Seismotectonics and seismic tomography

Wasja Bloch

GFZ German Research Center for Geosciences, Potsdam, Germany

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CLIENT II
International Partnerships for Sustainable Innovations

CATENA
CLIMATIC AND TECTONIC NATURAL HAZARDS IN CENTRAL ASIA

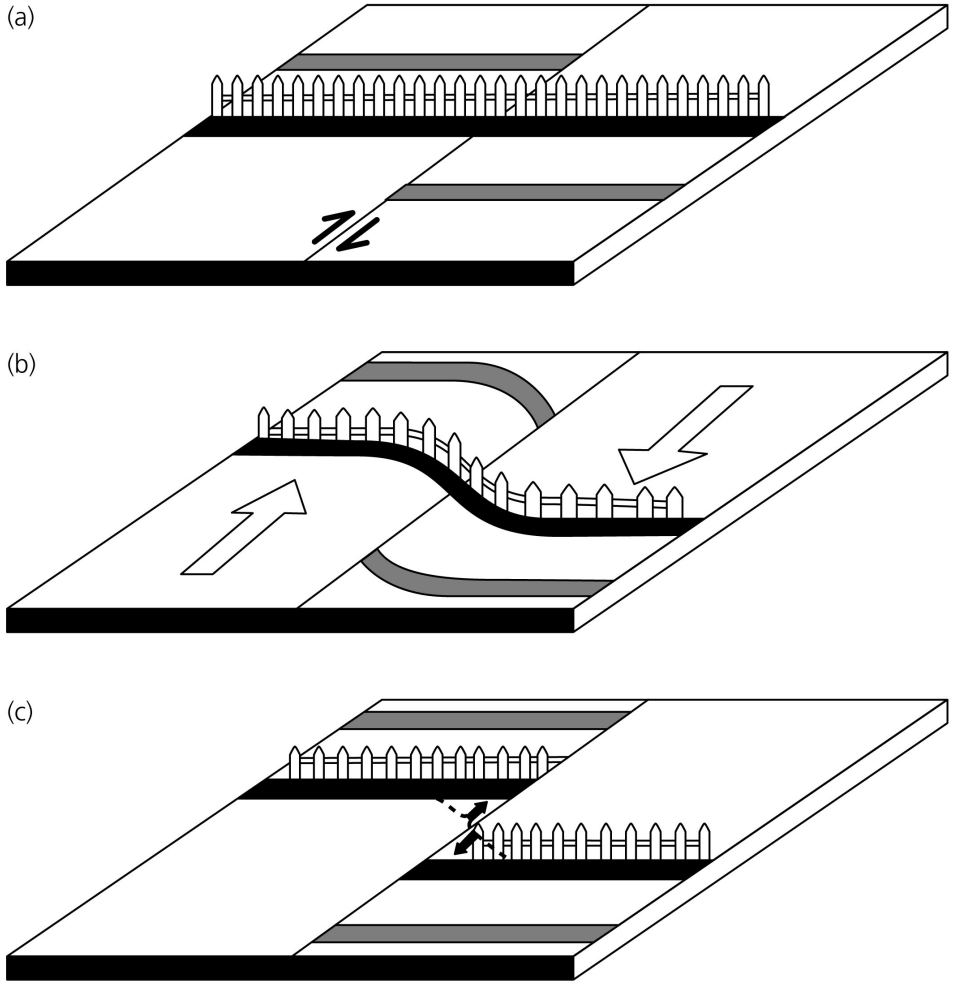
GFZ Helmholtz-Zentrum Potsdam

Introduction

1995 M_w 6.9 Kobe earthquake

- Offset: 1.5 m dextral (to the right) and 1.2 m upward
- Due to convergence between Eurasia and Philippine plate
- 17 km depth, 20 km away from Kobe, Japan (Population: 1.5 million)
- 6.434 casualties

Introduction



Stein and Wysession (2009)

(a) Tetonic units move relative to each other

(b) Elastic stress and strain accumulates inside the rock

(c) When a critical stress state is reached:

The rock fails and elastic energy is released

$$\text{Energy} = \text{Shear modulus} \cdot \text{Offset} \cdot \text{Area}$$

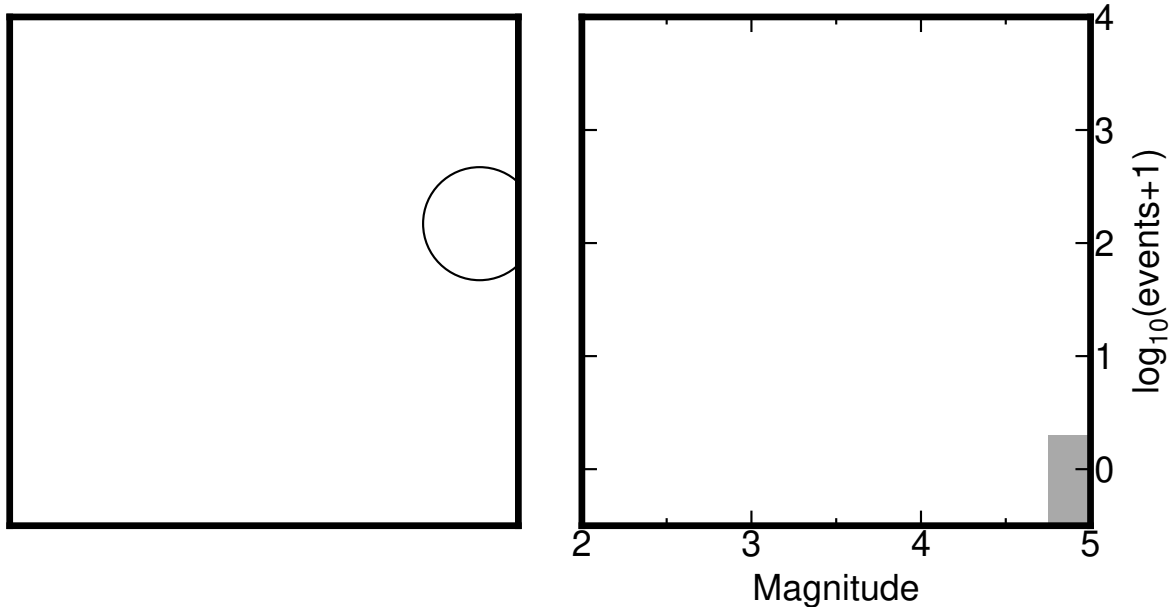
$$30\text{GPa} \cdot 1.5\text{m} \cdot 40\text{km} \cdot 10\text{km} = 1.8 \cdot 10^{19} Nm$$

Gutenberg-Richter relationship

$$\log N = a - bM$$

N: Number of earthquakes with magnitude M
M: Earthquake magnitude
a: Number of earthquakes with $M = 0$
b: Gutenberg-Richter b-value, approx. 1.

For each unit decrease in magnitude the number of earthquakes increases by a factor of 10.



