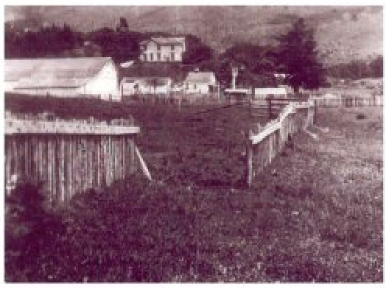
Ch. 11 Earthquakes

Mr. Aprill



Why do Earthquakes Occur?

1. Pieces of the earth suddenly shift.
2. The crust is mostly cold and brittle rock compared to the hot rock deeper inside.
3. This crust is full of large and small cracks called <u>faults</u>.
4. These faults can be <u>hundreds of miles</u> long
5. Usually you cannot see the cracks because they are buried deep underground.
6. Also, the pieces of crust are compressed together very tightly.

Why do Earthquakes Occur?

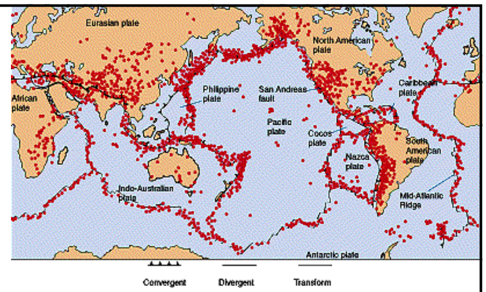
7. Powerful forces cause these crustal pieces to move very slowly.
8. The plates may get stuck together for many years.
9. The forces pushing on the plates can cause them to break apart and move suddenly.

When do they slip?

- When rocks past their *elastic limit.*
- They move along faults.
- The rocks remain bent after an earthquake.

Why do most earthquakes occur near plate boundaries?

- Forces inside of the earth including:
  1. Compression
  2. Tension
  3. Shear
- The movement occurs as an earthquake.



WHERE DO MOST OCCUR?

1. 80% of EQ occur along the pacific plate
2. 15% of EQ occur along the Mediterranean-Asiatic belt
3. 5% occur within interiors of plates or along oceanic ridge systems.

Types of Faults

Most earthquakes occur along plate boundaries.

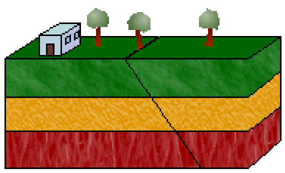
Different forces produce different fault types.

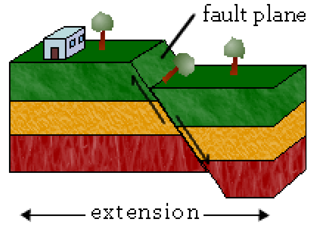
What are the three forces?

- ***Compression***—*force that squeezes & compresses.*
- ***Tension***—*stress that causes stretching and elongation.*
- ***Shear***—*force that causes slippage and the rocks on either side of the fault to move past each other.*

3 Types of Faults

1. Normal Fault
   - *What type of force?*
     - *Tensional Forces: rocks pull apart*
   - Rock above the fault surface moves downward in relation to the rock below.





Normal Fault

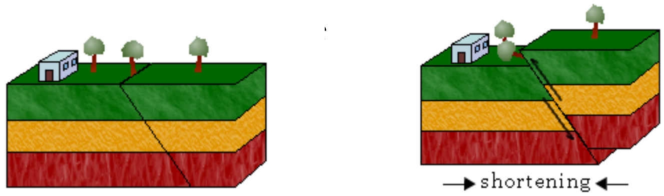
- This picture was taken after a 1999 earthquake near Dozce, Turkey

