Active faults and seismic source identification in Taiwan

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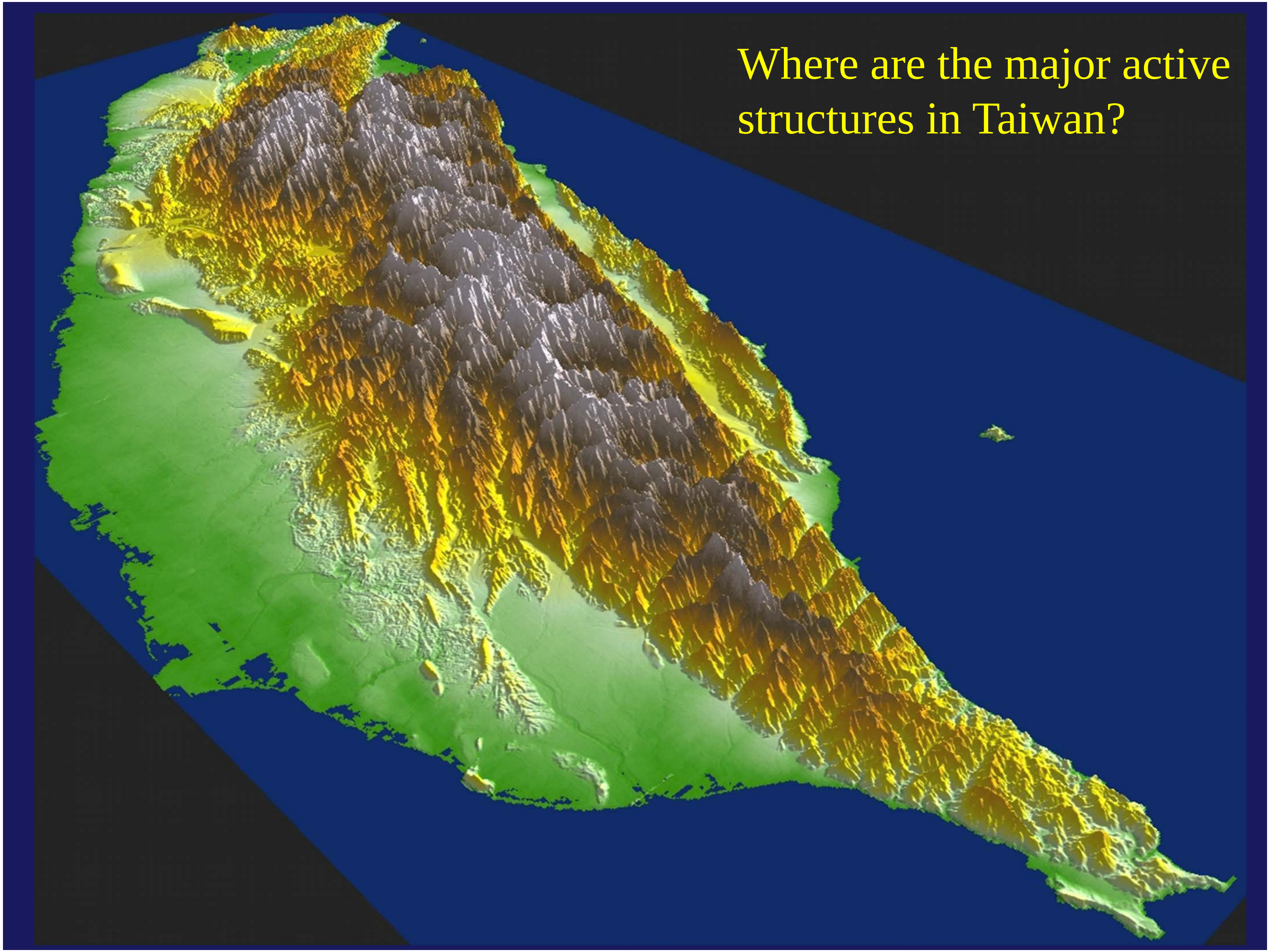
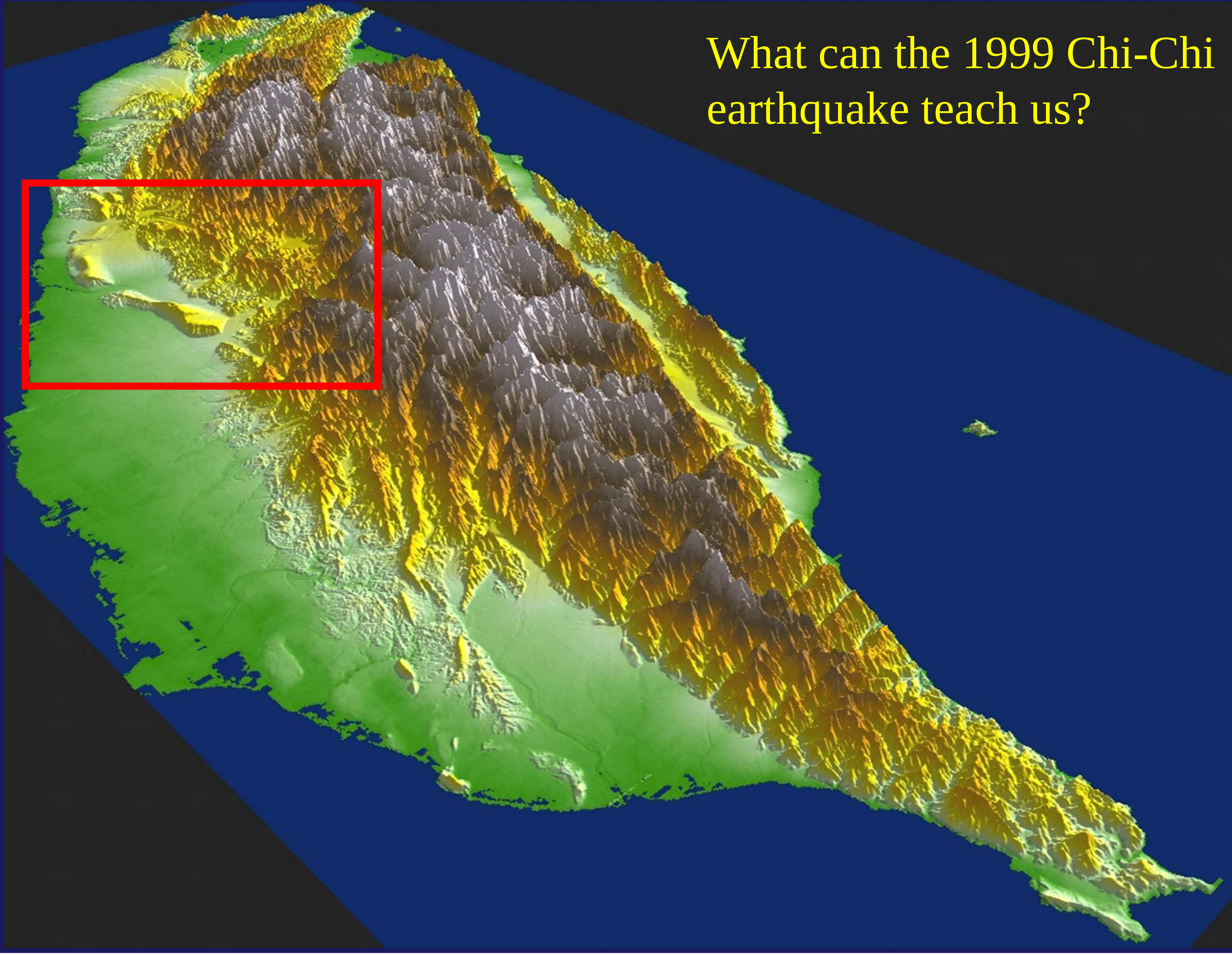
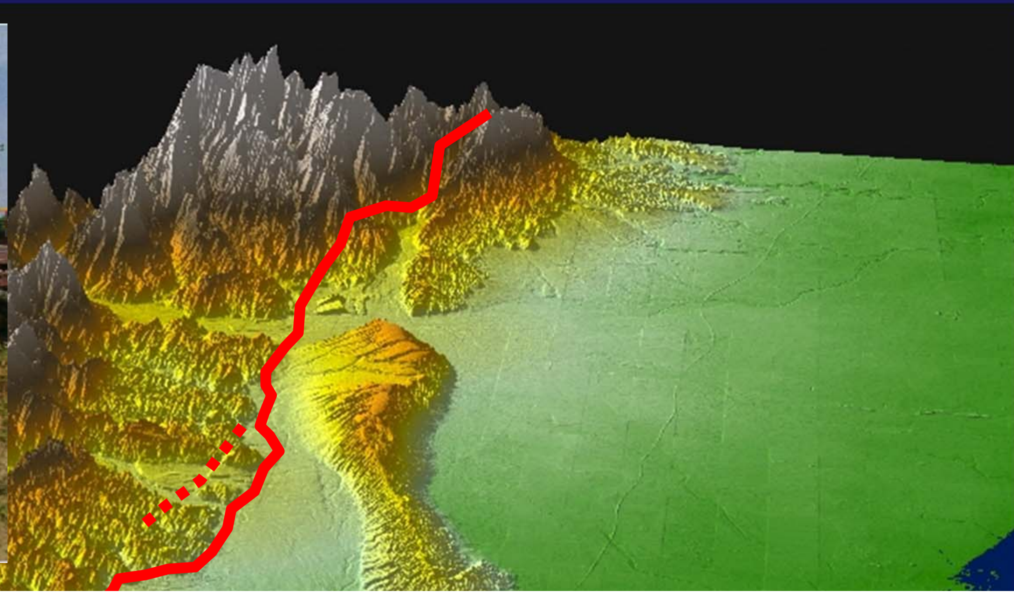
Department of Geosciences, National Taiwan University

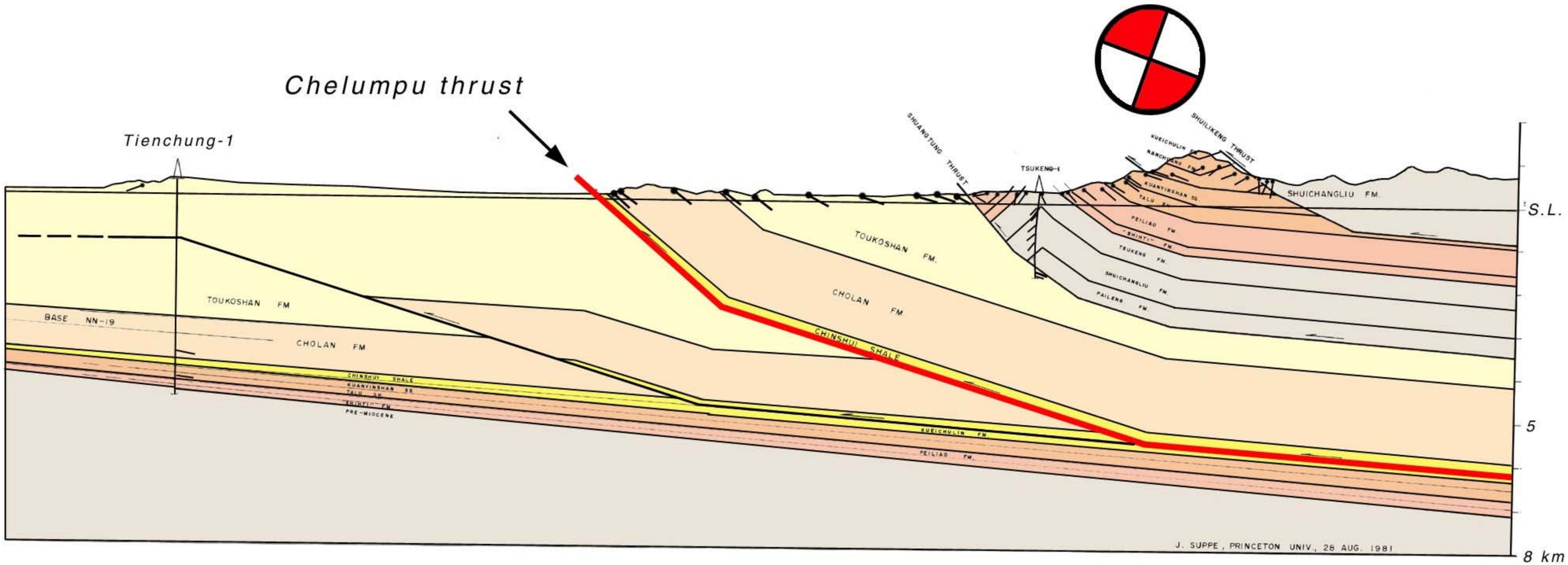
TEM-NIED Workshop, Chungli, June 4, 2012


Where are the major active structures in Taiwan?

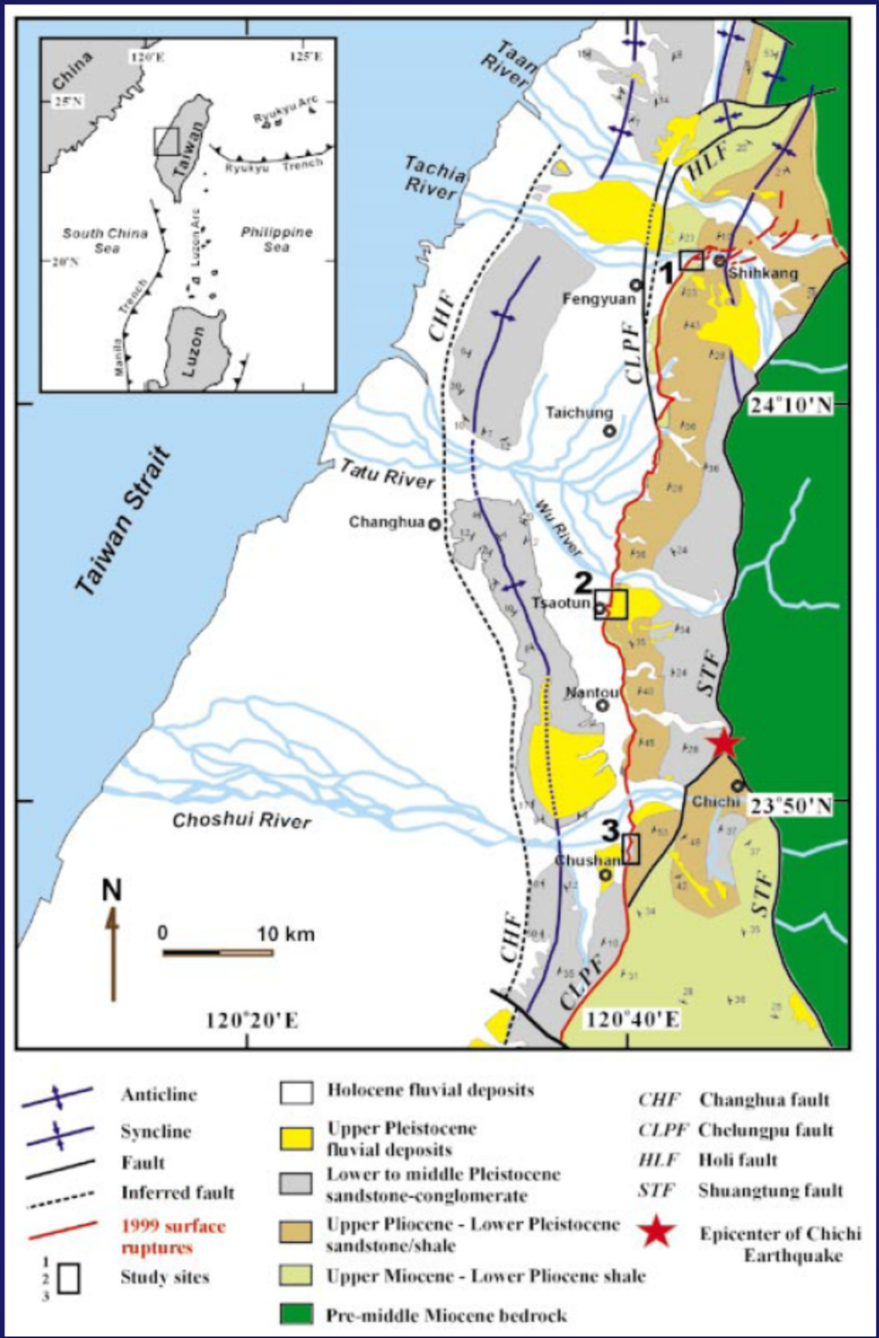
What can the 1999 Chi-Chi earthquake teach us?





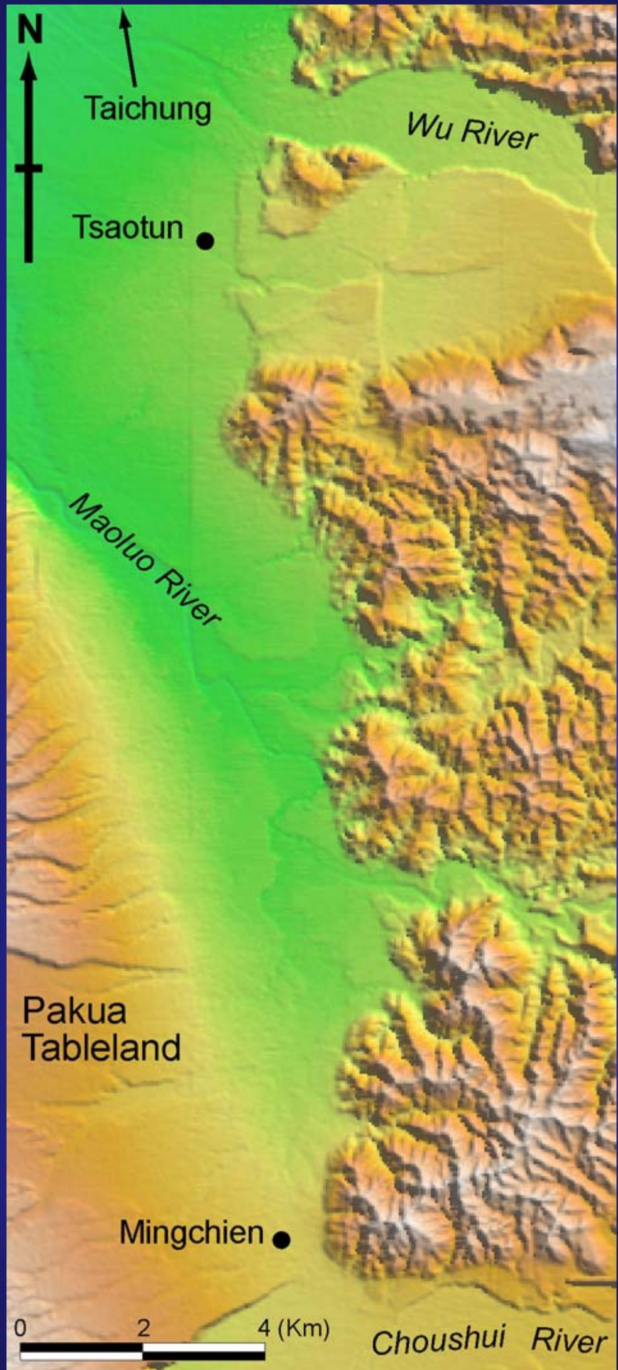

Chelumpu thrust
Tienchung-1
TOUKOSHAN FM
CHOLAN FM
TOUKOSHAN FM.
CHOLAN FM
CHINSHUI SHALE
SHUICHANGLIU FM.
S.L.
5
8 km
J. SUPPE, PRINCETON UNIV, 28 AUG. 1981

(Suppe, 1981)

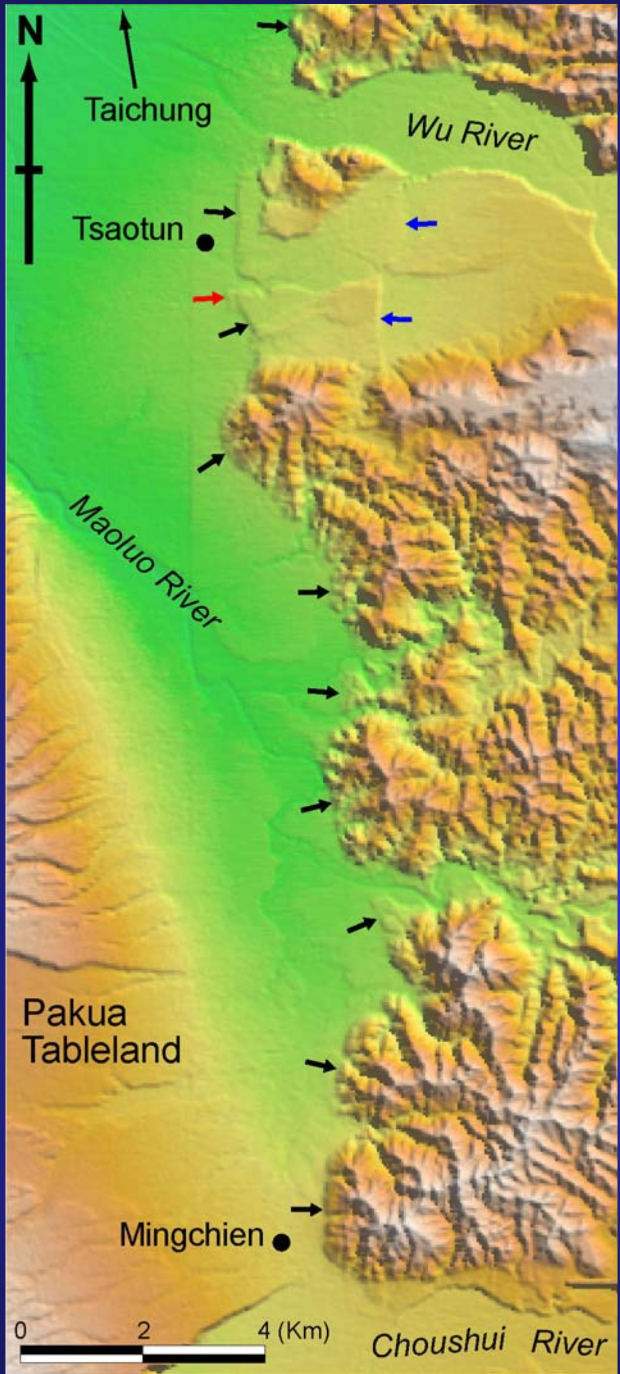


Most of the 1999 surface rupture appears to follow some pre-existing topographic features

(Chen et al., 2002)



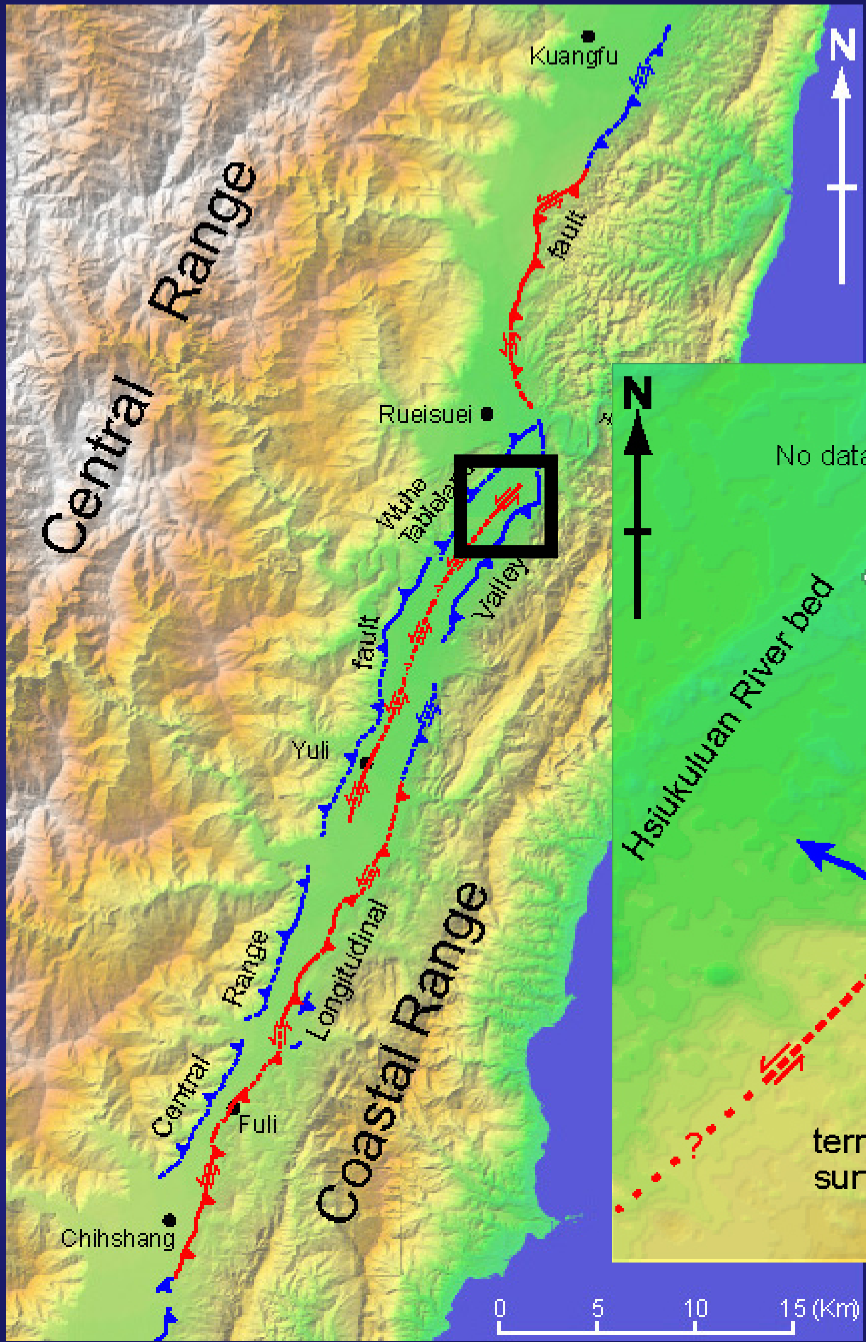
What can we see on the 40-m DEM?



