



Alfred Wegener

PLATE TECTONICS Solving the Puzzle

In the early twentieth century enough evidence from around the world had been compiled to make some people believe that the world's continents had not always been at their present location.

The boundaries of continents seemed to match up like a jigsaw puzzle, while similar plants and animals were found in Australia and South America; now separated by ocean. Even mountain ranges and particular strata of rock were found to be continuous from one continent to another.

Led by German thinker Alfred Wegener, the theory of Plate Tectonics gradually developed. This theory held that the earth's crust is divided into many plates, some oceanic, some continental, that all move independently of each other. Like a skim on milk, the continents are now understood

to float on the molten mantle, pushed this way and that by convection currents within the mantle. The lighter plates such as the large, but oceanic Pacific Plate, move as much as 25 mm a year.

When these plates collide or interact the geological fun begins. At some divergent plate boundaries, plates move apart and new mountain ranges are being formed. At other convergent boundaries, two plates collide with one being forced to slide under the other. Still a third form of fault is the transform boundary where two plates slip along side each other. Each of these plate boundaries have the potential to produce volcanoes and earthquakes, but the convergent boundaries that characterise the Pacific's 'Ring of Fire', are the most unpredictable and dangerous.

The process of Plate Tectonics is still under way, albeit very slowly. Inevitably Australia will drift north, the Himalaya Mountains will continue to rise, San Francisco will be on an off-shore island and east Africa will also be an island, torn off from the African continent.

Word Check: Plate Tectonics, Alfred Wegener, Pangaea, Gondwana, Lithosphere, Mantle, Convergent Boundary, Divergent Boundary, Transform Boundary, Subduction Zone, Ring of Fire.

Pre-viewing Questions:

1. Can anyone think of any evidence they have seen or heard that indicates that the continents have not always been in their present location?
2. How could whole continents move?

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ASTARTE RESOURCES

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Plate Tectonics: QUESTIONS

Chapter 1: The Theory of Plate Tectonics

1. What things in the world around him prompted Alfred Wegener (shown right) to think that the land masses had moved?
2. Why are continental plates lighter than oceanic plates?
3. How did icebergs influence Wegener's thinking about the nature of continents?
4. Between 1915 and 1929 Wegener wrote a book outlining his theory of Plate Tectonics. What is this book called?
5. What did the fossil evidence from different continents show?
6. Wegener suggested that in the past all land masses were joined together into one giant super continent. What did he call this super continent?
7. Now geologists believe that around 550 million years ago there were two continental masses, Laurasia and Gondwana. Which was the southern most land mass?
8. How many years ago did these two land masses collide to form Pangaea?



9. After this collision to form Pangaea, what happened?

Chapter 2: How the Plates Move

10. What is the lithosphere?
11. What does the theory of Plate Tectonics describe?
12. How do the plates move?
13. Why do the earth's plates move at different speeds?
14. What happens when plates that have been locked together suddenly shift?
15. What is the 'Ring of Fire'?

Chapter 3: Types of Plate Boundaries

16. What happens at the mid-ocean ridge that circles the earth?
17. What type of boundary is the mid-ocean ridge?
18. The Rift Valley of Africa is also a divergent boundary, although on land. What will happen in the future to the continent of Africa as we know it today?
19. With new rocks being formed at divergent boundaries, what happens to the old rocks since the earth always remains the same size?
20. What is a subduction zone?
21. What happens to the rocks of the oceanic plate in a subduction zone?

22. What forms deep ocean trenches?
23. How are non-volcanic mountains formed?
24. How were the Himalaya Mountains formed?
25. Are the Himalaya Mountains still growing?
26. The Himalaya Mountains grow at 10 mm a year, but they are not getting any taller. Why?
27. What is a transform boundary (also known as a strike-slip fault)?
28. How is the San Andreas Fault formed?
29. What is often associated with this type of plate boundary?

