Introduction of Fault Source Modeling

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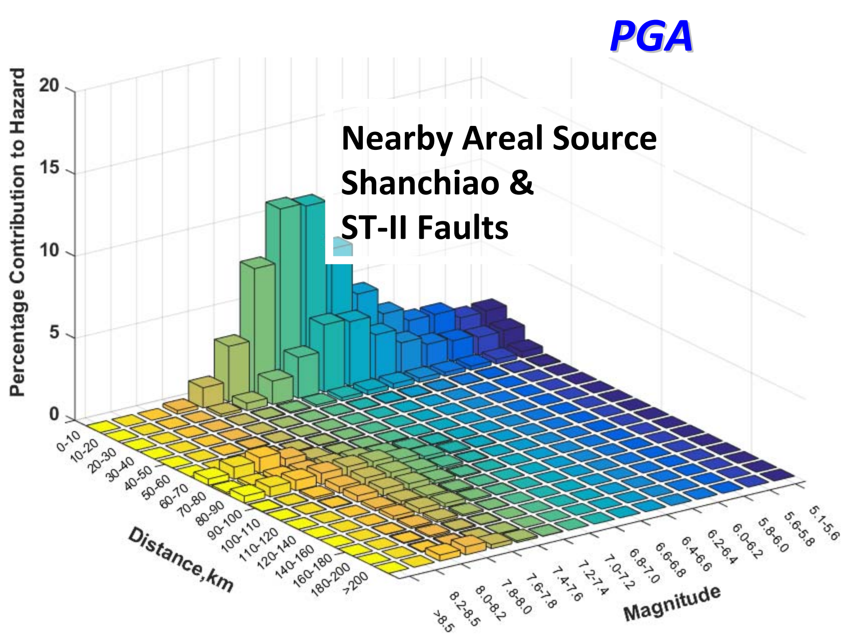
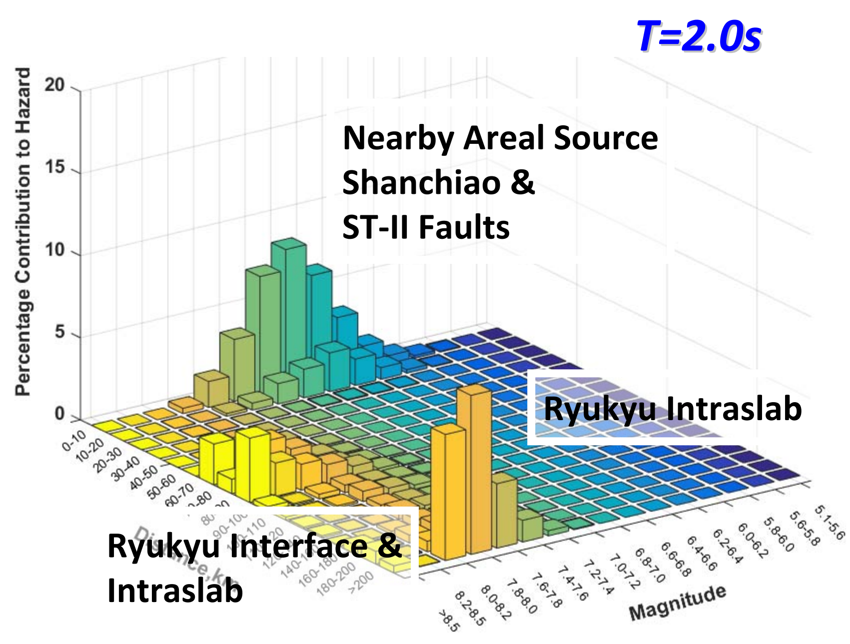
Outline

- **Hazard contribution of seismic sources at NPP sites**
- **Scope and classification of known active faults**
- **Structure of SSC logic tree for fault sources**
- **Fault geometry model**
  - Surface trace (segmentation & linkage)
  - Dip (dips at different depths)
  - Fault depth
- **Magnitude distribution model**
  - Maximum magnitude
  - Characteristic earthquake model
  - Truncated exponential model

Distribution of Hazard Contribution (NPP1)

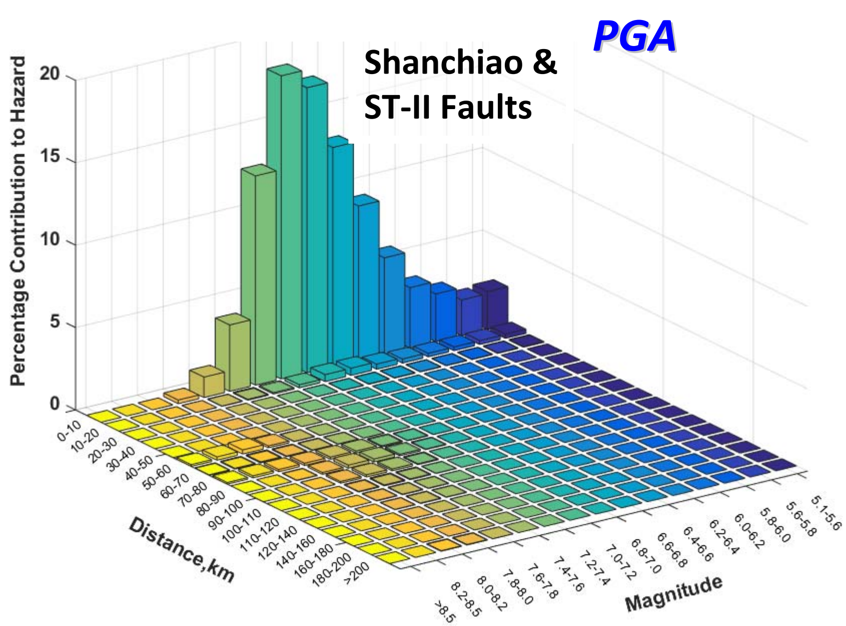
Source Name	Min. Distance(km)	Char. Magn.	AEF=10^{-4}		
	NPP1		PGA	T=0.2	T=2.0
Areal Shallow Zone			13.5%	13.4%	2.6%
Shanchiao Fault System	7	6.4-7.7	51.4%	53.3%	20.8%
ST-II Fault System	13.4	6.2-7.4	2.6%	2.7%	0.9%
Ryukyu Interface	64.8	7.7-9.2	11.3%	8.1%	31.5%
Ryukyu Intraslab	51.8~70.8	6.5-8.1	18.0%	20.0%	41.1%
Ryukyu Beneath Interface	57.8	6.9-7.7	1.5%	0.8%	2.3%

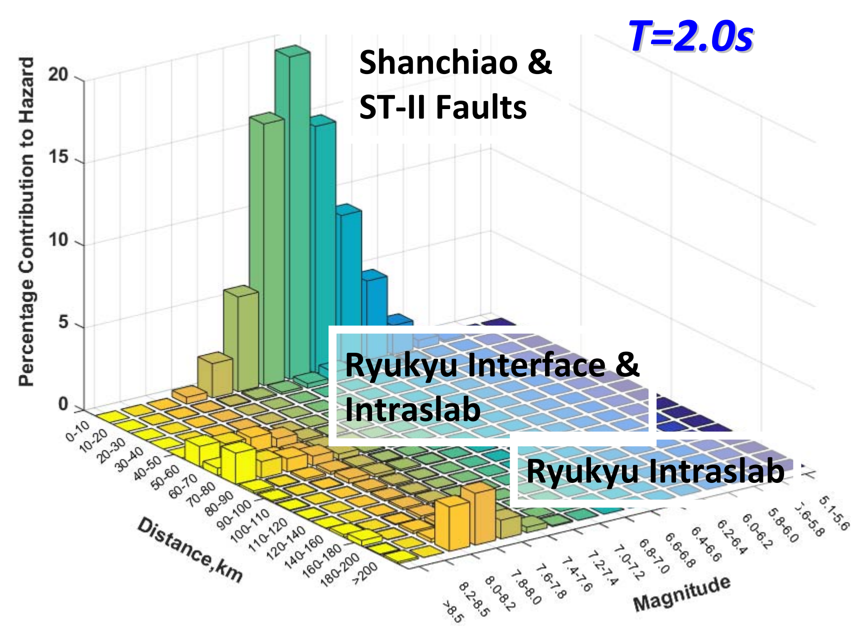




Distribution of Hazard Contribution (NPP2)

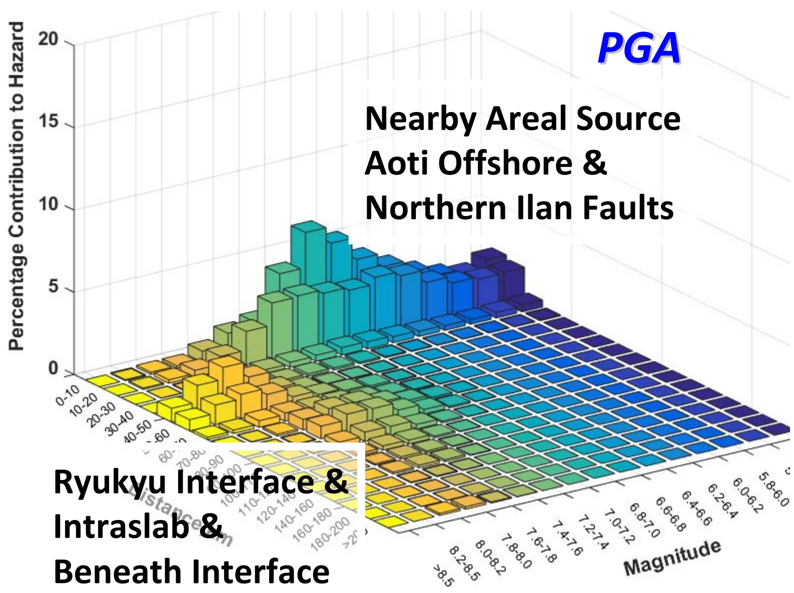
Source Name	Min. Distance(km)	Char. Magn.	AEF=10^{-4}		
	NPP2		PGA	T=0.2	T=2.0
Areal Shallow Zone			2.3%	2.2%	1.3%
Shanchiao Fault System	4.3	6.4-7.7	66.4%	69.4%	42.2%
ST-II Fault System	2.4	6.2-7.4	22.5%	20.2%	16.5%
Ryukyu Interface	55.5	7.7-9.2	3.1%	2.1%	20.7%
Ryukyu Intraslab	51~63	6.5-8.1	4.2%	5.1%	17.3%
Ryukyu Beneath Interface	51.5	6.9-7.7	0.3%	0.1%	1.1%

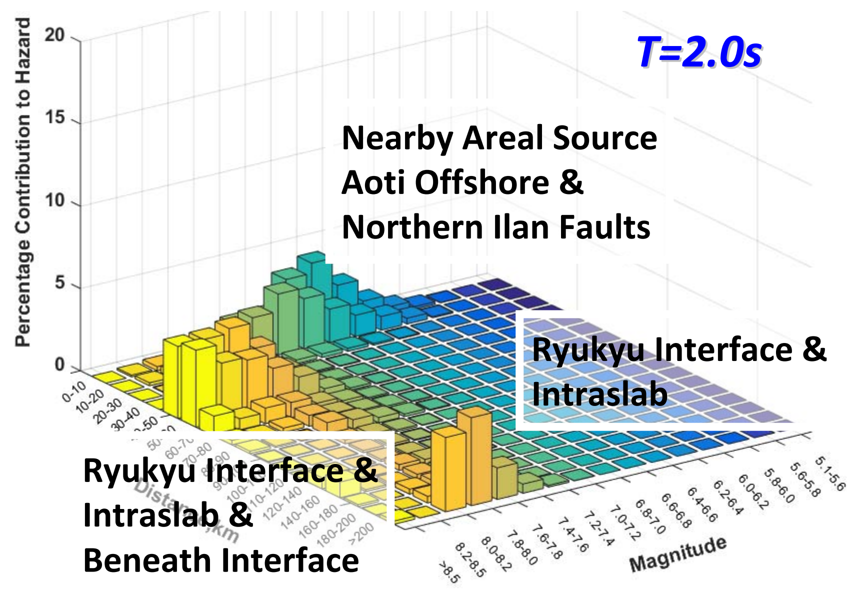




Distribution of Hazard Contribution (NPP4)

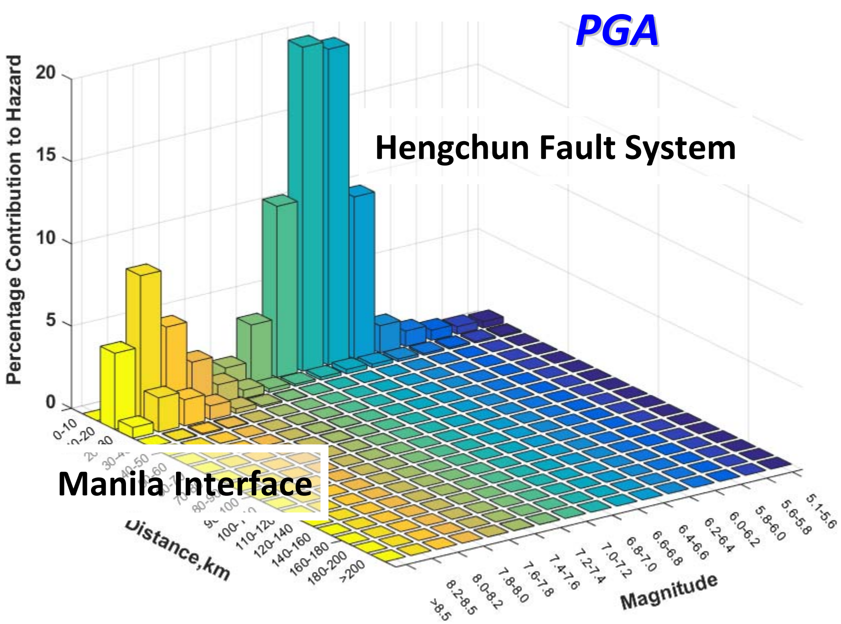
Source Name	Min. Distance(km)	Char. Magn.	AEF=10 $^{-4}$		
	NPP4		PGA	T=0.2	T=2.0
Areal Shallow Zone			27.6%	27.5%	6.3%
Shanchiao Fault System	18.9	6.4-7.7	2.1%	2.6%	1.4%
Aoti Offshore Fault	4	6.5-7.5	12.9%	12.7%	6.7%
Northern Ilan Fault System	11.2	6.5-7.6	6.5%	6.1%	4.1%
Ryukyu Interface	42.4	7.7-9.2	23.6%	19.4%	54.5%
Ryukyu Intraslab	47.5~58.7	6.5-8.1	20.9%	26.3%	22.1%
Ryukyu Beneath Interface	40	6.9-7.7	2.7%	1.9%	3.1%

