Virtual Earthquake - An Introduction

What's an earthquake?

Earthquakes occur because of a sudden release of stored energy. This energy has built up over long periods of time as a result of tectonic forces within the earth. Most earthquakes take place along faults in the upper 25 miles of the earth's surface when one side rapidly moves relative to the other side of the fault. This sudden motion causes shock waves (seismic waves) to radiate from their point of origin called the **focus** and travel through the earth. It is these seismic waves that can produce ground motion which people call an earthquake. Each year there are thousands of earthquakes that can be felt by people and over one million that are strong enough to be recorded by instruments. Strong seismic waves can cause great local damage and they can travel large distances. But even weaker seismic waves can travel far and can be detected by sensitive scientific instruments called **seismographs**.

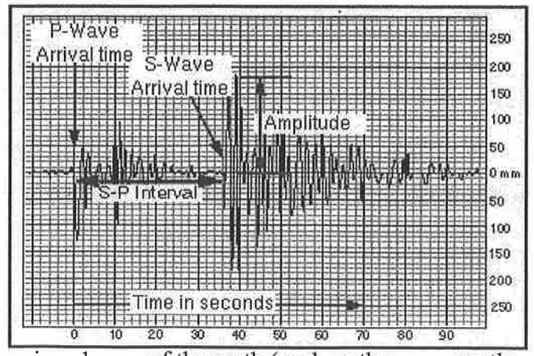
What are earthquake (Seismic) Waves?

A seismic wave is simply a means of transferring energy from one spot to another within the earth. Although seismologists recognize different types of waves, we are interested in only two types: P (primary) waves, which are similar to sound waves, and S (secondary) waves, which are a kind of shear wave. Within the earth, P waves can travel through solids and liquids, whereas S waves can only travel through solids.

The speed of an earthquake wave is not constant but varies with many factors. Speed changes mostly with depth and rock type. P waves travel between 6 and 13 km/sec. S waves are slower and travel between 3.5 and 7.5 km/sec.

What's a Seismogram?

A highly simplified simulated recording of earthquake waves (a seismogram) can be seen to the right. Study this sample seismogram and be sure you can identify these parts:



- **P-waves and the P-wave arrival time**
- **S-waves and the S-wave arrival time**
- **S-P interval (expressed in seconds)**
- **S-wave maximum amplitude (measured in mm)**

Note well: This seismogram is a simulation. The actual records of earthquake waves are far more complicated that what is presented here. As P and S waves travel through the earth, they are reflected by various layers of the earth (such as the core mantle boundary). This interaction produces additional seismic waves (phases) which will be detected by seismographs. Once you successfully complete this tutorial, you will be given links to some seismology labs, where you can see real seismograms.

How is an Earthquake's Epicenter Located?

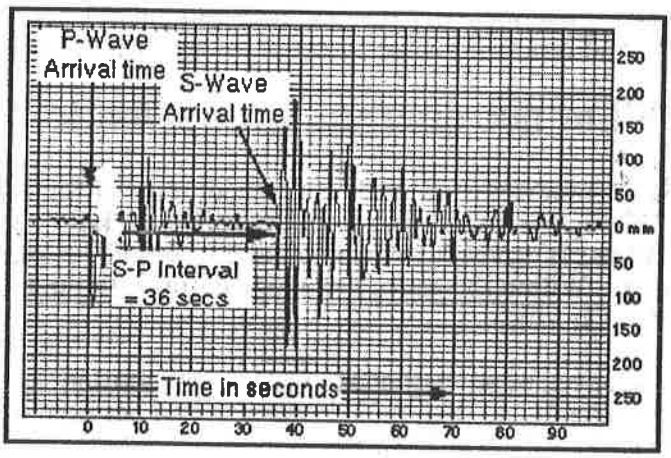
In order to locate the epicenter of an earthquake you will need to examine its seismograms as recorded

by three different seismic stations. On each of these seismograms you will have to measure the S - P time interval (in seconds). (In the figure above, the S - P interval is about 45 seconds. The vertical lines are placed at 2 second intervals.) The S - P time interval will then be used to determine the distance the waves have traveled from the origin to that station.

The actual location of the earthquake's epicenter will be on the perimeter of a circle drawn around the recording station. The radius of this circle is the epicentral distance. One S - P measurement will produce one epicentral distance: the direction from which the waves came is unknown. Three stations are needed in order to "triangulate" the location.

Measuring the S-P interval

There are hundreds of seismic data recording stations throughout the United States and the rest of the world. In order to locate the epicenter of this earthquake, you need to estimate the time interval between the arrival of the P and S waves (the S-P interval) on the seismograms from three different stations. You have to measure the interval to the closest second and then use a graph to convert the S-P interval to the epicentral distance. On the sample seismogram at the right the vertical lines are spaced at 2 second intervals and the S-P time interval is about 36 seconds.



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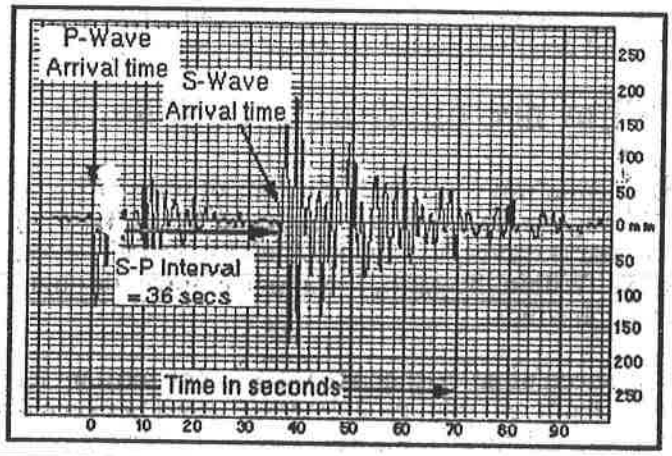


OK. Let's have an earthquake!