What can we see on the 40-m DEM?

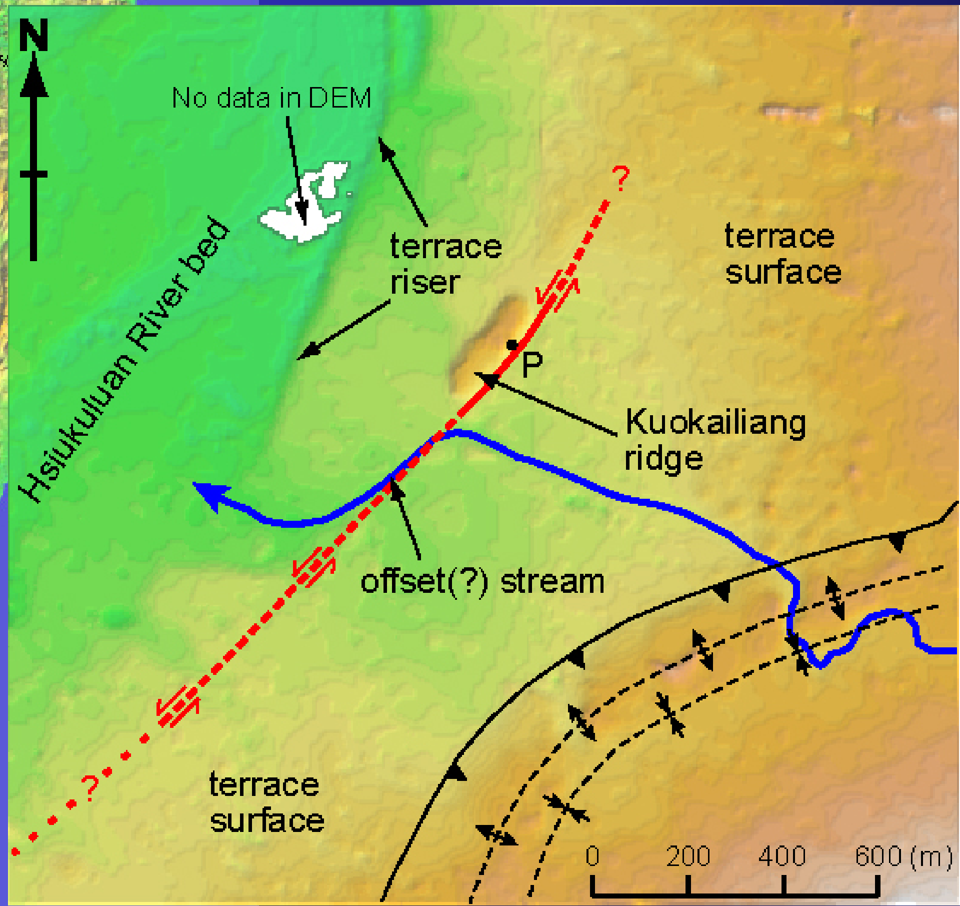
Most of the 1999 Chi-Chi surface rupture even before the earthquake!

(Shyu et al., 2005, JGR)

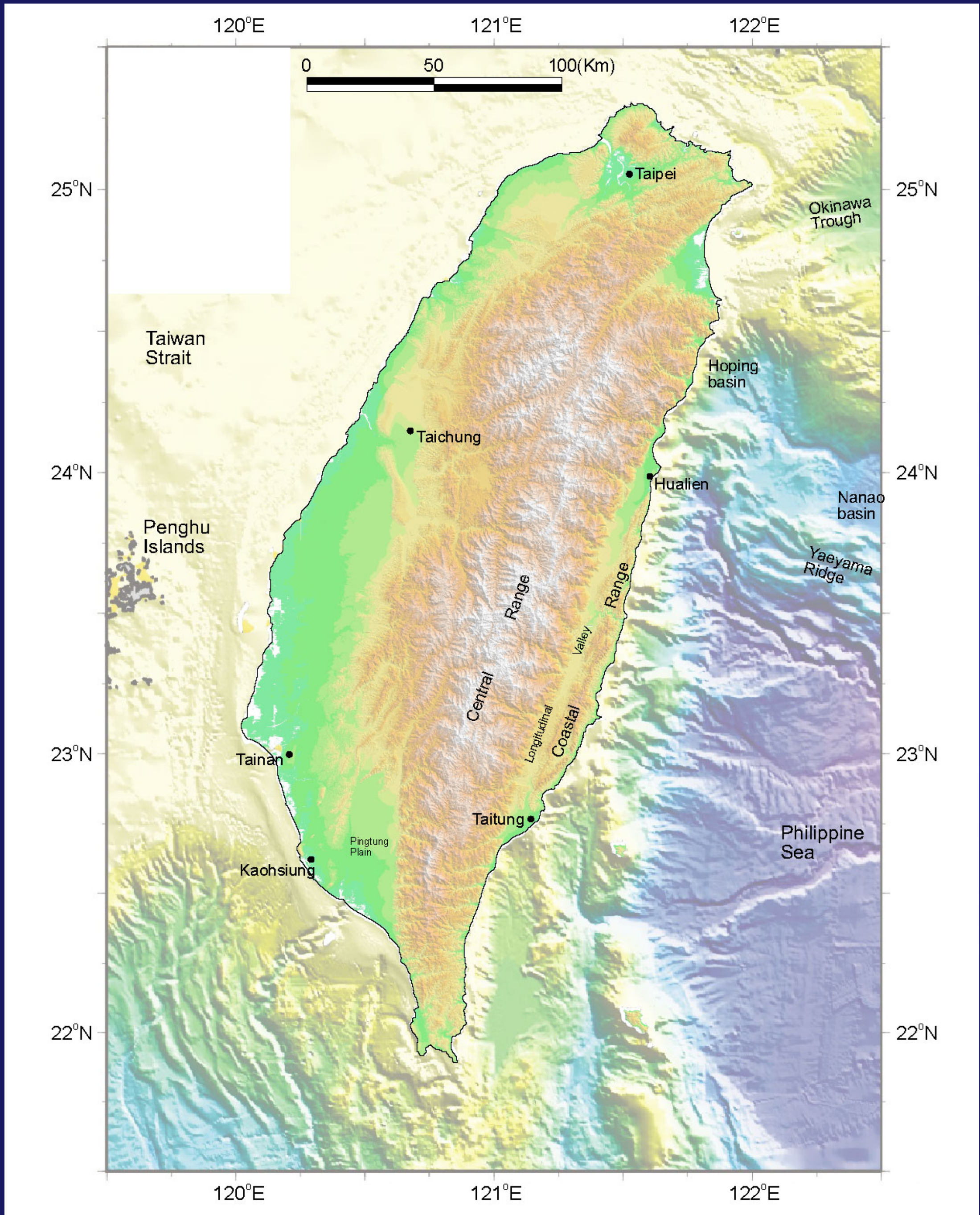


Red: 1951 rupture

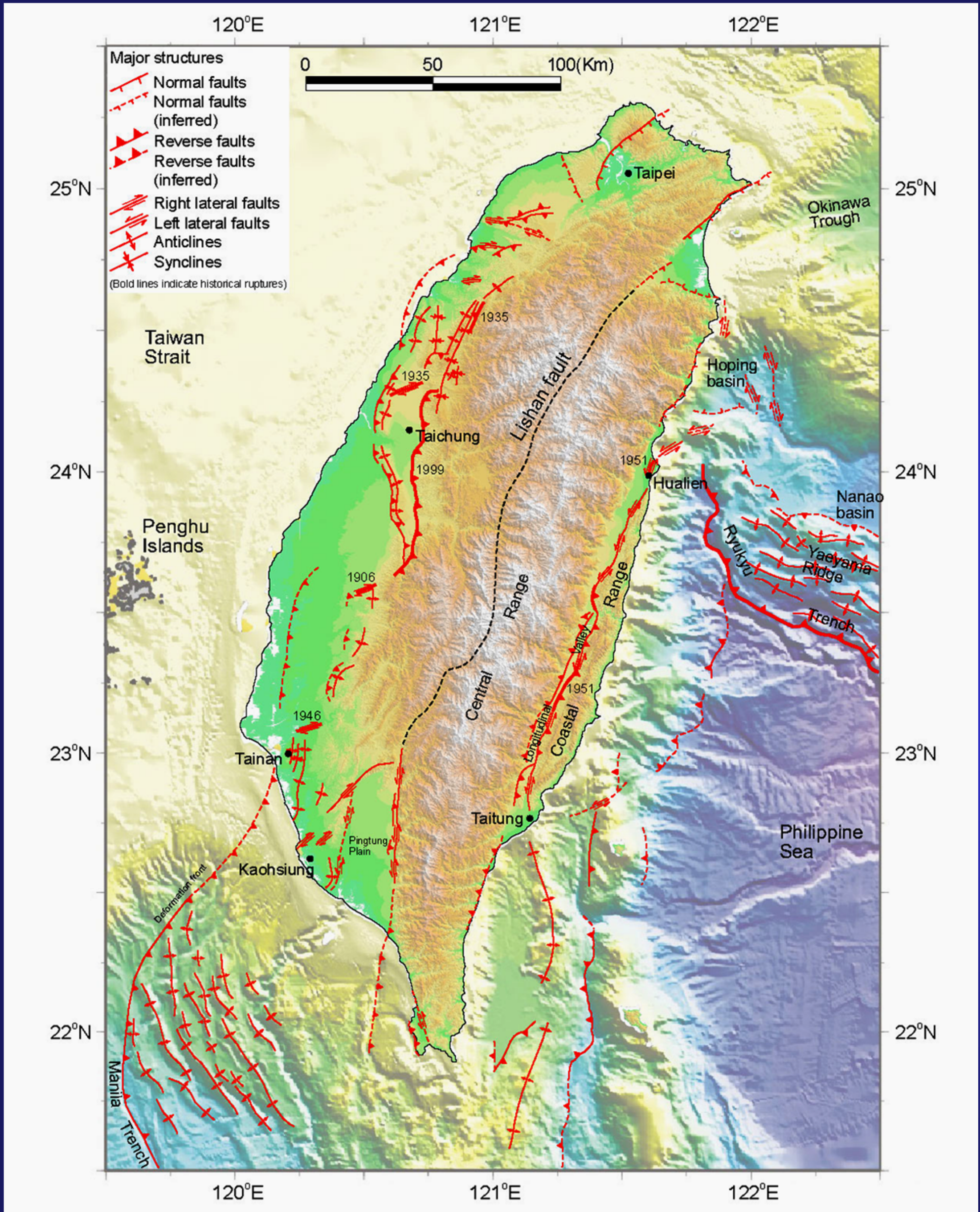
Blue: active faults not ruptured in 1951



(Shyu et al., 2007, JAES)

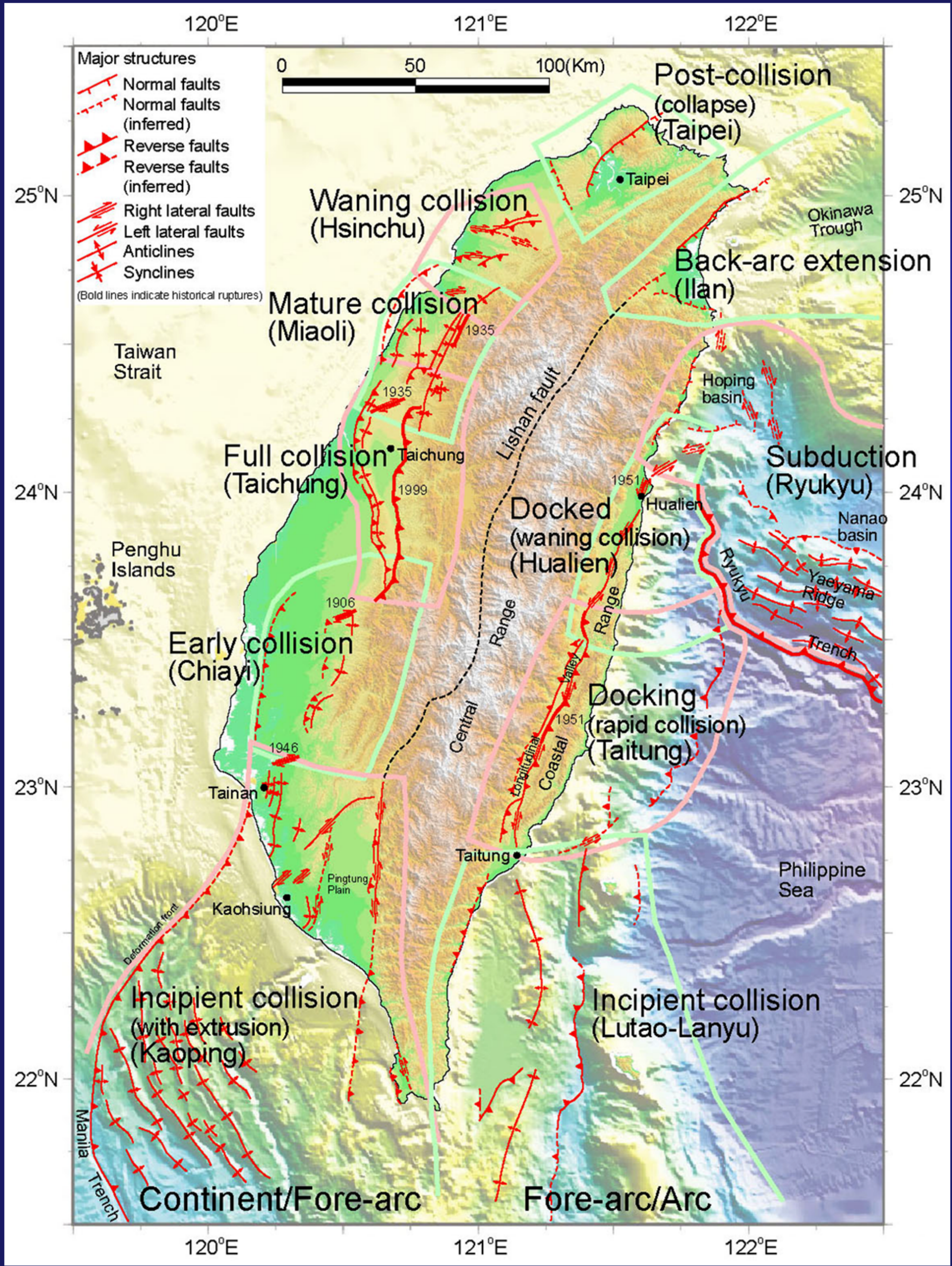


Where are the active structures in Taiwan?



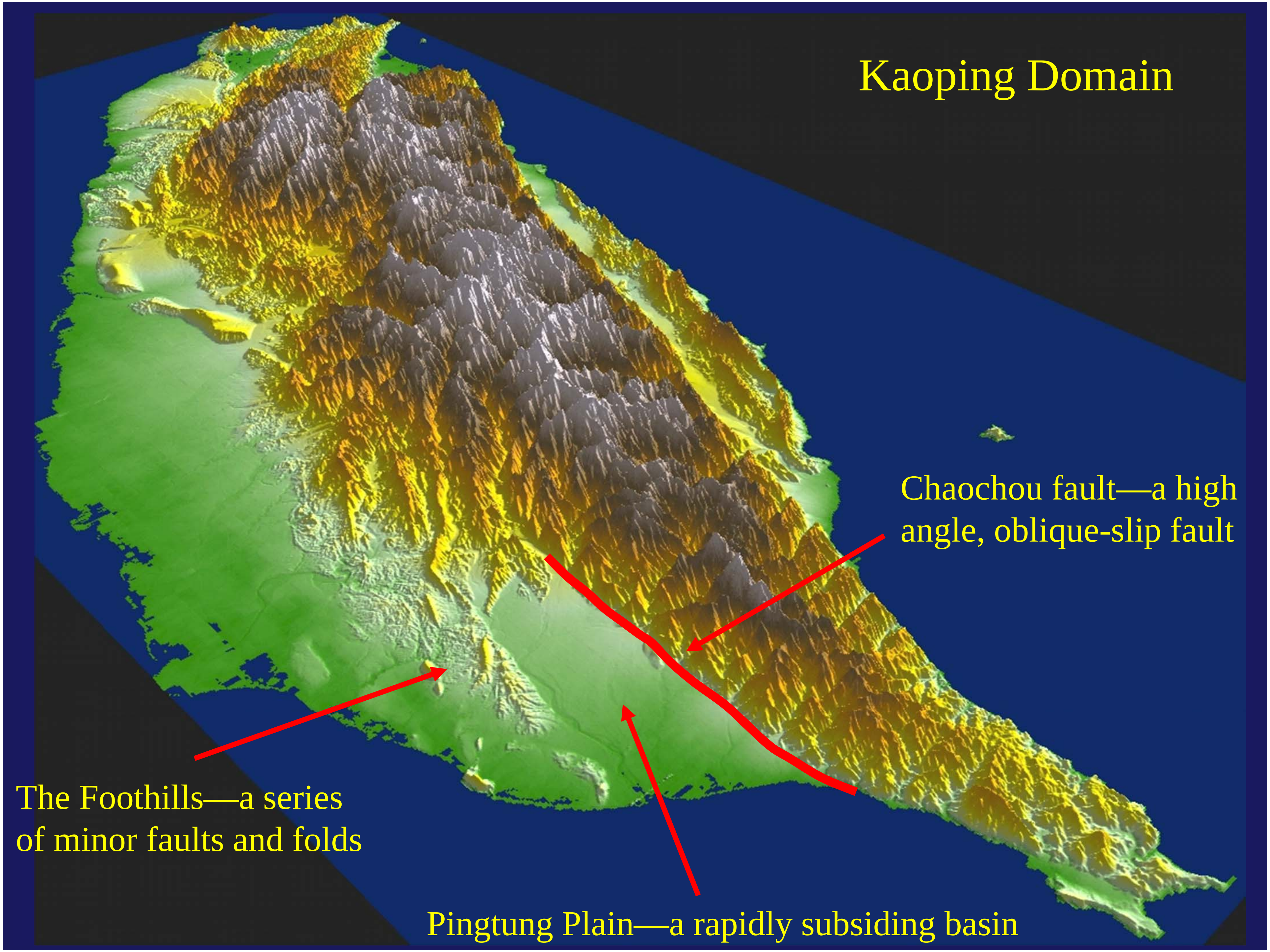
Active structure map of Taiwan

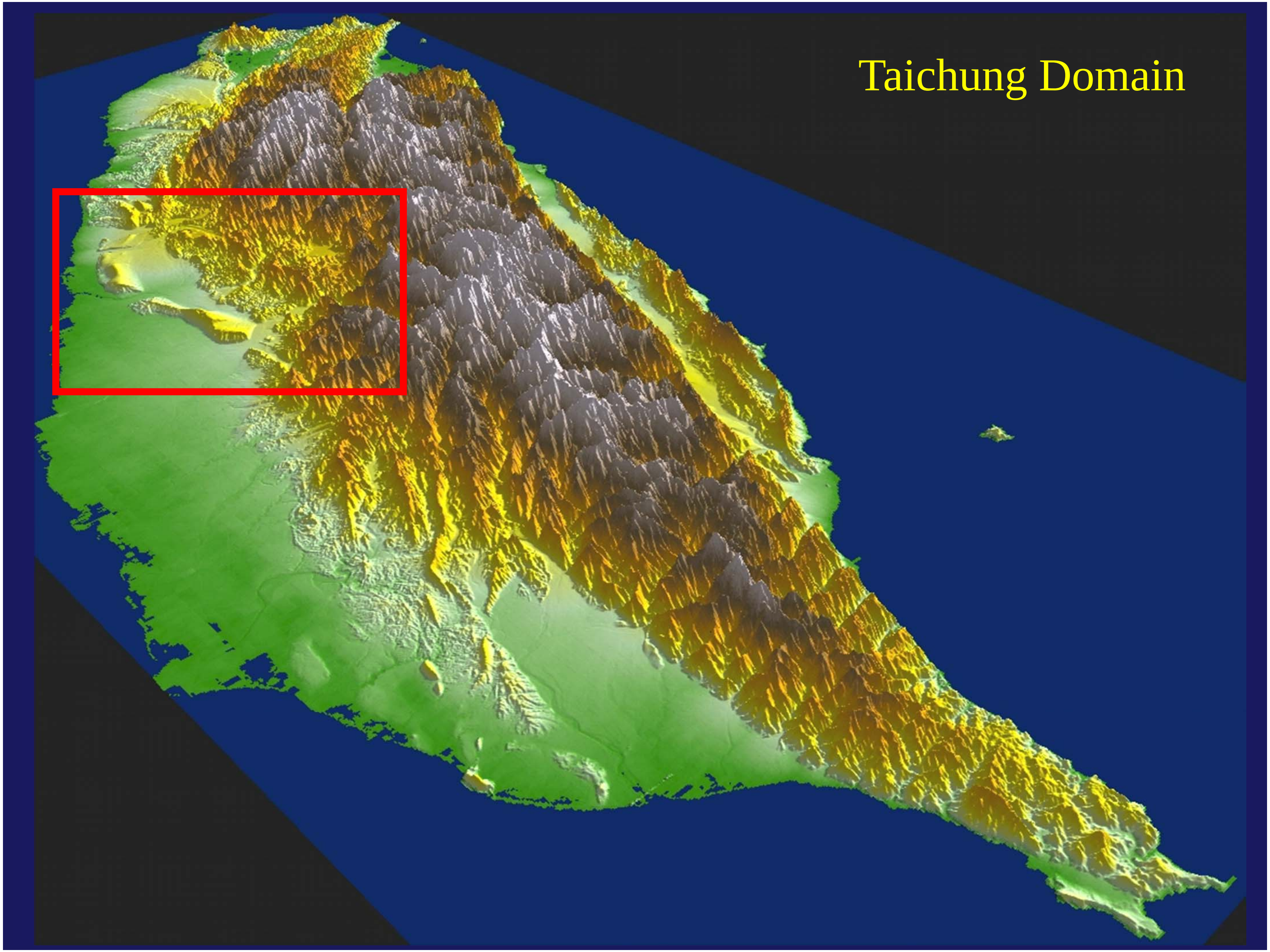
(Shyu et al., 2005, JGR)

