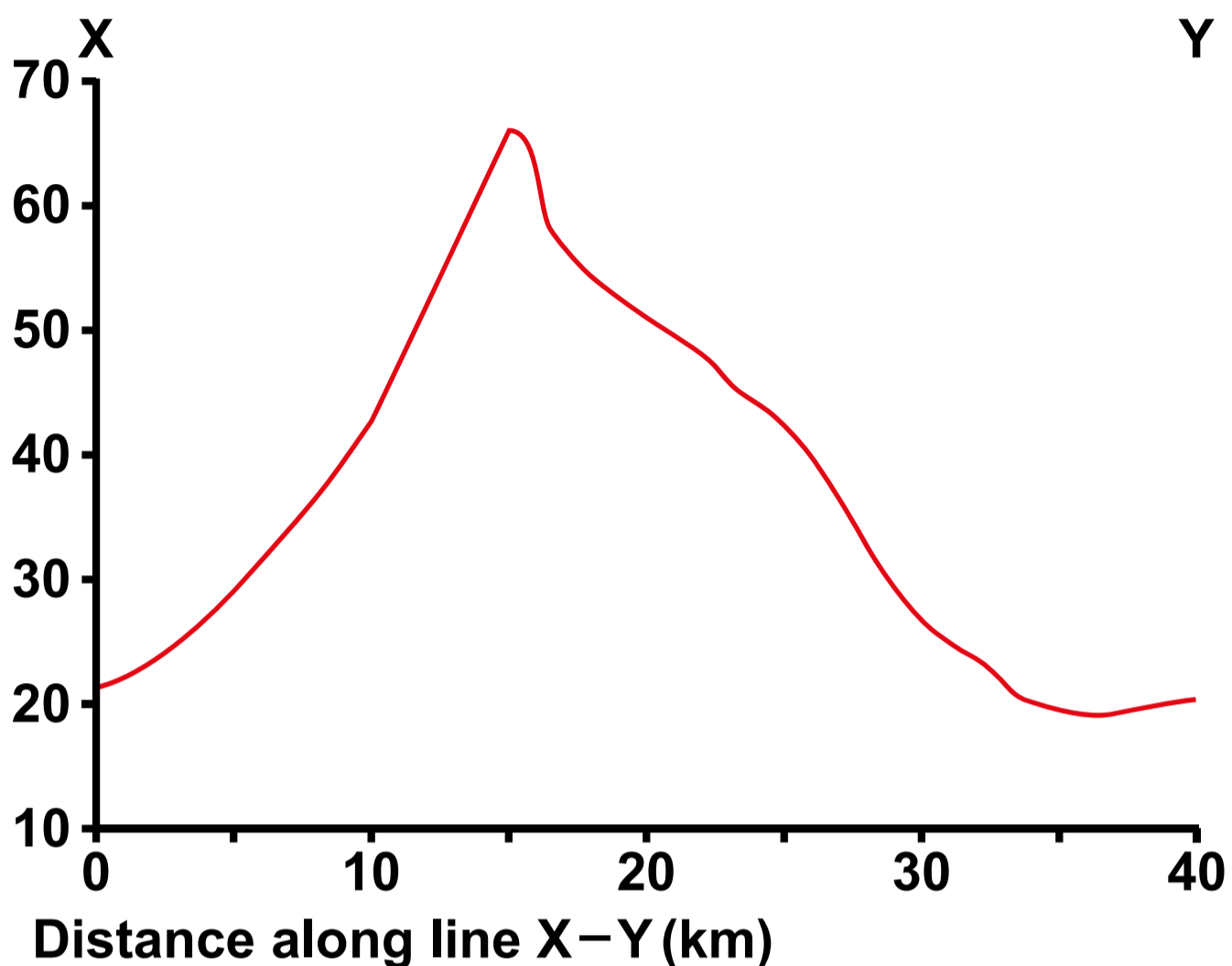


FIGURE 11a