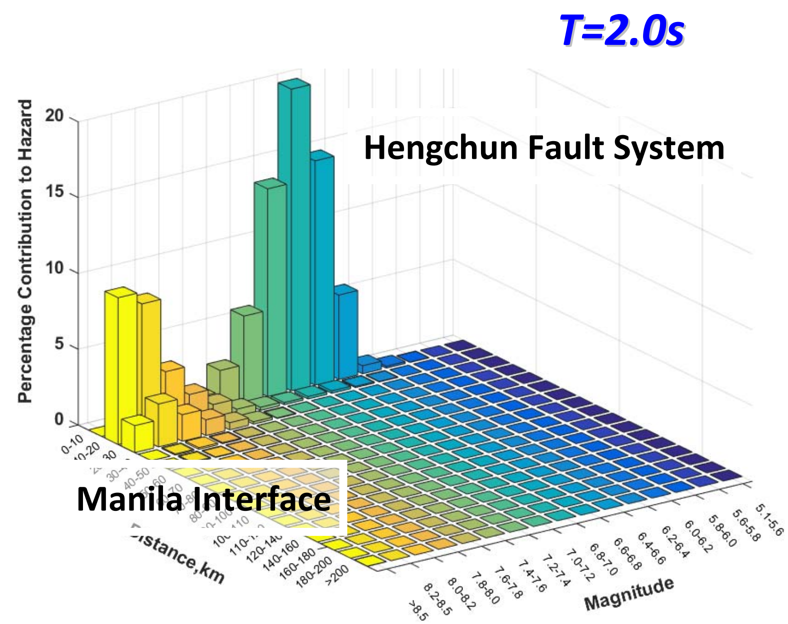




Distribution of Hazard Contribution (NPP3)

Source Name	Min. Distance(km)	Char. Magn.	AEF=10 $^{-4}$		
	NPP3		PGA	T=0.2	T=2.0
Areal Shallow Zone			1.6%	1.5%	1.8%
Hengchun Fault System	0.7	6.5-7.6	48.0%	41.8%	42.4%
West Hengchun Offshore Structure	11.6	6.5-6.8	0.4%	0.5%	0.1%
Manila Splay Fault	20.3	6.7-8.6	2.6%	3.6%	3.2%
Manila Interface	17.2	7.0-9.0	46.8%	51.4%	51.3%
Manila Intraslab	51.0	6.5-8.1	0.2%	0.3%	0.0%
Manila Beneath Interface	13	7.0-7.5	0.1%	0.1%	0.1%





Important Logic Tree Nodes for Primary Faults

- **Based on sensitivity study**
  - Geometry (dip and depth)
  - Slip rate
  - Maximum magnitude

Scope and Classification of Known Active Faults

Classification of Known Active Faults

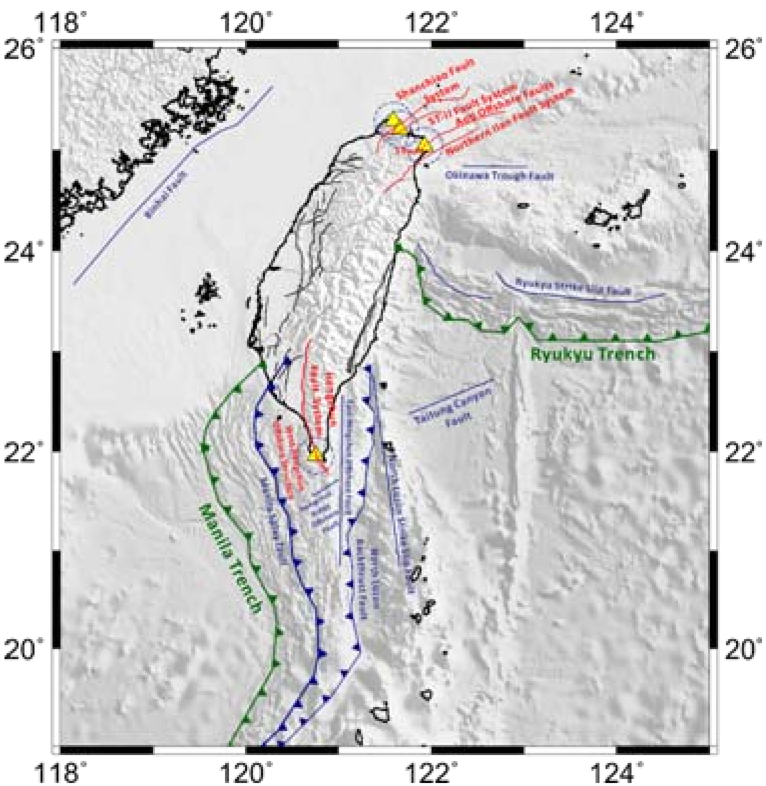
- **Primary faults: within 20 km of NPP sites**
  - Northern primary faults (**5**) **B. S. Huang**
  - Southern Primary faults (**2**) **A. T. Lin**
- **Other faults: 20 km outside of NPP sites**
  - Onshore faults (**39**): mainly from TEM 2016 (44) **C. T. Cheng**
    - Shanchiao fault, Northern Ilan fault, Chaochou fault, Hengchun fault, West Hengchun Offshore structure are considered as primary faults
  - Offshore faults (**9**) **C. T. Cheng**
    - Manila spray fault: closely related to Manila trench, but treated as one of other faults
    - Okinawa fault: newly added in WS#3
- **Subduction interfaces (2)**
  - Ryukyu trench **C. T. Cheng**
  - Manila trench **A. T. Lin**

7 Primary Faults

P1	Shanchiao Fault System
P2	ST-II Fault System
P3	S Fault
P4	Aoti Offshore Faults
P5	Northern Ilan Fault System
P6	Hengchun Fault System
P7	West Hengchun Offshore Structure

2 Subduction Interfaces

1	Ryukyu Trench
2	Manila Trench

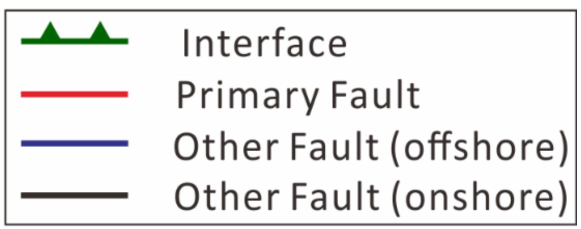


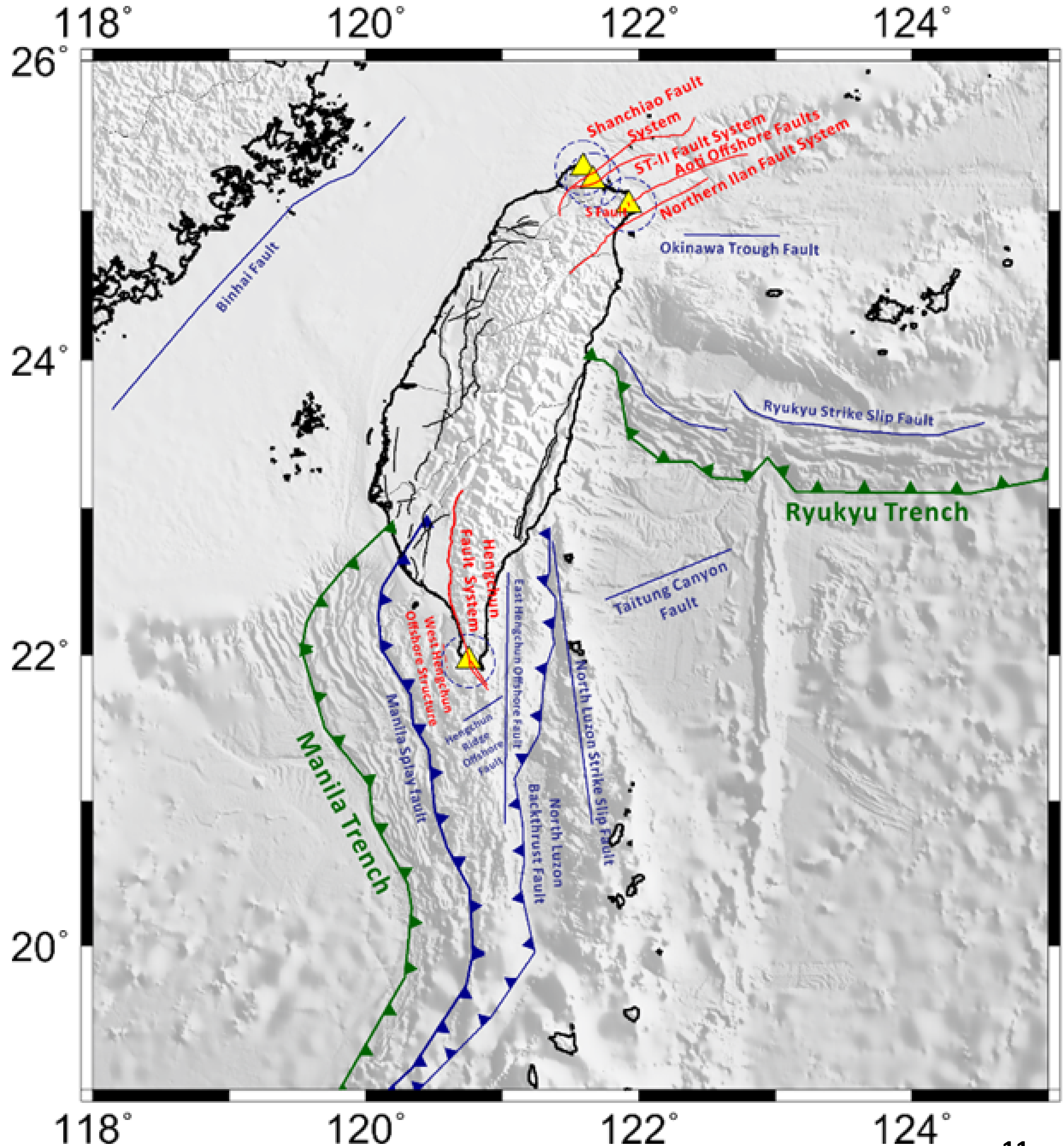
48 Other Faults

Onshore Offshore

1	Shuanglienpo structure	26	Hsiaokangshan fault
2	Yangmei structure	27	Kaoping River structure
3	Hukou fault	28	Milun fault
4	Fengshan river strike-slip structure	29	Longitudinal Valley fault
5	Hsinchu fault	30	Central Range structure
6	Hsincheng fault	31	Luyeh fault
7	Hsinchu frontal structure	32	Taimali coastline structure
8	Touhuanping structure	33	Southern Ilan structure
9	Miaoli frontal structure	34	Chushiang structure
10	Tunglo structure	35	Gukeng structure
11	East Miaoli structure	36	Tainan frontal structure
12	Shihtan fault	37	Longchuan structure
13	Sanyi fault	38	Youchang structure
14	Tuntzuchiao fault	39	Fengshan hills frontal structure
15	Changhua fault	40	Taitung Canyon Fault
16	Chelungpu fault	41	Binhai Fault
17	Tamaopu - Shuangtung fault	42	North Luzon Strike Slip Fault
18	Chiuchiungkeng fault	43	North Luzon Backthrust Fault
19	Meishan fault	44	East Hengchun Offshore Fault
20	Chiayi frontal structure	45	Hengchun Ridge Offshore Fault
21	Muchiliao - Liuchia fault	46	Manila Splay Fault
22	Chungchou structure	47	Ryukyu Strike Slip Fault
23	Hsinhua fault	48	Okinawa Trough Fault
24	Houchiali fault		
25	Chishan fault		

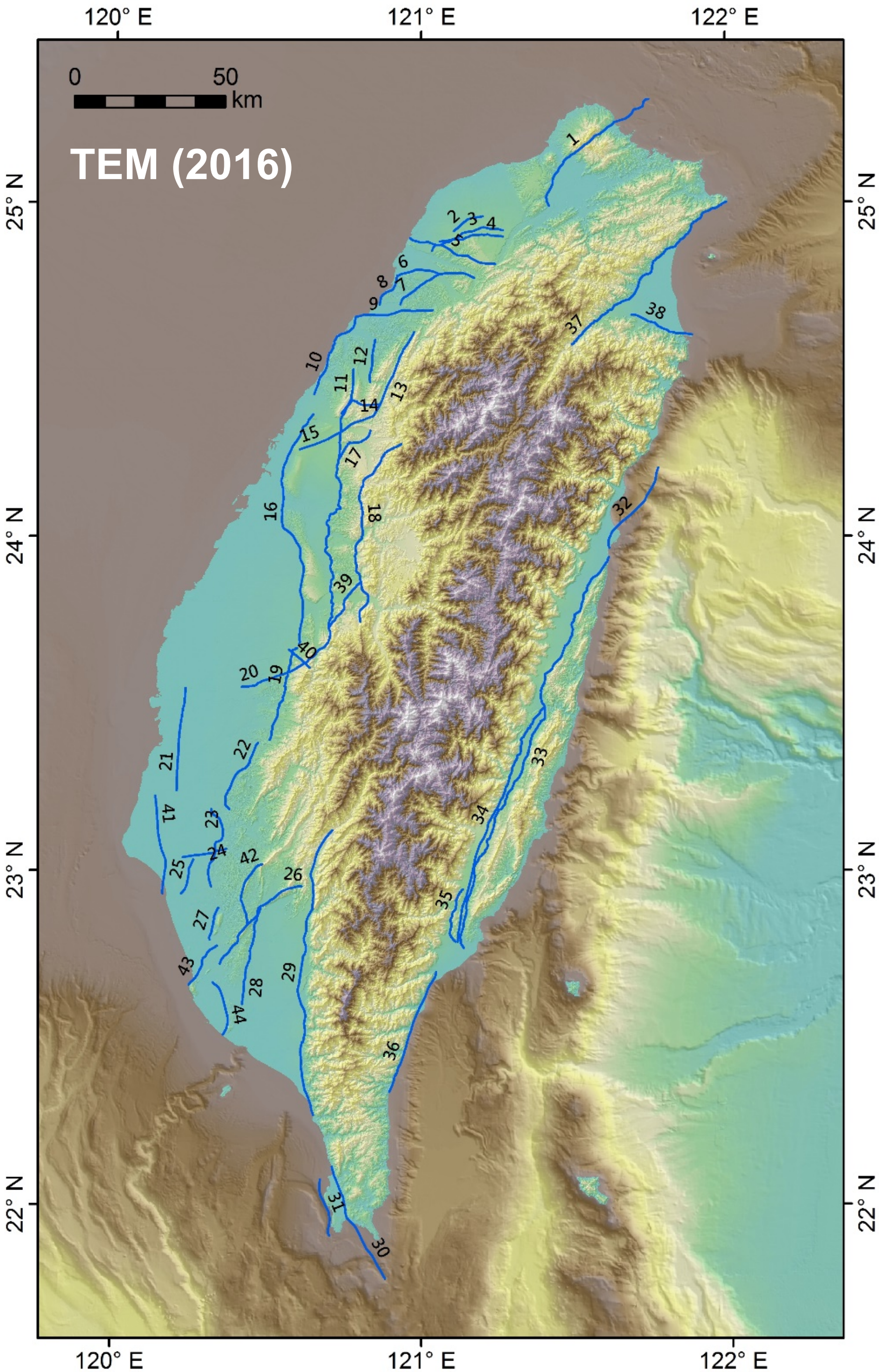
Distribution of primary faults, subduction interfaces and other faults





