

Features of seismic activity in Palmyride fold belt (Syria): a quantitative analysis

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Abstract

Palmyride fold belt is considered a keystone region to understand the tectonic and geological evolution of the northern part of Arabian plate. The Palmyride region was affected by the last major seismic event of magnitude MS 5.6, which occurred on 24th December 1996'. In this study, a special earthquake catalogue for Palmyride fold belt zone covering the period 1969-2020 has been compiled based on published seismic bulletins with the goal of deepening our understanding of the nature of this active seismic zone. A quantitative analysis of this catalogue showed that the seismic activity of the Palmyra fold zone during the last 50 years has produced moderate magnitude events. Generally, Palmyride fold belt is characterized by moderate instrumental seismic activity regarding the total number of recorded events (1444 events) and the maximum observed magnitude (M_S 5.6). The magnitude of completeness has been estimated to be 2.3. The Gutenberg-Richter relationship inferred that the b-value is about 0.87 using the maximum likelihood method. Accordingly, the return period for an event of magnitude 7.0 is assessed to be 600 years. The maximum likelihood Kijko's procedure has predicted the maximum possible magnitude to be 6.37. Such large earthquake is probable regarding the last historical earthquake occurred on 13 January 1043 AD. This new study has better quantified the seismic potential of the area and shows the probability of occurrence of potentially damaging earthquakes. This paper provides a geological framework and analysis of seismic activity in the Palmyride Fold Belt in Syria, a crucial topic for understanding the tectonic dynamics of the region.

Keywords: Palmyride fold belt; Instrumental Earthquake; Gutenberg-Richter relationship; Syria

1. Introduction

The Palmyride fold belt (PFB) represents the second major crustal deformed zone in Syria after the Dead Sea fault system due to its complex tectonic features. Since the PFB has a large economic importance for hydrocarbon exploration and production, numerous geological and geophysical investigations have been carried out using well logging, geophysical and geological data (Best et al., 1990 and 1993; Chaimov et al., 1990; 1992 and 1993; Al-Saad et al., 1991 and 1992; Seber et al., 1993; Alsdorf et al., 1995). However, whilst a considerable amount of the research on the long-term seismicity has been carried out along the Dead Sea fault system in western Syria (Salamon et al., 1996; Baer et al., 1999; Klinger et al., 1999; Brew, 2001; Megrhaoui et al., 2003; Abdul-Wahed and

Al-tahhan, 2010; Abdul-Wahed and Alissa, 2020), very little investigations has focused on the PFB (e.g. Chaimov et al., 1990; Barazangi et al., 1993). The deficit of seismotectonic investigations is due mainly to the absence of local seismic network in Syria until 1995 for detecting small magnitude earthquakes. The installation of the Syrian National Seismological Network (SNSN) by the end of the year 1994 has made possible the detection and location of sufficiently enough small earthquakes. The network’s design objective was to monitor all discernible earthquake activity along the Dead Sea fault system (DSFS) and its related branches in Syria and nearby Lebanon. The SNSN, officially operated since 14 January 1995, consists of 27 short period (1 Hz) stations of ~50 km seismograph spacing. More information about the SNSN data, such as acquisition, transmitting, recording, and processing, can be found in Dakkak et al., (2005), which offers a detailed description of the network and its significance for monitoring seismicity in Syria. Unfortunately, the SNSN stopped in 2012 due to the war in Syria, and most of its stations were stolen and vandalized.

The Syrian territory has been affected in the past by many large earthquakes. During the last millennium, between 1022 and 1872, at least ten large earthquakes occurred in this zone (Sbeinati et al., 2005), as did the recent 1996 M_S 5.6 Palmyra earthquake. The complex tectonic features of PFB, which were documented in previous studies e.g. Chaimov et al., 1990; Barazangi et al., 1993, impose a high level of seismic activity. This finding was confirmed when the PFB produced the strongest earthquake in Syria “Palmyra earthquake” with magnitude $M_S = 5.6$ during the twentieth century on December 24th, 1996. It was widely felt in Syria, Lebanon and in northern Jordan (Tan and Taymaz, 2003; Alchalbi, 2004; Abdul-Wahed and Asfahani, 2018). This earthquake has a sinistral strike-slip mechanism trending NE and can be linked to Palmyra fault (Abdul-Wahed and Al-Tahan, 2010). In this context, the current research attempts to characterize the seismic activity of this zone, and to estimate its contribution to the regional seismic hazard. This issue could be interesting for the scientific society, especially because of the scarce information available about this active zone. Furthermore, the evaluation of a potential seismic activity of tectonic zones, such as PFB, became a vital necessity in Syria after the Kahramanmaraş 2023 earthquake disaster.

2. Geological and tectonic setting

The PFB spans in central Syria for about 400 km from Damascus city in the southwest to the Euphrates River in the northeast (e.g. Brew et al., 2001). This intraplate belt is bounded (Fig. 1) by numerous deformed zones, less deformed and stable areas (Barazangi et al., 1993). They are the Aleppo plateau to the north, Hamad uplift and Jabal Al-Arab (a northern part of the basaltic Wadi Sirhan) to the south and southwest, Lebanese restraining bend of the

