

# Workshop on the Mechanics of the Earthquake Cycle

ICTP, Trieste, Italy, 16 – 27 October 2023

## **Strength of the subduction megathrust (Part 2)**

Kelin Wang

Pacific Geoscience Centre, Geological Survey of Canada

School of Earth and Ocean Sciences, University of Victoria

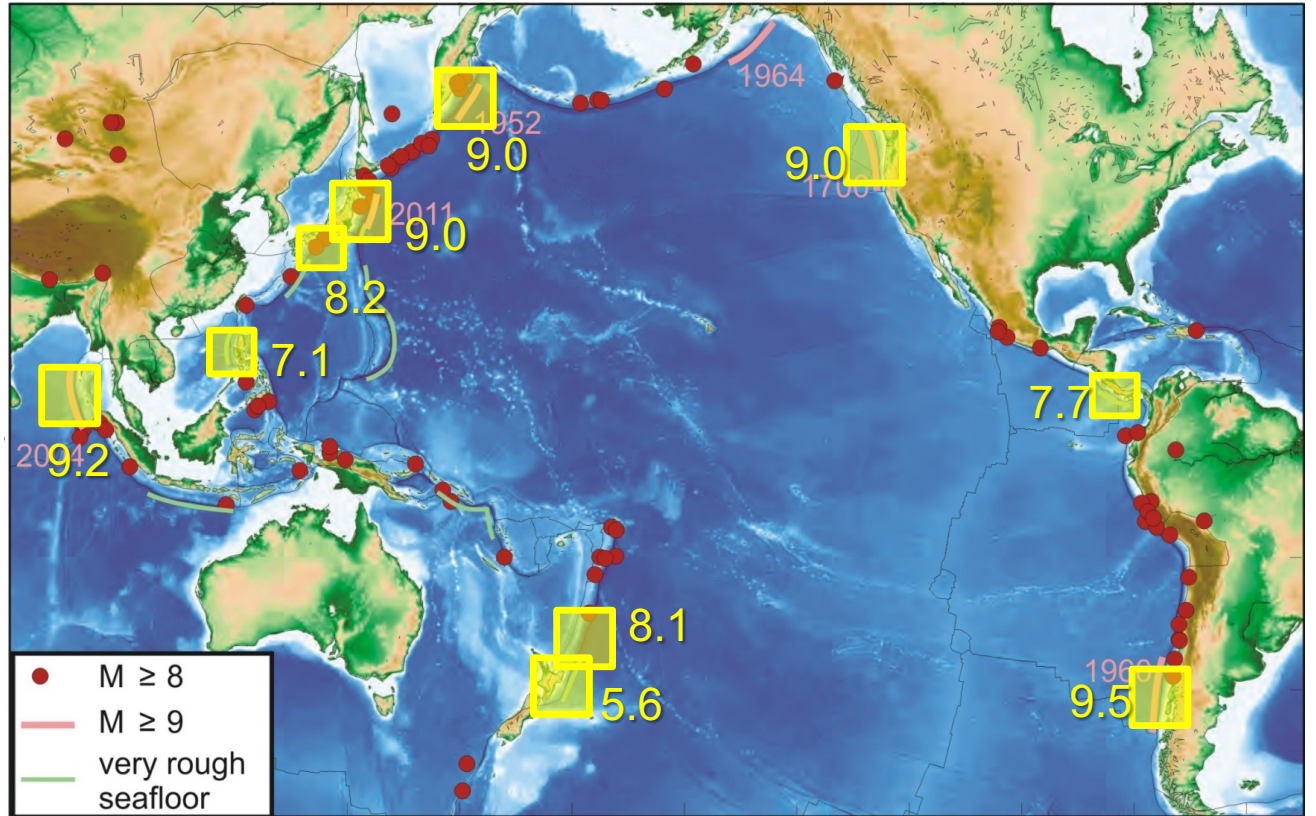
**Key contributors:** Xiang Gao, Institute of Oceanology, Chinese Academy of Sciences  
Ikuko Wada, University of Minnesota  
Susan Bilek, New Mexico Institute of Mining and Technology  
Lonn Brown, University of Alberta  
Tianhaozhe Sun and Jiangheng He: Geological Survey of Canada

1. Thermal-petrologic field of subduction zones
2. Defining megathrust strength
3. Low strength estimated from forearc force balance
4. Low strength estimated from frictional heating
5. Megathrust rheology and slip behaviour

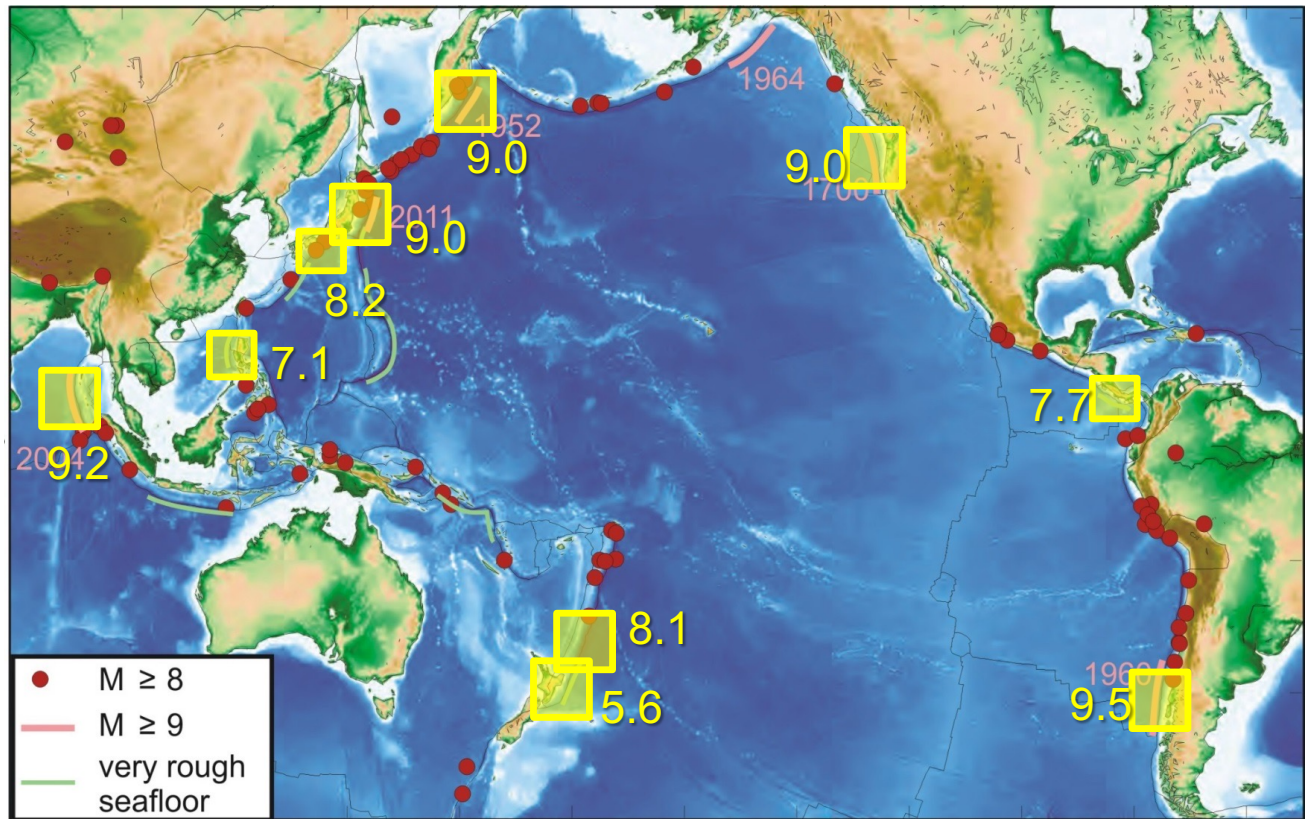
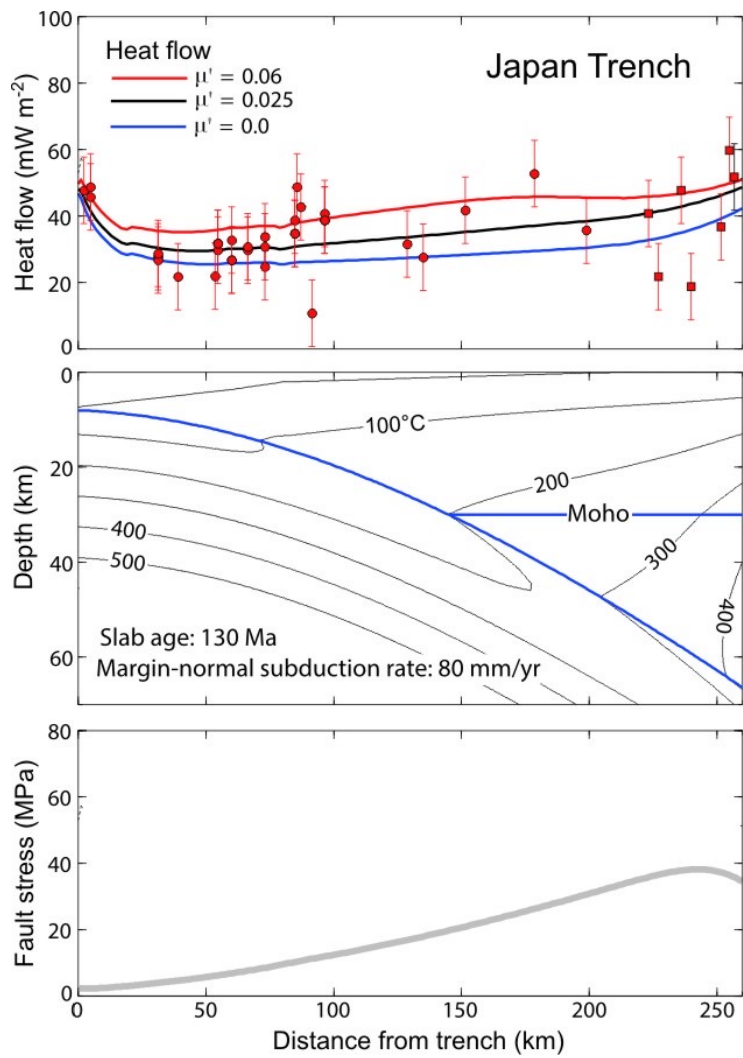
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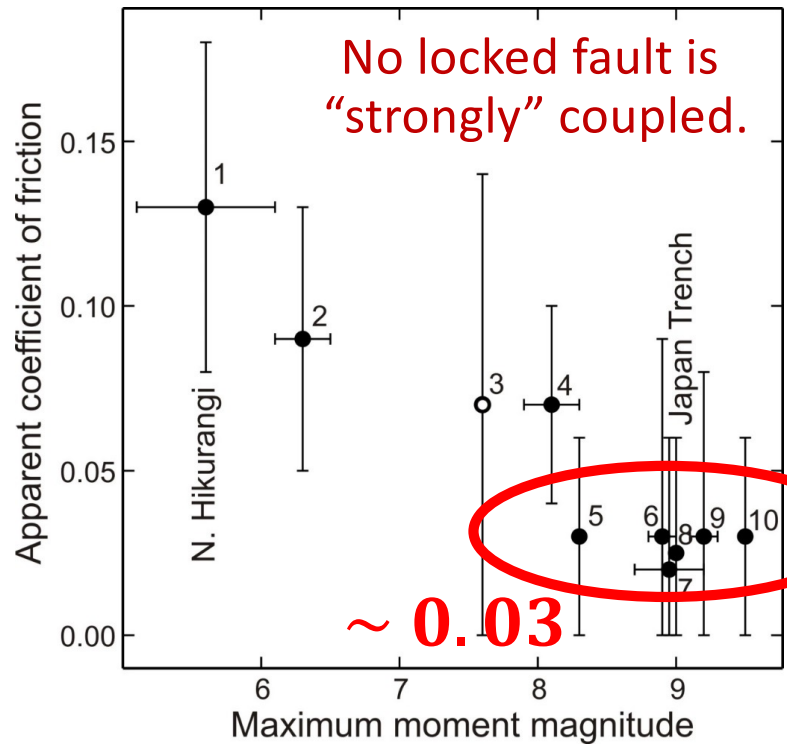


Kelin Wang  
(Younger)

