THE SEISMIC GAP IN THE PERU/CHILE BORDER REGION: THE NEXT PERUVIAN AND CHILEAN EARTHQUAKES WITH M_W NEAR 9.0, IN THIS REGION

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INTRODUCTION

The Central Andes region is one of the most seismically active areas of the world that includes the Peru-Chile Border seismic region, which has been violently shaken in the past by three very large earthquakes with M_W close to 9.0, occurred in 1604, 1868 and 1877, among many other of smaller magnitude, but also damaging earthquakes. Certainly, large earthquakes, like to those mentioned above, will occur in the future in the Peru-Chile Border region, and the consequences of those earthquakes will be more severe now than they were in the past, mainly due to the increased size of the cities existent in the Central Andes region, and to the grow of their populations.

According to Spence *et al. (*1999*)* the occurrence of significant earthquakes in, 1994 (very deep Bolivian event, Mw 8.2), 1995 (Antofagasta, Chile, Mw 8.0-8.1) and 1996 (Southern Ica, Peru, Mw 8.0), on the periphery of the great source gap of those very large earthquakes, may signal an increased seismic potential for that region. (See Figure 1). That seismic potential must have increased with the occurrence of the Ocoña, Southern Peru, Mw 8.4 earthquake in 2001. The Peru/Chile border region source gap has been studied also by other authors, among them Comte and Pardo, 1991, Comte and Suarez, 1995, Nishenko, (1985, 1991), Delouis et al. (1996),.

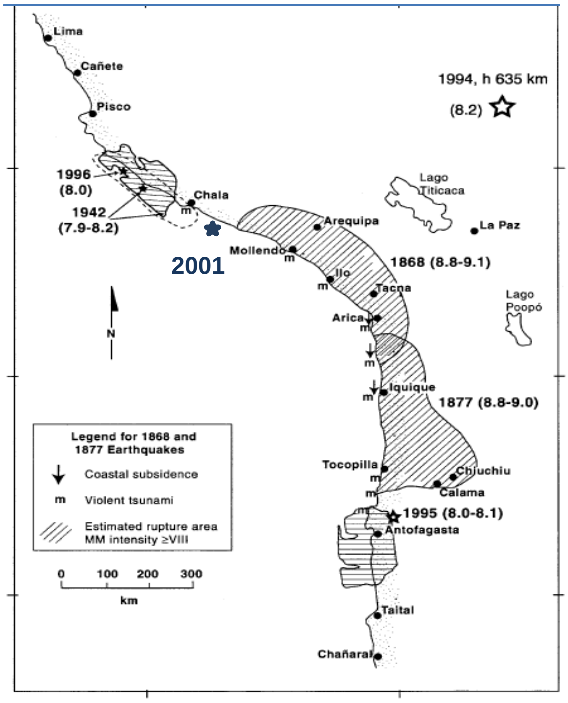


Figure 1- Seismic gap in the Peru/Chile border region. Isoseismals VIII MM represents the rupture of the earthquakes. Modified from Spence *et al.* (1999)

The aim of this work is to find a recurrence period for those huge earthquakes, considering the existent seismic gap in the Peru/Chile border region. We will analyze and discuss the return intervals for those Mw ~ 9.0 earthquakes given by other authors, and present our results obtained with different methods than those used before.

SEISMOTECTONIC SETTING OF THE PERU/CHILE SEISMIC BORDER REGION.

Barazangi & Isacks (1976, 1979) determined the main characteristics of the Wadati-Benioff Zone (WBZ) beneath the Andean region using hypocentres located with teleseismic data, and defined some important features of subducted Nazca plate structure. Other studies, performed with data collected from local temporary seismographic networks installed in southern Peru, ke those ones of Hasegawa & Sacks (1981), Grange et al. (1984) and Boyd et al. (1984), confirmed the results presented by Barazangi & Isacks (1979) of a WBZ dipping gently (~10°) in

Central Peru with a steeper dip (~30°) in Southern Peru. However, they replaced the tear suggested by Barazangi & Isacks (1979) to separate the portions of the slab with different dip, by a curved subducted slab.

