



GCE A LEVEL

A480U30-1

TUESDAY, 21 JUNE 2022 - MORNING

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

2 hours plus your additional time allowance

Surname

First name(s)

Centre Number

Candidate Number

2

ADDITIONAL MATERIALS

In addition to this examination paper, you will need:

- **a calculator**
- **a ruler**
- **the Geological Map Extract (Chesterfield)**

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 alongside 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 (a) **FIGURE 1a** opposite is a map of 20th century Mexican earthquakes.

(a) Refer to **FIGURE 1a**.

(i) Determine the distance, in kilometres, from the epicentre of the 1985 earthquake to Mexico City.

[1 mark]

_____ km

(ii) Calculate the time, in seconds, that it took the surface seismic waves to reach Mexico City from the epicentre of the 1985 earthquake if their velocity was 3.9 km s^{-1} . Show your working. [2 marks]

_____ s

(Turn over)

1 (a) (iii) With reference to FIGURE 1a only, explain why Mexico City is at risk from seismic geohazards.

[3 marks]

1 (b) **FIGURE 1b opposite shows some of the effects of the 1985 earthquake (M_w 8.1) in part of Mexico City.**

Refer to FIGURE 1b.

(i) **Describe the differences in the seismic traces between solid bedrock close to Mexico City and location A in Mexico City. [2 marks]**

2 FIGURE 2 opposite is a cross-section through an area where radon gas has been detected.

Refer to FIGURE 2.

(a) (i) State ONE risk to the local population created by the concentration of radon gas. [1 mark]

(ii) Suggest the most likely geological origin of the radon gas detected in this area. [2 marks]

(Turn over)

- 2 (b) The values of hydraulic conductivity (k) for weathered granite and clay are shown on FIGURE 2.
- (i) Calculate the hydraulic conductivity (k) of the sandstone using Darcy's Law. [3 marks]

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

where: $Q = 2.5 \times 10^{-2} \text{ m}^3 \text{ s}^{-1}$ (flow rate)

$A = 1.0 \text{ m}^2$ (cross-sectional area)

$h_2 - h_1 =$ difference in height of water table in boreholes 1 and 2 (m)

$L =$ horizontal distance between boreholes 1 and 2 (m)

Show your working.

$k =$ _____ ms^{-1}

(Turn over)

2 (b) (ii) Explain the geological reasons for the differences in the radon gas measurements at locations X, Y and Z. [4 marks]

2 (c) (i) Explain how radon gas measurements might be used to monitor earthquake activity along the fault. [3 marks]

2 (c) (ii) Explain ONE OTHER monitoring method that could be used to attempt to predict seismic hazards. [2 marks]

15

SECTION B

Answer ALL questions in the spaces provided.

Questions 3–6 relate to the BRITISH GEOLOGICAL SURVEY GEOLOGICAL MAP extract from the Chesterfield Sheet 112 (Solid and Drift)

3 Refer to the GEOLOGICAL MAP and key.

(a) Using the key on the GEOLOGICAL MAP, complete TABLE 3 opposite by stating the superficial deposit found at the grid reference (GR) indicated and the probable mode of formation of the superficial deposit where appropriate. [3 marks]

(Turn over)

- 3 (b) Refer to the **GENERALISED GEOLOGICAL COLUMN**, key and **BOX H** on the **GEOLOGICAL MAP**.

Complete **TABLE 4** opposite by inserting the following events from **BOX H** in order of their relative ages – oldest at the base.

Ashover Grit (AsG) landslide Head (B h)

[2 marks]

5

(Turn over)

- 4** **FIGURE 4** opposite shows a limestone fragment containing fossils. It was found by a student within the Head (B_h), at GR 342565 on the GEOLOGICAL MAP.

The student was able to accurately locate the position of the rock fragment in the field without the use of GPS.

- (a) Explain how the student might have located the position of this rock fragment in the field using traditional navigation and basic field survey skills, without the use of GPS.
You may choose to illustrate your answer with an annotated diagram. [3 marks]

4 (b) (i) State the fossil group to which the fossils within the fragment in FIGURE 4 belong.

Give ONE reason for your choice. [2 marks]

Fossil group _____

Reason _____

4 (b) (ii) Describe the environment of deposition indicated by the presence of these fossils. [3 marks]

4 (b) (iii) The presence of these fossils in the Head (B ^h) appears to contradict the environment of deposition indicated by the Head.
Explain this apparent contradiction. [3 marks]

11

5 The axial plane traces of two plunging folds (P and Q) are marked on FIGURE 5a opposite.

(a) Refer to FIGURE 5a and the GEOLOGICAL MAP.

(i) Complete TABLE 5 by stating the evidence from the GEOLOGICAL MAP for the characteristics of fold P.

[3 marks]

TABLE 5

Characteristics of fold P	Evidence
Antiform	•
Anticline	•
Plunge to the N–NNE	•

(ii) In each of the TWO blank boxes on FIGURE 5a, indicate the direction of plunge of fold Q at both locations. Use the plunge symbol in the key.

[2 marks]

(Turn over)

5 (a) (iii) A student described the plunging folds as having a wavelength of approximately 0.75 km. Evaluate this conclusion. [2 marks]

5 (b) Refer to the line of section S–T on the GEOLOGICAL MAP and the sketch cross-sections (W, X, Y and Z) in FIGURE 5b opposite.

(i) State which of the sketch cross-sections (W, X, Y or Z) is most likely to represent the geological structure along the line of section S–T. Justify your answer. [3 marks]

Sketch cross-section along S–T (W, X, Y or Z).

- 6** **FIGURE 6** opposite is a rose diagram showing the distribution of landslides in the Chesterfield region (which includes the area of the **GEOLOGICAL MAP**) based on the direction the landslide slope faces (slope aspect).

A student undertook a field investigation into the orientation of these landslides to test the hypothesis that slope aspect was important in landslide development.

TABLE 6 opposite is a partly completed chi-squared test used to test the null hypothesis (H_0) that “there is no significant orientation of the landslides”.

(a) Refer to FIGURE 6 and TABLE 6.

(i) Complete FIGURE 6 by plotting the observed frequency (O) of landslide orientations to the North (N) shown in TABLE 6. [1 mark]

(ii) Complete the blank cells in TABLE 6 for landslide orientations to the South (S). [2 marks]

6 (a) (iii) Using the significance chart (TABLE 7 opposite) explain why the chi-squared value of these data means the null hypothesis (H_0) can be rejected at the 0.01 confidence level. [2 marks]

(iv) Explain why it was important to test the data in the rose diagram statistically before making conclusions. [2 marks]

(Turn over)

6 (b) Explain how the freeze-thaw process might contribute to mass movement on slopes.

[3 marks]

(Turn over)

6 (c) Refer to the GEOLOGICAL MAP and GEOLOGICAL CROSS-SECTION (J–K).

The following conclusions are from a report into landslides in the Chesterfield area.

“In addition to slope aspect, landslide development appears to be directly influenced by

- dip angle and direction of the bedrock**
- bedrock type**
- river erosion**
- the formation of the superficial Head deposit.”**

Evaluate the report’s conclusions with reference to the THREE landslides labelled A, B and C on the GEOLOGICAL MAP. [6 marks]

(Turn over)

SECTION C

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

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

Quaternary Geology

Geological Evolution of Britain

Geology of the Lithosphere

OPTION 1: QUATERNARY GEOLOGY

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

- 7** **FIGURE 7a** opposite is a reconstruction of Antarctic sea surface temperature change over the last 40 Ma.

(Turn over)

7 (a) Refer to FIGURE 7a.

(i) Describe the change in Antarctic sea surface temperature over the last 40 Ma. [2 marks]

(ii) Explain how oxygen isotope evidence from oceanic sediments could be used to reconstruct sea surface water temperature over the last 40 Ma. [2 marks]

(Turn over)

7 (b) FIGURE 7b opposite shows the likely position of continents and oceanic circulation in the Palaeogene. FIGURE 7c opposite shows the position of continents and oceanic circulation in the Quaternary.

Refer to FIGURE 7b and FIGURE 7c.

(i) Describe how the changing position of the continents since the Palaeogene has altered patterns of oceanic circulation in the Atlantic and Pacific Oceans. [3 marks]

7 (b) (ii) Explain how the changes in oceanic circulation may have led to the change in Antarctic sea surface temperature over the last 40 Ma shown in FIGURE 7a. [2 marks]

7 (b) (iii) Suggest how the changes in oceanic circulation might have affected sea surface temperatures in Northern Europe at LOCATION T over the last 40 Ma. Give a reason for your answer.

[3 marks]

12

- 8 **FIGURE 8** opposite is a tree pollen diagram from a site at an altitude of 450 m in the Brecon Beacons, Wales, that was glaciated in the past.

Refer to **FIGURE 8**.

- (a) No pollen was found in this location at a depth of 6 metres. Suggest **ONE** reason for this. [1 mark]

(Turn over)

8 (b) (i) Juniper has been identified as a “pioneer species” that occupies bare ground rapidly after a change in climate. State how FIGURE 8 supports this interpretation. [2 marks]

(ii) Describe the changes in the tree pollen in pollen zones 2, 3 and 4. [3 marks]

8 (b) (iii) Suggest why the abundance of oak and alder changes in pollen zones 5, 6 and 7. [2 marks]

6

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 seismic section through part of the North Sea.
FIGURE 10b opposite is an interpretation of the geology in the section.

(a) Refer to FIGURE 10a.

Explain what is meant by “two-way travel time”.

[2 marks]

(Turn over)

10 (b) Refer to FIGURE 10b.

The Middle Triassic rocks of the North Sea area contain thick deposits of salt.

(i) Explain how thick deposits of salt were laid down in the British area during the Triassic. [2 marks]

(ii) Explain why the Middle Triassic rocks cut across younger rocks in some places. [2 marks]

(Turn over)

10 (c) The faulting shown on FIGURE 10b is largely related to the opening of the North Atlantic Ocean.

Refer to FIGURE 10b.

(i) State the type of stress (compression or tension) to which these rocks were subjected.

Stress type _____

Explain the reasons for your choice. [2 marks]

Explanation: _____

- 11 **FIGURE 11a** opposite is a simplified geological map of the **Builth Wells Inlier**, an area in **Wales**.
FIGURE 11b opposite page 49 shows the three types of graptolite named in the key to **FIGURE 11a**.

11 (a) State the type of boundary between the Ordovician and Silurian rocks from locations A to B on FIGURE 11a. Give ONE reason for your answer. [2 marks]

Type of boundary: _____

Reason: _____

11 (b) Refer to FIGURES 11a and 11b.

- (i) With reference to the key in FIGURE 11a, state which of the fossils, J, K or L shown in FIGURE 11b is **Glyptograptus**. Give **TWO** reasons for your answer.

[3 marks]

Fossil:

Reasons: _____

11 (b) (ii) The sedimentary environment of this area during the Ordovician has been interpreted as “a low energy marine environment”.

Explain why this interpretation is regarded as being correct. [3 marks]

11 (c) The rocks in BOX Z on Figure 11a have been folded.

(i) Mark in BOX Z the axial plane trace of ONE fold, using the correct symbol from the key. Describe the evidence for your choice of fold type. [2 marks]

11 (c) (ii) A student suggested that “the rocks of the Builth Wells Inlier were deformed during an early stage of the Caledonian Orogeny”. Evaluate this statement with reference to the evidence on FIGURE 11a. [3 marks]

13

6

OPTION 3: GEOLOGY OF THE LITHOSPHERE

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

13 FIGURE 13a opposite shows the age distribution of orogenic belts in the continental area of North America. FIGURE 13b opposite page 57 shows a simplified cross-section along the line W–X on FIGURE 13a as it might have looked 5 Ma ago.

(a) With reference to FIGURE 13a, describe the age distribution of orogenic belts in the continental area of North America. [3 marks]

(Turn over)

13 (b) Refer to FIGURE 13b opposite.

