EVALUATION OF PROBABILISTIC SEISMIC HAZARD IN NORTHERN ALGERIA.

A CONTRIBUTION TO THE ALGERIAN BUILDING CODE

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Abstract

The recent seismic activity in northern Algeria evidences the need for updating the current Algerian building code, and consequently, the need to update the probabilistic seismic hazard values in force in northern Algeria assessed in previous works. The seismic risk reduction uses the results of seismic hazard analysis, and includes consequence and probability.

This study is a large highlight on the used updated procedure. The spatially-smoothed seismicity approach was used for the computation of the seismic hazard values. The adopted method combines both zonified and non-zonified approches. It is well adapted to model disperse or background seismicity. Seismic hazard map in terms of peak ground acceleration (PGA) with 10% probability of exceedance in 50 years was initially obtained for rock. These maps are a crucial tools used in seismic risk reduction.

Also, we have computed spectral acceleration (SA) values for rock, corresponding to soils type A in Eurocode-8, and soils type S1 in the Algerian building code, damped at 5% for different periods. The compilation of seismic hazard in term of SA at different periods, damped at 5%, for three different types of soils (rock, and soft and stiff soils), and for return periods of 100 and 475 years, allow us to derive interesting relationships between SA (0.2-sec) *vs.* PGA and SA (1.0-sec) *vs.* PGA independent of the considered return period. In addition, uniform hazard spectra (UHS) have been obtained for different return periods at different locations. The computed UHS for different types of soils and for a 475 years return period have been proposed as design spectra. We have used the well known Newman-Hall approach with certain modifications. The SA (0.2-sec) is used to establish the spectral region for lower periods (region controlled by acceleration), while the SA (1.0-sec) is used to establish the spectral region for intermediate periods (region controlled by the velocity), just as it is proposed in the most recent International Building Code.

The results obtained in this study could improve the Algerian building code, which is a fundamental tool in seismic risk reduction.

Key words: Peak ground acceleration, spectral acceleration, uniform hazard spectra, design spectra.

Introduction

The recent seismic activity in northern Algeria, especially during the last 50 years is characterized by the occurrence of several damaging earthquakes. The EL Asnam region suffered the most destructive and damaging earthquake recorded in northern Algeria, namely those of September 9, 1954 (M_s6.8) and October 10, 1980 (M_w7.3). The most significant and recent event was the May 21, 2003 (M_w 6.9) Zemouri earthquake, located at around 50 km northeast of Algiers. In this context, the interest of the scientific community regarding seismology and seismotectonics has greatly increased in Algeria, especially in the fields related to the seismic risk assessment of urban seismic areas and its possible reduction. We focus on the probabilistic seismic hazard map in terms of PGA with 10% probability of exceedance in 50 years, which generally forms the basis for the seismic design provision of National building code.

The aim of this study is to evaluate the seismic hazard in northern Algeria in terms of ground motion parameters (PGA and SA) by using the new methodology proposed by Frankel (1995), Frankel et al., (1996) and developed here with certain modifications (Pelaez, et al., 2005a; 2005b). This methodology combines both parametric and non-parametric (nonzoning) probabilistic methods: seismic sources are used when considering zones where certain parameters may be considered homogeneous, as in parametric methods, while, on the other hand, earthquakes are considered wherever they have taken place, as in non-parametric methods. The Frankel (1995), Frankel et al., (1996) methodology is well adapted to model the seismicity that cannot be assigned to specific geological structures, which is usually known as background seismicity. Using this new methodology the seismic hazard for northern Algeria in terms of ground motion acceleration for a return period of 475 years have been computed. Also, we have computed spectral acceleration (SA) values for rock), corresponding to soils type A in Eurocode-8, and soils type S1 in the Algerian building code, damped at 5% for different periods. The compilation of seismic hazard in term of SA at different periods, damped at 5%, for three different types of soils (rock, and soft and stiff soils), and for return periods of 100 and 475 years, allow us to derive interesting relationships between SA (0.2-sec) vs. PGA and SA (1.0-sec) vs. PGA independent of the considered return period. In addition, uniform hazard spectra (UHS) have been obtained for different return periods at different locations. The computed UHS for different types of soils and for a 475 years return period have been proposed as design spectra. We have used the well known Newman-Hall approach with certain modifications. The SA (0.2-sec) is used to establish the spectral region for lower periods (region controlled by acceleration), while the SA (1.0-sec) is used to establish the spectral region for intermediate periods (region controlled by the velocity), just as it is proposed in the most recent International Building Code.

Seismicity and Seismotectonoc sketch

The area under study, northern Algeria, could be described in short by including four morphostructural domains: the Tell Atlas, the High Plateaus, the Sahara Atlas and the Sahara Platform (figure. 1). The tectonics of this region has been the subject of various studies, such as Meghraoui (1988), Meghraoui et al., (1986). Briefly, the Tell Atlas consists of a succession of mountain ranges and valleys parallel to the coastline, and showing different morphological aspects, with juxtaposed platforms (alluvial basins) and high topography.

Parallel ridges and valleys correspond to E-W to NE-SW trending alluvial basins and thrusts and folds systems with a transport direction to the south and southeast. The High Plateaus zone is situated in-between the Tell Atlas and the Sahara Atlas, in an elevated region of relatively tabular topography. The Sahara Atlas domain is a mountain range with a folded Mesozoic-Cenozoic cover. The Sahara Platform limits the whole region to the south. The Tell Atlas is among the most important geological domain in the region, and lies within the active collision zone between Eurasia and Africa plates. The tectonic regime in this part of the Alpine chain is mostly compressional since the early Cenozoic, with late Quaternary N-S to NWSE convergence. This complex tectonic setting, inside an active deforming zone that absorbs 5 to 6 mm/year (from Nuvel-1 model by Argus et al., 1989) of crustal shortening and dextral shearing (Bezzeghoud and Buforn, 1999; Henares et al., 2002), is responsible for the contemporary seismicity. The main faults with strike NE-SW correspond to structures often organized in echelon systems of thrust faults dipping to NW, such as the El Asnam and Tipaza faults. Northern

Algeria is known as the most active seismogenic area in the western Mediterranean region, in the eastern part of the Ibero-Maghrebian zone, therefore, during the last century, Algeria has experienced several strong earthquakes (CRAAG, 1994). The analysis of the distribution of earthquake epicenters during the last three century leads to the conclusion that earthquakes in Algeria occur mostly in some Tell Atlas zones, however a few earthquakes appear in the High Plateaus and in the Sahara Atlas. The seismicity analysis also shows that the seismogenic areas are located in the vicinity of the Quaternary Basins. These tectonic zones contained in Neogene and Quaternary deposits extend to the Messeta Basin (region of Oran) in the western Tell Atlas, in the center to the Mitidja Basin (Tipaza-Algiers) close to the Atlas blideen, and extends to the Soummam, Constantine and Guelma Basins in the eastern part, to the Hodna Basin in the southeast, which is an integral part of the Tell Atlas.

