Zeitschrift: Archives des sciences et compte rendu des séances de la Société
Herausgeber: Société de Physique et d'Histoire Naturelle de Genève
Band: 43 (1990)
Heft: 3: Archives des Sciences

Artikel: A manuscript of Horace-Bénédict de Saussure on avalanches in the Swiss Alps (1795) and a comparision between 18th century and modern ideas on snow and avalanches
Autor: Carozzi, Albert V.
DOI: https://doi.org/10.5169/seals-740134

Archs. Sci. Genève	Vol. 43	Fasc. 3	pp. 371-399	1990

A MANUSCRIPT OF HORACE-BÉNÉDICT DE SAUSSURE ON AVALANCHES IN THE SWISS ALPS (1795) AND A COMPARISON BETWEEN 18TH CENTURY AND MODERN IDEAS ON SNOW AND AVALANCHES

BY

Albert V. CAROZZI *

ABSTRACT

A manuscript by H.-B. de Saussure on a spectacular wet snow avalanche which fell at Amsteg, canton Uri, in Switzerland, on March 18 1795, illustrates the status of the knowledge on snow and avalanches at the end of the 18th century. His classification of avalanches, discussed in the light of the ideas of his predecessors J. Simler (1574), J. J. Scheuchzer (1746), G. S. Gruner (1760), J. C. Fäsi (1765-1768), and B. F. Zurlauben (1784), is compared with modern knowledge and classifications on the subject.

RÉSUMÉ

Un manuscrit de H.-B. de Saussure sur une avalanche de fond spectaculaire tombée à Amsteg, canton d'Uri, en Suisse, le 18 mars 1795, illustre l'état des connaissances sur la neige et les avalanches dans les Alpes à la fin du XVIII[e] siècle. Sa classification des avalanches, discutée à la lumière des idées de ses prédécesseurs: J. Simler (1574), J. J. Scheuchzer (1746), G. S. Gruner (1760), J. C. Fäsi (1765-1768) et B. F. Zurlauben (1784) est comparée aux connaissances et classifications modernes sur le sujet.

INTRODUCTION

From the unpublished works of Horace-Bénédict de Saussure (1740-1799) a translation into English is presented here of a manuscript in his own handwriting entitled *Description d'une avalanche remarquable arrivée dans les Hautes Alpes du Canton d'Uri en Suisse, le 18 mars 1795* (Description of a Noteworthy Avalanche which Occurred in the High Alps of the canton of Uri, in Switzerland, on March 18, 1795) preserved at the Public and University Library of Geneva. Comments to the translation by the author of this paper are given in italics between square brackets.

* Department of Geology, University of Illinois at Urbana-Champaign, Urbana, IL, 61801-2999, USA.

This unusual avalanche of wet snow occurred at Amsteg which is on the road from Altdorf to the St. Gotthardt, at a time when Saussure was leaving Amsteg for Altdorf. He returned three weeks later, on April 9, 1795, to make additional observations and he rode on horseback over the remains of the avalanche.

One might wonder why Saussure visited Amsteg since it is a rather remote locality. In 1794, Saussure wrote his last field notebook during a trip to the baths of Aix-les-Bains where he was trying to restore his deteriorating health. Throughout the year 1795, his active search for a teaching position abroad, after having lost a substantial part of his wealth during the French revolution, was interspersed by trips to a variety of spas. From his correspondence, one can speculate that in early spring 1795, he went to Leukerbad, crossed over to Andermat on his way to Lucerne, and witnessed the avalanche of Amsteg on March 18. The fact that he returned three weeks later indicates that he had plenty of time at his disposal and did not reside very far; he probably stayed in Lucerne. From there he proceeded to Neuchâtel to visit his printer and check on the forthcoming publication, the following year, of the last two volumes of his *Voyages dans les Alpes*... whose galleys were being corrected at the time by his son Théodore. In July 1795, Saussure visited more spas in France, namely those of Bourbon l'Archambault near Moulins, and Royat near Clermont-Ferrand. He retired from teaching at the Academy in 1796 for reasons of poor health, and visited Plombières in July 1797, the last time he left home.

Until his death on January 22, 1799, Saussure did not remain scientifically inactive. Besides his passing interest in avalanches, he read the following papers at meetings of the *Société de Physique et d'Histoire naturelle de Genève* (see Carozzi, 1990 for complete accounts of these previously unpublished documents): on the usage of the blowpipe in mineralogy (July 19, 1795), on the classification of granular rocks (July 21, 1796), and on the affinities between granite and basalt (March 22, 1798) which related directly to the controversy generated in Geneva by Hutton's theory of the earth.

MODERN STUDIES ON SNOW AND AVALANCHES

Textural Evolution of Snow

Our present understanding of avalanches results from modern studies of the complex processes of metamorphosis of snow after its deposition. Freshly fallen snow consists of complicated and delicate hexagonal crystals which aggregate into flakes. When snow reaches a certain thickness, crystals undergo an isothermal and destructive metamorphosis during which water vapor escapes from the most delicate branches of the crystals — which are gradually destroyed — and redeposits on their central portions which become thicker. This is how, fresh dry snow with a felted texture changes first into powder snow and subsequently into finely granular and coarsely granular snow. This metamorphosis is also responsible for the compaction of the snow since granules occupy less space than star-shaped crystals.

When a snow layer remains exposed to the air for a long period of time, at low temperature and without melting, the air its contains undergoes a convection movement. Air warmer and lighter at the base than at the top tends to rise, while air colder and heavier at the top tends to sink. Since the environment is supersaturated with water vapor, the latter deposits ice on crystals in the upper part of the snow layer at the expense of crystals of the lower part. This process called internal pseudo-frost is in fact a constructive or gradient metamorphosis which generates aggregates of stubby cup-shaped to prismatic crystals. Layers with this texture are called unstable snow and although they are resistant to static stresses, they are very fragile and break under the slightest shock. They become sliding surfaces for avalanches when covered by additional snow.

When a snow layer is submitted to alternating variations of temperature between day and night but without melting, its upper few centimeters also change texture. The crystals become coarser and massive and recall the cup-shaped ones mentioned above. Layers with this texture become relatively rigid and incompressible and when crushed by additional overlying snow, they become sliding surfaces for avalanches.

When a snow layer is submitted to temporary melting in daytime under the action of the sun, and to refreezing at night, melting water percolates through the layer increasing also the size of the crystals by a process of melting metamorphosis. The final product is wet snow consisting almost entirely of subspherical particles and hence very susceptible to generate avalanches. At the same time, a superficial crust of ice is formed at night, often reworked by the wind which breaks ice crystals, rolls them around, and even aggregates them into distinct compact layers. Under other circumstances, atmospheric water vapor precipitates at the surface of the snow as frost forming irregular crusty layers. These surfaces of discontinuity are also potential sliding planes for avalanches when overlain by additional snow.

Finally, under the overburden of thick accumulation of snow, crystals are variably compacted in proportion to the compressibility of each particular layer. This metamorphosis by simple compression creates internal shear stresses and ruptures which can also generate avalanches.

Modes of Release of Avalanches

The release of avalanches is a complex process and a function of four major factors: fresh snow fall, wind action, existence of internal sliding surfaces, and warming. These factors can be combined in many ways and are not directly related to particular seasons of the year but rather to local atmospheric and terrane conditions.

Fresh snow fall is the main cause of avalanches. Up to 30 cm thick, it threatens only travellers; above 50 cm, lines of communication are endangered, and above 1 m, it becomes catastrophic and destroys villages. This threat occurs during and immediately after major snow falls, and may last for a certain period of time during

very cold weather. Danger increases with additional falls of fresh snow, but disappears rapidly either by the formation of avalanches or compaction of snow in place.

Wind influences the deposition of snow during its fall, accumulating or blowing it away, generating slabs, ridges, and overhangs. Its influence is particularly easy to recognize during early winter and spring. Wind can create dangerous situations simply by displacing snow previously on the ground. Strong winds can also eliminate the danger of avalanches at high elevations by blowing snow to lower places.

After important falls of fresh snow, sliding can potentially occur along the weakest surfaces generated by the various processes of metamorphosis of underlying older snow mentioned above. However, it is very difficult to predict when and where sliding may occur within the snow cover. This potential danger is of variable duration and is eliminated either by avalanches, compaction, or warming.

Warming decreases cohesion and makes snow creep faster thus increasing traction tension and lateral shearing. If warming increases the danger of avalanches, it also eliminates it rapidly by compacting snow layers which become protected from fracturing.

