Tectonic Pattern of Strong Earthquake Activities around Block Boundaries in Southeast Margin of Tibetan Plateau

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Abstract

By analyzing 360 permanent and campaign GPS data from 1999 to 2017 in the southern Sichuan-Yunan block, we revealed a complex pattern of tectonic movement in the southern Sichuan-Yunnan block. Compared to the stable Eurasian plate, crustal surface deformation reveals a complex pattern of tectonic movement in the southern Sichuan-Yunan block. Xiaojiang Fault shows left-lateral strike-slip movement of significantly lower deformation. Red River Fault in right-lateral strike-slip with extension clearly shows segmental deformation pattern, where NW segment is obvious stronger than SE segment. The maximum shear-strain rate mainly concentrated around the Xiaojiang fault and at the junction of Red River Fault and Lijiang–Xiaojinhe Fault. Most earthquakes with magnitude of Ms≥4.0 in the study area are located in the zone of high shear strain rate and high strain rate gradient, indicating that earthquake activities are closely related to strain accumulation.

We also analyzed seismic data of 133 temporary broadband seismic stations from ChinArray and Western-Sichuan dense array to obtain crustal thicknesses by receiver functions, with the effect of low-velocity sedimentary layers eliminated. Crustal thickness shows obvious variation at two sides of Xiaojiang Fault, and at two sides of NW end and SE segment of Red River Fault.