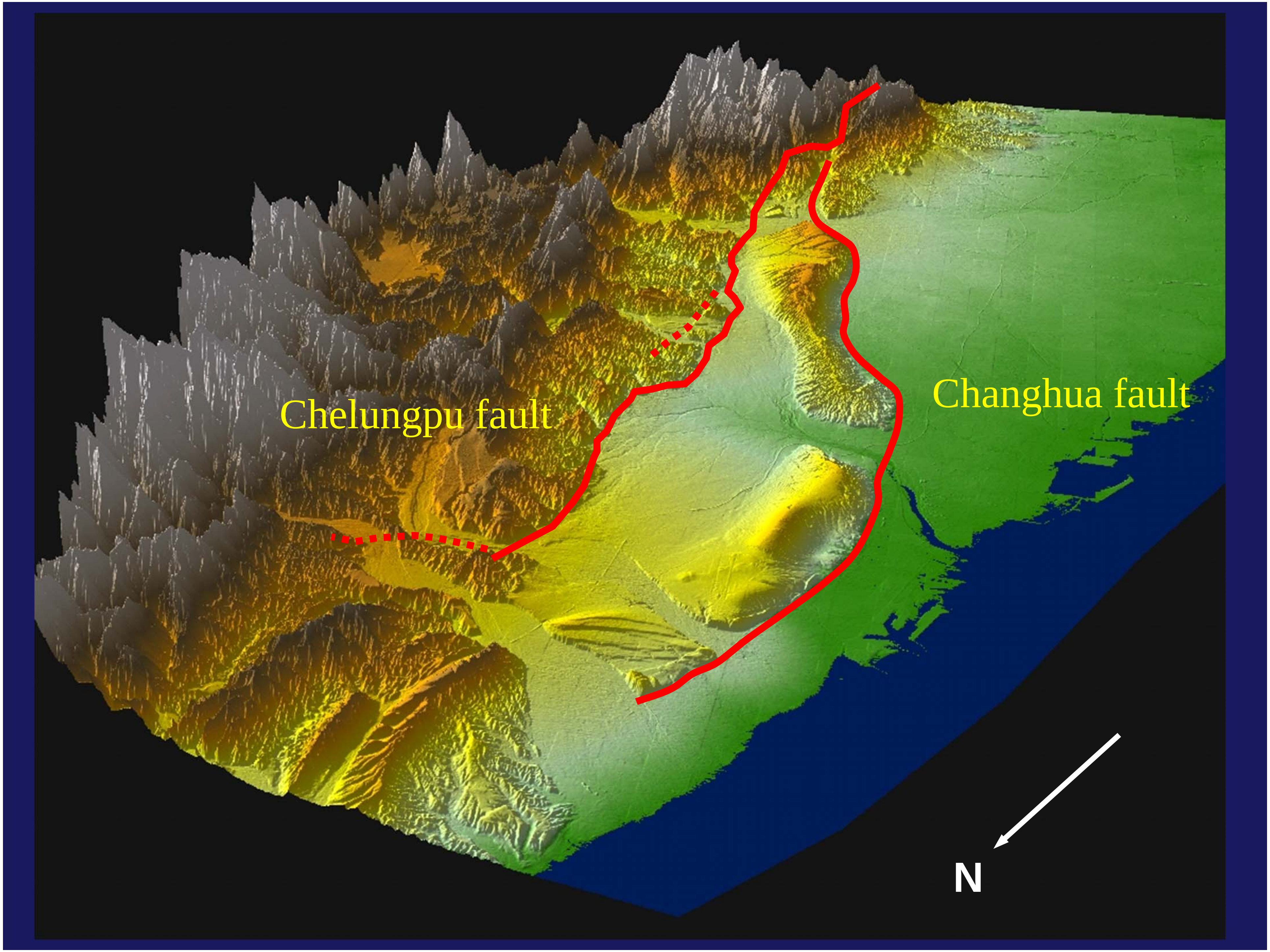


Neotectonic "domains" of Taiwan

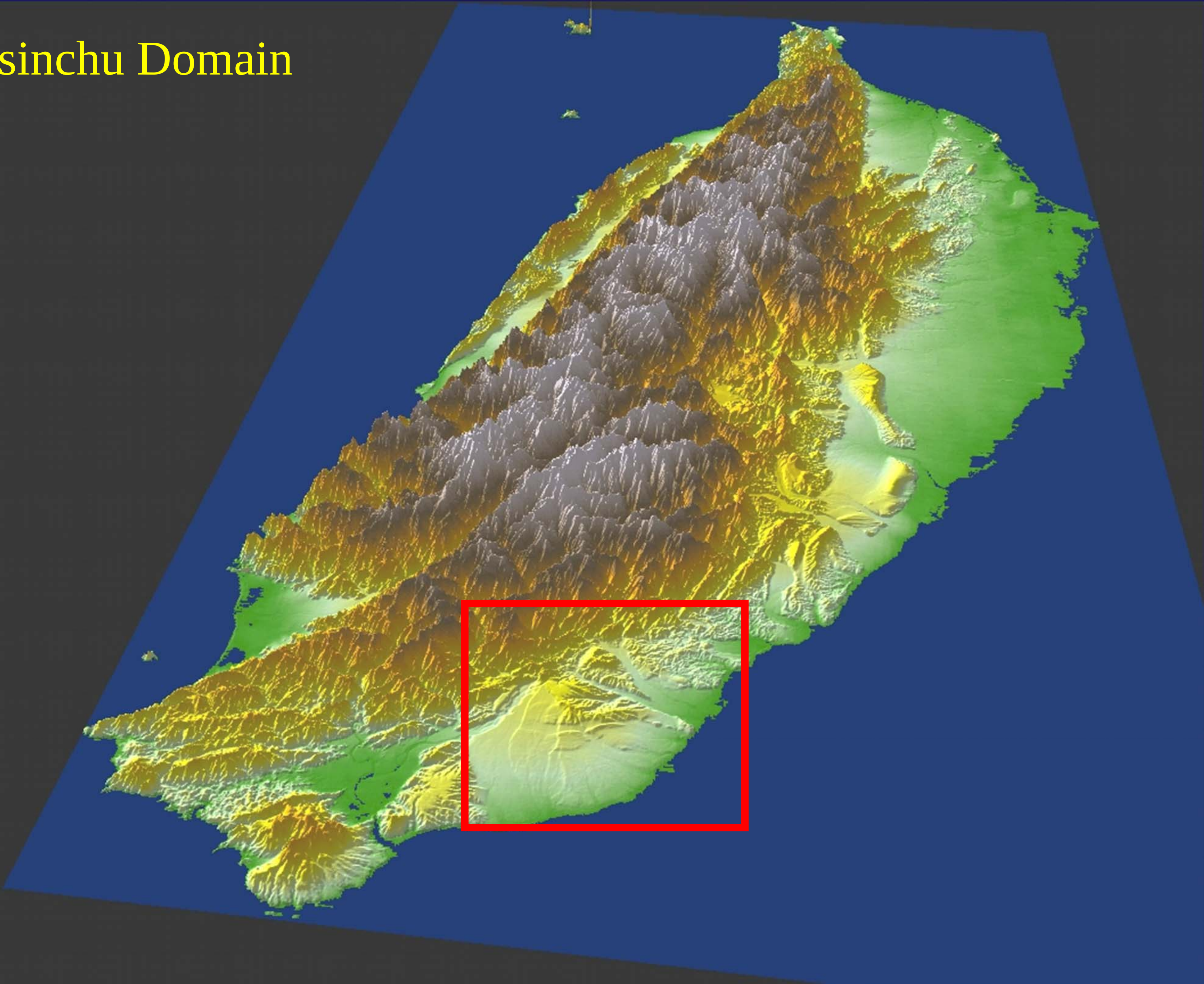
(Shyu et al., 2005, JGR)

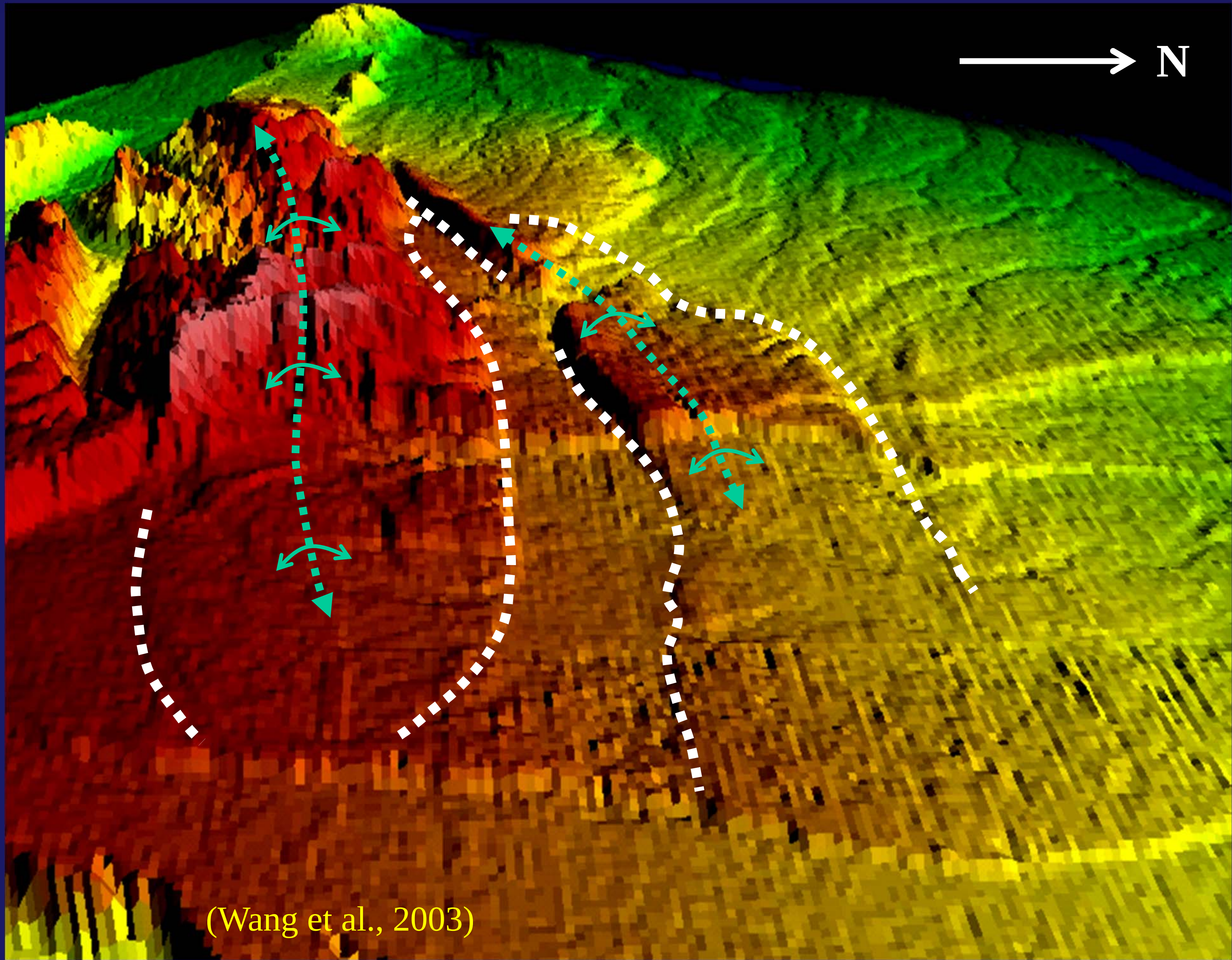

Kaoping Domain
Chaochou fault—a high angle, oblique-slip fault
The Foothills—a series of minor faults and folds
Pingtung Plain—a rapidly subsiding basin

