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Seismicity of Aksaray and Its Vicinity (Central Turkey)

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Abstract

The Arabian and African plates that monitor the development of seismic activity in Central Anatolia are influential in the development of contemporary tectonics in the study area. There is a decisive effect of the Ecemiş Fault Zone with the Tuzgölü Fault Zone together in the depression of Central Anatolia. The 190km Tuzgölü Fault Zone which is one of the most important tectonic elements in the Central Anatolian Crystalline Complex is a right-lateral strike-slip fault continuously observed from Aksaray to Bor inclined by NW-SE. The Aksaray and its vicinity are known as silent area in terms of seismicity. However, the LNG storage facility (1 billion m^3 in volume) constructed in the last years has been giving priority to the earthquake activity of the region. For this reason, the seismic activity of Aksaray and its vicinity during the instrumental period has been investigated by using well known statistical seismology method, Gutenberg-Richter. The distribution of the elastic deformation energy which is evolved as a result of the seismic activity of the zone has been determined. However, dynamic and kinematic parameters such as seismo-active properties, fault geometry, faulting mechanism of the Tuzgölü fault zone and nearby fault segments have also been investigated. According to the earthquake records examined, there is no destructive earthquake in the period of instrumental recording period in the region which shows a very intense seismic activity in the historical periods. Furthermore, according to the principles of the fracture mechanics, potential seismic risk areas in the region have been identified and presented for discussion. It is expected that along with the tectonic development of the region, it will provide important contributions to the determination of deformations and tectonic modeling

Keywords: Tuz Gölü Fault Zone, Aksaray seismicity, deformation energy, seismic risk.

1. Introduction

Generally speaking, earthquake risks of the Aksaray Province and its vicinity are controlled and affected by the tectonic movements of the Central-Anatolia region. The Aksaray region resides in the central Anatolia Crystalline Complex, and its earthquake or effective seismicity is mostly dominated and also controlled by Tuzgölü Fault Zone (TFZ). The tectonic units of Tuzgölü (the Salt Lake) and of close areas play important roles in the seismic activities seen in the Aksaray region. The TFZ is an important tectonic unit in the region lying in the Northwest–Southeast (NW-SE) direction at about 190 km long. Its width reaches 3-4 km in some places, it is known as one of the main fault zones in the area and it has a right strike slip fault type mechanism (Figure 1). Analysis of the measurements and readings of the seismic equipment placed in this zone have shown that the seismo-activity exits there and the seismicity has been seen as earthquakes with the magnitudes greater than or equal to 5.0 (M>=5.0) with different epicenter distributions.

