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ORIGINAL ARTICLE

Calculation of intensity and Ground Motion Parameters of Earthquakes around Taftan volcano

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ABSTRACT

Around of the semi-active Taftan volcanic system, despite importance of the seismic studies, the absence of seismic data is strongly felt. This research has performed for radius 150 Km of Taftan circumferences in order to obtain the earth motional parameters and to assessment earthquake intensity regarding to the intensity based on body waves (Mb) and surface waves (Ms). For this order, we collect earthquakes magnitude that occurred in the mentioned radius. Using tentative formula based surface waves, we plot dots related to each magnitude and accumulative abundance logarithm and then drew it's related diagram. So using the parameters of Gutenberg – Richter [5], we purposed Seismicity formula for radius 150 Km of Taftan. We also calculated the earth motional parameters based on the Risk formula for a few structures. For survey earthquake intensity in center of earthquake we used Ambraseys and Melville [1] tentative formula for Iran's earthquakes.

KEY WORDS: Seismicity, motional parameters, earthquake, intensity

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INTRODUCTION

When two groundmasses move with respect to one another, elastic strain energy due to tectonic processes is stored and then released through the rupture of the interface zone [3]. The distorted blocks snap back towards equilibrium and an earthquake ground motion is produced [3]. Taftan is a young, semi-active volcanic system with age Pliocene- Quaternary [4] and is located in longitude 61°08' E and latitude 28°36' N. To have knowledge of an area's neotectonics and also optimization for civil projects, seismicity investigations from a region based on registered instrumental earthquakes are necessary. For have a better view of seismicity in a global scale, we use Fig. 1, the digital active tectonics map of Earth from NASA [8] in 2002 that displays at least one million years ego's tectonics and volcanism. Alpine-Himalayas orogenic belt and the Iran's position in this belt can be seen. Subduction zones with reverse faults are seen in this map. As it seen the distribution of volcanoes are closely related to these zones. In Iran, particularly in the southeastern region of the Taftan and Bazman volcano this phenomenon is evident.

MATERIAL AND METHODS

Research process

In general, for seismic calculations the accredited data by earthquake seismograph stations must be available. So we've gathered instrumental earthquake have occurred in a radius of 150 km Around Taftan. Then, using experimental relationships from Ambraseys and Melville [1] and Raid and Meyers [10] based on surface waves, the chart of magnitude-log of cumulative frequency was obtained. Now with obtaining parameters of Gutenberg- Richter equation [5], the seismicity formula of Taftan in the mentioned radius can be calculated. Using the seismicity formula and according to the useful life of structures, it could be identified the risk limit in terms of the two parameter MCE and DBE. Also using experimental instruction from Ambraseys and Melville [1] for earthquakes in Iran we obtain the earthquake magnitude in the desired radius. Thus with corresponding of the points of same intensity, the intensity contour maps for occurred earthquakes around the Taftan volcano were provided after calculations corrections.

RESULTS AND DISCUSSION

Instrumental Earthquake

Earthquakes that have occurred after the twentieth century called instrumental earthquakes. For the study area the instrumental earthquakes have been recorded up to date are presented in Table 1. The area and distribution of earthquakes occurred related with the data in Table 1 which is in range 1929 to 2004 can be seen in Fig. 2.

Foundations of seismicity

1. Magnitude Ms and Mb and the linear relationship between them

Magnitude of earthquakes is the quantitative measure for the total energy released by an earthquake in a particular time and place. Based on various factors, the magnitude of the earthquake is reported. Surface wave (Ms) and body wave (Mb) earthquake magnitudes are the most common scales for magnitudes for seismic data. Iran's seismic data based are commonly expressed based on body waves and then surface waves. But because most estimations of seismicity are done based on Ms magnitude, So we have to use an equation to converte the most magnitude of Mb into the common Ms Magnitude in seismicity analysis. If it be set up a mathematical relationship between the two magnitude data, it should be found a line with a lowest Square return in line with these data. Then this line will have fewer characteristics of quadratic functions. It is apparent this assertion will be achievable when both Mb and Ms magnitudes be available with considerable frequency. For example, the data in Table 1 is based on Mb. Such relationships that might have such a property, we can mention the following empirical relationship. From such relationships that might have such properties, we can mention to the following empirical relationships from Ambraseys and Melville [1] in Eq (1) and Raid and Meyers [10] in Eq (2):

$$Ms = 1.61Mb - 3.7 \quad (1)$$

$$Ms = 1.605Mb - 3.774 \quad (2)$$

Therefore, the data of Ms can be derived from Table 1 as shown in Table 2.

