SEISMIC HAZARD ASSESSMENT IN ALGERIA: A CASE STUDY

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ABSTRACT :

This paper present results of the probabilistic seismic hazard analysis carried out in the Oran region, situated in the Northwest of Algeria. This part of Algeria was historically struck by strong earthquakes, it was particularly affected during the October 9, 1790 Oran earthquake of intensity (IX-X). The main purpose of this work is to assess seismic hazard on hard rock in order to provide engineers and planners a basic tool for seismic risk mitigation. The probabilistic approach is used in order to take into account uncertainties in seismic hazard assessment. Seismic sources are defined on the basis of recent results of seismotectonics studies. Source parameters are assessed for each seismic source either on the basis of seismicity data or geological data. The attenuation of ground shaking motion with distance is estimated by using attenuation relationships developed world-wide which fit the Algerian data. Different choices of source parameters values as well as attenuation relationships are assigned an appropriate weight in the framework of a logic tree model. Results are presented as relationships between values of peak ground acceleration (PGA) and annual frequency of exceedance, and map of hazard for a return period of 500 years. A maximum peak ground acceleration of 0.40g is obtained for the Oran site.

KEYWORDS : probabilistic analysis, seismic hazard, Algeria, earthquake.

1. INTRODUCTION

We learned from historical disasters that the first step in reducing the risk of the society from natural disasters is an assessment of the hazard itself. This means that the reduction of earthquake risk, whether it depends on other aspects such as the vulnerability of the exposed population, could be based on the knowledge about the expected level of ground motion that may be experienced in a given area within a given mean return period. Recent developments in the field of seismotectonics (Meghraoui, 1988; Bouhadad, 2001, Bouhadad & Laouami, 2002; Bellabes et al., 2008) and improvement in seismicity data (Benouar, 1994) make possible the construction of reliable seismic hazard maps in term of maximum peak ground acceleration. In Algeria, earthquake hazard constitutes a constant threat to human lives and properties. Indeed, Several strong and destructive earthquakes have been occurred in the past causing several hundreds of deaths and huge economic losses (CRAAG, 1994). For example during the last two decades the following disastrous moderate to strong earthquakes has been occurred: the El-Asnam 1980 (M_s=7.3), the Constantine 1985 (M_s=5.7), the Chenoua 1989 (M_s=5.7), the Mascara 1994 (M_s=5.6), the Ain Témouchent 1999 (M_s=5.6), the Beni-ourtilane 2000 (M_s=5.4) and the Zemmouri 2003 (M_w=6.8) earthquakes. In Algeria seismicity is concentrated along the costal region within a 150 km wide band where 90% of economic facilities and demographic centres are located. It is important to notice that because of the vulnerability of the building stock either moderate or strong earthquakes have often a disastrous consequences. Algerian experience in the field of seismic hazard analysis extends back to 1978 where the first seismic hazard study has been performed (Mortgat & Shah, 1978). Results of this study, based mainly on seismicity data, has been used for the zoning map of Algeria performed in the framework of the first Algerian seismic code elaborated in 1981.

Since then, more detailed studies based also on geological data, where conducted parallel to the development of seismotectonic studies (Meghraoui, 1988) and progress in assessing seismicity data (Benouar, 1994). In this work, we present the seismic hazard analysis of the Oran, western Algeria region, performed by using a probabilistic approach where it is assumed that the occurrence of earthquakes in a seismic source result from a Poisson process (Cornell, 1968; McGuire, 1978; NRC, 1988; Geomatrix, 1993). Where, the probability that at a given site a ground motion parameter, Z, will exceed a specified level, z, during a specified time, T, is represented by the following expression :

$$P(Z \succ z) = 1.0 - e^{-\nu(z).T} \le \nu(z).T ,$$

where $\nu(z)$ is the average frequency during time period T at which the level of ground motion parameter, Z, exceed level z at a given site. The function $\nu(z)$ incorporates the uncertainty in time, size and location of future earthquakes and uncertainty in the level of ground motion they may produce at the site. This study takes advantage from recent understandings in the field of faults identification and constrain of their seismic potential.

