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**Autor:** Orombelli, Giuseppe / Porter, Stephen C.

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# Boulder deposit of upper Val Ferret (Courmayeur, Aosta valley): Deposit of a historic giant rockfall and debris avalanche or a late-glacial moraine?

By GIUSEPPE OROMBELLI[1]) and STEPHEN C. PORTER[2])

ABSTRACT

A boulder deposit in the upper Val Ferret on the Italian side of Mont Blanc has been interpreted as geologic evidence of the historic 1717 Triolet rockfall. A recent restudy of the deposit again prompted the chaotic boulder accumulation to be ascribed to a late-glacial ice advance. However, previously cited and new evidence, including lithology, morphology, and lichenometric and dendrochronologic ages that accord with historic accounts, support our contention that the deposit is, in fact, a recent debris avalanche. Ambiguity of $^{14}C$ dates thus far obtained are likely a result of a hard-water effect.

RÉSUMÉ

Un dépôt de gros blocs anguleux dans le haut val Ferret (côté italien du Mont-Blanc), déja considéré une moraine, a été interprété comme évidence géologique de l'éboulement historique du Triolet (12 septembre 1717). Une étude récente rapporte le dépôt de nouveau à une avancée tardiglaciaire. Toutefois les observations sur la composition pétrographique, la morphologie, les sols, l'altération et l'âge obtenu par lichenométrie et dendrochronologie confirment que le dépôt de blocs a été formé par un éboulement récent. Les datations $^{14}C$ obtenues sont contradictoires, probablement à cause d'une contamination avec des eaux dures.

RIASSUNTO

Nell'alta Val Ferret (versante italiano del Monte Bianco) è presente un deposito di grossi blocchi angolosi, esteso per oltre 1 km lungo il fondovalle. Considerato in passato una morena, è stato dagli autori di questa nota interpretato come l'evidenza geologica principale della frana storica del Triolet, verificatasi nel 1717. Uno studio recente nuovamente ha attribuito il deposito di blocchi ad una fase di avanzata dei ghiacciai tardiglaciale. Tuttavia le osservazioni sulla composizione litologica, la morfologia, i suoli, l'alterazione e l'età, ottenuta mediante lichenometria e dendrocronologia, confermano che l'accumulo di blocchi è stato generato da un evento franoso recente, che ha prodotto una valanga di detrito. Le date $^{14}C$ ottenute su materiali torbosi sono contraddittorie, probabilmente a causa di contaminazione con acque dure.

## Introduction

In a previous paper we described the geologic evidence of the Triolet rockfall (PORTER & OROMBELLI 1980). This catastrophic event occurred in the night of 12–13 September 1717 in Val Ferret, on the Italian flank of the Mont Blanc massif, and was

[1]) Dipartimento di Scienze della Terra, Università di Milano and Centro di Studio per la Stratigrafia e Petrografia delle Alpi Centrali C.N.R., Via Mangiagalli 34, I–20133 Milano.

[2]) Quaternary Research Center, University of Washington, Seattle, Wash. 98195, USA.

related by contemporary witnesses and historians. According to a manuscript by MICHEL JOSEPH PENNARD, preserved in the church archives at Courmayeur (reproduced by OROMBELLI & PORTER 1981) and according to DE TILLIER (manuscript dated 1737, recently printed in 1968) a high ice-covered point of rock on the side of the Triolet Glacier suddenly collapsed. The produced debris of rocks and stones, mixed with water and ice traveled down into the main valley for a league, burying the settlements of Triolley and Ameiron and killing 7 men and 120 cows.

In our study, we considered as the main rockfall deposit the chaotic accumulation of coarse angular boulders which is discontinuously developed for about 2 km along the floor of upper Val Ferret, from the outer margin of the Little Ice Age moraines of Triolet Glacier down to the flat area of Ferraché, where it abruptly ends along a clear arcuate rim (Fig. 1). Both historic descriptions and geologic evidence point to a giant rockfall that produced a debris avalanche. According to our interpretation, an estimated 16–20 million $m^3$ of rock debris (plus glacier ice and snow) travelled through a vertical distance of about 1860 m at a speed of 125–160 km/h, covering a distance of 7 km.

Previously, the boulder deposit of the upper Val Ferret had been interpreted as a late-glacial or prehistoric Holocene moraine (SACCO 1918, ZIENERT 1965, MAYR 1969). Our interpretation of a rockfall deposit was mainly based on morphologic evidence and on the age assigned to the boulders by means of dendrochronology and lichenometry.