Modern Classification of Avalanches

Modern classifications of avalanches are numerous (Roch, 1955, 1980; Haefeli and De Quervain, 1955; Zingg, 1955; UNESCO, 1981). The latter is the one generally accepted today, but they all seem to take into account the following major features:

1. *Process of release.* It is either spontaneous due to increase of stresses or decrease of resistance of the snow, or accidental when resulting from a shock which in turn abruptly increases stresses generating a rupture and a decrease in resistance. Accidental causes may be internal and external in origin.

2. *Shape of release.* It can be irregularly angular in the case of a slab avalanche which originates from layers alternatively soft and hard due to melting and refreezing or compaction. It can be punctual in the case of a pear-shaped avalanche of dry, powder or wet snow with low internal cohesion.

3. *Position of sliding surface.* Superficial avalanches slide over a layer within the snow cover, whereas ground avalanches slide directly over the upper surface of the underlying terrane.

4. *Condition of the snow.* Its degree of humidity distinguishes avalanches of dry snow from those of wet snow.

5. *Morphology of the terrane along the avalanche path.* Slope avalanches develop over a uniform transversal slope whereas channeled avalanches are restricted to furrows in slopes.

6. *Main types of movement.* For avalanches of powder snow or of powder snow and ice, the movement is turbulent (aerosol) with predominant aerodynamic characteristics and very high velocities of the order of 300 to 350 km/h. For ground

avalanches which slide or flow down the slope, the movement has predominantly hydrodynamic characteristics.

A comparison of the modern classification of avalanches with those of early authors can be based on four major types:

1. Dry snow avalanche *(Trockenschneelawine)*
2. Powder snow avalanche *(Staublawine)*
3. Wet snow avalanche *(Nassschneelawine)*
4. Snow slab avalanche *(Schneebrettlawine)*

EARLY CLASSIFICATIONS OF AVALANCHES

Several major authors discussed avalanches before Saussure's contribution. The first is Josias Simler who in his *De Alpibus Commentarius* (1574) described avalanches in the Alps realizing the instability of snow on mountains as well as the fact that the slightest external influences could set it in motion. He stated that avalanches can occur at all places in the Alps, and throughout the year, but most frequently on barren slopes when snow becomes soft and melts by the increase of temperature in spring, or when large masses of fresh snow start to slide over the frozen and slippery surface of old snow during fall and winter, or finally during periods of very cold weather and clear sky (during which he said, snow was supposed to contract). Simler distinguished two types of avalanches, the first formed by freshly fallen snow which forms a ball and slides down, the second consisting of old snow which carries along a portion of the underlying soil. The latter are larger and cause more damage than the former. In essence, Simler described what are called today dry snow and wet snow avalanches, as well as the sliding surfaces of slab avalanches.

The second author is Johann Jacob Scheuchzer in his *Naturgeschichte des Schweizerlands* (1746). He wrote that avalanches are large lumps of snow at the top of mountains which fall down vertically from trees and rocky cliffs. When descending the slope of mountains they form into large balls which increase in power and size and eventually become as large as a house or even a mountain (Fig. 1). Scheuchzer stressed the fact that an avalanche occurs when any cause, directly or indirectly, sets the snow in motion on top of mountains and induces its fall. This sudden movement can originate in many ways: from freshly fallen snow itself, rain, increase of temperature in the spring, falling old trees, jumping of chamois, flights of birds, firearm shots, shouts and talks of travellers, ringing of bells, and so on.

Scheuchzer distinguished two types of avalanches. The first one is called *Wind-Lawinen*. These are mainly caused by the wind which sets in motion freshly fallen and still soft snow at high elevations and induces its fall. He added that it is possible that this type of avalanche takes its name from the fact that it moves as fast as the wind, and also from its own effect since its fall generates a strong wind which flattens everything, breaks the largest fir trees, suffocates people and cattle, and destroys houses and barns. These avalanches, he said, are also called *Staub-Lawinen* because

FIG. 1.

The early concept of the avalanche as a huge snow ball falling from the mountain. Etching by D. Herrliberger (1754-1773).

they cover entire valleys with snow dust. Some people call them also *Schnee-Lawinen* because they consist only of snow. In Italian, they are called *Lavine di Freddo* and in Engadiner *Lavigne da Fraid,* to indicate that they occur mostly in winter or during very cold weather when freshly fallen snow flakes are spongy and very porous and can be easily displaced by the wind.

The second type is called *Schloss-* and *Schlag-Lawinen.* They destroy everything resisting them, not so much by the wind they cause but by the effect of their own weight. They consist not only of old and strongly compacted snow, but also of trees, blocks, and rocks. Since they follow closely the surface of the ground, they incorporate large portions of it. Therefore, they are also called *Grund-Lawinen,* in Italian *Lavine di Caldo* and in Engadiner *Lavigne di Chiod,* because they mostly occur in spring when the return of warm weather makes the snow harder and heavier. These avalanches cause mountains and valleys to shake and produce a sound similar to heavy thunder.

Scheuchzer said that *Wind-Lawinen* are by far more dangerous than *Grund-Lawinen* because their velocity is greater and because they suddenly move either left or right according to the direction given to them by the wind. Consequently, it is difficult to escape them. However their snow is light and porous and when caught in them, it is possible to entangle oneself quickly or stay longer in them without being suffocated. *Grund-Lawinen* suffocate travellers instantly or enclose them so tightly that even if their head is free, they cannot extricate their body and hence they perish. They are therefore more dangerous than the first type, but at the same time they are less dangerous not only because their velocity is smaller than that of *Wind-Lawinen,* but also because they do not occupy such a large space, both in width and length, and therefore with adequate warning, it is possible to escape.

In summary, Scheuchzer presented a twofold classification: first, avalanches of fresh snow called *Wind-, Staub-,* or *Schnee-Lawinen* (cold avalanches in the popular terminology); second, avalanches of old snow, often contaminated by foreign debris, called *Schlag-, Schloss-,* or *Grund-Lawinen* (warm avalanches in popular terminology). He expressed the strange idea that the designation of *Wind-Lawine* came from the wind it generated rather than the wind that caused it in the first place. Scheuchzer seems also to be the author who strongly stressed the comparison of an avalanche with a gigantic ball of snow falling from the top of mountains, an interpretation probably suggested by the shape of some powder snow avalanches. Nevertheless, like Simler, Scheuchzer described what are called today dry snow and wet snow avalanches.

Johann Conrad Fäsi, rector of the parish of Uetikon, on Lake Zürich, in his *Genaue und vollständige Staats- und Erd- Beschreibung der ganzen Helvetischen Eidgenosschaft...* (1765-68) copied Scheuchzer while describing the canton of Berne, almost word for word, but did not mention the terms of cold and warm avalanches (Oechslin, 1955).

The third author, Gottlieb Sigmund Gruner in his *Eisgebirge des Schweizerlandes* (1760) stated that Scheuchzer's distinction of two types of avalanches (*Wind-* and *Staub-Lawinen,* and *Schloss-, Schlag-* and *Grund-Lawinen*) followed the usage of Alpine natives. Gruner wrote that Scheuchzer had failed to distinguish adequately the different types one from the other, and thus confused *Wind-,* and *Staub-Lawinen* which are two completely different types.

Gruner recognized three major types of avalanches with respect to their origin and effects. The first are the *Wind-Lawinen* which grow from small lumps of snow to huge balls picking up all what they encounter. Their original cause varies, but in general they are triggered by the wind, and in their incipient stages their course is also set by the wind. They always consist of freshly fallen snow or of snow which has not yet aged.

The second type are the *Schlag-, Schloss-* or *Grund-Lawinen* which are controlled by their weight. In their course, they transport with them houses, forests, and parts of soil all the way down to the bottom of valleys, destroying everything. They consist mainly of old snow forming large lumps, they do not roll down as snow balls but fall and strike altogether in a single blow.

Gruner said that both types of avalanches fall in general only in winter and are called in Italian *Lavine di freddo* and by Bündner *Lavigne du froid* (sic, *da Fraid*), thus contradicting Scheuchzer.

Furthermore, he maintained that the third type are the *Staub-Lawinen* which do not consist of lumps of snow, but only of easy separable snow which during its fall divides itself further into powder. These avalanches fall mainly at the height of the summer and not as Scheuchzer had said in winter. Gruner emphasized that this contradiction comes simply from the fact that Scheuchzer had confused *Staub-Lawinen* with *Wind-Lawinen* which fall only in winter. This third type of avalanche, Gruner said, is called in Italian *Lavine di caldo,* in Bündner *Lavigne di Choid.* This designation also includes *Wind-Lawinen* because the wind is responsible for giving the direction to both *Wind-* and *Staub-Lawinen.*

In summary, Gruner gave a threefold classification of avalanches:

1. *Wind-Lawinen* formed by fresh snow during the winter and building large snow balls.

2. *Schlag-, Schloss-,* or *Grund-Lawinen* which consist of old snow falling in large masses during the winter (*Lavine di freddo,* cold avalanches).

