AZORES 40'80 MEETING

06-07 October 2020

TÉCNICO LISBOA · UAc Universidade dos Açores · Universidade de Évora

INTERNATIONAL MEETING
40 YEARS OF THE 1980 AZORES EARTHQUAKE

Congresso internacional
40 anos do sismo dos Açores de 1980

PROCEEDINGS BOOK

UNIVERSITY OF ÉVORA

AZORES 40'80 MEETING

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Welcome Address

It is our great pleasure to organize the 40 Years of the 1980 Azores Earthquake (40|80) that will be held online between 6th and 7th October 2020.

As we move the 40|80 completely online, we look forward to offering you the same vibrant programming, impactful networking, and opportunities to reflect and connect over the emerging and salient topics in our field.

The theme of the 40|80 is to remind the 40 years of a devastating earthquake that affect mainly Terceira Island but also Graciosa and São Jorge Island. At 40|80, we would promote a state-of-the-art of the seismicity in general but also topics like volcanic seismicity, tsunamis, historical seismicity, crustal deformation, tsunamis, seismic hazard and risk. Since earthquakes cause economic and social losses, topics like case studies on the rehabilitation of buildings, retrofit techniques of heritage monuments, an overview of Eurocodes and construction codes, social and economic aspects are paramount to understand their impact and how to mitigate them. Thus, we would like at 40|80 to provide the time and place where attendees from around the world can share their experience and knowledge to build disaster-resilient societies and to create new directions through integrating various fields

The virtual meeting of 40|80 will include sessions and keynotes.

Organization

Organizing Committee:

Full Professor Carlos Sousa Oliveira – Chair – Instituto Superior Técnico, Lisboa, Portugal

Doctor João Fontiela – Vice Chair – University of Évora, Évora, Portugal

Professor Francisco Cota Rodrigues – University dos Açores, Azores, Portugal

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Doctor Mónica Amaral Ferreira – Instituto Superior Técnico, Lisboa, Portugal

Full Professor Mourad Bezzeghoud – University of Évora, Évora, Portugal

Support

The 40|80 is a joint organization of the following institutions:

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Three-dimensional crustal image of Arraiolos aftershock sequence, earthquake of M=4.9, in Alentejo region, Portugal.

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ABSTRACT

This work presents the results obtained after the Arraiolos aftershock sequence tomographic inversion in terms of velocity distribution. The study deals with the 4.9 ML magnitude earthquake (M_W4.3, Vales et al., 2018) which occurred on January 15th, 2018 at 11:51 UTC in *Aldeia da Serra* in the Northeast of Arraiolos (Alentejo, Portugal). The hypocentral location, determined by the Instituto Português do Mar e da Atmosfera (IPMA), has coordinates 38.79 N, 7.93 W at 11 km depth. After the main shock occurred, 437 events were recorded and inverted in order to obtain a three-dimensional velocity image of the region. These records were performed by 34 temporary stations during a period of 6 months including IDL and Evora stations. On a first stage of study, preliminary results were presented by *Hamak et al. (2020)* coming from the tomographic inversion of 317 aftershocks recorded by 21 short-period stations (CDJ, 2.0 Hz), of the Instituto Dom Luiz (IDL, Lisbon), along a month of records. After analysing the obtained three-dimensional velocity model, a poor ray coverage has been noticed leading to a poor model resolution especially on the edges of the studied area. Thus, additional stations and local data have been integrated to this second stage of study in order to increase the ray coverage which leaded to a more accurate three-dimensional velocity model.
Local Tomography Software (LOTOS program, Ivan Koulakov (2009)) was used to perform all the inversions, in order to relocate accurately the aftershock sequence and obtain velocity contrast over the entire region of interest. This program gives the ability to perform a simultaneous inversion of sources location and velocity model. Comparison between preliminary and new aftershock sequence inversion results are presented in this study in order to show the evolution and improvement of the 3D velocity model quality.
Nevertheless, despite the increasing model resolution, the studied area is still too small for a good understanding of the complex tectonic of the area. Therefore, in order to extend the area of study, local, regional and teleseismic events must be integrated. As tomographic resolution is related to waves propagation, as this second stage of study demonstrated, by increasing the ray density of the region a more accurate and reliable 3D velocity model will be obtained. Thus, the tectonic features responsible for the seismic activity in the region will be better constrain.