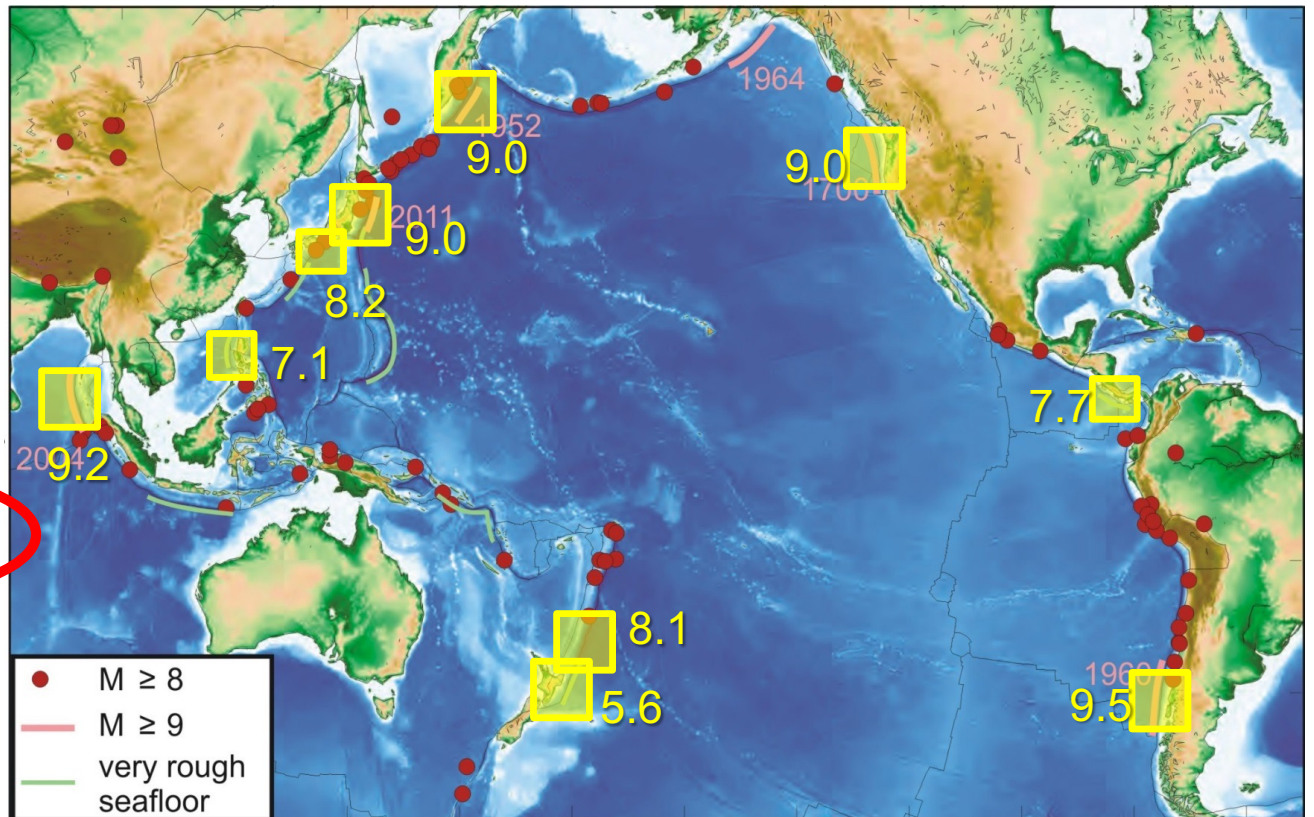






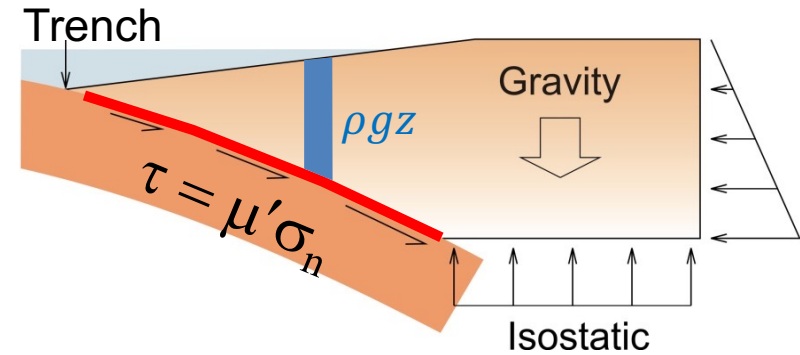


Gao and Wang (2014 Science)



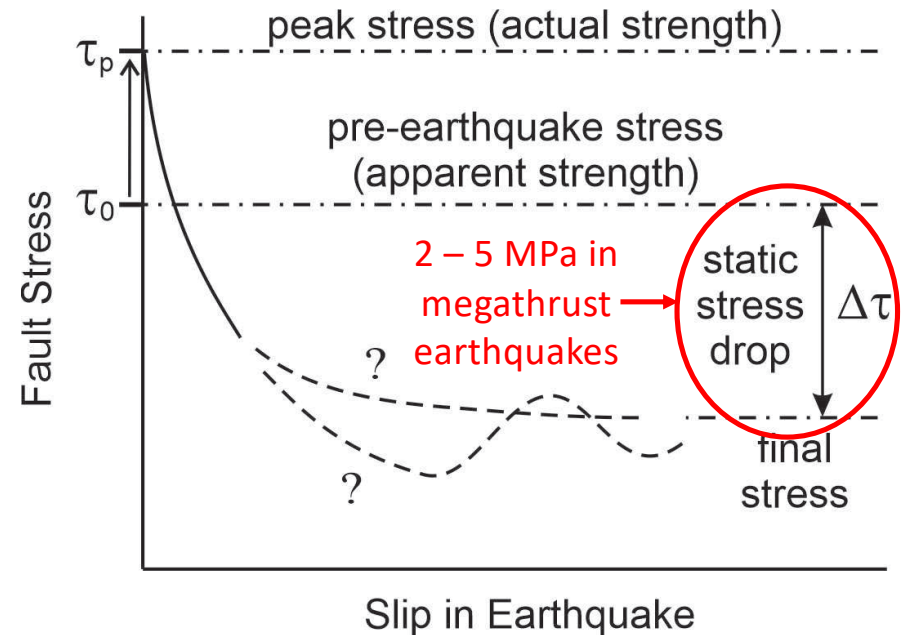
## Stress drop discussion

- Assuming  $\mu' = 0.03$ ,  $\sigma_n \approx \rho g z$ , then  $\tau$  increase with depth at 1 MPa/km. At 20 km,  $\tau = 20$  MPa.
- If  $\Delta\tau = 4$  MPa,  $\Delta\tau/\tau = 20\%$ .  
 $\Delta\tau$  is a significant fraction of total stress.



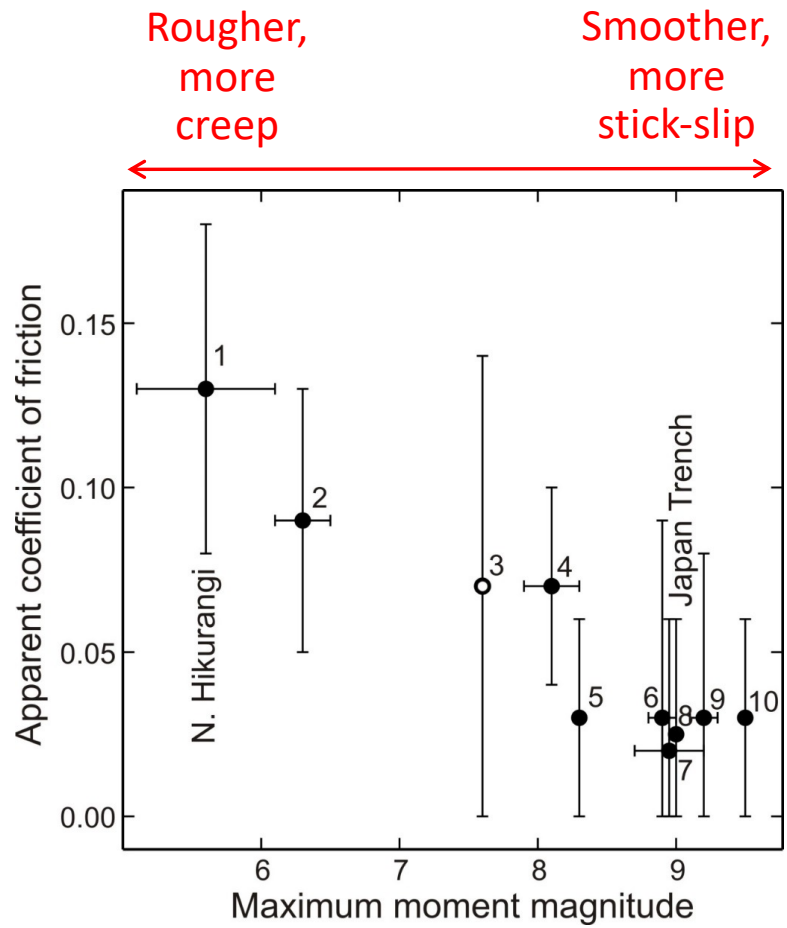
## Geodynamic importance

- Correcting two misconceptions:
  - (1) Tiny stress drop (e.g. 1%). Strong fault.
  - (2) Complete stress drop (e.g. 100%). Locally possible, but unphysical as rupture average.
- Fault stress takes time to rebuild. Concepts of characteristic earthquakes and recurrence intervals are valid (process to be discussed in “Viscoelasticity and earthquake cycles” lecture next). Justification for time-dependent hazard assessment.

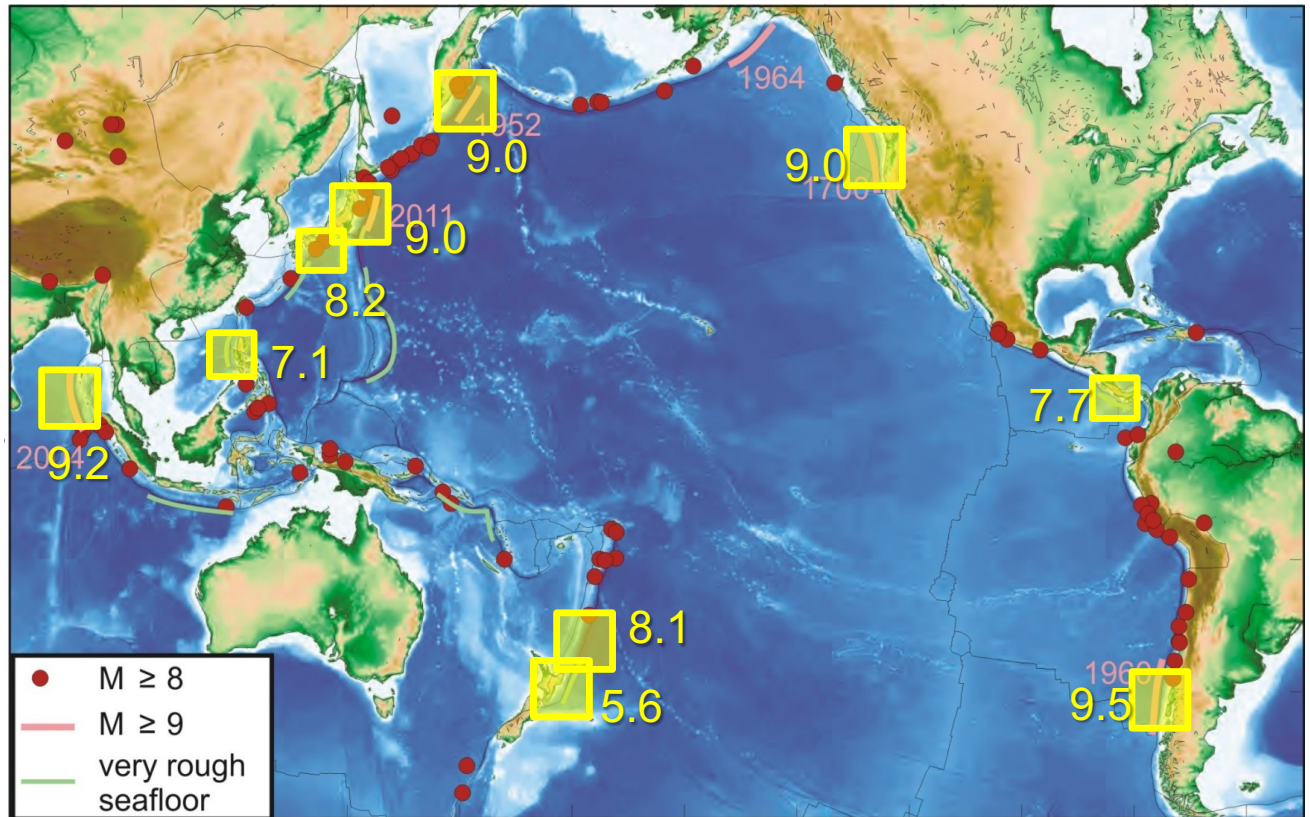


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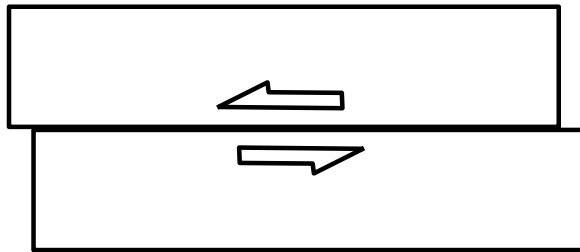


Gao and Wang (2014 Science)

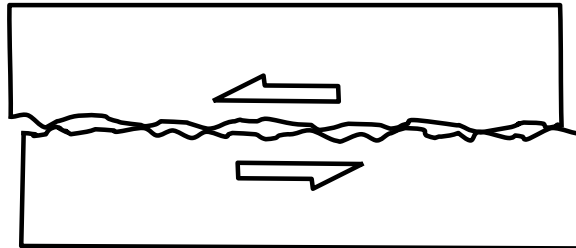


See Wang and Bilek (2014), Basset and Watts (2015), Scholl et al. (2015), Brizzi et al. (2018), Lallemand et al. (2018), van Rijsingen et al. (2018)

