Regional Plate Boundary Controls on the Potential for Future Earthquakes within Thailand and surrounding regions

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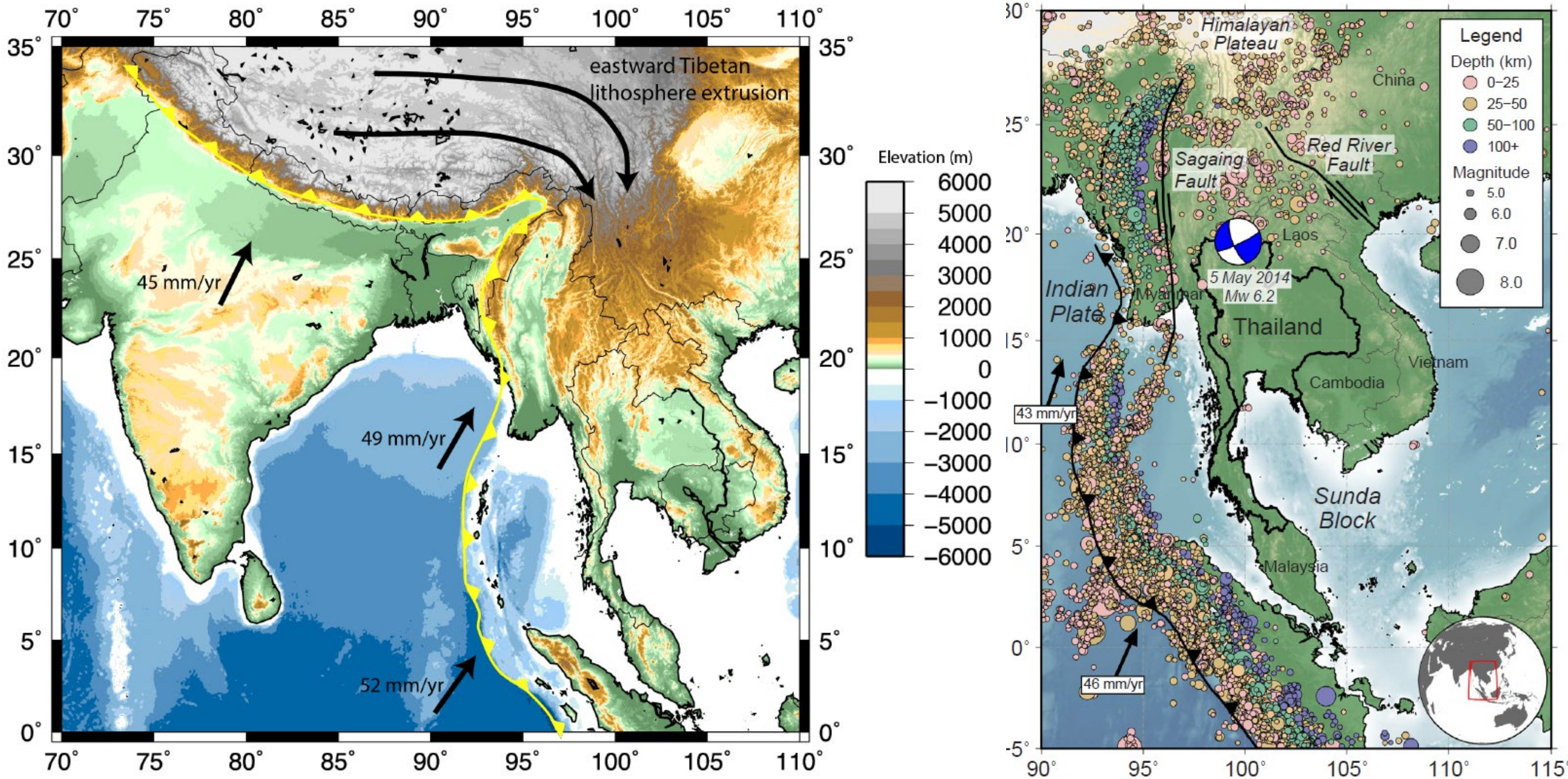
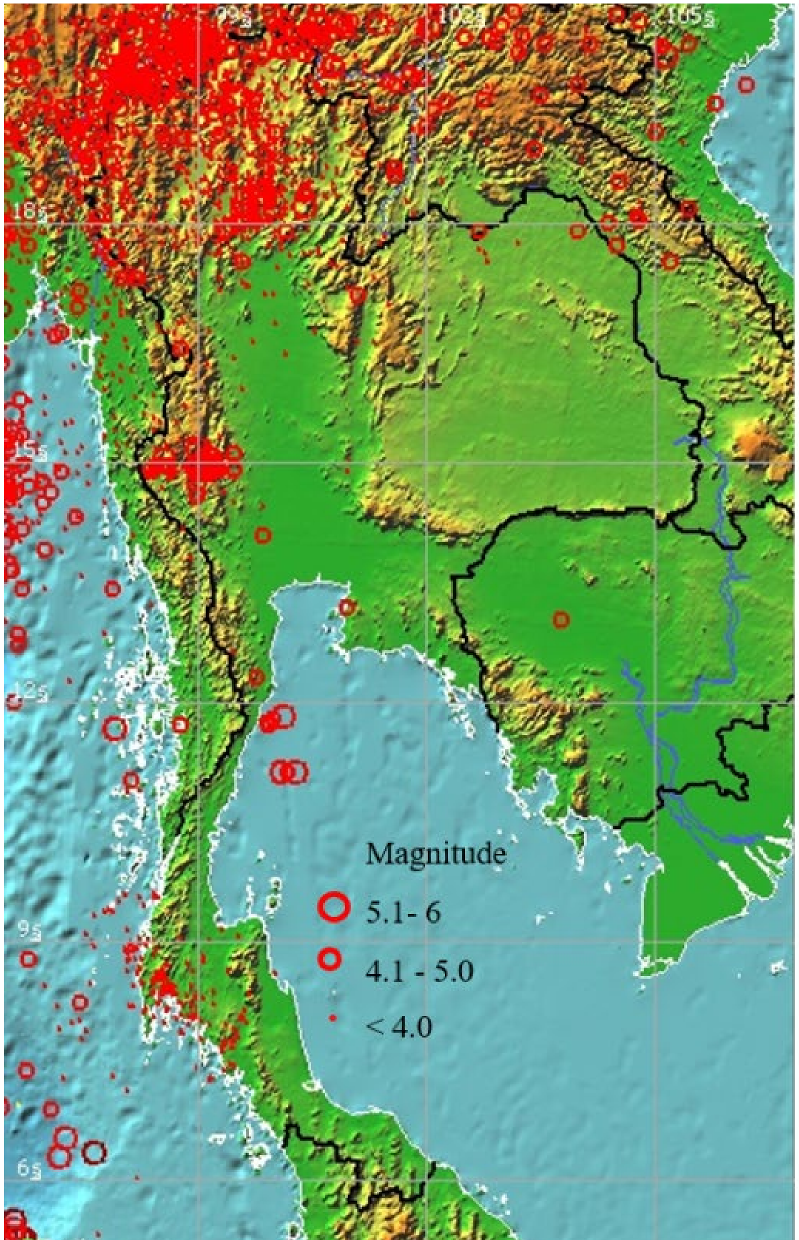
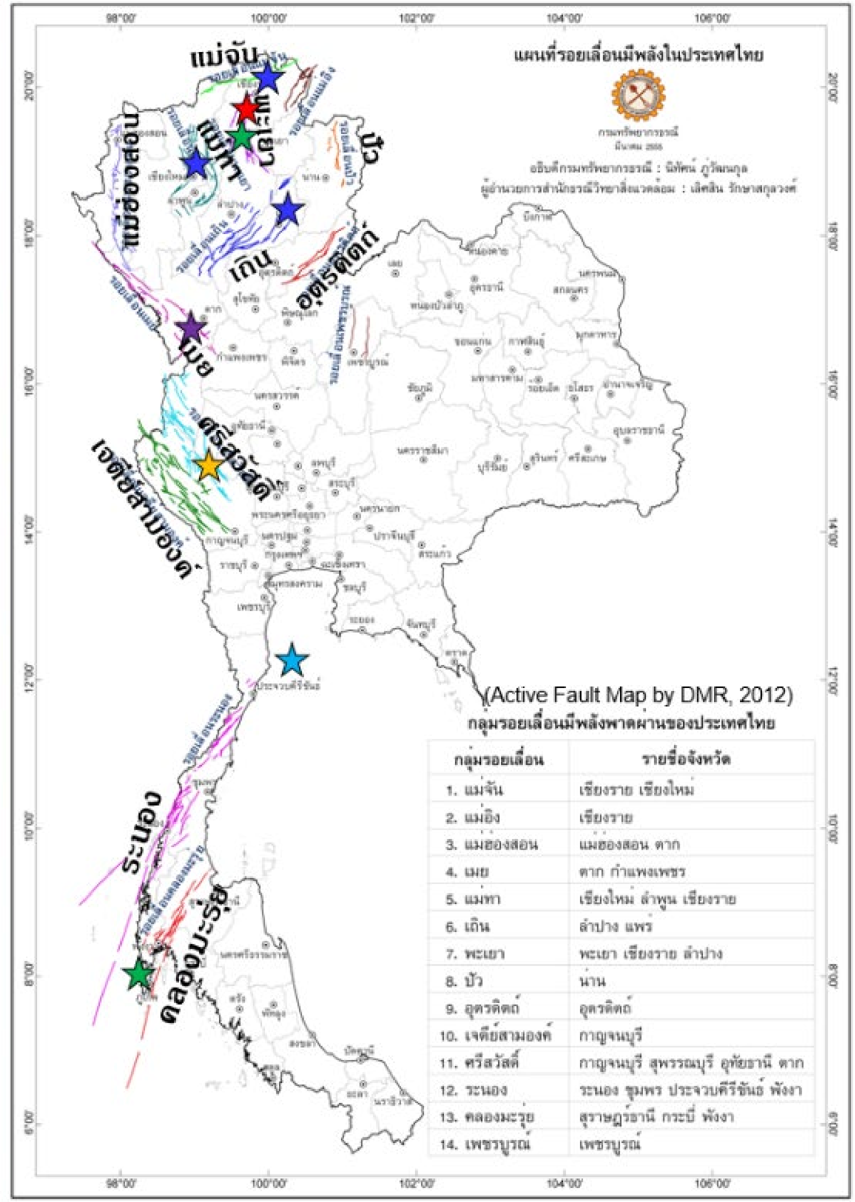
Tectonics of Southeast Asia



