WIND SLAB AVALANCHES

By Gerald Seligman

The consolidation of snow by wind action is perhaps the most interesting of all the metamorphoses undergone by fallen snow.

This article deals with only two aspects of a wide subject; one is theoretical and the other is of importance to the man in the field, since the hardened snow cover, sometimes extending over large areas of the hill-side, can break up into a very dangerous type of avalanche.

The Cause of Wind Slabs

Between the years 1932 and 1936 I carried out a large number of experiments on wind slab development. I submitted my results to Sir William Bragg, Sir Charles (then Mr. C. S.) Wright, Sir George Simpson and Mr. L. G. Dobbs. The experiments and the comments of these gentlemen are recorded in my book, *Snow Structure & Ski Fields* (London: Macmillan & Co., Ltd., 1936), which devotes much space to the subject. The conclusions reached were (p. 200):

> From all the above findings and arguments it is reasonable to conclude that wind-packing consists of the compacting of snow grains by the condensation of water vapour among them when subjected to the action of a moisture-bearing wind. It is practically certain that at any rate some of this moisture is derived from the grains themselves. *We can therefore define wind-packing as a special form of firnification accelerated by a wet wind.* The mechanism of the process is probably one of wind-accelerated diffusion which may or may not be influenced by pulsations or pressure variations of the wind.

Soon after this R. A. Bagnold published the results of his classic experiments with desert sand, later summarized in his *The Physics of Blown Sand and Desert Sand Dunes* (London: Methuen & Co., Ltd., 1941), in which he showed that even with perfectly dry sand a certain hardening takes place under wind action.* The general principle is that in drifting, grains of suitable size shake themselves into spaces between other grains just large enough to accommodate them and jam themselves firm.

No doubt the same holds good for snow. Nevertheless my experiments showed so conclusively that snow packing takes place when the wind contains a good deal of humidity and that there is a distinct alteration in the structure of most of the grains, that it is safe to say that the riddling action described by Bagnold is supplementary and not exclusive.

This two-fold cause of wind slab formation has now received satisfactory endorsement from Dr. R. U. Winterhalter, a well-known authority on the physics and crystallography of ice. In a private communication he writes that under all conditions (windy or otherwise) metamorphosis of the snow particles will take place. "Also," he says, "if there is snowfall with wind, or if, after the fall, snow transportation by wind takes place, it is evident that the snow particles will become riddled together and close packing will result."

* Seligman, G. *Zeitschrift für Gletscherkunde,* 1938, pp. 124–25.

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This, I think, corresponds tolerably well with my own definition italicised above, "metamorphosis" being equivalent, although broader in meaning, to my "firnification," but Winterhalter does not go so far as to say that the metamorphosis is accelerated by wind, which I am certain is the case. He also does not appear to believe in the humidity factor, but this too is a certain prerequisite, for dry wind evaporates snow and would retard or inhibit its firnification.

Winterhalter also brings in two new points. He continues: "A distinct separation of the effects of metamorphosis and of pure wind influence cannot be obtained; but the effect of both factors together can be measured experimentally and it is possible to vary the metamorphosis in nearly every degree by changing the temperature."

This aspect of temperature is new to me. The only observations I had made on this point were that wind-packing only takes place below freezing point and that it has been seen to occur at temperatures as low as −50° C. (*op. cit., p.* 201).

Winterhalter's other point is that slab avalanches occur "after many snowfalls without any wind." I must admit that I have never heard of this phenomenon before; nor have I seen it mentioned in any of the writings of the very large number of authorities I have consulted.

If, indeed, windless slabs occur which exhibit all the characteristics of wind-formed slabs, such as the causation of slab avalanches, it will need, as Winterhalter suggests, a new word, "snow slab" in our nomenclature. The Swiss certainly use the word "Schneebrett" as well as "Windbrett," but I had always thought that the two words were used loosely and interchangeably.

Winterhalter concludes his letter: "I think that in order to obtain more knowledge, the influence of wind (velocity, frequency etc.) must be measured in different fields (exposures) and much laboratory work must be done to understand the wind effect on metamorphosis and packing."

That is essential; indeed the purpose of this article is to draw attention to the field and laboratory work which needs to be done. My own experiments were conducted with the crudest of apparatus and in the crudest of laboratories or in the field under particularly severe and difficult conditions. My hope is that with their beautifully equipped research stations, their unrivalled opportunities for field observation near-by and their great theoretical interest in snow metamorphoses, the Swiss authorities will clear up these uncertainties.

The Orientation of Wind Slabs in Relation to the Wind

To the skier and ski-mountaineer it is of the utmost importance to know where wind slabs are to be found, so that they may know what slopes to suspect as being potentially dangerous and what slopes may be crossed with a degree of confidence.

In the work cited above (pp. 418–21) I gave the views of many authorities. A few held that wind slabs were to be found on ridges or in exposed positions, but the majority believed that they were prevalent to the leeward of ridges. I myself subscribed to the latter view, but later I qualified this by naming a series of cases where they might be found elsewhere.*

* Seligman, G. *British Ski Year Book*, Vol. 9, 1937, pp. 85–9.

