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The Arraiolos – Portugal – Moderate-Sized 2018 (M = 4.9) earthquake of January 15 and aftershocks: Preliminary results

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1- Abstract

On 15 January 2018 at 11:51 UTC, an earthquake of 4.9 ML occurred in the Northeast of Arraiolos region near Aldeia da Serra village. The hypocentral location, determined by Instituto Português do Mar e da Atmosfera (IPMA), has coordinates 38.79 N, 7.93 W at 11 km depth. The focal mechanisms determined by P-wave first motion polarities and waveforms inversion indicate a dominance of strike-slip events with nodal plans near NS (left lateral) and EW (right lateral) directions.

Due to the lower magnitude, the earthquake didn't cause damage but was widely felt in the Centre and South of Portugal mainland. In the vicinity of the epicentre, at the Aldeia da Serra village, it reached a maximum intensity VI, having been felt with intensity IV/V in the city of Évora, about 20 km from the epicentre. The event was also felt with intensity III in Lisbon at more than 100 km from the epicentre. This event caused alarm in the population that haven't felt an earthquake for several decades. It also raised the media attention with many reports and interviews on TV and newspapers.

The main earthquake was immediately followed by a sequence of aftershocks of which the largest one, with ML=3.1, occurred the 1st February, fifteen days after the main shock and was largely felt by the population in the region of Arraiolos.

2 - Seismotectonic framework of the region

The Arraiolos region is caracterized by apparently persistent seismicity of low magnitude (most earthquakes M <4), superficial (h <30 km) and concentrated mainly in Aldeia da Serra and its surroundings (figure 1). For the data of focal mechanisms obtained from the events of 1997 and 1998 (Borges, 2003), are of the strike-slip type (figure 3), which are compatibles with the tectonic model proposed by Araújo et al. (2010). The area where this earthquake occurred, although never it has produced an instrumental earthquake of this magnitude, was being observed by the scientific community for presenting an anomalous seismic activity in the regional context. The seismicity pattern in this area is usually organized by sequences, that seems to show two dynamics: 1) earthquake swarms without any relationship with any major event; 2) a main event followed by aftershocks. In any case, it is a superficial seismicity (H <7km) and of reduced magnitude (M <4).

Although this seismicity occurs in a region cutted by numerous faults, located in the Évora Massif, near the Lower Tejo-Sado basin border, where two important geological structures, with geomorphological evidence of activity are stand out (S. Gregorio and Ciborro Faults), it's not possible yet to establish a direct link between this earthquake and any of these faults. Of the few focal mechanisms that exist from the earthquakes in this region, predominates the strike-slip type.

