SM1.1
General Contributions on Earthquakes, Earth Structure, Seismology

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The May 7 - 11, 2016 Earthquake Sequence at Rivera Fault Zone

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Abstract

On May 7, an earthquake with MW = 5.6 took place in the contact area of the Rivera Plate, Cocos Plate and the Middle America Trench, subsequently occurred a seismic sequence with over 300 earthquakes until May 16.

To study of passive seismic activity in the region of the plate Rivera and Jalisco block, in addition to the Jalisco telemetric Seismic Network (RESAJ) Project TsuJal was carried out, from April to November 2016 a temporal seismic network (TSN) with 25 Obsidian stations with sensor Le-3D MkIII were deploying from the northern part of Nayarit state to the south of Colima state, including the Marias Islands, being a total of 50 seismic stations on land. Offshore, ten Ocean Bottom Seismographs (OBS) type LCHEAPO 2000 with 4 channels (3 seismic short period and 1 pressure sensors) were deployed and recover by the BO El Puma from UNAM in an array from the Marias Islands to off coast of the border of Colima and Michoacan state, in the period from 19th April to 7th November 2016.

We observed that location from USGS is north of the Rivera Fault Zone (RFZ) near the Middle America Trench, meanwhile location from OBS network is about 50 km southeast direction between the RFZ and the northern tip of the East Pacific Rise. The USGS reported a strike slip fault focal mechanism suggest, meanwhile the data from OBS network indicate a normal fault focal mechanism.

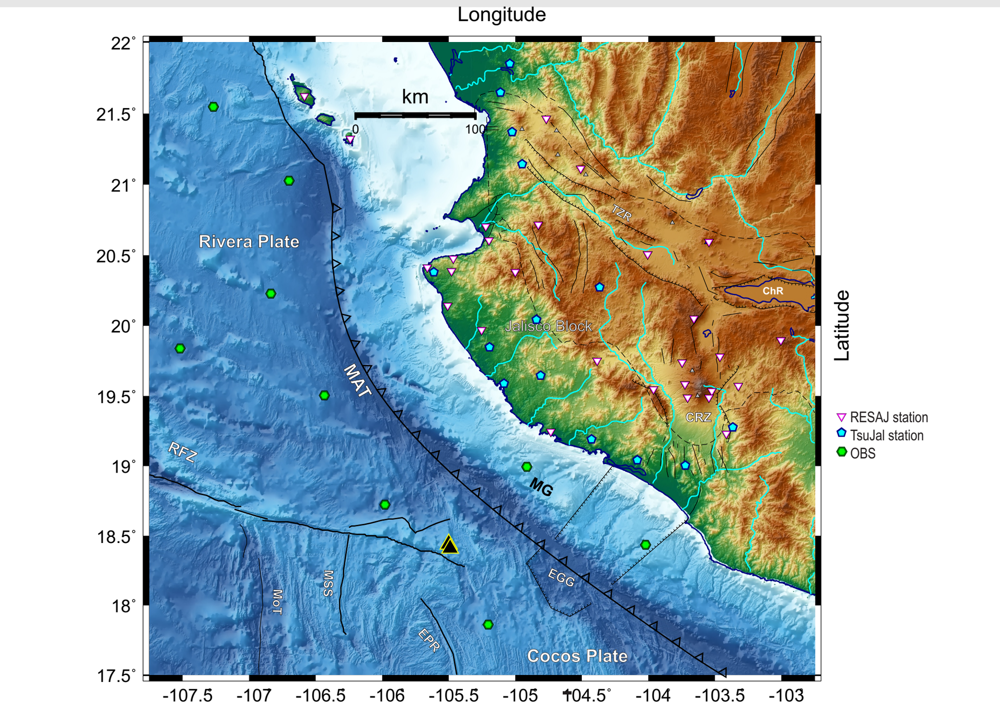

Figure 1. Tectonic frame of the region, TZR: Tepic-Zacoalco Rift zone; ChR: Chapal Rift zone; CRZ: Colima Rift zone; MG: Manzanillo Graben; MAT: Middle America Trench; EGG: El Gordo Graben; RFZ: Rivera Fault zone; MoT: Moctezuma Trough; MSS: Moctezuma Spreading Segment; EPR: East Pacific Rise. Seismic networks used in this study: *White*: RESAJ permanent stations; *Cyan*: TsuJal temporal network stations (TN) on land and *green*: OBS. Black triangles: epicenters of May 7, 2016 (E1 and E2) earthquakes as reported by CMT catalog.

