LETTERS

Trench-parallel flow and seismic anisotropy in the Mariana and Andean subduction systems

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Link : http://www.nature.com/nature/journal/v450/n7173/pdf/nature06429.pdf

- Mariana and Andean subduction systems are associated with the largest along-strike variations of slab geometry observed on the Earth

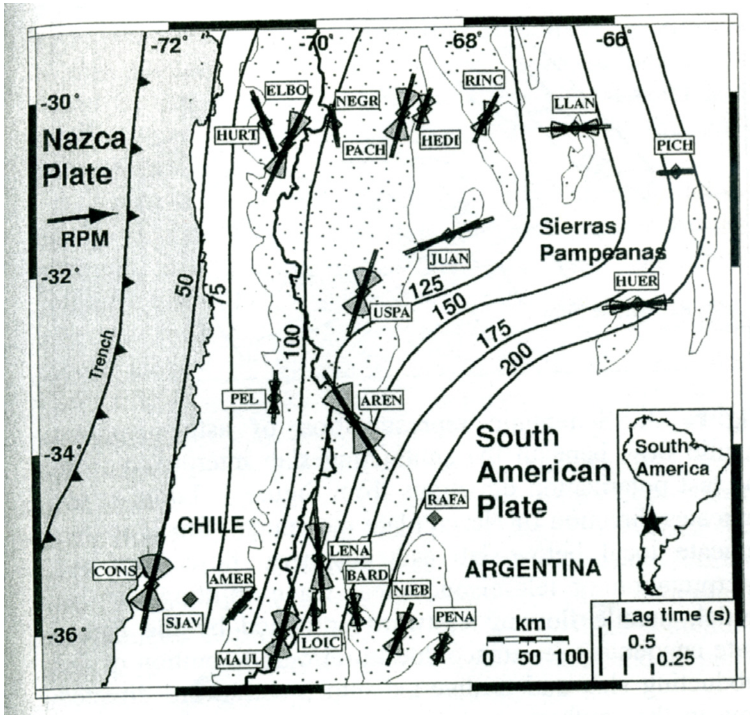
- Created by the subduction of Pacific Plate under the Philippine Plate.
- Depth 10.924 m

  (at 11° 22.4'N, 142° 35.5'E)
- Velocity: 44 mm/yr
- Age of the Marianas: 155 MY

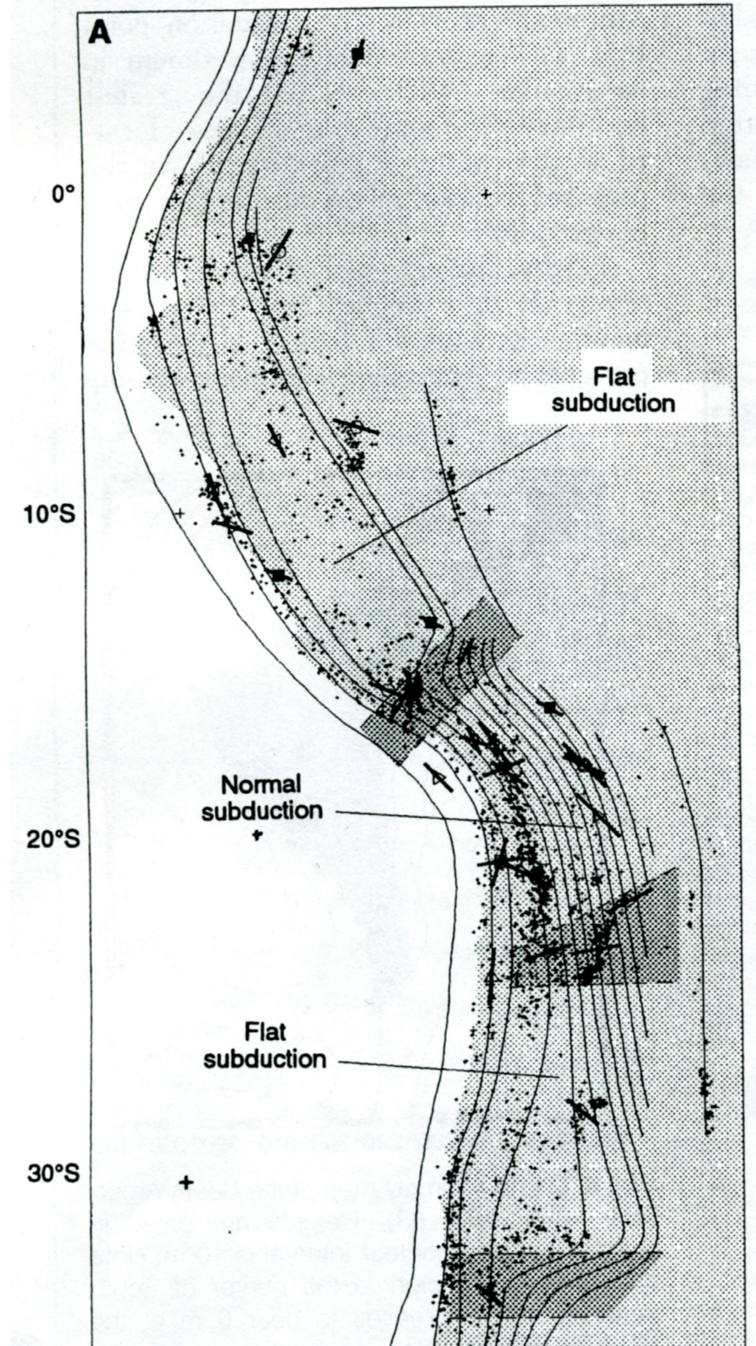
- The Andean subduction system fundamentally, created by the subduction of the Nazca plate beneath the South American plate.
- The boundary between the two plates is marked by the Peru-Chile **(Andean)** oceanic trench.