Schneider & Sacks (1987) by using data from the same network, but collected in a longer time interval, confirmed the existence of a twisted slab beneath southern Peru. Summarizing, those early works already presented some main features of subducted Nazca slab: the presence of intercalated flat and steep portions of WBZ, the absence of seismicity between 300 and 500 km of depth, and the existence of a twisted slab beneath southern Peru.

Later on, Cahill & Isacks (1992) using selected hypocentres determined by ISC and NEIC, and focal mechanism solutions of Andean region earthquakes, constructed a contours map of Nazca slab between latitudes 08°S to 35°S (see Figure 2), giving a detailed image of the shape of the subducted slab. Comte & Suarez (1994) suggested the existence of a double seismic zone beneath northern Chile from focal mechanism solution of intermediate-depth local events, by using data recorded in 1988 around Iquique (~21°S) and Antofagasta (~24°S). **GERMAN PICTURE**

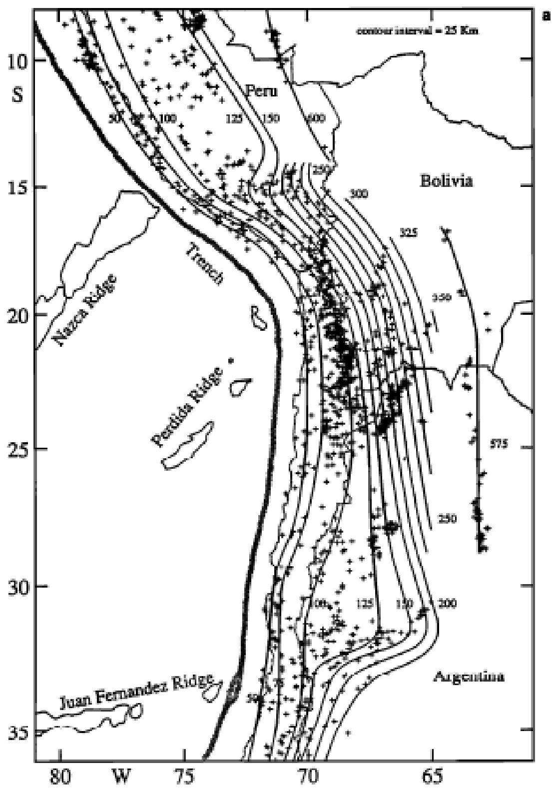


Figure 2- Contours map of Nazca slab showing some seismotectonic features beneath the Andean region. Cahill & Isacks (1992)

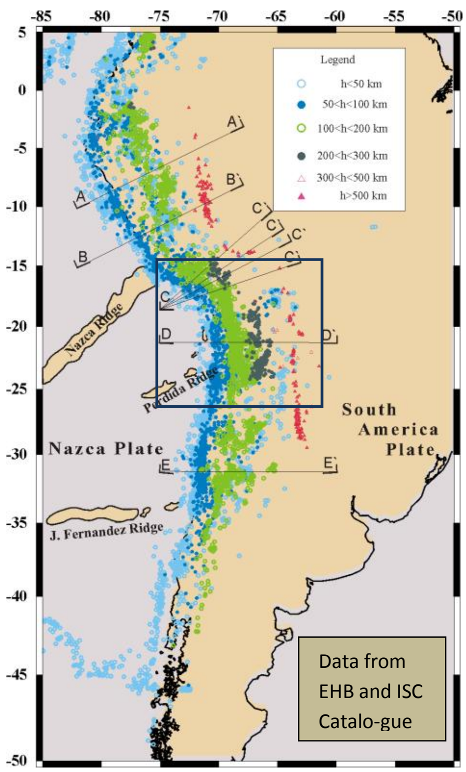
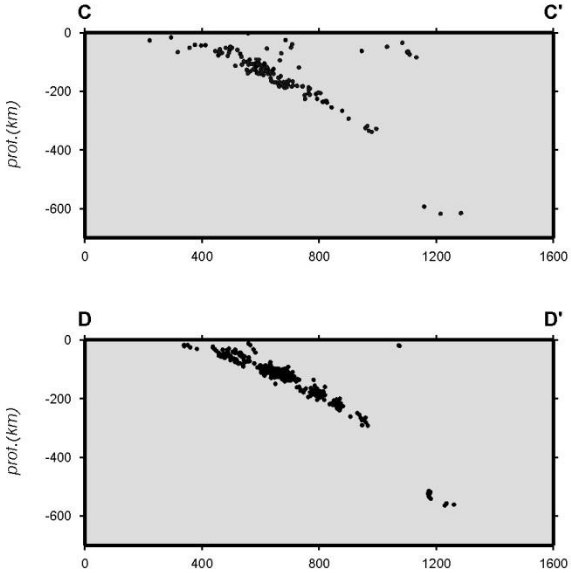