Velocity Field

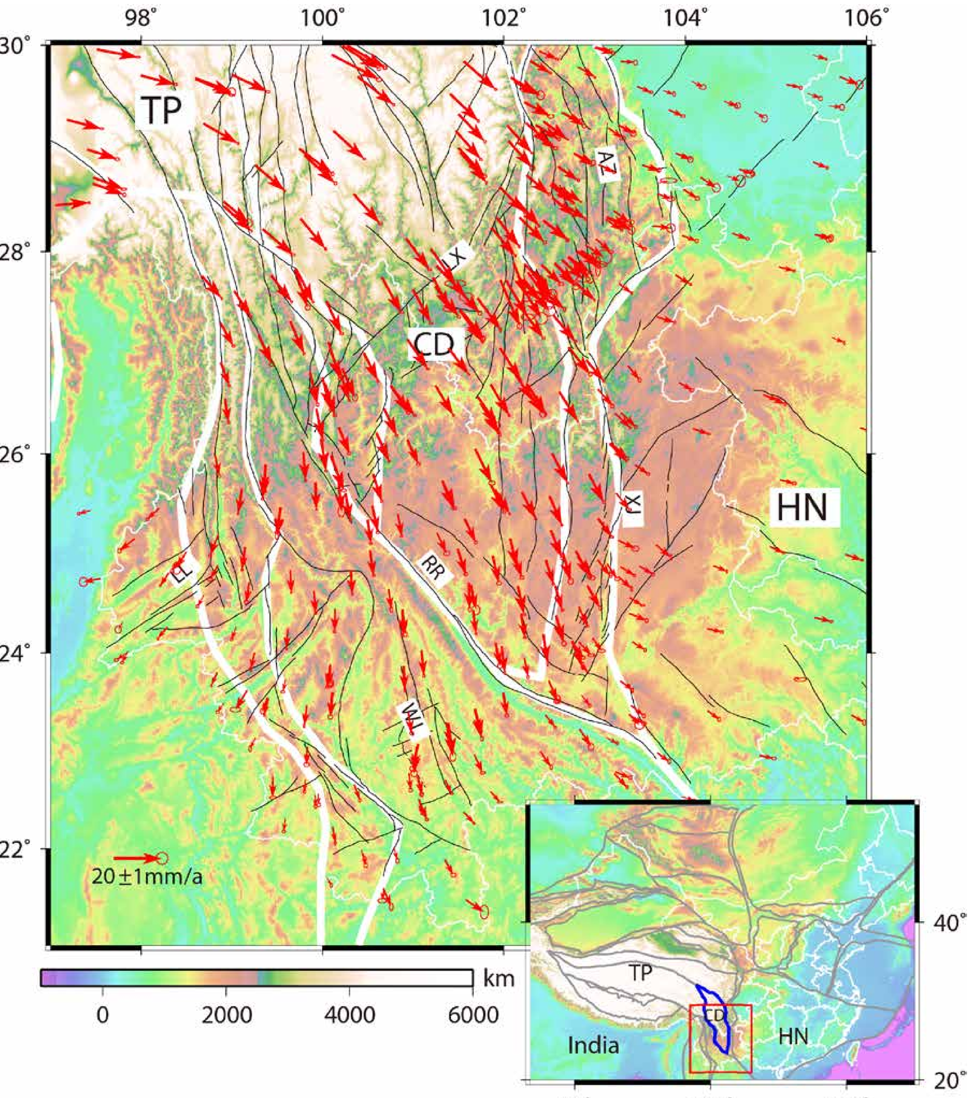

Fig 1. GPS velocity field of the southern part of the southern part of the Sichuan-Yunnan block relative to the Eurasian plate. The red rectangle in the bottom-right plot indicates the location of the study area. The bold white lines and solid black lines represent block boundaries and active faults, respectively. The red arrows represent the velocity field. AZ=Anninghe-Zemuhe Fault, XJ=Xiaojiang Fault, LX=Lijiang-Xiaojinhe Fault, RR=Red River Fault, WL=Wuliangshan Fault, LL=Longling Fault, CD=Sichuan-Yunnan block, HN=Huanan block,TP=Tibetan Plateau.

Strain Rate Distribution

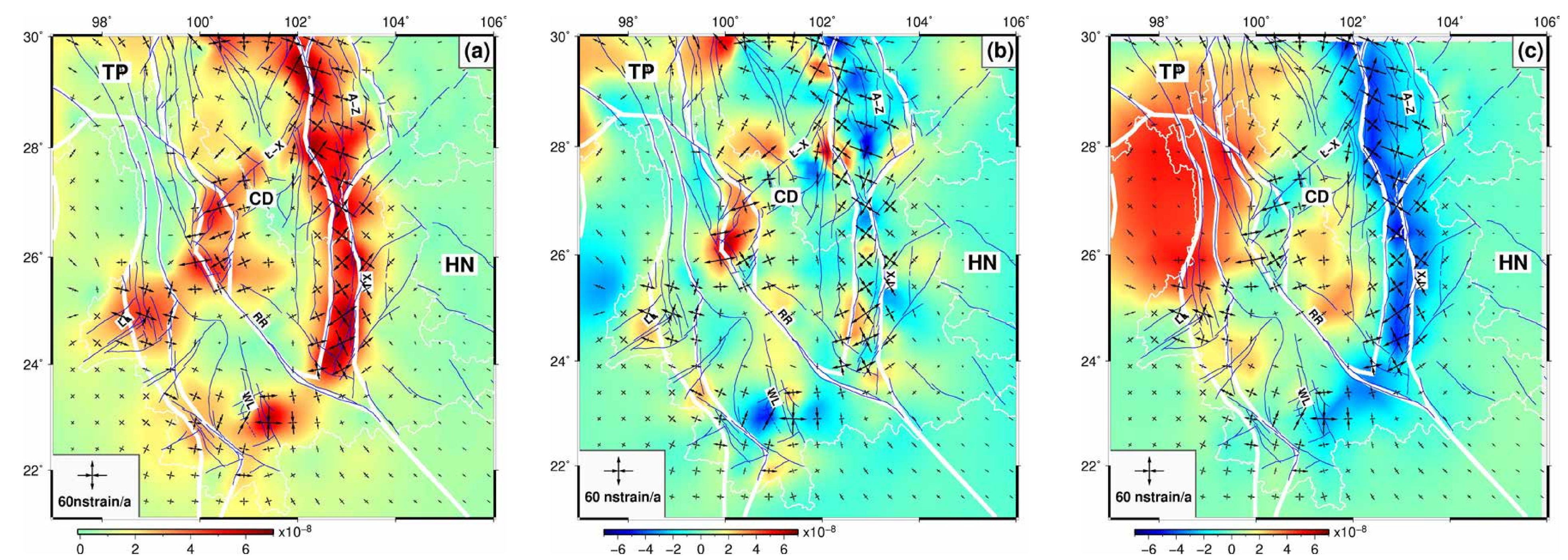

Fig 2. Strain rate distribution obtained from the GPS horizontal velocity in southern Sichuan-Yunnan block. (a) Distribution of shear- and principal-strain rates (black arrows indicate extension and compression); (b) Surface-strain rate distribution (positive values indicate expansion; negative values indicate compression); (c) Rotational-strain rate distribution (positive values indicate clockwise rotation; negative values indicate counterclockwise rotation).