- Models of two-dimensional wedge flow predict fast seismic anisotropy parallel to plate motion (**trench perpendicular**)
- Shear-wave splitting observations from most subduction zones show complex patterns of seismic anisotropy that usually have **trench-parallel** fast directions.

- Fast axis orientation of sheer waves in Andean Zone



Anderson et al 2004

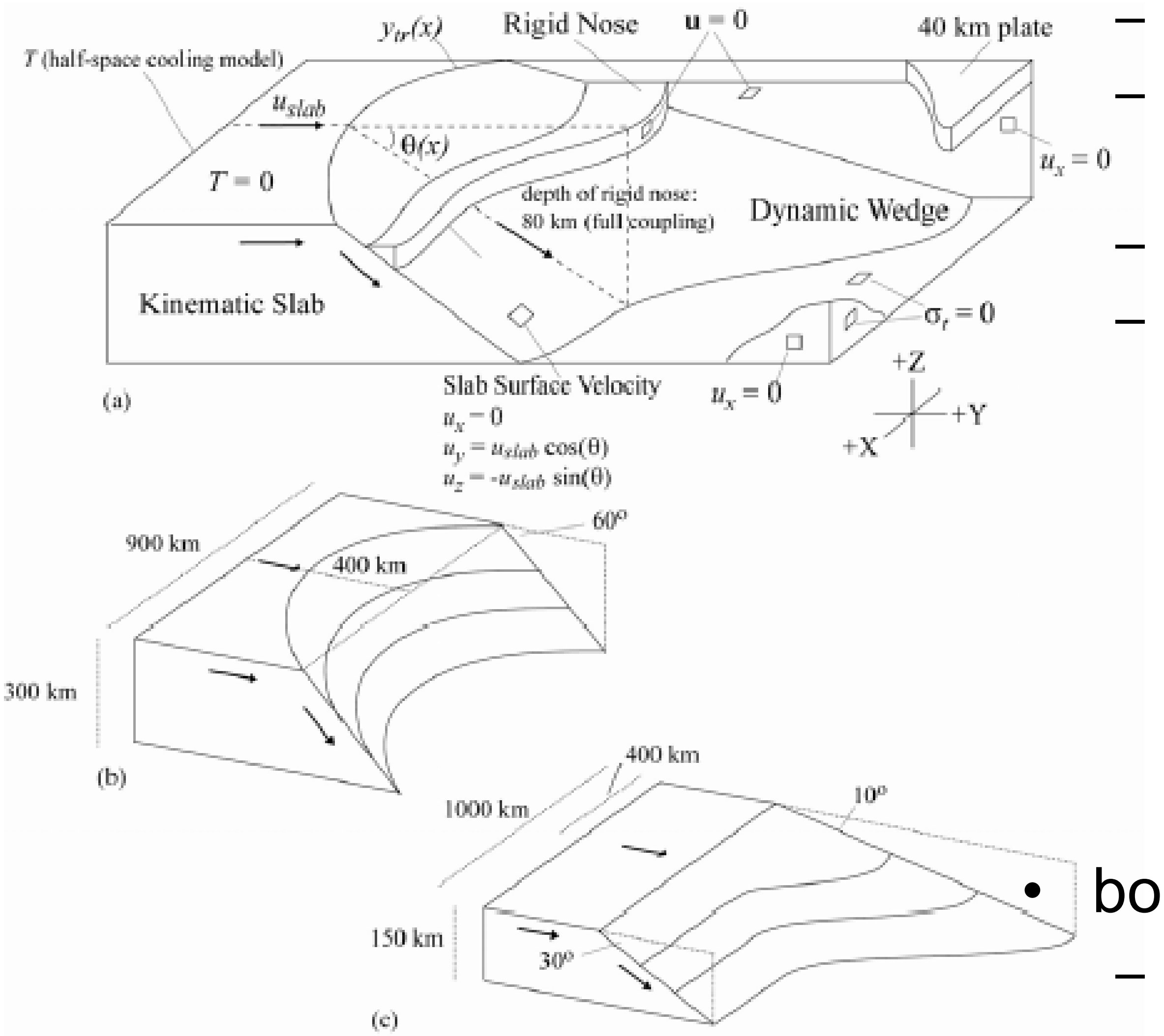


Russo et al 1994

- Possible causes for trench-parallel anisotropy and abrupt rotations in fast directions in the mantle wedge of subduction zones
  - Olivine fabric transitions
  - Melt-related anisotropy and
  - Three-dimensional flow with stretching-parallel olivine fabrics

- Three-dimensional flow caused by
  - Small-scale convection
  - Oblique subduction
  - Differential slab rollback
  - Trench-parallel motion of the overriding plate
  - Variations in slab geometry