Determining the Earthquake Distance

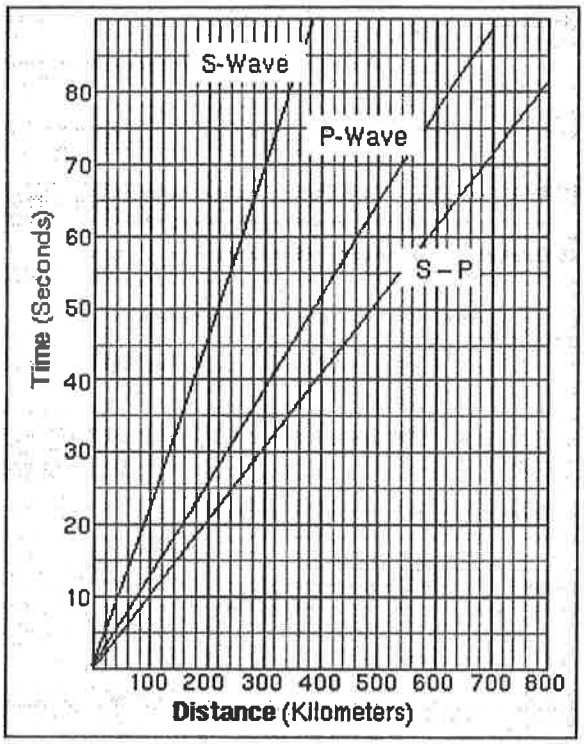
You can now determine the distance from each seismic recording station to the earthquake's epicenter using the known times of travel of the S and P waves.

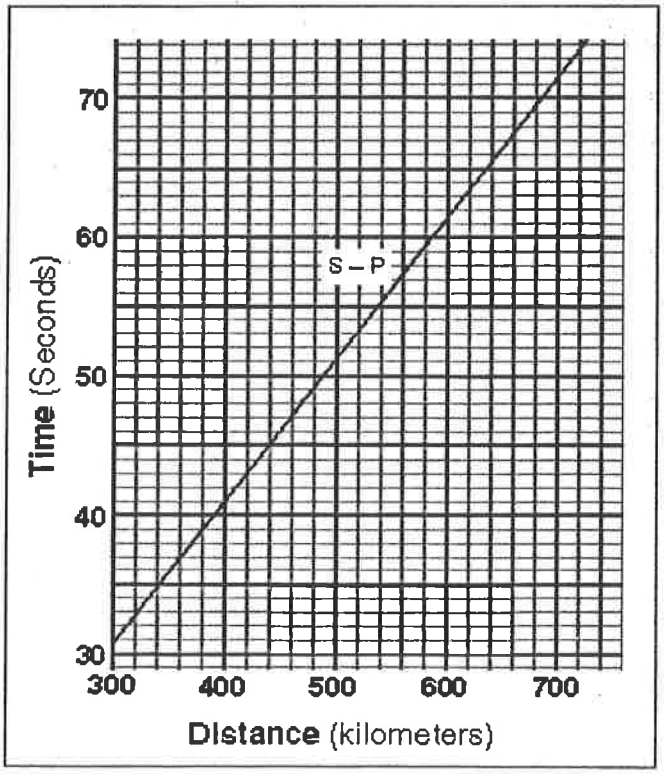
Examine the graph to the right, a graph of seismic wave travel times. There are three curves on the graph: The upper curve shows S wave travel-time graphed versus distance, the center one shows P wave travel time versus distance, and the lower one shows the variation in distance with the difference of the S and P travel times. It takes an S wave approximately 70 seconds to travel 300 kilometers.

For practice, how long does it take the P wave to travel this same distance?

For the rest of this exercise you won't be needing the S and P curves only the S-P curve.

To best estimate the epicentral distance, we need more details on graph. We will use the graph below which is the necessary part of an expanded version of the S-P curve.



