Science

Queensland Comparable Assessment Tasks (QCATs) 2012

On shaky ground

Student booklet

9

Given name: ....

Family name: ....

School: ....

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Setting the scene

Recent major earthquakes in Japan and New Zealand have shown that improving building design is a major factor in reducing damage and loss of life.

Can we predict where dangerous earthquakes are likely to occur?

Can we design buildings that won't fall down when vibrated by earthquakes?

These are questions that **seismologists** and **engineers** are working on, using scientific theory and modern technologies.

Their tools of trade include:

- **data** collected during earthquakes using technology including seismographs, lasers and GPS
- the **Theory of Plate Tectonics**
- **modelling** the effects of earthquakes on buildings.

The development of buildings that can resist earthquake vibrations is largely based on studies of earthquakes such as the one that devastated Mexico City in 1985.

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Images p.1 Landslide: <www.123rf.com/photo_8324038_the-landslide-of-a-rural-road-on-the-background-an-off-road-car.html>; p. 3 Photo right, "total collapse", p.14 "Hotel de Carlo" <www.tinyvital.com/images/mexcity1985/index.html>; p. 3 Photo left, "Mexico City earthquake" <http://vivirlatino.com/tags/mexico-city-earthquake>.
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Case study

On 19 September 1985, an earthquake struck Mexico City. Over 10 000 people were killed and over 30 per cent of the buildings were completely destroyed. Studies of the damage to buildings revealed a pattern: most of the collapsed buildings were 8–15 stories high.

Why did many of the taller and shorter buildings escape serious damage?

In this assessment, you will:

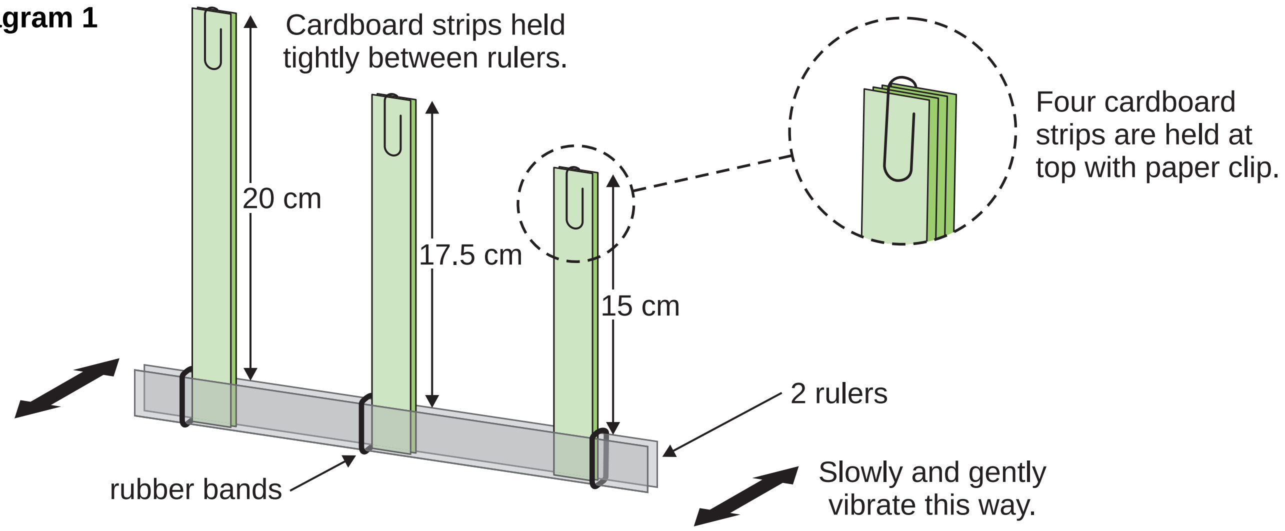
- model the effects of earthquake vibrations on buildings of different heights
- use your understanding of plate tectonics to explain causes of earthquakes
- analyse data to find earthquake location and magnitude
- analyse patterns in seismic data to make predictions
- use evidence and scientific concepts to explain patterns of building damage.

How do earthquakes affect buildings of different heights?

Investigation: Modelling the effect of earthquake vibrations on buildings of different heights

In this model, the rulers represent the ground being shaken by the earthquake and the cardboard strips represent buildings.

