

Gutenberg-Richter Recurrence Law to Seismicity Analysis of Southern Segment of the Sagaing Fault and Its Associate Components

Yin Myo Min Htwe, Shen WenBin

Abstract—The purpose of the present study is the calculation of Gutenberg-Richter parameters (a, b) and analyze the mean annual rate of exceedance of earthquake magnitude (λm) of southern segment of the Sagaing fault and its associate components. The study area is situated about 200 km radius centered at Yangon. Earthquake data file is using from 1975 to 2006 August 31. The bounded Gutenberg-Richter recurrence law for M_0 is 4.0 and M_{max} is 7.5.

Keywords—Gutenberg-Richter recurrence law, mean annual rate of exceedance, Sagaing fault.

I. INTRODUCTION

SCIENTISTS have been trying to understand earthquake process for centuries^[2]. Many different ways are explored to study earthquakes. Earthquake frequency-magnitude relation is a way to examine seismic activity in an area^[3]. The annual number of earthquakes of various sizes that are assigned to each fault is based on the slip rate information and is defined using a combination of two statistical distributions: (1) the characteristic earthquake model that implies that a typical size of earthquake ruptures repeatedly along a particular segment of the fault^[9], and (2) the exponential model that implies that earthquakes on a given fault follow the Gutenberg-Richter relationship: $n(m) = 10^{a-bm}$ where n is the incremental number of earthquakes, a is the incremental number of earthquakes of $m > 0$, b is the slope of the distribution, and m is moment magnitude^[8]. A combination of the two distributions is also thought to characterize the behavior of many fault systems^[7]. This composite model allows for more large earthquakes than predicted by the exponential distribution, and also for earthquakes of sizes different than the characteristic event.

Myanmar is situated on the boundary of Alpide-Himalayan earthquake Belt where devastating earthquakes had occurred from time to time and there is obviously the seismic risk in and near the country^[10,11]. The Sagaing Fault^[14], which is

located about 40 km east of the Shwedagon Pagoda, is a regional right lateral strike slip fault trending in north-south direction.

Each seismic source is characterized by an earthquake recurrence relationship, a maximum magnitude, and the variability in these parameters. For recurrence, the relationship expresses the expected number of earthquakes per year of magnitudes greater than some minimum magnitude. This distribution is developed from observed seismicity and geologic data. Since the level of seismicity in the region is low and historical record is 31 years (in Fig: 1), geologic data such as paleoseismic recurrence intervals and slip rates are expected to provide the primary basis for recurrence characterization of the fault sources. For volumetric source zones, the historical and instrumental seismicity records from the primary data for characterization of recurrence.

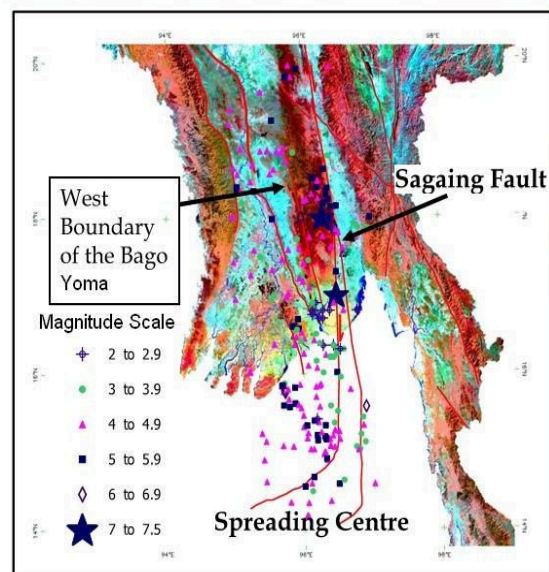


Fig. 1 Distribution of earthquake events (1975-2006 August 31) (From <http://www.usgs.gov.eq/>)

In this paper, I will calculate the a and b (Gutenberg-Richter parameters) and analyze the mean annual rate of exceedance of earthquake magnitude (λm) is carried out by applying both standard Gutenberg-Richter recurrence law and Bounded Gutenberg-Richter law.

