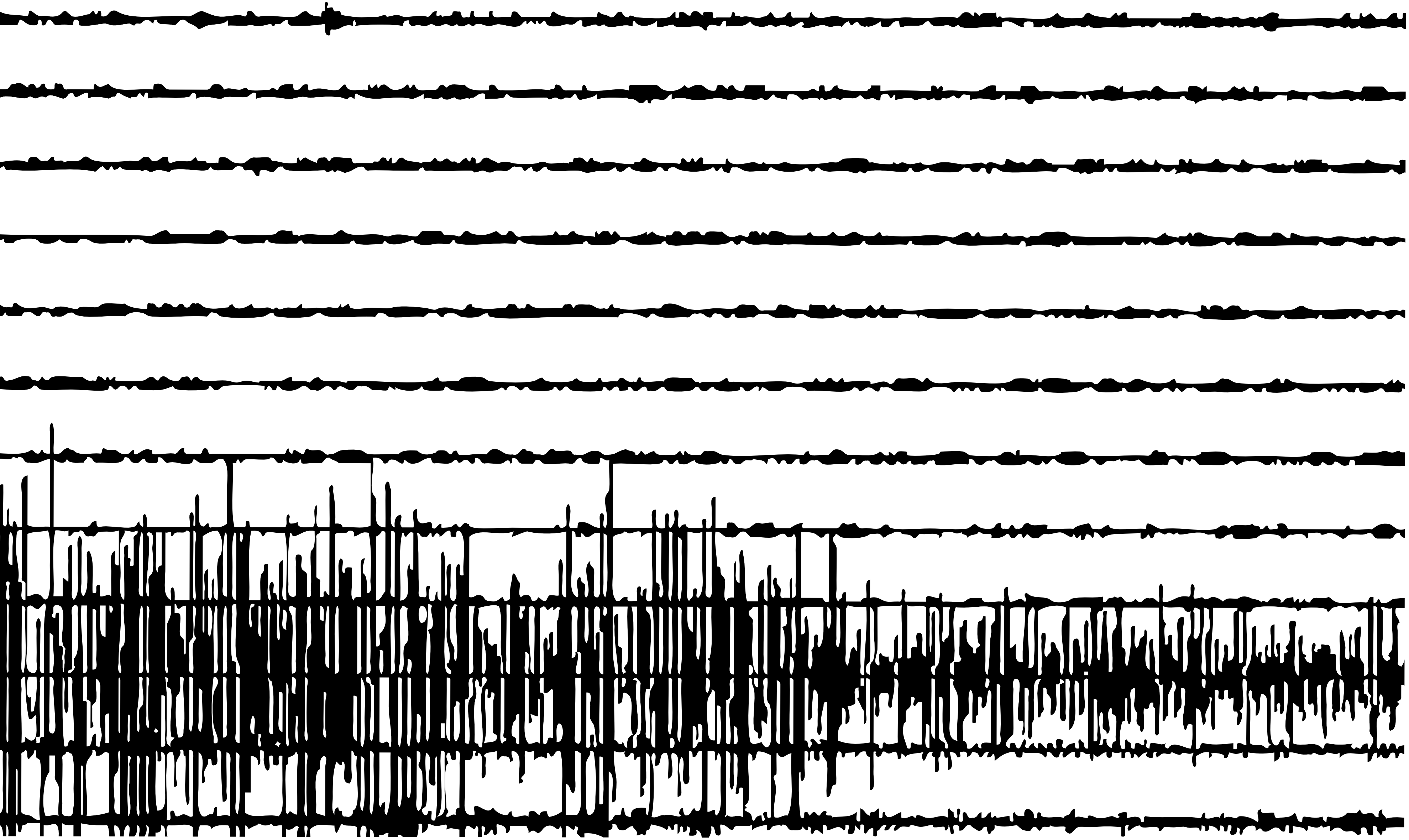
EARTHQUAKE LOCATION EXERCISE



Australian Government
Geoscience Australia

EARTHQUAKE LOCATION EXERCISE

The table below gives data for the December 26, 2004 Earthquake off Banda Aceh, Indonesia as was observed at 4 seismic observatories that were relatively close to the earthquake.

In normal earthquake determination, the origin time and location of the earthquake are unknown and one must use the observed data at a number of earthquake observatories to solve for these parameters.

The procedure is to assume an origin time and to compute seismic travel times at the various observatories. These times can be equated to distance travelled using experimentally derived relationships that have been developed over the last 100 years. These distances are plotted on a map and if the arcs from the various stations don't intersect, the origin time is made slightly earlier and the computation repeated. If the arcs overlap too much, the origin time is made slightly later and the computation is repeated.

