Lecture Part 3

Earthquakes around Northern Thailand

Past – Present - Future

Pailoplee and Charusiri *Earth, Planets and Space* (2016) 68:98
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FULL PAPER

Seismic hazards in Tha a compilation and upc analysis

Santi Pailoplee* and Punya Charusiri

Abstract

A probabilistic seismic hazard analysis (PSHA) for Thai
This PSHA was based upon (1) the most up-to-date p
(3) the seismicity parameters (*a* and *b* values), and (4)
as being suitable models for Thailand. For the PSHA m
ance (POE) were analyzed and mapped using various
were demonstrated for ten major provinces within Th
0.1–0.4 g and 0.1–0.2 g ground shaking, respectively,
earthquake-prone region evaluated in Thailand. In a c
Thailand, the Kanchanaburi and Tak provinces had co
tion plans for these areas should be made. Although
PSHA, a further study of seismic wave amplification d

Keywords: Seismic hazard analysis, Probabilistic met

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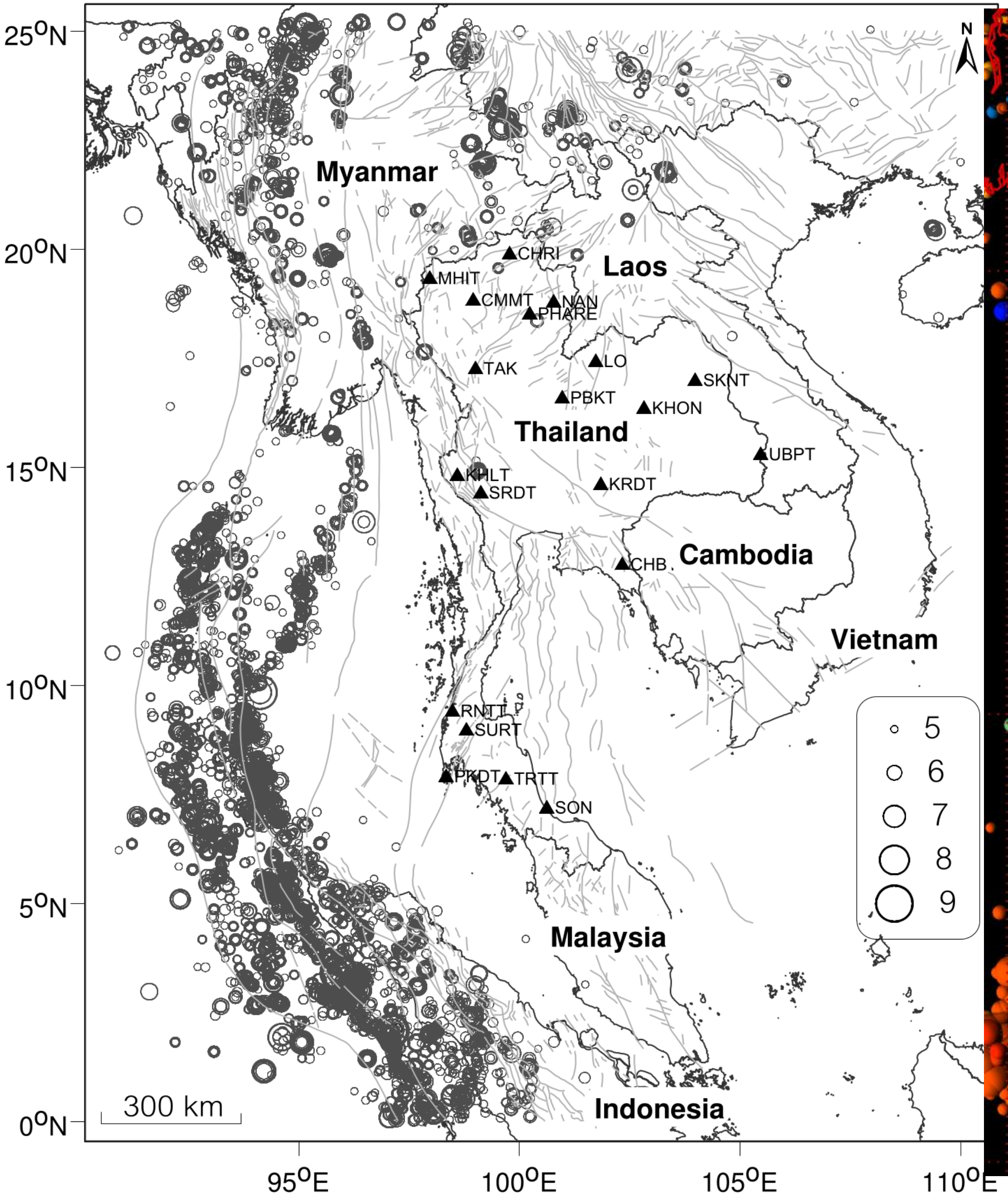

Figure 1. Map of mainland SE Asia showing the distributions of the earthquakes with a M_w of > 5.0 from the IRIS earthquake catalogue. The inland fault traces are interpreted from NOAA-11 satellite image, including fault traces data in the Andaman Sea from Hutchison (1989) and Curray (2005). The triangular symbols represent the location

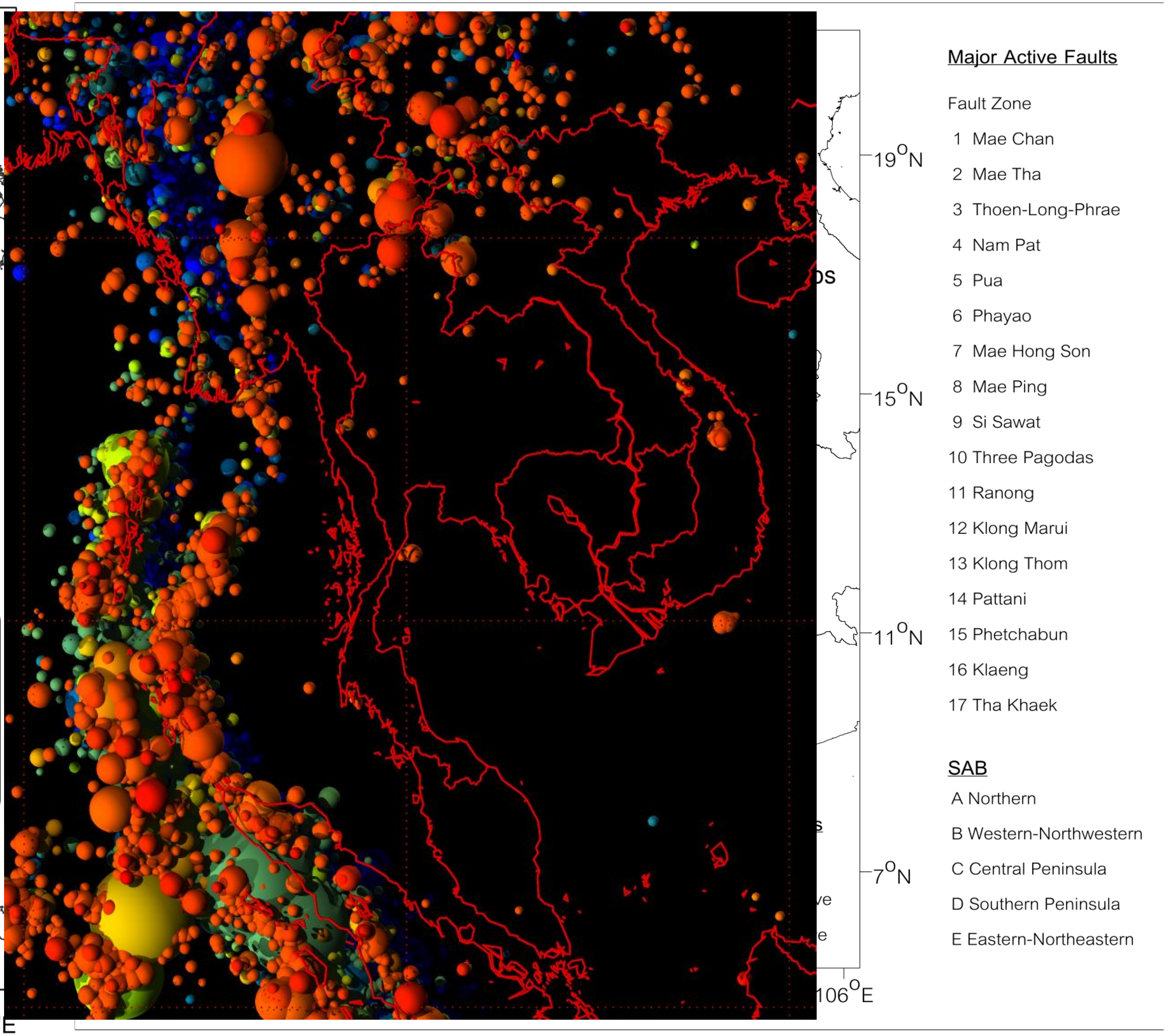

Figure 2. Map of Thailand showing the 17 major active fault zones, active fault class, and the five Seismically Active Belts (SABs), including the slip rate (mm/yr) of each individual fault segment.

Paleoseismology;
How to know historical earthquakes?

- Old documents and records
- Archaeological study about remaining ruins
- Traces of Fault Activity Left in the Terrain

  →Remote sensing etc.
- Trench or road-cut survey and Optically Stimulated Luminescence (OSL) dating.
- Etc.

The key to the future is the past!

