Deformation characteristics, activity and kinematics of deep-seated landslide in the Tienchih and Yakou areas (S Taiwan)

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Deep-seated gravitational slope deformations (DSGSD) gains new attention in Taiwan due to their catastrophic impacts on lives and infrastructures during Typhoon Morakot in 2009. As the main Taiwan island is located on a complex convergent plate boundary, conventional observations and analyses suggest that the island's strong tectonic activity has, along with its subtropical climate and intense human activity in mountain areas, contributed to the formation of deep-seated landslides. It is especially so for high-altitude areas featuring Miocene to Eocene meta-sandstone and slate successions, where reactivations of landslide terrains are observed from field observation and some GPS sites after specific events. Among them, Tienchih, located in Lalong River of Kaohsiung, and Yakou, few km east in Taitung County were assessed as highly landslide-prone area after the heavy precipitation of Typhoon Morakot (over 2700 mm of rainfall within only 5 days). In this areas, several deep-seated landslides were identified according to geomorphological features seen in the 1-m resolution LiDAR DEM and InSAR preliminary results. In Tienchih area, a catastrophic 240-mm displacement sized 6.7 ha was recorded by a continuous GPS site, TENC, in 2016 after a heavy rainfall occurred on June 2. The correlation in the temporal variation of continuous GPS displacement time series and rainfall suggests that the movement is possibly related to gravitational load overlying water-saturated sediments. In addition, the average annual displacement rate of this downslope movement was measured at 20-40 mm/yr using the recently developed temporarily coherence points InSAR (TCPInSAR) technique based on ALOS/PALSAR imagery collected between 2007 and 2011. Apart therefrom, the high-angle thrust with highly fractured metamorphosed sandstone on the hanging wall; and the river incision and lateral river bank erosion are considered as the triggering factor of this catastrophic landslide. Similar triggering factors are responsible for Yakou landslide, where the 2018 landslide event exposed an outstanding cross section of the predisposing geological setting characterized by a tightly folded sequence of metamorphosed sandstone and slates. Spectacular gravitational deformation structures (i.e. kink folds and shear zones) are also found along this slope testifying a long-term displacement history and shedding light on possible kinematic mechanisms controlling its evolution. Through field data, remote sensing techniques and optical methods (i.e. digital image correlation, 3D LiDAR point cloud comparison), we compared the two landslide sites unravelling different deformation styles and identifying nested sectors possibly evolving to collapse. Our primary results demonstrate that valley erosion and deep-seated gravitational creep are
significant to the deformation of slate, indicating a block movement with shear concentration at the basal sliding surface with a mainly rotational-translational movement in Tienchih and a translational failure mechanism in Yakou.

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