Integrated understanding of crustal deformation around the Itoigawa-Shizuoka Tectonic Line, central Japan, and its implications for regional tectonics and seismic hazard

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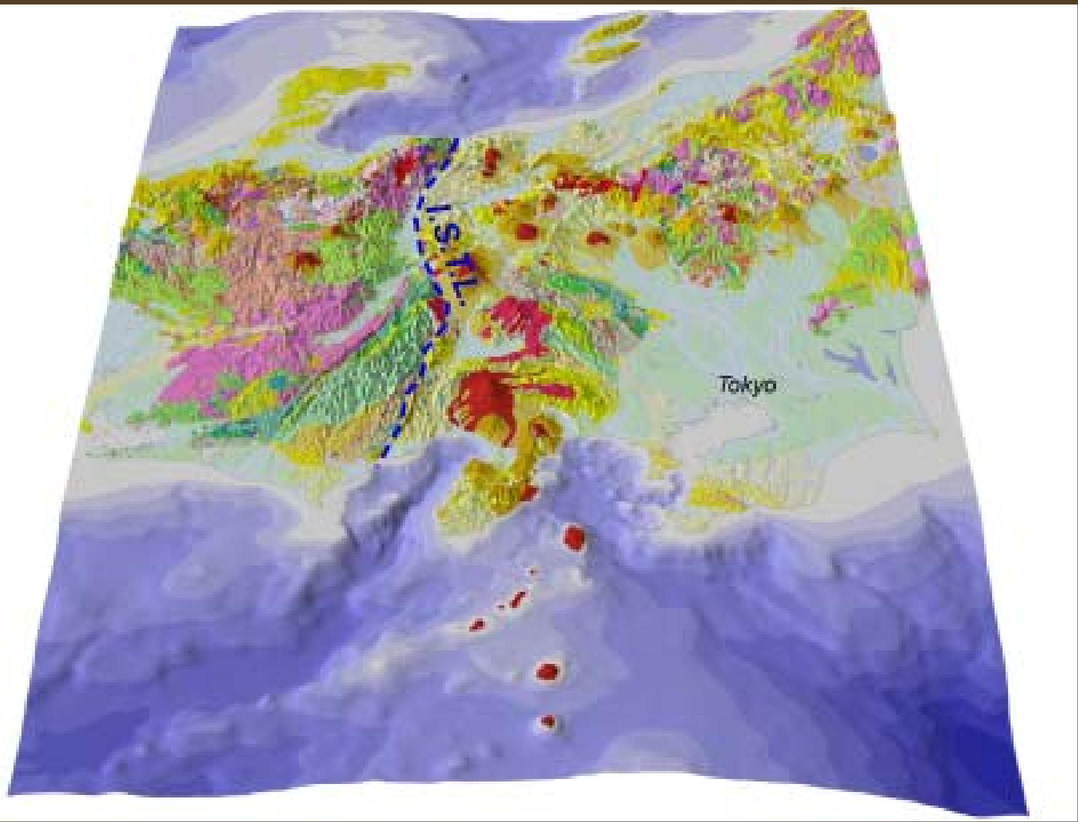
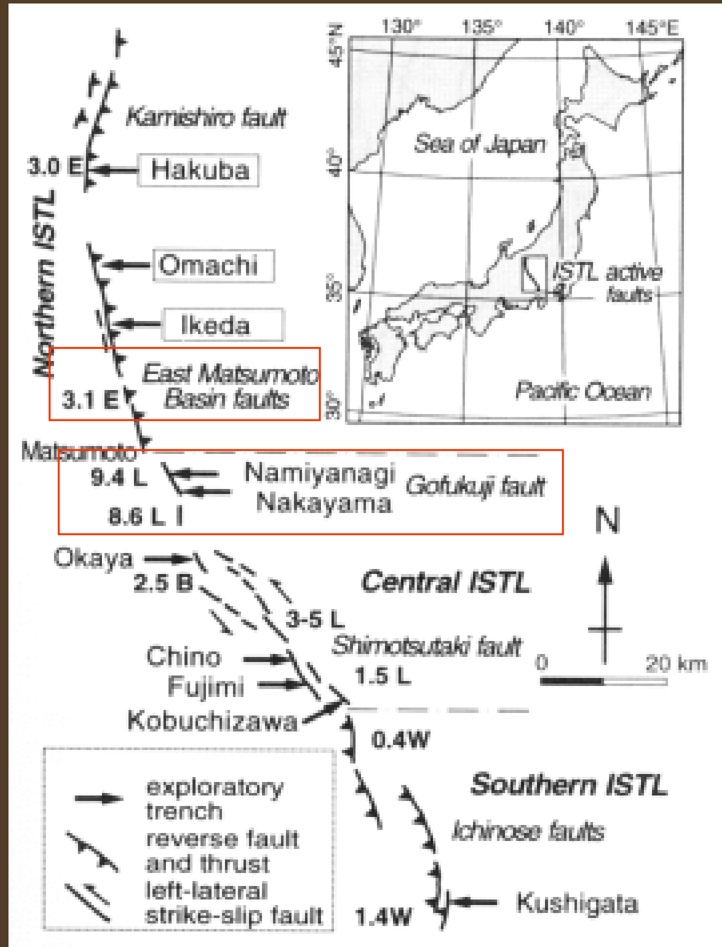
Concepts

- Deformation around active faults
  →Loading process of inland (intraplate) earthquake
- Various information sources→integrated interpretation
  - Geologic data (slip rate, shortening rate)
  - Geodetic data (GPS, triangulation, leveling, etc.)
  - Fault models
  - Structural data (Velocity, registivity)
- Implications for tectonic models, rheological structure, seismic hazard, …

- A part of “the Comprehensive Joint Research Project on the Modeling of Slip Process of Earthquake Source Fault and Plastic Flow near the Seismogenic Region”

The Itoigawa-Shizuoka Tectocnic Line (ISTL)





Okumura et al.(1998)

- Major geological boundary between NE-SW Japan
- One of the most active fault zones

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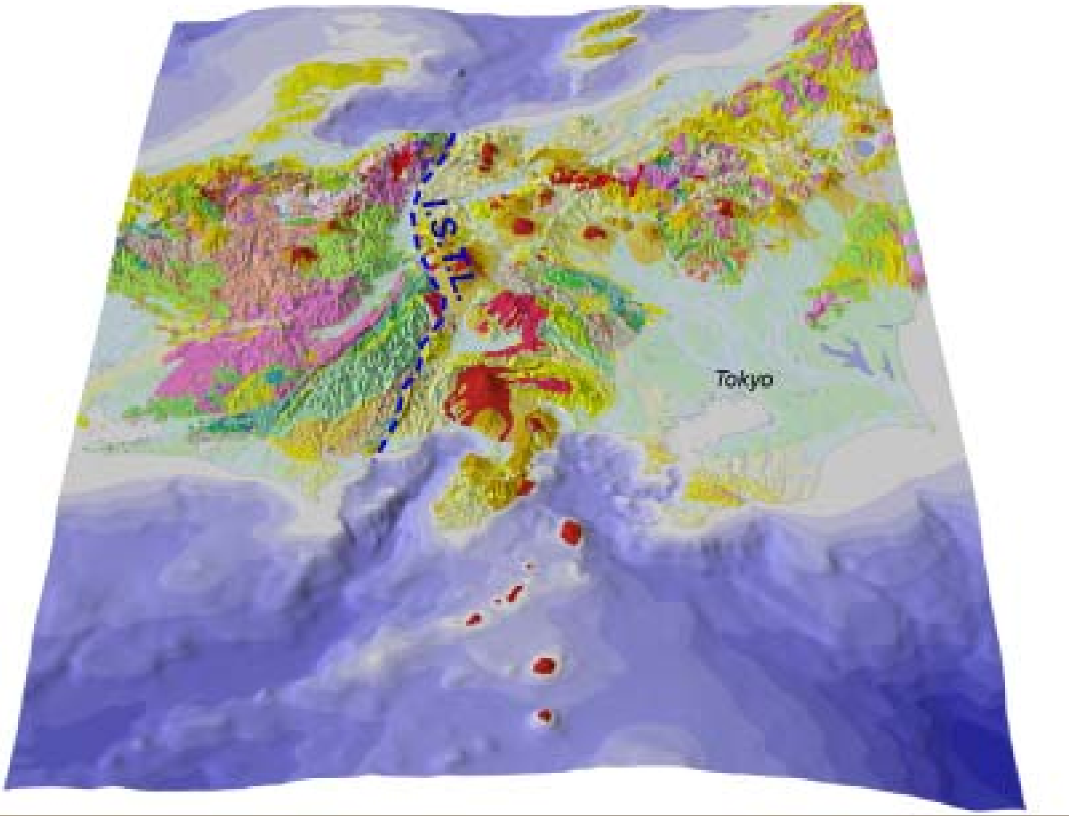

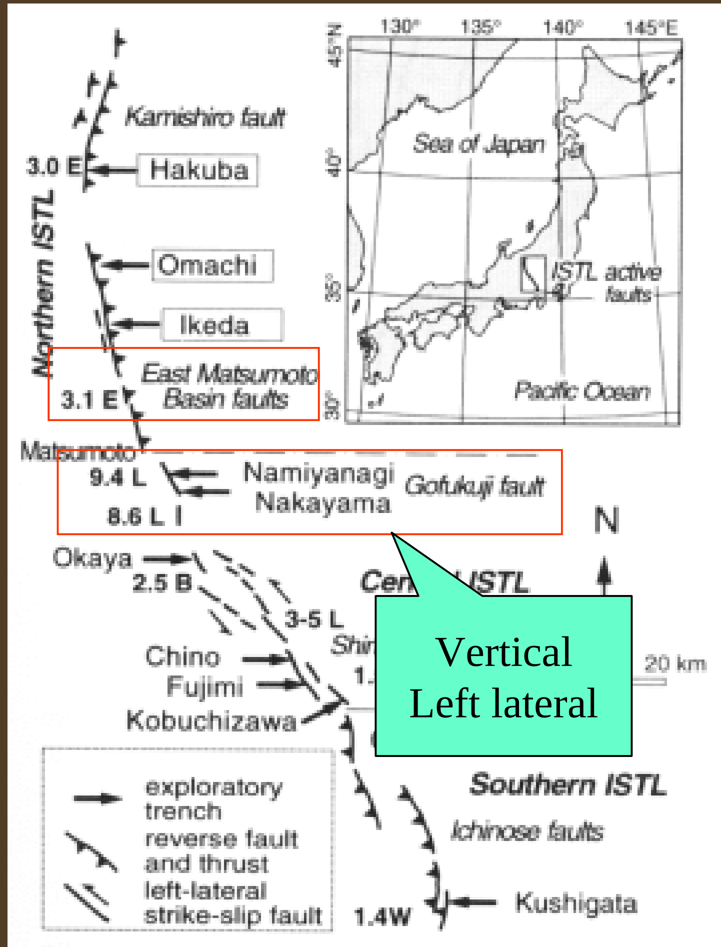

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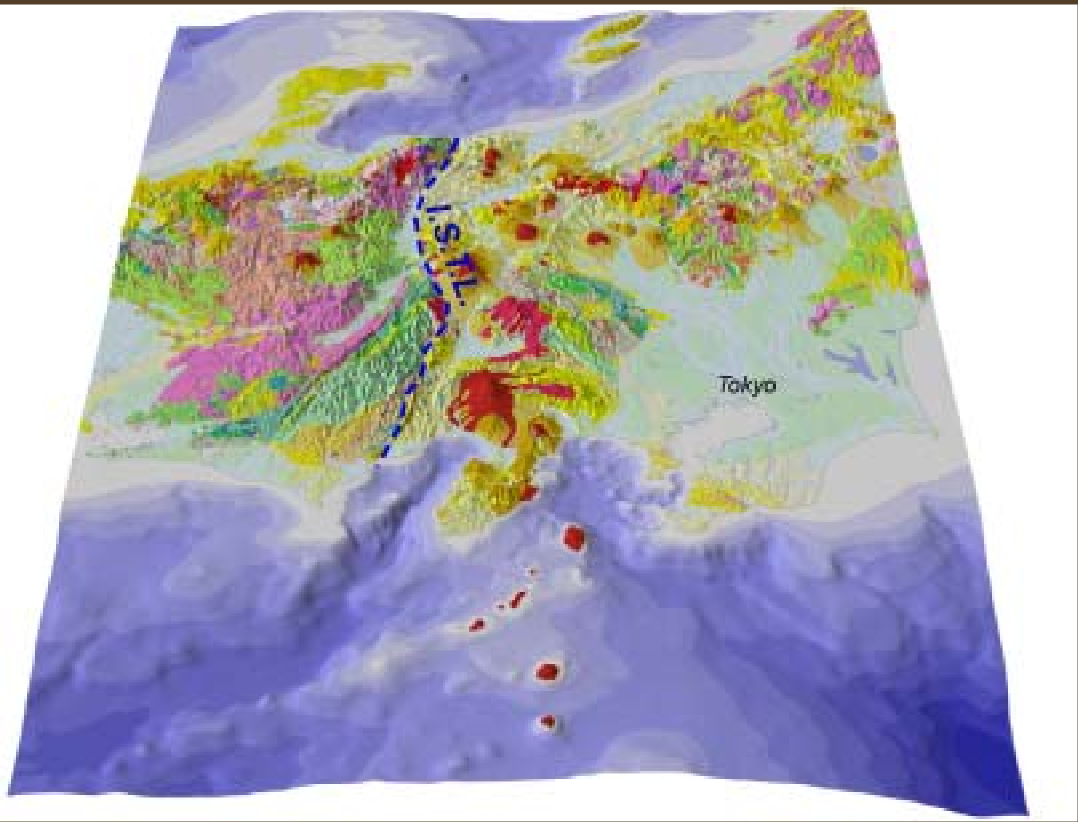

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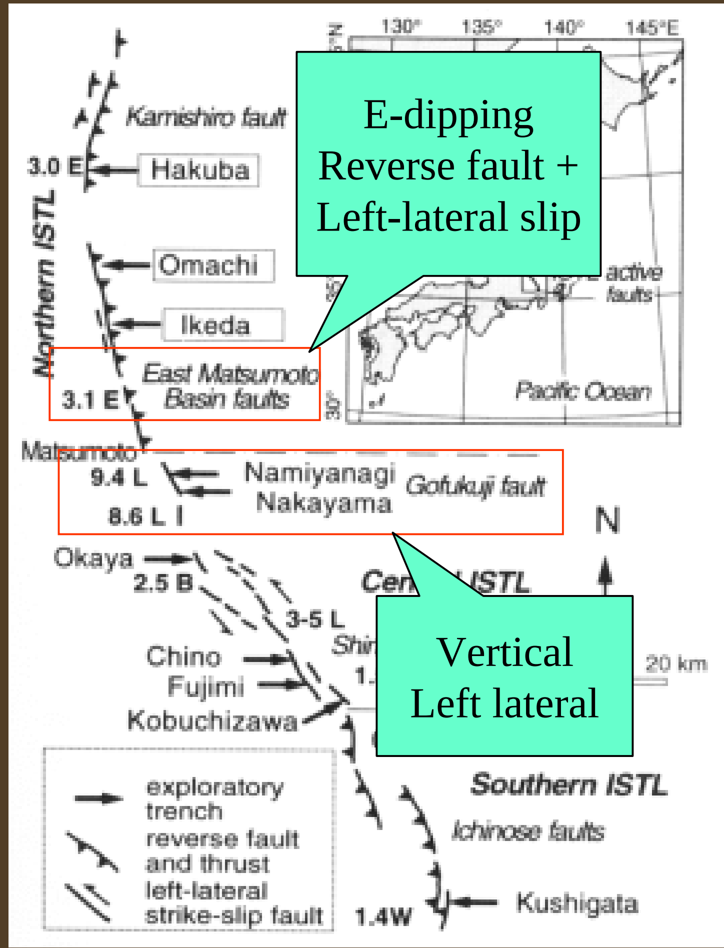

