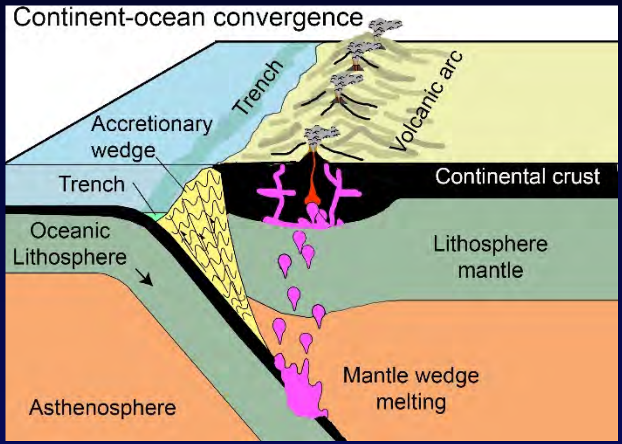
Geophysical constraints on geodynamic processes at convergent margins: A global perspective



Gondwana Research, 2015

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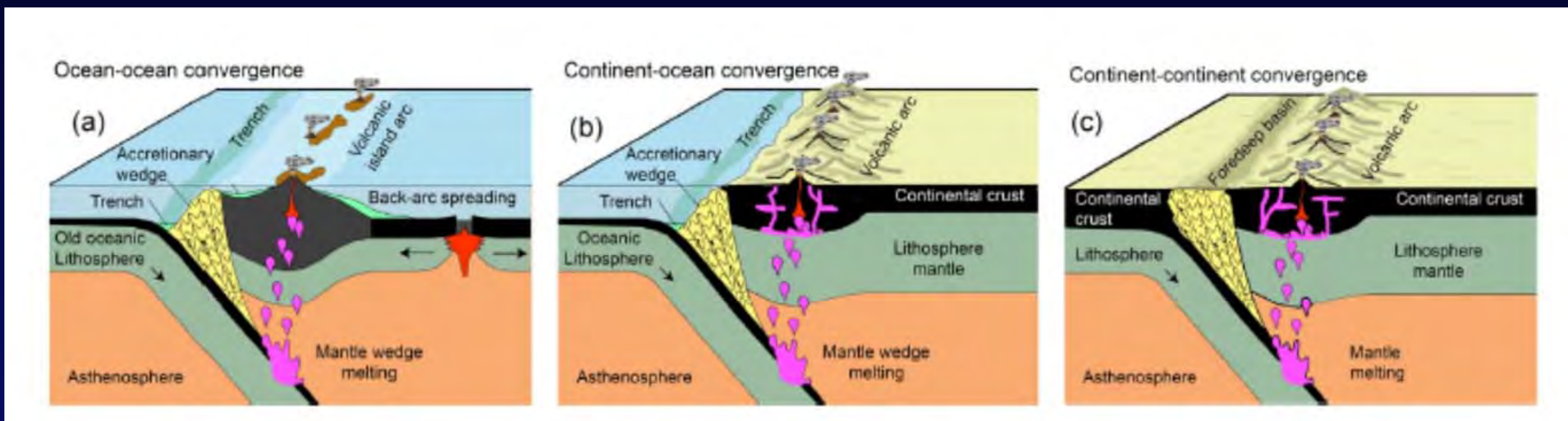
Three types of convergent margins

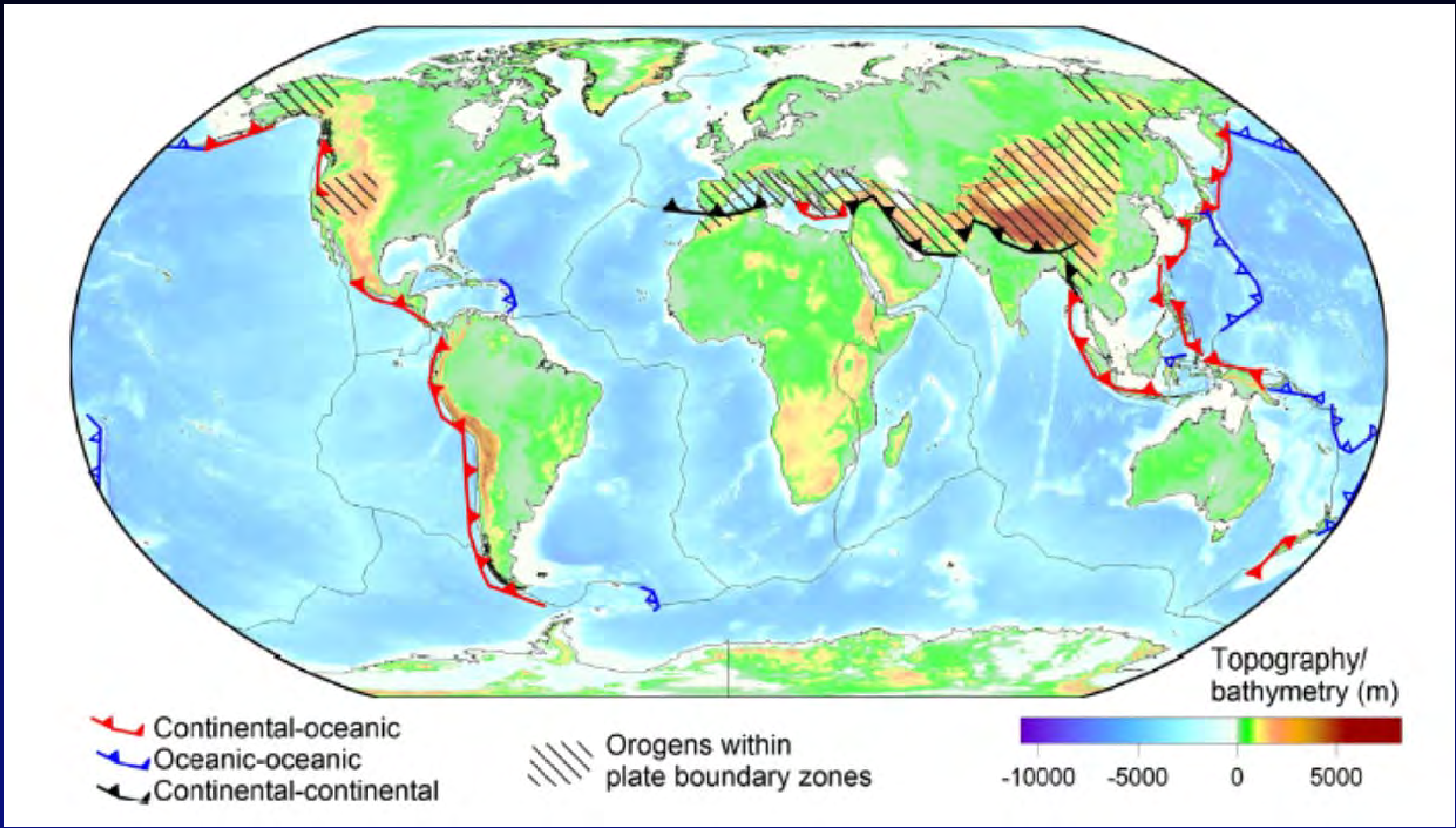
O-O C-O C-C



Incoming Oceanic

Overriding Continental

Three types of convergent margins



What happens at convergent margins and what are the controls?

"INPUT":

- Structure of incoming plate

  (crust: Moho, seds, topography,
  mantle: water, LAB, temperature
  -> age for ocean plates…)
- Structure of overriding plate
  - (LAB, temperature,…)
- Convergence rate

What happens at convergent margins and what are the controls?

<u>"OUTPUT":</u>

- Subduction angle

  may vary with depth

- Roll-back

  -> back-arc basins

- Seismicity

  Magnitude

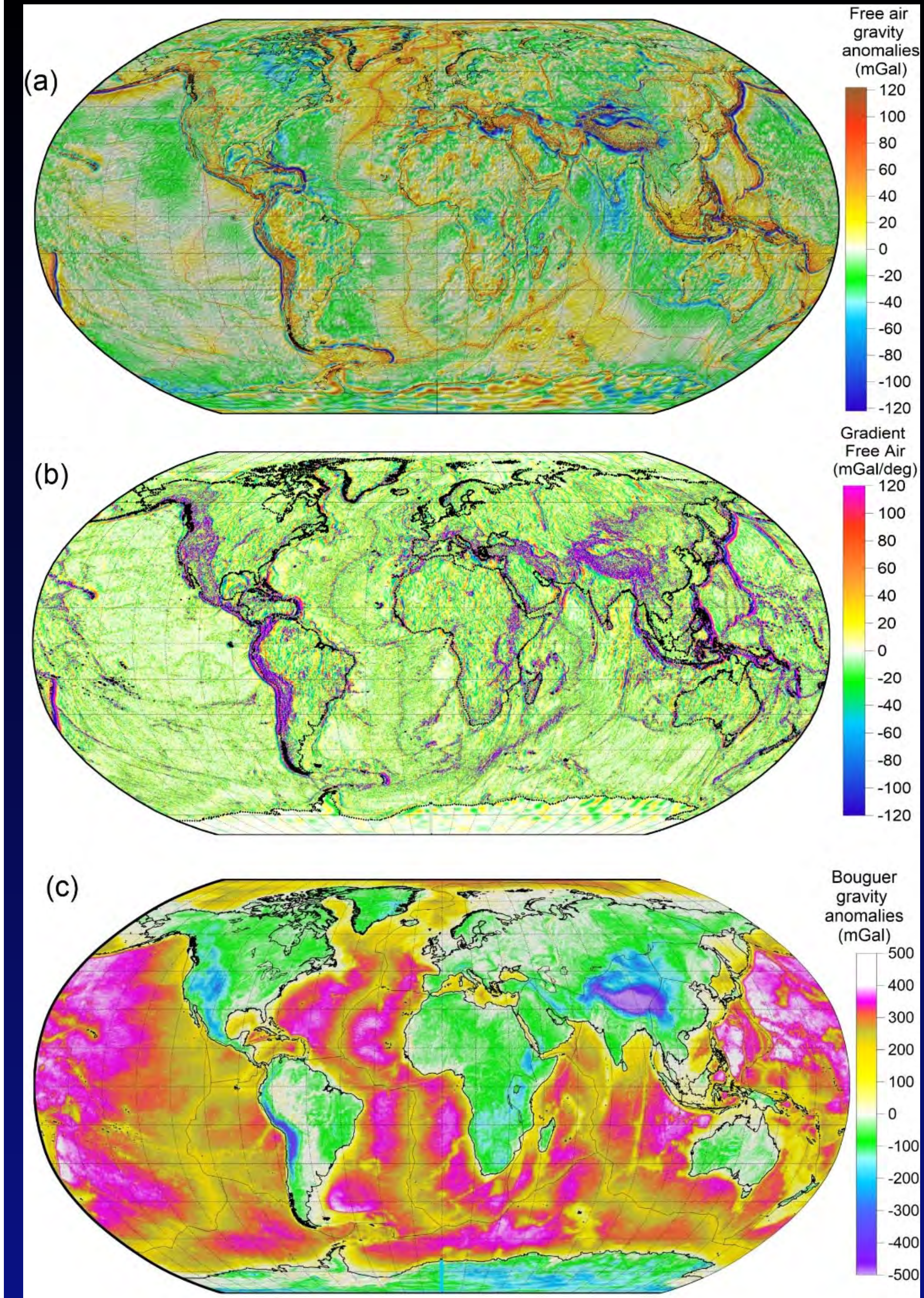
  Depth distribution

- Volcanism

What happens at convergent margins and what are the controls?

