The anomalous high transverse ridge developed along a transform fault

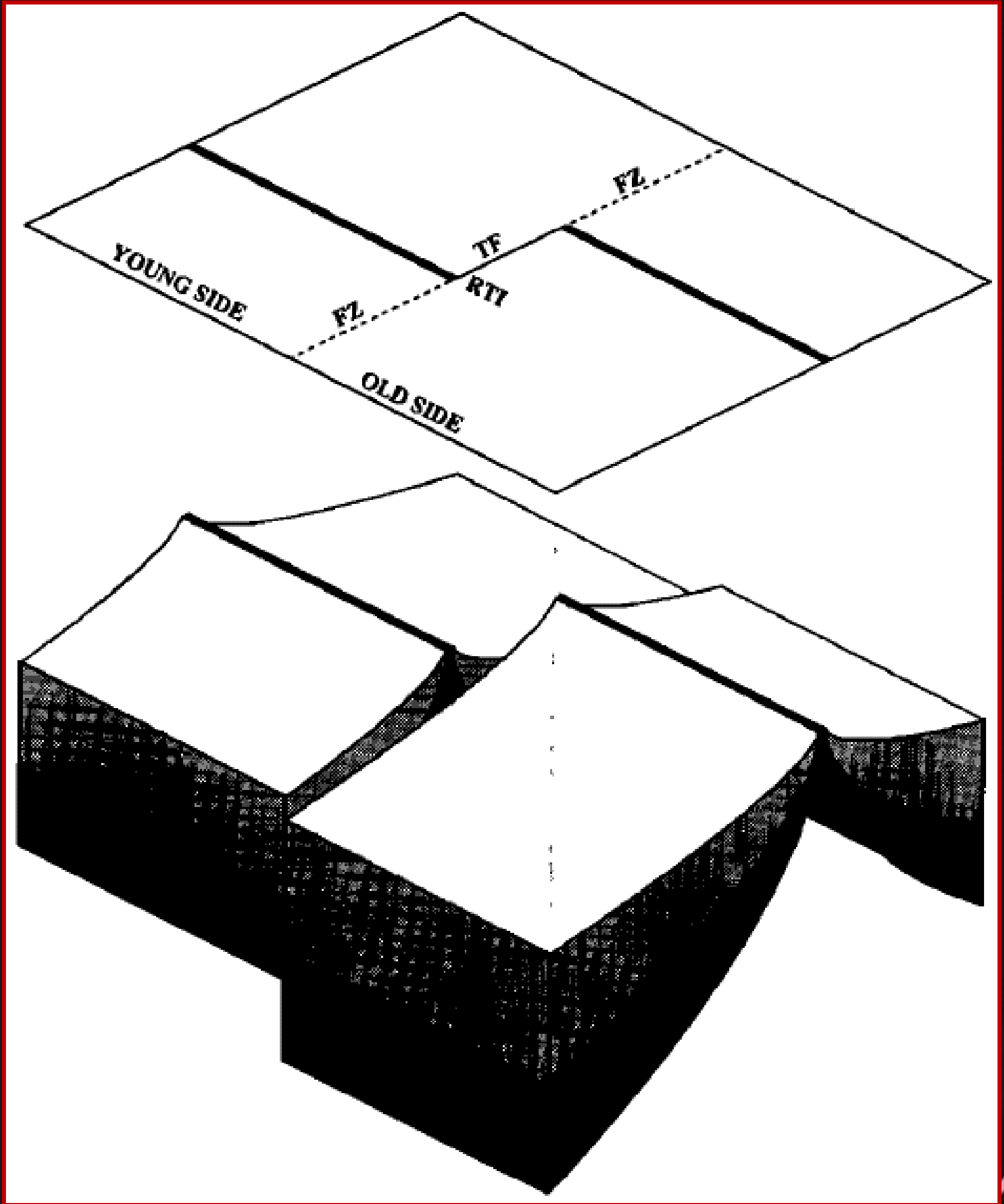
Speaker: Yen-Fu Chen

Reference

- Anne E. Deschamps, Serge E. Lallemand, and Jean-Yves Collot, 1998, A detailed study of the Gagua Ridge: A fracture zone uplifted during a plate reorganisation in the Mid-Eocene, Marine Geophysical Researches 20: 403-423.

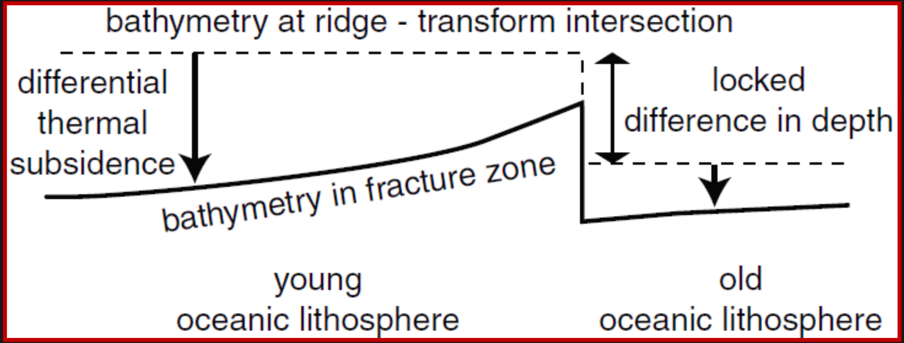
- Jean-Yves Collot, Geoffroy Lamarche, Ray A. Wood, Jean Delteil, Marc Sosson, Jean-Frederic Lebrun, Mike F. Coffin, 1995, Morphostructure of an incipient subduction zone along a transform plate boundary: Puysegur Ridge and Trench, Geology 23 (6):519-522.

What is transverse ridge?

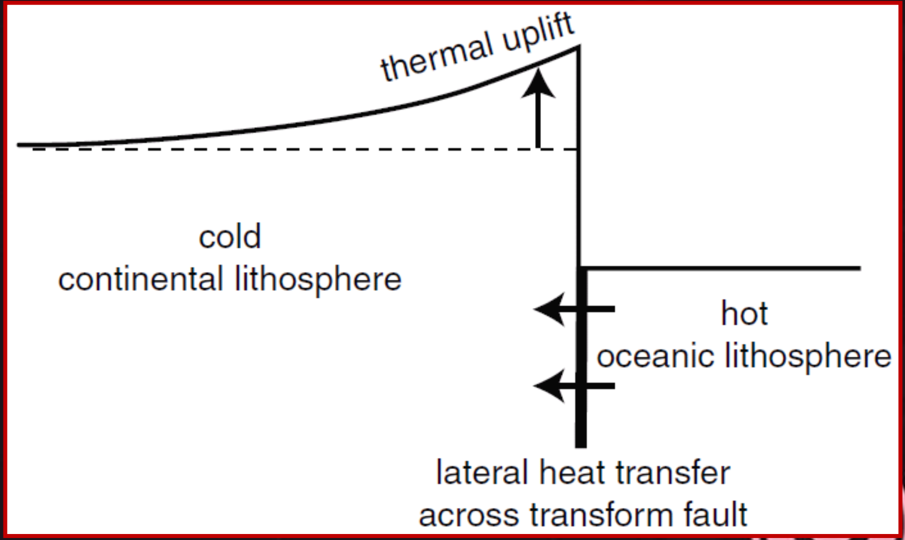


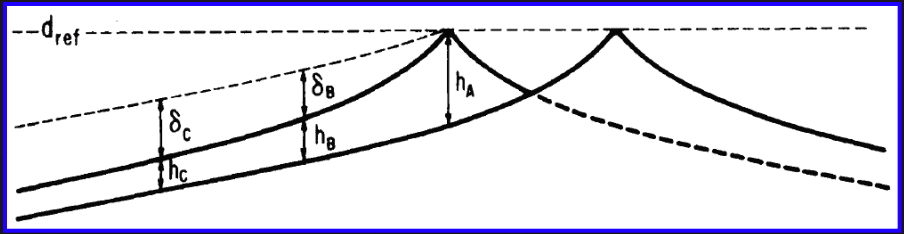
Motive

- As transform fault represent a mechanical contact between lithospheres of different ages and thermal structures, a flexure grows across the fault.
- It caused by differential subsidence and lateral heat flow.



