The recent 2007 Portugal earthquake (Mw=6.1) in the seismotectonic context of the SW Atlantic area

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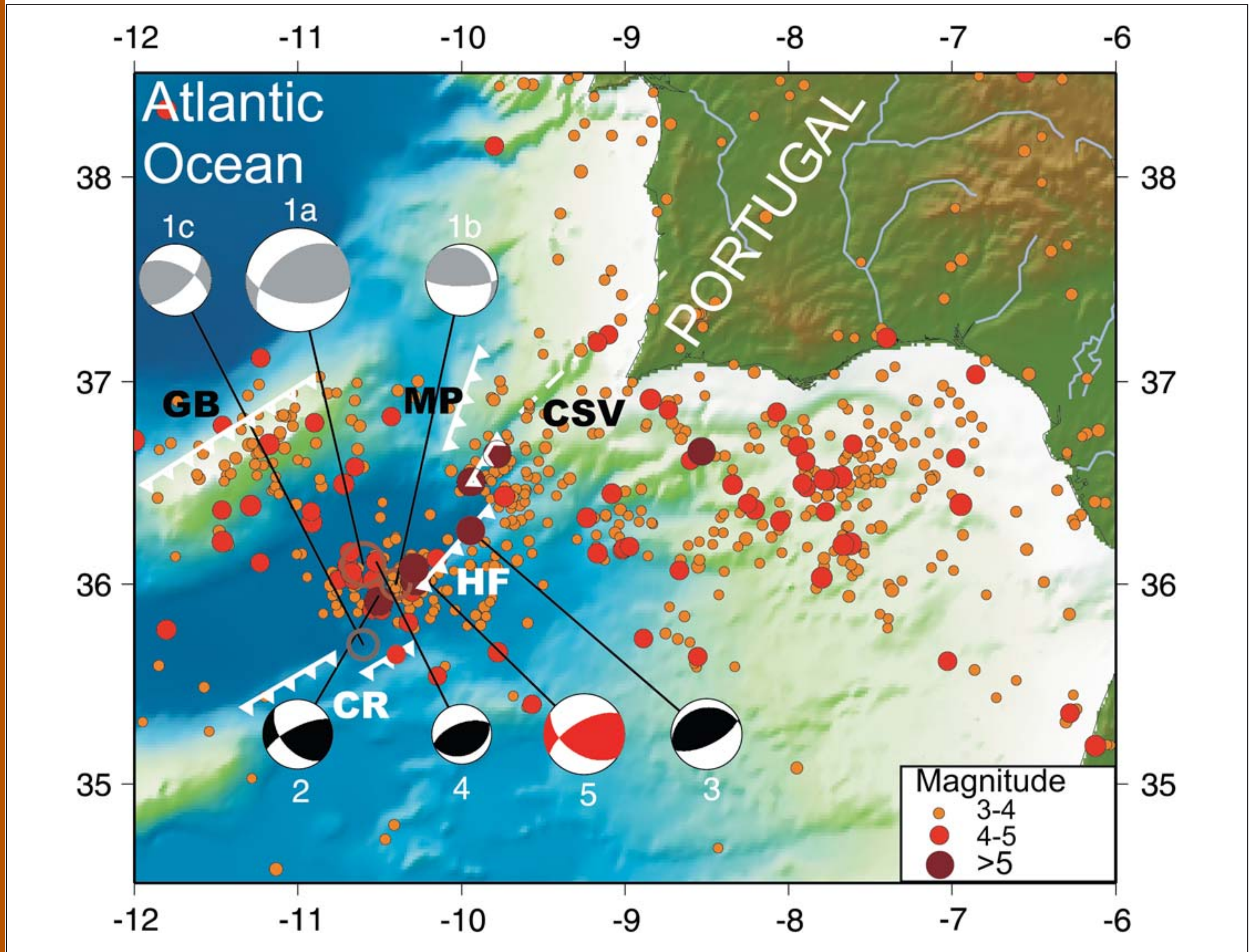
Figure 1: Seismicity provided by the Institute of Meteorology (IM- Portugal), focal mechanisms and major active faults of the region close to the epicentral area of 2007/02/12 earthquake; 1a, 1b and 1c are the 1969 earthquake and two major aftershocks; red mechanism represent the recent 2007 earthquake. CR= Coral Patch Ridge; HF= Horseshoe Fault; MP=Marquês de Pombal Fault; GB= Gorringe Bank; CSV= San Vicente Cape.