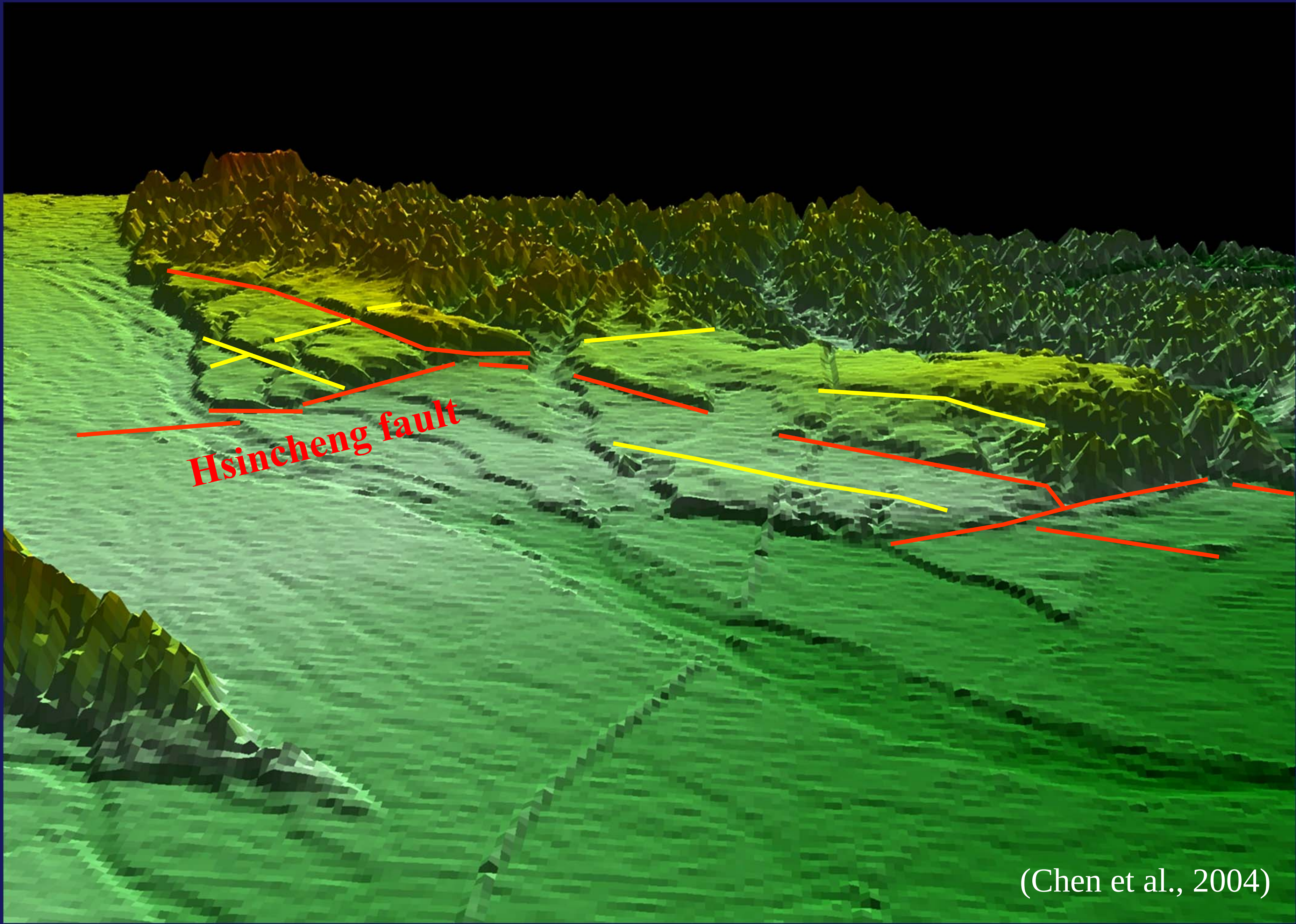

Taichung Domain


Chelungpu fault
Changhua fault
N

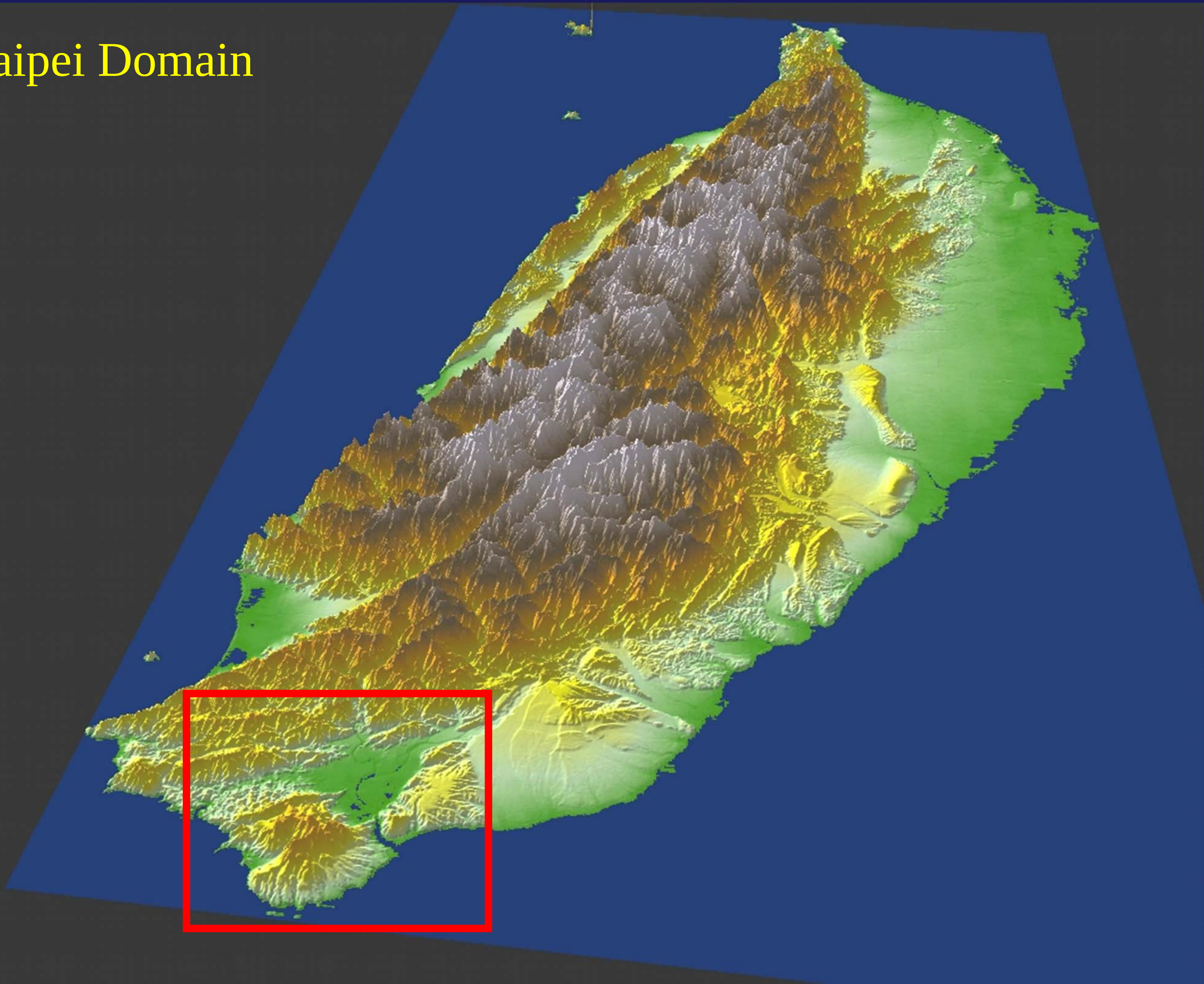
Hsinchu Domain

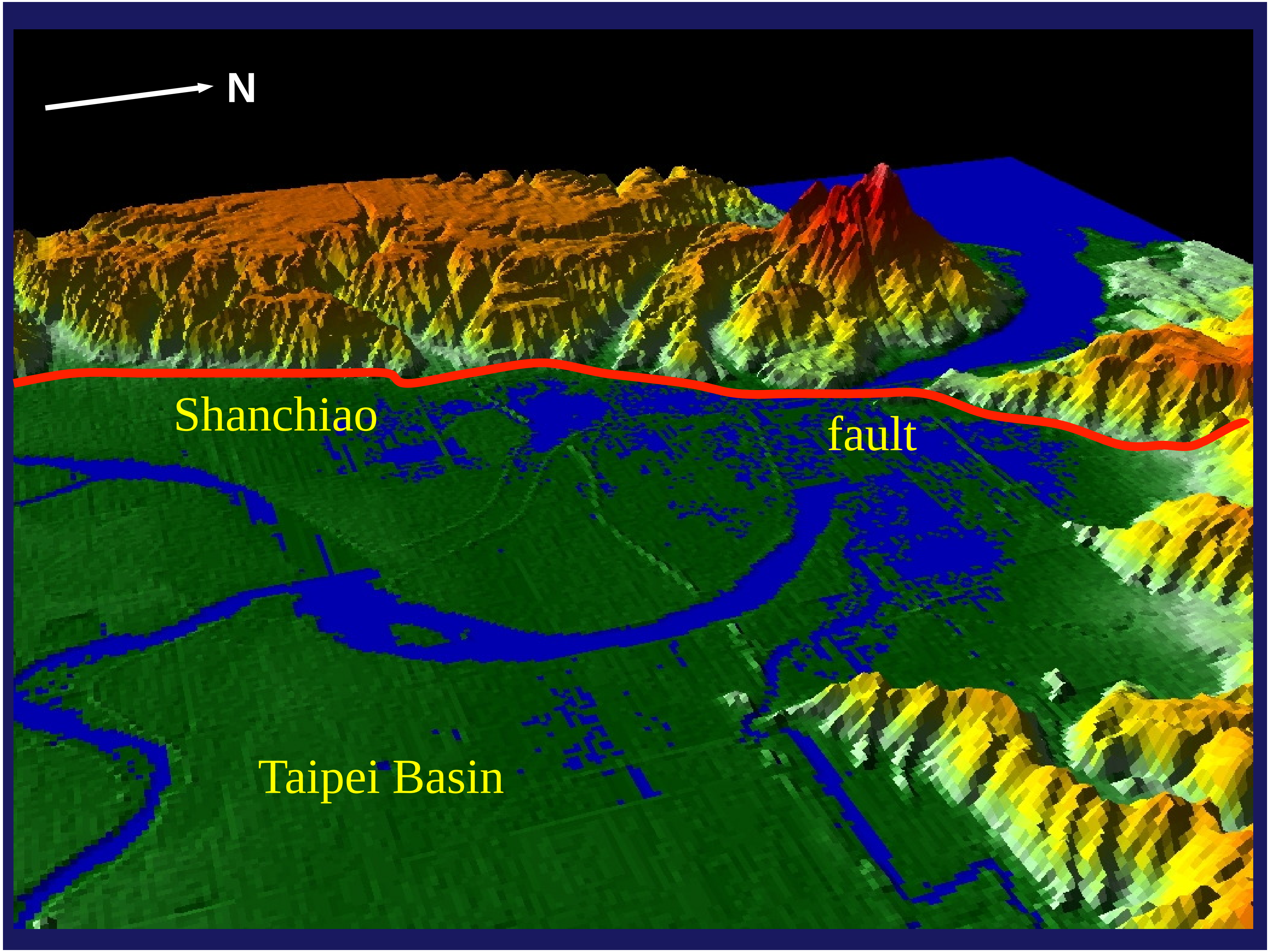


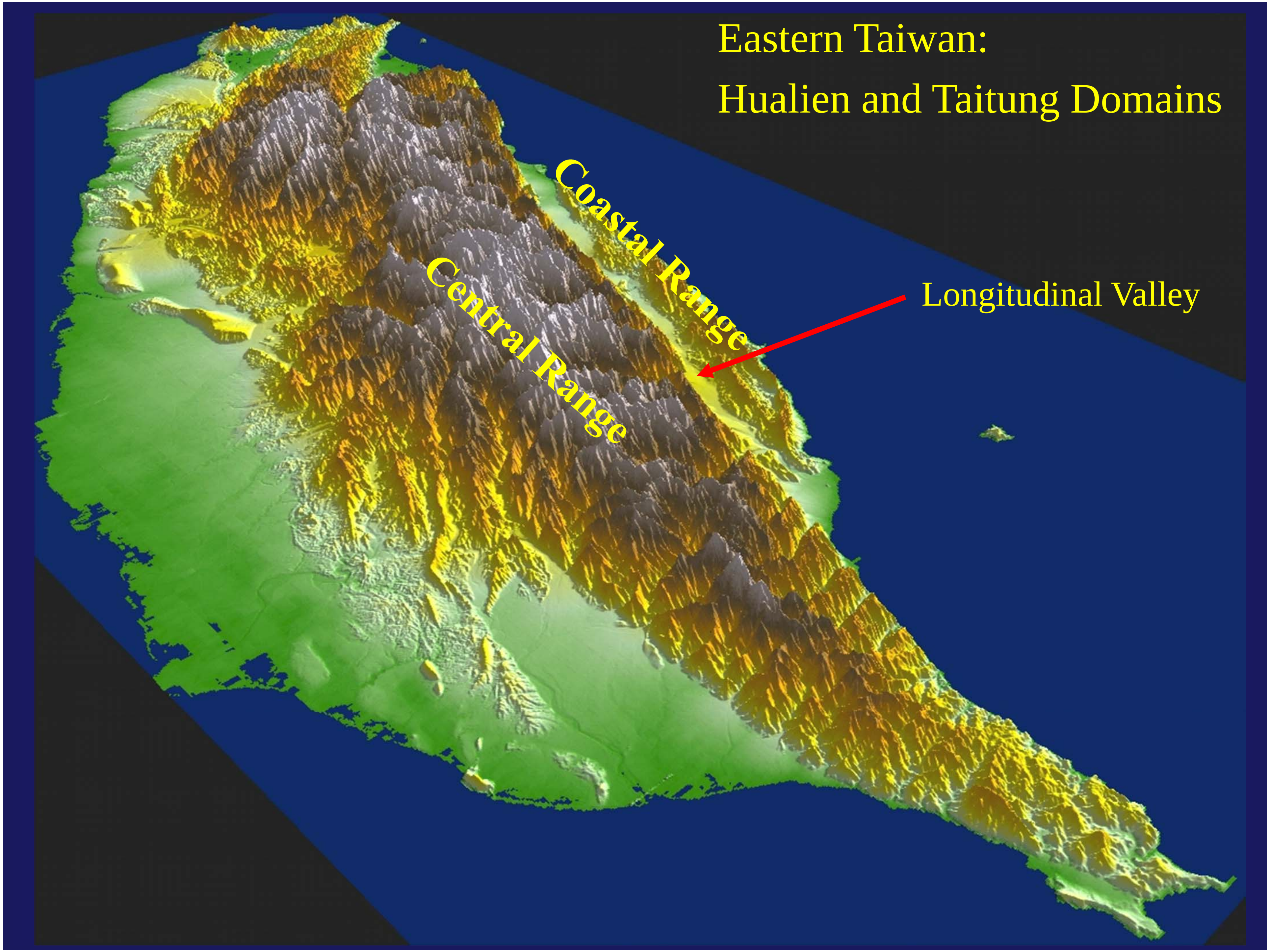

N
(Wang et al., 2003)

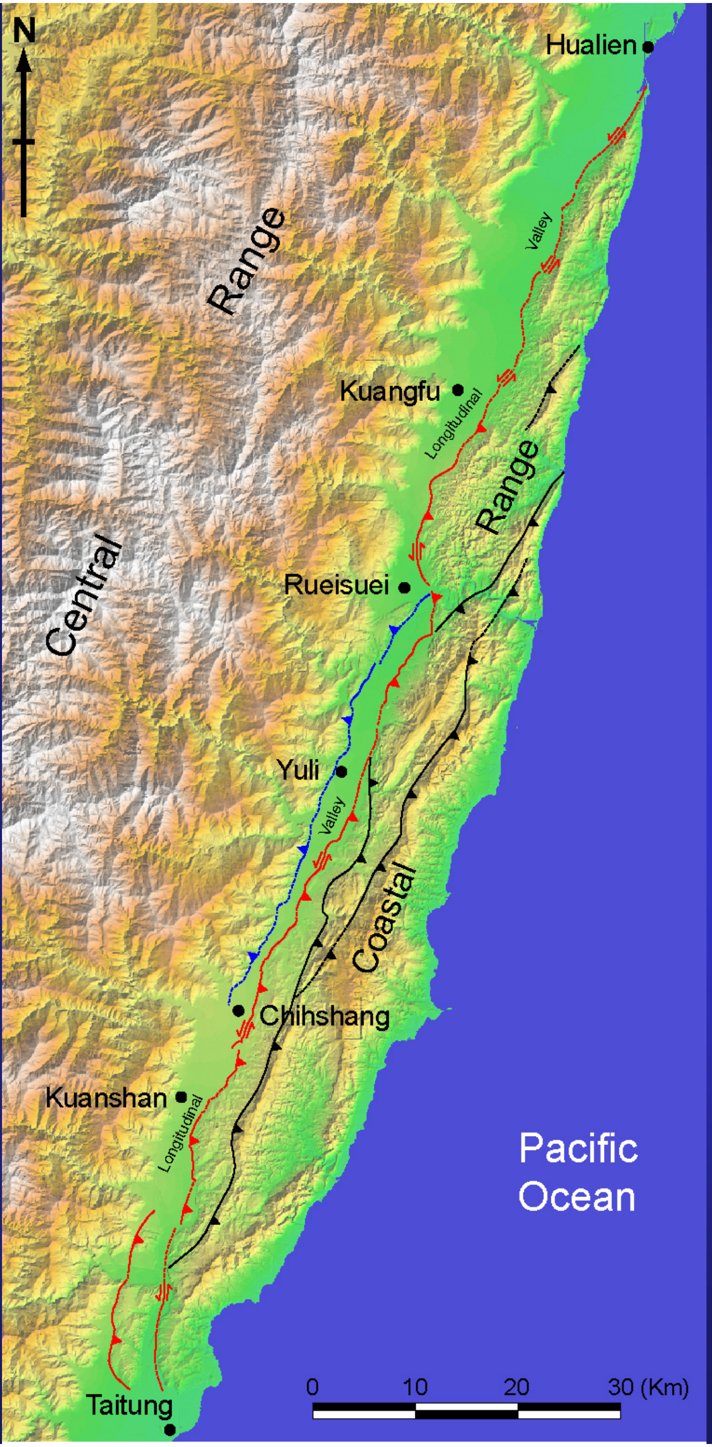

Hsincheng fault
(Chen et al., 2004)

Taipei Domain



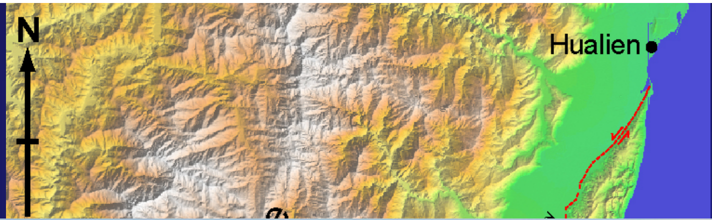

N
Shanchiao
fault
Taipei Basin


Eastern Taiwan:
Hualien and Taitung Domains
Coastal Range
Central Range
Longitudinal Valley

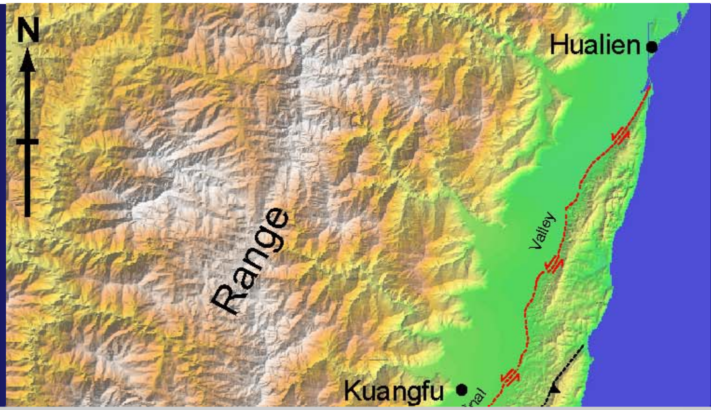


Major structural systems in the Longitudinal Valley

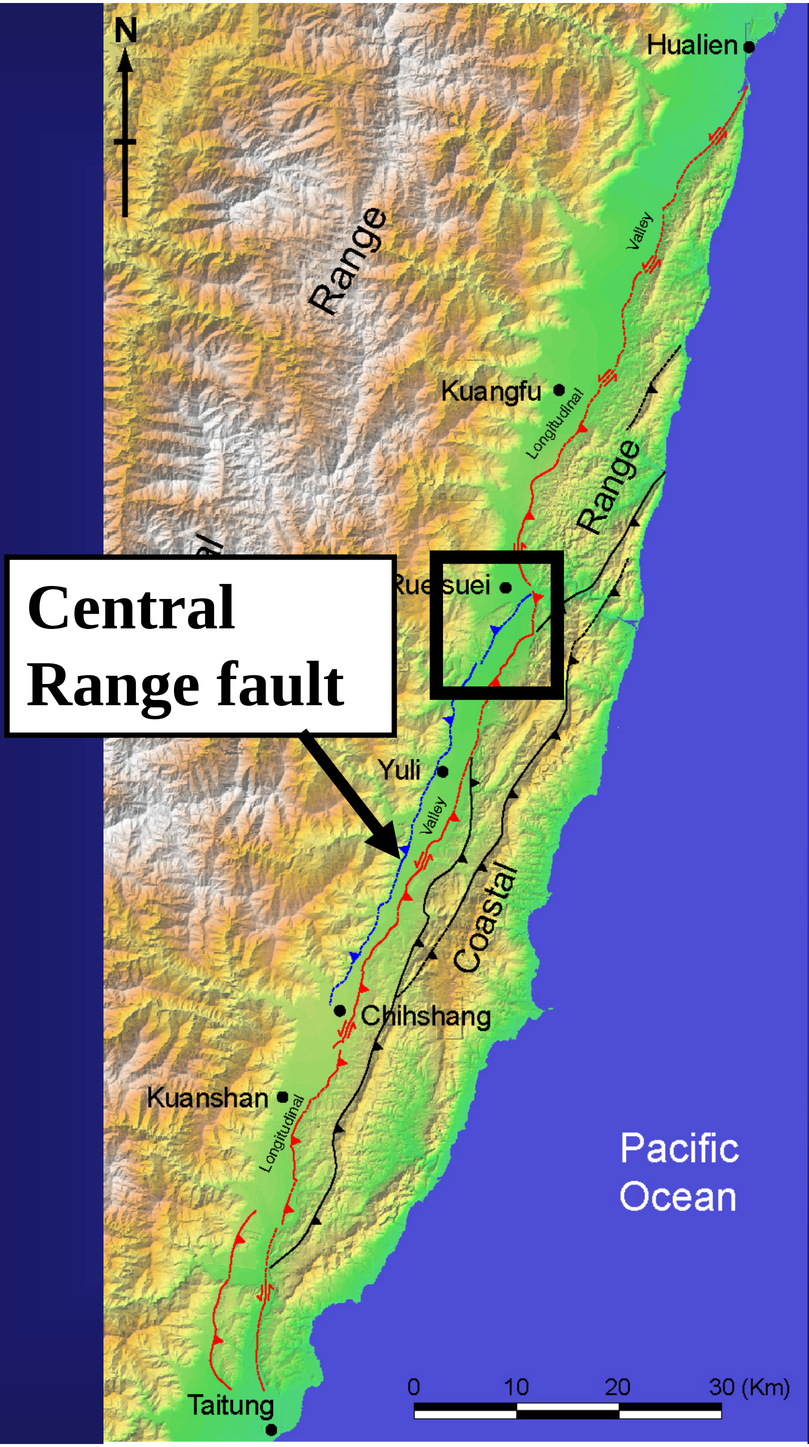
(Shyu et al., 2007, JAES)



Major structural systems in the Longitudinal Valley

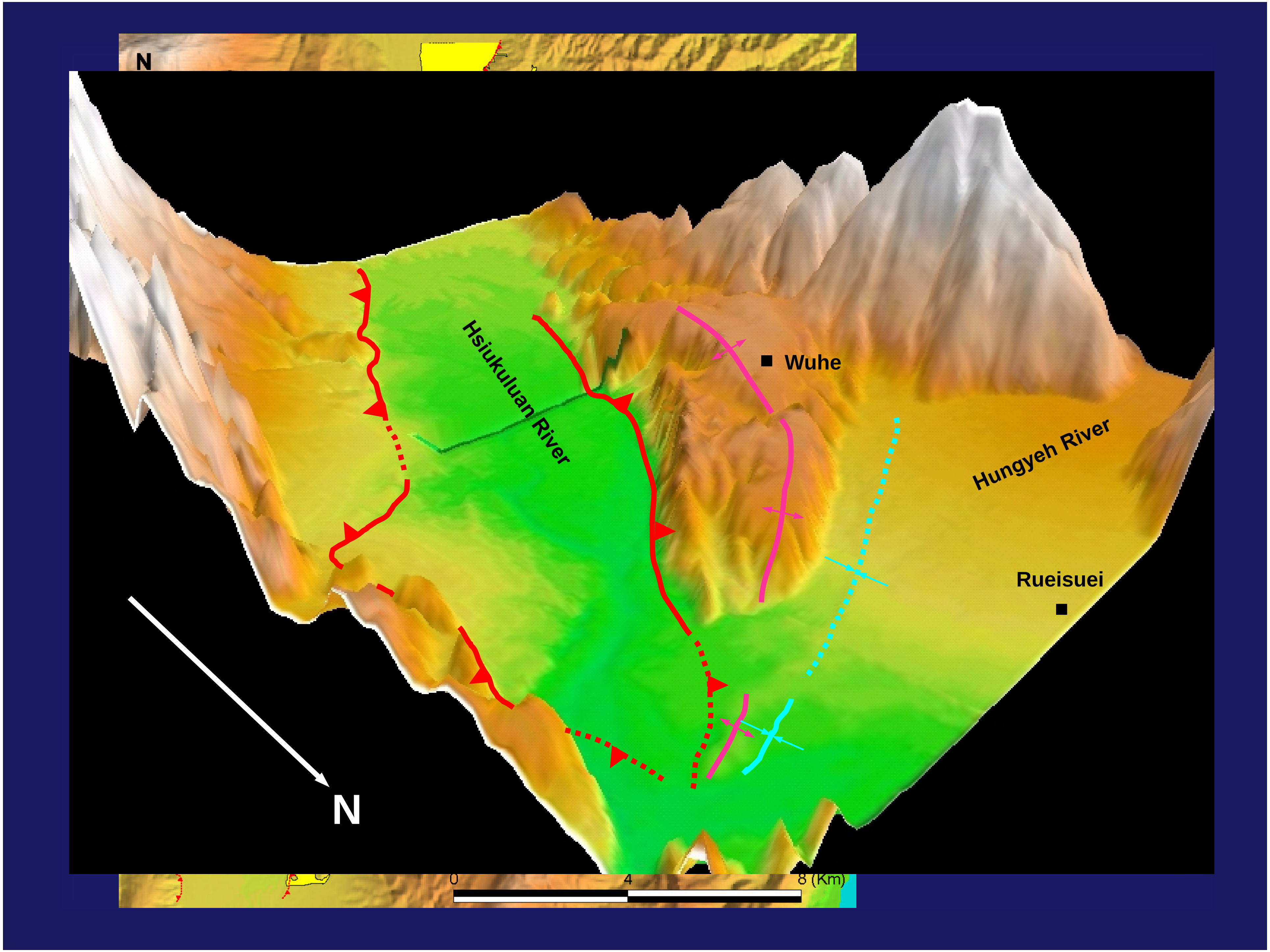


Major structural systems in the Longitudinal Valley

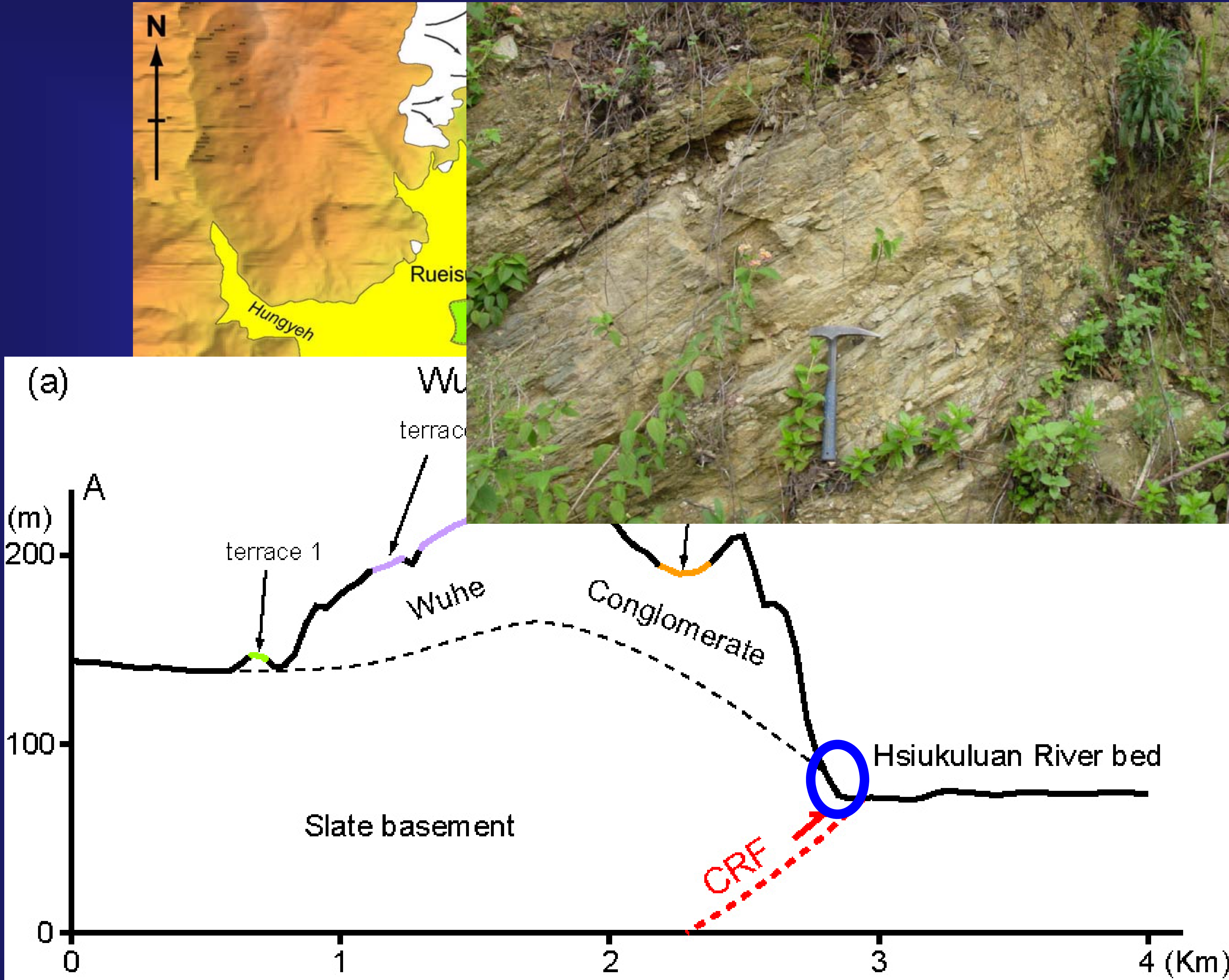


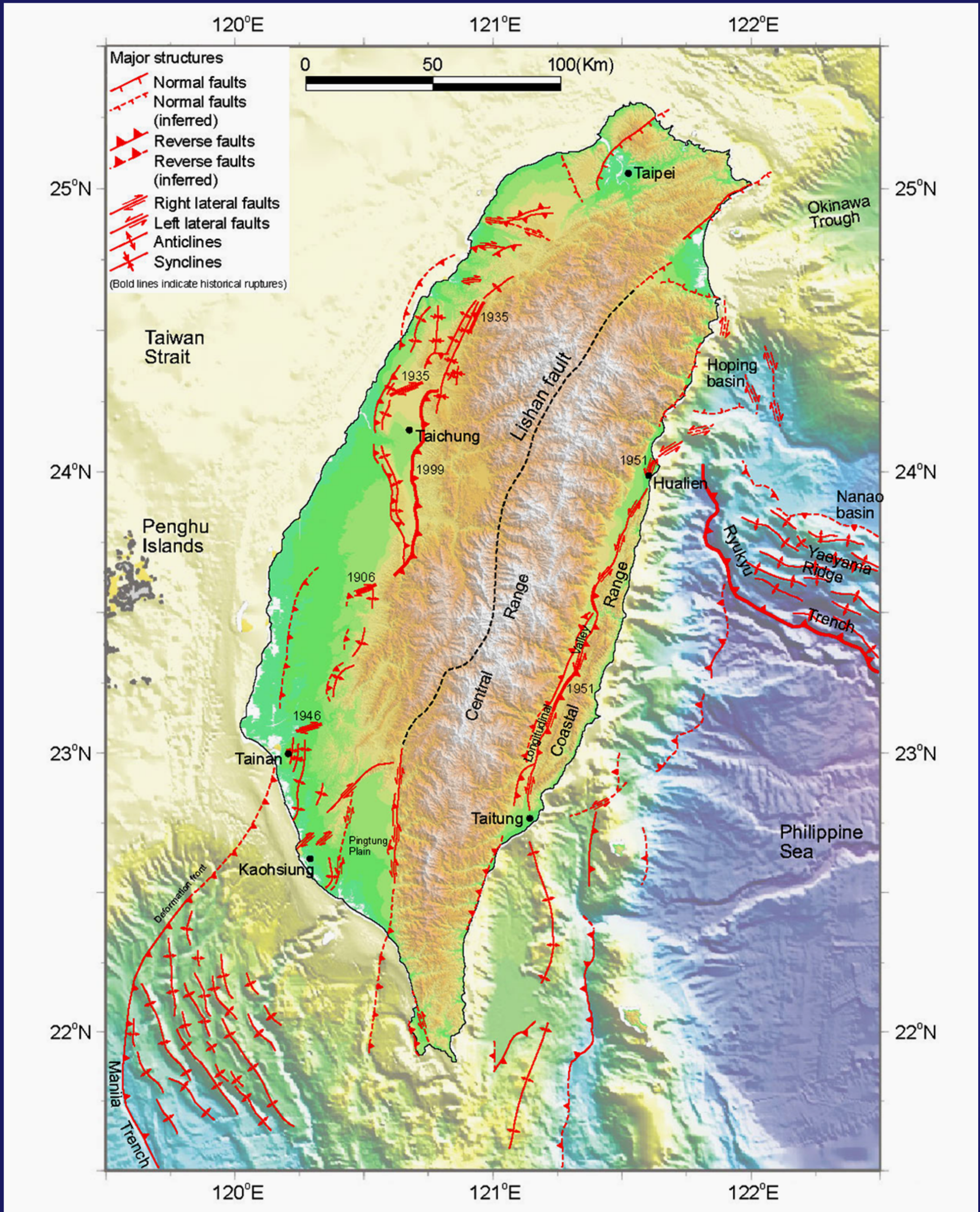
Major structural systems in the Longitudinal Valley

