Earthquake!

Slides from lectures preceding

Earthquakes and Spreadsheets Exercise

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What Is an Earthquake?

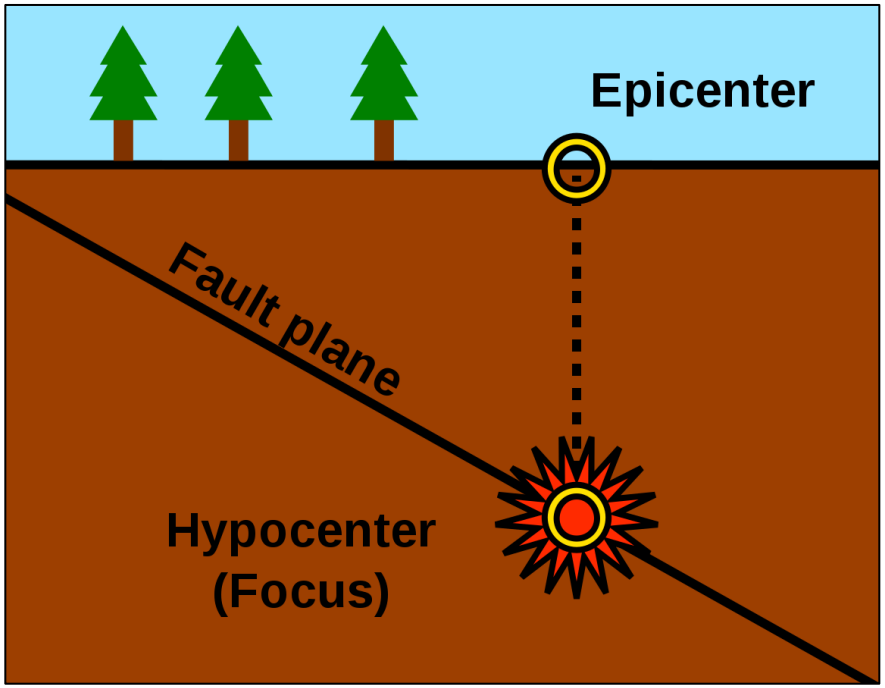
- Def: vibration of the solid Earth
- Occurs along a fault
  - Stressed rocks "bend" and store up energy
  - Until rocks break, slip, and release energy

Offset lettuce rows after 1979 quake in California. Image credit: NOAA/NGDC University of Colorado at Boulder.

https://www.ngdc.noaa.gov/hazardimages/#/earthquake/241/image/37

EQ Terminology

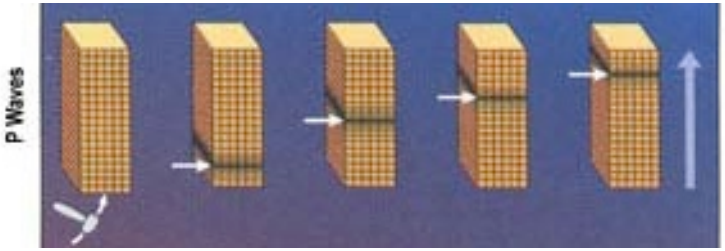
- When rocks break, energy radiates outward in all directions
  - *Focus* = point where rocks first break
  - *Epicenter* = surface point above focus



https://commons.wikimedia.org/wiki/File:Epicenter_Diagram.svg

Body Waves

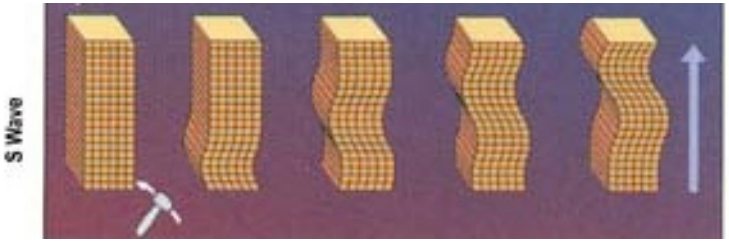
- **Def: travel through Earth's interior**
  - **P-wave = compressional = primary**
    - **Rocks are squeezed & stretched**
    - **Vibrations parallel to travel direction of wave**
    - **Fastest waves**