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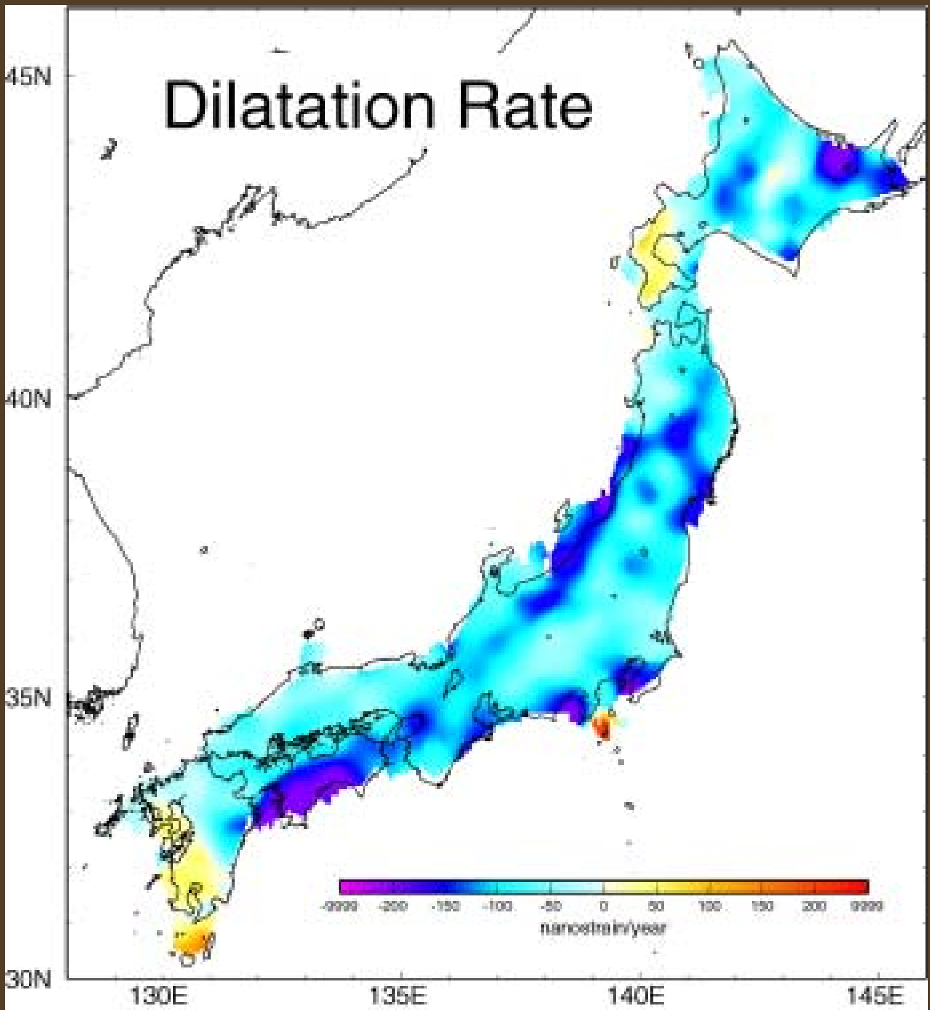
Present-day crustal deformation by GPS



- Northern ISTL is located in the high strain zone

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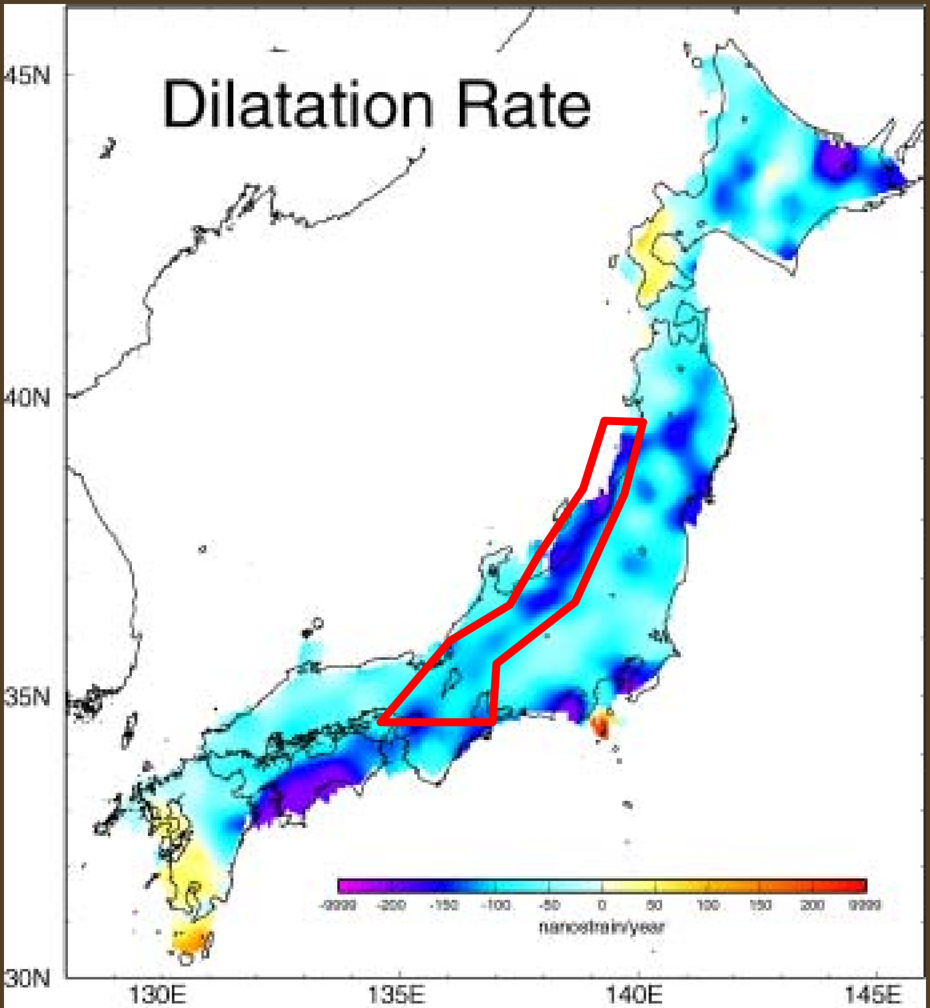

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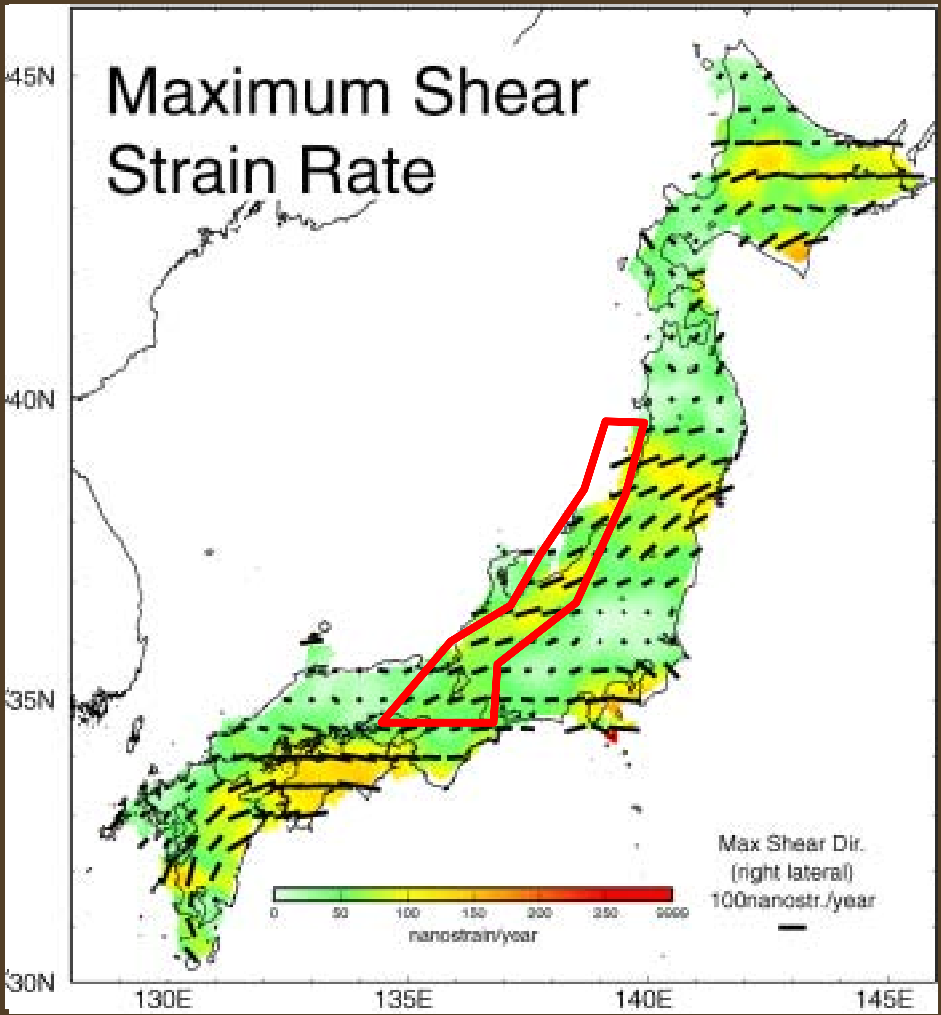

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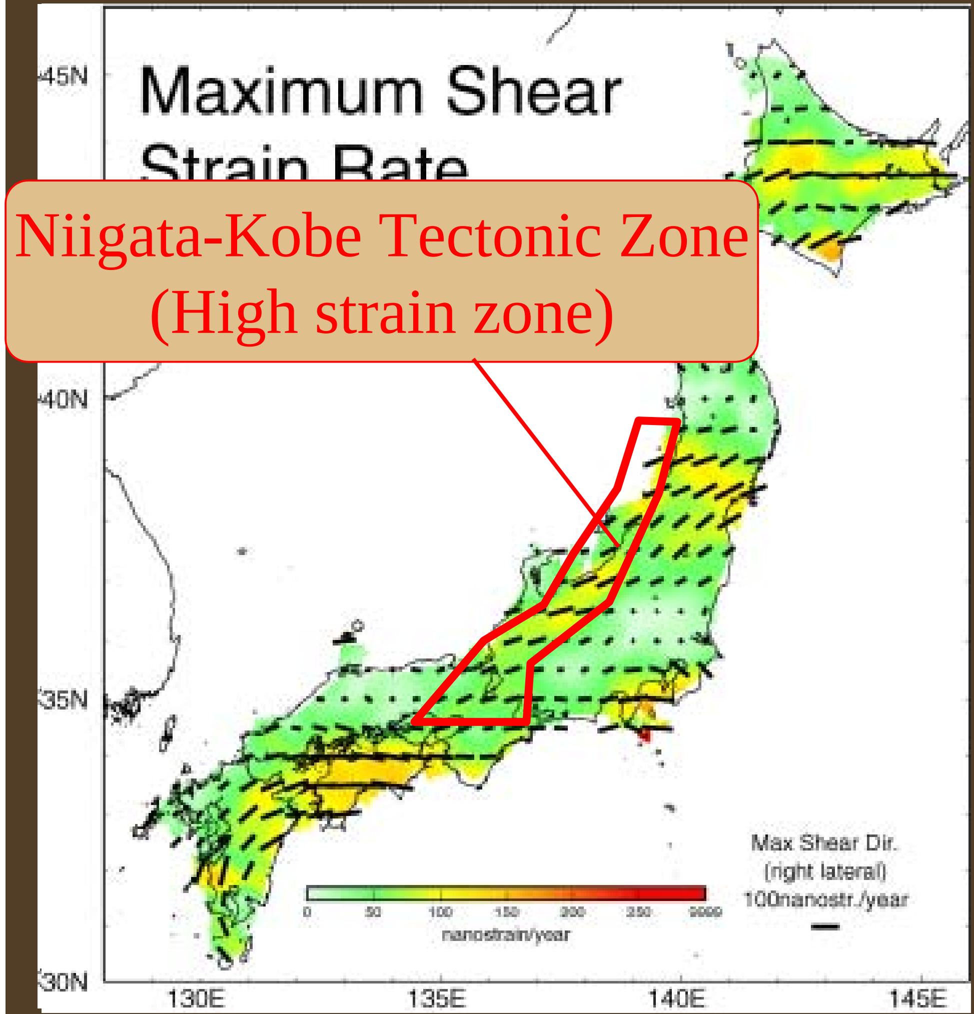

