STUDY OF JUJUY EARTHQUAKE OF OCTOBER 06, 2011 AND ITS AFTERSHOCK DISTRIBUTION

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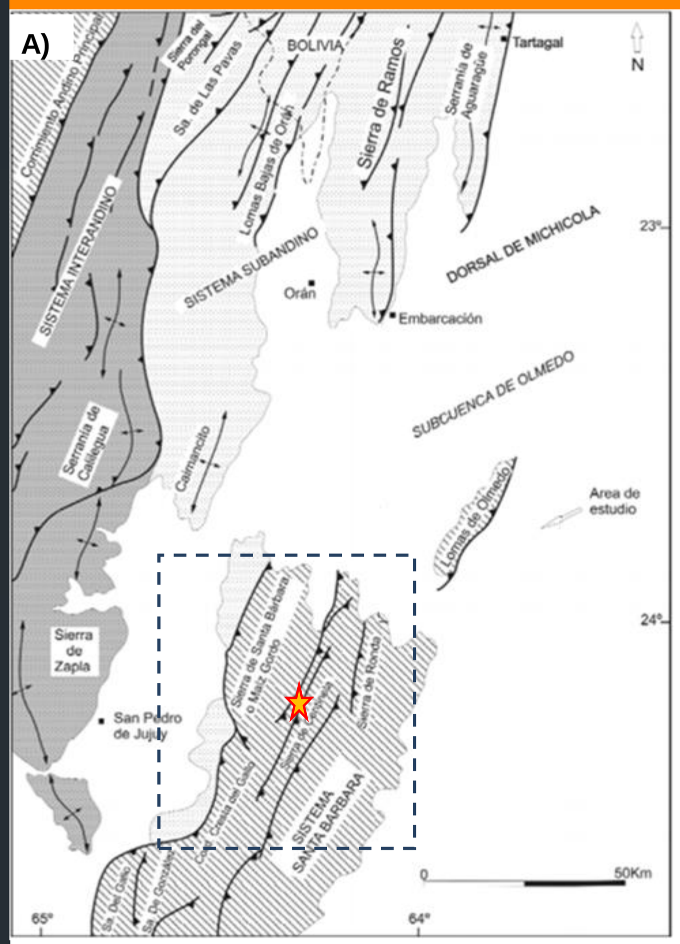
ABTRACT

The seismic deformation in the Andean retro-arc zone is characterized by having superficial and intermediate seismicity. Examples of these are the earthquakes of September 13th, 1962 in Talavera del Esteco, Salta with an associated magnitude of 7.0 and a maximum intensity of IX in the Modified Mercalli Scale, and the earthquakes of September 23rd, 1887 in the border between Argentina and Bolivia in the province of Salta with a maximum intensity of IX in the Modified Mercalli Scale (INPRES, 2017) and the earthquake of January 16th, 1944 in San Juan with a magnitude of 7.0 (Alvarado and Beck,2006).

The aim of this job is to obtain a seismotectonic analysis of the Jujuy earthquake on October 6th, 2011 at 11:12 a.m. local time (14:12 UTC), with epicentre at about 100 km east of San Salvador de Jujuy city. This research includes an accurate determination of its location parameters, focal mechanism and the aftershock sequence to have a better understanding of the seismogenic source of this seismic event. The relocation of the hypocentres was determined with HYPODD software (Walhauser, 2002) and the velocity model used in this process is the model used at INPRES (Sánchez et al., 2013). The results obtained show improvements in the definition on the rupture zone due to the aftershock propagation and detection of active secondary seismic sources associated to the main fault.

The results are compared with previous studies to understand the superficial seismic deformation in the transition zone between thin-skinned deformation observed in the Bolivian Andes and the Basement deformation observed in Sierras Pampeanas (Jordan et al., 1983).

DATA AND METHODOLOGY



The Jujuy earthquake occurred on October 6th, 2011 at 11:12 a.m. local time (14:12 UTC) with epicenter at about 100 km east of San Salvador de Jujuy city, located in the Santa Barbara System.

This retro-arc Andean segment has been describe as a transition between thin-skinned deformation observed in the Bolivian Andes and the Basement deformation involved in Sierras Pampeanas (Jordan et al., 1983).

