energy and we regained our sleeping quarters after twelve hours. By British standards the climb might be classed just ' very difficult.'

Apart from these two climbs I was only able to take part in two other big expeditions : a second traverse of the Corno Piccolo S. ridge led by one of the L.R.D.G. and the ascent of Torrione Cambi by the Camino Iannetta and central peak of the Corno Grande, led by James Joyce. This was our last expedition and to me at all events it was severe. The route followed the S. face of the Corno Grande to the Forchetta del Calderone. Here the serious work started and the next 300 ft. took four hours. The lower part of the chimney was steep ice up which steps had to be cut. Halfway up the gradient eased off to be followed by a perpendicular, if not overhanging section. This latter part was severe. From the summit of the Torrione Cambi the central summit was gained quite easily. For the descent we roped down using a very rickety piton for the bottom section.

There are many other magnificent climbs in this area : the traverse of all three peaks of the Corno Grande done by Douglas Side, E. to W., in fourteen hours from the hotel ; the Tre Spalle or W. ridge of the Corno Piccolo which was done twice, I think, by James Joyce—probably one of the finest climbs in the district ; S.S.E. arête of the Corno Grande which should only be attempted under summer conditions and defeated a strong American party, and many more climbs of all shades of difficulty.

This account has necessarily been a personal one and therefore very limited in scope, but it is hoped that some indication has been given of the possibilities of mountaineering in this region. If anyone should find himself in Central Italy and unable to reach the Alps or Dolomites, I do not think he will be disappointed if he pays a visit at any season of the year to the Gran Sasso.

SNOWCRAFT AND AVALANCHES

By GERALD SELIGMAN

Read before the Alpine Club, May 6, 1947

I HOPE that the title of this paper may not prove misleading. The term ' snowcraft ' has a wider meaning for the ski mountaineer than for the man whom, for lack of a better name, I will call the summer mountaineer.

I am going to be mildly controversial for a moment. I am going to affirm, without going into details, admittedly a provocative proceeding, that today the complete mountaineer must also be a ski mountaineer. That means that for him snowcraft must assume a wider meaning than is accepted by the summer climber. It must embrace two themes of little or no importance to the latter. These

are, the safety of the slopes over which he may have to ski, and the condition of the snow which will give him the easiest, and incidentally the most pleasant, skiing. It is of these last two that I am going to speak. Indeed, if the snowcraft of the summer mountaineer were the order of the evening I could, with advantage, change places with any of my audience.

I have no hesitation in grouping summer and winter snowcraft under a single heading, for all snowcraft depends primarily on the peculiar habits of snow. Take, for example, the old practice of the Alpine peasant negotiating deep, new snow. He puts his foot down twice in each footstep. The pressure of his first step tends to melt the snow in accord with the well known physical principle; the momentary release of the pressure allows the water to freeze and when the foot comes down again it finds firmer support.

In very cold or very warm weather this device will not work—and that enables me to elaborate my point: all snowcraft depends on the ever varying state of the snow with wind and weather. I want to talk about these changes—indeed I am going to inflict upon you for a few moments a brief scientific discourse to accompany the next few slides which illustrate these changes. This, I hope, will make clearer the rest of what I am going to say.

Not that many first class snowcraftsmen have not managed perfectly without knowing the scientific aspects of snow lore. What, for instance, does the peasant guide know of Thomson's ' pressure melting of ice,' or Faraday's ' regelation ' ? But I maintain, and I hold very strong views about this, that once basic micro-principles (if I may coin a word) have been mastered the subject is more easily understood by the inexperienced. Moreover, if difficulties of a novel kind develop, so that prior experience does not serve, they can often be overcome by an understanding of the basic principle.

Sun is one of the chief factors in bringing about surface changes, and it is clear that it will have its greatest effect according to the orientation of the hillside: south slopes will be most affected, then west, then east. The low winter sun will also have more power on those slopes which are more nearly at right angles to it, namely the steeper slopes. Let me give an example.

One day soon after a snowfall late in the winter season, a very mediocre skier was out with some good skiers. Their way led down a south-westerly slope of new snow in the afternoon. This was obviously going to be crusted. Our poor skier happened to notice that the hillside was studded with a number of hummocks, so low and flat that they cast no shadow, but he reasoned that the slight change in level meant that their uphill sides would be less directly exposed to the sun. As we ran down I found I was right. I placed my turns in the slight concavities of the hummocks and had no difficulties, whereas my friends had a few in the breakable crust. Skiers have generous souls and I feel sure my companions were delighted at thus seeing reversed the more usual order of arrival at the end of a run.

The slide showing the Kesch hut and Piz Kesch, gives a good illustration of this point. It will be seen that the tracks on level ground nearest the camera have been slightly sun-crusted but that those further away, slightly inclined to the north, hold good skiing snow. For the same reason snow in gullies is often in good condition for skiing much longer than on ridges. (This will strike a responsive note to those who have skied in Norway). For the same reason also, sunswept ridges are often to be preferred for climbing on foot and sometimes for climbing on ski when the snow lies too deep in shaded places. For the same reason too, drifted snow lies loose for a long time in the bottoms of crevasses, thus concealing articles or even bodies which may fall into them.