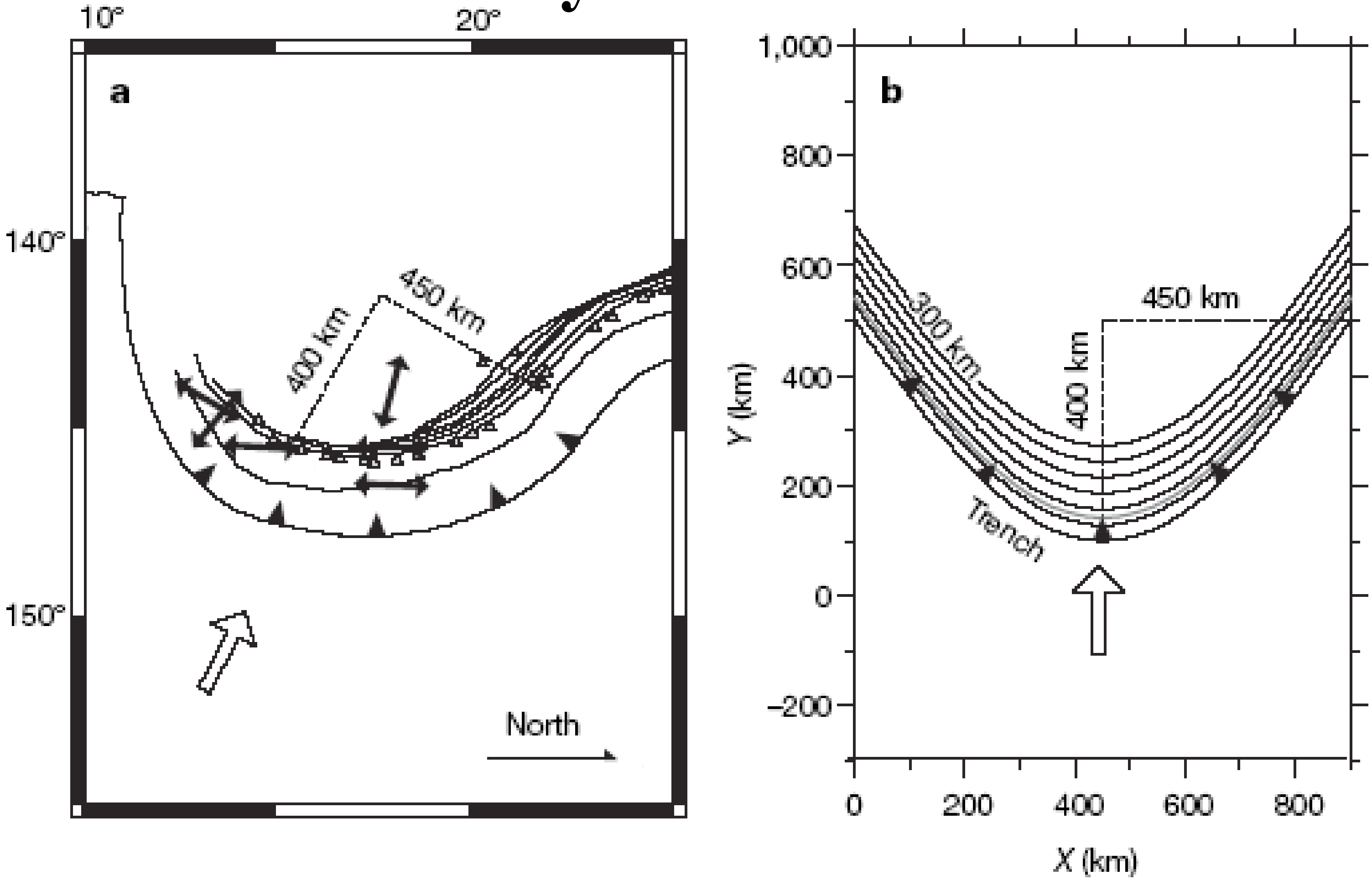
• Model



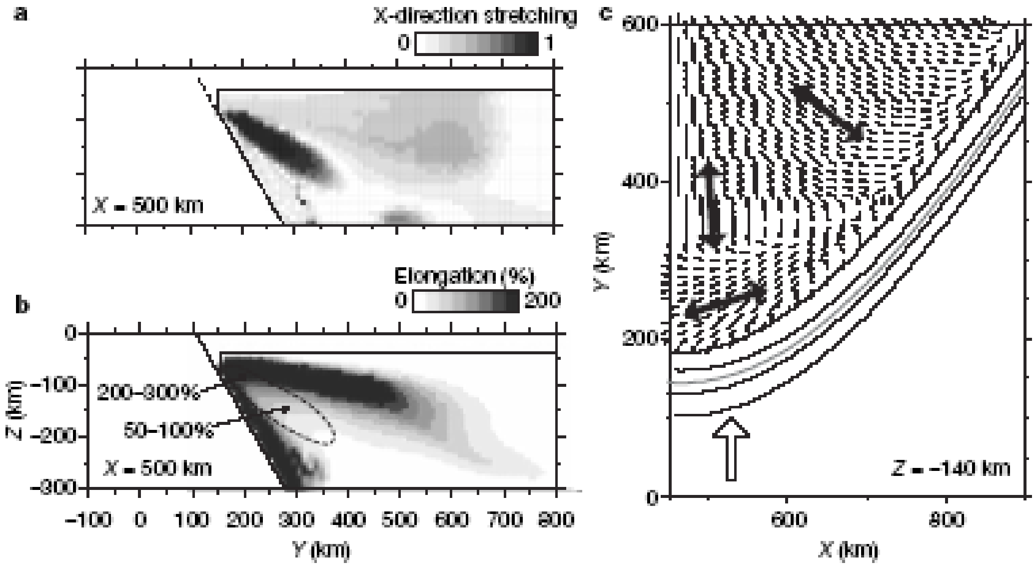
- divided into four parts:
  - (1) a kinematic slab,
  - (2) 40-km-thick rigid overriding plate,
  - (3) rigid wedge corner, and
  - (4) viscous mantle wedge