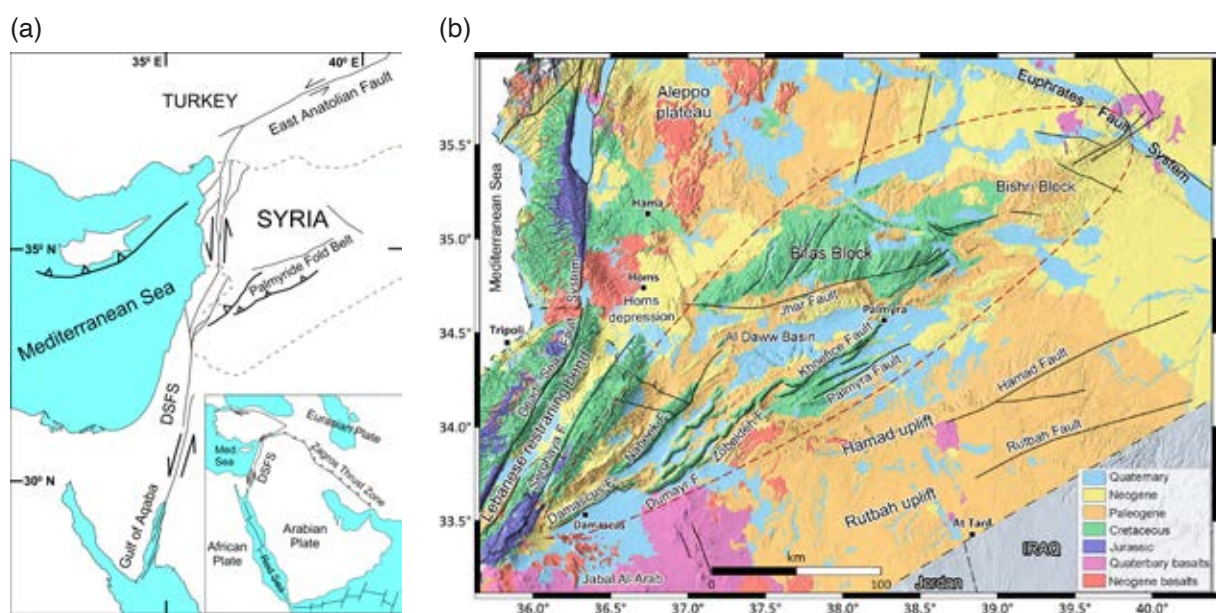


Figure 1. Regional setting (a), tectonic and geological map showing the main faults in Palmyride fold belt (b). The dashed line indicates the Palmyride fold belt (modified from Brew et al., 2001).

central transform Dead Sea fault system to the southwest, the extensional NW-SE Euphrates fault system to the northeast, and Homs depression to the west (Fig. 1).

Since the PFB is considered one of the keystones in understanding the tectonic and geological evolution of the northern Arabian plate and has an economic importance for hydrocarbon exploration, numerous geological and geophysical investigations have been carried out using well logging, geophysical and geological data. The Cornell-Syria project was among the most important one during the last 40 years. This project is an academic/industrial collaboration, started since the late 1980s in the goal of analyzing and mapping the tectonic history of the structurally deformed areas of Syria predominantly through geophysical analysis. Understanding this rich history can yield a fuller appreciation of the plate-tectonic processes in the eastern Mediterranean region. Some of the relevant results of this project can be found in the following references: Best et al., 1990 and 1993; Chaimov et al., 1990; 1992 and 1993; Al-Saad et al., 1991 and 1992; Barazangi et al., 1993; Seber et al., 1993; Alsdorf et al., 1995. The Cornell-Syria project has shown that the Palmyride area was a large Permo-Triassic rift, formed under a regional extension associated with the opening of the NeoTethys Ocean (Brew, 2001). In other words, the Palmyride area was a Paleozoic/Mesozoic northeast trending depocenter located in central Syria. During the Cenozoic, the area was subjected to a compression that led to its current shape. According to the topography and structure, the PFB can be divided into two distinguished mountainous regions. They are the SW Palmyride thrust-fold and the north Palmyrides which in turn consists of two blocks: the Balaas (Bilas) and the Bishri (Fig. 1). Between the SW Palmyrides and the Bilas block, there is a low-relief intermontane basin named Al-Daww depression. The SW PFB is a series of about 14 narrow, en echelon, asymmetrical folds with SE vergent. It extends from Damascus city to Palmyra town. The Nabeek anticline is the largest fold (Darkal, 2002) which is cut by Jayrud fault. The Qassyoun fold is the second largest one (53 km) associated with Damascus reverse fault along it. Both anticlines are located at the southernmost PFB. This means that a current shortening occurs at the southern Palmyrides. Chaimov et al. (1992, 1993) mentioned that these folds are cut by numerous deep, short EW and NE-SW inverted normal faults. The Bilas block consists of at least 8 large anticlines with a total width of about 100 km. Using well data, Chaimov et al. (1990) documented that these folds show a very little shortening and bounded by deep faults. The 200-km-long Jhar fault is the main regional fault located along the southern edge of the Bishri Block. It strikes east-northeast extending from north of As-Sukhneh village showing a dextral strike-slip sense (Al-Saad et al., 1992). The Bishri block is a broad NE-plunging anticline. It takes its present form through transpressive inversion in its structure since the Mid-Miocene (Brew et al., 2003). Most of the subsurface faults strike EW and NE-SW. The southern Bishri fault with SSW direction is approximately located between the Balas and Bishri blocks.

From the structural standpoint, during most of the Phanerozoic the PFB area was a sedimentary depocenter accumulating several kilometers of Paleozoic and Mesozoic formations through episodic rifting and broad subsidence (Brew et al., 2003). The crustal shortening is ongoing across the southern PFB as assessed by the near-field GPS survey (Alchalbi et al., 2010). Although its minor, it is about 1 mm/yr of north south shortening. The regional kinematic model predicts a crustal shortening rate of $\sim 2 \text{ mm a}^{-1}$ across the PFB (Abou Romieh et al., 2009). In this regard, it is appeared that the movements along the nearby plate boundaries (i.e. DSFS and EAFS) control the deformation observed in the PFB and other ones in Syria (Barazangi et al., 1993). Abou Romieh et al. (2012) has explained the low slip rate, recently measured on the northern DSFS in western Syria, by absorbance of the northward motion of Arabian plate, relative to African plate, by the observed crustal shortening within the PFB.