Resource Experts

Expert	Topic	Task and issue
Shyu Bruce 徐澔德	Taiwan active fault map	• Provide active fault map and seismic source parameters of TEM 2016 • Summarize fault maps and seismic source parameters from CGS, NCU and others
Hsu Ya-Ru 許雅儒	Ryukyu and Manila Subductions	• Provide geometry of subductions • Estimate slip-rate and coupling of subductions
Rau Juan-Jun/ Jing Kou-En 饒瑞鈞/景國恩	GPS data and its applications	• Estimate slip-rate of each fault • Compare geodetic and geologic slip-rate • Provide Block model
Chang Kou-Jen 張國楨	LiDAR reinterpretation	• NPP1&2 (Chinshan area ST-I onshore, ST-II onshore) • NPP4 (Lineaments onshore) • NPP3 (Hengchun fault trace)
Liu Char-Shine 劉家瑄	Offshore fault data	• West Hengchun offshore structure (Reflection seismic data)
Huang Wen-Cheng 黃文正	Fault modeling	• West Hengchun offshore structure
Hsu Shu-Kun 許樹坤	Offshore fault data	• Shanchiao fault (offshore part; NPP1,NPP2) • ST-I, ST-II • Ryukyu subduction complex zone • North Ilan fault (offshore part) • Taitung canyon fault



ID	Fault Name
1	Shanchiao fault
2	Shuanglienpo structure
3	Yangmei structure
4	Hukou fault
5	Fengshan river strike-slip structure
6	Hsinchu fault
7	Hsincheng fault
8	Hsinchu frontal structure
9	Touhuanping structure
10	Miaoli frontal structure
11	Tunglo structure
12	East Miaoli structure
13	Shihtan fault
14	Sanyi fault
15	Tuntzuchiao fault
16	Changhua fault
17	Chelungpu fault
18	Tamaopu - Shuangtung fault
19	Chiuchiungkeng fault
20	Meishan fault
21	Chiayi frontal structure
22	Muchiliao - Liuchia fault
23	Chungchou structure
24	Hsinhua fault
25	Houchiali fault
26	Chishan fault
27	Hsiaokangshan fault
28	Kaoping River structure
29	Chaochou fault
30	Hengchun fault
31	Hengchun offshore structure
32	Milun fault
33	Longitudinal Valley fault
34	Central Range structure
35	Luyeh fault
36	Taimali coastline structure
37	Northern Ilan structure
38	Southern Ilan structure
39	Chushiang structure
40	Gukeng structure
41	Tainan frontal structure
42	Longchuan structure
43	Youchang structure
44	Fengshan hills frontal structure

TEM (2016) serves as the main data source of Taiwan onshore active faults.

Most of the source parameters, such as surface trace, length, dip, depth, slip rate, etc. of the onshore faults were derived from it.

Five of them were considered as primary faults and we will put more attention to them

References for Offshore Faults (1/2)

Subduction Zones

Fault Name	References	data for justification
Ryukyu trench	Hsu et al., 2013	Bathymetric and seismicity data
	Klingelhoefer et al., 2012	Seismic refraction velocity model
	Lallemand et al., 2013	Seismic tomography
	Theunissen et al., 2010	Earthquake relocation
	http://earthquake.usgs.gov/data/slab/	USGS slab 1.0 model
	Strasser et al., 2010	Magnitude scaling law
	Hsu et al., 2012	Slip rate setting
Manila trench	Lin et al., 2008	Bathymetry, seismic refraction profile
	Hsu et al. 2004	free-air gravity anomalies, magnetic map
	Lester et al., 2013	wide angle seismic refraction
	Strasser et al., 2010	Magnitude scaling law

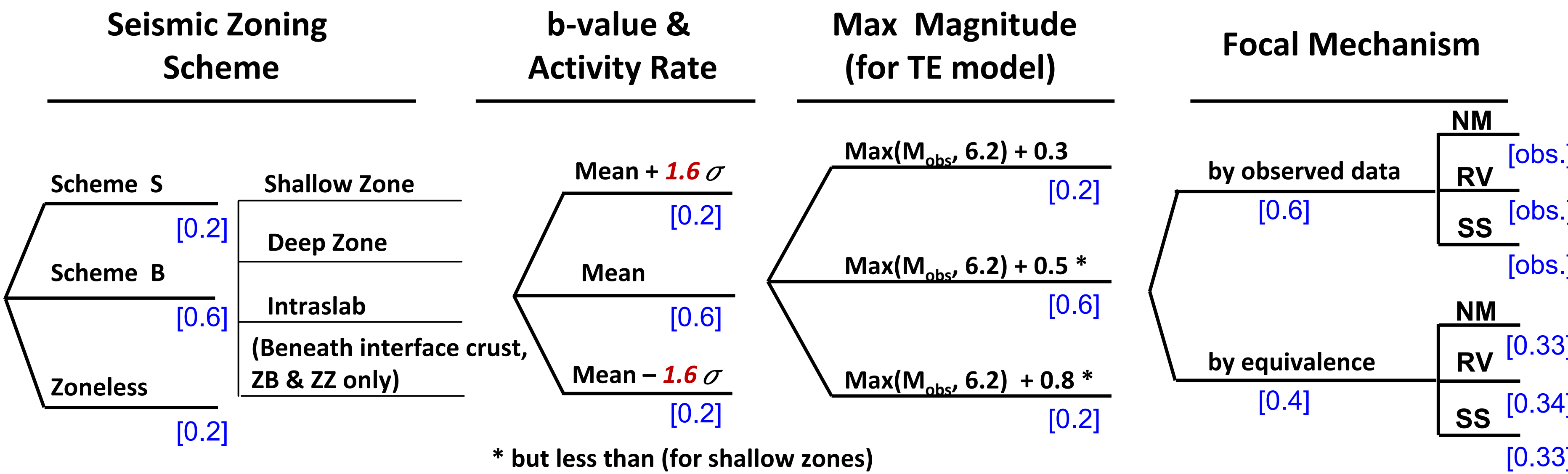
References for Offshore Faults (2/2)

Offshore Other Faults

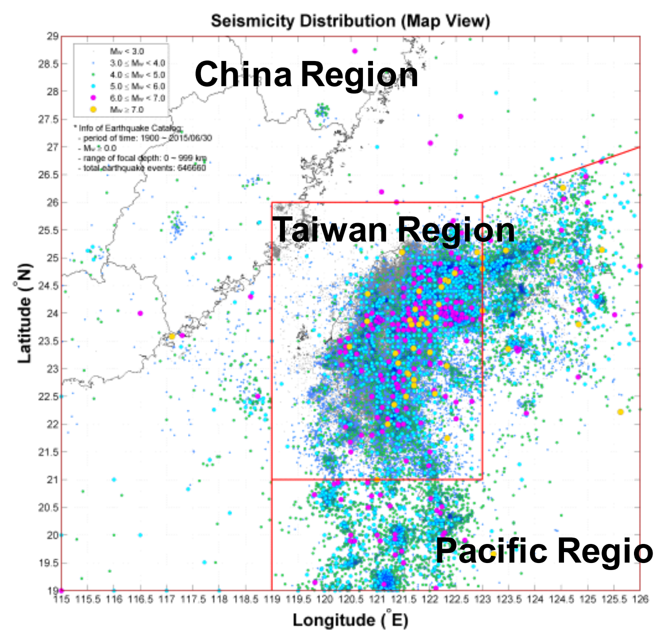
Fault Name	References	Status
Taitung Canyon fault	Schnurle et al.,1998	Although the surface traces may be identified, most of the offshore active faults still lack reliable underground geometry (dip, depth) and seismic activity (slip rate)
Binhai Fault	馬宗晉等，2002	
North Luzon Strike Slip Fault	Cheng et al., 1998	
North Luzon Backthrust Fault	Reed et al.,1992	
East Hengchun Offshore Fault	Cheng et al., 1998	
Hengchun Ridge Offshore Fault	Fuh et al., 1997	
Manila Splay fault	Lin et al., 2009	
Ryukyu Strike Slip Fault	Lallemand et al.,1999	
Okinawa Fault		

Structure of SSC Logic Tree for Fault Sources

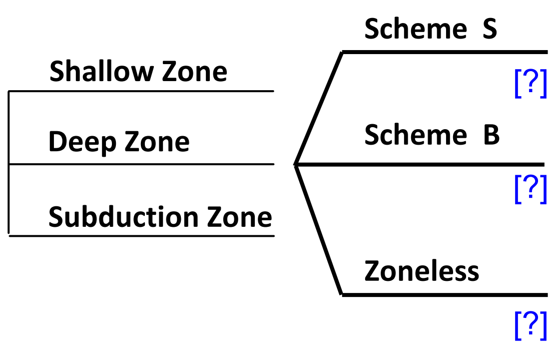
Logic Tree of Areal Sources



* but less than (for shallow zones)
7.7 (7.4+0.3) for China Region,
7.7 (7.4+0.3) for Taiwan Region, and
8.3 (8.0+0.3) for Pacific Region



Different from



Logic Tree Nodes for Fault Sources

- **Geometry**

Style of Faulting

Rupture Model | Rupture Source

Fault Geometry Model
- Dip
- Seismogenic Depth

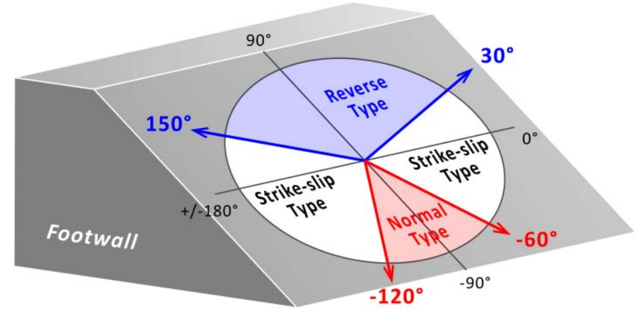
- **Seismic Activity Rate and Magnitude**

Seismogenic Probability

(Vertical) Slip Rate

Magnitude Distribution Model
- Max. Magn.
- Magnitude pdf

Seismic Source Parameters in Fault Model



Style of Faulting
RV, NM, SS, OB

•Segmentation or linkage
•May have diff. length at diff. depth

Length | **Depth** | **Dip** | **Rake** | **Vertical Rate**

May have diff. dip at diff. depth

Width (km)

$$\text{Width} = \frac{Depth}{\sin(Dip)}$$

Width

Slip rate (mm/yr)

$$Slip\ rate = \frac{Vertical\ rate}{\sin(Dip) \times \sin(Rake)}$$

Slip Rate

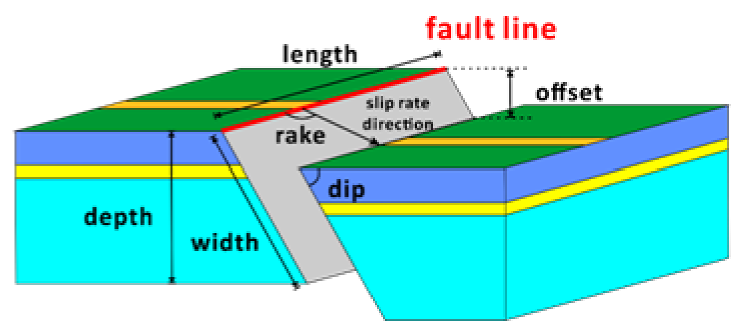
Area (km^2)

$$Area = Length \times Width$$

Area

M_w

Maximum Magnitude
- Wells and Coppersmith (1994)
- Yen and Ma (2011)
- Strasser et al (2010)
- Blaser et al (2010)



Investigation Techniques and Fault Parameters

Investigation Techniques	(Fault Parameters)	Segmentation (Length)	Fault Dip	Rupture Depth	Long-term Slip Rate
Structural Geology	Geologic cross-section	●	●	●	●
	Tectonic sequence stratigraphy	●			
	Balanced cross section		●	●	●
	Drilling boreholes	●	●		●
Surface Geological Survey	Earthquake surface rupture	●			
	Exploratory trenching		●		●
	Terrace dating				●
Exploration Geophysics	Seismic profile		●	●	
	Resistivity Image Profile	●			
Interpretation of Remote Sensing Image	D-InSAR or PS-InSAR	●			
	Satellite image interpretation	●			
	Aerial photo interpretation	●			
Seismology	Aftershock distribution	●		●	
	Seismicity cross sections		●	●	
	Focal mechanism solution		●		
	Seismic tomography			●	
Geodetic survey	GPS coseismic slip	●			
	GPS block model				●

Be time dependent

Need underground investigation

Can be observed on the ground surface

Shanchiao Fault System

Investigative Techniques	Fault Parameters	Segmentation (Length)	Fault Dip	Rupture Depth	Long-term Slip Rate
Structural Geology	Geologic cross-section	●	●	●	●
	Tectonic sequence stratigraphy	●			
	Balanced cross section		●	●	●
	Drilling boreholes	●	●		●
Surface Geological Survey	Earthquake surface rupture	●			
	Exploratory trenching		○		○
	Terrace dating				○
Exploration Geophysics	Seismic profile		●	●	
	Resistivity Image Profile	●			
Interpretation of Remote Sensing Image	D-InSAR or PS-InSAR	●			
	Satellite image interpretation	●			
	Aerial photo interpretation	●			
Seismology	Aftershock distribution	●		●	
	Seismicity cross sections		●	●	
	Focal mechanism solution		●		
	Seismic tomography			●	
Geodetic survey	GPS coseismic slip	●			
	GPS block model				●

ST-II Fault System

Investigative Techniques	Fault Parameters	Segmentation (Length)	Fault Dip	Rupture Depth	Long-term Slip Rate
Structural Geology	Geologic cross-section	○	○	○	○
	Tectonic sequence stratigraphy	○			
	Balanced cross section		○	○	○
	Drilling boreholes	○	○		○
Surface Geological Survey	Earthquake surface rupture	○			
	Exploratory trenching		○		○
	Terrace/scarp dating				●
Exploration Geophysics	Seismic profile	●	●	●	
	Resistivity Image Profile	○			
Interpretation of Remote Sensing Image	D-InSAR or PS-InSAR	●			
	Satellite image interpretation	●			
	Aerial photo interpretation	●			
Seismology	Aftershock distribution	○		○	
	Seismicity cross sections		○	○	
	Focal mechanism solution		○		
	Seismic tomography			○	
Geodetic survey	GPS coseismic slip	○			
	GPS block model				○

Aoti Offshore Faults

Investigative Techniques	Fault Parameters	Segmentation (Length)	Fault Dip	Rupture Depth	Long-term Slip Rate
Structural Geology	Geologic cross-section	○	○	○	○
	Tectonic sequence stratigraphy	○			
	Balanced cross section		○	○	○
	Drilling boreholes	○	○		○
Surface Geological Survey	Earthquake surface rupture	●			
	Exploratory trenching		○		○
	Terrace dating				○
Exploration Geophysics	Seismic profile		●	●	
	Resistivity Image Profile	○			
Interpretation of Remote Sensing Image	D-InSAR or PS-InSAR	○			
	Satellite image interpretation	○			
	Aerial photo interpretation	○			
Seismology	Aftershock distribution	○		○	
	Seismicity cross sections		○	○	
	Focal mechanism solution		○		
	Seismic tomography			○	
Geodetic survey	GPS coseismic slip	○			
	GPS block model				○