Diagram 1



Method

1. **Very slowly and gently** vibrate the rulers in the direction shown.
2. Slowly increase the rate of vibration.
3. When a strip begins to **resonate** (i.e. vibrate strongly and regularly), count the number of complete vibrations* in 10 seconds.
4. Record the result in the Trial 1 column for that strip.
5. Continue to increase the rate of vibration, repeating steps 3 and 4.
6. Repeat steps 1 to 5 until you have recorded the results of three trials for each strip.

* One vibration is a complete swing backwards and forwards.

Table 1: Results

Height of strip (cm)	Number of vibrations in 10 seconds				**Frequency** at which strip resonates **(vibrations per second)**
	Trial 1	Trial 2	Trial 3	Mean	
20.0					
17.5					
15.0					

Class discussion of results

Analysing the results

Work on your own to complete the task.

1. (a) Do the results support the following hypothesis?

A strip of a certain height resonates at a particular frequency.

- Yes
- No

(Circle one.)

Explain your choice.

. . . .

. . . .

. . . .

(b) Describe the relationship between the height of a strip and the frequency at which it resonates.

. . . .

. . . .

(c) If a nearby earthquake produces rapid (high frequency) ground vibrations, which buildings are more likely to be damaged?

- tall
- medium
- short

(Circle one.)

Explain your choice using the results of the investigation.

. . . .

. . . .

. . . .

. . . .

In the model, the independent variable is **height**.

Other variables may change the frequency at which a strip resonates, e.g. width, thickness, material (i.e. what it is made of).

2. Choose a different independent variable that may change the frequency at which a strip resonates.

. . . .

(a) How would the model be changed to test this variable? Include a diagram.

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

Use this space for your diagram.

(b) Write a hypothesis that you could test using the new model.

If . . . .

. . . .

then . . . .

. . . .

What causes the ground to vibrate during an earthquake?

3. Using the letters A–F, label Diagram 2 to show:

The Theory of Plate Tectonics explains the origin of earthquakes, volcanoes and other geological activity.

A. crust

B. mantle

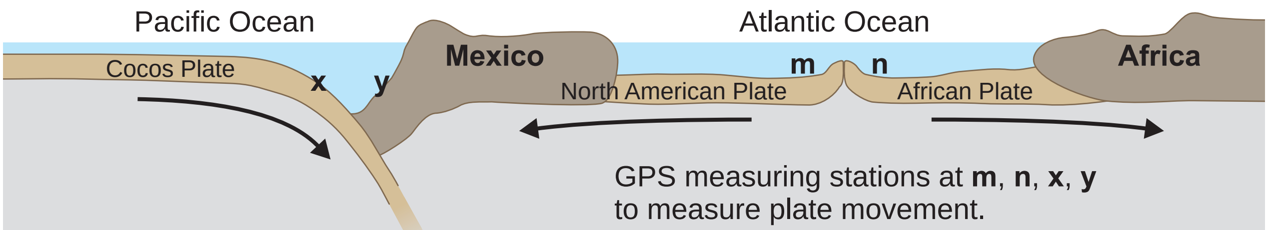
C. destructive plate boundary (crust being melted)

D. constructive plate boundary (new crust being formed)

E. likely location of an earthquake

F. likely location of a volcano.

Diagram 2: Tectonic plates



4. Complete Table 2 to predict how the distances between **m** and **n**, and between **x** and **y**, would change. Explain your predictions.

Table 2

Distance between … (See Diagram 2.)	**How the distance would change** (Circle one.)	**Speed of change** (Circle one.)	**Explanation** (Using the Theory of Plate Tectonics)
m and **n** (over many years)	increases decreases stays the same	slow rapid no change	....
x and **y** (in the months before an earthquake)	increases decreases stays the same	slow rapid no change	....
x and **y** (during an earthquake)	increases decreases stays the same	slow rapid no change	....

Finding the epicentre and magnitude of an earthquake

Use the information on pages 8 and 9 to answer Questions 5–9.