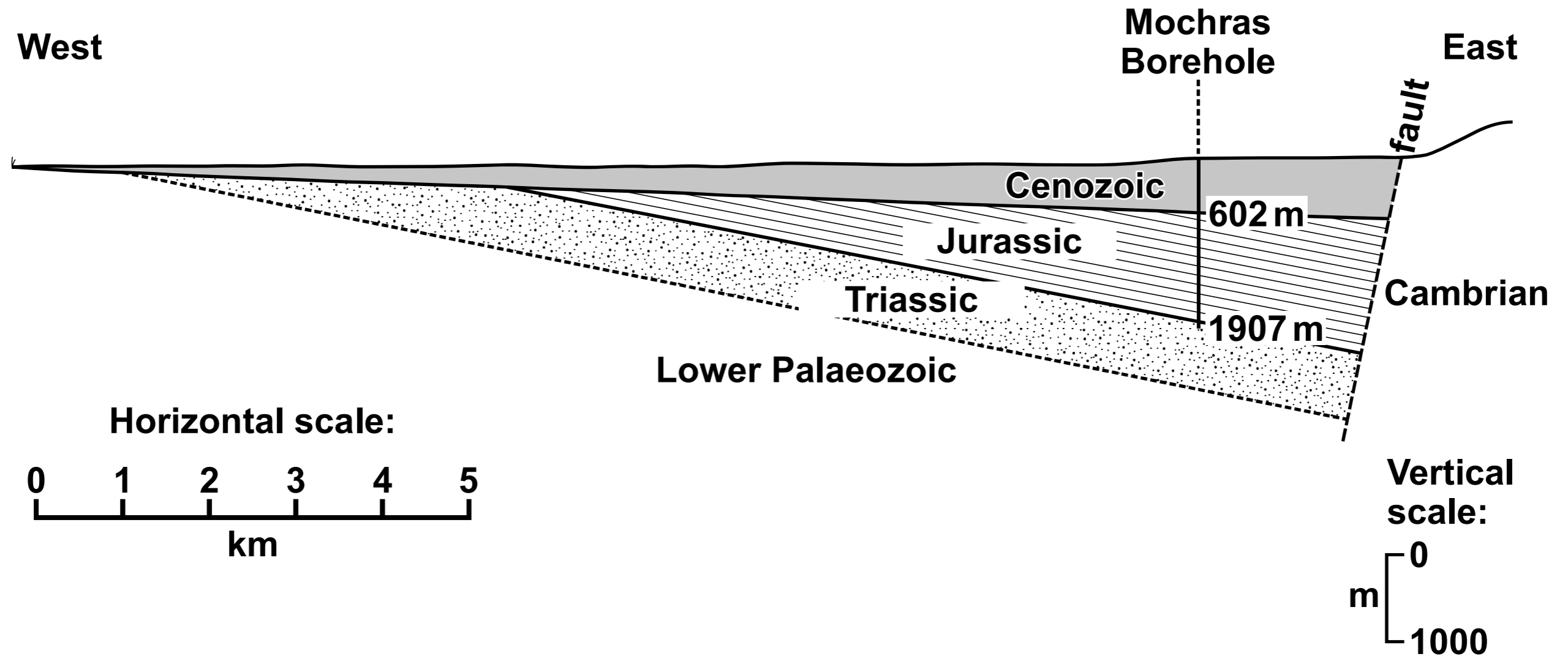


Figure 11b

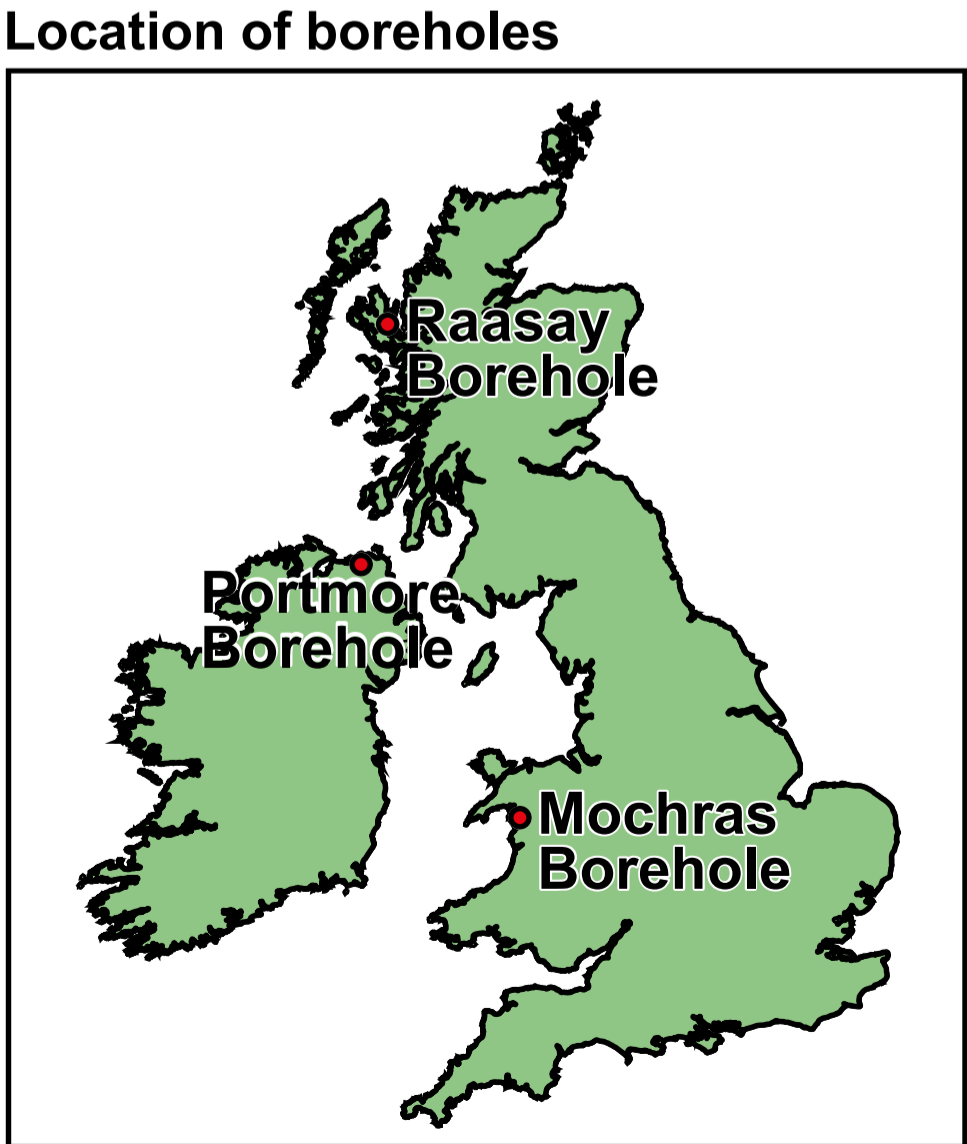