North Ilan Fault System

Investigative Techniques	Fault Parameters	Segmentation (Length)	Fault Dip	Rupture Depth	Long-term Slip Rate
Structural Geology	Geologic cross-section	●	●	●	●
	Tectonic sequence stratigraphy	●			
	Balanced cross section		○	○	○
	Drilling boreholes	●	●		●
Surface Geological Survey	Earthquake surface rupture	●			
	Exploratory trenching		○		○
	Terrace dating				○
Exploration Geophysics	Seismic profile		●	●	
	Resistivity Image Profile	○			
Interpretation of Remote Sensing Image	D-InSAR or PS-InSAR	●			
	Satellite image interpretation	●			
	Aerial photo interpretation	○			
Seismology	Aftershock distribution	○		○	
	Seismicity cross sections		○	○	
	Focal mechanism solution		○		
	Seismic tomography			●	
Geodetic survey	GPS coseismic slip	●			
	GPS block model				●

Hengchun Fault System

Investigative Techniques		Segmentation (Length)	Fault Dip	Rupture Depth	Long-term Slip Rate
Structural Geology	Geologic cross-section	●	●	●	●
	Tectonic sequence stratigraphy	●			
	Balanced cross section		○	○	○
	Drilling boreholes	●	●		●
Surface Geological Survey	Earthquake surface rupture	●			
	Exploratory trenching		●		●
	Terrace dating				●
Exploration Geophysics	Seismic profile		●	●	
	Resistivity Image Profile	●			
Interpretation of Remote Sensing Image	D-InSAR or PS-InSAR	●			
	Satellite image interpretation	●			
	Aerial photo interpretation	●			
Seismology	Aftershock distribution	○		○	
	Seismicity cross sections		○	○	
	Focal mechanism solution		○		
	Seismic tomography			○	
Geodetic survey	GPS coseismic slip	●			
	GPS block model				●

West Hengchun Offshore Structure

Investigative Techniques		Segmentation (Length)	Fault Dip	Rupture Depth	Long-term Slip Rate
Structural Geology	Geologic cross-section	○	○	○	○
	Tectonic sequence stratigraphy	○			
	Balanced cross section		○	○	○
	Drilling boreholes	○	○		○
Surface Geological Survey	Earthquake surface rupture	○			
	Exploratory trenching		○		○
	Terrace dating				○
Exploration Geophysics	Seismic profile		●	●	
	Resistivity Image Profile	○			
Interpretation of Remote Sensing Image	D-InSAR or PS-InSAR	○			
	Satellite image interpretation	○			
	Aerial photo interpretation	○			
Seismology	Aftershock distribution	○		○	
	Seismicity cross sections		○	○	
	Focal mechanism solution		○		
	Seismic tomography			○	
Geodetic survey	GPS coseismic slip	○			
	GPS block model				○

Ryukyu Trench

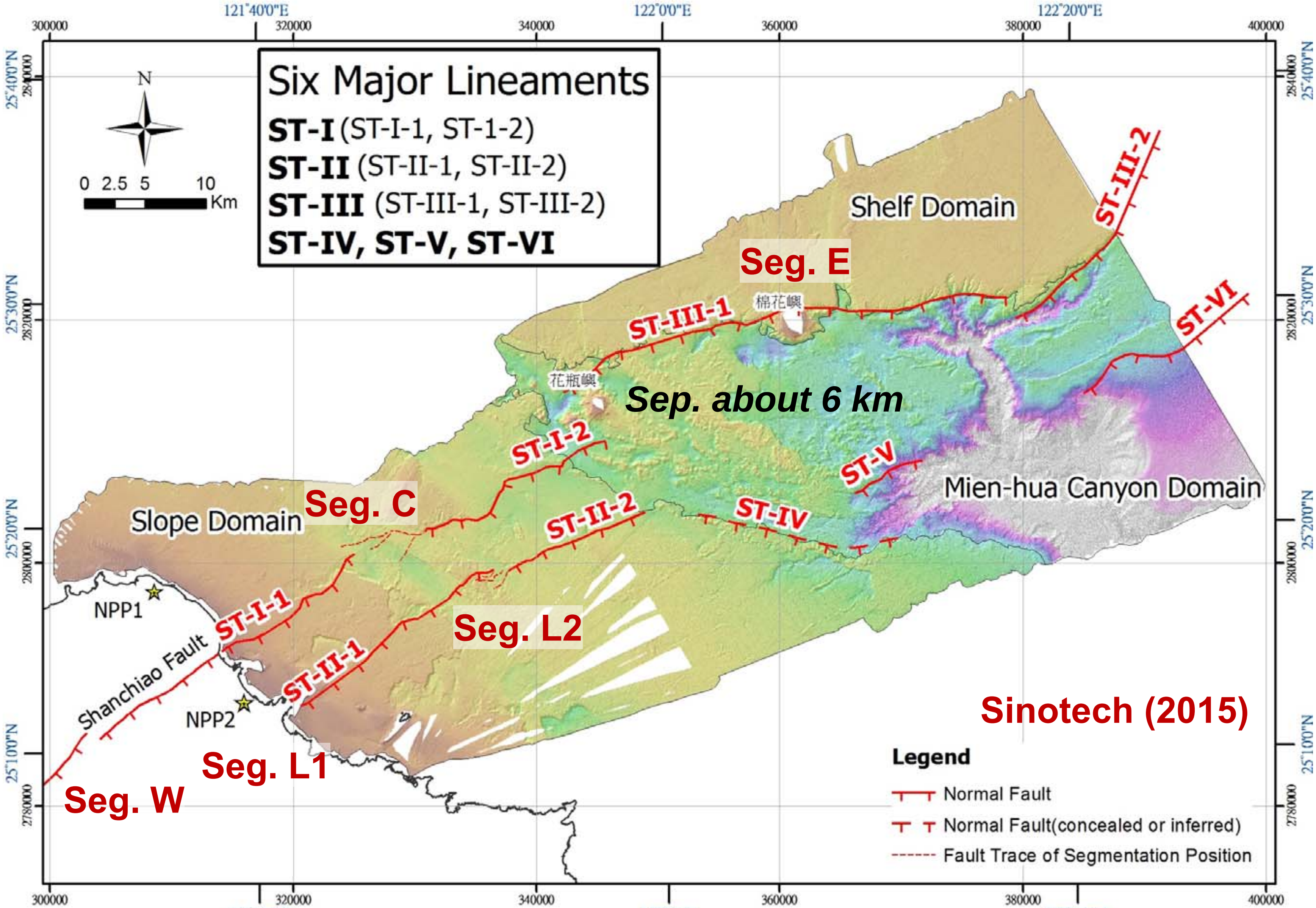
Investigative Techniques		Segmentation (Length)	Fault Dip	Rupture Depth	Long-term Slip Rate
Structural Geology	Geologic cross-section	○	○	○	○
	Tectonic sequence stratigraphy	○			
	Balanced cross section		○	○	○
	Drilling boreholes	○	○		
Surface Geological Survey	Earthquake surface rupture	○			
	Exploratory trenching		○		○
	Terrace dating				○
Exploration Geophysics	Seismic profile		●	●	
	Resistivity Image Profile	○			
Interpretation of Remote Sensing Image	D-InSAR or PS-InSAR	○			
	Satellite image interpretation	○			
	Aerial photo interpretation	○			
Seismology	Aftershock distribution	○		○	
	Seismicity cross sections		●	●	
	Focal mechanism solution		●		
	Seismic tomography			●	
Geodetic survey	GPS coseismic slip	●			
	GPS block model				●

Manila Trench

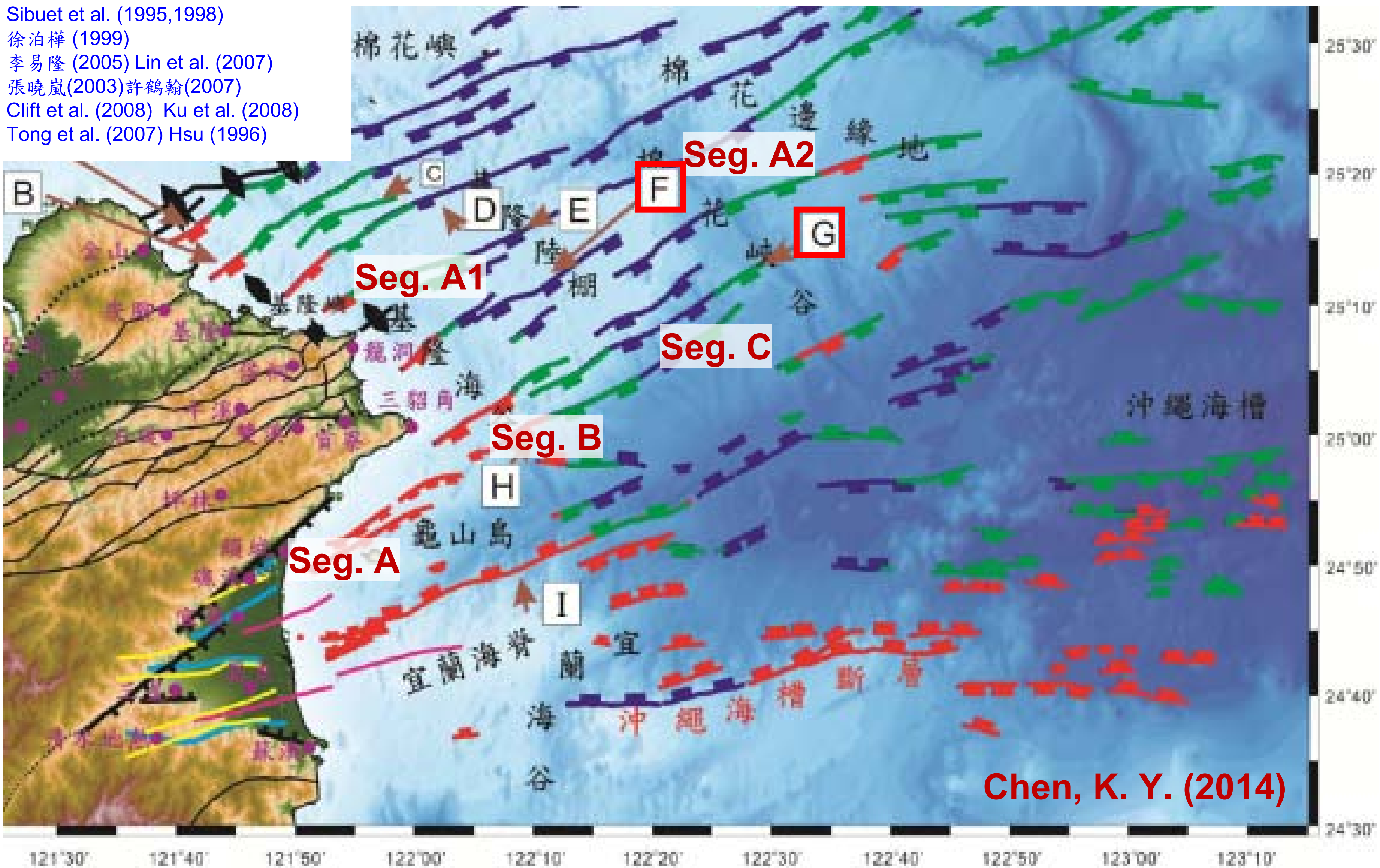
Investigative Techniques		Segmentation (Length)	Fault Dip	Rupture Depth	Long-term Slip Rate
Structural Geology	Geologic cross-section	○	○	○	○
	Tectonic sequence stratigraphy	○			
	Balanced cross section		○	○	○
	Drilling boreholes	○	○		
Surface Geological Survey	Earthquake surface rupture	○			
	Exploratory trenching		○		○
	Terrace dating				○
Exploration Geophysics	Seismic profile		●	●	
	Resistivity Image Profile	○			
Interpretation of Remote Sensing Image	D-InSAR or PS-InSAR	○			
	Satellite image interpretation	○			
	Aerial photo interpretation	○			
Seismology	Aftershock distribution	○		○	
	Seismicity cross sections		●	●	
	Focal mechanism solution		●		
	Seismic tomography			●	
Geodetic survey	GPS coseismic slip	●			
	GPS block model				●

Fault Geometry Model

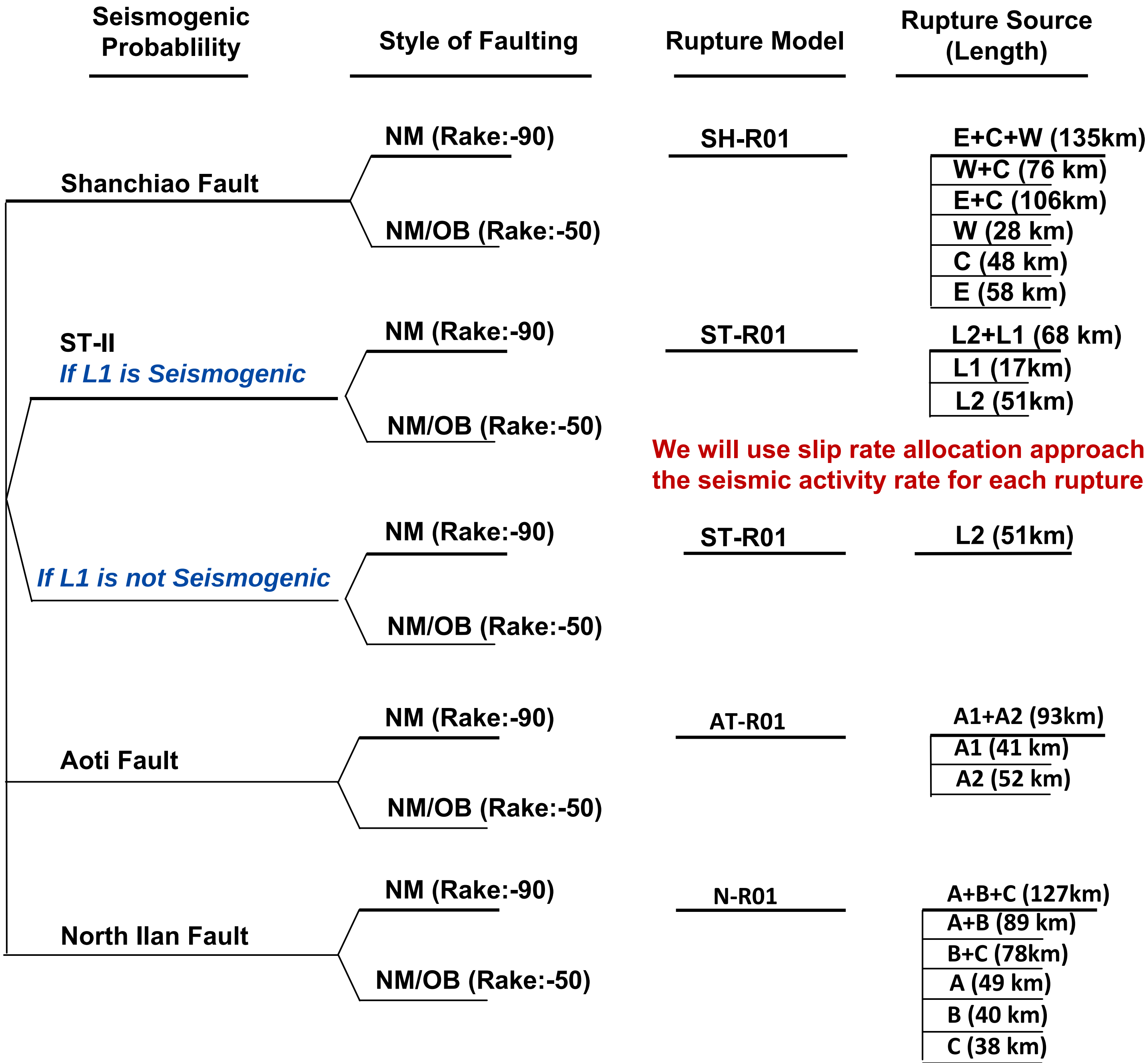
Surface Traces of Shanchiao and ST-II Faults



