The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

IAEA International Atomic Energy Agency

2464-37

Earthquake Tectonics and Hazards on the Continents

17 - 28 June 2013

Regional synthesis: Middle East Tectonics and Hazard

P. England

University of Oxford
UK

Strada Costiera, 11 - 34151 - Trieste - Italy • Tel. +39 0402240111 • Fax. +39 040224163 • sci_info@ictp.it • www.ictp.it
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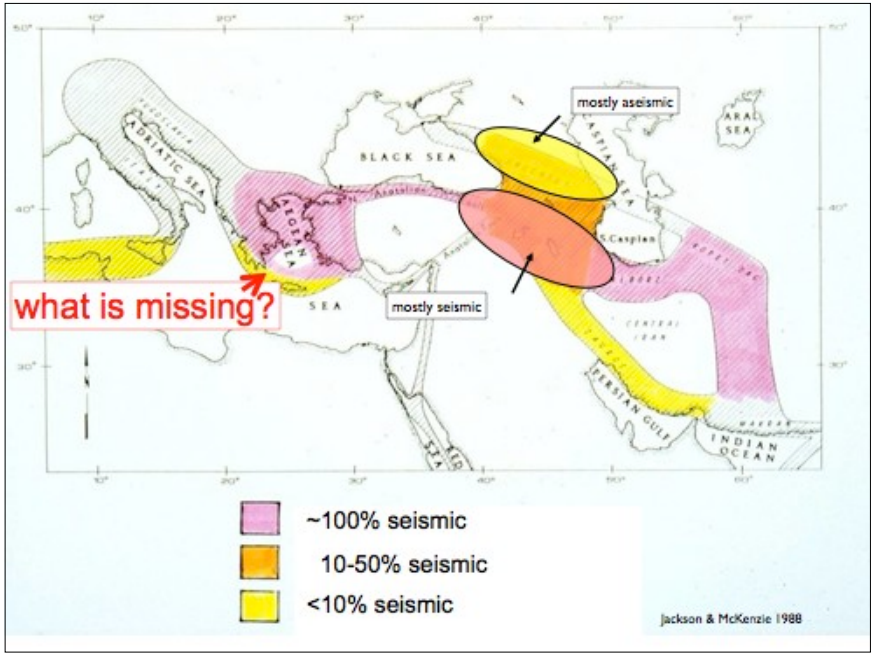
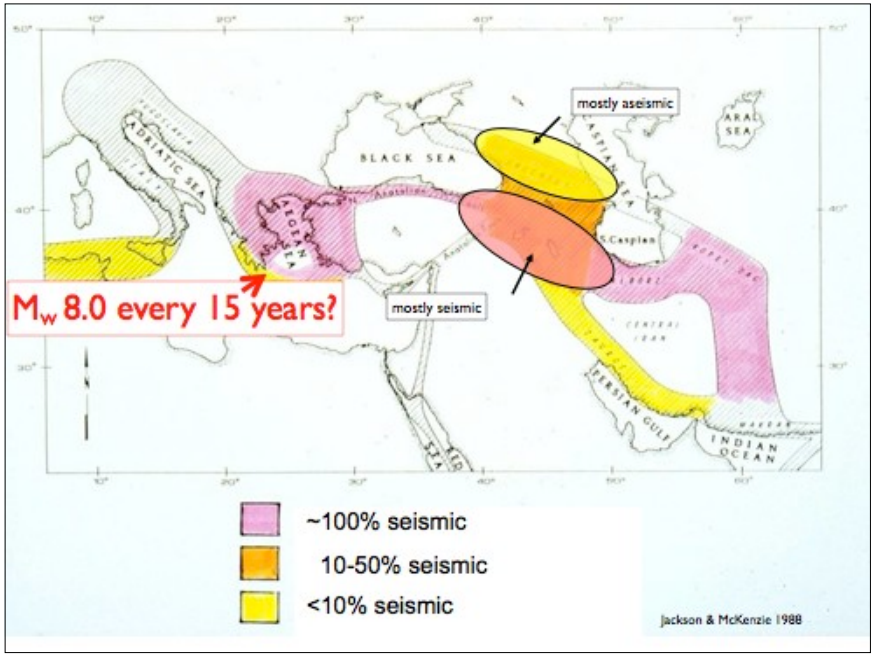


Devastating earthquake and tsunami: July 21 AD365 Alexandria

there was an earthquake such as had never been since the beginning of the world. The sea was agitated and ***threw above the walls of the city*** *some boats which landed in the middle of houses. The* ***sea abandoned its place, and dry land appeared****; the ships were stranded and the people went to pillage them;* ***but the sea flowed back*** *over them and engulfed them.*' (Mich. Syr. vii. 7/i. 292).[13]

'*I heard (and the entire city testifies to this) that when the seas* ***overran the shores*** *of the whole world during my childhood, the walls of a certain Areopolis* (sic is located near the Dead Sea) *collapsed on the same night.*' (Hieronym. Hist. *Comment. ad Ess*. 185/168). [5th]

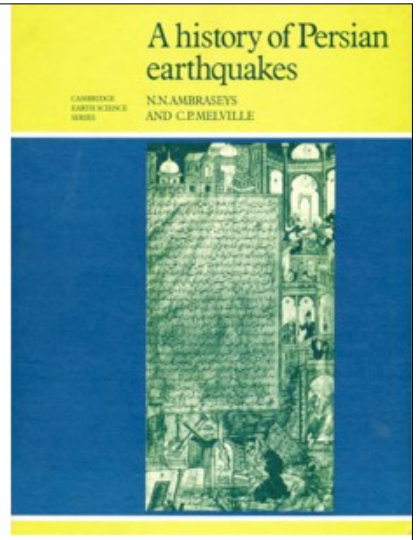


Historical earthquake catalogue

Is it complete? Above what magnitude?
How to interpret silence?

Is it accurate: dates? locations? magnitudes?