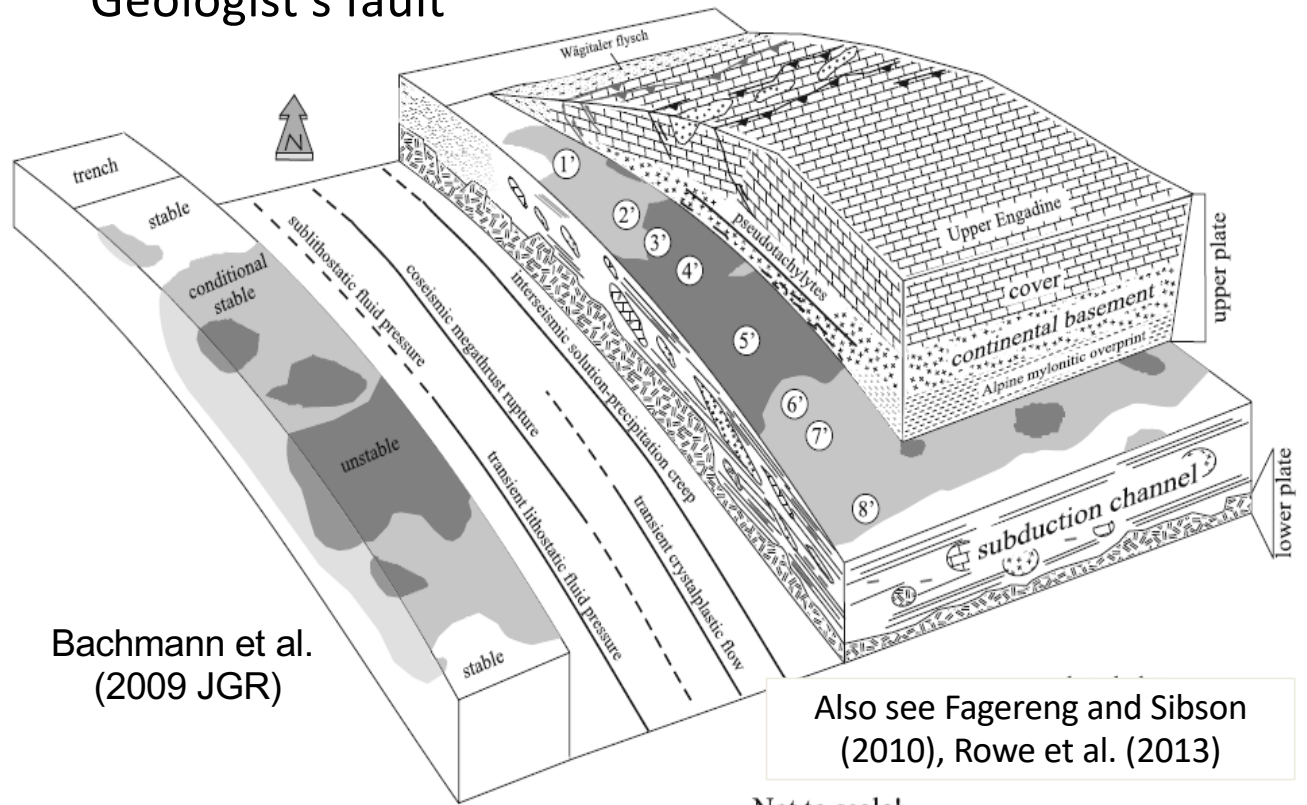
### Mathematician's fault



### Seismologist's fault



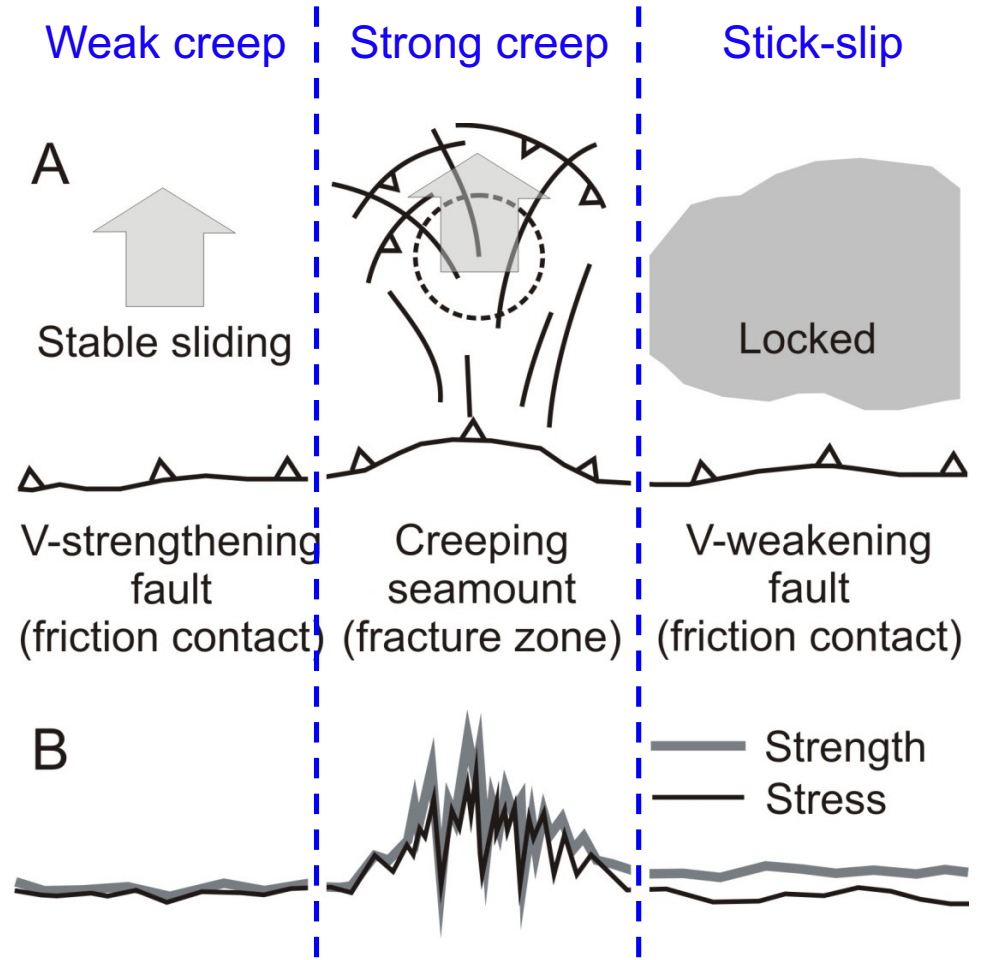
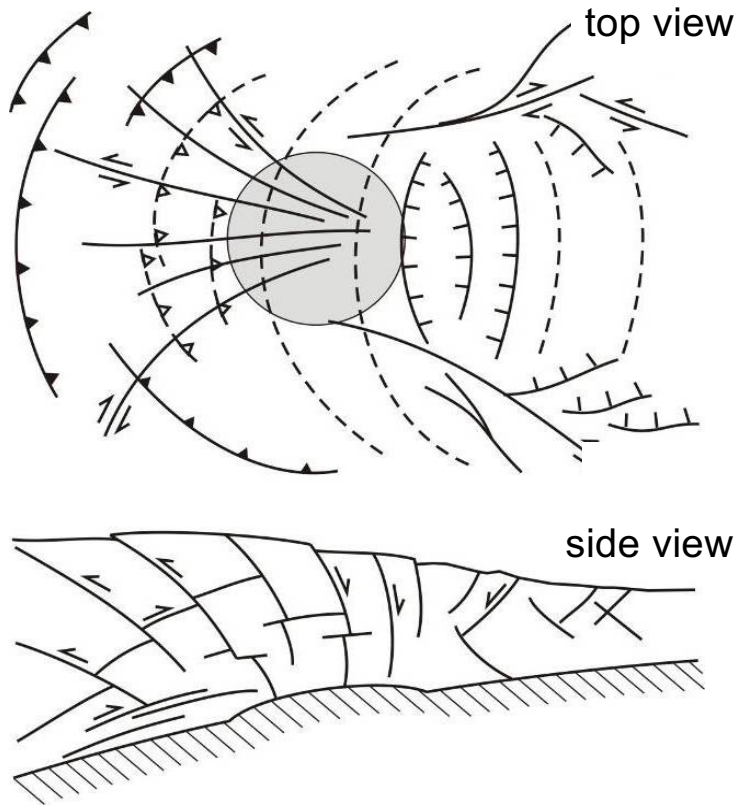
### Geologist's fault



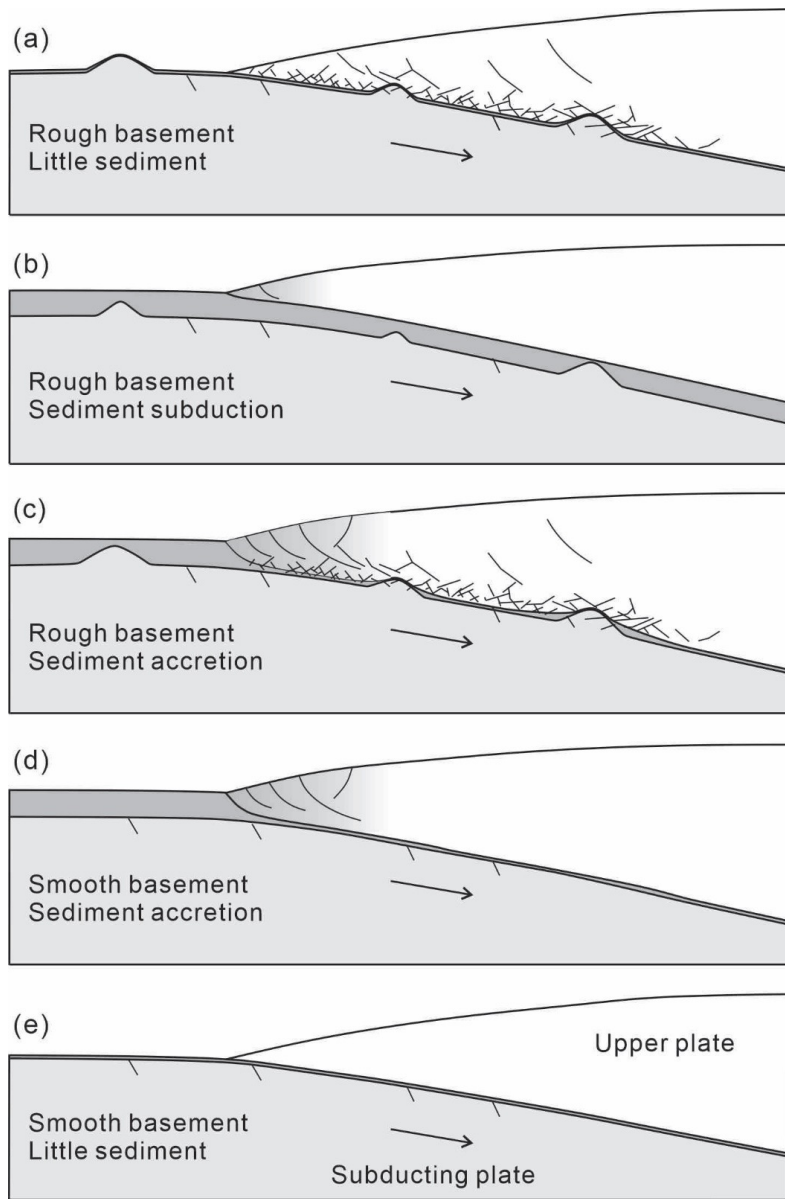
Bachmann et al. (2009 JGR)

Also see Fagereng and Sibson (2010), Rowe et al. (2013)

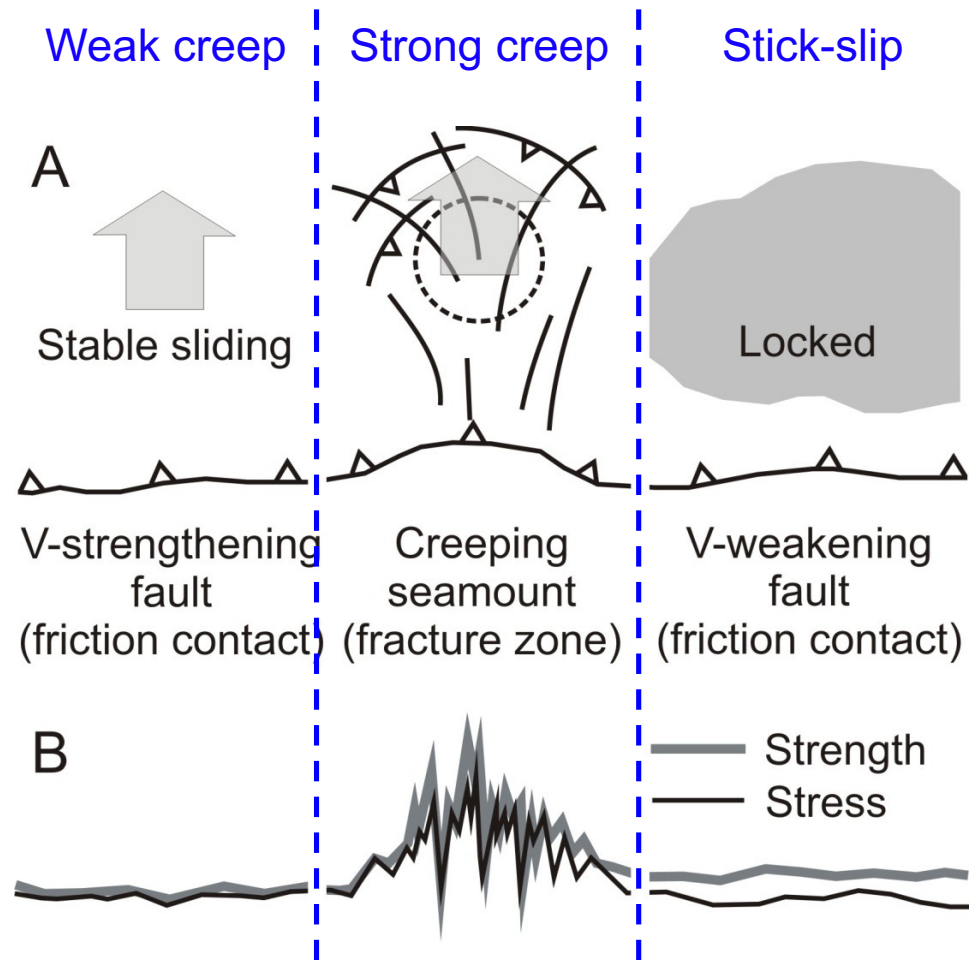
Not to scale!



