Il Quaternario
Italian Journal of Quaternary Sciences
24, (Abstract AIQUA, Roma 02/2011), 104 - 106

Congresso AIQUA
Il Quaternario Italiano: conoscenze e prospettive
Roma 24 e 25 febbraio 2011

POST-GLACIAL EVOLUTION OF GRAVITATIONAL SLOPE DEFORMATIONS IN THE UPPER SUSA AND CHISONE VALLEYS (ITALIAN WESTERN ALPS)

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ABSTRACT: Fioraso G. *et al.*, *Post-glacial evolution of gravitational slope deformations in the upper Susa and Chisone Valleys (Italian Western Alps).* (IT ISSN 0394-3356, 2011)
The upper Susa and Chisone valleys host the largest concentration of deep-seated gravitational slope deformations (DSGSD) and large landslides of the whole Alpine chain. This is due i) to the lithostructural characteristics of bedrock and ii) to the intense and the prolonged glacial scouring during the upper Pleistocene. Deep drill holes carried out on seven large landslides show that the evolution of gravitational phenomena has completely re-shaped the original post-glacial morphology of valley bottoms.

RIASSUNTO: Fioraso G. *et al.*, Evoluzione post-glaciale dei fenomeni gravitativi nelle alte valli di Susa e Chisone (Alpi Occidentali). (IT ISSN 0394-3356, 2011)
In alta Valle di Susa e in alta Val Chisone è ospitata la maggiore concentrazione di deformazioni gravitative profonde di versante (DGPV) e grandi frane dell'intero arco alpino. Questa particolarità è dovuta i) alle caratteristiche litostrutturali del substrato roccioso e ii) all'intenso approfondimento erosivo dei solchi vallivi operato dai ghiacciai nel corso del Pleistocene superiore. Le indagini di sottosuolo svolte su sette grandi frane evidenziano come l'evoluzione dei fenomeni gravitativi abbia completamente ridisegnato e/o mascherato l'originaria morfologia post-glaciale.

Key words: LGM, glacial scouring, gravitational slope deformations, landslide dams

Parole chiave: LGM, modellamento glaciale, deformazioni gravitative di versante, sbarramenti di frana

In tectonically active areas like Alpine chain, the geological work accomplished by glaciers include, beside erosion and removal of superficial deposits, over-deepening and reshaping of valley bottoms and valley sides respectively. This results in over-steepened slopes and increase of reliefs, in turn inducing diffuse rock mass disequilibrium. As a conseguence, after the complete retreat of glaciers, valley sides tend to adjust to the new morphological arrangement. This context is prone to the developement of diffuse instability phenomena such us landslides and deep-seated gravitational slope deformations (DSGSD).
In the northern Cottian Alps post-glacial gravitational deformations have given rise to diffuse and impressive collapse phenomena (FIORASO *et al.*, 2010), leading to the highest concentration of slope instability phenomena of the Alps. This is due to lithological composition of bedrock (MORTARA & SORZANA, 1987) and, secondly, to the structural set-up of the area (GIARDINO & POLINO, 1997; POLINO *et al.*, 2002). In many cases landslide dams have been formed (Fig. 1) with remarkably different age, genesis and characteristics (CARRARO & FORNO, 1980; TROPEANO & OLIVE, 1993; POLINO *et al.*, 2002).
To improve the knowledge of such a phenomena, detailed investigations has been focused on seven large landslides, four of them located in the upper Susa Valley and the others in the upper Chisone Valley. This study was based on geological mapping, morpho-structural analysis and subsurface investigations. Thirteen drill holes with continuous coring were performed up to 110 m in depth (with a total lenght of 1125 m), accompanied with the installation of an integrated monitoring system (inclinometers, piezometers and GPS bench marks network).
The large amount of new morphological and subsurface data collected led to the recognition of an unexpected stratigraphic arrangement, useful for a properly reconstruction of the original post-glacial valley bottom morphologies.
Bedrock geology is mainly characterized by a stack of tectono-stratigraphic units belonging to the Piedmont Zone and made up of monotonous calcschistes with ophiolitic intercalations (serpentinites, ophicalcites and metabasites). Only in the left side of the upper Susa Valley and along the French-Italian border, continental crust units (Ambin Massif) and carbonatic units (Chaberton - Grand Hoche - Grand Argentier Unit) referred to the internal Briançonnnais Zone are exposed.
In the Susa and Chisone valleys diffuse landforms and sediments testify the intensity of the glacial action during the upper Pleistocene. Detailed geomorphological and lithological field mapping have allowed the reconstruction of the former