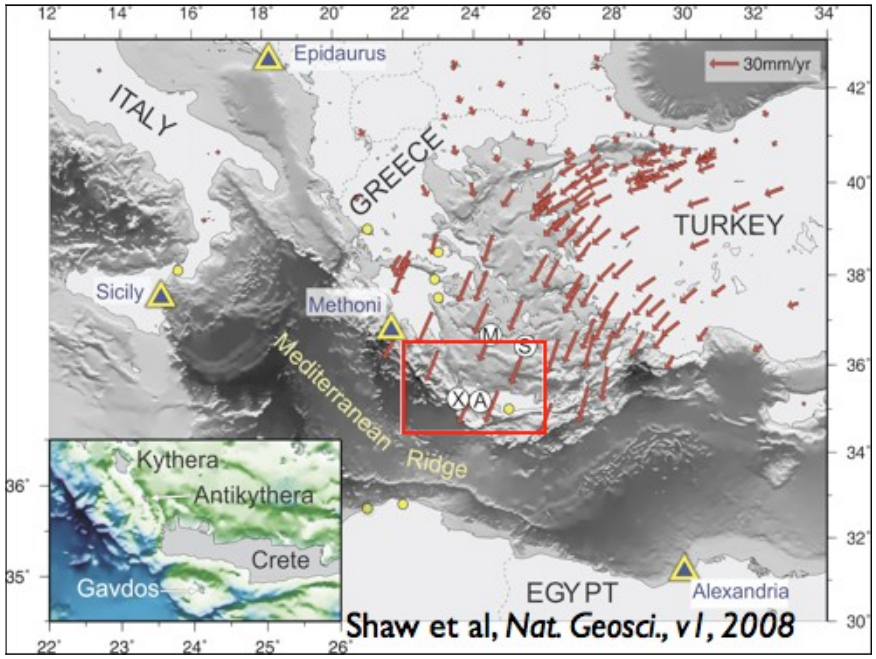
How to interpret the historical accounts: Are they exaggerated



Necessary skills:
Languages
History
Engineering/seismology/Geology

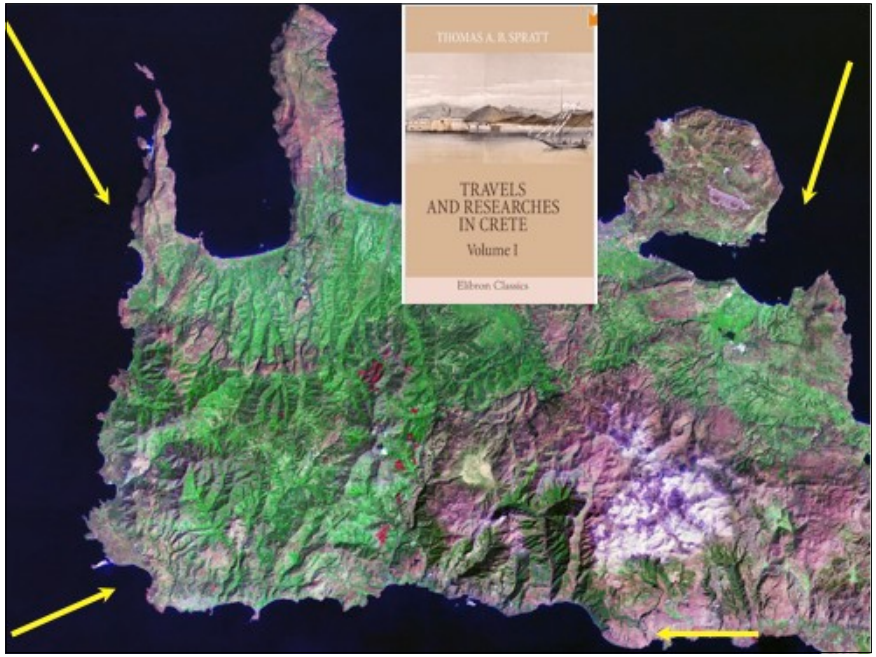
GHEA Global Historical Earthquake Archive