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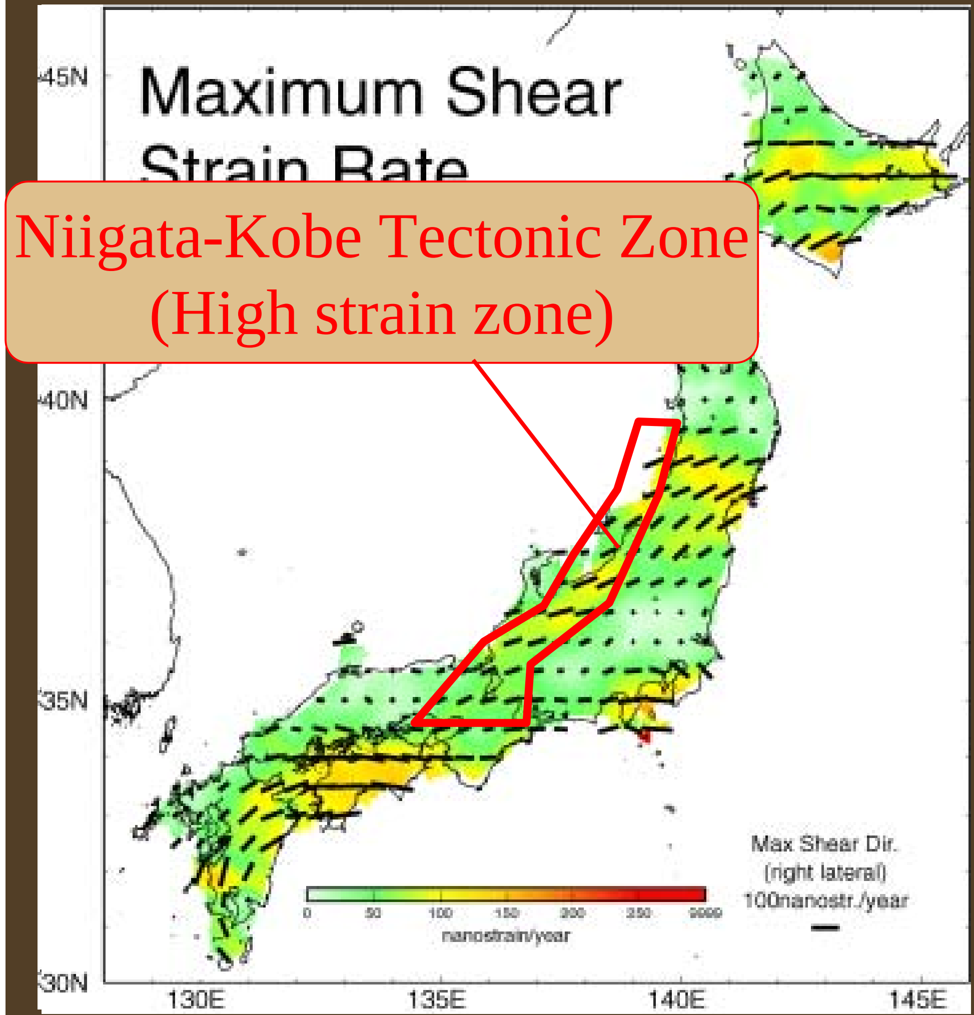
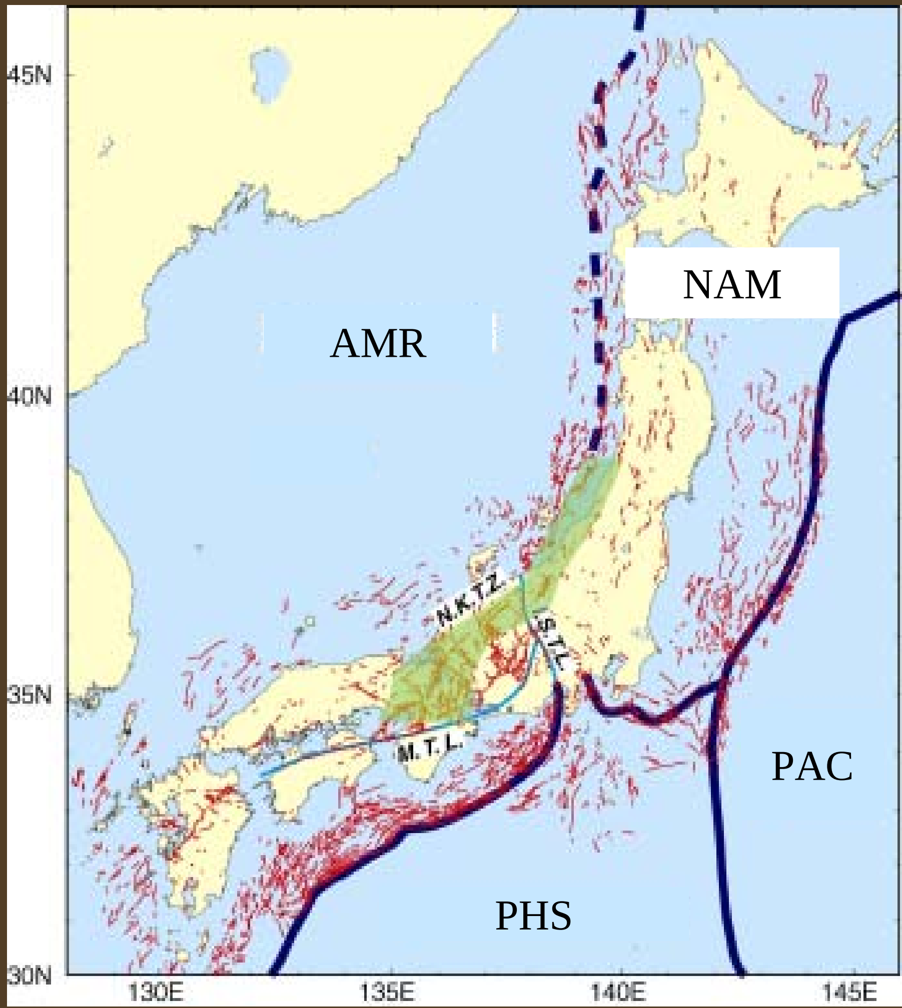
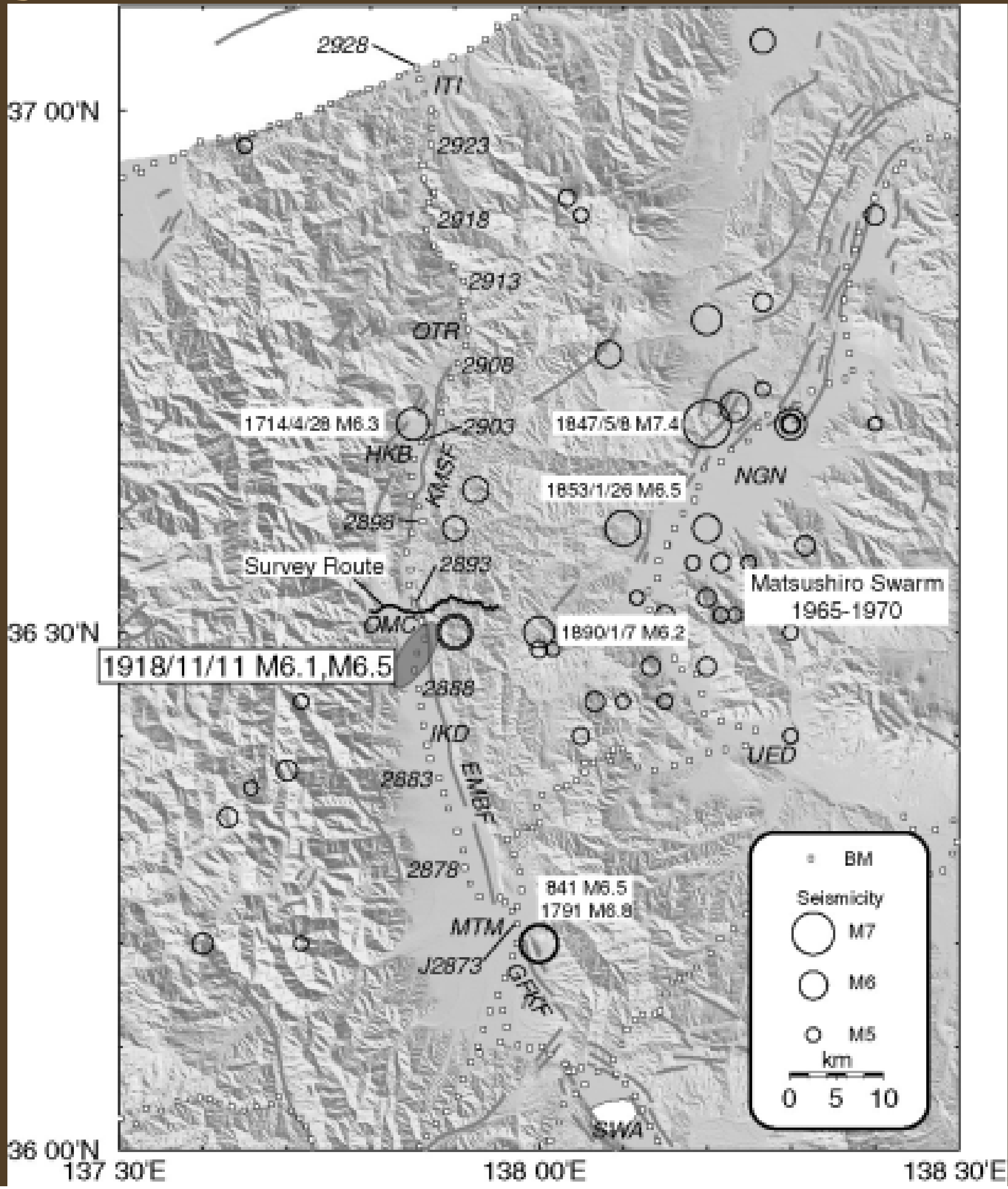




- Northern ISTL is located in the high strain zone

Seismicity around ISTL

- No earthquake larger than M7 has been recorded along ISTL.
- A large event is anticipated around the Gofukuji Fault.
- The 1918 Omachi Earthquake was the only disastrous event along ISTL with scientific investigations.



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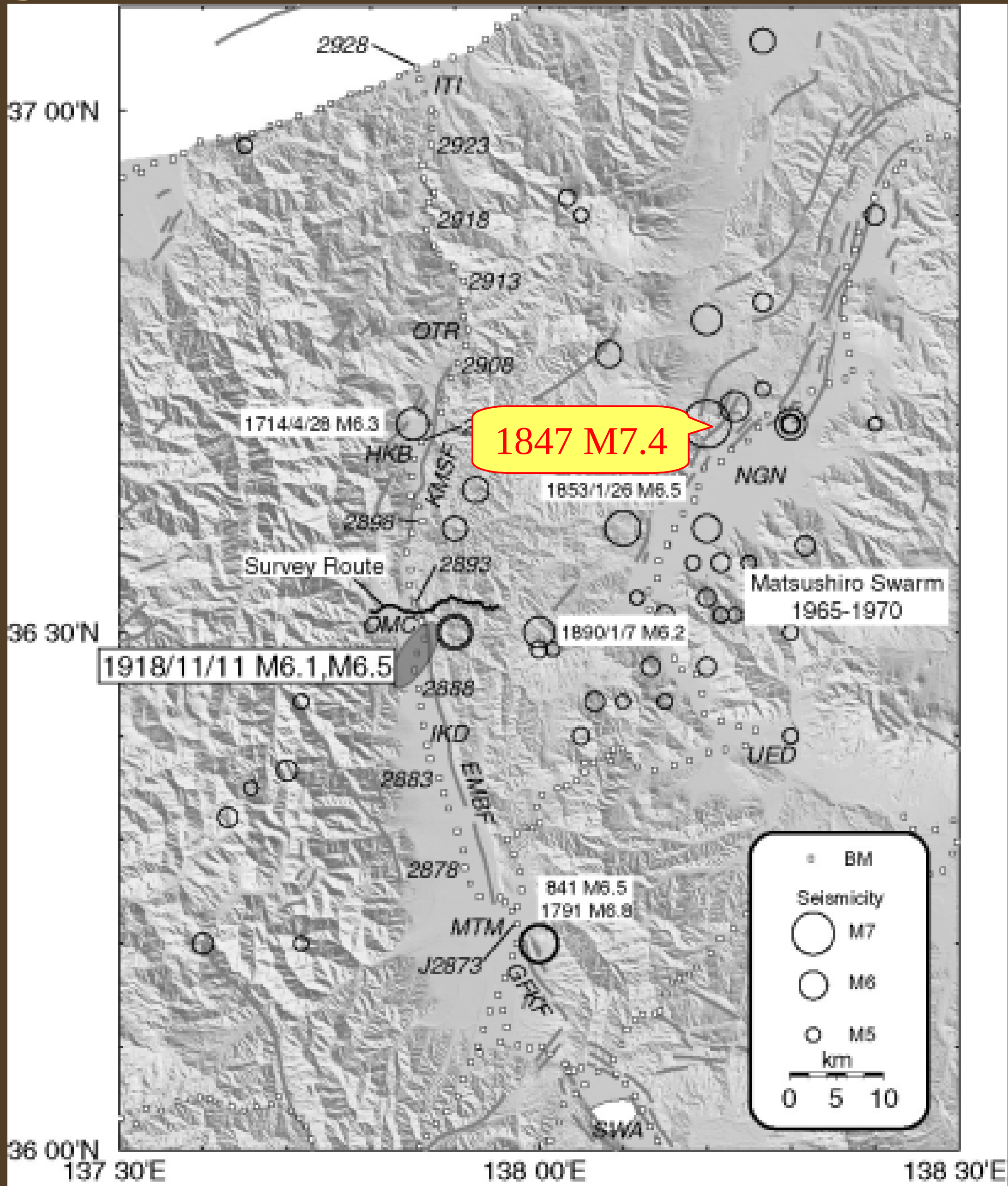

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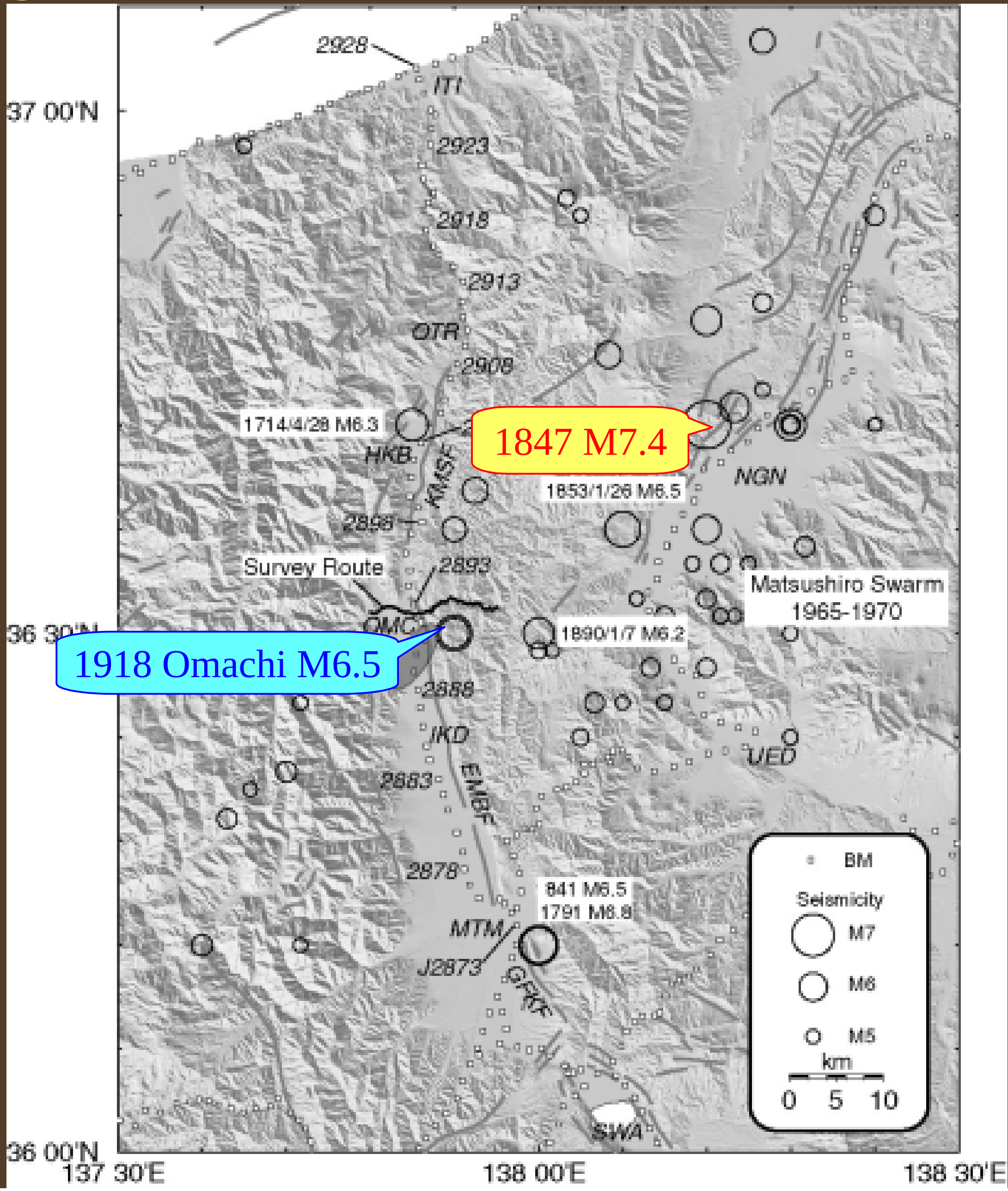

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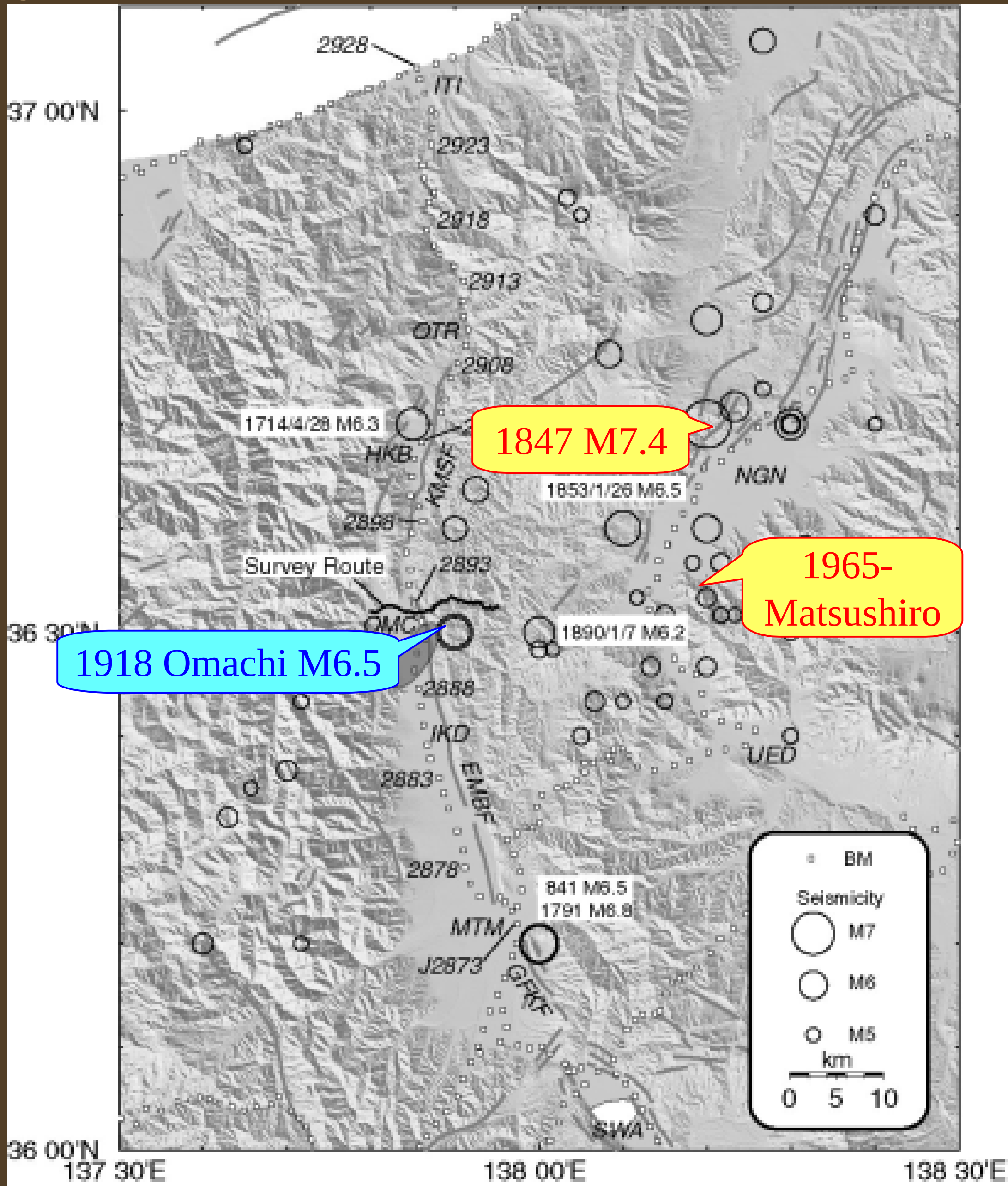