In the three photographs, taken in the bottoms of some of the crevasses we explored in the Great Aletsch Glacier just before the war, the snow lay thick and loose long after firn had formed on the surface.

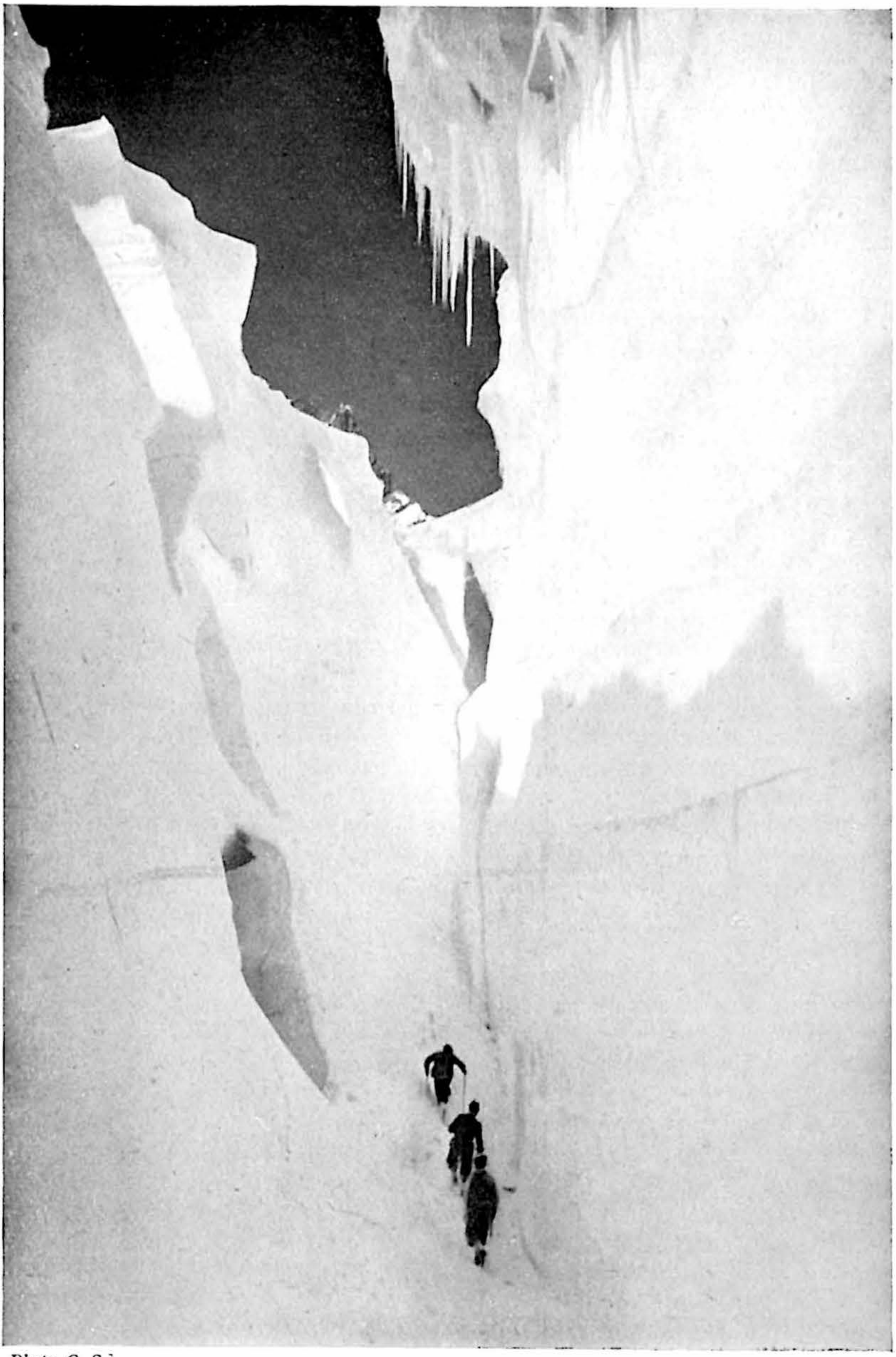
Once snow has become crusted, it is very difficult indeed to recognise ahead whether the crust is breakable or not, and this means that the skier must proceed with more care than is pleasant. The expedient of letting someone else go ahead and watching what he does answers admirably but is not considered sporting.

Sometimes it is possible to gauge the difficulties by considering the past weather conditions in connection with the orientation. To take a simple case, if a south slope has been exposed to sun for several days and the weather has become fine and cold, the probability is that the crust will be thick enough to bear. An easterly slope in winter might not become crusted at all.

