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Large rock avalanches in southern Perù: the Cerro Caquilluco - Cerrillos Negros rock slide - avalanche (Tacna, Tomasiri, Perù)

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The Andean bent which coincides with the Peruvian-Chilean border region is characterised by one of the largest relief contrasts on earth with depth of the subduction trench ranging from 5000 to 6000 m below sea level and mountain tops ranging from 5500 to 6300 m a.s.l.. The western flank of the Andes is subdivided in 4 major geologic zones (i.e. Coastal Cordillera, longitudinal Basin or depression, the Precordillera or western escarpment and western Cordillera). Local relief contrasts are also pronounced due to the incision of deep canyons into several million old uplifted surfaces, preserved because of the extremely dry climate with precipitation averaging a few mm and less per year. The Lluta collapse (minimum age of 2.5 Ma; volume 26 km3) is one of the largest non-volcanic non-marine landslides on Earth and has been mapped in that area (Wörner et al., 2002). Systematic mapping in northern Chile and Southern Peru has revealed that this is not the only gigantic landslide in the area but that further landslides of similar size occurred in the area, located both along the canyon slopes and along the western escarpment of the Cordillera. This suggests that landsliding has been a major factor in controlling erosion. This contribution describes first results on mapping a giant landslide complex in southern Perù called the Cerro Caquilluco – Cerrillos Negros Tomasiri rock slide – avalanche complex. The systematic mapping we have carried out in the area is presented in a further contribution to this conference. The Cerro Caquilluco – Cerrillos Negros Tomasiri rock slide – avalanche complex affected the upper part of a SW dipping paleosurface (8° to 9°) cut by a disconnected and regular primitive drainage network organized in a series of SW trending parallel valleys. This network developed within the lower Miocene pinkish tuffaceous deposits of the Huaylillas formation, whereas the main landslide scarp lies within the conglomerates of the Upper Moquegua formation (lower Oligocene). The same type of landscape is found to the southeast of Tacna and Arica (Huaylillas anticline, Oxaya anticline and Sucuna homocline)

The Cerro Caquilluco – Cerrillos Negros Tomasiri rock slide – avalanche complex has a total length of about 43 km, a source area width and length of about 4 km and 5.1 km, respectively. The computed fahrböschung is equal to 4.6° with an H/L ratio of about 0.08 and resulting in an extremely large excessive travel distance. The H/L value is well below the expected value computed according to the classical (H/L) vs volume empirical relationships presented in the literature. Deposition occurred along most of the transportation area and is evidenced by a series of wide lobes (10 to 65 m high) and levees (from a few meters to some tens of meters high) with an average extent of 8 km transversally to the flow direction. Flow structures are visible all over the transportation area and several lobes can be mapped out. Presently, we cannot determine if most of these failures belong to a consequent large retrogressive event or to different events separated in time. The longest lobe has only pristine morphology in the most distal part of the accumulation area. Here the deposit is represented by a unique tongue shaped deposit, 11 km long, 3 km wide and 25 to 60 m thick (rough volume estimate 1.15 km3)), deposited along the piedmont surface (ave. slope: 2°). This deposit presents a series of features typical of rock avalanches deposited on regular smooth surfaces, like: lateral levees, longitudinal and transversal ridges and furrows. The extreme runout of this failure could be explained assuming a single failure event or the detachment from a part of the slope located well below the present day upper scarp. In the middle part of the deposition/transportation area few lateral levees are preserved and deep valleys have been eroded into the deposit. Considering the relationship with the piedmont deposits and the faults cutting through the area the deposit could be up to 2-2.3 Ma old. The morphology of this lower lobe is contrasting to the upper lobes which smooth out the landscape. The minimum volume involved in the giant rockslide-avalanche complex amounts to about 9 km3.

The headscarp area is affected by smaller and likely younger rock avalanche lobes overlying the more massive rock-avalanche lobe complex. These features are well preserved also to the west of the main slide complex, along the E-W trending high scarp cutting the old paleosurface, where more pristine rock avalanche lobes with more blocky surfaces overlie older lobes characterized by a smooth topography cut by high scarps.

Conditioning factors of the slope instabilities could have been: the SW dipping of weak formations (tuffs and conglomerates), the presence of ENE trending sinistral faults offsetting the primitive drainage network close to the headscarp, the intense seismicity and/or a wetter climate, the continuous uplift (min. 0.04-0.3 mm/yr). This area is less than 230 km away from the subduction trench and magnitude 7 to 9 earthquakes occur on average every 100 years on the subduction segment. Megathrust earthquakes are quite common in the area on geological time scales and no big landslides of that site has been reported during multiple historic subduction earthquakes in southern Peru and northern Chile.

Some results concerning slope stability analyses and runout modelling are presented to support possible failure mechanisms and to understand the exceptional avalanche mobility.