FURTHER INFORMATION

For more on Plate Tectonics including images of the plates moving over time:

www.ucmp.berkeley.edu/geology/tectonics.html

Information on Alfred Wegener; the man who first proposed the theory of Plate Tectonics:

www.ucmp.berkeley.edu/history/wegener.html

Up to date theories on the mechanics of Plate Tectonics:

www.hartrao.ac.za/geodesy/tectonics.html

A comprehensive site including the history of Plate Tectonic theory:

<http://platetectonics.pwnet.org/>

The Australian Museum's site on Plate Tectonics:

www.amonline.net.au/geoscience/earth/tectonics.htm

Plate Tectonics: ANSWERS

Chapter 1: The Theory of Plate Tectonics

1. Wegener noted that continents seemed to fit together like a jigsaw and that plants, animals and rocks were identical on continents now separated by ocean.
2. Oceanic plates are heavier because they are mostly comprised of dense basalt. The less dense rocks of the continents 'float' on top of this heavier, dense material.
3. The floating iceberg gave Wegener the idea that the continents, although massive, could also float.
4. Wegener's book is *The Origins of Continents and Oceans*.
5. Fossil evidence showed that continents now separated by oceans had once been joined together.
6. Wegener called this land form Pangaea which means 'all land' in ancient Greek.
7. The southern most land mass, which contained Australia, was Gondwana.
8. Laurasia and Gondwana collided around 300 million years ago to form the super continent of Pangaea.
9. The super continent of Pangaea broke up to the continents we have today.

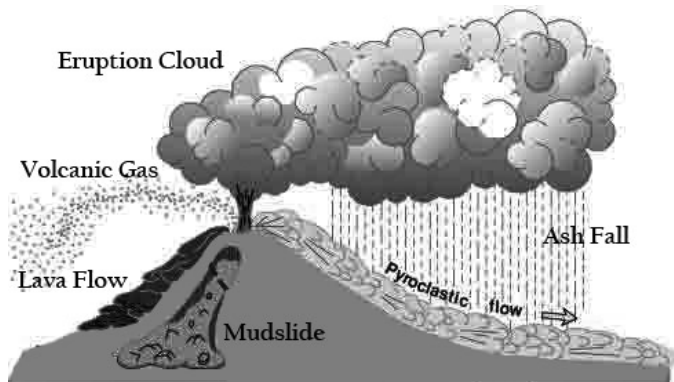
Chapter 2: How the Plates Move

10. The lithosphere comprises the earth's crust and the semi-molten upper mantle.
11. Plate Tectonics describes how the earth's crust is divided into separate plates that all move independently of each other.
12. The plates 'float' on top of the molten rocks of the mantle and they are driven by convection currents within the mantle.
13. Plates move at different speeds because some are weighed down by their size.
14. When plates collide and shift against each other volcanoes and earthquakes occur.
15. The Ring of Fire describes a zone of volcanoes surrounding the Pacific Ocean. This zone is the edge of the large Pacific Plate that collides with various continental plates.

Chapter 3: Types of Plate Boundaries

16. The mid-ocean ridge is a mountain range that is constantly growing as two plates separate.
17. When plates are moving apart as they are at the mid-ocean ridge, it is called a divergent boundary.
18. In a few million years ocean will flood the Rift Valley cutting East Africa off from the rest of the continent.
19. The old rocks are returned to the mantle at convergent boundaries where one plate sinks beneath another.

20. A subduction zone is where one plate (often a more-dense oceanic plate) is forced under another plate (often a less-dense continental plate).
21. The rock of the oceanic plate is forced downwards towards the mantle. As it travels down it melts and returns to the mantle. It may then rise again in one of the many volcanoes that line the continental edge of convergent boundaries.
22. Deep ocean trenches are associated with convergent boundaries and form when the oceanic plate is drawn downwards towards the mantle.
23. When two plates collide and one does not slip under the other, the rocks of the plates buckle and fold into mountains.
24. When the Indian Plate collided with the Eurasian Plate the pressure folded the earth's crust to create the Himalaya Mountains.
25. Yes, the Himalaya Mountains are increasing in height by an average of 10 mm (2 inches) a year.
26. At this point in the history of these mountains, their rate of growth is almost exactly matched by their rate of erosion - so there is no overall growth.
27. A transform fault occurs when two plates slide along side each other.
28. The San Andreas Fault is formed by the Pacific Plate sliding alongside the continental American Plate.
29. Earthquakes are frequent along transform faults.



VOLCANOES

Fire from the Earth

In 1993 scientists working at mapping the sea floor in the South Pacific Ocean discovered a vast field of volcanoes towering 2,500 metres above the sea floor. Of the 1133 volcanoes mapped, two or three could be erupting at any time and the discovery underlies that we still have much to learn about the processes and mechanisms of volcanoes.

