North Primary faults
Shanchiao, ST-II, Aoti, North Ilan and S fault

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Taiwan SSHAC Level 3 Project
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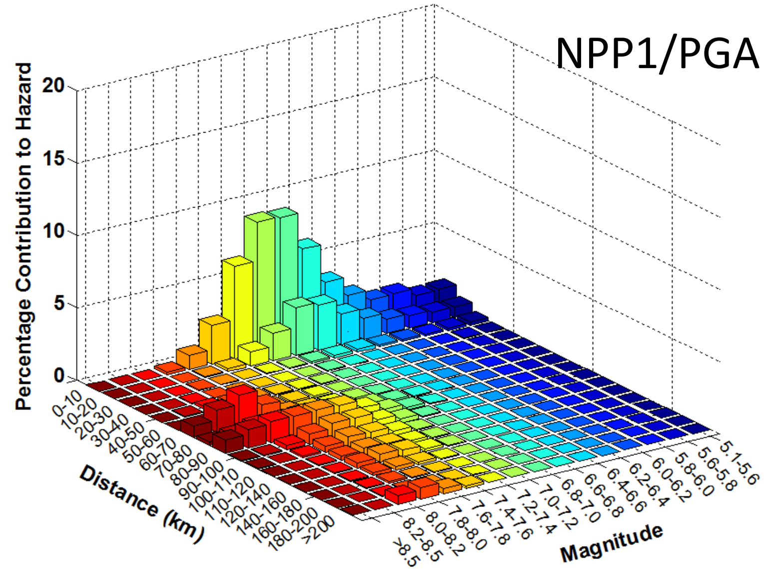
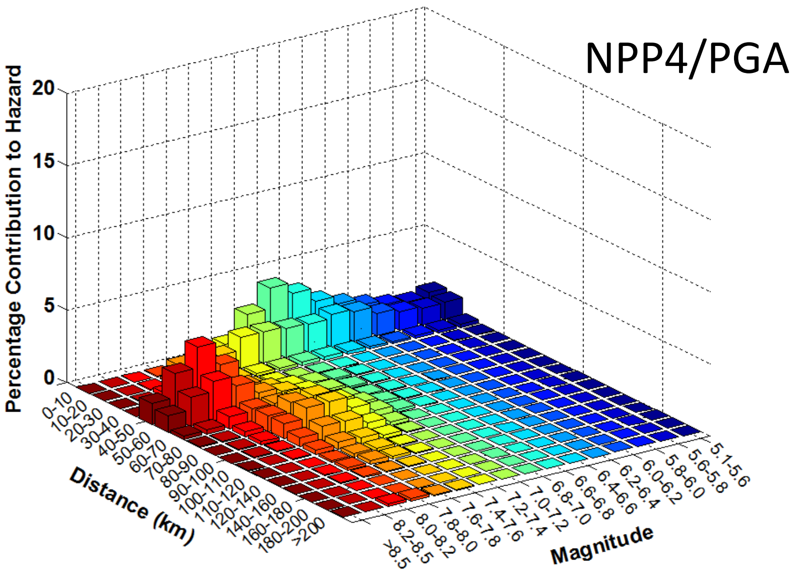
Taipei, Taiwan

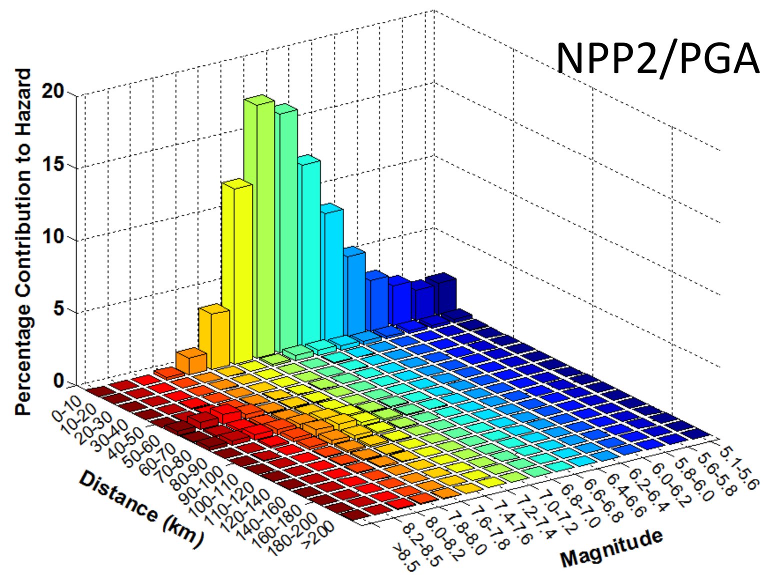
Definition of Primary Faults and Other Faults

- According to hazard deaggregation in PSHA, **the major hazards come from the seismic sources within 20 km range of NPP sites**

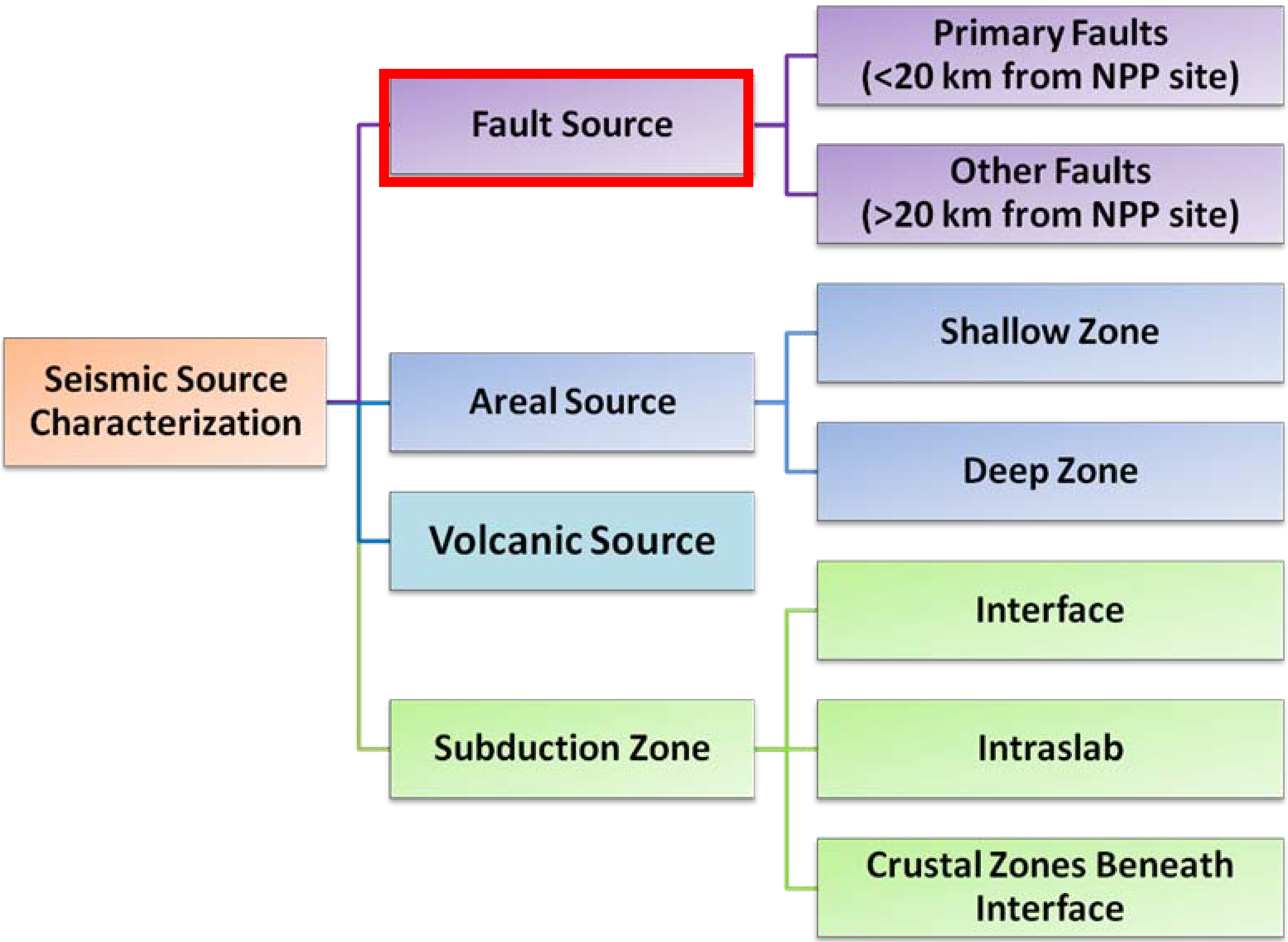
> - **Primary Faults: ≦ 20 km**
> - **Other Faults: > 20 km**
>   - Onshore
>   - Offshore



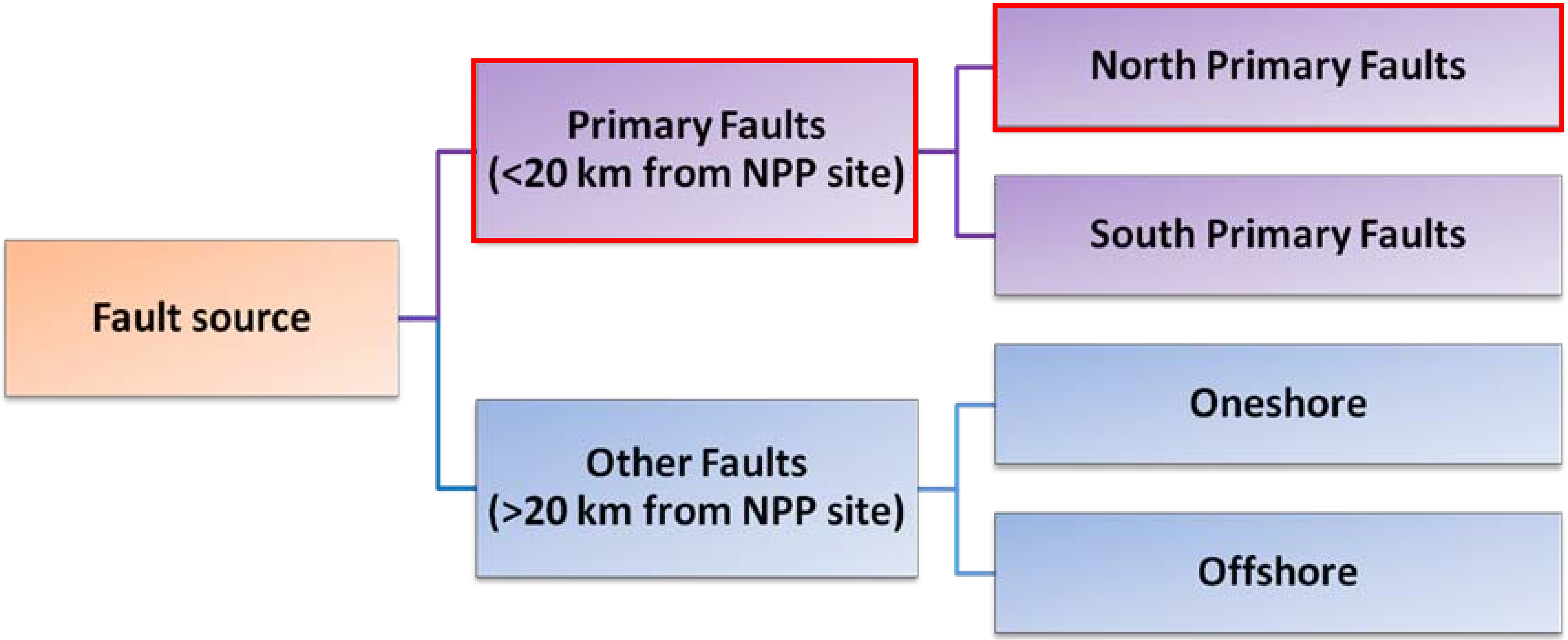




Seismic Source Characterization in Taiwan

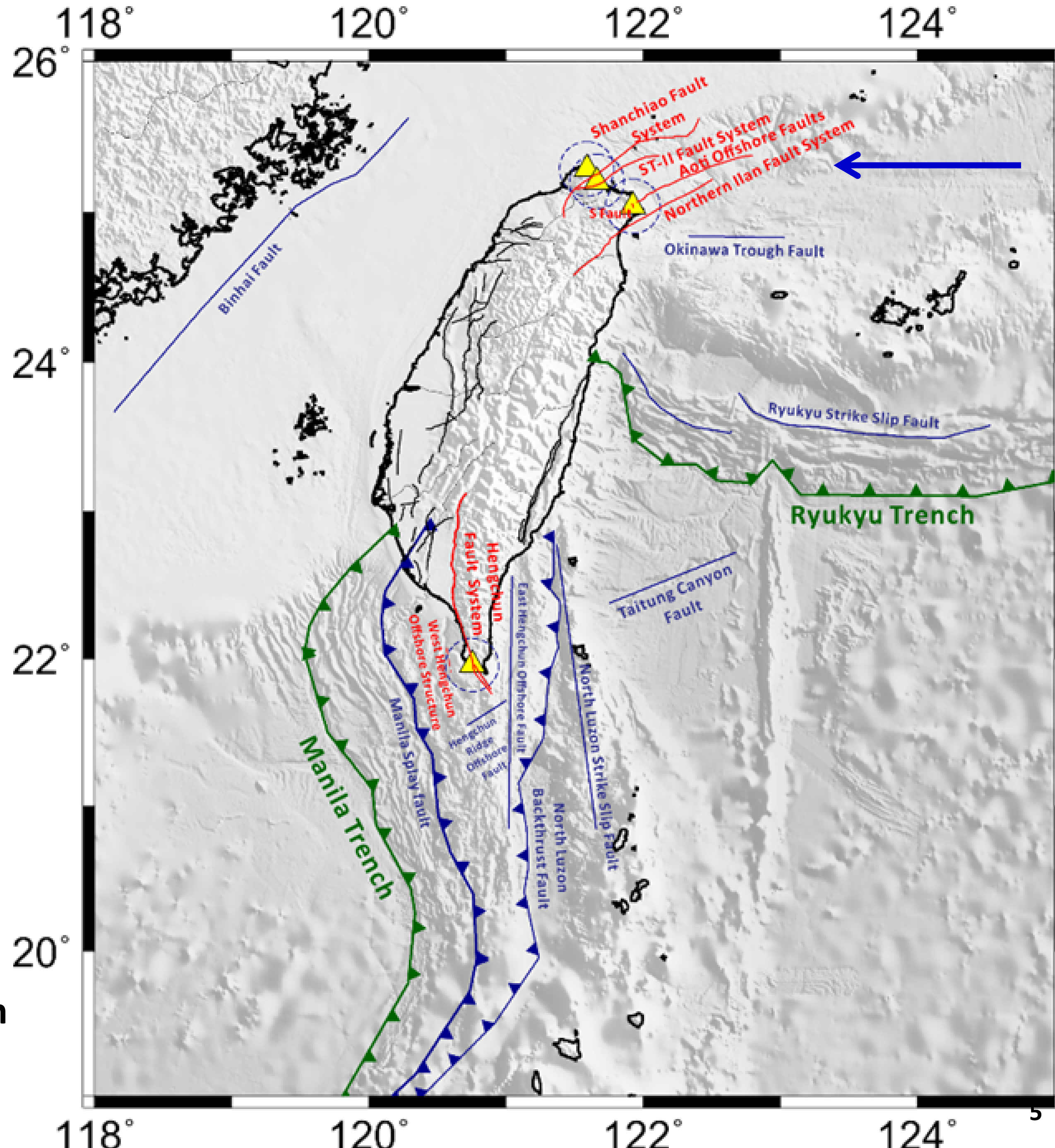


Seismic Source Characterization in Taiwan



▪ 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



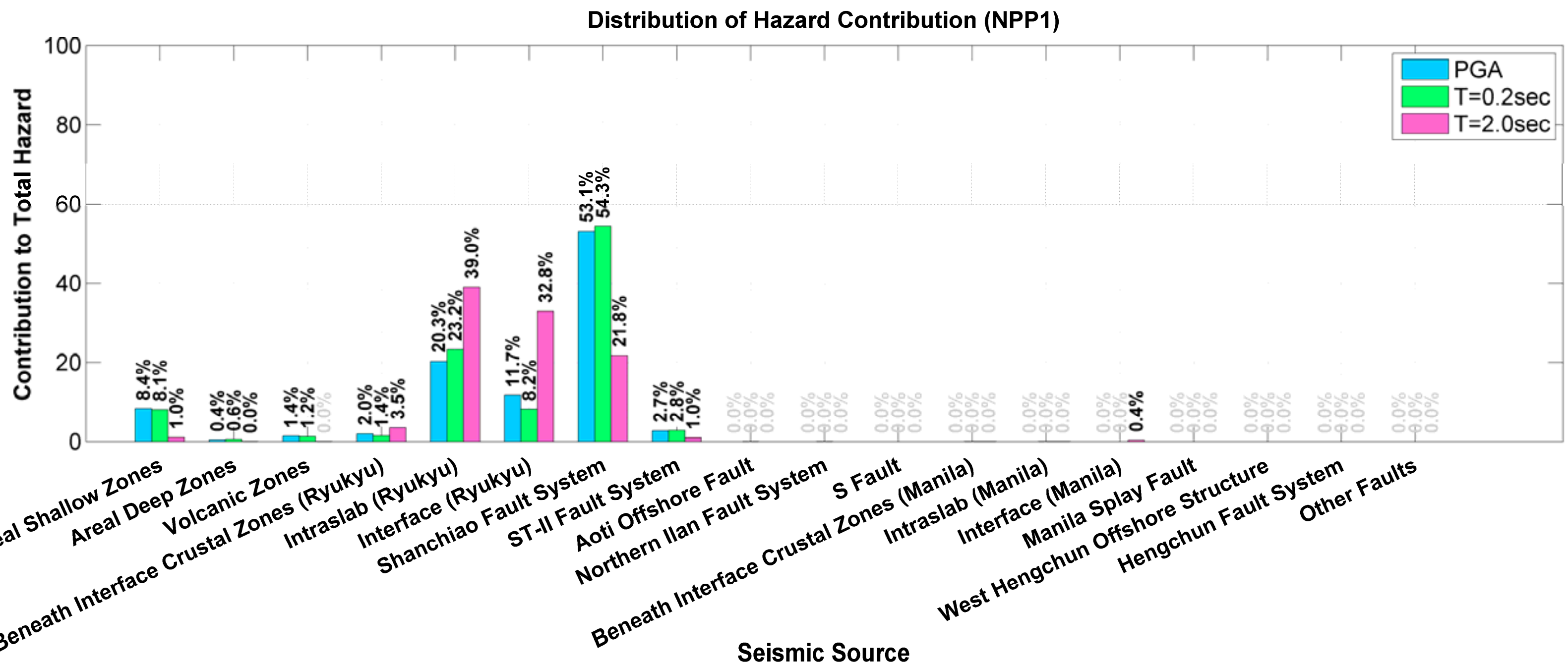
North Primary faults:

P1: Shanchiao Fault System
P2: ST-II Fault System
P3: S Fault
P4: Aoti Offshore Faults
P5: Northern Ilan Fault System

Outline

- **1. Overview**
  - Hazard Contribution for NPP sites in Northern Taiwan
  - Sensitivity analysis → Logic tree Nodes
  - Primary faults in Northern Taiwan
- **2. Geometry model in logic tree**
  - Observation of surface fault traces and related data
  - Style of faulting (Normal or oblique with different rake angles)
  - Seismogenic depth
  - Dips at different depths
  - Simplified geometry model (according sensitivity results)
- **3. Fault Rupture Model**
  - Analytic model and probable segmentations
- **4. Slip Rate Model**
  - Observations of (vertical) slip rates in each segment
  - Slip rate allocation method/estimation
- **5. Magnitude**
  - Scaling law
- **6. Current Logic tree of North primary faults**

Hazard contribution for NPP1



PGA

Shanchiao fault system : 53.1%

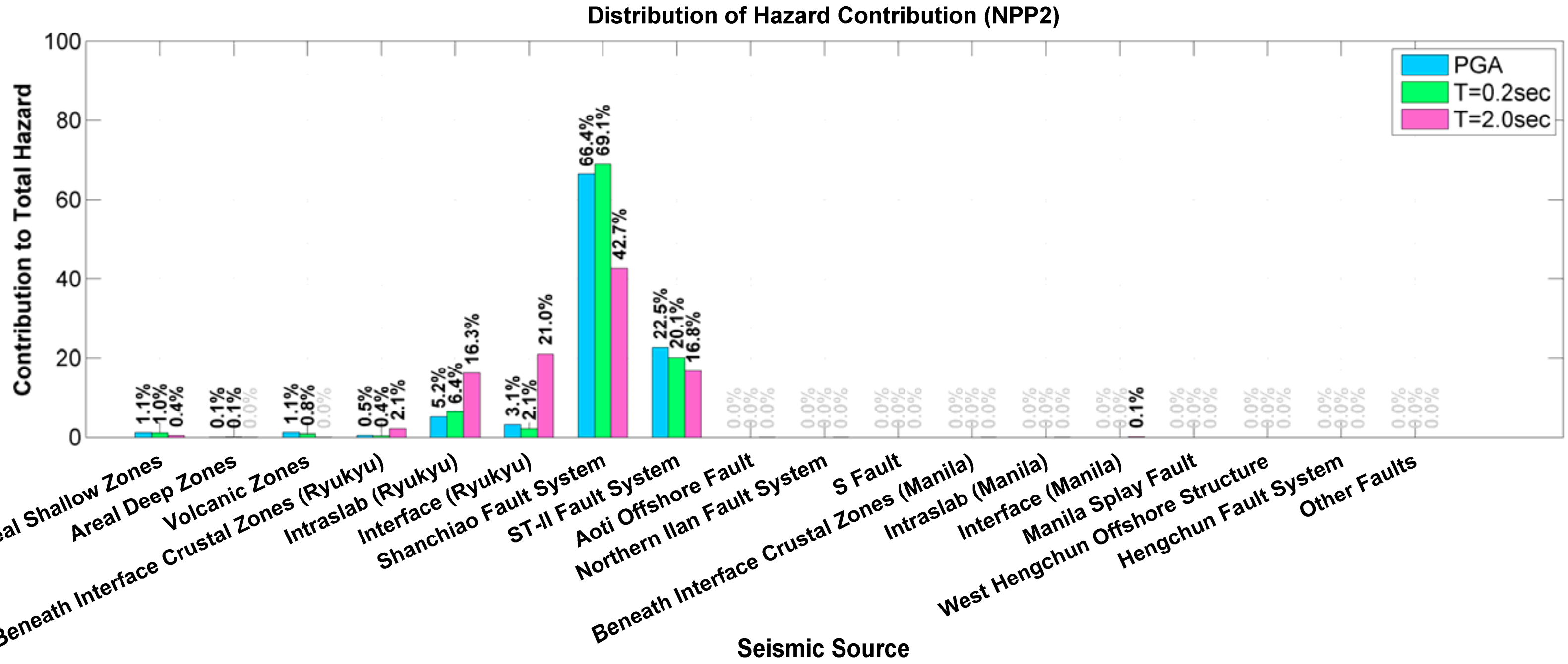
Ryukyu intraslab :20.3%

Ryukyu interface :11.7%

Areal shallow zone: 8.4%

ST-II fault :2.7%

Hazard contribution for NPP2



PGA

Shanchiao fault system : 66.4%

ST-II fault :22.5%

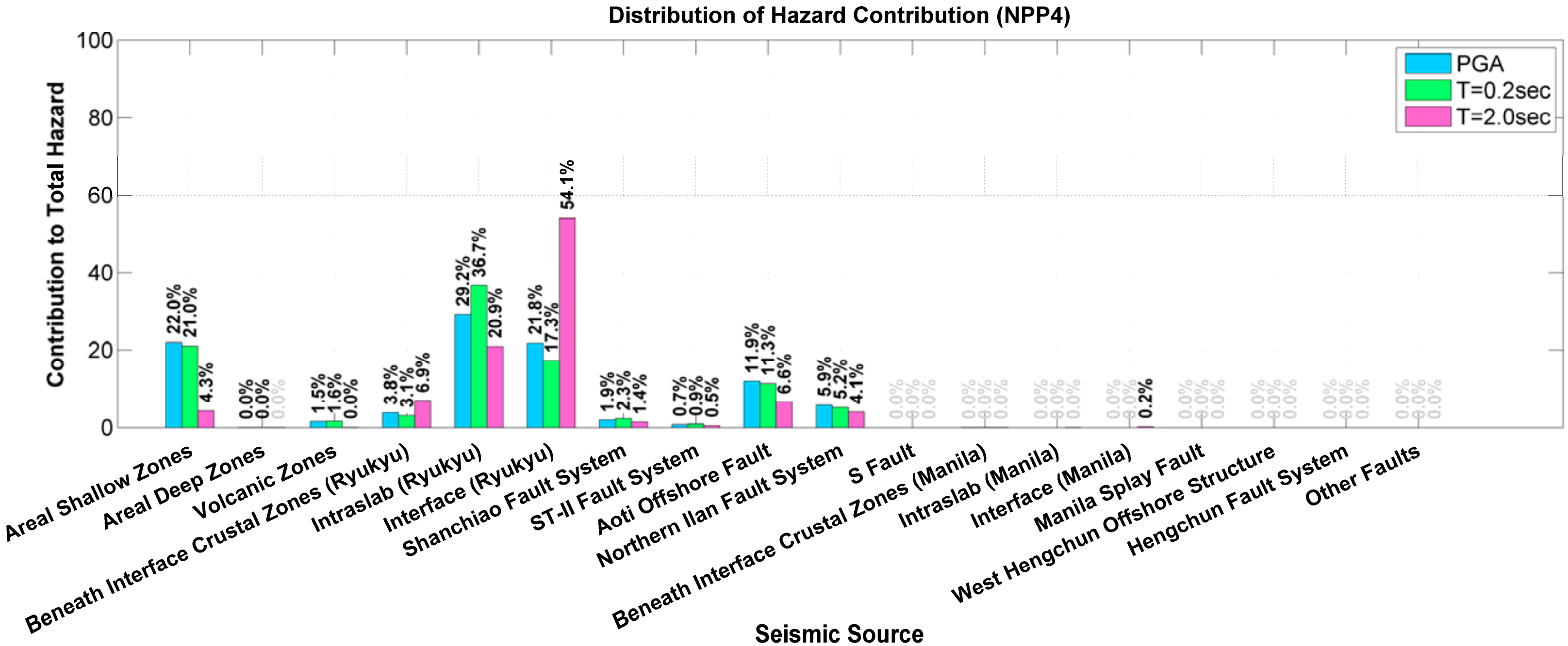
Ryukyu intraslab :5.2%

Ryukyu interface: 3.1%

Areal shallow zone:1.1%

Volcanic zones:1.1%

Hazard contribution for NPP4



PGA

Ryukyu intraslab :29.2%

Areal shallow zones: 22.0%

Ryukyu interface :21.8%

Aoti offshore faults:11.9%

Northern Ilan fault system:5.9%

Beneath Ryuku interface crustal zones:3.8%

Shanchiao fault system : 1.9%

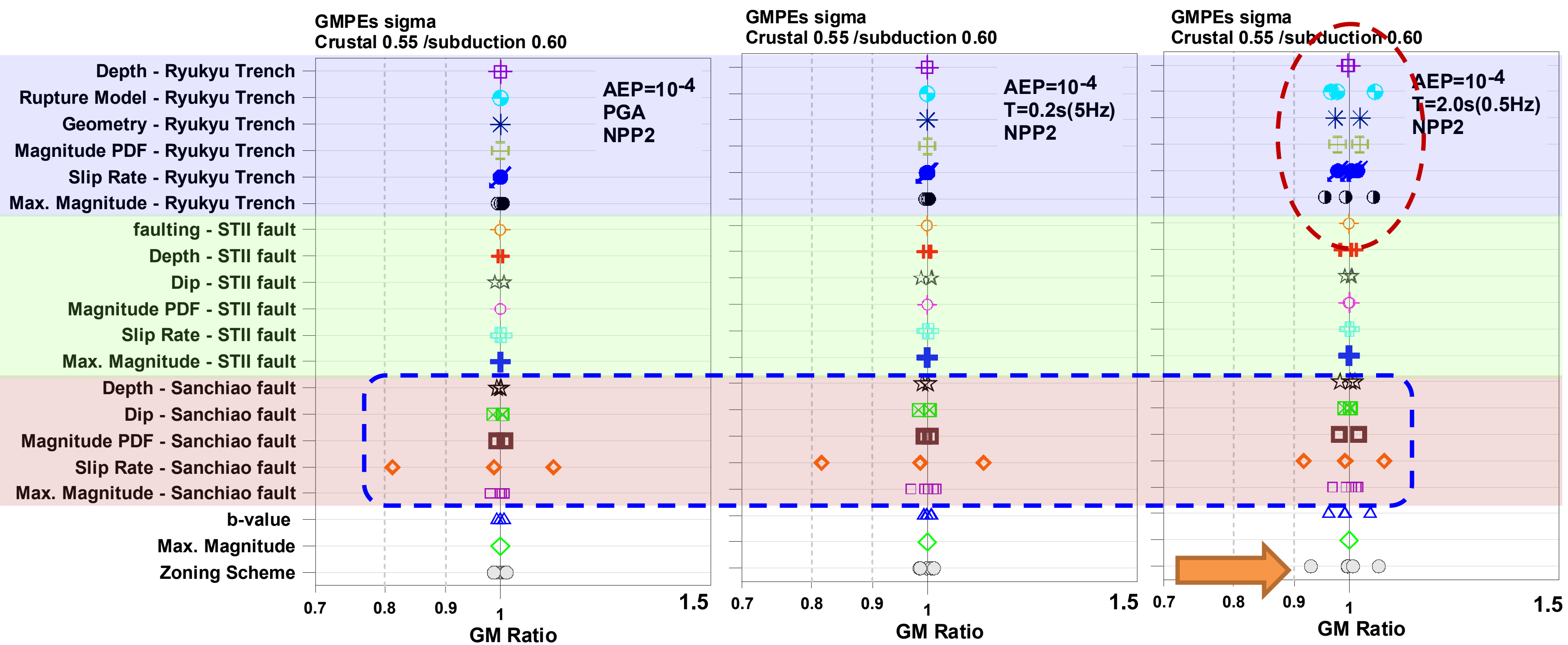
Volcanic zones: 1.5%

ST-II fault system:0.7%

S fault :0%

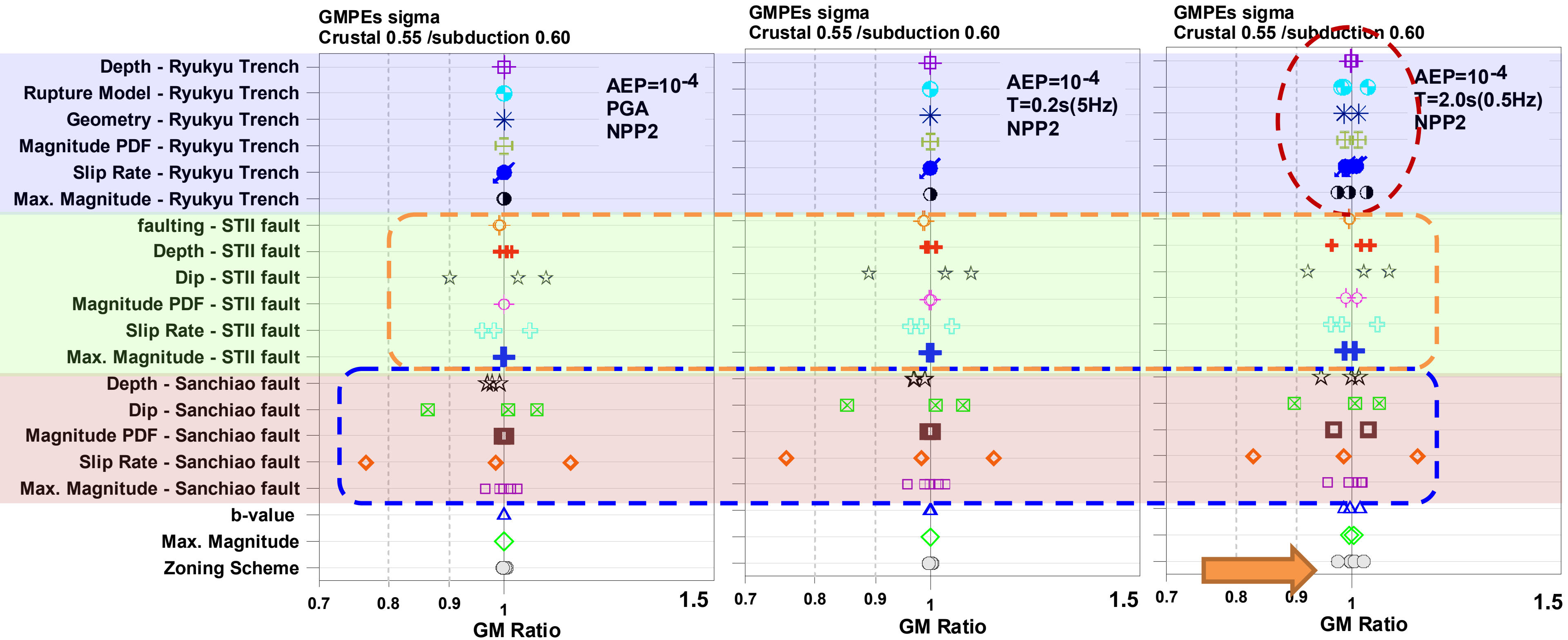
The Tornado Diagram (WS#2)

