**FAULTS NETWORK IN THE RIO COLCA VALLEY BETWEEN MACA AND PINCHOLLO, CENTRAL ANDES, SOUTHERN PERU**

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**INTRODUCTION**

The Rio Colca located in the Western Cordillera in southern Peru creates one of the deepest valleys in the Andes. The tremendous scale of the incision is strictly connected with the active tectonic processes related with the subduction zone of the Nazca Plate beneath South American Plate.

The conducted studies were focused on the attempt to determine an orientation, nature and a relative sequence of the faults network, what was important from both: scientific, as well as practical point of view. The processes of faulting associated with the volcanic processes are still very active in the area initiating earthquakes, mass movements, landslides, which may destroy both inhabited and agricultural areas.

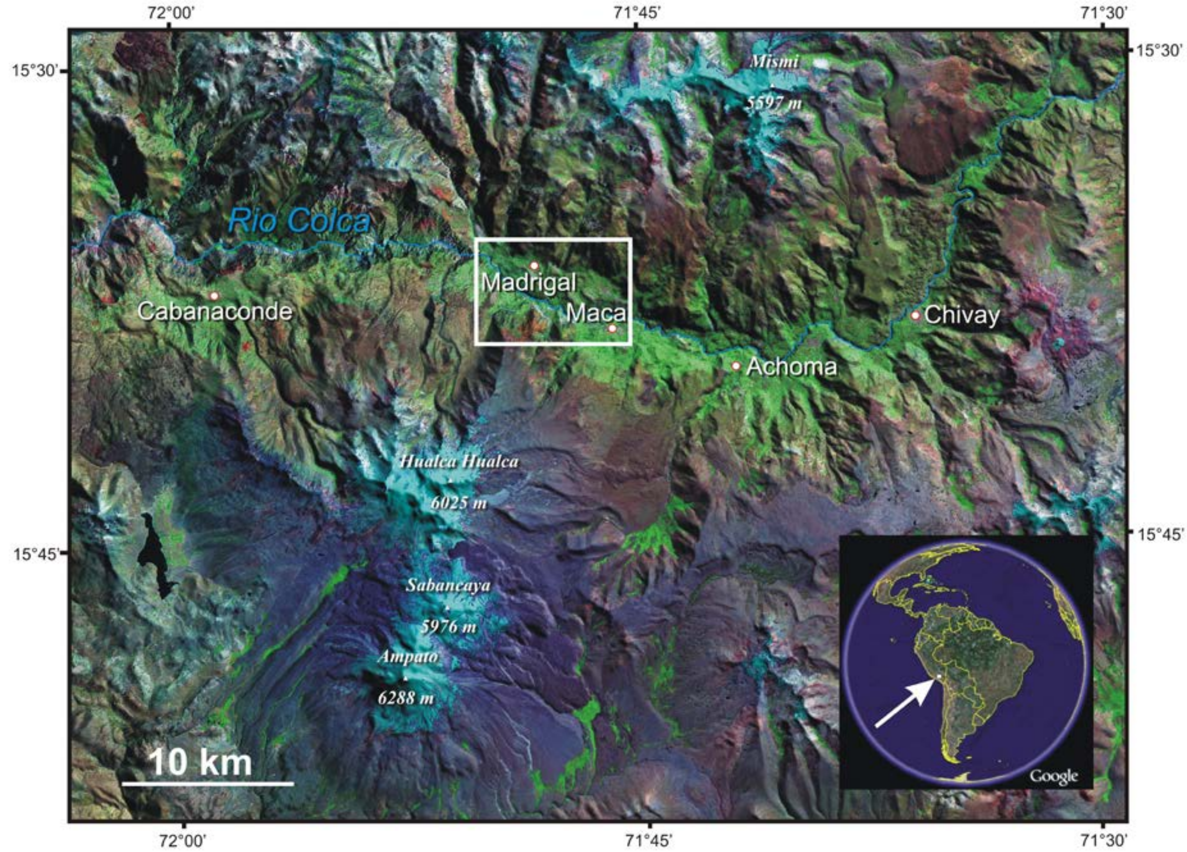


Fig. 1. Location of the studied area in the Rio Colca valley, southern Peru (Landsat 7).

