STUDENT-CENTERED EXPERIMENTS WITH EARTHQUAKE OCCURRENCE DATA

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An ever-growing catalog of earthquake locations, dates, times and magnitudes is available and easily accessed through Alan Jones' free Windows program Seismic/Eruption (Jones, et al., 2003; www.geol.binghamton.edu/faculty/jones). This program plots earthquake locations through time on a map of the world or on maps of various geographical areas (Figure 1). There are a number of teaching activities designed using Seismic/Eruption (e.g. Braile and Braile, 2001) which can help students see for themselves which areas of the Earth are more or less seismically active, where plate boundaries occur, typical depths of earthquakes, and sense that large earthquakes do not occur as often as smaller earthquakes. The activity presented in this paper allows the students to select their own region of interest and to interrogate the earthquake catalog to obtain quantitative data on the rate of occurrence of earthquakes of various magnitudes within their chosen region.

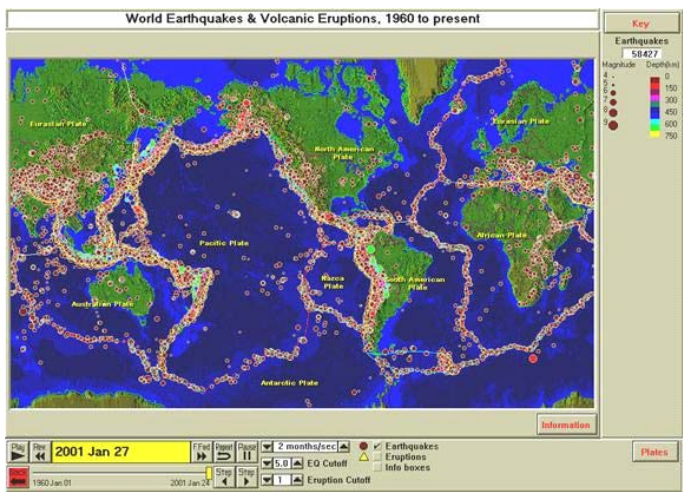

Fig. 1. Seismic/Eruption's World map showing earthquakes as circles plotted through time. The size of the circle indicates the magnitude, while the color indicates the depth of the earthquake.

After a suitable introductory activity or demonstration of Seismic/Eruption, students working individually or in small groups select a seismically active region of the world. Using a tool called "Make Your Own Map" (under the Map heading on the menu bar), they drag the mouse to create a zoomed view of their area of interest. Using the "Map menu" students should note of the latitude and longitude boundaries they have chosen. Next the time limits for the earthquake data they will analyze must be selected. The earthquake catalog in Seismic/Eruption begins in 1960 corresponding to the establishment of the World-wide Standard Seismograph Network. This global network, which later became the IRIS Global Seismic Network, greatly increased the accuracy and completeness of the catalog. If the student's computer has an Internet connection, the catalog contained in Seismic/Eruption can be updated (under the Options menu) so that the end of the catalog is essentially today. This functionality allows students' data sets to include earthquakes recently in the news. Within the time frame (1960 - present) students select starting and ending dates from the Control menu, and note the number of years selected. Reasonable choices may be 10 years, or 20 years, or even 45 years (the entire catalog to date).

Now the students are ready to "play" the earthquake data set for their chosen region and time window using the audio-style controls in Seismic/Eruption (Figure 2). By observing earthquakes occurring in accelerated time, students may draw preliminary estimates of how many large earthquakes will occur within their region and how many small earthquakes will occur. They may even attempt to predict when the next earthquake of a certain magnitude will plot on their map based on plotting "rhythms". To find out if their estimates and predictions are correct, students will run the program several times selecting each time a minimum magnitude threshold to plot.

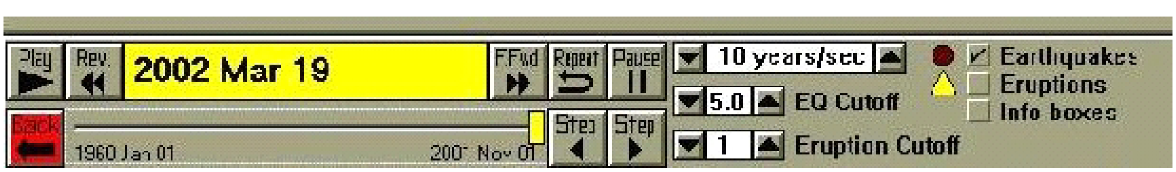

Fig. 2. A close-up view of Seismic/Eruption's controls.