The Jalisco, Colima and Nayarit coast in western margin of Mexico is one of the most seismically active areas in North America, which has experienced destructive earthquakes of great magnitude, that also has originated local tsunamis. Currently, an important seismic gap (Vallarta) is present in northern coast of Jalisco. Project TsuJal was designed to study the seismic and tsunamigenic potential associated to the interaction of the Rivera Plate, Jalisco Block and the North America plate. This Project was divided in two stages: a) Active geophysics offshore and onland; and b) Passive seismicity. Here we present the first results of the second stage of TsuJal Project.

The second stage of TsuJal project (Núñez-Cornú etal. 2016) was to study of passive seismic activity in the region of the plate Rivera and Jalisco block.

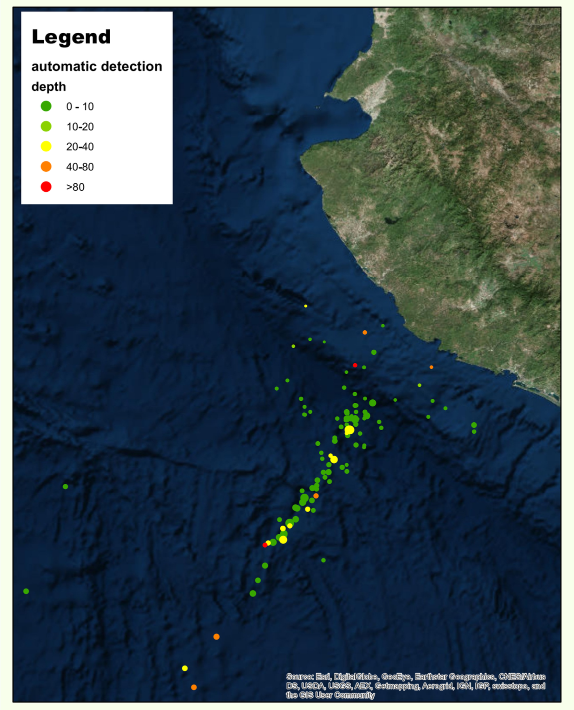

Figure 2. Preliminary automatic locations of seismicity for period May 7 -9 reported by Antelope system (Antelope uses IASP 91 velocity model).

In addition to the Jalisco Telemetric Seismic Network (RESAJ), from April to November 2016 a temporal seismic network (TN) with 25 Obsidian stations with sensor Le-3D MkIII were deploying from the northern part of Nayarit state to the south of Colima state, including the Marias Islands, being a total of 50 seismic stations on land.

Offshore, ten Ocean Bottom Seismographs (OBS) type LCHEAPO 2000 with 4 channels (3 seismic short period and 1 pressure sensors) were deployed and recover by the BO El Puma from UNAM in an array from the Marias Islands to offcoast of the border of Colima and Michoacan state, in the period from 19th April to 7th November 2016. (Figure 1).