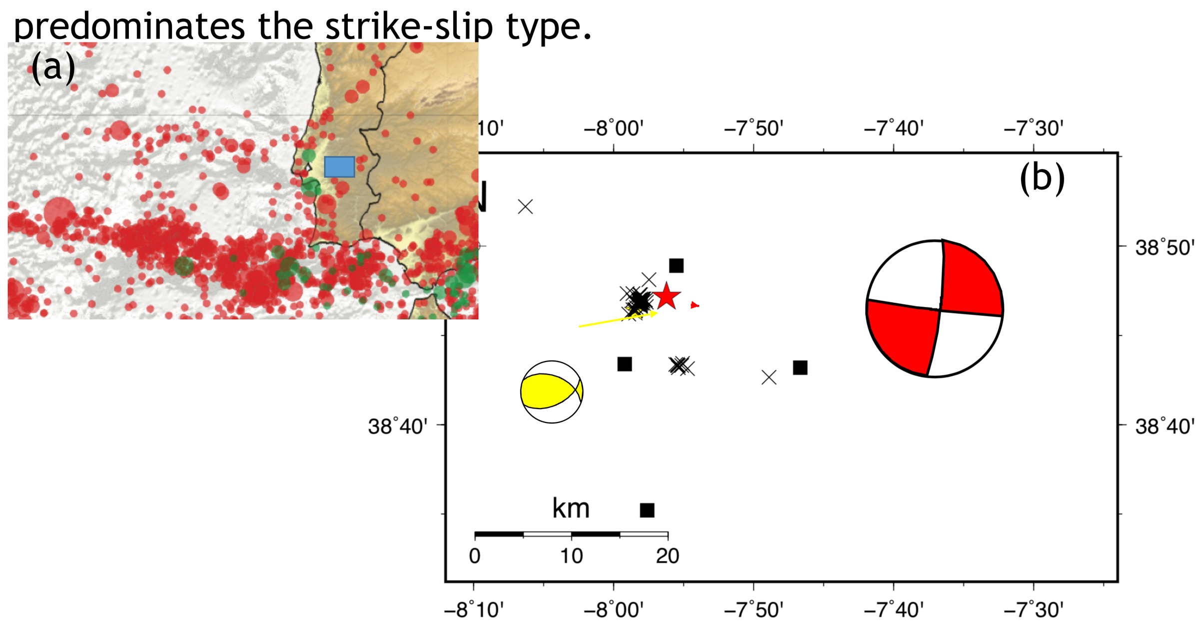


Figure 1 - (a) Geographic localization of Arraiolos Region (blue rectangle); **(b)** Epicentral distribution of earthquakes: Stars and red beach ball correspond to the epicenter of the main earthquake and its focal mechanism (CMT mechanism); Yellow star and beach ball correspond to the epicenter of the main shock fist motion mechanism). Black crosses represents the epicenter of the aftershock sequence.

3 - Previous work about the region

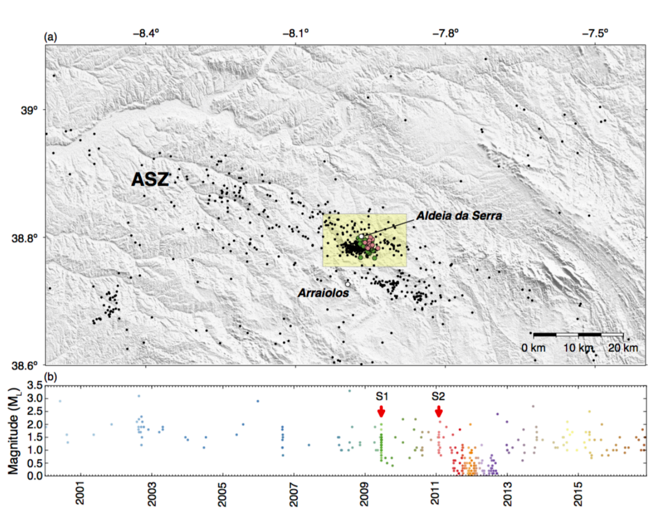


Figure 2 - (a) Seismic swarms in the Aldeia da Serra area of the Arraiolos seismic zone (ASZ). Panel (b) shows the evolution in time of the seismicity in the Aldeia da Serra area, which is delimited by the shaded yellow rectangle in (a) (Matos et al., 2018).

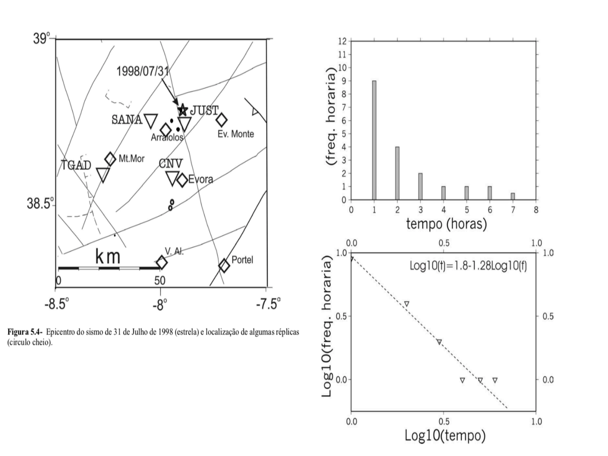


Figure 3 - The 31 de July 1998 (Mw = 4.1) Arraiolos Earthquake and the aftershock sequence analysis (Borges, 2003)