For example, to determine the number of earthquakes with magnitude greater or equal to 8.0, students increase the “EQ Cutoff” value to 8.0. They should increase the speed with which the data set is plotted to 10 years/sec (the “Fast” setting should be avoided for this experiment). Seismic/Eruption also displays and counts volcanic eruptions; and can be disabled for this experiment by clicking to remove the check mark next to Eruptions. Students then click the Repeat button to replay the earthquake data set using these settings. The total number of earthquakes displayed on the map is printed in the upper right corner of the screen (see Figure 1), and students should make note of this number in a table. Next, they decrease the magnitude threshold to 7.5, click repeat to replay the data set, and collect the total number of earthquakes for this magnitude or larger. This procedure is repeated for smaller magnitude thresholds in 0.5 magnitude increments down to, say, 3.5. Finally the students divide their total number of earthquakes by the number of years in the time window they selected to obtain the number per year of earthquakes with magnitudes larger or equal to certain values.

An example of this exploration, Table 1 shows the results obtained for a region that includes Indonesia and the Philippines (latitudes from 12^{o}S to 12^{o}N, longitudes from 90^{o}E to 130^{o}E), for a period of 40 years beginning 1/1/1960 and ending 1/1/2000. Following data collection, the number of earthquakes per year is plotted on semi-log graph paper to create a Gutenberg-Richter plot Figure 3, which allows students to explore the data set. The data for the example region are plotted as red dots. Ordinary graph paper may be used for this, or a blank Gutenberg-Richter plot may be downloaded from (www.geol.binghamton.edu/faculty/barker/labs.html). Also shown for illustration, are similar results obtained from a region including California and Nevada for a period of 10 years (green dots) and a region around Italy for a period of 40 years (blue dots).

Table 1. Example Earthquake Occurrence Data for Indonesia and the Philippines.

Magnitude	Number	Number per Year
8.0	4	0.1
7.5	18	0.5
7.0	63	1.6
6.5	179	4.5
6.0	508	12.7
5.5	2019	50.5
5.0	5203	130
4.5	8457	211
4.0	8457	211
3.5	8457	211

By examining the plots and data tables, students can draw a number of conclusions. For example, by connecting points on the plot, they will see a linearly decreasing trend. Large earthquakes occur less often than smaller earthquakes. In fact for most regions of the world, for each increase of one magnitude unit, the number of earthquakes per year is smaller by a factor of 10. Students working on a regional scale can deduce this global scale trend by comparing their results with those of other students who have chosen a different region of the world (for example, comparing the different colors of data in Figure 3). Students may also notice a departure from this trend of decreasing number with increasing magnitude. In particular, for small magnitudes, the number may not change at all. Students should be encouraged to speculate on the reason for this. For most of the world, the earthquake catalog used by Seismic/Eruption does not include earthquakes smaller than magnitude 4.5. Therefore, the number of earthquakes with magnitude greater than 4.0 is the same as the number with magnitude greater than 4.5 simply because there are no earthquakes in the catalog for the selected region with magnitudes between 4.0 and 4.5. Other regions, particularly within the U.S. the catalog used by Seismic/Eruption includes smaller magnitudes. Though smaller events are included, there still may be a departure from the linear trend at small magnitudes, because small earthquakes are difficult to detect. Incompleteness of the catalog may also be the cause of the departure from a linear trend at large magnitudes. The time between large magnitude earthquakes may be longer than the time window we have selected, or may be longer than the entire earthquake catalog used by Seismic/Eruption.