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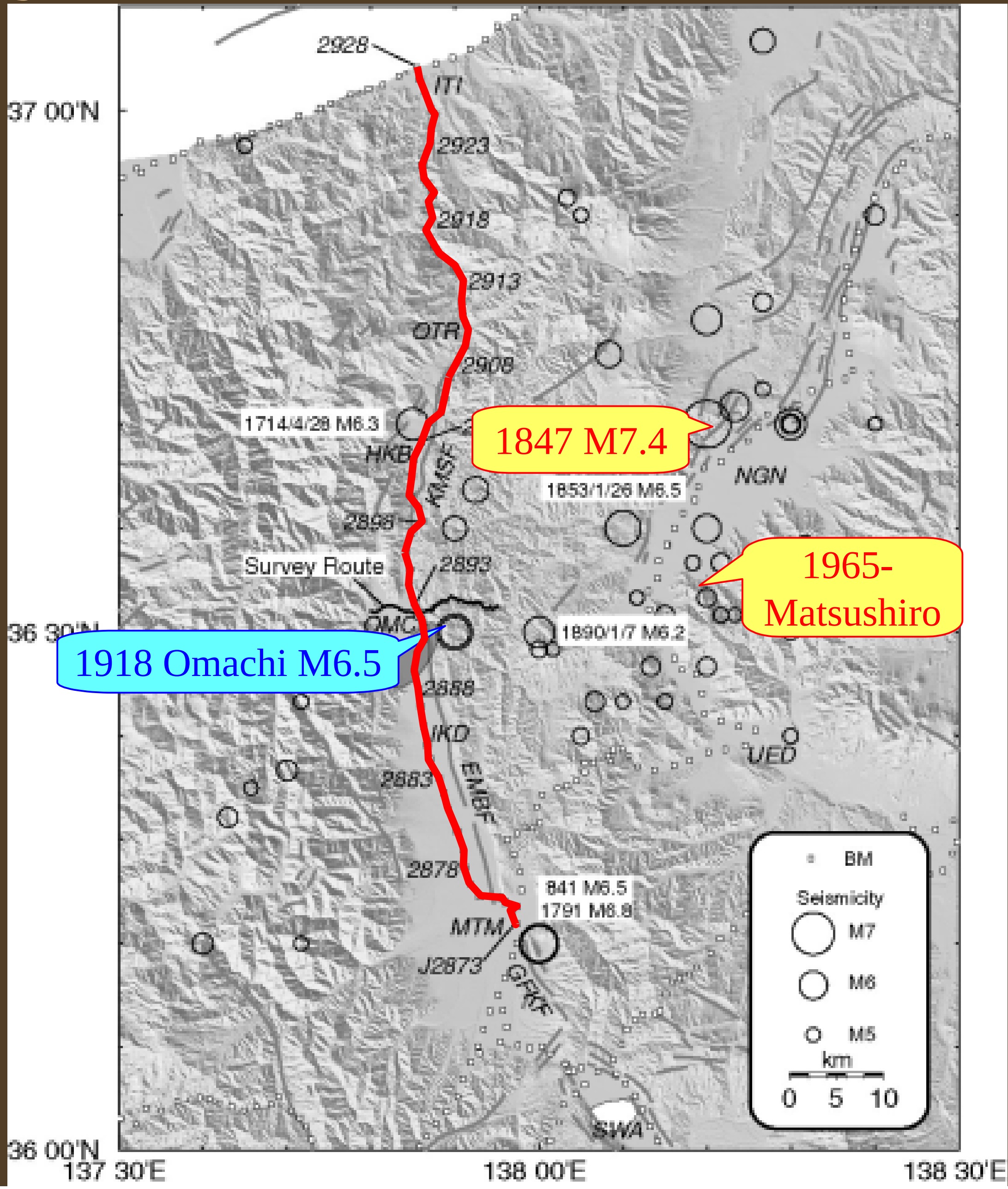
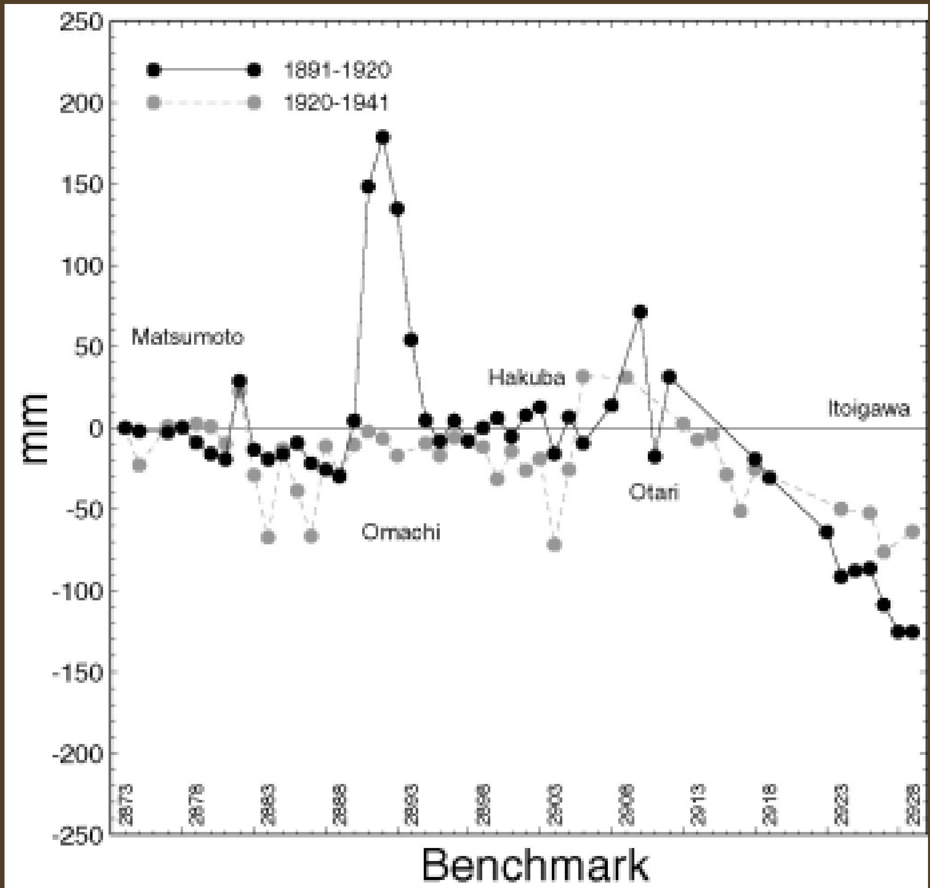
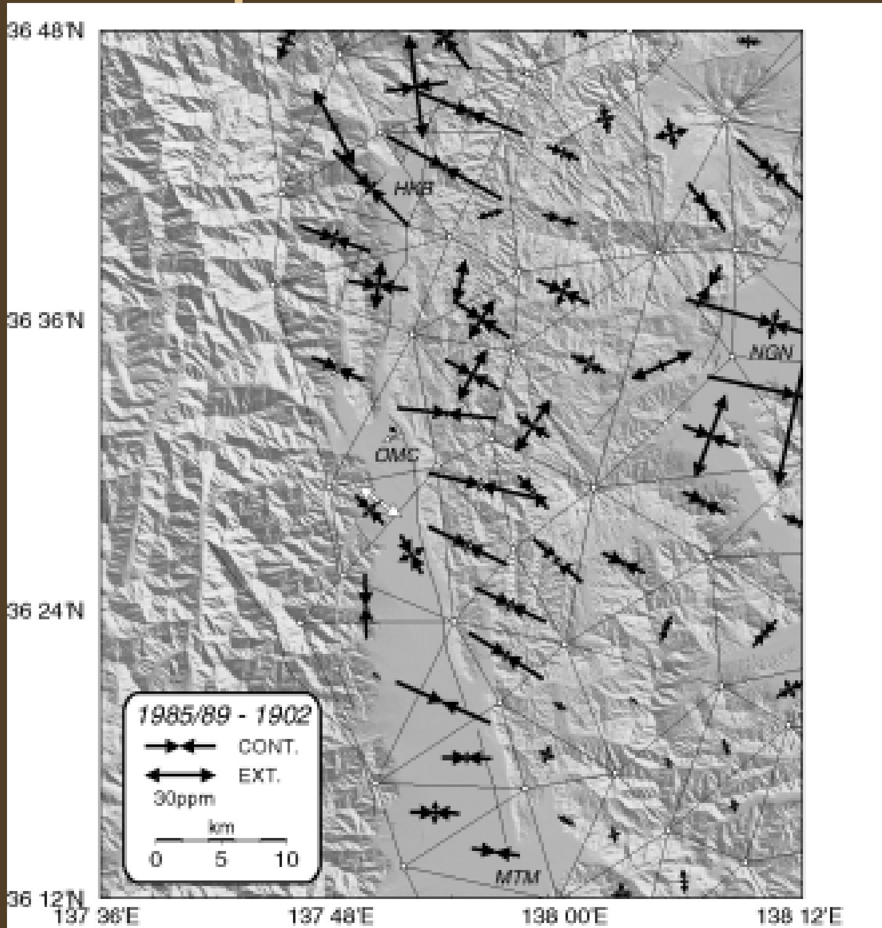


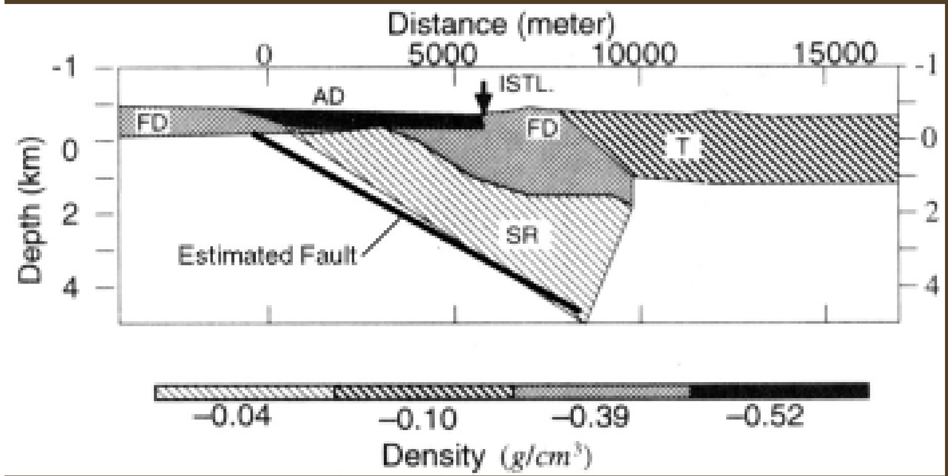
Crustal Movements Associated with the 1918 Omachi Earthquake

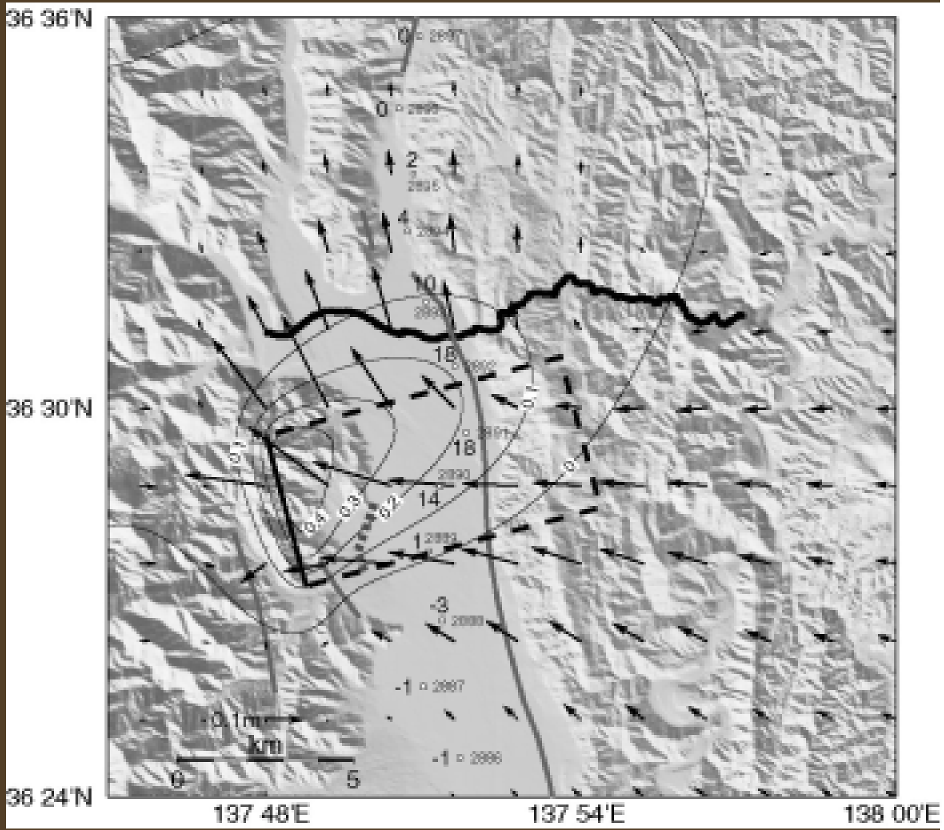




- 20cm uplift in Omachi
- E-W extension ?