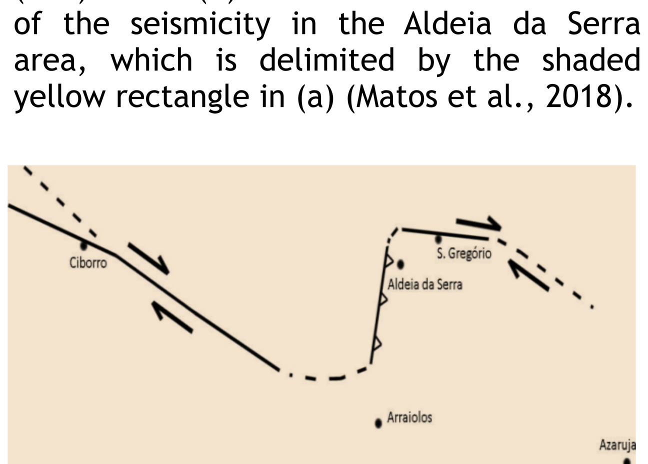


Figure 4 - Model proposed by Araújo et al., (2010), to explain the current seismicity and responsible for the genesis of relief of the study region.

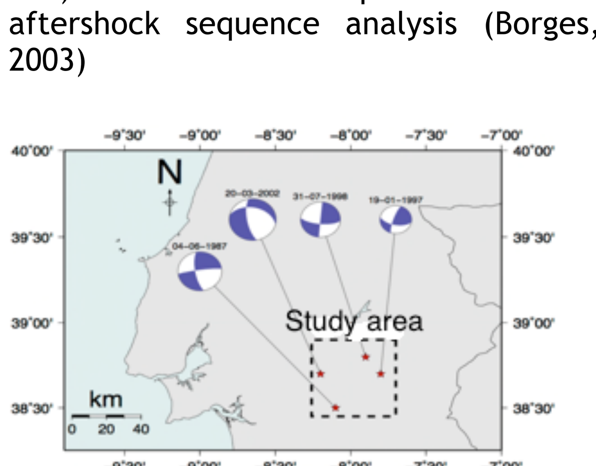
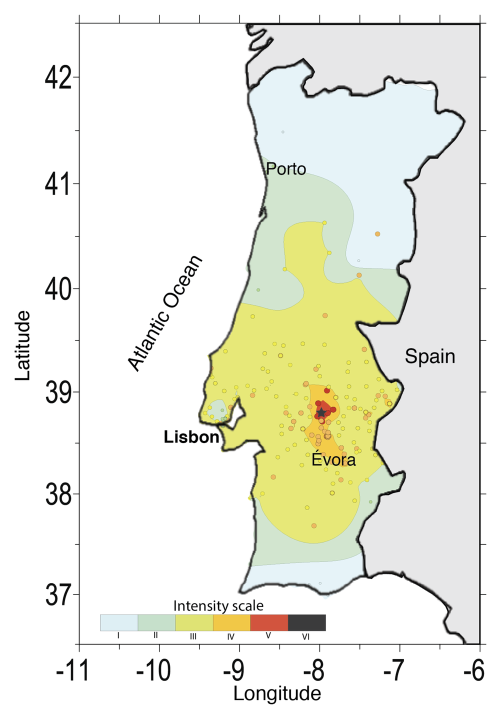


Figure 5 - Focal mechanisms the events 19 January 1997; 31 July 1998; 20 March 2002) and 04 June 1987 (Wachilala, 2015)

4 - Macroseismic Analysis



We performed a study about the macroseismicity associated to the Arraiolos earthquake, that occurred on January 15, (M=4.9), in order to construct a map of seismic intensities. Fieldwork took place in the second half of January, using the questionnaire available in the Web page of Portuguese Institute of the Sea and the Atmosphere (IPMA). We provided the same questionnaire on the Internet, and collected responses from many parts of the country. The results obtained allowed to construct a map of intensities

Figure 6 - Isoseismal map of the 15 January 2018 Arraiolos earthquake (4.9 ML).

5 – Temporary Seismic Network

Two hours after the occurrence of the main shock the Institute of Earth Sciences (ICT) and the Instituto Dom Luiz (IDL) started the installation of a seismic network for aftershock monitoring. The network is composed of 14 Broadband (CMG 6TD, 30 s) and 21 short period (CDJ, 2.0 Hz) portable seismic stations located around the epicentral area, with inter-station distances varying between 2 to 15 km. Thus, the coupling of the 35 temporary stations with IPMA's permanent network allowed the collection of a high-quality dataset of events with good azimuthal coverage, well controlled hypocenter depth and focal mechanisms.