OBSERVABLES:

- Gravity (FA & B)
- Heat flow
- Seismic Vp, Vs, Q
- Seismicity & volcanism



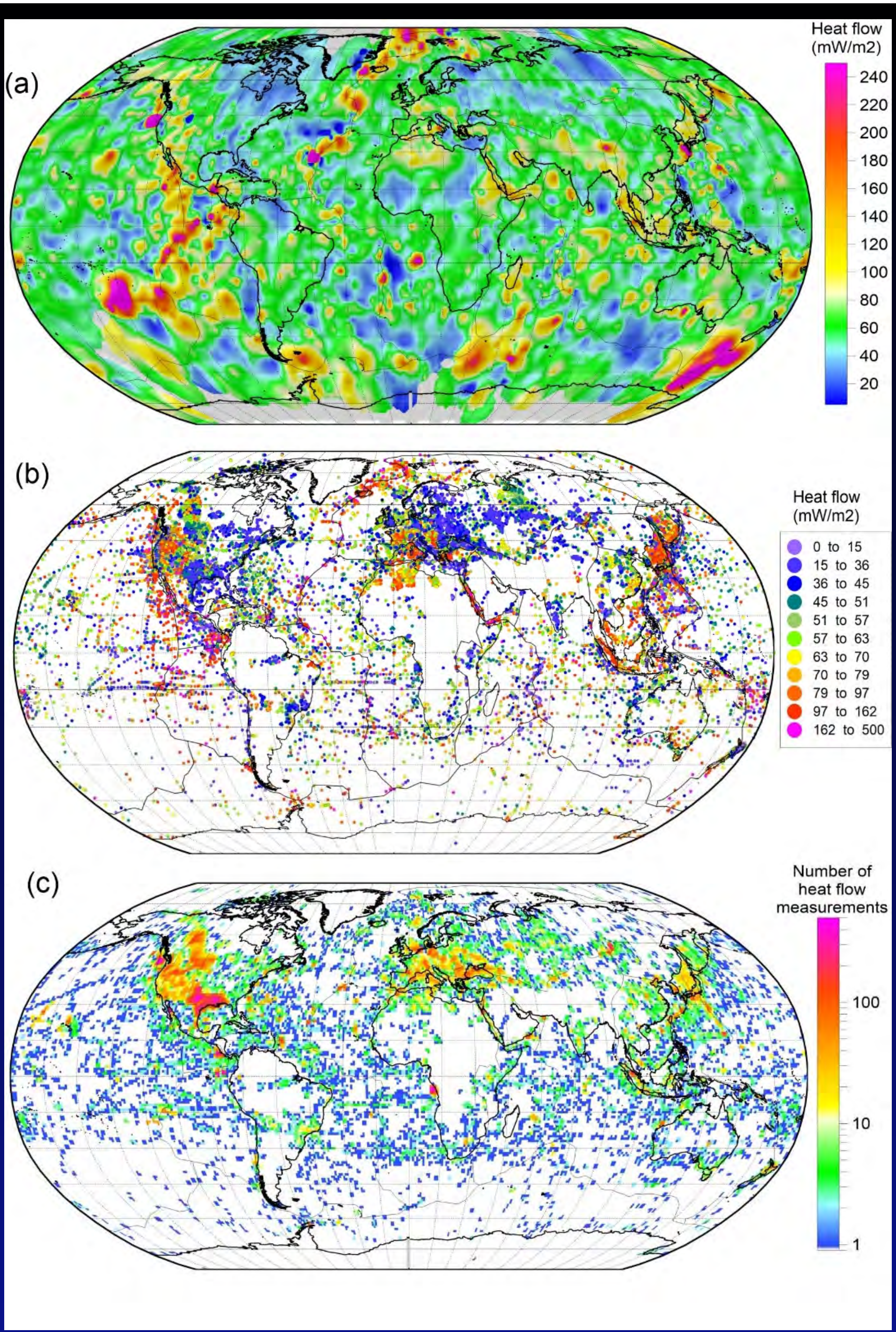
Gravity

Free Air

- Globally – proximity to isostasy
- No local isostasy at convergent margins

Extreme contrast in grad FA

Bouguer



Heat flow

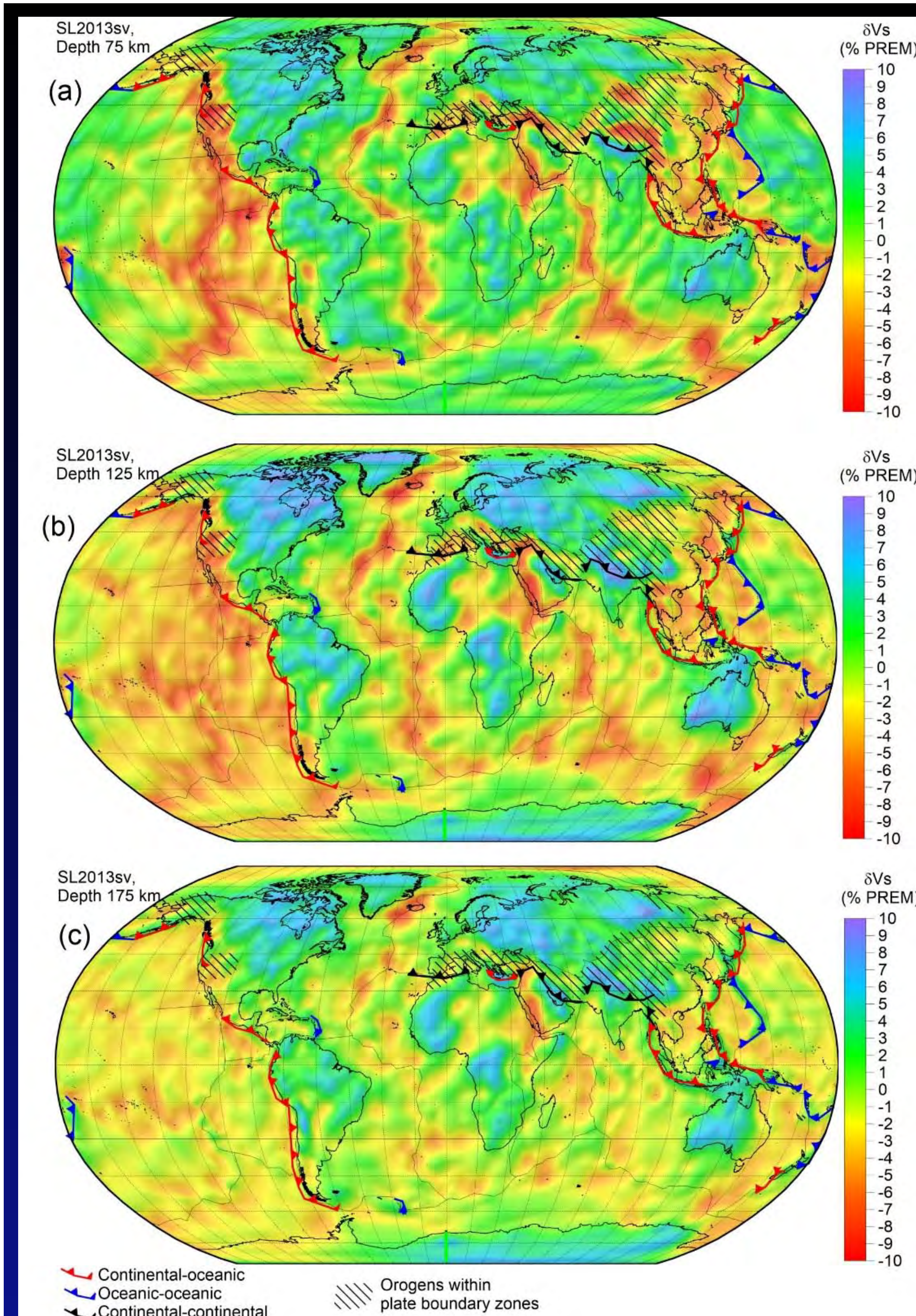
Interpolation

Point data

No systematic patterns are recognized in heat flow data due to strong heterogeneity of measured values, which are strongly affected by hydrothermal circulation, magmatic activity, crustal faulting, horizontal heat transfer, and also due to low number of heat flow measurements across many margins.