NPP1 AEP=10^{-4}



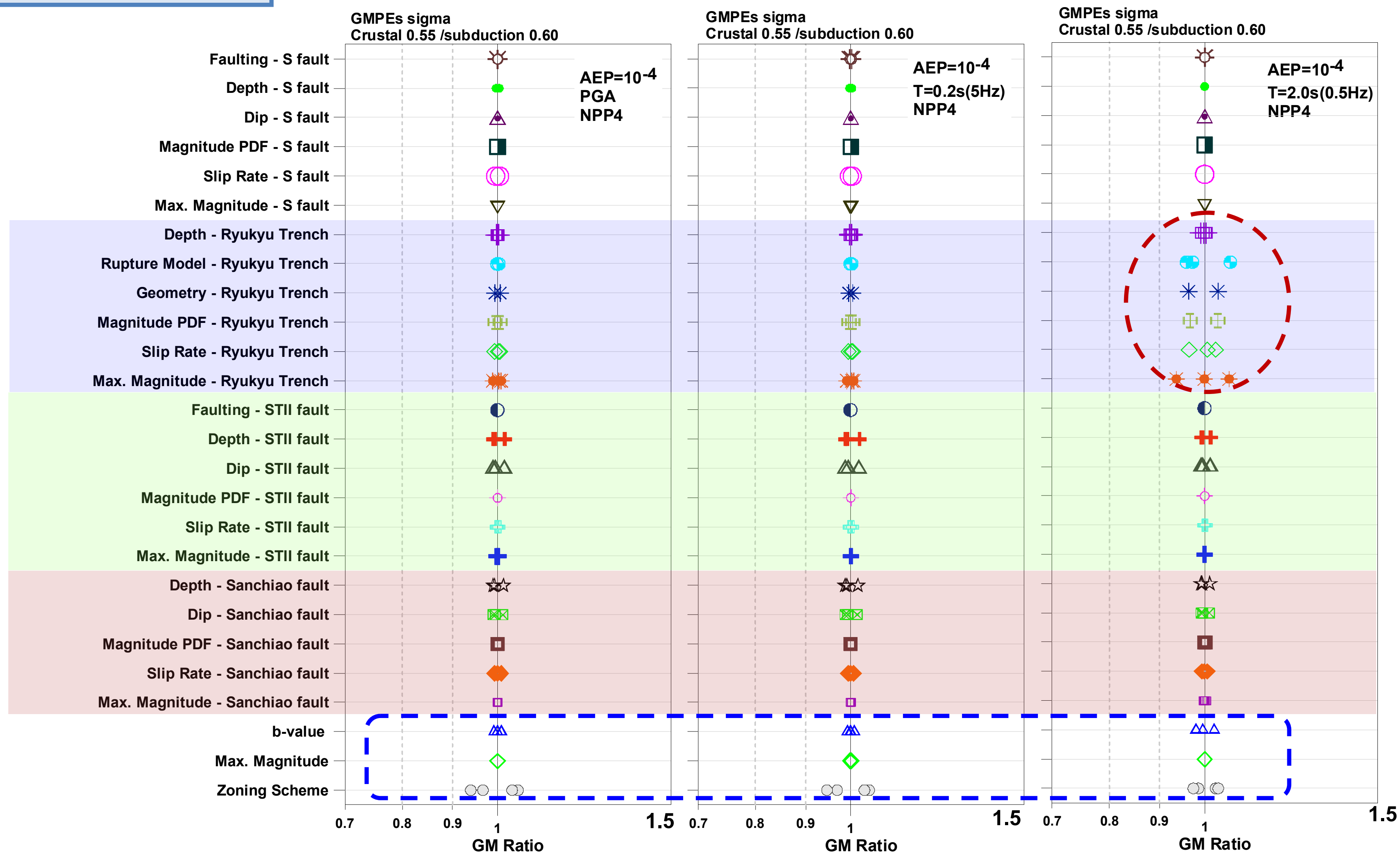
- **NPP1**
  - Shanchiao fault(6.9km) (Geometry, Slip rate, Max. Magnitude)
  - Areal Source (Zoning Scheme(activity rate), Max. Magnitude)
  - Ryukyu Trench (Geometry, Magnitude)

NPP2 AEP=10^{-4}



- **Sensitive parameters for NPP2**
  - Shanchiao fault(4.9km) (Geometry, Slip rate, Max. Magnitude)
  - STII fault (2.4km)(Geometry, Slip rate)
  - Areal Source (Zoning Scheme(activity rate), Max. Magnitude)
  - Ryukyu Trench (Geometry, Magnitude)

NPP4 AEP=10^{-4}



- **Sensitive parameters for NPP4**
  - Areal Source (Zoning Scheme, b-value)
  - Ryukyu Trench (Geometry, Max. Magnitude, Slip rate)

1. Overview _ Logic tree nodes

Geometry

- Style of Faulting
- Rupture Model
- Rupture Source
- Fault Geometry Model
  - Dip
  - Seismogenic Depth

Activity

- Seismogenic Probability
- Vertical Rate
- Magnitude Distribution Model
  - Max. Magn.
  - Magnitude pdf

Sensitive node

*****Max Magn.** :

•Max Magn. = Char. Magn. + 0.25

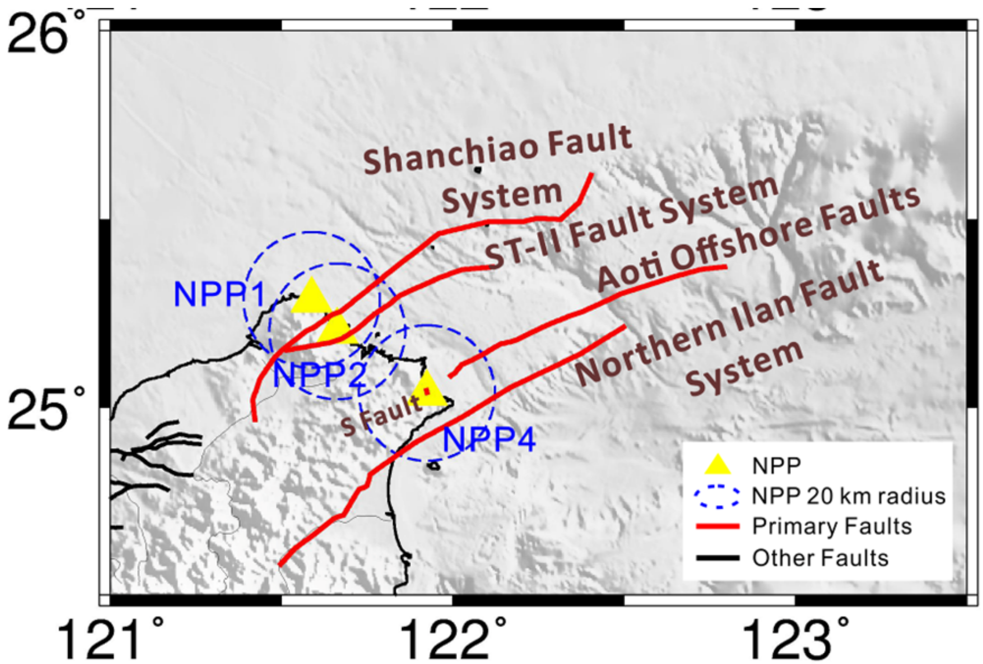
•Char. Magn. is calculated from Magnitude Scaling Law:

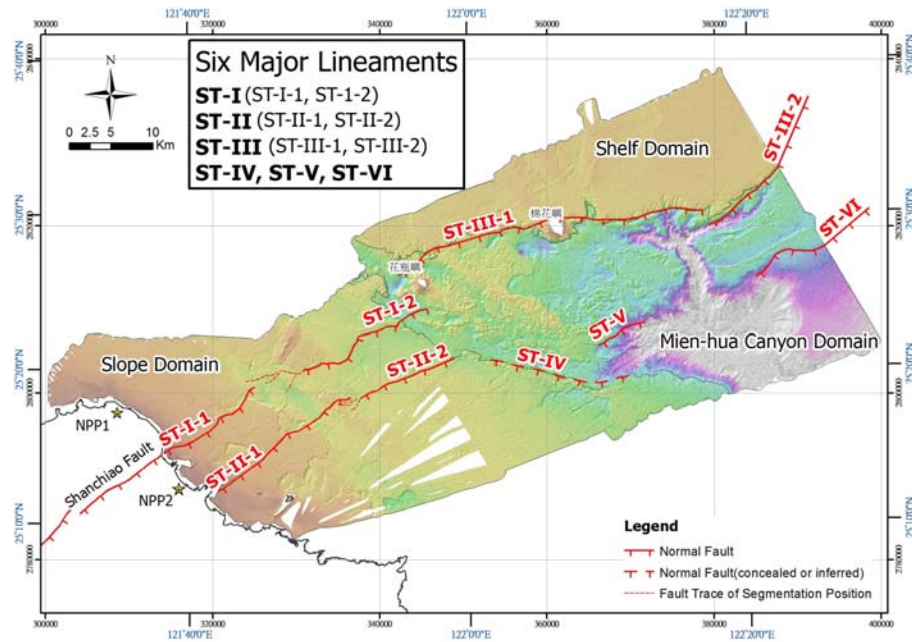
For Fault source: Wells and Coppersmith (1994), Yen and Ma (2011).

For interface source: Strasser et al (2010) and Blaser et al (2010).

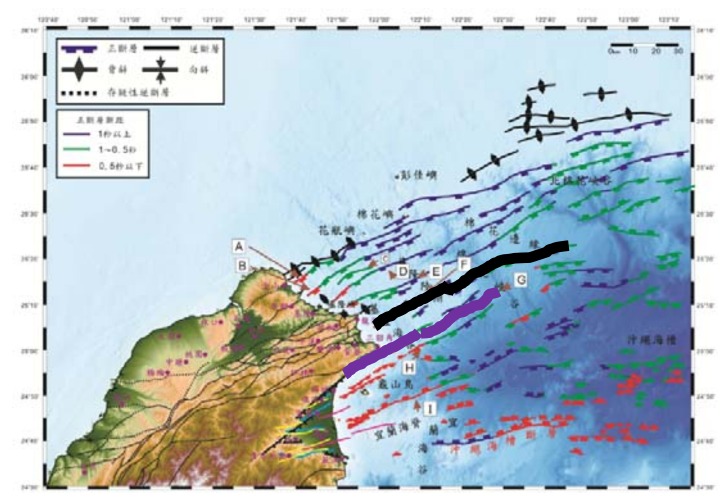
1. Overview _ Primary faults in northern Taiwan

Sinotech(2015)



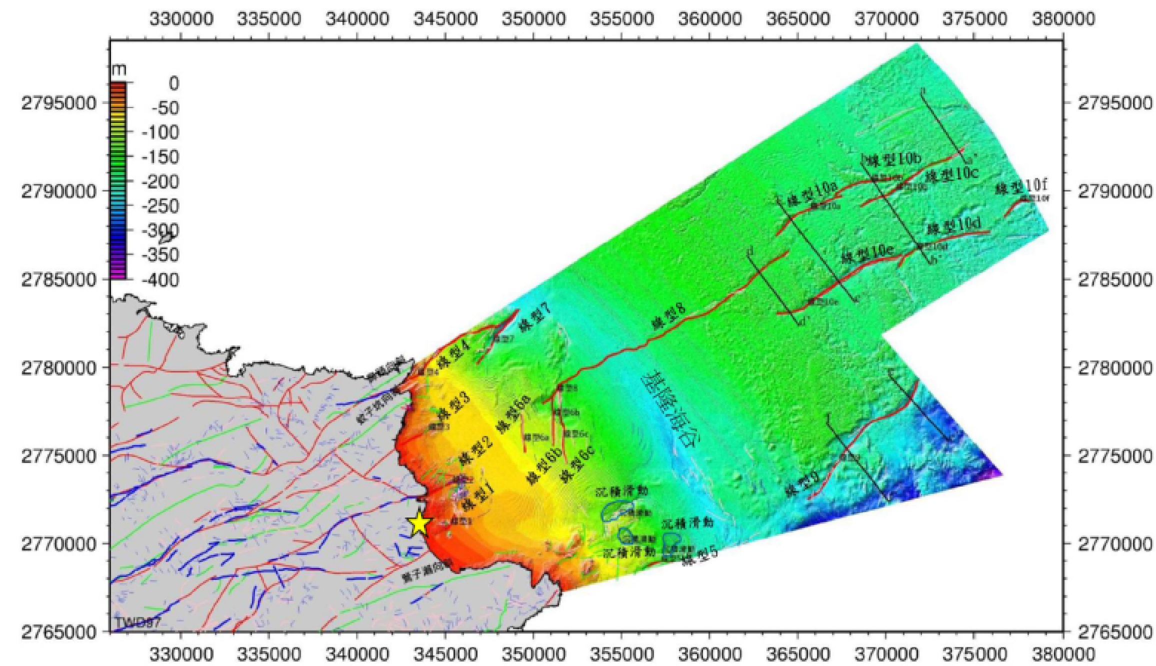


1. Sanchiao Fault System
2. ST-II Fault System
3. Aoti Offshore Faults
4. Northern Ilan Fault System
5. S Fault



Fault map from Chen,2014

Aoti Fault

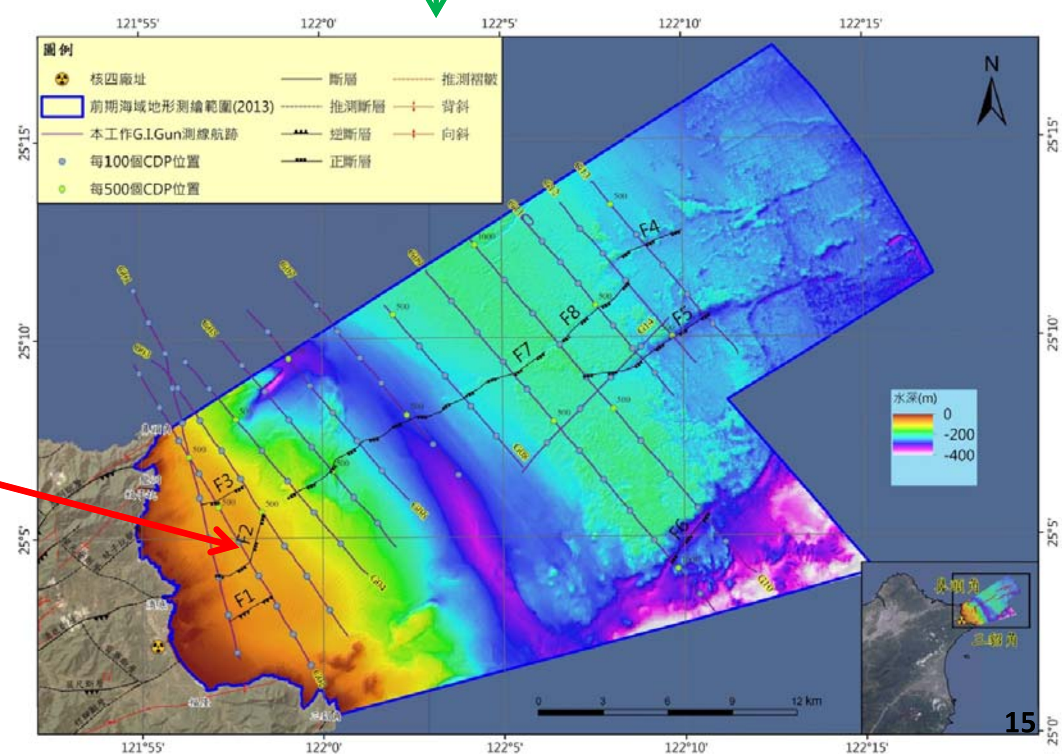


Identified lineament structures from boomer data. **(IOAR,2013)**

Normal faults are defined from reflection seismic data

Sinotech, 2014

Length of Aoti fault Extended



IAOR:

International **A**tmospheric and **O**ceanographic **R**esearch and Development Foundation

Investigation data of Shanchiao Fault Parameters

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				●

Investigation data of ST-II Fault Parameters

Investigative Techniques \ Fault Parameters		Segmentation (Length)	Fault Dip	Rupture Depth	Long-term Slip Rate
Structural Geology	Geologic cross-section	● (grey)	● (grey)	● (grey)	● (grey)
	Tectonic sequence stratigraphy	● (grey)			
	Balanced cross section		● (grey)	● (grey)	● (grey)
	Drilling boreholes	● (grey)	● (grey)		
Surface Geological Survey	Earthquake surface rupture	● (grey)			
	Exploratory trenching		● (grey)		● (grey)
	Terrace dating				● (grey)
Exploration Geophysics	Seismic profile	●	●	●	
	Resistivity Image Profile	● (grey)			
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			● (grey)	
Geodetic survey	GPS coseismic slip	● (grey)			
	GPS block model				● (grey)

Investigation data of Aoti offshore Fault Parameters

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				●

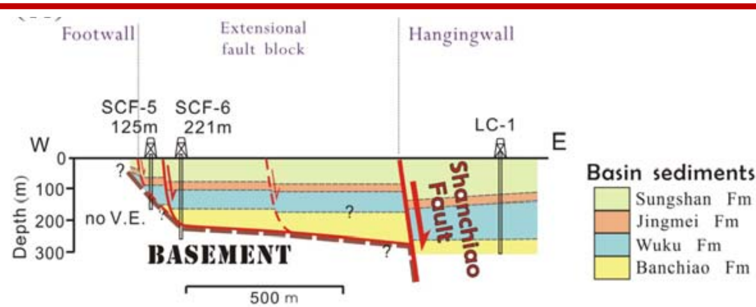
Investigation data of Northern Ilan Fault System Parameters

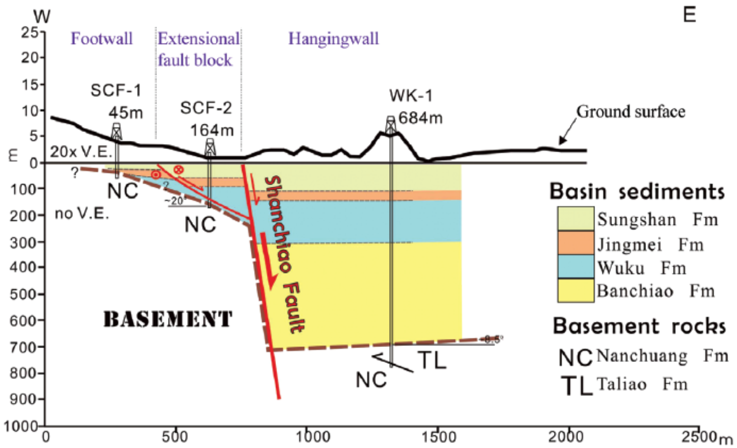
Investigative Techniques \ Fault Parameters		Segmentation (Length)	Fault Dip	Rupture Depth	Long-term Slip Rate
Structural Geology	Geologic cross-section	●	●	●	●
	Tectonic sequence stratigraphy	●			
	Balanced cross section		●	●	●
	Drilling boreholes	●	●		
Surface Geological Survey	Earthquake surface rupture	●			
	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				●

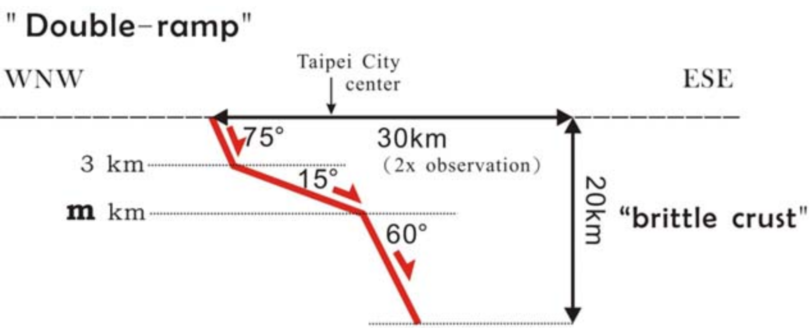
Investigation data of S Fault Parameters

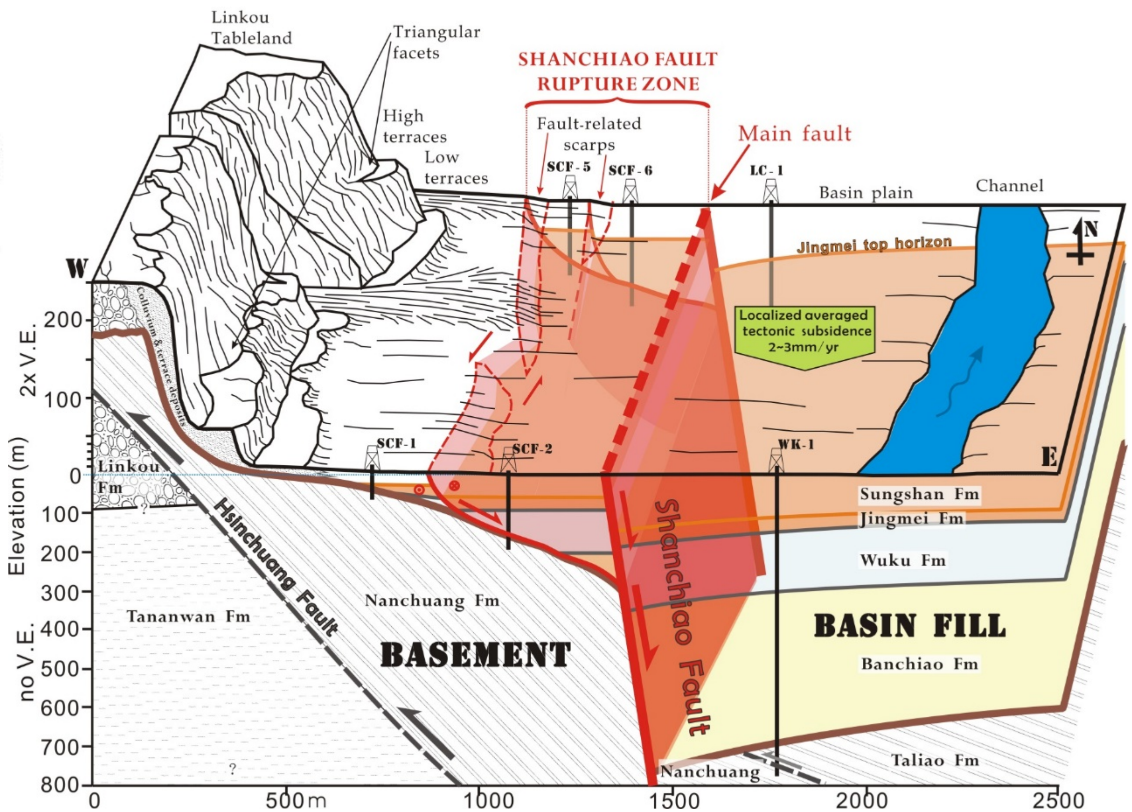
Investigative Techniques \ Fault Parameters		Segmentation (Length)	Fault Dip	Rupture Depth	Long-term Slip Rate
Structural Geology	Geologic cross-section	●	●	●	●
	Tectonic sequence stratigraphy	●			
	Balanced cross section		●	●	●
	Drilling boreholes	●	●		
Surface Geological Survey	Earthquake surface rupture	●			
	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				●

2. Geometry of Shanchaio Fault System _ Dip _ Constraints on shallow structure



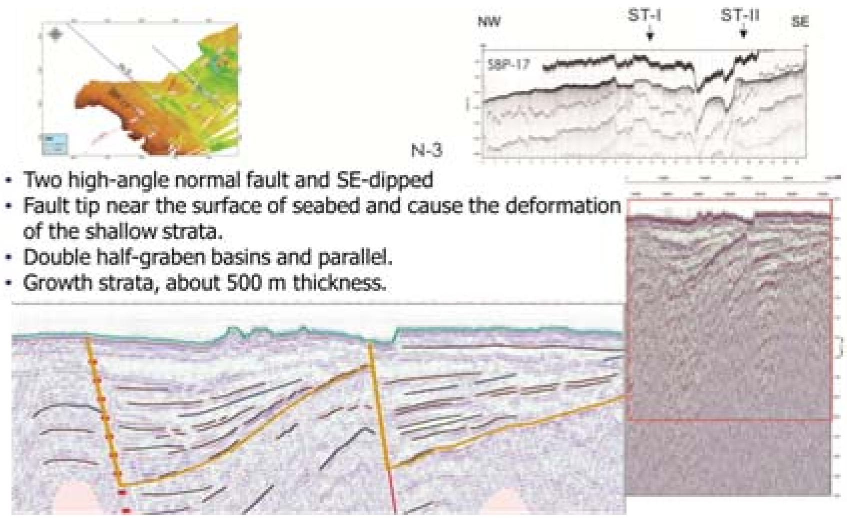






(Chen et al., 2014)

ST-II Fault System _ Style of Faulting



Double half-graben Basin

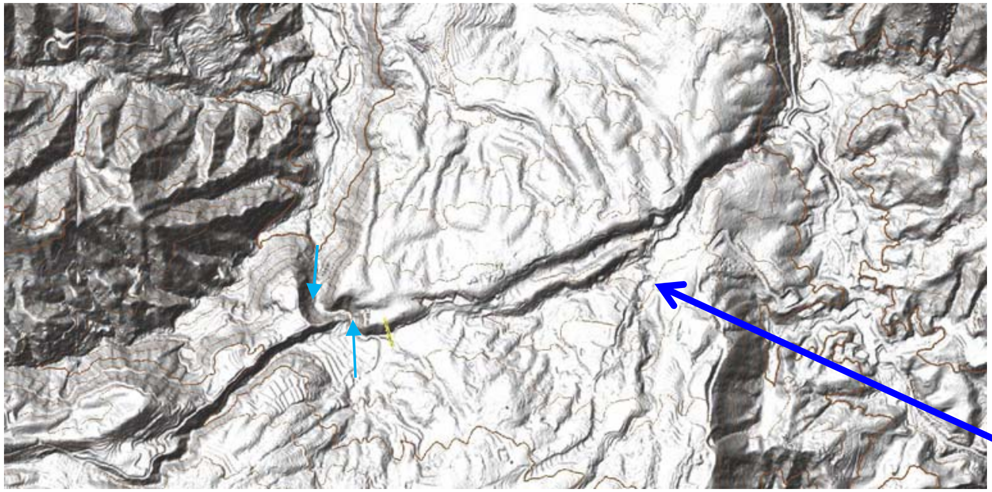
Offshore

Marin reflection seismic data shows ST-II offshore Part have normal fault features.

Style of Faulting

NM (Rake:-90) [0.4]

NM/OB (Rake:-50) [0.6]



Onshore

ST-II onshore part have oblique offset

(Sinotech, 2012; LCI, 2015)

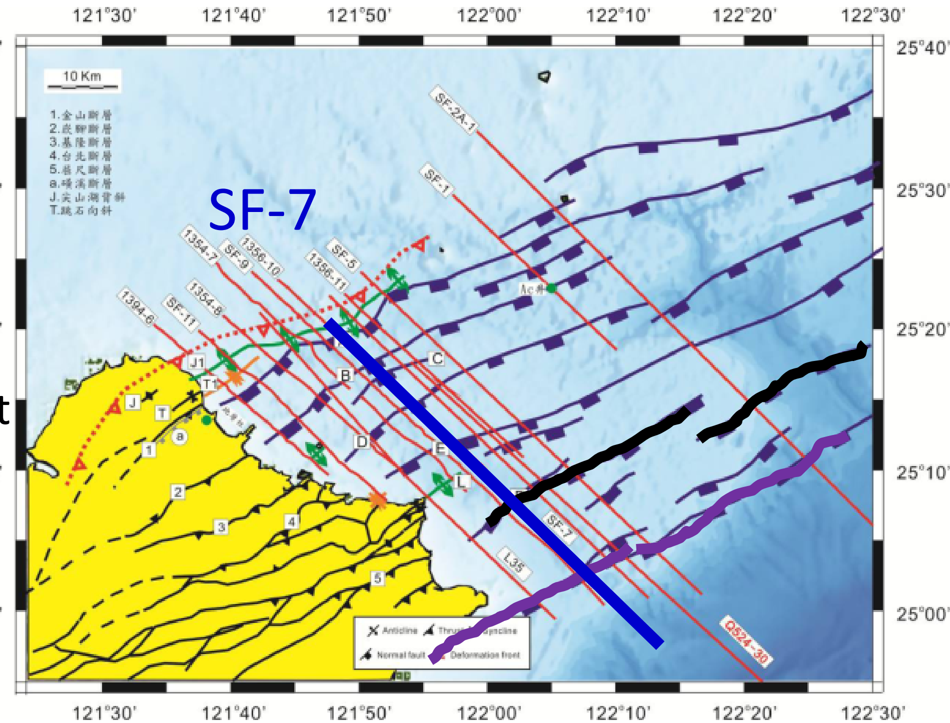
Offshore data

of Aoti offshore faults
and Northern Ilan fault system

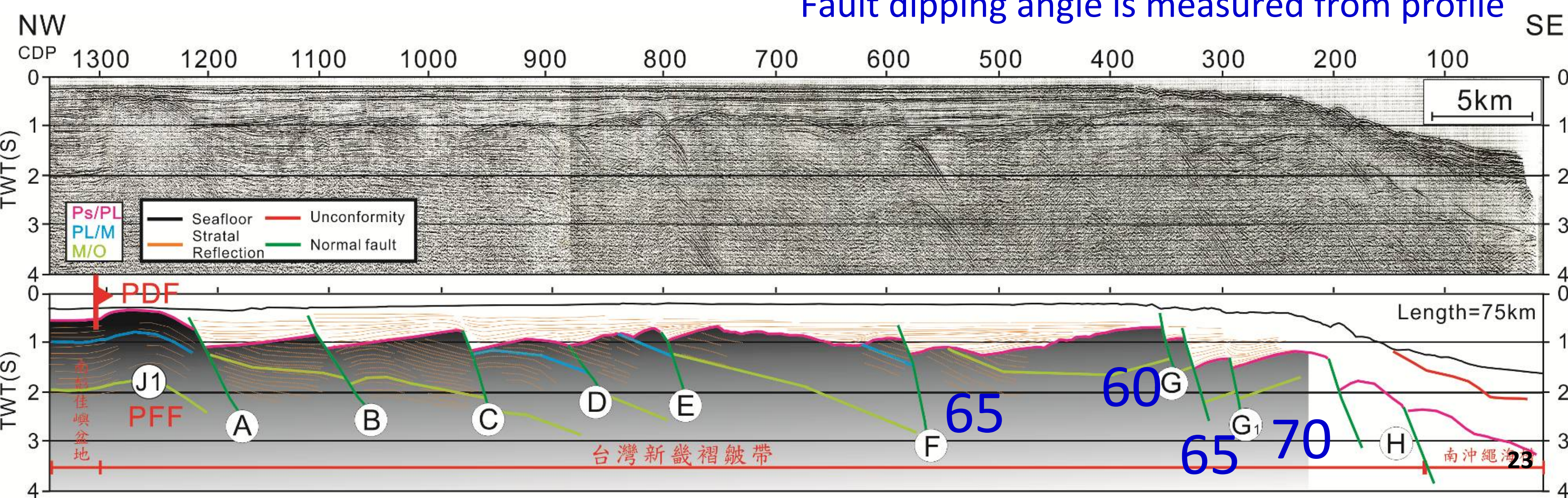
Submarine reflection seismic data show that F fault and G fault have large offset of basement
From Chen (2014)