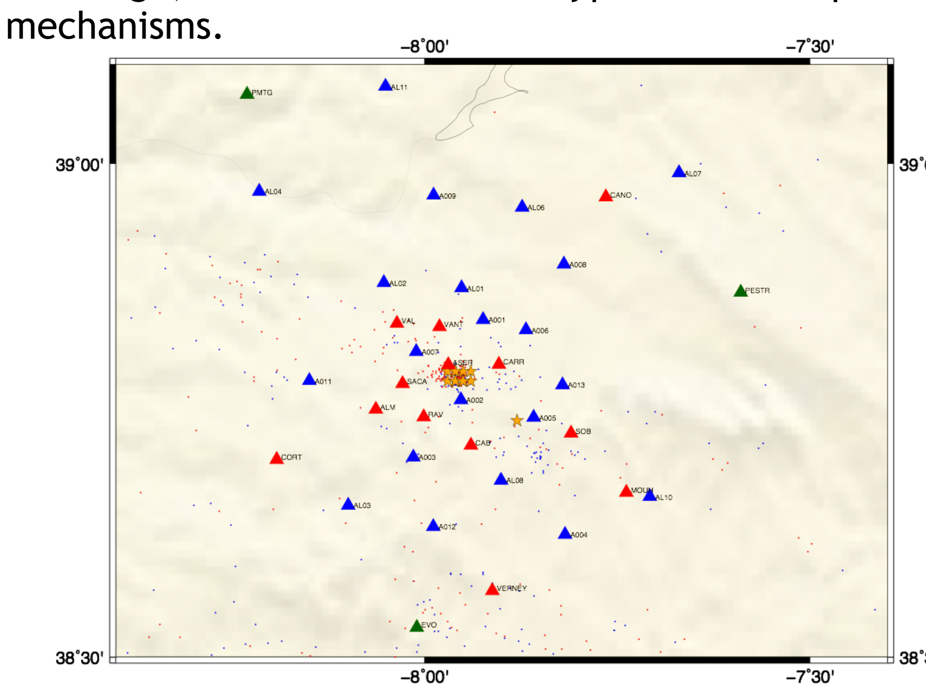


Figure 7 - Arraiolos Temporary Seismic Network deployed after the Arraiolos earthquake of 15 January.

- SP stations (2 and 4.5 Hz - IDL)
- BB station (Guralp 6TD 30 s - Uevora)
- IPMA stations (BB)

6 – Analysis of aftershock sequence

A good collection of well azimuthally distribution data have been recorded by the National seismic Network (IPMA) and and temporary Arraiolos Seismic Network. From this data it was possible locate with good precision the epicentral parameters. A statistical analysis of the seismic data is shown in the figure 8.