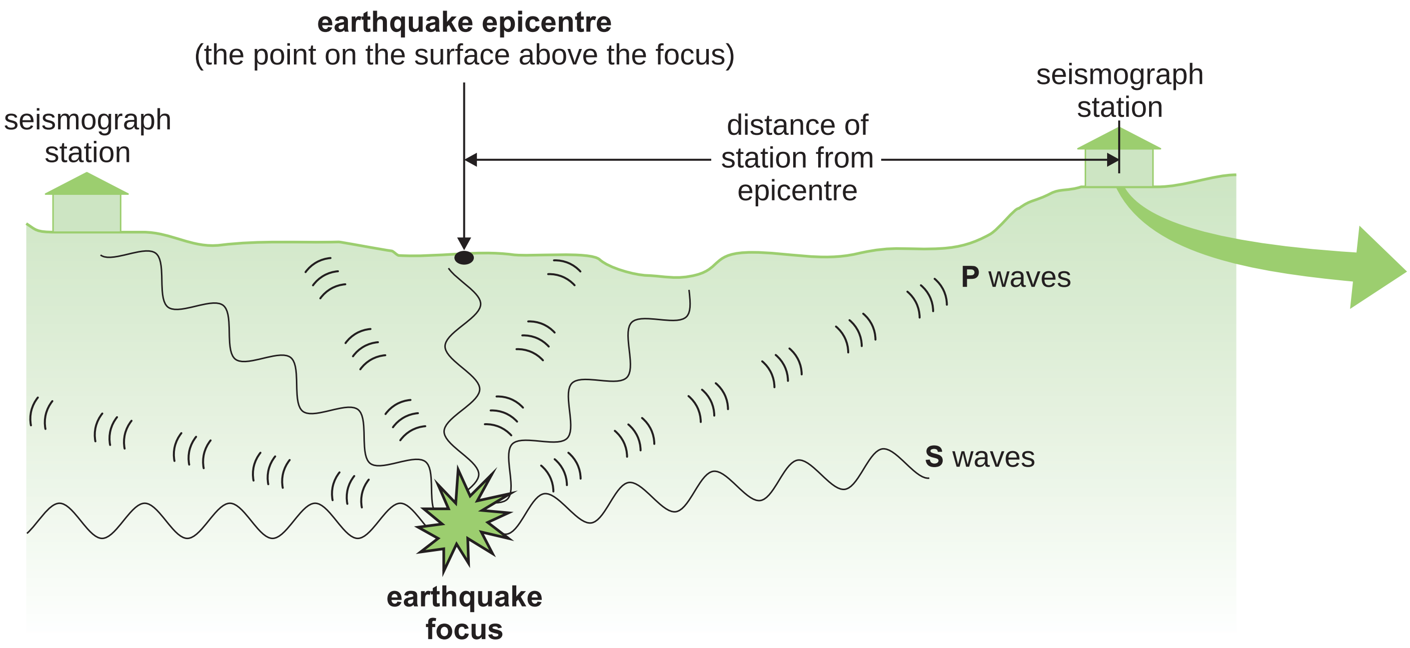
Seismic waves

The energy released by an earthquake is carried through the crustal rock as different types of waves.

P (primary) waves travel faster than **S** (secondary) waves.

When the waves arrive at the surface, they cause the ground to vibrate.

Diagram 3 (a): Seismic waves



When waves produced by an earthquake arrive at the surface, the vibrations are detected by a seismograph and recorded on a chart (a seismogram).