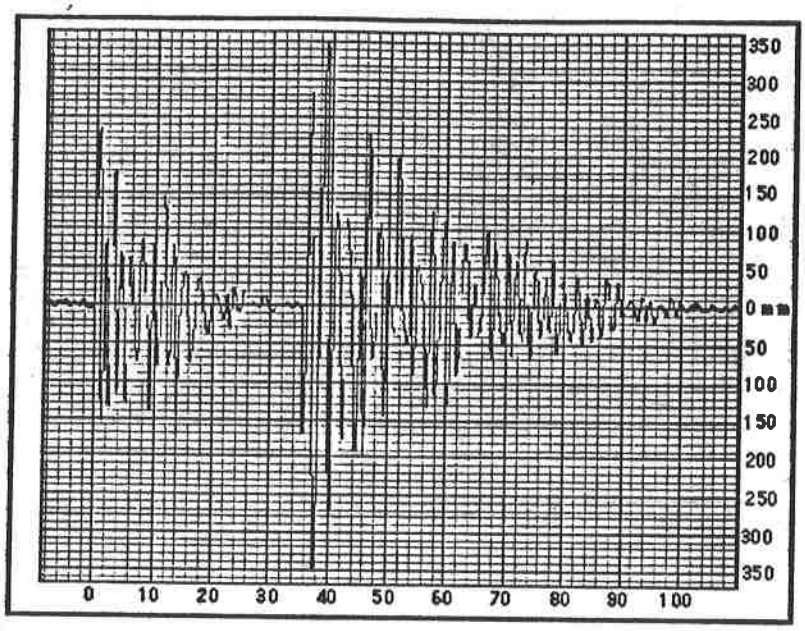


Determining Distance from S-P

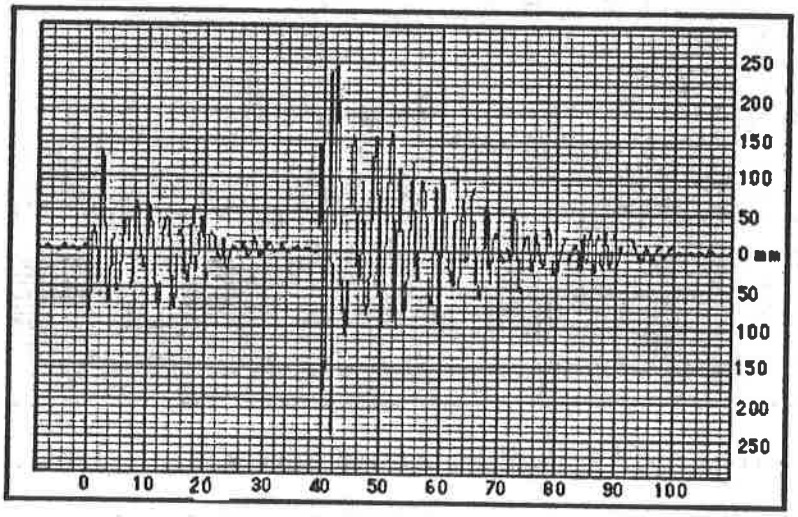
Use the S-P graph to the left and the estimates you made for the S-P time intervals for the three seismograms (shown again in the table below for your convenience), to complete the table below. The horizontal grid is in one second intervals. Then click the Find Epicenter button.

Station	S-P Interval	Epicenter Distance, KM
MAP I		
Eureka, CA	_____	_____
Elko, NV	_____	_____
Las Vegas, NV	_____	_____
MAP II		
Fresno, CA	_____	_____
Las Vegas, NV	_____	_____
Phoenix, AZ	_____	_____
MAPIII		
Chichuahua	_____	_____
Mazatlan	_____	_____
Rosarito	_____	_____
MAPIV		
Pusan	_____	_____
Tokyo	_____	_____
Akita	_____	_____

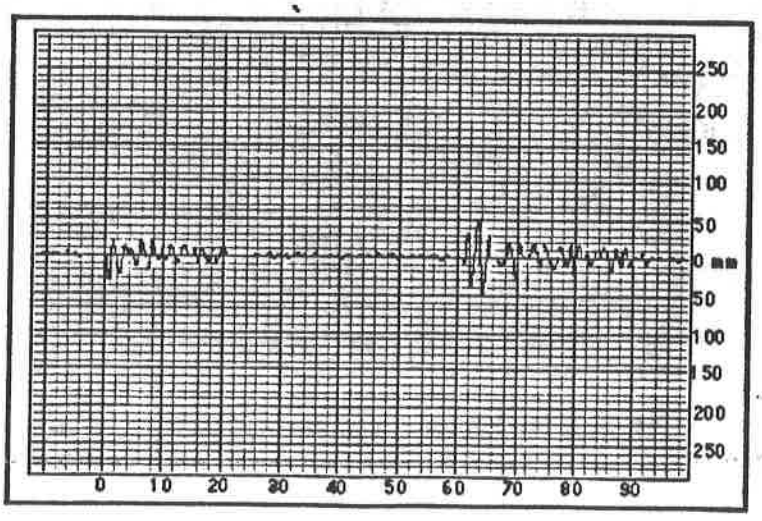
Use these three seismograms to estimate the S-P time interval for each of the recording stations. Record your measurement for the S-P interval in the box below each seismogram.



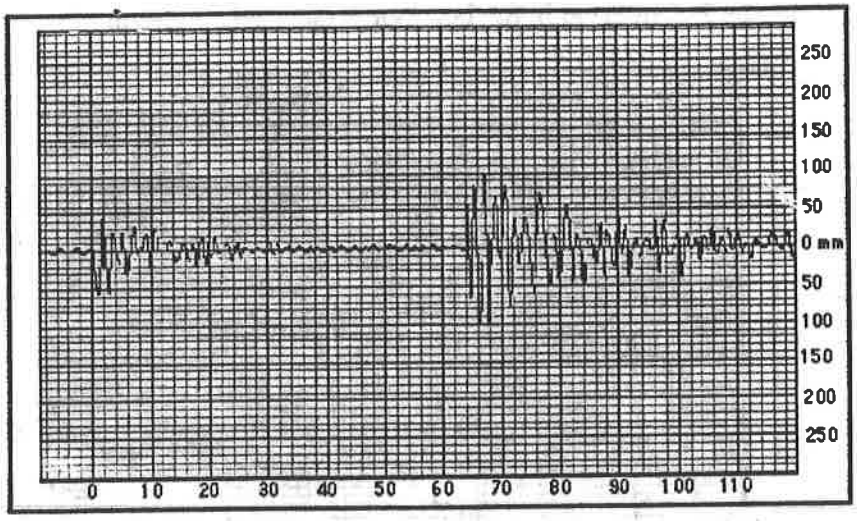
Fresno, CA Seismic Station S-P Interval = [ ] seconds



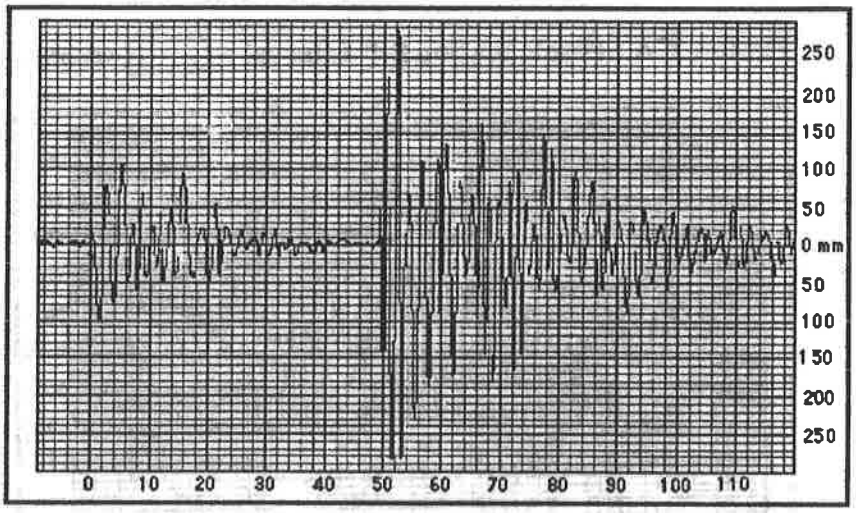
Las Vegas, NV Seismic Station S-P Interval = [ ] seconds