2. Seismicity calculation of research area

To have relative knowledge of future seismicity of the area, if we consider earthquakes with magnitude Ms more than those occur annually in a certain area and show with N as earthquakes period, we will use an equation that be established based on the magnitude and cumulative frequency. Richter and Gutenberg [5] have expressed such equation as follow:

$$LogN = a - bMs \quad (3)$$

Where N is the number of occurrence of earthquakes. α and β are respectively y-intercept and angular coefficient that are determined by the statistical studies and are used to estimate of seismic risk in certain area. using data from earthquakes in different regions of the world. Kaila [7] showed that variations of β relative to α is low and about 1 and for this reason is known as a universal constant. But this does not mean that α value should always be considered as 1 and to be calculated statistically. In Table 3 the cumulative frequency for earthquakes with magnitude Ms> 4 in study region is given. By drawing the mentioned diagram, the parameters of Gutenberg- Richter are obtained [5] as seen in Fig. 3. It is noteworthy that a direct line which optimally relates points with coordinates of Ms and LogN to each other will be as a reference to measure actual parameters on the Gutenberg- Richter formula. Statistically it should be available the average properties of all coordinates of points in this line. So with obtaining parameters related to the Gutenberg– Richter formula, it can be achieved seismicity formula about Taftan to a radius of 150 km from measuring the slope of the median line and y-intercept. This equation is obtained as follows:

$$LogN = 1.06 - 0.85Ms \quad (4)$$

As it can be seen the value of α in the study area is less than one and this fact is attested by the above that not always α can be considered equal to 1.

3. *Estimation of ground motion parameters*

Two applied parameters for quantitative measuring of acceleration and horizontal movements of the earth are MCE and DBE that are respectively risk limit of 20% and 10% [2]. Thus, MCE is the maximum credible earthquake and suggest that if we assume a 50-year return period for the next 50 years, probability of occurrence will be 10%. Also DBE or design basic earthquake is reflecting that if we assume a 50-year return period for the next 50 years, probability of occurrence will be 64% that commonly it is recommended during structures designing. The most severe ground movements where the structures are built is due to MCE that structures receive the most damage and thus threaten human societies. On the other hand the most imposed energy in the period of useful life of the structure is created by DBE. Therefore in designing of structures it must be considered the forces caused in this event. Designing of structures for low probability risk limit, which is based on MCE will be very costly and time consuming. Therefore in the most cases the ordinary structures are designed based on nearly 50% probability or a little more than it. So in this case, the expression DBE is more appropriate. The risk formula, expressing the probability of at least one occurrence of earthquakes of greater-than-design-value magnitudes over the economic life of a structure [6]. With this explanation, the applied following formula is used to estimate the risk percentage:

$$R\% = 1 - EXP\left(-T.10^{a-bMs}\right) \qquad (5)$$

Where R is risk percentage based on DBE, T is useful life of structure and (α-βMs) is seismicity formula. Also between the MCE and DBE the following relationship is available

$$DBE = 2/3MCE \qquad (6)$$

In the study area MCE and DBE are expressed for some structures in table 4.

As can be seen in Equation (6), DBE is less than MCE and that's why in the most unnecessary structures is base of designing. According to table 4 it is apparent that with increasing of the useful age for common structures in this area, DBM seriously increases. This shows that no building is safe in this area.