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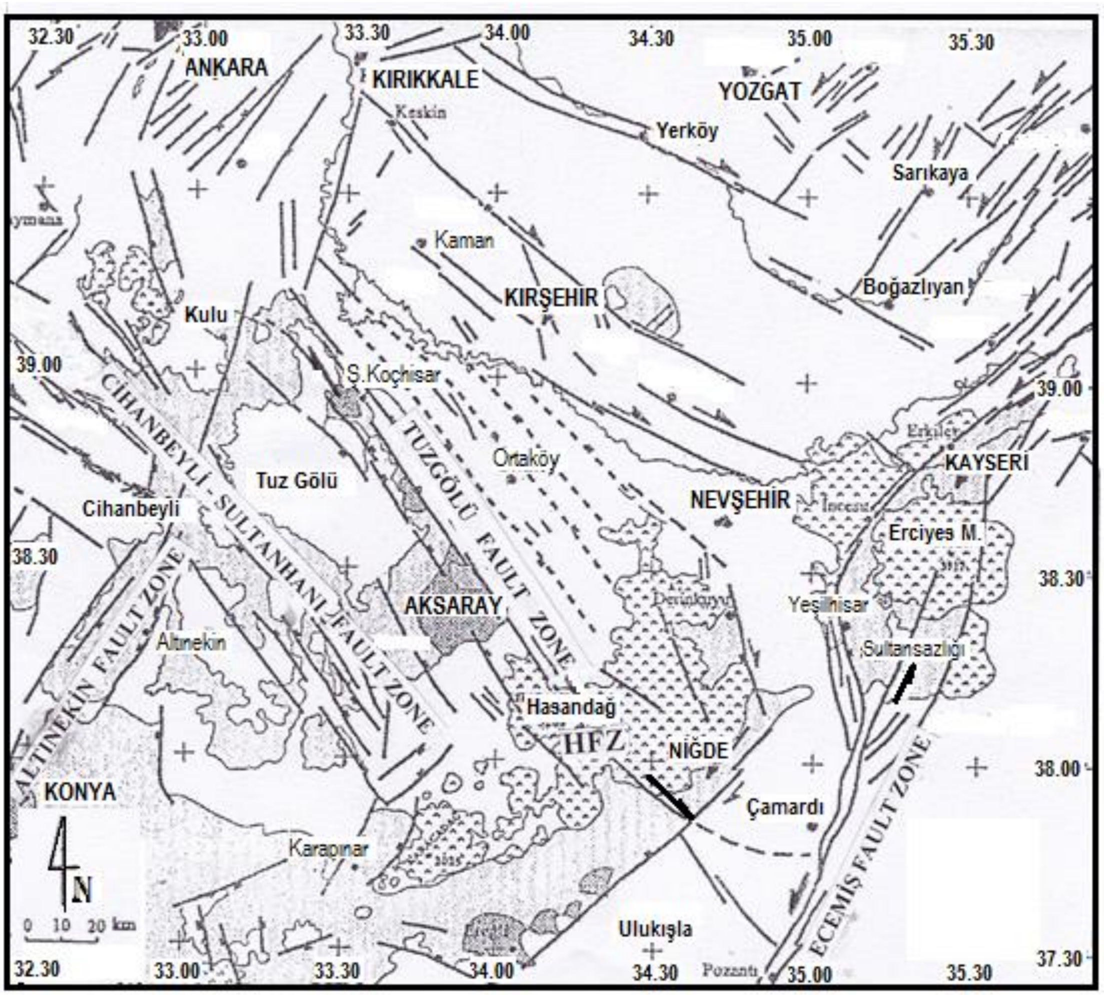

Figure 1. Neotectonics of the Tuzgölü and its vicinity (Dirik and Göncüoğu,1996)

The tectonic and earthquake or seismicity features and details of the Tuzgölü region and its vicinity (38,0-39,6 E 32,4-34,0 N) are studied and selected as the exploration and research area in this study. The area of interest resembles a large triangle surrounded by the Nigde and Central Anatolia fault zones in the southeast (SE), by the Sultanhanı fault zone in the west. It was reported that the Central Anatolia was characterized by two different neotectonic regimes, and these regimes are explained by two different fault systems [1]. First regime is a pull type neotectonic sytem with a normal faulting resulting from it. The second regime or approach is a compression-expansion compressed-expanding type neotectonic regime, and a strike-slip faulting system resulting from it. In addition, many and different studies have been done about the tectonic developments of the Tuzgölü and nearby areas as well as the Central-Anatolia regions such as [4,2,13,14].

2. Materials and Method

2.1. Seismic Risk Analysis

When considering and interpreting seismic risk analysis results based on simulation or likelihood methods, seismicity potentials with some time periods, seismological parameters and tectonic knowledge and inputs of the region play vital roles [8,9]. Information obtained from the seismic risk analysis studies in a region may provide important base knowledge for the design and development of urban areas or cities, also when planning locations of nuclear energy plants or dams. The seismic risk information should be consulted for the safety of the projects. Seismicity parameters used in seismic risk analysis and expectations should be site specific, and proper methods for the particular site should be selected and used as mentioned in [6, 9,10].

