

Large scale landslides in overthrust wedges: Genetic and paleomorphological relations in the Calca area, Cusco, Peru

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ABSTRACT

The abundance of giant landslides in the region of Cusco, as well as its slow evolution style, shows that the origin of many of them is related to tectonic and/or lithological factors. A special type of this genetic relationship has been identified in the lower Paleozoic wedges overthrusting Mitu Permo-Triassic group.

A morphological and structural difference exists among the landslides development in the Paleozoic rocks of the sub-Andean region (where the sliding mechanisms are related to erosion and to the conform structures) and those formed in the inter-Andean valley of Vilcanota slopes. In the upper and intermediate parts of this valley some wedges of metamorphic rocks of Paucartambo formation outcrop; thanks to overthrust process. Those wedges, without exception, have evolved toward large scale and slow landslides whose areas in some cases surpassing 5 km². Several of these giant landslides in overthrust wedges are located in deep depressions; there is not evidence that is due to faulting or subsidence processes.

REGIONAL GEOLOGICAL SETTING

The studied area corresponds to the middle basin of Vilcanota river in the Peruvian southeastern Andes. The outcropping unities are: Paucartambo formation (Siluro-Devonian), Copacabana group (Carboniferous), Mitu group (Permian-Triassic), Huancané formation (Neocomian), and Yuncaypata group (middle Cretaceous).

The predominant structures are Vilcanota, Colquepata and Paucartambo anticlines, which direction is SE-NW. The northeastern part of the zone is covered by a succession of sub-parallel-overthrust following a similar direction SE-NW. The main faults families have SE-NW and SW-NE directions. At north-east a N-S family of short folds exists.

The overthrust wedges that evolved to giant landslides have a morphological relationship with pre-overthrust depressions (probably glacial basins) and belong to Paucartambo formation –or Urcos formation according to the denomination given by Mendivil & Dávila (1978) –, overlying the Mitu group. Paucartambo formation is composed by series of shale and schist with quartzite levels. This unit is correlated with Ananea formation and with a part of Cabanillas group, as well as with the Siluro-Devonian series described by Marocco (1978) in Vilcabamba range.

NATURE OF THE OVERTHRUST WEDGES

Six overthrust wedges belonging to Paucartambo formation has been identified in the Southwestern part of the Calca geological sheet: a first group on the right riverbank of Vilcanota River (Amaru-Kuyo Grande, Ampay-Kuyo Chico, Masqha, Carachipampa), and the second group on the left margin (Totoraqocha and Q'ellounu).

Five of them are completely separated of its original geological unit, outcropping like isolated bodies. Only the Amaru-Kuyo Grande wedge presents a semi-isolated feature like a prolongation of the last oriental overthrust affecting the Paleozoic units of the sub-Andean region. The wedges of the oriental watershed (first group) are total or almost completely affected by giant landslides. Those of the second group on western Vilcanota riverbank have only partially evolved to landslides; because of low gradient of slopes.

As indicated, these wedges are located in well developed depressions. The analysis of their position and structural characteristics allow to discarding a tectonic origin for this localization (especially the existence of a graben). The morpho-structural analysis shows that they are occupying pre-existent depressions, which also contributed to their preservation and isolation. While the rest of the distal overthrust outcrops were eroded during the folding process that originated the Vilcanota anticline, the altitudinal lower position of these wedges allowed their conservation.

The dispersion of the overthrust sliding wedges could indicate (at least for this analyzed area) that the pre-overthrust morphology had certain similarities with the current one (existence of glacial depressions in the previous period to the compressive event that originated the overthrust). Only this interpretation could explain the survival of these wedges after the folding and the strong erosion processes.

MORPHODYNAMIC CHARACTERISTICS OF THE CALCA LARGE-SCALE LANDSLIDES

The large scale landslides developed into the overthrust wedges, in all the cases, are complex, with several juxtaposed and superimposed rupture levels. The field analysis shows that deepest and main landslide surface coincides largely with the overthrust plane, which followed the pre-existent morphological setting. The schist levels generally act like rupture levels.

