Seismic Tomography Reveals Breaking Crust and Lithosphere Beneath a Classic Orogen

Many collaborators: Ruey-Juin Rau, Yuan-Hsi Lee, Hao Kuo-Chen, Francis Wu, William Ouimet, Matthijs van Soest Chung Huang and many others...

Support from NSF, NSC and UConn Research Foundation

Abstract

Hypothesis

- The orogenic system in Taiwan is often considered a classic example of an accretionary prism that has grown to a steady-state size and shape above an also steady subduction zone. A new study of vertical and horizontal sections of a Vp tomographic model created by Kuo-Chen et al. (2012) suggests, however, that slab breakoff is actively occurring beneath Taiwan. Vertical sections of the regional velocity model show an east-dipping layer of high velocity overlain by a band of seismicity with a maximum depth of 200 km in southern Taiwan. The high velocity layer and the band of seismicity are interpreted as the upper mantle and Wadati-Benioff zone, respectively, of the subducting Eurasian plate. From south to north, however, the seismicity progressively disappears and the high velocity layer becomes more discontinuous, forming irregular patches beneath northern Taiwan. We interpret these south-to-north changes to reflect the progressive d[illegible] with the Philippine Sea plate. Progr[illegible]ual, ellipsoidal-shaped area of h[illegible]l trends. Taking into account the dip o[illegible]zed fracture zone in the Eurasian con[illegible]e Eurasian crust above relatively c[illegible]ither the Philippine Sea or Eurasian [illegible]hern Taiwan also suggests that sla[illegible]ction of the Philippine Sea Pl[illegible]

Geology and geologic history are critical in understanding collisions

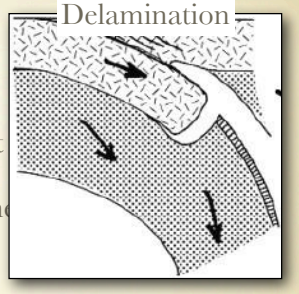
Evidence

- Support for this interpretation comes from: 1) new exhumation cooling data from Mt Yu, the highest peak in Taiwan; 2) a recent leveling survey along the South Cross-Island Highway that shows unusually high rates of surface uplift (up to 15 mm/yr; Ching et al., 2011); 3) Vp attenuation studies that suggest anomalously high temperatures and/or the presence of fluids; 4) earthquake focal mechanisms in the core of the southern Central Range that are dominated by NE-SW extension; and finally, 5) the core of the southern Central Range preserves anomalous areas of low topographic relief that straddle the crest of the range. These areas of low relief are fringed by stream channels with relatively high stream gradient indexes and do not appear related to weaker rock types, glacial erosion, or lower rock uplift rates along the range crest. We propose that the surfaces represent relict topography that formed prior to a recent acceleration in rock uplift rate, consistent with the presence of a propagating crustal-scale crack and slab breakoff. Taken together, these results raise questions about the notion of steady state topography and critically tapered wedges in Taiwan.

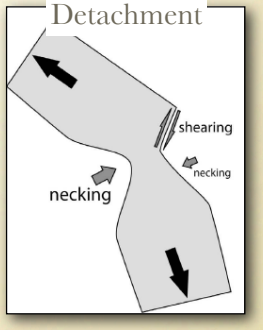
Outline

1. Initial collision - arc collides with transitional crust
2. Arc collides with a prong or promontory of contin
3. More recent research - anomalies in the geology
    1. Areas of low relief topography and low slope at high elevations
    2. Extension at high elevations
    3. Extreme uplift rates in Central Range
4. Are anomalous lithospheric scale processes needed?
    1. Lithospheric delamination
    2. Lithospheric detachment

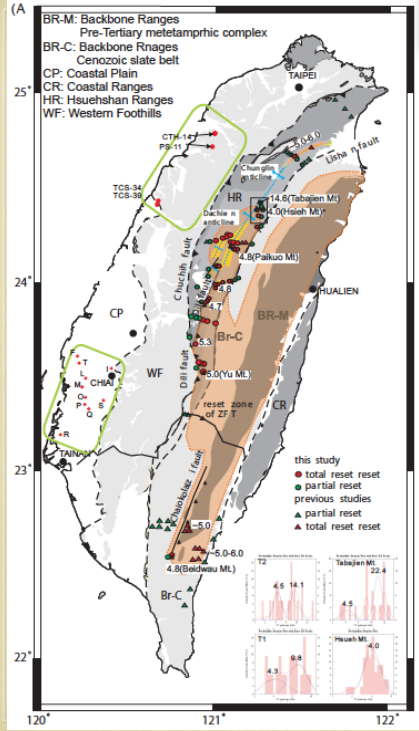
Delamination

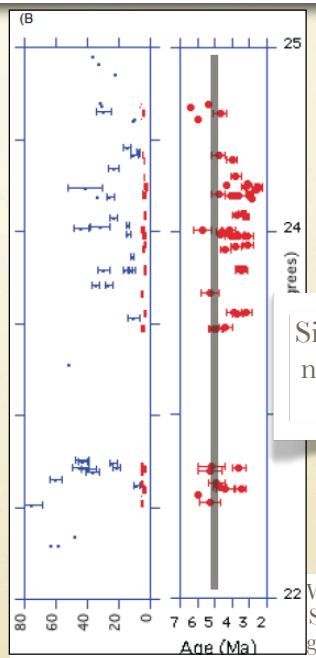


Detachment



60 new zircon fission track ages

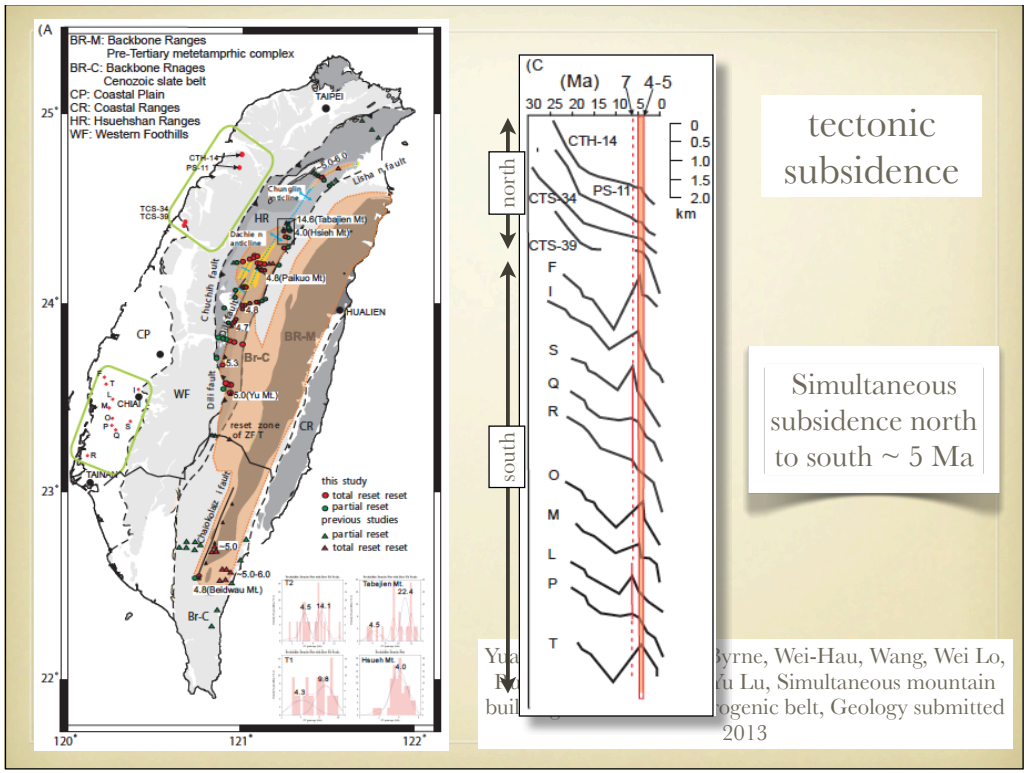




- not reset
- reset

Simultaneous uplift north to south ~ 5 Ma

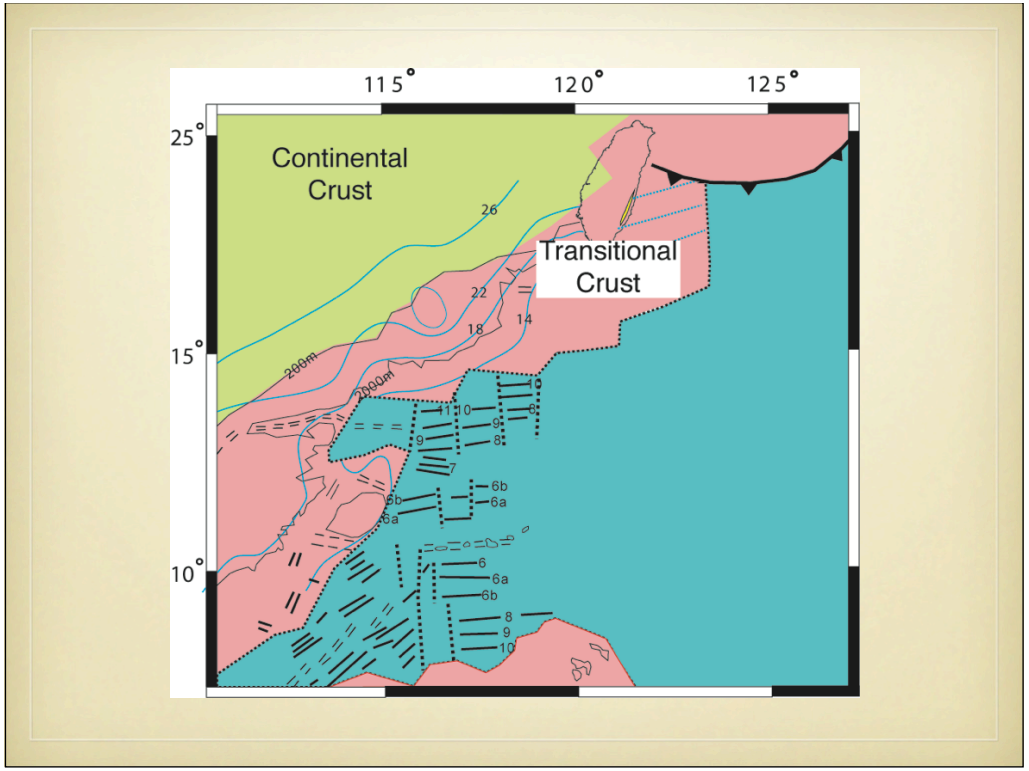
Wei-Hau, Wang, Wei Lo, Simultaneous mountain genic belt, ***Geology*** submitted 2013

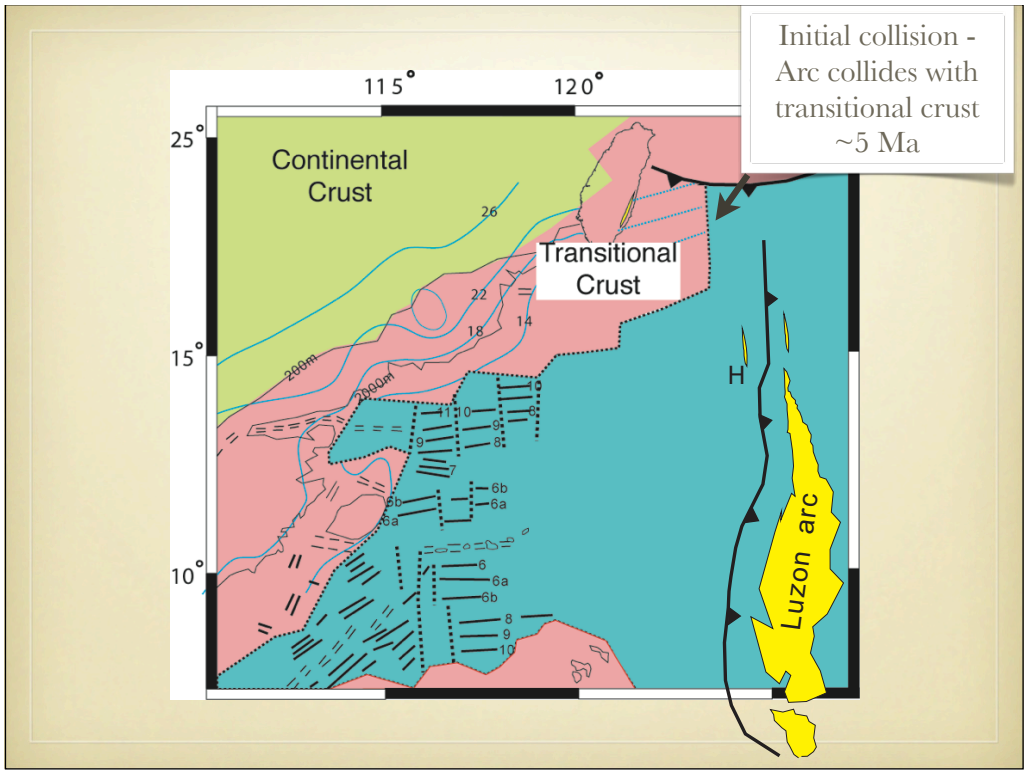


tectonic subsidence

Simultaneous subsidence north to south ~ 5 Ma

Yua… Byrne, Wei-Hau, Wang, Wei Lo, K… u Lu, Simultaneous mountain buil… ogenic belt, Geology submitted 2013


115°
120°
125°
25°
15°
10°
Continental
Crust
Transitional
Crust
26
22
18
14
200m
2000m
11
10
9
8
7
6b
6a
6
10


Initial collision - Arc collides with transitional crust ~5 Ma
115°
120°
25°
15°
10°
Continental Crust
Transitional Crust
Luzon arc
H
26
22
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2000m
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6b
6a
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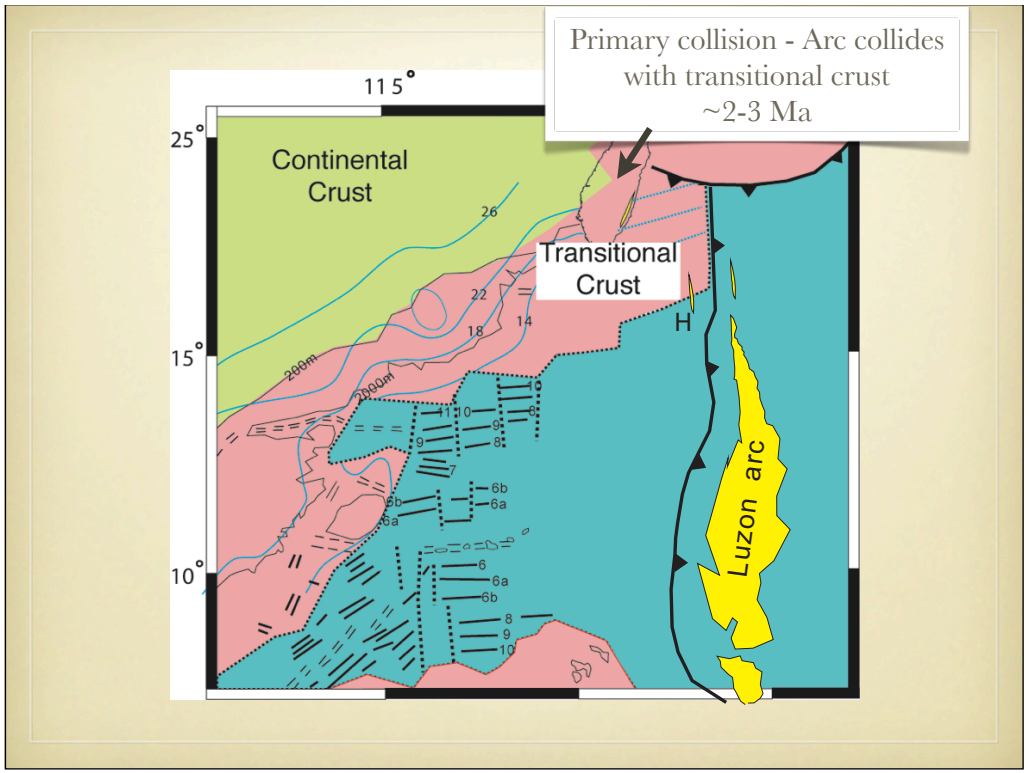
5


Primary collision - Arc collides with transitional crust ~2-3 Ma
115°
25°
15°
10°
Continental Crust
Transitional Crust
H
Luzon arc
26
22
18
14
200m
2000m
11
10
9
8
7
6b
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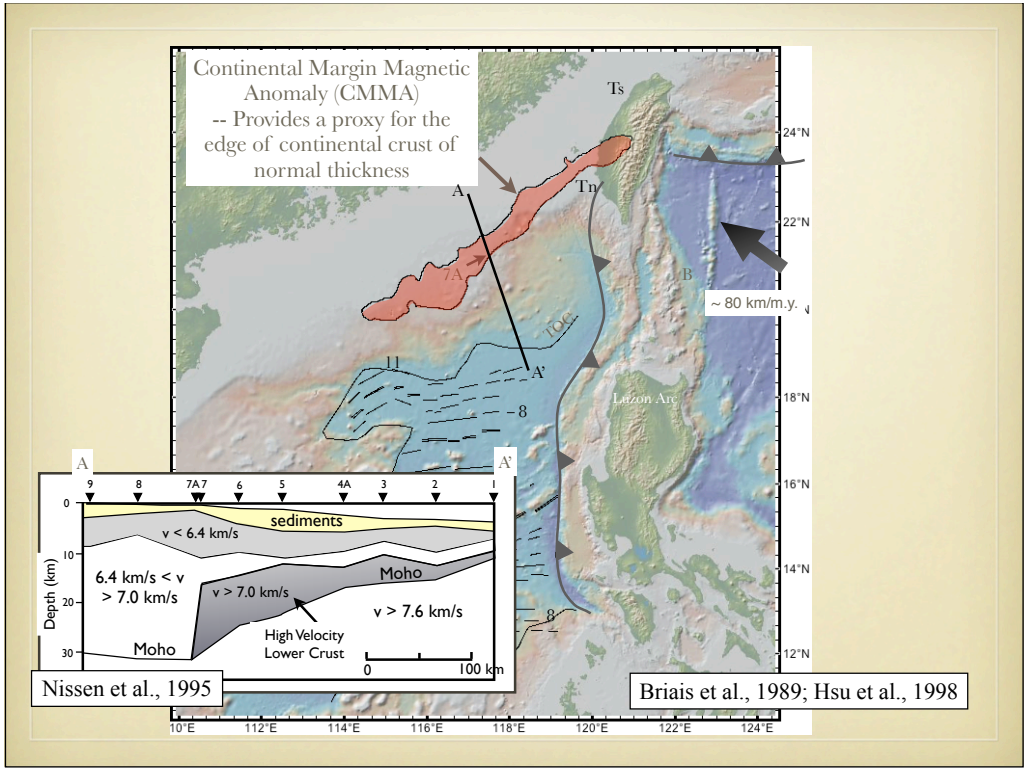
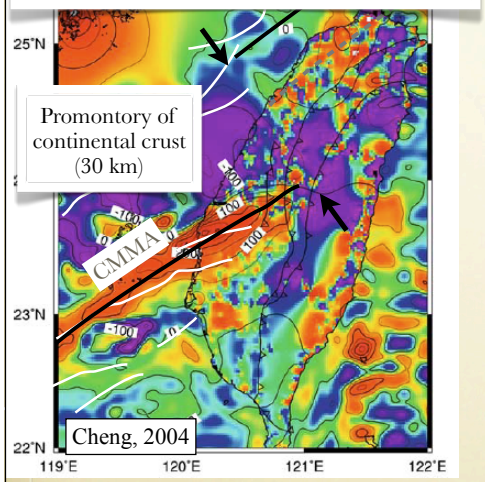
10

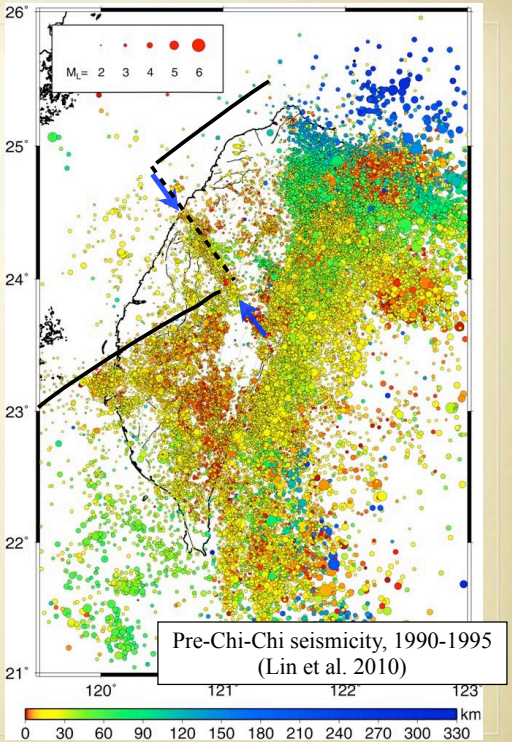


Note change in spreading direction
CMMA =

Truncated anomaly represents a partially subducted continental margin fracture zone