https://commons.wikimedia.org/wiki/File:Pswaves.jpg

More Body Waves

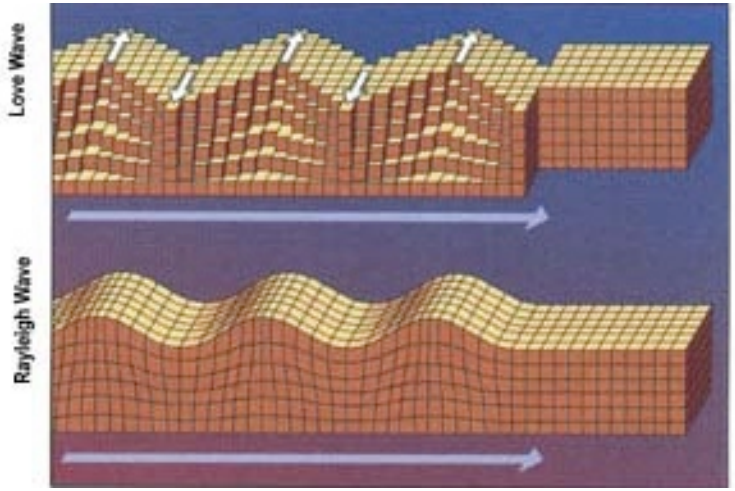
- **S-wave = shear = secondary**
  - **Rocks rise & fall**
  - **Vibrations perpendicular to travel direction**
  - **Slower than P-wave**



https://commons.wikimedia.org/wiki/File:Pswaves.jpg

Surface Waves

- **Def: travel along ground surface**
  - **2 types of many types are Love & Rayleigh waves**
    - **Various vibrations**
    - **Cause the most shaking → most destructive**
    - **Slowest**