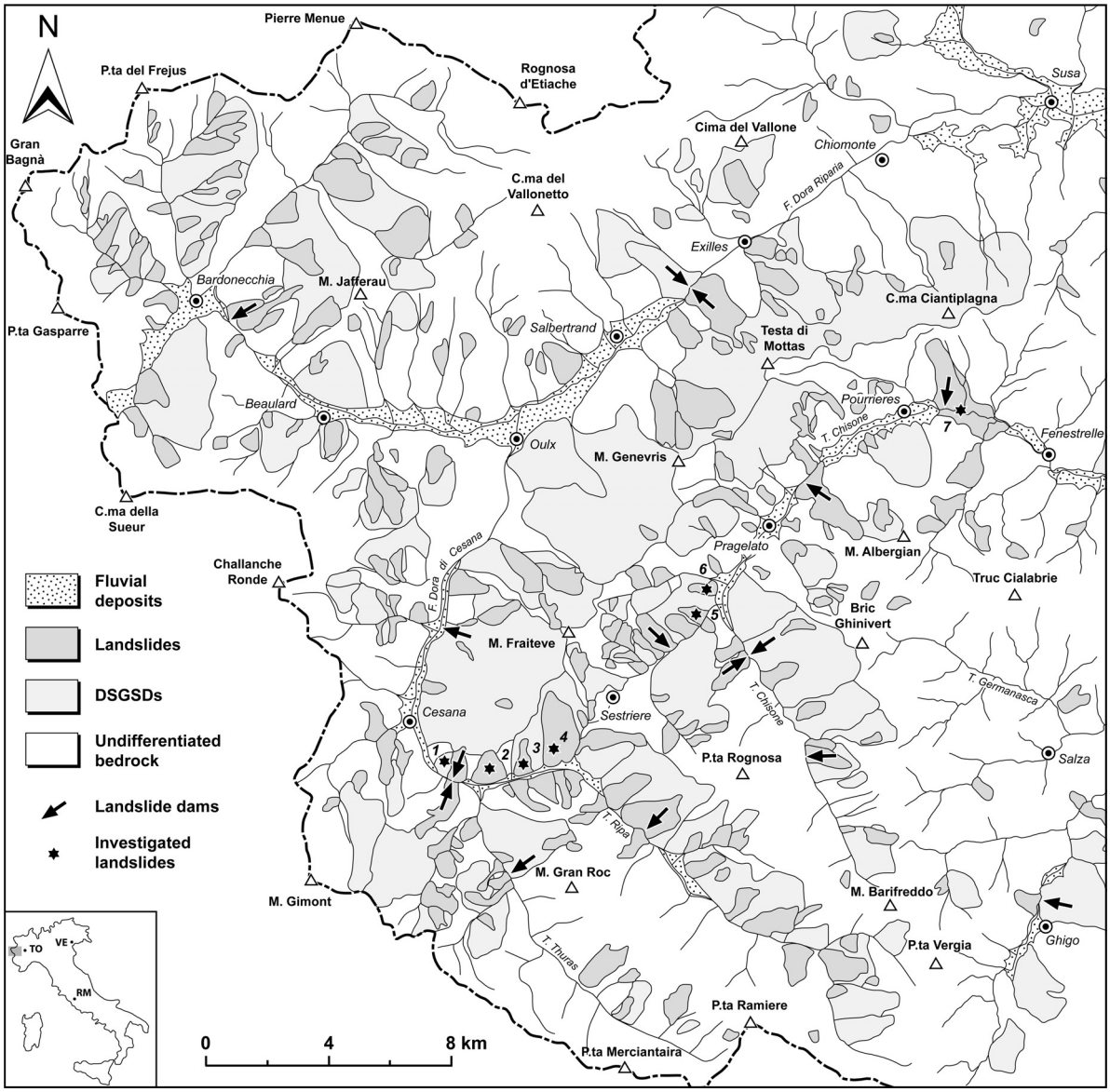

Fig. 1 - Landslides and DSGSDs distribution in the upper Susa and Chisone Valleys. Numbers refer to the investigated landslides. 1: Roche Rouge; 2: Champlas Seguin; 3: Champlas Janvier; 4: Champlas du Col; 5: Duc; 6: Plan; 7: Balboutet.

Distribuzione di frane e DGPV nell'alta Valle di Susa e nell'alta Val Chisone. I numeri indicano i fenomeni gravitativi investigati. 1: Roche Rouge; 2: Champlas Seguin; 3: Champlas Janvier; 4: Champlas du Col; 5: Duc; 6: Plan; 7: Balboutet.

glacier extents and successive over-deepening stages (POLINO *et al.*, 2002). After the Last Glacial Maximum (LGM) the retreat of the glaciers was quickly followed by the development of the gravitational phenomena such as rock falls, rock slides, rock flows and *sackungs*.

