THE PUNITAQUI EARTHQUAKE OF 14 OCTOBER 1997 (Ms=6.8): A DESTRUCTIVE INTRAPLATE EVENT IN CENTRAL CHILE

Mario PARDO(1), Diana COMTE(1) and Tony MONFRET(2)

(1) Departamento de Geofisica. U. de Chile. Casilla 2777. Santiago. Chile (mpardo. dcomte @dgf.uchile.cl)
(2) IRD. 209-213. rue La Fayette. 75480 Paris-Cedex 10. France (monfrett@faille.unice.fr)

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INTRODUCTION

On October 15. 1997. a magnitude Ms=6.8 earthquake stroke central Chile producing important damages into the Punitaqui-Ovalle region. located about 100 km south of Coquimbo city. Even though it magnitude was moderate. the reports indicate that eight people died. almost 5000 houses collapsed and about 16000 houses were strongly damaged. The earthquake was followed by many aftershocks for several months. being the most important the one which occurred on November 3. 1997 (Ms=6.2). with epicenter located inland similar to the main shock. but at a shallower depth.

About two months before this seismicity. a swarm type activity of thrust events occurred offshore central Chile. between 30°S and 30.8°S. during July and August. At least 13 shallow thrust earthquakes (mb≥4.9) were reported in the Harvard CMT catalogue (HCMT). with two of them with maximum magnitude mb=5.8. Although their hypocenters were located close to the cities of Coquimbo and La Serena. low damages and intensities were reported there.

Due to the lack of local seismological stations in the region. outside the coverage area of the seismological network that the University of Chile operates about 250 km to the south. it was not possible to accurately locate the hypocenters of these events. For that reason. we relocate the hypocenters determined from records of stations at teleseismic distances. in order to study this earthquake and its possible relation to the precedent swarm type activity.

SEISMOTECTONIC SETTING

The studied seismicity is located within the rupture zone of the large April 6. 1943 Illapel earthquake (Ms=7.9) (Kelleher. 1972) (Figure 1). According to historical reports. it has been affected by at least other two important earthquakes, on July 8, 1730 (M~8.7), and on August 15, 1880 (M~7.7). The 1943 event generated a local tsunami of 4.5 m (Beck et al., 1998). To the south, this region is limited by the 1971 Aconcagua (Ms=7.5) and 1906 Valparaíso (Ms=8.3) earthquakes rupture zones (Kelleher, 1972; Malgrange et al., 1981; Korrat and Madariaga, 1985) and to the north by the 1922 Copiapó (Ms=8.3) seismic event (Beck et al., 1998). These are thrust events related to the subduction of the Nazca plate beneath the overriding South American plate.

The region is included into the zone (27°S-33°S) where the dip of the subducted slab becomes nearly horizontal at depths of 100-120 km, for more than 250 km beneath the Andes and Argentina, before reassuming its descent into the mantle (Cahill and Isacks, 1992). This nearly horizontal slab geometry characterized the general tectonic of the zone: a strongly coupled interplate contact, a highly compressed continental crust with back-arc crustal shortening and seismic activity in Argentina, and absence of active Quaternary volcanism.

DATA AND ANALYSIS

The data used correspond to the hypocenters reported by ISC of earthquakes with magnitude mb>5, occurred in the region between 1964 and 1996, and the arrivals time of P, pP and S waves from the earthquakes occurred during 1997, with more than 15 of these phases reported by NEIC. The focal mechanisms of the events between 1977 and 1997 were obtained from the HCMT catalogue.

The P, pP and S waves arrival times, were used to relocate the 1997 hypocenters using the Joint Hypocenter Determination technique, JHD (Dewey, 1971). The largest 21 earthquakes were used as calibration events to determine the time residual correction matrix to be applied to the rest of the 1997 events. A total of 152 events were relocated (Figure 1-B).

The relocated seismicity during 1997 shows two clusters. The first one is located offshore between 30°S and 30.8°S, corresponding to the offshore swarm type activity during July and August, with at least 13 events with magnitudes 4.9≤mb≤5.8. The second one is located inland between 30.8°S and 31.3°S, corresponding to the Punitaqui earthquake sequence (Figure 1-B). These clusters in seismicity occurred in zones where, at least since 1964, very low seismicity was observed (Figure 1-A). At the plate interface between the shallow offshore activity and the Punitaqui seismicity, not important earthquakes occurred during 1997 (Figure 1-C), suggesting that this part of the interplate contact was not seismically activated and that it is strongly coupled.

The Punitaqui earthquake mainshock was relocated at 31.02°S, 71.21°W, and 67 km of focal depth, differing on about 35 km from the hypocenter obtained from the central Chile local network located ~250 km to the south (30.74°S, 71.33°W, 52 km). The largest aftershock was relocated at 30.84°S, 71.26°W and depth of 52 km. Though these earthquakes have similar epicenters, the focal mechanisms indicate that the mainshock was an intraplate event within the subducted slab with an almost vertical fault plane related to downdip tension, while the largest aftershock corresponds to an interplate event with reverse faulting related to compression along the plate interface (Figure 1-C).

