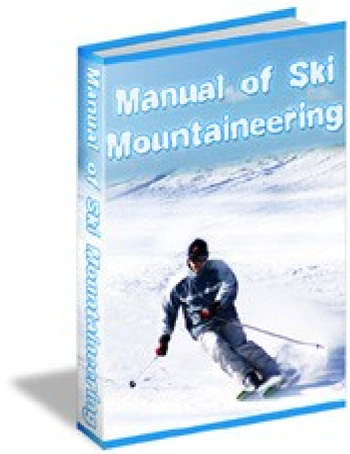
Manual Of Ski Mountaineering



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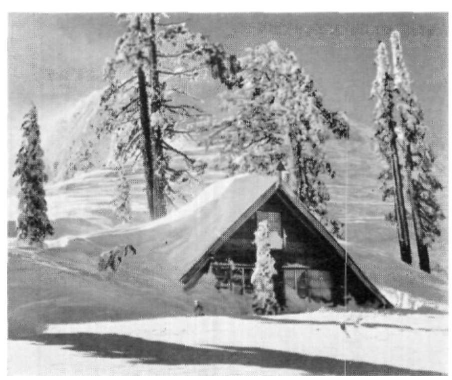
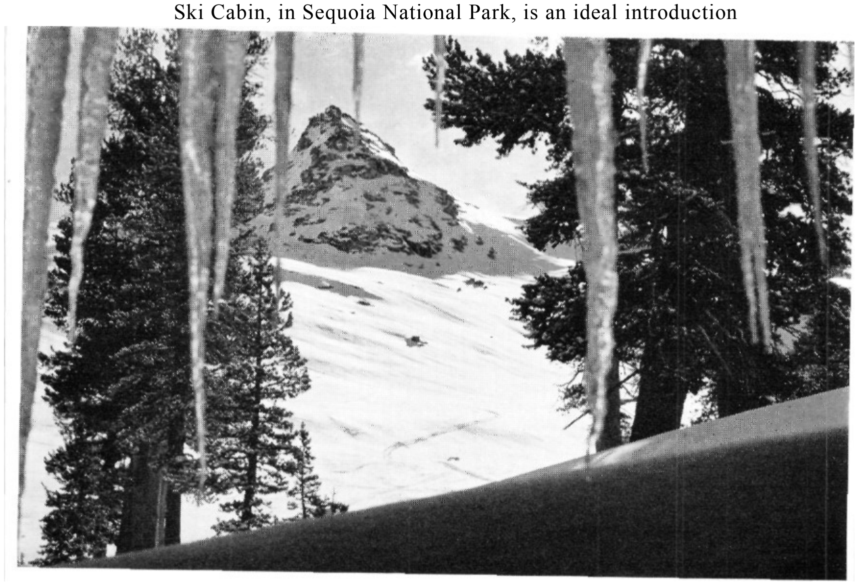


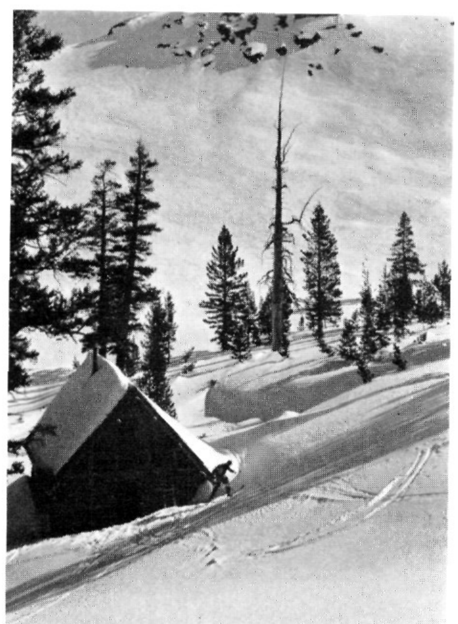
The main thing is to take off. We have nothing against the practice slopes and the standard runs; but if that's all you know, you have missed something special, something lost behind the ranges, a sparkling new white world, with its hard edges covered over for the winter, and you its discoverer.

