The structural architecture of fault zones at depth

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What do we know about the structural architecture of fault zones?

ierarchical volumetric systems:

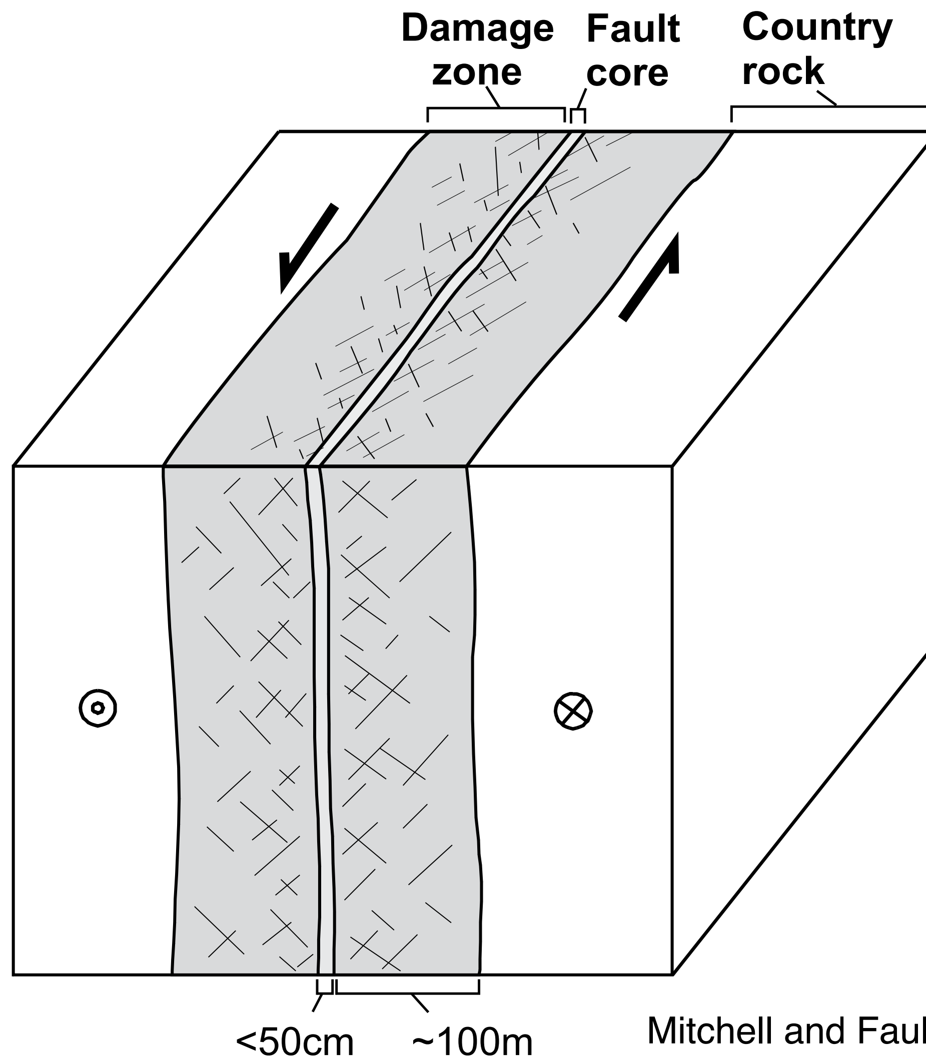
Principal slip surface (highly localized)