Table 1. Historical and instrumental earthquakes reported in Chiang Saen since 624 B.C. with observed intensities. Approximated distance to Chiang Saen from instrumental earthquakes has been determined from rupture area of past studies.

no.	date	maximum estimated/ observed intensities	description
historical earthquakes			
1	624 B.C.	VI [9]	earthquakes, thunder, mountains trembled violently, people's hair stood on end, no damage is mentioned
2	623 B.C.	VI [9]	earthquakes, thunder, mountains trembled, heavy rain, no damage is mentioned
3	594 B.C.	VI [9]	earthquakes, thunder, mountains trembled, no damage is mentioned
4	589 B.C.	VI [9]	earthquakes, thunder, mountains trembled more intensely than during the first three earthquakes, no damage is mentioned
5	460	XII [9]	in the evening, the Earth trembled violently and loudly once; in the middle of the night, it shook once more; late that night, the tremor hit again; the whole town submerged and became a big lake; the king and all of his subjects died except one old widow
6	534	VIII [9]	four pagodas were toppled, thunder
7	1715	VII [9]	earthquakes occurred; the finials of four jedis broke off and fell down in four districts and were destroyed; the Earth trembled throughout that month before q[illegible]
instrumental earthquakes			
8	16 May 2007 (distance, 75 km)	IV [3]	in the Chiang Saen district, bricks and cement were dislodged from the Chedi Luang Pagoda [illegible] the top of Wat Phra That Jomkitti [illegible] lotus-shaped tip of Wat Pasak Pagoda were knocked down. Cracks developed in the Jomkitti Pagoda
9	24 Mar 2011 (distance, 46 km)	VI [1,3]	a spire on the top of Chedi Luang fell down causing additional damage to the nearby stupa. Crack developed on Chedi Wat Pasak and Wat Phra That Jomkiti
10	5 May 2014 (distance, 79 km)	IV [2,11]	cracks developed at the top of Chedi Luang

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Table 3. Recorded ground motion from Mw 6.1, 5 May 2014 Mae Lao earthquake with their National Earthquake Hazards Reduction Program (NEHRP) site class. (Online version in colour.)

station	NEHRP site class	Rjb (km)	distance to Chiang Saen (km)	ground motion PGA (g)	PGV (cm s^{-1})	D5-D95 (s)
MEAJ	D	38	29	0.04	2.5	19.5

Table 4. Summary of observed damage to ancient monuments from 2011 Tarlay earthquake.

	Chedi Luang	Chedi Pasak	Pu Khao Temple	Chedi Prasad Khum
damage state	moderate	partial	moderate	moderate
structural type	stupa	stupa	arch and masonry solid core load bearing system	stupa
construction period	fourteenth century	fourteenth century	fourteenth century	seventeenth century
height (m)	35	21	4	8
ground floor solid core (m)	9	11	4	2.5
height/solid core width ratio	3.88 (35/9)	1.9 (21/11)	1 (4/4)	3.2 (8/2.5)
total base width (m)	[illegible]	14	4	8
number of stories	1	2	1	1
after 2011 Mw 6.8				

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Only religious ancient documents of questionable reliability remain.!

Table 7. List of different earthquake scenarios from five major active faults near Chiang Saen considered in this study.

no.	fault name	Rrup (km)	Mw (rupture length, km) scenario 1	scenario 2	scenario 3
1	Mae Chan	5	6.8 (29 km)	7.5 (150 km)	7.8 (230 km)
2	Mae Ing	41	7.1 (62 km)	7.5 (142 km)	—
3	Phayao	43	6.8 (29 km)	7.2 (65 km)	—
4	Nam Ma	46	6.8 (30 km)	7.5 (134 km)	7.8 (207 km)
5	Meng Xing	67	7.1 (51 km)	7.3 (81 km)	7.8 (237 km)

Seismic damage to ancient monuments in Chiang Saen (Northern Thailand), Ornthammarath T. 2019

Archaeological data

Figure 4. (a) The early photograph of Chedi Luang in 1957 (DOFA, 1979). (b) The schematic cross-section of Chedi Luang with reinstalled top spire in 2012. (c) The collapse of the 7-m spire due to the Mw 6.8 Tarlay earthquake in 2011. Its size is comparable to a person next to the toppled spire. A steel pipe could be clearly seen. (Online version in colour.)

But this is limited after 14th century!

Figure 5. (a) Chedi Pasak before 2011 earthquake. (b) The schematic plot of Chedi Pasak in different layers. (c) Observed wide cracks at the lower top part. (d) Tilt could be clearly seen at the top spire following the 2011 earthquake in Myanmar located at 50 km to Chiang Saen. (Online version in colour.)

Two scientific methods.

1) Traces of Fault Activity Left in the Terrain
→Remote sensing etc.

2) Trench or road-cut survey and Optically Stimulated Luminescence (OSL) dating.

Possible Active Faults from two scientific surveys

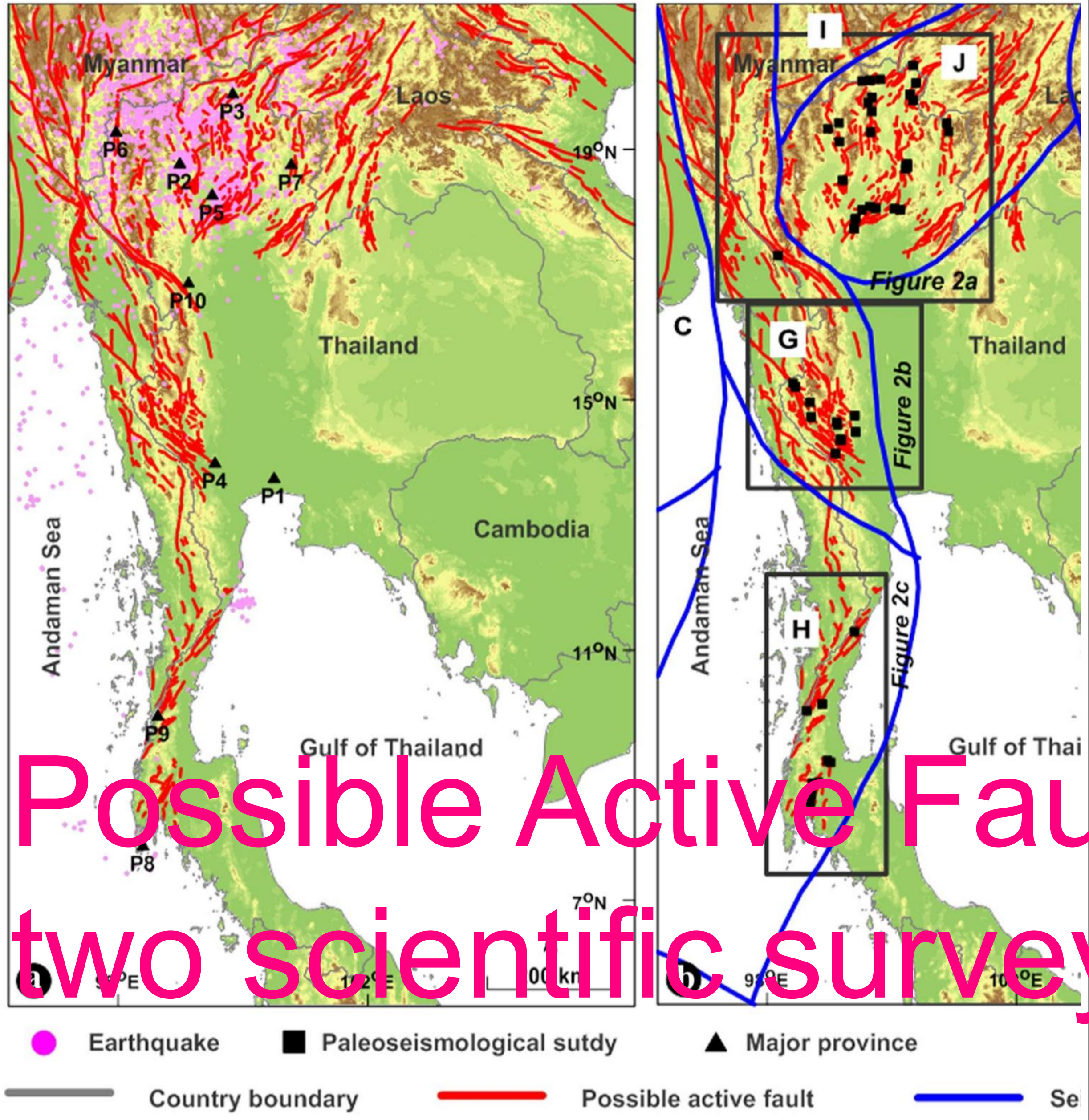

Fig. 1 **a** Map of Thailand and the neighboring area illustrating the possible active faults (*red lines*). The detailed location parameters of each fault are expressed in Additional file 1. The *pink dots* are the earthquake data recorded from 1912 to the locations of the ten significant provinces recognized in this PSHA. **b** Seismic source zones (*blue polygon*) recognized Choowong 2013). The *black squares* are the new sites of paleoseismological investigations used in this study with more

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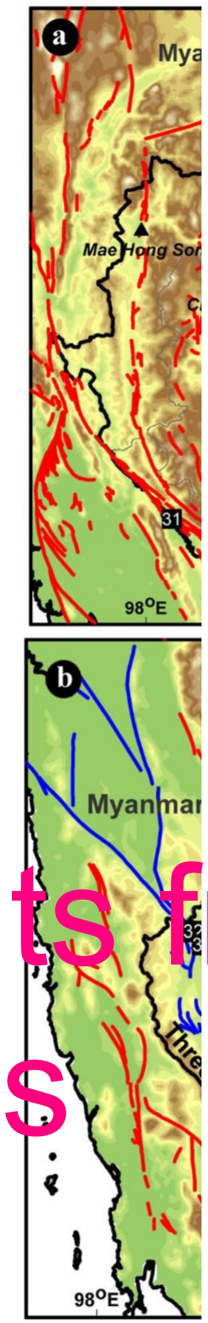

