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Fatal Accidents on Glaciers: Forensic, Criminological, and Glaciological Conclusions

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ABSTRACT: The rare event of a corpse immersed in glacier ice becoming exposed on a glacier surface is closely connected with the glaciological conditions at the scene and the site of the accident. Provided that the time since death is known, certain questions relative to the circumstances of a mountain accident can only be answered by considering glaciological aspects. How the scene of an accident can be reconstructed by inference from the site of discovery is discussed by means of three exemplary cases that occurred on Tyrolean glaciers (Austria) during the past 40 years: (1) Two corpses were discovered close above the equilibrium line in the accumulation area after 25 years. The two victims had fallen down a rock face after the breaking off of a cornice and had come to rest in the uppermost part of the accumulation area. (2) A victim was discovered in the lower ablation area 8 years after falling down a crevasse in the middle part of the ablation area. (3) A female alpinist was discovered at the very end of the glacier after 29 years; it was concluded that the accident must have happened in the accumulation area.

KEYWORDS: forensic science, glaciers, accidents, mountain climbing accidents, time since death, glaciological aspects

The discovery of a corpse immersed in glacier ice many years after an accident is a rare event and is closely connected with the glaciological conditions at the scene and the site of the accident. A bibliographical study going back to the year 1976 yielded only a very few reports on discoveries of this kind [*1,2*]. On a glacier, the site of discovery of a corpse many years after the accident is not the same as the accident site, and this is of particular interest to forensic scientists and criminologists.

Glaciological Fundamentals

Every glacier is subject to a specific flow pattern, which causes a body or object to be transported along the flow lines inside the glacier by the movement of the ice (Fig. 1). When attempting a forensic or criminological reconstruction of an accident, it is essential to distinguish between the accumulation area and the ablation area of a glacier (Fig. 1). In the accumulation area, snow accumulation[2] exceeds snow melt, whereas in the ablation

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[2]Snow accumulation = snow deposited by snowfall, wind, and avalanches.

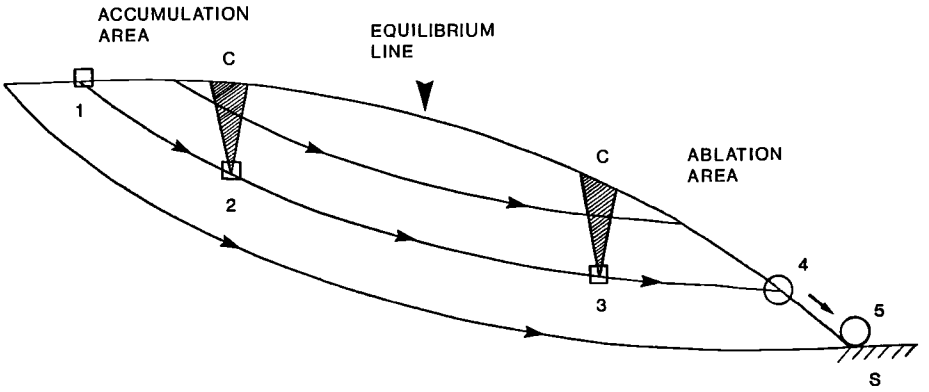

FIG. 1—*Flow lines with a glacier: C, crevasse; S, soil;* □, *sites of accidents (Positions 1, 2, and 3);* ○, *discovery of the victims (Positions 4 and 5).*

area, snow and ice melt exceeds accumulation (Fig. 1) [*3*]. The intermediate zone, where the snow melt equals the accumulation, is called the equilibrium line.

The flow movement, which is active in the accumulation area, transports a body or object deposited on the surface into deeper snow layers (vertical movement toward the interior of a glacier). In the ablation area, in contrast, the flow movement transports bodies immersed in glacier ice towards the surface (vertical movement towards the surface). At the equilibrium line, the flow lines run parallel to the surface.