Data coverage

Vs in the mantle



75 km

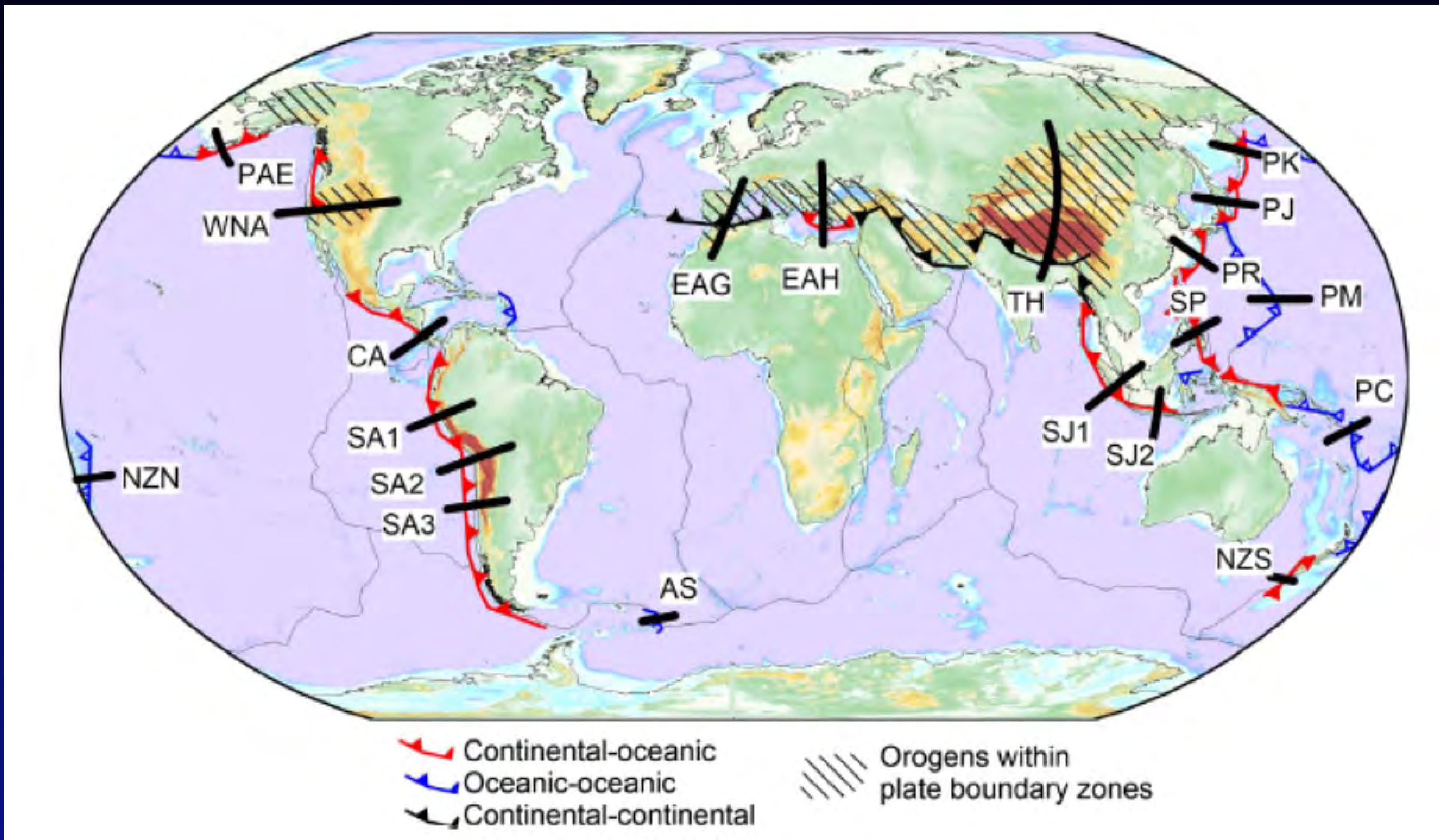
125 km

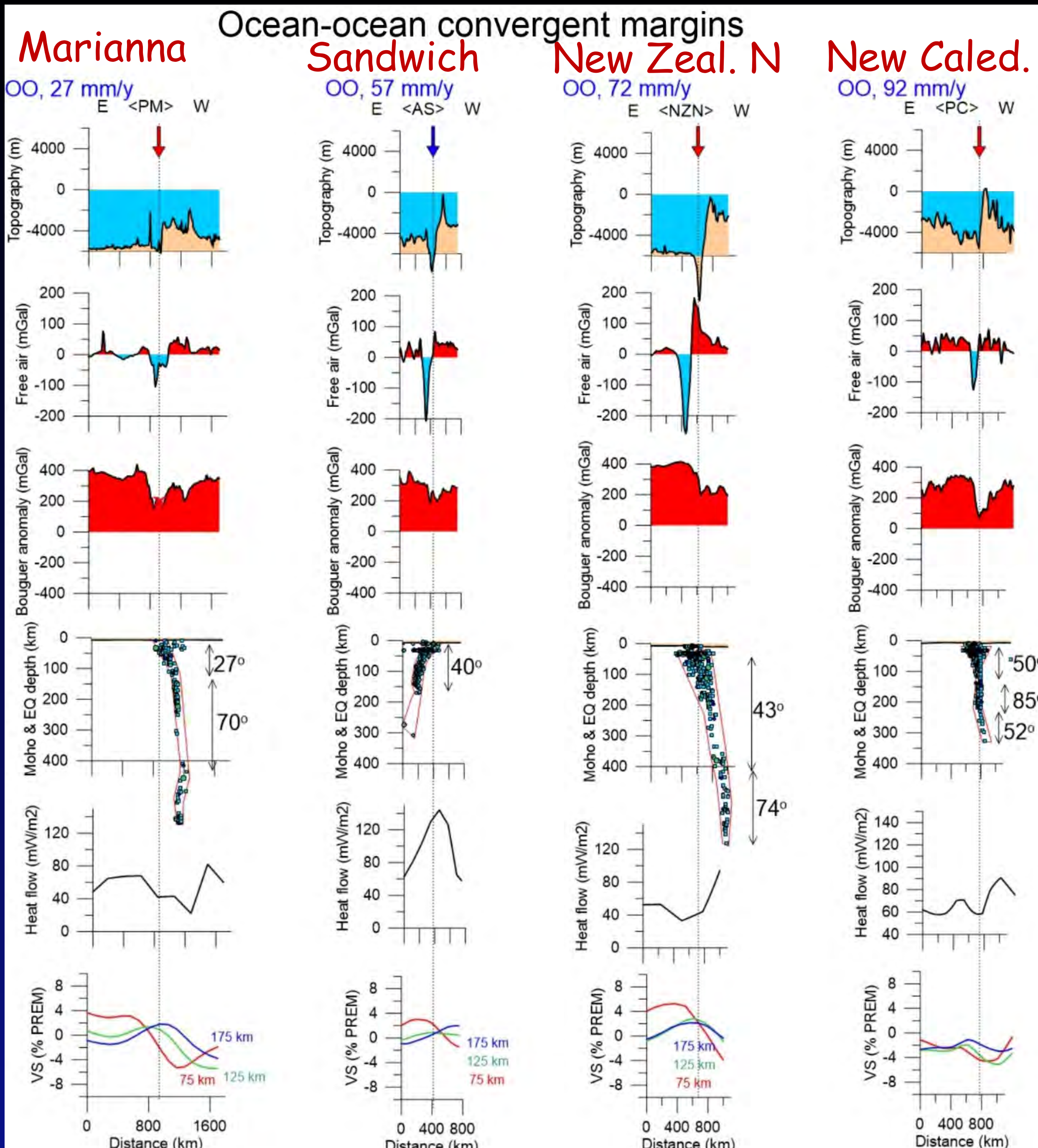
175 km

Low upper mantle Vs seismic velocities beneath the convergent margins are restricted to the upper 150 km and may be related to mantle wedge melting which is confined to shallow mantle levels

