Seismicity on the border of Parecis Phanerozoic basin, Mato Grosso State, Brazil

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ABSTRACT

The biggest earthquake ever observed in all Stable Continental Interior (SCI) of the South American plate occurred in Serra do Tombador (ST), Mato Grosso State, in 1955. 100km to northeast of ST, in Porto dos Gaúchos (PG), a recurrent seismicity has been observed since 1959 and earthquakes continues to be detected in this area up today. Two magnitudes 5 earthquakes occurred in 1998 and 2005 with intensities up to VI and V, respectively. Recently, on January 26 of 2015 it was detected, 17km away from the PG seismic zone, another seismic activity with a main shock of magnitude 4.0mb. This new seismic area, is parallel to PG fault, with similar Focal Mechanism to the 1998 and 2005 seismic sequences. The seismicity in these three seismic areas did not present any relation with geological structures presents in this region. However, in light of new studies on Intraplate seismicity, it seems that these seismicities are interconnected: Serra do Tombador earthquake of 1955 Triggered Porto dos Gaúchos (PG) earthquakes and PG earthquakes Triggered the seismicity that has being observed in the new seismic zone since January 2015. This work aims to present results of studies that has been made about this new seismic zone, but before that, we will do a revision on the studies made about the seismicity in ST and PG seismic zones.

INTRODUCTION

The seismicity on the border of the Phanerozoic Parecis basin is very expressive in relation to the rest of the country. Two seismic zones are known (Barros et al., 2018; Barros et al., 2017; Barros et al., 2012, 2011 and 2009, Assumpção and Suarez, ??, Berrocal et al., 1984): Serra do Tombador where it take place the largest earthquake ever observed in the SCI of the South American plate, on January 31, 1955 (M 6.2) (# 4 in square of Figure 1); Porto dos Gaúchos PG), located 100 km northeast of ST, where an recurrent seismicity has been observed since 1959, when arrived the first habitants to the region. Two magnitudes 5 earthquakes occurred in PG, in 1998 and 2005 with intensities up to VI and V (MMI), respectively (# 17 and 18 in square of **Figure 1**).

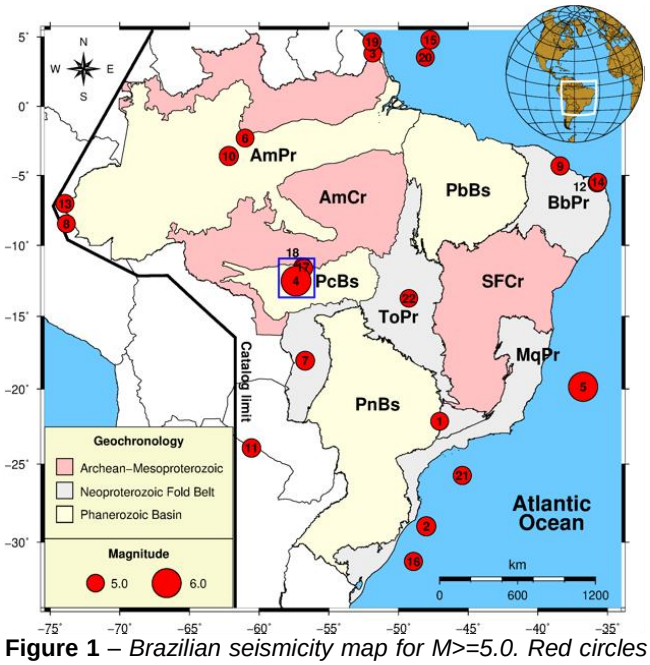

Figure 1 – *Brazilian seismicity map for M>=5.0. Red circles indicate the seismic events from the Brazilian Seismic Bulletin and the magnitudes as in the legend. The geological provinces are indicated by different colors: dark pink - Precambrian regions - São Francisco craton (SFC), Central Brazil Shield (CBS) and Guiana Shield (GS); light yellow - Phanerozoic regions, Parecis Basin (PcB), Paraná Basin (PrB), Amazon Basin (AmB) and Parnaiba Basin (PnB); mobile shield - light grey, Borborema Province (BB), Tocantins Province (TP) and Mantiqueira Province (MqPr). The blue square denotes the seismic zone of the border of Parecis Basin.*

These two main shocks were followed by aftershock sequences, studied with local seismic networks, that last up today. In the last 30 years it was detected in PG seismic zone more than seven thousand events. Both sequences occurred in the same WSW-ENE oriented fault zone with right-lateral strike-slip mechanisms. The epicentral zone is near the northern border of Parecis basin, where there are buried grabens, generally trending WNW-ESE, such as the deep Mesoproterozoic Caiabis graben which lies partly beneath the Parecis basin (**Figure 2**).

