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SEISMICITY AND EARTHQUAKE RISK IN PORTUGAL

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Abstract: The workshop "Earthquake monitoring and Earthquake Risk in WEstern Mediterranean" (EERWEM) will summarize the current knowledge, on-going projects and research plans with regard to seismic activity and risk in the region. This work is organized in two topics: i) presentation of our current research on seismic activity and earthquake risk in the Western Mediterranean region, particularly in Portugal and ii) a short training course about seismic data processing and waveform analysis. Some applications based on broad band teleseismic wave form will be presented using software currently available on the internet sites.
Ongoing research projects within the group will be presented and discussed. Some preliminary results will be shown, in particular for the following research topics: i) Seismic Tomography of the Continental Lithosphere of Algarve (Portugal); ii) Finite seismic source modelization and strong motion prediction in Portugal and iii) the University of EVOra (UEVO) Broad Band seismic station (STS2) and upcoming temporary broad band network.

Introduction

The interaction between Iberia and Africa results in a complex region located in the western part of the Eurasian-African plate boundary. This region corresponds to the transition from an oceanic boundary (between the Azores and the Gorringe Bank), to a continental boundary where Iberia and Africa meet (Borges et al., 2001; Buforn et al, 2004). Portuguese mainland is characterised by a low instrumental seismicity, with a large scattering (Fig. 1). The largest instrumental earthquake occurred in 1969 (Mw~7.3), but since then, only two earthquakes have reached a magnitude of 5 or more (2003/07/29, Mw=5.4 and 2004/12/13, Mw=5.4). These earthquakes all struck the region located between the Horseshoe Abyssal Plain and Cabo Sao Vicente. Most major submarine canyons are aligned with NE-SW trending faults onland. These faults have been reactivated since Miocene, and historical records of large earthquakes show that they are still active today. Indeed, large earthquakes have occurred in the past, but since the main seismogenic centres are located offshore, their epicentral locations are very uncertain. The largest earthquake ever reported in Europe occurred in the region, in 1755 (Mw~8.5), and was accompagned by a massive tsunami. For this event, at least four different seismogenic origins are currently supported by various authors (Moreira, 1985; Buforn et al., 1988; Baptista et al., 1998; Zitellini et al., 2001; Gutscher et al., 2002; Terrinha, 2003; Villanova et al., 2003).
This work is planned on two topics: i) presentation of our current research on seismic activity and earthquake risk in the Western Mediterranean region, focused particularly on Portugal and ii) a short training course about seismic data processing and waveform analysis will be done. Some applications based on broad band teleseismic wave form will be presented using body wave analysis software currently available on the internet sites.

Three research projects in progress, which may be the link for future collaboration between the CGE team and some associated partners of the EERWEM project, will be presented and discussed. Preliminary results will be shown, in particular for the following research works: i) Seismic Tomography of the Continental Lithosphere of the Algarve (Portugal); ii) Finite seismic source modelization and strong motion prediction in Portugal and iii) The University of EVOra (UEVO) Broad Band Station and the future perspectives.