Model of Schaeffer and Lebedev, 2013

Locations of profiles





Topography

Free Air

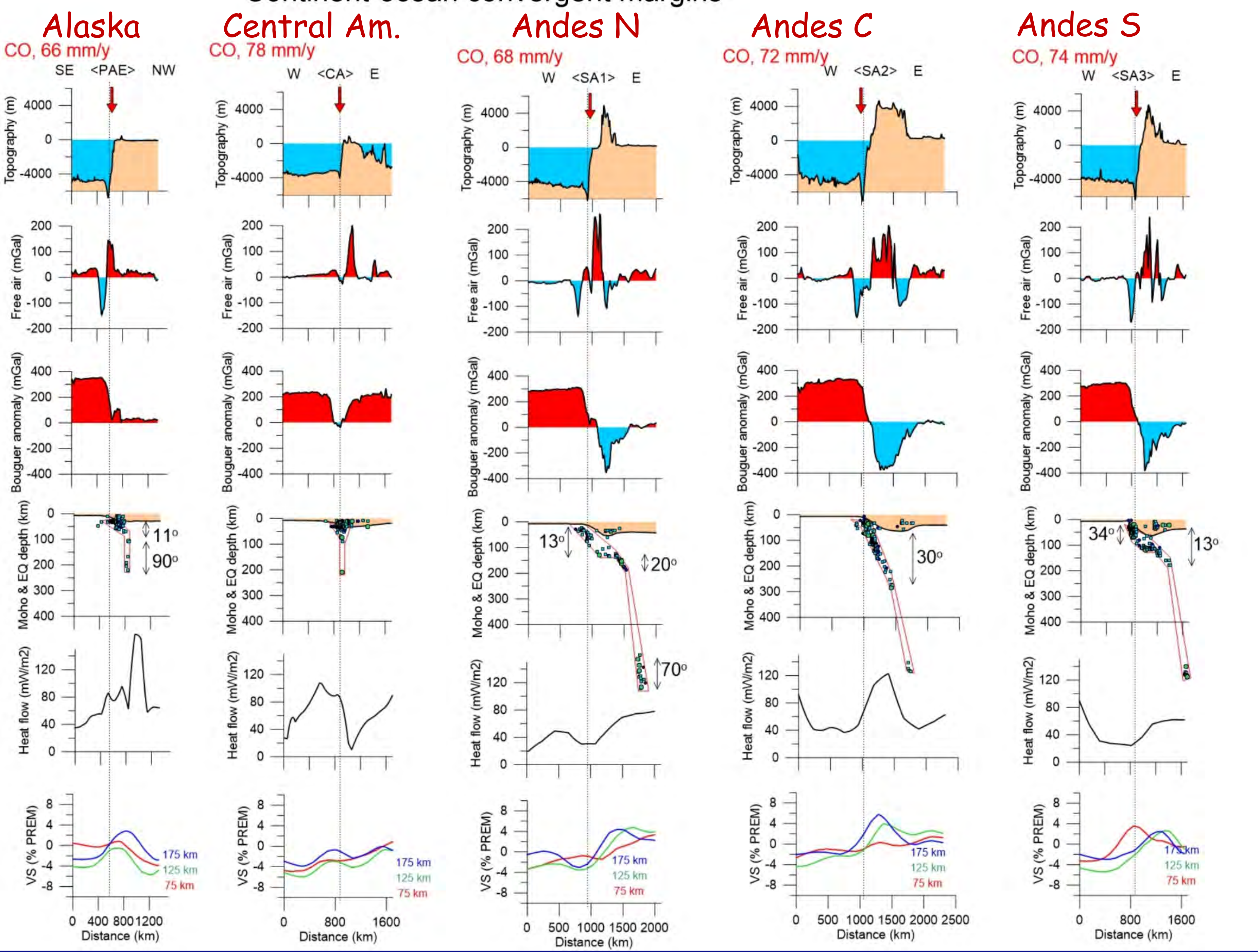
Bouguer

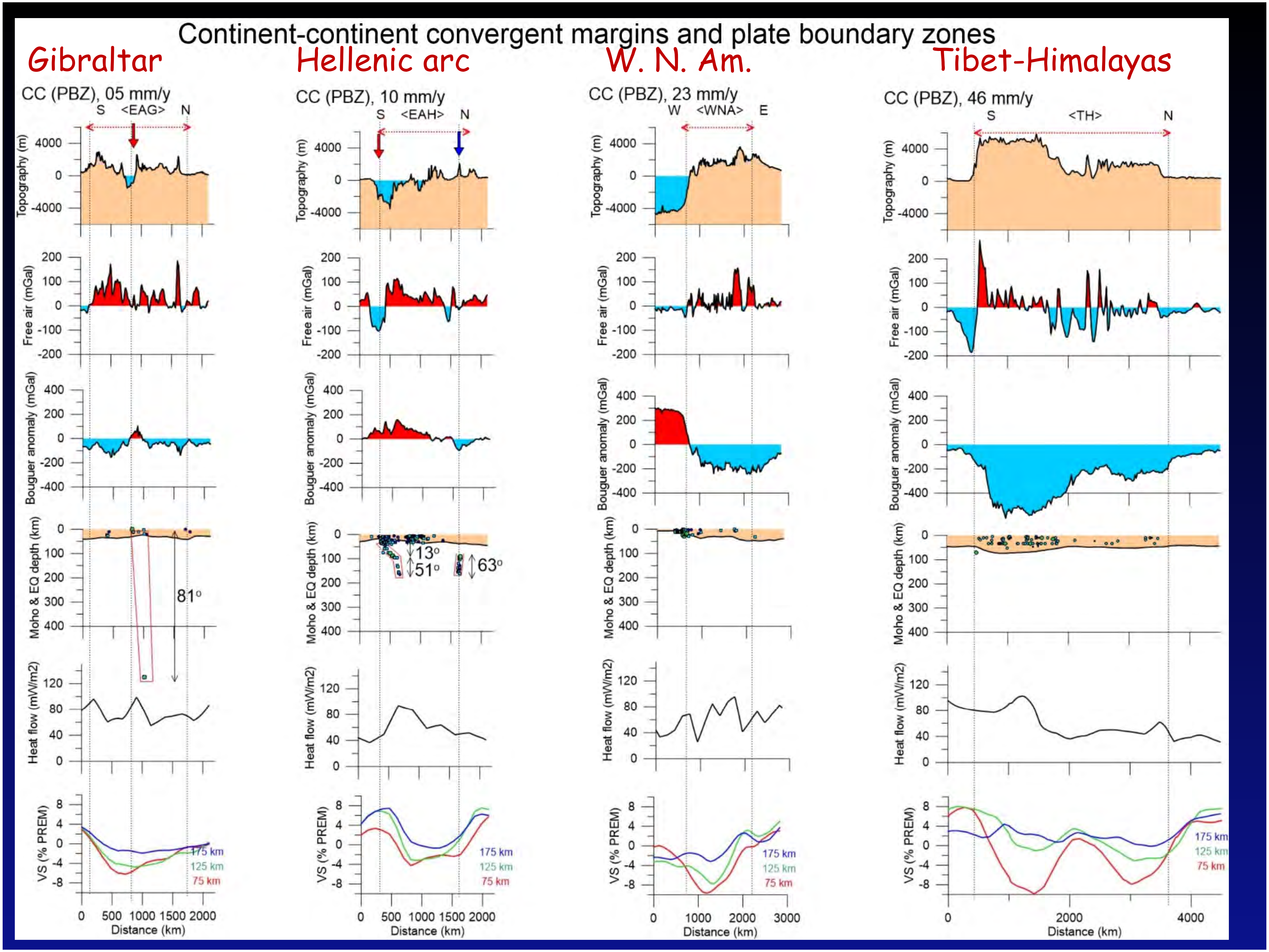
Seismicity, M>4.0

Heat flow

Vs@75, 125, 175 km

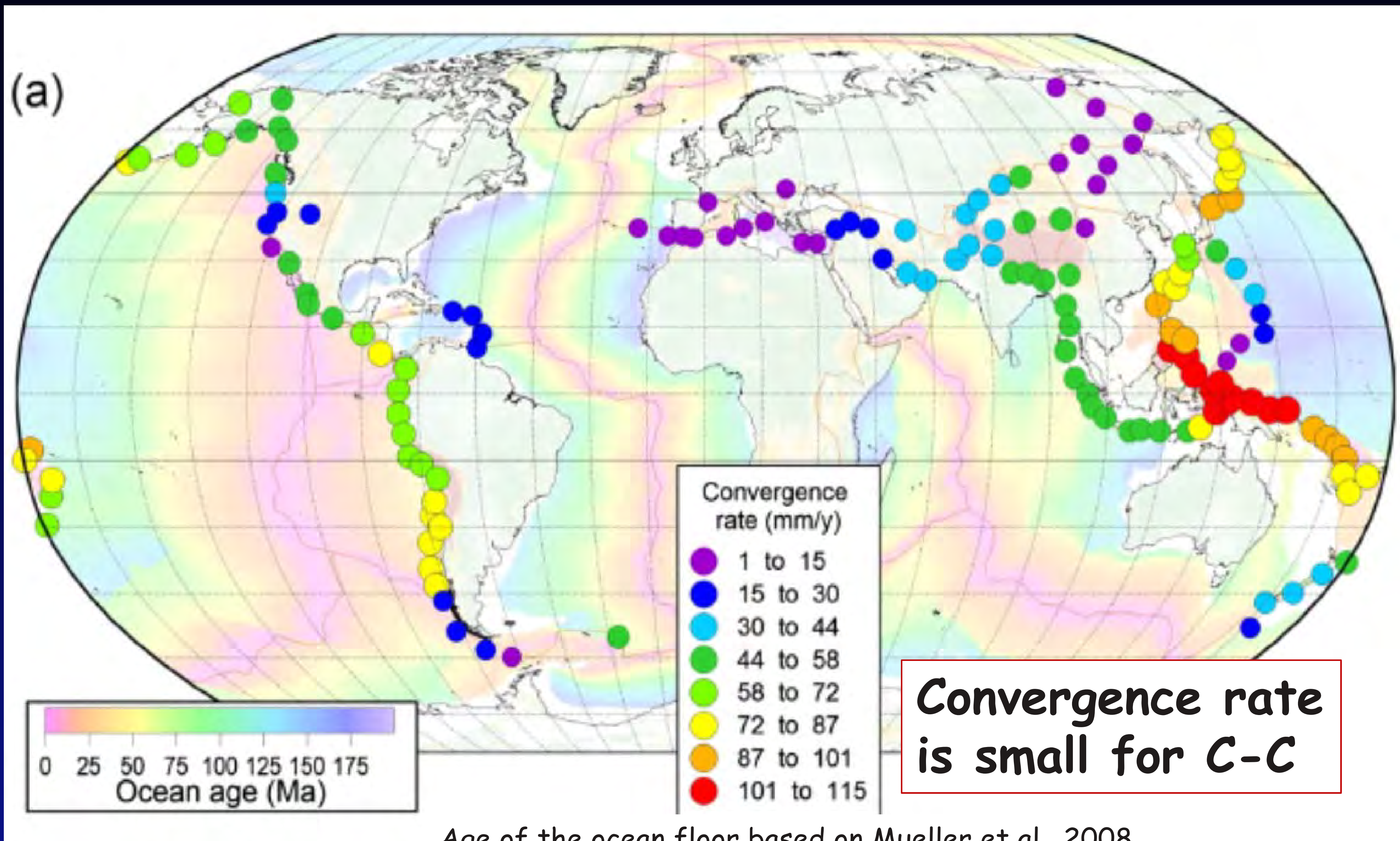
Continent-ocean convergent margins





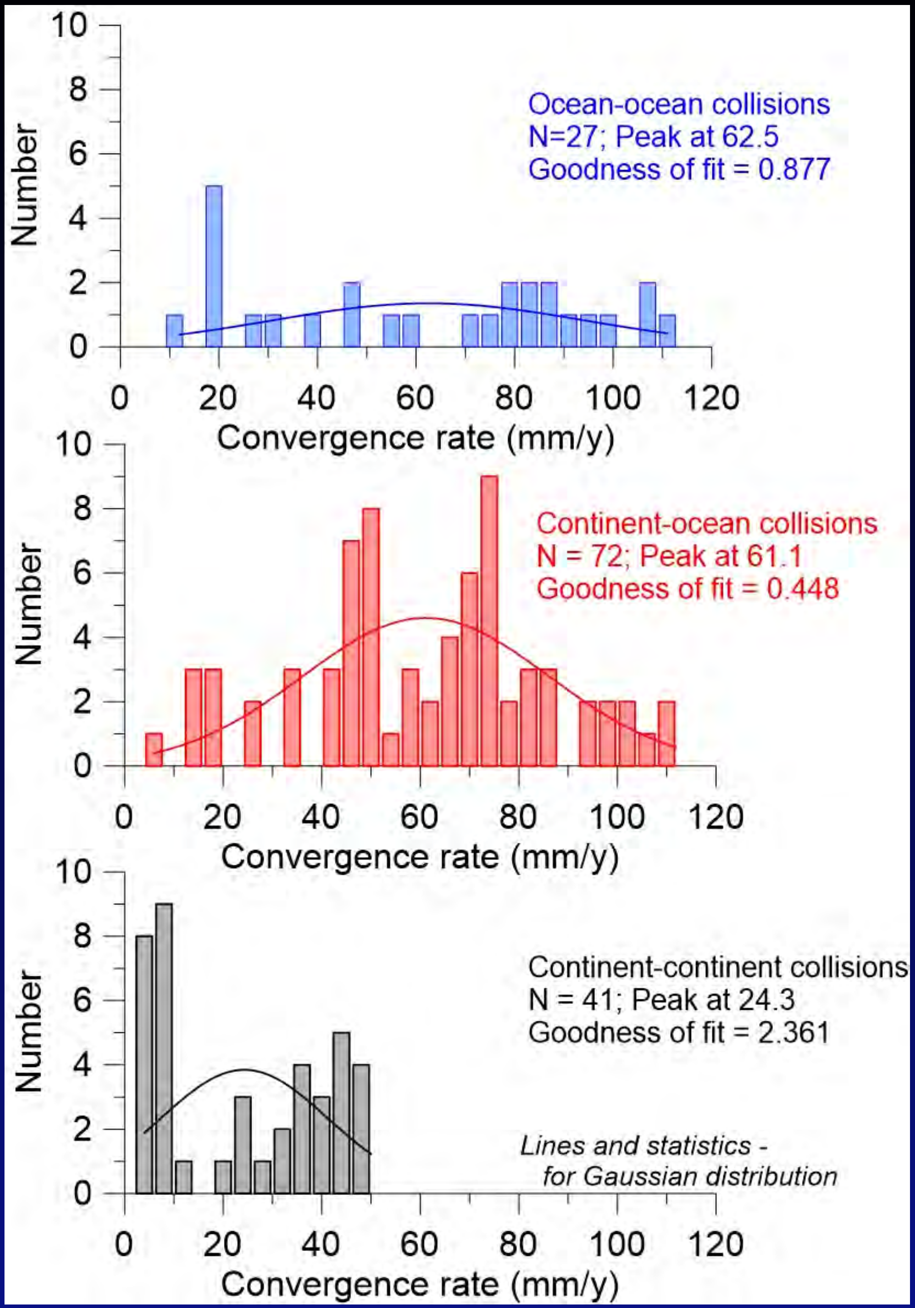
Continent-continent convergent margins and plate boundary zones
Gibraltar
Hellenic arc
W. N. Am.
Tibet-Himalayas
CC (PBZ), 05 mm/y
CC (PBZ), 10 mm/y
CC (PBZ), 23 mm/y
CC (PBZ), 46 mm/y
S <EAG> N
S <EAH> N
W <WNA> E
S <TH> N
Topography (m)
Free air (mGal)
Bouguer anomaly (mGal)
Moho & EQ depth (km)
Heat flow (mW/m2)
VS (% PREM)
81°
13°
51°
63°
175 km
125 km
75 km
Distance (km)