A fault model of the Omachi Earthquake

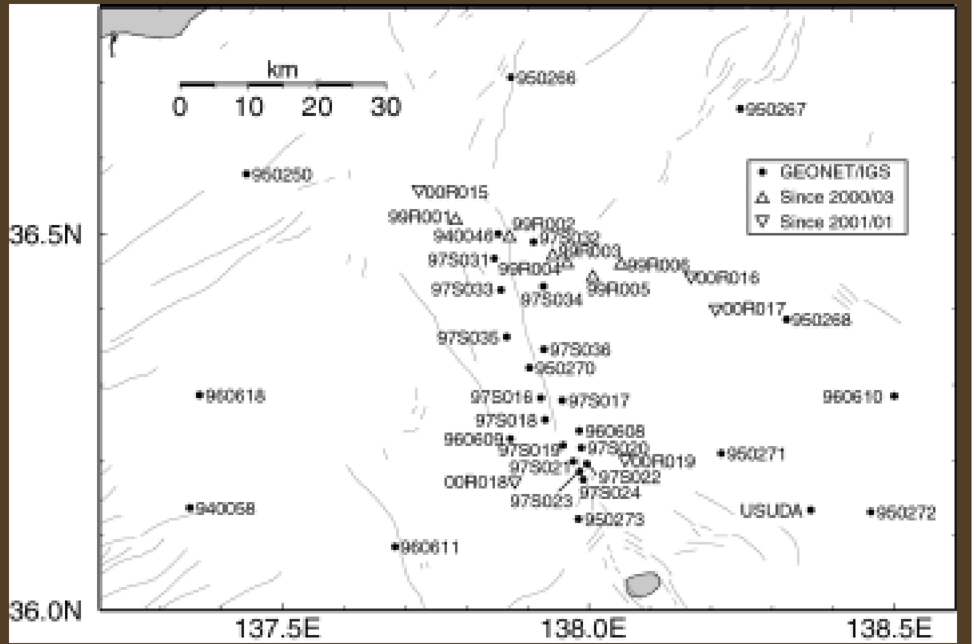




- Reverse faulting of a shallow east-dipping fault
- 1.2m slip, Mw=6.1
- Consistent with the uplift, E-W extension, and the crustal structure

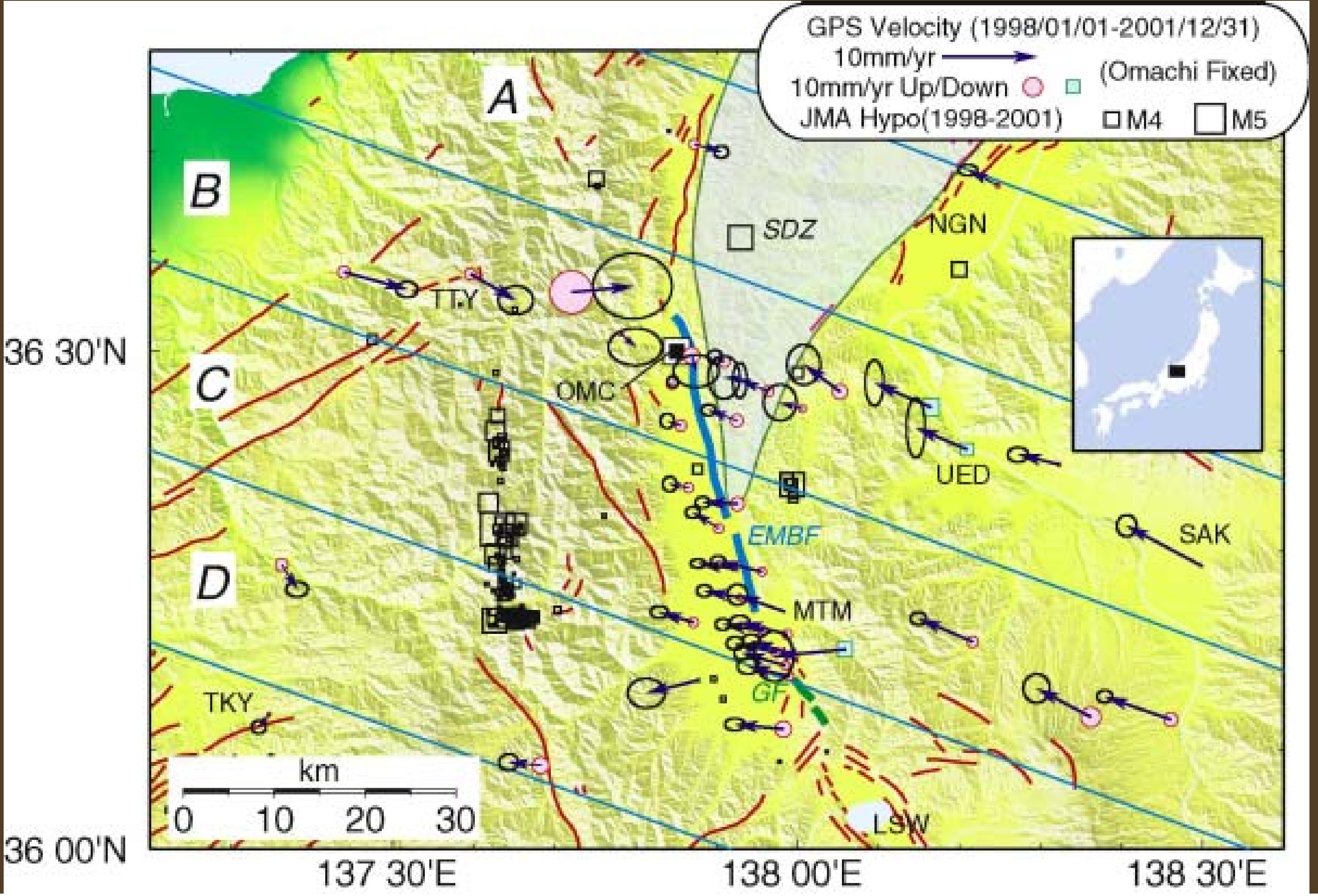
Present-day deformation around ISTL

- Established a dense GPS array around the northern ISTL (completed in December 2000)
- Deformation profile across the fault trace

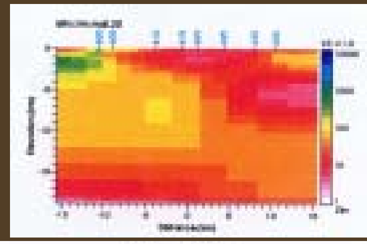


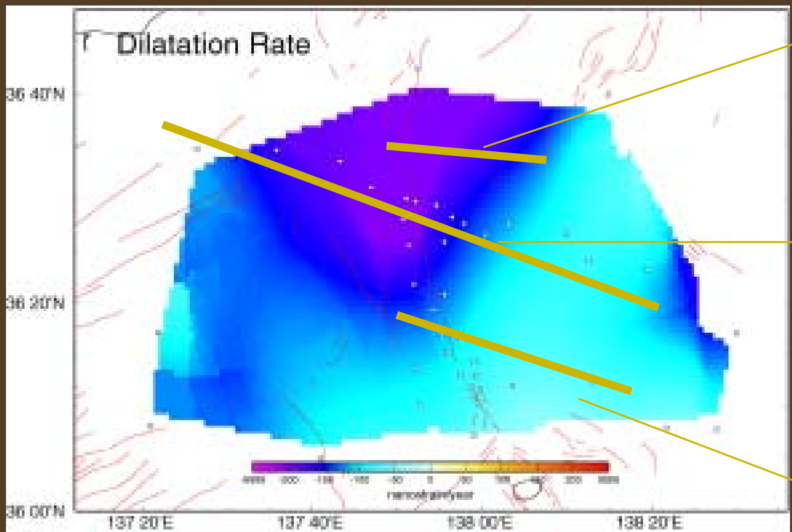
GPS velocity around ISTL

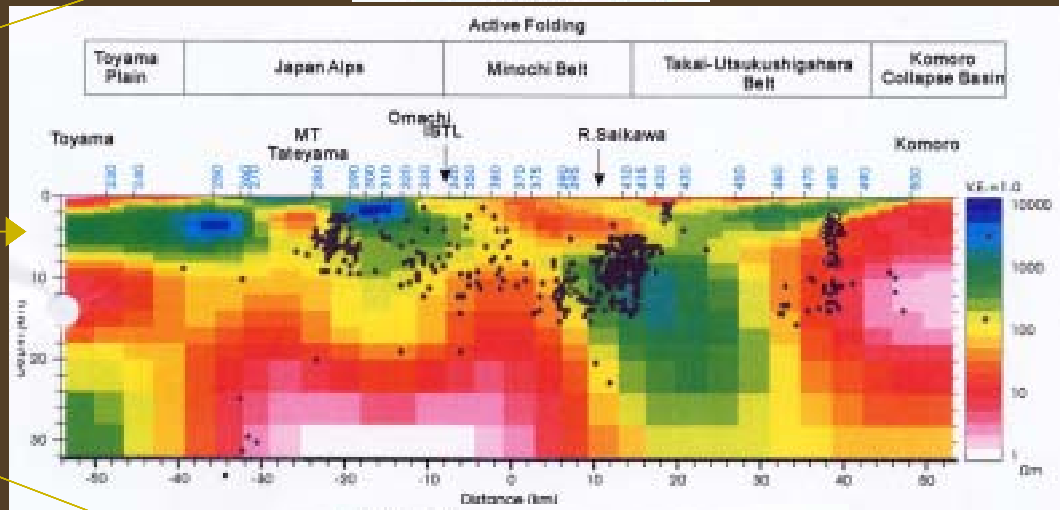
- Significant deformation near Omachi
- Smaller deformation near Matsumoto

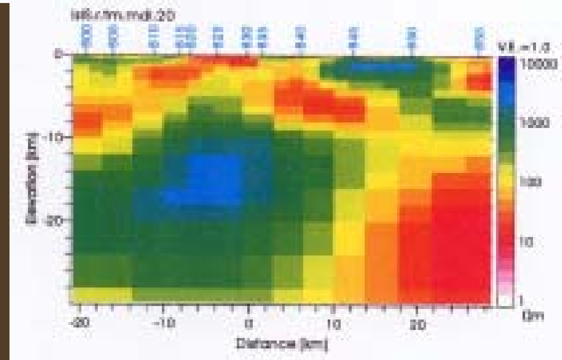


Crustal strain and electromagnetic structure





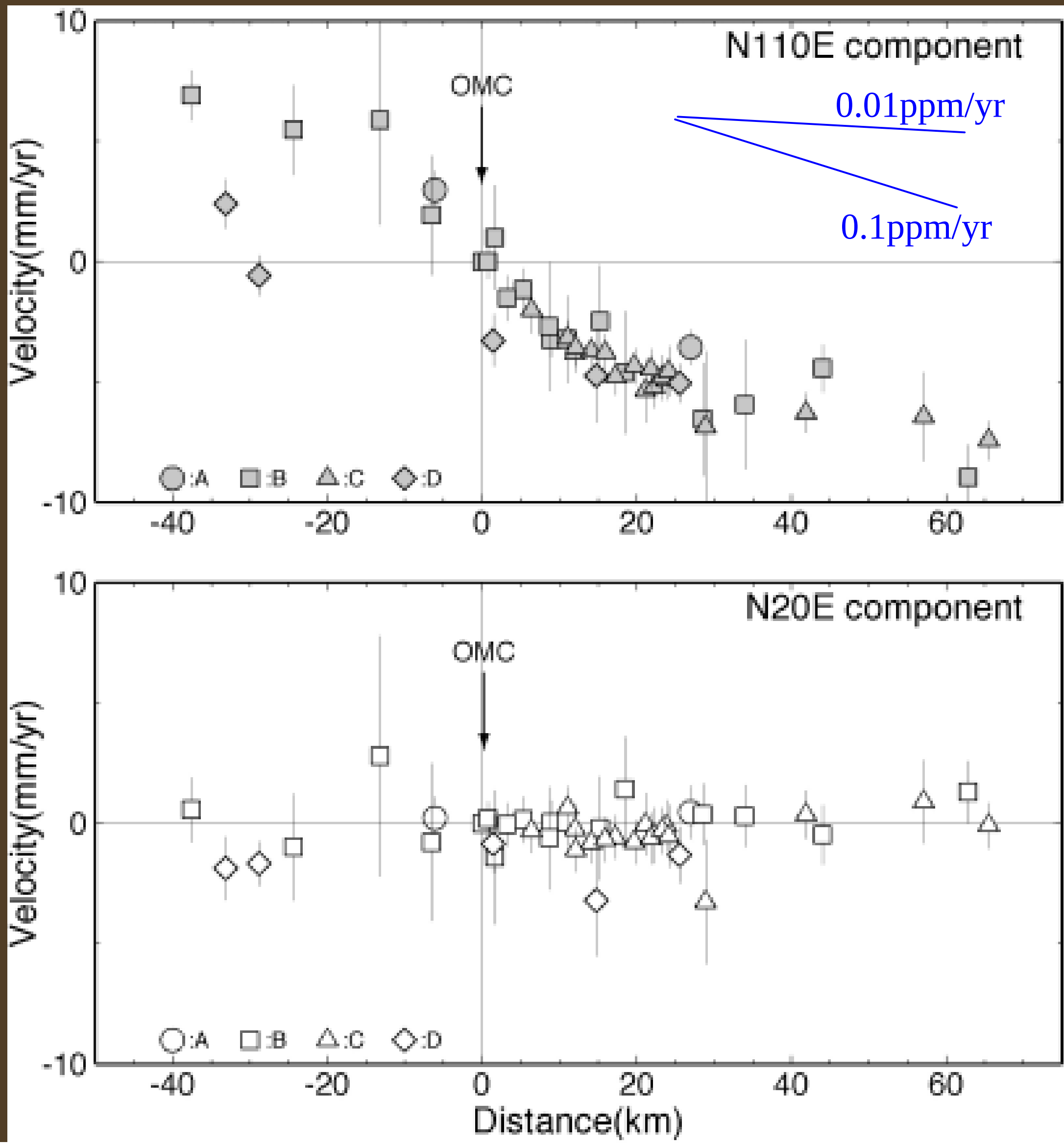




- Highly conductive lower mantle corresponds to large strain
- Implications for lower crustal deformation: water?

Velocity profile across ISTL

- 2-dimensional deformation oblique to the fault trace
- Concentrated strain around the surface fault
  - Inside:O(0.1ppm/yr)
  - Outside:O(0.01ppm/yr)



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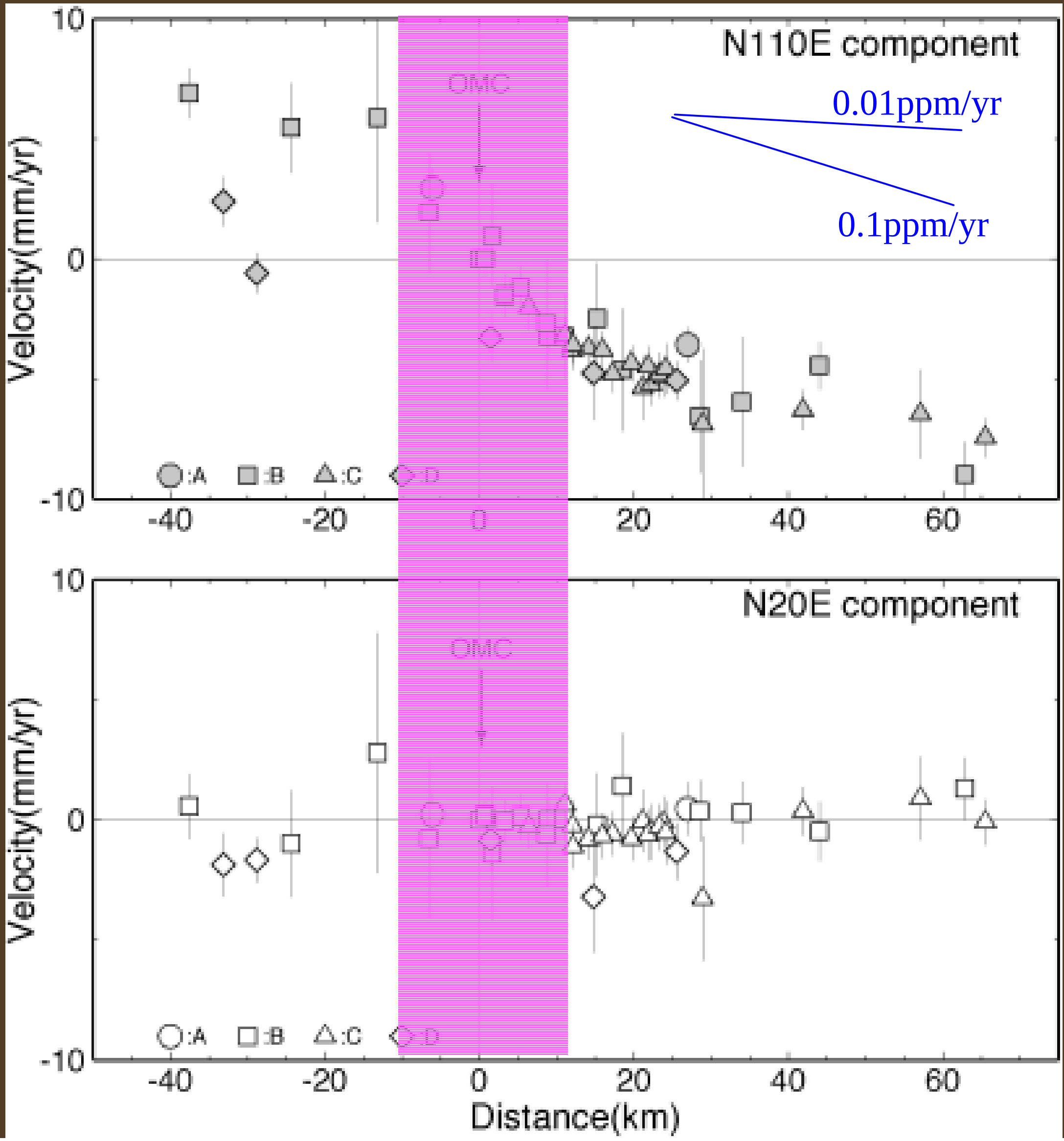
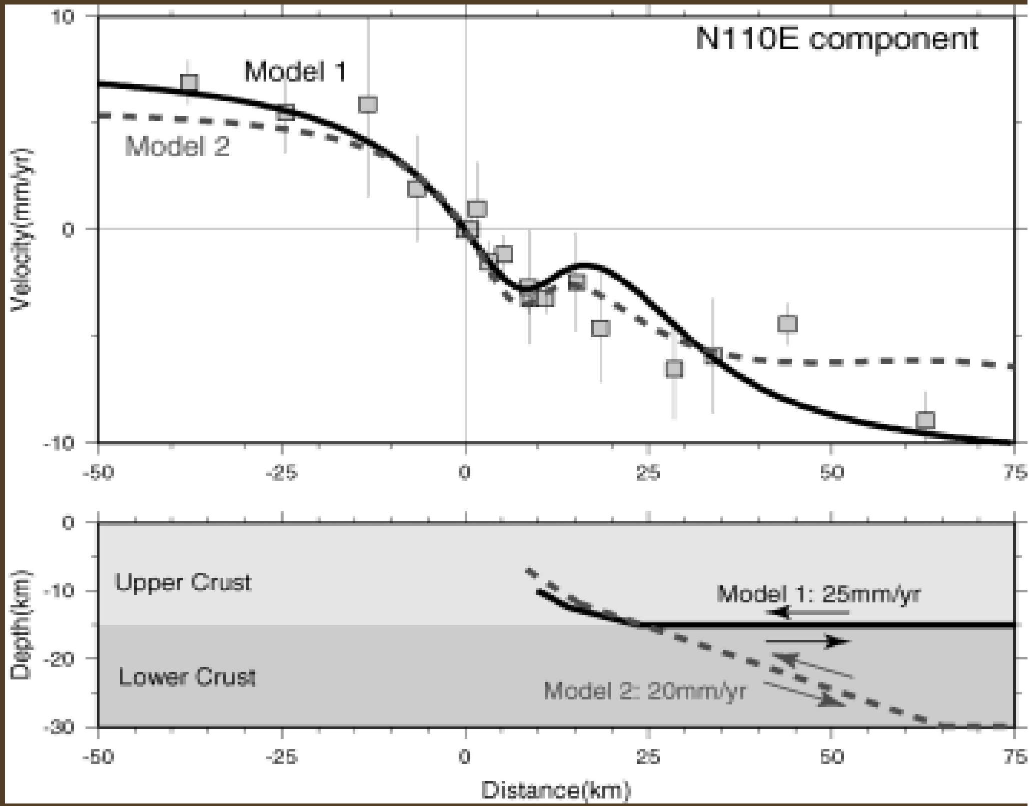