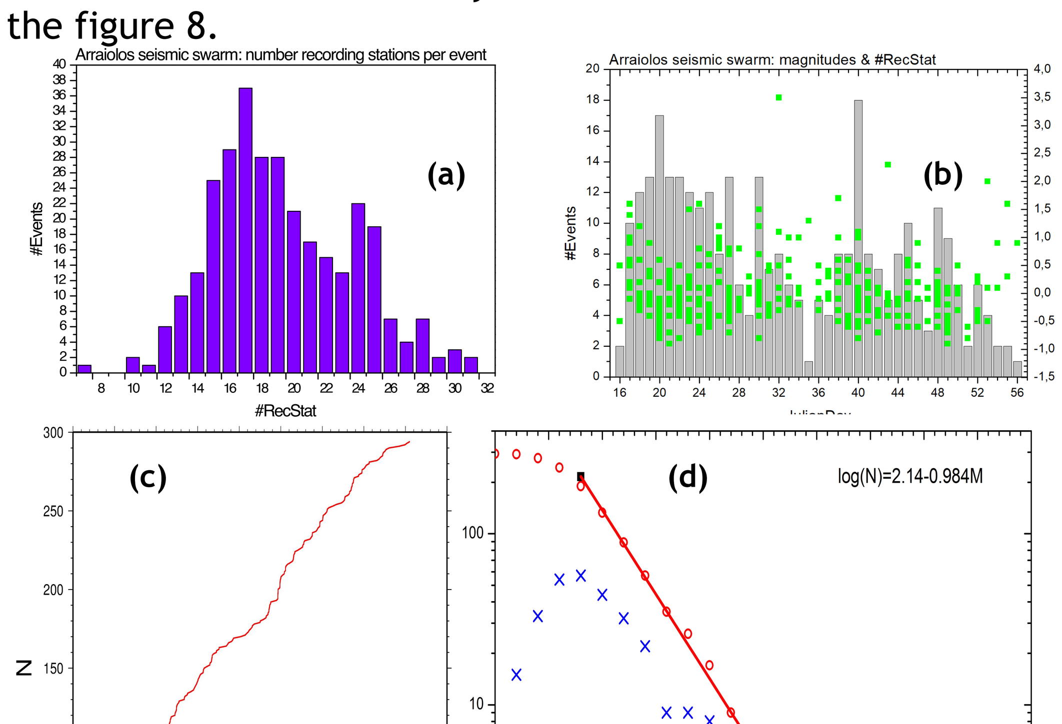


Figure 8 - (a) Number of recording stations per event; **(b);** Temporal distribution of number of events and magnitude; **(c)** Cumulative Number of aftershocks **(d)** Frequency-magnitude distribution of Gutenberg-Richter relationship for the aftershock sequences (blue=non-cumulative; red - cumulative)

