

陳有蘭溪流域的山崩作用在颱風及地震事件中與河流輸砂量之相對關係  
The relationships between sediment discharge and landslides induced by typhoon and earthquake along the Chenyoulan River

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摘要

從陳有蘭溪流域在 1996 年賀伯颱風、1999 年 921 地震、2001 年桃芝颱風及 2004 年敏督利颱風等四個事件所進行之研究中發現，921 地震後的五年內，山崩新生率上升至 70%，山崩重現率下降至 40%，四個事件之山崩面積機率迴歸指數均大於 1.5，此意義顯示山崩類型主要為小於 2000 m<sup>2</sup> 之小規模山崩。從山崩最低點的機率分布也可以發現，921 地震後仍有超過 90% 的崩塌材料堆積在山坡上。

從河流輸砂量的統計結果發現，921 地震後陳有蘭溪之平均年輸砂量達 37 百萬噸，較地震前增加 13 倍，單位懸浮沉積物濃度較地震前增加 4 倍以上，而桃芝及敏督利颱風期間，單位流量中之輸砂量也超過賀伯颱風的 1.5 倍，此意義顯示，地震後本研究區內的輸砂特性有了變化，不但平均年輸砂量上升，且在相同流量條件下，地震後之輸砂量會較地震前高。

就山崩與岩石強度之對應關係中可瞭解，921 地震後南莊層之崩塌率為地震前的 17 倍，和社層為 3.4 倍，變質岩層為 4.8 倍，其中以南莊層崩塌率的上升幅度最大，此原因可能是南莊層之岩石平均強度不到和社層及變質岩層的 2/3 使然。而南莊層及和社層在 921 地震後之山崩重現率下降 25%，變質岩層僅下降 6%，此結果可能與變質岩層之不連續面的分布比例為南莊層及和社層的 2 倍有密切關係。

從崩塌面積的分布與車籠埔斷層距離的關係中可以發現，921 地震的山崩與斷層距離超過 20km 後，崩塌率有明顯下降的趨勢，在桃芝颱風的山崩分布中亦可看到此現象，而敏督利颱風時，此現象已不明顯。從降雨量與山崩率的比對中可以發現，賀伯颱風時，降雨量越大的集水區，崩塌率就越高，其相關係數達 0.99，但降雨量與桃芝颱風及敏督利颱風的山崩卻無此明顯的關係，此現象可以說明賀伯颱風的崩塌主要是受到降雨多寡的影響，而桃芝及敏督利颱風除了降雨量的關係外，還包括了 921 地震的影響。

**關鍵詞：**陳有蘭溪；山崩；輸砂量

## Abstract

Examining the effects of four events -- typhoon Herb, 921-earthquake, typhoon Toraji and typhoon Mindulle -- along the catchments of Chenyoulan River, we found that newborn landslide rate increased to 70%, while the reactive landslide rate decreased to 40%. Regression exponent results show that the landslides associated with these four events were all greater than 1.5, indicating that the landslides in Chenyoulan watershed are dominated by small landslides, which tend to be less than 2000m<sup>2</sup>. Probability distribution in the upslope area at the lower most point reached by landslides shows that 90% of the landslides remained confined to hillslopes after 921-earthquake. In addition, the post-earthquake average sediment discharge was 37 Mt/yr, some 13 times the pre-earthquake amount. The post seismic unit sediment concentration also increased by 4 times in the Chenyoulan River.

The post-earthquake landslide rate for Nanchuang formation increased 17times. In contrast, the landslide rate for Hoshe formation only increased 3.4 times, and the metamorphic formation only increased 4.8 times. These results reveal that the rock strength of Nanchuang formation was smaller than that of Hoshe formation and metamorphic formation. The post-earthquake reactive landslide rate for Nanchuang formation and Hoshe formation decreased to 25%, but at the same time the metamorphic formation decreased only 6%. The controlling factor came from the discontinuities distribution, because the joints sets for Nanchuang formation and Hoshe formation were only 2/3 of the metamorphic formation.

Analysis of the correlation between landslide distribution and distance from the Chelungpu fault revealed that the 921 co-seismic landslide rates decayed more rapidly after 20 km; landslide effects of typhoon Toraji indicated similar results. The relation between accumulated rainfall and landslide rate display that during typhoon Herb the landslide rate increased with the accumulated rainfall, and the correlation coefficient reached 0.99. But during typhoon Toraji and Mindulle the landslide rate didn't have good relation with the accumulated rainfall, the landslides during typhoon Toraji and Mindulle maybe affected by 921 earthquake.

**Key words:** The Chenyoulan River ; landslide ; sediment discharge