LAB 6
INTRODUCTION TO EARTHQUAKE SEISMOLOGY METHODS

This laboratory exercise introduces you to some of the basic procedures used to estimate earthquake time and source locations, and helps you to see the relationship between earthquake locations and plate tectonics.

There are four parts to this exercise. In the first part, you will look at the amplitudes of P-waves from several stations. You will use this to see how amplitude changes as a function of direction and distance from the earthquake. In part two, you will plot the differences in travel times between P-and S- waves vs. the P-wave travel times for several stations and two different earthquakes to estimate the time of occurrence of an earthquake. Part three uses triangulation methods to graphically locate the epicenter of an earthquake using the arrival time of an earthquake at four different stations. In the last part, you will look at epicenter maps to relate earthquake locations to plate tectonics.

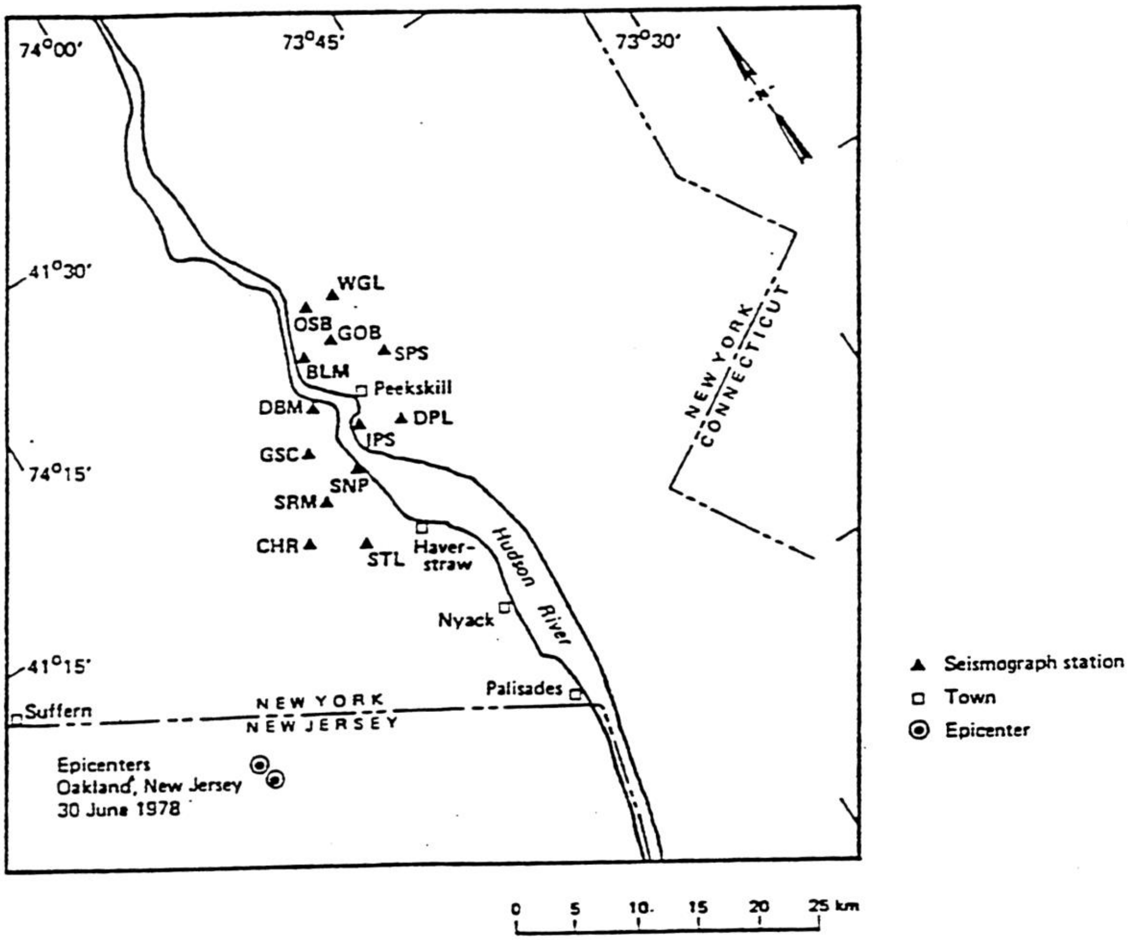
PART I.