Regional map of Southeast Asia showing the large scale tectonic features and vectors showing Indian plate motion with respect to the Eurasian plate (DeMets et al.,2010).

Thailand's seismicity and faultings

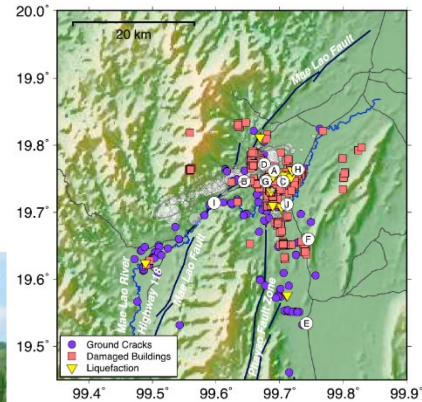


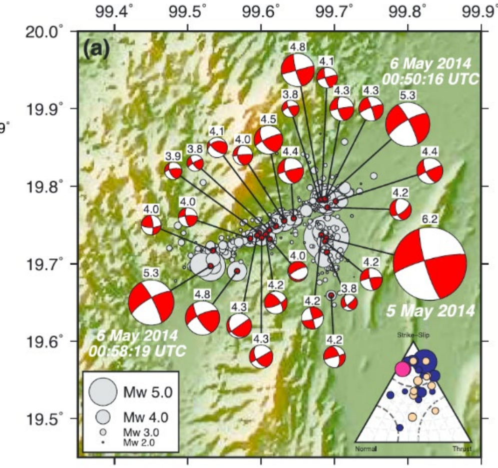


M6.2 Chiang Rai EQ

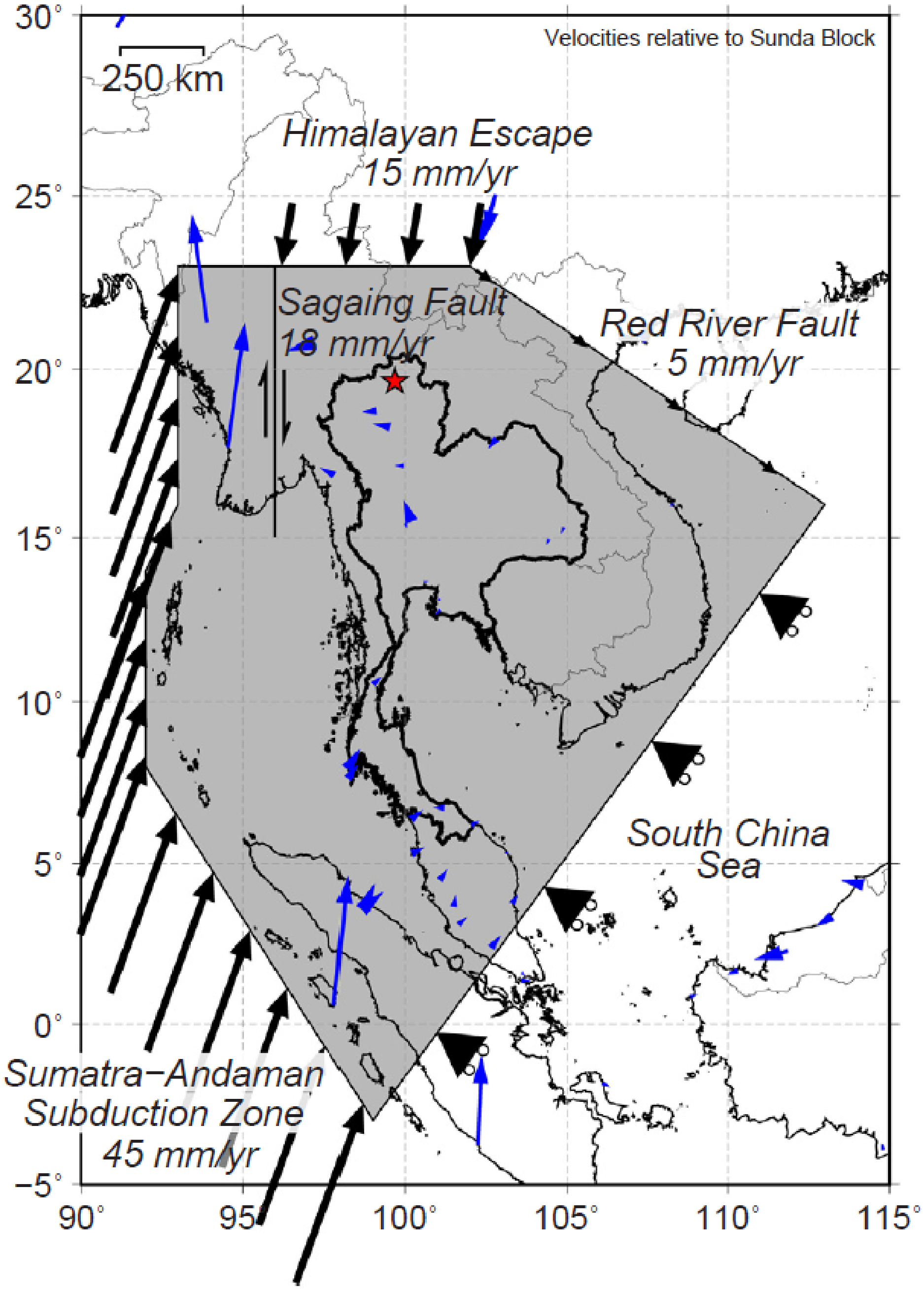
(MMI 7-8) $300M damages

(May 5th, 2014, 18:08 pm, 19.66◦N 99.67◦E 10km)





GTECTON's (2D) model geometry and boundary conditions



Himalayan Orogen: 15 mm/yr for the southward escape tectonics.

Red River Fault: 5 mm/yr to the strike-slip feature.

Sumatra-Andaman subduction zone: 45 mm/yr.

Sagaing Fault: 18 mm/yr of right lateral strike-slip motion

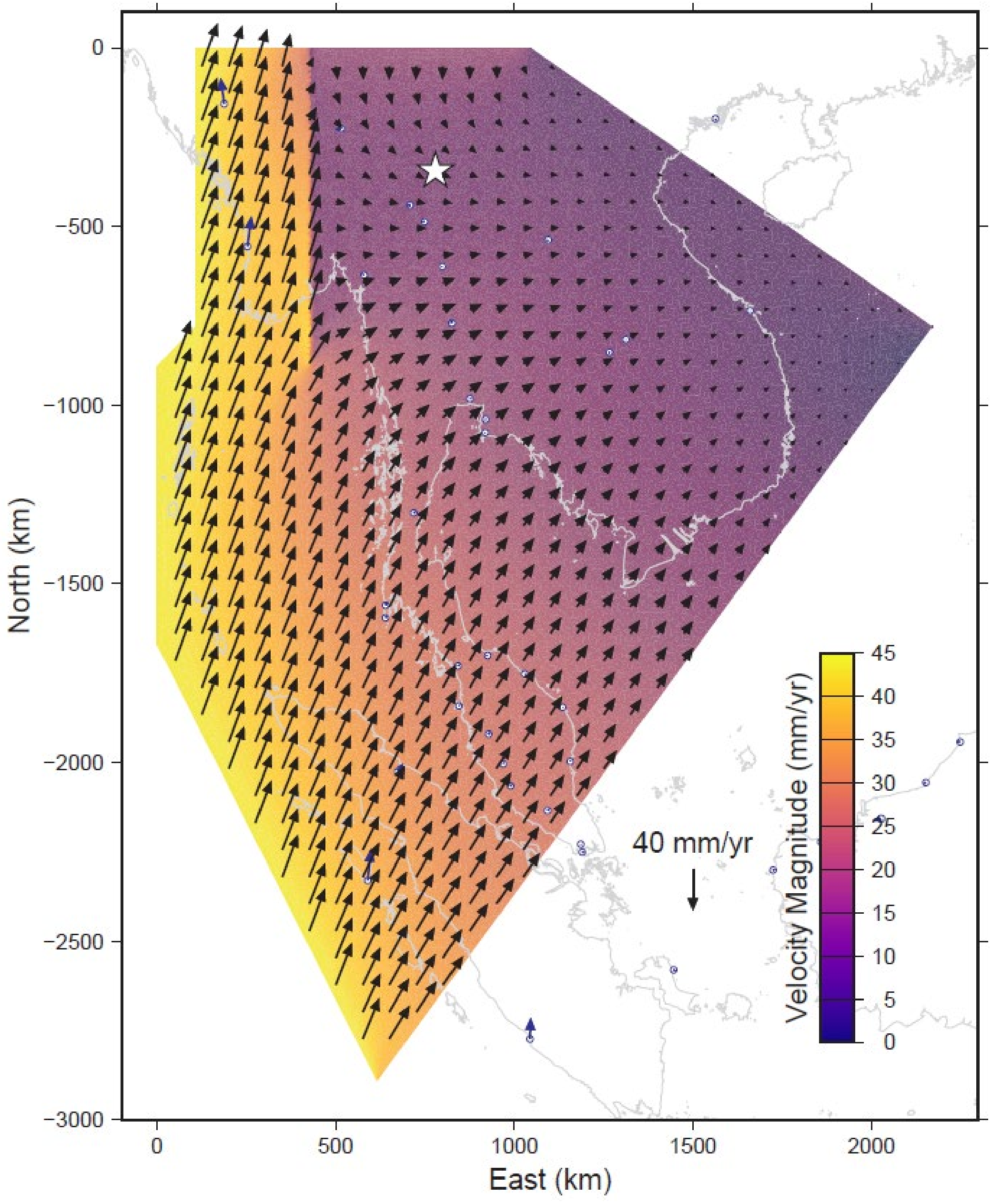
South China Sea: Fixed perpendicular to the boundary while allowing the boundary to shorten in response to convergence at the Sumatra-Andaman subduction zone.

