# Seismotectonic characterization of the 2012 Montes Claros, Brazil, aftershock sequence

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## Abstract

**The 2012 Montes Claros earthquake (M=4) affected the homonymous town causing alarm among the local population and initiating a sequence of aftershocks which persists until now (April 2013) with events of magnitudes up to 3.6. Shortly after the mainshock, a local seismic network was installed to record the seismicity. Using the more than 170 events detected, we performed velocity structure inversion and full waveform inversions in order to obtain a new 1-D local velocity model and moment tensor solutions. Vp/Vs values around 1.7 were calculated for the upper 0.5 km, while a ratio of ~1.6 was obtained for the lower layer. The analysed seismicity is located to the northwest of the town, at depths mostly lesser than 2 km and corresponds to aftershocks and quarry blasts from the nearby limestone quarries. Moment tensor solutions from two aftershocks indicate reverse faulting with strike NNW and dip to the NE, related to the compressional regional field prevailing in the area.**

## Introduction

On the 19th of May, 2012 a M=4 earthquake struck the town of Montes Claros in the state of Minas Gerais, Brazil, causing alarm among the local population and minor damage on several poorly built houses (see Assumpção et al., this congress). After this mainshock, a seismic network composed by 9 broadband stations was deployed by the Universities of Brasilia and São Paulo in order to record the aftershock sequence (see Fig. 1). More than 170 events were detected by this local network between May and November 2012. More recently, an earthquake M~3.5 occurred on April 18, 2012 which came to confirm that the area is still active and the aftershock sequence has not ended. Here we present the results of 1-D velocity structure inversion and moment tensor solutions for some of the events, aimed to characterize the aftershock sequence and the local velocity structure.

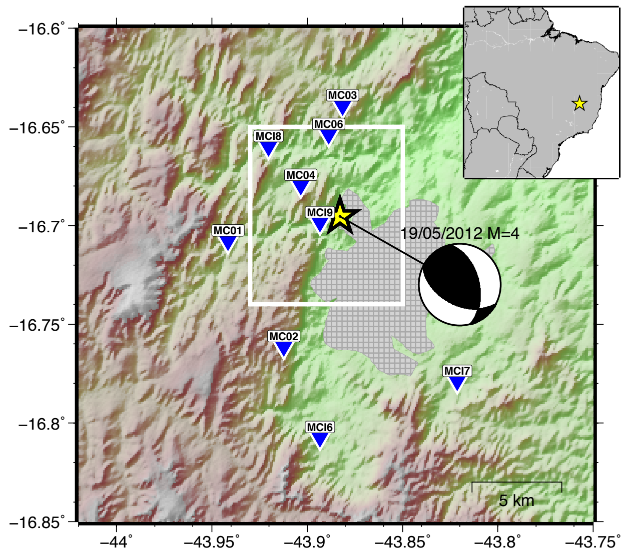


**Fig. 1**. Location of the study area. Yellow star indicates mainshock and composite focal mechanism from Assumpçao et al. (this congress). Blue inverted triangles show seismic stations; shaded grey area shows Montes Claros urban zone. White rectangle indicates area shown in Fig. 4.

## Method

From the continuous record (28/05/2012 - 05/11/2012), a total of 170 events (both aftershocks and quarry blasts from nearby limestone quarries) were detected and manually processed, obtaining 143 locatable events with 667 P and 711 S arrival picks. We calculated an average Vp/Vs ratio of 1.66 from a composite Wadati diagram (Fig. 2). After a preliminary location, a subset of 78 best events in terms of number of observations (>6) and stations gap (<180) was selected as the input dataset for the velocity structure inversion, comprehending 433 P- and 553 S-arrival times. For this processing, the software VELEST (Kissling et al., 1994) and a preliminary (a-priori) P-wave velocity model proposed by Chimpliganond et al. (2010) were employed. We first inverted simultaneously for velocity model and station corrections for the P-wave velocity model, and in a second inversion for the S-wave structure using the fixed best P-wave model from the previous inversion. This process was repeated for 1000 randomly created initial models in order to ensure the obtaining of the minimum 1-D velocity model. The final model and stations corrections were then used to re-locate the whole of the aftershock sequence.

For the waveform moment tensor inversion we employed the software package ISOLA (Sokos and Zahradnik,

2008) given its simplicity and emphasis on the processing of local to regional seismic events. Waveforms were band-pass filtered in the range 0.2-1 Hz. We used fixed epicentral locations and inverted simultaneously for moment tensor, centroid depth and origin time. Isola calculates the moment tensor solution by least squares minimization of the difference between observed and synthetic data, while best position (depth) and time are grid-searched in terms of the absolute value of the correlation coefficient between the data and synthetics.