Wang and Bilek (2011, Geology)

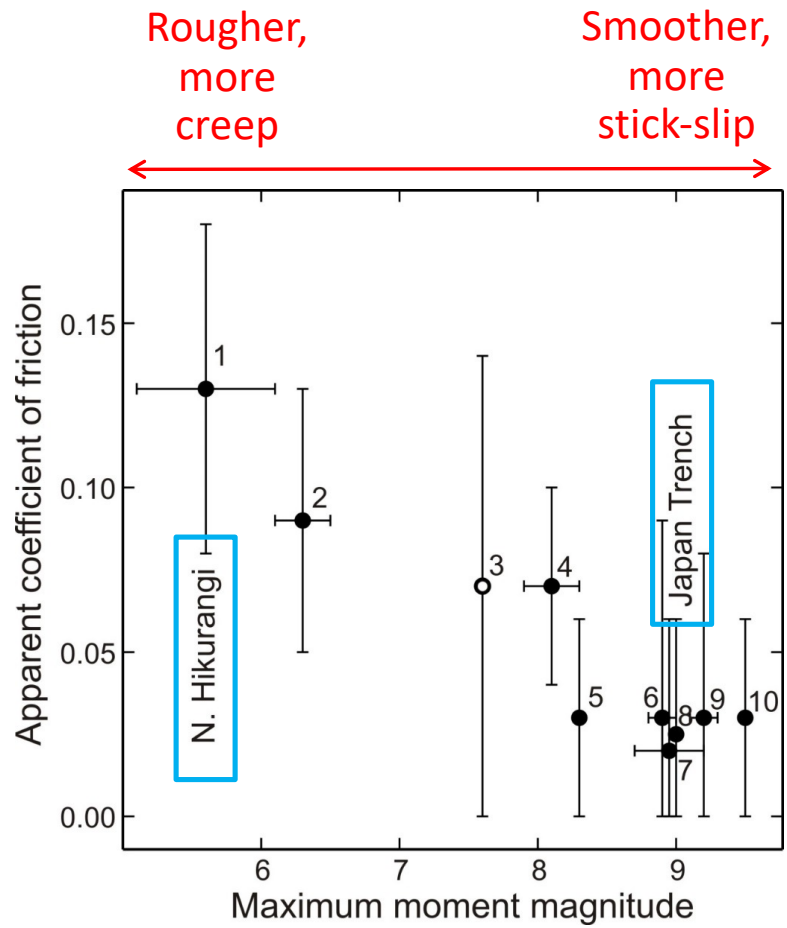


Tan et al. (2022, GRL)



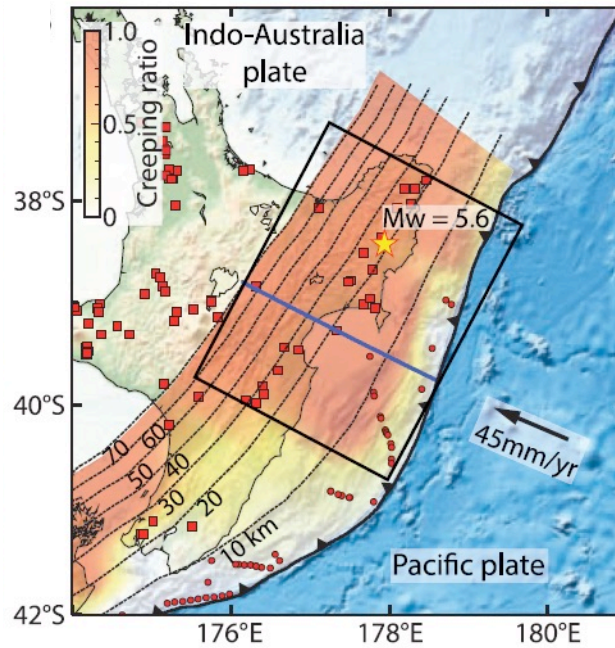
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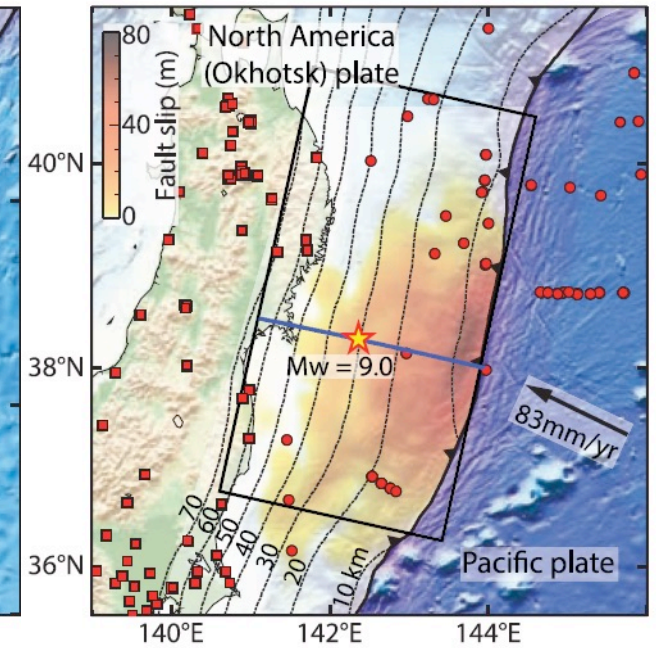
Gao and Wang (2014 Science)

N. Hikurangi



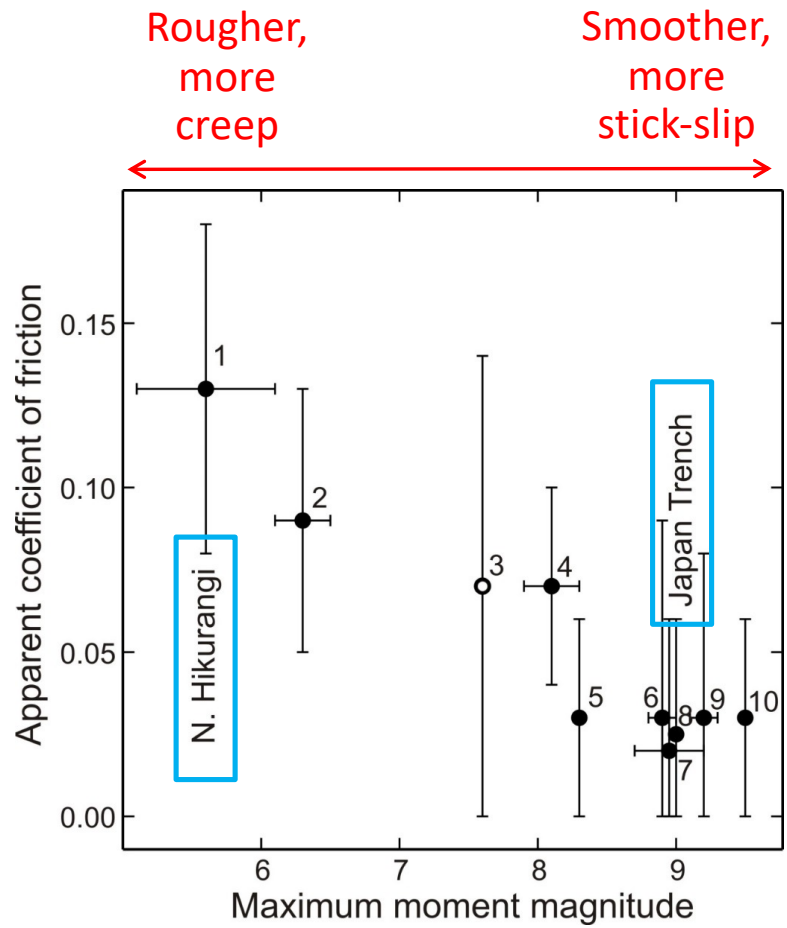
Megathrust creeping rate (from Wallace)

Japan Trench

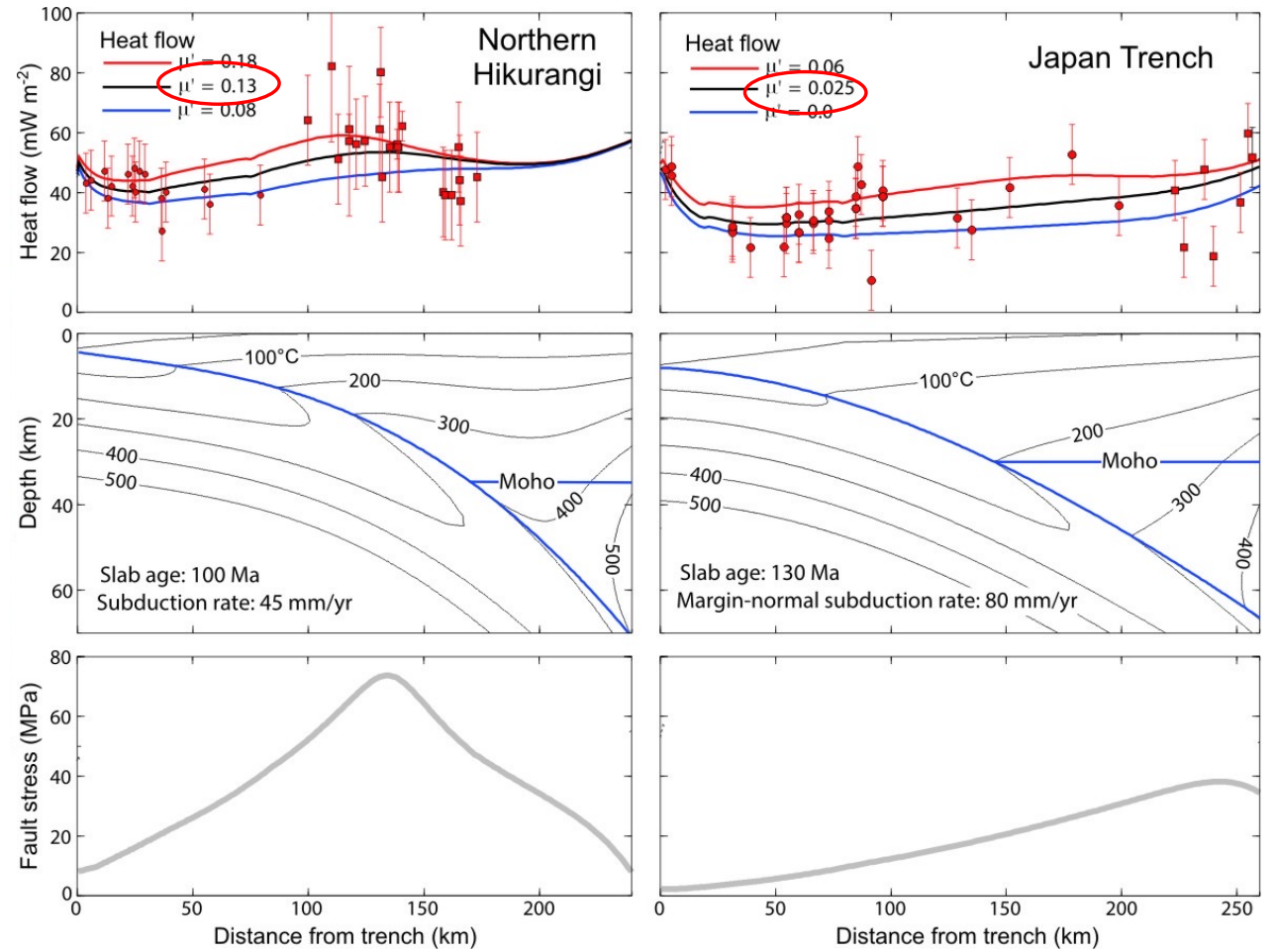


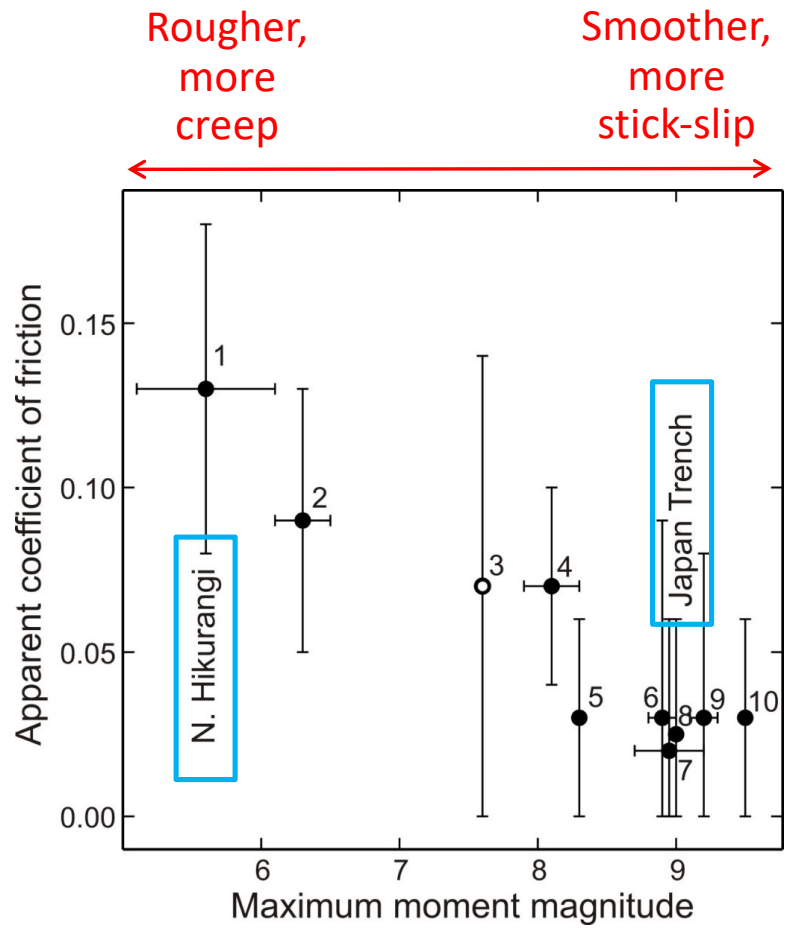
2011 M=9 rupture (from Iinuma et al.)