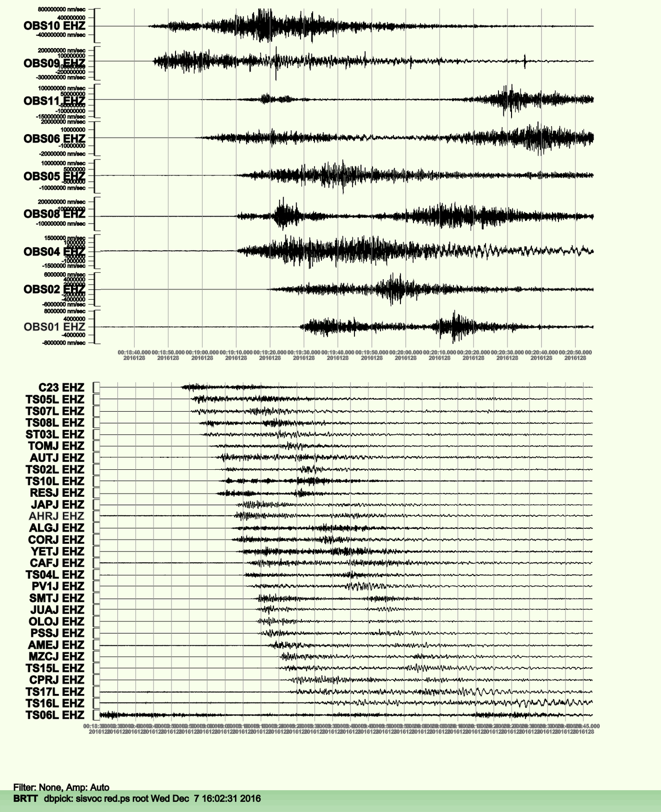

Figure 4. Seismic traces from OBS and TsuJal network (TSN) for May 7,00:18, 2016 earthquake.

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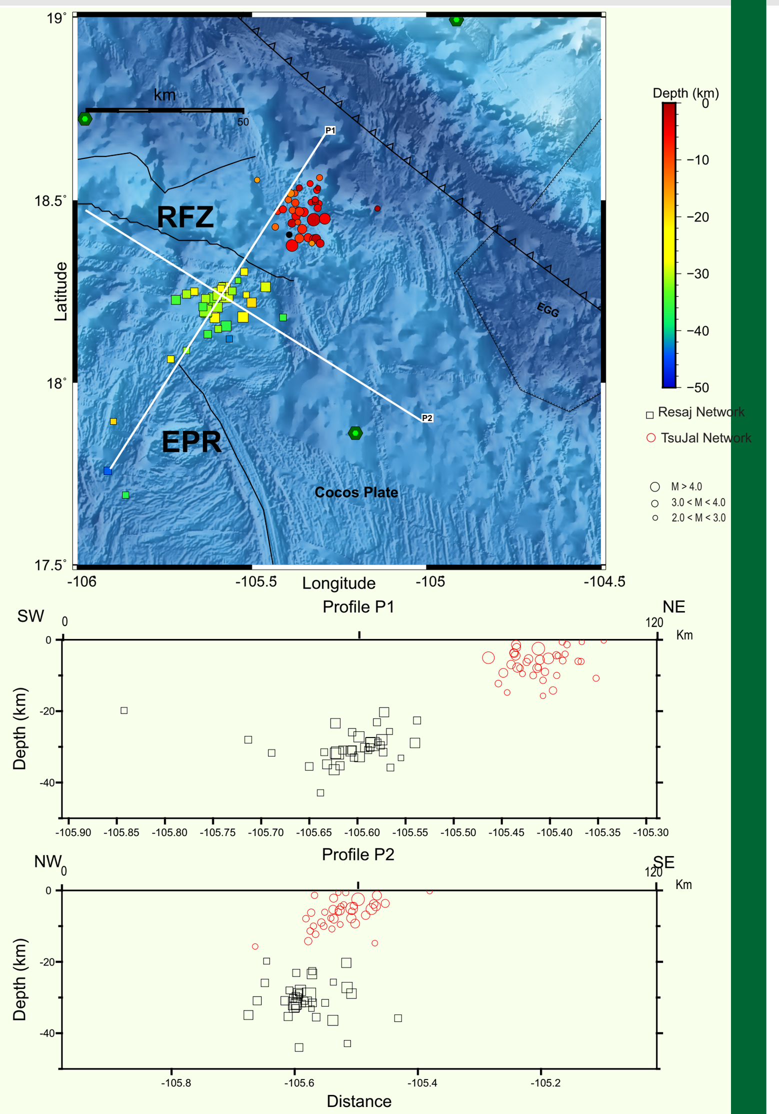

