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Short communication

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THE TRÉ-LA-TÊTE ROCKFALL ONTO THE LEX BLANCHE GLACIER, MONT BLANC MASSIF, ITALY, IN SEPTEMBER 2008

ABSTRACT: DELINE P., KIRKBRIDE M.P., RAVANEL L. & RAVELLO M., *The Tré-la-Tête rockfall onto the Glacier de la Lex Blanche, Mont Blanc Massif, Italy, in September 2008*. (IT ISSN 0391-9838, 2008).

In September 2008, a large rockfall (50,000 m^3) detached from 3470 m a.s.l. on the east-facing spur of Aiguille de Tré-la-Tête, in the upper part of the Val Veny (Valley of Aosta). It travelled for > 1 km onto the steep Petit Mont Blanc Glacier, the main tributary of the Lex Blanche Glacier. It is the largest rockfall that has occurred in the Mont Blanc massif since the 2005 rock avalanche (260,000 m^3) from the pillar of Les Drus, above Chamonix. While debuttressing of the rock wall due to ice downwastage during the last two decades could have reduced rock wall stability, permafrost degradation is probably the main triggering factor for this rockfall, as well as for 55% of the 62 other rockfalls observed in the massif in 2007 and 2008. (KEY WORDS: Rockfall, Rock avalanche, Mont Blanc Massif (Alps), Lex Blanche Glacier).

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Nel mese di Settembre 2008, un'importante frana di crollo (50.000 m^3) si è staccata dai 3470 m di quota della spalla orientale delle Aiguilles de Tré-la-Tête, nell'alta Val Veny (Valle d'Aosta); la massa coinvolta ha percorso più di 1 km lungo il ripido ghiacciaio del Petit Mont Blanc, tributario principale del ghiacciaio della Lex Blanche. Si tratta del crollo più importante all'interno del Massiccio del Monte Bianco, dopo quello avvento ai Drus nel 2005 (260.000 m^3). Se la destabilizzazione della roccia dovuta all'abbassamento del livello del ghiaccio avvenuto nell'ultimo ventennio ha potuto contribuire a indebolire la parete, la degradazione del permafrost rappresenta probabilmente il fattore principale d'innesco, come pure per il 55% degli altri 62 crolli osservati nel Massiccio nel 2007 e 2008. (TERMINI CHIAVE: Frana di crollo, Gruppo del Monte Bianco (Alpi), Ghiacciaio della Lex Blanche).

INTRODUCTION

Several large rock avalanches have occurred recently in the Alps (Brenva Glacier, 1997; Punta Thurwieser, 2004), and innumerable smaller rock falls have detached from steep rockwalls. These were especially frequent during the hot summer of 2003 (Gruber & *alii* 2004). The hypothesis that an observed increase of high mountain rockwall instability is related to permafrost changes (Gruber & Haeberli 2007) is supported by several indicators: (i) ice has been observed in many starting zones; (ii) the mean annual air temperature in the Alps has increased by > 1°C during the 20th Century; and (iii) the warming trend has accelerated since 1980. However, ongoing permafrost changes in rockwalls are poorly understood, as are the frequency and volume of rock slope failures in high mountains, not least because of a lack of systematic observations. For this reason, in the Mont Blanc massif, a network of observers (alpine guides and hut keepers) was established in 2005 in the framework of the French-Italian project *PERMAdataROC* (Deline & *alii*, 2008), in order to collect data as exhaustively as possible on current rock fall activity in this area (Ravanel & *alii*, submitted).

This short paper reports on a large rockfall that occurred on September 2008 in the Lex Blanche Glacier basin. Preliminary observations suggest that the volume of this event makes it the largest in the Mont Blanc massif since the June 2005 small rock avalanche at Les Drus (Deline, 2008; Ravanel & Deline, 2008), and continues a likely trend of increased slope instability in recent decades.

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THE ROCKFALL OF SEPTEMBER 2008 IN THE LEX BLANCHE GLACIAL BASIN

With an area of 3.7 km^2 in 1957 (Com. Glac. It., 1961), the Lex Blanche Glacier is one of the medium-sized glaciers of the Mont Blanc massif, flowing on its south-east (Italian) flank in upper Val Veny, Aosta Valley (fig. 1). The glacier tongue is supplied mainly by accumulation basins in two coalescent cirques, plus a steep tributary, the Petit Mont Blanc Glacier, and an hanging glacier, the Aiguille Orientale de Tré-la-Tête Glacier (Com. Glac. It., 1961). The ≤600 m high gneissic rock walls that limit the glacial basin rise from 2930 m a.s.l. at the Col d'Estélette to 3930 m at the Aiguille Centrale de Tré-la-Tête. Following a readvance culminating around AD 1988 at c. 2050 m a.s.l., the glacier terminus retreated a horizontal distance of 900 m to its present altitude of 2500 m a.s.l. above a steep rock slope. Frontal moraines that formed during the last maximum advance of the Little Ice Age (LIA) in AD 1820 (Aeschlimann, 1983) stand at an elevation of 1975 m, a horizontal distance of 1550 m from the present front.