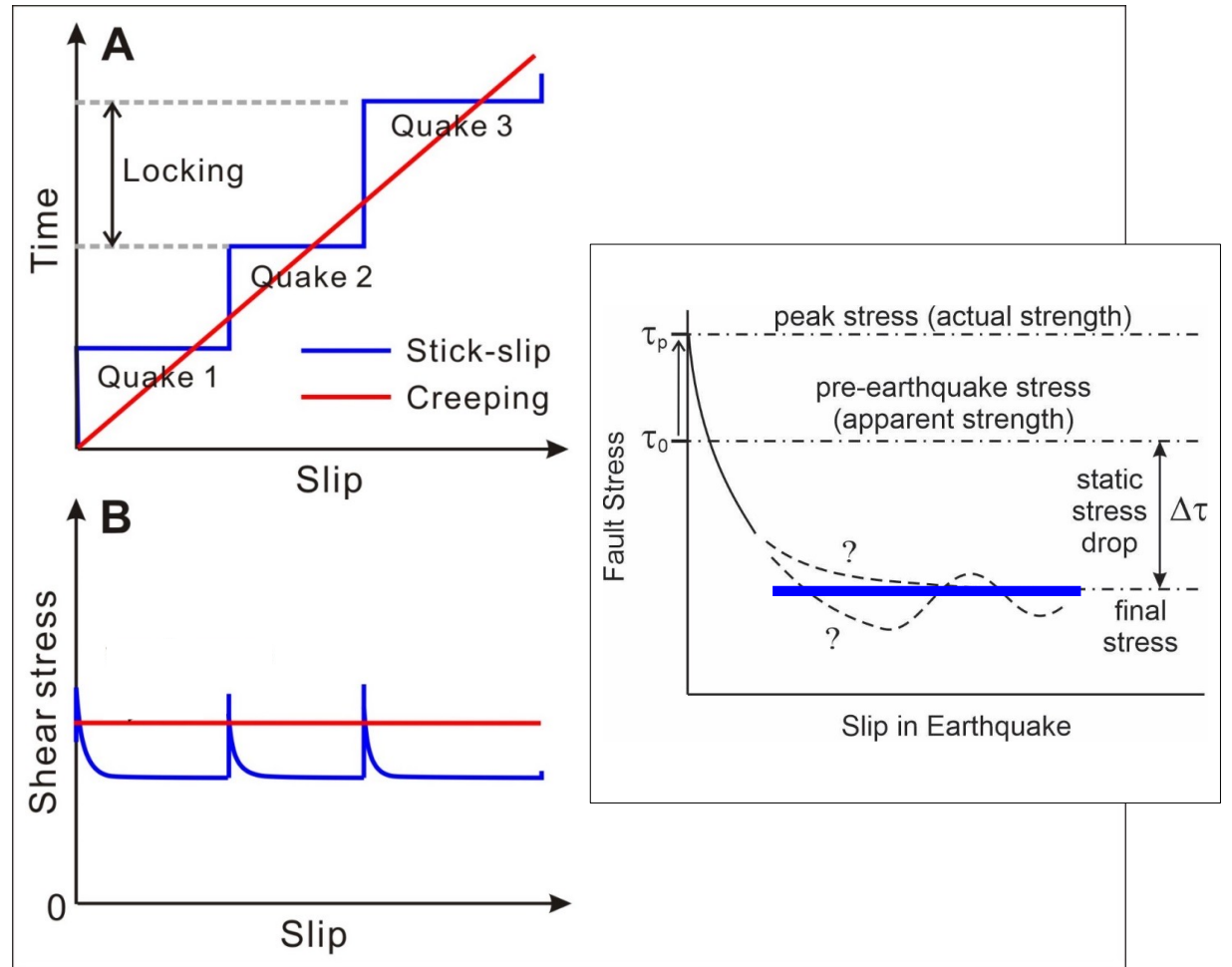


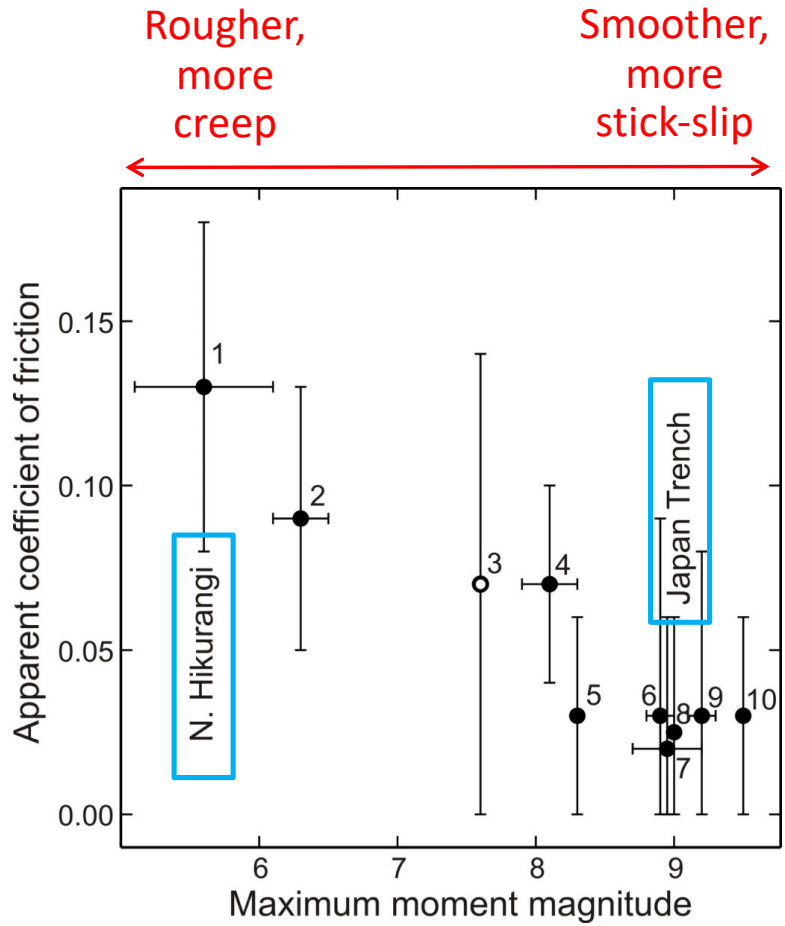
Gao and Wang (2014 Science)



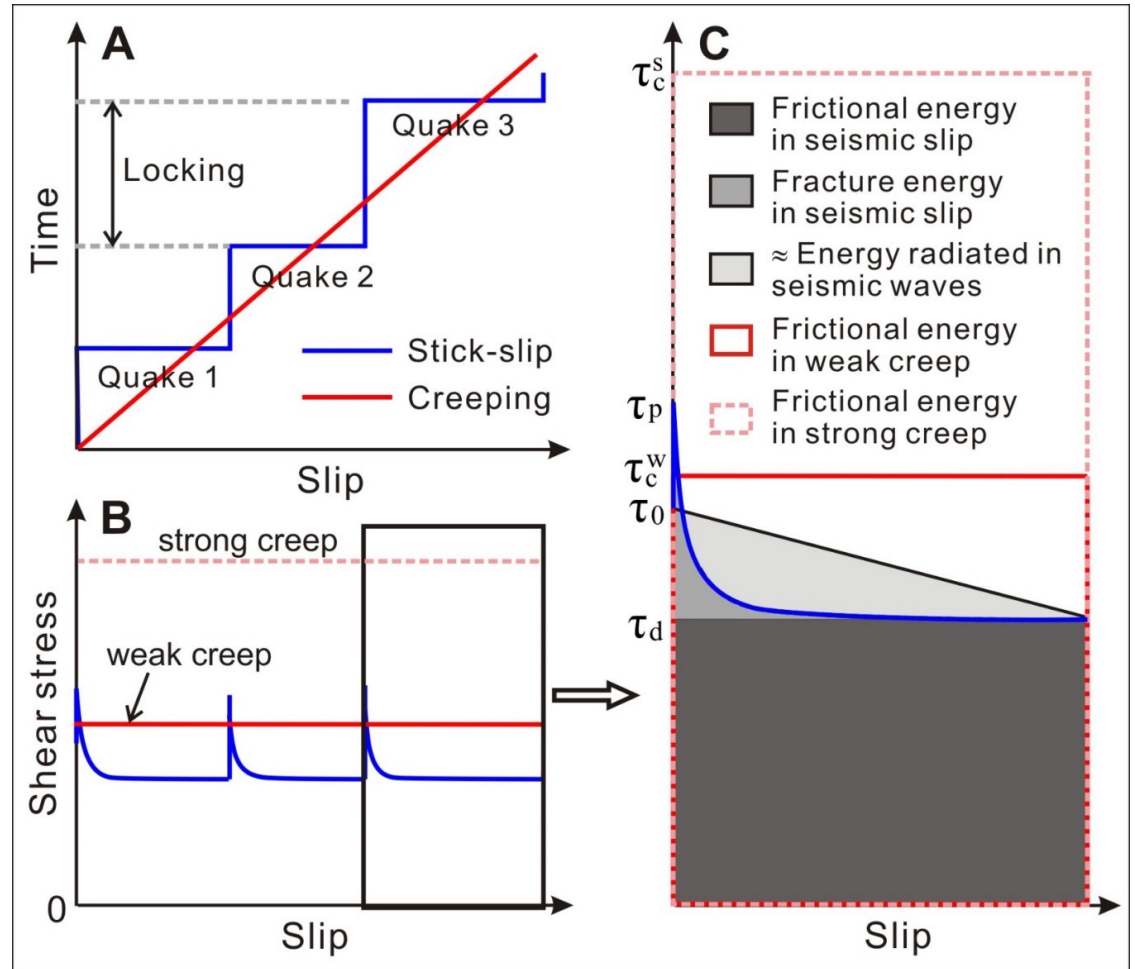


Gao and Wang (2014 Science)