Keywords: Local seismic tomography, Arraiolos earthquake, seismicity, seismogenic zone, LOTOS-09 code

INTRODUCTION

An earthquake occurred in *Arraiolos* a region localised in the north of *Évora (Portugal)* on the 15th of January 2018. This earthquake has recorded a magnitude of ML4.9 which was the highest magnitude in the region since 1969 (~M8.0) and has been located in a depth of 11km. After this main shock occur, several questions about the tectonic of the region were generated.

Therefore, geological and seismological studies have been carried out in the region (Wachilala et al (2019), Araújo et al (2018), Matos et al (2018), Borges et al (2018), Matias, et al (2019)), putting in light a moderate seismicity with an apparent difficulty to find correlation between outcropping faults and earthquakes distribution. Indeed, this is due to the slow plate deformation that generates earthquakes with a magnitude that barely reach M5. Also, the mapped faults are not active and not responsible for the seismicity observed in the studied region. This complexity in the understanding of tectonic events bring difficulty to seismological interpretation.

Nevertheless, a geological study made by Araujo et al. (2010), have detected lineaments which had been related to active faults. These faults are *São Gregorio* and Ciborro faults describing a strike slip focal mechanism, that are intersecting in Aldeia da Serra, highest point of the region, which shows compression motions. Indeed, this geological model proposed by Araujo et al. (2010*)* is a hypothetical model that must be explored. Thus, the two different types of deformation bring us to image the earth interior in order to figure out in more details the deformation within depth.

For this, a Local Tomography Software called LOTOS created by Ivan Koulakov in 2009 were used for the inversions. The choice of this program was based on its capacity to perform a simultaneous inversion of sources location and 3D velocity model. In a first stage of study, the aftershock sequence of 317 earthquakes recorded, along a month, by 21 short period stations coming from Arraiolos temporary seismic network (ATSN) were inverted in order to obtain a preliminary three-dimensional velocity distribution.

In the other hand a second stage of study was conducted performing an inversion of 437 aftershocks using the same program in order to increase the ray coverage and obtain a model with better quality. This aftershock sequence was recorded by 34 temporary stations composed of the 21 short-period stations (CDJ, 2.0 Hz) of the Instituto Dom Luiz (IDL, Lisbon) used in the first stage of study and 13 broad-band stations (CMG 6TD, 30s) of the Institute of Earth Sciences (ICT, Évora). By observing images of velocity distribution in three directions, an improvement of the model quality and resolution were observed.

Before proceeding to real data inversion an evaluation of the resolution limits of the area should be conducted. Thus, synthetic tests with several types of parametrization are set using checkerboard method. The reconstructed model obtained will be analyzed in order to target regions of poor and good resolution that must be considered in the interpretations. After performing the synthetic inversion, it is the place of real data to be inverted. A three-dimensional velocity distribution is obtained, and the sources relocated in a narrow area within this model. By observing the anomalies and the events location, we concluded that more data must be added to this study in order to extend and image the region with a better resolution.

MAIN RESULTS

By comparing preliminary and current results, an improvement of model quality and resolution were observed. By increasing the ray distribution, adding the 13 broad-band stations and aftershock sequence to the study, the area was better covered by waves and thus leaded to results improvement. Moreover, the aftershock distribution is starting to show a slight trend within depth and an anti-correlation between P and S velocity anomalies is still observed beneath both cross sections. The spatial distribution of aftershocks, along axis 2A2B (Fig. 1), shows alignment of aftershocks with a length of 8 km between 12 and 14 km depth. Nevertheless, despite the increasing resolution of the model, additional data still have to be integrated to the study in order to obtain better results and constrain accurately the seismogenic zone.

CONCLUSION

This tomographic study was performed for the first time in Arraiolos, in order to find geological features which could be responsible for the seismicity of the region. Also, it allows us to relocate sources within depth that knows an improvement simultaneously with the 3D velocity variations.
Nevertheless, despite the improvement of model resolution the ray distribution is still poor to image the entire area. The software is going to select the area of best ray coverage which tended to be smaller than the one that we wanted to image in the beginning of the inversion. Even across this small region, the ray distribution was not sufficient for an optimal coverage. Hence, more data must be added to this study in order to have a better coverage of the area in terms of ray distribution that will allows us to make more consistent interpretations. Data that we need to introduce, besides local events, are regional and teleseismic events recorded by the same temporary station network as used for the 437 aftershocks recordings. In addition to this temporary station network, we thought about considering the Instituto Português do Mar e da Atmosfera (IPMA) and DOCTAR networks which will bring supplementary records. By integrating these additional data to the study, we will manage to explore in more details the subsurface and figure out more accurately the causes of the seismic activity which drives the region.