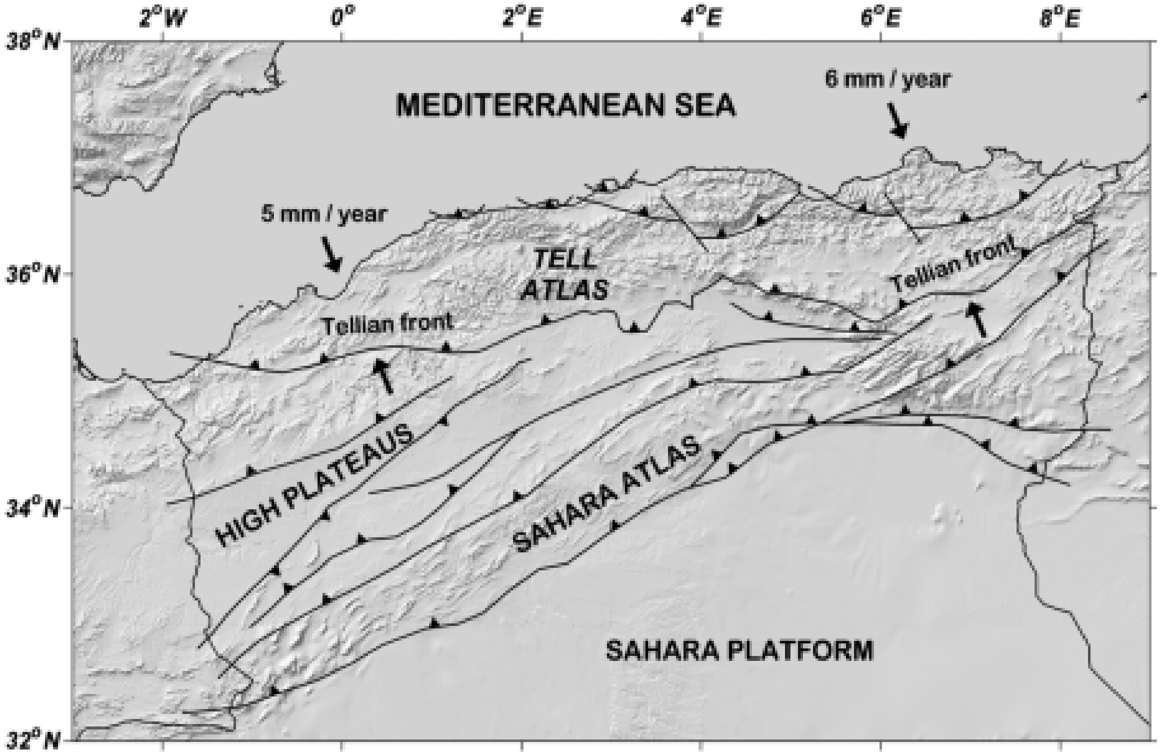

Figure 1 : Schematic map showing the regional tectonic setting (modified from Bracene et al., 2003).

Analysis of earthquake data file

The region under study is the northern Algeria which could be considered in terms of plate boundaries between Eurasia and Africa. The seismicity of this part of the Ibero-Maghrebian region is the result of the compressional movement between the Eurasia and Africa plate, which have been established. The tectonic regime in this part of the Alpine chain is mostly compressional since the early Cenozoic, with late Quaternary N-S to NW-SE convergence.

The earthquake catalog compiled for this area mainly consists of those of the Ibero- Maghrebian catalog published by the Spanish Instituto Geográfico Nacional, (IGN) (Mezcua and Martínez Solares, 1983), supplemented for the Algeria zone with data published by the CRAAG (CRAAG, 1994) and updated to 2002. The data published for the region by the EMSC (European-Mediterranean Seismological Center) and by the USGS (US Geological Survey) have also been incorporated in the data file.

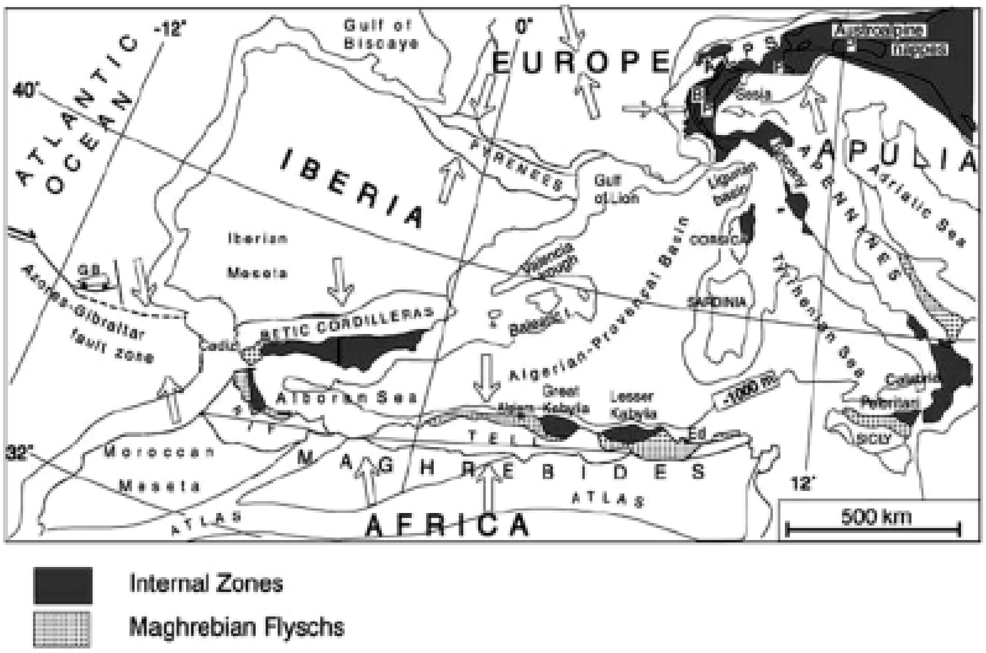

Figure 2 : Tectonic context of the Mediterranean basin.