Seismograms from several stations, shown on page 3, are for a small earthquake that occurred near Oakland, New Jersey on June 30, 1978. Each seismogram shows the amount of ground movement (up and down) changing over time, with time increasing to the right. The map on page 2 shows the location of each of the stations, and the small arrows on each seismogram point in the direction of first movement. It is the amplitude (amount) of movement at these arrows that will be of interest.

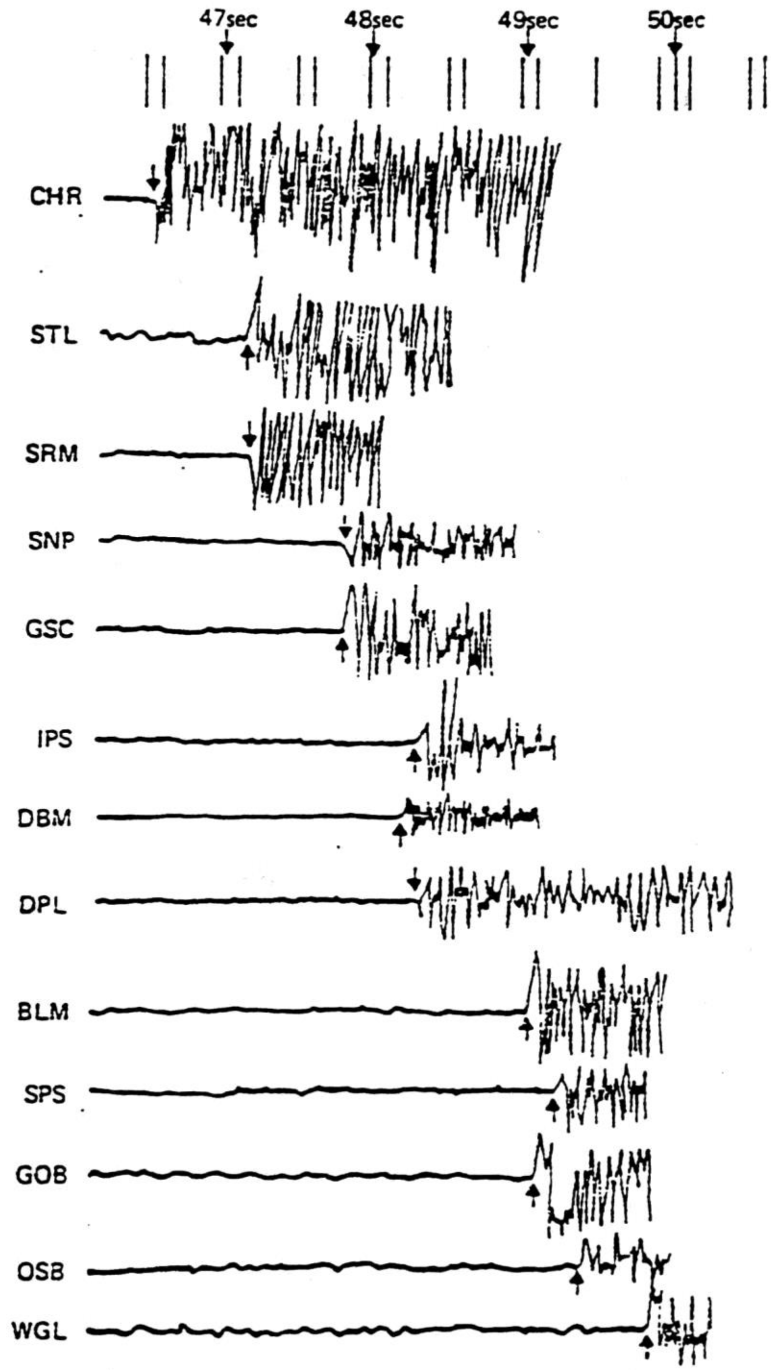
1. Compare the amplitudes of the first P-waves with the locations of the stations on the map. Does the amplitude always or usually get larger as one gets closer to the epicenter? Does it always get smaller as one gets farther from the epicenter?