3. *Staub-Lawinen* consisting of dry, old and lighter snow released at the height of the summer by melting of its overlying ice crust (*Lavine di caldo,* warm avalanches).

Gruner's introduction of a third type of avalanche was based on a single example which he witnessed falling from the highest summit of the Great Wetterhorn during the summer. He said that the cause of *Staub-Lawinen* had never been stated before.

According to him, the snow at the top of the mountains where it never melts, becomes covered with a thin crust of ice which holds it as long as the crust remains hard and entire. Under the effect of the summer heat, the thin crust partially melts and breaks, and a portion of the snow it previously held together falls. Gruner pointed out that this snow is in fact an old, dried up and lighter snow which when falling upon exposed rocky cliffs breaks up into powder with a loud crackling noise recalling thunder.

Gruner's threefold classification represented a progress in terms of the nature of avalanches since he recognized what are called today dry snow, powder snow, and wet snow avalanches. However, he introduced confusion with respect to the seasons when they occur because: 1. avalanches of old snow do not fall in winter but in spring, 2. avalanches of powder snow do not fall in summer (although Gruner had witnessed an unusual example) but generally in winter. Consequently, Scheuchzer's twofold classification, incomplete but correct in terms of seasons and in agreement with the popular terminology was abandoned. Gruner's ideas were repeated by M. de Kéralio in his highly unreliable "free" translation in French of Gruner's book under the title of *Histoire naturelle des glacières de la Suisse* (1770). It was further compounded by Kéralio's statement that the snow of the *Staub-Lawinen* turns into a fine powder by falling down from rock to rock. All of this was repeated again by B. F. Zurlauben (Fig. 2) in his *Tableaux de la Suisse ou Voyage pittoresque...* (1784).

Saussure, who apparently relied only on previous references in French, followed the same classification as follows:

1. *Avalanches de vent* (*Wind-Lawinen,* wind avalanches) due to the action of the wind on fresh snow which falls almost continuously on the high Alps. They occur all year long, but most frequently in the spring under the action of the foehn and in the fall during the action of the N-W wind.

2. *Avalanches de froid* (*Schloss-, Schlag-, Grund-Lawinen,* cold avalanches) consist of old snow and generally fall in winter hence their designation.

3. *Avalanches de poussière* (*Staub-Lawinen,* powder snow avalanches), called also avalanche de chaud (warm avalanche) because they fall only in the height of the summer. They consist of old, light, dry and indurated snow, released by melting or breaking of its overlying thin ice crust, which falling down from rock to rock becomes a fine powder by repeated impacts.

Saussure simply added a few more details on the particular seasons when *Wind-Lawinen* are supposed to occur as an expression of his own interest in meteorology.

COMPARISON BETWEEN EARLY AND MODERN IDEAS ON AVALANCHES

In the absence of any concept of the textural evolution of snow under meteorological variations, early classifications relied on restricted and casual field observations, seasonal occurrences, and popular traditions.

FIG. 2.

Portrait of Beat-Fidel Zurlauben, copper etching reproduced from E. Zumbach, 1932.

Simler, Scheuchzer, and Fäsi recognized fresh (dry) snow avalanches (*Wind-* and *Staub-Lawinen*) falling mostly in winter from old (wet) snow avalanches (*Schloss-, Schlag-* and *Grund-Lawinen*) falling mostly in spring and summer. This division was in agreement with the popular tradition of respectively cold and warm avalanches.

Gruner, on the basis of a single example he had observed, made a third category for *Staub-Lawinen* as resulting from a completely different process (which obviously did occur), namely old, dry snow falling in the height of the summer after melting of its overlying thin ice crust. By his threefold classification Gruner made progress in terms of types of avalanches, but introduced confusion in regard to their respective seasons of occurrence. Thus, he not only contradicted popular tradition, a situation which was perpetuated by Zurlauben and de Saussure, but ironically also modern ideas. Indeed, if a relationship is to be found between types of avalanches and seasons, an approach which is not stressed today, it is correct that avalanches of dry snow and powder snow occur in the winter or during cold spells in the spring whereas avalanches of wet snow take place mostly in the spring and summer.

In comparison with modern concepts, all the above-mentioned early authors exaggerated the importance of the wind in generating avalanches. Their so-called *Wind-Lawinen* are in reality peculiar and rare cases of avalanches of slabs of dry, wind-blown snow called "wind-slabs". Furthermore, powder snow does not originate, as suggested by Kéralio, from a fragmentation in minute debris of snow by repeated impacts with rocks during its fall, but is generated *in situ* by the previously mentioned isothermal and destructive metamorphosis of snow.

Only Simler gave a hint about the existence of sliding surfaces generating snow slab avalanches. This type is not mentioned in subsequent early classifications probably because snow slab avalanches are mainly high elevation and relatively restricted phenomena which rarely reached as such the lower parts of valleys where most of the observations of 18th century-naturalists were made.

DESCRIPTION OF A NOTEWORTHY AVALANCHE WHICH OCCURRED IN THE HIGH ALPS OF THE CANTON OF URI, IN SWITZERLAND, ON MARCH 18, 1795

"interdum subitam glacie labente ruinam mons dedit..."

Claudian, De Bell. Get., vers. 346

TABLE OF CONTENTS

INTRODUCTION

The name of High Alps is given to the chain of frightful rocky mountains which extends from the east to the west, from Grisons to Valais, and whose summits, always covered with snow and ice reach up to the clouds while its base is adjacent to the great lakes of Switzerland and Italy. Its major summits are Mont-Blanc, Mount Gemmi [*Wildstrubel*], Grimsel, Mount St. Gotthardt, Mount Crispalt, and so on. The Canton of Uri, inhabited in the past by the Taurisci, occupies the center of the chain and often displays most of the phenomena characteristic of the highest mountains. The one described here is an avalanche which occurred on March 18, 1795, on the northern slope of the Staeg Mountain [*Stäg or Steg, today called Amsteg, the mountain is called today Bristen, 3072 m*]. The latter is one of the impressive pyramids which form the group of Mount St. Gotthardt. The Kerstelenbach flows along its eastern foot, a torrent [*called today Chärstelen Bach, Maderanertal*] that originates at the boundary of Grisons. The Reuss, located at the bottom of its northern and western slopes, comes from Mount St. Gotthardt, and flows down the Urseren Valley.

This paper reviews avalanches in general and their classification, then describes the circumstances of this avalanche and its effects, and finally describes the measures to be taken against avalanches and the care to be given to those caught in them.

ARTICLE I

GENERALITIES ON AVALANCHES

Avalanches, *lavanches,* or *lavanges* are called in Italian *lavina,* in German *ein Leenen, ein Schnee Leen,* or *Schnee Lainen,* in Swiss German, *Lauwin, Lauwenen, Schnee Laue,* and in Grisons, *Labina,* name which certainly originates from the Latin verb *labi*: to fall. Indeed, avalanches are masses of snow, either accumulated by their natural fall, or piled up by the winds on the top of high mountains from which they become loose, now by the effect of their own weight, now of the wind, and sometimes of thaw and heat. These huge masses fall down toward the bottom of valleys with a tremendous roar. Their velocity is proportional either to their weight, the slope of the mountain, or the little resistance offered by lack of rugosity or of forests capable of stopping or slowing them down along their path.

Claudian, writer of the Fourth and Fifth century described avalanches when referring to the passage of the army of Stilicon through Rhetia as follows:

"Sed latus, Hesperiae quo Raetia iungitur orae,
praeruptis ferit astra iugis panditque tremendam
vix aestate viam, multi ceu Gorgone visa
obriguere gelu; multos hausere profundae

vasta mole nives, cumque ipsis saepe iuvencis
naufraga candenti merguntur plaustra barathro.
Interdum subitam glacie labente ruinam
mons dedit, et tepidis fundamina subruit astris
pendenti male fida solo. Per talia tendit
frigoribus mediis Stilicho loca."

De Bell. Get., vers 340-349

[*The translation of Claudian's citation from the Gothic War is as follows: "But on the side where Raetia marches with Italy precipitous mountains touch the sky, scarce even in summer offering an awful path. Many a man has there been frozen to death as though he has looked on the Gorgon's head; many have been engulfed beneath vast masses of snow, and often are carts and the oxen that draw them plunged into the white depths of the crevasse. Sometimes the mountain plunges downwards in an avalanche of ice, loosening [be]neath a warmer sky foundations that trust vainly [that hope in vain to be secure] in the precipitous slope. "*

Such was the country over which Stilicho passed in mid winter... (Claudian with an English translation by Maurice Platnauer, 1922, Loeb Classical Library, London, William Heinemann Ltd.; New York, G. P. Putnam's Sons, 2 vols].