While Australia may only have one active volcano (Big Ben on Heard Island), we are nearby to countries such as Papua New Guinea which rest on the Pacific Ocean's 'Ring of Fire'. At places like Rabaul in New Britain, volcanoes are a constant factor of life and only recently new volcanic sea mounts have risen out of the water in the town's harbour.

Volcanoes can occur at divergent faults between tectonic plates; such as the mid-ocean ridge where new rocks and mountains are being created everyday. This zone circles the globe and includes the island nation of Iceland whose many volcanoes and hot springs are testimony to the volcanic activity created in this zone.

Volcanoes can also occur at subduction zones and many of the Pacific Rim volcanoes fall into this category. Like those at Rabaul, the volcanoes in our region are created when the more-dense Pacific Plate is forced under the less-dense Indo-Australian Plate. As a result, a line of volcanoes such as those at Rabaul is created.

At other places, hotspots are formed in an area of weakness in the earth's surface, allowing magma to come near to the surface. Yellowstone National Park and the Hawaiian Island chain are both examples of hotspot volcanic activity.

While the volcanoes themselves come in the three major varieties of Shield, Cinder Cone and Composite Volcanoes, the types of explosions that can issue from these volcanoes is varied and depends on many factors. From the super-fast Plinian explosion to the soft rolls of pillow lava that form under water, volcanic eruptions can come in all shapes and sizes.

Due to their size, majesty and destructive powers, volcanoes are frequently studied by vulcanologists, but research into how to predict eruptions is still in its infancy and new discoveries concerning volcanoes are being made everyday.

Word Check: Plate Tectonics, Ring of Fire, Subduction Zone, Magma, Lava, Shield Volcano, Cinder Cone Volcano, Composite Volcano, Pompeii, Herculaneum, Volcanic Plug.

Pre-viewing Questions:

1. Has anyone ever seen an active volcano? What was it like?
2. What is happening to cause a volcano to erupt?

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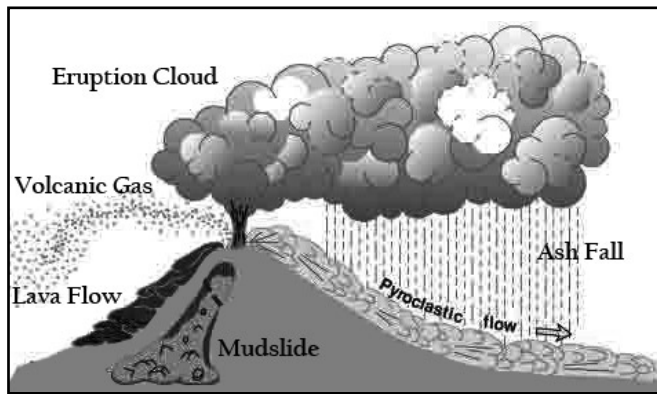
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Volcanoes: QUESTIONS

1. Which ancient Roman town was destroyed by a volcano in AD 79?

Chapter 1: What is a Volcano?

2. What is a volcano?
3. Where do volcanoes most frequently occur?
4. How fast do the plates of the earth's crust move?
5. Around what zone does 60% of the world's volcanic activity take place?
6. What is the 'Ring of Fire'?
7. What is a subduction zone?
8. What is magma?
9. What forms island chains such as Japan and Indonesia?
10. How does sea floor spreading work?
11. Which country is actually part of the mid-ocean ridge?

12. What is a hotspot?
13. Which national Park in the USA is a volcanic hotspot that attracts thousands of visitors to its hot springs and geysers?
14. How do geologists believe the Hawaiian Islands were formed?

Chapter 2: Types of Volcanoes

15. What are the three types of volcanoes?
16. How do you recognise a Shield Volcano?
17. What is found at the top of the Shield Volcano?
18. What is lava?
19. What happens when there is a lot of water in the lava?
20. High viscosity lava cools into what sort of rocks?
21. What are Cinder Cone Volcanoes made of?
22. How do Cinder Cone Volcanoes erupt?
23. What are Composite Volcanoes?
24. Name some famous Composite Volcanoes from around the world?

Chapter 3: Why do Volcanoes Explode?

25. What is a steam explosion?
26. What is a St Rombolian explosion?
27. What is a Plinian explosion?

28. What is a Glowing Cloud eruption?
29. What is a Paroxysmal eruption?
30. Which famous Indonesian volcanic eruption was a Paroxysmal eruption?
31. What is a Caldera?
32. How was the ancient Roman city of Herculaneum destroyed in AD 79?
33. What is a volcanic plug?
34. In February 1993, what was discovered in the South Pacific Ocean?