Normal Fault

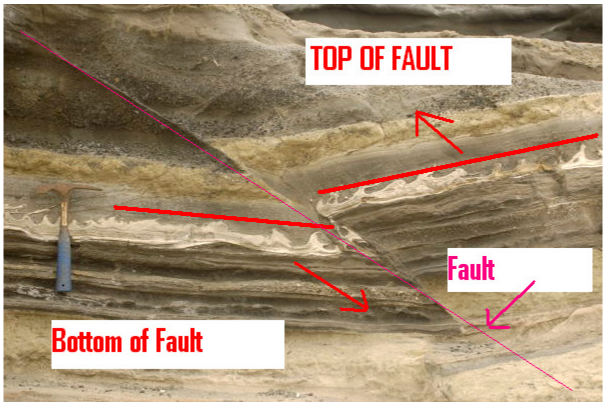
- Note: area above fault moved downward

3 Types of Faults

2. Reverse Fault
   - *What type of force?*
     - *Compression forces: forces push rock from opposite directions*
   - *Rock above the fault is pushed up & over the rock below the fault surface.*



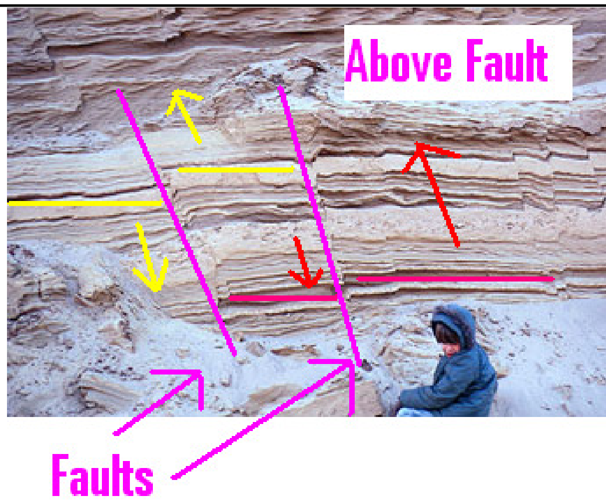
3 Types of Faults



Note: the area on top of the fault is moving upward. The area below the fault is moving downward.

Reverse Faults

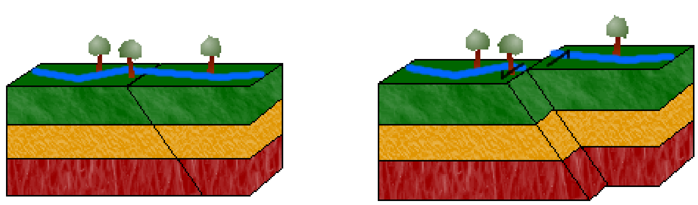
- In this example, you can see layers of sandstone laid down during the last ice age.
- This picture was taken about 5 miles west of Oshkosh, Wisconsin.



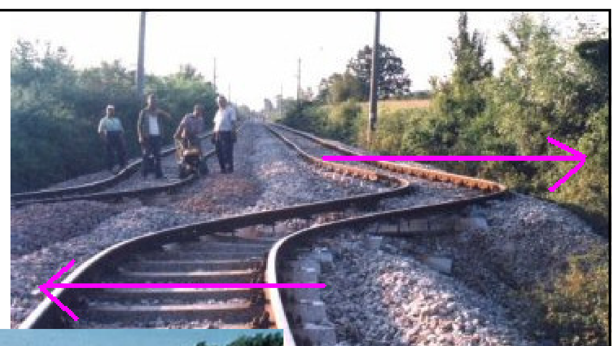
- Here we have two faults….but both are reverse since the area above each fault is moving upward in relationship to the area below the fault.

3 Types of Faults

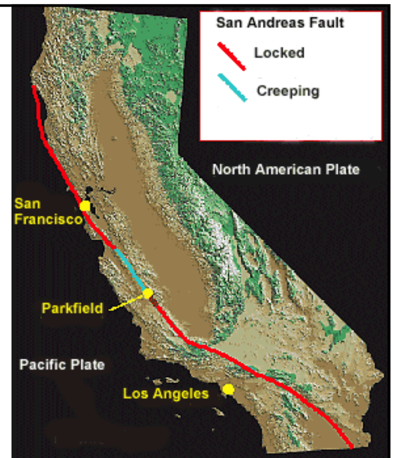
3. Strike-Slip Faults (Transform Fault)
   – Rocks on either side of the fault are moving past each.
   – There is no upward or downward movement.



