List of Publications

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A.1. Articles published in peer-reviewed journals (included in thesis)

[1] Sarma, V., Bora, D. K. and Biswas, R. Spatio-temporal analysis of b-value prior to 28 April 2021 Assam Earthquake and implications thereof. *Annals of Geophysics,* 65(5): p. SE534, 2022.

[2] Sharma, V. and Biswas, R. Probabilistic earthquake hazard parameterization for Indo-Burma region using extreme value approach. *Natural Hazards Research,* 2(4):279-286, 2022.

[3] Sharma, V. and Biswas, R. Spatio-temporal variation in b-value prior to the 26 November 2021 Mizoram Earthquake of northeast India. *Geological Journal,* 57(12): 5361–5373, 2022.

[4] Sharma, V. and Biswas, R. Seismic hazard assessment and source zone delineation in Northeast India: a case study of the Kopili fault region and its vicinity. *Indian Geotechnical Journal,* 54: 598–626, 2024.

[5] Sharma, V. and Biswas, R. Statistical analysis of seismic b-value using non-parametric Kolmogorov-Smirnov test and probabilistic seismic hazard parametrization for Nepal and its surrounding regions. *Natural Hazards,* 120: 7499–7526, 2024.

[6] Sharma, V. and Biswas, R. Revisiting b-value for extended Kopili region of Northeast India and probabilistic estimation of seismic hazard attributes thereof. *Journal of Applied Geophysics,* 207: 104842, 2022.

[7] Sharma, V., Bora, D.K., Hazarika, D. *et al.* Characterization of seismic b-value around Kopili fault and its neighboring region prior to 28th April 2021 earthquake. *Journal of Seismology,* 28: 1001–1025, 2024.

[8] Sharma, V. and Biswas, R. b-value as a Seismic Precursor: The 2021 Mizoram Earthquake Mw 6.1 in the Indo-Burma Subduction Zone. *Pure and Applied Geophysics,* 2024.

[9] Sharma, V. and Biswas, R. Unravelling b-value anomalies prior to the 6th February 2023 Gaziantep, Türkiye Earthquake (MW 7.8): Implications for Seismic Precursors and Regional Seismicity Patterns. (*Communicated*)

[10] Sharma, V. and Biswas, R. Seismic Quiescence and b-Value Anomalies Preceding the 6th February 2023 Earthquake Doublet (MW 7.8, MW 7.6) in Kahramanmaraş, Türkiye: A Comprehensive Analysis of Seismic Parameters along the East Anatolian Fault Zone. (*Accepted, Acta Geophysica*)

A.2. List of conferences

[1] Vickey Sharma, and Rajib Biswas, “Evidence of b-value anomalies prior to MW 6.4 Assam earthquake in the context of its source and neighboring region,” National Conference on Emerging Trends in Physics (NCETP-2021), Tezpur University, Assam, India, 2021.

ANNALS OF GEOPHYSICS, 65, 5, SE534, 2022; doi: 10.4401/ag-8802
OPEN ACCESS

Spatio-temporal analysis of *b*-value prior to 28 April 2021 Assam Earthquake and implications thereof

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Article history: received February 11, 2022; accepted June 14, 2022

Abstract

Here, we report a Spatio-temporal analysis of the frequency magnitude distribution of earthquakes (*b*-value) before the 28th April 2021 (Mw 6.4) earthquake event observed in northeast India. To estimate the average *b*-value for the study region, a data set of 750 earthquake events with magnitude Mw ≥ 3.9 is extracted from the homogenous part of the earthquake catalog (1950-2021) documented by the United States Geological Survey (USGS) and International seismological center (ISC) in the region. For spatial analysis of the disparities in *b*-value, the whole study region is subdivided into 16 square grids of dimension 1°×1° and the *b*-value is calculated for each subsection. In congruence with other studies, this work yields *b*-values ranging from 0.66 to 1.25. After the calculation of the *b*-value for each grid, it is observed that the grid with the epicentral location of the 28th April 2021 (6.4) earthquake has a low *b*-value. Accordingly, the spatial correlation and aberrant pattern between *b*-value and focal depth have been comprehensively explored. It is observed that the *b*-value significantly dips within a depth range of ~15-35 km which implicates high-stress accumulation and crustal homogeneity. The depth-wise variation in *b*-value infers the antithetical relationship between *b*-value and crustal stress. Mostly interplate earthquakes are observed in the study region; thereby hinting at intense seismicity at the upper crust.