Diagram 3 (b): A seismogram

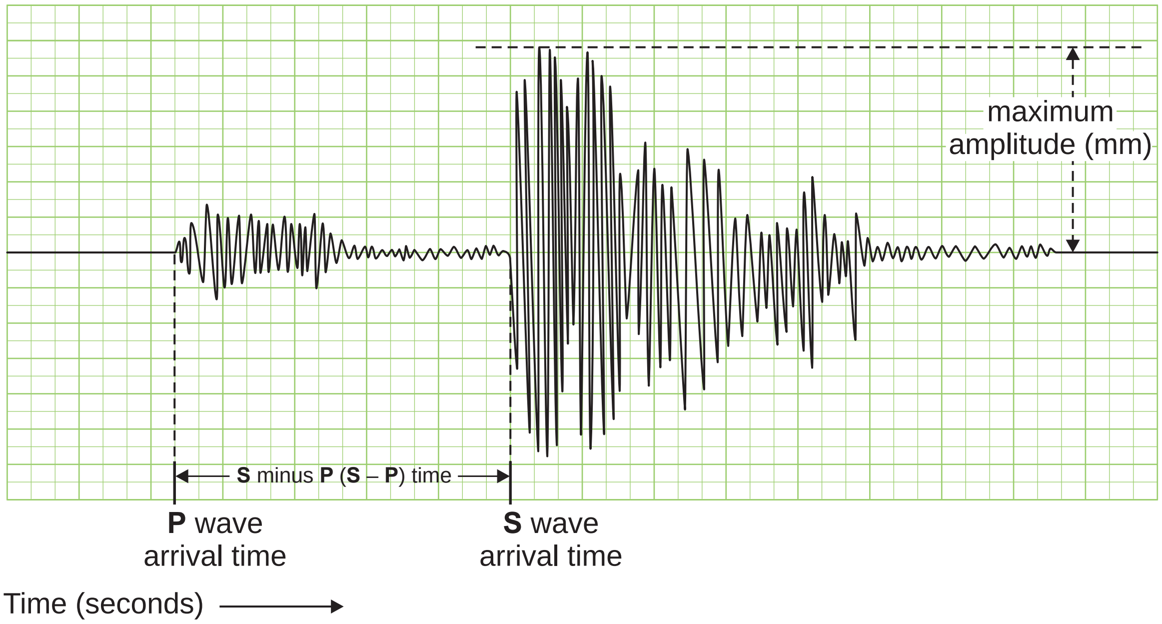
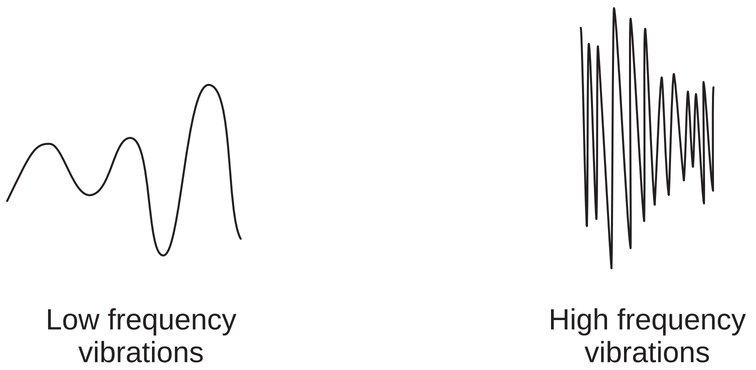


Diagram 3 (c): Different frequencies of vibrations on a seismogram

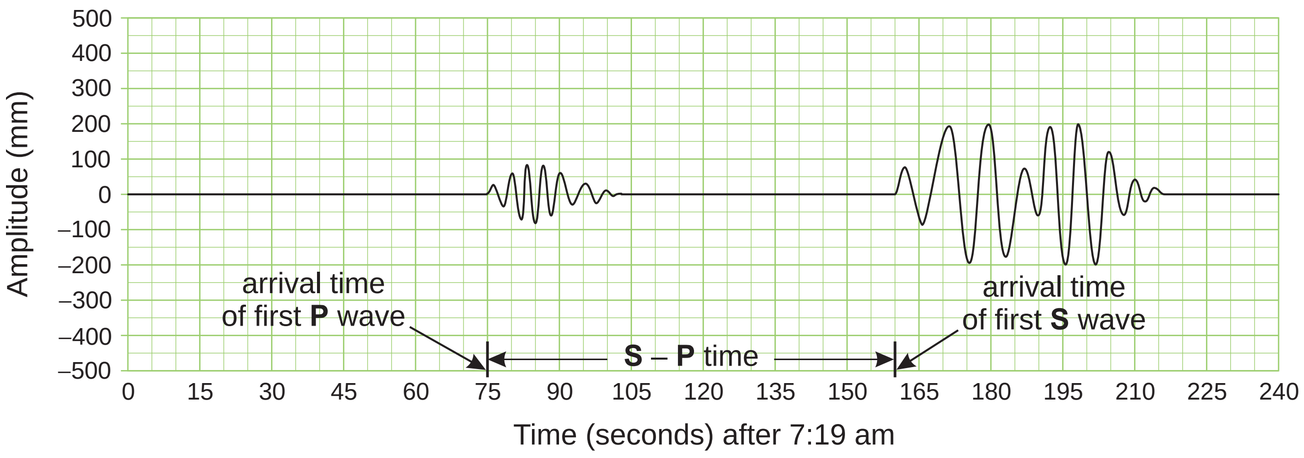


Finding the epicentre and magnitude (size) of an earthquake helps seismologists to see patterns of building damage.