Seismic Hazard around the Omachi Area

- The 1918 Omachi earthquake released elastic strain stored in the shallower part.
- The deeper portion of the fault is weak and creeping.
- Plastic folding occur in the soft oceanic sediments east of ISTL.
- Possibility of a large earthquake in the Omachi area is considerably low.
- Deformation is largely controlled by the structure.



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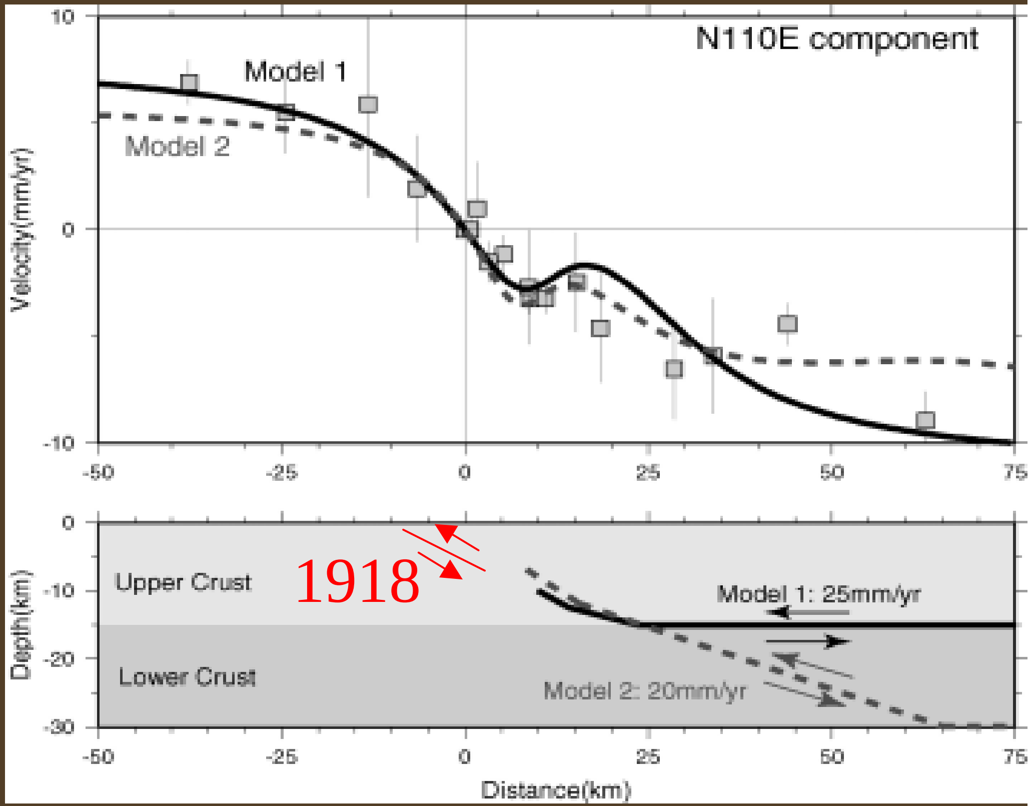

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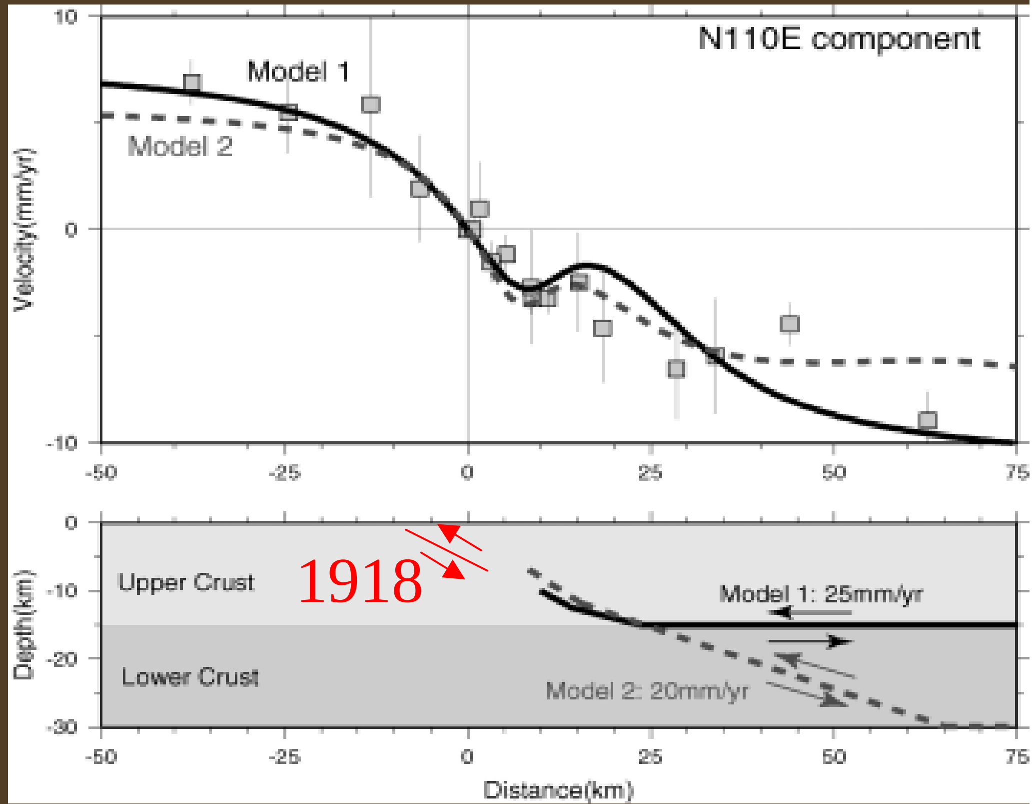
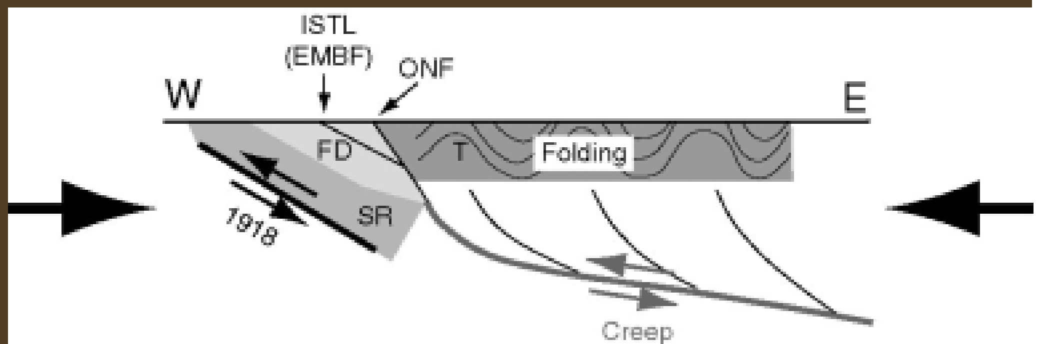




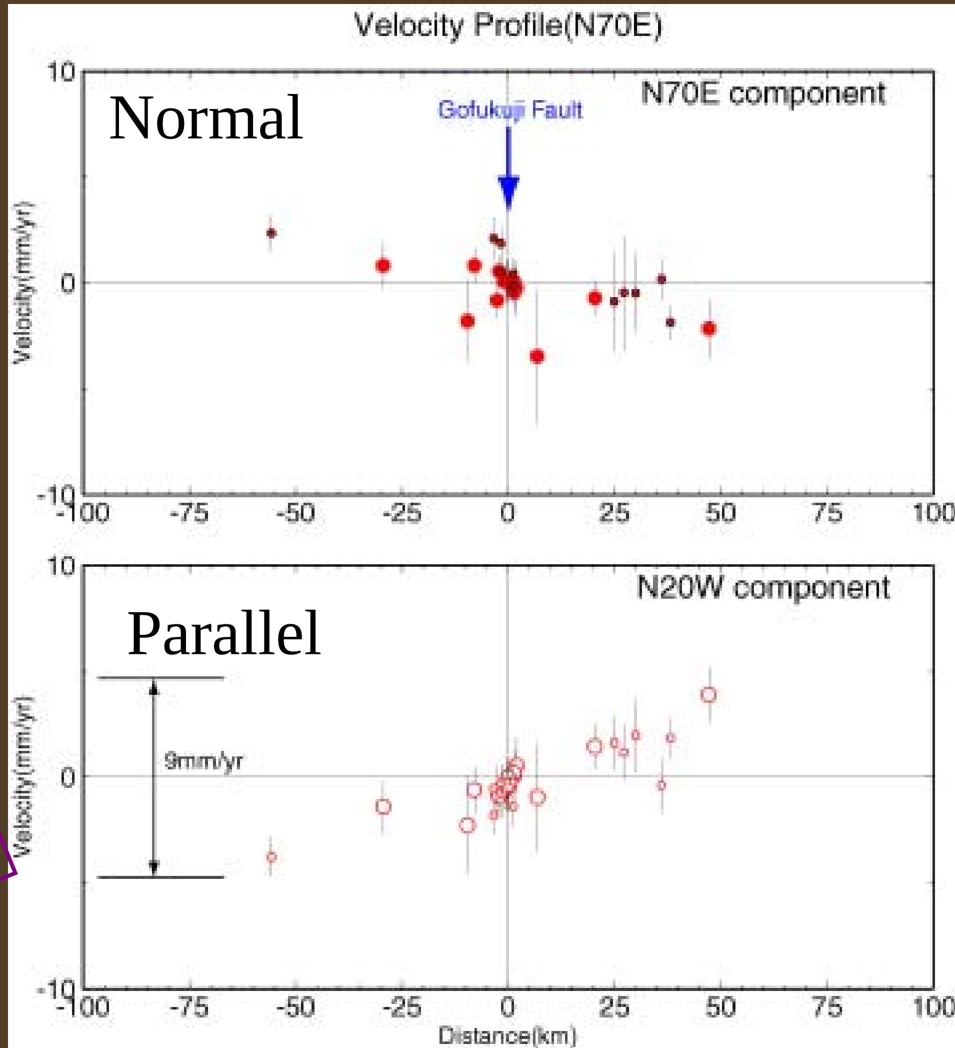
Paradox of the Gofukuji Fault

	East Matsumoto Basin Fault	Gofukuji Fault
Geological slip rate	3 mm/yr (Okumura et al., 1998)	9 mm/yr (Ikeda and Yonekura, 1986, Okumura et al., 1994)
Geodetic strain (85years)	40-50 ppm* (Tada and Hashimoto, 1990) *Including effects of 1918 Omachi EQ	10-20 ppm (Tada and Hashimoto, 1990)
GPS strain rates (1-3 years)	0.2 ppm/yr (This study)	0.05 ppm/yr (This study)

- Are geological and geodetic data inconsistent?
- We need to take a finite width around the fault.
- Comparison in terms of displacement rate is necessary.

Deformation around the Gofukuji Fault

- Relative displacement comparable to the long-term slip rate
- Wide area responsible for loading the Gofukuji Fault



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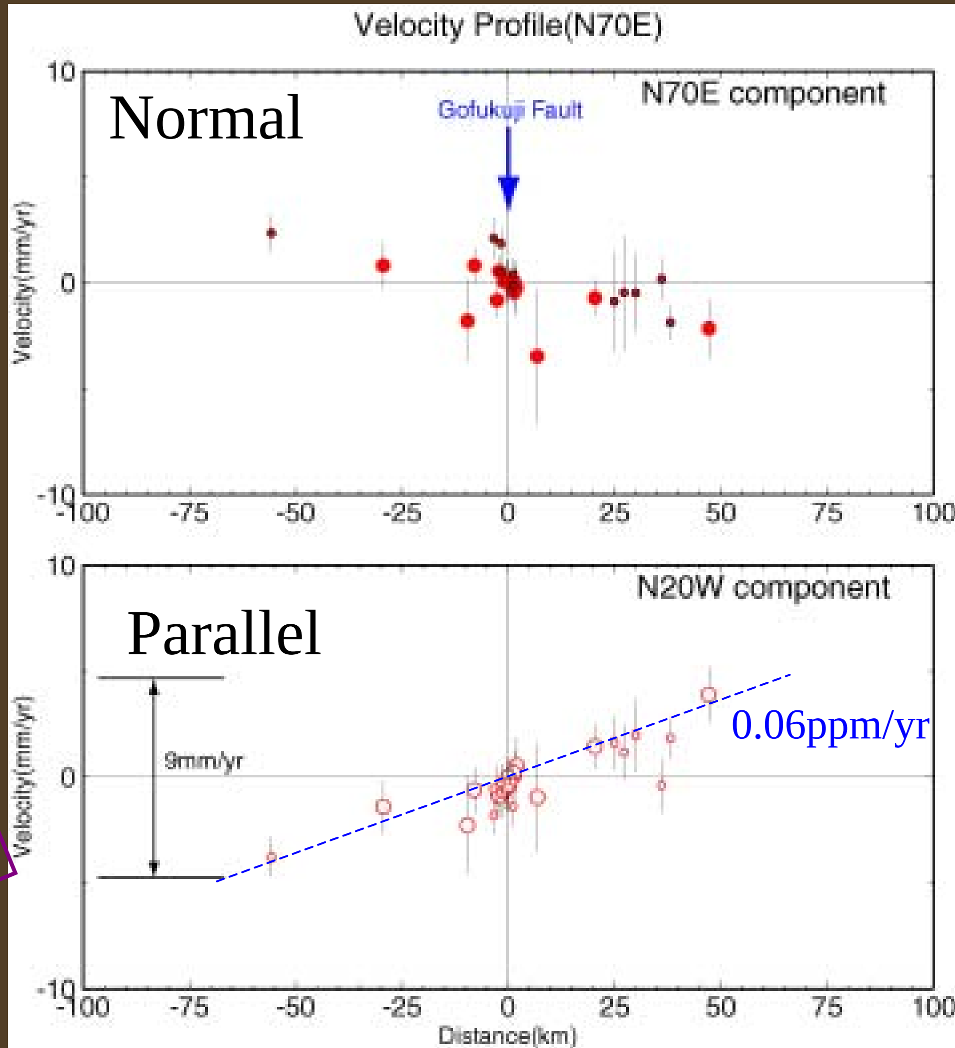