Keywords: *b*-value; Seismicity; Fault mechanisms; Stress; Seismotectonics

1. Introduction

Earthquakes are very frequent in Northeast (NE) India. During the past 100 years, this region has experienced 18 large earthquakes. The 12 June 1897 Shillong earthquake (M_w 8.1) [England and Bilham, 2015] and the Assam-Tibet earthquake of 15 August 1950 (M_w 8.4) [Ajanta and Farha, 2019] caused large human causalities along with severe property losses. In NE India, the Mikir hills plateau flanks two major faults namely the Bomdila fault in the east and the Kopili fault to the west. Both these faults are characterized by strike-slip kinematics. A recent study [Sharma et al., 2018] inferred that the Strike-slip fault can produce major earthquakes ($M > 8$). Kopili fault and its neighboring region

Received: 11 January 2022 | Revised: 16 October 2022 | Accepted: 21 October 2022
DOI: 10.1002/gj.4635

SPECIAL ISSUE ARTICLE

WILEY

Spatio-temporal variation in *b*-value prior to the 26 November 2021 Mizoram earthquake of northeast India

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Handling Editor: A. K. Singh

In this study, the variation in frequency magnitude distribution factor (*b*-value) before the main shock has been assessed for the 26 November 2021 Mizoram earthquake (M_w 6.1) in northeast India. The study area covering the Indo-Burma Ranges is divided into square grids of equal dimension and spatial mapping of the *b*-value for each square grid has been carried out. The maximum likelihood method is implemented for the estimation of the *b*-value of each grid. The epicentral location of the 26 November 2021 Mizoram earthquake (M_w 6.1) is found to be in the intermediate *b*-value square grid. The temporal variation in the *b*-value indicates a considerable decline in the *b*-value before the occurrence of the main event. The depth-wise variation in the *b*-value suggests an antithetical relationship between the *b*-value and crustal stress. The spatio-temporal and depth-wise fluctuation in the *b*-value results have been strengthened by employing a non-parametric Kolmogorov–Smirnov (K–S) test. Based on our study, we infer that interplate earthquakes occur mostly in the upper crust of the study region.

KEYWORDS
b-value, earthquake precursor, focal depth, Mizoram earthquake

1 | INTRODUCTION

The northeastern region of India, categorized as zone V of the national seismic zoning Map of India (Bureau of Indian Standards, 2002), is well-known to the geoscience community for its diverse geological units which overall contribute to active tectonics as well as seismicity. It includes the Eastern Himalayas in the north, the Shillong Plateau in the west, the Indo-Burma Region (IBR) to the east, and the Brahmaputra plains extending from west to east. The unremitting subduction of the Indian Plate under the Burmese plates endows this region with high seismic activity; triggering several earthquakes throughout the year. The Indo-Burma subduction region is considered the most potential hot spot for various major earthquakes. Seismic records for the past 100 years implicate that more than 25 strong earthquake events with $M_w \geq 7$ are recorded in this region (Hazarika & Kayal, 2022). The G-R power law (Gutenberg & Richter, 1944) is an important statistical relation that is used for various seismic studies. The frequency-magnitude distribution relationship is given by

$$\log_{10} N(M) = a - bM \tag{1}$$

where *a* and *b* are two constants and *N*(*M*) is the number of earthquake events with a magnitude greater than or equal to M. The constant '*a*' can be named as the seismicity constant that defines the level of seismicity of any region based on its geographical area. The region with a high *a*-value is tagged as more seismically active. The frequency of earthquakes based on their magnitude sizes is defined by the slope obtained from the frequency magnitude distribution plot for any seismogenic zone. The region with a high *b*-value is predominated by a large number of minor earthquakes as compared to major earthquakes. On the contrary, the region with a low *b*-value entails a significant number of major earthquakes. The *b*-value acts as an earthquake size distribution parameter which depicts the proportion of the number of major earthquakes to minor earthquakes for any seismogenic region. The *b*-value also acts as a scaling factor and is used for the demarcation of the seismically active region based on its value. The studies carried out on the global and regional scale inferred that the *b*-value can vary up to 1.5 (Wiemer et al., 1998) for