Surface Traces of Aoti Offshore Fault (F) / Northern Ilan Fault (G)

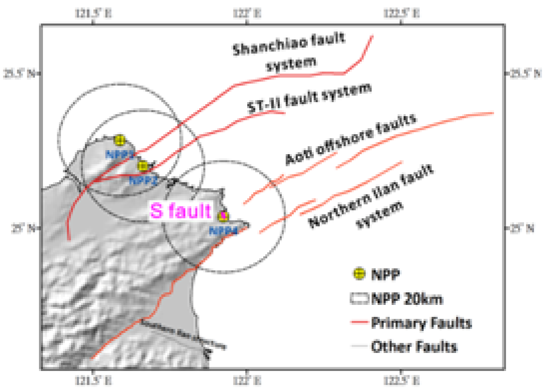


Rupture Sources of Northern primary faults

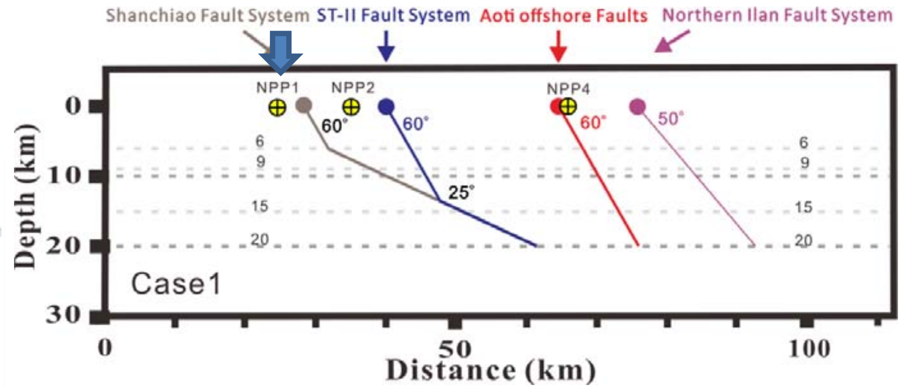


We will use slip rate allocation approach to assign the seismic activity rate for each rupture source

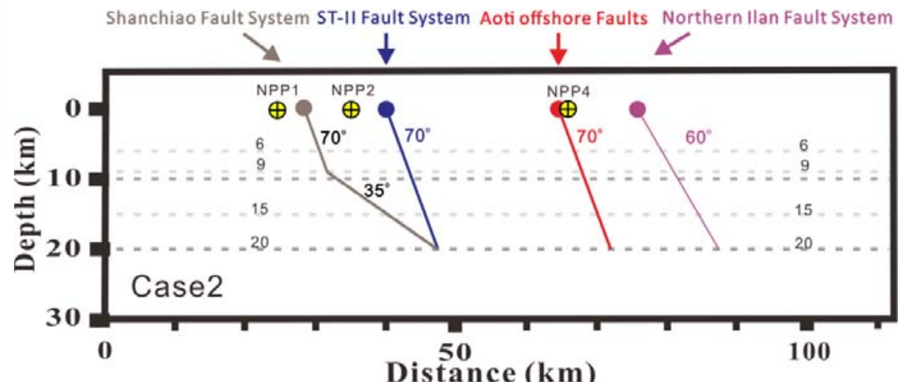
Underground Geometry (dip and depth) of Northern Primary Faults



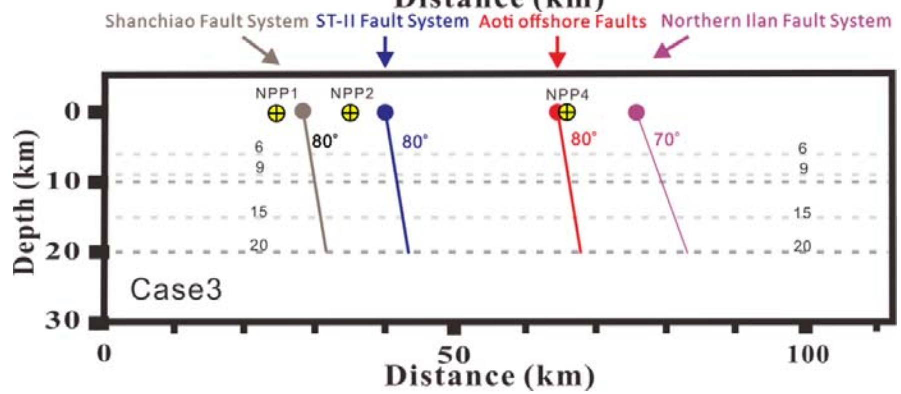
Case 1

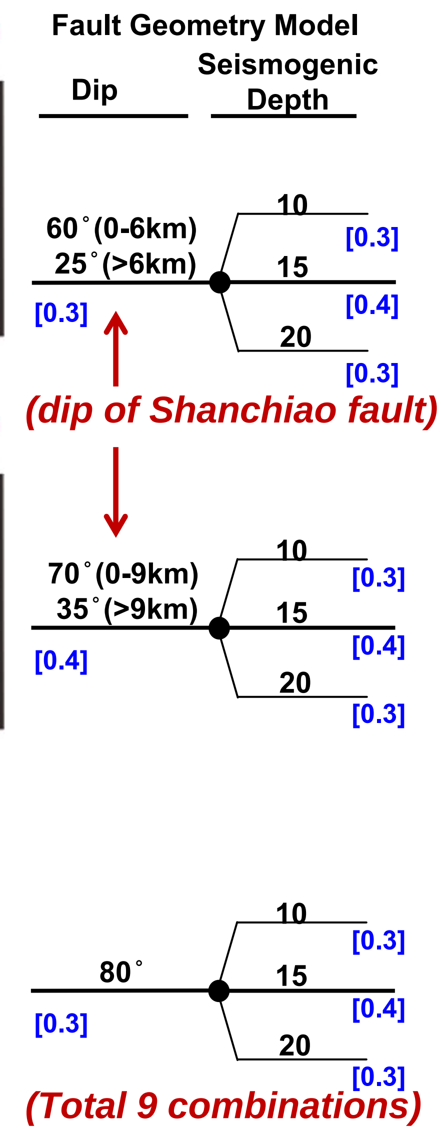


Case 2



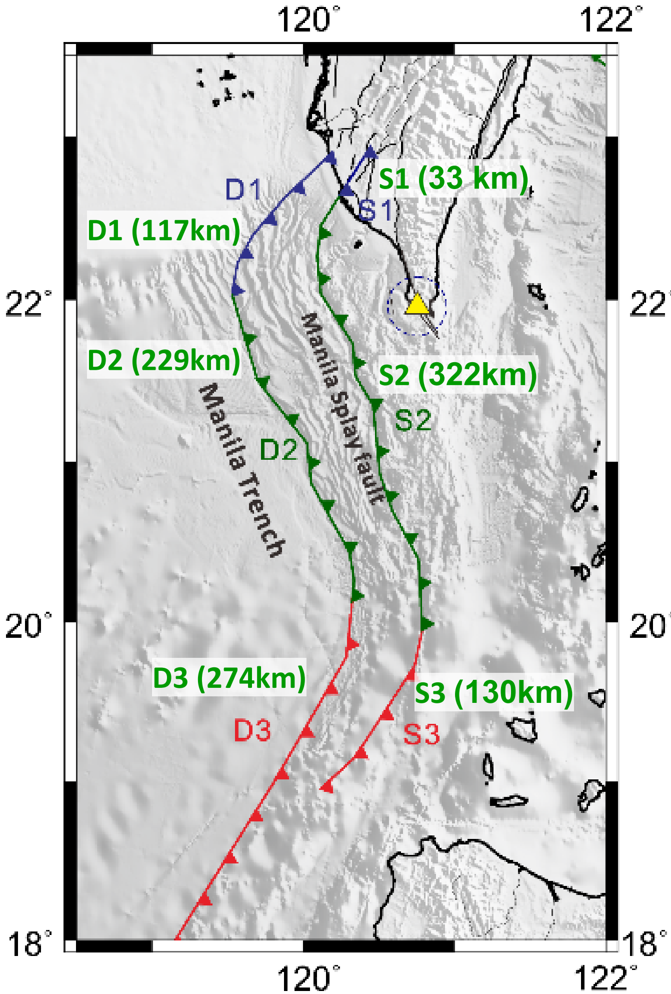
Case 3



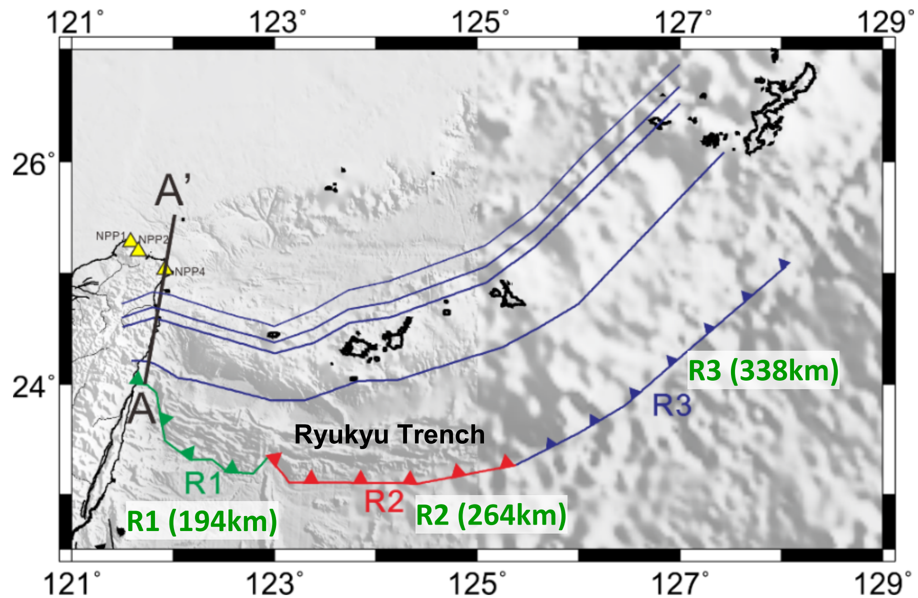


Manila and Ryukyu Subduction Interfaces

Manila Subduction Interface



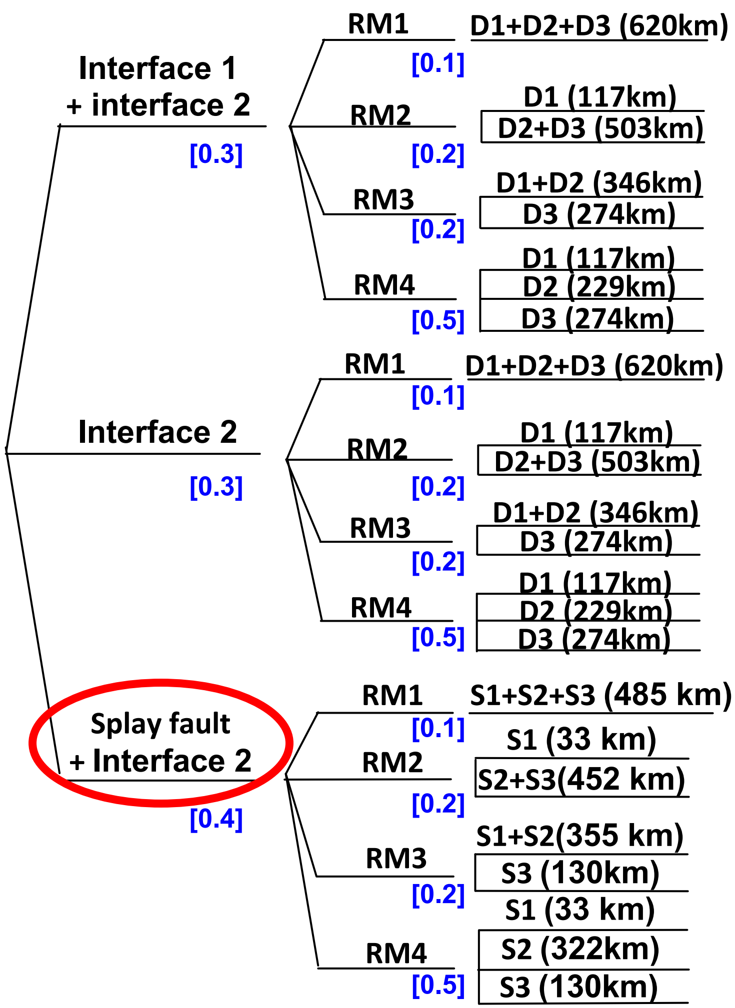
Ryukyu Subduction Interface



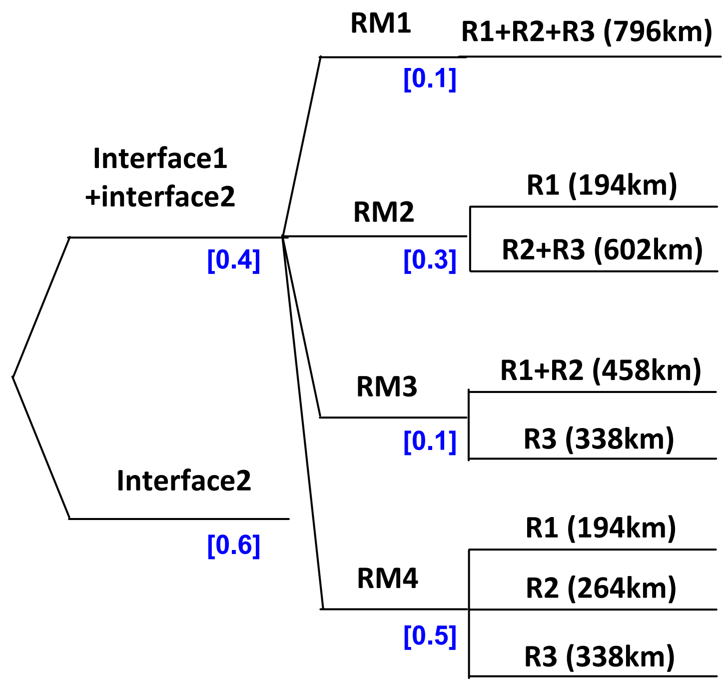
Gagua Ridge ~125°E

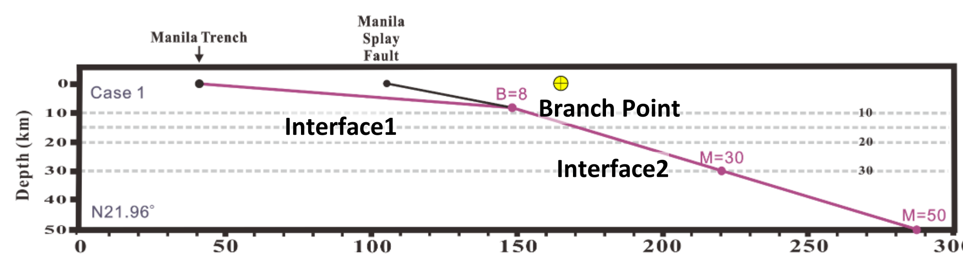
Rupture Models for Manila and Ryukyu Subduction Interfaces