Fig. 2 Maps of different prov

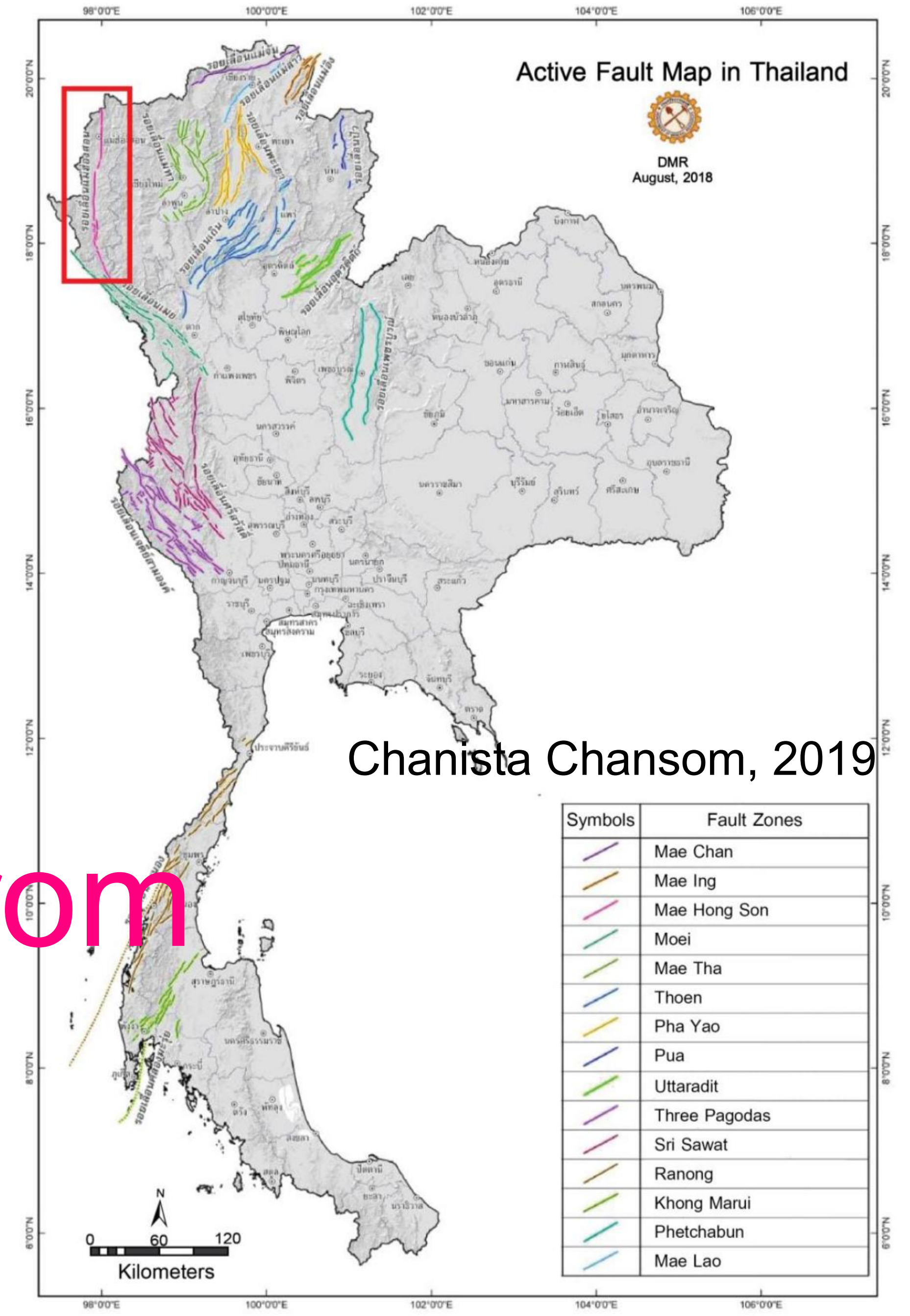

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Figure 9 Map shows active faults in Thailand consist of 15 fault zones (from DMR (2018)). Red box shows the study area.

Traces of Fault Activity Left in the Terrain

2019

Neotectonics and pale earthquakes along Mae Hong Sc northern Thailand

Chanista Chansom
Faculty of Science

Chanista Chansom, 2019

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science in Geology
Department of Geology
Faculty of Science
Chulalongkorn University
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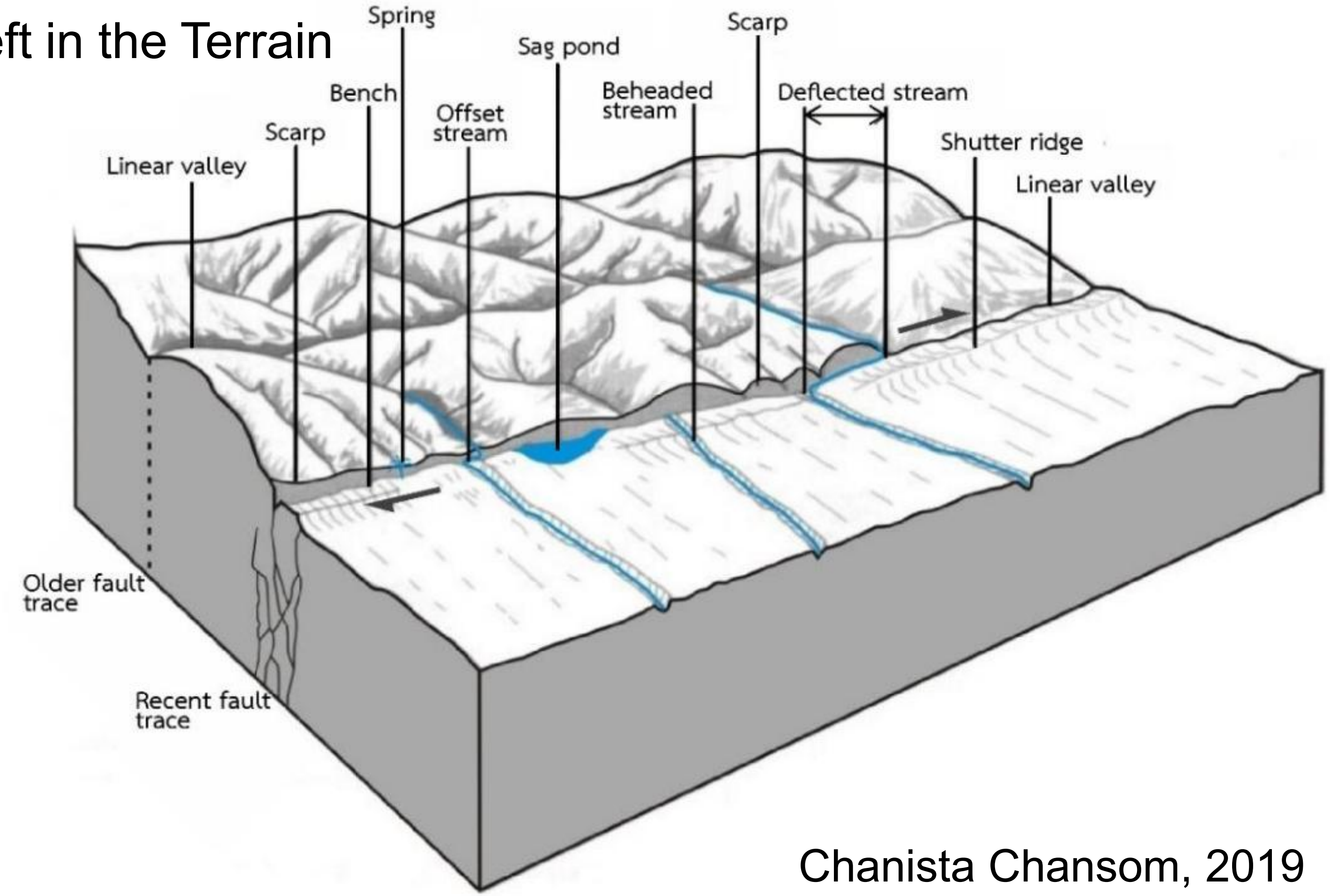

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Figure 12 Morphotectonic landforms associated with active strike-slip movement (from Keller and Pinter (1996)).

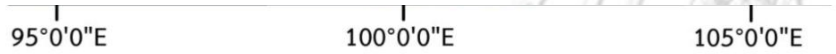

Figure 1 Map of Thailand and adjacent areas showing major active faults (compiled from DMR (2018), Wang et al. (2014) and Morley, Charusiri, and Watkinson (2011)) and epicentral distribution from 1912 to 2018 (TMD, 2016 and USGS, 2016). The rectangle shows the location of the study area.

Remote sensing example

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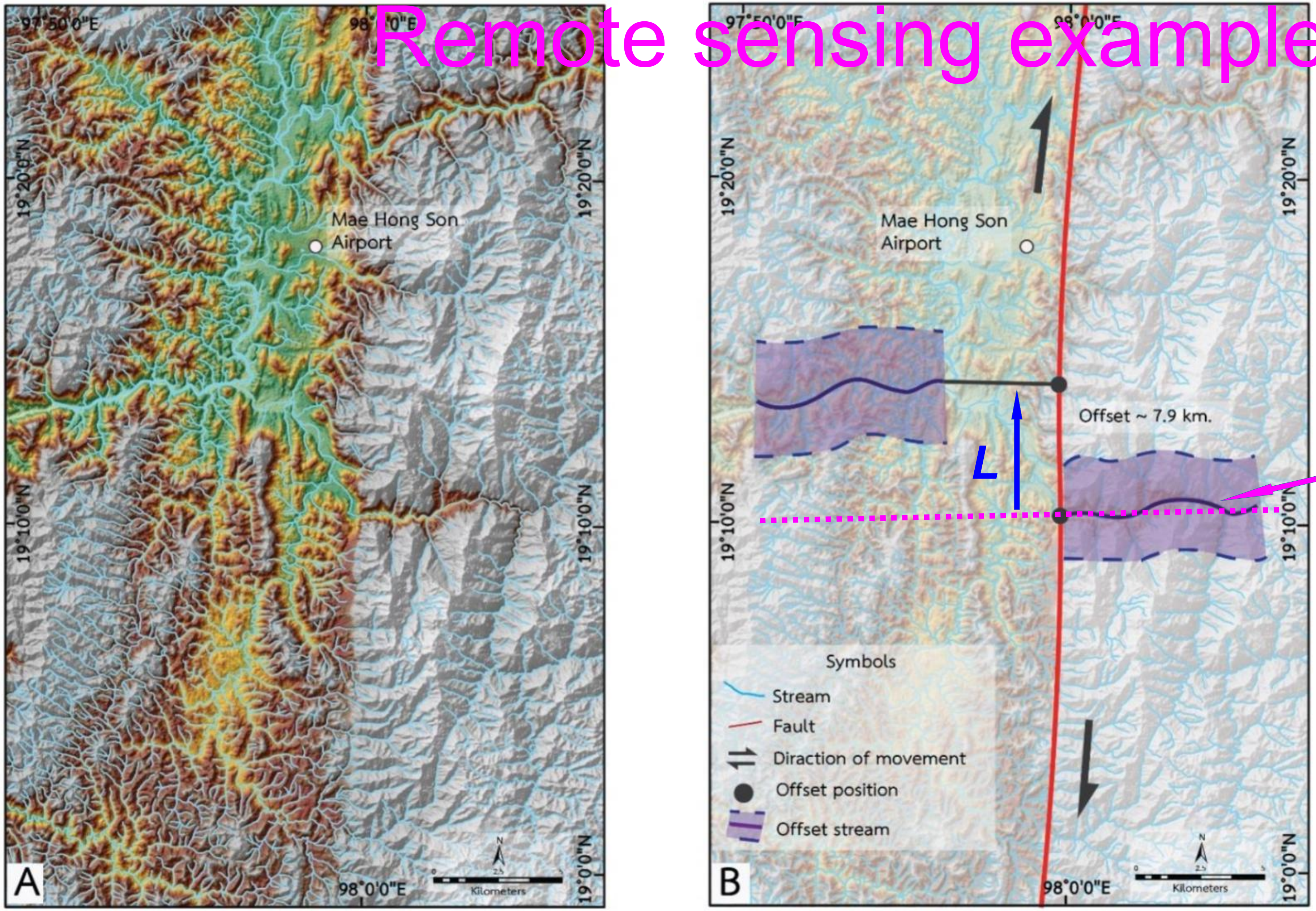


$V = L / T$

$Tn\text{-}To = T$

Figure 17 Detail interpreted map from ALOS DEM at Ban Pha Bong show offset stream of Sa Mad river is about 7.9 km. from right lateral strike-slip fault movement. Location shows in Figure 16B.