Indian Geotech J
https://doi.org/10.1007/s40098-023-00792-7

ORIGINAL PAPER

Seismic Hazard Assessment and Source Zone Delineation in Northeast India: A Case Study of the Kopili Fault Region and Its Vicinity

Vickey Sharma[1] · Rajib Biswas[1]

Received: 29 July 2023 / Accepted: 30 September 2023

Abstract The present study aims to delineate potential seismic zones within a 300 km radius centered at Tezpur in the Kopili fault region, recognizing that the region has experienced numerous devastating earthquakes due to its complex tectonic features. The high seismicity rate in the area results from these complex geological conditions. The study area, characterized by its complex tectonic structure and varied seismic movements, has been divided into four distinct seismic zones, namely (1) the Northeast Himalayan seismic zone (NEHSZ), (2) the Shillong–Assam seismic zone (SASZ), (3) the Bengal subsurface seismic zone (BSSZ), and (4) the Indo-Burma seismic thrust zone (IBSTZ). To evaluate the potential seismic risk attributes for each seismic source zone, the study utilized an exhaustive and consistent earthquake catalog specific to each zone. These attributes encompass factors such as the maximum earthquake magnitude (M_{max}), return period, mean annual activity rate, and likelihood of exceeding. The study determined the *b*-values for all identified seismic zones using the maximum likelihood technique. The calculated *b*-values are as follows: 0.83 ± 0.04 for NEHSZ, 0.91 ± 0.04 for SASZ, 0.81 ± 0.07 for BSSZ, and 0.94 ± 0.03 for IBSTZ. The highest rate of earthquake occurrence is observed in the IBSTZ. Similarly, the study estimated the maximum credible earthquake (M_{max}) for each zone and found that the SASZ has the largest M_{max}, with a magnitude of M_W 8.6 (± 0.52). This finding is supported by historical data from the 1897 Shillong earthquake, which had a magnitude of M_W 8.1, serving as evidence of the region's seismic potential. To estimate the most likely annual largest earthquake (*H*), the study employed the Gumbel extreme value method (EVT), resulting in values of 5.3, 5.4, 4.7, and 5.5 for NEHSZ, SASZ, BSSZ, and IBSTZ, respectively. The study also estimated the probability of earthquake occurrences within the magnitude range M_W 4.0–8.5 in the next 100 years for the four seismic zones. The implications drawn from this study provide valuable insights into earthquake risks and their potential impacts, facilitating effective mitigation efforts, as well as prudent preparedness and response measures. These outcomes are envisioned to contribute to the overarching goal of reducing loss of life and property associated with seismic events while ultimately enhancing the overall resilience of the region.

Keywords Kopili fault · Seismic zonation · Das magnitude scale (M_{Wg}) · Extreme value theory

Introduction

The Northeastern India and the adjacent areas in Southeast Asia constitute a region characterized by intense tectonic activity. This northeastern region holds great significance in the field of geoscience, owing to its diverse geological formations that play a crucial role in tectonic deformation and seismic occurrences. This region is designated as zone V on the national seismic zoning Map of India [1]. The Eastern Himalayas lie to the north, while the Indo-Burma ranges stretch to the east. Bangladesh is situated to the south, and the southeast is occupied by the region encompassing Andaman and Sumatra. Northeast India has been witnessing several earthquakes. Being juxtaposed between two tectonic plates boundary, the occurrence of earthquakes is very frequent in this region. The first involves the Indian subcontinental plate colliding with the Eurasian lithospheric plate to

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Published online: 31 October 2023

Journal of Applied Geophysics 207 (2022) 104842

Contents lists available at ScienceDirect

Journal of Applied Geophysics

journal homepage: www.elsevier.com/locate/jappgeo

Revisiting b-value for extended Kopili region of Northeast India and probabilistic estimation of seismic hazard attributes thereof

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ARTICLE INFO

Keywords:
Kopili fault
B-value
Gumbel's extreme value method
Seismic hazard analysis

