STRATEGy
Seismic neTwoRk/Array in norThwEstern arGentina: Study of the 2015 El Galpón earthquake and its aftershock sequence

M. Zeckra[1], F. Krüger[1], A. Landgraf[1], G. Aranda[2], F. Hongn[2], F. Morales[3] y P. Alvarado[3]

[1] *University of Potsdam, Germany. zeckra@uni-potsdam.de*
[2] *Universidad Nacional de Salta (CONICET – IBIGEO).*
[3] *Dpto. Geofísica y Astronomía, FCEFN Universidad Nacional de San Juan - CONICET (GIGEOBIO).*

Introduction

After a damaging, medium-sized earthquake (Mw 5.8; October 17, 2015) in El Galpón area in the Salta Province, we installed a local seismological network around the estimated epicenter covering also remarkable tectonic and geological orographic structures.

The 2015 earthquake took place in the Andean foreland at about 17km depth. The so called Santa Bárbara System is the easternmost morphostructural region of the central Andes. As a part of the broken foreland it is bounded to the north by the Subandean Belt and the Sierras Pampeanas lying in the south; to the east joins the Chaco-Paraná basin.

There is a north to south segmentation which is reflected in different tectonic styles: The Subandean Belt is dominated by thin-skinned deformation mainly observed in its sedimentary cover with records of the strongest shortening along the Andes (Kley et al. 1999). Instead, shortening decreases suddenly in the Santa Bárbara System, where basement-cored ranges show a thick-skinned style related to inversion of Cretaceous rift normal faults. According to Iaffa et al. (2013) and Barcelona et al. (2014), thick sedimentary basins partly which exhibit thin-skinned deformation enclose ridges uplifted by high-angle dipping faults. The Metán basin (Fig. 3) recording both Cretaceous-Paleogene rifting and Cenozoic foreland sedimentation is an outstanding geological feature in the Santa Bárbara System. The Sierras Pampeanas to the south show the least amount of shortening with deep rooted basement thrusts just to the east of the thin-skinned Precordillera (Jordan and Allmendinger, 1986). From north to south the Santa Bárbara system shows a tectonic transition from pure thin-skinned *deformation to foreland basement thrusts. This also correlates with changes in the subduction zone geometry (Alvarado et al., 2009).*

Deep seated earthquake hypocenters are located along the subducted Nazca plate with two depth clusters at around 250 km and 600 km (Fig. 1). Besides the slab seismicity, the study area is also affected by shallow crustal earthquakes. Thus, releasing of stresses from the foreland deformation can result in strong earthquakes, i.e. the Esteco (M>7) 1692 earthquake (INPRES, 2017).

The Metán basin where the 2015 earthquake has occurred, has been well studied using seismic line analyses (Iaffa et al. 2011; 2013). Location and orientation of faults are known as well as depocenters and thickness of the sedimentary units in the basin. However, much less is known from seismicity and active faults. Hence we installed a temporary seismic network around the 2015 epicenter and the major orographic structures such as Cerro Colorado and Sierra de la Candelaria.

Seismic deployment and processing of seismic data

The network extends 110 km from north to south and 60 km from east to west (see Fig. 3). Each station consists of a Lennartz LE-3D/5s seismometer and a DATA-CUBE^3 digitizer. Power supply is provided by a battery, which is recharged through a solar panel. This system is recording with 100 Hz on all three components and running fully autonomously. The data is stored on the digitizer. Maintenance is done every 5 months in order to download the data and release memory. It is planned to obtain seismic records continuously for up to 15 months.

Detection and location of all recorded earthquakes is the first step of data processing. Thus, a first step consisted of using an automatic detector (Heimann, pers. Comm) based on synthetic seismograms and doing a grid search through the whole dataset. Then, an automatic autoregression picker searches for P and S wave arrival times in combination with a network coincidence trigger to select events only with similar arrival time picks at four different stations minimum (Leonard and Kennett, 1999). All picks are manually controlled and repicked if necessary. In the end, the events are located using HYPOSAT a FORTRAN routine to calculate hypocenters of seismic events (Schweitzer, 1997, 2001).

Up to now, a global seismic velocity model is used to locate seismic events. The first months of seismological records contain earthquakes of different epicentral distances. Local earthquakes within the network are the most frequent observations (Fig. 2). Many of these events are supposed to be categorized as aftershocks of the 2015 El Galpón earthquake. For some events residents noticed macroseismic activity and reported it. A second category of earthquakes with an emergent onset in the arrival of their seismic records are events located at regional distances with several 100 km of epicentral distance. Less frequent events are local very deep earthquakes as well as teleseisms. The latter are difficult to identify due to the limited frequency bandwidth of the instruments.

Results

Preliminary results of earthquake epicenters are shown in figure 3. Within the first month of recording approximately 230 events have been registered and 160 earthquakes have been located. Although using the IASP91 global seismic velocity model (Kennet, 1991), the epicenter errors are small for earthquakes located inside the network. We also observed a small cluster of earthquakes in between the two mountain ranges Cerro Colorado and Sierra de la Candelaria.

