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Observatorio San Calixto

NEW FOCAL MECHANISM SOLUTIONS FOR SHALLOW EARTHQUAKES AND STRESS OBSERVATIONS FOR BOLIVIA (PLURINATIONAL STATE OF).

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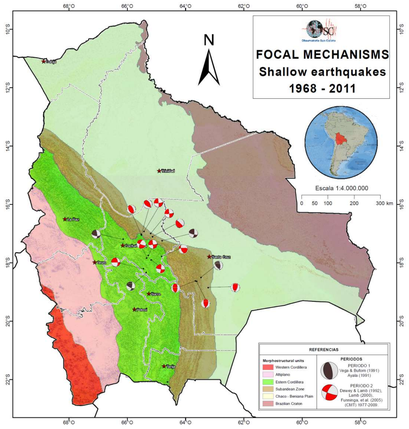
ABSTRACT

On this research we present 22 new focal mechanism solutions for shallow earthquakes (<70km depth) located at Bolivia region, most of them were felt by people and caused some damage to structures. Until 2016 the way of data processing with a small network did not allow us to get focal mechanism solutions for magnitudes below 4.5 Ml. After 2016 with the seismic network enhanced and the data merging from LPAZ - PS06, SIV-AS08 and Penas-IS08 under the NDC-in-a-BOX Seiscomp 3 - Seisan software allow us to have accuracy data to implement the focal mechanism procedure. We applied the Double Couple method which takes the elastic wave radiation from an earthquake and they can be modeled in two equivalent ways, it means that there is a point force which applies exactly to a point in an elastic medium that is represented as pairs of point forces, so the result can be used to show a shear faulting. Our solutions were tested numerically and verified in situ, all of them are coherent with the geology and stress system maps for the region, all solutions were presented to Civil Defense Minister to contribute to National Hazard Map.

BACKGROUND



The studies carried out, about the calculation of the focal mechanisms for Bolivia come from publications by Vega & Buforn (1991), Ayala (1991), Dewey & Lamb (1992), Lamb (2000), Funninga, et al. (2005), Devlin, et al (2012) and Harvard Tensor Moment Catalog (CMT) 1977-2009. Compiling this data, a database was obtained with 18 cortical tensor moment solutions available for the period 1968-2009, the majority concentrated in the central part of Bolivia.

Vega and Burfon, (1991) present ten solutions of focal mechanisms for surface seismic events registered in the national territory greater than 4.5 mb through the application of telesismic data, in Ayala (1999) proposes seven solutions of focal mechanisms (in addition to the revision of the solutions of Vega and Burfon, apply again the use of telescopic data and local stations, in both works the methodology proposed by Aki & Ridchards 1980, also known as the "Double - Cupla" is applied, however the minimum working threshold It was the magnitude of 4.5mb.

TECTONIC AND SEISMIC FRAMEWORK

The tectonic activity in Bolivia is associated with the subduction process of the Nazca Plate that is subducted below the South America Plate in the Peru-Chile Trench, with an ENE-WSE convergence direction, at a constant speed of 78 mm.a- 1 (DeMets et al., 1994). The effort generated due to the relative movement of the plates causes the shortening and formation of the Andes Mountains (15 Ma). Much of the Bolivian territory is in the area with the highest cortical deformation, known as "Bolivian Oroclino", which consequently generates a variation of complex tectonic styles, which involve important structural elements, which manifest themselves from the cratonic (eastern) domain to the western tectonic domain.

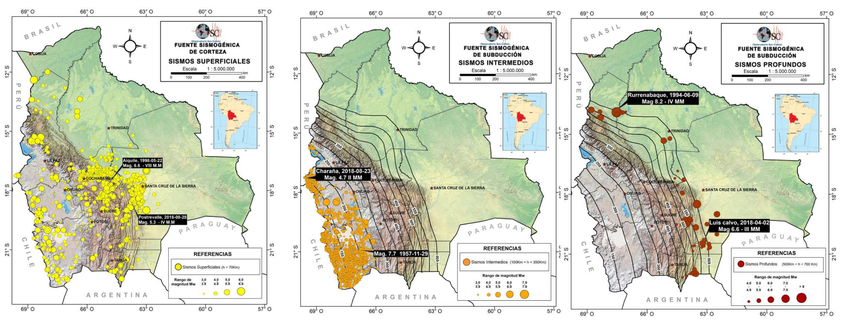
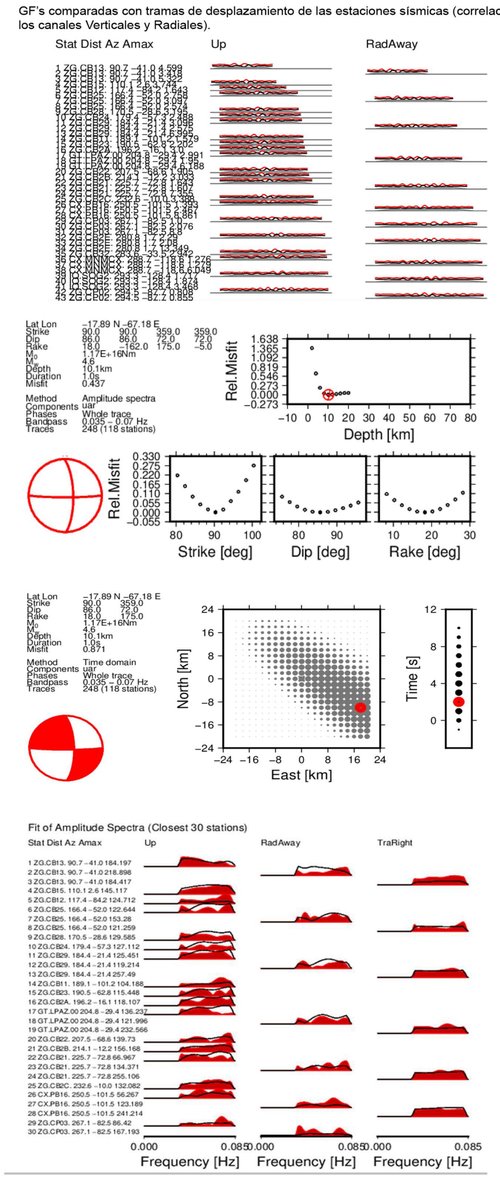


