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Research article

Earthquake Activities along the Ranong-Klong Marui Fault Zone, Southern Thailand: Implication from the Seismicity Data

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ABSTRACT

In this study, the earthquake activities along the Ranong-Klong Marui Fault Zone (RKFZ) are investigated using the power law of earthquake frequency-magnitude distribution (FMD). The possible maximum magnitudes, recurrence periods, including the probabilities of earthquake occurrences are determined according to the constant a- and b-values obtained from the FMD. The results reveal that the RKFZ has a potential to generate the earthquake with 6.3 and 6.9 M_w in the next 50 and 100 years. Meanwhile, the M_w-7.4 earthquake proposed previously as the maximum credible earthquake has the return period around 230 year. Moreover, for the probabilities of the M_w-7.4 occurrences in the next 10, 25, 50, and 100 years, this study concludes that there are around 4, 10, 20, and 36%, respectively.

Keywords: Frequency-Magnitude Distribution, Earthquake Magnitude, Return Period, Ranong-Klong Marui Fault Zone, Southern Thailand

1. Introduction

The 220-km Ranong-Klong Marui Fault Zone (RKFZ) strikes NE-SW direction along the southern peninsular of Thailand (figure 1). Based on remote sensing interpretation, the RKFZ illustrates obviously the tectonic geomorphology indicating seismogenic faults such as the series of fault scarps, triangular facets, shutter ridges, including offset streams (Kaewmuangmoon *et al*., 2008). In October 8^{th}, 2006, the earthquake with 5.0 M_w posed at the northernmost part indicates that the RKFZ is active presently (EQ1 in figure 1; Thipyupas, 2010). This earthquake event causes the ground shaking with the Modified Mercalli Intensity Scale up to the level of V (Thipyupas, 2009). In addition in March 16^{th}-22^{th}, 2013, totally 26 events of earthquakes with the magnitude range 2.0-3.3 M_L were generated in the southernmost part of the RKFZ (EQ2 in figure 1).

Although these events are small in sense of the magnitude size, the shallow of focal depths beneath the major city, *i.e*., Phuket Island, cause the shaking intensity up to the level III panicking both Thai and foreign peoples. Based on the previous work, there are a large number of paleoseismological investigation complied carefully by Pailoplee (2012). The obtained results reveal only the activities of strong-major earthquake showing the long period of recurrence time. However, the activities of the minor-moderate earthquakes still myths and needed to be clarified. This study, therefore, attempt to investigate the minor-moderate earthquake activities along the RKFZ using the seismicity data.

2. Dataset and Completeness

In this study, the earthquake database is obtained from 3 earthquake catalogues recorded instrumentally within the study area consisting of i) the Thai Meteorological Department (TMD), ii) the National Earthquake Information Center (NEIC), and iii) the Incorporated Research Institutions for Seismology (IRIS). Totally, 183 earthquake events with the magnitude range 2.0-5.0 were reported during the time span 1984 to 2012. The depth is defined 0-33 km implying the shallow crustal earthquake.

2.1 Earthquake magnitude conversion

The obtained data are reported variously in the magnitude scales composed of surface-wave magnitude (M_S), body-wave magnitude (m_b), local magnitude (M_L), and moment magnitude (M_w) respectively. Empirically, it is noted that each magnitude scale is derived from a different analytical method that have a unique meaning. Therefore, the conversion of the different magnitude scales to only one standard, viz. the M_w scale, is inevitably important for the qualitative improvement of the composite earthquake catalogue. The magnitude conversions are performed according to the regression relationship between M_w to m_b and M_S, as proposed by Pailoplee *et al.* (2009). For M_L, the empirical relationship between M_L and m_b of Palasri and Ruangrassamee (2010) are used and then converted m_b to M_w using Pailoplee *et al.* (2009).

2.2 Earthquake declustering

In nature, when any cluster of earthquakes occurs, the earthquake can be classified temporally into three types, *i.e.*, foreshock, main shock, and aftershock. In quantitative analyzing the earthquake occurrence, only the main shock, which represents the exact seismic stress released from the tectonic activities, is herein considered. To satisfy this requirement, the earthquake data obtained from the previous procedures need to be declustered by filtering only the main shocks.