The quality of our basis catalog has been appreciated during the Ibero-Maghrebian Workshop (under the auspices of the European Seismological Commission, ESC) in their 1979 meeting in Rabat (Morocco). It has been pointed out that this is the most reliable catalog covering the Ibero-Maghrebian region, evidently for regional use. Under the auspices and funding of UNESCO, an enormous effort has been done to complete, homogenise and improve the previous one. All these efforts were concretized in the publication by Mezcua and Martínez Solares (1983). This catalog is being updated periodically. As mentioned by the authors, they used 131 catalogs (catalogs in the strict sense of the word, and papers on the seismicity of a certain region spanning more than one year) and 313 papers about specific earthquakes to compile it. At the beginning of 2003, it included more than 23800 earthquakes. For example, starting in the 60's this catalog reported macroseismic intensities in northern Algeria above or equal to degree III in the MSK scale. In 1990, after their most important station restructuring, earthquakes in northern Algeria above mb 3.0 - 3.5 were reported (Bezzeghoud et al., 1994). After Bezzeghoud et al., (1994), events with magnitude larger than 1.0 are detected in northern Algeria; those with magnitude 3.0 are generally detected in seven stations. Today, they report earthquakes in this region above mb 2.0-2.5. This catalog has been improved, when ever data were available, with the Algerian catalog compiled by the Algerian Centre de Recherche en Astronomie, Astrophysique et Géophysique (CRAAG). Besides, MS magnitude reliable data from USGS and EMSC has been included as well. All the magnitudes and intensities were converted to MS magnitudes using the relationships by Lopez Casado et al., (2000), after testing different empirical relationship as the one proposed by Benouar (1994) and CRAAG (1994). The comparison shows that the relationships by Lopez Casado et al., (2000) are the more appropriate one for data file compiled. These empirical relations are given by;

$$Ms = -3.44 + 1.65\, mb + 0.40\, P$$

$$Ms = -1.52 + 0.0051\, I^{2}0 + 0.70\, P$$

In both equations P is equal to 0 for the mean value and 1 for the 84-percentile.
The next step consists to remove all the identified aftershocks and the foreshocks. In this study we have used the methodology proposed by EPRI (1986) to identify and to remove all the non-poissonian earthquakes. The Poissonian character of the final catalog has been analyzed by considering the cumulative earthquake number as a function of time above different magnitude values (Benjamin and

Cornell, 1970). After removing the non-Poissonian earthquakes, the poissonian character of the final catalogue has been analysed by considering the cumulative earthquake number as a function of time above a different threshold magnitude, the analysis is presented in Hamdache et al., (2007). This check is a key step to establish different complete and poissonian, seismic models to be used in the calculation of the seismic hazard (Pelaez et al., 2003, 2005; 2007; Hamdache et al., 2007). For this instance four complet and poissonian seismic models have been derived.

The figure 3, shows the representation of the cumulative earthquake number as a function of time above a threshold magnitude chosen on completeness analysis.

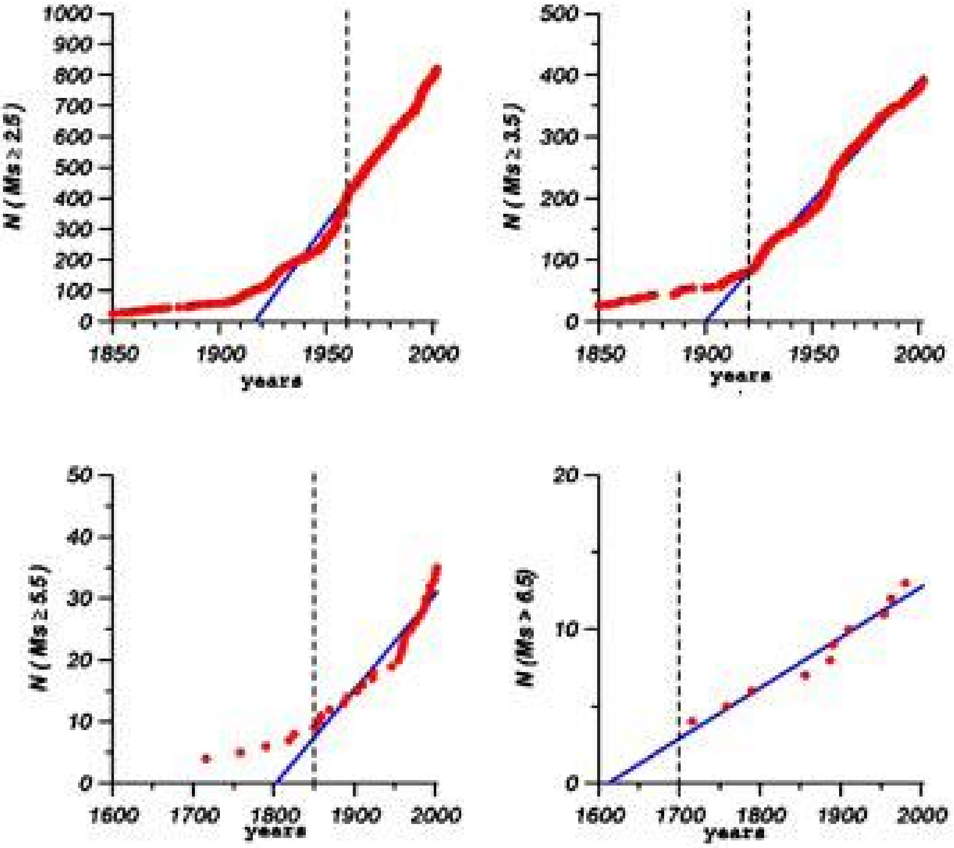

Figure 3 : Cumulative number of earthquake as a function of time.

These four seismic models are summarized below.

Model I : It includes earthquakes with magnitude greater or equal than Ms 2.5 (~ mb 3.6, I_0 = IV, according to the relationship by Lopez Casado et al., 2000) after 1960. This model is the most complete from a spatial point of view. An analysis of their Poissonian properties gives a constant annual rate of 9.4 earthquakes above the minimum magnitude chosen. The model includes a total of 425 earthquakes

Model II : It includes earthquakes with magnitude greater or equal than Ms 3.5 (~mb 4.2, I_0 = VI) after 1920. An annual activity rate equal to 3.9 earthquakes is obtained for this model. The total number of events included in this model is 313.

