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## THE FRONTAL ICE AVALANCHE OF FREBOUGE GLACIER (MONT BLANC MASSIF, VALLEY OF AOSTA, NW ITALY) ON 18 SEPTEMBER 2002

**ABSTRACT:** DELINE P., CHIARLE M. & MORTARA G., *The frontal ice avalanche of Frébouge Glacier (Mont Blanc Massif, Valley of Aosta, NW Italy) on 18 September 2002.* (IT ISSN 0391-9838, 2002).

In September 2002, a part ( $>0,1 \times 10^6 \text{ m}^3$ ) of the Frébouge Glacier (Val Ferret) front avalanched onto the apex of the polygenic fan. The  $0,1 \times 10^6 \text{ m}^2$  deposit was composed of poorly-sorted, subspherical, open-work ice particles and formed a lobate front; the lateral margins are steep metric ridges, along longitudinal shear zones. Some big ice boulders rolled 100-150 m ahead the front.

Following Alean's (1985) ice avalanching typology, the Frébouge event is a type IA event: that is to say, avalanching of a low elevation temperate glacier front on a steep rock bed. Others type IA ice avalanches have probably occurred in recent decades, but the rapid fusion of avalanche deposits makes their survey difficult. The ignorance of this process frequency explains its underestimation in alpine hazard analysis.

**KEY WORDS:** Ice avalanching, Mont Blanc Massif, Frébouge Glacier, Natural hazards.

**RIASSUNTO:** DELINE P., CHIARLE M. & MORTARA G., *Il crollo frontale del Ghiacciaio di Frébouge (Massiccio del Monte Bianco, Valle d'Aosta) del 18 settembre 2002.* (IT ISSN 0391-9838, 2002).

Nel Settembre 2002 una porzione ( $>0,1 \times 10^6 \text{ m}^3$ ) della fronte sospesa del Ghiacciaio di Frébouge (Val Ferret) crollò sul conoide poligenico sottostante. Il deposito, di superficie pari a  $0,1 \times 10^6 \text{ m}^2$ , risultava formato da frammenti di ghiaccio eterometrici, subsferici con una struttura *open-work* e fronte plurilobato. I margini si presentavano ripidi e di altezza plurimetrica, con evidenti strutture di taglio. Alcuni blocchi avevano sopravanzato di 100-150 m il fronte dell'accumulo. Il caso descritto, trat-

tandosi di un crollo parziale di una fronte di un ghiacciaio temperato localizzato su un pendio ripido, rientra nel tipo IA secondo la classificazione proposta da Alean (1985). È probabile che fenomeni simili siano avvenuti negli ultimi decenni, ma è difficile che se conservi la traccia a causa della rapida fusione dei depositi. L'incompletezza di informazione può spiegare la sottostima del rischio legato a questa categoria di fenomeni dell'ambiente alpino.

**TERMINI CHIAVE:** Crollo di ghiaccio, Monte Bianco, Ghiacciaio di Frébouge, Rischi naturali.

**RÉSUMÉ:** DELINE P., CHIARLE M. & MORTARA G., *L'écroulement du front du glacier de Frébouge (Massif du Mont Blanc, Vallée d'Aoste) du 18 Septembre 2002.* (IT SNN 0391-9838, 2002).

En septembre 2002, une partie ( $>0,1 \times 10^6 \text{ m}^3$ ) du front du glacier de Frébouge (Val Ferret) s'est écroulé sur l'apex du cône polygénique aval. Le dépôt de  $0,1 \times 10^6 \text{ m}^2$  était formé de particules de glace très hétérométrique, subsphériques, avec une structure *open-work*. Son front est constitué de plusieurs lobes, ses marges, de raides cordons de hauteur métrique qui résultent de cisaillement longitudinaux; quelques gros blocs ont roulé 100-150 m en avant du front du dépôt. Selon la typologie des écroulements de glace proposée par Alean (1985), celui de Frébouge est du type IA, i.e. l'écroulement du front localisé sur une pente raide d'un glacier tempéré. Si d'autres écroulements du même type ont pu affecté ce glacier dans un passé récent (ex: 1968), leur recensement exhaustif est rendu difficile par une fusion rapide du dépôt. La méconnaissance de la fréquence de ce phénomène conduit à le sous-estimer dans l'analyse du risque en milieu alpin.

