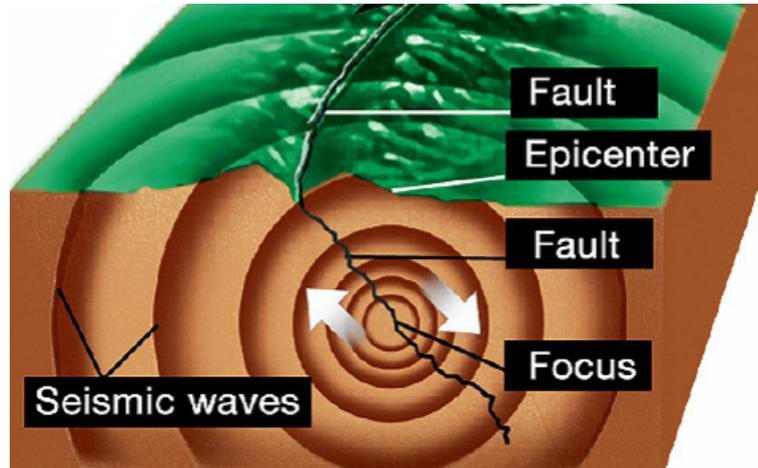


9.1 What is an earthquake?



In this first video on the earthquake unit, you'll learn what causes an earthquake, how the movement of lithospheric plates compares to the opening of a stuck door or the movement of a line of grocery shopping carts, what a slickenslide is, and how foreshocks and after-shocks are usually found on either side of the main earthquake event.

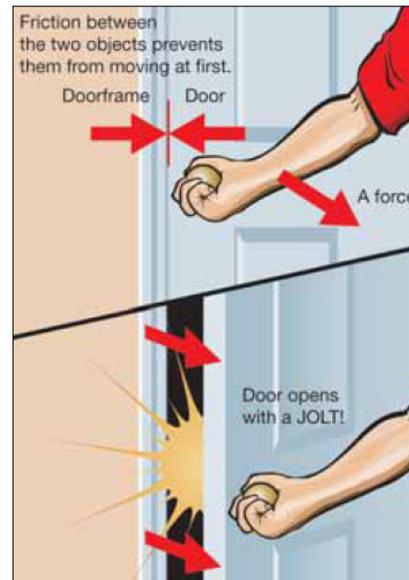
Chapter Nine: Earthquakes

- **9.1 What is an Earthquake?** 
- **9.2 Seismic Waves**
- **9.3 Measuring Earthquakes
& Learning about Tsunamis**
- **9.4 Tsunamis**

As you can see, there are four videos in the series. This is the first video – an introduction to Earthquakes.

9.1 What is an earthquake?

- An **earthquake** is a form of stick-slip motion.
- Stick-slip motion can be compared to a stuck door.



If you think of lithospheric plates as pushing together and becoming stuck – and then tension and pressure builds up just as when you try to open a door that is jammed. When the door finally opens, it opens with a jolt. This same thing happens to large lithospheric plates. Pressure builds up and sections of the plate resist moving until finally they move with a jolt. This “jolt” is when the earthquake occurs.

9.1 Stick-slip motion

- Three conditions are needed for stick-slip motion:
 1. Two objects that are touching each other where at least one of the objects can move.
 2. A force, or forces, that will cause the movement.
 3. Friction strong enough to temporarily keep the movement from starting.

Use the stick-slip door model to identify these conditions.

Lithospheric plates are always in motion. As two plates move in opposite directions, some sections get stuck. The friction between the two plates is strong enough to temporarily stop their movement. Pressure from the mantle builds up and eventually, the stuck place in the crust “gives” and releases its energy through a jolt. We call this “jolt” a “stick-slip” motion.

9.1 Friction



- Friction is a resistance to slip that occurs when two objects rub against each other.

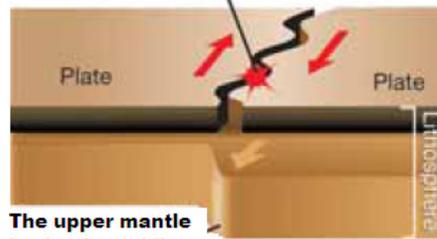
Friction is the resistance to slip that occurs when two objects rub against each other. In this example, the sock is smooth on the bottom and so will have much less friction on the floor than the sneaker, which has a rubber tread designed to increase friction. If you wanted to slide easily across the floor, you would have much better luck in socks than you would wearing sneakers.

9.1 What causes earthquake?

- An **earthquake** is the movement of Earth's crust resulting from the release of built-up potential energy between two stuck lithospheric plates.

Stick-slip motion

Brittle crust sticks and releases.



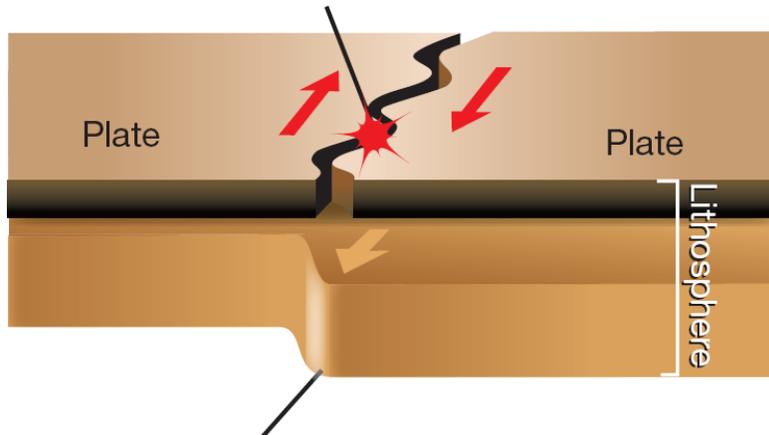
The upper mantle
is plastic and flows

The stick-slip motion we have been talking about is where two sections of the brittle crust stick at first and then are released, causing energy to be sent out from the stick-slip site in the form of earthquake seismic waves.

Plate Stick-Slip Motion

Stick-slip motion

The brittle crust sticks and releases.

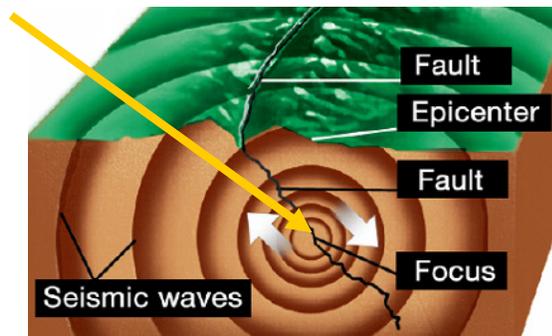


The upper mantle is plastic and flows.