In the upper Susa Valley four gravitational phenomena has been analysed: Roche Rouge, Champlas Seguin, Champlas Janvier and Champlas du Col. They are located on the right side of the Ripa Torrent between the villages of Cesana and Sestriere (Fig. 1). Such landslides take up an area ranging from 0.4 to 3.4 km^2 and reach a maximum depth of 80 m. Although involved by huge DSGSDs, the whole slope preserve scattered morphological features and deposits related to the LGM and subsequent glacial retreat stages.

Translational movements of rock masses (with minor rotational components) take place along sliding surfaces having complex geometry, that reactivate pre-existing low and high angle discontinuities affecting bedrock. However, in spite of uniformity of the geological and structural context observed around sites, the landslides are characterized by different morphology and kinematic behaviour. Moreover, each landslide display independent and multistage evolution,

involving glacial and fluvial deposits in the valley floor. The foots of Champlas Janvier and Champlas du Col landslides mask an ancient thick (80 m) fluvio-lacustrine succession (Fig. 2), part of which outcrops on the left side of the valley bottom. This sediments has been accumulated as a consequence of the contemporary rapid movement of the Roche Rouge rock slide and the Buon Soccorso rock flow (located in the opposite side of the valley), causing in the early stage of the Holocene the dam of the Ripa Torrent and the genesis of the Bousson Lake (with an estimated area of al least 1.6 km^2 and a lenght of 3.5 km), now extinct.

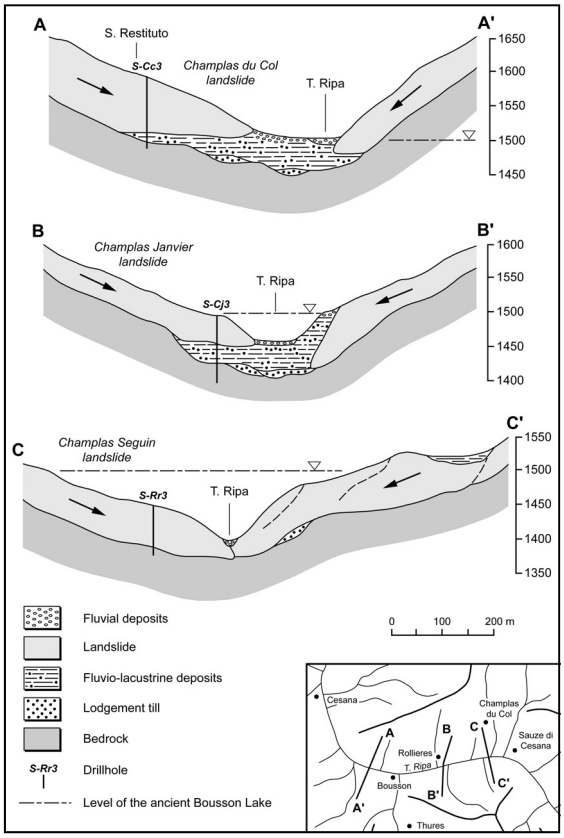

Fig. 2 - Schematic geological cross sections of the Roche Rouge, Champlas Janvier and Champlas du Col landslides.
Sezioni geologiche schematiche dei fenomeni gravitativi di Roche Rouge, Champlas Janvier e Champlas du Col.

In the upper Chisone Valley three gravitational phenomena has been analysed (Fig. 1). The Duc and Plan landslides, located on the left side of the Chisonetto Torrent between the villages of Sestriere and Pragelato, correspond to complex rock slides both with an area of 0.29 km^2.
The Balboutet landslide, located on the left side of the Chisone Valley between Pourrieres and Fenestrelle, corresponds to a huge rock avalanche detached from the southern slope of the Ciantiplagna Peak (2849 m). The blocky deposit covers an area of 3.53 km^2 with a maximum thickness of 120-130 m. Rock avalanche accumulation has dammed the valley, causing upstream the development of a broad fluvio-lacustrine plane 4 km long (POLINO *et al.*, 2002).
Continuous coring drill hole performed on valley bottom up to 90 m in depth, reveals that the rock avalanche deposits rest on a large rock slide (30 m thick) in turn resting above a glacial and fluvio-lacustrine succession.
- The detailed investigation carried out on some landslides in the northern Cottian Alps points out that the present day morphology of the upper Susa and Chisone valley sides is significantly different from that followed the glacial retreat at the end of the LGM. Erosional action of glacier led to over-deepening of the valley bottom and progressive slope steepening: increase of relief and undermining of slopes cause shear stress of sufficient magnitude to induce widespread relaxation of rock masses and the development of landslides and DSGSDs.
The study confirm that gravitational phenomena repeatedly interacts with fluvial dynamics, re-shaping the valley profile compared to the original slope configuration present soon after the post-LGM glacial retreat. In some cases (Roche Rouge and Balboutet) landslides obstruct the drainage system, creating impounded lakes and variations on base level and rivers planform extending much farther downstream and upstream.

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Ms. received: *January 14, 2011*
Testo ricevuto il *14 gennaio 2011*