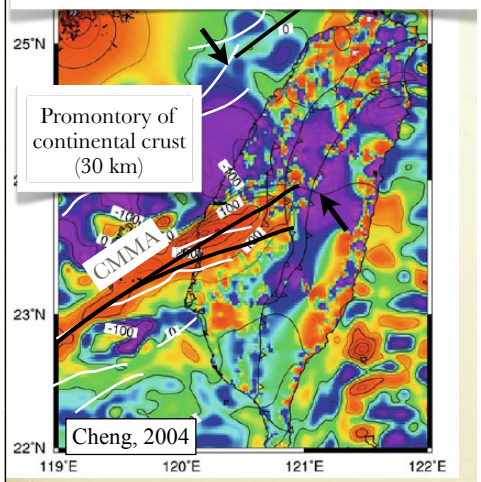


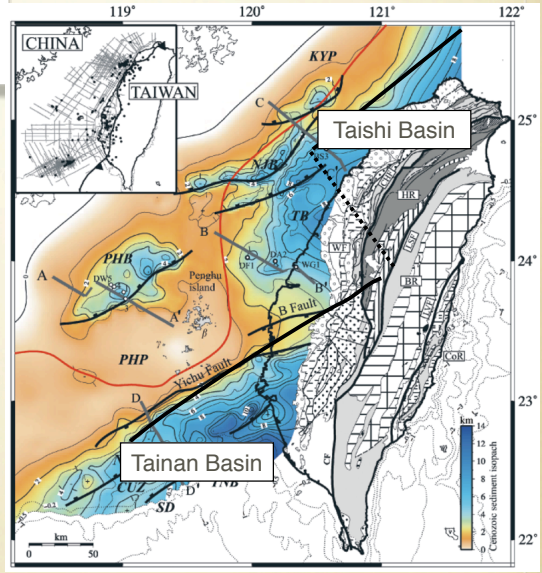
Promontory of continental crust (30 km)



Pre-Chi-Chi seismicity, 1990-1995 (Lin et al. 2010)

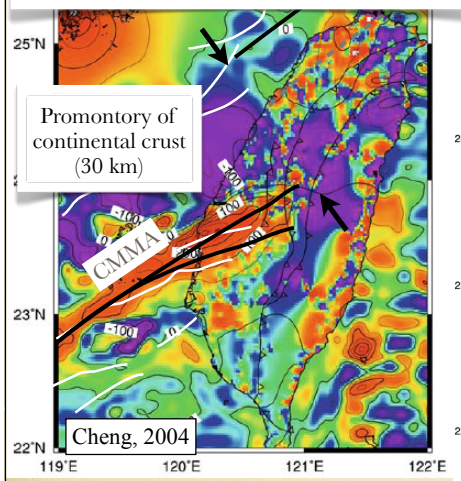
Truncated anomaly represents a partially subducted continental margin fracture zone



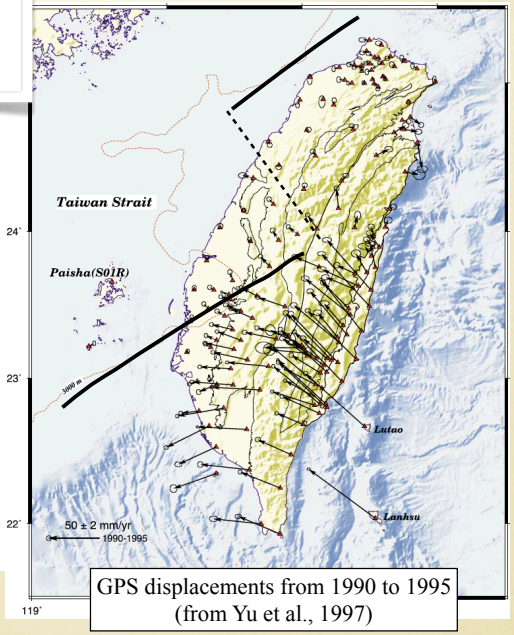


Depth to Mesozoic basement (Lin et al., 2003)

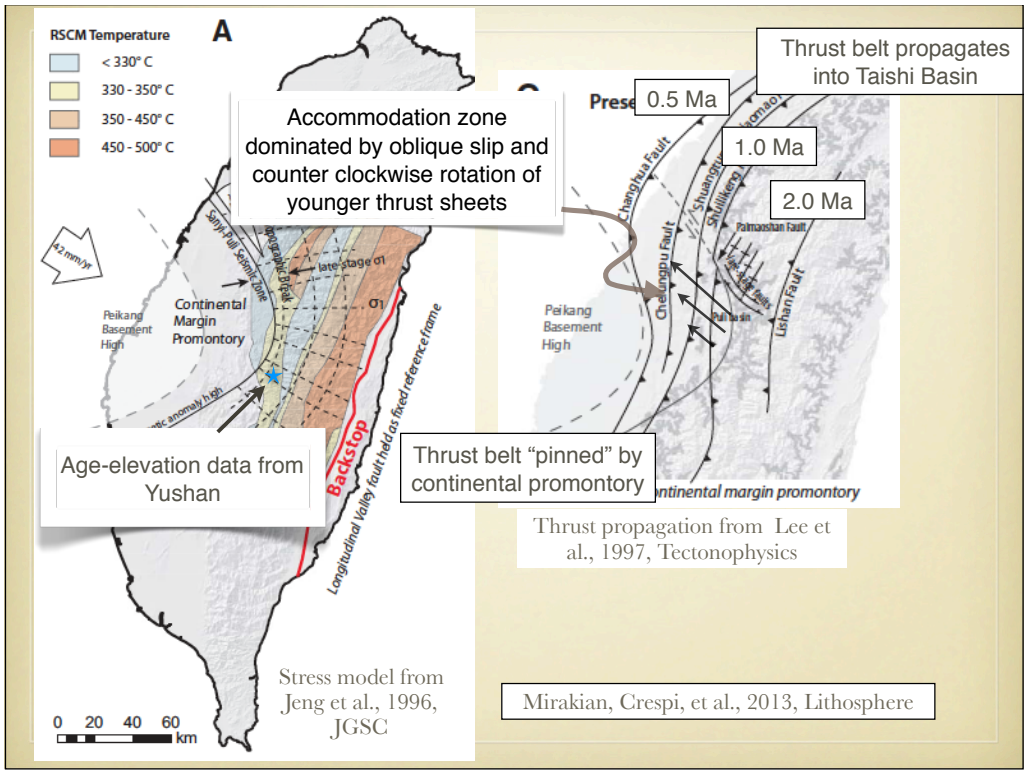
Truncated anomaly represents a partially subducted continental margin fracture zone

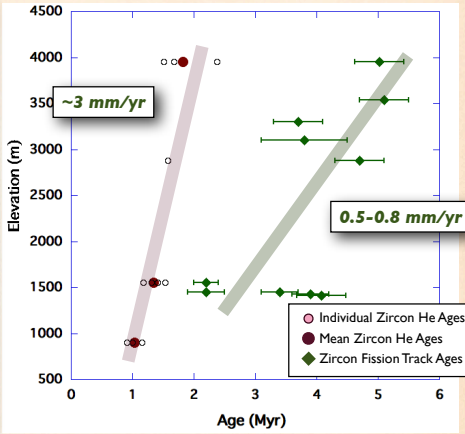


Promontory of continental crust (30 km)

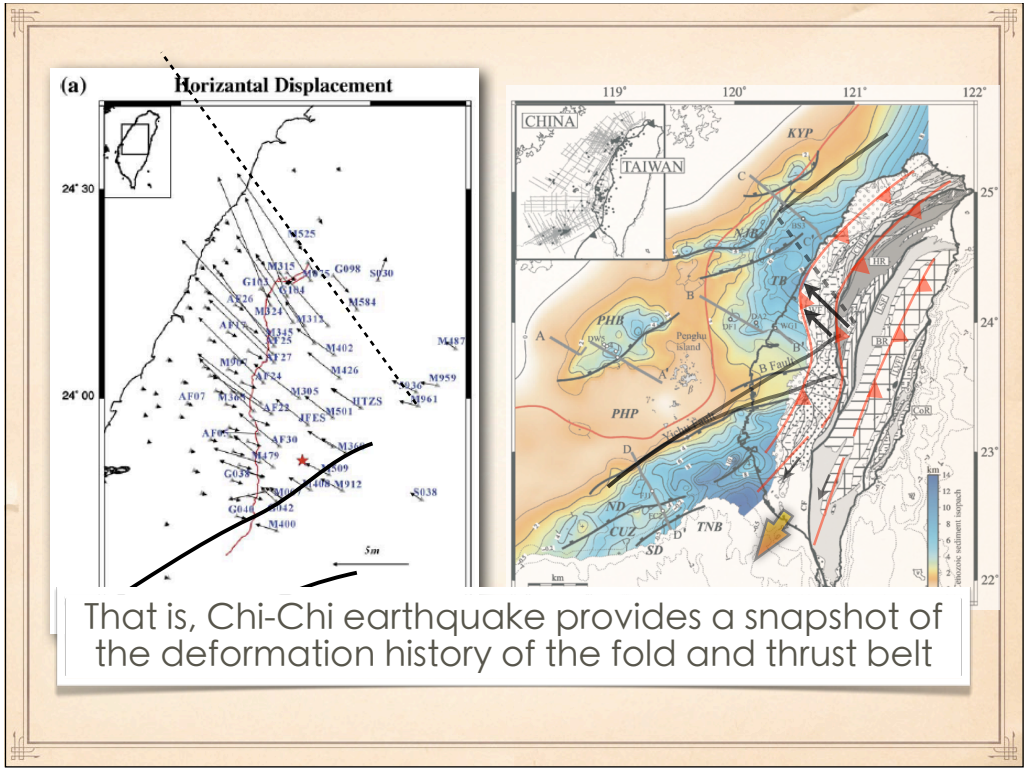


GPS displacements from 1990 to 1995 (from Yu et al., 1997)


RSCM Temperature
< 330° C
330 - 350° C
350 - 450° C
450 - 500° C
A
Accommodation zone dominated by oblique slip and counter clockwise rotation of younger thrust sheets
Thrust belt propagates into Taishi Basin
0.5 Ma
1.0 Ma
2.0 Ma
Age-elevation data from Yushan
Thrust belt "pinned" by continental promontory
Peikang Basement High
Continental Margin Promontory
Backstop
Longitudinal Valley fault held as fixed reference frame
Changhua Fault
Chelungpu Fault
Shuangtung Fault
Shuilikeng
Paimaoshan Fault
Lishan Fault
Pull basin
Peikang Basement High
ntinental margin promontory
Thrust propagation from Lee et al., 1997, Tectonophysics
Stress model from Jeng et al., 1996, JGSC
0 20 40 60
km
Mirakian, Crespi, et al., 2013, Lithosphere

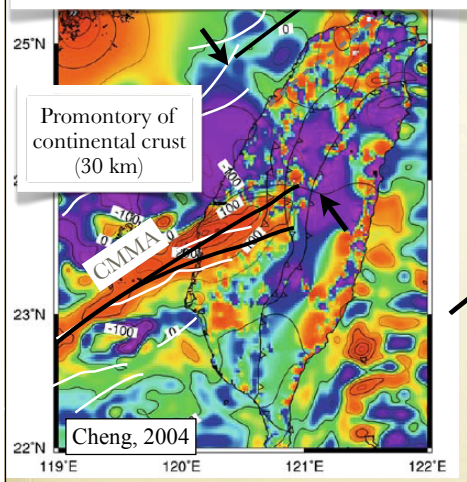


Accelerated uplift Yushan ~2 Ma
-- Arc collides with continental prong --

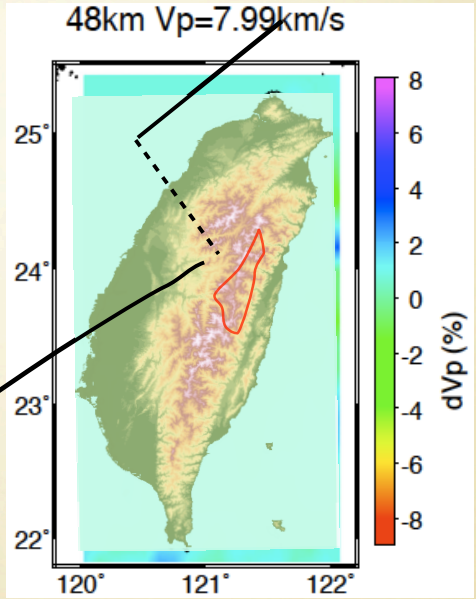


--> snapshot of the kinematics of the fold and thrust belt in this region
--> this pattern of displacements accommodated CCW rotation of the fold-and-thrust belt in this area.
--> note that there is also an increase in displacement SE to NW or parallel to the slip direction -
Propose that southwest to northeast increase in displacement during Chi-Chi reflects the geometry of the partially subducted continental margin promontory.

Truncated anomaly represents a partially subducted continental margin fracture zone

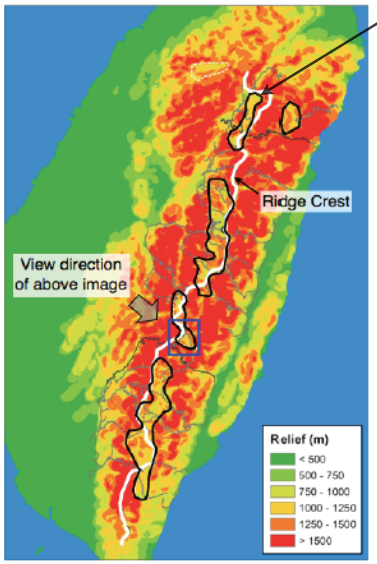


Promontory of continental crust (30 km)



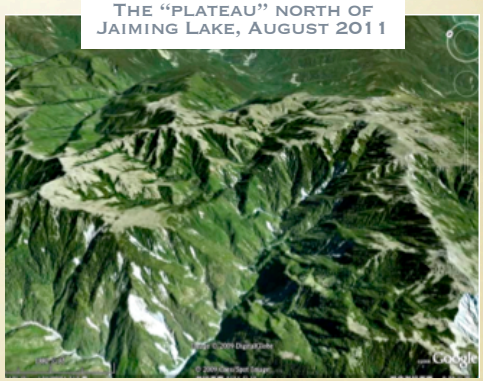
Crustal root from local Vp tomographic model (from Kuo-Chen et al., 2012)

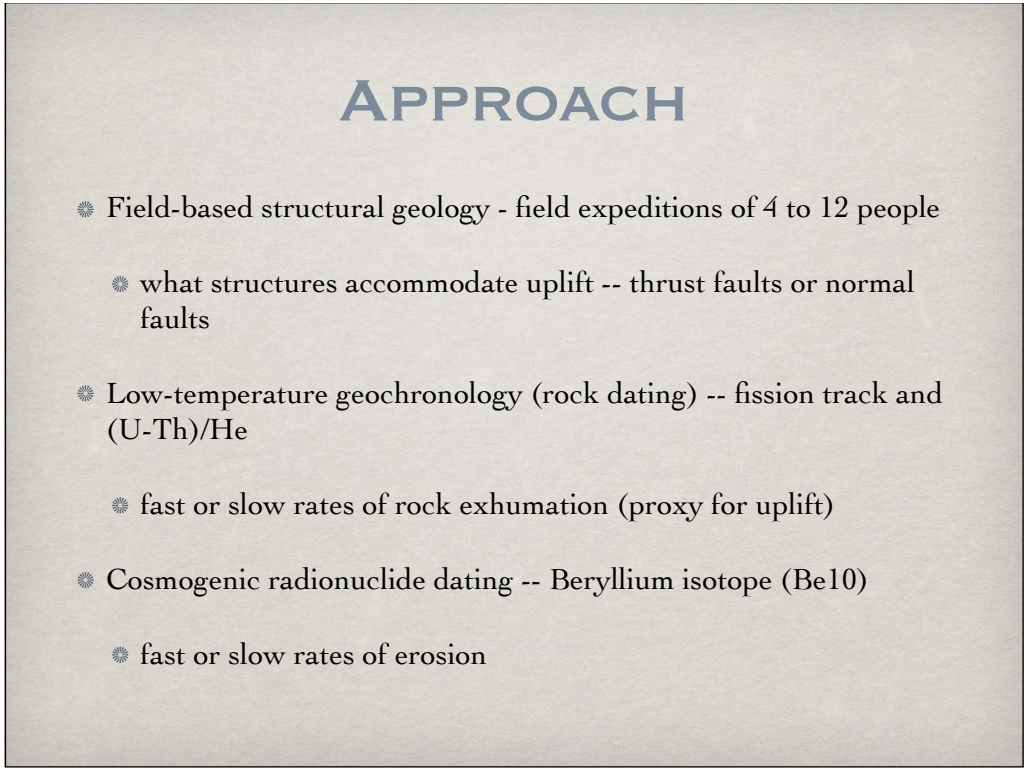
Anomalous Topography…



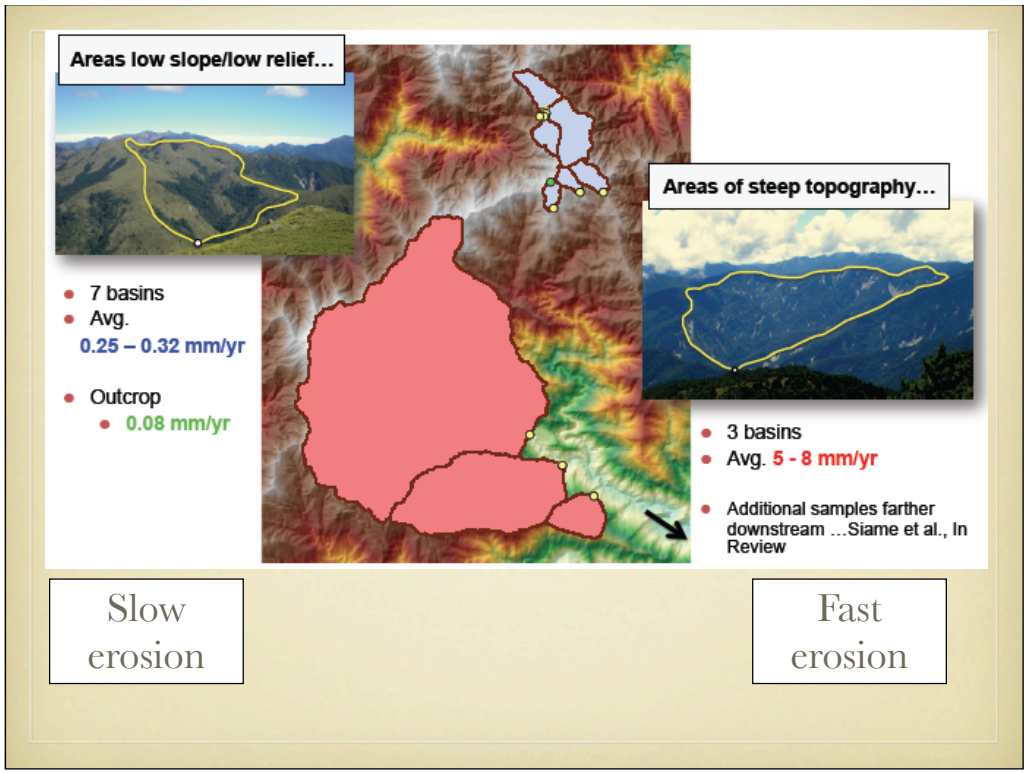
Large areas (20-100 sq km) of anomalously low relief in the higher elevations of the Central Range

The "plateau" north of Jaiming Lake, August 2011

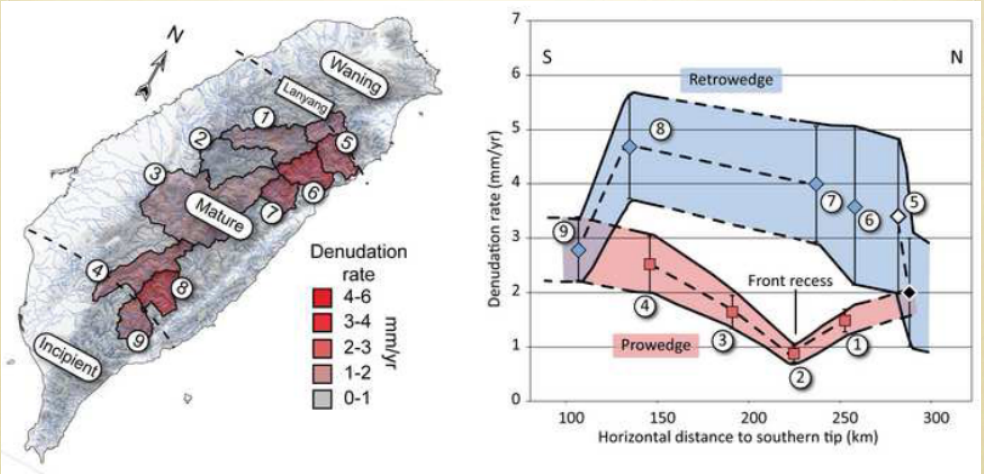




The most common of these dating techniques is *Cosmogenic radionuclide dating*. Earth is constantly bombarded with primary cosmic rays, high energy charged particles — mostly protons and alpha particles. These particles interact with atoms in atmospheric gases, producing a cascade of secondary particles that may in turn interact and reduce their energies in many reactions as they pass through the atmosphere. By the time the cosmic ray cascade reaches the surface of Earth it is primarily composed of neutrons.[1] When one of these particles strikes an atom it can dislodge one or more protons and/or neutrons from that atom, producing a different element or a different isotope of the original element. In rock and other materials of similar density, most of the cosmic ray flux is absorbed within the first meter of exposed material in reactions that produce new isotopes called cosmogenic nuclides. At Earth's surface most of these nuclides are produced by neutron spallation. Using certain cosmogenic radionuclides, scientists can date how long a particular surface has been exposed, how long a certain piece of material has been buried, or how quickly a location or drainage basin is eroding. The basic principle is that these radionuclides are produced at a known rate, and also decay at a known rate.[2] Accordingly, by measuring the concentration of these cosmogenic nuclides in a rock sample, and accounting for the flux of the cosmic rays and the half-life of the nuclide, it is possible to estimate how long the sample has been exposed to the cosmic rays.