All mountains are prone to avalanches because of their elevation and steep slopes, but they occur more particularly in the Alps, from the Gulf of Genoa to Tyrol. Accounts published in Switzerland, Valais, Grisons, and Savoy contain descriptions of numerous accidents caused by these enormous slides, of houses carried away, of destroyed villages, of buried soldiers and travelers, of forests uprooted and transported randomly over long distances.

Pirckheimer of Nuremberg, high-ranking officer of the Empire, at the service of Maximilian I, recalls an event which took place in 1499 in Engadin, in the land of Grisons [1], in his history of the war that Maximilian I waged against the Swiss

[1] *Bellum Helveticum,* Lib. II, p. 20 in *Thesaurus Historiae Helveticae.* Tiguri, 1735, In fol. The author of this work is the German humanist Bilibald P. Pirckheimer (5 December 1470-22 December 1530). His father was an important public servant at Nuremberg and Eichstädt, and attendant at the Bavarian and Austrian court. His only son, Bilibald P. Pirckheimer, studied *Humaniora* at Eichstädt (that is, not only the Humanities, but also music and horse-riding). He spent seven years in Italy, not only a few months as was the norm at that time. In Padua and Pavia, he studied law, commerce, and trade while acquiring a thorough knowledge of Greek. To become fluent in the Italian language, he avoided his German compatriots.

In 1497, he returned to Nuremberg. After his father's death, he chose not to enter the services of the Emperor Maximilian, as his father had wished, but he became a public servant of the city of Nuremberg during the following twenty-five years. He was ambassador between 1511 and 1512, and the commander of a contingent of soldiers from Nuremberg against the Eidgenossen in 1499. During this war, he earned the title of "imperial advisor" and the respect of the emperor. This status aroused the jealousy of courtiers that made him quit his job for various periods of time. He finally retired, partly because of his health and partly because he wanted to dedicate the rest of his life to sciences.

With the exception of his friendship with Albrecht Dürer, he lived more and more isolated, becoming embroiled with a rival philosopher (Reuchlin) and finally with Luther, whom he denounced. Being a very independent thinker, he had both the Protestants and the Catholics against him.

in 1499, and during which Pirckheimer held a command. Four hundred men of a large detachment of the Imperial army were surprised, buried, and carried away by an avalanche so that for a while they were out of sight of their comrades who, as one can easily judge, were astonished by such an event. But their fright quickly changed into laughter when they saw them rise from their sepulchre, get rid of the snow as of a shroud, and emerge from the ground like newly-sprouted mushrooms. However, they had lost their spears, their helmets and other weapons, and their shoes in this kind of tomb. Many of them were injured either for having collided with each other, or hit rocks and masses of ice [2].

In St. Oswald church in the city of Zug, which is the main town of that canton, one can see the tomb and the effigy of the Knight Gaspard von Brandenberg (Fig. 3), who died as *Amman* or President of that Republic, on March 14, 1628. He is depicted with a spaniel at his feet which was rather common at the time and even earlier for persons of his rank as related in historical accounts[3], but in this case the reason is different. It is said, that this knight, being lieutenant-colonel in the service of Spain and in charge of defending Mount St. Gotthardt, was on his way to join his troups

---

No complete analysis of Pirckheimer's works exists. Most of his writings were in Latin, sometimes lengthy, in the style of Italian Renaissance. Toward the end of his life, he wrote a historical description of the Swiss wars, but he died before its completion. The first book traces the time between the beginning of the Eidgenossenschaft and the war against Burgundy. The second book treats the Schwabenkrieg. Only his travels with the army through the Engadin is historically of great interest because it rests on his personal experience.

[2] Baron von Zurlauben. *Tableaux topographiques, pittoresques, physiques, historiques, moraux, politiques, littéraires de la Suisse.* Paris, Clousier, 1780, in 4°, Tome 1er, 556 p., Tit. V, p. 70. [We have used the edition entitled: *Tableaux de la Suisse ou voyage pittoresque fait dans les XIII cantons du Corps Helvétique, représentant les divers phénomènes que la nature y rassemble, et les beautés dont l'art les a enrichis.* Seconde édition, 3 vols, Paris, Lamy, 1784, in 4°, vol. 1, p. 70].

Beat-Fidel Zurlauben, Baron de La Tour-Châtillon, was born and died in Zug (August 3, 1720-March 13, 1799). He went to school in Radolfzell a/Untersee until his parents passed away. At the age of ten, his oncle Franz Placidus Zurlauben, mercenary in the French army, had him move to Mantes, near Paris, where he entered the Collège Mazarin at Paris. He enrolled in the French army in 1735 but remained two years longer at the Collège. There he became interested in the Classics and history and decided to study the history of Switzerland. His first work *Histoire helvétique des Suisses et de leurs alliez* (1740) remained unpublished. During his military service, he wrote eight volumes in 8° *Histoire militaire des Suisses au service de la France* (1751-1753) which has remained a classic. Later he published *Code militaire des Suisses* in 4 vols (1755-1764) and *Bibliothèque militaire, politique et historique* in 3 vols (1760). He worked on the genealogy of Swiss soldiers in the French army but most of the collected material was published by others with the exception of what he used for his last great work *Tableaux topographiques de la Suisse...* in 2 vols, fol. with 430 etchings (1780-1786), followed by numerous other editions. In 1786, Zurlauben retired from the French army and settled down in Zug. In his *Tableaux topographiques...*, he used his personal observations made during his many trips to Switzerland from Paris. During the French Revolution, he lost a large part of his fortune but his home remained open to learned men and to French emigrants. In 1795, he had to sell his beautiful collection of books, rich in French and Swiss history, and his manuscripts to the Convent of St. Blasien. In 1802, the Swiss government bought Zurlauben's books to give them to the newly founded canton Aargau for their Kantonsbibliothek.

[3] See for instance, R. P. Dom Augustin Calmet, *Histoire généalogique de la maison du Châtelet, branche puînée de la maison de Lorraine.* Nancy, Vve J.-B. Cusson, 1741, fol., 204 pp.

FIG. 3.

Portrait of Kaspar Brandenberg, copper etching reproduced from E. Zumbach, 1932.

when suddenly, in the Leventine Valley, a league and a half from Airolo, he was surprised by an avalanche which buried him together with his valet. Fortunately, the small dog which accompanied him was spared. Having lost sight of his master, this faithful animal began to scratch the snow at the spot where he had disappeared. When it was unsuccessful in reaching him, it returned to the hospice at the top of the mountain where it began to bark, to run a short distance on the slope toward Airolo, and to come back to the hospice, repeating the same behavior during several hours until the people of the hospice, amazed by its running back and forth and barking, realized what had happened, and followed the spaniel, carrying with them spades, picks, crowbars, and other similar tools. As soon as they reached the site of the avalanche, the dog ahead of them, began to scratch the hole it had previously dug. The men of the hospice began to dig further, and after 36 hours they succeeded in delivering the knight and his valet of their terrible hardship. During their agonizing wait both could hear quite well the barking of the spaniel and the conversation among workers without being able to make themselves heard. It is said, that in memory of this service, the knight ordered the dog to be represented next to him on his tomb[4].

On March 19, 1737 a large avalanche descended from the summit of the mountains which separate Piemont from the Country of Nice and the Dauphiné, in the marquisate of Saluces, near the village of Bergamoletto or Berghemoletto[5]. It carried with it a house in which were a mother, her two children and their aunt, as well as a stable with a donkey, six goats, and a rooster. The donkey died on the first day; of the six goats, four disappeared without leaving any trace, and one of the children died the sixth day. The others survived on goat milk while these animals fed on left-over fodder, humans and animals drank water from hand-melted snow. The crow of the rooster served as a clock and even provided consolation inside that kind of tomb in which every minute spent implied a forthcoming and almost inevitable

---

[4] *Tableaux topographiques...* ibid., p. 70-71. *Tableaux de la Suisse,* 1784, vol. I, p. 70-71.

Kaspar Brandenberg held several positions for the city and the canton of Zug, in particular Ratsherr [alderman] between 1623 and 1626, and Statthalter [governor] between 1620-1623. As captain in the services of the house of Savoy, he went to Graubünden in 1620 with 400 mercenaries from Zug. Since 1618, he was frequently sent as representative of Zug to the many meetings of the Eidgenossen, in particular those that involved Graubünden. He was at the conference at Lindau where a temporary settlement was achieved on September 30, 1622. As a result of his services he was appointed lieutenant colonel in a Spanish regiment. On May 7, 1623 the people from Zug gave him the highest title of Ratsherr. He established an altar in the church of St. Oswald where he was buried on March 14, 1628. However, the tombstone visible today on the northern wall inside that church is not his as mentioned by Zurlauben but belongs to Veronika Letter-Uttinger according to the Archives of the city of Zug. References on Brandenberg are: Hans Jacob Leu. *Allgemeines Helvetisches Eydgenössisches oder Schweizerisches Lexicon...* Zürich, bey Hans Ulrich Denzler, 1741-1795, 26 books in 24 vols, in 4°, see vol. III, 1768, p. 260-261, Ernst Zumbach. *Die Zugerischen Ammänner und Landammänner. Rechtsgeschichtliche Entwicklung des Landammannamts und nach den Quellen bearbeiteter Katalog seiner Inhaber. Sonderabdruck aus dem Geschichtsfreund,* Bd. 85 und 86, Stans, P. von Matt & Cie, 1932, 10 portraits, 284 p., see p. 152-153.