4. Estimating the intensity of earthquake

In order to estimate the intensity in focal area, we use experimental instruction from Ambraseys and Melville [1] for earthquakes in Iran:

$$I_0 = 1.04Mb + 2.6 \qquad (7)$$

$$I_0 = 1.3Mb + 0.09 \qquad (8)$$

Where I_0 is intensity and Mb is magnitude based on body waves. For focus with focal depth less than 60 km it is useful the experimental instruction from Nowroozi [9]:

$$I_0 = 1.7Ms - 2.8 \qquad (9)$$

In Fig. 4 it is calculated focal depth distribution per 40 earthquakes from Table 1. It is apparent that for most occurred earthquakes given in Table 1, the focal depth is less than 60 km. Therefore, in most cases the intensity of earthquake is calculated from experimental instruction from Nowroozi [9]. For all cases of existence earthquakes in desired radius, intensity data are considered as quantitative dots. These dots are plotted based on geographical coordination and are connected to each other accordance with the principles of contour curves. The co- intensity map for earthquakes occurred in radius of 150 km around the Taftan volcano is shown in Fig. 5 after calculating and correcting.

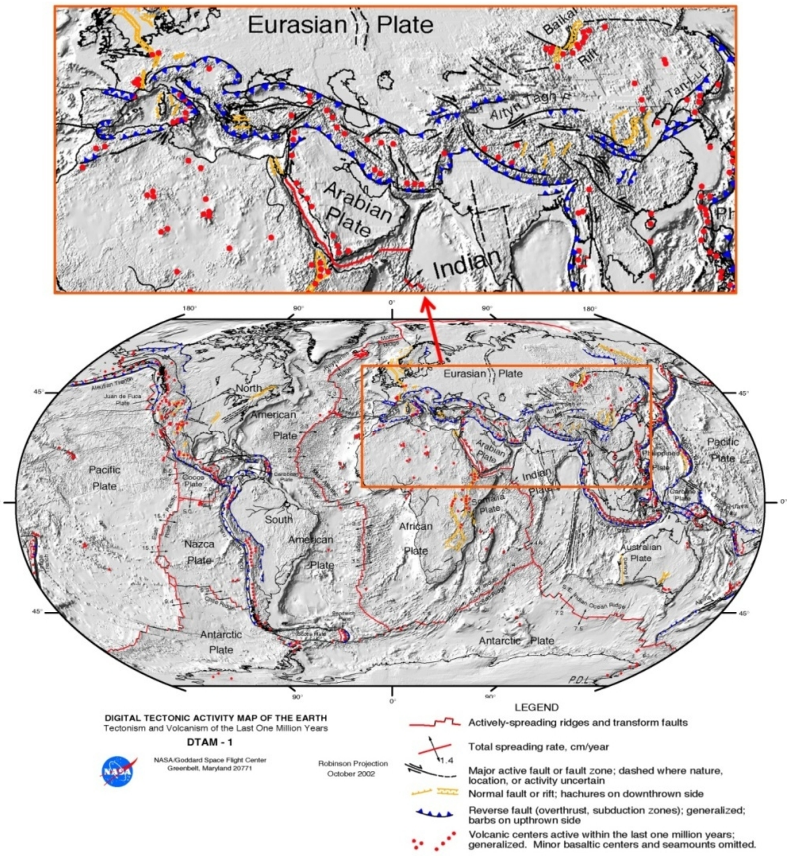

Fig. 1. Digital map of active tectonics on Earth (NASA, 2002); marked square indicates the Alpine- Himalayas orogenic belt.

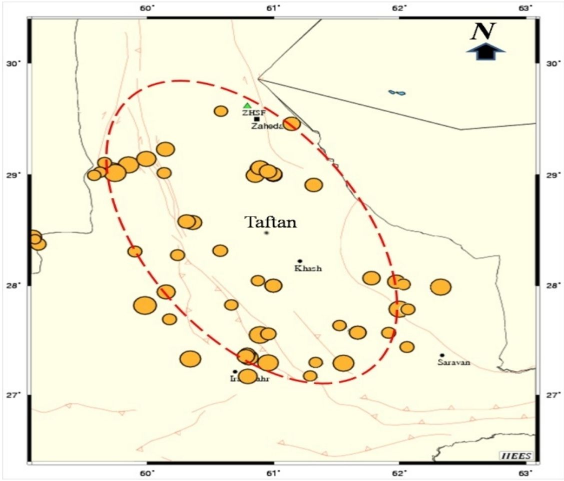

Fig. 2. View the epicenters of the earthquake occurred in radius of 150 km around Taftan (data from IIEES).