3. Seismicity of PFB

Compiling a specific seismic catalog covering the PFB region requires the systematic collection of earthquakes from local, regional and international agencies. Such catalog serves as an essential dataset for performing seismic hazard assessments. The instrumental seismic activity of PFB has been collected essentially from three sources: International Seismic Center (ISC) for the period before 1995, the Syrian National Seismological Network (SNSN) for the period from 1995 until 2011, and the European-Mediterranean Seismological Centre (EMSC) for the period from 2012 until 2020. The catalog doesn't contain any multiple or recurring events because its sources cover separate time periods. The dataset consists about 1444 seismic events, with 110 events coming from ISC, 1254 events coming from SNSN, and 80 coming from EMSC. Generally, the PFB is characterized by moderate instrumental seismic activity in terms of the total number of recorded events (1444 events) and the maximum observed magnitude

is M_S 5.6. The SW part is well defined by more intense seismic activity (Fig. 2), where a high concentration of micro-earthquakes occurs in this part of PFB. Most of events of the SW part are located along the NE reverse faults such as Nabeek, Jayrud and Zobeideh faults associated with thrust-folding tectonic (Abdul-Wahed, 2019; 2022). However, some more significant earthquakes of relatively moderate magnitudes are scattered over a much wider area in the NE part of PFB, e.g. Oct. 5, 1970 (Ben-Menahem et al., 1976), May 20, 1987 (Chaimov et al., 1990). The SNSN has recorded some more significant earthquakes such as: December 18, 1994 and December 24, 1996 (Abdul-Wahed and Al-Tahan, 2010) of magnitudes 4.6 m_b and 5.6 M_S respectively. The distribution of earthquakes over a large area reveals a tectonic complex pattern in the northeast Palmyride. This scattered seismicity suggests that the Palmyrides region is still tectonically active (Brew et al., 2001, Abdul-Wahed and Asfahani, 2018). The most important seismic event was the earthquake of Palmyra, which occurred on 24th December 1996 with a magnitude of about 5.6 (Alchalbi, 2004; Tan and Taymaz, 2003). This event has a sinistral mechanism trending NE, and can be linked to Palmyra fault (Abdul-Wahed and Asfahani, 2018).

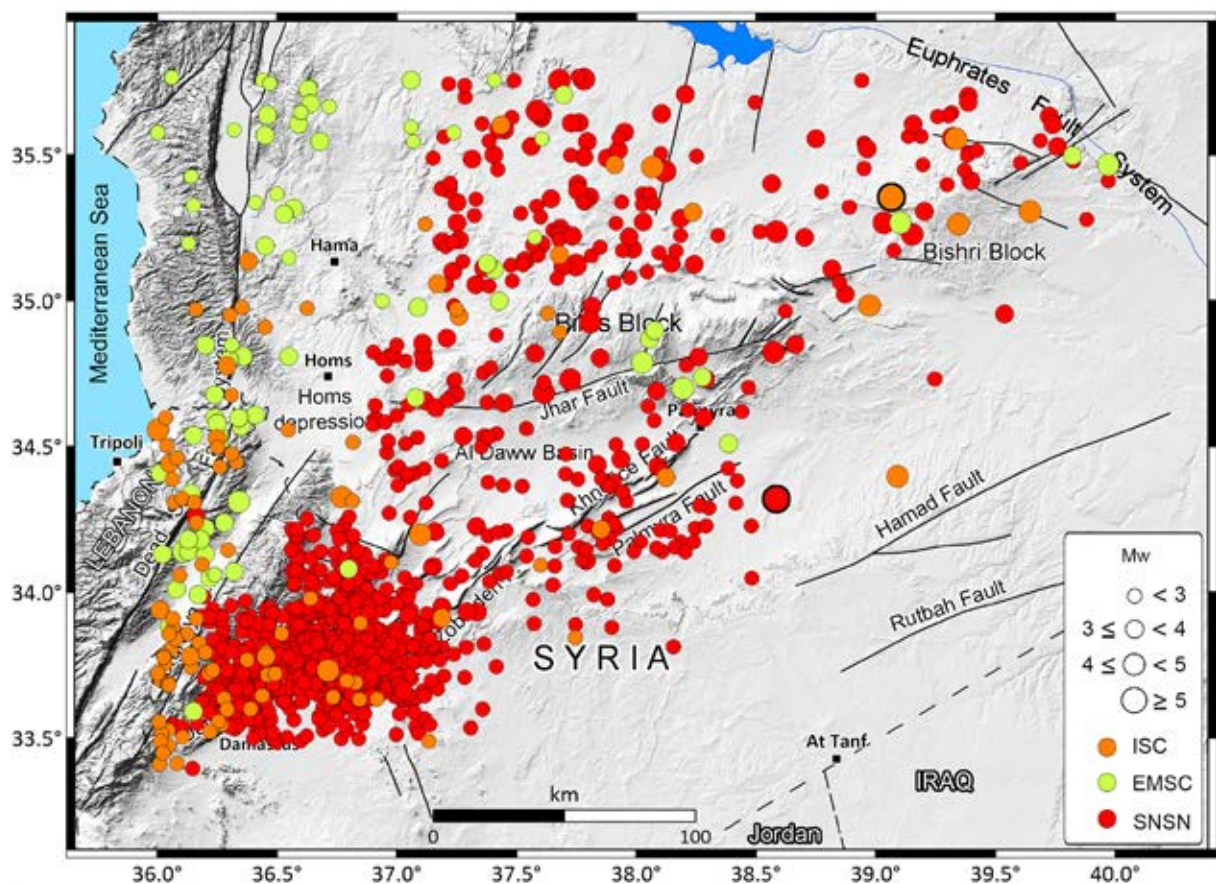


Figure 2. Epicenter map showing the instrumental seismic activity published by ISC, EMSC and SNSN during the period 1969-2020 and the main cities in Palmyride fold belt region. The red circle with a black border indicates the December 24, 1996 earthquake. The orange circle with a black border indicates the December 18, 1994 earthquake.

