Accurate Location of the Montes Claros Main shock with Relative Epicentral Determination Using Lg Waves

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Abstract

In the city of Montes Claros, Brazil, in the north of Minas Gerais state, hundreds of earthquakes have been occurring. On 19-May-2012 an earthquake of magnitude 4,0 caused great panic in the city. A study of relative epicentral determination was done to relocate the main shock epicenter. To do this study it was necessary to know the location of a large aftershock and find the relative position between the aftershock and the main event epicenter. Our studies show the main shock epicenter is in a direction of 1° at distance of 0,74 km in relation to the reference event occurred in 12-Sep-2012.

Introduction

The area of study is located in northern Minas Gerais, Brazil, in the city of Montes Claros. In this region, since 27-Aug-1995 the local population feels seismic activity. Recently, the seismic active increased registered hundreds of earthquake of small magnitudes have been recorded.

In 19-May-2012 the city felt an earthquake of 4.0mb, the largest earthquake registered in the region. A few months later an aftershock with 2.9 mb occurred in 12-Sep-2012. In this study we analyzed these two events that occurred in Montes Claros.

This method consists in finding the position of the epicenterof the main shock in relation to a reference event with a known location. We used the program SAC to read and analyze the seismograms.

Stations can only be used if they recorded the two earthquakes. For the determination of the epicenter of the 19-May-2012 main shock, we used the aftershock of 12-Sep-2012 as the reference event with known location that is shown in the table 1 below.

***Table 1**: Initial Origin Times and Final Origin Times .*

Date	Initial O.Time	Final Time	Mag
YYYY-MM-DD	(UT)	(UT)	
2012-05-19	13:41:22.82	13:41:22.40	4.0
2012-09-12	23:56:46.00	23:56:45.75	2.9

The stations that were used are shown in Fig. 1a. The initial positions of the epicenters are shown in Figure 1b, before the relative determination.

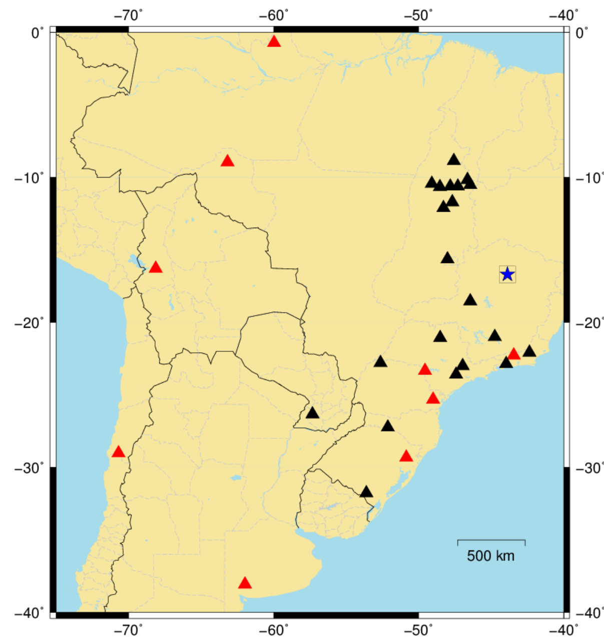

***Fig. 1a**: Stations used in this study. Black triangles are the stations which generated good results and the red triangles are stations that didn't show good correlation The blue star in the square represents the area of study and the main shock epicenter.*

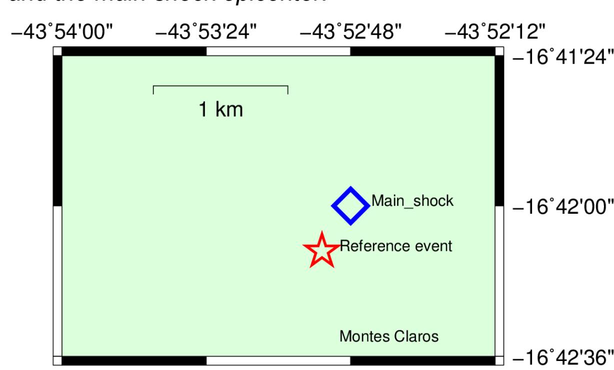

***Figure 1b**: The initial epicenters, the red star is the reference event with a known location and the blue diamond is the main shock event.*

Method

The method of relative determination requires many seismographic stations spread in different azimuths. In all seismograms we analyzed the Rayleigh surface waves, and Lg, filtered with periods between 0,5 and 1s. To locate the relative position between the events, it was necessary to fix the position of the reference event with higher magnitude and known position.

