

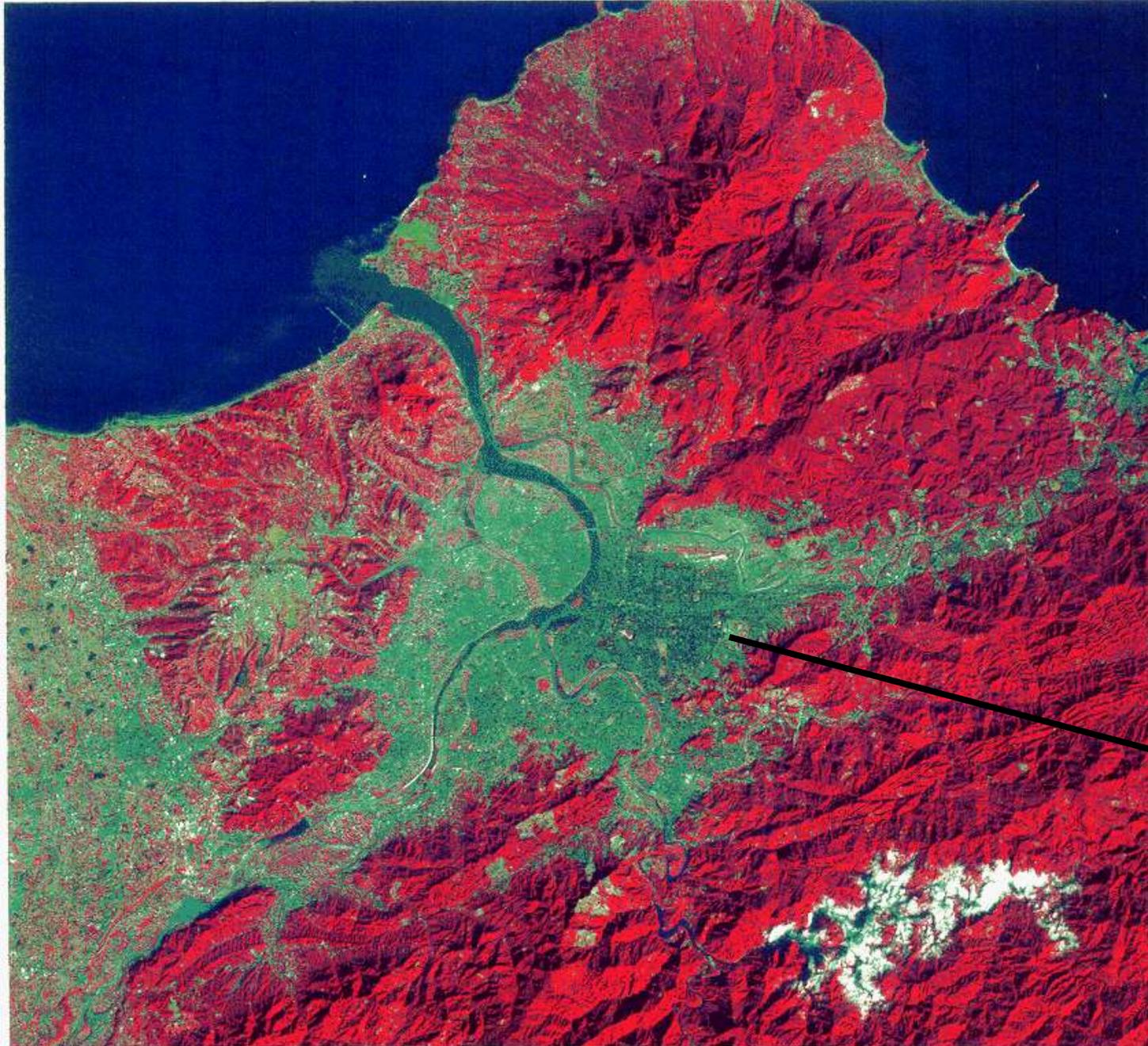
**The 2nd Annual Meeting of the Strategic
Chinese-Korean-Japanese Cooperative Program
Jeju island, Korea, 2012/10/29-31**

Site Amplification Study **— Case of Taipei Basin —**

Kuo-Liang Wen
NCU, Taiwan



- **Geological structure**
- **Strong motion observations**
- **Ground motion responses**
- **Earthquake damages**
- **Recent researchs**



NCU NCU

國立中央大學

Three Faults

NW: SanChiao Fault

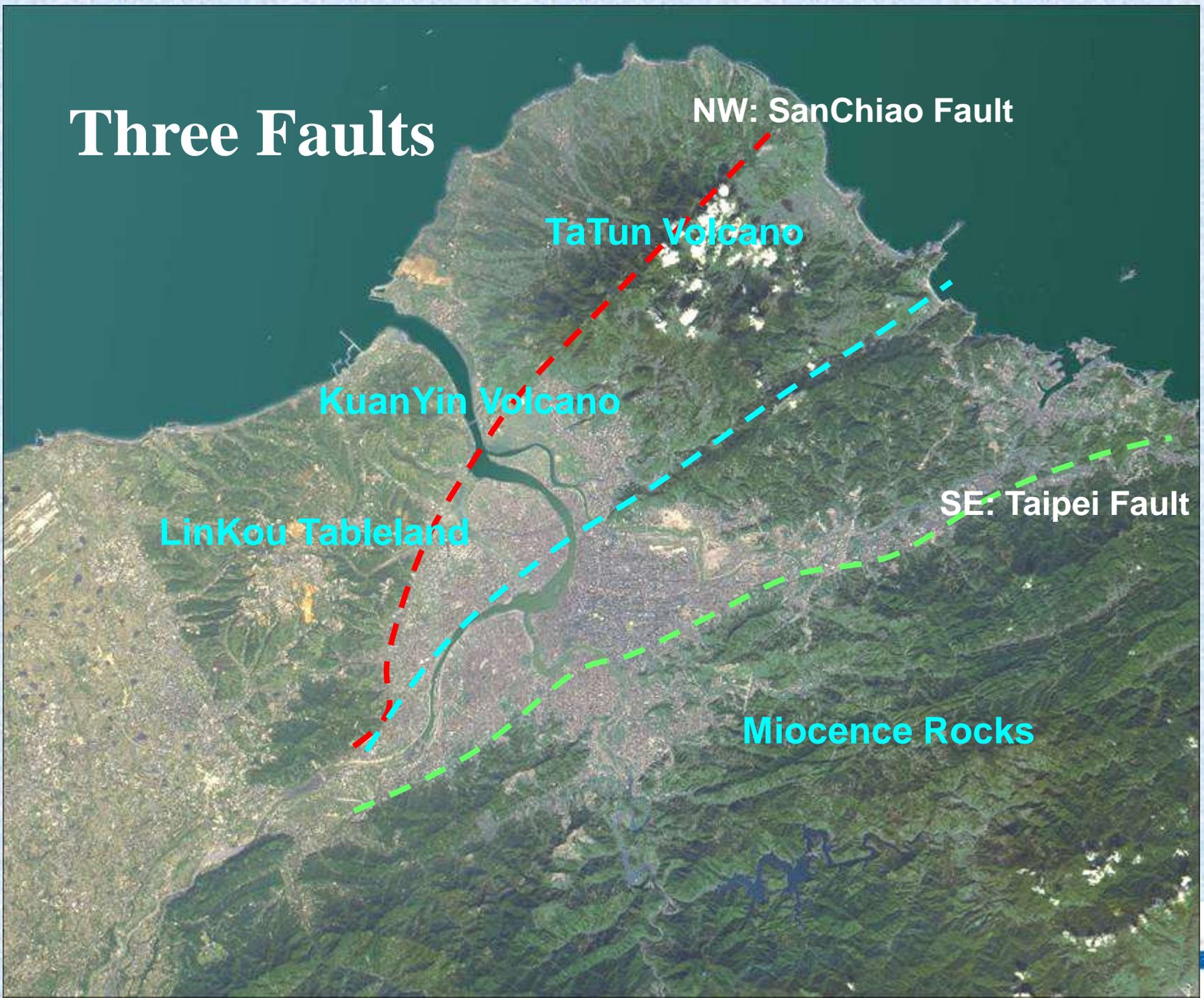
TaTun Volcano

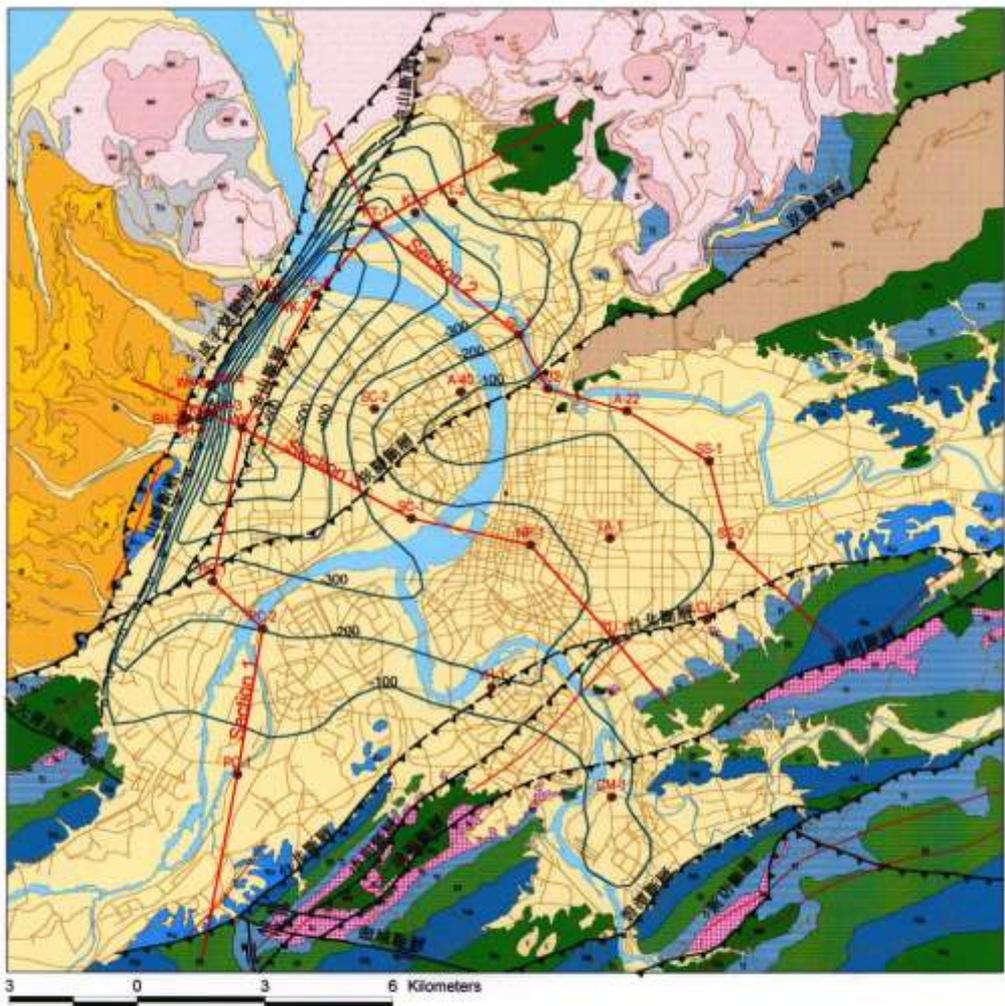
KuanYin Volcano

LinKou Tableland

SE: Taipei Fault

Miocence Rocks





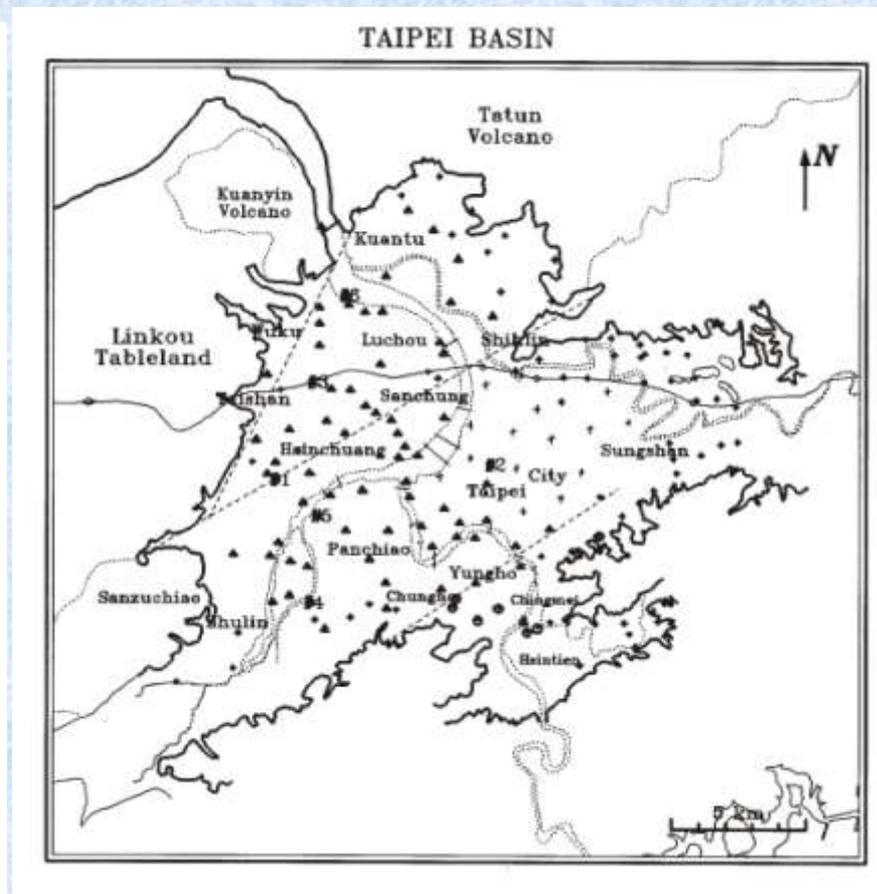
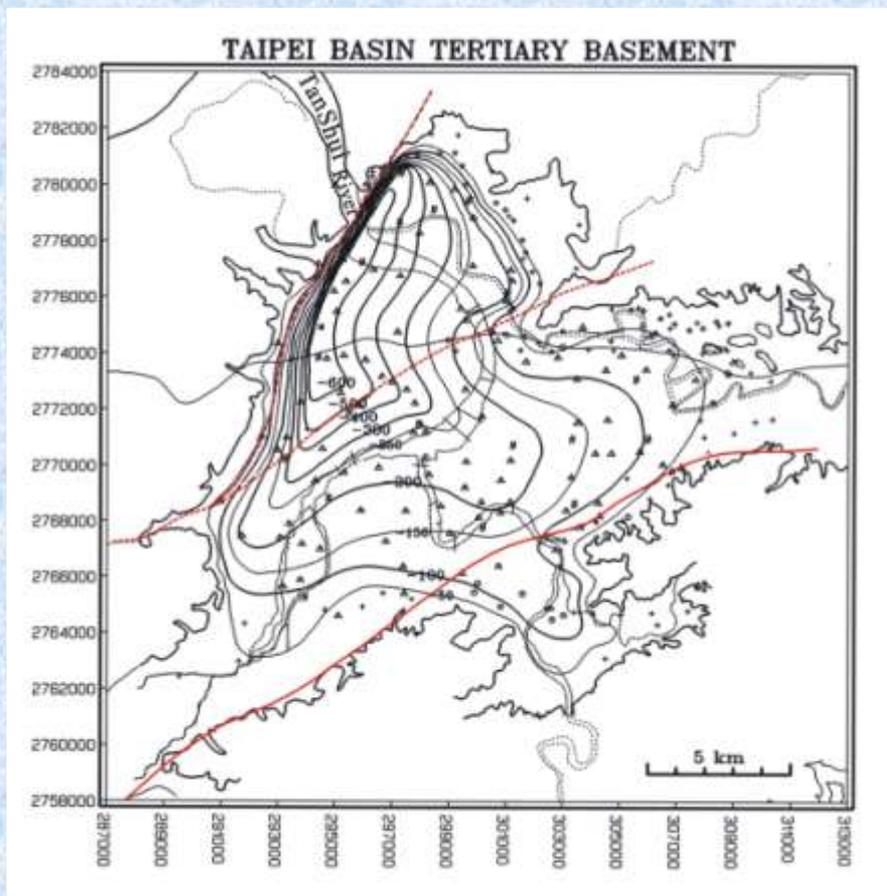
Depth contour to the basement top
From deep drilling.
Central Geol. Surv.



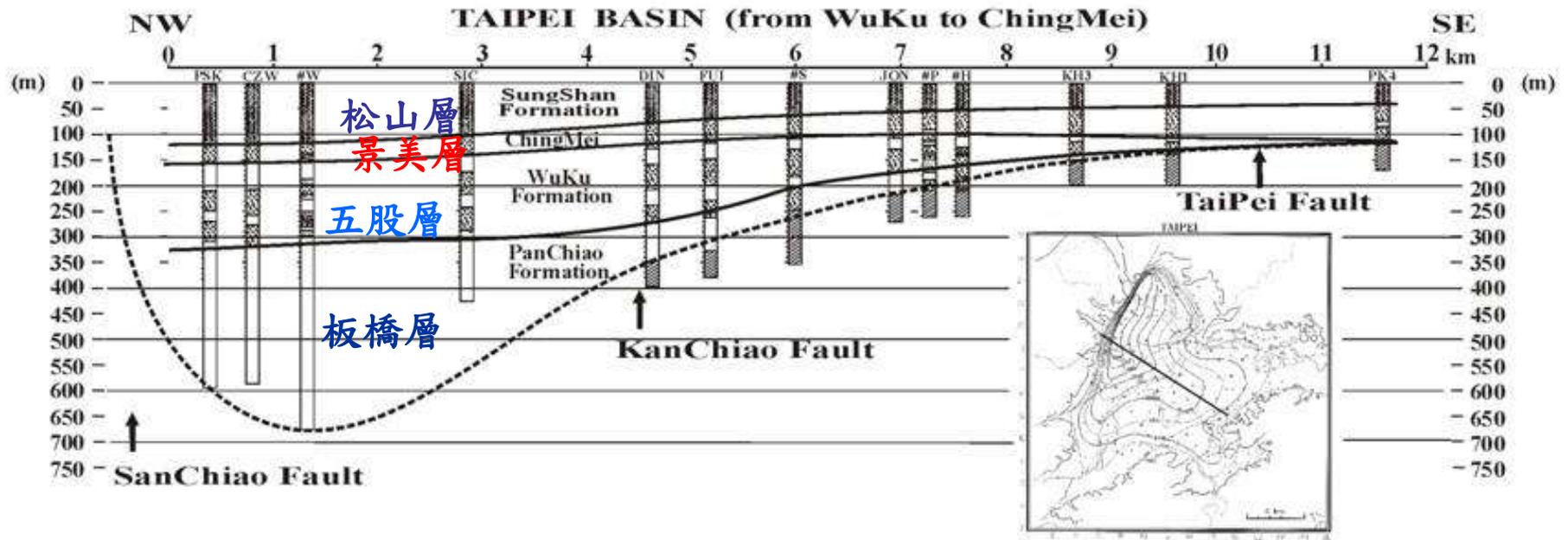
井號	基盤深度	井深	井名	鑽井單位	井號	基盤深度	井深	井名	鑽井單位
A-22	70.0	75.0		高公局	SC-2			三重二號井	地調所
A-32	71.6	76.7		高公局	SL-1	202.5	230.0	士林一號井	地調所
A-40	112.0	118.1		高公局	SS-1		100.0	松山一號井	地調所
BB-1	14.2	90.0		住都局	SS-2	112.0	150.0	松山二號井	地調所
BB-2	30.0	80.0		住都局	TU-1	112.0	280.0	台次一號井	地調所
CM-1	126.3	234.3	景美一號井	經濟部	WK-1	679.0	760.0	五股一號井	地調所
HC-1	296.0	2317.0	新莊一號井	中油	WK-2	45.0	60.0	五股二號井	地調所
KT-1	499.0	520.0	關渡一號井	地調所	WK-3	164.0	165.0	五股三號井	地調所
KT-2	197.0	230.0	關渡二號井	地調所	WK-4		100.0	五股四號井	地調所
KT-3	302.0	320.0	關渡三號井	地調所	WK-5	45.0	50.0	五股五號井	地調所
LC-1		300.0	蘆洲一號井	地調所	WK-6	125.0	182.0	五股六號井	地調所
LCL-2	51.2	248.6	六張犁二號井	經濟部	WK-7	222.0		五股七號井	地調所
NP-1	215.9	260.7	新莊二號井	台北市	YH-1	174.2	200.0	永和一號井	地調所
PC-1	58.8	88.0	板橋一號井	地調所	TA-1	157.5	220.0	大安一號井	地調所
PC-2	206.0	300.0	板橋二號井	地調所					
SC-1	244.9	300.0	三重一號井	地調所					

