The Earthquake of May 26, 1994, Al Hoceima, Morocco; Intensity distribution and macroseismic epicenter

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Abstract: On 26th May 1994 a significant earthquake (M_d = 5.5) occurred in the north of Morocco, and caused great damage in adobe constructions in the vicinity of the Al Hoceima region. This represents one of the strongest seismic phenomena, which occurred in Morocco after the Agadir 1960 earthquake. This earthquake has attracted the attention of seismologists of various countries and was the subject of special studies.
The mean epicentral intensity resulted to be IX degrees (MSK scale) and the macroseismic epicenter was situated near the Tafensa village (35.205° N, 4.025° E).
These results are based on the macroseismic data gathered from different sources: 50 photographs which show the damage caused by this earthquake in Al Hoceima city and surrounding villages, and data collected during the macroseismic study carried out on the field after the main shock.
The present paper intends to demonstrate that soil conditions strongly influence the observed intensity even at very short distances from the epicenter.

Key words: macroseismic, Al Hoceima-Morocco, damage distribution, site effects.

Introduction

On Thursday, 26th May 1994 at 08 h 26 min 55 sec local time, a damaging earthquake took place in Al Hoceima region in the north part of Morocco. Its high intensity, the great number of aftershocks (1000 a year) and the consequences of the main shock and the strongest aftershocks, four of them having a duration magnitude M_d larger than 4, and more than 1000 events a M_d larger than 1.0, have attracted the attention of many seismologists (Jabour et al. 1995; 1995, Hahou et al. 1995, Vidal et al. 1995, Calvert et al. 1997; El Alami et al. 1998). It also attracted the attention of the Geophysics Laboratory researchers, who have managed to record the consequences of the aftershocks from this earthquake for almost a whole year, thus providing a rich source of data.
From instrumental data (Ben Sari 1978,1987; Cherkaoui 1990; 1991; Jabour et al 2001), it appears that throughout the years before the main shock of May 26, 1994 at 08 h 26 min 55 sec, many events occurred which passed unnoticed by the

inhabitants, because of their low intensity. The strongest event of magnitude M_d = 3.0 degrees, occurred early on May 26, 1994 at 06 h 17 min 36 sec. The main event was of a magnitude M_d = 5.5 causing many victims among the population and great property damage, not only in the city itself but also in the surrounding villages.

The relatively heavy toll of the earthquake was due to the weak materials and the old way of building rather than to the intensity of the earthquake. Apart from this, much damage was brought about by the big boulders and rocks falling from the Heights Mountains the neighborhood.

In fact, the poor quality of the buildings - walls built of stones, and covered with heavy roof-mud - was apparent; good buildings suffered no damage. Another important factor is structures formations.

This earthquake caused 2 deaths and injured a number of people ranging from 200 up to 300. The seismologists have evaluated the epicenter and the intensity of this earthquake as:

H = 08 h 26 min, 35.14° N, 3.92° W, M_d = 5.4 (N. Jabour et al 1995)
H = 08 h 26 min, 35.2187° N, 3.9548° W, I_0 = VII MSK scale, M_d = 5.4 (Vidal et al 1994)
H = 08 h 27 min, 35.28° N, 3.99° W, I_0 = VIII-IX EMS scale, M_d = 5.6 (Alami et al 1998)
H = 08 h 26 min, 35.159° N, 3.955° W, M_w = 6.0 (Calvert et al 1997)
H = 08 h 26 min 52 sec, 35.305° N, 4.103° W, M_w = 6.0 (USGS)

Where I_0 = highest epicentral intensity.
We went on a seismological and seismotectonic expedition to the Al Hoceima region in the Summer of 1995, to test the veracity of the macroseismic data gathered from various sources, as well as to study the seismological conditions of the Al Hoceima region. We made observations in all the villages of the epicentral zone and in the damaged zone, reevaluating the intensities of this earthquake on the MSK scale.
Only one aspect of this earthquake is presented in this paper: that of the evaluation of its intensity and the determination of the macroseismic epicenter.

The epicentral zone of earthquake

The epicentral zone of the earthquake of May 26, 1994, included the southwestern part of the Al Hoceima city, the south part of the Kimmat Boussekkoûr and northwestern part of the Izemmouren and Nador Chain (Fig. 1).