[5] See in particular the anonymous Italian work entitled: *Ragionamento sopra il fatto avvenuto in Bergemoletto,* in 4°, Turin, 1738.

death. However, providence spared them when on April 23, that is 37 days after being buried under the avalanche, they were rescued from their terrifying prison[6]. This particular avalanche was remarkable by its final accumulation which was 66 feet thick, 94 feet wide, and 400 feet long. One can imagine the devastation it brought to the landscape along its path.

ARTICLE II

THE VARIOUS TYPES OF AVALANCHES

In general, the slightest movement of the air or of the ground is sufficient to trigger an avalanche, particularly when mountains are covered by large amounts of snow. These movements may be a slight gust of wind, the fall of a stone from a rocky cliff, the fall of a tree limb, the run of the smallest animal on the snow, the voice of a traveler, the flight of a bird near the surface of the snow, the lash of a whip, the ringing of church bells, even cow bells. A snow flake set in motion agglomerates with others into a clod, the mass increases, the flow accelerates, the sound is echoed back, new masses are added to the first one, and thus in a short time thousands of cubic toises *[The toise of Geneva was 2.59 m]* of snow furrow down from top to bottom the most impressive pyramid of the Alps, sweeping along blocks of granite, portions of rocky cliffs, entire forests, topsoil, houses, dams and cattle.

In reality, avalanches have only two causes: any transmission of movement regardless of its origin, and thaw. However, tradition has led to the distinction of three types of avalanches. The first, called *wind avalanche,* in German *Wind-Lauwenen,* starts with a whirlwind which at first picks up a small amount of freshly fallen snow, drags it, and increases its volume until carried by its own weight along the slope of the mountain, it doubles continuously its mass and velocity until it reaches the bottom of the valley. Since fresh snow falls almost continuously on the High Alps and wind action is also very common, this type of avalanche occurs often in these regions. They are particularly frequent in the spring, when a strong southerly wind is blowing, called in Swiss German *Foehn,* and in Italian *scirocco*[7]. Its effects are such that it blows away roofs, destroys houses, prevents in certain places to light fire in houses, interrupts navigation on lakes, in particular in the upper part of the Vierwaldstättersee. As soon as it starts blowing, grass turns green overnight, snow disappears from the mountains, glaciers melt, torrents swell, rivers overflow, and floods cover Switzerland, Germany, Holland, France, and Italy. It is therefore easy

---

[6] *Tableaux topographiques...,* ibid. p. 69, *Tableaux de la Suisse...* 1784, vol. I, p. 69.

[7] The Swiss call this wind le *balayeur de neige,* in German *der Schnee Putzer.*

to imagine that under the influence of the *Foehn,* huge masses of snow, released as avalanches, fall down from the top of the Alps to the shores of the lakes that surround the slopes of these mountains.

The sunset wind, in German *Nord-West,* which is common in Switzerland after the fall equinox, generates similar effects. It is the *iapyx* or *argestes* of the Greeks, the *caurus* or *corus* of the Latins, about which Silius italicus wrote:

"interdum adverso glomeratas turbine Caurus
in media ora nives fuscis agit horridus alis;
aut rursum immani stridens avulsa procella
nudatis rapit arma viris, volvensque per orbem
contorto rotat in nubes sublimia flatu."

De Bello punico secundo, Lib. III, vers. 523-527

[The translation of Silius Italicus' quotation on the crossing of the Alps by Hannibal is as follows: "At times, the North-west wind, menacing with dark wings, drove the snow, packed tight by the opposing gale, full in their faces; or again, the fury of the raging storm stripped the men of their shields, and, rolling them round and round, whirled them aloft into the clouds with its circling blast." (Silius Italicus Punica with an English translation by J. D. Duff, 1961, The Loeb Classical Library, London, William Heinemann Ltd, Cambridge, Harvard University Press, 2 vols].

The second type of avalanche, called *cold avalanche,* in German *Schloss-Lauwenen*[8] consists of masses of old snow which transmit the same movement to whatever object they encounter along their path down to the bottom of the valley. This kind occurs more frequently in the High Alps over barren, vertical cliffs rather than on reliefs covered with trees. Since they generally fall only in winter, Italians and Grisons called them cold avalanches (Fig. 4).

These first two types form large masses and produce a powerful roar during their descent which can be predicted when knowing the location of the ravines and furrows of the mountain. Therefore, they are easier to avoid than the next type.

The third type is called *powder avalanche,* in German *Staub-Lauwenen,* because the snow falling from rock to rock, is reduced, together with the ice, by repeated impacts into a fine powder which sometimes rises obscuring the air and leading the traveler astray. Under the influence of the wind, this type of avalanche occupies a larger space and becomes difficult to avoid. When strong, it sometimes knocks down people from a distance of several hundred toises, it could even suffocate those who do not take the precaution to turn their face in the opposite direction. I know of an observer whose desire to examine such an avalanche almost led to his death. When he approached the avalanche too closely and neglected to turn his mouth in the opposite direction, he was brutally knocked down backwards by the shock of the

[8] Germans distinguish further *Schlag-Lauwenen* and *Grund-Lauwenen.*

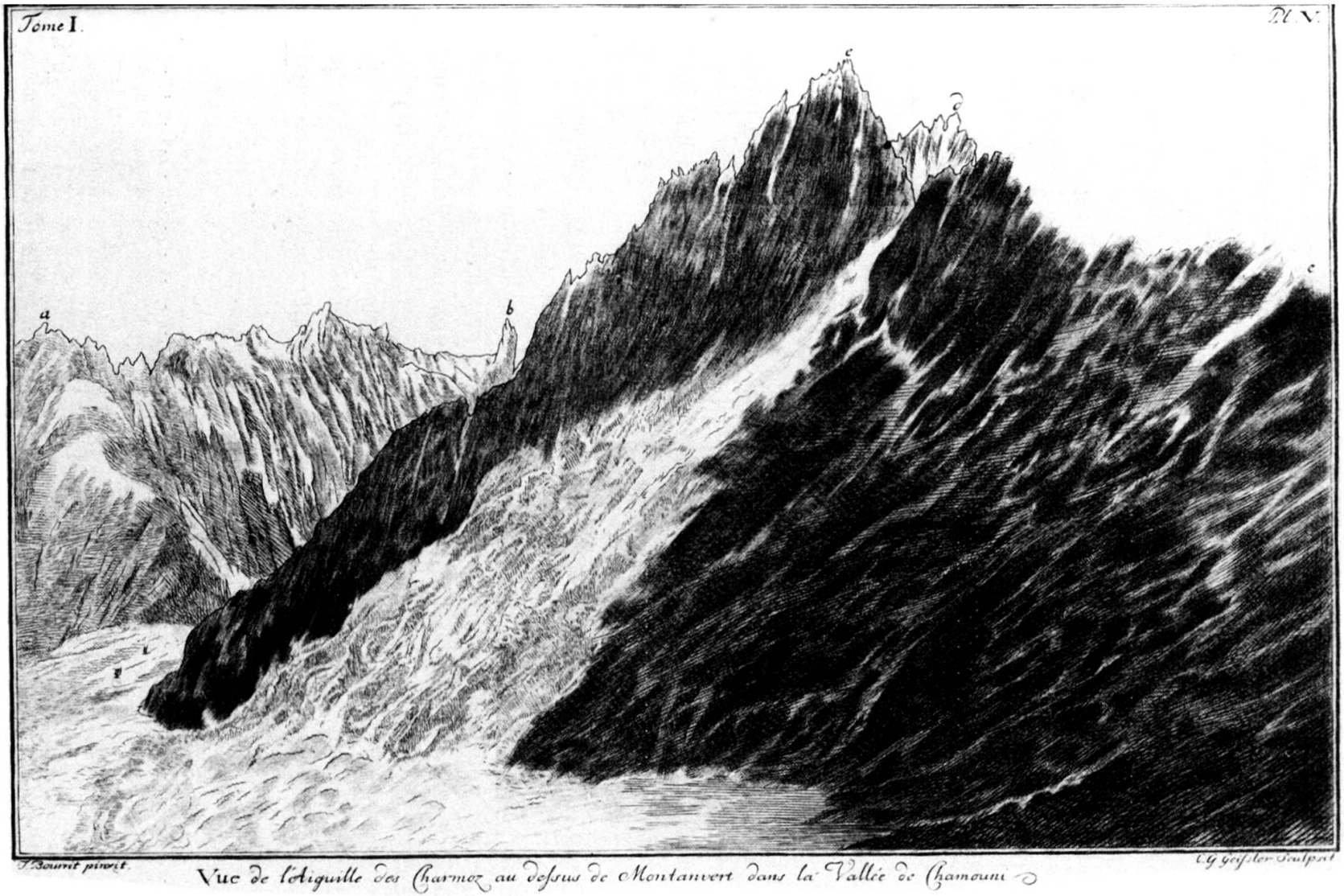

FIG. 4.