Concerning the historical earthquake activity, two strong historical earthquakes have damaged Palmyra city located within the PFB (Sbeinati et al., 2005). The Arabian historian Sibte Ibn Al-Jawzi (b. 1186 - d. 1256) documented in his work, consisting of 22 volumes, that an earthquake damaged Palmyra city in Jamada I of 434 AH. (i.e. 16 Dec. 1042-13 January 1043 AD.) to the extent that most population of Palmyra was killed under the debris (Ibn Al-Jawzi, 12: 215) (Fig. 3). This book, one of the world's oldest books, is a universal history covering the period from creation to the year 1256 AD for the area of interest. The second event occurred in 1089 AD and damaged Palmyra (Sieberg, 1932).

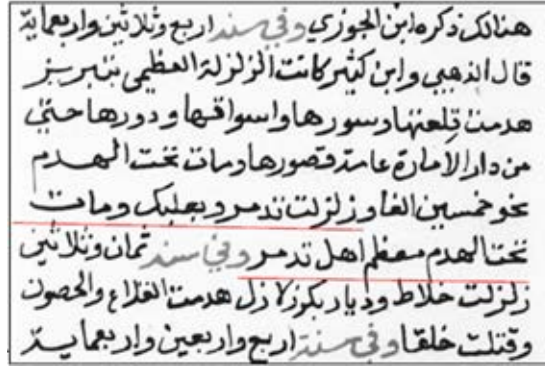


Figure 3. An original account of the manuscript by Ibn Al-Jawzi regarding the 1042 earthquake (Ibn Al-Jawzi, 12: 215).

4. Data and methods

Specific catalogue of earthquakes for PFB covering the period from 1969 to 2020 has been compiled by using essentially the data published by ISC, EMSC and SNSN bulletins. A total of 1444 events have been recorded in PFB region during a period of 51 years. The annual average is about 28 events, which could be considered very low compared to other regional active faults such as Yammounah fault or Aqaba fault, which consequently indicates that PFB is in a relatively quiescent period.

Magnitudes have been calculated for the three bulletins mentioned above using various types of magnitude scales, such as M_b , M_d , M_L and M_C . Therefore, it is necessary to homogenize the magnitude scales and to use the most recommended type: the moment magnitude M_w . This procedure can be done using the regression relations of Alissa et al. (2021). For example, the following relations are used to convert M_C and M_L to M_w :

$$M_w = 0.84 * M_C + 1.73 \pm 0.36 \quad (1)$$

$$M_w = 0.70 * M_L + 1.40 \pm 0.16 \quad (2)$$

The seismic activity is frequently described by using Gutenberg and Richter relation (G-R relation) (Gutenberg and Richter, 1944; 1954), which statistically examines the frequency-magnitude distribution of recorded seismic events. The G-R relation is given as:

$$\log N = a - b \cdot M \quad (3)$$

In this relation, N is the number of events with magnitude larger or equal to M , and a and b are empirical constants, where a -value indicates the level of seismic activity describing the total number of earthquakes, and b -value is the slope of G-R relation indicating the rate of occurrence within a given magnitude range. In addition, the b -value describes the relative abundance of large to small earthquakes. A lower b -value means a higher frequency of larger earthquakes relative to smaller ones. The b -value has been widely used in seismic researches, seismic hazard assessment, and seismic risk analysis. It has significant implications in probabilistic seismic hazard assessment (e.g., Meletti et al., 2008; Coppersmith et al., 2009; Schmid and Slejko, 2009; Wiemer et al., 2009) and guiding the formulation of earthquake recurrence models (Marzocchi and Sandri, 2003; Lamessa et al., 2019). Some researchers (e.g. Scholz, 1968, 2015; Amitrano, 2003) indicated the b -value as a representative of the level of differential stress. Scholz (2015) found that the b -value decreases linearly with differential stress for both continental and subduction zones. It can be used to map out stress variations and its temporal variations during the seismic cycle.

Thus, the b-value could be an indicator of the state of preparation of a future strong earthquake (Gulia and Wiemer, 2010; Gulia et al., 2020).

G-R relation could be applied to cumulative number “N” as well as to incremental numbers “n”. In the first case, N is the cumulative number of earthquakes with magnitude larger than M. However, n is the number of events within an interval of magnitudes: $M \pm \Delta M$ in the second case, where ΔM is a binning interval which should be carefully chosen for any incremental b-value evaluation. The magnitude data are usually discrete quantities and calculated with a precision of 0.1 magnitude binning interval in approximately all global catalogs. Thus, a proper choice of ΔM will be a compromise between the magnitude sampling as close to 0.1 as possible and statistically sizeable numbers of events by every magnitude bin. Further, the cumulative distribution of magnitudes is preferable; it provides satisfactory linear fit since large numbers are less degraded by statistics of small numbers.

