Possible Mega-thrust earthquake along the Ryukyu trench:

event the historical data can't tell

Kuo-Fong Ma

馬國鳳 教授

Department of Earth Sciences,
National Central University

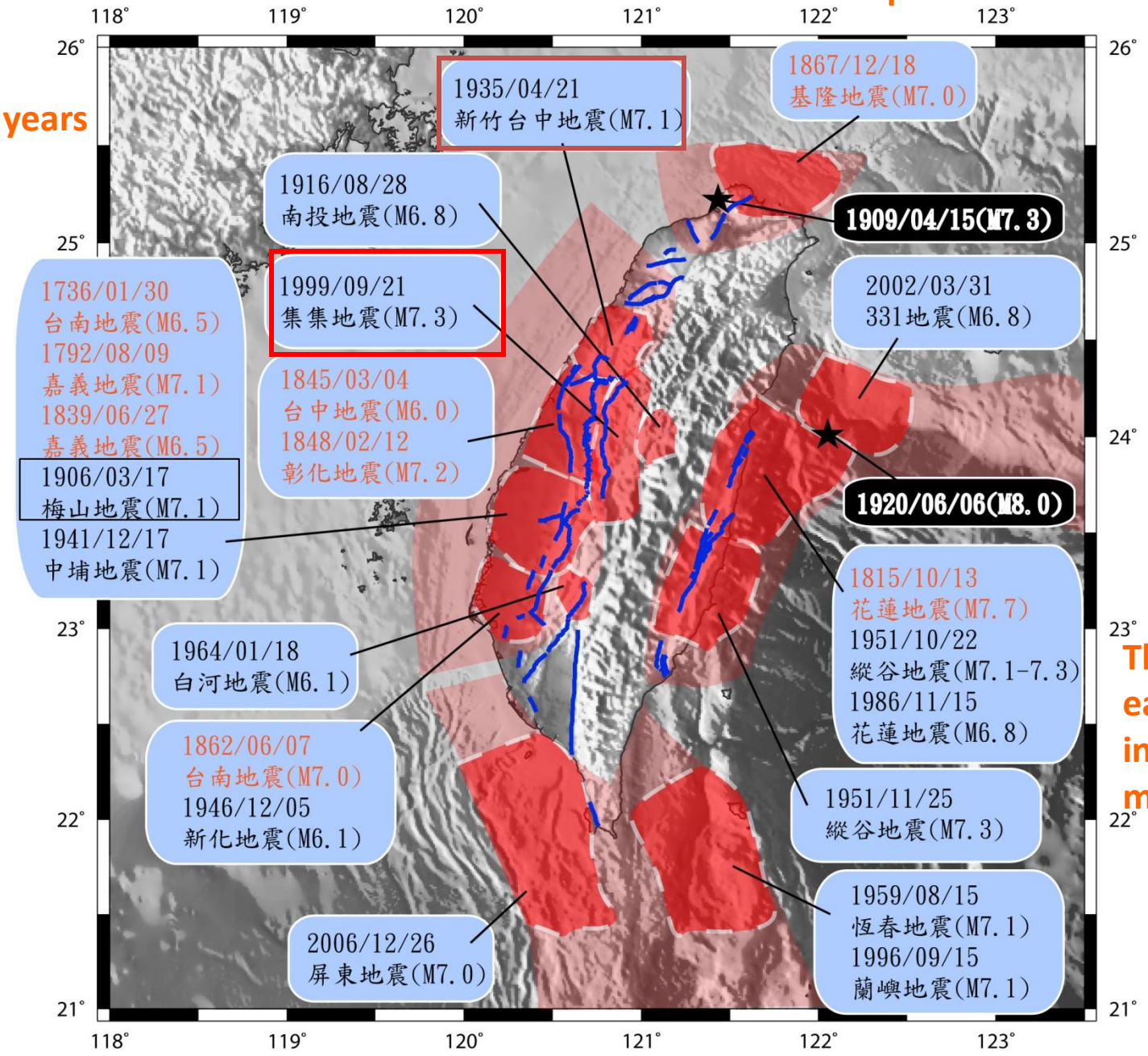
中央大學地球物理研究所

Damaging Earthquakes in Taiwan since 1700s

Relative quiet in seismicity

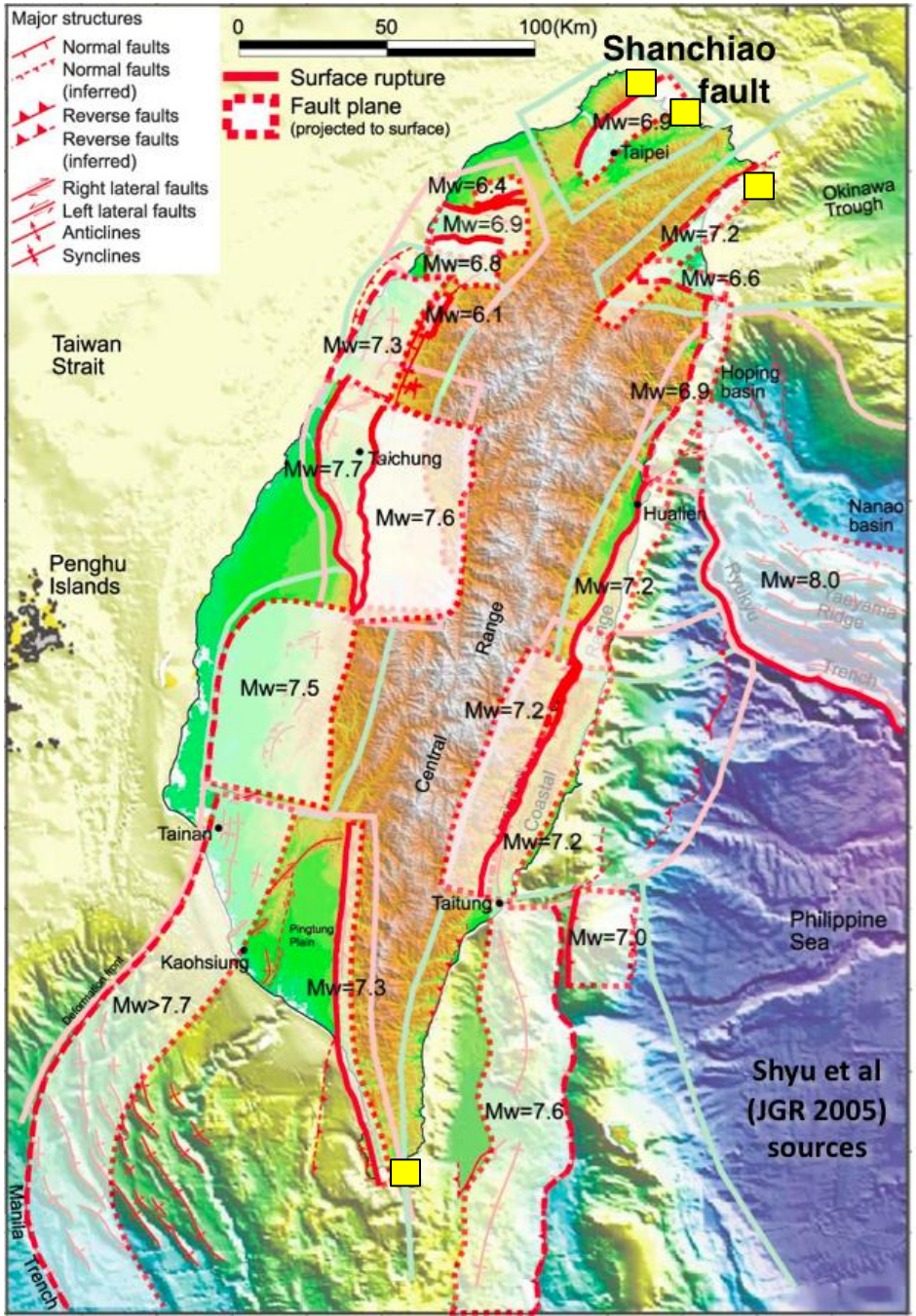
M>7 inland earthquake ~ every 100 years

Western Taiwan ~every 30-40 years



Three M>7 earthquakes in two months

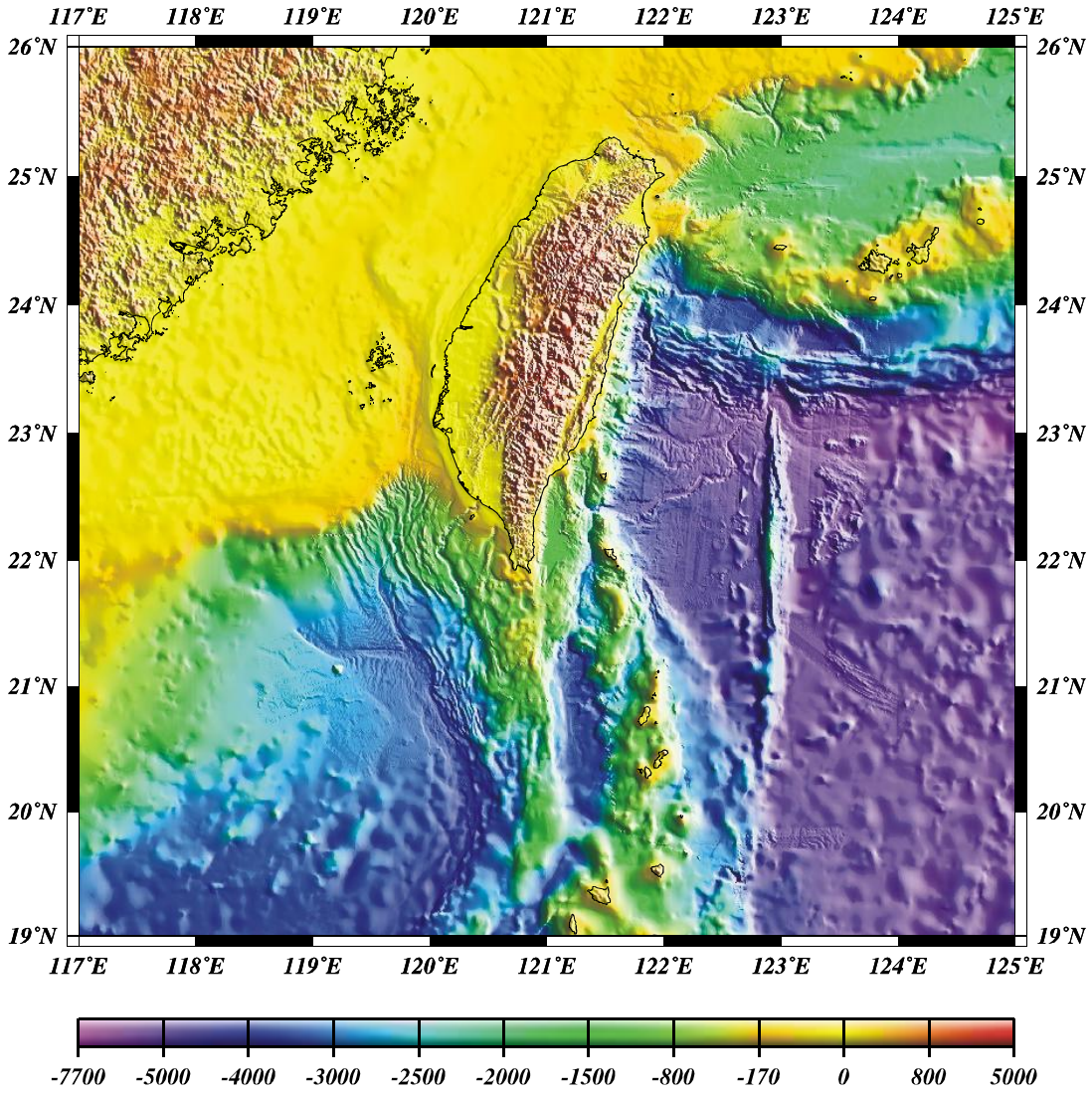
Earthquake Source Model

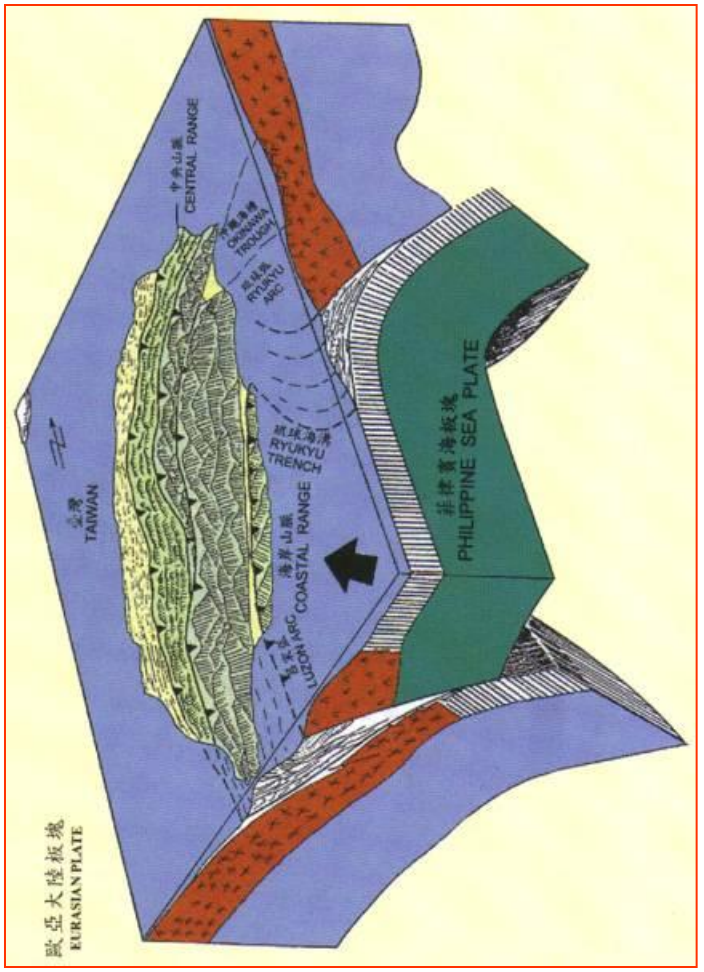


- Subduction Zone Earthquake
- Inter- and Intra-slab events
- Study of Historical Earthquakes
  - 1909 Taipei M6.8 Earthquake
  - 1920 Hualian M8.0 Earthquake

