Frequency and volume of rockfalls in permafrost-affected rockwalls in the Mont Blanc massif

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PermaNET • Permafrost long-term monitoring network

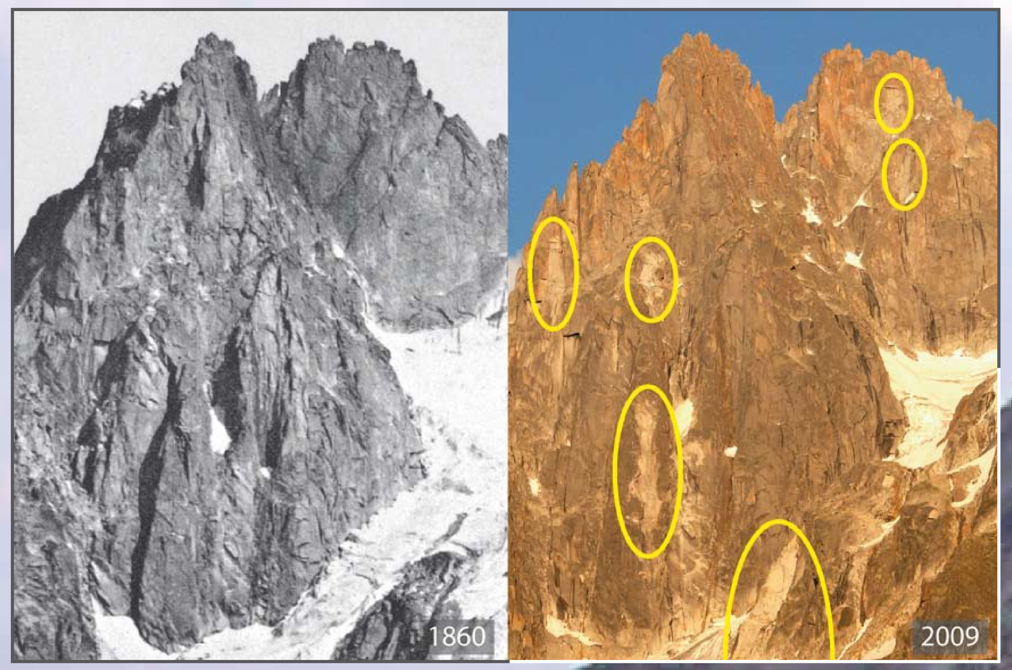
Abstract: Rockfalls strongly affect high mountain rockwalls, and can threaten both people and infrastructures. However, their frequency and magnitude are still poorly known in this environment. These processes appear nonetheless increasing while permafrost degradation is hypothesized as one of the most important triggering factor. Several inventories of rockfalls have been realised in the Mont Blanc massif by using four methods: (i) comparison of photographs, (ii) recognition of rockfall deposits on a satellite image (iii) observation by a network of local observers, and (iv) diachronic comparison of high resolution 3D models. These inventories were jointly analysed in terms of volume and frequency.

Methods of data acquisition

M1: Comparison of photographs

Period: End of the Little Ice Age - 2009 = 150 years.

Overview: Based on the comparison of old, recent and present photographs, this method has been developed in order to identify morphological and colour changes and to date the corresponding rockfalls in two areas of the massif (Drus, Aig. de Chamonix).



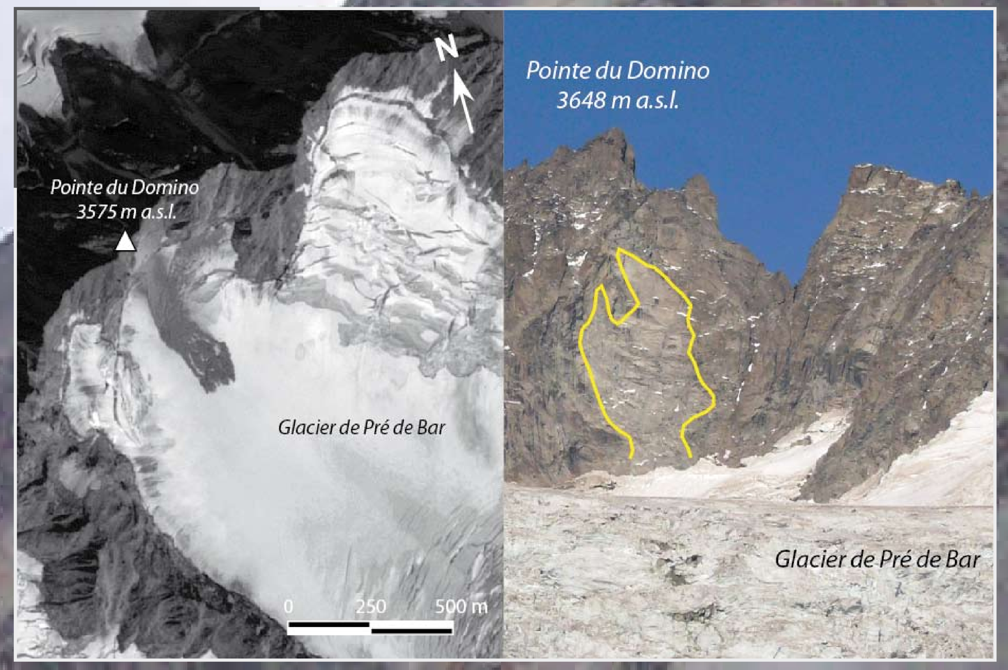
Results: 50 rockfalls (500 to 265 000 m³).

