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18806. A P-wave Seismic Reflection Study of an Intraplate structure: the Azambuja Fault, Portugal

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Main objectives

1) Improve seismic hazard evaluation of the Lisbon, Portugal and the Lower Tagus Valley area; 2) To locate and image a fault under the Holocene alluvium that is known to affect Pliocene sediments and deform Pleistocene units; 3) confirm or not if the fault affects 14 000 years aged sediments;

New aspects covered

First image of the active fault in the Holocene cover

Summary

The Azambuja fault is a NNE oriented fault zone located 50 Km north of Lisbon, the capital of Portugal and has been considered as a possible source of historical earthquakes. Therefore, its study is a priority in seismic hazard evaluation. It has a clear morphological signature and Miocene and Pliocene sediments are tilted eastwards and cut by steeply dipping meso-scale faults presenting reverse and normal offsets with a net downthrow to the east. Neotectonic studies indicate Quaternary slip on the fault in the range 0.05 to 0.06 milimetres/year. However, the fault has not been observed to affect Pleistocene or Holocene sediments. Here, we present a P-wave seismic reflection study carried out to image the fault below the Holocene alluvium cover southwards of the fault outcrop. We show that the fault is present below the Holocene cover as suspected and, with the aid of nearby well data, that fault segments are affecting the 14 000 year aged alluvium cover, suggesting a larger slip rate then previously admitted.

Topic(s)

1. Environmental Geophysics and Natural Hazards
2. Near Surface Geophysics for Forensic Applications
3. Not selected

Presentationtype

Oral only

Introduction

The Lower Tagus Valley, located in central Portugal, includes the densely populated area of Lisbon. The region has been affected in the past by multiple earthquakes causing loss of lives and considerable material damages. It is, therefore, important to evaluate correctly the seismic hazard potential of the region. In the last 1000 years, large plate-boundary-generated earthquakes occurred in 1755 and 1969, whereas local intraplate earthquakes in this area occurred in 1344, 1531 and 1909 (Fig. 1). In this work, we study the Azambuja fault, which is an intraplate structure located about 50 km north of Lisbon.

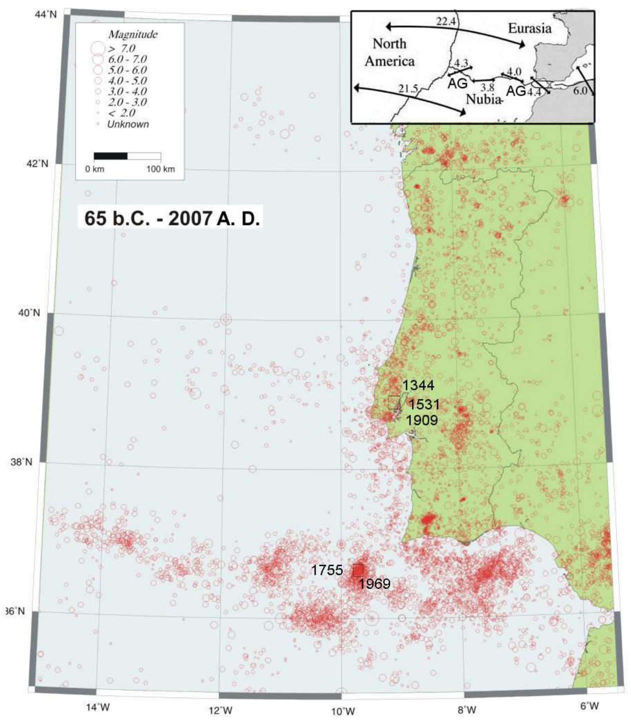

Fig. 1 *Seismicity of Portugal mainland and the adjacent offshore area. Source: Instituto de Meterologia; Squares represent historical earthquakes located in the Lower Tagus Valley area after Martins and Mendes-Victor [1] and offshore. Inset: Eusasia-Nubia plate boundary and relative motions of the Eurasia, Nubia and North America lithospheric plates in mm/yr; AG: Azores Gibraltar fault zone.*

The Azambuja fault is considered to be an active fault ([2; 3]) but its activity in the Holocene has not been established so far. Due to small slip-rates and the long recurrence time interval in the area ([4;3]), the surface ruptures are easily erased by erosion and are covered by the river Tagus sedimentation. To study the fault activity in the alluvial plain of the Tagus, the use of geophysical methods is thus needed.