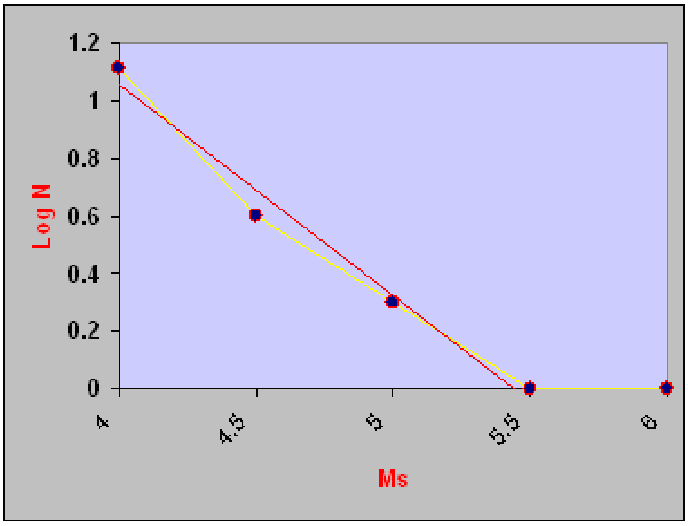

Fig. 3. Diagram of magnitude - cumulative frequency for data of Ms> 4.

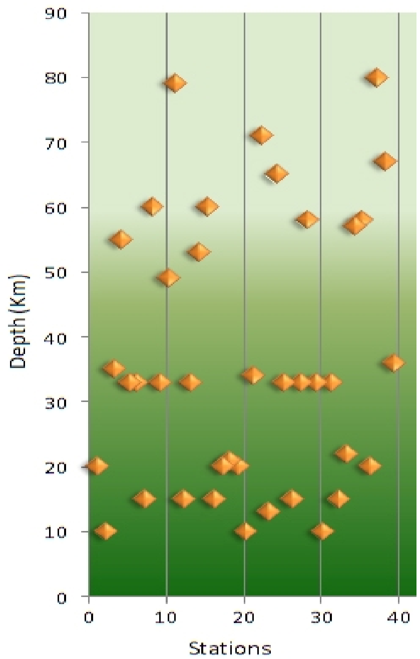

Fig. 4. Deep distribution of hypocenters for 40 earthquakes.