Assuming homogeneous elastic material
Young's modulus = 75 GPa
Poisson's ratio = 0.30

(Blue arrows represent GPS velocities from Simons et al. (2007) scaled the same as the boundary condition displacements.)
GTECTON: Rob Govers, Utrecht University: FEM

Results

Plate Velocity from Reference Model



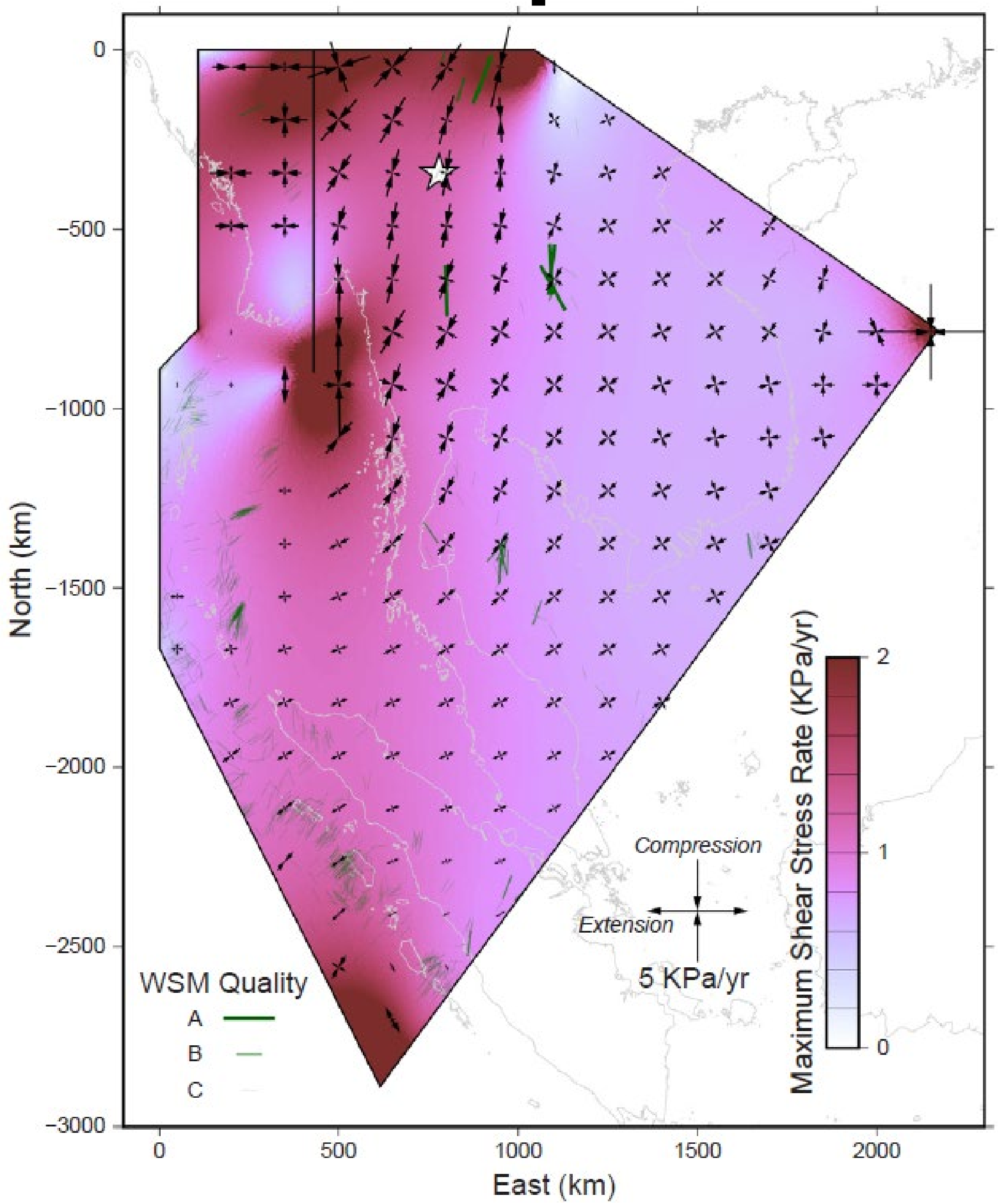
The largest velocities are associated with the convergence at the locked subduction zone.

Slip on the Sagaing Fault partitions the velocities in the northern part of the model; the region west of the Sagaing Fault moves northward at 40–45 mm/yr, while the region to the east has velocities lower than 15 mm/yr.

Throughout much of mainland Thailand and eastward, predicted velocities are 10 mm/yr or less.

•Note: Background colors indicate velocity magnitudes. Observed horizontal velocities from Simons et al. (2007) are shown as blue arrows and scaled the same as the model results. GPS misfits are results of the simplicity of the model such as no internal faults and elastic-only assumption

Principal Stressing Rate



Stresses accumulate most rapidly in the model in the northern region, between the Sagaing and Red River Faults. The southward directed motion of the Himalayan Plateau along the northern boundary of the model: NS oriented compressional maximum principal stress rates (σ1) up to 3 KPa/yr.

The minimum compressional (or maximum extensional) principal stress (σ2) throughout this region is compressional.Significant extensional stresses are not generated anywhere in the reference model.

Near Sumatra-Andaman subduction zone, σ1 is still compressional, relatively smaller in magnitude (~1 KPa/yr), and rotated to NE-SW.