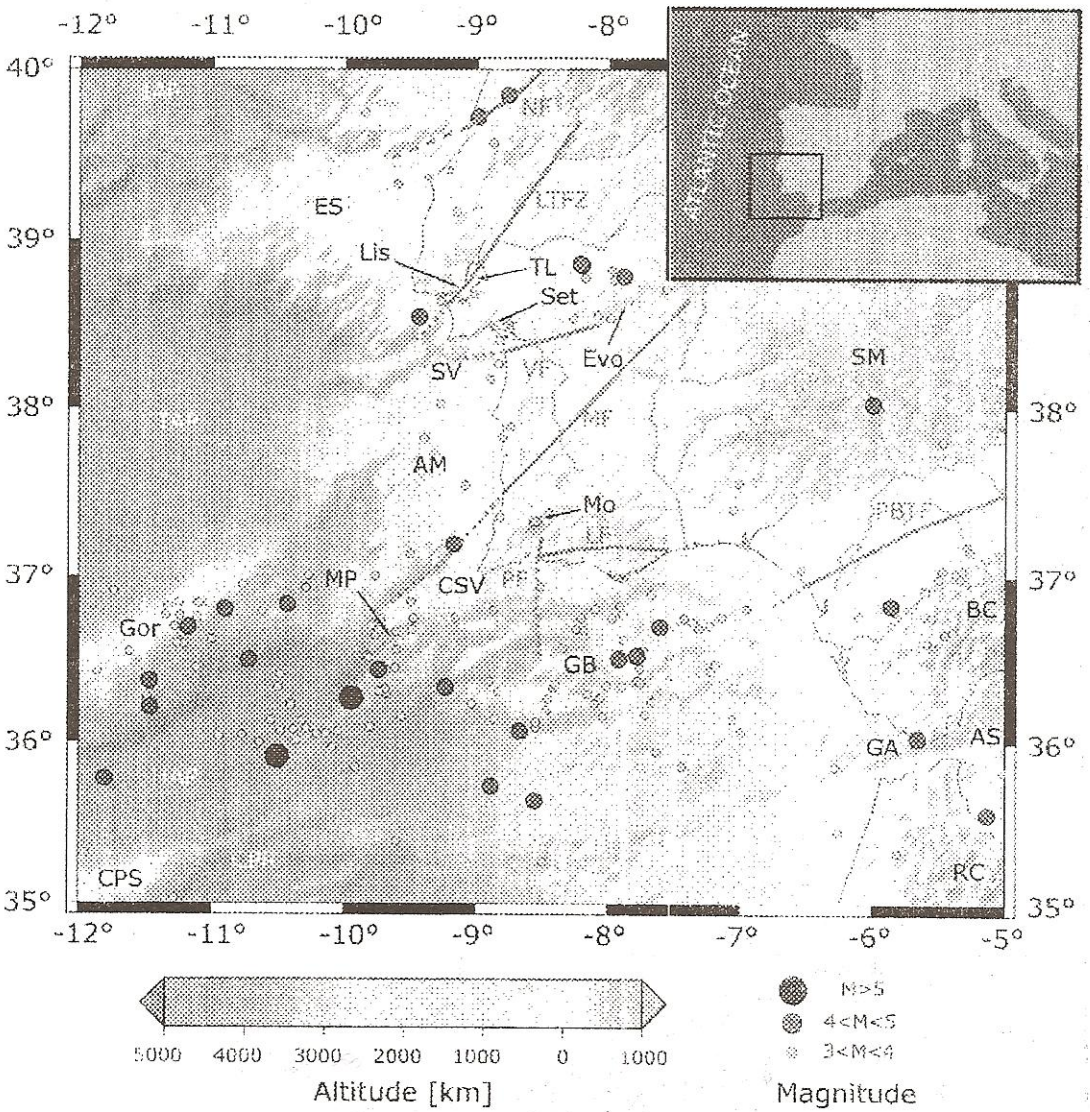

Figure 1 - Bathymetric map of the area of study (British Oceanic Data Centre, 2003), with the location of earthquakes epicenters (data provided by the Instituto de Meteorologia, Lisbon) that occurred between January 1995 and December 2005 (see Carrilho, 2005). Major accident affecting the crust, and their inferred prolongation into the ocean are also shown. AM= Alentejo Margin; AS= Alboran Sea; BC= Betic Cordillera; CPR= Coral Path Ridge; CPS=Coral Path Seamount; CSV= Cabo São Vicente; ES= Estremadura Spur; Evo= Évora city; GA= Gibraltar Arc; GB= Guadalquivir Bank; Gor= Gorringe Bank Seamount; HAP= Horseshoe Abyssal Plain; IAP= Iberian Abyssal Plain; Lis= Lisbon city; LF= Loulé Fault; LTFZ= Lower Tagus Fault Zone; MF=Messajena Fault; Mo= Monchique range; MP= Marquês de Pombal; NF= Nazaré Fault; PBTF= Pre-Betics Thrust Front; PF= Portimão Fault; RC= Rif Cordillera; Set= Setúbal city; SM= Serra Morena; SV= Sado Valley; TAP= Tagus Abyssal Plain; VF= Vilariça Fault.