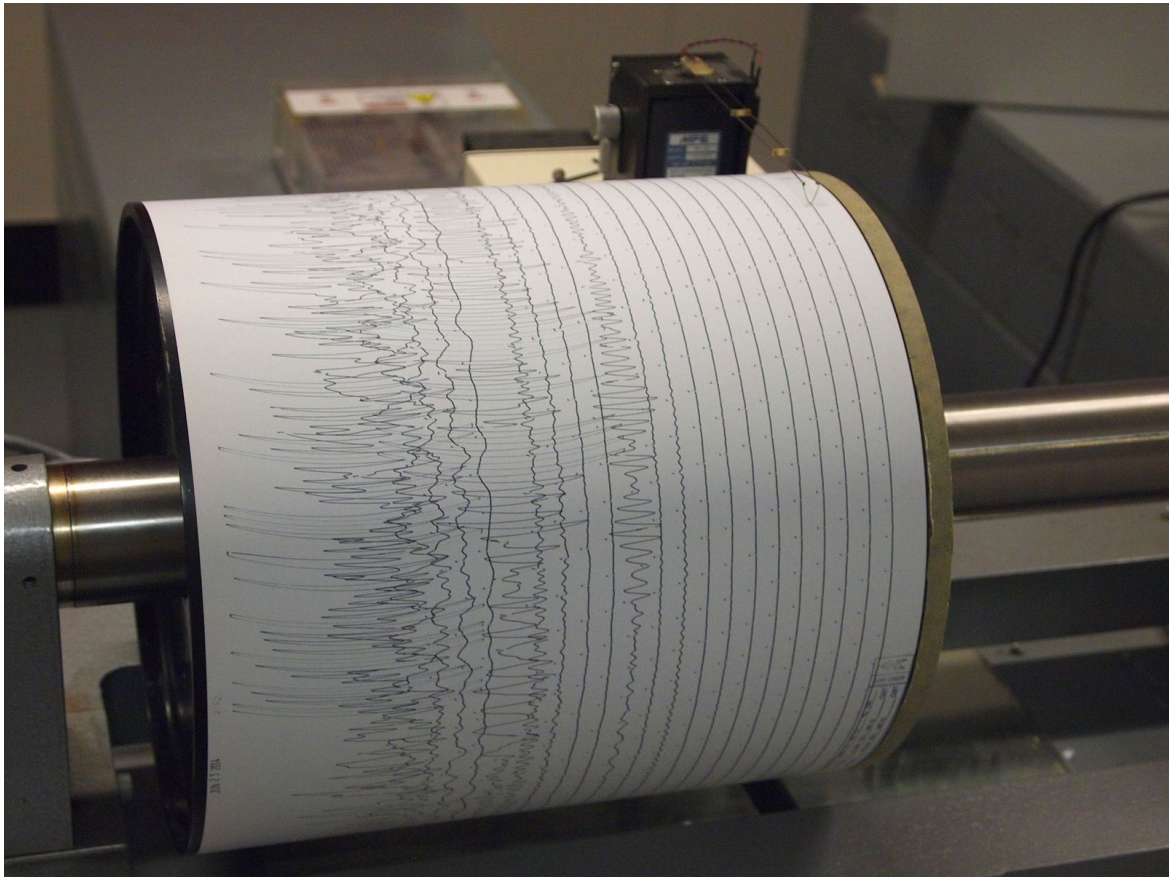


https://commons.wikimedia.org/wiki/File:Pswaves.jpg

Measuring EQs

- **Study of EQs = *seismology***
  - ***Seismometer*: instrument that records ground motion**
  - ***Seismogram*: the record of an EQ**
    - **Shows P, S, surface wave arrivals**
    - **Also shows time**