A GEM HAZARD GLOBAL COMPONENT

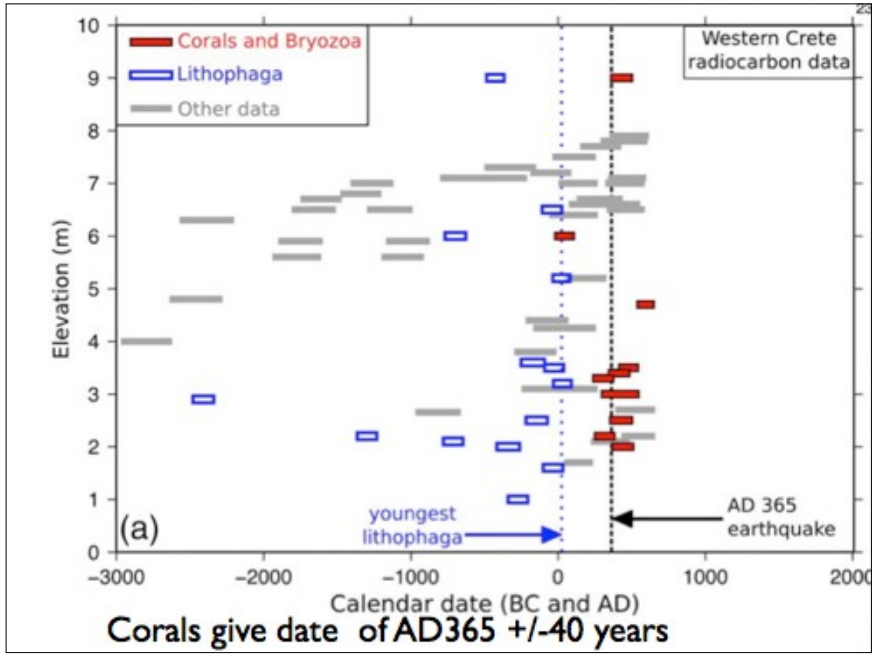


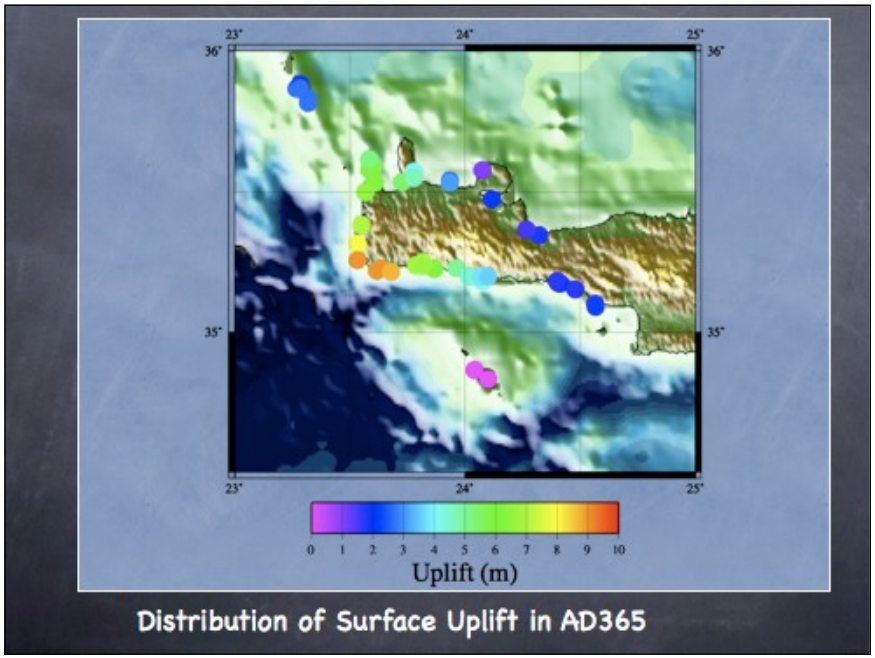
Hence, many ships were stranded as if on dry land, and … many men roamed without fear in the little that remained of the waters, to gather fish and similar things with their hands…… the great mass of waters, returning when it was least expected, killed many thousands of men by drowning; and ….. the lifeless bodies of shipwrecked persons lay floating on their backs or on their faces.

Ammianus Marcellinus, writing after AD 378:

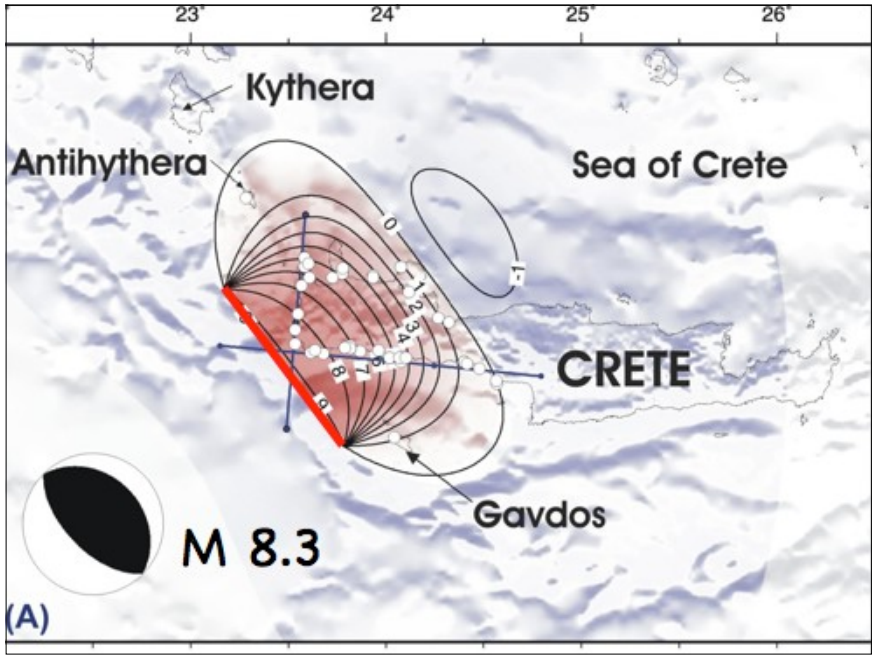


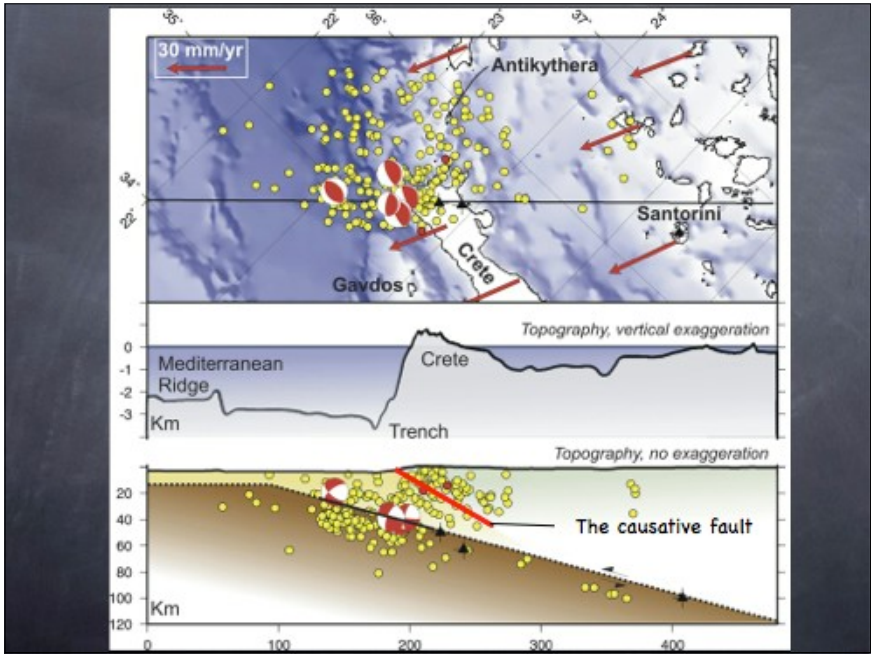

~3m


Corals and Bryozoa
Lithophaga
Other data
Western Crete
radiocarbon data
Elevation (m)
10
9
8
7
6
5
4
3
2
1
0
(a)
youngest
lithophaga
AD 365
earthquake
−3000
−2000
−1000
0
1000
2000
Calendar date (BC and AD)
Corals give date of AD365 +/-40 years