To the end, the assumptions of Gardner and Knopoff (1974) are applied in this study. Using the Gardner and Knopoff (1974) algorithm, 25 clusters are distinguished and a total of 149 events are classified as foreshocks or aftershocks, which eliminated. Finally, the quantitative earthquake catalogue, derived from the RKFZ region contains 34 main shocks (figure 1). This meaningful catalogue which can be related directly to tectonic activities is used here to evaluate the earthquake activities, as described in the next section.

3. Frequency-Magnitude Distribution

In order to evaluate the seismicity of the RKFZ, the frequency-magnitude distribution, (FMD) of the earthquake is applied (Ishimoto and Iida, 1939; Gutenberg and Richter, 1944). This FMD define empirically the number of earthquakes (N_m) with respect to their magnitude (m) as expressed in equation 1.

$$\log_{10}(N_m) = a - bm \quad \text{or} \quad \ln(N_m) = \ln\alpha - \beta m \qquad (1)$$

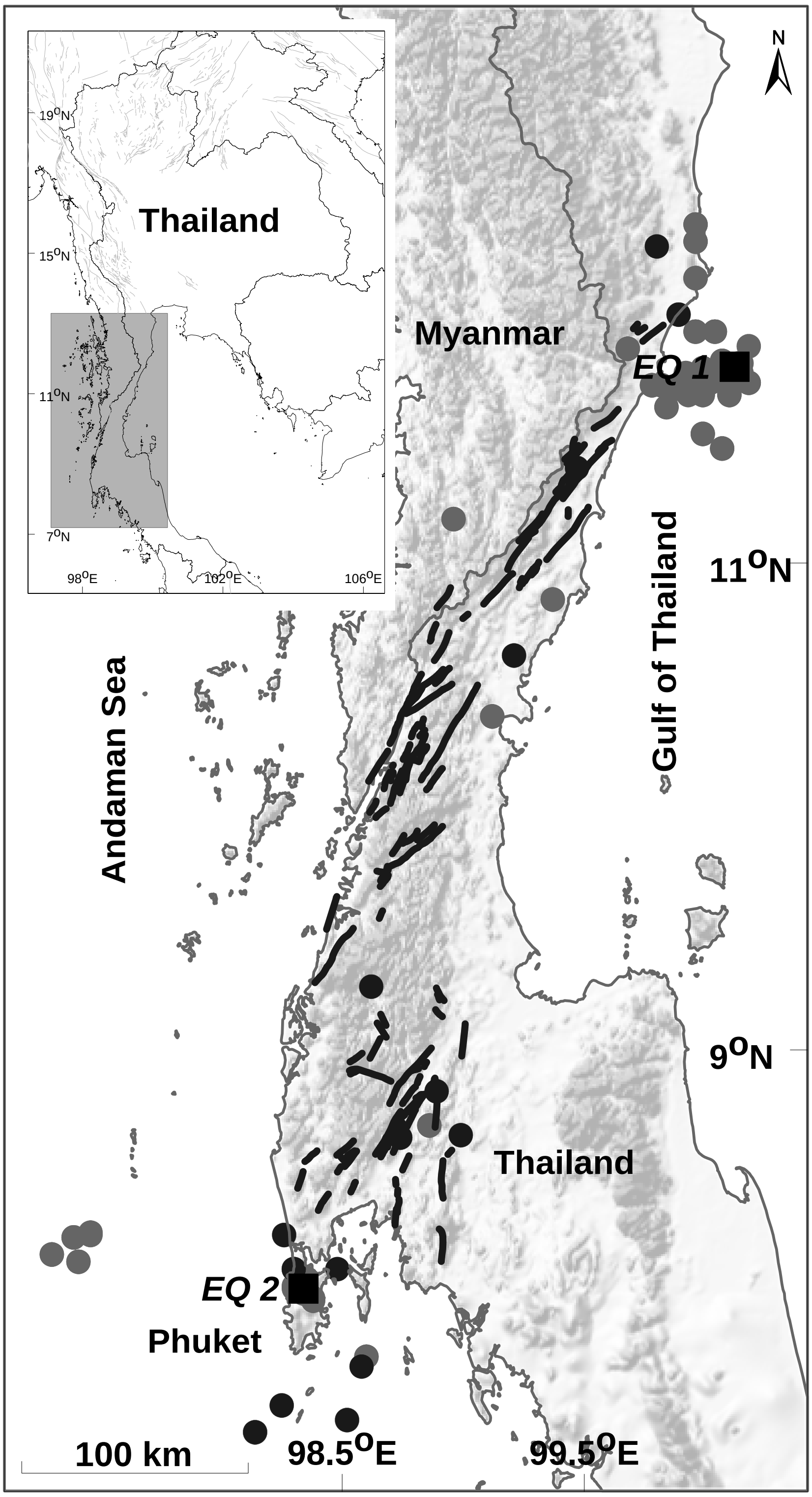

Figure 1. Map of Southern Thailand showing the earthquake epicentral distribution along the RKFZ. Black squares show the location of the significant earthquake whereas the grey and black circles illustrate the earthquake before and after declustering process, respectively.

For any specific region and time interval of interest, the a- and b-values are positive, real constants implying the entire seismicity rate and the ratio of small-to-large size earthquake, respectively. The α and β are related to a- and b-values by: $\alpha = \exp(a\ln(10))$ and $\beta = b\ln(10)$.