**THE STUDIED AREA**

The middle section of the Rio Colca valley between Pinchollo and Maca villages (15˚ 36’ 09” S and 71˚ 50’ 17” W to 15˚ 38’ 13” S and 71˚ 45’ 45” W) was chosen for the detailed tectono-structural studies (Fig. 1). The river flows mainly to the WNW, W, whereas the bottom of the valley in this area is located at the altitude of 3,030–3,220 m a.s.l. Down-cutting of the Rio Colca to the present valley floor was more or less completed between 9 and 3.8 Ma, but was followed by a refill owing to pyroclastic flows until 1.36 Ma and finally a re-incision (Thouret *et al*. 2007).

The oldest rocks exposed only in the central and north-western part of the studied area are Late Jurassic – Early Cretaceous dark grey quartz sandstones and shales of the Yura Group (Klinck & Palacios, 1985; Paulo, 2008). Above them lies Neogene white tuffs. However, the most common deposits within the studied area are Pleistocene-Holocene colluvial sediments overlapping the alluvial ones, which form an extensive colluvial cover with thickness of up to several dozens of meters, and locally even exceeding 100 m. Fragments of volcanic rocks formed in the Neogene as a result of activity of the surrounding volcanoes compose the main residual material on the slopes and the floor of the valley.

## FAULT NETWORK

The studied area is characterized by a complex, multi-phase developed faults network (Fig. 2; Żaba & Małolepszy, 2008a). Most of them cross-cut and displace the Mesozoic, Miocene, as well as Pleistocene-Holocene deposits, proving their tectonic activity at that time.