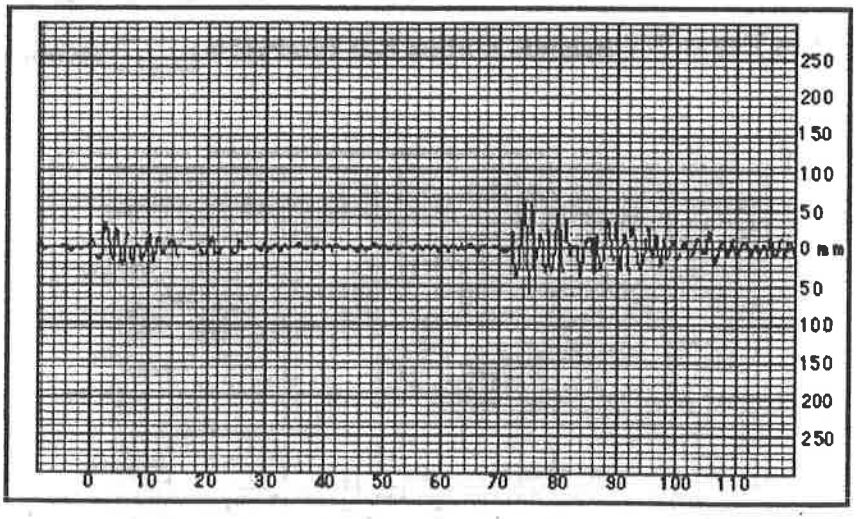
Phoenix, AZ Seismic Station S-P Interval = [ ] seconds



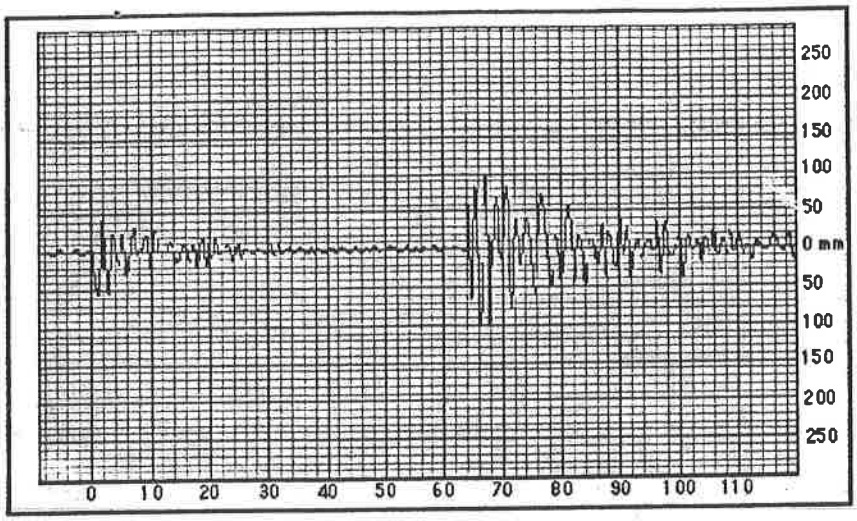
Las Vegas, NV Seismic Station S-P Interval = [ ] seconds



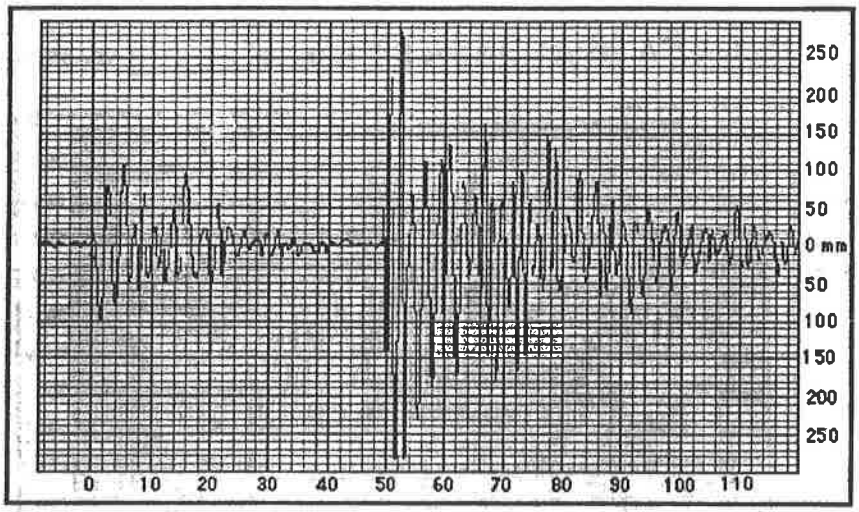
Eureka, CA Seismic Station S-P Interval = [ ] seconds



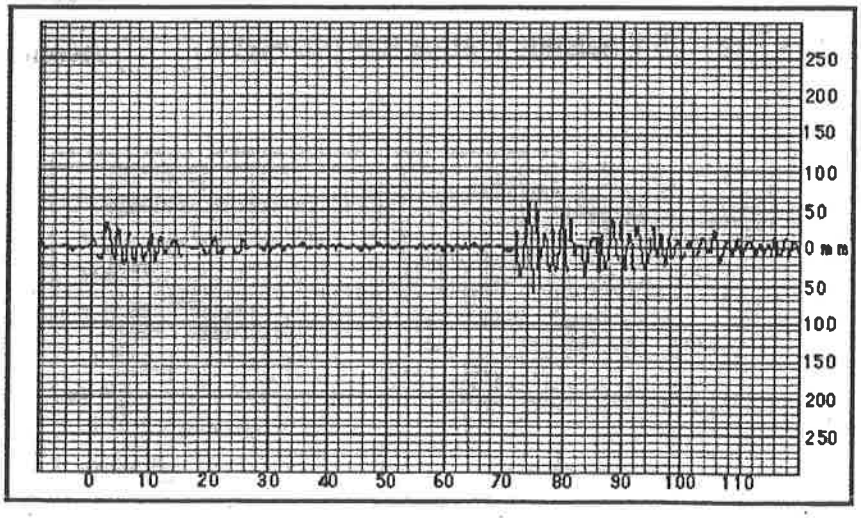
Elko, NV Seismic Station S-P Interval = [ ] seconds