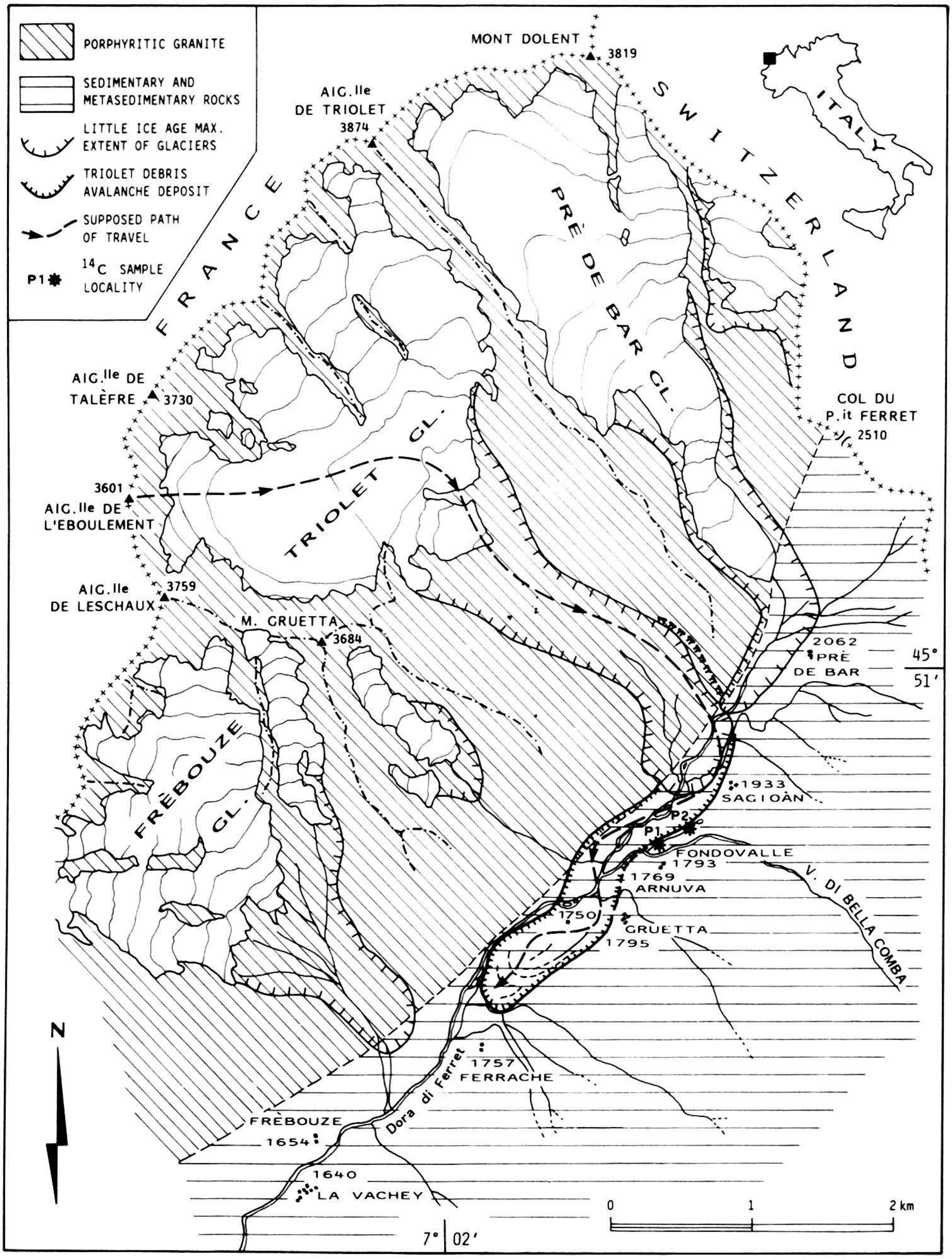
The new interpretation is significant for two reasons: 1. The Triolet rockfall deposit is one of the largest of many rockfall deposits present in the Italian valleys of the Mont Blanc group (OROMBELLI & PORTER 1981, PORTER & OROMBELLI 1981, GIANBASTIANI 1983). The correct interpretation of these deposits has great importance for the evaluation of potential geologic hazards in this crowded resort area. 2. The misinterpretation of rockfall deposits as moraines leads to the inference of a complicated pattern of late-glacial and Holocene ice advances, which appears inconsistent with regional or global patterns.

In a recent paper dedicated to the glacial morphology of the Italian side of Mont Blanc, AESCHLIMANN (1983) rejected our interpretation and again attributed the upper Val Ferret boulder deposit to late-glacial ice advances (Ferraché I and II) which he correlates with the Bocktentälli and Kromer stands of MAISCH (1982). He considers these to be the last two minor advances of the Egesen Stage, and assumes that they correspond to the latest part of the Younger Dryas chronozone and possibly to the earliest part of the Preboreal chronozone. Only the uppermost portion of the boulder deposit, near Arnuva, is attributed by AESCHLIMANN to the 1717 Triolet rockfall.