台北盆地第三紀基盤面等深線及測線分布

Seismic survey



Quaternary Depositions



1:5

1:1

P and S Velocities

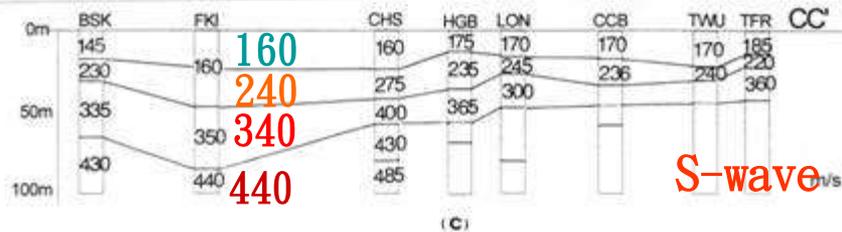
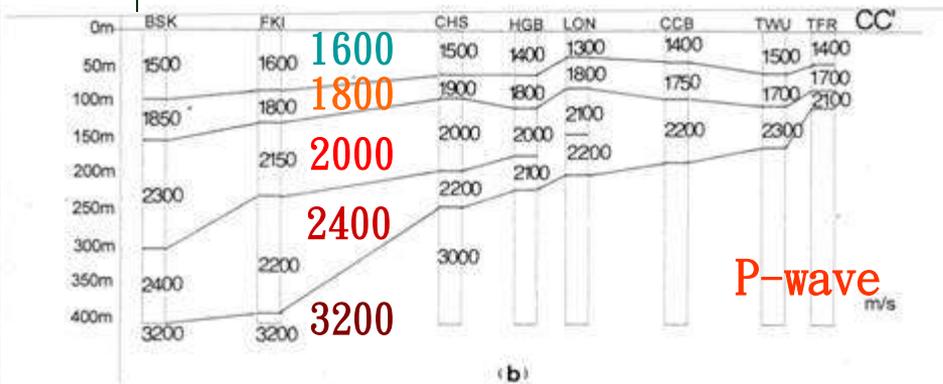
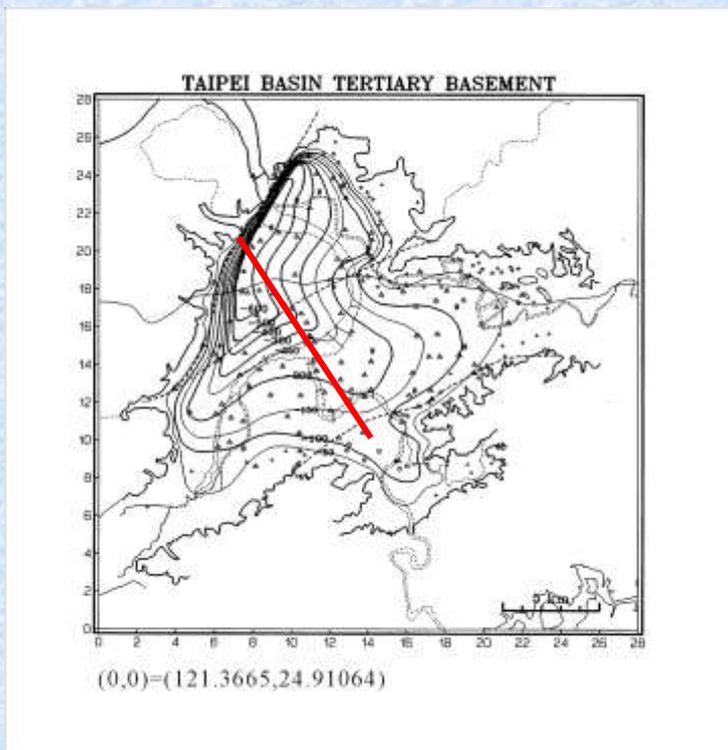
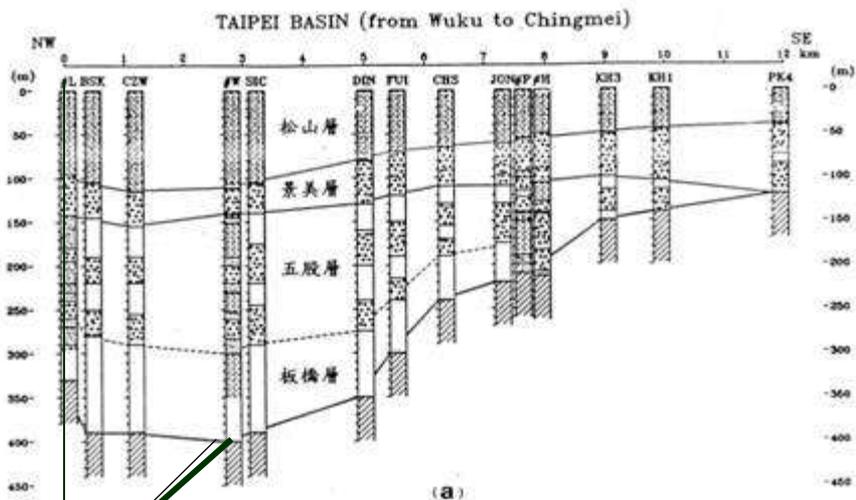
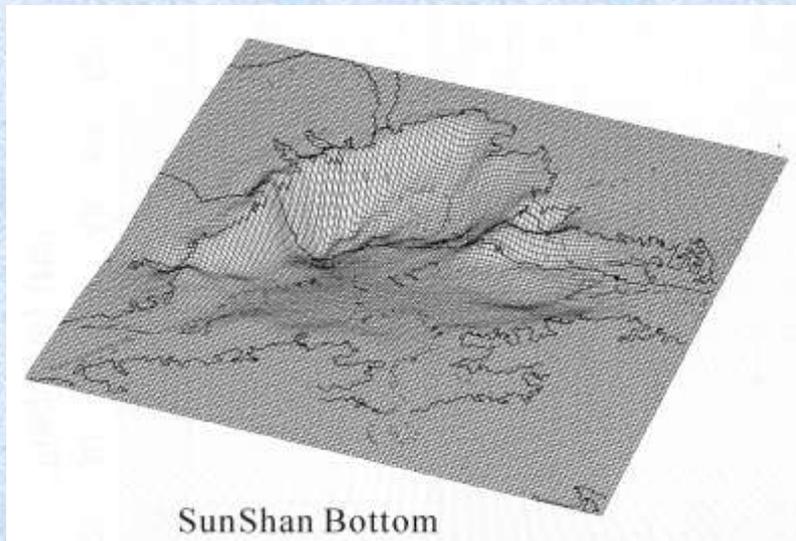
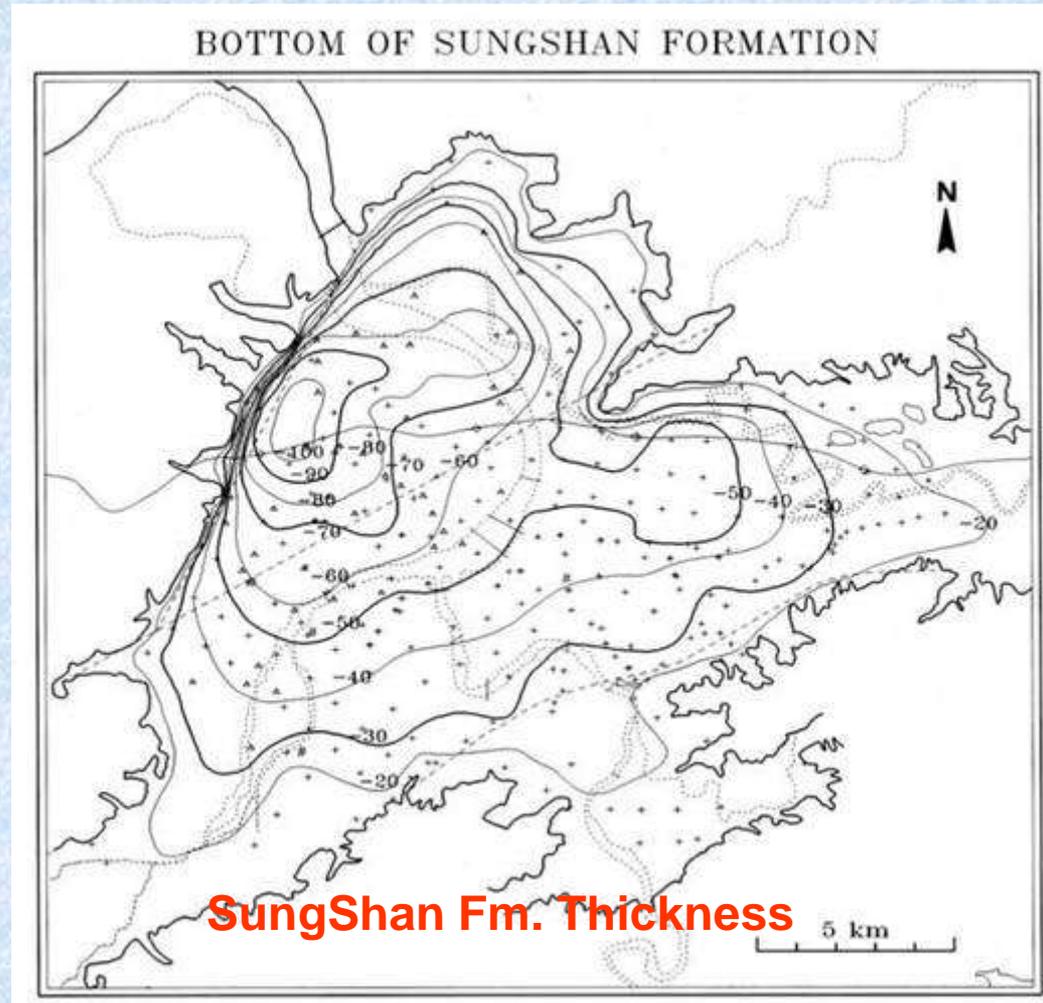
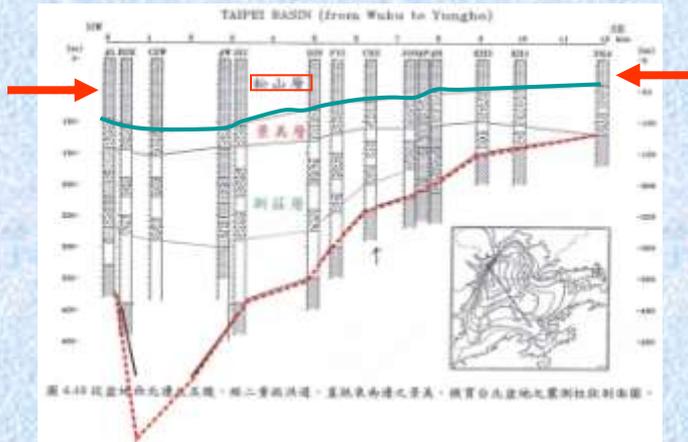


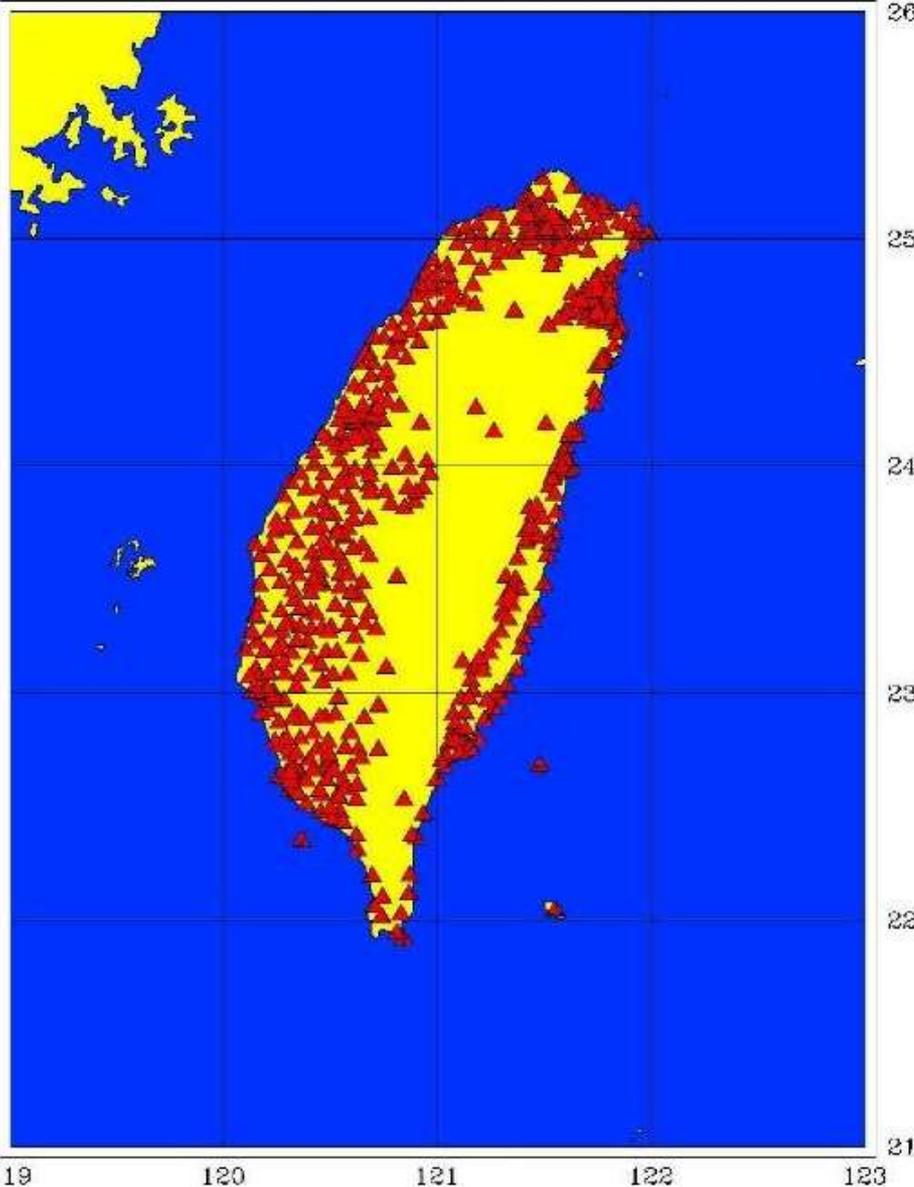
圖 4.11 台北盆地西北至東南地層及速度剖面：(a)第四紀地層剖面（摘自 Wang et al., 1995），沉積厚度與基盤深度變化一致；(b) P 波速度剖面 (c) S 波速度剖面，可分為三層。平均而言，台北盆地內 S 波速度在 150-600m/s，P 波在 1400-2300。

Shape of SungShan Formation



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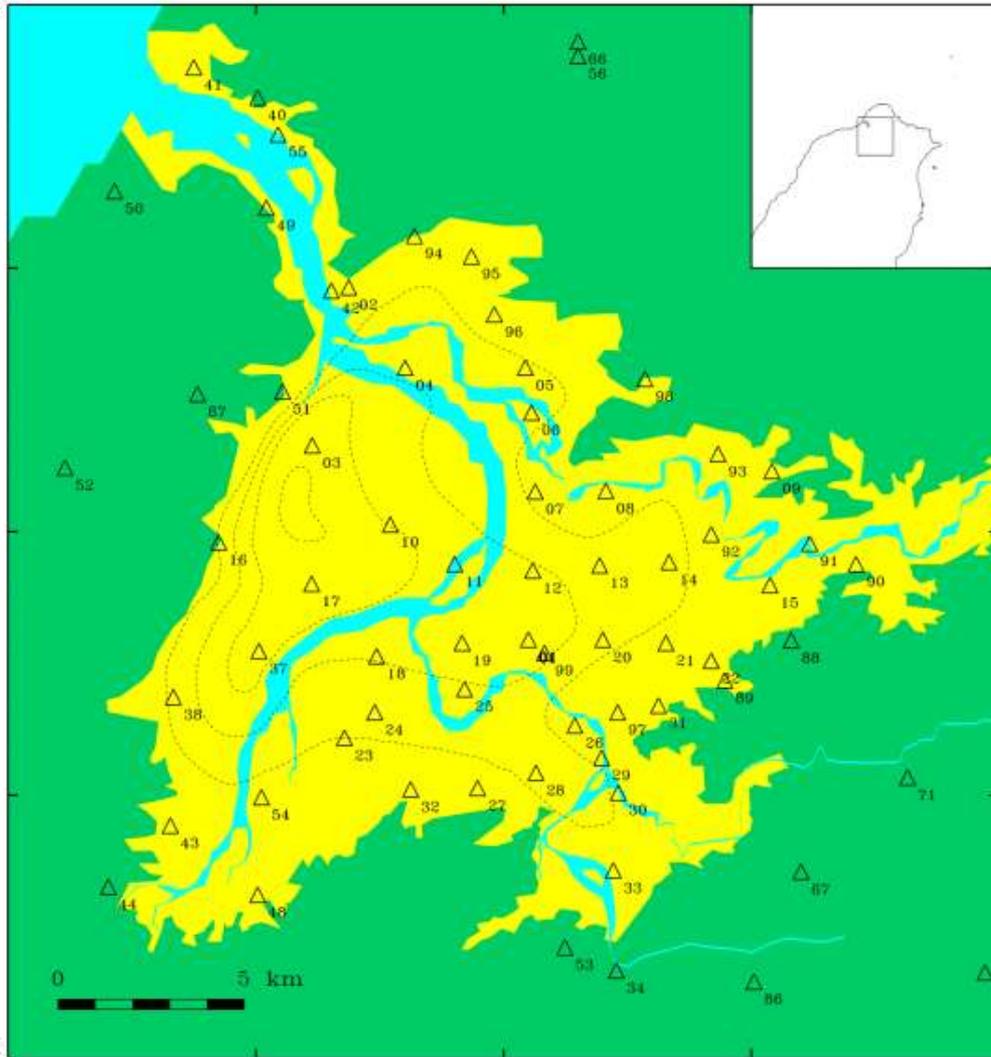
TSMIP Network



Taiwan Strong Motion Instrumentation Program (TSMIP) is a plan operated from July 1991 by the SOC, CWB. The program installed more than 600 digital free field strong motion instruments, and 400 x 3 digital channels of strong motion monitoring systems in nine metropolitan areas.

TSMIP - TAIPEI AREA

25-12



24-56

121-22

121-38

Locations of the strong motion stations in Taipei area. Numbers indicate the station codes of TSMIP network (CWB).

**IDS, A900
16 bits
Mem. Chip**

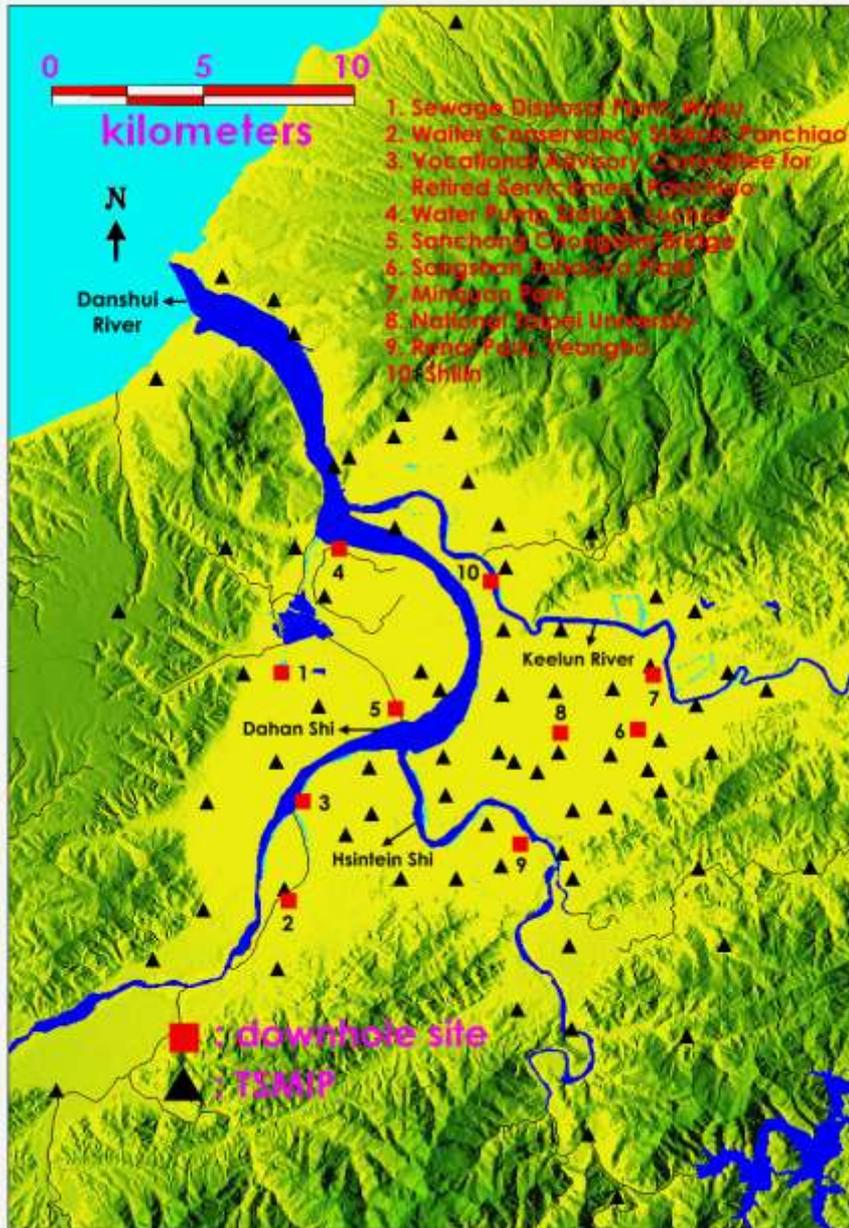
**ETNA
18 bits
PCMCIA**

**200 sps
250 sps (IDS)**



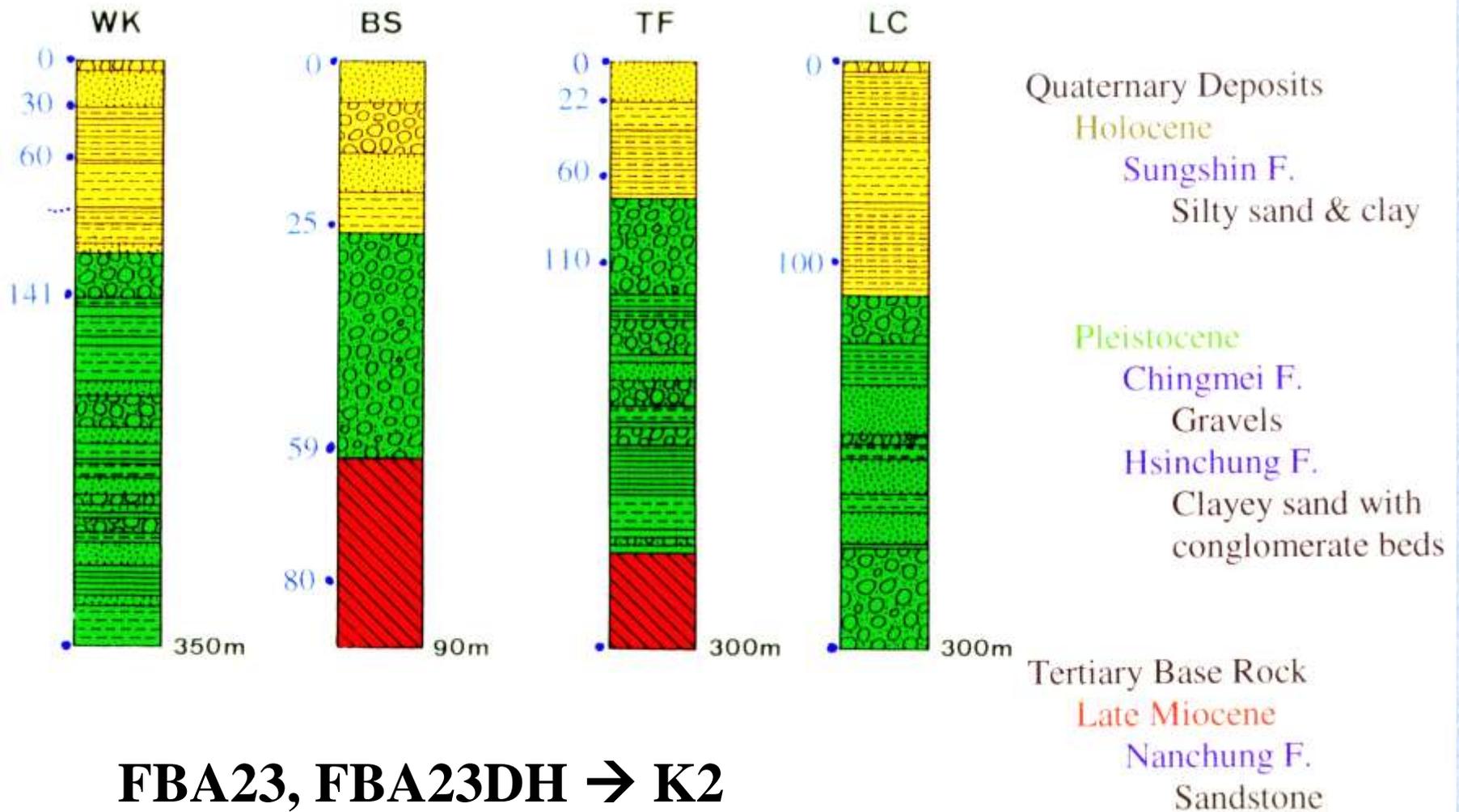
國立中央大學

Downhole Arrays in Taipei Basin



A plan conducted by the CGS, MOEA since Aug. 1991. This project proposed the installation of downhole arrays in Taipei Basin one site per year to analyze the variation of seismic waves propagated from basement to ground surface.

In February 2002, the CGS finished the research project and removed it to IES. After few months rearranging and planning, four additional downhole sites were under consideration.