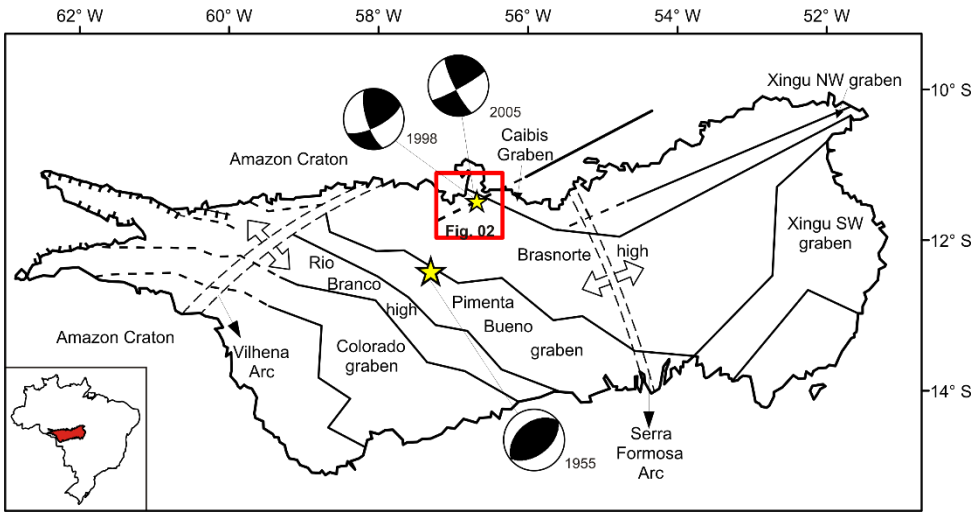

Figure 2. - *Tectonics domains of the Phanerozoic Parecis basin, Amazon craton – Brazil The study area is represented by the reed square. The below yellow star represents the epicenter of ST earthquake, and the above the PG earthquakes of 1998 and 20005. The beach ball represents the focal mechanism determined for ST1955 (Mendiguren and Richter 1978), PG1998 and PG2005 (Barros et al., 2009).*

A 1D velocity model determined with shallow refraction experiment in PG seismic zone helped to convert Ps–P time differences to basement depths at 15 stations of the two aftershocks seismic networks (**Figure 3**) (Barros and Rancan, Barros and Caixeta). The results of the receiver function integrated with the shallow refraction reveal that the basement depth in the PGSZ increases from the basin border in the north up to almost 600 m depth in the south (Barros and Assumpção, 2012) (**Figure 4**).

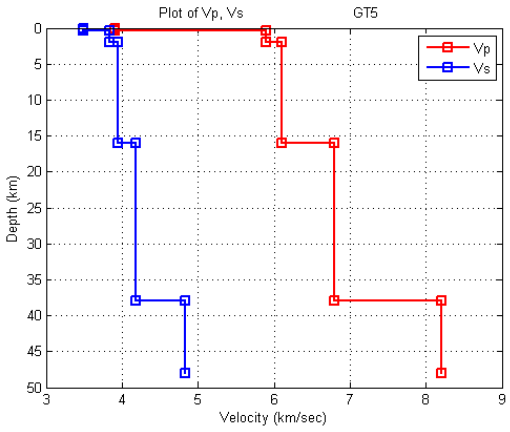

Figure 3. – *1D velocity model used for new area events locations*.

The 1998-2002 and 2005 seismogenic fault is located in a basement high (**Figure 4**), which is probably related with the same seismogenic feature responsible for the earthquakes in PGSZ. The outcrop inside the Parecis basin present in PDRB station location is really related with crystalline basement of Amazon Craton. A 40 m deep hole opened close to PDRB station for the calibration explosion showed that the basement is shallow, it was found 20 m.