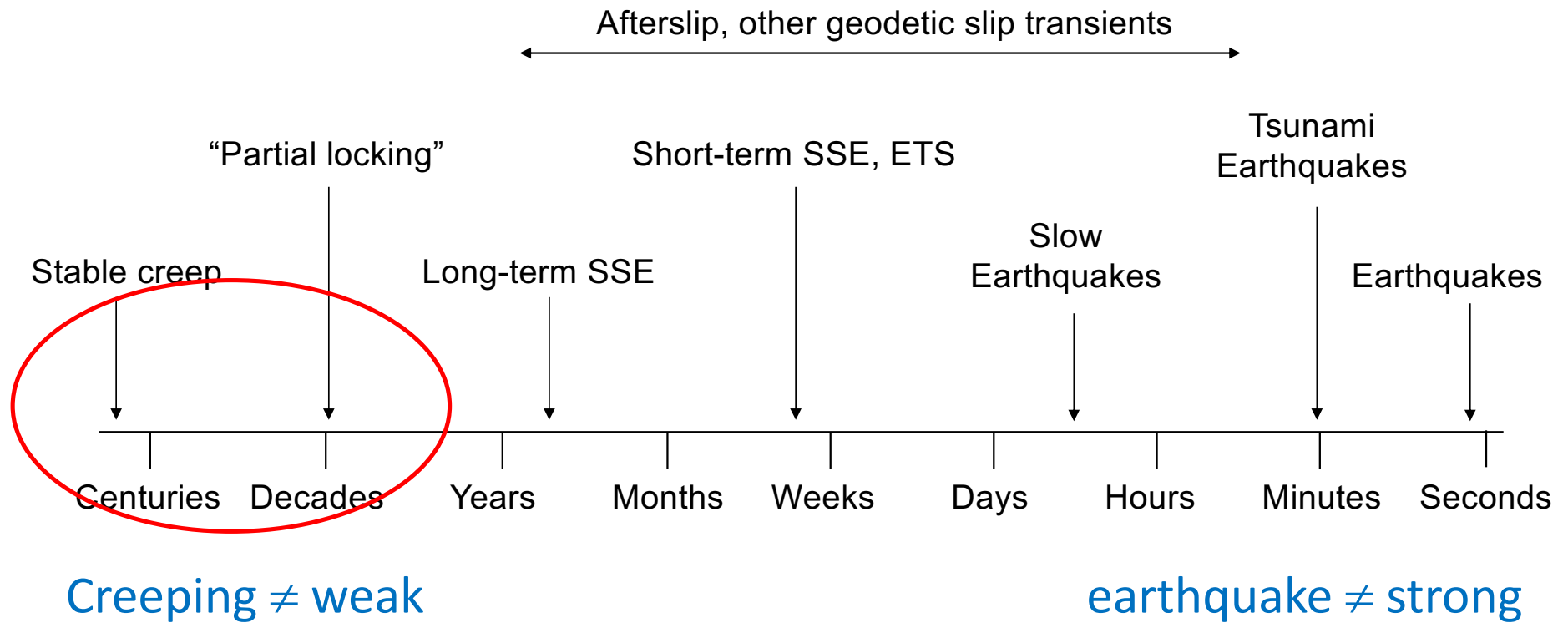




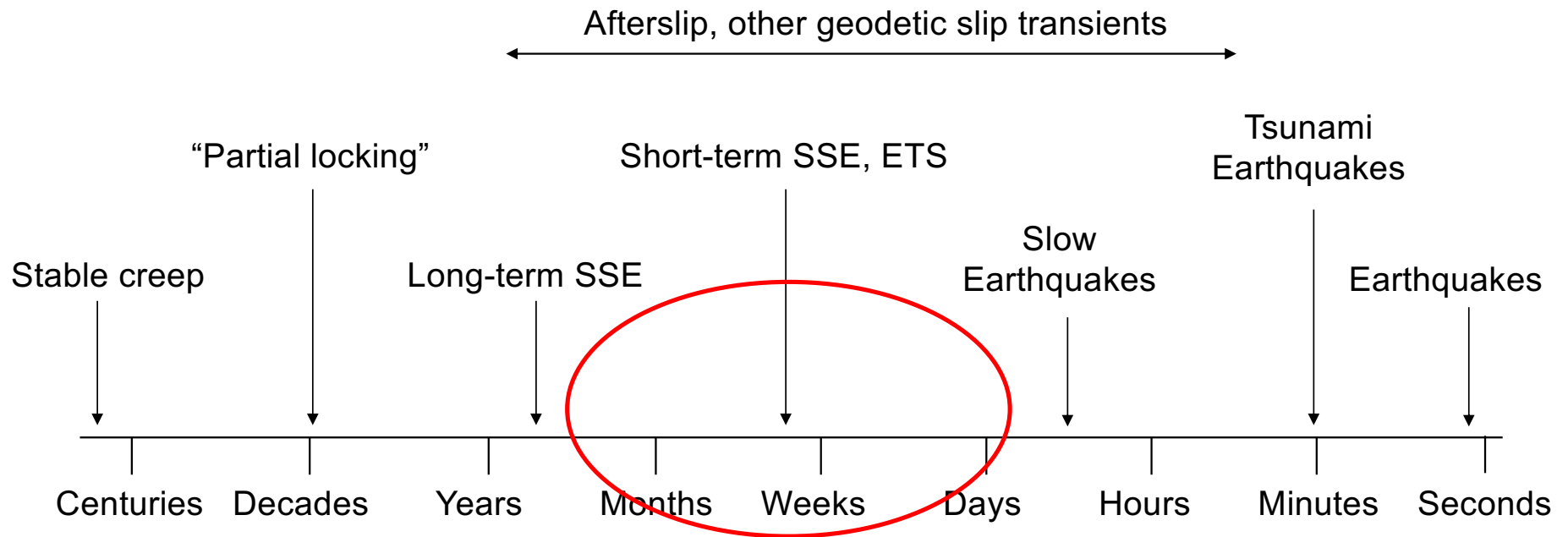
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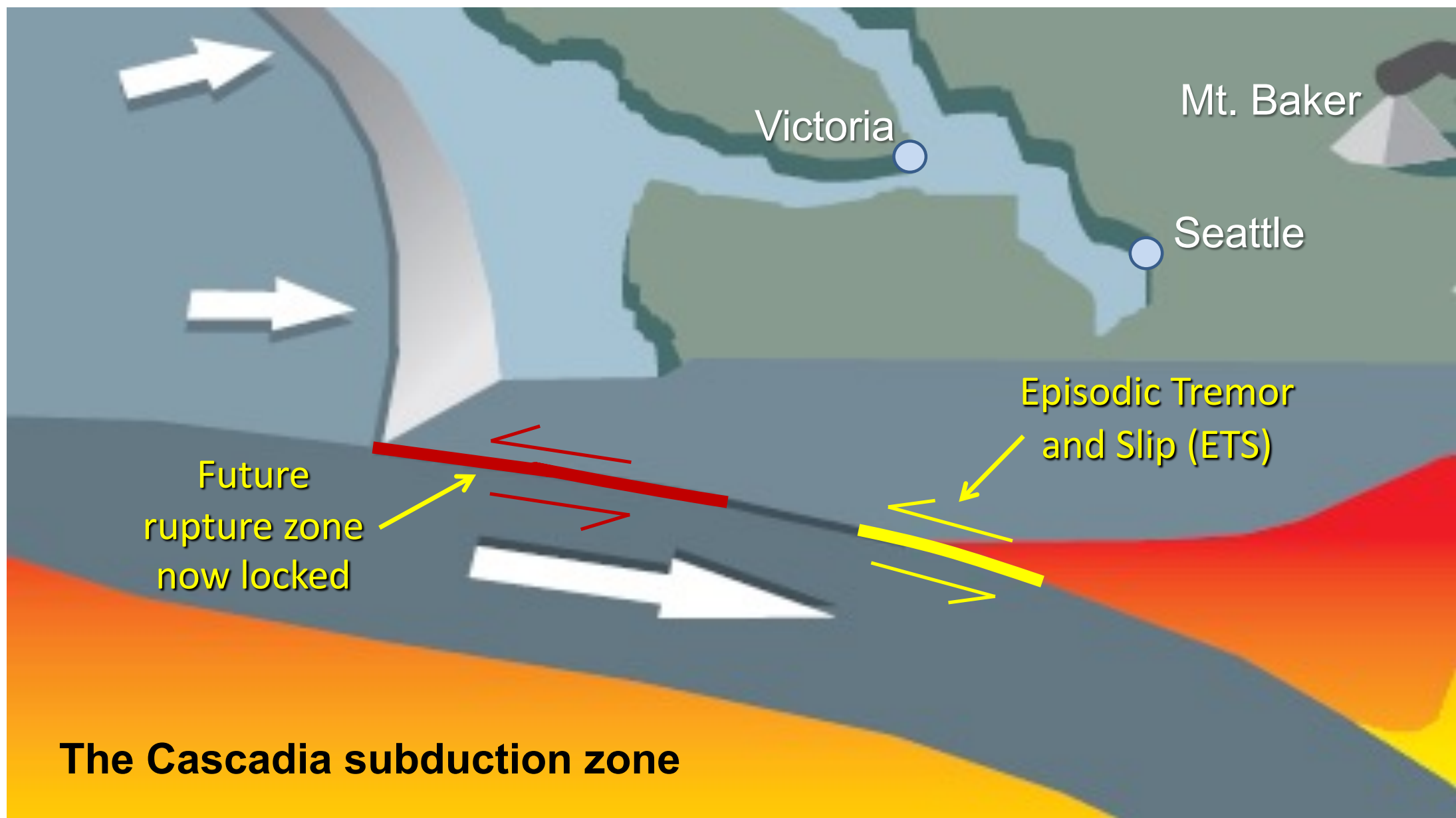
# Geodetically detectable fault slip or creep



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Victoria

Mt. Baker

Seattle

Episodic Tremor and Slip (ETS)

Future rupture zone now locked

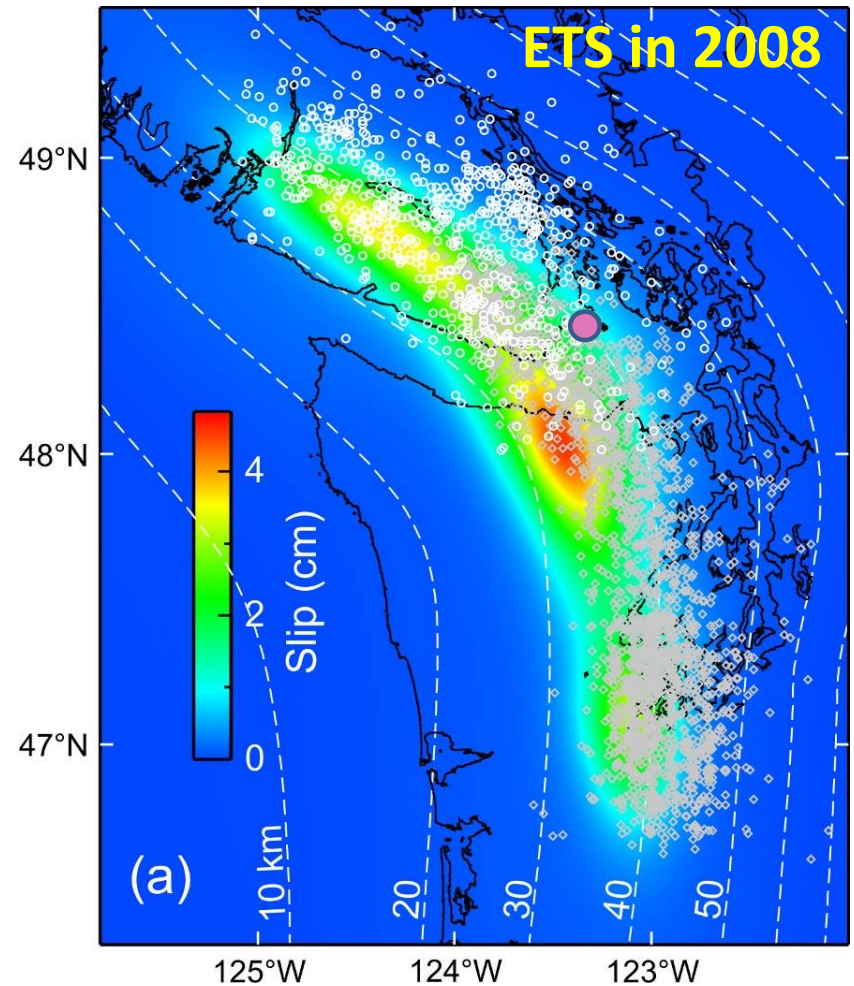
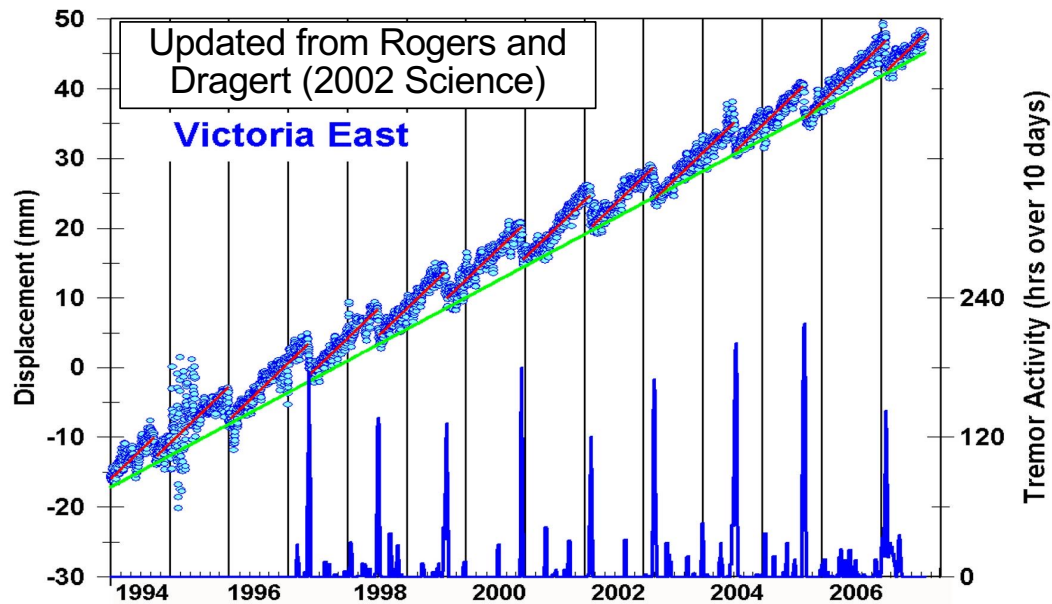
**The Cascadia subduction zone**

## History of discovery:

Slow slip: Dragert, Wang, James (2001, Science)

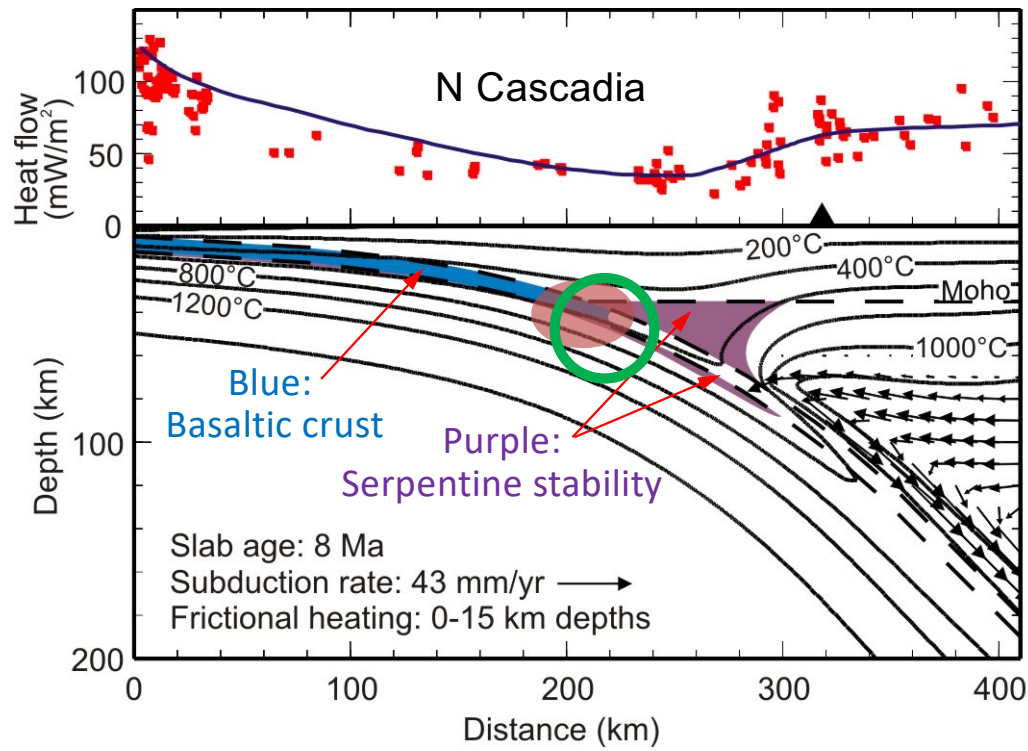
Tremor: Obara (2002, Science)