2. Can you explain the smaller amplitudes of some of the stations along the river, such as SNP and DBM?

3. On your map, draw a 'D' next to stations whose first movement is down, and a 'U' next to stations whose first movement is up. Are the U's and D's grouped together, or are they random?



Map showing locations of stations in WCC array. The stations were operated by Woodward-Clyde Consultants, Clifton, New Jersey, for Consolidated Edison Company of New York.



ARROWS INDICATE P ARRIVALS

These records were traced from the original

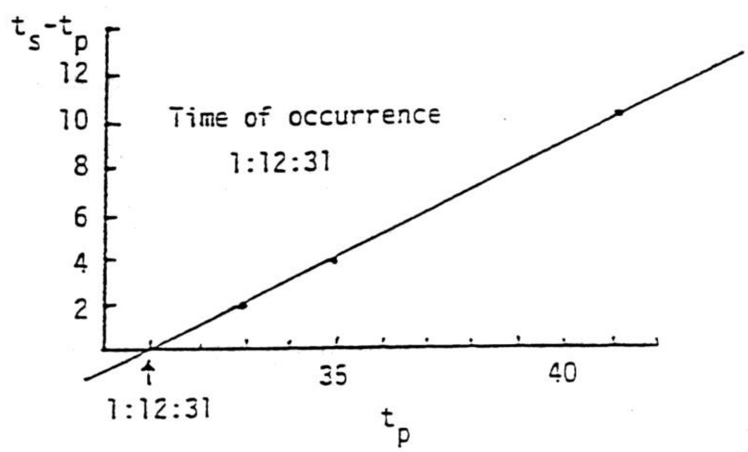
PART II.

We know that P-waves travel faster than S-waves, and can assume that this travel will be along about the same path. This means that the P-wave will always be the first arriving wave, and the S-wave will usually arrive afterwards (depending on the location of the earthquake and the station). If it is true that both waves move through the same real estate, then we would expect that, as we get further from the earthquake, the S-wave would lag further and further behind the P-wave, since the S-wave travels slower. Of course, if we are recording the earthquake at the epicenter, then both P-waves and S-waves will arrive at the same time, since they are created at the same time. We also know that the arrival time of the waves will be later, if the recording station is further from the earthquake. Even if we don't know where an earthquake occurred, we can get a good estimate of when it occurred by the following procedure:

1. Collect data of the arrival times of P-waves and S-waves at several stations and tabulate these data.
2. Find the first P-wave arrival. Call this t_{p0}.
3. Calculate the time after t_{p0} that the P-wave reached each station. Call this number t_L.

Example:

t_p	t_s	$t_s - t_p$
1:12:33	1:12:35	02 sec
1:12:35	1:12:38	03 sec
1:12:41	1:12:51	10 sec



4. Calculate the difference in travel times between the P-waves and S-waves, t_s-t_p and enter these in a table in a spreadsheet.
5. Make a plot of t_s-t_p vs. t_L.
6. Find the equation of the best-fit line through this plot.

7. Find the value of t_L on this best-fit line where $t_s - t_p = 0$. This is the calculated time that the earthquake occurred. (It should be a negative number.)
8. Add this starting t_L value to t_{p0} to find the time that the earthquake occurred.

The times of arrival for two recent earthquakes occurring in Maine are given below. From these data, determine the time of occurrence for both of the earthquakes.

Station		**P-time**	**S-time**	$t_s - t_p$
	Livermore Falls, Maine, January 3, 2000			
WVL	Waterville, ME	21:05:57.89	21:05:65.74	
HNH	Hanover, NH	21:05:79.10	21:05:100.22	
VT1	Waterbury, VT	21:05:83.60	21:05:106.09	
BCX	Chestnut Hill, MA	21:05:84.56	21:05:116.75	
WES	Weston, MA	21:05:84.90	21:05:115.35	
PQ1	Presque Isle, Me	21:05:94.55	21:05:135.76	
BRY	Smithfield, RI	21:05:98.03	21:05:131.04	
	Dixfield, Maine, January 17, 2000			
WVL	Waterville, ME	08:16:30.59	08:16:38.22	
HNH	Hanover, NH	08:16:47.73	08:16:67.86	
VT1	Waterbury, VT	08:16:49.43	08:16:70.90	
WES	Weston, MA	08:16:57.44	08:16:83.50	
BCX	Chestnut Hill, MA	08:16:59.25	08:16:86.43	
BRY	Smithfield, RI	08:16:64.20	08:16:104.17	