FURTHER INFORMATION

For more on volcanoes in all their guises:
<http://volcano.und.nodak.edu/vw.html>

The Australian Museum's pages on volcanoes:
www.amonline.net.au/geoscience/earth/volcanism.htm

A central site for all things volcano:
www.volcanoes.com

A educational look at how volcanoes work:
http://www.geology.sdsu.edu/how_volcanoes_work/

A huge site on volcanoes by Australian volcanologist John Seach:
www.volcanolive.com

Geoscience Australia's Volcano site:
www.ga.gov.au/urban/factsheets/volcanoes.jsp

An interesting case study of living with volcanoes in Papua New Guinea:
www.globaleducation.edna.edu.au/archives/secondary/casestud/png/4/volcanoes.html

Volcanoes: ANSWERS

1. The town of Pompeii, along with the neighbouring town of Herculaneum, were destroyed by the volcano Vesuvius.

Chapter 1: What is a Volcano?

2. It is simply a point where molten rock (magma) rises from the mantle to the earth's surface.
3. Volcanoes most frequently appear along the boundaries of plates and are closely related to the activity of Plate Tectonics.
4. They move at about the same rate as your fingernails grow.
5. The majority of the world's volcanoes are clustered around the Pacific Ocean's 'Ring of Fire'.
6. The Ring of Fire describes a zone of volcanoes surrounding the Pacific Ocean. This zone is the edge of the large Pacific Plate that collides with various continental plates.
7. A subduction zone is where one plate (often a more-dense oceanic plate) is forced under another plate (often a less-dense continental plate).
8. Magma is molten rock.
9. About 150 kilometres behind a subduction zone, a range of volcanic mountains form. If the subduction zone is at sea, then these volcanic mountains become islands such as Japan and Indonesia.
10. Sea floor spreading occurs when two plates move apart creating a line of volcanic mountains.

11. The nation of Iceland with its many volcanoes is part of the mid-ocean ridge.
12. A hotspot is a weak area of the earth's crust in the middle of a plate where volcanic activity takes place.
13. Yellowstone National Park is famous for its low-level volcanic activity.
14. The Hawaiian Islands are volcanic formed one after the other as the Pacific Plate inched its way north over a fixed hot spot.

Chapter 2: Types of Volcanoes

15. Shield, Cinder Cone and Composite are the three major forms of volcanoes.
16. A Shield Volcano has gently sloping sides created by lava flowing over the side.
17. A steep walled crater with fissures would be at the top of a Shield Volcano.
18. Lava is magma (molten rock) when it is on the surface.
19. With a lot of water present, the lava has a low viscosity and it flows very fast.
20. High viscosity lava with low water content forms rough, chunky rocks.
21. A Cinder Cone Volcano is created when cinders and ash build up after spewing from a single vent.
22. A Cinder Cone Volcano erupts when water is superheated by underground magma causing a build up of pressure that is released in an explosion.
23. Composite Volcanoes are built up of alternating layers of lava and ash.

24. Mount Vesuvius (Italy), Mount St Helens (USA) and Mount Fuji (Japan) are all Composite Volcanoes.

Chapter 3: Why do Volcanoes Explode?

25. A steam explosion occurs when a rising column of magma heats the water table generating enough steam pressure to break through the crust.
26. In a St Rombolian explosion the lava is vicious and escapes in lumps or bombs.
27. A Plinian explosion consists of the lava being forcibly ejected from the volcano at great speed (twice the speed of sound).
28. A Glowing Cloud is created when viscous, gas rich magma erupts to form a huge cloud of ash and pumice over a volcano. This ash and pumice then falls to the ground.
29. A Paroxysmal explosion is a sudden eruption from a large, shallow magma chamber.
30. The eruption of the island of Krakatoa in the late nineteenth century was a sudden and massive Paroxysmal eruption.
31. When an eruption empties the magma chamber the volcano can collapse down into the chamber to form a caldera.
32. Herculaneum was destroyed by a mud-flow caused by volcanic ash mixing with water.
33. A volcanic plug is cooled magma in a volcanic vent that remains after the rest of the mountain has eroded away.
34. Scientists mapping the sea floor discovered a vast cluster of 1,133 sea mounts; some of which were 2,500 metres tall.