Distribution of Surface Uplift in AD365



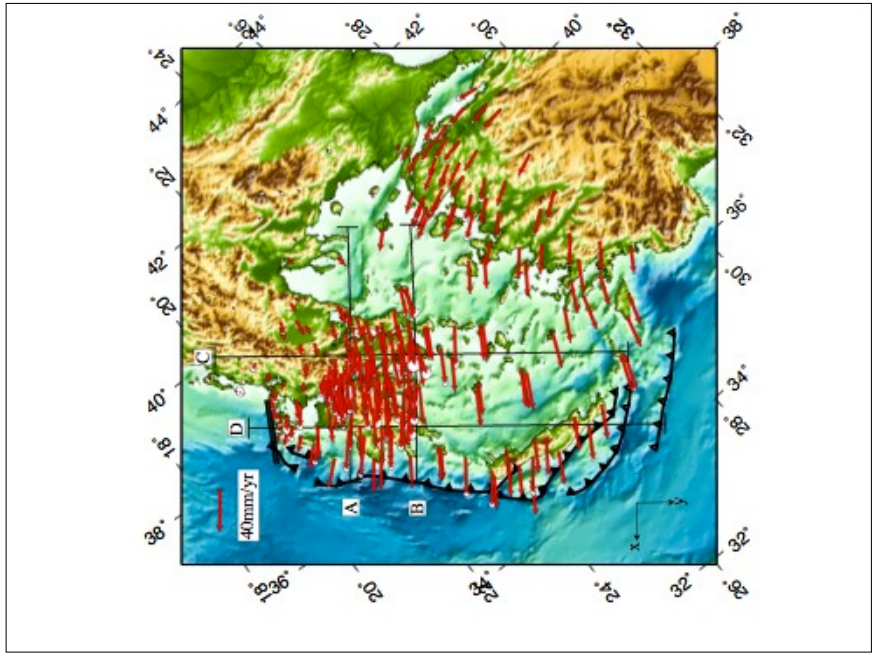


Future

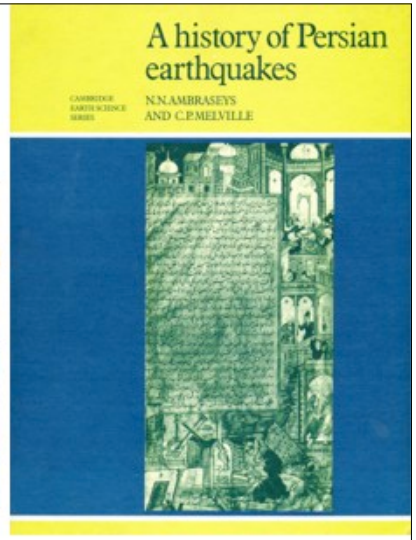
- Shortening rate between Cyclades and Crete ~1 mm/a, representing 2--4 mm/a on the fault.
- At this rate, slip of ~20m in AD365 requires 5,000 to 10,000 years to accumulate. So previous event in W Crete probably occurred when sea-level much lower.
- Long-term average uplift rate ~2.5 mm/a: equivalent to AD365 event every 4,500 years.
- BUT subduction boundary is ~600km long, so frequency of all events could be ~1/800 years
- Last major tsunami earthquake in E Med: 1303.

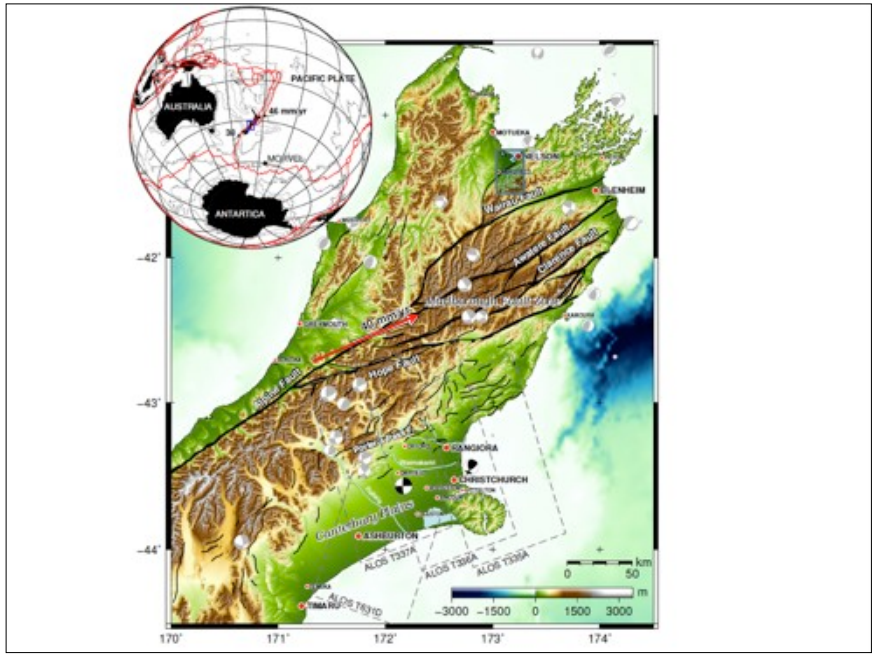
GHEA Global Historical Earthquake Archive