Figure 3. Relocation using P and S waves readings. Squares: RESAJ data using Antelope System and velocity model model IASP91; Circles: RESAJ and Tsujal Network data locations using Hypo-71 and P-wave velocity model VJB02 (Nuñez-Cornu et al. 2004)

On May 4, an earthquake with ML = 4.2 took place in the contact area of the Rivera Plate, Cocos Plate and the Middle America Trench, subsequently occurred a seismic swarm with over 300 earthquakes until May 16, including an earthquake with Mw= 5.5 on May 7. A second swarm took place between May 28 and Jun 4 including an earthquake with ML = 4.8 on Jun 1.

An analysis of the seismicity between May 7 and May 10 using data from the three seismic networks (RESAJ, TN and OBS) is presented. This period includes the (**E1**) May 7, 00:18, Mw=5.5 (Figure 1) and(**E2**) May 7, 01:06, Mw = 5.2 as reported by CMT, which locate the earthquakes between the Rivera Fault zone and the Middle America trench (MAT) near of the eastern tin of the RFZ and north of the East Pacific Rise (EPR) and area with a very complex tectonics where the features that delimit the Pacific, Rivera and Cocos Plates are not clearly defined (Figure 1). Figure 2 shows preliminary automatic locations carried on by Antelope system using RESAJ for period May 7 -10; Antelope uses IASP91 P-wave velocity model. A manual picking of P and S waves for a group of earthquakes was done for RESAJ and Antelope located the swarm about 50 km SW of CMT locations and a depth below 20 km (Figure 3). The same group de earthquakes using data from TN were located using Hypo71 and P-wave velocity model VJB02 (Nuñez-Cornu et al. 2004); hypocenters obtained are in the region as the hypocenters reported by CMT (Figure 4).

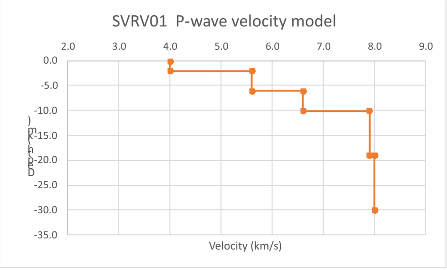

Figure 5. P-wave velocity model SVRV01.

Readings from OBS (Figure 4) were difficult due to noise and in many cases in some stations the signals were masked by other oceanic signals. For the studied period it was possible to identify 83 earthquakes in four or more OBS. However, when we joint the three set of data (RESAJ, TN, OBS) solutions were not reliable and/or P and S wave residuals were high using Antelope system or Hypo71.

To solve the problem, the first step was to locate the seismic swarm using only OBS data and Hypo71, we select 30 earthquakes that was recorded in most of the OBS as test group. Using the Rivera Crustal velocity models proposed by Núñez-Cornú, et al. (2016) and Núñez et al. (2019), we adjust model SVRV01 (Figure 5) for which P and S waves residuals were minimum.

