Plate tectonics and associated hazards

This Question and Answer examines a Plate Tectonics and Associated Hazards question from AQA Unit 3, Contemporary Geographical Issues. Tectonic disasters and plate tectonics form part of the specifications for other exam boards too (see Box 1). The question is printed in bold type and the students' answers are in italic. The examiner comments are the responsibility of GEOGRAPHY REVIEW and have neither been provided nor approved by AQA. They may not be the only possible answers

Box 1 Questions on tectonics

Other boards cover the topic as follows:
- Edexcel AS Unit 1 World at Risk and, in more depth, A2 Unit 4, Option 1 Tectonic Activity and Hazards.
- OCR A2 Unit F763 Global Issues Earth Hazards (Option A1).
- WJEC Unit G1 Changing Physical Environments.

This question investigates the 2011 Tohoku earthquake in Japan, which generated the world's costliest ever tsunami in terms of economic losses. The question was originally set in June 2014 as Option 1 (questions 1, 2 and 3) on the exam paper.

Question 1

Figures 1a and 1b show information relating to Japan and the Tohoku earthquake, 2011. Describe the tectonic setting shown in Figure 1a and relate the intensity of the Tohoku earthquake shown in Figure 1b to that setting. (7 marks)

AQA 2014

Question 1 has two parts, and care must be taken to cover both. It is easy to miss the 'describe the tectonic setting' part of the question. This relates to Figure 1a, which shows plate margins and plate motion around Japan. A clear pattern is shown on Figure 1b, with intensity decreasing away from the epicentre. It is also important to remember that this question is *not* about the causes or impacts of the now famous tsunami generated by the earthquake.

A mark scheme for question 1 is given in Table 1.

Table 1 Mark scheme for question 1

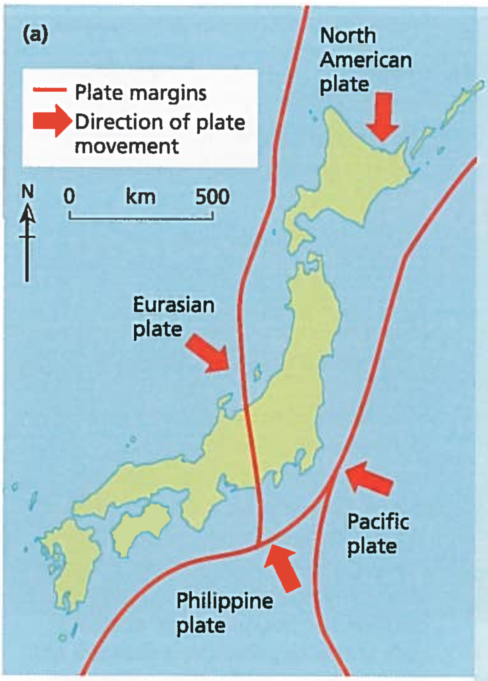
Level 1	1–4 marks	Generalised or basic statements about the tectonic setting or the relationship between setting and intensity. Lacks full coverage of the question.
Level 2	5–7 marks	Describes the tectonic setting and the relationship to intensity clearly, with reasoning and evidence of geographical thinking.

The aftermath of the Tohoku earthquake

Lucy's answer

Japan's tectonic setting is complex because it sits across the boundary of four different tectonic plates which are all in collision. The two plates moving west are oceanic plates (Pacific and Philippine) and these are being subducted beneath the two continental plates moving south (North American) and east (Eurasian). The subduction zone is an area of active earthquakes and volcanic activity.

The epicentre of the Tohoku earthquake is on the plate margin between the Pacific and North American plates. The earthquake was caused by movement in the subduction zone. The greatest ground shaking as measured on the Modified Mercalli scale took place just to the west of the epicentre on the coast of Japan between Mito, Sendai and east of Morioka. Intensity declines in a uniform pattern to the southwest