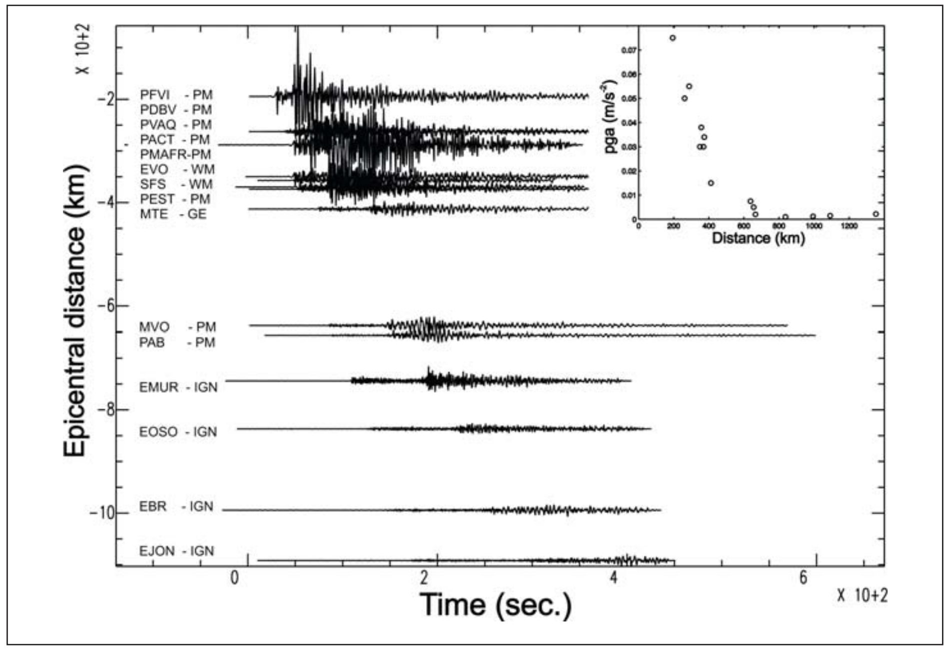
Introduction

An event of magnitude Mw 6.1(EMSC) occurred on 12/02/2007 at 10:35 UTC off coast of South-Western Portugal. The earthquake had its epicentre in the eastern Horseshoe Abyssal Plain, at 175 km South-West of San Vicente Cape (Figure 1). This earthquake is the largest earthquake since the great instrumental earthquake, Ms=8.0 (USGS), occurred on February 28th, 1969 in the same epicentral area. This earthquake was followed by four small aftershocks with magnitude less or equal to 3.5. There has been no reported damage associated to the event since habitated regions are too far away from the epicentre. This event has been widely felt in Portugal, particularly in the Algarve Region (I=IV – IM information), Southern Spain and Western Morocco and up to 700 km away of the epicentre (Salamanca, Madrid) (EMSC report in http://www.emsc-csem.org).

Table 1: Epicentral coordinates and focal mechanisms projected in the Figure 1

Nº	Date	Lat	Lon	Depth	M	Strike	Dip	Rake	REF.
	(d/m/yr)(°N)	(°W)	(km)			(º)	(º)	(º)	
1a	28/02/1969	36.1	10.6	22	8.0Ms	324	24	142	Buforn et al. (1988)
1b	28/02/1969	36.2	10.5	37	5.6Ms	46	63	38	Borges (2003)
1c	05/05/1969	36.0	10.4	29	5.5Ms	231	47	54	Buforn et al (1988)
2	29/07/2003	35.90	10.51	30	5.4Ml	245	70	110	Carrilho (2005)
3	13/12/2004	36.29	9.88	29	5.4Ml	260	25	105	Carrilho (2005)
4	21/06/2006	36.10	10.47	30	4.6Mw	249	60	90	Grandin et al. (2007)
5	12/02/2007	36.08	10.29	44	5.9Mw	125	49	144	CMT(Harvard)

Figure 2: Seismic section of the 2007 earthquake recorded by the Instituto de Meteorologia (PM), Western Mediterranean (WM), Geofon (GE) and IGN Networks. In the top right corner, the Peak Ground Acceleration (PGA), in m/s2, as function of the epicentral distance.



Tectonic and seismicity of the area

In the last four years there was an increase in the seismic activity in the area between Gorringe Bank and the Horseshoe Fault (Figure 1 and Table 1).