The seismic reflection method is one of the most suitable methods in clayey and shallow water-table environments and has been applied many times in the past to locate faults (e.g. [5; 6; 7]). Here, we test the P-wave seismic reflection profiling to study the presence of the Azambuja fault in the Holocene sediments at the Tagus alluvial plain.

Together with well data located at both ends of the seismic reflection profile, we show that the fault affects the 14 Kyear old alluvium in at least two places. The acquisition of a shear wave seismic reflection profile followed by the opening of a trench will be the next steps to study the Azambuja fault activity during the last 14 Kyears.

Seismic reflection data acquisition and processing

The data were recorded with an end-on geometry using 36 active receivers and a source-receiver spacing of 1.5m, providing a nominal CMP fold of 18. Figure 2 shows the location of the previously known Azambuja fault relative to the seismic profile. The source to the nearest receiver distance was 4m; an accelerated weight drop seismic source was used. The data were acquired over a flat, hard, non-asphalt road and the receivers were planted close to the edge of the road.

The compacted surface condition was responsible for a strong reverberation in the source signal; this reverberation was difficult to be eliminated from the shot gathers through processing. The processing included geometry installation, bandpass filtering, first arrival muting, f-x deconvolution, residual (surface consistent) static correction, velocity analysis and CMP stacking.

The data were afterwards migrated with a phase-shift algorithm followed by post-stack filtering and amplitude enhancement. Non-migrated and migrated stacked sections for the Azambuja P-wave reflection profile are shown in Figure 3. In the migrated image we have overlain the fault interpretation.

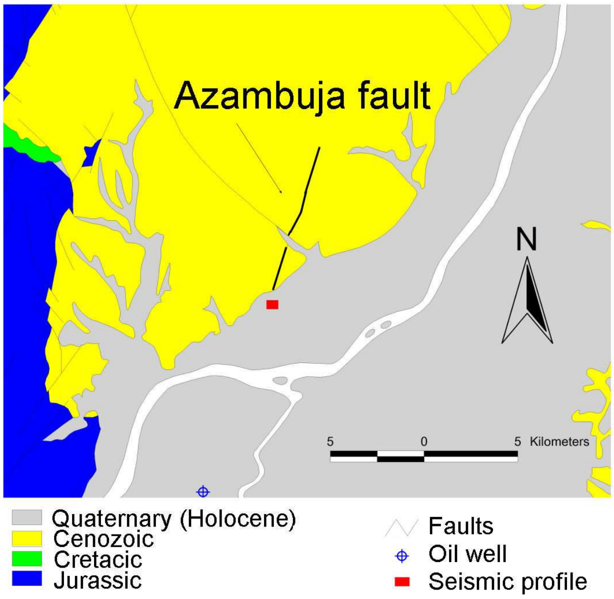

Fig. 2 *Location of the seismic reflection line relative to the anticipated Azambuja fault. The geology is simplified after reference [8].*

Well data and seismic interpretation

Several wells are available at a distance range of less than 1 km from the seismic reflection profile. These wells were earlier drilled for water supply and geotechnical investigation purposes. They are located at the western and eastern ends of the seismic profile, giving a good control to the depth of the Holocene alluvium in this area.

The sandy and clayey alluvium is thicker to the west of the profile, reaching about 33 m depth. To the east of the seismic reflection profile, an average depth of 17 m is found for the alluvium.

Using an 1D velocity function obtained from the stacking velocity field, we have depth-converted our profile, which is shown at an approximate 1 : 1 vertical/horizontal scale in Figure 4. The image of the fault suggests the presence of a steep reverse fault verging to the east, with some splay faults reaching the surface, in agreement with the geological outcrop data [3]. Some of the observed normal faults maybe the result of slight stretching of the sediments due to bending.