(Shyu et al., 2007, JAES)



N
Hsiukuluan River
Wuhe
Hungyeh River
Rueisuei
N
0
4
8 (Km)

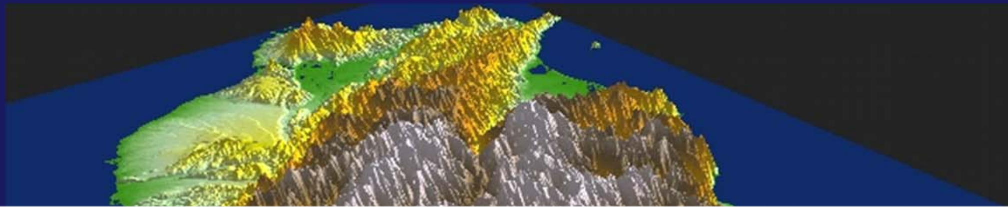

N
Hungyeh
(a)
A
(m)
200
100
0
terrace 1
Wuhe
Conglomerate
Hsiukuluan River bed
Slate basement
CRF
0
1
2
3
4 (Km)

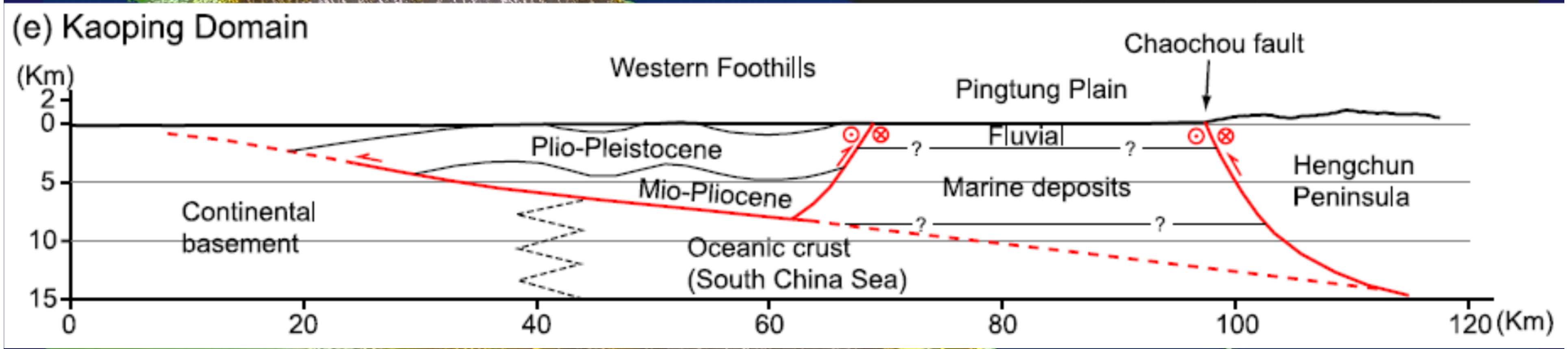


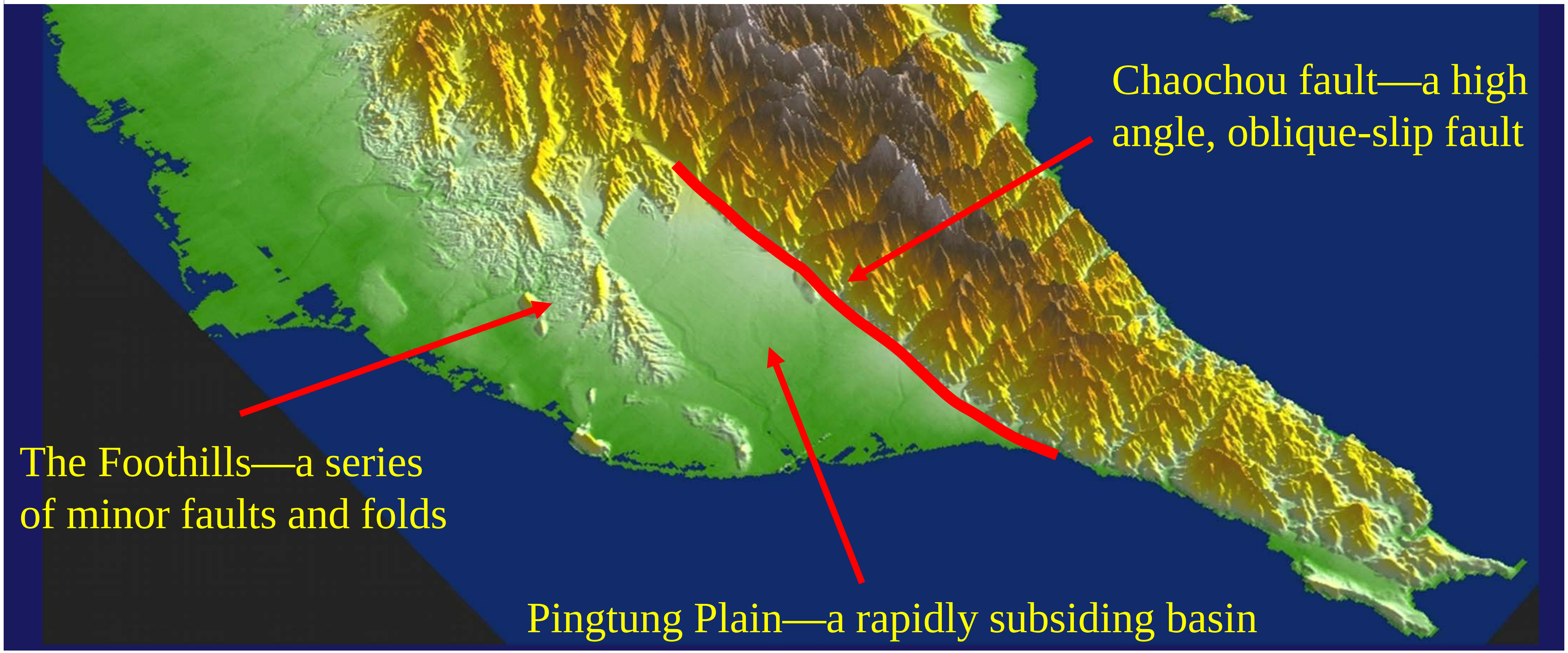
How do we propose future seismic sources from these active structures?

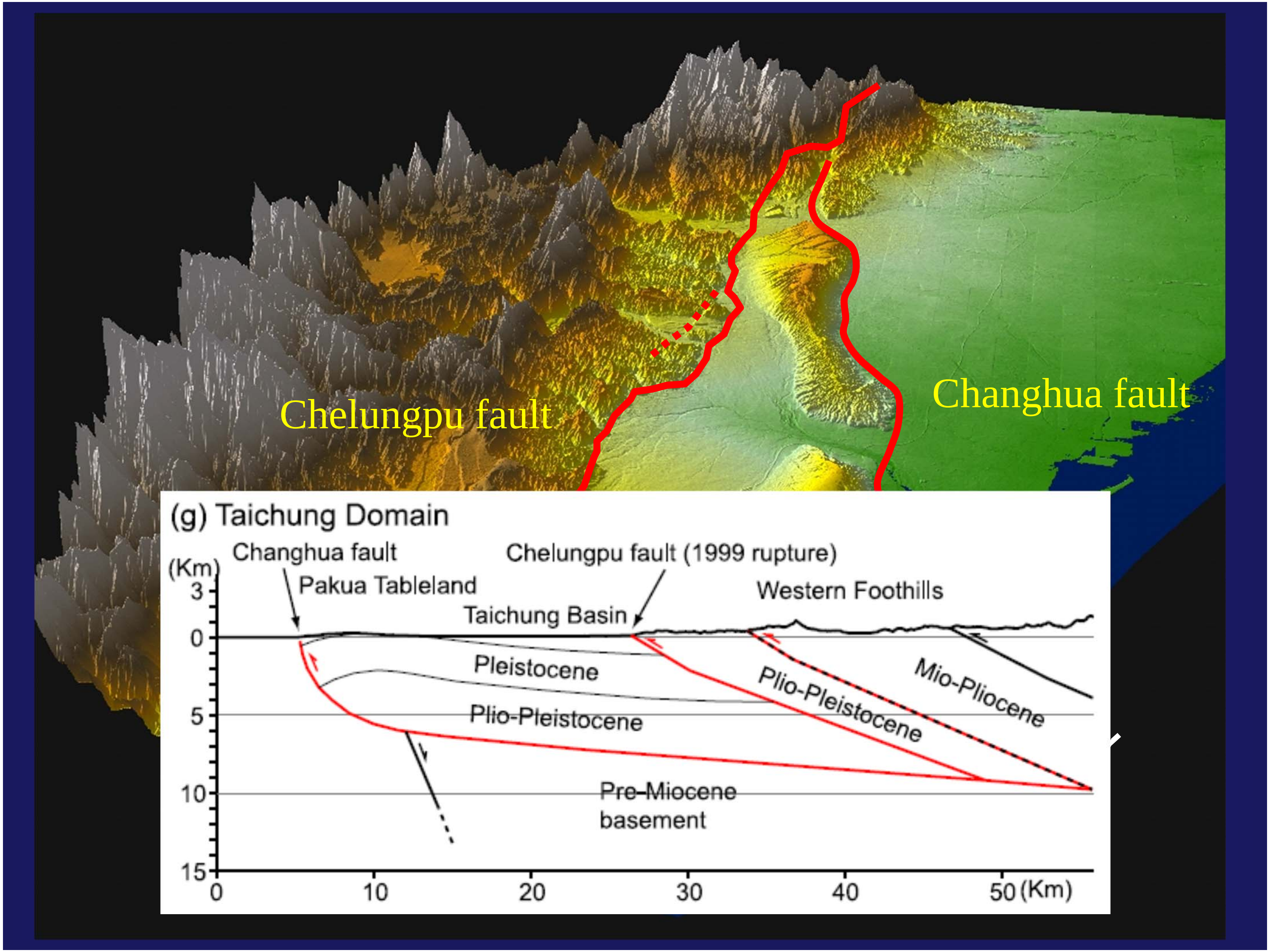
(Shyu et al., 2005, JGR)

Kaoping Domain

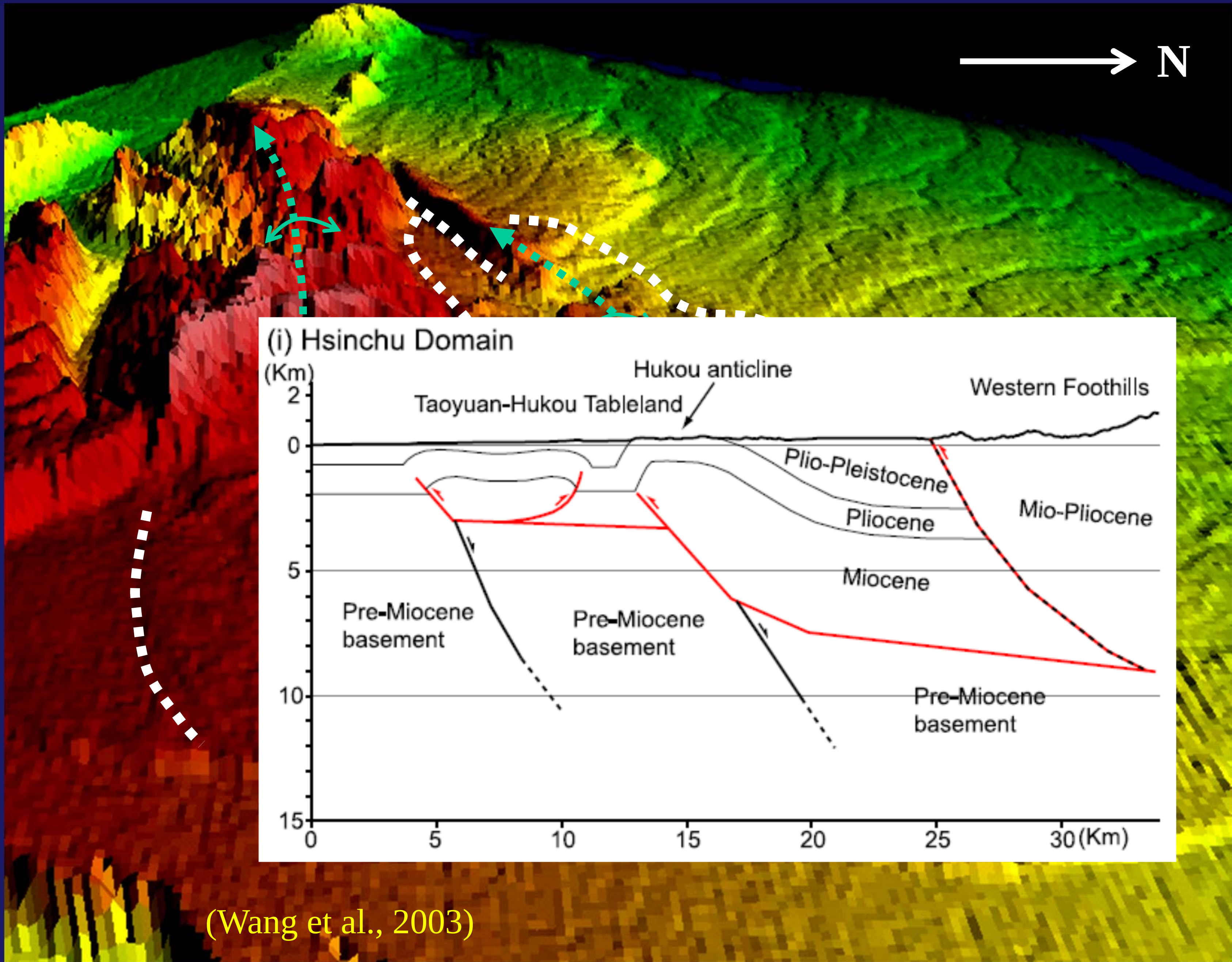


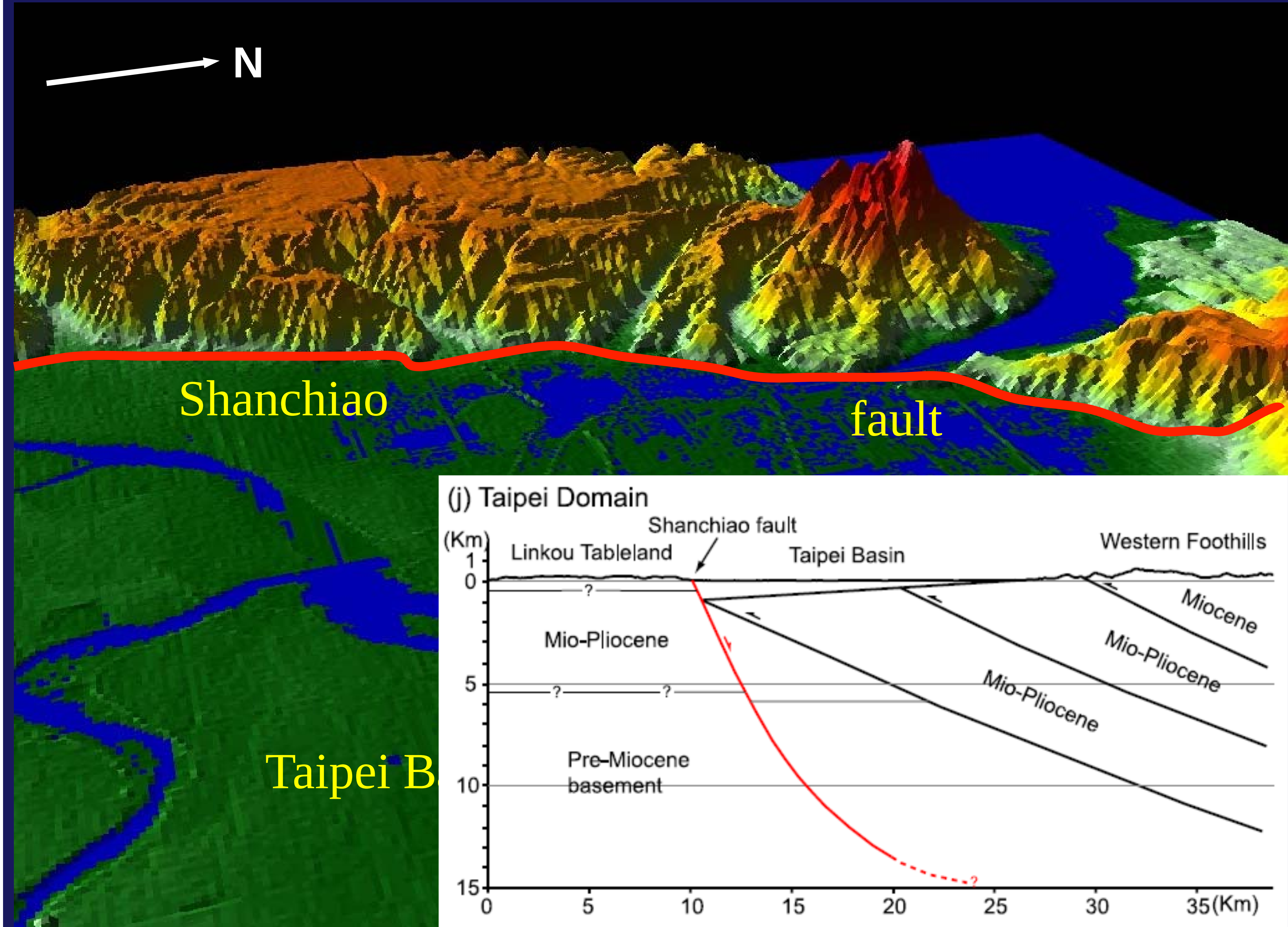


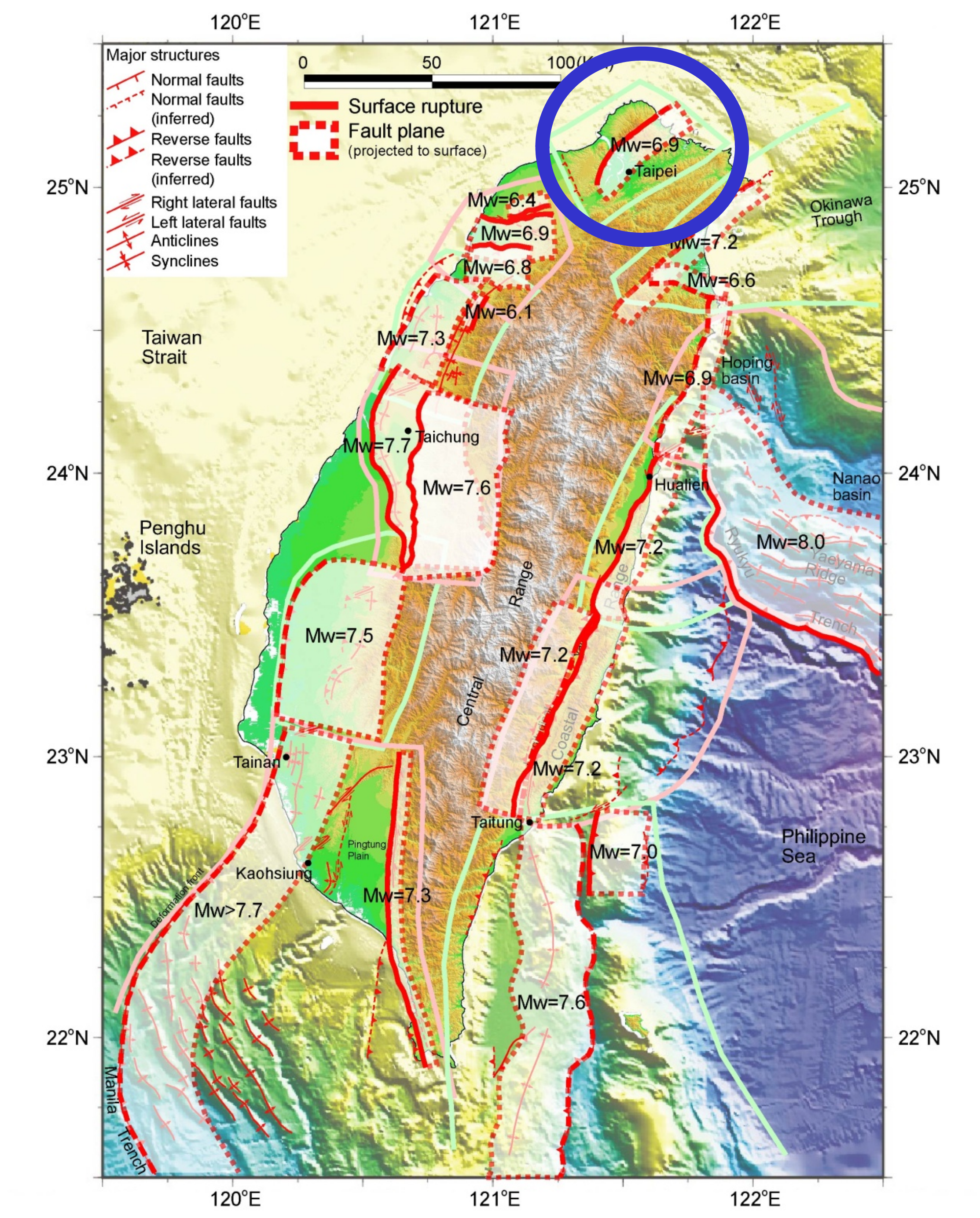




Chelungpu fault
Changhua fault
(g) Taichung Domain
Changhua fault
Chelungpu fault (1999 rupture)
(Km)
Pakua Tableland
Taichung Basin
Western Foothills
Pleistocene
Plio-Pleistocene
Mio-Pliocene
Plio-Pleistocene
Pre-Miocene
basement
3
0
5
10
15
0
10
20
30
40
50 (Km)


N
(i) Hsinchu Domain
(Km)
Hukou anticline
Taoyuan-Hukou Tableland
Western Foothills
Plio-Pleistocene
Pliocene
Mio-Pliocene
Miocene
Pre-Miocene basement
Pre-Miocene basement
Pre-Miocene basement
2
0
5
10
15
0
5
10
15
20
25
30 (Km)
(Wang et al., 2003)

