The Mara Rosa 5.0 m_b earthquake and aftershock activity

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Abstract

In October 8th, 2010, a 5.0 m_b (MMI VI) earthquake occurred close to Mara Rosa, in the North of Goiás State, Brazil, in an area where previous low magnitude seismicity had been observed. However, this was the biggest earthquake ever detected in this area, felt up to 300 km away from the epicenter. This event may be associated with reactivation of some geological fault of the Transbrazilian Lineament (TL), since the aftershock activity observed from October of 2010 to January of 2011 indicates a SW-NE trending fault, parallel to TL and consistent with one nodal plane of the composite focal mechanism solution. This work presents preliminary results of studies on seismicity, geology and geophysics conducted by the Seismological Observatory of the University of Brasília on the main earthquake of Mara Rosa of October 8th, 2010 and aftershock activity detected by a local seismic network.

Introduction

The recent seismicity observed in Mara Rosa started on October 4 of 2010, at 16h07m (local time), with an earthquake of magnitude 3.6 m_D felt by the local population of Mara Rosa, Mutunópolis and Santa Tereza. However, other earthquakes had been recorded in this area in 1995, 1998, 2001 and 2006. Historical data, collected recently, realize that in 1962 an earthquake was felt in this area with intensity V Modified Mercalli Scale (MM).

The seismicity occurring in the States of Goiás, Tocantins and part of Mato Grosso has a preferential distribution to NE-SW direction and has been called Goiás-Tocantins seismic range (GO/TO-SR). The map of Figure 1 shows the seismicity of GO/TO-SR part, with the study area highlighted by the red square and the yellow star denoting the epicenter of Mara Rosa earthquake.

The GO/TO-SR is defined by the distribution of epicenters of lower earthquakes magnitude, ranging from the NE of Parana Basin to the SW of Parnaiba Basin. It is parallel but not coincident with the Transbrasiliano Lineament (TL), whose geophysical expression is characterized by high Bouguer gravity anomalies along to the Araguaia Folding Belt (Assumpção et al., 1986 and Fernandes et al. 1991). The TL consists of a set of geologic features formed in the Neoproterozoic to Lower Paleozoic, by the convergence of São Francisco-Congo Craton and Amazonian Craton, during the formation of the eastern part of the super continent Gondwana (Fuck, 1994, Fuck et al., 1994) (Fig. 2). This tectonic process generated the Brasília tectonic folding Belt, located in the Tocantins Province.

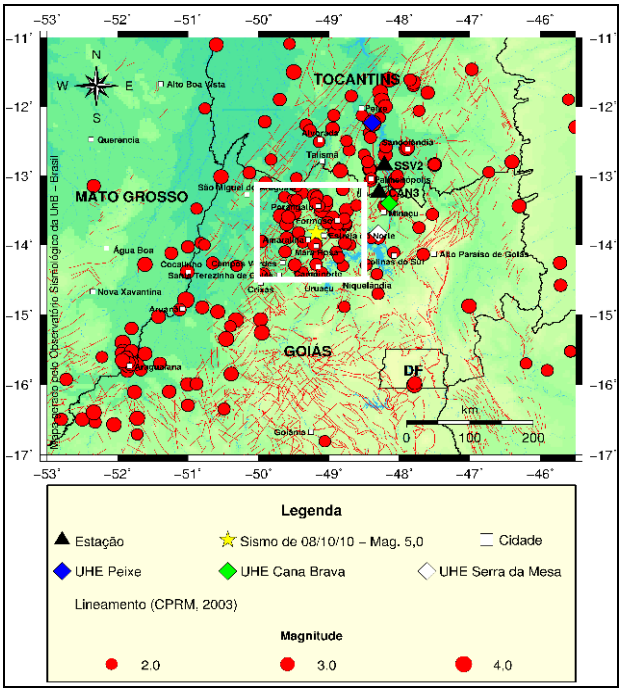

***Fig. 1** – Epicentral map of part of the Goiás-Tocantins Seismic Range and features of the Transbrasiliano Lineament. The white square indicates the study area (Fig.2).*

On October 8th of 2010, at 17h17m (local time) occurred the biggest earthquake ever detected in the GO/TO-SR, magnitude 5.0 m_b and Imax = VI MM, felt even in Brasilia and Goiania. About 10 minutes later, another earthquake of magnitude 4.0 m_b was detected. On October 19 of 2010 the Seismological Observatory (SIS) of the University of Brasília (UnB) started local studies, with the installation of a seismographic network and making macroseismic surveys. This paper aims to present preliminary results of studies of seismicity that are being conducted by SIS-UnB with a local seismic network.

