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Spanish National Strong Motion Network. Recording of the Huelva Earthquake of 20 December, 1989

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Abstract—In recent years a network of 30 accelerographs has been installed through the zones of highest seismic activity of Spain. For the first time, digital strong motion records have been obtained in Spain, with a maximum horizontal acceleration value of 0.06 g. A comprehensive study is made of the strong motion recordings of an earthquake which occurred in southwest Spain, on December 20, 1989. The isoseismal map is drawn and the data confirm the main attenuation directions in the area observed in other shocks.

Key words: Strong-motion, focal mechanism, attenuation, acceleration–intensity, spectral response.

Introduction

The Instituto Geográfico Nacional of Spain, (I.G.N.), began in the last decade to establish a network of strong motion instruments distributed through regions of high seismic activity. Initially, the instruments were 9 with analogue recording, SMA-2 Kinemetrics. The program was interrupted for 3 years, and a new one was started as digital accelerographs became available on the market. The installation of the digital equipment began in 1989 with 11 Spanish instruments ACD-3 Ofiteco. Later, we continued with the installation of 10 digital instruments SSA-1, Kinemetrics.

The first digital accelerogram in Spain was obtained as a consequence of the December 20, 1989, earthquake of 4.8 magnitude that took place in South Spain at the boundary with Portugal. As an area of seismotectonic interest and because a new digital accelerograph was in operation near the epicenter, a comprehensive study was carried out.

The focal mechanism of this event is analyzed and an interpretation based on the tectonics of the region is given. In order to compare the intensity values with other parameters a detailed macroseismic survey was carried out also showing characteristics related to the general tectonics of the region.

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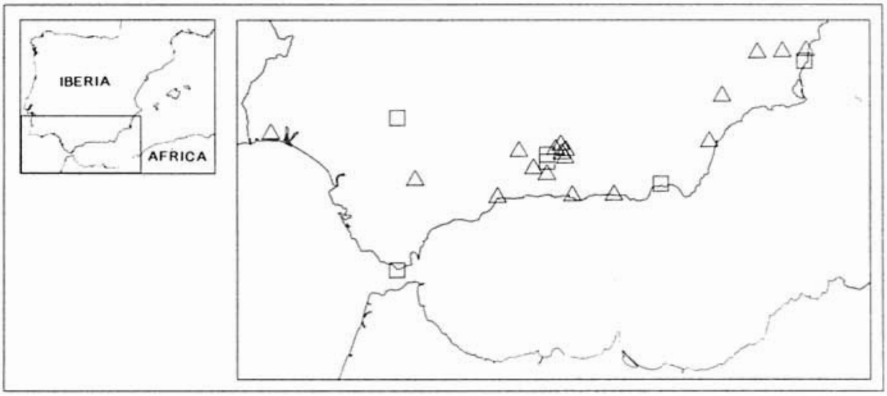


Figure 1
Spanish National Strong Motion Network. Triangles represent digital instruments while squares are analogical.

Network Instrumentation

Figure 1 shows the actual distribution of strong motion instruments in Spain. The analogical accelerographs are the triaxial model SMA-2 of Kinemetrics. These instruments may have their acceleration vertical component adjusted to a trigger level. The natural frequency of these instruments is roundly 30 Hz with a 1 g full scale.

The digital instruments are of two types: ACD-3 (Ofiteco) and SSA-1 (Kinemetrics); both types have a large dynamic range and solid state memory, allowing the recording of a complete accelerogram.

For the establishment of the instruments, criteria have been followed, based on the maximum intensity maps, isolation of buildings, where possible in order to obtain free field recordings. Also, for future implementation, the possibility of connecting by modem with the seismic center in Madrid has been considered.

20 December, 1989 Earthquake

Focal Parameters

The focal parameters of the 20 December, 1989, earthquake are listed in Table 1. The epicenter is located approximately at Isla Cristina (Huelva), at a hypocentral depth of about 23 km.

After the earthquake, questionnaires were sent to an extensive area of the South and South-West of the Peninsula; knowing that it had been felt at distant sites from the epicenter. The isoseismal map (Figure 2) has been drawn from 991 completed

Table 1

Focal parameters of the 20 December, 1989 earthquake.