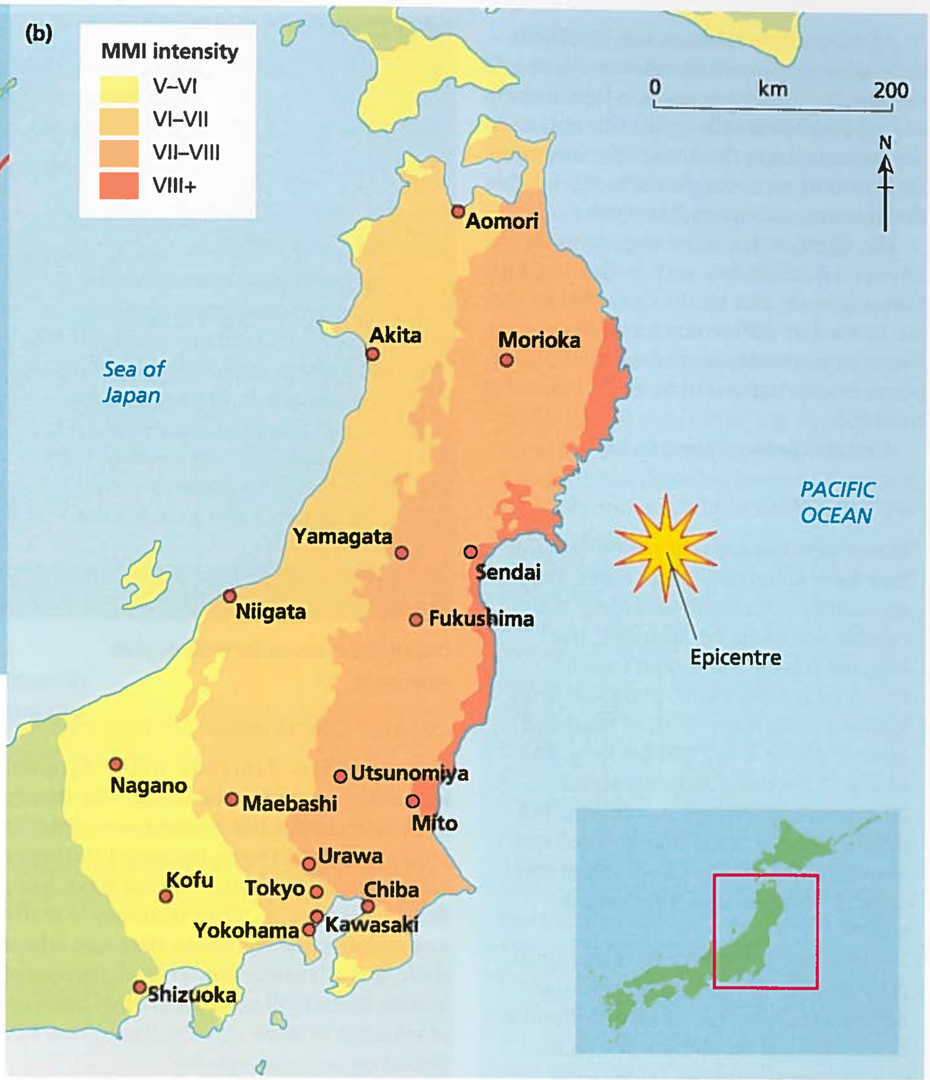


Figure 1 Tectonic setting and earthquake intensity for the 2011 Tohoku earthquake

and is concentric as far as can be seen on the land of Japan. Lowest intensities are further from the epicentre and highest ones are in a narrow coastal area close to it, following the line of the plate margin that caused the earthquake. There are some exceptions, such as an area of intensity V–VI between Niigata and Nagano.

Examiner comment

Lucy's is a Level 2 answer. It is precise. By using plate names and place names the answer avoids vague location statements such as 'at the top' or 'close to the middle' which are common when describing maps. Both parts of the question are covered, so the tectonic setting is described and then this is linked to the intensity map. Although the question does not require explanation, the use of terminology and brief mentions of cause help to show understanding.

Box 2 explains how earthquake intensity and magnitude are quantified.

Question 2

Describe the characteristics, and explain the formation, of deep-sea trenches and island arcs.

(8 marks)

AQA 2014

This question has two parts:

- describe the characteristics
- explain the formation

Box 2 Intensity vs magnitude

Earthquakes such as the 2011 earthquake off the coast of Japan can be measured in different ways. There are three commonly used scales:

- The **Mercalli scale** (or Modified Mercalli Intensity scale) is an intensity scale that dates from 1902, and has 12 categories using Roman numerals I–XII.
- The **Richter scale** dates from 1935 and is a magnitude scale using numbers 1–*n*. It is logarithmic, which means a magnitude 6.0 earthquake is 10 times larger on the scale compared to a magnitude 5.0 (and has roughly 30 times more energy).
- The 1979 **Moment Magnitude scale** is a more modern, and arguably more accurate, magnitude scale similar to the Richter scale.

