Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 8, Issue, 04, pp.29952-29959, April, 2016

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

ESTIMATING THE FREQUENCY, MAGNITUDE AND RECURRENCE OF EXTREME EARTHQUAKES IN MEDINA AREA, SAUDI ARABIA

*Said Ali El-Quliti

Department of Industrial Engineering, King Abdulaziz University, Jeddah, Saudi Arabia

ARTICLE INFO

Article History:
Received 23rd January, 2016
Received in revised form
14th February, 2016
Accepted 16th March, 2016
Published online 26th April, 2016

Key words:
Earthquakes,
Extreme event analysis,
Frequency,
Magnitude,
Recurrence,
Saudi Arabia.

ABSTRACT

Humans coexist with extreme events all the time, only when the intensity of the event becomes greater than a certain level there is a resulting disaster. Small earthquakes occur all of the time with no adverse effects. Only large earthquakes cause disasters. Statistical analysis reveals that larger events occur less frequently than small events. In a year, we would have many values for the events; the annual maximum is the greatest of those values. Within an annual series, only the largest value per year is allowed, even if an additional significant peak occurred. As the magnitude of a hazardous increases, the frequency of occurrence (how often a given magnitude is equaled or exceeded) decreases. Thus, major disasters result from a small number of large events that rarely occur. A plot of recurrence intervals versus associated magnitudes produces a group of points that also approximates a straight line on semi-logarithmic paper. Historical data are analyzed to gain an understanding of an event past behavior and to provide guidance on expected future. The extreme event analysis is concerned with the distribution of annual maximum values at a given site. These events are given a rank in a descending order. The Weibull equation is used for estimating the annual frequency, the return period or recurrence interval, the percentage probability for each event, and the annual exceedence probability. The probability of a certain-magnitude earthquake occurring in the region during any period can be also calculated. Past records of earthquakes at the Western region of the Kingdom of Saudi Arabia (Medina and surrounding area) for years 1921 G- 2010G are used to predict future conditions concerning the annual frequency, the return period, the percentage probability for each event, and the probability of a certain-magnitude earthquake occurring in the region during any period.

Citation: Said Ali El-Quliti, 2016. "Estimating the frequency, magnitude and recurrence of extreme earthquakes in medina area, Saudi Arabia", *International Journal of Current Research*, 8, (04), 29952-29959.

INTRODUCTION

One of the most destructive disaster of nature is a severe earthquake and its destroying effects. If the earthquake occurs in a populated area, it may cause many deaths and injuries and extensive property damage regions. The ultimate goal of seismic hazard assessment and risk evaluation for a particular site or area is to condense seism-tectonic knowledge and experience into parameters used for predicting seismic parameters which in turn can be applied by engineers in design and subsequent earthquake resistant construction. Statistical surveys support researches on the likelihood of future earthquakes. A primary goal of earthquake research is to increase the reliability of earthquake probability estimates. With a greater understanding of the hazard parameters of earthquakes, we may be able to reduce damage and loss of life from this destructive event. Statistics help us to predict the future events based on previous events.

***Corresponding author: Said Ali El-Quliti**
Department of Industrial Engineering, King Abdulaziz University, Jeddah, Saudi Arabia

Seismicity of the Western Region of Saudi Arabia

Recently, there has been an increasing concern about the seismic activity along the western coast of the Kingdom. Several studies were conducted to estimate the level of the seismic risk in the Kingdom (AL-Haddad *et al.,* 1992 and 1994). Western Region of Saudi Arabia is considered to be a moderately active seismic zoneas shown in Figure 1 (Ashour, *et al.,* 1994). Seismic events in the region that have been reported in literature include a significant earthquake, with a magnitude of 6.25in Richter scale, that occurred in 1941 at about 30 km to the east of Jizan city (Gutenberg *et al.,* 1965). Seismic events also include a sequence of earthquakes which occurred in 1967 along the Red Sea rift system at a distance of about 150 km to the south west of Jeddah (Barazangi, 1981). Recently, (EI-Isa *et al*., 1984) reported that about 500 local earthquakes with magnitudes less than 4.85, occurred in the

Gulf of Aqaba area duringthe period from January 21 to April 20, 1983. Merghelani (1979) has also reported that a high level of micro-earthquake activity was detected near the border of the Red Sea and near the transition from oceanic to continental crust.

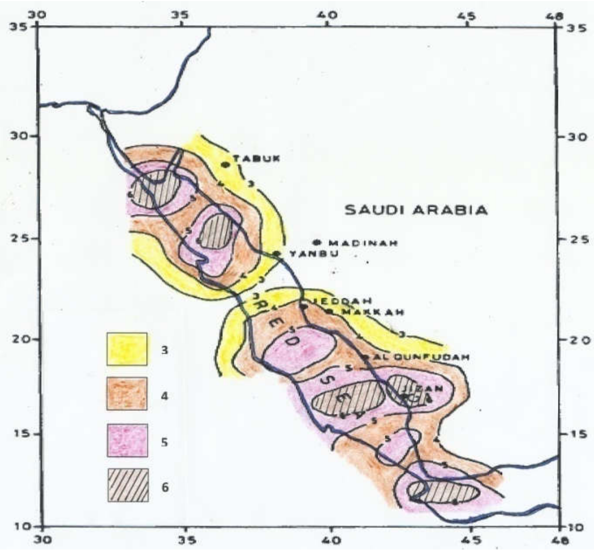

Figure 1. Earthquake intensity map for the Western Region, return period = 100 year