State the name for the sequence of rocks
labelled Z in FIGURE 13b.

Explain your answer. [2 marks]

Name _____

Explanation _____

13 (c) The Columbia River Basalt Plateau in FIGURE 13b is an example of a large igneous province (LIP), interpreted as the product of a mantle plume. Explain the evidence in FIGURE 13b which might support this interpretation. [3 marks]

14 FIGURE 14a opposite is a model of partial melting associated with continental lithosphere showing the geothermal gradient (geotherm), together with the melting point curve (solidus) for the crust and upper mantle. FIGURE 14b opposite is a variation of the model with a thinner continental lithosphere.

(a) Refer to FIGURE 14a.

(i) State the approximate thickness of continental crust in FIGURE 14a. [1 mark]

_____ km

(Turn over)

14 (a) (ii) State TWO pieces of evidence in FIGURE 14a to confirm that the crust refers to CONTINENTAL crust and NOT oceanic crust. [2 marks]

1. _____

2. _____

14 (b) (i) Explain why partial melting does NOT occur under the conditions shown in FIGURE 14a.

[1 mark]

(ii) Shade on FIGURE 14b where the model predicts that partially molten material will be generated.

[2 marks]

14 (c) The continental lithosphere in FIGURE 14b is half as thick as in FIGURE 14a. FIGURE 14c opposite shows the process of delamination that has been proposed to account for thinning of the continental lithosphere beneath a thick orogenic belt.

Refer to FIGURE 14c.

Explain how it is proposed the continental lithosphere is thinned beneath the orogenic belt in FIGURE 14c. [3 marks]

14 (d) Describe the pattern of pluton ages in the orogenic belt in FIGURE 14c. Suggest an explanation for this pattern. [3 marks]

12

ACKNOWLEDGEMENTS

FIGURES 1b and 1c: Adapted from: Frampton, S. et al (2000) Natural Hazards: causes, consequences and management. Hodder & Stoughton.

FIGURE 8: Adapted from: Walker, M.J.C. Craig Cerriglesiad: pollen stratigraphy and dating. In Carr. S.J. et al (2007) Quaternary of the Brecon Beacons; Field Guide. Quaternary Research Association, London.

FIGURES 10a and 10b: Charles, R. & Ryzhikov, K. (2015). Merganser Field; managing subsurface uncertainty in the UK Central North Sea. Geol. Soc. Spec. Pub. 403, 261-298.

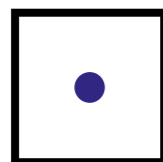
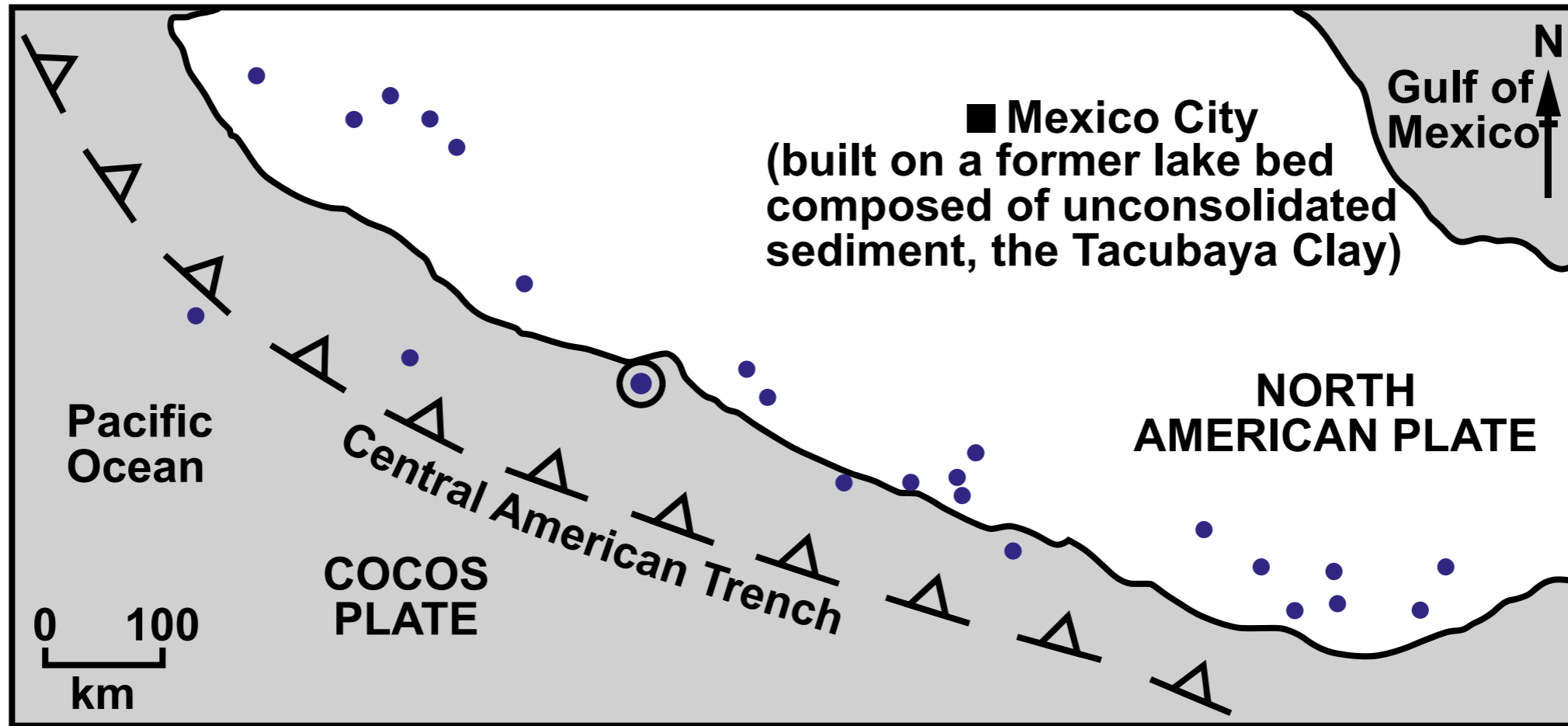
FIGURE 11a: Bevins, R.E & Metcalfe, R. (1993) Ordovician Igneous Rocks, Builth. In: Bassett, M.G. & Woodcock, N.H. (eds.) Geological Excursions in Powys. University of Wales Press.

FIGURE 11b: Photographs M. Walsh; specimens courtesy of the National Museum of Wales.

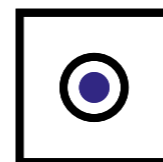
For Examiner's use only			
	Question	Maximum Mark	Mark Awarded
Section A	1.	15	
	2.	15	
Section B	3.	5	
	4.	11	
	5.	13	
	6.	16	
Section C option		12	11
		12	13
		6	
	Total	105	

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

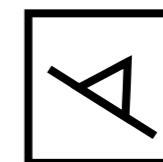
FIGURE 1a



epicentres of 20th century Mexican earthquakes (>M_w7.75)