Seismic tomography in the Algarve region

Portable seismic network consisting of 30 short-period stations, including a subnet of 7 telemetred stations was installed for the first time, in January 2006, in the Algarve region (Monchique-Portimão and Loulé-Faro) (Fig. 2). This network will be operating for a period of 6 month (until June 2006) or more. This seismic experiment is coordinated by the "Centro de Geofisica de Évora" (University of Évora, Portugal) with the collaboration of the "Institut de Physique du Globe de Strasbourg" (France), the "Instituto de Meteorologia (Lisboa, Portugal)" and the "Centro de Geofisica da Universidade de Lisboa" (University of Lisbon, Portugal). The telemetred network stations are installed in the same local as the "Transfrontiere" telemetred network of the "Instituto de Meteorologia" (Lisbon, Portugal) which was in activity for the period 1999-2003. These data together with those recorded by the network in activity will constitute a seismic data base for the regions of Monchique-Portimão and Loulé-Faro. Using the TomoDD programme (Zhang and Thurber, 2003) with this data base we project to determine a high resolution 3-D velocity model in these regions. The area is of interest for a tomography study for several reasons: the crustal thickness and the velocity structure is poorly determined in this area. Improvement of the 1D and 3D velocity structure and the earthquake hypocenters may help to reveal details about geological structures, seismic active faults, and focal mechanisms. This information may be useful to provide a key in order to constrain the updip limit of the seismogenic zone in view to determine the earthquake source areas and active fault zones of the regions. The results will contribute yet again to a better control of the seismic risk assessment of the region under study. Local seismic events were recorded during the three last months at short and regional distances. Some preliminary results about the local seismicity will be presented.

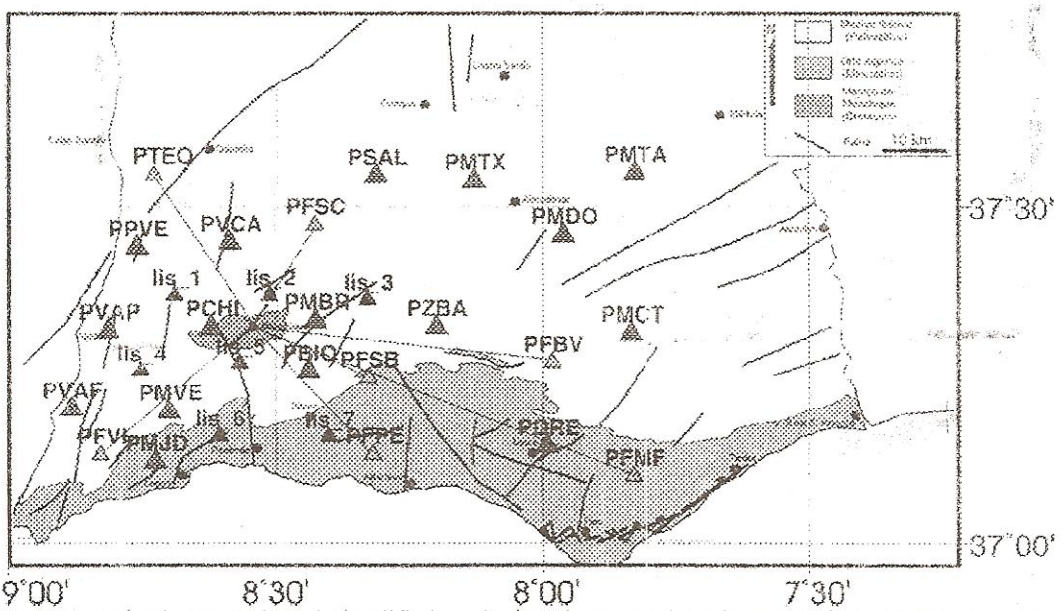

Figure 2 - Seismic network and simplified geologic scheme of the Algarve region (adapted from the Geologic map of Portugal to scale 1/500,000, SGP, 1992). The station codes beginning by the letter P are of the responsibility of the CGE (University of Évora) and EOST (University of Strasbourg), the station codes indicated by "Lis" are of the responsibility of the CGUL (University of Lisbon). Telemetred stations are linked by a solid line.

New 3D crustal model and Ground Motion in SW Iberia due to the adjacent oceanic earthquakes

Based on available geophysical data and geological evidences, we will present a 3D velocity model of the upper mantle, crust, and sedimentary cover, for south Portugal and the adjacent Atlantic area. The model is constrained thanks to data available from recent instrumental earthquakes. Using data provided by wide-angle refraction/reflection profiles (e.g. Matias, 1996; Afilhado et al., 1999), we elaborated a 3D velocity model of the shallow lithosphere (depth < 35km) in SW Iberia and its adjacent Atlantic area. This model intends to integrate the effects of the large variations of crustal thickness across the ocean/continent transition (OCT), as well as the complexity of major basins structures. Thanks to a finite-difference seismic wave propagation code, we simulated the occurrence of two recent earthquakes of particular interest, located in the Horseshoe Abyssal Plain, 250 km SW Cabo São Vincente. First, the July 29th, 2003 earthquake (M_w=5.4) was implemented, and we were able to compare Fourier amplitude spectra of recorded and synthetic ground-motion velocity at 5 sites in continental Portugal, at large distance from the source (243km<d<353km), on different geological settings. In the frequency range considered (0.3Hz<f<0.7Hz), predicted and observed spectral amplitude are in very good agreement for 2 stations, and for the 3 other stations, the ratio of synthetic and real spectral amplitude remains inferior to 4.