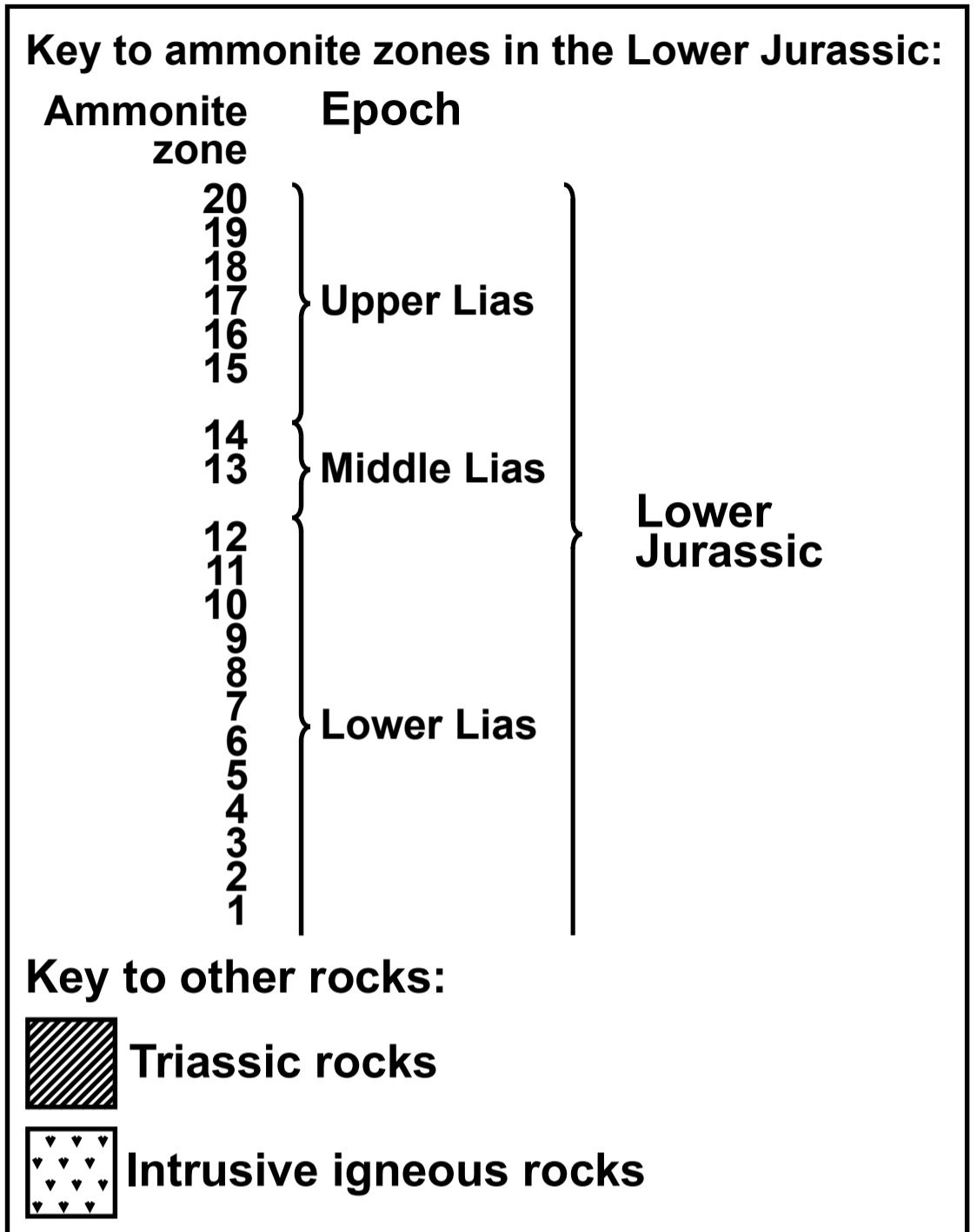
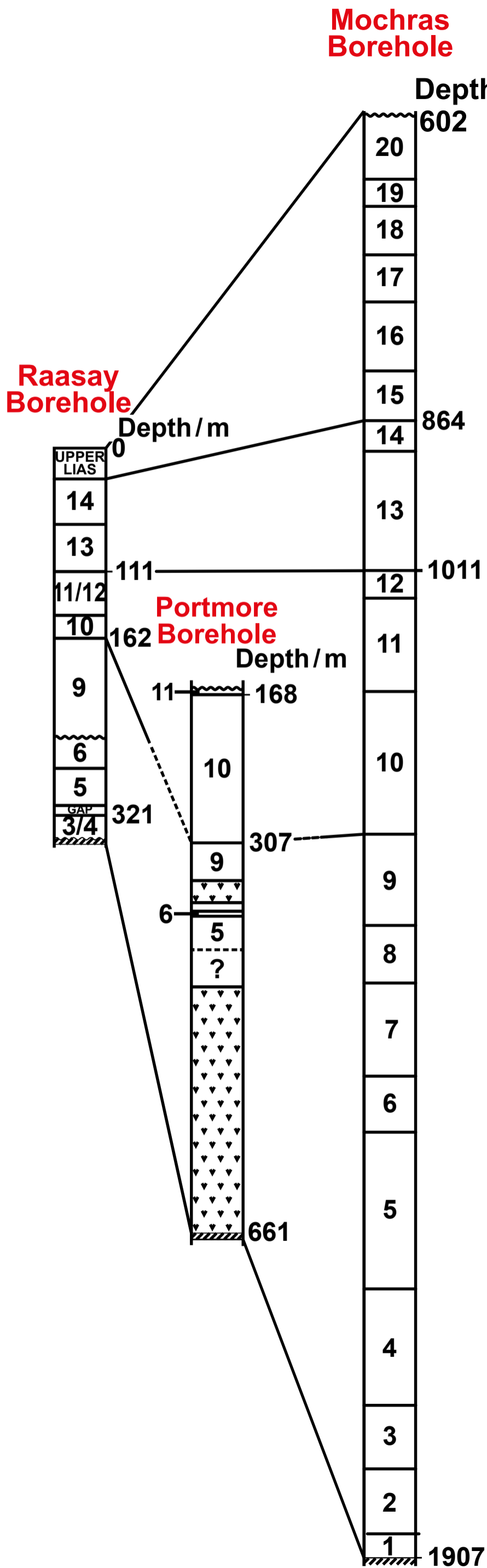