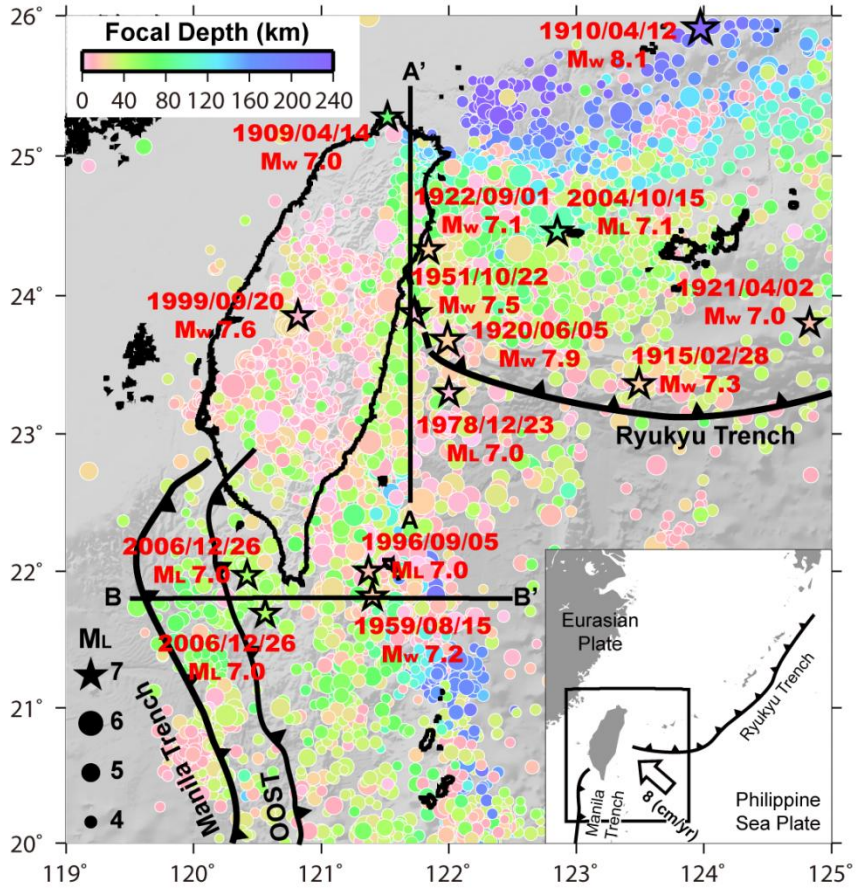
Historical Earthquakes
-Location, Magnitude
(Documents)
-Focal Mechanism
(Historical records)
-Earthquake and Tsunami Potential
(Ground Motion Prediction, Tsunami Simulation)

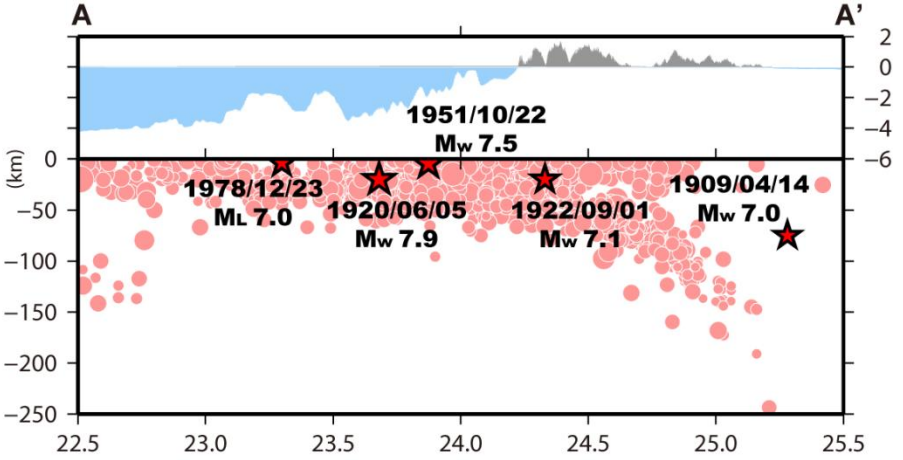
Bathymetry and Tectonic Setting near Taiwan

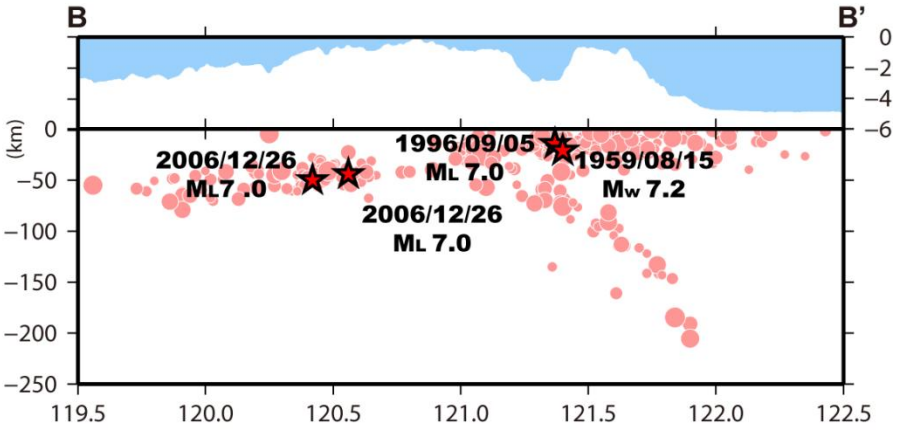


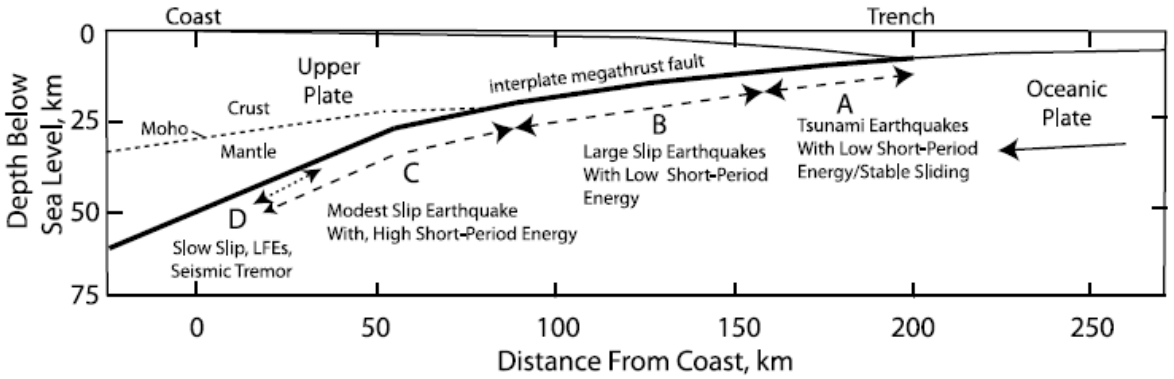


Seismicity M>5.0 earthquakes with historical M>7.0 earthquake since 1900



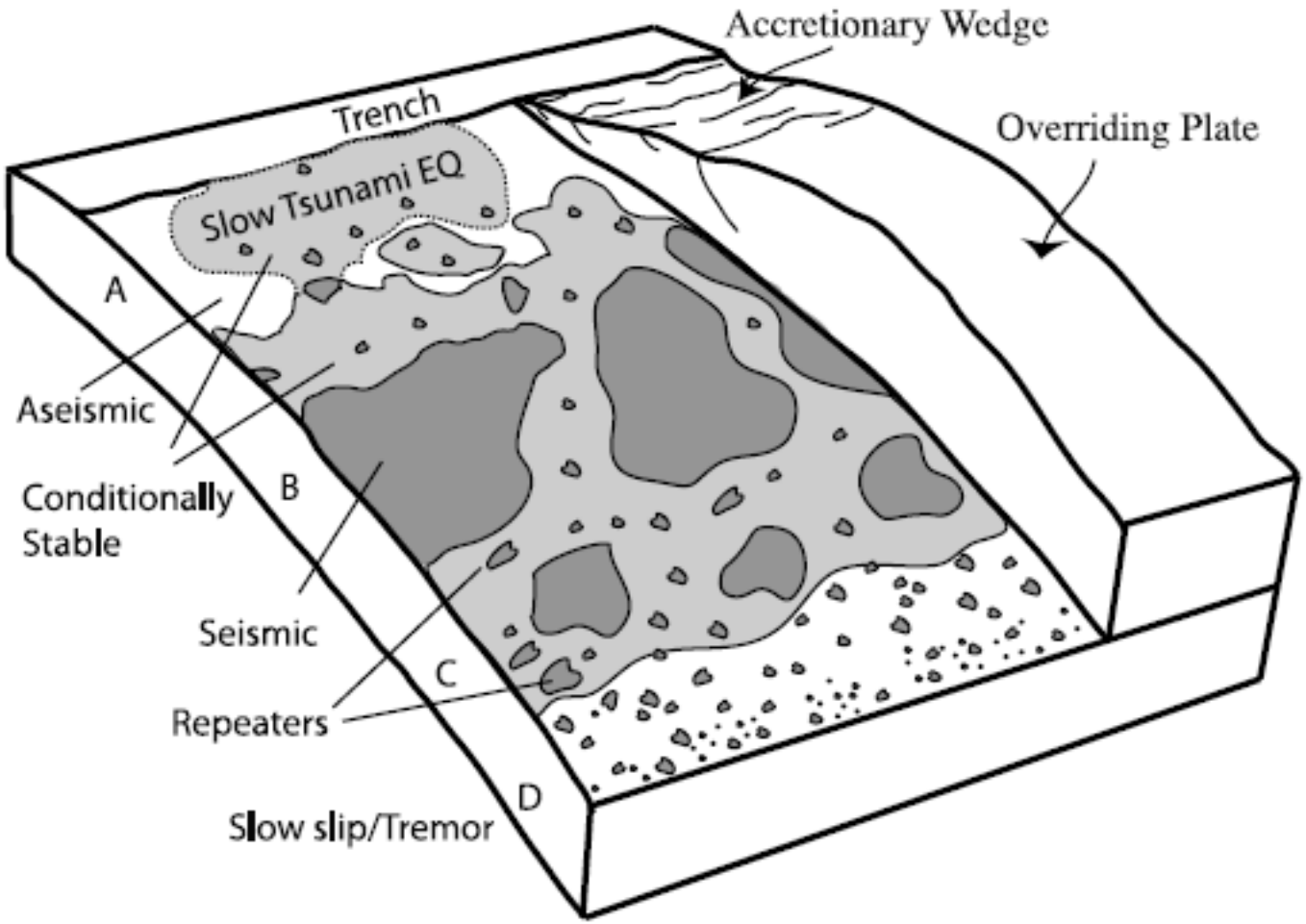






Lay et al. (2011)

Ryukyu and Manila subduction behave similarly as this model?
Possible trench ruptured mega-thrust events?
No long historical data to tell.
(Historical literature records of only about 300 years.)