A GEM HAZARD GLOBAL COMPONENT



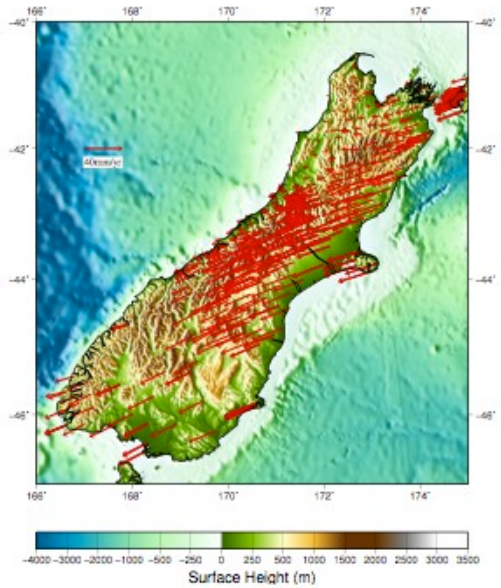
Historical earthquake catalogue must be taken seriously





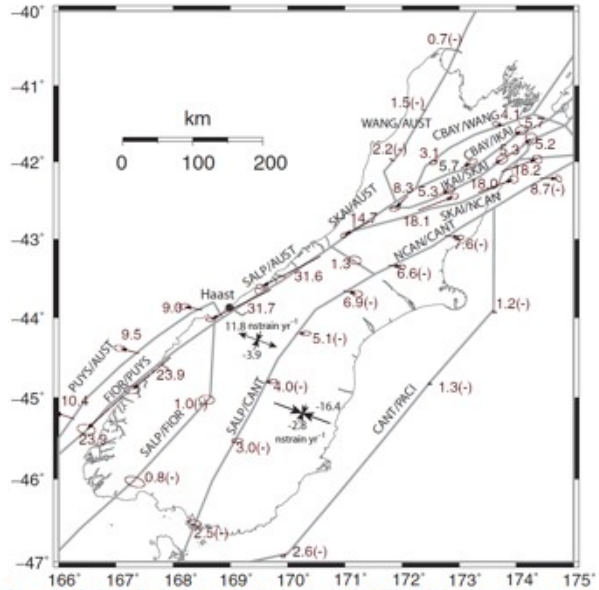
Wallace et al,
2007, Geophys. J.I.

Velocities relative to
Australia

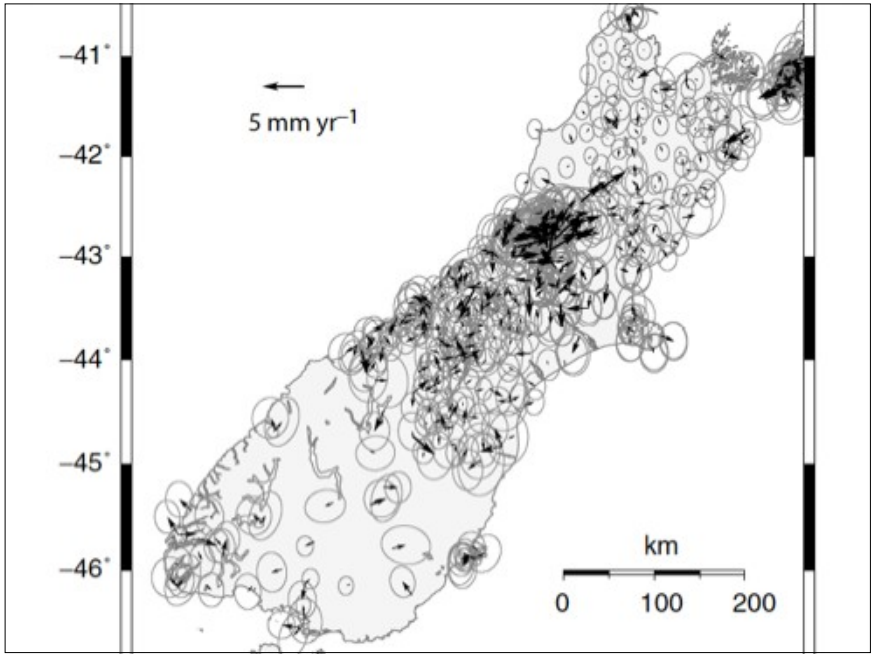


For the ... blocks, we .... calculate a residual strain rate from the velocity residuals for the best-fitting elastic block model. In nearly all cases, the residual strain rates are small and marginally significant, ...
indicating that the data can be fit well by assuming that there is negligible internal deformation of the blocks.

Wallace et al., 2007, Geophys. J. Int.



Block Model for S Island, NZ, Wallace et al., 2007



In general, we obtain an excellent fit to the GPS velocities and geological fault slip rates and azimuths in the Marlborough region.

However

Our PPAFZ rate is nearly double that of previous geological estimates .....

Our GPS velocities indicate that approximately half of the total slip rate across the PPAFZ has been accounted for in geological studies, while the remaining 2– 4 mm yr−1 of slip must occur on other uncharacterized or undiscovered faults within the PPAFZ.