Different methodologies for assessing the b-value of G-R relation are available in literature. The least-squares method (LSM) is often used, although not formally suitable since magnitude is not error free, cumulative event counts are not independent, and the error distribution of the number of earthquake occurrences does not follow a Gaussian distribution. For a more reliable estimation of the b-value, it is recommend using the formula developed by Aki (1965) and Utsu (1965), which is known as the maximum likelihood estimation (MLE) method. This method assumes a continuous exponential distribution of magnitudes. The formula is expressed as follows:

$$b = \frac{\log_{10} e}{\bar{m} - \left(M_{min} - \frac{dM}{2}\right)}, \quad m \geq M_{min} \quad (4)$$

where: \bar{m} is the mean value of the magnitude of the considered dataset, M_{min} is the completeness magnitude and $\frac{dM}{2}$ represents half of the bin width (for ex. 0.05). Studying in detail the statistical distribution of b-value, Shi and Bolt (1982) suggested the following formula for the standard deviation σ_b of the continuous distribution:

$$\sigma_b = \ln(10)b^2 \sqrt{\frac{\sum_{i=1}^N (M_i - \bar{M})^2}{N(N-1)}} \quad (5)$$

In this research, G-R relation is evaluated from the available recorded events by the LSM and MLE methods using the code “bvalue.exe” from the Seisan 10.3, software 2015. The G-R relation is widely used to assess parameters of seismic hazard like maximum expected magnitude and return period. However, other key parameters in the seismic-hazard, such as: the mean seismic activity λ , and, the maximum regional magnitude M_{max} could be assessed by Kijko’s procedure (Kijko, 1983). This procedure (Kijko and Sellevoll, 1989; Kijko, 2004; Kijko et al., 2021) is based on the estimation of maximum likelihood of the seismic activity rate (λ), b-value in the G-R relation, and the maximum possible magnitude M_{max} . Supposing that in the area of concern, within a specified time interval T, all n of the main earthquakes that occurred with a magnitude greater than or equal to m_{min} are recorded. Let us assume that the value of the magnitude m_{min} is known and is denoted as the threshold of completeness. Kijko’s procedure assumes further that the magnitudes are independent, identically distributed, random values with Cumulative Distribution Function (CDF), $F_M(m)$. The unknown parameter m_{max} is the upper limit of the range of magnitudes and is thus termed the maximum regional magnitude, and is to be estimated. Kijko’s procedure assume that all n recorded magnitudes are ordered in ascending order, i.e. $m_1 \leq m_2 \leq m_n$. The m_n , which is the largest observed magnitude (denoted also as m_{max}^{obs}), has a CDF:

$$F_{M_n}(m) = \begin{cases} 0, & \text{for } m < m_{min}, \\ [F_M(m)]^n, & \text{for } m_{min} \leq m \leq m_{max}, \\ 1, & \text{for } m > m_{max}. \end{cases} \quad (6)$$

After integrating by parts, the expected value of M_n , $E(M_n)$, is

$$E(M_n) = \int_{m_{min}}^{m_{max}} m dF_{M_n}(m) = m_{max} - \int_{m_{min}}^{m_{max}} F_{M_n}(m) dm. \quad (7)$$

Hence:

$$m_{\max} = E(M_n) + \int_{m_{\min}}^{m_{\max}} [F_M(m)]^n dm. \quad (8)$$

This expression, after replacement of the expected value of the largest observed magnitude, $E(M_n)$, by the largest magnitude already observed, m_{\max}^{obs} , provides the equation:

$$m_{\max} = m_{\max}^{obs} + \int_{m_{\min}}^{m_{\max}} [F_M(m)]^n dm, \quad (9)$$

Kijko's procedure is applicable in the extreme case when we do not have any information about the earthquake magnitude distribution. The procedure can also be used in the case of an incomplete earthquake catalogue, which could be the case of the earthquake catalogue for PFB.

5. Results and discussion

The largest observed magnitude in the PFB area is about M_W 5.5, which occurred on 24th December 1996 (Fig. 4). Only 30 events, about 2% of the established catalogue, have exceeded the magnitude 4.0. The empirical G-R relation has been evaluated using Seisan software (Seisan 10.3, 2015; Havskov and Ottemoller, 2020) by applying two methods: LSM and MLE, where an incremental distribution of magnitudes (ΔM): 0.1 was used in the both methods (Fig. 5). Observing the frequency-magnitude distribution shown in Fig. 5, it is evident that the catalog suffers from significant incompleteness.

The calculation of the magnitude of completeness, has been done using a free web application (IS-EPOS, 2016: <https://episodesplatform.eu>). The results show the following estimations for $M_{\text{completeness}}$: 2.1 according to Goodness of fit test at 90% confidence bounds, 2.3 according to Modified Goodness of fit test, and 2.5 according to Maximum Curvature Method. An average value of 2.3 can be used for further analysis. The fitting of G-R relation to the observed frequency-magnitude distribution has shown a magnitude completeness down to $M_{\text{completeness}} = 2.3$ (Fig. 5). This indicates that a considerable number of micro-earthquakes ($M_W < 2.3$) has been omitted by the SNSN. Some too small events were not recorded on a sufficiently number of stations to trigger the recording system in the SNSN and to initiate the location procedure, thus these events have not been reported. It might also that the network operators decided that some micro-events below a certain threshold ($M_W < 2.3$) are not of interest. The incomplete part of the PFB catalog has been discarded before the applying of LSM and MLE methods, and the parameters calculation.