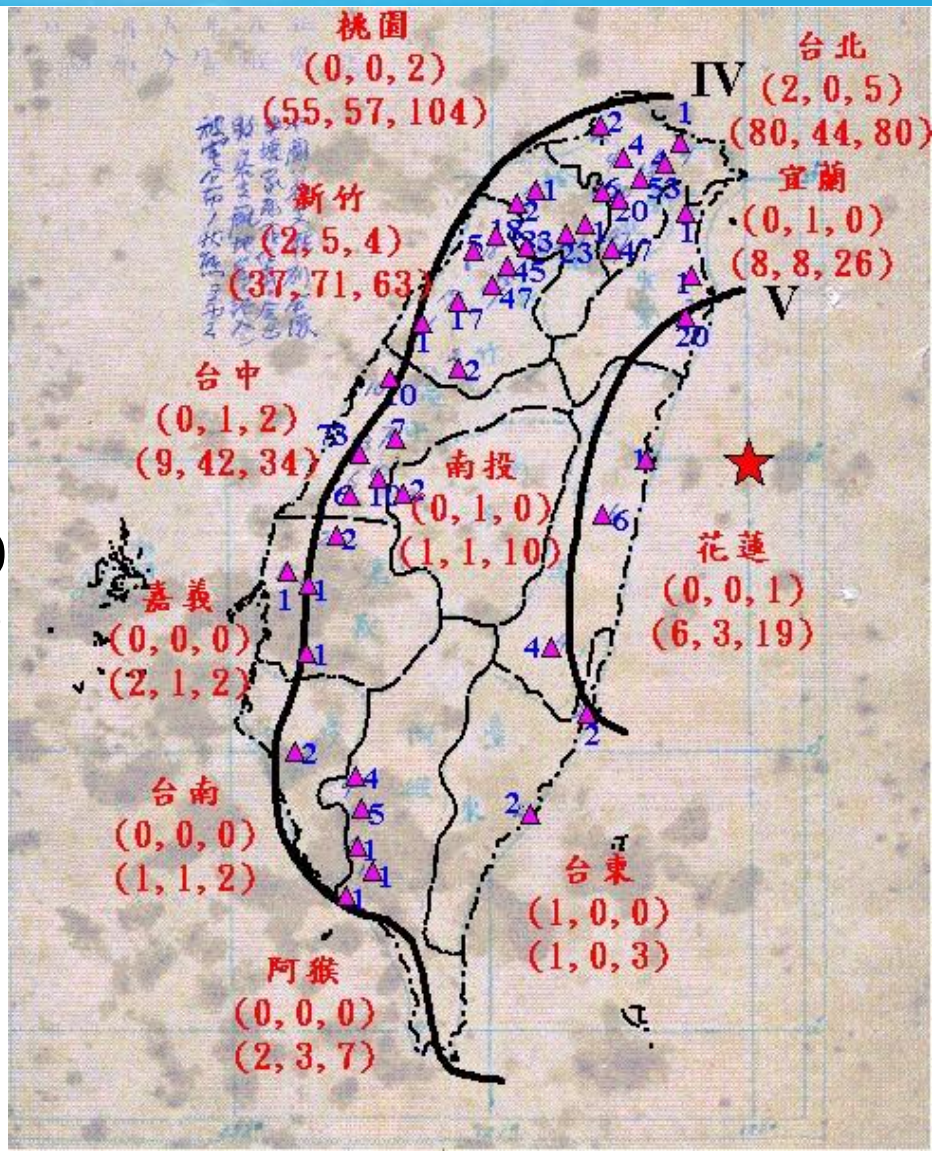


The 1920 Hualien Earthquake

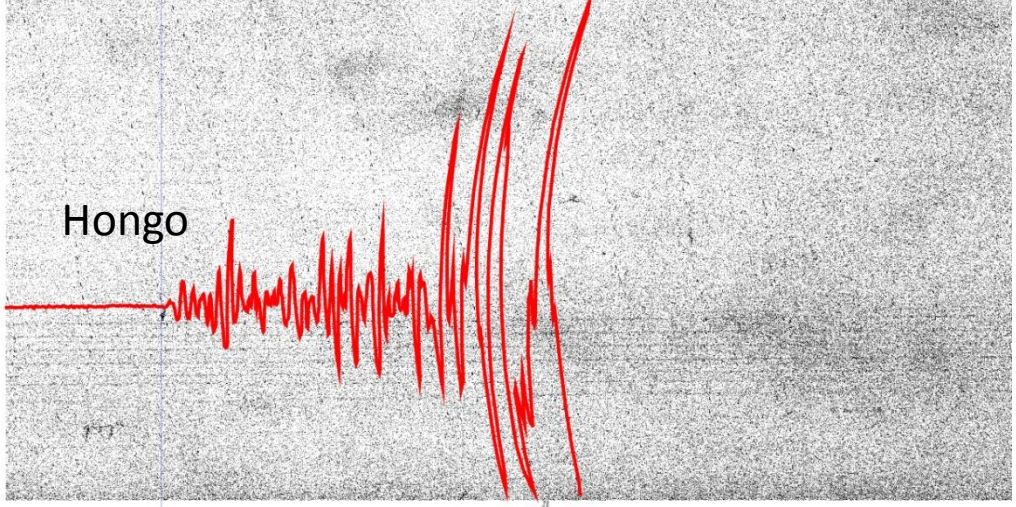
1920 Hualien Earthquake

- 12:21 on June 6, 1920
- Location:24°N, 122°E, Dep=20 km
- Magnitude

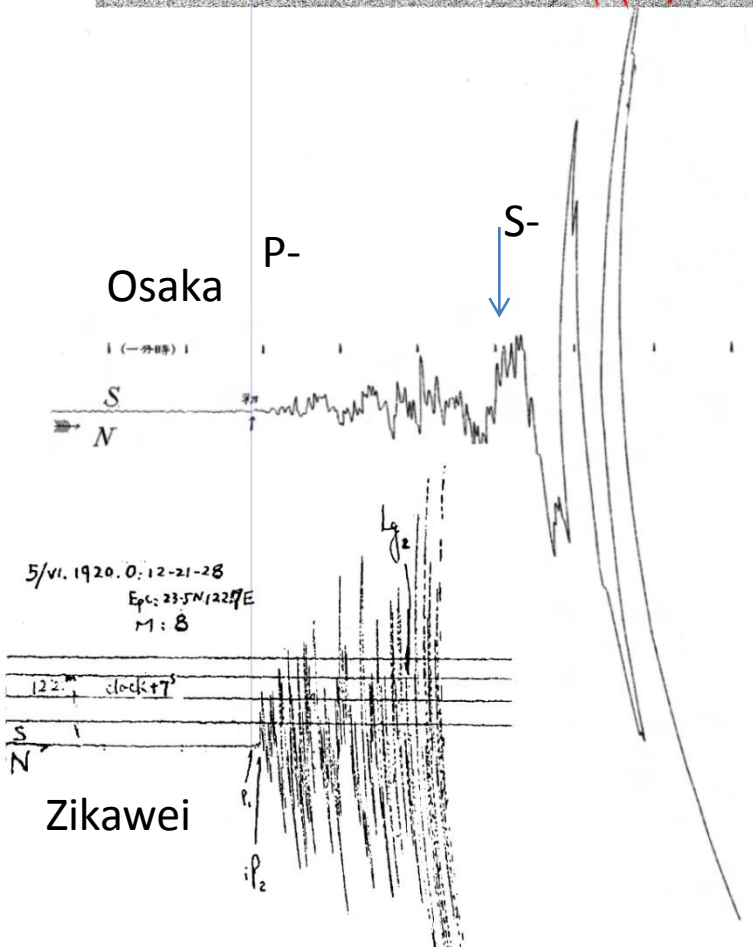
M_{GR}=8.0(Gutenberg and Richter,1954)
M_S=8.0(Abe,1981,1984, Lee et al.1978
M=8.3(Bath and Duda, 1979)
M_H=8.3(Hsu, 1971,1979, 1980, 1989)
M_L=8.0(Cheng et al., 1996)
M_L=7.5, M_W=8.0(Cheng et al., 2010)

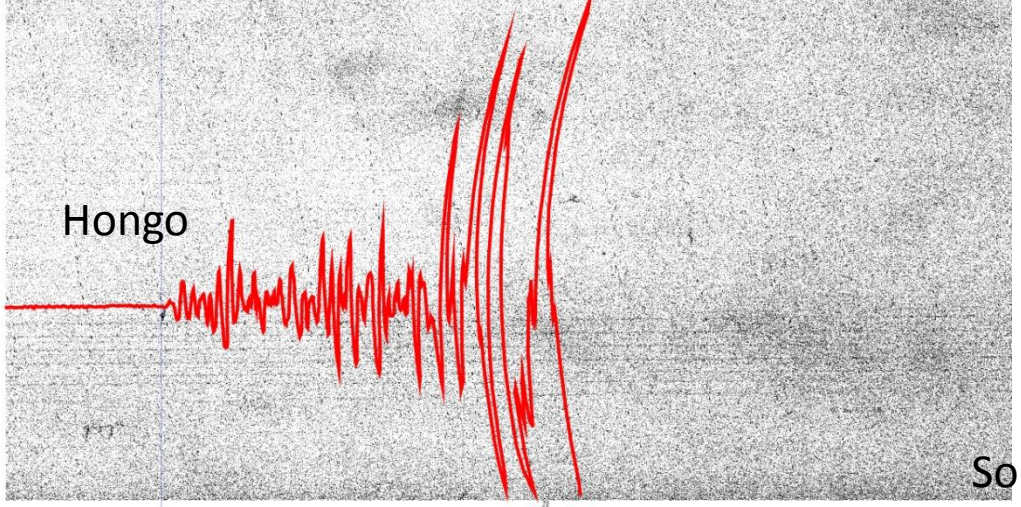


(鄭世楠)

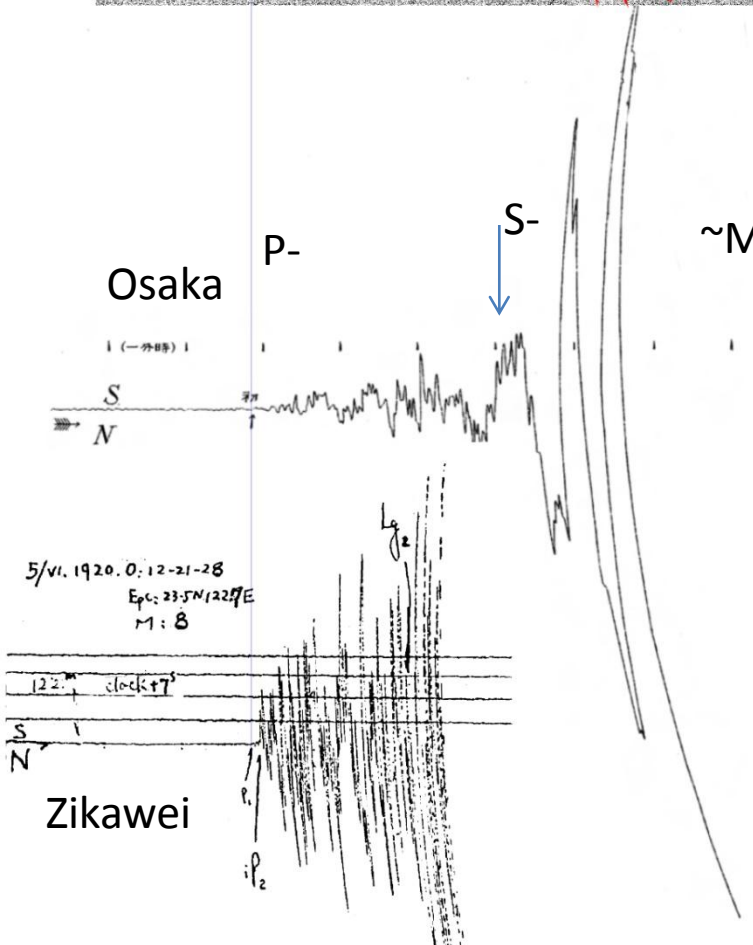


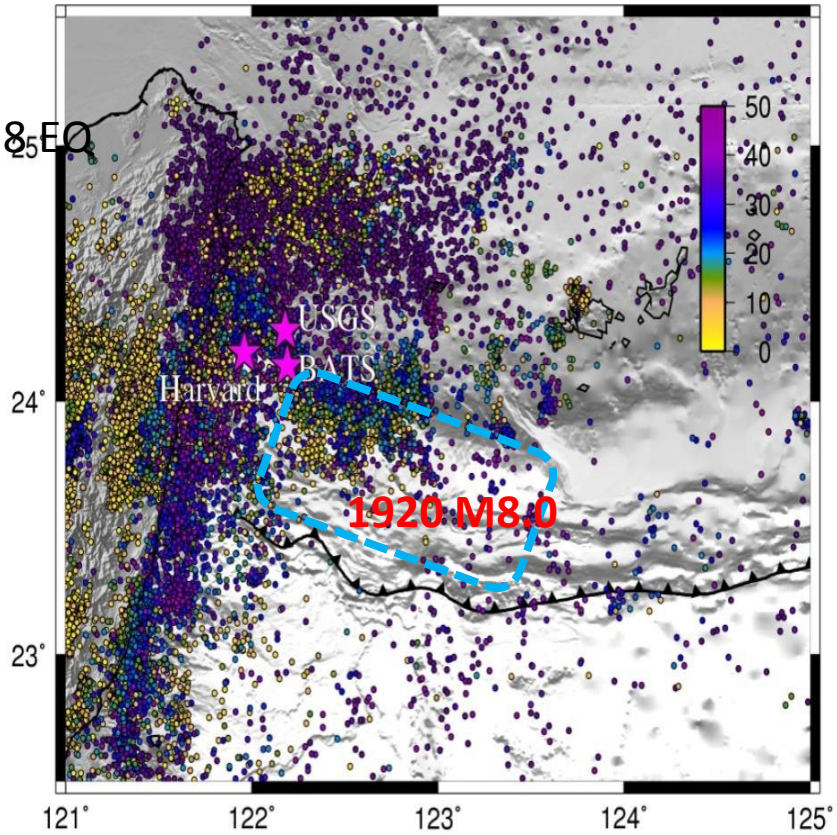
Source Duration ~ 120sec
Rupture for about 300km