Fault core ~1m

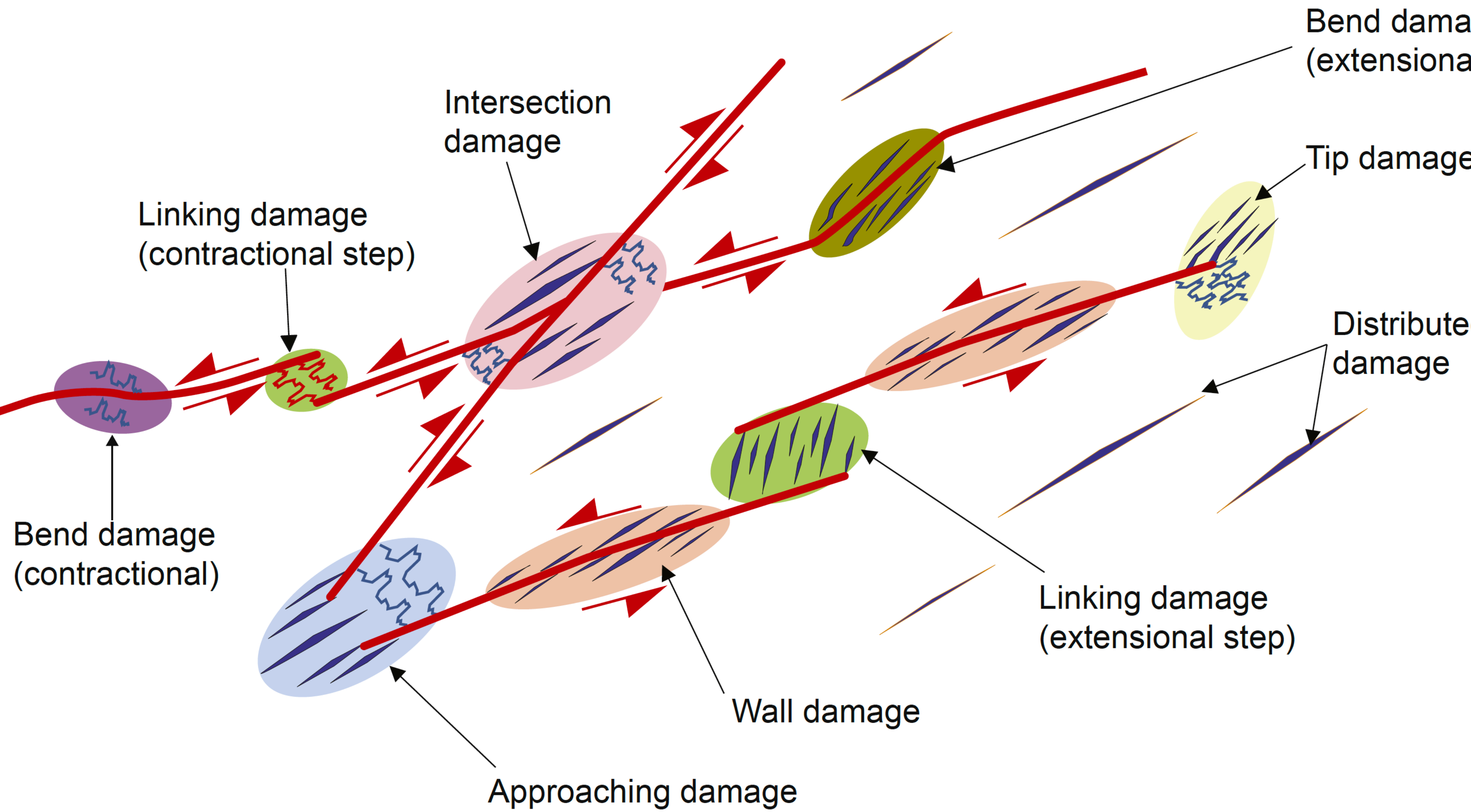
Inner damage zones ~100-200 m wide

Distributed damage zones ~1-10 km wide

Many smaller embedded faults



Mitchell and Faul



Peacock et al. (2017), *J. S*

h-resolution tomography studies show
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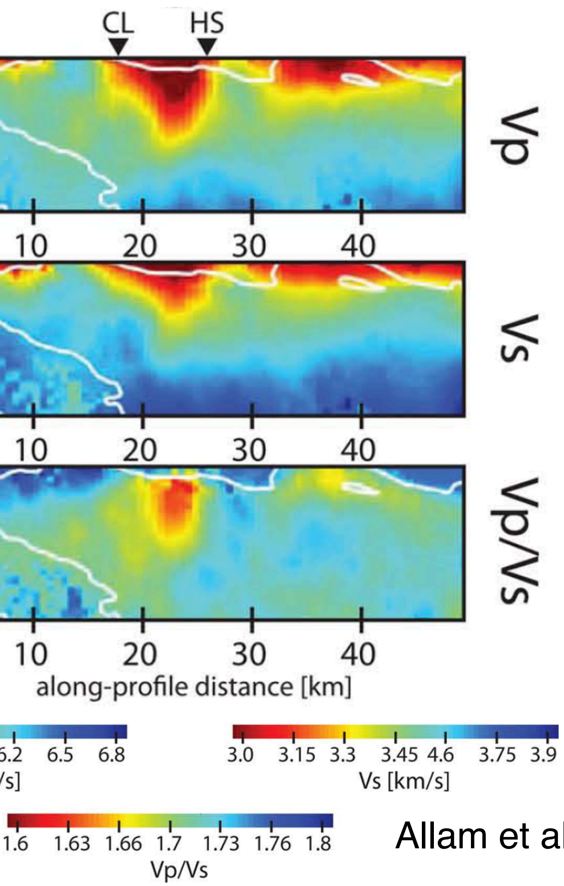
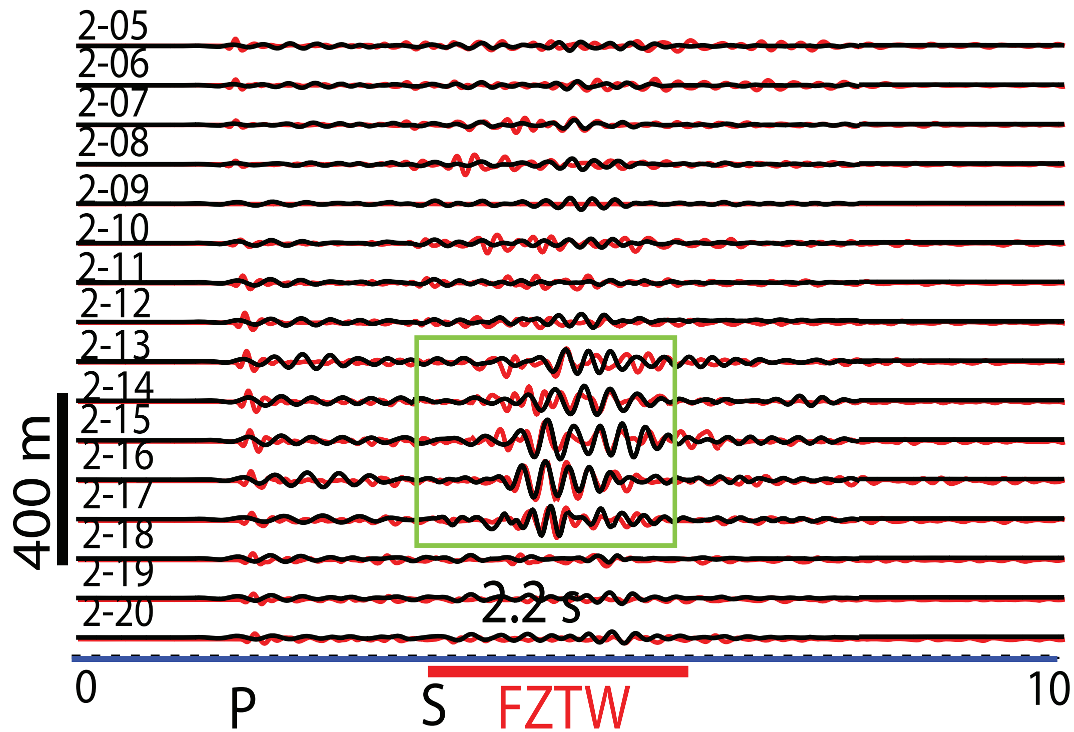


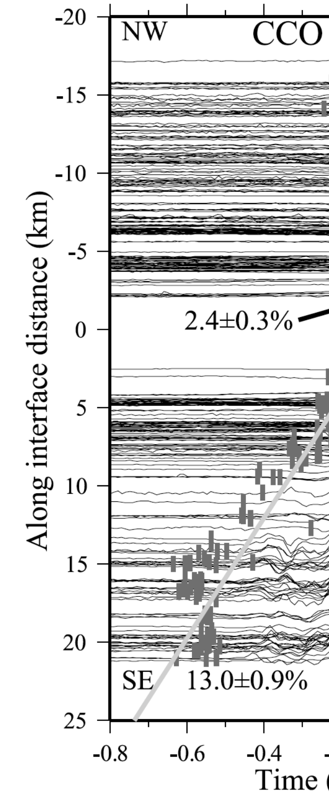
Allam et al (2014), GJI

Fault zone trapped waves provide
constraints on damage zone width,
shear wave velocity, *Q*



Li et al. (2016)

Waves that refract alon
faults provide constraint
contrast across int



Zhao and

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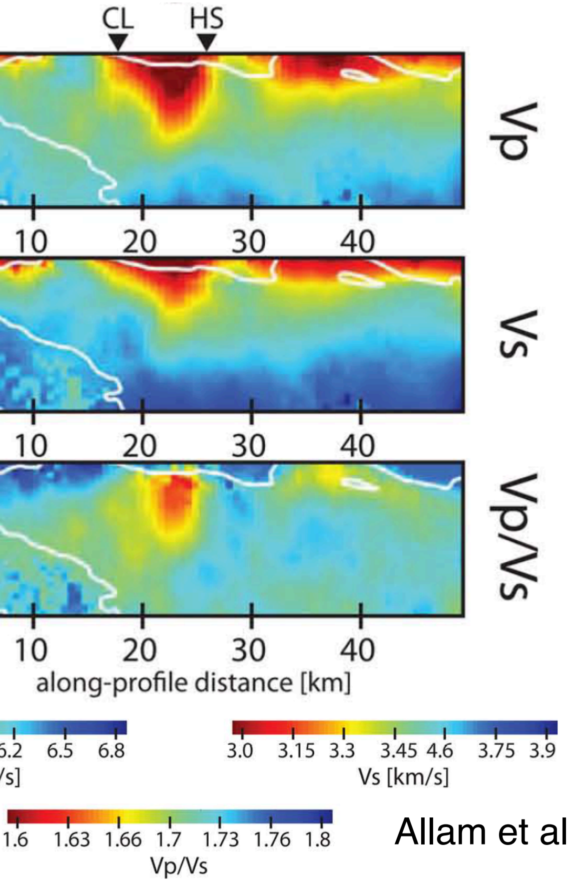

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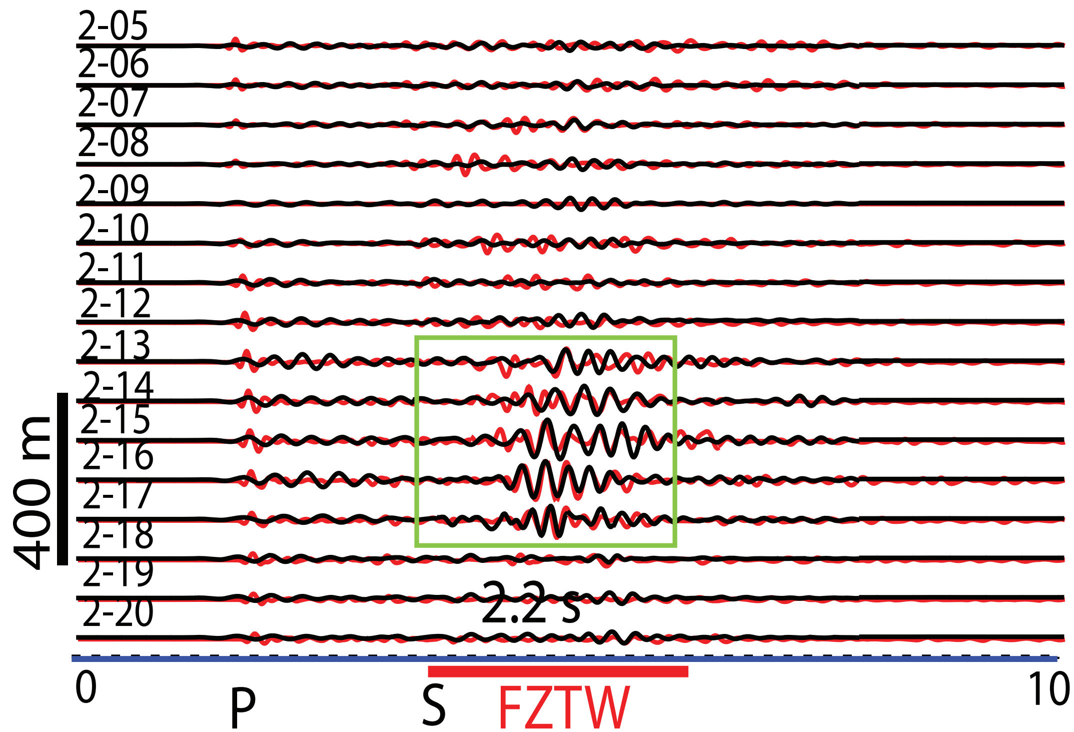

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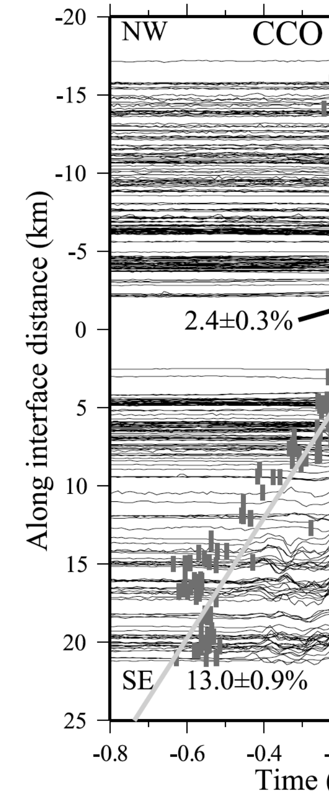


Zhao and

- How do these properties vary in space and time?
- How do they control fluid flow within fault zones?
- How do these properties depend on cumulative offset and slip rate?