The final results, summarized in Table 1, show the best regression fit for LSM method indicated a- and b-values of 5.35 and 0.98, respectively. For MLE method, the best regression fit indicated a- and b-values of 5.03 and 0.87, respectively. The least squares method is not considered appropriate for accurately estimating the b-value, especially when dealing with an incomplete seismic catalog. This approach tends to give excessive weight to lower magnitudes, which are numerically dominant but often incompletely recorded, leading to either underestimation or overestimation of the b-value. This is particularly problematic for the catalog in question, which exhibits incomplete data. The calculated b-value using least squares regression, in Table 1, raises some concerns regarding its appropriateness for this context. While the reported high regression coefficient ($\text{Cor} = 0.99$), and very low residual ($\text{RMS} = 0.11$) suggest a good fit, these values may not accurately reflect the reliability of the b-value estimate. The least squares method assumes symmetric and normally distributed errors, which may not hold true for seismic data influenced by catalog incompleteness and magnitude thresholds. However, the maximum likelihood estimation (MLE) method described above can give a more reliable estimation and the calculated a and b values could be reasonable for further interpretations.

According to the published literature (e.g., Frohlich and Davis, 1993), the b-value commonly ranges from 0.60 to 1.30 depending on the different tectonic regimes. Shorlemmer et al. (2005) found the thrust zones are associated with small b-value (≈ 0.90), which corresponds to the PFB and indicates that the calculated b-value by MLE method is compatible with the literature. Furthermore, the obtained b value is similar to the typical b values of 0.8-0.9 found by Arieh (1967), Ben-Menahem and Aboodi (1981), Shapira and Feldman (1987), Salamon et al. (1996), Shapira and

Hofstetter (2001) and Hofstetter (2003), although different magnitude scales and parts of the Dead Sea fault were used in these studies. Therefore, this b-value can be accepted regarding the reported values in the literature and valid for further interpretations.

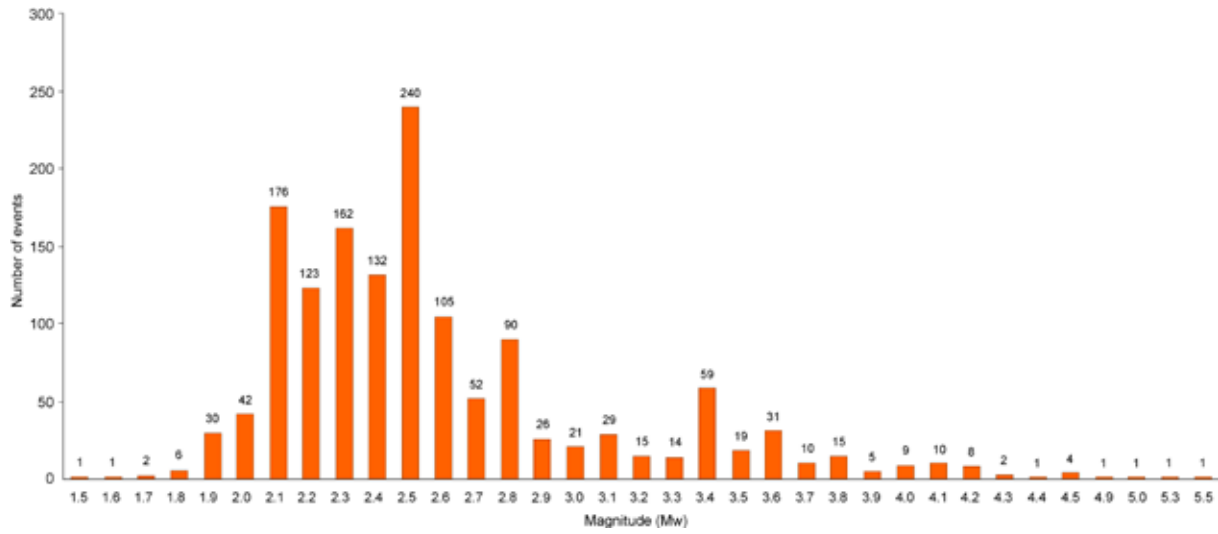


Figure 4. Distribution of the recorded events according to their magnitudes (M_w). The incremental distribution (ΔM) is 0.1.

Method	M_{min}	M_{max}	a-value	b-value	Accuracy	
LSM	2.3	5.5	5.35	0.98	COR = 0.99	RMS = 0.11
MLE	2.3	5.5	5.03	0.87	SD = 0.0255	

Table 1. a-value and b-value calculated by using two methods LSM and MLE, where SD is the standard deviation of estimator, COR is the regression coefficient, and RMS is the root-mean-square error of estimate.

The b-value uncertainty in MLE method is calculated by Aki-Utsu estimator, using the Eq. (5) proposed by Shi and Bolt (1983): $\sigma_b = 0.0255$. The low standard deviation ($\sigma_b = 0.0255$), indicates that the return periods can be calculated by extrapolating the obtained G-R relation to larger earthquakes. The return periods for higher magnitude events than those included in the catalogue can be deduced using the formula of Shlanger (1960) as:

$$T(M) = 10^{(b \cdot M - a)} \text{ years} \tag{10}$$

The extrapolated return periods are shown in Fig. 6. A return period for an event of magnitude 7.0 is extrapolated to be 600 years according to the least square method, which could be reasonable regarding the historical seismic activity.

The earthquake catalogue of PFB, established in this research for the period of 1969-2020, could be considered as incomplete. In this case, the Kijko's procedure may be more appropriate to apply on the instrumental earthquake catalogue of PFB. It has been applied using a Fortran code: hn2.exe: Release: 2.10, 24 June 2005. (The code availability is on request from his author Andrzej Kijko, University of Pretoria, Pretoria, South Africa, andrzej.kijko@up.ac.za).