Before we leave sun-crusted slopes I would like to give a tip—it is obvious but often neglected. If good or bad snow is found on a slope of a certain angle and orientation it is safe to say that, other influences being absent, all similar slopes in the vicinity will offer identical skiing conditions.

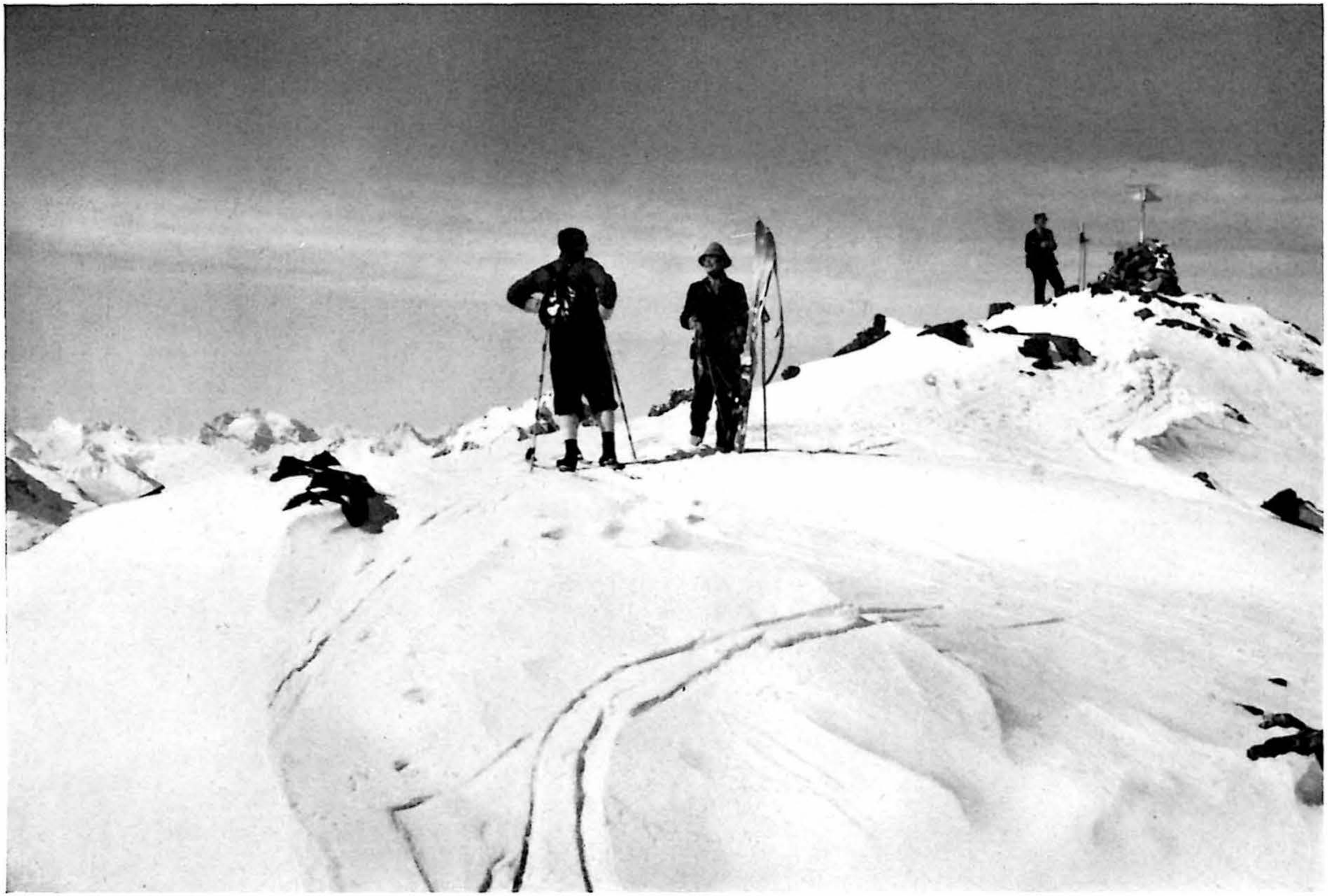
The effect of wind on snow is threefold. First it may pack it as hard and as solid as prolonged sun. This is wind crust ; it is common on exposed ridges. The essential fact in wind crust formation is that it always develops in the *absence of drift*. The snow hardens *in situ*. Secondly we have wind slab. This is formed when the wind drives the snow so that it collects on slopes still subjected to wind but of less force than the drifting wind. Both these types of wind-packed snow occur only when the wind carries a high percentage of moisture. When the wind is dry it has a third effect. Its evaporative power will then actually loosen and carry away grains of hard, crusted snow. Such a wind, or indeed any wind that will not form wind slab, will produce loose-lying deposits of drifted snow in protected places and here is another interesting point of snowcraft—skiers' snowcraft.

I remember once running down a glacier, the Ducan Glacier. Wind was blowing the snow across it. The drifted snow was accumulating to leeward of a snow-covered moraine in a calm area, whose width could be measured in yards, running nearly the whole length of the



Photo, G. S.]