7– Event detection and Localization

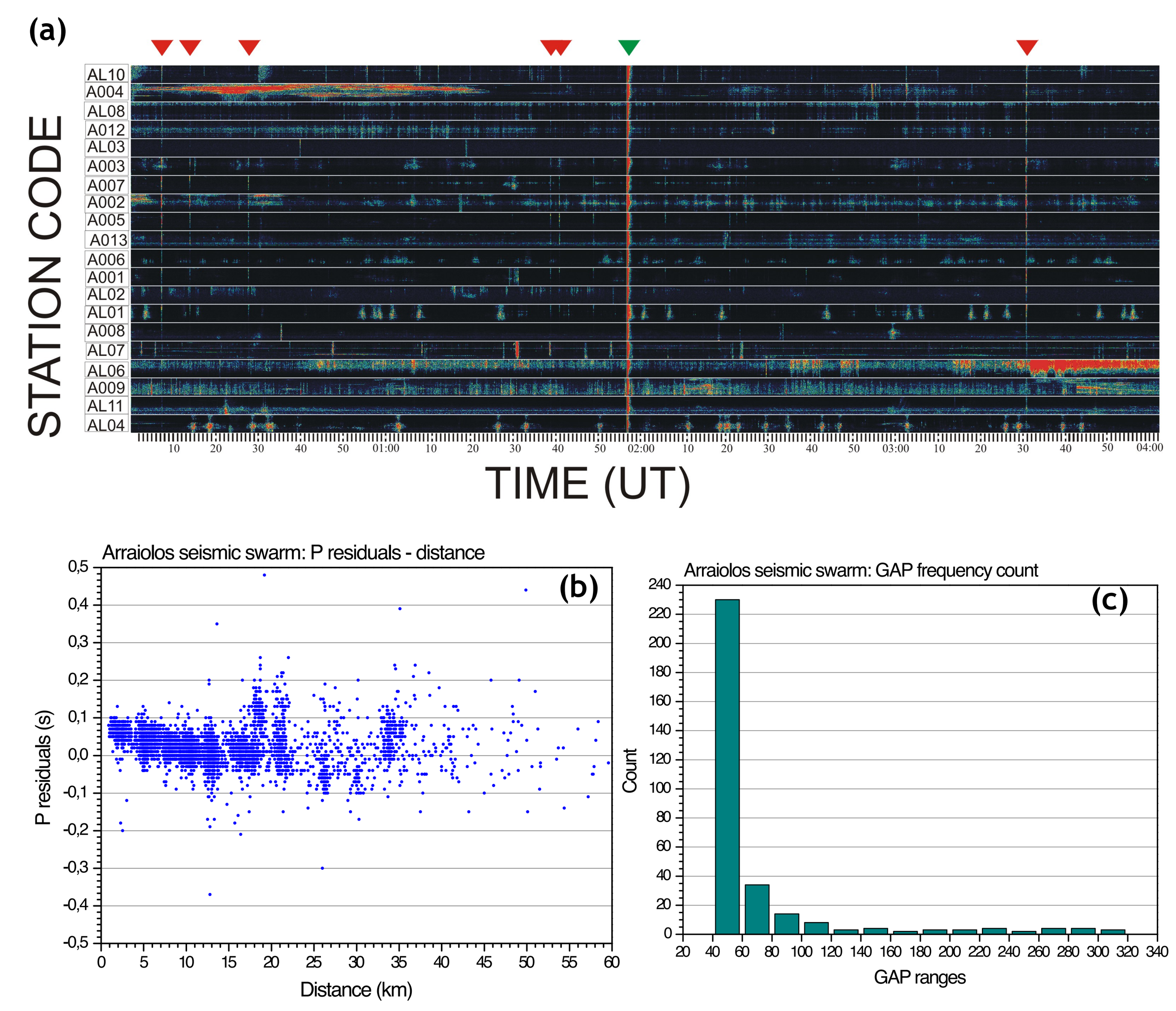


Figure 9 - (a) Temporary network spectrogram, composed of spectrograms of vertical-component seismic data recorded on January 23rd 2018. The coherent vertical line marked with a green arrow correspond to an event detected and reported in real-time by IPMA with the permanent network data. Events detected by the temporary network spectrogram method that had not been previously detected are marked with red arrows; **(b)** P wave residuals as function of epicentral distance; **(c)** distribution of number of recorded events by class of the maximum station gap.