We thus conclude that bodies or objects deposited in the highest part of the accumulation area will pass through the glacier along its flow lines in the deep layers of the glacier and will surface in the lowest part of the ablation area. A body deposited on the surface of the ablation area, however, remains on the surface and is transported downhill along the surface. The flow velocity changes with longitudinal and transverse profiles, with the highest velocities occurring at the equilibrium line (Fig. 2) [*4*].

In connection with accidents caused by falling down a crevasse, it is important to consider that crevasses, too, are subject to the flow movement. As they are, however, normally concealed by new snow or drifting snow in the course of the winter or compressed by compressive stresses, they are no longer visible on the surface. Later on, another crevasse opens up again in the original place. This means that crevasses can be expected to reemerge in the same places for years.

Case Reports

Following the discovery of two corpses in the Wildspitze Glacier area (Oetztal Alps, Tyrol, Austria), we investigated two further exemplary cases discovered in the past 40 years from a glaciological point of view.

Case 1 (604/90, 605/90)

On 21 Sept. 1990, the corpses of two alpinists were discovered in the upper part of the Mitterkarferner (a glacier in the Oetztal Alps, Tyrol, Austria), at altitudes of 3320 and 3340 m above sea level, respectively, and at distances of 150 and 130 m from the base of a rock face. One of the corpses was still completely immersed in glacier ice, while the back of the second corpse was frozen to the glacier surface and was resting on a socle of ice (glacier table) because of the advanced melt. After establishing their identities by

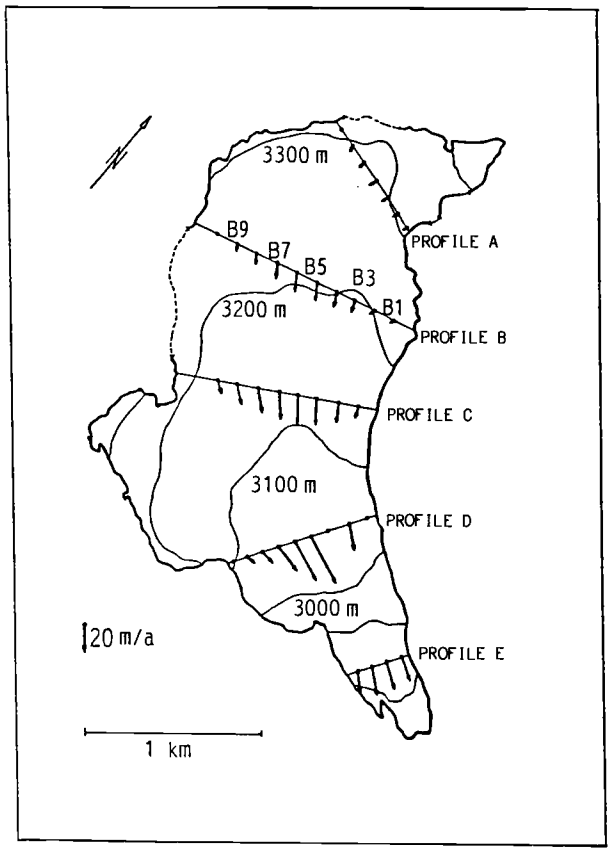

FIG. 2—*Longitudinal and transverse velocity profiles on the Kesselwandferner (a glacier in the Oetztal Alps, Tyrol, Austria) measured in 1965–1966 (Schneider, H., 1990).*

documents in their knapsacks, it was found that the persons had been reported missing 25 years before. Furthermore, it was possible to determine the meteorological conditions on the day of the accident, which was 25 Aug. 1965, and the original route taken by the alpinists. In one corpse, examination showed severe skull fractures and injuries of the upper cervical spine as the cause of death. The other alpinist had died from severe injuries of the chest, and multiple bone fractures with pulmonary fat embolism.