Only example of a cold (wet snow) avalanche illustrated by H.-B. de Saussure in his *Voyages dans les Alpes...*, 1779, vol. 1, plate V.: *Vue de l'Aiguille des Charmoz au-dessus de Montanvert dans la vallée de Chamouni* (drafting by J. Bourrit). This plate also illustrates the morphological changes of mountain crests from very sharp to less sharp crenulations when highly titled to vertical "beds" of granite (joint wedges in reality) contain increasing amounts of softer hornstone. The black crest in the foreground, right to left from *e* to *c* shows increasingly sharper crenulations with increasing proportion of granite over hornstone. The summit *d* which is farther away is also very sharply crenulated. From the top of the Aiguille des Charmoz *c* toward the left, all the way down to the *Glacier des Bois* (with two perssons for scale), crenulations become gradually less pronounced because the vertical beds of granite contain again an increasing amount of softer hornstone. The high chain in the background, between *a* and *b,* is *Mont Mallet* consisting of hard and massive granite, which alone can display, from a distance, such bold and well-defined shapes.

air although the avalanche was farther than 250 toises away from him. He felt palpitations, difficulties in breathing, and such painful anxieties that he would probably have died had he not been helped by his valet who was watching the event from a distance, and who gave him some drops of fluor volatile alkali which were of great help *[fluor is used here as the adjective "flowing" meaning that the substance cannot be made solid, volatile alkali are solutions of ammonia].*

A learned observer compared these avalanches rather cleverly with the sudden blowing of fine sands across the immense plains of Africa[9].

Since powder avalanches fall only in summer, Italians and Grisons call them *warm avalanches.* They consist of old, light, dry and compacted snow which covers the summit of the Alps. But, since they generally fall only during periods of highest heat, it is probable that the ice crust which was holding them, melted.

ARTICLE III

Circumstances of the Staeg avalanche

On March 18, 1795, at about 7.47 am, with a mild weather and a thin misty rain, the common barometer showing "variable" in the Uri Valley and at Staeg, and the thermometer of Lyon indicating 9 degrees above the ice point[10], I had just left the village of Staeg on my way to the town of Altdorf, 3 leagues away while other travelers with whom I had spent the night had taken the road to Mount St. Gotthardt, when I heard behind me a strong but still distant noise which seemed to get closer.

I was 40 feet away from the village, near the rock on which the famous Hermann Gessler, Imperial Bailli for the first two Swiss cantons had built a castle called *Solathurn* or *Solothurm* [11] for the purpose of conquering that land. When looking immediately behind me, I saw clearly what was causing this disturbing noise. In spite of the thin misty rain, I noticed a huge avalanche starting from the very top of the Staeg pyramid — a very high mountain which had been covered with snow for the last six months — heading northward in my direction. The avalanche had not covered

---

[9] M. Besson. *Discours sur l'Histoire Naturelle de la Suisse,* art. *Hôpital ou Hospice sur le St. Bernard* at the beginning of *Tableaux de la Suisse...,* 1784, vol. I, p. XXX-XXXIX; or *Manuel pour les savans et curieux qui voyagent en Suisse, avec notes par Jacob Samuel Wyttenbach,* Lausanne, J. P. Henbach, 1786, 2 vols in 8°. There is no extant biography of Besson, he is given as mining inspector and mineralogist.

[10] *Encyclopédie ou Dictionnaire raisonné des sciences, des arts et des métiers* (Diderot), première édition, vol. 2, 1751, art. Baromètre, p. 77-87.

[11] The rock on which it was built is called *Flühli.*

much distance as yet and had not reached the timberline, but its course was already irregular. Its head was at first single and consisted of one clod of snow as I could see from the single furrow it was forming at the beginning, but soon it increased by several others, of about the same size, formed right and left by the shock of the air generated by the first. These began to move in the same direction until their bases increased on both sides and joined into a single huge mass to which additional material was continuously added during its course, or rather its fall.

Until that time, velocity did not appear high, either because of some mist consisting of powdery snow which rose above the avalanche, or because of the lateral heads of avalanches generated on each side by the noise and the shock of the first one. However, the various heads came closer to each other while their bases increased and eventually merged into a single huge mass. After a sliding fall over the inclined rocky surface which is barren until one third of the mountain, the enormous body of snow met a less inclined terrane of a few toises. This area seems to have acted as a springboard which propelled a portion of that mass toward the entrance of the forest in which several cuttings contributed further to increase, for some distance, its huge velocity.

Now, the avalanche was seen encountering on both sides two rocky protrusions which by narrowing its width increased its velocity. Then, it collided head-on with several firtrees located along its path, which although sufficient to stop its first thrust, eventually gave way under the accumulated mass thus further increasing its weight and velocity. Finally, the avalanche reached an elevation where the temperature was sufficiently high for the snow to melt at the base. Hence, the snow of this particular area having lost its adherence made the inclined surface (consisting almost everywhere of sandy topsoil) even more slippery because the thawing had made it wet and smooth. Furthermore, that same area was strewn with blocks of granite and of common stones which, once set in motion, further increased by their mass the overall velocity.

Thus, over the increasingly inclined slope, made slippery by melt water, this huge mass gradually engulfed everything and increased its velocity and power to the extent that nothing could resist. The strongest trees were uprooted, broken, dragged along or thrown away from the path of the avalanche like bodies too light to be able to follow its movement, unless the piling up of their branches, roots, and trunks made them become an intimate part of the general mass. The largest boulders were loosened, transported, often broken into pieces by the fall, and incorporated together with entire masses of disintegrated and destroyed soil in that enormous accumulation of debris *[contaminated wet snow avalanche of modern terminology].*

At this stage, the avalanche was two thirds down the mountain, and encountered there several immovable rocky protrusions covered by various types of trees, mainly firs. Nonetheless, the frightful course of the avalanche did not slow down but it separated into three branches, the strongest being the most southern one. However,

all branches continued their paths of destruction, reached the foot of the mountain, and finally fell into the bed of the Reuss, which at that place is wide and swift.

As much as I could figure out from the beating of my pulse, the various falls lasted between 15 and 18 seconds. As soon as they were finished, I returned to the village of Staeg to obtain news of the travelers I had just left and to examine the destruction caused by this huge avalanche. I observed the following.

1. Avalanches are apparently very frequent in that region and along that particular path, because in the middle of the furrow carved by this one, one can see on the road to Mount St. Gotthardt a masonry vault built against the mountain to be used as a shelter for potential travelers surprised by such dangerous events.

2. My first action was to have people dig into the accumulation of snow and ice which closed its entrance, but nobody was there. I also had the pleasure to hear that the travelers with whom I had spent the previous night at Staeg had been fifteen minutes away when the noise of the avalanche was first heard.

3. No persons, nor cattle, house, stable or hayloft had been lost in this accident although there were stables near the path of the avalanche, but experience had taught to build them in protected places.

4. Although avalanches are frequent along this path as witnessed by natives, and particularly by the construction of the masonry vault mentioned above, such an enormous one had not occurred for a long time because along its natural path, partially carved by running water, were found topsoil, sand, rocks, and a large number of trees, among them firs more than 60 feet high and one and a half foot in diameter.

5. Destruction caused by this avalanche in the pastures it covered was estimated at about 4000 florins or guldens, but damage to the forests was much larger, and should increase in the future because the freshly uprooted trees used to act as a barrier against normal avalanches which were usually stopped there, right in the middle of their course, before reaching cultivated lands. Now, the smallest avalanche will find nothing to stop it in the future so that it shall easily extend its destruction all the way down to the riverbed that shall be obstructed.

6. The largest and most southern of the three columns into which the avalanche was divided at the bottom of the valley, was after final accumulation, 300 toises long, 6 toises high in the bed of the river, and 30 toises wide; the second and the third columns were a little smaller.