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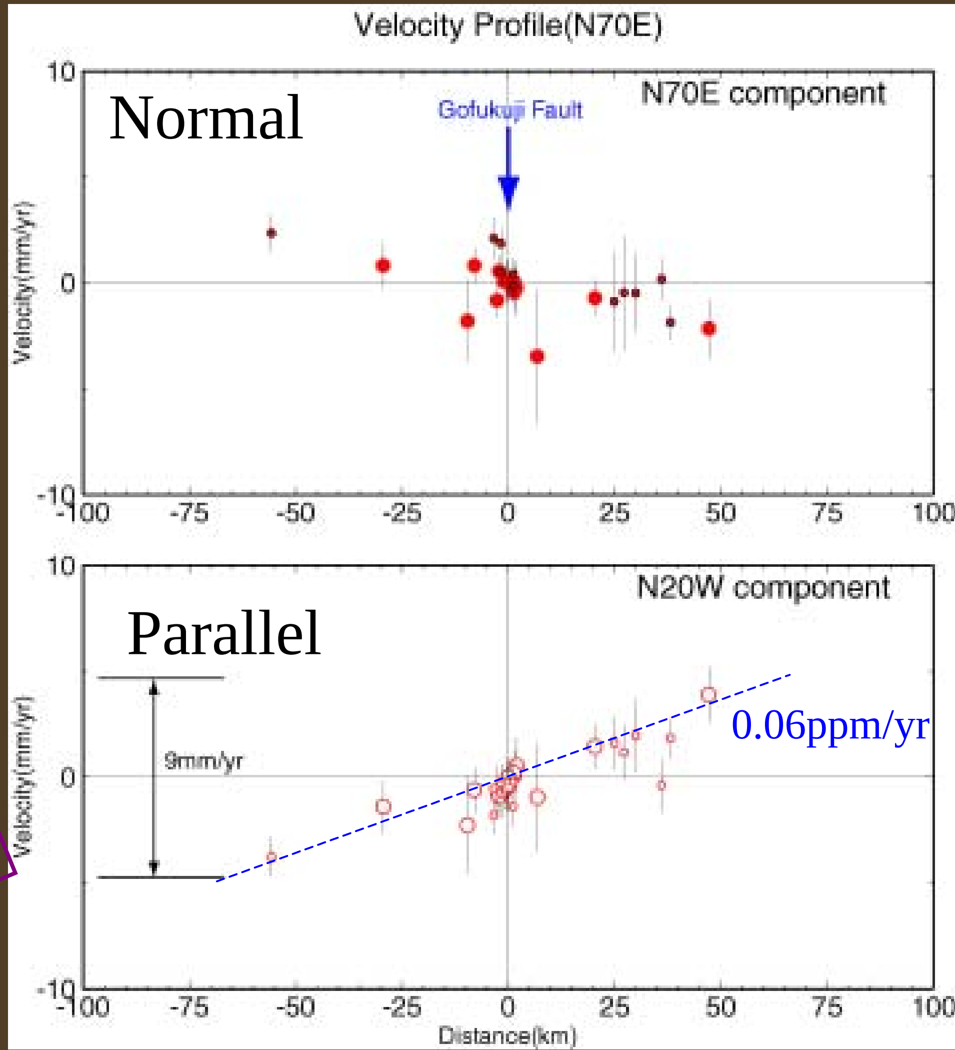
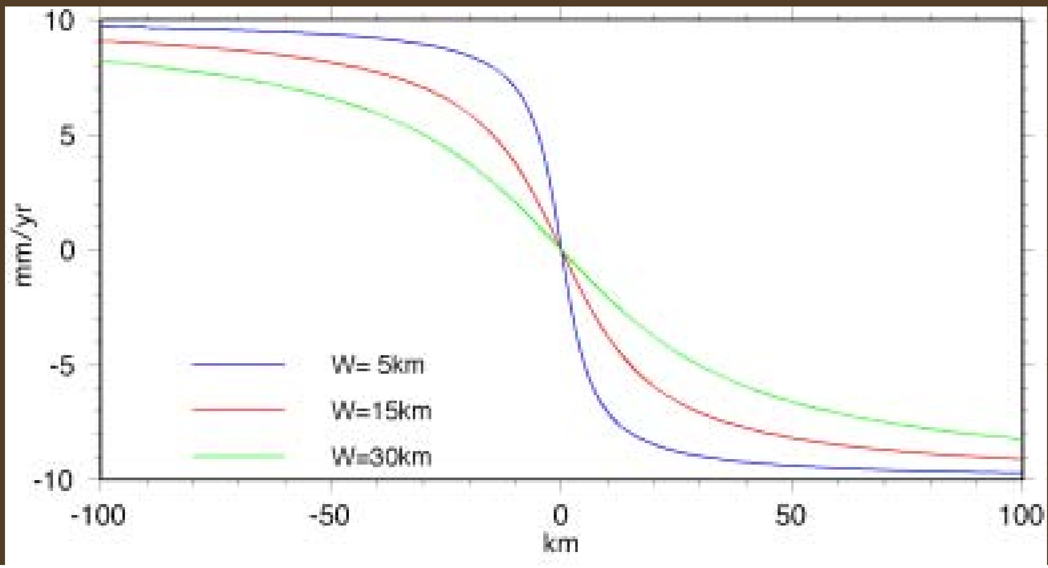
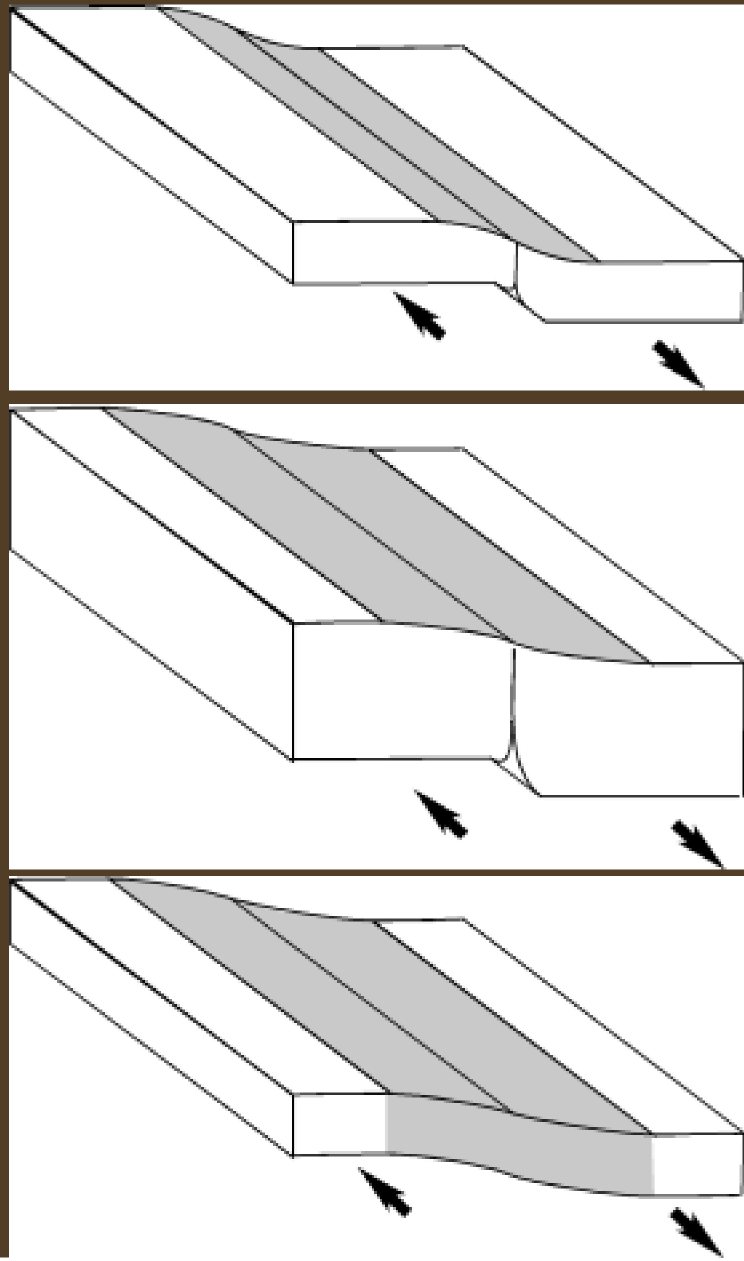


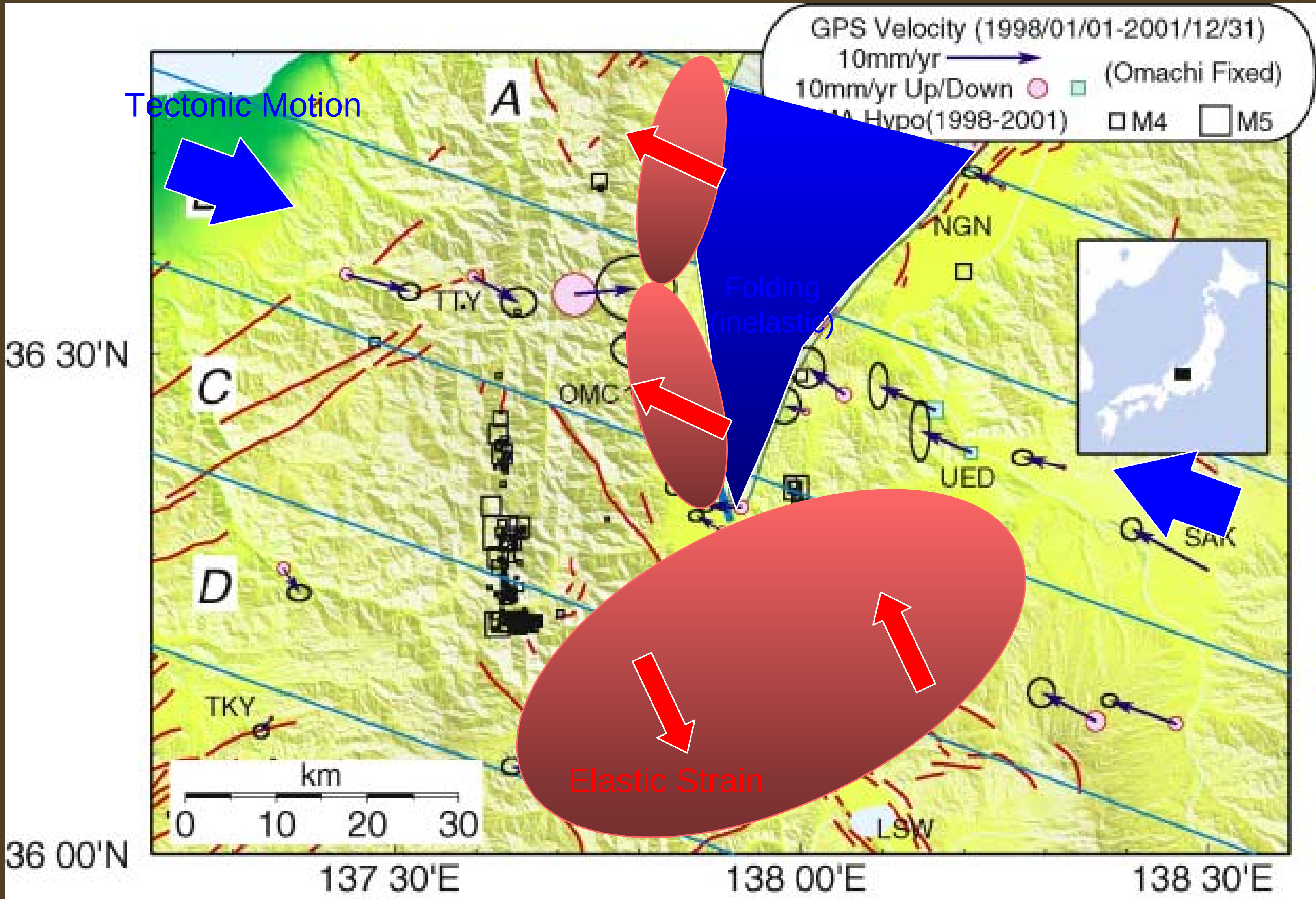
Possible Deformation Mechanisms

- Dislocation model
  - Large coupling width:30km
  - Concentrated deformation in substratum
- Distributed shear
  - Strong basal coupling
  - Large viscosity of substratum





Tectonic deformation around ISTL

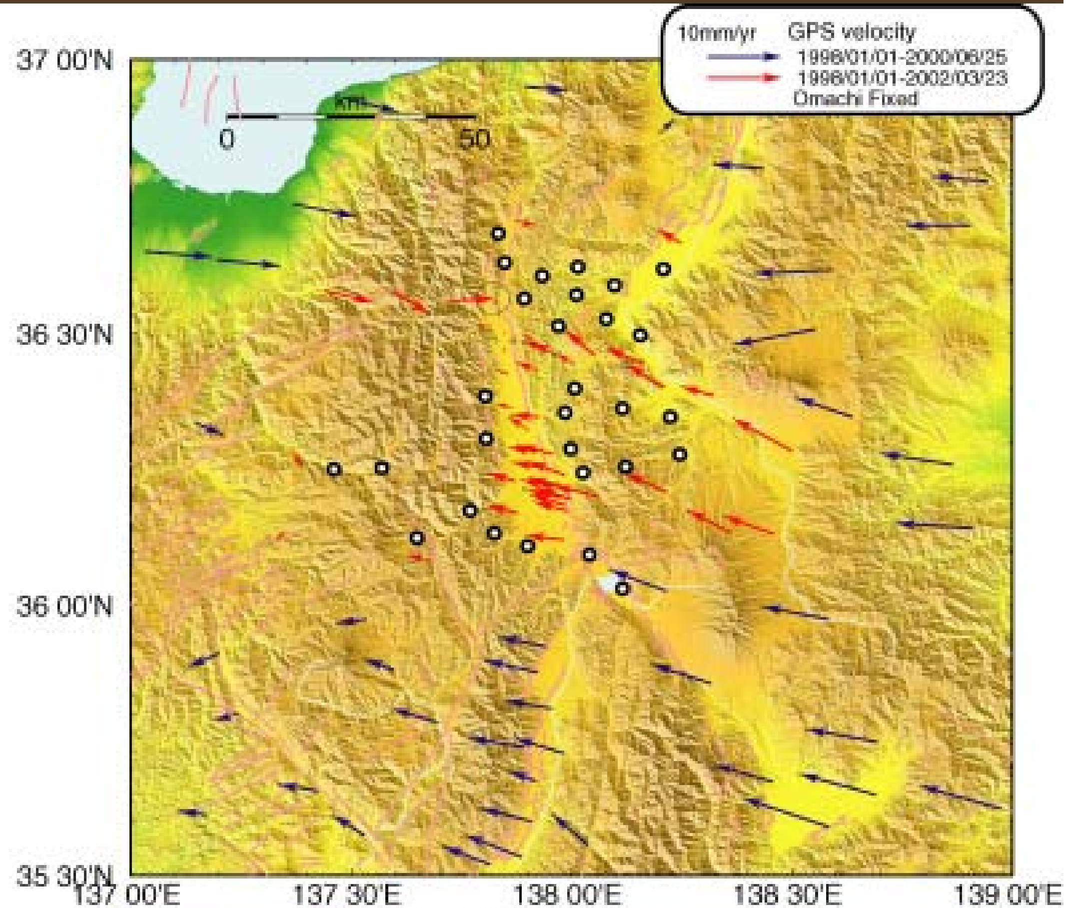


Seismic hazard around the Gofukuji Fault

- Crustal strain is NOT concentrated around the fault.
- The geodetic relative displacement rate around the fault is comparable to the geological slip rate if we consider a 100km wide area.
- Possible mechanisms:
  - Large elastic width + Large coupling depth?
  - Distributed shear in the highly viscous layer beneath the upper crust?
- Tectonic stress has been accumulated for 1,000 years.
- A large earthquake can occur along the Gofukuji Fault.