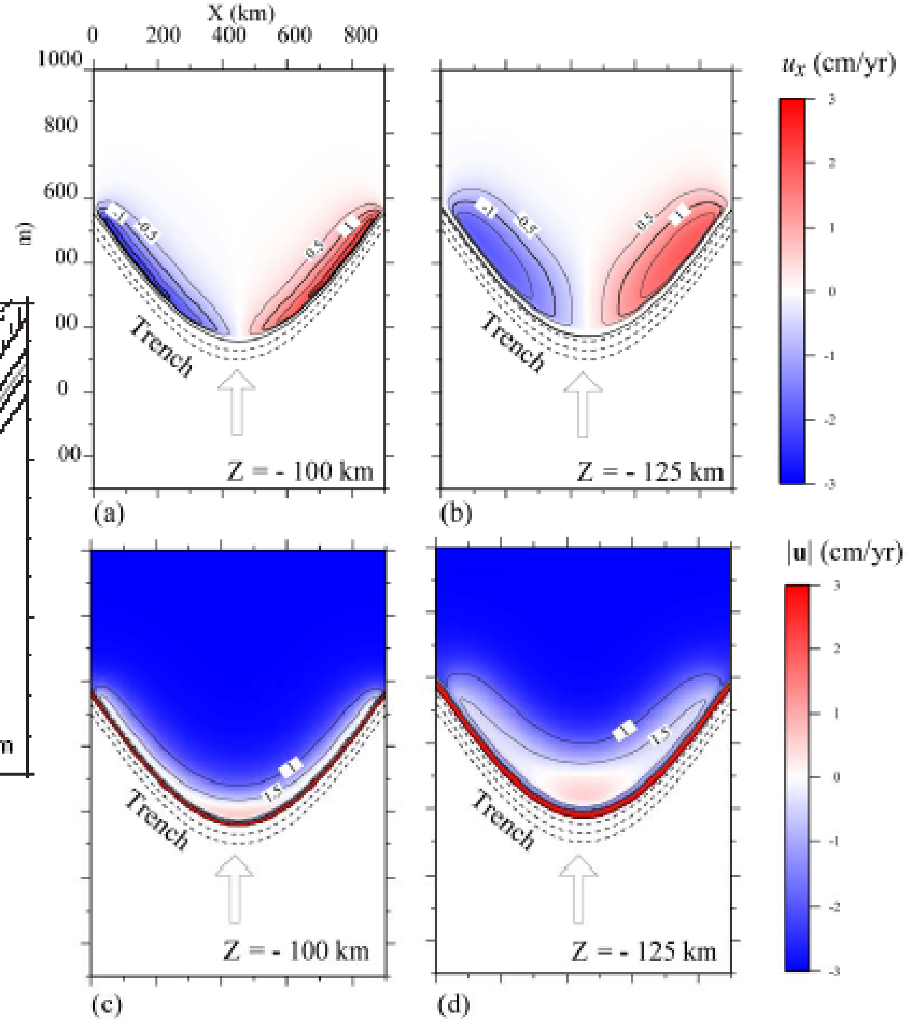
- boundary conditions, which
  - 1. zero normal velocity,
  - 2. zero heat flow and
  - 3. zero tangential stress.

- # Observations and Approximate slab model of the Mariana System



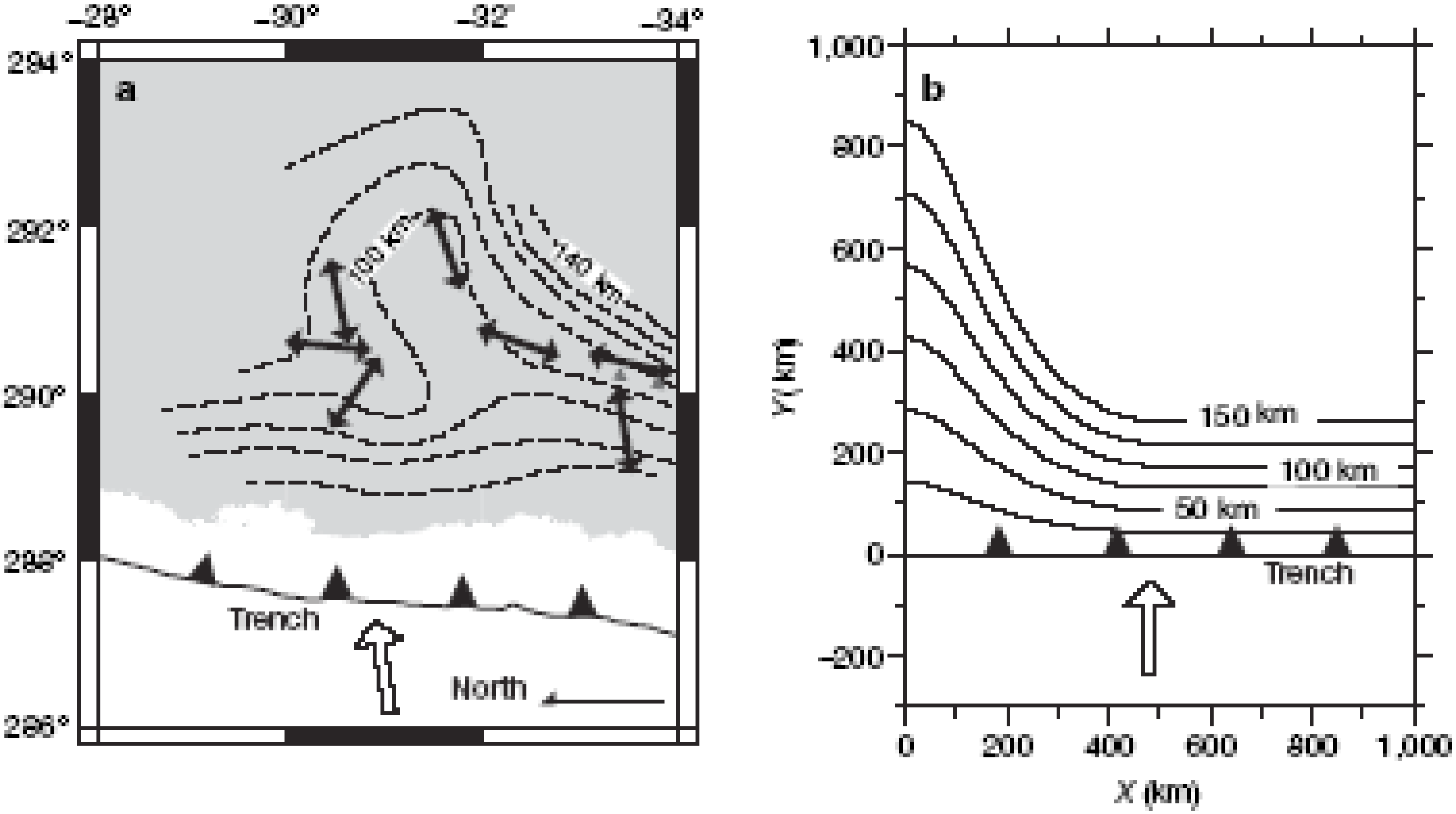
- **Fig 1. Black double arrow shows Finite strain Calculation from the Mariana model**