It's believed that Santa Bárbara System was formed by tectonic inversion of normal faults related to the Cretaceous rift with vergence toward the west (Ramos et al. 2006)

The earthquake generate around 425 aftershocks, these were detected with an automatic detection integrated in SEISAN 9.1 (Havskov and Ottermöller, 2011). This method is based on differences in S and P waves arrival times at the stations closest to the epicenter (located around 20 km and 140 km).

The aftershock had an east southeast - west northwest (ESE - ONO) orientation and their distribution was transversal to the Santa Barbara System. All the replicas extended over 29 km to northwest From the main event.

The range of calculated local magnitudes M_L is 0.6 – 4.3 and the range of depth is 3 – 20 km.

Seven minutes after the main earthquake, the largest aftershock with a local magnitude M_L 4.3 occurred.

The main event and its aftershock were located with a velocity model that best fit in relation to P and S wave's arrival time. The model was chosen by comparing two existing velocity models: a regional model used at INPRES (Sánchez, 2013) and a local model, designed for the northern area of Argentina (Cahill, 1992). Only 381 aftershock could be located of the all events detected with Sánchez's model.

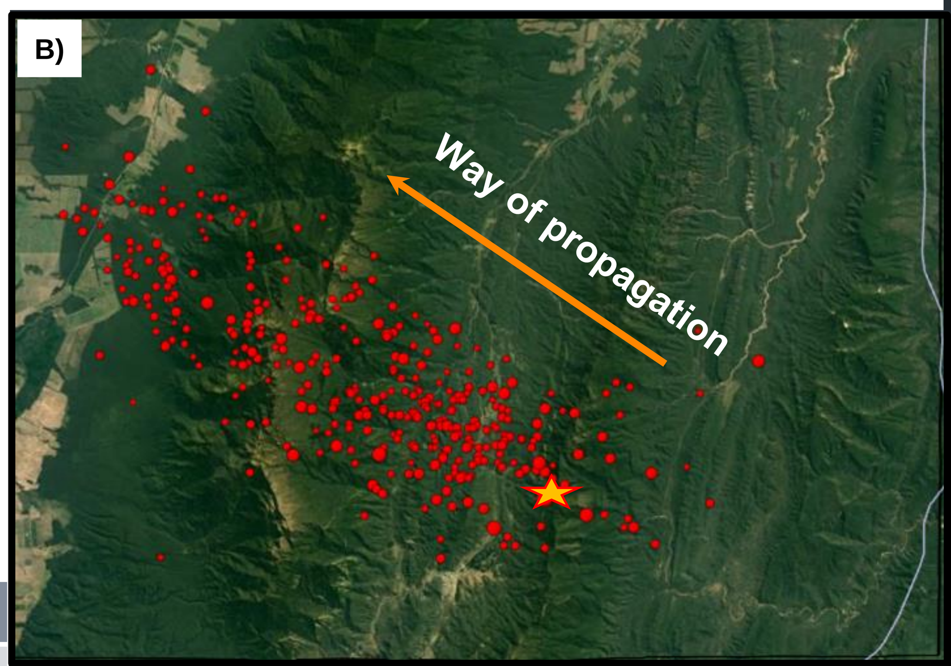


*FIG 1– **A)** Study region **B)** Main earthquake and aftershock distribution location.*

TABLE A

Vp	Vs	Depth
5.0	2.87	0
6.2	3.56	10
7.8	4.48	40
7.9	4.54	60
8.2	4.71	80
8.3	4.77	100
8.35	4.79	120
8.4	4.82	140
8.5	4.88	160
8.55	4.91	180
8.65	4.97	200
8.75	5.02	225
8.85	5.08	250