Basile and Allemand, 2002

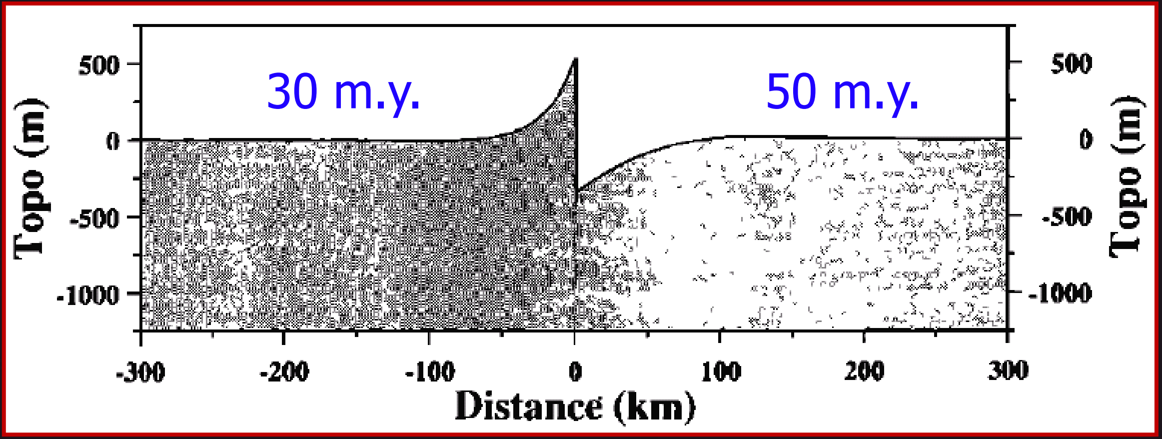




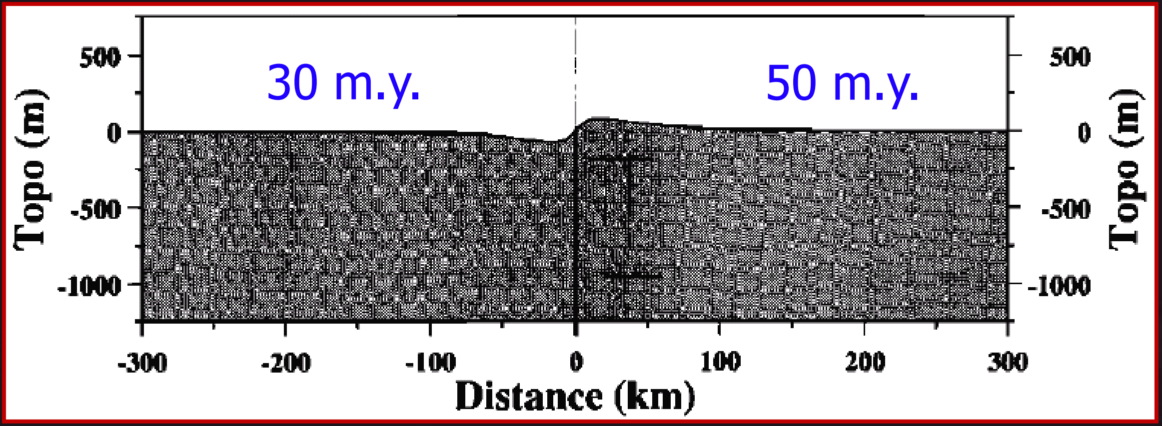
Sandwell and Schubert, 1982

Motive

- Flexure due to differential subsidence



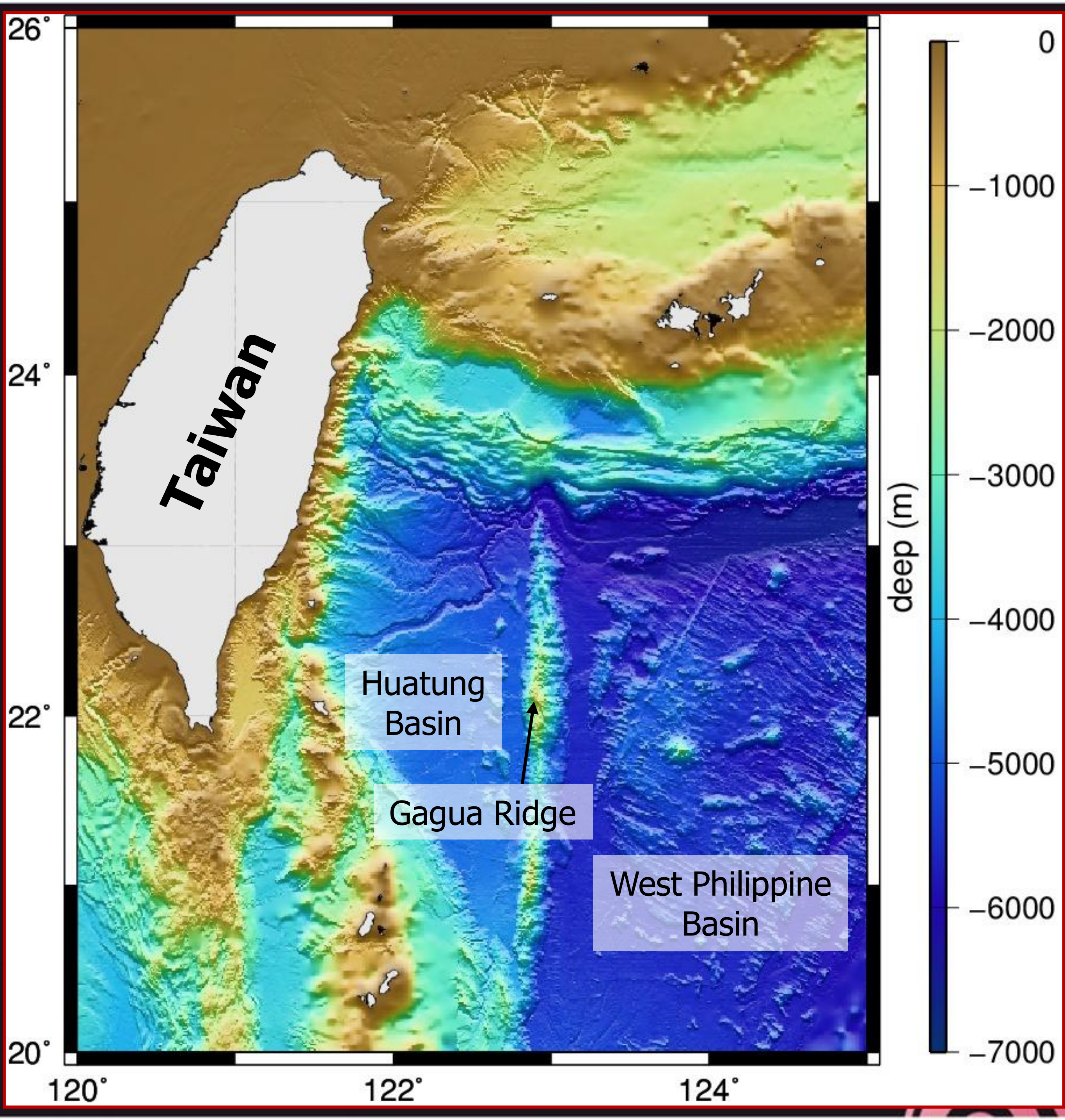
- Flexure due to lateral heat flow



Wessel and Haxby, 1990

Motive

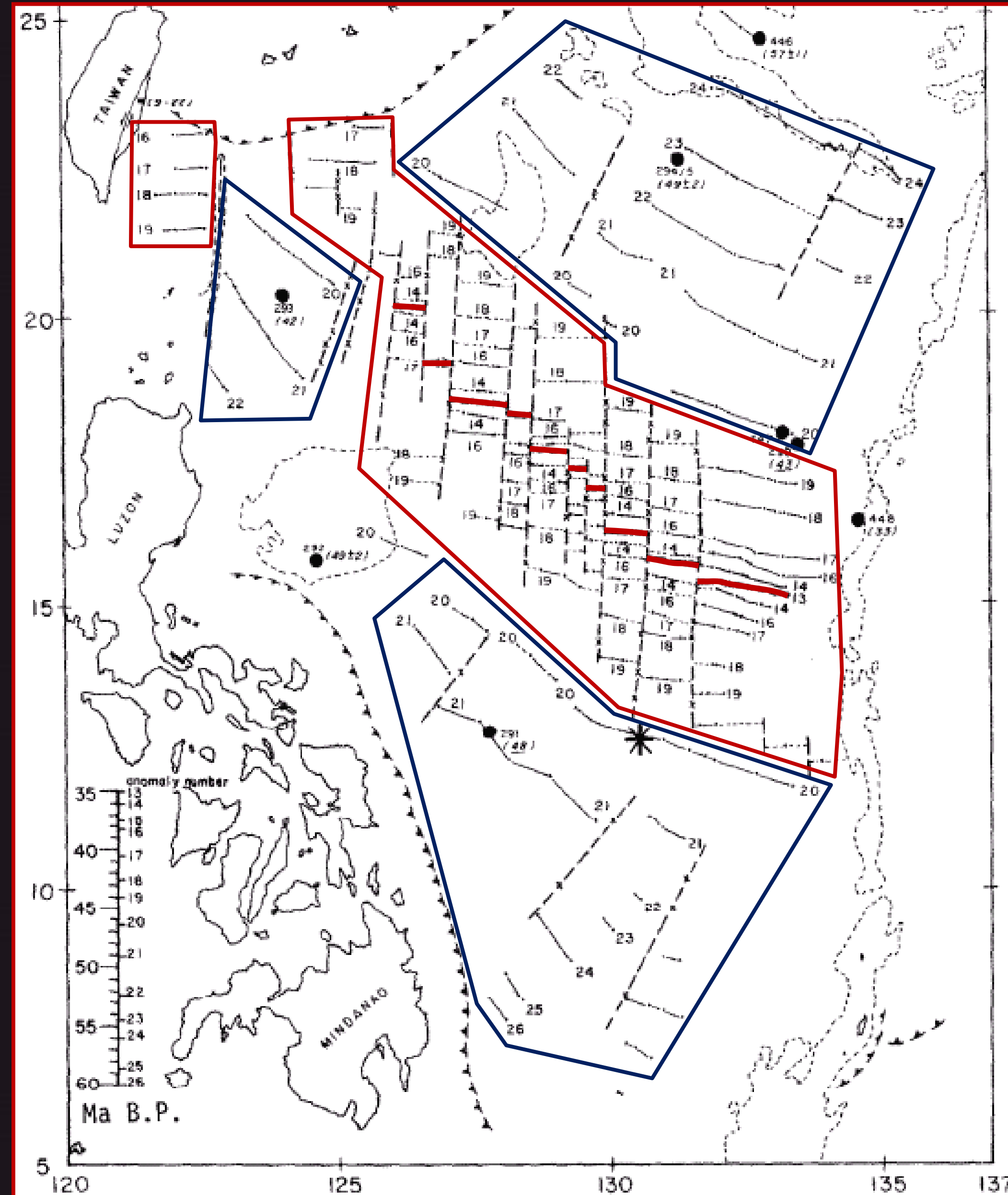
- In the Central Pacific fracture zone, the age difference across this fracture zone is less than 5 m.y. and the maximum height of the ridges above seafloor is 1 km. (Nakanishi, 1993)


26°
24°
22°
20°
120°
122°
124°
Taiwan
Huatung
Basin
Gagua Ridge
West Philippine
Basin
0
−1000
−2000
−3000
−4000
−5000
−6000
−7000
deep (m)

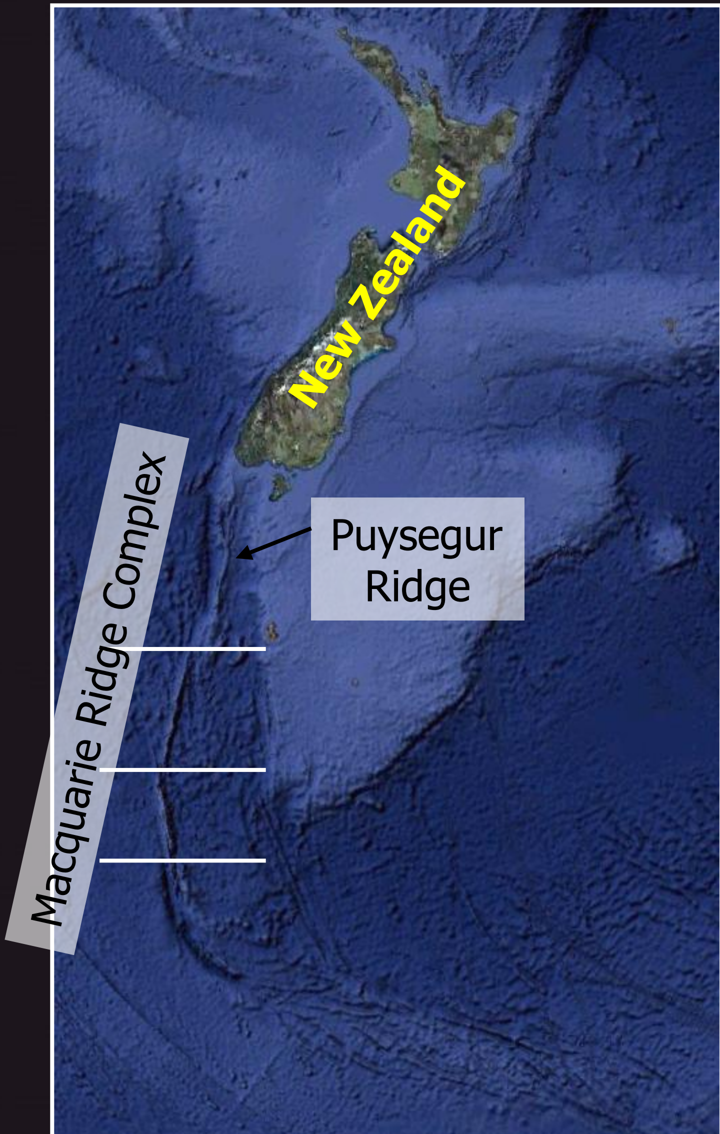
Philippine Sea Plate underwent two spreading episodes.