Why are three different scales used? The answer is that the Mercalli scale measures the impacts of an earthquake using qualitative statements such as 'Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight' for intensity VI. The Richter and Moment Magnitude scales measure the energy released by an earthquake, although in slightly different ways. Although older and less accurate, 'Richter scale' is a well known and understood phrase so it continues to be used. Both magnitude and intensity scales have uses:

- Each earthquake only has one magnitude, making for an easy 'size' comparison between earthquakes.
- Magnitude is a quantified measure of the physical properties of an earthquake, so is accurate.
- Intensity varies from place to place (see Figure 1b) so is useful for comparing impacts spatially.
- Intensity of damage will vary from place, and is related to the human geography of an area, so is less useful when comparing very different locations.

As the question relates to two landforms — deep-sea trenches and island arcs — it should be clear that the answer needs to take the form of a grid with four cells to fill. This is a useful way of visualising the answer because equal time should be spent on each cell, i.e. two descriptions and two explanations.

The question has a few trap-doors for the unwary. Island chains, such as Hawaii or the Galapagos, do not fit the question as they are formed in different ways to island arcs. Knowing your continental from your oceanic plates is also important to avoid becoming confused.

A mark scheme is given in Table 2.

Table 2 Mark scheme for question 2

Level 1	1–4 marks	Generalised or basic statements about causes and features, limited detail for either or both. May only consider either trenches or arcs.
Level 2	5–8 marks	Detailed information about causes and features, may use examples. Covers both trenches and arcs with breadth of understanding for both.

Ray's answer

Ocean trenches are sub-marine features that form when two plates meet. They are usually curved and very long, but narrow and deep. For example, the Mariana trench is an ocean trench found where the Pacific plate and small Mariana plate meet. Both of these are oceanic plates. It is 2,500 km long, and nearly 11 km deep, but only about 70 km wide at the top, narrowing with depth. Island arcs are chains of volcanic islands found in long curves sometimes close to trenches, e.g. the Mariana Islands.

Subduction is the process responsible. It happens when two plates converge and one is subducted or sinks under the other. This can be two oceanic plates or one oceanic and one continental. Magma forms as the descending plate sinks and wet partial melting takes place in the very upper mantle. Subduction zones also have very frequent earthquakes along a zone called a Benioff Zone.

Examiner comment

Ray's answer is rather unbalanced. It provides a good description of ocean trenches, using an example to support the description, but is less convincing when describing island arcs. Ray's explanation of subduction processes is good, but it is not well linked to the two landforms. This produces a rather fragmented answer which scores just into the Level 2 mark band.

Question 3

Discuss the evidence for tectonic plate movement. (10 marks)
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This question demands quite detailed knowledge and understanding. The theory of plate tectonics has evolved over time, as more evidence has been discovered and better explanations for plate motion have been developed (Box 3). Plate tectonics is really a cumulative theory, rather than one where there was a 'eureka' moment. A successful answer needs to discuss the gradual build up of evidence to show why the theory now has almost universal acceptance.

A mark scheme is given in Table 3.

Jenna's answer

Plate tectonics is the theory that explains the motion of Earth's tectonic plates. There are two parts to the theory. First, there is evidence that continents that are now separated by oceans were once joined together, and have moved apart. Second, there are explanations of how tectonic plates move.

Alfred Wegener's theory of continental drift from 1912 was based on physical evidence that continents were once joined. The most basic evidence is the 'jigsaw fit', best shown by the east coast of South America fitting into the coast of west Africa. This could be a coincidence, but geological evidence such as the Appalachian mountains of the USA being geologically related to the Caledonian mountains of Scotland confirms it. Identical fossil remains of reptiles are also found in South America and southern Africa. Glacial deposits from the Permo-Carboniferous glaciation 300 million years ago are found in Antarctica, Africa, South America, India and Australia which suggests parts of all places were once together in a high-latitude location.