Figure: seismic sourse of Bolivia

METHODOLOGY

Along the research we used the "First Motion Polarity" and the "Double Couple" method to obtain the focal mechanism solutions. Depending on the earthquake and the period of time (due to the azimuthal coverage and the seismic stations installed), we had clear compression or dilatations polarities, those were mapped on a focal sphere and then plotted. Initially SEISAN (Havskov and Ottemoller, 1999) and FOCMEC (Snoke, 2003) were applied to obtain results, however a quality control method called FPS (Fault Plane Solution) developed by Marcelo Assumpcao from University of Sao Paulo was used in order to certify and validate each solution. Basically FPS review the polarities, the incident angle and azimuth to model the planes.

Due to the ambiguity of some solutions we decided to start implementing the Full Moment Tensor Inversion from Dreger et al. (2000) and from Cesca & Heimann (2013), this methodology let us certify the solution of at least one plane based on the best fit of the strike, dip and rake, moreover the depth and moment magnitude were calculated. The use of Green Funtions Database for a certain region helped us to improve our solutions.



Synthetics and displacement data fit based on Full Waveform Inversion, KIWI algorithm (Cesca et al., 2013) was applied.

Best misfit (best proposed solution) for the strike, dip and rake (both planes), the "NA" algorithm was applied at this stage.

Time and Displacement measures due to the velocity model applied, for the Full Waveform Inversion we are using the Chile_Crustal_70km Green's Function.

Spectral Amplitude fit for each station, red spectrum represent the full waveform inversion and black line is waveform signal amplitude.

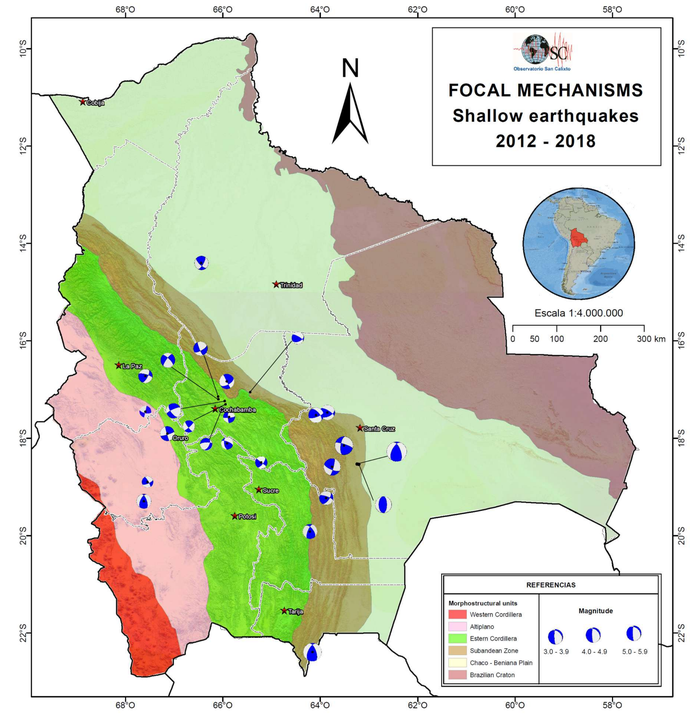
It is such as quality control for each seismic station.

RESULTS AND DISCUSSION

The new focal mechanism solutions let us to improve the knowledge of shallow seismicity for our country. Most of them are strike – slipe coherent with the geological context, specially on the Bolivian Boomerang region. Moreover we found also shallow seismicity at Altiplano, it is related to some geological faults potentially active, however there were not huge swarms (only four or five aftershocks). Most of the solutions were calculated between 2014 to 2019, an improvement of our seismic network has let us do it. The modified velocity model proposed also improve the locations, however we were not yet able to build our own Green's Function database.

We just start to compute the Moment Tensor Inversion based on KIWI algorithm proposed by Cesca et al. (2013), for this task we are using a regional velocity model combined with its iown Green's Function database. Quality control was performed with Assumpcao algorithm (FPS).

There is the need to improve our solutions with base in our velocity model and our own Green's Functions.



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