EARTHQUAKES

Predicting the Big One!

Earthquakes are one of the more poorly understood natural disasters that periodically affect people around the world.

Recently in China, Iran, Turkey and many other countries, the devastating effect of earthquakes have been felt. These events can decimate communities and obliterate towns; often towns that have stood impregnable for hundreds of years.

Naturally, due to the appalling loss of life and property caused by earthquakes, a lot of effort has been devoted to understanding how earthquakes occur and how it might be possible to predict the arrival of major earthquakes.

Not until the theory of Plate Tectonics was advanced did people have any hope of understanding the origins of the enormous amounts of energy seen in earthquakes. Now, with highly accurate instruments, many based in space, seismologists can map the minute movements of the many plates that comprise the earth's crust.

At the boundaries of these plates several things can happen. If one plate buckles and rises against another plate a normal fault is created and the resulting earthquakes tend to be small. When two plates slide along side each other to create a strike-slip fault, the resulting earthquakes also tend to be small. But when one plate is forced under another

in a reverse, or thrust, fault, severe earthquakes can result.

While earthquakes might originate in three major ways, they all have common features such as hypocentres, epicentres and seismic waves. Our knowledge about these features has increased along with the science for recording and mapping the many earthquakes of different magnitude that affect the world each day.

While the science of recording earthquakes is well advanced, the science of predicting earthquakes is a very imprecise science. However, as long as earthquakes continue to be a threat to both life and property, scientists from around the world will work at ways for allowing us to better understand the tremendous forces of earthquakes, and perhaps, to predict or prevent the Big One!

Word Check: Lithosphere, Mantle, Normal Fault, Reverse Fault, Strike-Slide Fault, Tsunami, Ring of Fire, Hypocentre, Epicentre, Seismic Waves, Seismograph, Seismometer, Richter Scale.

Pre-viewing Questions:

1. Have any earthquakes or tsunami affected our region recently? How do these events affect the lives of people where they occur?
2. Have there ever been any earthquakes in Australia?

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Earthquakes: QUESTIONS

1. What are some common types of natural disasters that occur around the world from time to time?
2. What is the 'Ring of Fire'?
3. Where have some major earthquakes occurred in recent history?
4. Why did the 1989 San Francisco earthquake not cause a greater loss of life?
5. Why did the Los Angeles 1994 earthquake also result in a low loss of life?

Chapter 1: Causes of Earthquakes

6. What causes the ground to split open in earthquakes?
7. How many major plates are there?
8. What the lithosphere?
9. How do the semi-molten rocks in the earth's mantle help the plates move?
10. What are fault zones?
11. What happens when two plates that are locked together suddenly give way and shift?

Chapter 2: Types of Earthquakes

12. What are the three types of faults that result in an earthquake?
13. Can earthquakes occur in places such as Australia which is in the middle of the Indo-Australian Plate?
14. Mid-ocean spreading ridges are an example of what type of fault?
15. A reverse fault (a upward sloping fault, also known as a thrust fault) often occur in subduction zones. What are subduction zones?
16. Where do the majority of the earth's earthquakes occur?
17. What causes a Tsunami?
18. A strike-slip fault (or transform fault) is what type of fault?
19. What produces the San Andreas Fault in California?
20. What type of fault produces the worst earthquakes?

Chapter 3: Features of Earthquakes

21. What is the hypocentre of an earthquake?
22. What is the epicentre of an earthquake?
23. What are Seismic Waves?
24. What is the difference between an earth-flow and a landslide?



Questions Continue

Earthquakes: QUESTIONS - Continued

25. Seismic Waves come in two main forms; Body Waves and Surface Waves. Why are they called Body and Surface Waves?
26. Compression Waves compress and expand the rock through which they travel. What happens when these waves reach the surface?
27. Shear Waves travel like a wave through the rocks of the earth's crust. What happens when these waves reach the surface?
28. What causes more damage to towns and cities; Body or Surface Waves?

Chapter 4: How to Predict Earthquakes

29. What are seismographs?
30. To accurately position an earthquake, why are three seismometers used?
31. What is the Richter Scale?
32. An increase of one point in the Richter Scale means how much more energy has been released?
33. Above what point on the Richter Scale are earthquakes considered major?