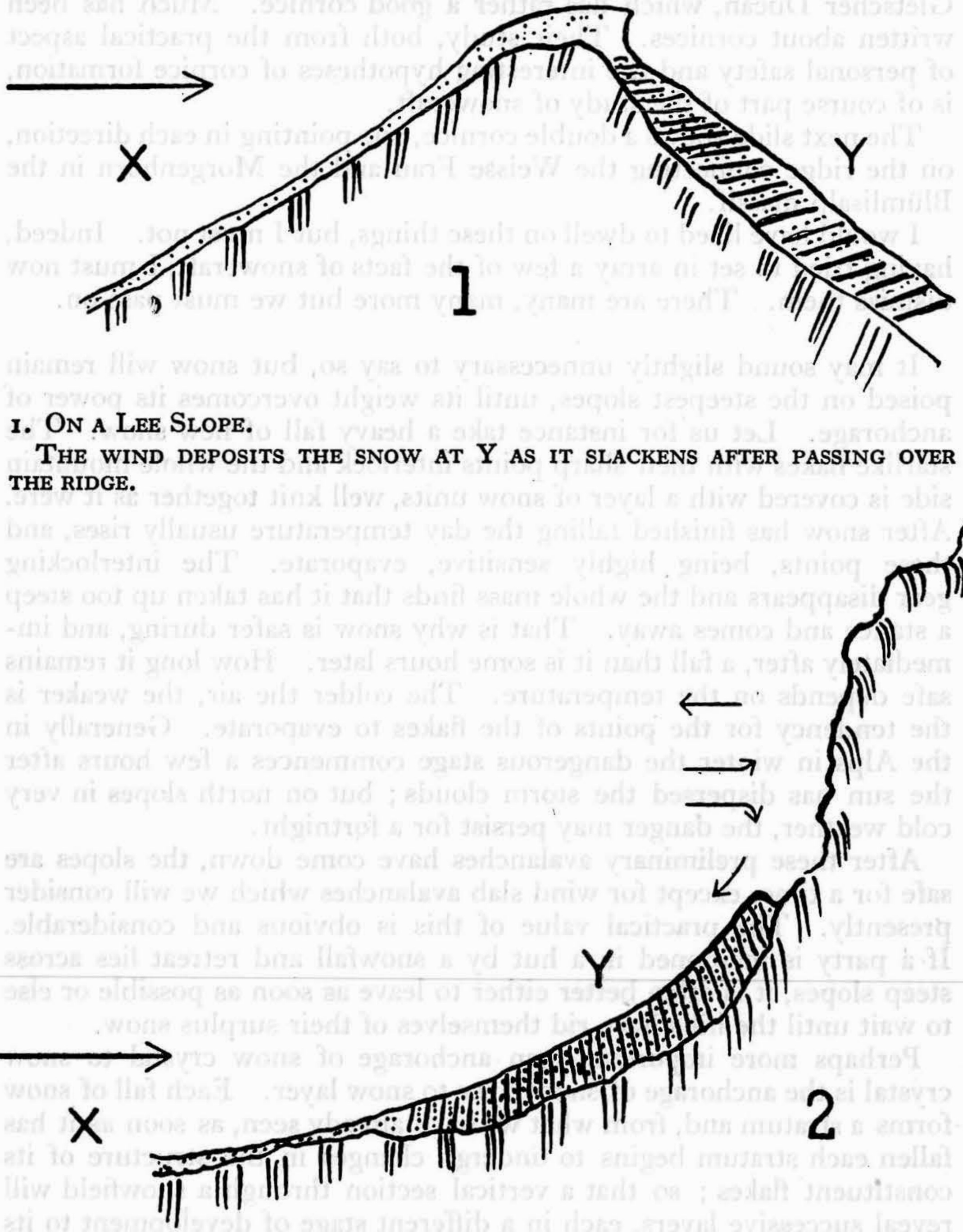
CREVASSE IN THE JUNGFRAUFIRN.



Photo, G. S.

PIZ SARSURA, GRISONS, SHOWING WIND CRUST.

THE MOST COMMON POSITIONS OF WIND SLABS.



1. ON A LEE SLOPE.

THE WIND DEPOSITS THE SNOW AT Y AS IT SLACKENS AFTER PASSING OVER THE RIDGE.

2. AT THE BASE OF A CLIFF OR STEEP INCLINE.

EDDIES FORM AS THE WIND STRIKES THE CLIFF AND THE SNOW IS DEPOSITED AT ITS BASE, AT Y.

glacier. It formed a narrow ribbon of perfect powder snow a few inches deep. A hundred yards away the glacier surface was breakable crust. Some skiers we saw there exhibiting unmistakable signs of tribulation complained of an unpleasant run when we met them later at the Grialetsch hut. While on the subject of the Ducan, the

next slide shows the summit of one of the peaks of that group, the Gletscher Ducan, which has rather a good cornice. Much has been written about cornices. Their study, both from the practical aspect of personal safety and the interesting hypotheses of cornice formation, is of course part of the study of snowcraft.