Head toward the Sierra Club's John Benson Hut, for instance, named for a young man who loved to ski tour very much, but lost his life in Italy with the Mountain Troops. It isn't too easy or too hard—*provided* . . . read on. *(Photos 6,* 7)

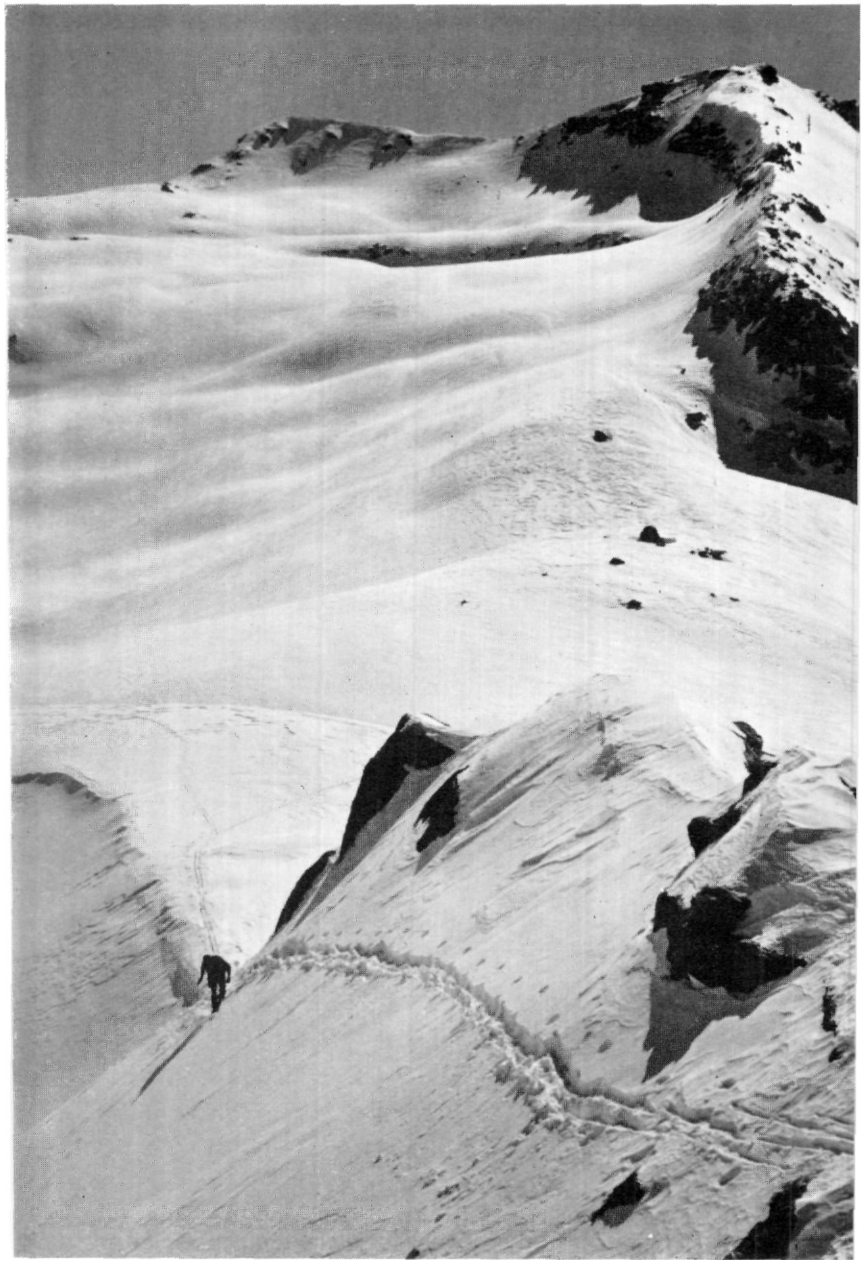
Let your beginning days end snug—in a cabin. The Pear L:
Ski Cabin, in Sequoia National Park, is an ideal introduction