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RAV

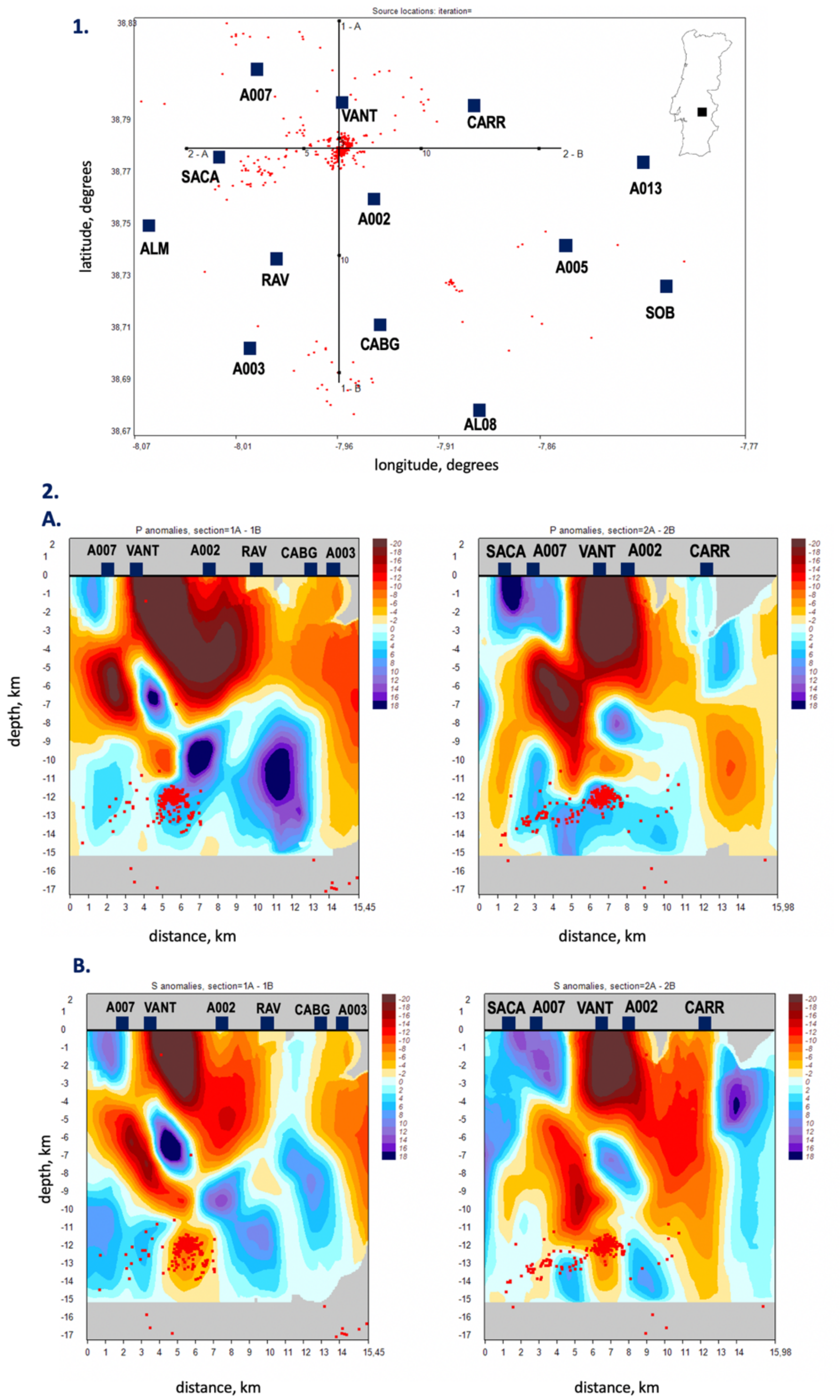

Figure 1. 1- Localization of earthquakes and stations used. 1A-1B and 2A-2B represents the selected cross sections. 2 - Real data inversion results A- P anomaly distribution beneath the two cross sections 1A-1B and 2A-2B. B- S anomaly distribution beneath the two cross sections 1A-1B and 2A-2B. *Blue squares* represent seismological stations and *red dots* indicate aftershocks locations. The scale anomalies shown at the top right of each figure is given in %.

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