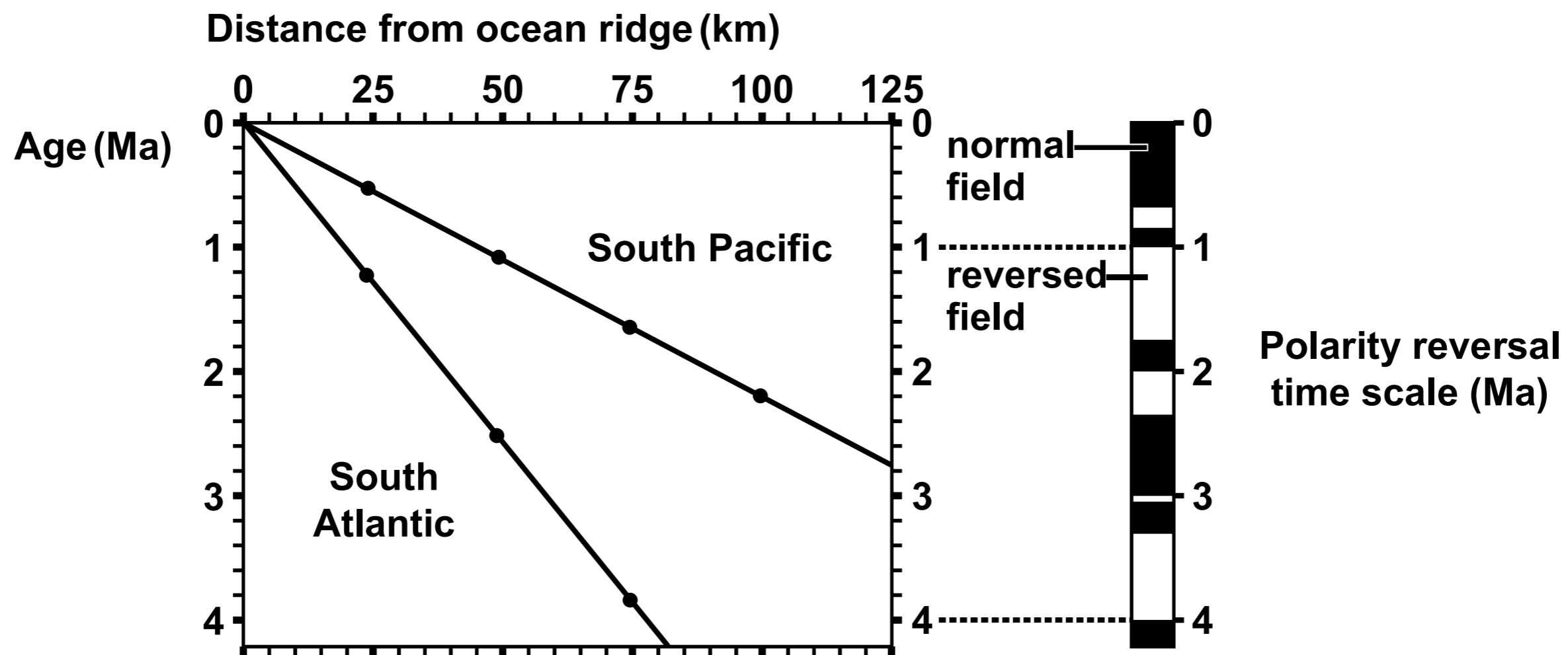


FIGURE 13a