Glaciological Comment—This case is particularly interesting because the corpses were discovered close to the equilibrium line in the accumulation area after only 25 years. In view of the flow movement of the glacier, it would have been assumed that the corpses would become exposed in the ablation area, at a much later date, after passing the interior of the glacier. The path and time yield a mean flow velocity of less than 6 m $year^{-1}$ for the two corpses. A glaciological approach to account for this relatively low flow rate suggests the following explanation: As a result of the breaking off of a cornice, the alpinists fell 200 or 250 m and came to rest in the accumulation area at the base of the rock face. In the course of the years, the vertical movement of the glacier flow transported them into deeper layers below the surface. In general, one cannot expect that the flow lines above the equilibrium line will reach the surface again. In this instance, however, the premature discovery of the two corpses can be explained by the heavy snow melt in

the years before.[3] Flow velocities under 6 m year^{-1} can be obtained when the casualties have slid down the surface during the accident because of the steepness of the glacier surface (35° to 40°).

Case 2 (ENr. 1474/73)

In 1973, the strongly putrefied, partly mummified corpse of an alpinist reported missing in 1965 was found on the surface of the Gurglerferner (a glacier in the Oetztal Alps, Tyrol, Austria) at an altitude of 2800 m above sea level. The victim had fallen down a more than 40-m-deep crevasse. The man was identified by his wearing apparel and personal objects and his engraved initials. The medical examiner diagnosed severe injuries of the chest and the abdomen.

Glaciological Comment—In this case, the documented circumstances of the accident are fully consistent with glaciological analyses. The time and path yield a flow velocity of approximately 20 m year^{-1}. Considering the glaciological conditions, this value coincides largely with glaciological measurements [*4*]. From a depth of more than 40 m, the corpse was transported along a flow line in the ablation area over a distance of 150 m before it reached the surface.

Case 3 (195/52)

At the very end of the Madatschferner (a glacier in the Oetztal Alps, Tyrol, Austria), the corpse of a female alpinist was discovered on ice-free terrain, but not at the terminus of the glacier, after 29 years. Identification was done with the aid of the identity documents and the wearing apparel. The circumstances of the accident in 1923 were unknown. The medical examiner supposed that there was a fall down into a crevasse, as severe bone fractures of the extremities were determined at the autopsy. The cause of death remained in doubt, because of a complete transformation of all organs to adipocere. Probably, the cause of death was hypothermia or a pulmonary fat embolism.

Glaciological Comment—There is a trail leading across the uppermost part of the glacier. Assuming that the accident happened on this trail, the path and time would result in an average flow velocity of the immersed corpse of between 25 and 35 m year^{-1}. This value is too high in comparison with the glaciological conditions on the Madatschferner, which is a relatively small glacier (length, 1.1 km; maximum width, 0.6 km). We must therefore assume that the accident happened off the trail, at a much lower altitude. It is further remarkable that two alpinists accompanying the victim, who were also reported missing, have not yet been found.

Discussion

When corpses immersed in glacier ice after fatal accidents are discovered after a long time, and when the time since death is known, glaciological expertise facilitates the reconstruction of the scene and the site of the accident. It is essential to know that bodies deposited or immersed on or inside a glacier are transported downhill along the flow lines, which explains why the site of the accident and the site of discovery do not coincide. Besides the examples dealt with in the case reports described, the flow conditions in a glacier permit various reconstructions (Fig. 1). If a body emerges in the ablation area (Position 4), the following accident sites are possible: an accident on the surface of the accumulation area (Position 1), a fall down a crevasse in the accumulation area (Position

[3]Kuhn, M., personal communication, 1990. Data available from the Institute of Meteorology and Geophysics, University of Innsbruck, Innsbruck, Austria.

2), and a fall down a crevasse in the ablation area (Position 3). The three possibilities differ with regard to the time of the accident. A body that emerges on the surface of the ablation area (Position 4) will be transported farther downhill and is finally deposited at the very end of the glacier (Position 5). This site of discovery, in turn, permits various possible accident sites along the corresponding flow line, as described in Fig. 1. If a body is recovered in the glacial creek at the glacier terminus, for example, the only possible conclusion is that the victim fell into one of the channels connecting with the glacial creek. Such connecting channels are often formed, especially with glacier moulins, in the ablation area.

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