INTRAPLATE SEISMICITY IN CENTRAL CHILE

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SUMMARY

Shallow intraplate seismic activity in Chile is poorly understood. This is mainly the result of lack in association of seismic activity with recognizable fault features at the surface. This work is an attempt to understand the tectonic environment which gives rise to earthquake activity in the occidental flank of the Andes of central Chile. This region, located less that 100 km away from Santiago, has been subjected in the past to earthquakes with magnitudes up to 6.9, and several smaller shocks have taken place in the last few years. Because most of the events lie outside, to the east, of the Central Chile Seismic Network, it is essential to have an adequate knowledge of the velocity structure in the Andean region to produce highest quality epicentral locations. A north-south refraction line using mining blasts of Disputada de Las Condes open pit mine has been acquired. These blasts have been detected as far as 250 km to the south; preliminary interpretation of the travel times indicates a model consisting of 3 layers, 1.5, 5.35 and 8.6 km thick, overlying a halfspace; their associated P wave velocities are 5.2, 5.95, 6.35 and 7.0 km/s respectively.

Hypocentral relocation of earthquakes occurring in the last 10 years, using the newly developed velocity model, reveals several regions of concentration of seismicity. One of them clearly delineates the fault zone, and its extensions, of the strike-slip earthquake that took place in September, 1987. Other pockets of activity are the regions near San José volcano and the birth of the Maipo river. A temporary array of seismographs, installed in the high Maipo region, allowed us to establish the hypocentral location of events with errors less than 1 km. Focal mechanisms of these events were determined using waveform modeling of the records produced by a recently deployed broad-band seismograph at 20 km distance. Focal mechanisms indicate that the region is currently subjected to E-W compression.

INTRODUCTION

In general, seismogenic zones in Chile are basically well established: large shallow (0-50 km) thrust earthquakes along the coast, large deeper (70-100 km) tensional events within the subducting plate, and in few places, like Magellan Strait and the cordilleran region of central Chile, where very shallow seismicity (0-20 km) occurs.

The large thrust earthquakes are located along the coast from Arica (18°S) to Taitao Peninsula (46°S). With magnitudes that can reach values over 8, these events are usually accompanied by tsunamis; their rupture extent is limited to the coupled region between the Nazca and South American plates (Tichelaar

and Ruff, 1991). Their spatial and time distributions have been studied (Barrientos, 1981; Martin, 1991), so the seismic hazard due to these large events has been assessed.

More recently, the hazard produced by large, deep tensional earthquakes has been recognized. These events are caused by faulting within the subducting Nazca plate at depths between 80 and 100 km with apparently high stress drops (Kausel, 1991). A clear example of these type of events is the 1950 Calama earthquake (Kausel and Campos, 1992) and possibly the 1939 Chillán event (Beck et al, 1993).

Another seismogenic region, which has not been fully studied and quantified in the past, is the one located at shallow depths in the Andean cordillera in the central part of Chile. Two relatively large, shallow (less than 30 km depth), earthquakes have taken place in this region: September 4, 1958 (M=6.9, Lomnitz, 1961; Piderit, 1961) and September 13, 1987 (M=5.9, Barrientos and Eisenberg, 1988), the former producing a maximum Mercalli intensity of X. Only recently, with the permanent operation of the Central Chile Seismic Network (CCSN), we have recognized this region as highly active with its corresponding seismic potential (Fig. 1). After 10 years of operation of the CCSN we are now able to adequately locate the seismogenic zones as well as define their geometric characteristics and rates of activity.

The understanding of the seismotectonic phenomena in this area is crucial for the assessment of the seismic hazard in central Chile. In fact, three large mines (El Teniente, Disputada, and Andina) as well as water supply for the city of Santiago are located in this seismic area; five medium size hydroelectric plants and several smaller ones are less than 50 km away from the area of interest.

DATA and RESULTS

To produce highest quality epicentral locations in the area we needed to establish an adequate velocity model in the Andean region and a set of station corrections, particularly because most of the events lie outside, to the east, of the CCSN.