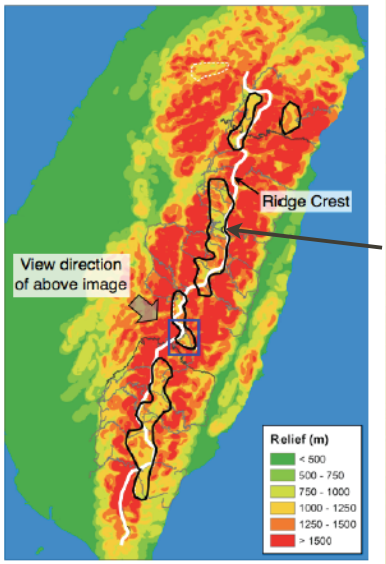

Areas low slope/low relief…
7 basins
Avg.
0.25 – 0.32 mm/yr
Outcrop
0.08 mm/yr
Areas of steep topography…
3 basins
Avg. 5 - 8 mm/yr
Additional samples farther downstream …Siame et al., In Review
Slow erosion
Fast erosion

Denudation rates in large watersheds around Taiwan



Derrieux, Siame et al., in review, JAES

Anomalous Topography…



Most recent field expedition:

Seven Colors Lake area
April-May, 2013

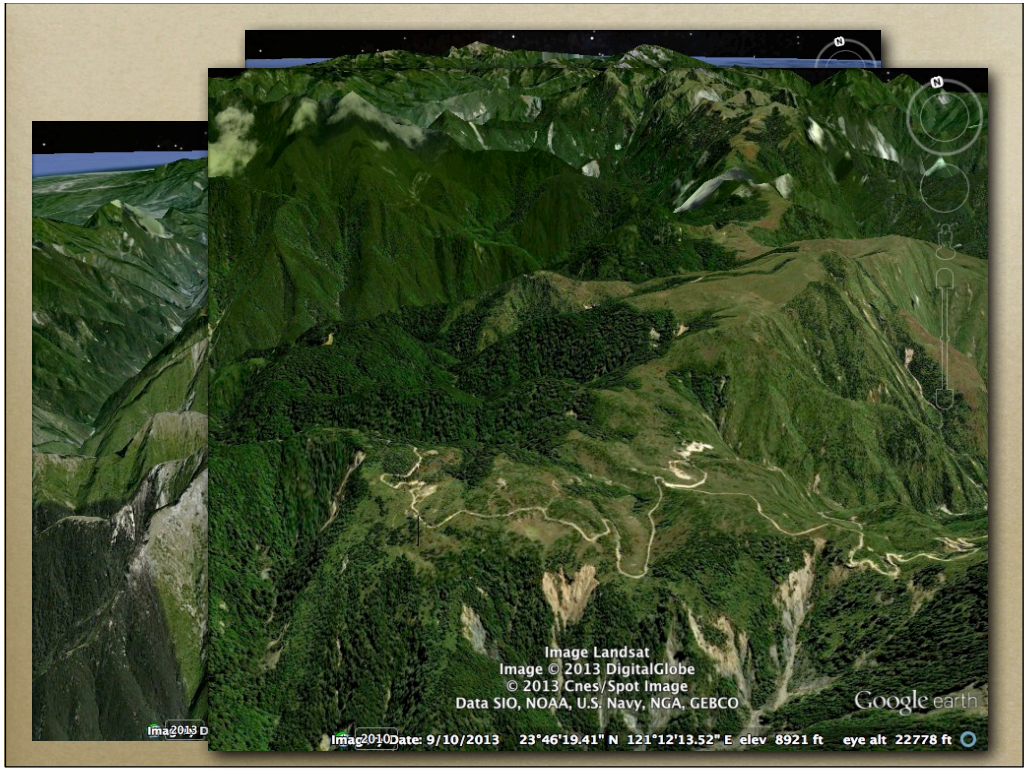
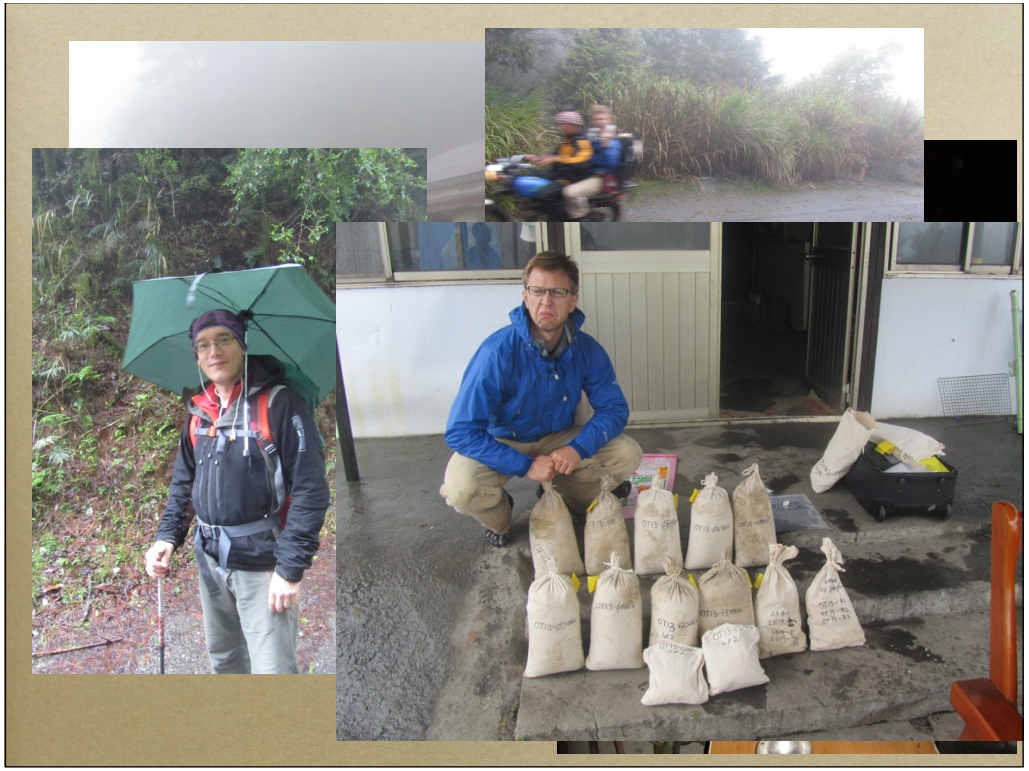
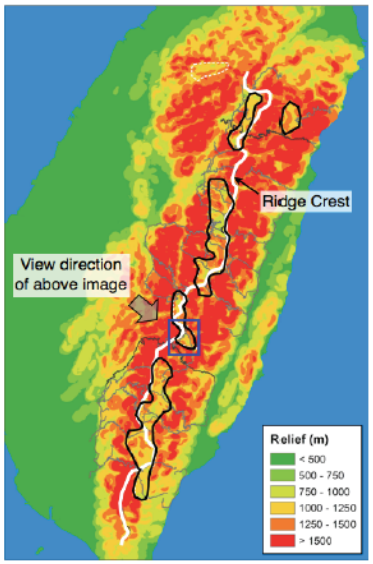


Image Landsat
Image © 2013 DigitalGlobe
© 2013 Cnes/Spot Image
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google earth
Date: 9/10/2013 23°46'19.41" N 121°12'13.52" E elev 8921 ft eye alt 22778 ft

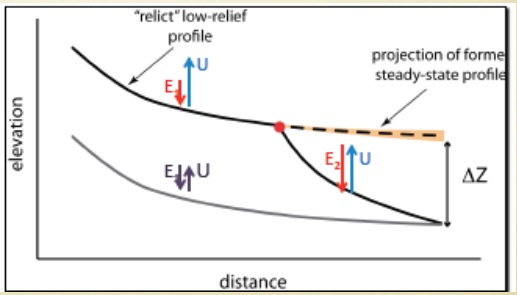


Anomalous Topography…

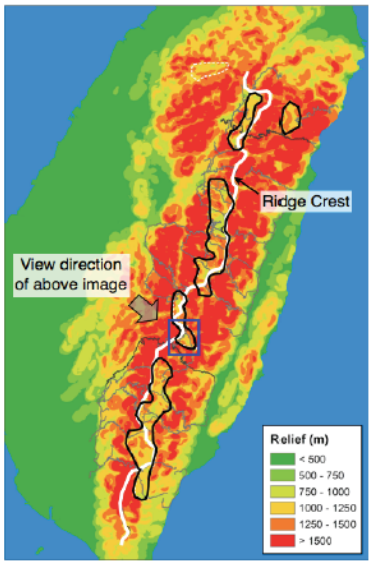


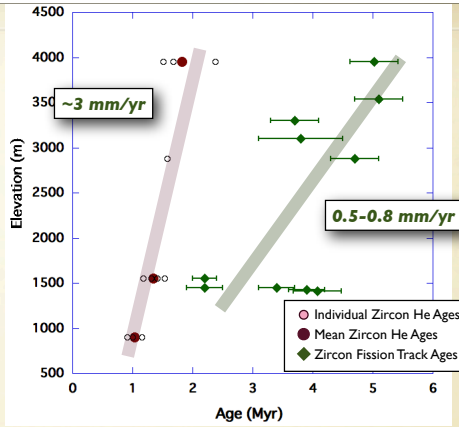
Hypothesis:

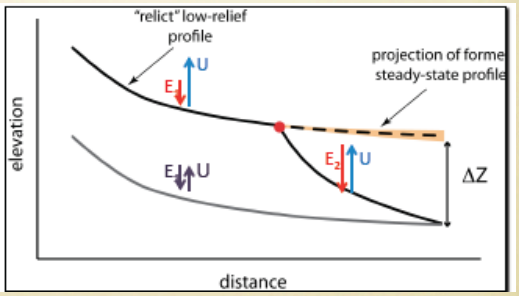
Areas of subdued, low slope topography are eroding slowing and represent a relict landscape that formed prior to a recent acceleration in rock uplift rate



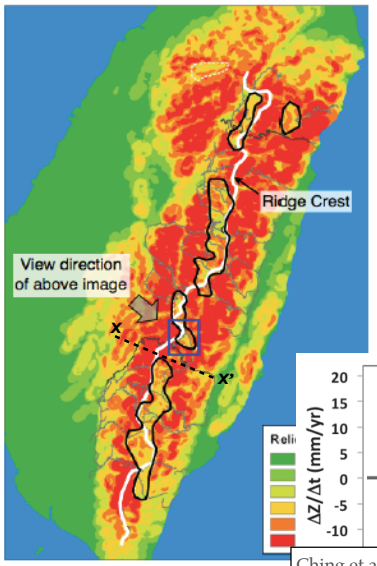
Anomalous Topography…

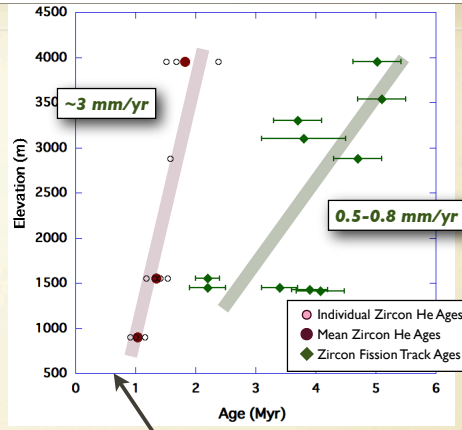


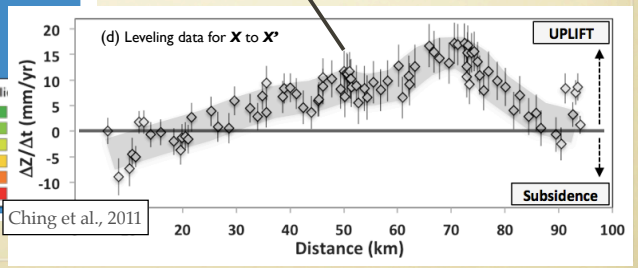




Anomalous Topography…

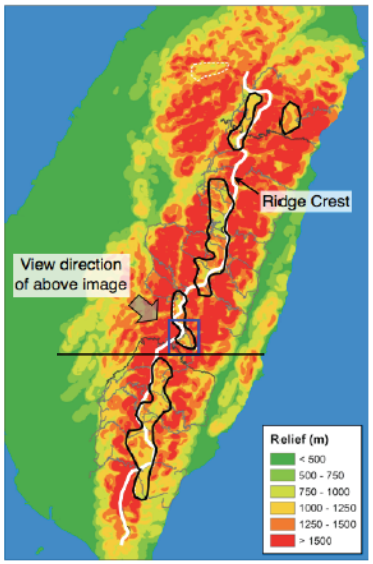






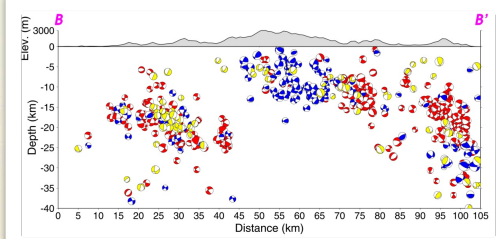
Ching et al., 2011

Anomalous Topography…



-- Additional Anomaly --

Extension in upper crust; compression in lower crust



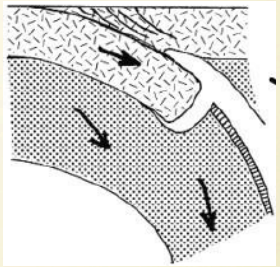
over 1400 focal mechanisms from 1991-2010 with 2.4≦ML≦6.5 (Rau, pers. comm.)

Are lithospheric scale processes needed to drive uplift and extension?

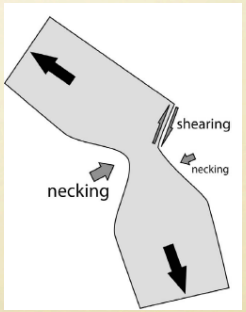
Crustal and Lithospheric processes:

Lithosphere delamination - more
delan
crust

1. acceleration in uplift
2. increased heat flow
3. mafic volcanism
4. possibly extension

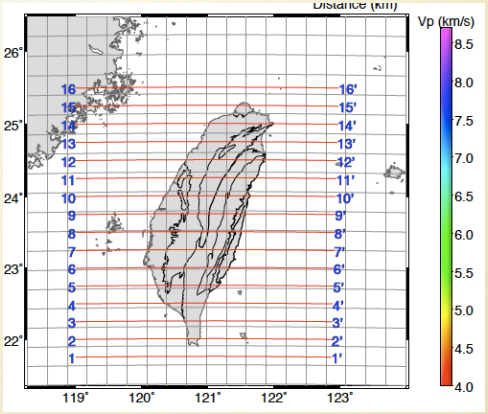


Lithosphere "break off" - stretches or shears and detaches



APPROACH

- Simultaneous inversion of P- and S-wave arrival times and velocity structure - Tomographic model of Kuo-Chen et al., 2012[1]
- Active and passive sources, OBSs and permanent seismic networks; two models with different resolutions - "**local**" and "**regional**"
- Color scale and contours to help identify possible structures
- Evaluate geological validity of the structures



1 Kuo-Chen,H., F. Wu, S. W. Roecker, Three-dimensional P velocity structures of the lithosphere beneath Taiwan from the analysis of TAIGER and related seismic data sets. *Journal Geophysical Research* **117**, (2012).

20-30 km east-west and north-south grid spacing
Sections spaced about 25 km

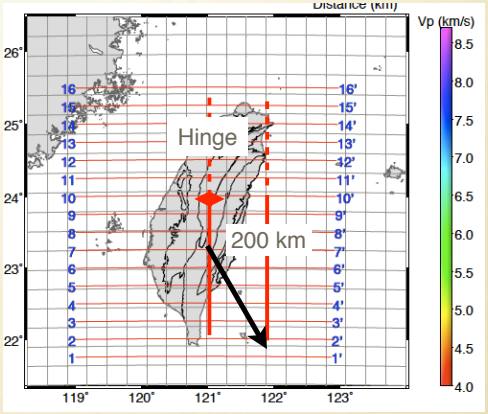
RESULTS

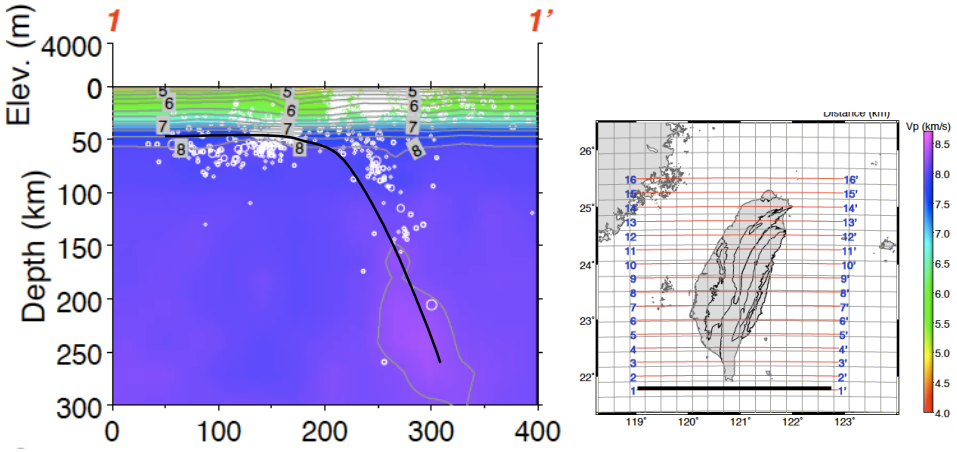
Regional model: E-W sections to 300 km

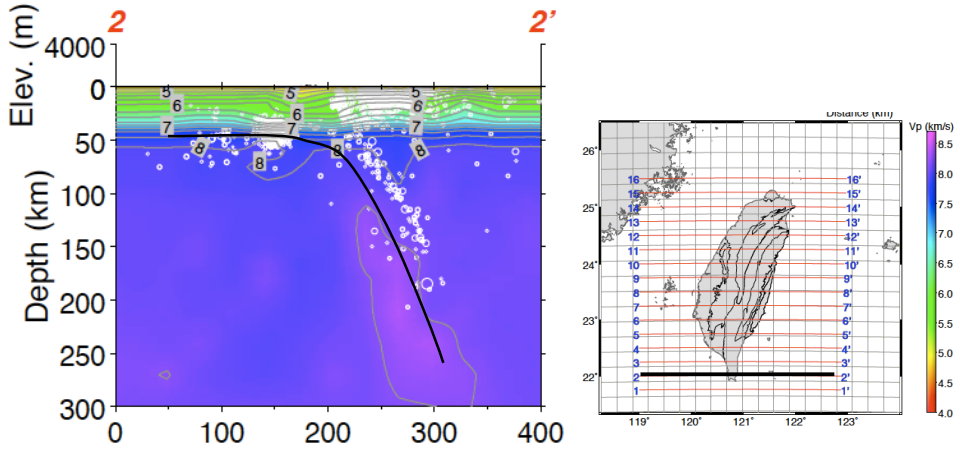
- Lithospheric slab strikes north-south, dips 60° east
- Lithospheric slab becomes less coherent south to north, consistent with stretching or detachment in northern Taiwan

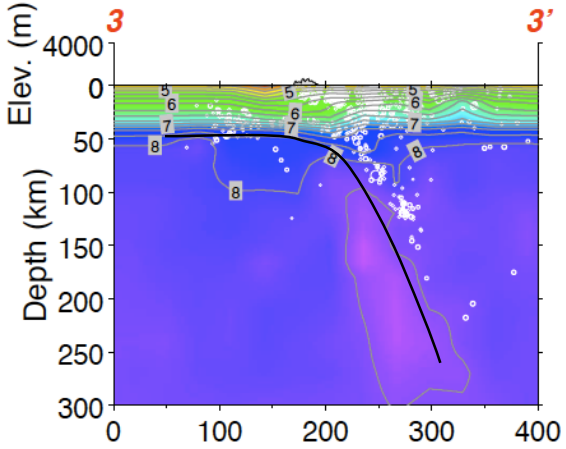
Local model: Horizontal sections to 110 km