**FIGURE 13b**

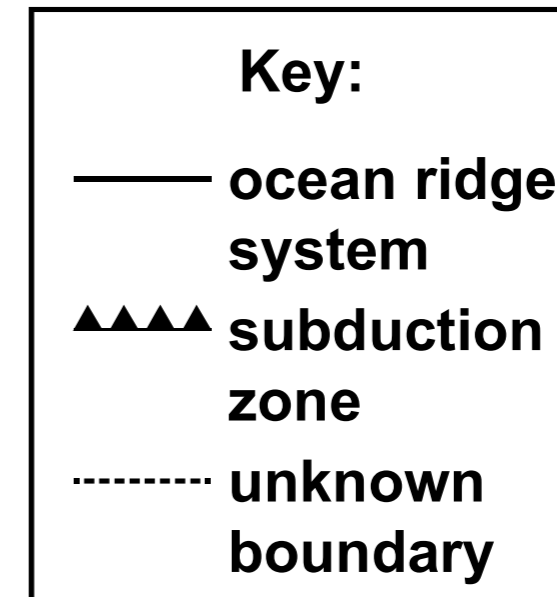
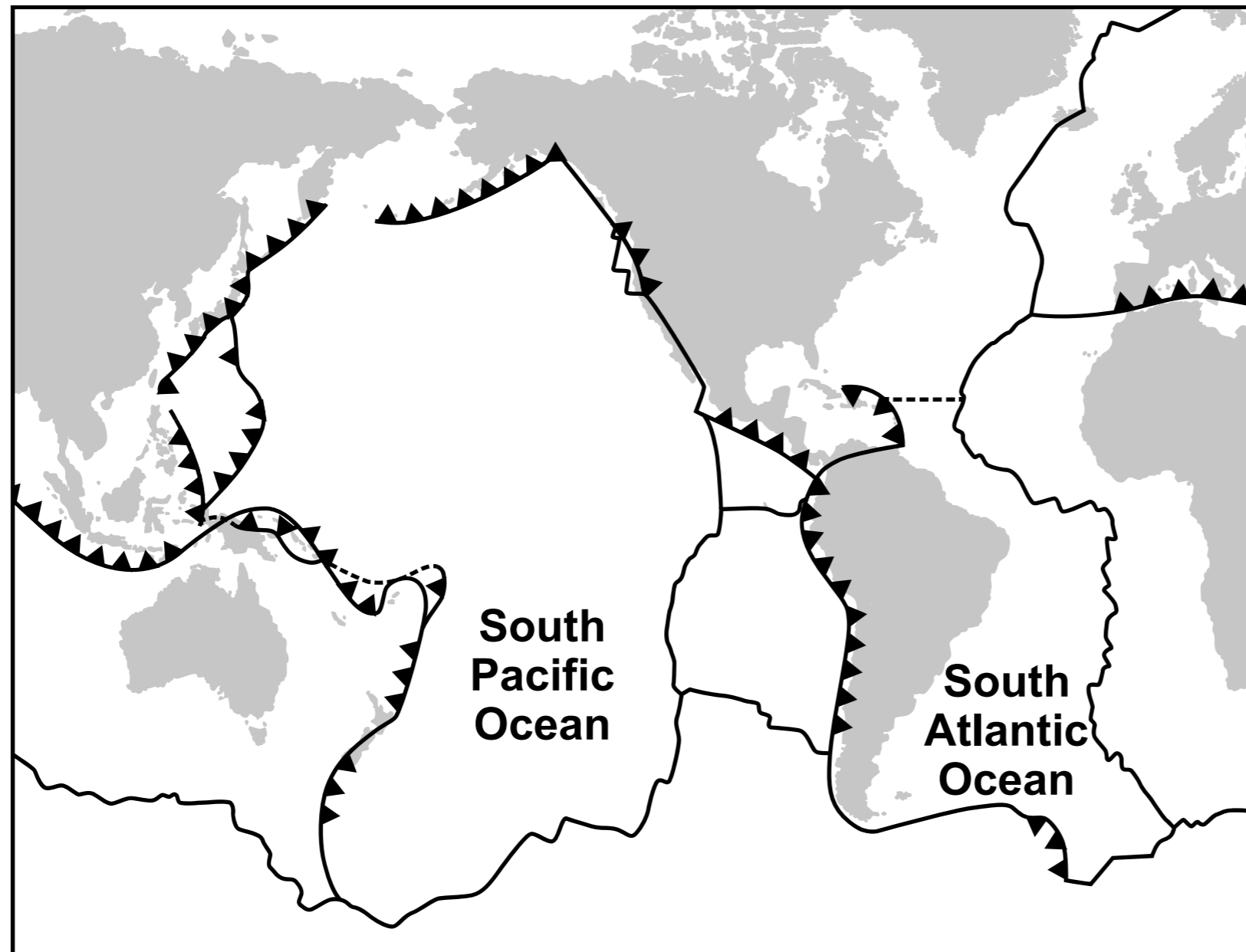