epicentre of 1985 earthquake



trench

FIGURE 1b

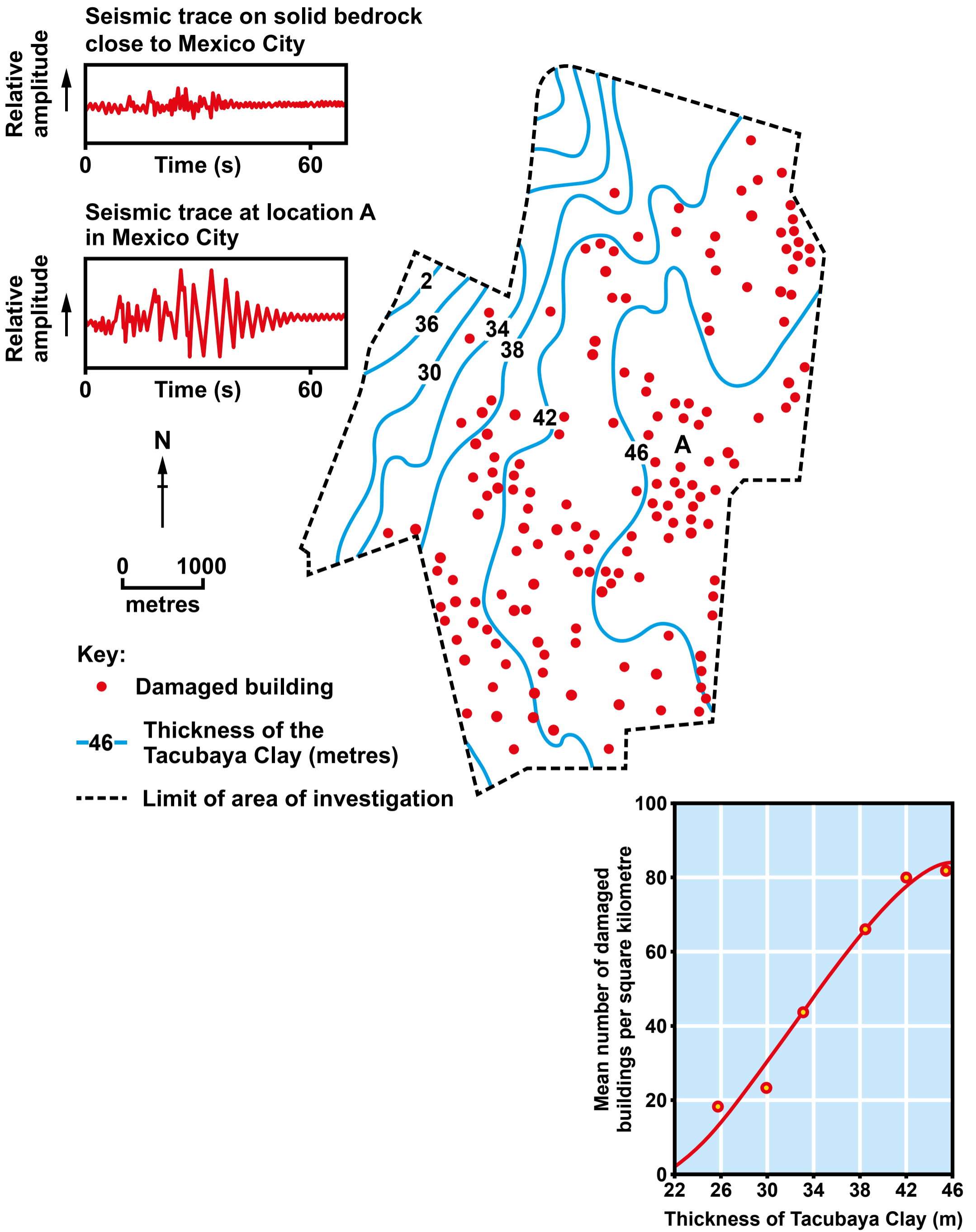


FIGURE 1c

**Percentage of damaged buildings
in Mexico City**

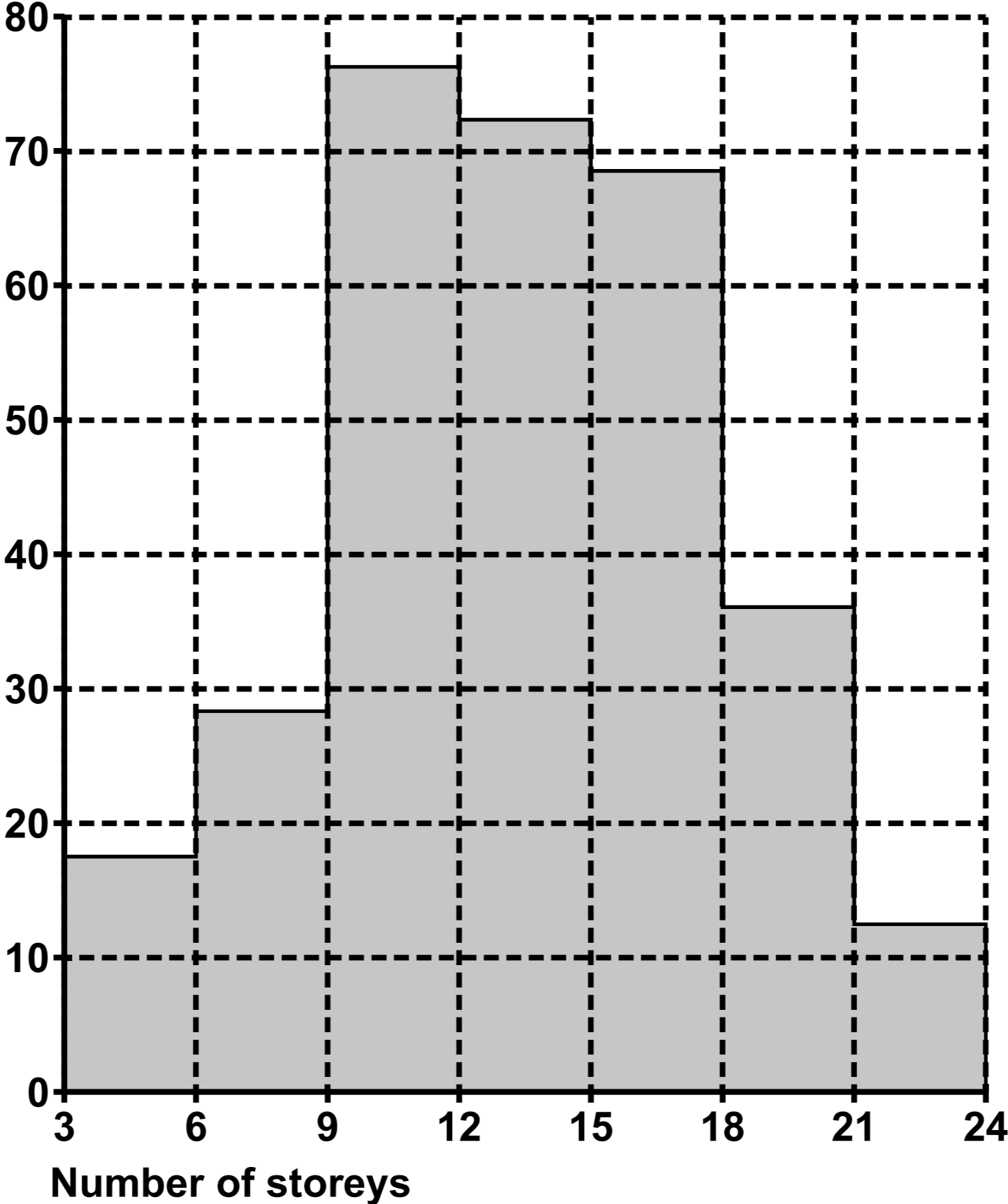
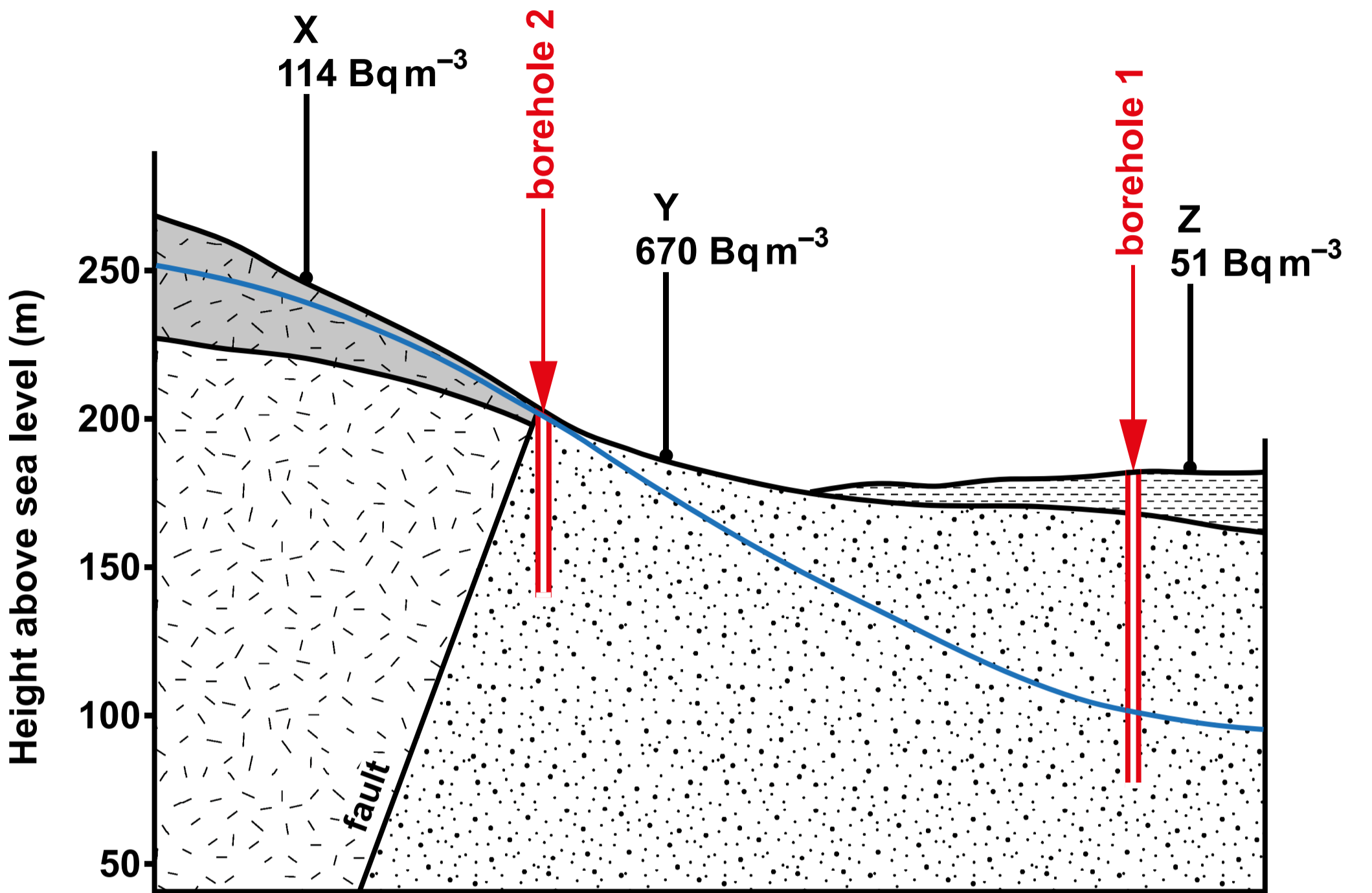



FIGURE 2



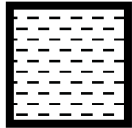
Key:

Lithology

 weathered granite
 $k = 10^{-4} \text{ m s}^{-1}$

 granite

 sandstone

 clay
 $k = 10^{-8} \text{ m s}^{-1}$

Horizontal scale:

0 1000
metres

Other features

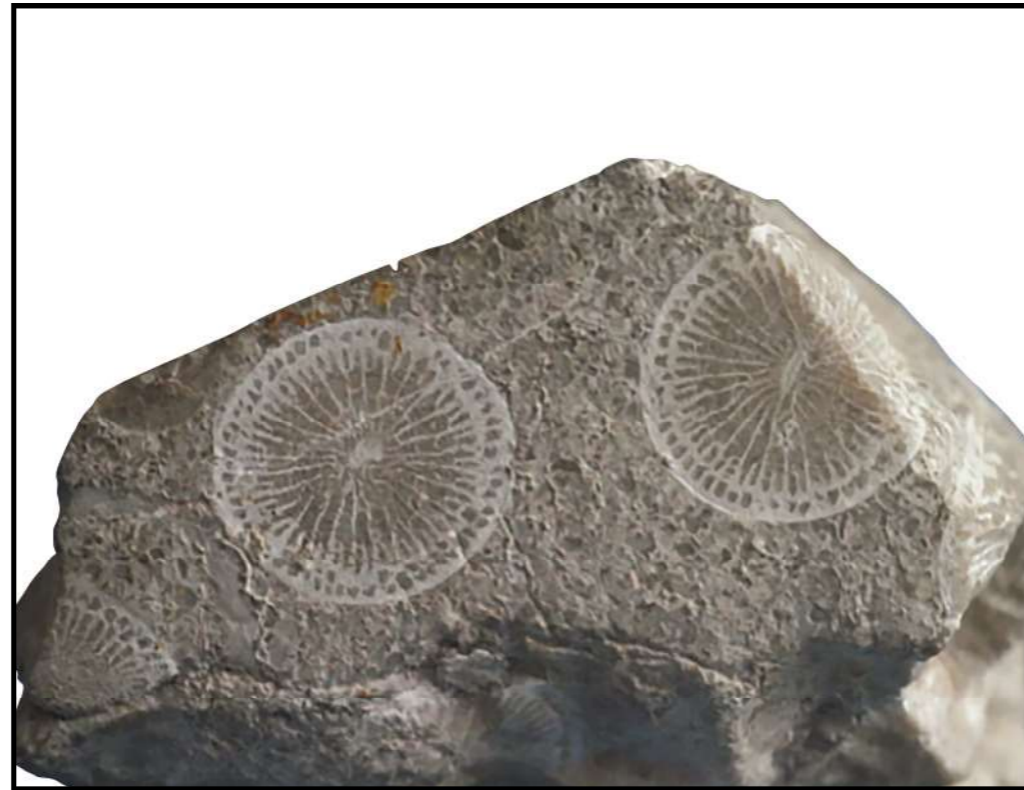
 water table

363 Bq m⁻³
radon gas measurement
(units are number of
radioactive decays per
second (Bequerels – Bq)
per cubic metre)

TABLE 3

Grid reference (GR)	Superficial deposit	Formation
303570	•	•
330555	•	Freeze-thaw processes during the Quaternary