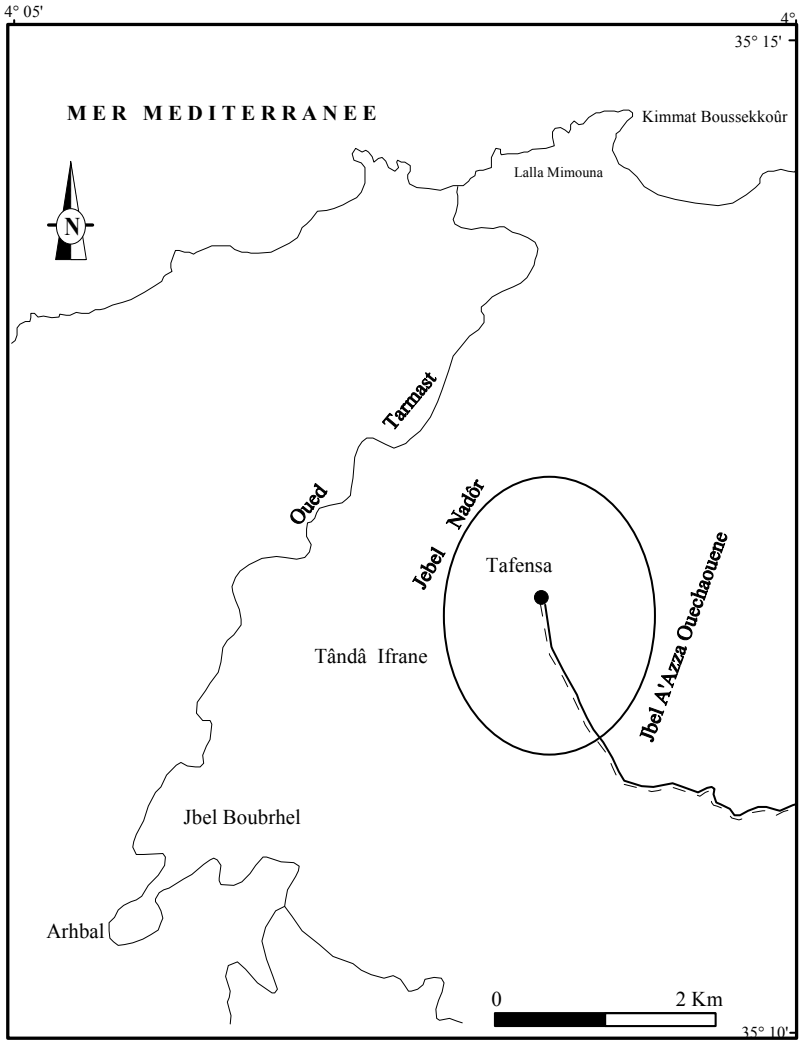

Fig.1- Epicentral zone of the earthquake of May 26th, 1994.

Natural phenomena

The only primary effect of the event was the high ground acceleration level felt over a large epicentral area. No surface rupture was encountered or reported consistent with what is expected from this kind of earthquakes. Secondary effects included induced landslides; rock falls; soil falls occurred on many of the steep slopes; fissures and cracks in the ground and significant changes in water systems in the epicentral region and the surrounding regions (Fig. 2a and b).

In the epicentral and the surrounding regions there were a series of ground cracks and fissures with several centimeters of width and about one hundred meters length, which are often very discontinuous (Fig. 3).

Fig. 2a- Soil falls in the coast cliffs of the Mediterranean Sea west of Al-Hoceima city.

Fig. 2b – Rock falls in the cliffs of the Carabonita beach.

Fig. 3 – Fissures affecting ground in Tanda Ifran.

Fig. 4 – Fissures observed in Carabonita terrain..