Model III : This model includes earthquakes with magnitude greater or equal to Ms 5.5 (~mb 5.4, I_0 = VIII-IX) after 1850. An annual rate of 0.16 earthquakes has been obtained. The total number of events included in this model is 27.

Model IV : It includes earthquakes with magnitudes greater or equal than Ms 6.5 (~mb 6.0, I_0 = IX-X) after 1700. Only ten earthquakes are included in this last model. The obtained annual rate is 0.033.

Using the empirical relation by Murphy and O'Brien (1977), the threshold magnitude for each seismic model is given in magnitude volume scale. The completeness and Poissonian character of our four seismic models is inferred from figure 5. It is shown how the annual rate of earthquakes is constant for those are considered in each model. Also, it is shown that earthquakes agree very well with a Gutenberg-Richter relationship for the dates and magnitude ranges taken into account in each seismic model. It is important to point out that seismicity included in the first two models (1 and 2) is the instrumental seismicity, with minimum uncertainty in their epicentral location. The last two models (3 and 4) include moderate and large earthquakes that have taken place in the region. Some of them are historical and thus, they may have a high uncertainty, not only in their epicentral location but also in their intensity or macroseismic magnitude. These models are really necessary, because they reveal the areas tending to have high seismic hazard.

Methodology outline

As in probabilistic zonified methods, we have used a delimitation in seismogenic source zones. Yet, without the standard general practice and methodologies employed, the delineation of the seismic sources remains mostly subjective. In this study, seismogenic source zones are defined as areas with seismic characteristics that are as homogenous as possible. Based on the work of Aoudia et al., (2000), some modifications have been introduced into the seismogenic source zones previously proposed (Hamdache, 1998a, Hamdache et al., 1998b; Hamdache and Retief, 2001) for northern Algeria. The geological description given in Aoudia and al., (2000) has been used to incorporate the geological knowledge in the seismogenic sources considered in this study. Different geological structures have been included to identify ten seismogenic zone sources in northern Algeria. Each proposed source zone, which seems homogeneous in its seismic characteristics, is often related to active or potentially active geological structures. Some of them are included in the Quaternary basins previously mentioned. This seismogenic source model shown in Figure 3, is consistent with the distribution of the seismicity in the northern Algeria.

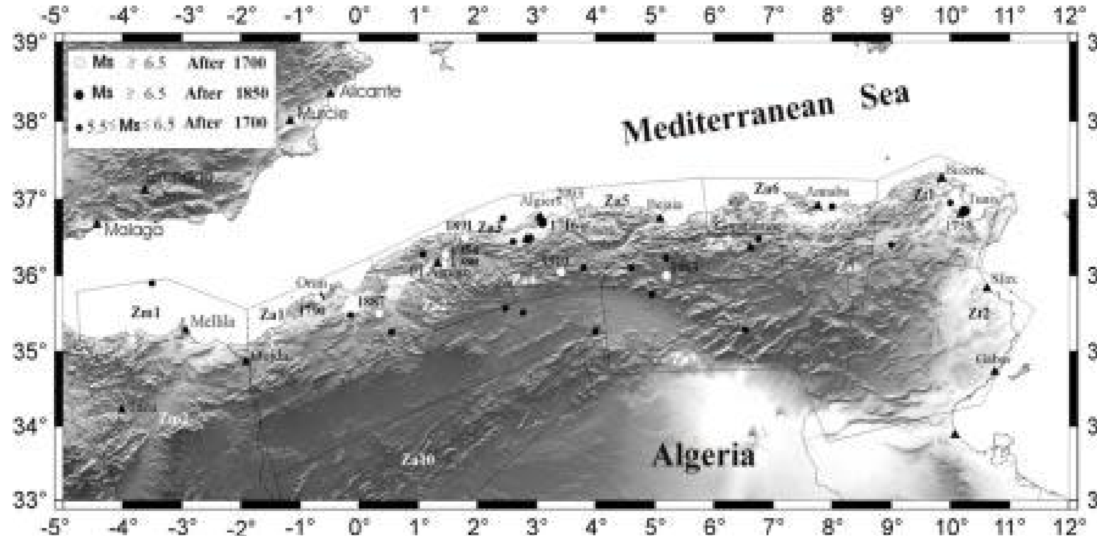

Figure 4 : Seismicity map showing 5.5 ≤ Ms < 6.5 (small gilled circles) and Ms ≥ 6.5 (large gilled circles) earthquakes since 1850 and Ms ≥ 6.5 (large open circles) since 1700.

In northeastern Morocco and northern Tunisia, the sources have been defined without taking into account the geological context (seismicity sources), just to incorporate the contribution of the seismicity of these regions to the calculation of the seismic hazard in northern Algeria.

The procedure of the seismic hazard calculation is the usual one in the spatially smoothed seismicity methodology (i.e Frankel, 1995; Pelaez et al., 2003, 2005, 2007). The area under study is first divided into square cells (10 km x 10 km), then we count the number of earthquake Nk recorded in the k-ieme cell. The Gaussian filter (Frankel, 1995; Frankel et al., 1996) has been used to smooth the N values, thus, including the uncertainty in the earthquake location in the seismic hazard results. The fraction of q earthquakes in the interval magnitude m ± Δm/2 is given by the expression (Pelaez and al., 2003).

$$q(m,\Delta m) = N.\frac{10^{-b(m-m_0\,)}}{1-10^{-b(m_{max}-m_0)}}\,.\left\{10^{b\frac{\Delta m}{2}} - 10^{-b\frac{\Delta m}{2}}\right\}$$

Where the truncated Gutenberg-Richter relationship has been used (Cosentino et al., 1977). The b, m0 and mmax parameters characterize the adopted model recurrence, Δm is the magnitude interval in the computation of the seismic hazard and Nk is the total number of earthquakes in the k-ieme cell. The calculation methodology to evaluate the seismic hazard is based on the well know total probability theorem, expressed in terms of rate of exceedance of a certain level of ground motion. The final results are obtained by weighting the output of each of the four models. For the calculation of the seismic hazard with 10% probability of exceedance in 50 years, which corresponds to a return period of 475 years, the respective weights are 0.2, 0.2, 0.3 and 0.3. In both cases, the weighted values are proposed according to the return period, always trying that the models for an interval comparable to the return period provide a higher contribution.