FIGURE 4

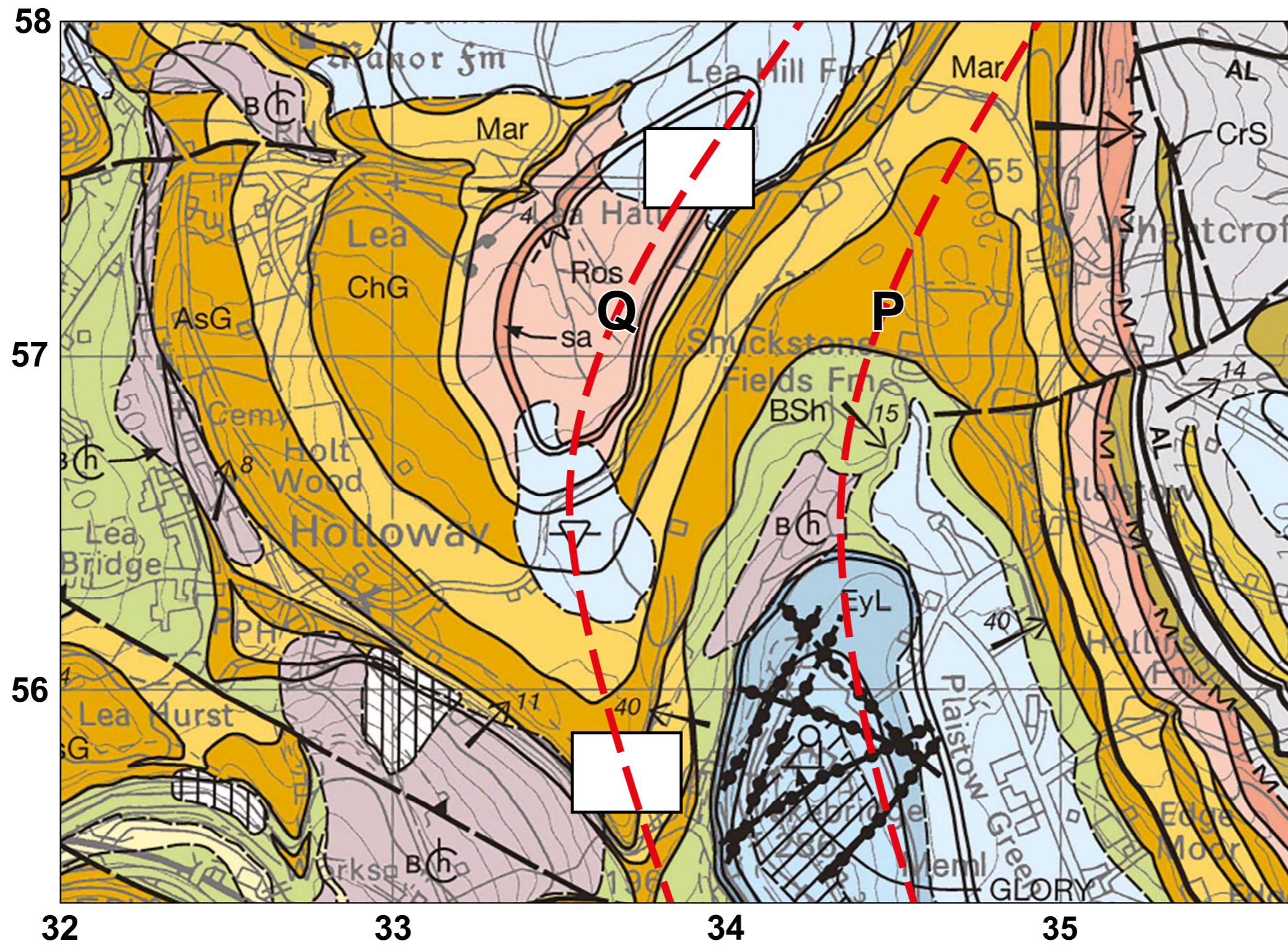


0 1
cm

TABLE 4

Relative age	Events
Youngest	•
	•
Oldest	•

FIGURE 5a




Key:
 Axial plane trace
(arrow heads show
direction of plunge)

FIGURE 5b

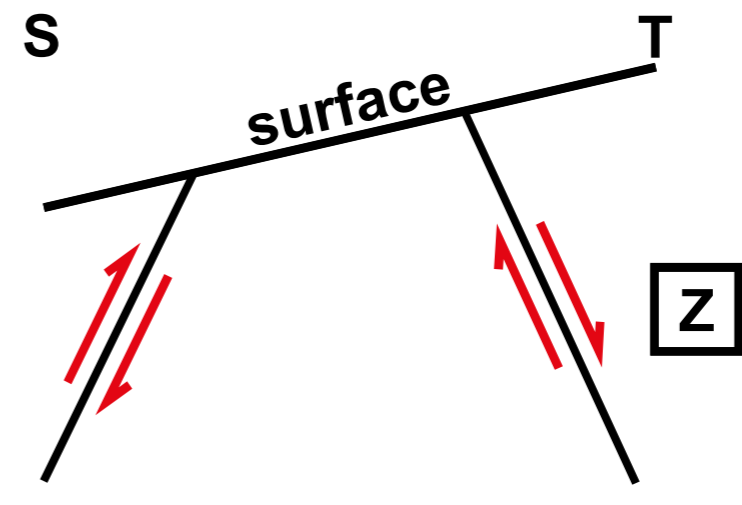
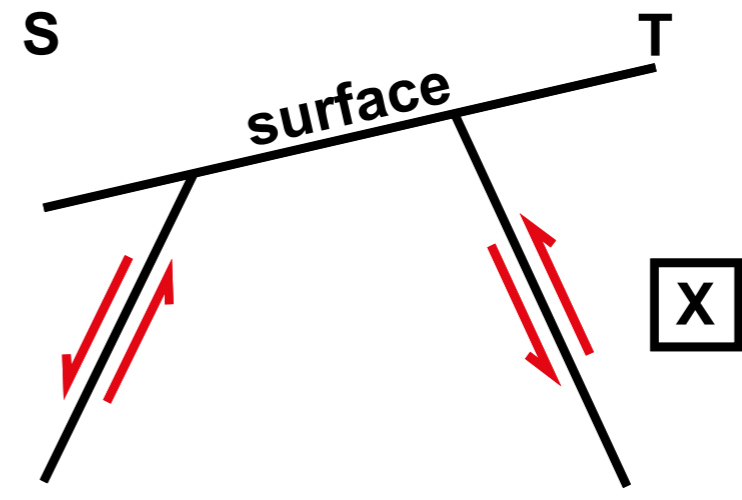
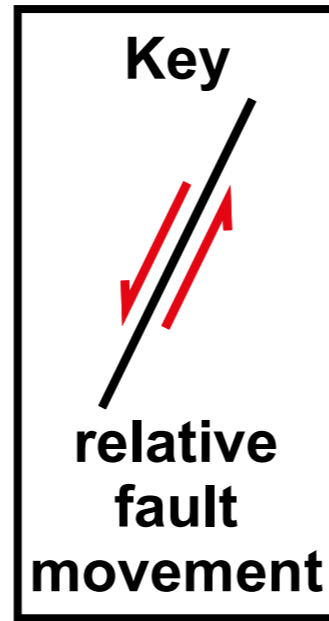
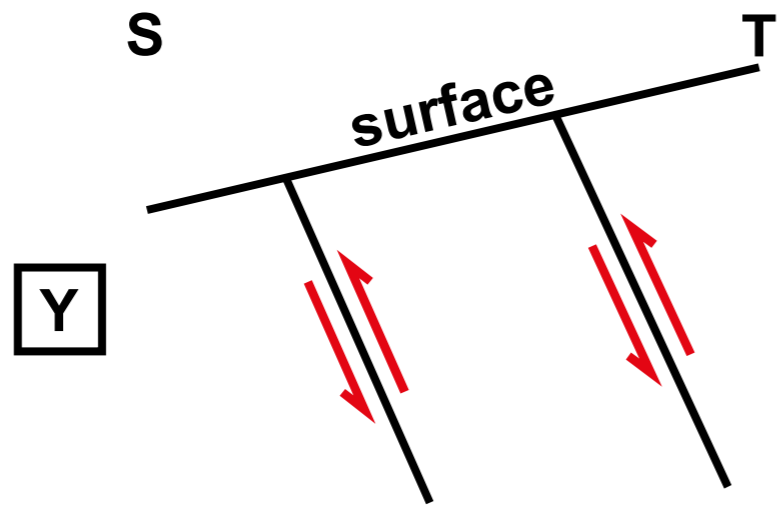
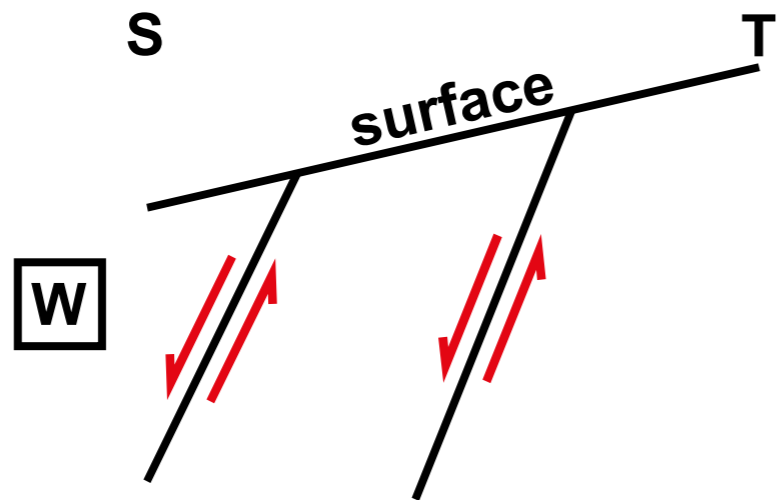
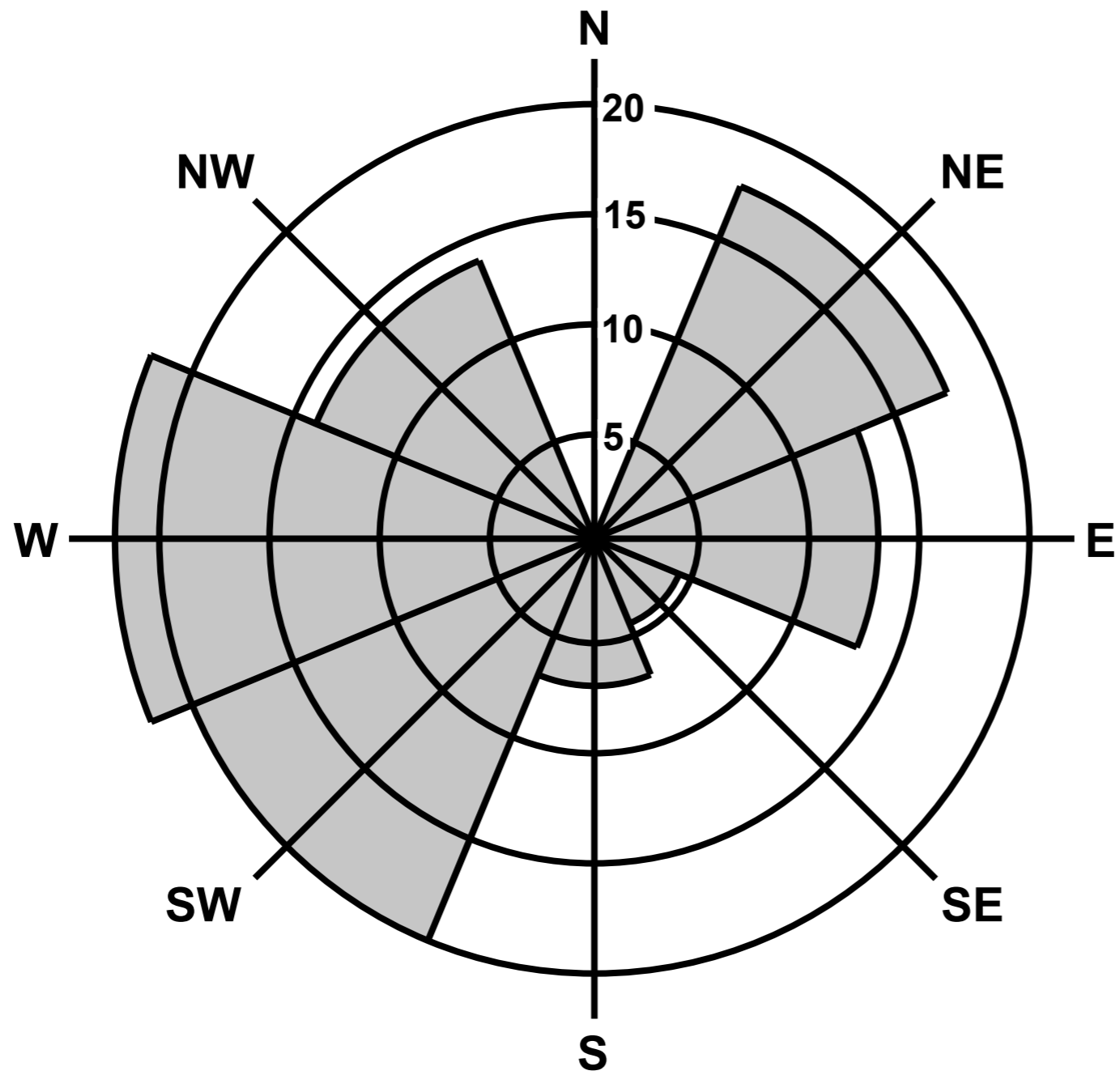


FIGURE 6



**Numbers refer
to observed
landslide
frequency**

TABLE 6

Landslide Orientation	Observed frequency (O)	Expected frequency (E)	(O - E)	(O - E)²	$\frac{(O - E)^2}{E}$
N	14	14	0	0	0
NE	18	14	4	16	1.14
E	13	14	-1	1	0.07
SE	4	14	-10	100	7.15
S	7	14	•	•	•
SW	20	14	6	36	2.57
W	22	14	8	64	4.57
NW	14	14	0	0	0
Total	112	112	CHI-SQUARED VALUE		19.00