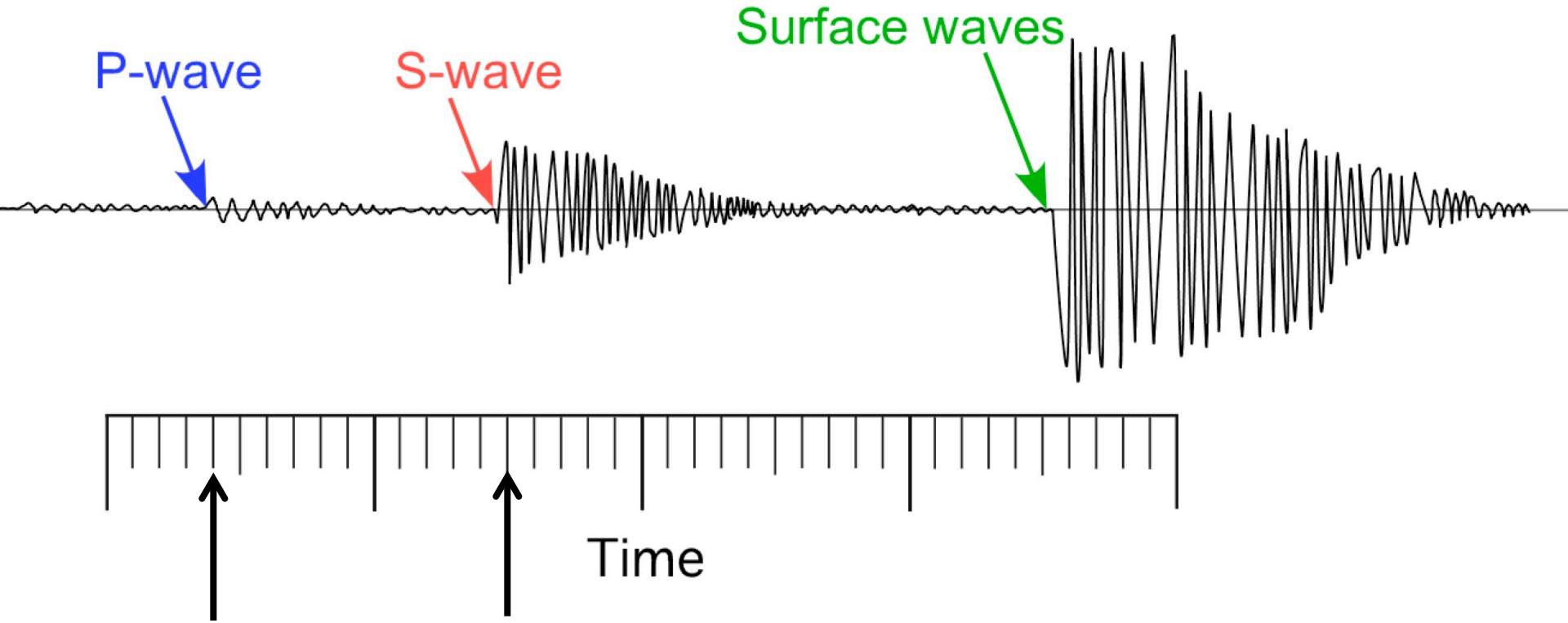
A Seismometer



https://commons.wikimedia.org/wiki/File:Seismogram_at_Weston_Observatory.JPG

Paper wrapped around cylinder = seismogram

A Seismogram



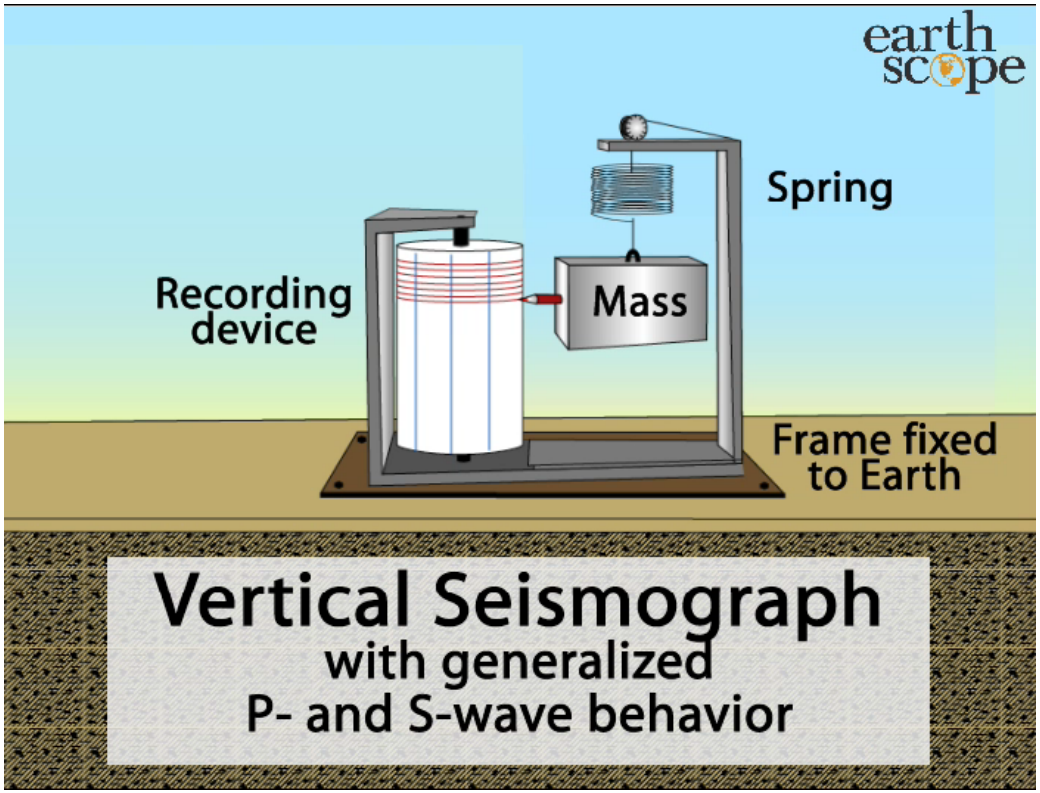
P-wave arrival time

S-wave arrival time

Motion in 3D: Vertical

- **Seismometer measures movement in 1 direction**
  - **Vertical direction**

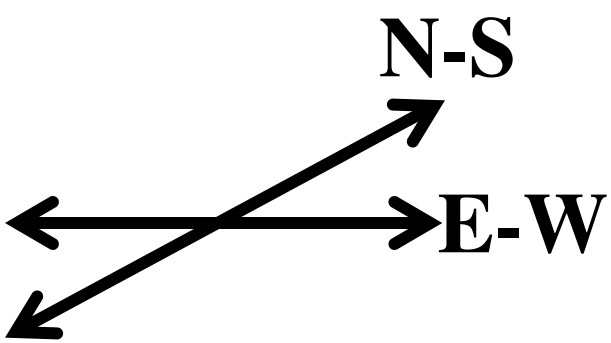
