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Control of huge faults on rock mass structure: implications for the landslides triggered by the 2008 Wenchuan Earthquake

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Introduction

Earthquakes and earthquake induced landslides are the most threatening geological disasters in nature. Coseismic landslide, as a surface catastrophic effect induced by earthquakes, has drawn much scientific attention. The fact that seismic faults play a control role in the occurrence of landslide has been generally recognized. However, how the faults affect the occurrence of landslides has not been clearly understood. Therefore, in this study we examined this issue based on a case study on the landslides triggered by the 2008 Wenchuan earthquake, in China.

Method

We selected Qingping section of Longmenshan faults generating the Ms 8.0 earthquake as a target region. In-situ field rock mass structure investigations in 2m*2m measurement network and detailed fracture measurements through 0.3m*0.3m network in laboratory were conducted along profiles oriented across the faults, then fracture density and cumulative fracture density were calculated to determine the sequence characteristics of fractured system of the crustal rock mass in the fault zone. Regional statistical laws of Wenchuan earthquake landslides distribution pattern was combined to deeply discuss the effects of faults on landslides.

Result

The results of spatial variations in fracture density and cumulative fracture density with increasing distance from the Jiangyou-Dujiangyan fault were shown in Figs. 1 and 2. As can be seen in Fig. 1, the occurrences of fractures are strongly concentrated around the faults zone, such as Yingxiu-Beichuan fault and Jiangyou-Dujiangyan fault, presence of secondary faults also has a strong relation with fracture density distribution. Fracture density is much higher in the faults zone than other areas and sharply decreases with further increase after it exceeds a certain distance (CD) from the main fault. In Yingxiu-Beichuan fault, this CD is 3030 m in hanging wall and 1170 m in footwall, while in Jiangyou-Dujiangyan fault, this CD is 1350m in the hanging wall.

Fig. 2 indicates slope gradients variations of cumulative frequency with increasing distance from the Jiangyou-Dujiangyan fault. Slope gradients of cumulative frequency become steep with the presence of faults. For hanging wall in Yingxiu-Beichuan fault, the slope gradient of cumulative fracture density decreases gradually with increasing distance from the fault, and becomes a constant after it exceeds a certain distance.

Fig. 3 presents the concentration parts of fracture density and cumulative fracture density in plane. The concentration parts were devided into five zones. We found that most landslides were located all these zones, and many landslides were confined by the partion boundary and secondary faults (shown with purple dotted line in Fig. 3).

Discussion

In this study, we found that there are controlling effects confined to a certain range of huge faults on the surrounding regional rock mass structure, which is different from the damage zone, showing a greater impact on rock mass structure in a larger scale. Thus,

a concept named “fracture zone” is defined to express this phenomenon and corresponding characteristics. Based on the results (Figs.1 and 2), the width of fracture zone of hanging wall in Yingxiu-Beichuan fault is 3030 m, which can be subdivided into 3 parts: damage zone (220 m wide), strongly fracture zone (1450 m wide), medium fracture zone (1360 m wide), the width of fracture zone of footwall in Yingxiu-Beichuan fault is 1170 m, the width of fracture zone of hanging wall in Jiangyou-Dujiangyan fault is 1350 m. The results suggest the existence of remarkable hanging wall effect of rock mass structure and the width of fracture zone in the hanging wall is obviously greater than that in the foot wall, which presents good consistency with the distribution pattern of landslides triggered by the earthquake.

Conclusion

1. Faults have a control effect limited to a certain range on the structure of surrounding rock mass in the whole mountain, which is different from the “damage zone” effect, and could be defined as “fracture zone” effect. This effect has directly impacts on the distribution of coseismic landslides.

2. The rock mass structure resulting from the faults presents long-term effect on the instability of these mountainous slopes along the faults, because these rock masses are more vulnerable to heavy rainfall and/or earthquake. These results may have significant implications for disaster prevention and mitigation in mountainous areas where faults are active.