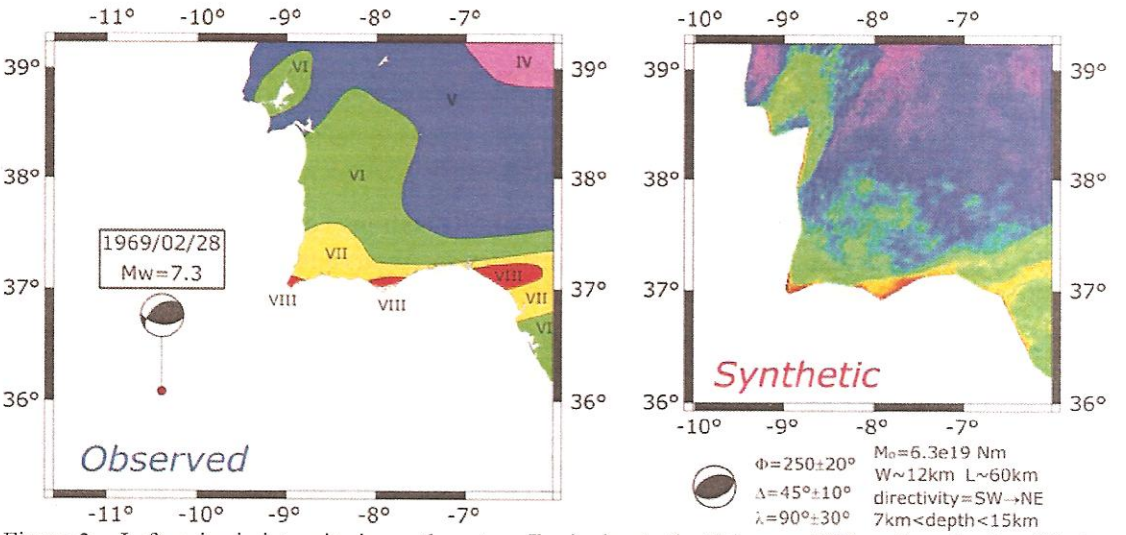

Figure 3 – Left, seismic intensity in southwestern Iberia due to the February 1969 earthquake (modified from Paula and Oliveira, 1996; Martinez-Solares, 1979). Right, synthetic seismic intensity map (see text for details). Both site effects and directivity may explain the difference in estimated intensity between the Tagus and the Guadalquivir basins, and the particular "L" shaped pattern. The best fitting focal mechanism is also shown.

This overestimation of spectral amplitude can be reduced by implementing seismic attenuation in the numerical model. Secondly, in the case of the February 28th, 1969 earthquake (M_w=7.3), we were able to compute seismic intensity maps based on an empirical relation between peak ground velocity (PGV) and seismic intensity (Fig. 3). By fixing a particular set of source parameters (seismic moment, coseismic displacement direction, fault area), and varying other source parameters (dip, rake, strike, rupture directivity) within uncertainty ranges proposed by several authors, we compared synthetic and observed intensity map. A rupture direction towards NE may explain the high level of ground shaking in the Guadalquivir basin, and a particular set

of source parameters reproduces well the observed seismic intensity pattern in the whole region. In this work, we study two earthquakes that struck the Horseshoe Abyssal plain, focusing on the influence of source parameters on the synthetic ground motion pattern, and we show that, when a certain set of source parameters are constrained, it is possible to reproduce the observed seismic intensity distribution by varying the source parameters that most strongly control this distribution, namely the fault strike and rupture directivity. We are able now to test several possibilities, and to compare synthetic ground motion obtained onshore with historical evaluations of seismic intensity. Directivity of the source, as well as site effects, may explain the particular distribution of strong ground motion observations (Grandin et al., 2006; Fig. 3).