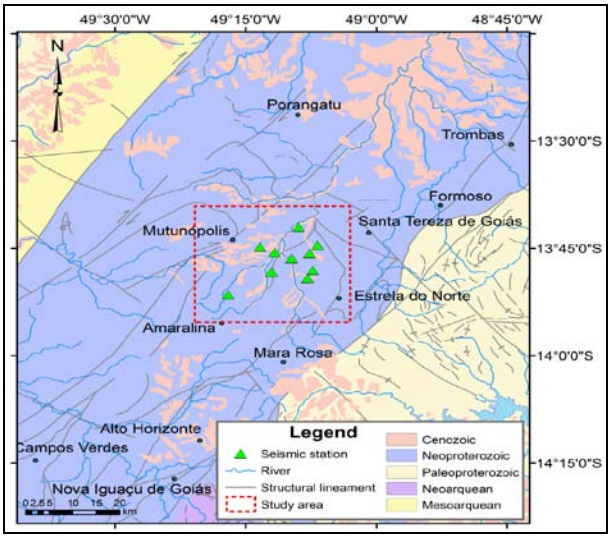

Fig. 2 - *Geological map with the geographic distribution of the local seismic stations. The hatched box indicates the location of the study area. Faults, fractures and shear zones were obtained from CPRM (2004).*

Mara Rosa-GO seismicity

After the earthquake of October 4th, 2010 (3.6 m_D) until the begging of the deployment of the local network (in 10/19/2010), beyond the two events of October 8th (5.0 mb, 4.0 m_b), seven other earthquakes, with magnitudes ranging from 2.0 to 2.3 m_D, were detected by the nearest station, located in the Cana Brava reservoir (CAN3 station), 115 km distant from the epicentral area.

Mainshock of 10/08/2011 (5.0 m_b) at 17h17m (local time)

This was the biggest earthquake ever observed in the GO/TO-SR. The second one occurred in Aruanã (magnitude 4.3 m_b and V MM) in July of 1993.

Hypocentral location

The earthquake was located by the USGS (United States Geological Survey), with data from 107 stations and a gap of 34º and by Seismological Observatory (SIS) of Brasília University (UnB) with data from 20 regional stations and a gap of 46º. The SIS-UnB used two velocity models. The first location (UnB1, green star in Fig. 3) used the velocity model developed by Kwitko and Assumpção (1990) and in the second location was used the model developed by Assumpção et al. (2010) (UnB2, green star in Fig. 3). The code used for hypocentral location was Hypocenter (Lienert, 1994) in the Seisan package (Havskov and Ottemöller, 2008). The locations are: USGS (13.88 ° S, 49.22 º W), depth (h) fixed at 10 km and origin time (O.T) = 20h16m55.6s; UnB1 (13.730 ° S, 49.213 ° S), h = 7.8 km and O.T = 20h16m53.6s; UnB2 (13,747 ° S, 49 248 ° W), h = 8.6 km, O.T = 20h16m55.9s. Figure 4 shows the mainshock waveforms (only the vertical components) in eleven stations, nine located in Brazil and two in neighboring countries (CPUB-Paraguay) and (LPAZ - Bolivia).