Here is a close-up of the same graphic. Two lithospheric plates are trying to pass by each other, one going away from us, and one moving towards us. At the stick-slip site, friction (let's call it POTENTIAL ENERGY) builds up until the moving plates are able to overcome the blockage. At the point when the blockage is released, an earthquake will occur.

9.1 What causes earthquakes

- The point below the surface where the rock breaks is called the earthquake **focus**.



The FOCUS of an earthquake is the point below the surface where stick-slip motion occurred. Rocks break and seismic vibrations are released.

9.1 What causes earthquakes

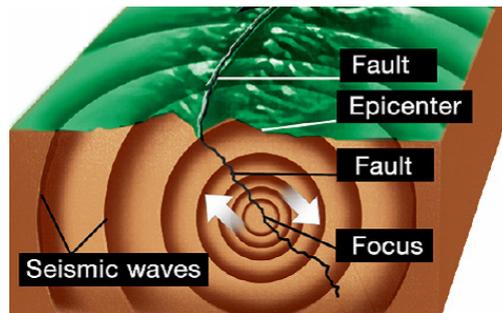
- As soon as the rock breaks, there is movement along the broken surface causing a split in the surface called a **fault**.



A fault line, such as the San Andreas Fault in California, represents the area where two plate boundaries intersect. Fault lines are generally NOT perfectly straight. Sometimes, they are difficult to locate and are only revealed through the tracking of repeated small earthquakes.

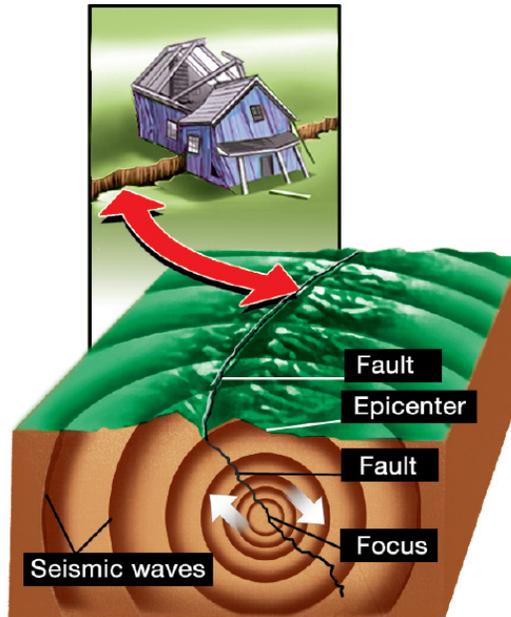
9.1 The nature of plates

- The seismic waves from an earthquake are usually strongest at the **epicenter**, the point on the surface right above the focus.



The focus is the point below ground where the earthquake occurred. Deep focus earthquakes can occur at subduction zones as deep as 700 kilometers down. Shallow focus earthquakes can be less than 50 kilometers below the surface. If a line is extended straight up to the surface over the focus of the earthquake, we call this the EPICENTER – the point on the surface right above the focus.

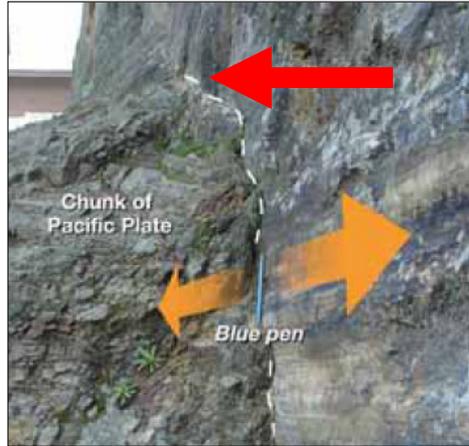
Parts of an Earthquake



If buildings are located above the focus at the earthquake EPICENTER, much damage can occur as this is the area of the strongest seismic waves.

9.1 Slickensides

- The effect of rock moving against rock is evidence of plate boundaries.
- The rock surface moving to the right is called **slickensides** because it is smooth and polished.



A SLICKENSLIDE is an area of rock that is smooth and polished and can only occur when plate boundaries move against each other with a grinding and smoothing action. Typically this would occur along a transform boundary.

9.1 The nature of plates



- A cracked shell on a hard-boiled egg is similar to lithospheric plates on Earth's surface.

Earth's crust is like the shell of an egg – very thin compared with the rest of the egg. So earth's crust is just a thin skin around the planet – quite brittle and easy to crack and break.

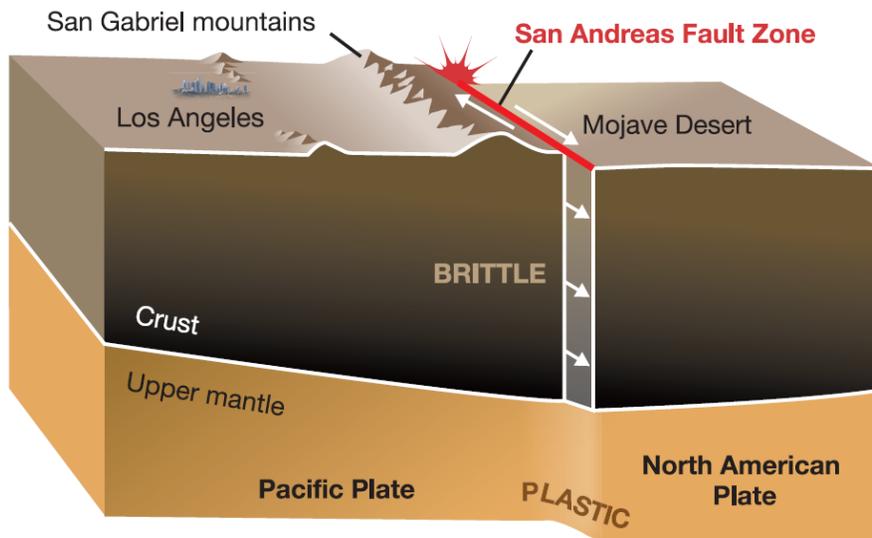
9.1 The nature of plates

- A moving line of grocery carts is a better example of a moving lithospheric plate.
- Although a plate may be moving as a single unit, its boundaries act like they were made of many small sections like the line of carts.



In this picture a line of grocery carts is being pushed across a parking lot. Just as the grocery carts jostle and move back and forth in the line, so too do sections of lithospheric plates move. Although a plate may be moving as a single unit, its boundaries act like they were made of many small sections, just like the grocery carts in line.