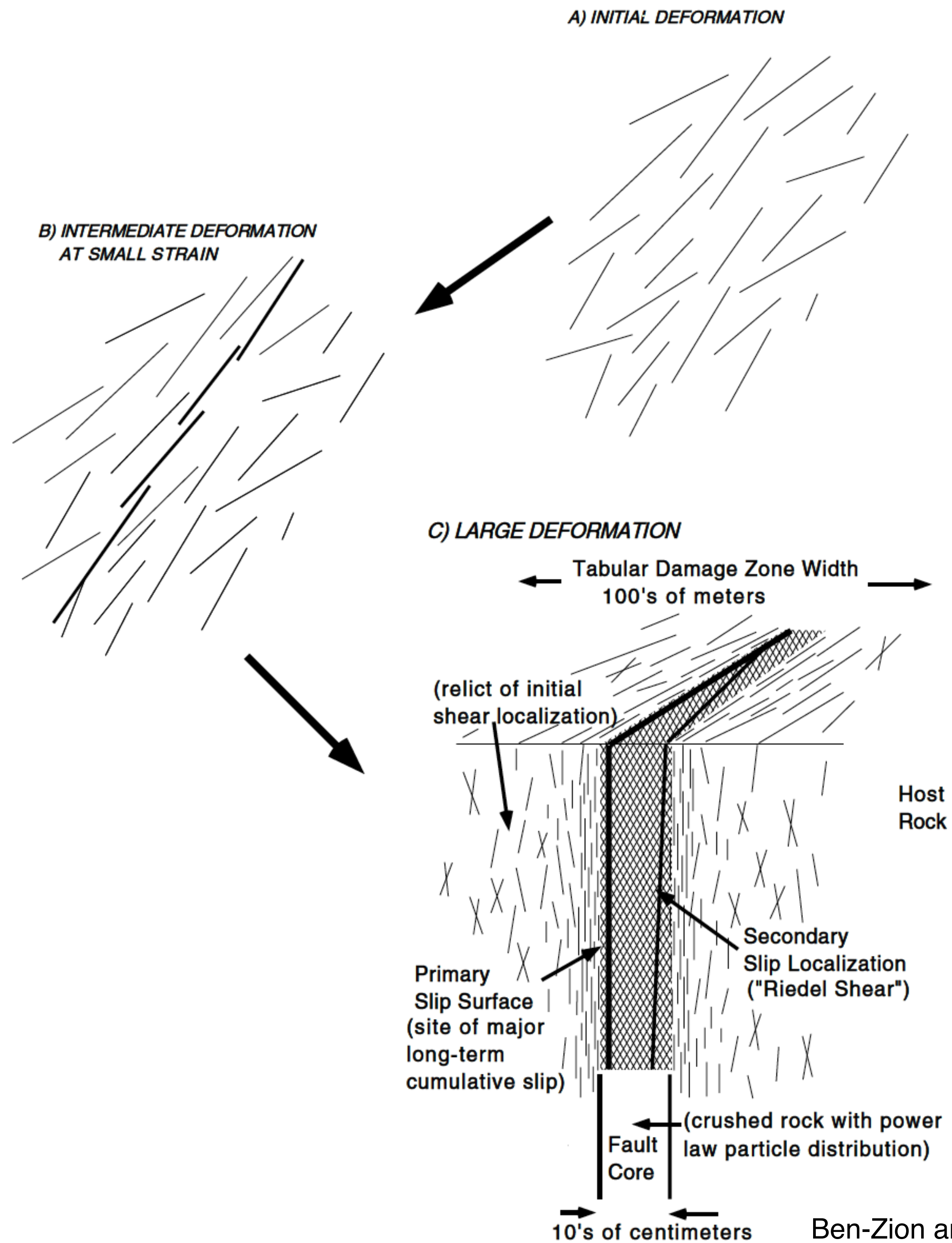
life cycle of a fault zone

eneral tendency to localize with ongoing
formation

veral key ingredients:

Increasing confining pressure with depth
Depth-dependent healing
Strain-weakening rheology

he geometric and mechanical
operties evolve with time, what are the
pected effects on the physics of
rthquakes?