Seismic hazard map in terms of PGA

In this study we have used the attenuation relationship for ground motion parameters, PGA and SA, developed by Ambraseys and al., (1996), especially to avoid the insufficient acceleration records database in northern Algeria to develop reliable regional attenuation model for the ground motion parameters. This attenuation model for peak ground acceleration is given by the following equation:

$$LnA = 3.408 + 0.612\ M\ - 0.922\ Ln(r^2 + 3.5^2) + \varepsilon$$

where, M surface wave magnitude, R the epicentral distance and μ normal variable with standard deviation equal to 0.576. The result obtained for each seismic model in terms of PGA with 10% probability of exceedance in 50 years is given on the following figure.

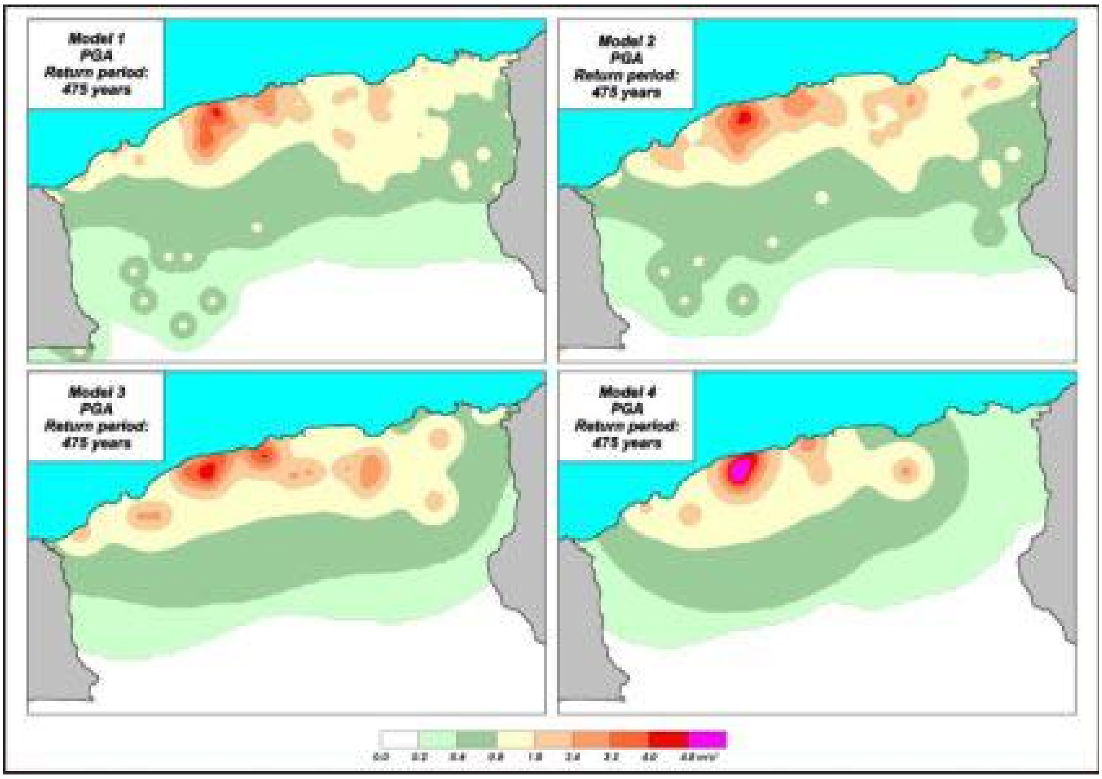

Figure 5 : Seismic hazard maps in terms of PGA for a return period of 475 years, for the four seismic models.

Using the weights explained previously, the figure 6 shows the seismic hazard map obtained for northern Algeria in terms of PGA for a return period of 475 years.

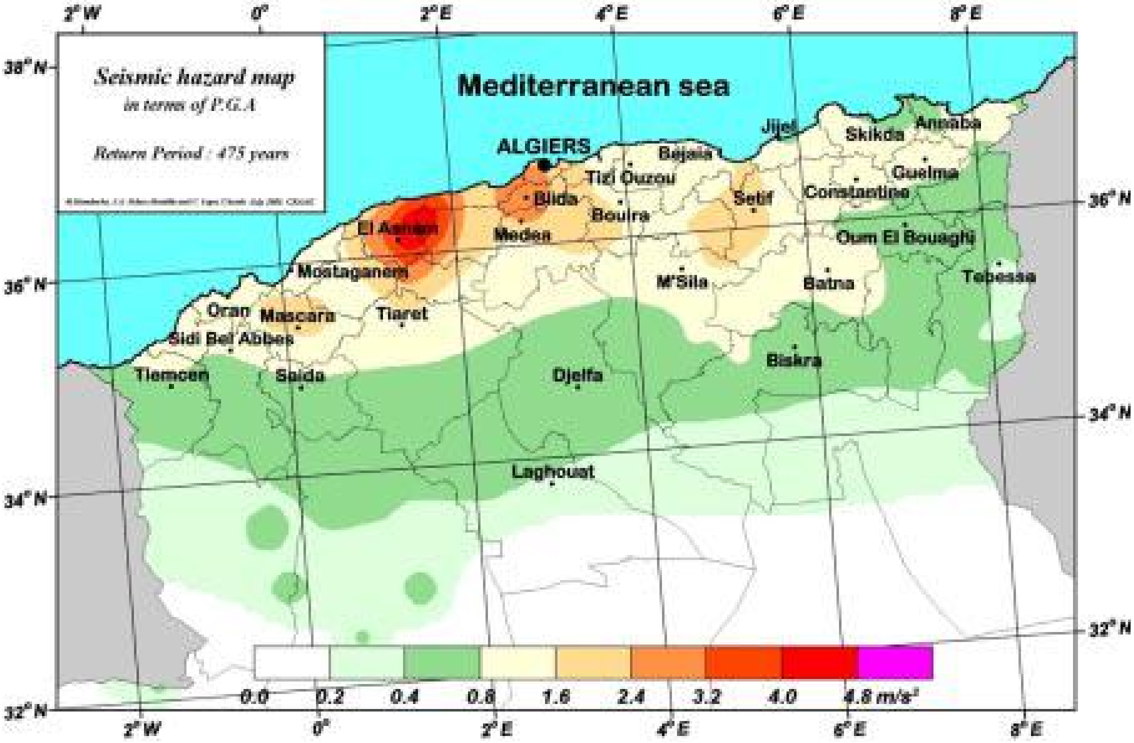

Figure 6 : Seismic hazard map for northern Algeria in terms of PGA acceleration with 10 % probability of exceedance in 50 years.