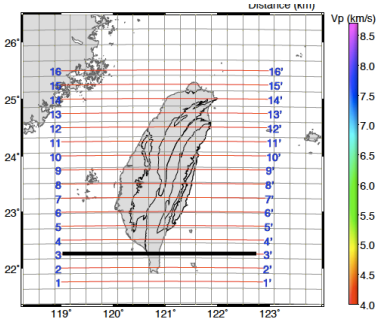
- Crustal root beneath central part of Central Range
- Crust may be delaminating along a partially subducted fracture zone in southern Taiwan



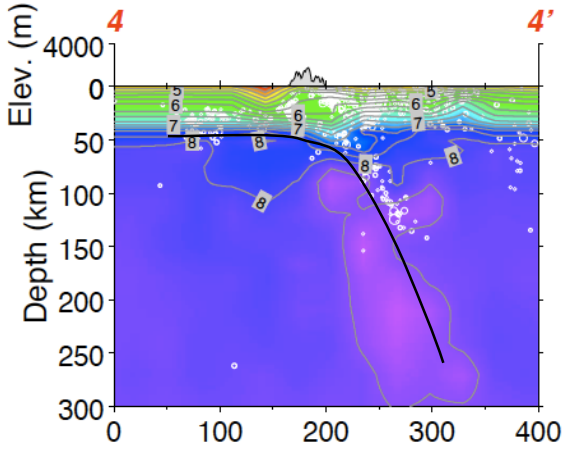

1
1'
Elev. (m)
Depth (km)
4000
0
50
100
150
200
250
300
0
100
200
300
400
5
6
7
8
Distance (km)
Vp (km/s)
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
26°
25°
24°
23°
22°
119°
120°
121°
122°
123°

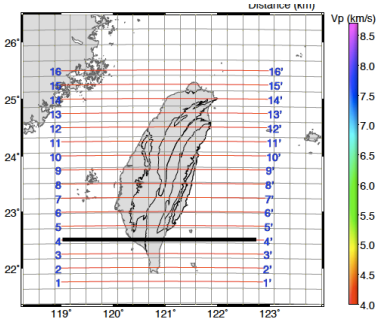

2
2'
Elev. (m)
Depth (km)
4000
0
50
100
150
200
250
300
0
100
200
300
400
5
6
7
8
Distance (km)
Vp (km/s)
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
26°
25°
24°
23°
22°
119°
120°
121°
122°
123°


3
3'
Elev. (m)
4000
0
Depth (km)
50
100
150
200
250
300
0
100
200
300
400

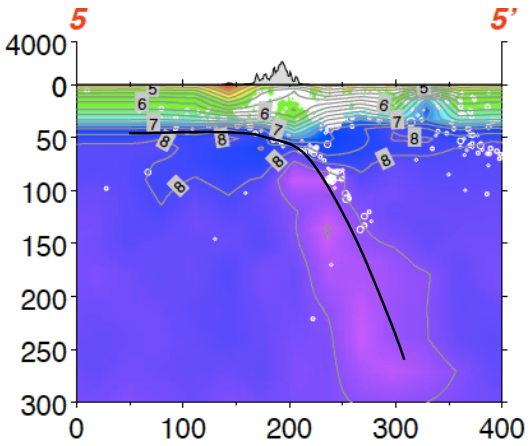

26°
25°
24°
23°
22°
119°
120°
121°
122°
123°

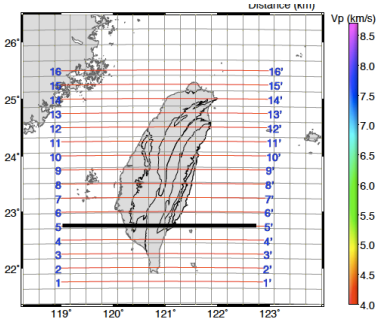
Vp (km/s)
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0


4
4'
Elev. (m)
Depth (km)
4000
0
50
100
150
200
250
300
0
100
200
300
400
5
6
7
8
8'

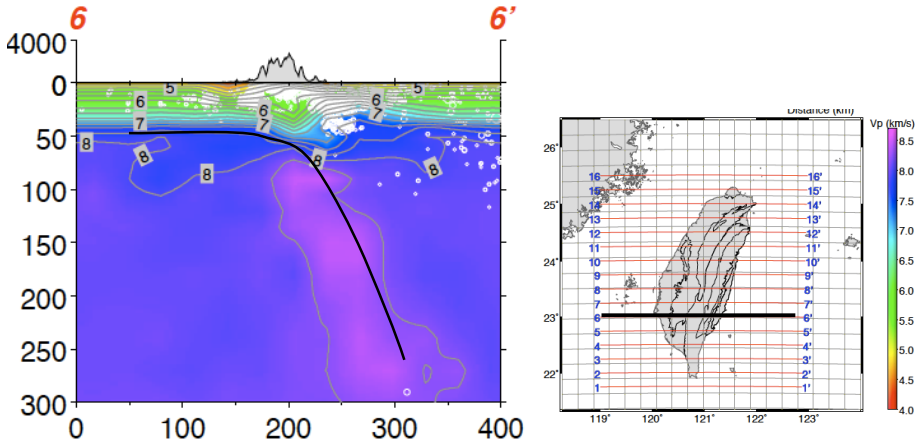

26°
25°
24°
23°
22°
119°
120°
121°
122°
123°

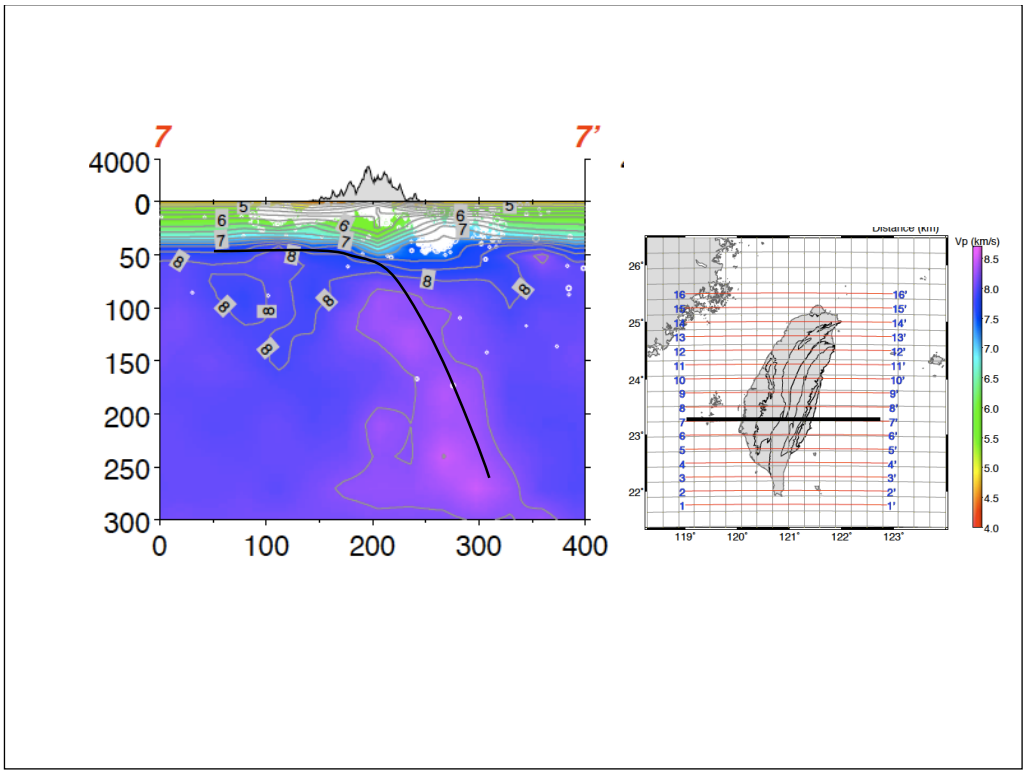
Vp (km/s)
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0

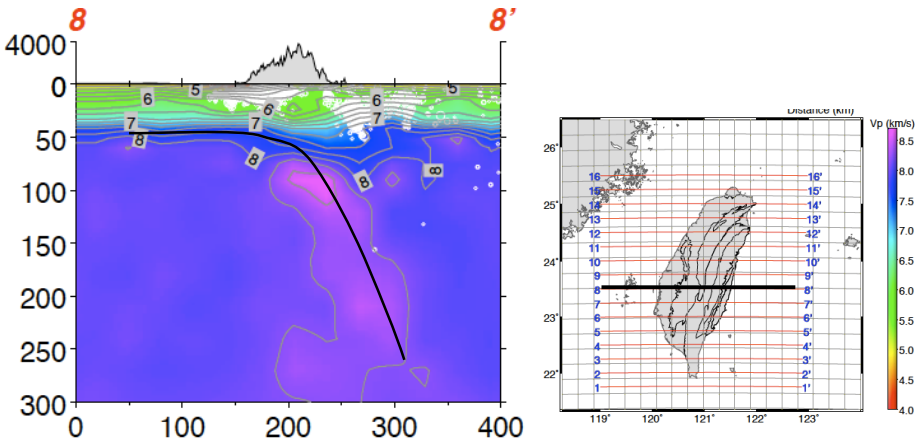

5
5'
4000
0
50
100
150
200
250
300
0
100
200
300
400

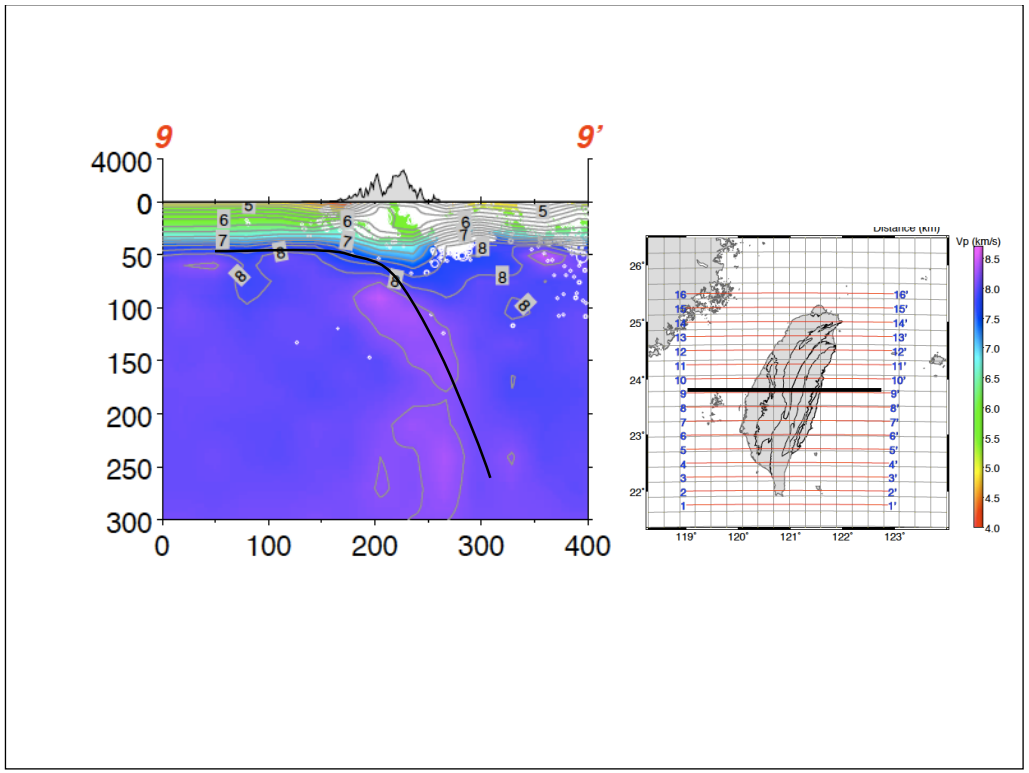

Distance (km)
26°
25°
24°
23°
22°
119°
120°
121°
122°
123°

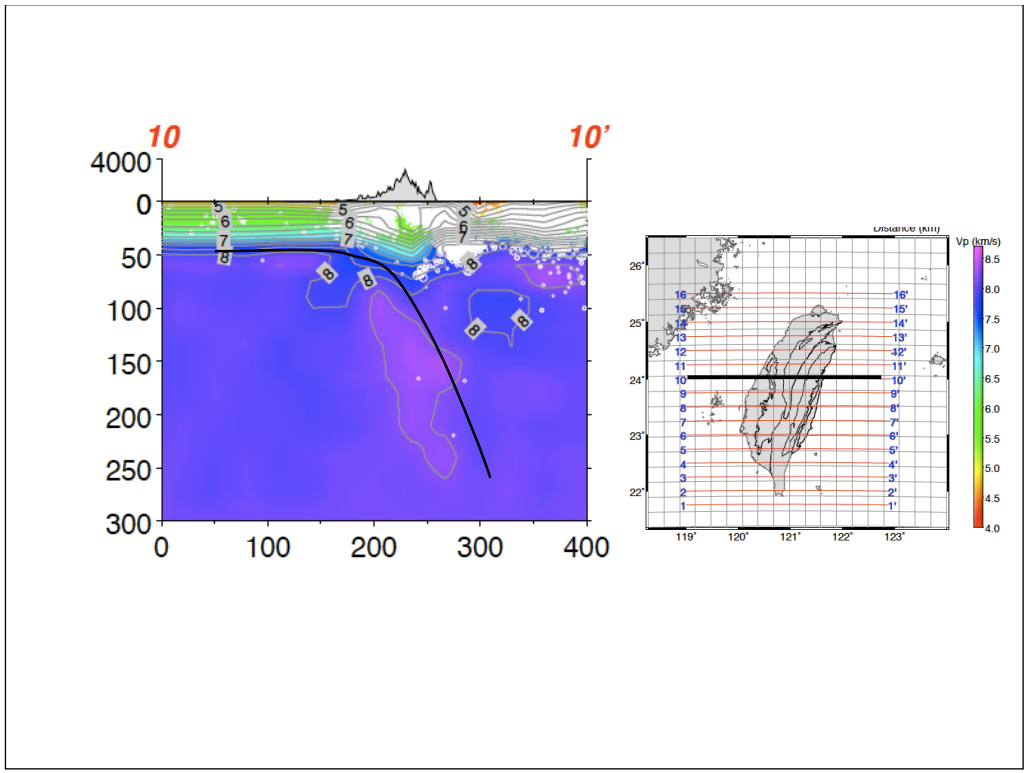
Vp (km/s)
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0

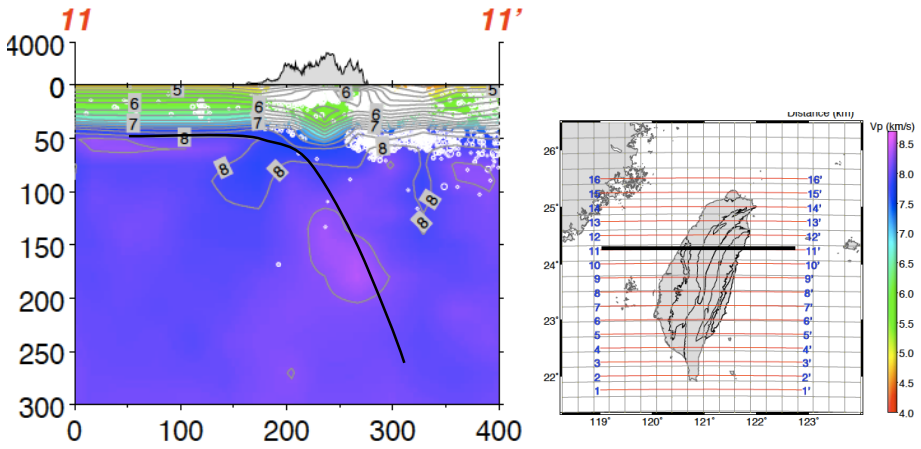

6
6'
4000
0
50
100
150
200
250
300
0
100
200
300
400
5
6
7
8
Distance (km)
Vp (km/s)
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
26°
25°
24°
23°
22°
119°
120°
121°
122°
123°
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
16'
15'
14'
13'
12'
11'
10'
9'
8'
7'
6'
5'
4'
3'
2'
1'

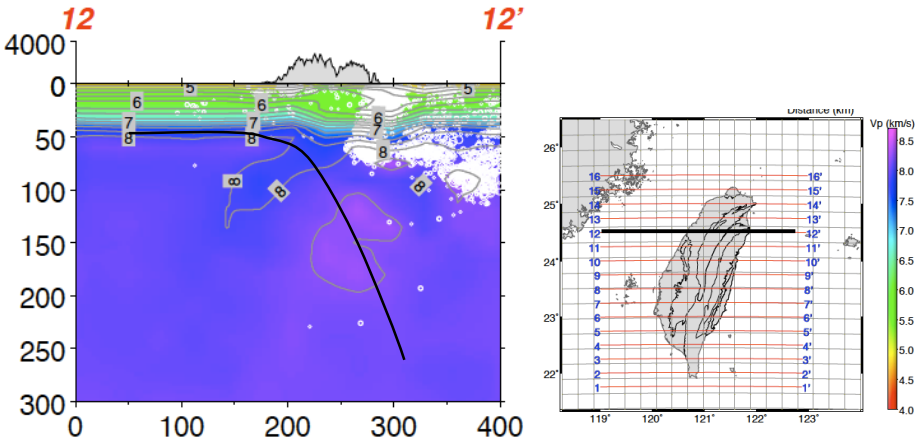

7
7'
4000
0
50
100
150
200
250
300
0
100
200
300
400
Distance (km)
Vp (km/s)
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
26°
25°
24°
23°
22°
119°
120°
121°
122°
123°

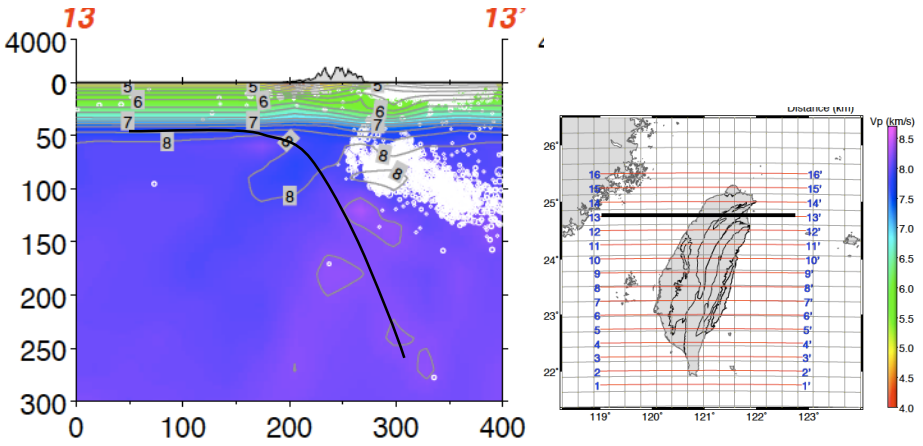

8
8'
4000
0
50
100
150
200
250
300
0
100
200
300
400
5
6
7
8
Distance (km)
Vp (km/s)
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
26°
25°
24°
23°
22°
119°
120°
121°
122°
123°

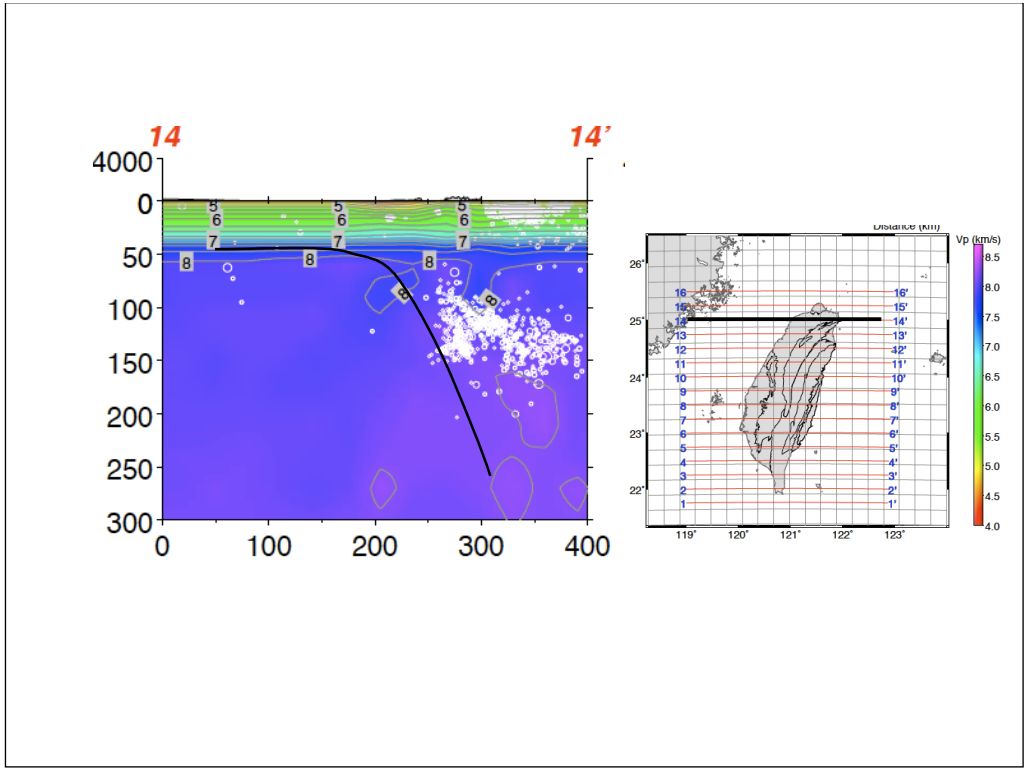

9
9'
4000
0
50
100
150
200
250
300
0
100
200
300
400
Distance (km)
Vp (km/s)
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
26°
25°
24°
23°
22°
119°
120°
121°
122°
123°