FIGURE 14a

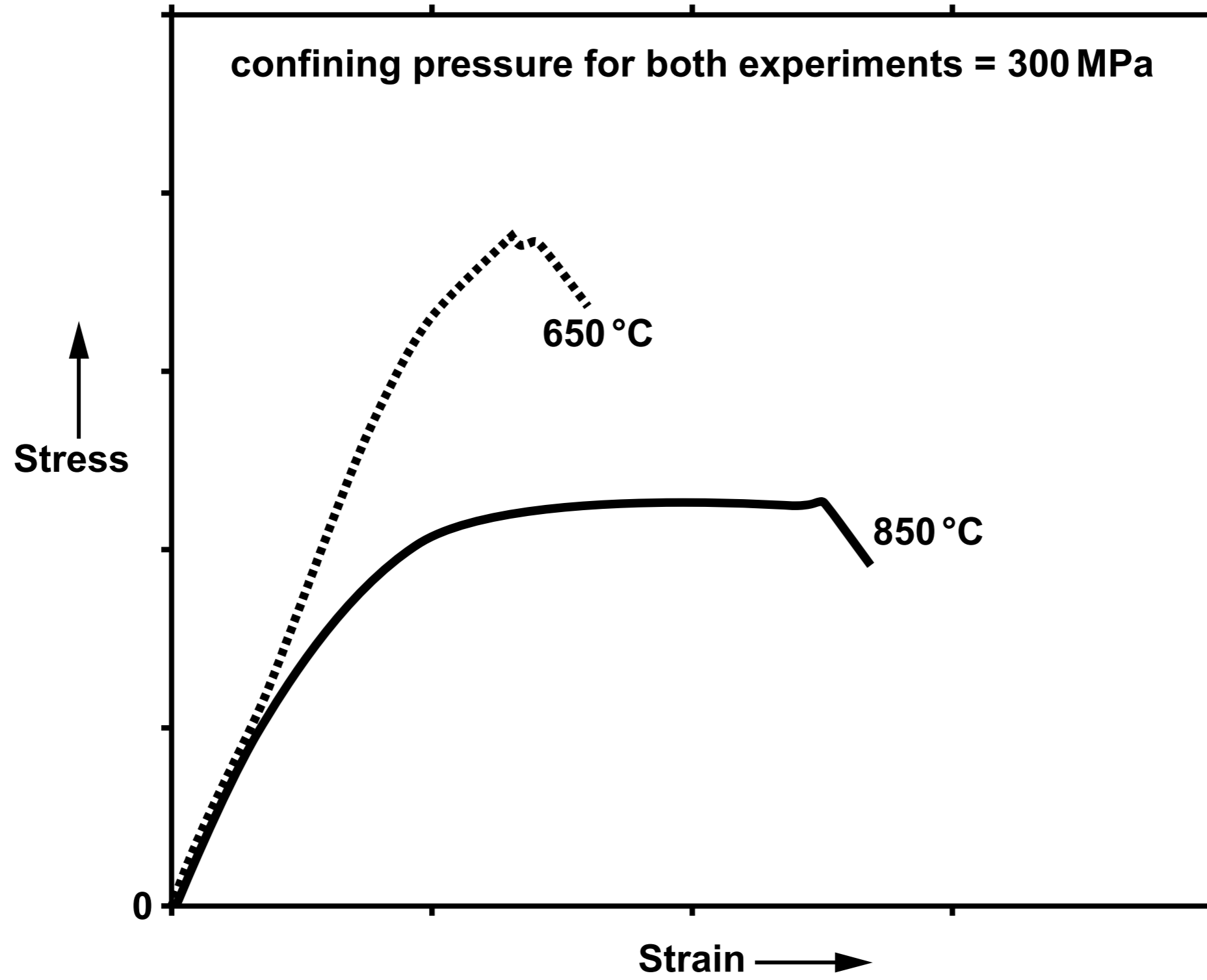