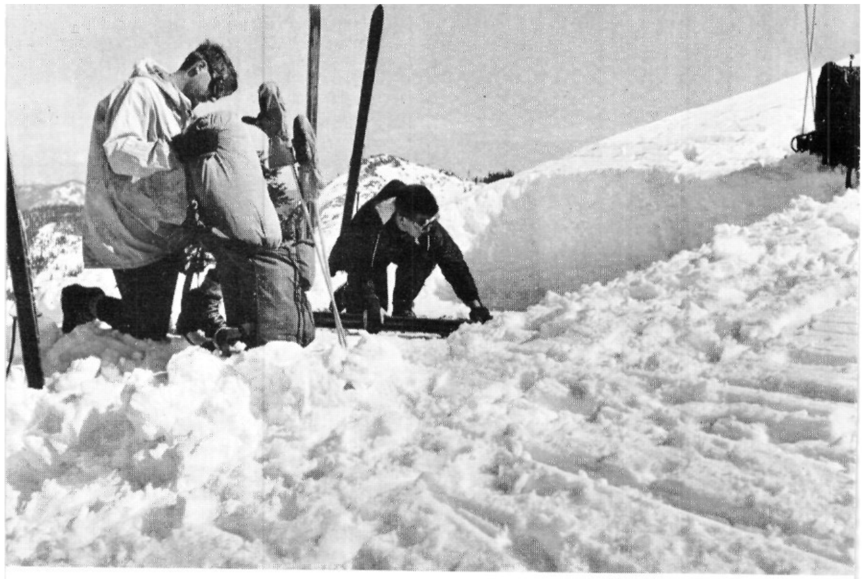


—*in a cabin.* The Pear Lake k, is an ideal introduction to ski mountaineering. There are some challenging places on the way in . . .

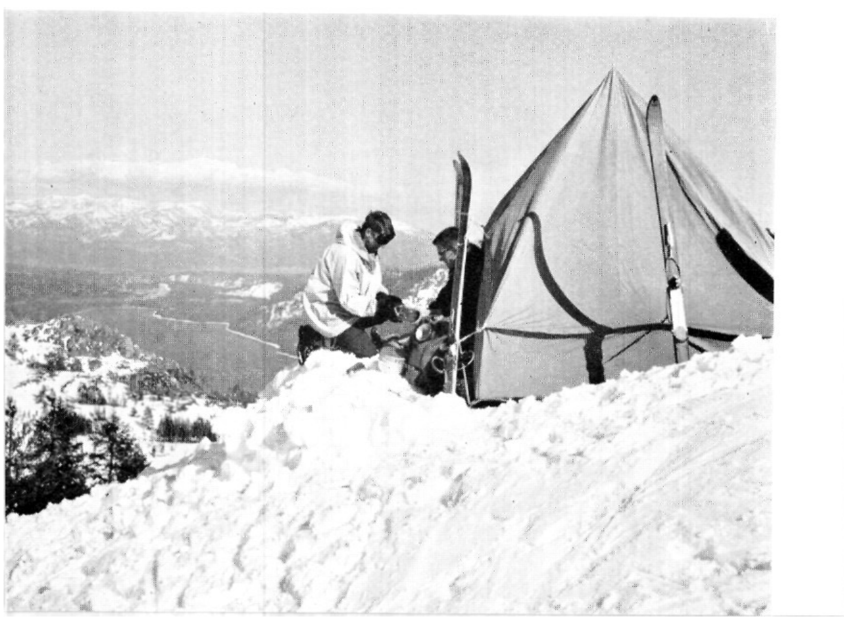


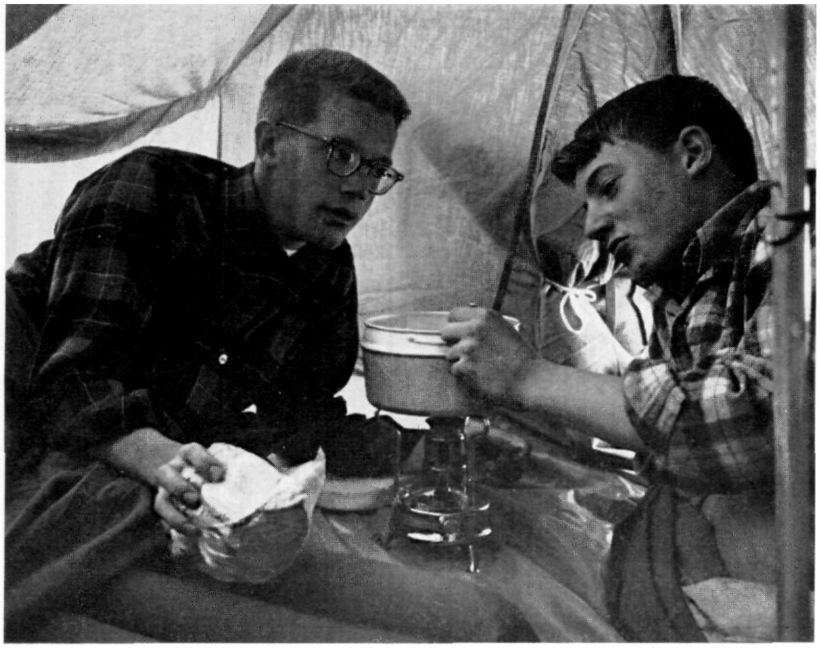
. . . and there are the magnificent slopes of Alta Peak near by on which to get the feel of winter wilderness. (<?, *9,10)*