F fault - Aoti offshore faults

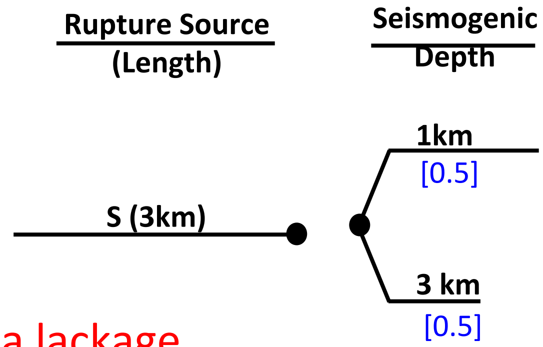
G fault - Northern Ilan fault System

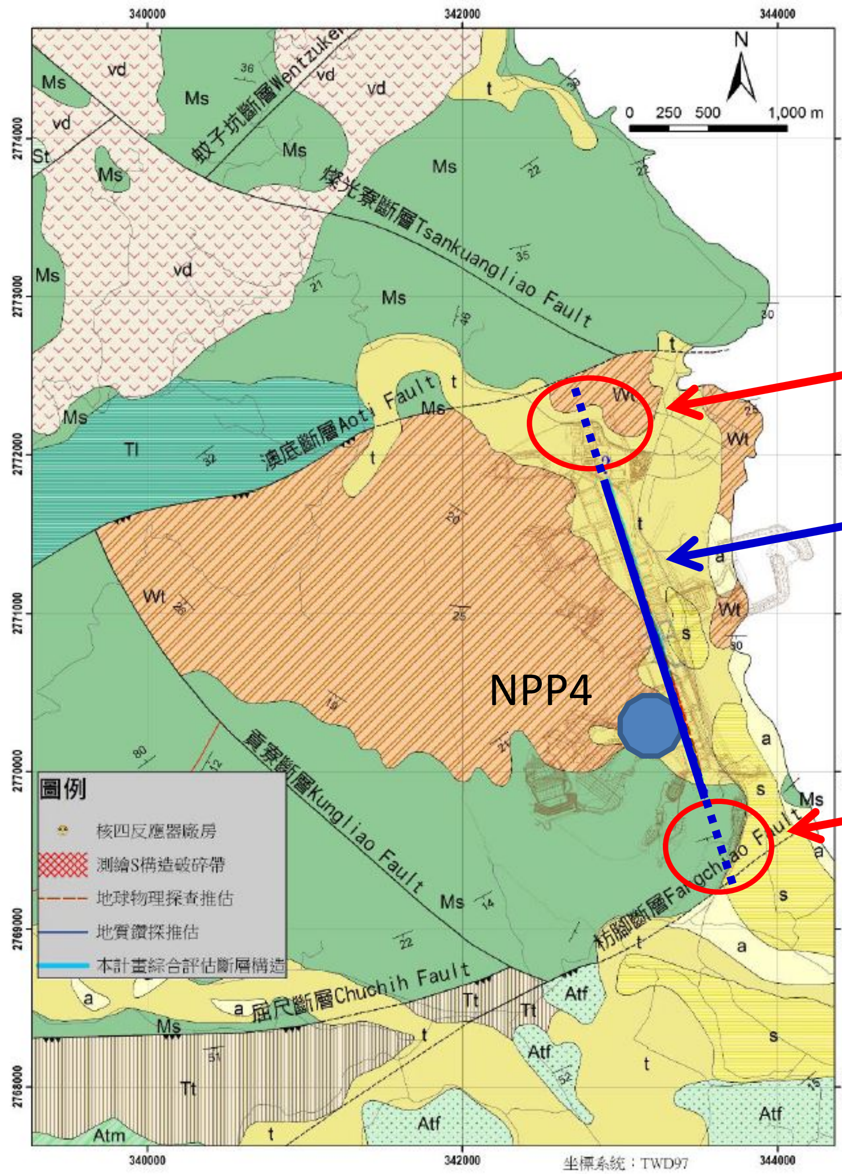


Fault dipping angle is measured from profile



S fault data

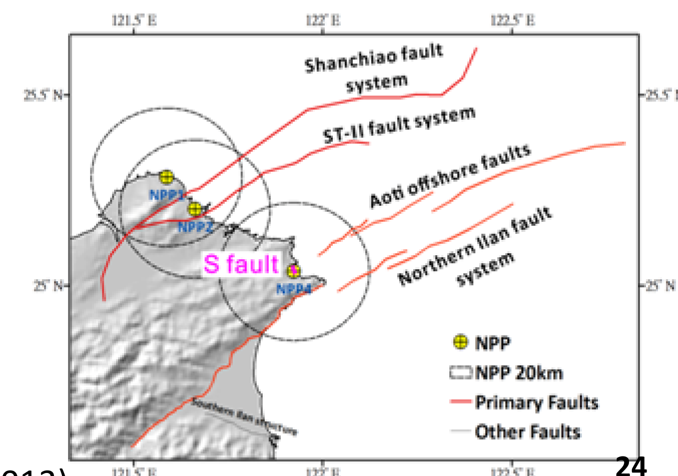




Data lackage

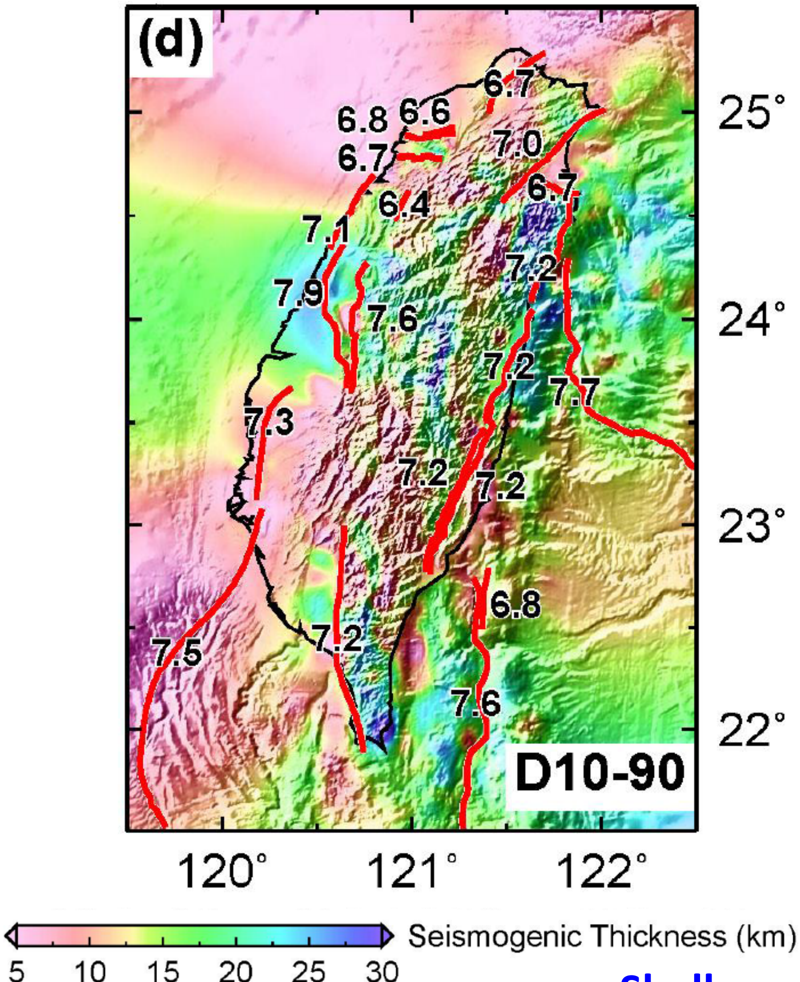
3km Length

Trenching Data supported fault length 2km Sinotech,2013



(Sinotech Ltd.,2013)

2. Geometry of Shanchaio Fault System_ Seismogenic depth

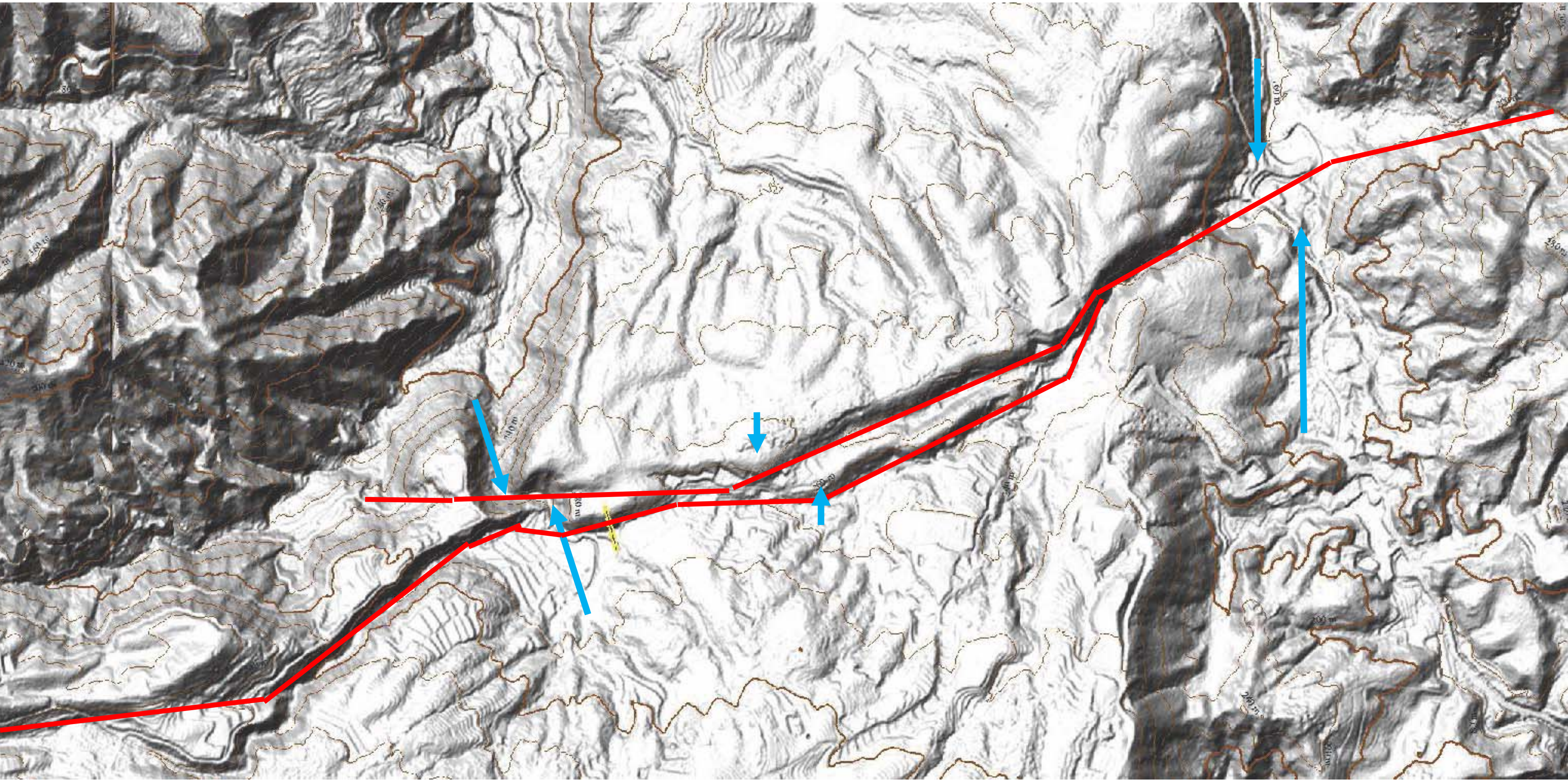


D10-90:10%-90% depth

Shallow crustal fault
Seismogenic depth 10/15/20 km

(Wu et al., 2017)

ST-II Fault Trace – left lateral displacement



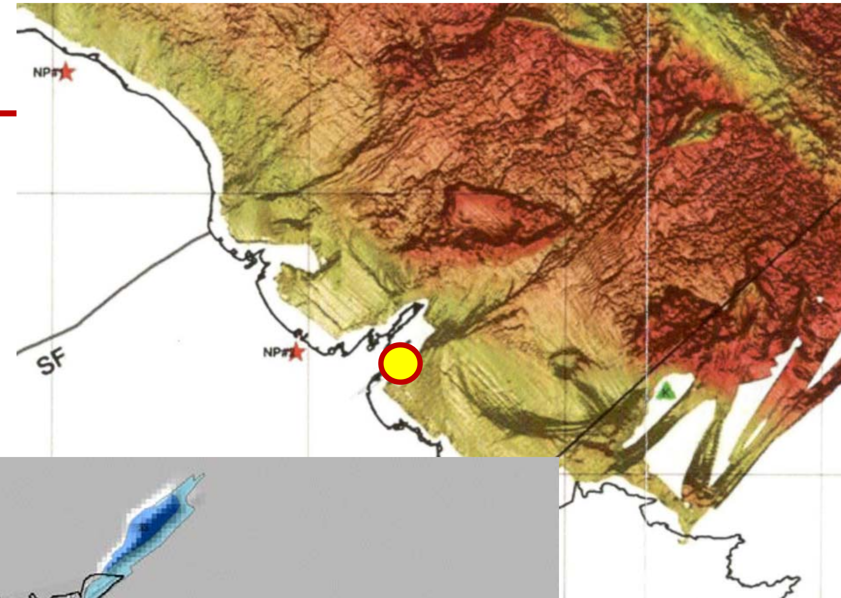
(Sinotech, 2012; LCI, 2015)

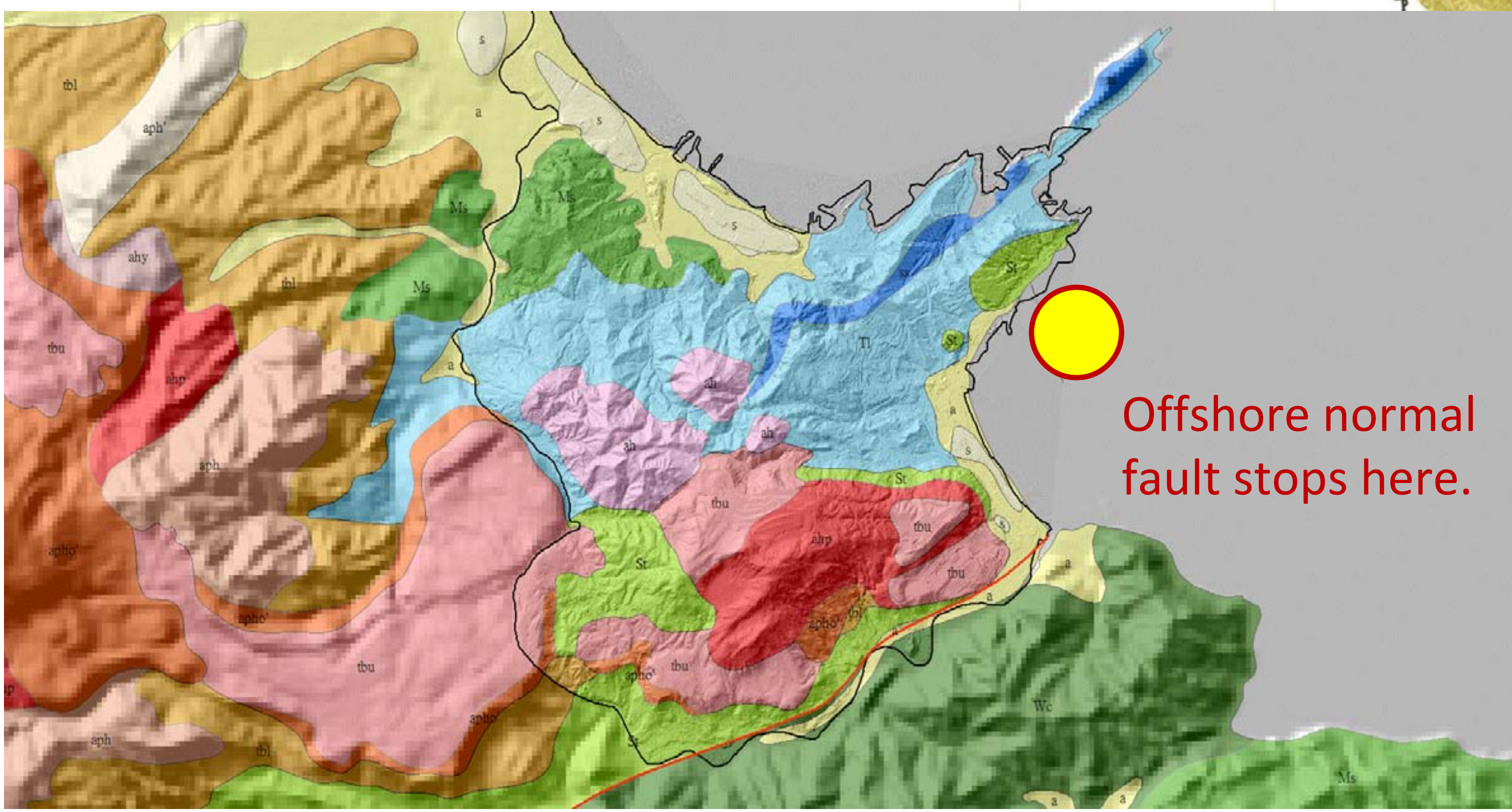
Restoring ~90 m left lateral displacement

Investigation Methods: Tatun LiDAR DEM

The volcanic body possibly hinders normal fault extension onshore.

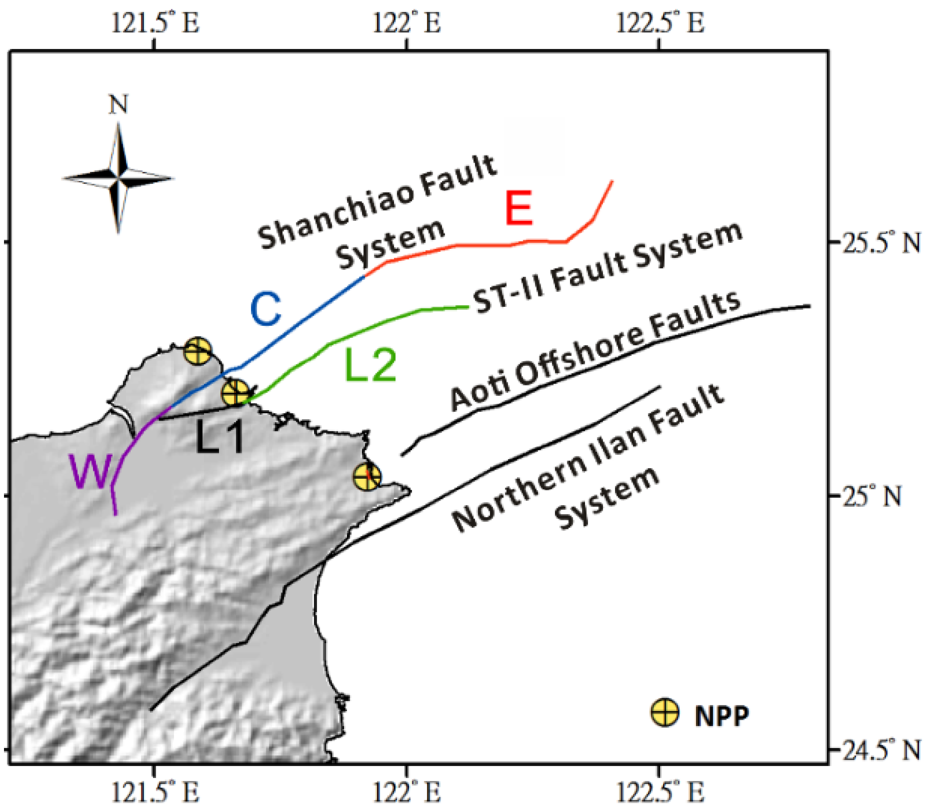
(Workshop#2 Yu-Chang Chan)



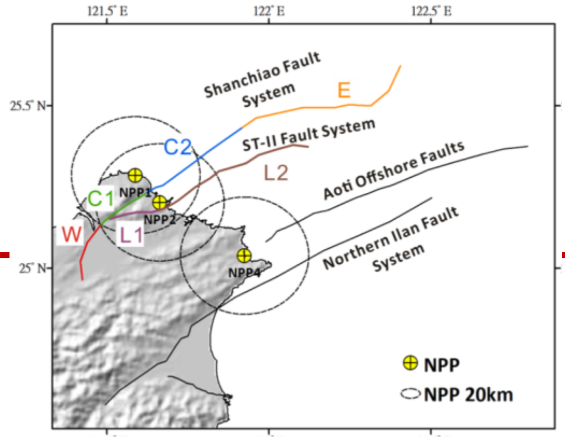


Offshore normal fault stops here.

Fault Rupture Model _ ST-II Fault System



Seismogenic Probablility	Rupture Model	Rupture Source (Length)
If L1 is Seismogenic [0.6]	ST-R01	L2+L1 (72 km) L1 (18km) L2 (54km)
If L1 is not Seismogenic [0.4]	ST-R01	L2 (54km)

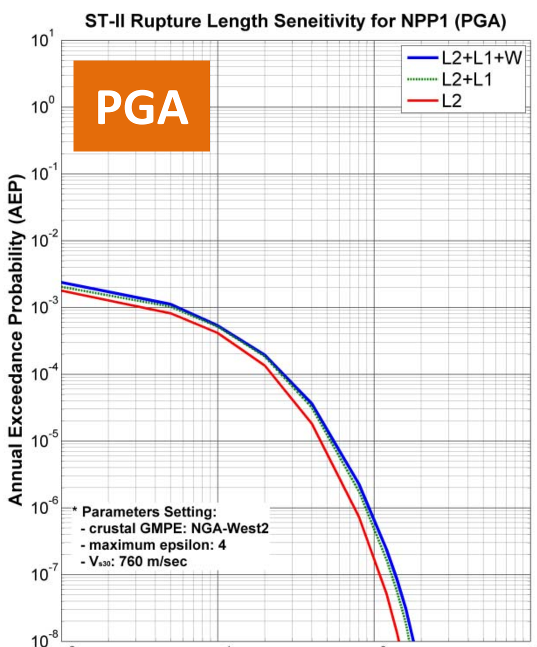


➢Considering the W section connected with L1 /L2 don't have a large contribution to hazard calculation.

➢Have little difference between the hazard curves of W+L1+L2 and L1+L2.

Rupture Source	Min. Dis. to NPP1	M_{max}	Min. Dis. to NPP2	M_{max}	Min. Dis. to NPP4	M_{max}
L2+L1+W	13.4 km	7.18	2.4 km	7.18	26.2 km	7.18
L2+L1	13.4 km	7.03	2.4 km	7.03	26.2 km	7.03
L2	14.5 km	6.89	2.6 km	6.89	26.2 km	6.89

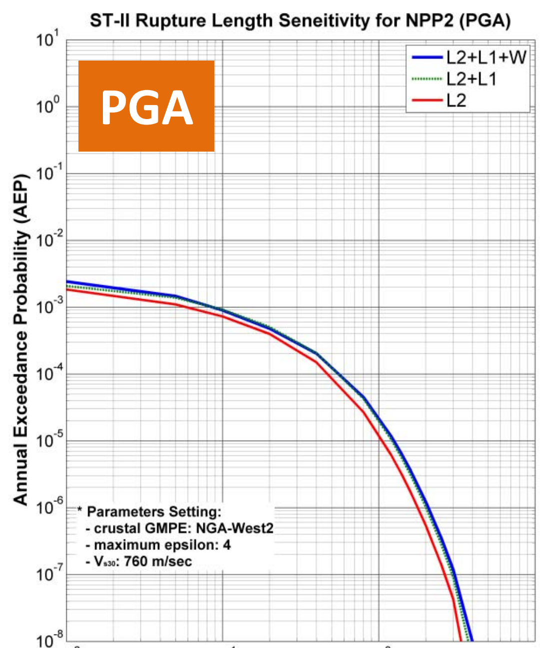
NPP1



same

1E-4	L2	L2+L1	L2+L1+W
SA(g)	0.22	0.25	0.26
Ratio to mean	0.90	1.03	1.07

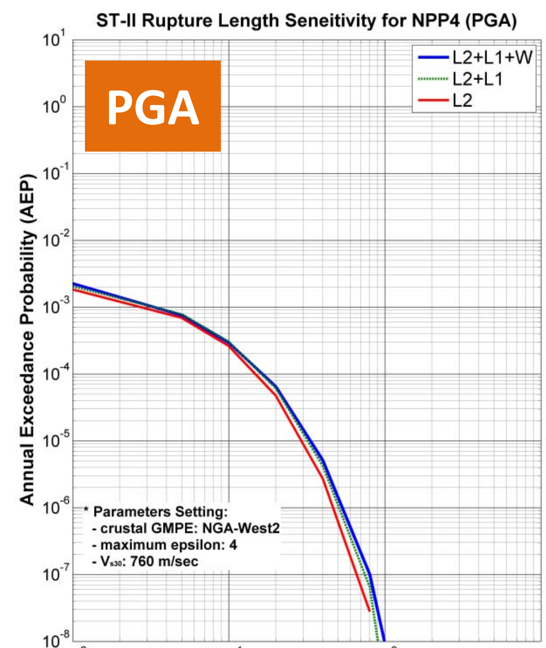
NPP2



same

1E-4	L2	L2+L1	L2+L1+W
SA(g)	0.47	0.55	0.55
Ratio to mean	0.90	1.05	1.06

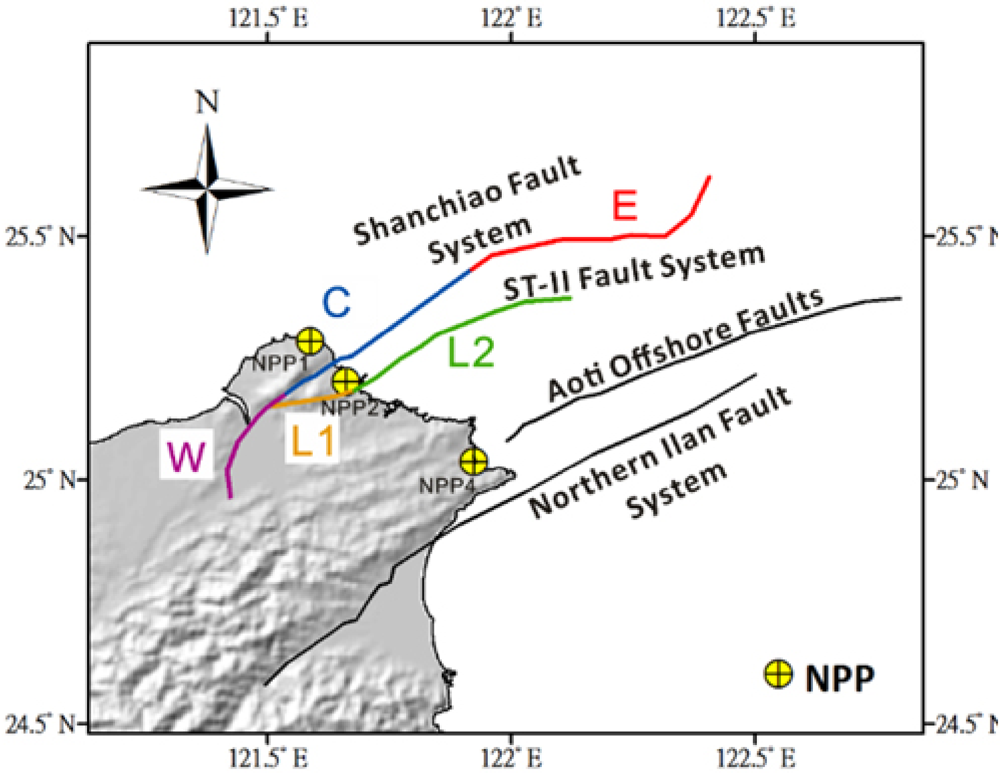
NPP4



same

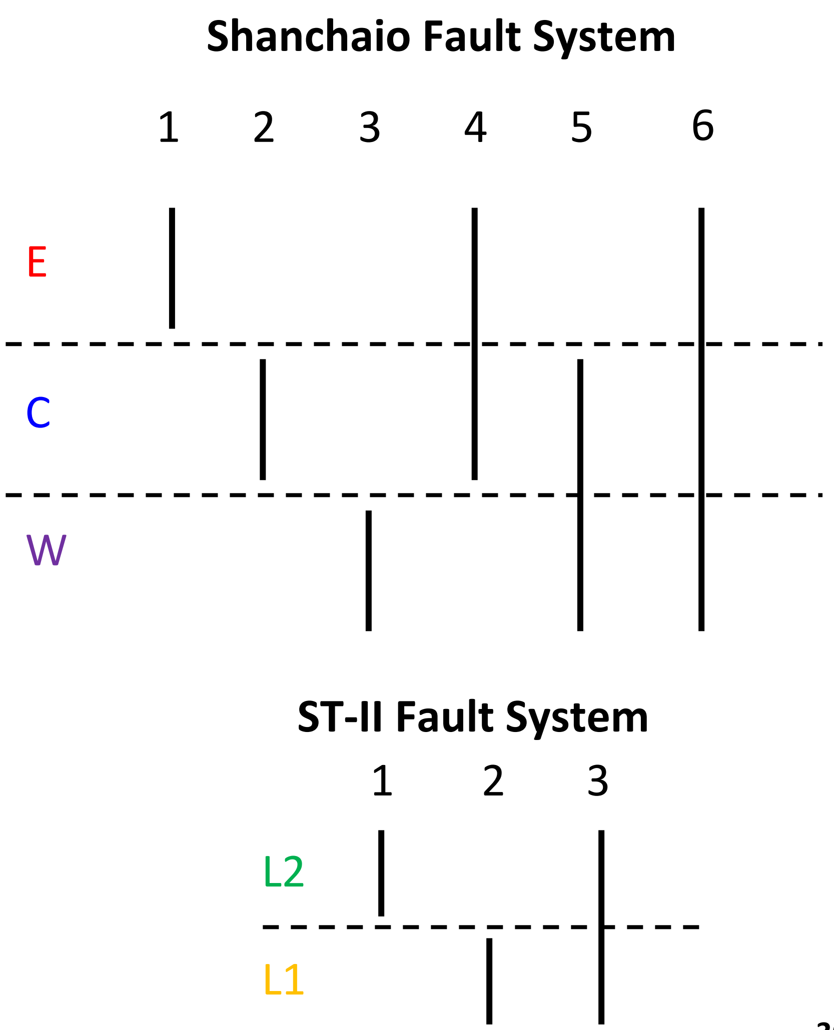
1E-4	L2	L2+L1	L2+L1+W
SA(g)	0.15	0.16	0.16
Ratio to mean	0.94	1.02	1.04

3. Fault rupture model - Shanchaio Fault System ST-II fault sytem



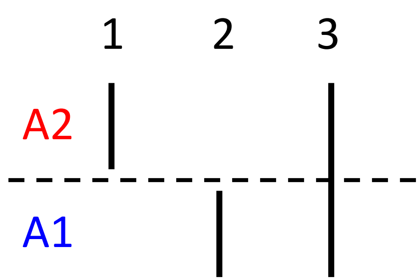
- E: 58 km
- C: 48 km
- W: 28 km
- Total: 135 km

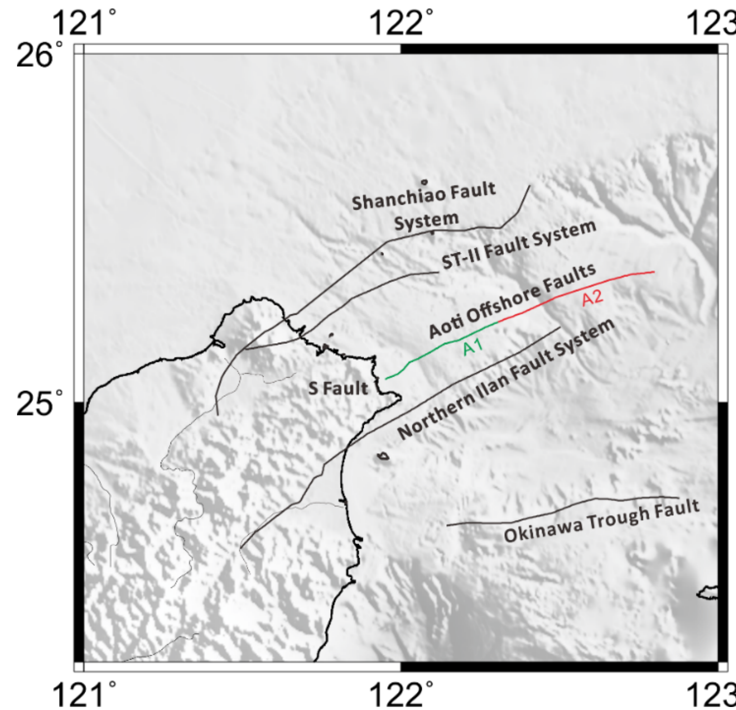
Rupture Source

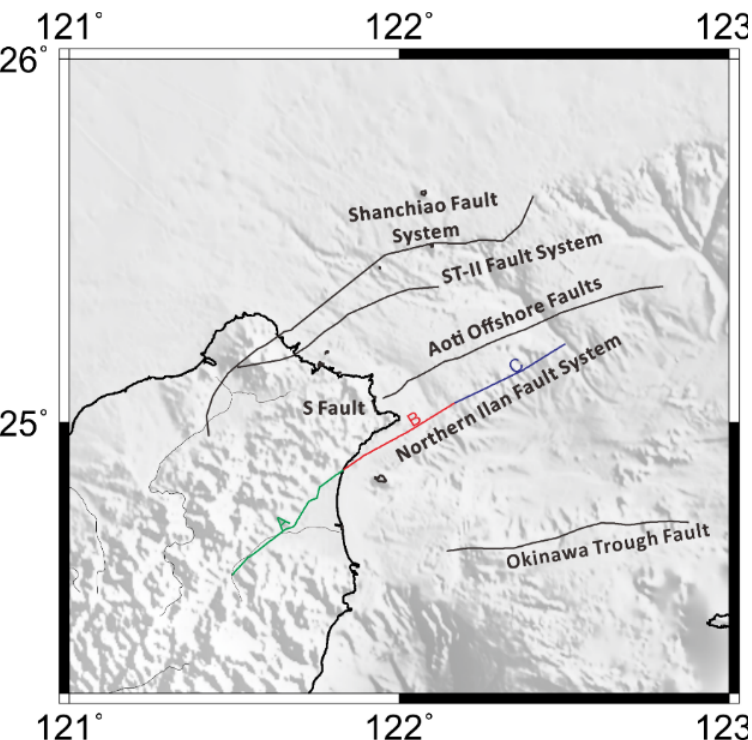


3. Fault rupture model –Aoti offshore faults and Northern Ilan fault system

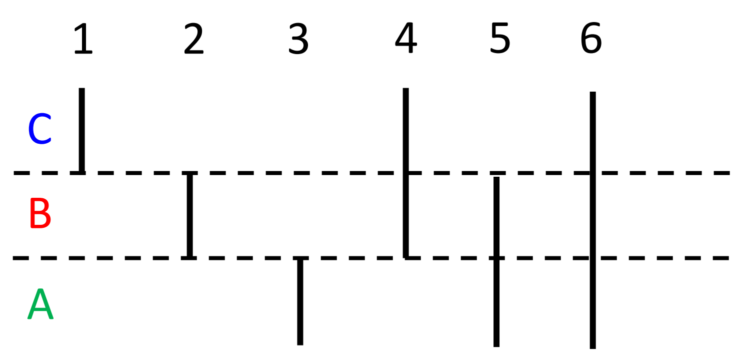
Aoti offshore faults







Northern Ilan fault system



4. Slip rate data collection

Style of Faulting
NM ; NM/OB

Length | Depth | Dip | Rake | Vertical Rate

Width (km)