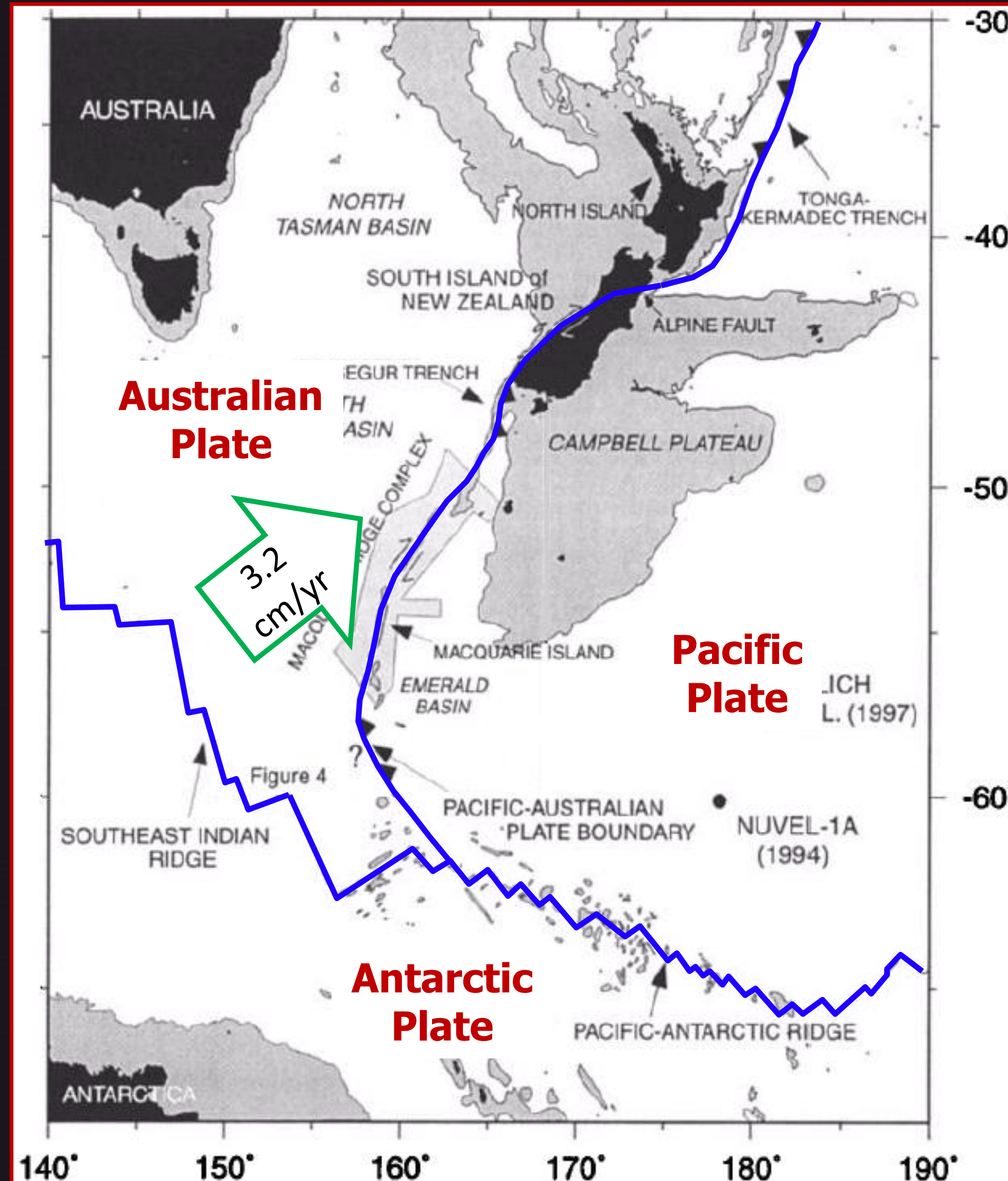
The crust on both sides of Gagua Ridge formed at different ages about 4 m.y..

	Central Pacific fracture zone	Gagua Ridge
Horizontal offset	About 150 km	About 150 km
Age difference	Less than 5 m.y.	4 ± 2 m.y.
Maximum height	1 km	**4 km**



