University of Arkansas

GEOPHYSICS - GEOL 4433

LAB 04 - SEISMIC REFRACTION v.2.0

Due Date 02 October 2006

"In the earth's interior, where seismic waves travel invisibly and inaudibly, they can be followed only by mathematical equations." - attributed to D. Skoko and J. Mokrovic, 1982 in Mohorovicic's biography

Andrija Mohorovicic's detailed analysis of an earthquake that struck the former Yugoslavia on 10 October 1909 led to his discovery of a significant seismic discontinuity (a 'boundary' across which seismic velocities vary significantly). This discontinuity was subsequently shown to be a global phenomenon defining Earth's crust-mantle boundary, and in honor of its discoverer, bears his name - the Mohorovicic Discontinuity (or 'Moho').

Mohorovicic's analysis stands as a classical example of a seismic refraction experiment wherein analysis of travel-time vs. distance curves led to discovery of a fundamental aspect of Earth's layered internal structure. It is also a fine example of a simple refraction experiment involving a single, prominent, non-dipping velocity discontinuity such as was modeled for your laboratory assignment last week.

For this week's laboratory exercise, we will attempt to recreate Mohorovicic's classic analysis using actual earthquake records (seismograms) obtained from the Rapid Earthquake Viewer, an interactive online resource for viewing earthquake data developed by the seismology program at the University of South Carolina.

For this laboratory, you will:

1. gather data from REV;
2. tabulate these data in Microsoft Excel;
3. creat plots of travel-time versus distance from the earthquake (in degrees of arc and kilometers);
4. determine from your data the p-wave velocity of the crust;
5. determine from your data the p-wave velocity of the mantle;
6. determine the depth to the Moho;
7. compare this result to known information from the region of the earthquake.

To begin, go to the REV web site and familiarize yourself with the interface. Note that you can view seismograms from a number of recent earthquakes. At the REV Home Page, locate the 'Earthquake View' link and click on it.

Locate and click on the 'Contiguous US' link above the map of worldwide earthquakes. Below the map of the United States, you will see a drop-down menu of events that can be investigated using REV. Drop down this list and choose the event of 2006-09-14, a magnitude 4.0 earthquake in the California-Baja California border region (alternatively, you can click on the circle associated with this event on the U.S. or world map).

Once you choose this event, you will be presented with a display providing basic information about the event (location, time, magnitude, depth of focus) and a plot showing a series of seismograms from this event. You can also insert additional seismograms from other stations to this plot by selecting them from the drop-down menu.

The plot of seismograms shows each record plotted in distance (degrees) from the earthquake source and time (seconds) since the event - note that it is a travel-time vs. distance plot, just as we have been modeling in class. Plotting seismograms in the way creates what is known as a 'record section' showing the arrival of seismic energy at stations progressively farther from the source. You will use records for this earthquake to identify the existence and location (depth) of the Moho in the U.S.-Mexico border area.

Use the drop-down menu to locate and display seismograms from the following stations:

Table 1. Stations reporting data from event of 2006-09-14

CI.DVT
CI.BAR
AZ.PFO
AZ.RDM
CI.BBR
CI.HEC
TA.X14A
CI.ISA
TA.U05C
US.CMB

Once you have loaded all sites onto the record section, note that you can view individual seismograms by clicking on the station identifier in the table at the bottom of the page. Do this first for CI.DVT.

Notice there are three records for this (and all other) stations. The top seismogram records vertical displacement where as the other two record N-S and E-W displacements associated with earthquake energy arriving at the station. For this exercise, we will be plotting only data from the vertical (top) seismogram.

While viewing the seismograms, locate the 'Select Zoom' box at the bottom of the page and click on the radio button associated with 'Around P Wave'. This will zoom into the seismogram so you can better determine the arrival time of the first-arriving p-wave from this event. Note that the scale at the top of the page is in seconds from the origin time of the earthquake. Note both the distance of this station (degrees and kilometers) from the earthquake source and the arrival time of the first p-wave and record these data in a spreadsheet. Repeat this procedure for each station in the list above.

Create scatter plots showing these data (distance versus travel-time). On these plots, label each point with its station identifier so you will know which stations are which. Using your plot of distance (km) versus travel-time, attempt to resolve p-wave arrivals associated with 'direct' arriving p-waves from the crust from those arriving as a result of refraction along the Moho. Attempt to fit straight lines to your data to determine which points should be associated with crustal versus mantle p-waves (Note: seismologists label p-waves emanating from a source in the crust 'Pg' whereas those originating in the crust but refracting through the mantle are 'Pn'.

When you believe you have identified the appropriate arrivals, select these points and use Excel to fit a trend line to your data (this tool creates a regression line through your data); select trend line options to display the equation for the line and its r-squared value on the plot. You can refine your 'picks' for arriving p-waves by selecting data in such a way as to maximize the r-squared value of your trend line.

Using what you know of seismic refraction, determine the p-wave velocity through the crust and within the upper mantle (as represented by the Pn line on your plot). Compare these values to published ranges of p-wave velocity for the region of this earthquake - how well do your calculations agree with this information? (Note: please provide a full citation for these data so I can check this information myself).

From your data, determine the intercept time of the Pn trend line. Using your geophysics textbook or other resources, determine the depth to the Mono from your data - how well do your results agree with published depths to the Moho in this area (Note: please provide a full citation for these data so I can check this information myself).

Provide a written report from this exercise including;

1. plot of travel-time versus distance (degrees) with stations labeled;
2. plot of travel-time versus distance (km) with stations labeled;
3. plot showing trend lines (i.e. regression lines) through your data with stations labeled, equations for the regression lines indicated, and r-squared values for each regression line;
4. p-wave velocity derived from your data for Pg (crustal p-waves);

5. p-wave velocity derived from your data for Pn (mantle-refracting p-waves);
6. critical angle of incidence at the Moho;
7. depth to the Moho calculated from your data; include a description of the equation you used to calculate depth to the Moho (there are a variety of ways to derive this using the data you will have at your disposal for this lab and I need to know which equation you use as answers could vary somewhat depending on the chosen equation - why do you think this might occur?)

For your reading pleasure, two references are provided. One is a paper that excerpts the important aspects of Mohorovicic's original work and the other paper is composed of notes on this topic taken from Dr. Seth Stein's course, Earth's Interior, at Northwestern University.

Article from *Episodes* v. 24, no.1 (2001) by A. Grubic excerpting Mohorovicic's work:
http://www.episodes.org/backissues/241/37-40%20Classic.pdf#search=%22grubic%20mohorovicic%22

Reference on Moho recognition method from Dr. Seth Stein, Northwestern University:
http://www.earth.northwestern.edu/people/seth/202/lectures/Seismology/refrac.pdf