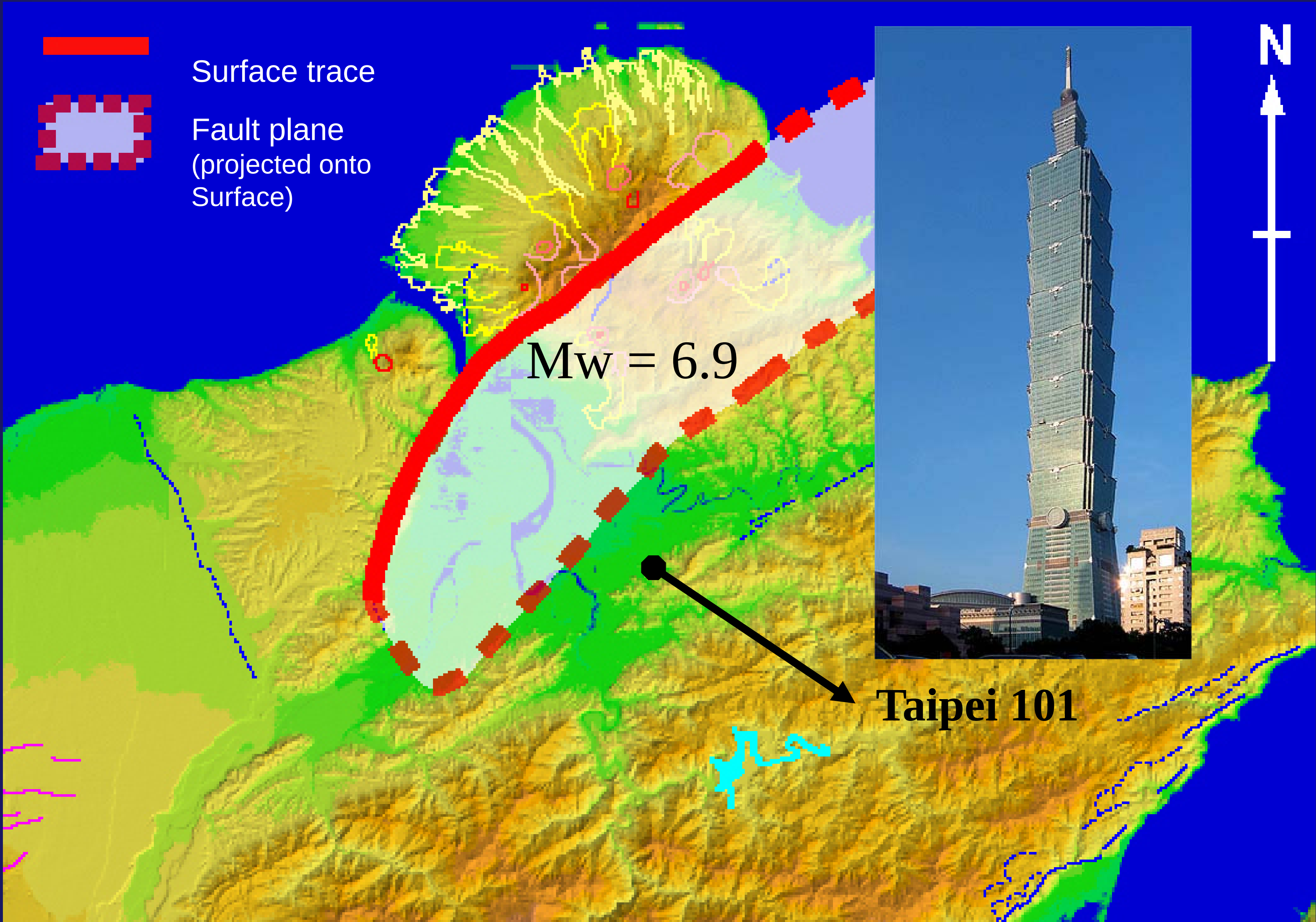

N
Shanchiao
fault
Taipei B
(j) Taipei Domain
Shanchiao fault
(Km)
Linkou Tableland
Taipei Basin
Western Foothills
Miocene
Mio-Pliocene
Mio-Pliocene
Mio-Pliocene
Pre-Miocene
basement
1
0
5
10
15
0
5
10
15
20
25
30
35(Km)

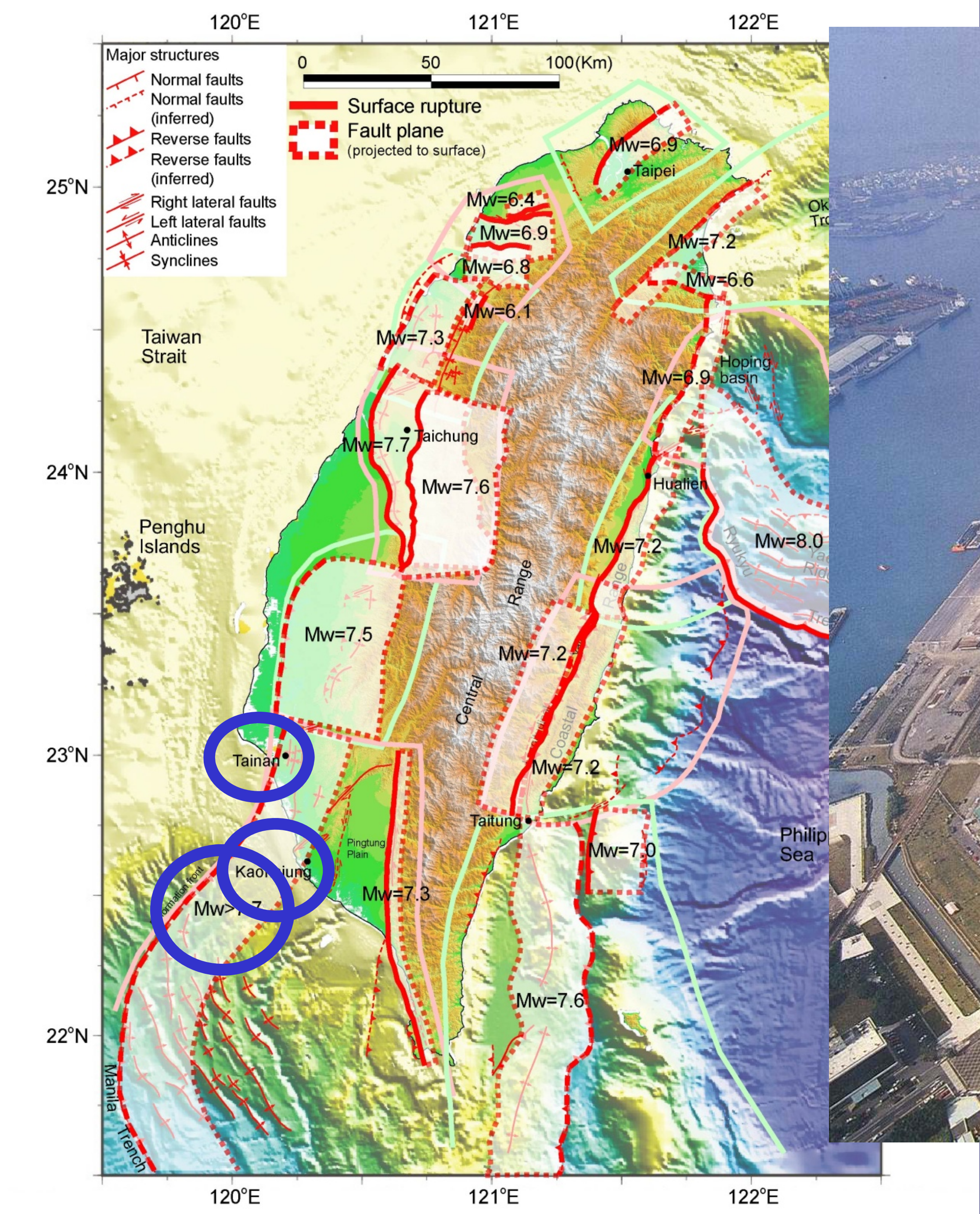


A rudimentary map of potential sources of large earthquakes in and around Taiwan

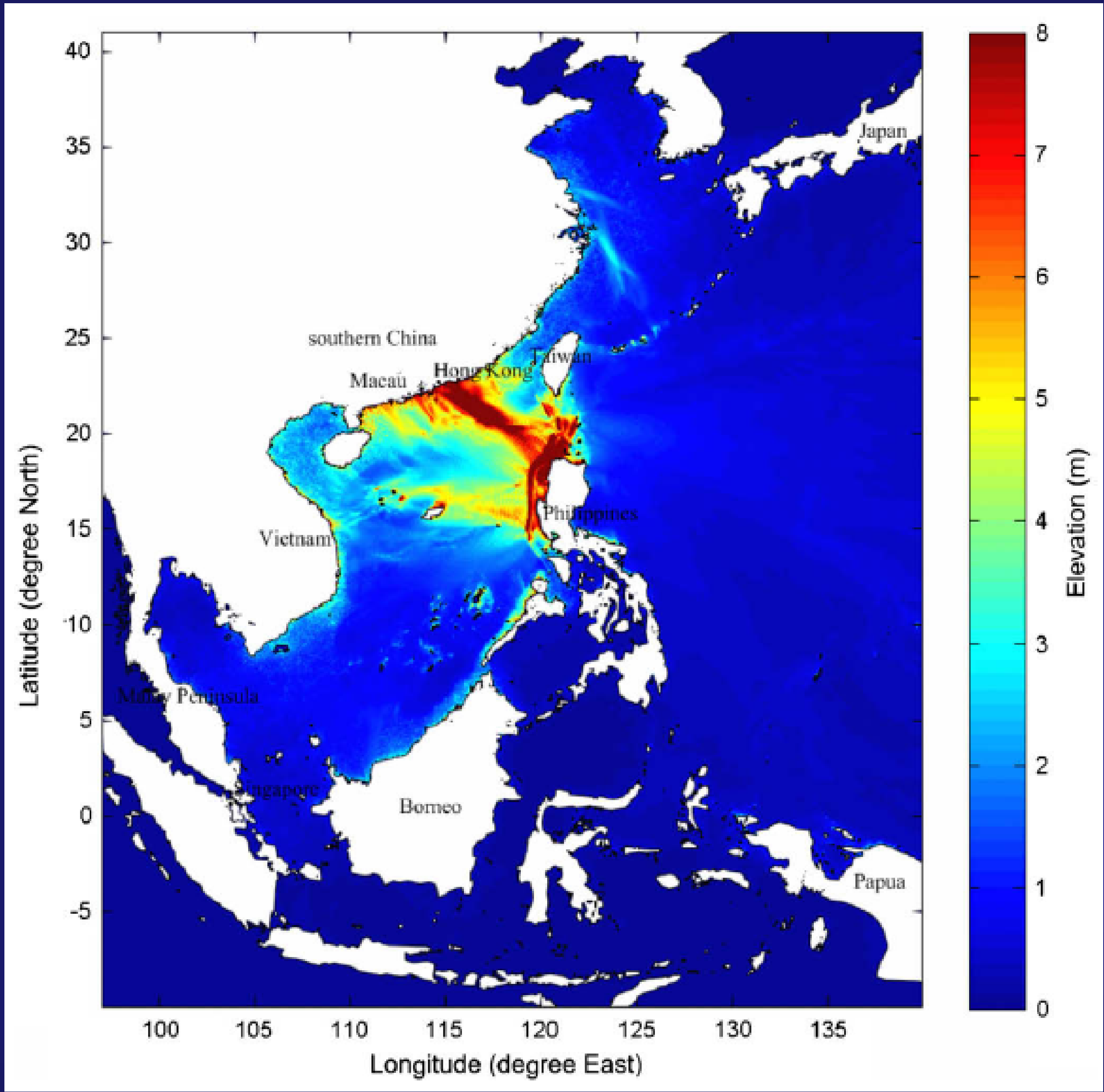
(Shyu et al., 2005, JGR)

The area overlying Shanchiao fault includes much of the Taipei Basin

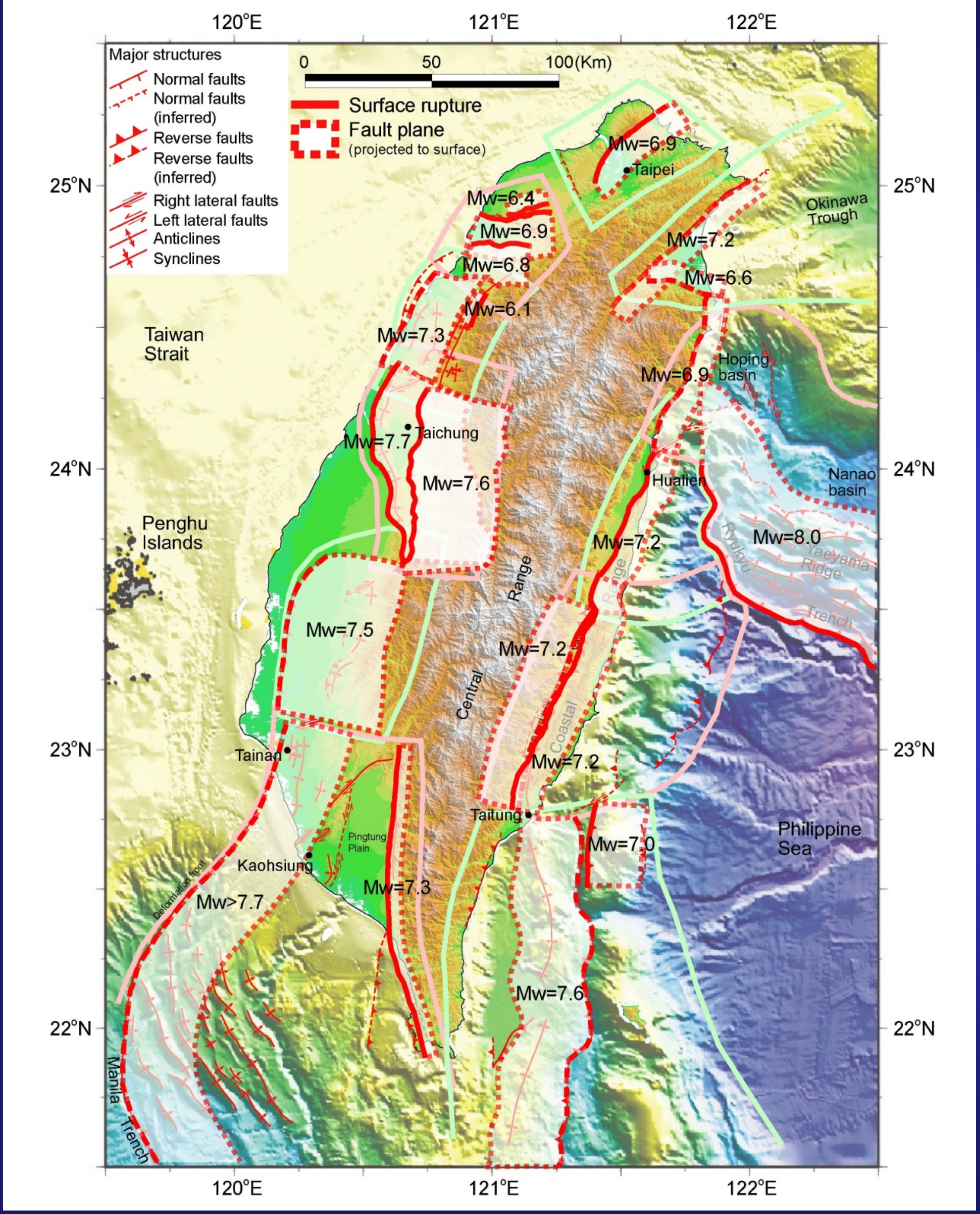




(Shyu et al., 2005, JGR)

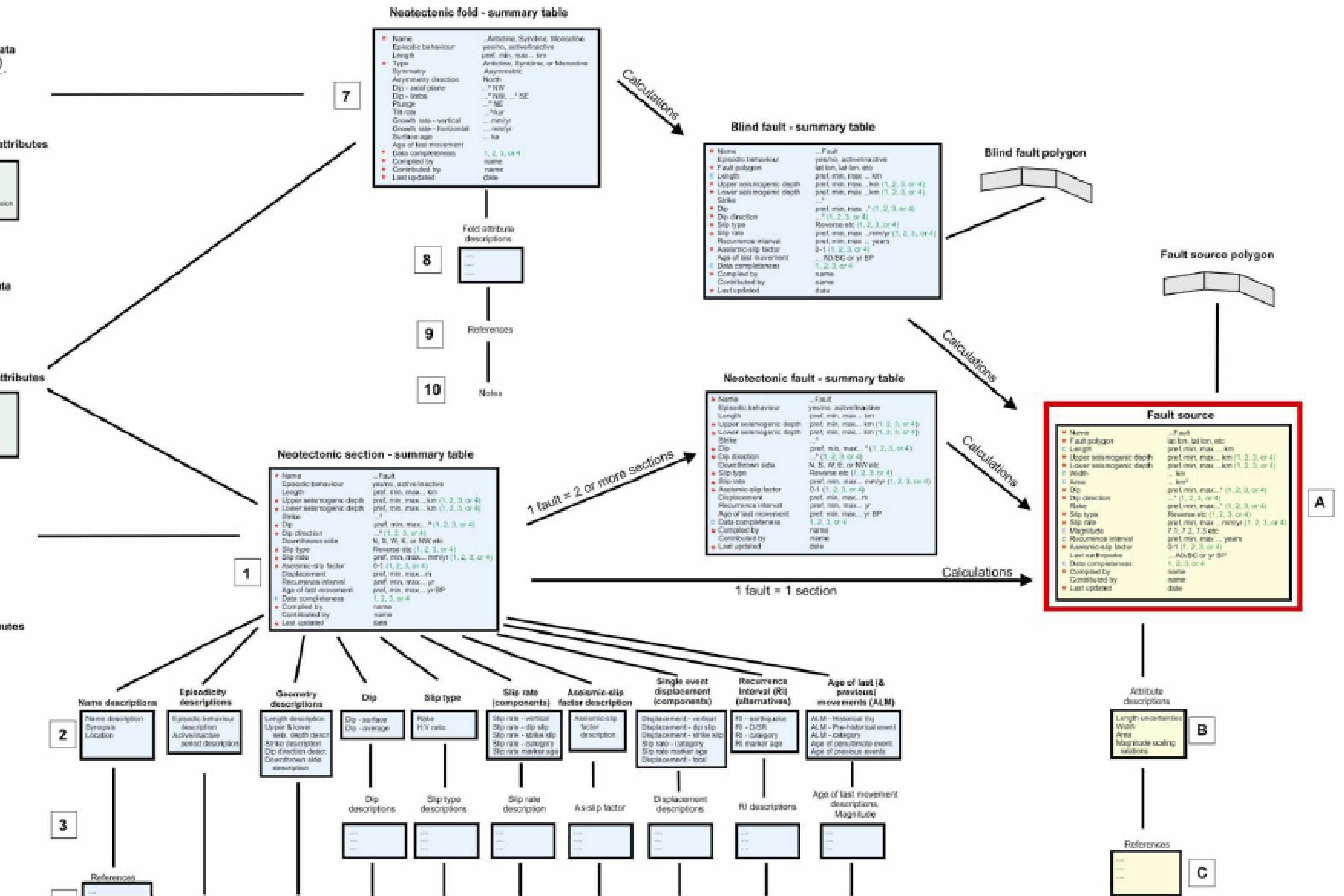


(Megawati et al., 2009)

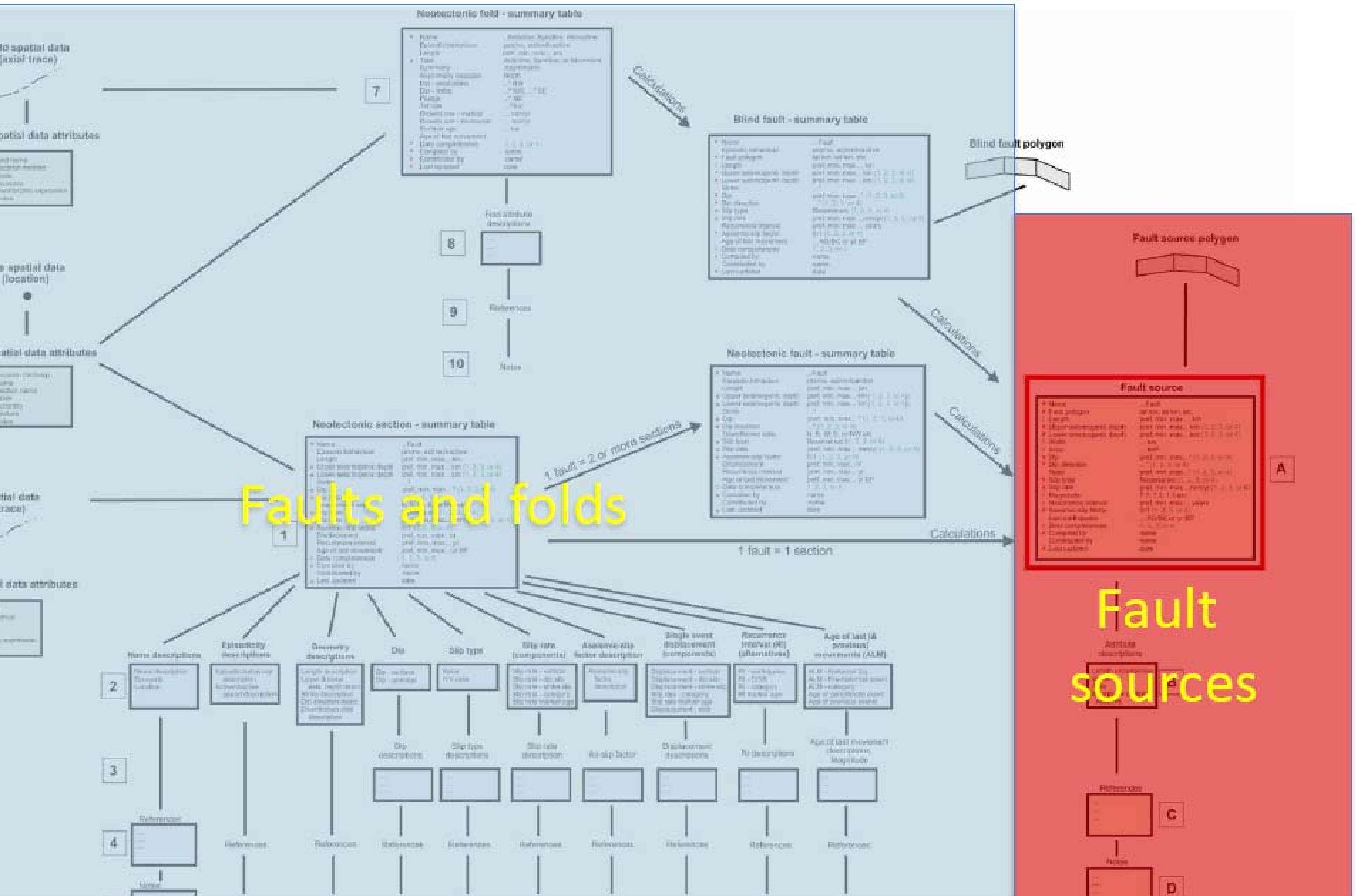


For the TEM database, we need some more information.