The region at East of 16°W is dominated by a transpressive tectonic regime, with a very low convergence rate of 4mm/year trending NW to NNW, consistent with the observed maximum horizontal stress direction (Borges et al., 2001). In this region we don't see a clear limit between plates and the deformation is distributed over an increasingly large area that can reach an N-S width of 300 km near the continental margin of Iberia. The seismicity is scattered, but most events are concentrated along a 100 km wide band, trending ESE-WNW from 16°W to 9°W. In the area, a series of topographic structures trending WSW-ENE occur (Figure 1). The Horseshoe scarp and the Marquês de Pombal scarp, parallel to the San Vicente canyon, have experienced deformation since, at least, the Miocene. The latter scenario is supported by the occurrence of unusually large oceanic earthquakes inside the area of scattered seismicity such as the 1969 earthquake (Ms=8.0) and the historical 1755 Lisbon earthquake.

Seismic data and Peak Ground acceleration

Due to the proximity to the epicentre and the magnitude of the event, the Portuguese seismic network (IM), the Western Mediterranean Network (WM) and Spanish network (IGN) (Bento et al., this issue), have recorded a high quality and unsaturated broadband seismic data. The regional broadband records of this event will provide, in the future, an excellent opportunity to an accurate analyses of the source parameters and of the seismic ground motion effects of this earthquake. As example a seismic record section of this earthquake is presented (Figure 2) as well as the peak ground acceleration (PGA) as function of the epicentral distance, for a distance between 200 km and 1200 km. From this plot one can observe that the maximum PGA reached 7.5 cm/s^2 and was measured in the PFVI station.

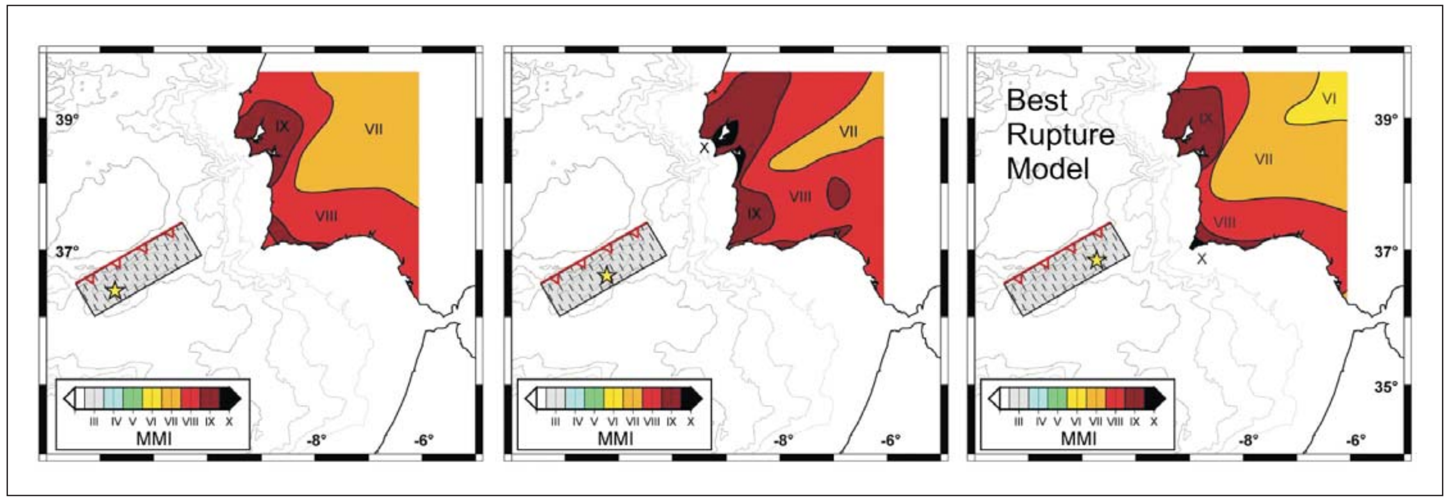
The 2007 earthquake in the context of the SW C.S. Vicente area

The 2007/02/12 earthquake was the strongest event occurring in the area since the 1969 earthquake (M8.0). All the four events (events 2 to 4, Table 1) fall in the same region, and could have been originated on the same fault, although the uncertainties on epicentral locations do not allow this hypothesis to be confirmed (Table 1 and Figure 1 shown thrust mechanisms, with a strike-slip component, consistent with a N-S to NNW-SSE direction of maximum compression (Borges et al., 2001)). All four solutions agree on a NE-SW striking nodal plane which has almost the same configuration as the inferred fault plane of the 1969 earthquake. Both 2004 and 2007 events occurred closer to the coast, at the south-western extremity of the San Vicente Canyon (CSV), and could be attributed to the seismic activity of the Horseshoe Fault (Figure 1), a NE-SW striking thrust fault, with a dip towards SE.