Manila Subduction Interface



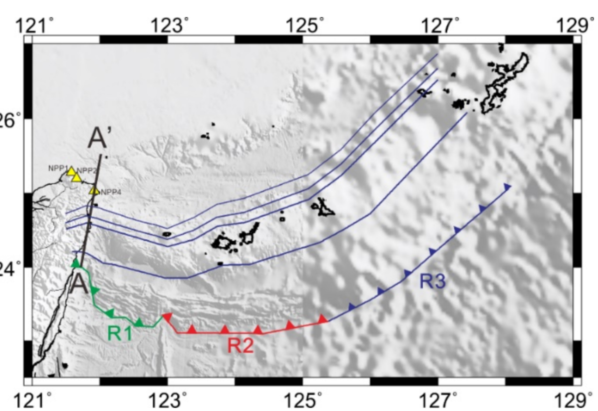
Ryukyu Subduction Interface

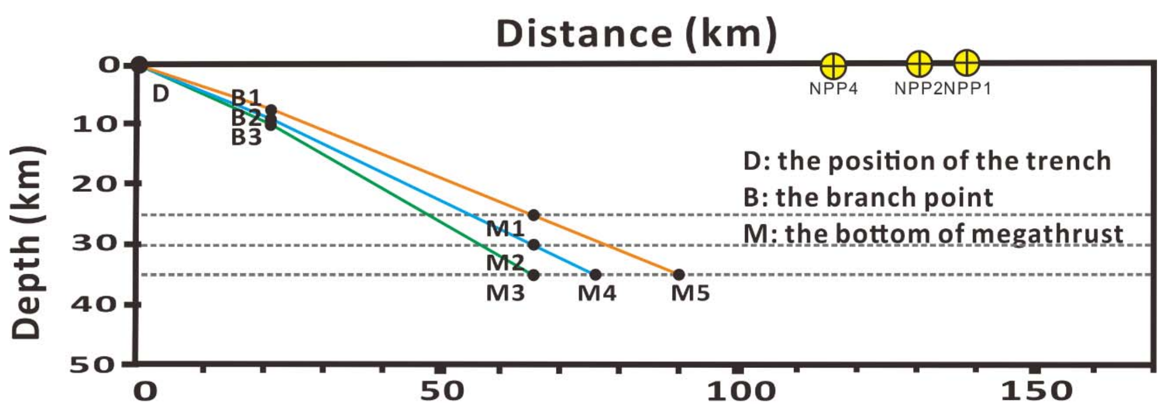




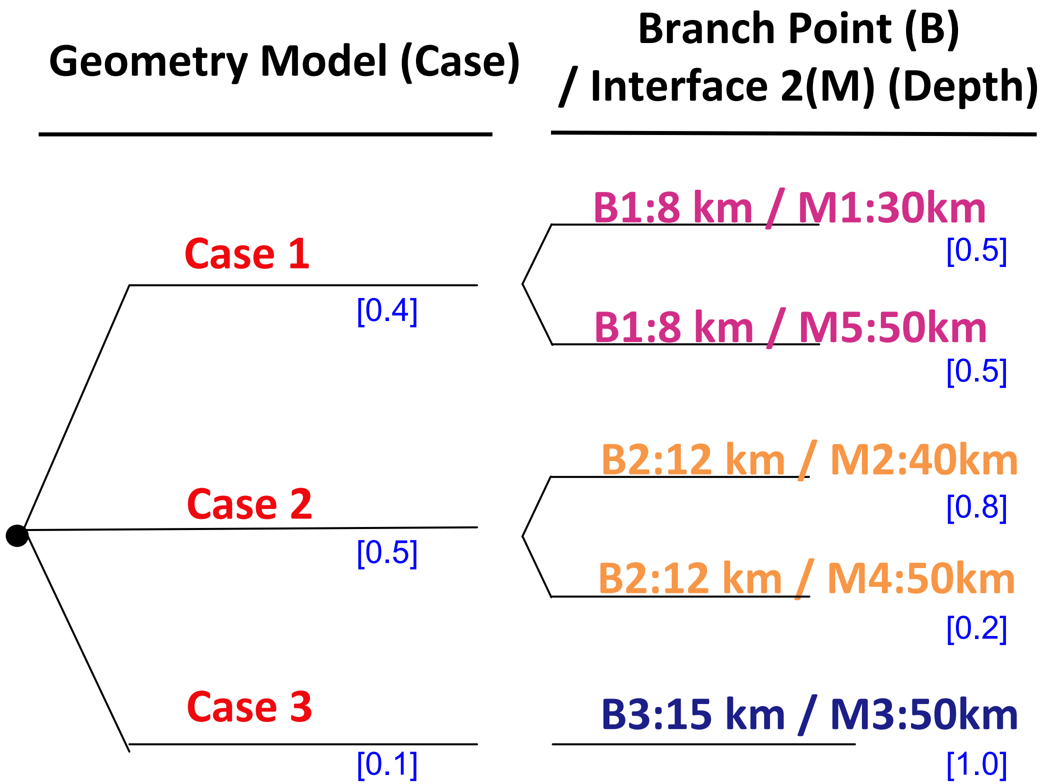
Underground Geometry (dip and depth) of Ryukyu Subduction Interface

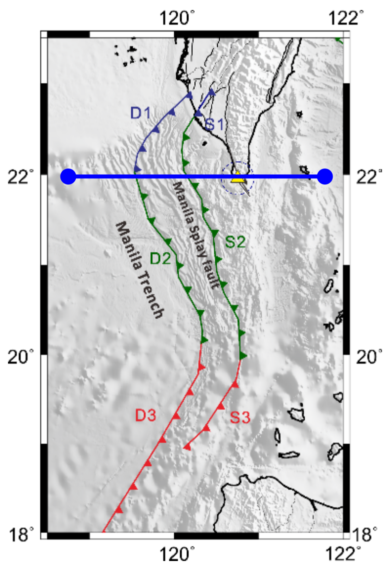
Geometry Model (Case)	Branch Point (B) / Interface 2(M) (Depth)
Case 1 [0.4]	B1:7.5 km / M1:25km [0.5]
	B1:7.5 km / M5:35km [0.5]
Case 2 [0.5]	B2:9 km / M2:30km [0.8]
	B2:9 km / M4:35km [0.2]
Case 3 [0.1]	B3:10 km / M3:35km [1.0]

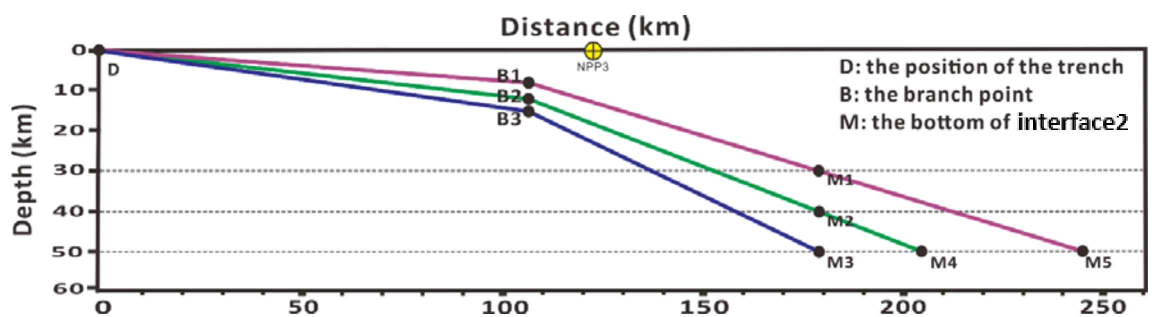




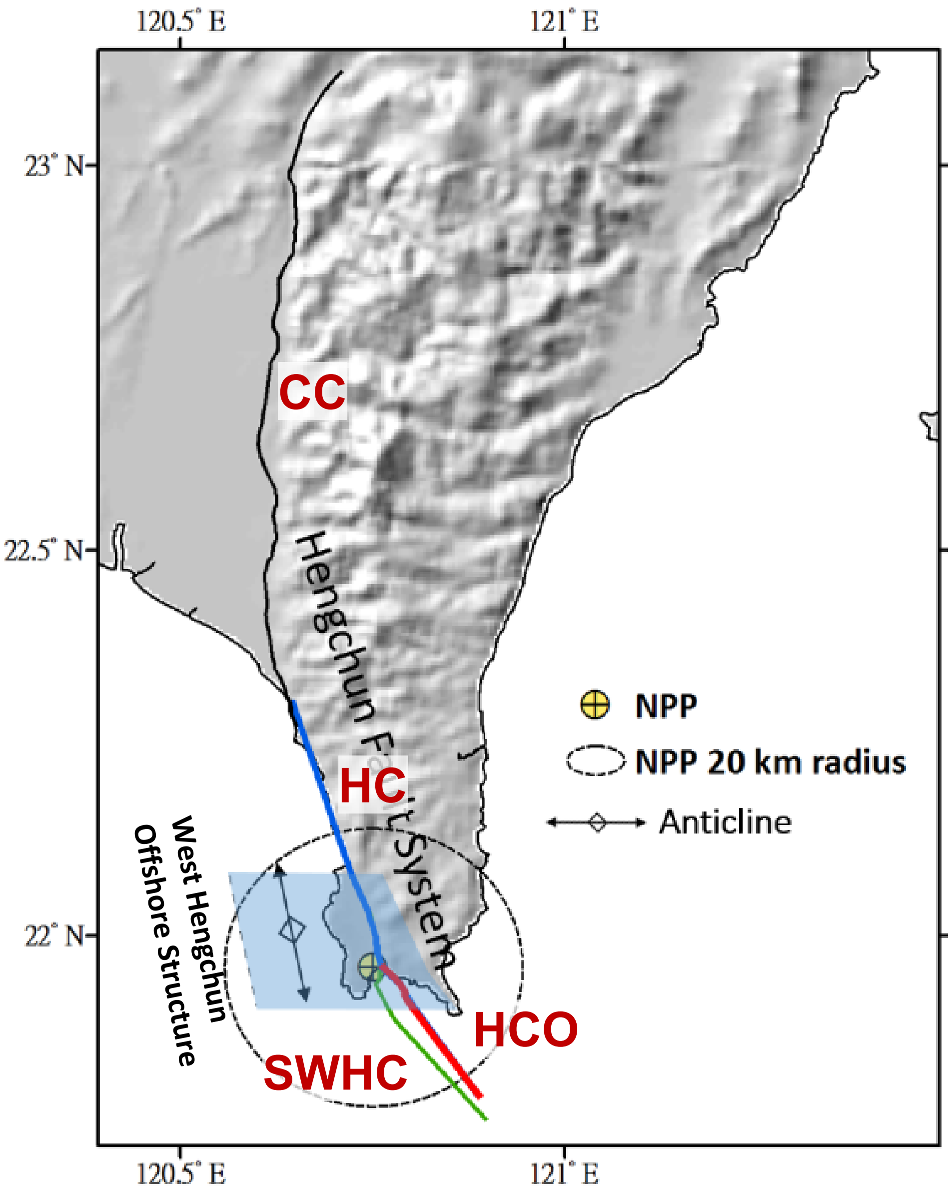
Underground Geometry (dip and depth) of Manila Subduction Interface