Figure 3- Map of epicentres of the Andean region compiled from EHB and ISC catalogues for the period 1960 – 2009.

In order to present those Central Andes region seismotectonic features with updated data from modern seismic catalogues, it was compiled from the EHB catalogue of relocated hypocentres by using a method presented by Engdahl *et al.* (1998), for a time interval between 1960 and 2008, and the hypocentres determined by ISC for 2009, performed with the method mentioned above. In Figure 3 is presented a epicentral map of that region, by using more than 20.000 very precise hypocentres.

In Figure 4 is presented the composed profile CC' for Southern Peru and DD' for Northern Chile, In Figure 5 is presented the longitudinal NS profile of the Andean Region. From these profiles and the epicentral map it was possible to separate the seismogenic zones for Southern Peru (SPSZ) and for Northern Chile (NCSZ). The Peruvian seismic zone is composed by earthquakes occurring in at the beginning of the Nazca plate subduction up to 70 km of depth, and extended from 15^o to 18^o S. The Chilean seismic zone is composed also by earthquake of the beginning of the Nazca plate subduction up to 70 km of depth and extended from 18^o to 25^o S.



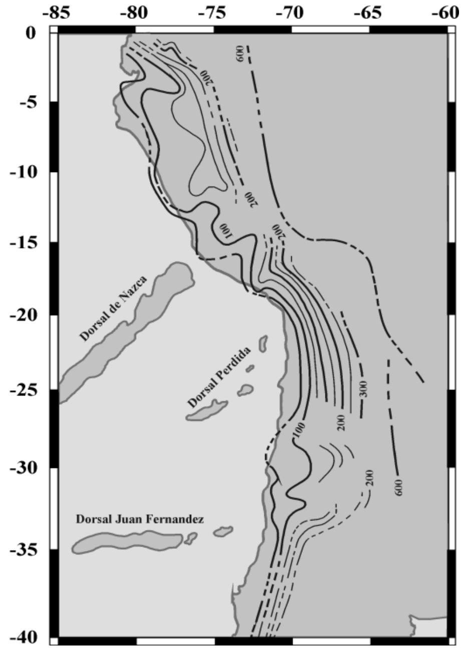


Figure 4- Profiles CC' and DD'showing the subducted Nazca Plate beneath Southern Peru and Northern Chile

Figure 5- Contours map of Nazca slab elaborated in this work

The subducted slab beneath the Central Andes region presents smooth contours down until 300 km of depth, showing in the contour map of Figure 5 elaborated with new data in this work, completely different topography compared with the existent in central and northern regions of Peru. Cahill & Isacks (1992), using selected hypocentres determined by ISC and NEIC constructed a contours map of the Nazca presented in Figure 2, although with less detail than the one presented in Figure 6, due to the larger number of hypocentres nd the better quality of the relocated hypocentres used in the contour map proposed in this work.

