Seismic Profiles from TAIGER Project

Chien-Ying Wang

Central University

王乾盈、顏宏元、溫國樑、 黃柏壽、林正洪、劉忠智、梁文宗、 陳朝輝、黃瑞德
中央大學 中研院 中正大學 文化大學

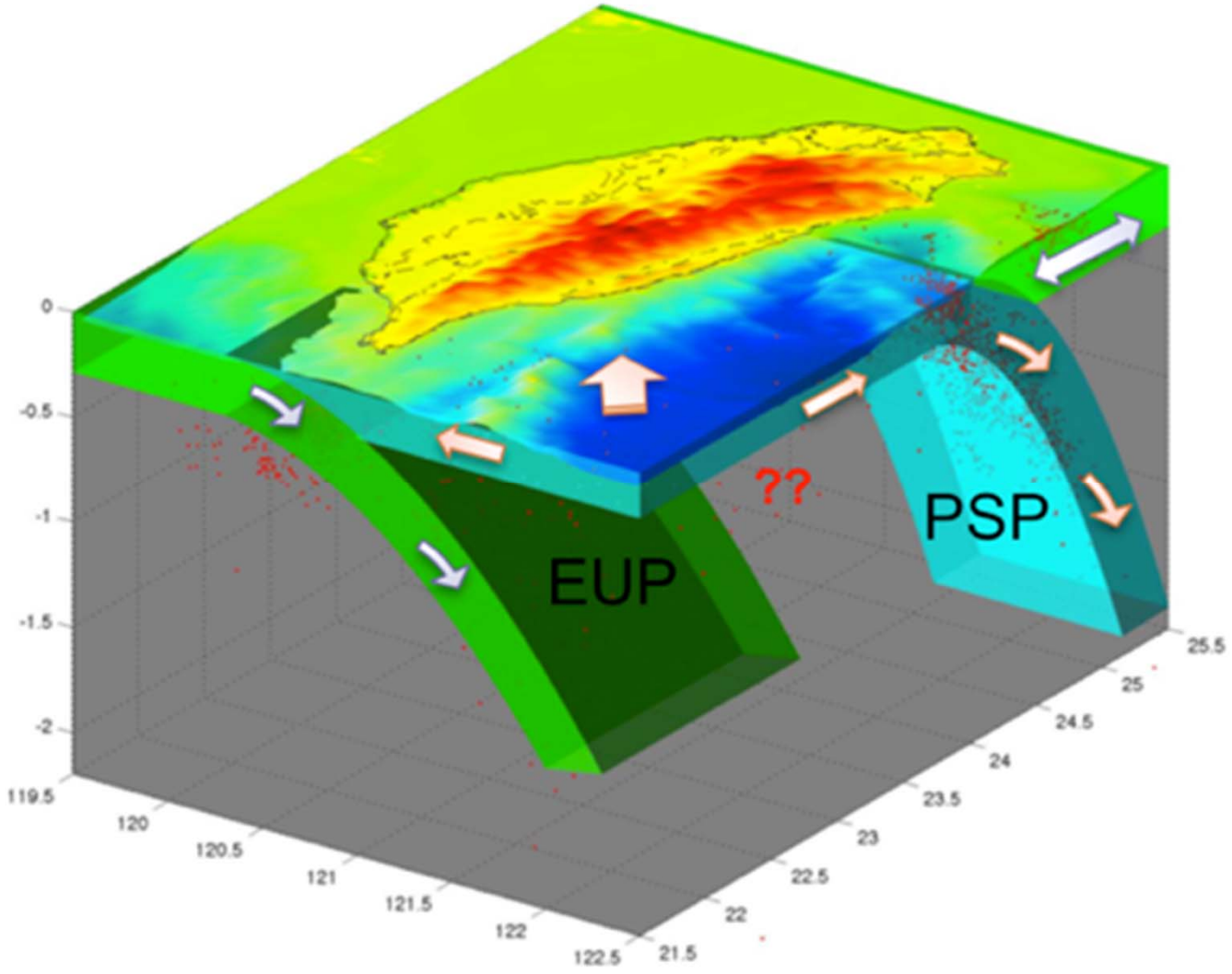
張建興 李昭興、黃怡玲、許樹坤 、林靜怡
氣象局 海洋大學 中央大學

金星、鄭斯華、黃昭、李松齡
福建省地震局 鄭州物探中心

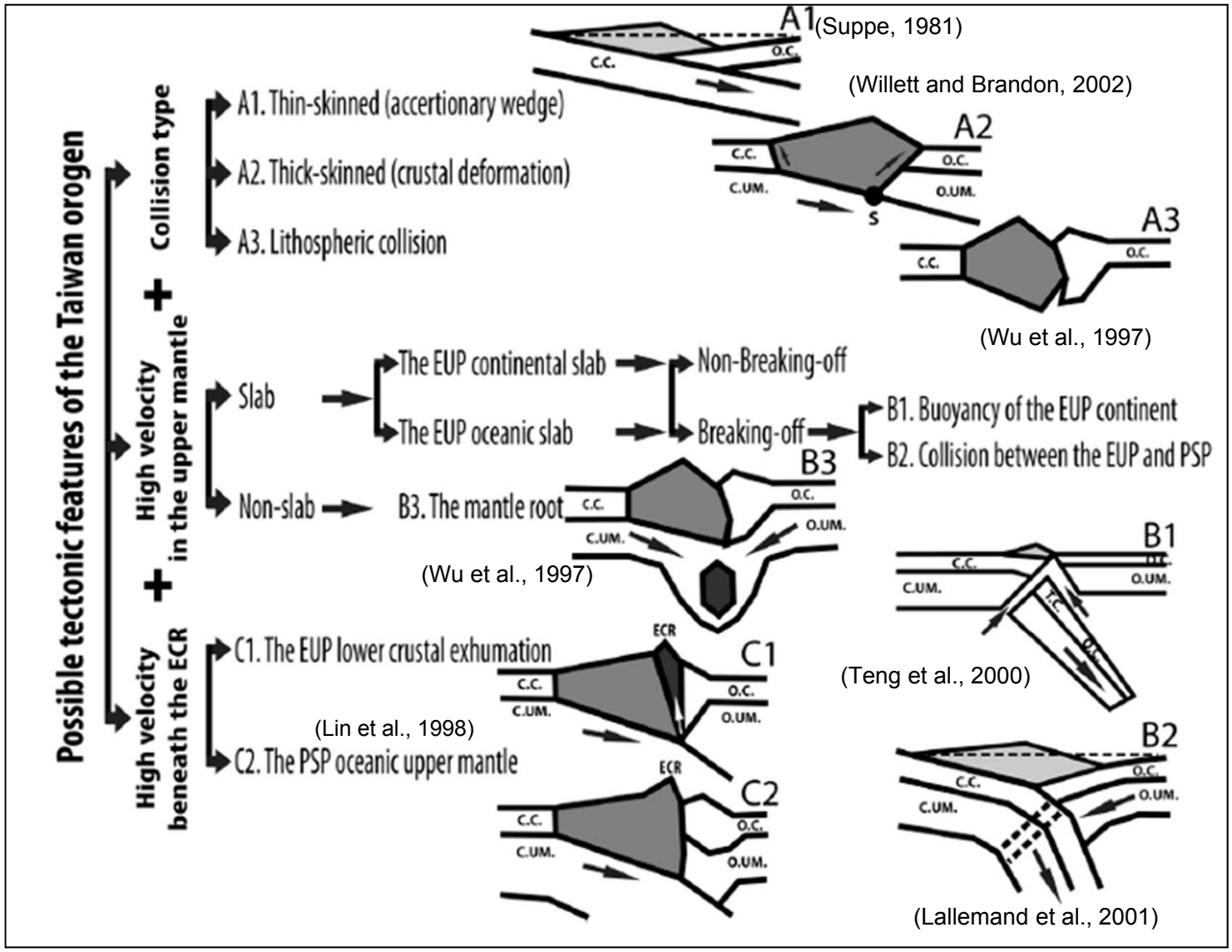
Outline

1. TAIGER 2008～2009
2. ATSEE 2010
3. ATSEE 2011
4. ATSEE 2012

Taiwan Tectonics（dual subduction）



Different Taiwan Tectonic Models



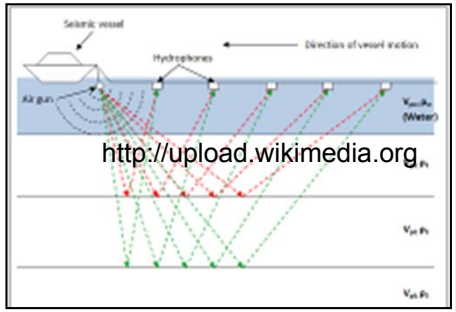
TAIGER 2008~2009

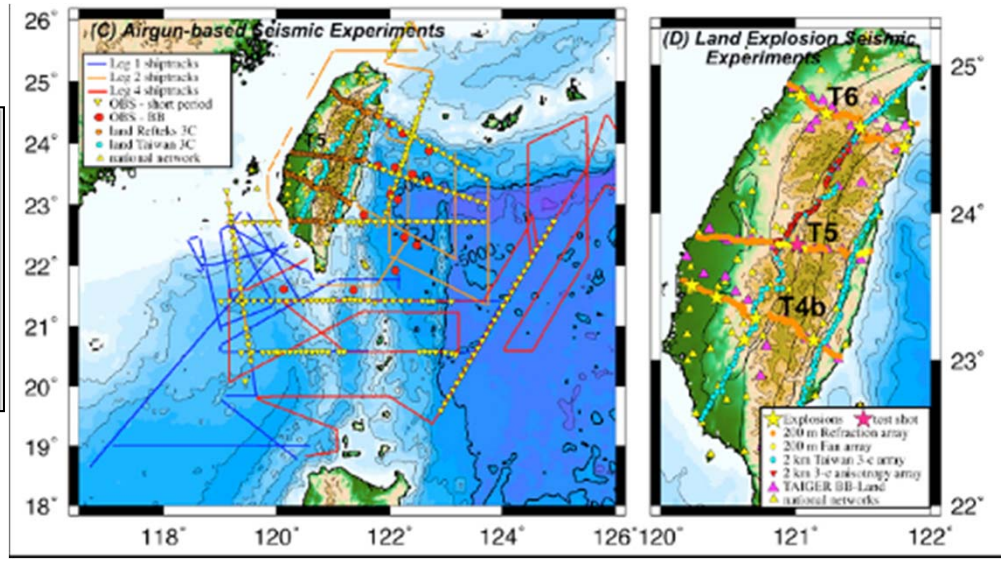
(land explosion、sea-land shooting)

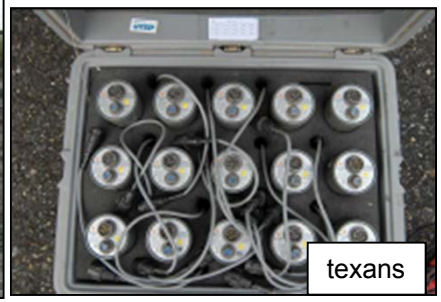
higher resolution, shallower velocity structures

2009 海陸聯測　　2008 陸地炸測

海上震測 MCS



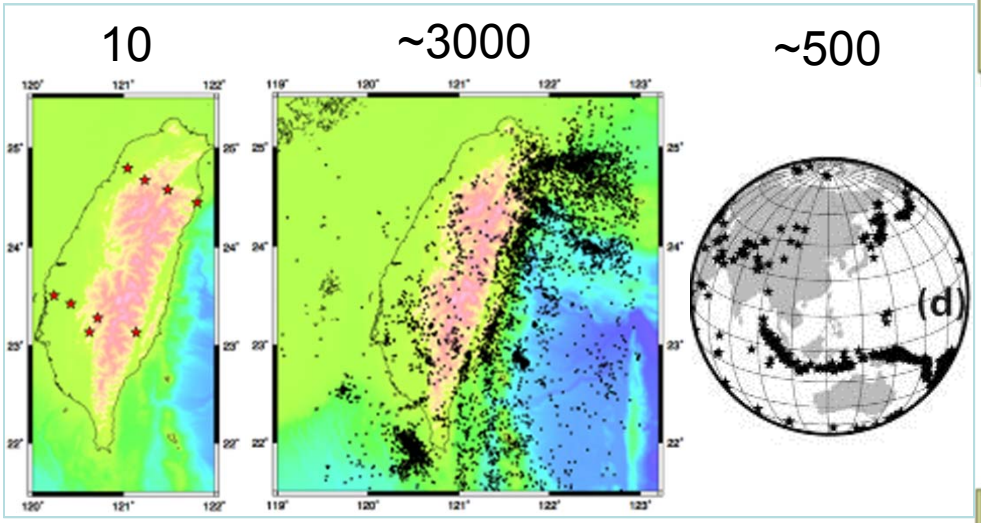




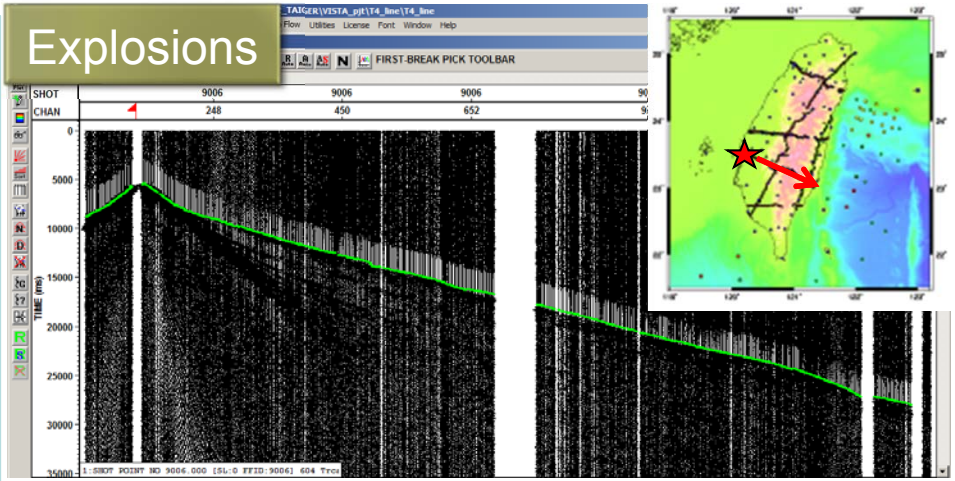
郭陳澔，2012

Tomographic Inversion
-- local and worldwide earthquakes

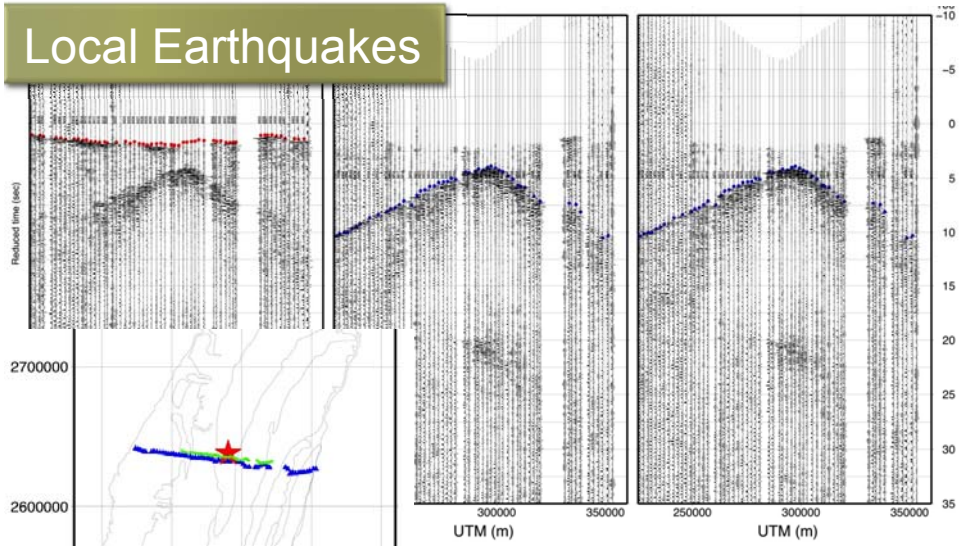
Coherent picking from dense seismic array



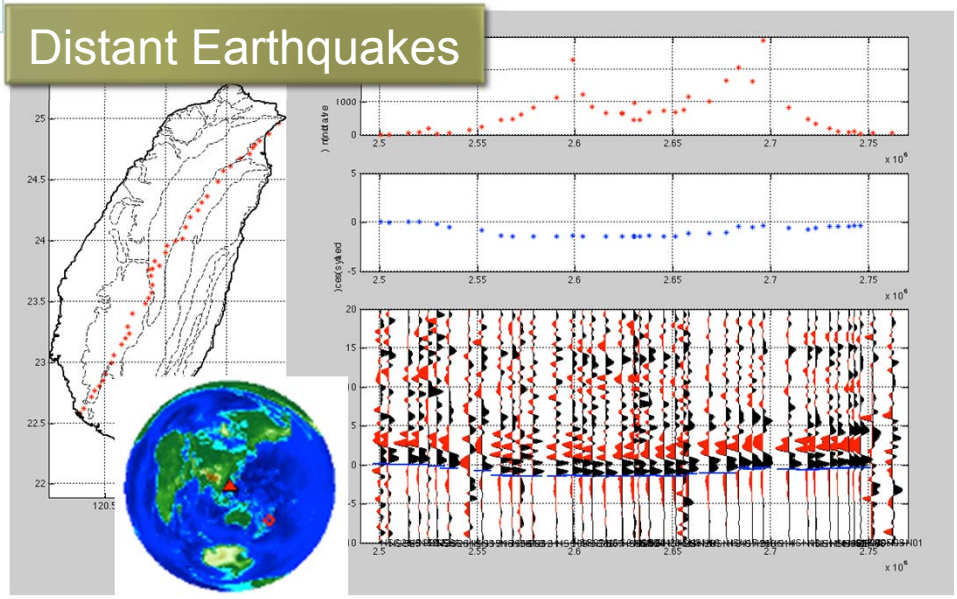
Explosions



Local Earthquakes

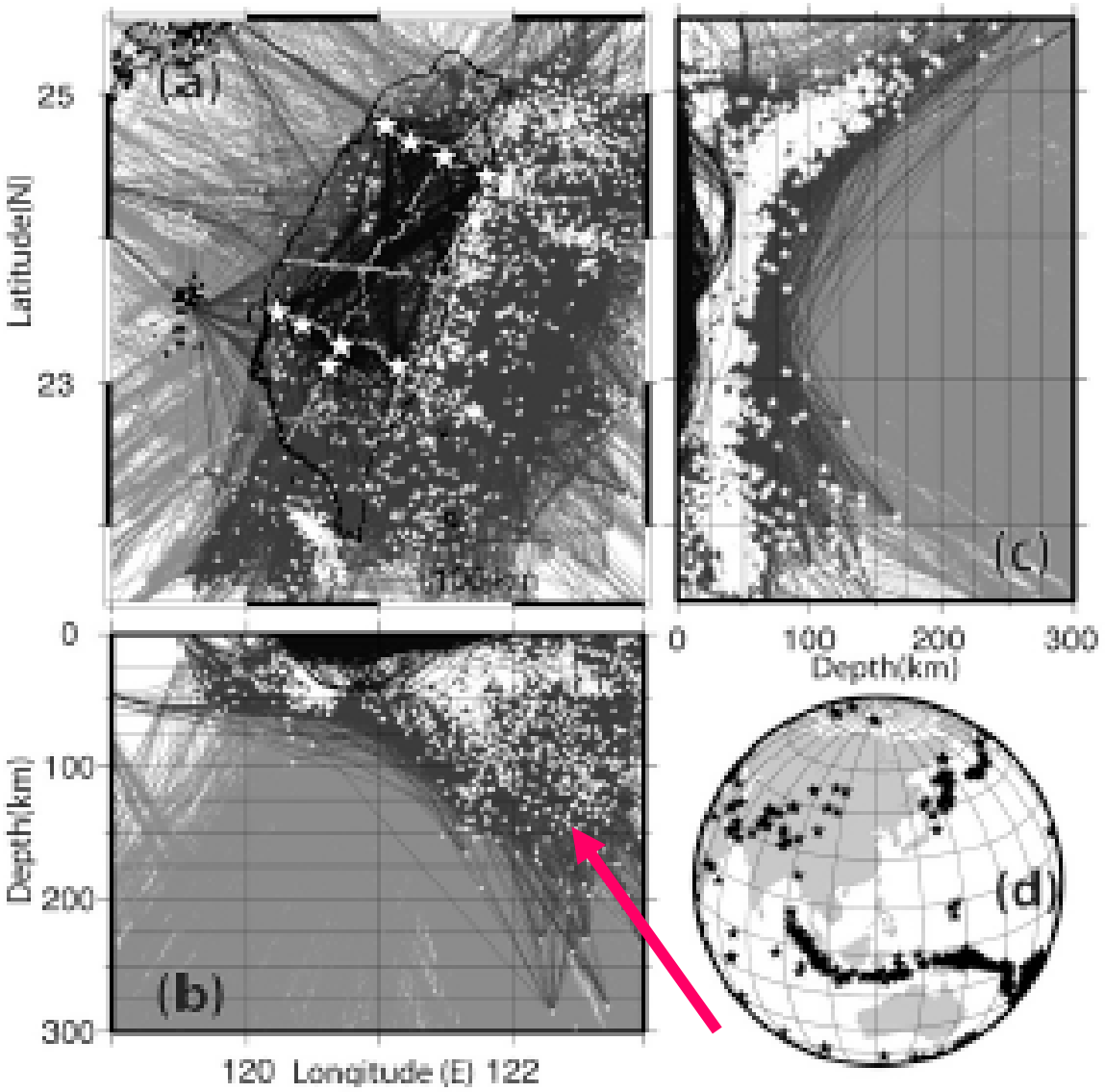


Distant Earthquakes

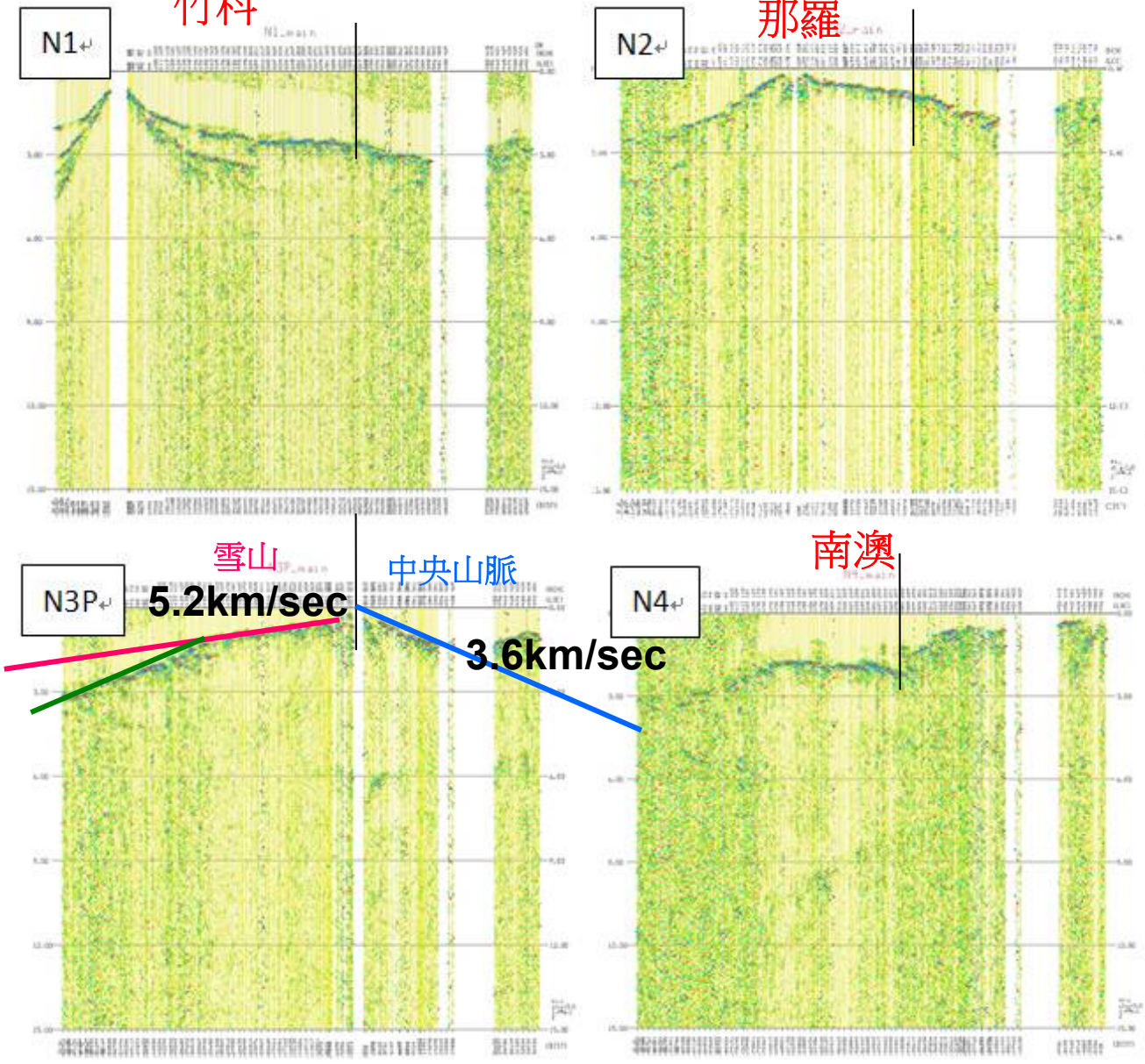


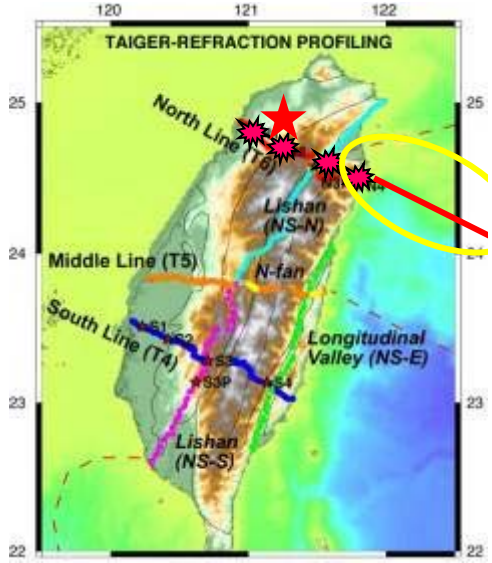
郭陳澔，2012

Ray Coverage

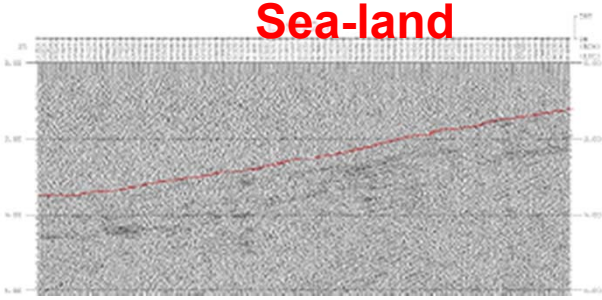


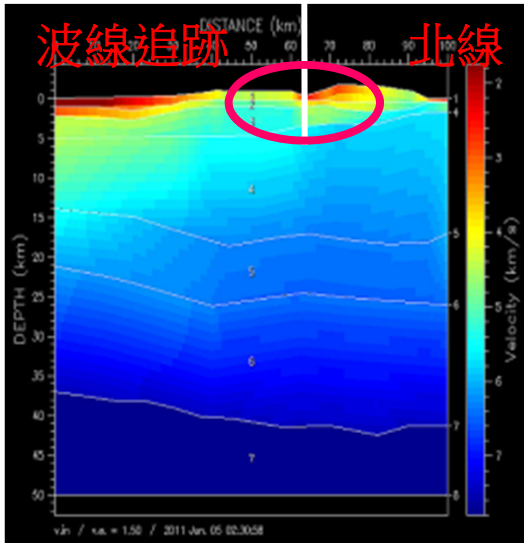
2008 Land Explosion (N line)
2009 Sea-land Airgun