According to the obtained results in terms of PGA for a return period of 475 years, a preliminary seismic hazard zonification has been carried out (Pelaez and al., 2003) using the guidelines by Giardini and al., (1999).

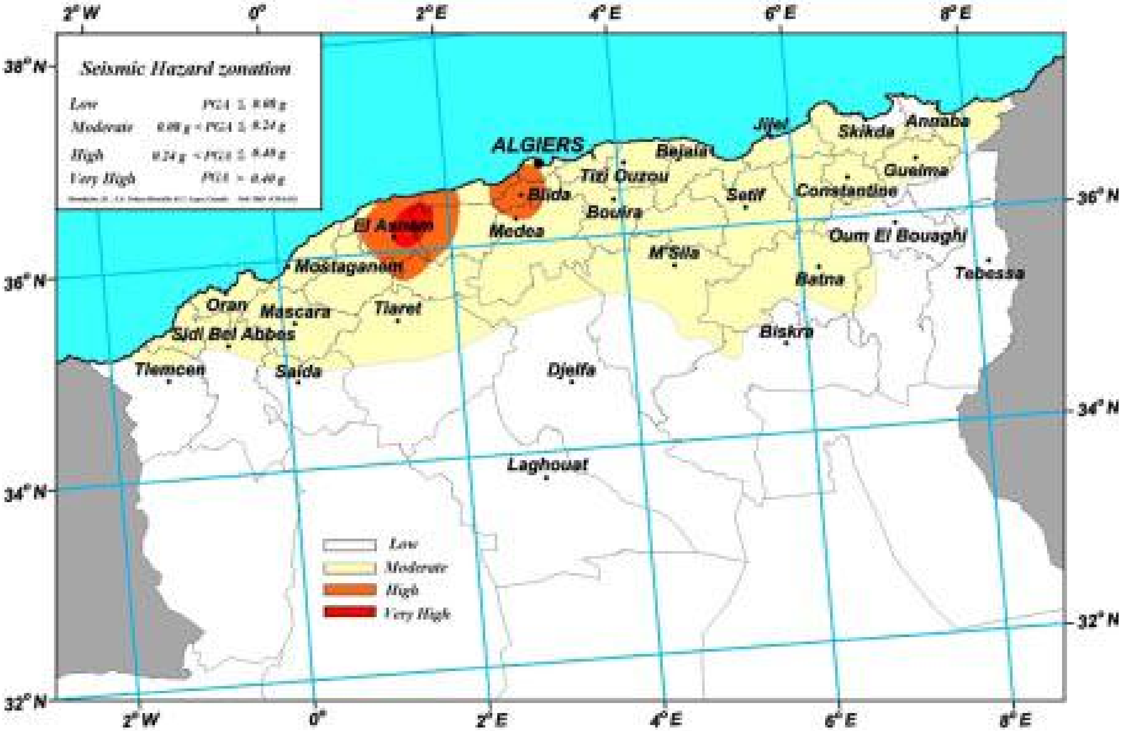

Figure 7 : Seismic hazard zoning in northern Algeria.

The seismic hazard zoning obtained include four parts, low, moderate, high and very high. The low part is defined by a level of PGA lower than 0.08g, the moderate part by a level of seismic hazard between 0.08 g and 0.24g, the high level part is defined by a PGA between 0.24g and 0.40 and the last one, the very high level seismic hazard part is defined by PGA greater than 0.24g

Seismic hazard maps in terms of spectral acceleration

In this section we use the spectral acceleration for rock soil and 5 % damping, to evaluate the seismic hazard in terms of spectral acceleration. We use the Ambraseys and al., (1996) attenuation model which could be written as follow:

$$\log y = C_1 + C_2 M + C_3 \log r + \varepsilon , \ r^2 = d^2 + h^2$$

In this relationship C_1 , C_2 , C_3 and h_0 are coefficient depending on the periods, log y is dependent variable (log of spectral acceleration), M is the Ms magnitude, and d is the Joyner-Boore distance (Joyner and Boore, 1981) usually denoted r_{jb} , and μ standard deviation which depends on the periods. We are deriving SA values for rock (V s >750 m/s), corresponding to soil type A in Eurocode 8 (EC 8, 1998) and S1 in the Algerian building code (RPA, 1999 revised 2003), damped at 5%, at periods of 0.1, 0.2, 0.3, 0.4, 0.5, 1.0, 1.5 and 2.0 s. The results obtained are shown on figure 8.

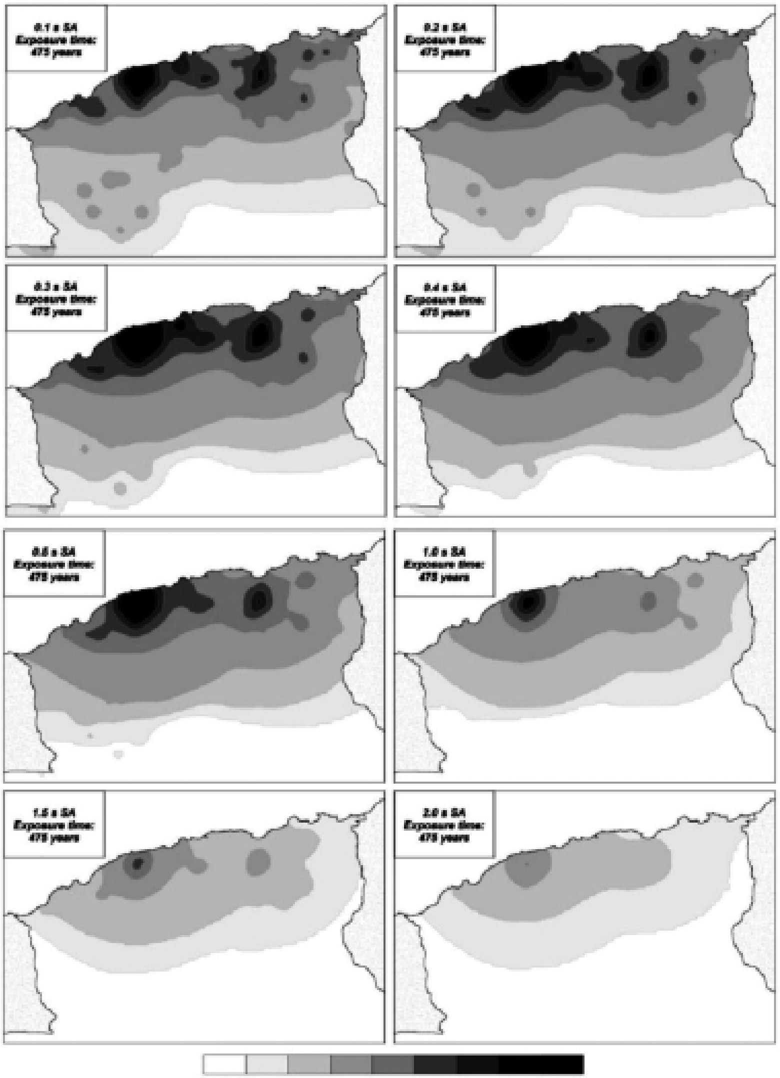

Figure 8 : Seismic hazard in terms of SA for rock and 5 % damping at different period 0.1 to 2.0s for a return period of 475 years.