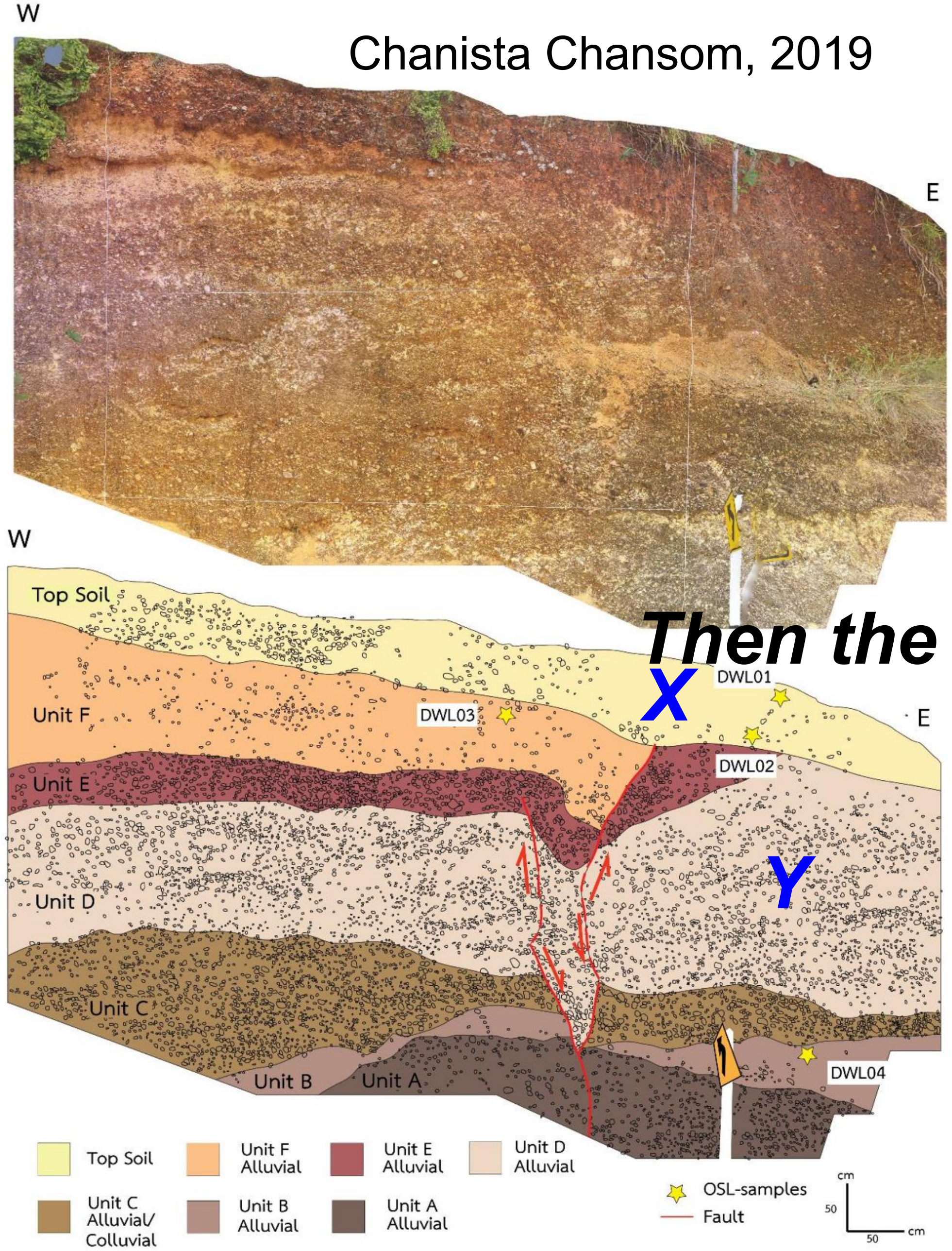


Figure 31 Road cut outcrop section and wall log section on the north wall at Doi Wiang Luang showing sediment stratigraphy, fault orientation and sample location for dating. Location shows in Figure 26A.

The two important principles in Geology

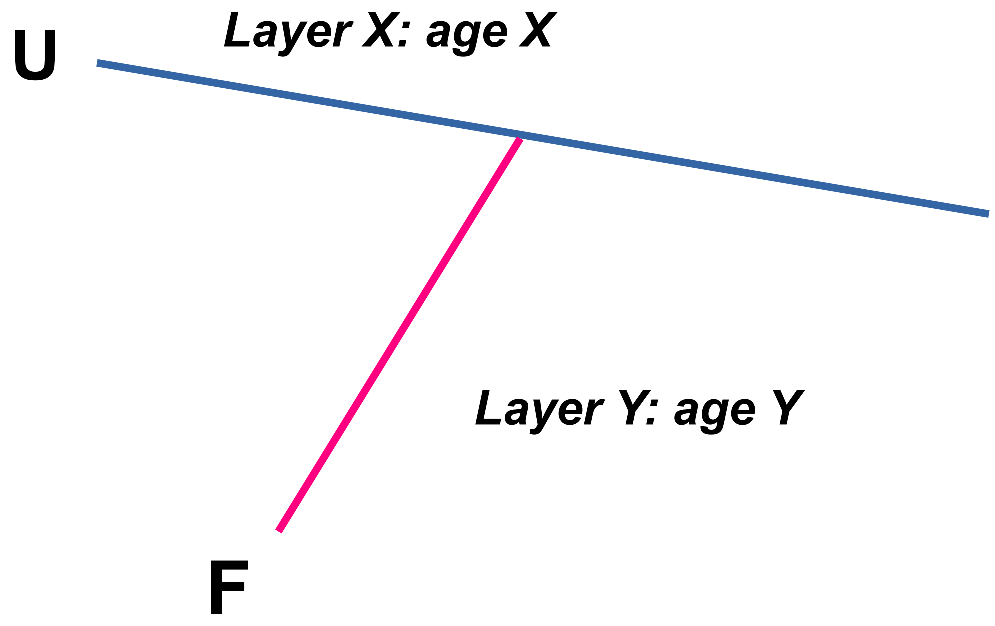
Law of super position

→ ***Layer X is younger than Layer Y***

Cross-cutting relationship

→ **U cuts F: U is younger than F**

Then the earthquake age (F) is between X and Y



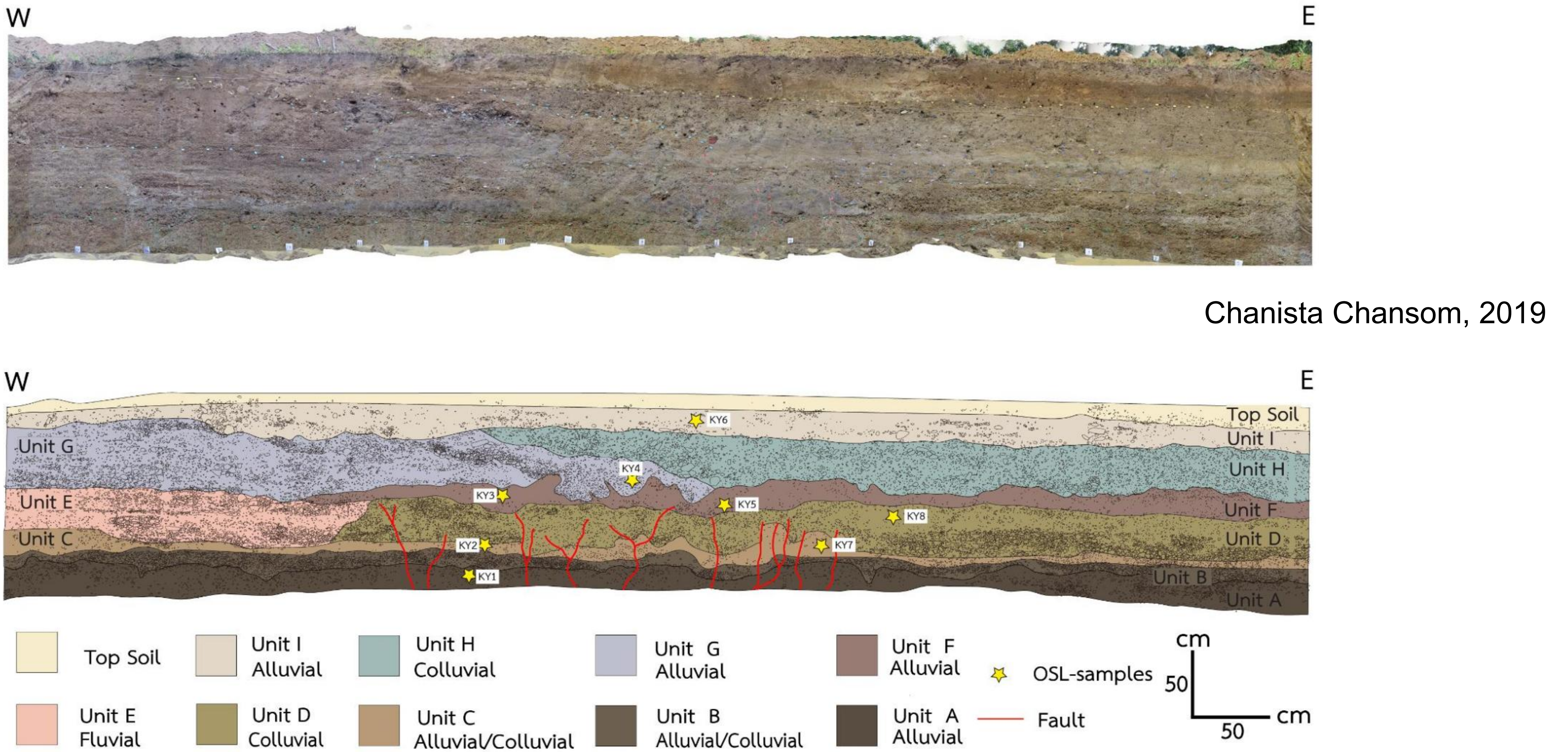


Figure 35 Paleoearthquake trench section and wall log section on the north wall at Ban Khun Yuam showing sediment stratigraphy, fault orientation and sample location for dating. Location shows in Figure 26A.