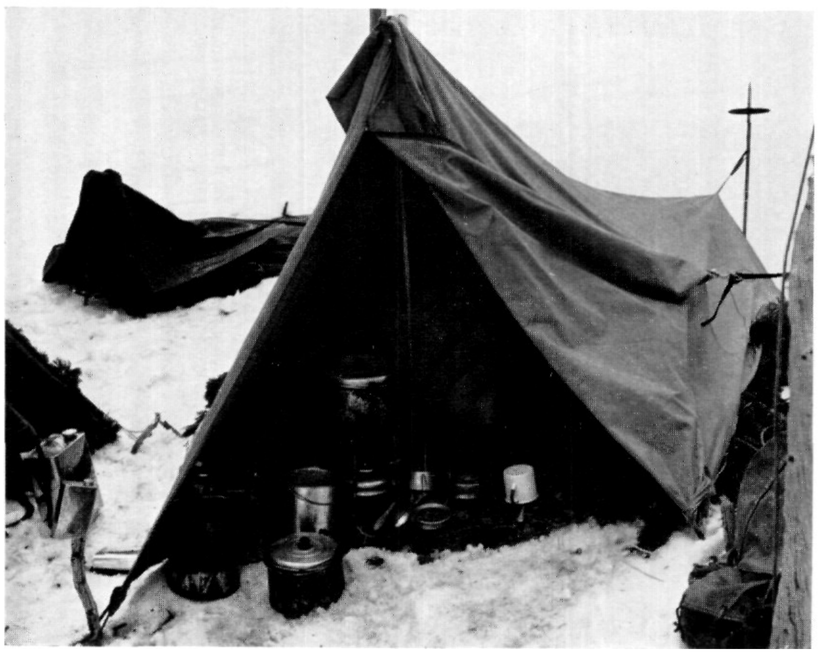




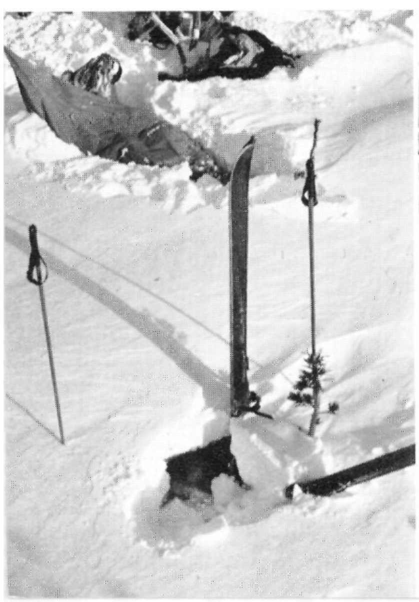
Do-it-yourself snugness has its own rewards. Excavate a platform, set up a Logan tent, climb in, and take your dinner lying down—but don't spill it! Or use a home-on-the-snow model, with floorless cooking space under the slanting front, and spill all you please. *(11-14)*