Ben-Zion and

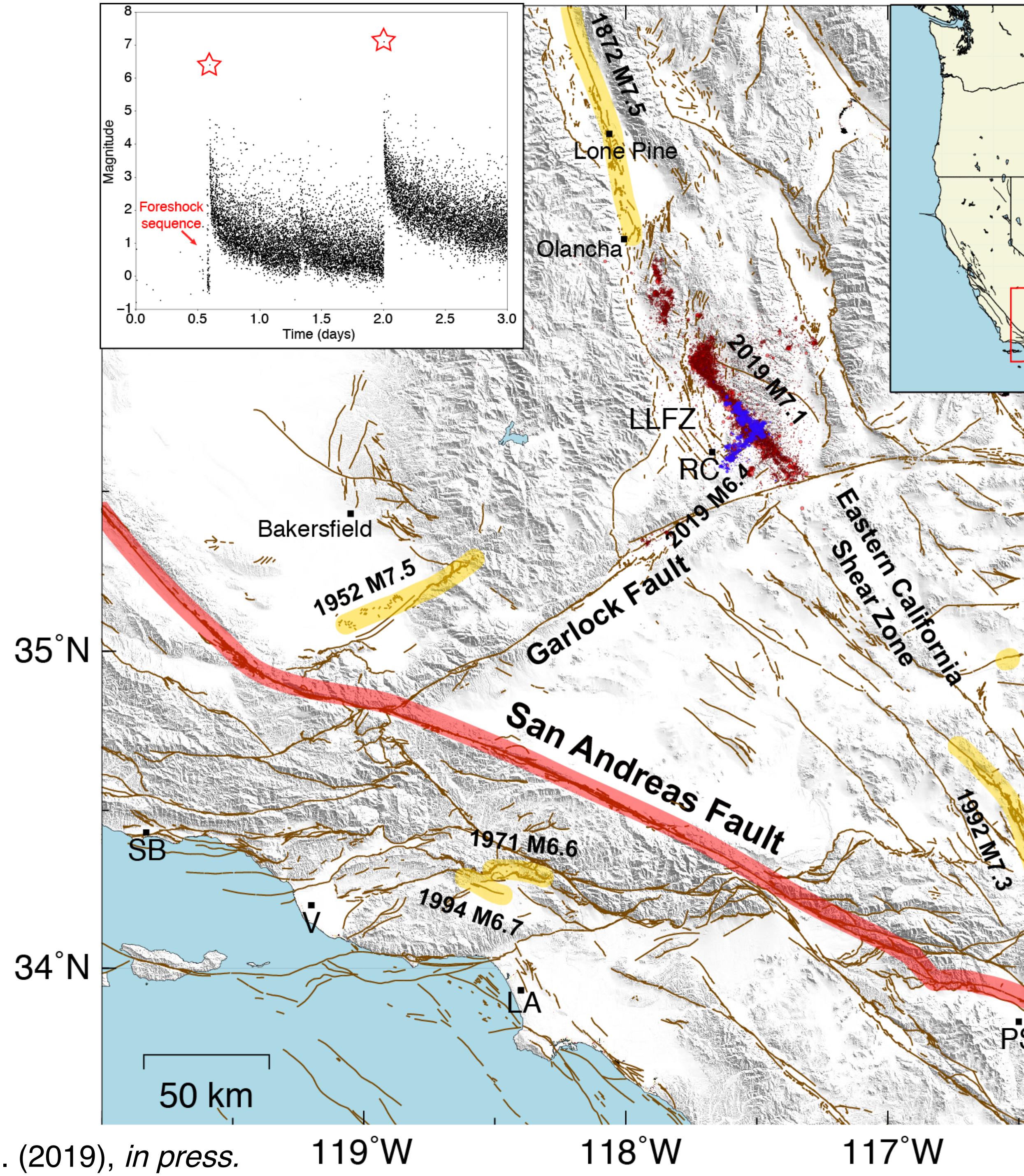
e 2019 Ridgecrest sequence

6.4 foreshock on July 4, 2019

7.1 mainshock 34 hours later

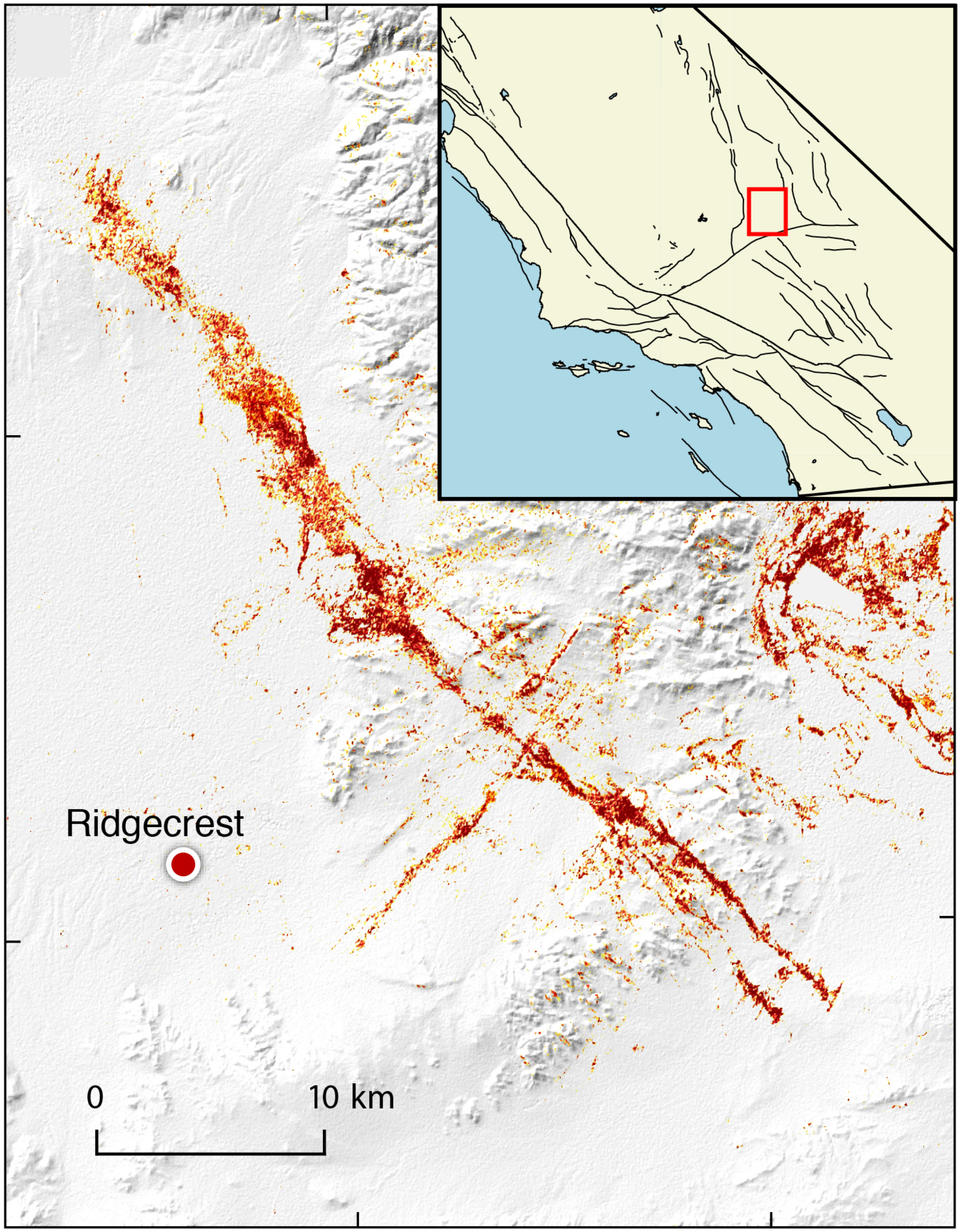
ured an unmapped fault network with
ulative length >75 km

ociated with Little Lake and Airport Lake
zones



Ross et al. (2019), *in press.*

e proxy map from
l-1 SAR data



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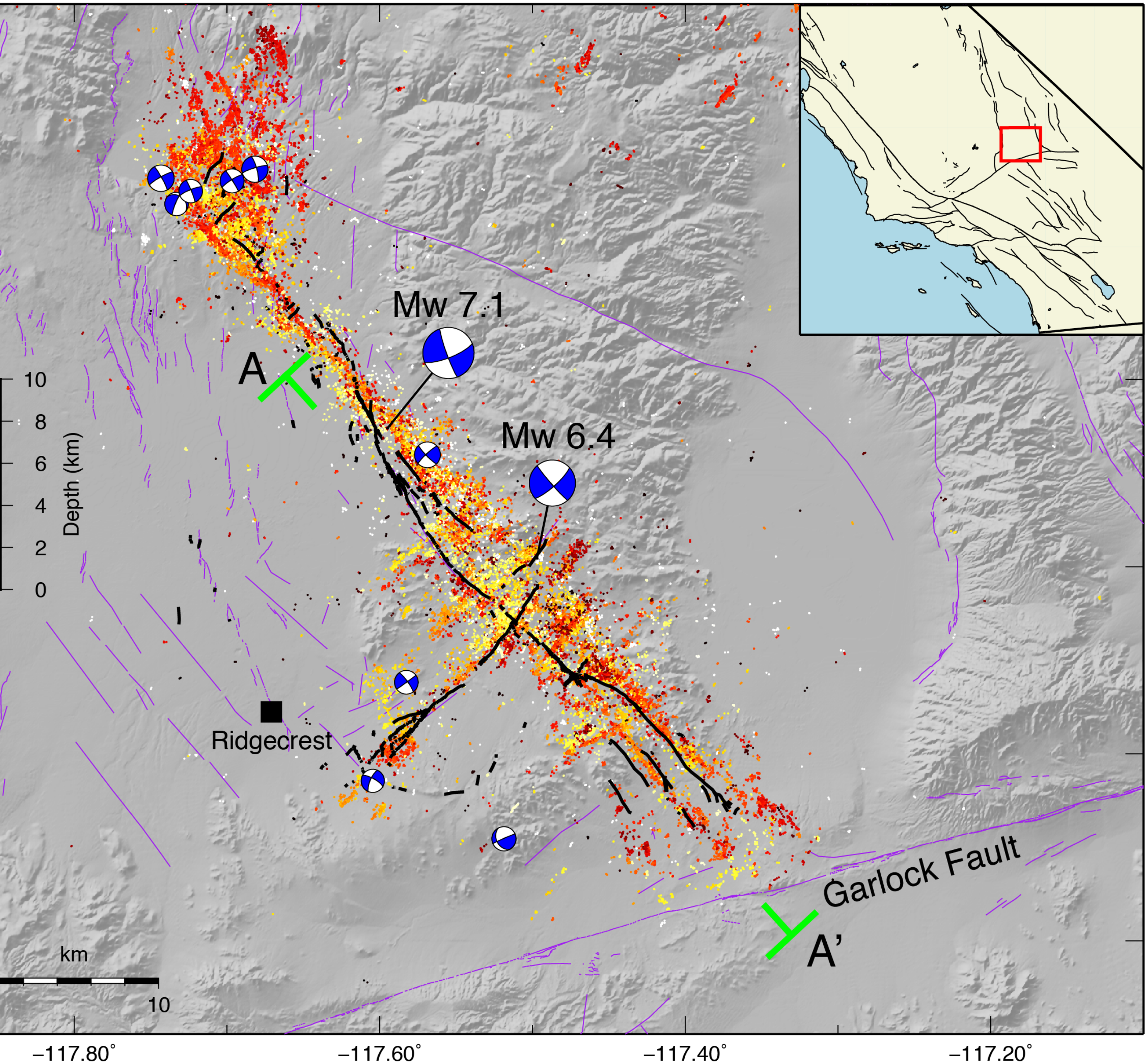
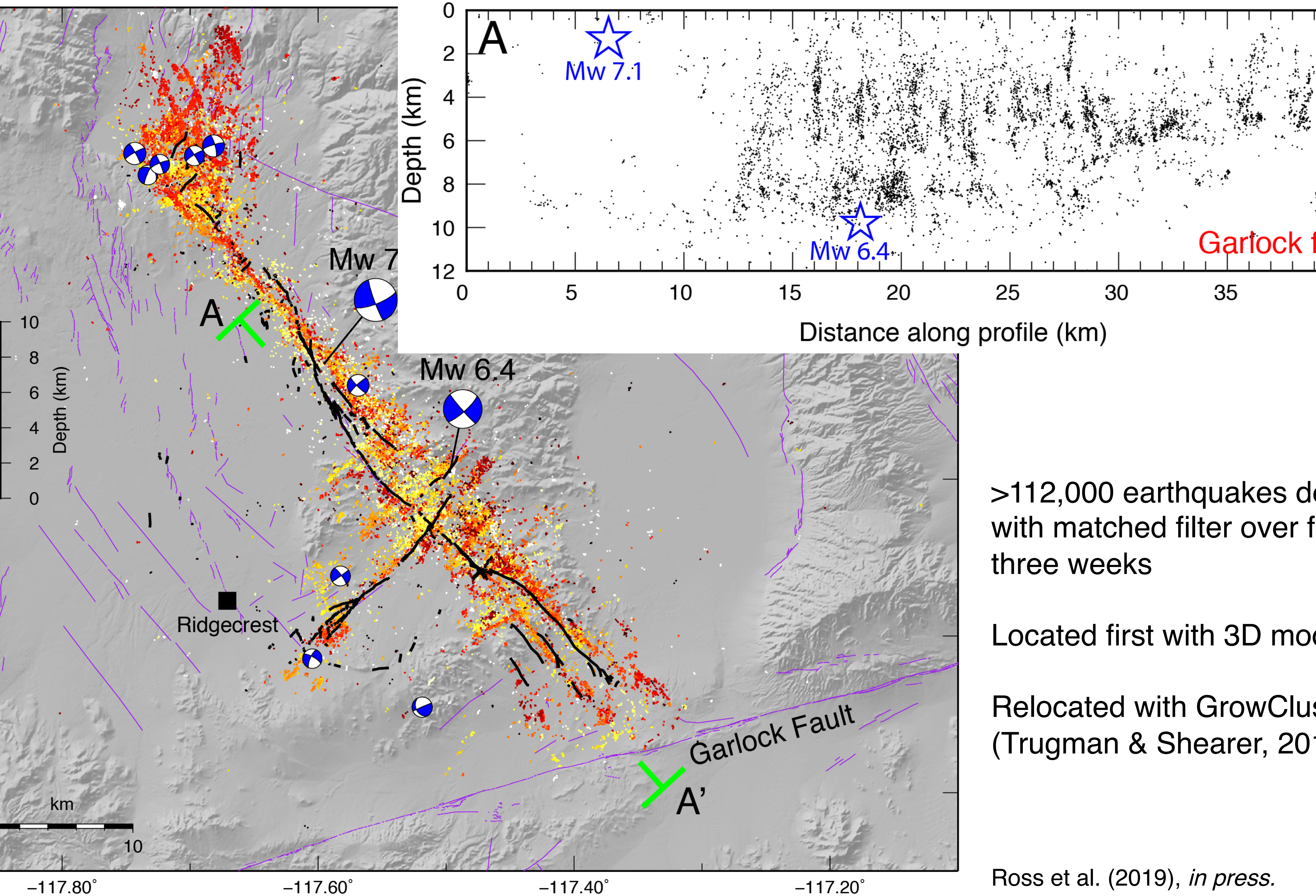