Sea-land

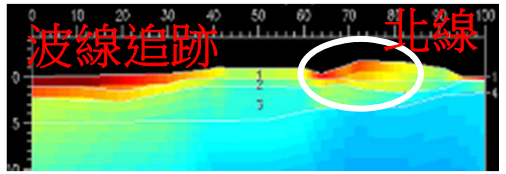


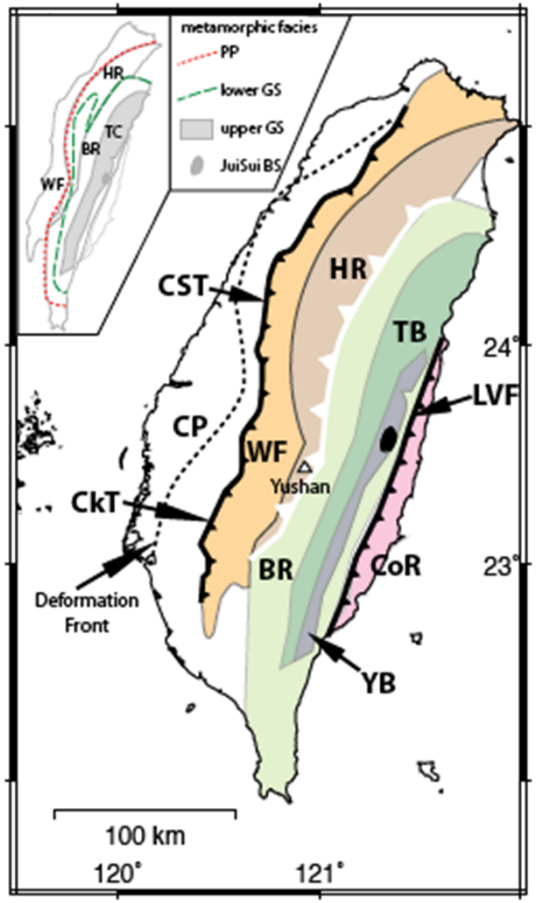


郭陳澔，2012

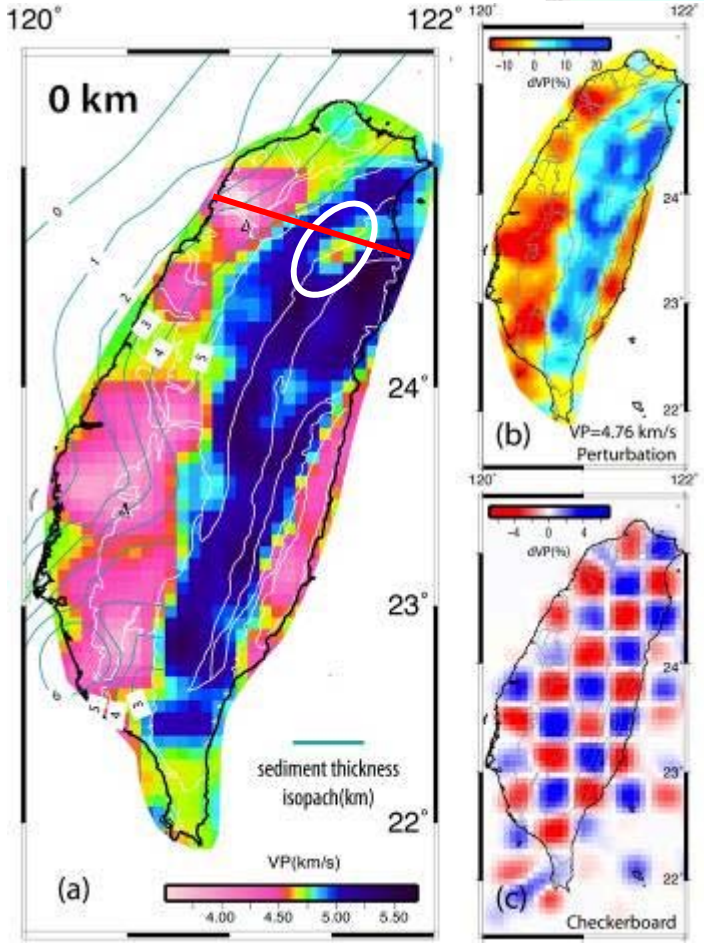
Tomographic Inversion
-- explosions and dense arrays

- Shallow 5km velocity



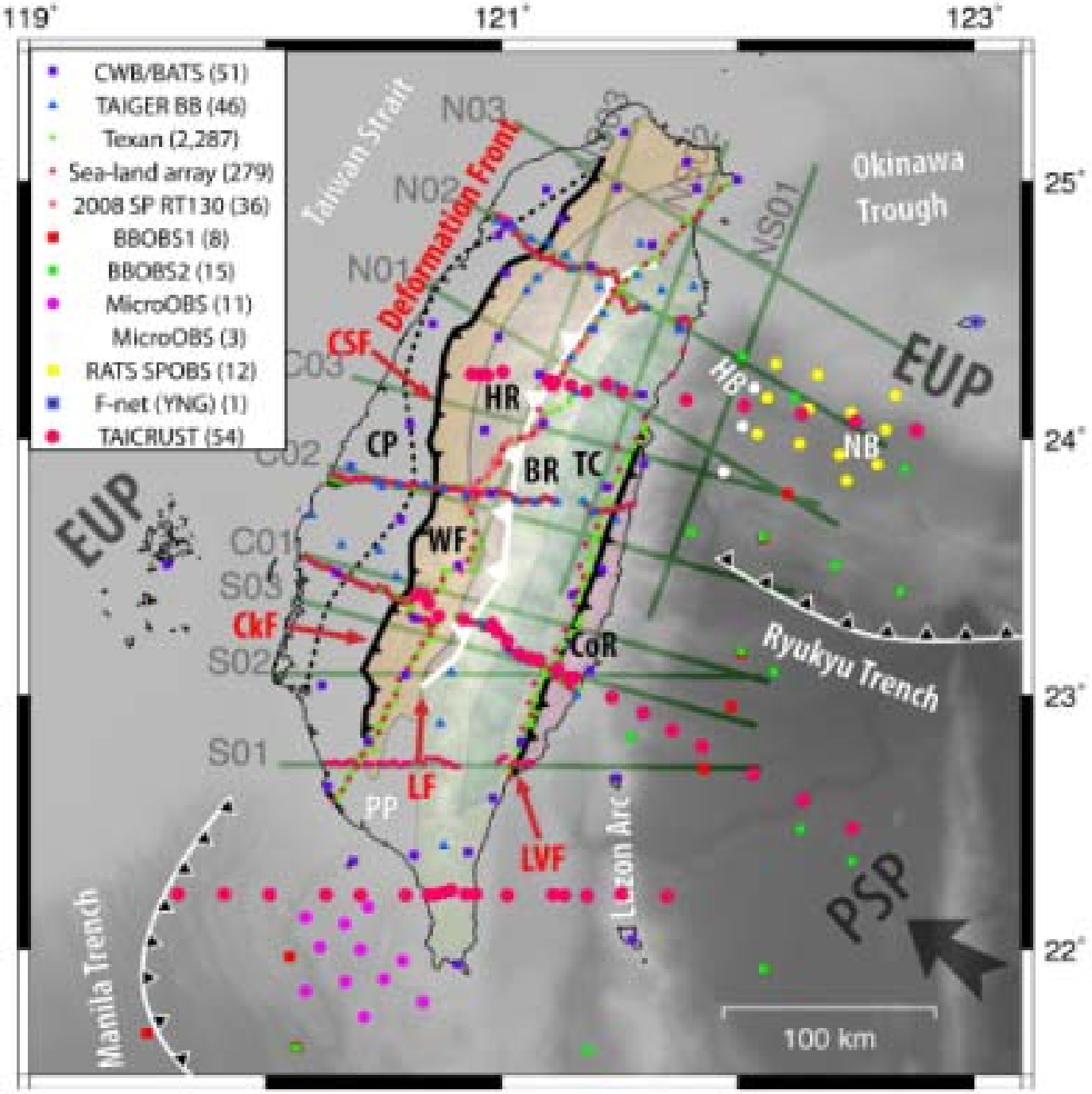


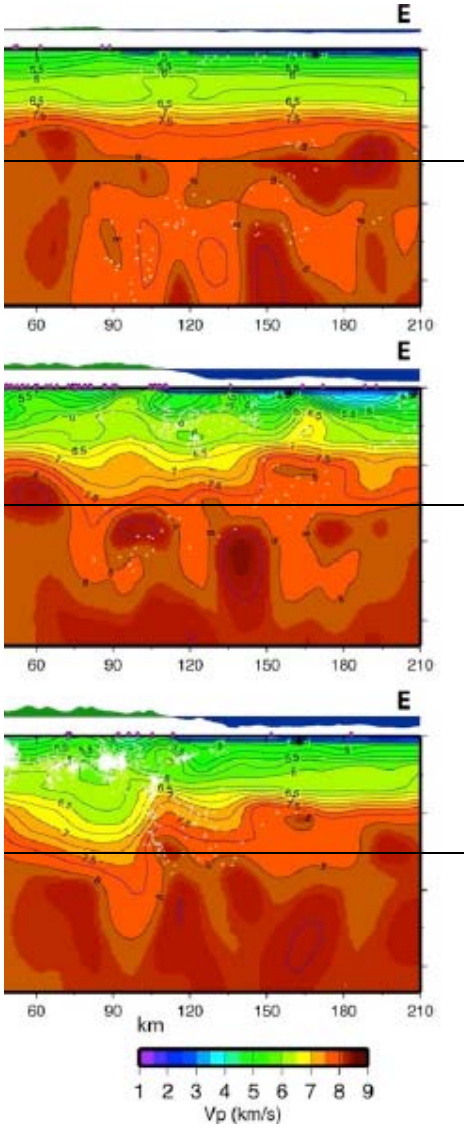
Vp



郭陳澔，2012

version）Models

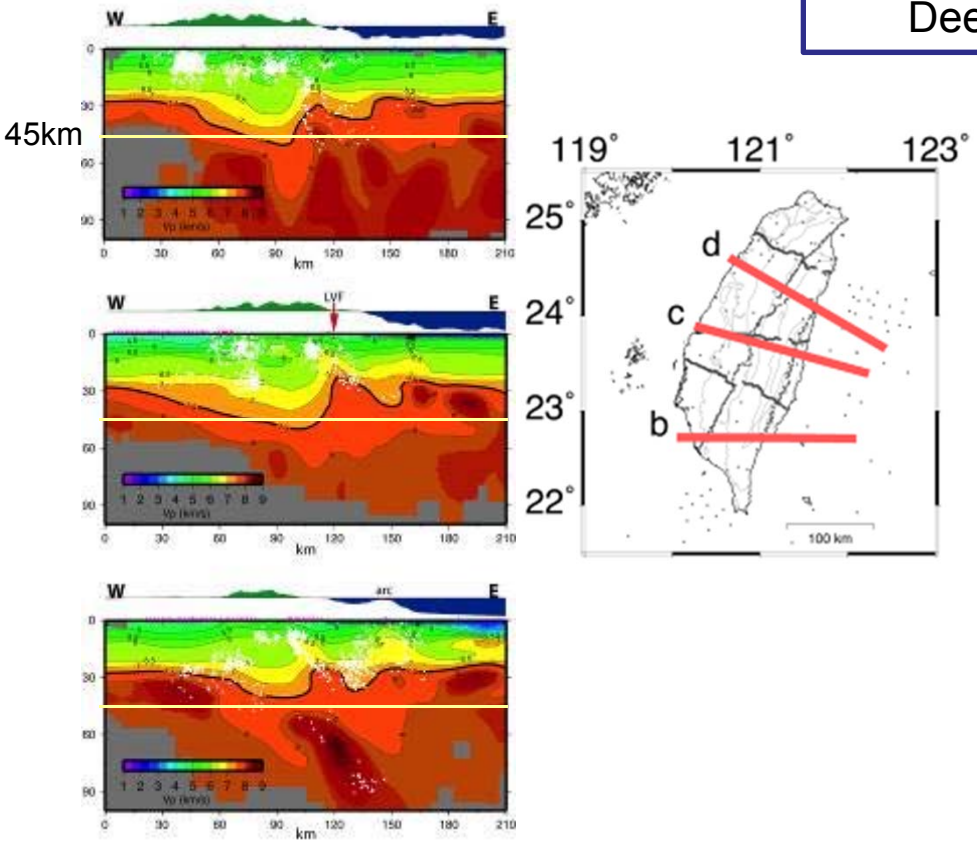


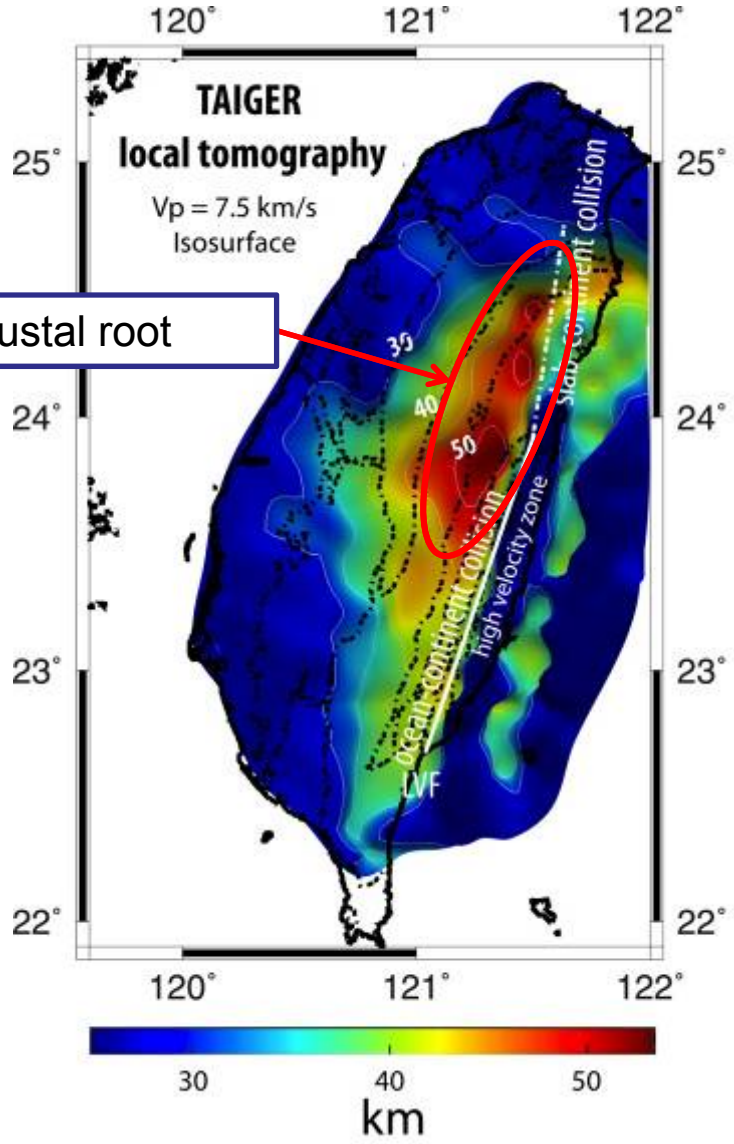


郭陳澔，2012

Moho（7.5km/sec)

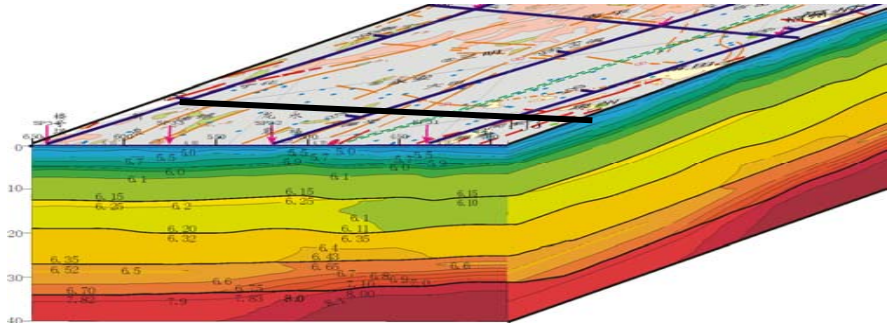
- Approximately 3D Moho shape from Vp tomo (7.5 km/s Isosurface)