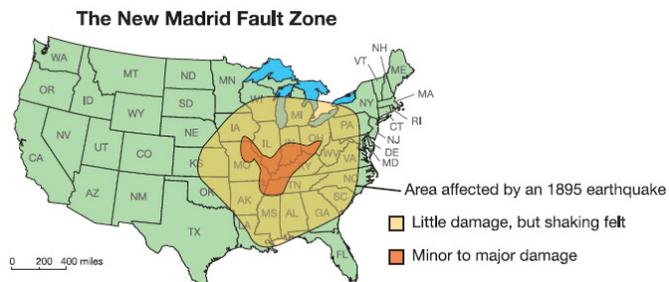
Cross-Section of the San Andreas Fault Zone



An earthquake in one section of the San Andreas fault can increase the stress and built-up energy in another section. The added stress can trigger a second earthquake in the new section.

9.1 When do earthquakes happen?

- The release of built-up potential energy causes earthquakes.
- An earthquake is a stress reliever for a lithospheric plate.
- Once a quake occurs, potential energy builds up again.



The red area in Tennessee, Kentucky, Indiana, Illinois, Missouri, and Arkansas is called the **NEW MADRID FAULT ZONE**. This is an ancient plate boundary. Throughout Earth's history, lithospheric plates have been torn apart, added to, and joined to other plates. As a result of this reshaping there are old plate boundaries inside of the plate boundaries we see today. In 1895 there was a major New Madrid event.

9.1 When do earthquakes happen?

- The second longest ever recorded earthquake occurred in 1964 in Alaska and lasted for four minutes.
- **Foreshocks** are small bursts of shaking that may precede a large earthquake.



In 1964 Alaska experienced the second largest earthquake ever recorded in the United States. The pink area on the map slipped seaward up to 66 feet. The earthquake was preceded by FORESHOCKS, small bursts of shaking.

9.1 When do earthquakes happen?



- **Aftershocks** are small tremors that follow an earthquake, lasting for hours or even days after the earthquake.

Aftershocks are additional small tremors that may last hours or days or months after the initial earthquake.

9.1 Secret Code

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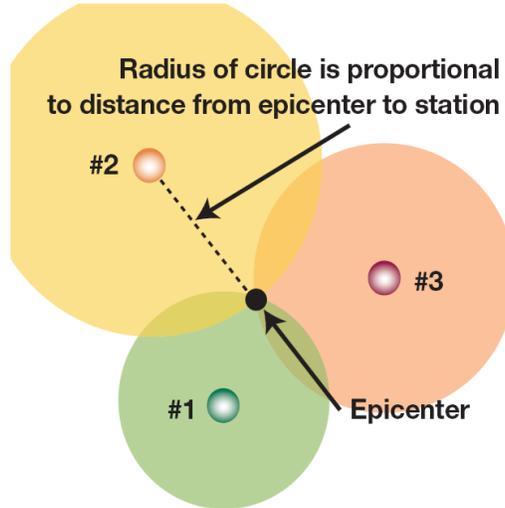
^ ∩ ∩

^ ∩ - Г \ / • ∅ ∩ < /

(5 Words) Read from the top DOWN to the bottom.

Try your hand at decoding this secret message. There are five words. Read the message from the top of the column DOWN to the bottom.

9.2 Pinpointing an Earthquake



This video deals with seismic waves and how you can use 3 pickup stations to determine the position of an earthquake epicenter.

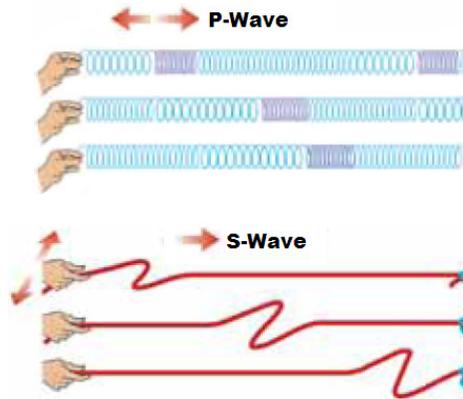
Chapter Nine: Earthquakes

- 9.1 What is an Earthquake?
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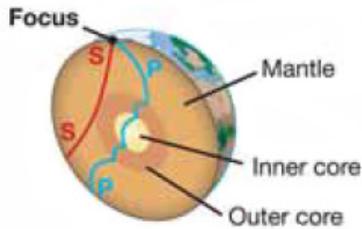
This is the second video in our four-part series on earthquakes.

9.2 Seismic waves

- Seismic waves that travel through Earth's interior are called **body waves**.
- The two main kinds of body waves are **P-waves** and **S-waves**.



Seismic waves that travel through the earth are called "BODY WAVES." The two main kinds are P-waves (called PRIMARY WAVES), which travel faster than other waves. These waves push and pull on rock as they travel. The rock moves in the same direction that the wave moves. The second main kind of waves are S-waves (called SECONDARY WAVES). These travel more slowly and cause the rock to move in a side-to-side motion.



9.2 Seismic waves

- Seismic waves bend when they contact different materials.
- Liquid—like the liquid outer core of Earth—acts as a barrier to S-waves.
- P-waves pass through liquid.
- Waves on the surface, or body waves that reach the surface, are called **surface waves**.

Because of different materials inside the Earth, seismic waves may be bent and even deflected. Seismic waves can also change speeds by moving faster in cooler material and slower in hotter material. The liquid outer core blocks S-waves, while P-waves pass right through. Some seismic waves travel along the surface, and are called SURFACE WAVES.

9.2 Measuring seismic waves

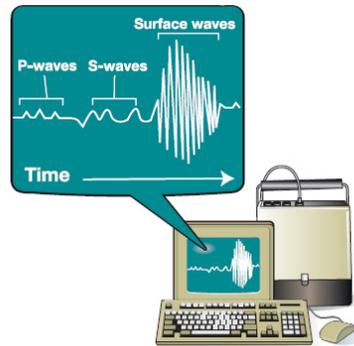
- People who record and interpret seismic waves are called **seismologists**.
- Seismic waves are recorded and measured by an instrument called a **seismograph**.



A scientist who records and interprets seismic waves is called a SEISMOLOGIST. Seismologists study the interior of our planet by observing the way seismic waves travel through Earth. This process is similar to using X rays to create a CAT scan of the interior of the human body. The instrument that records the waves is called a SEISMOGRAPH. Seismographs can be used to study earthquakes along fault zones. From their readings scientists can determine the strength of an earthquake, how far away it was, and, if they have data from at least two other stations, the location of the epicenter of the earthquake.