## Discussion

The interpretation of AESCHLIMANN is based principally on a $^{14}C$ date of peat from a small peat bog near Fondovalle (Fig., P1), some hundred meters upvalley of Arnuva, that was assumed to be younger than the boulder accumulation. The age obtained is 885±60 yr BP (UZ-293).

First, we can observe that the peat bog of Fondovalle is located in a sheltered position, behind a rock spur with respect to the flow pattern of the rockfall debris. The




Sketch map of the upper Val Ferret (Aosta Valley) showing the boulder deposit considered as the geologic evidence of the 1717 Triolet rockfall. The supposed path of travel of the debris avalanche from Aiguille de l'Eboulement down to the valley floor is also shown. The coarse boulder accumulation is entirely made of granite, has a very low surface gradient and a chaotic topography. Soil development, weathering of blocks, lichenometry and dendrochronology all suggest a recent and single origin for the entire accumulation, in accordance with the historic documents.

debris, moving at high speed, possibly could have passed over the peat bog without covering it. A second observation is that the peat bog is fed by a spring issuing from carbonate rocks (Jurassic limestone; CITA 1953). Consequently, an anomalously old age due to hard water can be suspected (DEEVEY et al. 1954, BOWEN 1978). In our cited paper we described the morphology of the boulder deposit; in particular we pointed out the difference between its very low surface gradient (2%) whith respect to the steeper longitudinal gradient of nearby moraines (20–40%). Moreover, the petrographic composition of the boulder deposit is strictly monolithologic. All the exposed boulders are of granite and in natural and excavated sections only granite clasts are present. This petrographic composition argues for an exclusive provenance on the northern side of the Val Ferret; if the boulder accumulation was a moraine, it should also contain the sedimentary and metasedimentary rocks which compose the southern side of the upper Val Ferret. The size and location of the boulder deposit correspond well with the descriptions contained in the contemporary accounts.

The maximum age of the trees (*Picea excelsa* and *Larix decidua*) growing on the boulder accumulation was found (in 1977) to be about 235 years. Older larches present in Val Ferret outside the boulder deposit have up to 400–500 rings. Over the surface of the deposit, boulders have a uniform lichen cover, with the maximum diameter of the *Rhizocarpon geographicum* group reaching 75 mm (1977). By contrast on early Little Ice Age moraines (Miage Glacier) larger *thalli* are present and on late-glacial surfaces they have diameters of up to 230 mm. The largest *Rhizocarpon* observed on the boulder deposit equated with an age of 255±5 years in 1977, based on the growth curve reconstructed for the Italian side of the Mont Blanc.

Thus, both lichen and tree ring age estimates suggest that the accumulation of the boulder deposit occurred in the first half of the 18th century, an age more consistent with the Triolet rockfall event than with early Holocene or late-glacial ice advances.

After publication of the paper by AESCHLIMANN (1983), we collected new data which we believe strengthen our interpretation.

## *Soils*

It is well known that in the Alpine environment the soils present on late-glacial moraines or deposits are much more developed than soils on Little Ice Age moraines, which typically constitute the largest part, if not the totality, of the exposed Holocene glacial record. On the Italian side of Mont Blanc, soils developed on late-glacial moraines have a *solum* more than 20 cm thick (25–45 cm is a common range), a well developed B horizon with yellowish-brown (10YR5/6) to dark-brown (7.5YR3/4) color, and a pH less than 6.

Soils developed on Little Ice Age moraines have a *solum* generally less than 10 cm thick, lack a well developed B horizon, have a color immediately below the A horizon of light olive brown (2.5Y5/4) to brown (10YR4/4), and have a pH higher than 6. Soils developed on the boulder deposit of the upper Val Ferret, uniformly from Arnuva to Ferraché, have a *solum* up to 12 cm thick, have a color of light olive brown (2.5Y5/4) to brown (10YR4/3) immediately below the A horizon, and have a pH higher than 6. Therefore, they are much more similar to soils developed on Little Ice Age moraines than to those present on late-glacial deposits.

## *Rock weathering*

Boulders exposed on late-glacial moraines are clearly more weathered than boulders cropping out on the Little Ice Age moraines. In Val Ferret large boulders are almost entirely composed of coarse-grained porphyritic granite. Exposed boulders of late-glacial age have an irregular surface with protruding K-feldspar phenocrysts, whereas boulders on Little Ice Age moraines are less weathered, having smoother surfaces and lacking protruding K-feldspar crystals.