"Seismograph" = old word for "seismometer"

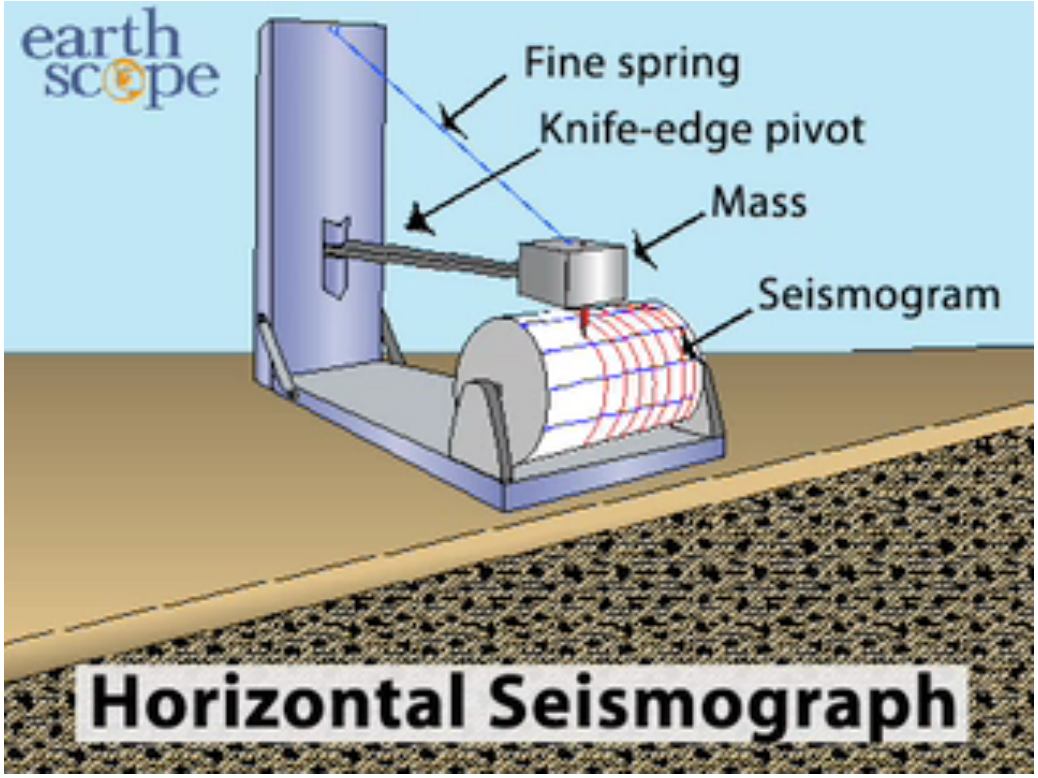


https://www.iris.edu/hq/inclass/animation/seismograph_vertical_slow_motion

Motion in 3D: Horizontal

- **There are two horizontal directions:**
  - **Horizontal directions**





https://www.iris.edu/hq/inclass/animation/seismograph_horizontal

Locating Epicenters

- **Determine S - P**
  - **Difference in arrival times**
- **=> Distance from epicenter to seismometer**