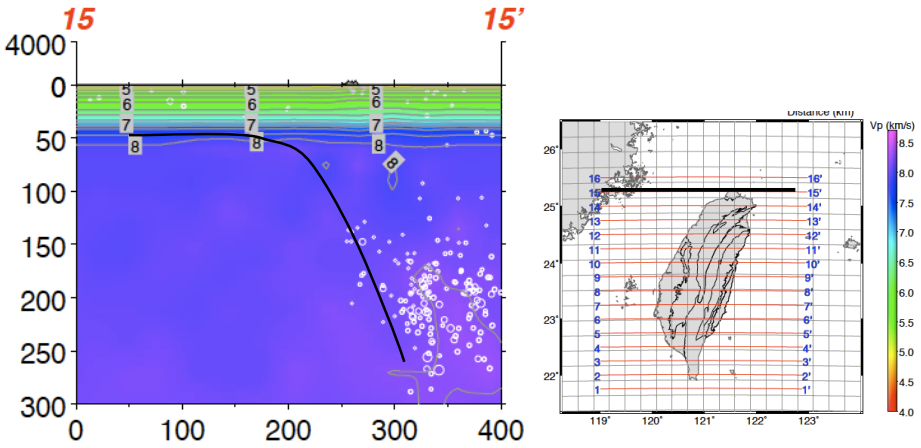

10
10'
4000
0
50
100
150
200
250
300
0
100
200
300
400
5
6
7
8
Distance (km)
Vp (km/s)
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
26°
25°
24°
23°
22°
119°
120°
121°
122°
123°

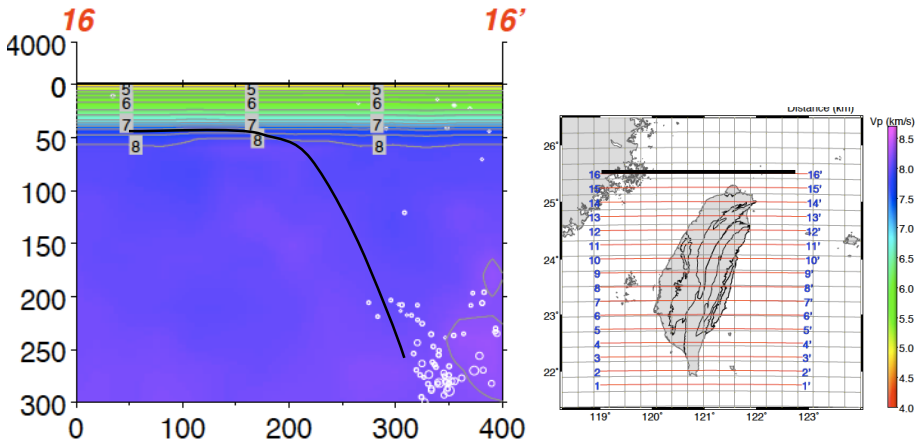

11
11'
4000
0
50
100
150
200
250
300
0
100
200
300
400
Distance (km)
Vp (km/s)
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
26°
25°
24°
23°
22°
119°
120°
121°
122°
123°

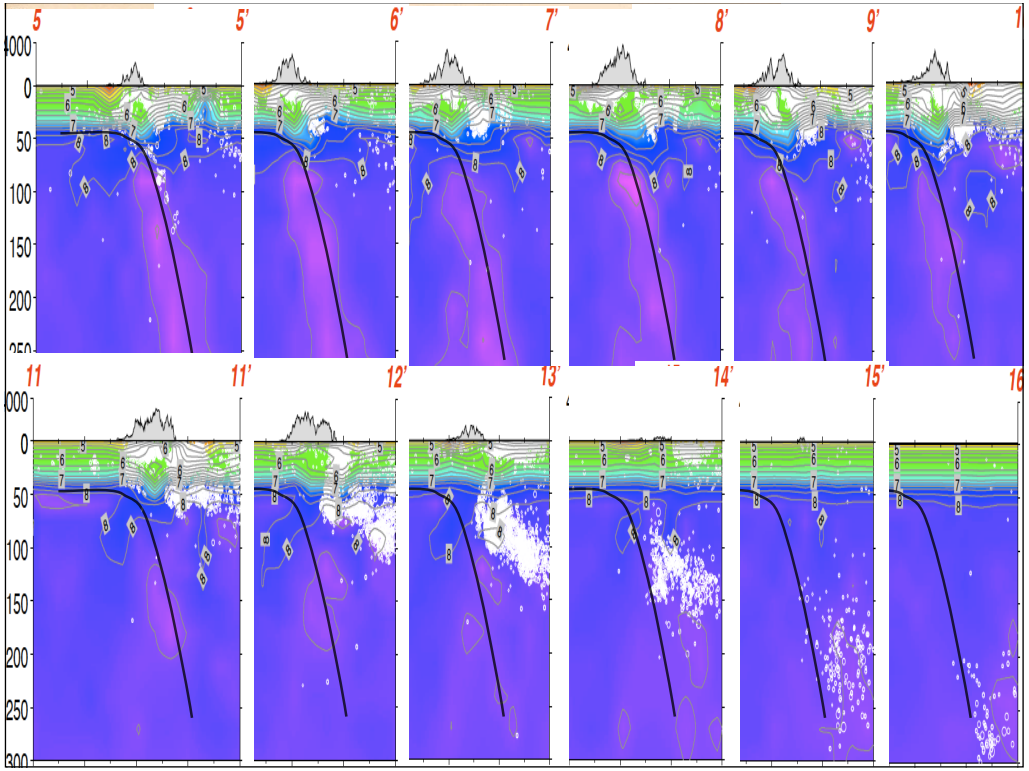

12
12'
4000
0
50
100
150
200
250
300
0
100
200
300
400
5
6
7
8
Distance (km)
Vp (km/s)
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
26°
25°
24°
23°
22°
119°
120°
121°
122°
123°


13
13'
4000
0
50
100
150
200
250
300
0
100
200
300
400
Distance (km)
Vp (km/s)
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
26°
25°
24°
23°
22°
119°
120°
121°
122°
123°


14
14'
4000
0
50
100
150
200
250
300
0
100
200
300
400
5
6
7
8
Distance (km)
Vp (km/s)
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
26°
25°
24°
23°
22°
119°
120°
121°
122°
123°

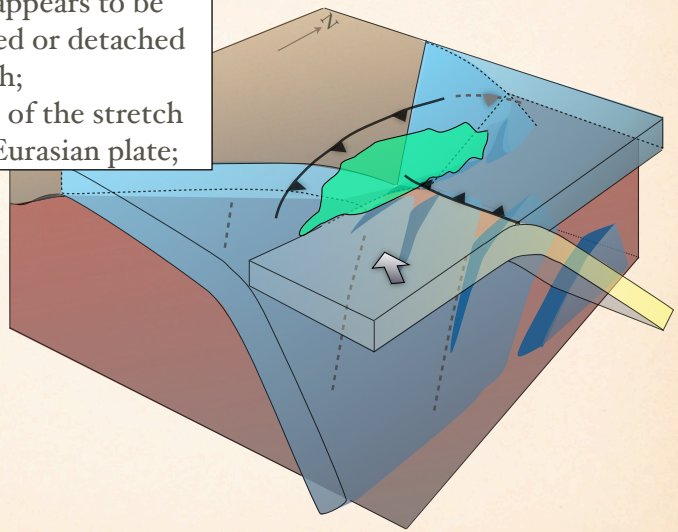

15
15'
4000
0
50
100
150
200
250
300
0
100
200
300
400
5
6
7
8
B
Distance (km)
Vp (km/s)
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
26°
25°
24°
23°
22°
119°
120°
121°
122°
123°

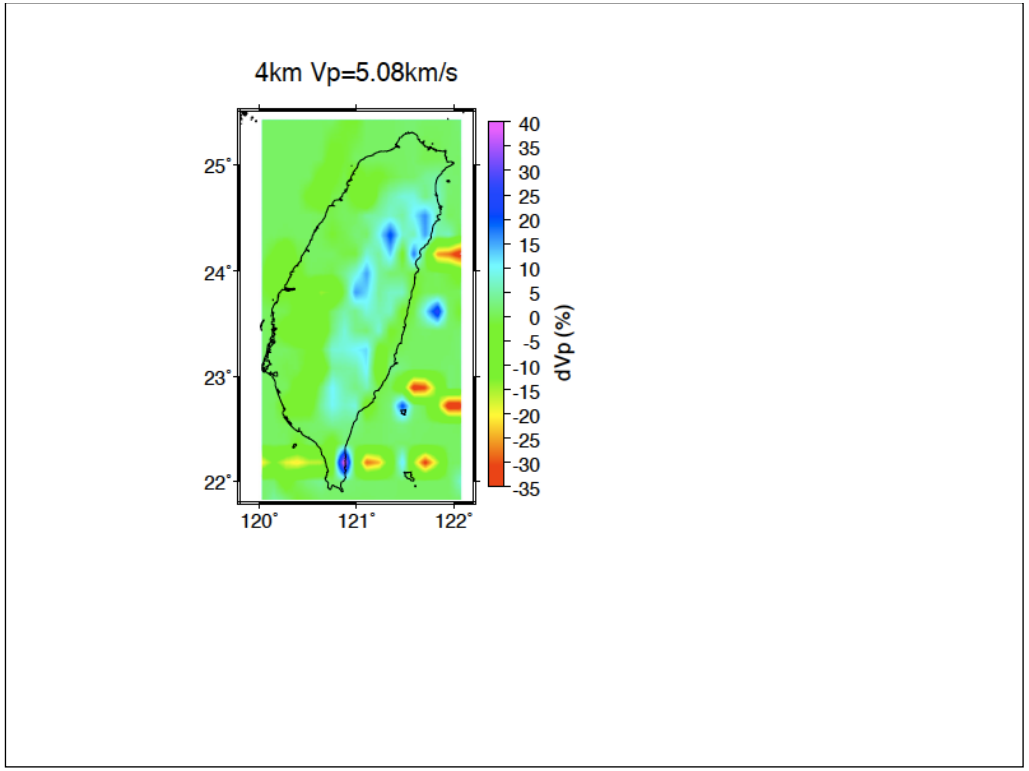

16
16'
4000
0
50
100
150
200
250
300
0
100
200
300
400
5
6
7
8
Distance (km)
Vp (km/s)
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
26°
25°
24°
23°
22°
119°
120°
121°
122°
123°

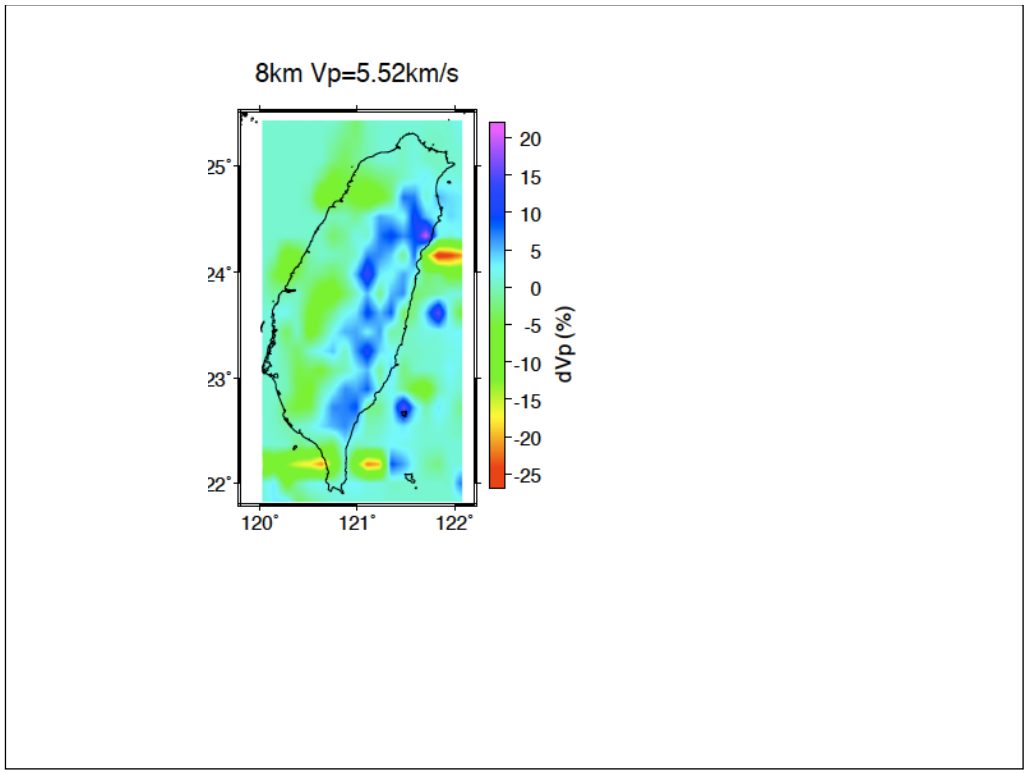

5
5'
6'
7'
8'
9'
1
11
11'
12'
13'
14'
15'
16
4000
0
50
100
150
200
250
300

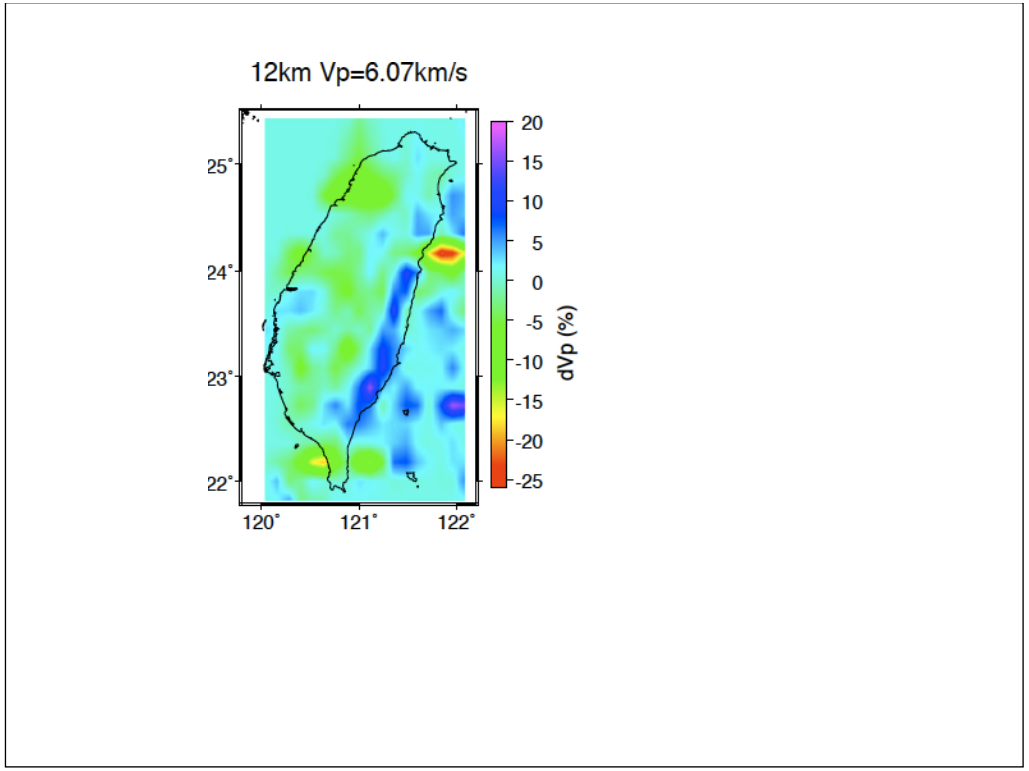
Summary:

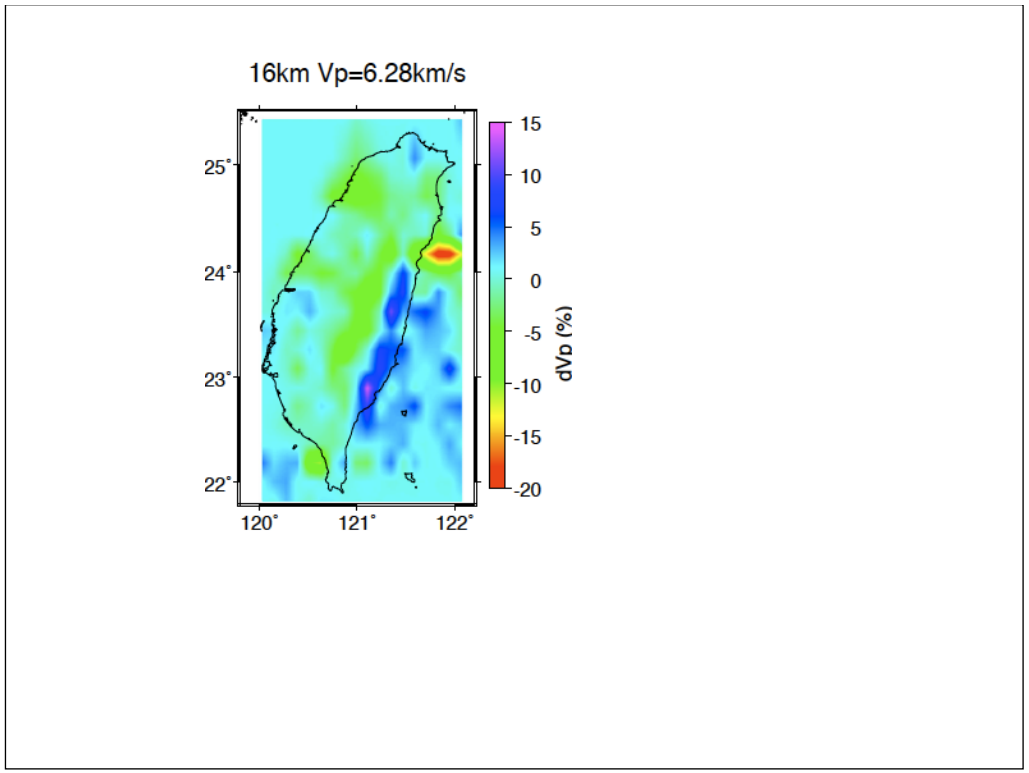
1) Eurasian plate appears to be more stretched or detached south to north;
2) PSP sits on top of the stretch or detached Eurasian plate;

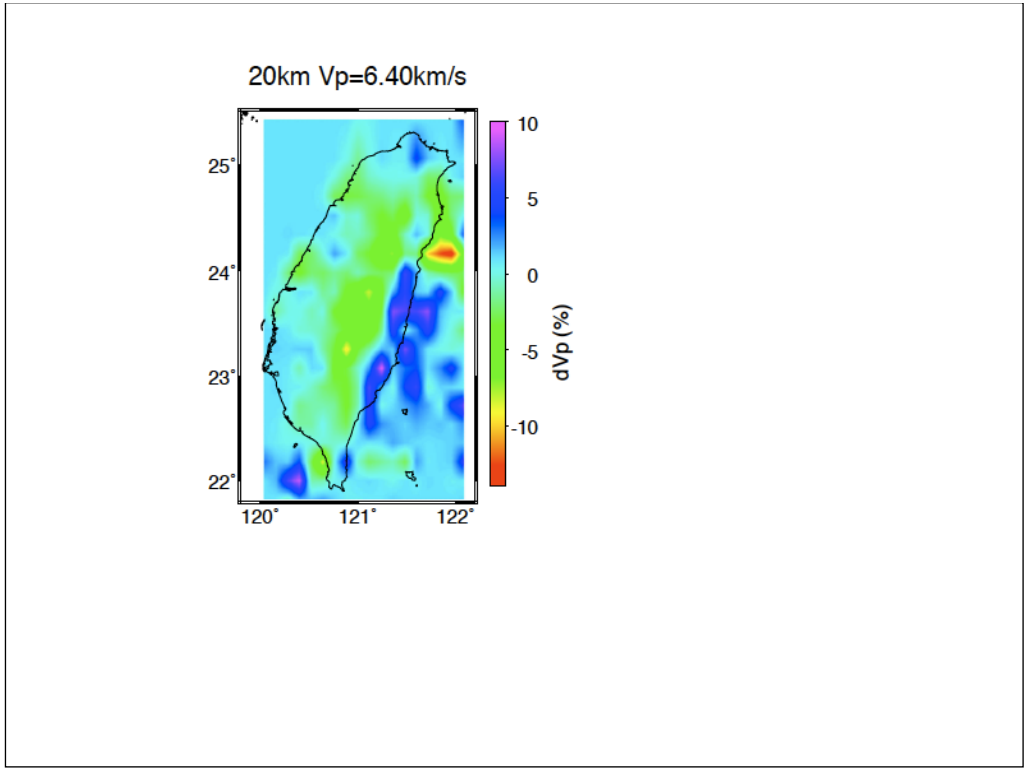


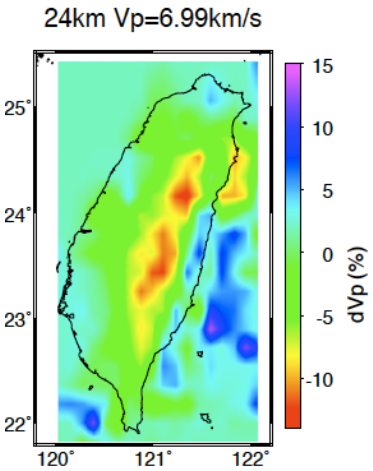

4km Vp=5.08km/s
25°
24°
23°
22°
120°
121°
122°
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
dVp (%)