2. SEISMOTECTONIC SETTING

The studied area belongs to the westernmost part of the Chelif Neogene basin, a part of the Tell Atlas chain of Algeria. This area is under a compressional tectonics resulting from 3-6mm/yr convergence between African and Eurasian plates (Argus & al. 1989). The Eurasian plate is moving towards Africa in the NW (315°) direction (Nocquet et Calais, 2004) (figure 1). Consequently, several active reverse faults blind or not has been identified in the region (Thomas, 1985; Meghraoui, 1988; Meghraoui, 1991; Meghraoui & al., 1996; Aoudia & Meghraoui; Bouhadad et al., 2003; Bouhadad et al., 2004; Meghraoui & al., 2004). A relatively high and destructive seismicity has been resulted from the tectonic activity during at least the last two centuries covered by the seismicity catalogues (figure 2). it appears that the seismicity is well concentrated in some areas such as Chellif-Ain Defla, Algiers-Tipaza, Babor, Constantine-Guelma and the region of Oran-Beni Chougrane, which is the concern of this study (squared area in figure 2).

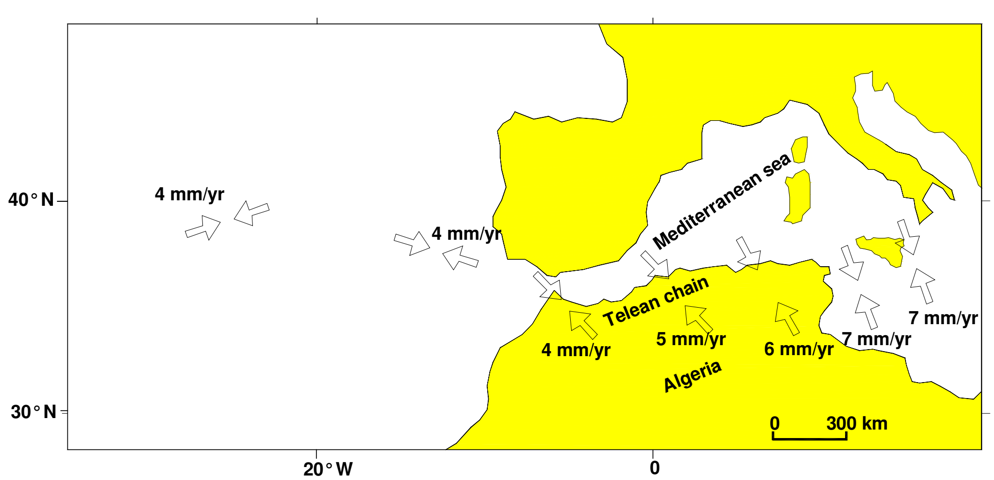

Figure 1 Seismotectonic setting of northern Algeria (redrawn from DeMets et al., 1989)

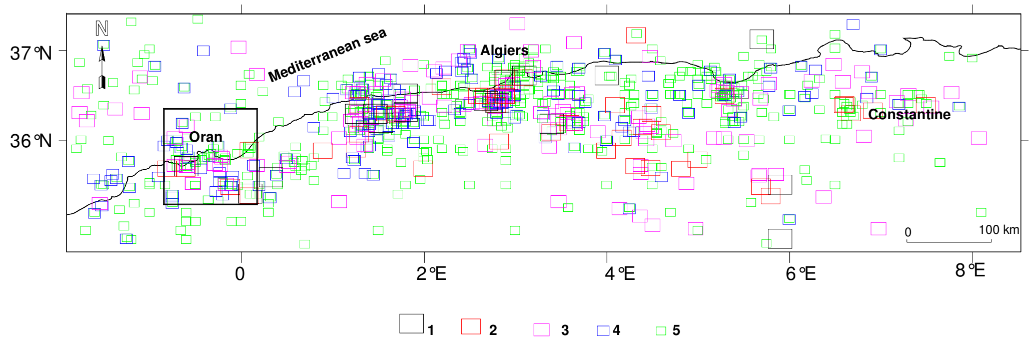

Figure 2 Seismicity of northern Algeria for the period 1365-2006. 1= M_s>6.0, 2= 6.0 ≥M_s ≥5.0, 3= 5.0 >M_s ≥4.0, 4= 4.0 >M_s ≥3.0, 5= M_s<3.0 (Benouar, 19984; CRAAG, 1994).