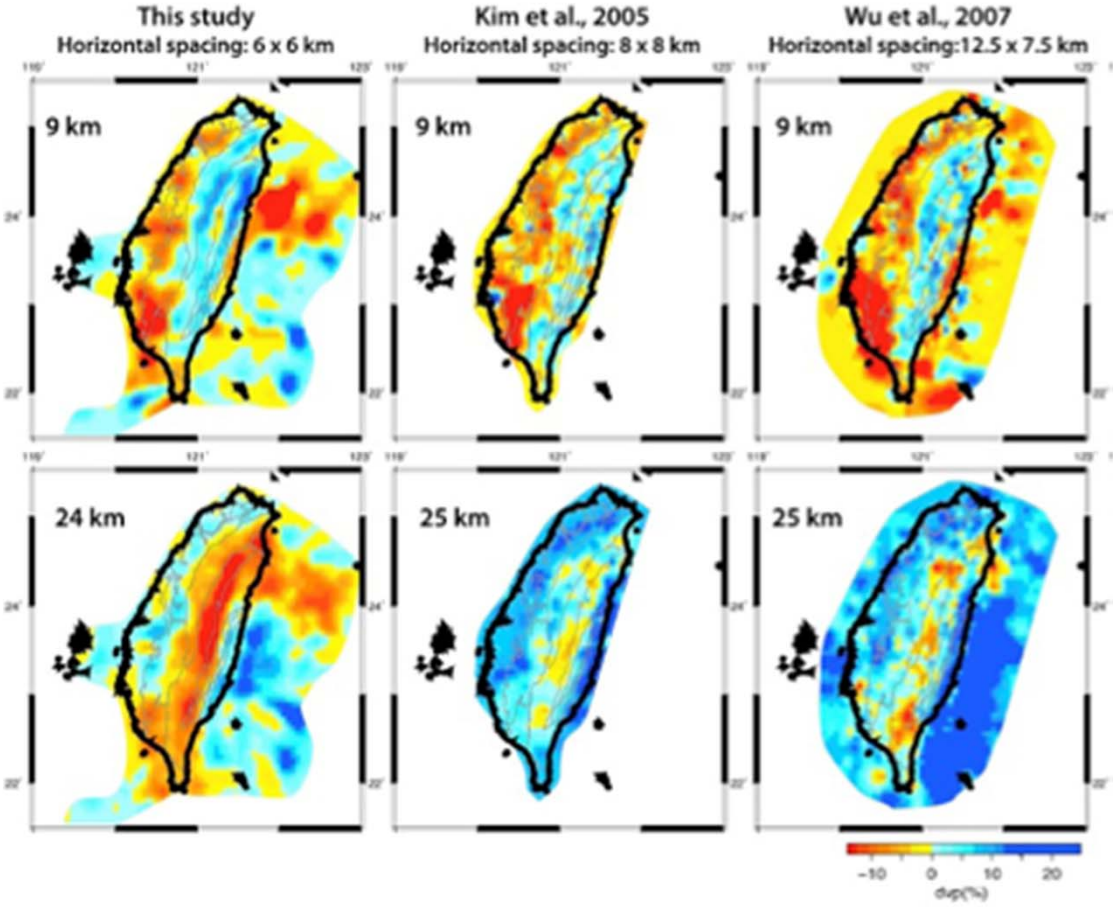
Fujan

福建



Taiwan

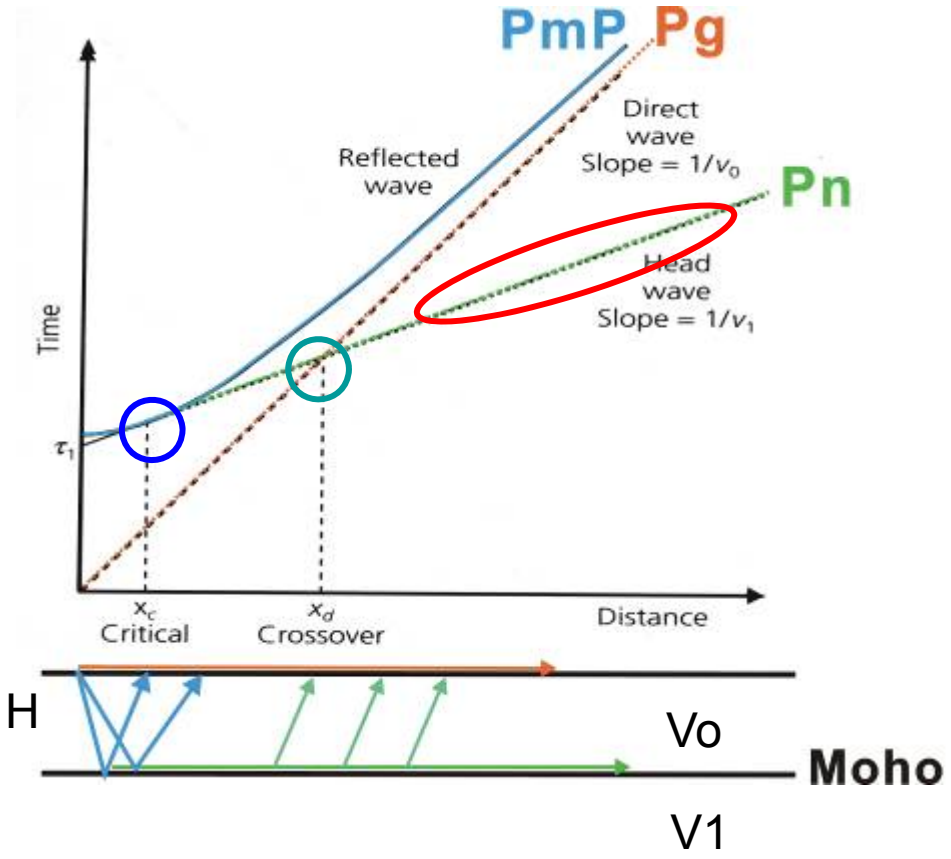
台灣



內容

1. TAIGER 2008～2009
2. ATSEE 2010
3. ATSEE 2011
4. ATSEE 2012

A single-layer crust model



$$X_c = H\ 2\frac{V_0}{\sqrt{V_1^2 - V_0^2}}$$

$$X_d = H\ 2\sqrt{\frac{V_1 + V_0}{V_1 - V_0}}$$

V_0 = 6 km/s $X_c = H \times 2.2$

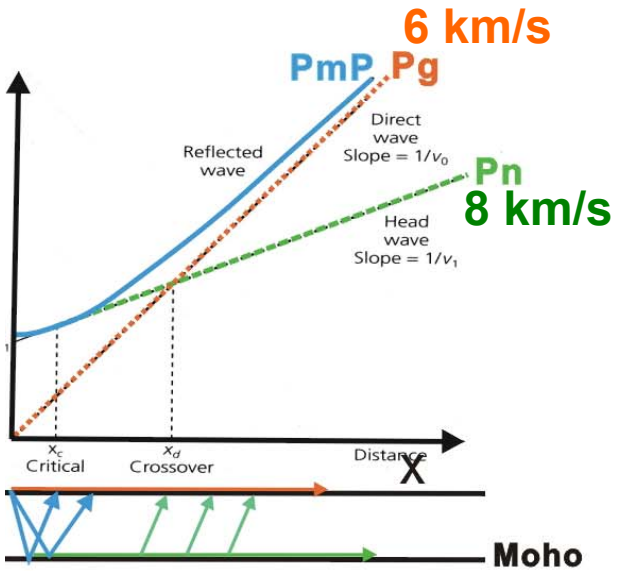
V_1 = 8 km/s $X_d = H \times 5.3$

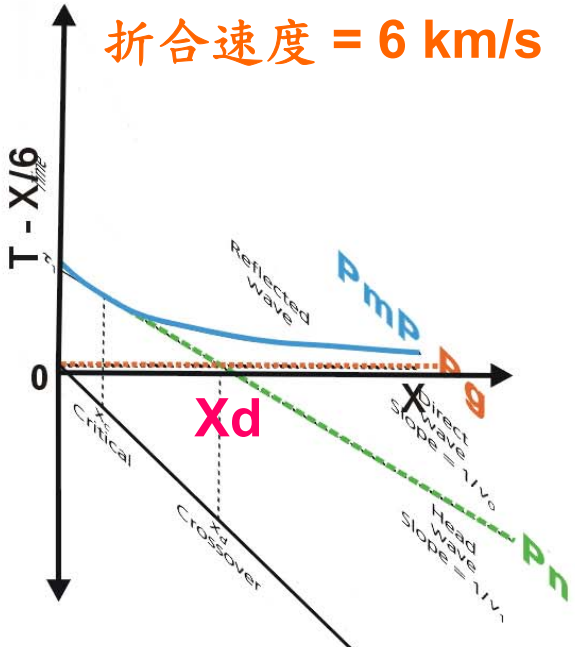
critical angle θ = 50度

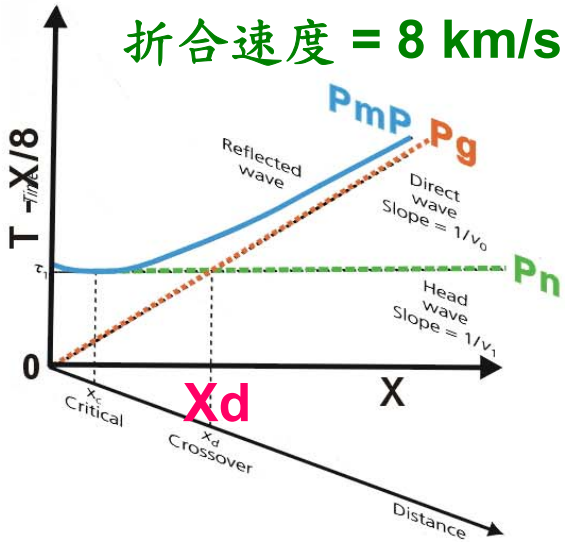
sin **θ** = 0.75

cos **θ**= 0.66

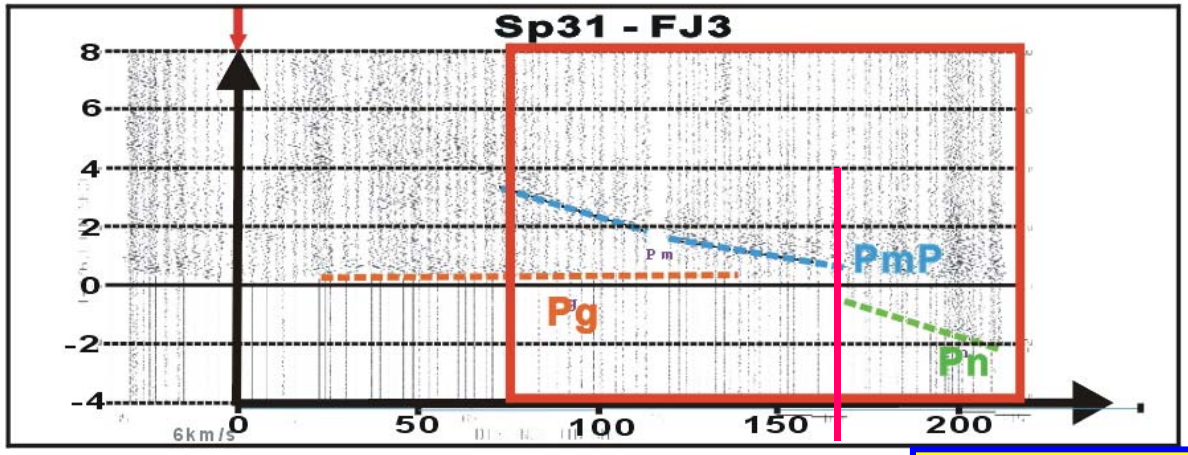
Reduced velocity







折合速度
6 km/s



FJ3 (SP31)

Xd

170/5.3=32km

Mohorovicic for Moho

莫霍洛維奇　　莫荷面

1. Need Pn。

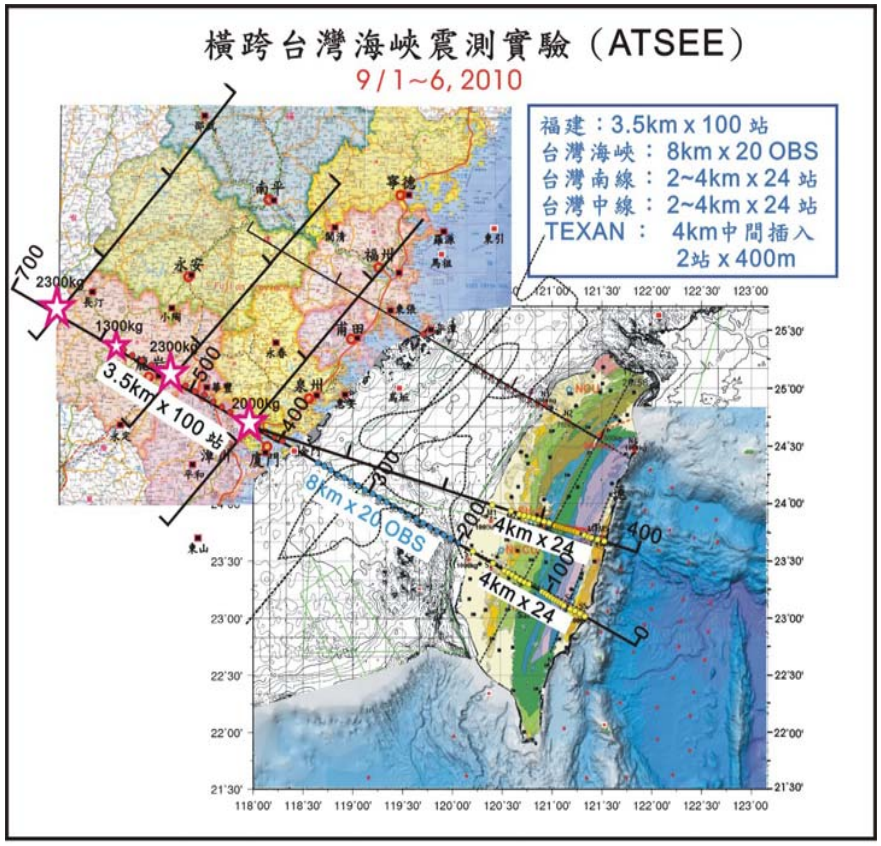
2. Crust 30km，Xd = 160 km (30x5.3)！
   i.e. beyond 160km to see Pn。

3. Taiwan wideness only 120km，NOT able to see Pn。
   → Need outside sources：sea-land or Fujan福建！

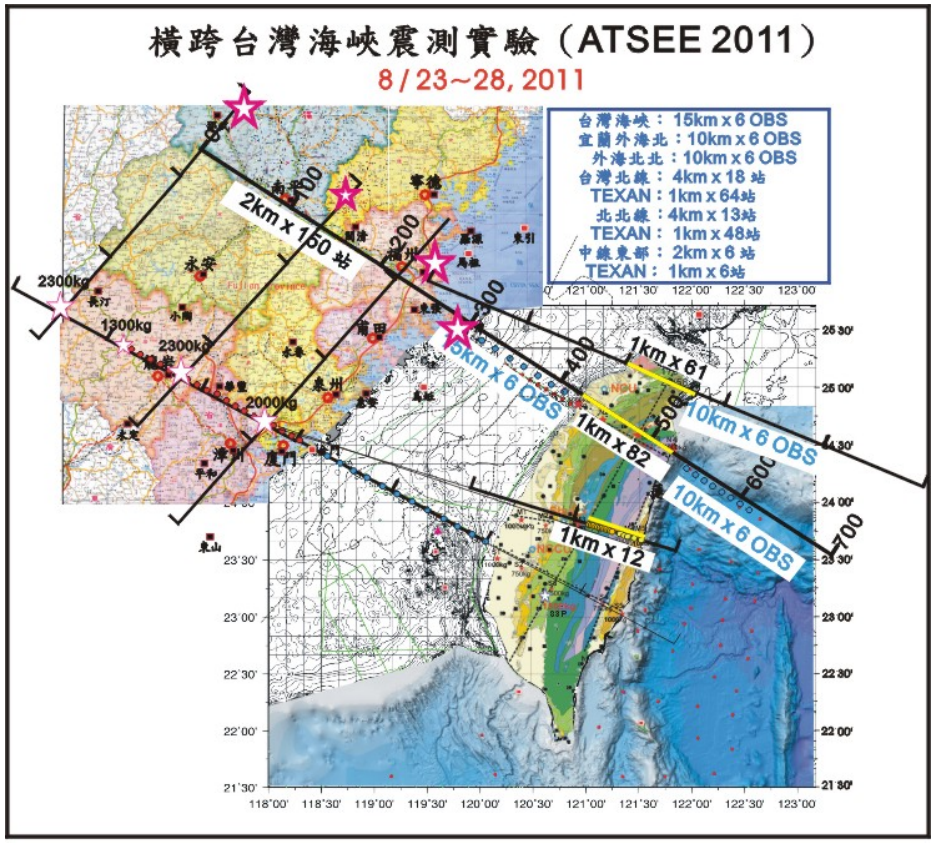
2010~2011: ATSEE 計畫

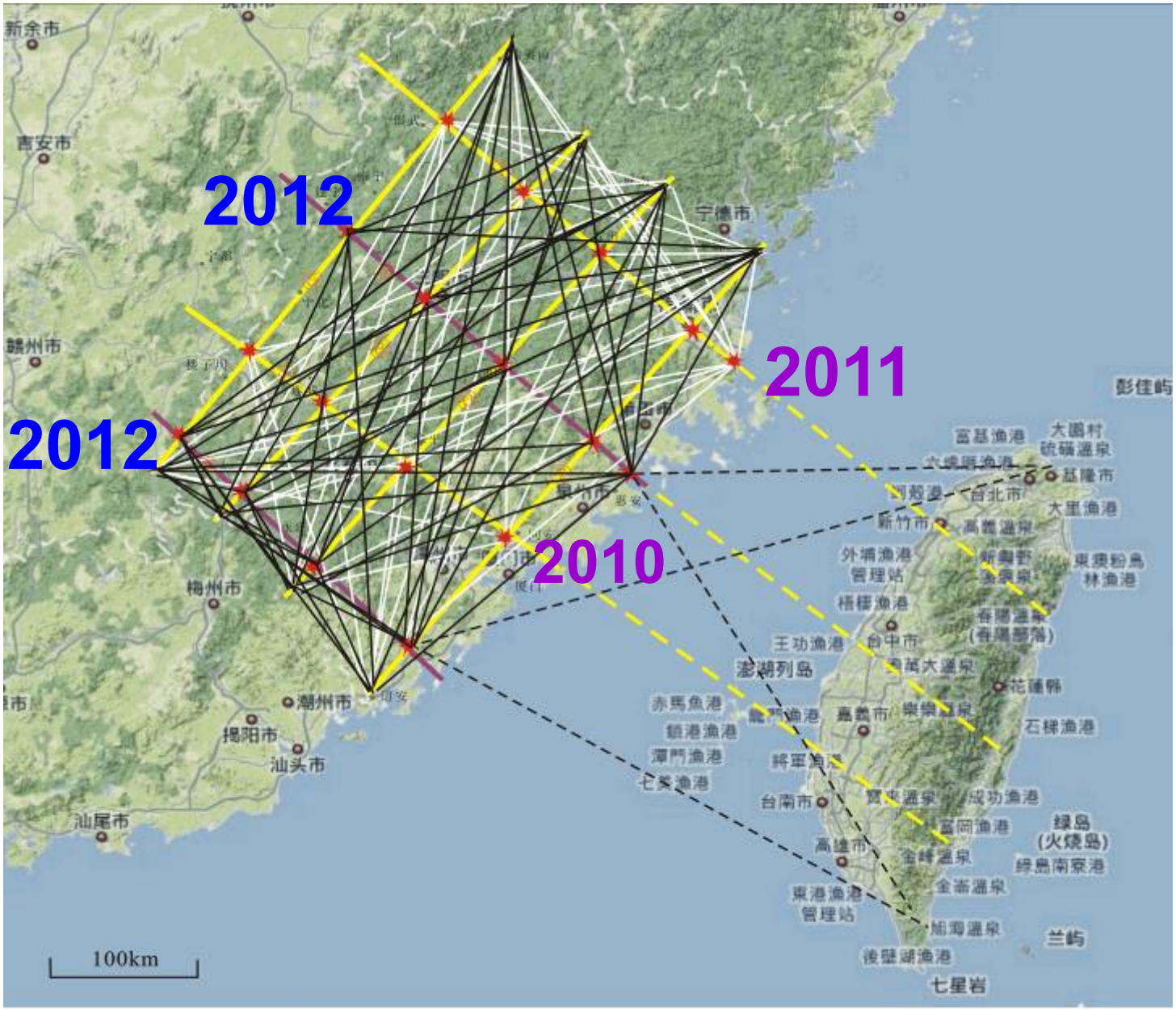
(Across Taiwan-Strait Explosion Experiment)

2010



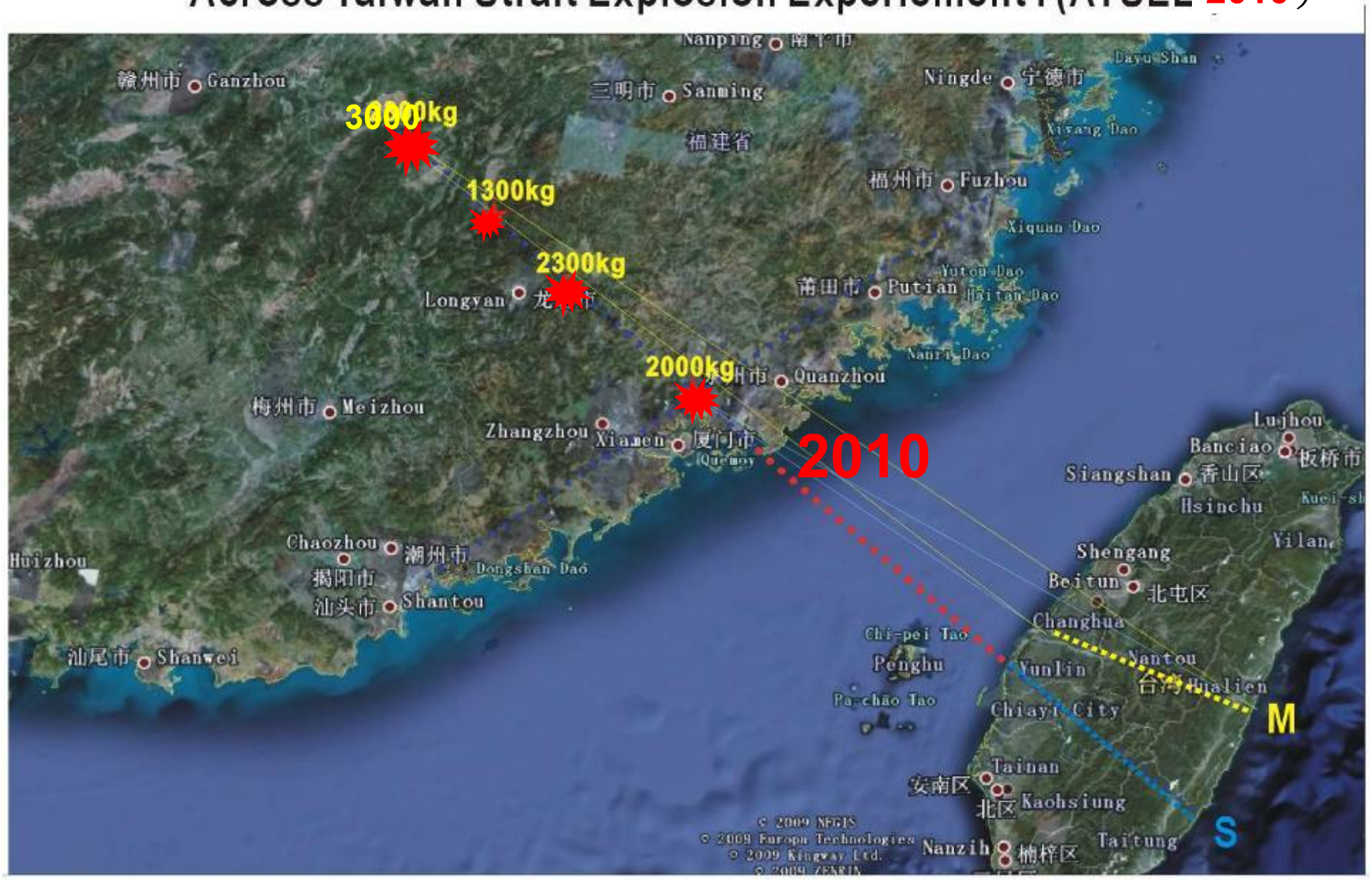
2011



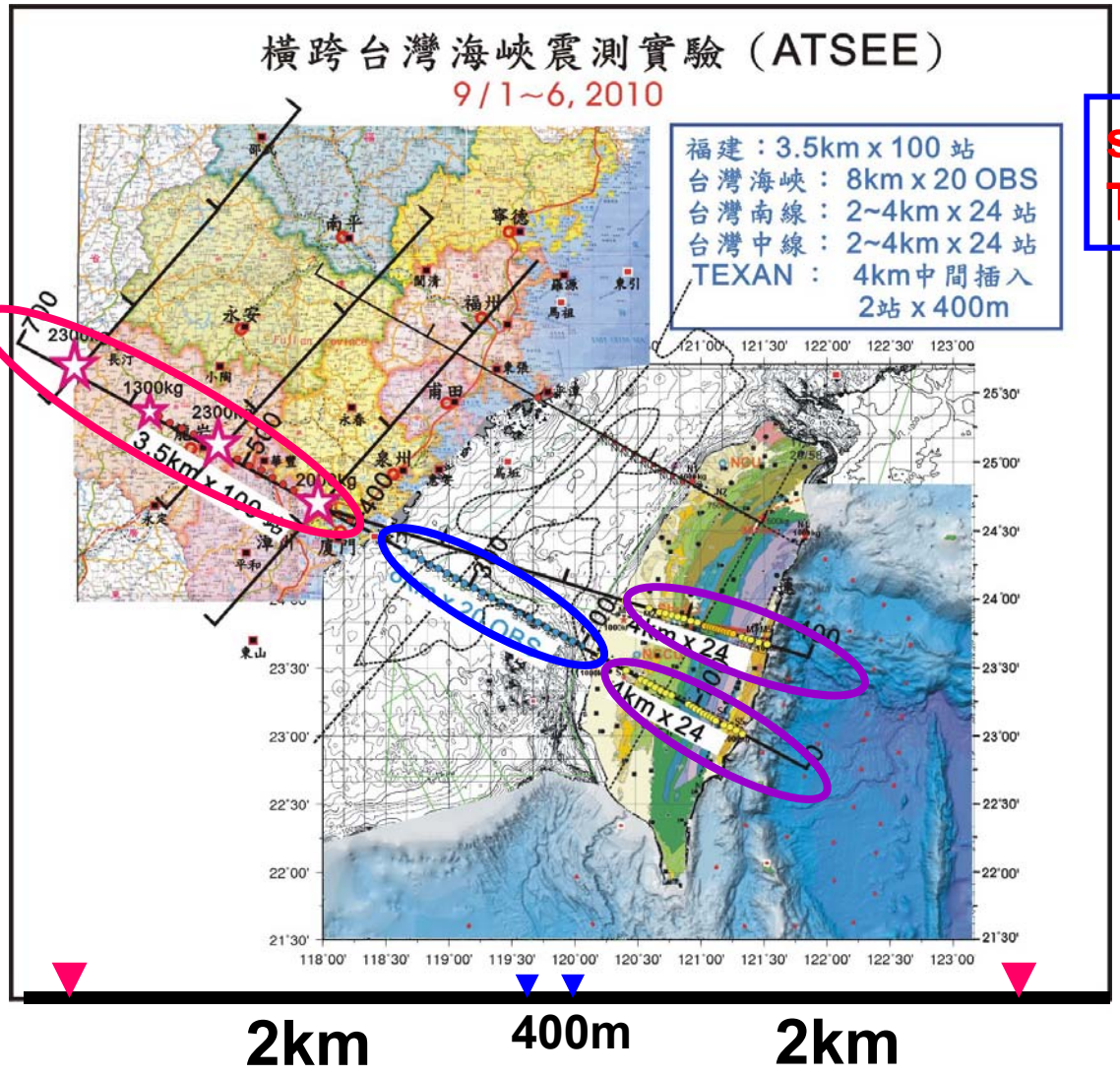


福建及台湾海峡台阵深地震测深2012 观测系统及射线分布

Across Taiwan Strait Explosion Experiement I (ATSEE 2010）



台灣海峽： **15km/站，共 10 OBS**
台灣南線：**2~4km/站，共 24 站**　台灣中線：**2~4km/站，共 26 站**
台灣 **TEXAN**：南線插入（ **400m x 2站 x 19處**）
中線插入（ **400m x 2站 x 18處**）