9.2 Measuring seismic waves

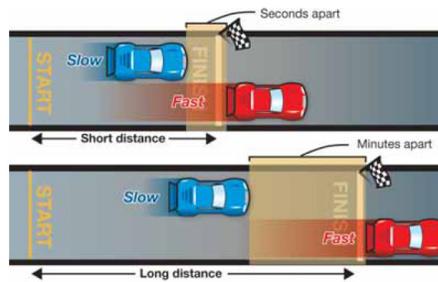
- After an earthquake occurs, the first seismic waves recorded will be P-waves.
- S-waves are recorded next, followed by the surface waves.



After an earthquake occurs, the first seismic waves recorded by a seismograph will be P-waves (called PRIMARY WAVES). These waves travel the fastest in a push-pull fashion. Next, S-waves (called SECONDARY WAVES) arrive, followed by the slowest of all – SURFACE WAVES.

9.2 Measuring seismic waves

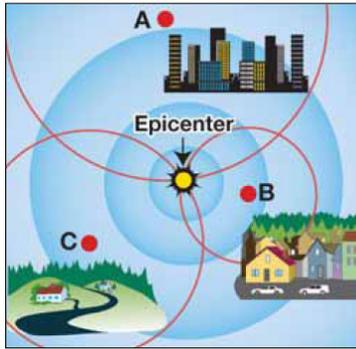
- In a quarter-mile race, the track is so short that fast and slow cars are often just fractions of a second apart.
- In a long race, like the Indianapolis 500, the cars might be minutes apart.



- The time difference between slow and fast cars is related to the length of the race track.

As in this race car example, if the earthquake is close by, the difference between the arrival times of P-waves and S-waves will be very small. The further away the earthquake occurs, the farther apart the arrival time will be between the beginning of P-waves and the beginning of S-waves.

9.2 Measuring seismic waves



- Seismic waves radiate from the focus after the earthquake.
- Three seismic stations can accurately determine the times of body wave arrival.

Seismic waves radiate out from the earthquake epicenter in a circular fashion. Seismic stations located at points A, B, and C will pick up the seismic vibrations at different times because they are different distances from the epicenter. Using data from each of the three stations, it is possible to plot the exact epicenter of the earthquake.

9.2 Distance to epicenter

- Seismologists use computers to determine the distance to an epicenter.

Station name	Arrival time difference between P- and S-waves	Distance to epicenter
1	10 seconds	80 km
2	50 seconds	420 km
3	30 seconds	250 km

A seismologist would begin with readings from three different pick-up stations. As you can see for stations 1, 2, and 3 --- the difference in arrival times between P and S waves varies -- yielding different distances to the epicenter.

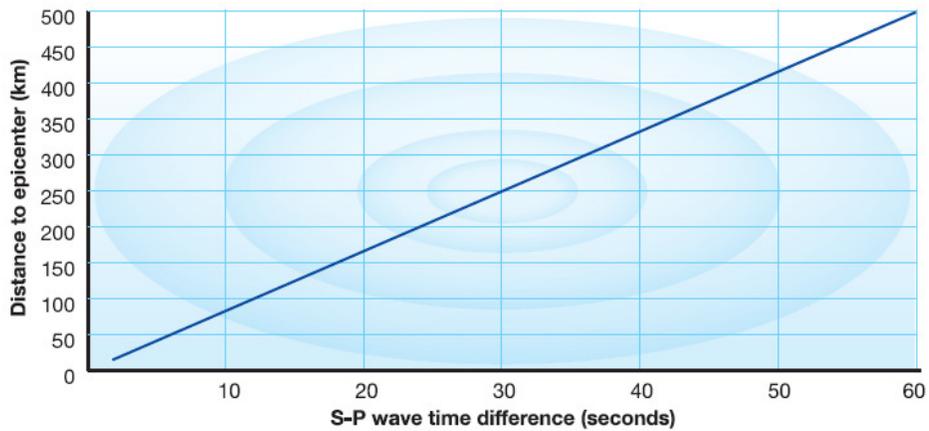
9.2 Distance to epicenter

1. Identify three seismic stations and locate them on a map.
2. Determine the time difference between the arrival of the S-waves and the P-waves at each station (Use chart data).
3. Convert the time differences into distances to the epicenter (Use graph).
4. Set a geometric compass so that the space between the point and pencil on the compass is proportional to the distances that you found in Step 3. (Use graph scale)
5. Draw a circle around each seismic station location.
6. The intersection of the 3 circles is the epicenter!

In class we will do a lab using these steps to locate an earthquake epicenter. We'll start with readings from three seismographs to determine the time difference between the arrival of S-waves and P-waves. From this time difference you will be able to use a graph to determine how far away from the epicenter the pick-up station was. Finally, using a geometric compass you'll be able to draw concentric circles around the seismic station. Where the three circles intersect is the location of the earthquake epicenter.

9.2 Distance to epicenter

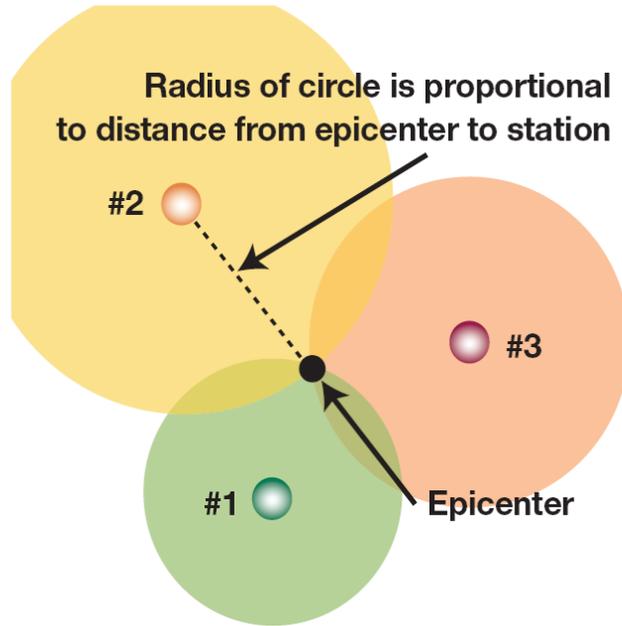
Distance to the epicenter vs. Time difference



A graph is used to plot S-P wave differences versus distances to the epicenter. For instance, a time difference of 30 seconds yields a distance of 250 kilometers. A time difference of 60 seconds yields a distance of 500 kilometers.

Finding the Epicenter

Radius of circle is proportional to distance from epicenter to station



Once these distances are calculated, a compass can be used to draw three circles on a map. Where the circles intersect is where the earthquake epicenter is located.

