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Waveform inversion and focal mechanisms of two weak earthquakes in Cordillera Principal (Argentina) between 35° and 35.5° S

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ABSTRACT

Only few (six) focal mechanism, in CMT Catalog, have been so far known for intraplate shallow events in the Andean chain close to Chile–Argentina state border at latitudes ~35° S. We add two more mechanisms, depths and moment magnitudes by carefully analyzing full waveforms of weak events recorded by broad-band stations of the Chile Argentina Geophysical Experiment (southern profile). The moment magnitudes of both events (Mw = 3.6 and 3.7) are lower than the duration magnitudes (Md = 4.0 and 4.29) reported by NEIC. The source depth, constrained by waveforms for one of the studied events (5.5 −8.5 km) seems to be considerably shallower than the hypocenter depth located by means of arrival times (~20 km). The waveform analysis was complemented by first-motion polarities which resulted in an uncertainty assessment of the focal mechanism. Event 1 (2001-11-03) has a strike-slip mechanism with a small normal component and almost vertical nodal planes in the north-south and east-west directions. The north-south nodal plane could be related to the Calabozos faults system. Event 2 (2002-02-16) has a strike-slip mechanism with a small thrust component. The latter event (its sub-horizontal nodal plane) could be associated with the El Diablo-El Fierro fault system. Dextral strike-slip solutions are consistent with recent studies in the area.

1. Introduction

The subduction of the Nazca plate beneath the South American plate generates the mountain building in the Andes. In these active margins large interplate underthrusting earthquakes occur and are the main goals of several research works (Christensen and Ruff, 1988; Beck et al., 1998; Moreno et al., 2009; Lange et al., 2012; Ruiz et al., 2013; Lay, 2015; among others). Intraplate shallow earthquakes from the overriding plate exhibit lower magnitudes and their occurrence is less frequent (Fig. 1). Those earthquakes are located in the forearc (Andean chain) and in the backarc. A noticeable aspect is the important seismicity increase between ~33° and 36° S documented by NEIC-USGS International Catalog. The only solution in CMT catalog at the latitudes analyzed in this paper is Mw = 6.5, 2004-08-28. This solution is a strike-slip focal mechanism, which could be associated to the subduction obliquity of Nazca plate (Comte et al., 2008).

Focal mechanism solutions from waveform inversion techniques are generally available for earthquakes with magnitude greater than 5.0. However, in this region majority of the seismic events has magnitudes less than 5.0 (Fig. 2). Therefore, the goal of this research is the application of moment tensor determination to waveform data available for events with magnitude less than 5.0 (http://www.iris.edu/SeismiQuery/). Every focal mechanism of these relatively weak events is important, even if they are not numerous. This study was made possible thanks to temporary network of the CHile ARgentina Geophysical Experiment

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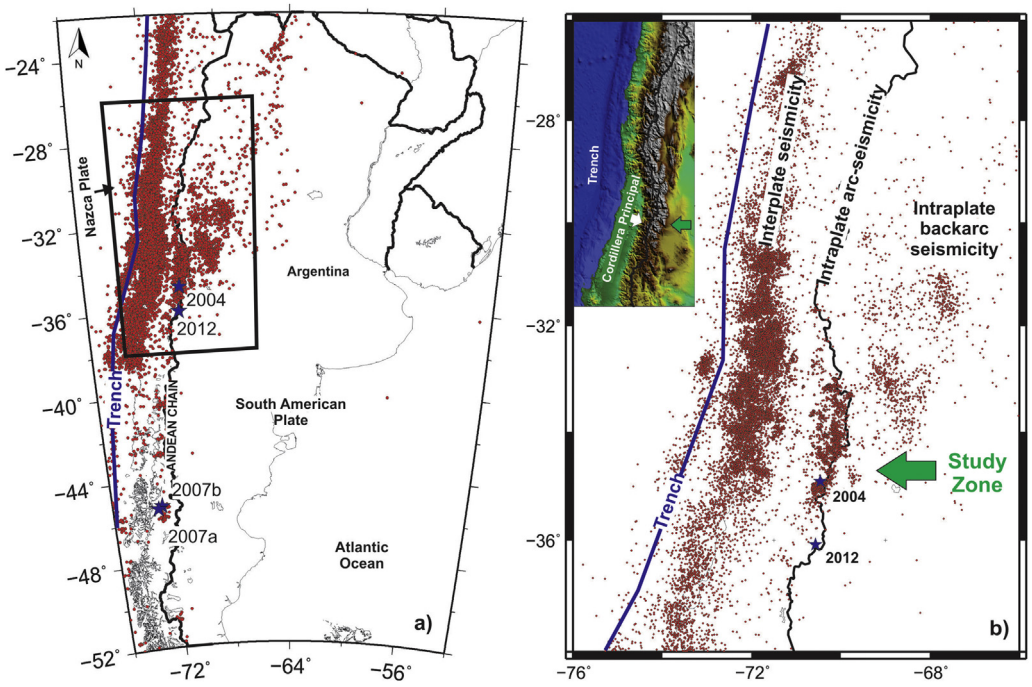