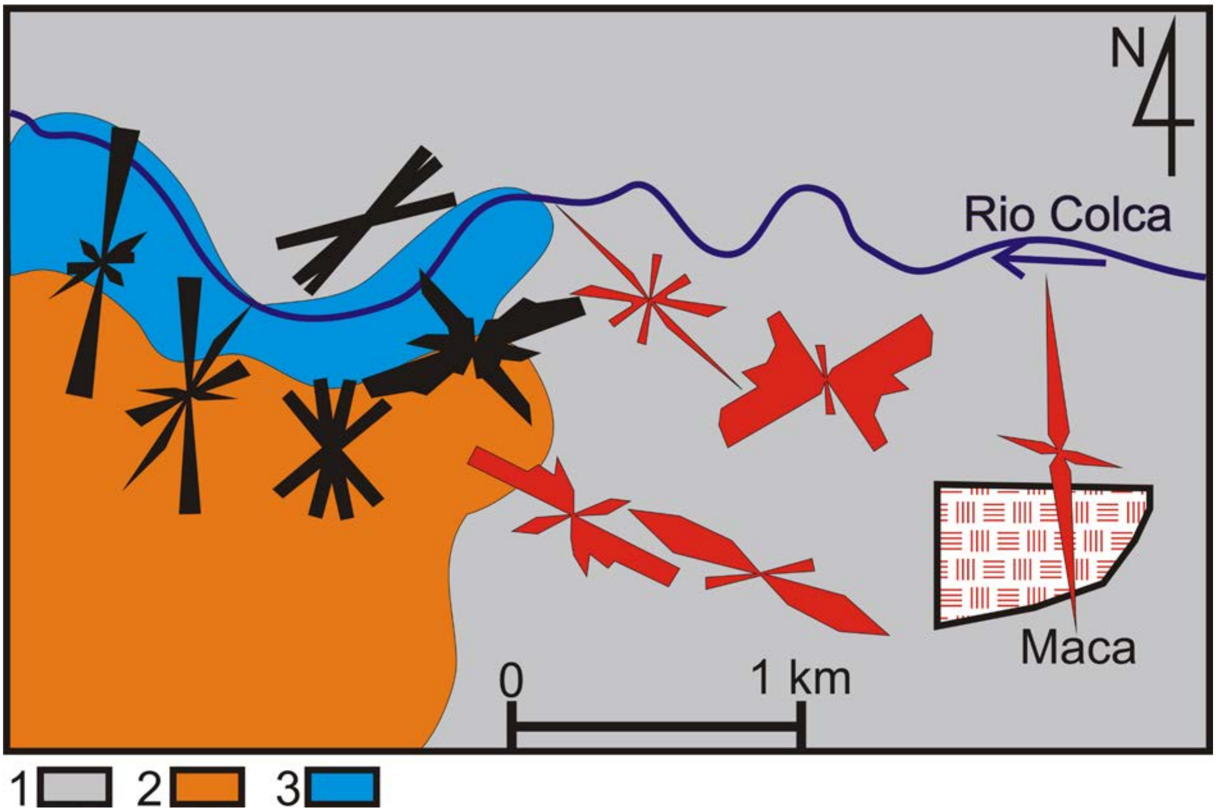


Fig. 2. Lateral variability of faults orientation in Pleistocene-Holocene colluvial deposits (red) and Upper Jurassic formation (black) in Maca-Lari area (modified after Żaba & Małolepszy, 2008b); 1 – alluvial and colluvial deposits (Pleistocene-Holocene), 2 – tuffs and tuffs with breccias (Neogene), 3 – sandstones intercalaced with shales (Late Jurassic).

The oldest fault structures are normal faults bearing N-S occurring in the Mesozoic series and emphasized by tectonic grabens in the Pleistocene-Holocene deposits, proving their long-term activity lasting up to the present.

The strike-slip faults of multi-phase development, oriented NE-SW and NW-SE (both dextral and sinistral) belong to the younger generation. After the Miocene, in the final stages of their evolution, they were transformed into normal dip-slip faults. Both described fault sets form distinct and well marked scarps, arranged in a step-like structures. Their multi-stage evolution resulted in the exposure of Jurassic rocks in the eastern part of the studied area. Usually they are well marked also in the

Pleistocene-Holocene deposits, producing primary tectonic scarps, as well as grabens and horsts, which prove their current activity (extensional regime).
The faults network in the Pleistocene-Holocene colluvial deposits was developed under sinistral shear conditions (D, R, P and probably X shears were recognized), as a result of NE-SW (ENE-WSW) shortening (see Sébrier *et al.* 1985; Sébrier & Soler, 1991; Cembrano *et al.* 2007). Subsequently, these faults were transformed into dip-slip faults of normal nature, accompanied by tectonic grabens development in the following order (from the oldest ones to the youngest): 1 – WNW-ESE, associated with D shears, 2 – WSW-ENE, associated with R shears, 3 – NW-SE, associated with P shears, 4 – NNW-SSE, associated with X shears (probably).
The joints network in most cases reflects faults directions (Żaba & Małolepszy, 2008a). The joints sets quite commonly form orthogonal systems. The major part of the observed joint surfaces are parallel to the axis of macro-folds in the Mesozoic complexes (W-E).

**GEOHAZARD**

Within the analyzed area five large landslides have developed on the slopes of the Rio Colca valley between 3,050 and 3,350 m a.s.l.: beneath Pinchollo, in Madrigal, between Madrigal and Lari, in Lari and in Maca (Fig. 3). First four landslides occur on the northern slopes of the Rio Colca valley and consist mainly of poorly consolidated sediments represented by a lacustrine series of tuffites and - to a much lesser extent - overlapping with them colluvial and alluvial deposits. Located on the southern slope landslide in Maca is developed in poorly consolidated mainly Holocene colluvial and associated alluvial deposits.