Las Vegas, NV Seismic Station S-P Interval = [ ] seconds

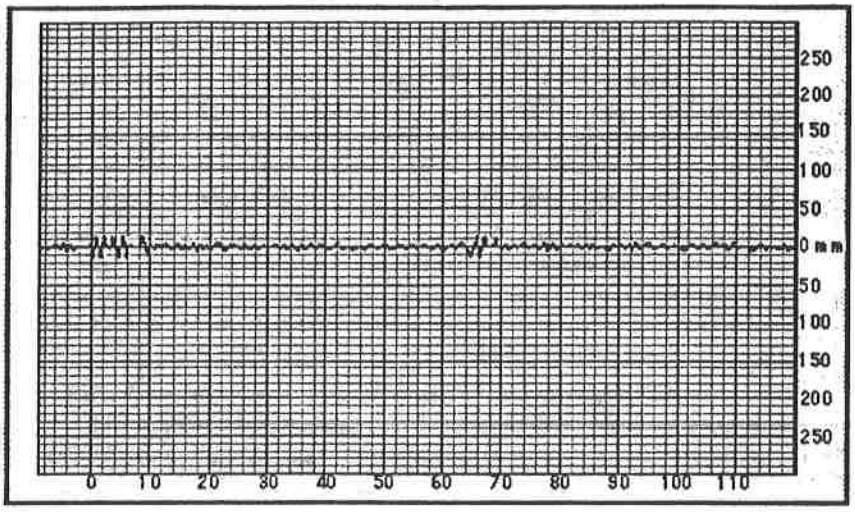


Eureka, CA Seismic Station S-P Interval = [ ] seconds

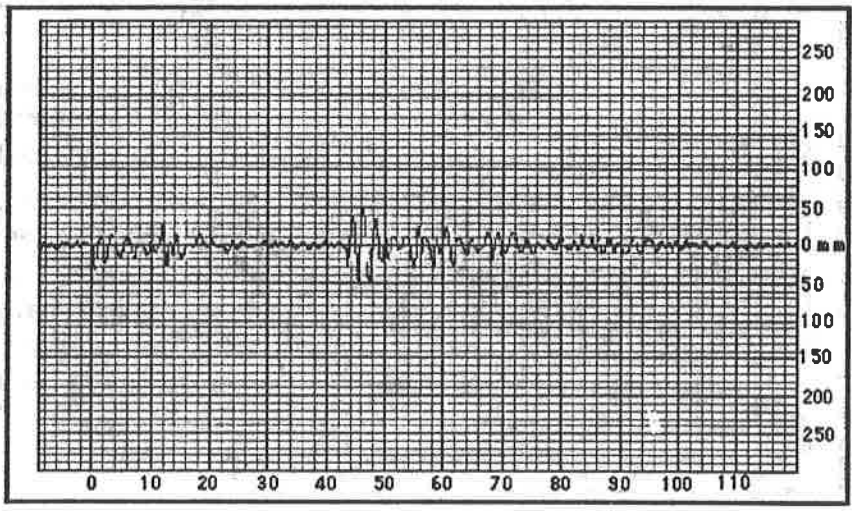


Elko, NV Seismic Station S-P Interval = [ ] seconds

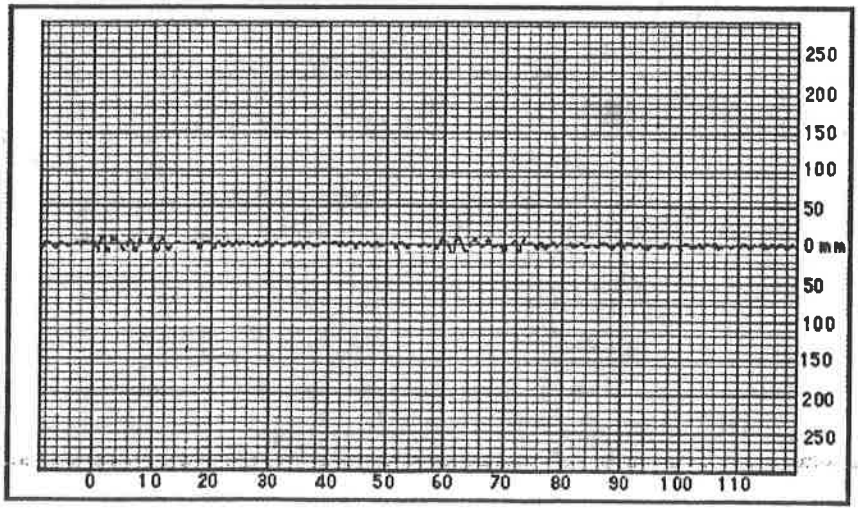
Use these three seismograms to estimate the S-P time interval for each of the recording stations. Record your measurement for the S-P interval in the box below each seismogram.