In some cases, we observed change of underground waters' level. The level of underground waters changed over the whole zone affected by the earthquake, resulting in changes of the flow of existing spring and the level of water in wells as in Imernissene. Fissures appearing in the Kimmat Boussekkoûr, Kimmat Imassinene and Tafensa were the most interesting phenomenon of the earthquake of May 26, 1994. As a consequence of the main shock, some effects were observed at the surface, such as fissures; cracks at Idssouliyene, with a N40 to N50 trend, and land slides; soil falls and rock fall along the coastal cliffs west of Al Hoceima city. The cracks in the soil were observed over a large zone, especially on the Mediterranean coast in the western part of Al Hoceima. There were even landslides which caused the opening of ditches and great indentations. Such were observed especially in the Tafensa, Tanda Ifran and Carabonita beach (Fig. 4), as well as in many neighboring villages.

In the whole region of the epicentral zone many rocks fell from the mountainous terrain, and in many cases added to the extent of the damage suffered by the buildings especially in Douar Tafensa (Fig. 5 and 6).

Fig. 5 – Wall destruction caused by rock fall in Douar Tafensa..

Fig. 6 – Adobe construction strongly affected by earthquake in Douar Tafensa.

Subsequent phenomena in built-up areas

This earthquake caused widespread damage and was felt strongly throughout the northern of Morocco and south of Spain. Building construction was of very different types ranging from adobe and loose masonry of very poor quality to well constructed and good quality buildings. Adobes constructions suffered large cracks in walls in many cases (50-70%), partial destruction of walls in few cases and also total collapse

in many cases (Fig. 7). In Rwadi, Beni Abdella; Ait Kamra, Izmouerne; Immezouren and Beni Bouaiych, there were small cracks in several walls in many cases and heavy damage in a few ones. The constructions by bricks suffered large cracks; few wall displacement (Fig. 8) and many cases of cracks with multiple directions in Rwadi; Izmourene; Immzeroune and Beni Abdellah and beni Bouaiych. In general, the older constructions in Al Hoceima city suffered small cracks observed in many cases, but few ones suffered heavy damage. But in the buildings little non-structural damage was noticed in few cases.

Fig. 7 – Total destruction of house in Izemmourene.

Fig. 8 – Few displacement of the wall in Douar Rwadi.

Distribution of the intensity and isoseismal map

After the May 26, 1994 the Al Hoceima earthquake, a detailed macroseismic campaign was carried out in order to evaluate the intensities distribution. The macroseismic campaign consists on many questionnaires that have been completed in the field and others have been distributed to different organizations and to individuals. We proceeded to make our work in each observation points uniform in all the area around the epicenter. Over 300 questionnaires that cover the entire Al-Hoceima region were thus completed.

The data collected was treated, with the aim of enhancing the attenuation pattern of the regional macroseismic field and the eventual site effect. The MSK scale was used to estimate seismic intensity. Each village's average intensity was obtained from all observed damage taking into account structural vulnerability of the constructions and

topographical conditions. Moreover, the ground effects were also considered. The earthquake was felt within Morocco from the northern part to Oujda in the east; to Fez and southern of Spain. The isoseismal map of the main event was compiled on the basis of the elaboration of the whole macroseismic data gathered.