2.2.Gutenberg - Richter Method

Based on Richter and Gutenberg method is developed to predict magnitude of a future earthquake in an area. In the method, passed earthquakes are listed in a predefined area, a threshold magnitude (M) is defined, the earthquakes with greater than the threshold magnitude are counted, and the total number is assigned to N. The qualifying earthquakes are plotted and a graphical relationship is developed [24]. Using the Least Squares Method (LSM) an equation representing the graphical curve can be determined, the relationship can be explained as

$$\text{Log } N = a - b\,M \quad (1)$$

where the a and b are the regression coefficients. The Richter equation given in (1) is for a seismic year time period T_2; similarly same equation can be written for time period T_1 , when the difference between the two time period is taken, a relationship is obtained,

$$N_1 / N_2 = T_1 / T_2 \quad (2)$$

After taking the logarithms of both sides and rearranging

$$\text{Log } (N_1 / N_2) = \text{Log } (T_1 / T_2) \quad (3)$$
$$\text{Log } N_1 = \text{Log } N_2 + \text{Log } (T_1 / T_2) \quad (4)$$
$$\text{Log } N_1 = a - b\,M + \text{Log } (T_1 / T_2) \quad (5)$$

equation (5) is obtained [7]. The equations can be rearranged for the time periods of interests, and for the yearly seismic observation period a regression analyses can be obtained. According to these studies;

T_2 is a maximum magnitude which might happen in a year,

$$\text{Log } N = a - b\,M \quad (N = 1) \quad M_{max} = a / b \quad (6)$$

I. For a possible earthquake of a maximum magnitude M_{max}, the repeatability period is T_2 years.
II. In the year of T_2 a possible maximum number of earthquakes that might happen is N_2;

$$\text{Log } N = a - b\,M \quad (M = 0) \quad N_2 = 10^a \quad (7)$$

III. For a new time period T_1, using equation (5) where considered as a possible earthquakes with magnitudes greater than possible maximum threshold magnitude,

$$M_{max} = [a + \text{Log } (T_1 / T_2)] / b(N_1 = 1) \quad (8)$$

IV. Equation (8) can be simplified thinking that happens once a year (i.e. repeat period is one year) and setting $T_1 = 1$ in equation (8), an average magnitude value can be obtained as

$$M_m = (a - \text{Log } T_2) / b \qquad (9)$$

V. For a maximum magnitude a T_d repeat period using equation (5) ;

$$N_3 = 1,\ \text{Log } N_1 = a - b\,M + \text{Log } (T_3 / T_1)\ \ (N_3 = 1, T_1 = T_d)$$
$$\text{Log } T_d = \text{Log } T_2 - (a - b\,M_d) \qquad (10)$$

A likelihood of an earthquake of magnitude M_d that might happen in a year can be given as

$$R = p_r = 1 / T_d \qquad (11)$$

where R is the possibility coefficient to have an earthquake with magnitude that exceeds M_d .

3. Tectonic Developments

The Tuzgölü basin, which is one of the largest continental basins in Central Anatolia, is located in a NW-SE directional depression. The development of the basin continues from the Late Cretaceous to present. The western section of this basin is controlled by fault systems extending from Sultanhan to Cihanbeyli. The eastern part of the basin is controlled by the Tuzgölü Fault Zone (TFZ), starting from Kulu NE and extending towards Nigde in the direction of NW-SE, with a right lateral strike slip of about 190 km in length (Figure 1). About 100 km of the Tuzgölü fault morphologically limits the Tuzgölü from the east. The Quaternary Tuzgölü Fault lies along the tectonic line between the Miocene and older units. According to the morphological data, it is determined that the northern part of the Tuzgölü fault is likely alive [13, 12, 11,]. The southern part of the Tuzgölü fault is about 80 km long and extends from Aksaray to Nigde. Another important factor that determines the seismic activity of Aksaray and its vicinity is the Hasandagı Fay Zone (HFZ). However, the fault system that plays an important role in the active tectonics of the region is the Altınekin Fault Zone. Starting from near Konya, it extends to Kulu by cutting Cihanbeyli-Sultanhanı Fault Zone which controls the western part of Tuzgölü basin in the direction of SW-NE. The direction of the HFZ, which corresponds to the westernmost member of the Tuzgölü Fault Zone, is NW-SE direction by Hasandag [3, 5, 22]. The fault set is monitored continuously from Aksaray to nearby Niğde. The quaternary alluvium funs around HFZ cut through and are right-lateral. Following the ascension and erosion in the Late Eocene-Oligocene, a large plateau (Anatolian Peneplenia) was formed in Central Anatolia during the Early-Middle Miocene period. NW-SE-trending fault-controlled basins started to develop with the Tuzgölü, Cihanbeyli-Sultanhanı fault zones on the large plateau formed in Late Miocene and other fault systems parallel to them. In the interval between Early Pliocene and Late Pliocene, the marginal fault activities of these basins have disappeared, whereas the Tuzgölü basin continues to develop fault-controlled development. It is observed that the old lake shoreline tectonics dating from the Early Pleistocene to nowadays controlled the development of the Tuzgölü during this period [13, 15, 23].