Seismicity of Alais Province

Ais province is located in the northwestern part of Yanbu with an area (2,863 km^2), representing 15.86% of the Yanbu area. It is located to the north-east of Yanbu and 150 kilometers by Quraishtrading to Syria -ancient-, called the path of Marib-Petra.It is bounded on the west by Amlag city at 120 kilometers distance, and from east of Medina, 240 kilometers, and from north-Elola town, 200 kilometers. It is characterized by its geographical location of being located at the crossroads of ancient and modern group roads and rising from the sea about 1,200 meters, a summer hot cold winter. The population is 12,812 people, and ranks second in terms of population at the level of Yanbu. It is surrounded by mountains from most destinations, and intertwined in the mountains with steep slopes with a number of valleys which constitute an important tributary of the Wadi (Ais) and represent vast stretches of plains planted with wheat when it rains. Many mountains that comprise Ais: Abu ElKetta, Toraa, Alagrad, Radwh, Hisham, Alselaa, AlMokannaa, Alracib, and Habishi.These mountains permeate several valleys including:Toraa, Arafa, Arran, Allahyan, Hegag, Alhafer, Alsafeha, sale, and the Valley Alramas, and others. A permanent reservoir of water for the region is formed (AlHarra) and is sustained reservoir of water for the region; it has a length from east to west about 60 kilometers, from north to south about 25 kilometers. It is planted after heavy winter rains, and there is also a dormant volcanoes area known as Halian (Emirate of Madinah, 2015).

Alais area city is located within an active tectonic environment where it has experienced considerable earthquakes in the historical and instrumental period. Recently, in May 2009 Alais city exposed a series of earthquakes of 5.7 on the Richter scale, because of the renewed volcanic activity in Harrat Al-Shaka (Lunayyirir). More than 3,000 earthquakes happened during the month, of which 30 reached 3.7 on the Richter scale, while citizens feltonly 15 shakes of them. The authorities had started on Tuesday, May 19th, 2009 the compulsory evacuation of people on a circumference of 20 kilometers around the volcano Alais center and the region remains free of the population to the date of June 27, 2009 for an indefinite period because of the frequently continuing earthquakes and at a rate of 4 to 5 shakes a day and its strength ranging from 3.5 to 4 on the Richter scale. The Alaisis considered to be located within the existing areas of the seismic belt in the region (Alsenany, 2015). Figure 2 shows the position of Alais province and the surrounding area relative to the map of the Kingdom of Saudi Arabia. Table 1 shows the important volcanic eruption places (Harrat) in Alais province and its surrounding area. Figures 3and 4 (Google maps website, 2015) show the cracks in the ground as a result of earthquakes in Lunayyir (Al-Shaqa) eruption and other places near Alais province. Figure 5 represent the most important places of volcanic eruption (Harrat) in Alais and surrounding area.

Table 1. Important volcanic eruption places (Harrat) in Alaisprovince and itsand surrounding area

Lava Name	Distance from Alais city (km)	Position from Alais City
Al ShakaaLunayyir	42.466	North-West
Alkab	78.162	South-West
Shayhoob	127.809	North-West
Khaybar	152.504	East
Alhazm	186.243	South-East
Alkafeeef	212.667	South-East
Medesees	233.752	South-East
BanyRasheed	268.630	North-East

Literature Review

When considering the earthquake, we have to answer the four questions: Where? How often? How big? And When? The goal of the earthquake prediction is to give warning of potentially damaging earthquakes early enough to allow appropriate response to the disaster, enabling people to minimize loss of life and property (Brillinger, 1993). Many studies have been presented to develop reliable estimates, of probability, magnitude and recurrence relations given the large pattern of earthquake occurrence. The primary advantage of probabilistic seismic hazard analysis (PSHA) is that it integrates over all seismicity: temporal and spatial along with ground motions to calculate acombined probability of exceedence, which incorporates the relative frequencies of occurrence of different earthquakes and ground-motion characteristics. Practically in any earthquake catalogue the quality of different parts (periods and areas) varies significantly with respect to completeness, magnitude reliability, homogeneity and location accuracy (Ameer *et al.,* 2002 and 2005). Statistical theory of extreme values has been used to analyze the observed extremes of any phenomena and to forecast the further extremes based on the appropriate distribution, (Gumbel, 1958). In earthquake engineering, this theory has been applied successfully by many researchers in the past few decades (Nordquist, 1945; Epstein, 1966; Yegulalp *et al.,* 1974; Al-Abbasi *et al.,* 1991 and Jaiswal *et al.,* 2000).

Figure 2. Alais province and the surrounding area

Figure 3. Cracks in the ground as a result of earthquakes in Lunayyir (Al-Shaqa) eruption

Figure 4. Cracks in the ground as a result of earthquakes in Alais area

This theory does not require analysis of the complete record of earthquake occurrence, but uses the sequence of earthquakes constructed from the largest values of the magnitude over a set of predetermined intervals. (Abe and Suzuki, 2005) analyzed the seismic data from the viewpoint of science of complexity, whereone of the main goals of seismology is to predict when and where the next main shock will occur after an earlier main shock. The rate of recurrence of earthquakes on a seismic source can be represented with the Gutenberg-Richter relation (Gutenberg and Richter, 1944).