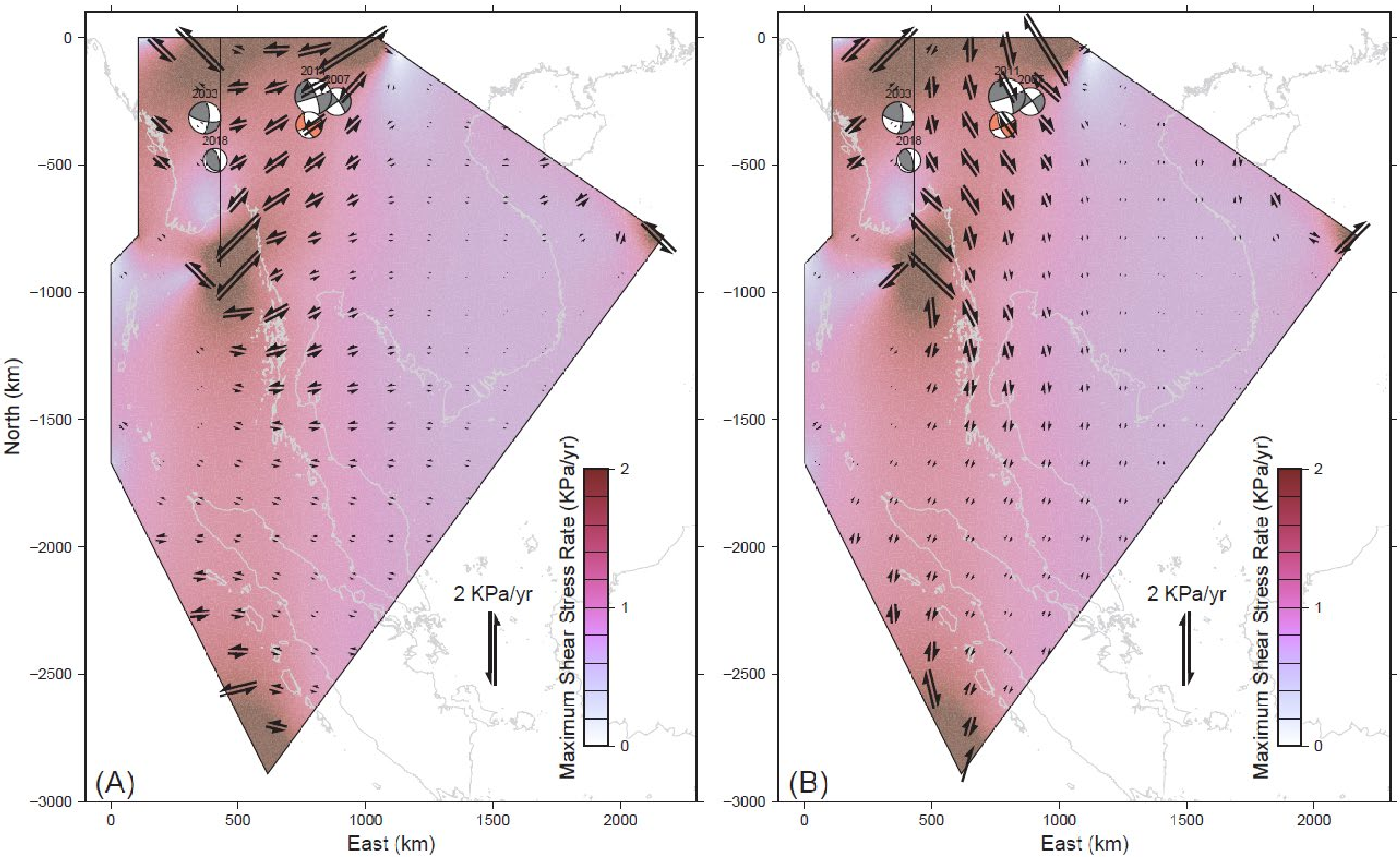
The orientations of the principal stress rates generated by the model in central Thailand are compatible with those inferred by Tingay et al. (2010) based on borehole breakouts and earthquake focal mechanisms.

Note: Background colors indicate the maximum shear stressing rate.

Arrows indicate the principal stress magnitudes and orientations.

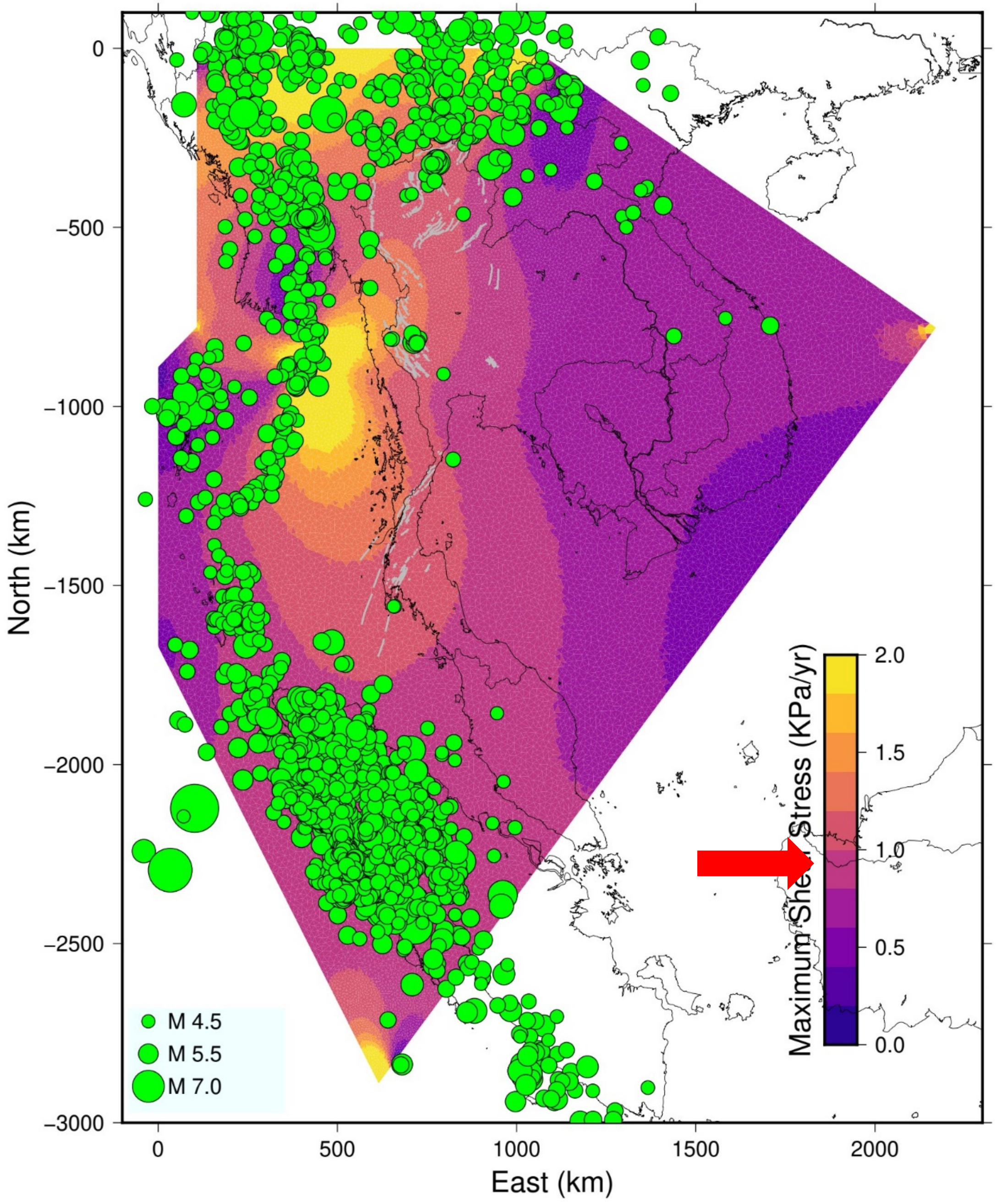
Green bars represent Shmax orientations from the World Stress Map Project