FBA23, FBA23DH → K2

19 bits, 200 sps

- **Geological structure**
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Ground Motion Responses

Earthquake ground motions

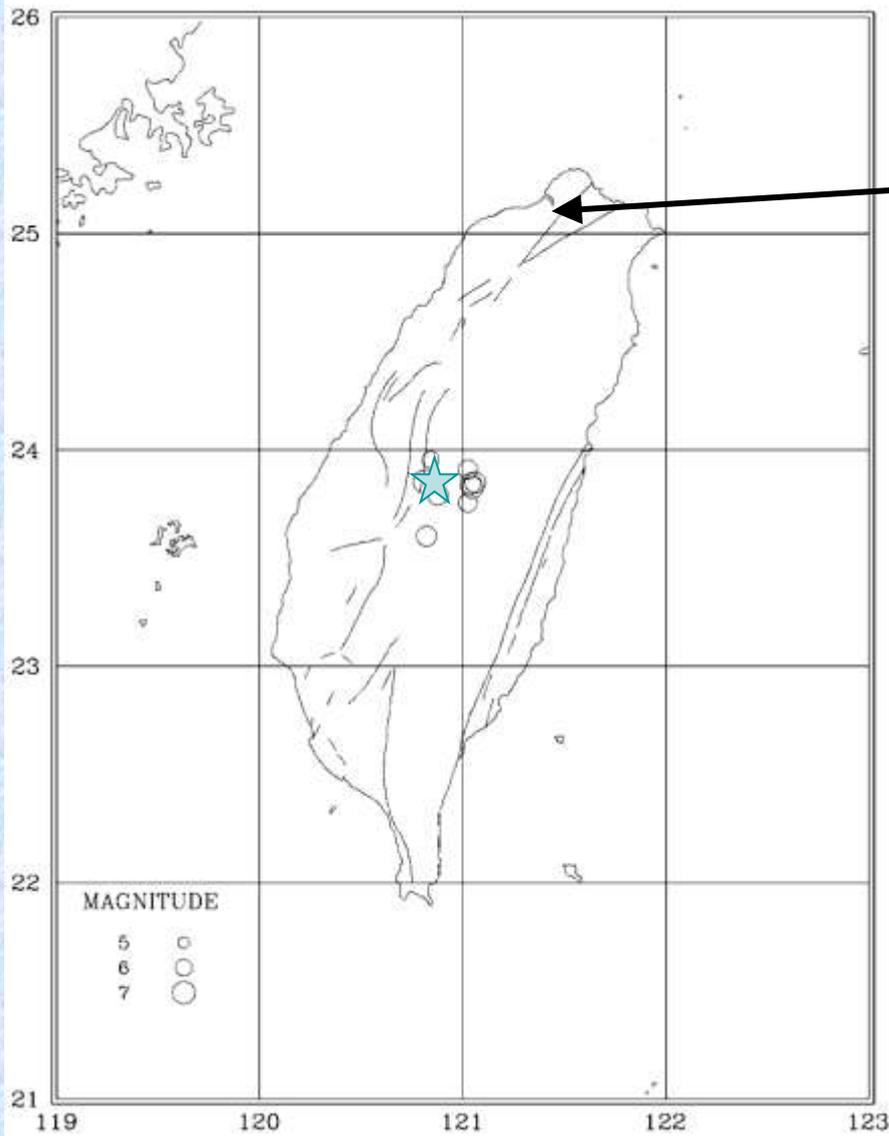
Microtremor survey

Theoretical modeling



Source parameters of the Chi-Chi earthquake sequence

Event No	Origin Time	Epicenter	Depth (km)	M _L
1	1999 9 20 17:47:16	23.85N 120.82E	8	7.3
2	1999 9 20 17:57:15	23.91N 121.02E	2	6.5
3	1999 9 20 18:03:41	23.79N 120.88E	4	6.6
4	1999 9 20 18:05:53	23.95N 120.84E	20	6.0
5	1999 9 20 18:11:53	23.85N 121.06E	5	6.7
6	1999 9 20 18:16:16	23.84N 121.04E	4	6.7
7	1999 9 20 21:46:37	23.60N 120.82E	5	6.6
8	1999 9 22 00:14:41	23.83N 121.05E	8	6.8
9	1999 9 22 00:49:43	23.76N 121.02E	9	6.3



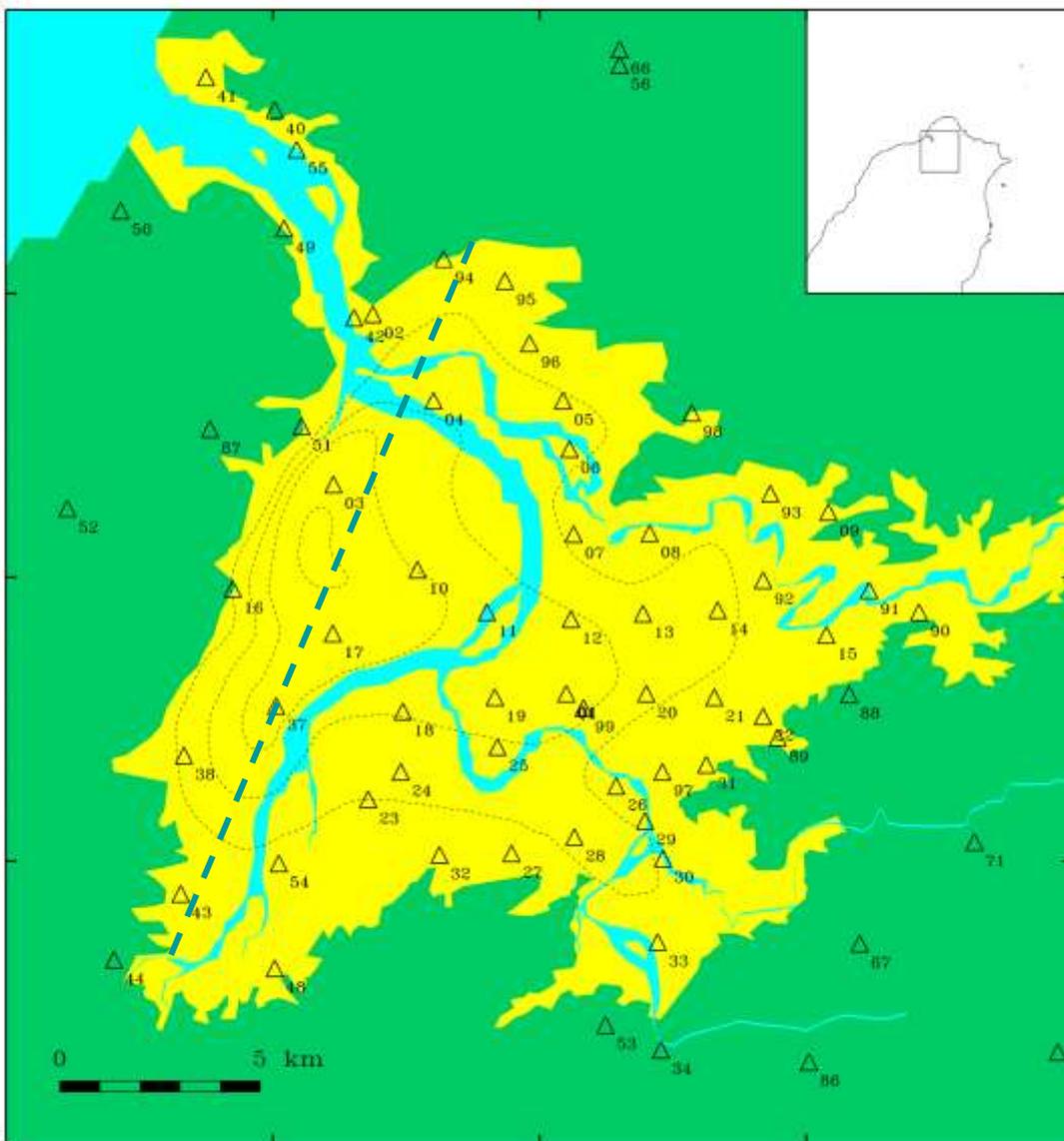
Tapei Basin

1999/09/20 17:47

Chi-Chi earthquake

TSMIP - TAIPEI AREA

25-12



24-56

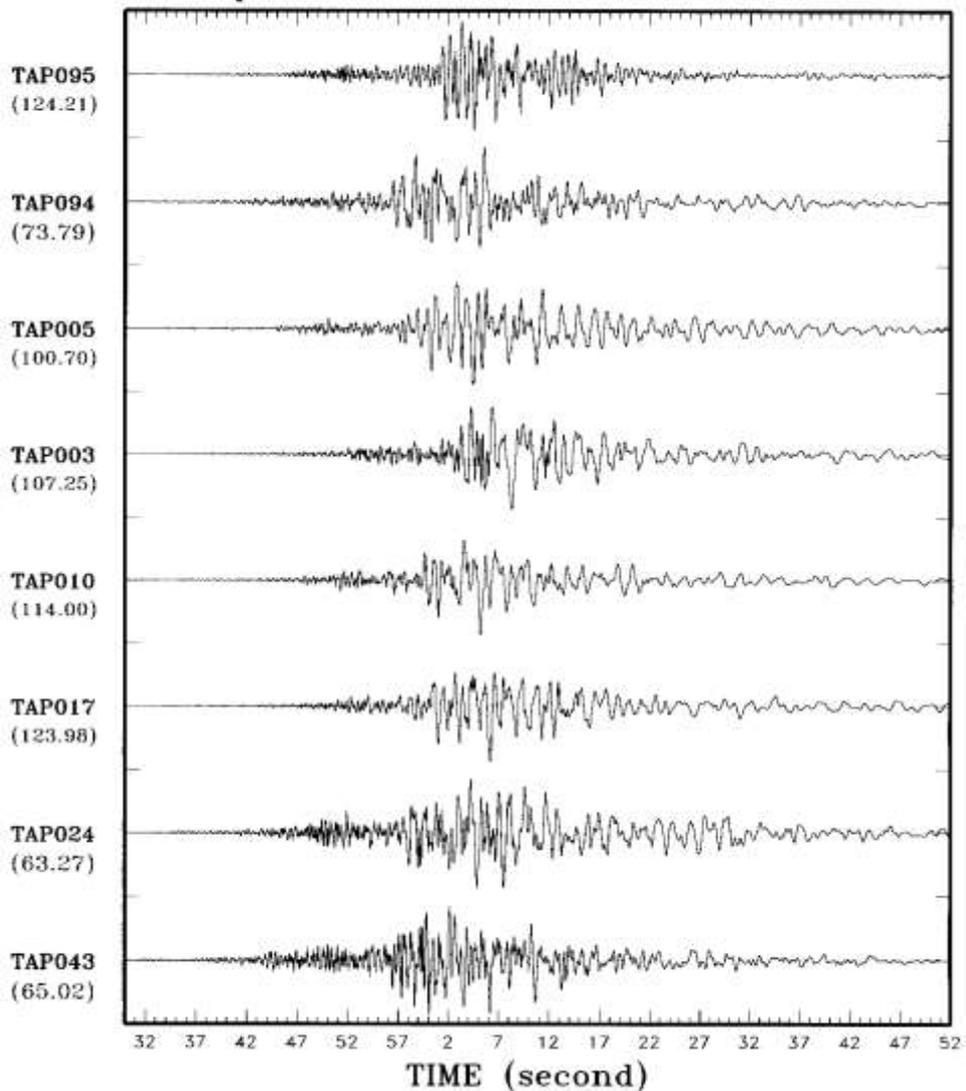
121-22

121-38

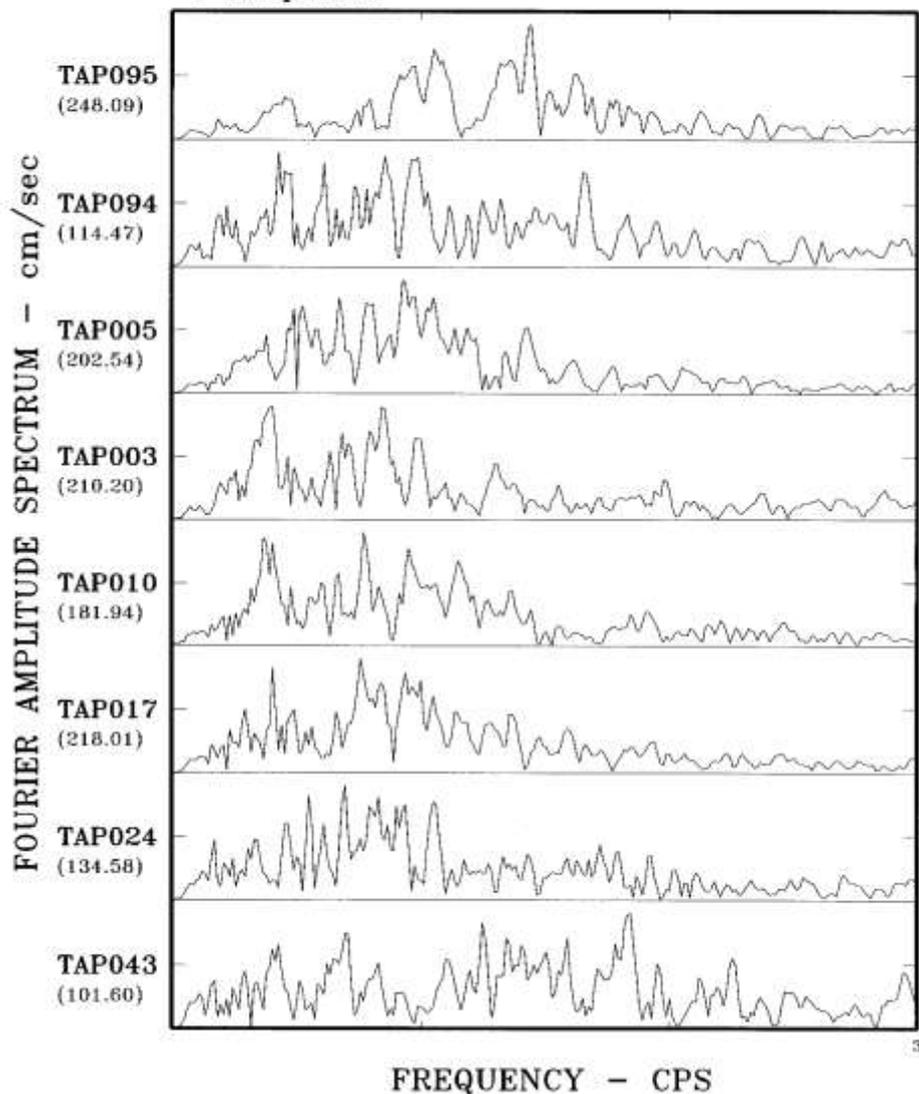
中央大學



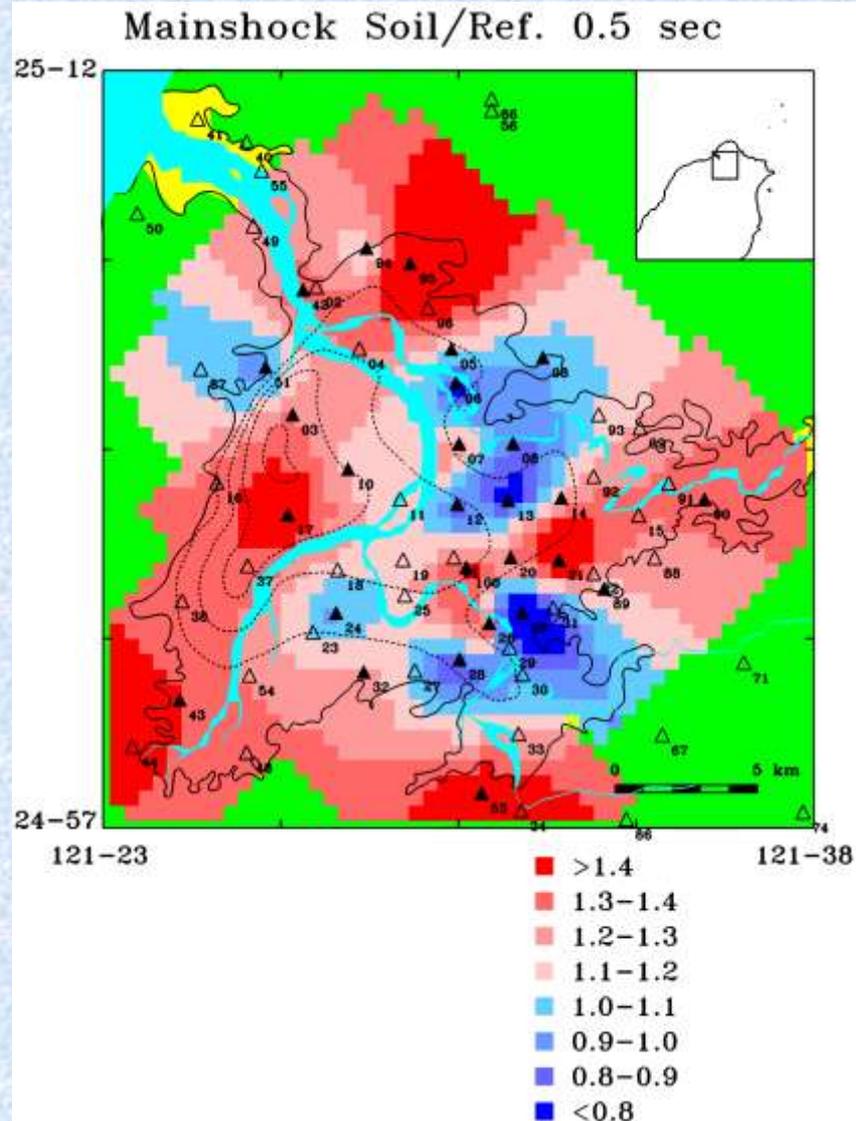
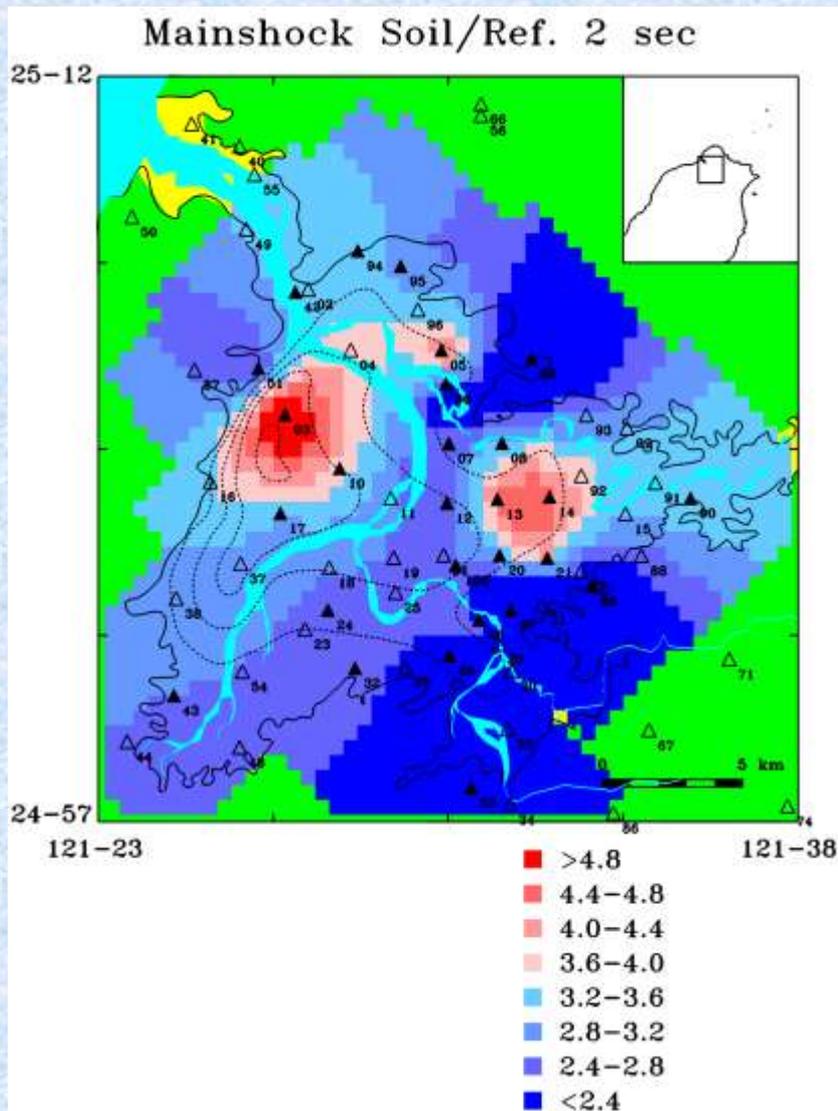
ACCELEROGRAM OF EQ. 1999-9-20 17:47 UT
T Component



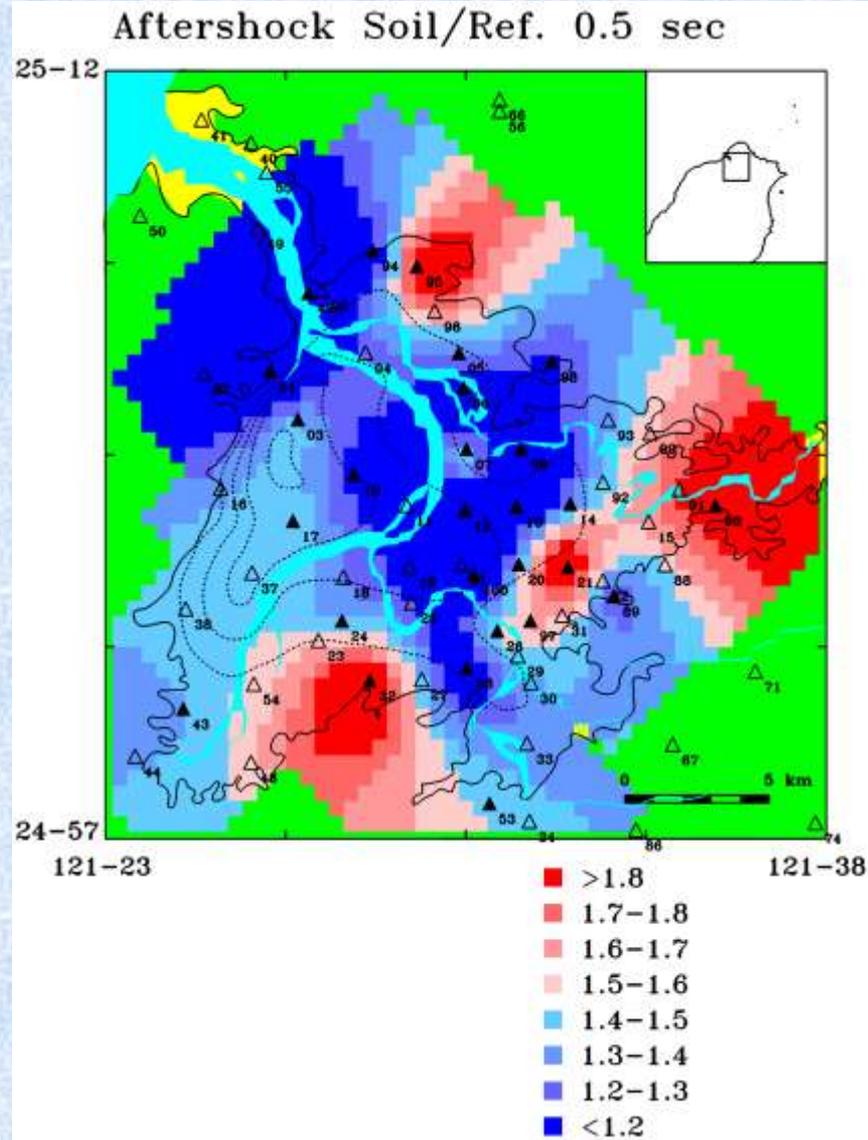
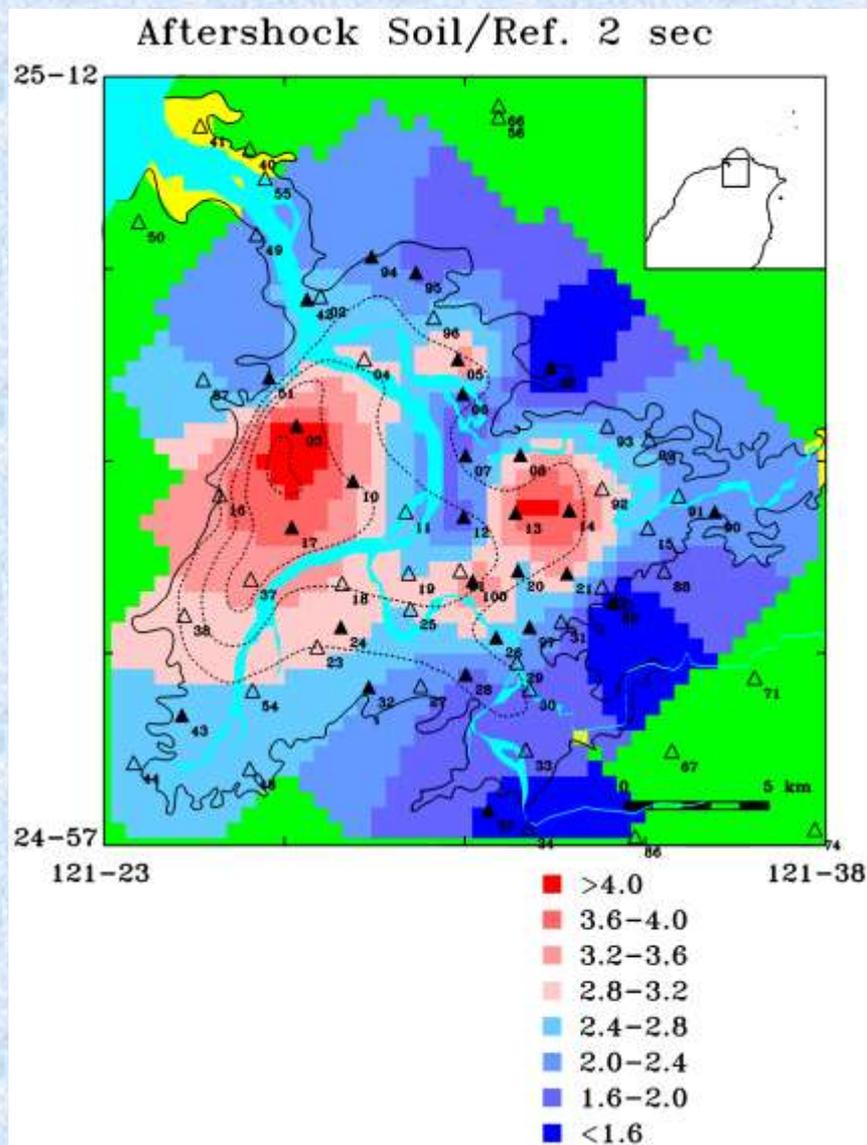
EARTHQUAKE 1999-9-20 17:47 UT
T Component