**MOTS CLES:** Ecroulement de front glaciaire, Massif du Mont Blanc, Glacier de Frébouge, Risques naturels.

### INTRODUCTION

Avalanching of alpine glaciers ice is a common process. Most avalanches have a small size ( $10^3$ - $10^4 \text{ m}^3$ ), and are due to seracs falls from hanging glaciers, and have travelled short horizontal distances ( $L < 500 \text{ m}$ ). Some avalanches comprise the entire ice body, such as high elevation steep hanging glaciers. For example, in June 1970 the NE face glacier of the Aiguille Verte (4122 m, Mont Blanc Massif)

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The names of the Aosta Valley glaciers are taken from the Regional Technical Topographic Map. These names may thus differ from those adopted by the Italian Glaciers Inventory (vol. II, 1961).

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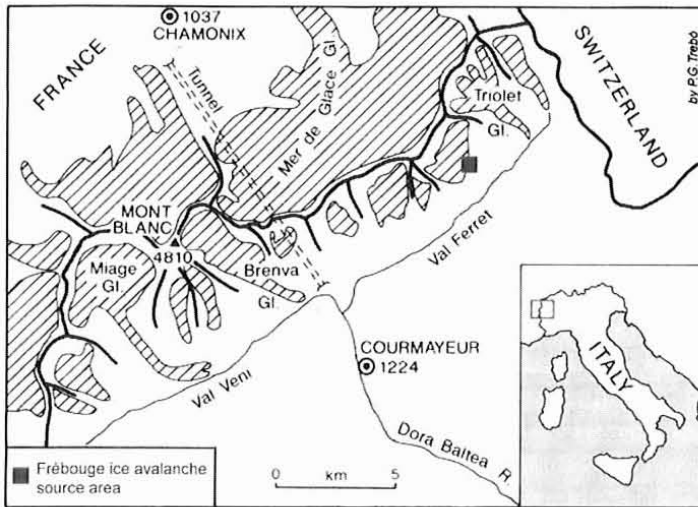


FIG. 1 - Location map (after Barla & alii, 2000, modified).

fell. The ice avalanche travelled as far as the left margin of the Glacier d'Argentière ( $L > 1500$  m) (Vivian, 1975). When ice avalanching occurs at valley or cirque glacier fronts, the hazard for people in the vicinity can be high. On 14 August 1949, the Glacier du Tour (Mont Blanc Massif) ice avalanche ( $0,2 \times 10^6$  m<sup>3</sup>,  $L > 1000$  m) killed six walkers; and on 30 August 1965, a volume of ice  $> 0,5 \times 10^6$  m<sup>3</sup> fallen from the Allalingsletscher front (Saastal, Valais) killed 88 workers (Chiarle, 2000). This paper describes a recent large ice avalanche from the Frébouzie Glacier front.

### THE FREBOUGE GLACIER CHARACTERISTICS

With an area of 2.3 km<sup>2</sup> in 1970 (Vivian, 1975), Frébouge is one of the medium-sized glaciers on the south-east (Italian) flank of the Mont Blanc Massif (fig. 1). According to the *World Glacier Inventory* classification, Frébouzie is a mountain glacier with a compound basin (Muller & alii, 1977), because it is formed by four coalescent cirques, with

medium-sized (200-750 m) headwalls culminating between 3480 m at the Col des Hirondelles to ~4150 m at the Grandes Jorasses. During the Little Ice Age (LIA), its 300 m large front covered the apex of the present large downstream colluvial fan: its frontal moraines stand at an elevation of 1800-1825 m. Since the end of the LIA (1860), Frébouge Glacier has experienced a major retreat: its present front, about 1 km wide, is located on a steep rockwall at an elevation of 2500-2550 m, which means a post-LIA retreat of 1600 m along the topographical profile, but punctuated by short readvances. In 1929, the front reached the foot of the rockwall at an elevation of 2092 m (Capello, 1953). The eastern glacier in the Frébouge basin, named Ghiacciaio Occidentale di Greuvettaz has been separated from the main glacier during this post-LIA withdrawal.