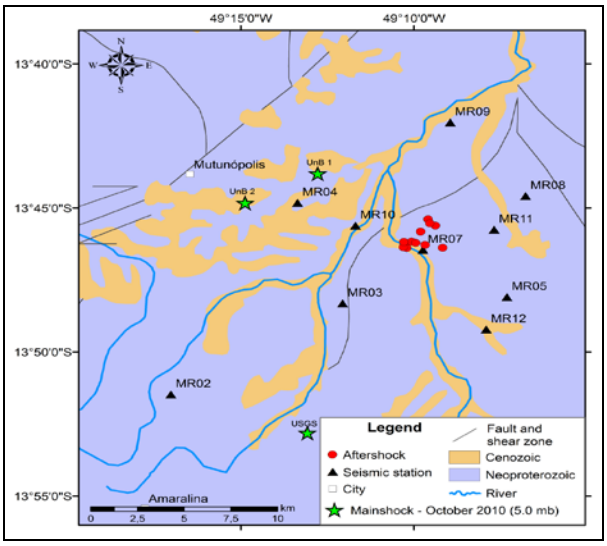

Fig. 3 - *Geological map of study area. Stars denote the mainshock epicenters determined by USGS and UnB, using the velocity models of Kwitko and Assumpção, 1990 (UnB1) and Assumpção et. al., 2010 (UnB2). Red circles denote the best events epicenters (eleven) detected simultaneously by four local stations.*

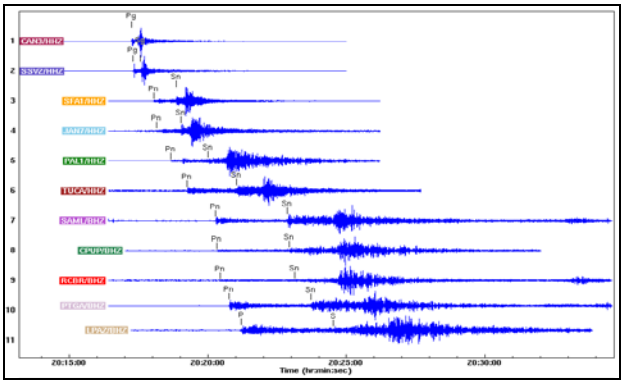

Fig. 4 – *Seismic waveforms of the 5.0 m_b mainshock of October 8th (only the vertical components) in eleven regional stations, nine in Brazil and two in neighboring countries, Paraguay (CPUP) and Bolivia (LPAZ).*

Macroseismic survey

Figure 5 shows the map with isoseismic curves for the mainshock, felt in several cities of Goiás and Tocantins (not all shown in the map) and in almost of satellite cities of the Distrito Federal (DF) and Goiania, located about 300 km away from the epicenter.

Single focal mechanism

The single focal mechanism solution was attempted; however, due to the small number of clear polarities it was not possible to get a consistent solution.

Local Seismic network and aftershock activity

The deployment of the local seismic network started on October 19, 2010. Initially, composed by four portable stations and in November another station was installed and the station MR02 was moved to the point of MR07. In March, the network was increased by four more stations, totaling nine stations. The data is being recorded continuously and acquired at a sample rate of 200 samples by second. Figure 3 shows the map with the spatial distribution of stations and epicenters of eleven events located with data from four stations with the code hypocenter (Lienert, 1994). In all cases the station MR07 was present.

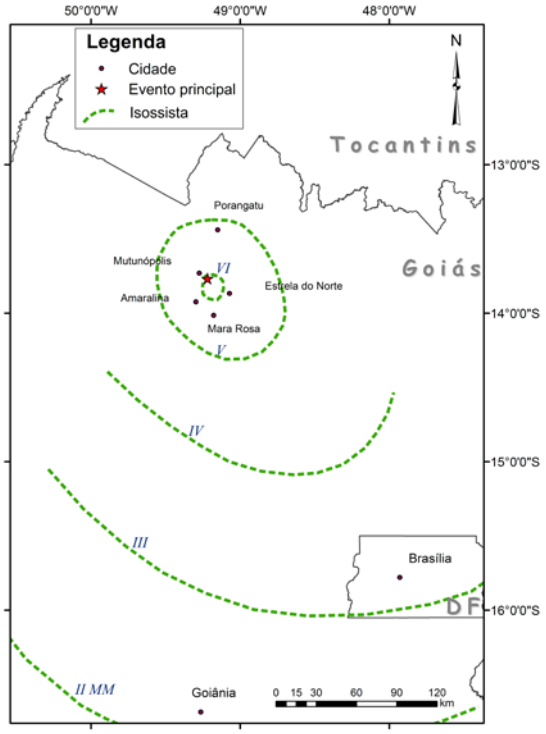

Fig. 5 – *Preliminary Isoseismal map of the October 8th, 2010 mainshock (5.0 m_b). In Brasilia the effects of this earthquake caused the evacuation of some buildings.*