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

Width

Area (km²)

$$Area = Length \times Width$$

Area

Slip rate (mm/yr)

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

Slip Rate

M_w

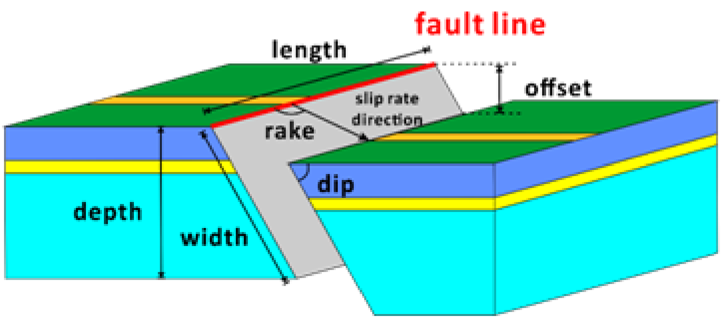
Maximum Magnitude

-Wells and Coppersmith (1994)

$M_W = 3.93 + 1.02Log(A)$

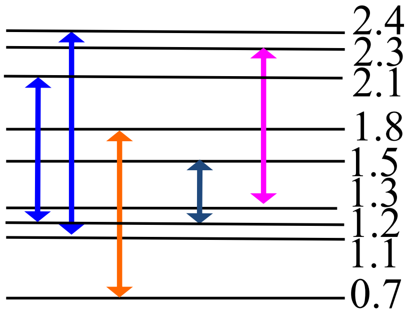
A = area (km^2)

Std = 0.25



4. Slip rate data collection
Shanchiao fault onshore

	Subsidence rate(mm/yr)	Slip rate (mm/yr)	Data	Reference
W	1.1~2.4	1.2~2.6 (90 kyr)	Wuku-1	Wei et al., 1998
	1.2~2.1	1.3~2.3 (220 kyr)	Banchiao Fm. in Wuku-1	
	0.69~1.8	0.8~2.0 (11 kyr)	SCF-1, 2, 5, 6, 14, 15, 16, 17	Huang et al., 2007
	1.2~1.5	1.3~1.7 (11 kyr)	蘆洲1號，Wuku-1	Chen et al., 2008
	1.3~2.3	1.4~2.5	SCF-1， SCF-2，Wuku-1	Chen et al., 2010
	0.71 ~ 1.82	0.82 ~ 2.1 (60) 0.75~1.94 (70) 0.82 ~ 1.84 (80)	1. Borehole 2. GPS model 3. Vertical separate	Sinotech(2012) Chen et al., 2008，2009，2010 Huang et.al.(2007) Rau et al., 2010 Song et al., 2007 Rau et al., 2010
	1.03 ~ 2.25	1.1 ~ 2.94	TEM2017	Liu et al. (2015), Huang et al. (2007) Rau et al., 2006
		1~3 (60)	NCU 2002	
		0.02/1.31/ 2.6 (65)	CGS 2012,2015	

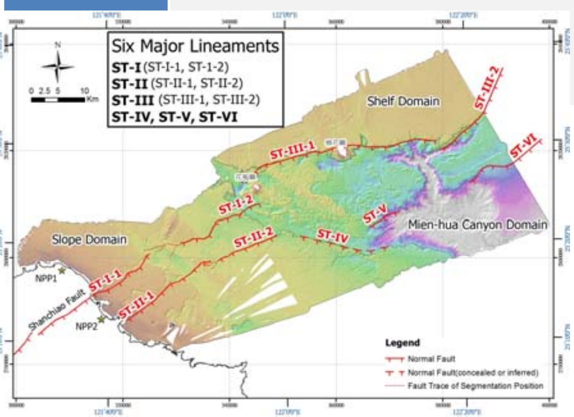


This study:

Vertical Rate
mm/yr
0.15 (0.3)
1.5 (0.4)
3.3 (0.3)

4. Slip rate data collection
Shanchiao and ST-II fault offshore

Fault	Activity	Long term slip rate	Base on
ST-I-1	Shallow strata of the SBP shows disturbed and deformation that indicated the fault ever activity .	0.81~1.52mm/yr	1. Offset： Vertical separation 2.Age： a.Possibility initial age of the Shanchaio fault is 0.75Ma b.Possibility initial age of the Taipei Basin is 0.4Ma
ST-I-2		1.02~1.93mm/yr	
ST-II-1		0.81~1.52mm/yr	
ST-II-1		0.25~0.51mm/yr	
ST-III	Activity age older than lava flow or deposits of the East China sea shelf	0.44~2.79mm/yr	1.Offset：the nano-fossil of the YAC-1 borehole 2.Age： a.Possibility initial age of the Okinawa trough rifting is P/P boundary b.Possibility initial age of the Shanchaio fault is 0.75Ma c.Possibility initial age of the Taipei Basin is 0.4Ma

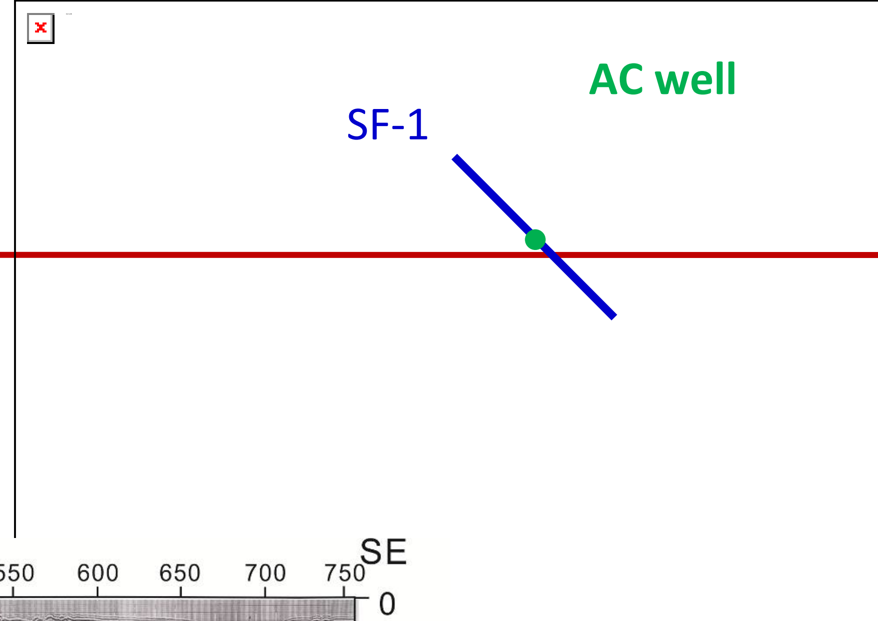


- C: ST-1-1 and ST-1-2
- E: ST-III

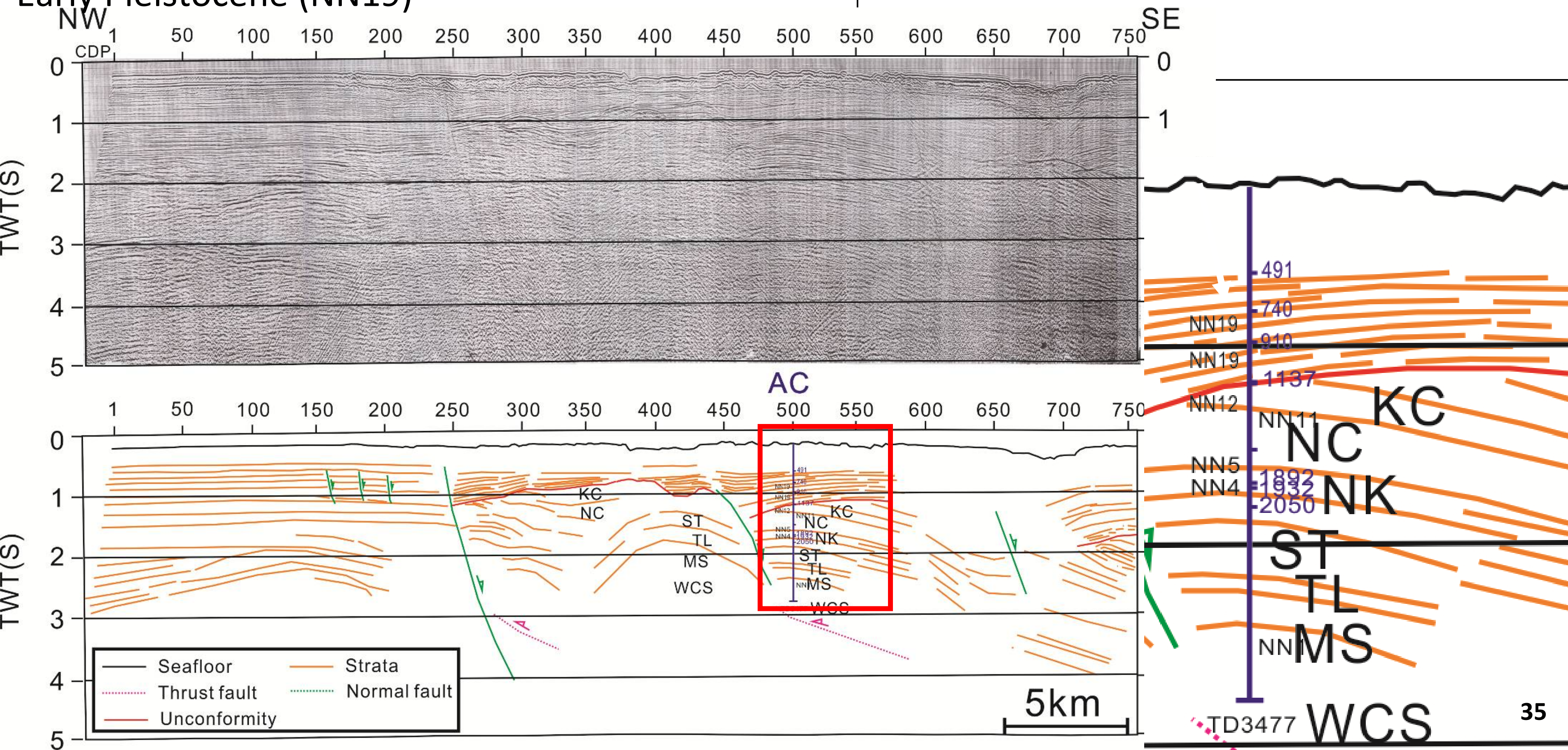
Sinotech(2015)

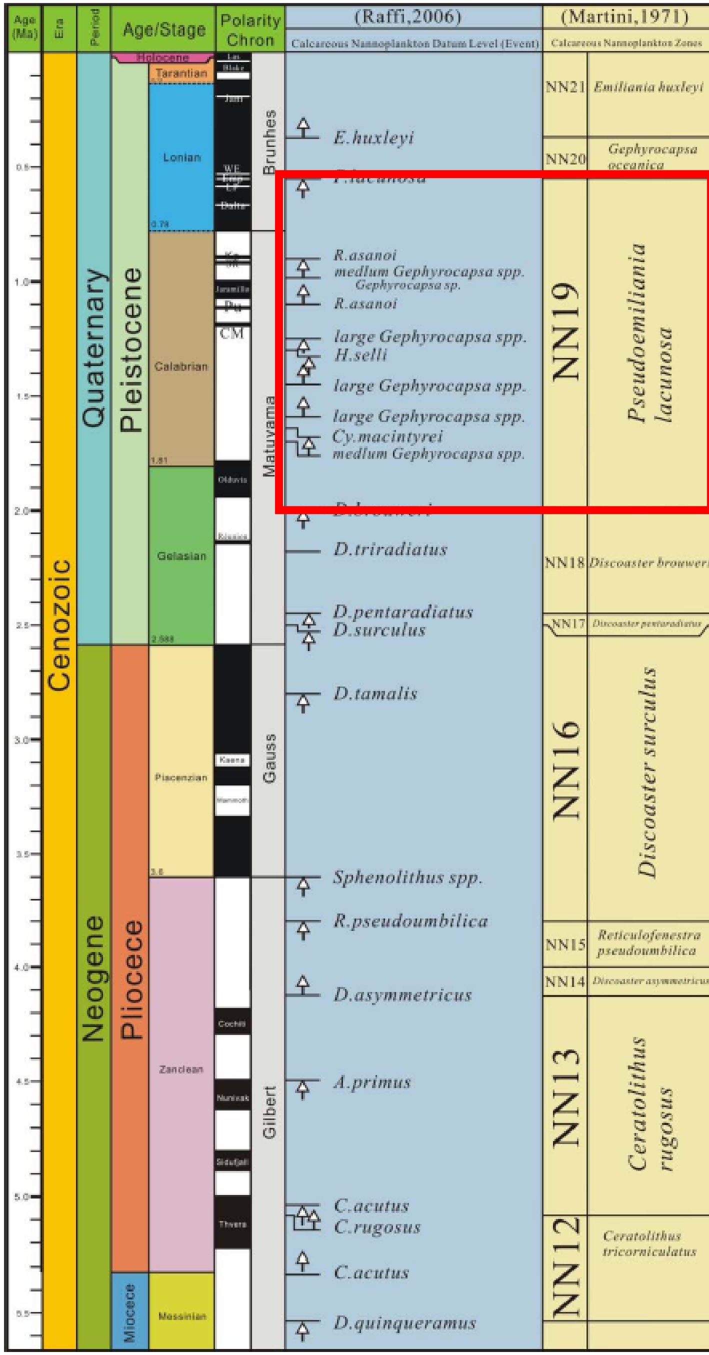
Vertical Rate
mm/yr
0.15 (0.3)
1.5 (0.4)
3.3 (0.3)

Slip rate of Aoti offfshore fault



Profile SF-1 and AC well data
AC well drilled through unconformity ,
Nano fossils show the age of strata above unconformity:
Early Pleistocene (NN19)





Early-late Pleistocene (NN19):0.5-1.8Ma.

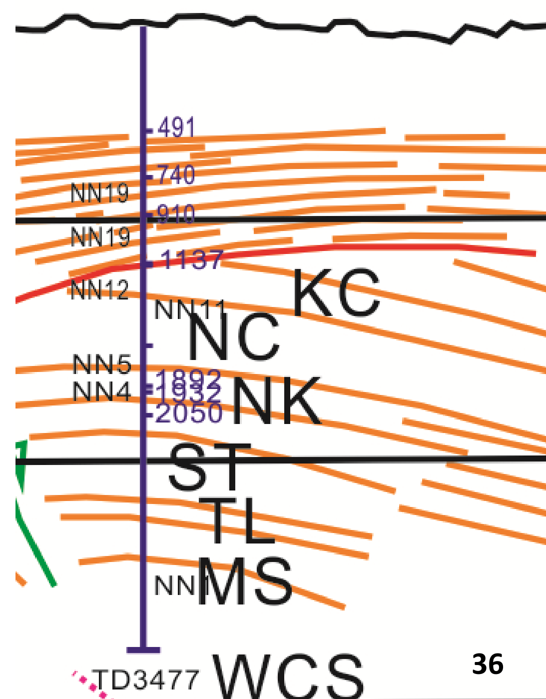
Dating data is limited, uplift rate of offshore fault are estimated from simple calculation:

Thickness from seafloor to unconformity/Age = vertical rate

1137m/0.5Ma~1.8Ma
=0.63-2.27mm/yr

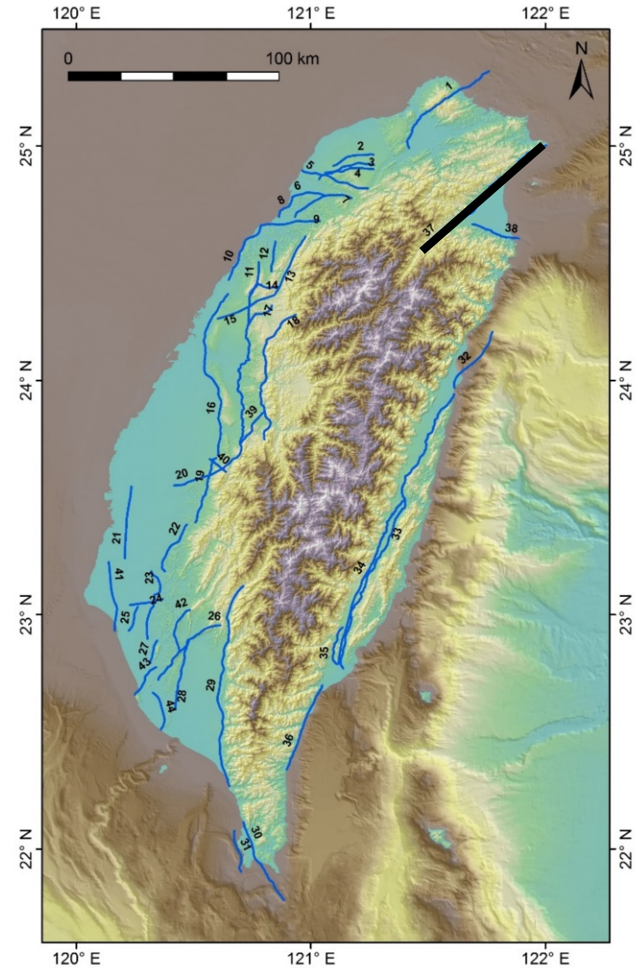
The value will contain :

- Tectonic subsidence rate
- Deposition rate
- Sedimentary loading rate
- Normal fault slip rate



Slip rate of Northern Ilan Fault System

TEC-TEM2017(Taiwan earthquake center-Taiwan earthquake model)
Include CGS2012, NCU2002 and others
(Bruce Shyu, NTU)



We assumed that the North Ilan fault geometry and activity of offshore part will be similar to onshore part.

Fault name	Type	Length (km)	Depth 0 (km)	Depth 1 (km)			Dip (degree) between depth 0-1			Width (km)			Area (km^2)			Mw (W&C)			Mw (Y&M)		
				min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max
Northern Ilan structure	N	74.9	0	7.41	9.41	11.41	50	60	70	7.89	10.87	14.89	590.96	814.16	1115.26	6.76	6.90	7.04	6.77	6.91	7.05

M0 (10^{25} Dyne-cm)			Displacement (m)			Uplift rate (mm/yr)			Long-term slip rate (mm/yr)			Recurrence interval (yr)			Last event	Data source
min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max		
17.18	28.35	46.77	0.97	1.16	1.40	0.90	2.85	4.80	0.96	3.29	6.27	150	350	1460	< 4160 - 4430	a: Liu et al. (2015), b: 蘇清全, 2011

Slip rate Allocation

- **Slip rate data of each fault segments.**
- **TI judgment**
  - Large magnitude is directly proportional to fault length which follows the scaling law.
  - Fault with longer/smaller length has longer/smaller returned period, smaller/larger (long term) slip rate.
  - Possibility of linked fault. (offset < 5km)
- **Slip rate allocation rule**
  - Slip rate of Individual fault segments > whole fault zone
  - Slip rate of high possibility of fault segment linkage > low possibility of fault segment linkage
  - Slip rate of fault segment with smaller length > with longer length

4. Slip rate Allocation

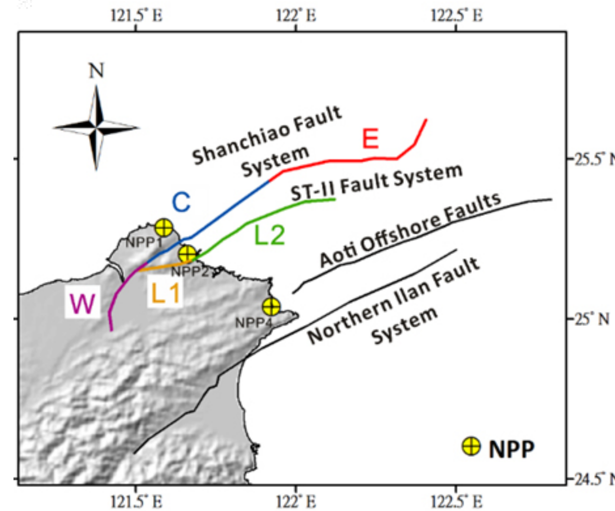
Example:
Vertical Rate: 1.5 mm/yr
Dip: 70
Style of Faulting: NM (Rake= -90)

Slip rate (mm/yr)

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

Slip rate: 1.6 mm/yr

	Total	1 E1	2 E2	3 E3	4 D	5 C	6 B
Offshore	A1 E 1.5	1.13			0.2		0.09
Offshore	A2 C 1.5		0.92		0.2	0.29	0.09
Onshore	A3 W 1.5			1.22		0.29	0.09



A1-B-C-D=E1
A2-B-C-D=E2
A3-B-C-D=E3

Slip rate of high possibility of fault segment linkage > low possibility of fault segment linkage

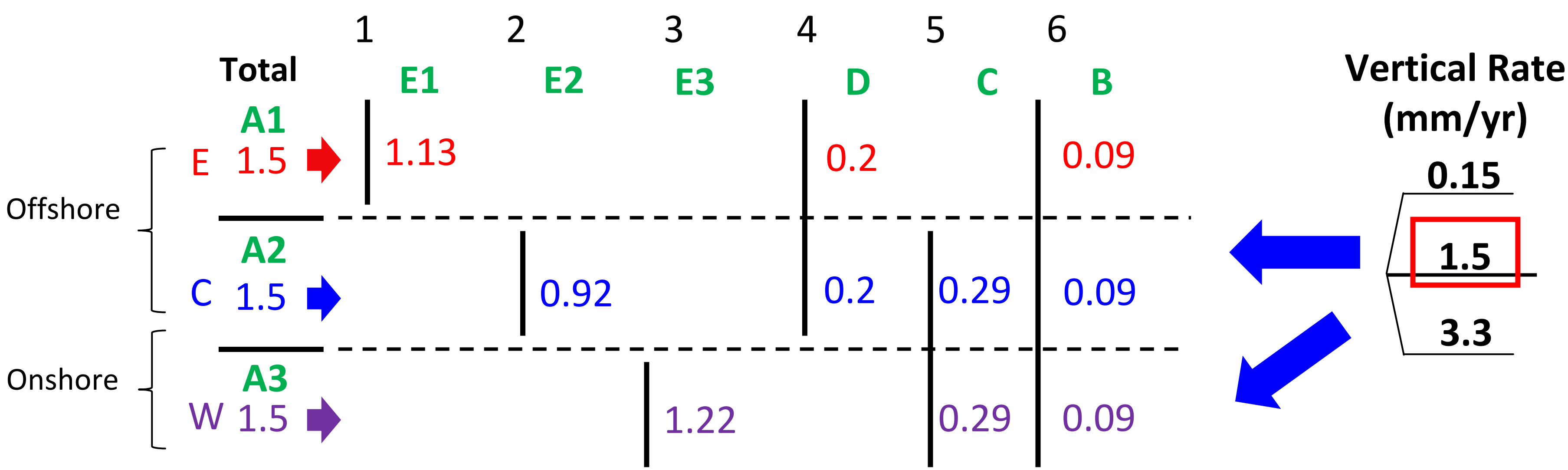
Possibility of 5 > 4 [W+C(Step over: 1.5 km)> C+E(Step over: 6 km)]

Slip rate of fault segment with smaller length > with longer length

Slip rate of Individual fault segments > whole fault zone

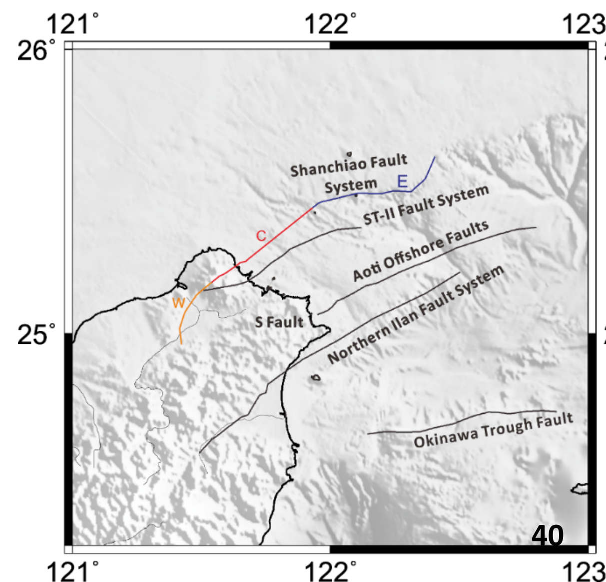
6 <5<4<1,2,3

Shanchiao fault system
Slip rate allocation method/estimation



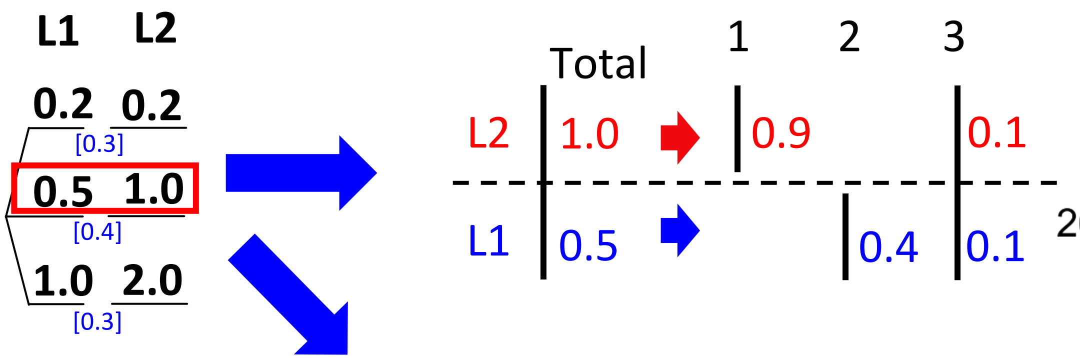
Sanchiao Fault System-Mean

Rupture Source	W		C		E	
	Rate(mm/yr)	% of total	Rate(mm/yr)	% of total	Rate(mm/yr)	% of total
W	1.13	75%				
C			0.92	62.5%		
E					1.22	81%
W+C	0.29	19%	0.29	19.0%		
E+C			0.20	12.5%	0.20	13%
E+C+W	0.09	6%	0.09	6.0%	0.09	6%
Totals	1.5	100%	1.50	100%	1.50	100%



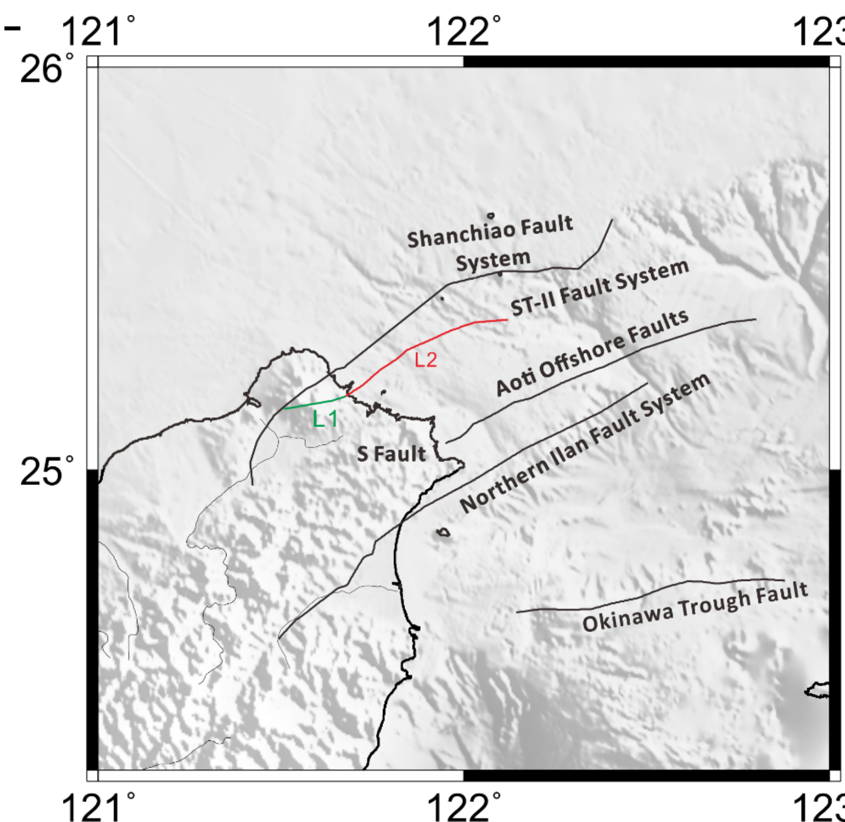
ST-II
Slip rate allocation method/estimation

Vertical Rate mm/yr — Using mean value of vertical rate for allocation



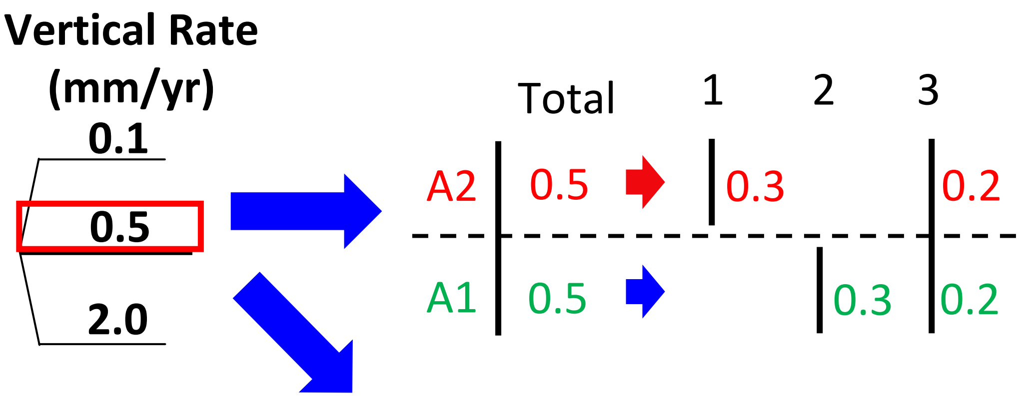
ST-II Fault System-Mean

Rupture Source	L1		L2	
	Vertical Rate(mm/yr)	% of total	Vertical Rate(mm/yr)	% of total
L1	0.4	80%		
L2			0.9	90%
L1+L2	0.1	20%	0.1	10%
Totals	0.5	100%	1.0	100%