THE NEW SEISMIC ZONE

On January 5, 2015 occurred the first foreshock in the new area, and in 26 January, at 23:32h the main shock of magnitude 4,0 was detected 17 km to the north of PG Seismic Zone. This event was registered by 25 stations of the Brazilian Seismographic Network (RSBR), such distances ranges from 17 km to 1800 km (Figure 5).

Main shock location

The event location was determined using all stations Figure 5 *(reed circle that originates the all rays – white lines) using the NewBR 1D velocity model (Assumpção et al., 2010), and by only PDRB station (red circle in the end of the PDRB station ray), using the local model (**Figure 3**). Despite the greeter number of stations, the last epicenter is more precise than the first one.*

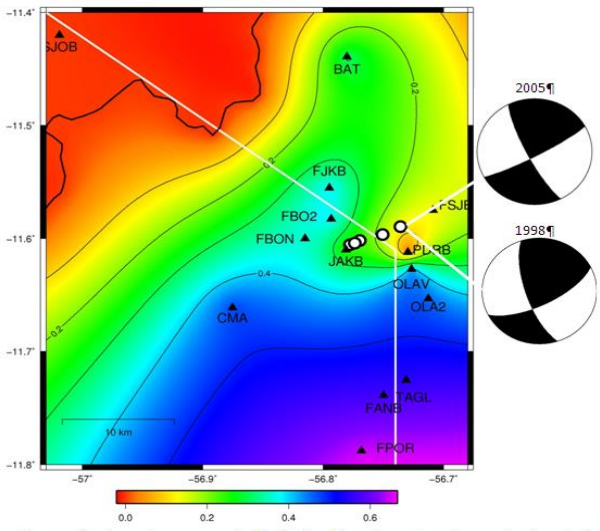

Figure 4.- *Topography of the basement in the Parecis basin, Porto dos Gaúchos seismic zone, as obtained by RF technique applied to local events recorded in the 15 stations indicated by triangles. Circles. indicate the best five epicenters of 2005 seismic sequence. Dashed line indicates the limit between craton and basin (Barros and Assumpção, 2012).*

Aftershock sequence

The aftershock sequence is being monitored locally by PDRB station, located about 17 km away from the seismic zone. Then, only events with magnitudes above 1.0mD can be detected. In this sense a great number of events was lost due to the high threshold magnitude. In the other hand, events with magnitude up to -0.2 was detected by PDRB station in the old zone.
After this occurrence about 100 other events have already been registered at this location. Therefore, the earth is currently trembling in two places in the border of Parecis basin, separated by a distance of 17 km, in the municipalities of Porto dos Gauchos and Tabaporã. However, the seismicity of the new area is vanishing, while in the PG there is a background seismicity more less constant.

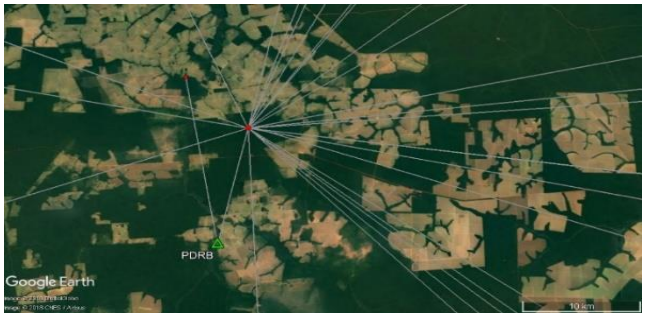

Figure 5. – *Epicenter main shock location by all stations of the RSBR network (reed circle that originates the all rays – white lines), and by only PDRB station (red circle in the end of the PDRB station ray).*

Table 1 summarizes the best events detected in the new area. This set was used for studies on epicenter location, composite focal mechanism determination and waveform inversion for moment tensor. Figure 6 shows a graphic for the seismicity in both areas. The different number of events could be due to the threshold magnitude for bot area (1,0 mD for the new and -02.mD for the old one).

Table 1. – The best set of events used for location and focal mechanism determination Dmin is the distance from the PDRB and the epicenter.