Hilde and Lee, 1984





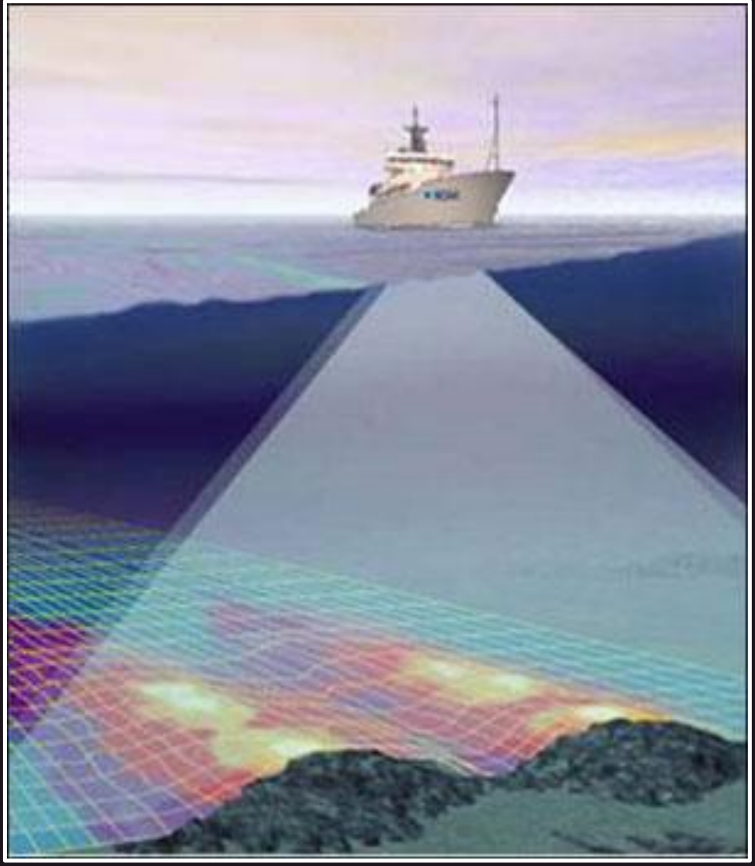
Massell et al., 2000

Puysegur Ridge

- Data
  - Multi-beam sonar and side-scan sonar

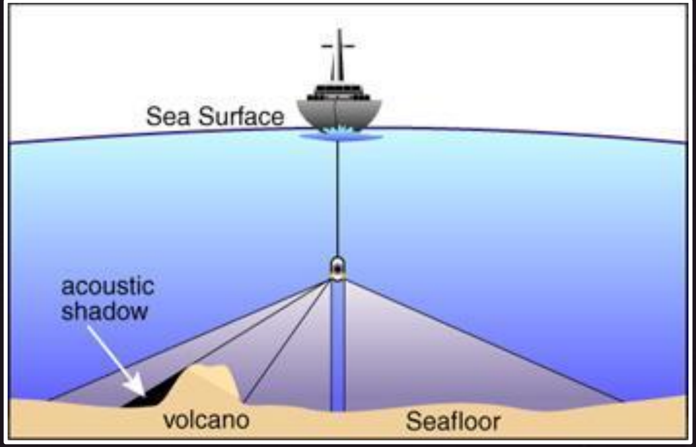
Multi-beam sonar and side-scan sonar

Multi-beam sonar

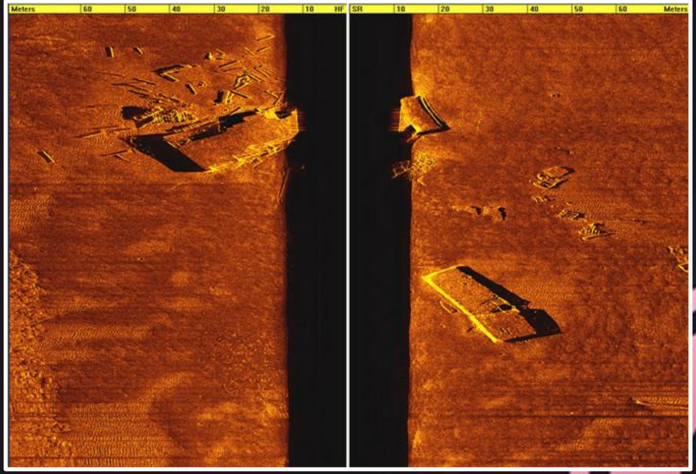


http://www2.hawaii.edu/

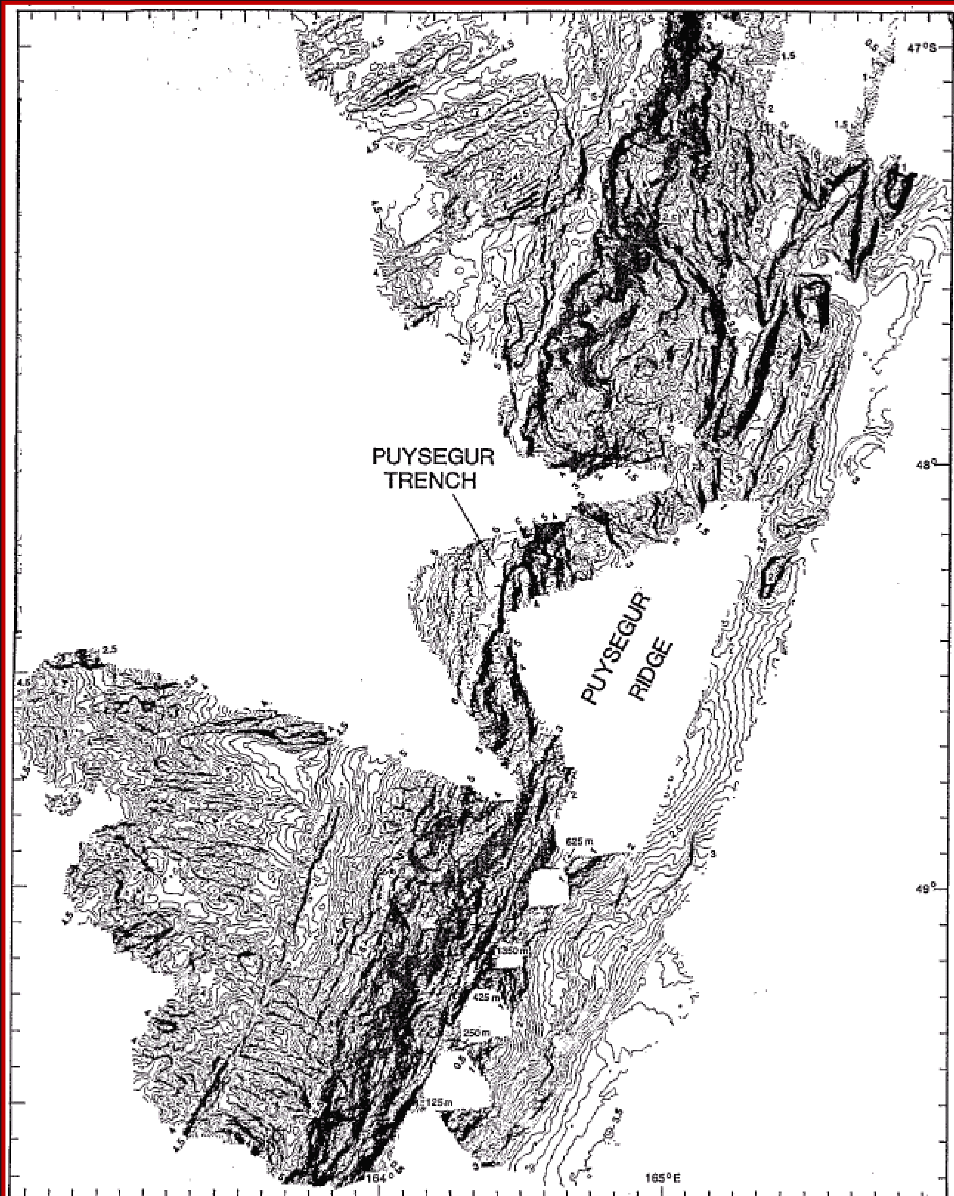
Side-scan sonar



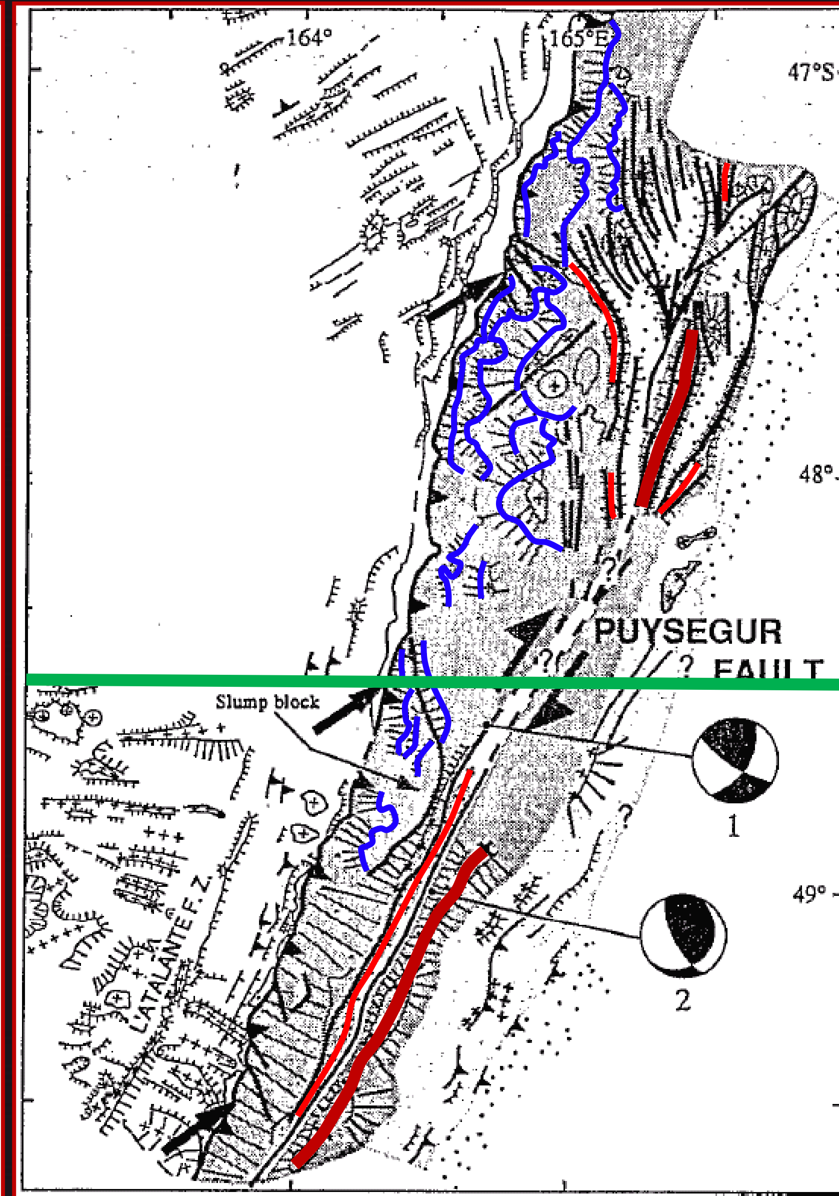
http://gralston1.home.mindspring.com/



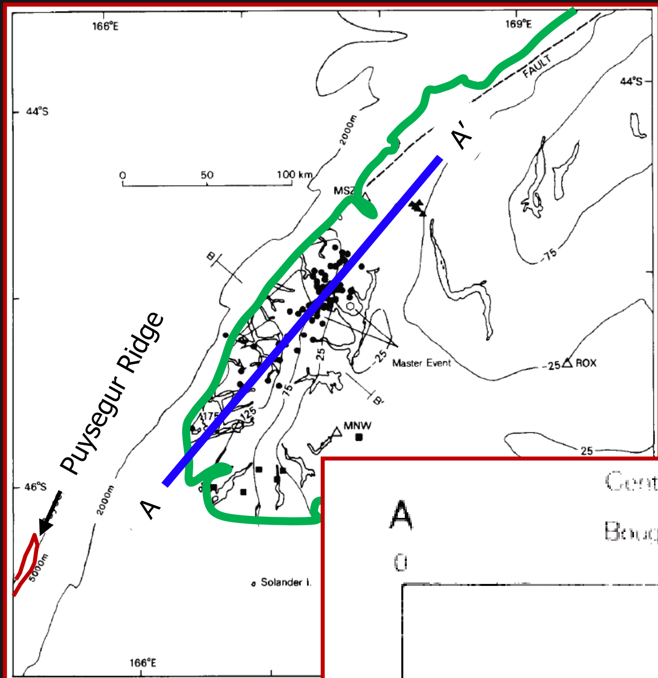
http://www. edgetech.com/

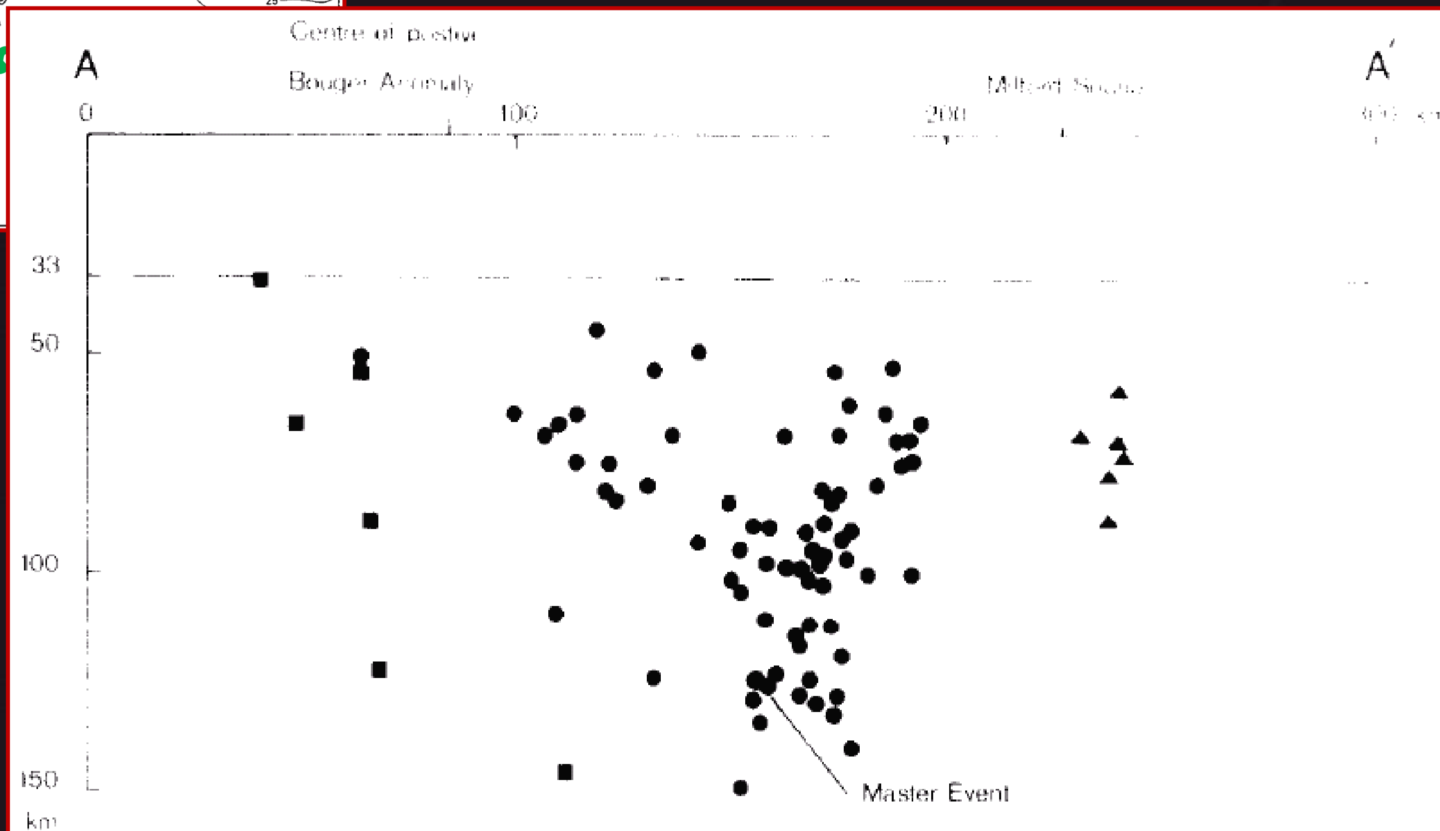


47°S
48°
49°
PUYSEGUR
TRENCH
PUYSEGUR
RIDGE
625 m
1350 m
425 m
250 m
125 m
164°
165°E



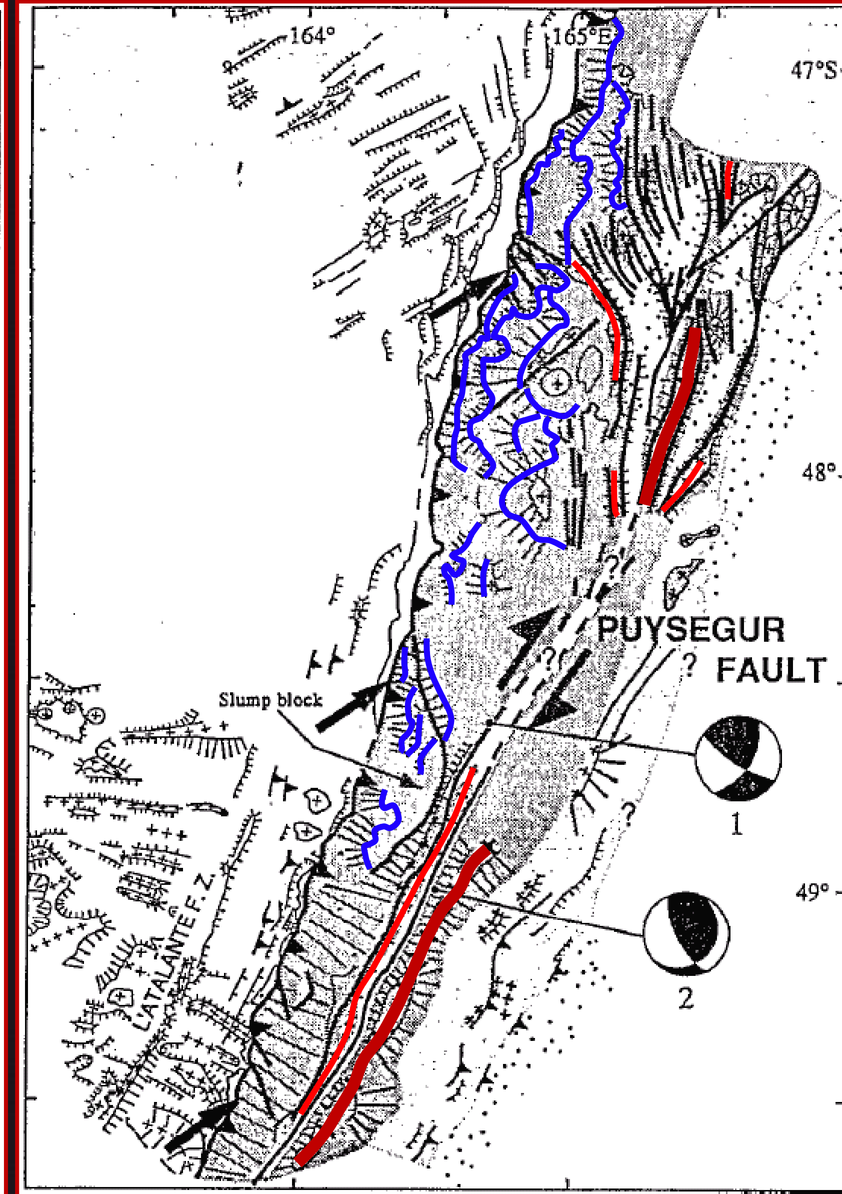
164°
165°E
47°S
48°
49°
PUYSEGUR
FAULT
Slump block
L'ATALANTE F. Z.
1
2