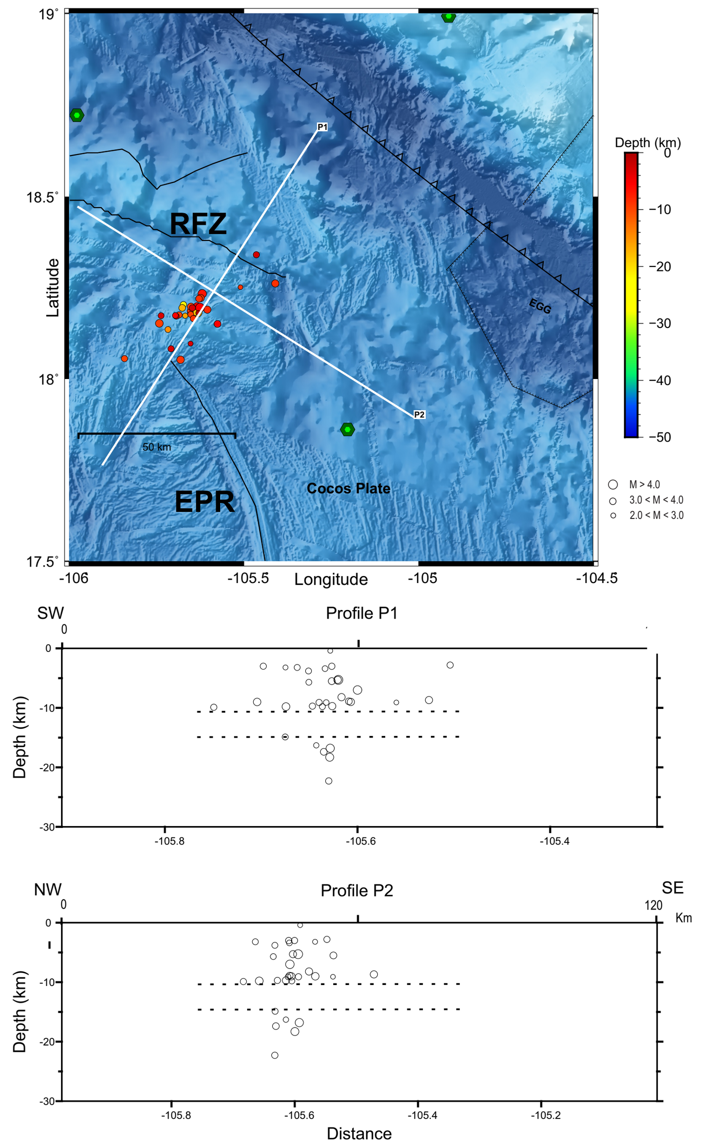

Figure 6. Hypo 71 locations of test group using data from OBS and P-wave velocity model RVSV01.

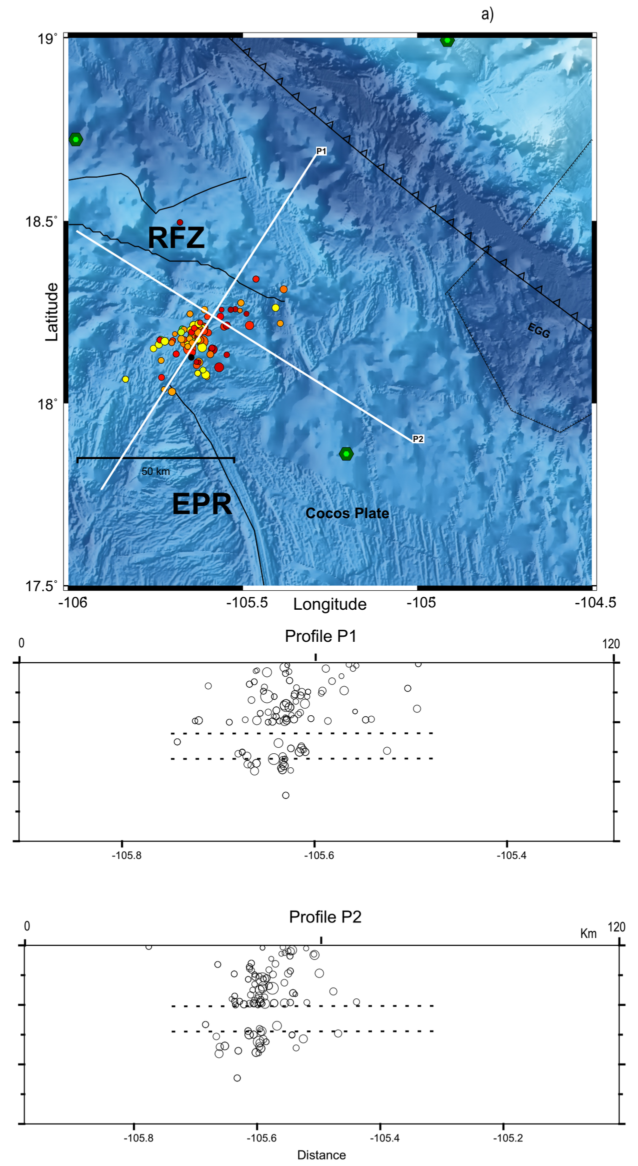

Figure 7. Hypo 71 locations of the 87 earthquakes using data from OBS and P-wave velocity model RVSV01.