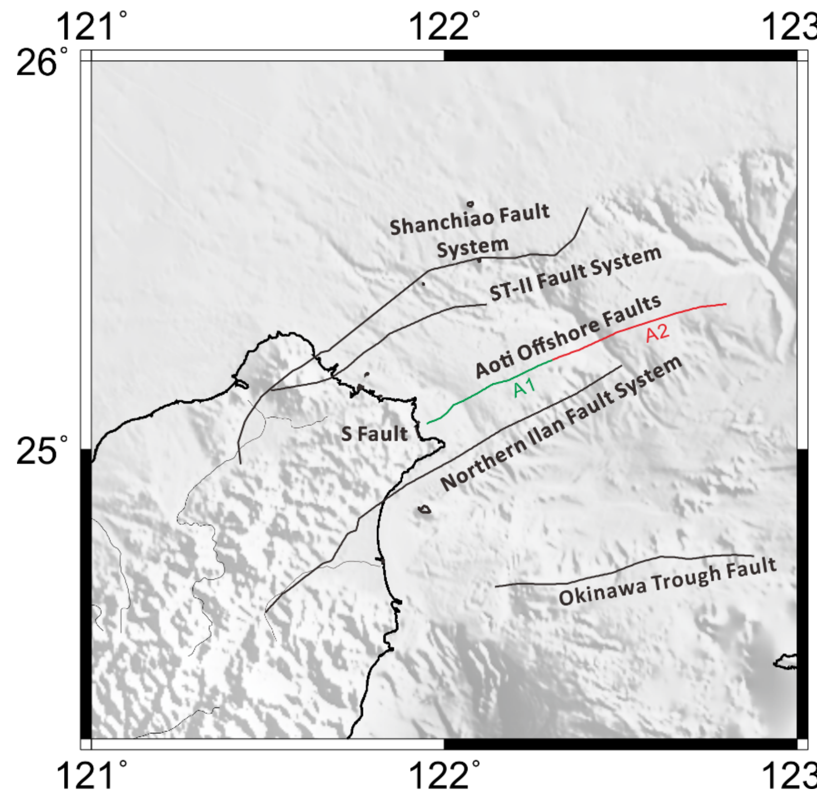
Aoti offshore faults
Slip rate allocation method/estimation

Using mean value of vertical rate for allocation

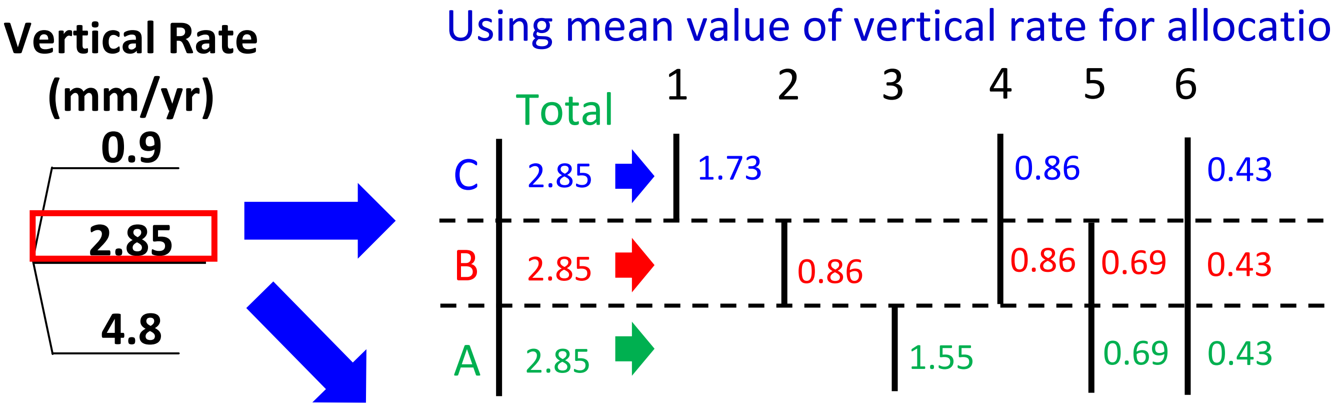


Aoti Offshore Faults-Mean

Rupture Source	A1		A2	
	Rate(mm/yr)	% of total	Rate(mm/yr)	% of total
A1	0.3	60%		
A2			0.3	60%
A1+A2	0.2	40%	0.2	40%
Totals	0.5	100%	0.5	100%

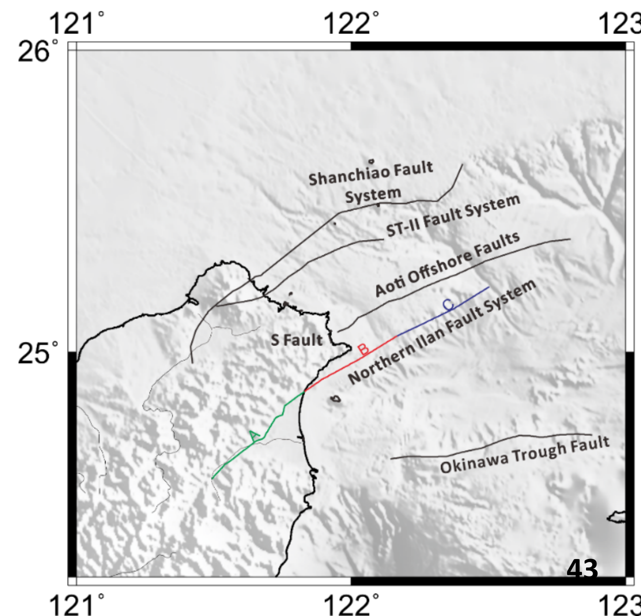


Northern Ilan fault system
Slip rate allocation method/estimation

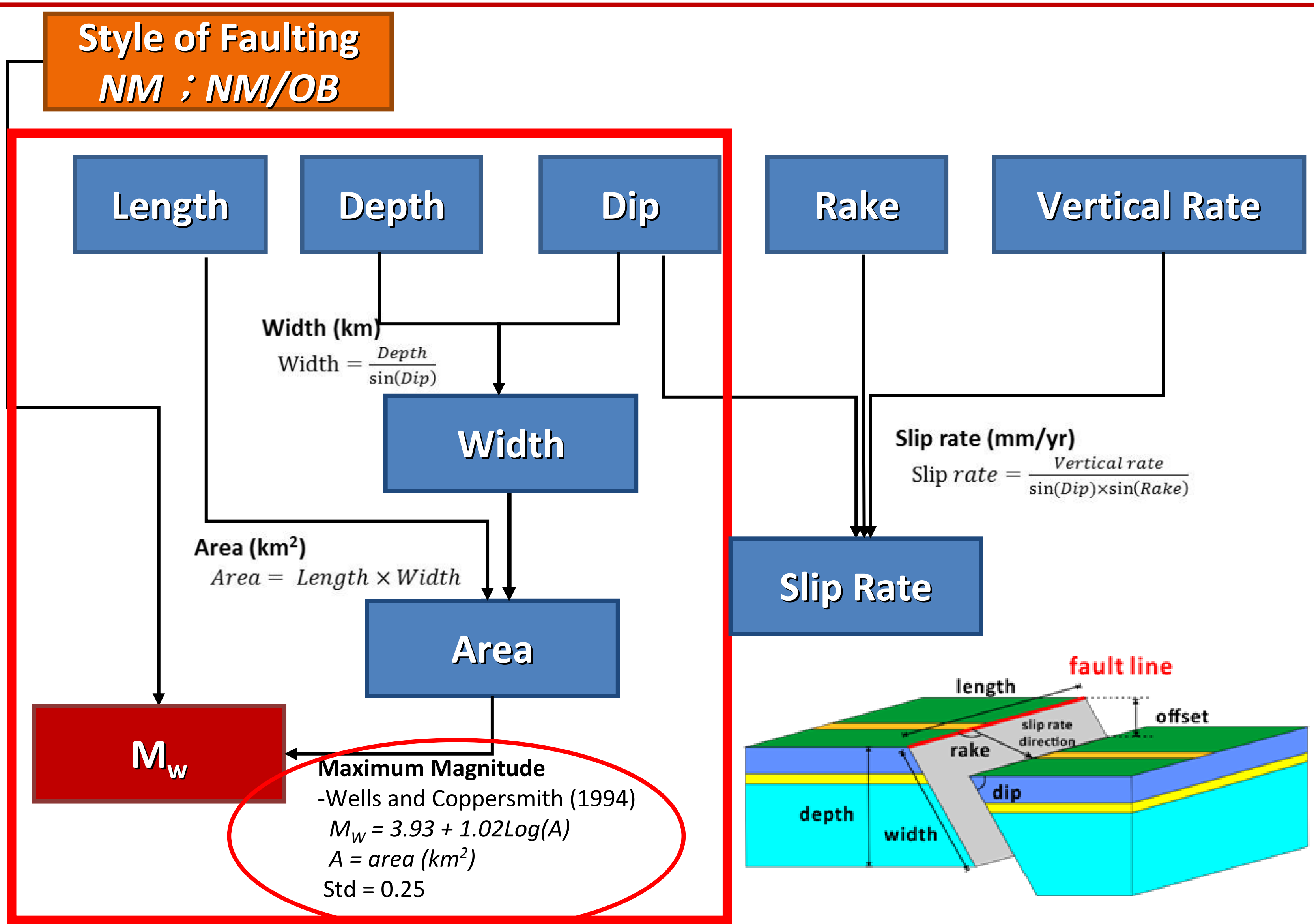


Northern Ilan Fault System-Mean

Rupture Source	A		B		C	
	Rate(mm/yr)	% of total	Rate(mm/yr)	% of total	Rate(mm/yr)	% of total
A	1.55	54.5%				
B			0.86	30.3%		
C					1.73	61%
A+B	0.86	30.3%	0.86	30.3%		
B+C			0.69	24.2%	0.69	24%
A+B+C	0.43	15.2%	0.43	15.2%	0.43	15%
Totals	2.85	100%	2.85	100%	2.85	100%



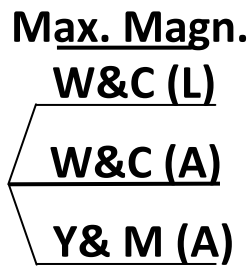
5. Magnitude _ Flowchart of Parameters Setting



5. Magnitude

■ Scaling law selection

1. The values are derived from Wells and Coppersmith(1994) & Yen and Ma(2011).
2. W&C A and Yen&Ma consider the fault rupture area, so we give them a total weighting of [0.6] and spilt equally as [0.3].
3. The first branch, W&C L, considers the fault rupture length, and we give it a weighting of [0.4].



Wells and Coppersmith (1994)

for Crustal fault, Surface Rupture Length

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

for Crustal fault, 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)

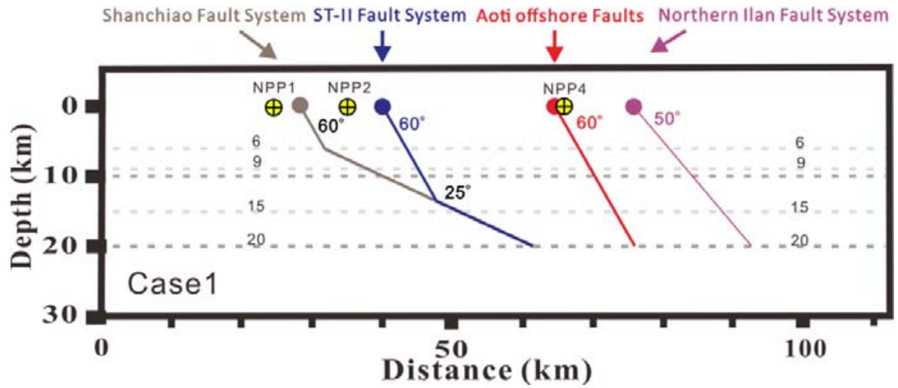
DS	Log(Ae) = -12.45 + 0.80Log(Mo), Log(Mo) = 9.05 + 1.5Mw
SS	Log(Ae) = -14.77 + 0.92Log(Mo), Log(Mo) = 9.05 + 1.5Mw

6. Current Logic tree of North primary faults _ Simplified geometry model

Fault Geometry Model

Dip	Seismogenic Depth

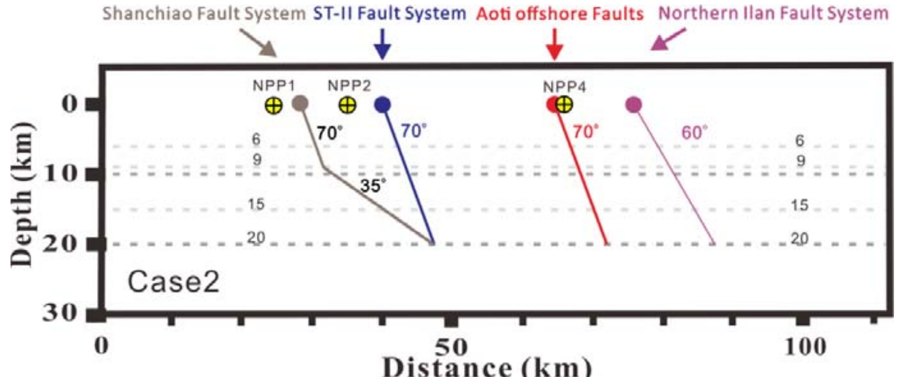
Case 1
[0.3]



60° (0-6km)
25° (>6km)

10 [0.3]
15 [0.4]
20 [0.3]

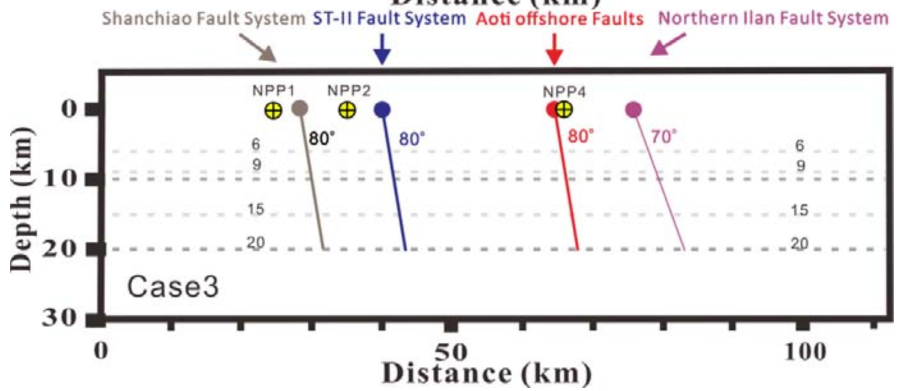
Case 2
[0.4]



70° (0-9km)
35° (>9km)

10 [0.3]
15 [0.4]
20 [0.3]

Case 3
[0.3]



80°

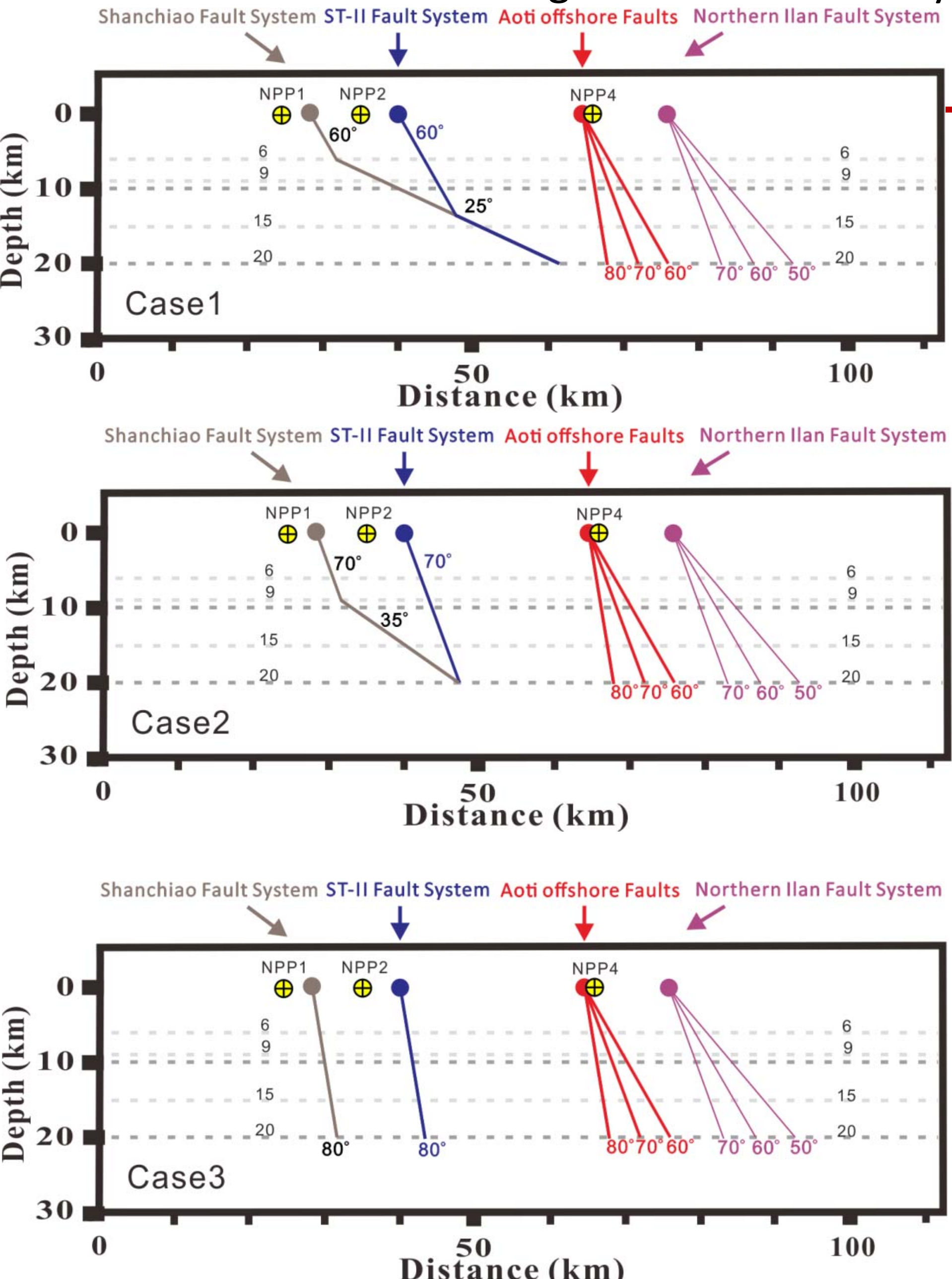
10 [0.3]
15 [0.4]
20 [0.3]

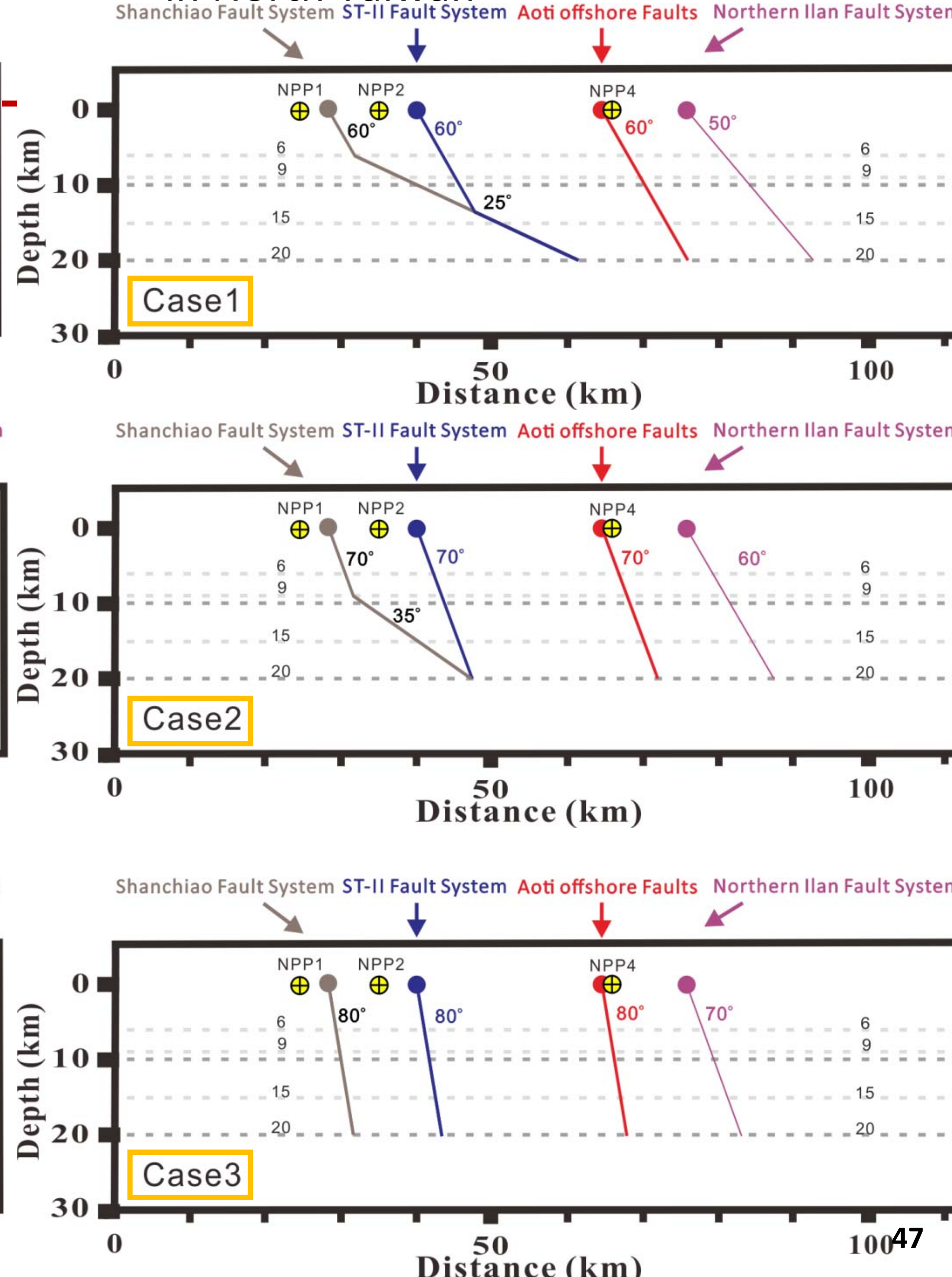
WM3

Same mechanism setting of SC and ST-II only

WS3-Simplified model

Same mechanism setting of all fault in North Taiwan

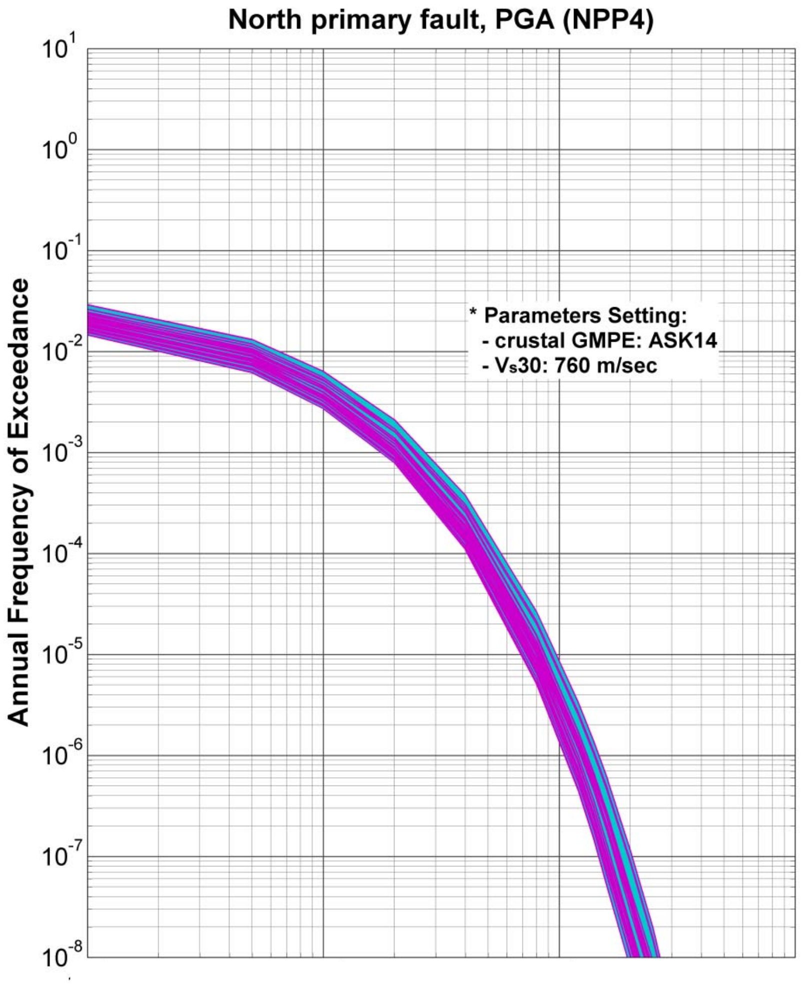


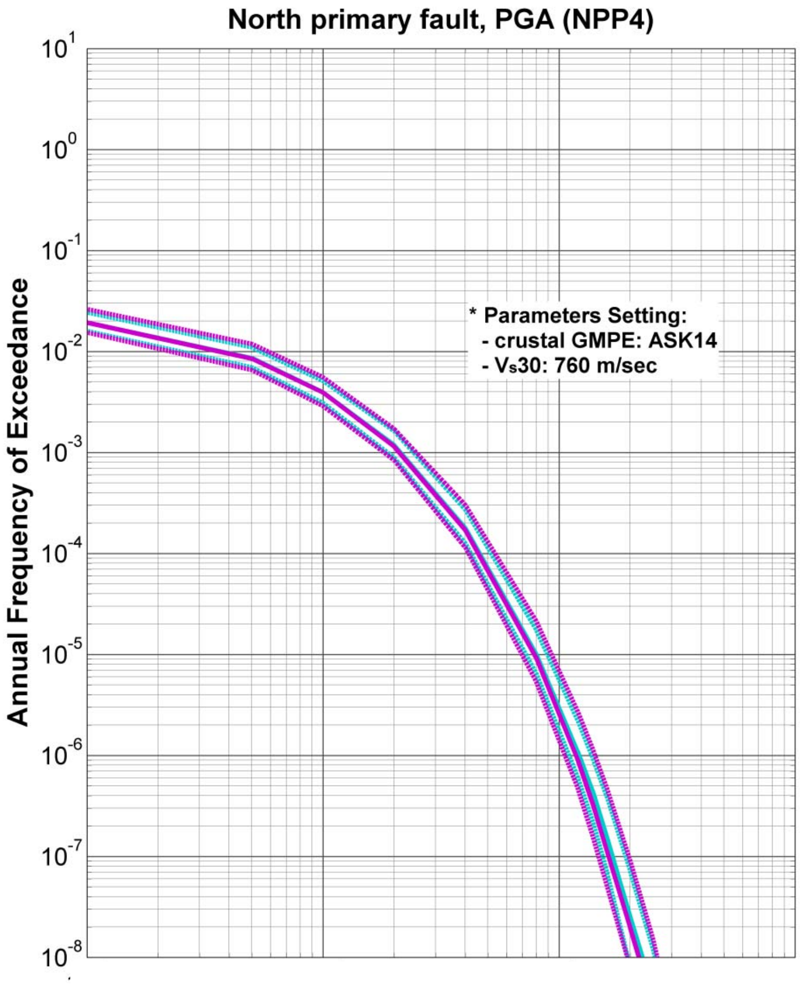


NPP4

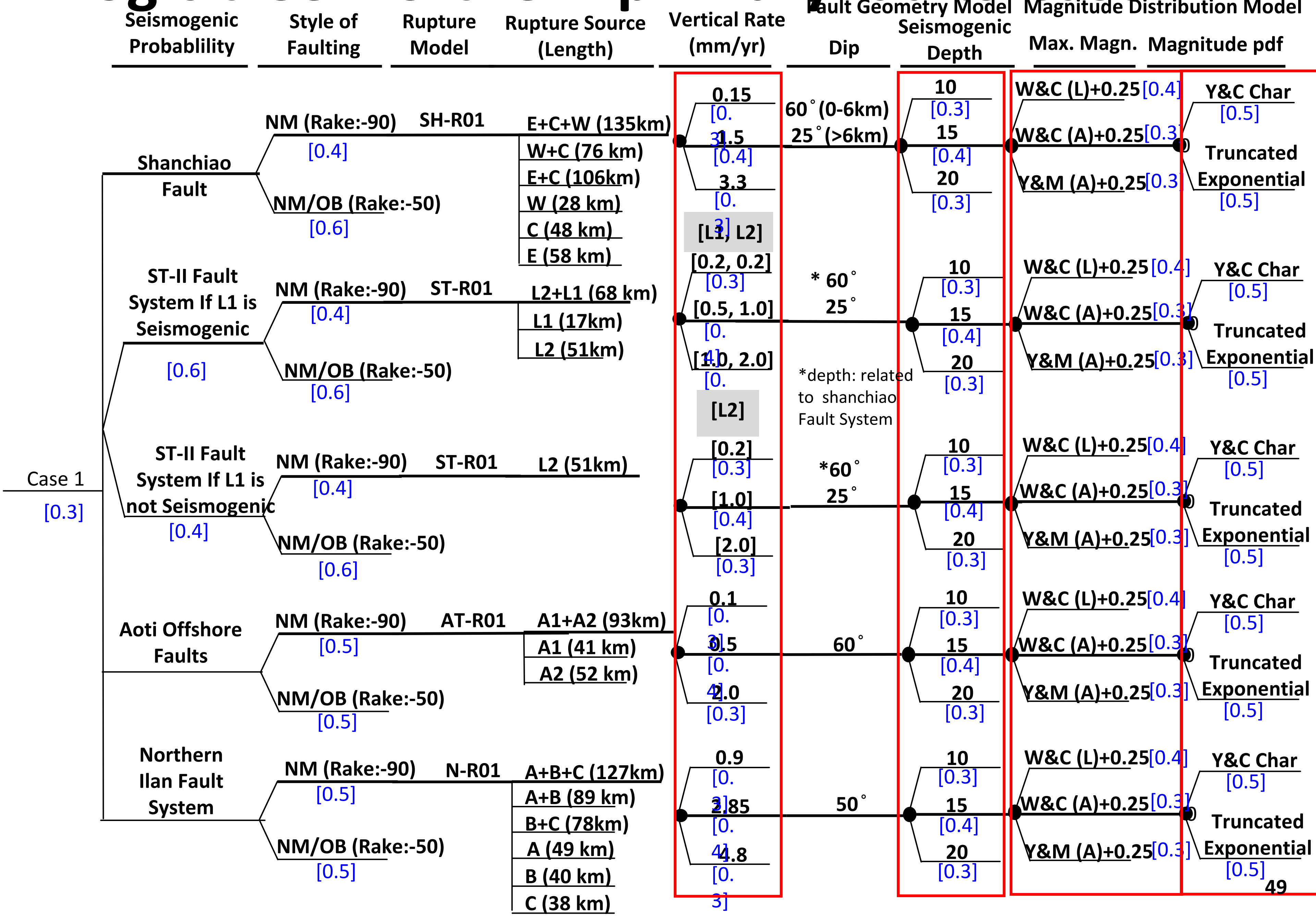
Blue: 19,683 hazard curves
Purple: 27 hazard curves

Sensitivity test shows the simplified geometry model(right) still cover the range of uncetainty