Orig. Time	4h 15 m 05.99 s
Latitude	37°17′.2 N
Longitude	7°19′.7 W
Depth	23 km
Magnitude (Mb)	4.8
Max. Intensity	VI
N° Observations	25

questionnaires. From the isoseismal map, we have computed the corresponding areas for the zones of each intensity value. Since the epicenter is near the sea, as can be seen on the isoseismal map, the isoseismal lines do not close southwards. For this reason we have had to make an approximation to compute this area. From the isoseismal map we can observe a lower attenuation in the higher intensities along the Guadiana river in a north-south direction.

From the intensity map, we have obtained the average radius of the circular area of each grade of intensity, and have drawn the attenuation curve shown in Figure 3 together with attenuation curves obtained by MARTIN (1984) for South Spain from near earthquakes and from distant earthquakes from the Azores-Gibraltar fault. This figure shows that the attenuation for this earthquake is lower than the two cases studied by MARTIN (1984). One possible explanation, which has been observed in several earthquakes, is that there are preferred directions which coincide with the maximum of the nonconsolidated sediments.

Seismicity of the Area

This earthquake is located near the northern boundary of the active region of South Spain (Figure 4). The main feature of this region is that it constitutes part of the contact between Africa and Eurasia plates with moderate earthquake magnitude ($M < 5$), but also the occurrence of large earthquakes separated by long time intervals with maximum intensities of *IX* and *X*. The distribution of epicenters for the period 1965 to 1985 shows that earthquakes are located south of the Cádiz-Alicante fault and that they can be associated with observed geological faults (BUFORN *et al.*, 1988).

The mechanism of this earthquake (I.G.N., 1991) shows a strike-slip mechanism; with a horizontal pressure axis in the NW-SE direction. The fault plane with a strike in the E-W direction has been chosen in accordance with the dominant geological lineaments in the region. Motion on that plane is right lateral with the north block moving east in agreement with the horizontal motion in the Azores-Gibraltar fault.