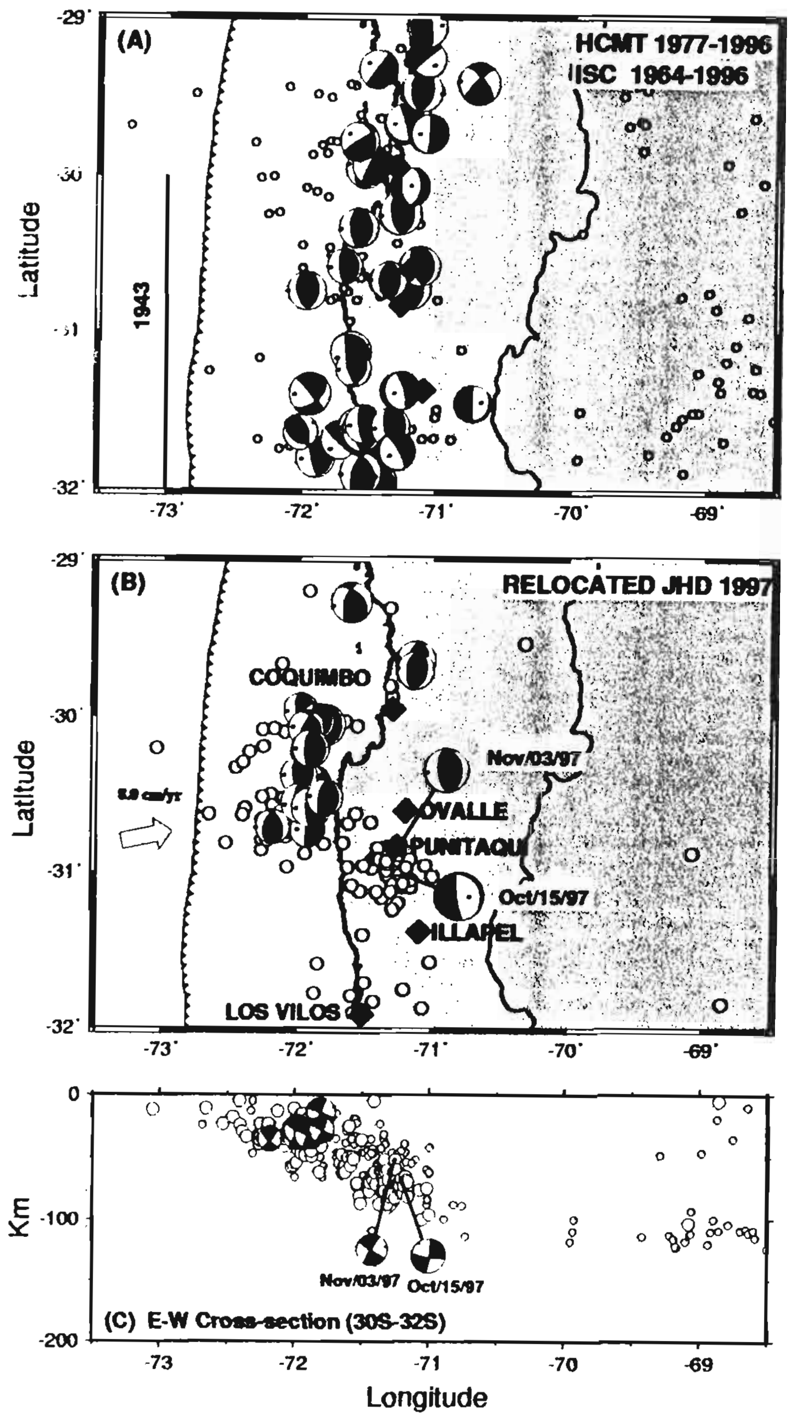

Figure 1.

(A) Epicenters for the indicated time periods before 1997, reported by the ISC with magnitude mb>5, with focal mechanisms from the HCMT catalogue on lower hemispheric projection with size proportional to the magnitude and showing P and T axis (black and white dots), Also are shown the 1943 earthquake rupture length, the trench and the Chile-Argentina border line.

(B) Relocated epicenters using the JHD method of all the events, mb>5.0, reported by NEIC during 1997. Focal mechanisms are from the HCMT catalogue, as in Fig 1-A. The Punitaqui mainshock and its largest aftershock are indicated. Solid diamonds indicate some cities in the zone. The arrow shows Nazca-South America convergence direction.

(C) East-West cross-section of the seismicity presented on Fig. 1-A and B, between 30°S and 32°S, using the same symbols. Focal mechanisms are on lateral back hemispheric projection.

Though the magnitude of the intraplate Punitaqui earthquake was moderated (Ms=6.8), the structures in the zone were highly damaged as the result of the strong ground motion and also site-amplification effects. In contrast, the offshore thrust events (mb≤5.8) that occurred about two months before, produced almost no damages and were felted with low intensities at populated cities located at similar hypocentral distances than the structures that collapsed with respect to the Punitaqui earthquake. This suggests that the potential of damage or strong ground motion, of intraplate earthquakes is higher than the one of thrust events. Other destructive intraplate earthquakes have been observed along the Chilean subduction zone, as the downdips 1939 Chillan earthquake (Ms=7.8) and the 1965 Aconcagua earthquake (Ms=7.5), which occurred at similar depths than the Punitaqui earthquake, and the 1950 Calama earthquake (Ms=8.0) at a depth of 120 km.

CONCLUSIONS

The Central Chile subduction zone, corresponding to the rupture zone of the last large thrust earthquake occurred in this region in 1943 (Ms=7.9), was partially activated during 1997. The shallowest part of the Nazca-South America interplate contact was activated on July and August, by an offshore swarm type seismicity with thrust events in the magnitude range 4.9≤mb≤5.8. On October 15, an intraplate tensional event (Ms=6.8) occurred downdip, below the village of Punitaqui, generating many compressional aftershocks that activated the deepest part of the interplate contact. Not important earthquakes occurred at the central part of the interplate contact indicating that the interacting plates are strongly coupled in this region.

The Punitaqui earthquake generates unexpected damages for an event of this magnitude. The large damages produced by this moderate size intraplate tensional earthquake, along with the observation of other destructive intraplate tensional events in Chile, suggests that these type of earthquakes have a higher potential of producing strong ground motion than the thrust type events.

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