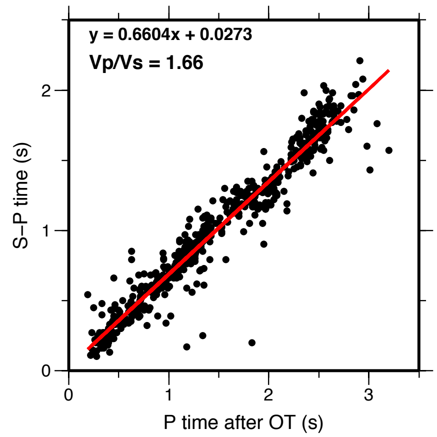


**Fig. 2**. Composite Wadati diagram made from 143 events of the sequence (661 P+S observations).

### Results and Discussion

The results from the 1-D velocity structure inversion are shown in Fig. 3 and Table 1. After the simultaneous inversion, the RMS arrival-time residual was diminished from an initial 0.099 to 0.055 seconds.

**Table 1.** Final 1-D velocity model. Depth is indicated as the top of each layer. (*) = fixed values.

| **Depth** (km) | **Vp** (km/s) | **Vs** (km/s) | **Vp/Vs** |
|---|---|---|---|
| 0.0 | 4.52 | 2.68 | 1.69 |
| 0.1 | 5.22 | 3.00 | 1.74 |
| 0.5 | 5.56 | 3.50 | 1.59 |
| 5.0 | 6.00* | 3.61* | 1.66* |

The final velocity model shows for the upper two layers (limestone) a P-wave velocity of 4.52 and 5.22 km/s respectively, and for the third layer a Vp value of 5.56 km/s, associated to rocks belonging to the cratonic basement. For the upper two layers (0.1 and 0.5 km) a Vp/Vs ratio higher than the average (1.66) was obtained. We infer that this is due to the likely presence of fractures and percolated water on the upper most stratum corresponding to weathered limestone. From 0.5 km down to 5 km the Vp/Vs ratio seems to be lesser than the average, although given the shallow depths of the aftershocks we could only obtain reliable information for the upper first km of crust.

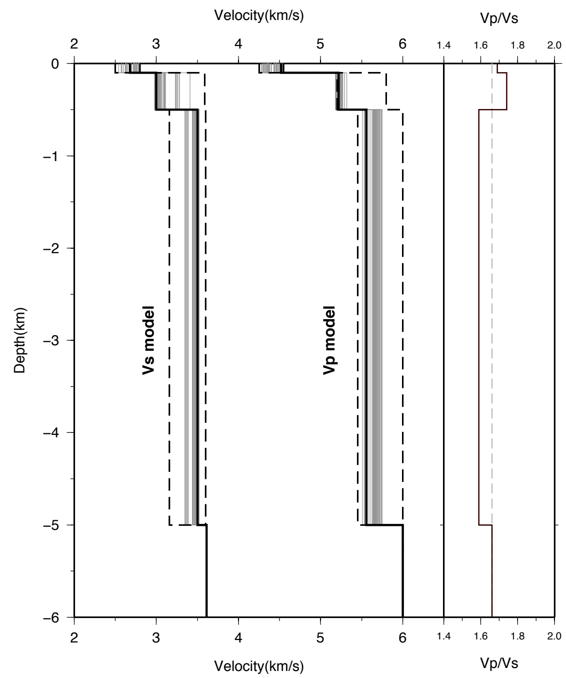


**Fig. 3**. Results from the velocity model inversion. Segmented lines indicate range of initial models, grey lines show best 5% (RMS) of final models, and thick black line shows best final model.

The final location of the aftershock sequence is displayed in Fig. 4, showing that the seismicity is concentrated at the northwest of the town. Hypocentral depths were found down to 2.9 km, although most of the seismicity occurs in the upper two km. The bulk of the epicentres seem to extend for about 1.5 to 2 km (the main activity near station MC09). This extension is larger than our calculation made from scaling relationships (Wells and Coppersmith, 1994) for a reverse fault of magnitude 4 which corresponds to only 0.8 km. This might indicate that the events subsequent to the mainshock of May 2012 are not located exclusively on its rupture area but extend beyond likely associated to increase of stress due to the mainshock.

Most of the events nearby station MC04 are spatially associated to limestone quarries, as well as the events located at ~16.71S/43.9W associated to the Sobritas quarry (see Fig. 4). Therefore these events would correspond to quarry blasts in the vicinity of the town.

Unfortunately, the seismograms of the two biggest aftershocks (M=3.6) presented saturation given the short epicentral distance to stations, and therefore it was impossible to invert for accurate moment tensor solutions. Nevertheless we successfully inverted full waveforms from the recordings of 2 smaller aftershocks (e.g. Fig. 5) in order to derive their moment tensor solutions.

As shown in Fig. 4, the obtained moment tensor solutions presented Mw 2.8 and 1.9 respectively, and reveal a reverse fault with strike NNW and dip to the NE, matching the data presented by Assumpção et al. (see this congress), based on P-wave polarities (Fig. 1). The reverse faulting in this area would be associated to the compressional regime ~EW-oriented that prevails in this area and in general in the São Francisco craton.