This process is repeated iteratively in a computer until a solution that best fits all the data is determined. It takes fractions of a second.

For this exercise we will assume the origin time is: 00:58:53.49 GMT, 26 December 2004

Observatory	Code	Observed P-Wave Time	Travel Time of P wave	Distance in Degrees of arc	Azimuth Degrees From N	Amplitude *
Cocos Island Indian Ocean	COCO	01:02:23.71		15.4˚	177˚	28 mm
Pallekele Sri Lanka	PALK	01:02:28.98		15.7˚	285˚	7.8 mm
Lhasa Tibet	LSA	01:04:29.60		26.6˚	351˚	15.2 mm
Tennant Ck Australia	WRAB	01:06:58.93		44.2˚	123˚	8.2 mm

* Adjusted for "standard seismograph"

EARTHQUAKE PHYSICS BACK GROUND

1. **Using the origin time and the Observed P-wave time at each observatory, compute the actual travel time of the P-wave from the earthquake epicentre to the seismic observatory. This calculation involves subtracting times (hour, minutes and seconds) from each other. This is more difficult than normal subtraction, but is an essential skill in determining flex-time.**

   The greater the P-wave travel time, the further the apart the earthquake epicentre and the observatory are. Tables exist to translate these travel times into distances (kilometres) or degrees of arc (when measuring on a sphere). These distances can be plotted on a map or globe as arcs around the various observatories, and where they intersect is the estimated earthquake epicentre.

   In this exercise the supplied map has circular arcs drawn around each of the observatories. The arcs are spaced at 1-minute units of travel time and are coloured red and dotted. We don't need kilometres, nautical miles or degrees of arc, any useful unit will do. The 5-minute arc is solid and coloured purple to make counting lines easier.

2. **Plot circular arcs, around each of the observatories, equivalent to the measured P-wave travel time.**

   If the measured times are good, the arcs should intersect in a small area. As discussed before, if the intersections fall short, more travel time is needed, which means an earlier Origin Time for the earthquake.

3. **Could your intersections be better if the Origin Time was adjusted? Should the origin time be earlier or later?**

   Of course plotting the results on a map as we have done, is not truly representative of the earth (it is curved). Also the projection used (Mercator) has some distortion and the arcs drawn should probably have been more elliptical with the long axis north-south. In a real analysis the arcs are plotted on a sphere or inside a computer which takes care of all the spherical geometry issues.

EARTHQUAKE MAGNITUDE EXERCISE

Earthquakes also have a Magnitude which is a figure that represents the total energy release in an earthquake. Various estimates are possible, but essentially all use the size of the maximum observed displacement on the seismograph for a particular seismic phase and relate this to actual ground motion. This relationship is achieved by regular calibration of the seismometer. The ground motion is a function of the size of the earthquake and the distance between the earthquake and the observatory.

Once the earthquake is located (see above), the distance between the earthquake and the observatory can be computed. The maximum displacement can be measured off the seismogram and these figures input into a formula to compute the Magnitude.

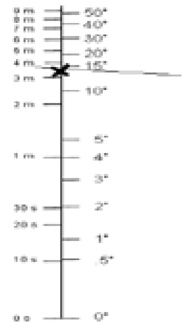
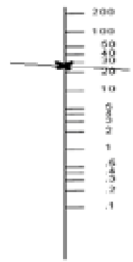
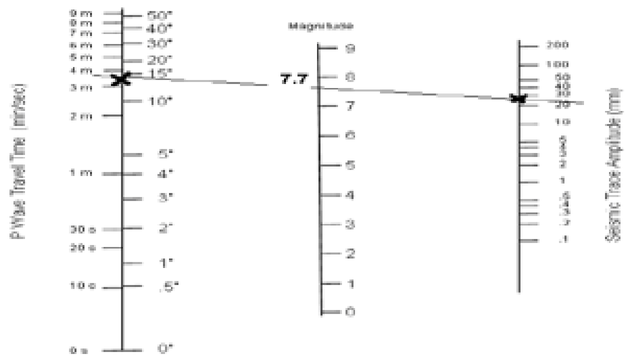
For this exercise, we will dispense with the formula and use a construct (pre-calculators) called a nomogram, which allows one to plot the values one knows on two scales and read off the answer on a third scale. The positioning of the scales in the nomogram takes care of all the mathematics.