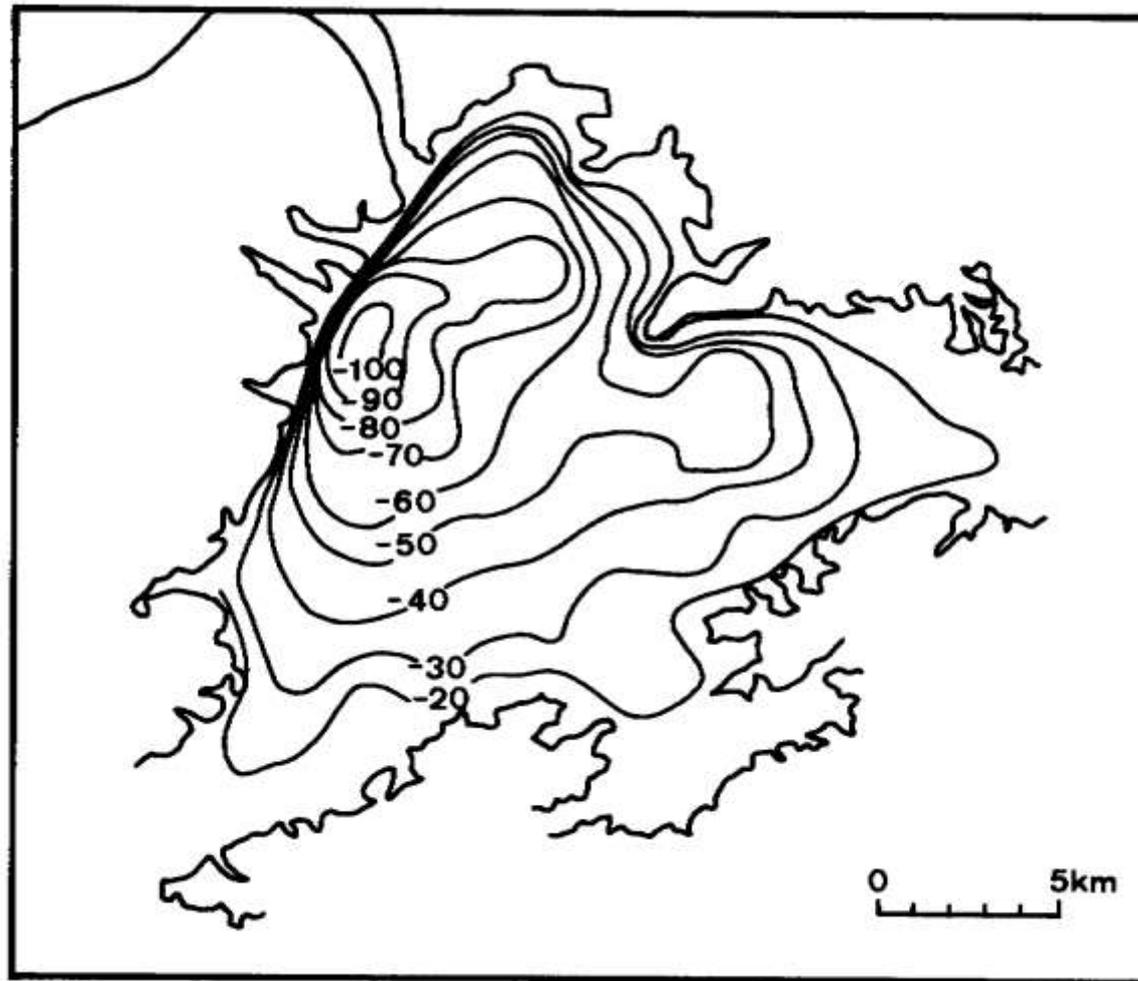
Spectral ratio contours of the Chi-Chi earthquake in the Taipei basin.



Spectral ratio contours of the Chi-Chi aftershocks in the Taipei basin.

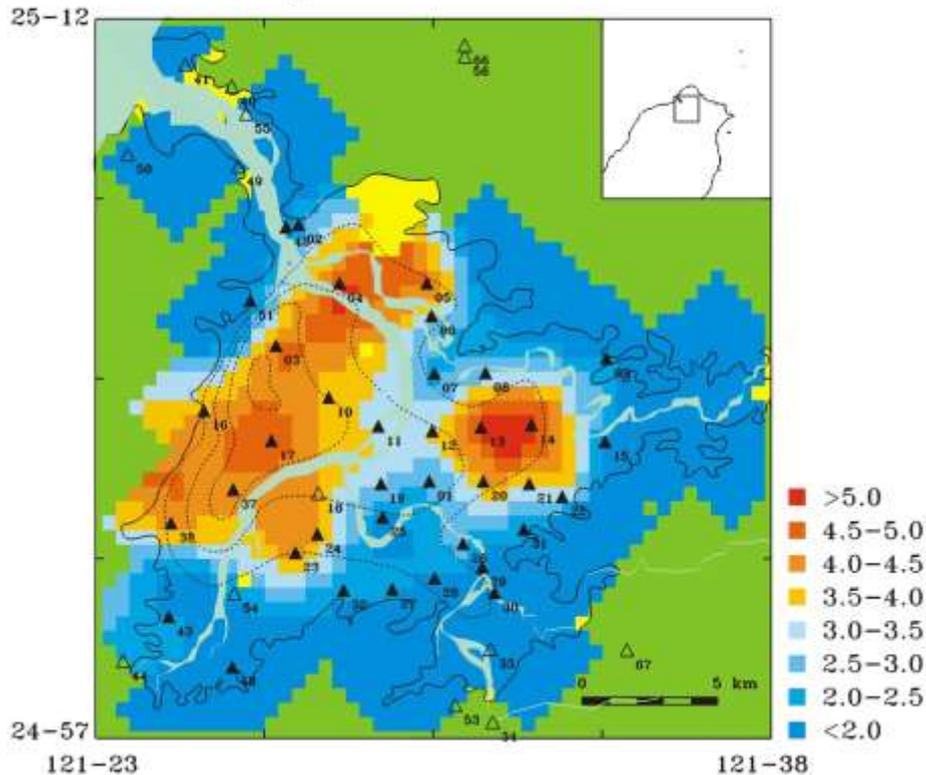


Sungshan Formation Bottom - Taipei Basin -

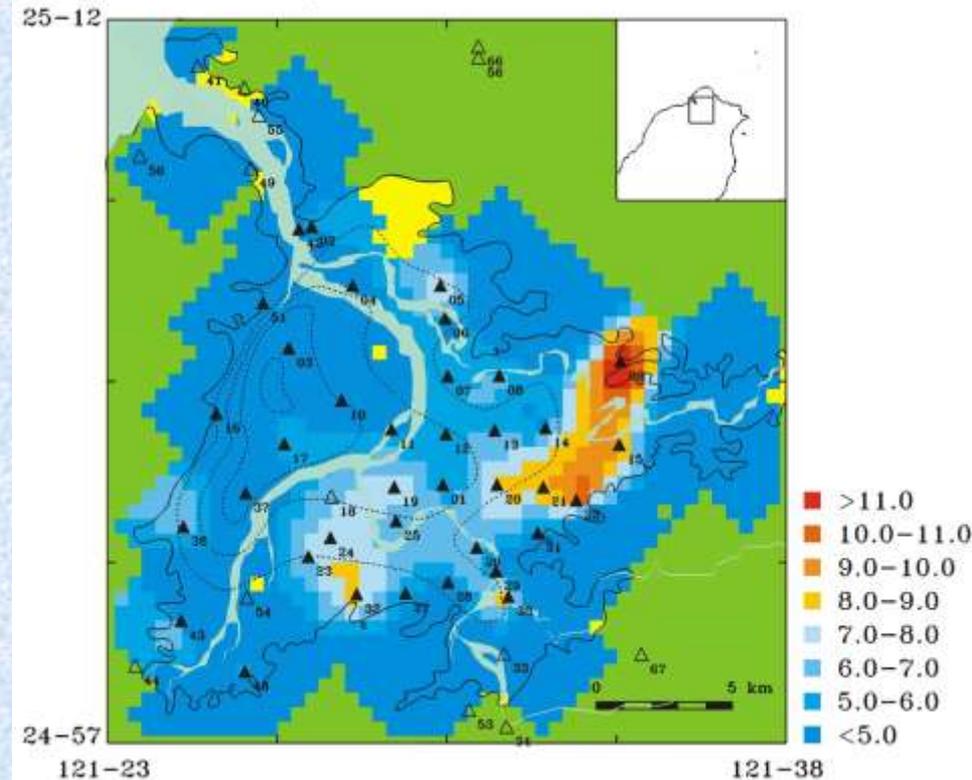


Mean spectral ratio obtained before the Chi-Chi earthquake. The earthquake used are occurred at south-eastern and eastern direction of the Taipei basin.

Soil/Rock - 2.0 sec

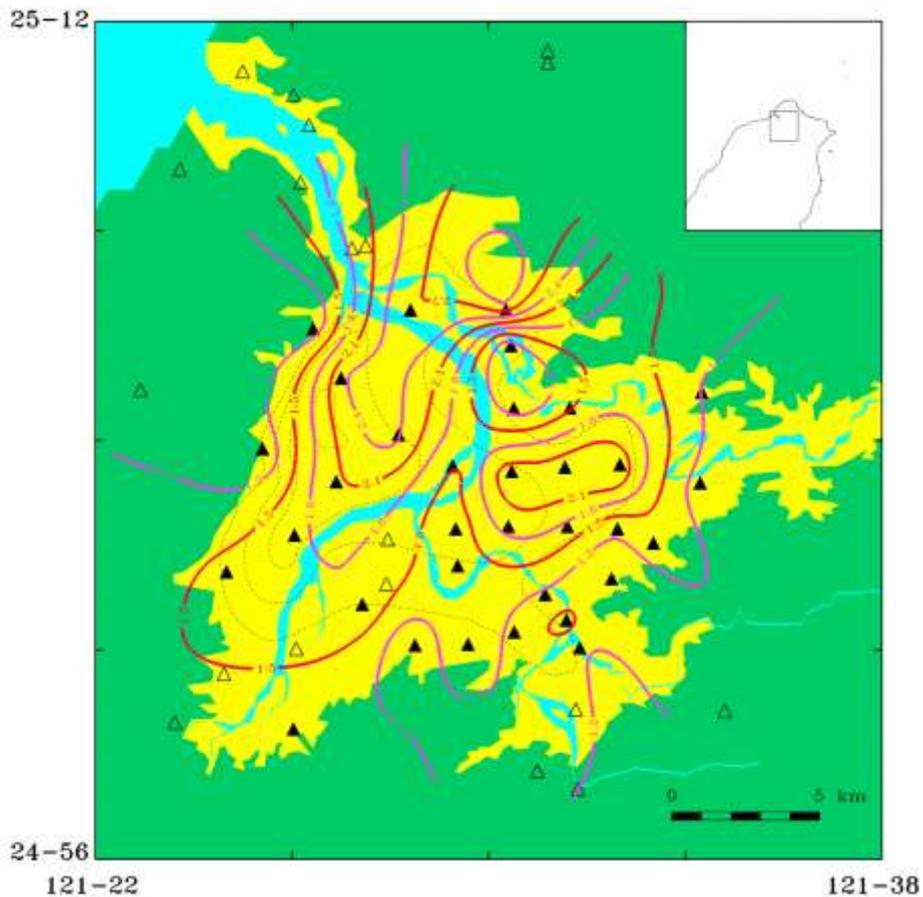


Soil/Rock - 0.5 sec

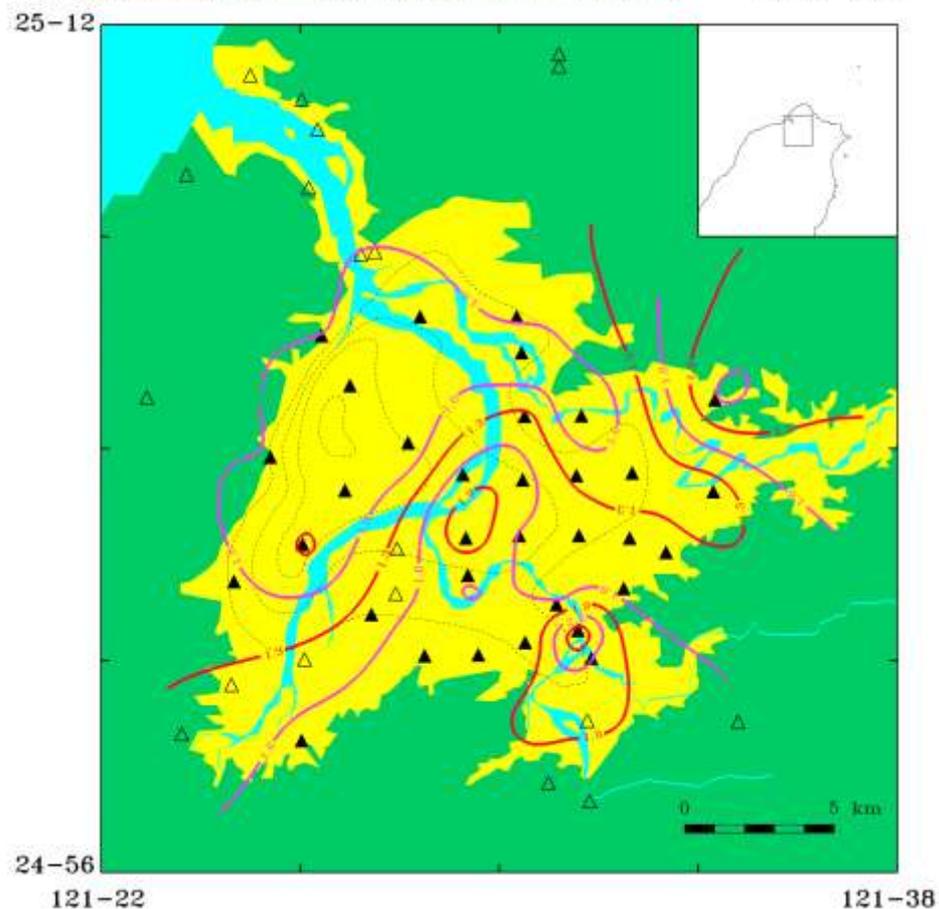


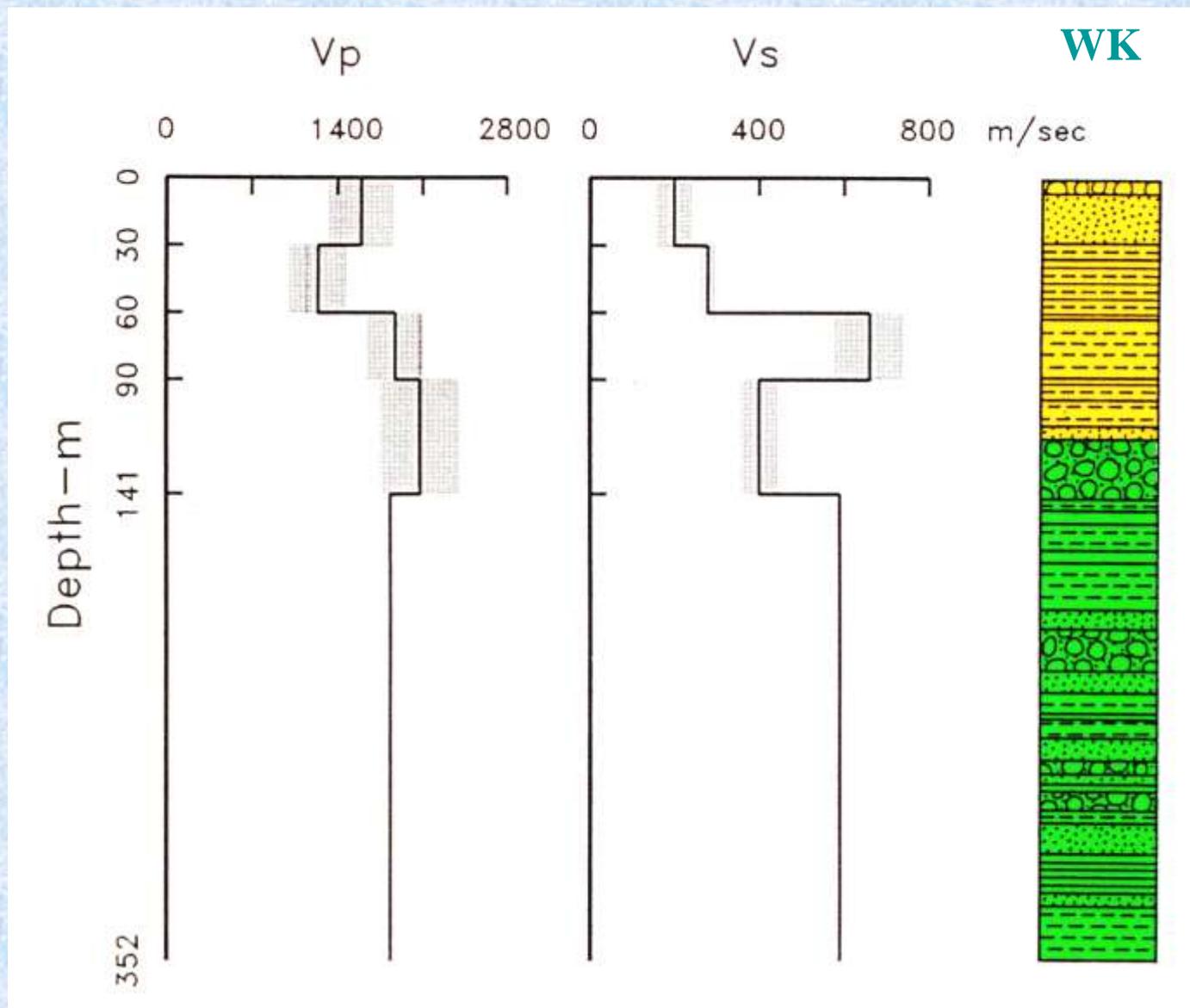
TSMIP測站微地動資料於2秒與0.5秒之Nakamura比等值圖。

Microtremor Nakamura's Ratio - 2 sec



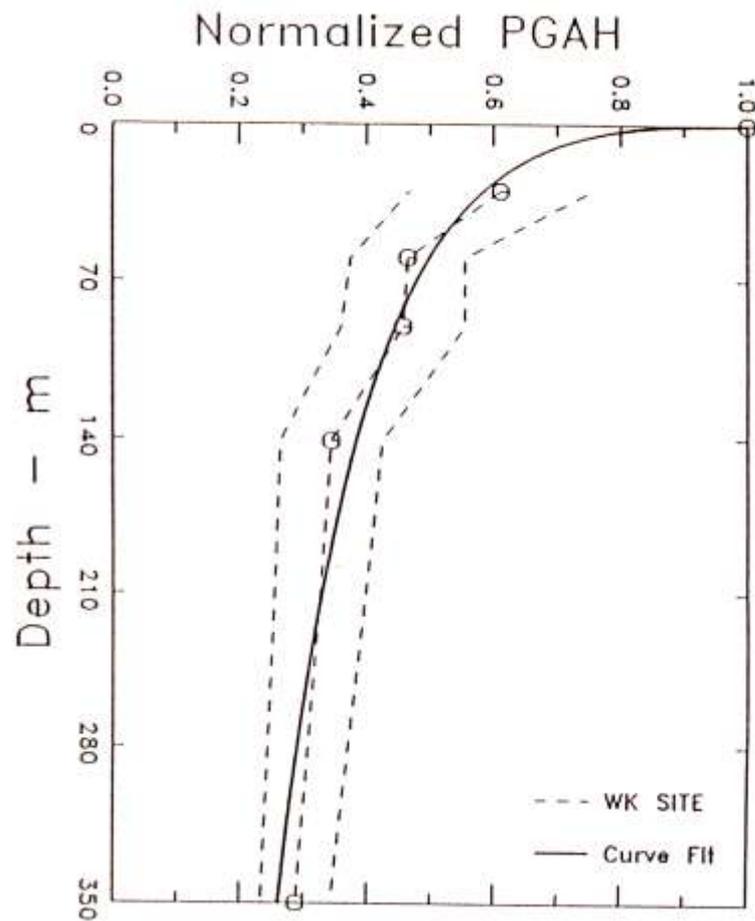
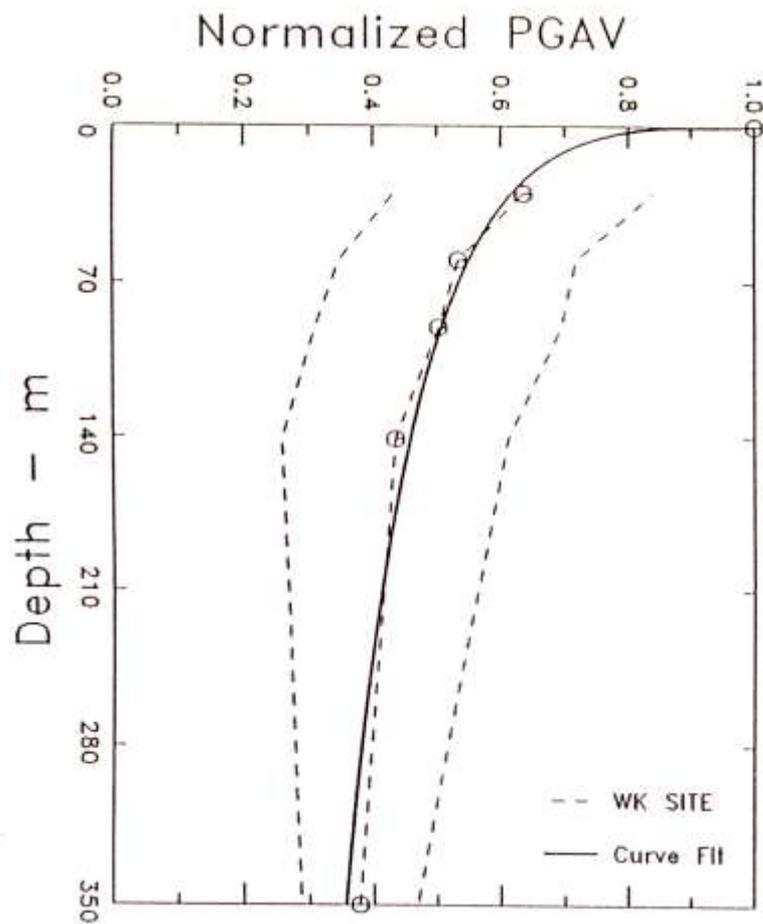
Microtremor Nakamura's Ratio - 0.5 sec