Discussion and implications for the 1755 earthquake Lisbon earthquake

The November 1st, 1755 earthquake was the strongest earthquake ever reported in Europe, and was extremely destructive throughout Portugal, and Morocco; the

Figure 3: Synthetic isoseismic maps for three proposed scenarios of the 1755 Lisbon earthquake. The most realistic hypothesis to fit the observed isoseismic pattern is in the right panel.



shock was even felt in Northern Germany, the Azores and the Cape Verde Islands. The large tsunami-waves generated by the earthquake also provoked extensive damage along the coasts of Portugal, southern Spain and Morocco.

The problem of epicentral location has been addressed by various early studies, and, since the beginning of the instrumental period, a consensus attributed the origin of the earthquake to a structure located between the Gorringe Bank and the Coral Patch Ridge, area where the recent 2007 earthquake occurred. Several scenarios were tested and we concluded that a NE-SW trending fault, possibly outcropping at the base of the NW flank of Gorringe Bank, could be responsible for the 1755 earthquake, as shown in Figure 3.

The epicentral region of the February 12th, 2007 and the events presented in the Figure 1 and listed in Table 1 (events 1 to 5), must be considered as a possibility also for a seismogenic area of 1755 earthquake. This new possibility will be tested using the same methodology already employed for the scenarios built for the Gorringe area (Figure 3).

Acknowledgements

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The Cape St. Vincent Earthquake of February 12, 2007 Macroseismic effects

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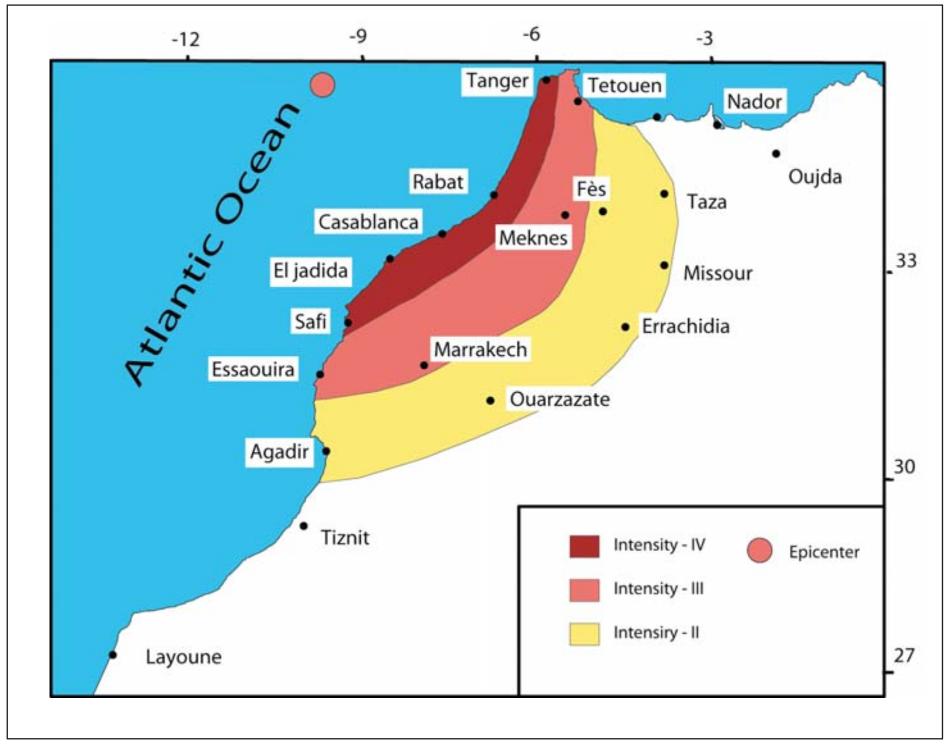
On the 12 February 2007, at 10:35:31 GMT, a strong earthquake of magnitude (M_w=6.1 EMSC; Mb=6.2 USGS) took place off-shore of Portugal, Spain and Morocco. This seismic event caused panic in several moroccan cities. The epicentre was located by the moroccan network in the Atlantic Ocean south of Cape St. Vincent at Latitude 35.45° N and Longitude 9.94° W, M_d=6.0, with an estimated focal depth of 45 km.