Granite boulders of the upper Val Ferret deposit display surfaces with the same distinctive features as boulders of the Little Ice Age moraines.

A numerical evaluation of the different degrees of weathering has been obtained by measuring the surface hardness with a Schmidt hammer, as suggested by DAY & GOUDIE (1977). Mean rebound values (R), with 95% confidence intervals were obtained for n = 100 impacts on vertical rock surfaces of boulders on moraines of known age and on the Triolet boulder deposit (Table).

These data show that mean R values obtained for the boulder accumulation near Ferraché and Fondovalle are much more similar to the mean R values obtained for the boulders on Little Ice Age moraines than to those obtained for late-glacial erratic boulders.

Table: *Surface hardness of blocks as a measure of the degree of weathering. Schmidt hammer mean rebound values (R) on vertical rock surfaces, for n = 100 impacts.*

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|---|---|
| Late-glacial erratics near Sagioàn (1875 m) | R = 50.47 ± 1.32 |
| Little Ice Age boulders, Triolet Glacier | |
| 18th century moraine | R = 60.21 ± 1.49 |
| Same, early 19th century moraine | R = 61.71 ± 1.62 |
| Same, middle 19th century moraine | R = 61.25 ± 1.88 |
| Same, early 20th century moraine | R = 66.21 ± 1.33 |
| Same, middle 20th century moraine | R = 66.48 ± 1.26 |
| Triolet rockfall deposit near Ferraché | R = 63.93 ± 1.64 |
| Same, near Fondovalle | R = 63.22 ± 1.29 |

## *Radiocarbon dates*

A sample of basal peat was obtained from a peat bog just outside of the boulder accumulation near Arnuva (Fig. 1, P2), in company with Dr. Aeschlimann during the summer 1984. The peat bog is younger than the boulder accumulation, as judged from stratigraphic and geomorphic relationships. The sample, split in two parts, has been dated by two laboratories. The subsample dated in Paris by the Laboratoire d'Hydrologie et de Géochimie Isotopique, directed by Prof. J. Ch. Fontes, gave an age of 105 ± 70 yr BP (OROMBELLI 1987), while the subsample dated in Zurich gave an age of 1020 ± 65 yr BP (H. Aeschlimann, written communication, 1986).

A further sample of basal peat collected in the same place in 1986 has been dated in Rome and produced an age of 2320 ± 150 yr BP (R-1890).

The discrepancy between the three dates places doubt on their relevance. The peat bog near Arnuva could be affected by hardwater contamination, for it is fed by water flowing from the left side of the valley where carbonate rocks occur.

## Concluding remarks

Soils, weathering, and botanical dating confirm that the entire boulder accumulation of the upper Val Ferret, from Fondovalle down to Ferraché, is a single and uniform body of sediment of Late Holocene age. It is not partly a rockfall deposit of 1717 and partly a late-glacial moraine, as concluded by AESCHLIMANN (1983). More precisely, it is older than 1742 (tree-ring age) and immediately older than 1722 (lichenometric age).

Due to the downvalley extent of the deposit from the present glacier front (up to about 4 km) and its being clearly external to the well-known Little Ice Age moraines (for up to 2 km), the chaotic low-relief boulder deposit of upper Val Ferret cannot reasonably be attributed to a recent glacier advance; in all the Mont Blanc area, no important Holocene glacier advance more extensive than the Little Ice Age advances is known.

Lithology, morphology, age, and accordance with historic accounts all suggest that the boulder deposit of upper Val Ferret is, in fact, the 1717 Triolet rockfall accumulation. Many other rockfall deposits, interpreted by AESCHLIMANN as moraines, have been observed and dated in Val Ferret by means of lichenometry (PORTER & OROMBELLI 1981, GIANBASTIANI 1983). They include the Frébouze rockfall deposit resting on alluvial fan sediments near La Vachey, and the La Vachey and Pra Sec rockfall deposits, dating to 350–650 years ago. Courmayeur itself lies on a huge rockfall deposit that originated on Mont Blanc and which is bracketed between 2600 and 2400 yr BP (PORTER & OROMBELLI 1981). Rockfalls and resulting debris avalanches (Sturzströme) are therefore a serious potential hazard in this area. To DE SAUSSURE (1803), who travelled in this area in 1781, 64 years after the Triolet landslide, Val Ferret appeared as a barren valley, still exposed to rock falls and suggesting a vision of desolation and ruin. Today it is one of the most beautiful and green valleys in the Alps.

The geologic record of large highly destructive rockfalls and debris avalanches which lie scattered along the verdant valley floor, bear witness to the potential for future destructive events which, although rare, are an ever-present hazard, as proved recently by the Valtellina rockfall of 28 July 1987.

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