seismometer 50
TEXAN 74

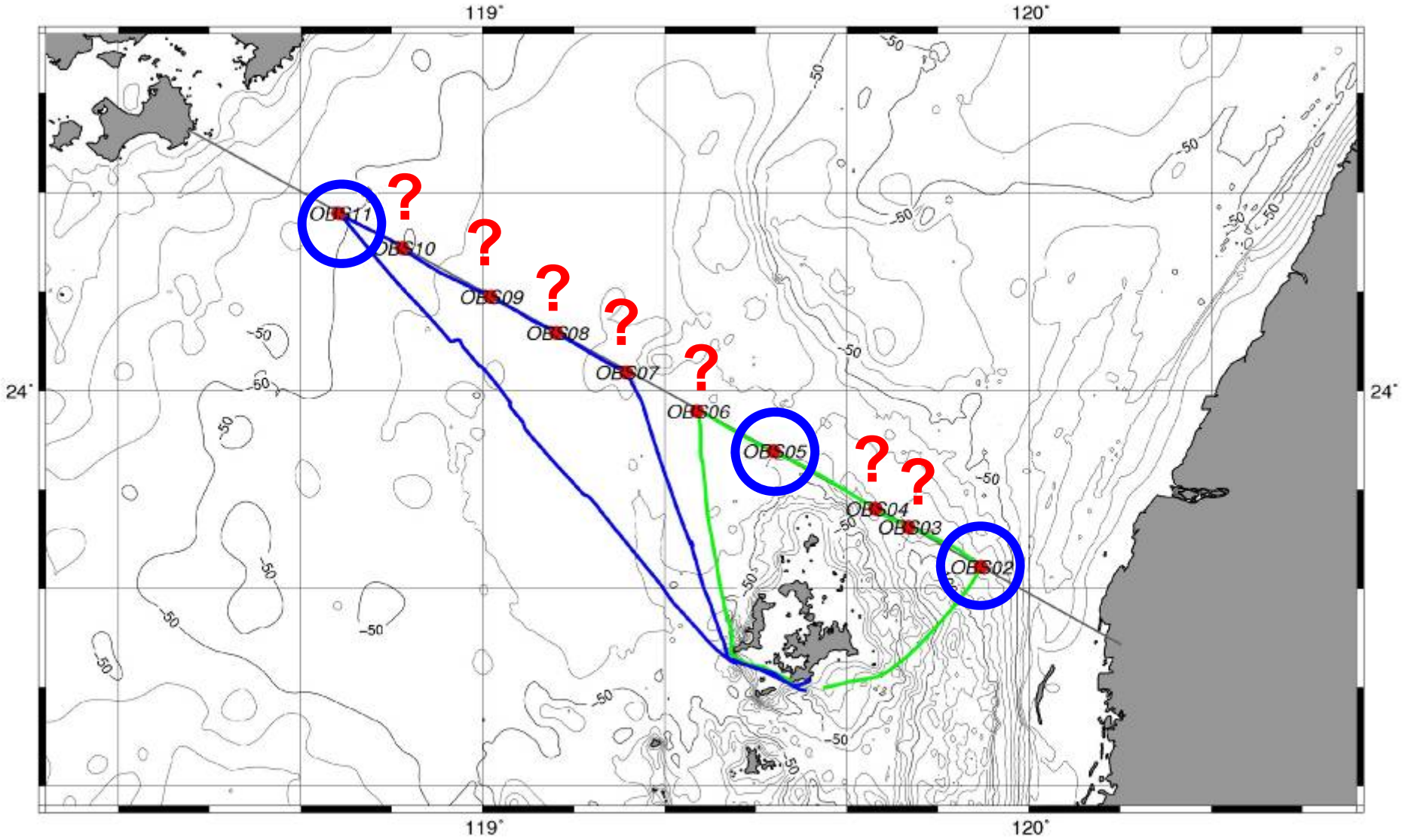
Seismometer deploy

TEXAN

M line 丹大林道 七彩湖站M50

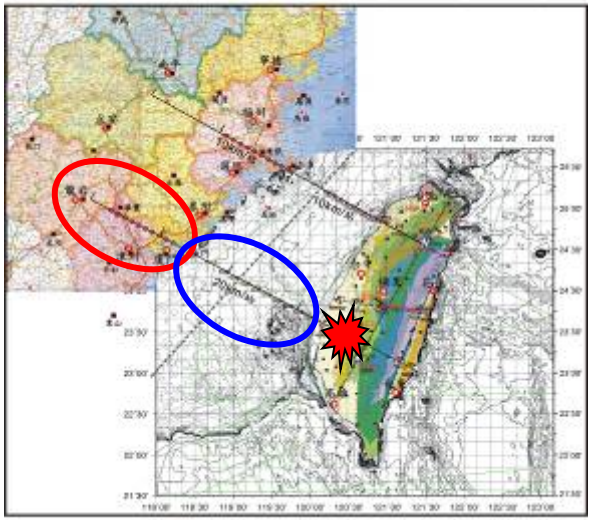
OBS
海底地震儀

10 個 OBS只回來 3 個！（損失慘重）

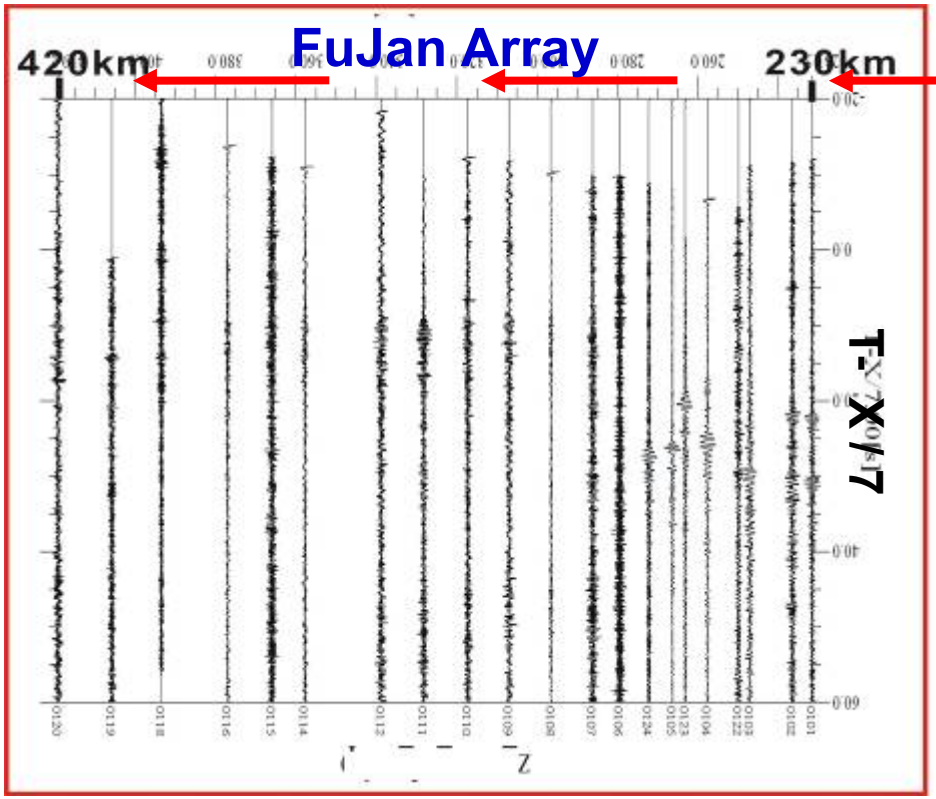


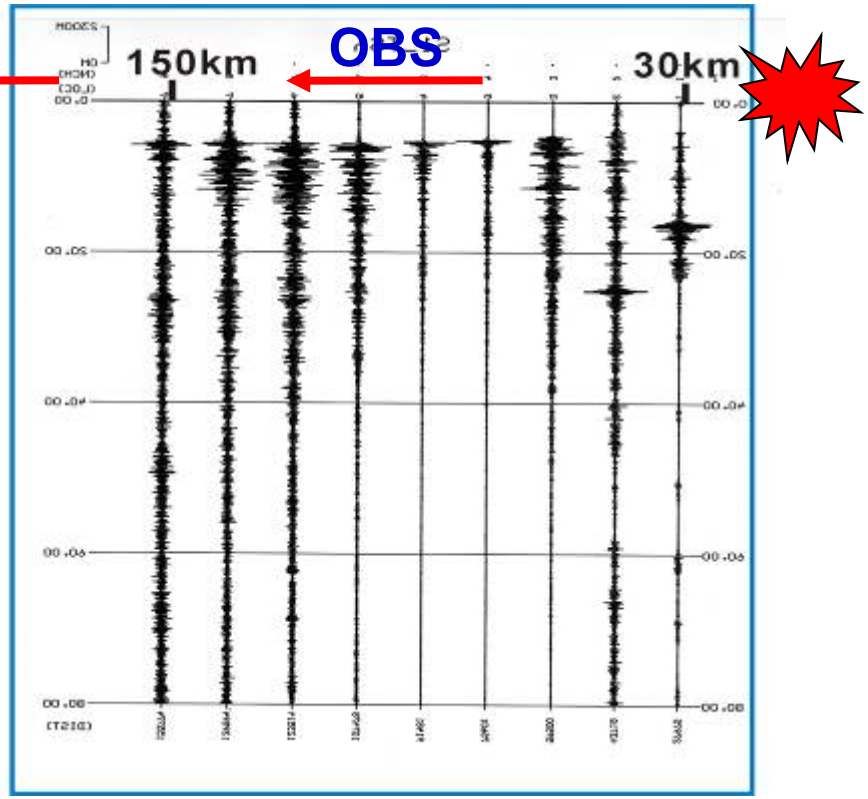
跨越台灣海峽震測實驗

Across Taiwan-Strait Explosion Experiment (ATSEE)



2008 S1





Explosion Points in Fujan

跨越台湾海峡地震联合震测实验爆破点信息表

时间：9/1 （SP1及SP3） 及9/11 （SP4及SP2）

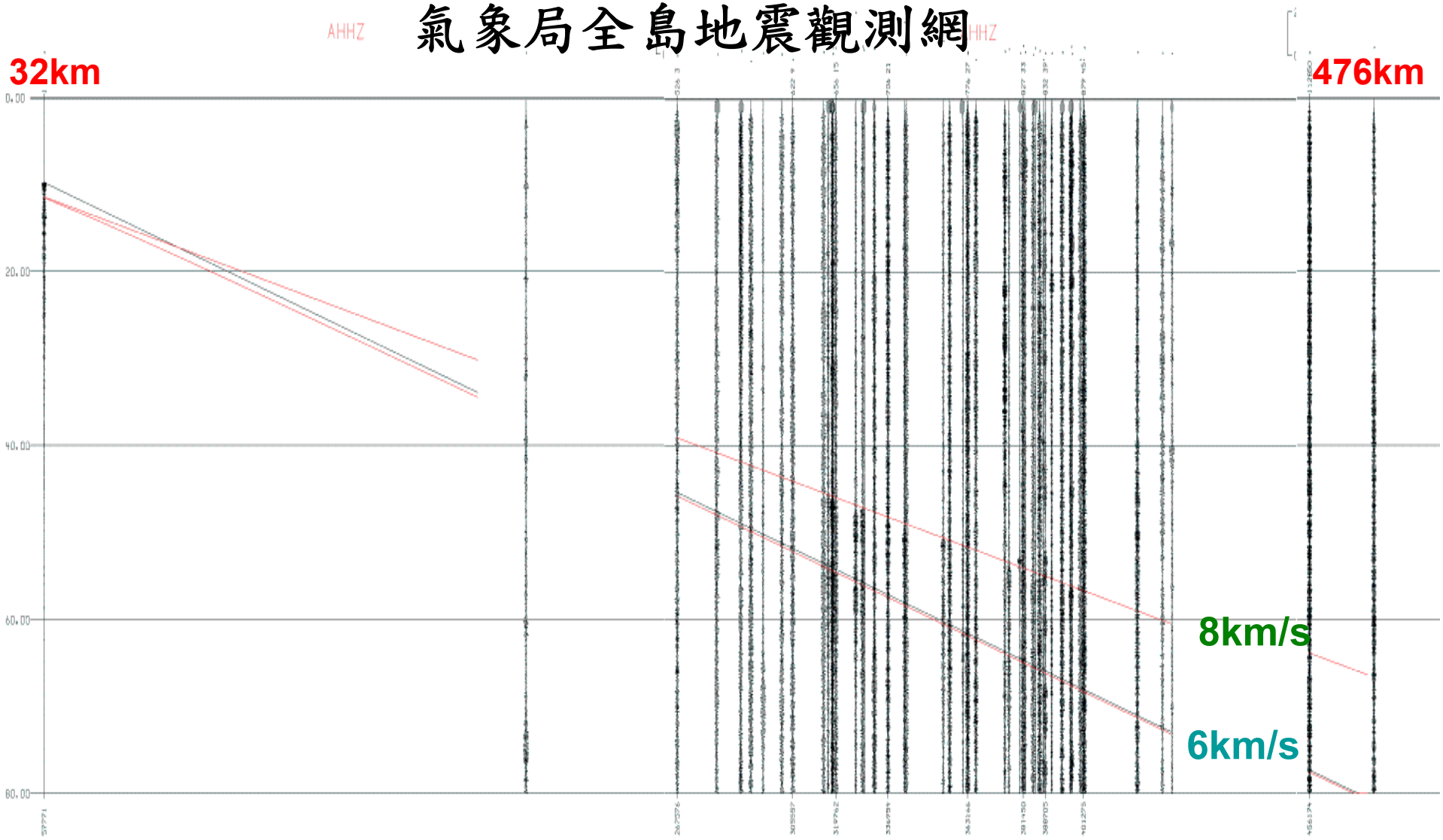
第一炮：01:00 第二炮：01:10

爆破点	位置	地理座标	高程	爆炸药量（KG）	相對震級	起爆时间
SP1	长泰	N24°40.539' E117°52.071'	250m	2000	M1.9	01h00m13.111s
SP2	漳平	N25°3.8166' E117°13.8858'	970m	2500	M1.8	01h10m14.472s
SP3	连城	N25°23.8026' E116°34.9518'	300m	1300	M1.5	01h10m14.752s
SP4	长汀	N25°37.283' E116°4.770'	540m	3000	M1.9	01h00m13.284s

2010年9月，SP31引炸時，氣象局地震中心觀察CWBSN收錄情形

SP31 – CWB Broadband All Stations

氣象局全島地震觀測網



M Line SP31

Western Taiwan ***Q330S in Danda*** ***Eastern Taiwan***

ATM05 310.65km
MX13B 333.82km
ATM12 340.11km
ATM21 364.47km
ATM22 366.93km
ATM26 388.2km

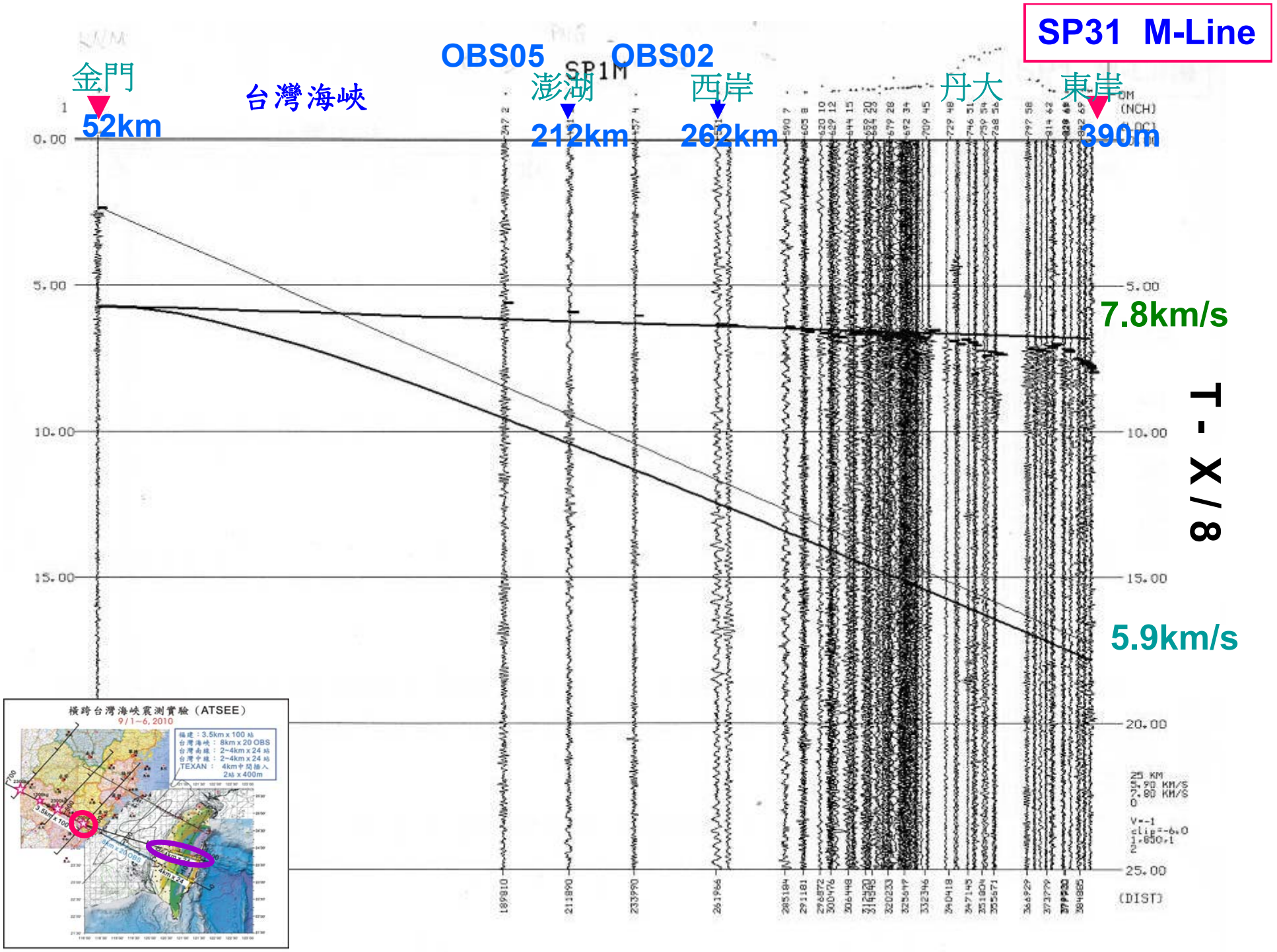
西部平頂 丹大林道 東部縱谷

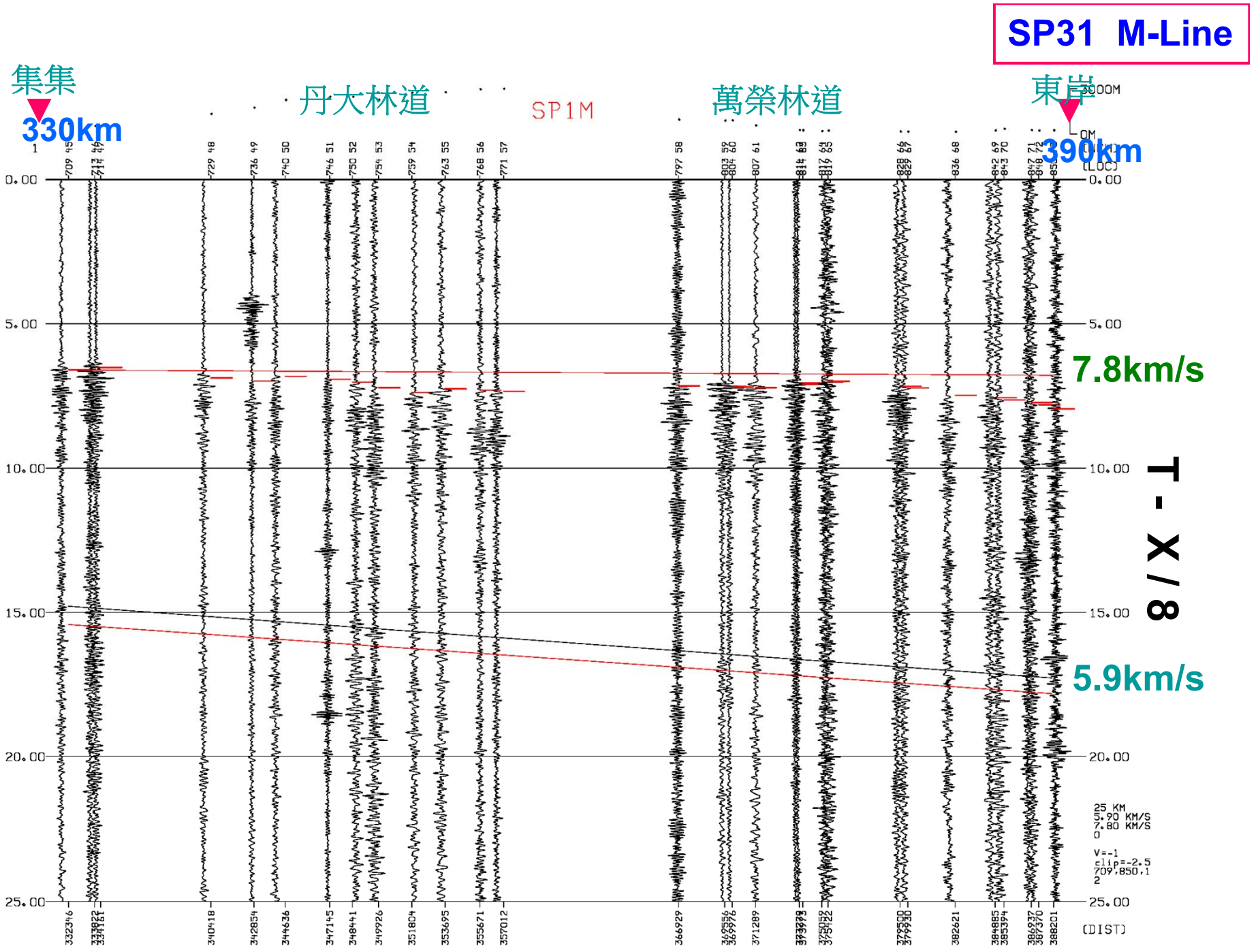
SP1M

Pn

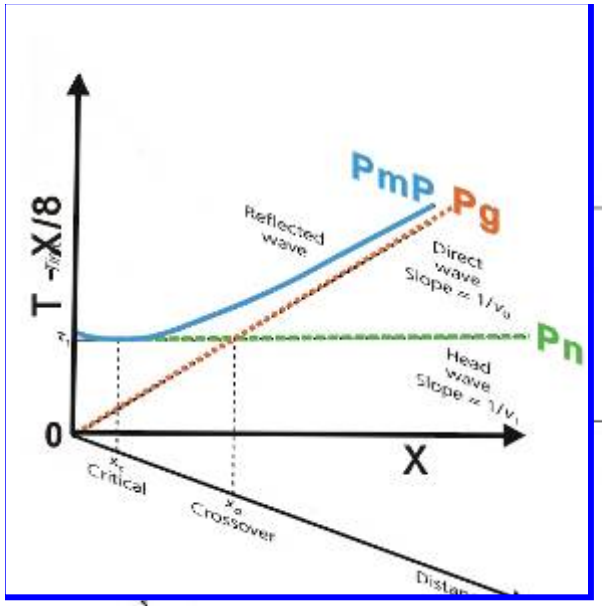
Pg

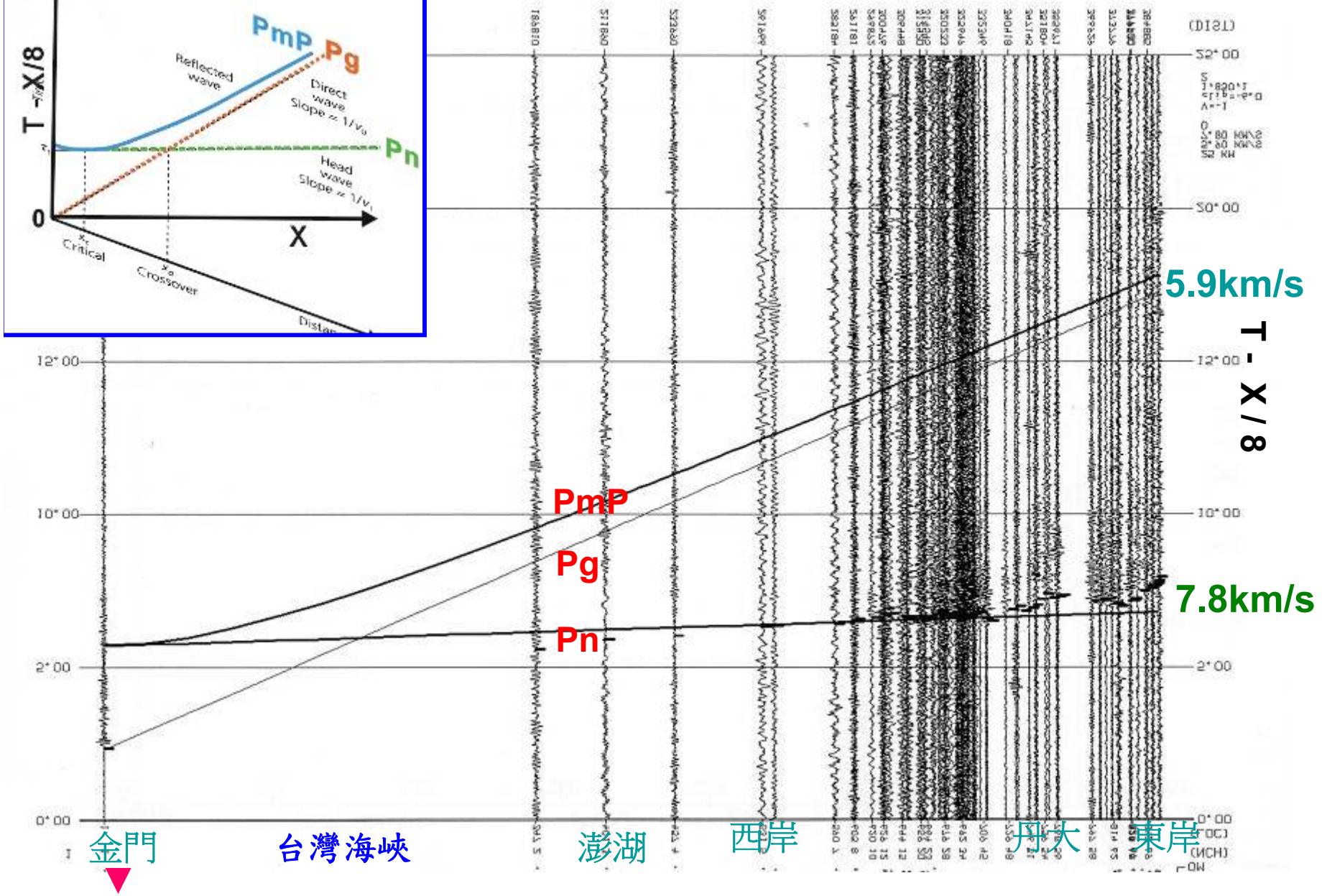
Reflections


SP31 M-Line
金門
52km
台灣海峽
OBS05
澎湖
212km
OBS02
西岸
262km
丹大
東岸
390m
SP1M
7.8km/s
5.9km/s
T - X / 8
0.00
5.00
10.00
15.00
20.00
25.00
(DIST)
橫跨台灣海峽震測實驗（ATSEE）
9/1~6, 2010