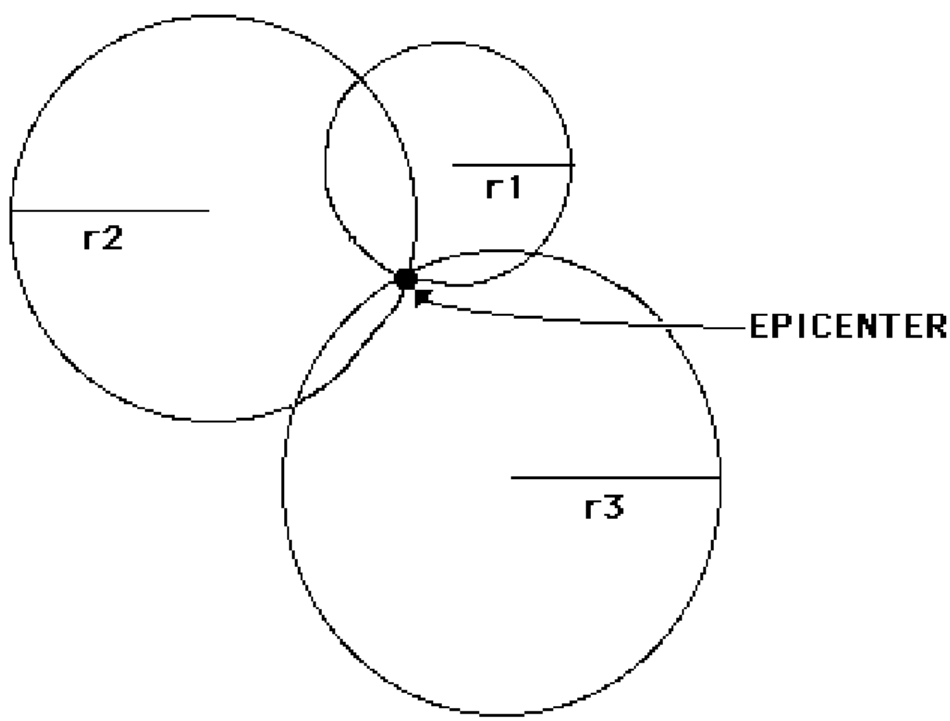
PART III.

Once time of occurrence has been determined, the epicenter can be estimated by assuming that the P-waves travel at a constant velocity of about 6 km./sec. If we subtract the time of occurrence from the time that the P-wave arrived at a station, we determine the time it took for the wave to get from the earthquake to the station. If we multiply this time by the velocity of travel, we know the distance to the source. Using data from many stations (four in these cases) we can use a map and a compass to locate the earthquake approximately. Once the distance from the station to the earthquake has been determined, as described above, draw a circle of that radius about the station. Do the same for each station. The circles will intersect, or come close to intersecting, at the epicenter.

Example:

t = time of occurrence = 1:01:05 AM

Station	P-wave arrival	Distance traveled
1	1:01:10	5 sec X 6 km/sec = 30 km.
2	1:01:13	8 sec X 6 km/sec = 48 km.
3	1:01:17	12 sec X 6 km/sec = 72 km.



Find the approximate locations of the epicenters for the two data sets given below.

Use an average P-wave velocity of 6 km/sec for these problems.