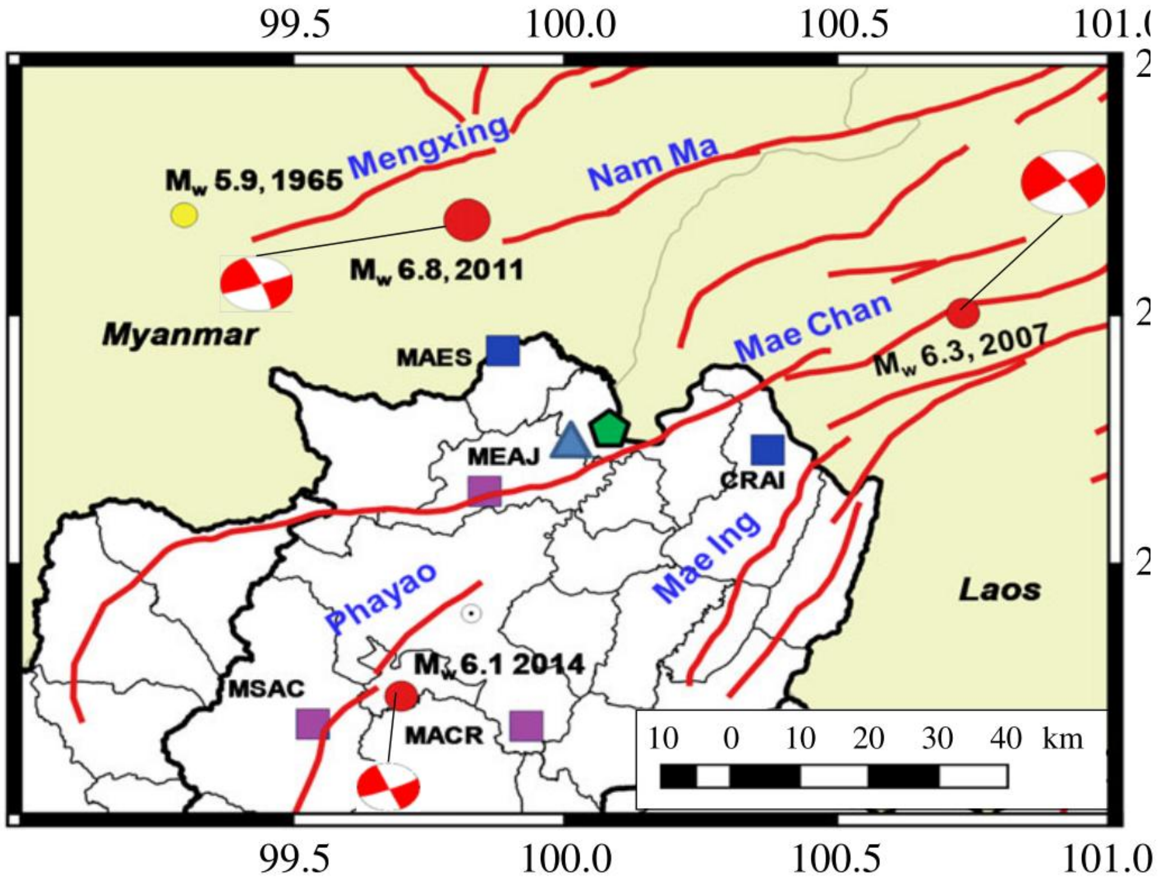


Figure 1. Chiang Saen and its surrounding seismicity from earthquakes greater than 5.0 since 1902. The red lines represent active faults from the Department of Mineral Resources (DMR) (http://www.dmr.go.th/main.php?filename=fault_en). The blue and purple squares represent seismic stations that record ground motion from Mw 6.8 2011 and Mw 6.1 2014, respectively.

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Research

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Seismic damage to ancient monuments in Chiang Saen (Northern Thailand): implication for historical earthquakes in Golden Triangle area

Teraphan Ornthammarath

Department of Civil and Environmental Engineering, Faculty of Engineering, Mahidol University, Nakhon Pathom, Thailand

TO, 0000-0002-3401-7076

Over the last few decades, three moderate

Teraphan Ornthammarath, 2019

Many of historical earthquakes were closely related to the **Three Pagoda Fault, the Mae Ping Fault, and the MHSF.**

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Their estimation

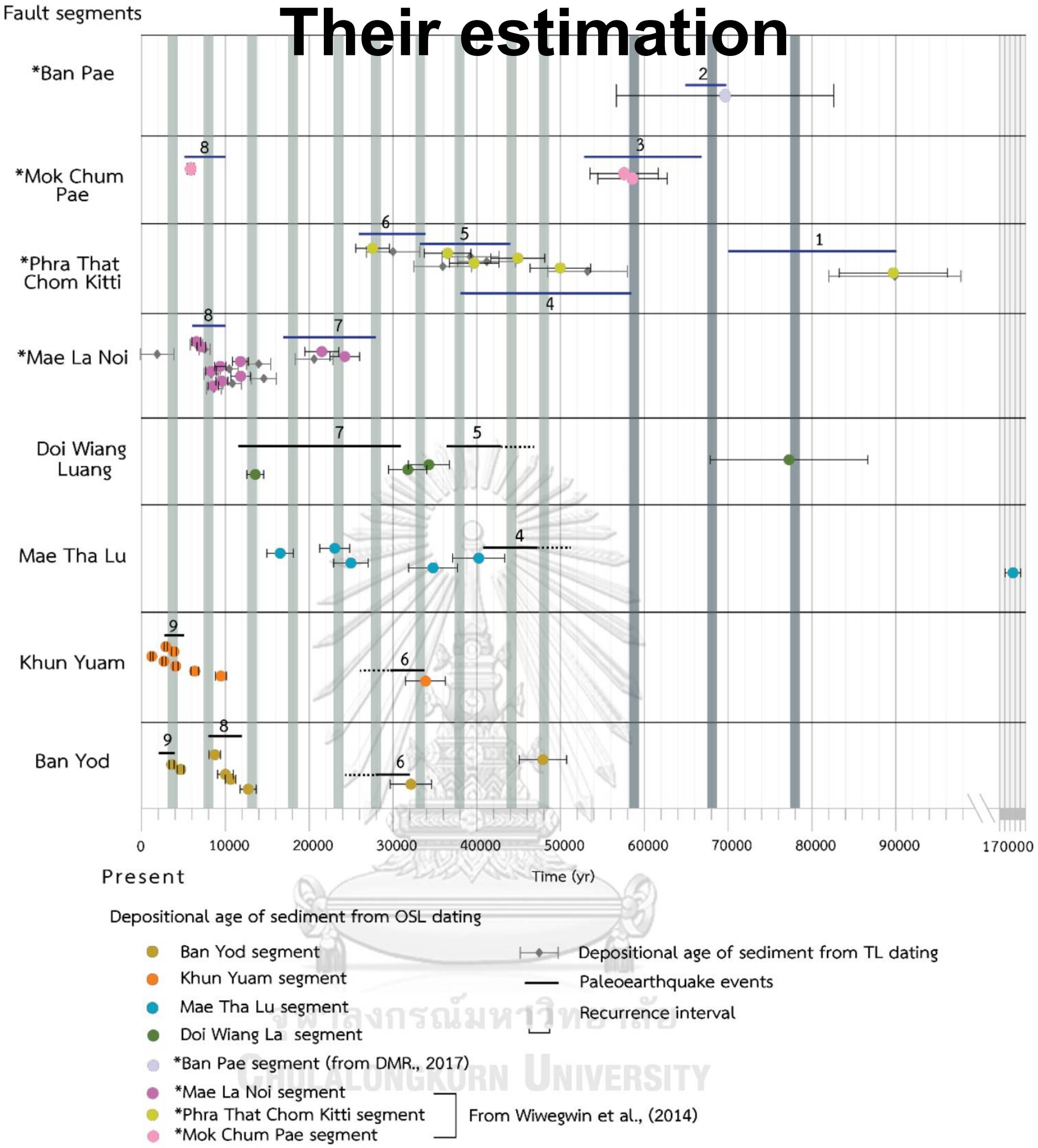

Figure 48 Diagram showing the depositional ages of sediments in the road-cut wall and trenches from the OSL ages and paleoearthquake events.

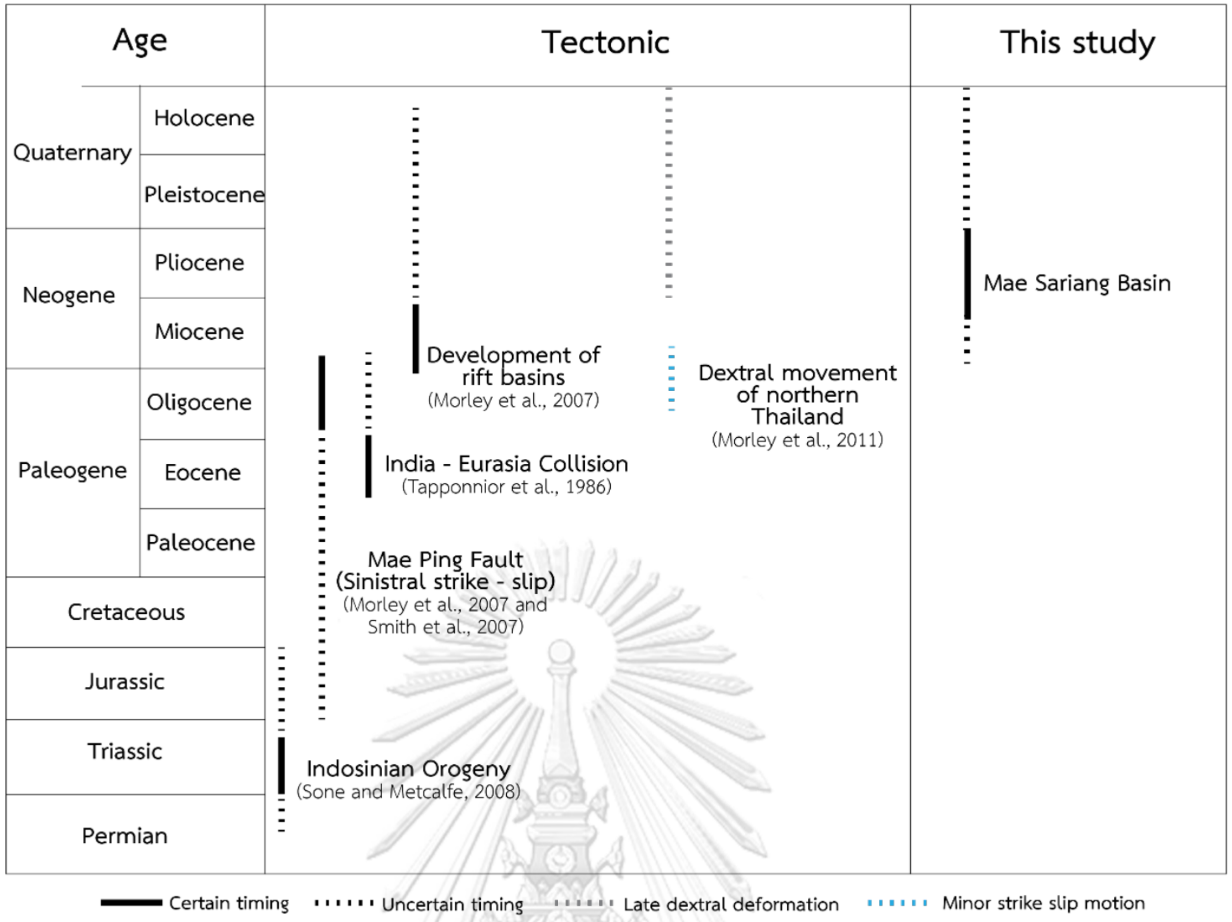

Figure 49 Comparative chart of the regional tectonic events (modified from Kaewpradit., 2018 and Morley et al., 2011) and the evolution of the MSB from this study.