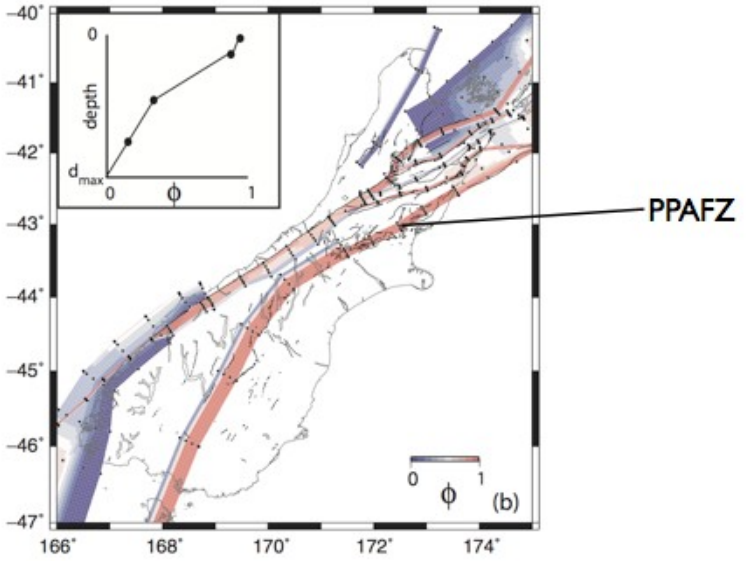
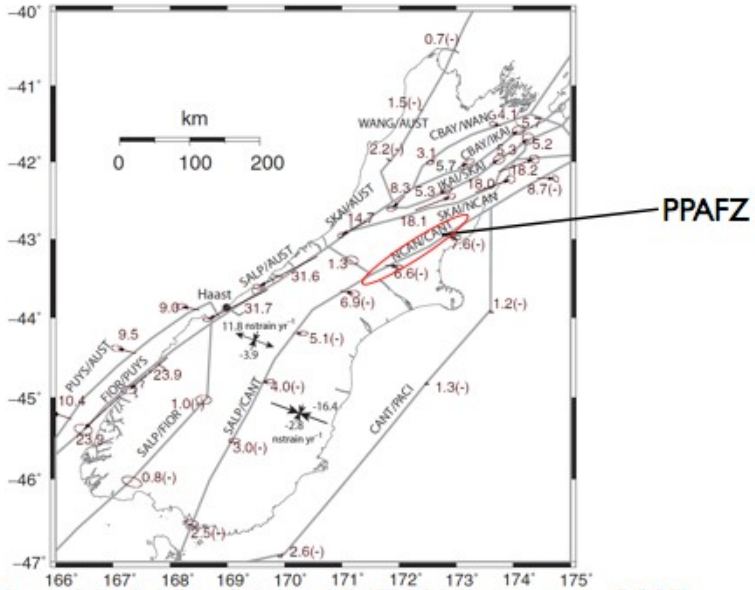
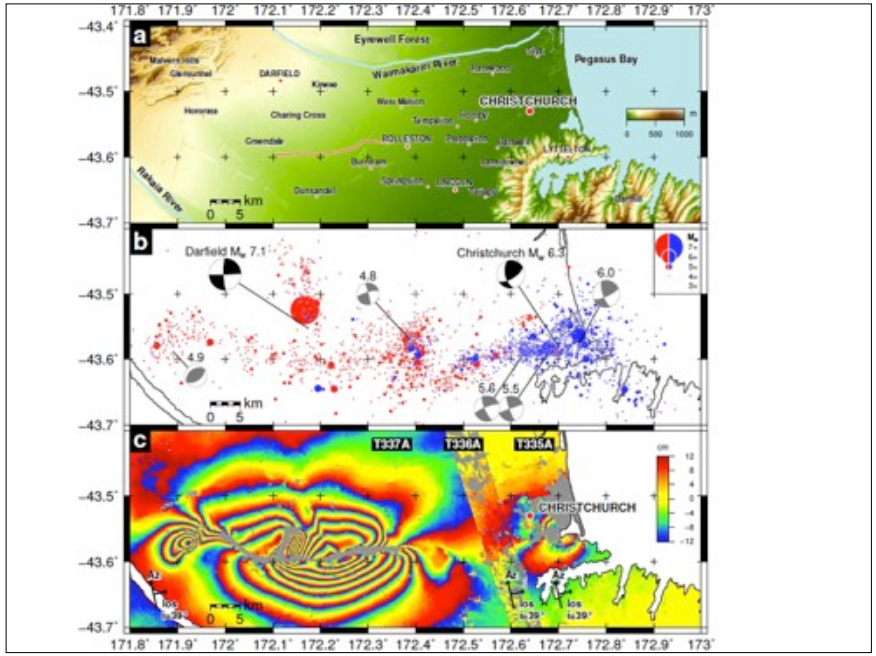


Figure 5. (a) Magnitudes of slip rate deficits (mm yr^{-1}) on block-bounding faults in the South Island. Dashed lines show locations of profiles in Fig. 11.



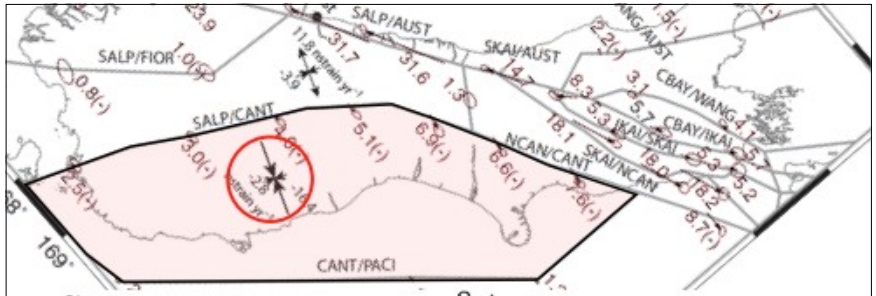
Block Model for S Island, NZ, Wallace et al., 2007



For the ... blocks, we .... calculate a residual strain rate from the velocity residuals for the best-fitting elastic block model. In nearly all cases, the residual strain rates are small and marginally significant, ...

indicating that the data can be fit well by assuming that there is negligible internal deformation of the blocks. The one exception is the North Canterbury (NCAN) block, that has a residual strain rate of $\varepsilon 1 = -8.8 \pm 3.1$ nstrain/year, and $\varepsilon 2 = 19.7 \pm 8.1$ nstrain yr^{-1}, with $\varepsilon 1$ oriented $-83^{\circ} \pm 8^{\circ}$.

Wallace et al., 2007, Geophys. J. Int.