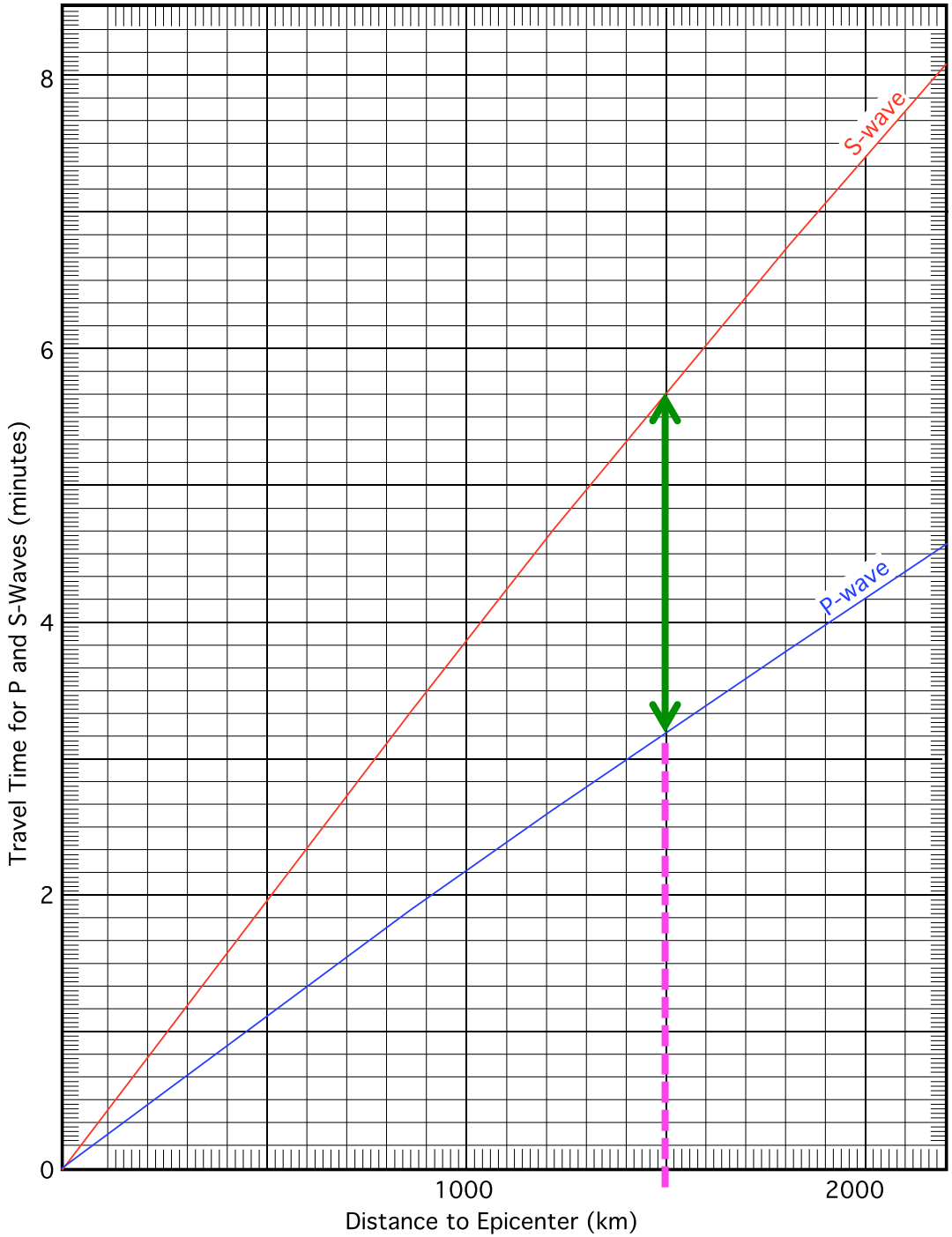
How??