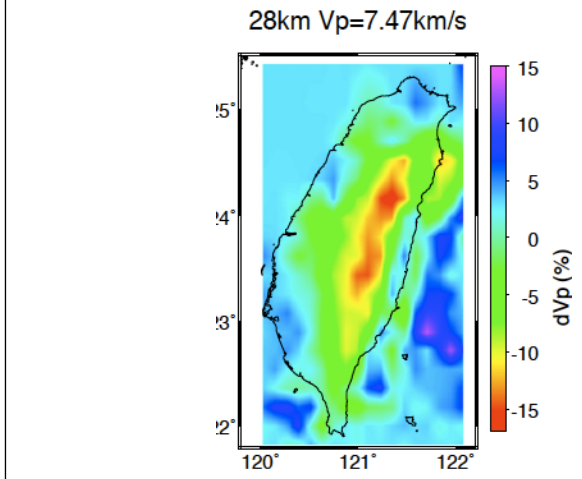

8km Vp=5.52km/s
25°
24°
23°
22°
120°
121°
122°
20
15
10
5
0
-5
-10
-15
-20
-25
dVp (%)

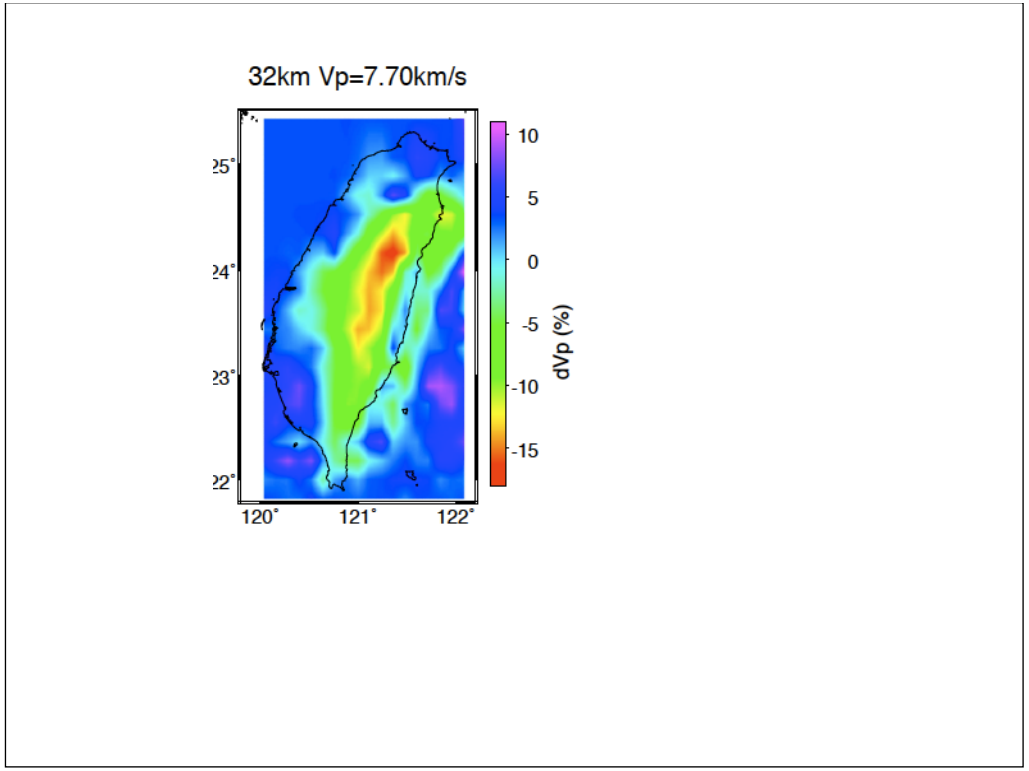

12km Vp=6.07km/s
25°
24°
23°
22°
120°
121°
122°
20
15
10
5
0
-5
-10
-15
-20
-25
dVp (%)

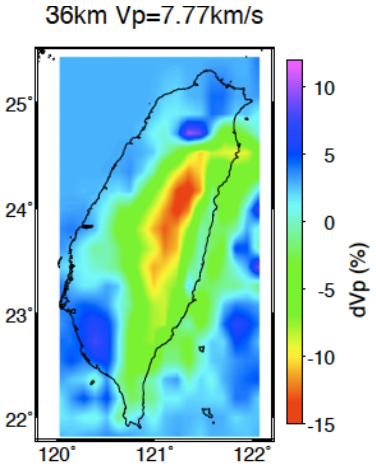

16km Vp=6.28km/s
25°
24°
23°
22°
120°
121°
122°
15
10
5
0
-5
-10
-15
-20
dVp (%)

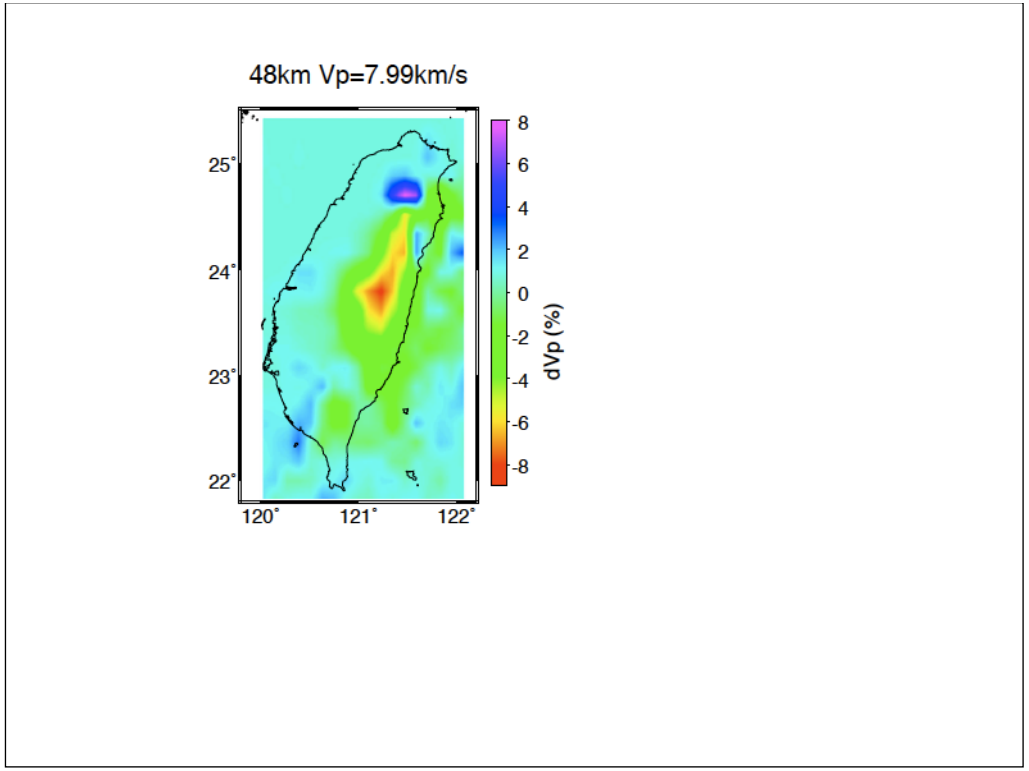

20km Vp=6.40km/s
25°
24°
23°
22°
120°
121°
122°
10
5
0
-5
-10
dVp (%)

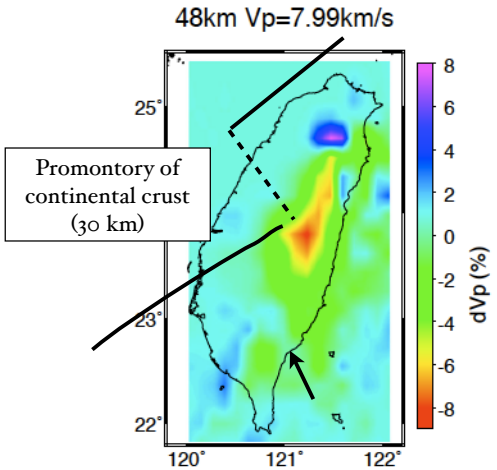

24km Vp=6.99km/s
25°
24°
23°
22°
120°
121°
122°
15
10
5
0
-5
-10
dVp (%)


28km Vp=7.47km/s
15
10
5
0
-5
-10
-15
dVp (%)
120˚
121˚
122˚


32km Vp=7.70km/s
25°
24°
23°
22°
120°
121°
122°
10
5
0
-5
-10
-15
dVp (%)


36km Vp=7.77km/s
25°
24°
23°
22°
120°
121°
122°
10
5
0
-5
-10
-15
dVp (%)

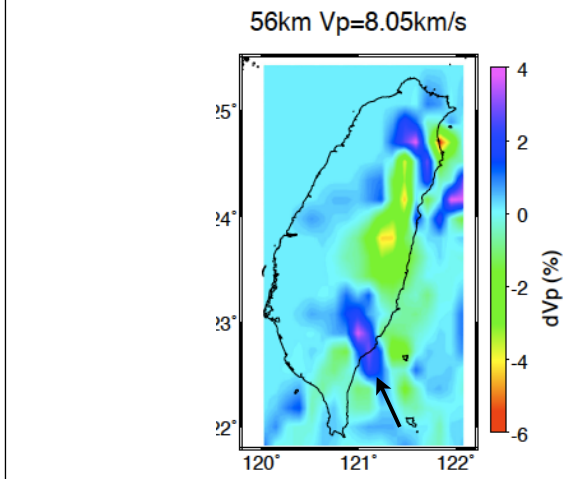

48km Vp=7.99km/s
25°
24°
23°
22°
120°
121°
122°
8
6
4
2
0
-2
-4
-6
-8
dVp (%)

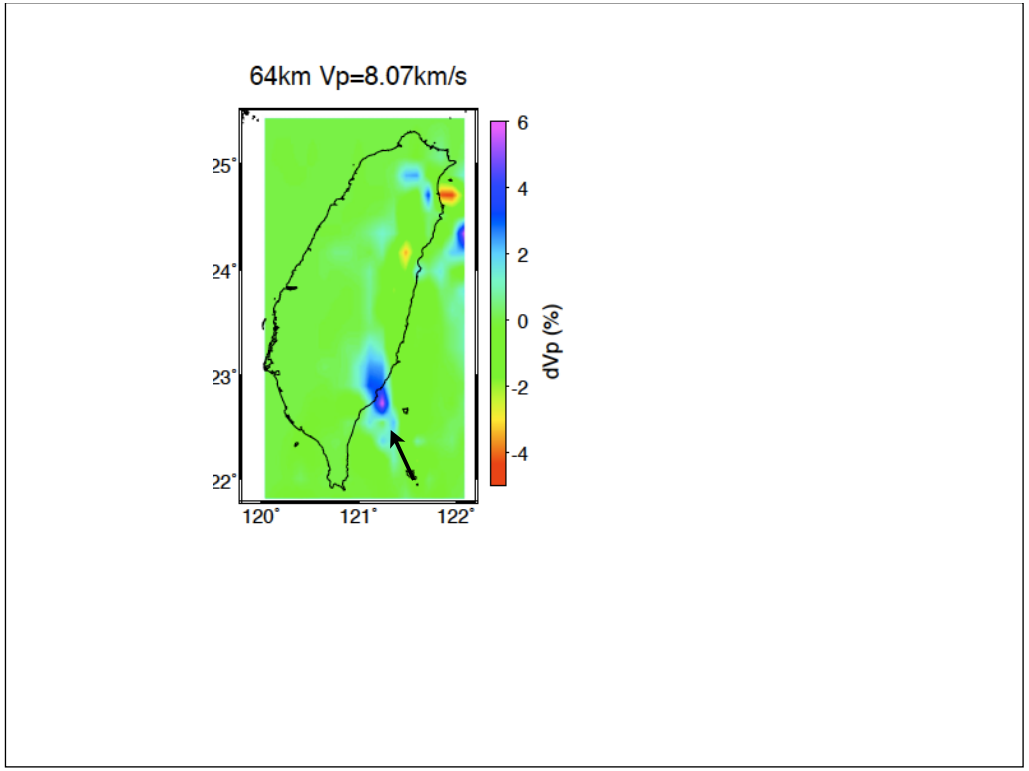


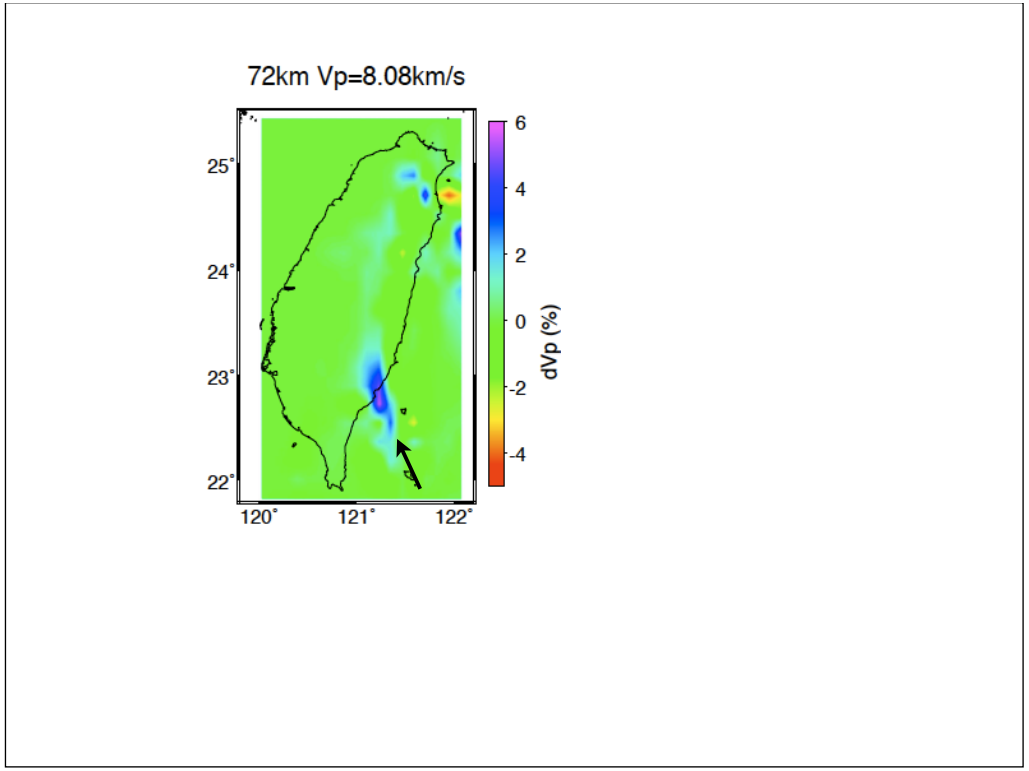
Promontory of continental crust (30 km)

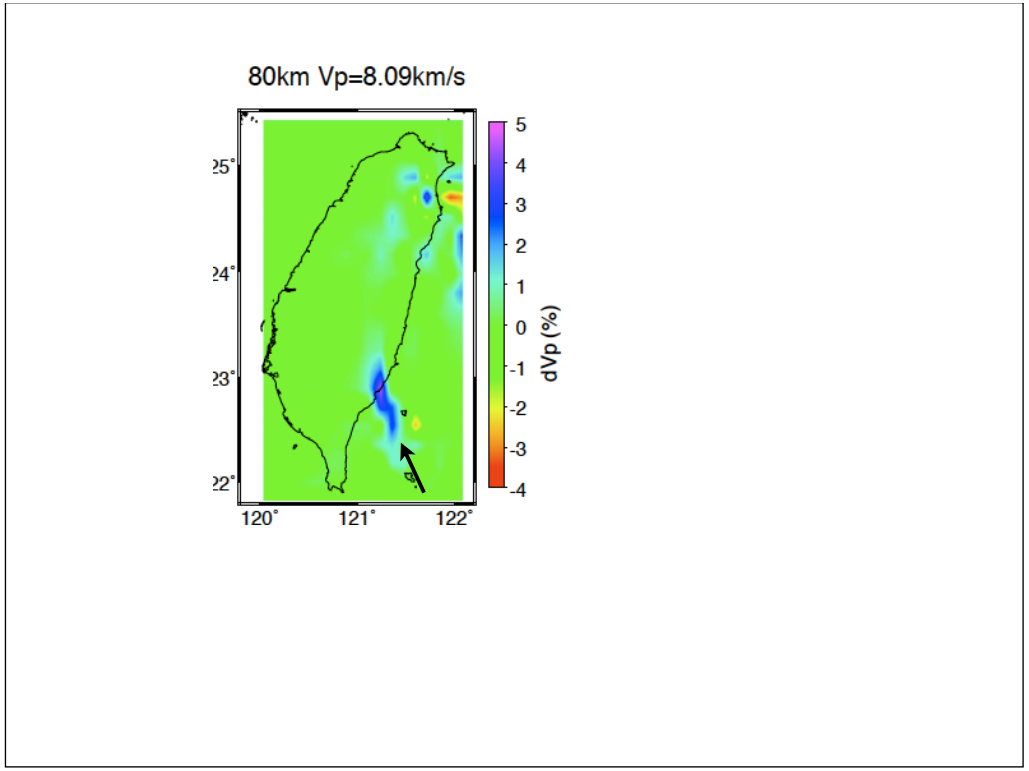
Thickest orogenic crust forming between arc and promontory of strong continental crust

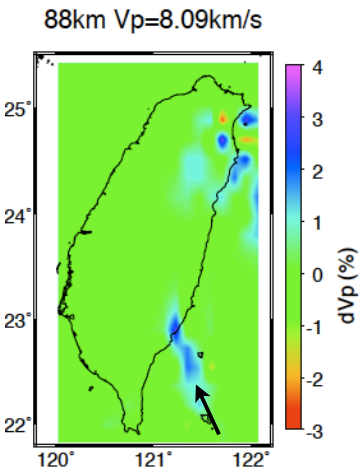
Area of thin orogenic crust in southern Central Range

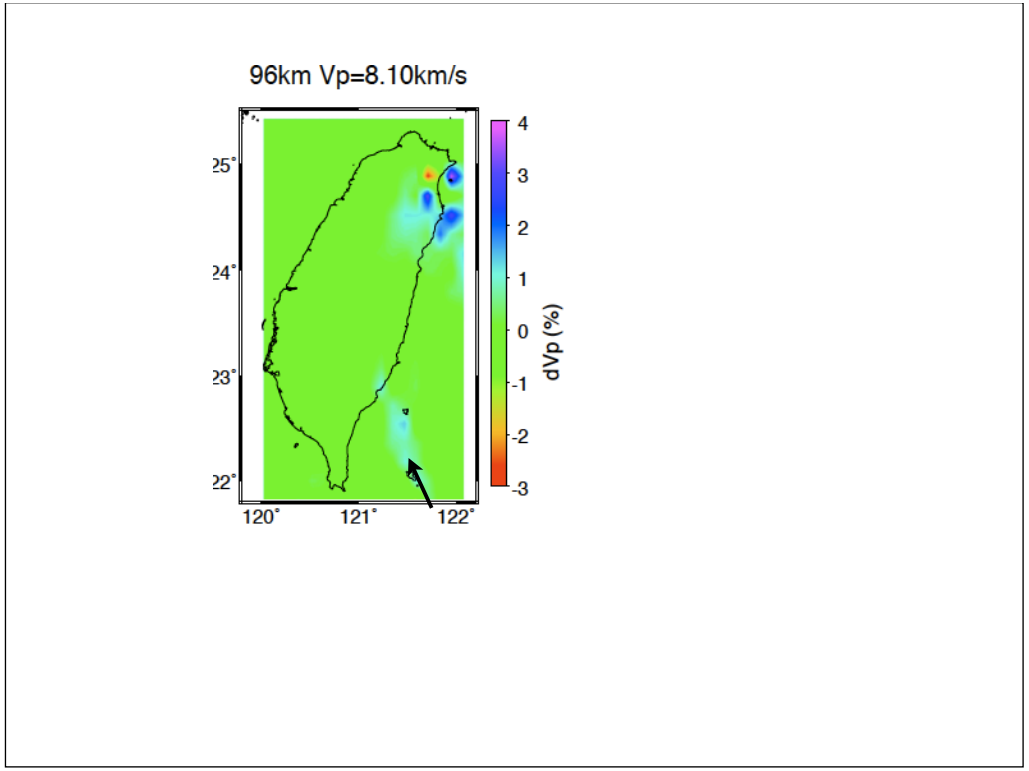

56km Vp=8.05km/s
25°
24°
23°
22°
120°
121°
122°
4
2
0
-2
-4
-6
dVp (%)