3. SEISMIC SOURCES AND ATTENUATION MODELS

Seismic hazard analysis requires definition of the location and geometry of the potential seismic sources. It's assumed that characteristics such as rate of activity within a given source are uniform. Earthquakes occur following slip of an earth block along faults planes; Therefore it's more realistic, firstly, to model seismic sources as line sources corresponding to active faults. Furthermore, we used three seismic source area in order to model the randomly distributed seismicity and the probably blind active structures. The defined source zones correspond globally to the inter-faults blocks. The active faults used for hazard calculation are shown on figure 3. After that, we assessed the seismicity and geological parameters of the identified sources (Table 1). The expected maximum magnitudes are assessed by using the Wells and Coppersmith, (1994) relationships. Slip rate of faults is assessed based on uplift of marine and alluvial terraces and by analogies with the well studied faults in the region (Merrits & Bull, 1988; Meghraoui & Doumaz, 1996). In terms of earthquakes recurrence two models are used in this work. The truncated exponential recurrence model (Cornell and Van Marke, 1969) for seismic source areas and the characteristic model (Young & Copersmith, 1984) for specific faults. In terms of ground motion attenuation we used the worldwide developed attenuation laws which fit the Algerian data (Ambraseys & Bommer, 1991; Sadigh & al., (1993). The two attenuations laws has been given an equal weight of 50% in the model.

4. RESULT AND DISCUSSION

Results of the seismic hazard assessment of the Oran region are presented herein as curves of relationships between values of peak ground acceleration and annual frequency of exceedance (figure 4). Furthermore, mean values of accelerations are presented as a map for a return period of 500 years obtained by calculating hazard for different sites in a grid of 10 km X 10 km (figure 5). Uncertainties dues to the choices and weight of parameters values as well as attenuation laws are presented as the mean, median (50% percentile), 15th, and 85th percentiles values of annual probability of exceedance. It appears from the obtained result that seismic hazard in the studied region is dominated by the Oran fault (F2 on figure 3), which is a major geological structure that likely produced the Oran earthquake of October 9, 1790 of intensity X. The proposed seismic hazard assessment is based on the assumed seismic potential of geological structures which we believe, despite the lack of paleoseismic data, are sufficient to perform a reliable seismic hazard analysis. On the other hand the obtained results shows that previous studies based mainly on seismcity data underestimate seismic hazard of the area (Mortgat é& Shah, 1978; Benouar & al., 1996; Jiménez & al., 1999).

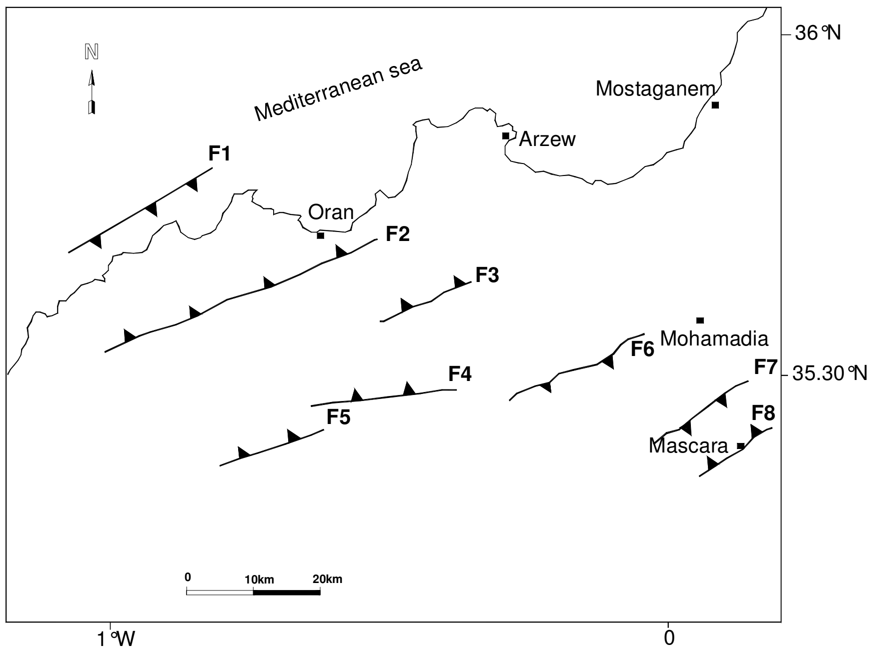

Figure 3 seismic source model of the studied area showing the location and dipping of the identified active faults.