(Kasap and Gürlen, 2003) studied the return periods of earthquakes. (Ogata, 1988) investigated the statistical models for earthquake occurrences. (Utsu, 1984) applied gamma, log-normal, Weibull and exponential distributions to describe the probability distribution of inter-occurrence time of large earthquakes in Japan. (Aktaş *et al.,* 2009) used Poisson distribution to describe the recurrence times, and estimated the expected value and variance computed for the loss of life and damaged buildings after the change point using the compound Poisson process (Bayrak *et al.,* 2009).

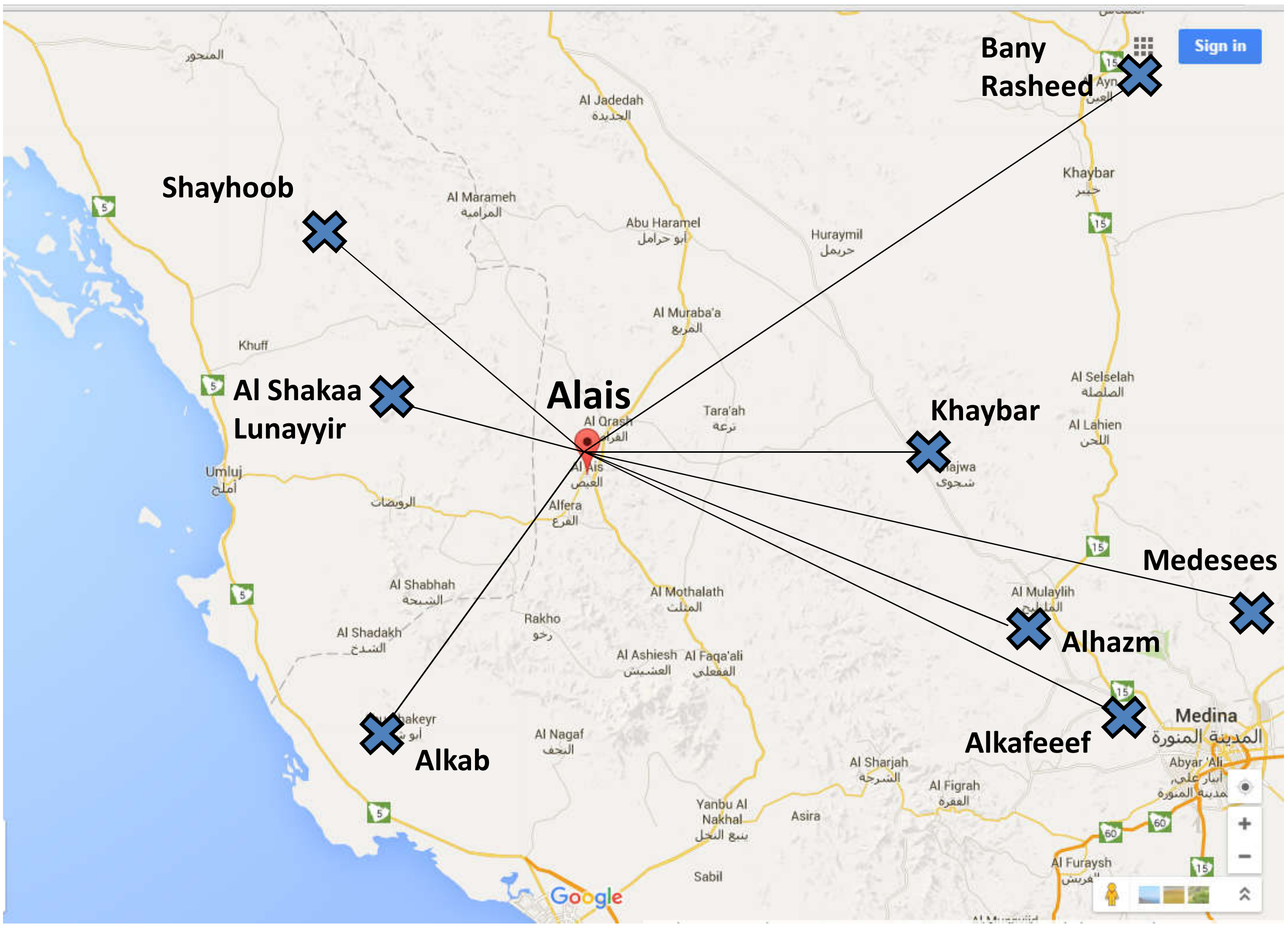

Figure 5. The most important volcanic eruption places (Harrat) in Alais and surrounding area.