In a first phase, the overthrust wedges should be retained in the pre-existing basins. The landslide mechanism should triggered when the erosion (probably, in a first time, glacier erosion and then, during the deglaciation phases, torrential erosion) reached the contact level between the base of the basin and the underlying metamorphic rocks bodies. The deepening torrents erosion reached the contact level creating instability fronts followed by plastic deformation of the rocky mass; that induced the progressive rupture which started at the foot of the masses. Very probably the first landslides were rotational, isolated and concentrated in the lower part of the basins. Then, when the deglaciation finished (and with the contribution of the elastic rebound of the rocks after the glacier retreat) a general instability threatened the watershed evolving to giant landslides. In that phase the translational and complex mechanisms prevailed.

The activity levels of these unstable masses have not been evaluated instrumentally. However, it is evident that several secondary blocks are very active, representing high levels of danger (cases of Ampay-Kuyo Chico, Amaru, Kallaqhasa); the landslides motion should overcome, in certain points, 20 cm/year. In the cases of Ampay and Masqha, several episodes of paroxysmal acceleration have taken place, with destruction of roads, houses, schools and cultivation lands. The most recent episode in March 2003 affected part of the archaeological group of P'isaq.

CONCLUSIONS

- The isolated or semi-isolated metamorphic wedges (slates, schists and quartzites) constitute distal relicts of the overthrust affecting the Paucartambo formation during the Andean orogeny.
- These wedges could be settled in pre-existent depressions or glacial basins not related with tectonic accidents. That would indicate, at least locally, that the pre-overthrust morphology was similar to the current one.
- These wedges, after glacier and torrential erosion phases, have evolved to giant and complex landslides whose rupture level corresponds to the overthrust plane (contact between the Paucartambo formation and Mitu group).

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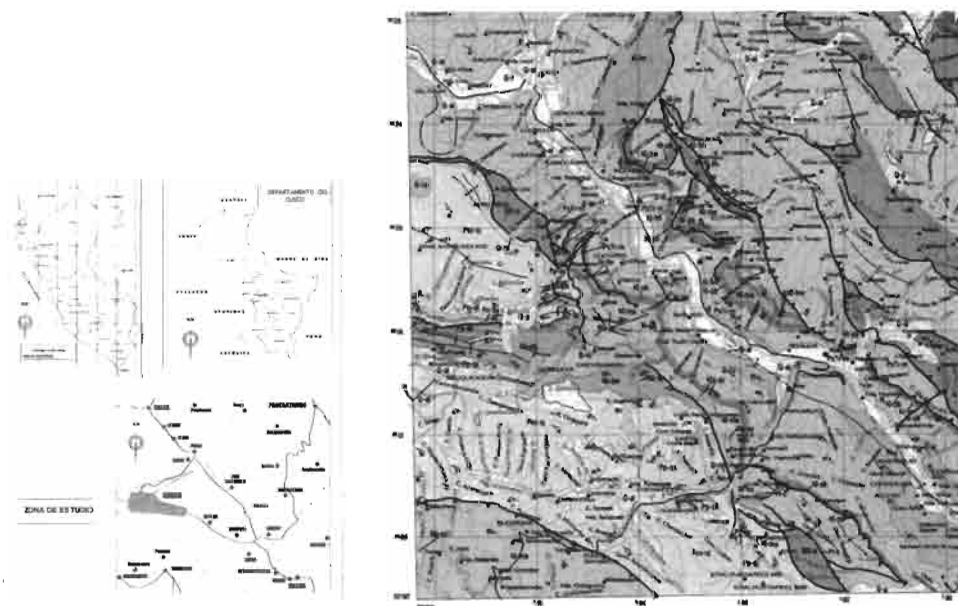


Fig. 1 Geological map of Calca region (extract from Carlotto et al. 1996). The over thrust wedges-giant landslides correspond to the Paucartambo formation (dark brown)



Fig. 2 Partial view of Amaru-Kuyo Grande giant and slow landslide developed in a Paucartambo formation overthrust wedge. In the backside the hills with Mitu Group outcrops



Fig. 3 General view of the Ampay-Kuyo Chico overthrust wedge entirely covered by a giant complex landslide (easily recognized thanks to the verdure), and surrounded by Mitu group mountains.