TABLE B

Vp	Vs	Depth
4.0	2.3	0
5.3	3.1	3
6.2	3.6	10
6.5	3.8	20
6.8	4.0	35
8.0	4.7	42

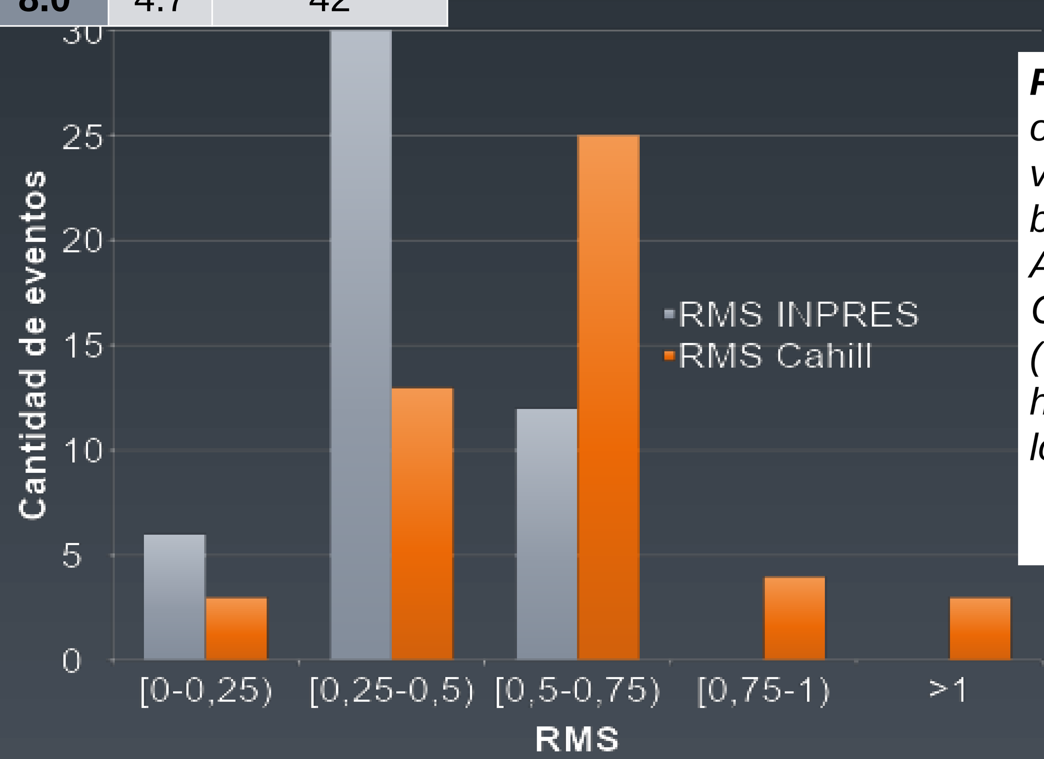


***FIG 2 -** The error obtained with the velocity model used by INPRES (Table A) is less than with Cahill's model (Table B). This happened for all locations errors.*

After locating all aftershock, they were re-located with the ***HYPODD*** program. First, the ***PH2DT*** program was used to obtain the travel time differences for pairs of earthquake at common stations. The input parameters were, MINWGHT:0 - MAXDIST:1000 - MAXSEP:12 - MAXNGH:8 - MINLNK:8 - MINOBS:8 - MAXOBS:52

These parameters were chosen as mentioned above to reduce the possible amount of links. Finally, the output file is used in the HYPODD as input file. The results obtained are shown in the figures below

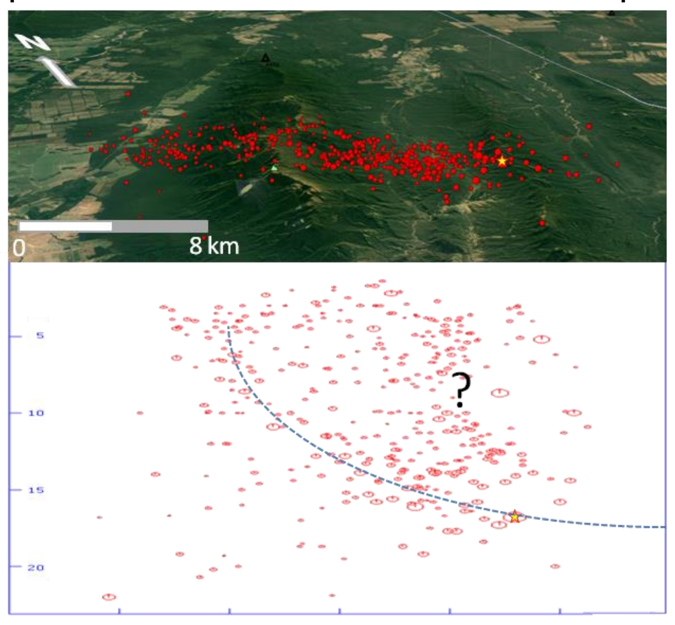


***FIG 3 -** October 6th, 2011 earthquake location (yellow star) and 381 aftershocks located during a 4 months period, and in a profile located along the aftershocks distribution direction. The intermittent blue line indicates a group of seismic events that could indicate contact between the fault active by the event of M_L=5.8 and a listric fault present in the Santa Barbara System. There is a second group of seismic events indicated with "?", from which, a clear interpretation could not be made.*