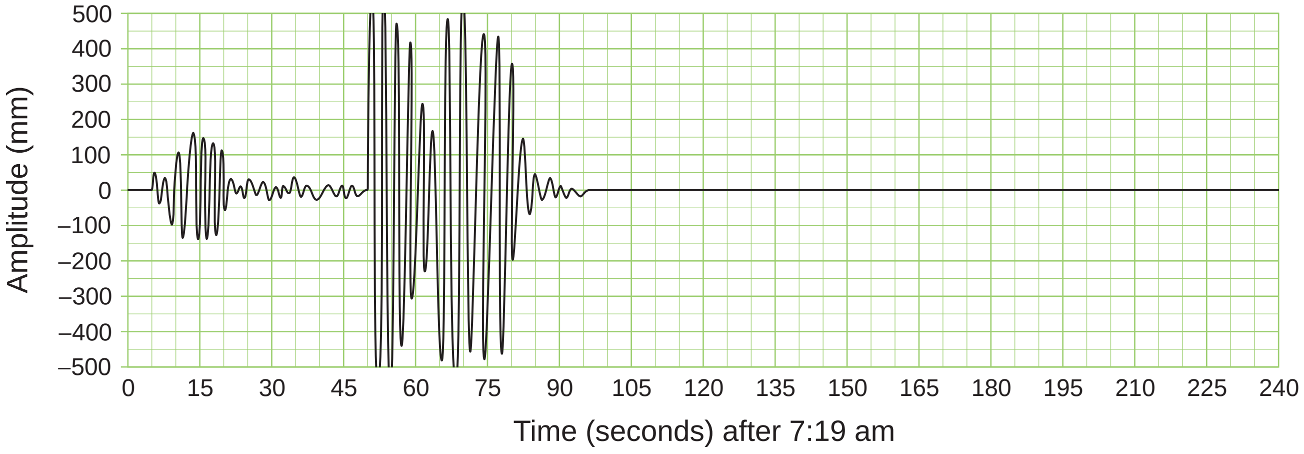
Finding the epicentre and magnitude of the 1985 Mexican earthquake

Below are two seismograms, each of which recorded vibrations from the earthquake that struck Mexico soon after 7:19 am on 19 September 1985.

Seismogram 1: Mazatlan seismic station



Seismogram 2: Mexico City seismic station



5. Mark on Seismogram 2:

- the arrival time of the first **P** wave and
- the arrival time of the first **S** wave.

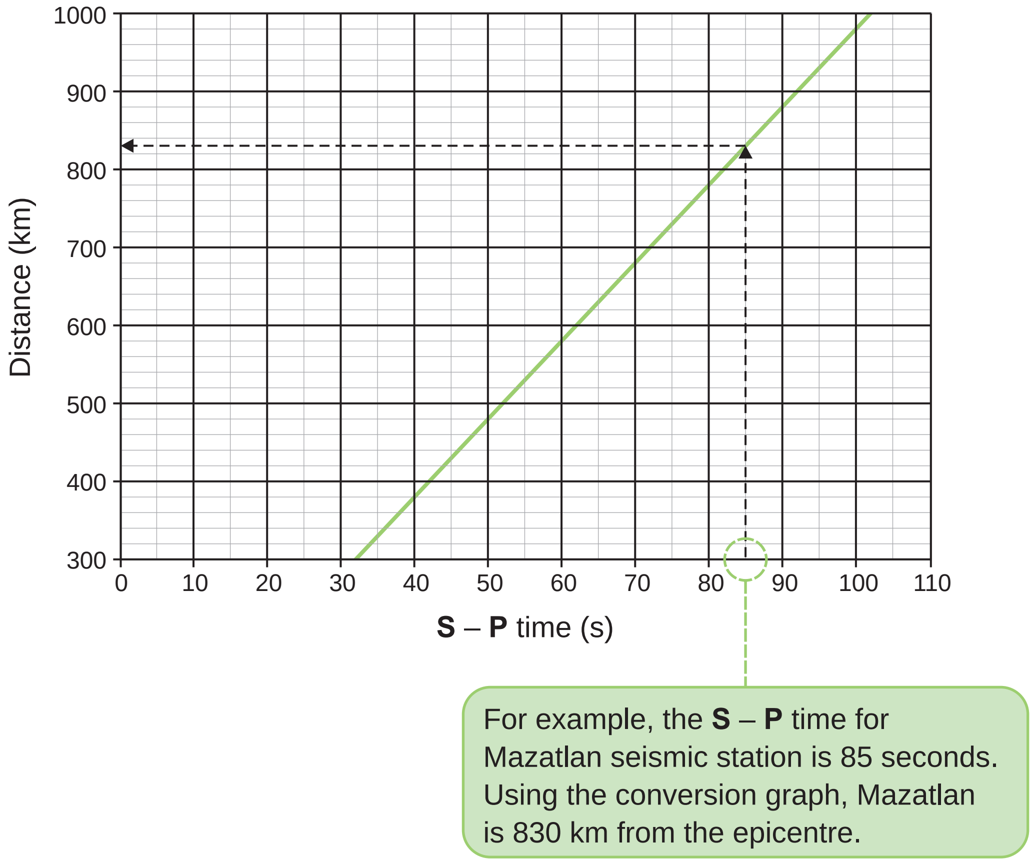
Note that the amplitude is greater than Seismogram 2 can display.