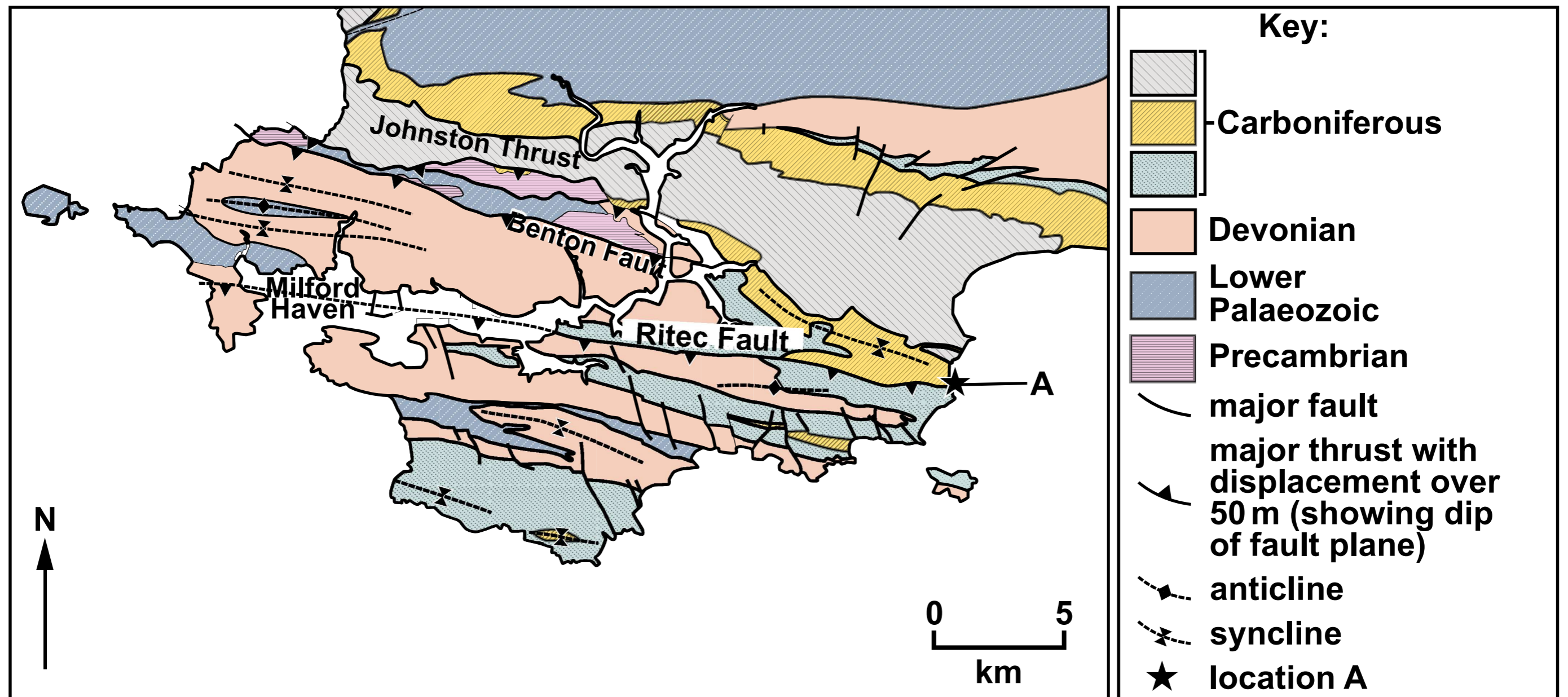
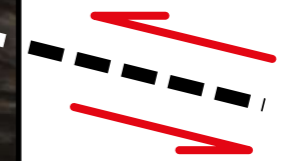


FIGURE 14b



**FIGURE 14c**



**Relative fault  
movement**