ABSTRACT

Kopili fault and its' surroundings of northeast India have remained witness to some devastating earthquakes. The complex tectonic feature of this region incurs a high seismicity rate relative to other regions. Very recently, an earthquake of magnitude 6.4 (M_W) has jolted this region. Considering the persistently rising seismicity pattern of this region, the present study intends to integrate the frequency magnitude distribution of earthquakes with other pertinent seismic hazard parameters. This work presents the estimation of the return period and probability of non-exceedance of medium to large earthquakes for the Kopili fault and its' surroundings via the extreme value method. Two statistical methods, namely the Gutenberg-Richter(G-R) power law and Gumbel extreme value method (GEVM), are applied for the correct estimation of the b-value for the Kopili fault and its' surrounding region. The uniform and homogenous magnitude scale dataset consisting of 550 events observed within a limit of 350 km from the Kopili fault (1964 to 2022) are used in the study. The b-value computed using GR relation was found to be unsatisfactory (0.73) due to an inadequate dataset—thus Gumbel's extreme value method is used for the estimation of the b-value (0.97). Gumbel's extreme value method is used for the calculation of the probability of occurrence of earthquakes, return period, and the most probable earthquake magnitude for the study region. The most probable annual earthquake is found to be ~ M_W 4.99. The return period and probability of occurrence of design-based earthquakes are also calculated. The correlation between b-value, seismic moment, and fractal dimension for seismic hazard analysis is also investigated. The antithetical relationship between seismic moment and b-value is observed for the region while the deep-root character of the Kopili fault and the strong, unfractured character of the Shillong plateau is highlighted with the spatial distribution of fractal dimension in the study region.

1. Introduction

Northeast India, bounded between 89^0 and 98^0 E and 22^0–30^0 N, is considered as an active seismic lab for its diverse tectonic features (Fig. 1). Two major earthquakes, namely the 1897 Shillong earthquake (M_W 8.1) and the 1950 Assam earthquake (M_W 8.7) ripped this region (Bhattacharya et al., 2011). The north front collision of the Indian plate with Tibet and eastward collision with the Burmese landmass make this region unstable and ultimately makes it a highly potential seismic zone. According to the Bureau of Indian Standards (BIS., 2002), northeast India is categorized as seismic zone V with a zone factor of 0.36 g. Researchers (Dutta, 1964; Gupta et al., 1986; Yadav et al., 2010) subdivided entire northeast India into four seismogenic source zones—comprising the eastern syntaxis (zone1), Arakan-Yoma subduction belt (zone2), the Shillong plateau (zone3), the main central thrust, and the main boundary thrust of east trending Himalayan thrust (zone4) for the description of independent seismogenic source zone in northeast India for better seismic hazard assessment. The demarcation of these seismogenic source zones has been done by considering the seismicity level, the focal mechanism solutions of the earthquakes observed, and the tectonic setup of the examined region. The Shillong plateau zone is one of the most seismically active zones in northeast India. The east-west 450 km running Dauki fault, forming the southern boundary of the Shillong plateau, is considered the source zone of the 1897 Shillong earthquake (M_W8.7) (Das et al., 2016). Likewise, the 300 km long NW-SE trending Kopili fault is one of the most seismically active faults in northeast India which forms a virtual boundary between the Shillong plateau and the Mikir hills. The Kopili fault and its neighboring regions have witnessed two major earthquakes in the past 1941(M_W 6.5) and 1943 (M_W 7.2) (Baruah et al., 1997). Recently an earthquake of

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https://doi.org/10.1016/j.jappgeo.2022.104842
Received 13 March 2022; Received in revised form 12 July 2022; Accepted 7 October 2022
Available online 13 October 2022

J Seismol
https://doi.org/10.1007/s10950-024-10232-5

RESEARCH

Characterization of seismic b-value around kopili fault and its neighboring region prior to 28th April 2021 earthquake