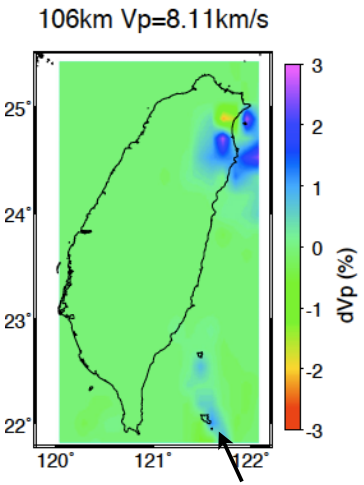

64km Vp=8.07km/s
25°
24°
23°
22°
120°
121°
122°
6
4
2
0
-2
-4
dVp (%)

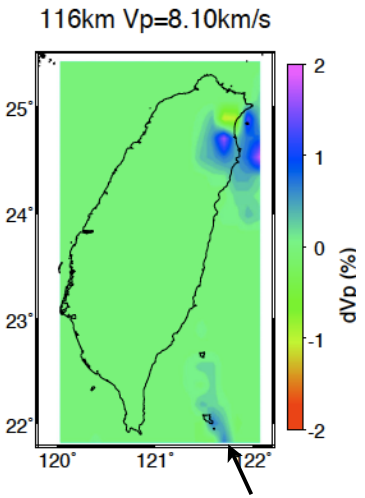

72km Vp=8.08km/s
25°
24°
23°
22°
120°
121°
122°
6
4
2
0
-2
-4
dVp (%)

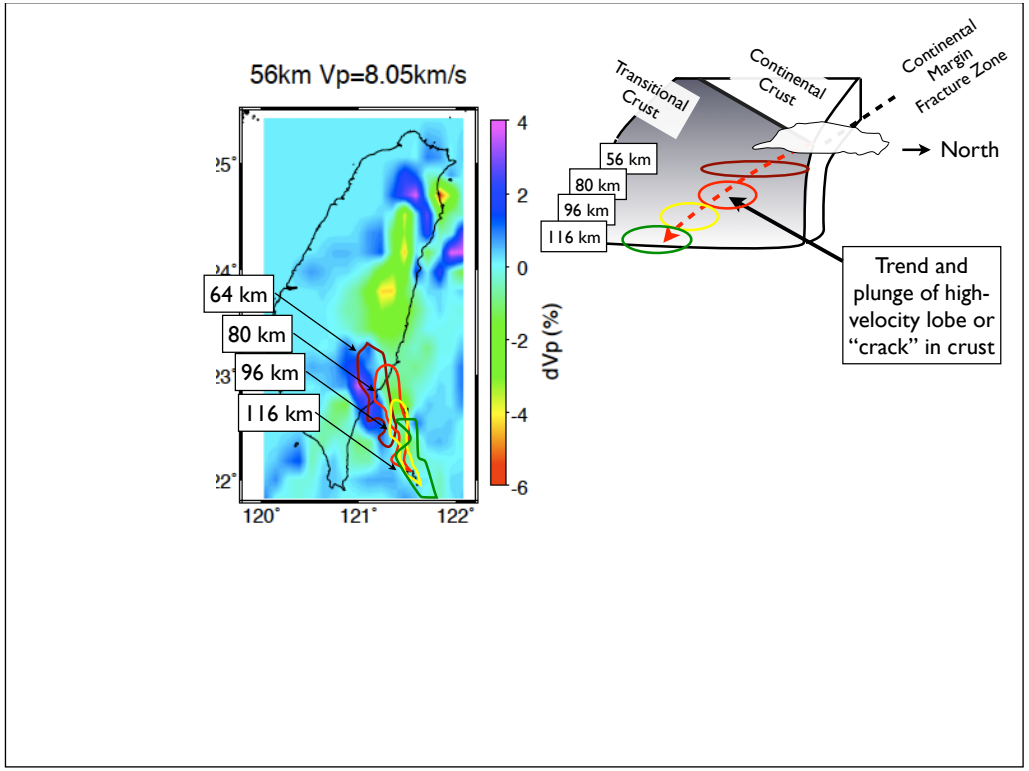

80km Vp=8.09km/s
25°
24°
23°
22°
120°
121°
122°
5
4
3
2
1
0
-1
-2
-3
-4
dVp (%)

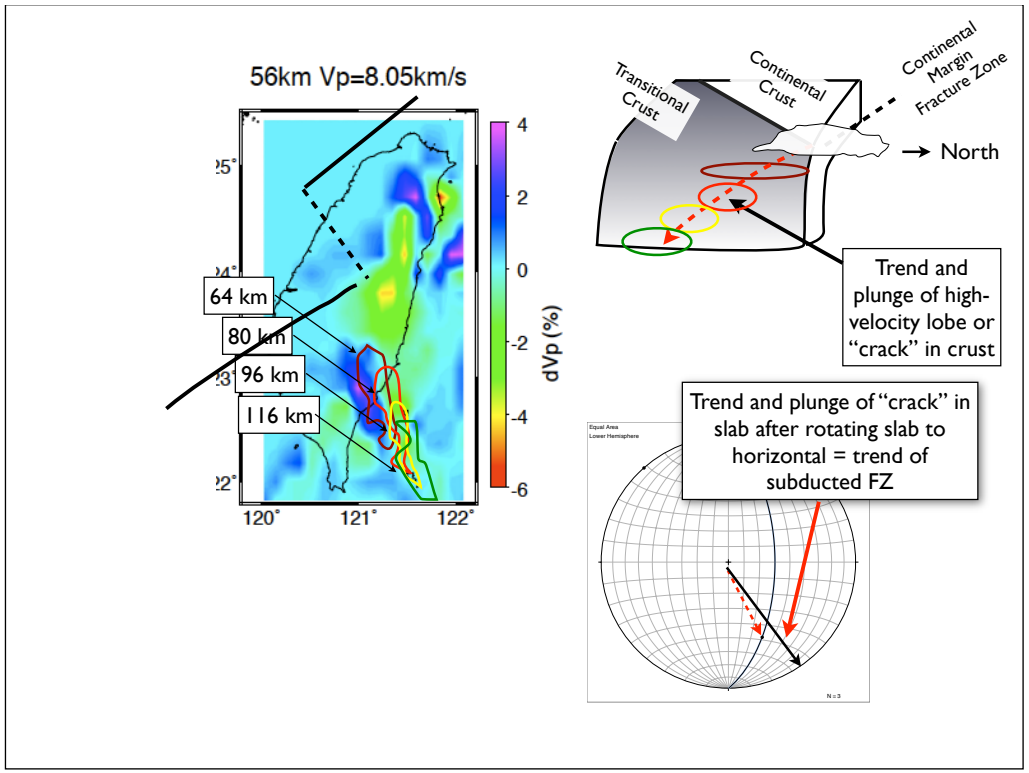

88km Vp=8.09km/s
25°
24°
23°
22°
120°
121°
122°
4
3
2
1
0
-1
-2
-3
dVp (%)

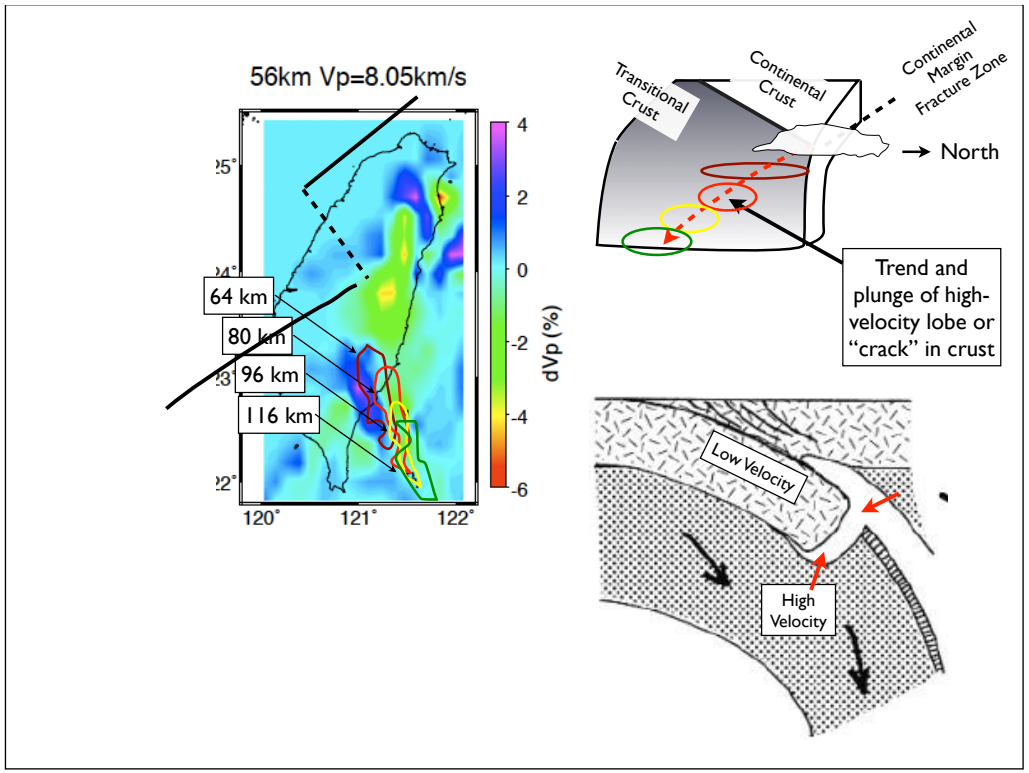

96km Vp=8.10km/s
25°
24°
23°
22°
120°
121°
122°
4
3
2
1
0
-1
-2
-3
dVp (%)

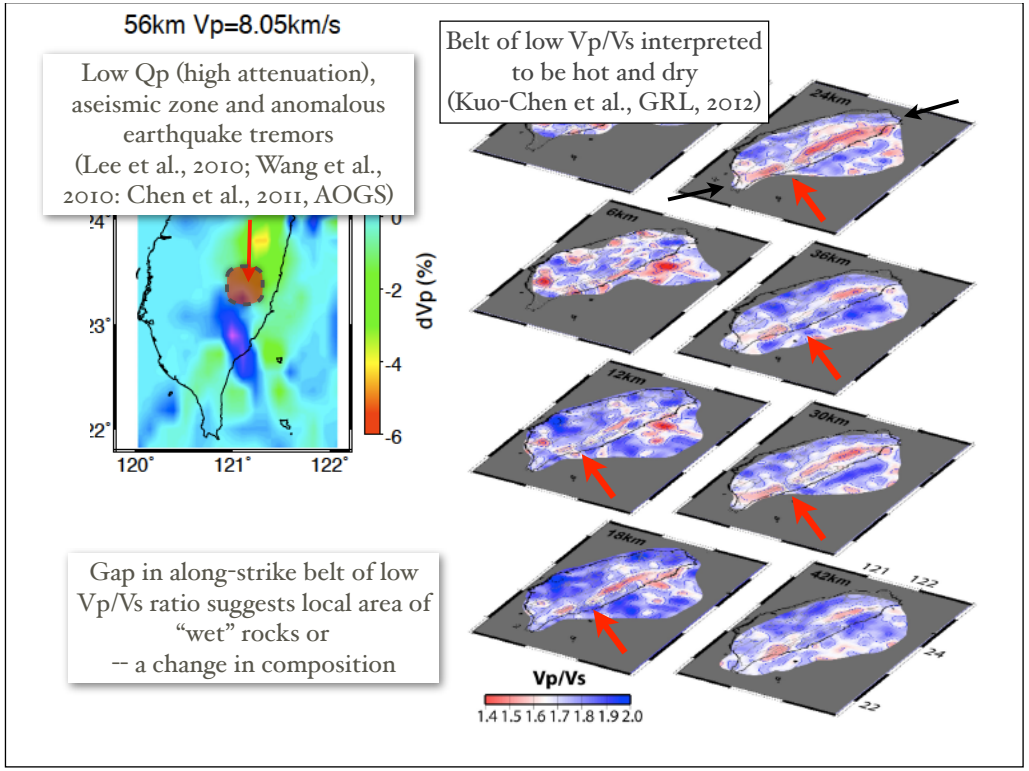

106km Vp=8.11km/s
25°
24°
23°
22°
120°
121°
122°
3
2
1
0
-1
-2
-3
dVp (%)


116km Vp=8.10km/s
25°
24°
23°
22°
120°
121°
122°
2
1
0
-1
-2
dVp (%)


56km Vp=8.05km/s
64 km
80 km
96 km
116 km
120°
121°
122°
4
2
0
-2
-4
-6
dVp (%)
Transitional Crust
Continental Crust
Continental Margin Fracture Zone
North
56 km
80 km
96 km
116 km
Trend and plunge of high-velocity lobe or "crack" in crust


56km Vp=8.05km/s
64 km
80 km
96 km
116 km
120°
121°
122°
4
2
0
-2
-4
-6
dVp (%)
Transitional Crust
Continental Crust
Continental Margin Fracture Zone
North
Trend and plunge of high-velocity lobe or "crack" in crust
Trend and plunge of "crack" in slab after rotating slab to horizontal = trend of subducted FZ

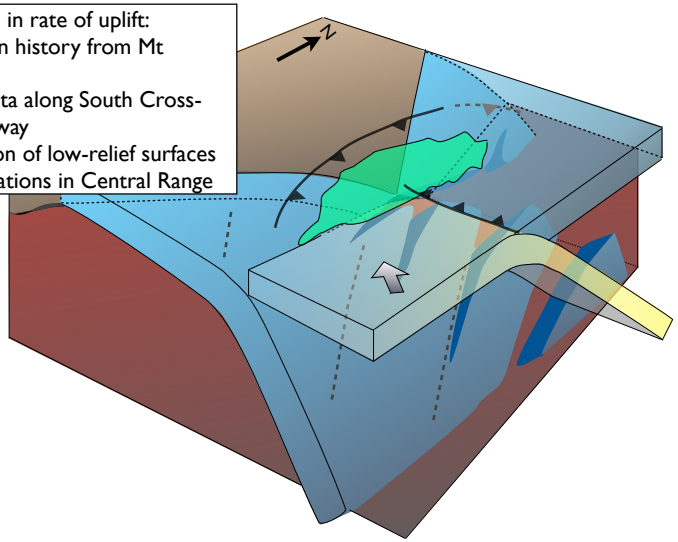

56km Vp=8.05km/s
64 km
80 km
96 km
116 km
120°
121°
122°
4
2
0
-2
-4
-6
dVp (%)
Transitional Crust
Continental Crust
Continental Margin Fracture Zone
North
Trend and plunge of high-velocity lobe or "crack" in crust
Low Velocity
High Velocity


56km Vp=8.05km/s
Low Qp (high attenuation), aseismic zone and anomalous earthquake tremors (Lee et al., 2010; Wang et al., 2010: Chen et al., 2011, AOGS)
Belt of low Vp/Vs interpreted to be hot and dry (Kuo-Chen et al., GRL, 2012)
Gap in along-strike belt of low Vp/Vs ratio suggests local area of "wet" rocks or -- a change in composition
dVp (%)
0
-2
-4
-6
120°
121°
122°
24km
6km
36km
12km
30km
18km
42km
121
122
24
22
Vp/Vs
1.4 1.5 1.6 1.7 1.8 1.9 2.0

Geologic consequences of delaminating/ detaching lithosphere

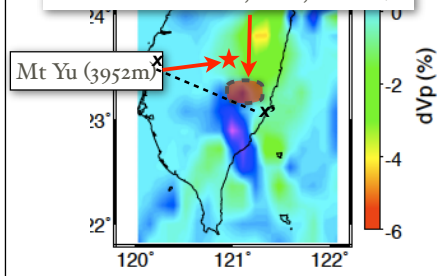
I) High-heat flow - zone of anomalously high attenuation above broken crust

II) Acceleration in rate of uplift:
1) Exhumation history from Mt Yushan;
2) Leveling data along South Cross-Island Highway
3) Preservation of low-relief surfaces at high elevations in Central Range

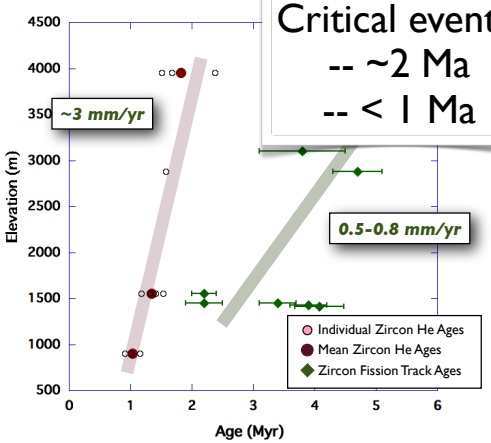


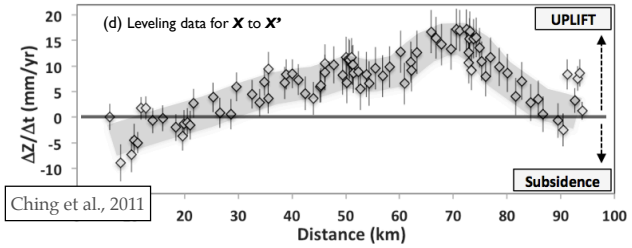
56km Vp=8.05km/s

Low Qp (high attenuation), aseismic zone and anomalous earthquake tremors (Lee et al., 2010; Wang et al., 2010: Chen et al., 2011, AOGS)



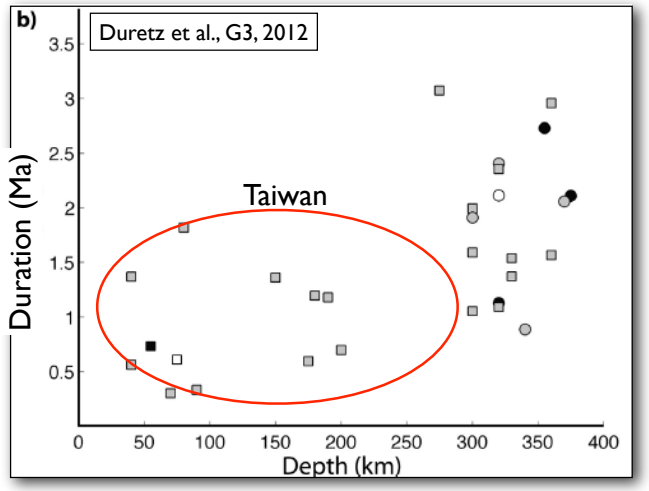
Critical events:
-- ~2 Ma
-- < 1 Ma





Ching et al., 2011

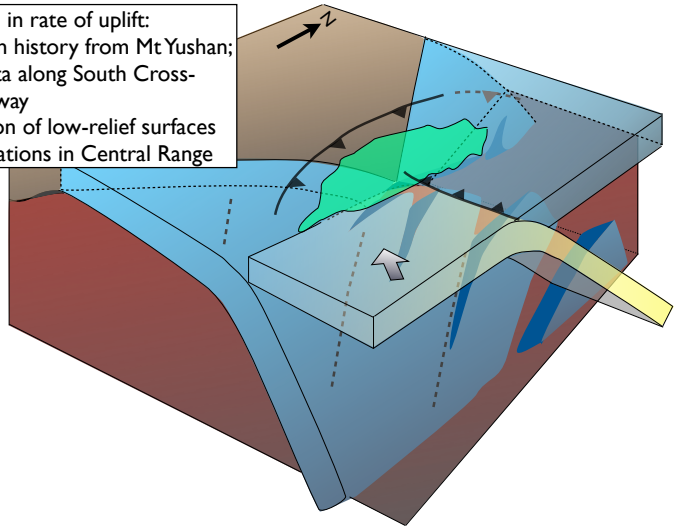
Is there enough slab and has there been enough time for slab detachment?