Evaluated the seismicity and earth- quake hazard parameters of Turkey based on maximum regional magnitude. (Öztürk *et al.*, 2008) estimated the mean return periods, the most probable magnitude in a time period of t-years, and the probability of earthquake occurrence for a given magnitude during a time span of t-years for different regions in and around Turkey. They also showed that in the specific region, the most probable earthquake magnitude in the next 100 years would be over 7.5. (Bayrak *et al.,* 2008) calculated the seismicity parameters for the 24 seismic regions of Turkey according to Gumbel and Gutenberg-Richter methods and concluded that b-values obtained from the maximum likelihood approach gives better results for the tectonics of the examined area. In a study (HandeKonşuk and SerpilAktaş, 2013), 231 earthquake data of magnitude 5 and higher, between north (39.00° - 42.00°) and east (26.00° - 45.00°) coordinates in Turkey from July 12, 1900 to July 25, 2011 are analyzed. In this study, the probability distribution of magnitude is attempted and the statistical models are taken to interpret the observed frequency distribution. The earthquake catalog for Iraq covering an area between latitude 39 ° □ 50° E and longitude 29° □ 50° N and containing more than thousand events for the period 1905 – 2000 has been compiledThe statistical parameters for Gumbel's have beenestimated using both the least squares and maximum likelihood techniques. The goodness of fit is evaluated employing Kolmogorov-Smirnov test (Ameer *et al.*, 2004).

METHODS

Earthquake prediction can be considered into two types. First is the statistical prediction which is based on previous events; Data are collected from the records. Second is deterministic prediction which is made from the earthquake signs. Table 2 shows the data for earthquakes in Alais province and surrounding area representing the range and maximum magnitude. Most extreme event analysis is concerned with the distribution of annual maximum or minimum values at a given site. These events are given a rank, *m*, starting with *m*=1 for the highest value, *m*=2 for the next highest and so on in descending order. Each earthquake magnitude is associated with a rank, *m*, with $m = 1$ given to the maximum magnitude over the years of record, $m = 2$ given to the second highest magnitude, $m = 3$ given to the third highest one, etc. The smallest earthquake magnitude will receive a rank equal to the number of years over which there is a record, *n*. Thus, the earthquake with the smallest value will have $m = n = 90$. There are several formulas for calculating the probability value. The Weibull formula will be used because of its easiness. The US Geological Survey (http://www.usgs.gov/), among others, also uses this formula. According to the Weibull equation (Şenocak *et al.,* 2015), the return period or recurrence interval *T* (in years) is calculated using the following equation:

Table 2. Data for the earthquakes in Alais province and surrounding area

No.	Year	Number of Earthquakes	Range
1	1921	1	6.8
…..	…..	…..	…..
44	1964	1	4.8
…..	…..	…..	…..
59	1979	1	7.4
…..	…..	…..	…..
67	1987	1	3.32
68	1988	1	5.1
…..	…..	…..	…..
72	1992	1	4.8
73	1993	1	3.4
75	1995	2	3.4-3.44
76	1996	3	3.09-3.5
77	1997	1	3.09
78	1998	2	3.05-3.34
78	1999	4	3.1-3.7
80	2000	18	3.34
81	2001	7	3.06-3.76
82	2002	2	3.04-3.43
83	2003	1	3.3
84	2004	13	3.08-4.12
85	2005	17	3.0-3.62
…..	…..	…..	…..
87	2007	11	3.02-4.22
88	2008	3	3.04-3.15
89	2009	472	3.0-5.7
90	2010	4	3.16-3.96

T (years)=$(n+1)/m$ …………………………….. (1)

Where: m=event ranking (in a descending order), and n=number of events in the period of record.

The percentage probability (annual exceedence probability)for each magnitude in any year is calculated using the inverse of the Weibull equation as follows:

P (per cent) = $100.m/(n+1)$ ………………………….. (2)

From equations (1) and (2) it is clear that $P = 100/T$ %. For example, an earthquake equal to that of a 10-year one would have an annual exceedence probability of 1/10 = 0.1 or 10%. This would say that in any given year, the probability that anearthquake with a magnitude equal to or greater than that of a 10 year earthquake would be 0.1 or 10%. Similarly, the probability of anearthquake with a magnitude exceeding the 50 year one in any given year would be 1/50 = 0.02, or 2%.Note that such probabilities are the same for every year, but in practice, such an earthquake could occur next year, or be exceeded several times in the next 50 years.

RESULTS

Annual Exceedence Probability and Return Period

Return period or Recurrence interval is the average interval of time within which a flood of specified magnitude is expected to be equaled or exceeded at least once. 100-year earthquake is an earthquake that is expected to occur, on the average, once every 100 years, or has a one percent chance of occurring each year. Figure 6 is a plot of earth quake magnitude and annual exceedence probability relationship (linear scales) with the annual maximum magnitude per year on the Y axis versus the annual exceedence probability on the X axis. The X and Y axes both use linear scales. A best-fit curve is drawn through the data points. From the best-fit curve, one can determine the earthquake magnitude associated with anearthquake with a recurrence interval of say 10 years, it is about 4 on Richter scale. This would be called the 10-year earthquake. Similarly the recurrence interval associated with an earthquakemagnitude of magnitude of 3 on Richter scale is about 24 years. The annual peak information may also be presented with a logarithmic rather than a linear scale. This is often done to make the curve appear as a straight line and also to avoid a graph that will suggest either a zero or a one–hundred percent exceedance probability. Moreover, a straight line curves are more easily allow extrapolation beyond the data extremes. Figure 7 represents the earthquake magnitude and the annual exceedence probability (log scale) relationship.