Vickey Sharma · Dipok Kumar Bora · Devajit Hazarika · Rajib Biswas

Received: 30 January 2023 / Accepted: 10 July 2024

Abstract In the present study, the spatio-temporal variation of the seismic b-value in the vicinity of the Kopili fault and its surrounding area has been analysed using the unified and homogenous earthquake catalog of historical and instrumental (1950–2021) earthquake events. The study region is subdivided into 16 equisized square grids of $1° \times 1°$ dimension, and the b-value is computed for each grid using the maximum likelihood method. The spatial distribution of the b-value varies from 0.58 to 1.14. The Kolmogorov–Smirnov (K-S) test has been conducted to check the significance of the spatial-temporal and depth-wise distributions of the b-value. The epicentral location of April 28th, 2021, lies in the low-b-value square grid. Likewise, the temporal b-value curve shows a decreasing trend before the occurrence of the April 28th, 2021 earthquake. The mean return period of the April 28th, 2021earthquake and the most probable maximum annual magnitude earthquake are also computed for this region. Meanwhile, the spatial associations and anomalous patterns between the b-value and factors like seismic moment or energy release and focal depth are assessed, as they contribute to a more comprehensive understanding of the seismicity in this area. The antithetical relationship between the b-value and seismic moment or energy release is established. While variation in b-value with depth provides new insights, low b-values are linked to the top of the crust, which could mean that the crust is uniform and that a lot of stress is building up.

Keywords b-value · Focal depth · Seismic moment or energy · Return period · K-S test

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1 Introduction

The northeast (NE) region of India (Fig. 1) is a well-known natural research laboratory for seismic studies due to its varied geological system, which includes the world's highest Eastern Himalayan Mountain range in the north, the outlier Indian peninsular Shillong plateau in the south, the Indo-Burma Range in the east, and the great Brahmaputra plains of Assam and its neighbouring regions (Nandy and Dasgupta 1991). The prominent faults that make this region seismically active are shown in Fig. 1, which include the Dauki fault, Dapsi thrust (DT), Kopili fault (KF),

Natural Hazards
https://doi.org/10.1007/s11069-024-06531-2

ORIGINAL PAPER

Statistical analysis of seismic b-value using non-parametric Kolmogorov–Smirnov test and probabilistic seismic hazard parametrization for Nepal and its surrounding regions

Vickey Sharma[1] · Rajib Biswas[1]

Received: 3 February 2023 / Accepted: 27 February 2024

Abstract

This study aims to characterize the frequency magnitude distribution factor (b-value) for Nepal and its surrounding area-thereby focusing on conducting spatiotemporal and depth-wise analysis of b-value fluctuations before the November 9, 2022 earthquake of magnitude M_W 6.3. Using the non-parametric Kolmogorov–Smirnov (K–S) test, earthquake events with a magnitude $M_W \geq 3.5$ reported between 1900 and 2022 from the earthquake catalog compiled by the International Seismological Centre (ISC) and the United States Geological Survey (USGS) were analysed. We determined the minimum magnitude of completeness (M_C) using the Maximum Curvature Method (MAXC). Furthermore, we divided the study region into equal-sized square grids and computed b-values using the maximum likelihood technique for each grid. We analysed the relationship between the b-value and seismic parameters such as focal depth, seismic moment release, and radon gas anomalies, along with their spatial correlations and patterns. Results indicate minimal seismicity in the lower crust compared to the upper crust and lead to establish an inverse relationship between the b-value and seismic moment release. We established plausible correlations between temporal variations of the b-value and variations in radon gas concentration as an earthquake precursor in different medium. Additionally, we utilized the Gumbel extreme value theory to estimate the mean return period, the most likely maximum yearly earthquake, and probabilities of recurrence of different magnitudes across different periods for credible seismic hazard analysis. We found the most likely maximum yearly earthquake for the region to be 5.53, with a mean return period of 5 years for the November 9, 2022 earthquake. The mean return period of earthquakes with magnitudes ranging from 5.0 to 6.5 (M_W) was estimated to be 5–10 years. These findings contribute to a better understanding of the intricate seismotectonic configuration of the region and serve as earthquake precursors for potential future destructive earthquakes.

Keywords Seismic b-value · Focal depth · Seismic moment · K–S test · Probabilistic seismic hazard attributes

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Published online: 13 March 2024

Natural Hazards Research 2 (2022) 279–286

Contents lists available at ScienceDirect

Natural Hazards Research

journal homepage: www.keaipublishing.com/en/journals/natural-hazards-research

Probabilistic earthquake hazard parameterization for Indo-Burma region using extreme value approach

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A R T I C L E I N F O

Keywords:
Seismic hazard parameterization
Gumbel extreme value
Indo-Burma region
b-value