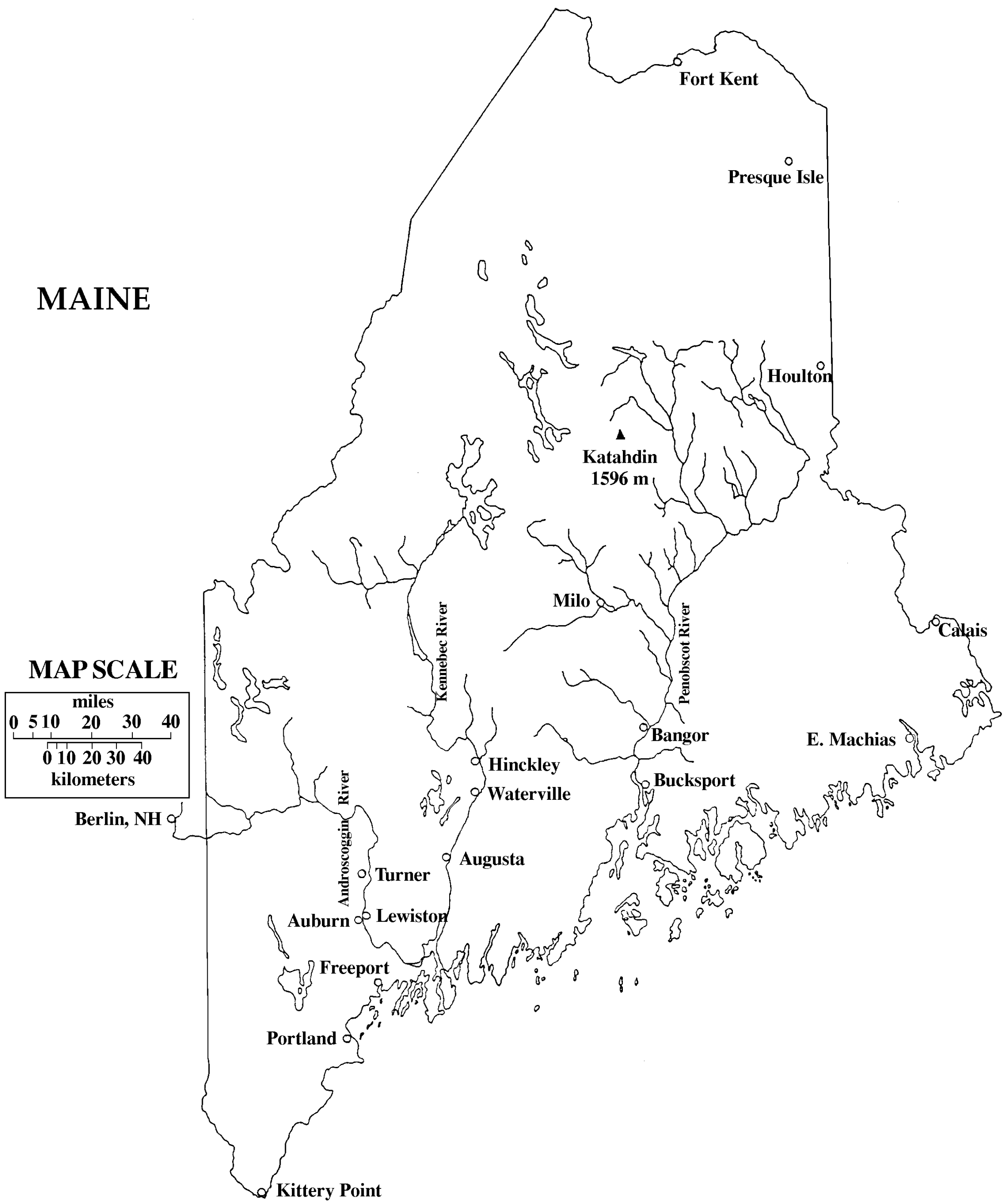
Data Set 1
Time of Occurrence 12:18:35.2

Station	P-wave arrival time	Δt (s)	Distance (in km)
Turner, ME	12:18:62.00		
Milo, ME	12:18:58.6		
Hinckley, ME	12:18:57.0		
E. Machias, ME	12:18:49.6		

Data Set 2
Time of Occurrence 06:28:37.9

Station	P-wave arrival time	Δt (s)	Distance (in km
Hinckley, ME	06:28:41.8		
Bucksport, ME	06:28:53.0		
Milo, ME	06:28:54.0		
Berlin, NH	06:28:55.5		

Map for Data Set 1



Map for Data Set 2