9.2 Secret Code

⓪σσ

πσ

⓪* * ⓪

ρ η ⓪ ⓪

π 2 √ * *

⓪ ⓪

⓪ * η ⓪ ⓪ η ⓪

* ⓪ √ π 2 * ⓪ ⓪ * *

⓪ π ⓪ π η σ ⓪ ⓪

* √ η ⓪ * ⓪ π π * √

Read DOWN the first column, and then DOWN the second column. (10 words)

Now that you have learned how to plot the epicenter of an earthquake, you are ready for our EPICENTER LAB and... this secret code. There are ten words. Read DOWN the first column and then again, DOWN the second column to figure out the message. Good luck!

9.3 Measuring an Earthquake



Seismograph with a recording of the Loma Prieta, California earthquake, October 17, 1989.

Once data on an earthquake is recorded, scientists use different scales to rate the intensity of the event.

Chapter Nine: Earthquakes

- 9.1 What is an Earthquake?
- 9.2 Seismic Waves
- 9.3 Measuring Earthquakes
& Learning about Tsunamis
- 9.4 Tsunamis



This is video number 3 in our four part series on earthquakes.

9.3 Measuring Earthquakes

- The **Richter scale** rates earthquakes according to the size of the seismic waves recorded on a seismograph.

The Richter scale					
Level	Magnitude	Effects			
Micro	Less than 2.0	Barely felt	Moderate	5.0 - 5.9	Major damage to poorly-designed buildings
Very minor	2.0 - 2.9	Recorded but not felt by most people	Strong	6.0 - 6.9	Serious damage over a 100-mile area or less
Minor	3.0 - 3.9	Little damage but felt by people	Major	7.0 - 7.9	Serious damage over a larger area
Light	4.0 - 4.9	No serious damage, objects shake	Great	8.0 - 8.9	Serious damage over several hundred miles
			Rare great	9.0 or greater	Serious damage over several thousand miles

The Richter scale rates earthquakes according to the size of the seismic waves recorded on the seismograph. Seismic wave energy increases 10 times for each Richter number change. This means that a magnitude 9 earthquake on the Richter scale would be 1,000 times more powerful than a magnitude 6 earthquake. The Richter scale assumes that the measurements were taken near the earthquake center. A close relative of the Richter scale is the MOMENT MAGNITUDE scale. These two scales are the same up to level 5. For larger earthquakes, however, seismologists tend to use the more descriptive Moment Magnitude scale since it rates the total energy released by an earthquake.

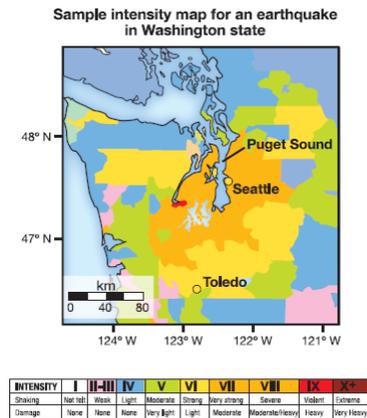
9.3 Measuring Earthquakes

- The largest earthquake recorded occurred in Chile in 1960.
- It was off the Richter scale; seismologists estimated this quake to be 9.5.



The largest earthquake recorded occurred in Chile in 1960. It was off the Richter scale at an approximate 9.5 level.

9.3 Measuring damage



- The **Mercalli Intensity scale** has 12 descriptive categories.
- Each category is a rating of the damage suffered by buildings, the ground, and people.

The Mercalli Intensity scale has 12 descriptive categories. Each category is a rating of the damage suffered by buildings, the ground, and people.

Mercalli Intensity	Characteristic Effects	Approximate Richter Magnitude
I. Instrumental	Not felt	1
II. Just perceptible	Felt by only a few people, especially on upper floors of tall buildings	1.5
III. Slight	Felt by people lying down, seated on a hard surface, or in the upper stories of tall buildings	2
IV. Perceptible	Felt indoors by many, by few outside	3
V. Rather strong	Generally felt by everyone; sleeping people may be awakened	4
VI. Strong	Trees sway, chandeliers swing, bells ring, some damage from falling objects	5
VII. Very strong	General alarm; walls and plaster crack	5.5
VIII. Destructive	Felt in moving vehicles; chimneys collapse; poorly constructed buildings seriously damaged	6
IX. Ruinous	Some houses collapse; pipes break	6.5
X. Disastrous	Obvious ground cracks; railroad tracks bent; some landslides on steep hillsides	7
XI. Very disastrous	Few buildings survive; bridges damaged or destroyed; all services interrupted (electrical, water, sewage, railroad); severe landslides	7.5
XII. Catastrophic	Total destruction; objects thrown into the air; river courses and topography altered	8

Because earthquake damage can be different from place to place, a single earthquake may have different Mercalli numbers depending on how far away the seismic station is from the earthquake's epicenter.

9.3 Where do earthquakes occur?



- Earthquakes commonly occur at the boundaries of lithospheric plates.
- This is because plate boundaries tend to be *zones* of seismic activity.

Earthquakes commonly occur at the boundaries of lithospheric plates and less commonly at faults that are inside plate boundaries. Plate boundaries tend to be ZONES of seismic activity. Therefore, earthquakes do not just occur along neat lines showing the general plate boundary. The California coast lies along the San Andreas Fault. Many branches of the fault form a large EARTHQUAKE ZONE.

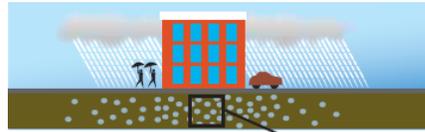
Earthquakes and Plate Boundaries



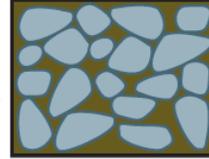
With both convergent and divergent boundaries, earthquakes signal the build up of potential energy and its release as plates move towards and away from each other. As seismic stations pick up earthquakes a fairly accurate plate boundary map can be constructed over time which clearly shows the size and positions of the major tectonic plates.

9.3 Earthquakes

- Soil types can affect the amount of damage caused by earthquakes.
- When seismic waves pass through the ground, the soil can act as a liquid.
- This is called **liquefaction**.

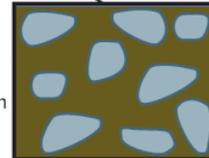


- Water-saturated soil
- Particles slightly separated
- Water pressure is low



Liquefaction

- Particles are further separated
- Water pressure is high



Soil types can affect the amount of damage caused by earthquakes. When seismic waves pass through the ground, the soil can act as a liquid. This is called LIQUIFACTION. The 1989 Loma Prieta earthquake caused a lot of damage in San Francisco. The area most damaged had been built on top of San Francisco Bay mud. Liquefaction occurs when soil is saturated with water. An earthquake increases pressure on the soil so that the particles separate with water between them. The result is that the soil acts like a liquid and any building on the surface will begin to sink, just as if it were sinking in water.