ETS: Rogers and Dragert (2002, Science)

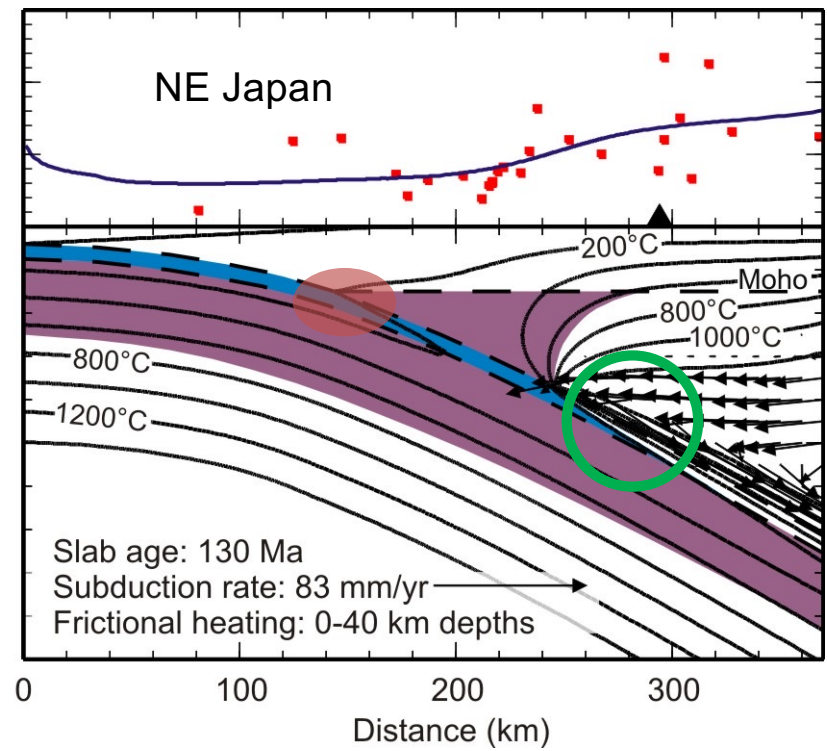


Dragert and Wang (2011 JGR)

## End-member warm-slab and cold-slab subduction zones

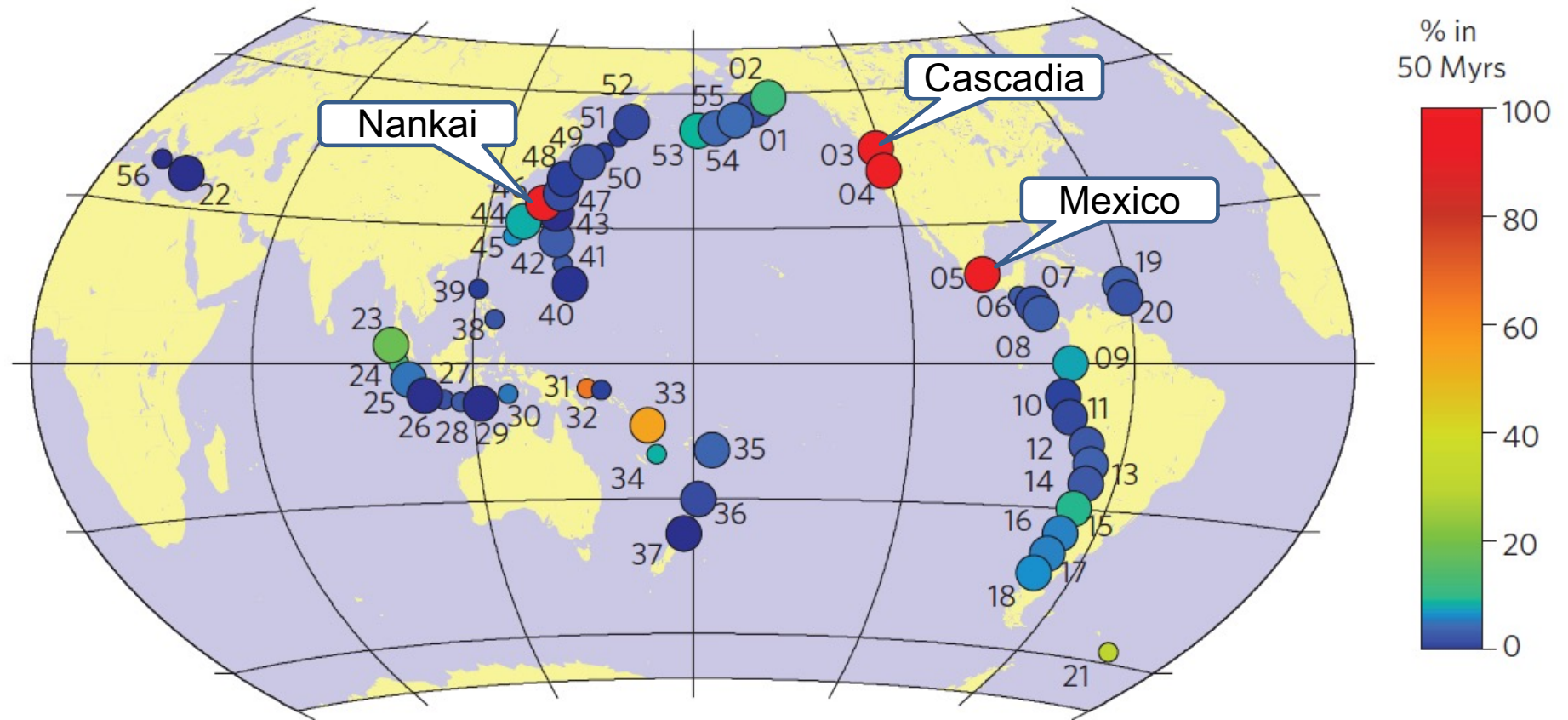


Hydrated forearc mantle wedge corner



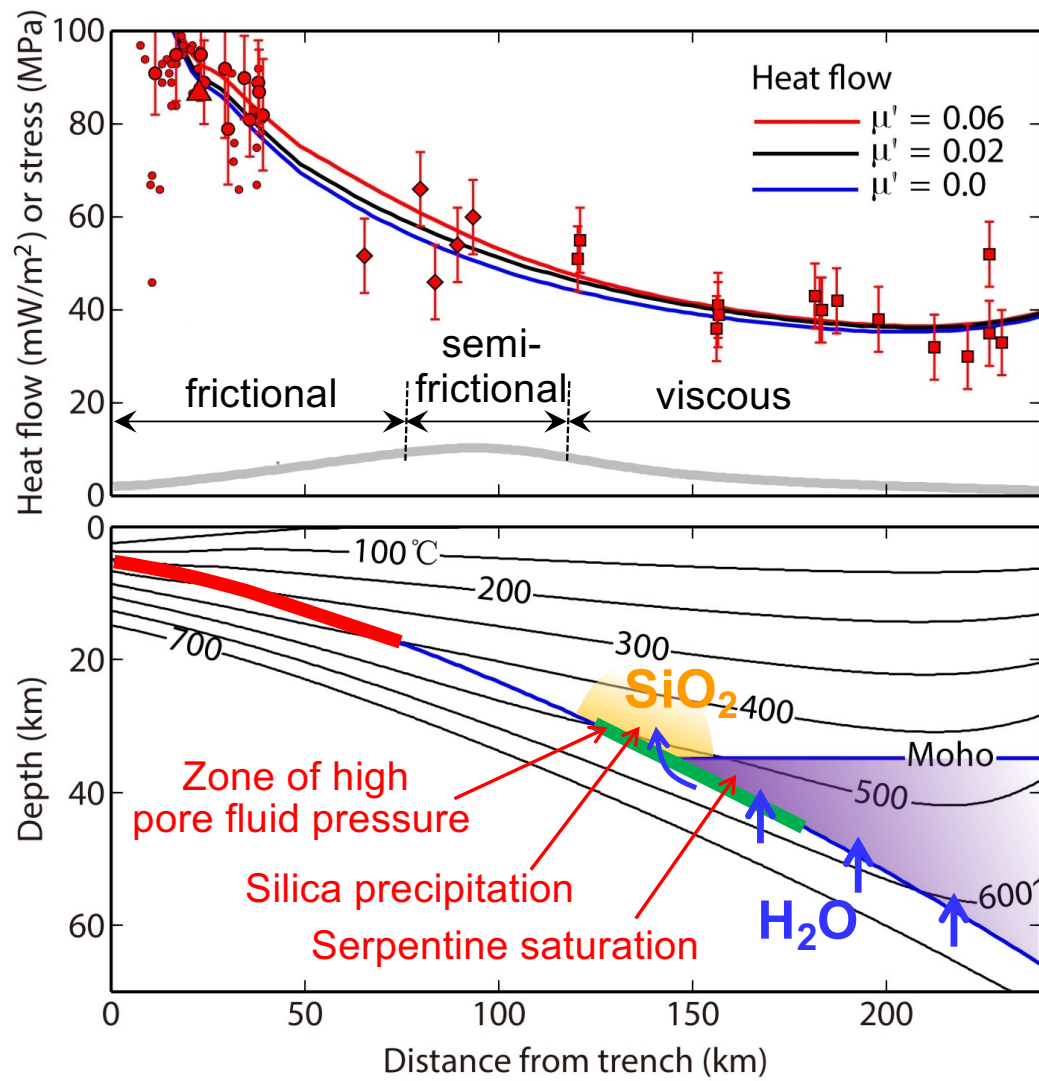
Dry forearc mantle wedge corner

Hydration of the mantle wedge: Not much except for hot subduction zones

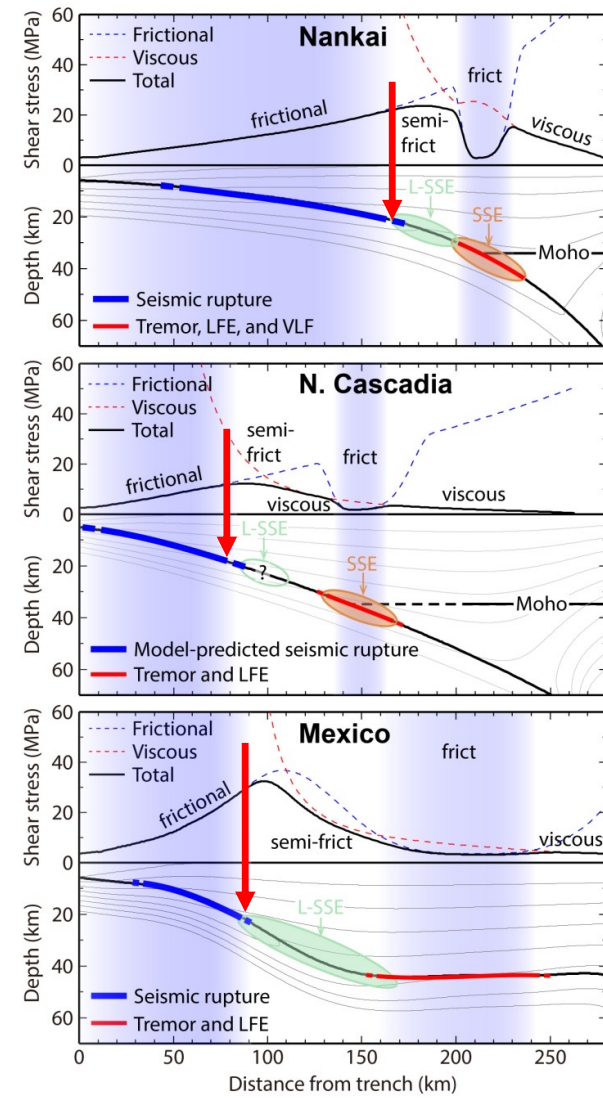
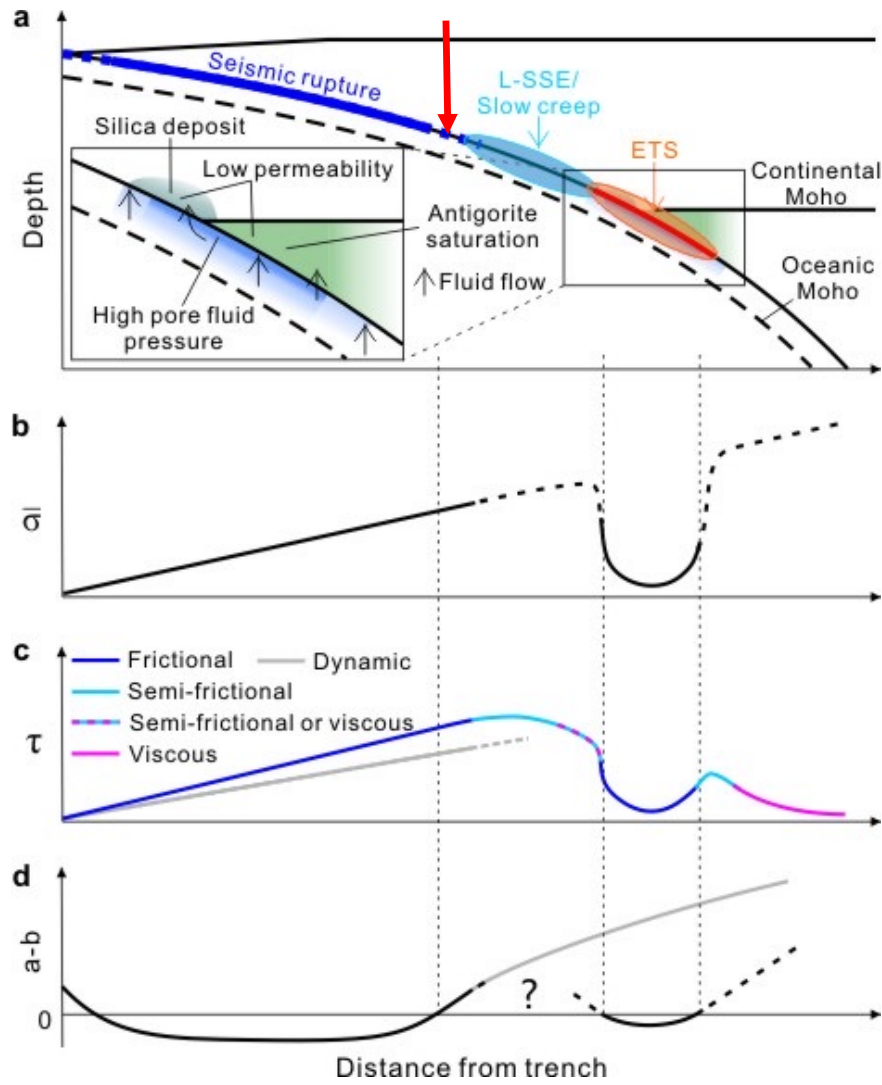