Distance, from Travel Times

- **Suppose a car and a bike start at same place & time, travel on same road. Car travels 60 mph, bike travels 10 mph.**
  - **How far apart after 1 hour?** **50 mi**
  - **After 2 hours?** **100 mi**
  - **If they are 150 miles apart, how long have they traveled?** **3 hours**

Travel Time Curve

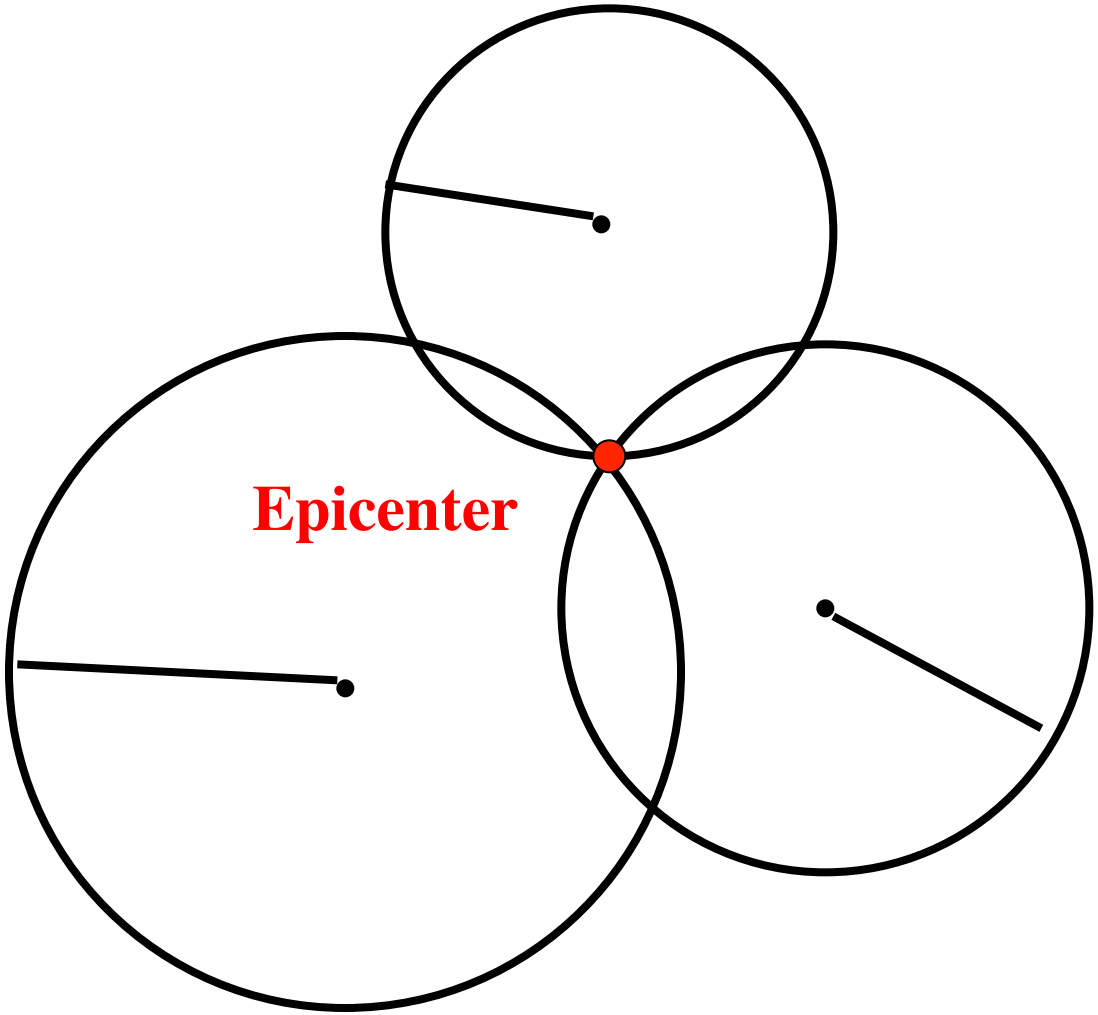
- If …
  - S-P = 2.5 min
  - Distance = 1500 km