9.3 Earthquakes – Building Materials

Easily damaged by earthquakes	Earthquake resistant
Brittle building materials	Flexible building materials
brick	steel
mortar	wood
adobe	

- Earthquake vibrations easily damage heavy, brittle building materials like brick, mortar, and adobe.
- Buildings with well-designed steel supports are less likely to be damaged during quakes.

It is the vibrations caused by seismic waves that results in the most damage in earthquake areas. Brick, mortar, and adobe construction tends to suffer the most. Steel-reinforced buildings are more earthquake resistant.

9.3 Earthquakes – Buildings

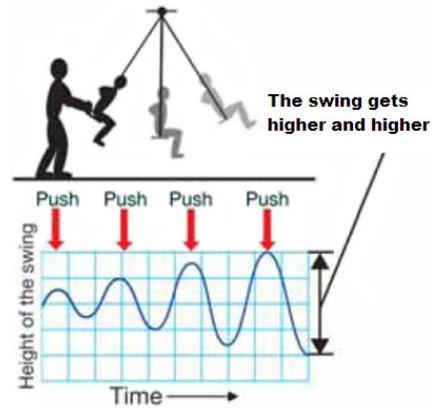
- Mexico City had short, medium, and tall buildings before an earthquake struck in 1985.
- Many of the medium-height buildings were destroyed.
- Why did short and tall buildings survive?



Taller buildings should be more susceptible to earthquake damage – but, this is not always the case. In the Mexico City earthquake of 1985, it was the medium-sized buildings that were destroyed. The swaying of the medium-sized buildings happened to match the earthquake vibrations.

9.3 Earthquakes – Vibrations

- The swaying of the medium-height buildings happened to match the earthquake vibrations.
- This is similar to how you can make someone go higher on a swing if you push them at the right time.



This made the Mexico City medium-sized buildings sway more and more with each seismic push of the earthquake. This is similar to how you can make someone go higher and higher on a swing if you give them a push each time they swing back towards you.

9.3 Earthquakes – 7 Steps to Safety



1. Secure it



2. Plan



3. Disaster Kit



4. Safety Check



5. Drop, Cover, Hold on



6. Check it out



7. Communicate & Recover

Here are 7 steps to Earthquake Safety:

Step 1: Secure it. Conduct a "hazard hunt" to help identify and fix things such as unsecured [televisions](#), [computers](#), [bookcases](#), furniture, unstrapped [water heaters](#), etc. Securing these items now will help to protect you tomorrow.

Step 2: Make a plan

Make sure that your emergency plan includes evacuation and reunion plans; your out-of-state contact person's name and number; the location of your emergency supplies and other pertinent information. By planning now, you will be ready for the next emergency.

Step 3: Make disaster kits

Your disaster supplies kits should include food, water, flashlights, portable radios, batteries, a first aid kit, cash, extra medications, a whistle, fire extinguisher, etc.

Step 4: Safety Check

Most houses are not as safe as they could be. There are [things that you can do to improve the structural integrity of your home](#). Some of the things that you might consider checking include [inadequate foundations](#), unbraced [cripple walls](#), [soft first stories](#), [unreinforced masonry](#) and [vulnerable pipes](#). [Consult a contractor or engineer](#) to help you identify your building's weaknesses and begin to fix them now.

Step 5: DROP, COVER, and HOLD ON!

During earthquakes, drop to the floor, take cover under a sturdy desk or table, and hold on to it firmly. Be prepared to move with it until the shaking stops.

Step 6: Check it out!

One of the first things you should do following a major disaster is to check for injuries and damages that need immediate attention. You should be able to administer first aid and to identify hazards such as damaged gas, water, sewage and electrical lines. Be prepared to report damage to city or county government.

Step 7: Communicate and recover!

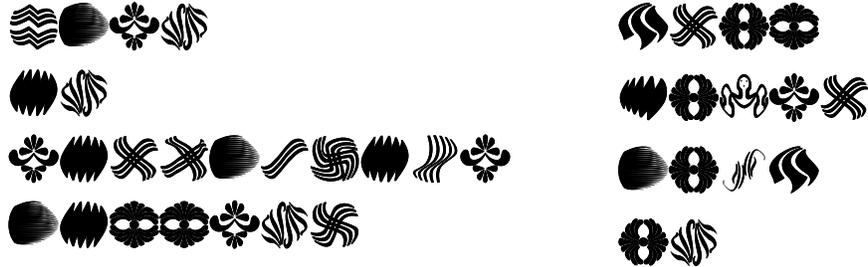
Turn on your portable radio for information and safety advisories. Communicate with friends and relatives to let them know that you are safe.

9.3 Earthquakes -- Response



Learn what to do during an earthquake --- drop to the floor, take cover under a sturdy desk or table, and hold on to it firmly. Be prepared to move with it until the shaking stops. After the shaking stops, exit the building and head for an agreed upon meeting place outside.

9.3 Secret Code



(8 WORDS)

Read DOWN the left column and then DOWN the right column.

The secret code has 8 words. Start on the left column and read DOWN, then read the right column DOWN from the top. Good luck!

9.4 Tsunamis



A tsunami is a series of ocean waves that sends surges of water, sometimes reaching heights of 100 feet onto land. These surges of water can cause widespread destruction when they crash ashore.

Chapter Nine: Earthquakes

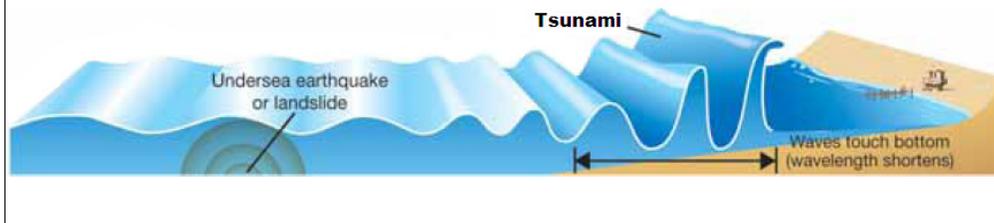
- 9.1 What is an Earthquake?
- 9.2 Seismic Waves
- 9.3 Measuring Earthquakes
& Learning about Tsunamis
- 9.4 Tsunamis 

This is the 4th and final video in our series on earthquakes.