The next slide shows a double cornice, one pointing in each direction, on the ridge connecting the Weisse Frau and the Morgenhorn in the Blümlisalp massif.

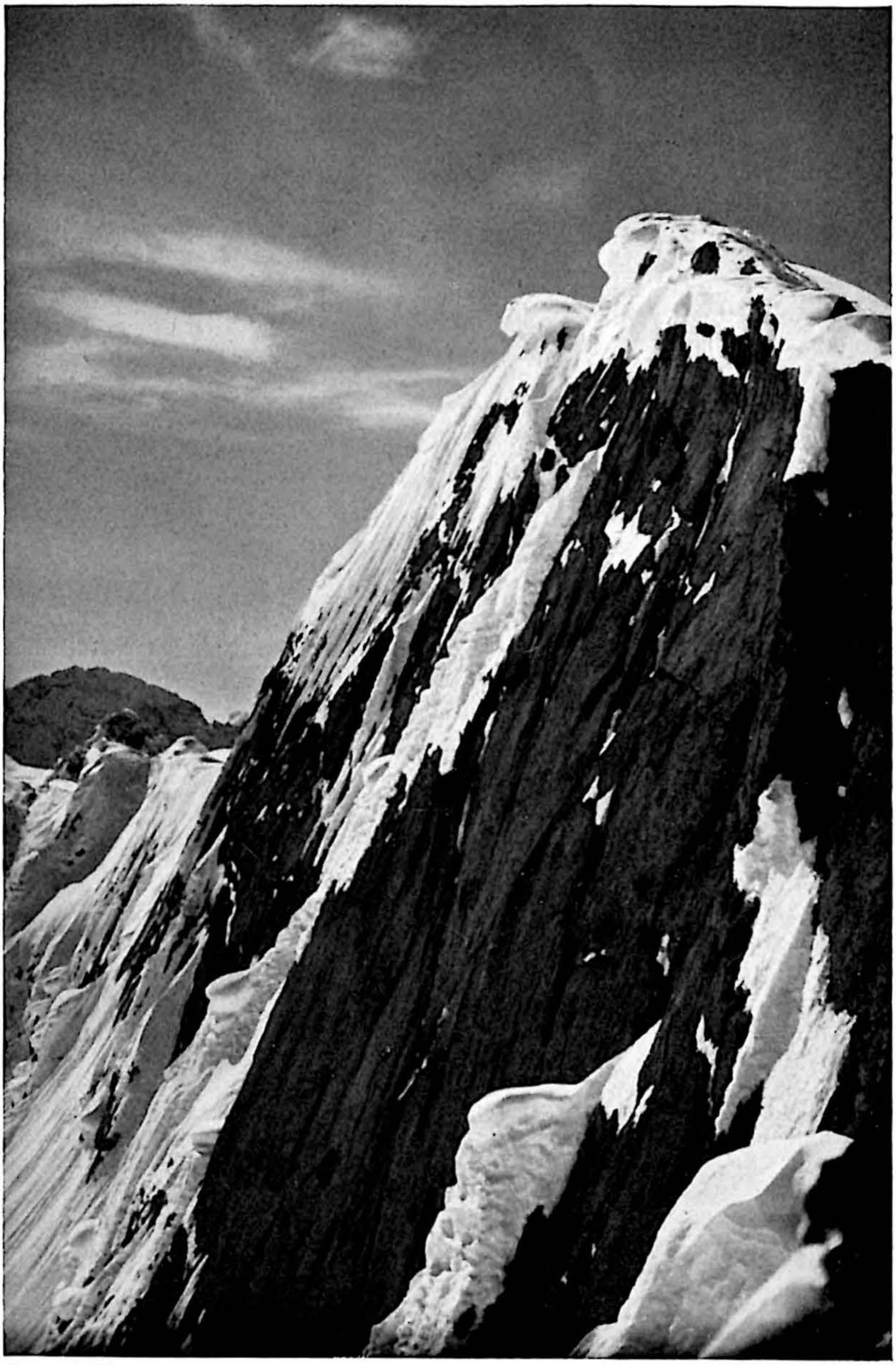
I would have liked to dwell on these things, but I must not. Indeed, having tried to set in array a few of the facts of snowcraft, I must now dismiss them. There are many, many more but we must pass on.

It may sound slightly unnecessary to say so, but snow will remain poised on the steepest slopes, until its weight overcomes its power of anchorage. Let us for instance take a heavy fall of new snow. The starlike flakes with their sharp points interlock and the whole mountain side is covered with a layer of snow units, well knit together as it were. After snow has finished falling the day temperature usually rises, and these points, being highly sensitive, evaporate. The interlocking gear disappears and the whole mass finds that it has taken up too steep a stance and comes away. That is why snow is safer during, and immediately after, a fall than it is some hours later. How long it remains safe depends on the temperature. The colder the air, the weaker is the tendency for the points of the flakes to evaporate. Generally in the Alps in winter the dangerous stage commences a few hours after the sun has dispersed the storm clouds; but on north slopes in very cold weather, the danger may persist for a fortnight.