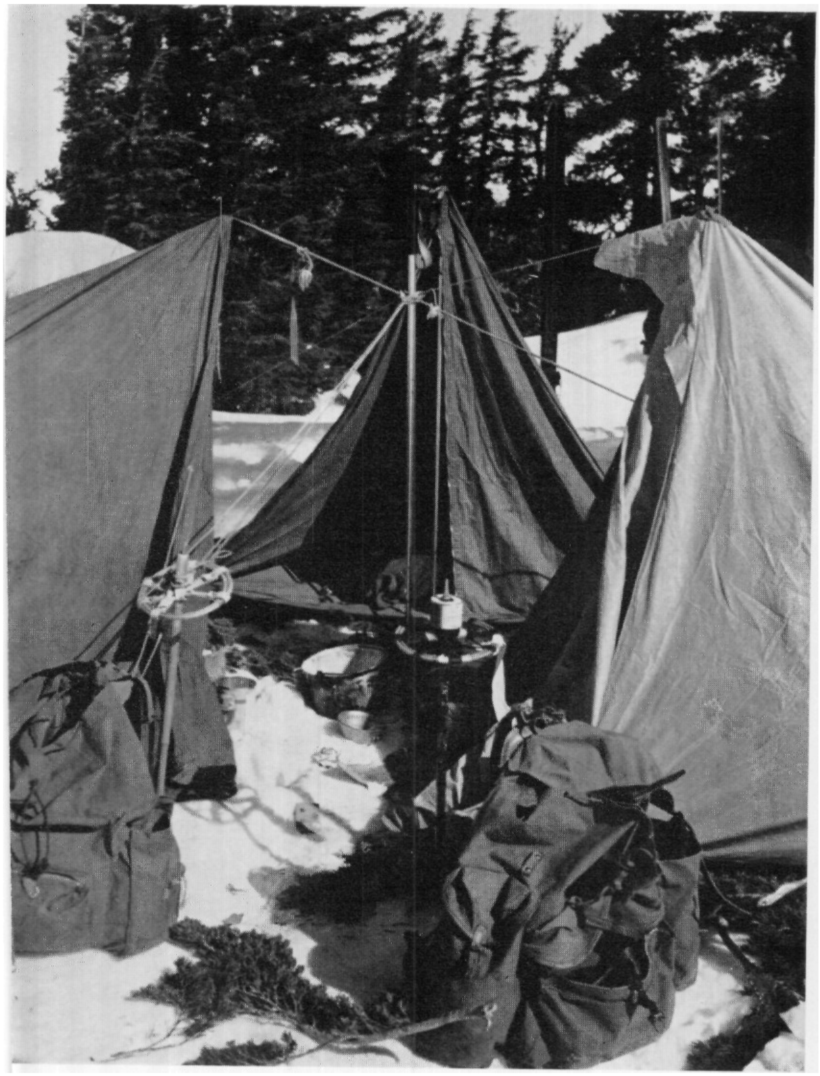




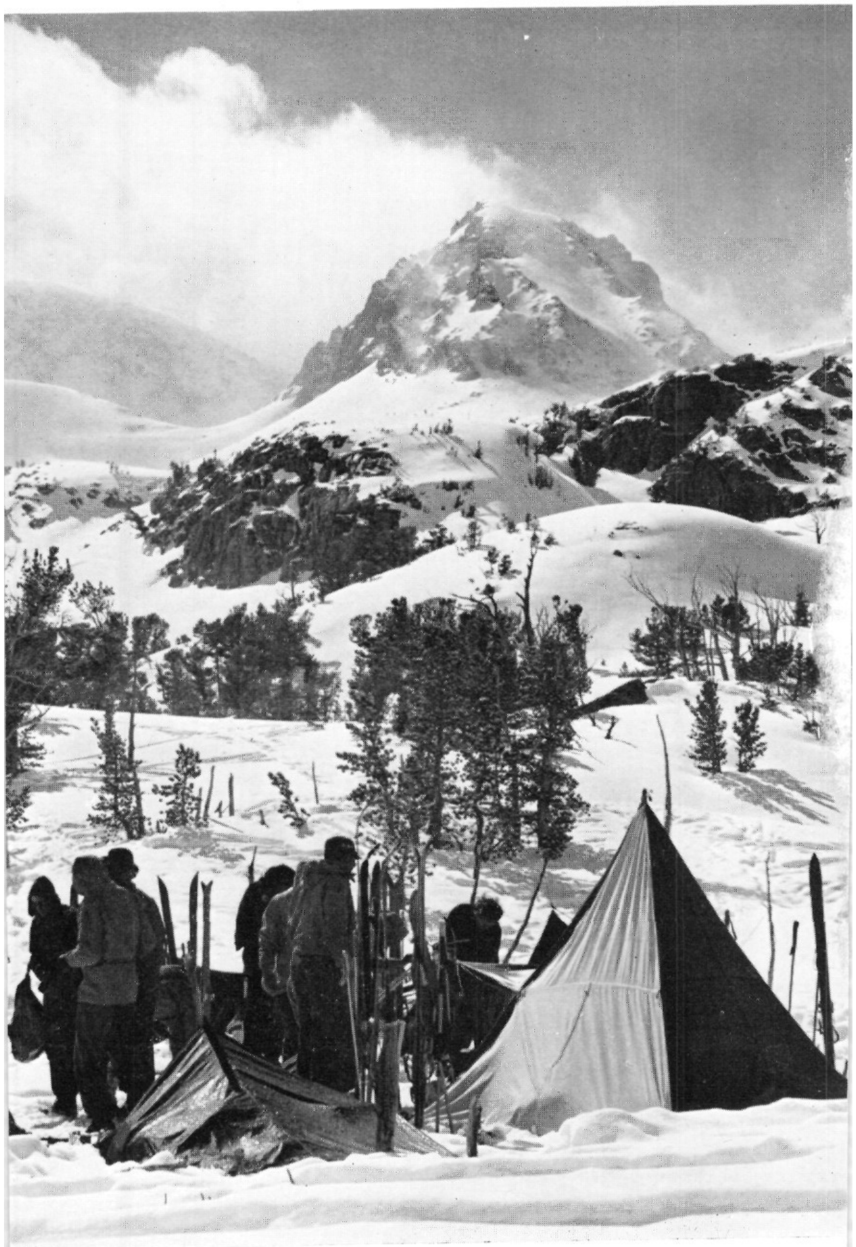


There are other routes to snugness, too. It was so windy up at Hell Hole, on the first winter ascent of Mount Lyell, that indoor plumbing was installed in the tent—with a scout knife. For a calm night, try a branch-roofed snow cave. This one withstood 18 inches of new powder the night before; so did the occupant, shown emerging. *(15-17)*



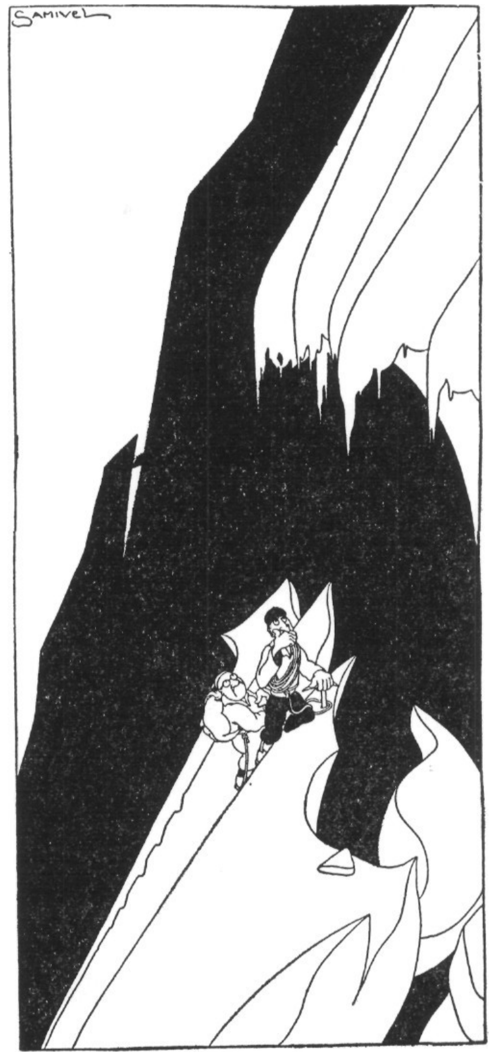


Community center. Pitch three three-man tents this way and each can specialize on one of the dinner courses, to be self-served with a long reach. On stormbound days, try Robert Service poems, told in a low voice—especially "The Cremation of Sam McGee." *(18)*



Ski-mountaineering camp (co-educational) in Little Lakes Valley *(19)*

MANUAL OF SKI MOUNTAINEERING



Hmm!

Skis to the Winter Wilderness

AN INTRODUCTION

THE WIND HAD A MEAN EDGE on it as it curved to cross the crest of the Sierra Nevada and found us there, two thousand feet above the site of the Donner Party tragedy, trying to find out how to camp in deep snow. It was deep snow that caught the Donners' immigrants back in 1846. Thirty-six people died from cold and starvation, and more would have starved, probably, but for cannibalism.

Our exposed spot on the crest was not where you would expect to find a father pushing fifty, much less being pushed by his two teenage sons. But there we were anyway, and by plan.