Year	day/month	Origin	lat	long	Dmin	depth	Mag
2015	10/jan	06:55	-11.485	-56.685	16.0	3	3.0
2015	26/jan	06:12	-11.480	-56.691	15.6	3	3.9
2015	05/jun	23:32	-11.505	-56.648	15.7	3	2.9
2015	06/aug	02:22	-11.482	-56.755	15.0	3	1.9

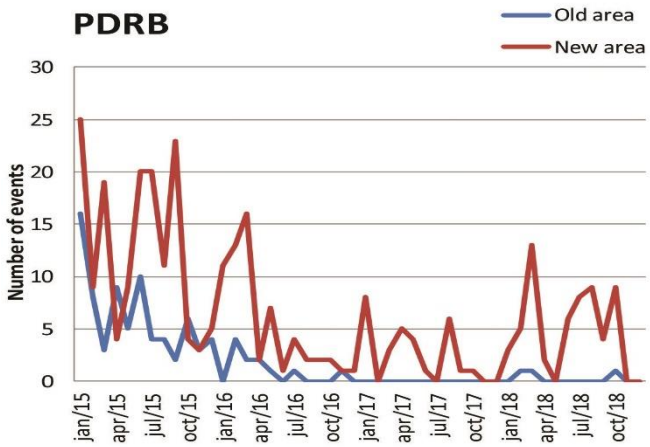

Figure 6. *– Seismic evolution of the seismicity in both areas.*

This set of five events was locate with PDRB station using hypocenter code (Lienert, 1994) installed in SEISAN data Base (Havskov and Ottomöller, 2015). The 1D velocity model used for location was developed by Barros & Rancan (2003) and Barros & Assumpção (2012) (Figure 3). Figure 7 shows the epicentral distribution of the best located events in the three seismic sequences: sequence of 1998-2002 (rede circles), sequence of 2005 (green squares), and the new area sequence (higher orange circles).