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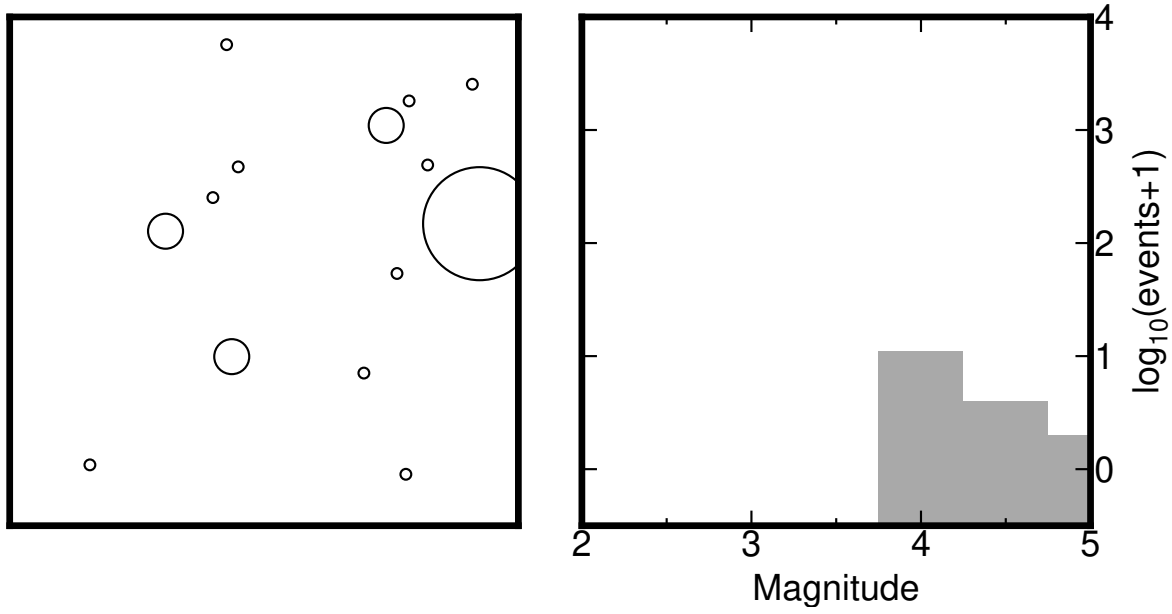

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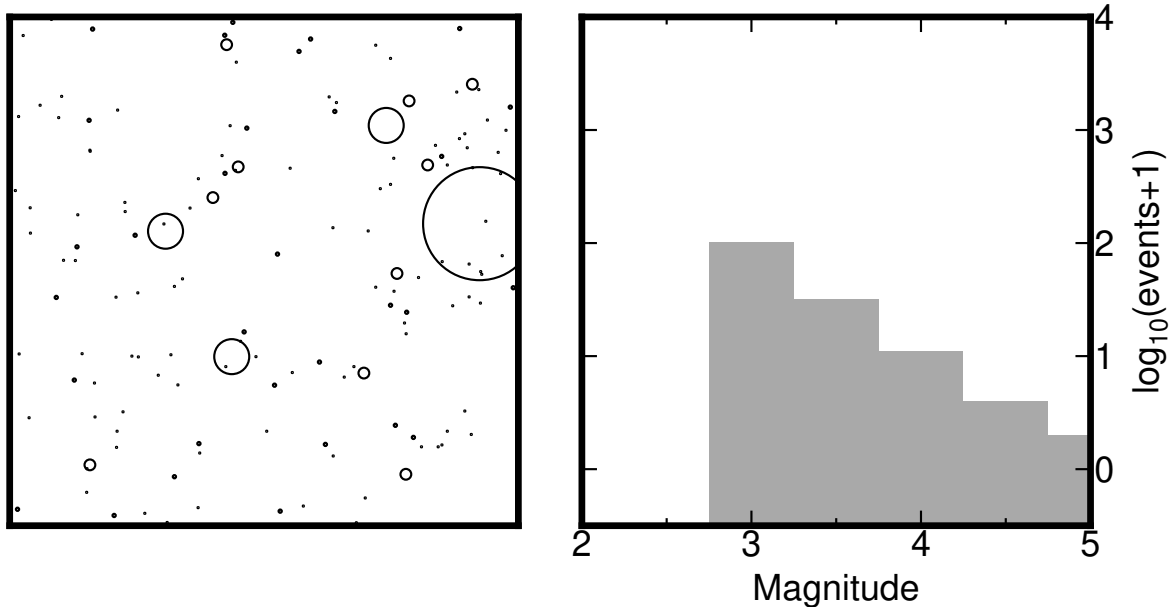