Students may draw additional conclusions regarding the rate of earthquake occurrence within their area of interest, assuming that earthquakes are, on average, equally distributed through time. Thus in the example data (Figure 3), Indonesia and the Philippines, potentially damaging earthquakes of magnitude 6.5 or greater occur at a rate of 4.5 earthquakes per year. Therefore a damaging earthquake can be expected about every 80 days in this region. For California and Nevada, the trend suggests that magnitude 6.5 or greater earthquakes occur at a rate of about 0.3 earthquakes per year, or one earthquake approximately every 3 years. For Italy, the trend is for 0.1 earthquakes per year with magnitude 6.5 or greater, or one every 10 years. The actual data values collected for magnitude 6.5 or greater for California and Italy are greater than and less than the trend, respectively. The reasons for this difference could be discussed with students. Perhaps a different time window for the same region would produce slightly different results. Finally, although the time window for Indonesia did not include the 2004 M_W 9.3 Sumatra earthquake, we can extrapolate our data trend to estimate the expected rate of occurrence of earthquakes with magnitude greater than 9.0. If the trend is appropriate for earthquakes of that size, our data indicate we could expect approximately 0.015 earthquakes per year, or one magnitude 9.0 or greater earthquake every 67 years somewhere within the region of Indonesia and the Philippines. Our example data suggest that such an earthquake would be expected once every 1,000 years in the California and Nevada region or once every 3,000 years in Italy. This could (and should) lead to a discussion of whether such an extrapolation is reasonable (see Stein and Okal, this issue). Students could also test the assumption that earthquakes are evenly distributed through time by observing when earthquakes of a given magnitude threshold occur within their chosen region.

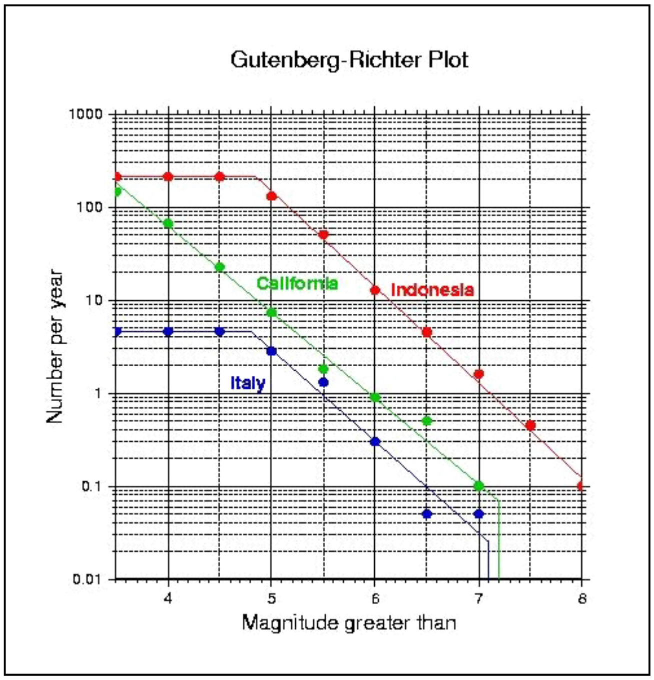

Fig. 3. Gutenberg-Richter plot of earthquake occurrence for the example data set including the region of Indonesia and the Philippines (red) and for other data sets from the California-Nevada region (green) and a region including Italy (blue). Students' plots will typically include only the data set from their chosen region, but others may be plotted for comparison.

Allowing students to interrogate the most accurate, complete and up-to-date earthquake catalog about a region of their own choosing provides “ownership” of the experiment. Perhaps they will choose an area with a recent newsworthy earthquake such as the 2004 Sumatra event. Or perhaps they will choose their family's ancestral region. Or perhaps they will choose a geographical area they are studying in another class. After some simple data processing, graphing and analysis, they can pose questions and obtain answers about the occurrence of earthquakes in their chosen region.

References

Braile, L.J. and S.J. Braile (2001). Introduction to SeisVolE teaching modules - Lessons, activities and demonstrations for the Seismic/Eruption (SeisVolE) earthquake and volcanic eruption mapping software, www.eas.purdue.edu/~braile/edumod/svintro/svintro.htm (as of 3/11/05).

Jones, A.L., L.W. Braile and S.J. Braile (2003). A suite of educational computer programs for seismology, Seismol. Res. Lett, 74, 605.