Table 1. Values of parameters of the identified faults. The values between brackets correspond to the attributed weight for each parameter in the logic tree model. Positions of faults F1 to F8 are shown on figure 3. Values separated by commas correspond to alternative choices of values.

Faults	Magnitude Max	B-value	Slip rate in mm/yr
F1	6.75 (0.7), 7.0 (0.3)	0.47 (0.2), 0.30 (0.6), 0.13 (0.2).	0.30 (0.6), 0.50 (0.4)
F2	7.25 (0.6), 7.5 (0.2), 7.0 (0.2)	0.47 (0.2), 0.30 (0.6), 0.13 (0.2)	0.30 (0.15), 0.40 (0.14), 0.50 (0.15), 0.70 (0.14), 1.80 (0.42)
F3	6.5 (0.5), 6.75 (0.5)	0.32 (0.2), 0.30 (0.6), 0.28 (0.2)	0.30 (0.15), 0.40 (0.4), 0.50 (0.15), 0.65 (0.3)
F4	7.0 (0.5), 6.75 (0.5)	0.29 (0.2), 0.27 (0.6), 0.25 (0.2)	0.30 (0.2), 0.50 (0.3), 0.15 (0.50)
F5	6.5 (0.5), 6.75 (0.5)	0.29 (0.2), 0.27 (0.6), 0.25 (0.2)	0.30 (0.2), 0.50 (0.3), 0.15 (0.50)
F6	7.0 (0.5), 6.75 (0.5)	0.29 (0.2), 0.27 (0.6), 0.25 (0.2)	0.30 (0.2), 0.50 (0.6), 0.70 (0.1) 0.30 (0.1)
F7	7.0 (0.5), 6.75 (0.25) 6.50 (0.25)	0.34 (0.2), 0.24 (0.6), 0.14 (0.2)	1.40(0.42), 0.70 (0.14), 0.50 (0.34), 0.30 (0.1)
F8	6.50 (0.5), 6.75 (0.5)	0.34 (0.2), 0.24 (0.6), 0.14 (0.2)	0.30 (0.2), 0.50 (0.3), 1.40 (0.3), 0.70 (0.1), 0.50 (0.1)

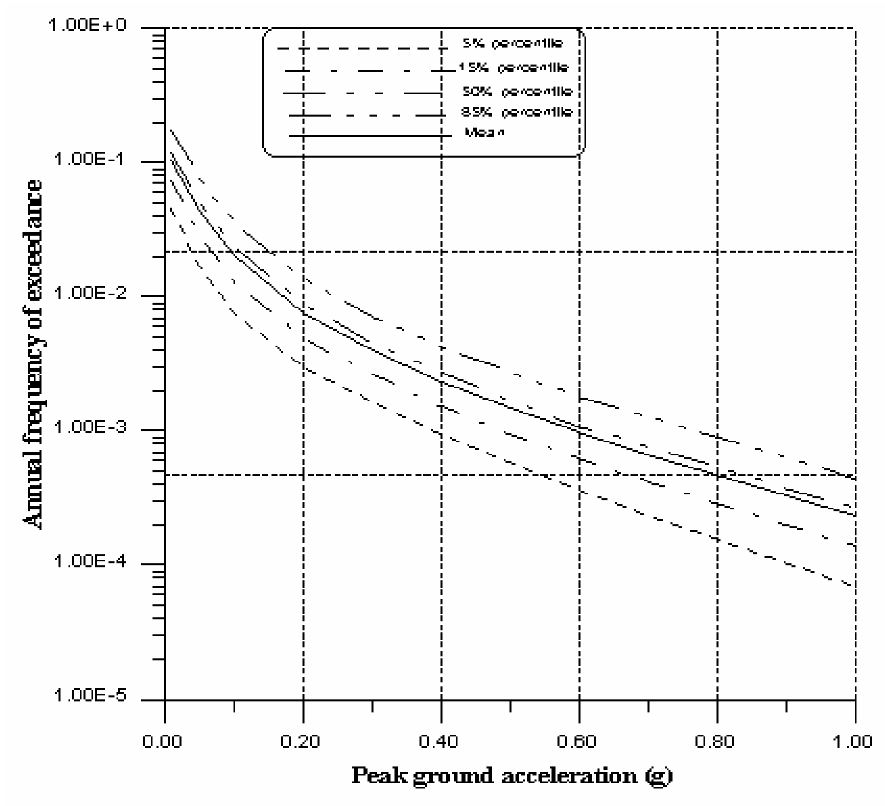

Figure 4 peak ground accelerations versus annual frequencies of exceedance for the Oran site.