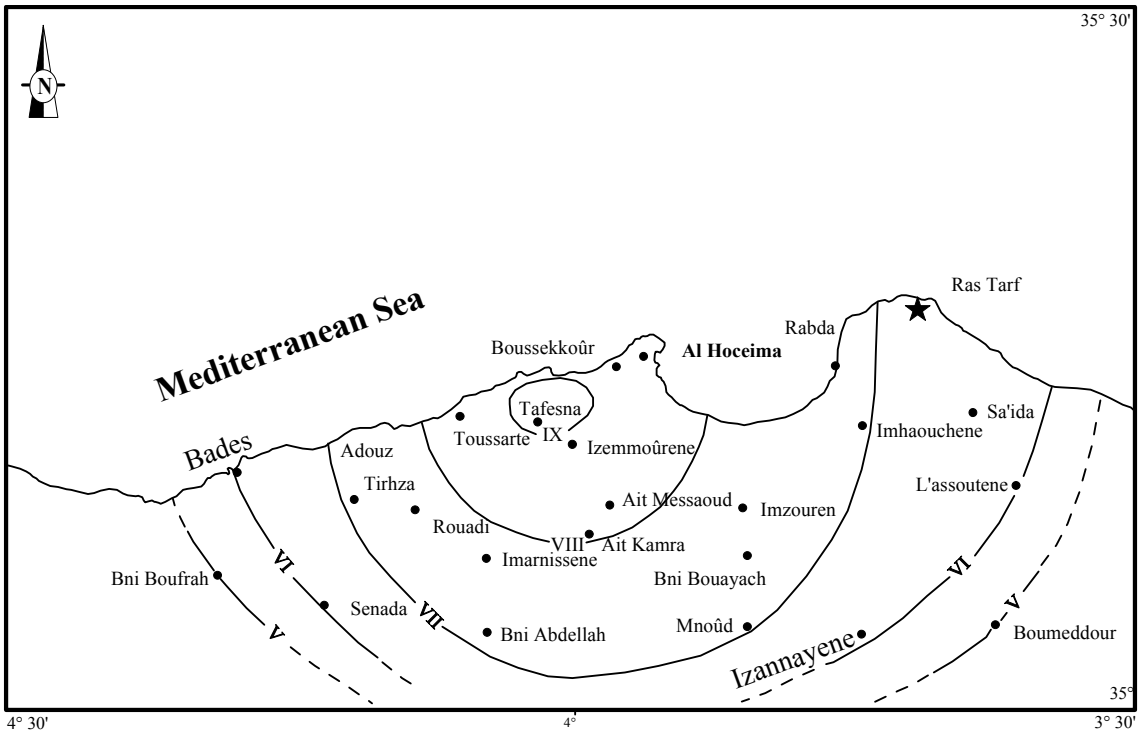

Fig. 9 – Isoseismal map of the earthquake of May 26th, 1994.

Data collected during the macroseismic study carried out on the field after the main shock, allowed us to draw an isoseismal map (Fig. 9) based on MSK scale. The isoseismal lines are elongated in the same direction; this strongly suggest that the fault, which generated the main shock, may have the same trend. An alternative view is due to a site effect within the Nekor basin that extends along the south-eastern of Al Hoceima city. As a consequence of the main shock, some effects were observed at the surface, such as fissures; cracks at Idssouliyene, with a N40 to N50 trend, and landslides; soil falls and rock falls along the coastal cliffs west of Al Hoceima.

The general macroseismic field of this event (Fig. 9) display some interesting aspects: firstly, a minor attenuation of intensity in south-eastern direction of the Al-Hoceima city, due to a large amount of quaternary sediments from the lower Nekor basin; secondly, a large attenuation in south-western direction, towards the Rif chain; and finally the remarkable variability felt within the rural area of Al Hoceima, ranging

from the not felt to the characteristic damage of the IX MSK scale corresponding to the epicentral zone Douar Tafensa.
It is shown that the mean epicentral intensity of this earthquake was IX degrees (MSK scale) and that the macroseismic epicenter is situated near the Tafensa village (35.205° N; 4.025° E).

Conclusions

The Al Hoceima earthquake of may 26, 1994, is one of the strongest earthquake to strike the northern part of Morocco area in the last century and the largest instrumentally earthquake recorded in Al Hoceima region. This area has been intensely populated in the last decades (the population exceeds 396 000 inhabitants), thus the social impact of the 1994 earthquake was much more than that expected from a magnitude M_d = 5.5 earthquake. It produced significant injuries, losses of life and serious damages to properties. The most important damages have been signaled in the region of Tafensa and Izmourene, but most damages concern traditional constructions and old masonry. Minor damage such as small cracks on walls have been noted in modern constructions of the Al Hoceima city.

From the interpretation of the isoseismal map, it can be affirmed that the isoseismal line obtained from the data collected show, in general, a good agreement with previous results and it allows the demonstration of patterns of macroseismic phenomena that can help better understanding correlations with geological structures, geophysical and geographical parameters.

The primary reason damaged structures performed poorly during the Al Hoecima earthquake was their lack of structural design. Many of these structures collapsed or must be demolished. The Al Hoceima earthquake should be an example for other important cities of Morocco, which should be prepared for future earthquakes. This earthquake also shows that it is necessary to proceed with the adequate seismic retrofitting of weak structures and to build new ones, which will properly perform in future events.

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