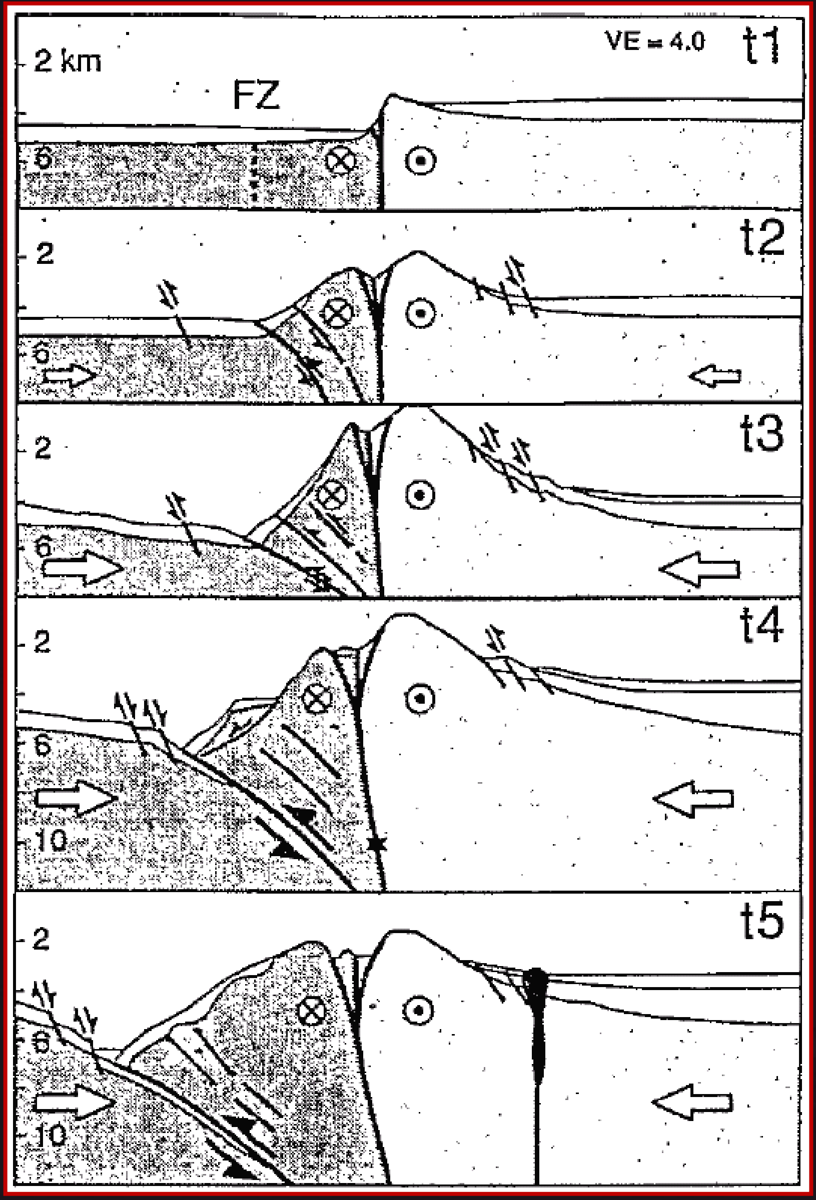


Smith and Davey, 1984


PUYSEGUR
TRENCH
PUYSEGUR
RIDGE
47°S
48°
49°
164°
165°E


164°
165°E
47°S
48°
49°
PUYSEGUR
FAULT
Slump block
L'ATALANTE F. Z.
1
2

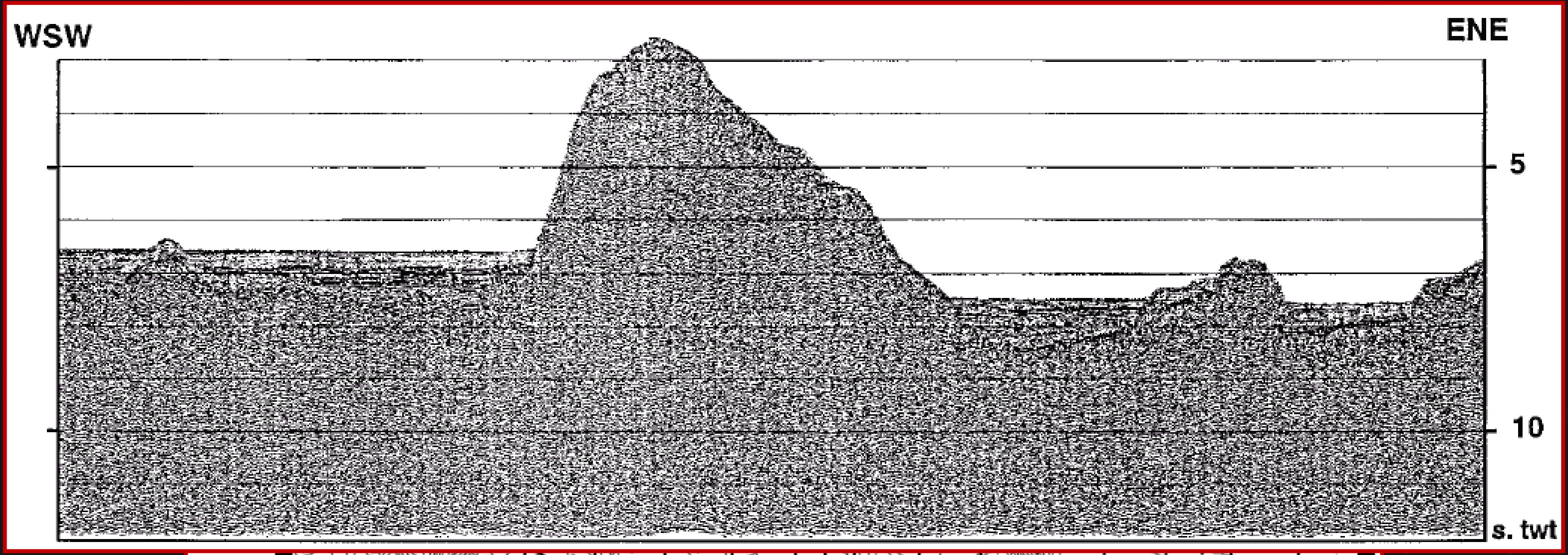
Puysegur Ridge origin and formation mechanisms

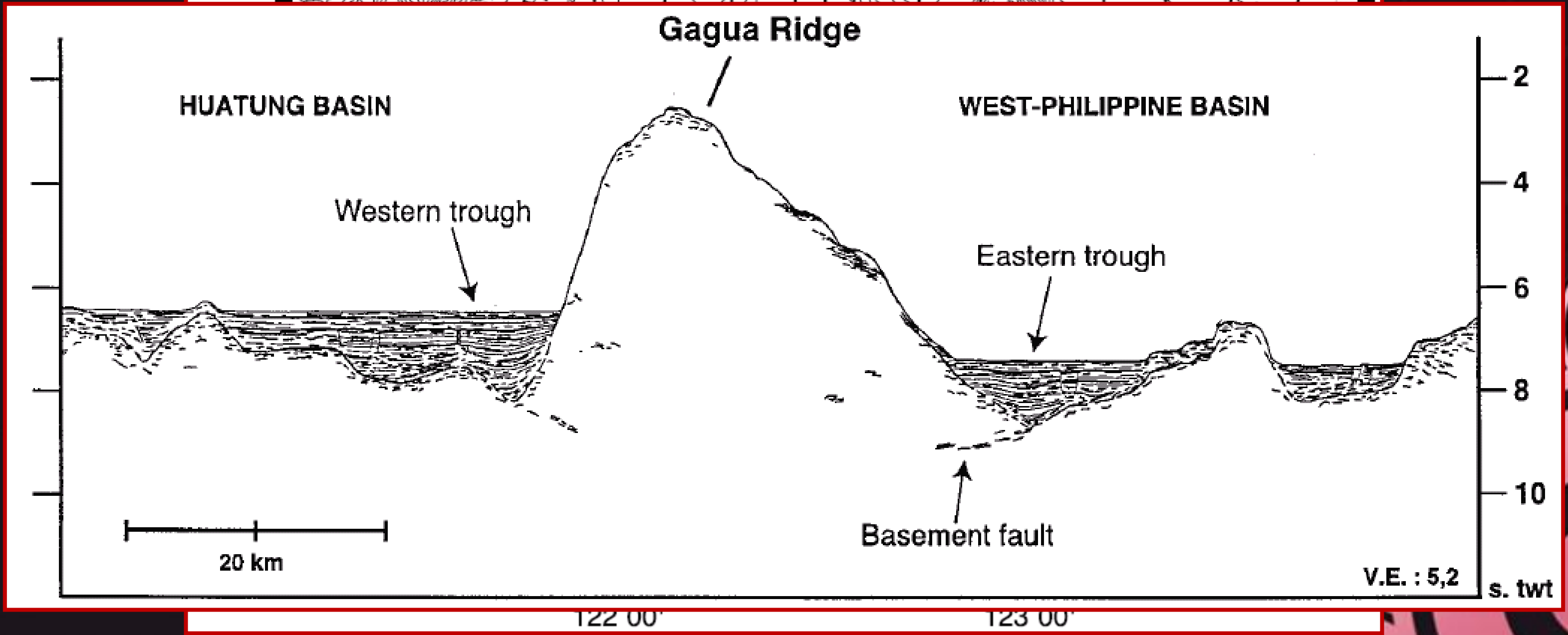


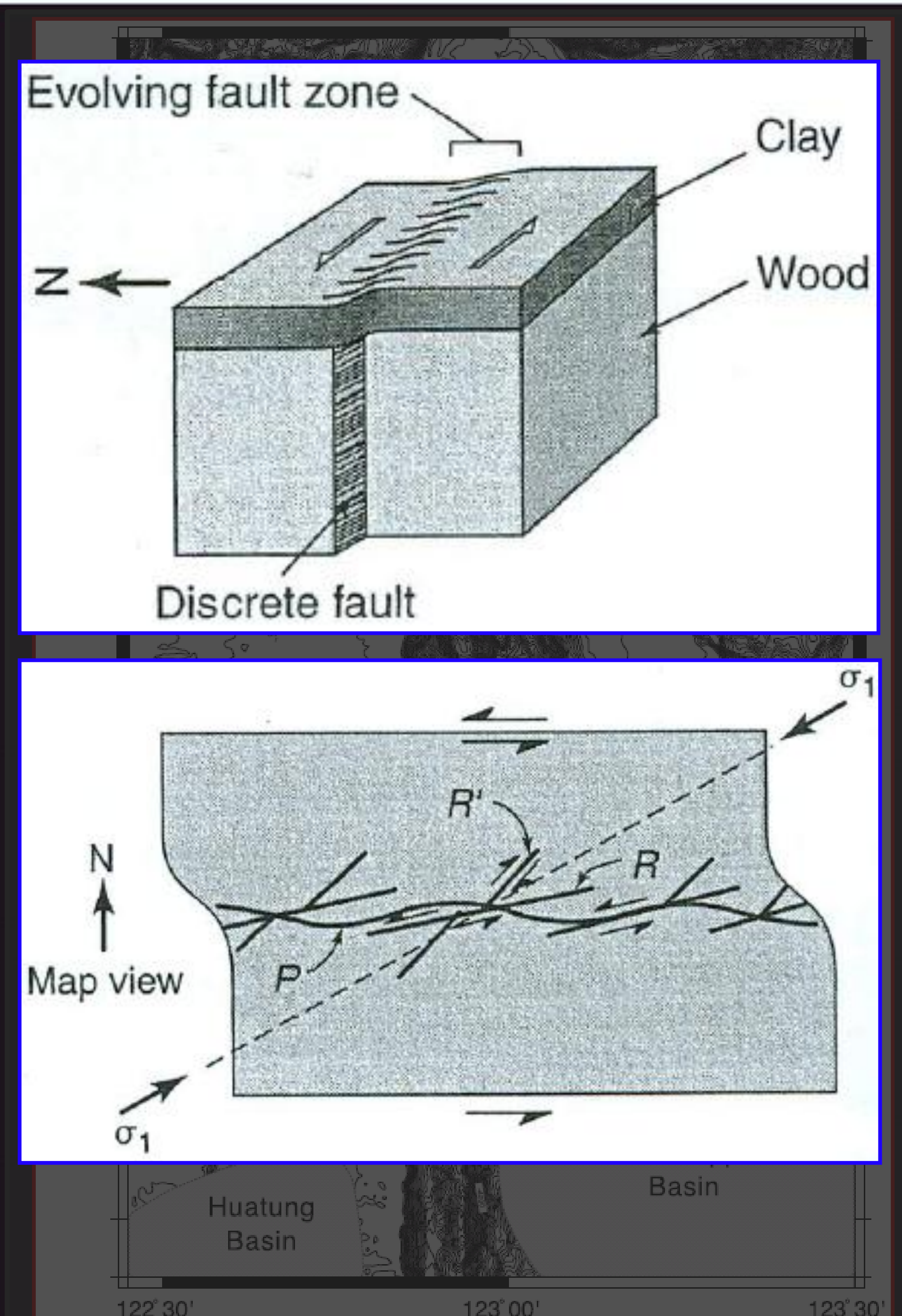
Gagua Ridge

- Data
  - Seismic reflection data
  - Multi-beam sonar and side-scan sonar
  - Gravimetry
    - Gravity modeling
  - Flexural modeling