The results obtained could be adjusted to other level of damping by using the procedure developed in 2000 by the International building code (ICC, 2000) for adjusting 5 % damping spectra to other level of damping. These adjustments are given by the equation $SA\mu = SA\ 5\%/\ C(\mu)$. Where $C(\mu)$ is the corresponding damping adjustment factor. Newmark and Hall (1982) proposed C values or more recently Naeim and Kircher (2001) give more reliable values, for example $c(10\%)= 1.239\ \sigma = 0.133$.

Uniform hazard spectra – Elastic design spectra

A standard probabilistic seismic hazard assessment (PSHA) output is the uniform hazard spectra (UHS), which is a response spectrum having uniform (or constant) probability of exceedance at the particular site, UHS does not represent the effect of just one earthquake, but instead, will represent the envelope of the effects of earthquakes of varying magnitudes and source-to-site distances. It is customary to find that the short period part of the UHS is governed by contribution from small-to-moderate earthquakes from nearby sources, whereas the larger magnitude earthquakes from distant sources affect the long period of the spectrum (range 0.5 to 2.0s). It should be acknowledged that UHS assumes that spectral ordinates at different periods are statistically independent of specific scenario. It is established (Malhotra, 2005) that the spectral accelerations increase with the increase of the return period, but they cannot be adjusted for the return period, they have to be calculated for each period. Nontheless, the UHS represents an appropriate probabilistic representation of the earthquake action and represents a key element of seismic design codes such as the International Building Code (ICC, 2000).

We have computed the UHS at 33 cities located in the northern Algeria, the highest estimated seismic prone areas in Algeria, as shown in figure 3. The calculation has been performed for three soil types, rock, soft and stiff soil type and for 475 years return periods.

As in Pelaez et al., (2006), to obtain a high definition of the spectrum and since the attenuation equation by Ambraseys et al., (1996) allow it, we calculate the ordinate of the UHS at 0s (PGA value) and at 36 different period values ranging from 0.1 to 2.0s, using a step size of 0.02s between 0.1s and 0.5s and a step size of 0.1s between 0.5 and 2.0s.

From the obtained UHS, shown on figure 9, different SA characteristic values for the chosen site are derived for the three soil types (rock, soft and stiff) and for 475 years of return period. The obtained results are very similar and in agreement with those obtained for a return period of 475 years and for rock soil type, by Pelaez et al., (2006). For the chosen return period, 475 years, the greatest values of PGA and SA_{max} are obtained in the city of Ech-Chlef. The obtained PGA values are of the order 0.42g, 0.45g and 0.44g for respectively rock, soft and stiff soil. The maximum spectral acceleration SA_{max} equal to 1.32g for rock, to 1.44 for soft and to 1.32g for Stiff soil, are reached at period equal to 0.32s.

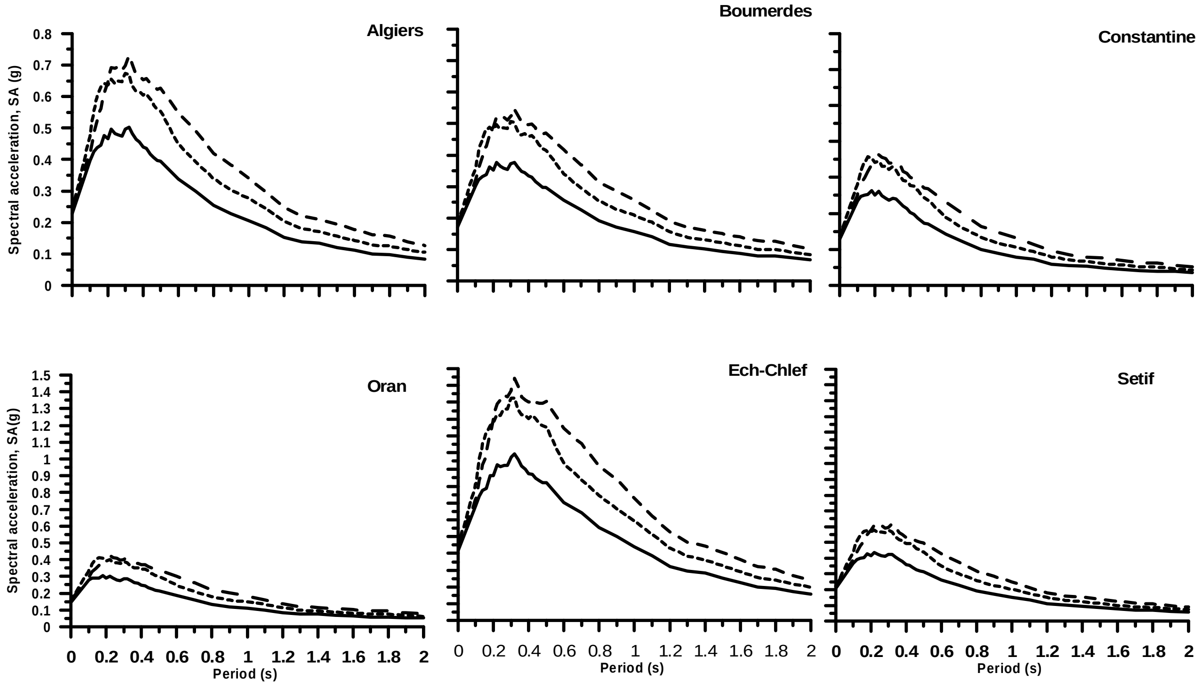

Figure 9 : UHS (for rock and 5% damping) with 39.3% and 10% probability of exceedance in 50 years for 6 selected cities among the 33 one studied in northern Algeria. The unit of the y-axis is in g (g - 10m/s²)

It is well known that the elastic response spectra calculated specifically for a certain location are an indispensable tool in a seismic design of buildings. It allows, estimating the forces in a building due to ground motion caused by future earthquake.