Strike Slip Faults



San Andreas Fault



- Probably the best known example of a strike slip fault
- Largest Fault in California
- 1100 km through the state
- So, is California going to fall into the Pacific? (Why or Why Not?)

San Andreas Fault

- So, is California going to fall into the Pacific?
  - NO…it's a transform fault
  - It would have to be a divergent plate boundary.

What is a Seismic Wave?

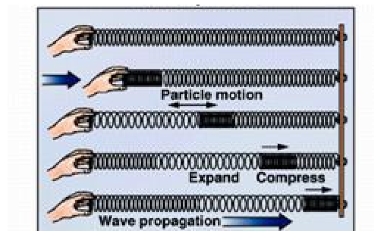
- Seismic Wave—the wave of energy generated in an earthquake.
- Three Types:
  - Primary Waves
  - Secondary Waves
  - Surface Waves

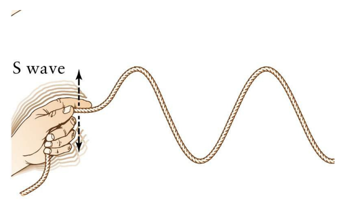
Earthquake Terminology

- Focus (plural = foci)—point where energy release first occurs.
  - Most are within 65 km of the earths surface.
  - Some have been recorded as deep as 700 km
  - Waves travel outward in all directions
- Epicenter—place at the Earths surface, directly above an earthquake focus.

Types of Seismic Waves

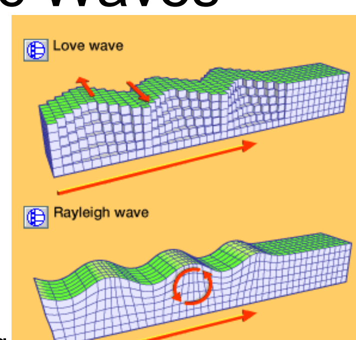
- Primary Waves (P Waves)
  - Rock compresses and stretches as the wave moves.
- Secondary Waves (S Waves)
  - Rocks move at right angles to the direction of wave travel.





Types of Seismic Waves

- Surface Waves
  - These are the most destructive.
  - Two types:
    - Love Waves (Q-Waves)
      - Move rock particles in a backward rolling motion and a side-to-side, swaying motion
    - Rayleigh Waves
      - Rock particles move in a rolling motion.
      - The slowest moving wave

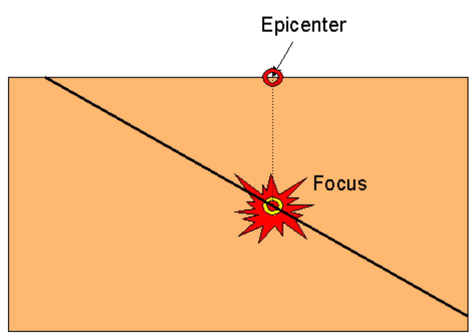


Why do surface waves cause so much damage?

- Many buildings are unable to withstand these waves since they are too stiff.
- They fall apart because parts of the buildings move in different directions.

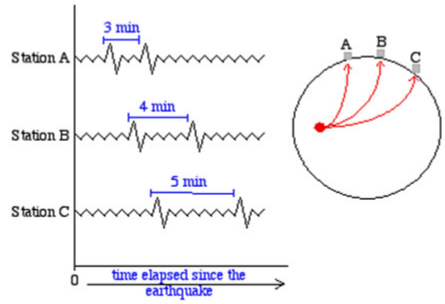
When do surface waves occur?