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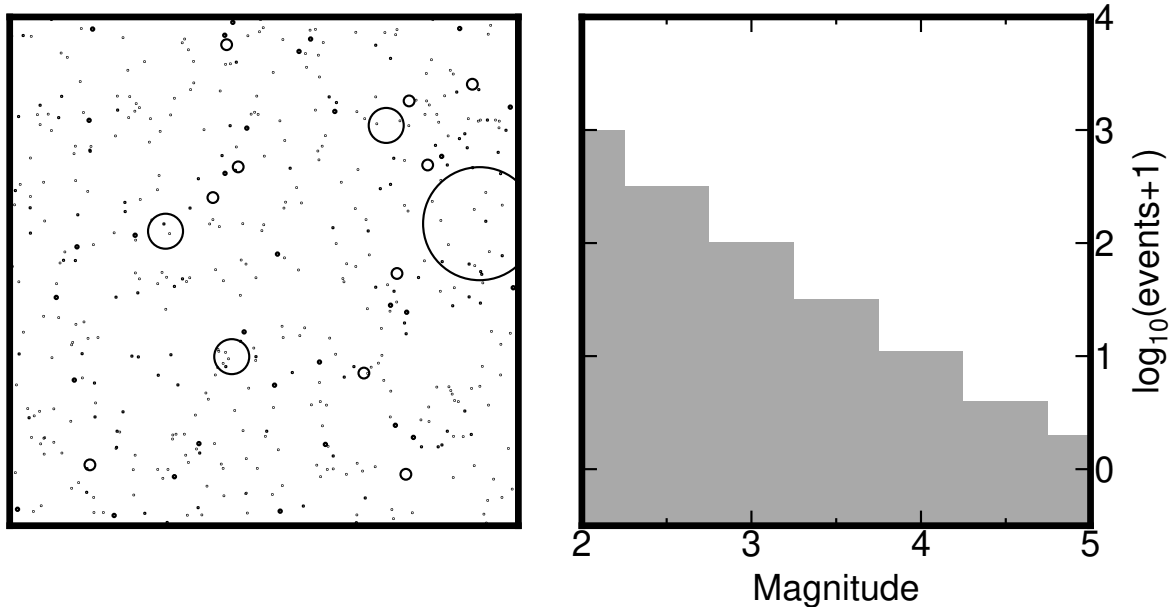
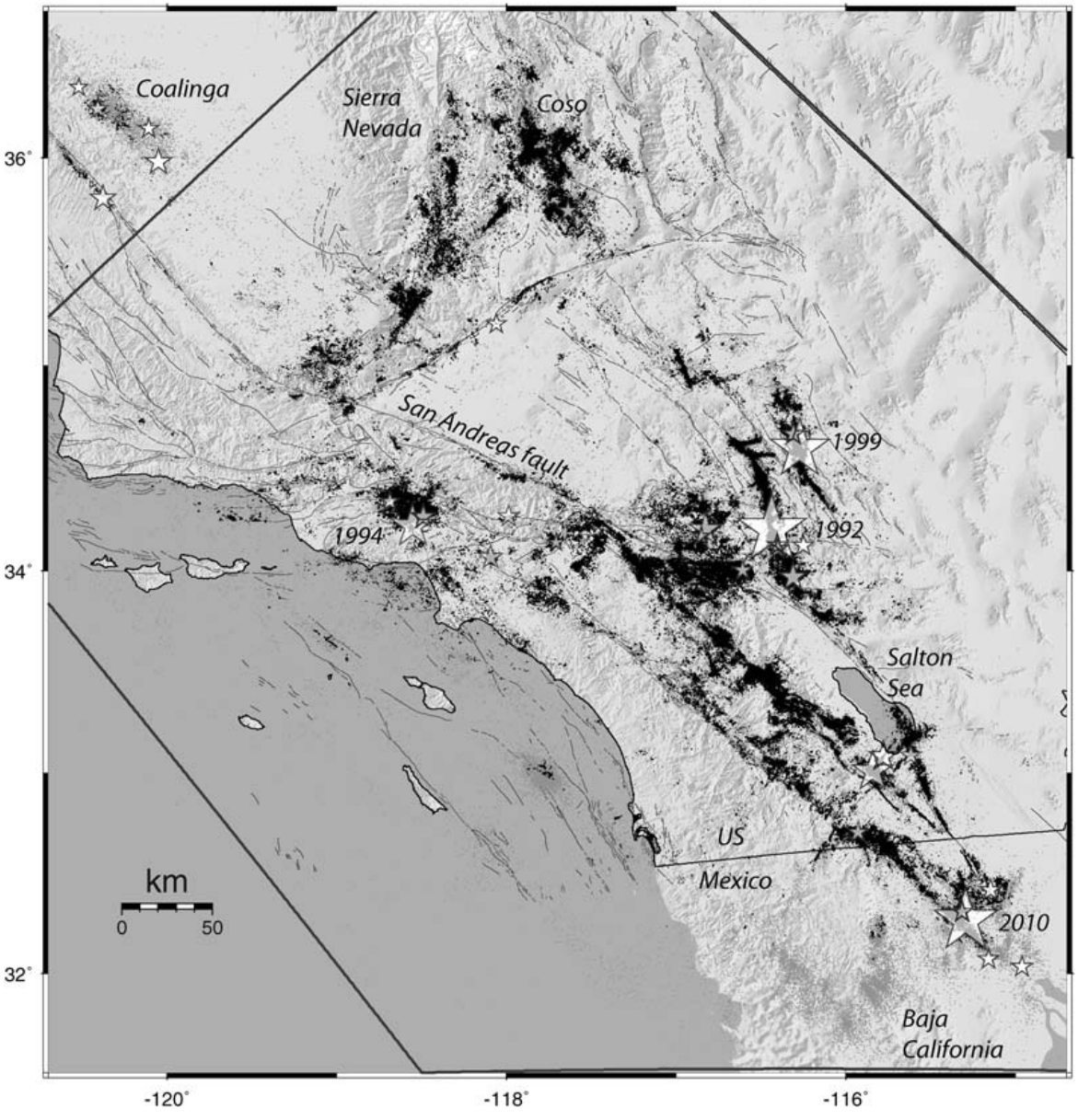


Seismicity

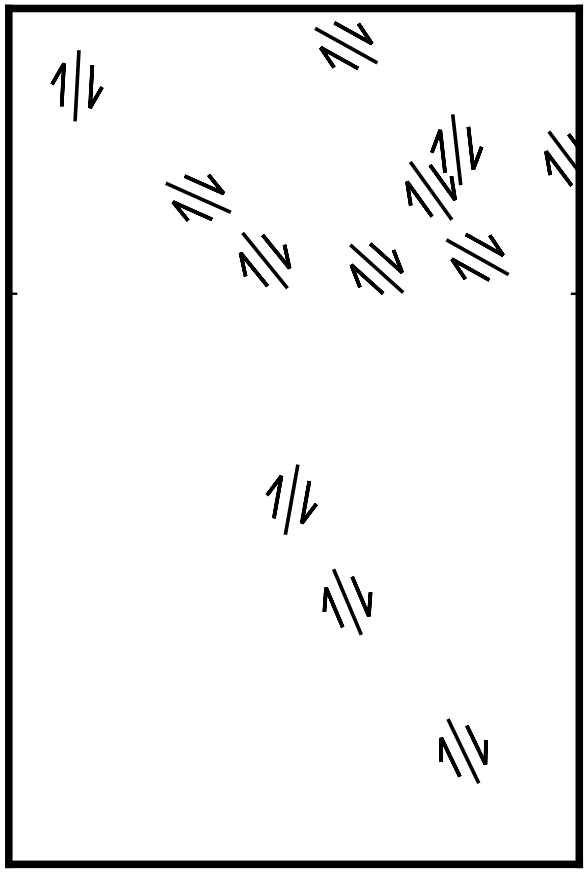


Hauksson et al. (2012)

Precisely relocated seismicity in southern California, USA 1981 – 2011

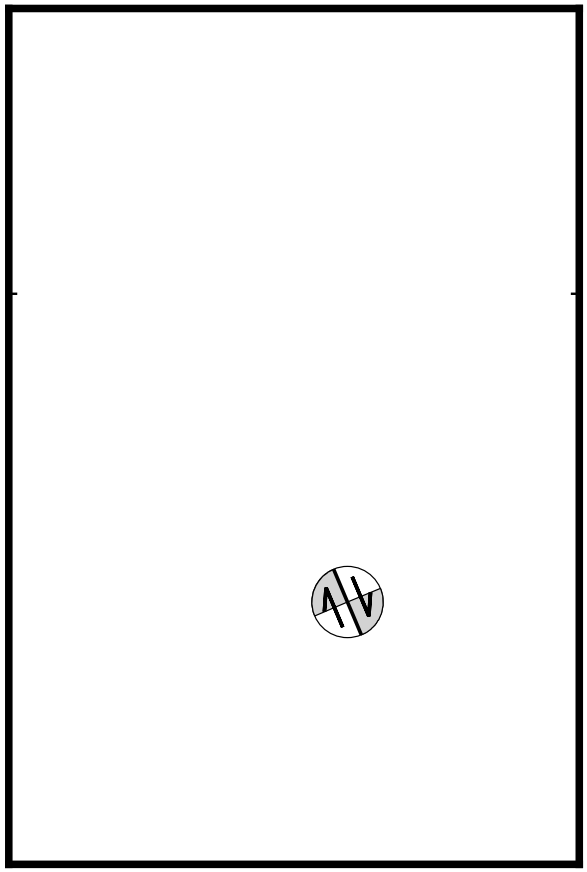
- Small earthquakes deliniate fault zones
- Aftershock activity of large earthquakes indicates rupture extent
- e.g. 1992 M_w7.2 Landers earthquake