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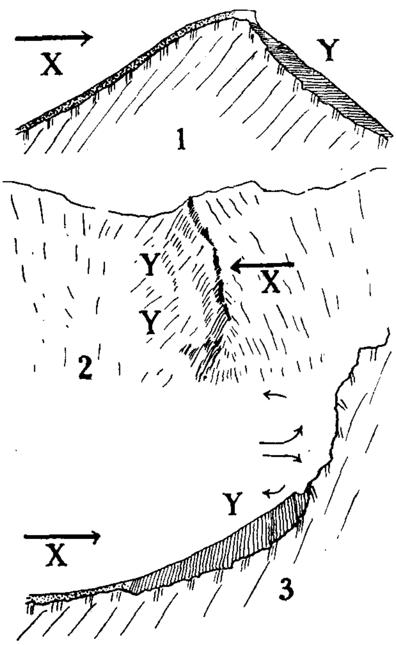
Fig. 1 is, in my opinion, the normal case. The wind driving from X looses speed and carrying power as it crosses the ridge and the snow it has collected is deposited at Y.

Fig. 2 shows a slope orientated at an acute angle to the snow-bearing wind. When snow drifts from X to Y enormous slabs are found at Y. An actual example of this is shown in the photograph (Fig. 4, Pl. III), taken in the Haupter Täli, Davos. This valley runs a little west of south and the snow-bearing wind blew almost straight up it, from right to left in the photograph. A great wind slab collected to leeward, i.e. to the left, of the great buttresses seen to the right of the avalanche. Had it not been for the protective influence of these the slab would not have formed. This, then, is only a specialized case of the conditions seen in Fig. 1.

Fig. 1.⟶

Fig. 2.⟶



⟵*Fig. 3.*

Fig. 3 shows quite a different effect. Here we have a not very steep slope culminating in a cliff; the wind is blowing straight against this cliff. Vortices are formed there and the wind loses its carrying power so that snow is thrown back to windward and deposited as a wind slab at Y. Fig. 5, Pl. III shows an example of this in the Zillertal, Tirol. The arrow denotes the scar of an enormous wind-slab avalanche which fell from there.

These three cases are typical of the great majority of positions in which I have found wind slabs. If these were the only possible positions there would be no problem. All that the ski-mountaineer would have to do would be to ascertain the direction of the snow-bearing wind—this is generally not difficult—and the configuration of the terrain would tell him the rest.

But the facts have not been fully established, and in spite of the many who support my view expressed above, there are others who, speaking with authority, oppose it.

Particularly strong opposition comes from Canada. Mr. J. C. Mackey, Chairman of the Snowcraft Committee of the Rocky Mountain Zone of the Canadian Amateur Ski Association, writes that in his experience 95 per cent. of wind slabs are found on the windward side of a mountain, and mentions that the two chief guides in Banff National Park, Engler, a Swiss, and Kutschera, an Austrian, both confirm this. Mr. Don Munday, the well-known Canadian mountaineer and skier, has told me that in his view slabs in the Rockies are found mostly on exposed ridges. It has been suggested that the western Canadian conditions of extreme cold—the winter average is said to be in the neighbourhood of zero Fahrenheit—induce a new factor, but I doubt it.

Dr. Winterhalter believes that the fact that more wind slabs are found on the lee sides of a mountain may be due rather to the bigger accumulation, which one would naturally expect there, facilitating the metamorphosis, but adds, "... often after windy weather you can see slab avalanches on all sides of a mountain, leeward and windward alike."

May I here again express the hope that a research be carried out by the authorities at the Weissfluhjoch. This would mean the collection of very simple data from a large number of districts. It may be that the results will show that it is impossible to dogmatize too much, but if, on the other hand, it is found that certain principles can be laid down, and I believe this will be the case, the result will prove of the greatest value.

INSTRUMENTS AND METHODS

Under this heading it is intended to describe any new apparatus or method of research likely to be of value to glaciologists. The Editors will be pleased to receive contributions for this section.

SUB-SURFACE TEMPERATURE MEASURING EQUIPMENT*

DURING the United States Antarctic Service Expedition of 1939–41† resistance thermometers were used for measuring sub-surface temperatures at "Little America." The temperature-sensitive elements consisted of copper resistance coils wound on a brass tube (Fig. 1, Pl. IV). The finished coil, wound with 0·0035 in. diameter wire, was about $\frac{3}{8}$ in. in diameter and 2 in. long. The resistance of the coil in each thermometer was accurately adjusted to 100 ohms at 20°C. Each coil was connected to the conductors of a 3-lead rubber-covered cable to form a thermometer of the Siemen's compensated type.

Each coil was protected by a closed end brass tube about $\frac{1}{2}$ in. in diameter and $4\frac{1}{2}$ in. long (Fig. 2). The end of the brass tube that carried the coil (arrow *a*, Fig. 1) was soldered to the inside of the closed end of the protecting tube in order to enhance the heat transfer between the latter tube and the coil. The protecting tube was attached to the cable by rolling the brass into the rubber covering at three points (arrow *b*, Fig. 2). This, in addition to a wrapping of waterproof tape over the coil, provided the required protection against moisture.

The temperature readings were made with portable instruments of the balanced Wheatstone bridge type (Fig. 3). Each instrument had two scales each 10 in. long, graduated in intervals of 0·2° C. One scale was from −70° to −28° C. and the other from −32° to +10° C. The resistance

* These details are published by permission of the Director, National Bureau of Standards, U.S.A.
† See *Journal of Glaciology*, Vol. 1, No. 1, 1947, pp. 23–31.