After these preliminary avalanches have come down, the slopes are safe for a time, except for wind slab avalanches which we will consider presently. The practical value of this is obvious and considerable. If a party is marooned in a hut by a snowfall and retreat lies across steep slopes, it is often better either to leave as soon as possible or else to wait until the hills have rid themselves of their surplus snow.

Perhaps more important than anchorage of snow crystal to snow crystal is the anchorage of snow layer to snow layer. Each fall of snow forms a stratum and, from what we have already seen, as soon as it has fallen each stratum begins to undergo changes in the structure of its constituent flakes; so that a vertical section through a snowfield will reveal successive layers, each in a different stage of development to its neighbour—the metamorphosis being, of course, most advanced in the lower layers.

Now under certain conditions we find a curious and very beautiful change in the snow. When we have great cold, especially in the early winter after the first snow falls, the snow becomes cooled to very low air temperatures but the earth below gives off heat. The result is that there is a steep temperature gradient. This causes the lowest snow layer to evaporate and for the water vapour to recrystallise higher up into beautiful crystals. These have the peculiarity of being abso-



Photo, G. S.]

CORNICE ON THE SUMMIT OF THE GLETSCHER DUCAN, GRISONS.

lutely unable to coalesce, or 'crust,' together and always remain friable. In the central Alps they call them *Schwimmschnee*, 'quick snow,' on the analogy of quick sand. Some years ago I translated this, inadequately enough, into the rather less picturesque 'depth hoar' and the name seems to have persisted. It will be clear that as an anchorage, depth hoar, resembling small shot, is of minus value; in fact a layer of it will have an encouraging effect on any snow strata above it which may have a tendency to avalanche.

This is the second example I have given of the value of knowing past weather conditions. I will give a third.

If we have a hardened snow surface and snow falls on it at a low temperature, the flakes cannot bind upon the crust, so that the new snow layer, as soon as it becomes thick and heavy enough, will tend to slide down over the smooth surface. On the other hand, snow storms at low altitudes often begin with wet sleet, after which the temperature falls. The new layer therefore freezes to the crust and we get a more stable structure.

It will be readily seen, therefore, how important it is to know what the weather conditions have been, at least as far back as before the last snowfall. It may not always be possible to know about the weather of many weeks before, and, in any case, the structure of most of the layers changes after a long time, sometimes, in the state of our present knowledge, unaccountably. The Swiss authorities at the Snow Research Station at the Weissfluhjoch, Davos, who are responsible for broadcasting avalanche warnings, get over this difficulty by digging snow sections, thus keeping in touch with the degree of stability of the snow cover.

Actually the skier can himself, with a little practice, gain a good deal of information by reversing his ski stick and thrusting it into the snow. Unstable layers, especially depth hoar, can soon be recognised by the ease with which the stick passes through them. It is in fact an operation not unlike that of testing for crevasses with an ice-axe. I have one of my ski sticks with a handle made to unscrew, revealing a pointed ferrule like the one at the other end, but of course without the snow disc. This gives a more delicate touch than if the blunt handle is used. By moving the thrust-in stick in a small circle a 'mill' can be made and the inner layers, at least those near the surface, can be seen. In ticklish places this operation has the added advantage of provoking humorous sallies beneficial to morale.

In addition to the avalanches of new snow, which may be expected with great regularity after a snowfall, other avalanches come down at most erratic times. What is this tendency to avalanche? Why should a snow layer which has remained stable for some weeks suddenly come away?

One answer is that it may have become impregnated with melt water which can either act as a lubricant of individual grains or may collect on a crusted layer or upon the ground and form a gliding plan for the whole snow deposit. But these wet avalanches, which come

in winter thaw or in spring, are more calculable than any others. They are therefore less interesting and I do not, in the short time at my disposal, propose to describe them in further detail.

I come back to avalanches which are not wet and which may consist of old snow (if only the slope is steep enough) and which yet avalanche quite unexpectedly. Here we have an instance of the practical value of scientific research beautifully elaborated by the Swiss. The principle involved is 'snow creep' which is analogous to creep in metals, or the creep in flowing glacier ice. I will not dwell on scientific intricacies here and will only say that research has now established that, if snow lies on a slanting bed, it will begin a very slow plastic flow, quite imperceptible to the naked eye. I must say at once, however, that neither the originator of the idea, who published it in 1929, nor I, in my attempts to elaborate it in 1936, fully understood the significance of the discovery, or how general was its occurrence.

This creep of snow sets up internal stresses. These ultimately become so strong that a break in the snow cover takes place and its cohesion vanishes, so that an avalanche develops. The action has been likened to that of the fracture of the glacier surface to form a crevasse. The deeper the snow the more likely it is to avalanche, for it is clear that the snow crystals near the ground, no doubt mainly on account of friction, have less facility for movement than those higher up.