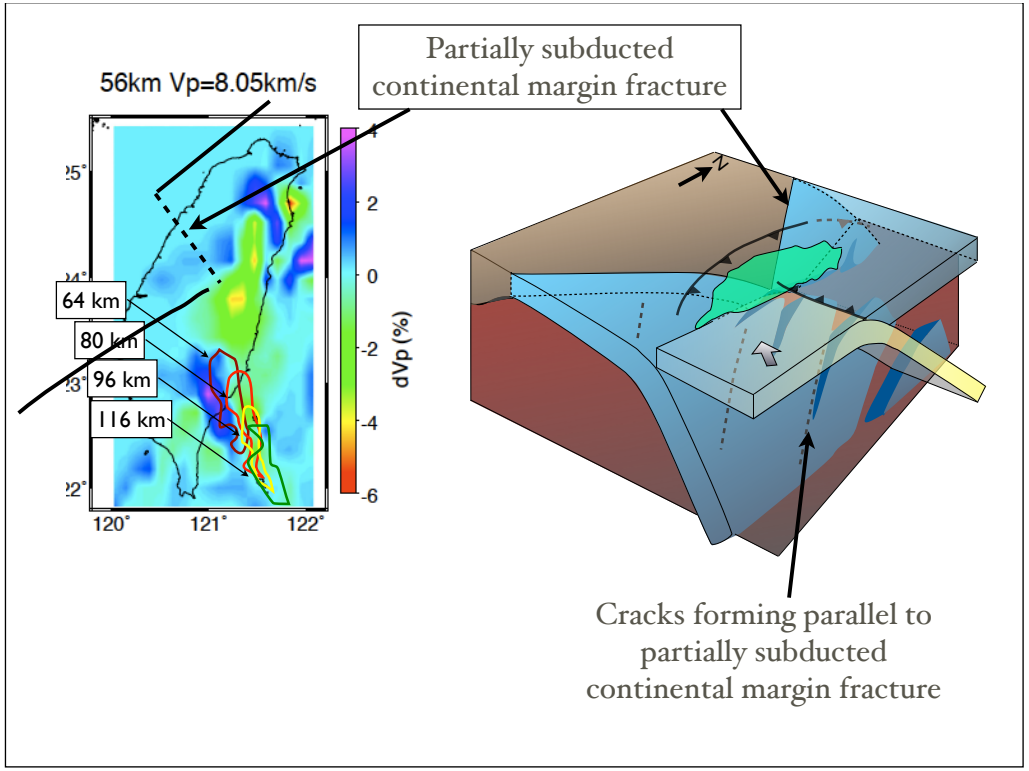


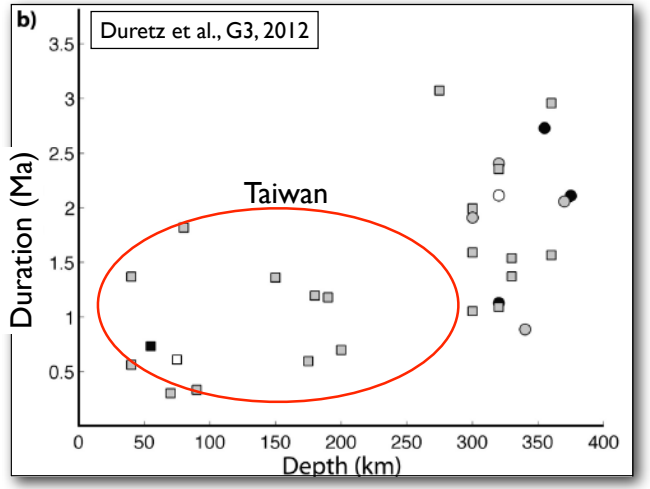
Geologic consequences of delaminating/ detaching lithosphere

I) High-heat flow - zone of anomalously high attenuation above broken crust

II) Acceleration in rate of uplift:
1) exhumation history from Mt Yushan;
2) leveling data along South Cross-Island Highway
3) Preservation of low-relief surfaces at high elevations in Central Range




56km Vp=8.05km/s
Partially subducted
continental margin fracture
64 km
80 km
96 km
116 km
120°
121°
122°
2
0
-2
-4
-6
dVp (%)
Cracks forming parallel to
partially subducted
continental margin fracture

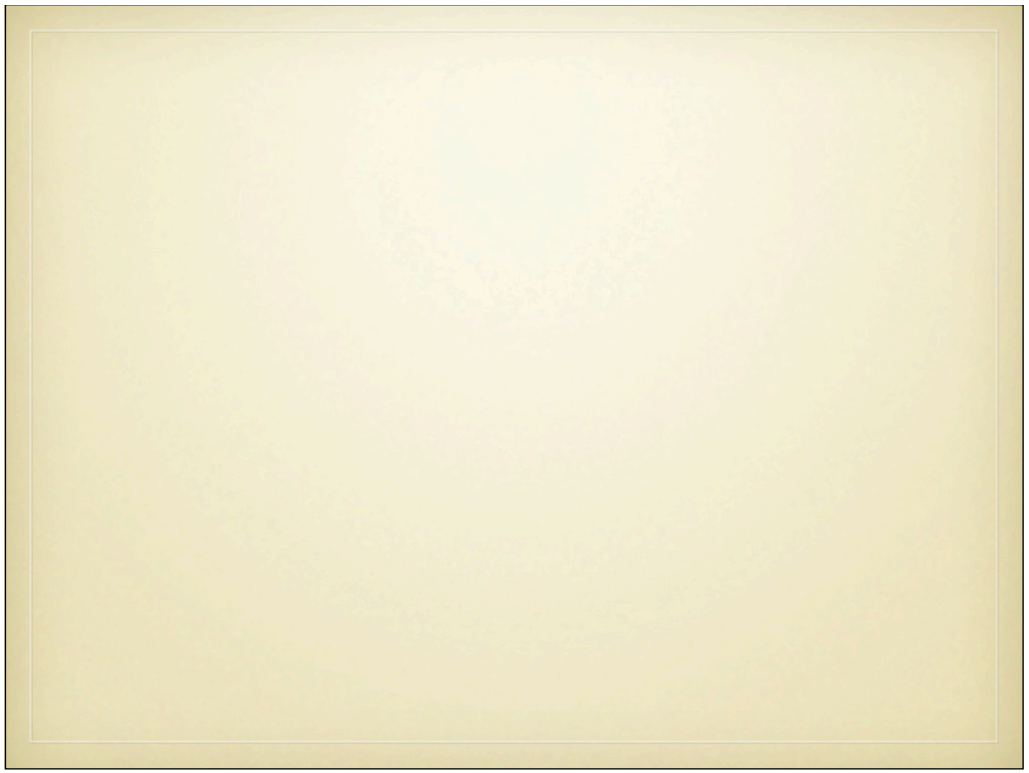

b)
Duretz et al., G3, 2012
Taiwan
Duration (Ma)
3.5
3
2.5
2
1.5
1
0.5
0
50
100
150
200
250
300
350
400
Depth (km)

Crustal and Lithospheric processes:

- Crustal delamination - transitional crust delaminates from down-going plate
- Lithosphere “breaks off” -

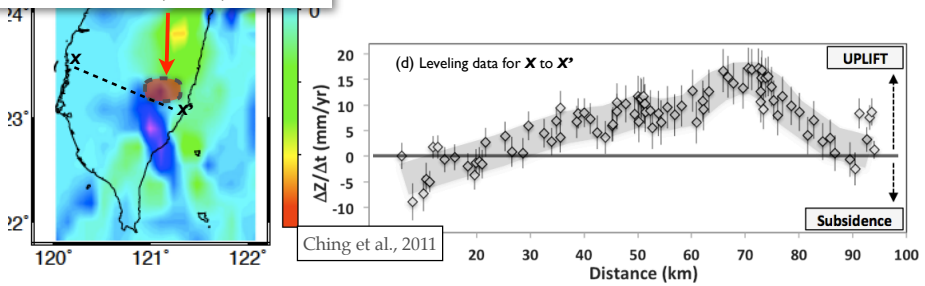
Crustal and Lithospheric processes:

1. acceleration in uplift
2. extension
3. volcanism

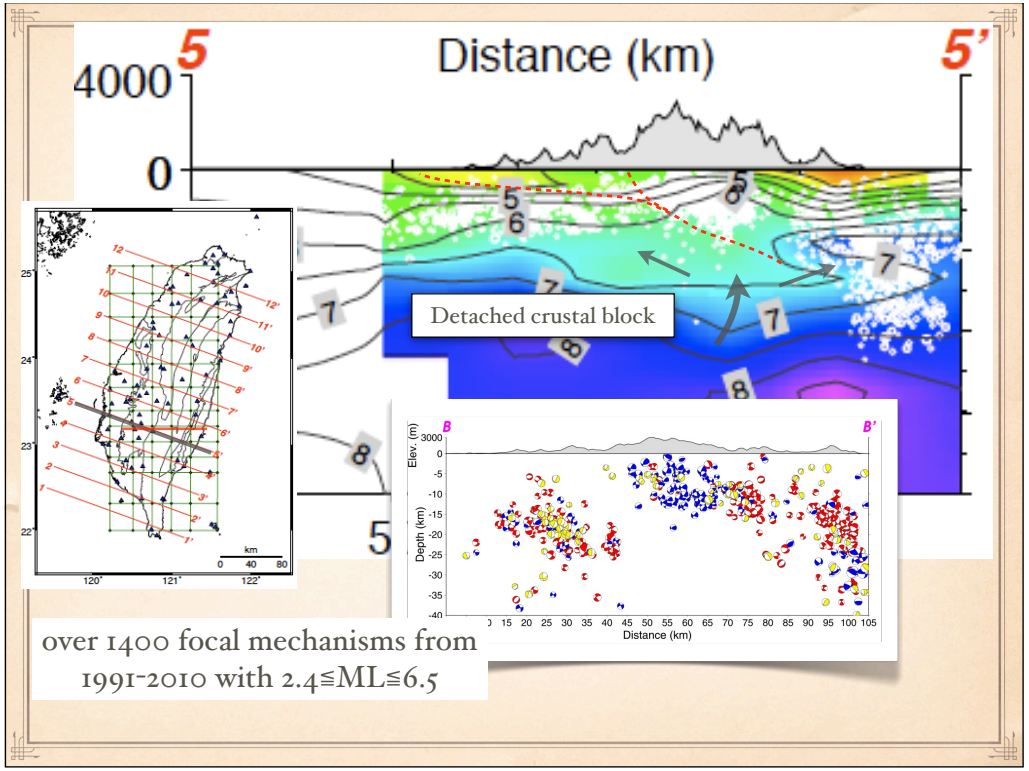


56km Vp=8.05km/s

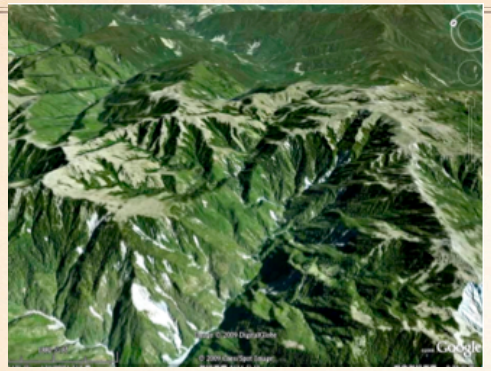
Low Qp (high attenuation), aseismic zone and anomalous earthquake tremors (Lee et al., 2010; Wang et al., 2010: Chen et al., 2011, AOGS)

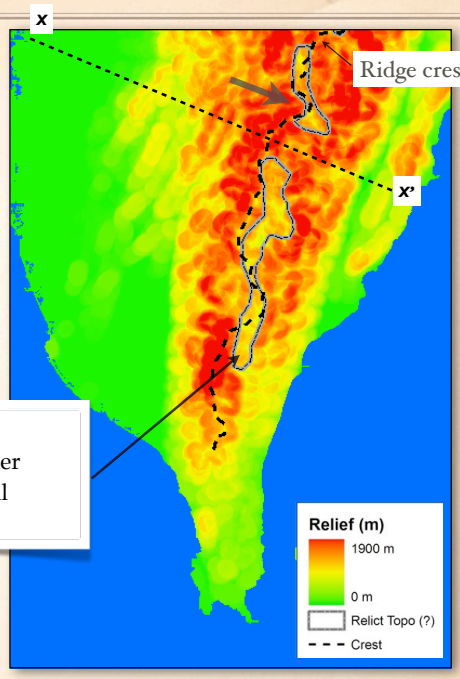


Ching et al., 2011



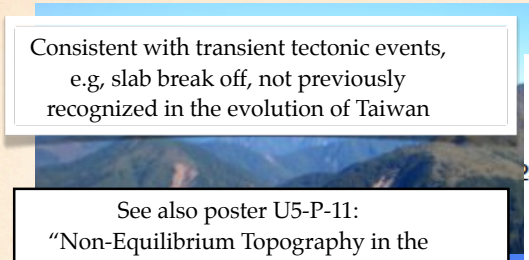
over 1400 focal mechanisms from 1991-2010 with 2.4≦ML≦6.5



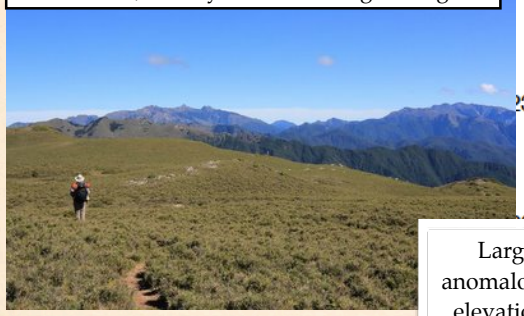


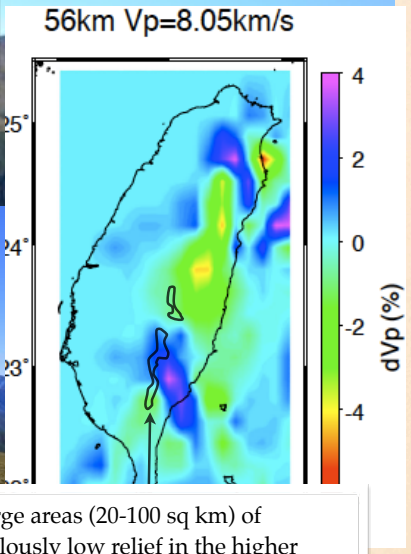
Large areas (20-100 sq km) of anomalously low relief in the higher elevations of the southern Central Range

Consistent with transient tectonic events, e.g, slab break off, not previously recognized in the evolution of Taiwan

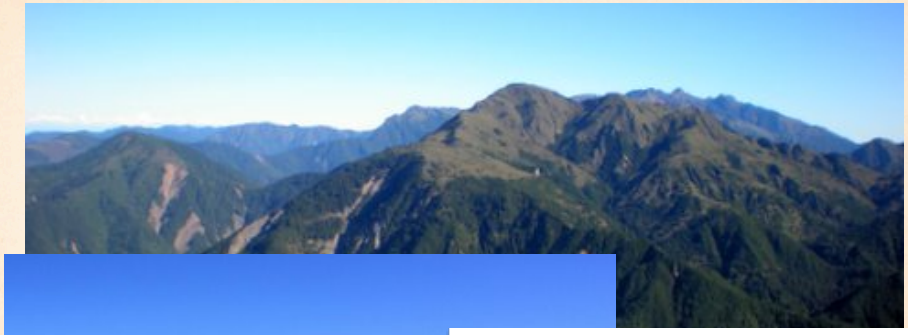


See also poster U5-P-11:
"Non-Equilibrium Topography in the southern Central Range of Taiwan"
Will Ouimet, Tim Byrne and Chung Huang





Large areas (20-100 sq km) of anomalously low relief in the higher elevations of the southern Central Range sit above detached crust



Consistent with transient tectonic events, e.g, slab break off, not previously recognized in the evolution of Taiwan

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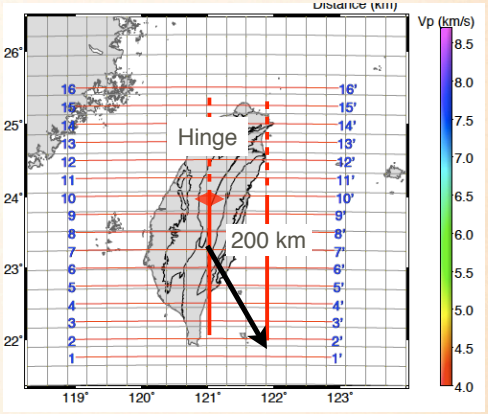
RESULTS

E-W sections to 300 km

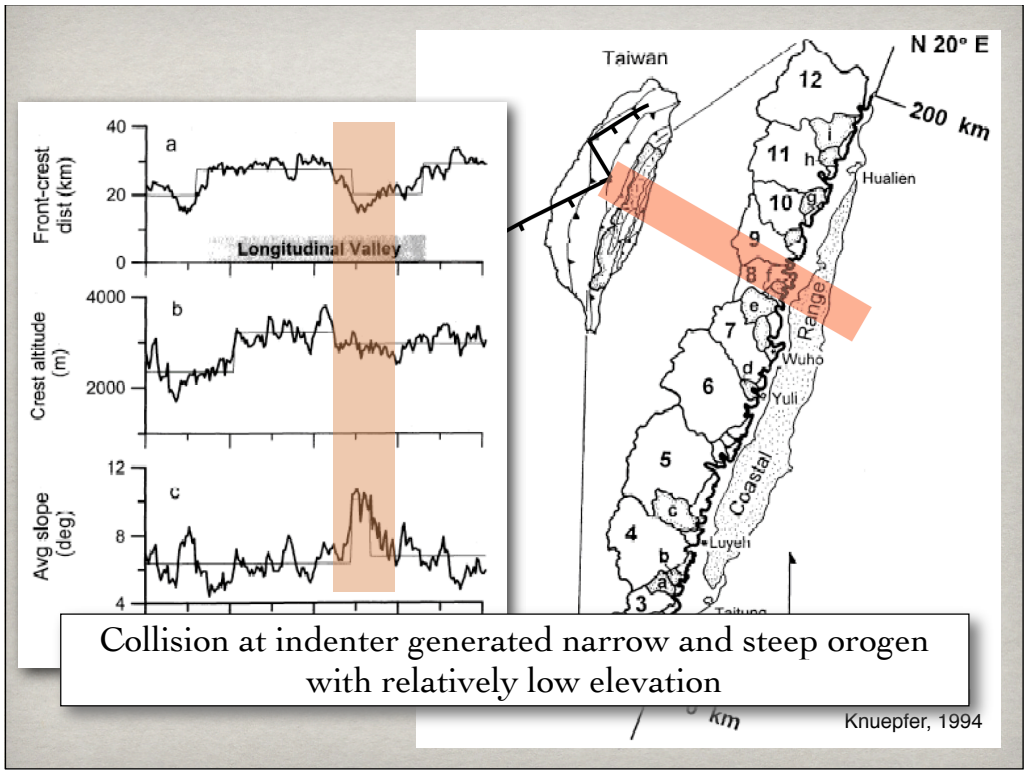
- Lithospheric slab strikes north-south, dips 60° east
- Lithospheric slab becomes less coherent south to north, consistent with slab break of in northern Taiwan.

Horizontal sections to 110 km

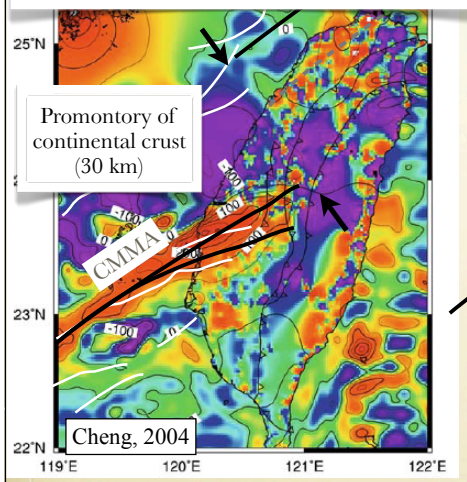
- Crustal root beneath central part of Central Range
- Crustal-scale crack forming in southern Taiwan (black arrow)
- Crack following pre-existing fracture zone in subducting plate

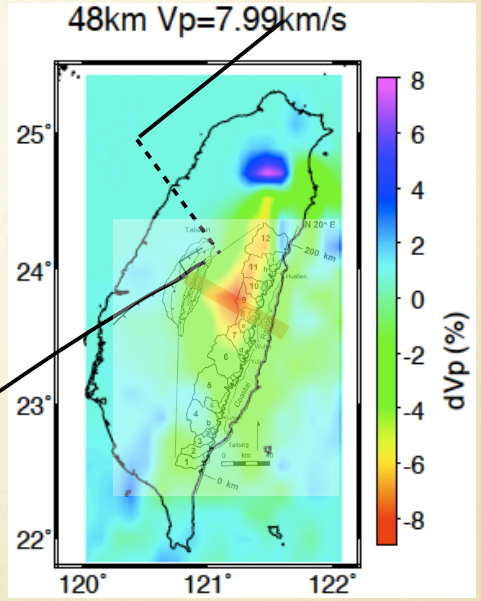


Geologic consequences of slab break off


Front-crest dist (km)
Crest altitude (m)
Avg slope (deg)
Longitudinal Valley
Taiwan
N 20° E
200 km
Hualien
Wuho
Yuli
Luyeh
Coastal
Range
Collision at indenter generated narrow and steep orogen with relatively low elevation
Knuepfer, 1994

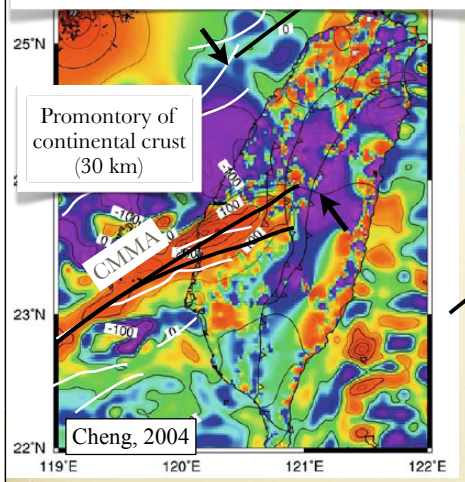
Truncated anomaly represents a partially subducted continental margin fracture zone



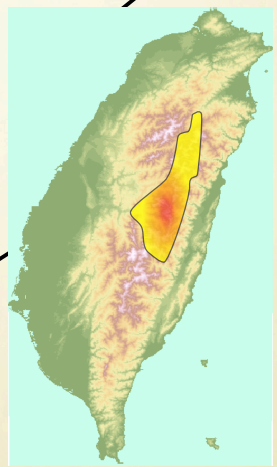


Crustal root from local Vp tomographic model (from Kuo-Chen et al., 2012)

Truncated anomaly represents a partially subducted continental margin fracture zone



Promontory of continental crust (30 km)



Thickest crust