>112,000 earthquakes de
with matched filter over f
three weeks

Relocated with GrowClus
(Trugman & Shearer, 201

Ross et al. (2019), *in press.*



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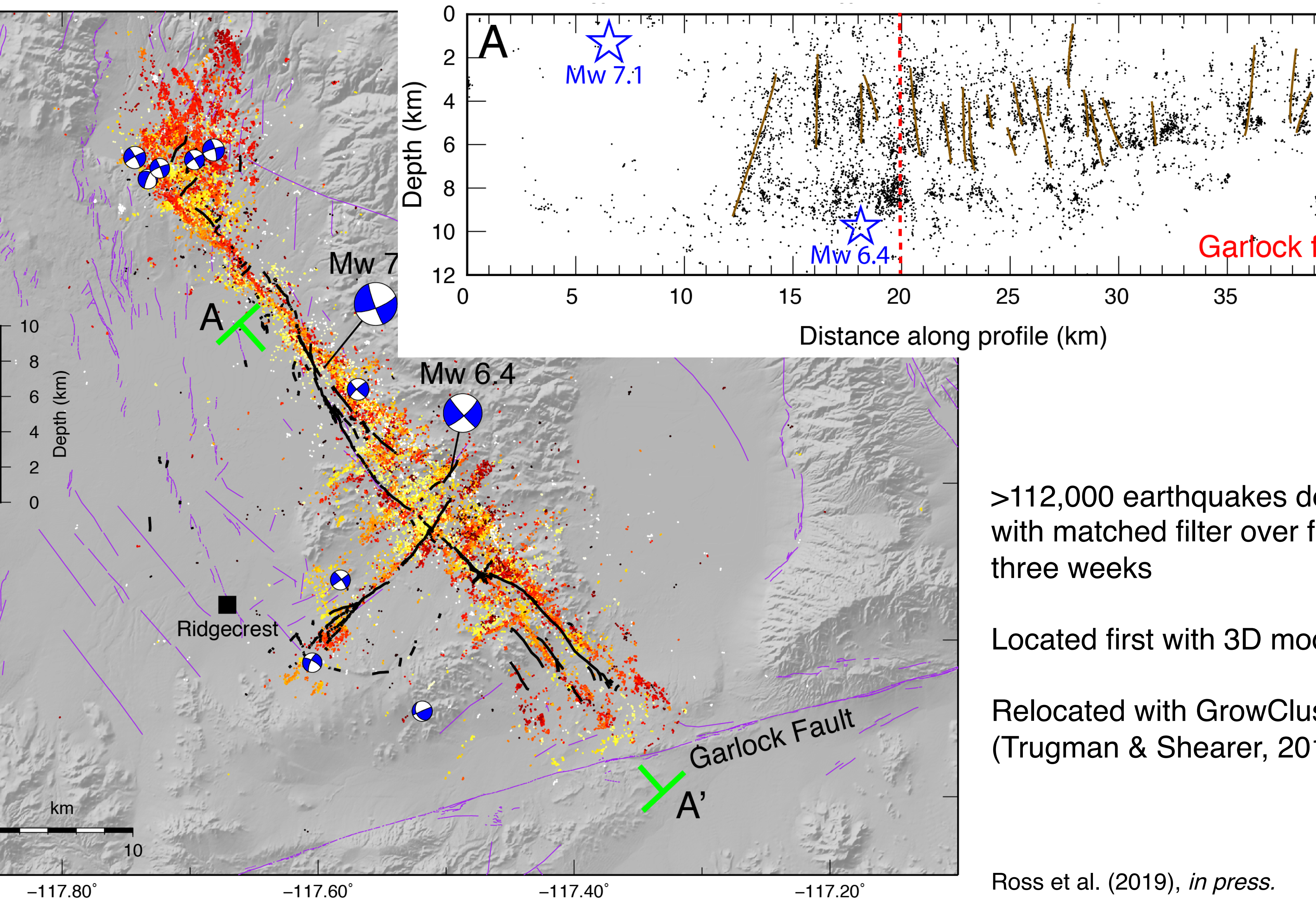