6. (a) Find the time difference (**S** – **P** time) between the arrival of **P** and **S** waves at Mexico City seismic station (Seismogram 2).

	Seismic station	
	Mazatlan	**Mexico City**
S – **P** time	85 sec	. . . . sec

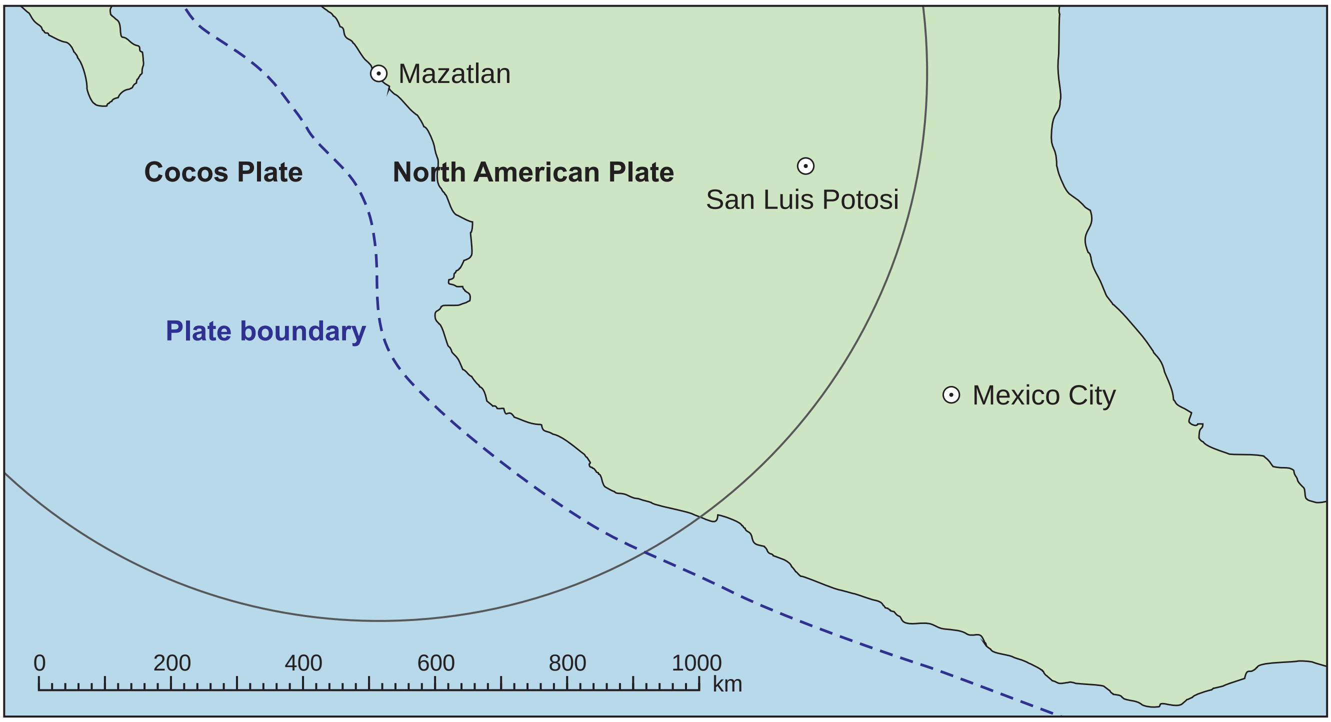
(b) Use Graph 1 below to find the distance of Mexico City seismic station from the epicentre. (The distance of Mazatlan from the epicentre is given as an example.)

Graph 1: Conversion graph of S – P time to distance from epicentre



	Seismic station	
	Mazatlan	**Mexico City**
Distance from epicentre	830 km	. . . . km

Map 1: Southern Mexico



Map 1 above shows a circle with a radius of 830 km and Mazatlan at its centre.

The epicentre of the 1985 earthquake lies somewhere on this circle.