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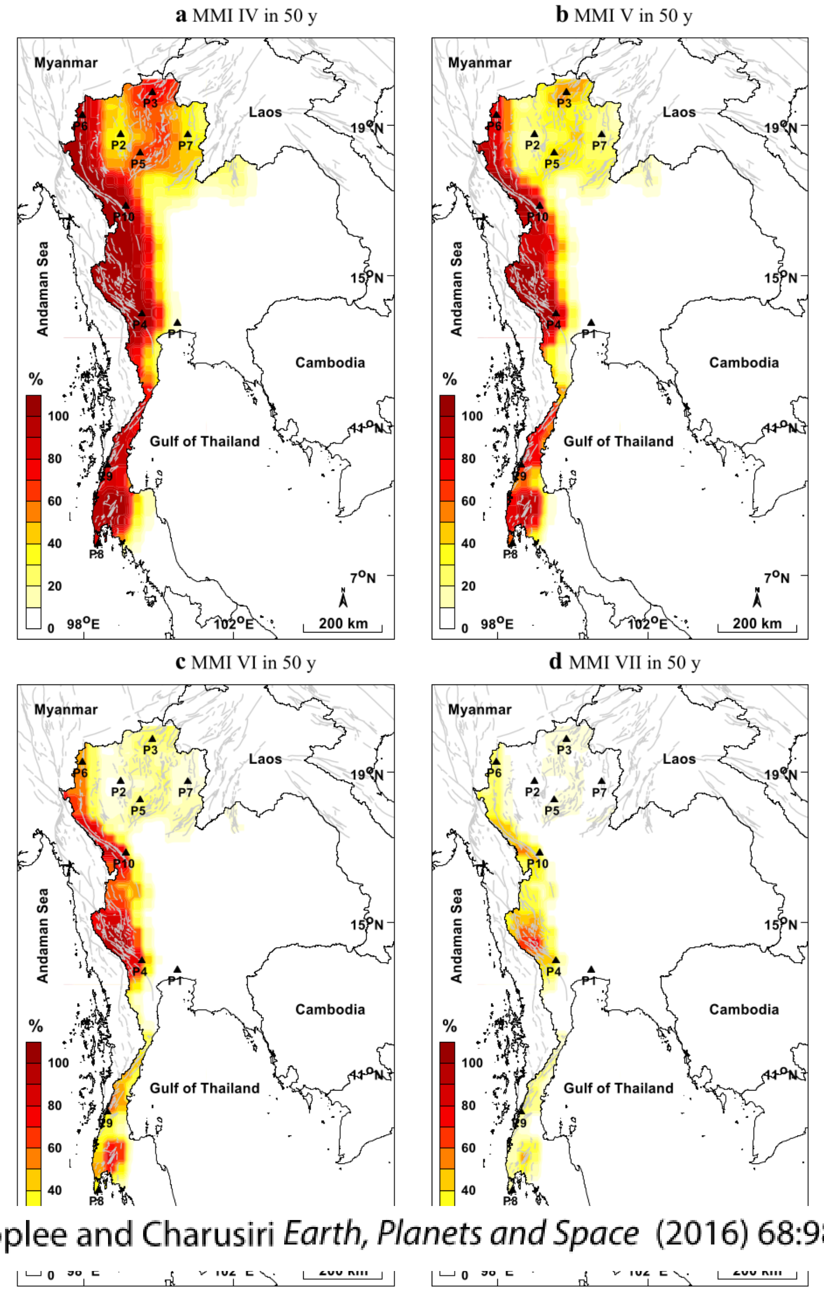

Pailoplee and Charusiri *Earth, Planets and Space* (2016) 68:98

Fig. 6 PSHA maps of Thailand showing the probabilities (%) that earthquake intensity will be equal to or greater than each MMI level in the next 50 years. **a** IV: Felt indoors by many, outdoors by a few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. **b** V: Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop. **c** VI: Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight. **d** VII: Damage slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken

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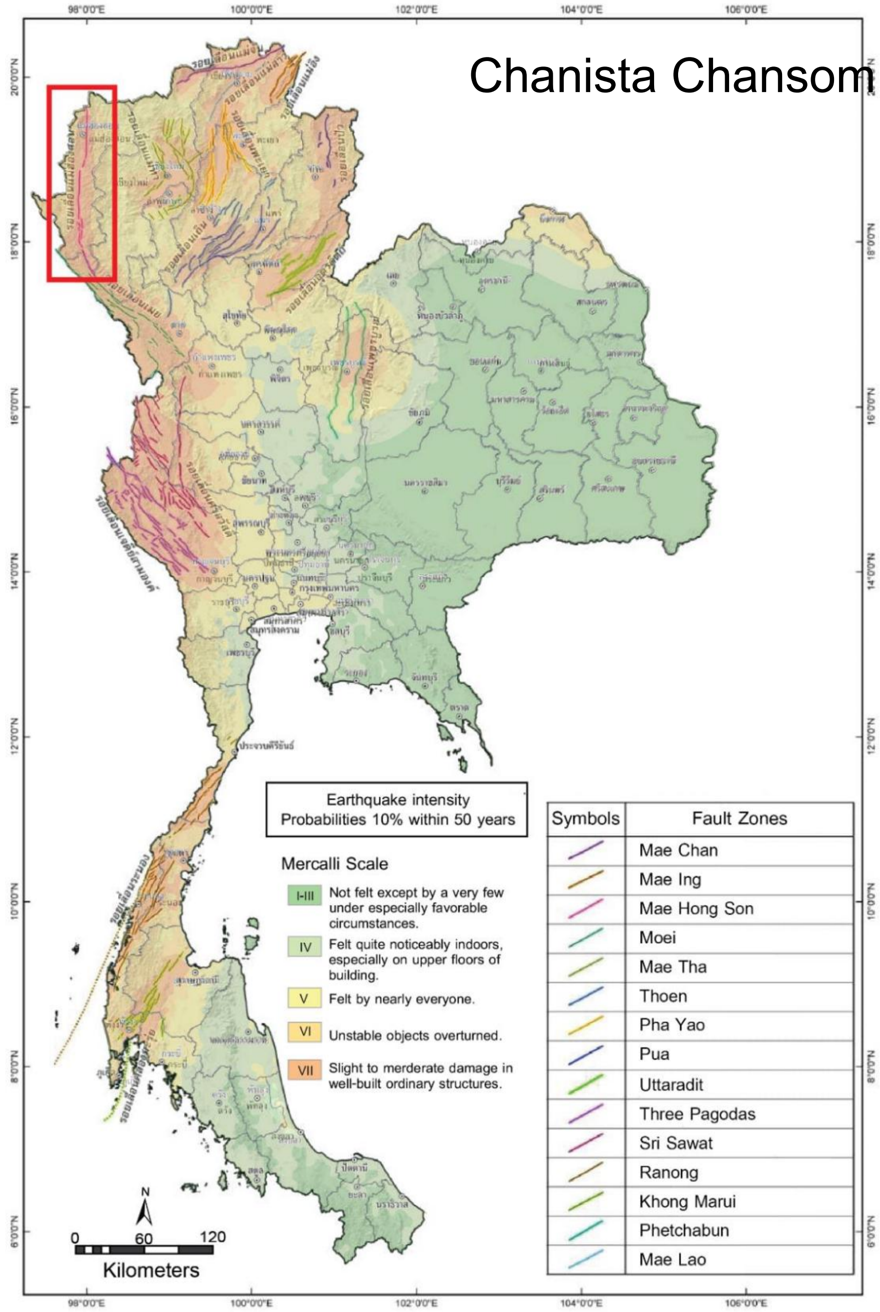


Figure 10 Map shows seismic hazard zones in Thailand related with 15 active fault zones (from DMR (2016) and DMR (2018)). Red box shows the study area.

Can We Estimate the Maximum Earthquake Magnitude from Fault Slip Rate and Recurrence Time?

1. The Scientific Question

In active fault studies, especially using geomorphology and trench investigations, we often obtain:

Slip rate of a fault:

v [mm/y]

Average recurrence interval of large earthquakes:

T [years]

A natural question is: If we know v and T, can we calculate the maximum earthquake magnitude M?

This question is fundamental in seismic hazard assessment.