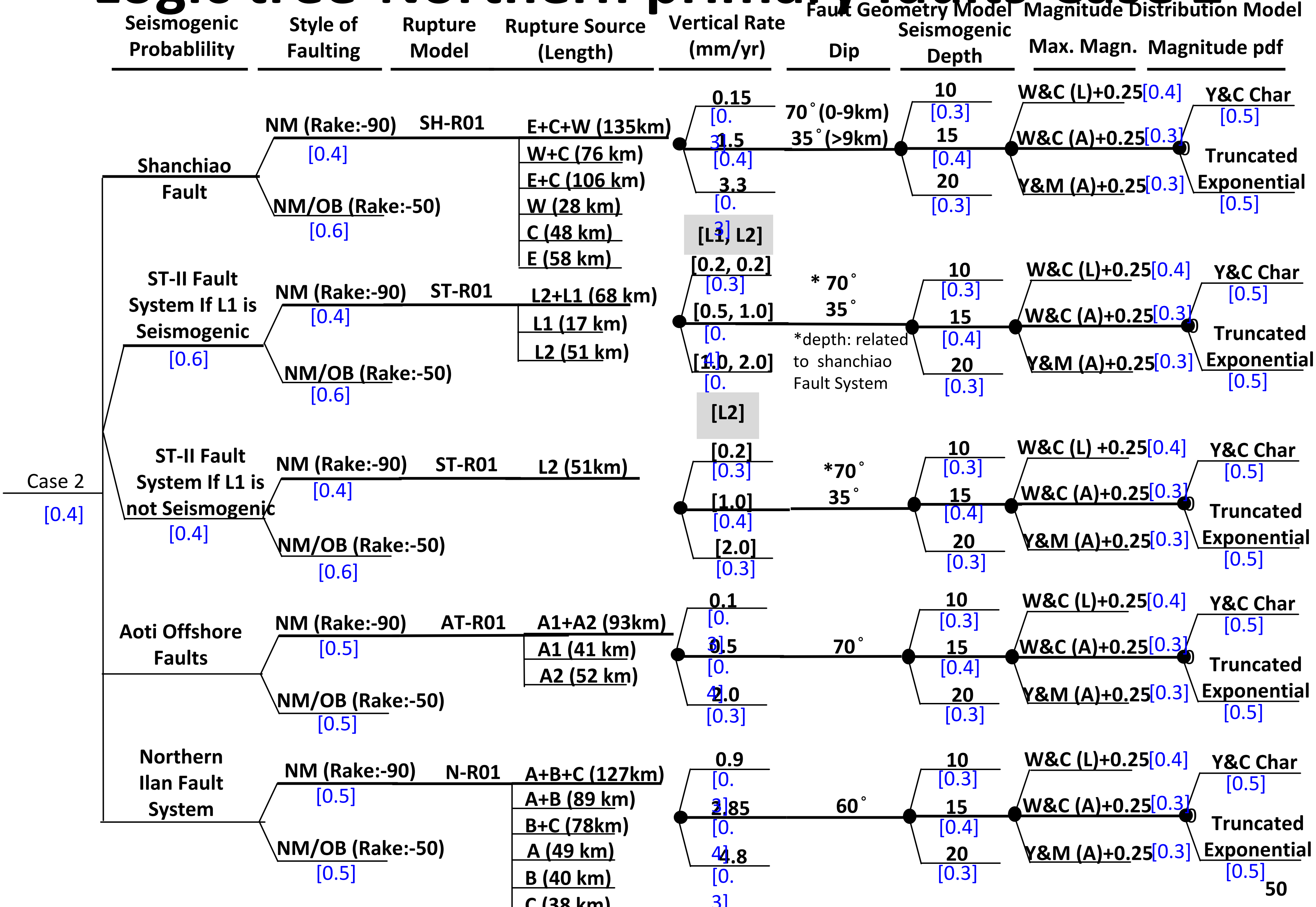




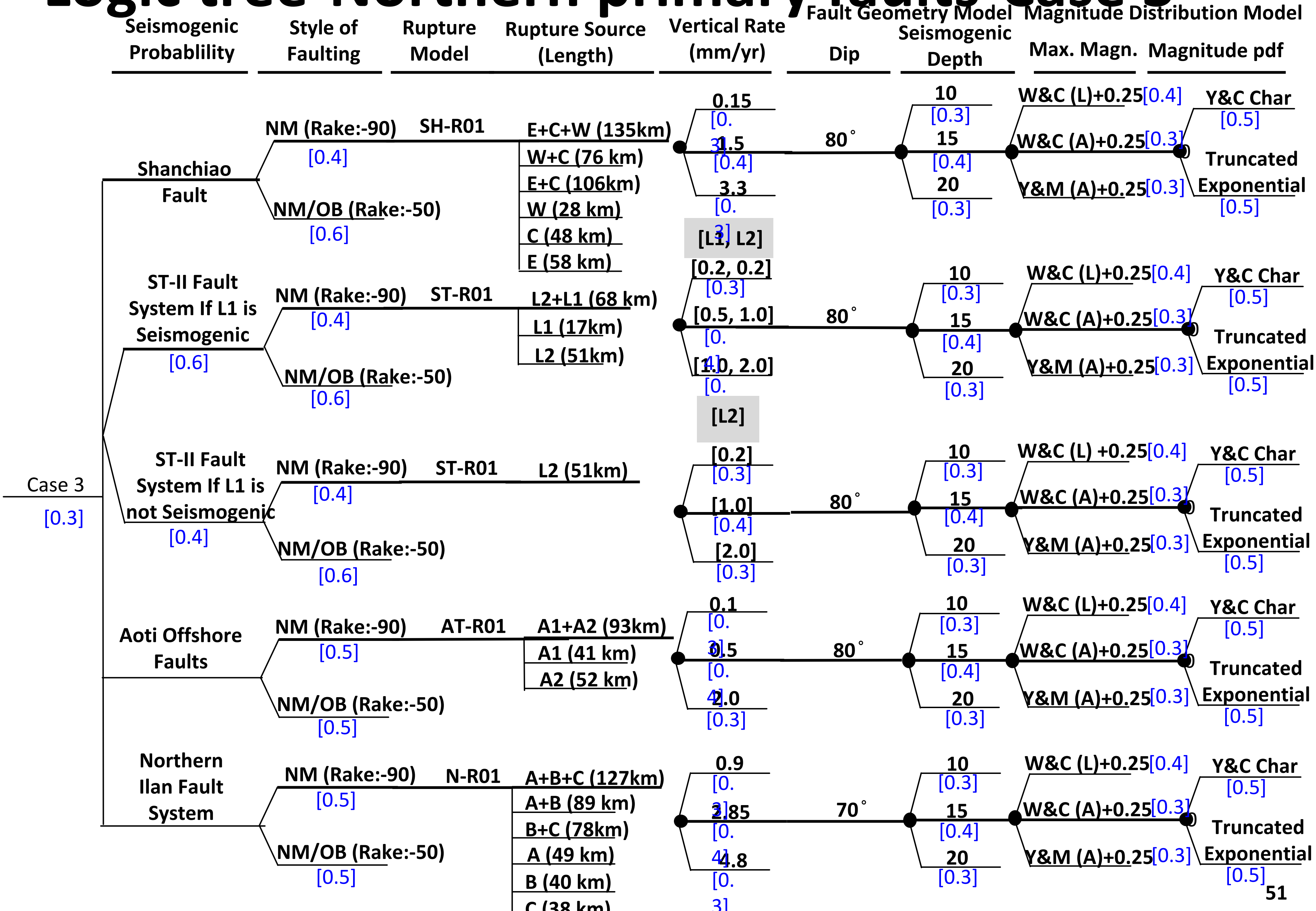
Logic tree-Northern primary faults-Case 1



Logic tree-Northern primary faults-Case 2



Logic tree-Northern primary faults-Case 3

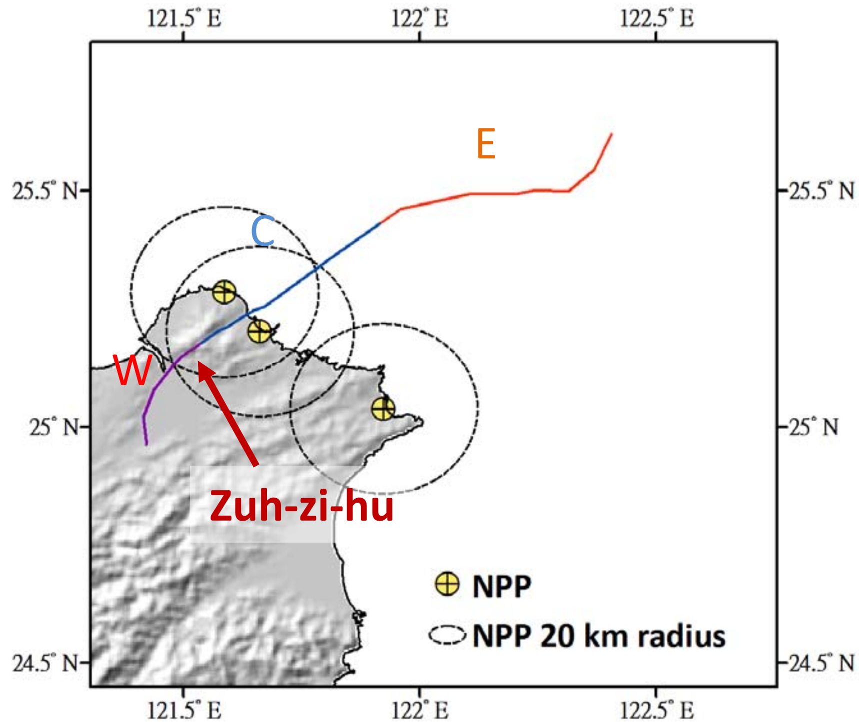


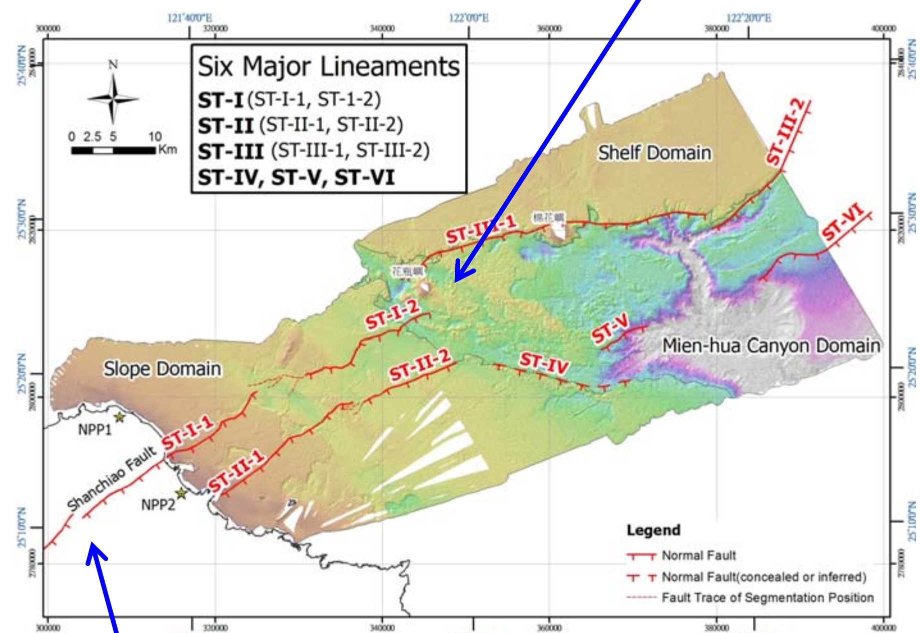
Thank you

Shanchaio Fault System - Segmentation

Break point between W and C at Zuh-zi-hu;
(Hu et al., 2014)

6 km offset

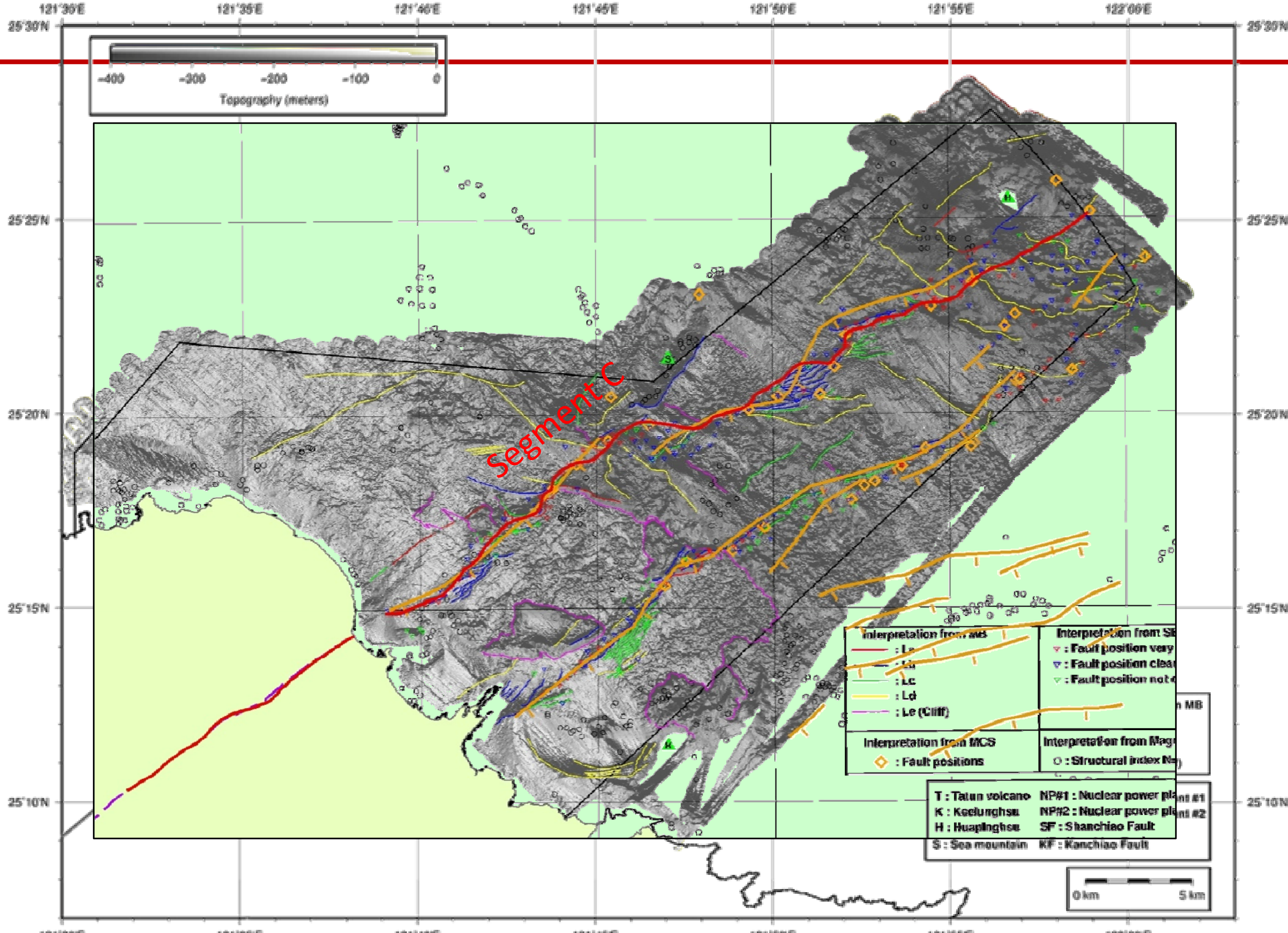




1.5 km offset

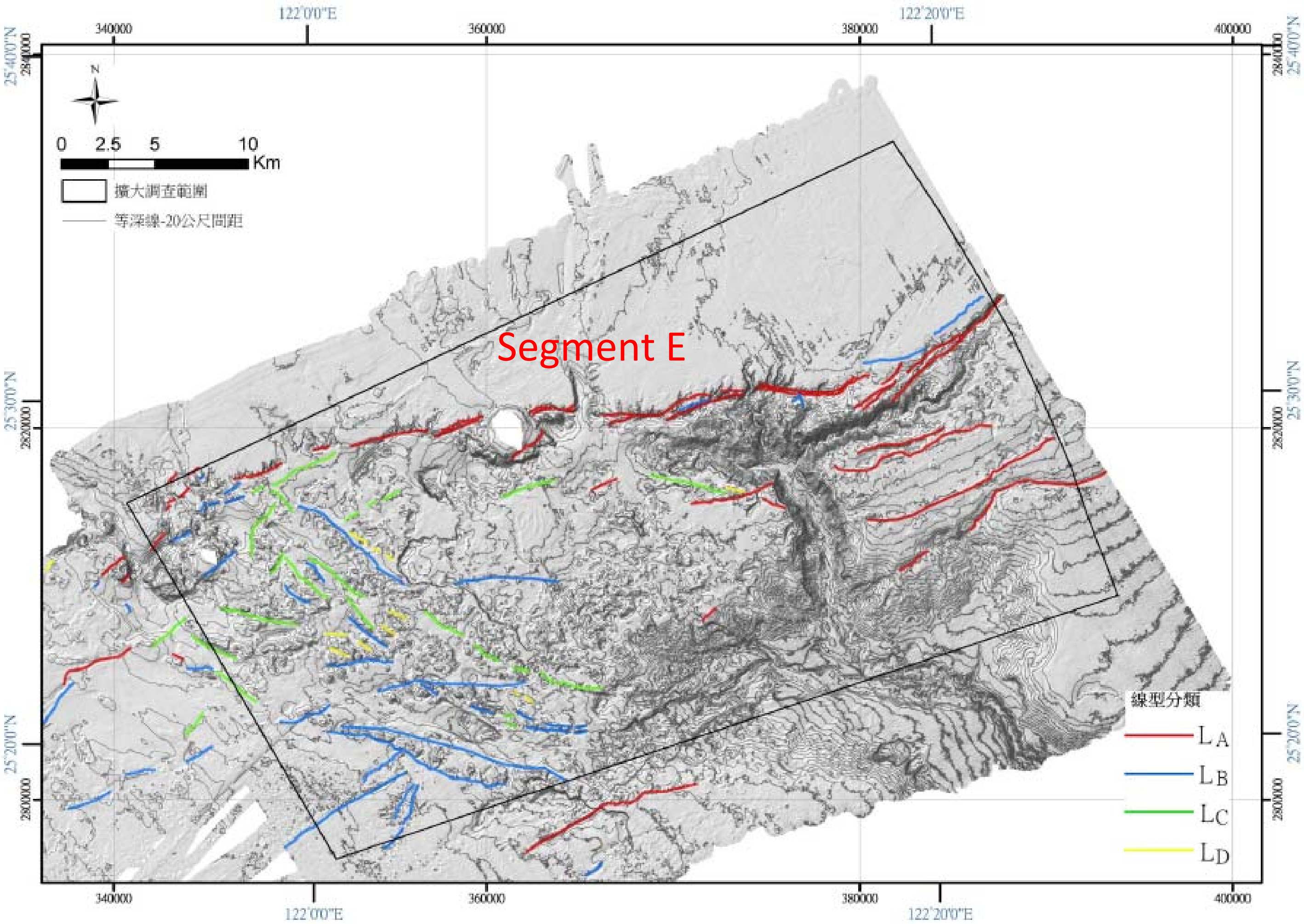
W+C(Step over: 1.5 km)> C+E(Step over: 6 km)]

2. Geometry of Shanchaio Fault System _ Observation of surface fault trace _ Segment C



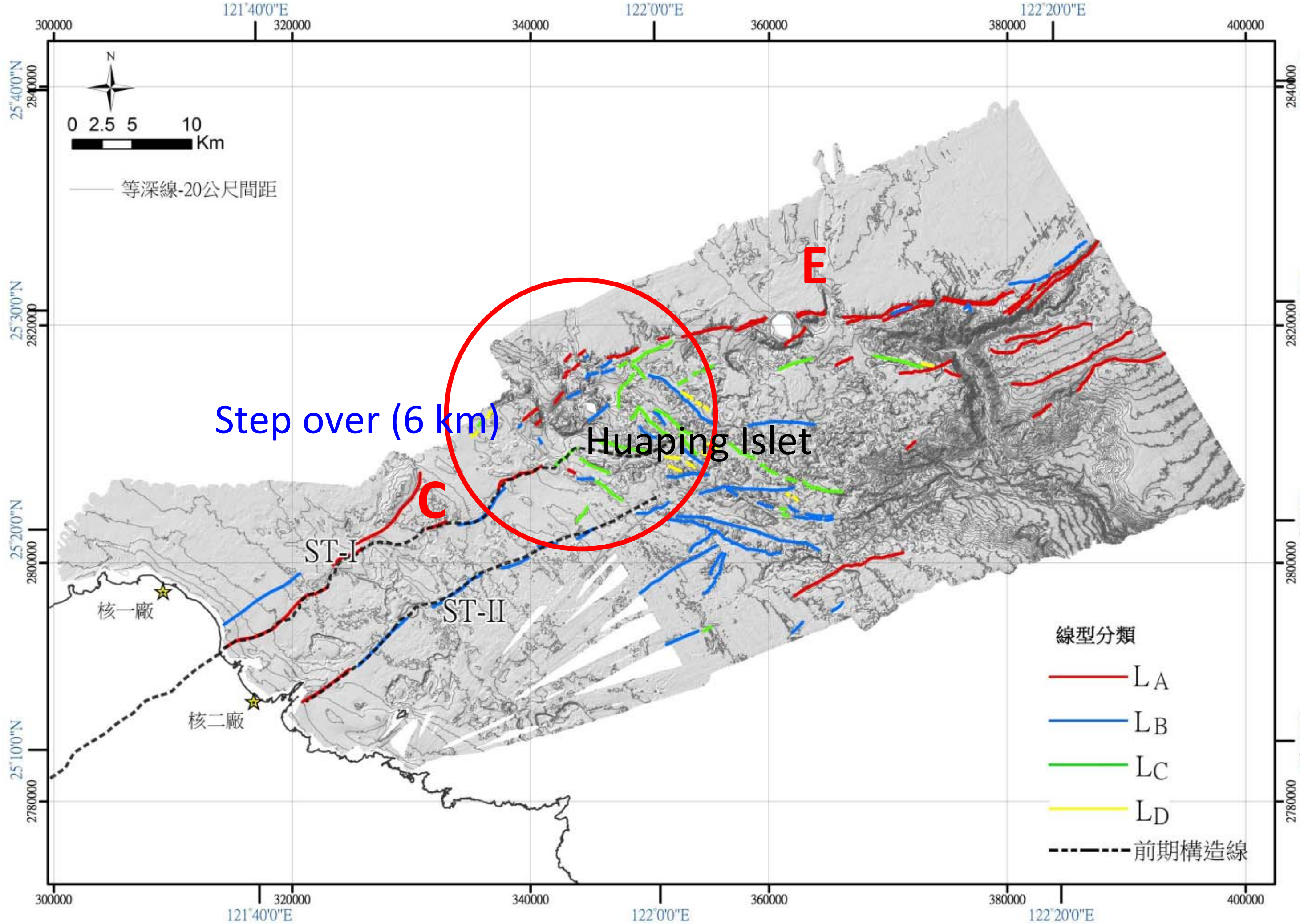
(Sinotech, 2012)

2. Geometry of Shanchaio Fault System _ Observation of surface fault trace _ Segment E



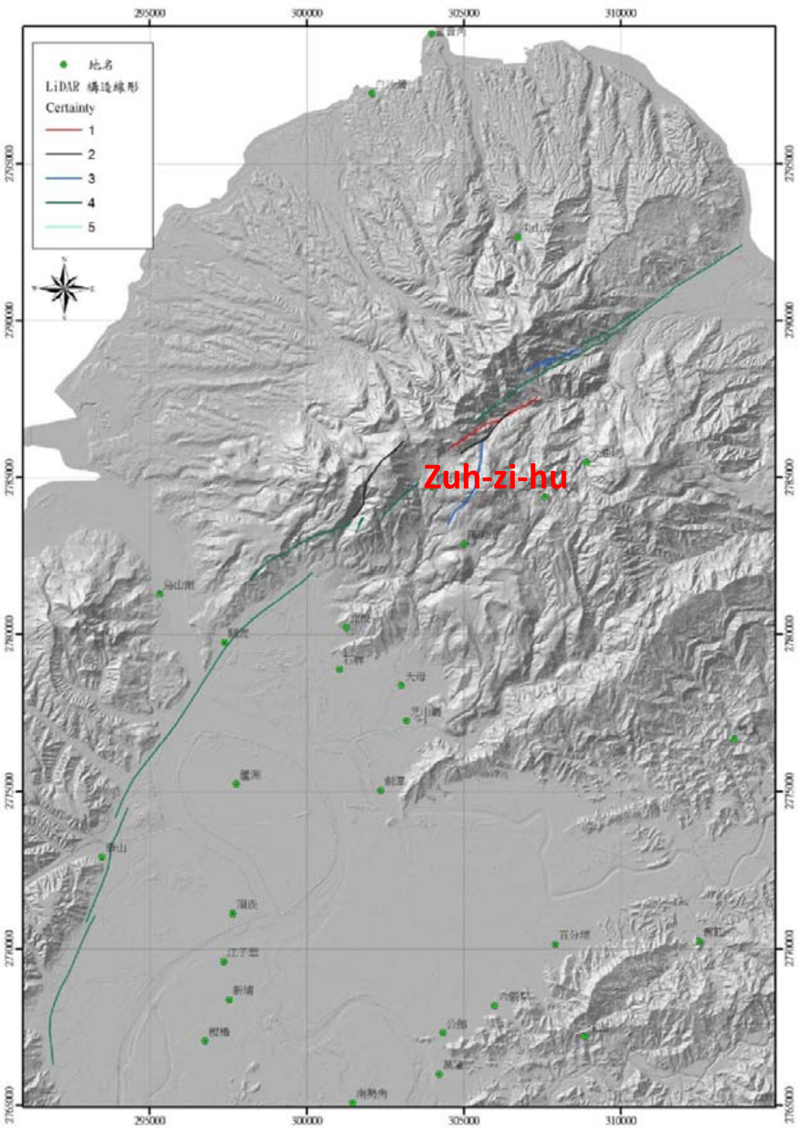
(Sinotech, 2015)

2. Geometry of Shanchaio Fault System _ Observation of surface fault trace _ Segment point between C &E

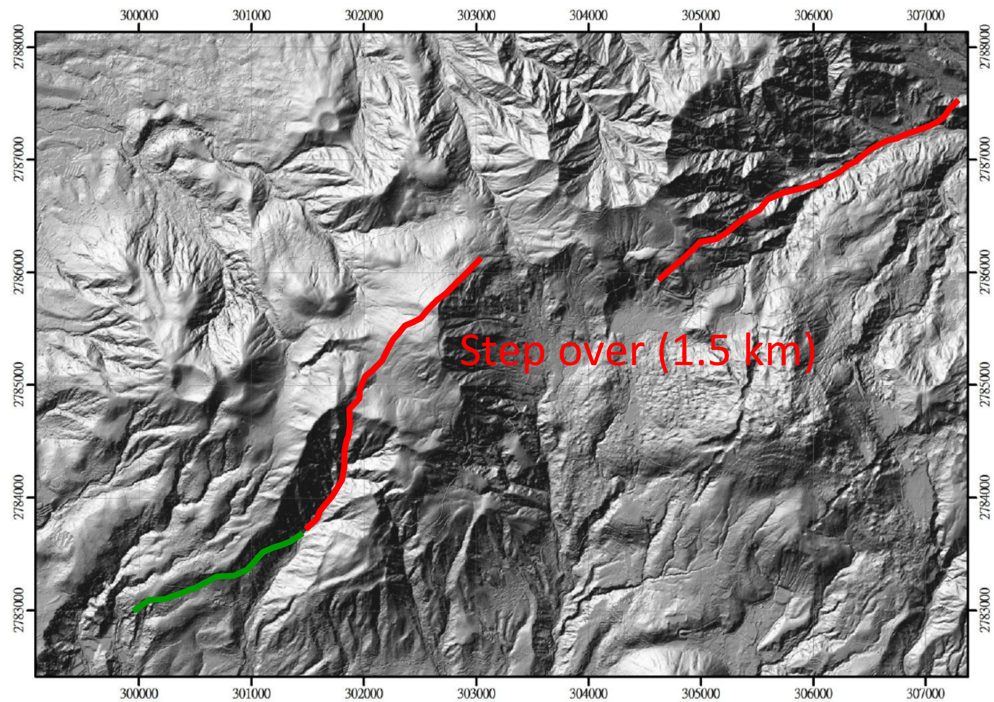


(Sinotech, 2015)

2. Geometry of Shanchaio Fault System _ Observation of surface fault trace _ Segment point between W & C



5 m LiDAR DEM

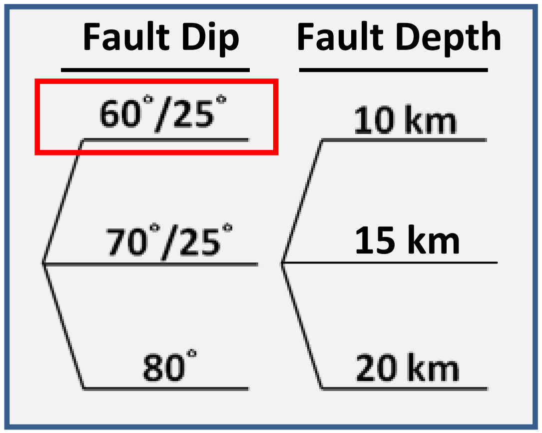


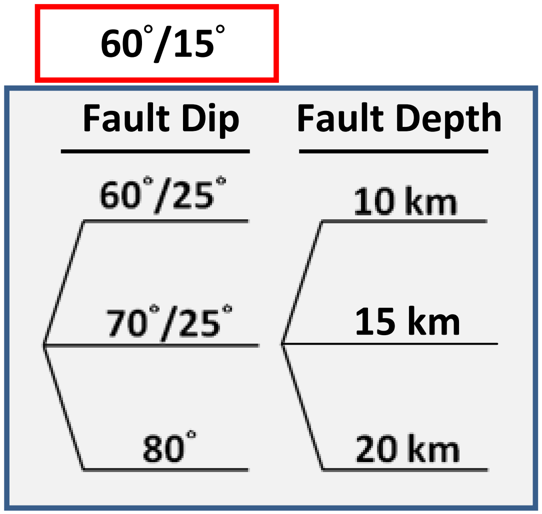
- **Step over of the lineaments in Tatun Mt.**

張國楨等人(Chang et al., 2011)

2. Geometry of Shanchaio Fault System _ Simplified geometry model

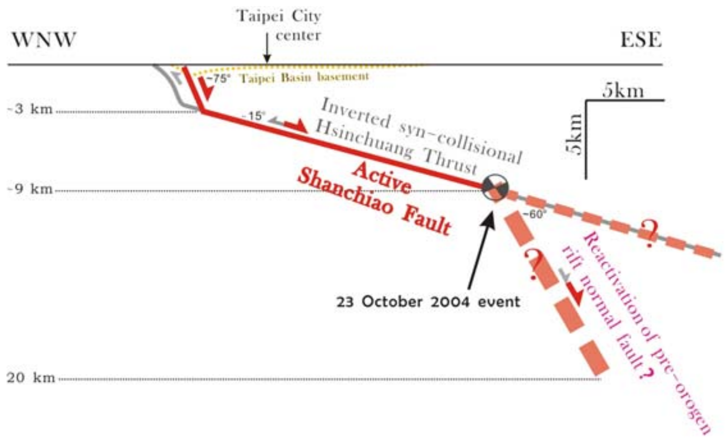
Fault Dip Change





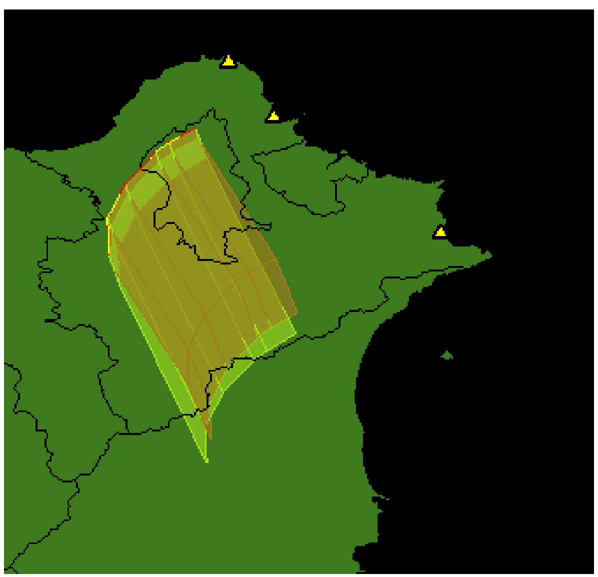
WS #2

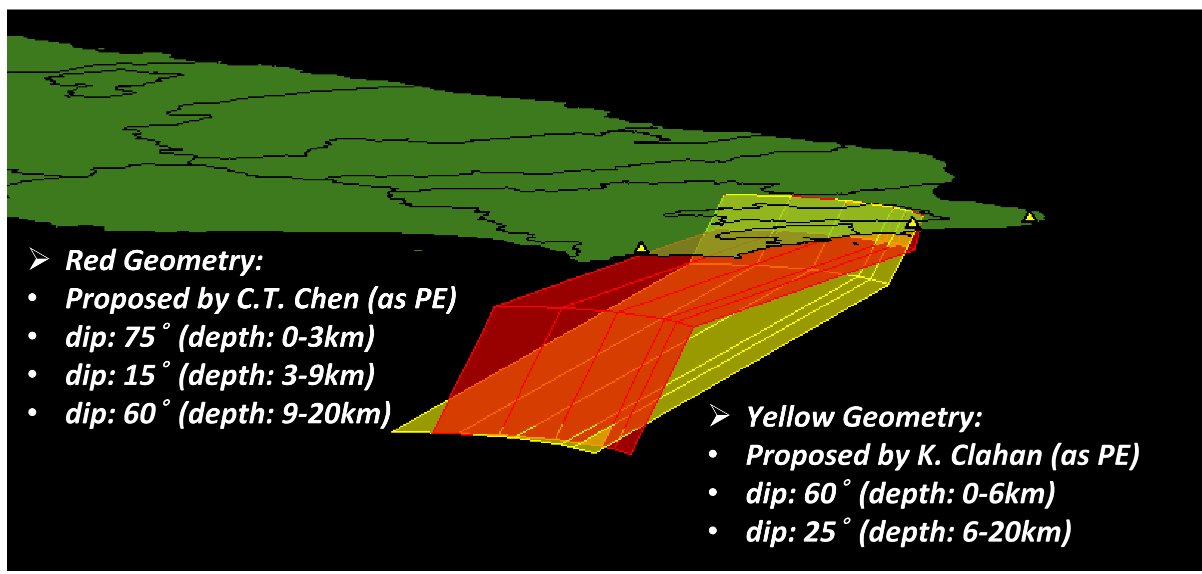
C. T. Chen



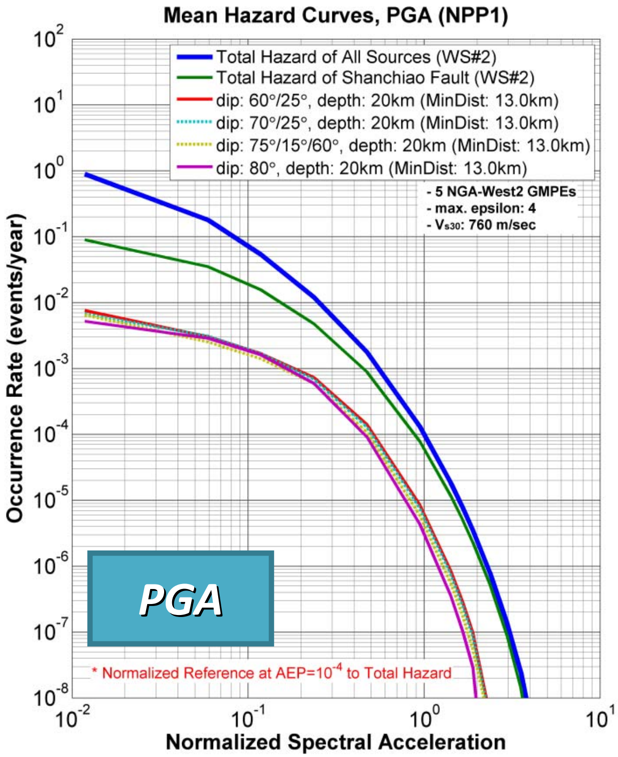
2. Geometry of Shanchaio Fault System _ Simplified geometry model _ SSC Sensitivity for W Section of Shanchiao Fault