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五股抽水站最大地動加速度與地下深度關係圖。



WK

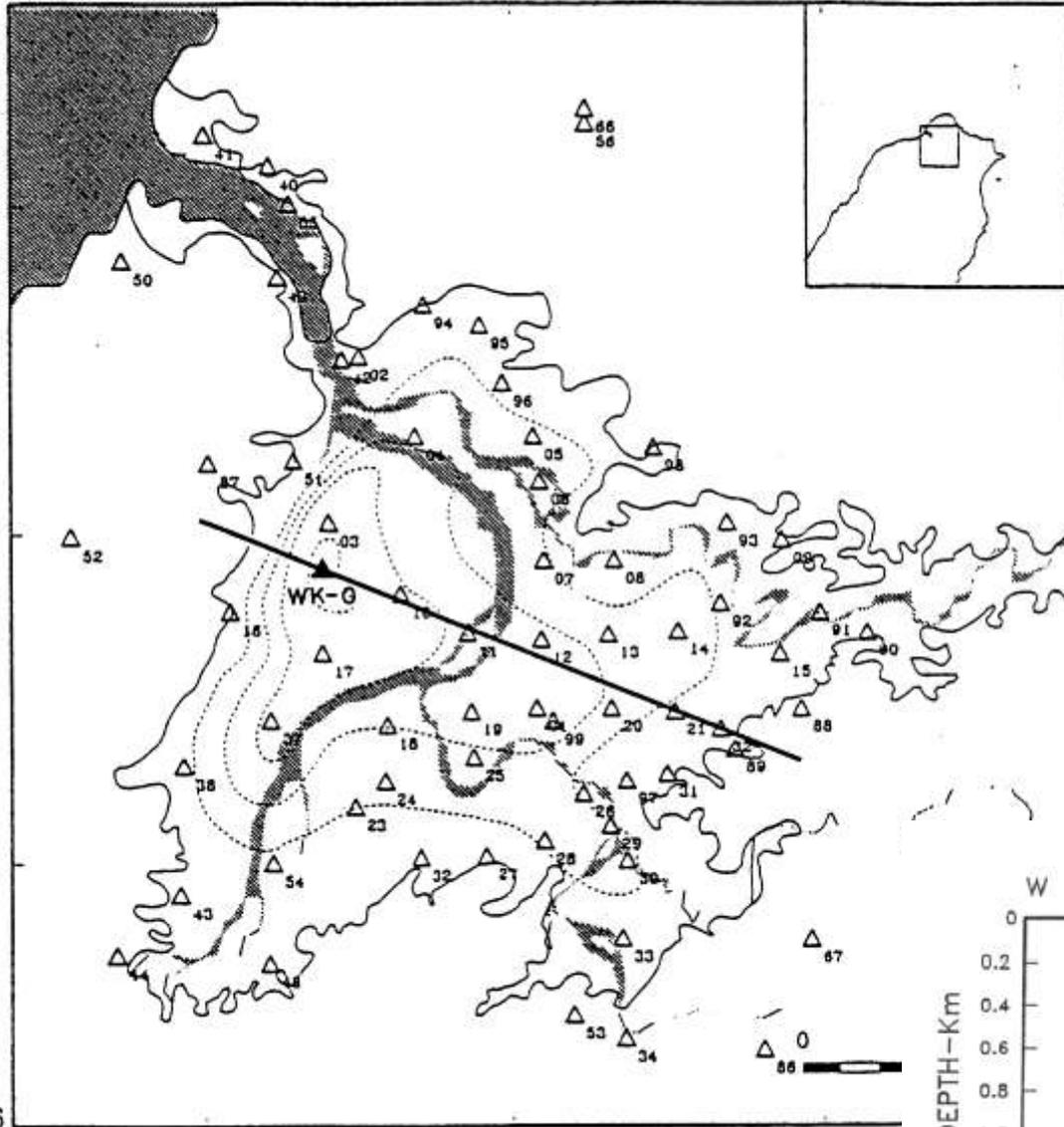


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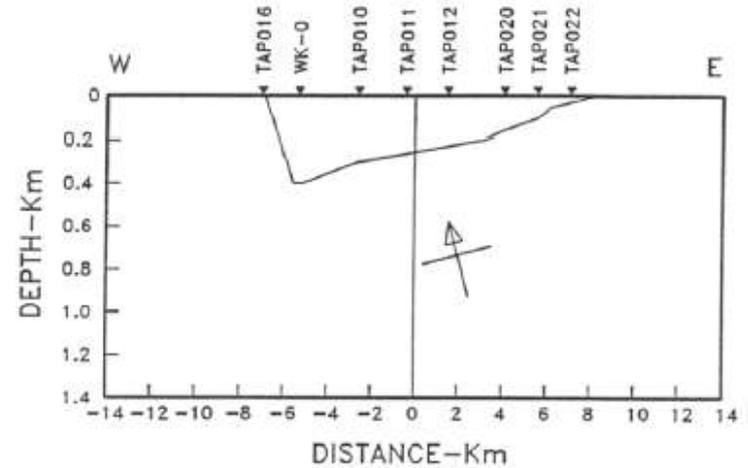
25-13

24-56

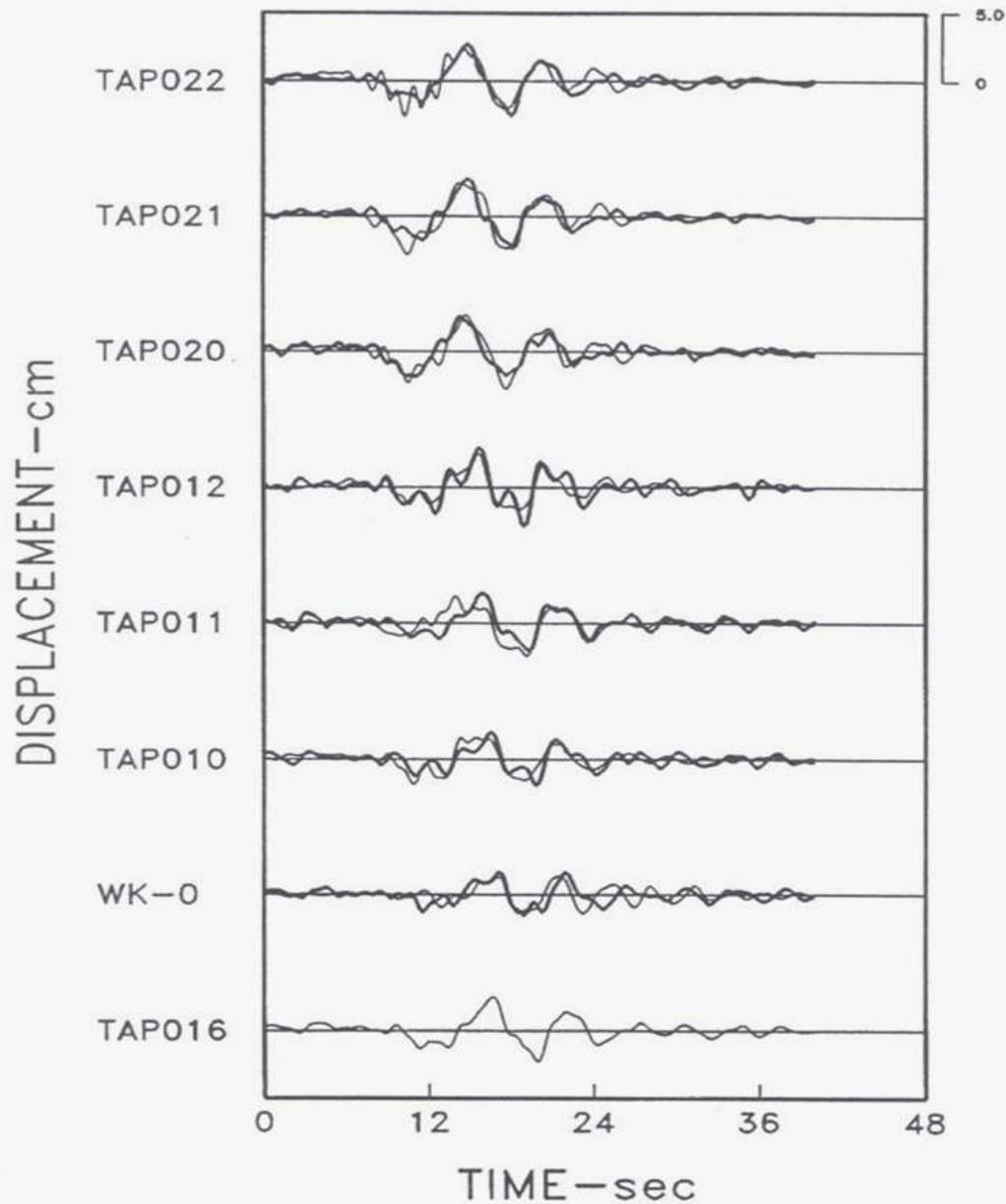
121-22



**Peng & Wen
(1998)**



1994 6 5 1:9 UT



2D模擬

2D Modeling

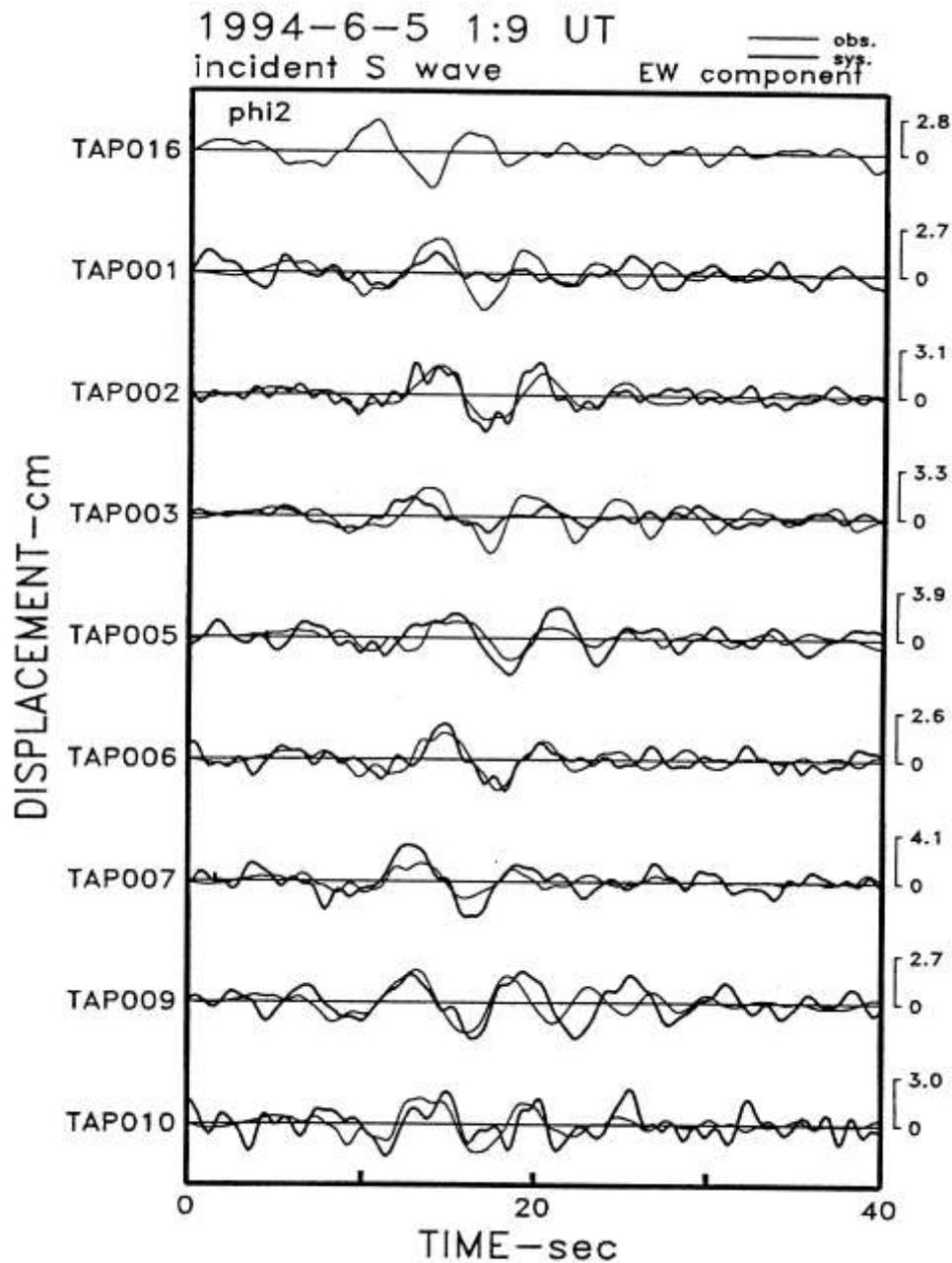
WK site

0-30m: $Q(f)=3.6f^{0.96}$

30-60m: $Q(f)=7.2f^{0.99}$

60-90m: $Q(f)=10.2f^{1.17}$

90-141m: $Q(f)=40.7f^{1.24}$



台北盆地3D模擬 3D Modeling

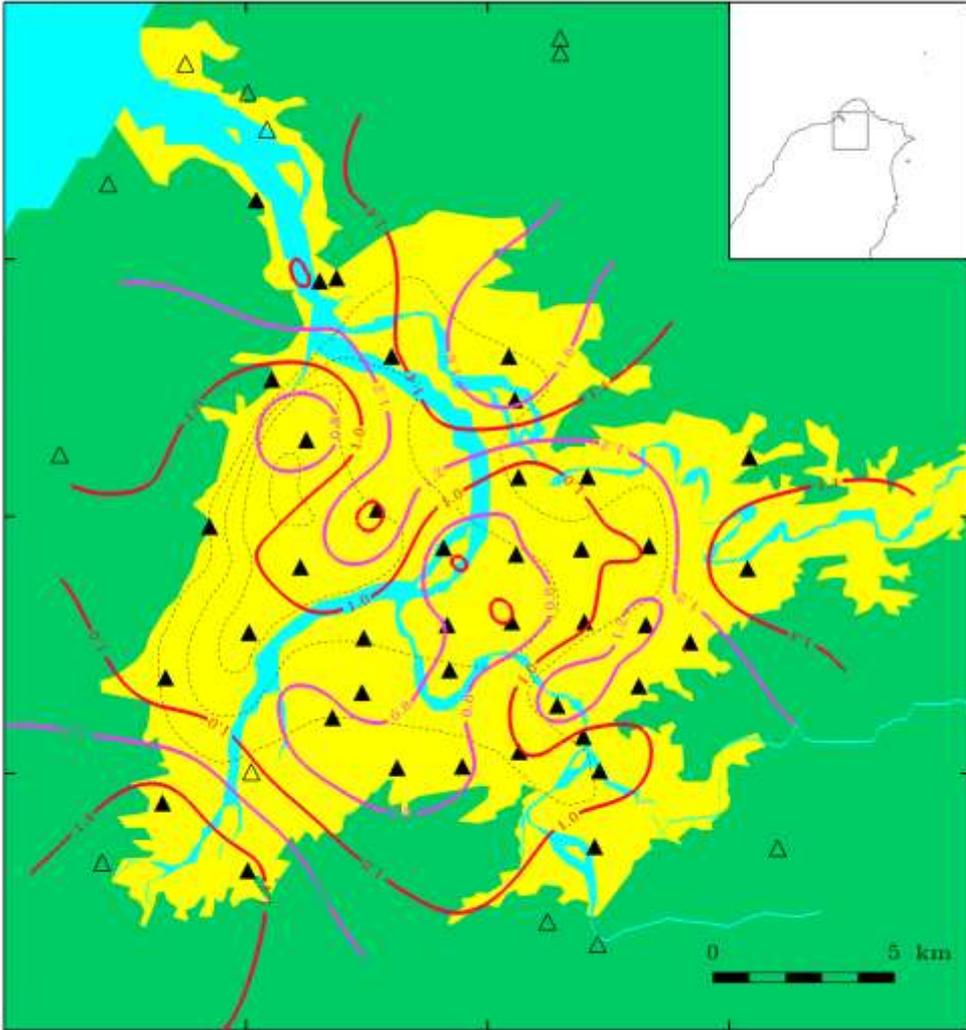
3D Modeling - 2 sec

25-12

24-56

121-22

121-38



三維理論模擬TSMIP
地表與參考站
(TAP016)
於2秒之頻譜比等值圖



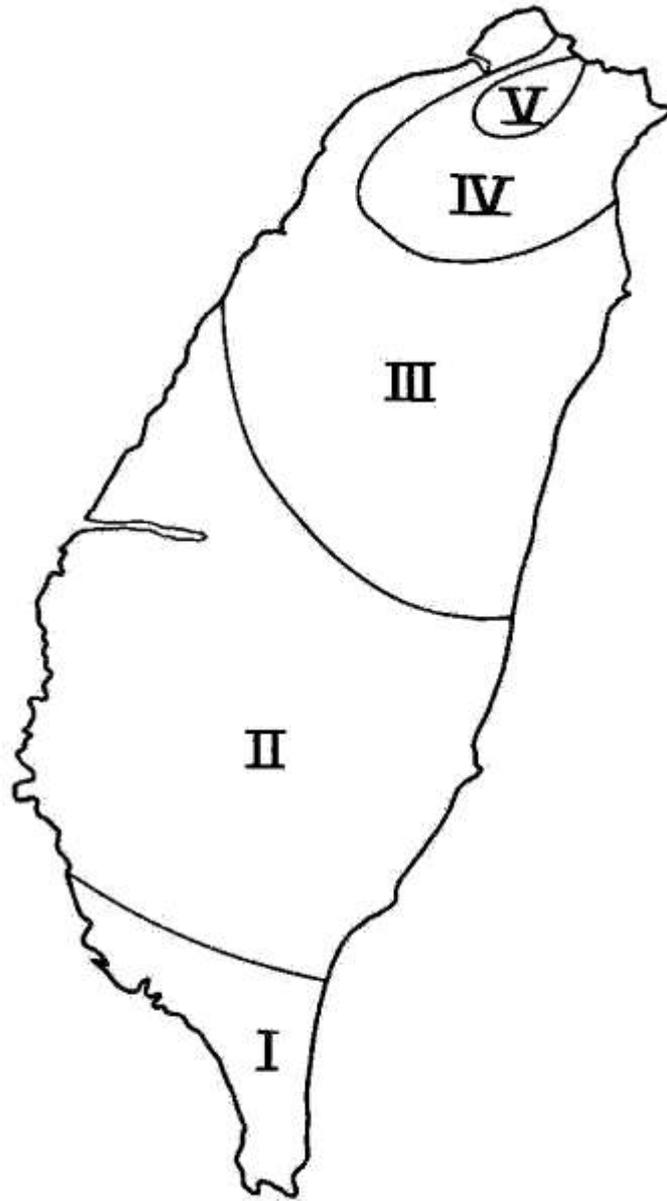
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- **Ground motion responses**
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- **Recent researchs**

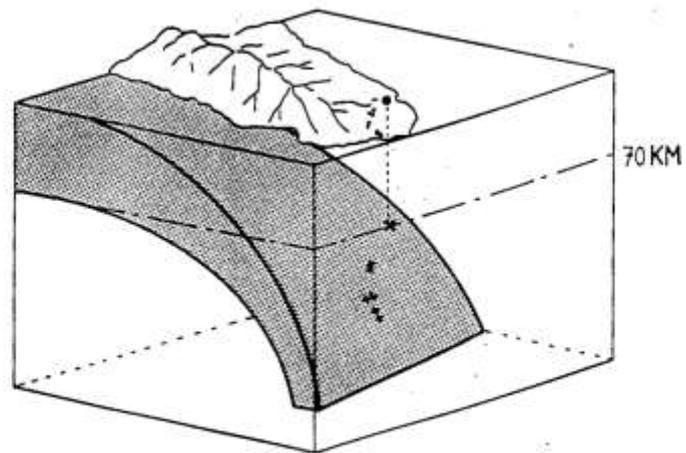
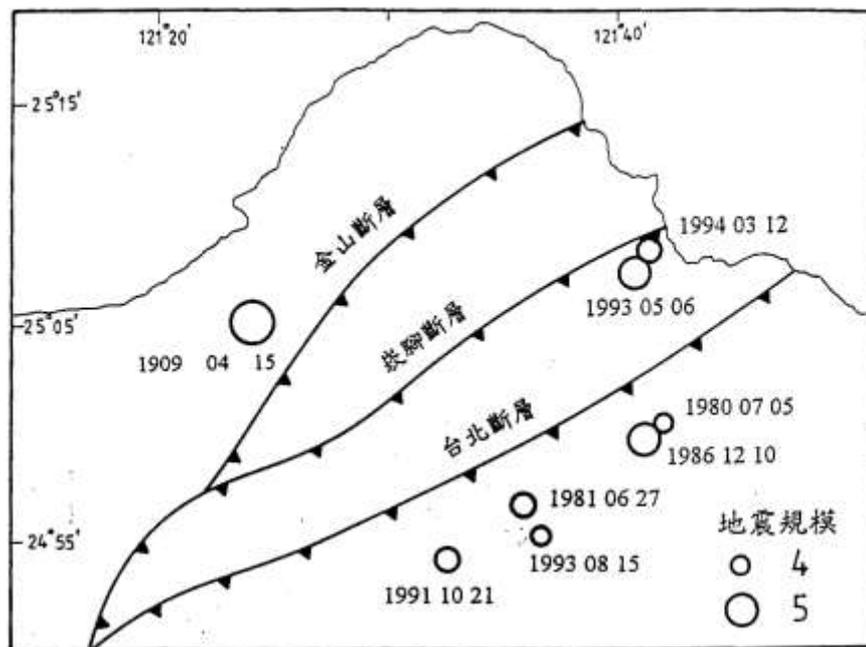
■ **Historical Damaged Earthquakes**

- **Apr. 15, 1909 7.3**
- **Nov. 15, 1986 6.8**
- **Sep. 21, 1999 7.3**
- **Mar. 31, 2002 6.8**

**1909/4/15
Taipei Eq.**



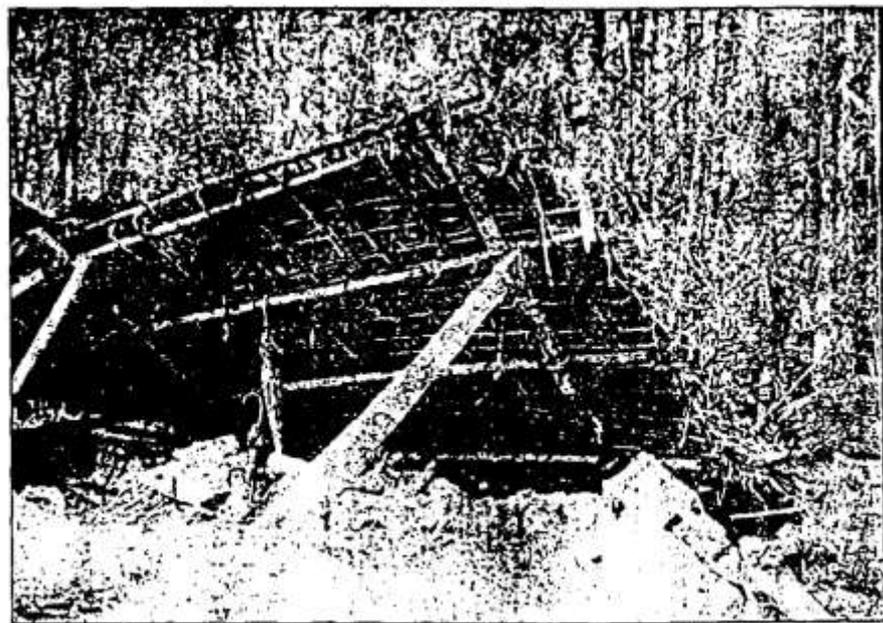
1909年4月15日所發生地震之等震度圖 (Hsu, 1971)



