Recent large earthquake events in Chile.

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Abstract

Earthquakes constantly affect Chile as the most countries across the Andes Mountain Range, such as seen recently in Ecuador, April of 2016 (7.8 of Magnitude in the Richter scale). The Andes is amongst the most seismically active regions in the planet. These events are direct responses to the convergent boundary between the two tectonics plates: South America and Nazca plates. In March 2010, Chile suffered a major shock due to an 8.8 magnitude earthquake in the Richter scale. This event released such a huge amount of energy and had many other smaller events attached to it. This study focused on observing the distribution on time and space of the major and minor events. All the study was supported by acquired data from the United States Geological Survey (USGS) Earthquake Catalog. The results showed the relation with the shocks and the evolving convergent boundary where Chile is located. Also reached the relation of magnitude and the depth of each earthquake.

Introduction

Chile and most countries in the Pacific Coast of South America sit over a huge convergent boundary with a subduction zone between the South American and Nazca Plates. The Andes Mountains have been built in the past 500 million years (Winter, 2002) largely due to this subduction zone, and its growth has increased in the last 65 million years.

The seismicity in the Andes is not evenly distributed, it is in some way controlled by the angle of the subduction plate, the segments beneath northern and central Peru (about lat 2° to 15° S) and beneath central Chile (about lat 27° to 33° S) have very small dips (about 10°), whereas the three segments beneath southern Ecuador (about lat 0° to 2°S), beneath southern Peru and northern Chile (about lat 15° to 27°S), and beneath southern Chile (about lat 33° to 45°S) have steeper dips (25° to 30°) (Barazangi and Isacks, 1976).

In addition, Chile is situated in convergent boundaries and Transform boundaries, where earthquakes and volcanism are frequent. It is important observing and investigating the nature of Earthquakes in this type of boundary once there they occur frequently and large earthquakes can continue to produce aftershocks.

The aim of this study is to observe the nature of Chile Earthquake of February 2010 to the present, attempting to identify patterns in the behavior and geographic distribution of the large magnitude earthquakes and its aftershocks through the time in respect to their frequency, magnitude and depth. Also it is relevant to understand the temporal distribution of the events and the amount of energy involved to better describe the major event's nature.

Methods

The first step included the acquisition of data from the USGS website, specifically from the NEIC (National Earthquake Information Center Catalog) to be downloaded into the CSV format and displayed with Microsoft Excel ®, setting the download process to collect data relative to the seismic activity from 2010-2-26 00:00:00 to the present, magnitude minimum 4.0, and in the area from -30N to -42S, -77W to -68E covering the area correspondent to Chile and Argentina in the Southwestern edge of South America.

Then the acquired data was tabled into Microsoft Excel ® and formatted, converting time and date into numeric values to count the number of events based on defined ranges of magnitude, and calculating the energy and cumulated energy based on the Gutenberg – Richter relationship using the magnitudes via the following equation, which M is the magnitude, in the Richter Scale of Magnitude, for each event:

$$\text{Seismic Energy} = 10^{11.8 + (1.5M)}$$

With the prepared data, plots relating cumulated energy and time, focal depth versus time, cumulated number of events and time, and a Richter-Gutenberg curve were created. Subsets of selected data based on different ranges of magnitudes and depths are displayed using ESRI ArcGIS® online, adjusting the symbols to represent the ranges of values in respect to their location and also a plot of magnitude versus depth was made in this study.

In Seismology, the Gutenberg-Richter Law states that for every earthquake event of magnitude x, there will be 10 events of magnitude x-1. For instance, for every magnitude 7 event that occurs during a given period of time, there will likely be 10 magnitude 6 events in that same period of time. This relationship, while somewhat dependable, will vary slightly during volcanically induced seismicity, earthquake swarms, etc. However, there is typically linearity in a semi-log plot that can be observed.

For example, the plot below **(Figure 1)** is a Gutenberg-Richter plot generated from the Mogul Earthquake

Sequence that occurred in 2008 (Anderson et al., 2009). Notice the linear relationship between the maximum magnitude observed (about 4.7) and the aftershock sequence. The curve at the lower end of the magnitude scale represents where the catalog of events becomes incomplete. This is always observed in Gutenberg-Richter plots if the lowest magnitudes are plotted and is a result of the physical fact that for earthquake magnitudes this small, not all of them will be measured successfully.

To construct a Gutenberg-Richter Curve, each point represents the number of events that are larger than the magnitude listed. In this case, magnitudes were plotted that are greater than 0 at increments of 0.01.

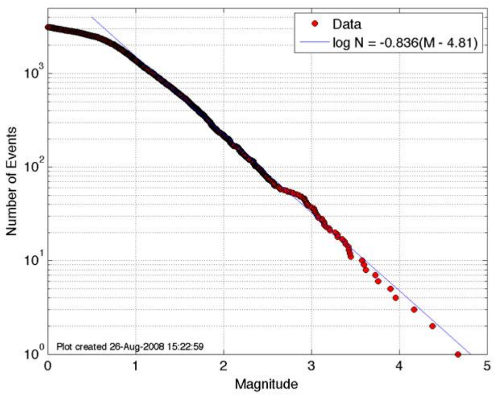

Figure 1 – Example of Gutenberg-Richter curve, for the Mogul Earthquake Swarm (Anderson et al. 2009).

Results

This work produced three important plots: a Gutenberg-Richter curve expressing the magnitudes versus the number of events **(Figure 2)**, a plot relating time to the amount of energy released **(Figure 3)** and a plot of magnitude versus focal depth **(Figure 4)**.

