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Estimating the Recurrence Periods of Earthquake in Sabah Using the CTBTO International Monitoring System Data

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NUKLEAR MALAYSIA

INTRODUCTION

Sabah is located in the northeast region of East Malaysia and recognised as the most active seismic area in Malaysia.

This study aims at quantifying the recurrence periods and probabilities of occurrence of earthquake in Sabah using the CTBT IMS data.

METHODS/DATA

Extreme Value Distribution.

CTBT IMS Data.

START

RESULTS

The results demonstrate consistency with the stability postulate from which distributions of extremes are deduced and provide further confidence in the application of such method.

CONCLUSION

IMS data contributes to strengthen the earthquake science in Malaysia.

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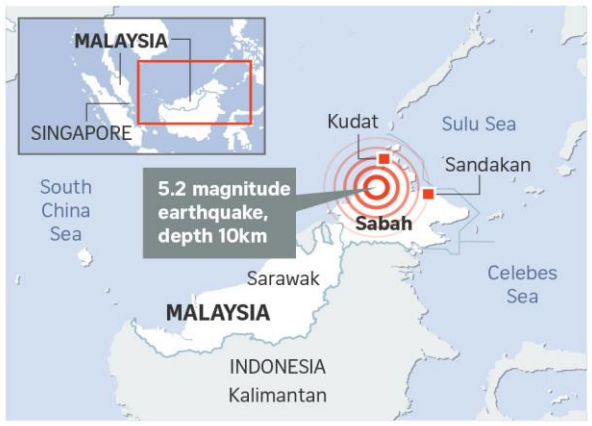
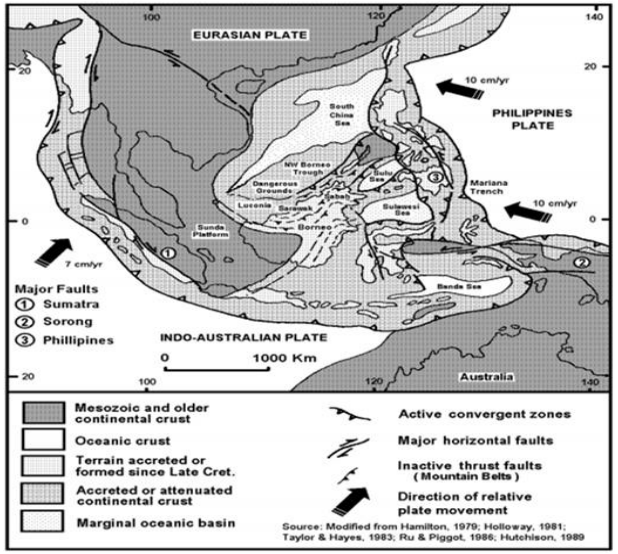
Background of the study



Source: UNITED STATES GEOLOGICAL SURVEY
STRAITS TIMES GRAPHICS

Major tectonic in Malaysia



The region of Sabah is known as prone to earthquake activities as compared to other parts of Malaysia. The region has suffered several earthquakes of moderate magnitude for the past decades, where of these events have caused structural damage to buildings and other infrastructures and injuries to humans.

The seismicity map of Sabah shows the presence of two zones of distinctive seismicity, which are Ranau in Kota Kinabalu and Lahad Datu in the southeast of Sabah.

The IMS recorded 33 moderate events, ranging from 3.3 to 5.2 mb, originated in this region from January 2002 to June 2020.

2015 has recorded the highest number of earthquake occurrence, where the IMS recorded event on June 4, 2015 23:15:43 UTC is consistent with the Ranau's moderate earthquake on June 5, 2015 7:15 am local time as reported by the Malaysia's local authority.