But it is in wind slab avalanches where the creep of snow plays the greatest part and where it also *partially* explains what has been a mystery to us all for years.

What is a wind slab avalanche? I have said that when a wet wind causes snow to drift the grains come to rest when they reach an area where the wind slackens and deposits them, just as a river deposits mud and sand as the stream slows up on reaching the ocean.

The next slide shows well the difference between wind crust formed without drift and wind slab.

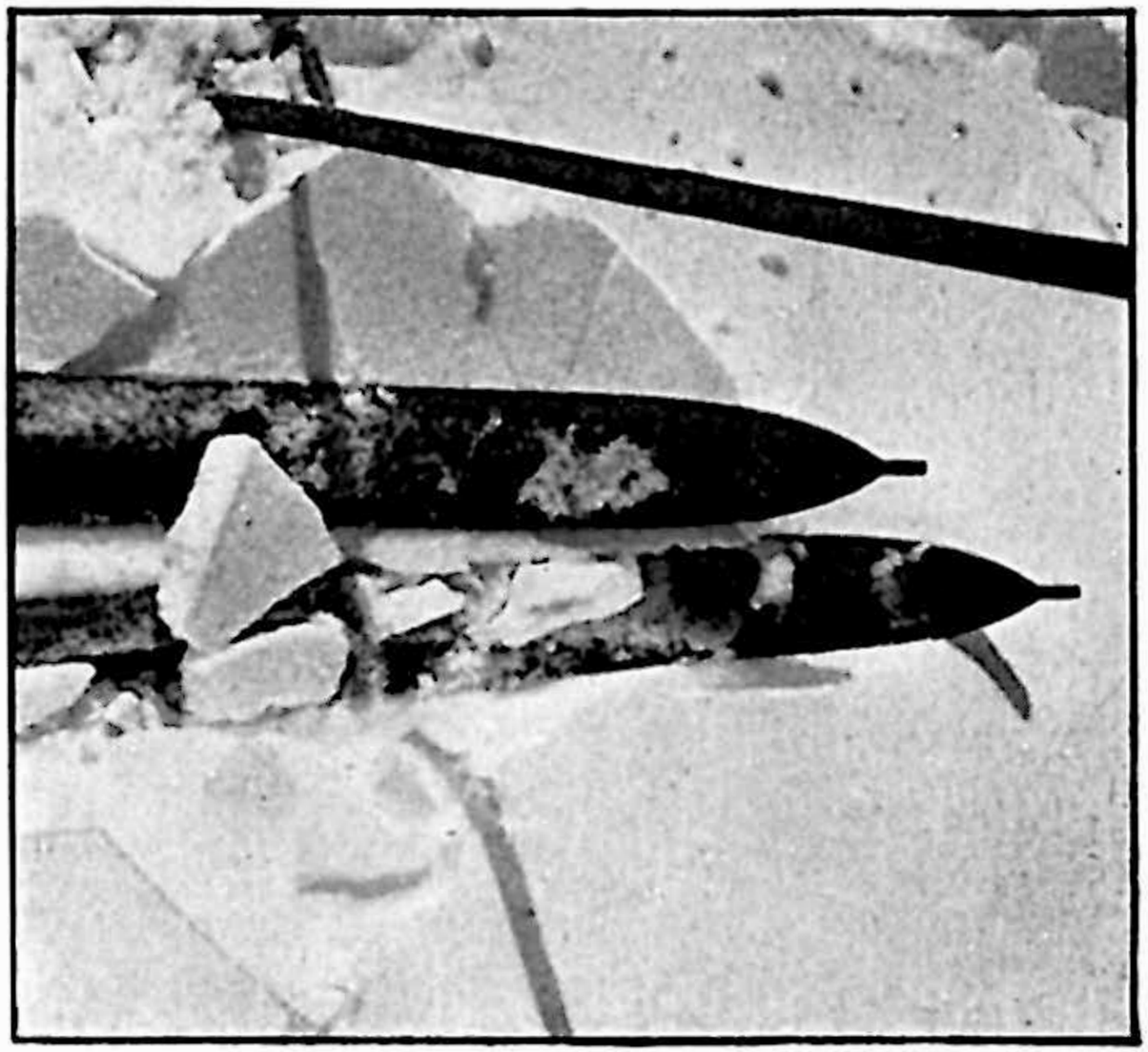
It will be seen that crust does not break off in well defined slabs but is fused, as it were, to the snow below. This of course is due to its mode of formation.

The causes of wind slab formation are twofold. First, there is a molecular transference under the influence of the wind, the grains becoming cemented together. Secondly, our member, R. A. Bagnold, has shown that even wind-driven sand can harden by a kind of selective packing. Grains of suitable size fall into spaces between other grains and get jammed there.

There is a certain amount of controversy as to where on the hillside wind slabs are most common, but my own experience points definitely to the slopes which lie just to leeward of a ridge or else to those under a cliff to windward. The snow beneath a slab will usually settle away from it leaving it poised with a space sometimes several inches deep below it. When first formed, this hardened snow layer will harbour immense stresses, caused, not only by its inclination, but by the

Photo, Meerkamper, Davos.