- Surface waves are produced when the earthquake energy reaches the Earth's surface.
- They travel outward from the <u>epicenter</u>.
  - This is the point directly above the focus.



How can we locate an epicenter?

- We use certain properties of seismic waves to locate the epicenter.
  - Primary waves are the fastest.
  - Secondary waves are slower.
  - Surface waves are slower yet.
- How can we use this information?
  - Since they travel at different rates, the time between the two waves increases with distance.



Example: Biking

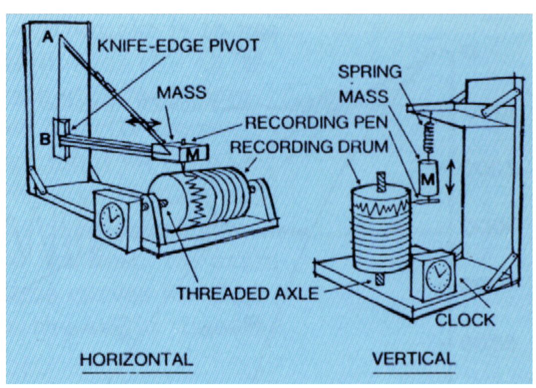
- Both of you leave your house at the same time to go to the store.
- One of you rides your bike faster then the other.
- **<u>The longer your riding, the further ahead the other gets.</u>**
- If you know how long it took each of you to get to the store, you can determine how fast you each were going, and then locate.

Measuring Seismic Waves

- After serious earthquakes in China, the Chinese scientist and mathematician invented the first seismograph in 132 A.D. to predict the next one.
- He called it an "earthquake weathercock"
  - When the ground shook, it moved a pendulum inside the jug.
  - The pendulum pushed a lever that opened the dragons mouth.
  - The ball landed in the toads mouth below, sounding an alarm.
  - The opened dragon's mouth pointed in the direction of the earthquake, notifying the emperor.

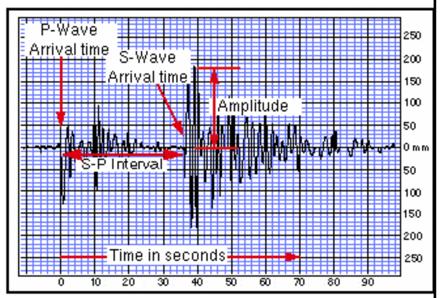
Modern Seismographs

- Today's seismographs have a rotating drum of paper and a pendulum with an attached pen.



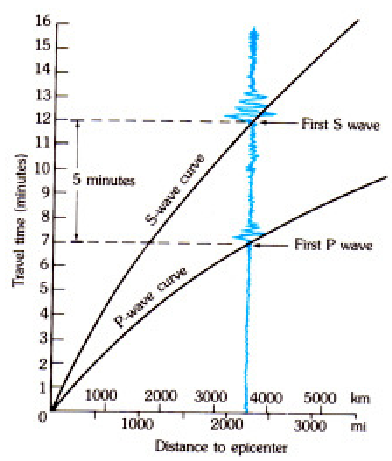
Seismograph Stations

- Each type of seismic wave reaches a seismograph station at a different time, based on it's speed.
  - Which arrives first?
  - Which arrives second?
  - Which arrives last?



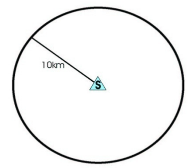
Seismograph Stations

- Since we know rates of travel for P and S waves, we can use a graph to determine distance from an epicenter.
  - P waves travel at 4 mi/sec (6 km/s)
  - S waves travel 2.5 mi/sec (4 km/s)
- Scientist use this to determine the lag time, that is the time between P and S waves.
- Using this, we can determine distance to the epicenter.
- Data is then compared with other seismic stations.