Step 2: Earthquake Size Is Measured by ***Seismic Moment***

Earthquake magnitude is not defined directly by slip, but by seismic moment.

$$M_0 = \mu A D$$

Where: M_0 = seismic moment [N·m]

μ = rigidity of rocks ≈ 3×10^{10} [Pa]

A = rupture area of the **fault** (length × depth)

D = average slip per earthquake

Step 3: **Moment Magnitude**

$$M_w = \frac{2}{3}\log_{10}(M_0) - 6.06$$

How Scientists Estimate Maximum Magnitude in Practice

Method 1: Fault Geometry Approach

Fault length ***L***

Seismogenic depth ***W*** (typically 10–15 km)

Then rupture Area

$$\boldsymbol{A} = \boldsymbol{L} \times \boldsymbol{W}$$

So we can get $M_0 = \mu A D$

And finally

$$M_w = \frac{2}{3}\log_{10}(M_0) - 6.06$$

Method 2: Empirical Scaling Laws: Wells & Coppersmith (1994)

Log $D = \boldsymbol{a} + \boldsymbol{b}\, M$

D = average slip per earthquake ($D = vT$)

Appendix: Numerical Example (Northern Thailand Case Study)

Applying the Method to a Northern Thailand Typical Fault

Slip rate:	v = 1 mm/y
Recurrence interval:	T = 1,000 years
Fault length:	L = 50 km
Seismogenic depth:	W = 15 km
Rigidity:	$\mu = 3 \times 10^{10}$ Pa

Calculation

Step 1: Slip per Earthquake

$D = v \times T = (1 \times 10^{-3}\ \text{m/yr}) \times (1{,}000\ \text{yr})$

$D = \mathbf{1.0\ m}$

Step 2: Rupture Area

$A = L \times W = (50{,}000\ \text{m}) \times (15{,}000\ \text{m})$

$A = \mathbf{7.5 \times 10^{8}\ m^{2}}$

Step 3: Seismic Moment

$M_0 = \mu A D$

$M_0 = (3 \times 10^{10}) \times (7.5 \times 10^{8}) \times (1.0)$

$M_0 \approx \mathbf{2.3 \times 10^{19}}\ \text{N·m}$

Step 4: Moment Magnitude

$Mw = (2/3)\log_{10}(M_0) - 6.06$

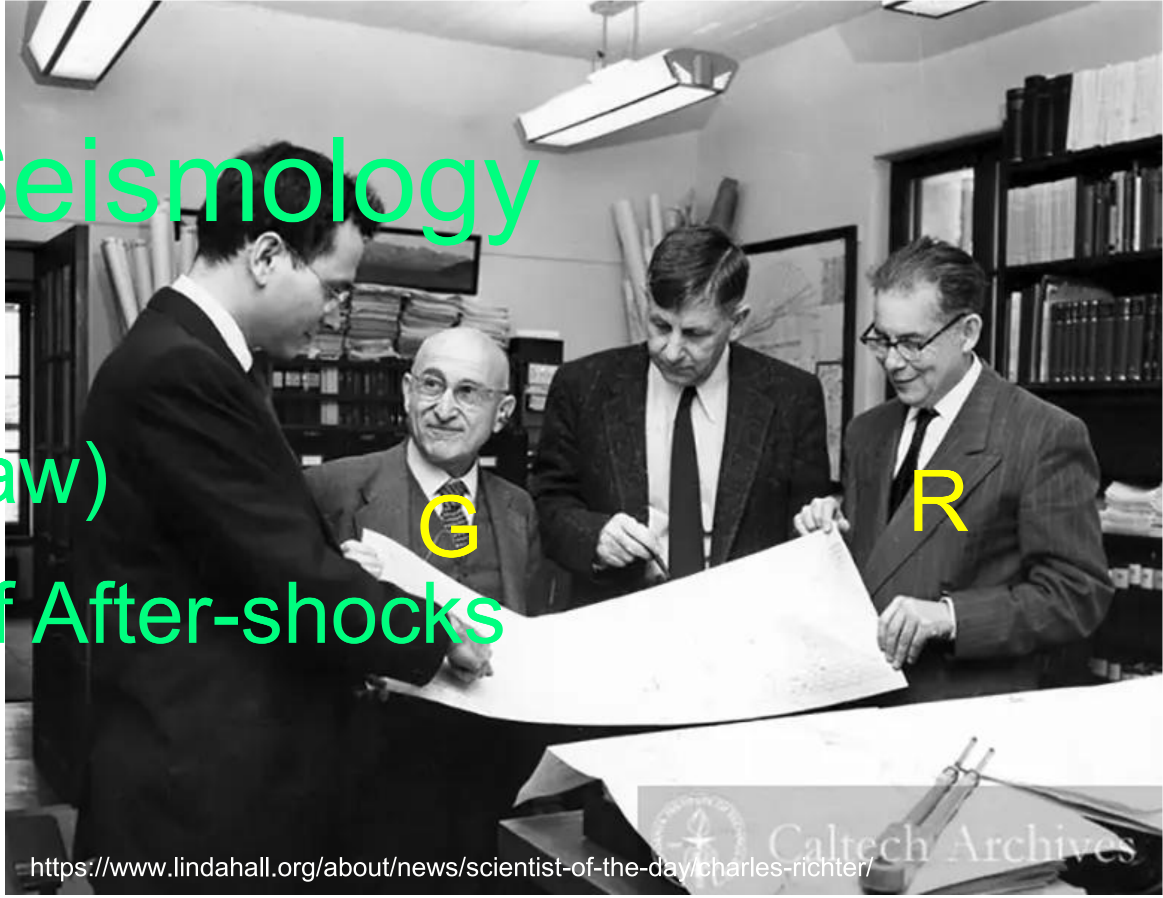
$Mw \approx \mathbf{6.8}$

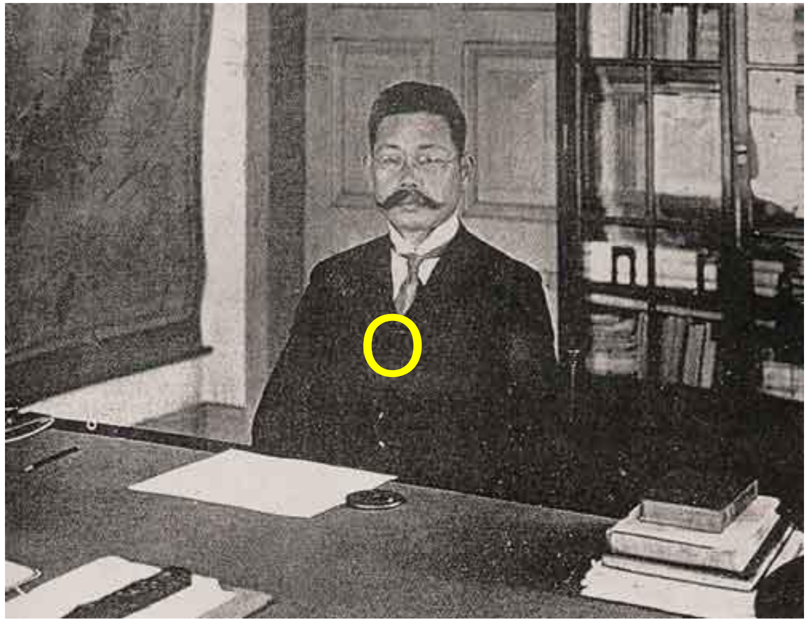
From the Statistics; my idea!

- Statistics are sometimes boring!
- But it is essential in seismology
- With the help of *Santi Pailoplee and Punya Charusiri* (2016) suggestion, I will try to use the statistics to estimate the maximum magnitude in northern Thailand.
- There are two famous empirical laws

Two Empirical Laws in Seismology

- G-R Law (Gutenberg-Richter's Law)
- Omori Law: Exponential Decay of After-shocks





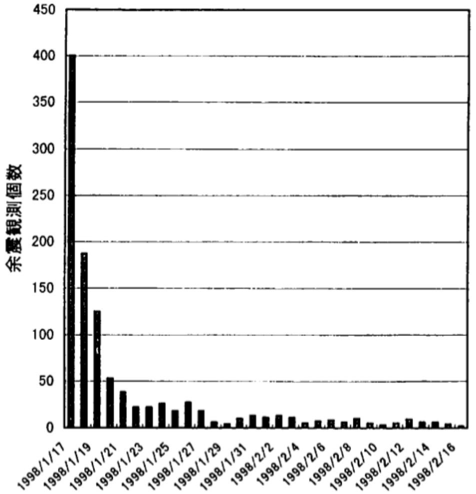
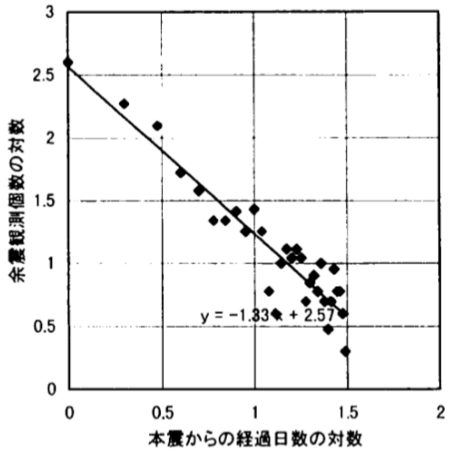