YEAR	CTBT IMS Seismic Network						
	Event ID	Date	Time	Latitude	Longitude	Magnitude	Depth (KM)
2020	18767431	14/04/2020	20:04:22	5.0212	118.9558	mb 3.6	0
2019	17680942	03/08/2019	15:31:06	6.2831	117.2185	mb 3.6	0
2018	15530461	08/03/2018	13:06:10	5.8856	116.5306	mb 4.4	0
	15848813	27/05/2018	7:53:42	5.2794	119.0089	mb 3.8	0
	15916404	16/06/2018	7:47:58	1.0666	111.3856	mb 3.8	0
2017	14228945	26/03/2017	9:30:49	4.7966	118.7287	mb 3.7	53
	14888716	24/09/2017	0:25:23	5.9464	118.3581	mb 3.5	0
2016	13497338	26/08/2016	1:39:32	6.4172	117.3407	mb 3.6	0
2015	11783042	19/03/2015	21:56:00	5.4795	118.3777	mb 3.8	0
	11997735	14/05/2015	10:25:07	1.8141	110.5797	mb 3.6	0
	12047012	04/06/2015	23:15:42	6.039	116.6377	mb 5.2	0
	12048513	05/06/2015	13:12:14	6.6386	117.191	mb 3.7	0
	12048801	05/06/2015	15:13:32	6.0524	116.6861	mb 3.9	0
	12050340	06/06/2015	5:45:13	6.2528	116.8675	mb 4.1	0
	12068968	12/06/2015	18:25:34	6.4085	117.3888	mb 3.4	0
	12068970	12/06/2015	18:29:24	6.0878	116.8661	mb 4.4	75
	12098600	23/06/2015	9:32:34	5.9739	116.5596	mb 3.7	49
	12199515	26/07/2015	10:04.9	6.2731	117.0466	mb 3.9	0
2014	10715051	14/04/2014	20:42:03	4.5645	117.7927	mb 3.4	0
	10471451	01/02/2014	11:35:08	6.095	116.6187	mb 4.1	0
2013	10099555	19/09/2013	21:50:37	5.6921	116.223	mb 3.6	0
	9440838	29/01/2013	1:04:30	5.1358	118.7193	mb 4.0	0
2012	8726575	28/05/2012	16:44:08	4.7371	118.3378	mb 4.1	0
2011	-	-	-	-	-	-	0
2010	6607825	21/08/2010	19:43:27	5.4801	118.5899	mb 3.5	0
2009	-	-	-	-	-	-	0
2008	4536681	10/01/2008	13:18:35	4.2583	116.5442	mb 3.6	0
2007	4428540	23/10/2007	20:34:39	5.6865	119.2532	mb 4.3	0
2006	3550325	06/02/2006	14:54:07	5.1248	118.8151	mb 3.6	0
	3674353	22/04/2006	2:01:25	6.0392	117.5982	mb 3.7	0
	3859855	28/09/2006	15:11:34	6.4085	118.0916	mb 3.7	0
2005	3249883	23/05/2005	19:58:12	6.2446	117.713	mb 4.3	0
2004	-	-	-	-	-	-	0
2003	1978643	02/11/2003	8:43:19	6.2718	117.5447	mb 3.5	0
	1852956	22/08/2003	18:01:00	5.8225	119.2862	mb 3.3	0
2002	1328028	06/10/2002	21:03:24	5.9584	117.8815	mb 3.8	0

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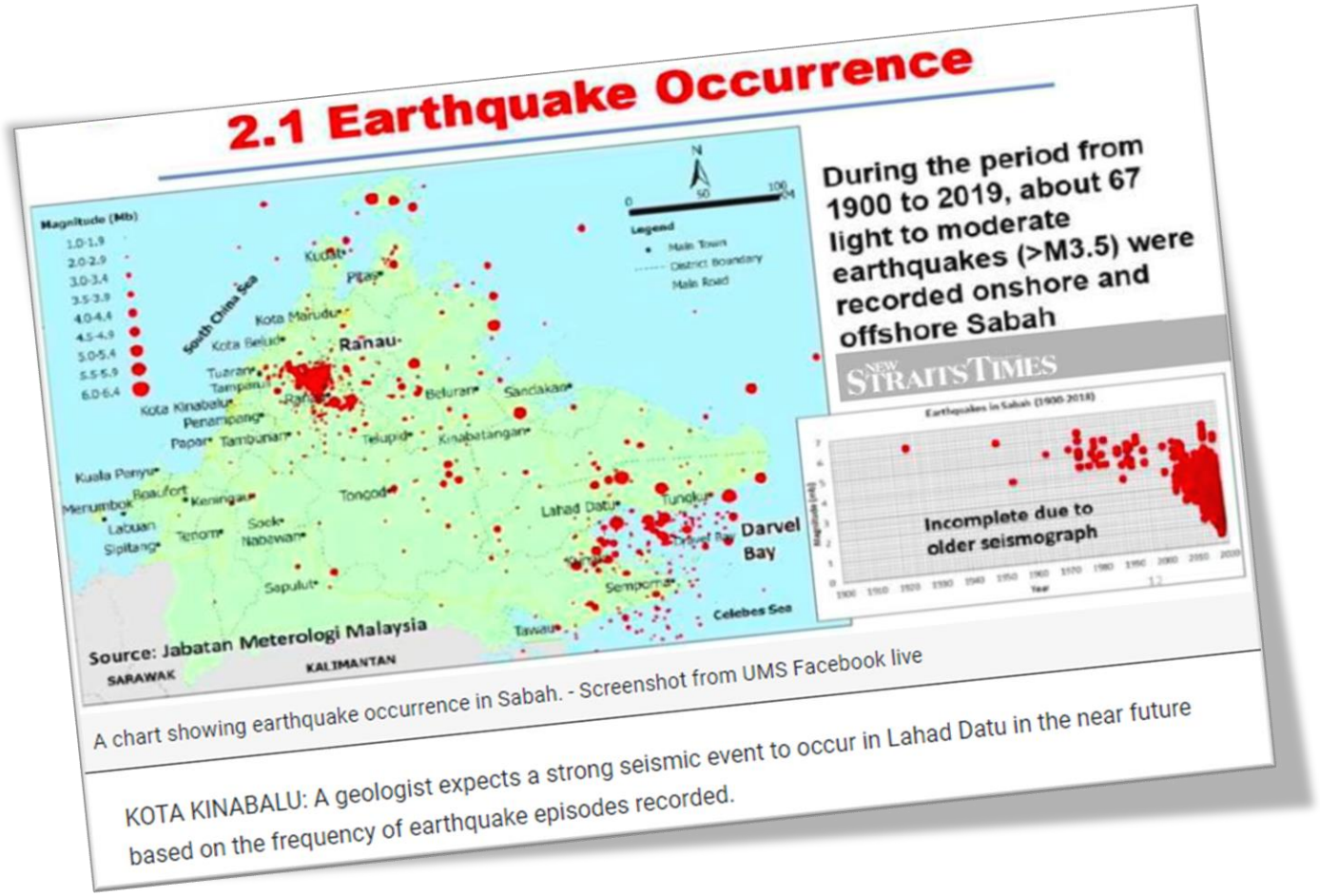
Objectives of the study