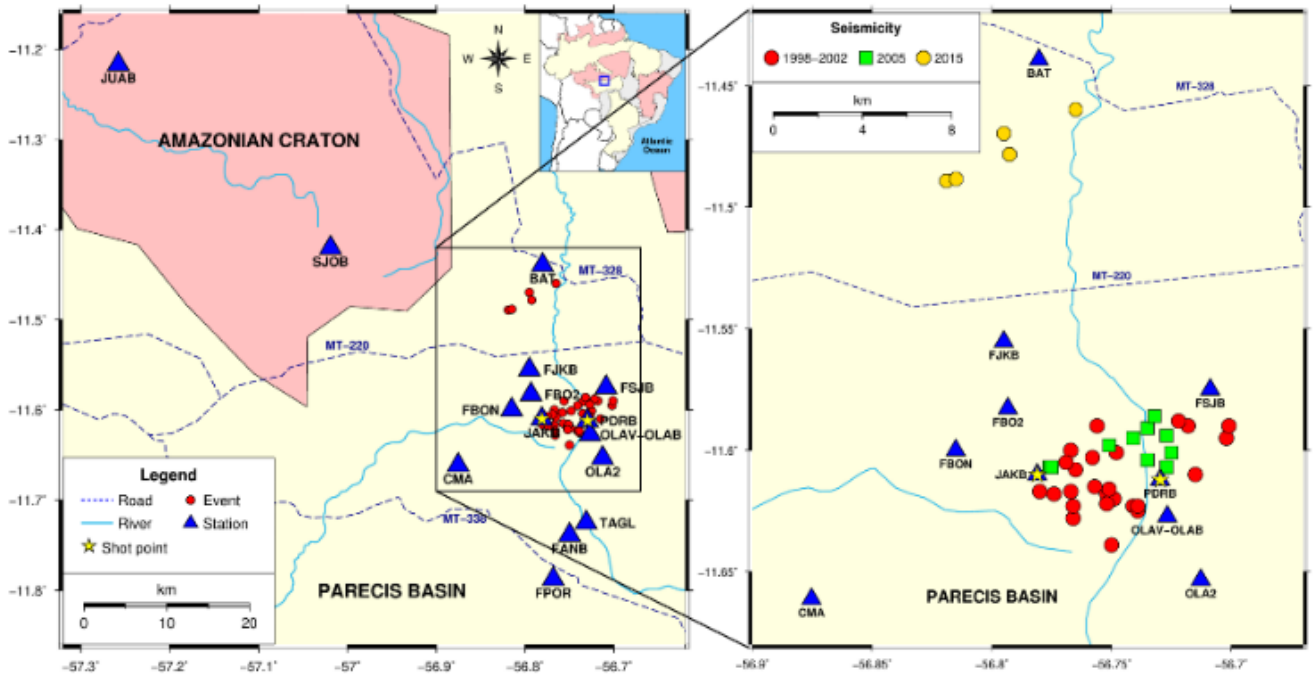

Figure 7. *– Epicentral map for the seismic sequences of 1998 -2002 (reed circles), 2005 (green square) and new one (up yellow circles). The Amazonian craton is represented by the dark pink color, and Phanerozoic terrenes by the white color. Triangles (15) denotes seismic station the run in the 1998-2002 and 2005 seismic sequences. The new one is monitored by PDRB station. The two stairs denote the place where it was made the calibration explosion for the 1D velocity model determination*

Focal Mechanism Determination

A composite focal mechanism was determined for the mainshock using 21 polarities (Figure 7). The inconsistent polarities occurred very close to the nodal planes, as it is the case of PDRB station. However, all the aftershocks polarities for the PDRB station shows opposite polarities.

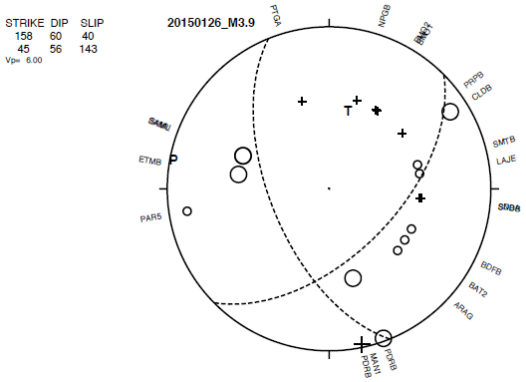

Figure 8. *– Composite focal mechanism for the mainshock of January 26. The nodal plane, more consistent with figure trace determined by the five events in Figure 7, is strike = 158, dip = 60 and rake = 40 degrees.*

Waveform Inversion

We used the event of June 05 at 23:32h for waveform inversion. The results are the figures 9 and 10.

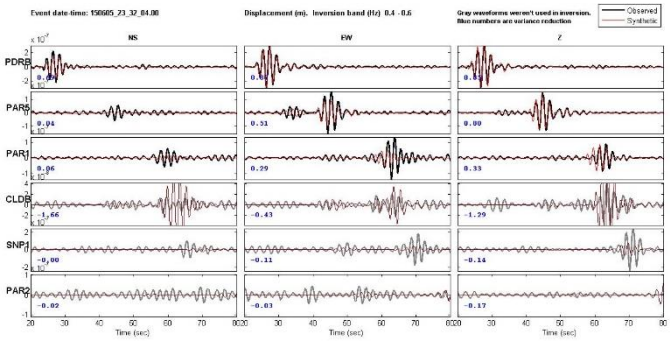

Figure 9. *– Correlation between theorical data (red traces) and observed data (black traces). Observe that only the stations PDRB, PAR5 and PAR1 were used in the inversion.*