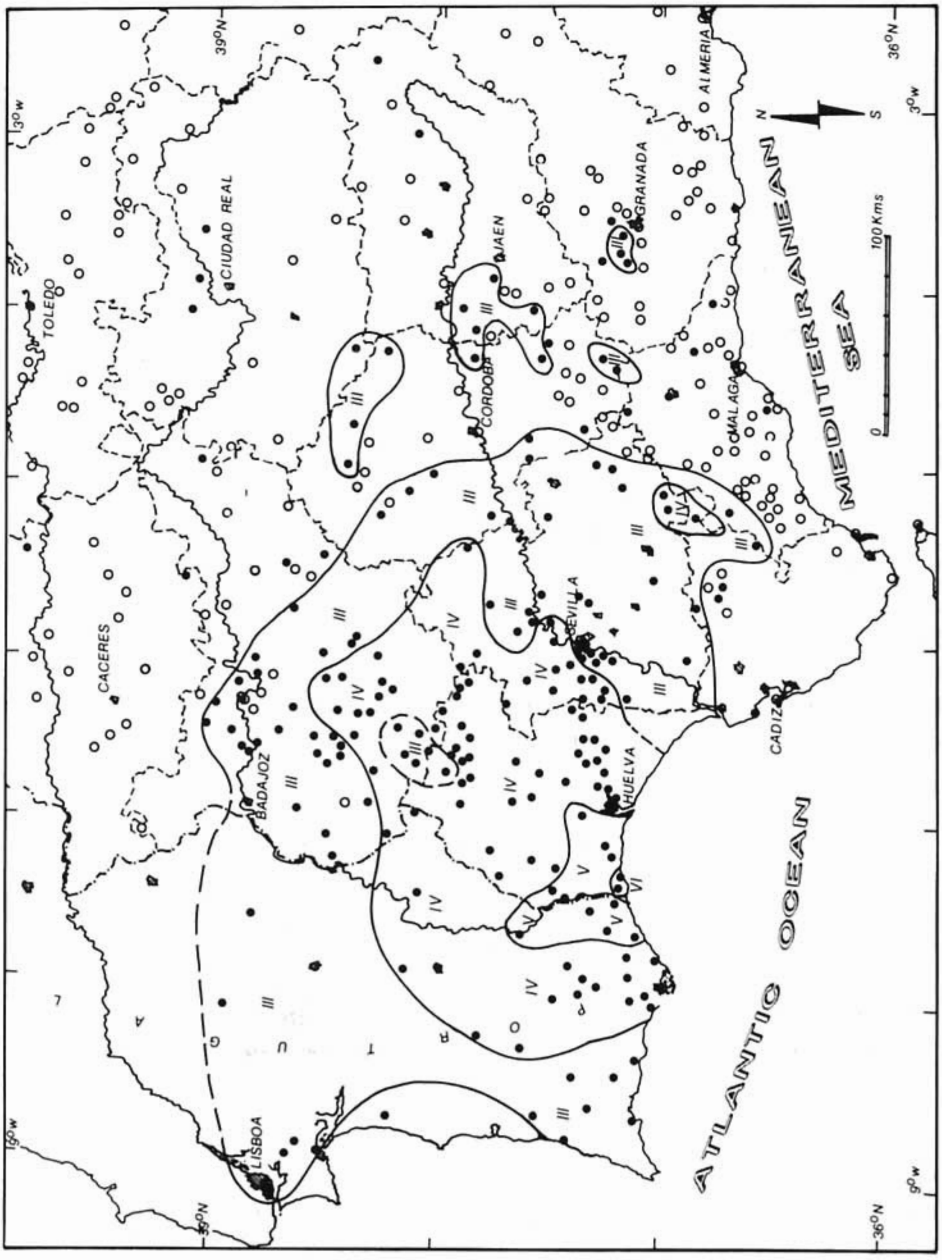


Figure 2
Isoseismal map of 1989 December 20, earthquake. Open circles show sites where the earthquake was not felt.

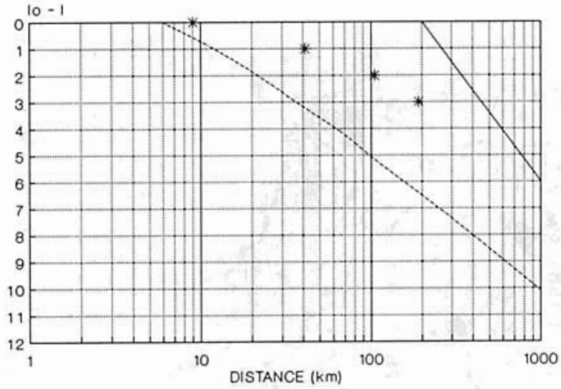


Figure 3
Attenuation values of 20 December, 1989 earthquake (asterisk) compared with those obtained taking the influence of Azores-Gibraltar zone (dotted) and without (continuous) as given by MARTIN (1984).

Comparing it with the mechanism of the 10–20–1986, and 3–11–1987 earthquakes, the orientation of *P* axes are in agreement with the general idea of a general regional stress with NW-SE compression in the area (Figure 4). In contrast, the 5–26–1985 earthquake corresponds to a reverse faulting with planes oriented North-South, and the *P* axis in E-W direction.

Analysis of Strong Motion Data

The strong motion instrument located in Cartaya (Huelva), was the one nearest the epicenter (19 km). The accelerograph, an Ofiteco ACD-3P digital instrument, was the only one that triggered. The accelerograph is placed on a concrete peer, located in the basement of a building. Geologically, the soil is composed of recent marine terrace of Pliocene sandy loam.

Only the two horizontal components were processed because the vertical sensor failed.

Direct numerical integration of the accelerations appears to be contaminated by long periods. We have obtained the acceleration, velocity and displacement using parabolic correction and a band-pass filter between 0.7 and 30 Hz.

Figure 5, shows the acceleration, velocity and displacement of the EW and NS components respectively after having been filtered between 0.7 and 30 Hz. The maximum values are listed in Table 2 as well as values from analogical accelerograms of the 24 June, 1984 earthquake, magnitude 5.0, CARREÑO *et al.* (1988).

In Figure 6, we observe the trilogarithmic plots of pseudovelocity for 0, 5 and 10% damping; corresponding to the E-W and N-S components.