SP31 M-Line
集集
330km
丹大林道
SP1M
萬榮林道
東岸
390km
7.8km/s
5.9km/s
T - X / 8
0.00
5.00
10.00
15.00
20.00
25.00
25 KM
5.90 KM/S
7.80 KM/S
(DIST)

SP31 M-Line

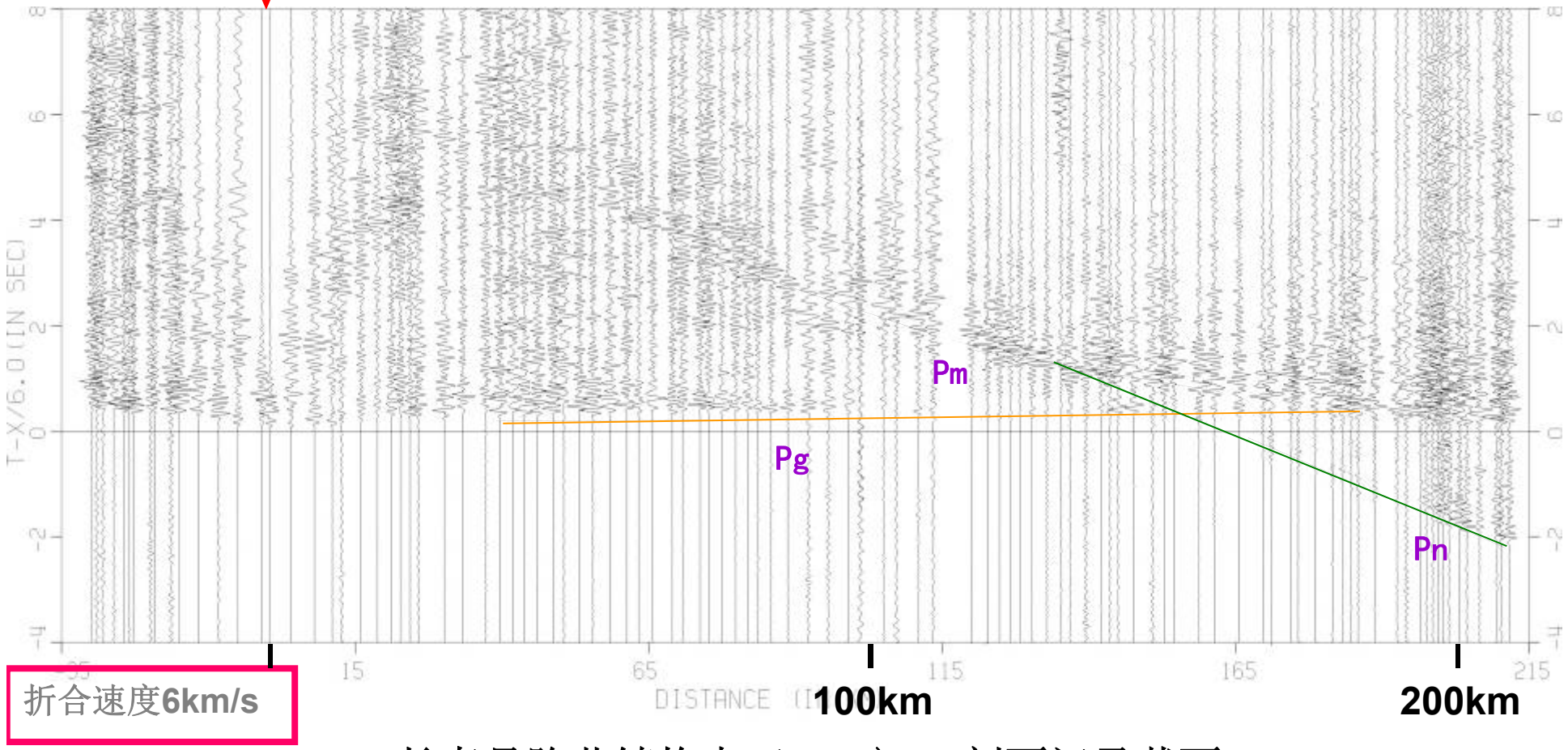

PmP
Pg
Pn
Reflected wave
Direct wave
Slope ≈ 1/v₀
Head wave
Slope ≈ 1/v₁
T -X/8
0
X
Critical
Crossover


5.9km/s
7.8km/s
T - X / 8
PmP
Pg
Pn
12" 00
10" 00
2" 00
0" 00
金門
台灣海峽
澎湖
西岸
丹大
東岸

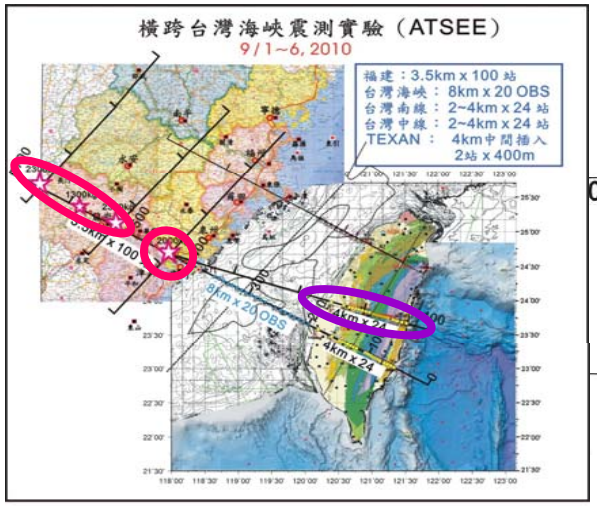
Fujan Records

记录观测主要地震波组

长泰县陈巷镇炸点（SP31），药量2000kg



长泰县陈巷镇炸点（SP31）FJ3剖面记录截面



SP31 M-Line

PNG 西岸 丹大 東岸

PmP

Pg

8.0

7.8

Pn

Pn差1.2sec

差0.8sec

reduced vel = 8 km/s

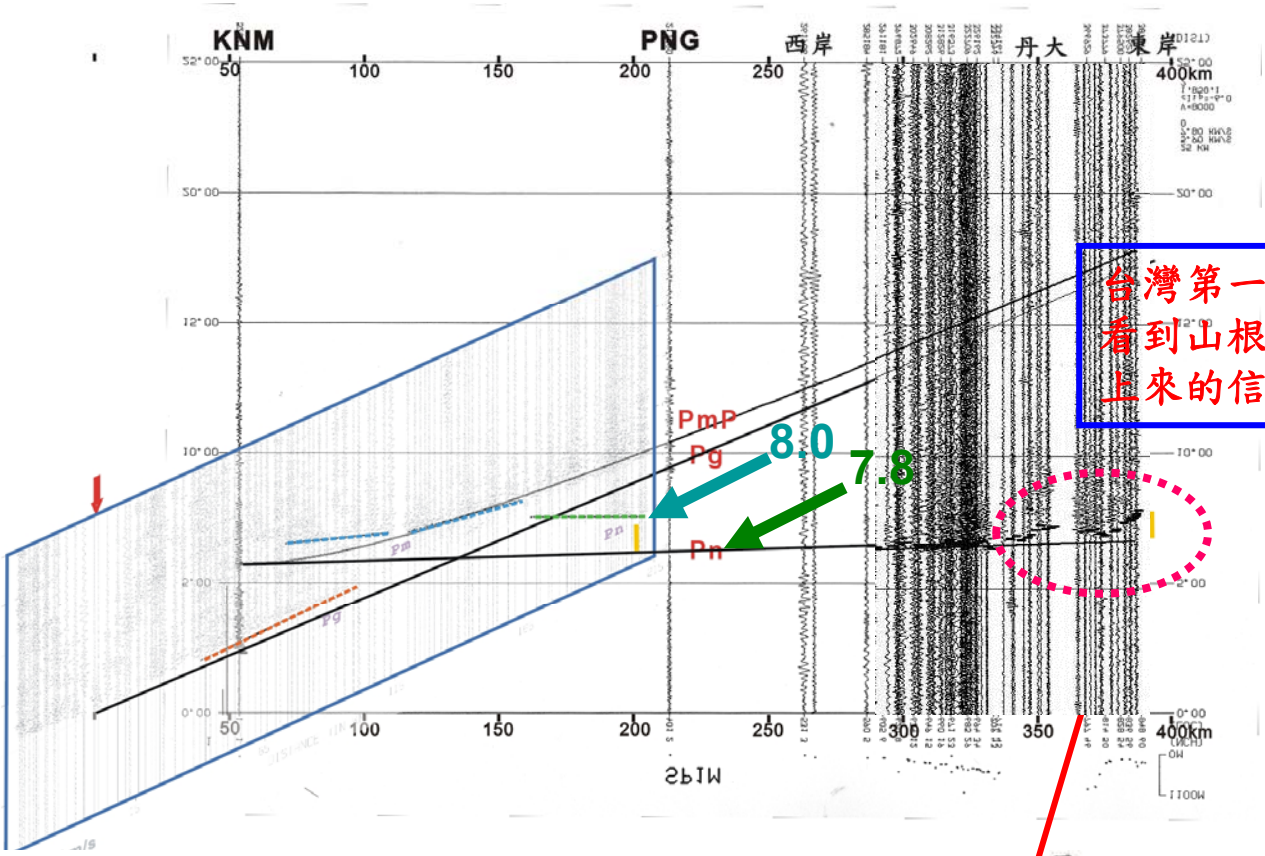
cosθ

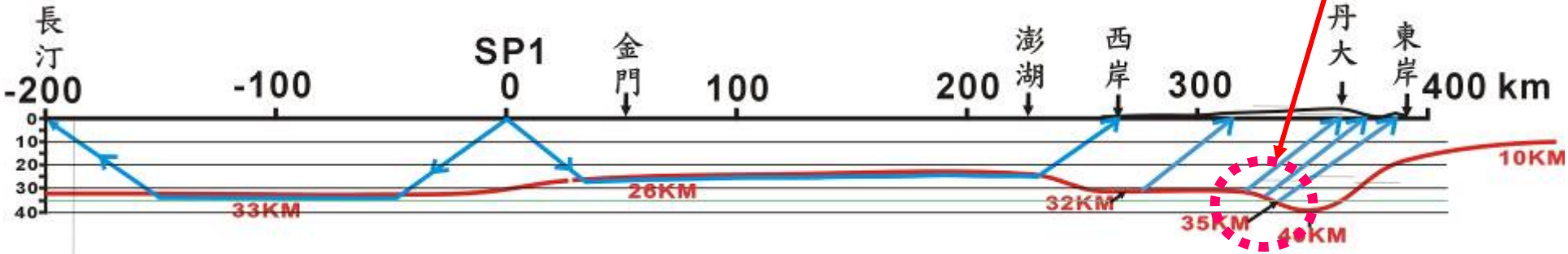
0.8s x 6km/s x 0.66 = 3 km

即 深了3km

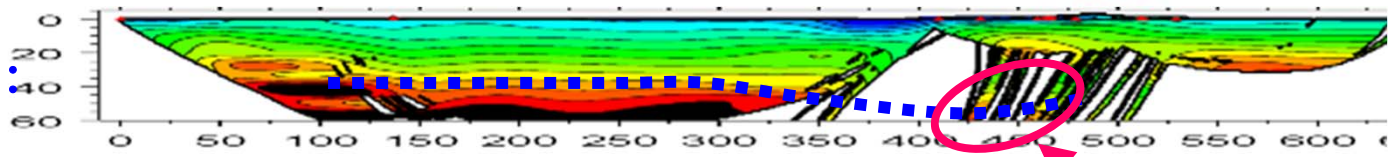
球磁后僅6km/s

SP31 M-Line



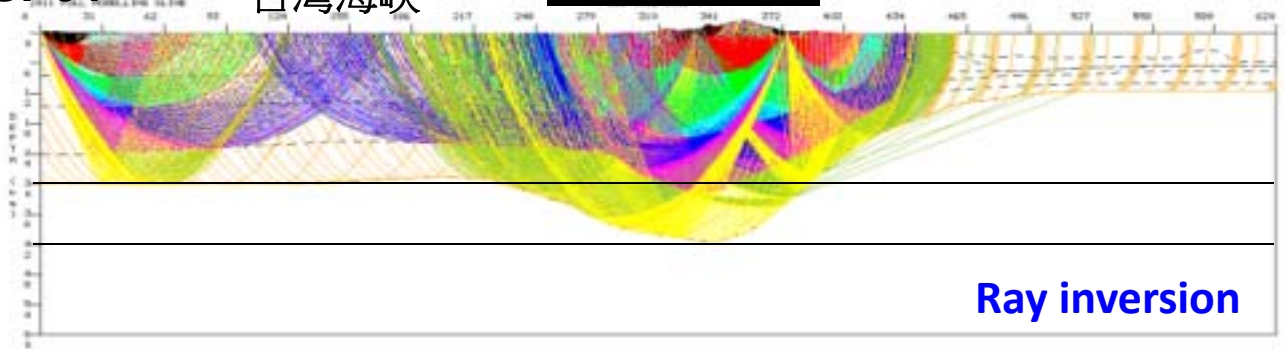


所有資料反演：

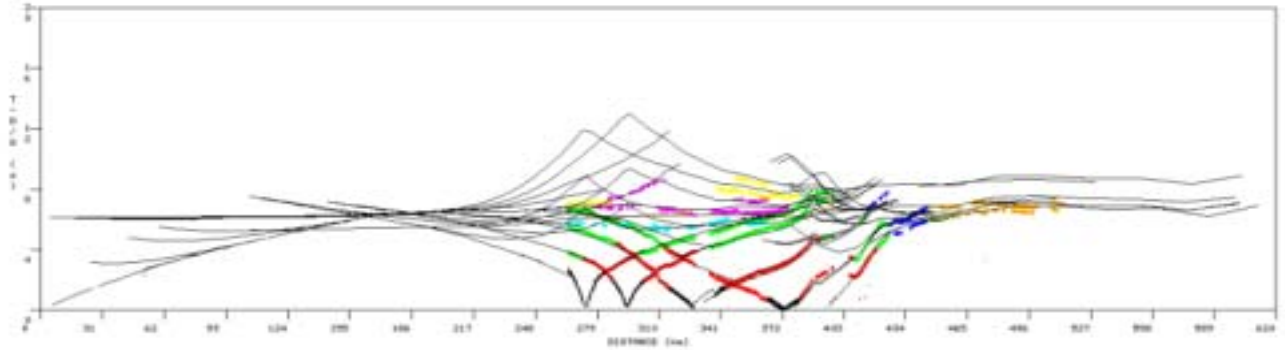


SP31給的Pn

SP31 台灣海峽 Taiwan



Ray inversion

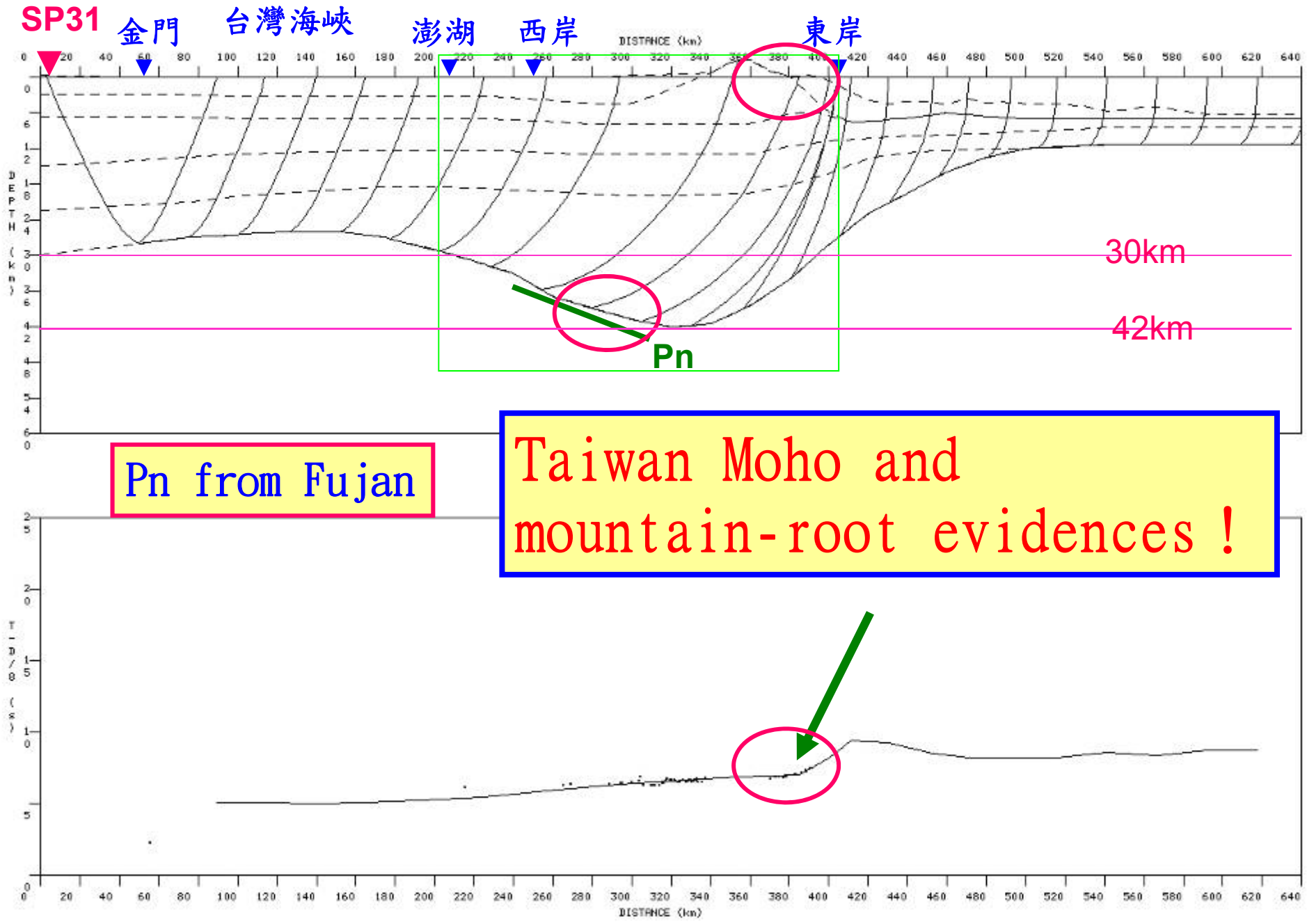


Travel-time matching

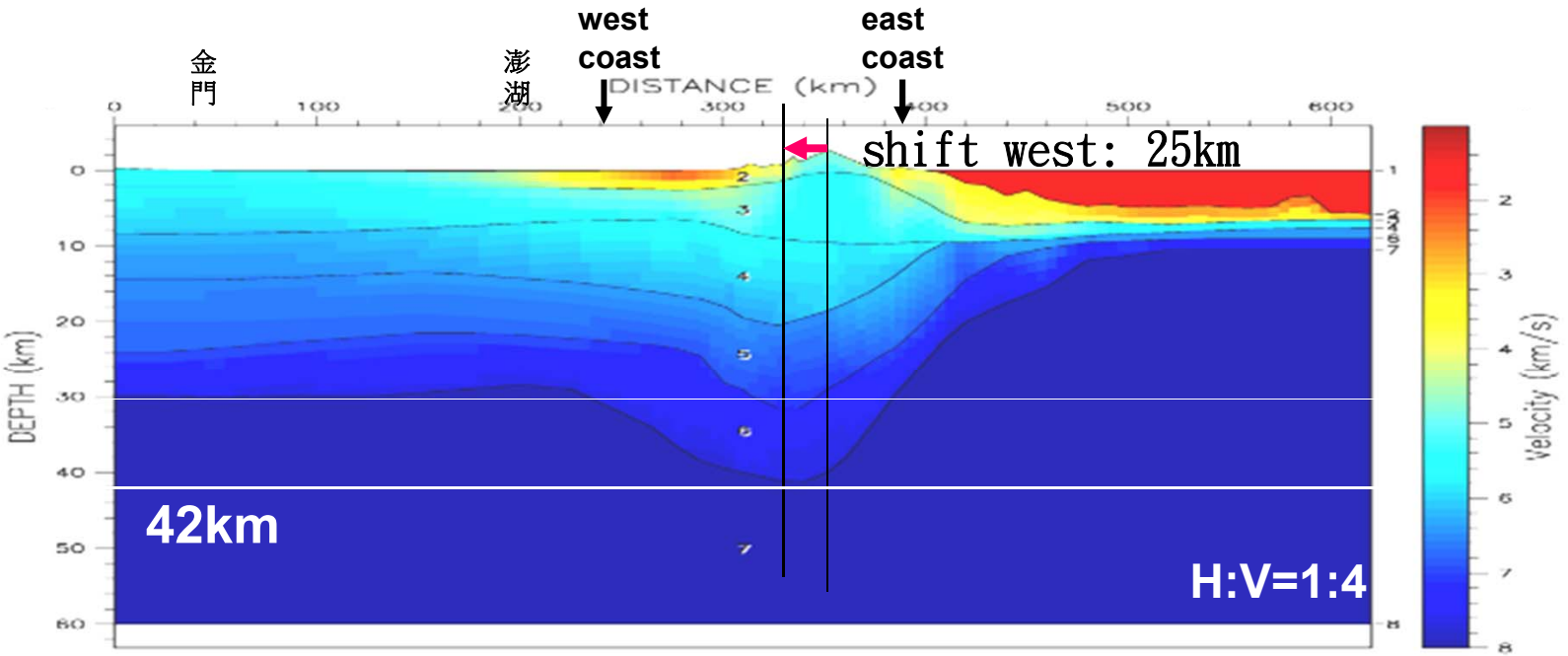
```
|-----------------------------------------------------------------|
|                                                                 |
| total of   4510 rays consisting of   171180 points were traced |
|                                                                 |
|           model consists of  7 layers and 345 blocks            |
|                                                                 |
|-----------------------------------------------------------------|
```

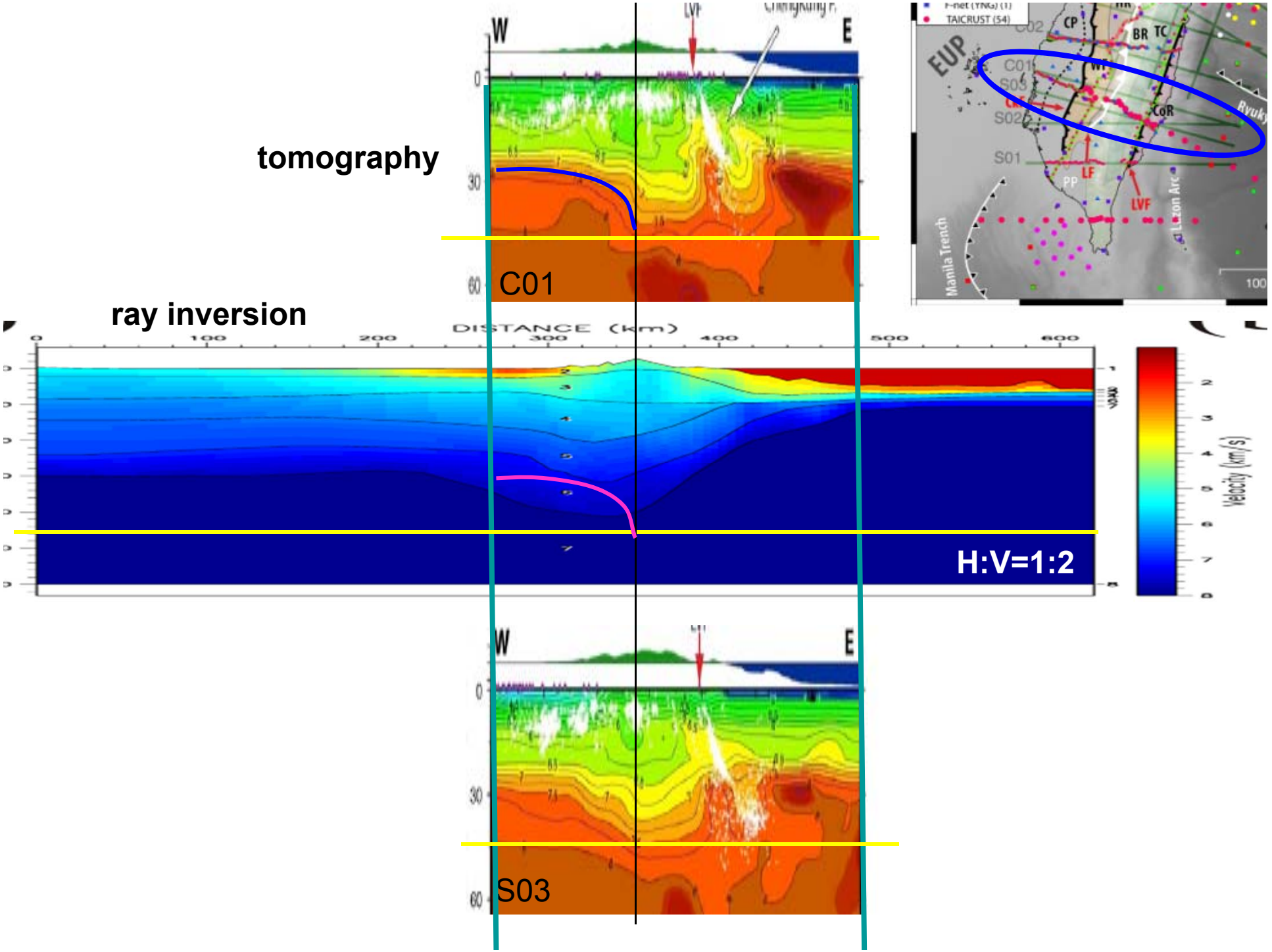
```
Number of data points used:      5979 -- Traced Data Points
RMS traveltime residual:        0.261 -- RMS Value
Normalized chi-squared:         6.824 -- Chi-Squared Value
```