On 10 or 11th of September 2008 at about 7.00 a.m. (L. Covolo, personal communication), a rock mass detached from the Épaule orientale de Tré-la-Tête, a large spur forming the inside of a bend in the Petit Mont Blanc Glacier (fig. 1). Avalanche debris travelled down the 25-30° corridor of this glacier, with the main mass coming to rest at the change of slope at the confluence with the main glacier. Several small run-out lobes diverged from the main debris track. The maximum horizontal and vertical displacements of avalanche debris were 1150 m and 770 m respectively (fig. 1). The scar is clearly visible on an east-facing rock face of 50-55° angle (fig. 2). The detached volume, estimated from photographs of the scar compared to AD 2000 orthophotograph and 1:10,000 topographic map, is c. 50,000 m^3, with the top and bottom of the scar at 3470 and 3320 m a.s.l. Maximum depth of the scar is several tens of meters. The runout path on the glacier covers c. 150,000 m^2, but debris (generally < 1 m-thick) came to rest over only part of this area due to zones of steeper slopes and seracs. The deposit on the Petit Mont Blanc Glacier is too small to change the dynamics of the glacier by forming a debris cover, unlike the much larger rock avalanches onto Brenva Glacier in 1997 and, especially, 1920 (Deline, 2008).

The Tré-la-Tête rockfall did not have an excessive horizontal travel distance (L_e). This is the horizontal runout beyond the expected runout distance, assuming an apparent coefficient of friction (height-over-length H/L ratio) of 0.62 (Hsü, 1975), where $L_e = L - H/0.62$. For the Tré-la-Tête rockfall, $L_e = -92$ m. Unlike larger rockfalls and rock avalanches, few recent rockfalls of < 100,000 m^3 in the Mont Blanc massif have had an excessive runout, in spite of incorporation of ice and snow into the moving debris mass (Deline, 2008).

ROCKFALL TRIGGER

Loss of ice cover in the area of the rockfall is shown by the disappearance of the ice connection between the Petit Mont Blanc Glacier and the smaller Aiguille Orientale de Tré-la-Tête Glacier (only snow patches usually remain by late summer, and even these melted away in 2003). The Petit Mont Blanc Glacier has thinned by > 10 m since the last advance of the glacier (AD 1955 to 1988), as shown by a rock ridge which continues the Épaule orientale downstream and has appeared since the end of this advance (fig. 1). Basal debuttressing of the rockwall of >10 m of the 150 m height of the failed mass has therefore likely occurred over 20 years, and may have acted as a preparatory factor for the rock mass failure.

After a century of generally warming climate, modeling by Gruber & *alii* (2004) and Noetzli & *alii* (2007) of ground temperature distribution both at and below rock wall surfaces, in relation to elevation, aspect, and slope angle, suggests that the temperature in the rock wall affected by the