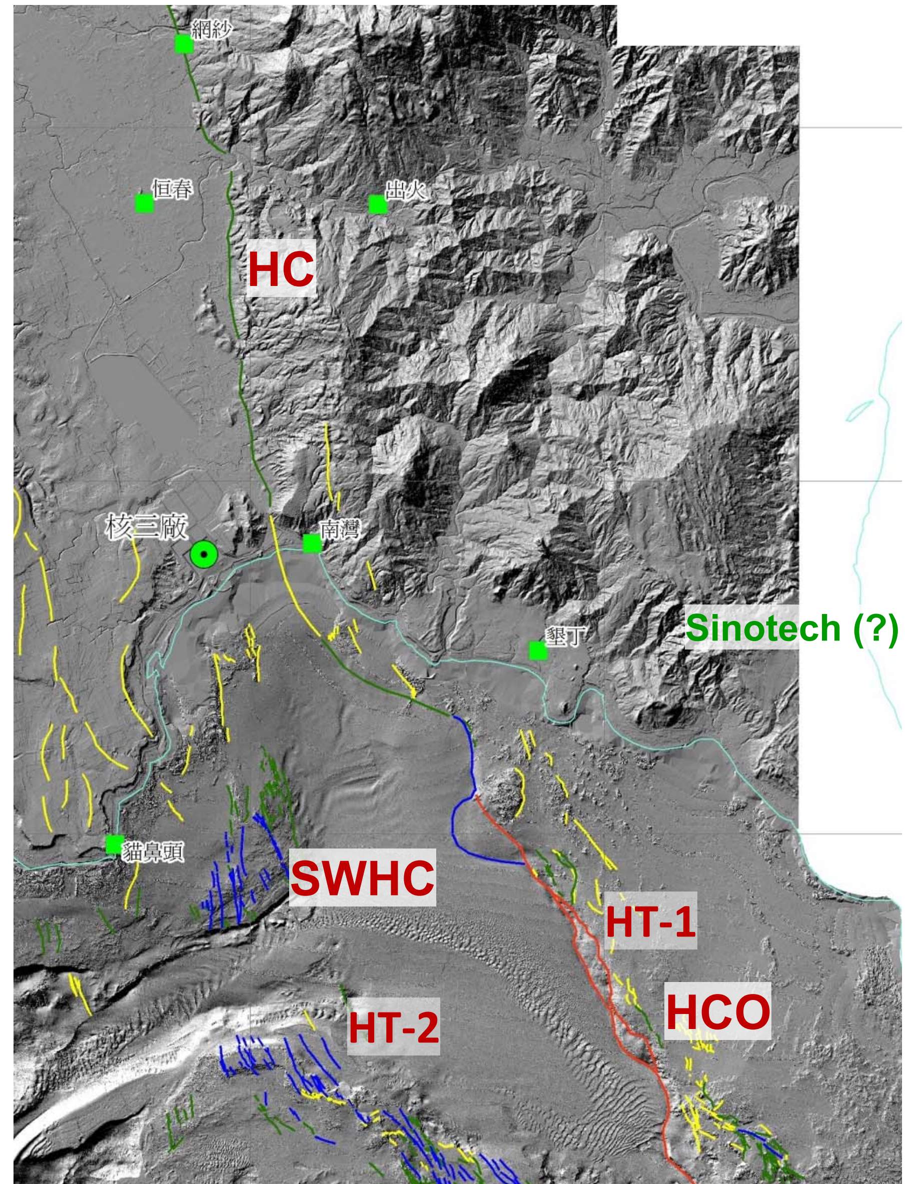




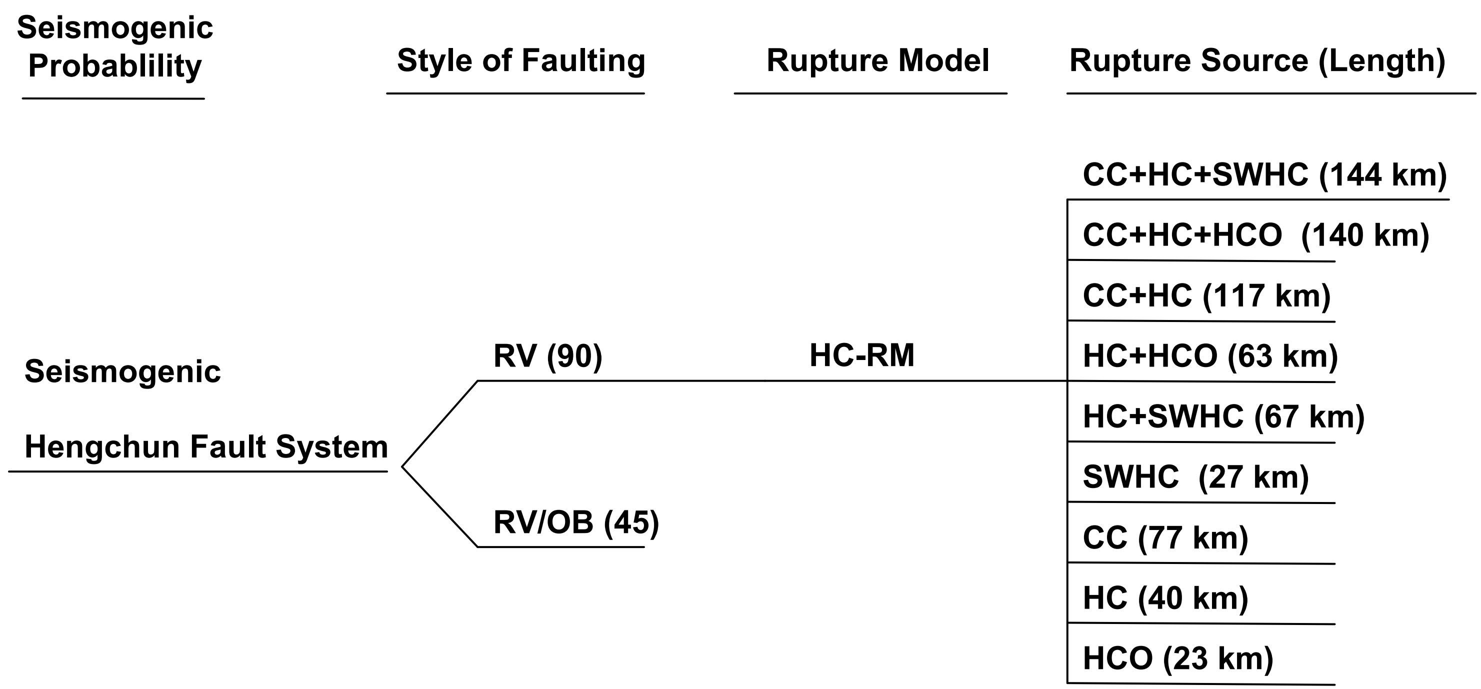


Surface Trace of Hengchun Fault System

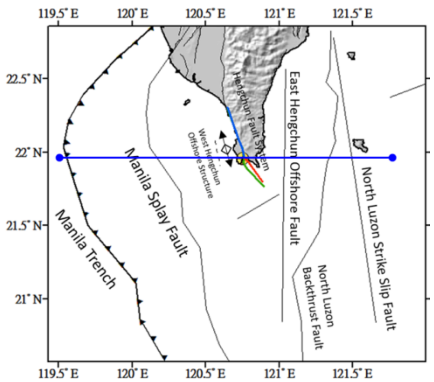


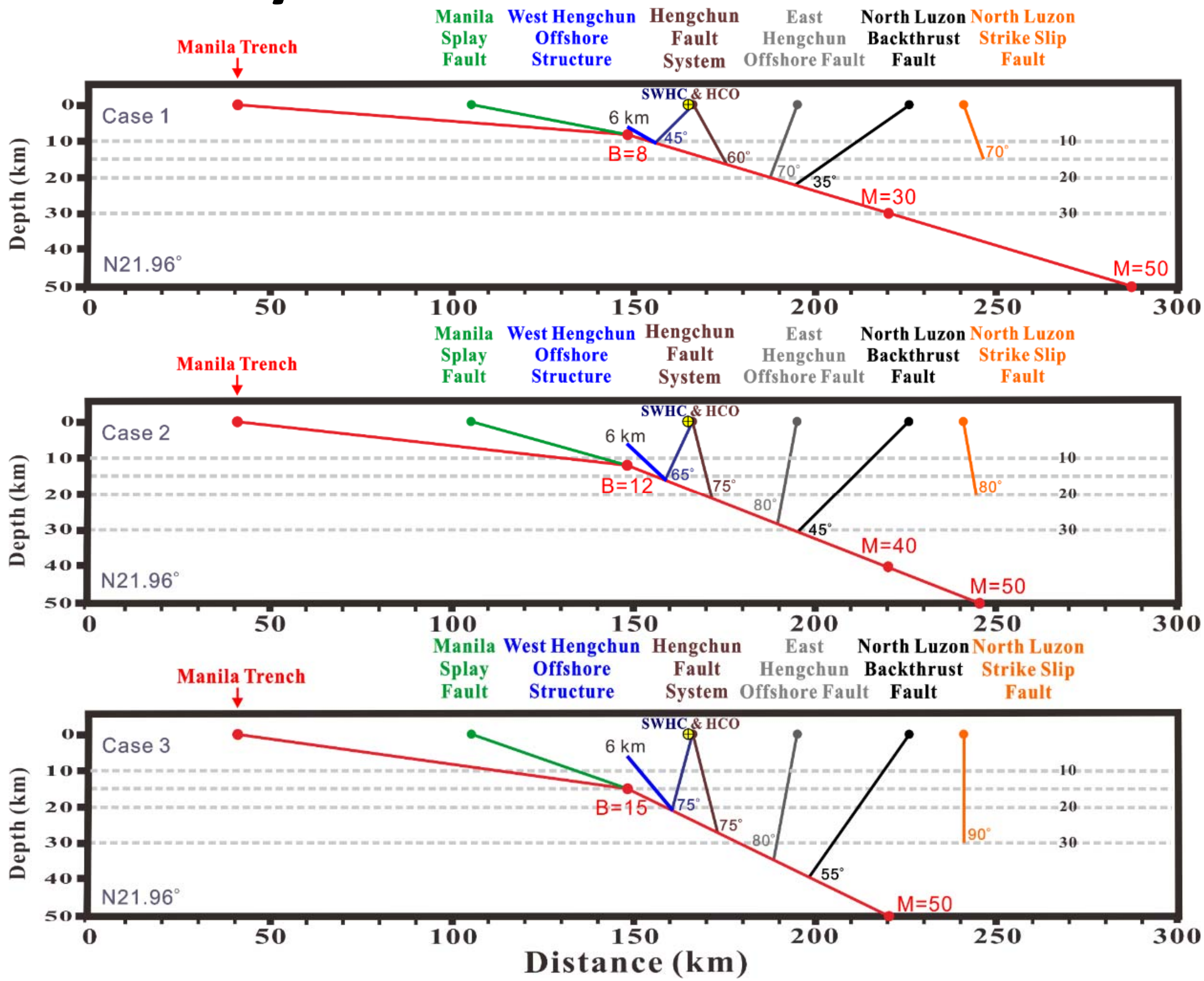


Rupture Sources of Southern Primary Faults



Underground Geometry (dip and depth) of Southern Primary Faults and Other Faults





Relate the fault depths to geometry of Manila subduction interface

(Total 3 combinations)

Magnitude Distribution Model

Candidate Magnitude Scaling Relationships

Tectonic Regime	Reference	Source type	M range	Relation
Crustal (global scale or local scale for Taiwan)	Wells and Coppersmith, 1994	All, SS, R, N	surface : 5.2-8.1 subsurface : 4.8-8.1	M-L
			4.8-7.9	M-A
	Hanks and Bakun, 2008;2014	SS	5-8	M-A
	Wesnousky, 2008	All, SS, R, N	5.9-7.9	M-L
	Leonard, 2010	All, SS, DS(R,N)	5.0-8.0	M-A&M-L
	Yen and Ma, 2011	All, SS, R, N	4.6-7.6 (8.9)	M-A&M-L
Suduction (oceanic)	Blaser et al. 2010	All, SS, R, N	5.3-9.5	M-L
Subduction – interface	Murotani et al., 2008 Murotani et al., 2013	interface	6.7-8.4 6.7-9.2	M-A
	Strasser et al, 2010	at the contact between the subducting and the overriding plate	6.3-9.4	M-A&M-L
Subduction – intraslab	Ichinose et al., 2006	Undefined	5.3-7.9	M-A
	Strasser et al, 2010	within the subducting slab	5.9-7.8	M-A&M-L

(from Yen, Yin Tung in WS#2)

Magnitude Scaling Laws for Crustal Faults

- **Wells and Coppersmith (1994) [Surface Rupture Length]**

SS	Mw = 5.16 + 1.12Log(SRL)
RV	Mw = 5.00 + 1.22Log(SRL)
NM	Mw = 4.86 + 1.32Log(SRL)

- **Wells and Coppersmith (1994) [Rupture Area]**

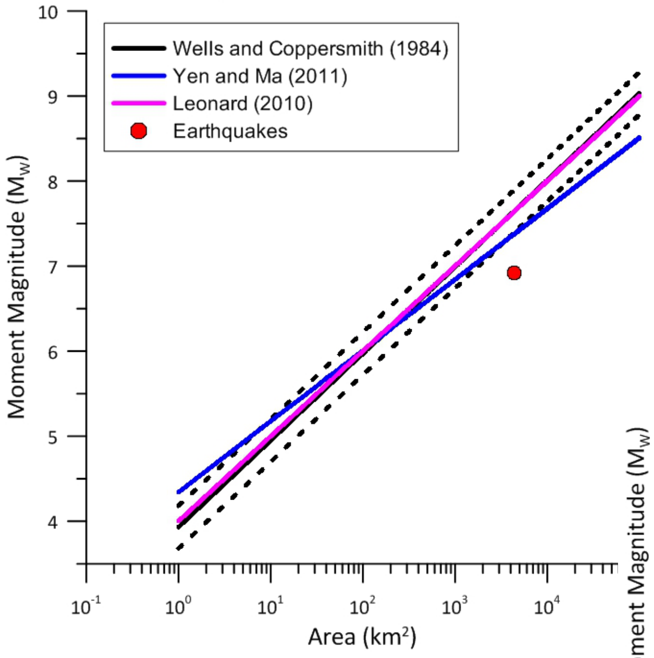
SS	Mw = 3.98 + 1.02Log(A)
RV	Mw = 4.33 + 0.90Log(A)
NM	Mw = 3.93 + 1.02Log(A)

- **Yen and Ma (2011) [Area]**

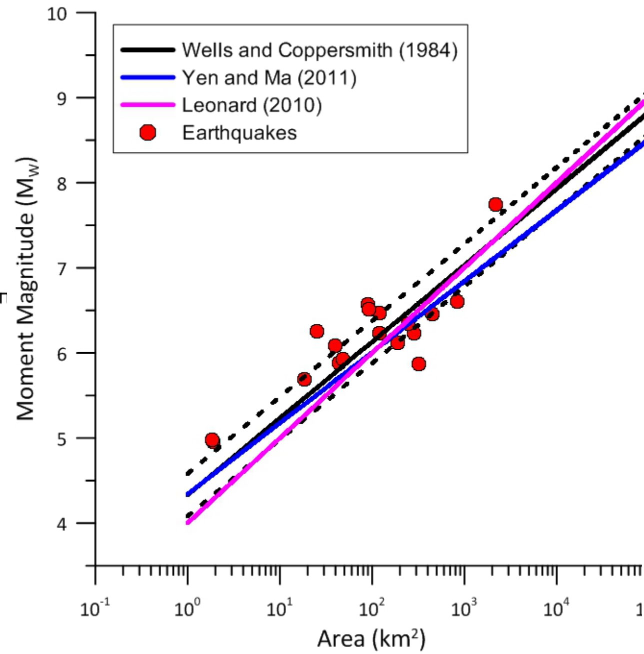
DS	Log(Ae) = -12.45 + 0.80Log(Mo), Log(Mo) = 9.05 + 1.5Mw
SS	Log(Ae) = -14.77 + 0.92Log(Mo), Log(Mo) = 9.05 + 1.5Mw