The maximum values encountered in these accelerograms are the largest recorded in Spain and they allow, with the previous analogue records in Granada

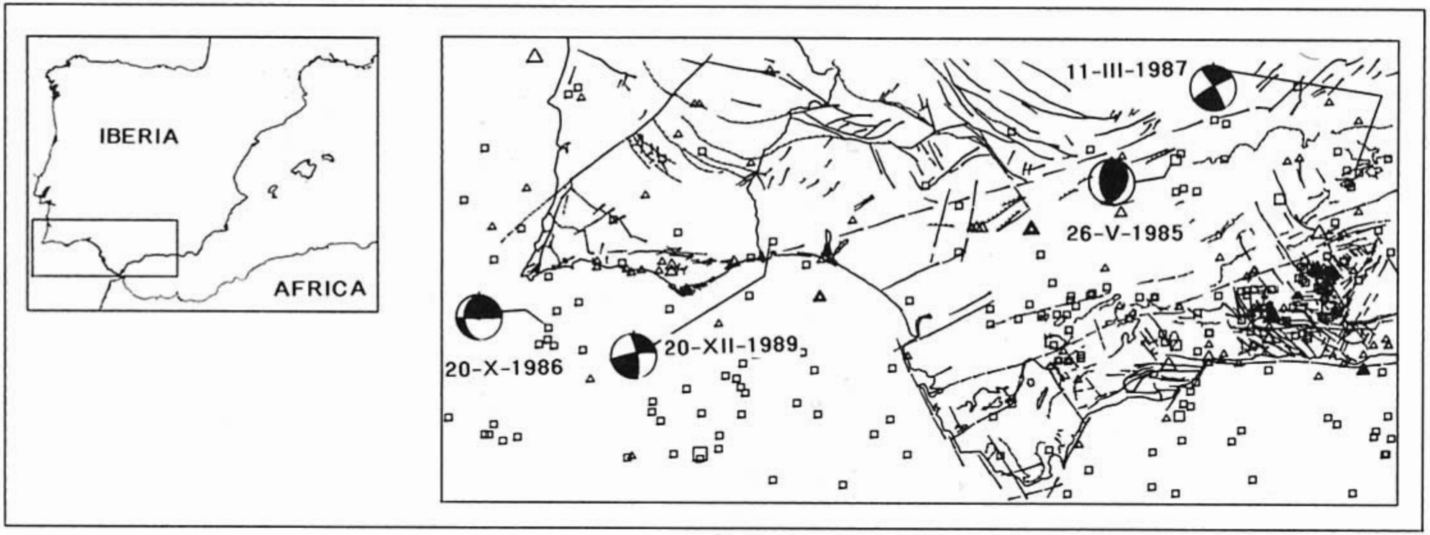
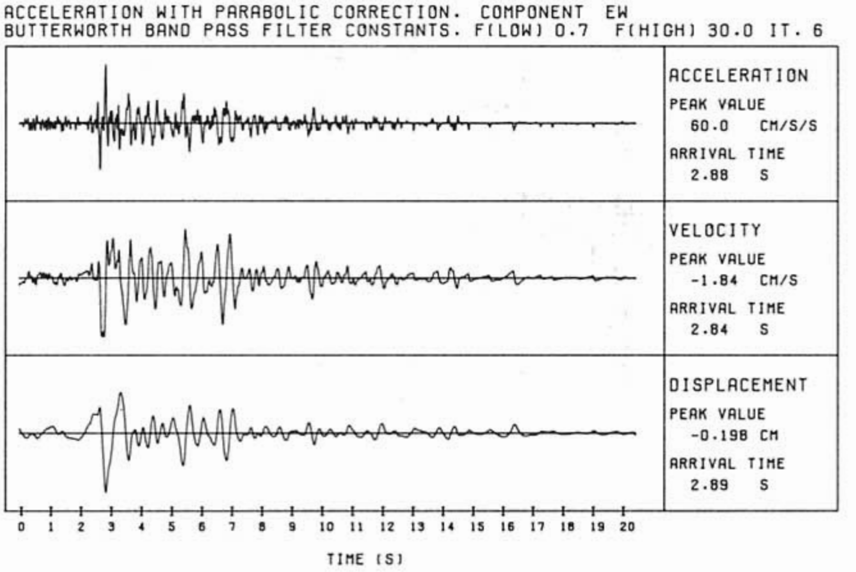


Figure 4
Seismicity map from Seismic Data Bank (I.G.N.), with main fractures for the zone (SANZDE GALDEANO, 1983). The mechanism corresponds to 11–20–89, 10–20–86, 3–11–87, and 5–26–85 earthquakes (BUFORN *et al.*, 1988).