Ravanel L., Deline P. (2011). Climate influence on rockfalls in high-Alpine steep rockwalls. *The Holocene*, 21-2: 357-365

M2: Analyses of a satellite image

Period: 2003

Overview: Rockfalls were identified for the entire massif from their supraglacial deposits through the analysis of the SPOT-5 image 051/257 taken at the end of the 2003 Summer heatwave (23/08).



Results: 182 rockfalls (100 to 45 000 m³).

Ravanel L. *et al.* (2011). Les écroulements rocheux dans le massif du Mont Blanc pendant l'été caniculaire de 2003. *Géovisions*, 36: 245-261.

M3: Network of observers

Period: 2007 to 2009 (2010 data not already processed)

Overview: A network of observers (alpine guides, hut keepers) allow to survey rockfalls in the central area (57%) of the massif. A form is filled for each observed rockfall or deposit. Data are checked and completed on the field during each fall.

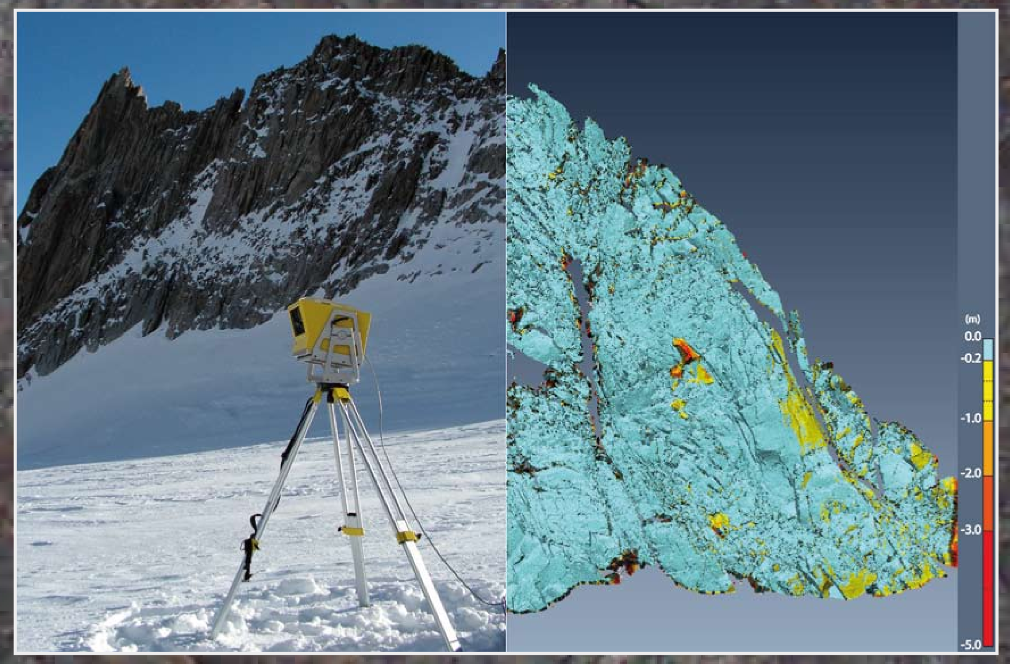
Results: 139 rockfalls (100 to 33 000 m³).

Ravanel L., Allignol F., Deline P., Gruber S., Ravello M. (2010). Rock falls in the Mont Blanc Massif in 2007 and 2008. *Landslides*, 7: 493-501.

M4: Terrestrial Laser Scanning

Period: 2005 to 2009 (2010 data not already processed)

Overview: Each year, a dozen of rockwalls is laser scanned at high resolution and high accuracy. 3D models are diachronically compared in order to identify rock detachments and quantify their volume.