7. (a) Draw a circle with Mexico City at the centre and a radius equal to the distance of Mexico City from the epicentre (from Q6).

(b) On Map 1, mark with a cross (**X**) the most likely epicentre of the earthquake.

(c) Explain your choice using your understanding of plate tectonics.

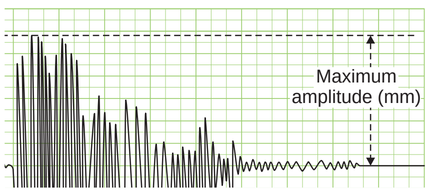
. . . .

. . . .

. . . .

. . . .

The magnitude of an earthquake (on the **Richter scale**) is found by measuring the maximum amplitude of **S** waves at a seismic station.



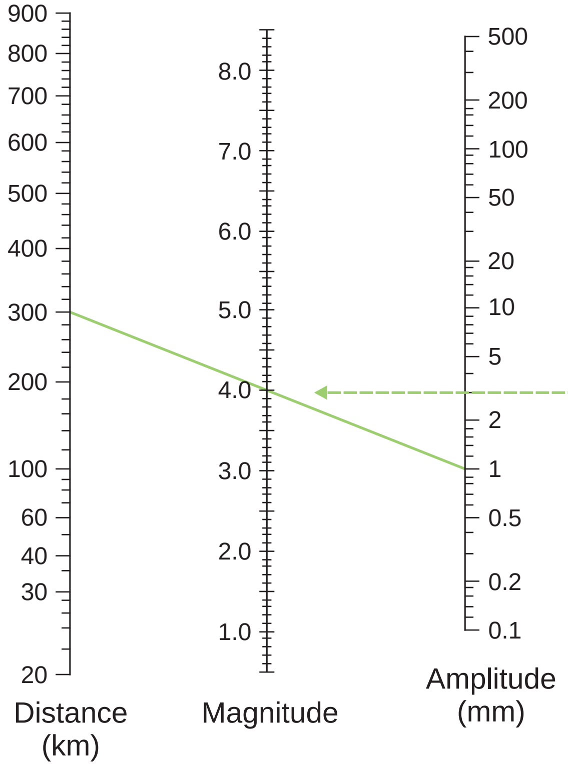
8. (a) Use Seismogram 1 (page 10) to find the maximum amplitude of **S** waves at **Mazatlan** seismic station.

	Maximum amplitude of **S** waves	Distance from epicentre
Mazatlan seismic station	. . . . mm	830 km

Earthquake magnitude is determined by plotting amplitude and distance on a **Richter nomogram**.

(b) Plot the data from question 8(a) on the Richter nomogram below. An example is given.

Figure 1: The Richter nomogram



Using the Richter nomogram
Example: When **S** waves have a maximum amplitude of 1 mm at a distance of 300 km, the magnitude is 4.0

Magnitude of Mexican earthquake (on the Richter scale)	= . . . .

Patterns in the seismic data

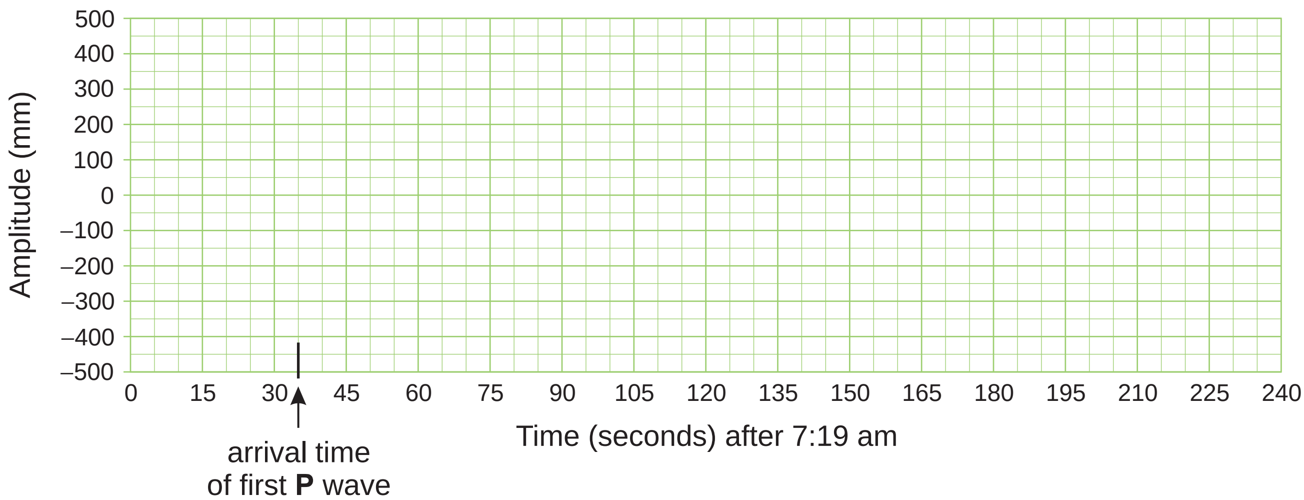
San Luis Potosi is 580 km from the epicentre and does not have a seismic station.