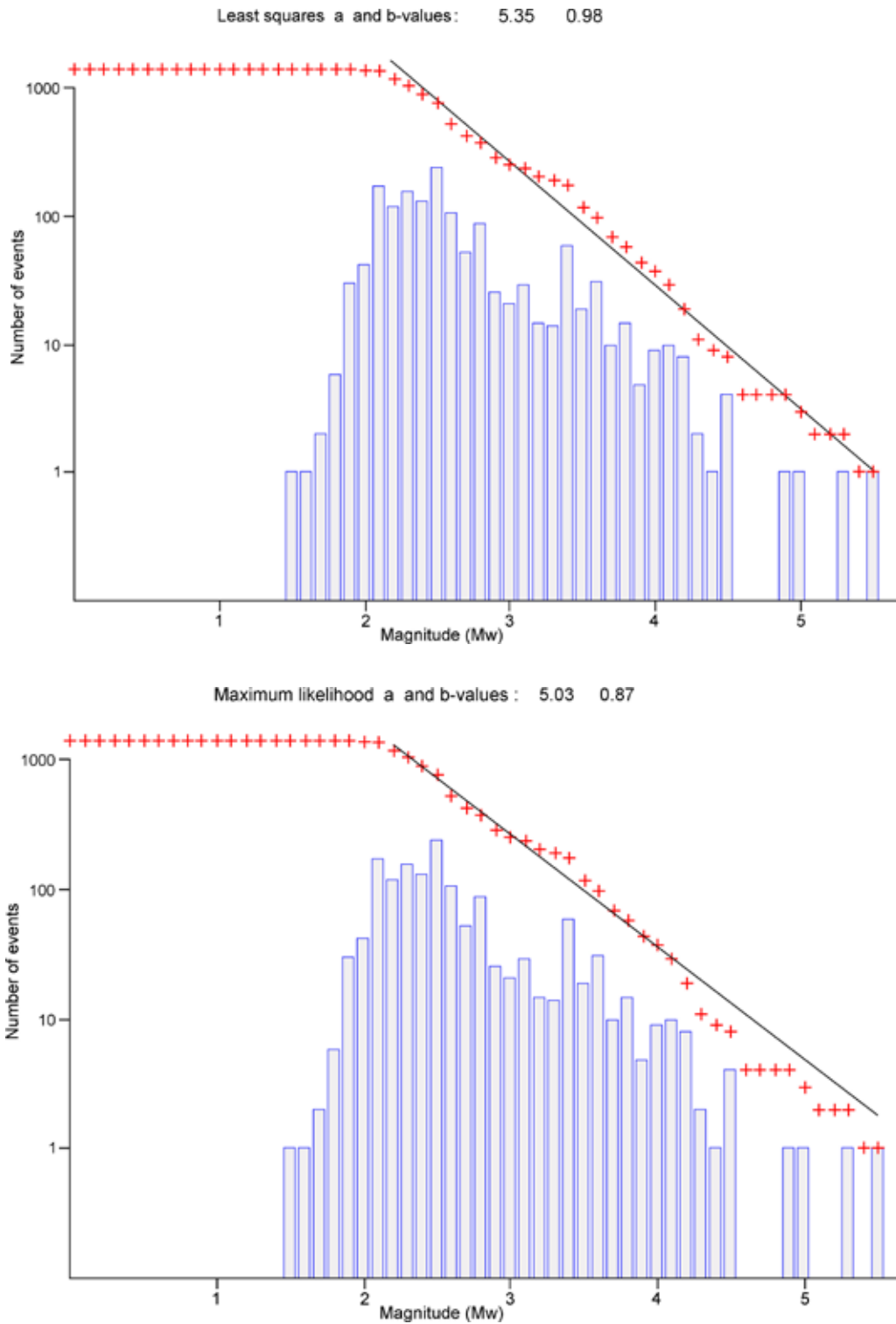


Figure 5. Comparison between the two methods: LSM in the top and MLE in the bottom using a magnitude interval: $\Delta M = 0.1$. Histograms are showing the number of events in selected magnitude intervals and crosses are showing the accumulated number of events.

The obtained results are:

$$\beta = 2.71 \pm 0.04 \text{ (b-value} = 1.18 \pm 0.02, \text{ where } \beta = \text{b-value} \cdot \ln(10))$$

$$\lambda = 263.44 \pm 7.18$$

$$M_{\max} = 6.37 \pm 0.9$$

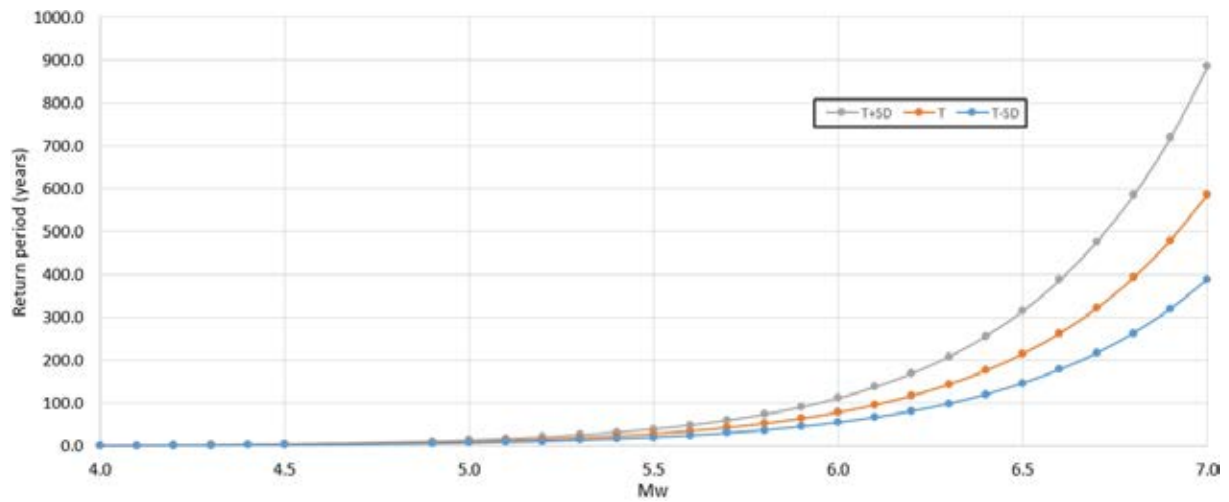


Figure 6. Predicted return periods by MLE method.