Convergence rate & Age of ocean floor



Convergence rate is small for C-C

Age of the ocean floor based on Mueller et al., 2008.
Rates based on theMORVEL plate velocity model, DeMets et al., 2010



Convergence rate

Is larger when overriding plate is oceanic

O-O:

- Broad range
- uniform distribution

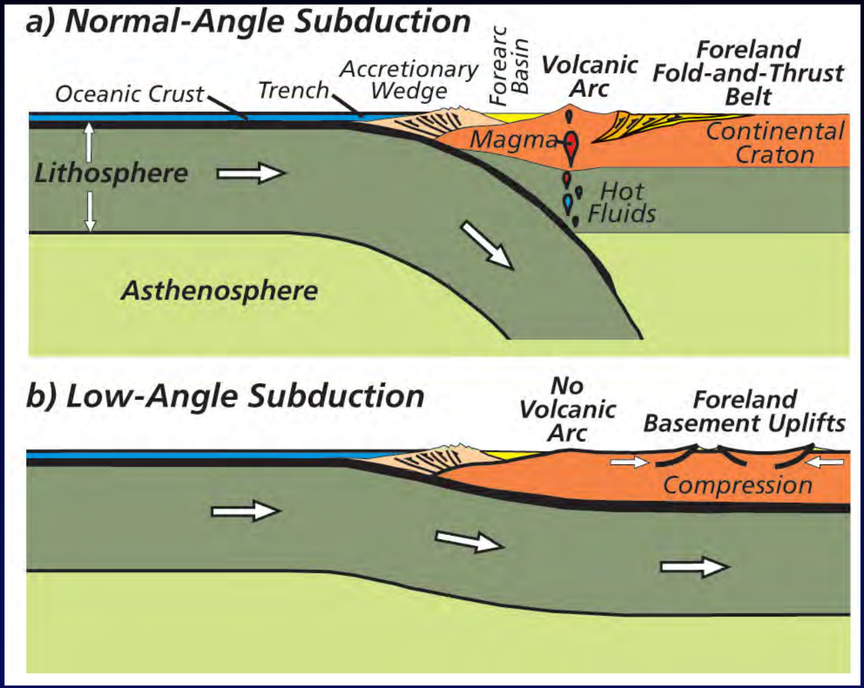
C-O:

- Broad range
- Two peaks at ca. 45 and 75 mm/y

C-C:

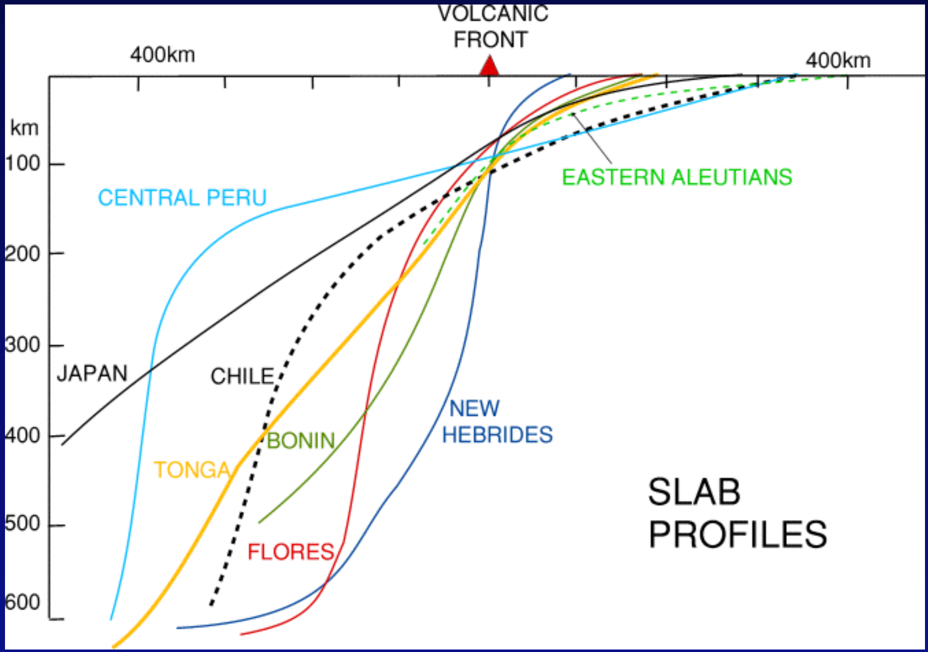
- Small values
- Two peaks: sharp at ca. 5 mm/y and broad at 30-50 mm/y

Subduction angle



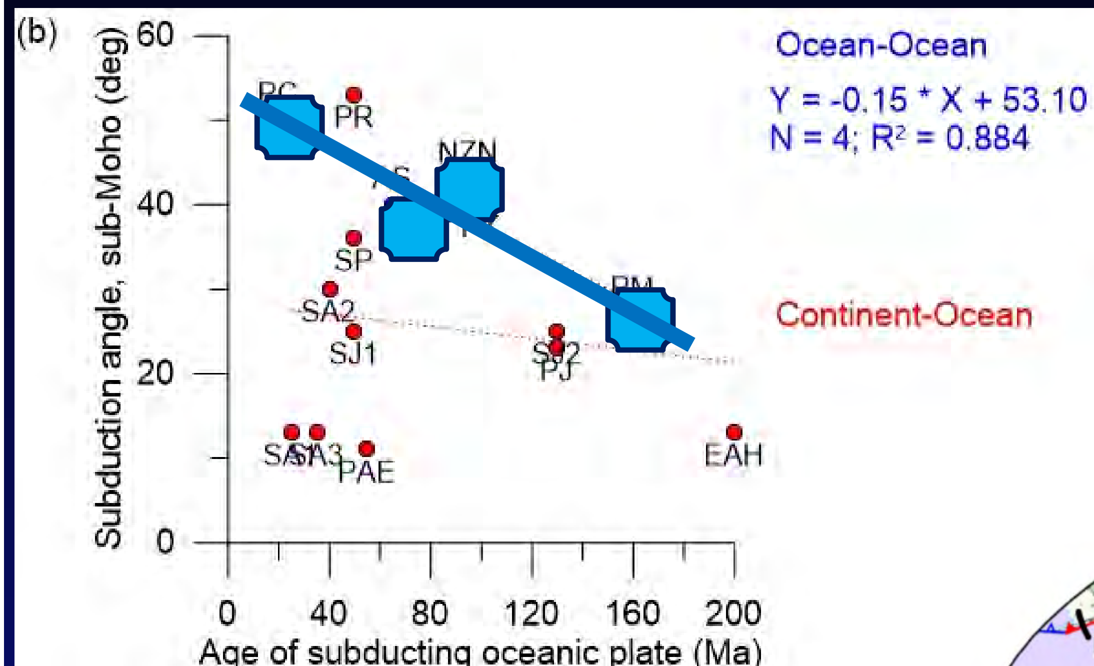
Mariana Type

Chilean Type



Subduction angle: sub-Moho

vs age of incoming plate

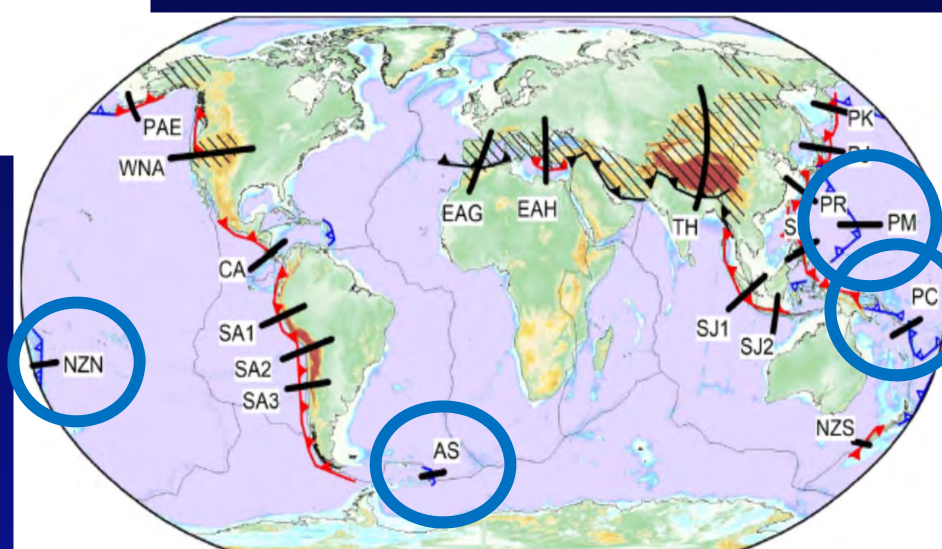


O-O:
Depends on the age of incoming plate
(smaller for older plates)

C-O: No correlation

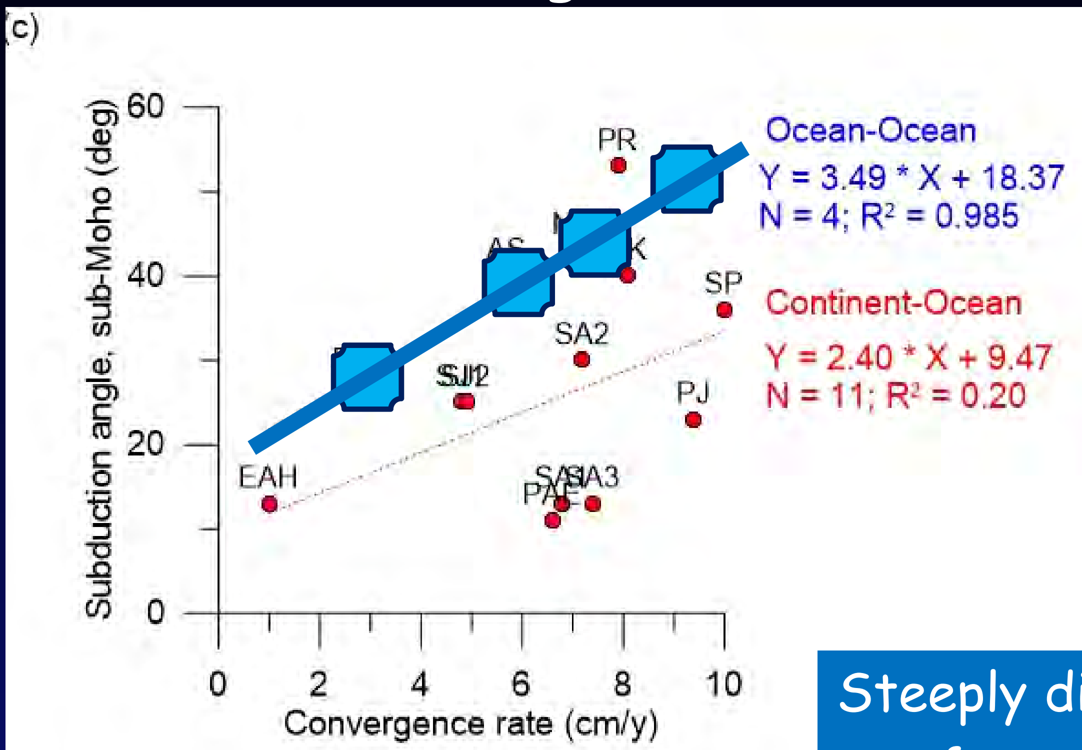
O-O:

Marianna — New Zeal. N
Sandwich — New Caled.