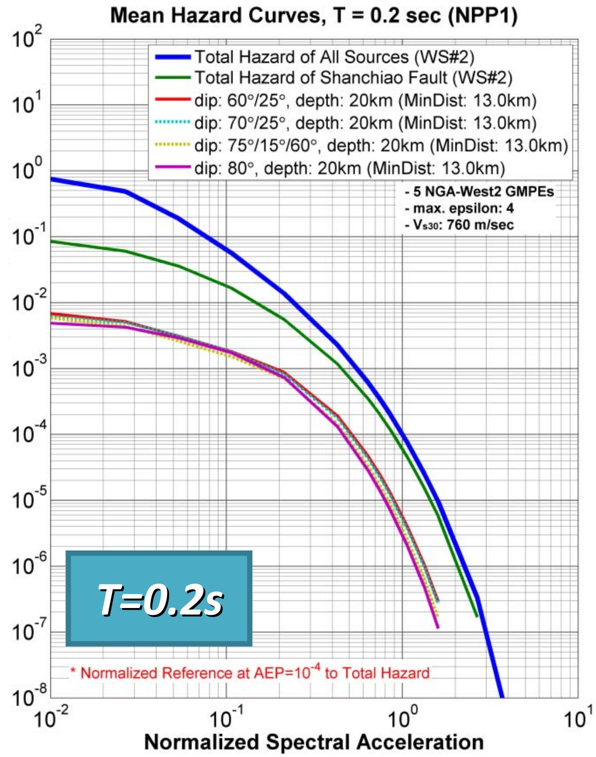
Proponent Expert	*Geometry*					*Activity*			
	Focal Mech.	Length (km)	Depth (km)	Dip	Area (km^2)	Slip Rate (mm/yr)	Mag. pdf Model	b-value	Max. Magnitude
K. Clahan	NM	29	0-6-20	60° /25°	979	1.73	Y&C Char.	1.00	6.98
K. Clahan			0-9-20	70° /25°	906	1.60			6.95
K. Clahan			0-20	80°	576	1.52			6.75
C.T. Chen			0-3-9-20	75° /15° /60°	995	1.55			6.99

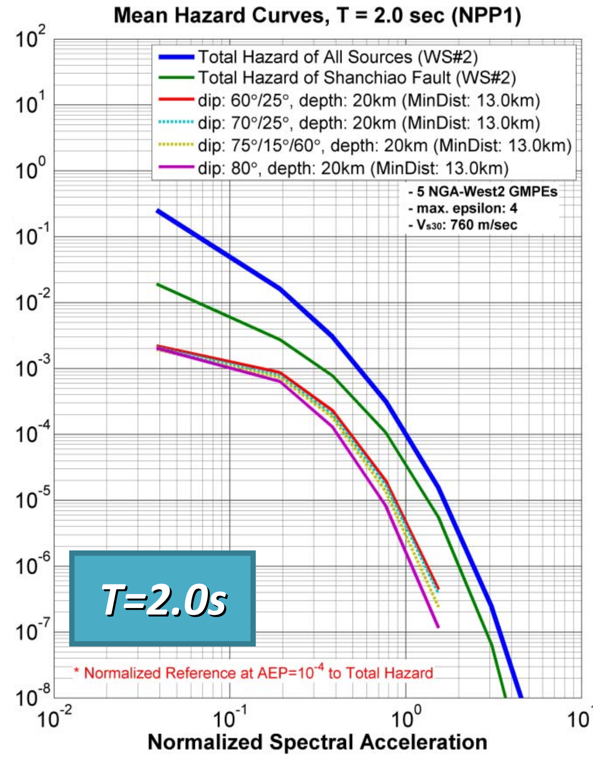




2. Geometry of Shanchaio Fault System _ Simplified geometry model _ Sensitivity Study (NPP1) _ W Section of Shanchiao Fault

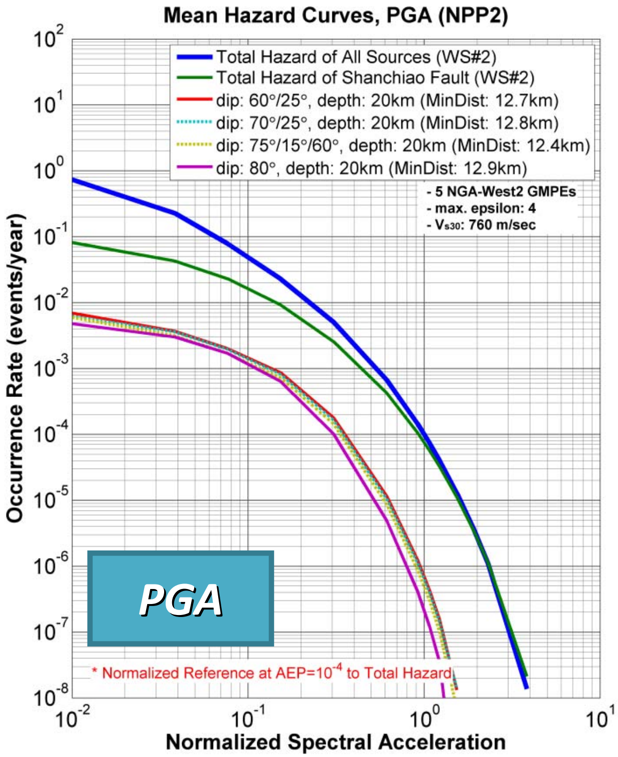


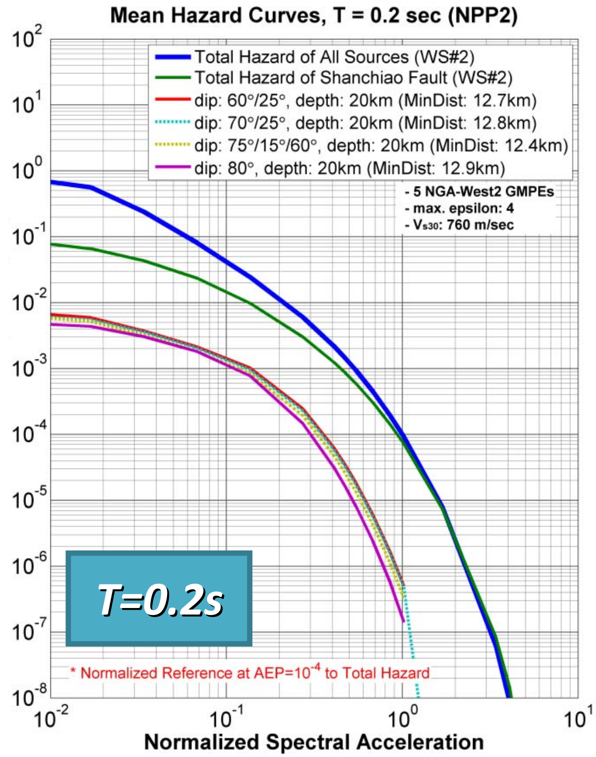


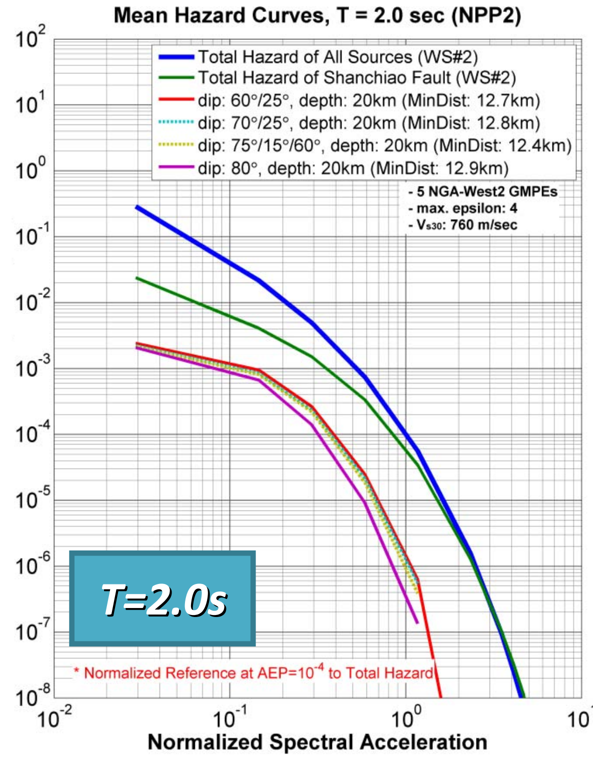


Proponent Expert	*Geometry*					*Activity*				*Min. Distance (km)*
	Focal Mech.	Length (km)	Depth (km)	Dip	Area (km^2)	Slip Rate (mm/yr)	Mag. pdf Model	b-value	Max. Magnitude	
K. Clahan	NM	29	0-6-20	60˚ /25˚	979	1.73	Y&C Char.	1.00	6.98	13.0
K. Clahan			0-9-20	70˚ /25˚	906	1.60			6.95	13.0
K. Clahan			0-20	80˚	576	1.52			6.75	13.0
C.T. Chen			0-3-9-20	75˚ /15˚ /60˚	995	1.55			6.99	13.0

2. Geometry of Shanchaio Fault System _ Simplified geometry model _ Sensitivity Study (NPP2) _ W Section of Shanchiao Fault

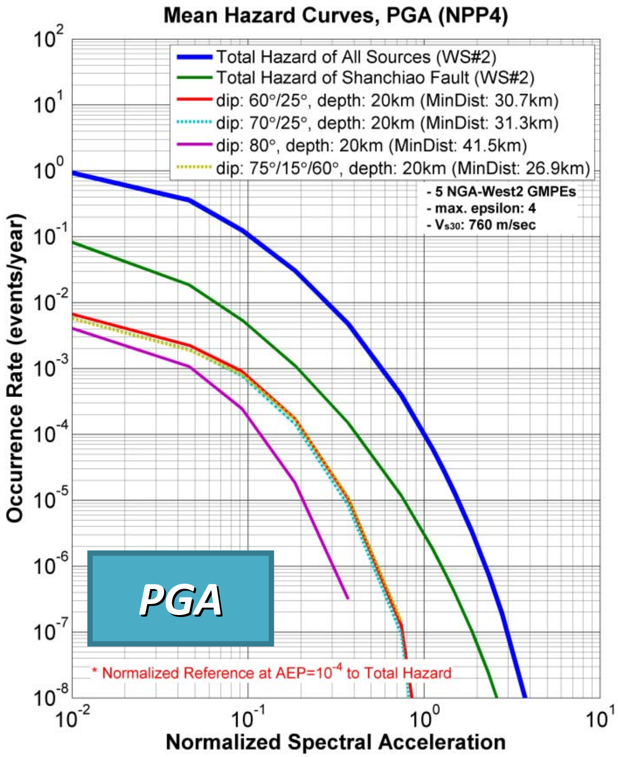


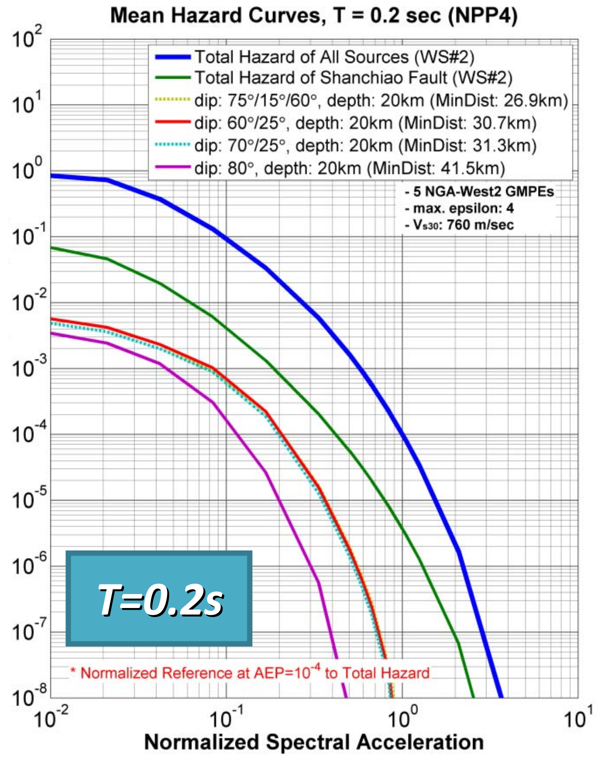


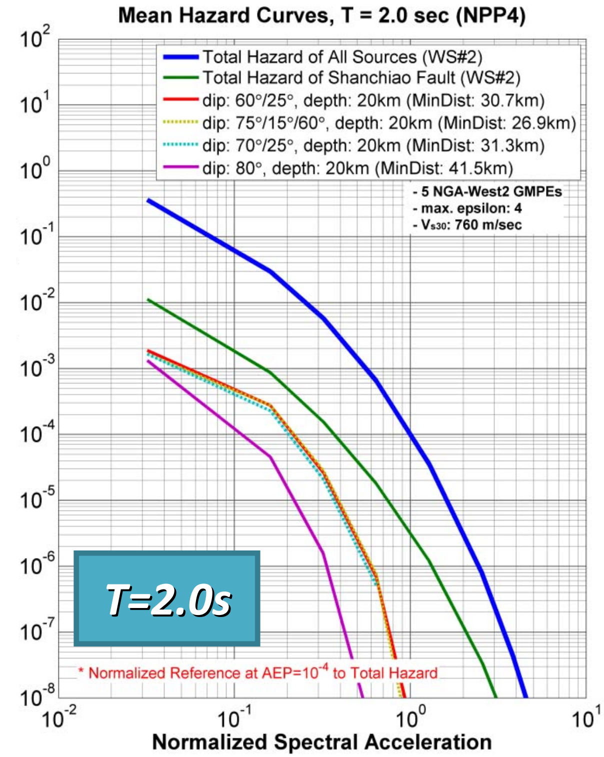


Proponent Expert	*Geometry*					*Activity*				*Min. Distance (km)*
	Focal Mech.	Length (km)	Depth (km)	Dip	Area (km^2)	Slip Rate (mm/yr)	Mag. pdf Model	b-value	Max. Magnitude	
K. Clahan	NM	29	0-6-20	60˚ /25˚	979	1.73	Y&C Char.	1.00	6.98	12.7
K. Clahan			0-9-20	70˚ /25˚	906	1.60			6.95	12.8
K. Clahan			0-20	80˚	576	1.52			6.75	12.9
C.T. Chen			0-3-9-20	75˚ /15˚ /60˚	995	1.55			6.99	12.4

2. Geometry of Shanchaio Fault System _ Simplified geometry model _ Sensitivity Study (NPP4) _ W Section of Shanchiao Fault





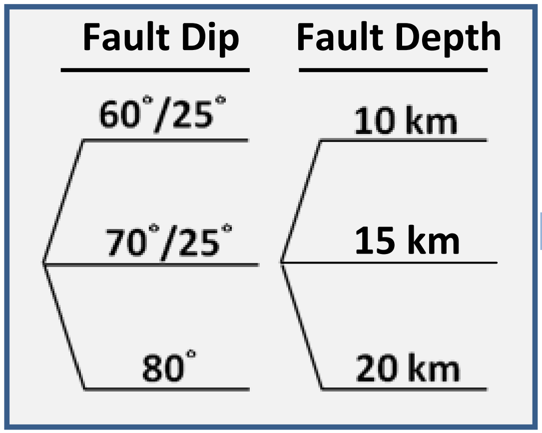


Proponent Expert	*Geometry*					*Activity*				*Min. Distance (km)*
	Focal Mech.	Length (km)	Depth (km)	Dip	Area (km²)	Slip Rate (mm/yr)	Mag. pdf Model	b-value	Max. Magnitude	
K. Clahan	NM	29	0-6-20	60˚ /25˚	979	1.73	Y&C Char.	1.00	6.98	30.7
K. Clahan			0-9-20	70˚ /25˚	906	1.60			6.95	31.3
K. Clahan			0-20	80˚	576	1.52			6.75	41.5
C.T. Chen			0-3-9-20	75˚ /15˚ /60˚	995	1.55			6.99	26.9

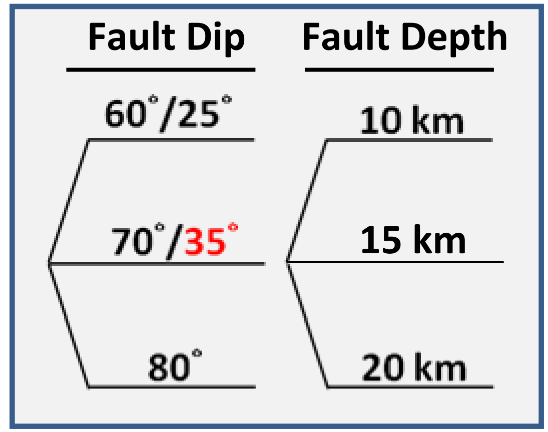
2. Geometry of Shanchaio Fault System _ Simplified geometry model _ WS#2 → WM#3

Fault Dip Change

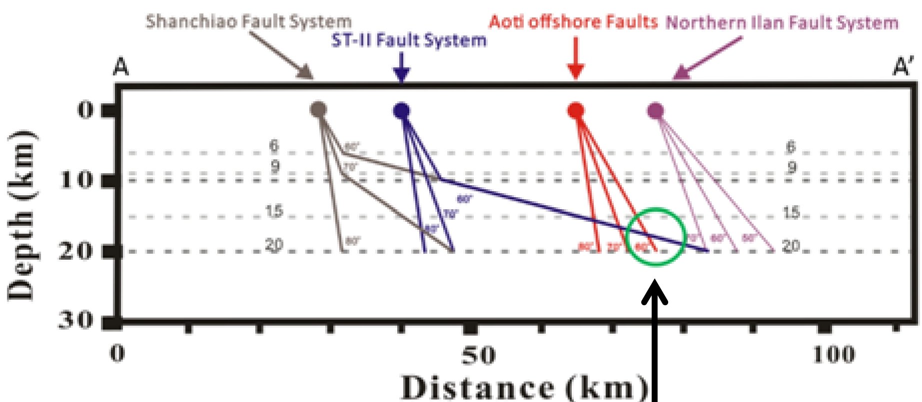
60°/15°



Dip

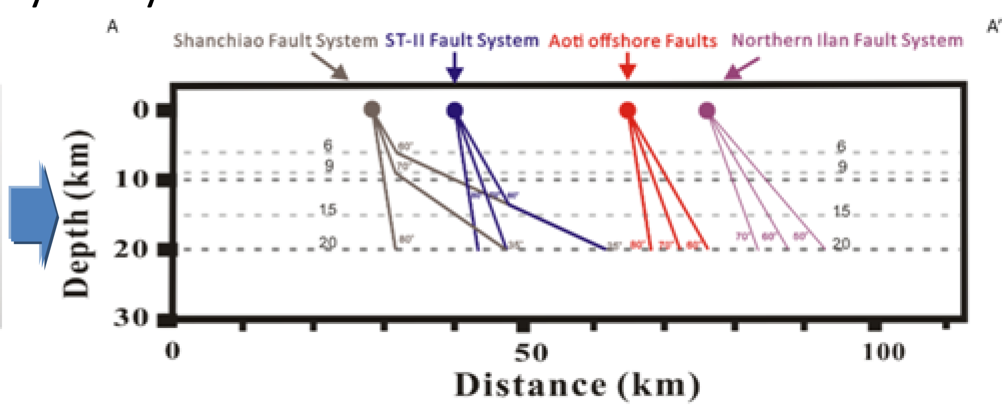


Sensitivity analysis

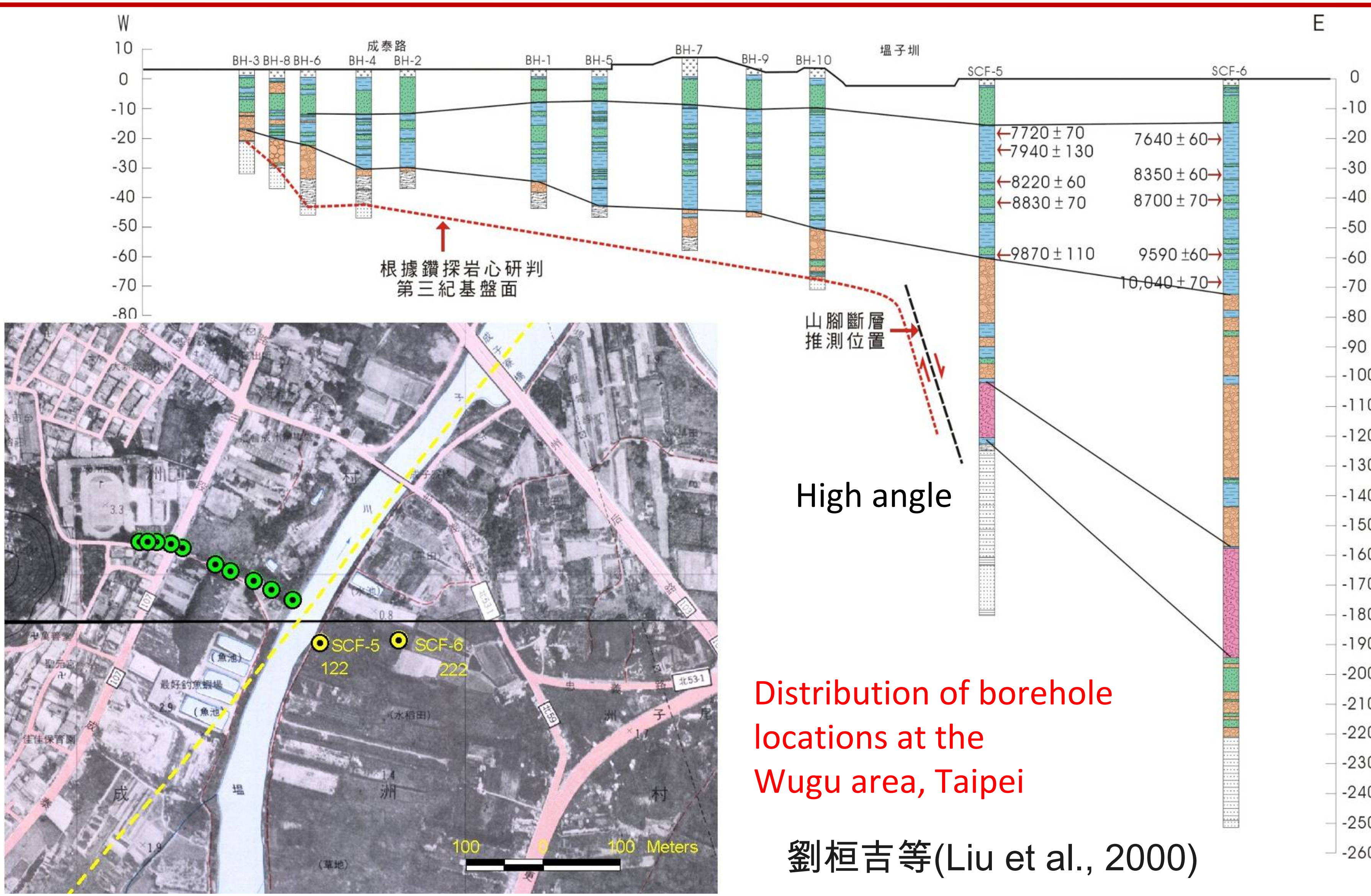


The extension of the Shanchiao ft is too long

WM #3



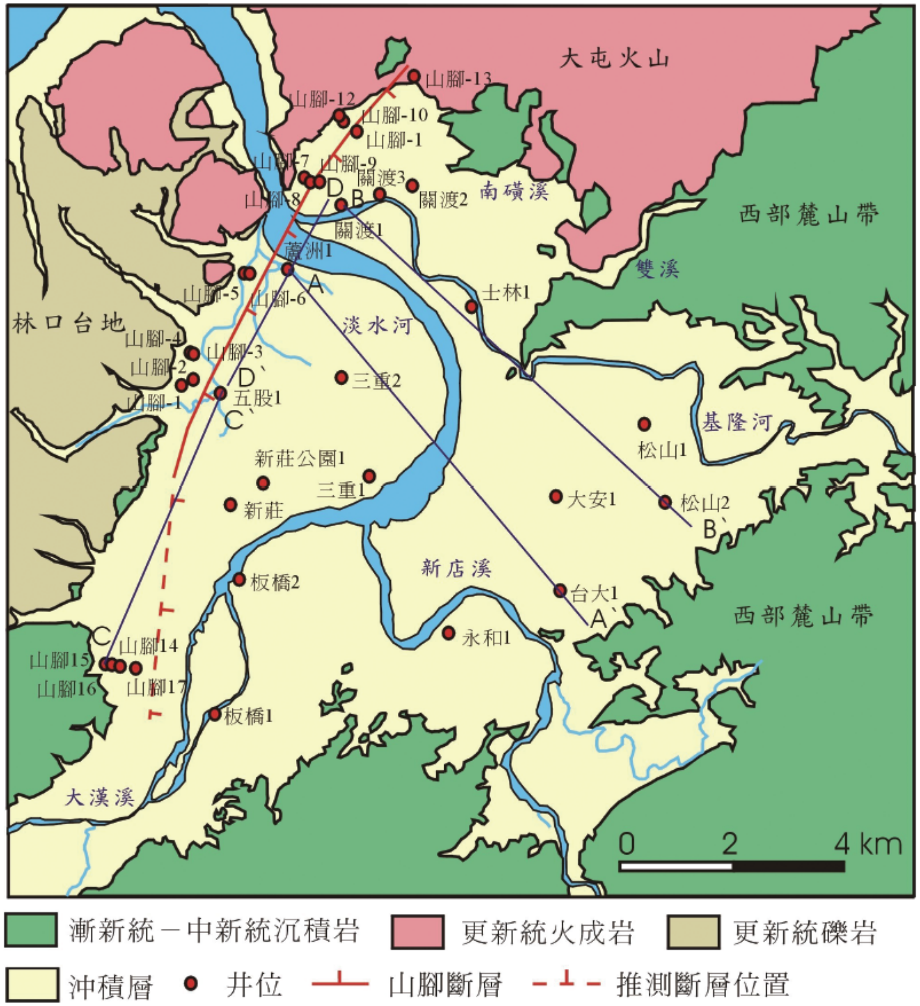
2. Geometry of Shanchaio Fault System _ Style of faulting _ Drilling and Borehole Correlation (Wugu Area)

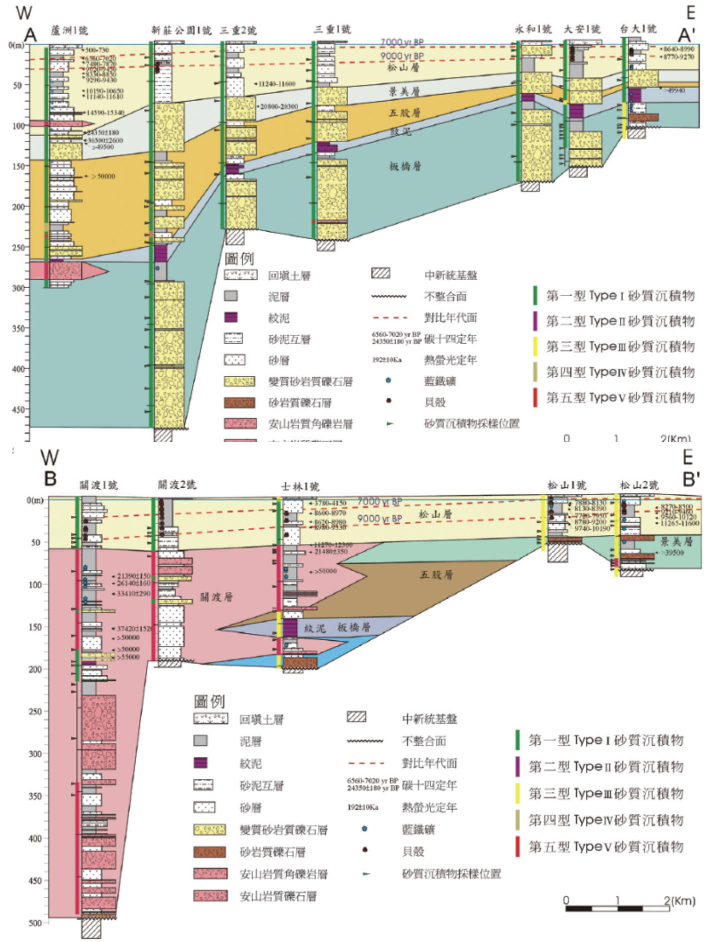


Distribution of borehole locations at the Wugu area, Taipei

劉桓吉等(Liu et al., 2000)

4. Slip rate at Taipei Basin using the alluvial-lacustrine depositional sequences, and radiocarbon dating

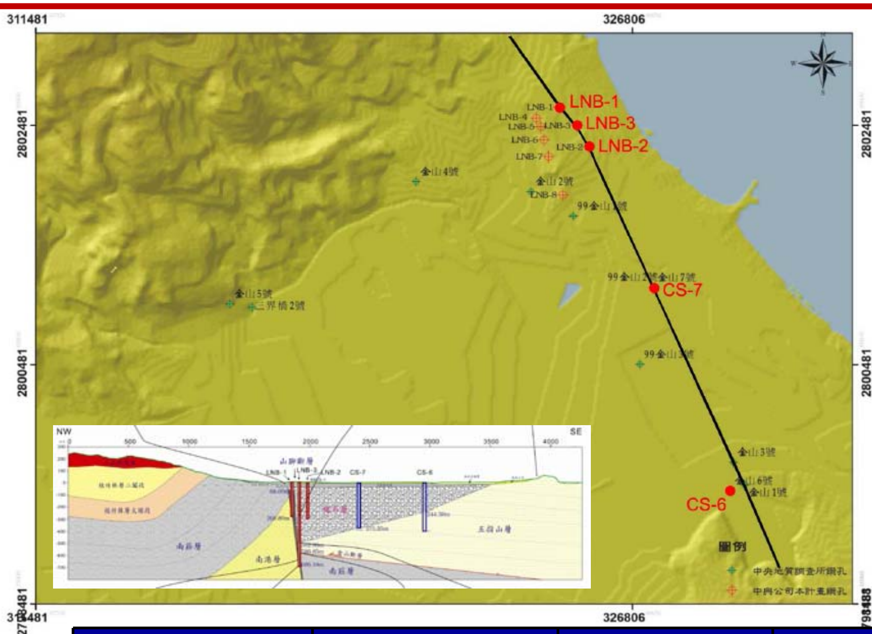




陳文山等（Chen et al., 2008）

The subsidence rate of the northwest side of the basin is 1.2~1.5 mm/yr;
While the south side and the east side is less than 1.0 mm/yr.