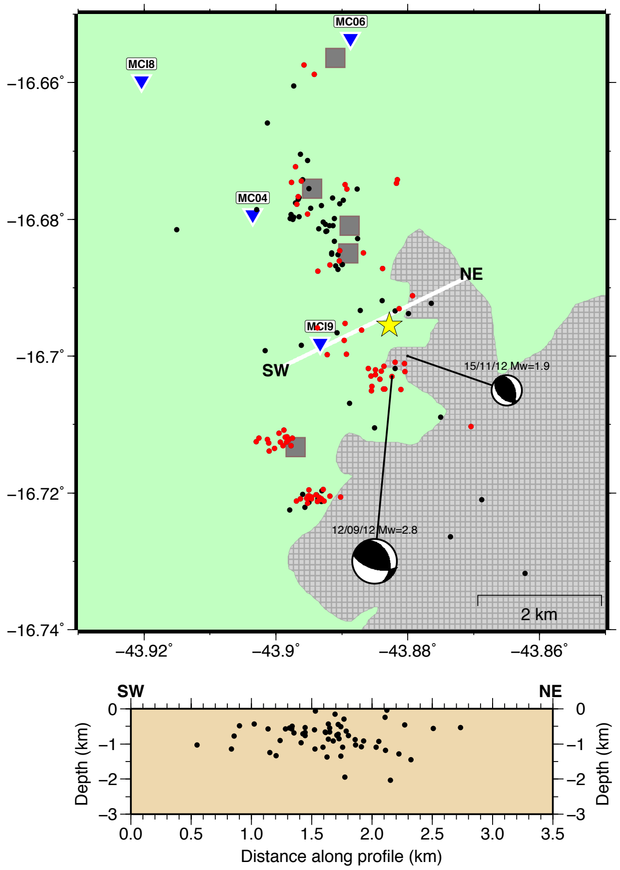


**Fig. 4**. Final locations and moment tensor solutions. White line indicates depth profile shown in bottom plot. Grey squares indicate quarries. Other features same of Fig. 1. Swath of the profile is 4 km.

## Conclusions

In this work we characterized the local seismotectonics of the area around Montes Claros, where a seismic sequence started on May 2012 with an event M=4. The local upper crust presents an average Vp/Vs ratio of 1.66, with higher values for the upper 0.5 km, and then values around 1.6 for the lower 5 km.

The aftershock sequence would be consequence of the reactivation of a shallow (~1-2 km) reverse fault which in turn is originated by the ~EW compressional regime that governs the tectonics of the São Francisco craton. The aftershocks, which continue to occur up to now (April 2013), are located to the northwest of the Montes Claros town, and related to a NNW reverse fault inferred from two moment tensor solutions obtained here. Depths were mainly located in the upper 2 km, and magnitudes of the aftershocks have reached up to 3.6 $M_R$ (Assumpçao et al., this congress).

We expect for the near future to analyse more data (period between December 2012 to present) and calculate more moment tensor solutions, thus providing a more solid and accurate image of what are the characteristics of the Montes Claros seismic sequence and its origin.

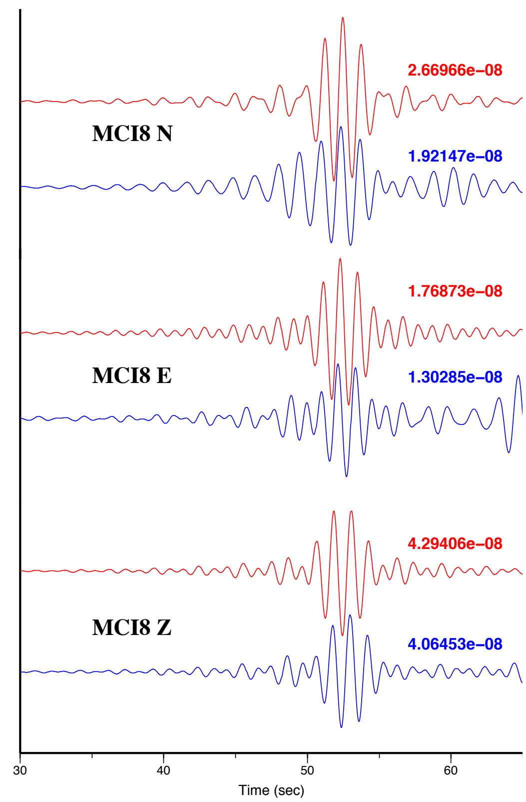


**Fig. 5**. Example of waveform modelling for the event 20121115_0303 with Mw=1.9. Traces correspond to station MCI8 bandpass filtered between 0.6-1 Hz. Observed data and synthetics are shown in blue and red colours respectively. The peak displacement in metres is indicated on the top of each trace.

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