A B S T R A C T

The Indo-Burma area is one of the most seismically active regions because of subduction of the Indian plate under the Burmese plate. The Indo-Burma area, which is bordered by 22°–27°N and 92°–97°E, has of late witnessed multiple moderate-to-large earthquakes. Seismic hazard assessment has been performed using the well-known extreme value theory, including estimate of return periods and likelihood of occurrence of medium to large earthquake events. The Indo-Burma region's seismic hazard parameterization has been computed using a homogeneous and thorough earthquake database created for the time span between 1973 and 2021. Due to an insufficient dataset, the b-value calculated using the GR relation was determined to be unsatisfactory (0.58). Therefore, the b-value was estimated using Gumbel's extreme value approach (0.902). The findings show that earthquake of 5.352 magnitude is likely to be the greatest annual earthquake in the study area. Additionally, the most likely large earthquakes that might happen throughout a wide range of periods have been projected and displayed.

1. Introduction

The geoscience community is well-aware of the north-eastern part of India, which is designated as zone V, for its varied geological units that collectively contribute to active tectonics and seismicity. It encompasses the vast Brahmaputra plains, the east-lying IBR, the eastern Himalayas in the north, and the Shillong plateau in the south. This region experiences considerable seismic activity due to the continuous sinking of the Indian plate beneath the Burmese plate, which causes several earthquakes to occur annually. It is thought that the Indo-Burma subduction zone has potential for large earthquakes. More than 25 big earthquake occurrences with a magnitude of $M_W \geq 7$ are believed to have been recorded in this region during the last 100 years (Hazarika and Kayal, 2022; Sharma et al., 2022, Vickey Sharma and Biswas, 2022; V. Sharma and Biswas, 2022). The earthquake occurrence is extremely intricate and uncommon. It is impossible to predict when or where a potentially damaging rupture will occur in a region. A seismic hazard appraisal and suitable remedial measures are one way to reduce the detrimental effects of an earthquake. Both deterministic and probabilistic models can be used to model the seismic hazard of any place, but the probabilistic approach is more widely used by researchers since it takes into consideration the likelihood of all potential sources and any associated uncertainties (Kijko 2011; Biswas, 2021; Pavlenko and Kijko, 2019). In addition to these methodologies, several statistical techniques have been proposed and put into practice whose characteristics and parameters have been used to determine the likelihood of occurrence, seismic hazard, and risk due to an earthquake in a specific period for any region of the world (Kijko and Sellevoll, 1989, 1992; Pisarenko et al., 1996; Tsapanos et al., 2002; Tsapanos, 2003; Tsapanos and Christova, 2003; Lyubushin et al., 2002; Lyubushin and Parvez, 2010; Yadav et al., 2010a, b, 2011, 2012a, b; Kijko, 2011; Chingtham et al., 2016). The evaluation of seismic hazard parameters, such as return periods and earthquake likelihood, is frequently done using the extreme value theory method. It was first introduced by Gumbel (1935) for the analysis of floods and has since been used by other researchers around the globe to estimate seismic threats. Gumbel's extreme value theory has a major advantage in that it simply needs a series of earthquakes with the highest magnitudes that occurred at various predetermined time intervals rather than the entire records of earthquake occurrences. The frequency-magnitude correlation is critical for understanding the distribution of seismic occurrences throughout time. The regression parameter known as the b-value provides insight into the seismicity pattern of the area and the stress transferred in the region while considering the physical features of the medium. Gutenberg and Richter presented the well-known statistical

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https://doi.org/10.1016/j.nhres.2022.11.001
Received 12 September 2022; Received in revised form 23 October 2022; Accepted 6 November 2022
Available online 11 November 2022

Pure Appl. Geophys.

https://doi.org/10.1007/s00024-024-03530-z

Pure and Applied Geophysics

b-value as a Seismic Precursor: The 2021 Mizoram Earthquake Mw 6.1 in the Indo-Burma Subduction Zone

Vickey Sharma[1] and Rajib Biswas[1]