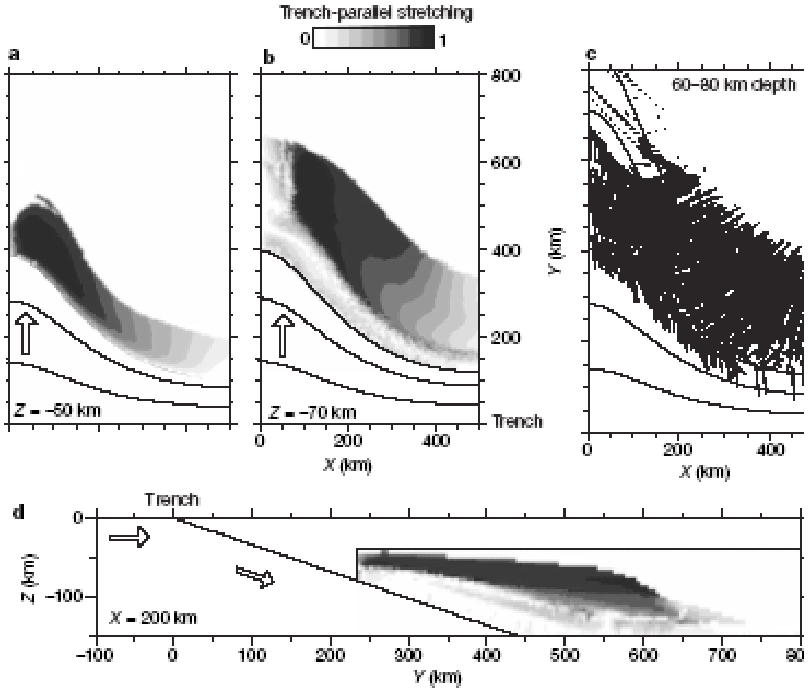


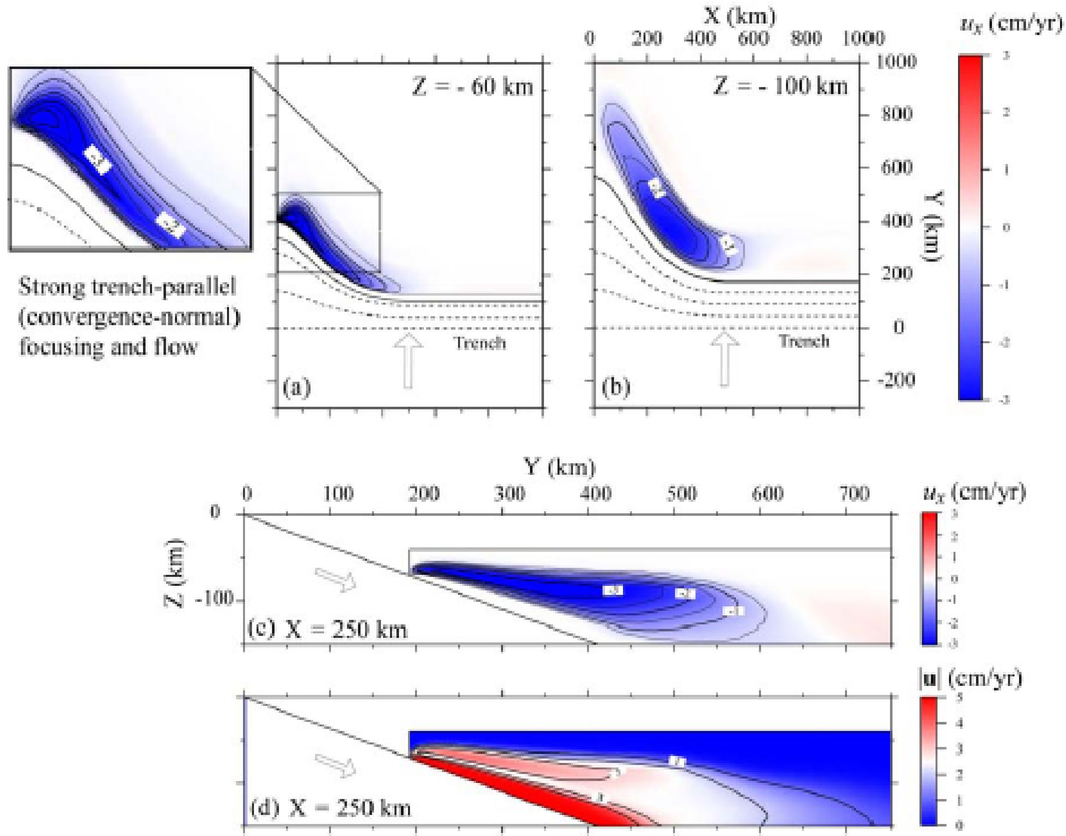
- Fig 2. Finite strain Calculation from the Mariana model