Chichuahua Seismic Station S-P Interval = [ ] seconds

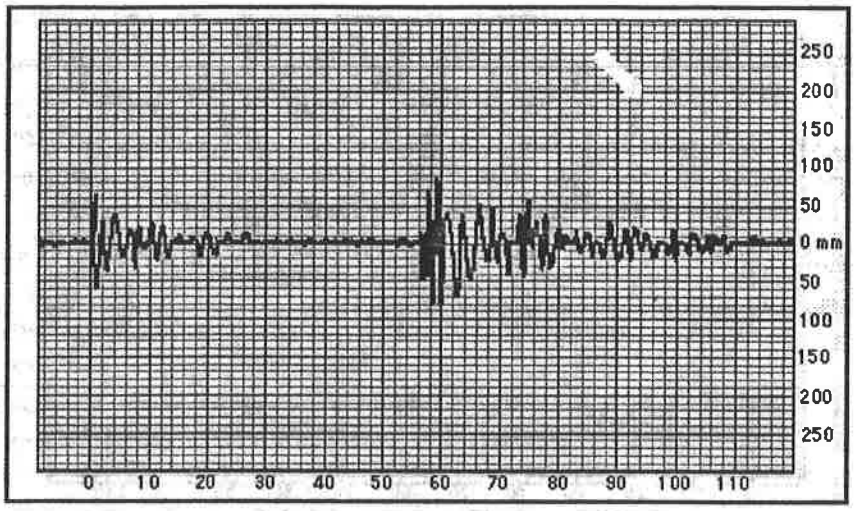


Mazatlan Seismic Station S-P Interval = [ ] seconds

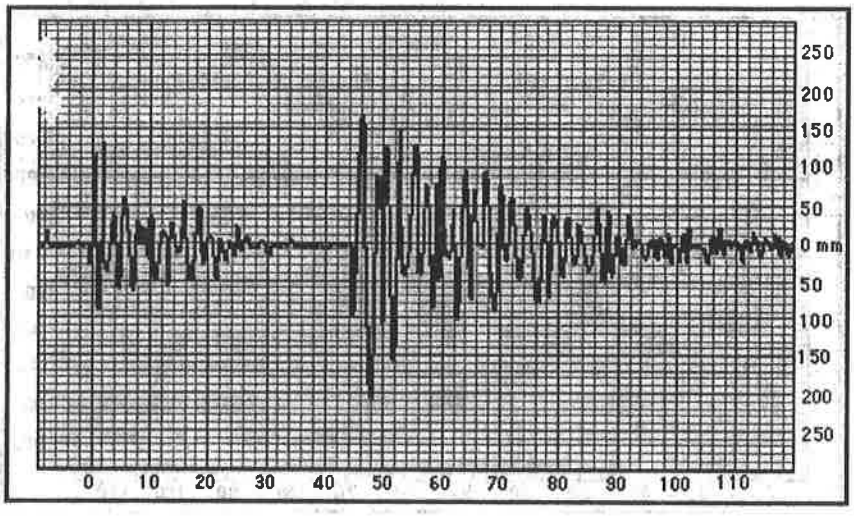


Rosarito Seismic Station S-P Interval = [ ] seconds

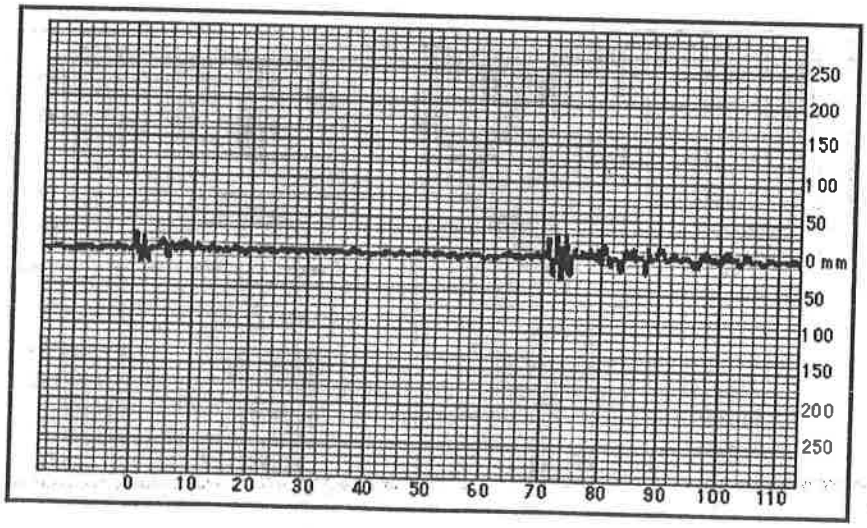
Use these three seismograms to estimate the S-P time interval for each of the recording stations. Record your measurement for the S-P interval in the box below each seismogram.