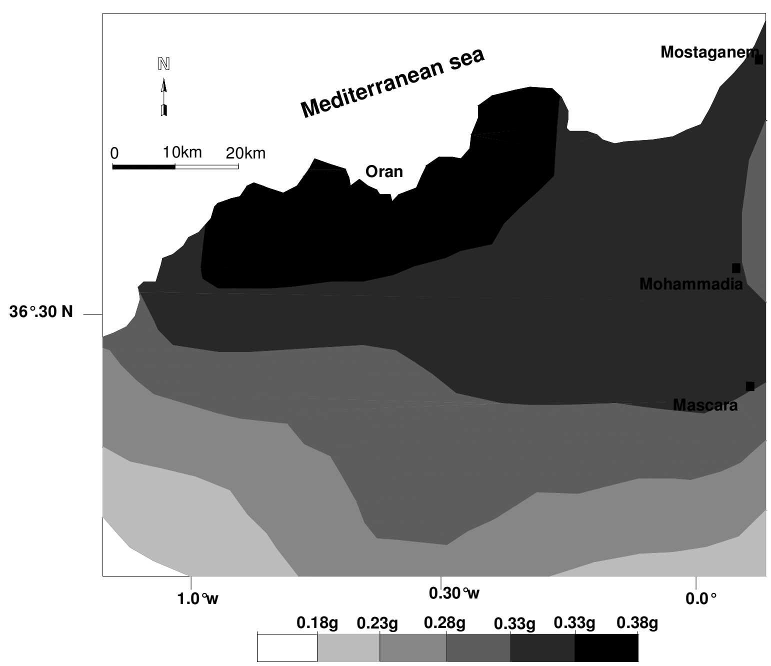

Figure 5 Seismic hazard map of the studied area for a return period of 500 years.

REFERENCES

Ambraseys, N. N., Bommer, J.J. (1991). The attenuation of ground accelerations in Europe, *Earthquake Eng. Struct. Dyn*., **20:** 1179-1202.

Aoudia, A., Meghraoui, M. (1995). Seismotectonics in the tell atlas of Algeria: The Tenes -Abou-El hassan earthquake of 25/08/ 1922 M = 6.0. *Tectonophysics*, **248:** 263-276.

Argus, D.F., Gordon, R.G., De Mets, C., Stein, S. (1989). Closure of the Africa-Eurasia-North America plate Motions circuit and tectonics of the Glauria fault. *J. of geophys. Resea*., **94:** 5585 - 5602.

Bellabes, S., Meghraoui, M., Cakir, Z., Bouhadad, Y., (2008b). InSAR analysis of a blind thrust rupture and related active folding : The Ain Témouchent earthquake (M_w 5.7, Algeria) case study, (submitted to Journal of Seismology).

Benouar, D., (1994) the seismicity of Algeria and adjacent regions. Annali di geofisica, **37:** 459-862.

Benouar, D., Molas, G. L.,Yamazaki, F. (1996). Earthquake hazard mapping in the Maghreb countries. *Earthq. Eng. & Struct. Dyn.,* **25:** 1151- 1164.

Bouhadad, Y. (2001). The Murdjadjo, western Algeria, fault-related fold: implication for seismic hazard, *Journal of Seismology, **5:** 541-558.*

Bouhadad., Y. Laouami, N. (2002). Earthquake hazard assessment in the western of Algeria, *Journal natural hazards, **26**: 227-243.*

Bouhadad, Y., Nour, A., Laouami, N., Belhai, D. (2003). The Tachaouaft-Beni-ourtilane fault and seismotectonic aspects of the Babors region (Eastern Algeria). *Journal of Seismology, **7:** 79-88.*

Bouhadad, Y., Nour, A., Slimani, A., Laouami, N., Belhai, D. (2004). The Boumerdes (Algeria) earthquake of May 21, 2003 M_W=6.8): Ground deformation and intensity. J. of Seismology, **8:** 497-506.