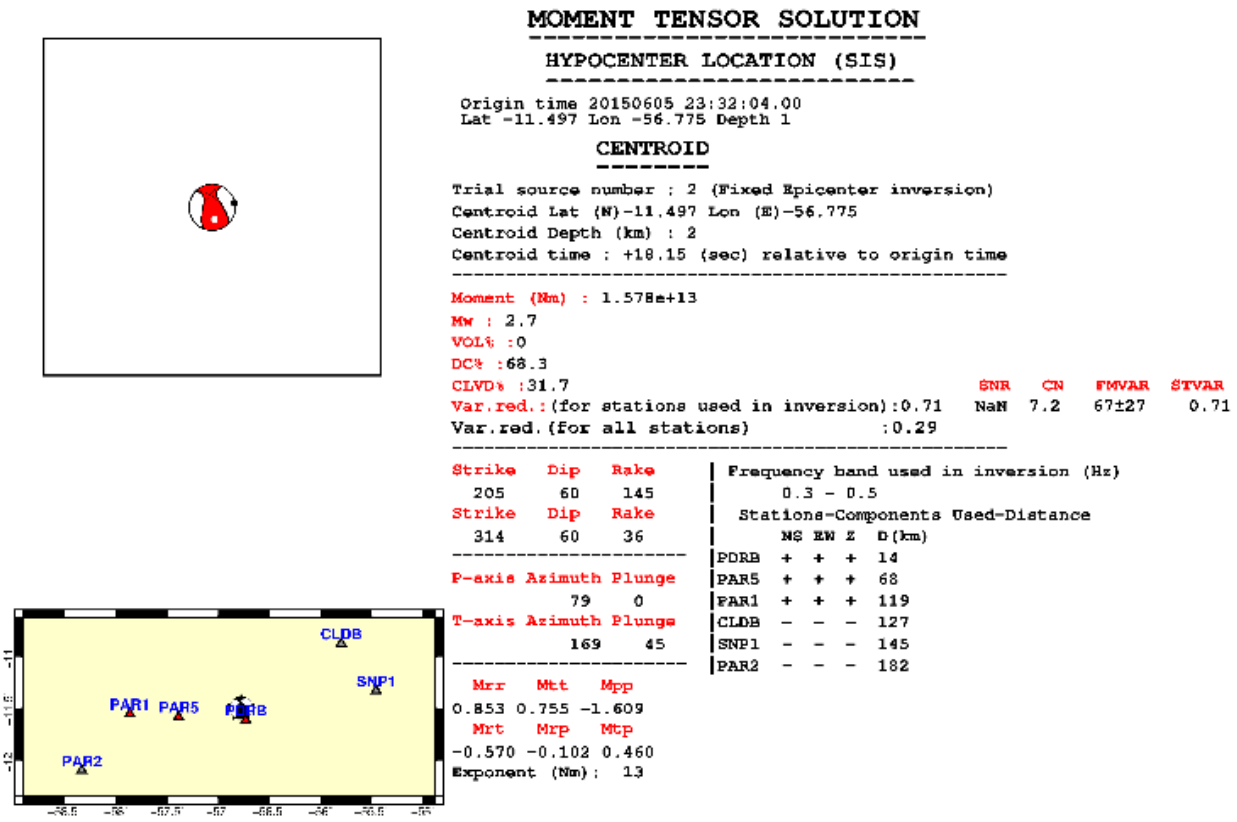

***Figure 10**. – Output summary solution of the waveform inversion for the event of June 05, at 23:32h.*

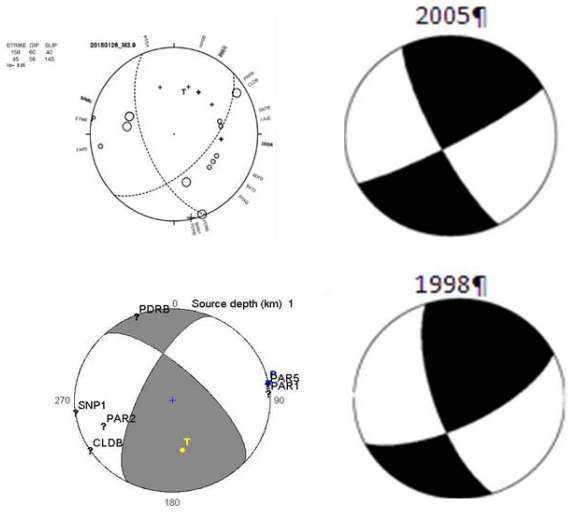

Figure 11. – *Focal mechanism solutions for 1998, 2005 sequences and 2015 sequence composite and by waveform inversion*

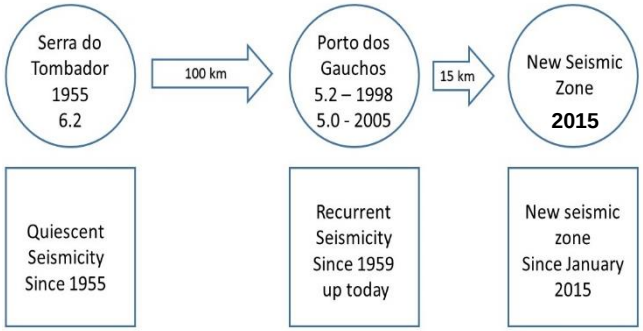

***Figure 11.** – Diagram showing the possible relation between the seismicity of Serra do Tombador, Porto dos Gaúchos and new area.*

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