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ICE PYRAMIDS ON GLACIERS

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Paper communicated to a Meeting of the Society on 17 February 1949

ABSTRACT. Waves of ice on the Gorner Glacier (Switzerland) are described. These finally assume an appearance very similar to the ice pyramids of the Himalaya. The author shows that the former originate as avalanche snow which remains above the general surface of the glacier through its lightness and greater resistance to ablation than the denser glacier ice, and suggests, as do Visser and others, that some Himalayan ice pyramids also originate as avalanche snow.

ZUSAMMENFASSUNG. Eiswellen des Gornergletschers (Schweiz) werden beschrieben. Diese nehmen schliesslich eine sehr ähnliche Form an wie die Eis-Pyramiden des Himalaja. Der Verfasser zeigt, dass die ersteren aus Lawinenschnee entstehen. Diese bleiben infolge ihrer Leichtigkeit und ihrer Widerstandsfähigkeit gegen Ablation, die grösser ist als die des dichteren Gletschereises, auf der Oberfläche des Gletschers haften. Der Verfasser vermutet, dass einige der Himalaja Eis-Pyramiden ebenfalls aus Lawinenschnee hervorgegangen sind.

MANY accounts of Himalayan mountaineering expeditions give short descriptions of ice pyramids, unique spires of glistening white ice rising to considerable heights above the flat valley glaciers (see Figs. 1 and 2, p. 376).

They have the following characteristics:

1. They consist of unusually clean, white ice. I have been informed by members of the American Alpine Club expeditions to K2 that this ice is more "snowy," definitely whiter than the ice which constitutes the glacier proper in the same vicinity.
2. They rise from the flat, debris-covered floor of the dry glacier.
3. Their height may be 150 ft. (45 m.) or more.
4. They are ranged in a narrow file, lengthwise of the glacier and exist only in one particular lane of the glacier.
5. Along that lane the file of these towers may be one or two miles (1·6–3·2 km.) in length.

There appear to be no photographs in which one can follow an ice pyramid up the glacier to the point of its first appearance with sufficient certainty to ascertain from what particular surroundings the *névé* of that lane was derived. The obvious beauty of these pinnacles and the doubt concerning their origin poses a challenge to us to endeavour to seek the factors which bring them into existence.

While traversing the Gorner Glacier in 1948 I noticed certain phenomena which suggested to me conditions which might be responsible for the formation of at any rate one type of pyramid. The Gadmen-Bétemps trail crosses a lane of ice notably whiter than the rest of the glacier. This white lane is clearly shown in Fig. 3, p. 376. Very conspicuous on the white lane are small ablation holes which, increasing in size as one proceeds towards the valley, ultimately merge into one another until the glacier surface is covered with large holes a metre in diameter, of irregular round shape and some 70 cm. deep. These are the *Kryokonit* holes of von Drygalski.

Following the lane downwards the holes are no longer a prominent feature but as they begin to vanish the ice becomes more and more billowy, like a "stale" sea in the Atlantic, with waves 3–5 metres high. Still farther down the rounded troughs between the waves expand by eating into adjacent waves and become flat, debris-covered areas. The remaining disconnected waves now look, for all the world, like the ice pyramids of the Himalaya, except that they are of course much smaller and not so rugged as in the Himalayan photographs. The photograph in Fig. 4, p. 377, gives an idea of these pyramids on the Gorner Glacier.

Walking still farther down the glacier there is no longer any white ice; the surface consists of debris; the white lane has vanished. This is seen in Fig. 3, which shows the wedge of the white ice lane disappearing in the normal process of ablation and leaving only debris on the glacier surface.

Samples showed that the ice of the white lane was full of air bubbles, whereas the rest of the ice appeared more or less air-free (see Fig. 5, p. 377). Density measurements, subsequently made, showed a specific gravity of 0·82 as against 0·91 for the normal ice.

The nature of the white ice thus gives a clue to its origin and this is confirmed if its course is traced up-stream. It is easy to follow it to its origin in the *névé* of the north-facing cliffs of the Nordend of Monte Rosa, which are capped by a hanging *névé* field.

The tributaries on either side of it derive from the Cima di Jazzi and Grenz *névés*, fed by direct accumulation of snowfalls which have been subjected to spells of sun and rain so that they develop under almost constant exposure to weathering. On the other hand the white ice lane *névé* is largely supplied by the debris of avalanches cascading down the Nordend cliffs and delivered to the *névé* as irregular but very deep additions of snow and ice in finely powdered form. It is thus well aerated and colder, coming as it does from higher regions.

Such fine, cold aerated material, accumulated in great avalanche dumps, can hardly be expected to firnify in the same way as snow under normal conditions. It may be expected to retain its air content better and thus provide the aerated and therefore less dense ice of the white lane. As this lane travels down the glacier, flanked on either side by denser ice, the parallel walls of denser ice will tend to gravitate sidewise under the less dense ice, lifting it up. This lighter ice will probably melt away slower through radiation than the adjacent darker ice, and it is a fact that it rides higher, by 20 metres or so, than the main body of the glacier.

Visser believes that the pyramids he saw in the Karakoram owed their origin to avalanche snow. But he ascribes their ultimate form to their being subjected to cleavage in all directions. These stresses would provide the necessary conditions for selective melting into their characteristic shape.

While I have been able to show that the Gorner pyramids originate as avalanche snow my view of their development is different. As I have pointed out, the white lane is covered with ablation holes and my view is that the merging together of these starts the hollows between the pyramids. Clearly there is much work to be done before the problem of ice pyramids is completely solved.

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DISCUSSION

The CHAIRMAN, Mr. W. V. Lewis (Dept. of Geography, Cambridge University), then opened the meeting for discussion.