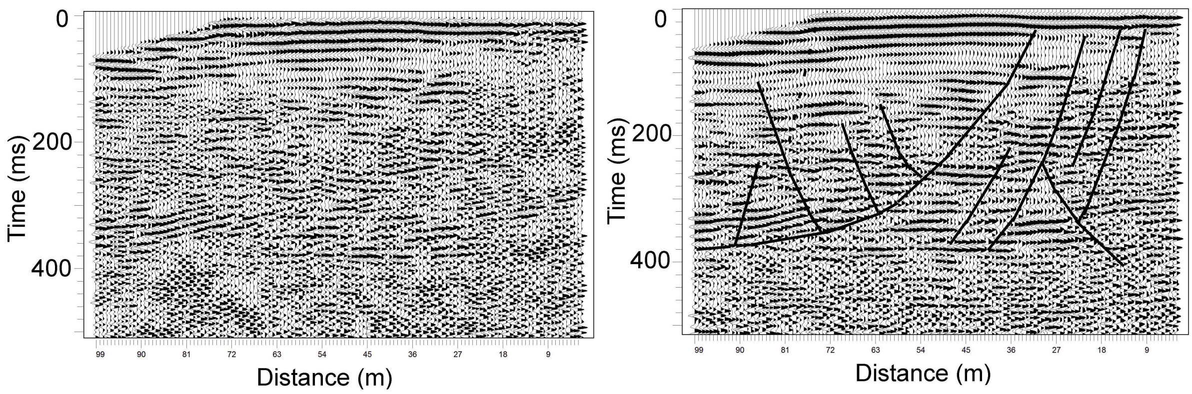

Fig. 3 *Non-migrated (left) and migrated (right) time stacked seismic sections for the Azambuja P-wave seismic reflection profile. The* migrated section shows our interpreted fault segments (black lines).

We can also see that the pattern in the shallowest seismic reflectors showing strong amplitude and a good continuity is in good agreement with the depth of the alluvium sediments deduced from available well data.

We can further identify that this seismic pattern is disrupted at four locations- around location 30 m, and also approximately at 25, 15 and 10 m lateral locations. The first location (30 m) seems to mark a sudden decrease in the alluvium cover thickness to the east. At the three easterly locations, the faults seem to be approaching the surface. The non-migrated image indicates that these faults are less affected by the processing steps which are meant for signal-to-noise ratio improvement; these faults are possibly affecting the whole alluvium cover.

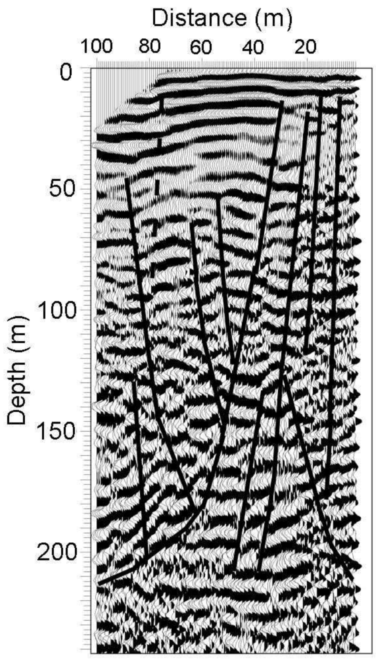

Fig. 4 Migrated, depth-converted seismic section using a 1D velocity model derived from the average stacking velocity field. The section is presented here at an approximate 1:1 horizontal:vertical scale.

To confirm this, a shear-wave seismic reflection profile is now being planned. Shear (S) waves can, in this type of unconsolidated soils, provide superior resolution to P-waves [9; 10]. Using the typical velocity and frequency values, the vertical resolutions in this type of soils and at locations about 10 km south of Azambuja have been found to be about 2-3 meters and 0.3 meters, respectively, for P waves [4] and S waves [10].

Therefore, an S-wave seismic reflection profile is expected to be able to adequately image the alluvium cover and check if the fault segments affect the near surface. That will require a careful investigation of the shot gathers, horizon-specific velocity analysis and a search for faulting-related diffractions as well as discontinuities in the reflectors in the stacked sections [10]. The opening of trench should follow in case the fault segments are found to approach the near surface region, thereby allowing constraining the recurrence rates of the fault and helping to estimate the maximum expected earthquake magnitude.

Conclusions

The Azambuja fault is known to have deformed the Miocene-to-Pliocene sediments; post-Pliocene (Plistocene) deformation has been inferred, but so far it has not been possible to establish directly its effect on the Holocene sediments. Here, we present first evidence suggesting that the fault has affected the alluvial sediments of age 14 Kyears. We have acquired and processed a P-wave seismic reflection dataset. We have interpreted with the aid of the available well data. The interpretation supports the existing hypothesis about the activity of this fault in the Holocene. Next, we plan to acquire an S-wave reflection dataset along the same line in order to image the fault in the alluvium with greater details and to check if the fault segments are approaching the surface. If the latter is true, then a trench will be opened in order to study the fault behaviour in the last 14 Kyears, thereby improving considerably the assessment of seismic hazard potential in this area.

Ackowledgements

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