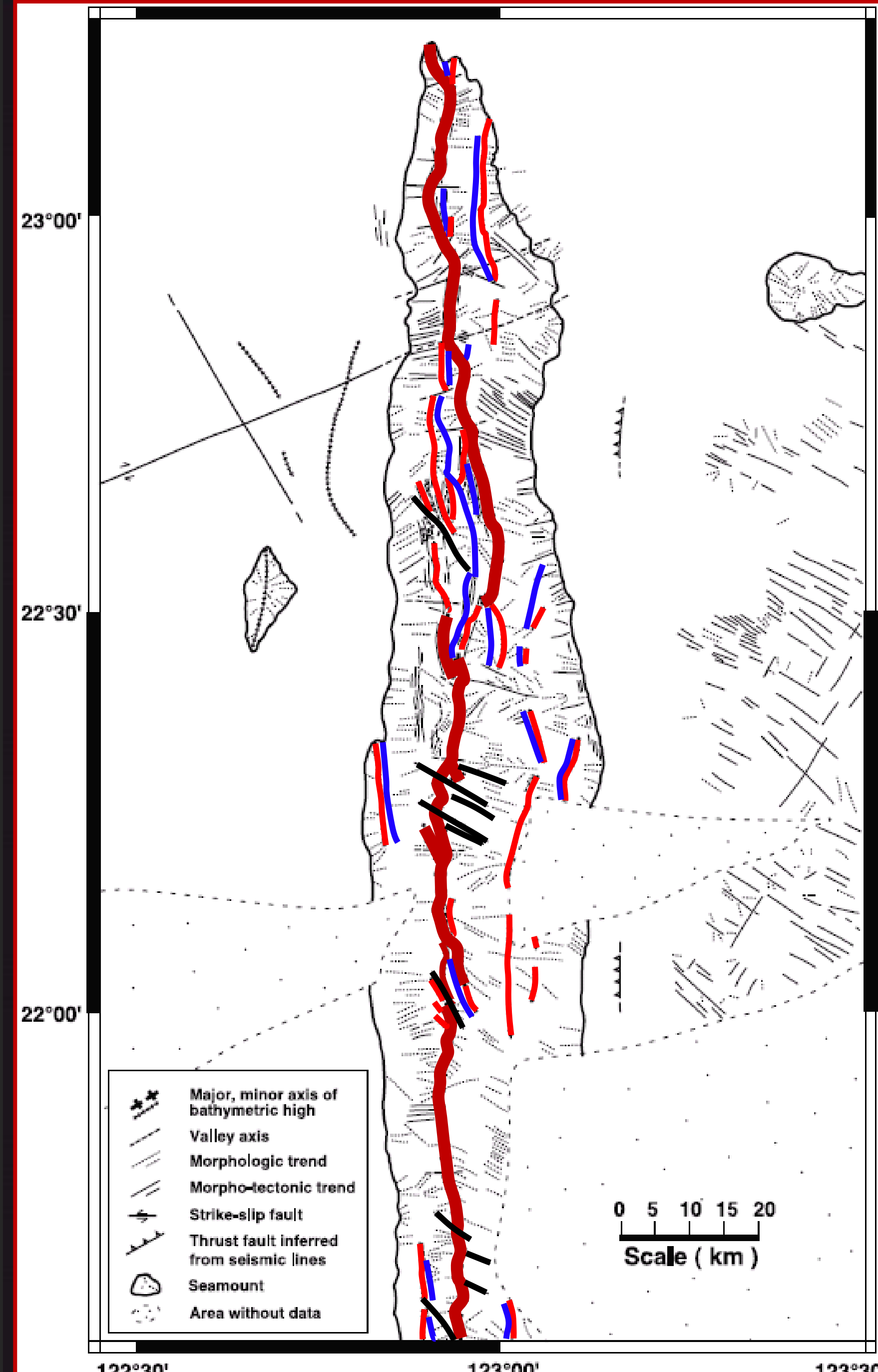
Seismic reflection data







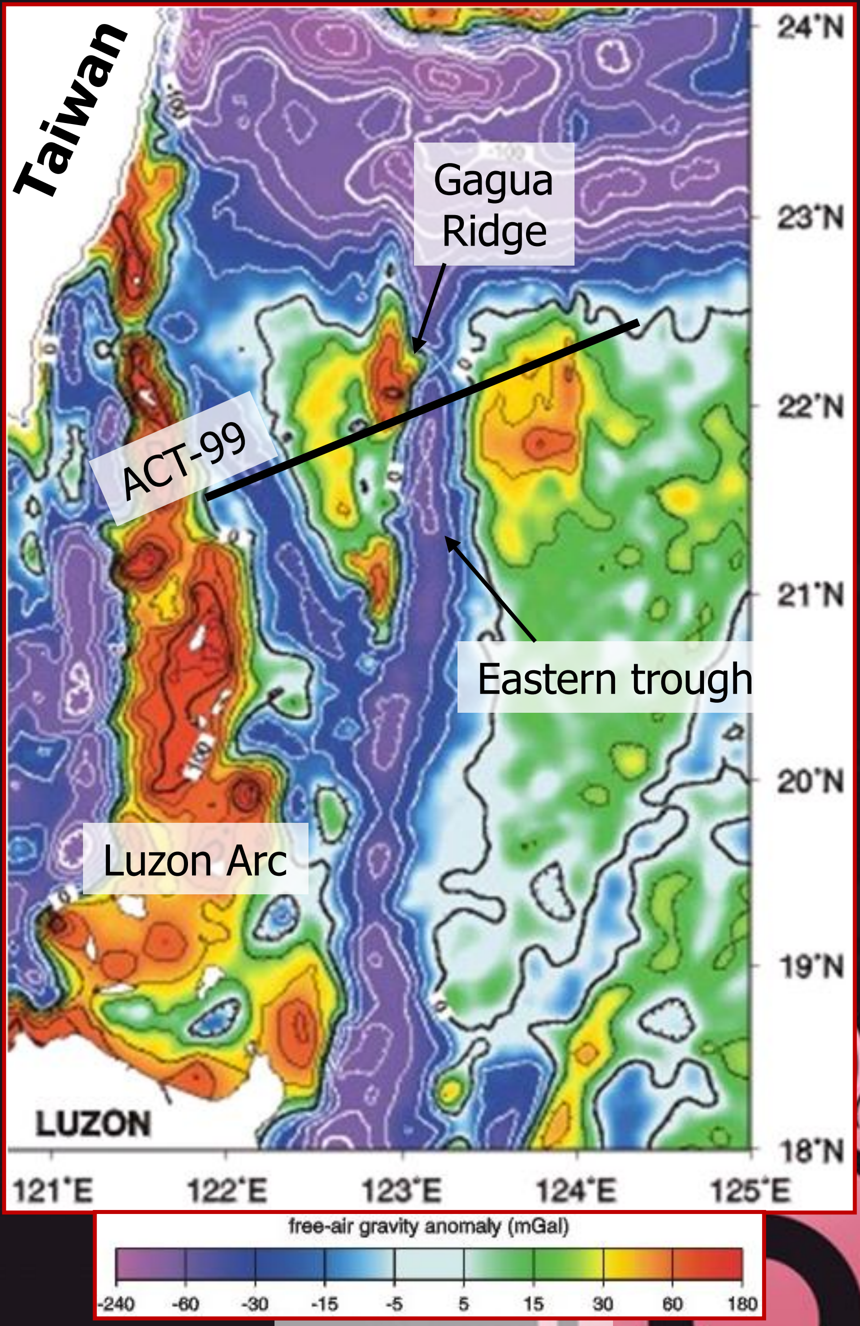
Evolving fault zone
Clay
Wood
N
Discrete fault
σ1
R'
R
N
P
Map view
σ1
Huatung
Basin
Basin
122°30'
123°00'
123°30'



23°00'
22°30'
22°00'
Major, minor axis of bathymetric high
Valley axis
Morphologic trend
Morpho-tectonic trend
Strike-slip fault
Thrust fault inferred from seismic lines
Seamount
Area without data
0 5 10 15 20
Scale (km)
122°30'
123°00'
123°30'

Gravimetry

- Gagua Ridge (up to 90mgal)
  - Disappear locally near 21°40’N because of the reduced height
- Eastern trough (-70 mgal)
  - Extend continuously
- Western trough (-10 mgal)
  - Express unclearly



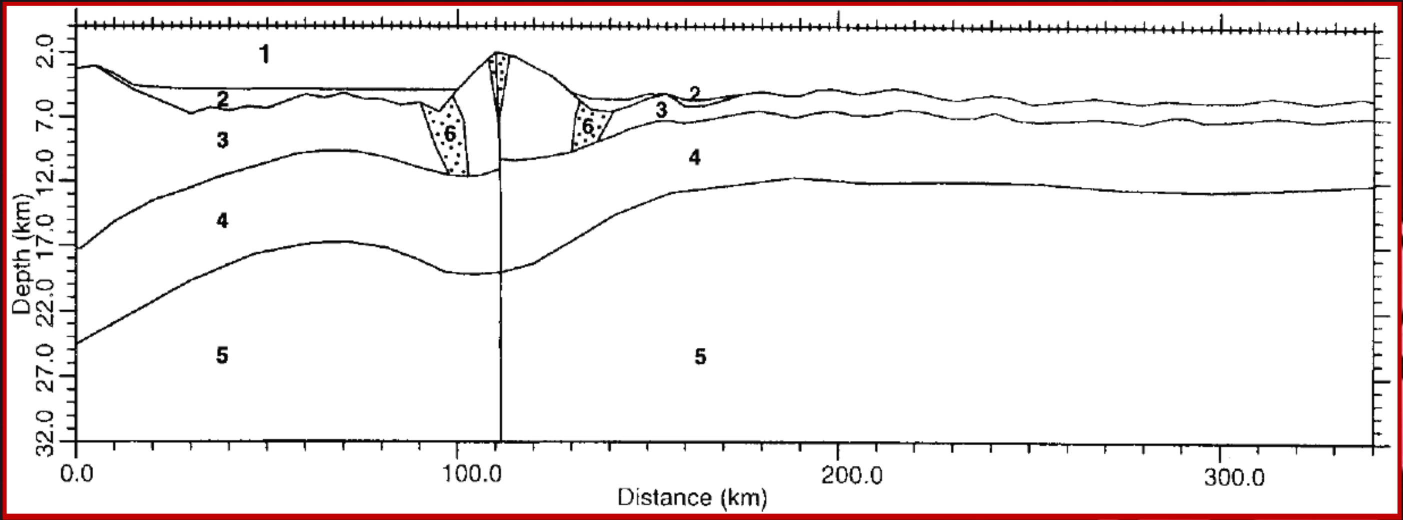
Hsu et al., 1998

Gravity modeling

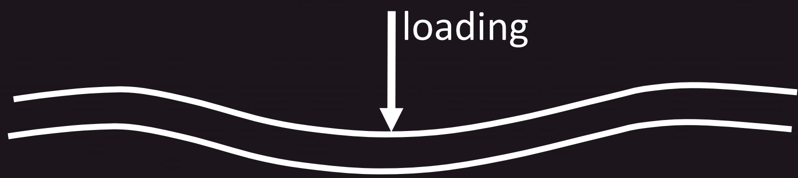
The difference of crustal thickness indicates different ages for the two basins.