RAY INVERSION



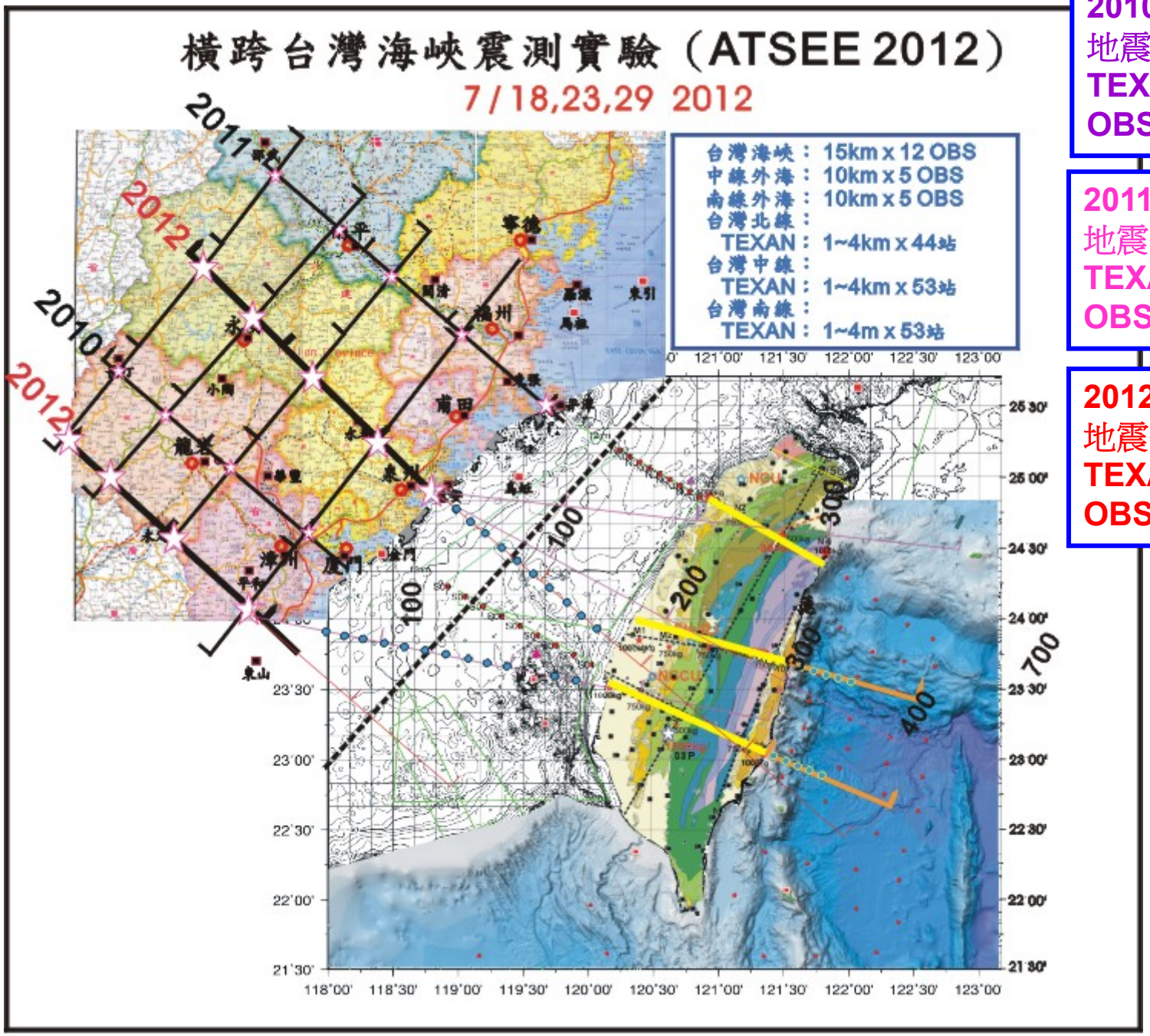
Southern Taiwan Crust Model




tomography
ray inversion
W
E
C01
S03
DISTANCE (km)
H:V=1:2
Velocity (km/s)
EUP
CP
BR
TC
CoR
LF
LVF
PP
Manila Trench
TAICRUST (54)

內容

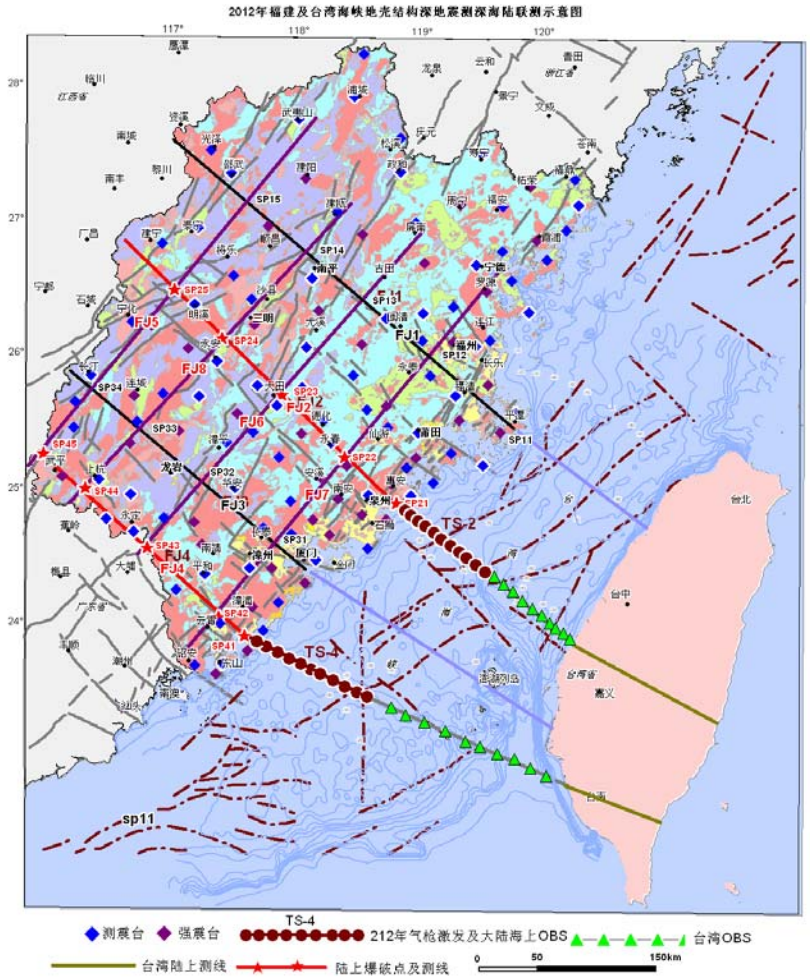
1. TAIGER 2008～2009
2. ATSEE 2010
3. ATSEE 2011 ← skip
4. ATSEE 2012

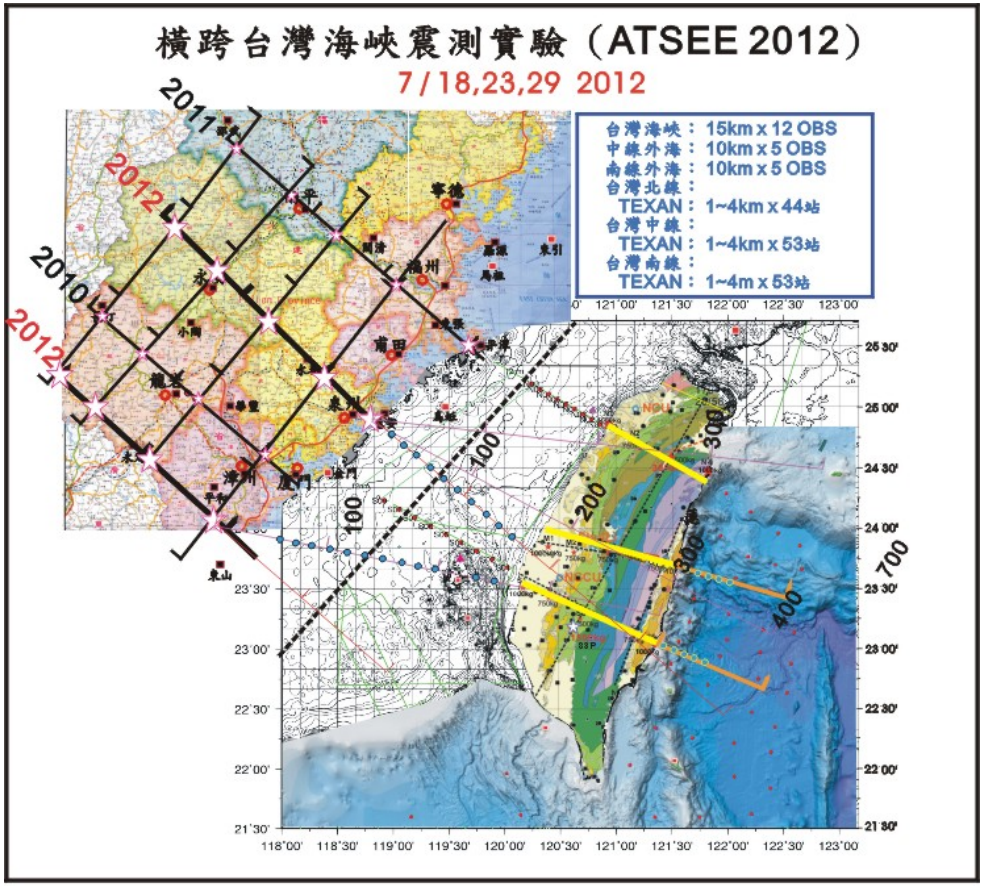


2010
地震儀 **50台**
TEXAN 74台
OBS 10台

2011
地震儀 **34台**
TEXAN 118台
OBS 20台

2012
地震儀 **0台**
TEXAN 150台
OBS 22台



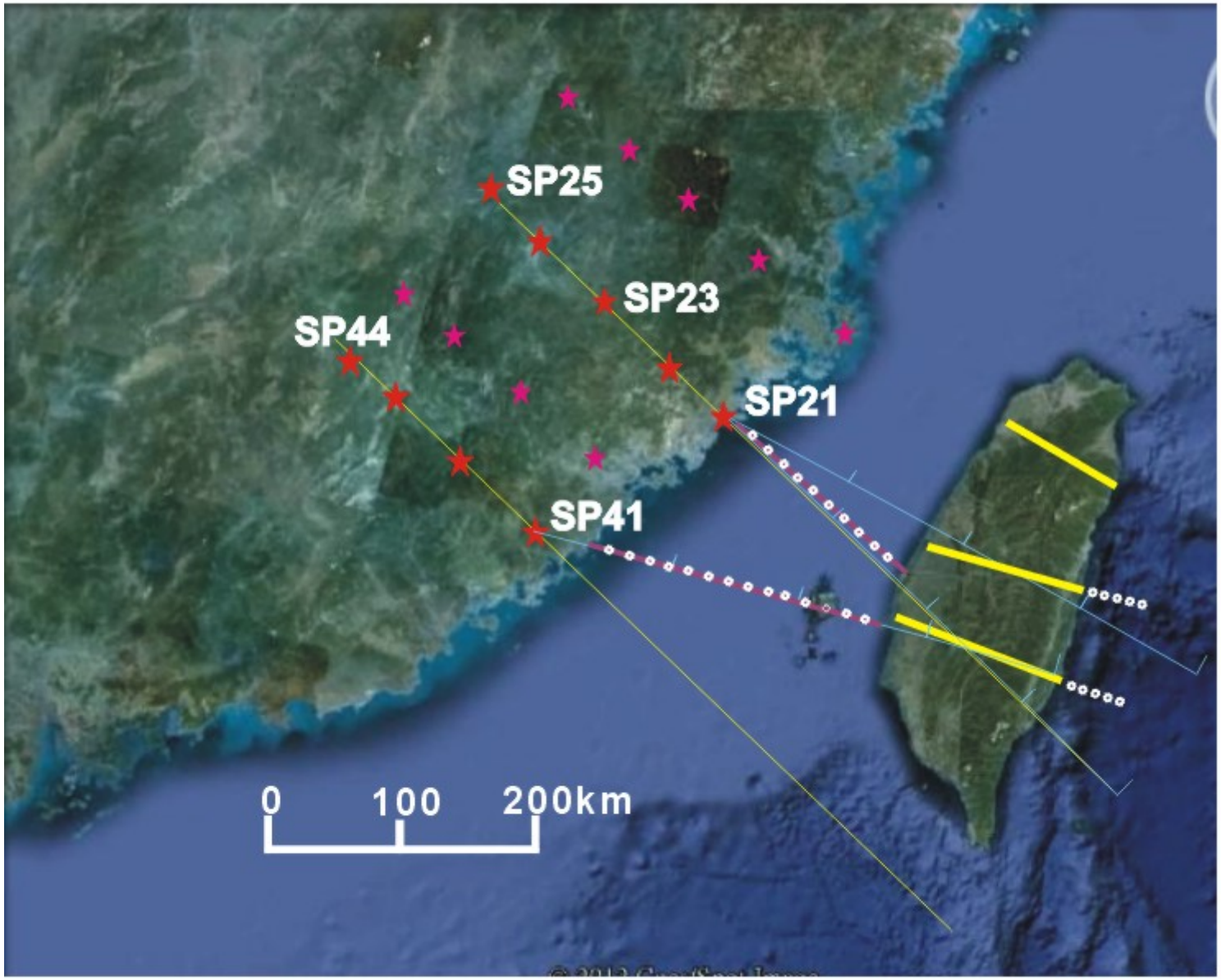


海上:
24台OBS
2条测线
220km长
720炮

丘學林**1** (提供實驗二號**MCS**和**OBS**)、
阮愛國**2**、李家彪**2** (提供**OBS**)

林靜怡、許樹坤 、
葉一慶、梁進維 、李昭興 (提供**OBS**)

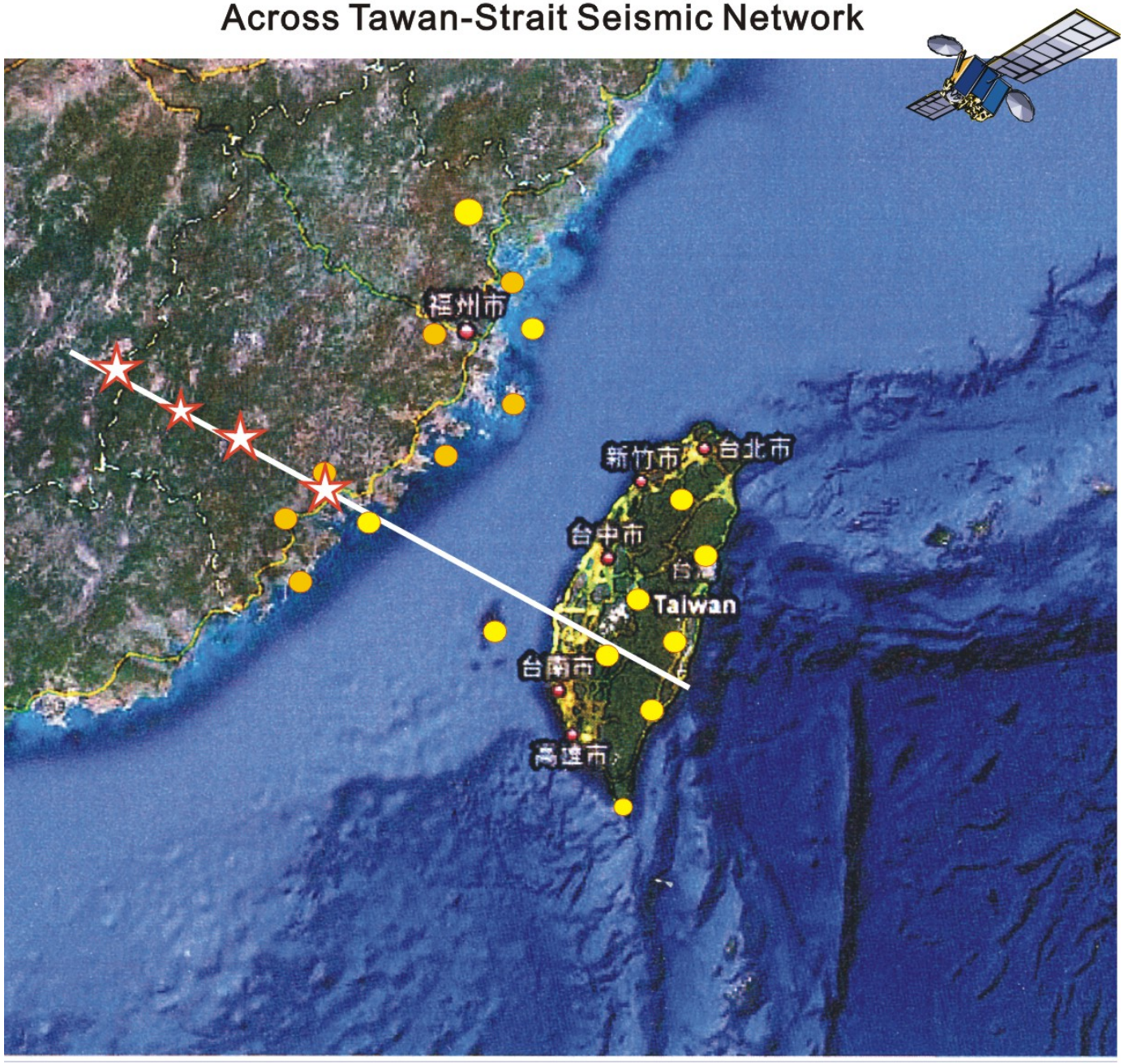
Across Taiwan Strait Explosion Experiement (ATSEE)