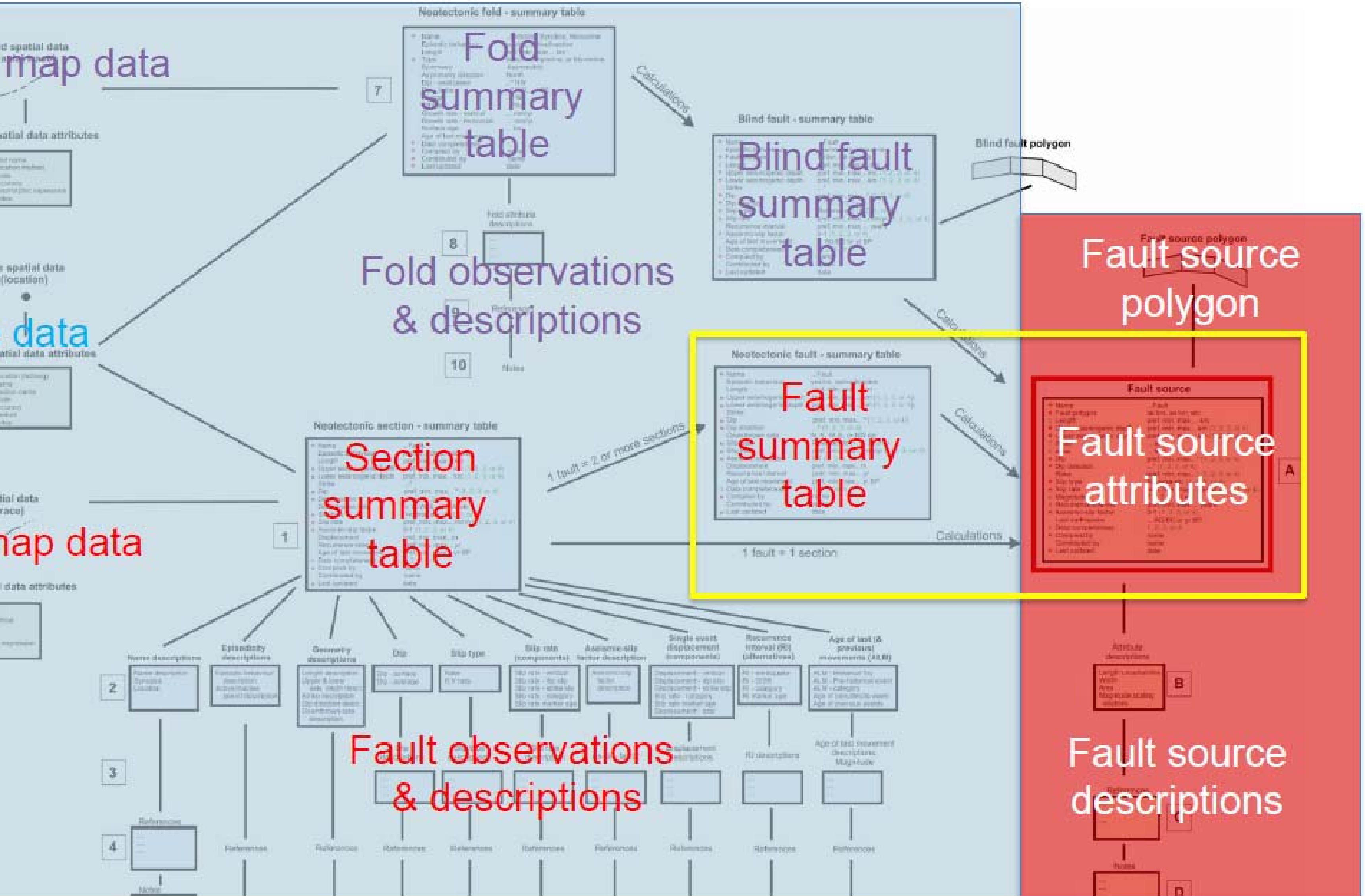
(Shyu et al., 2005, JGR)



Neotectonic fold - summary table
7
Calculations
Blind fault - summary table
Blind fault polygon
Fold attribute descriptions
8
9
References
10
Notes
Fault source polygon
Calculations
Neotectonic fault - summary table
Calculations
Fault source
A
Neotectonic section - summary table
1 fault = 2 or more sections
Calculations
1 fault = 1 section
1
Name descriptions
Episodicity descriptions
Geometry descriptions
Dip
Slip type
Slip rate (components)
Aseismic-slip factor description
Single event displacement (components)
Recurrence interval (RI) (alternatives)
Age of last (& previous) movements (ALM)
2
3
Dip descriptions
Slip type descriptions
Slip rate description
As-slip factor
Displacement descriptions
RI descriptions
Age of last movement descriptions, Magnitude
Attribute descriptions
B
References
C
References



Neotectonic fold - summary table
Calculations
Blind fault - summary table
Blind fault polygon
Fault source polygon
Neotectonic fault - summary table
Fault source
Neotectonic section - summary table
1 fault = 2 or more sections
Calculations
1 fault = 1 section
Faults and folds
Fault
sources
References
Notes
A
C
D
1
2
3
4
7
8
9
10



map data
Fold summary table
Blind fault summary table
Fold observations & descriptions
data
Fault source polygon
Fault summary table
Section summary table
Fault source attributes
map data
Fault observations & descriptions
Fault source descriptions
Calculations
1 fault = 2 or more sections
1 fault = 1 section

onic fault - summary table

	...Fault
viour	yes/no, active/inactive
	pref, min, max... km
genic depth	pref, min, max... km (1, 2, 3, or 4)
genic depth	pref, min, max... km (1, 2, 3, or 4)
	...°
	pref, min, max... ° (1, 2, 3, or 4)
	...° (1, 2, 3, or 4)
ide	N, S, W, E, or NW etc
	Reverse etc (1, 2, 3, or 4)
	pref, min, max... mm/yr (1, 2, 3, or 4)
factor	0-1 (1, 2, 3, or 4)
	pref, min, max...m
terval	pref, min, max... yr
vement	pref, min, max... yr BP
eness	1, 2, 3, or 4
	name
y	name
	date

Calculations

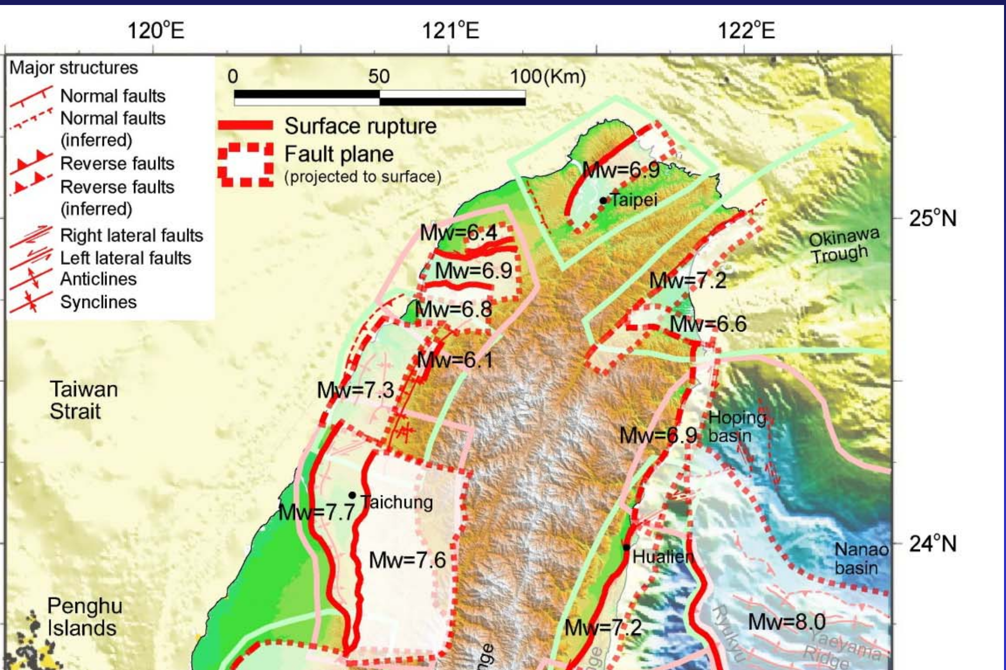
Fault source

*	Name	...Fault
*	Fault polygon	lat lon, lat lon, etc
c	Length	pref, min, max ... km
*	Upper seismogenic depth	pref, min, max... km (1, 2, 3, or 4)
*	Lower seismogenic depth	pref, min, max ...km (1, 2, 3, or 4)
c	Width	... km
c	Area	... km^2
	Dip	pref, min, max...° (1, 2, 3, or 4)
*	Dip direction	...° (1, 2, 3, or 4)
	Rake	pref, min, max...° (1, 2, 3, or 4)
*	Slip type	Reverse etc (1, 2, 3, or 4)
*	Slip rate	pref, min, max ...mm/yr (1, 2, 3, or 4)
c	Magnitude	7.1, 7.2, 7.3 etc
c	Recurrence interval	pref, min, max ... years
*	Aseismic-slip factor	0-1 (1, 2, 3, or 4)
	Last earthquake	... AD/BC or yr BP
c	Data completeness	1, 2, 3, or 4
*	Compiled by	name
	Contributed by	name
*	Last updated	date

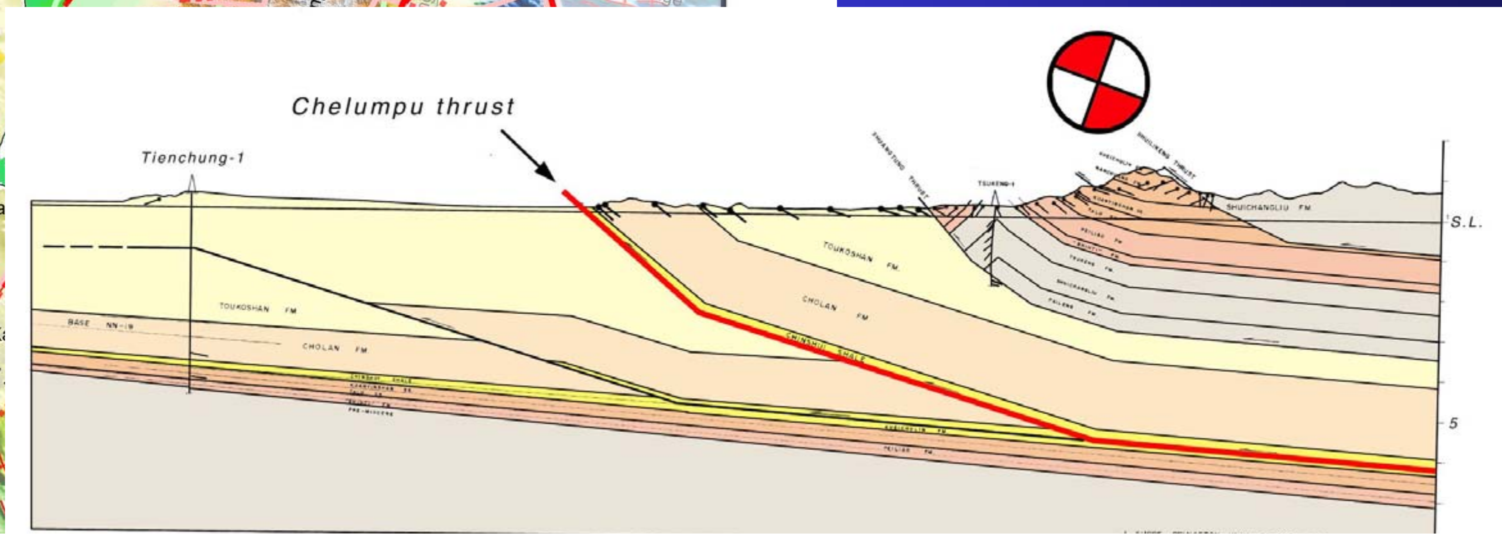
Compulsory

Calculated

Data completeness factors



A rudimentary map of potential sources of large earthquakes in and around Taiwan



roposed Major Seismic Structures of Taiwan[a]

Fault Name	Fault Type[b]	L, km	Fault Dip, deg	Downdip Limit, km	W,[c] km	A,[d] km^2	M_w[e]	M_o,[f] 10^{25} dyne cm	D,[g] m
			Lutao-Lanyu Domain						
ge fault	R	140	30	15	30.00	4200.00	7.59	302.96	2.40
fault	R	40	45	15	21.21	848.53	6.97	34.97	1.37
ault	R	40	45	15	21.21	848.53	6.97	34.97	1.37
g Ridge fault	R	30	45	15	21.21	636.40	6.85	23.72	1.24
			Taitung Domain						
Valley fault, total	R/SS	160	60	15	17.32	2771.28	7.43	172.83	2.08
Valley fault, Taitung Domain only	R/SS	96	60	15	17.32	1662.77	7.23	86.72	1.74
e fault, total	R	80	45	15	21.21	1697.06	7.24	89.14	1.75
e fault, emerged part only	R	40	45	15	21.21	848.53	6.97	34.97	1.37
ore fault	R	120	45	15	21.21	2545.58	7.40	154.10	2.02
			Hualien Domain						
Valley fault, Hualien Domain only	SS	90	60	15	17.32	1558.85	7.24	89.12	1.91
			Ryukyu Domain						
h	R	~180	30	35	70.00	12600.00	8.02	1335.06	3.53
ateral accommodation structure	SS	50	90	15	15.00	750.00	6.91	29.10	1.29
l fault system	N	50	60	15	17.32	866.03	6.93	30.51	1.17
			Kaoping Domain						
ult connecting Hengchun fault	SS/R	120	75	15	15.53	1863.50	7.32	117.11	2.09
ult connecting the offshore fault	R/SS	120	75	15	15.53	1863.50	7.27	101.15	1.81
ochou fault only	SS/R	75	75	15	15.53	1164.69	7.11	57.06	1.63
g Plain fault (Kaoping River fault)	SS	50	90	15	15.00	750.00	6.91	29.10	1.29
front	R	>200	30	15	30.00	>6000.00	>7.73	>490.34	>2.72
			Chiayi Domain						
nent	R	60	15	15	57.96	3477.33	7.52	234.79	2.25
	SS	15	90	15	15.00	225.00	6.38	4.61	0.68

onic fault - summary table

	...Fault
viour	yes/no, active/inactive
	pref, min, max... km
genic depth	pref, min, max... km (1, 2, 3, or 4)
genic depth	pref, min, max... km (1, 2, 3, or 4)
	...°
	pref, min, max... ° (1, 2, 3, or 4)
	...° (1, 2, 3, or 4)
ide	N, S, W, E, or NW etc
	Reverse etc (1, 2, 3, or 4)
	pref, min, max... mm/yr (1, 2, 3, or 4)
factor	0-1 (1, 2, 3, or 4)
	pref, min, max...m
terval	pref, min, max... yr
vement	pref, min, max... yr BP
eness	1, 2, 3, or 4
	name
y	name
	date

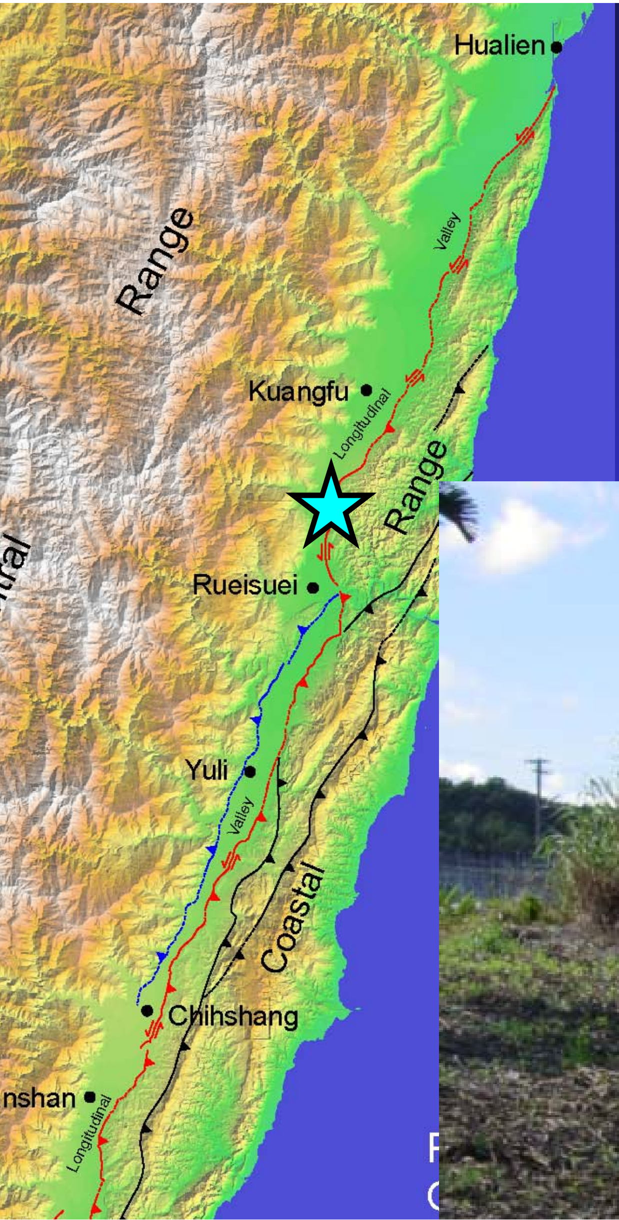
Calculations

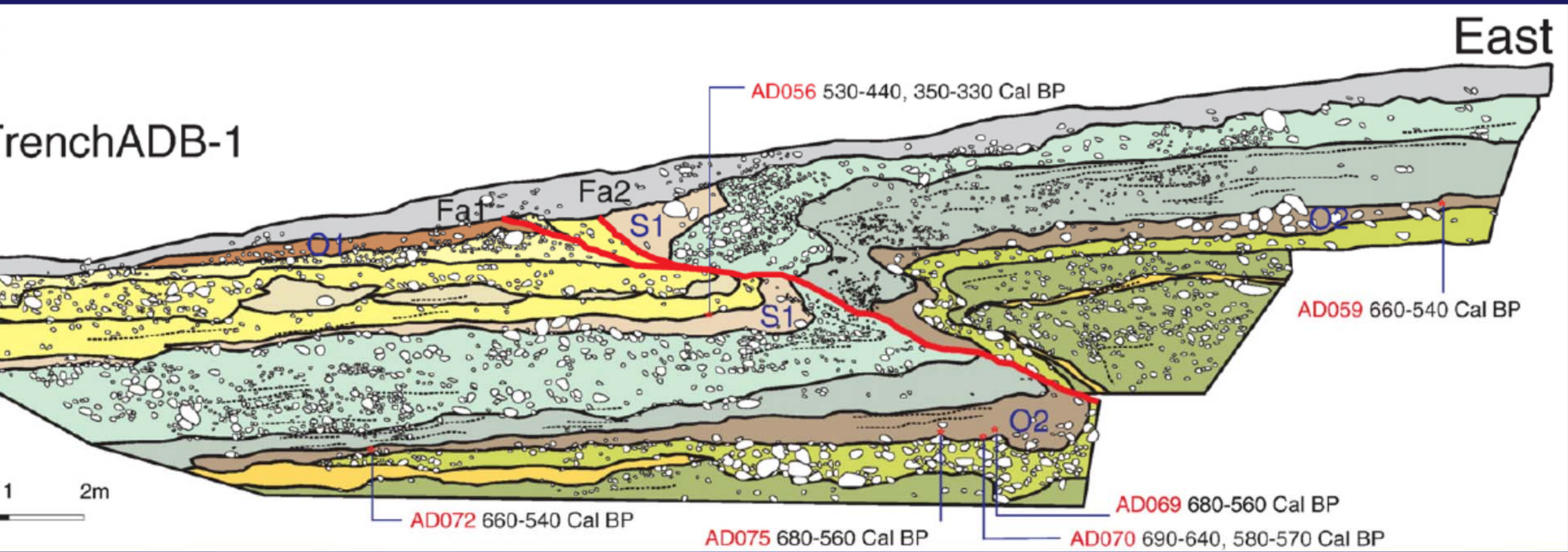
Fault source

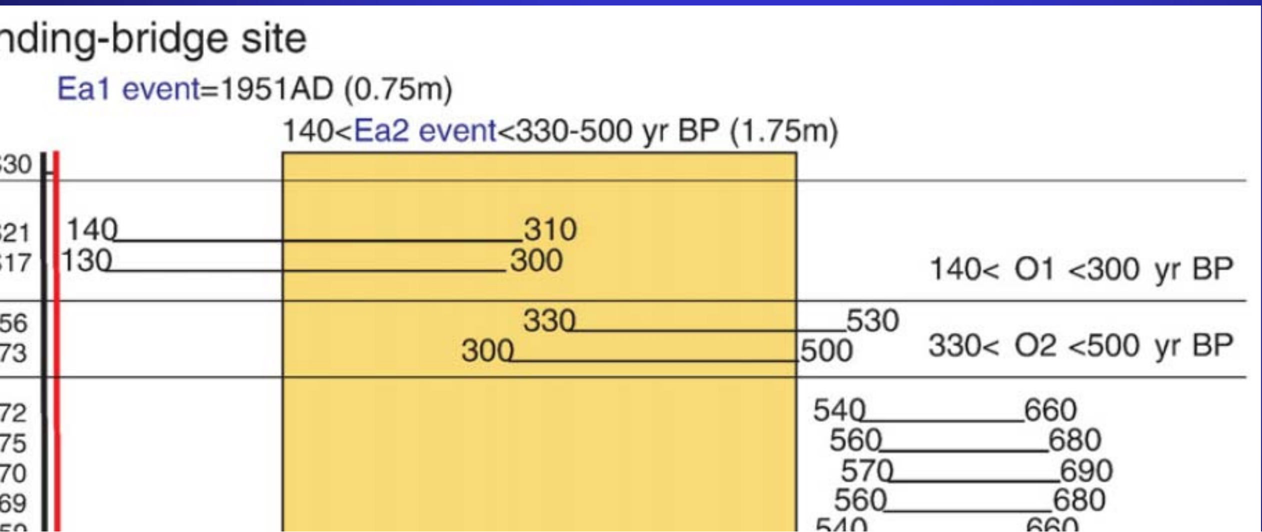
*	Name	...Fault
*	Fault polygon	lat lon, lat lon, etc
c	Length	pref, min, max ... km
*	Upper seismogenic depth	pref, min, max... km (1, 2, 3, or 4)
*	Lower seismogenic depth	pref, min, max ...km (1, 2, 3, or 4)
c	Width	... km
c	Area	... km^2
*	Dip	pref, min, max...° (1, 2, 3, or 4)
*	Dip direction	...° (1, 2, 3, or 4)
	Rake	pref, min, max...° (1, 2, 3, or 4)
*	Slip type	Reverse etc (1, 2, 3, or 4)
*	Slip rate	pref, min, max ...mm/yr (1, 2, 3, or 4)
c	Magnitude	7.1, 7.2, 7.3 etc
c	Recurrence interval	pref, min, max ... years
*	Aseismic-slip factor	0-1 (1, 2, 3, or 4)
	Last earthquake	... AD/BC or yr BP
c	Data completeness	1, 2, 3, or 4
*	Compiled by	name
	Contributed by	name
*	Last updated	date