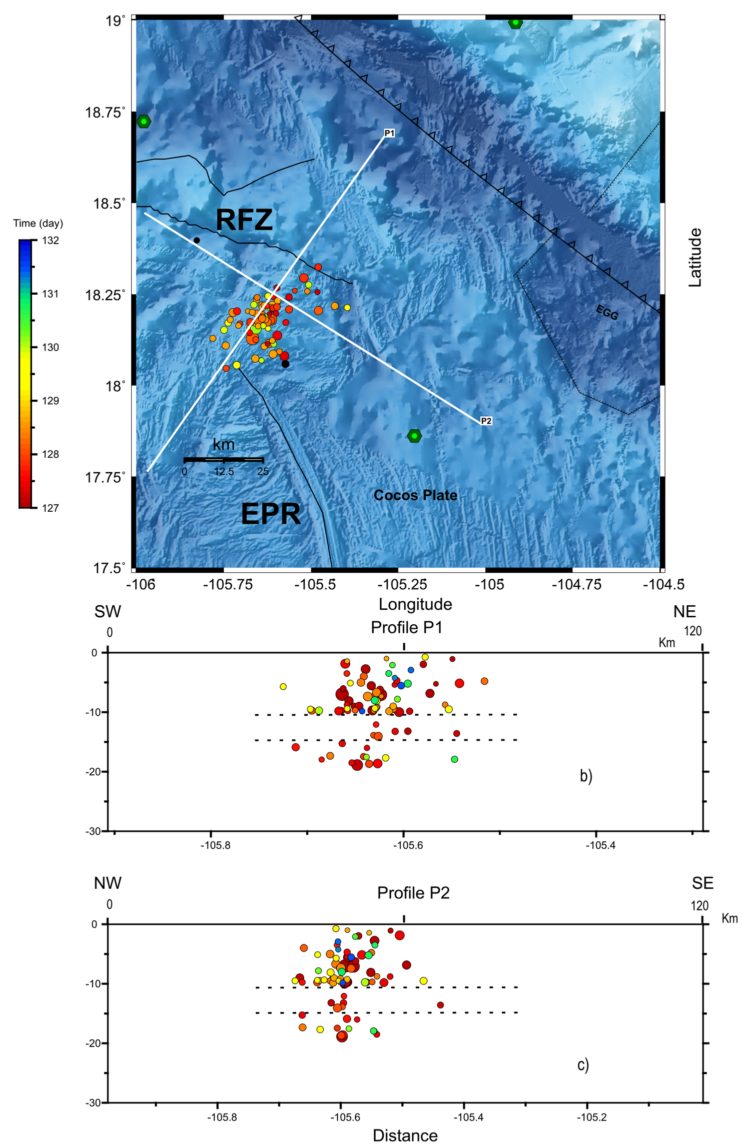

Figure 8. Hypo 71 locations of the 87 earthquakes using data from OBS, RESAJ and TSN and P-wave velocity