Subduction angle: sub-Moho

vs convergence rate



O-O:
Depends on convergence rate
(higher for higher rates)

C-O: Similar trend with weak correlation

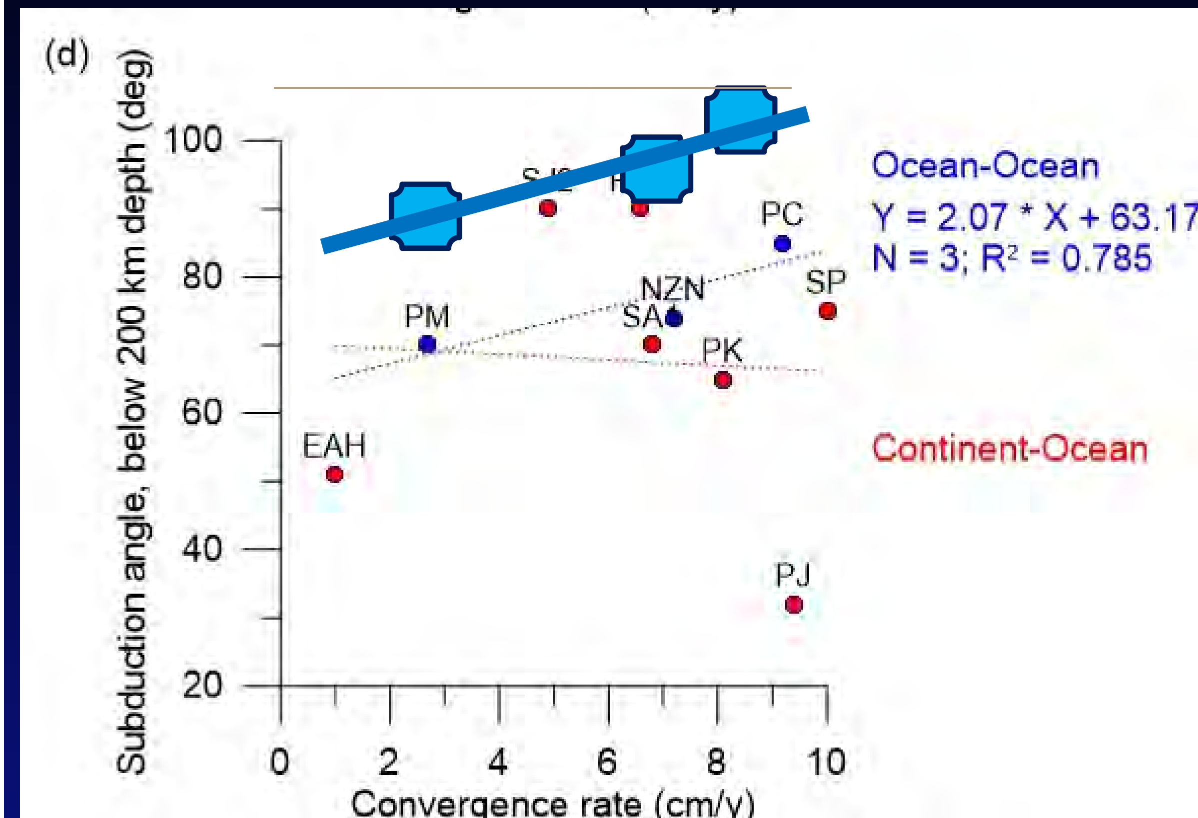
Marianna and Chile belong to different types (O-O and C-O)
-> comparing apples and pears?

Steeply dipping slabs are characteristic:
- of young oceanic subducting plates;
- of oceanic plates with high convergence rate,

with slab rotation towards a near-vertical dip angle at depths below ca. 500 km at very high convergence rate.

Subduction angle: below 200 km

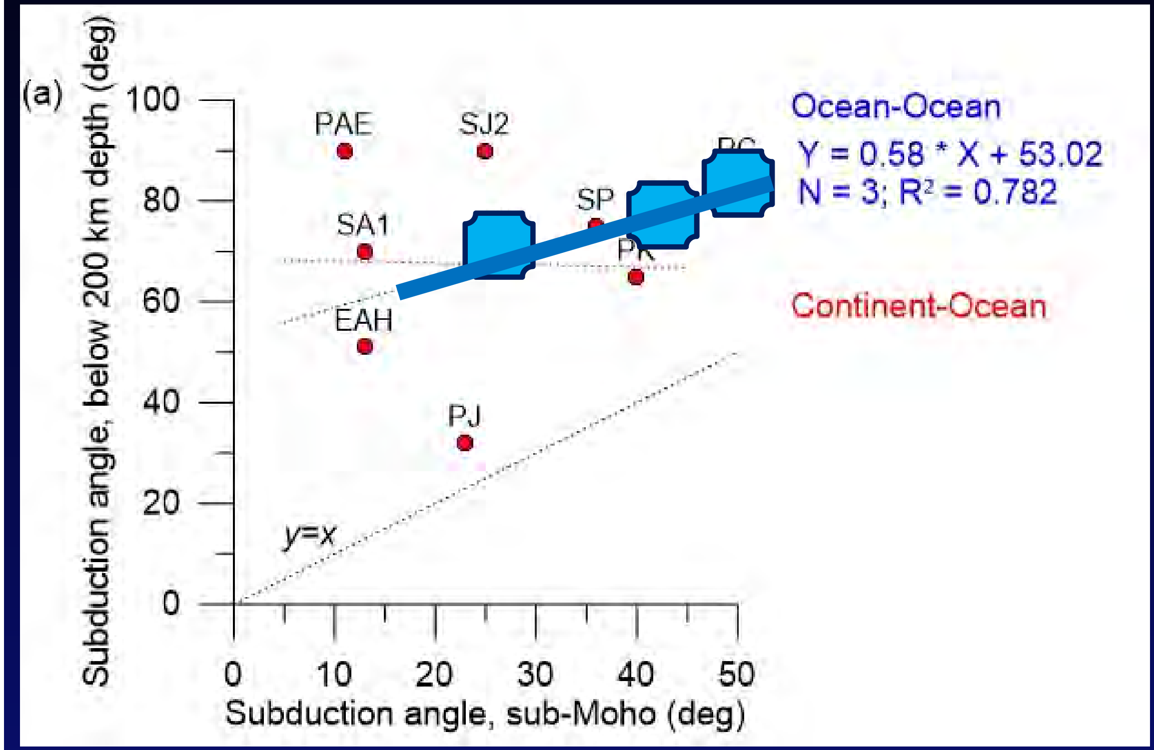
vs convergence rate



O-O:
Depends on convergence rate (higher for higher rates)

C-O: No correlation

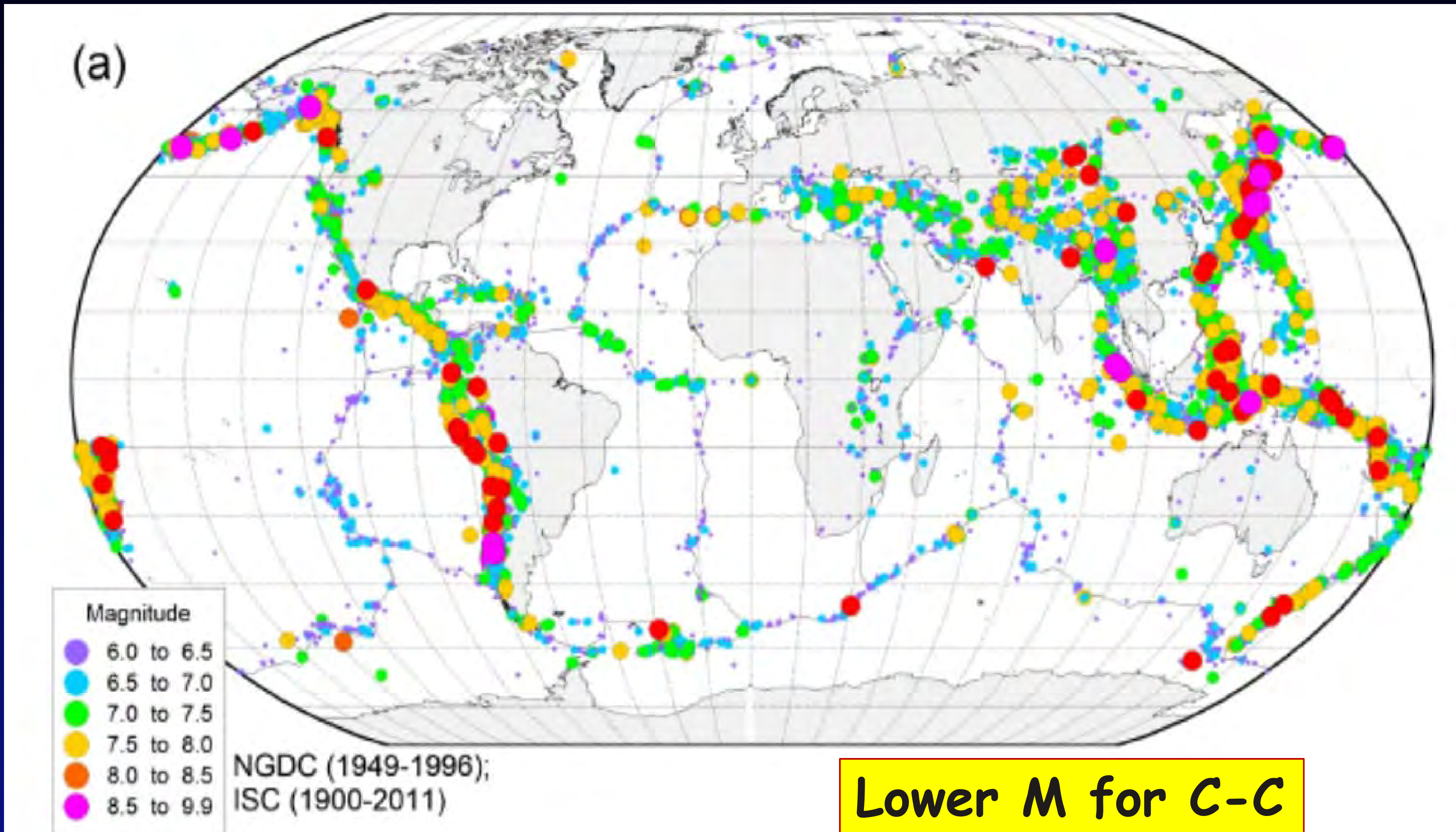
Subduction angle:
below Moho and >200 km