The Kijko’s procedure predicts the maximum possible earthquake magnitude (M_{max}) to be 6.37. Furthermore, this procedure estimates the probabilities of occurrence of large earthquakes within a given interval of time. Fig. 7 shows the probabilities of occurrence of earthquakes during the time intervals 1, 50, 100 and 1000 years. The magnitude of the strongest earthquake in these time intervals could attain 3.2, 4.4, 4.8 and 5.8, respectively.

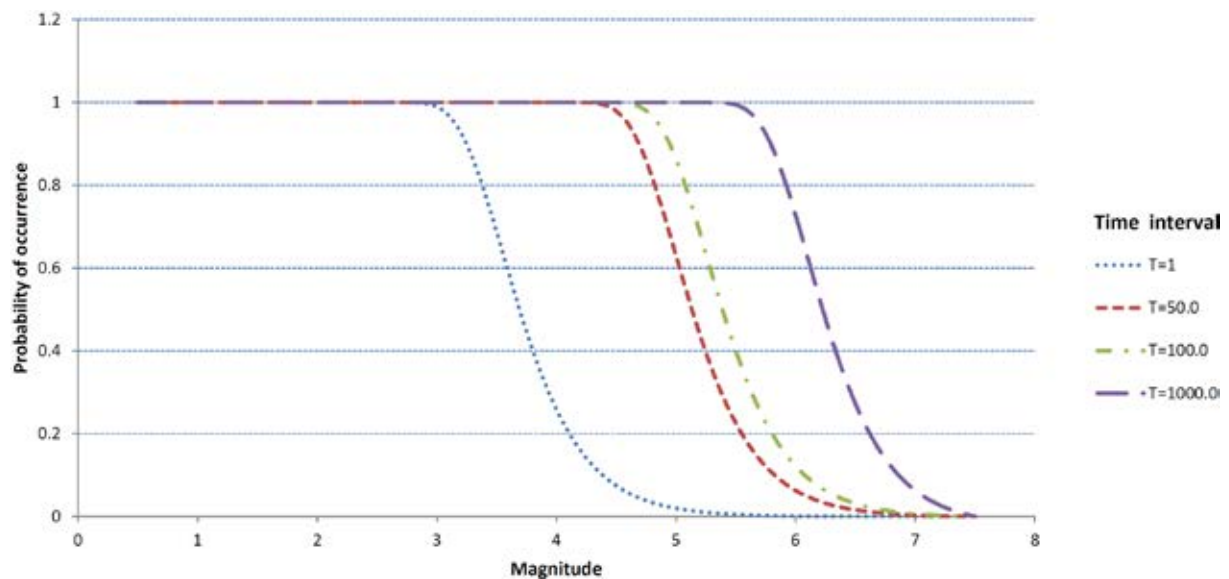


Figure 7. Probabilities of occurrence of earthquakes during the time intervals 1, 50, 100 and 1000 years.

6. Conclusions

The Palmyride Fold Belt region is a complex tectonic setting characterized by the crustal shortening giving rise to the seismic activity. The established catalogue for Palmyride Fold Belt, covering the period 1969-2020, reveals that the earthquake activity produces moderate magnitude events and probably passes through a relative status of quiescence in contrast with other adjacent faults segments of DSFS. The seismic catalog used in this study is essentially complete for $M_W = 2.3$ for Palmyride region. The analysis of G-R relationship yields a-value equals to 5.03 and b-value equals to 0.87 using maximum likelihood method. Also, these values could be reasonable for

further interpretations. Since the a-value (seismic activity rate) implies seismically the entire rate of seismicity, the Palmyride region could be interpreted as a moderate seismic activity region. The calculated b-value is useful in shaping seismic hazard models and practical hazard mitigation efforts. Extrapolation of G-R relation reveals very long return periods of large earthquakes. The seismic hazard parameters, maximum possible magnitude M_{max} , earthquake activity rate λ , and the Gutenberg-Richter b-value, have been estimated using the maximum likelihood Kijko's procedure. Moreover, comprehending and precisely determining seismic hazard parameters, hold paramount significance and play a pivotal role in assessing potential hazards and evaluating the consequences of seismic occurrences.

The maximum possible magnitude is crucial for defining the range of potential seismic events that need to be accounted for in seismic hazard assessments. The Kijko's procedure has predicted the maximum possible magnitude to be 6.37. Such large earthquake is probable regarding the last historical earthquake occurred on 13 January 1043 AD. This result needs to be confirmed by additional evidence such as palaeoseismological investigation. Some trenches across the Palmyride Fold Belt faults could provide reliable information about the slip rate for these faults and their past seismic activities. Based on possible palaeoseismological evidence, it is suggested to evaluate the recurrence interval for surface faulting events. This paper provides a geological framework and analysis of seismic activity in the Palmyride Fold Belt in Syria, a crucial topic for understanding the tectonic dynamics of the region.

Data availability statement. No available.

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