(A)

(B)

(C)

Fig. 6 - *Pictures with the mainshock macroseismic effects: In A) and B) decreased crack grouting in masonry wall in homes near the epicentral area and, in C) unroofing.*

The velocity model used the locals events location, is a half-space with a velocity of 5.9 km/s, obtained by testing velocities of 5.0 to 6.4 km/s. The best result in terms of the mean of the root mean square of the time residual for the best 11 events was obtained for v = 5.9 km / s (RMS average = 0.009 s) and 0.01 s for each event individually. The Vp/Vs ratio was obtained by Wadati diagram. Vp / Vs = 1.69 + - 0.01. Location tests yielded the best results for Vp / Vs = 1.70. With this model we tested the initial depth, varying from 5 km to 20 km. The results have been insensitive to the initial value of h. This shows the model consistency.
In Figure 3 - geological map of study area, is shown the epicenters of the main earthquake located by the USGS and by UNB, using the velocity models of Kiko and Assumpção, 1990 (UnB1) and Assumpção et. al. (2010) (UnB2). Epicenters are also shown (red circles) of 11 events detected simultaneously by four local network stations.

Seismicity evolution

Local stations detected between 19/10/2010 and 09/01/2011, a total of 376 events. The temporal distribution of seismic activity in this period is shown in the histogram of Figure 7. Note the peaks of activity in the second week of November and in the month of January. The gaps are related to operational problems at the stations.

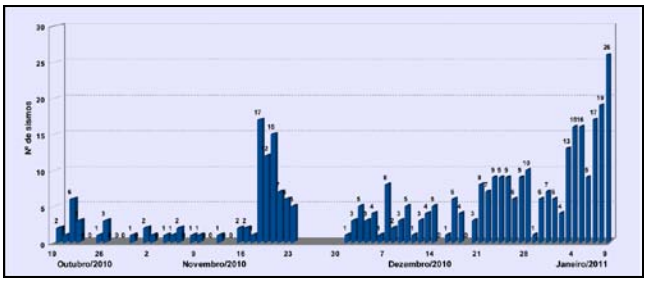

Fig. 7 - *Histogram of the evolution of seismic activity of Mara Rosa, Goiás, detected by local seismic network in the period 10/19/2010 to 01/09/2011. During that time were detected 370 micro-tremors.*

Composite focal mechanism

The composite focal mechanism was determined with the program FOCMEC (Snoke et al., 1984) using the first P-wave polarities (33 polarities) of eleven events detected simultaneously by four stations, with only one inconsistency. The results show a reverse fault, with azimuth 41°, dip 52° to SE and rake of 79° (Fig. 8).

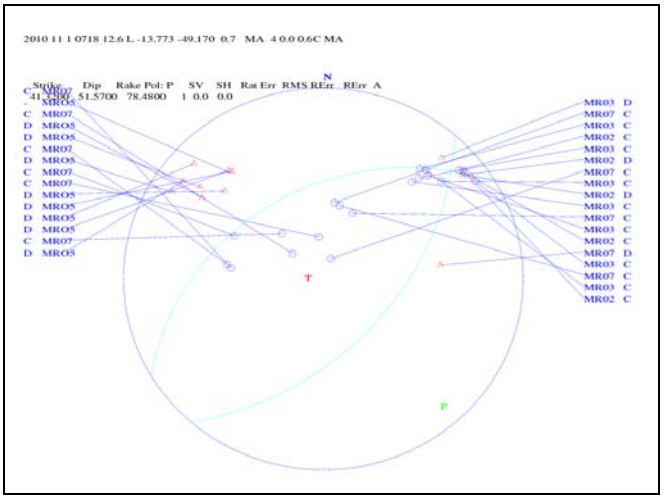

Fig. 8 - *Composite focal mechanisms solution for aftershocks activity, where circle (C) means compression (up), triangle (D) expansion (down). We used 11 events detected by four stations, with 33 polarities and one inconsistency.*

Geophysical setting

An analysis of gravity and magnetic data for the epicentral area was made and the final products are presented on the maps of Bouguer anomaly (Fig. 9) and Analytical Signal Amplitude (ASA) (Fig. 10). Strong positive Bouguer anomaly is observed at NW of the seismic area (yellow circles), trending in NE-SW direction (Fig. 9). The ASA map (Fig. 10) shows features with preferential NW-SE directions, but directions NS and NW-SE, although less evident, can also be inferred.