With the filtered seismograms we calculated the crosscorrelation between the main shock and the aftershock reference event. This produces a similarity measure between the signal of the main shock and the aftershock as function of delay applied to one of them (eg. Fig. 2). For each station the delay will be different, varying as function of azimuth, because for each station the relative distances between the epicenters will be different.

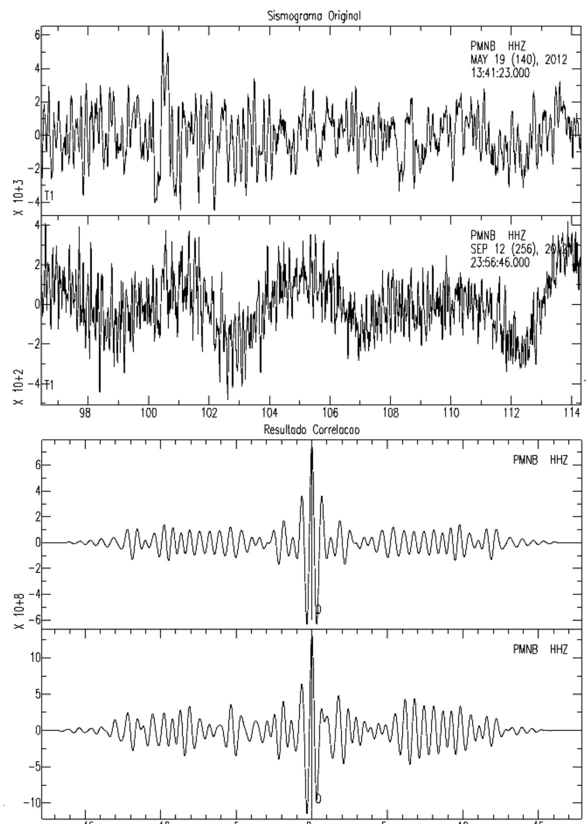

***Fig. 2**. The seismograms of station PMNB, network BL. The two seismograms above represent the data without filter, in the surface wave window. The two traces below are the autocorrelation and the crosscorrelation, where it can be seen that the delay between the signals is only 0,003s.*

To find the distance and direction between the epicenter of main shock and the reference event, we used the equation (1) below that represents the delay variation as a function of azimuth and distance:

$$T_m - T_r = A_o - d * \cos(A_s - A_e) / V_{ap} \qquad (1)$$

where T_m is the travel time of the Lg wave from the Main shock, T_r is the travel time from the Reference aftershock (both assuming the origin times as in Table 1), A_o is the correction of the origin time of the main event, d is the distance between the epicenters, A_s is the azimuth of the station measured at the reference epicenter, A_e is the angle between the epicenters, and V_{ap} is the Lg-wave apparent velocity. The model used V_{ap} of 3.0 km/s.

Results

With the correlations made for all stations (Table 2), it is possible to find the distance and direction of the main shock epicenter in relation to the fixed reference event epicencer. We found the best curve by minimizing the RMS residual between equation 1 and the observed points, by trial and error. Table 2 below shows the results of the crosscorrelation between the reference event and the aftershock.

***Table 2**: Time delay measured by crosscorrelation and the azimuth A_e for each station. Delay = T_r - T_m.*

Network	Station	Azimuth (°)	Delay (s)
BL	BB19B	224.6	-0.0061
	BSCB	190.9	-0.0913
	FRTB*	218.0	0.9767
	ITAB	214.0	-0.0223
	PEXB	316.0	0.3465
	PLTB	208.7	-0.0705
	PMNB	232.0	0.0029
	TRCB	232.2	0.0700
	VABB	204.3	-0.0700
G	SPB	205.3	-0.0471
GT	BDFB	284.0	0.2236
	CPUP	230.2	0.0128
ON	DUB01	165.0	-0.0634
	MAN01	181.0	-0.0463
	TIJ01*	208.0	0.5896
BR	MATE	337.4	0.4050
	MOCA	326.9	0.3968
	NTVD	322.7	0.3950
	PATO	330.0	0.3939
	PIUM	320.2	0.3592
	RET1	322.3	0.3705
	SAMA	334.7	0.4032
	SFTO	337.0	0.3905

*Station that was removed from the analysis.

