Earthquake Mechanism Lab Exercise

Fog2 Lab 4/2007 Dueker

Estimating a Mechanism from First Motions

As explained in the text and in lecture, the P waves radiated from the double-couple mechanism of an earthquake are compressional in some directions and dilatational in others. The two compressional quadrants are orthogonal to the dilatational quadrants (about the intermediate principal strain axis that is along the fault plane).

A P wave propagating out of a compressional quadrant will initially shift the ground upwards when it reaches a seismic recorder. We will use recorders that have recorded ground motion in the vertical direction. Seismograms from such instruments will initially move up or toward positive *polarity* when they are from a compressional quadrant. Seismograms from vertical instruments in a dilatational quadrant will show negative polarity from an initial downward motion.

The polarity of seismogram motions after the first motion can be extremely complicated. Usually it quickly becomes a series of positive-negative vibrations. Seismometers that are on the *nodal plane* between the compressional and dilatational quadrants of an earthquake do not record a strong first motion. Instead of being impulsive, their first arrivals are *emergent*. These are called *nodal* seismograms.

Problem 1 - First-Motion Polarities

The seismogram plot below shows 13 seismograms recorded from a magnitude 4.7 aftershock of the the M6.2 May 1990 Weber II earthquake on the east side of the North Island of New Zealand. All the seismograms are from vertical instruments, located as indicated. Seismogram swings in the up direction have positive polarity. Look for an initial rise (or fall) out of the pre-arrival noise that looks more like an exponential curve than a sine wave. Note how the vibrations recorded by more distant stations have lower frequency. Relative record time increases to the right; these seismograms only plot arrivals in a 3-second window with the first motion about one second from the left side.

Print the seismograms. Circle the first motion on each one. Identify whether each first motion is compressional, dilatational, or nodal, and write your identification to the right of each seismogram.

Problem 2 - Plotting Polarities on the Focal Sphere

The data that you can use to interpret a focal mechanism are your first-motion polarities plotted on a stereonet representing the *focal sphere*. Inferring the compressional and dilatational quadrants of the focal sphere allow you to suggest the strikes and dips of the fault plane and the auxiliary plane.

Longitude	**Latitude**	**Distance, km**
176.35°	-40.250°	3.403
176.17°	-40.292°	14.414
176.37°	-40.061°	19.072
176.28°	-40.408°	20.154
176.06°	-40.106°	25.886
176.47°	-40.453°	27.993
176.63°	-40.339°	29.118
176.09°	-40.429°	29.880
176.27°	-40.618°	43.544
176.81°	-39.989°	48.965
176.35°	-39.699°	59.008
176.88°	-39.665°	78.454
176.82°	-39.541°	87.502

To plot a seismogram's first-motion polarity on the stereonet, you need to estimate the take-off angle of the seismic ray at the focal sphere. Two angles are needed: the ray's azimuth from North and its inclination above horizontal. Assume that all the rays here propagate more or less in a straight line from the source at depth to the station at the surface. Since none of the rays are refracting off a deeper interface, we use the stereonet to represent the *upper* hemisphere of the focal sphere.

To get the ray's inclination, use the (horizontal) distance in the table below from the earthquake's epicenter to the recording station, and the earthquake's 16.7 km depth. The depth divided by the distance is the tangent of the inclination. The order of the stations in the table is the same as in the seismogram plot. The easiest way to get the azimuth is to use a protractor on a printout of the map below. Measure from the earthquake (filled, hatched circle) to each station (crosses). I also have codes for computing the azimuth from the source and receiver coordinates. The epicenter is Lon=176.3284° Lat=-40.2295°.

Turn in a stereonet with all 13 polarities plotted on it. Use a filled circle for a compressional first motion, an open circle for a dilatational first motion, and a plus sign for a nodal seismogram.

Problem 3 - Interpreting the Focal Mechanism

This is the most difficult part of the lab. You will notice that your first motions plotted on the stereonet do not define unique focal planes. You have to make an interpretation of the most likely type of fault, and its likely strike and dip. Then you have to draw the focal plane of the fault on the stereonet (remember, we are using it for the upper hemisphere). You also have to draw the auxiliary plane, at exactly a right angle to the fault plane (this is a cinch with a good stereonet).

If you have made the correct interpretation, all the compressional first motions will fall within the compressional quadrants, all the dilatational motions in the dilatational quadrants, and all the nodal rays within 10° of the fault or auxiliary plane. This rarely happens; you may have to look at the seismograms again and re-interpret a polarity or two. To make your interpretation, it may help you to know that the Weber II earthquake sequence is above a shallow zone of westward subduction, that the subduction zone strikes northeast, and that the Weber II aftershocks trend along a northwest-dipping plane.

Turn in your stereonet copy with the first motions plotted on it. Also plot in the fault and auxiliary planes, with your interpreted fault plane a solid line and your auxiliary plane a dashed line. Hatch in the compressional quadrants (try not to obscure your first motion symbols). Describe the fault you have interpreted. Describe the possible range of fault strike and dip that could still fit the polarities. List any polarities that you can't fit. You may have one or two.

Tectonic Interpretation from Mapped Mechanisms

The map of the Tibetian Plateau and India shows hundreds of mechanisms determined by a group at Harvard for the Tibet and Himalaya region. Each mechanism is a lower-hemisphere projection with the compressional quadrant darkened. The dots locate the compressional axis directions.

Problem 4 -

Identify a strike-slip, a normal-fault, and a thrust-fault mechanism on the map. Circle them on a copy of the map (print one if you need to by clicking on the map image for a PDF file). State the approximate strikes and dips of the planes you interpret as the fault, for each. Try to pick examples for which the selection of the fault plane is more certain, given the tectonic setting.

Problem 5 -

Describe at least three different mixed-mode mechanisms. State interpreted, approximate strikes and dips.