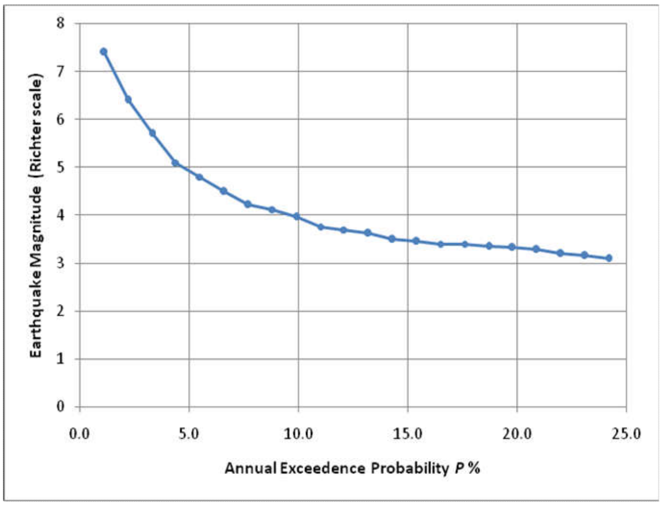

Figure 6. Earthquake magnitude and probability relationship (linear scales)

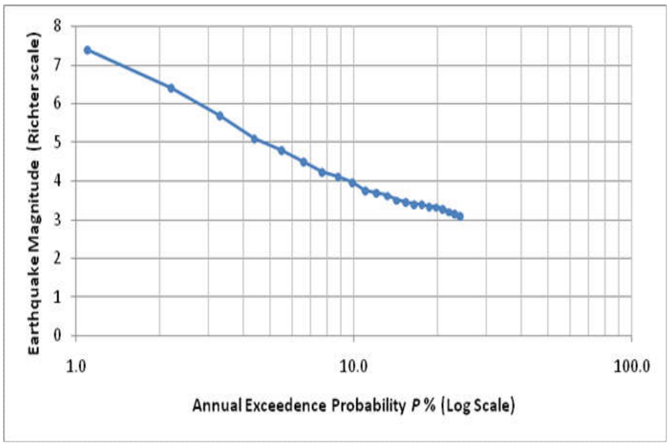

Figure 7. Earthquake magnitude and annual exceedence probability (log scale) relationship

Percentage probability is determined by dividing one by the recurrence interval and multiplying by 100. For example, the probability that an earthquake magnitude will exceed the 100-year earthquake this year or any other year would be 1%. Figure 8 shows the earthquake magnitude and return period relationship on linear scales and Figure 9 shows the earthquake magnitude and return period relationship using a log scale.

Table 3. The rank, probability and the return period results

Rank (*m*)	Year	Maximum Magnitude	Probability (*P*) %	Return Period (*T*)
1	1979	7.4	1.1	91.0
2	1921	6.8	2.2	45.5
3	2009	5.39	3.3	30.3
4	1988	5.1	4.4	22.8
5	1992	4.8	5.5 Average =	18.2
6	1964	4.8	6.6 6.05	15.2
7	2007	4.22	7.7	13.0
8	2004	4.12	8.8	11.4
9	2010	3.96	9.9	10.1
10	2001	3.76	11.0	9.1
11	1999	3.7	12.1	8.3
12	2005	3.62	13.2	7.6
13	1996	3.5	14.3	7.0
14	1995	3.44	15.4	6.5
15	2002	3.43	16.5	6.1
16	1993	3.4	17.6	5.7
17	1998	3.34	18.7 Average =	5.4
18	2000	3.34	19.8 19.25	5.1
19	1987	3.32	20.9	4.8
20	2003	3.3	22.0	4.6
21	2008	3.15	23.1	4.3
22	1997	3.09	24.2	4.1
…….				
90				

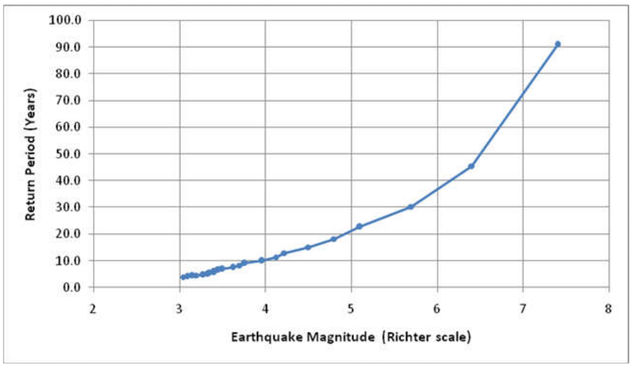

Figure 8. Earthquake magnitude and return period relationship (linear scales)

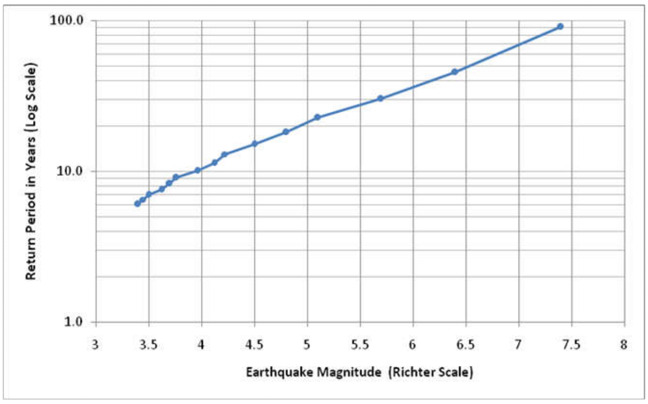

Figure 9. Earthquake magnitude and return period (log scale) relationship

From the figure it can be noticed that the return period of an earthquake of magnitude 7.4 on Richter scale is about 91 years, and an earthquake of magnitude of 5.8 on Richter scale has a recurrence interval of about 30 years. Sometimes it is suitable to add a second X–axis to represent the return period to the first X-axis representing the annual exceedence probability.