圖四 台北地震與台灣北部隱沒帶關係示意圖 (M ≥ 4)
 (x: 震源、•: 震央)

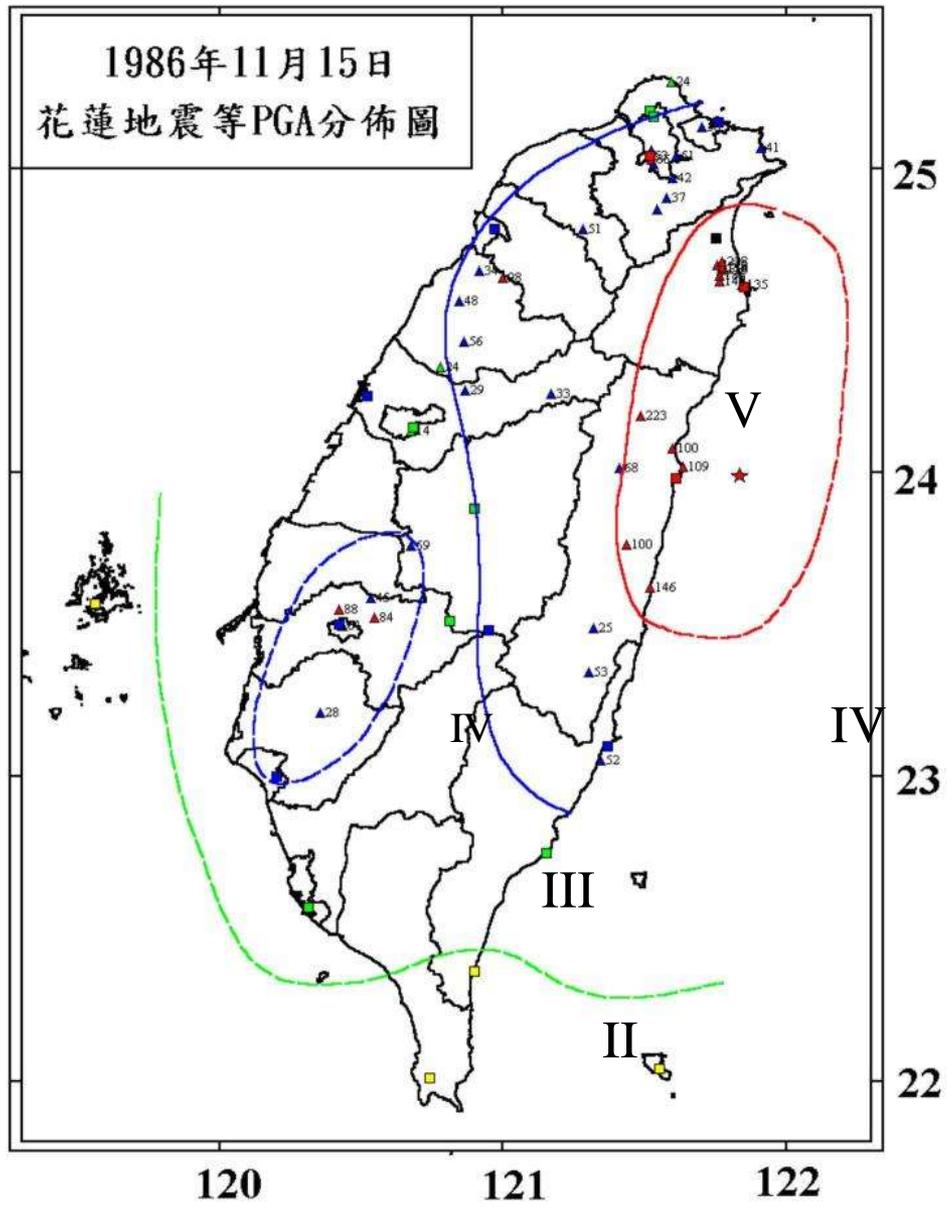


1909年4月15日台北地震於桃園堡圳岸腳庄的災害



1909年4月15日台北地震於桃園堡圳岸腳庄的災害

1986年11月15日
花蓮地震等PGA分佈圖



1986/11/15
Hualien Eq.
 $M_L=6.8$

3F



台北縣中和市員山路之華陽市場，原為三層多柱少牆鋼筋混凝土的市場建築物，由於2、3層改為住家後砌築了許多磚造外牆與隔間牆，使得建築物成為上剛下軟的結構，加上過大的超載，在耐震上十分不利。在此次地震襲擊下，幾乎大部份一、二樓的支柱折斷，造成12人死亡，數十人受傷的慘劇。

14F



台北市復興南路一段某大廈，一樓剪力牆腳及牆邊構材部份被壓碎，鋼筋暴露且扭曲變形，牆面呈斜向之剪力龜裂，一、二樓間之混凝土樓板破裂並下陷。

12F



台北市二棟大廈因棟距過近且振動頻率不相同，造成頂樓碰撞受損，5月20日花蓮地震受損後修補的位置再次損壞。

12F



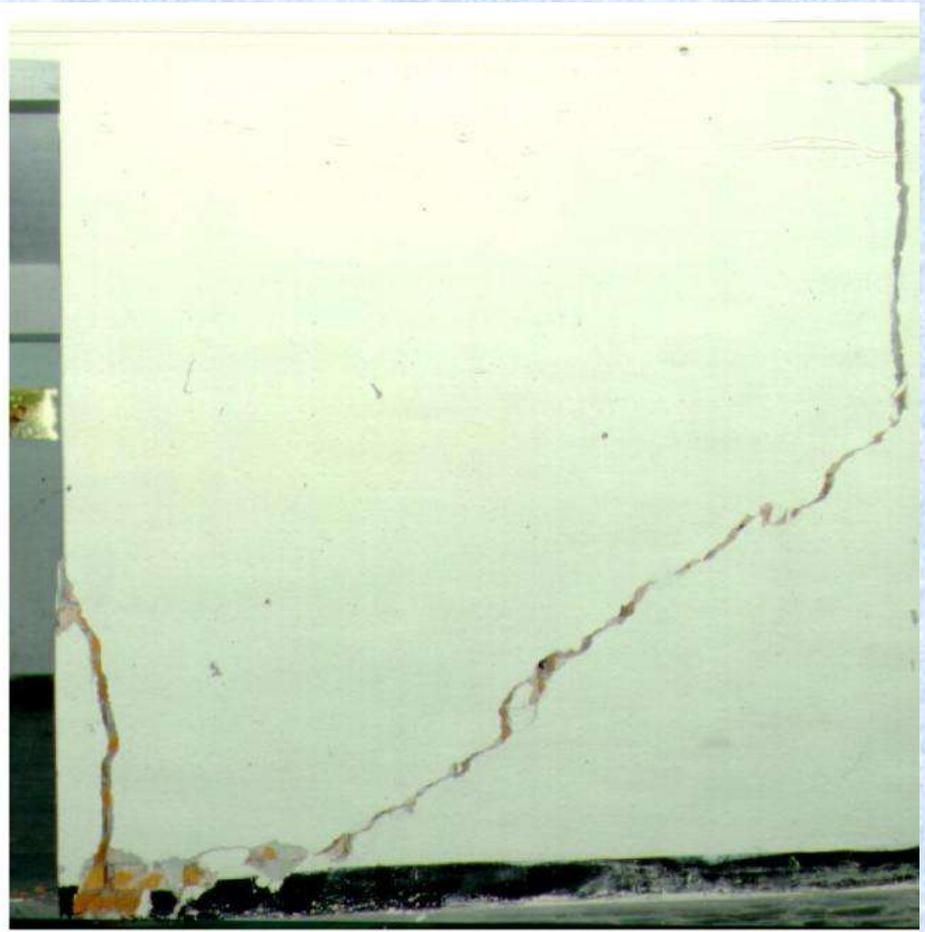
台北市基隆路某汽車公司，門前與建築物中之鋼筋混凝土柱暴裂，鋼筋扭曲變形。



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13F

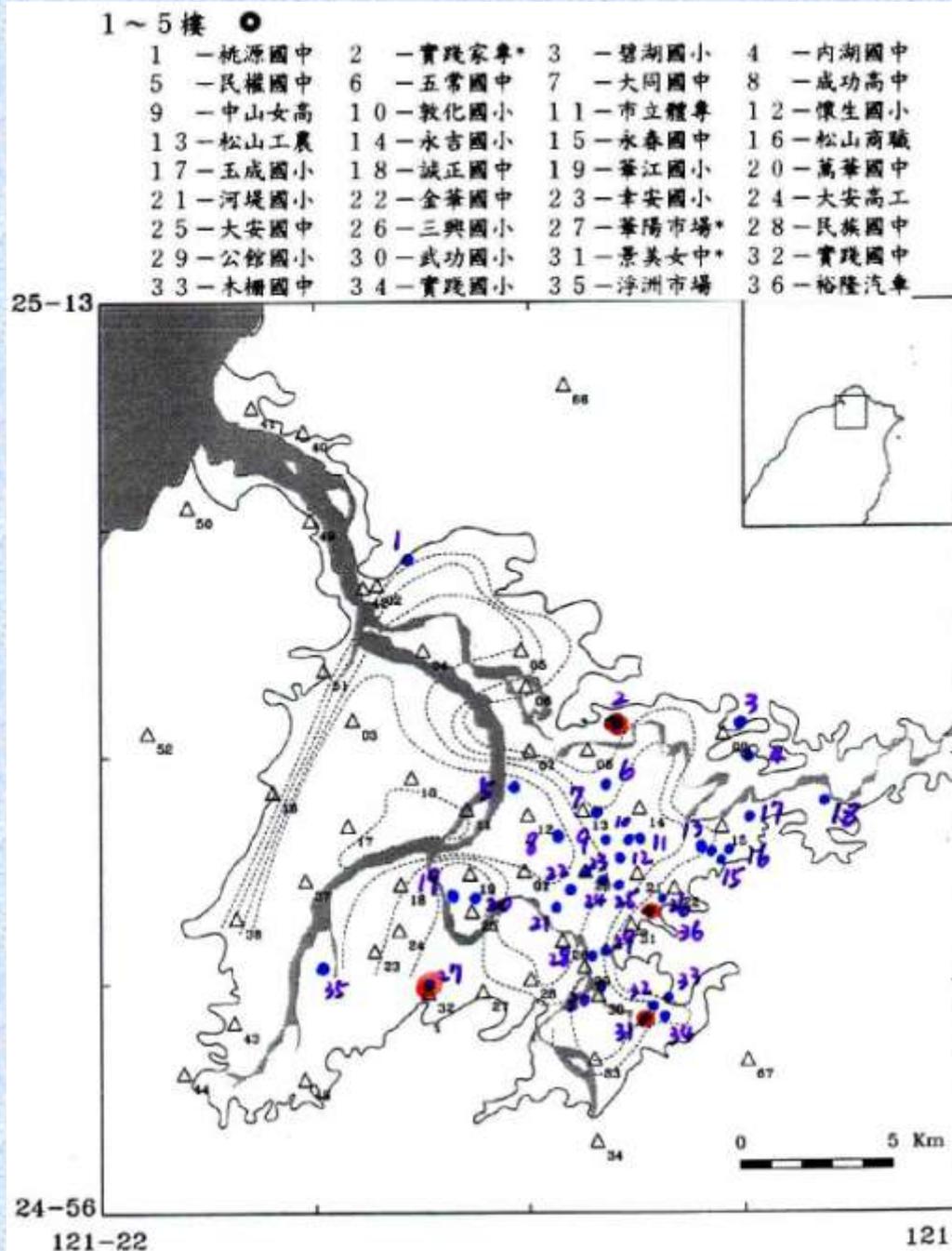


台北市基隆路一段某大廈外牆破壞情形，該大樓自9樓以下
電梯間大樑、樓梯間牆壁，大樓外牆均發生龜裂，部份樑
柱牆壁龜裂處之水管斷裂；8樓之牆壁呈斜向之剪力破壞。

1986/11/15

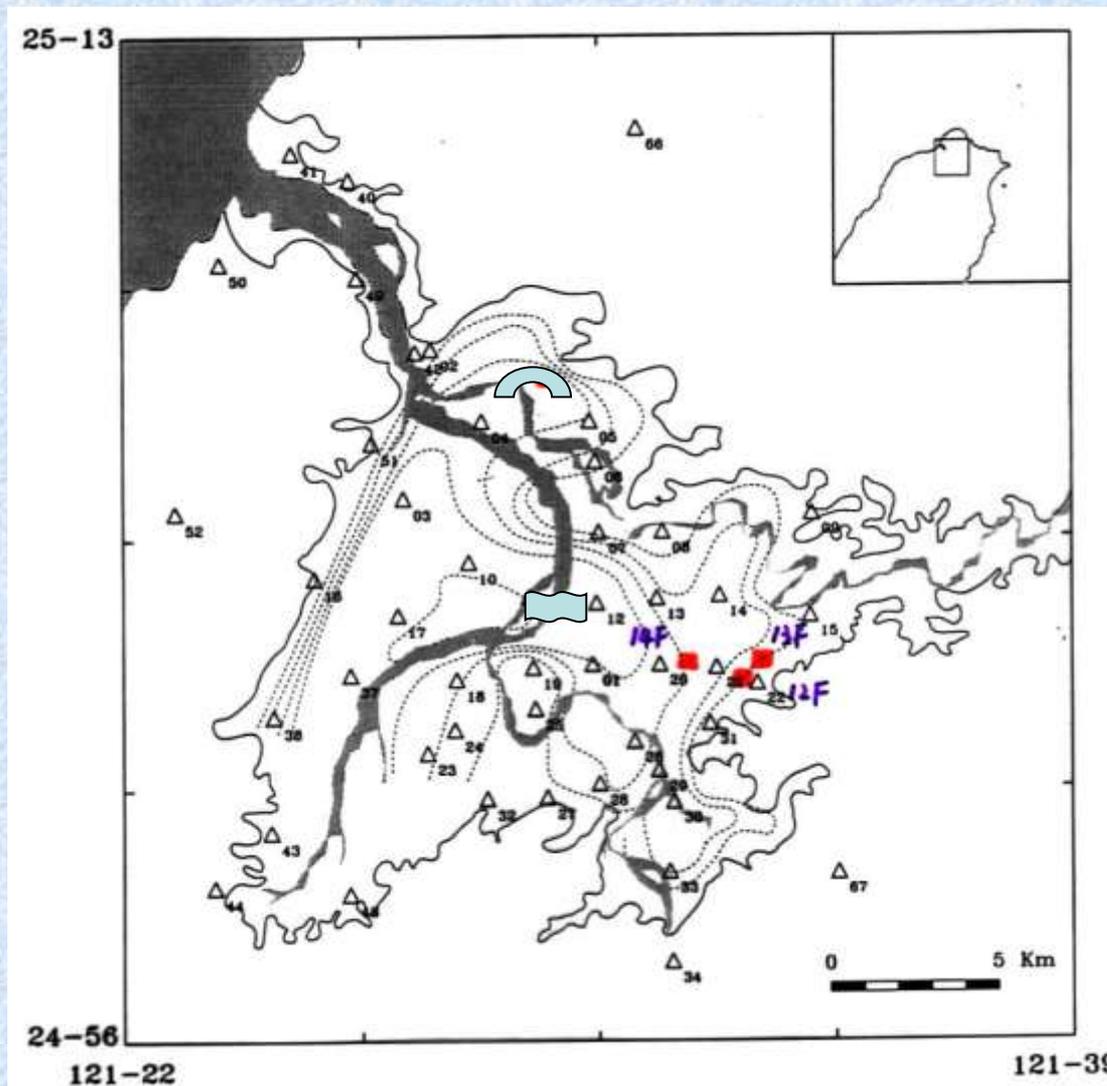
$M_L=6.8$

1~5F



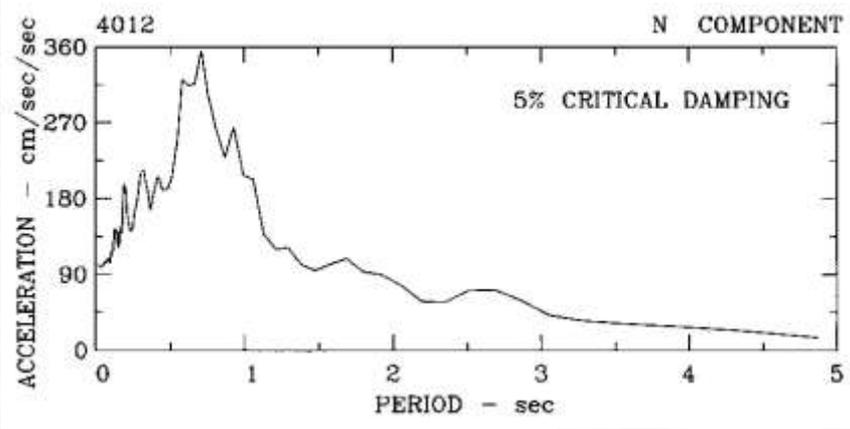
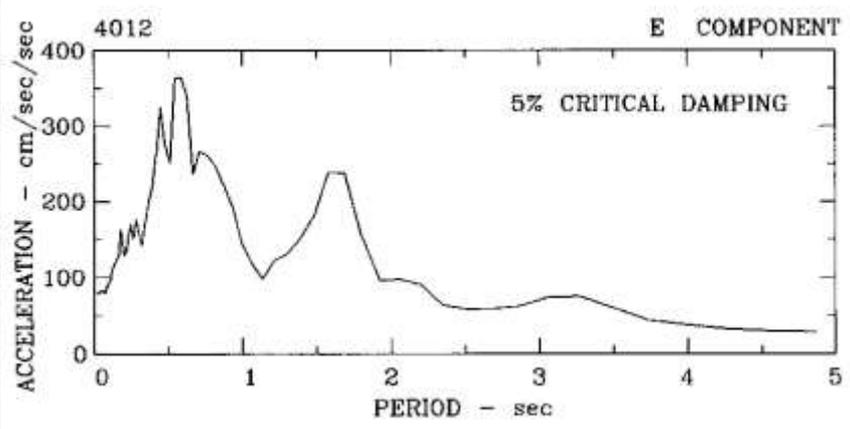
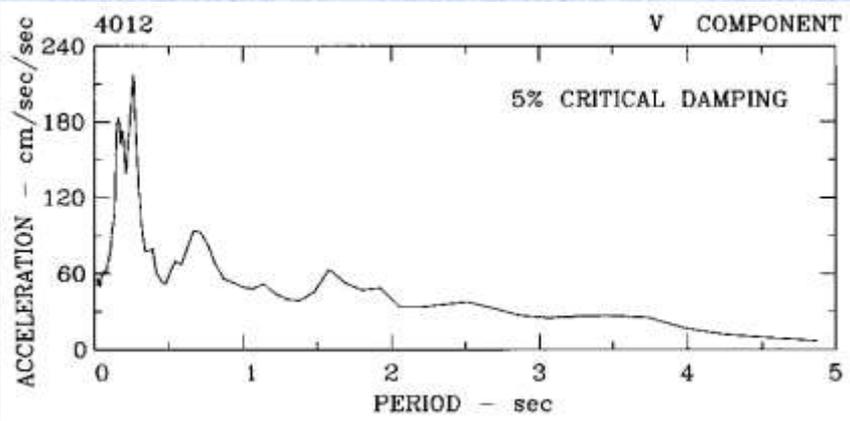
忠孝大橋  陽明山瓦斯 西安街 

14F-裕台大樓* 13F-惠寶大樓* 12F-富貴大樓 (必勝客)*



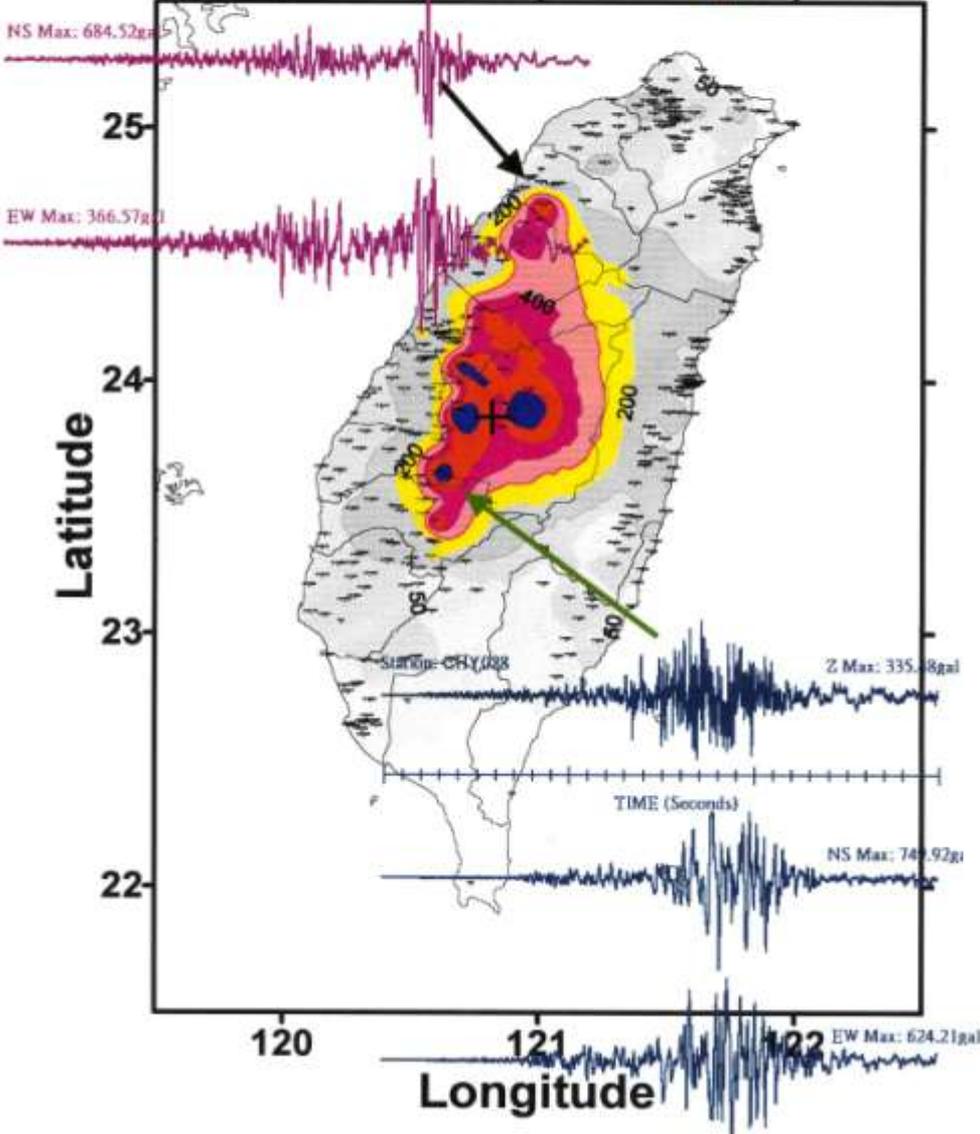
1986/11/15

$M_L=6.8$



Station: TCU095
Z Max: 250.81gal

Isoseismal Map



1999/9/21 Chi-Chi Eq.
Critical information
available in 102 seconds :

Time : 1:47 AM

Magnitude : $M_L 7.3$

Epicenter : Near Chi-Chi

Regional intensity map.