Thus, for the RKFZ, the a- and b- values of the FMD are estimated by observing a plot of earthquake number, Nm, with a magnitude ≥ m, as shown in equation 1 (see also figure 2). The optimal values of a = 2.08 and b 0.599±0.1 are calculated to yield the least-square observed from the FMD by using the ZMAP software (Wiemer, 2001). The magnitude of completeness (Mc) = 3.7 defining as the magnitude above which all earthquakes are detected effectively by the existing seismic recording networks (Woessner and Wiemer, 2005).

4. Magnitude and Recurrence Interval

According to Yadav *et al*. (2011), the situation of earthquake hazard in individual site of interest can be presented in terms of possible maximum magnitude and the recurrence interval of any specific earthquake size. Based on the obtained α- and β–value, the most probable earthquake magnitude in t year (u_t) can be presented by equation 2 (Yadav *et al*., 2011).

$$u_t = \frac{\ln(\alpha t)}{\beta} \qquad (2)$$

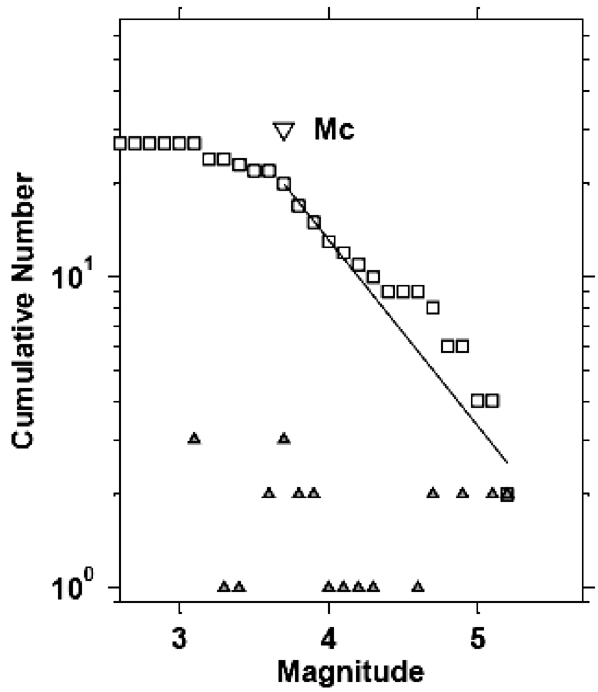

Figure 2. FMD plot of the earthquake data recorded along the RKFZ. Triangles are the number of earthquakes of each magnitude whereas squares mean the cumulative number of earthquakes ≥ individual magnitude of interest. Mc is defined as the magnitude of completeness.