Figure 10 shows the earthquake magnitude on the Y-axis and the annual exceedence probability on the first X-axis and the return period on the second X-axis. Both the two X-axes use a variable scale so the relationship appears as a perfect straight line, this will allow for easier findings. From the fit line, one can determine the magnitude associated with an earthquakeof a recurrence interval of say 30 years. This would be called the 30-year earthquake. The magnitude associated with the 30-year earthquake is about 5.3 Richter scale. Similarly the magnitude associated with anearthquake with a recurrence interval of 50 years (the 50-year earthquake) would have a measure of about 7.0Richter scale.

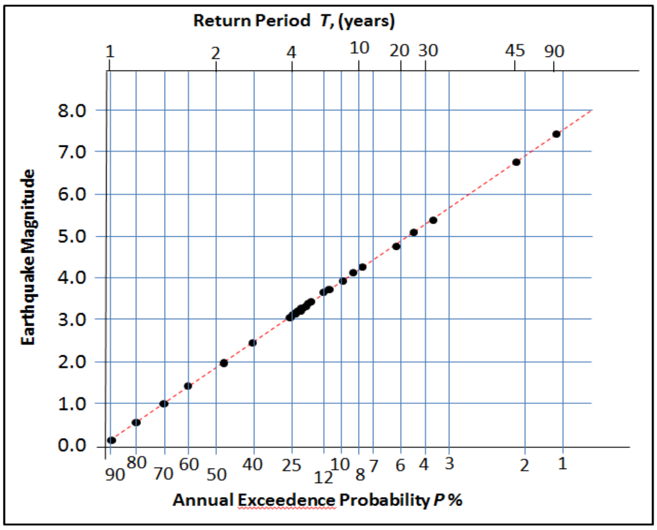

Figure 10. Earthquake magnitude, probability and return period relationship

The Probability During a Time Period

The probability of a certain-magnitude earthquake occurring during any period *t* can be calculated using the following equation:

$P_t = 1\text{-}(1\text{-}P)^t$ ………………………….. (3)

Where P is the probability of occurrence over the entire time period, t, and P is the probability of occurrence in any year.
It is worth to apply equation (3) for earthquakes of highest magnitudes which represent the most dangerous events in the location. The equation is applied for earthquakes of magnitudes 5.4, 6.8 and 7.4 Richter scale of probabilities of 3.3%, 2.2% and 1.1% respectively. The result is depicted in Figure 11 for earthquakes of magnitudes: 5.4 Richter scale (P = 3.3%), 6.8Richter scale (P = 2.2%) and 7.4 Richter scale (P = 2.2%). A homeowner considering the costs of reinforcing a house against earthquakes will want to know how the risk varies during an average mortgage span of 30 years**.** Figure 12 shows the earthquake probability and earthquake magnitudes in a time span of 30 years. An earthquake of magnitude of 4 on Richter scale for example, has a 94% probability of occurrence but, if the earthquake of magnitude 7.4 on Richter scale is chosen, the probability drops to 28%.

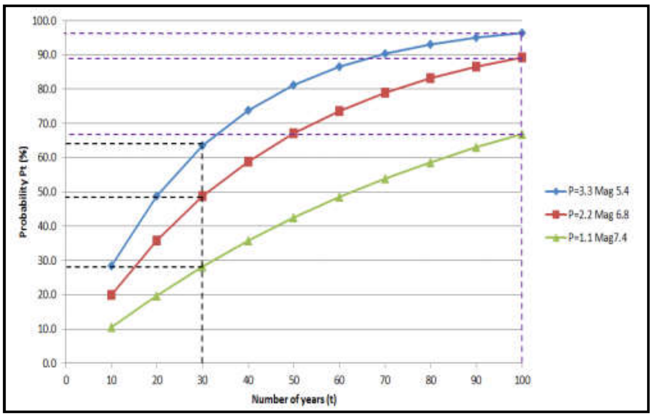

Figure 11. Earthquake probability for some earthquake magnitudes in a time span period

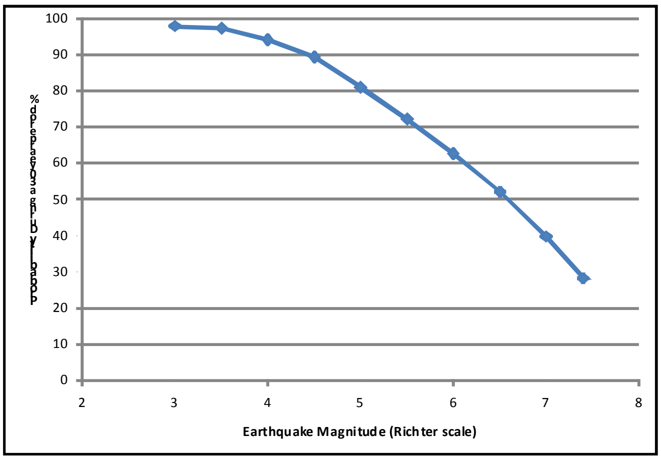

Figure 12. Earthquake probability and earthquake magnitudes in a time span of 30 years