Cornell,C.A. (1968). Engineering seismic risk analysis. Bull. Seismol. Soc. Am., **58**, 1583-1606.

Cornell, C.A.,Van Marke, E.H., (1969). The major influence on seismic risk. Proceedings of the third conference on earthquake engineering. Santiago, Chile.**V: A-1**, 69-93.

Centre de Recherche en Astronomie Astrophysique et Géophysique (CRAAG) (1994). Les séismes de l'Algérie de 1365 à 1992. Publication du craag, Alger, pp. 227.

Geomatrix Consultants (1993). Probabilistic seismic hazard analysis computer program: A user manual.

Jiménez, M. J., Garcia-Fernandez, GSHAP Ibero-Maghreb Working Group (1999). Seismic hazard assessment in the Ibero-Maghreb Region. Annali di Geofisica, **42:** 1057-1066.

Mc Guire, R.K.(1978). FRISK: computer program for seismic risk analysis using faults as earthquake sources. U.S. geological survey. Open file report 78-1007.

Meghraoui, M. (1988). Géologie des zones sismiques du Nord de l'Algérie. Paléosismologie, tectonique active et synthèse sismotectonique. Thèse Doct. Univ. Paris Sud France, pp. 356.

Meghraoui, M.(1991). Blind reverse faulting system associated with the Mont Chenoua -Tipaza earthquake of 29 October 1989 (North central Algeria). Terra nova, **3 :** 84-93.

Meghraoui, M., Morel, J..L., Andrieux, J., Dahmani, M. (1996). Tectonique plio-quaternaire de la chaîne tello-rifaine et de la mer d'Alboran. Une zone complexe de convergence continent-continent. *Bull. Soc., Géol. France*, **167 :1**, 141-157.

Meghraoui, M., Doumaz, F. (1996). Earthquake-induced flooding and paleoseismicity of the El Asnam (Algeria) fault- related fold, *J. Geophys. Res*. **101:** 17617- 17644.

Meghraoui, M., Maouche, S., Chemaa, B., Cakir, Z., Aoudia, A., Harbi, A., Alasset, P.J., Bouhadad, Y., Benhamouda, F**.** (2004). Coastal uplift and thrust faulting associated with the (M_w=6.8) Zemmouri (Algeria) earthquake of 21 May, 2003. *Geophys. Res. Let. (GRL*), **31:** L19605.

Merrits, D., Bull, W.B (1988). Quaternary uplift rates at the Mendocino triple junction , Northern California from uplifted marine terraces. *Geology*, **17:**1020-1024.

Mortgat, C.P., Shah, H.C. (1978). Seismic hazard analysis of Algeria, technical report, the John A. Blume Earthquake Engineering Center, California, pp. 97.

National Research Concil (NRC), (1988). Probabilistic seismic hazard analysis. National academy press*,* Washington, D.C. 96 pages.

Nocquet, J.M., Calais, E. (2004). Geodetic measurements of crustal deformation in the western Mediterranean and Europe. *Pure and applied Geopys*. **161:** 661-681.

Sadigh, K., Chang, C.Y., Abrahamson, N.A., Chiou, S.J., Power, M.S. (1993). Specification of long period ground motion. Updated attenuation relationships for rock site conditions and adjustment factors for near fault effects. Proceedings of ATC-17-1 seminar on seismic isolation, passive energy dissipation, and active control. March 11-12 San -Francisco, California, 59-70.

Thomas, G.(1985). Géodynamique d'un bassin intramontagneux. Le bassin de Chellif occidental (Algérie) durant le mio-plio-quaternaire.Thèse. Doct. Univ. de Pau et pays de l'Addour. France, pp. 548.

Wells, D.L., Coppersmith, K.J. (1994). Updated empirical relationships among magnitude, rupture length, rupture area, and surface displacement. *Bull. Seismol. Soc. Am*., **84:** 974-1002.

Youngs, R.R., Coppersmith, K.J. (1985). Implication of fault slip rates and earthquakes recurrence models to probabilistic seismic hazard estimates. *Bull. Seismol. Soc. Am*., **75:** 939-964.