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II. RATE OF EARTHQUAKE RECURRENCE

The frequency-magnitude occurrence relationship helps to characterize the activity of each source. The occurrence rate of events in a given region, the random magnitude and spatial distribution of epicenter given the occurrence in time can be used to model the temporal and spatial randomness of future events. The rate of recurrence of earthquakes on a seismic source is assumed to follow the Gutenberg-Richter relation^[4].

$$\log_{10} \lambda m = a - bM \tag{1}$$

$$a = \log_{10} \left(\frac{1}{B} AN_0 \right) \tag{2}$$

$$b = 2.3B \tag{3}$$

where λm is the number of events per year having magnitudes greater than M , a and b are Gutenberg-Richter parameters, N_0 is the annual number of shocks per unit area, A is area and B is the seismic severity (distribution parameter).

III. AREA SOURCE DETERMINATIONS

Area sources are generally employed due to the lack of recognizable earthquake faults and seismically active geologic structure. Empirical correlation equations between fault rupture parameters and earthquake size, therefore, have limited application to these source types^[1]. Maximum magnitudes for these sources are typically assessed from an extrapolation of the historical seismicity of the region, from the regional tectonic setting, from regional paleoseismologic data and interpretations (if available), or simply from the judgments of experts.

Such techniques assume that the addition of magnitude increments to historical maximum observations accounts, to some extent, for the relative shortness of the historical reporting period. For a b -value of 1.0 in the Gutenberg-Richter recurrence relationship, the addition of 1.0 magnitude unit to the historical maximum observation is equivalent to multiplying the length of the observation period by a factor 10^[1]. Justification is then required for expecting the maximum magnitude event within this period of time. A primary issue with this technique is the correct characterization of the form of recurrence-frequency relationship. Minor changes in the Gutenberg-Richter b -value imply greatly differing time periods of catalog compensation, and other forms of recurrence-frequency relationships may also be appropriate^[12,13].

In this paper, the present study area is situated about 200 km radius centered at Yangon (in Fig: 2) and in table-1. Partition of seismic sources is based on area of evenly distributed earthquake occurrences in connection with surface traces of geological structural framework.

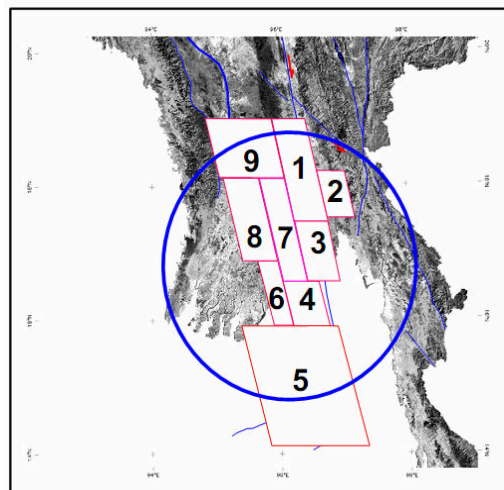


Fig. 2 Area of interest

TABLE I
THE SELECTED AREAS

| Source Zone | Area (km ²) | N ₀ | B |
|-------------|-------------------------|----------------|-------|
| 1 | 9570 | 0.00156 | 1 |
| 2 | 3564 | 0.00254 | 1 |
| 3 | 5580 | 0.00221 | 1 |
| 4 | 4620 | 0.00203 | 0.917 |
| 5 | 33177.6 | 0.00035 | 0.875 |
| 6 | 3663 | 0.00317 | 0.75 |
| 7 | 7216 | 0.0013 | 0.917 |
| 8 | 8178 | 0.00136 | 1 |
| 9 | 7050 | 0.00165 | 1.421 |

IV. APPLICATION OF GUTENBERG-RICHTER LAW TO SEISMICITY OF THE SOUTHERN SEGMENT OF THE SAGAING FAULT

The nine sources of the Gutenberg-Richter parameters are look in table-2;