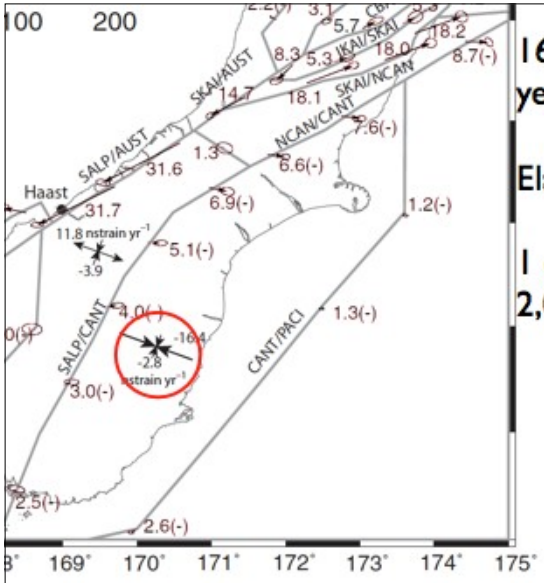
Strain rate $\sim 2 \times 10^{-8}$/year.

Kostrov: $\Sigma M_0/t = \mu V \dot{\varepsilon}$

Area: $\sim 10^{11}$ m^2; Volume: $\sim 10^{15}$ m^3;

Moment rate: $\sim 5 \times 10^{17}$ Nm/year

1 Darfield earthquake every 200 years



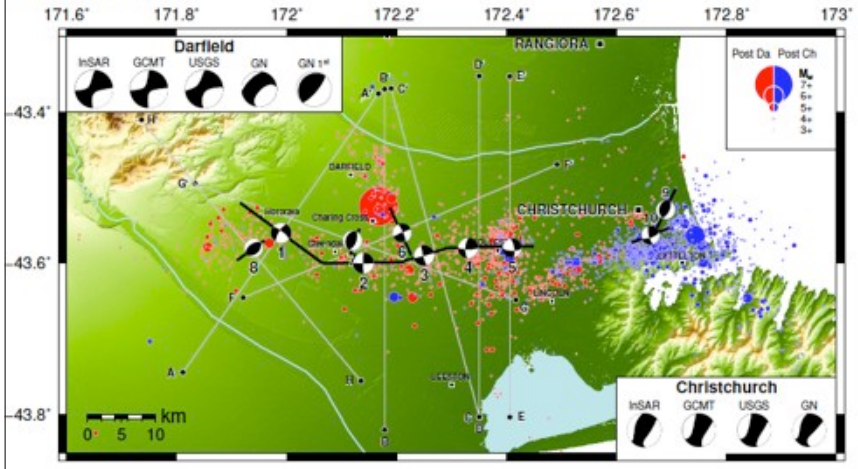
16 nano-strain per year 16×10^{-9}:

Elastic limit $\sim \pi \times 10^{-5}$

1 earthquake every 2,000 years.

Block Model for S Island, NZ, Wallace et al., 2007

Slip in the 2010–2011 Canterbury earthquakes, New Zealand
J. R. Elliott, E. K. Nissen, P. C. England, J. A. Jackson, S. Lamb, Z. Li, M. Oehlers, and B. Parsons
J. Geophys. Res. 2012



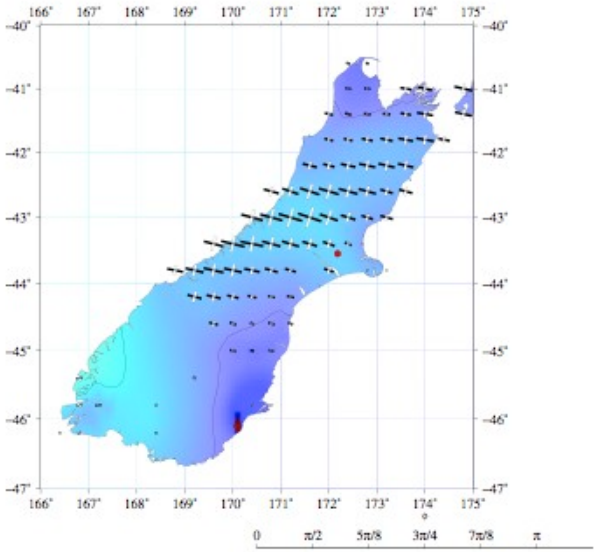


Plate Motion Direction

Contraction Direction in Earthquakes AND IN GPS

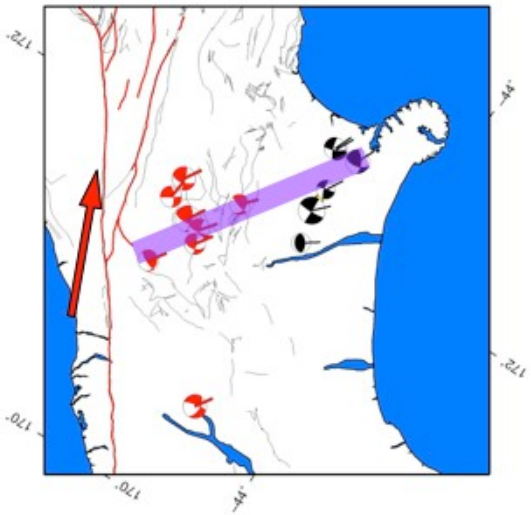
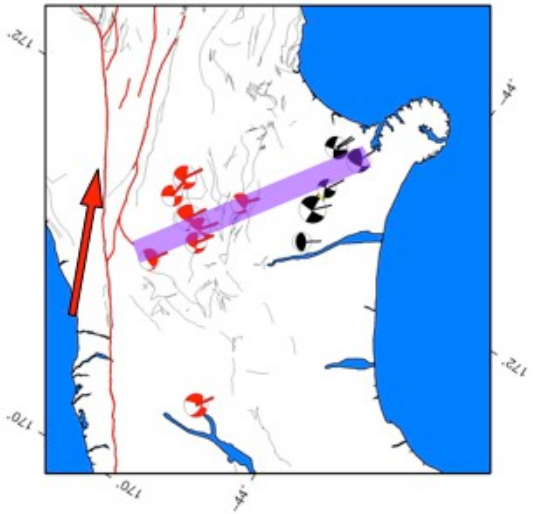
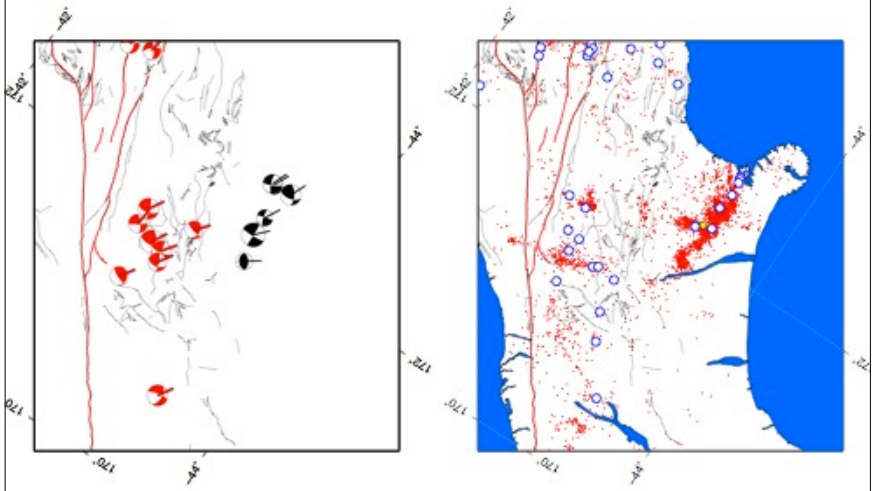