THE FOUR FOOT HIGH SCAR OF A WIND SLAB AVALANCHE, NULLISGRAT, DAVOS.



Photographs, H. Hoek.]

(A) (B)

WIND SLAB (FIG. A) AND WIND CRUST (FIG. B) SHOWING THE CLEAN CUT FRACTURE OF THE FORMER

lateral pressure of the moisture from the wet wind which has become frozen into it. Now comes the downhill creep and the already big stresses slowly increase until, suddenly, a rift appears and the whole snow cover caves in and breaks into thousands of pieces which hurtle down as a wind slab avalanche. The size, the power and the destructiveness of these avalanches are colossal.

This creep may act quickly or slowly. This explains why there is no rule yet discovered to say when a wind slab avalanche will fall. It may be released during a storm or at any time thereafter. But it *does* explain satisfactorily why a wind slab avalanche may be released at a distance, for it can easily be imagined how the forces stored up in the snow cover may extend into the valley. Therefore a party remote from the actual site of the point of danger can release stresses which communicate with those on the hillside and cause the snow to come down.

While it must be admitted that there is yet no solution to the question of *when* slab avalanches will fall, we are at last beginning to know *why* they fall and that is a distinct step forward. If I may be allowed to hazard a guess I would like to suggest that the depth of the space beneath the slab and the inclination of the slope may be found to provide a clue. But at present there is no evidence to substantiate this.

There is one last aspect of snow study to mention. Earlier this year a Canadian friend wrote to me :

'At Lake Louise there is a lady who often has to travel about 12 miles over a pass on ski. She became very bored with that run. With some misgiving she started to study a work on snow. Last winter she told me the journey is never dull now because she is constantly thinking of possible explanations and looking for new snow forms.'

I can well echo that. On a skiing climb no short stretch of snow is like the next. A long climb is full of interest and beauty to the enthusiast. The next few photographs show how much there is to observe and to wonder at, be it some form of hoar on the surface or on bushes ; wind effects in the woods ; evidences of snow fallen in calm, in whirlwind or in storm ; or, as we go higher, the snowbridge over a crevasse, or the fantastic forms these bridges take when seen from below ; or going higher still, the summit cornice, or just the way the snow has shaped itself upon the summit ridge. There is always something to stimulate the contemplative mind or to delight the appreciative eye.

I fear I have done poor justice to the enormously complicated and wide-reaching phenomena I have tried to describe. So much remains to be said of snow, of avalanches, of glaciers (I have not even broached the many problems arising from the last named). I do not imagine that I have been able to give sufficient information to enable even the least reluctant student to understand very much more than he did before. At the very best, I can only hope that I have engendered a thirst which its owner himself will desire to quench.

In extenuation may I plead that to describe avalanches and snowcraft—each in some twenty minutes, is rather like attempting to explain wireless or ballistics in a few sentences. Snowcraft has meant a lifetime study for men who have felt at the end that they have but made a beginning. May this, too, be my excuse tonight.

OLD FRIENDS AND NEW HUTS, MAY–JUNE 1947

By E. H. PECK

After eight years' absence from the Alps, a kindly Providence brought me to Geneva to work during April and May, and on finishing work there I was able to take three weeks' leave at the very best period of the year. A few week ends well spent from Geneva in brushing up one's skiing on the Rochers de Naye and the Brévent, together with some exhausting early morning scrambles on the Salève, were valuable training which enabled me to extract the utmost from the holiday that followed. Perhaps the most interesting of these excursions from Geneva was an unpremeditated ascent of the Haute Cime of the Dents du Midi early in May when the small snow traverses and the scramble through the Pas d'Encel, of which I retained childish memories of 23 years before, gave a foretaste of greater things to come, while the climb of the 2200 metres from Champéry and back in a single day made a good contribution to training.

Meanwhile, weeks of fine weather slipped by in Geneva, and I fretted with anxiety lest both my earlier plans for a skiing holiday and my subsequent ones for climbing should be thwarted by some untimely break in the weather, but these fears proved wholly unjustified. While in Geneva I had already noticed the growing popularity enjoyed by spring skiing and ski mountaineering among the Swiss, as compared with the comparative obscurity of this aspect of Alpine sport in the days before the war. In particular an all-Swiss version of the 'Haute Route,' running from Verbier in the Val de Bagnes to Saas, had been worked out and was being followed by skiers until late in May. Also, the war had kept the Swiss and more particularly the Genevese, whose natural playground was Savoy, within their frontiers. This led not only to a fuller development of spring skiing but also to the construction of a number of new huts by the Swiss Alpine Club; thus the Velan and Vuignettes huts, as well as the enlargement of the old Bétemps, now known as Monte Rosa, were completed during or shortly after the war and were intended to meet the needs of spring ski mountaineers rather than of summer climbers.