TABLE II
THE OUTPUT OF GUTENBERG-RICHTER PARAMETERS

| Source Zone | a | b |
|-------------|---------|---------|
| 1 | 0.75967 | 0.35759 |
| 2 | 0.54407 | 0.43422 |
| 3 | 0.6721 | 0.43422 |
| 4 | 0.59827 | 0.47369 |
| 5 | 0.71078 | 0.44345 |
| 6 | 0.77608 | 0.3799 |
| 7 | 0.59671 | 0.47369 |
| 8 | 0.63144 | 0.43422 |
| 9 | 0.49976 | 0.43422 |

Thus,

- Source Zone-1; $\log \lambda m = 0.75967-0.35759 M$
- Source Zone-2; $\log \lambda m = 0.54407-0.43422 M$
- Source Zone-3; $\log \lambda m = 0.6721-0.43422 M$
- Source Zone-4; $\log \lambda m = 0.59827-0.47369 M$
- Source Zone-5; $\log \lambda m = 0.71078-0.44345 M$
- Source Zone-6; $\log \lambda m = 0.77608-0.3799 M$
- Source Zone-7; $\log \lambda m = 0.59671-0.47369 M$
- Source Zone-8; $\log \lambda m = 0.63144-0.43422 M$
- Source Zone-9; $\log \lambda m = 0.49976-0.43422 M$

And then the application of Gutenberg-Richter law to seismicity of southern segment of the Sagaing fault becomes the following (in Fig.3);

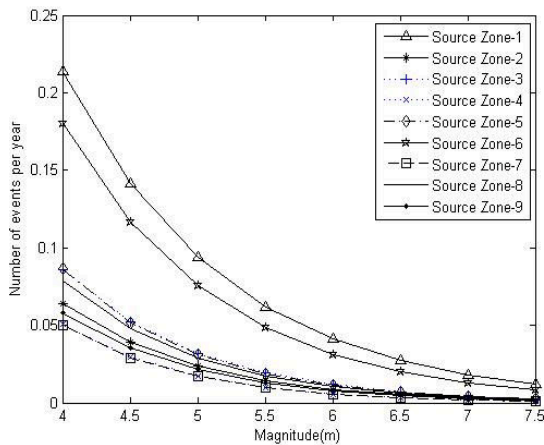


Fig. 3 Standard Gutenberg-Richter Recurrence Law

When I consider the return period (T year), the effect of earthquake magnitude becomes the following (in Fig.4);

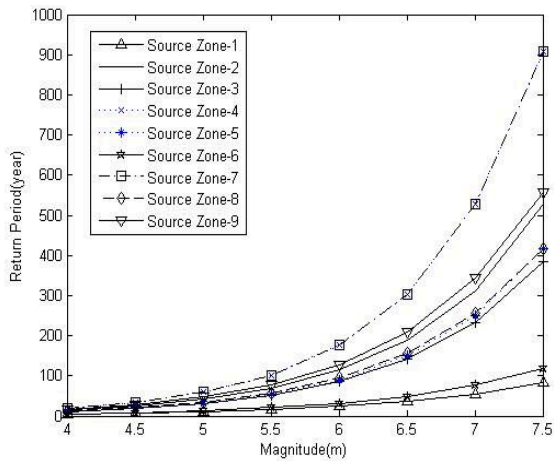


Fig. 4 Effect of Earthquake Magnitude on Return Period (T year)

V. BOUNDED GUTENBERG-RICHTER RECURRENCE LAW

The Gutenberg-Richter recurrence law often is bounded to capture the maximum event believed possible at a site or the minimum event of engineering significance. In this law, the

distribution of magnitudes has a maximum (m_{max}), which is determined from historical or geological evidence. For engineering purposes, a lower threshold magnitude (m_0) is also implemented, which is defined as the magnitude of earthquake below which significant damage is unlikely to occur^[5,6]. By considering both lower threshold magnitude and the maximum magnitude, the mean annual rate of exceedance of an earthquake of magnitude is:

$$\lambda m = v \frac{\exp[-\beta(m - m_0)] - \exp[-\beta(m_{max} - m_0)]}{1 - \exp[-\beta(m_{max} - m_0)]} \quad (4)$$