Source Duration ~ 120sec ?
Rupture for about 300km





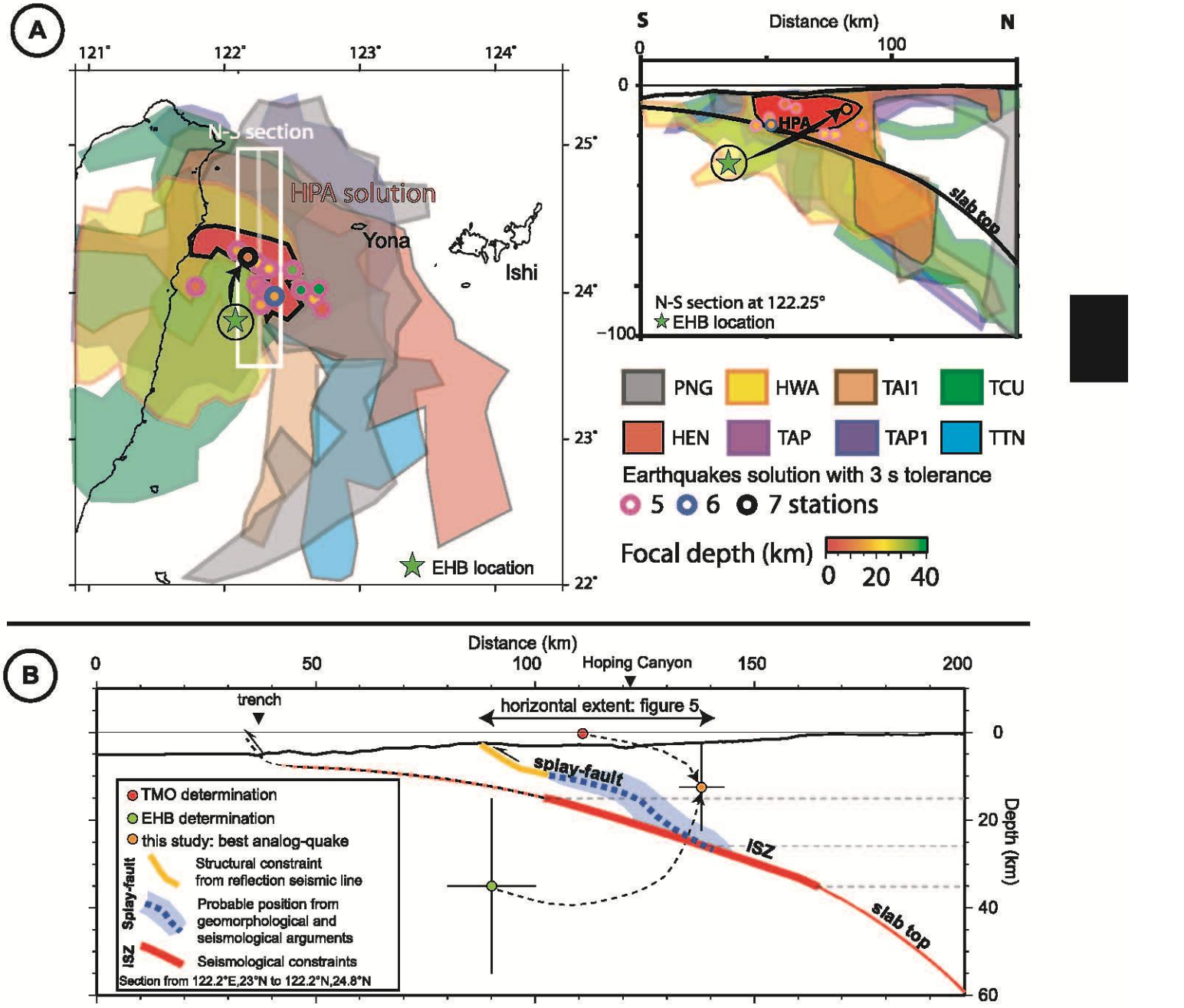


Figure 4. (a) Determination of the high probability area (HPA) where the M'_W 7.7 1920 earthquake occurred and (b) location of the best analogue-quake from Font *et al.* (2004) compared to the position of the ISZ and the possible splay fault. The tolerance for each envelope is ± 3 s (see text for more details). The best '1920 analogue-quake' (1994/10/09) solution is unique. Other earthquakes are selected with the same maximum 3 s tolerance on SP_{RES} but with less correlated stations. The area defined in surface is more extended than in section because all envelopes do not cross in depth to the north. The slab top is built

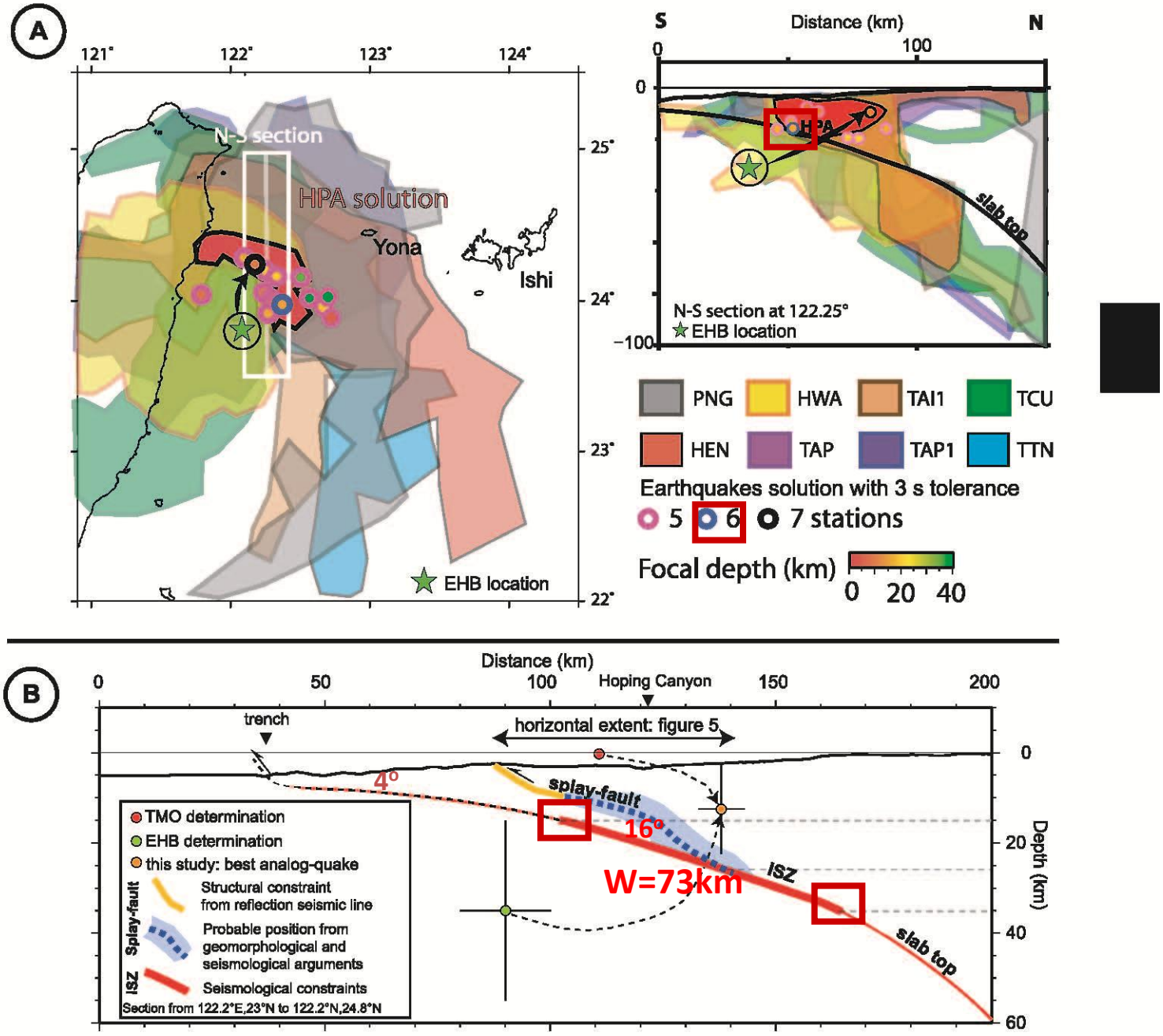


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Scaling using AREA

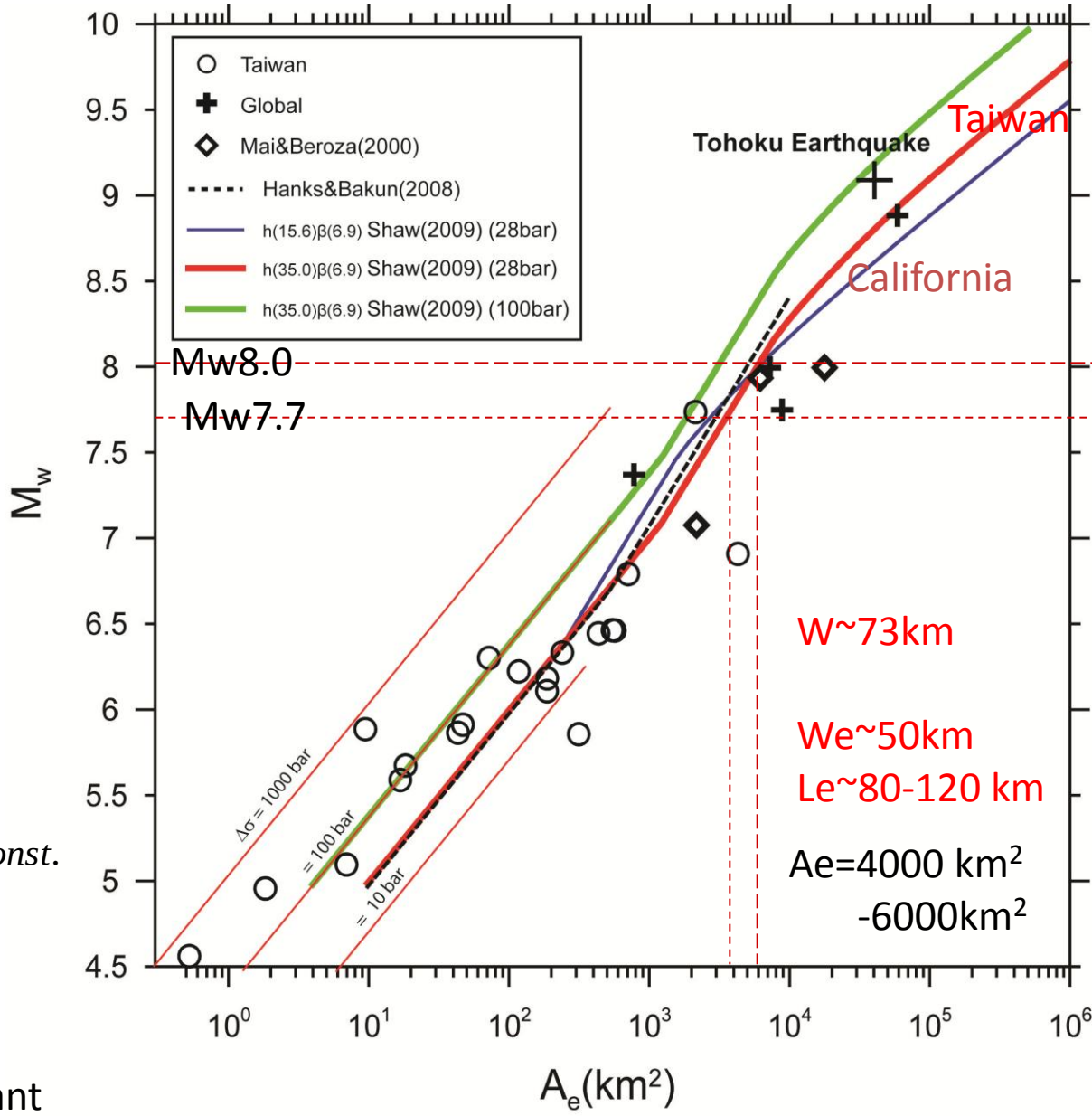
h : seimogenic depth
β: scaling parameter related to the effective fault width