DISCUSSION

Earthquake is an unavoidable natural disaster for the region. Hence, to take precautions for the future by utilizing the past experiences are very substantial. This can be a kind of a proposition to the higher authorities to have an open eye to this particular region. In this study, the statistical frequency analyses are applied to the recorded annual maximum earthquake magnitudes for Alais province and the surrounding area in the western region of Saudi Arabia since 1921. The earthquake hazard parameters are estimated, these are: the mean return periods (recurrence intervals), the frequency, the probability of earthquake occurrence (annual exceedence probability) for a given magnitude during any year, and the probability of earthquake occurrence for a given magnitude during a time span of t-years with a stress on a 30-year period. The Weibull equation is applied to estimate the return period, while the inverse of the Weibull equation is used to calculate the probability of occurrence. The relation between magnitude and frequency and between magnitude and return period is represented as a curve in a linear scale graph and as astraight line on a logarithmic scale and variable scale graphs to facilitate the findings. The results lead to a general conclusion that Alaisis considered to be located within the existing areas of the seismic belt and the regionis exposed to earthquakes with strength ranging about 3.0or less on the Richter scale with a high probability. The maximum magnitude is 7.4 with a return period of 91 years and probability of about 1.1%.

The conventional approach of hazard estimation based on magnitude frequency relationship is more useful when the data set is complete for the entire time span and for the magnitude range. With good and complete data sets, the method is more appropriate and accurate for seismic hazard estimation.

Points for future researches can be summarized as follows:

- To study in details the influence of missed data like that for the years in the intervals (1921-1964), (1964-1979), (1979-1987) and (1988-1992) on the earthquake parameters.
- To use other methods for evaluation of earthquake parameters and compare the obtained results.
- To estimate earthquake hazard parameters for other regions in Saudi Arabia.
- To estimate hazard parameters for other events like: floods, subsidence, volcanic eruptions and severe stormsin different regions of Saudi Arabia.
- To draw a seismic map for Alais region and for other regions in the Kingdom of Saudi arabia.

REFERENCES

Aktaş, S., H. Konşuk and A. Yiğiter, "Estimation of Change Point and Compound Poisson Process Parameters for the Earthquake Data in Turkey," *Environmetrics*, Vol. 20, No. 4, 2009, pp. 416-427. doi:10.1002/env.937

AL-Haddad, M., Siddiqi, G.S., Al-Zaid, R., Arafah, A., Necioglu, A., and Turkelli, N., " A Study Leading to a Preliminary Seismic Design Criteria, for the Kindom," Final Report, KACST project No. AR-9-31, Riyadh, 1992.

Al-Haddad, M., Siddiqi, G.S., Al-Zaid, R., Arafah, A., Necioglu, A., and Turkelli, N., "A Basis for Evaluation of Seismic Hazard and Design Criteria for Saudi Arabia", *Journal of Earthquake Engineering Research Institute*, EERI, Spectra, Vol. 10, No. 2, May 1994, Okland, California.

Alsenany, M. E., Alais, General Presidency for Youth Welfare, issued in the series:This Is Our Country. Google maps website, visited on 24 December 2015, available at: https://www.google.com.sa/maps/@24.266906,45.0983499,5z

Ameer, A.S., Sharma, M. L., Wason, H. R. and Alsinawi, S. A., "Seismic hazard characterization and risk evaluation using Gumbel's method of extremes (G! and G3) and G_R formula for Iraq", 13th World Conference on Earthquake Engineering, Vancouver, B.C., Canada, Paper No. 2898, 2004.

Ameer, S. A., Sharma, M.L. Wason, H.R. and Alsinawi, S. A. 2005. Probabilistic seismic hazard assessment for Iraq using complete earthquakes catalogue files, *Pure & Applied Geophysics*; May2005, Vol. 162, Issue 5, p951.

Ameer, S.A., M.L. Sharma and H.R. Wason, 2002. Completeness of earthquake catalogue and its implications in seismic hazard estimation- A case study for Iraq, Proc. 12th Symposium on Earthquake Engineering, Roorkee, India, Vol. 1, 342- 349.

Ameer, S.A., M.L. Sharma and H.R. Wason, 2002. Maximum likelihood estimation of seismic hazard for Iraq from complete data files, Proc. 12th Symposium on Earthquake Engineering, Roorkee, India, 1, 306- 312.

Ashour, S.A. and Abdel-Rahman, H.H., Application of Seismic Risk Analysis and Earthquake Simulation Methods to the Western Region in Saudi Arabia, *Journal of Kong Abdulaziz University*, JKAU: Eng. Sci., vol. 6, pp. 3-23 (1414 A.H./1994 A.D.).

Barazangi, M., Evaluation of seismic risk along the western part of the Arabian Plate: Discussion and recommendations. Bulletin of Faculty of Earth Science.King Abdulaziz University. 4: 77-87 (1981).

