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STATISTICS OF THE MAJOR EARTHQUAKES IN CHILE

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ABSTRACT

Historical earthquakes (from 1900 up 2010) with epicenters in zones bounded by 19-40◦S latitude are considered. Applying the technique of Gumbel's first asymptotic distribution we estimate that during the next decade strong earthquakes with magnitudes greater than 8.9 will occur.

INTRODUCTION

The high mountain peaks, the volanoes of the Andes, and the great earthquakes along the coast of South America, are dramatic manifestation of ocean-continent plate convergence (Norabuena et al., 1998). The oceanic Nazca Plate subducts belove the South American continent. The interactions of these two colossal plates is the most significant reason for very high seismic activity in this region, one of the highest in the world. Prior papers studied the possibility to determine the exact subduction geometry of this zone (Lindo et al., 1992). One major earthquake of 8 has occurrend every 10 years (Ruegg et al, 2009).
The Nazca Plate is easily bent and homogeneous with higher density rocks. The area between 35◦S and 37 ◦S is placed in the north of the rupture zone associated with the great 1960 earthquake, of 9.5 (Cifuentes, 1989) and south of the rupture zones corresponding to the 1928 Talca earthquake of 7.1 (Beck et al., 1998), the 1906 and 1985 Valparaiso earthquakes of 7.9 and 7.5, respectively.(Barrientos, 1995). Cisternas and Vera, (2008) studied earthquakes in Magallanes, southern Chile showing a seismicity low as compared with northern Chile. In Magallanes however, two main historical earthquakes (of 7.5) occurred in 1879 and 1949.

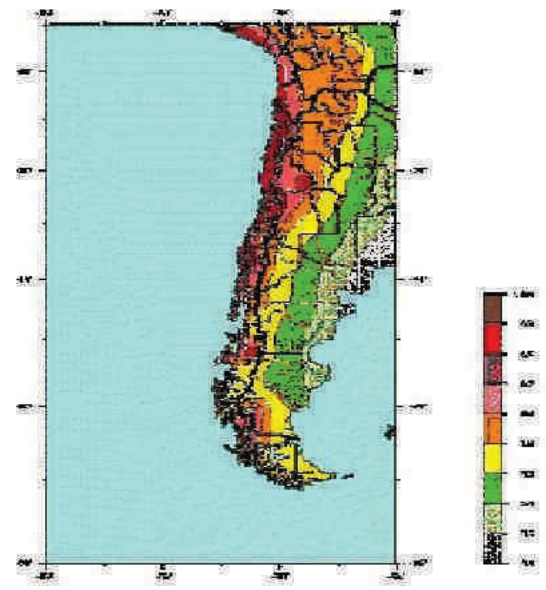

Figure 1. Seismic hazard map downloaded at: http://earthquake.usgs.gov /earthquakes/ world/chile/gshap.php

The Gumbel's asymptotic distributions were applied by Siscoe (1976) and Silbergleit (1996). Kulikov et al, (2005) applied the theory of Extreme Statistics to determine earthquakes return periods for tsunamigenic earthquakes in the coasts of Peru and northern Chile. Fig. 1 shows Chilean earthquake zones.

	M	Probability
1.	7.3	4,62E+04
2.	7.7	1,29E+05
3.	7.8	2,11E+05
4.	7.8	2,94E+05
5.	7.9	3,76E+05
6.	8.2	4,59E+05
7.	8.3	5,41E+05
8.	8.3	6,24E+05
9.	8.3	7,06E+05
10.	8.39	7,89E+05
11.	8.5	8,71E+05
12.	8.8	9,54E+05

Table 1. *Maximum earthquakes per decade and probabilities values considered in the present article.*

PREDICTION TECHNIQUE

For a given maximum observation, the probability that this value be less than M is defined as $p = \Psi(M)$. The probability that this value be equal or grater than M is $P = [1-\Psi(M)]$.
The theory of extremes gives the mathematical expression of $\Psi(M)$:

$$\Psi(M) = \exp\{-\exp[-(\alpha + \beta M)]\} = \exp\{-\exp[-A(M - mo)]\} \quad (1)$$

were α and β are constants determined by a linear square fit and mo is the mode.
As the probability function for the maximum amplitude for each solar cycle is not known, the observed values of $\Psi(M)$ are calculated according to Gringorten (1963).
For N observed extreme values the relationship between $\Psi(M)$ and M is obtained.
Extreme M are calculated by considering data observed between the years 1900 and 2010 (see Figure 2) and by using the maximum magnitude (M) per decade in ascending order:M1 <M2 < ... <M12.
For each observed peak values it was assigned a probability according to:

$$Pi = (i - 0.44) / (N + 0.12) \quad (2)$$

where i is the ordinal number and N is equal to 12. The related Gi values are defined by:

$$Gi = -\ln[-\ln(Pi)] \quad (3)$$

Figure 2 shows the points obtained by Eqs. (2) and (3).
The return periods T(M) and t(M) are calculated by using the expressions:

$$T(M) = [1-\Psi(M)]-1 \quad (4)$$

$$t(M) = T(M)[T(M) -1]-1 \quad (5)$$

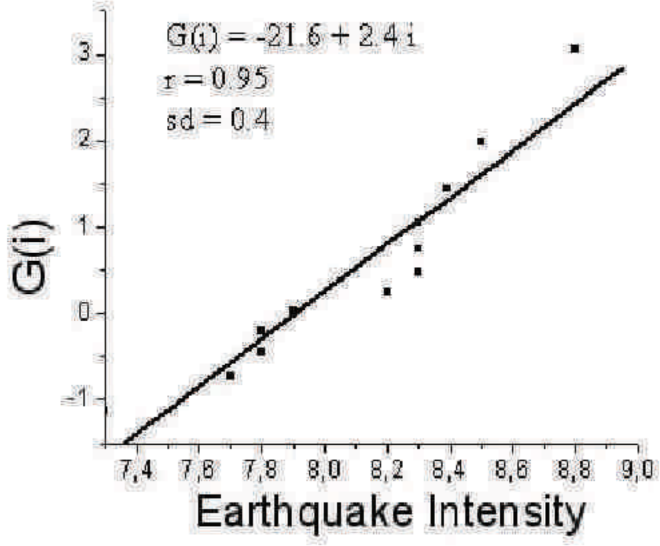

Figure 2. The squares indicate the points obtained by Eq. (3. The terms r and sd refer to the coefficients of correlation and the average error, respectively.

Both bounds are determined by considering K = T(M) and K = t(M), respectively. As it is pointed by Kulikov et al, (2005) data prior 1900 are deficient and uncertain.

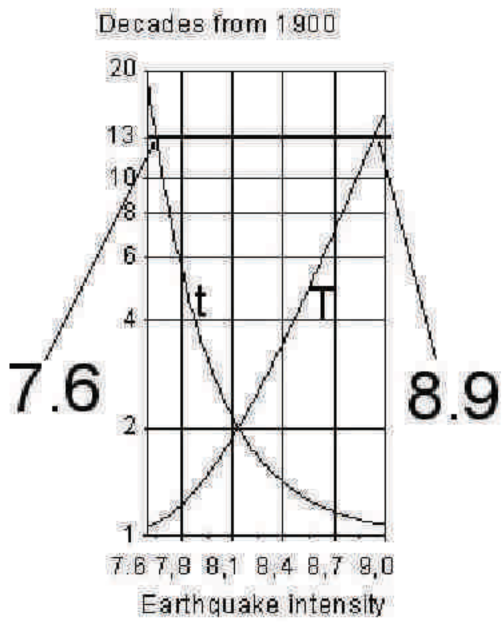

Figure 3. The ascending branch shows the waited number of decades required to detect one earthquake with extreme equal to or exceeding M. The descending one exhibits the expected number of decades necessary to obtain one earthquake with the extreme value less than M.

The median value (mv), which is the mid-point of the distribution is calculated by plotting the observations (from Figure 3) when T(M) = t(M) = 2, the related abscissa is equal to mv= 8.2. According to Gumbel (1967), the arithmetic mean (am), which is the average of all results is related to the standard deviation Sd as defined by Siscoe (1976) by Sd = 1.2825/A.

The measure of the scatter as called Rd (relative dispersion), it is obtained to divide Sd by the mode.
The statistical characteristic parameters of extreme values obtained are: the mode (mo = 8.0), and the mean (am=8.1), with Sd = 0.48 and Rd = 0.06.

RESULTS

Figure 3 shows the return periods vs. earthquake magnitude, the upper and lower bounds are shown for 13 decades. It is expected to observe one value outside to the right and one outside to the left of the defined bounds (see Fig. 3). The magnitude of the earthquake happened on July 30, 1995 is less than 7.6, then the another value out of the interval will be greater than the upper bound. According to these results, during the next decade, it is expected to observe an earthquake with magnitude higher than 8.9. The present analysis is useful to understand the risk of future strong earthquakes and tsunamis in Chile.

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