TABLE 7

Degrees of Freedom	Probability											
	0.95	0.90	0.80	0.70	0.50	0.30	0.20	0.10	0.05	0.01	0.001	
1	0.004	0.02	0.06	0.15	0.46	1.07	1.64	2.71	3.84	6.64	10.83	
2	0.10	0.21	0.45	0.71	1.39	2.41	3.22	4.60	5.99	9.21	13.82	
3	0.35	0.58	1.01	1.42	2.37	3.66	4.64	6.25	7.82	11.34	16.27	
4	0.71	1.06	1.65	2.20	3.36	4.88	5.99	7.78	9.49	13.28	18.47	
5	1.14	1.61	2.34	3.00	4.35	6.06	7.29	9.24	11.07	15.09	20.52	
6	1.63	2.20	3.07	3.83	5.35	7.23	8.56	10.64	12.59	16.81	22.46	
7	2.17	2.83	3.82	4.67	6.35	8.38	9.80	12.02	14.07	18.48	24.32	
8	2.73	3.49	4.59	5.53	7.34	9.52	11.03	13.36	15.51	20.09	26.12	
9	3.32	4.17	5.38	6.39	8.34	10.66	12.24	14.68	16.92	21.67	27.88	
10	3.94	4.86	6.18	7.27	9.34	11.78	13.44	15.99	18.31	23.21	29.59	
	Non-significant								Significant			

FIGURE 7a

**Antarctic sea surface temperature
change from present (°C)**

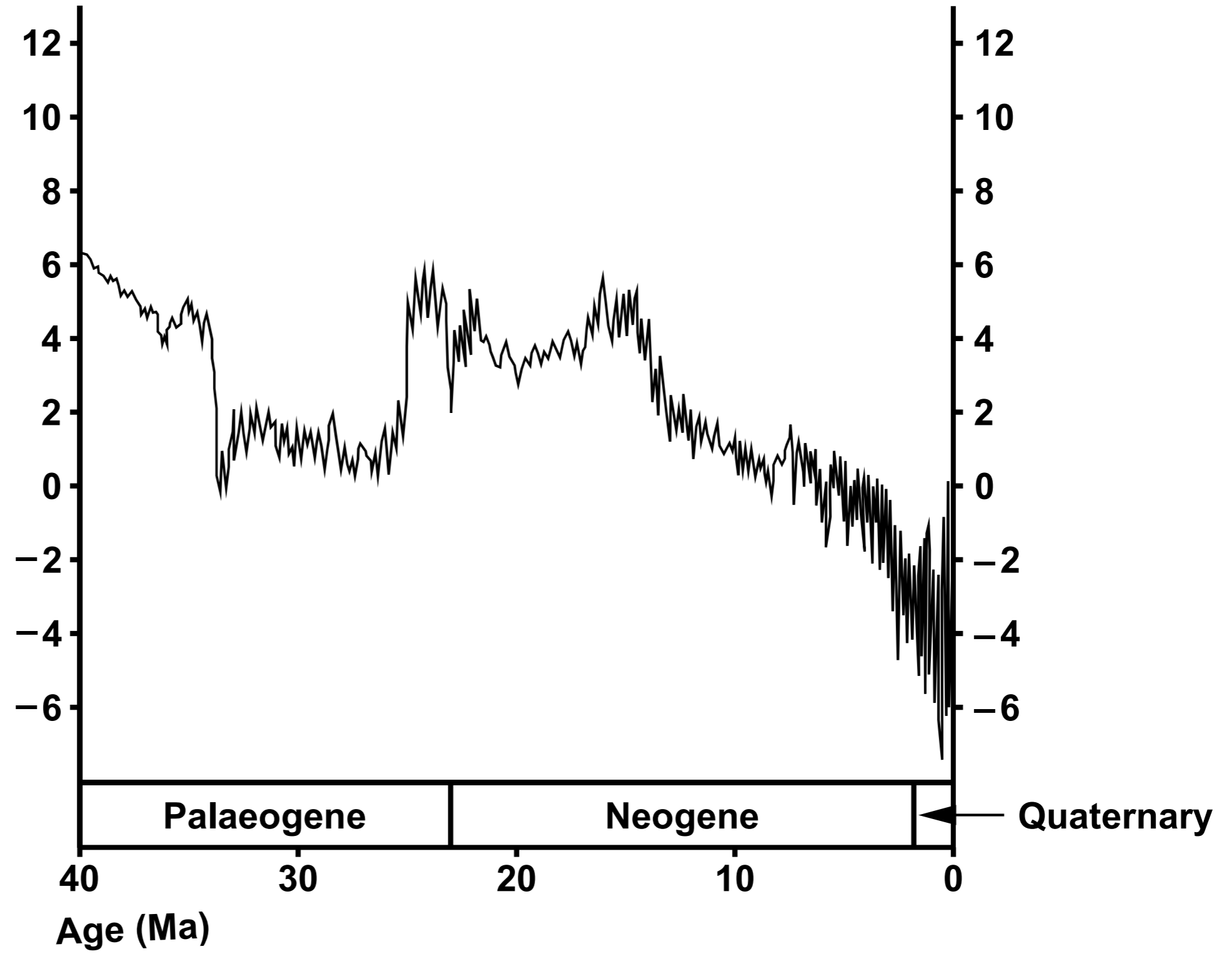


FIGURE 7b

**Palaeogene
40 Ma**

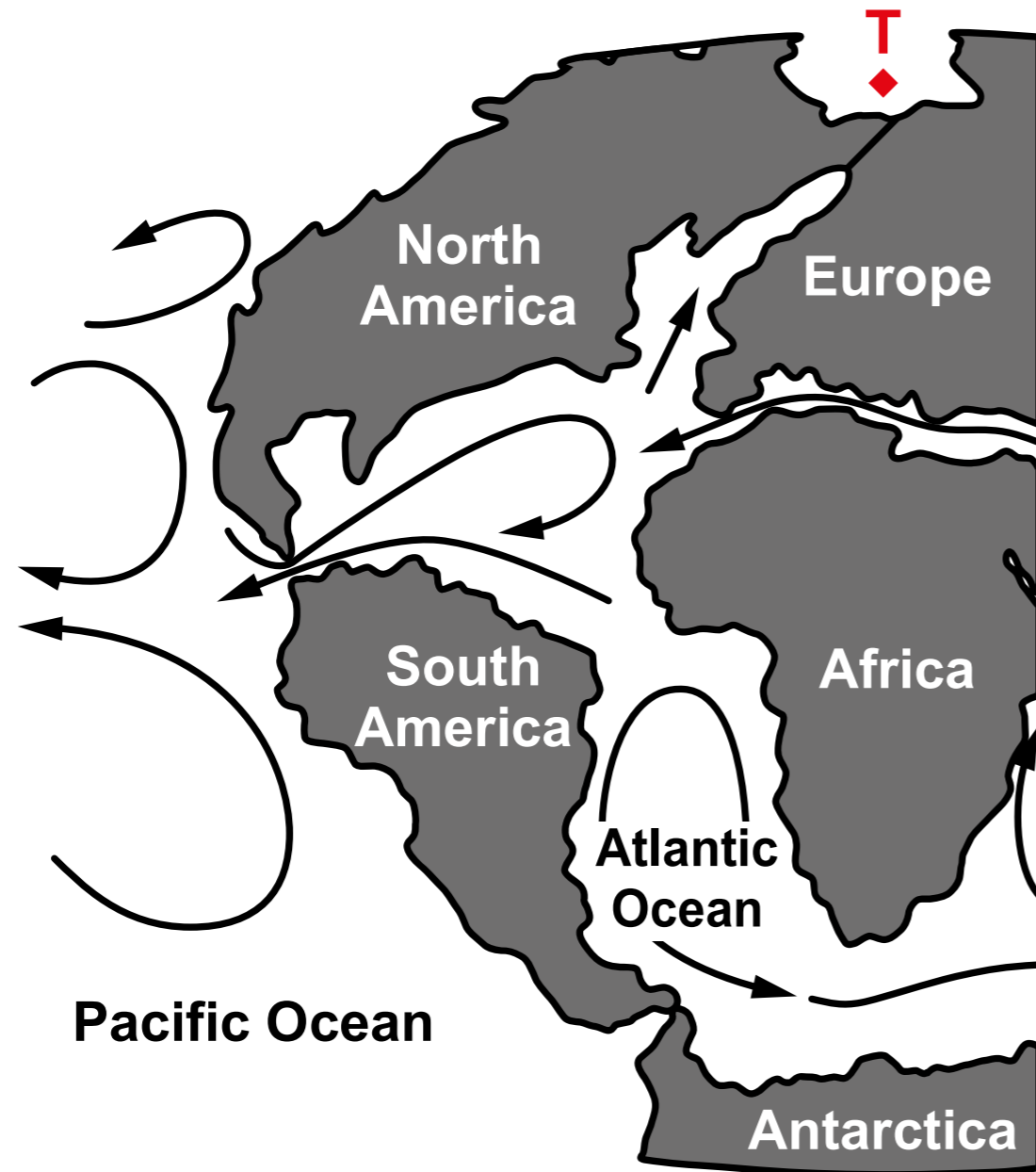


FIGURE 7c

**Quaternary
2 Ma**



Key:



Location T

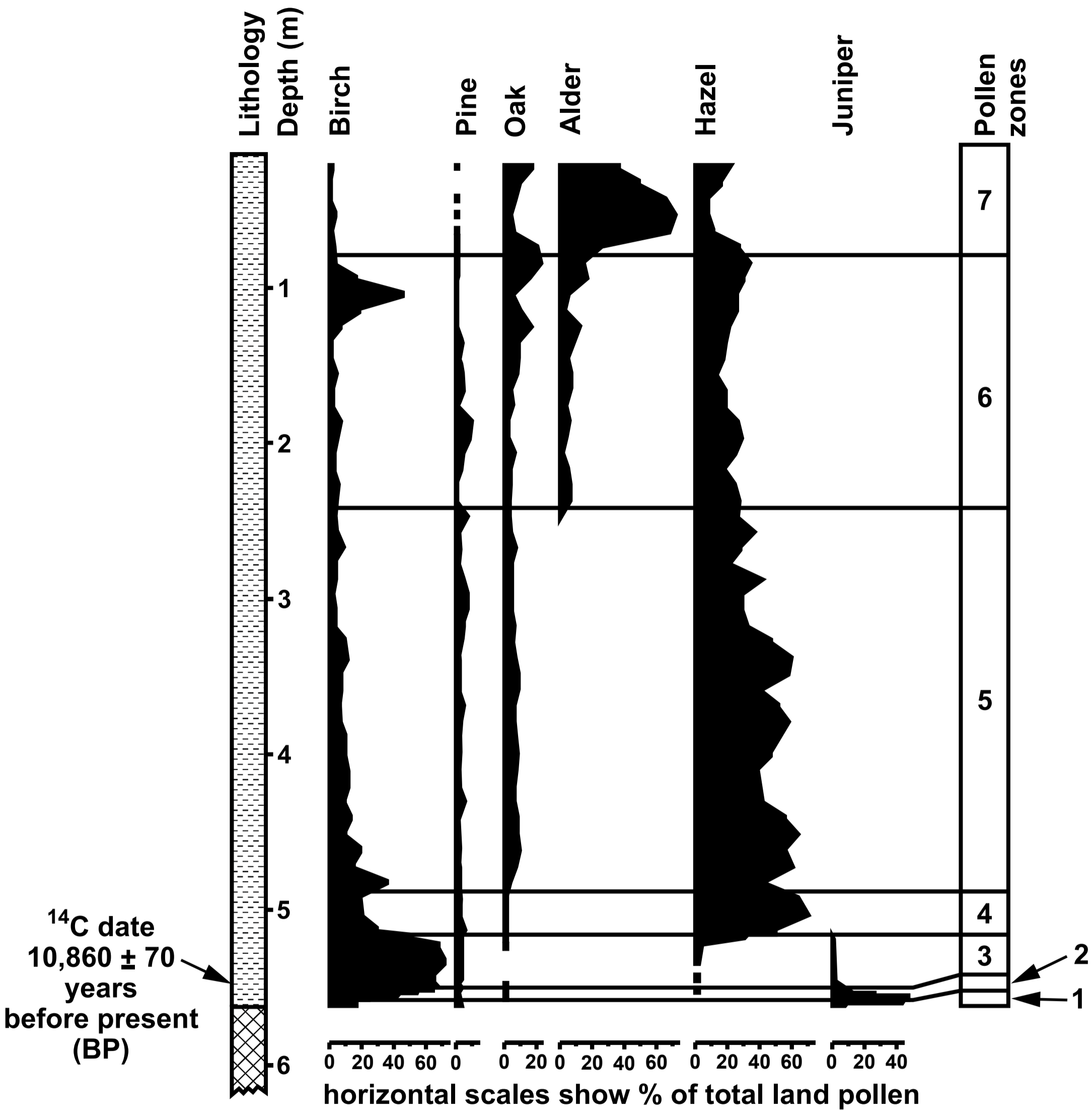


continent





**oceanic current (arrows show
direction of movement)**

FIGURE 8

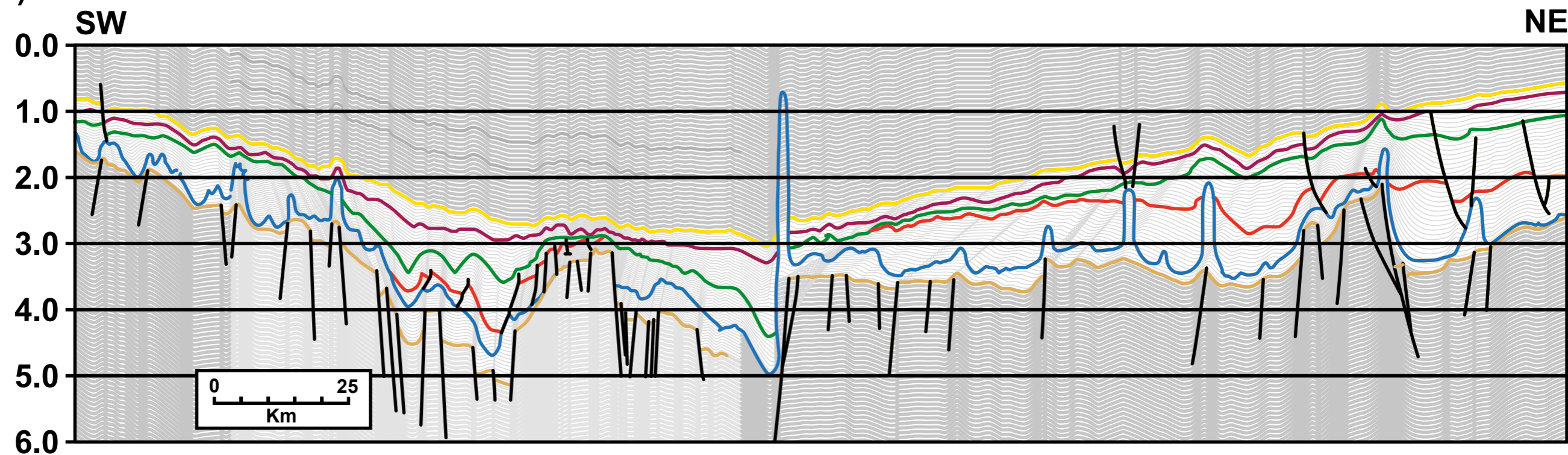


Key:

-  organic-rich sediments (peat)
-  clay with angular pebbles

Two-way travel
time (s)

FIGURE 10a



Two-way travel
time (s)

FIGURE 10b

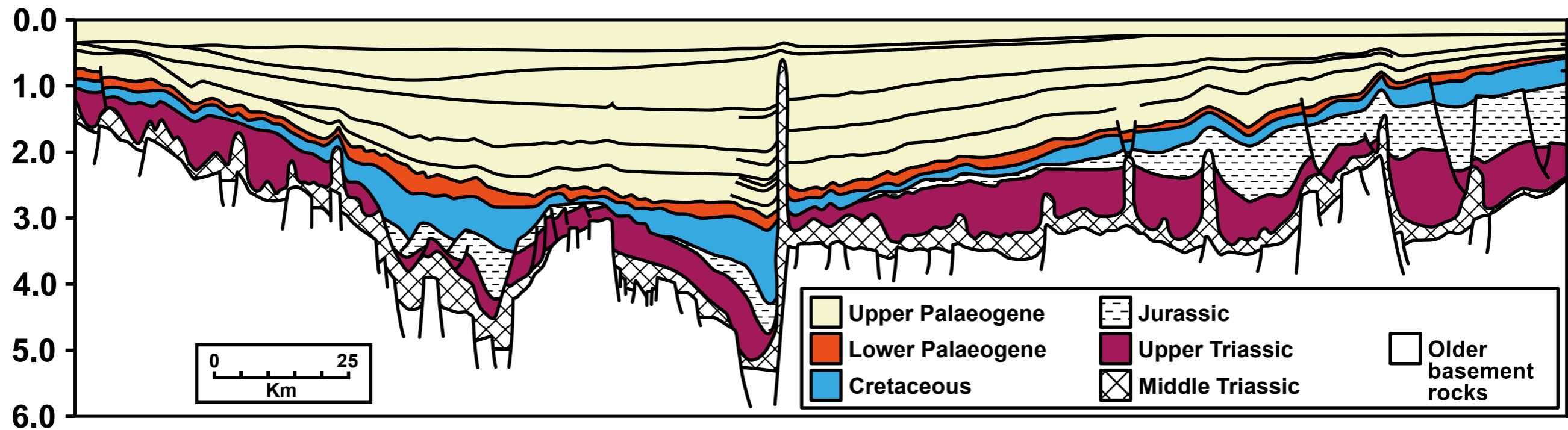
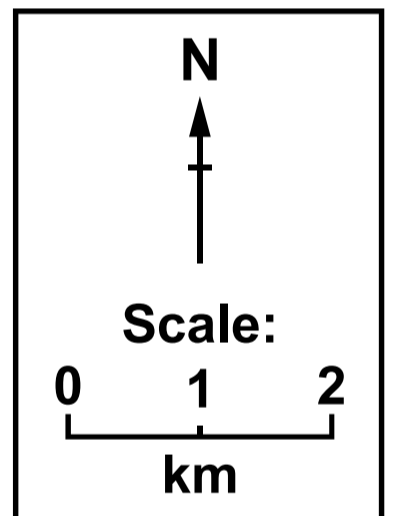
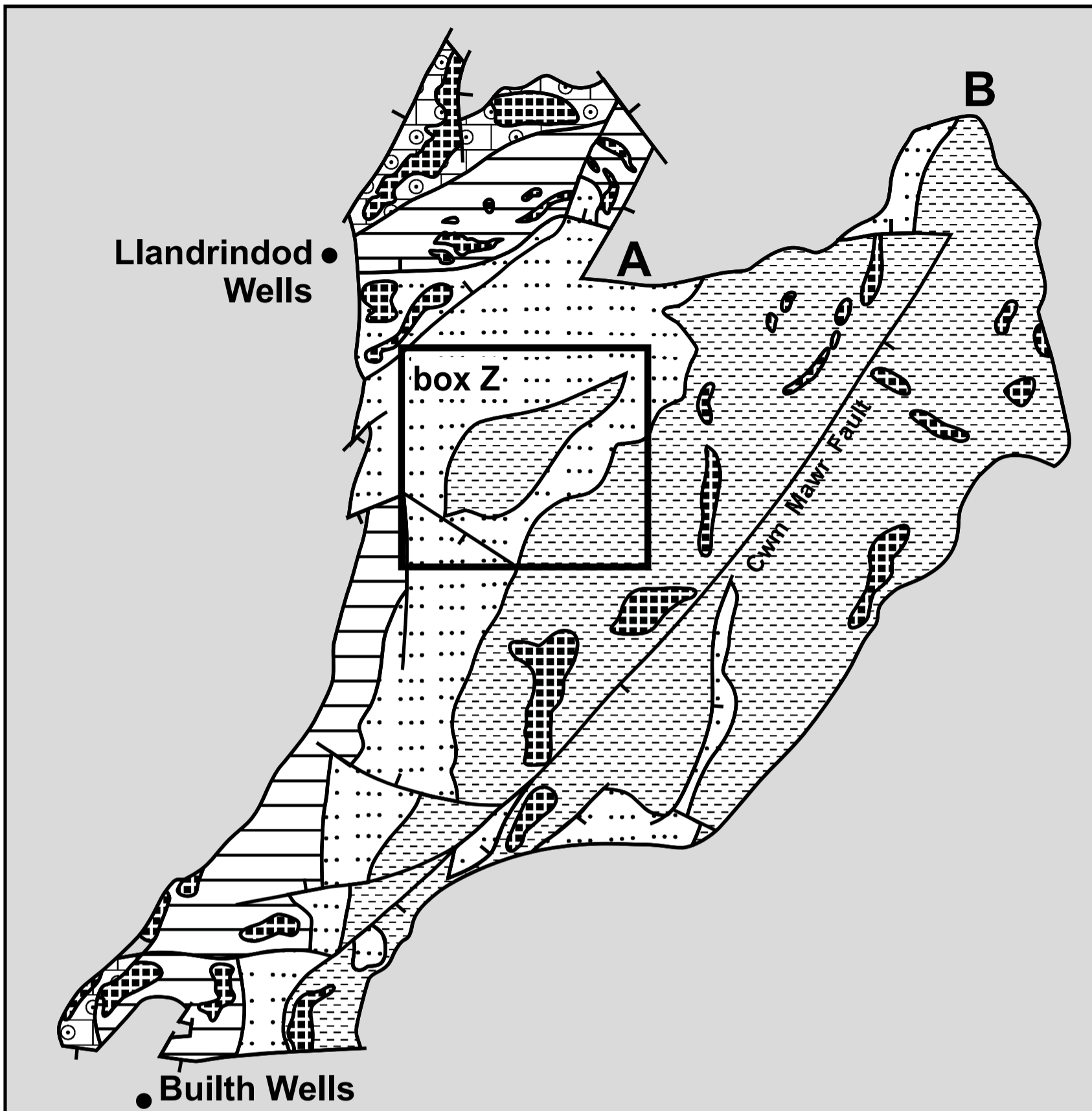

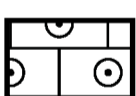
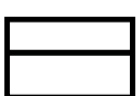
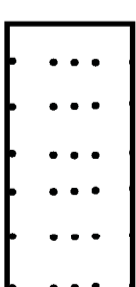
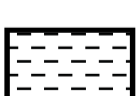


FIGURE 11a



Key:
Rocks in age order

- | | |
|--|--------------|
|  | Silurian |
|  | } Ordovician |
|  | |
|  | |
|  | |
- black shales
black shales (containing graptolite *Glyptograptus*)
pyroclastic deposits interbedded with black shales (containing graptolite *Didymograptus*)
black shales (containing graptolite *Tetragraptus*)