In order to improve the seismic location and reduce its errors a local velocity model is needed. This will be derived from ambient noise cross correlation. This technique assumes when calculating the cross correlation of the waveform at two seismic stations that one of the sensor is a virtual source. The result of the cross correlation is the Green's function, which only contains information of the path in between both stations. After correlating all possible pair-station combinations (forward and backward) a local shallow underground model can be interpolated.

Another analysis of deeper structures can be done using receiver functions. We plan to use conversion of teleseismic P to s wave to derive information about the depth and the orientation of the Mohorovičić crust-mantle discontinuity. We will try to identify the Nazca slab conversion phases. It is worth to note that the subducted plate seems to be aseismic underneath the network (Fig. 1). Some of the deep neighbor earthquakes with focal depths deeper than 200km will be tested fo a local receiver function analysis. This can produce steep incidence angles of the seismic ray path at the STRATEGy seismic stations and help to identify the Moho and mid-crustal discontinuities. A similar technique has been applied in the eastern Sierras Pampeanas by Perarnau et al. (2012).

Earthquake locations can be improved using the double difference method (Waldhauser and Ellsworth, 2000). This relocation method relates the residuals between observed and theoretical travel-time differences of pairs of close hypocenters at two stations. This will help to create images of the local seismicity and improve the ability to relate it to the seismotectonics of the region of study.

In the end, all the derived information will be used for moment tensor inversion. These results are necessary to identify the mechanisms of deformation at different parts of the fault system beneath the Metán basin. Furthermore, we expect to gain more details about kinematic and orientation of faults which led to the uplift of the surrounding mountains ranges.

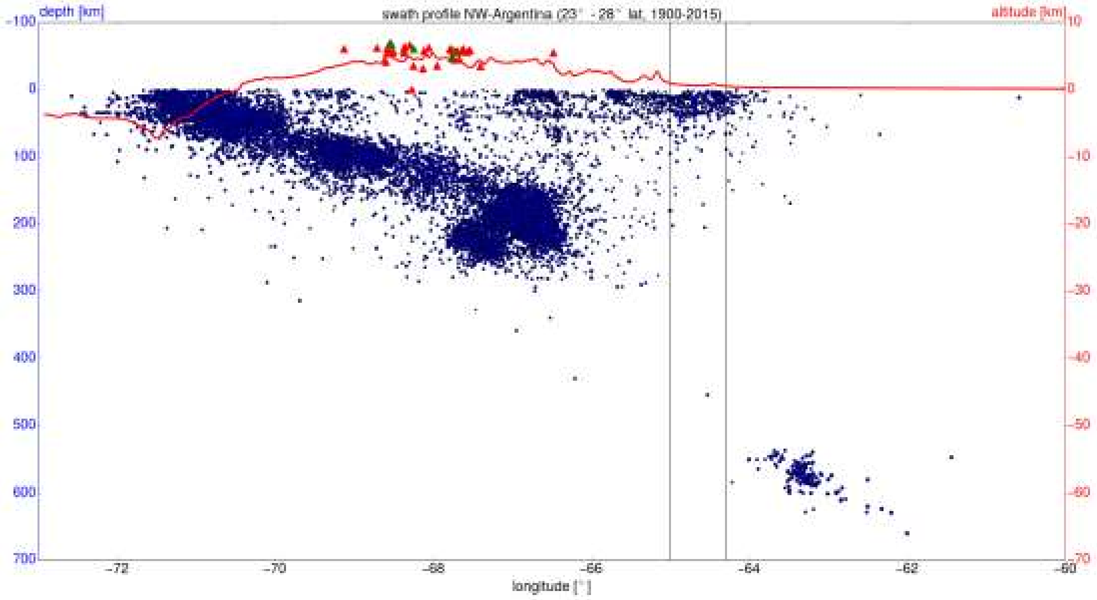

Figure 1: Hypocenters (blue dots) between 1900 – 2015 in the 23 – 28°S latitude region from the ISC Bulletin plotted as a function of depth and longitude; elevation profile (red line) and location of volcanoes (red – inactive, green – active, triangles) exaggerated by a factor of 10; black lines indicate the region of the temporary installed seismological network.