- **Observations and Approximate slab model of the Andean System**



• Andean Model





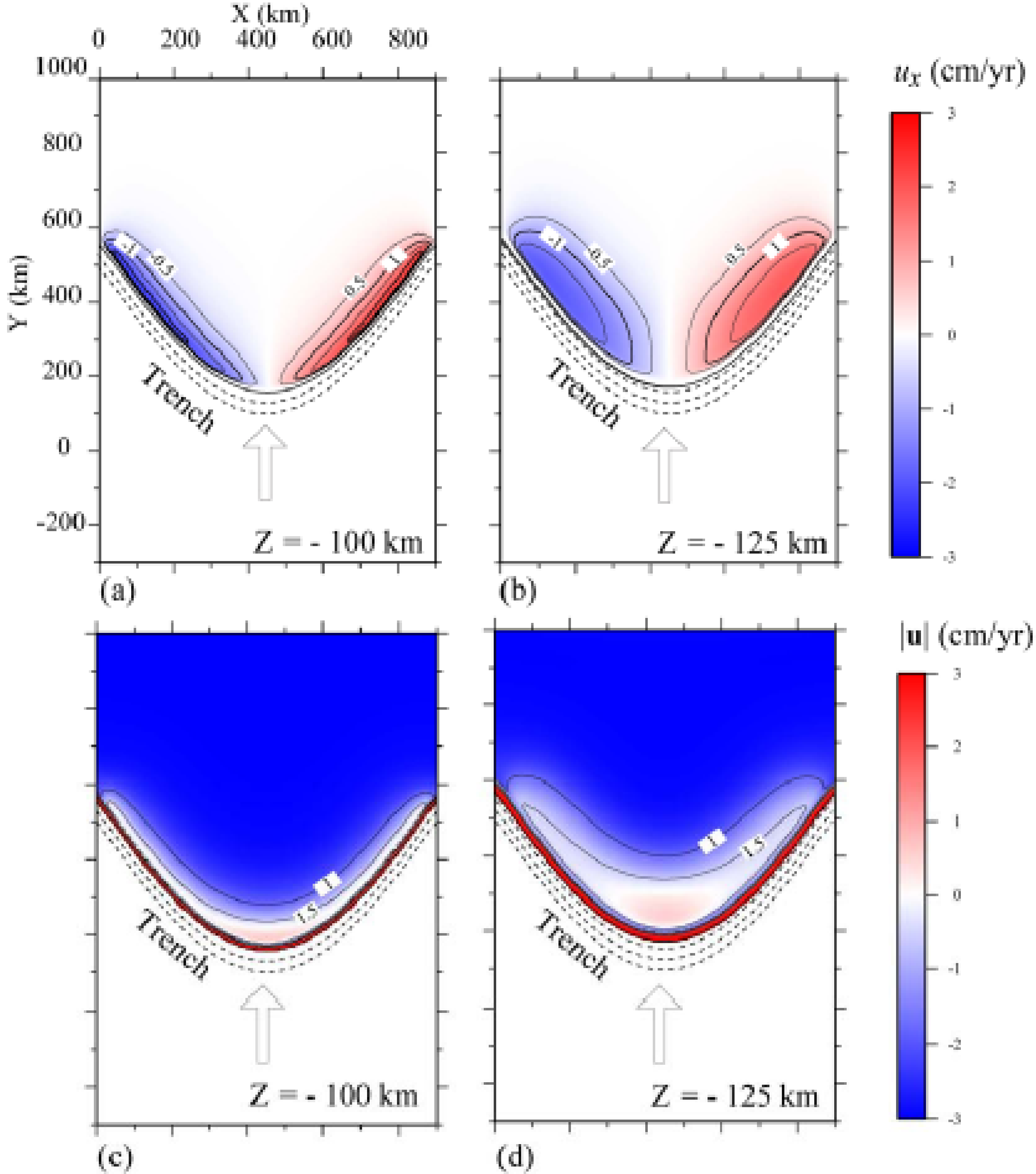
- Fig 4. Finite strain Calculation from the Andean model

Conclusions

- **Anisotropy in the mariana wedge is controlled by three-dimensional stretching induced by slab curvature.**
- **Strong trench –parallel stretching is present in arc mantel of the Andean system**

- **Strong three-dimensional flow exists in the Mariana and Andean subduction systems**

  This flow significantly affects the formation of seismic anisotropy in the mantle wedge.



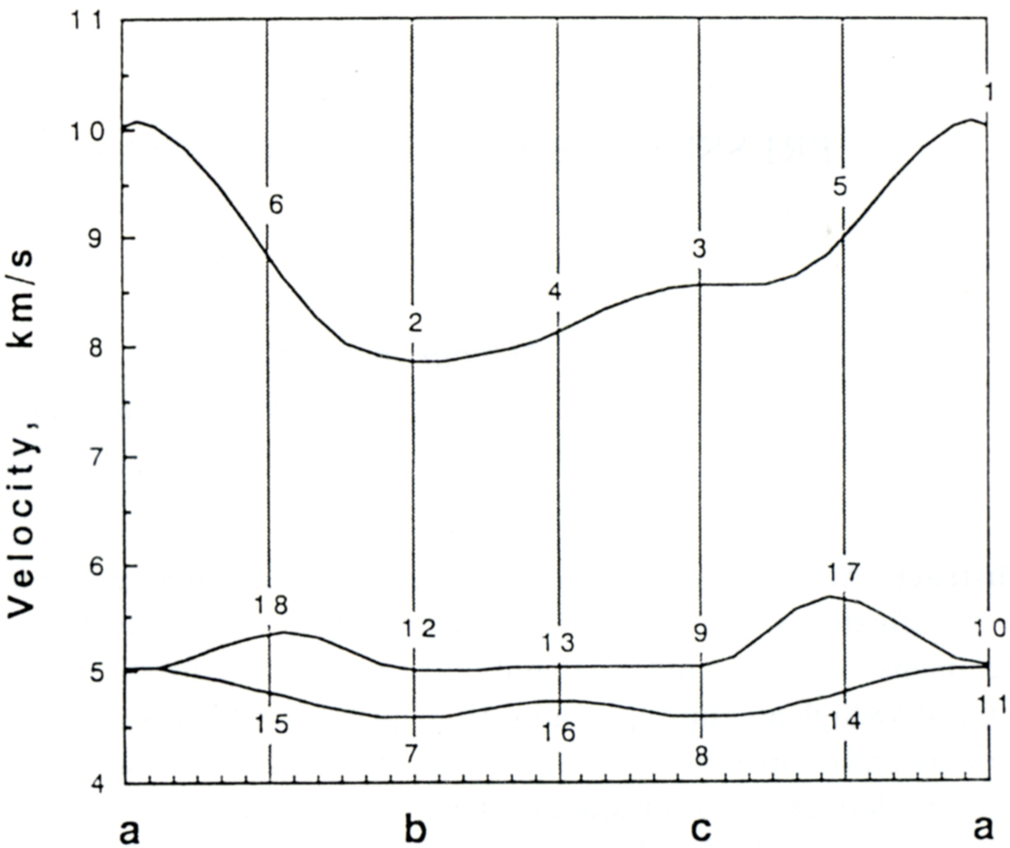
X (km)
0
200
400
600
800
1000
800
600
400
200
0
-200
Y (km)
Trench
Z = - 100 km
Z = - 125 km
(a)
(b)
u_x (cm/yr)
|u| (cm/yr)
(c)
(d)