Earthquake hazards are still poorly understood and yet to be properly quantified in Malaysia. This is due to the lack of basic scientific data and lack of usable earthquake hazard model or map which could be referred to for mitigation planning and reduction of impacts. [1]

This study aims at quantifying the recurrence periods and probabilities of occurrence of earthquake at any given magnitude in Sabah using seismic IMS data.

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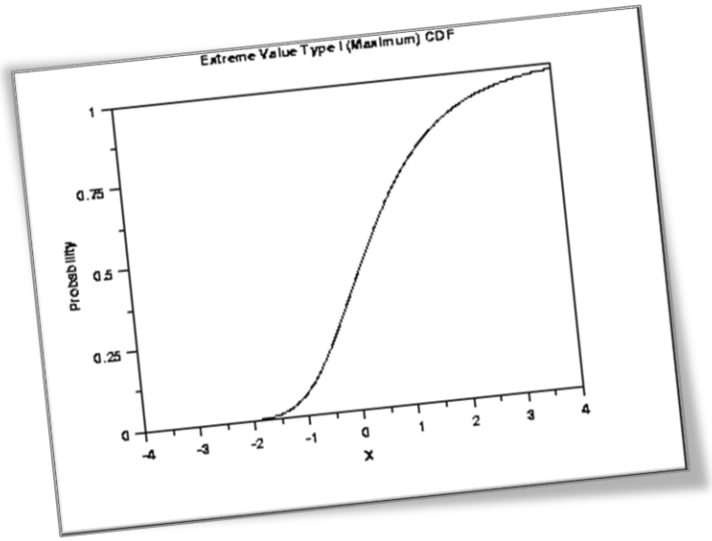
Graphic source: https://www.nst.com.my/news/nation/2020/11/642205/geologist-warns-strong-earthquake-strike-lahad-datu-near-future

[1] Felix Tongkul *An Overview of Earthquake Science in Malaysia*, ASM Sc. J., 14, 2021. https://doi.org/10.32802/asmscj.2020.440

Methods and data



- The method of Extreme Value Distribution Type-I, which is also known as Gumbel's Type I, has certain clear and advantages If compared with other methods requiring the whole data set, and rarely completely reported.
- The Gumbel's need only part of the event data, such as, the largest earthquakes i.e. extremes. The CTBTO IMS data represent a continuous and complete set of annual maximum magnitude events, thus, it is very useful to apply such method for the calculation process of this study.
- The results obtained are useful to determine a variety of statistics including average recurrence periods of annual maximum magnitude earthquakes and probabilistic seismic hazard assessment of the region. Results also are informative for seismic threat and related earthquake engineering determinations that usually require estimation of return periods or probabilities of exceedance of specific levels of design load criteria or external safety conditions.

Graphic source: the CTBTO Web Portal

- For this study, the data of earthquake events occurred around Sabah region (bounded by 3.95°N to 7.16°N latitude and 115.4°E to 119.3°E longitude) from January 2002 to June 2020 have been taken from the CTBT's Reviewed Event Bulletin (REB).
- In order to study the earthquake risk, probability of occurrence and return periods, the earthquake data distributed over 19 years periods has been divided into one year time interval such as at least one event in each year duration is observed.