where $v = \exp(\alpha - \beta m_0)$, $m_0 \leq m \leq m_{max}$,

$$\alpha = 2.303a \text{ and } \beta = 2.303b .$$

TABLE III
THE MEAN ANNUAL RATE OF EXCEEDANCE FOR NINE SOURCE ZONES

| Source Zone | λm (m=4) | λm (m=4.5) | λm (m=5) | λm (m=5.5) | λm (m=6) | λm (m=6.5) | λm (m=7) | λm (m=7.5) |
|-------------|-------------------|---------------------|-------------------|---------------------|-------------------|---------------------|-------------------|---------------------|
| 1 | 0.2134 | 0.1371 | 0.0866 | 0.0531 | 0.0309 | 0.0162 | 0.0064 | 0 |
| 2 | 0.0641 | 0.0381 | 0.0223 | 0.0128 | 0.0069 | 0.0034 | 0.0013 | 0 |
| 3 | 0.0861 | 0.0512 | 0.03 | 0.0171 | 0.0093 | 0.0046 | 0.0017 | 0 |
| 4 | 0.0505 | 0.0288 | 0.0162 | 0.0089 | 0.0047 | 0.0022 | 0.0008 | 0 |
| 5 | 0.0865 | 0.0509 | 0.0296 | 0.0167 | 0.009 | 0.0044 | 0.0017 | 0 |
| 6 | 0.1804 | 0.1133 | 0.07 | 0.0421 | 0.024 | 0.0124 | 0.0049 | 0 |
| 7 | 0.0503 | 0.0287 | 0.0161 | 0.0089 | 0.0047 | 0.0022 | 0.0008 | 0 |
| 8 | 0.0784 | 0.0466 | 0.0273 | 0.0156 | 0.0085 | 0.0042 | 0.0016 | 0 |
| 9 | 0.0579 | 0.0344 | 0.0202 | 0.0115 | 0.0063 | 0.0031 | 0.0012 | 0 |

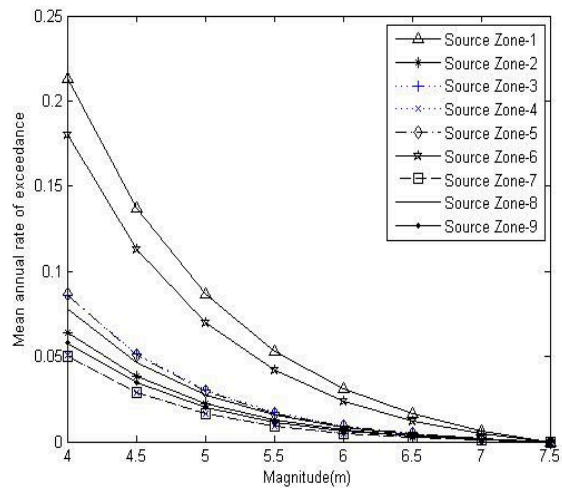


Fig. 5 Bounded Gutenberg-Richter Recurrence Law for $M_0 = 4.0$ and $M_{max} = 7.5$

VI. RESULTS AND CONCLUSIONS

When I comparing the processes of the application of Gutenberg-Richter law to seismicity of the southern segment of the Sagaing fault and bounded Gutenberg-Richter recurrence law, I have found the standard law covers an

infinite range of magnitude and in bounded Gutenberg-Richter law, increasing the maximum magnitude requires a substantial decrease in the mean annual rate of exceedance of lower magnitude events. Bounded Gutenberg-Richter law gives smaller mean annual rate of exceedance and longer time span for large event. These events are rare in the region in compare with the results from the standard law and on the record list.

Prediction of earthquake return period and the mean annual rate of exceedance (λm) is reasonably obtained by standard Gutenberg-Richter recurrence law. The Gutenberg-Richter parameters (a, b) are resulted from the standard law. This study provides us a great opportunity to study for probabilistic seismic hazard analysis (PSHA).

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