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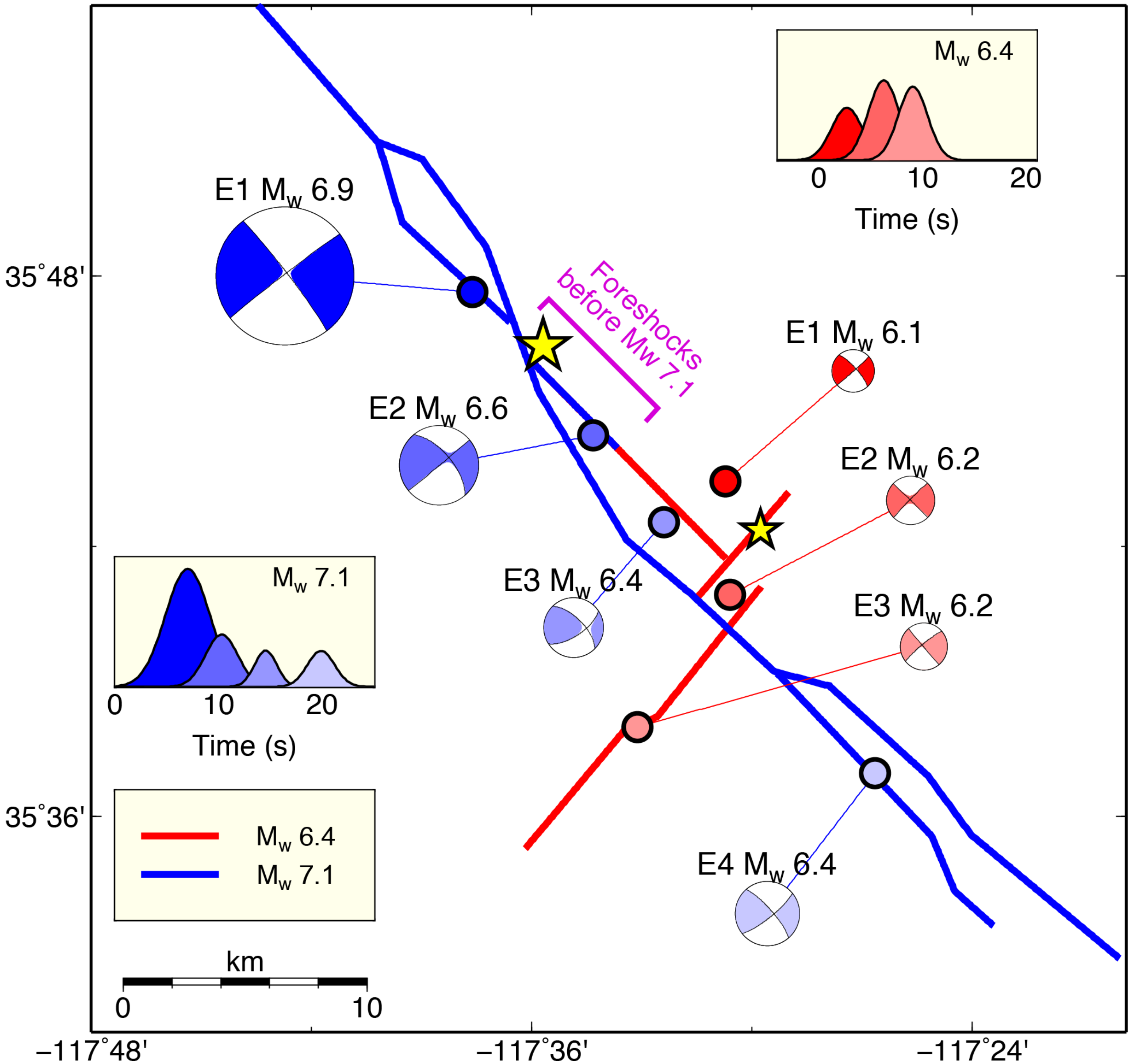
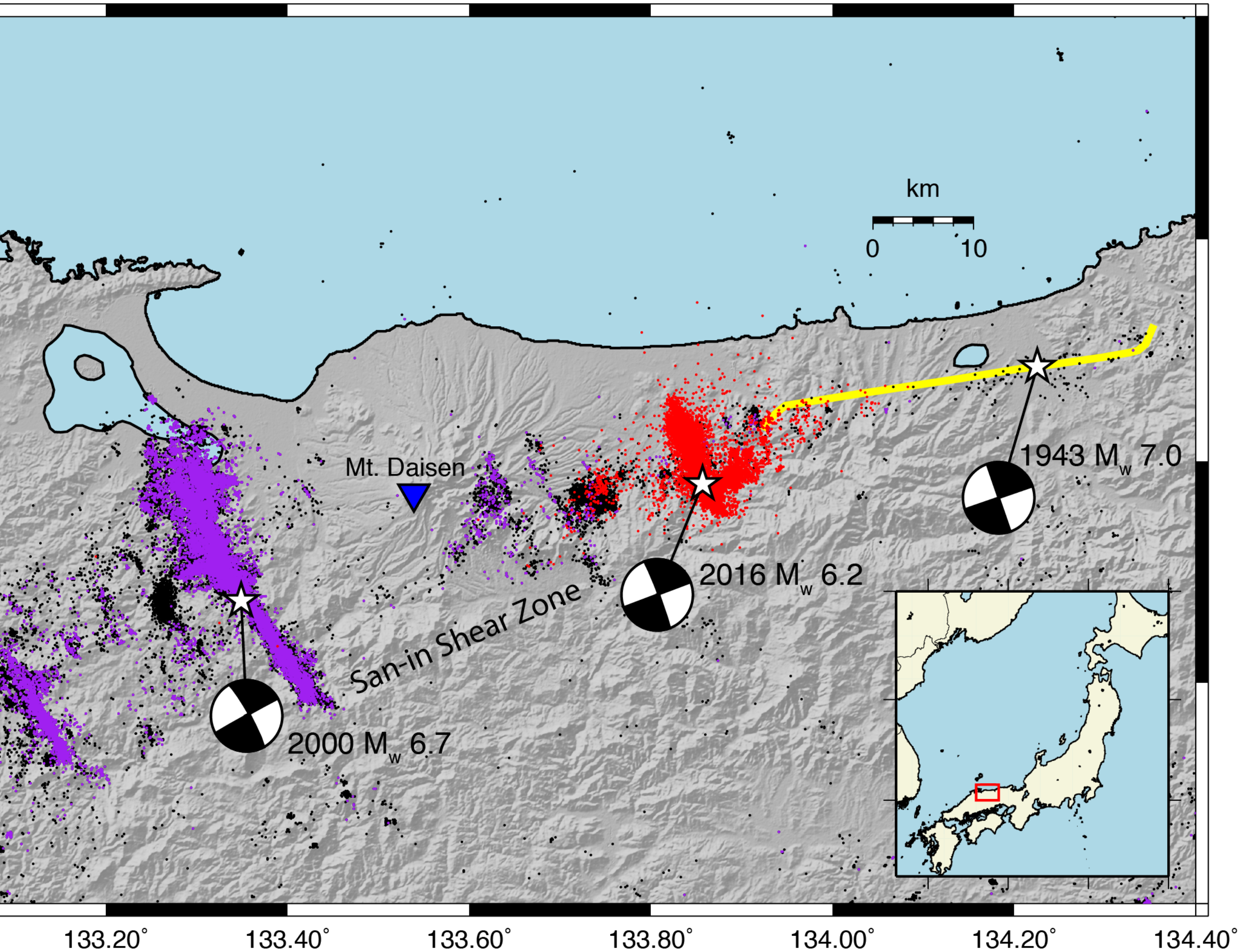


Ross et al. (2019), *in press.*

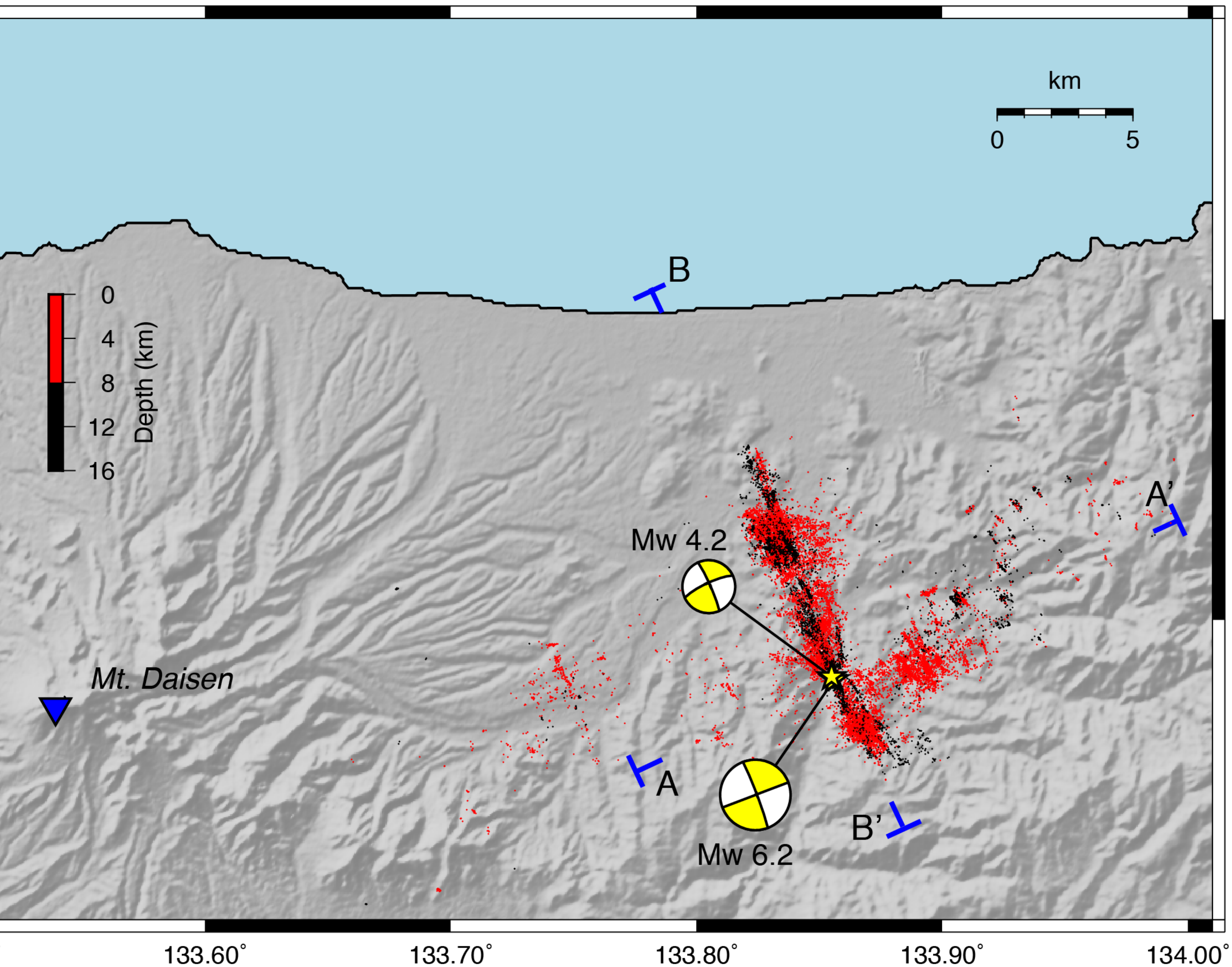
Formation of a major fault system in Japan: The San-in shear zone