4. **Take the observed maximum displacement for a particular observatory and plot it on the right scale. Next plot the P-wave travel time for that observatory on the left. Draw a line between the two points and read off the Magnitude of the quake on the middle axis. What is the magnitude? Check it with the data from another observatory. Is this a big quake?**

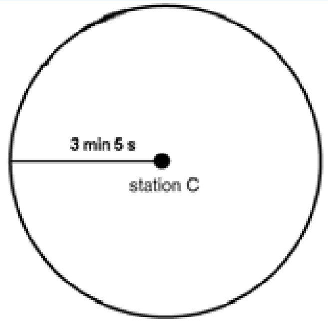
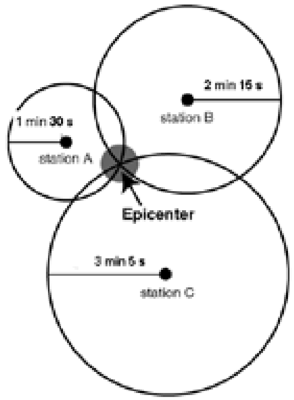
   It appears that large earthquakes (Magnitude greater than 8+) that occur in the ocean should be treated as potentially able to generate ocean wide tsunamis.

5. **Given that the distribution of earthquakes in the Banda Aceh shows that most quakes occur offshore, how would you rate this earthquake for its potential to cause an ocean wide tsunami? If you were the duty seismologist, would you ring the Emergency Hotline?**

Earthquake Magnitude

Step #	Description	Graphic
1	Plot the time taken for the P-wave to reach the observatory on the P-wave Travel Time axis (Graphic column on right).	
2	Plot the observed seismic trace deviation (in millimetres) on the Seismic Trace Amplitude axis (Graphic column on right).	
3	Connect the points you have plotted on the axes with a straight line. Read the calculated magnitude value off the central axis.	

Earthquake Location

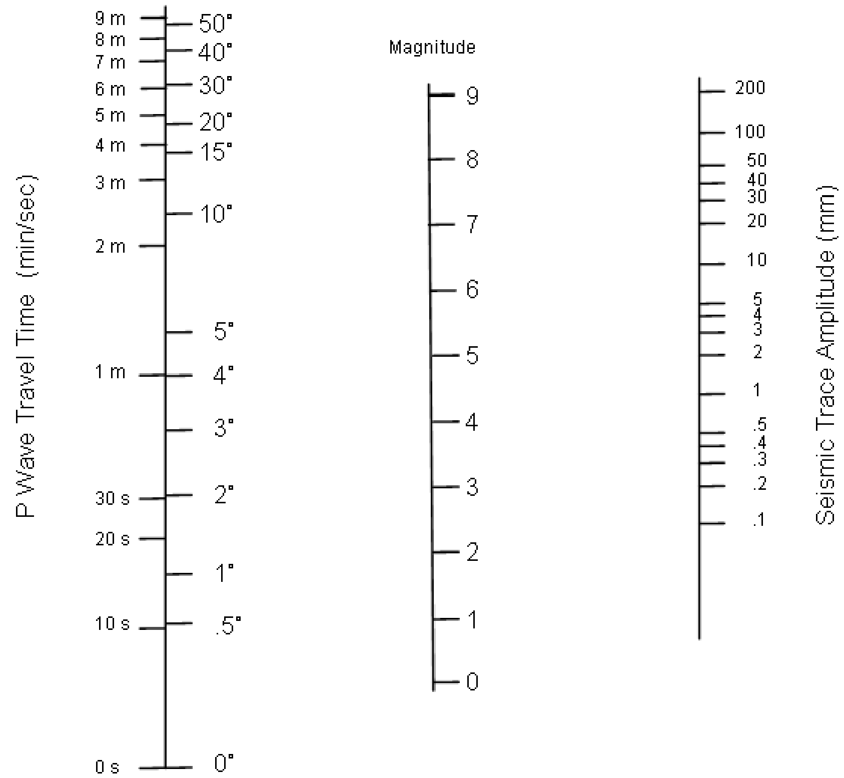
Step #	Description	Graphic
1	Calculate the time taken for the P-wave to reach an observatory.	01:02:23.71 - 00:58:53.49 02:23.71 + 01:06.50
2	Draw a circle around the observatory that represents this time.	
3	Repeat steps 1 and 2 for three (or more) observatories. The circles from the various seismic stations should intersect at the earthquake's location.	

Earthquake Magnitude Determination:

The determination of the magnitude of an earthquake involves measuring the amplitude of a specific seismic phase, knowing the distance from the earthquake to the seismic observatory and entering the values in a formula.

A quick method (pre electronic calculators), involved using a graphical construct (called a Nomogram) that takes care of the mathematics by constructing the axes in a particular fashion.