4. Slip rate of Shanchioa Chinshan area

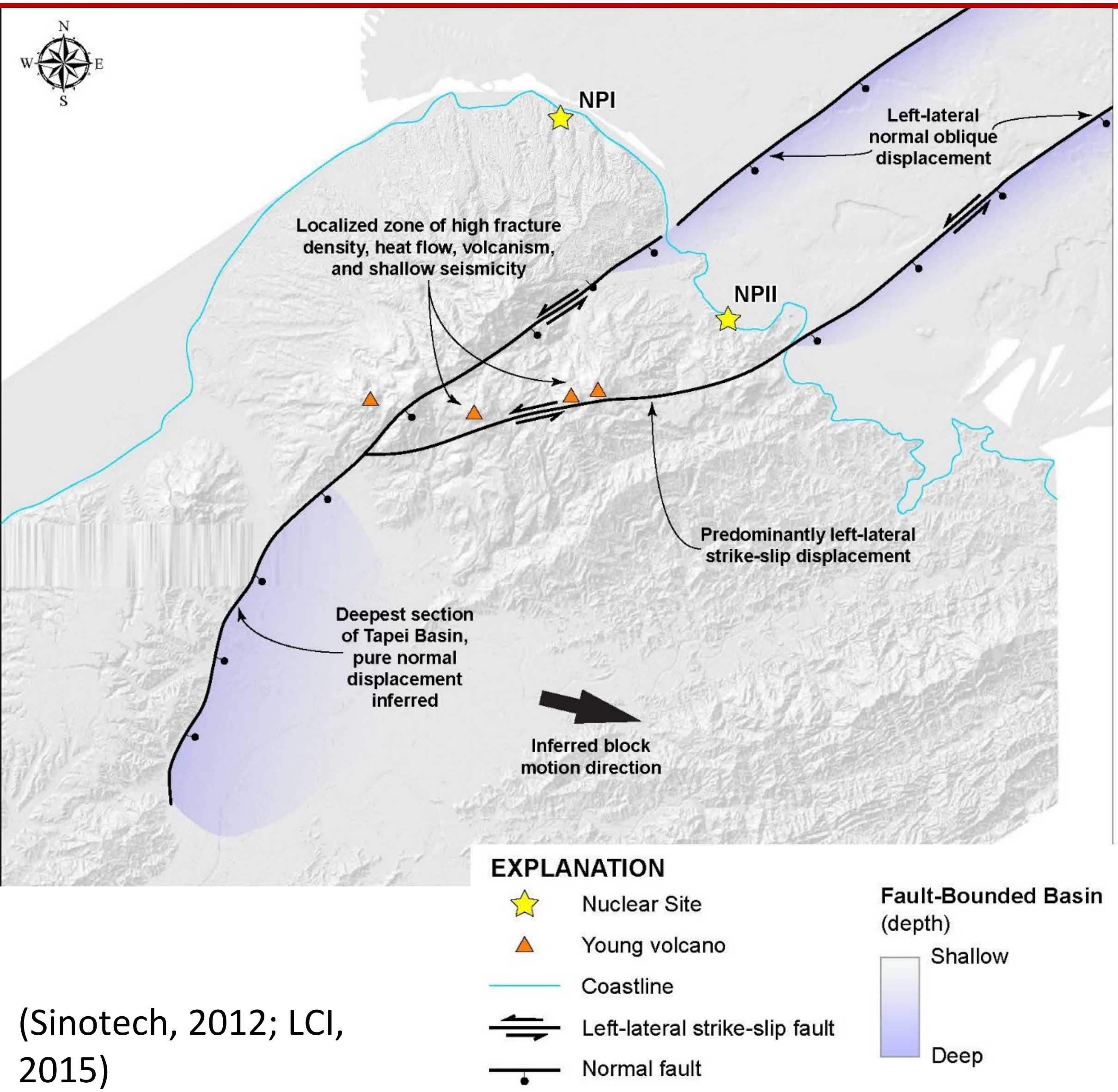


- **The long term slip rate in the Chinshan area**
  - Vertical rate
    - 0.6~-0.5 mm/yr
  - Long-term slip rate
    - (sum Vertical variation rate/number)/ Arc tan82^{o}
    - About 0.13 mm/yr

(Sinotech, 2012)

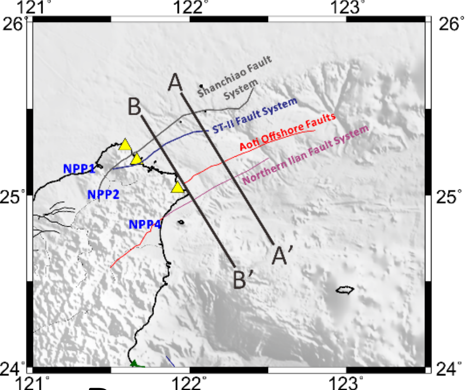
Borehole	Elevation	Depth	Paleo-water depth	^{14}C dating 2 Σ	Vertical variation rate (mm/yr)	Note
LNB-1	12.451m	33.70m	0－2m	8,960-8,460	0±0.3	
LNB-1	12.451m	41.60m	0－2m	9,560-9,520	-0.1±0.1	
LNB-2	10.820m	31.60m	0－2m	9,250-8,630	0.3±0.4	
LNB-3	10.377m	42.85m	0－2m	9,550-9,480	-0.5±0.5	
LNB-4	5.432m	16.65m	0－2m	8,160-7,870	0.6±0.2	
LNB-5	5.511m	27.20m	0－2m	8,980-8600	0.0±0.3	
LNB-6	6.430m	22.56m	0－2m	8,600-8,420	0.4±0.2	
LNB-7	5.759m	16.90m	0－2m	7,920-7,680	0.4±0.2	
LNB-7	5.759m	27.40m	0－2m	9,010-8,720	0.0±0.3	

2. Geometry of Shanchaio Fault System _ Style of faulting _ Kinematic Block Model of the Shanchiao Fault System

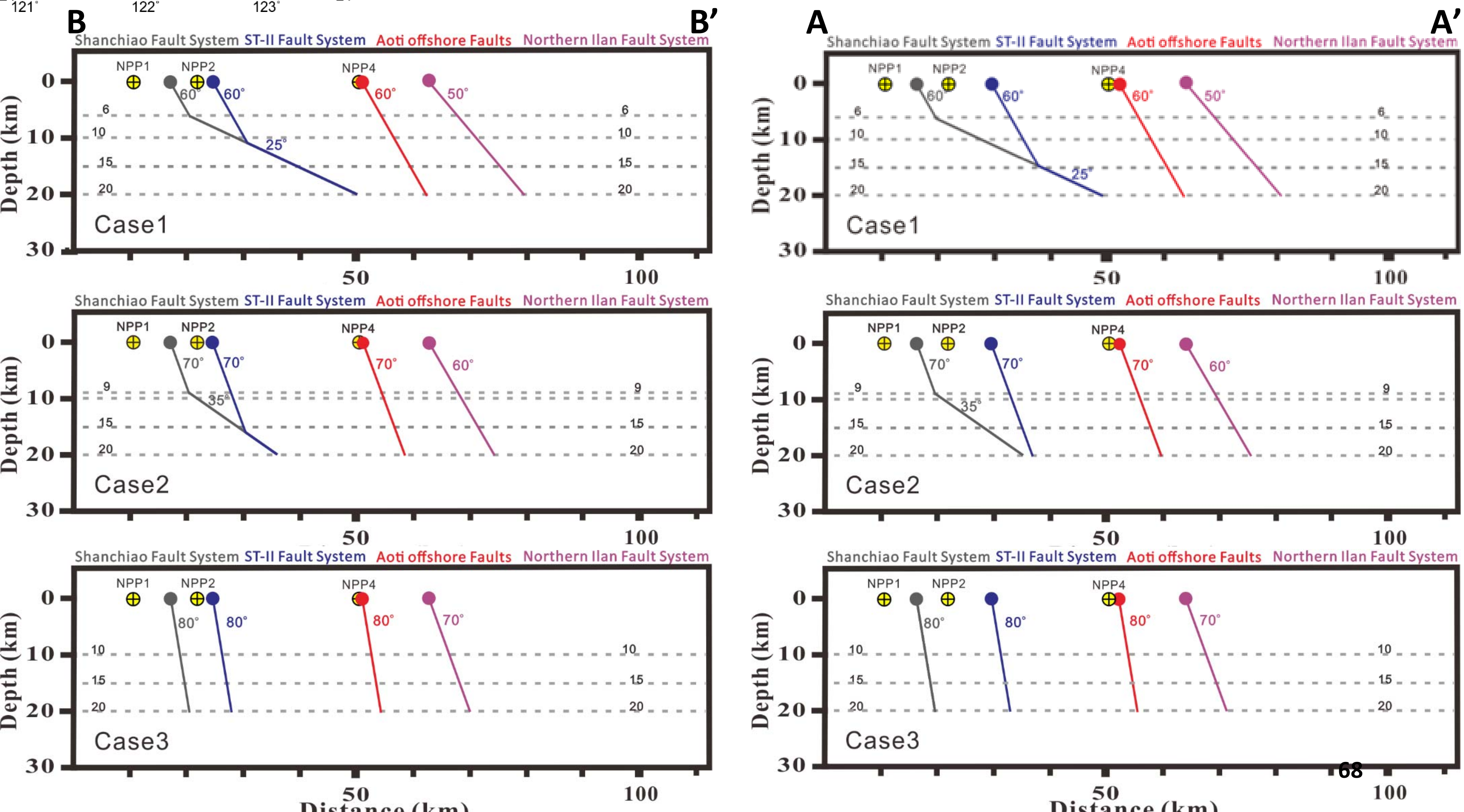


- Based on GPS observations as well as geologic observations (numerous authors), relative extension in the area is oriented roughly east-west.
- Model predicts nearly pure normal displacement along the western margin of Taipei Basin where the Shanchiao fault (ST-I) trends north-south.
- Left-lateral oblique normal displacement is predicted along the northeast-southwest-trending sections of the Shanchiao fault (ST-I), consistent with half grabens observed in borehole and geophysical data.

(Sinotech, 2012; LCI, 2015)



Geometry proflies



5. Magnitude (1/7)

Magnitude -**Shanchiao fault system-NM**

Rupture Source	Style of Faulting	Length (km)	Dip (°)	Depth (km)	Area (km2)			W&C (L)+0.25	W&C (A)+0.25	Y&M (A)+0.25
					A1	A2	A3	M	M	M
W	-90 (NM)	28	60/25	10-20	411	698	979	7.03	6.69-7.23	6.64-7.08
			70/35		311	526	744			
			80		288	432	576			
C		48	60/25	10-20	766	1325	1867	7.33	6.92-7.52	6.83-7.32
			70/35		537	944	1350			
			80		484	726	969			
E		58	60/25	10-20	892	1535	2157	7.44	7.01-7.58	6.90-7.37
			70/35		647	1120	1592			
			80		591	887	1183			
W+C		76	60/25	10-20	1178	2022	2846	7.59	7.13-7.70	7.00-7.47
			70/35		847	1470	2094			
			80		772	1158	1544			
E+C		106	60/25	10-20	1659	2860	4024	7.78	7.27-7.86	7.12-7.60
			70/35		1184	2064	2942			
			80		1075	1613	2152			
E+C+W		135	60/25	10-20	2070	3557	5003	**7.92**	7.38-7.95	7.20-7.67
			70/35		1495	2590	3686			
			80		1364	2045	2727			

5. Magnitude (2/7)

Magnitude -**Shanchiao fault system-OB**

Rupture Source	Style of Faulting	Length (km)	Dip (°)	Depth (km	Area (km2)			W&C (L)+0.25	W&C (A)+0.25			Y&M (A)+0.25		
					A1	A2	A3	M1	M1	M2	M3	M1	M2	M3
W	-90 (NM)	28	60/25	10-20	411	698	979	7.03	6.69-7.23			6.64-7.08		
W	-50 (NM)	28	60/25	10-20	411	698	979	7.03	6.69-7.23			6.64-7.08		
			70/35		311	526	744							
			80		288	432	576							
C		48	60/25	10-20	766	1325	1867	7.33	6.92-7.52			6.83-7.32		
			70/35		537	944	1350							
			80		484	726	969							
E		58	60/25	10-20	892	1535	2157	7.44	7.01-7.58			6.90-7.37		
			70/35		647	1120	1592							
			80		591	887	1183							
W+C		76	60/25	10-20	1178	2022	2846	7.59	7.13-7.70			7.00-7.47		
			70/35		847	1470	2094							
			80		772	1158	1544							
E+C		106	60/25	10-20	1659	2860	4024	7.78	7.27-7.86			7.12-7.60		
			70/35		1184	2064	2942							
			80		1075	1613	2152							
E+C+W		135	60/25	10-20	2070	3557	5003	**7.92**	7.38-7.95			7.20-7.67		
			70/35		1495	2590	3686							
			80		1364	2045	2727							

5. Magnitude (3/7)

Magnitude –ST-II fault system-NM+OB

Rupture Source	Style of Faulting	Length (km)	Dip (˚)	Depth (km)			Area (km²)			W&C (L)+0.25	W&C (A)+0.25	Y&M (A)+0.25
				D1	D2	D3	A1	A2	A3	M1	M	M
L1	-90 (NM)	17	60/25	10-20			215	423	624	6.74	6.47-7.03	6.46-6.92
			70/35				183	293	428			
			80				175	263	351			
L2		51	60/25	10-20			558	1041	1612	7.36	6.94-7.45	6.85-7.26
			70/35				535	803	1154			
			80				511	767	1023			
L1+L2		68	60/25	10-20			773	1465	2236	7.53	7.07-**7.60**	6.96-7.38
			70/35				718	1095	1582			
			80				687	1030	1374			
L1	-50 (NM)	17	60/25	10-20			215	423	624	6.74	6.47-7.03	6.46-6.92
			70/35				183	293	428			
			80				175	263	351			
L2		51	60/25	10-20			558	1041	1612	7.36	6.94-7.45	6.8-7.26
			70/35				535	803	1154			
			80				511	767	1023			
L1+L2		68	60/25	10-20			773	1465	2236	7.53	7.07-**7.60**	6.96-7.38
			70/35				718	1095	1582			
			80				687	1030	1374			

5. Magnitude (4/7)

Magnitude – Aoti Offshore Faults NM+OB

Rupture Source	Style of Faulting	Length (km)	Dip (°)	Depth h (km)	Area (km^2)			W&C (L)+0.25	W&C (A)+0.25	Y&M (A)+0.25
					A1	A2	A3	M	M	M
A1	-90 (NM)	41	60	10-20	466	702	935	7.23	6.85-7.21	6.77-7.07
			70		432	649	864			
			80		413	619	826			
A2		52	60	10-20	604	908	1211	7.38	6.96-7.32	6.86-7.16
			70		558	837	1116			
			80		533	799	1065			
A1+A2		93	60	10-20	1070	1610	2145	7.71	7.22-7.58	7.07-7.37
			70		990	1486	1980			
			80		946	1418	1891			
A1	-50 (NM)	41	60	10-20	466	702	935	7.23	6.85-7.21	6.77-7.07
			70		432	649	864			
			80		413	619	826			
A2		52	60	10-20	604	908	1211	7.38	6.96-7.32	6.86-7.16
			70		558	837	1116			
			80		533	799	1065			
A1+A2		93	60	10-20	1070	1610	2145	7.71	7.22-7.58	7.07-7.37
			70		990	1486	1980			
			80		946	1418	1891			

5. Magnitude (5/7)

Magnitude -**Northern Ilan Fault System-NM**

Rupture Source	Style of Faulting	Length (km)	Dip (°)	Depth (km)	Area (km^2)			W&C (L)+0.25	W&C (A)+0.25	Y&M (A)+0.25
					A1	A2	A3	M	M	M
A	-90 (NM)	49	50	10-20	615	924	1231	7.34	6.94-7.33	6.85-7.17
			60		551	828	1106			
			70		512	771	1026			
B		40	50	10-20	515	775	1030	7.22	6.86-7.25	6.78-7.10
			60		456	686	916			
			70		422	634	844			
C		38	50	10-20	497	748	995	7.20	6.84-7.24	6.77-7.09
			60		441	664	887			
			70		408	614	817			
A+B		88	50	10-20	1131	1699	2261	7.68	7.21-7.60	7.07-7.39
			60		1007	1514	2022			
			70		935	1405	1870			
B+C		78	50	10-20	1012	1522	2025	7.61	7.16-7.55	7.02-7.35
			60		897	1350	1803			
			70		830	1248	1661			
A+B+C		127	**50**	10-20	1628	2447	3256	**7.89**	7.37-7.76	7.20-7.52
			60		1448	2178	2908			
			70		1343	2019	2687			

5. Magnitude (6/7)

Magnitude -**Northern Ilan Fault System-OB**

Rupture Source	Style of Faulting	Length (km)	Dip (°)	Depth (km)	Area (km^2)			W&C (L)+0.25	W&C (A)+0.25	Y&M (A)+0.25
					A1	A2	A3	M	M	M
A	-50 (NM)	49	50	10-20	615	924	1231	7.34	6.94-7.33	6.85-7.17
			60		551	828	1106			
			70		512	771	1026			
B		40	50	10-20	515	775	1030	7.22	6.86-7.25	6.78-7.10
			60		456	686	916			
			70		422	634	844			
C		38	50	10-20	497	748	995	7.20	6.84-7.24	6.77-7.09
			60		441	664	887			
			70		408	614	817			
A+B		88	50	10-20	1131	1699	2261	7.68	7.21-7.60	7.07-7.39
			60		1007	1514	2022			
			70		935	1405	1870			
B+C		78	50	10-20	1012	1522	2025	7.61	7.16-7.55	7.02-7.35
			60		897	1350	1803			
			70		830	1248	1661			
A+B+C		127	50	10-20	1628	2447	3256	7.89	7.37-7.76	7.20-7.52
			60		1448	2178	2908			
			70		1343	2019	2687			

5. Magnitude (7/7)

Magnitude –**S Fault-NM+OB**

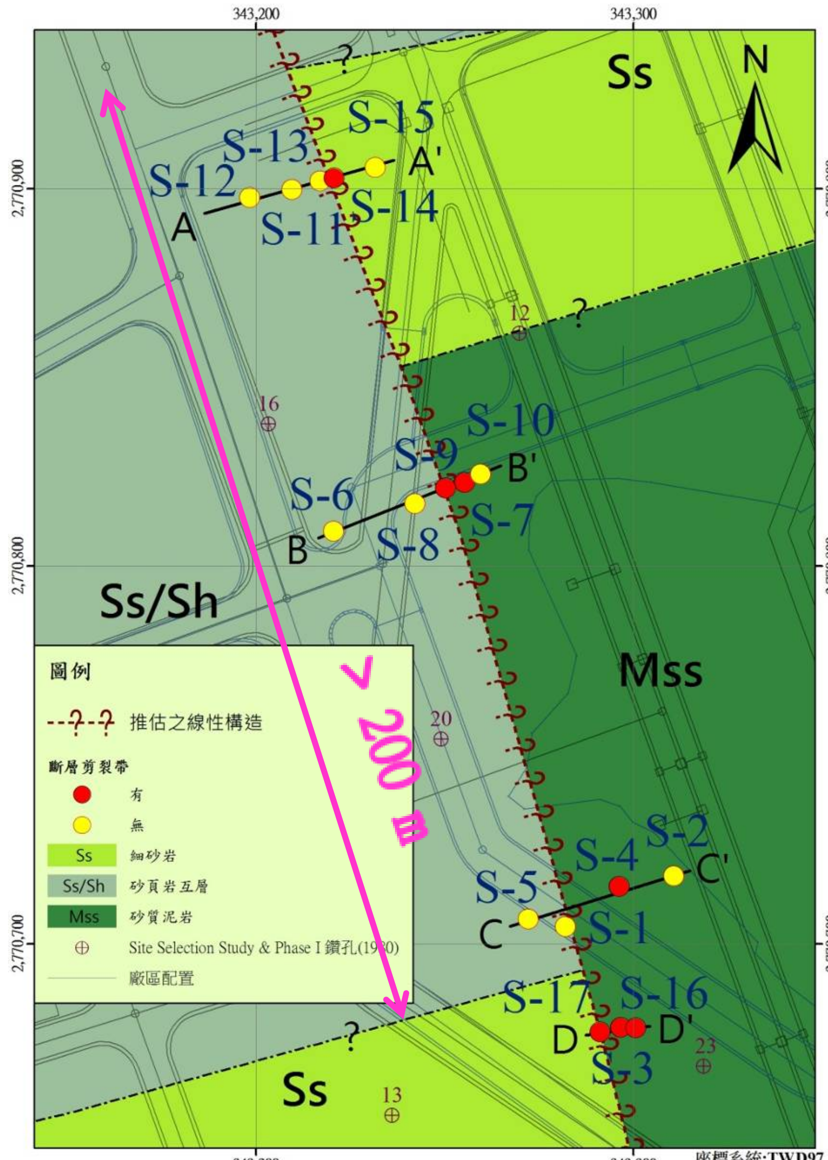
Rupture Source	Style of Faulting	Length (km)	Dip (°)	Depth (km)		Area (km^2)		W&C (L)+0.25	W&C (A)+0.25		Y&M (A)+0.25	
				D1	D2	A1	A2	M1	M1	M2	M1	M2
L1	-90 (NM)	3	70	1	3	4	11	5.80	4.74-5.23		5.04-5.25	
			80	1	3	3	10					
L1	-45 (NM)	3	70	1	3	4	11		4.74-5.23		5.04-5.25	
			80	1	3	3	10					

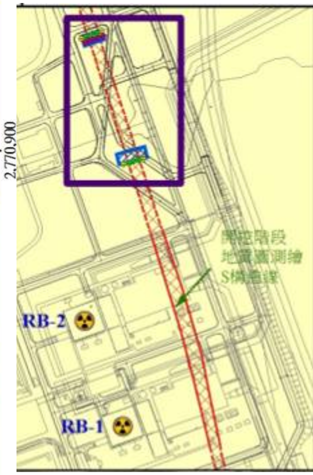
S Fault _Borehole Survey to S Structure

- Borehole:
  - Total 17 boreholes.
  - 7 red circle means shear gouge existing in these cores.
  - According to both side of Sandstone (SS), the displacement of S Structure is more than 200m.
  - S structure is sinistral with normal faulting characteristic.

Strike slip fault component

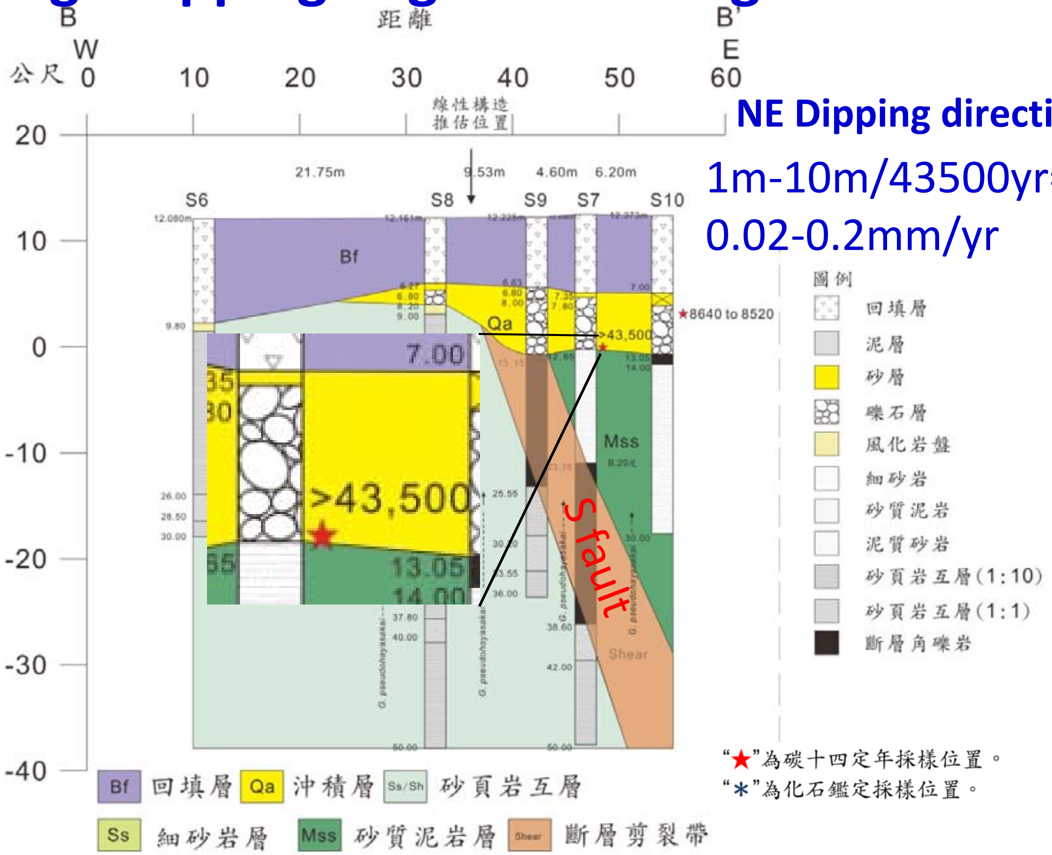
(Sinotech Ltd.,2013)





S Fault _Geological Profile and Dating Results

High dipping angle 70-80 degree

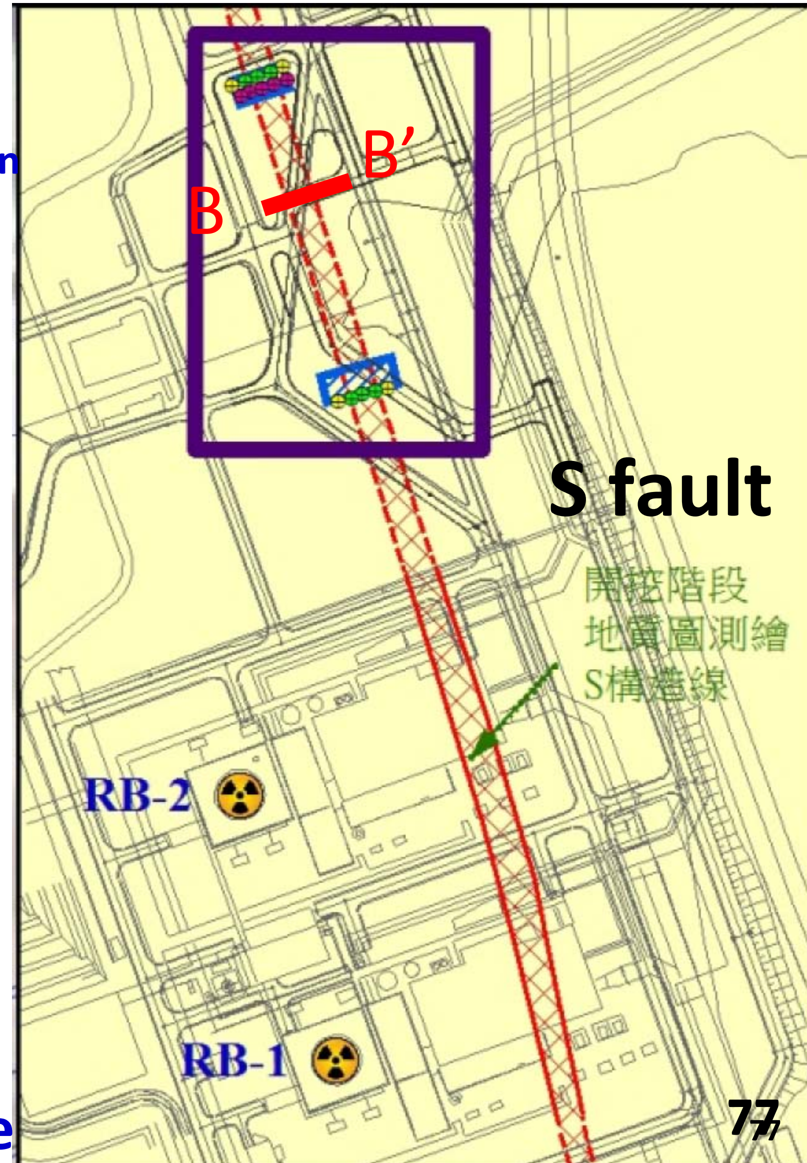


NE Dipping direction

1m-10m/43500yr=
0.02-0.2mm/yr

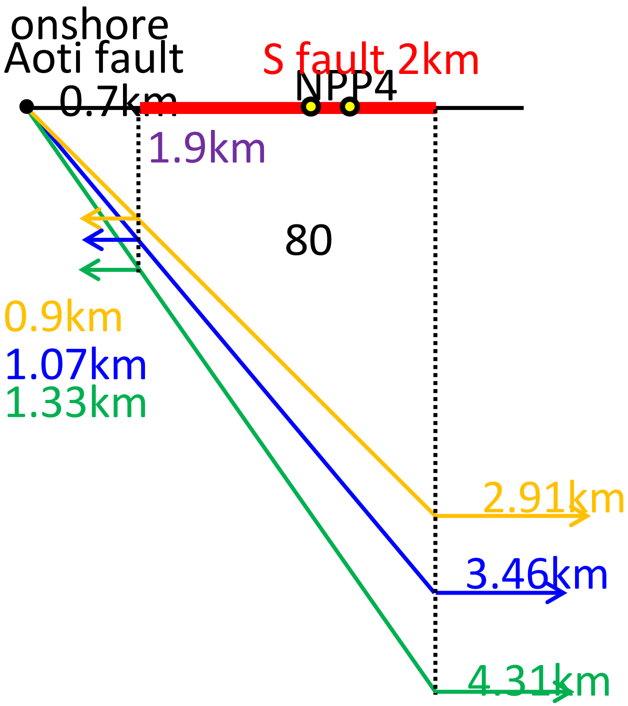
Qa is **older than 43,500 yr**,
S structure is not a active fault.

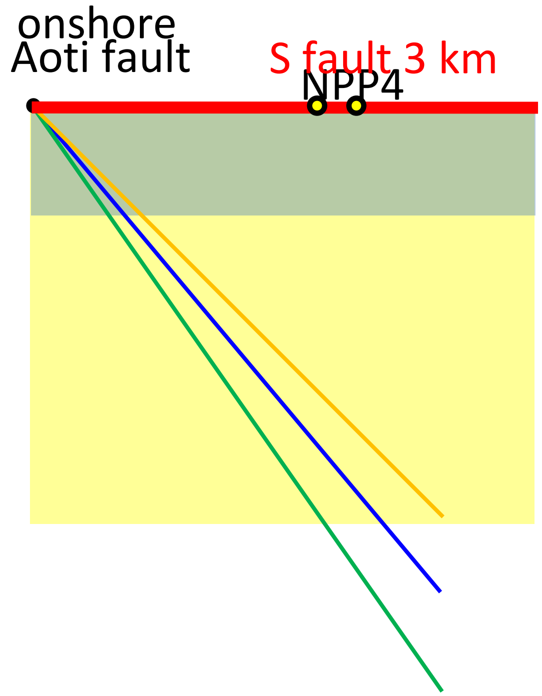
(Sinotech Ltd.,2013) **Low activity-Low slip rate**

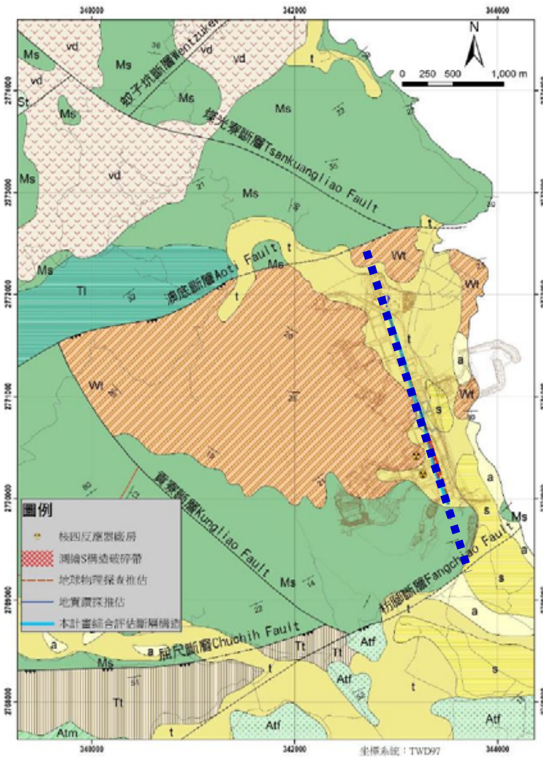


45°,50°,56° south dipping

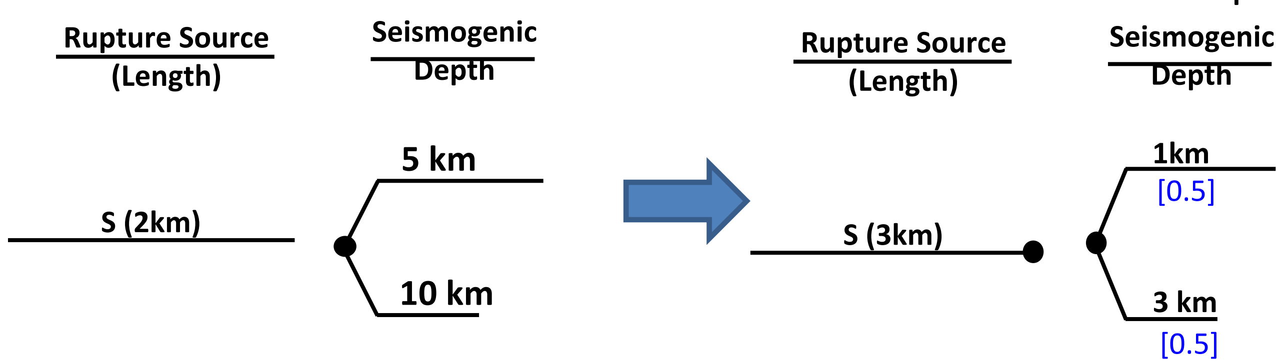
45°,50°,56° south dipping







Length from 2 to 3 km
Depth from 5-10 to 1-3 km



WM#3

WS#3