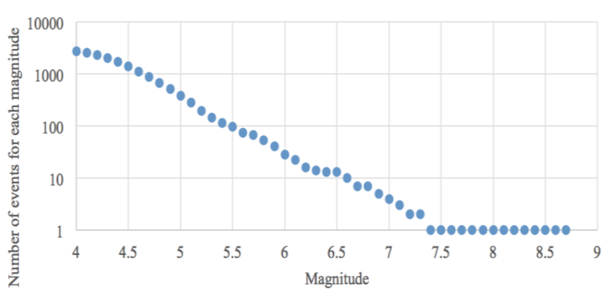

Figure 2 – Gutenberg-Richter curve.

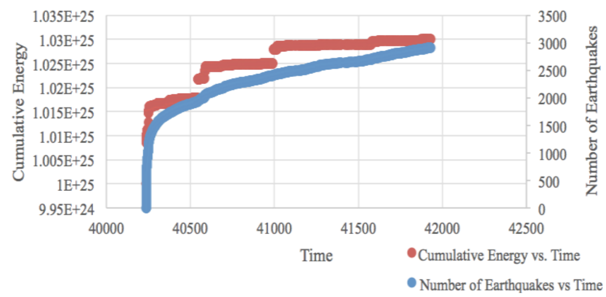

Figure 3 – Cumulative Energy and Number of Earthquakes versus Time curves.

Discussion and Conclusions

The number of earthquakes and cumulated seismic energy through time follow the same pattern once they report the seismic activity from the great magnitude earthquake in March of 2010 that released such a great amount of energy and was followed by a great number of aftershocks with smaller magnitude until nowadays. However, what can be seen is the huge amount of energy and increase in number of events in a small range of time at the beginning, which then turned to a smooth rate of growth in accumulation as seen in the **Figure 3.** Also the number of events with magnitude greater than 5 is smaller than the number of events with magnitude smaller than 4.5 when displayed the Gutenberg-Richter curve in **Figure 2**.

The spatial distribution of the earthquakes with the greatest magnitudes is completely related with the geography of the main fault, the trench of subduction and movement of the plates. Earthquakes of great magnitude occur in shallower depths as seen in **Figure 4,** which makes sense because the magnitudes are the measurement of events that can be felt at the Earth's surface.

Also, there is a break of events in the range of depths between 60 and 70 km that is related to the angle and velocity that the plates have in relation to each other and in that range of depth is ineffective to cause sensible events.

Another notable aspect was the fact that earthquakes with magnitudes bigger than 5.0 are concentrated near the shore and some in the continent as shown by **Figure 5.** The earthquakes deeper than 50km are located due to the presence of the slab of the Nazca plate that has been dragged under the South America plate towards the east that uplifts the Andes Mountains as shown in **Figure 6**.

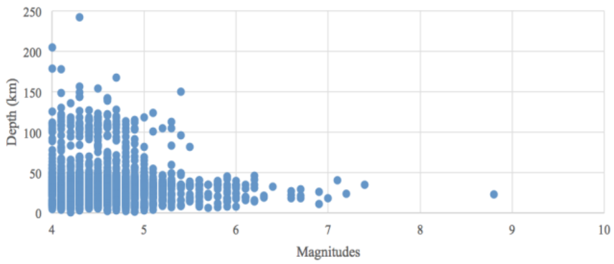

Figure 4 – Magnitude versus focal depth (km) plot.

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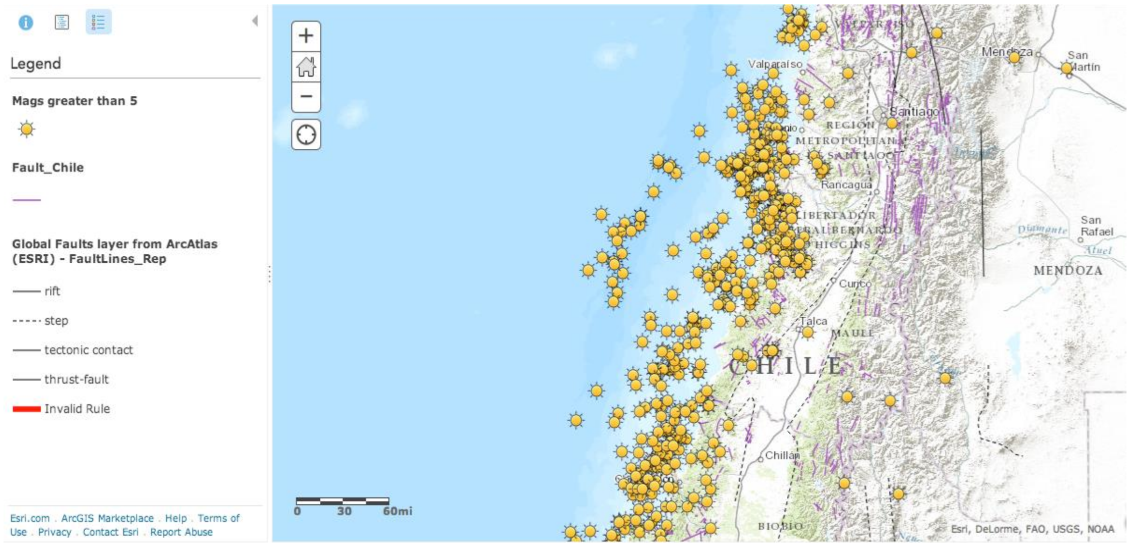

Figure 5 - Earthquakes greater than 5 in magnitudes. Great part concentrated in the shoreline.

Figure 6 - Earthquakes deeper than 50km. Most are concentrated in the continent.