Maximum horizontal shear stressing rates



Maximum horizontal shear stressing rates and Mw 6+ earthquake mechanisms since 2000 (4 events). Background colors indicate maximum shear stress magnitude. (A) Left lateral shear stresses. (B) Right lateral shear stresses.

Maximum shear stress and seismicity of Thailand



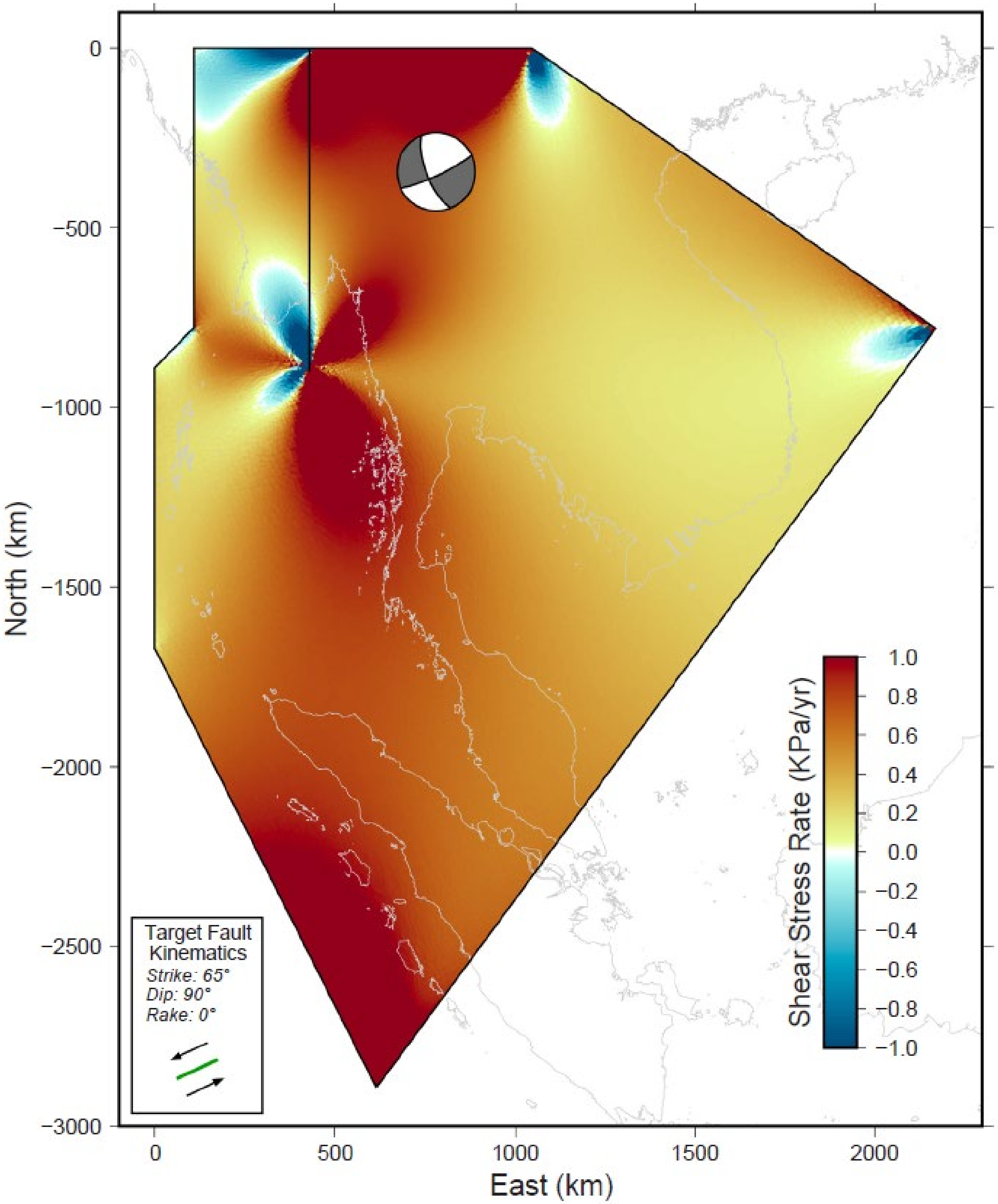
Biggest maximum shear stress of Thailand in:

North (>2.0 KPa/yr)

West: (1.0–1.5 KPa/yr)

(1 KPa/Yr = 0.1 MPa/100 Yrs)

Shear stressing rate resolved onto the left lateral fault plane of the 2014 Mae Lao event