The velocity model stems out from a north-south refraction line (Fig. 2a) using several mining blasts of Disputada de Las Condes open pit mine (70.27°W, 33.15°S) as seismic source. These blasts were recorded in some of the permanente stations of the CCSN as well as portable seismographs deployed in several complementary locations (Fig. 1) when a sufficiently large blast took place. We used the closest permanent station at Farellones as a reference for the zero- time after recording simultaneously three monitored explosions in the mine; the P-waves travel time from the mine to Farellones is 3.5 s. These blasts have been detected as far as San Fernando, 180 km to the south of the Disputada mine (Fig. 2a). preliminary interpretation of the travel times indicates a model consisting of 3 layers, 1.5, 5.35 and 8.6 km thick, overlying a halfspace; their associated P wave velocities are 5.2, 5.95, 6.35 and 7.0 km/s respectively (Fig. 2b).

Analysis of ten years (1986-1995) of shallow seismicity in the Andean region of central Chile clearly delineates the pattern of activity (Fig. 1). The most important feature is the concentration of events south of Pangal river and east of Cipreses river centered about 34.4°S and 70.2°W. This region was the site of an Ms=5.9 earthquake in 1987; the focal mechanism and aftershock distribution reveals strike-slip faulting on a NE-SW trending feature. This is mainly the result of an east-west compression. Other sites of activity are the Maipo valley, about 20 km south of Las Melosas (epicenter of the Ms=6.9, 1958 earthquake) where most of the activity began in November, 1994. Concentrated activity is also evident near Disputada de Las Condes and El Teniente, both are product of induced seismicity; blasting at Disputada and blasting and rockburtsts at El Teniente. Minor seismicity nearby San José volcano is thought to be of volcanic origin; 50% of this activity took place in the first 4 months of 1990. During this period, events with magnitudes between 3.6 and 5.0 are well represented by $\log N = 7.14 - 1.55M$ (N is the annual cumulative number), but this relationship underestimates the frequency of occurrence of events with magnitudes $M > 5.5$.