- Small-Moderate earthquakes
  Mw ~ LogA
- Large earthquakes
  Mw ~ 4/3logA
- Extra largest earthquakes
  Mw ~ 2/3logA

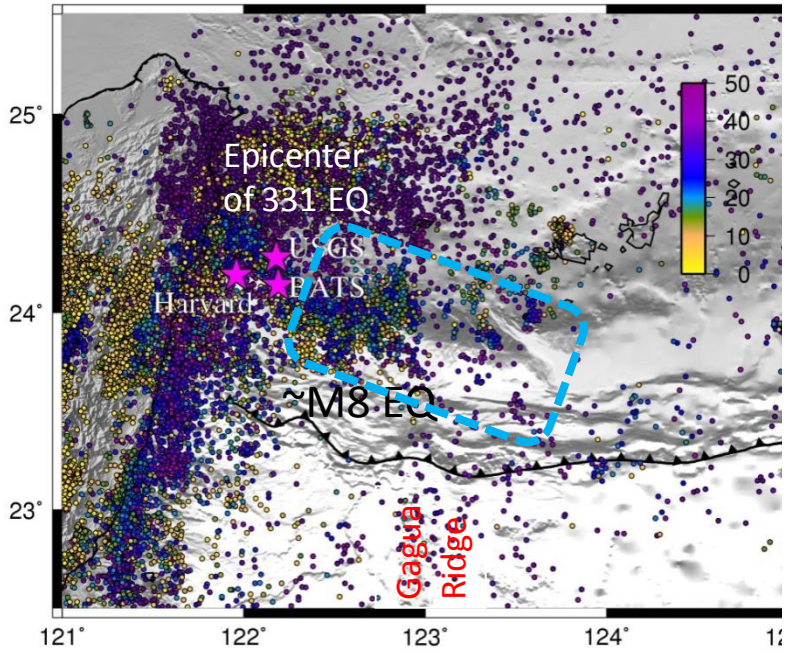
$$M = \log A + \frac{2}{3}\log \frac{\max(1, \sqrt{\frac{A}{H^2}})}{[1 + \max(1, \frac{A}{H^2\beta})]/2} + const.$$

(Shaw, 2009)

Const.: Stress drop related constant

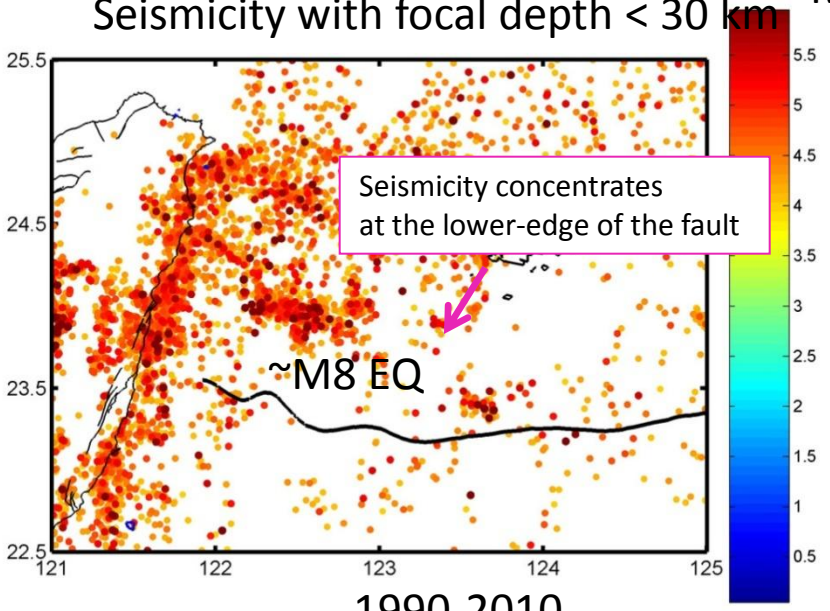


(Yen and Ma, 2011)



Seismicity with focal depth < 30 km

M_L



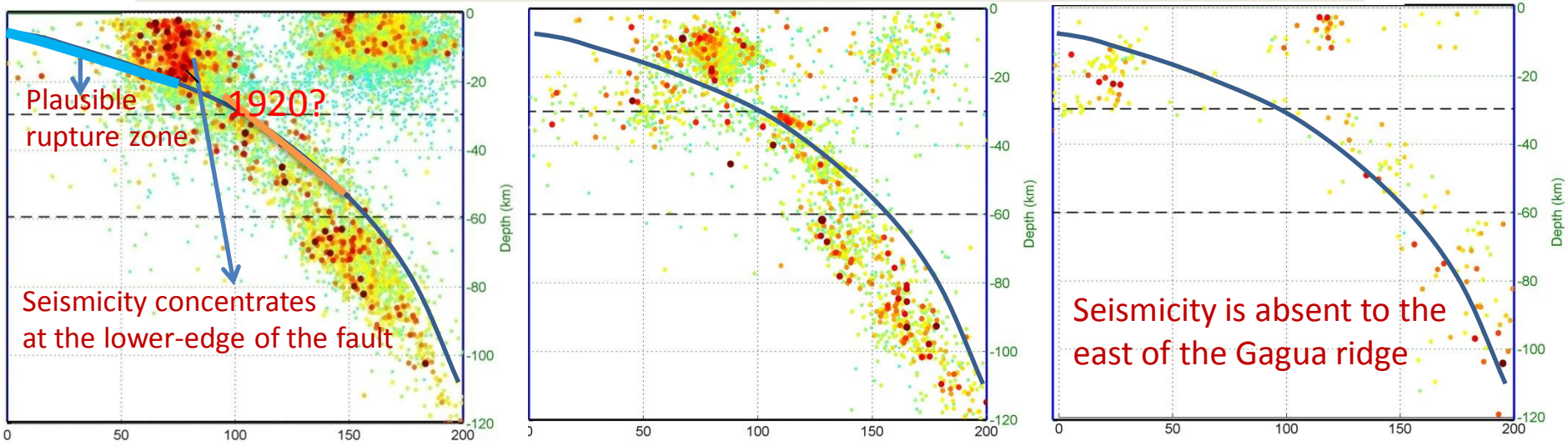
1990-2010

Yaru Hsu (personal communication)

122.5° E

123° E

124° E



Distance from trench (km)

