

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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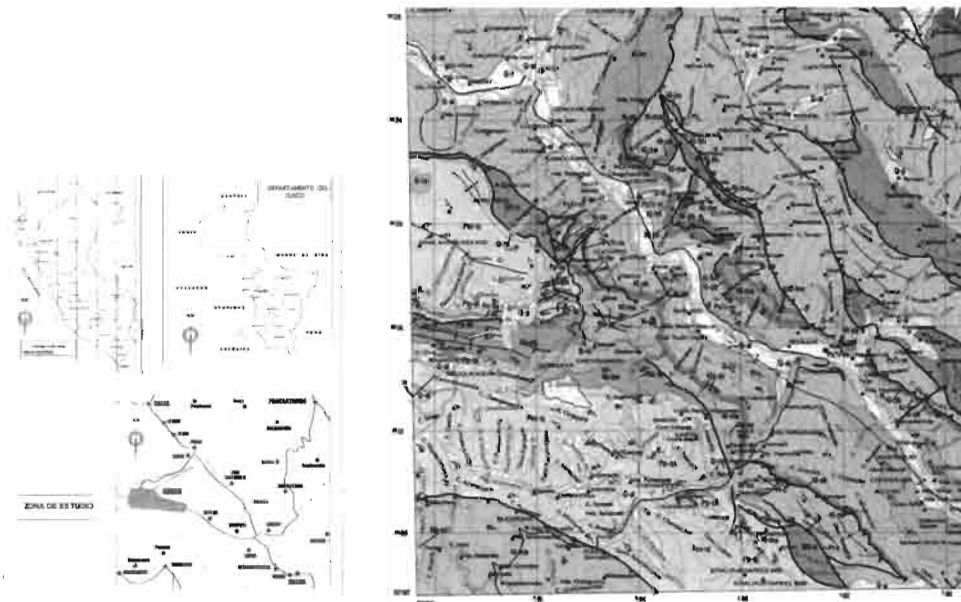


Fig. 1 Geological map of Calca region (extract from Carlotto et al. 1996). The over thrust wedges-giant landslides correspond to the Paucartambo formation (dark brown)



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.