Strain and Seismicity

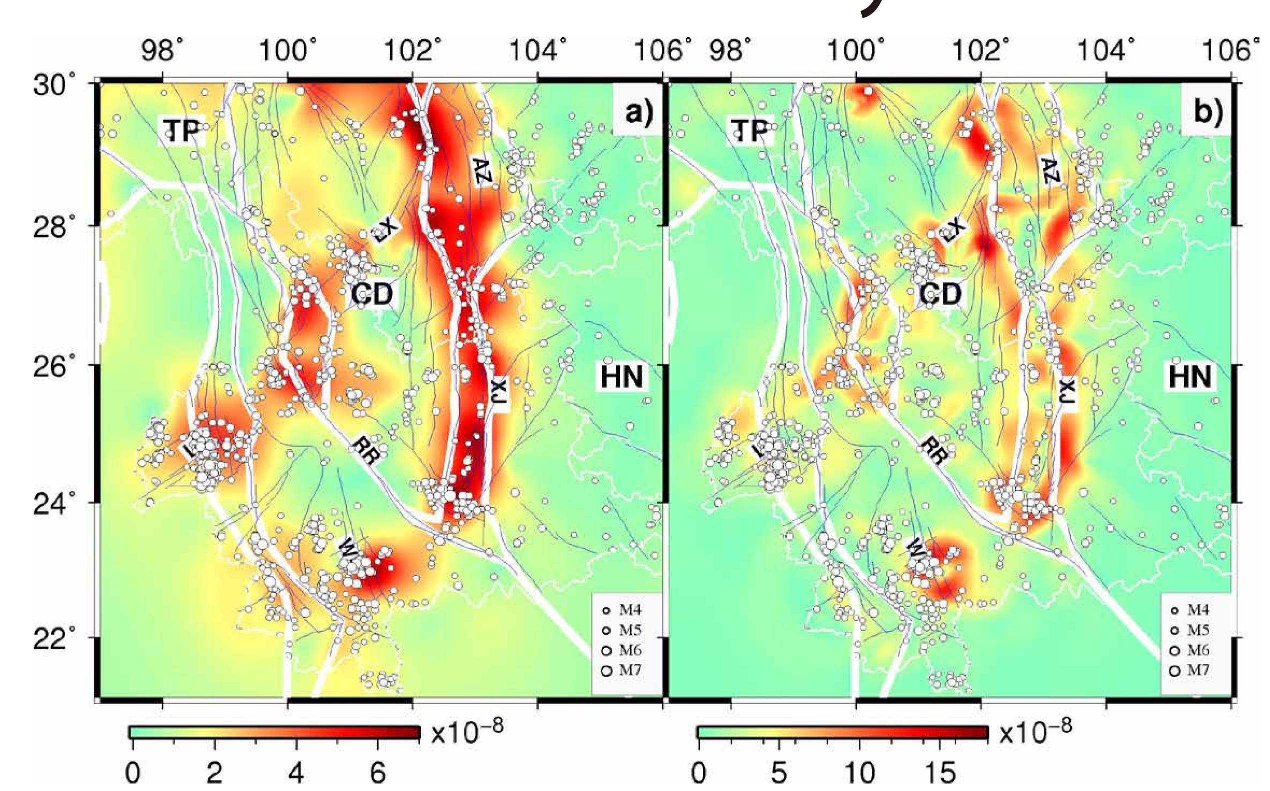

Fig 3. Comparison between the shear-strain rate (a) and strain rate gradient (b) with seismic activity distributions in the southern Sichuan-Yunnan block. Shear-strain results obtained from the inversion of GPS observations collected from 1999 to 2017 (color isogram). Data of earthquakes with magnitude of M≥4.0 from January 1966 to June 2018 are obtained from the China Seismic Network Catalog (circles).