Pusan Seismic Station S-P Interval = [ ] seconds

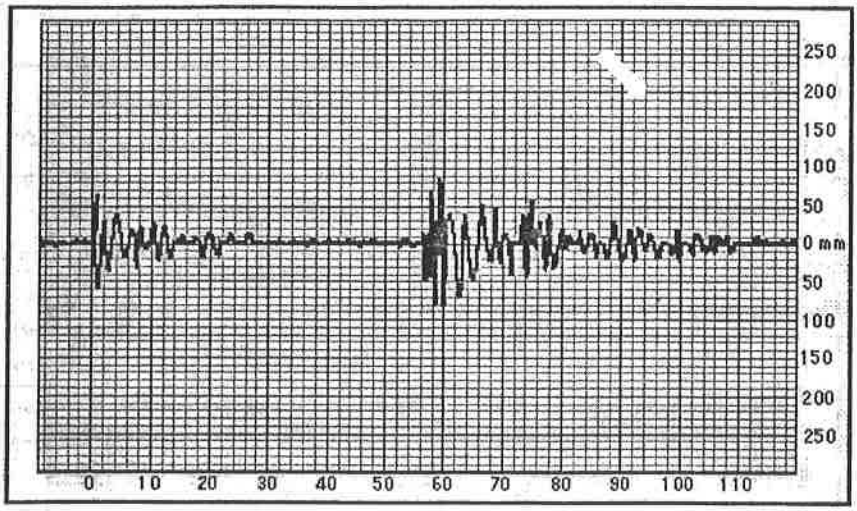


Tokyo Seismic Station S-P Interval = [ ] seconds

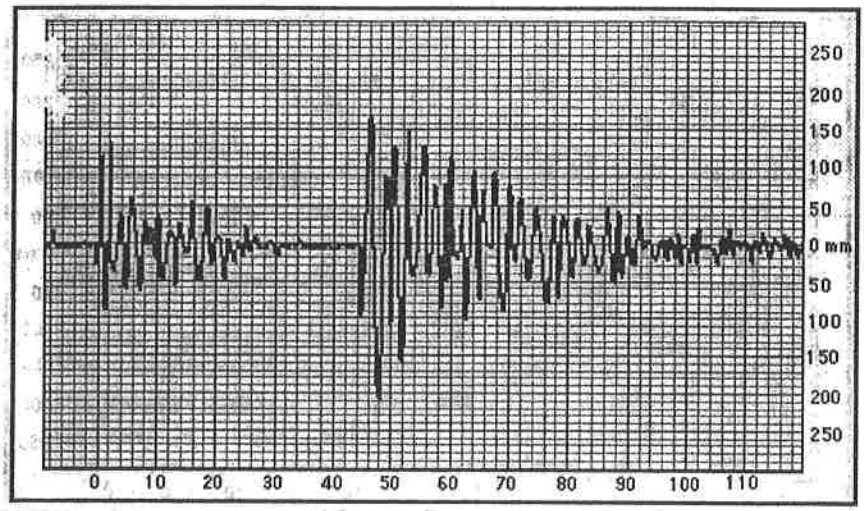


Akita Seismic Station S-P Interval = [ ] seconds

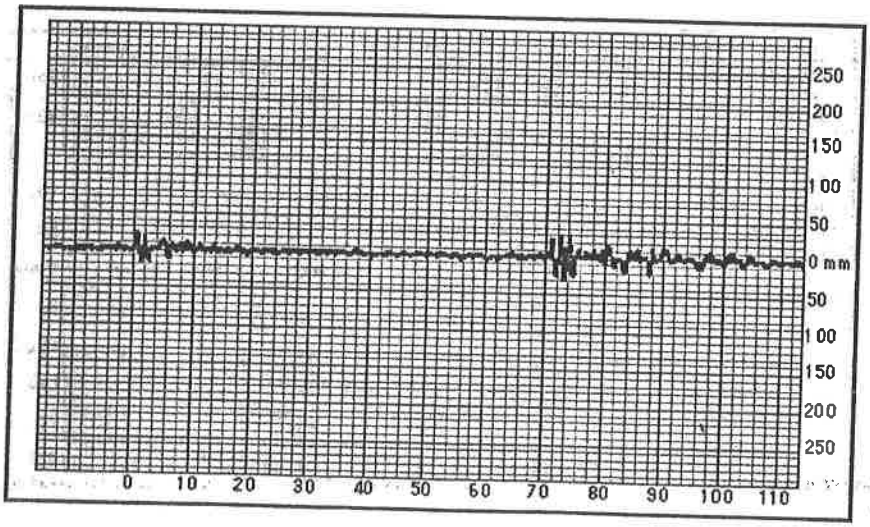
Use these three seismograms to estimate the S-P time interval for each of the recording stations. Record your measurement for the S-P interval in the box below each seismogram.



Pusan Seismic Station S-P Interval = [ ] seconds



Tokyo Seismic Station S-P Interval = [ ] seconds



Akita Seismic Station S-P Interval = [ ] seconds


OREGON
Klamath Falls
Boise
IDAHO
Eureka
Elko
Ogden
Reno
Salt Lake City
Sacramento
Provo
San Francisco
NEVADA
CALIFORNIA
Tonopah
UTAH
Fresno
Las Vegas
Bakersfield
ARIZONA
Los Angeles
San Bernardino
Miles
0 50 100 200
0 100 200 400
Kilometers
Phoenix
San Diego
Yuma
Baja