Mr. W. H. WARD (Building Research Station, Watford): The whiter, less dense, ice described by Mr. Fisher could stand up above the denser and darker ice after the two streams have joined up for one or more of the following reasons:

1. The dark ice of the main glacier has, as it were, priority at the bottom and the white ice comes in on top and cannot sink immediately.
2. The white ice being lighter in weight would tend to ride lightest.
3. The white ice probably melts less rapidly than the dark; it certainly reflects more radiation.

It would be difficult to decide which of these processes predominates without some quantitative evidence.

Dr. N. E. ODELL (Visiting Professor, University of British Columbia) (Communicated): Mr. Fisher kindly sent me a copy of his paper, which I have read with interest. Although his is an ingenious and perhaps possible explanation of ice hummocks on the Gorner Glacier, and perhaps other glaciers, I am dubious of its application to most occurrences I have seen. It will certainly not do for example for the pinnacles of the Everest glaciers. These do not originate from zones of avalanche debris. On the contrary they originate, as I have pointed out in the Appendix of H. W. Tilman's *Mount Everest* 1938, where "sun-pit" hummock structure operates in the vicinity of a "glacier trough." The trough is formed of up-ended and sheared bedding planes along ablation junctions of convergent ice streams which are often marked by medial moraines. The origin of the pyramids on the East Rongbuk Glacier can actually be traced to the walls of the upper part of the trough. The trough is a corridor some 50 ft. (15 m.) deep and 100 ft. or more wide, with steep sides buttressed and pillared with fretted ice of exquisite tints of blue and white and green. It runs longitudinally down the East Rongbuk Glacier from about the 20,000 ft. (6100 m.) contour continuing to about 18,750 ft. (5715 m.) and lying some 400 yds. (366 m.) from the true left bank. At its upper end was a beautiful development of "ogive" banding. There was much evidence of severe stresses above the trough which seems to be a line of special stress between two ice streams, one from the tributary glaciers from the North Col and Changtse, the other from the main glacier mass from the east. Its formation appears to be due to the compression of the smaller western streams by the main eastern mass, especially in the narrow constriction near the western spur of Khartaphu.

I visualize the development of the pyramids in the following way: the salients, or buttresses, of the ice walls are progressively wasted back by ablation processes other than melting until isolated individually along the trough margins. Then, with progressive wastage and general spread of moraine-floored troughs, one finds in the lower glacier reaches the long lines of pinnacles alone left to mark the original trough margins.

As one of my illustrations in *Mount Everest* 1938 shows, these pinnacles often retain evidence of both bedding (upturned) and foliation due apparently to pressure and shear at the initiation of a trough along converging lines of tributary glaciers.

Mr. G. SELIGMAN: I have always thought that the pyramids were the remains either of avalanche snow or of ice from a hanging glacier falling on to the main glacier and I was interested to note that both Visser and Fisher subscribe to that view. Some of the photographs shown us this evening also seem to indicate clearly that the pyramids are of adventitious ice, if I may call it so, that is to say they appear to be of different ice to that on which they stand as though they had been deposited upon it. But, the opinion of Dr. Odell, who has seen these phenomena, is entitled to greater respect than that of one, like myself, who has not. Perhaps we have two types of pyramid with different origins. Here, as in so many other cases, we need careful records of the crystal structure of the ice of pyramids and of the ice on which they stand.

A further paper read at this Meeting—The origin of dirt cones on glaciers, by Charles Swithinbank, is held over.—Ed.

Fig. 1. Ice pyramid on the Baltoro Glacier 45 m. high. Note figure near base
Photograph by P. Petzoldt

Fig. 2. Ice pyramids. Note figure
Photograph by Ph. C. Visser

Fig. 3. The Gorner Glacier showing (left centre) the cliffs of the Nordend (Monte Rosa) from which avalanches fall forming the "white lane" which finishes in the centre of the photograph. The ice hummocks shown in Fig. 4 were photographed at the sharp bend of the white lane beneath Monte Rosa
Photograph by J. E. Fisher

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Fig. 4. Ice hummocks near the end of the white lane shown in Fig. 3

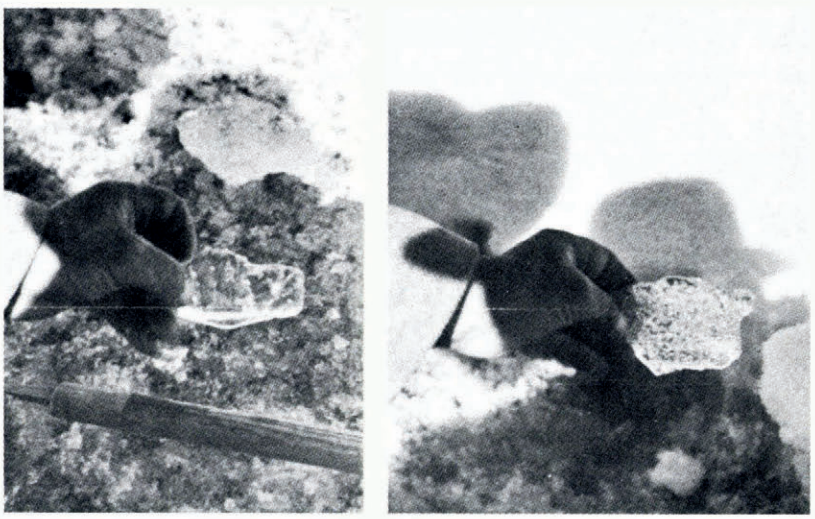

Fig. 5. Left, clear ice from the main mass of the glacier
Right, bubbly ice from the white lane

Photographs by J. E. Fisher

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