- Intraplate region of Japan with lo strain accumulation
- Yet, several large events in last
  - 1943 M_w 7.0
  - 2000 M_w 6.7
  - 2016 M_w 6.2
- No geological evidence of active

Ross et al. (2018), *J. Geop*

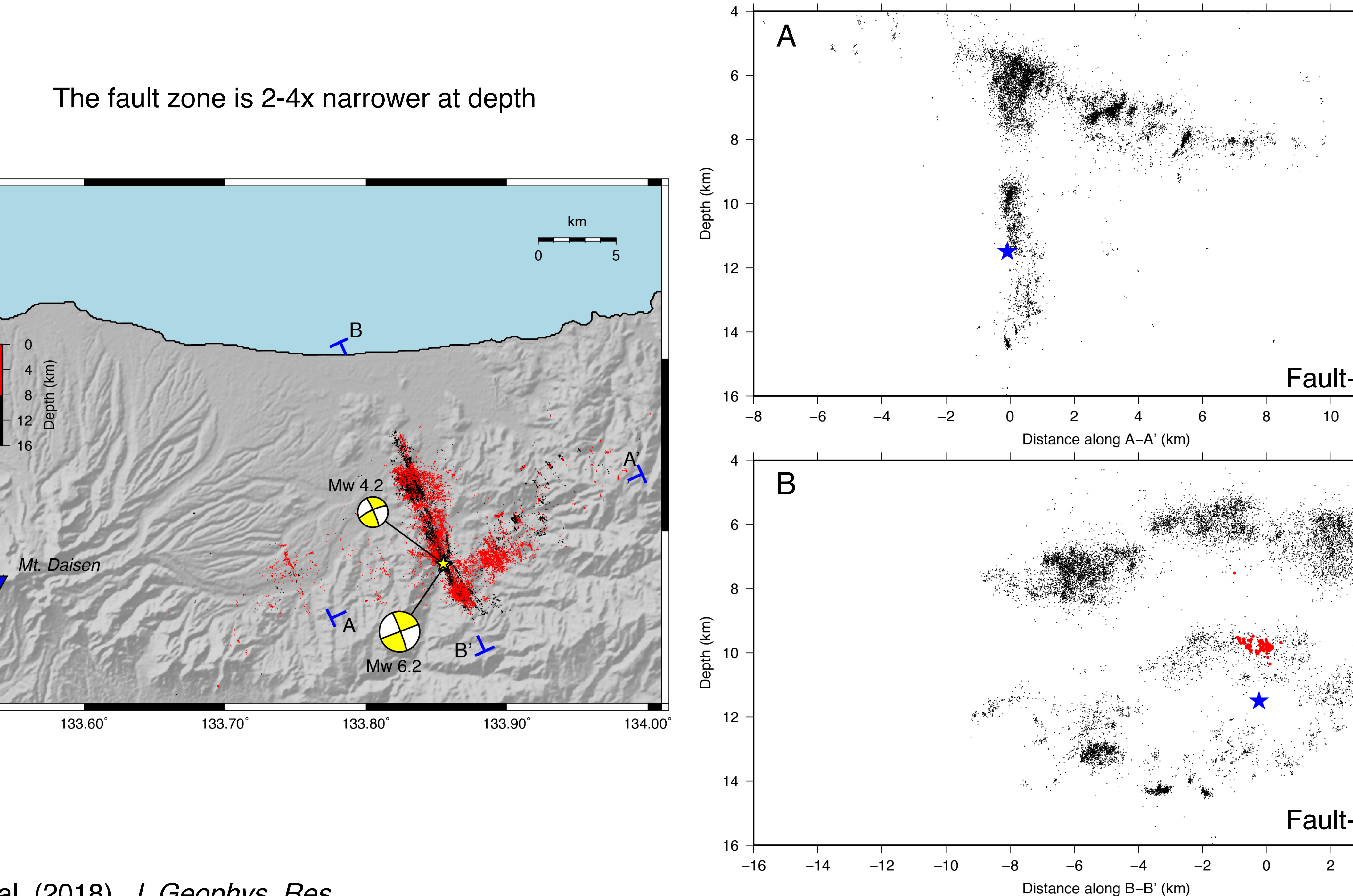
2016 Mw 6.2 Tottori, Japan sequence



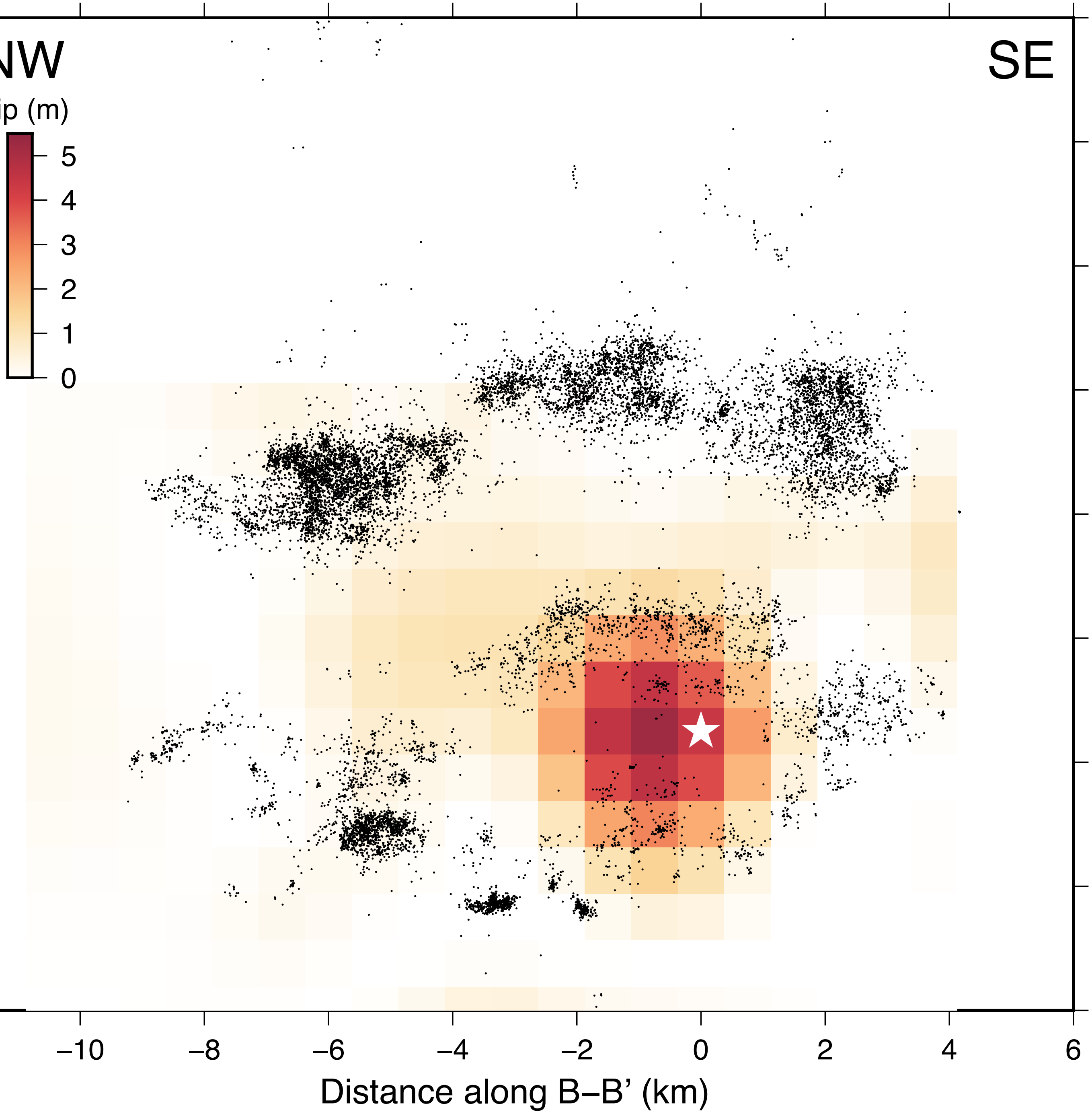
- ~40,000 aftershocks pr
located
- Numerous lineations tre
generally NW-SE
- Extensive branching an
segmentation
- Deeper aftershocks are
more localized
- Significant off-fault trigg