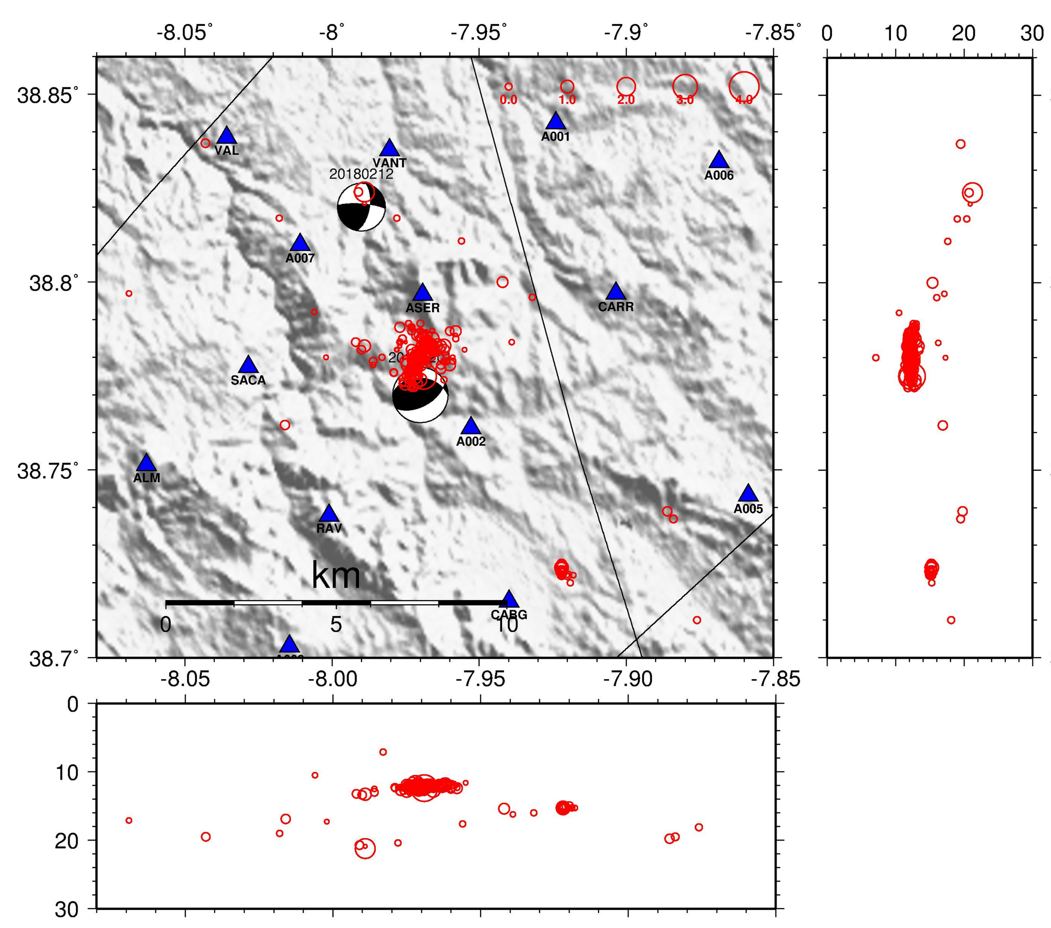


Figure 10 - Epicentral and hypocentral distribution of seismic sequence. Red circle and beach balls correspond to the epicenter of the aftershock sequence and and focal mechanism of two earthquakes (earthquake data processed with SEISAN software; azimuthal GAP < 180◦).

8 - Moment Tensor Solution of the Main Shock

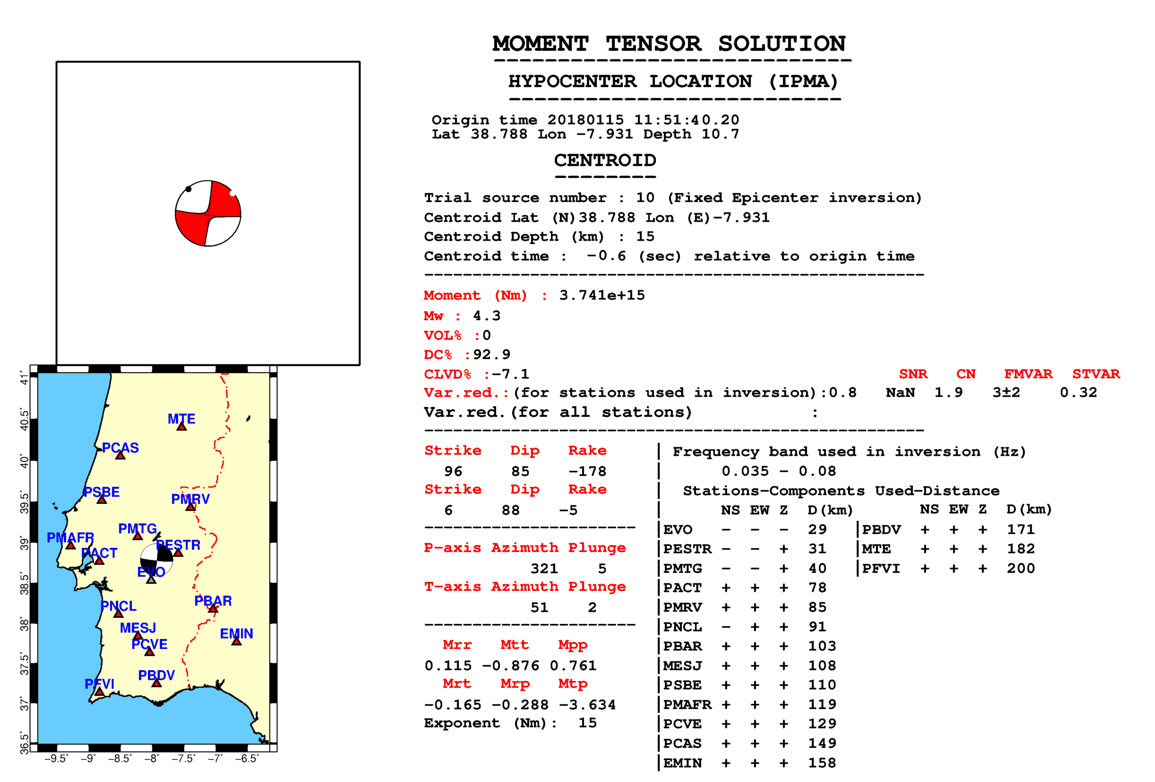


Figure 11 - CMT solution of the Arraiolos event, using 15 stations at high-frequency range (0.035-0.8 Hz). We applied the DC-constrained inversion and obtained a very high global variance reduction 0.8.

9 – Conclusions

This temporary network allowed the detection of several low magnitude events not detected by the permanent network, lowering significantly the magnitude detection threshold. The fine azimuthal coverage allowed also a good precision on the determination of the hypocenter parameters. This is an work in progress and from a more depth analysis of the data we expect to extract more definitive conclusions about seismicity and seismotectonic of this region.

Acknowledgements

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