4. Seismic Activity

The likelihood based on Seismic Risk Analysis method provides information about sites not only for city urban developments but also about the sites where nuclear power plants or dams are to be built. It provides information about an earthquake risk analysis of any locations in general the information could be used when the sites are considered to be developed for any civilization purposes [9,16, 8]. A seismicity risk analysis map of Turkey was completed, it was one of the studies based on the peak gravity and magnitude [16,20,19]. In the study, seismicity parameters combined with the uncertainties were explored in detail, and a simple approach was developed to determine the uncertainties in the prediction of seismic risk analyses [18, 9, 21].

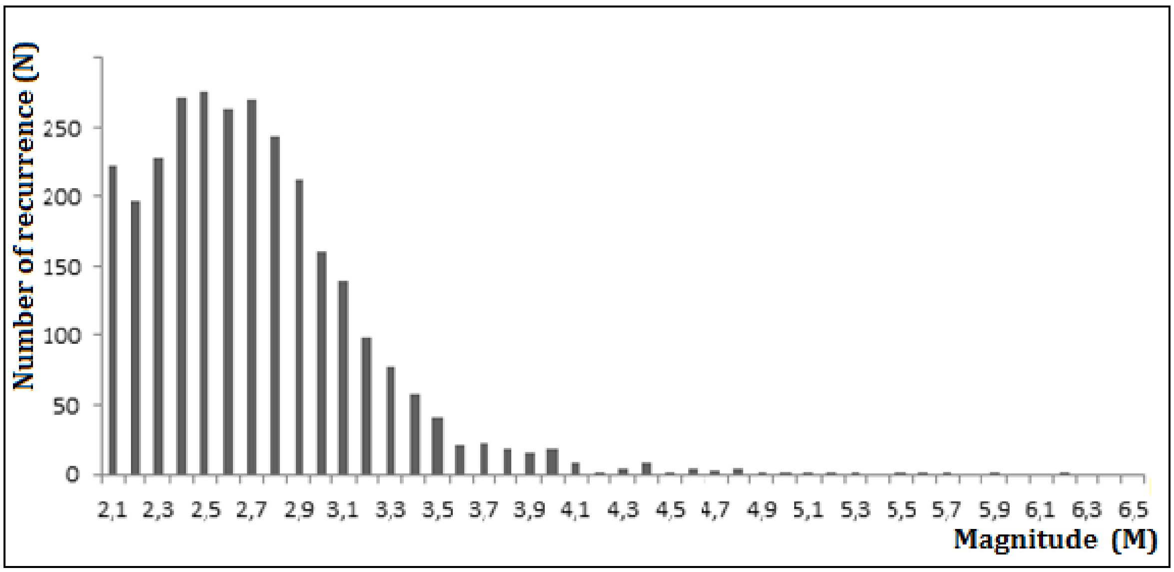

Figure 2. Magnitude representation of the earthquakes occurred at Tuzgölü and vicinity region (1900-2017)

The instrumental period records show that the study area has been characterized by lower magnitude earthquakes (Figure 2). The epicenter distribution map also shows that the northern part of the TFZ has higher seismic activity comparing with other tectonic structures in the study area. The TFZ and Ecemis Fault have been divided into 5 segments as shown Figure 3. Based on the analysis of the frequency of the earthquakes, and their sizes, magnitudes, and epicenters in the study area, one can conclude that the fault system that control Tuzgölü is more active than nearby structures [22, 23].