7. The whole of this very thick and very hard material, compacted by its weight and by its fall, was of a dirty gray color, sometimes yellowish by admixture of soil; one could see various types of topsoil that were once part of the entire surface, from the beginning of vegetation down to the bottom; furthermore, blueish massive ice as found all year round on top of the Alps; ice pulverized into minute, hard, angular, and prickly particles; snow properly speaking, and finally uprooted trees which however had not been carried down to the bed of the river.

8. The bed of the river was therefore cluttered by three dams of ice mixed with clods of snow, soil, and small pebbles. The river's flow had been interrupted, and formed a lake upstream of the first dam which was more than 40 feet high.

9. The mixture of these various materials formed a very hard and very resistant mass over which men and horse walked without sinking. However, many pores and small holes, similar to those of pumice, were visible.

ARTICLE IV

Effects of the Staeg avalanche

The first and most perceptible effect was a loud and continuous noise produced by the shock of the air reverberated many times by the collision of the rocks, the trees, and the masses of ice and snow which were hurled with tremendous violence from the top of the mountain down to its foot. This noise, amplified and propagated by thousand echos from valley to valley, resembled fairly well a strong thunderstorm accompanied by cannon and musket fire.

The second effect was a strong shock at the foot of the opposite mountain *[Grosse Windgällen]*, some kind of earthquake whose effect reached as far as some stables between Hirschfelden and Altdorf, that is more than two leagues *[The league used by Saussure was 4.25 km]*. This shock transmitted to the foot of the opposite mountain, which is exposed solid rock, was so strong that several fragments were loosened at high elevation and rolled down as far as the bed of the Reuss.

The third effect was a perceptible cooling of the previously mild air. Th is is no surprise if one considers the huge amount of ice and snow which was suddenly hurled down from the mountain to the bottom of the valley.

The fourth effect was a strong smell of sulfur spread throughout the atmosphere. Did it originate from the reciprocal impact of some stones or rocks which contained sulfureous matters, or from some electric phenomena? *[probably the effect of the reciprocal impact of quartzose rocks]*. I found no evidence on this fact, but it is certain that the smell was very obvious and that the coolness of the air, which had just been renewed, had something to do with it.

The fifth effect was the uneasy attitude of quadrupeds, even inside the stables of the area, as well a high degree of agitation and piercing shrieks among birds. Was it because of the shock of the air, the noise, or the smell of sulfur?

The sixth effect was an excavation among rocks and pebbles forming the bed of the river. Several of them were removed and projected, together with pieces of ice, to a high elevation on the opposite slope where they smashed tree branches, even fish were torn away from their deep waters and several trouts were found projected at more than thirty feet from the river and crushed against rocks.

The seventh effect was the interruption of the flow of the river, from the time of the avalanche until the next day at about 6 am, that is for about 22 hours. During

that time span, no water was flowing, except for a very slight seepage, so that the river, at the time rather powerful, backed up forming a small lake whose drainage would certainly have destroyed the village of Staeg located downstream on the bank of the river. If the drainage were to take place, as I feared, by a sudden rupture of the dam, I advised most of the inhabitants of the village to dig a moderately-sized channel for the water so that they would escape a danger which I thought was imminent. They answered that experience had taught them that the accumulation of such huge masses of ice, snow, and earth were strong enough to resist the pressure of the water regardless of its volume and weight, and also that before the water reached the crest of the dam and would be able to tear it down, it was likely that the flow would gradually begin at the bottom, at the very contact of the dam with the bed of the river, thus generating a small stream incapable of creating the slighest damage.

This confidence of the inhabitants appeared to me poorly founded, particularly because I recalled having read in a learned work on Switzerland[12] that: "It often happens that avalanches block valleys, that the waters normally flowing in them find no outlet and cover fertile lands, and that their floods last sometimes for a whole year."

The eight effect was that I decided to stay in the area to observe the event. I went to bed with a certain apprehension because the village was located downstream from the dam. I even took the precaution to sleep fully clothed, and asked the people in the house repeatedly to wake me up if the water should start to flow again during the night. How great was my surprise when I was informed the next day that the water had formed a moderate size outlet, between the river bed and the dam, and that the flow was occurring without any danger.

The ninth effect is that I became so interested in this natural event that I decided to return to the area as soon as possible to study these accumulations of ice, being convinced that they would show other remarkable facts. Indeed, I returned on the ninth of April, namely three weeks after the avalanche, the weather was dry and rather warm for the season.

I found the three dams still in position and without any major changes with respect to their volume. It was noon, the sun was hot, and its heat was causing the dams to ooze a small amount of water, drop by drop. The opening that the river had made below the dams was just a inch higher than the level of the water.

In fact, the three masses of ice were as strong as on the first day, and without any danger I crossed and recrossed them several times on horseback over the bed of the Reuss which at that place is more than 60 feet wide.

It is true that the heat had melted in places some portions of fresh snow which were mixed with the ice, but this did not prevent the whole mass from remaining

---

[12] *Tableaux Topographiques...*, ibid., p. 73, *Tableaux de la Suisse...*, 1784, vol. I, p. 73.

very solid. I cannot compare it better than with a random accumulation of blocks of calcareous tuff, some flat, others pointed and convex.

The ice pulverized by the shock had also melted, it was possible to distinguish within the mass, old ice from young ice by the blue-greenish color of the former. One could recognize the compacted and clodded snow which bound together these different fragments of ice, although their weight and their intimate adhesion were sufficient to make one single solid mass.

Tenth effect. On March 18 and 19, snow and ice were accumulated in the bed of the Reuss in such large amounts that I was not able to evaluate the size of all the blocks carried along by the avalanche. However, I observed boulders of granite which were 15 feet long, 10 feet wide, and 4 feet high; cubic-shaped rocks 20 feet in diameter, and several other similar blocks of all kinds of rocks. They had all been transported by the avalanche as shown by fresh markings of general abrasion visible on the various surfaces. In the bed of the river were a great number of other masses of rocks also just transported down from the mountain, but it was not possible to measure them because they were partially covered by the remains of the avalanche for which they acted as a substratum in the river bed.

Many of the other effects of the avalanche had already disappeared. The road to Mount St. Gotthardt which had been cut off, was open; woods had been cleared; soil, and stones had been removed from pastures. However, frightful prospects remained for the future: a great number of trees and masses of rocks which until now had acted as a barrier against most avalanches were gone and, for the time being, there was no way to replace them effectively. The owners should fear that these lands could be destroyed any time by the smallest avalanche, whereas travelers who cross the area, even during the least dangerous times, should take all the precautions suggested by wisdom, lest they increase the number of victims killed each year by these huge masses, which hang from the summit of the Alps to provide, during periods of drought, water to all of Europe.

ARTICLE V

MEASURES AGAINST AVALANCHES

These disasters deserve all the attention of inhabitants and travelers as well. Indeed, inhabitants take all precautions to protect themselves, their houses, their guests, and their possessions. They avoid carefully to construct on steep and smooth slopes of reliefs which are not protected by rocky salients, by forests of strong trees, nor by any kind of similar barrier. They construct even less at the foot of a steep mountain, unless a protruding rock provides a shelter, and only if storing hay from an isolated meadow or wood from some cuttings forces them to chose such a location. In such a case, they build a high and thick wall, well embanked and anchored directly on the rock. They give to the wall a half-moon shape like a fortification whose axis

points in the direction of the probable path of the avalanche, because the latter always follows the deepest portion of the slope previously used by small torrents and rainfall. Before crossing dangerous areas, during their trips, travelers make loud noises by clapping hands or stomping the ground, by lashes of whip or pistol shots so as to give to the air of the valley a sufficient shock to trigger the fall of loose masses of snow. Marching troops usually make a general shooting of musketry and artillery, preceded by a few volleys by platoons. The safest way is to cross these areas before sunrise, and if one does not know them, to hire guides.

During the crossing of these dangerous areas, natives avoid the slightest noise such as blowing their nose, spitting, or talking. They fill the bells of their draught animals with hay. They carefully advise foreign travelers to take similar precautions, and when they find them unaware of the danger because they do not realize its magnitude, they repeat their advice with great concern.

In several Swiss cantons of the Alps, for instance in Uri, on the road to Mount St. Gotthardt, as previously mentioned in the case of the village of Staeg (Article III, No. 1), and in other more elevated areas where nature does not offer any rocky reentrant or some salient suitable for protecting travelers from the surprise of an avalanche, natives usually entrench roads as deep as the height of a man, to serve as refuge for those that would be unable to escape elsewhere, and they build such roads in areas that are most exposed to such accidents. In several places of Grisons, particularly between the villages of Garda and Lavin[13], in Lower Engadin, such refuges for travelers are built into the rock itself. In other places of Grisons, like Avers, church bells hang only a few feet above the ground for fear that if put too high, their ringing would produce a shock capable of generating an avalanche. There are even places where, for the same reason, bells are not used at all.