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Results

- The earthquake yearly numbers and their return period for different magnitude expected in Sabah region are summarized in Table 1. These indicate that as return period increases, frequency of earthquake occurrences decreases.
- From the histories of maximum earthquake magnitude recorded, earthquake hazard probabilities for different magnitudes with time are calculated for 10, 20, 30, 50, 75 and 100 years periods.. The relation between of these yearly numbers of earthquakes, their return periods and the calculated earthquake hazard is illustrated in Figure 1 and Figure 2. The observations suggest that within hundred year period the probability of occurrence of larger magnitude earthquakes decrease with time. The general interpretation of this curve reveals that the probability of an earthquake of magnitude 4.1 occurring in the considered region with 20-years period is estimated to be 0.999. This means that at least one earthquake of magnitude 4.1 is predicted to occur within that period of time. However, probability of such particular event is never absolutely certain.
- The probability P (t ≥ T) that the recurrence period of the design earthquake of magnitude m exceeds a random recurrence period of T years is given by P (t ≥ T) = exp (-T/Tm). For example, recurrence period for at least one earthquake of magnitude m within a probability of 90% is given by T90 = -Tm ln (1-90)
- The design earthquake recurrence period with 90% probability is calculated and the values are presented in Table 2. The 90% probability recurrence period could be understood that in Sabah region, there is 90% probability in 29 years period that at least one earthquake of magnitude 4.5 or greater will occur and conversely that 10% probability an earthquake of the same magnitude or more will not occur.

Table 1

Magnitude	N_m	T_m
3.5	1.867965642	0.535341752
3.5	1.867965642	0.535341752
3.6	1.454205854	0.687660552
3.6	1.454205854	0.687660552
3.6	1.454205854	0.687660552
3.7	1.132095054	0.883318054
3.7	1.132095054	0.883318054
3.7	1.132095054	0.883318054
3.8	0.881332728	1.134645257
4	0.53413853	1.872173497
4	0.53413853	1.872173497
4	0.53413853	1.872173497
4	0.53413853	1.872173497
4.1	0.415825302	2.404856065
4.1	0.415825302	2.404856065
4.3	0.252014147	3.968031205
4.4	0.196192285	5.097040379
4.4	0.196192285	5.097040379
5.2	0.026469026	37.78000723
3	***6.532566815***	***0.153***
3.5	***1.867965642***	***0.535***
4	***0.53413853***	***1.872***
4.5	***0.152735127***	***6.547***
5	***0.043674099***	***22.897***
5.5	***0.012488463***	***80.074***
6	***0.003571034***	***280.031***
6.5	***0.001021125***	***979.312***
7	***0.000291987***	***3424.806***
8	***2.38745E-05***	***41885.712***

Figure 1

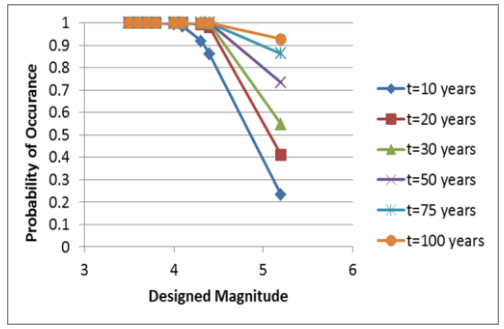

Figure 2

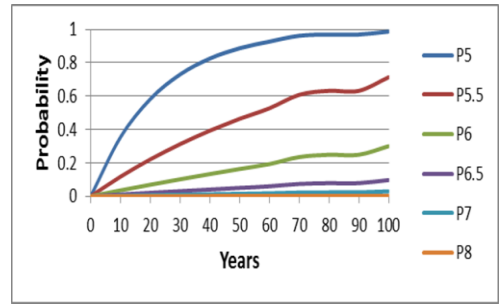

Table 2

Magnitude (m)	Return Period (years)	Recurrence Period (years)
3	0.153	0.69
3.5	0.535	2.40
4	1.872	8.40
4.5	6.547	29.39
5	22.897	102.78
5.5	80.074	359.42
6	280.031	1256.96
6.5	979.312	4395.77
7	3424.806	15372.71
8	41885.712	188009.73

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Conclusion

- The study has managed to produce the preliminary findings of seismic hazard assessment in Sabah using the IMS data of the CTBTO. The results of analysis have enabled the quantification of recurrence periods and probabilities of occurrence of earthquake at any given magnitude in Sabah using seismic IMS data.
- The results of this preliminary study demonstrate consistency with the stability postulate from which distributions of extremes are deduced and provides further confidence in the application of such method.
- The study shows the IMS data is useful for earthquake sequence analyses of the region and has an important role in seismological research, contributing in strengthening the overall earthquake science in Malaysia.
- Such study also may contribute to increase and promote the utilisation of IMS data for civil and scientific applications, as well as optimising Malaysia's benefits as a Member States to the CTBT.