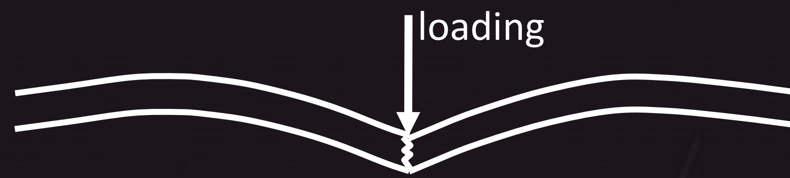
The overthickened crust under Gagua Ridge indicates it is locally compensated.

Bodies number	Bodies nature
1	Water
2	Sediment
3	Basalt
4	Gabbro
5	Mantle
6	Altered basalt



Flexural modeling





- Effective elastic thickness (related to the rigidity) ↓, amplitude of the flexural bulge ↑.

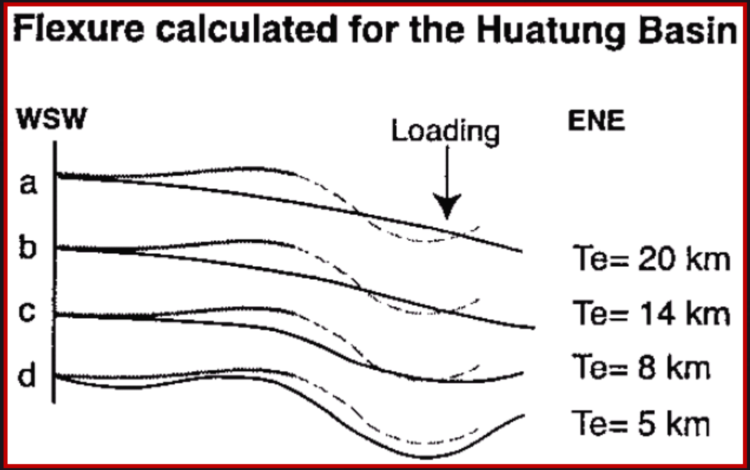
Semi-infinite plate — Model

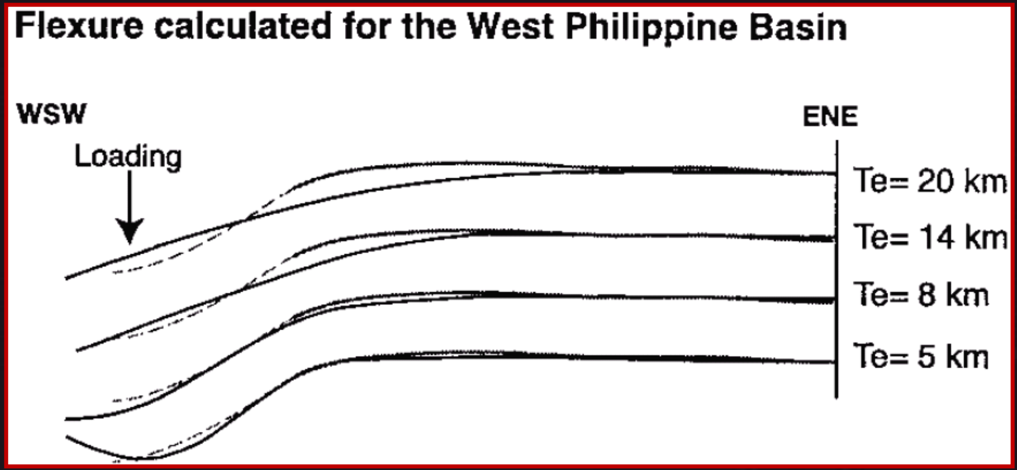
Estimated volume of Gagua Ridge — Loading

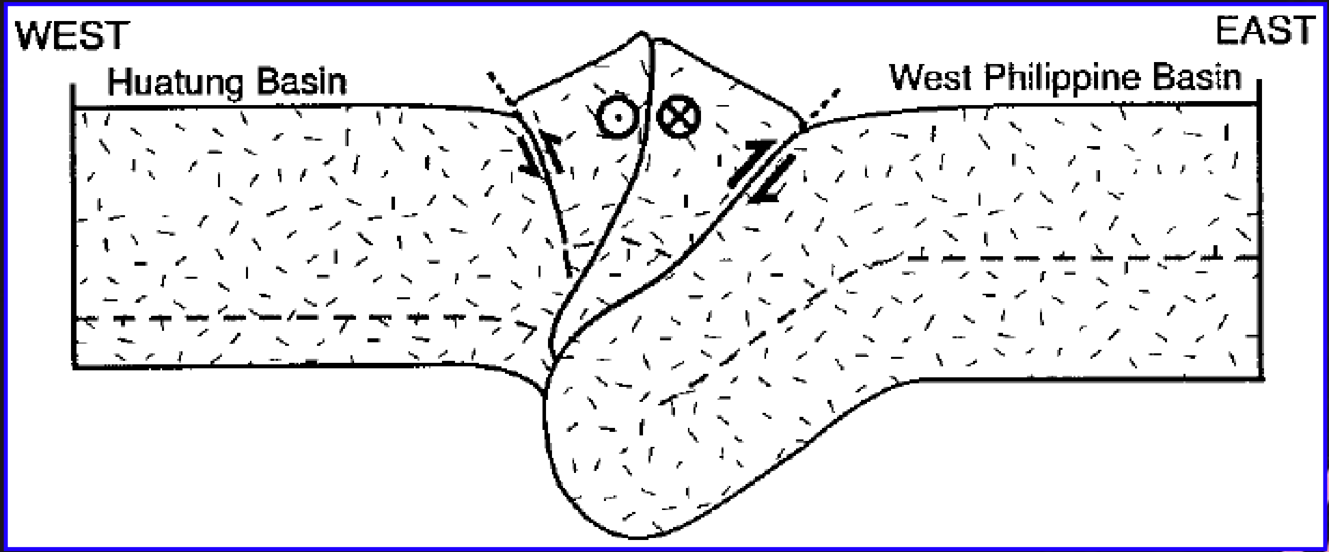
Parameter of plate (include Te)

→ Flexural shape

Flexural modeling







Summery

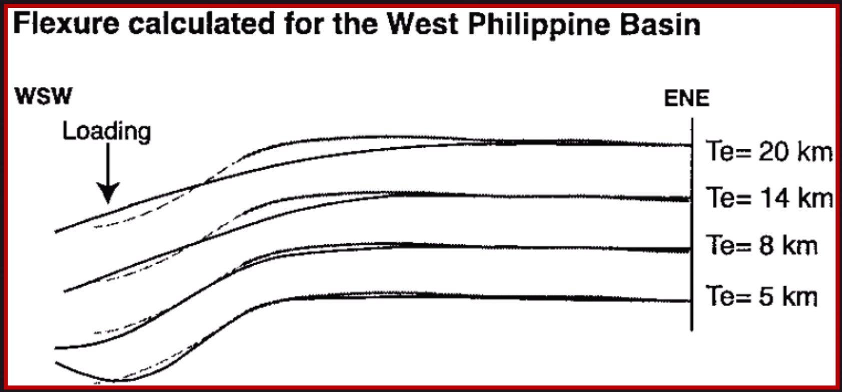
- Seismic reflection data
  - The sediments lack deformation in the trough and indicates the age of the last deformation episode. (late Eocene)
- Multi-beam and side scan sonar
  - Two crests separated by an axial valley, and the Riedel shear show that the ridge influenced by strike-slip.
- Free-air gravity anomaly
  - The eastern trough is expressed continuously and clearly, but the western trough is not.
- Gravity modeling
  - The different thickness of the crust reflects different ages.
  - Gagua Ridge to be locally compensated
- Flexural modeling
  - A sliver of the Huatung Basin is loading the West Philippine Basin.

Chronology

$$Te \approx 3.6 \times \sqrt{age}$$

Watts et al., 1990

age: age of oceanic lithosphere at the time of loading



5 Ma
2 Ma

Age of plate
in the West Philippine Basin
(from magnetic lineation)

Age of plate
in the Huatung Basin
(from magnetic lineation)