Whenever close to an avalanche, one must, as soon as it comes within sight, turn the head in the opposite direction, because the velocity of the air produced by the fall of this mass could suffocate a person as happens to people when a cannon shell propelled by the initial force of the powder passes right in front of their mouth. The best way to avoid the avalanche is to run away from it; but if such an escape is not possible, one should seek shelter behind some rock, either salient or at least vertical. If this is also not possible, one should attach oneself as strongly as possible to the nearest rocky outcrop because even the largest trees are uprooted and dragged away. Finally, if none of these measures is feasible because of time or field conditions, one should turn the back toward the avalanche, that is, in an inclined way against it, so that the first shock would not throw the person with its face to the ground.

In the case of a powerful powder avalanche, one should throw oneself with the face against the ground, leaving enough space with the hands to breathe. It is easy afterwards to untangle oneself from the light snow which is devoid of cohesion.

---

[13] This name originates certainly from the Italian *Lavina,* avalanche.

ARTICLE VI

CARE TO BE GIVEN TO THOSE CAUGHT IN AVALANCHES

Since it occurs frequently that both foreigners and natives of the Alps are caught in avalanches and buried under them, it is appropriate to recall here the various means to save them. In the case of an avalanche of old snow, always more compact and harder than new snow, travelers or other persons who have seen someone being buried in such masses, should make the greatest effort to dig them out as fast as possible. If they do not succeed at once, it is wise to send one of their party to the nearest house to request help in men and tools, such as picks, pickaxes, shovels, and even crowbars, because some avalanches are known to have deposited masses of ice in such a way that, from place to place, areas were left between them where several rescuers could start working in zones where ice had been crushed and reduced to powder[14].

If the snow is fresh, it is easy to make enough space with the hands in front of the face in order to breathe, besides, the warmth of the breath alone can do that. Moreover, fresh snow is very porous. In fact, some persons have spent up to three days in such a tomb and eventually untangled themselves. The event at Berghemoletto, reported above in Article I, proves that as long as a person remains conscious, his fate depends on those who witnessed his accident. In the valley called Envers des Fouéneuses in Mount St. Bernard *[north slope of the Pointes de Moline (3.033 m) and southern slope of the valley of the torrent Perche which joins, flowing from the east. the Dranse at Bourg St. Bernard],* one can see a large fallen rock, at the foot of which an unlucky woman, more than 60 years old, had taken refuge when caught by an avalanche. She remained there longer than 36 hours and was eventually carried to the hospice with no particular harm done following the cold she had endured [15]. One can never praise enough the few institutions established in the Alps, either for hospitality, or for helping travelers in any manner. Such are those of the regular chanoines of Grand St. Bernard, of the Capuchin friars of Mount St. Gotthardt, of Mount Grimsel in the canton of Bern, and of a few others in Grisons, institutions that are of great value to humankind and worth the attention of governments, as well as the gratitude of travelers.

If the digging into an avalanche exposes human bodies with a corpselike appearance, they should not be exposed to fire. The first thing to do is to dip them

[14] *Tableaux Topographiques...,* ibid., p. 72, *Tableaux de la Suisse...,* 1784, vol. I, p. 72.

[15] M. Besson, *Discours sur l'Histoire Naturelle de la Suisse,* art. *Hôpital ou Hospice sur le St. Bernard,* at the beginning of *Tableaux de la Suisse...,* 1784, vol. I, p. XXXII. There is also a separate edition under the title of : *Manuel pour les sçavants et les curieux qui voyagent en Suisse.* Lausanne, Henbach, 1786, 2 vols in 8°.

in cold water so that they become as if covered by an ice coating. Then they should be dipped into lukewarm water, then in warmer water, and finally put in a well-heated bed. This treatment has returned to life persons believed to be dead[16]. The bodies of those who died in avalanches are preserved there for a long time, but as soon as they are in contact with the air, they decompose rapidly.

ACKNOWLEDGEMENTS

The author is grateful to Dr. C. Jaccard, Director of the Swiss Federal Institute for the Study of Snow and Avalanches at the Weissfluhjoch above Davos and his coworkers for their helpful comments on early and recent classifications of avalanches, and to Dr. Christian Raschle, Archivist of the City of Zug for his kind help in securing documentation on Kaspar Brandenberger and Beat-Fidel Zurlauben. Gratitude is expressed to Philippe Monnier, curator of manuscripts at the Public and University Library of Geneva, and to his associate Daniel Ryser for their devoted help during the author's research in the Saussure's archives.

REFERENCES

CAROZZI, Albert (1990). *Histoire des sciences de la terre entre 1790 et 1815 vue à travers les documents inédits de la Société de Physique et d'Histoire Naturelle de Genève. Trois grands protagonistes: Marc-Auguste Pictet, Guillaume-Antoine Deluc et Jean Tollot:* Mémoires Soc. Phys. Hist. Nat. Genève, 45, 2, 411 p.

FÄSI, Johann Conrad (1765-1768). *Genaue und Vollständige Staats- und Erd-Beschreibung der ganzen Helvetischen Eidgenossschaft, derselben gemeinen Herrschaften und zugewandten Orten...* 4 vols, Zürich, Gessner und Compagnie. See vol. I, pp. 813-815.

GRUNER, Gottlieb Sigmund (1760). *Die Eisgebirge des Schweizerlandes.* 3 vols, Bern, Im Verlag der neuen Buchhandlung, Abraham Wagner, Sohn. See vol. I, pp. 196-203.

—— (1770). *Histoire naturelle des glacières de Suisse, traduction libre de l'allemand de M. Grouner par M. de Kéralio,* Paris, Panckoucke. See pp. 349-356.

HAEFELI, R. and M. de QUERVAIN (1955). Gedanken und Anregungen zur Benennung und Einteilung von Lawinen: *Les Alpes,* 31, pp. 77-84.

HERRLIBERGER, David (1754-1773). *Neue und vollständige Topographie der Eydgenossschaft, in welcher die... Städte, Bischtümer, Stifte, Bäder, Bruggen, Wasser Fälle, seltsame Naturprospecte... perspectivisch und künstmässig in Kupfer gestochen vorgestellt werden.* Zürich, J. K. Ziegler, 3 vols.

---

[16] Physicians and surgeons are referred on this matter to M. Ruchon, *La Médecine Domestique.* Edition of Paris in 8°, Tome IV, Part II, Chapter LV, § III, where is described the manner to treat these particular cases.

OECHSLIN, M. (1955). Wie unsere Altvordern die Lawinen beschrieben: *Les Alpes,* 31, pp. 58-62.

ROCH, A. (1955). Le mécanisme du déclenchement des avalanches: *Les Alpes,* 31, pp. 94-104.

—— (1980). *Neve e valanghe.* Edizione originale in lingua italiana con la collaborazione del Prof. F. G. Agostini. Milano, Club Alpino Italiano. Commissione centrale delle pubblicazioni, 267 p.

SAUSSURE, Horace-Bénédict (1795). *Description d'une avalanche remarquable arrivée dans les Hautes Alpes du Canton d'Uri en Suisse, le 18 mars 1795.* BPU, Genève, Archives Saussure, No. 119-9.

—— (1779-1796). *Voyages dans les Alpes, précédés d'un essai sur l'histoire naturelle des environs de Genève.* Neuchâtel, S. Fauche, 4 vols in 4°.

SCHEUCHZER, Johann Jacob (1746). *Natur-Geschichte des Schweizerlandes, samt seinen Reisen über die Schweizerische Gebürge, aufs neue herausgegeben, und mit einigen Anmerkungen versehen von Johann Georg Sulzer.* 3 vols, Zürich, David Gessner. See vol. I, pp. 294-307; vol. II, pp. 71, 92-93, 105, 343-350.

SIMLER, Josias (1574). *Vallesiae descriptio, libri due. De Alpibus Commentarius... accessit his appendix descriptionis Vallesiae.* Tiguri, excudebat Ch. Froschoverius. See *Commentarius,* pp. 113-116.

UNESCO (1981). *Atlas des avalanches. Classification internationale des avalanches.* Publié par la Commission internationale pour la neige et la glace de l'Association internationale des sciences hydrologiques. In English, French, Spanish, German and Russian, 265 p.

ZINGG, T. (1955). Wetter und Lawinenkatastrophen: *Les Alpes,* 31, pp. 77-84.

ZURLAUBEN, B. F. (1784). *Tableaux de la Suisse ou voyage pittoresque fait dans les XIII cantons du Corps Helvétique, représentant les divers phénomènes que la nature y rassemble, et les beautés dont les arts les a enrichis.* Seconde édition, 3 vols, Paris, Lamy. See vol. I, pp. 67-80.