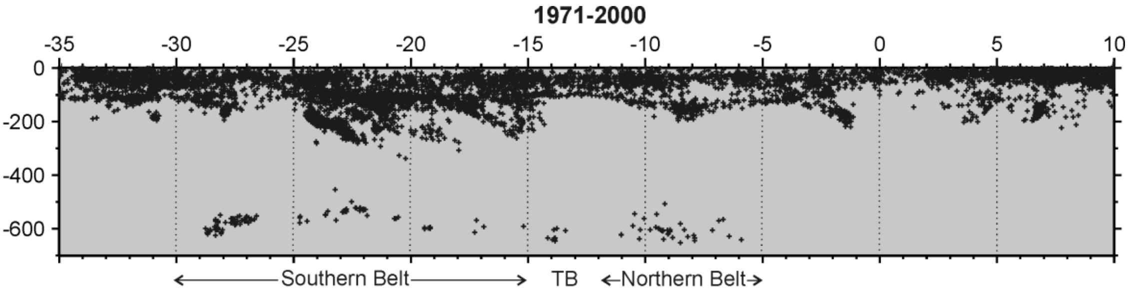


Figure 5- Longitudinal NS profile beneath the Andean Region showing several important seismotectonic features of the Nazca subducted slab. The Central Andes region is located between 15^{o} and 18^{o} S.

The longitudinal NS profile of Figure 6 shows several features that characterize the subduction process of the Nazca plate, and presents a clear difference between the subducted slab under the Central Andean region an the rest of the subducted slab.

SEISMIC POTENTIAL AND RECURRENCE INTERVAL OF LARGE EARTHQUAKES IN CENTRAL ANDES REGION

Nishenko (1985) carried out a study on seismic potential for great interplate earthquakes along the Peru/Chile border region. The tsunami magnitude M_t 9,0, which was calculated by Abe (1979) for the 1868 and 1877 earthquakes occurred in this region, corresponding to a seismic moment of about 350-400 x 10^{27} dyne.cm, was used by Nishenko (1985) to estimate the displacement of 800 to 1200 cm for the 1877 event. He assumed the zone of highest intensity extended along the coastline in approximately 550 km (mean value from estimates made by Lomnitz, (1970). He divided that displacement by the convergence rate of 9 cm.yr^{-1}, assuming no aseismic slip, to estimate the interval of recurrence for this earthquake in 88 to 133 years (i.e., with occurrence estimated in the interval 1966-2010).

The results obtained in this work are presented in the table below. The average values of recurrence interval obtained with the cumulative distribution (ARIc) in the two sources are not coherent with the similar values obtained with the single distribution (ARIs), too low in the case of NCSZ and excessively high in the case of SPSZ. The results obtained with the single distribution are more reliable, considering the catalogue used in this case is continuous and complete in the time interval 1960-2009. In the other hand the same time interval is not sufficiently large to include earthquakes with magnitude larger than m_b 6.6, in the case of NCSZ, and m_b 6.2 in the case of SPSZ, which were the largest events in both sources during the referred time interval, therefore representing the cumulative magnitudes only for the time interval of the used catalogue.

The recurrence intervals obtained with FMs and ML methods are more coherent between them for Source 1 than for Source 4. That recurrence interval varies with the value of magnitude being considered. Using the M_W values adopted in Table 1 for those events, in the case of the earthquake of 1877 with M_W 8.7occurred in NCSZ, the recurrence interval is 153 years and the probable occurrence year is 2030, while for the 1868 earthquake with M_W 8.8 occurred in SPSZ those values are 291 years for the recurrence interval, similar with the 296 years interval inferred by Nishenko (1985), and 2159 for the probable occurrence year.

SOURCE	Mw	GR	MP	IRMs	GR	VE	IRMa	Year of occurrence from IRMs Result
NCSZ	**8.8**	186	170	**178**	138	74	**106**	2055
SPSZ	**8.8**	354	229	**291**	496	424	**460**	2159

GRs: single magnitude freq. distribution; **MP:** máximum likelihood; **IRMs:** recurrence interval with single distribution **GRa:** frequency distribution magnitude; **VE:** extreme values; **IRMa:** medium recurrence interval od accumulative distribution

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