The University of ÉVOra (UEVO) Broad Band Station and the future perspectives

Seismology is one of the targets of the "Centro de Geofísica de Évora" (Centre of Geophysic of Évora, CGE). Nowadays, a permanent Broad Band (BB) station (UEVO) has been installed in Mitra (12 km away from the city of Évora) and is integrated in the Western Mediterranean network (WM) in collaboration with the "Real Observatorio de la Armada" (ROA, Real Spanish Navy Observatory) and "Universidad Complutense de Madrid" (UCM). This station is equipped with an STS2 seismometer and SeisComp PCs, software originally developed for the GEOFON network, in connection with Earth data PS6-24 digitizer with three converters. UEVO station transmit the data in quasi real-time from Mitra to Évora and to San Fernando. The information and coordinates of the UEVO station are listed in the following table:

Network	Station code	Station Name	Latitude	Latitude	Elevation (m)
WM	UEVO	Universidade de Évora	-8.01674	38.52940	232.0

Figure 4 shows recent earthquake recorded at UEVO station. Temporal network with five BB stations is also planed and will be installed in Algarve region (South of Portugal) during 2006.

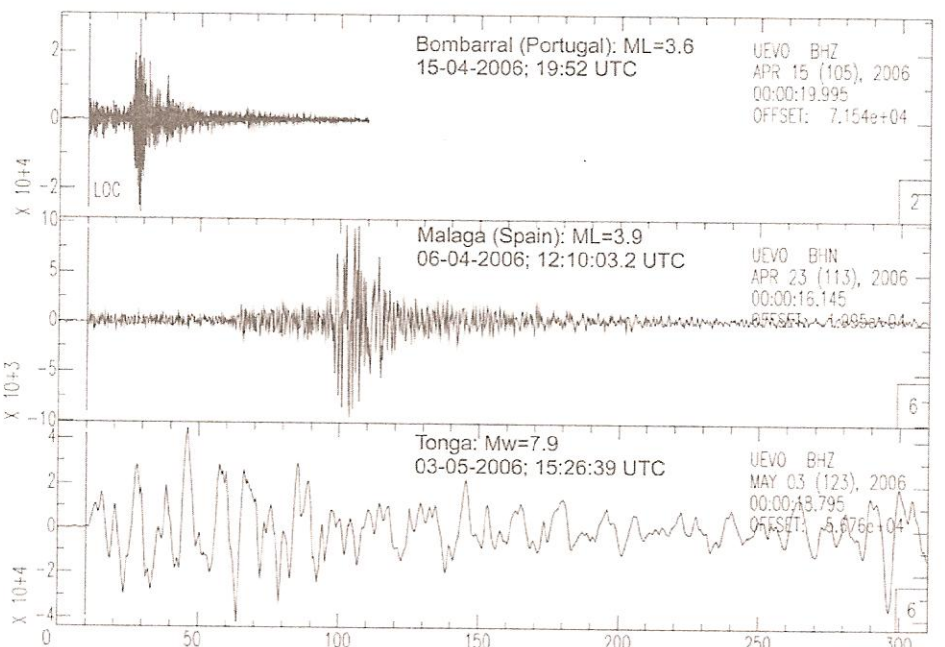

Figure 4 – Examples of 3 recent earthquakes recorded at UEVO: Bombaral (Portugal), Malaga (Spain) and Tonga.

Conclusion

We recognized that if we are to make progress, then the identification of specific actions that we could achieve would solidify our investigation on seismicity and earthquake risk. The relationship between European institutions, particularly from Portugal, Spain and France with Maghrebian institutions from Morocco, Algeria and Tunisia is essential to better understand the seismic activity and estimate the seismic hazard in the Western Mediterranean region, particularly in the Ibero-Magrebian area. The projects, described in this paper, will give new insights on seismic risk in SW Iberia, and will help identify regions that are most exposed to strong ground motion in association with acknowledged fault rupture scenarios, in particular for the great "Lisbon" earthquake, in November 1st, 1755 (M_w~8.5), in order to discriminate between possible source the one that fits best the observed intensity pattern.

There are numerous Institutions in Western Mediterranean region with a common interest in seismicity and earthquake risk. In aggregate, they comprise a large resource of scientific and engineering expertise. Furthermore, the basic messages that these institutions seek to communicate regarding earthquake impacts and risk mitigation are similar. Nevertheless, the community is consistently surprised by the effects of earthquakes and does not realize that there are effective actions that could be implemented to save lives and reduce social economic impacts in future events.

Acknowledgments

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