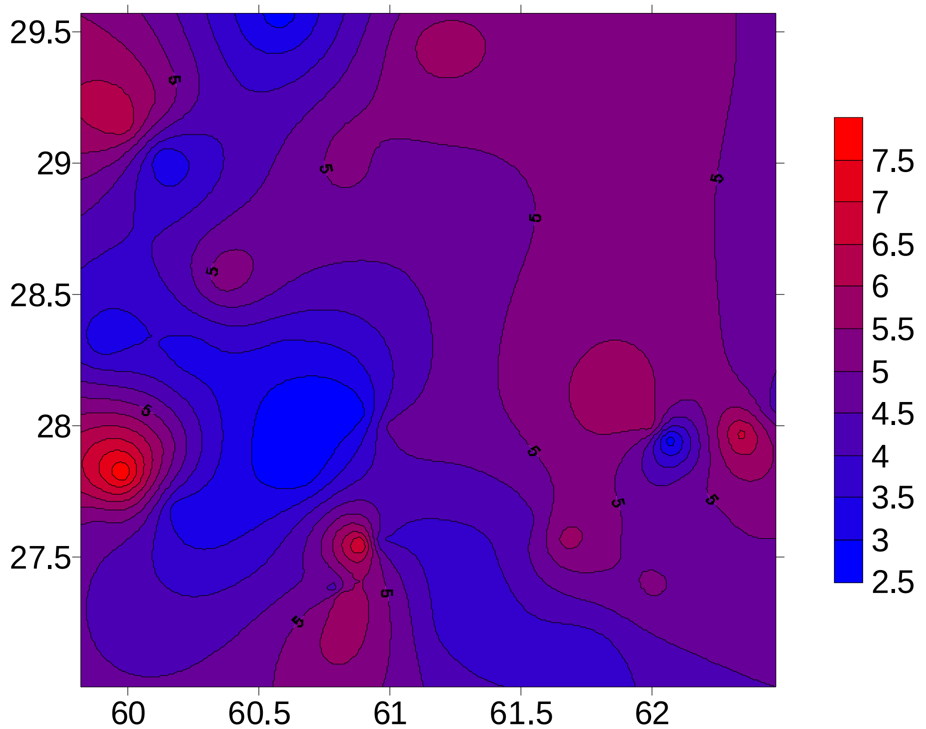

Fig. 5. Contour map fore intensity of the earthquakes occurred in radius of 150 km around Taftan. Red spectrums indicate high and blue ones do low intensity.

Table 1 Earthquakes recorded in the radius of 150 km around Taftan (data IIEES).

N	Date(yyyy/mm/dd)	Time(UTC)	Latitude	Longitude	Depth	Magnitude	Reference
1	1929/03/26	14:00:10.0	28	62		mb:5	ISS
2	1935/09/22	01:40:23.0	29	61		mb:4.5	ISS
3	1936/09/07	08:52:30.0	29	61		mb:4.7	ISS
4	1943/12/31	09:35:35.0	28	61		mb:4.5	ISS
5	1947/10/29	22:05:38.0	28	61		mb:4.5	ISS
6	1967/03/25	22:26:27.0	28.57	60.36	36	mb:4.9	ISC
7	1968/08/02	13:30:25.0	27.55	60.89	67	mb:5.7	EHB
8	1969/11/07	18:34:06.0	27.82	59.98	80	mb:6.1	EHB
9	1971/09/08	12:53:37.0	29.14	59.99	20	mb:5.3	EHB
10	1973/04/02	01:27:14.0	27.57	61.67	58	mb:5	ISC
11	1973/04/26	14:30:09.0	27.17	60.80	57	mb:5	EHB
12	1973/04/27	16:09:16.0	27.94	60.15	22	mb:4.8	ISC
13	1974/09/04	06:43:31.0	27.38	62		mb:4.7	ISC
14	1977/09/13	11:48:46.0	27.66	59.89	15	mb:4.7	EHB
15	1980/03/30	04:42:13.0	29.23	60.14	33	mb:4.8	ISC
16	1982/01/03	00:46:23.0	28.58	60.31	10	mb:4.6	ISC
17	1983/03/25	10:40:22.0	27.55	61.91	33	mb:4.7	ISC
18	1983/04/18	17:39:14.0	27.76	62.13	58	mb:4.6	ISC
19	1983/04/19	20:36:28.0	27.63	62.17	33	mb:4.5	ISC
20	1983/10/09	15:25:36.0	28.91	61.32	15	mb:4.7	EHB
21	1984/05/28	19:40:41.0	27.01	61.51	33	mb:4.2	ISC
22	1984/09/12	18:00:46.0	27.35	60.81	65	mb:5.1	EHB
23	1985/06/22	12:41:02.0	29.45	61.15	13	mb:5	EHB
24	1988/11/15	05:04:06.0	27.24	61.24	71	mb:4	ISC
25	1990/09/27	12:34:52.0	29.05	60.91	34	mb:4.8	ISC
26	1990/09/29	03:33:13.0	29.01	61	10	mb:4.6	ISC
27	1990/09/29	17:53:07.0	29	60.86	20	mb:4.8	ISC