図1　表1のデータをグラフに示したもの（2／18以降は省略）



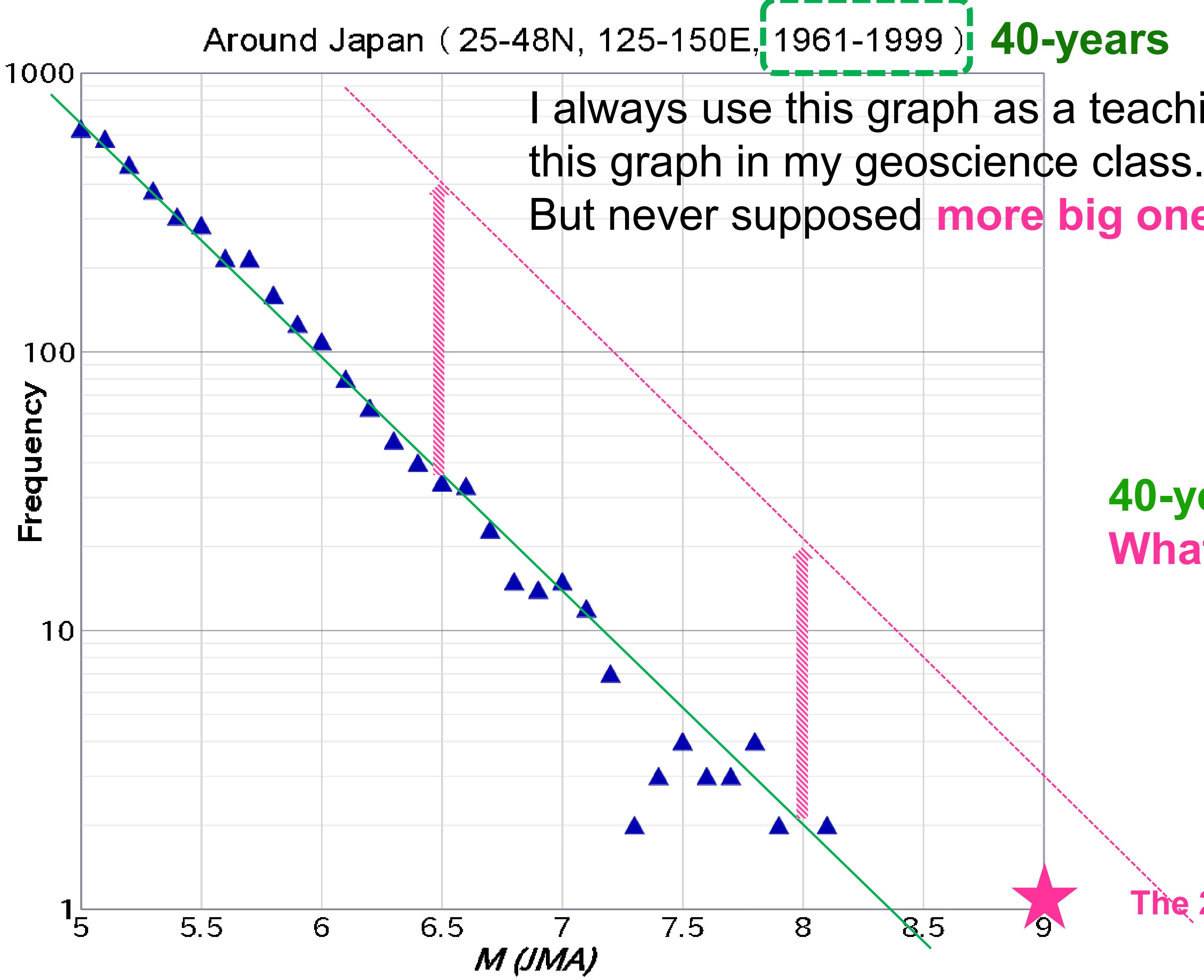
Okamoto,1999

図2　図1のグラフの両軸を対数に代えたもの

The Gutenberg-Richter's Law

- Earthquake-size: Magnitude(Size)
- Number of earthquakes (Frequency)

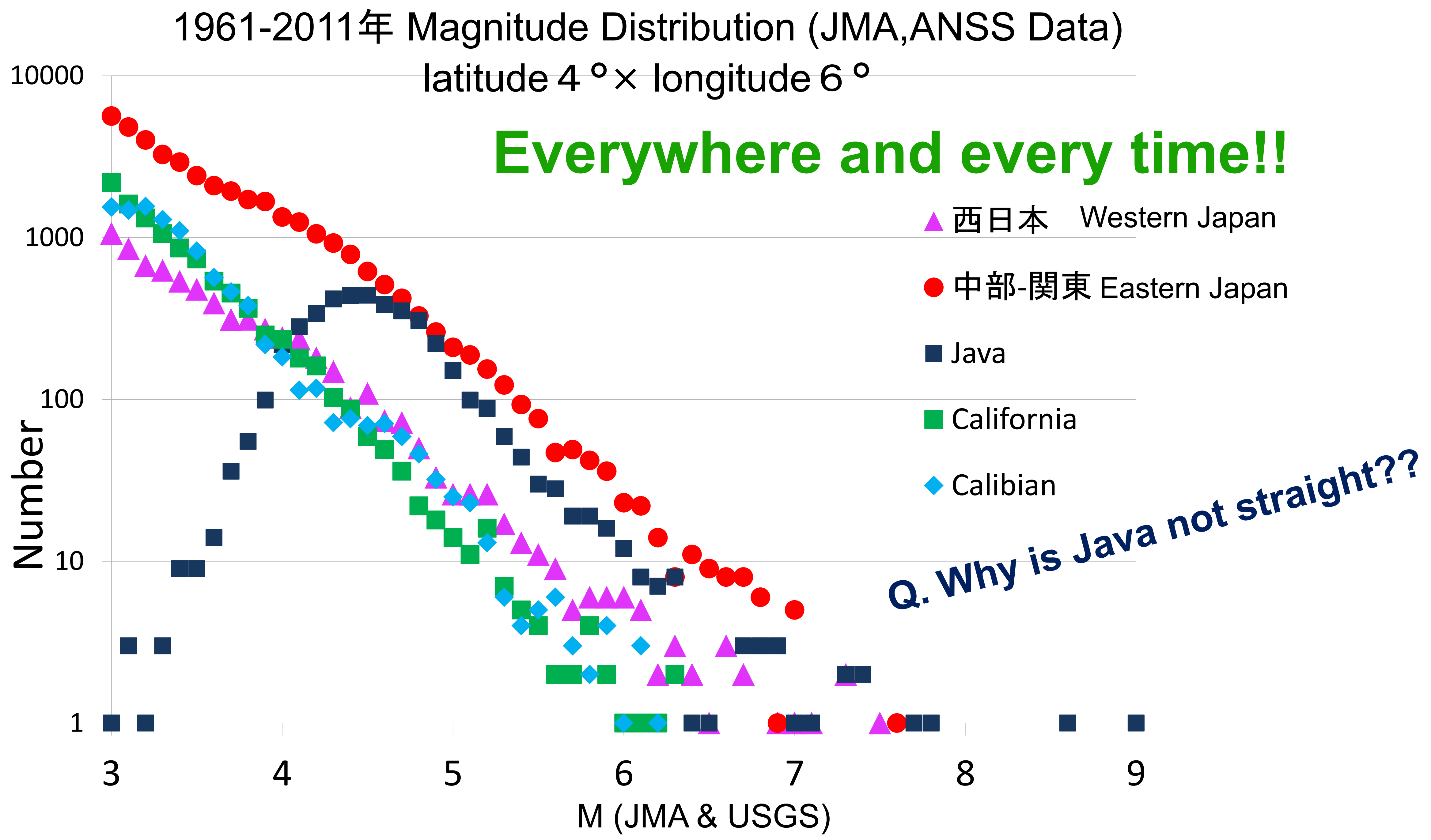
- The most important statistical Law in Seismology



I always use this graph as a teaching tool. My students plot this graph in my geoscience class.
But never supposed **more big one** would come soon after!!

40-years -> 400 years
What happen?

The 2011 Tohoku-Oki Earthquake!!


1961-2011年 Magnitude Distribution (JMA,ANSS Data)
latitude 4 °× longitude 6 °
Everywhere and every time!!
西日本 Western Japan
中部-関東 Eastern Japan
Java
California
Calibian
Q. Why is Java not straight??
10000
1000
100
10
1
Number
3
4
5
6
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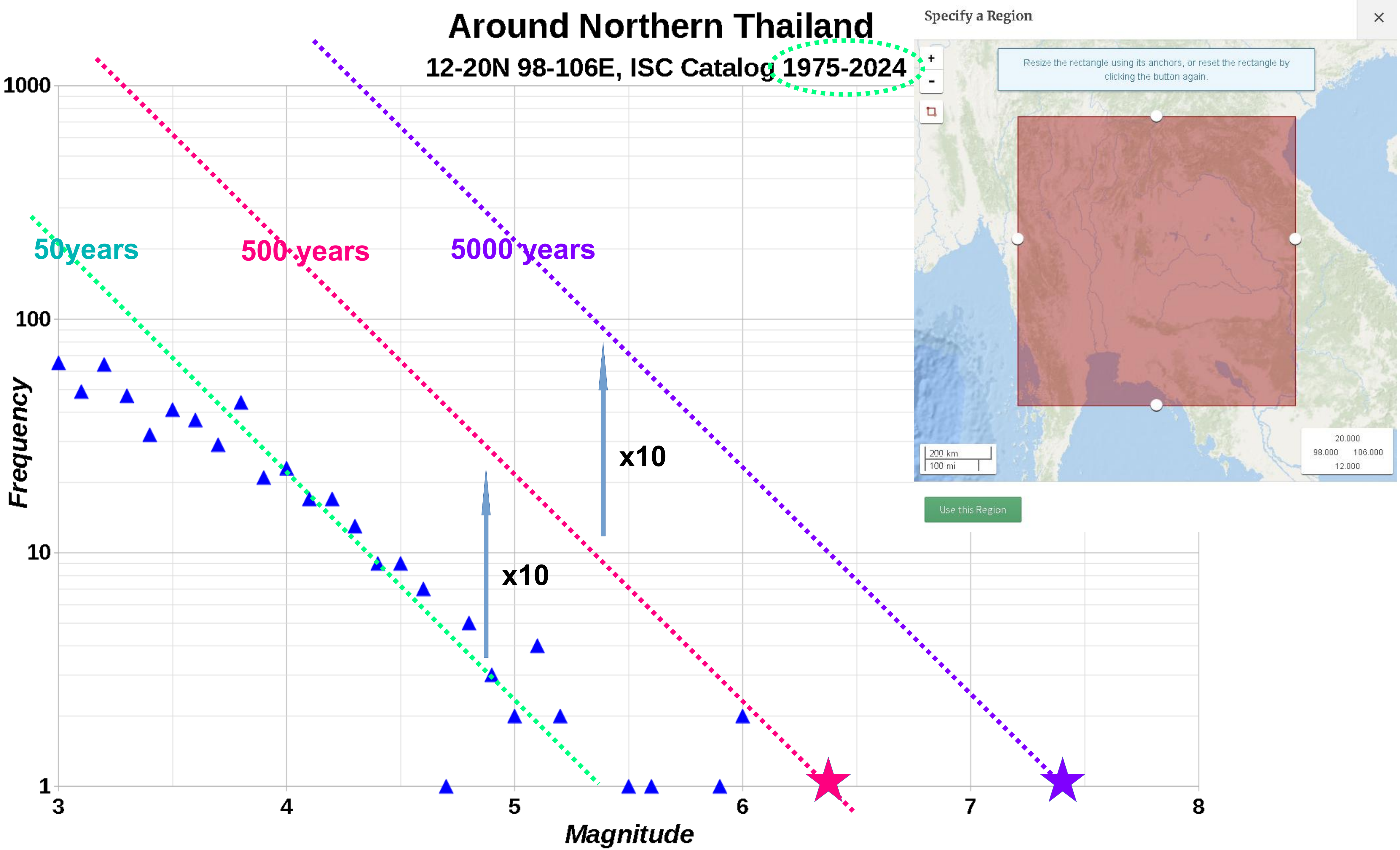
8
9
M (JMA & USGS)

Around Northern Thailand

12-20N 98-106E, ISC Catalog 1975-2024



Conclusion

- **In Thailand, especially in Northern Thailand, the potential for big future earthquakes is not so small.**
- **However, the day of these events can not be forecasted at our present scientific level.**
- **Also, the Paleo Seismology has just kicked off in Thailand.**
- **So, I hope some students will challenge to study this area.**
- **Also, I hope the next event will not cause heavy damage in your country.**

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Question and Answer Time!