O-O:
Dip angles for sub-Moho and deep portions are different, but correlated

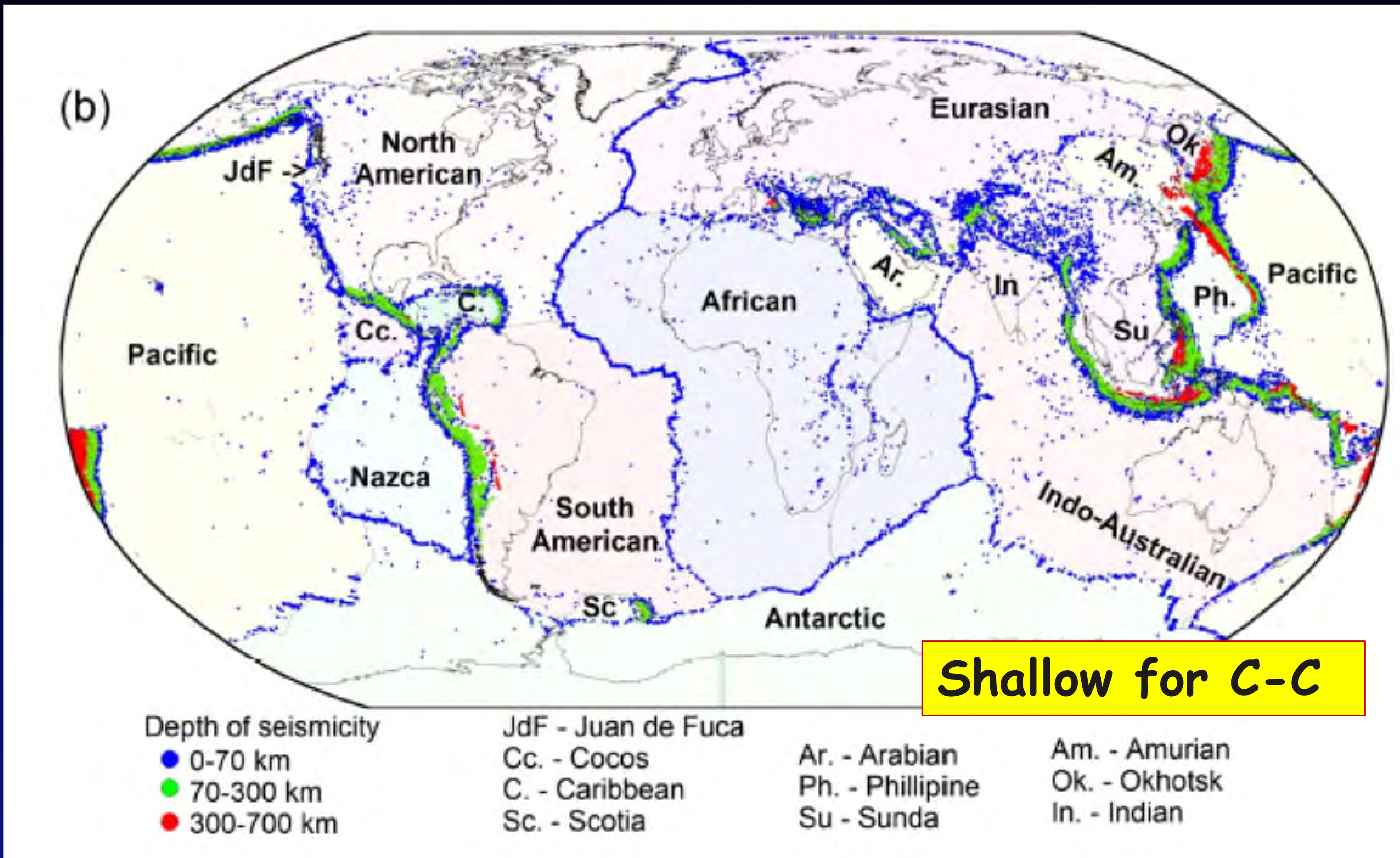
C-O: No correlation

Seismicity: Magnitude



Lower M for C-C

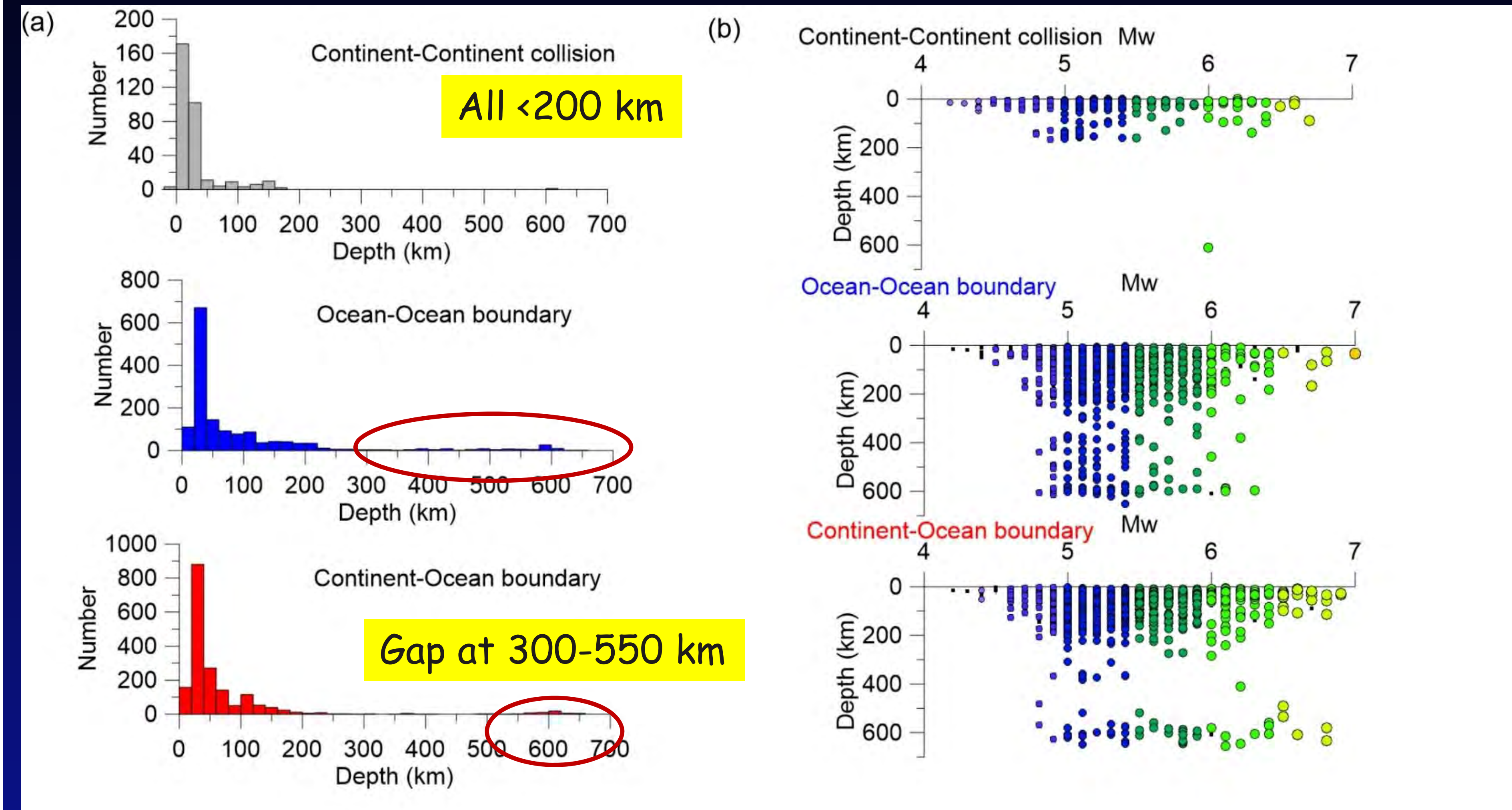
Seismicity: Depth



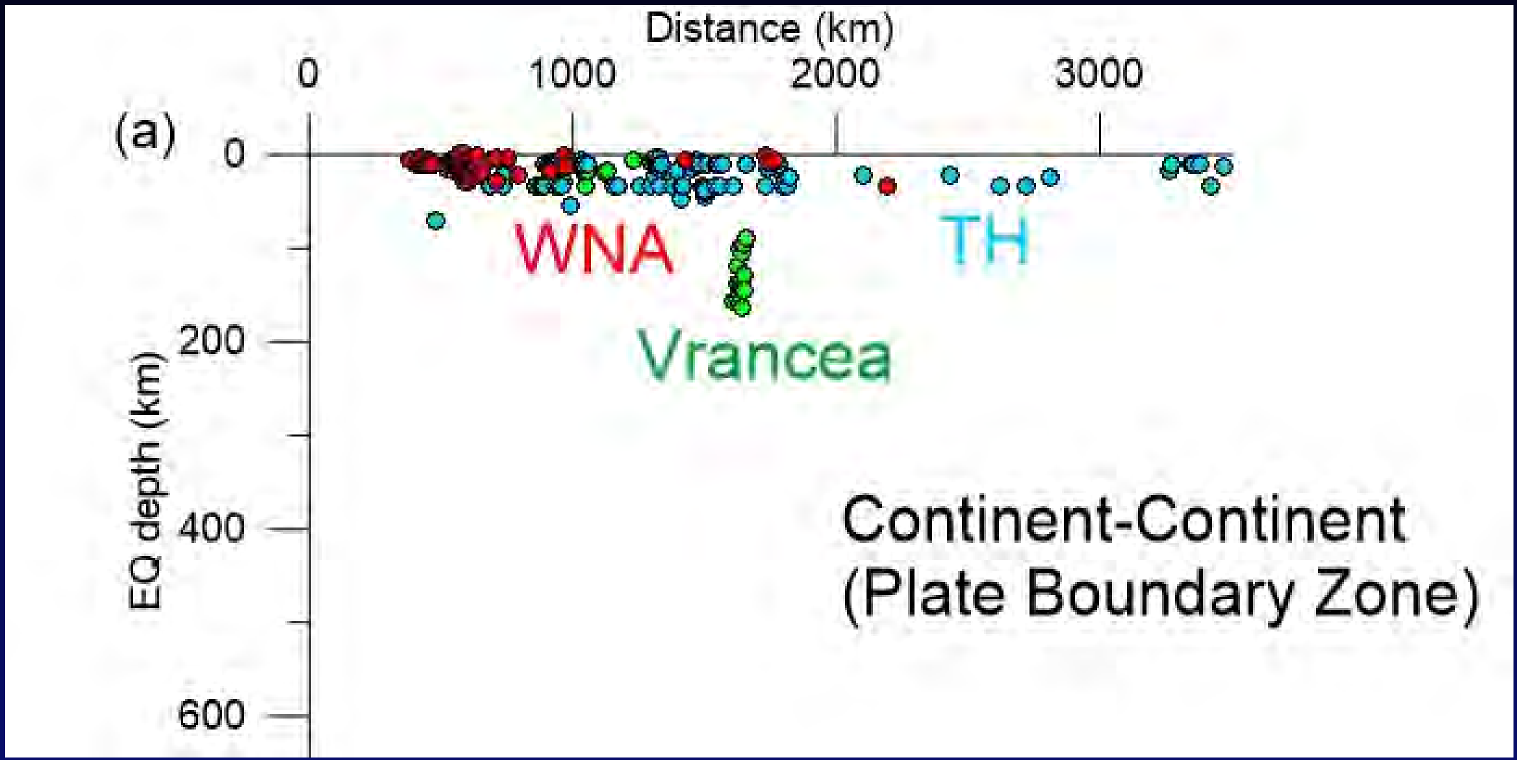
Shallow for C-C

Seismicity vs Depth

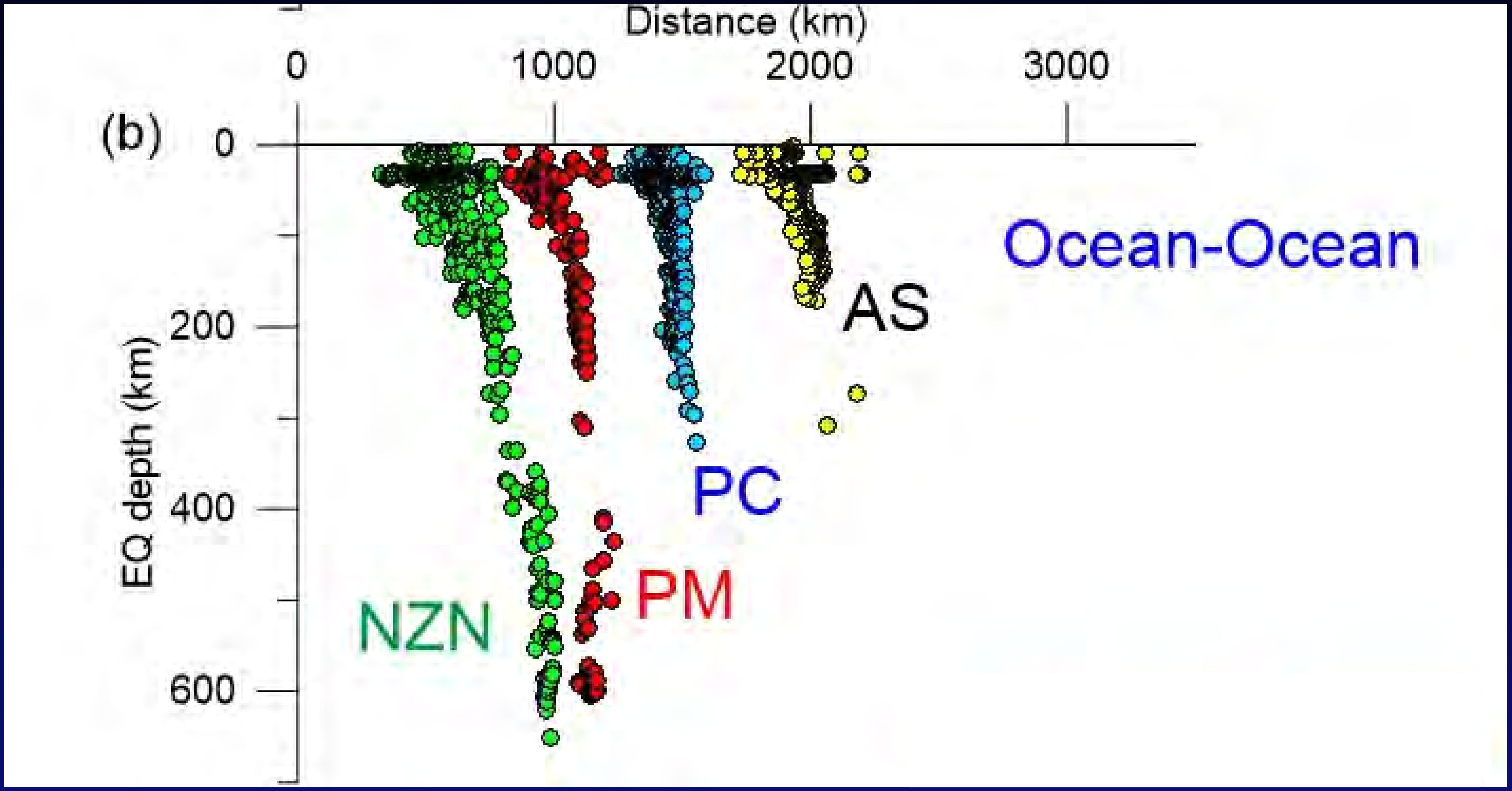
M>8 occur only when the overriding plate is oceanic



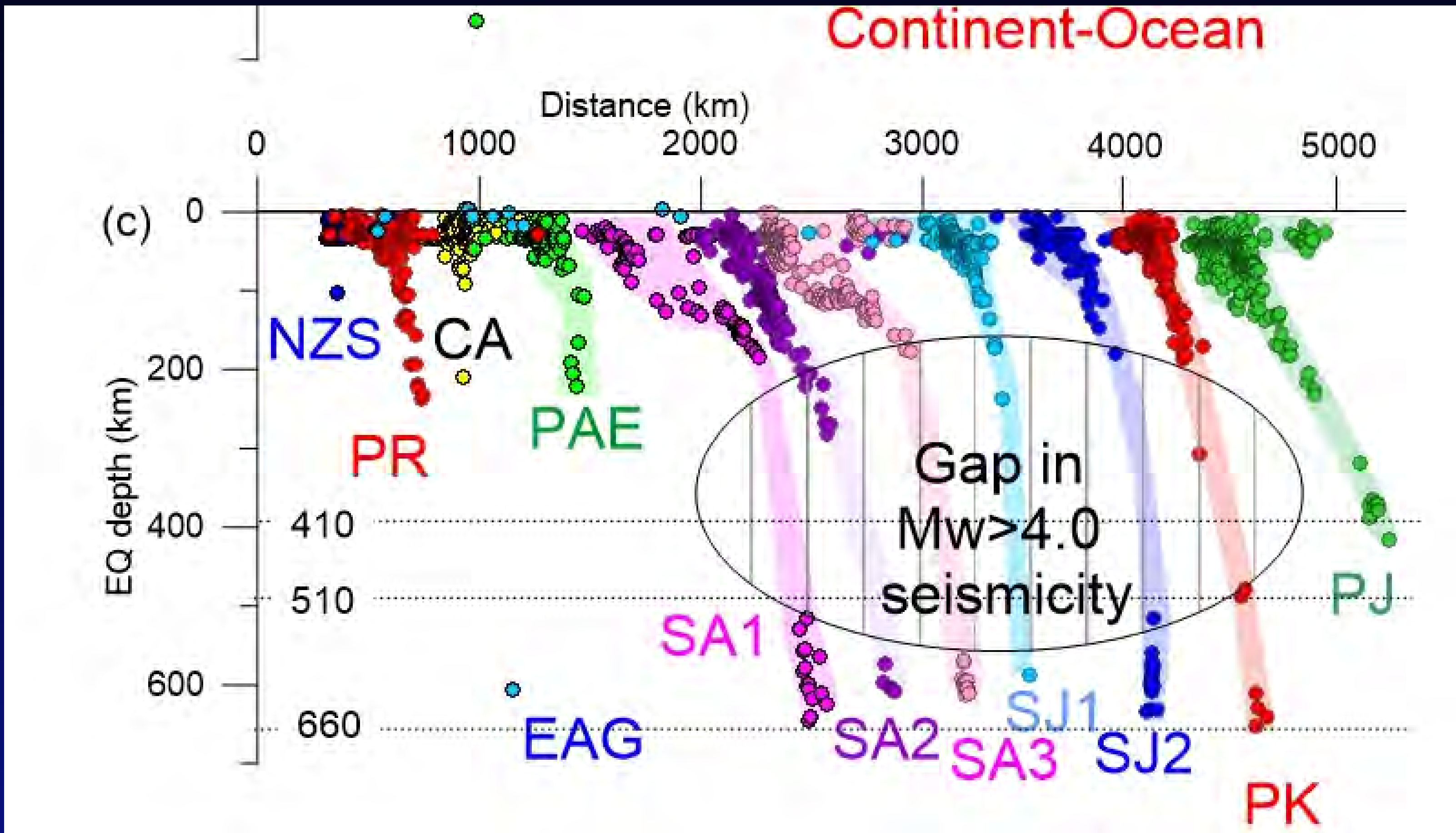
Seismicity vs Depth



Seismicity vs Depth



Seismicity vs Depth



Conclusions

1. Systematic patterns across subduction zones:

- Exist for Free Air and Bouguer;
- Do not exist for heat flow and Vs in global models
- -> large variability and "individuality" of subd. Zones

2. Subduction angle correlates **<u>only</u>** for O-O subd.:

- Sub-Moho:
  - smaller for older plates;
  - higher for higher conv. rates;
- Below 200 km:
  - weakly correlates with sub-Moho dip;
  - higher for higher conv. rates

3. Seismicity

- Gap at ca. 300-520 km at C-O margins