Bayrak, Y., S. Öztürk, G. Ch.Koravo, G. A. Leventakis and T. M. Tsapanos, "Seismicity Assessment for the Different Regions in and around Tyrkey Based on İnstru- mental Data: Gumbel First Asymptotic Distribution and Gutenberg-Richter Cumulative Frequency Law," *NHESS*, Vol. 8, 2008, pp. 1090-1122.

Bayrak, Y., S. Öztürk, H Cinar, D. Kalafat, T. M. Tsapano, G. Ch. Koravos and G. A. Leventakis, "Estimating Earth-quake Hazard Parameters from İnstrumental Data for Different Regions in and around Turkey," *Engineering Geology*, Vol. 105, No. 3-4, 2009, pp. 200-210. doi:10.1016/j.enggeo.2009.02.004

Brillinger, D. R. "Earthquake Risk and Insurance," *En-vironmetrics*, Vol. 4, No. 1, 1993, pp. 1-21. doi:10.1002/env.3170040102

EI-Isa, Z.H., Merghelani, H.M. and Bazzani, M.A., TheOulf of Aqaba earthquake sworn of 1983, January-April. Geophys. *J.R. Abstr. Soc*.. 78: 711-722 (1984).

Emirate of Madinah, Ministry of the Interior, Kingdom of Saudi Arabia, website, visited on 23 december 2015, available at: http://www.imaratalmadinah.gov.sa/ar-SA/MedinaRegion/centers/Pages/ais.aspx

Epstein, B., and C. lomnitz, 1966. A model for the occurrence of large earthquakes, *Nature*, 211, 954-956.

Fahmi, K.J. and J.N. Al Abbasi, 1991. GEMPAK: A Fortran 77 program for calculating Gumbel's first, third and mixture upper earthquake magnitude distributions employing maximum likelihood estimation, *Computer and Geosciences*, 17(2), 271-290.

Gumbel, E. 1958. Statistics of Extremes, Columbia University Press, New York, USA.

Gutenberg, B. and Richter, C., Seismicity ofthe Earth and Associated Phenomena. *Hafner Publishing Co.,* New York and London.p. 310 (1965).

Gutenberg, R. and C. F. Richter,"Frequencies of Earth-quakes in California," *Bulletin of the Seismological Socie- ty of America*, Vol. 34, No. 4, 1944, pp. 185-188 .

Hande Konşuk, SerpilAktaş, "Estimating the Recurrence Periods of Earthquake Data in Turkey", *Open Journal of Earthquake Research,* 2013, 2, 21-25, http://dx.doi.org/10.4236/ojer.2013.21002.

Jaiswal, K., S. Gupta and R. Sinha, 2002. Estimation of maximum magnitude earthquakes in Peninsular India using extreme value statistics, Proc. 12th Sym. Eq. Engg., IIT Roorkee, India.[21] S. Abe and N. Suzuki, "Scale-Free Statistics of Time Interval between Successive Earthquakes," *Physica A*: *Statistical Mechanics and Its Applications*, Vol. 350, No. 2-4, 2005, pp. 588-596.

Kasap, R. and Ü. Gürlen, "Deprem MagnitüdleriIçin Tekrarlanma Yıllarının Elde Edilmesi: Marmara Bölgesi Örneği," *Doğuş Üniversitesi Dergisi*, Vol. 4, No. 2, 2003, pp. 157-166.

Merghelani, H.M., Seismicity of the Tihamat-Asir Region. Kingdom of Saudi Arabia.US.Geological Survey Saudi Arabian Proj.Report.251, p. 20 (1979).

Nordquist, J. M. 1945. Theory of largest values applied to earthquake magnitudes, *Trans. Am. Geosphys. Un*., 26, 29-31.

Ogata, Y. "Statistical Models for Earthquake Occurrences and Residual Analysis for Point Processes," *Journal of the American Statistical Association*, Vol. 83, No. 401, 1988, pp. 9-27. doi:10.1080/01621459.1988.10478560

Öztürk, S., Y. Bayrak, G. Ch. Koravos and T. M. Tsa- panos, "A Quantitative Appraisal of Earthquake Hazard Parameters Computed from Gumbel I Method for Different Regions in and around Turkey," *Natural Hazards*, Vol. 47, No. 3, 2008, pp. 471-495. doi:10.1007/s11069-008-9234-6

Şenocak, S., DÜzgÜn, O. and ŞengÜl, S., Frequency analysis of annual maximum earthquakes for Aşkale, Erzurum (Turkey) province, Recent Advances in Civil Engineering and Mechanics, pp. 72-78, Mathematics and Computers in Science and Engineering Series 36, North Atlantic University Union, Proceedings of the 5th. European Conference of Civil Engineering (ECCIE'14), Florence, Italy, 20114, ISBN: 978-960-474-403-9. Accessed on 29 December 2015. Available at: http://www.wseas.us/e-library/conferences/2014/Florence/SEMOTEC/SEMOTEC-08.pdf

The US Geological Survey website, visited on 22 December, 2015.Available at: http://www.usgs.gov/

Utsu, T. "Estimation of Parameters for Recurrence Mod-els of Earthquakes," *Bulletin of the Earthquake Research Institute*, Vol. 59, 1984, pp. 53-66.

Yegulalp, T. M. and J. T. Kuo, 1974. Statistical prediction of the occurrence of maximum magnitude earthquakes, *Bull. Seism. Soc. Am*., 64, 393

****