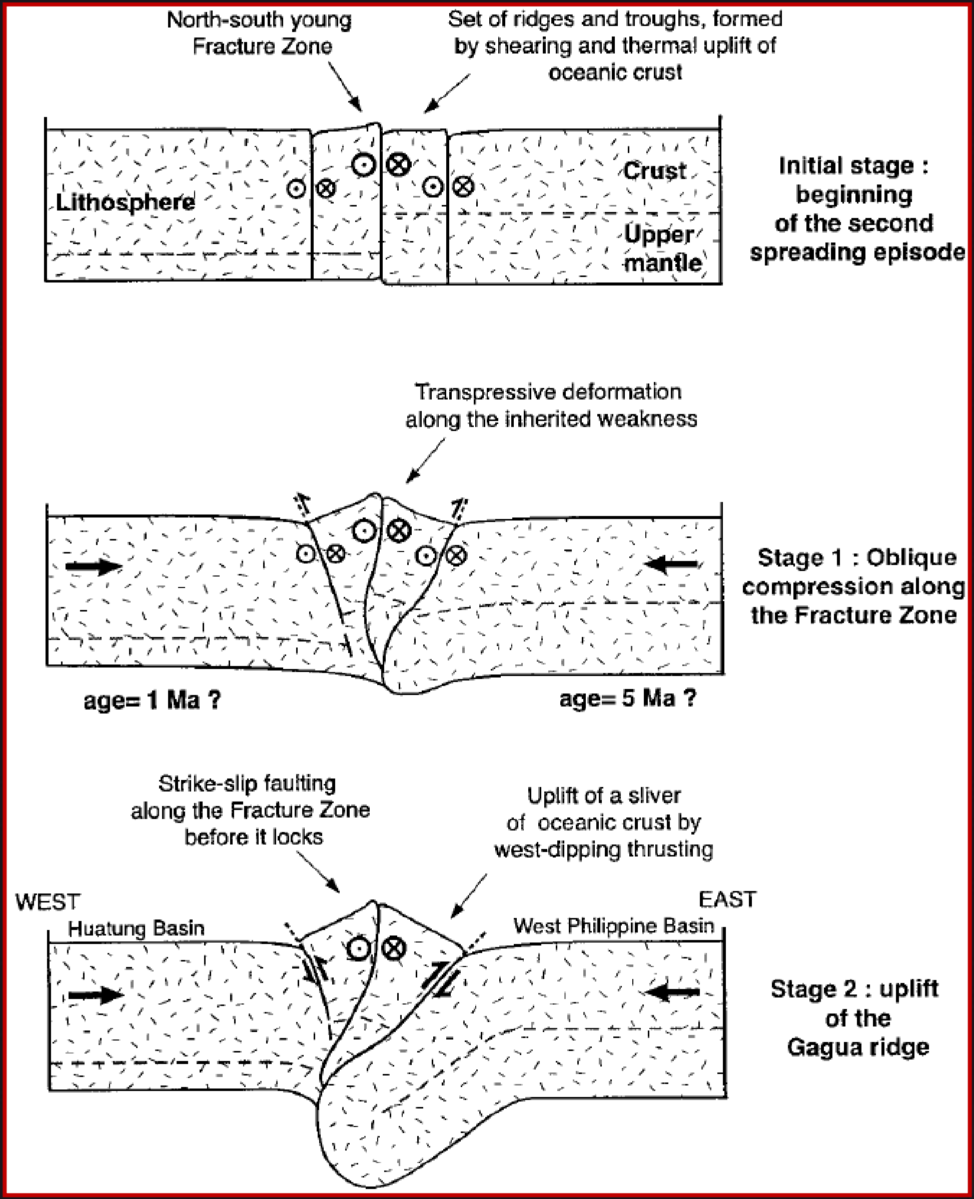
46Ma 45Ma 44Ma 41Ma 39Ma

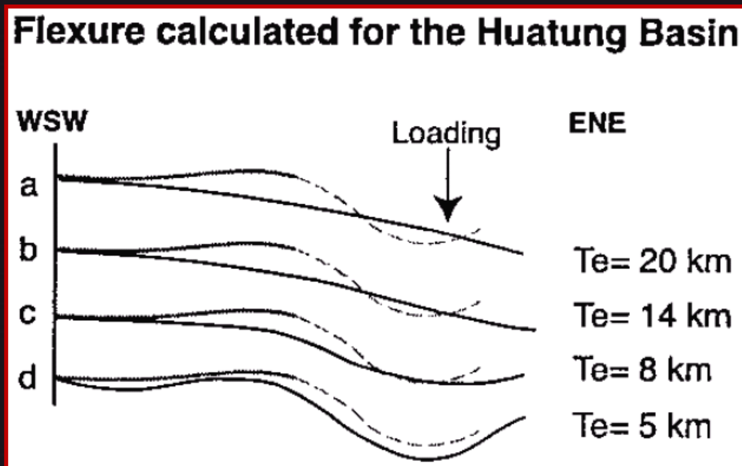
Gagua Ridge formation
(from result of flexural model)

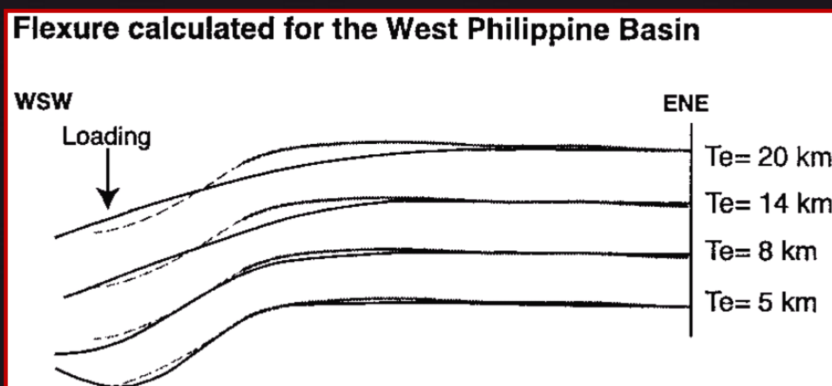
First spreading
episode

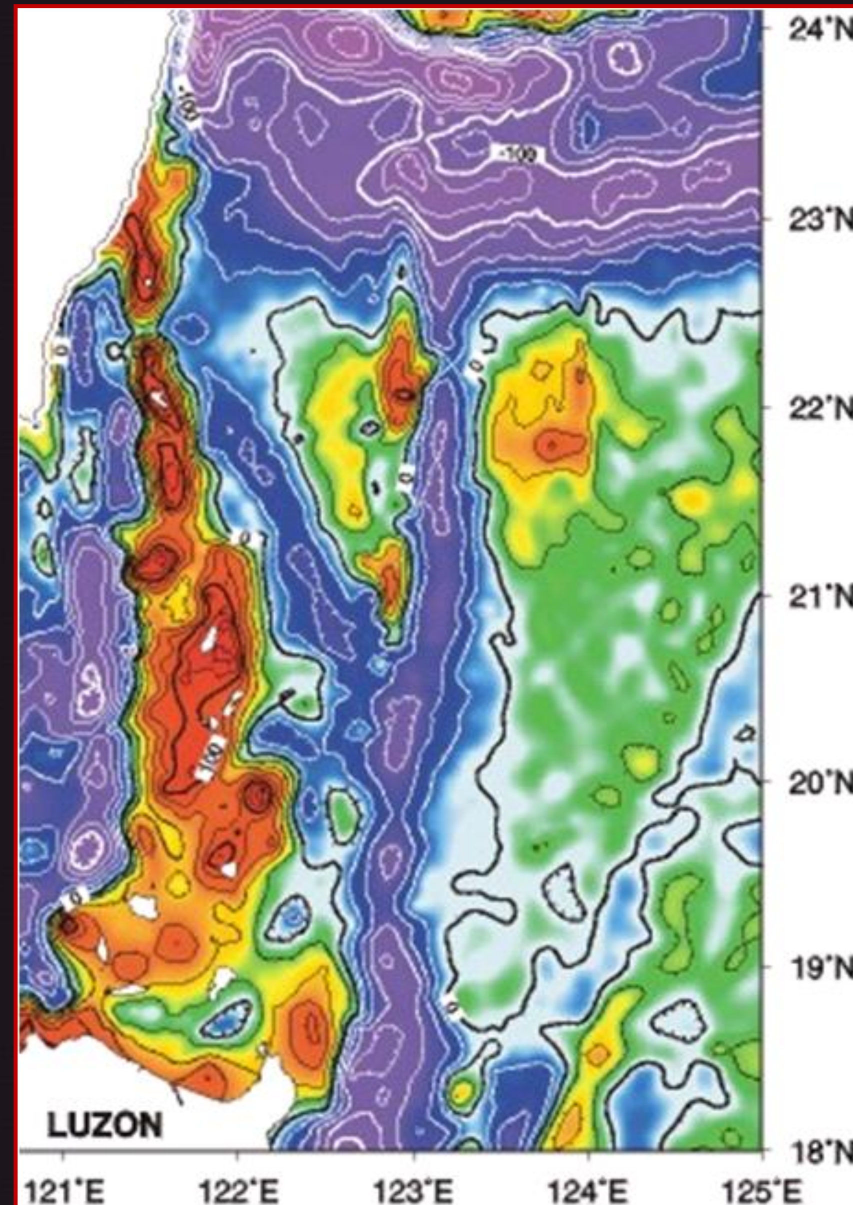
Second spreading
episode

Gagua Ridge origin and formation mechanisms



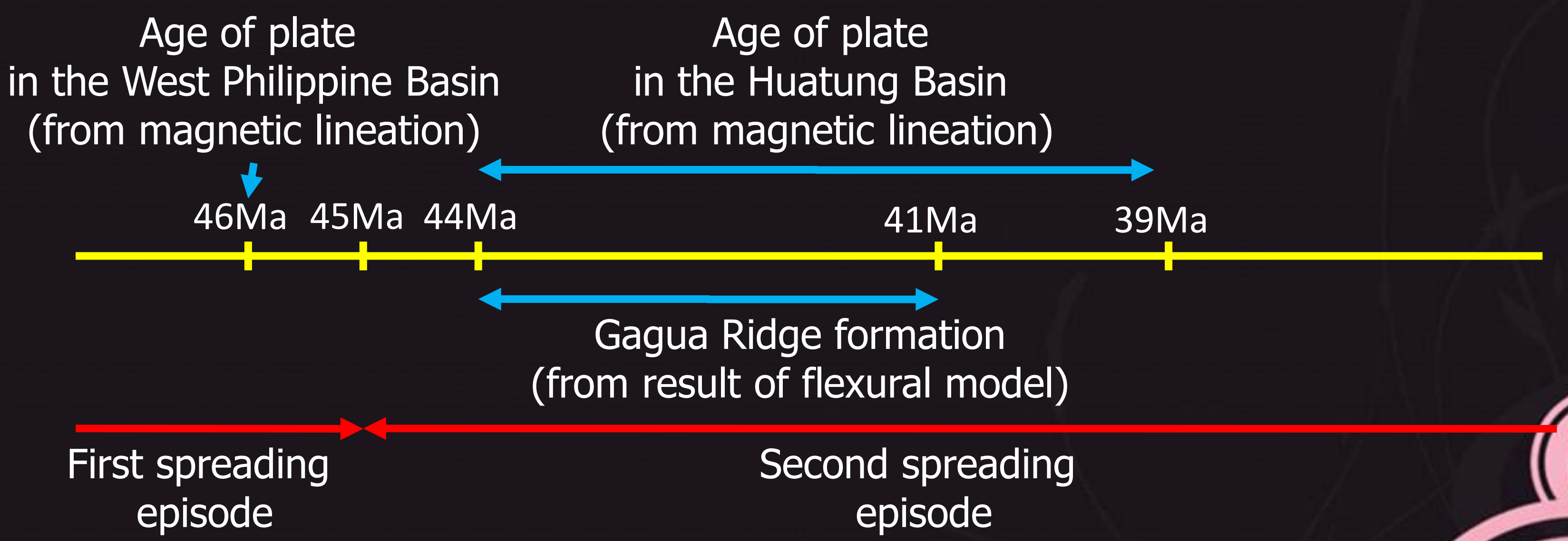

Flexure calculated for the Huatung Basin
WSW
Loading
ENE
a
b
c
d
Te= 20 km
Te= 14 km
Te= 8 km
Te= 5 km


Flexure calculated for the West Philippine Basin
WSW
Loading
ENE
Te= 20 km
Te= 14 km
Te= 8 km
Te= 5 km


24°N
23°N
22°N
21°N
20°N
19°N
18°N
LUZON
121°E
122°E
123°E
124°E
125°E

The formation mechanisms of Gagua Ridge are similar to Puysegur Ridge, but we can’t find any evidence that the plate subduct beneath Gagua Ridge. Why?

The crust on both sides of Puysegar Ridge is such a great difference in density that the greater could subduct beneath another one easily.

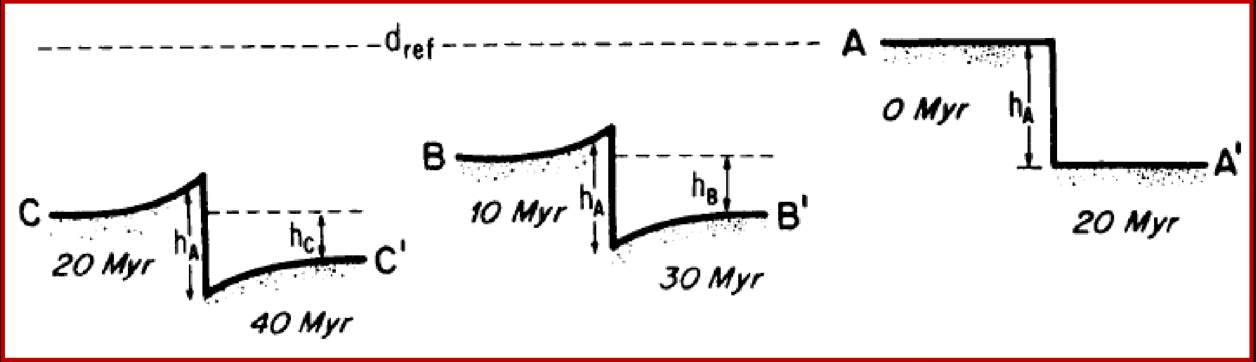


Conclusions

- In this two examples, we show that compression is the major factor of the anomalous high ridge formation.

- Although the formation mechanisms of Gagua Ridge are similar to Puysegar Ridge, the crustal density of Huatung Basin and West Philippine Basin are so close that it couldn’t develop to a subduction zone.

Thanks for your attention!



d_{ref}
A
0 Myr
h_A
A'
20 Myr
B
10 Myr
h_A
h_B
B'
30 Myr
C
20 Myr
h_A
h_C
C'
40 Myr