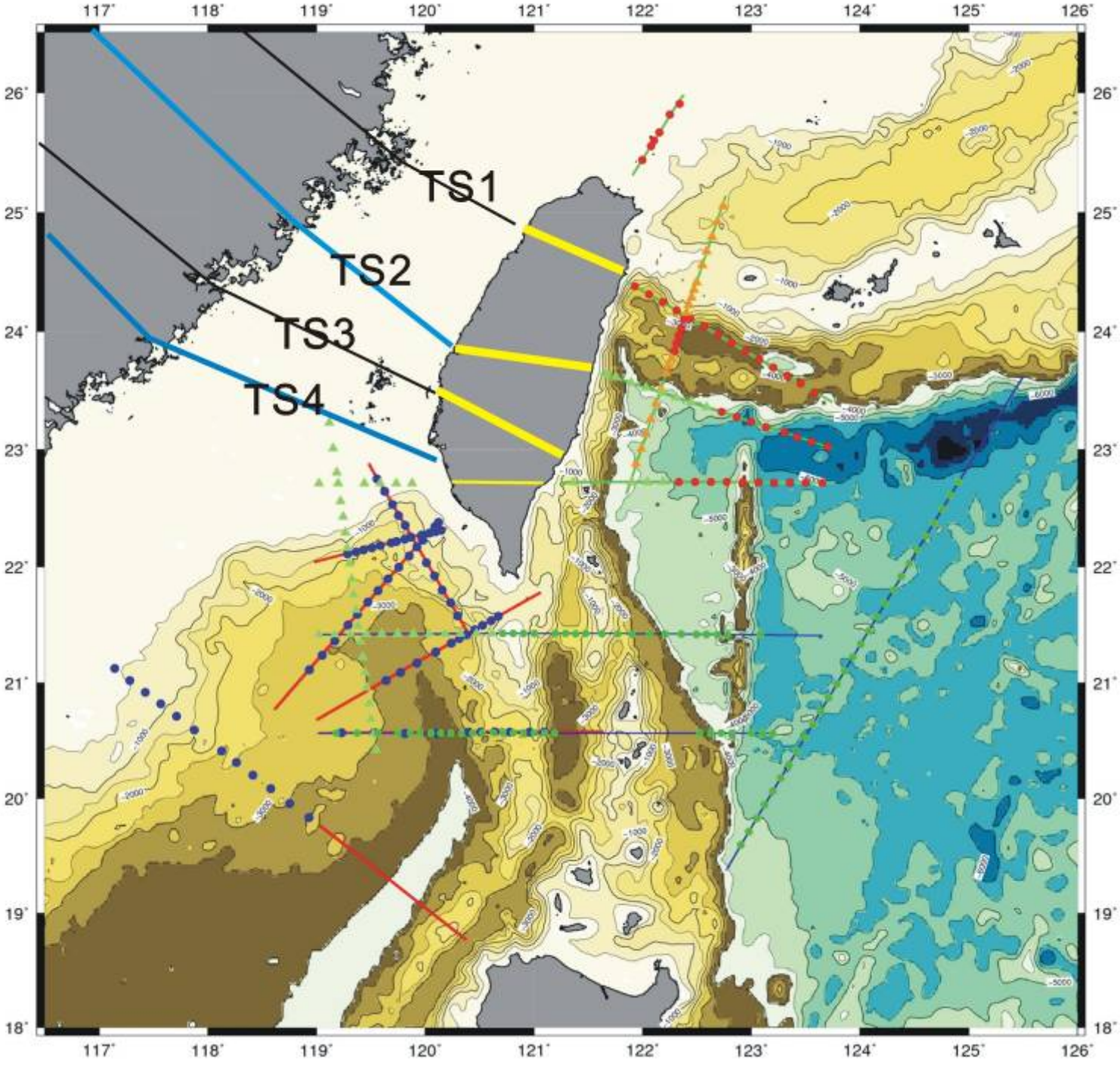


July 18, 23, 29, 2012

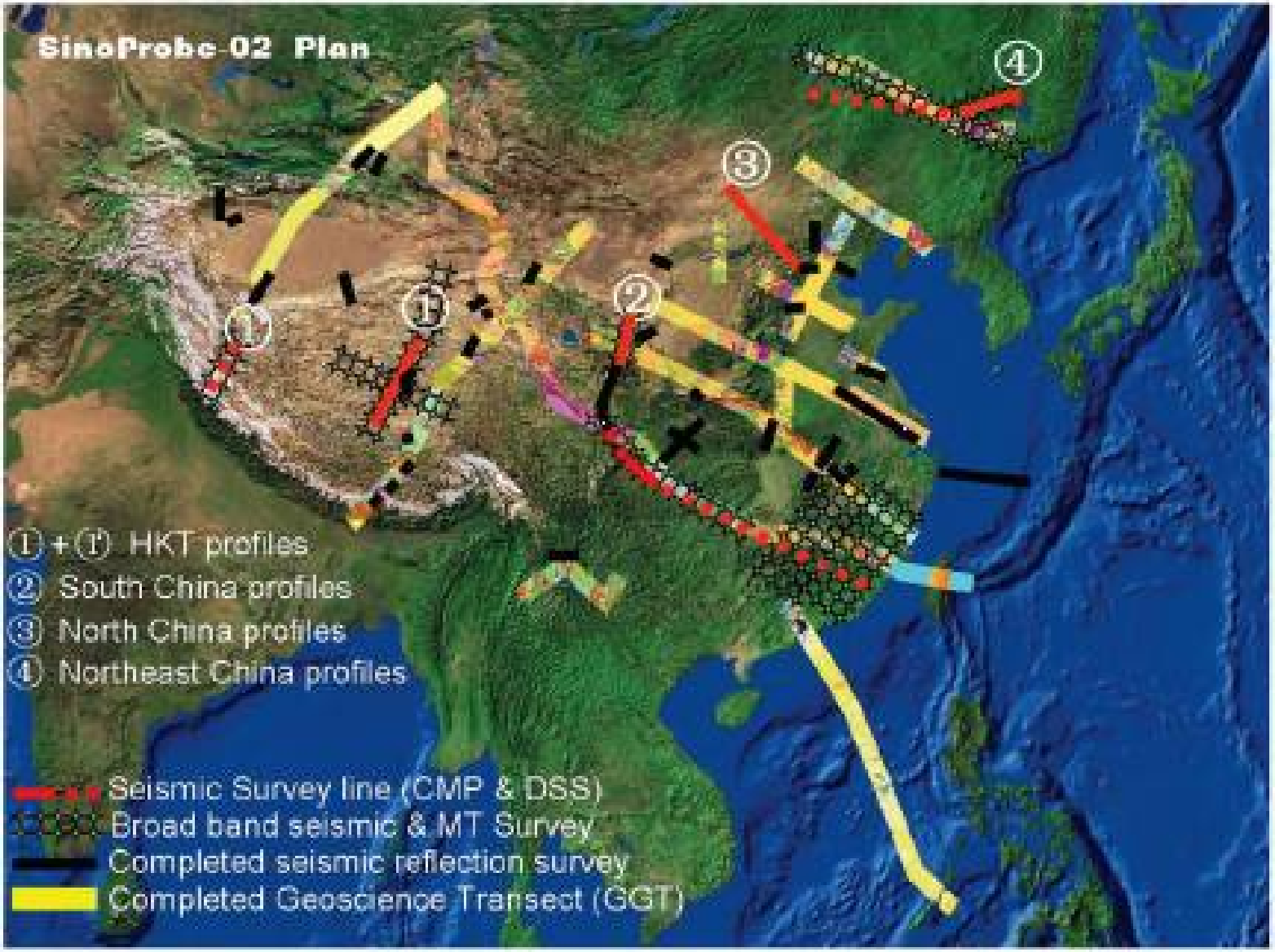
台灣海峽地震觀測網

Across Tawan-Strait Seismic Network




TS1
TS2
TS3
TS4
117°
118°
119°
120°
121°
122°
123°
124°
125°
126°
26°
25°
24°
23°
22°
21°
20°
19°
18°

SinoProbe



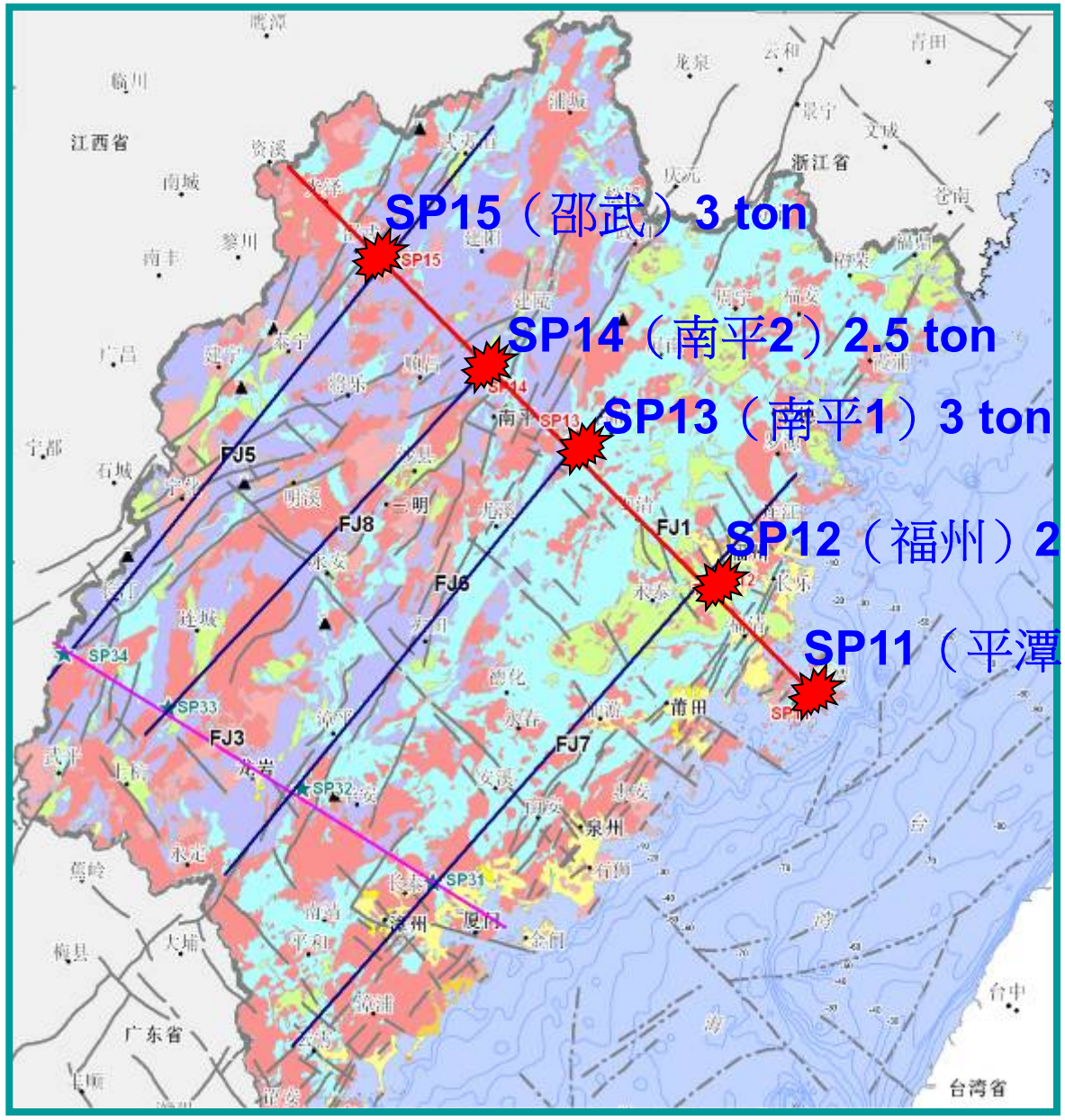
Plan of the SinoProbe-02

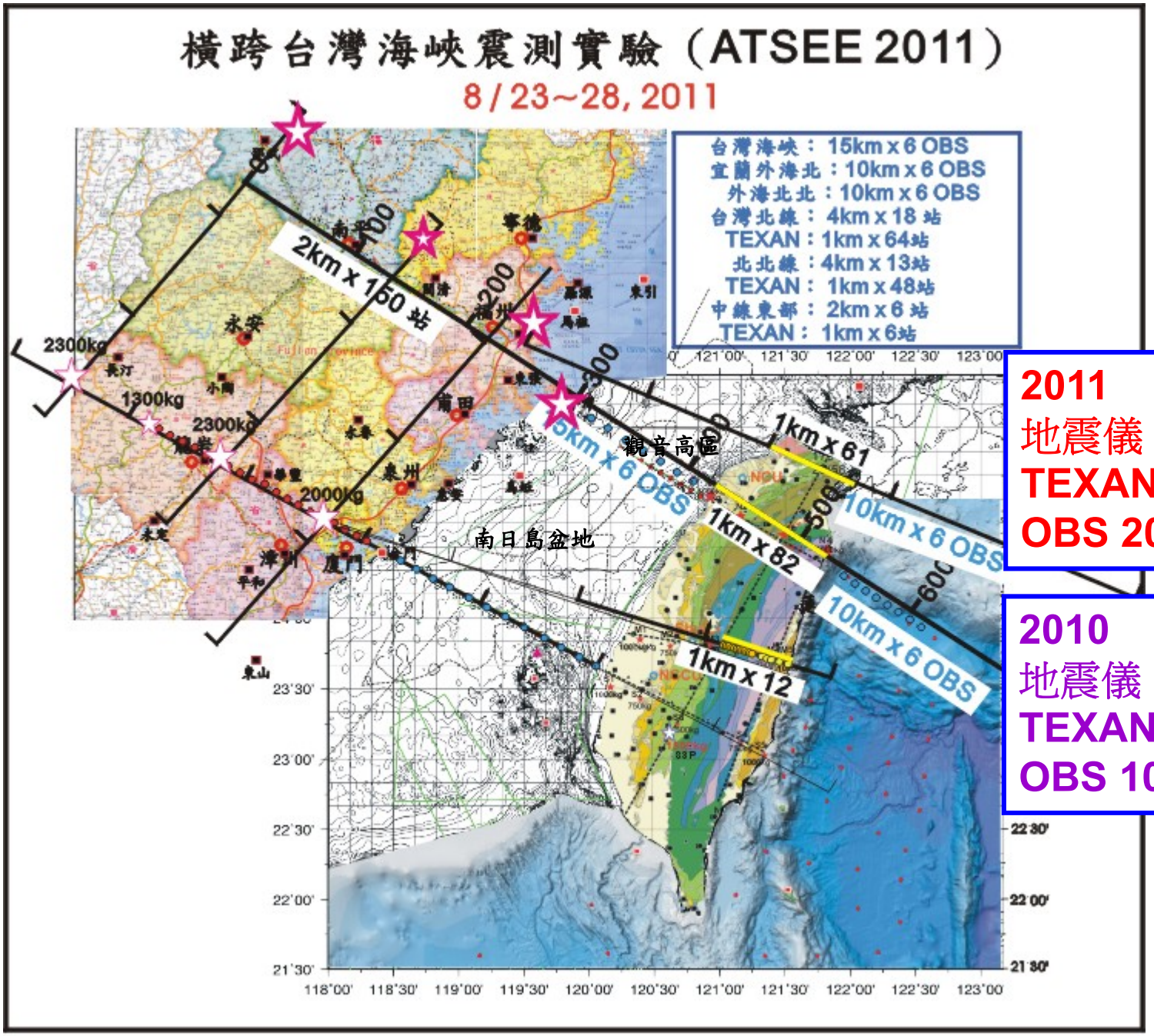

THANKS!

內容

1. TAIGER 2008～2009
2. ATSEE 2010
3. ATSEE 2011
4. ATSEE 2012

2011
8 / 23, 28
五炸點

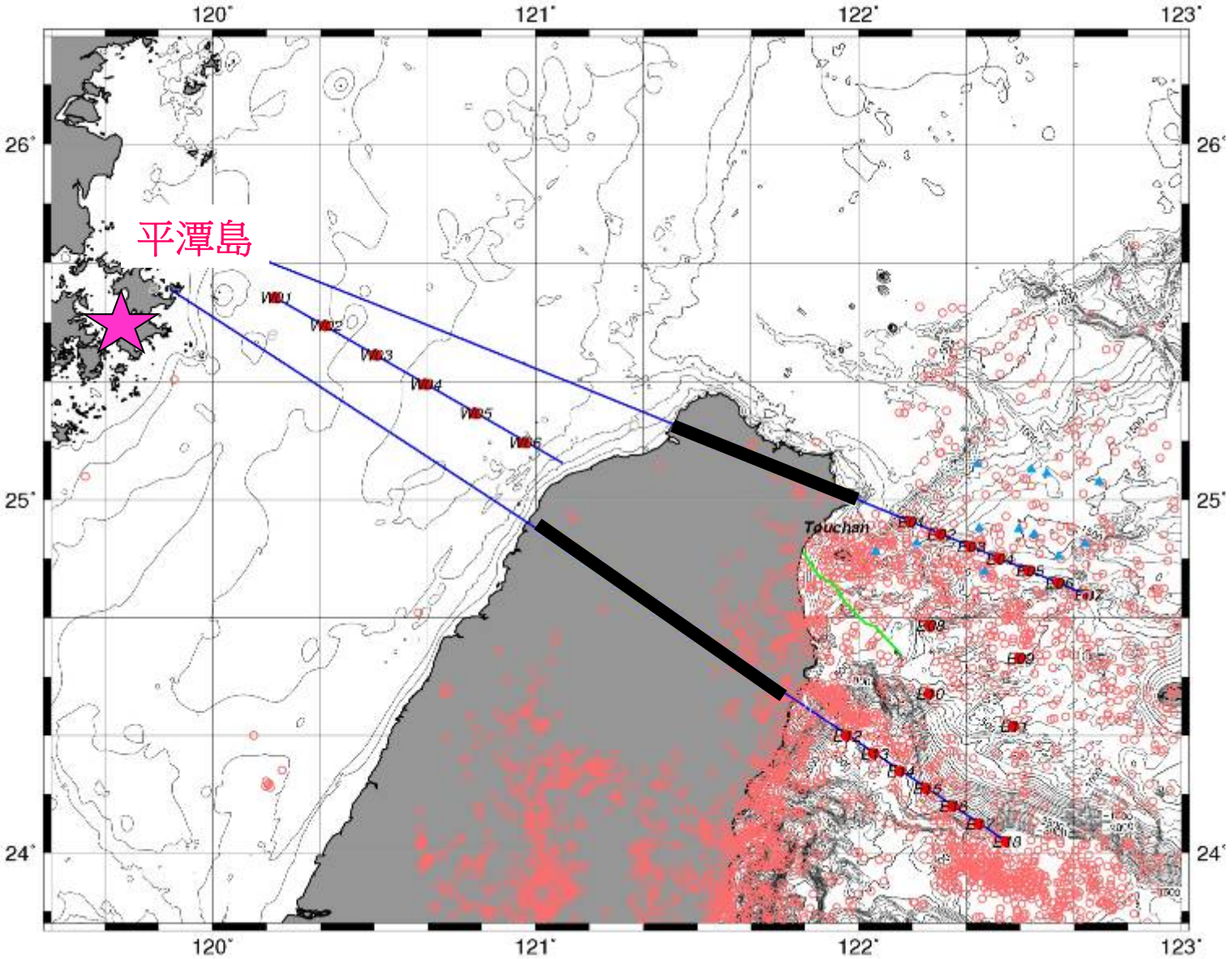




2011
地震儀 34台
TEXAN 118台
OBS 20台

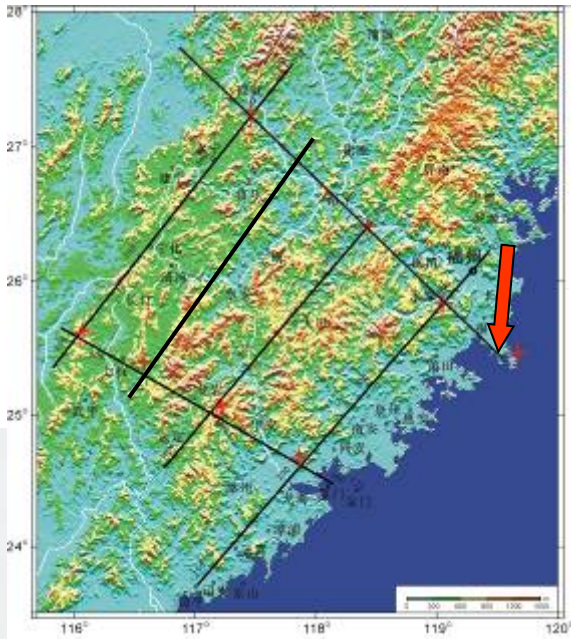
2010
地震儀 50台
TEXAN 74台
OBS 10台

海底地震儀



FJ1测线炸点简述：

平潭县北厝镇炸点
(SP11,高程5m,药量1.9T)



2011/08/23/00:45

大陸人工地震 助我研究地殼構造

中時電子報 www.chinatimes.com 更新日期:2011/08/24 05:30 *李宗祐／台北報導*

中國時報【李宗祐／台北報導】

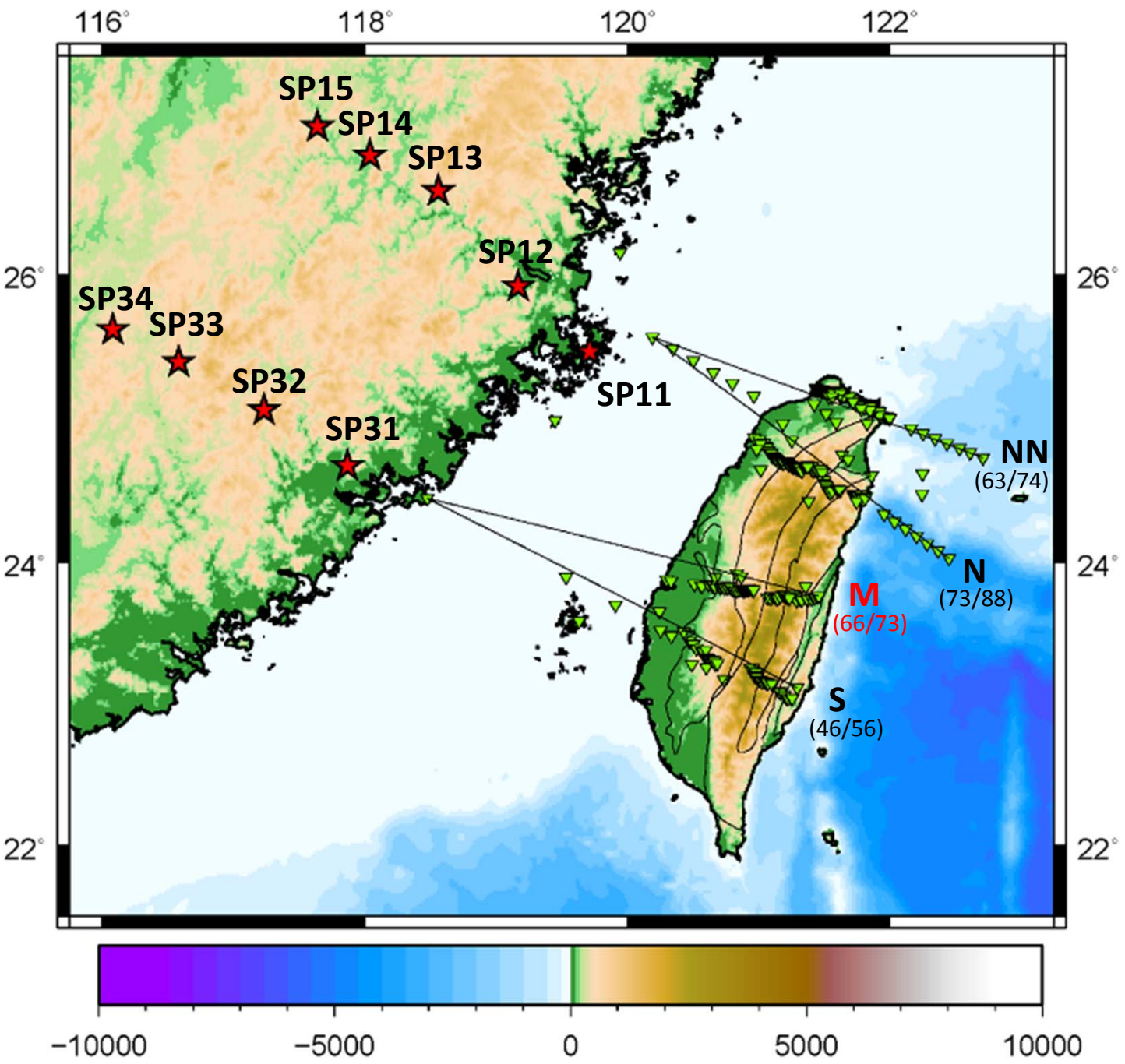
地震是海峽兩岸共同的天然災害，一九九九年九二一大地震重創台灣；二○○八年五一二汶川大地震造成慘重傷亡，促使兩岸地震學界攜手對抗地牛翻身。福建省地震局昨日以炸藥在平潭和福州地底引爆「人工地震」，協助台灣研究團隊觀測研究台灣本島和海峽地殼構造，建立全台地震災害評估模式。

昨日凌晨一時，中央大學地球科學院長王乾盈帶著研究團隊，緊盯中央氣象局地震預報中心電腦監測螢幕上波浪般的訊號，他興奮地說，這些資料對台灣很重要，有助了解台灣地震活動和造山運動，找出台灣地殼弱帶，分析那些地區較容易發生災害性地震，並模擬地震災害對每個地方的危害度。

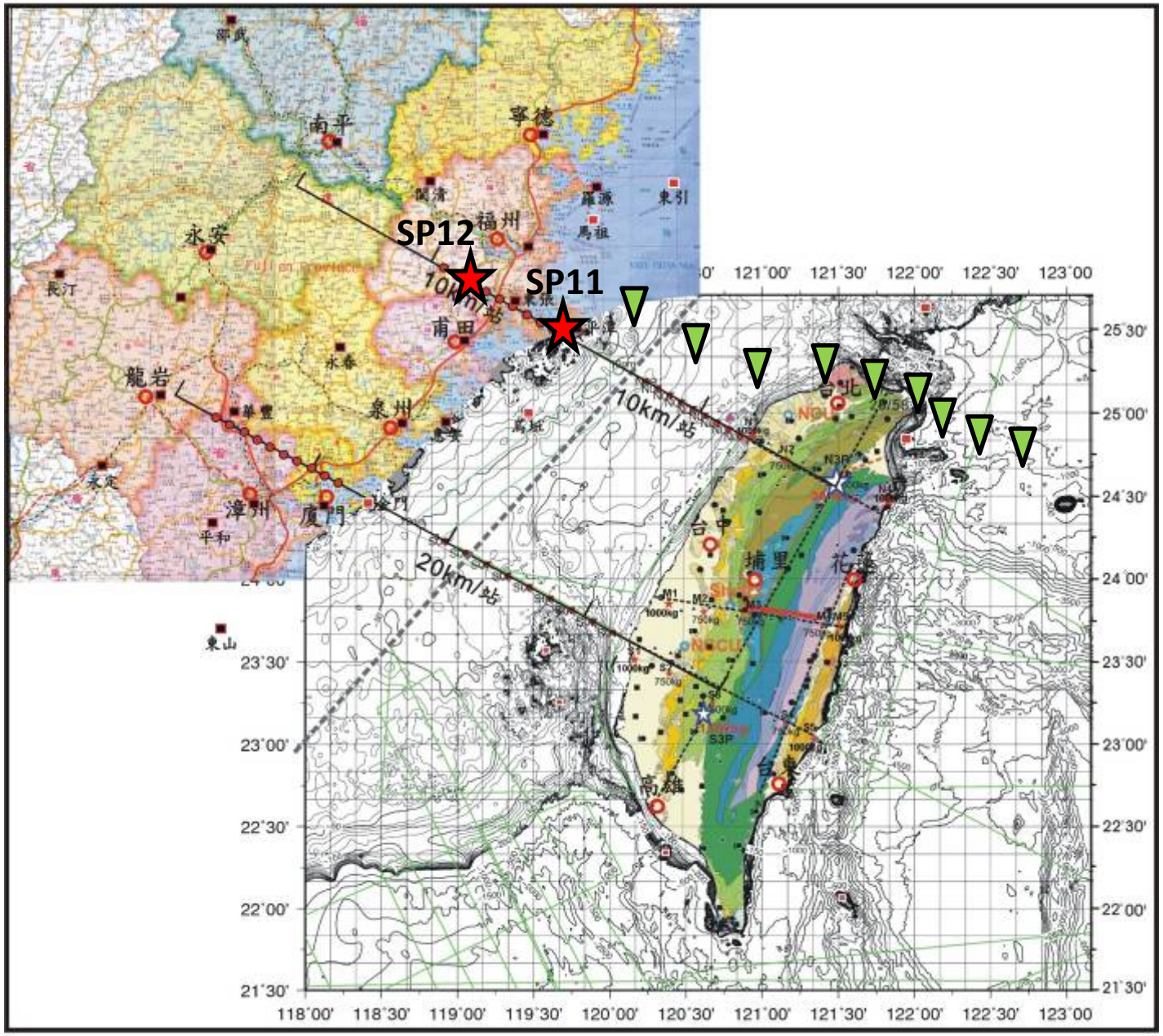
這些地震波訊號從距台北一五○公里外的福建省平潭，穿越台灣海峽傳遞到台灣本島。地震中心技正張建興表示，炸藥引爆人工地震產生的地震波，就像X光源照向台灣，透過布建在海底和台灣本島的地震儀接收地震波訊號，就可以把台灣的地殼構造「照得」清清楚楚。

王乾盈指出，「跨越台灣海峽震測實驗」（ＡＴＳＥＥ）分別在平潭和福州地底四十公尺處埋設二千公斤炸藥，自凌晨一時起、間隔十分鐘內，連續引爆兩起人工地震。這是兩岸去年九月首度在福建省長泰和漳平等四地進行聯合炸測實驗後，再度攜手合作。

王乾盈說，去年炸測觀測線以南台灣爲主，今年以北台灣爲主，明年鎖定中台灣，預估明年完成聯合炸測觀測後，就可測繪出台灣完整的地殼構造模型。


116°
118°
120°
122°
26°
24°
22°
SP15
SP14
SP13
SP12
SP34
SP33
SP32
SP31
SP11
NN
(63/74)
N
(73/88)
M
(66/73)
S
(46/56)
−10000
−5000
0
5000
10000

NN LINE

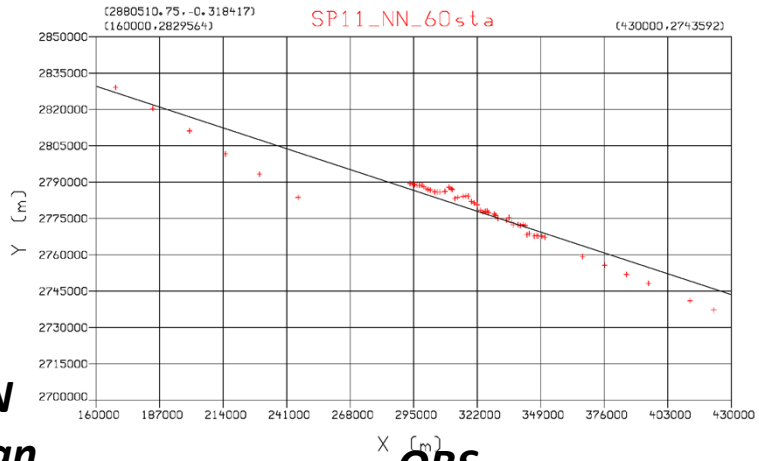

SP12
SP11
10km/站
10km/站
20km/站
南平
寧德
福州
永安
長汀
龍岩
泉州
漳州
廈門
平和
東山
台北
台中
花蓮
118°00'
118°30'
119°00'
119°30'
120°00'
120°30'
121°00'
121°30'
122°00'
122°30'
123°00'
25°30'
25°00'
24°30'
24°00'
23°30'
23°00'
22°30'
22°00'
21°30'