In this study from the UHS derived specifically at 33 cities in northern Algeria, computed for different soil types (rock, soft and stiff) damped at 5% and for a return period equal to 475 years, are proposed as design spectra. We use, with certain modifications the Newmark-Hall (1982) approach. The spectral acceleration for 0.2s, SA(0.2s), is used to establish the spectral region of lower periods (region controlled by the acceleration), while the spectral acceleration value for 1.0s, SA(1.0s), is used to establish the spectral region for intermediate periods (region controlled by the velocity), as such it is proposed in the recent International building Codes (IBC, 2006).

The procedure starts, as described in Malhotra (2005) by,

1- The SA(0.2s) and SA(1.0s) for the desired return period are read from the uniform hazard spectra. The control period T_S is calculated $T_S = 1s \frac{SA(1s)}{SA(0.2s)}$

2- The spectral acceleration in various period ranges are calculated by

$$SA(T) = \begin{cases} 0.4SA(0.2s) + 3SA(0.2s)\frac{T}{T_S} & T < 0.2T_S \\ SA(0.2s) & 0.2T_S < T < T_S \\ SA(1s)\frac{1s}{T} & T > T_S \end{cases}$$

The spectral acceleration SA(0.2s) and SA(1.0s) damped at 5%, obtained at the 33 cities for the three soil types (rock, soft and stif) and for a return period 475 years are used to derive spectral acceleration design for a return period of 475 years at the 33 studied cities and the different soil types. Particularly, and taking into account the soil classification by Ambraseys et al, (1996), for rock soil characterized by Vs(30) > 750 m/s, corresponding to the soil type A in the EC8 classification and to class S1 in the Algerian building code, stiff soil characterized by 360 < Vs(30)< 750 m/s corresponding to class S2 in Algeria provision and soil type B in EC8, soft soil characterized by 180 < Vs(30)< 360 m/s corresponding to soil type C in the EC8 and class S3 in the Algerian building code.

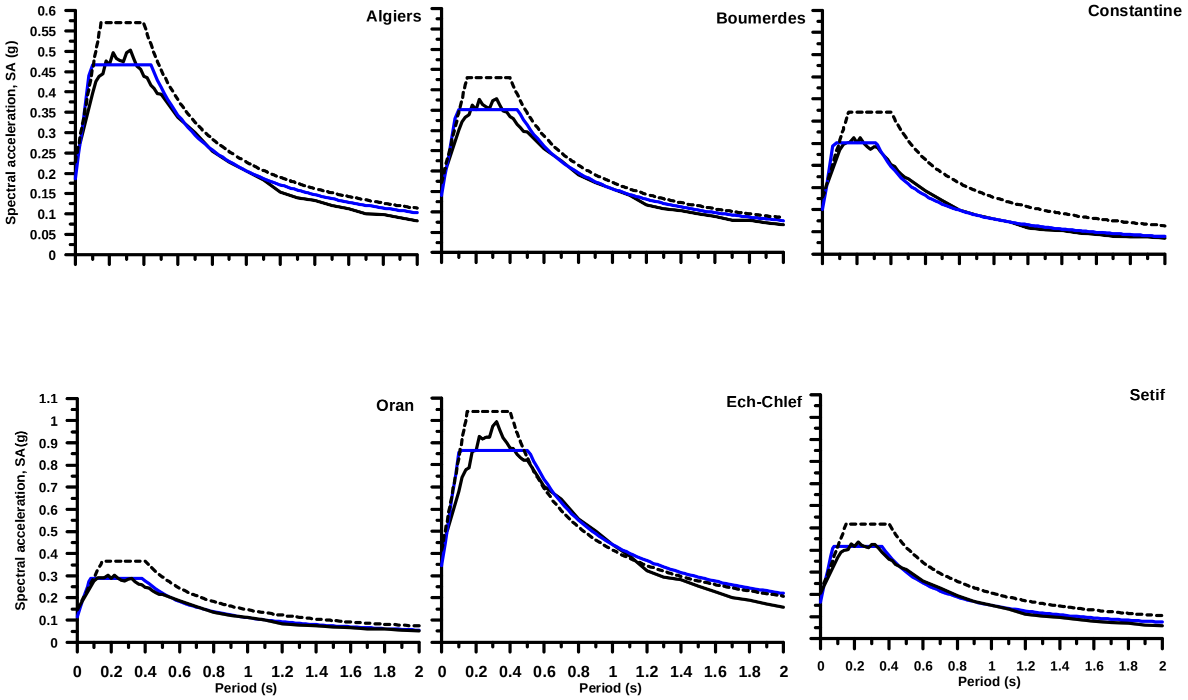

Figure 10 : Uniform Hazard Spectra (UHS) vs period, damped at 5% for a return period of 475 years. The graph shows the plot of the proposed design spectra and the EC8 response spectra of type I.

Discussion and Conclusion

In this study we summarised the most important recent results in seismic hazard estimation in northern Algeria by Pelaez et al., (2003, 2005 and 2006). The spatially smoothed seismicity has been used to derive probabilistic seismic hazard in northern Algeria in terms of PGA and SA for rock soil damped at 5%. We have presented the obtained results as SA maps at different periods with 10% probability of exceedance in 50 years, which correspond to a return period of 475 years. The seismic hazard zoning proposed is a fundamental tool in seismic risk reduction, it allows us to identify the most dangerous part in the studied area. Besides, the UHS have been derived at thirty three of the most important cities of northern Algeria. These results have been used to propose at each city elastic design response spectra for a return period of 475 years. Some characterics of the obtained results have been explored in Pelaez et al., (2005 and 2006). Especially from the seismic hazard maps, it has been noticed that high values are observed in the central part of the Tell, with some very well defined areas and slow decay also toward the east and west respectively. Such areas appear to be related to the regional geological context, with known geological structures being potentially active. It is also important to note that the morphology of the distribution of the seismic hazard level bands is clearly affected by the distribution of the seismicity, i.e, higher spatial density of moderate and large earthquakes implies a higher seismic hazard. Great attention has been devoted to the last major earthquake which occurred near the Algiers city (Hamdache et al., 2004a), to evaluate clearly the contribution of this new event in the seismic hazard evaluation (Hamdache et al., 2004b; Pelaez et al., 2005, 2006)

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