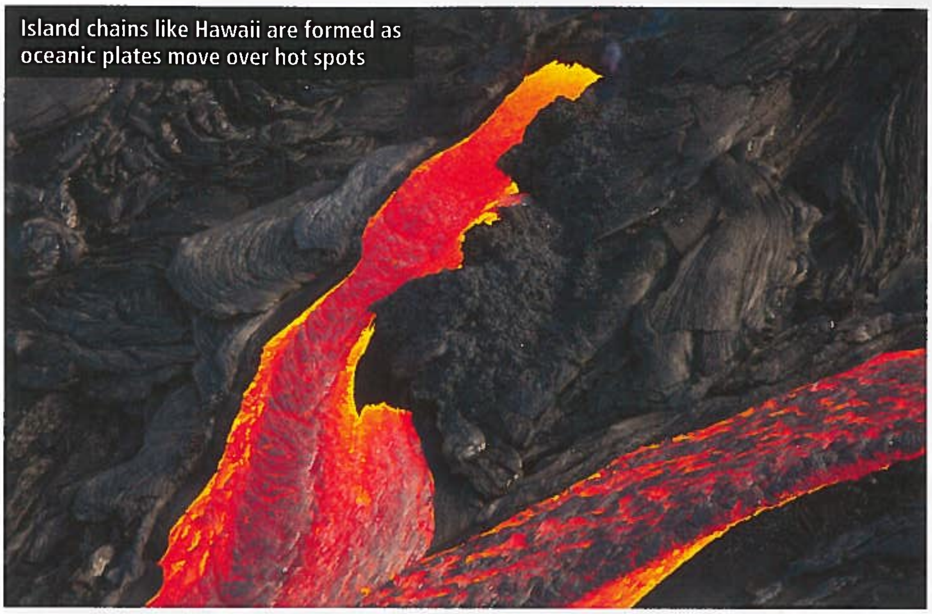

The Appalachian mountains of the USA are geologically related to the Caledonian mountains of Scotland

Box 3 Continental drift and plate tectonics

The two theories of continental drift and plate tectonics are good examples of the difference between 'evidence' and 'explanation'.

The idea of continental drift was put forward by Alfred Wegener in 1912, although there had been many earlier claims that the continents 'fitted together like a jigsaw' (Figure 2). There is ample evidence that continents were once joined together.

Wegener's idea was largely rejected for 40 years, because there was no mechanism to explain how once-joined continents could move apart. In other words, evidence wasn't supported by a convincing explanation. Explanation came in the 1950s and 1960s as geologists began to understand that convection forces in the mantle could indeed 'move continents'. This led to the theory of plate tectonics. It's worth remembering that plate tectonics is still a theory — no human eye has ever gazed upon the forces in action.



Island chains like Hawaii are formed as oceanic plates move over hot spots

Table 3 Mark scheme for question 3

Level 1	1–4 marks	Basic statements about how continents 'fit' together or fossil remains; lack understanding and detail. Does not discuss.
Level 2	5–8 marks	Some detailed statements and use of evidence and how this supports the theory of plate tectonics, with some limited discussion.
Level 3	9–10 marks	Detailed answer with developed statements, using a range of evidence within a discussion. May take a breadth or depth approach.

Figure 2 Re-fitting the continents based on matching rock types

This early theory based on evidence needed more convincing material to provide an explanation. The theory of sea-floor spreading was developed by Harry Hess in the 1960s. Hess showed that mid-ocean ridges were places where new sea floor was created by eruption at what became known as constructive plate margins. Vine and Matthews confirmed this through the discovery of magnetic stripes on the sea floor. This palaeo-magnetic evidence proved that new oceanic plate close to mid-ocean ridges was younger than sea floor some distance away. The magnetism in basaltic rocks recorded periodic magnetic reversals and is mirrored either side of ocean ridges.

Tuzo-Wilson recognised that island chains like Hawaii are produced as oceanic plates move over fixed mantle 'hot-spots' creating active volcanoes as well as chains of older, extinct ones. In the late 1960s, the idea of convection motion in the mantle was accepted as the power-source for moving tectonic plates. The geophysics of earthquakes and mapping of the sea floor has also helped explain the geology of subduction through the discovery of Benioff Zones (earthquake locations which reveal the form of subducting plates) as well as ocean trenches. Evidence gradually built over the last century to not only confirm the former position of continents, but also to provide an explanation of how they have moved.

Examiner comment

Jenna's is a Level 3 answer. This is because:

- A range of evidence is presented to support the original continental drift theory, including geology, ice-age deposits and fossils.
- The transformation of continental drift into modern plate tectonic theory is outlined with specific reference to the scientists involved in key discoveries.
- The answer is logically structured. When answering this question a 'timeline' is a sensible approach to show how the case for plate tectonics was constructed over time.
- There is some discussion, as the answer recognises the cumulative nature of the evidence and the 'pause' in understanding in the few decades after 1912.
- Good terminology is used, and there is reference to some key locations such as Hawaii.

Overall, this is a solid answer showing good knowledge and understanding.