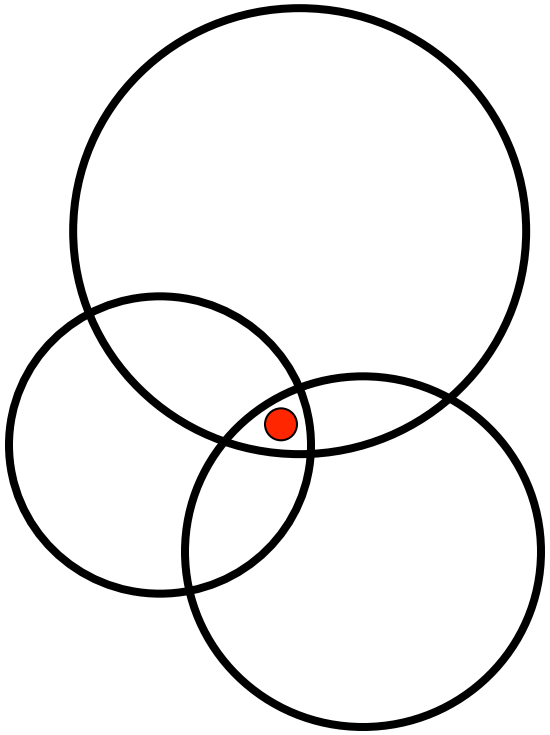
Triangulation

- **Need least 3 different seismometers & a graph called a "travel time curve"**
  - **S - P time from seismogram (Y-axis)**
  - **Distance (X-axis)**
- **Draw a circle around each seismometer**
  - **Radius = distance**
  - **Circles intersect in 1 point = epicenter**

Triangulation Examples



Ideal: single intersection point



More common outcome

Measuring the Size of an EQ

- ***Richter Magnitude*** **is based on amount of energy released**
  - **Measure highest wave on seismogram**
  - **Calculate magnitude**
    - **Logarithmic formula**
    - **Increase RM by 1 => ~10 x more shaking**
    - **Ranges from < 2.5 to ~ 9.5**

Another Way to Describe the Size of an EQ

- ***Mercalli Intensity*: twelve levels based on observed destruction**
  - **Qualitative**
  - **From interviews & written records**
  - **Used to estimate size of older EQs**
  - **Ranges from I to XII**

Mercalli (MI) vs. Richter (RM)

- **Consider an earthquake**
  - **One and only one overall RM**
    - **= Average of local RMs at every seismometer**
  - **Many different MIs, depending on…**
    - **Distance from epicenter**
    - **Type of rock or ground surface**
    - **Type and number of structures**

Teaching Notes and Tips

This exercise is divided into three complementary sections. The exercise may be completed in one extended laboratory period, or individual sections may be assigned as separate, shorter activities or as homework.

Note that the Excel workbook file includes two worksheets that contain the key. The workbook given to students should have only the Cells and Quake worksheets.

Aa an alternative in Part II, the instructor could provide compasses and maps for students to draw circles and triangulate the epicenter manually. Locations for the epicenter will vary, and students should answer subsequent questions based on their own maps.

On the GSP Visualizer web page, in the paragraph above the map, students may click to download their maps from GPSVisualizer.com and either print them or submit them electronically. This option works best in a small class.

Because many students are unfamiliar with spreadsheets, the instructor should be aware of possible difficulties using Excel.

Please note that the data used in this activity pertain to the Illapel, Chile, earthquake on September 16, 2015. The US Geological Survey information page about this earthquake is listed in the references.