Comparison of Scaling Laws for Crustal Faults

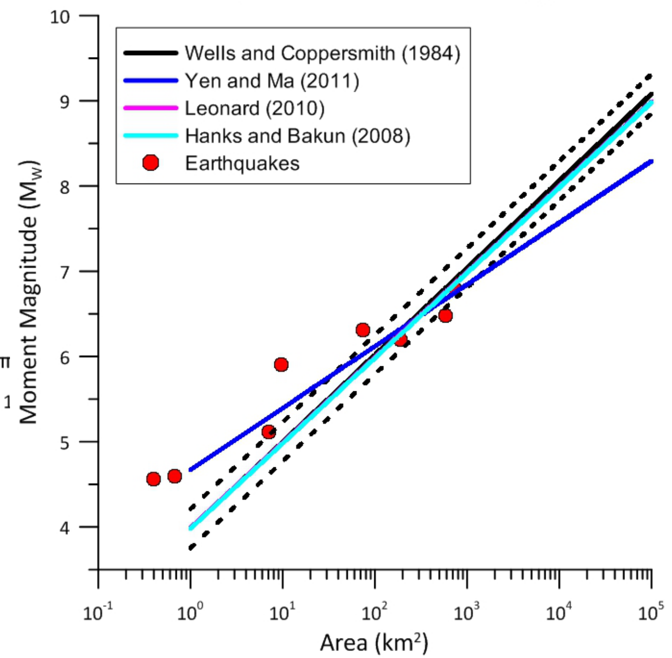
Scaling Law for Crust, NM Type



Scaling Law for Crust, RV Type



Scaling Law for Crust, SS Type



Scaling Laws for Subduction Interfaces

Strasser(2010)

$$M_w = 4.868 + 1.392\log_{10}(SRL)$$

95 events used in fault length

$$M_w = 4.441 + 0.846\log_{10}(A)$$

85 events used in fault area

Magnitude Range: 6.3-9.4

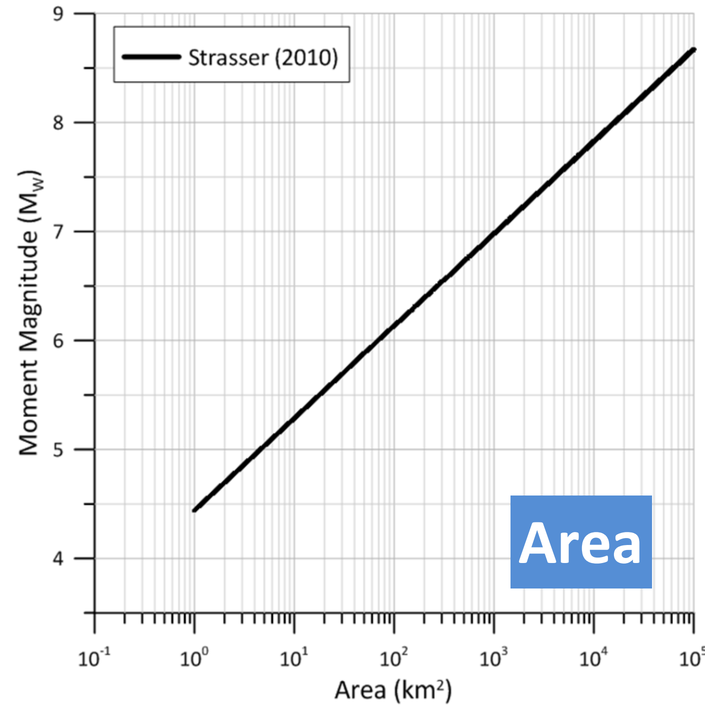
Blaser(2010)

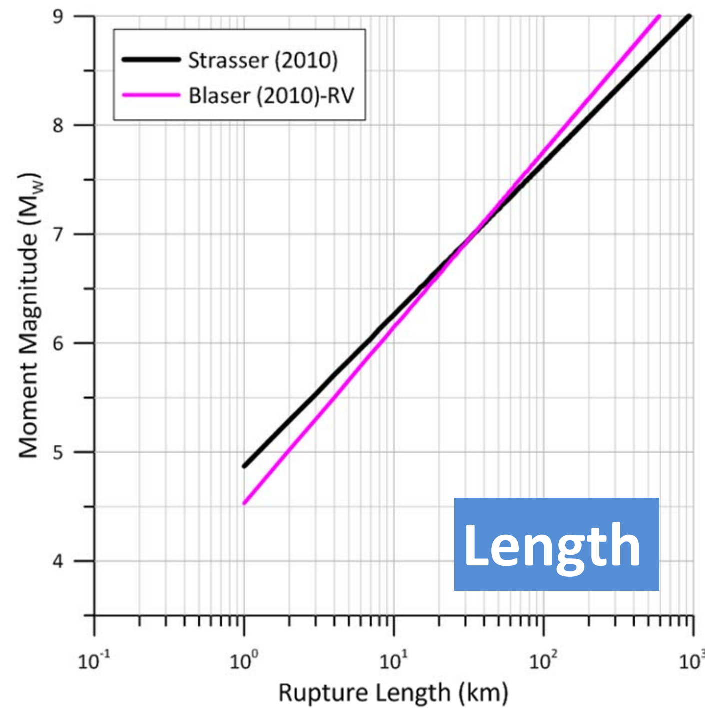
$$\log_{10}(RLD) = -2.81 + 0.62M_w$$

26 events used in reverse-slip

Magnitude Range: 6.1-9.5

Length Range: 13km-1400km





Estimated Magnitude due to Rupture of Manila Subduction Interface (D1+D2+D3)

Branch points	interface model	Length	Area	Strasser		Blaser [RV]
				Mw (SRL)	Mw (area)	Mw (RLD)
B1/M1	D+M	621	91,497	8.76	8.64	9.04
B1/M1	M	553	38,828	8.69	8.32	8.96
B2/M2	D+M	621	92,953	8.76	8.64	9.04
B2/M2	M	553	39,994	8.69	8.33	8.96
B3/M3	D+M	621	94,898	8.76	8.65	9.04
B3/M3	M	553	41,648	8.69	8.35	8.96
B1/M5	D+M	621	124,895	8.76	8.75	9.04
B1/M5	M	553	72,226	8.69	8.55	8.96
B2/M4	D+M	621	106,287	8.76	8.69	9.04
B2/M4	M	553	53,328	8.69	8.44	8.96
			In this case:	Med. (8.69~8.76)	Min. (8.32~8.75)	Max. (8.96~9.04)

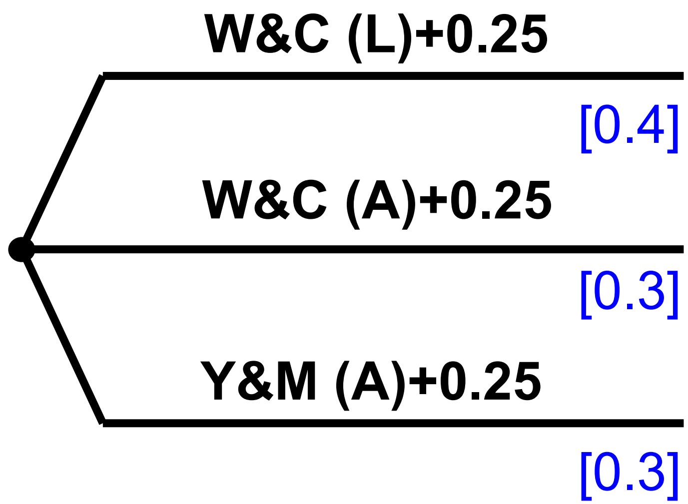
Estimated Magnitude due to Rupture of Ryukyu Subduction Interface (R1+R2+R3)

Branch points	interface model	Length	Area	Strasser		Blaser [RV]
				Mw (SRL)	Mw (area)	Mw (RLD)
B1/M1	D+M	796	111,545	8.91	8.71	9.21
B1/M1	M	684	41,367	8.81	8.35	9.10
B2/M2	D+M	796	111,397	8.91	8.71	9.21
B2/M2	M	684	41,091	8.81	8.34	9.10
B3/M3	D+M	796	113,480	8.91	8.72	9.21
B3/M3	M	684	43,076	8.81	8.36	9.10
B1/M5	D+M	796	132,324	8.91	8.77	9.21
B1/M5	M	684	62,146	8.81	8.50	9.10
B2/M4	D+M	796	120,374	8.91	8.74	9.21
B2/M4	M	684	50,067	8.81	8.42	9.10
			In this case:	Med. (8.81~8.91)	Min. (8.34~8.77)	Max. (9.10~9.21)

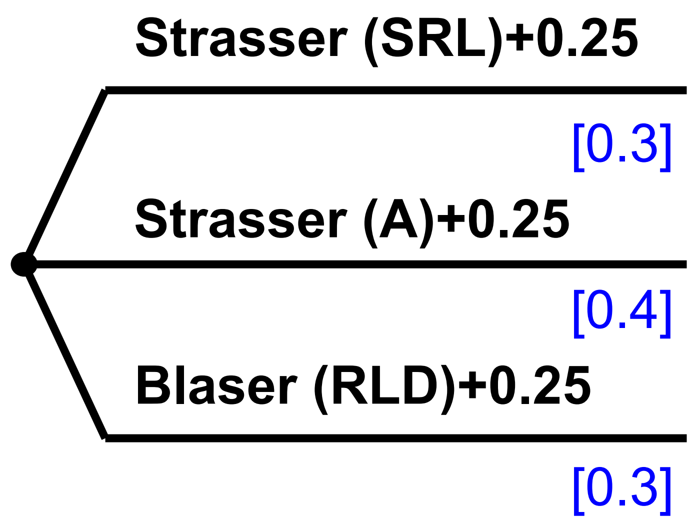
Logic Tree Node for Maximum Magnitude

- **Idea behind the weight settings**
  - Moment magnitude is directly related to rupture area
  - However, only surface rupture length can be measured directly and may provide a more reliable quantity
- **Crustal faults**
  - Both W&C (A) and Y&M (A) use the rupture area, so we give them a total weighting of [0.6] and spilt equally as [0.3]
  - Only W&C (L) uses rupture length, and we give it a weighting of [0.4]
- **Subduction interfaces**
  - Both Strasser (SRL) and Blaser (RLD) use rupture length, so we give each of them a weighting of [0.3]
  - Only Strasser (A) use rupture area, and we give it a weighting of [0.4]
  - From previous slides, Strasser (A) gives lowest magnitude; in addition, the the magnitude difference due to change of rupture areas is not significant

Crustal Faults



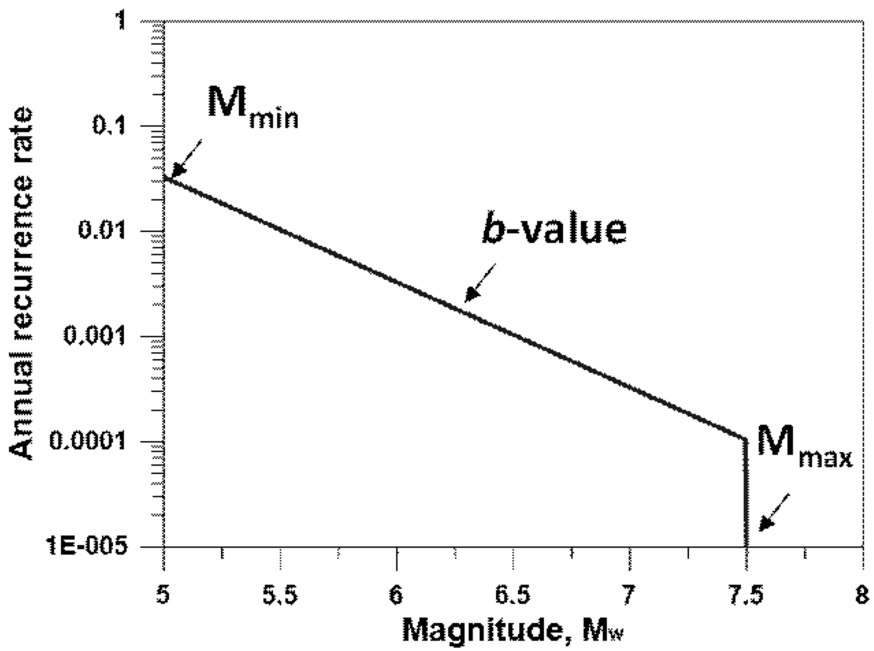
Subduction Interfaces



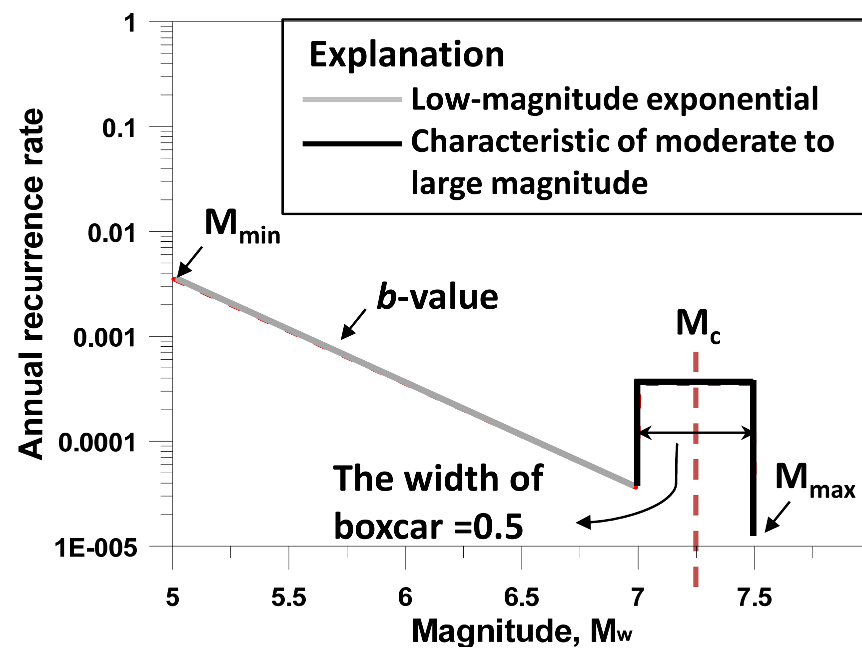
Magnitude PDF for Faults and Interfaces

– **Magnitude PDF:**
  - Characteristic Earthquake Model (Youngs and Coppersmith,1985)
  - Truncated Exponential Model (Cornell and Vanmarcke, 1968)
– **b-value = 1.0**
– **M_{min} = 5.0**

Truncated Exponential Model

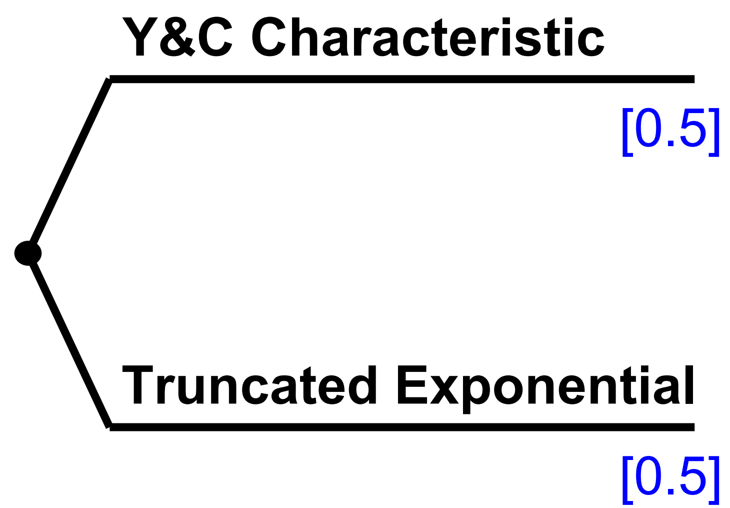


Characteristic Earthquake Model



Logic Tree Node for Magnitude Distribution

- **Idea behind the weight settings**
  - Characteristic earthquake model seems more realistic; however, it still needs historical earthquake data and geologic survey for individual fault to verify the model suitability
  - In most cases, the faults in the scope, especially offshore faults, do not have sufficient data to fully support the characteristic earthquake model; therefore, we give Characteristic earthquake model and Truncated exponential model equal weighting



Thank You for Your Attention