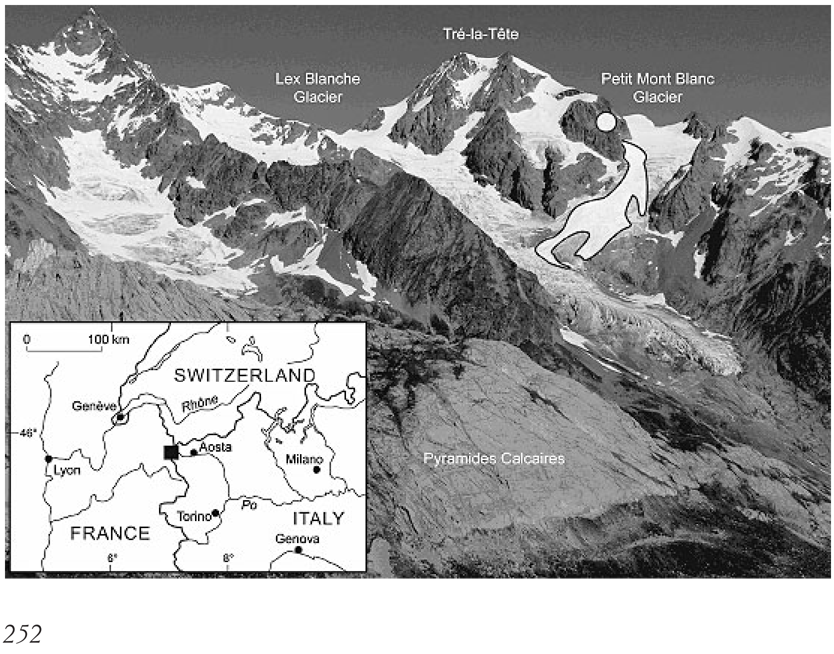
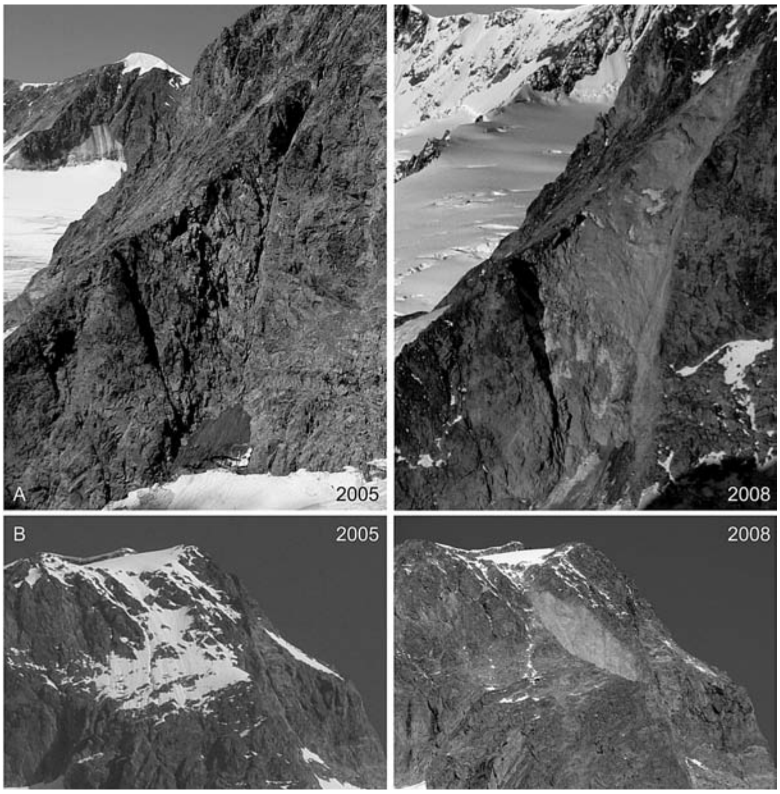


FIG. 1 - South-west area of the Italian side of the Mont Blanc massif and location map. Tré-la-Tête culminates at 3930 m a.s.l. (Aiguille centrale, on left) and 3895 m (Aiguille orientale, on right). Summit on the left is Aiguille des Glaciers (3816 m), towering above the Glacier d'Estelette. The scar of the 2008 rockfall (white circle) is located on the east face of the Épaule orientale de Tré-la-Tête. White area with black line: runout path of the 2008 rockfall on Petit Mont Blanc Glacier.

FIG. 2 - Area of the east face of the Épaule orientale de Tré-la-Tête affected by the rockfall. A: photographs taken from the summit of Petit Mont Blanc on 04.09.2005 and 25.10.2008 (2008 photograph: M. Tamponi); B: photographs taken from the Elisabetta hut on 26.06.2005 and 10.10.2008.



rockfall is slightly below 0°C, at a temperature where frozen rock joints were shown to become unstable (Davies & *alii*, 2001). This implies that permafrost degradation could be implicated as a trigger factor in a densely-fractured rock mass at an angle allowing winter snow accumulation, so that snowmelt percolation along joints will provide significant amounts of melt water (fig. 2). Although heat transfer to depths greater than the seasonal freeze/thaw penetration in steep rock walls occurs primarily by heat conduction, percolation advects heat through fractured rock and may have increased the ductility of ice within joints.

EVIDENCE OF EARLIER ROCK SLOPE INSTABILITY AROUND THE LEX BLANCHE GLACIER

In addition to the 2008 event, two of the authors witnessed a rockfall from the south spur of Petit Mont Blanc in June 2005 (fig. 3), of the order of 10^3 m^3 volume. Other evidence of previous rockfall activity in the basin of the Lex Blanche is from source-area scars and ice-transported deposits.