In addition, the mean return period (T_m) of an earthquake with magnitude ≥ m is given by equation 3.

$$T_m = \frac{\exp(\beta m)}{\alpha} \qquad (3)$$

For the RKFZ, the a- and b-values obtained from the FMD plot (figure 2) are converted to α and β, respectively. Thereafter the possible maximum magnitude and the return period of the RKFZ are estimated according to equations 2-3. For the maximum magnitude, the case studies of period ranged between 10-100 years are considered (figure 3a). It reveals that the RKFZ can generate the earthquake with magnitude 6.3 in 50 years meanwhile the magnitude 6.9 is possible in 100 year.

For the return period, Thipyupas *et al.* (2012) suggested that the maximum credible earthquake that can be generated by the RKFZ is about 7.4 Richter according to the empirical relationship between surface rupture length and moment magnitude (M_w) suggested by Wells and Coppersmith (1994). The estimation of return period recognized in this study is limited to the M_w-7.4 earthquake. Figure 3b illustrates the return period of the earthquake with magnitude 7.0 and 7.4 are estimated 130 and 230 years, respectively.

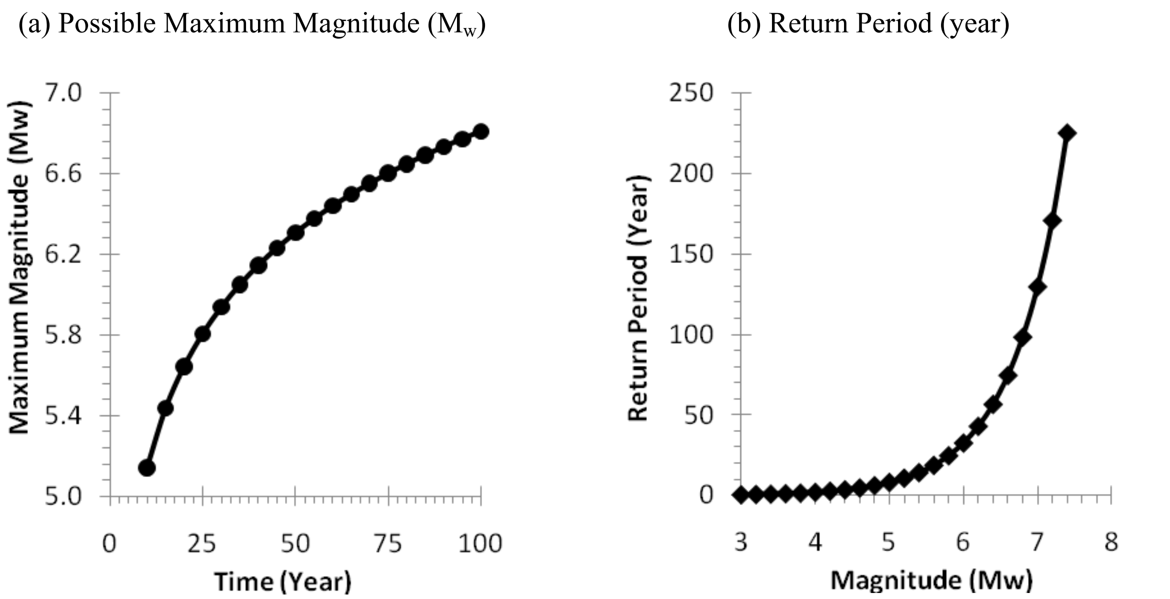

Figure 3. (a) The possible maximum magnitude of individual time of interest. (b) The earthquake return period of individual magnitude level for the RKFZ.