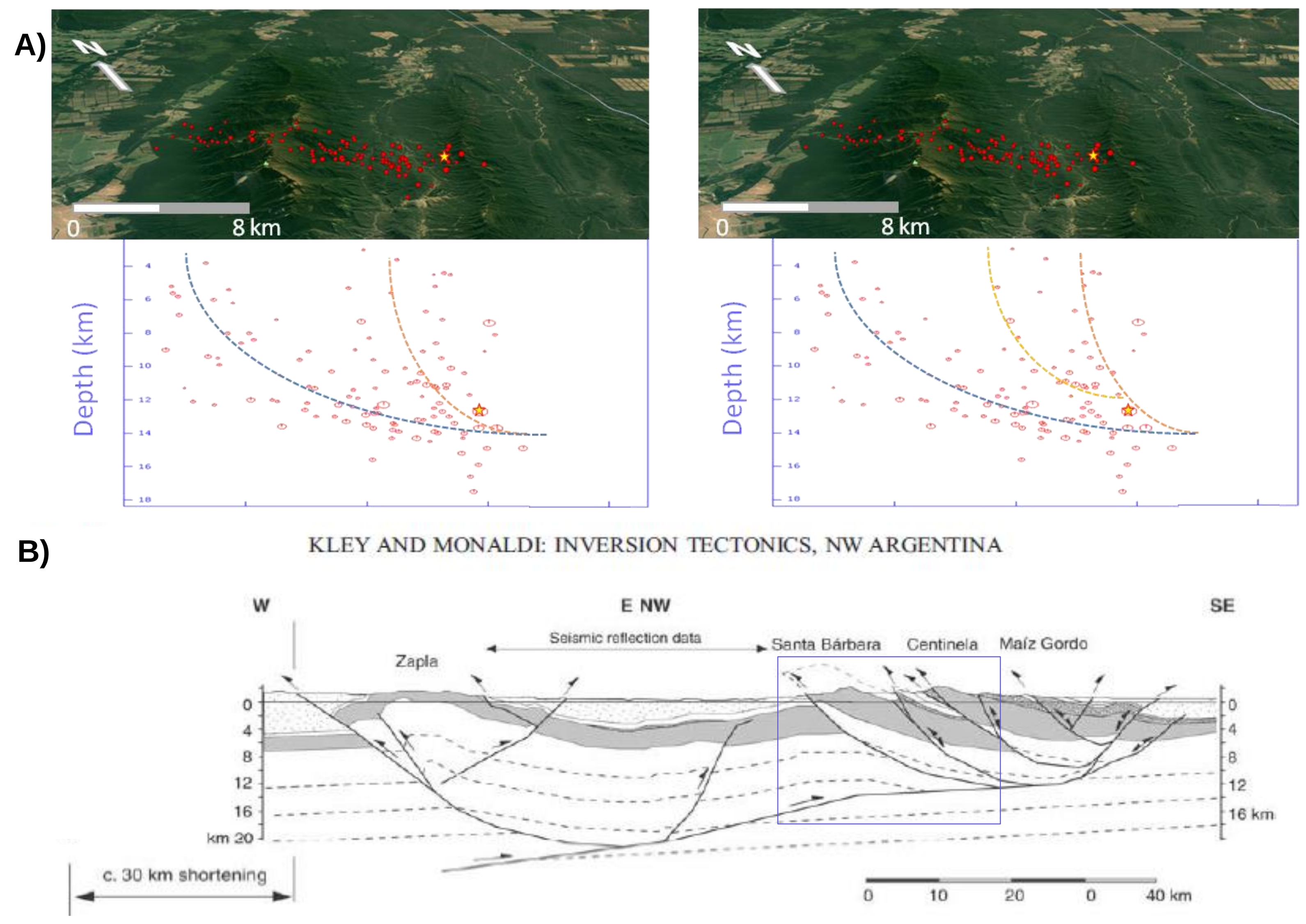


***FIG 4 – A)** Group of the better relocated 111 seismic events, which includes the main earthquake and 110 aftershocks. The figures indicate two possible interpretations of the aftershocks concentration occurred along the propagation plane of the October 6th, 2011 earthquake associated fault. The left figure shows the aftershocks distribution associated to 2 faults structures, while the right figure shows that said distribution could be related to 3 existing faults. **B)** Cross section of the Santa Barbara System north, modified from Kley et al., 2002.*

Subsequently, the focal mechanisms were calculated with FOCMEC (Snoke, 2003), a program on the SEISAN platform (Havskov et al., 2011). These mechanisms were obtained based on a first the analysis of the arrival of P wave motion (compression or dilatation) then, they were classified, in a second analysis all the records as emerging and impulsive. Besides, we used amplitude relationships between P and S waves (Pg, Sg and Pn, Sn), these relationships reduced the number of possible solutions to the earthquake of October, 6 and its aftershock.