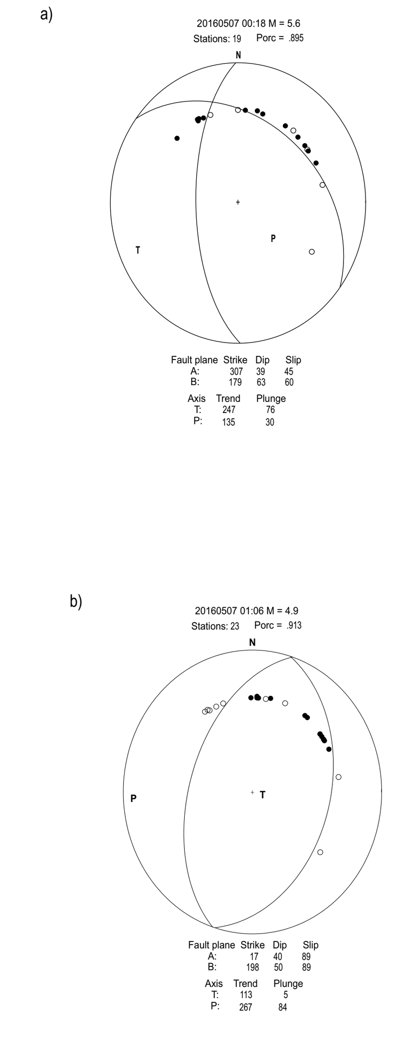

Figure 10. Focal Mechanism for main earthquakes (**E1**) May 07 00:18 (a); (**E2**) May 07, 01:06 (b).

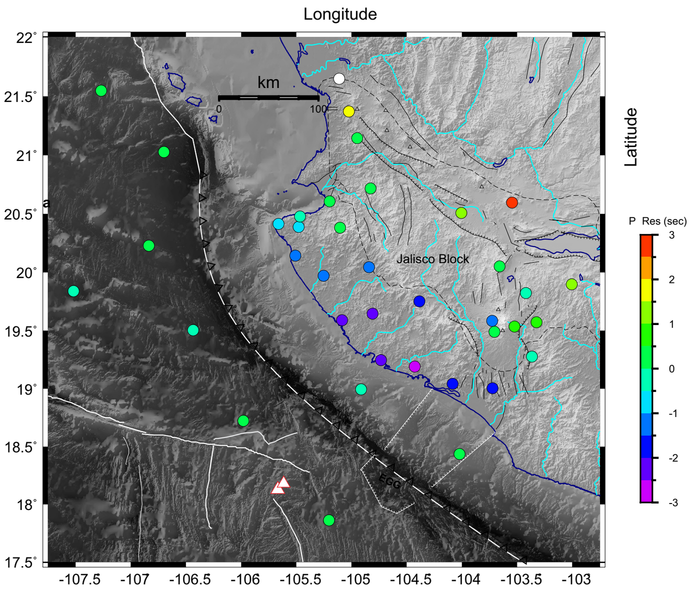

Figure 9. P-wave residuals for OBS, RESAJ and TSN stations from locations using model RVSV01.

To obtain the best solutions using Hypo71, eight different depths were used as the initial solution. Those with the lowest location errors were selected. The local magnitude (Lay and Wallace, 1995) relation was used in this study.

The locations obtained for the test group are shown in Figure 6, where it can be seen that the epicenters are distributed almost aligned between the northern tip of the EPR and where the eastern tip of the RFZ looks like to be located. In depth, two groups are observed one between 0 and 10 km and the second between 14 and 25 km deep. There is a gap between 10 and 14 km depth. Figure 7 show the location of the 87 earthquakes using only OBS data, hypocentral distribution is similar to Figure 6. The Gap between 10 and 14 km depth suggest the existence of a ductile layer below the oceanic crust.

When we included the RESAJ and TN data, we observed conflicts with earthquake locations and residuals from P and S waves.

We use as master events the earthquakes located with OBS and the weight was taken off for the stations on the continent. It was noted that the stations in the range 140 to 240 km away from the epicentral zone the residuals for the P wave are less than -1.0 sec, for distances greater than 330 km the residuals are greater than 1.0 sec. Figure 8 shows the locations obtained with the OBS, RESAJ and TN data without including the stations in the aforementioned distance ranges; the hypocenters are plotted with a time color code, but no pattern is observed. Hypocentral distribution is similar to Figure 6 and 7; and the proposed ductile layer can be observed also. Figure 9 shows the distribution of P-wave residuals for RESAJ; TN and OBS, it can be seen that the effect is clearly related to the pathways of the waves in the continental crust.