Abstract—This study explores the feasibility of using fluctuations in the recurrence magnitude dispersion factor (b-value) as a seismic precursor for the Mizoram earthquake that occurred on November 26, 2021, in the Indo-Burma region of northeast India. Employing a comprehensive and homogeneous earthquake catalog spanning from 1900 to 2020, the seismic analysis involved delustering and completeness testing. The research implements a subsectional b-value calculation method, dividing the study area into uniformly sized grid cells ($2° \times 2°$) and performing temporal b-value mapping for each grid. The epicenter of the Mizoram earthquake was located within a grid cell characterized by an intermediate b-value. Time-series analysis of the b-value indicated a notable decline preceding the main event, suggesting its potential as a seismic precursor. The study also examines depth-dependent variations in the b-value, revealing an inverse relationship between the b-value and crustal stress. To evaluate the significance of b-value anomalies, the Kolmogorov–Smirnov (K-S) statistic was employed instead of visual inspection. Additionally, the research provides probabilistic estimates of seismic hazard parameters, including the most probable maximum yearly earthquake, mean return period, and probabilities of earthquakes of varying magnitudes. These findings contribute to a deeper understanding of the complex seismotectonic framework and high lithospheric variability in the investigated region.

Keywords: Seismic precursor, b-value, Mizoram earthquake, seismic analysis, seismotectonic configuration.

1. Introduction

The northeastern region of India, referred to as NER, is recognized as one of the most seismically active and geologically challenging areas globally (refer to Fig. 1). This region falls under zone V on India's seismic zoning map, indicating the highest potential for seismic activity across the country (Bureau of Indian Standard 2002). It is characterized by the convergence of the India, Eurasia, and Sunda tectonic plates. Within northeastern India, the Eastern Himalayas lie to the north, while the Indo-Burma Ranges (IBR) are situated to the southeast. Over a span of 200 years, this region has experienced 20 significant earthquakes with magnitudes of M_W 7 or higher. Various compression patterns have been observed in this intraplate region (Bora et al., 2018). The northeast of India is characterized by diverse geological features. It encompasses the Northern Eastern Himalayas in the north, a region of towering mountain ranges formed by the ongoing collision of the Indian Plate and the Eurasian Plate, resulting in intense tectonic activity and significant seismic hazards. To the west lies the Shillong Plateau, known for its unique topography and active fault systems. In the east, the Indo-Burma region exhibits a north–south convex fold and thrust belt, formed by the subduction of the Indian Plate beneath the Burmese Plate, connecting with the Eastern Himalaya in the north and the Andaman Sumatra subduction zone in the south. The Brahmaputra plains, stretching from west to east, are characterized by fluvial processes, with the Brahmaputra River carving its path through this low-lying terrain (Nandy & Dasgupta, 1991). These diverse geological features contribute to the region's rich geological history and ongoing geological activity. The intersection of the Indo-Burma ranges and the Eastern Himalaya has given rise to the Eastern Himalayan Syntaxis, which is recognized as one of the most geologically complex areas and was the site of the massive Assam earthquake (M_W 8.7) in 1950 (Bora et al., 2021). To assess seismic risks and enhance our understanding of various seismotectonic characteristics within a seismogenic zone, it is crucial to study patterns of seismicity. The Gutenberg-

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Published online: 06 July 2024

Acta Geophysica
https://doi.org/10.1007/s11600-024-01443-y

RESEARCH ARTICLE - SOLID EARTH SCIENCES

Seismic quiescence and *b*-value anomalies preceding the 6th February 2023 earthquake doublet (M_W 7.8, M_W 7.6) in Kahramanmaraş, Türkiye: a comprehensive analysis of seismic parameters along the East Anatolian Fault Zone

Vickey Sharma[1] · Rajib Biswas[1]