On the south buttress of Aiguille Centrale and below the summit of Aiguille Orientale de Tré-la-Tête, two light grey scars contrast with weathered reddish rock walls nearby. Their colour indicates rockfalls several centuries ago (Böhlert & *alii*, 2008). Downvalley, an unusually large clast-supported lateral moraine, dating from c. AD 1860 (Aeschlimann, 1983), bounds the Little Ice Age (LIA) proglacial margin of the glacier. Its sedimentological and morphological character suggests a genesis as an ice-transported rock avalanche of larger volume than the 2008 event. This rock avalanche must have occurred up to a century before AD 1860 given the likely residence time of debris in glacial transport.

Tentative evidence of a changing tempo of rockfall activity is suggested by comparing these deposits with the two medial moraines of the Lex Blanche Glacier. On a photograph taken in AD 1920 (Com. Glac. It., 1961, p. 173) both moraines are present on the glacier. The largest is fed mainly by a mixed rock/snow/ice supraglacial debris cone

FIG. 3 - Rockfall of the south spur of Petit Mont Blanc (visible in fig. 1, on the right margin) at 10.46 am on 19 June 2005. The deposit came to rest on the debris slope above the tongue of the Lex Blanche Glacier.

formed by avalanching from the hanging Aiguille Orientale de Tré-la-Tête Glacier, and from rockfall from the Épaule méridionale (the south-west buttress) of Tré-la-Tête, to form a medial moraine at the confluence of the main glacier and the Petit Mont Blanc Glacier. The continuous band of supraglacial moraine along with the small size of its constituent debris suggest that only low-magnitude high-frequency rockfalls have affected the rock walls of the south side of Tré-la-Tête since the LIA termination, indicating surficial frost-shattering of rock walls. An absence of more substantial deposits from this period suggests that large rockfalls and rock avalanches of magnitudes indicative of permafrost degradation were rare until recent decades.

OTHER ROCKFALLS IN THE MONT BLANC MASSIF IN 2007 AND 2008

A network of observers, comprising about 30 French and Italian alpine guides and several hut keepers, became fully effective in 2007. The aim is to compile a comprehensive inventory of current rockfall activity in the Mont Blanc massif. 44 rockfalls were observed in 2007 (Ravanel & *alii*, submitted) and a further 19 in 2008. Most of these events took place between mid-July and mid-September: the only one not occurring in summer was from the Rognon Inférieur du Plan in January 2007 (volume of c. 3000 m^3). In 2008, all the observed events occurred between 25 June and 10-11 September. The two largest 2007 rockfalls occurred from the Dent de Jethoula (about 15,000 m^3) and the Tour des Jorasses (about 10,000 m^3).

After the Tré-la-Tête event, the second largest rockfall in 2008 was from the Aiguille des Thoules (about 10,000 m^3). 2007 and 2008 rockfalls detached on slopes with an angle mainly in the range 50-60°, while 85% of these 63 events occurred at an elevation > 3000 m a.s.l. The permafrost modelling suggests that most of the rockfalls of these two last years have affected rock walls with permafrost, but events probably directly related to the permafrost warming are (i) those occurred at > 3000 m a.s.l., (ii) with a scar deeper than the active layer, where sometimes massive ice was observed (Ravanel & *alii*, submitted). Thus, permafrost degradation should have been the main triggering factor for about 55% of the 63 rockfalls observed in the Mont Blanc massif in 2007 and 2008. Continued monitoring has the potential to uncover significant systematic patterns in the geography of high-mountain rockfall activity in the Mont Blanc Massif, based on a much larger sample size than hitherto possible.

CONCLUSIONS

Although a relatively small event, the 2008 Tré-la-Tête rockfall exemplifies the present morphodynamics in high mountain areas like the Mont Blanc massif. Such rockfalls are hypothesised to result from the ongoing degradation of permafrost as climate warming affects many mountain ranges globally, and acts as one of the controlling factors of the instability of steep high-alpine rock walls (Fischer & *alii*, 2006). The four main rockfalls in the Mont Blanc massif in 2007 and 2008 were located on the steepest (Italian) side of the massif, where many large rockfalls and rock avalanches occurred during the Holocene (Deline, 2008; Deline & Kirkbride, 2008). They show that structural conditions and geomorphological heritage have to be taken into account in the analysis of permafrost-related instabilities and potential risk for permanent and temporary inhabited areas.

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