Focal mechanisms and stress



Earthquake focal mechanisms can be used to estimate the regional stress field

Focal mechanisms and stress



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- The focal mechanism of an earthquake is ambiguous
  - There are two possible fault planes
  - The dark (‘compression‘) quadrants move away from the source
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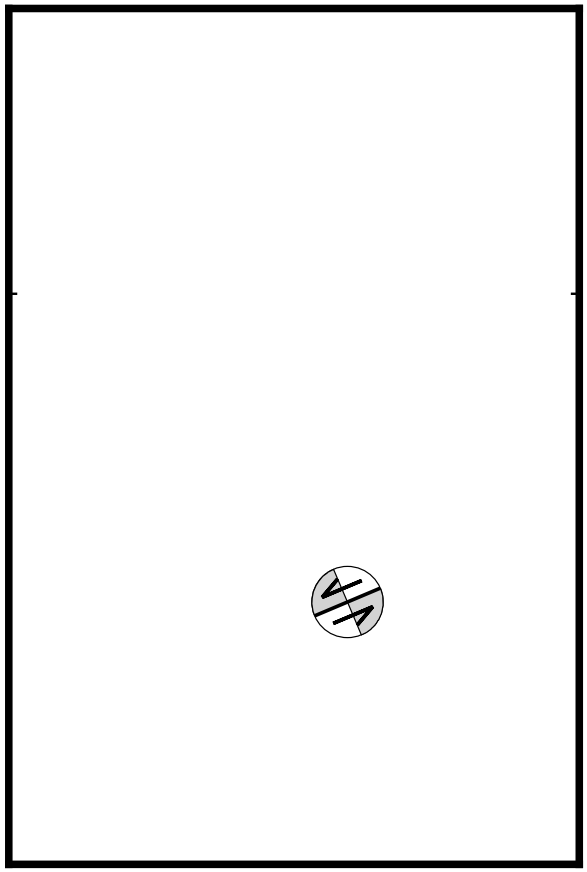

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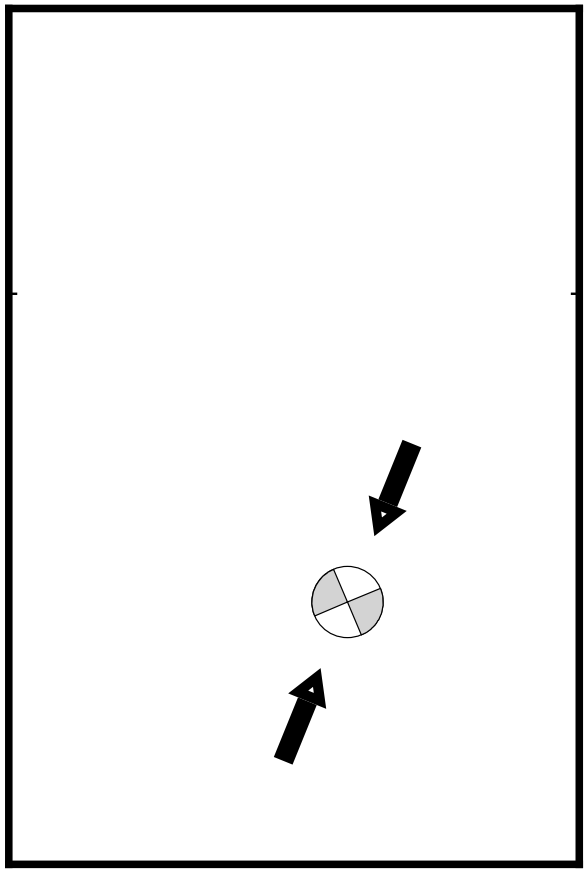

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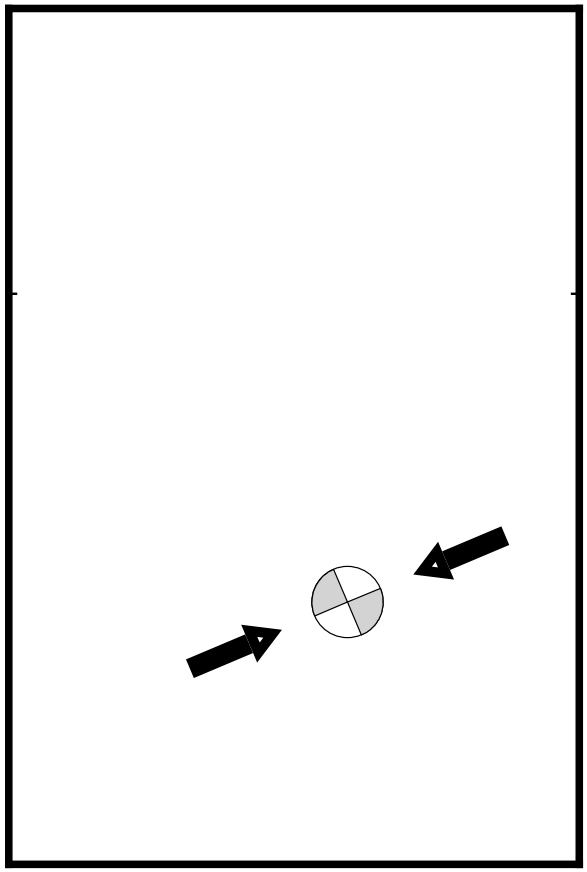

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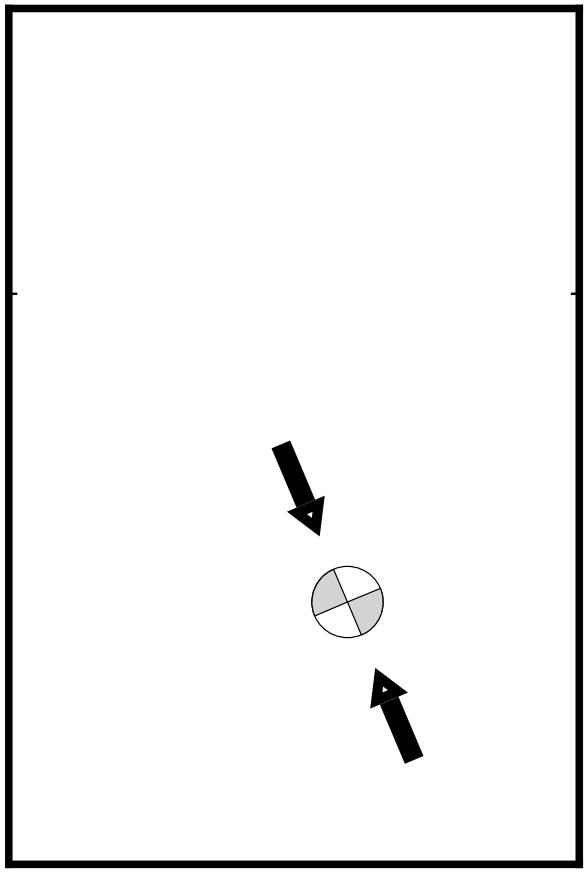

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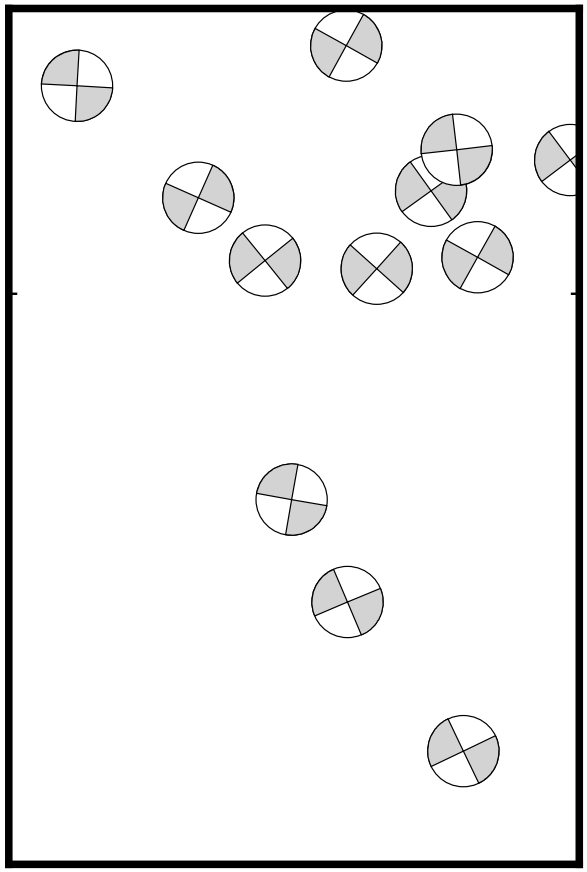