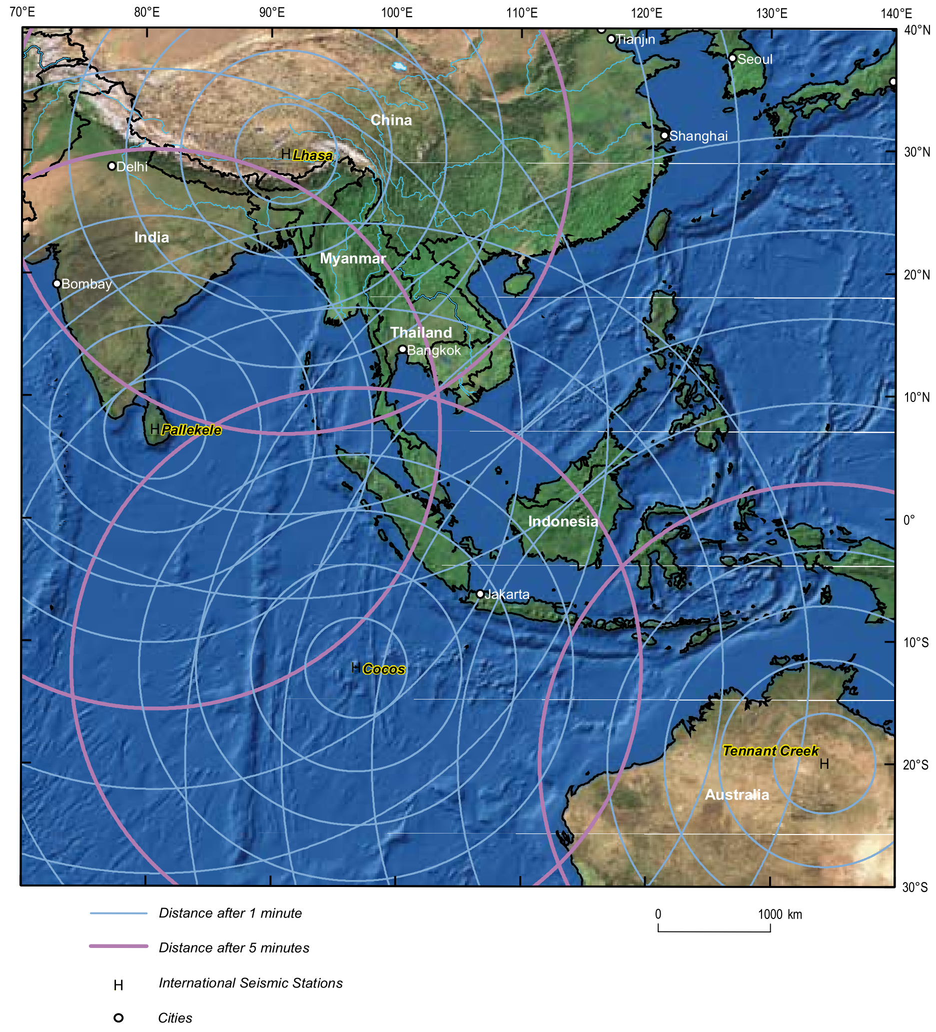
The Nomogram below allows one to compute the Body Wave Magnitude (M_b) by plotting the distance between the quake and observatory on the left axis (in degrees of arc or P-wave travel time), and the seismometer deflection in millimetres on the right axis. (The amplitude of the deflections in the supplied table have been adjusted so that they are what would have been recorded by a Wood-Anderson seismometer – essentially the actual ground motions have been multiplied by 2000 which is the amplification of the Wood-Anderson seismometer at these frequencies). The points on the left and right axes are connected by a straight line, and the intersection on the middle axis is the earthquake magnitude.



1. **For the Tennant Creek seismic station, plot the travel time on the left hand axis and the trace deflections on the right scale.**
2. **Connect the two points by a straight line and measure the intercept on the middle axis. What is the earthquake magnitude?**
3. **Check the answer with the times and deflections from the observations at the other observatories.**

EARTHQUAKE LOCATION EXERCISE

1. **Circular arcs represent successive 1 minute seismic wave travel times from the respective seismic observatories.**
2. **From the table showing the arrival times at each of the seismic observatories and assuming the origin time of the earthquake to be the supplied value (normally this would be solved for iteratively), calculate the seismic travel time to each observatory**
3. **Around each observatory, draw an arc equivalent to value of the travel time for that observatory. The arc will usually lie between two of the supplied 1 minute arcs. A rough estimation is good enough.**
4. **The intersection of the arcs represents the earthquake's epicentre**



Exercise prepared by Mike Sexton (Geoscience Australia)