Received: 17 January 2024 / Accepted: 27 August 2024

Abstract

This study investigates seismic quiescence (*Z*-value) and *b*-value anomalies preceding the 6th February 2023 earthquake doublet in Kahramanmaraş, Türkiye (M_W 7.8, M_W 7.6), via compiled earthquake catalog from various sources, including Tan (Nat Hazard 21: 2059 2073,2021), KOERI, ISC, and USGS. We converted the catalog to both moment magnitude scale (M_W) and das magnitude scale (M_{Wg}) and conducted a comparative analysis—following which we adhered to the magnitude scale (M_W) for further study. Temporal completeness was assessed using the cumulative visual inspection method (CVI), while magnitude completeness was determined through the maximum curvature method (MAXC). The estimation of the *b*-value was carried out using the maximum likelihood method (MLM). Analyzing the spatial distribution of *b*-value revealed a low *b*-value region ($b < 1$) well before the events. Similarly, the temporal decline in the *b*-value curve was noted before the occurrence of the Türkiye earthquakes (M_W 7.8, M_W 7.6). Furthermore, the spatial distribution of the *z*-value indicated seismic quiescence, with the epicenters of the recent Kahramanmaraş, Türkiye, earthquakes (M_W 7.8, M_W 7.6) located in the positive *z*-value region which considerably aligned with the observed decrease in seismic activity from 2015 to 2023. Utilizing the Gumbel extreme value approach, we estimated seismic parameters, including maximum likelihood magnitudes, average recurrence intervals, and the probability of different magnitude occurrences for four sections of the East Anatolian Fault Zone (EAFZ): Amanos fault section, Pazarcık fault section, Erkenek fault section, and Çardak fault section. The study anticipates that the maximum annual earthquake magnitude for the Amanos fault segment exceeds that of the Pazarcık, Erkenek, and Çardak fault sections. Similarly, it expects the Amanos fault segment to experience major earthquakes ($M_W \geq 6.5$) more frequently compared to the Pazarcık, Erkenek, and Çardak fault sections. Over the next century, the study projects a higher probability of major earthquakes for the Amanos fault segment compared to the Pazarcık, Erkenek, and Çardak fault segments. This study emphasizes the significance of these parameters in seismic hazard analysis, providing essential insights for evaluating seismic hazards in the East Anatolian fault region.

Keywords 2023 Kahramanmaraş earthquakes (M_W 7.8, M_W 7.6) · East Anatolian fault · *b*-value anomalies · Gumbel extreme value approach · Seismic quiescence · Das magnitude scale (M_{Wg})

Introduction

Türkiye is located in a highly active region owing to its intricate tectonic configuration, where four major tectonic plates converge: the Eurasian Plate to the north, the Arabian Plate to the south, the Anatolian Plate to the west, and the African Plate to the south (as shown in Fig. 1). These plates motions and interactions give rise to various tectonic processes, including earthquakes, crustal deformation, and volcanic activity (Şengör and Yilmaz 1981;

Edited by Dr. Rodolfo Console (ASSOCIATE EDITOR) / Prof. Ramón Zúñiga (CO-EDITOR-IN-CHIEF).

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Page count:	75
Word count:	28,566
Character count:	159,443
Submission date:	16-Aug-2024 10:15AM (UTC+0530)
Submission ID:	2428130813

Abstract

The Gutenberg-Richter (GR) power law stands as a cornerstone in seismology, elucidating the relationship between earthquake magnitude and frequency. Central to this relationship is the b-value, a key parameter that typically hovers around 1.0 in seismically active regions but can fluctuate based on geological conditions. This b-value reveals the stress regime of the Earth's crust: lower b-values signify higher stress levels and a heightened risk of larger earthquakes, while higher b-values suggest a prevalence of smaller quakes and lower stress. Monitoring variations in the b-value, both temporally and spatially, can thus offer crucial insights into impending seismic events. A sudden drop in the b-value may signal increasing stress and the potential for a major earthquake, making it an essential tool for forecasting and risk assessment.

In the northeastern region of India, the Kopili fault and its surrounding area present a significant tectonic feature. Stretching through Assam and Meghalaya, this fault zone is part of the intricate tectonic framework of the eastern Himalayas and the Indo-Burma ranges (IBR), known for its active seismicity and substantial tectonic movements. The history of significant earthquakes in this region highlights the importance of continuous research, monitoring, and preparedness to manage seismic hazards effectively.

While pinpointing the exact location and timing of future earthquakes remains elusive, a thorough analysis of earthquake precursors like the b-value offers valuable insights for seismic hazard analysis and safety measures in seismically active regions worldwide.

Accordingly, ***Chapter 1*** offers a captivating overview of earthquakes, delving into the factors that influence their occurrence. This chapter unfolds with a discussion on earthquake precursors and the intriguing application of the GR power law in predicting major seismic events through b-value monitoring. Additionally, it explores previous studies conducted in this region, setting the stage for the primary objectives of the thesis. To provide a clear roadmap, the chapter concludes with a detailed outline of the entire thesis.

Frequency magnitude distribution of large earthquakes with special reference to Kopili fault and surrounding regions of NER, India

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