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Assumption: Fault slip is parallel to tangential traction

(highest principal stress projected onto the fault plane)

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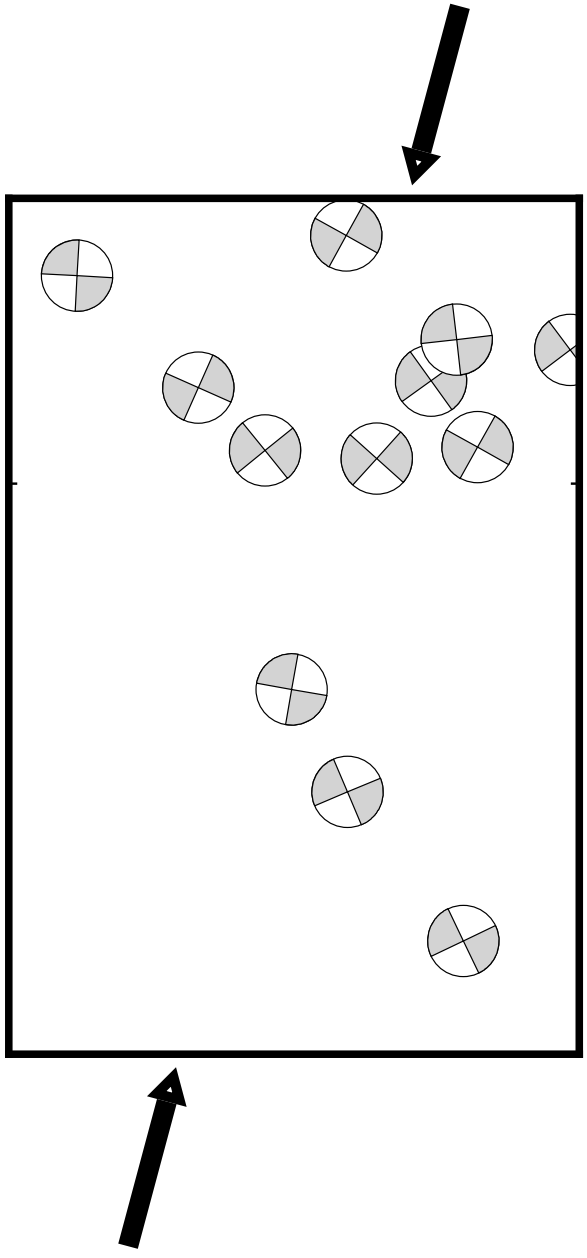

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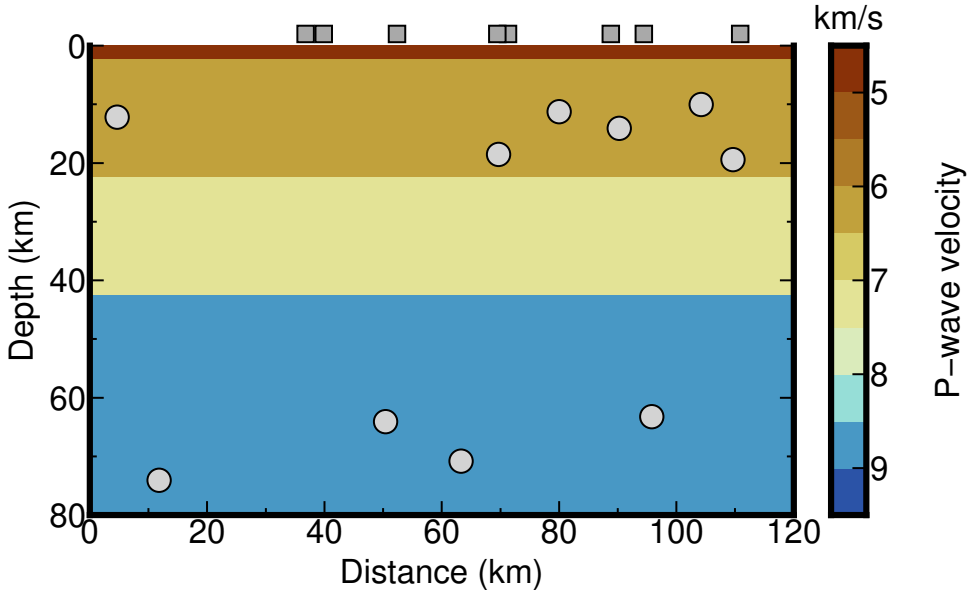
- Applying this assumption to many focal mechanisms allows the determination of a best fitting regional stress field

Seismic tomography

The arrival times of earthquake waves can be used to estimate the subsurface velocity structure.



- Seismic stations at the surface
- Earthquakes in the crust an in the mantle
- Typical velocity structure of the continental crust:
  - <5 km/s Sediments
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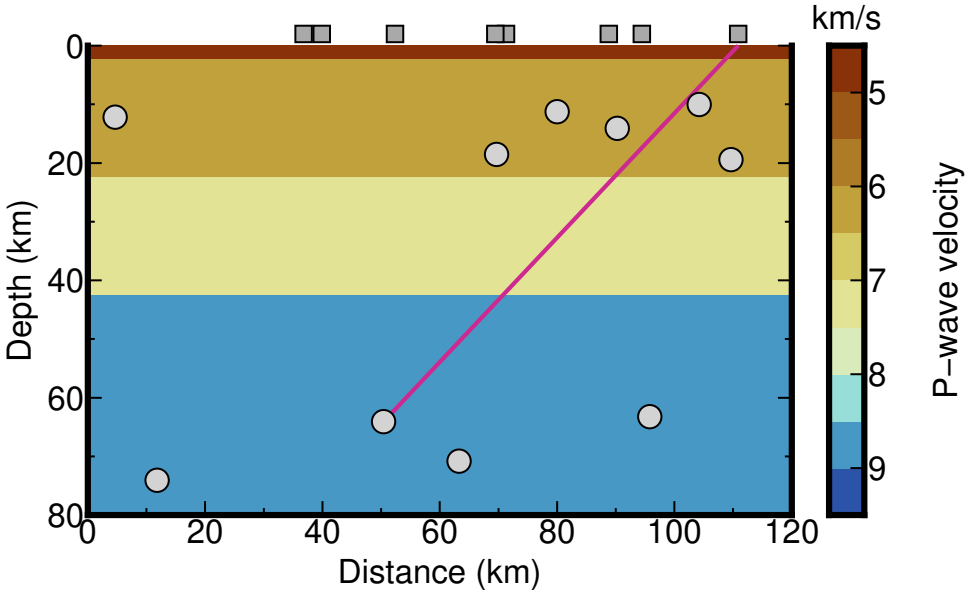