9. Sketch (below) the predicted seismogram for San Luis Potosi during the 1985 earthquake.

Your answer should show the **S – P time** and estimates of **amplitude** and **frequency**.

Look for patterns in the data by comparing Seismograms 1 and 2 on page 10.

Seismogram 3: San Luis Potosi (580 km from epicentre)



Explaining the pattern of building damage in Mexico City

After determining the position and magnitude of the 1985 earthquake in Mexico, a seismologist said:

> Even though the 1985 earthquake was a strong quake, it was not very close to Mexico City. I was surprised that there was so much damage to buildings from 8 to 15 stories high, while many of the taller and shorter buildings were not damaged.
>
> This pattern of damage was not observed in locations closer to the epicentre.
>
> I found that Mexico City is built on clay that resonates at a particular frequency.
>
> I wonder if that has something to do with the pattern of building damage.

10. Propose an explanation for the pattern of damage to buildings in Mexico City.

Use the examples shown in the photo below.

Justify your response with reference to:

- ☐ the seismologist's statement above
- ☐ the frequency of ground vibrations at different distances from the epicentre
- ☐ the results of the modelling investigation on page 4
- ☐ similarities and differences between the buildings
- ☐ any other relevant information in this assessment task.

Use this space to plan your ideas. Use the list on page 14 as a checklist.

Guide to making judgments — Year 9 Science

Student name . . . .

Focus: To analyse data to draw conclusions and develop an evidence-based argument.

Understanding	Skills		
Science Understanding	**Science Inquiry Skills**		
Identifies tectonic features and uses the Theory of Plate Tectonics to explain geological events. Questions 3, 4, 7b–c	Analyses trends in experimental data to identify the relationship between two variables. Proposes modifications to an investigation and a testable hypothesis to improve the quality of evidence. Uses scientific concepts to analyse and present seismic data and draw conclusions. Questions 1, 2, 5, 6, 7a, 8	Analyses patterns in seismic data to make predictions. Reviews evidence and scientific understandings to construct an evidence-based argument for the pattern of building damage. Questions 9, 10 Uses appropriate scientific language, conventions and representations. Questions 1–10	
Identifies all tectonic features and uses the Theory of Plate Tectonics to provide well-reasoned explanations of crustal movements over time and the most likely location of the earthquake epicentre.	Uses frequency data to explicitly support the given hypothesis. Clearly justifies which buildings are more likely to be affected by high frequency vibrations. Proposes a hypothesis that can be validly tested using the modifications suggested.	Provides a detailed explanation for building damage, justified by a thorough analysis of all relevant evidence. Constructs a seismogram that reflects all patterns evident in the seismic data. Accurately interprets and presents data and makes clear, purposeful use of appropriate scientific language.	**A**
	Suggests a set of valid modifications to the investigation. Analyses data to accurately determine the magnitude and possible epicentres of the earthquake.		**B**
Identifies most tectonic features. Correctly predicts some crustal movements over time. Uses the Theory of Plate Tectonics to explain a crustal movement or the most likely location of the earthquake epicentre.	Uses data to partially explain the given hypothesis. Describes the relationship between height and frequency. Makes a valid prediction about which buildings are more likely to be affected by high frequency vibrations. Makes significant progress in determining magnitude and possible epicentres of the earthquake.	Constructs a seismogram that reflects some of the patterns evident in the seismic data. Provides a partial explanation for building damage justified by some evidence. Makes appropriate use of scientific language, graphs and diagrams.	**C**
	Partially describes the relationship between height and frequency. Some success in determining magnitude and possible epicentres of the earthquake.	Makes statements about building damage with some reference to information in the task. Uses some scientific terms.	**D**
Identifies some crustal features.			**E**

Feedback: . . . .

. . . .