Compulsory
Calculated
Data completeness factors

Major structural systems in the Longitudinal Valley




East
TrenchADB-1
AD056 530-440, 350-330 Cal BP
Fa1
Fa2
S1
O1
O2
S1
O2
AD059 660-540 Cal BP
1
2m
AD072 660-540 Cal BP
AD069 680-560 Cal BP
AD075 680-560 Cal BP
AD070 690-640, 580-570 Cal BP


nding-bridge site
Ea1 event=1951AD (0.75m)
140<Ea2 event<330-500 yr BP (1.75m)
140
310
130
300
140< O1 <300 yr BP
330
530
300
500
330< O2 <500 yr BP
540
660
560
680
570
690
560
680

onic fault - summary table

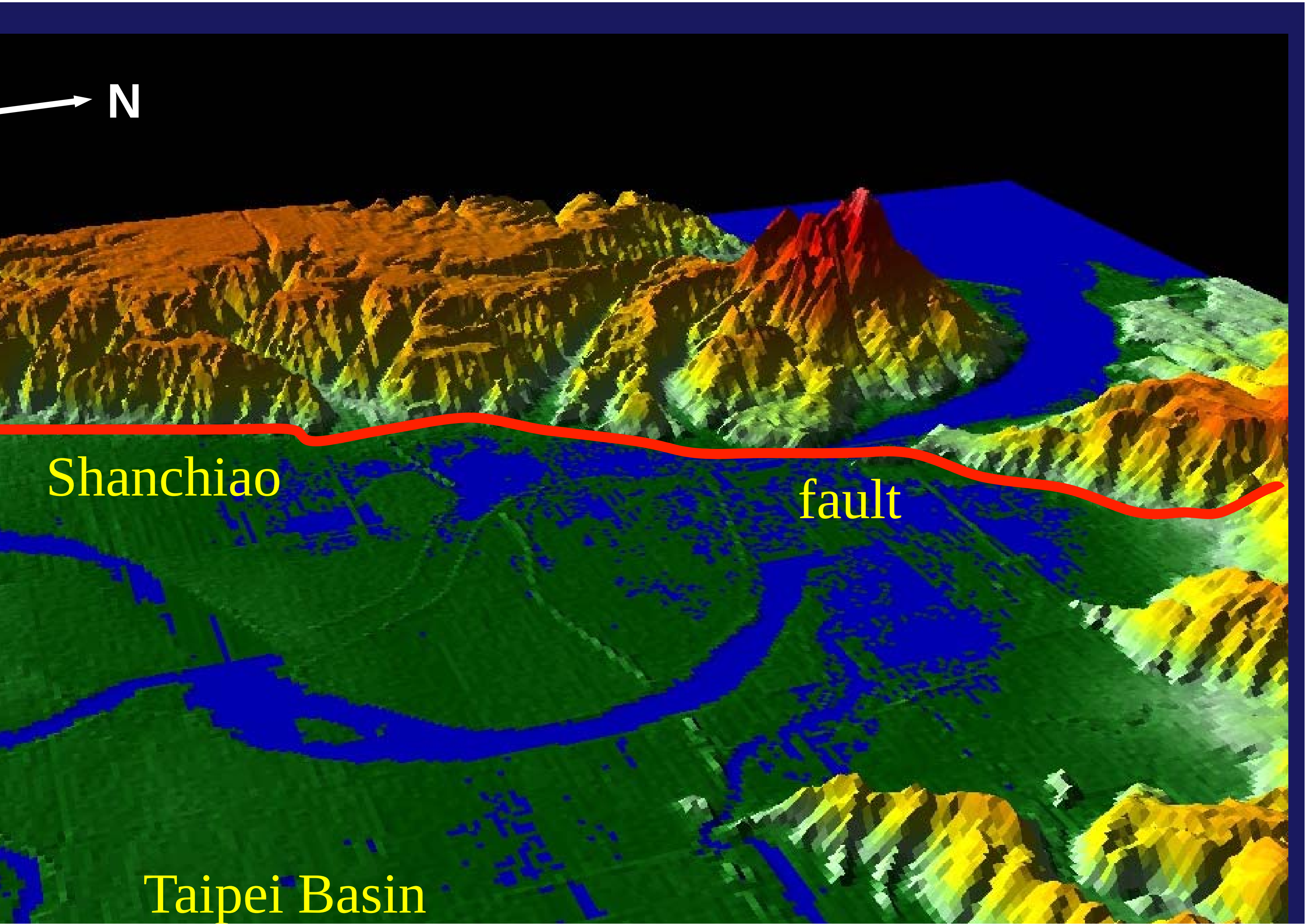
	...Fault
viour	yes/no, active/inactive
	pref, min, max... km
genic depth	pref, min, max... km (1, 2, 3, or 4)
genic depth	pref, min, max... km (1, 2, 3, or 4)
	...°
	pref, min, max... ° (1, 2, 3, or 4)
	...° (1, 2, 3, or 4)
ide	N, S, W, E, or NW etc
	Reverse etc (1, 2, 3, or 4)
	pref, min, max... mm/yr (1, 2, 3, or 4)
factor	0-1 (1, 2, 3, or 4)
	pref, min, max...m
terval	pref, min, max... yr
vement	pref, min, max... yr BP
eness	1, 2, 3, or 4
	name
y	name
	date

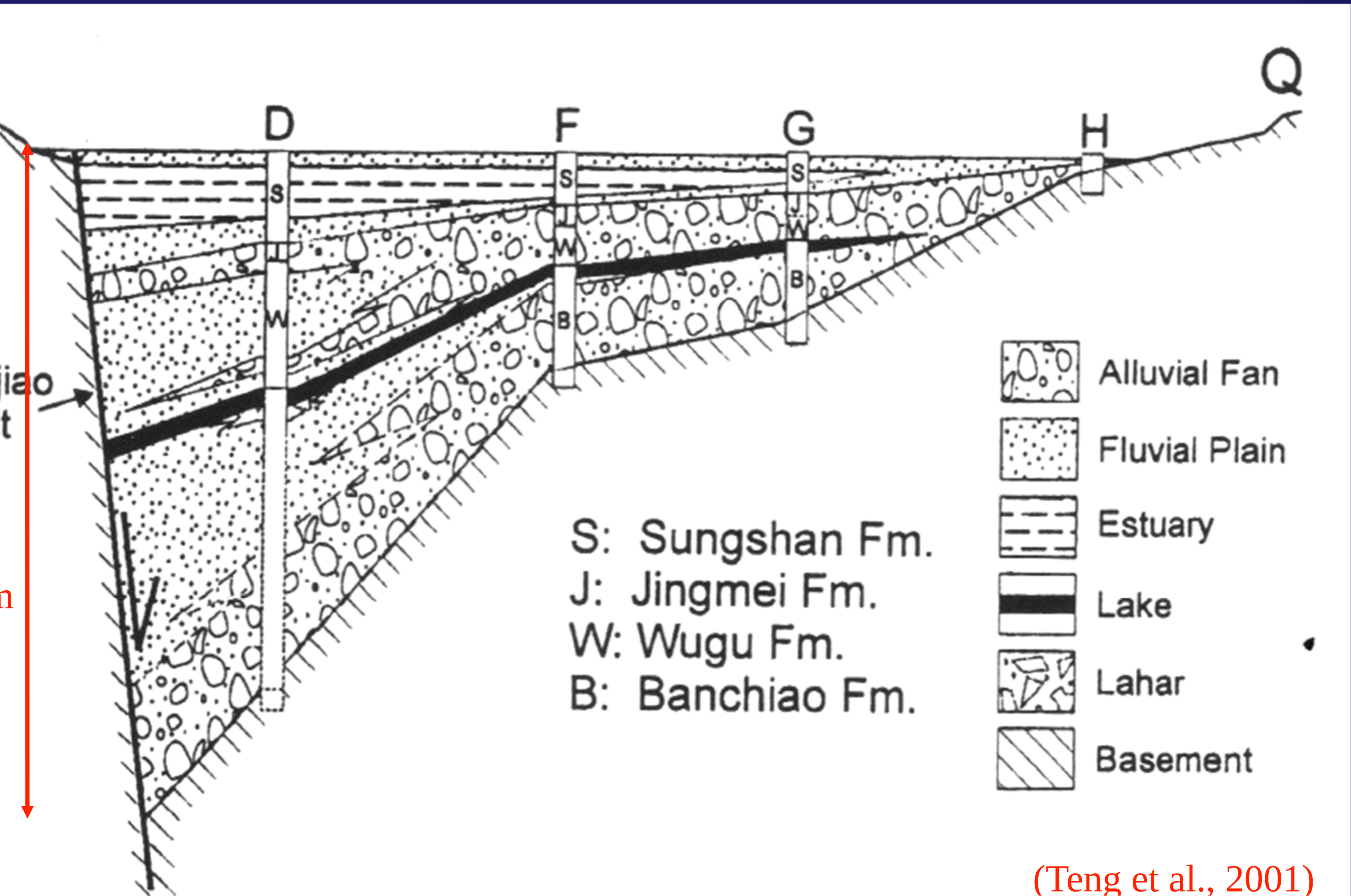
Calculations

Fault source

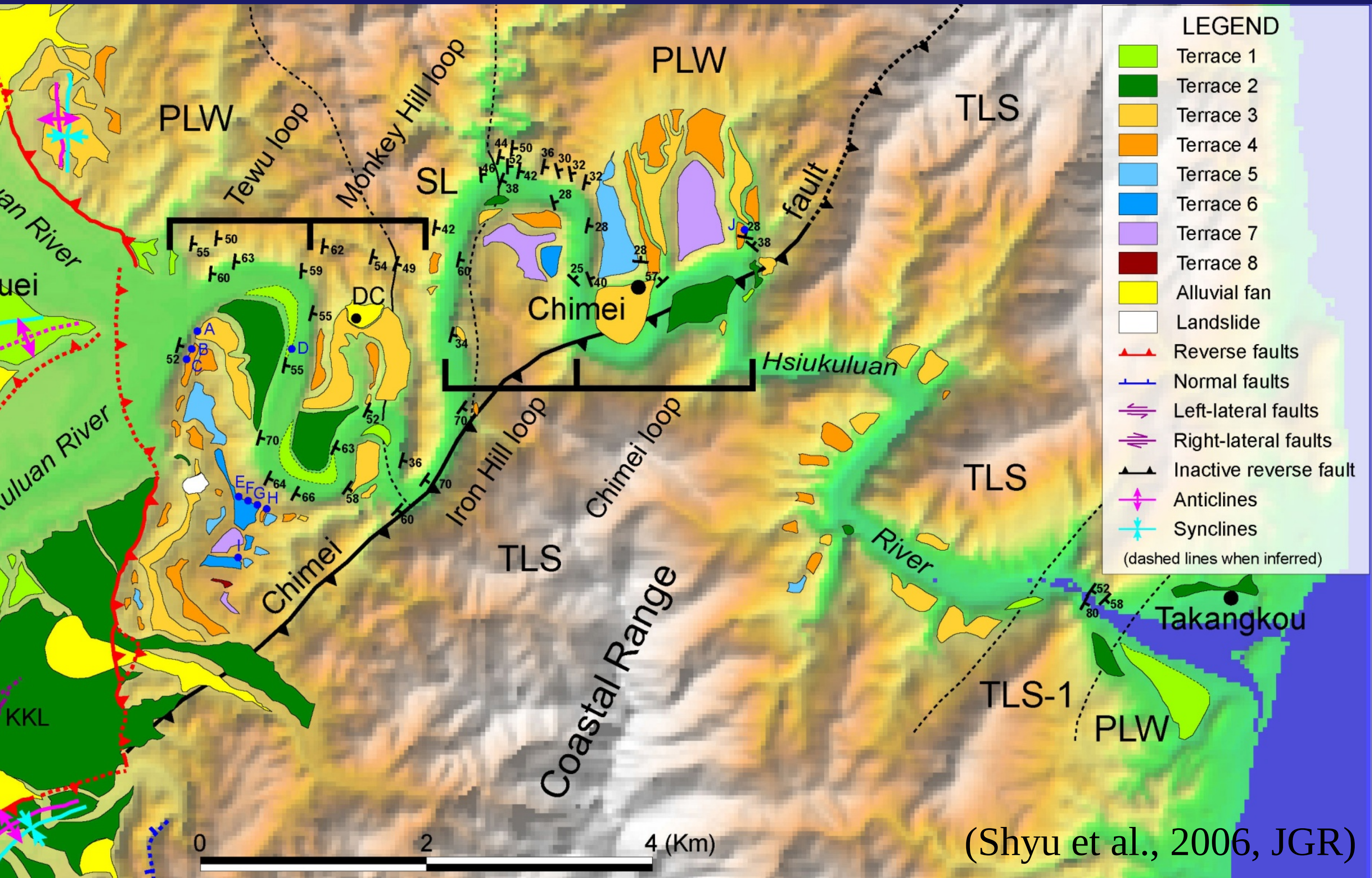
*	Name	...Fault
*	Fault polygon	lat lon, lat lon, etc
c	Length	pref, min, max ... km
*	Upper seismogenic depth	pref, min, max... km (1, 2, 3, or 4)
*	Lower seismogenic depth	pref, min, max ...km (1, 2, 3, or 4)
c	Width	... km
c	Area	... km^2
*	Dip	pref, min, max...° (1, 2, 3, or 4)
*	Dip direction	...° (1, 2, 3, or 4)
	Rake	pref, min, max...° (1, 2, 3, or 4)
*	Slip type	Reverse etc (1, 2, 3, or 4)
*	Slip rate	pref, min, max ...mm/yr (1, 2, 3, or 4)
c	Magnitude	7.1, 7.2, 7.3 etc
c	Recurrence interval	pref, min, max ... years
	[illegible]	0-1 (1, 2, 3, or 4)
	Last earthquake	... AD/BC or yr BP
c	Data completeness	1, 2, 3, or 4
*	Compiled by	name
	Contributed by	name
*	Last updated	date

Compulsory
Calculated
Data completeness factors

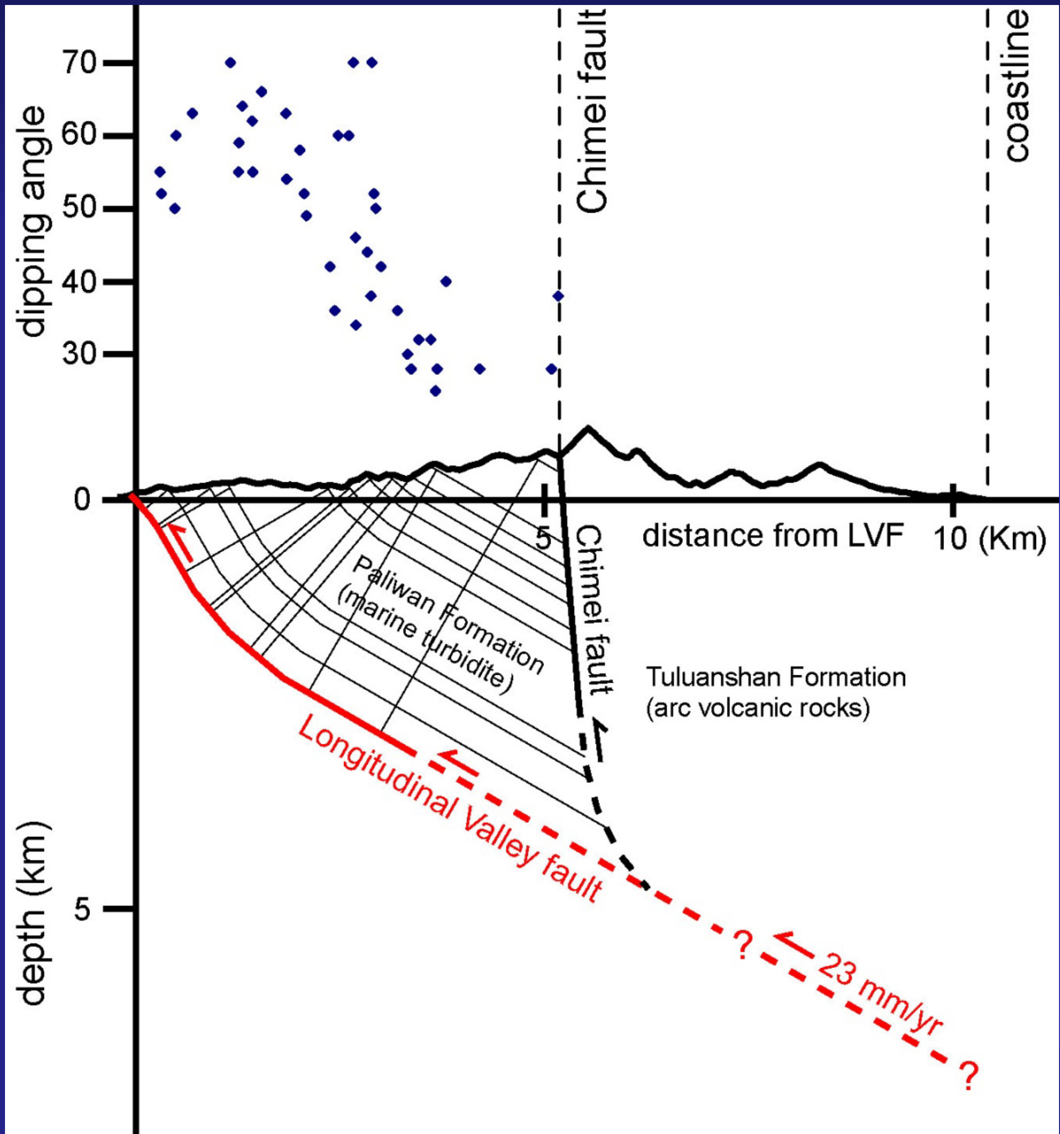

N
Shanchiao
fault
Taipei Basin



(Teng et al., 2001)



siukuluan River: The only river that flows across the Coastal Range



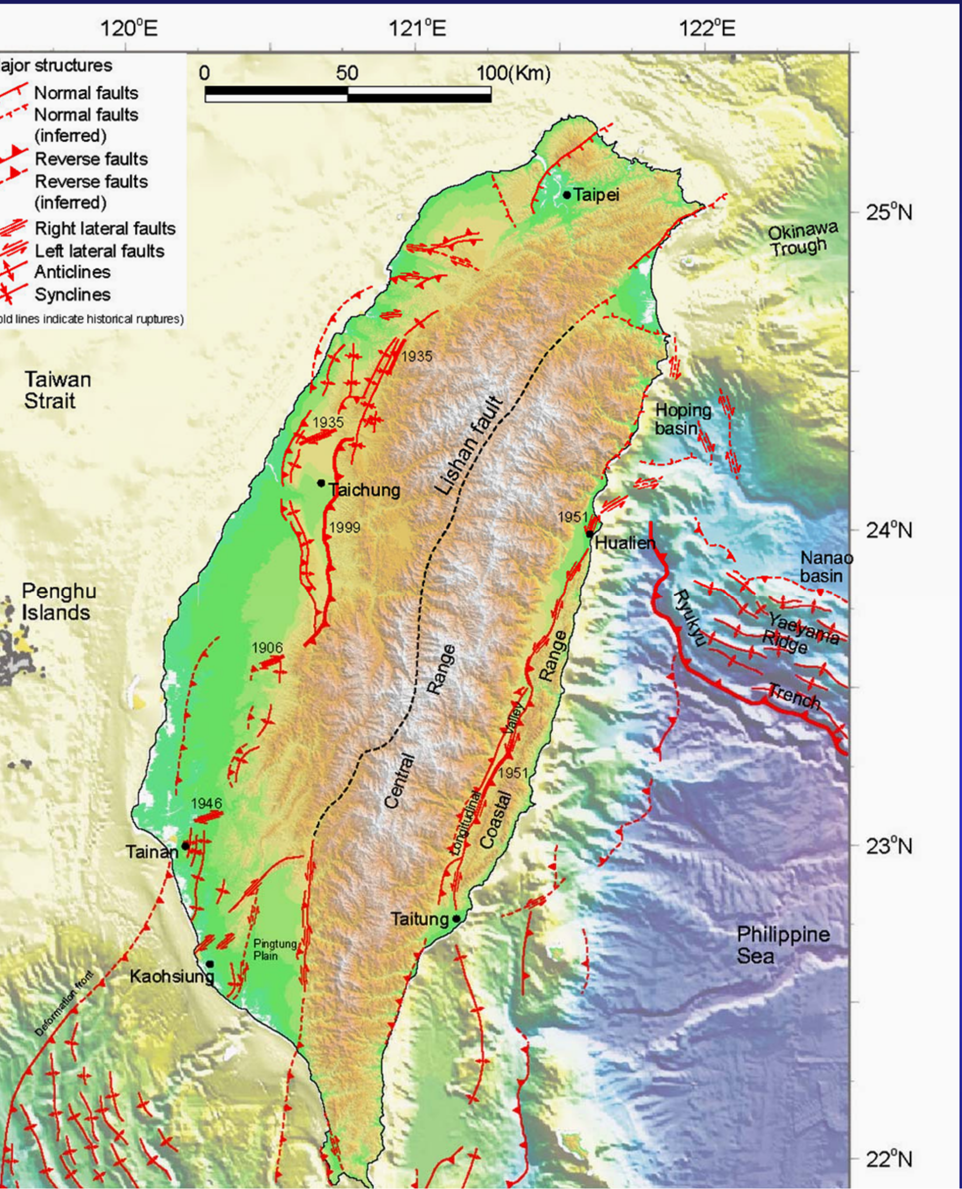
Horizontal shortening

om magnitude obtain Single Event Displacement (SED) and then
Recurrence Interval (RI) by:

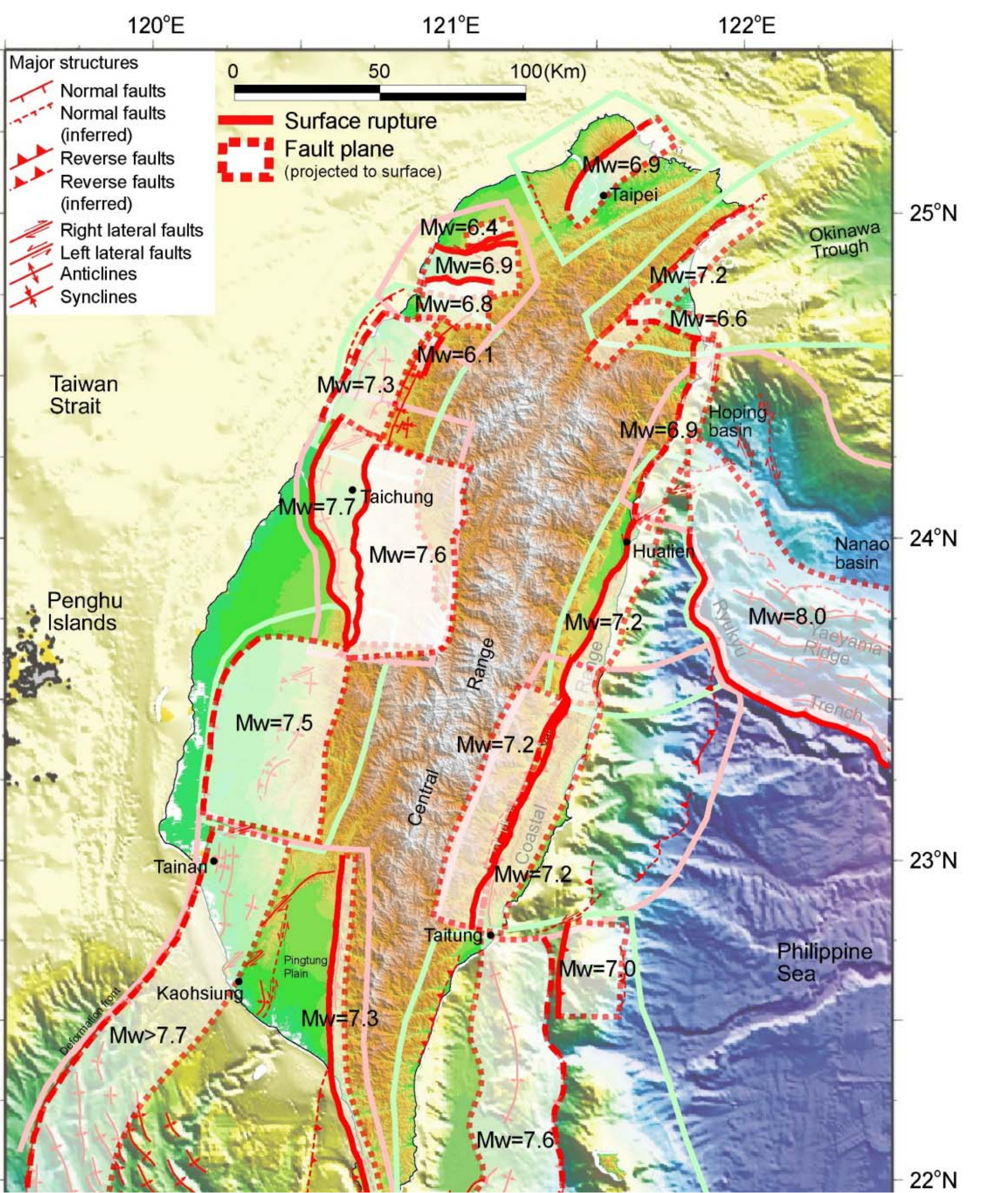
M_w = 2/3 log M_o - 10.7 (Hanks & Kanamori, 1979)

M_o =μAD (Aki & Richards, 2002)

) RI = Slip Rate / SED



Active structure map of Taiwan



Map of potential sources of large earthquakes in and around Taiwan

We are still working on completing the needed information