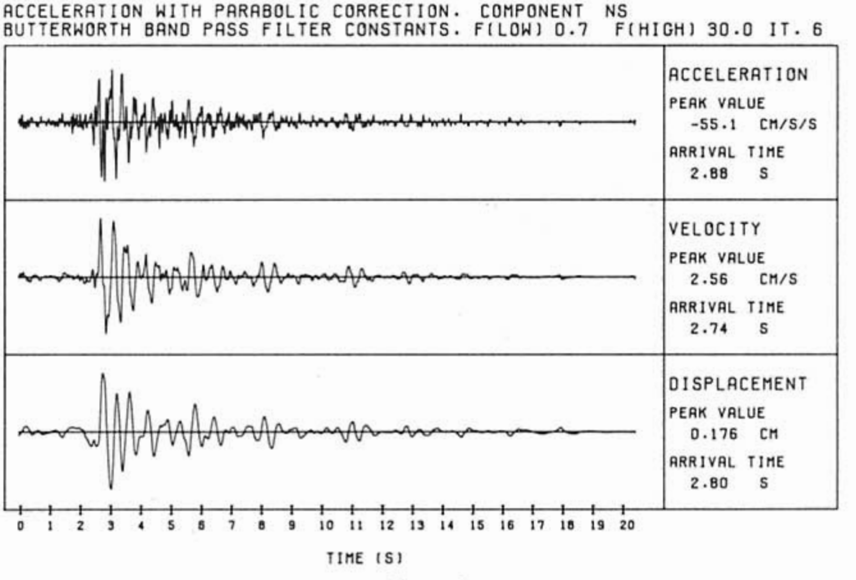


Figure 5

Acceleration, velocity and displacement of the EW and NS components. A parabolic correction and a Butterworth filter band pass of order ten, between 0.7 and 30 Hz have been made.