Figure 3 below shows the fit to the delay between the reference event and the main shock using the results shown in Table 2. The best fit was obtained for the values of distance *d* = 0,74 km and a direction of *Ae* = 1° in relation to the reference event, and a correction to the origin time of *Ao* = 0,17s.

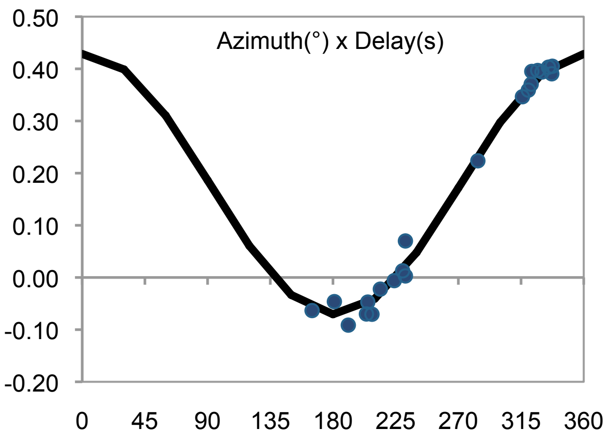

***Fig. 3**. The graph above shows the fitting of the theorical curve (equation 1) to the observed time difference. The vertical axis represents the delay generated in the correlation between the events and the horizontal axis represents the station azimuth in degrees.*

The fitting was obtained by trial and error and the best RMS residual was 0.017s. It is also possible to see that there are no observations between 0 and 135°. This happens because we could not get records from this direction.

With the results obtained from the graph above, it was possible to obtain the coordinates of the main shock (Fig. 4). The origin time was also determined as 13:41:22.4, which differs form the origin determined by Assumpção et al.(2013) by only 0.2s.

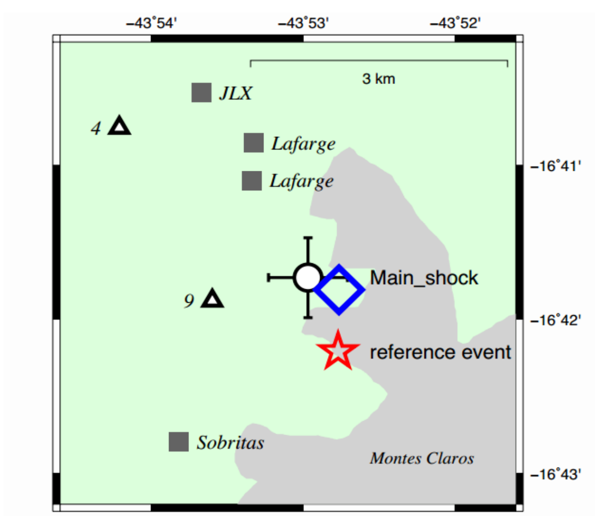

***Fig. 4**: Relative positions between the epicenters. Red star is the reference event epicenter with fixed coordinates, the white circle represent the main shock epicenter calculated by P and S correlation and the blue diamond is the main shock epicenter calculated by the relative determination of Lg waves.*

Conclusions

This method is useful to relocate epicenters of main shocks not recorded locally. When some seismograms are very difficult to be interpreted the correlation can retrieve useful signal. This method of relative determination is easy to be done but requires a large number of stations in all directions. Depth cannot be determined by this method of cross-correlation using surface waves, only the epicenter.

References

Assumpção, M., et al., 2013. The 2012 Montes Claros earthquake sequence in the São Francisco craton: another evidence of inverse faulting and compressional stresses in Eastern Brazil.; 13th International Congress of the Brazilian Geophysical Society held in Rio de Janeiro, Brazil, August 26-29, 2013.

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