Reference

Keefer, D. K. (1984). Landslides caused by earthquakes. GSA Bulletin 95(4): 406-42

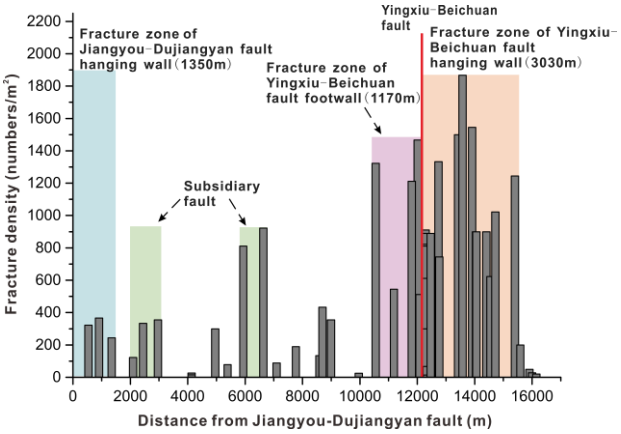

Fig 1. Spatial variations in fracture density with increasing distance from the Jiangyou-Dujiangyan fault

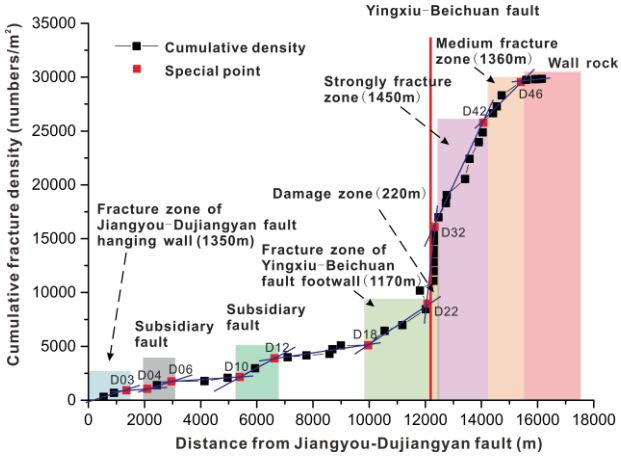

Fig 2. Spatial variations in cumulative fracture density with increasing distance from the Jiangyou-Dujiangyan fault

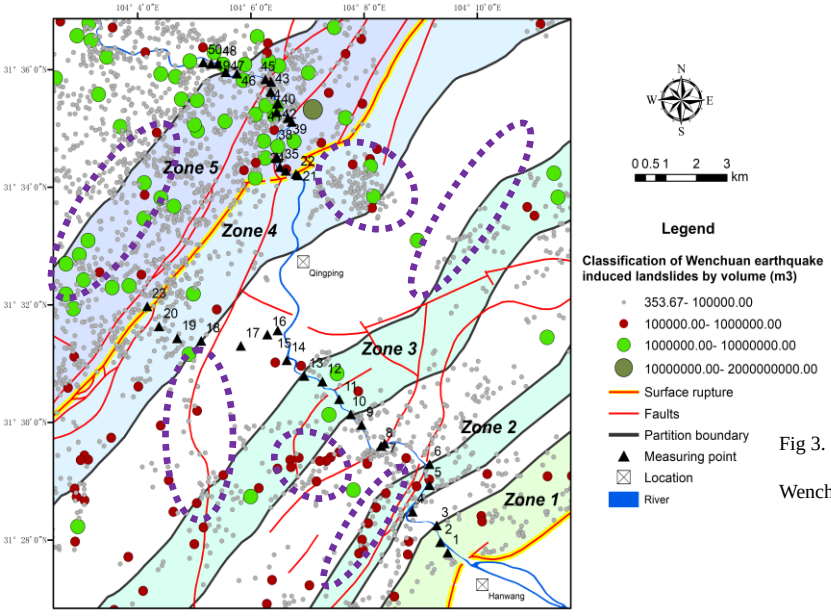

Fig 3. Relationship between rock mass structure partition and Wenchuan earthquake induced landslide