5. Probability of Earthquake Occurrence

The probability of earthquake occurrence, $P_t(m)$ can be evaluated in any specific magnitude, m, in t year of interest as illustrated by equation 4.

$$P_t(m) = 1 - \exp(-\alpha t . \exp(-\beta m)) \quad (4)$$

The probability of exceedance of the earthquake with 3.0-7.0 M_w in 10, 25, 50, and 100 years will be expressed by figure 4. The result indicates that the earthquake with 7.4 M_w as mentioned by Thipyupas *et al.* (2012) has the probabilities 4, 10, 20, and 36% to be generated by the RKFZ in 10, 25, 50, and 100 years, respectively. Meanwhile for the earthquake with magnitude 4.0, there is 100% that the RKFZ may pose the earthquake with 4.0 M_w even in the next 10 years.

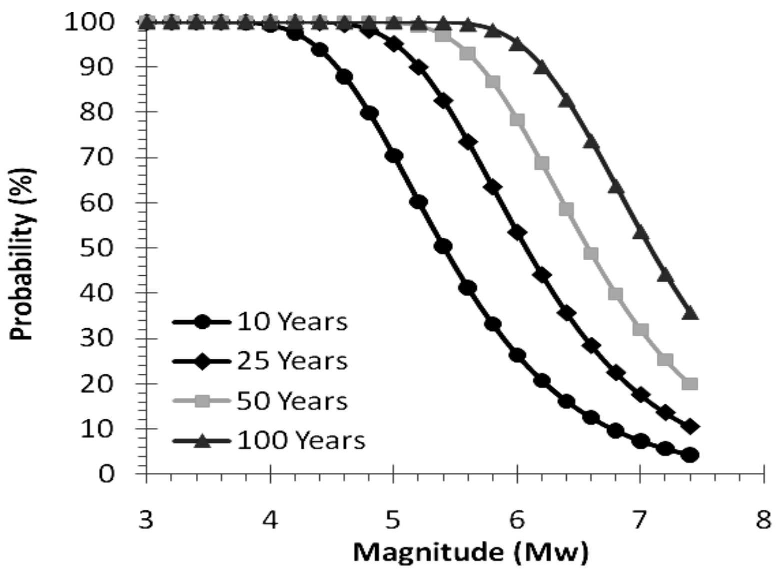

Figure 4. Probability-magnitude curves for the Ranong-Klong Marui Fault Zone.

5. Conclusion and Recommendation

In this study, the earthquake activities along the RKFZ are investigated using the FMD. The earthquake catalogue is screened and adjusted in order to get the earthquake events representing exactly the seismotectonic activities along the RKFZ. Thereafter, the coefficients of the FMD (*i.e.*, a- and b-values including Mc) are evaluated. Finally, three terms of the earthquake activities are presented consist of i) the possible largest earthquake magnitude capable to generate by the RKFZ in a given time period, ii) the expected recurrence interval of individual earthquake magnitude, and iii) the probability of earthquake occurrence in a specified time of interest.

The result reveal that the RKFZ can generate the earthquake with magnitude 6.3 in 50 years meanwhile the magnitude 6.9 is possible in 100 year. In addition for the M_w-7.4 earthquake, the probabilities of earthquake occurrence in 10, 25, 50, and 100 years are around 4, 10, 20, and 36%, respectively. The maximum credible earthquake, i.e., 7.4 M_w, might be posed at the RKFZ with the 230-year return period. However, the 230-year recurrence time of the M_w-7.4 earthquake proposed in this seismicity study is quite shorter than the 2,000 year obtained from the paleoseismological investigation (Thipyupas, 2012). Two possibilities are assumed as follows.

1. Insufficient of the instrumental earthquake records, in particular for the small earthquake magnitude. The 3.5 Richter of Mc implies capability and density of the seismic recording network. The more seismic recording network, the lower magnitude earthquake can be detected. In addition, the lower detected magnitude, the higher accuracy of fitting the FMD.

2. Empirically, the FMD of the earthquake may not match with the basic linear regression as so call "characteristic earthquake" (Youngs and Coppersmith, 1985). Thus, in order to further refine the FMD of the RKFZ, more detailed paleoseismological data are indispensable.

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