Receiver Function Analysis

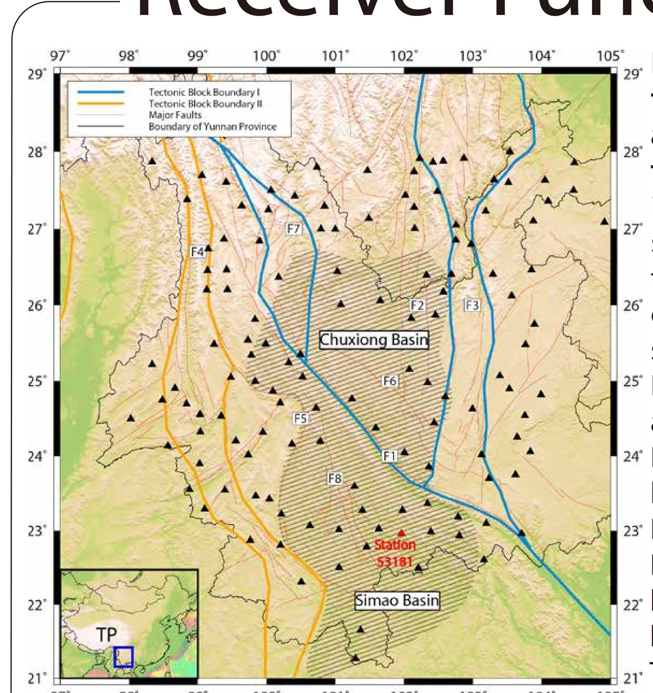

Fig 4. Distribution of seismic stations used in the receiver function analysis and tectonic features in the study area. The black triangles indicate the temporary seismic stations adopted in this study, and the shadow area indicates Chuxiong and Simao Basins. The red solid lines are faults: F1-Red River Fault, F2-Anninghe Fault, F3-Xiaojiang Fault, F4-Nujiang Fault, F5-Lancangjiang Fault, F6-Nanhua-Chuxiong-Jianshui Fault, F7-Xiaojinhe Fault, F8-Middle axial Fault. The blue rectangle in the bottom left plot indicates the location of the study area to the Tibetan Plateau (marked as TP).

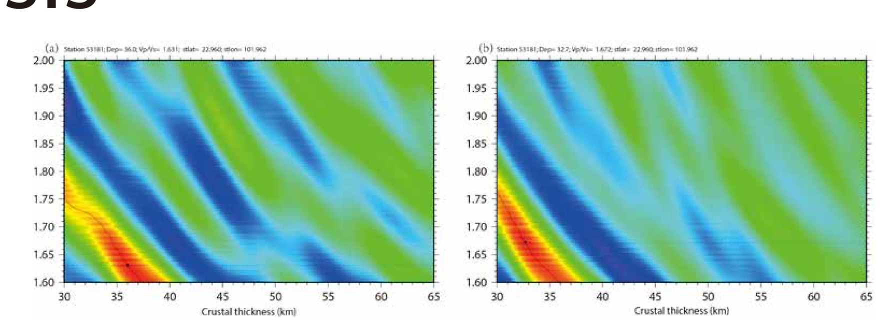

Fig 5. Example of H-κ stacking of Station 53181 in Simao Basin. (a) Conventional method; (b) Improved method. In the improved method, we first apply a resonance removal filter to the RFs, then apply a time-corrected H-κ stacking, to eliminate the effect of sedimentary layer. The location of Station 53181 is shown in Fig 4.