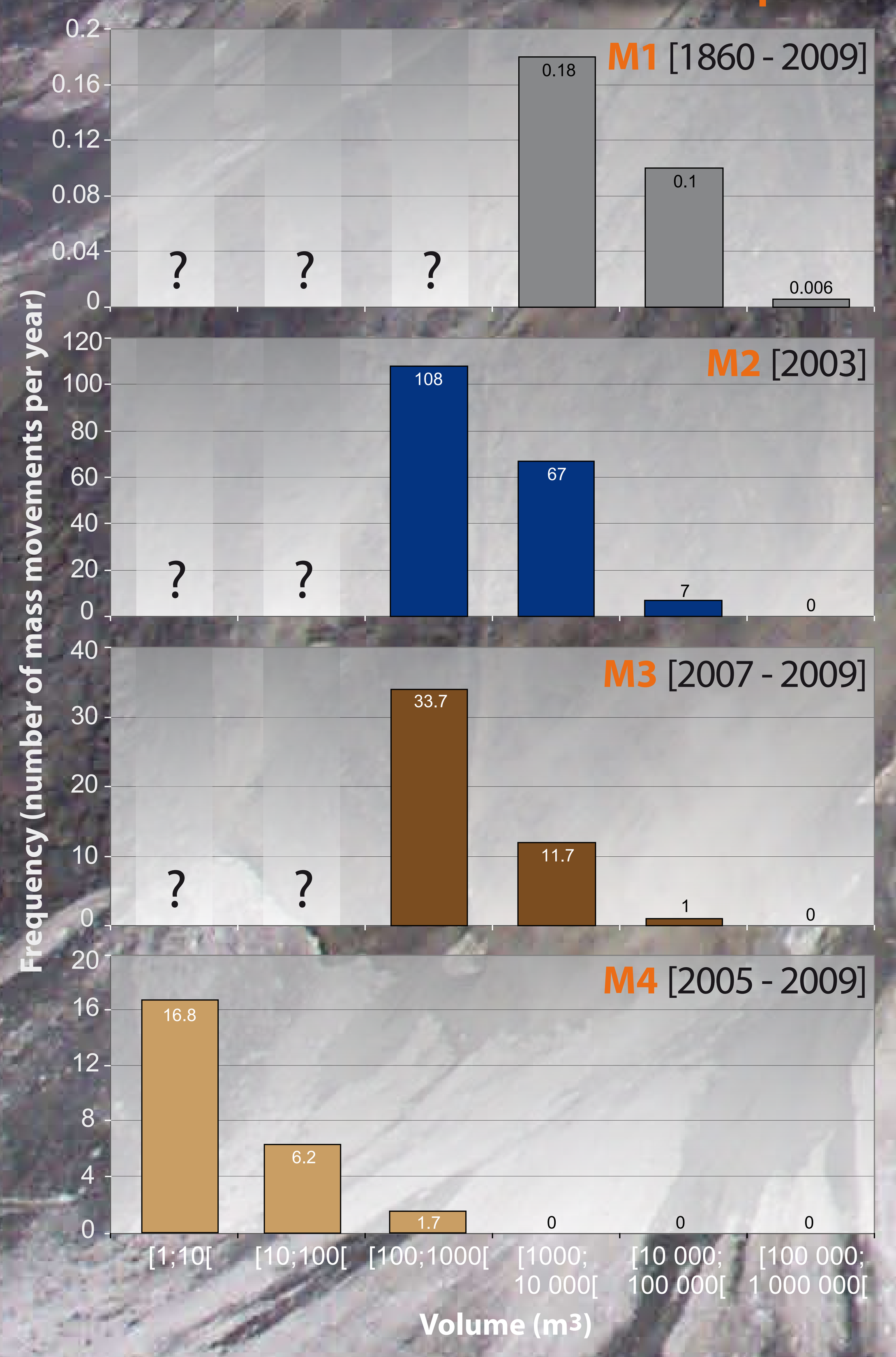


Results: 69 rockfalls (1 to 426 m³).

Ravanel L. *et al.* (2010). Quantification des écroulements dans les parois à permafrost de haute montagne. *Revue de la SFPT*, 192, 10 p.