For the 86 earthquakes located including data from OBS, RESAJ and TN we got the Root Mean Square (RMS) error with a mean value of 0.36 sec. The standard error of the epicenter (ERH), which represent the diameter of the epicentral error circle, has a mean value was 2.0 km and the standard mean value error of the focal depth (ERZ) was 3.1 km.

The earthquakes **E1** and **E2**, as the seismic swarm, were located about 50 km SW from the locations reported by the continental networks (SSN, TN) and CMT Catalog. This difference is mainly due to two reasons, station coverage and the velocity model, the OBS data are basic for correct location of the seismic swarm. The distance of 50 km may not be important in another tectonic area, but in this case the possible source of the earthquakes changes completely (Figure 12). The focal mechanism obtained for the **E1** earthquake is a normal fault (Figure 11a) and for the **E2** earthquake a reverse fault (Figure 11b). The mechanisms reported by CMT for these earthquakes are strike-slip fault (Figure 12) as most of those reported for RFZ using regional and global data (Sánchez and Núñez-Cornú, 2009).

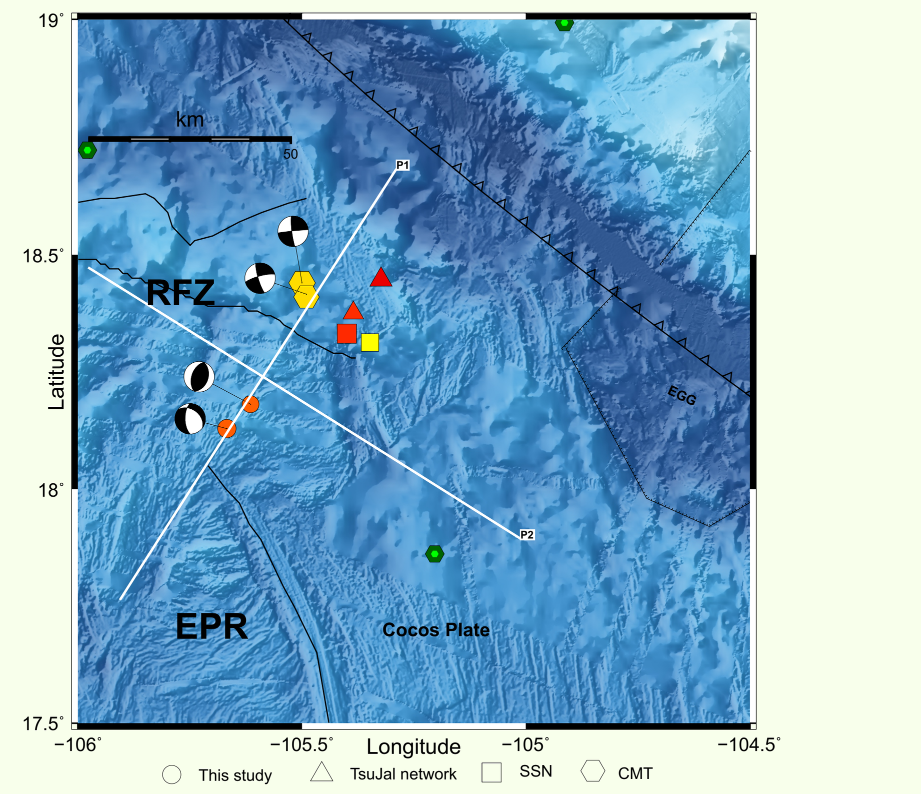

Figure 12. Different locations reported for earthquakes **E1** and **E2**.

Preliminary Conclusions....

- A P-wave velocity model was obtained for the Rivera Plate
- The OBS data was definitive for the relocation of the seismic swarm 50 km SW from others sources.
- The seismicity pattern and the focal mechanism suggest the propagation (opening?) of the EPR to the RFZ.
- The ductile layer could be a magmatic shallow reservoir.

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