Thermomechanical **model**.

- Fluid flow in the mantle wedge is governed by the
  - conservation of momentum and
  - mass for an incompressible infinite Prandtl number fluid
  - velocity boundary conditions that are parallel to the surface of the subducting slab.

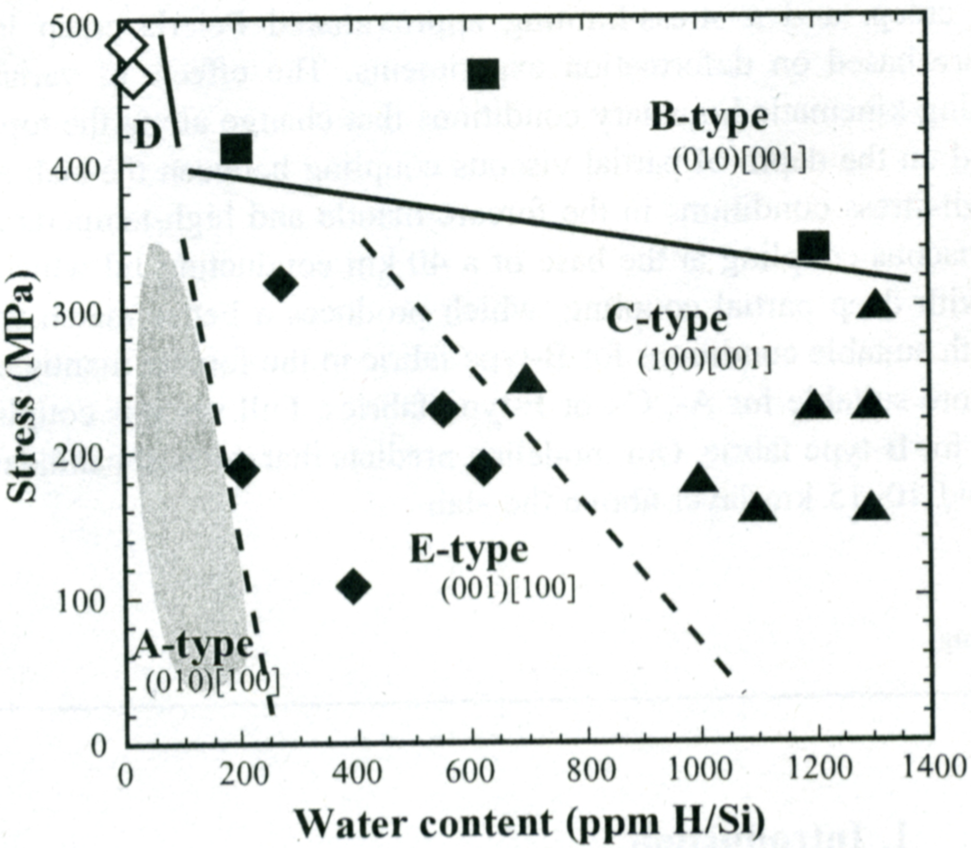
$$\varepsilon_{t,ij} = A\exp(-E/RT)\sigma^{(n-1)}\sigma_{ij}$$

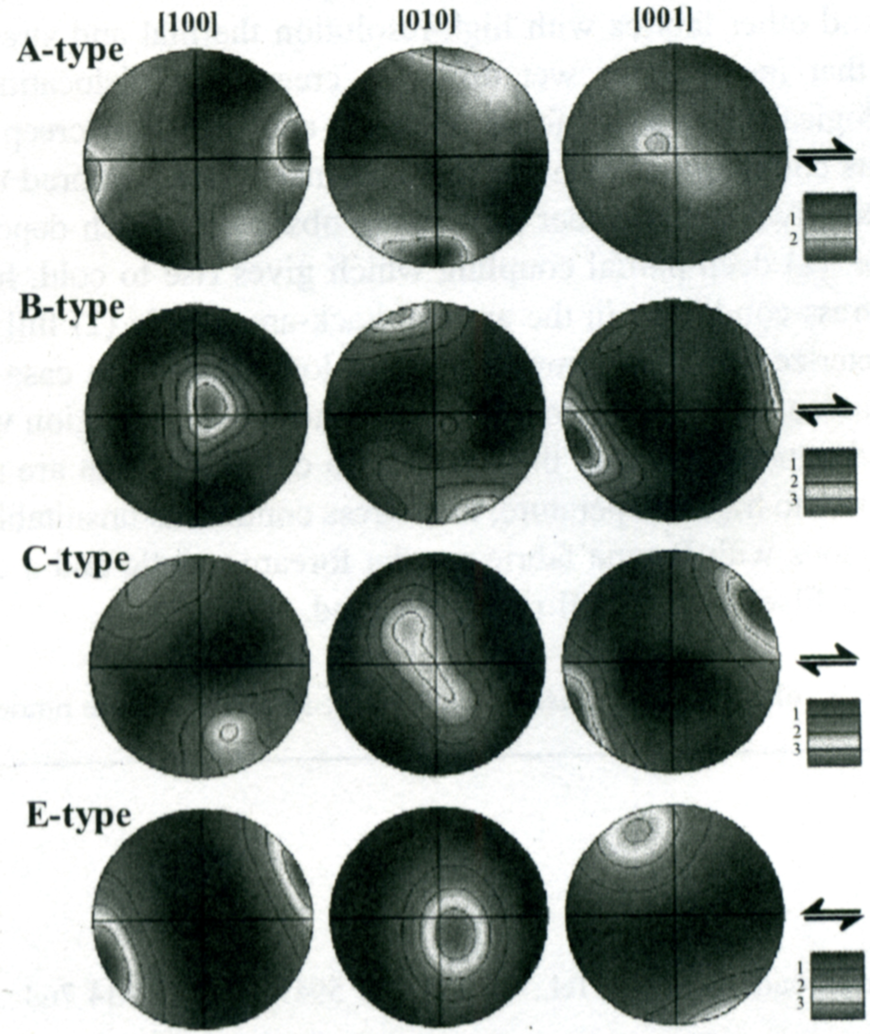
- where $\xi_{t,ij}$ are the components of the strain-rate tensor,
- σ_{ij} are components of the stress tensor,
- σ is the second invariant of the stress tensor,
- T is the absolute temperature, and
- R is the gas constant.
- A=10-11.9 s^{-1} Pa^{-3}, E=510 kJ mol^{-1} and n=3