28	1990/09/30	06:24:02.0	29.06	60.89	21	mb:4.8	ISC
29	1990/10/12	01:49:19.0	29.03	60.96	20	mb:4.7	EHB
30	1993/02/11	19:37:52.0	27.61	59.82	15	mb:4.6	EHB
31	1994/09/08	13:33:37.0	28.05	61.81	60	mb:5	EHB
32	1996/05/08	03:05:39.0	27.69	60.18	53	mb:3.8	ISC
33	1997/05/17	09:03:56.0	28.28	60.24	33	mb:3.8	ISC
34	1998/03/11	15:39:45.0	27.64	61.52	15	mb:4.3	EHB
35	1998/04/03	02:56:36.0	28.07	62.47		mb:3.7	ISC
36	1999/11/16	17:40:11.0	28.32	60.58	79	mb:3.9	ISC
37	2000/04/16	06:30:14.0	27.13	61.74	49	mb:3.9	EHB
38	2000/06/19	00:26:17.0	28.31	59.90	33	mb:3.8	ISC
39	2001/04/13	11:30:43.0	27.56	60.96	60	mb:4.2	ISC
40	2002/01/18	18:26:16.0	27.38	60.79	15	mb:4.3	EHB
41	2002/01/30	18:39:01.0	27.36	60.78	33	mb:4.6	EHB
42	2002/05/24	22:27:15.0	27.82	60.67	33	mb:3.5	ISC
43	2003/01/14	14:13:58.0	27.97	62.34	55	mb:5.5	EHB
44	2003/06/30	22:22:45.0	29.57	60.58		mb:3.6	ISC
45	2003/07/23	01:42:38.0	27.39	61.25	35	mb:4	ISC
46	2003/08/08	10:55:20.0	29.02	60.13	10	mb:3.7	ISC
47	2003/11/09	10:28:28.0	28.05	60.88	20	mb:3.6	ISC

Table 2 Ms calculating from tow references.

N	Mb	Ms	
		AM&M	R&M
1	5	4.34	4.65
2	4.5	3.53	3.84
3	4.7	3.58	4.16
4	4.5	3.53	3.84
5	4.5	3.53	3.84
6	4.9	4.17	4.49
7	5.7	5.46	5.77
8	6.1	6.11	6.41
9	5.3	4.82	5.13
10	5	4.34	4.65
11	5	4.34	4.65
12	4.8	4	4.33
13	4.7	3.85	4.16
14	4.7	3.85	4.16
15	4.8	4	4.33
16	4.6	3.7	4
17	4.6	3.7	4
18	4.6	3.7	4
19	4.5	3.53	3.84
20	4.7	3.58	4.16
21	4.2	3	3.36
22	5.1	4.5	4.81
23	5	4.34	4.65
24	4	2.73	3
25	4.8	4	4.33
26	4.6	3.7	4
27	4.8	4	4.33
28	4.8	4	4.33
29	4.7	3.58	4.16
30	4.6	3.7	4

31	5	4.34	4.65
32	3.8	2.4	2.72
33	3.8	2.4	2.72
34	4.3	3.2	3.52
35	3.7	3.2	2.56
36	3.9	2.6	2.88
37	3.9	2.6	2.88
38	3.8	2.4	2.72
39	4.2	3	3.36
40	4.3	3.2	3.52
41	4.6	3.7	4
42	3.5	1.9	2.24
43	5.5	5.1	5.45
44	3.6	2	2.4
45	4	2.73	3
46	3.7	2.24	2.56
47	3.6	2	2.4

Table 3 Cumulative frequency (Nc) and Log of data (Log N) for Ms> 4.

Ms	Nc	logN
Ms>4	13	1.11
Ms>4.5	4	0.6
Ms>5	2	0.3
Ms>5.5	1	0
Ms>6	1	0

Table 4 Assessment of risk percentage for a several structures in the research area.

N	1	2	3	4
T(useful age)	10	15	20	30
Based MCE	21.10	30.91	40.72	99.57
Based DBE	14.07	20.61	27.15	66.38

CONCLUSION

In a radius of 150 km around Taftan volcano, it can be seen a moderate low to level of risk percentage based on MCE and DBE as shown in table 4. Regarding to these results it is quite evident that common structures in this area around Taftan volcano seriously are at risk. Also with attitude to the co- intensity map fore occurred earthquakes in mentioned radius, we can realize that of self volcano towards the surrounding parts, intensity of earthquakes increases so that it can be seen a low-intensity space within this area. This point is also obvious in Fig. 2 that shows distribution of instrumental records from earthquakes around Taftan. Extension of this low seismic zone is mainly from north-west to the south-east more.

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