Ongoing Investigatioin around ISTL

- Campaign-type GPS observation is conducted every year at about 30 sites
- Detailed deformation pattern
- Lateral heterogenity



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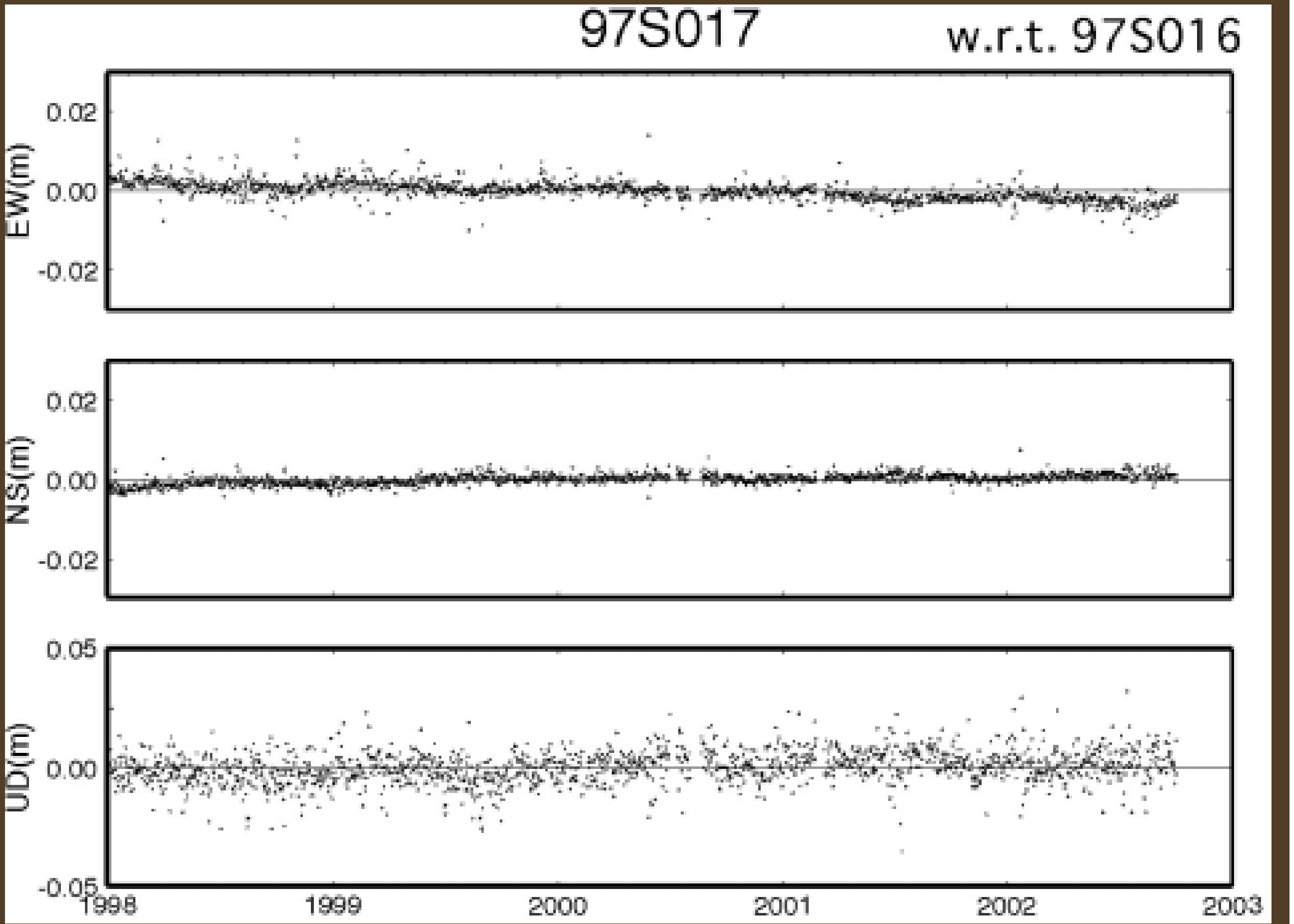
Conclusions

- Crustal deformation around the northern and central parts of the Itoigawa-Shizuoka Tectonic Line is laterally heterogeneous.
- Such a complicated deformation is partly caused by structural heterogeneity. Soft oceanic sediments accumulated in the extensional stage causes plastic deformation of the upper crust. In addition, detachment faults created during the extension may now act as creeping fault near the bottom of the upper crust. These are possible explanations for the high strain zone located east of ISTL.
- Widely spread deformation associated with the Gofukuji Fault is caused by the long interseismic period (>1000 yrs).
- Concentrated deformation around the East Matsumoto Basin Fault does not imply high seismic risk in the near future. On the other hand, large strain energy is accumulated around the Gofukuji Fault, which may cause a large earthquake.

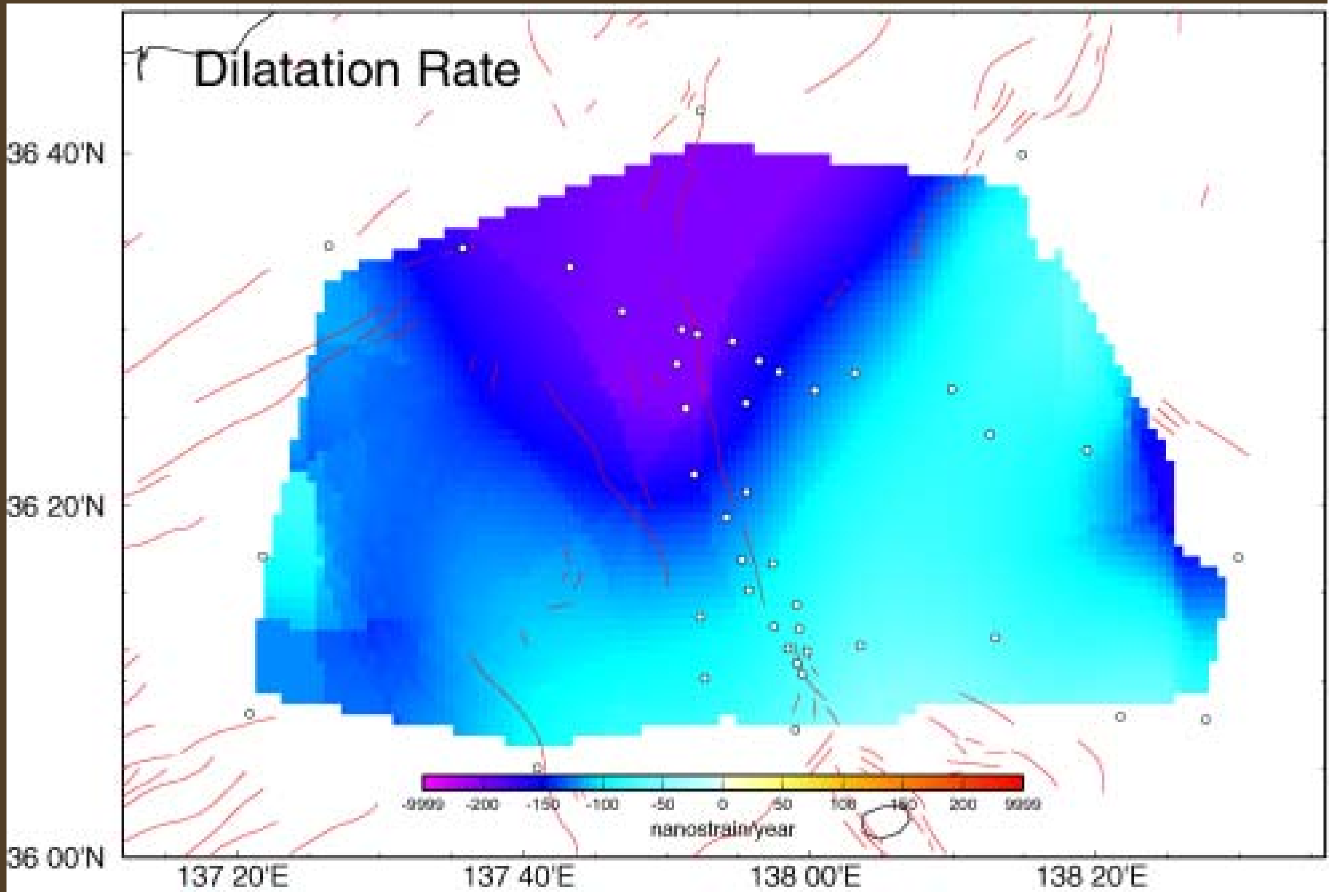
GPS coordinate time series

- Repeatability
  - 2-3mm (H)
  - 10-20mm (V)
- Velocity error
  - 1-2mm/yr
  - With flicker noise model



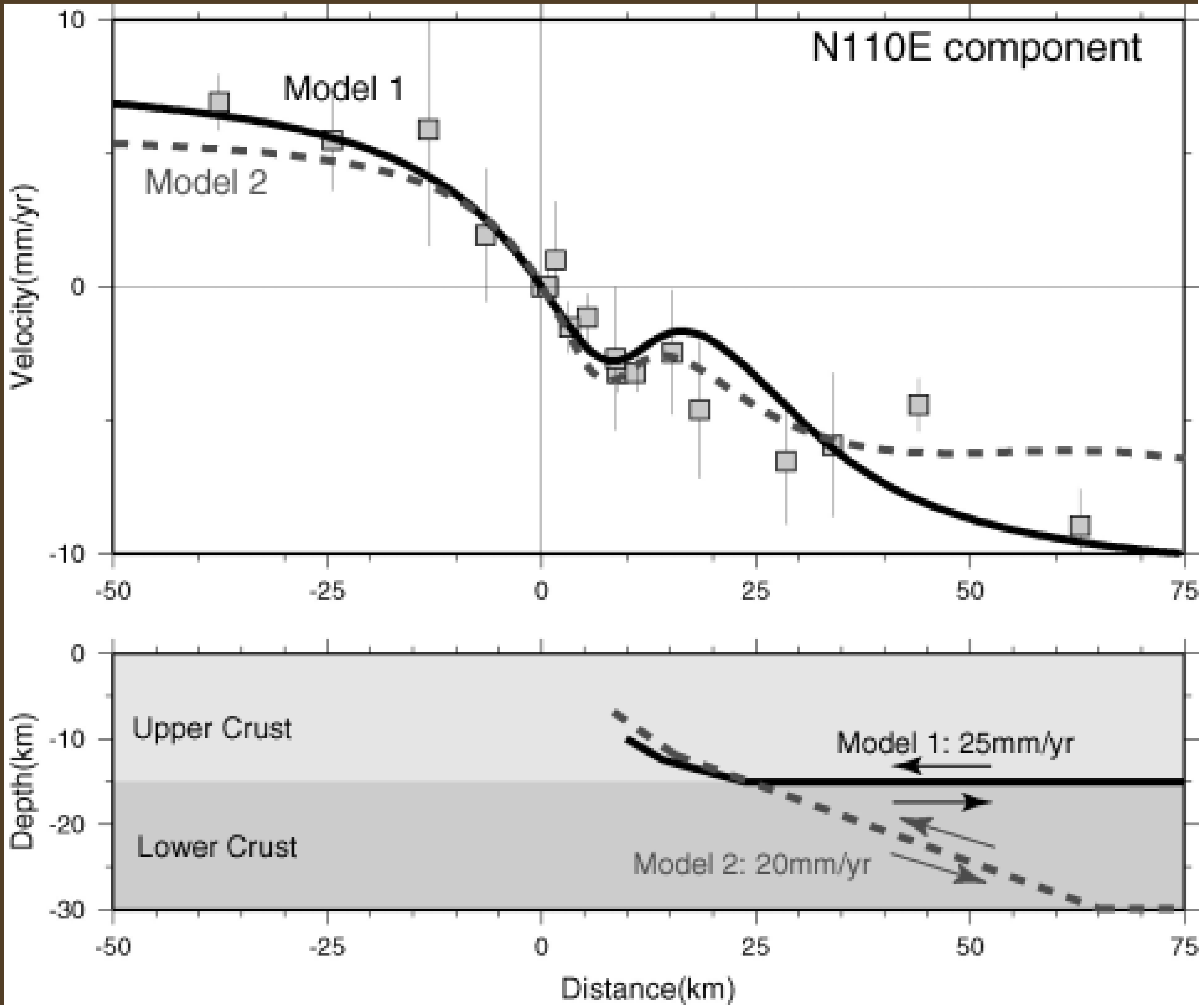
GPS Strain Rate around ISTL

- Large deformation in SDZ and west of the northern ISTL.
- Smaller strain in the central ISTL.



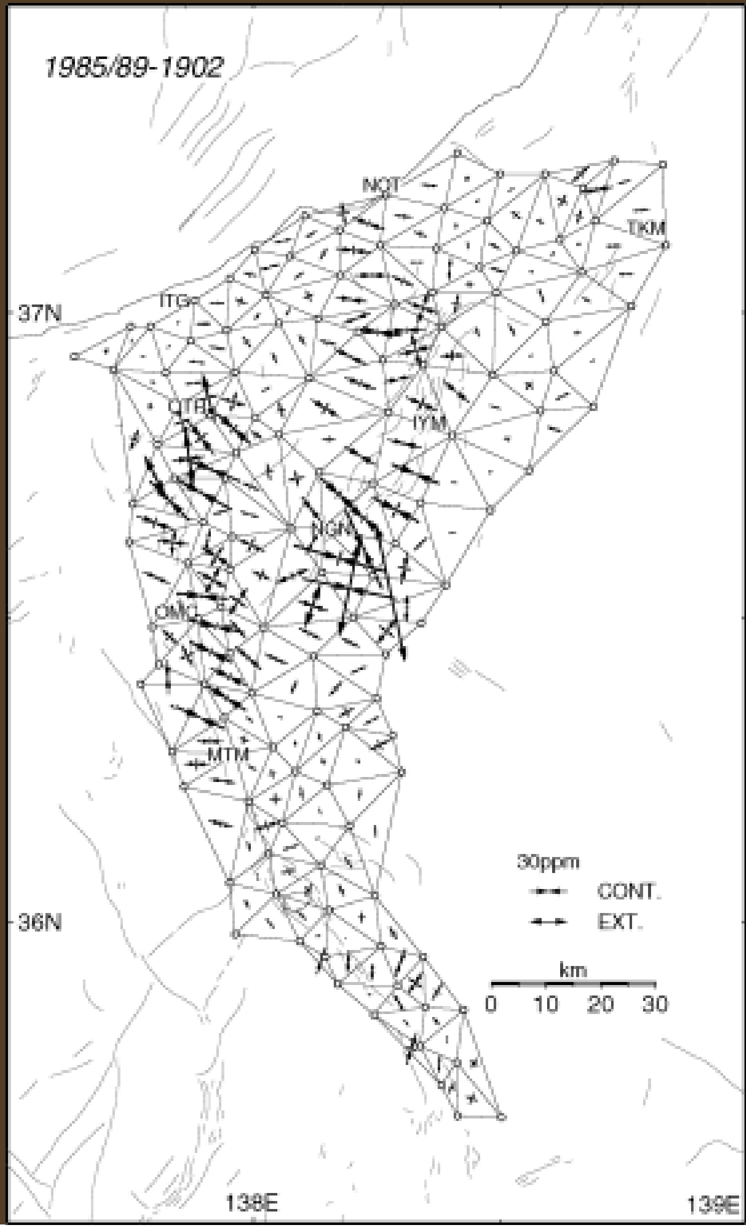
A Kinematic deformation model

- Creep at the depth of the fault
- Upper limit of the slip area must be shallow
- Configuration in the lower crust cannot be resolved.
- Accompanying plastic deformation of upper crust?



Crustal strain by triangulation

- Strain for about 85 years.
- Large strain (40-50ppm) around the northern ISTL
- Concentrated on the eastern side of the fault trace
- Possible effects of the 1918 Omachi earthquake?



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- The inland deformation zone of Japan and the Itoigawa-Shizuoka Tectonic Line (ISTL)
- The 1918 Omachi Earthquake
- Present-day deformation of the northern ISTL
- Deformation around the Gofukuji Fault
- Tectonic implications
- Implications for seismic hazard