34. How is the epicentre of an earthquake located by seismologists?
35. Why does the world have a good network of seismological stations?
36. How have advances in space technology advanced our understanding of plate movement?
37. There are many methods that seismologists use to try to predict large earthquakes, but how accurate are they?
38. Seismologists were not able to predict the 1994 Los Angeles earthquake. Why not?
39. Rather than predicting the arrival of earthquakes, what is a better strategy for dealing with earthquakes?

FURTHER INFORMATION

Recent Australian earthquakes, large and small:

www.seis.com.au/EQ/Earthquakes.html

Up to the minute information on earthquakes around the world:

<http://neic.usgs.gov/neis/current/world.html>

The Australian Museum's pages on Plate Tectonics and Earthquakes:

www.amonline.net.au/geoscience/earth/tectonics.htm

Earthquakes: ANSWERS

1. Floods, blizzards, storms and fires are some of the more common natural hazards to affect people around the world.
2. The Ring of Fire is a zone of encircling the Pacific Ocean where earthquakes commonly occur.
3. Major earthquakes have occurred in China, Mexico, Armenia and the USA. More recently major earthquakes have also affected Iran.
4. The 1989 earthquake occurred when most people were at home and not on the freeways that were severely damaged.
5. This 1994 earthquake struck at 4 am when freeways and shopping malls were deserted.

Chapter 1: Causes of Earthquakes

6. The ground sometimes splits occur due to constant movement of the plates that make up the earth's crust.
7. There are about 10 major plates and 20 smaller ones.
8. The lithosphere includes the earth's crust and the semi-molten mantle beneath it.
9. The molten rocks of the mantle act as a lubricant that help the solid rocks of the earth's crust slide across the mantle.
10. Fault zones are the boundaries between plates.
11. The release of energy when plates slip against each other results in an earthquake.

Chapter 2: Types of Earthquakes

12. Normal, reverse and strike-slip faults are the major causes of earthquakes.
13. Although the majority of earthquakes are interplate earthquakes that occur at plate boundaries, some intraplate earthquakes do occur in the middle of plates where there may be a weakness in the crust.
14. Normal faulting (a downward sloping fault) causes mid-ocean ridges where two plates are spreading apart.
15. A subduction zone occurs when one plate slides under another.
16. Earthquakes most commonly occur in subduction zones where 80% of the world's earthquakes are registered.
17. A Tsunami can occur when an earthquake (and land collapse) occurs at sea.
18. A strike-slip fault occurs when two plates slide along side each other.
19. The San Andreas Fault is caused by the Pacific Plate sliding horizontally alongside the American Continental Plate.
20. Reverse faults create the largest and deepest earthquakes.



Answers Continue

Earthquakes: ANSWERS - Continued

Chapter 3: Features of Earthquakes

21. The hypocentre is the point of origin of the earthquake within the earth's crust.
22. The epicentre is the closest point on the earth's surface above the hypocentre.
23. Seismic Waves are shock waves from an earthquake that travel through the earth's crust.
24. A landslide occurs under dry conditions.
25. Body Waves travel through the body of the earth, while Surface Waves only travel along the surface of the earth.
26. Compression Waves cause damage to buildings by compressing and expanding them.
27. Shear Waves cause buildings to sway from side to side.
28. Body Waves cause far more damage than Surface Waves.

Chapter 4: How to Predict Earthquakes

29. Seismographs are instruments for measuring shifts in the position of the earth's crust.
 30. To accurately record movements in the earth; one seismometer registers up-down movements, another, east-west movements, and the third, north-south movements.
 31. The Richter Scale is a logarithmic scale for measuring earthquakes.
 32. A one point increase in the Richter Scale means a 32 times increase in the energy of the earthquake.
 33. A reading above 7 on the Richter Scale often indicates a severe earthquake.
 34. Three seismographs at different locations record the distance of an earthquake to each seismograph. When this information is combined, then the epicentre can be mapped.
 35. The seismological stations were built during the 1960s by the USA and the Soviet Union who wanted to monitor each other's nuclear testing.
 36. Both high resolution photography and accurate measurements by satellites have led to a far greater understanding of how much the plates are moving relative to each other.
 37. No one method in use today gives a reasonable prediction, but when several methods are combined the chance of prediction increases.
 38. The 1994 earthquake occurred in a previously unmapped fault and behaved in a way that had not been seen before. Therefore due to the lack of our knowledge, it was unpredictable.
 39. The best strategy is to build earthquake resistant housing in earthquake prone areas.
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