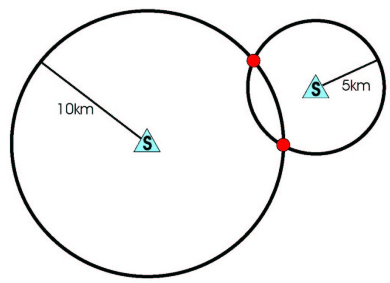


How many seismograph stations are needed to locate an epicenter?

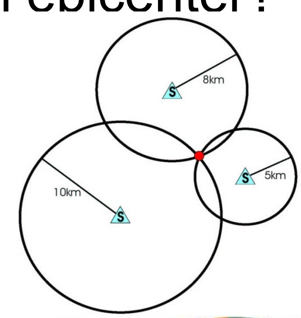
- If you have one station, how many possible sites are there?



- If you have two stations, how many possible sites a there?

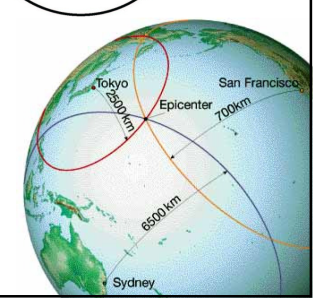


How many seismograph stations are needed to locate an epicenter?

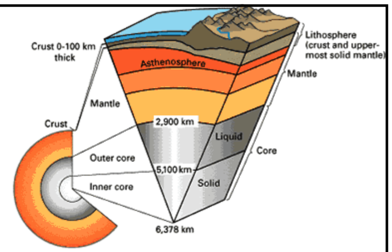


- If you have three stations, how many possible sites are there?

- What would be the advantage of four sites?

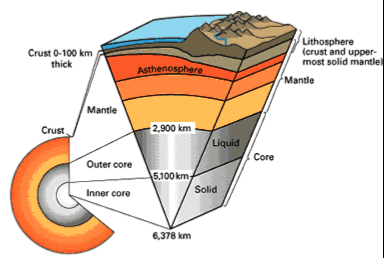


- We know a lot of information about the inside of the earth because of earthquakes.
- Crust (5-60 km)—outer most layer.
  - **Moho Discontinuity**—transition area that separates the crust from the Mantle.
  - Seismic waves speed up when they reach the bottom of the crust.
  - Discovered by and Yugoslavian scientist, **Andrija Mohorovičić**—he discovered that the waves were speeding up because they were passing into a denser layer of the lithosphere



Basic structure of Earth

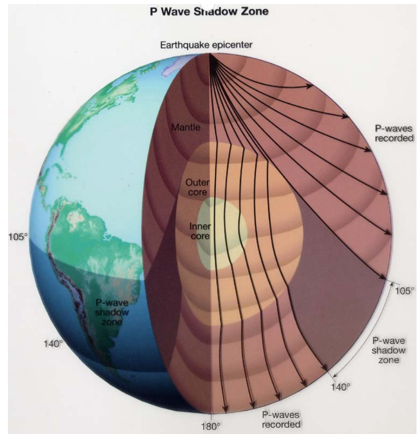
- Mantle, largest layer, mostly silicon, oxygen, magnesium, & iron. It is divided based on changes of seismic wave speed.
  - Upper Mantle (660 km)
    - Upper portion is called the asthenosphere since rock flows.
  - Lower Mantle (2225 km)
- Outer Core (2270 km)
  - Liquid layer, mostly iron.
- Inner Core (1216 km)
  - Solid dense layer, mostly iron. Has some nickel, oxygen, silicon, & sulfur.
  - Pressure from above causes it to be solid.



Basic structure of Earth

Mapping Earth's Internal Structure

- Since speeds and paths of waves change with density, we can map out the layers of the earth.
  - <u>Shadow Zone</u>: 105-140 degrees from an earthquake focus, no p or s waves are detected. The reason follows:
    - Secondary Waves—don't travel through liquid. (Therefore they stop at the liquid outer core)
    - Primary Waves—are slowed/bent by the liquid outer core. They speed up again as they travel through the solid inner core.