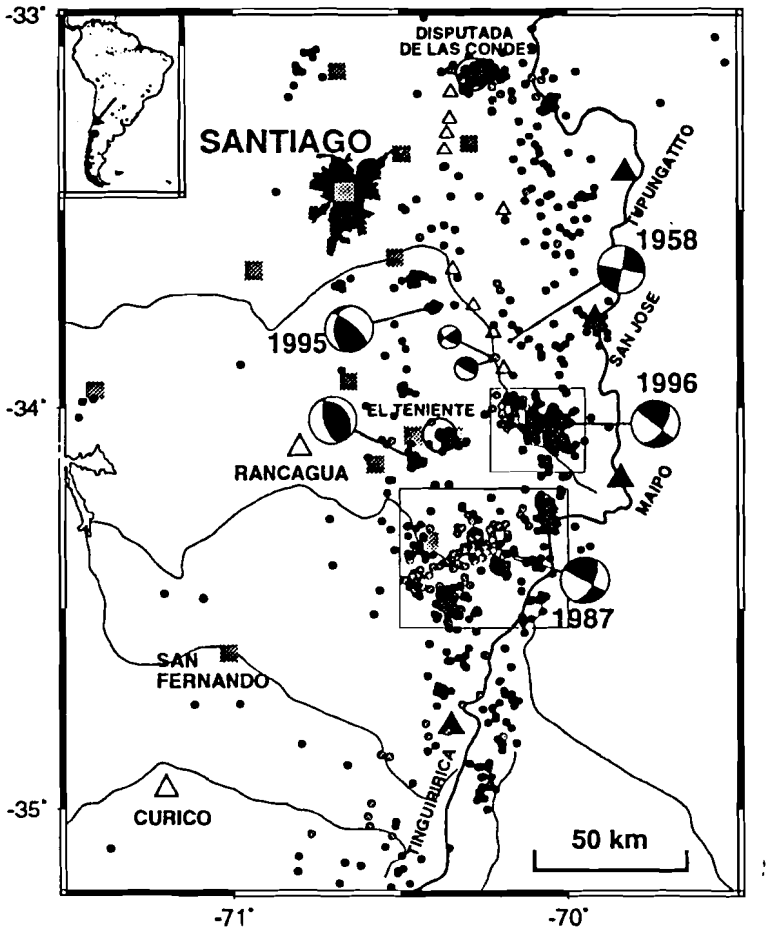

Fig. 1. Epicenters of shallow (< 20 km depth) earthquakes in the Central Chilean Andes during the period 1986-1995 as determined by the Central Chile Seismic Network (squares) of the Dept. of Geophysics of the University of Chile. The two highlighted regions are zones of recent high activity. Portable seismographs deployed for the acquisition of the refraction line (Fig.2) are represented by open triangles.

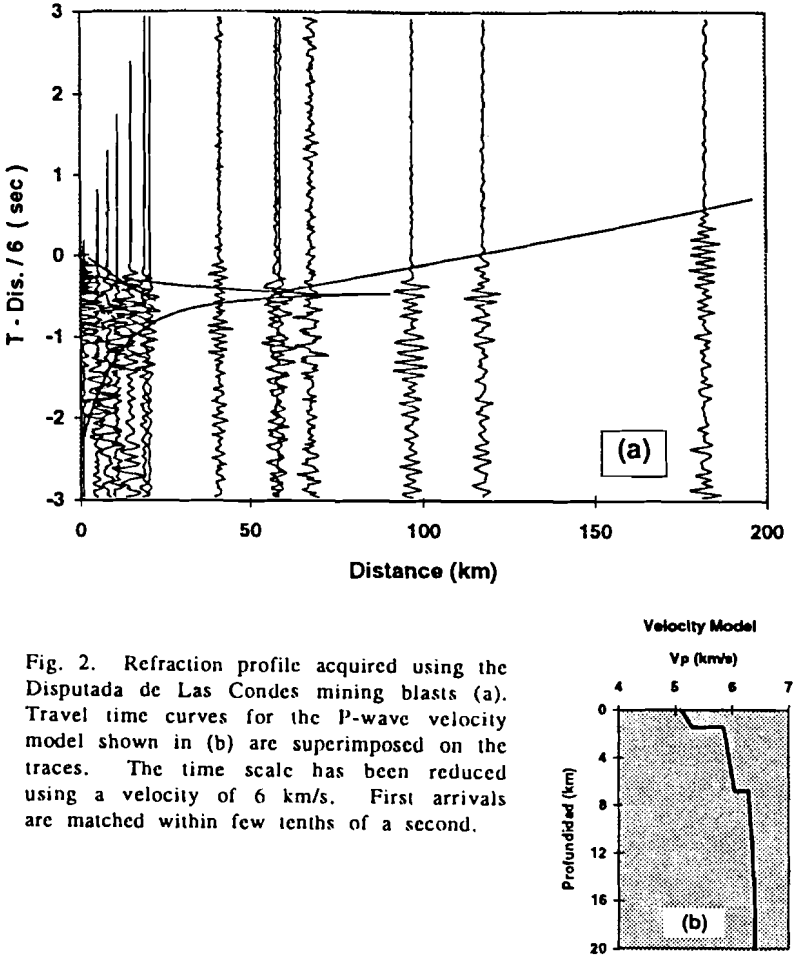

Fig. 2. Refraction profile acquired using the Disputada de Las Condes mining blasts (a). Travel time curves for the P-wave velocity model shown in (b) are superimposed on the traces. The time scale has been reduced using a velocity of 6 km/s. First arrivals are matched within few tenths of a second.

A portable network, consisting of 8 L4C Mark Products and EDA digital recorders operated for a period of one and a half month (January-March, 1996) in the region between Maipo and Volcán rivers, one the sites of highest activity in the past few years. During this period, more than 20 shallow earthquakes were recorded at 4 or more stations. We are currently analyzing the characteristics of this seismicity in addition to developing moment tensor inversion at local distances.

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