Crustal Thicknesses

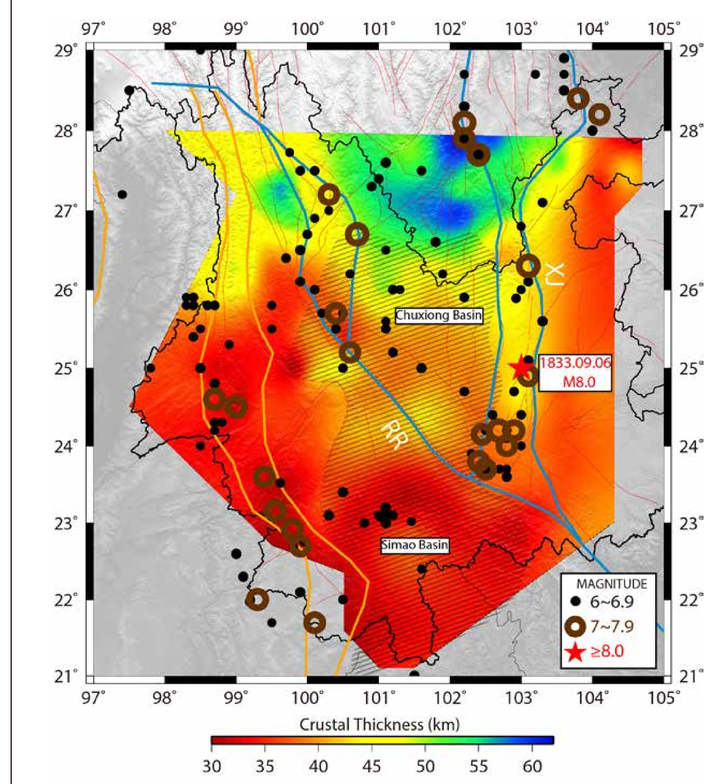

Fig 6. Overall distribution of crustal thicknesses obtained from H-κ stacking in the southeast margin of the Tibetan Plateau and distribution of large earthquakes. The blue and yellow bold lines indicate the first and second tectonic block boundaries, respectively. The red lines indicate major faults. RR and XJ indicates Red River Fault and Xiaojiang Fault, respectively. The black dots, brown circles and red star indicates the location of large earthquakes with mgnitude of M≥6.0.

The results show that crustal thickness varies greatly in the study area. The Red River Fault draws an apparent boundary on crustal thickness. The strong variation of crustal thickness on the different side of Xiaojiang Fault indicates that it blocks the southeaster escape of the Tibetan Plateau. Large earthquakes located concentraely along Xiaojiang Fault and the northern part of Red River Fault.

Note: Earthquake data are from historical earthquake cata-

Poisson's Ratios

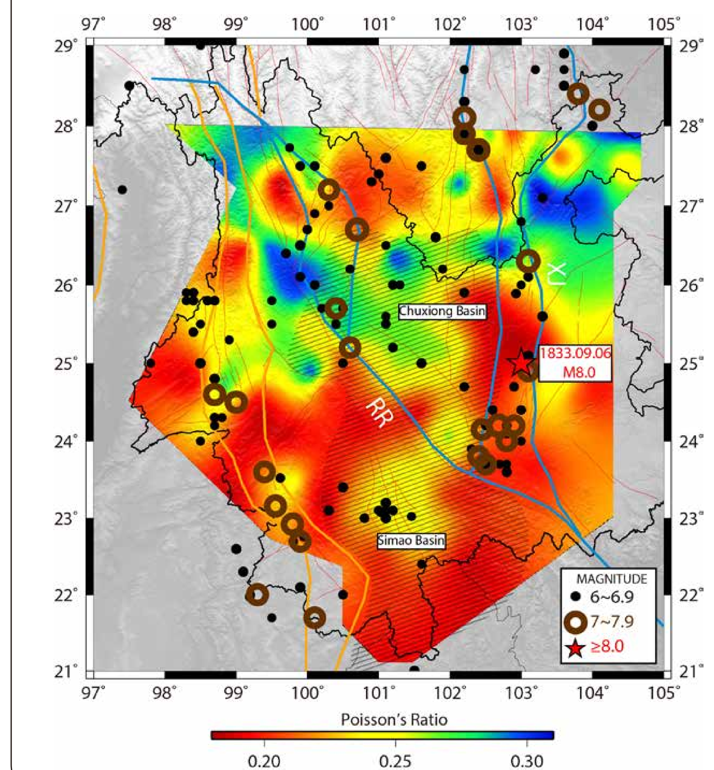

Fig 7. Overall distribution of Poisson's ratios obtained from H-κ stacking in the southeast margin of the Tibetan Plateau and distribution of large earthquakes. The blue and yellow bold lines indicate the first and second tectonic block boundaries, respectively. The red lines indicate major faults. RR and XJ indicates Red River Fault and Xiaojiang Fault, respectively. The black dots, brown circles and red star indicates the location of large earthquakes with mgnitude of M≥ 6.0.

Poisson's ratios are generally high in the north and low in the south, the feature of which is positively correlated with the variation of crustal thickness, indicating lower crust thickening in the study area. Higher Poisson's ratio around the Red River Fault may be related to partial melt at the bottom of the lower crust. The relatively low Poisson's ratio in the southeastern part of the study area infers that there are more felsic components in this region than the average continental crust. Large earthquakes seem to happen at areas with dramatic changes in Poisson's ratios.

Discussions

▲ The distribution of shear strain rate and its gradient is closely related to the seismicity; i.e., areas with high shear strain rate or strain rate gradients are seismically active.

▲ The location of large earthquakes (M≥7.0) shows no relationship with the crustal thickness; however, they seem to happen at areas with dramatic changes in Poisson's ratios.

References and Acknowledgments

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