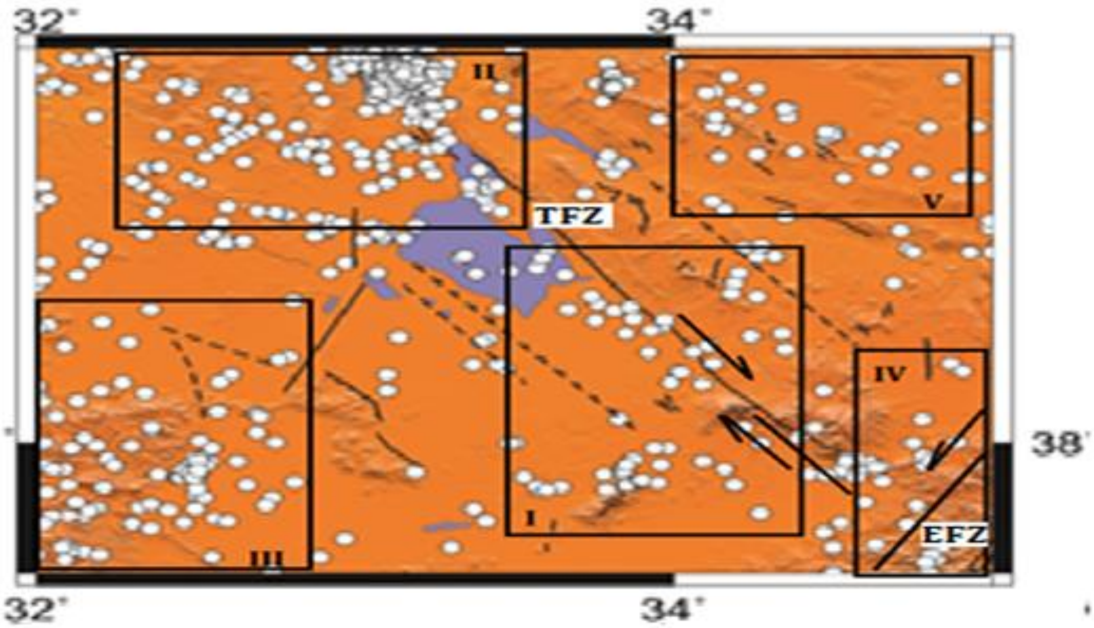

Figure 3. Seismicity map for the study area. (White circles indicated epicenters of earthquakes, 1903-2017)

5. Results and Discussions

The instrumental period data show that there was no large an earthquake generated since 1903, and seismic activity has been characterized by lower magnitude earthquakes.

The magnitude and frequency relationship for the study area obtained as:

Log N(M) = -0.8+5.189M

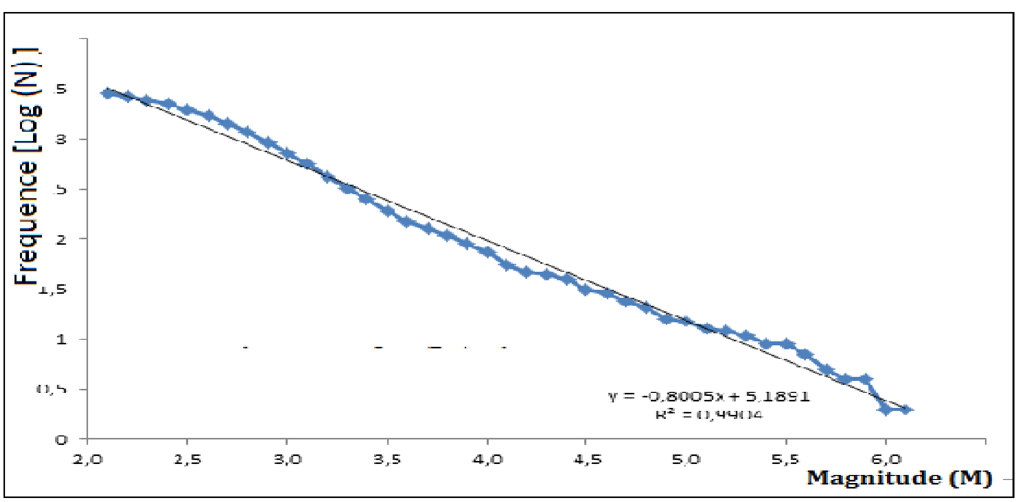

Figure 4. Magnitude-frequency relationship for the study area.

