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Longmanshen fault zone still hazardous, suggest new reports

Seismological Research Letters *publishes special issue on 2013 Lushan, China earthquake*

SAN FRANCISCO, Jan. 2, 2014 – The 60-kilometer segment of the fault northeast of the 2013 Lushan rupture is the place in the region to watch for the next major earthquake, according to research published in Seismological Research Letters (SRL). Research papers published in this special section of SRL suggest the 2008 Wenchuan earthquake triggered the magnitude 6.6 Lushan quake.

Guest edited by Huajian Yao, professor of geophysics at the University of Science and Technology of China, the special section includes eight articles that present current data, description and preliminary analysis of the Lushan event and discuss the potential of future earthquakes in the region.

More than 87,000 people were killed or went missing as a result of the 2008 magnitude 7.9 Wenchuan earthquake in China's Sichuan province, the largest quake to hit China since 1950. In 2013, the Lushan quake occurred ~90 km to the south and caused 203 deaths, injured 11,492 and affected more than 1.5 million people.

"After the 2008 magnitude 7.9 Wenchuan earthquake along the Longmenshan fault zone in western Sichuan of China, researchers in China and elsewhere have paid particular attention to this region, seeking to understand how the seismic hazard potential changed in the southern segment of the fault and nearby faults," said Yao. "Yet the occurrence of this magnitude 6.6 Lushan event surprised many. The challenge of understanding where and when the next big quake will occur after a devastating seismic event continues after this Lushan event, although we now have gained much more information about this area."

Preliminary rupture details

The southern part of the Longmenshan fault zone is complex and still only moderately understood. Similar to the central segment where the 2008 Wenchuan event occurred, the southern segment, which generated the Lushan rupture, includes the Wenchuan-Maoxian

fault, Beichuan-Yingxiu fault, the Pengxian-Guanxian fault and Dayi faults, a series of sub-parallel secondary faults.

Although the Lushan earthquake's mainshock did not break to the surface, the strong shaking still caused significant damage and casualties in the epicentral region. Three papers detail the rupture process of the Lushan quake. **Libo Han** from the China Earthquake Administration and colleagues provide a preliminary analysis of the Lushan mainshock and two large aftershocks, which appear to have occurred in the upper crust and terminated at a depth of approximately 8 km. While the Lushan earthquake cannot be associated with any identified surface faults, Han and colleagues suggest the quake may have occurred on a blind thrust fault subparallel to the Dayi fault, which lies at and partly defines the edge of the Chengdu basin. Based on observations from extensive trenching and mapping of fault activity after both the Wenchuan and Lushan earthquakes, **Chen Lichun** and colleagues from the China Earthquake Administration suggest the Lushan quake spread in a "piggyback fashion" toward the Sichuan basin, but with weaker activity and lower seismogenic potential than the Wenchuan quake. And **Junju Xie**, from the China Earthquake Administration and Beijing University of Technology, and colleagues examined the vertical and horizontal near-source strong motion from the Mw 6.8 Lushan earthquake. The vertical ground motion is relatively weak for this event, likely due to the fact that seismic energy dissipated at the depth of 12-25 km and the rupture did not break through the ground surface.

Possible link between Lushan and Wenchuan earthquakes

Were the Lushan and Wenchuan earthquakes related? And if so, what is the relationship? Some researchers consider the Lushan quake to be a strong aftershock of the Wenchuan quake, while others see them as independent events. In this special section, researchers tackled the question from various perspectives.

To discover whether the Lushan earthquake was truly independent from the Wenchuan quake, researchers need to have an accurate picture of where the Lushan quake originated. **Yong Zhang** from the GFZ German Research Centre for Geosciences and the China Earthquake Administration and colleagues begin this process by confirming a new hypocenter for Lushan. To find this place where the fault first began to rupture, the researchers analyze near-fault strong-motion data (movements that took place at a distance of up to a few tens of kilometers away from the fault) as well as long distance (thousands of kilometers) teleseismic data.

Using their newly calculated location for the hypocenter, Zhang and colleagues now agree with earlier studies that suggest the initial Lushan rupture was a circular rupture event with no predominant direction. But they note that their calculations place the major slip area in the Lushan quake about 40 to 50 kilometers apart from the southwest end of the Wenchuan quake fault. This "gap" between the two faults may hold increased seismic hazards, caution Zhang and colleagues.

Ke Jia of Beijing University and colleagues explore the relationship of the two quakes with a statistical analysis of aftershocks in the region as well as the evolution of shear stress in the lower crust and upper mantle in the broader quake region. Their analyses suggest that the Wenchuan quake did affect the Lushan quake in an immediate sense by changing the overall background seismicity in the region. If these changes in background seismicity are taken into account, the researchers calculate a 62 percent probability that Lushan is a strong aftershock of Wenchuan.

Similarly, **Yanzhao Wang** from the China Earthquake Administration and colleagues quantified the stress loading of area faults due to the Wenchuan quake and suggest the change in stress may have caused the Lushan quake to rupture approximately 28.4 to 59.3 years earlier than expected. They conclude that the Lushan earthquake is at least 85 percent of a delayed aftershock of the Wenchuan earthquake, rather than due solely to long-term tectonic loading.

After the Wenchuan quake, researchers immediately began calculating stress changes on the major faults surrounding the rupture zone, in part to identify where dangerous aftershocks might occur and to test how well these stress change calculations might work to predict new earthquakes. As part of these analyses, **Tom Parsons** of the U.S. Geological Survey and **Margarita Segou** of GeoAzur compared data collected from the Wenchuan and Lushan quakes with data on aftershocks and stress change in four other major earthquakes, including the M 7.4 Landers and Izmit quakes in California and Turkey, respectively, and the M 7.9 Denali quake in Alaska and the M 7.1 Canterbury quake in New Zealand.

Their comparisons reveal that strong aftershocks similar to Lushan are likely to occur where there is highest overall aftershock activity, where stress change is the greatest and on well-developed fault zones. But they also note that by these criteria, the Lushan quake would only have been predicted by stress changes, and not the clustering of aftershocks following the 2008 Wenchuan event.

Future earthquakes in this region

After Wenchuan and Lushan, where should seismologists and other look for the next big quake in the region? After the 2008 Wenchuan quake, seismologists were primed with data to help predict where and when the next rupture might be in the region. The data suggested that the Wenchuan event would increase seismic stress in the southern Longmenshan fault that was the site of the 2013 Lushan quake. But that information alone could not predict that the southern Longmenshan fault would be the next to rupture after Wenchuan, say **Mian Liu** of the University of Missouri and colleagues, because the Wenchuan earthquake also increased the stress on numerous others faults in the region

Additional insights can be gained from seismic moment studies, according to Liu and colleagues. Moment balancing compares how much seismic strain energy is accumulated

along a fault over a certain period with the amount of strain energy released over the same period. In the case of the Longmenshan fault, there had been a slow accumulation of strain energy without release by a major seismic event for more than a millennium. After the Wenchuan quake, the southern part of the Longmenshan fault became the fault with the greatest potential for a quake. And now, after Lushan, Liu and colleagues say that the 60 kilometer-long segment of the fault northeast of the Lushan rupture is the place in the region to watch for the next major earthquake.

The bimonthly *Seismological Research Letters* serves as a general forum for informal communication among seismologists, as well as between seismologists and those nonspecialists interested in seismology and related disciplines. *SRL* is published by the Seismological Society of America, which is a scientific society devoted to the advancement of earthquake science. Founded in 1906 in San Francisco, the Society now has members throughout the world representing a variety of technical interests: seismologists and other geophysicists, geologists, engineers, insurers and policymakers in preparedness and safety.

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