Plate Motion Direction

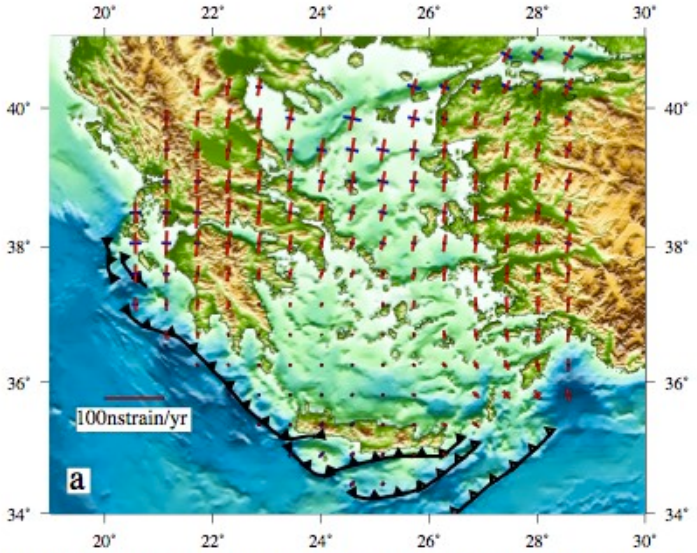
Contraction Direction in Earthquakes



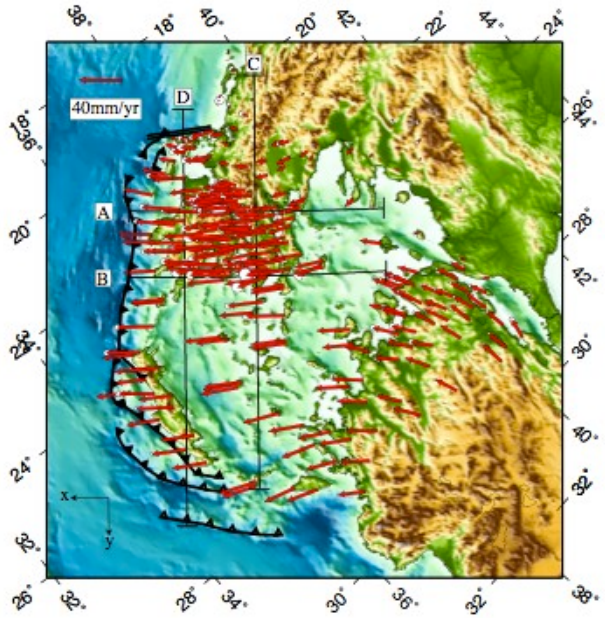


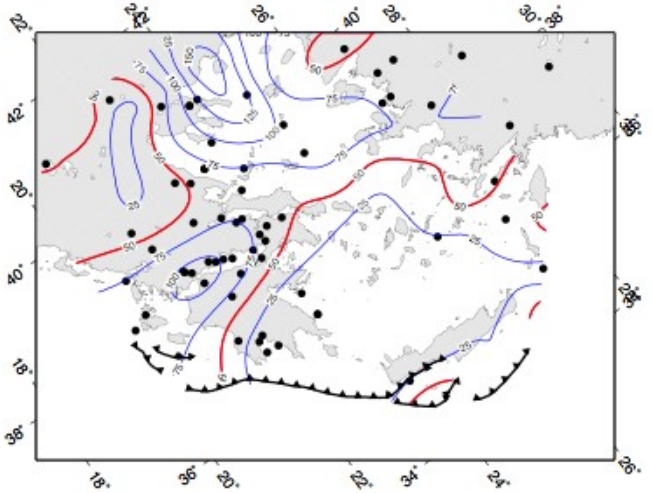
Beware the tyranny of the obvious. At an active plate boundary such as New Zealand, it is easy to be seduced by prominent active fault traces (you can see the Alpine fault from space) and belts of high seismicity in the highest strain regions of the plate boundary. But we should not forget that regions further removed from the plate boundary still need to absorb measurable strain, and will eventually produce damaging earthquakes (albeit with long recurrence).

Martin Reyners Seismol. Res. Lett. June 2011



Principal axes of smooth strain-rate field: red extension, black contraction





More than 90% of the moment released by M>5.8 earthquakes in past 100 years (black dots) was within the regions of strain rate >30 nanostrain/yr. (30 nanostrain/yr is a strain of 3×10^{-5} in 1000 years.)