OREGON
Klamath Falls
Boise
IDAHO
Eureka
Elko
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Reno
Salt Lake City
Sacramento
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NEVADA
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Yuma
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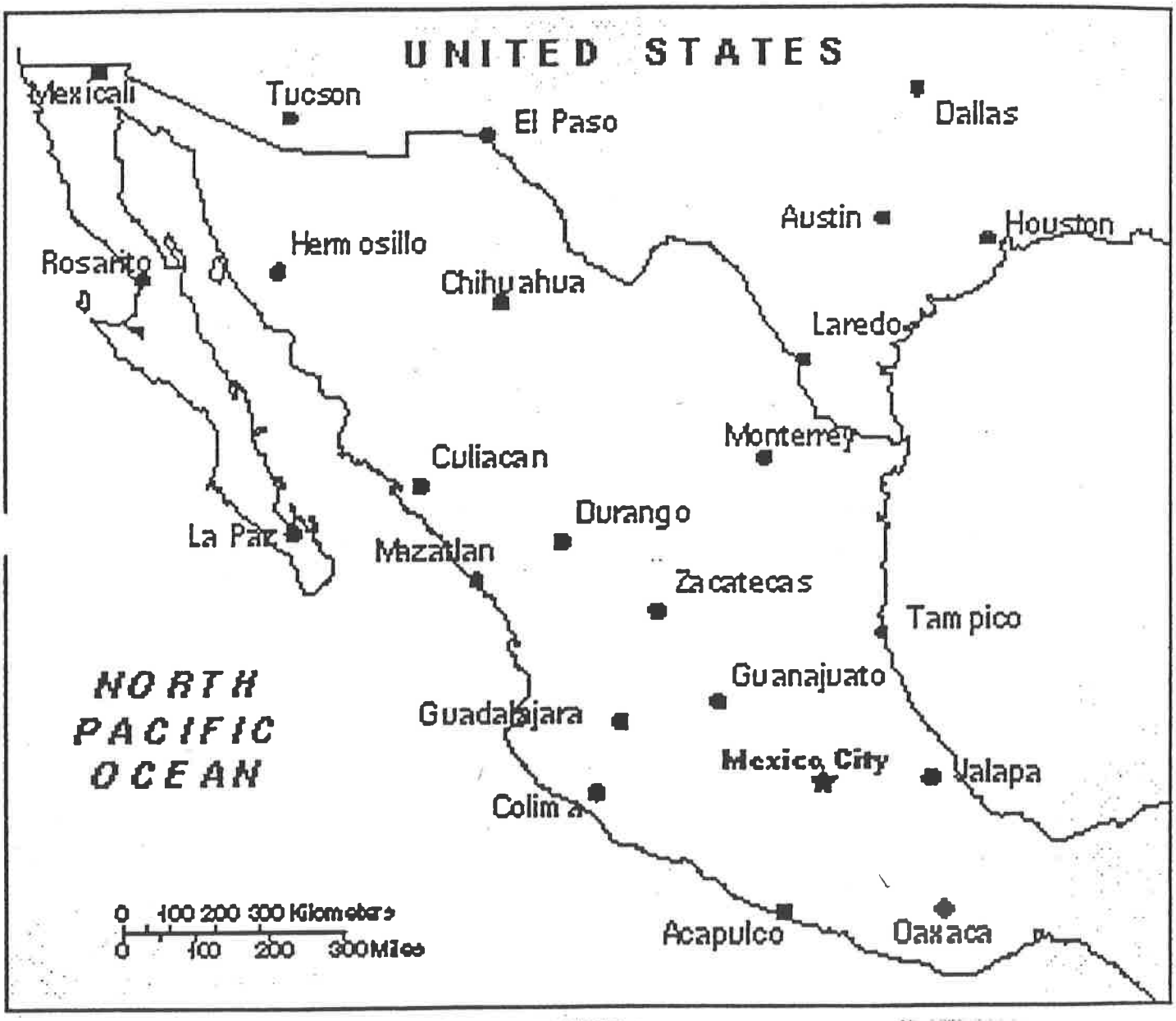
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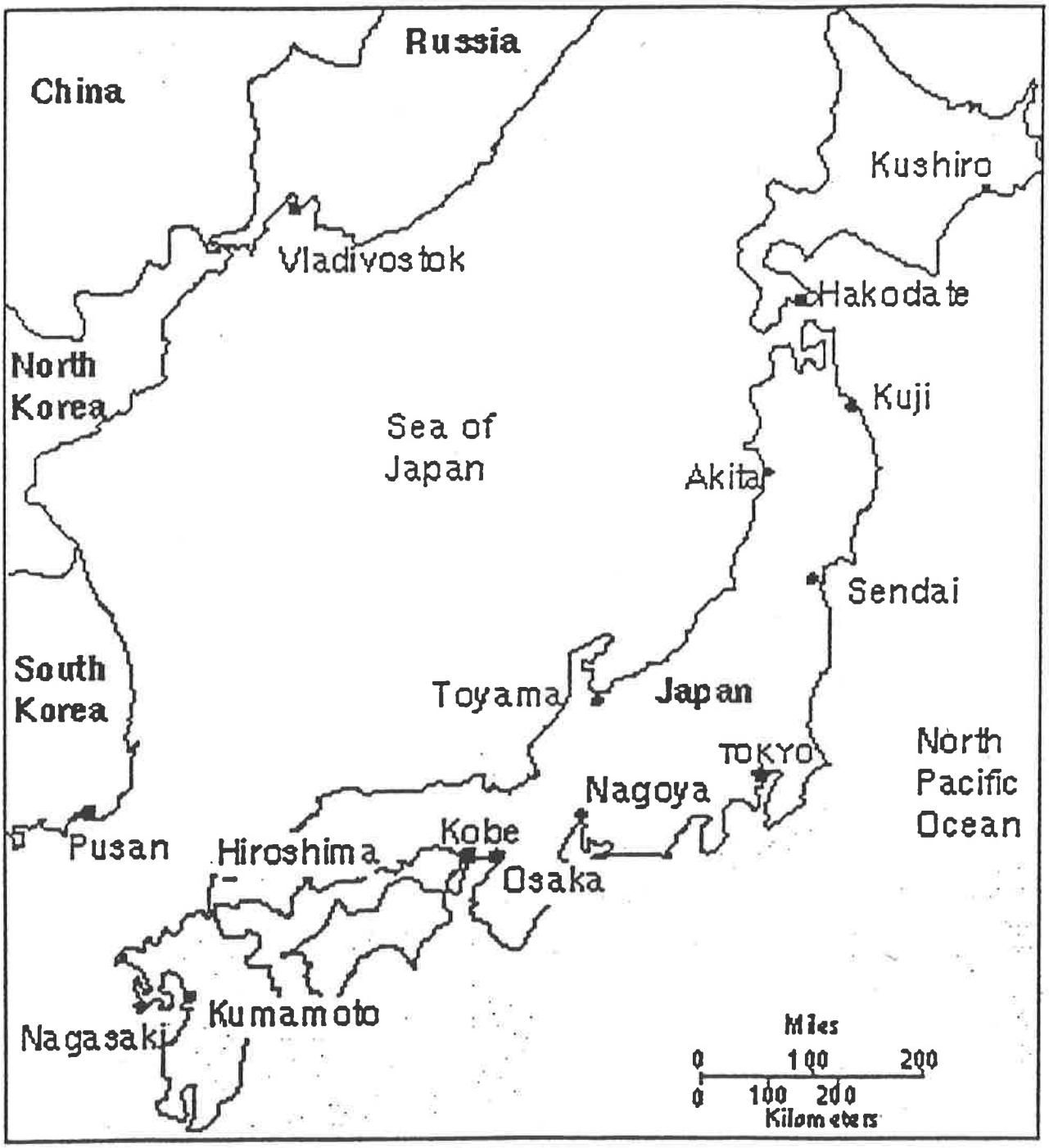
Russia
China
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Japan
Akita
Sendai
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Korea
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