NN Line SP11

THEORETICAL CURVES

-- crust thickness of 31 km
-- crust velocity 5.9 km/s
-- upper mantle velocity 8.0 km/s with 2° updip Moho

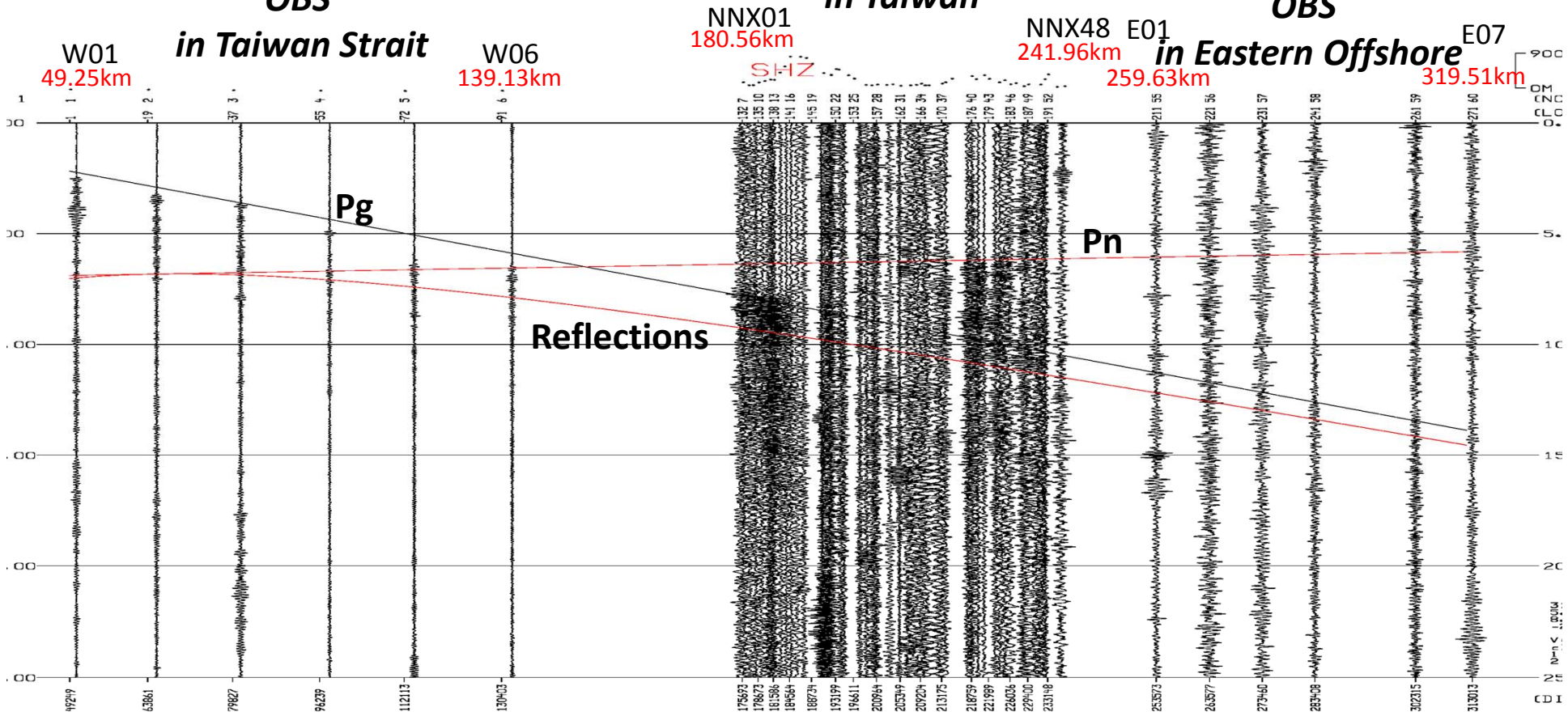
Map



TEXAN in Taiwan

OBS in Taiwan Strait

OBS in Eastern Offshore



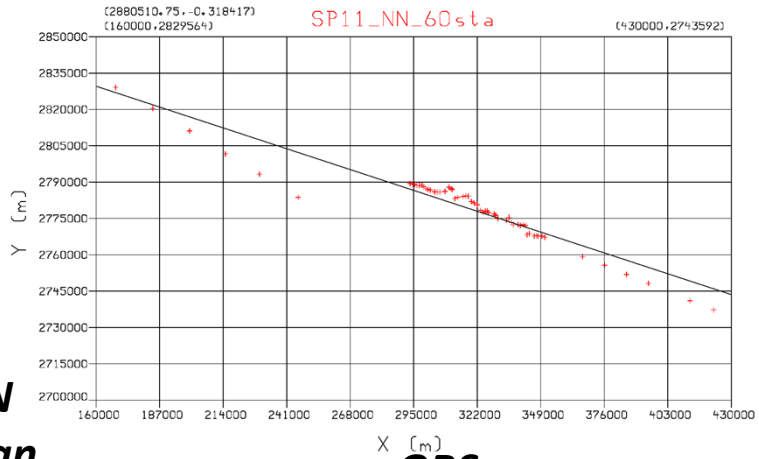
NN Line SP11

FAT PICKS

-- 36 picks from 60 stations

-- Possibly, 16 Pg Phases & 20 Pn Phases

Map



TEXAN in Taiwan

OBS in Taiwan Strait

OBS in Eastern Offshore

W01 49.25km

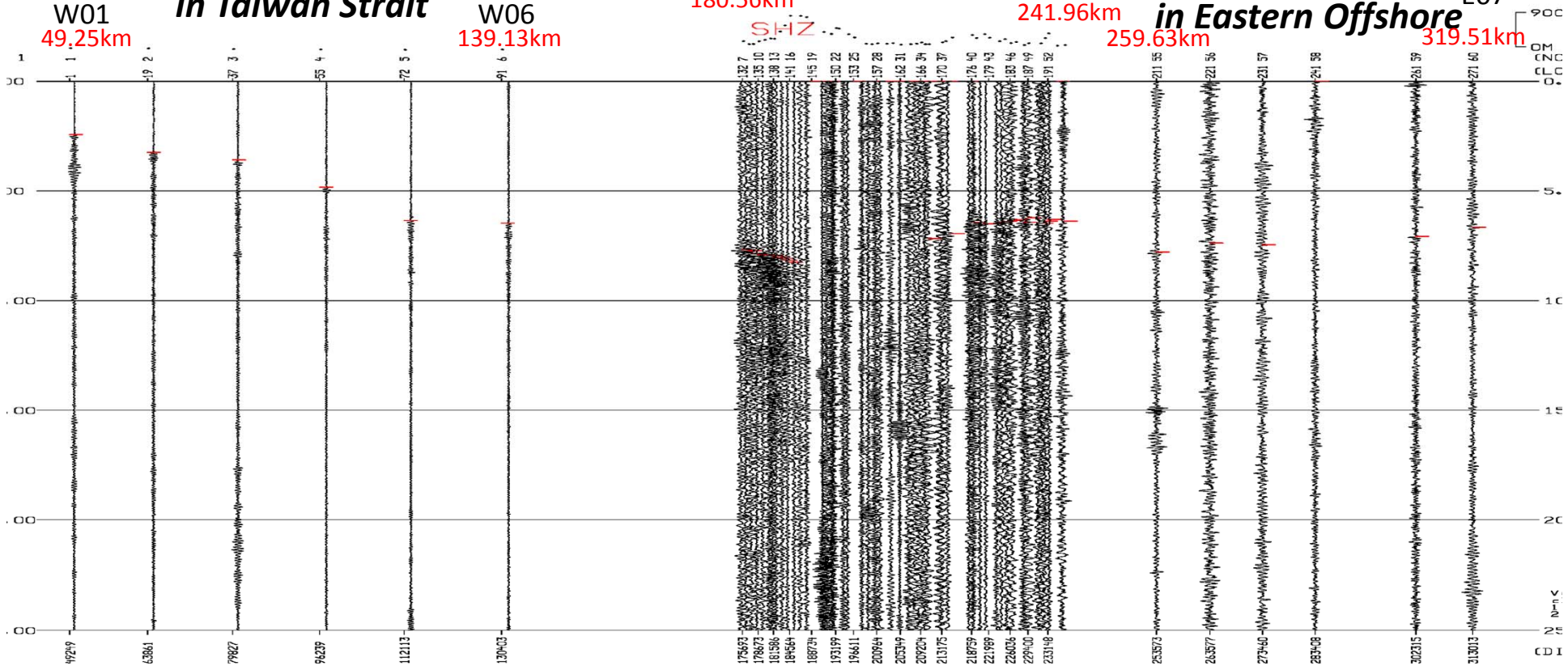
W06 139.13km

NNX01 180.56km

NNX48 241.96km

E01 259.63km

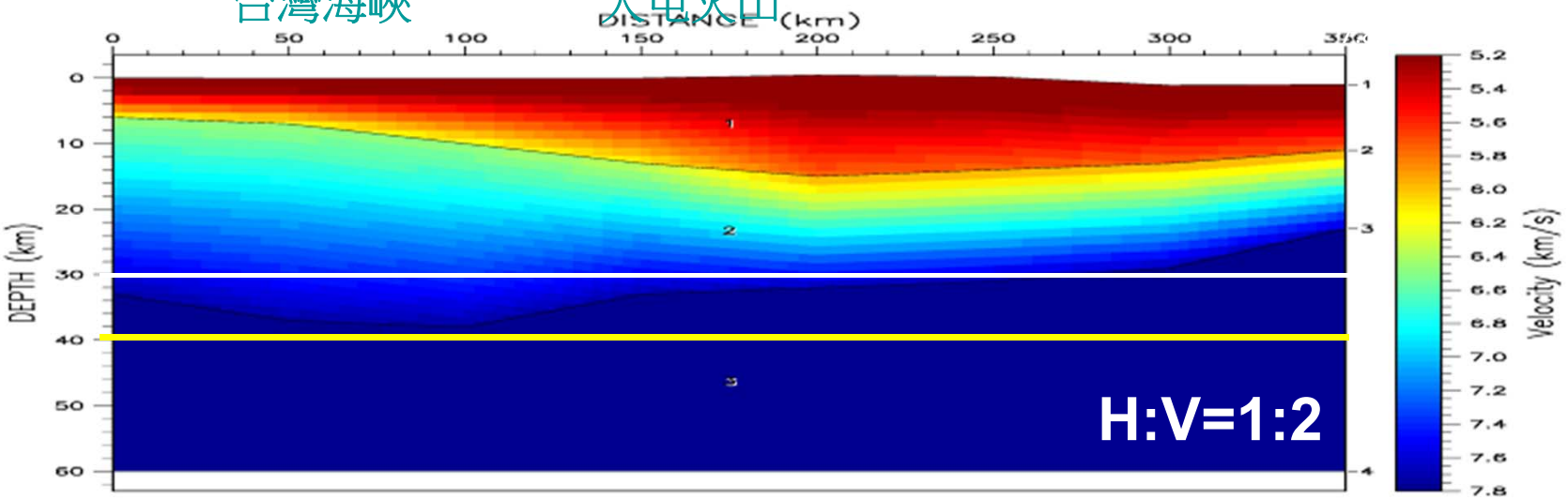
E07 319.51km

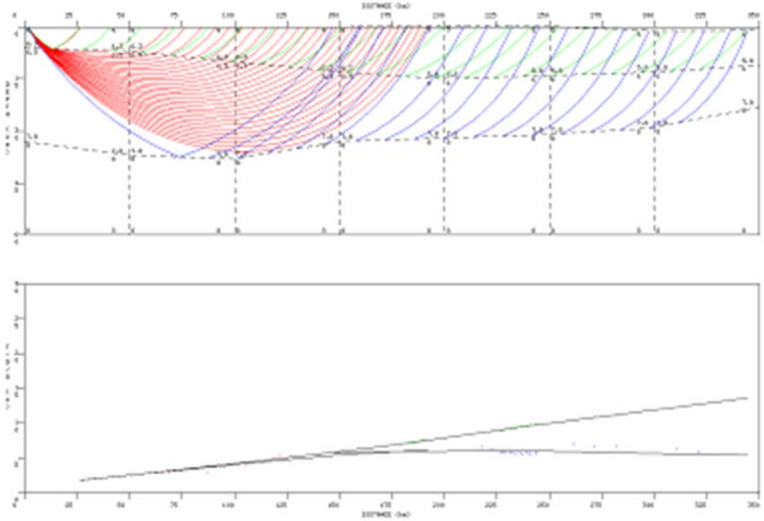


波線走時模擬

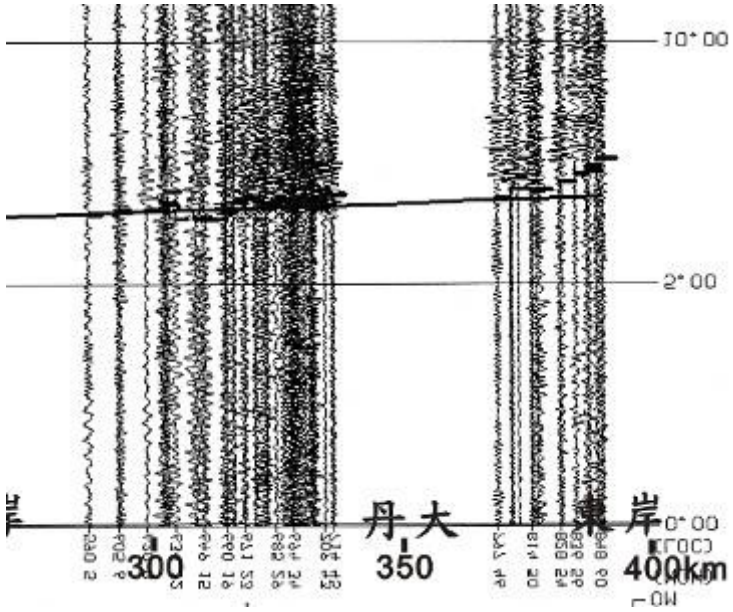
NN (SP11)

台灣海峽　　大屯火山



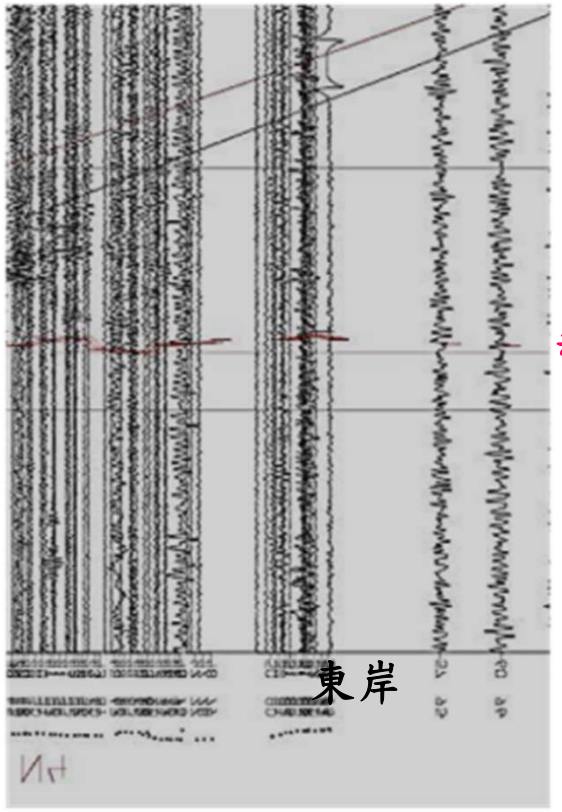


M-line(2010)



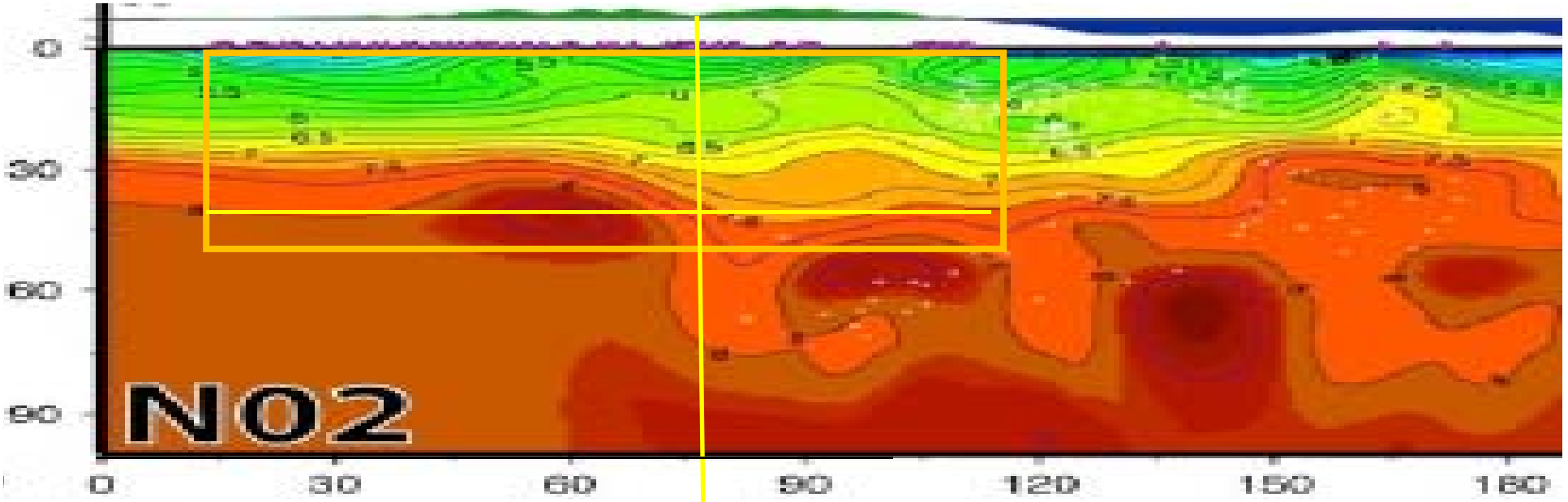
南台灣有山根

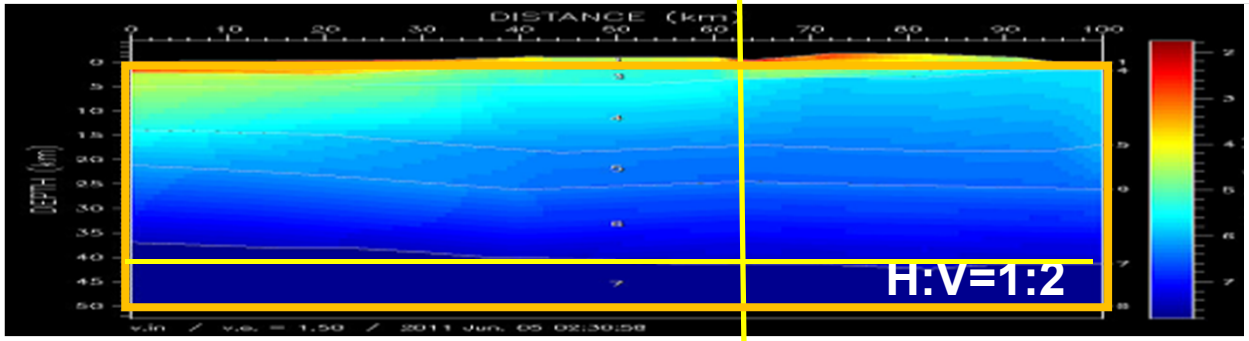
N-line(2011)

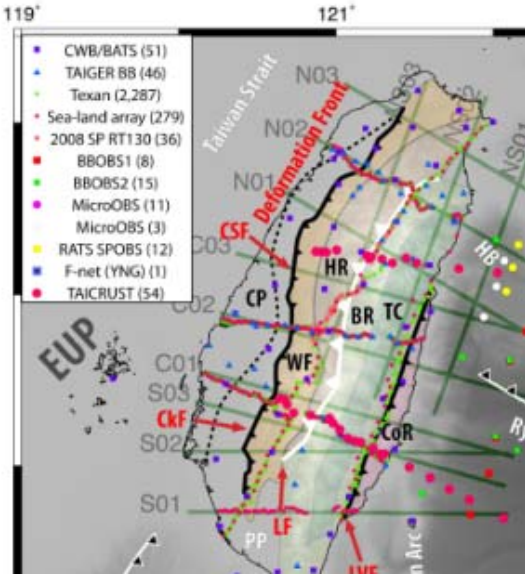


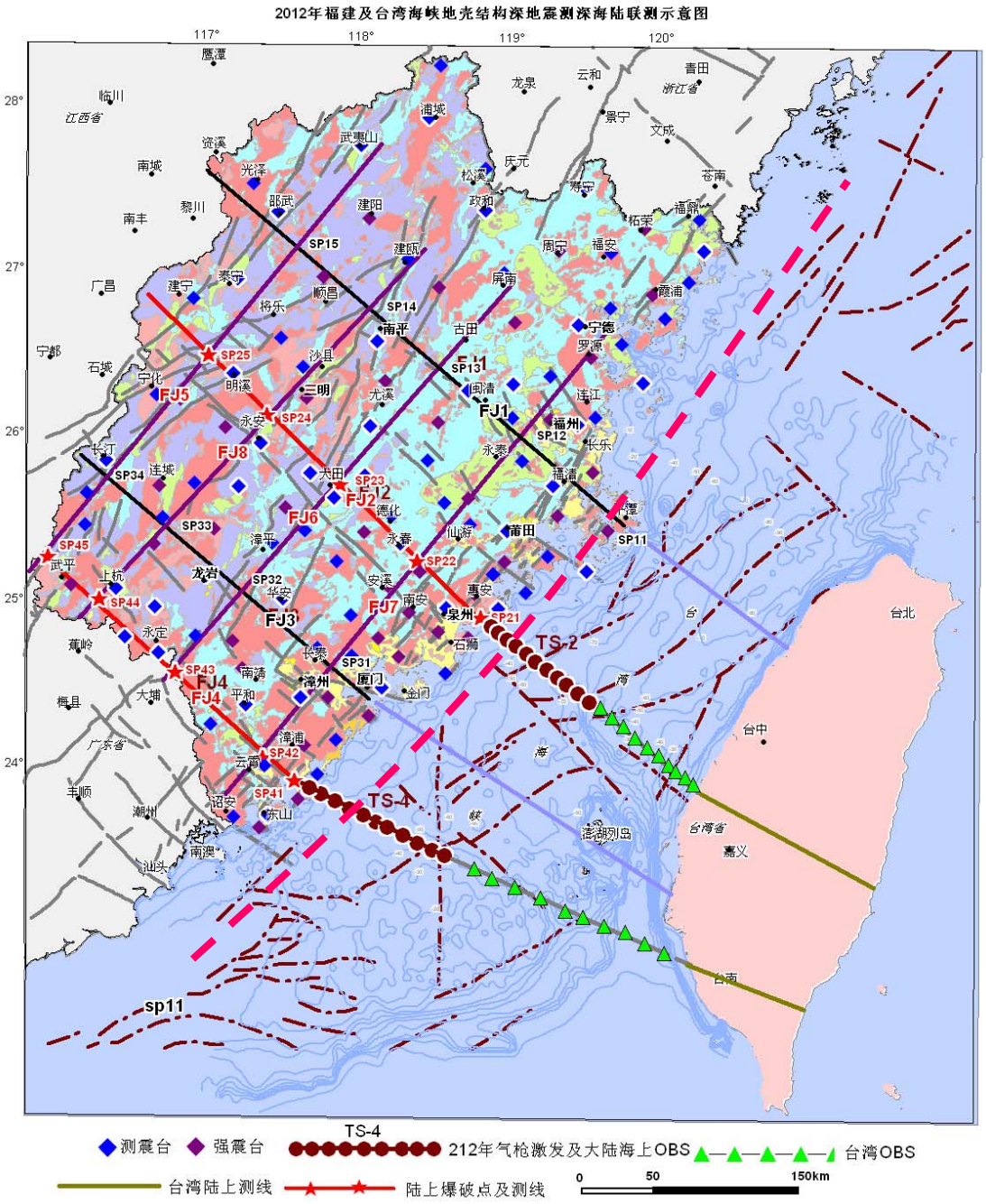
無翹起

北台灣無山根


0
30
60
90
N02
0
30
60
90
120
150
180


DISTANCE (km)
DEPTH (km)
H:V=1:2


119°
121°
CWB/BATS (51)
TAIGER BB (46)
Texan (2,287)
Sea-land array (279)
2008 SP RT130 (36)
BBOBS1 (8)
BBOBS2 (15)
MicroOBS (11)
MicroOBS (3)
RATS SPOBS (12)
F-net (YNG) (1)
TAICRUST (54)
Taiwan Strait
Deformation Front
CSF
HR
CP
BR
TC
WF
CkF
CoR
LF
PP
EUP
N03
N02
N01
S03
S02
S01
C03
C02
C01
HB



工作方案

海上:
24台OBS
2条测线
220km长
720炮

2012年台湾海峡西部海底地震仪探测和海陆联测的测线与站位布设示意图