9.4 Tsunamis – “Harbor Wave”

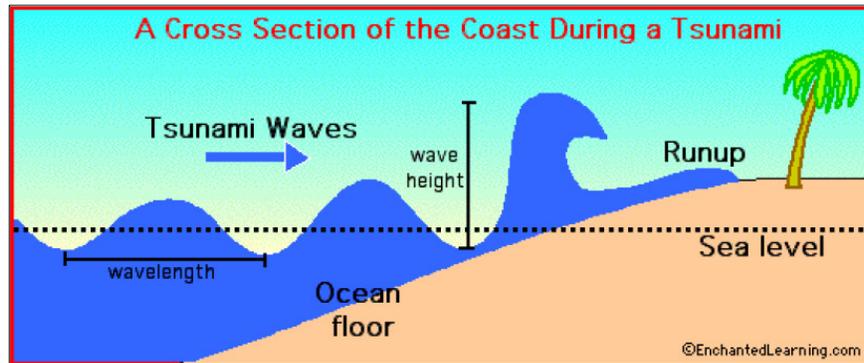


- **Tsunami** is a Japanese word that means “harbor wave.”
- Sudden movements of the sea floor cause tsunamis.



Tsunami is a Japanese word that means “harbor wave.” Sudden movements of the sea floor cause tsunamis. These movements may be earthquakes, volcanic eruptions, landslides on a steep underwater face, or even a meteor impact. You have learned that earthquake energy is spread by seismic waves. In a similar way, energy from underwater movements is sent out as waves on the ocean surface.

9.4 Tsunamis – Cross Section



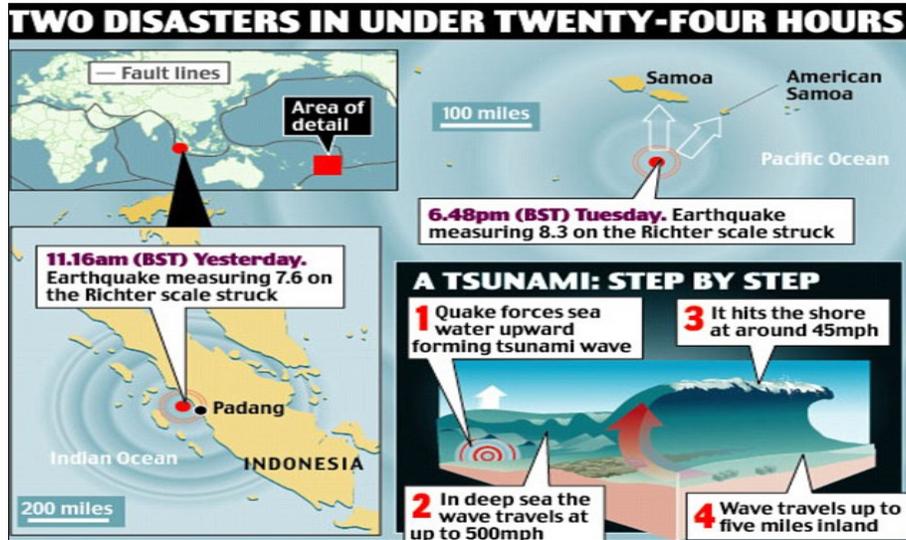
In the open ocean, wind-driven waves and tsunamis are about the same height. But the wavelength of a tsunami is much longer than the wavelength of a wind-driven wave. The wavelength of a wind-driven wave may measure 20-40 meters from crest to crest. It may take ten seconds or so for a wind-driven wave to pass by. The wavelength of a tsunami is hundreds of kilometers long! If a tsunami approached your ship at sea, it would cause the ship to rise gently, less than 10 feet perhaps and then settle gently back after several minutes. When the tsunami approaches land, the lower front edge of the wave begins to drag on the shallow bottom. As the front slows, the back of the wave catches up. This shortens the wavelength. Shortening the wavelength makes the wave crest higher. It's this huge crest of water, between 10 and 100 meters high, that comes flowing over beaches and harbors and can flow up to five miles inland.

9.4 Tsunamis – Sumatra, 2004



On December 26, 2004 monstrous tsunami waves struck the coasts of Sumatra island, Bangladesh, India, Malaysia, Myanmar, Thailand, Singapore, Maldives, and other territories bordering the Indian Ocean, affecting 14 countries in total. During the Indian Ocean earthquake, 1,200 kilometers (750 miles) of the plate boundary slipped when the Indian Plate slid under the Burma Plate (part of the Eurasian Plate). The seabed rose over 6 feet, causing huge tsunami waves.

9.4 Tsunamis – Sumatra, 2004



The tsunami was triggered by a very powerful magnitude 9.1-9.3 earthquake with an epicenter off the west coast of Sumatra, Indonesia. The tsunami and earthquake caused the deaths of 230,000 people. Waves reached 65 to 100 feet in height and swept over and destroyed the shores of Indonesia, Sri Lanka, and Thailand. The tsunami even traveled as far as Africa, nearly 8,000 kilometers (5000 miles) from its start. Tsunami waves can travel up to 500 miles per hour and move up to five miles inland when they reach the shore.

9.4 Tsunamis – Japan, 2011



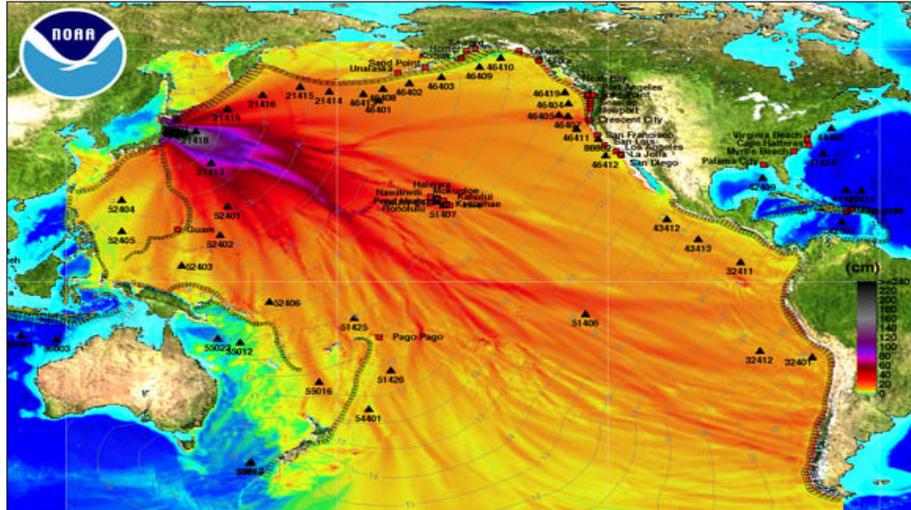
The massive tsunami generated by the March 2011 earthquake off the coast of northeastern Japan was a "merging tsunami" — a type of tsunami long thought to exist, but seen in 2011 for the first time. In this picture you can see the huge volume of water that overflows the sea wall in this Japanese harbor. So much water came into the harbor that boats were carried right over the sea wall into flooded city streets.