Shaking time histories.



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1999/9/21

Sungshan area

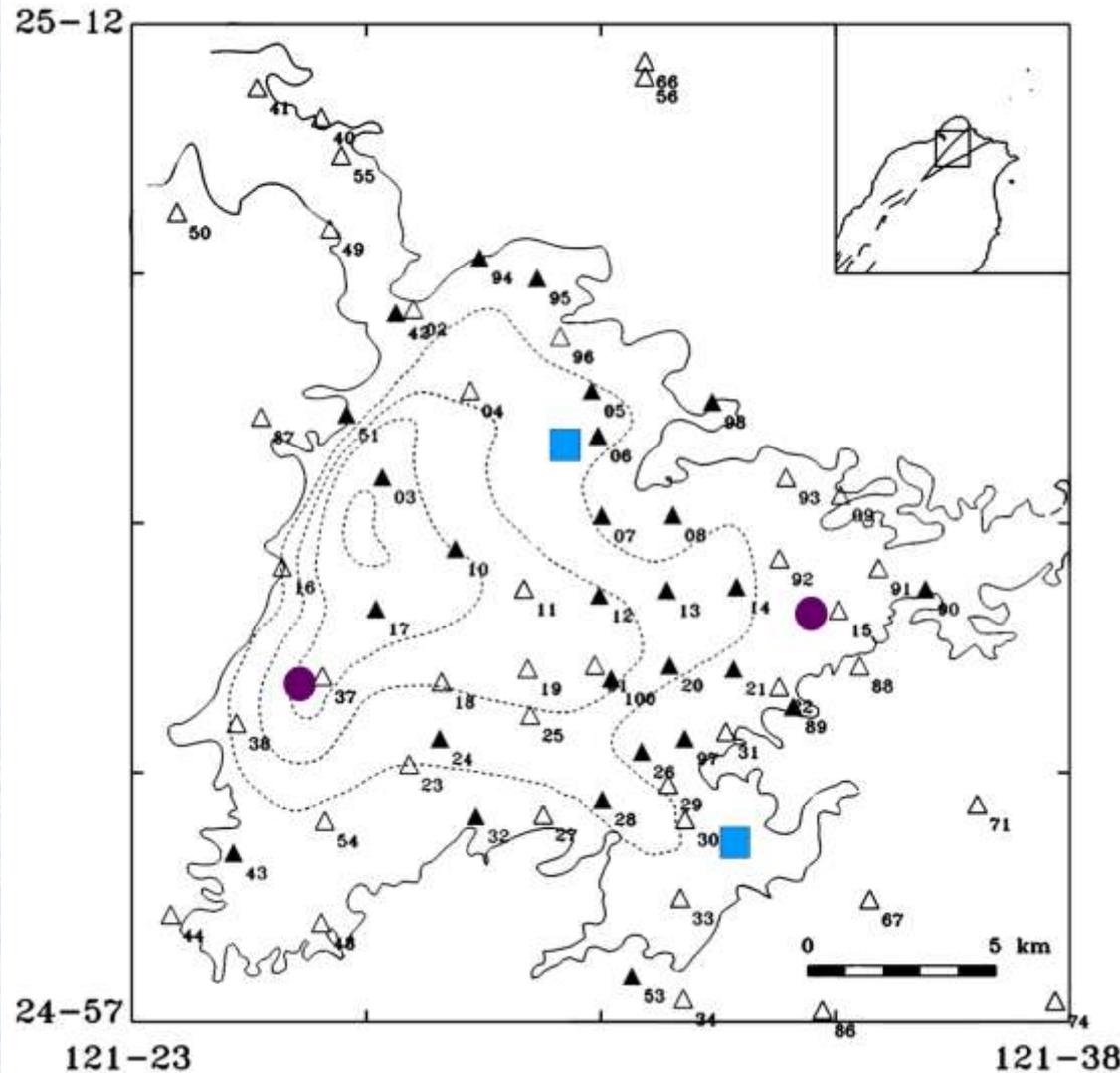


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1999/9/21

Hsinchung area



Distribution of the collapsed buildings due to the 1999 Chi-Chi earthquake

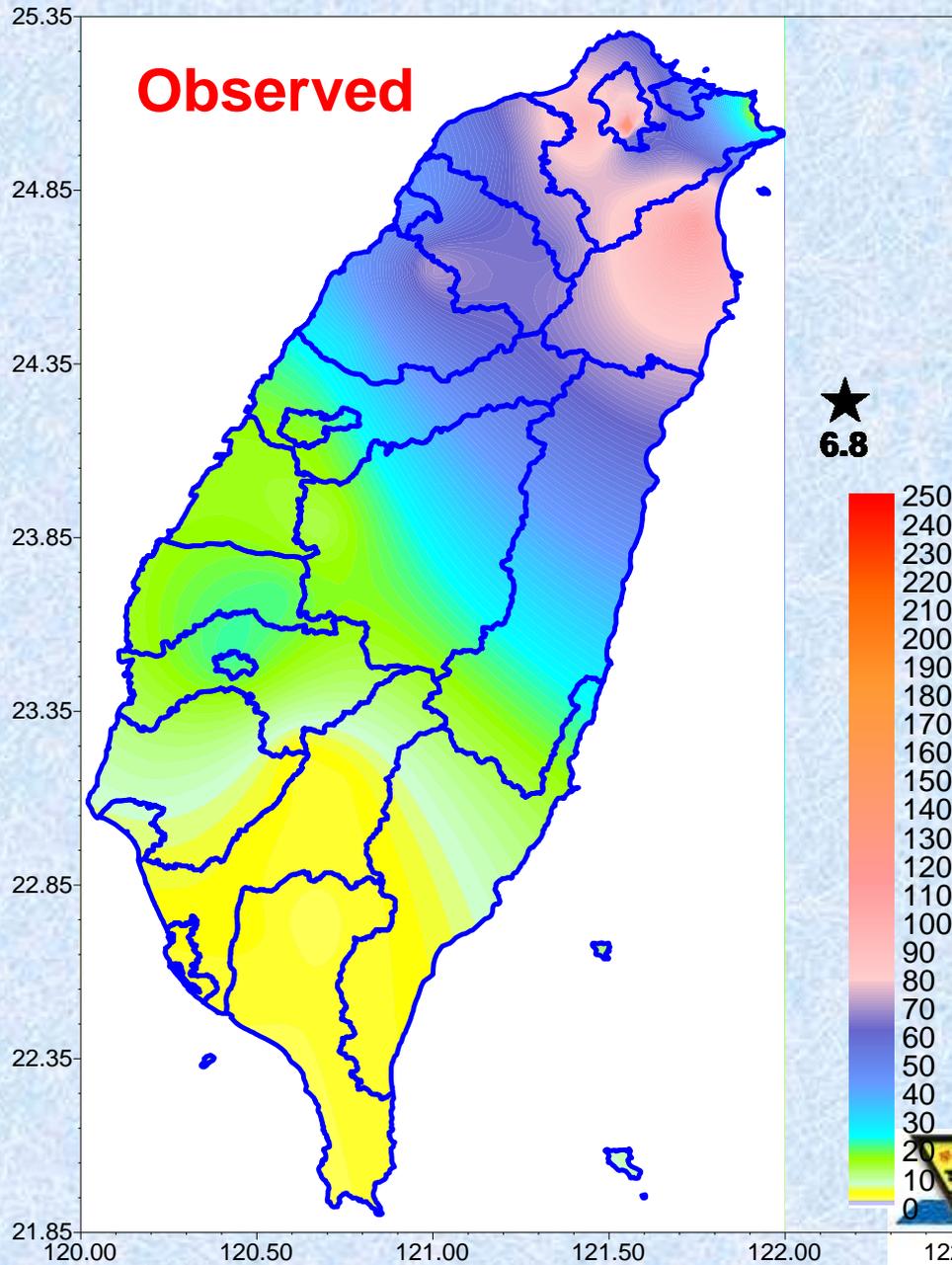
■ < 5F

● 12F



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20020331 Earthquake



March 31, 2002
 $M_L=6.8$

5人死亡
272人受伤



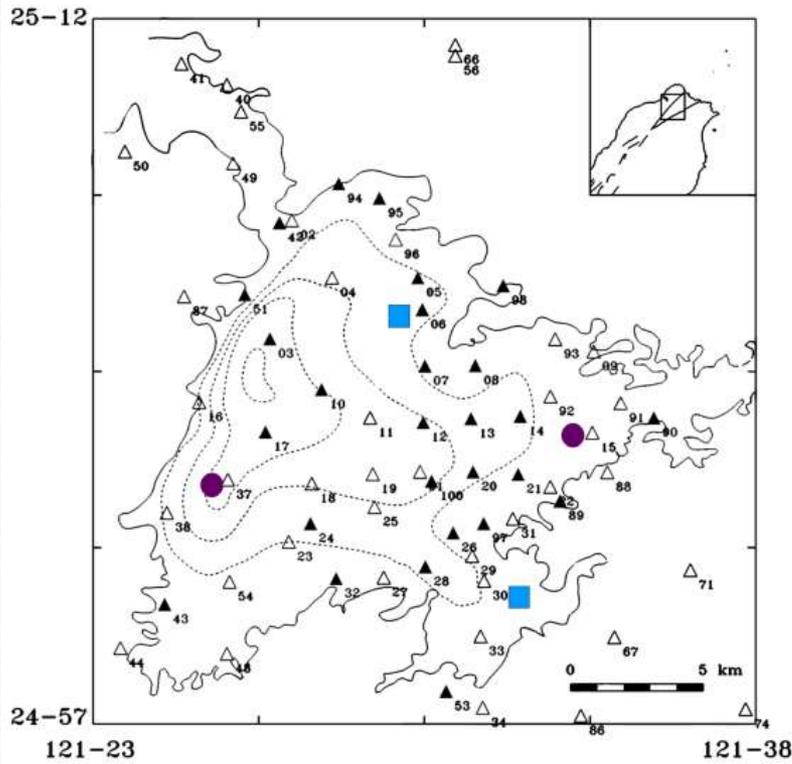
NCU NCU

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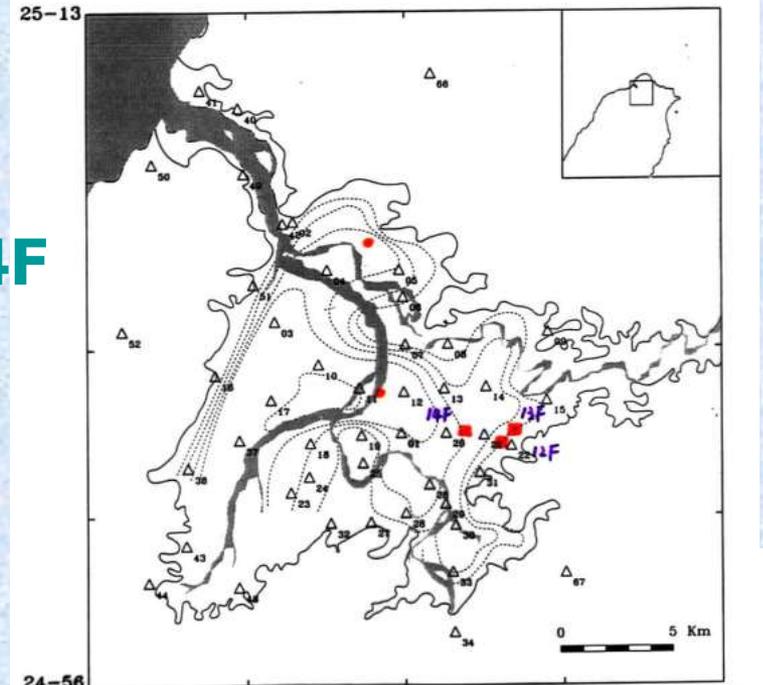
March 31, 2002



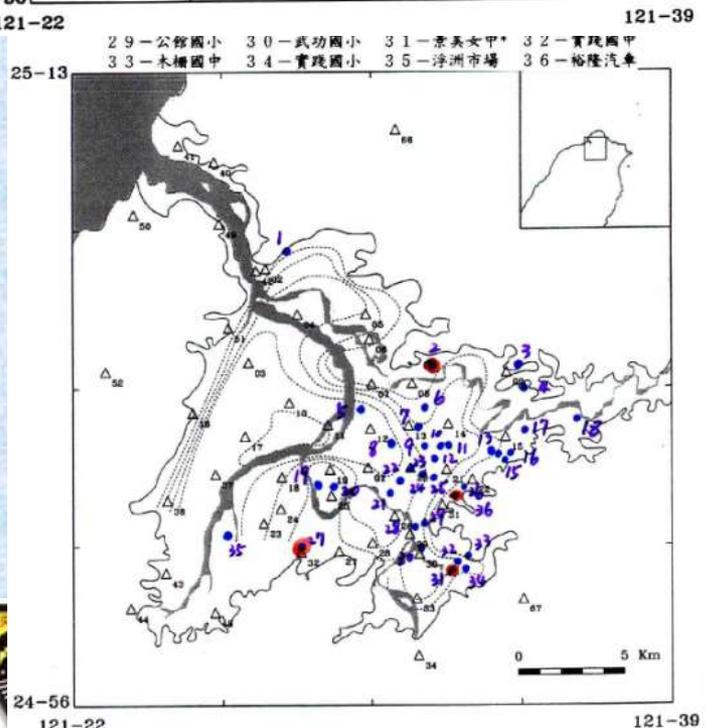




12~14F



1~5F



Distribution of the collapsed buildings due to the 1999 Chi-Chi earthquake

1986/11/15 Hualien Eq.

- < 5F
- 12F



Summary

The low frequency responses on the western part of the Taipei basin and Sungshan area are correlated with the basin structure and the top soft soil layer (Sungshan formation).

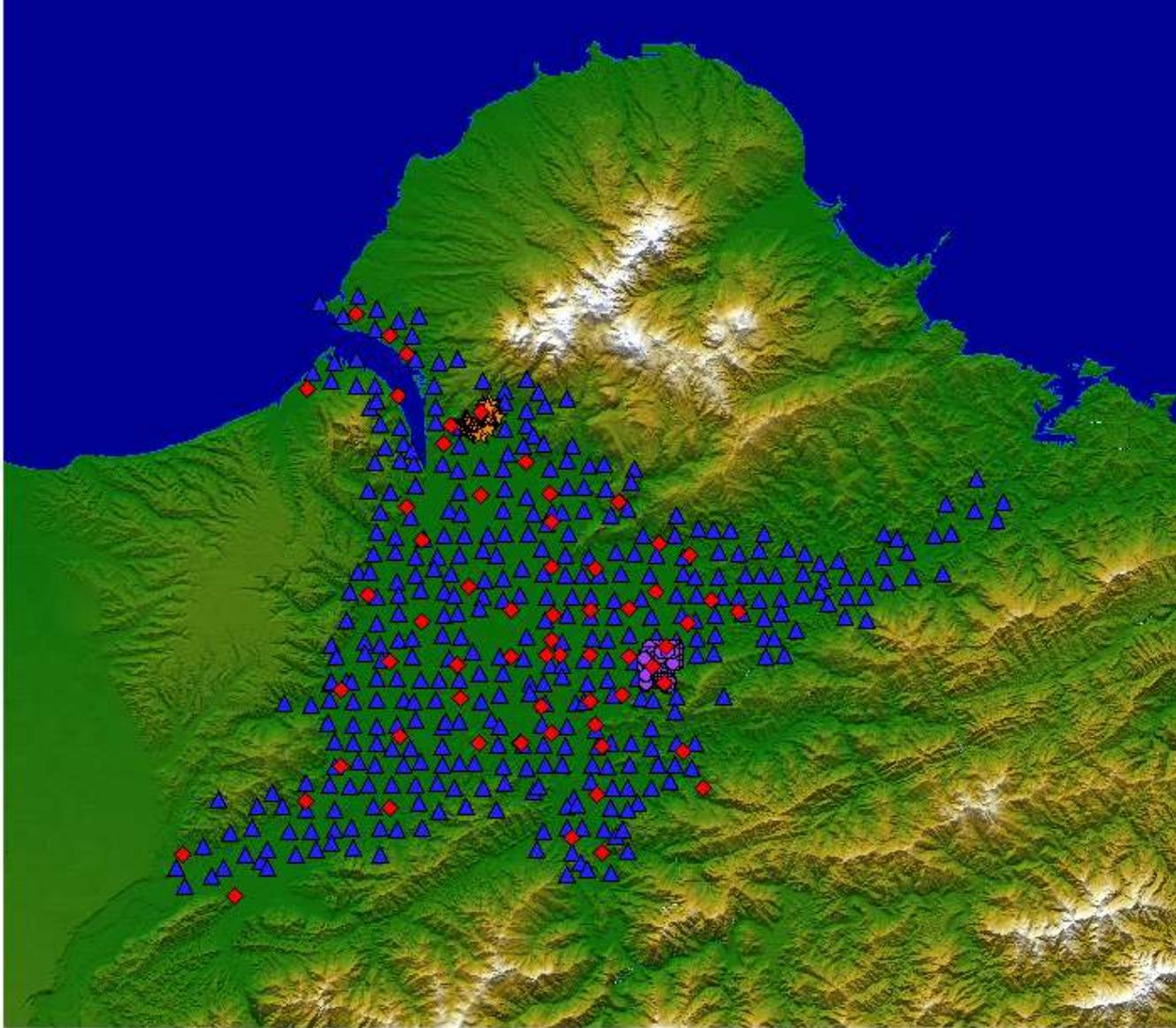
The high frequency responses are mainly occurred near the edge of the Taipei basin except the western boundary of a steep structure.

The soft soil layer of the Sungshan formation may dominate the site response in the Taipei urban area.

During the 1986, Hualien earthquake and 1999, Chi-Chi earthquake, there are some buildings damaged. By comparing between the distribution of damaged buildings and spectral ratio contours, we found that the patterns can be correlated.



- **Geological structure**
- **Strong motion observations**
- **Ground motion responses**
- **Earthquake damages**
- **Recent researchs**

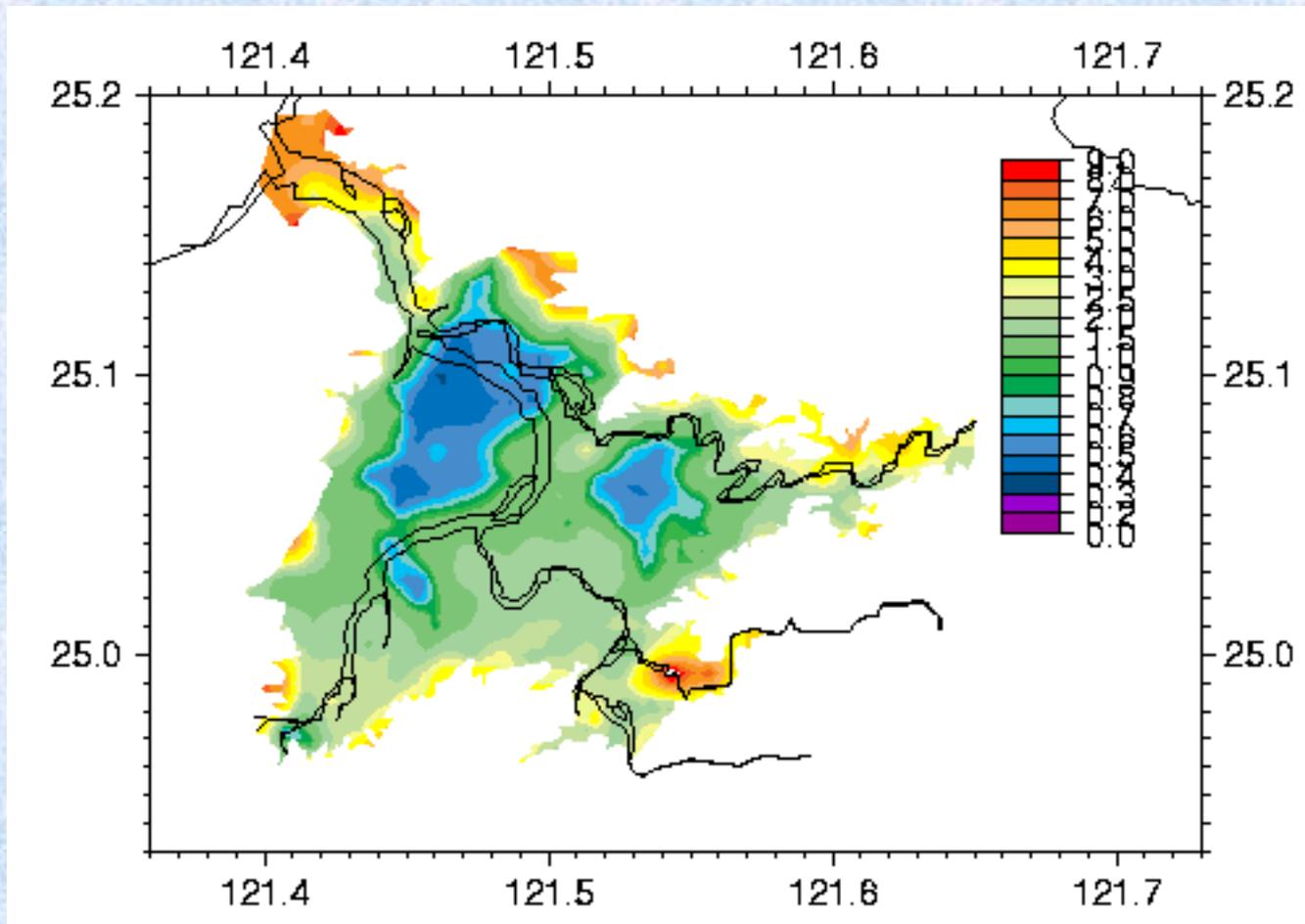


▲ Strong motion station
: 69

▲ 500 stations

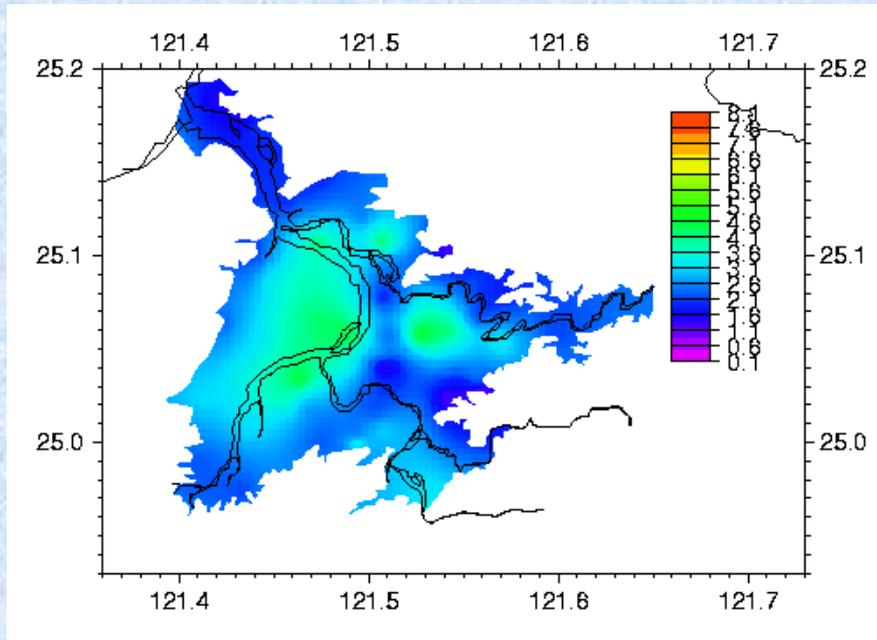
Interval ~ 1 km

Locations of the microtremor survey points in the Taipei area. Red symbols indicate the strong motion stations.