Layer Boundaries

[Simulation]

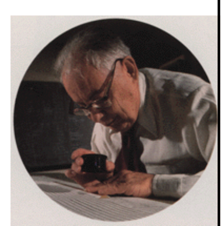
- Look at what happens when waves hit the bottom of the crust, upper mantle, lower mantle, outer core, & inner core.

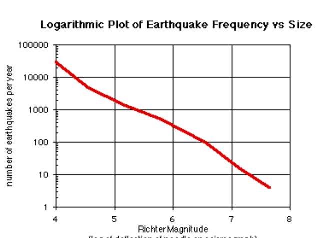
Studying Earthquakes

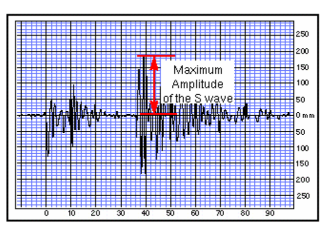
- Scientists who study earthquakes are called <u>seismologists</u>

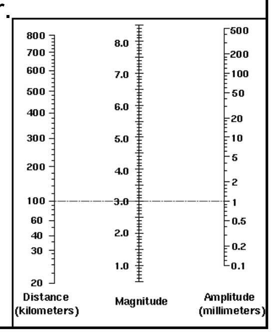
Richter Scale

- <u>Richter Magnitude</u>: measure of the amount of energy released in an earthquake. It is based on the maximum amplitude of the seismic waves.
- The Richter Scale:
  - Charles Richter (1934) developed the scale.
  - It is based on a logarithmic scale (base 10)
  - For every increase in 1 on the scale, the amplitude increases by 10.
  - Note: there is no high limit. However, the strongest recorded Earthquake was in China (9.7).
  - A graph shown here, illustrates how you can use amplitude to determine distance to the epicenter.









Richter Scale

- For example: an earthquake of 5 would have an amplitude 10 times greater than an earthquake of 4. Ex: Compare an 8 to a 7.
- Energy released: for every increase in 1, 32 times more energy is released at the focus. Ex: Compare a 5 to a 3.
- Example:
  - Magnitude 1= energy released by 6 oz TNT
  - Magnitude 8 = energy released by 6 million tons of TNT

Moment Magnitude

- Based on Earth movement or surface waves.
- Derived by multiplying the length of the fault rupture by the amount of rock movement and then again by the rock stiffness.
- Related to strength and size of fault movement.

Mercalli Scale

- Giuseppe Mercalli (1902)—invented another way to measure an earthquakes strength.
- This scale uses observations people experienced to determine intensity.
- It is not considered as scientific. Some examples follow.
  - 8—total damage, waves seen on the ground, Objects thrown in the air.
  - 6—Slight to moderate damage in well built, ordinary structures. Considerable damage to poorly built structures. Some walls may fall.
  - 1 to 2—Felt by few people, barely noticeable.

Large & Small Scale Earthquakes

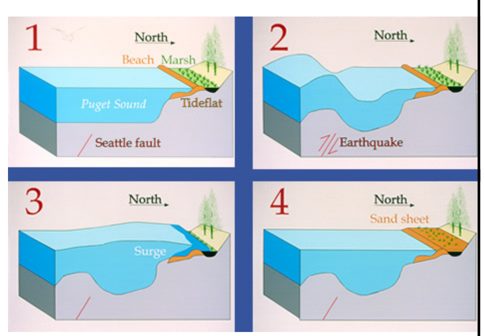
- Each year, about 55,000 earthquakes are felt but cause little or no damage—3.0 to 4.9.
- More than 1,000 earthquakes with magnitude 2 occur daily.
- See table 1 (Pg 314)
- Most deadly known earthquake: 1556 Shensi, China (Estimate of 9.7), 830,000 deaths.

Other Problems

- Liquefaction—when an earthquake causes the ground to become more liquid. This causes buildings to collapse.
  – People should avoid building on loose soils in these areas.