Other features




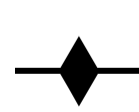

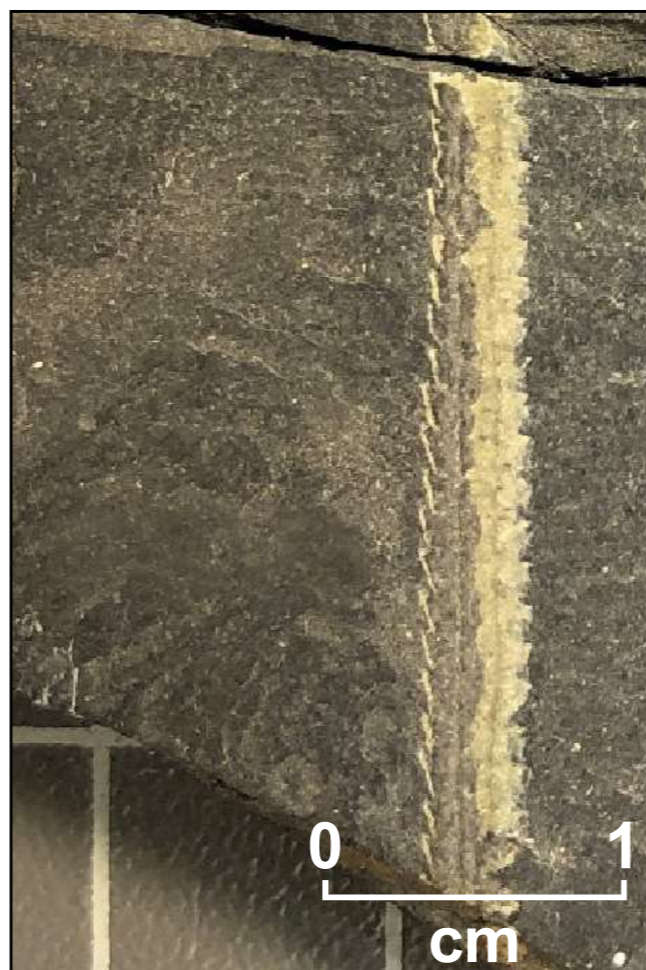
- | | |
|---|-----------------------------------|
|  | dolerite intrusion |
|  | fault |
|  | axial plane trace of a syncline |
|  | axial plane trace of an anticline |
|  | town |

FIGURE 11b

Fossil J



Fossil K



Fossil L

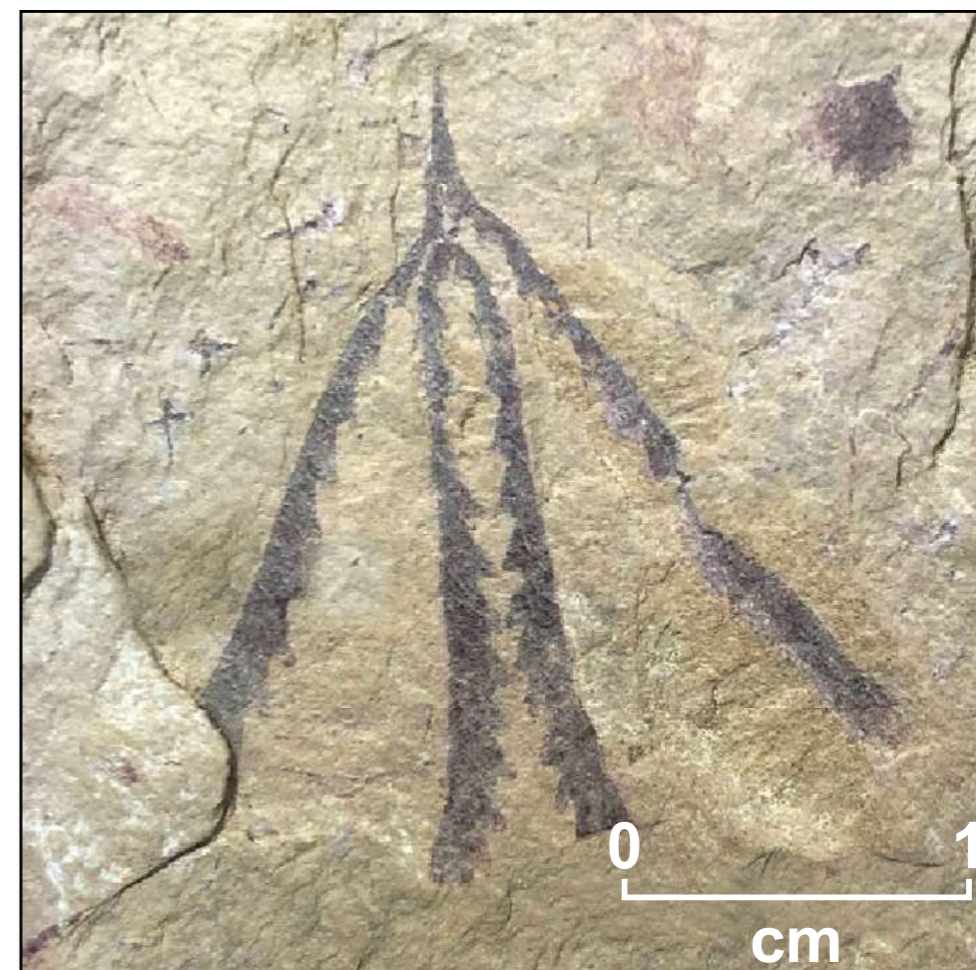
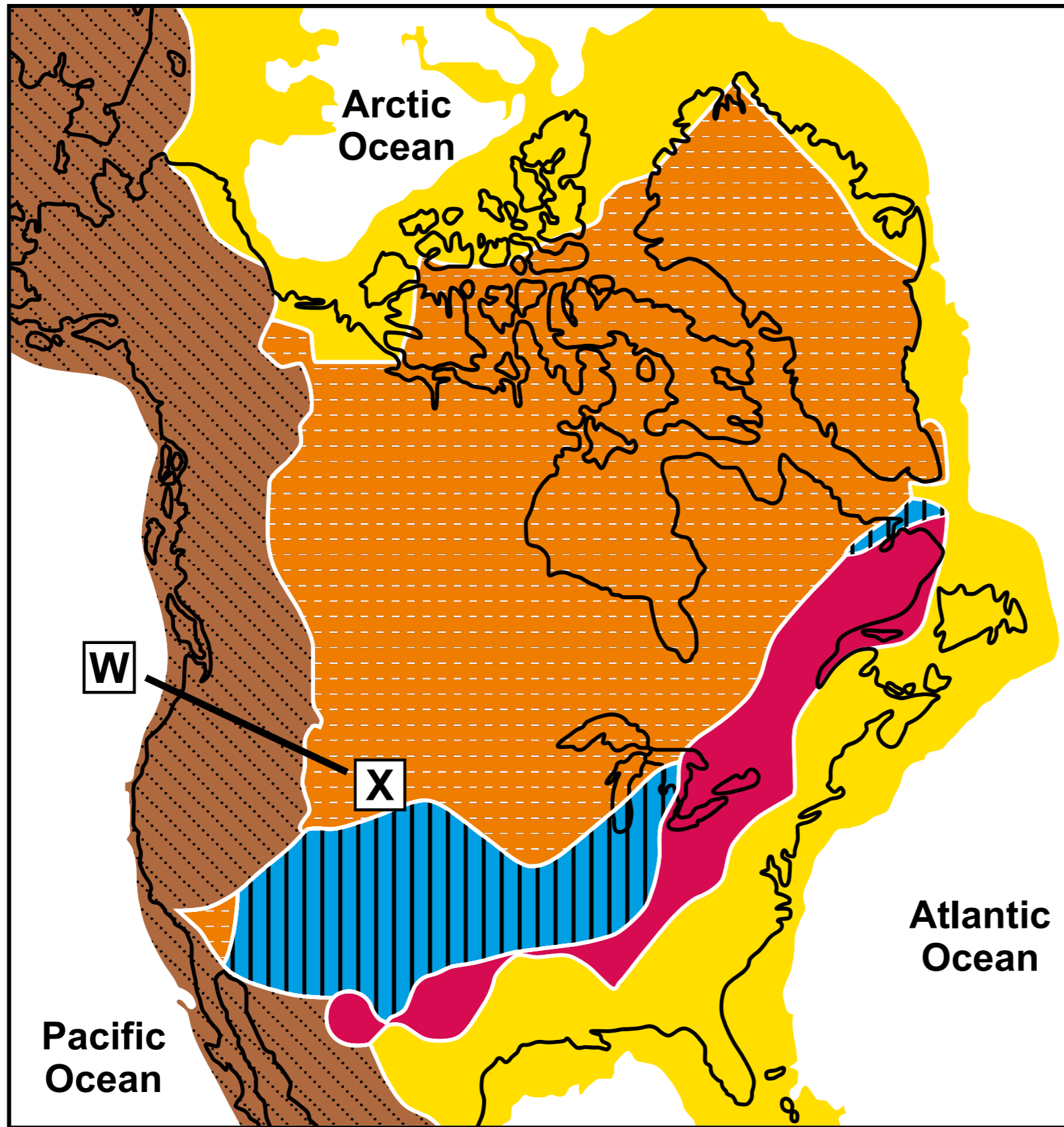


FIGURE 13a

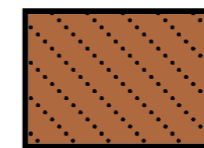


Key:



Oceanic crust

Age of Orogenic Belts



Mesozoic-Quaternary



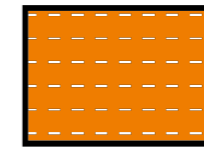
Palaeozoic



1300 – 1000 Ma



1800 – 1600 Ma



older than 1800 Ma



N

0 1000
km

FIGURE 13b

Cross-section along the line W–X as it might have looked 5 Ma ago (not to scale)

Columbia River Basalt Plateau - more than 350 basaltic lava flows up to 4 km thick, 93% of which were erupted over a million-year time span, covering 210,000 km² of the plateau.