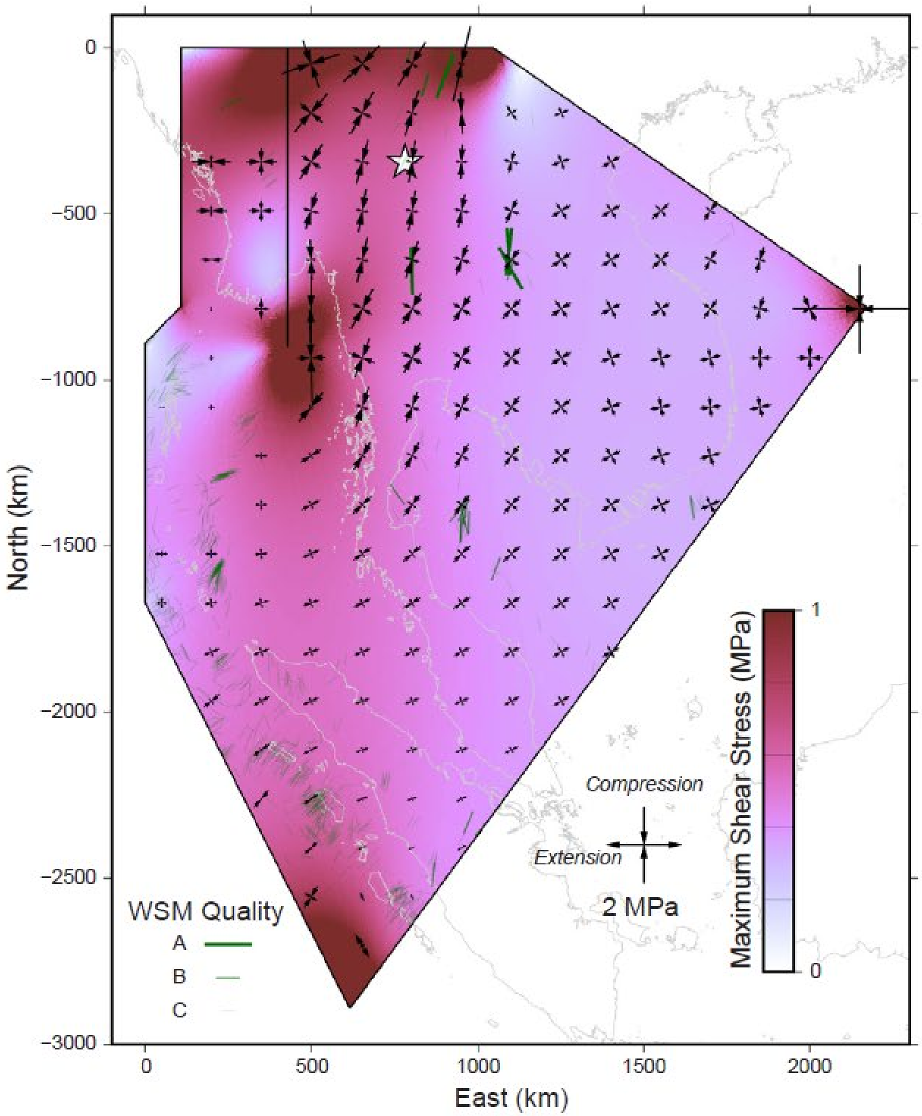
The regional stress fields acting on the Thailand intraplate region are oriented and distributed in patterns favorable to earthquake activity on faults throughout Thailand.

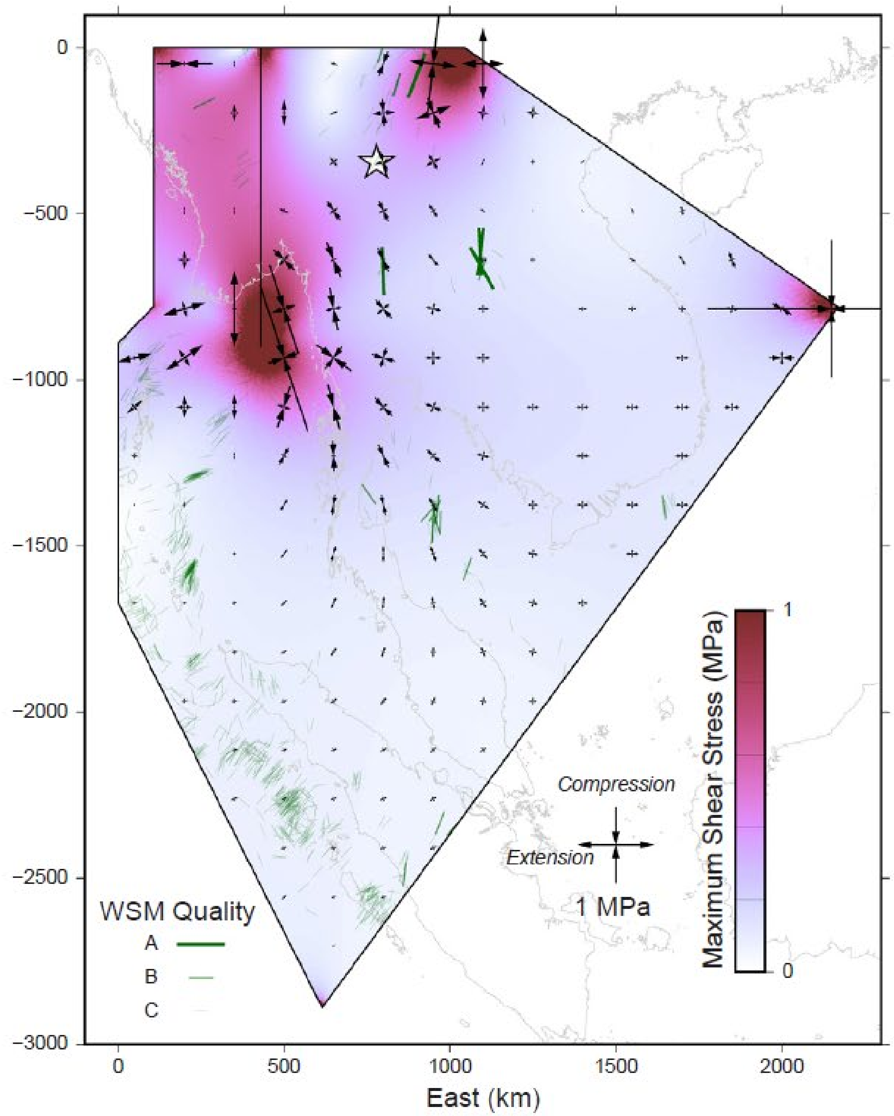
The rate of shear stress accumulation resolved onto left lateral strike-slip faults with a strike of 65◦ (the kinematics of the Mae Lao Earthquake are largest (> 0.5 KPa/yr) east and south of the Sagaing Fault. The Mae Lao earthquake epicenter lies within a region of high shear stress accumulation rate.

Assuming a ~20,000-year recurrence interval, these maximum shear stresses would grow to be>10 MPa from event to event compared to Mw 7.0 Darfield, New Zealand, earthquake that had a stress drop of 15 MPa @25,000 Yrs interval.