9.4 Tsunamis – Japan, 2011



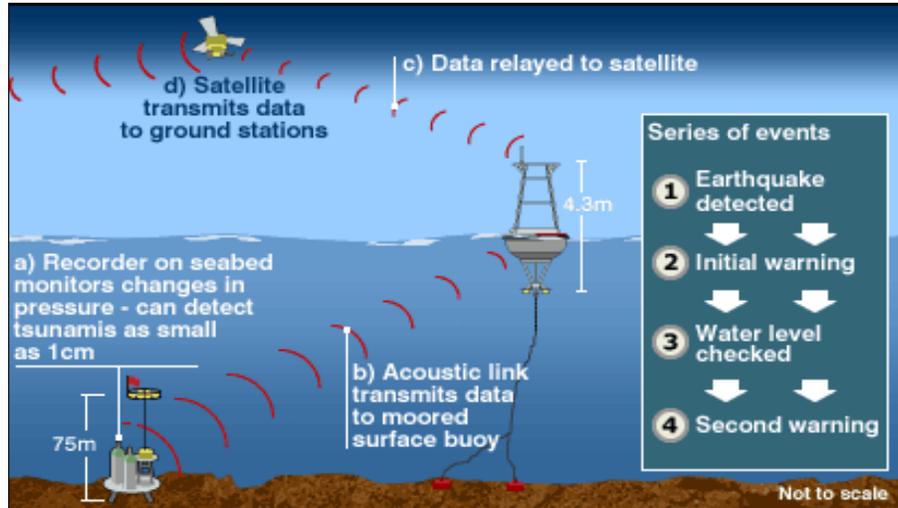
The magnitude-9.0 Tohoku-Oki temblor, the fifth-most powerful quake ever recorded, triggered a tsunami that doubled in intensity over rugged ocean ridges, amplifying its destructive power at landfall. The fronts merged to form a single, double-high wave far out at sea. With the on-rushing height of the wave at 30 to 100 feet higher than normal, Tsunami waves easily swept aside entire buildings and towns as they moved inland.

9.4 Tsunamis – Japan, 2011



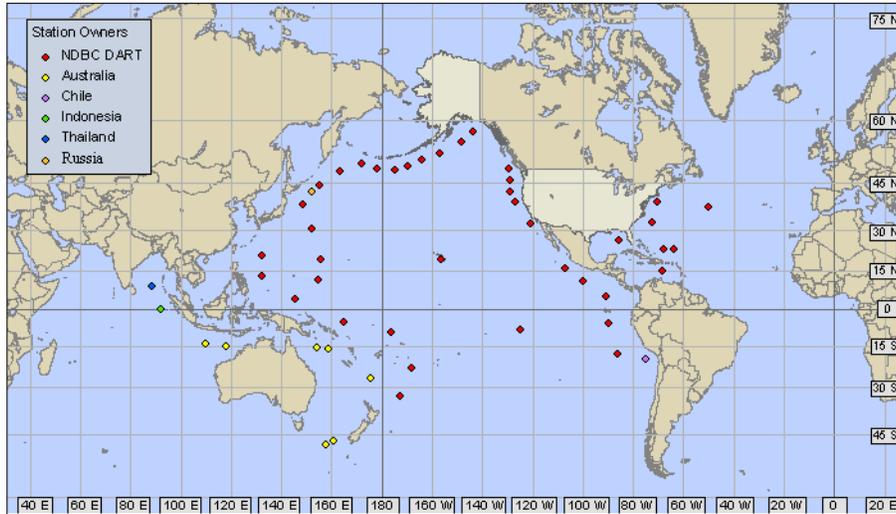
This wave was capable of traveling long distances without losing power. Ocean ridges and undersea mountain chains pushed the waves together along certain directions from the tsunami's origin. The NASA Jason-1 satellite passed over the tsunami on March 11, as did two other satellites — the NASA-European Jason-2 and the European Space Agency's EnvisAT. All three satellites carry radar altimeters, which measure sea-level changes to an accuracy of a few centimeters. Each satellite crossed the tsunami at a different location, measuring the wave fronts as they occurred. Researchers think ridges and undersea mountain chains on the ocean floor deflected parts of the initial tsunami wave away from each other to form independent jets shooting off in different directions, each with its own wave front.

9.4 Tsunami – Detection Buoy



We now have a series of tsunami detection buoys that ring the Pacific Ocean. A recorder on the sea floor monitors changes in water pressure. These stationary monitors can detect tsunamis as small as 1 centimeter. The seabed monitor then relays its information to a floating buoy on the surface which transmits its data to a satellite, which then relays it to a ground station.

9.4 Tsunami – Detection Buoy Network



Tsunami detection buoys have been placed along the coasts of Pacific Plate continents to try to give nations advance warning of approaching tsunamis. Since the Sumatra earthquake of 2004, additional buoys have been placed in the Indian Ocean area to give those nations coverage as well. The Pacific Tsunami Warning System is based in Honolulu, Hawaii. It monitors Pacific Ocean seismic activity. A sufficiently large earthquake magnitude and other information triggers a tsunami warning.

9.4 Tsunamis – In Case of

- **RUN to higher ground!**
- **Do not wait, do not investigate, RUN!**



A tsunami's trough, the low point beneath the wave's crest, often reaches shore first. When it does, it produces a vacuum effect that sucks coastal water out to sea and exposes the harbor bottom and sea floor. This is called DRAWBACK. This retreating of sea water is an important warning sign of a tsunami, because the wave's crest and its enormous volume of water typically hit shore five minutes or so later. Recognizing this phenomenon can save lives. So, if you see the water draw back from the beach – RUN to higher ground. A tsunami is usually composed of a series of waves, called a WAVE TRAIN, so its destructive force may be compounded as successive waves reach the beach. People experiencing a tsunami should remember that the danger may not have passed with the first wave and should wait until official word is given that it is safe to return to vulnerable locations.

9.4 Secret Code

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(9 Words) Read DOWN the left column, then DOWN the right column.

Now that you know all about tsunamis, try your hand at this secret code. There are 9 words. Read DOWN the first column and then DOWN the second column. Good luck!