Like the fronts of the glaciers Triolet (Val Ferret), Frêne and Breuillat (Val Veny), the Frébouge front is located on a confluence step which results both from structural geology and Quaternary glaciations. Because of these frontal positions, these glaciers experience frequent ice avalanching through serac falls. Usually, ice volumes are small, but the high frequency of the process allows (i) formation of pulverized ice fans on ledges on the rock steps and at their feet, or even (ii) small regenerated glaciers, as occurred at Frébouge Glacier in the late 1960s and the early 1970s, during its last advance (Cerutti, 1971). Some ice avalanches are larger: for example in 1933 (Chiarle, 2000), 1956 (Capello, 1959) and 1971 (Lesca, 1971), the polygenic fan downstream from Frêne glacier was partially covered by ice avalanche deposits. In the Frébouzie case, no large ice avalanches are historically known (Chiarle, 2000).

### THE FREBOUGE ICE AVALANCHE ON 18 SEPTEMBER 2002

In the late afternoon of 18 September 2002, a part of the Frébouge Glacier front avalanched (fig. 2). The ice avalanche descended 400 m of the steep rock step and covered a large area ( $\sim 0,1 \times 10^6$  m<sup>2</sup>) of the apical part of the polygenic fan (fig. 3; fig. 4). The gradient of this part of

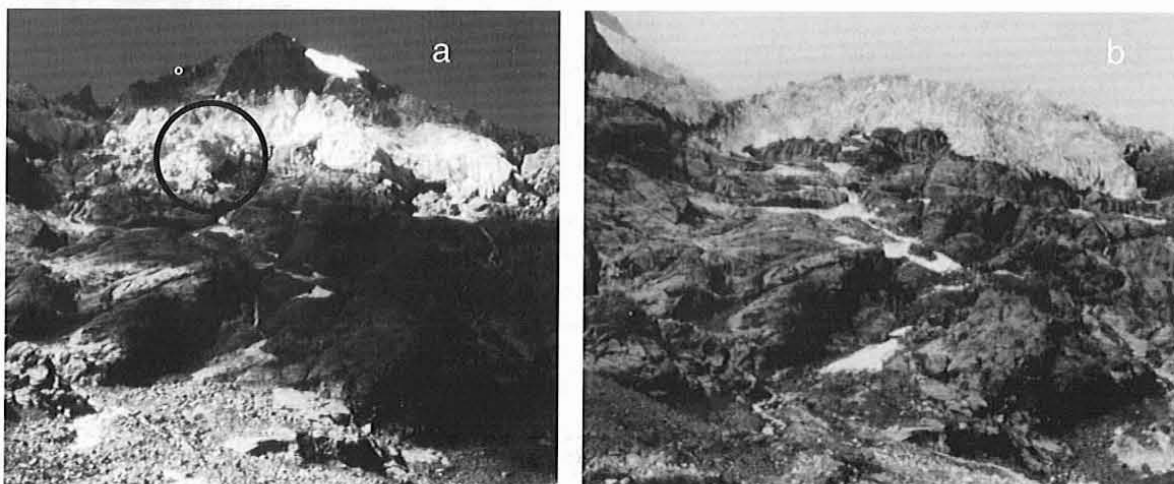


FIG. 2 - East part of the Frébouge Glacier front before (a, 28.08.2002) and after (b) the ice avalanche on 18 September 2002.



FIG. 3 - The Frébouge ice avalanche deposit map. 1: Starting point; 2: ice avalanche deposit. [Topographical map 1:10 000; contours: 10 m. *Archivi topocartografici della Regione Autonoma Valle d'Aosta - autorizzazione n. 52 del 18.08.1999*].

the fan is  $\sim 20^\circ$ . The deposit formed lobate tongues, mainly because of fan surface topography: channelized by a stream bed, the lower front reached an elevation of 1855 m. A few ice boulders reach lower elevations, coming to rest 100-150 m ahead the front of the main mass.