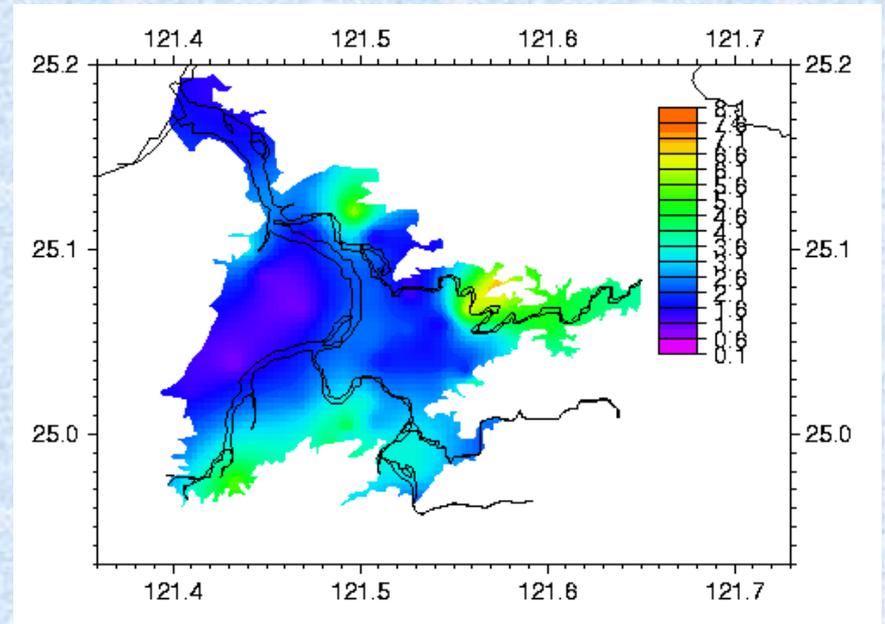


Dominant frequency contour in the Taipei basin area, result from the H/V ratio of dense microtremor survey

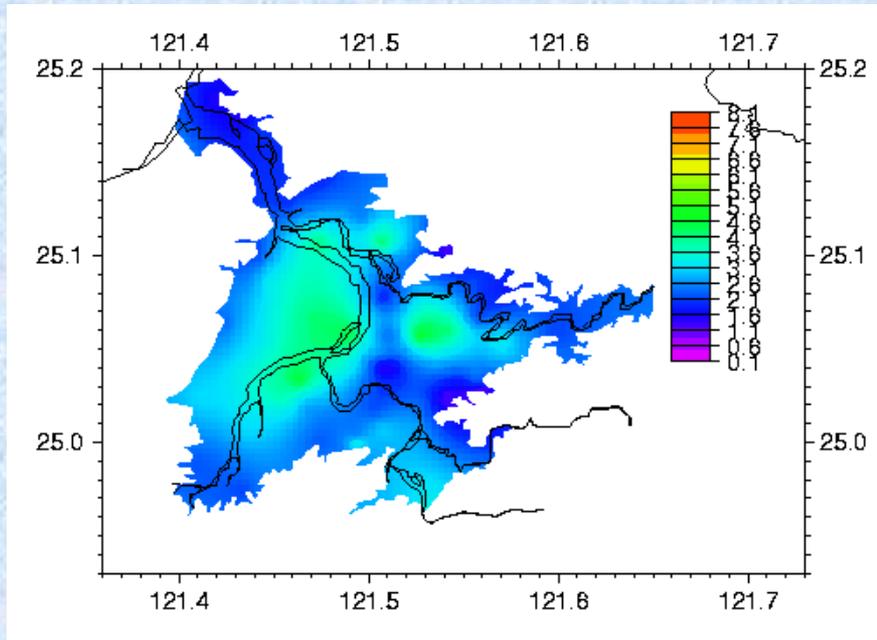
0.5 Hz



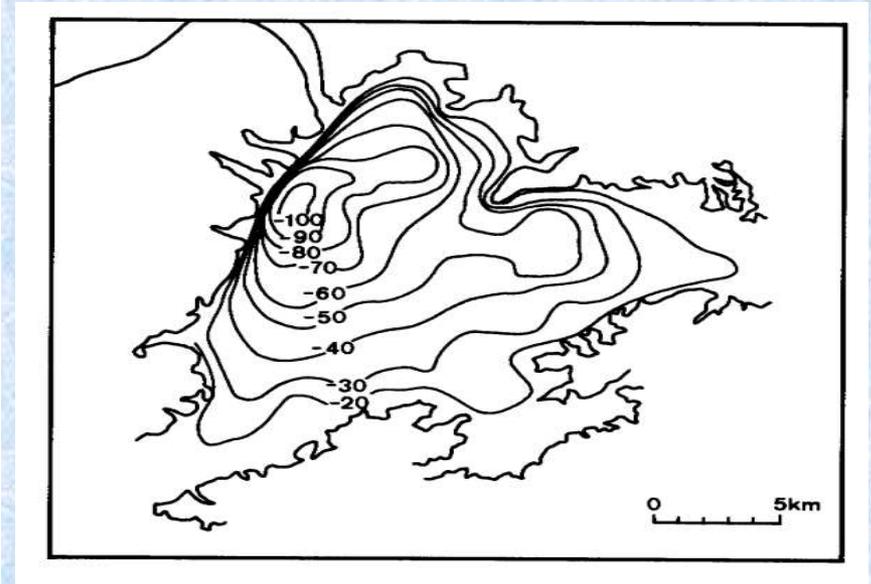
2.0 Hz



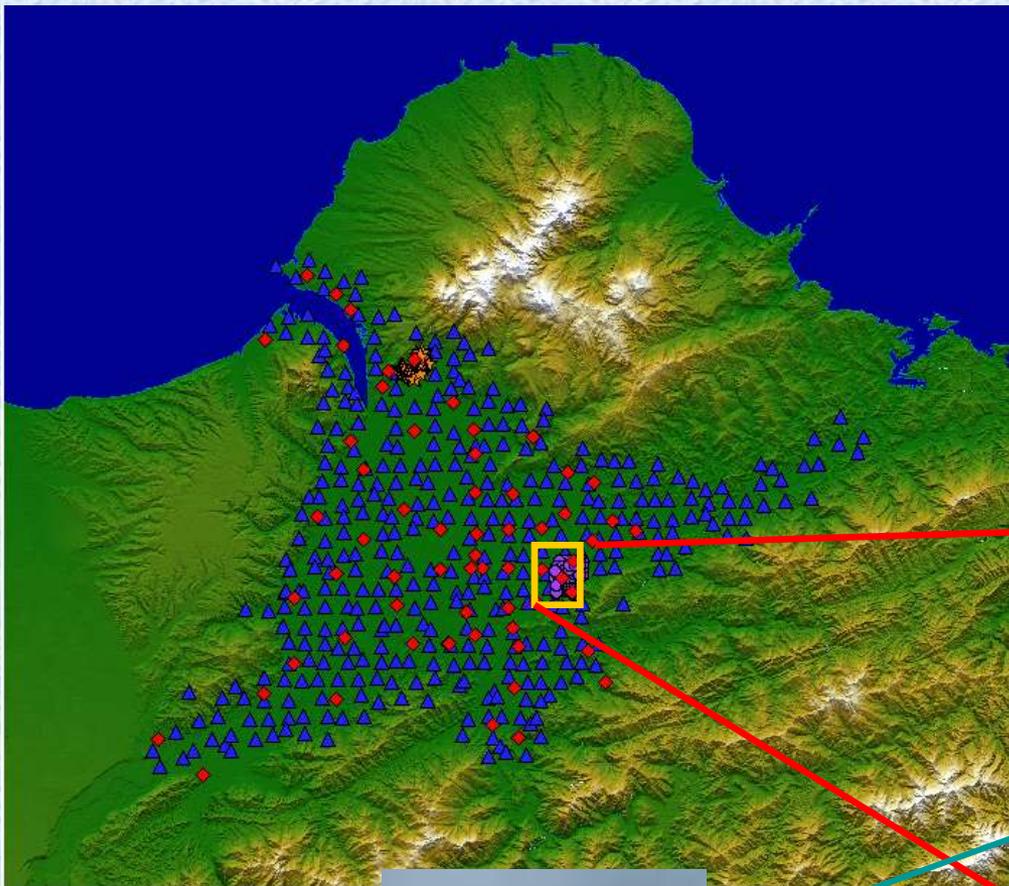
H/V spectral ratio contours at 0.5 and 2.0 Hz.



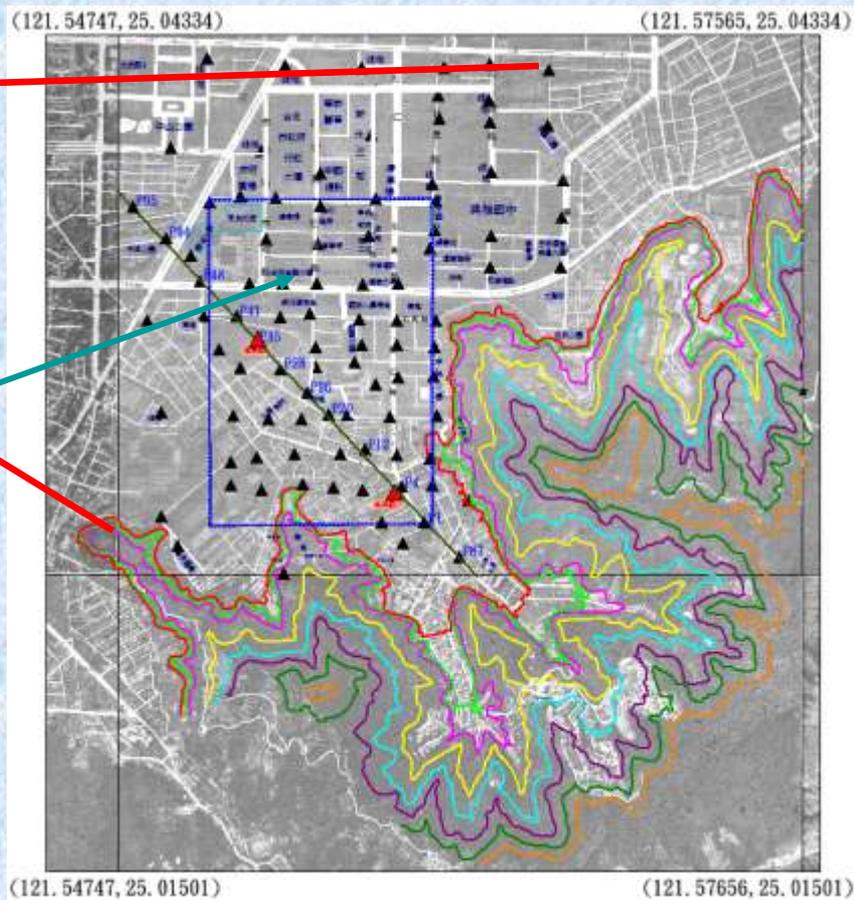
**H/V spectral ratio contour
at 0.5 Hz.**

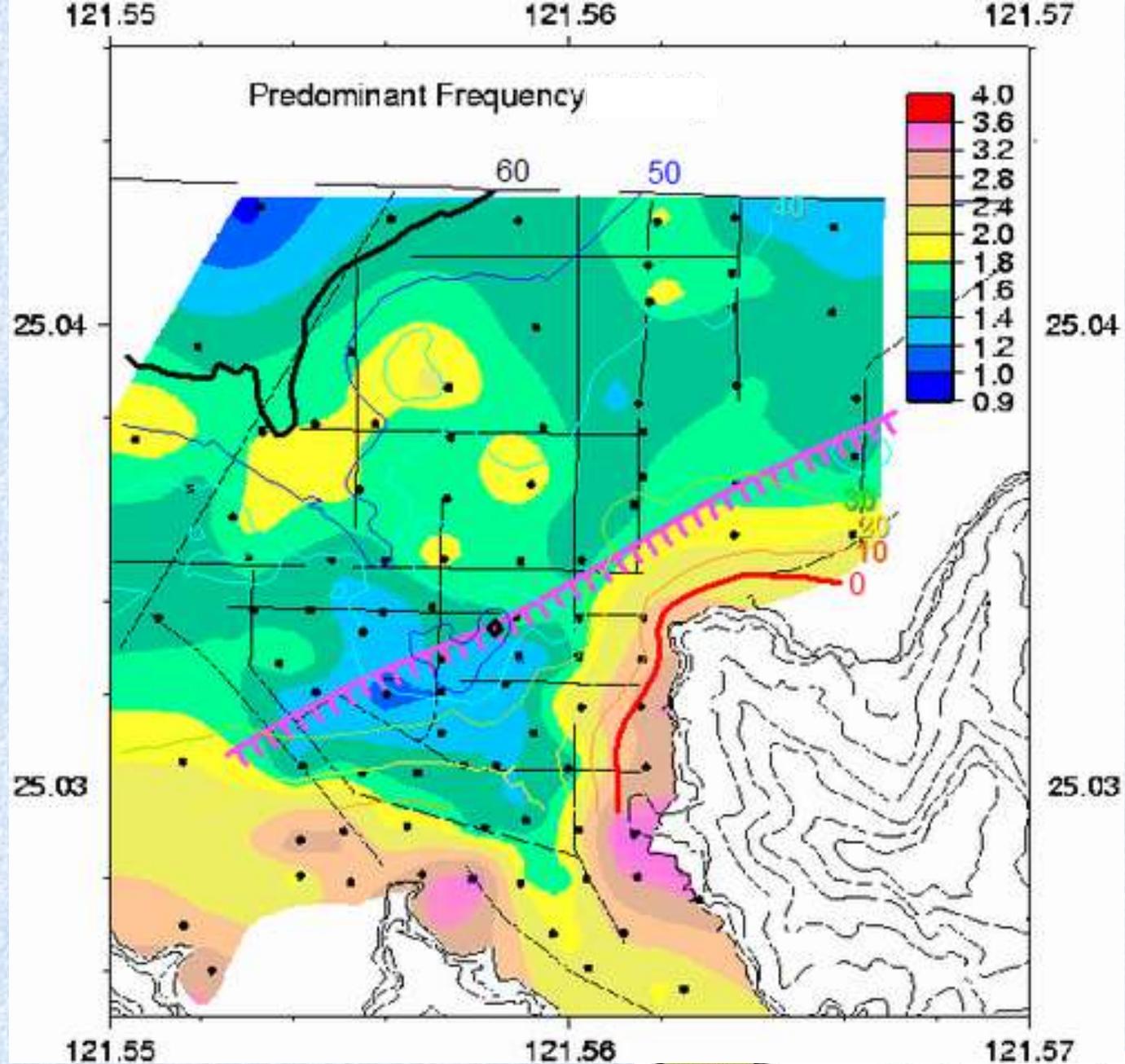


**Sungshan Formation Bottom
--- Taipei Basin**



Interval ~ 100 m



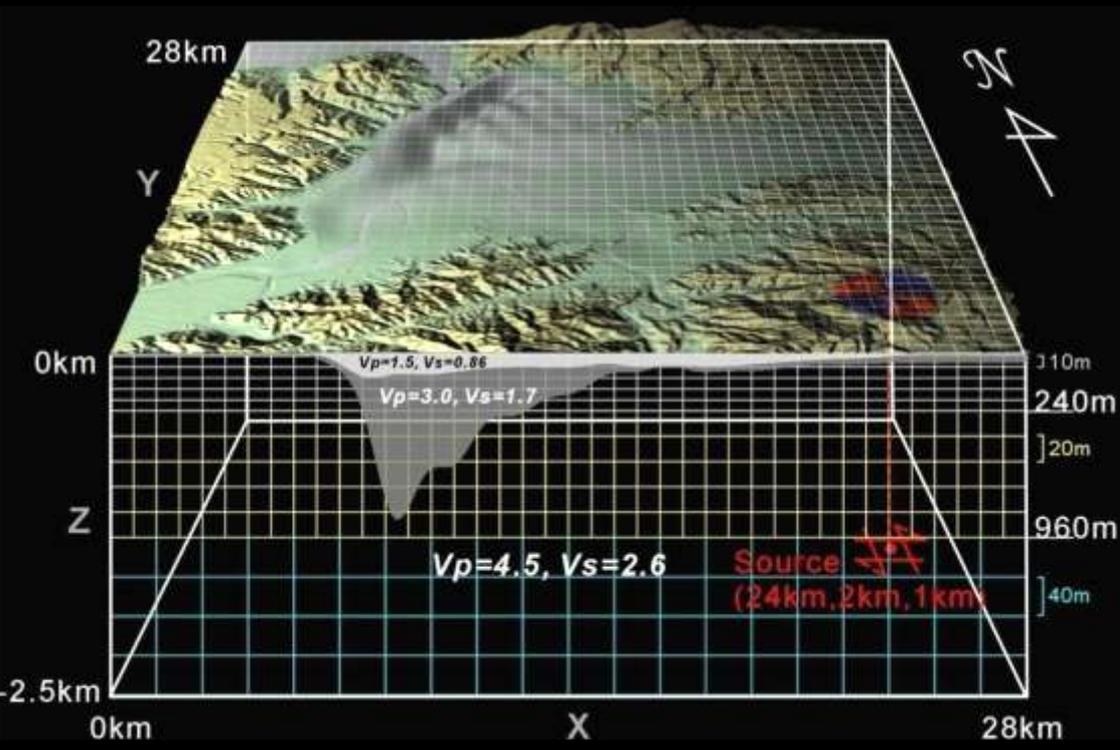


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3D Finite-Difference Modeling of Strong Ground Motion in the Taipei Basin

Model Setting

Modeling Parameters



Model dimension (km^3)	28(W) x 28(L) x 2.5(H)
Absorb boundary (grids)	± 100
Source type	Double-Couple
Source location (km)	(24,2,1)
Source time function (sec)	0.16, 0.0, 0.16
Velocity (km/s^2)	
SunShang formation	$V_p=1.5$, $V_s=0.86$
Basin Basement	$V_p=3.0$, $V_s=1.70$
Outside the Basin	$V_p=4.5$, $V_s=2.60$

00.00 sec

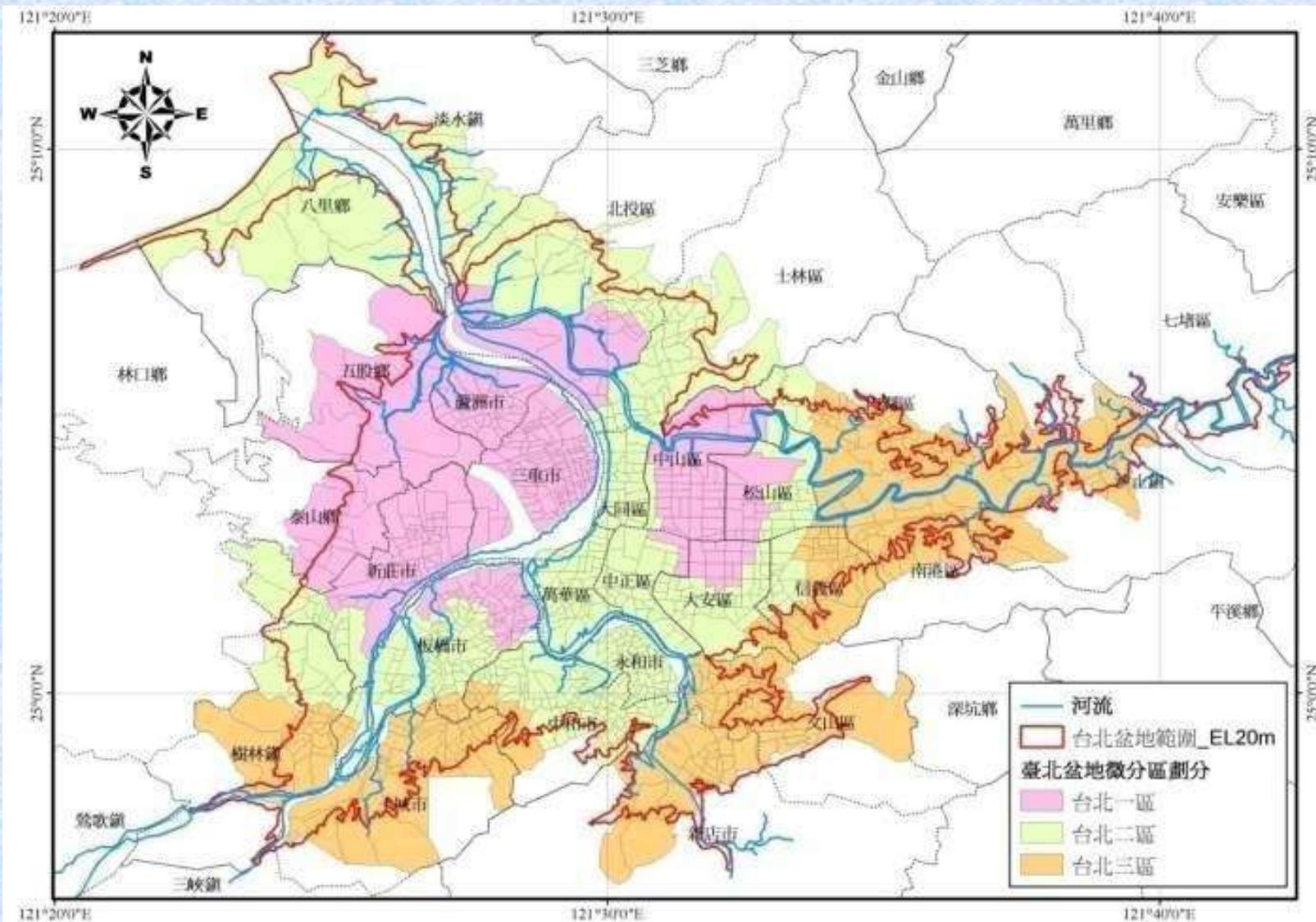


Basement + SunShang Formation

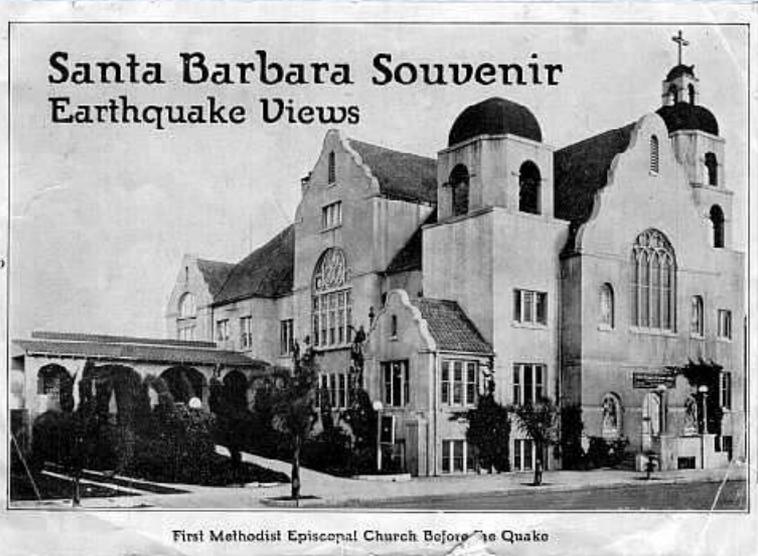


2011.1修訂後公告之臺北盆地設計地震微分區圖

Microzonation Map of Taipei Basin in the Building Code Modified on 2011.



ESG 2011



4th IASPEI / IAEE International Symposium:

Effects of Surface Geology on Seismic Motion

August 23–26, 2011

University of California Santa Barbara

Session 1: Recent Significant Earthquakes

Session 2: Site Response Modeling Using Borehole Data

Session 3: Ground Motion Simulation

Session 4: Nonlinearity in Site Response

Session 5: Spatial Variability of Ground Motions

Session 6: The Vs30 Debate: How We Can and Cannot Use Vs30 in Site Response Estimation

The 5th ESG International Symposium will be held in Taipei, Taiwan, 2016 or 2017.

The **main theme** of the symposium and **the date** will be discussed.



**The 2nd Annual Meeting of the Strategic
Chinese-Korean-Japanese Cooperative Program
Jeju island, Korea, 2012/10/29-31**

Thank you for your attention!

Kuo-Liang Wen

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