Note: Warm colors indicate areas where slip is promoted and cool colored areas are where slip is

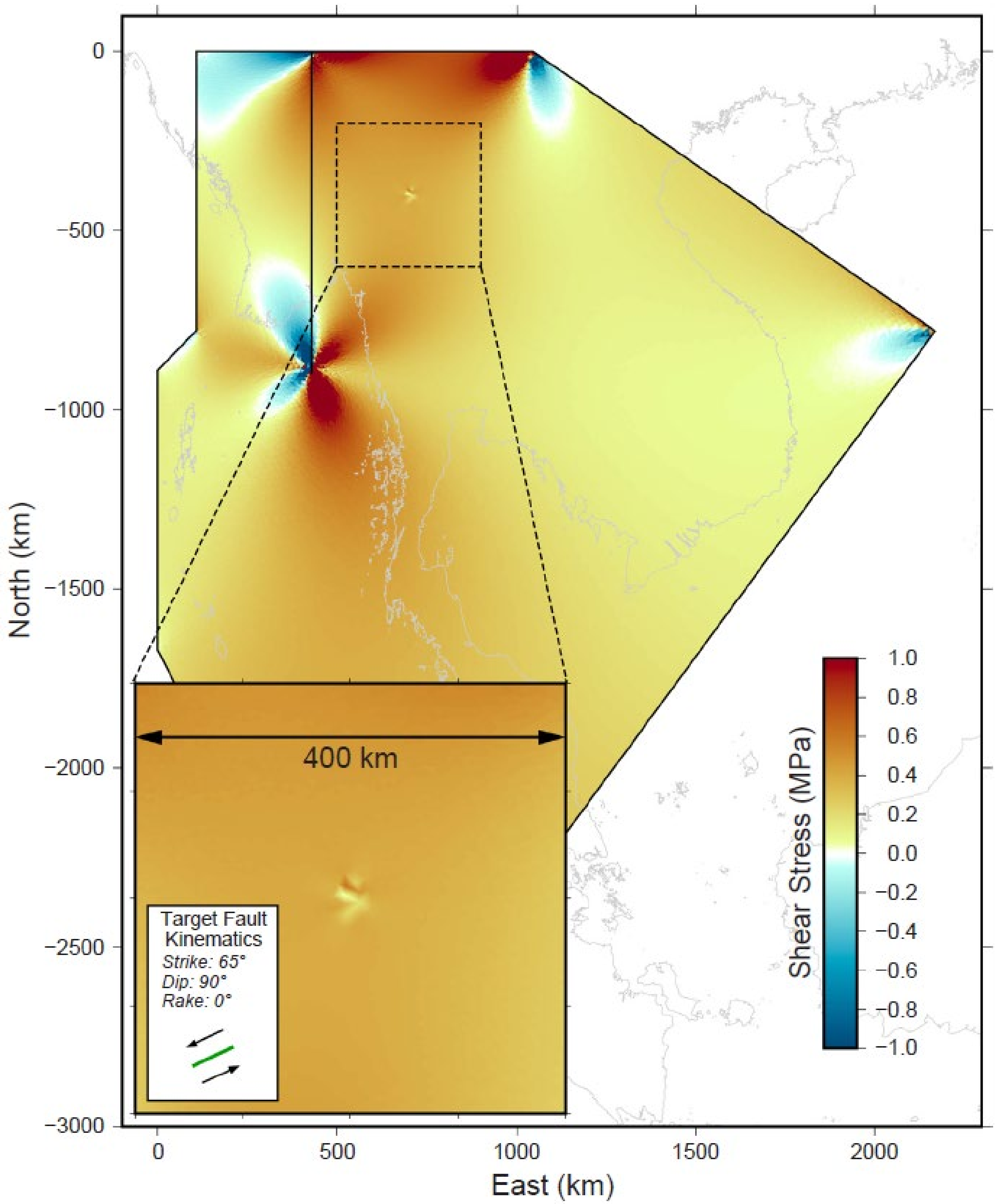
Time-integrated stresses





(left) accumulated in the 500 years before 2004 Mw 9.1 earthquake.
(right) after the 2004 earthquake.
(Note: the principal stress arrows have different scales in the two panels.)

500-year shear stresses resolved onto the left lateral fault plane of the 2014 Mae Lao earthquake



500-year shear stresses resolved onto the left lateral fault plane of the 2014 Mae Lao earthquake, plus the co-seismic stress changes of the Mae Lao earthquake (assuming the left lateral fault plane: strike=255◦, dip=80◦, rake=10◦).

Inset figure shows the sum of these stress fields in a 400-km wide region around the earthquake epicenter. This earthquake did little to perturb the stress field outside of a ~50 km diameter region surrounding the epicenter.

Conclusion

1. The stress conditions of Thailand are sensitive to plate boundary kinematics, the nature of coupling along major structures, and the effects of major earthquakes along those boundaries, primarily by interactions with adjacent plates along four major boundaries: the Himalayan Orogen, the Sumatra- Andaman subduction zone, the Red River Fault, and the Sagaing Fault.

2. The Mae Lao earthquake is consistent with the stress state expected in that region, and the abundant aftershocks imply high regional stress conditions prior to the event. The stress reductions associated with that earthquake are only local and do not significantly reduce regional stress conditions.

3. We the Sagaing Fault has a strong influence on the stress regime, implying that its coupling behavior and how it links to the fault systems of the Andaman Sea play a key role in controlling regional stress conditions.

4. The occurrence of the 2004 Mw 9.1 Sumatra earthquake likely had a substantial reducing effect on stress conditions in the southern and western parts of the region and also caused a substantial change in direction of maximum shear stress, affecting the earthquake potential on specific faults.

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Full length article

Evaluating the state of stress and seismic hazard in Thailand and vicinity through finite element modeling

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A B S T R A C T

Thailand is surrounded by seismically active plate boundary zones and large-offset crustal faults, but there is comparatively little seismic activity within its borders. On 5 May 2014, a moment magnitude (M_W) 6.2 earthquake occurred in the Mae Lao district of northern Thailand. To better anticipate future seismic hazards from events like this, we model the state of stress in Thailand and its vicinity using a finite element approach. We identify northern Thailand as a region with significant stress accumulation, consistent with being caused by convergence at the Sumatra-Andaman subduction zone and southward escape of the Himalayan Orogen. The stress field in this region is compatible with the kinematics of the Mae Lao event. Our modeling also shows that the magnitude of the stress field throughout southeast Asia is particularly sensitive to the stage of the earthquake cycle at the Sumatra-Andaman subduction zone, although the Sumatra-Andaman subduction zone produces a smaller effect on the orientations of stresses in the source region of the Mae Lao earthquake. Finally, we find that the stress change effect from the Mae Lao earthquake is geographically limited and the broader region remains in nearly the same state of stress as prior to the event.

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