The deposit was mainly composed of poorly-sorted subspherical pebble- to boulder-sized ice particles, with some huge boulders exceeding  $20 \text{ m}^3$ . The structure was open work, but a continuous layer quickly appeared on the undulating topographic surface by ice fusion. The deposit thickness was very variable: (i) on the east margin, the ice avalanche has slightly planed down the fan surface but left no deposit; (ii) on the front, it reached in some parts 5 m. A conservative estimate of the mean thickness for the deposit of 1 m equates to a minimal ice avalanche volume of  $0,1 \times 10^6 \text{ m}^3$ .

The front and lateral margins of the deposit were typically steep and 1-3 m high. In places at the front, superposition of two flows formed a distal rim. Along the margins,

a longitudinal shear zone separated a narrow *levée* from the main body of the ice avalanche, similar to the characteristics of a wet snow avalanche.

Poorly-sorted rock particles were present on the whole deposit, and were locally abundant. This granitic material, mobilized by the ice avalanche, was derived (i) from till cover from ledges on the rock step; and (ii) from colluvial fan sediments. Rock material appeared to be more abundant on the margins. In the apical and central parts of the deposit, the torrent flowed on its surface to leave abundant alluvial material before its incision.

Ice melt rapidly destroyed the September 2002 deposit: two weeks after the avalanche, only some ice boulders remained on the fan (M. Bois, oral com.). Though no large ice avalanche at Frébouge has been reported by historical sources, an aerial photographic study suggests a similar or even larger event in 1968, during the last glacial advance in the Alps.

#### ICE AVALANCHING TYPES ON THE ITALIAN SIDE OF THE MONT BLANC MASSIF

Alean (1985) has proposed an ice avalanche typology, according to which the last decades events on the SE flank of the Mont Blanc Massif can be described:



FIG. 4 - Frontal view of the Frébouge ice avalanche (22.09.2002).

- **Type IA.** In a low elevation temperate glacier, the front is not frozen to a steep rock bed. Gravity and subglacial water circulation can affect the front and allow it to avalanche. 20<sup>th</sup> Century ice avalanches from Frêne Glacier were type IA events, as was the latest 2002 Frébois avalanche. Climatic conditions associated with these events seem variable: (i) abundant rainfall and cold night-time temperatures in the days preceding the 25/06/1956 Frêne event (Capello, 1959); (ii) sunny weather and high temperature in the days prior to the 18/09/2002 Frébois ice avalanche. However, abundant water supply appears to have been common to both cases.
- **Type IB.** At high elevation (> 3800 m), glaciers are cold-based. When hanging glaciers are wholly located above ELA, frontal ice avalanching is the dominant form of glacial ablation. The 1993, 1997 (15.000 m<sup>3</sup>) and 1998 ice avalanches which affected the Upper Glacier of the Grandes Jorasses, in Val Ferret (Chiarle, 2000; Deline, 2002) were type IB events.
- **Type II.** When bed rock presents a rough break of slope, as on a bedrock step, low-elevation hanging glacier fronts are affected by frequent small-volume (<1000 m<sup>3</sup>) toppling of seracs. Brenva and Breuillet glaciers (Val Veny) experience type II ice avalanching several times per day (or even per hour). Such behaviour typifies Frébois Glacier also.

## CONCLUSION

Type IA ice avalanching represents a serious threat to the alpine population and to tourists. The 2002 Frébois event covered a section of the Gervasutti hut path, on which fortunately nobody was present on the afternoon of 18 September. The long retreat of the Frébois Glacier front and its present hanging state, which allow ice avalanching, result from post-LIA climate change. But the rela-

tionship between the avalanching process and climate variation cannot be established at shorter time spans. During recent decades, some events occurred during a glacial advance period, others during a period of retreat. The short duration of survival of ice deposits makes them difficult to survey using aerial photography. As a result, there is a relative ignorance of type IA ice avalanching frequency. The difficulty of observing this high-magnitude low-frequency process explains its present underestimation in alpine hazard analysis.

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