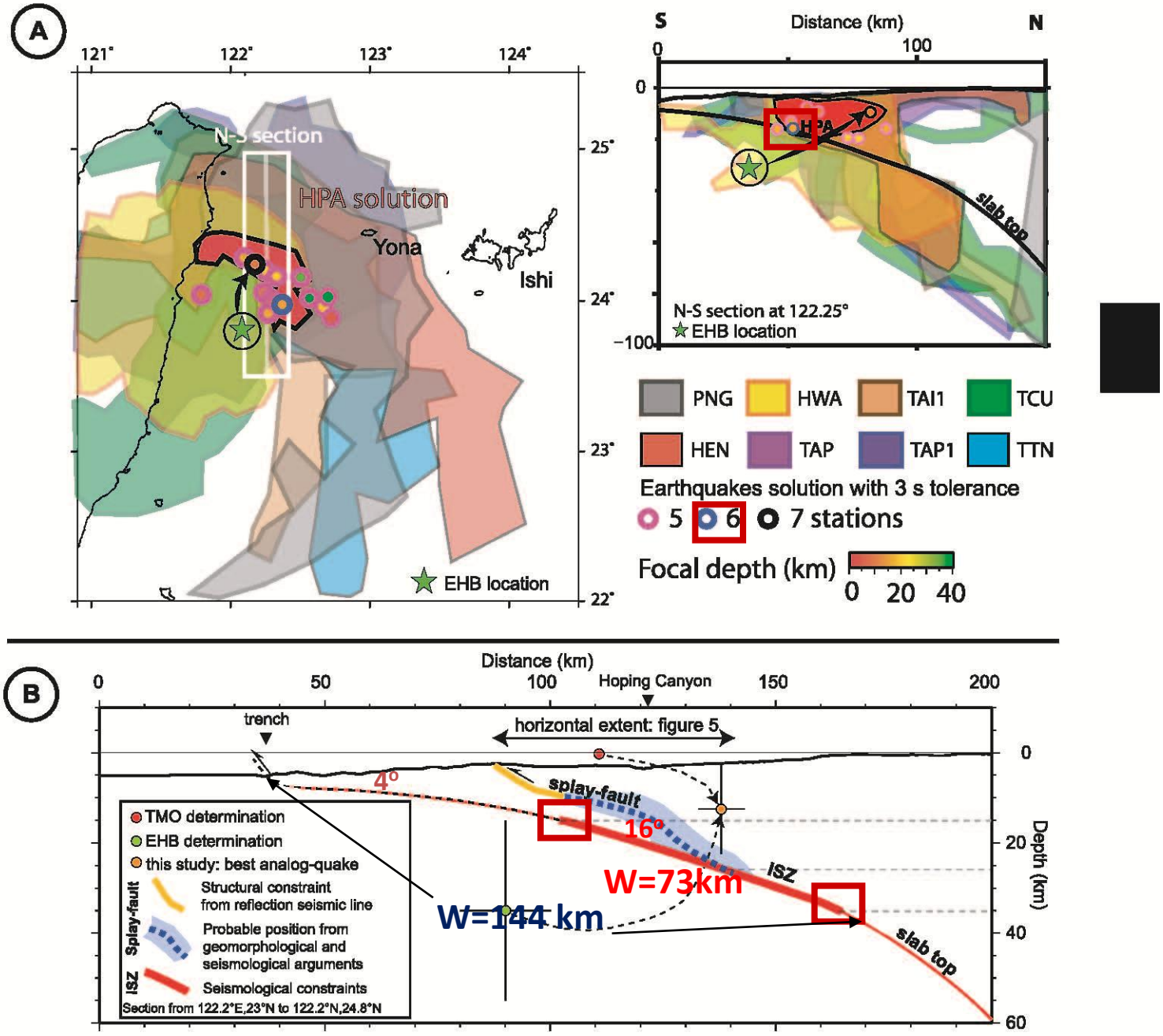


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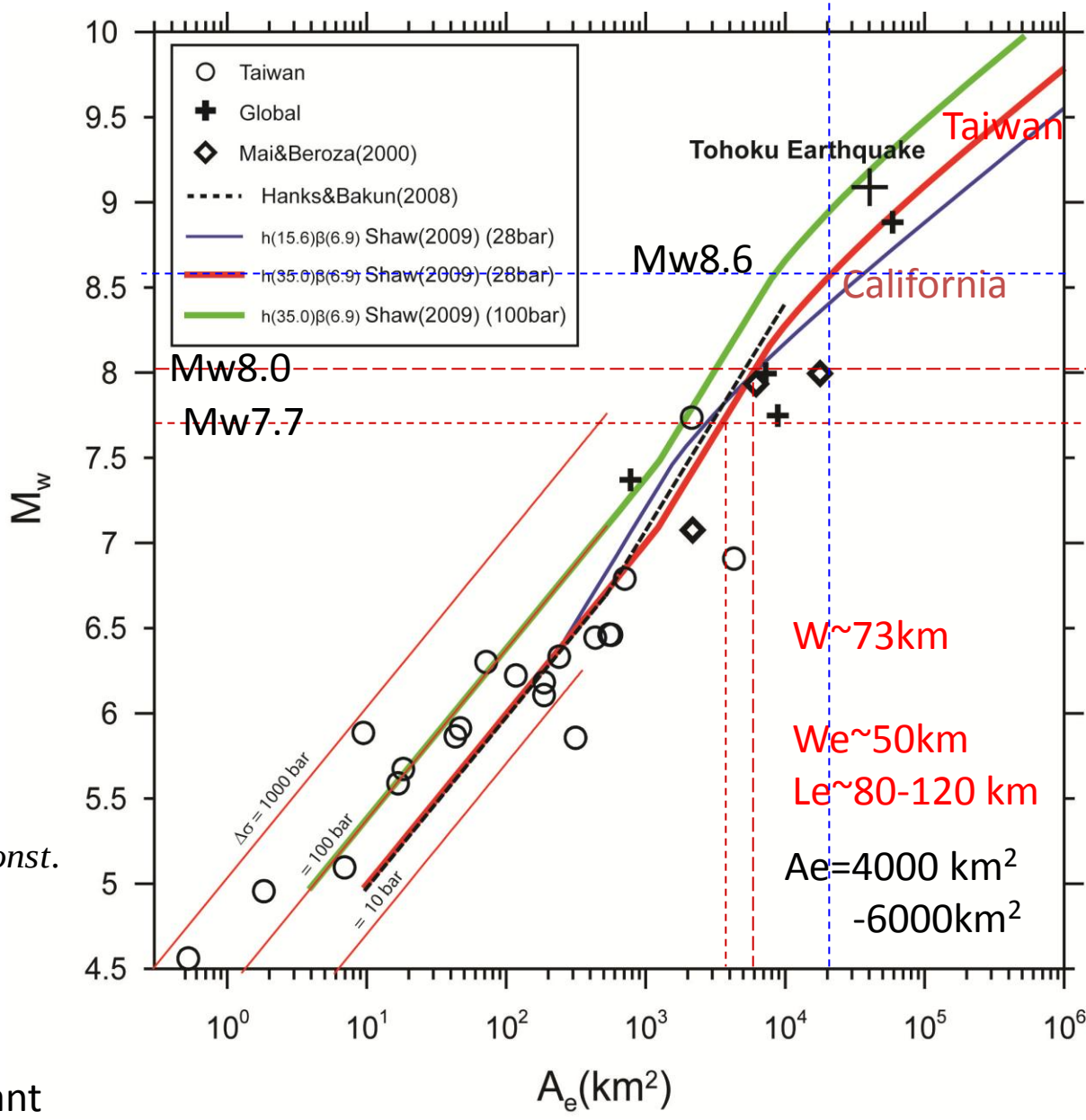
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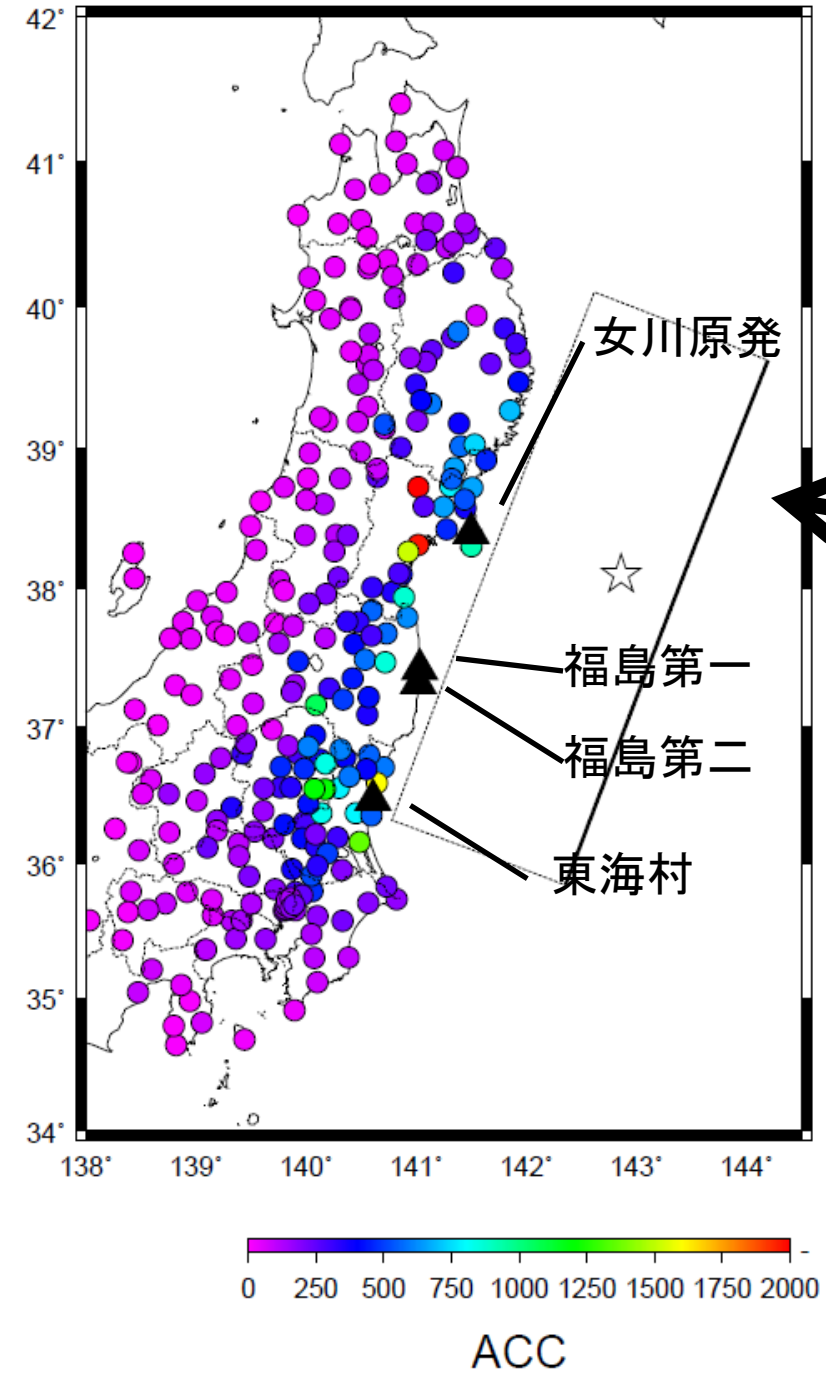
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(Shaw, 2009)

Const.: Stress drop related constant





断層最短距離

福島第一原子力発電所：46.1km ：550gal

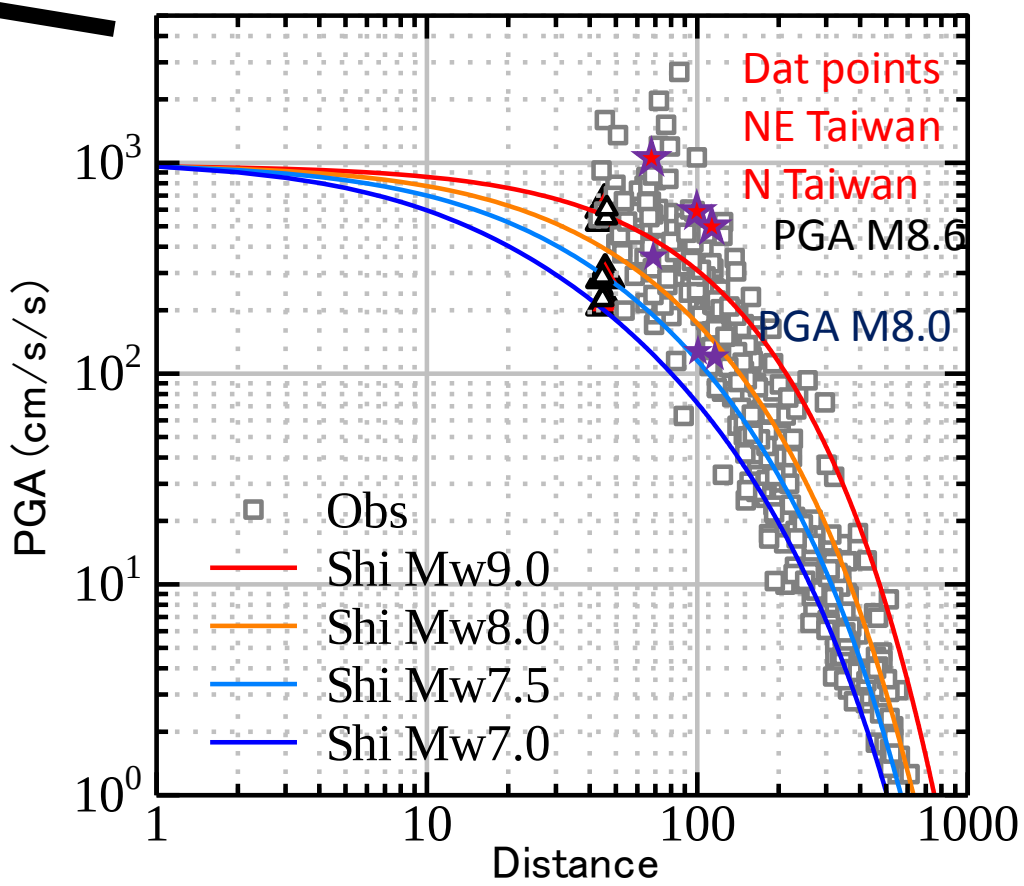
福島第二原子力発電所：44.5km ：288gal

女川原子力発電所：46.3km ：607gal

東海第二発電所：44.6km ：225.4gal

2011/03/11 14:46 Mw9.0

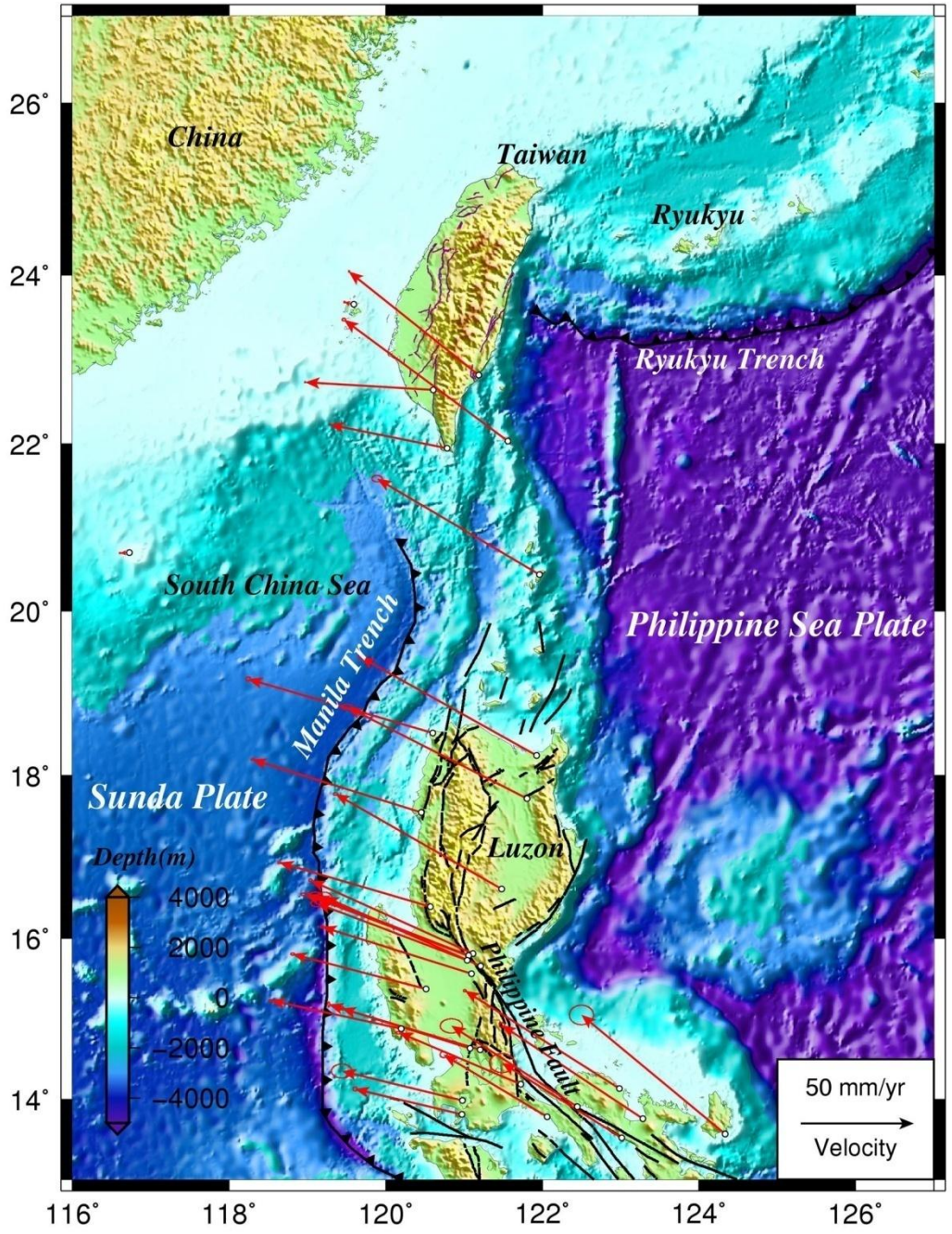
Str: 201 Dip:9 23.7km



Manila Trech
Tectonic setting

GPS horizontal velocity w.r.t the Sunda Plate gradually decrease from north to south along the western Luzon at rates of 81 to 50 mm/yr in the west-northwest direction.