Abers et al. (2017, Nature Geoscience)

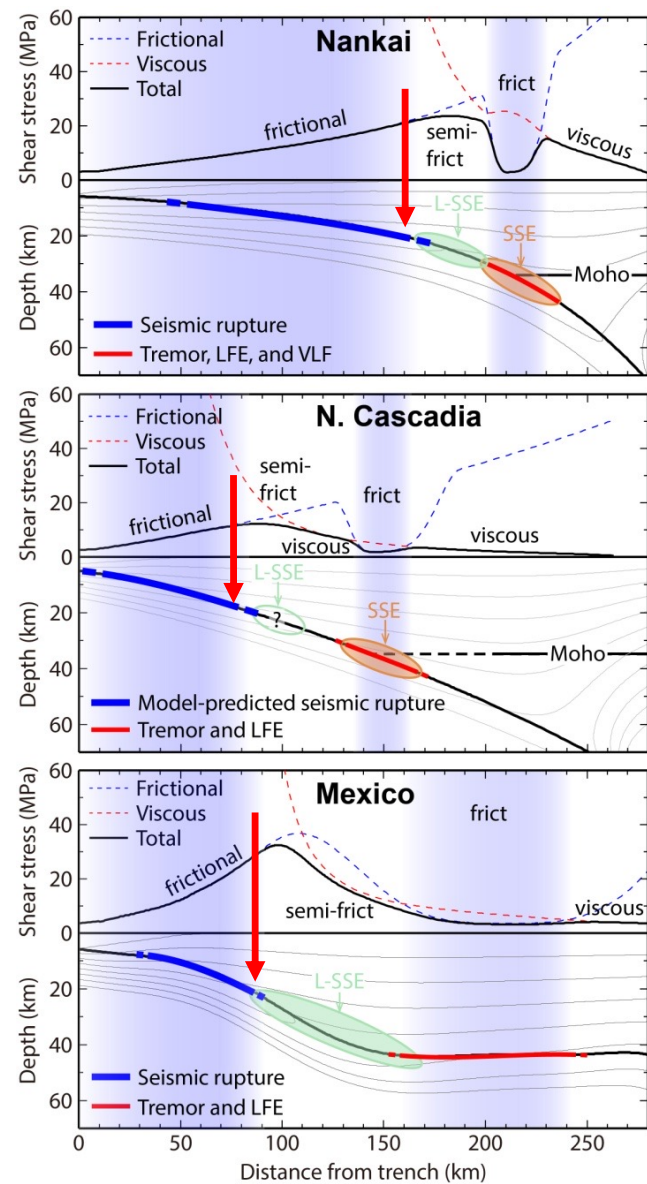
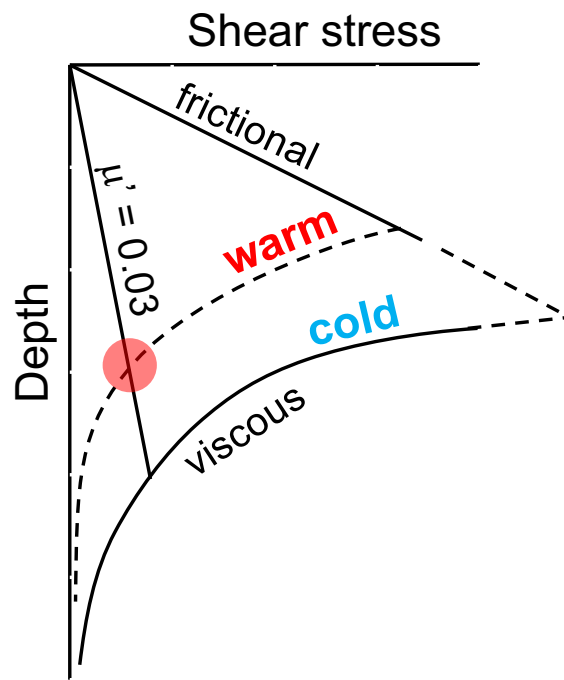
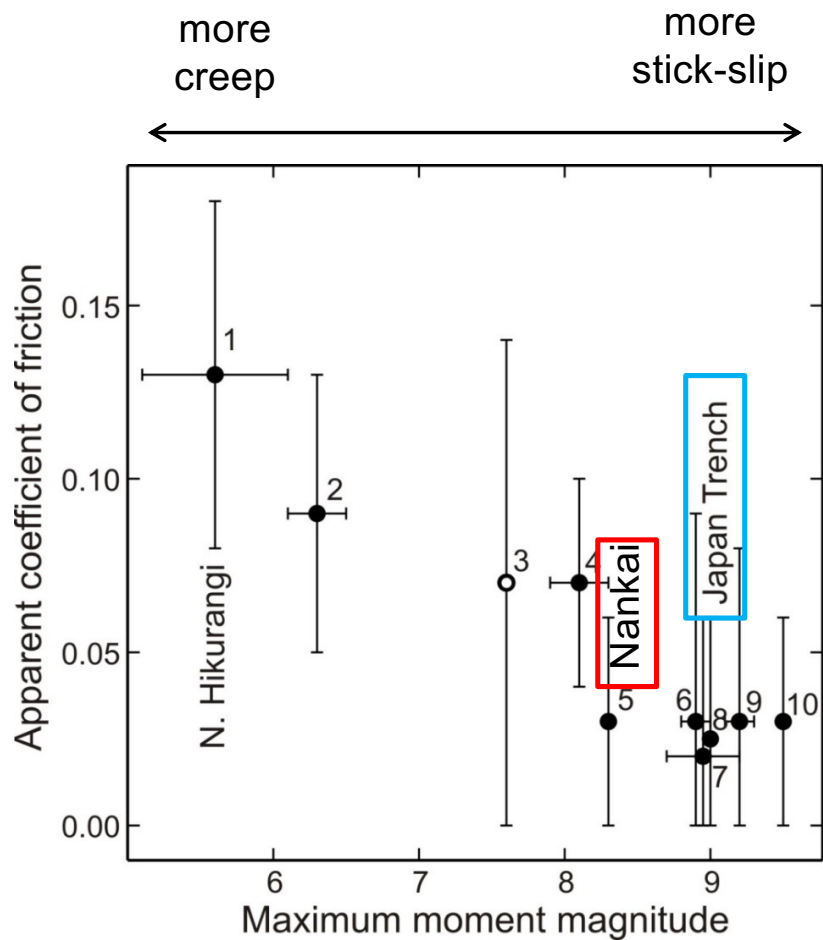


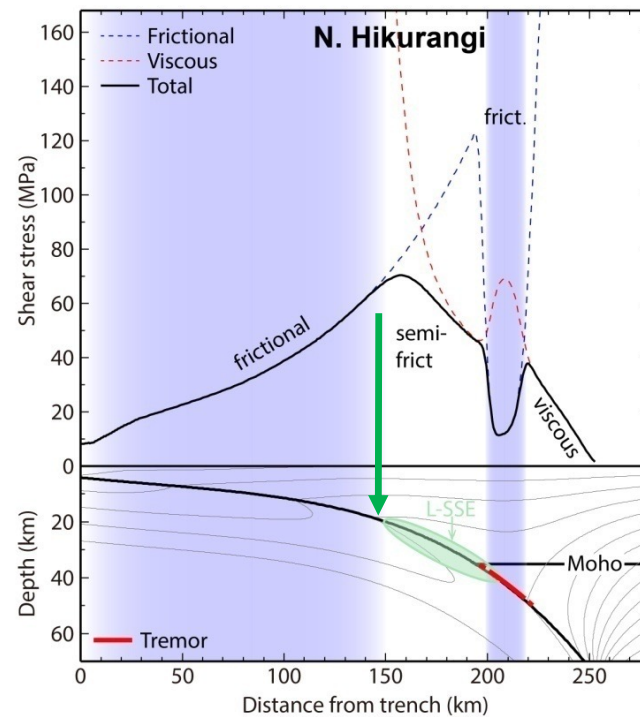
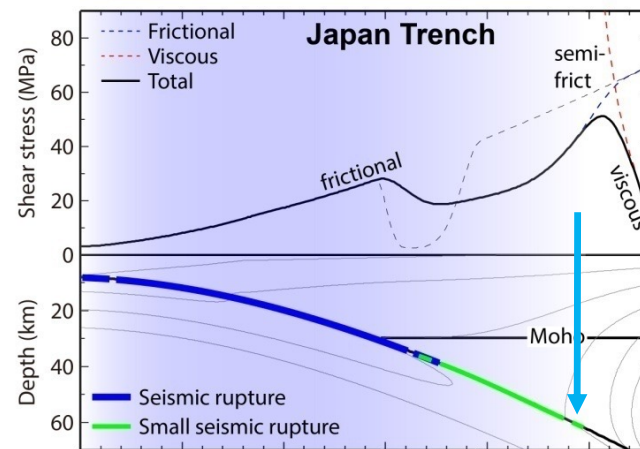
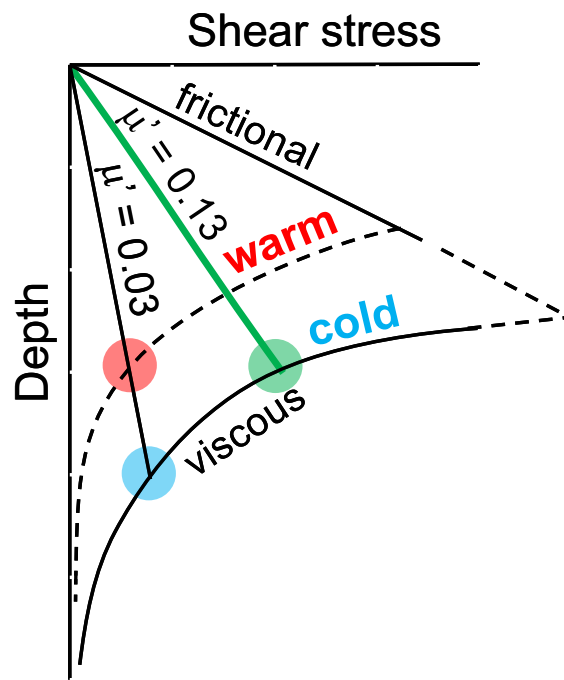
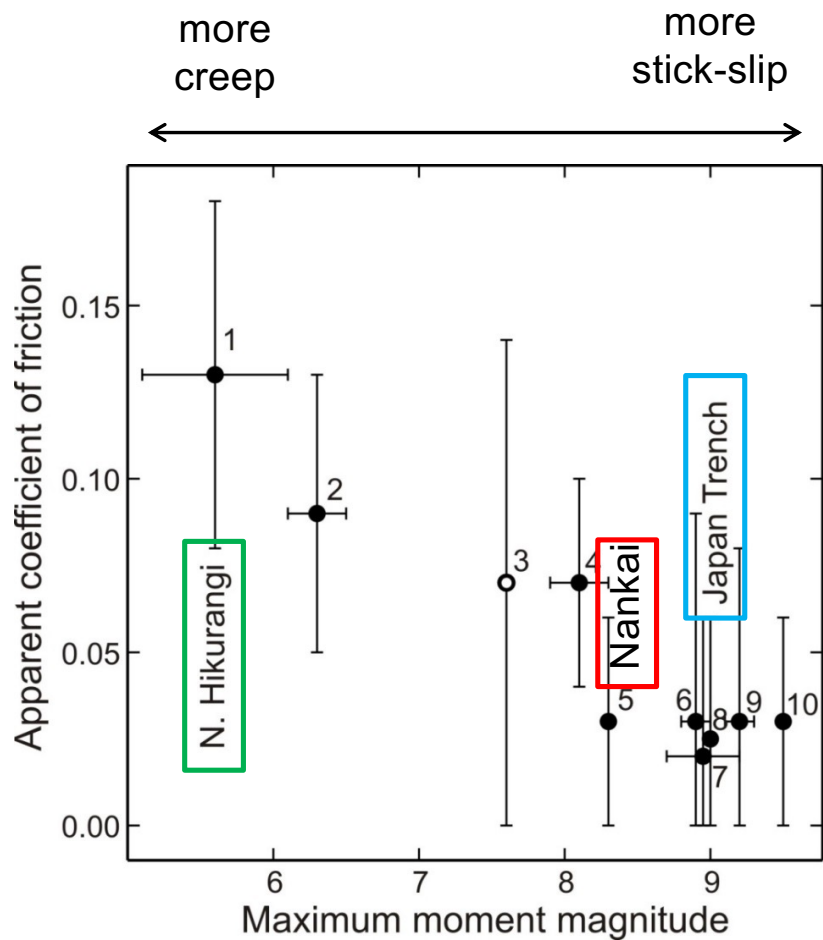






Gao and Wang  
(2017 Nature)





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