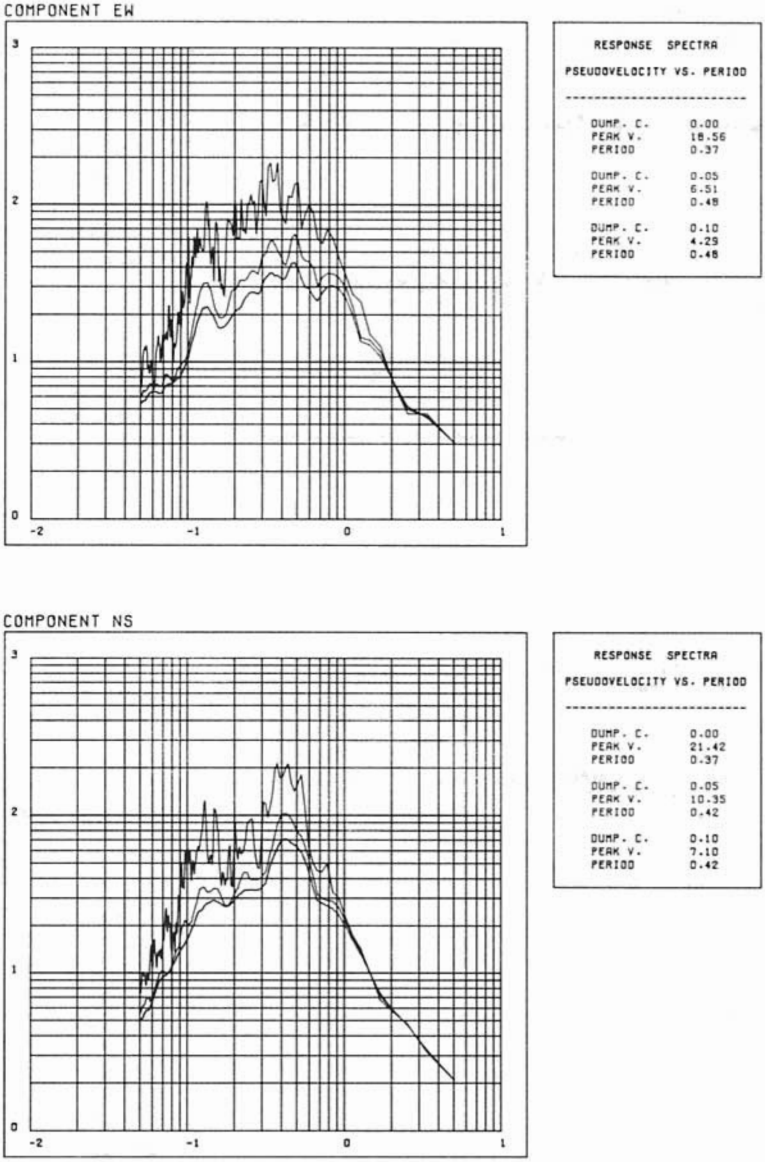


Figure 6

Spectral response for the EW and NS components and damping curves of 0, 5 and 10%.

for the 1984 earthquake, the accomplishment of some correlations for earthquake engineering in which acceleration is one parameter. In Figure 7 the values of maximum acceleration for the two earthquakes (20–12–89 and 24–6–84) are plotted against intensity. In the same figure several relations by different authors, COULTER *et al.* (1973), AMBRASEYS (1975) and TRIFUNAC and BRADY (1975), are given.

Table 2

Acceleration, velocity and displacement for 24 June, 1984 and 20 December, 1989.

Earthquake	Stat.	Comp.	cm/s^2	cm/s	cm	Ep.D. (k)	Mg.
24–6–84	Alhama	E–W	12.9	0.31	0.02	28.4	5.0
		N–S	15.3	0.19	0.01		
		Z	35.5	0.70	0.09		
24–6–84	Beznar	E–W	19.8	0.77	0.06	20.0	
		N–S	19.7	0.78	0.04		
		Z	29.0	1.34	0.09		
24–6–84	Santa Fe	E–W	35.0	1.59	0.09	38.6	
		N–S	29.7	1.72	0.07		
		Z	23.4	0.56	0.03		
20–12–89	Cartaya	E–W	60.0	1.85	0.19	17	4.8
		N–S	55.0	2.56	0.17		

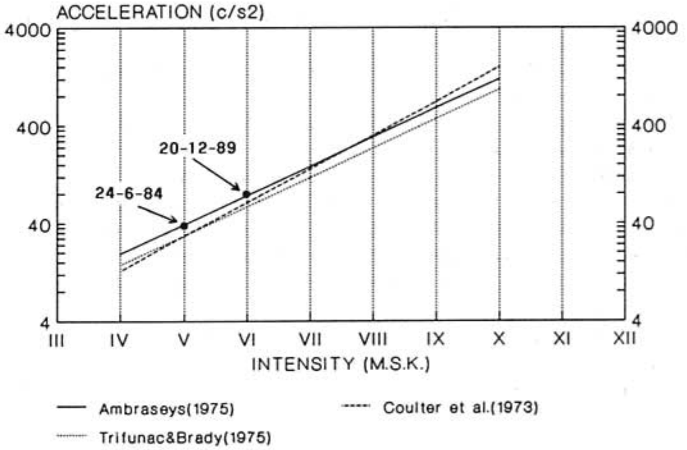


Figure 7

Maximum intensity, horizontal acceleration relation following several authors. It shows the corresponding values for the earthquakes of 20 December, 1989, and 24 June, 1984.

The best agreement in the intermediate range of intensity values is with the curve given by AMBRASEYS (1975). Beyond intensity VI, the tendency could be fitted also by COULTER *et al.* (1973).

Conclusions

From the isoseismal map we can observe a slow attenuation in the higher intensities along the Guadiana river in a north-south direction.

This fact can also be appreciated in the isoseismal map obtained for the following earthquakes: 15 March, 1964, 28 February, 1969, 23 May, 1980 and 7 ctober, 1983 (MEZCUA, 1982).

The strike-slip mechanism confirms the general idea of a Northwest-Southeast compression in the area.

We can deduce from the attenuation/distance curve that this attenuation is very low and selective in different azimuths.

The obtained horizontal acceleration values with respect to intensity agree with those corresponding to AMBRASEYS (1975) relation. This is also true for the values of the other strong motion data from South Spain corresponding to the 24 June, 1984 earthquake.

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