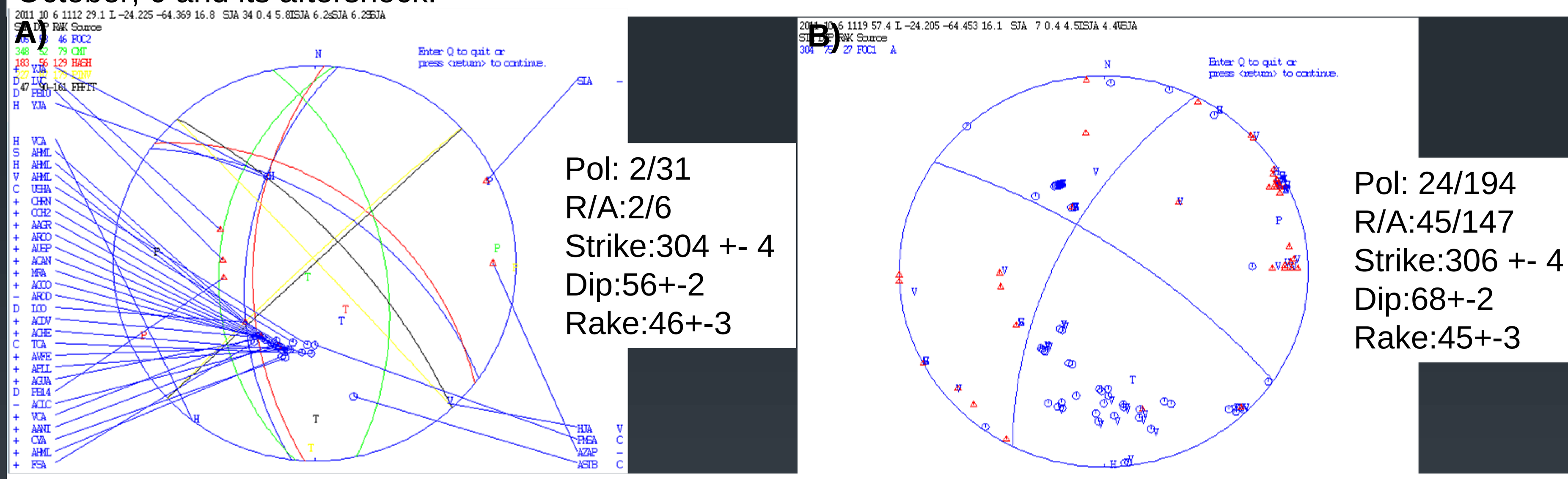


***FIG 5 – A)** The main event focal mechanism is inverse**,** with a strong left side component the strike. The main plane is defined by an azimuth of 304° in direction WNW - ESE, a dip of 56º to the NW and a rake of 46° (in blue) and the other solutions were obtained with the programs (remaining colors), HASH, FPFIT and PINV. **B)** The compounded focal mechanism behavior is very similar to the earthquake behavior and it was obtained with twenty six aftershocks.*

CONCLUTIONS

- The aftershock distribution shows a ESE-WNW active fault plane that matches with the focal mechanism solution with ~120° azimuth and dip towards NNE. It is transverse to the system main axe which is NNE - SSW. The propagation of the replicas towards the surface is concentrated in the WNW - ESE alignments observed in the longitudinal profiles.
- After the relocation with HYPODD, the aftershocks were more constricted in both, depth and offset.
- The analysis of the relocated aftershock distribution allows to identify a fault structure system similar to that studied by Kley and Monaldi in 2002 for the Santa Bárbara System.
- Comparing both focal mechanisms we can see that, the fault behavior along time was mostly on strike direction with respect to the active fault.
- The similarity of the strain axes for Mw 6.0 Salta earthquake ocurred in 2010 and those obtained for this study case, could be explained considering the earthquakes in the north of Argentina are generated by the accumulation of regional strain.

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