The 12 February 2007 earthquake was felt throughout northern cities of Morocco. This earthquake had a maximum macroseismic intensity of IV (all intensities are given in MMS scale) in costal cities of Morocco, Tangier, Rabat, Casablanca, El Jadida and Safi. The event was felt more strongly in Casablanca where the highest buildings in Morocco are grouped.

The occurrence of the 12 February 2007 Cape St. Vincent earthquake that was diffusely felt in the most cities of Morocco, allowed us to arrange the macroseismic survey in the region within the Western Rif and Atlas mountains zone.

The earthquake was slightly felt (intensity II), in Agadir city, Ouarzazet, Errachidia, Taza which are located some 650 km from the epicenter. In this

Figure 1: Morocco macroseismicity map of the February 12th 2007, Cape St Vincent earthquake.



regard, the large extent of the macroseismic area (see figure 1), may be explained by the depth of the hypocenter.

The macroseismic map is somewhat similar to those obtained for the 1969 and 1755 earthquakes and shows a general pattern of macroseismic phenomena of Atlantic seismic events, (Levret, 1991).

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Recorded ground accelerations in the 2007/02/12 SW CAPE ST. Vincent Earthquake

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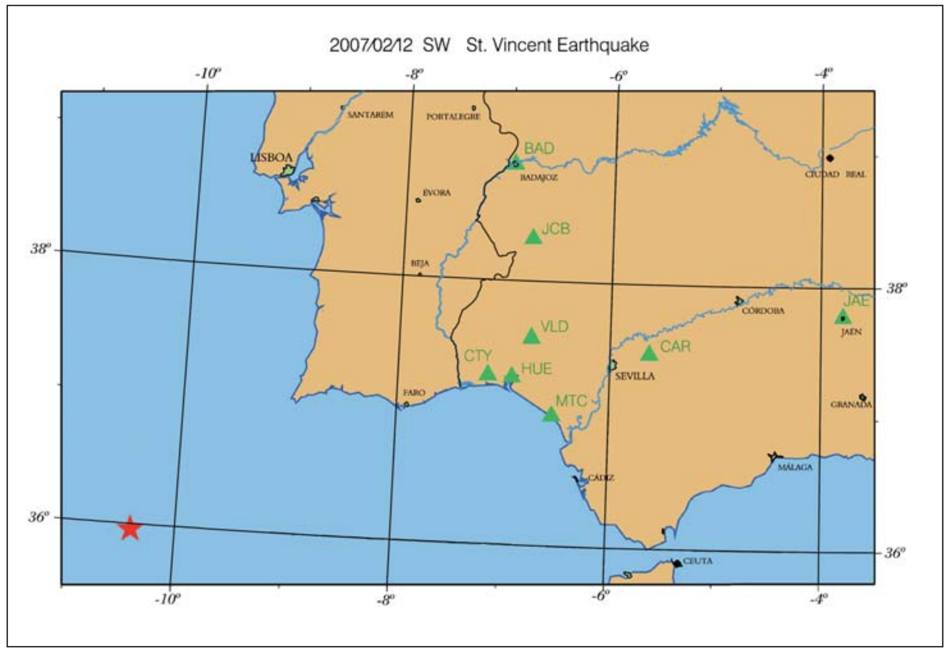
Figure 1: Strong motion stations (green triangles) that were triggered by the earthquake of 12 February 2007



The offshore Mw=6.1, SW Cape St. Vincent earthquake of 12 February 2007 is one of the largest seismic events in the surrounding areas of Spain in last decades. The hypocentral coordinates estimated by the Instituto Geográfico Nacional (IGN) were lat=35.96°N, long=10.41°W, depth=65 km. The earthquake was extensively felt in the SW provinces of Spain, such as Huelva, Sevilla or Córdoba, with EMS intensities III-IV, but also in some distant places (more than 900 km far away from the epicentre) like Madrid, Zaragoza or Santiago de Compostela among others, with EMS intensity II.