Causes of Tsunamis

- Three main causes of tsunamis:
  1. Underwater landslides
  2. Cosmic impacts
  3. Seismic activity



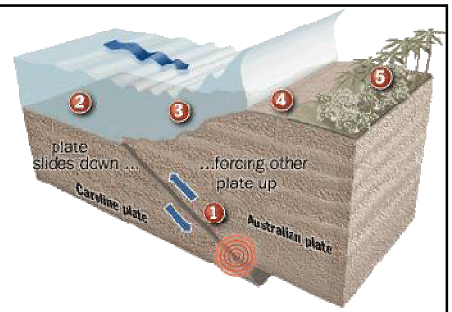
The ocean floor deforms.

This causes a displacement of water.

Tsunamis simulation

Tsunamis

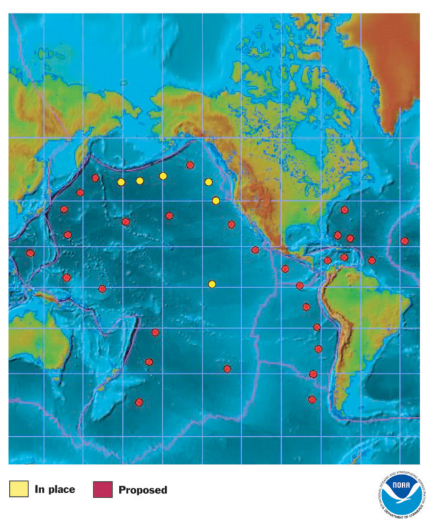
- EQ under the sea causes abrupt movement of ocean floor.
- The movement pushes against the water, generating a powerful wave that travels to the surface.
- After reaching the surface, the waves can travel thousands of km's in all directions.
- Once they get near shore, they begin to rise above the surface as high as 30m.



Tsunamis Warning Systems

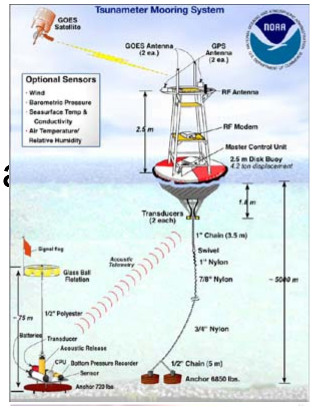
- The Pacific Tsunami Warning Center—near Hilo, Hawaii
- Provides predicted tsunami arrival times at coastal areas.
- This warning system is mostly for the Pacific Ocean.
- After the 2004 Tsunami, a expansion of the warning system was proposed.
- By 2007, the US will have deployed 27 additional DART (Deep Ocean Assessment & Reporting of Tsunami) Buoys
- This will give the US almost 100% protection to warn of tsunamis in the Caribbean, Atlantic, or Pacific Coasts.

Proposed DART Buoy System



Buoys

- Anyone can view the data a
  buoys at anytime.
- [DART Data Website]



Earthquake Safety

- Structures can be built seismic safe.
  - They stand up to vibrations
  - Support buildings with flexible circular moorings placed under the buildings.
  - They are made of alternating layers of steel and rubber.
  - Buildings should be able to survive an 8.3 earthquake.

What can be done to make homes safe?

- Move heavy objects to low shelves
- Learn how to turn off gas, water, electrical.
- This will protect against fire.
- Placing sensors on gas lines. They shut off gas in an earthquake.

During an earthquake

- Move away from windows and any objects that could fall.
- Seek shelter in a doorway or under a sturdy table or desk.
- If outdoors, stay in open areas away from power lines
- Stay away from buildings, chimneys, or other parts that may fall.

After an Earthquake

- Check water and gas lines for damage
- Shut off valves if damaged
- If you smell gas, leave
- Be careful around broken glass and rubble.
- Stay away from beaches—danger of tsunamis