Fig. 1. Epicenters (red circles) from NEIC-Catalog (US Geological Survey) located between depths 0 and 50 km since January 1973 to January 2015. State borders are shown by thick black line and the Trench Zone by thick blue line; a) Blue stars denote the crustal seismicity located at the Andean chain with magnitude greater than 6.0. From north to south: M = 6.5, August 28th 2004; M = 6.0, June 6th 2012; M = 6.2, April 21st 2007 and M = 6.1, April 1st 2007 (NEIC-Catalog). There is a noticeable seismicity increase below Andean chain between ~33° and 36° S. The black box shows the region plotted in b); b) The western and eastern seismicity patterns represent the interplate events related with the contact of Nazca and South American plate and intraplate events (arc and backarc seismicity) related with the overriding South America plate, respectively. Inset: Topography and bathymetry from http://maps.ngdc.noaa.gov; the white and green arrows indicated the "Cordillera Principal" and the study zone, respectively. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

(CHARGE), November 2000 to May 2002. We used two methods for crustal events on the high Andes to find their centroid moment tensor solution: ISOLA software (Sokos and Zahradník, 2008, 2013) and a new approach called Cyclic Scanning of the Polarity Solution "CSPS" (Fojtíková and Zahradník, 2014). We combine the two techniques with intention to better resolve the mechanisms of the events recorded only by few stations.

2. Seismotectonic setting

The zone of interest corresponds to the southern Central Andes comprising the high chain of Chile and Argentina from 35°S to 35.5°S. At these latitudes, geological units and continental border strike NNE-SSW encompassing part of the southern volcanic zone. The Nazca plate is subducting underneath the South American plate with a normal angle of 27° (Pardo et al. 2002; Anderson et al. 2007) at a rate of 6.7 ± 0.2 cm/yr, as constrained by GPS measurements along the Chile–Peru oceanic trench (Kendrick et al., 2003). As is observed in Fig. 1b, at the given latitudes the Cordillera Principal takes an important role, focusing the major seismic activity in the upper plate. Also, the higher percentage of crustal seismicity is located on the western flank of the Andean mountain chain as documented by the international catalog (NEIC-USGS or EHB-ISS), regional data (Marot, 2013) and local data (Alvarado, 1998; Barrientos et al., 2004; Nacif, 2012; Marot, 2013). This seismicity is constrained to the first 20 km of the crust (Barrientos et al., 2004). Fig. 2a and b, shows the crustal seismicity (0–50 km) for the study region and surrounding areas from NEIC Catalog (1973–2015) and the focal mechanism solutions from Harvard CMT (1976–2015) and Alvarado et al. (2009). The Mw = 6.5 earthquake of August 28th 2004, located at a depth of 16 km (depth constrained from Harvard CMT) and its aftershocks sequence were recorded by a local network in Chile. The aftershocks, located at depths less than 15 km, are distributed along a trend of the NNE–SSW direction (Comte et al., 2008), consistently with one of the nodal plane from Harvard CMT oriented NNE–SSW dextral strike-slip. In the NNE direction at ~70 km from the 2004 earthquake a similar solution was found (Harvard CMT) for Mw = 5.9, September 13th 1987 earthquake. The actual state of the Cordillera Principal, proposed by Farías (2007), principally presents a dextral kinematic with a forearc moving toward to the north. Also, thrust solutions are resolved by Harvard CMT. Additionally, Alvarado et al. (2009), using body-wave modeling estimated fault orientation, depth and size of Mw = 6.3, September 4th 1958, "Las Melosas" earthquake. They found a focal mechanism solution with nodal planes on an east-west and north-south direction with right-lateral and left-lateral displacement, respectively. Their interpretation focused on the activation of east-west structures, which could be accommodating differences in the higher and lower shortening to the north and south of ~33°S respectively.

From microtectonic analysis of Quaternary faults Lavenu and Cembrano (1999), deduced the principal directions of the maximum horizontal compressional stress "σHmax". They obtained a NNE–SSW direction for σHmax at ~34°S.

3. Data

Data are from CHile ARgentina Geophysical Experiment (CHARGE) recorded from November 2000 to May 2002. Stations were disposed in two E–W transects at 30°S and at 36°S, with other stations deployed between those transects (22 broadband stations in total). In this work only data from the southern transect were used (Fig. 3). Seismic events (magnitude ≥ 4) located at high Andes by U.S. Geological Survey (NEIC-Catalog) were selected. The