The event triggered eight accelerographs of the IGN strong motion network, located at epicentral distances between 326 and 623 km. These sites and the epicentre of the earthquake are represented in the map of the figure 1. The maximum horizontal ground accelerations recorded by these instruments range between 1.65 and 12.95 cm/s^2. Table 1 shows these peak values together with geographical coordinates, epicentral distances and epicentre-station azimuths of the recording stations.

Acceleration response spectra for a 5% critical damping ratio, SA, were calculated from the acceleration records, after being corrected for baseline errors and bandpass filtered between 0.1 and 25 Hz. Horizontal spectra of six of these accelerograms are shown in figure 2.

As a general characteristic, all response spectra show at least two distinct amplification peaks. The first, the predominant period in most of the cases, is located roughly in the range of periods from 0.1 to 0.2 seconds, while the second peak ranges between 0.4 and 0.6 seconds, approximately. Ordinates of both peaks are relatively small, as it is expected as a result of the epicentral distances of the stations and the magnitude of the earthquake.

The largest values of PGA and SA are obtained for the three nearest stations of table 1, all of them on rather soft soils. Specially, this is the case of the stations CTY and MTC that are situated on marine deep deposits of sand and gravel. When most of the spectra of earthquake of February 12 are compared with those spectra calculated from local earthquakes recorded at the same stations (magnitudes lesser than 4.5), it can be seen (not shown here), that the quoted first peak appears inside the same range from 0.1 to 0.2 seconds, but the second peak disappears. Also interesting is the case of CAR, situated on the top of a hill with steep slopes and in the middle of the Guadalquivir valley, at an epicentral distance of almost 460 km. Its PGA values are greater than other nearer stations for the same event and the response spectra show several peaks, possibly as a contribution of topographical effects

Figure 2: Acceleration response spectra (5% damping) for components EW and NS from six of the recorded motions

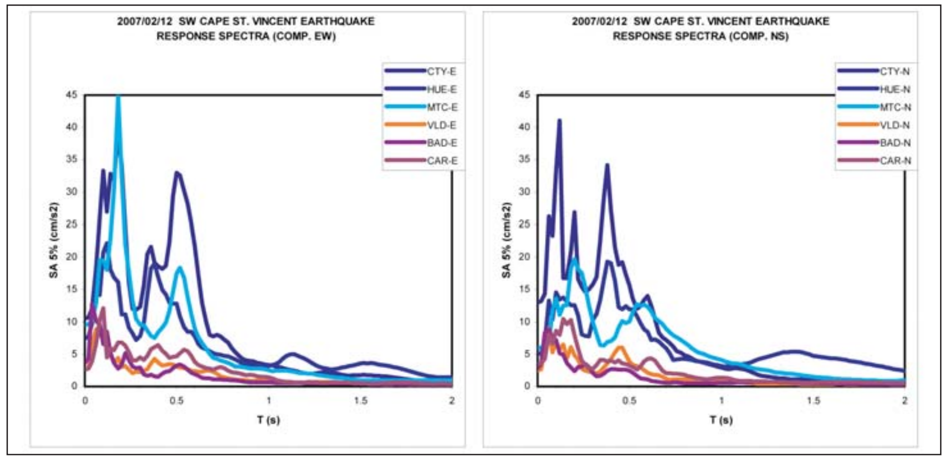


Table 1: Stations of the IGN strong motion network that recorded the earthquake

STATION	PLACE	LON(°)	LAT(°)	Rep (km)	AZIMUTH(°) Epic-Est	PGA (cm/s^2) NS	V	EW
CTY	CARTAYA	-7.153	37.284	326.3	62.3	12.96	6.10	10.53
HUE	HUELVA	-6.925	37.274	344.1	63.9	4.95	3.75	7.41
MTC	MATALASCAÑAS	-6.539	36.992	365.3	70.6	5.90	3.57	9.50
VLD	VALVERDE DEL CAMINO	-6.753	37.572	372.3	60.2	2.45	2.06	2.76
JCB	JEREZ DE LOS CABALLEROS	-6.772	38.322	416.1	49.9	1.77	2.36	1.41
BAD	BADAJOZ	-6.971	38.879	444.5	42.2	2.82	1.62	3.69
CAR	CARMONA	-5.632	37.475	458.7	67.1	3.50	3.25	2.57
JAE	JAEN	-3.789	37.773	623.5	69.2	1.89	0.89	1.65