Ross et al. (2018), *J. Geop*

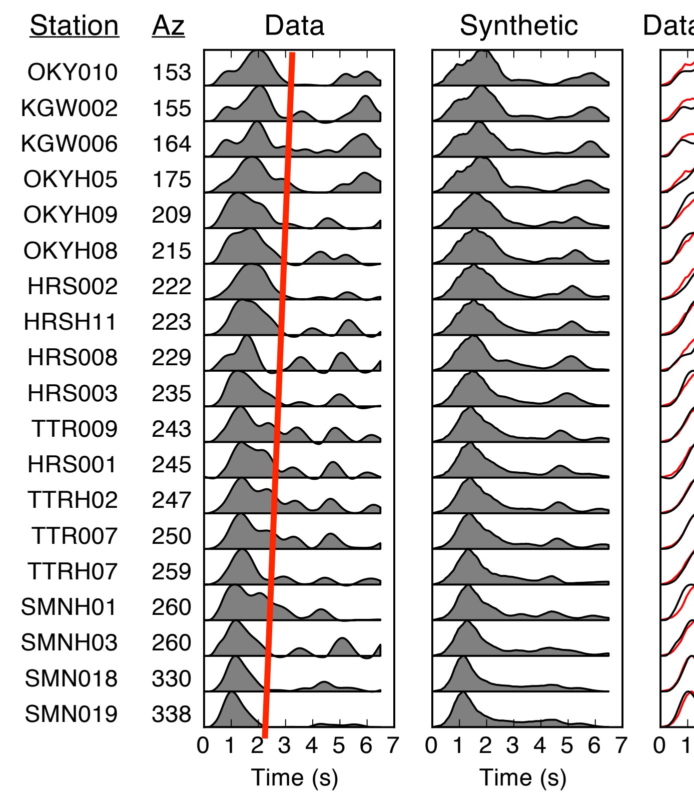
The fault zone is 2-4x narrower at depth



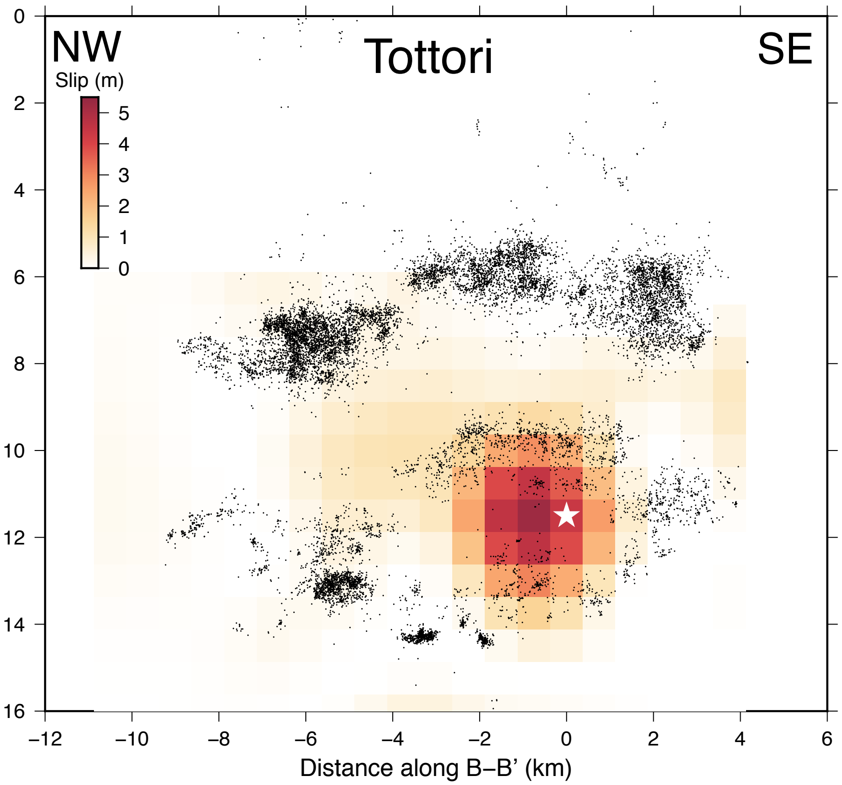
al. (2018), *J. Geophys. Res.*

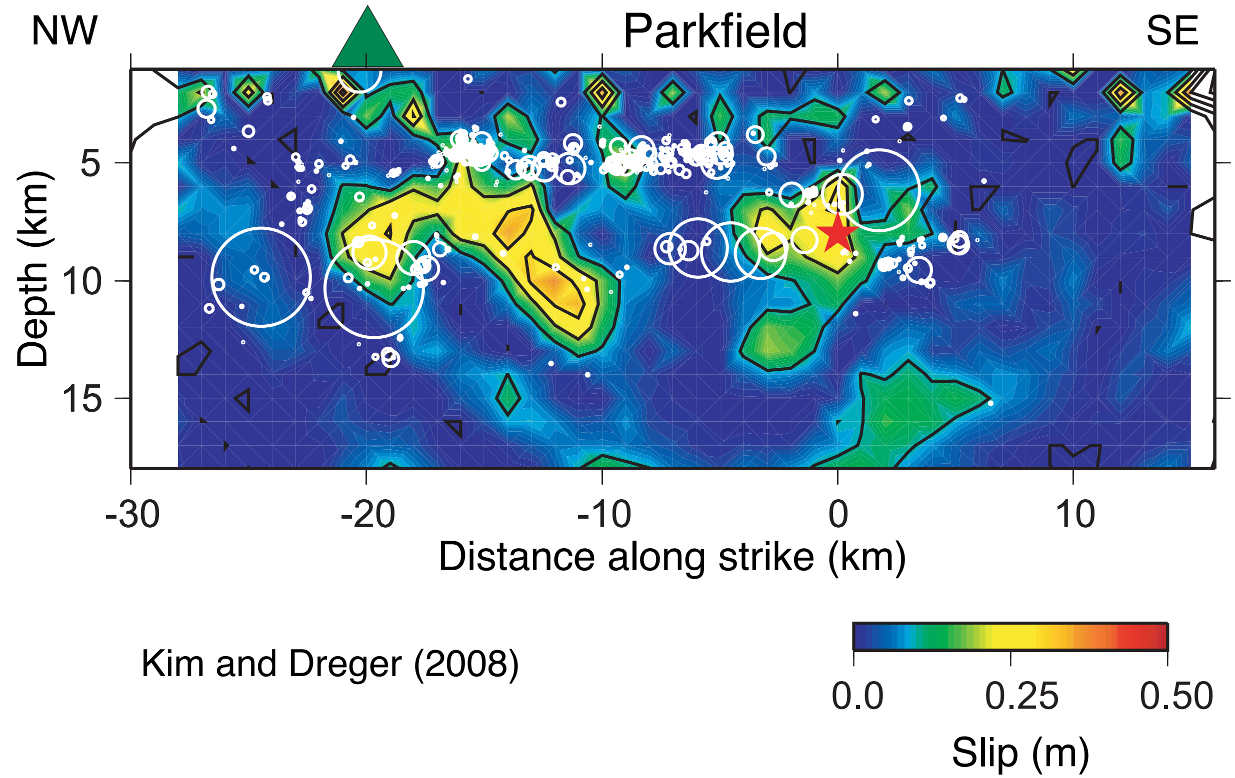


- Rupture velocity estimated at 1
- From slip model, $\Delta\sigma$= 18-27 M
- E_R= 5.7 x 10^{13} J
- 95% of seismic moment is belo depth. Why?

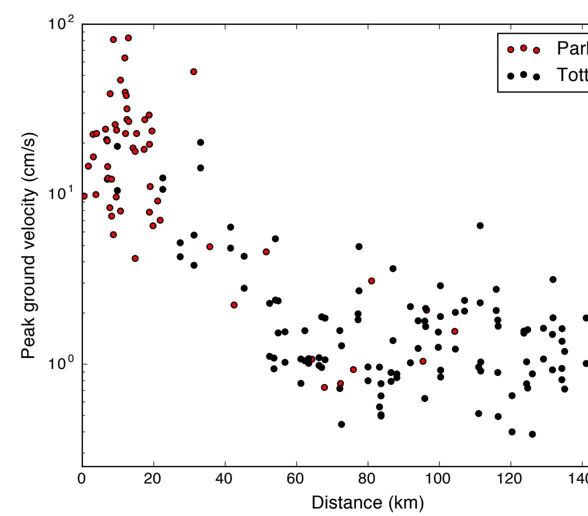


2016 M_w 6.2 Tottori vs 2004 M_w 6.0 Parkfield (San Andreas)





	Tottori	Parkfield
ture length	6 km	20 km
ated energy	5 x 10^{13} J	~5 x 10^{13}J
ss drop $\Delta\sigma$	18-27 MPa	2 MPa
ation efficiency $\eta_R = E_R / \Delta W_0$ $\mu/\Delta\sigma_E \ (E_R / M_0)$	5-7%	50-70%



Tottori earthquake was ~10x more dissipative

Summary

Fault zones are 3D structures that are continuously evolving

They exhibit many different length scales

Their geometric and mechanical properties influence energy dissipation, rupture velocity, fluid flow, rupture area, and much more

These factors therefore probably depend on fault maturity