Frequency and volume

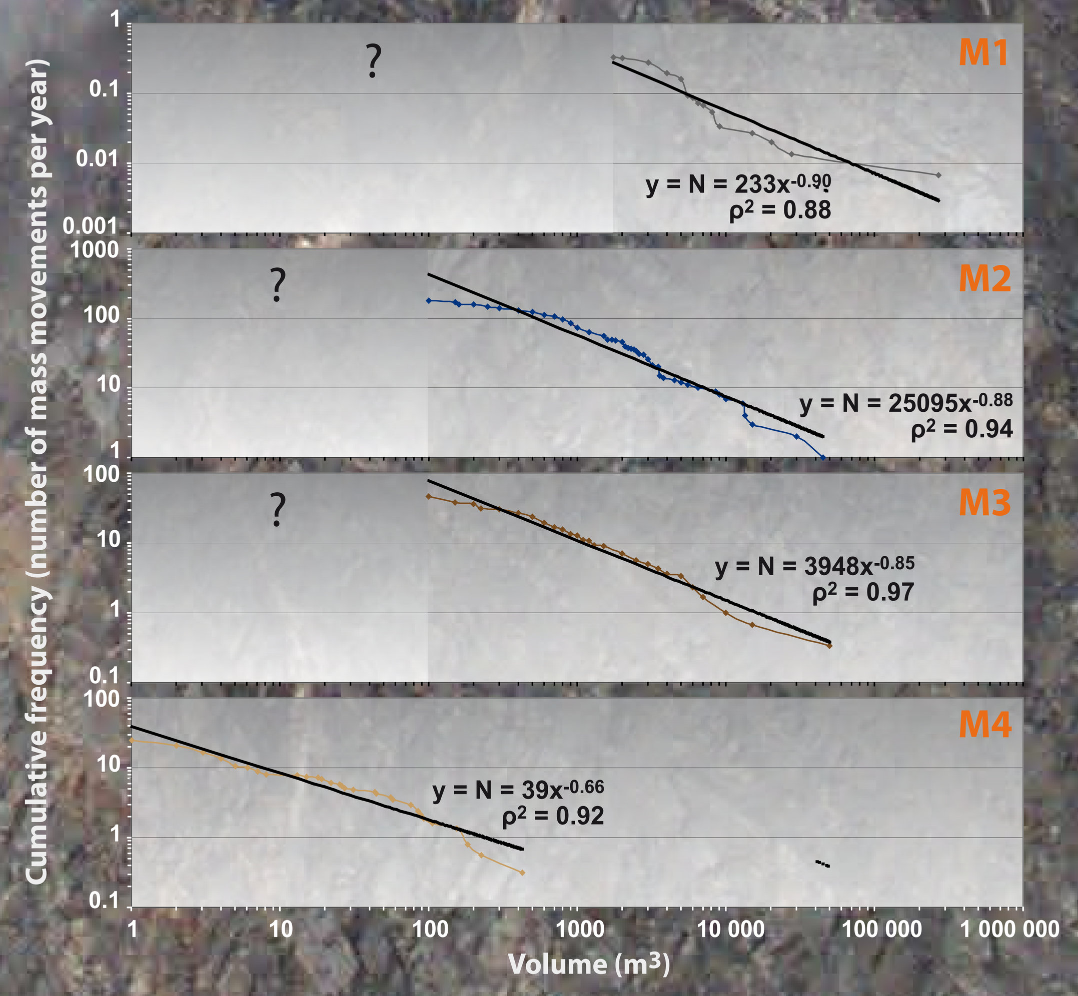
Variable frequencies



Variable volumes

	Volume (× 10³ m³)				
	total	mean	median	extremes	standard deviation
M1 (Area 1)	335	42	8	0.35 - 265	90
M1 (Area 2)	390	9	3.5	0.5 - 65	13.5
M2	350	1.9	0.8	0.1 - 45	4.5
M3 (2007)	72	1.6	0.6	0.1 - 15	2.8
M3 (2008)	73	3.3	0.7	0.1 - 33	10.5
M3 (2009)	57	0.8	0.4	0.05 - 7	1.3
M4	2.223	0.032	0.005	0.001 - 0.426	0.067

Cumulative frequencies



Erosion rates

	Volumetric rate of erosion (m³/year)			Area (m²)	Linear rate of erosion (mm/year)		
	1-100 m³	> 100 m³	total		1-100 m³	> 100 m³	total
M1	?	4 828	?	3.6×10^6	?	**1.34**	?
M2	?	350 000	?	126×10^6	?	**2.8**	?
M3	?	67 000	?	84×10^6	?	**0.8**	?
M4	325	363	687	423 500	0.76	**0.85**	**1.6**

Discussion and conclusion:

Rockfalls frequency and volume are highly variable. This can be mainly explained by the variable density of discontinuities.

Large collapses are rare and the estimation of their frequency can be rough, but the distribution of the **cumulative frequencies** of mass movements can be described by a power law:

$$N = a\,x^{-b}$$

Exponents b have here values well above literature values, suggesting that the rockfall mechanisms are different if compared to low altitude conditions and therefore from permafrost area.

Similarly, calculated **erosion rates** are often much higher than those calculated for mountain regions without permafrost. The highest rate is the 2003 one, a year characterized by a significant summer heat wave, particularly favourable to the permafrost degradation.

→ Beyond the many elements that support the **role of permafrost degradation** in the rockfall triggering (see references above), **frequency and volume of rockfalls in the Mont Blanc massif tend to confirm the preponderance of this permafrost degradation in the triggering.**

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