from the results of the Regression Analysis:

1. T_2 is the maximum magnitude that might happen in a year

Log N = 5.189 – 0.8 * M ,

where setting N=1, obtain M_{max} = a / b , and using the *a* and *b*,

M_{max} = 5,189 / 0,8 = 6.49

2. For maximum probable earthquake with magnitude of M_{max} the recurrence period is T_2 years, that is for this study 101 years (T_2 = 101);

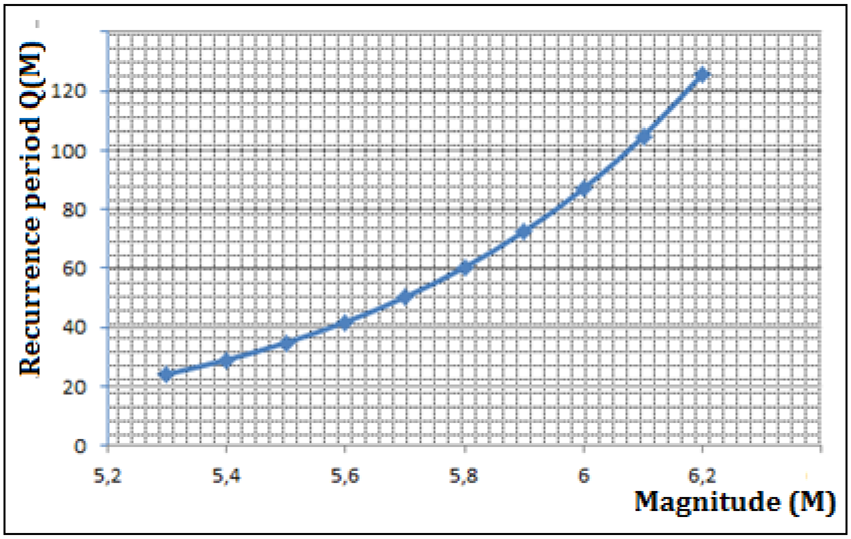

Figure 5. Recurrence Period - Magnitude relationship

3. within T_2 years the number of earthquakes that might happen is N_2. In the relationship $log\ N = a - b * M$ and setting $M = 0$; obtain $logN_2 = 10a$ that is $N_2 = 10^a$.

4. For year period of T_1 a probable maximum magnitude value can be obtained from

$$log\ N_1 = a - b * M + Log\ (T_1 / T_2)$$

as $M_{max} = [a + Log\ (T_1 / T_2)\ ] / b$

using the *a* and *b* values

$M_{max} = [\ 5{,}189 + log\ (50\ /\ 101)\ ]\ /\ 0{,}8$

$M_{max} = 6.10$

5. when the equation is reduced to every year case (recurrence period is $T_1 = 1$), the average magnitude value is obtained from

$M_{max} = [\ a + Log\ (T_1\ /\ T_2)\ ]\ /\ b$

where setting $T_1 = 1$,

$M_m = (\ a - logT_2)\ /\ b$

$M_m = (5.189\ -\ log101)\ /\ 0.8$

$M_m = 3{,}98$

6. For any maximum magnitude (M_{max}) the period is obtained using relationship

$T_d = 10^{logT2-(a-b*M)}$

Probability likelihood of an earthquake with magnitude of M_d that might happen within a year is

$R = P_r = 1\ /\ T_d$

where the construction lifetime is taken 50 years T_1=50

Table 1. Expected magnitude values for the study area.

	Magnitude
M_{max} (for 101 years)	6,49
M_{max} (for 50 years)	6,10
M_m	3,98

The sizes or magnitudes of the earthquakes and their recurrence intervals are controlled and depended on the deformational stresses caused by active regional faults, their tectonic situations within the fault system, and their structural integrities.

Although this region was considered as a safe zone for earthquakes, our results indicated that this may not be the case. An earthquake larger than 6 could be happens in the study area according to statistical analysis. It is highly recommended here that the seismicity of the region should be studied further in detail as the new information and recordings are collected from the study area.

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