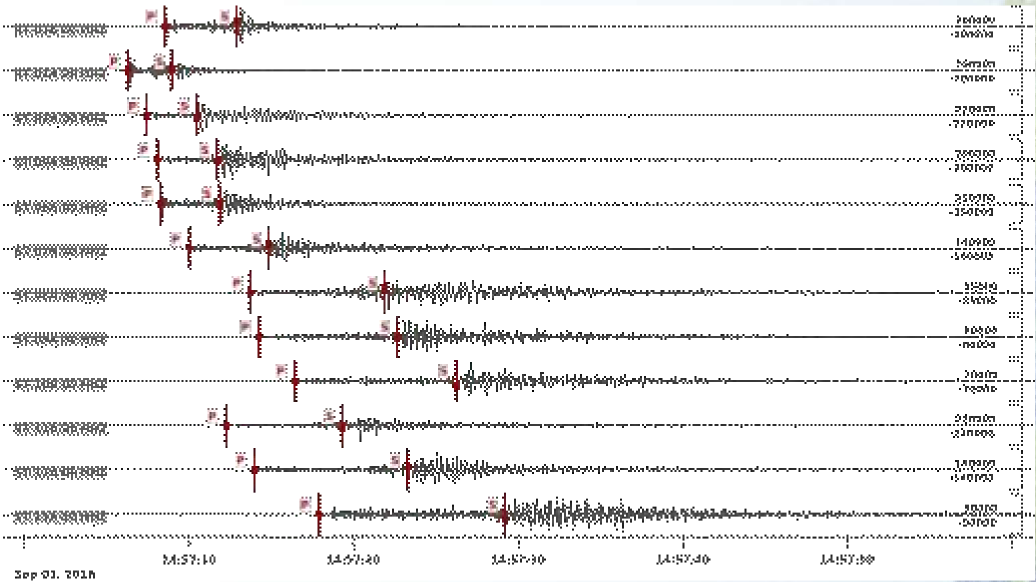

Figure 2: A local earthquake on September 1, 2016 with epicenter location within the seismic network; note it is very close to station 02A. P and S wave propagation throughout the network can be observed. Only vertical component displayed, bandpass filter 1 – 20 Hz.

Conclusions

Analyses of one month of data using the 13 temporary seismic Strategy stations shows around 60 crustal earthquakes, none slab events beneath the El Galpón area and approximately 120 outside the network.

We are on the way to obtain and refine a seismic velocity model that could improve characterization of seismic sources and estimate pattern of deformation in the area.

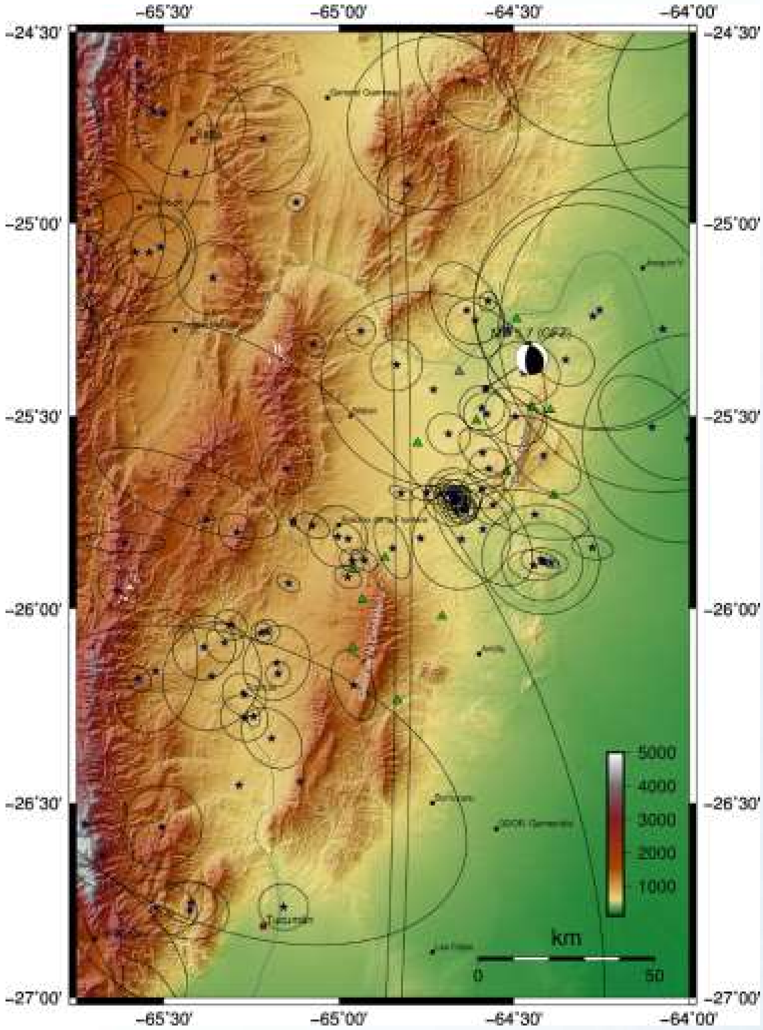

Figure 3: Preliminary epicentral locations (blue stars) considering the first month of recording of the STRATEGy seismic network (green triangles). Location error ellipses are black. Elevation background map is derived from SRTM data. Superimposed is the focal mechanism information for the 2015 El Galpón Mw 5.7 earthquake (GEOFON Data Centre). Some cities are indicated by squares and circles. Former position of station 01A (grey triangle) indicates location of the village El Galpón.

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