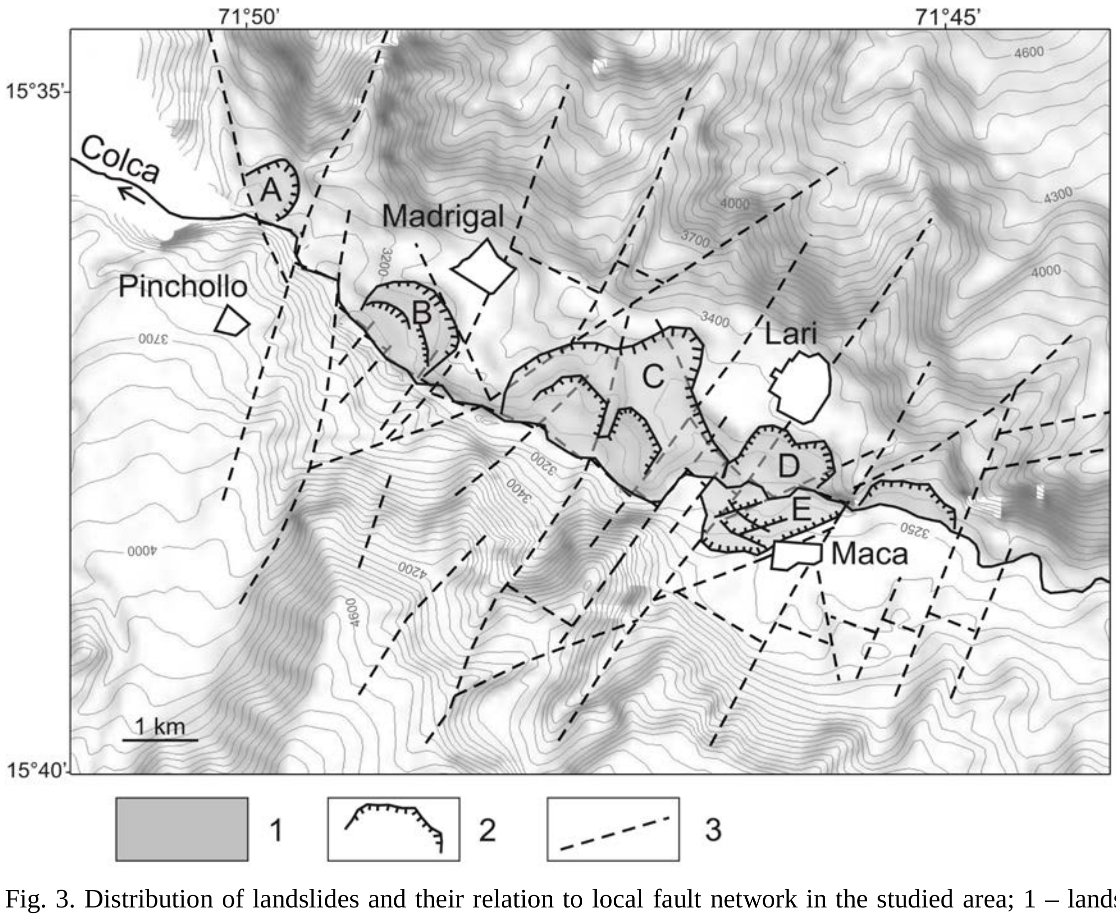


Fig. 3. Distribution of landslides and their relation to local fault network in the studied area; 1 – landslide, 2 – landslide scarp, 3 – fault; landslides: A – beneath Pinchollo, B – in Madrigal, C – between Madrigal and Lari, D – in Lari, E – in Maca.

These five landslides are closely related to the distribution and orientation of observed faults (Fig. 3; Żaba & Małolepszy, 2008b). Most of the identified landslide scarps follow the orientation of stated mesofaults, which initiated and controlled the landslide processes. Faults, which originally acted as strike-slip faults (mainly dextral) have undergone subsequent transformation into the normal faults, triggering the formation of extensional tectonic/landslide grabens and horsts. Such forms are particularly common in landslide close to Maca.

The initiation of landslide processes in the studied area, located above the active subduction zone, is closely connected with volcanic and seismic activity in this region. For instance: in Pleistocene the explosion of Hualca Hualca volcano caused gigantic ground and rock flow, which dammed the Rio Colca in the area of Pinchollo to the height of about 200 m, whereas the earthquake from 1991 of 5.6 on the Richter scale initiated massive landslide which completely destroyed the Maca village.

Tectonic/seismic and volcanic activity of the studied section of the Rio Colca valley resulted in recognition it as the zone of very high geohazards – 9th degree (on a ten degree scale; Ocola & Gómez, 2005).

## CONCLUSIONS

The Rio Colca valley between Maca and Pinchollo is characterized by a complex, multi-phase developed fault network. High scale geohazard of mass movements in the studied area is caused by their nowadays activity, related with the subduction zone of the Nazca Plate.

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