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LUDOVIC RAVANEL (*,**) & PHILIP DELINE (*)

A NETWORK OF OBSERVERS IN THE MONT-BLANC MASSIF TO STUDY ROCKFALL FROM HIGH ALPINE ROCKWALLS

ABSTRACT: RAVANEL L. & DELINE P., *A network of observers in the Mont-Blanc massif to study rockfall from high Alpine rockwalls*. (IT ISSN 0391-9838, 2013).

The study of rockfall (volume > 100 m^3) in high mountain is essential to understand landscape evolution and to evaluate natural hazards. The number of rockfalls is presently rising in the Alps, while vulnerability is increasing at high elevation and in valleys. Due to the lack of systematic observations, frequency and volume of rockfalls, as well as their triggering factors remain poorly understood. Until today, most of the studies on rockfall carried out in high Alpine rockwalls were indeed devoted to individual events, while systematic surveys are needed to clarify the role of regional factors such as permafrost degradation. Here we present the network of observers (guides, hut keepers, mountaineers) which sets aside the documentation of all the rockfall events that occur in the central part of the Mont-Blanc massif. Operational since 2007, this network allowed identifying and documenting 251 rockfalls between 2007 and 2011. Checked and completed each year by extensive field work, data from the network are then analysed through a Geographic Information System to statistically characterise these rockfalls. The results of the first five years of survey indicate that permafrost degradation is the main rockfall triggering factor.

KEY WORDS: Rockfall, Permafrost, High Alpine rockwalls, Network of observers, GIS, Mont-Blanc massif.

INTRODUCTION

Due to their steep topography, high mountain areas are affected by significant gravity-related transfers of material such as rockfall (Fort & *alii*, 2009), which represents the sudden collapse of a rock mass from a steep rockwall with a volume exceeding 100 m^3. Rockfall is the most unexpected process because of its possible high speed and large rock volume, it may imprint profound changes to rock slopes, and it generates risks for populations and infrastructures (Haeberli & *alii*, 1997): destruction of infrastructures, damages on infrastructures and flows of people (tourists, workers) located along the rockfall path, and material and human risks on the valley floor through cascading effects.

In the last two decades, many rockfalls and rock avalanches affected high Alpine rockwalls throughout the World. Several mixed both rock and ice, with a volume exceeding 1 × 10^6 m^3: Mount Cook in New Zealand in 1991 (14 × 10^6 m^3; McSaveney, 2002), Kolka-Karmadon in the Caucasus in 2002 (100 × 10^6 m^3; Huggel & *alii*, 2005), Punta Thurwieser in Italy in 2004 (2.5 × 10^6 m^3; Pirulli, 2009), and Piz Cengalo in Switzerland in 2011 (3 × 10^6 m^3; Allen & Huggel, 2012). Other rockfalls with a smaller volume occurred at the Matterhorn in Switzerland in 2003 (1000 m^3), the Cima Una in Italy in 2007 (40,000 m^3; Coratza & De Waele, 2012), and the Drus (Ravanel & Deline, 2008) in the Mont-Blanc massif in France in 1997 (27,000 m^3), 2003 (6500 m^3), 2005 (250,000 m^3), and 2011 (15,000 then 43,000 m^3).

The failure mechanisms differ according to the topographic and structural configuration. However, rockfall generally occurs in hard rocks along pre-existing geological discontinuities. In high mountain areas, three major factors, possibly combined, were identified as rockfall triggers (Evans & Gardner, 1989): (i) glacial debuttressing following glacial retreat (Cossart & *alii*, 2008), (ii) seismic activity (Becker & Davenport, 2003), and (iii) permafrost degradation (Harris & *alii*, 2009), which corresponds to the warming up of the permafrost, ground (*i.e.*, substratum) that remains at or below 0°C for at least two years, thus generating physical changes of the potential interstitial ice (Gruber & Haeberli, 2007).

The characterisation of rockfall and the understanding of its evolution (in terms of frequency, volume and location) are prerequisites to any response of management. However, data on rockfall at high elevation are rare, with the danger to interpret non-representative data. It is thus necessary to systematically collect and process rockfall da-

(*) *EDYTEM UMR 5204 CNRS, Université de Savoie, CNRS, F-73376 Le Bourget du Lac cedex*. E-mail: Ludovic.Ravanel@univ-savoie.fr

(**) *Computer Engineering and Networks Laboratory, ETH Zurich, CH-8092 Zurich.*