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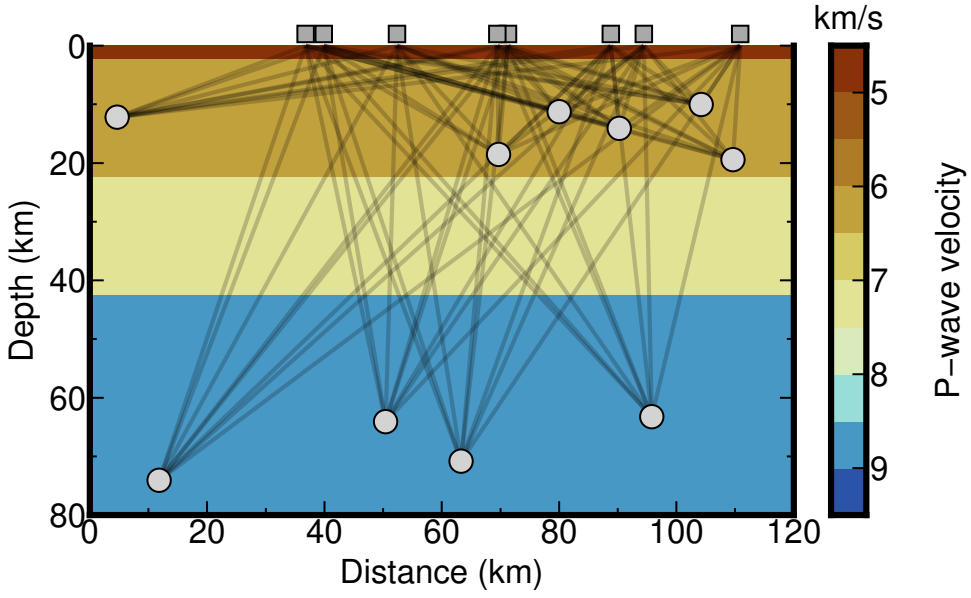

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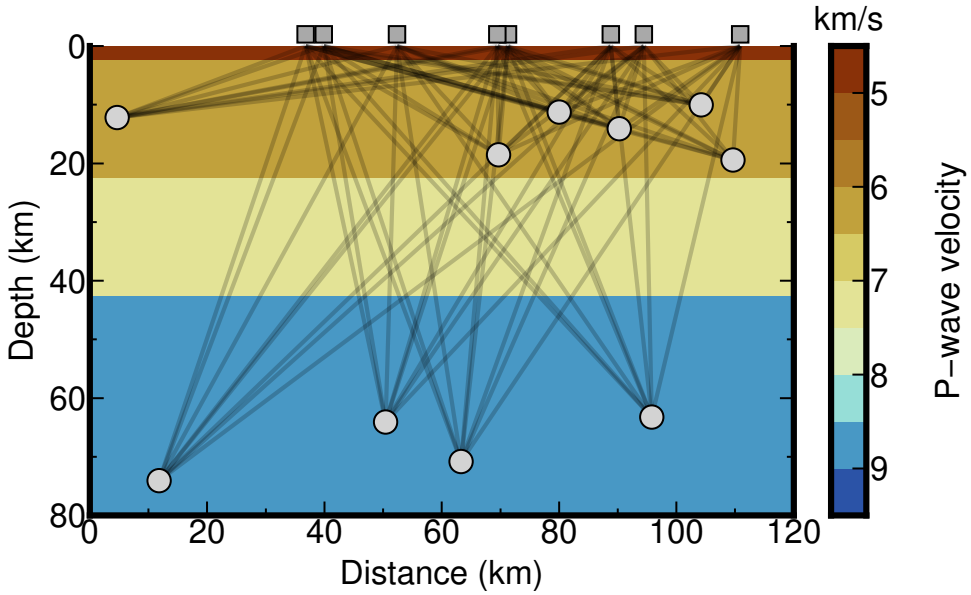

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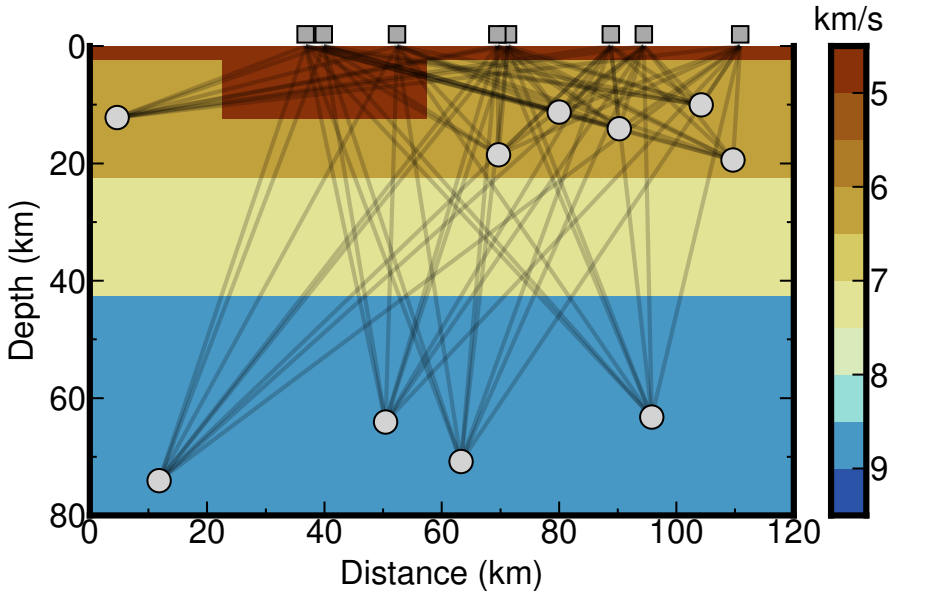

A sedimentary basin in the left of the profile

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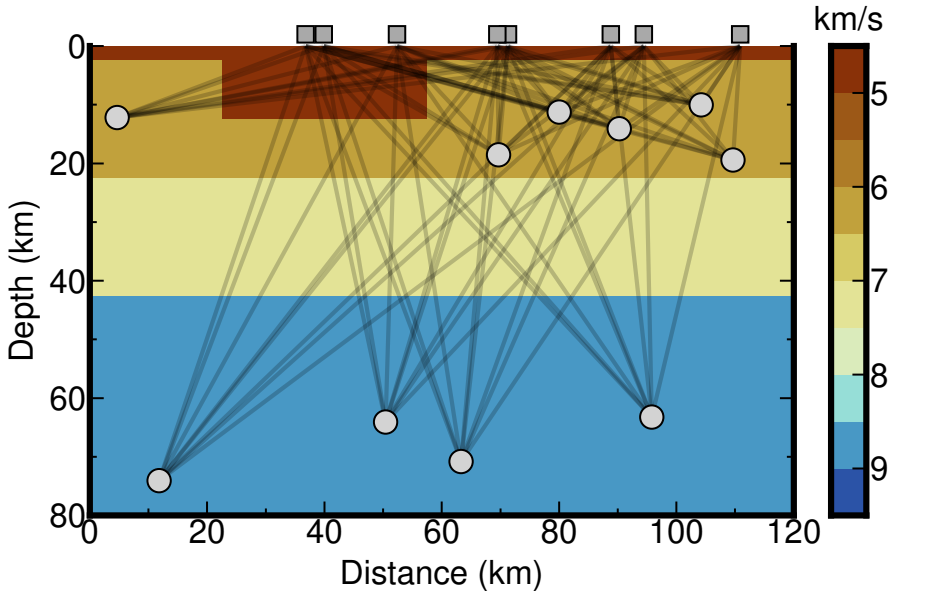