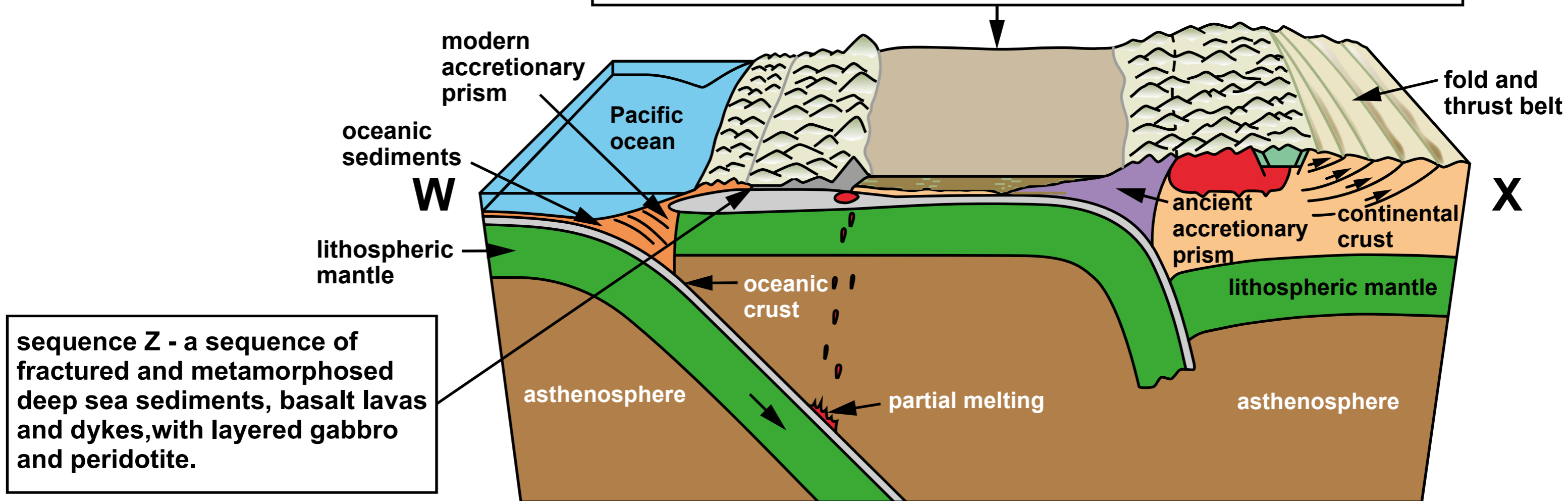


FIGURE 14a

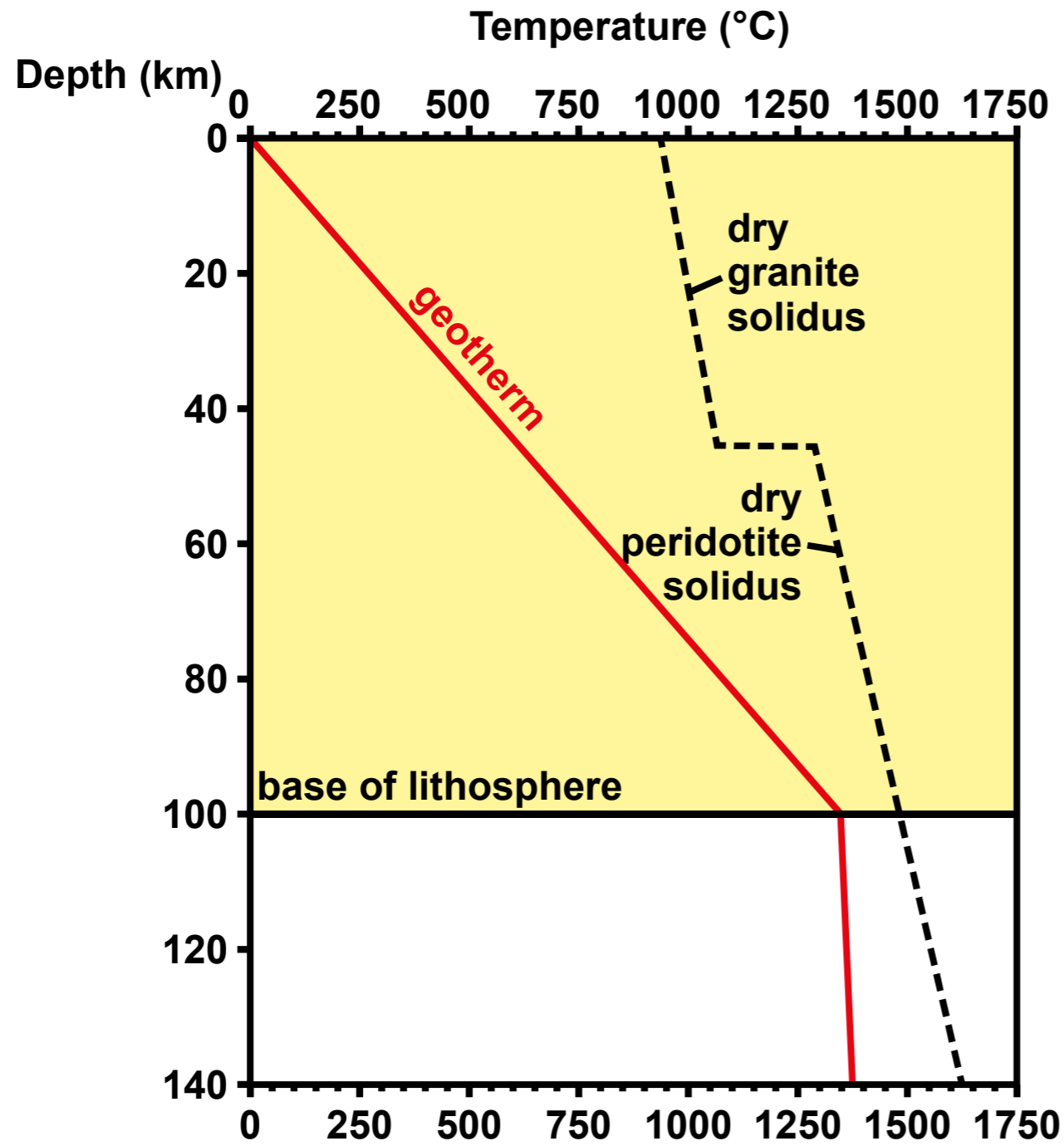


FIGURE 14b

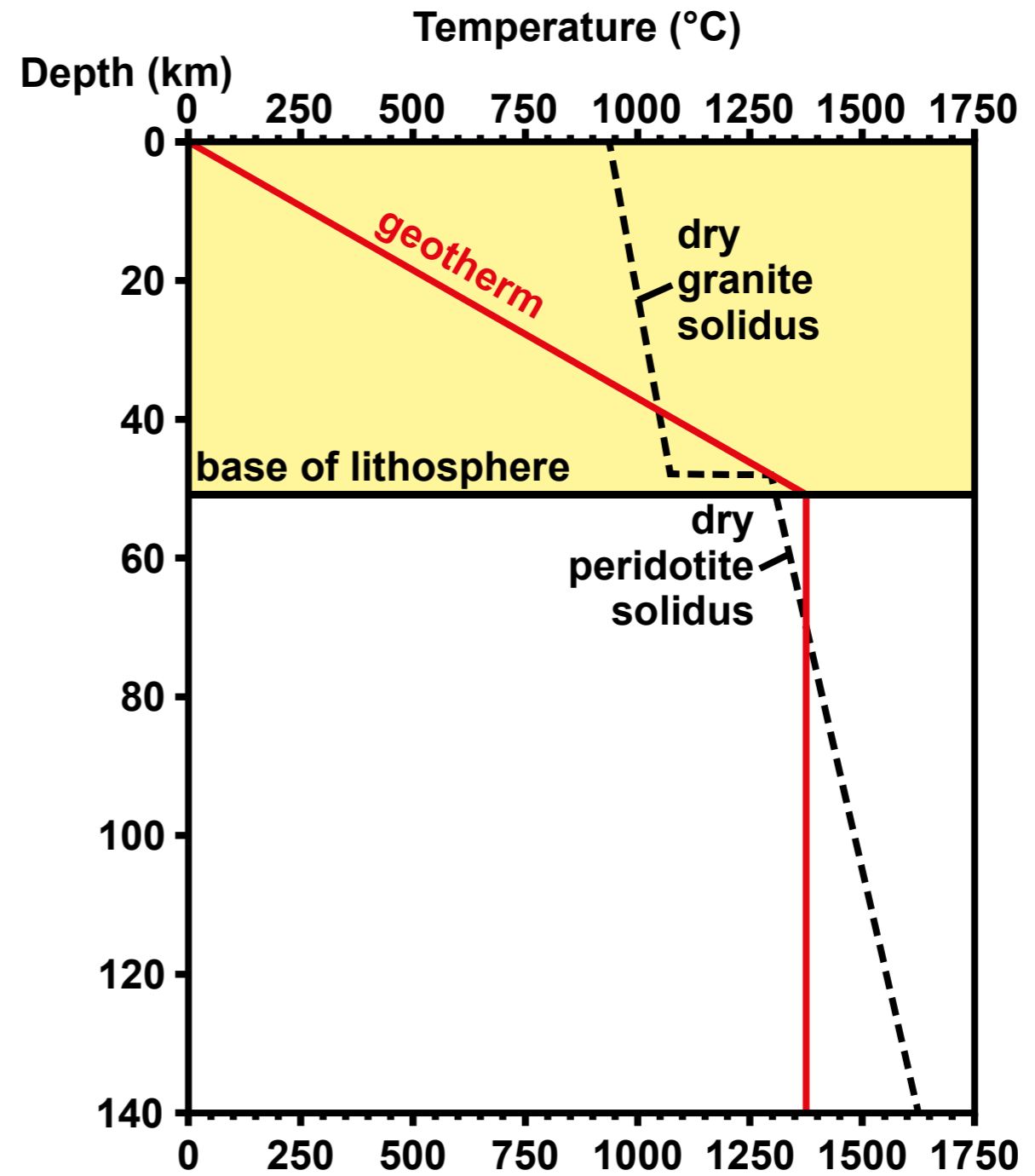
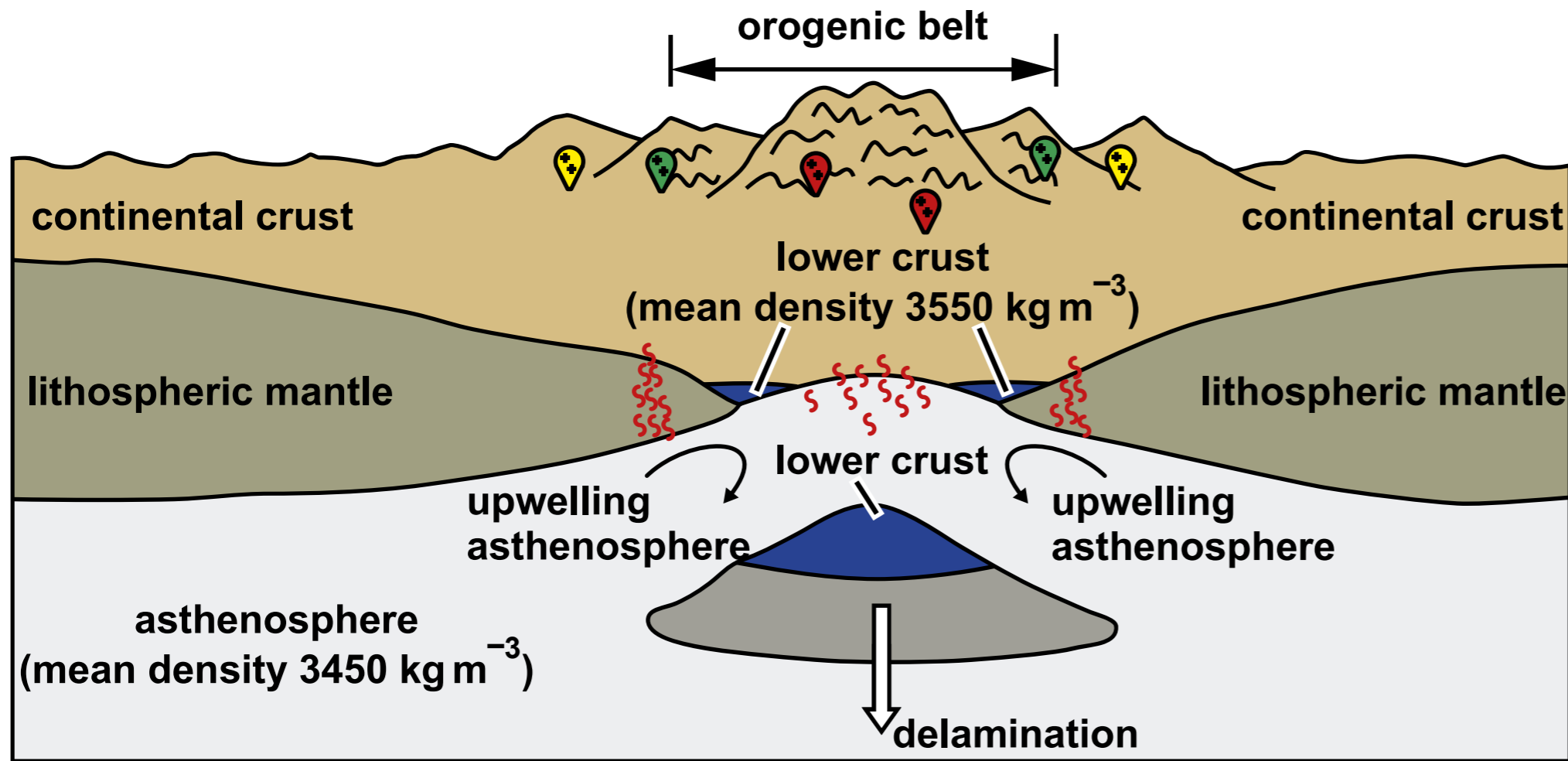
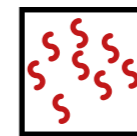


FIGURE 14c



Key:



zone of partial melting



late stage plutons ~415 Ma



middle stage plutons ~430 Ma



early stage plutons ~445 Ma