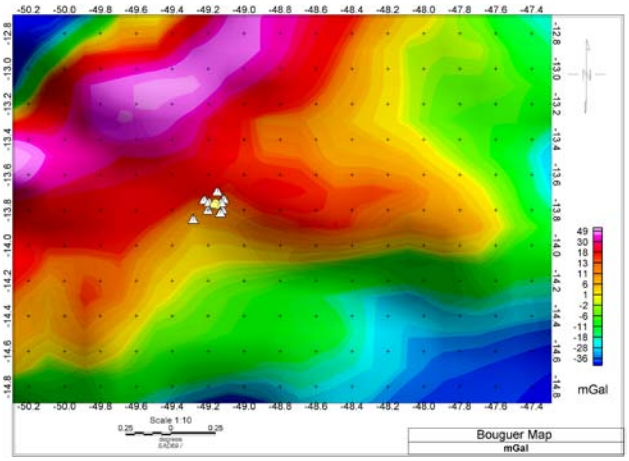

Fig. 9 - *Bouguer anomaly map for the seismic area of Mara Rosa, Goiás. White triangles indicate seismic stations and yellow circles epicenters.*

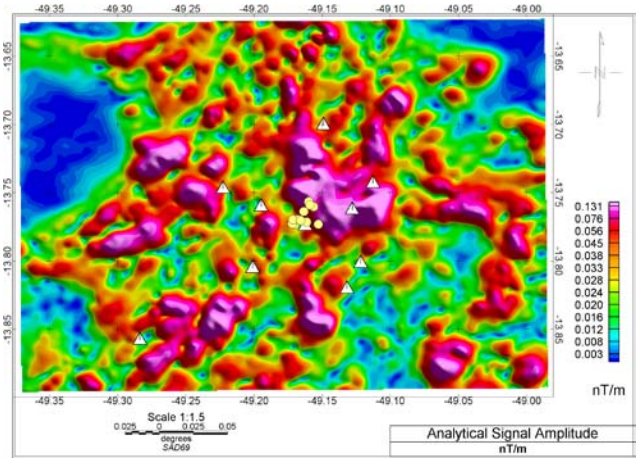

Fig. 10 - *Map of Analytical Signal Amplitude for the Mara Rosa-Goiás seismic area. White triangles indicate seismic stations and yellow circles the epicenters of the best located events.*

Discussion and conclusions

The seismicity that has been observed near the Mara Rosa town, Goiás State, or, to be more precise, in the municipality of Mutunópolis, may be associated with reactivation of some geological feature of Transbrasiliano Lineament (TL), considering that the trend of the seismogenic fault is almost parallel to the TL, trending in SW-NE direction and is consistent with a nodal plane of composite focal mechanism solution. In the maps of figures 2 and 3 it is possible to see some lineament consistent with seismogenic fault, however, none is coincident.

Another important fact which must be observed with respect to the mainshock macroseismic effects, felt in Brasilia (260 km) with intensity III and Goiânia (300 km) with intensity II and produced little damage in the epicentral area (intensity VI). In Brasilia, some buildings

were evacuated. This can be associated with good quality of buildings, all masonry, and the depth of the hypocenter, about 8 km. Similar magnitude earthquake in Caraibas/Itacarmbi/MG (4.9 m_b), in December 7 of 2007, produced effects much more intense in the Village of Caraibas, particularly due to two factors: focal depth (about 3 km) and poor quality of buildings) (Chimpliganond et al., 2009).

Despite of the Serra da Mesa Reservoir already has been presented induced seismicity, the Mara Rosa earthquakes did not appear to be associated with this reservoir, or are not triggered by this reservoir, since the epicenters are outside of its influence area.

Acknowledgments

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