A sedimentary basin in the left of the profile

- Later arrivals at the 3 stations on the left

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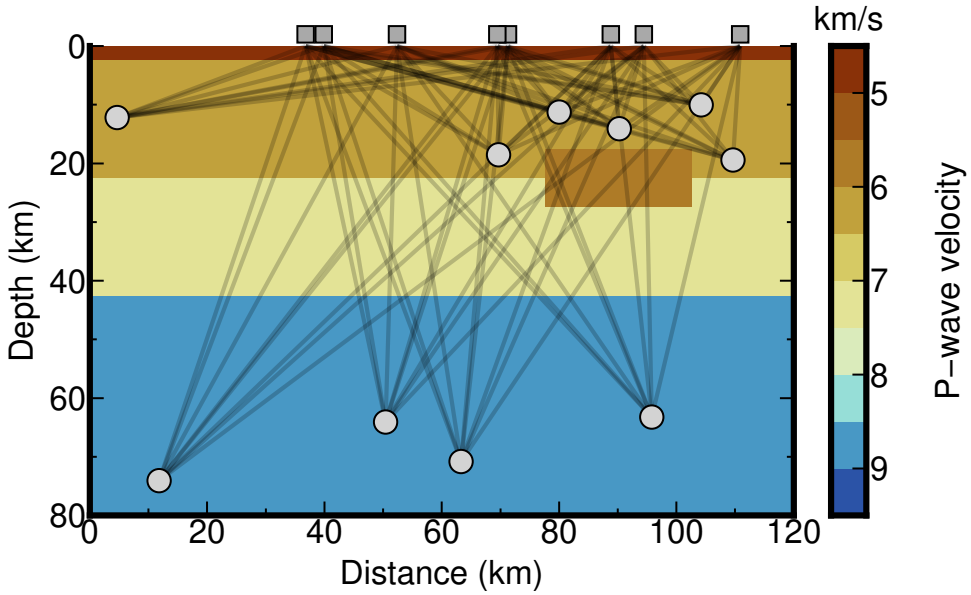

A mid crustal magma chamber

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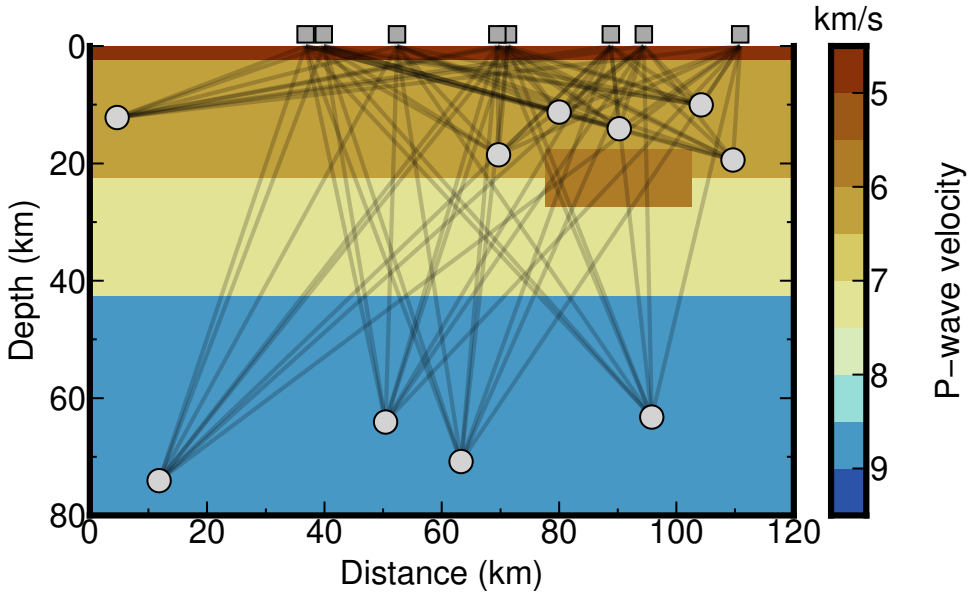

A mid crustal magma chamber

- Unchanged arrivals from crustal earthquakes
- Later arrivals from mantle earthquakes at right hand side stations

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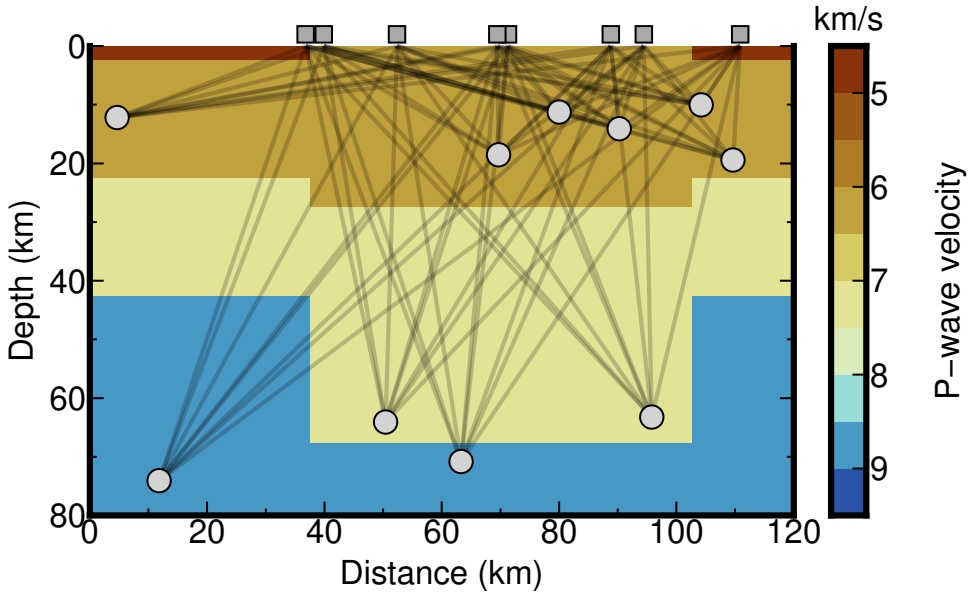