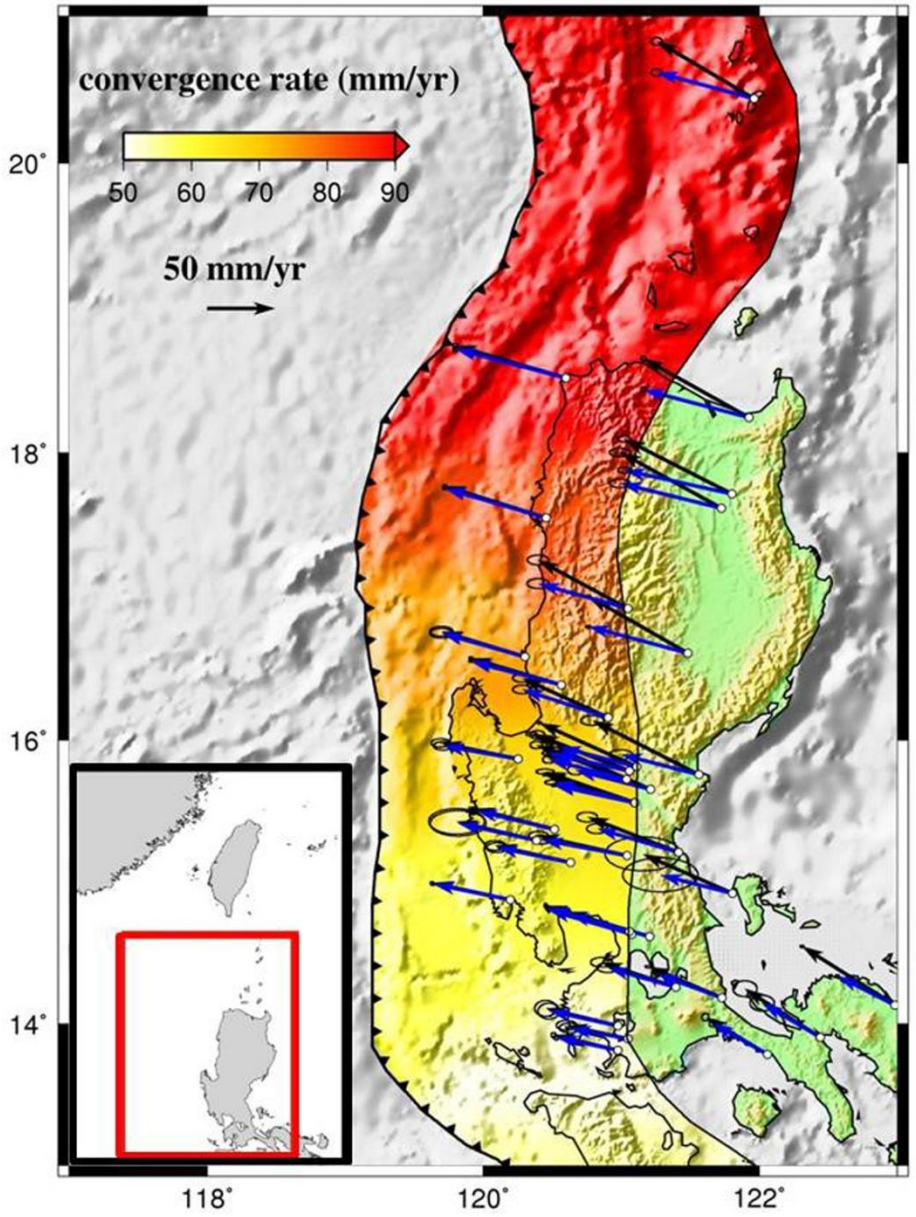
(1996-2008)



Convergence rate along the Manila Trench

Velocities w.r.t to the Sunda Plate

The fault locking effect on the Philippine Fault is removed from GPS velocity field (Yu *et al.* 2010)



- GPS horizontal velocities decrease from north to south suggesting a southward decrease of convergence rate along the Manila Trench .

Historical Tsunami=>
Paleo-tsunami Studies (古海嘯)

時間	地點	出處	描述	備註
1781年4、5月間	高雄、屏東	台灣采訪冊「祥異。地震」	「鳳港西里有加藤港，……乾隆四十六（1781）年四、五月間，時甚晴霽，忽海水暴吼如雷，巨湧排空，水漲數十丈，近村人居被淹，皆攀援而上至尾，自分必死，不數刻，水暴退，人在竹上搖曳呼救，有強力者一躍至地，兼救他人，互相引援而下。間有牧地甚廣及附近田園溝壑，悉是魚蝦，撥刺跳躍，十里內村民提籃挈筒，往爭取焉。……漁者乘筏從竹上過，遠望其家已成巨浸，至水汐時，茅屋數椽，已無有矣。	文中提海水退卻及第二海嘯波，深具科學意義。由內文描述可了解第一海嘯波波高約3m，第二海嘯波約4-5m，與情境分析雷同，可信度高。

Field Studies: 相關地點調查結果

From: Prof. T.R. Wu's student, Mr. Tsai

- 東隆宮
- 鎮海宮
- 鎮海公園
- 嘉蓮宮
- 南隆宮

1781 ?

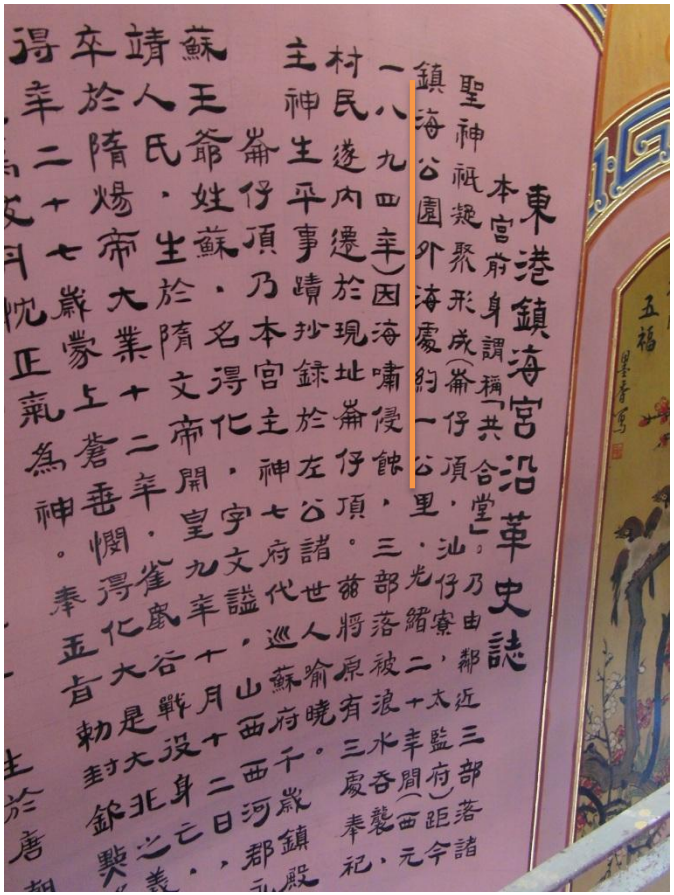
1894

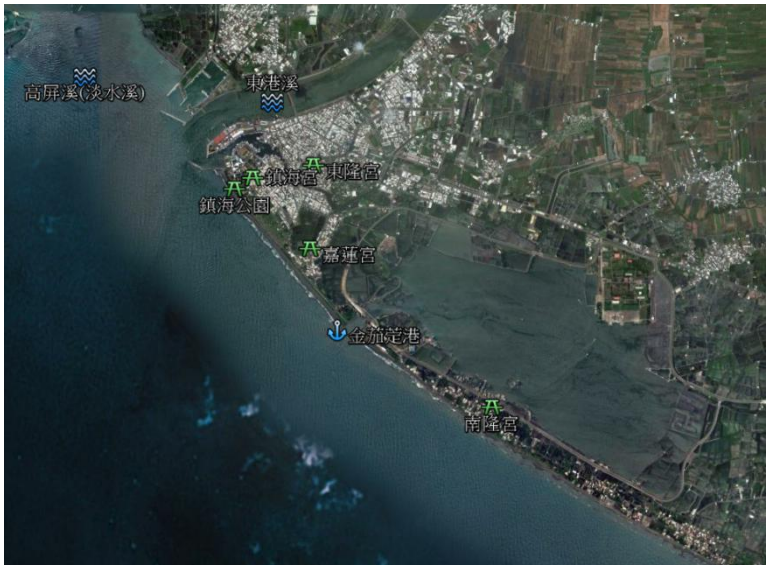


鎮海宮

- 崙仔頂(鎮海宮)、汕仔寮、太監府(東隆宮)三個村落在1894年遭海嘯襲擊，盡沉海底。
- What happened in 1894?







圖片來源：鎮海宮沿革史誌

Conclusions

- Earthquake Scaling on Length, Width and Slip for Ground Motion Prediction Simulation is useful for crustal events, however, width extension of the Subduction zone events needs to be addressed differently.

  But, how? What is the Mmax of a subduction zone?

- How to deal with extreme event which was not yet occurred? e.g. 1920 M8.0 Hualiean earthquake => rupture to the trench

- How to implement this historical not yet occurred event into PSHA or SHA?

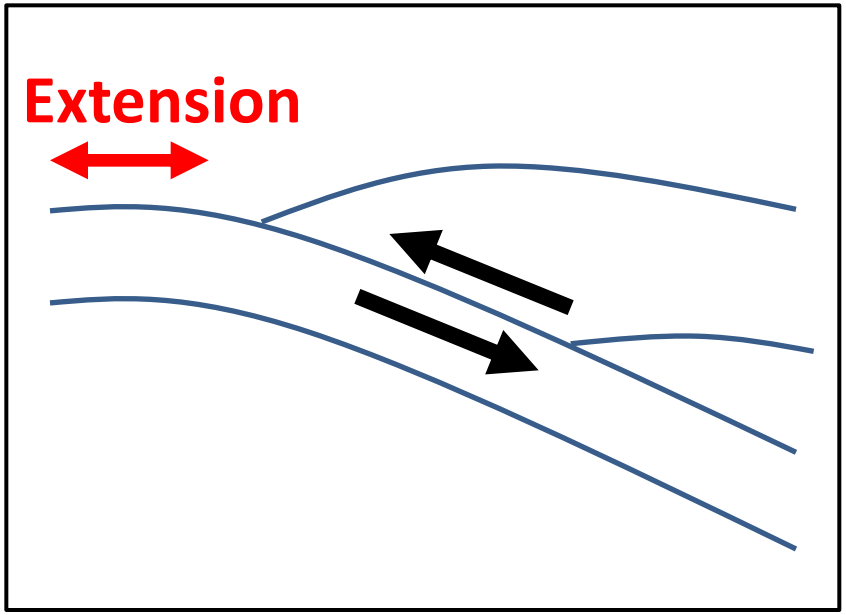
  Shall be included or not to be included?

- Continuing the literature search on paleo-earthquakes/tsunamis and modeling of the historical earthquakes

THANK YOU!

