San Francisco Earthquake
April 18th 1906

The epicenter was just north of San Francisco on the San Andreas Fault

Resulted in important discoveries concerning the origin of earthquakes
San Francisco Earthquake
April 18th 1906

- 10-20 ft of movement along the San Andreas fault for 250 miles (little vertical movement).
- Damage along entire 250 miles and up to 20 miles on either side (about 5,000 sq. miles of damage).
- Shock wave lasted for about 60 seconds and was felt as far away as Oregon and Nevada.
Damage to San Francisco

- Five square miles were totally destroyed (about 490 city blocks).
- Out of an initial population of 400,000 people, about 250,000 were left homeless and about 700 people were killed or missing.
- What caused most damage, the earthquake or the subsequent fire?
Composite Photos of San Francisco
Ground movement caused by the earthquake
Buildings collapse because of ground slumping
Faulting outside San Francisco

Note about 8-10 ft of horizontal movement with very little vertical movement.
250,000 homeless

700 people dead or missing
The San Francisco earthquake gave valuable insights into how earthquakes develop:

- Geodetic surveys showed that during the 50 years prior to the earthquake, distant points on either side of the San Andreas fault had moved a total of about 10 - 20 feet.

- The fault itself, however, had not moved during the same 50 year period.

**IT HAD REMAINED LOCKED!!!**
After the earthquake, the fault had also moved about 10-20 feet in about one minute!

The damage was not caused by the fault movement, but by undulating and shaking ground (the earthquake) that accompanied the fault movement.

A lot of the damage was caused by the subsequent fire.
These observations following the San Francisco earthquake in 1906 led to the development by H. F. Reid of the **ELASTIC REBOUND THEORY**
Summary of the Elastic Rebound Theory

- Slow and gradual movement on either side of a fault builds up ELASTIC STRAIN in the surrounding rocks.
- At some point the fault ruptures (breaks) releasing all of this elastic energy as EARTHQUAKE WAVES.
- Waves radiate outwards from this point of rupture (focus). Note, the point at the surface above the focus is known as the \textit{epicenter}.
- It follows that once the energy is released, there will be no more earthquakes on this specific part of the fault for some time to come.
- How long, is the multi-million dollar question!!
Types of Seismic Waves

- BODY WAVES - these move within the body of a rock and through the earth. There are two types:
  - P-Waves - or primary waves. These have the fastest velocities (about 300 km/minute), depending on the rock density.
  - S-waves - or secondary waves. They have slower velocities than P-waves (roughly half) and are felt after the P-waves (hence the name).
SURFACE WAVES - only travel near the earth’s surface. There are two types:-

- Love Waves - are similar to but slightly slower in velocity than S-waves.
- Rayleigh Waves - are also slightly slower than S-waves.
Primary Waves
Secondary Waves
Rayleigh Waves
Love Waves

Remember Milne’s three type of waves
Recording Seismic Waves

A typical seismic wave pattern recorded on a seismograph during an earthquake looks like this:-

- This record contains information about:-
  - Distance to epicenter (how far).
  - Magnitude of earthquake (how big).
  - Relative movement on fault
If you are a long way from the epicenter (or the earthquake is small), the record may look like this:

![Earthquake record 1](image1.png)

If you are closer to the epicenter (or the earthquake is large), then the record may look like this:

![Earthquake record 2](image2.png)

Actually, these are records of the same earthquake at different places.
This explains why P and S waves travel directly through the earth but S waves are slower. Surface waves are also slow and travel a greater distance at the earth’s surface.
Locating an earthquake

Which is the fastest of the seismic waves?

The distance to the epicenter is given by the arrival time difference between the P and S waves.
Distance to the epicenter is given by the time interval between the P and S waves (note here we are using km)
Earthquake is located near Seattle.

Denver ~ 2000 km
St Johns ~ 5300 km
Lima ~ 9000 km
A quick and dirty method for locating an earthquake

Since S-waves travel through rock more slowly than P-waves, the time that elapses between the arrival at a seismograph of the first P-wave and the first S-wave will be proportional to the distance to the earthquake epicenter (remember Milne!).

Distance to Epicenter = 5.7 miles x seconds

[Note this is very rough - also if you want the distance in km the factor will be 5.7/0.62 = 9.2]
Example:-

Suppose we have three seismic stations that record the arrival times of the P and S waves from the same earthquake.

<table>
<thead>
<tr>
<th>S - P (seconds)</th>
<th>Distance (miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station A</td>
<td>21.0 x 5.7 = 120</td>
</tr>
<tr>
<td>Station B</td>
<td>20.4 x 5.7 = 116</td>
</tr>
<tr>
<td>Station C</td>
<td>11.4 x 5.7 = 65</td>
</tr>
</tbody>
</table>

(remember - we need three locations (or more) to locate the epicenter of an earthquake)
120 miles

65 miles

116 mile

Epicenter

Station A

Station B

Station C