A thick crustal mountain root

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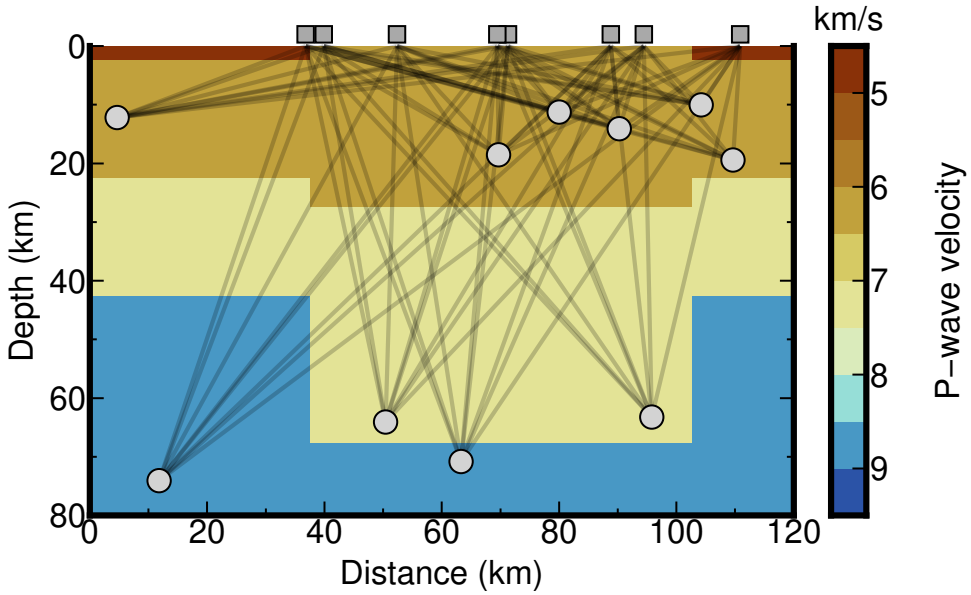
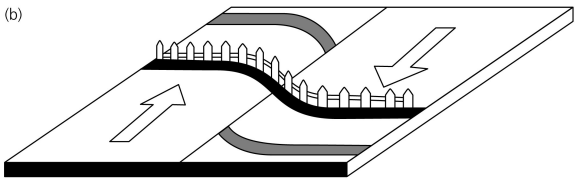


A thick crustal mountain root

- Later arrivals from mantle earthquakes at all stations

Summary



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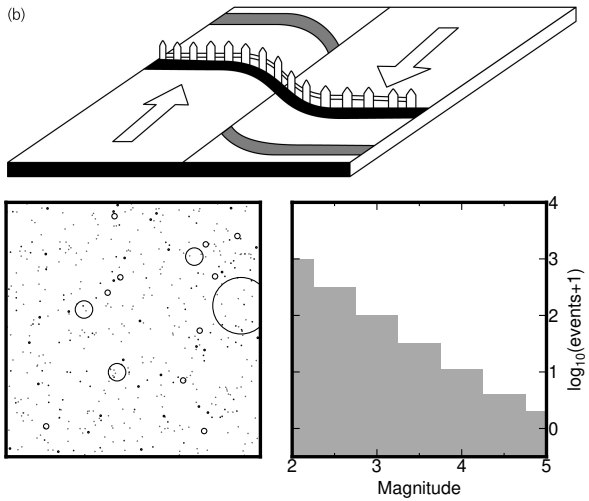

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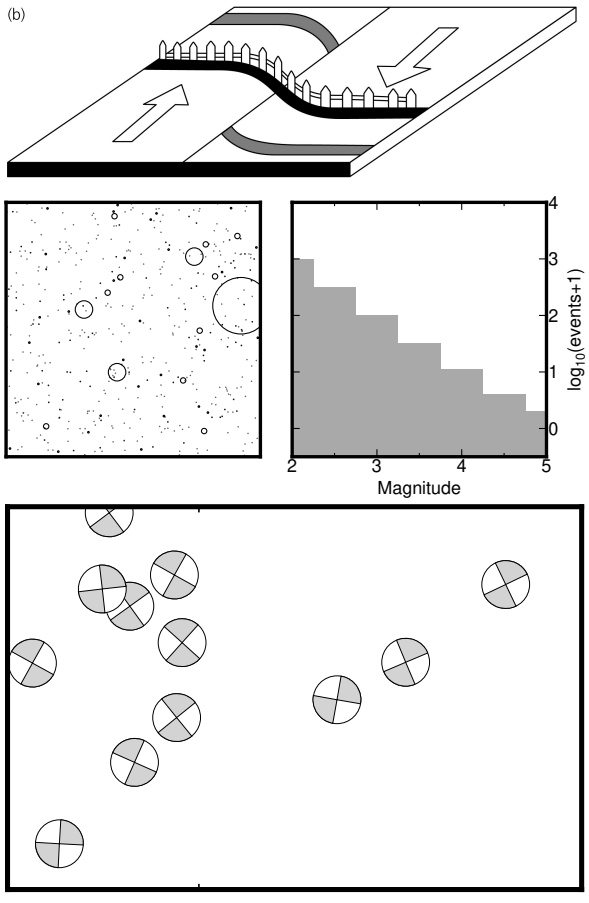

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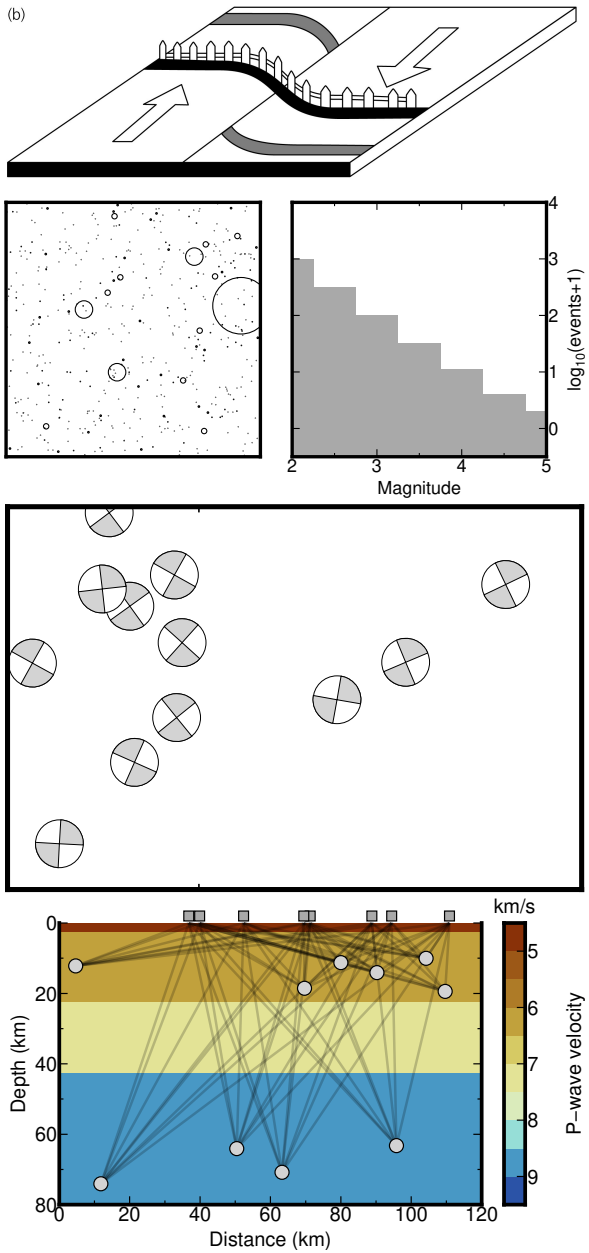

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- Arrival times of seismic waves allow the estimation of the subsurface velocity structure

References

Hauksson, E., Yang, W., and Shearer, P. M. (2012). Waveform relocated earthquake catalog for southern california (1981 to june 2011). *Bulletin of the Seismological Society of America*, 102(5):2239–2244.

Stein, S. and Wysession, M. (2009). *An introduction to seismology, earthquakes, and earth structure*. John Wiley & Sons.