Seismicity between 1973 and 2010

NEIC (M_w 4.6-7.7)



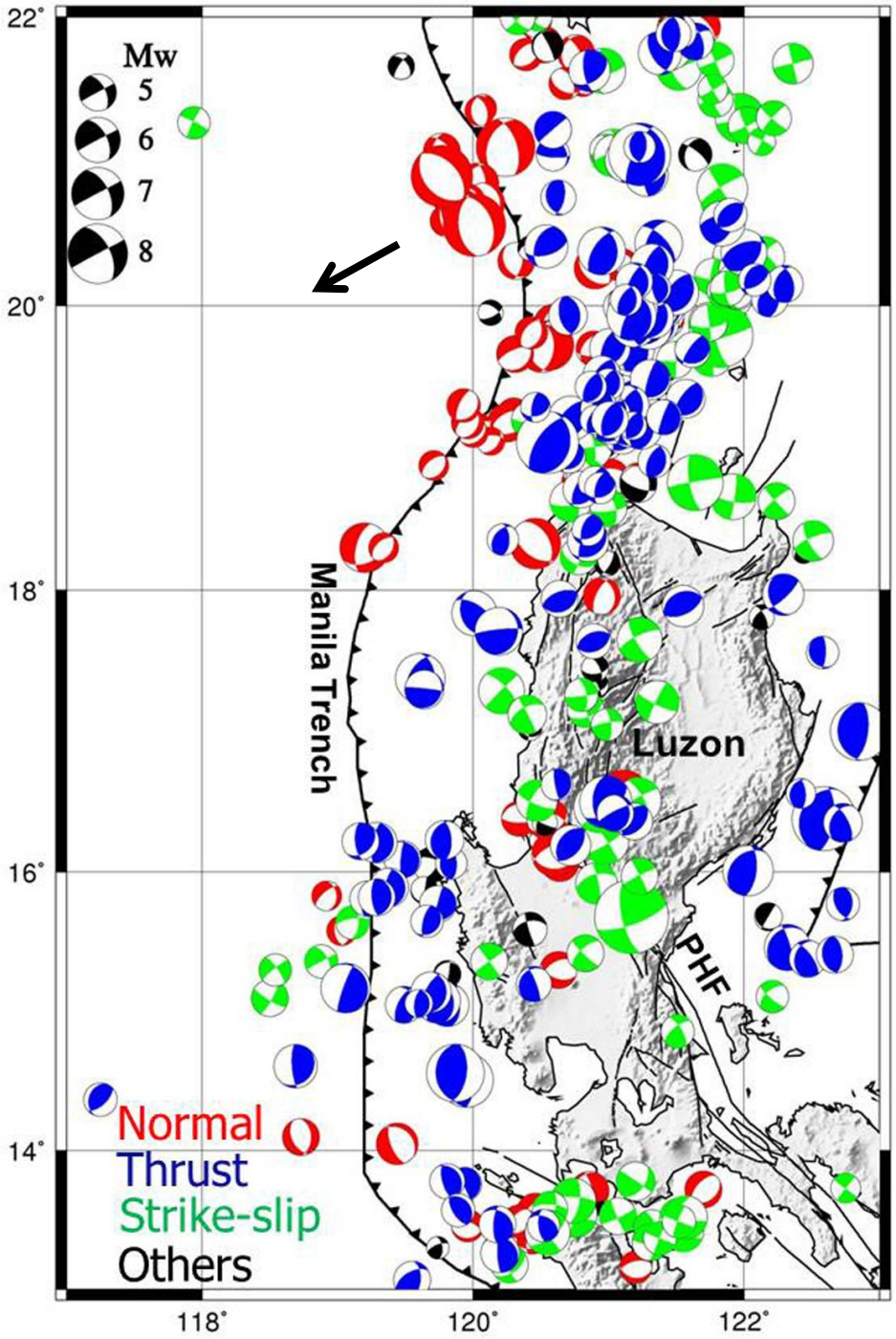
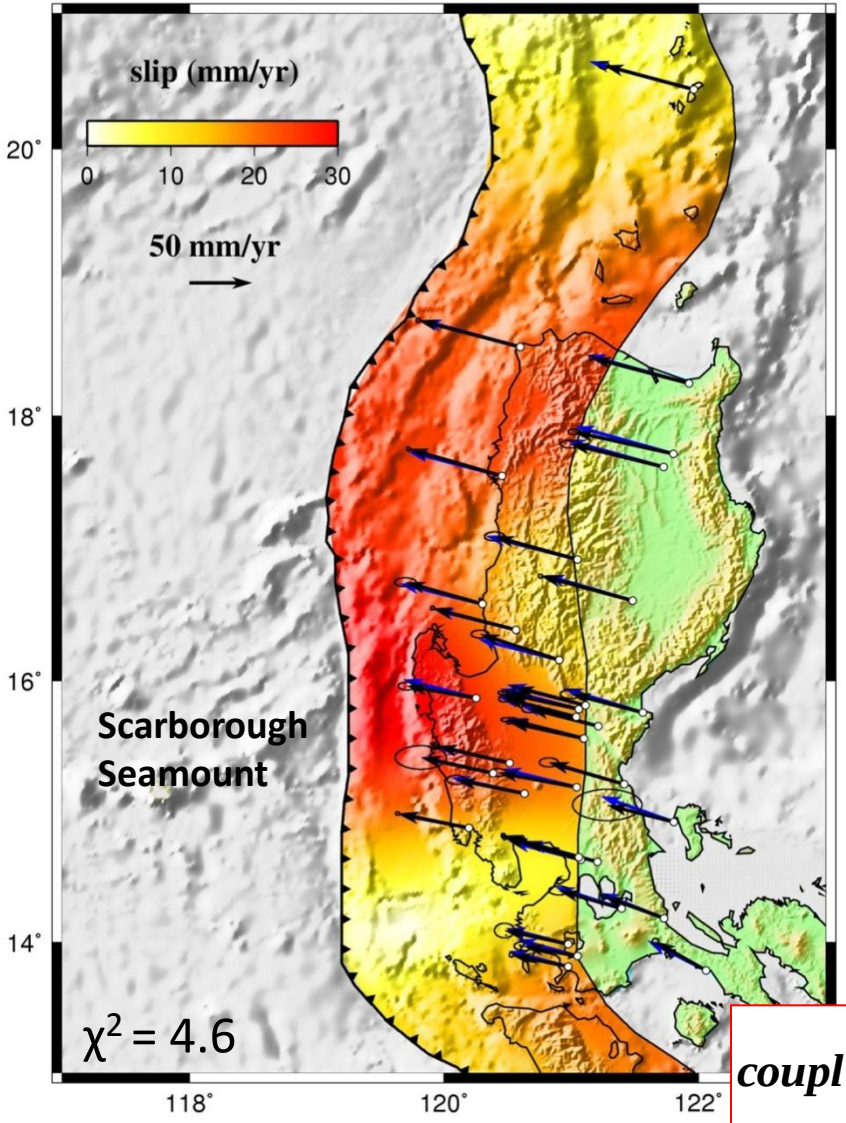


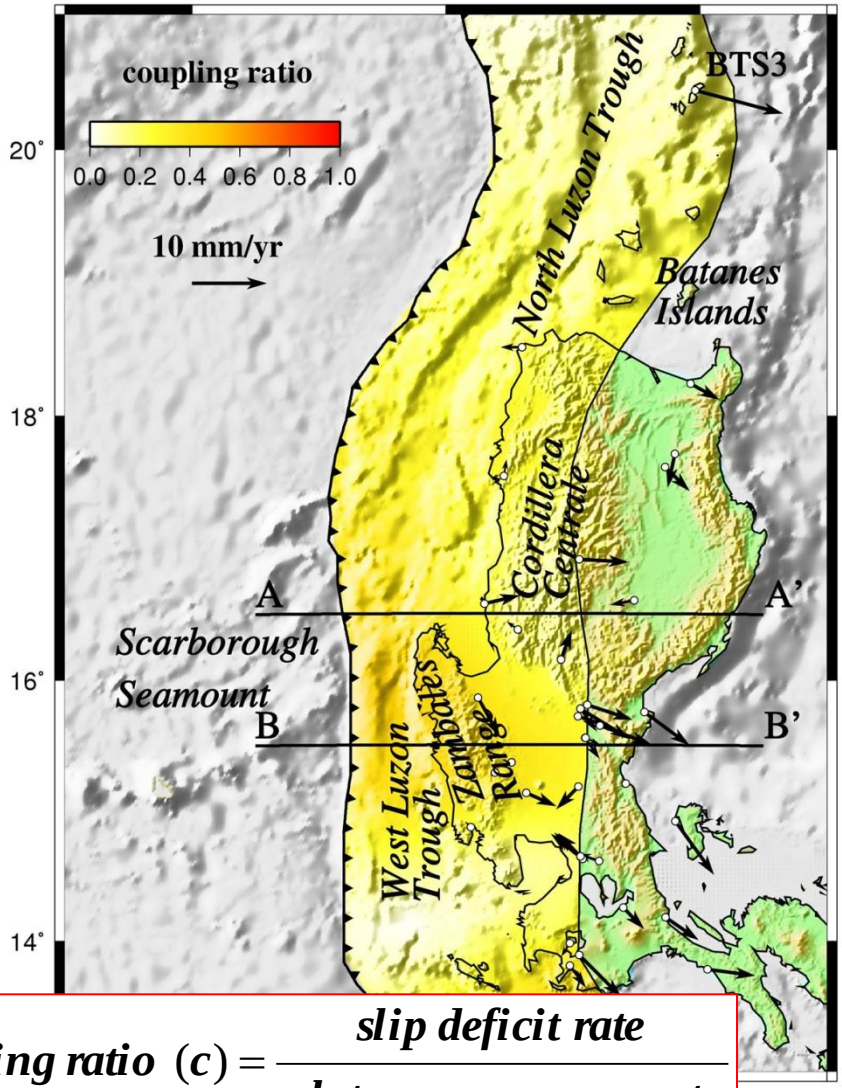
Plate coupling ratio derived from inversions of GPS data

Hsu Yaru et al., 2012

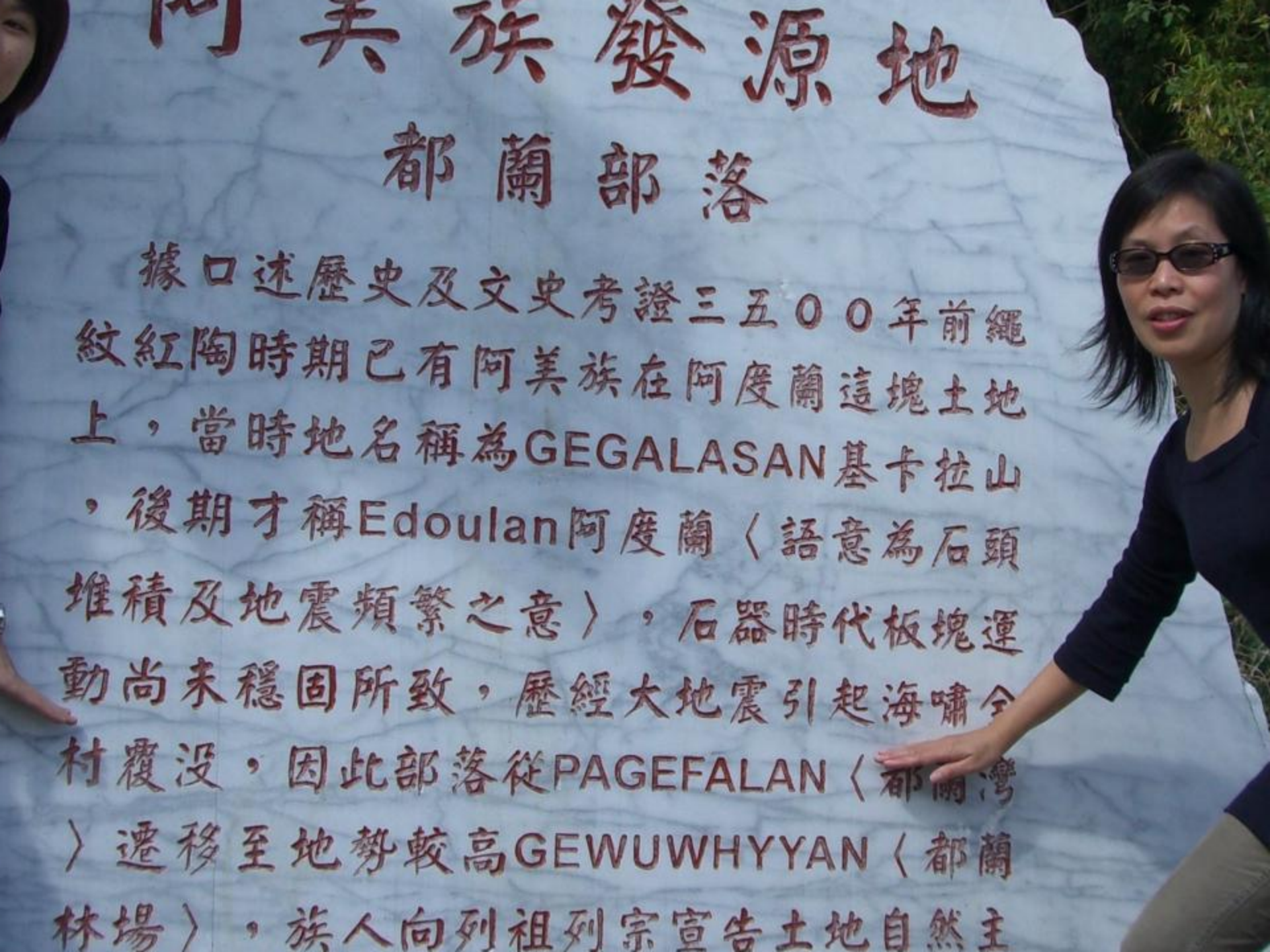
Observations v.s. Predictions



Residuals of horizontal displacements



$$\textit{coupling ratio}\ (c) = \frac{\textit{slip deficit rate}}{\textit{plate convergence rate}}$$


阿美族發源地
都蘭部落
據口述歷史及文史考證三五００年前繩
紋紅陶時期已有阿美族在阿度蘭這塊土地
上，當時地名稱為GEGALASAN基卡拉山
，後期才稱Edoulan阿度蘭〈語意為石頭
堆積及地震頻繁之意〉，石器時代板塊運
動尚未穩固所致，歷經大地震引起海嘯全
村覆沒，因此部落從PAGEFALAN〈都蘭灣
〉遷移至地勢較高GEWUWHYYAN〈都蘭
林場〉，族人向列祖列宗宣告土地自然主