CRYOSPHERE CONDITIONING TO DEBRIS FLOW DEVELOPMENT

Marta Chiarle[1], Marten Geertsema[2], Stephan Gruber[3], Giovanni Mortara[1]

[1]CNR-IRPI, Institute of Research for Hydrogeological Protection, Strada delle Cacce 73, 10135 Turin, Italy, marta.chiarle@irpi.cnr.it
[2]British Columbia Forest Service, 1011 4th Ave, Prince George BC V2l 3H9, Canada
[3]Department of Geography, University of Zurich, Winterthurerstr. 190, CH-8057 Zurich, Switzerland

1. Introduction - On several occasions the cryosphere proved to be a crucial factor in conditioning debris flow occurrence – their location, timing, volume and dynamics. The role played by the cryosphere varies from one case to another, but in any case cryosphere's involvement add a significant margin of unpredictability to instability processes.

2. Melting of buried ice –The presence of ice cores can influence the stability of the moraines, where important ice masses may be preserved beneath moraine cover, as glaciers retreat.

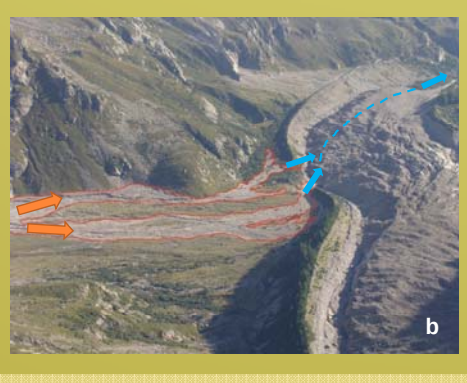
29 July 2005 - Val di Fosse (Eastern Italian Alps). Melt of a buried ice mass, exposed in a 20-m long detachment zone at 3000 m a.s.l. (**b**), triggered in fair weather a debris flow (15,000 m^3) that flowed downslope for over 1 hour (**a**), causing threat to a popular trail which was cut off by the flow (**c**).

Photo courtesy of Public Works Service, Bolzano Province (I)

3. Permafrost as a water barrier – In case of rainfall, frozen horizons in debris layers can act as barriers to water percolation, causing rapid saturation of the surface material and preferential flow occurring along their upper boundaries. Additionally, thaw-consolidation of the ice-rich transient layer can cause excess pore water pressure.

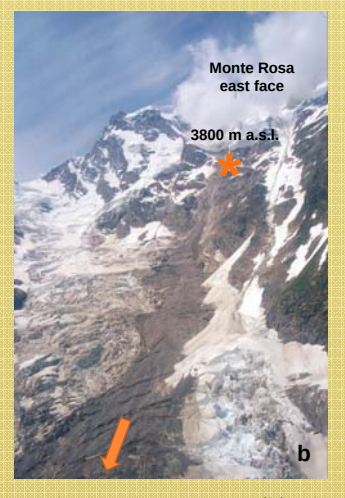
September 2008 - Pink Mountain (northeastern British Columbia, CA). A steep 32°, matrix supported talus slope failed, resulting in a landslide (**a**). The rupture surface occurred 3 m below the pre-slide ground surface. Ice-rich permafrost was visible in the rupture surface (**b**), which mirrored the slope of the ground surface. After 90 m of sliding, the moving mass transformed into a slow-moving debris flow. The total travel distance of the landslide was 260 m.

4. Glacier ice contribution – Remnants of glacier ice along a drainage network, consequent to glacier shrinkage and fragmentation or to ice fall/avalanche, can condition debris flow inception and dynamics. The flow in these cases can assume an "anomalous" behavior, adding unpredictability to the process.



September 2008 - Castelfranco catchment (Monte Rosa, Italian Alps). On occasion of rainfalls (39 mm in 22 hrs), a debris flow developed, starting at an elevation (3600 m a.s.l.) unusually high for debris flow initiation in the Alps (**a**). Unusual was also the dynamics of the event, which continued through a series of pulses several hours after the end of the rainfalls. At the junction with the Belvedere Glacier, the flows continued their path beneath the ice mass (blue arrows in **b**). The remnants of the Castelfranco Glacier, along with snow avalanche accumulations, are thought to have played a critical role in the initiation and dynamics of the event, acting as temporary dams for the flow.

5. Processes' combination – Different processes induced in high mountains by climate change (like enhanced glacial melting, glacial slope cover reduction, permafrost degradation) can combine to increase slope instability.



Years 2000-2004 – Monte Rosa (Italian Alps). Frequent debris flows develop in the Canalone Imseng (**b**). The continuation of instability processes during the winter-months points to a substantial change in glacier and rock conditions rather than to seasonal melting effects alone. Debris flows in summer 2002-2003 used to stop in the "Effimero Lake", causing threat to workers managing the emergency related to a possible glacial lake outburst (**a**).

6. Concluding remarks - The present work aims to point out the specificities of debris flow occurrence in presence of cryosphere, which are expected to increase in frequency under climate warming. Specific investigations and hazard assessment procedures have thus to be undertaken analyzing debris flow hazard in glacial and periglacial environments, which only partially can rely on the experience gained in ice-free contests.

It should be noted that evidence of permafrost is often covered by landslide debris. For example, when it was fresh, the Pink Mountain debris flow had a clearly visible frozen rupture surface. A year later the rupture surface was covered with more than a meter of debris. Had the landslide been discovered a year later the permafrost would not have been observed. The point is that the number of permafrost-related debris flows is probably underestimated.