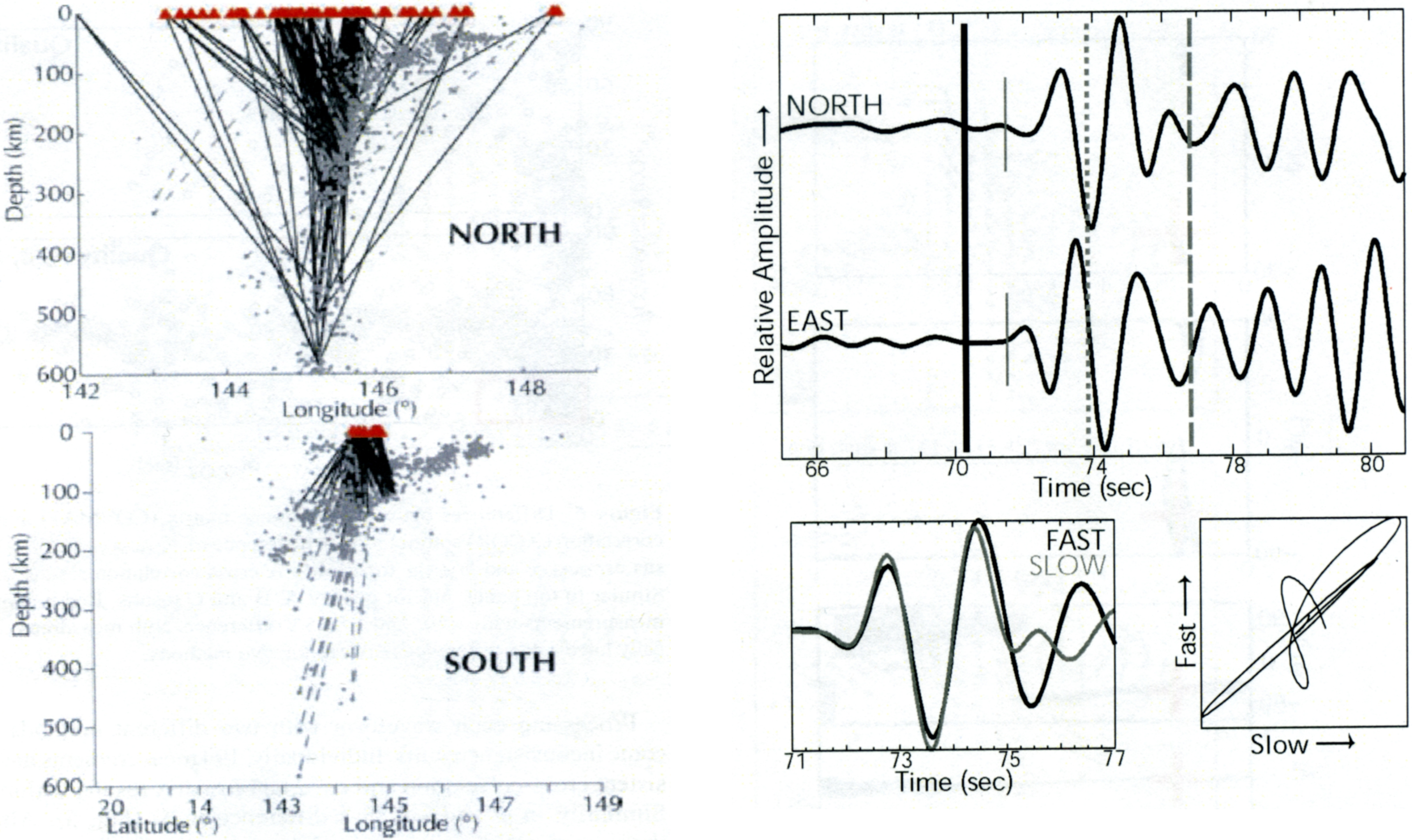
- Acoustic wave velocity of Fosterite on different crystallographic directions (Yoneda at el 1990)

Fabric map of Olivine for high temperature





- Kneller et al 2005



NORTH
Depth (km)
0
100
200
300
400
500
600
142
144
146
148
Longitude (°)
SOUTH
Depth (km)
20
14
143
145
147
149
Latitude (°)
Longitude (°)
NORTH
EAST
Relative Amplitude
66
70
74
78
80
Time (sec)
FAST
SLOW
71
73
75
77
Time (sec)
Fast
Slow