We knew that California has come (or gone) quite a distance since the Donner Party's ordeal. Skiing technique has progressed quite a bit too since Snowshoe Thompson carried the trans-Sierra mails in the late 'fifties (the *eighteen-fifties,* that is) on his eleven-foot skis and since his contemporaries set 85-mile-per-hour speed records in the earliest American ski races on record.

More relevantly, we also knew that California has gone a fair distance in making a sport of the best of what the Donners and Thompson learned—how to survive in snow and how to ski safely through rugged, untracked terrain. The ice-edged wind found us looking at the very peaks upon which that new sport, ski mountaineering, had been adapted to California terrain by the Sierra Club and then exported to help the armed forces in World War II. I was exported too, and saw how our ski-mountaineering technique and equipment aided the troops, myself included, giving them combat mobility and *esprit* that should be recorded better than it has been before it is forgotten.

Now, after too long a lapse, I was back in old Sierra haunts. I brought my sons to this crest, not to expose them to danger but to try to show them how to avoid it. I wanted very much to see them feel at home on the snow, far back in the winter wilderness, all around the clock and all around the compass.

Moreover, I also had a suspicion that every generation needs to invent contests which it can be first to win. This certainly seems to be true of people who look to mountains for their contests. The two generations before mine won their contests—most of them—on the great peaks of the Alps and the major summits of the United States. My generation finished off the Himalayan giants. I mean, that's what climbers did who could afford such expeditions; the less affluent of us settled for little-known peaks or for switching seasons or routes on climbs of the well-known summits.

To pioneer, father never had it so rough; he had only to find a peak. I myself could still pioneer merely by finding hard ways up easy peaks—and going back down to spend the night in comfort. Today's mountaineers, however, must look for the hardest way up the hardest peaks, and be willing to spend several successive nights trying to sleep partly inside a sack partly suspended from a cliff. The suspense is tremendous!

What next? As a parent of children who may momentarily join the ranks of today's mountaineers, I care. I dread their feeling they must outdo the Eiger and Yosemite men. I hope their pioneering can have more fun in it, no less challenge, and fewer of the spices of danger.

Not too subtly, then, I was trying to expose my delegates to the new generation to the good things that could happen if they were to turn their skis to the wilderness for a few winter week ends at least. I hope the exposure will take. For one thing, it will really stretch their skiing budget—four ski week ends for the price of one!—and will simultaneously shorten the ski-lift lines.

More important, they'll have new frontiers to explore every time there is a new fall of snow. They'll find country—especially the Western uplands—measured in millions of acres where skis have never penetrated. And they'll learn that there is need for all their new skill in inventing ways to achieve more mobility and safety with less weight. In the course of all this they'll also find out that in winter one of the finest methods of transportation ever invented is a man's own two feet—plus seven-foot skis.

I'm not just dreaming. I'm lucky enough to have children who walk. They simply take it for granted—so far—that walking is the only way to get to the best places, those wild places where cars can't go and shouldn't.

My sons Ken, who is 17, and Bob, 16, like the look of snow where the only ski tracks are those behind them and where, ahead, the tracks of wildlife are mysteries to try to unravel. They like to top a rise and start down into the far valley knowing that there's no one there, that it is just as wild as if creation had been yesterday. They may even like the sense of relief, of getting away from the compulsion to perfect skiing form—and forget its sub-stance—in succession after frenetic succession of turns down the beat, nicked slopes above the long chair-lift lines.

I'm not trying to paint my boys as antisocial, nor myself as averse to resort skiing. We are all, however, prone to like change of scene. Fending off the chiselers in the lift lines, relaxing briefly while we ride the chairs, and fighting our way back down the slopes, running over the tails of the slow skis ahead of us or trying not to be run over by the faster skis behind—all this is good fun for a certain number of week ends. Then we're ready to get back to fundamentals.

Out our way Spring is the best time for those fundamentals. The days are long enough to light a several-mile ski tour and the sun is usually mature enough to warm a lunch-time bask. The snowpack is at its deepest, smoothing out the high country. The Sierra Club's touring huts are especially inviting then, each an easy day's travel sandwiched between snug nights. Well, not *too* easy. They are a good warm-up for ski mountaineering.

Borrowing what I could remember of my early ski-mountaineering days, I appointed myself coach. In accepting me in that role, Ken and Bob tacitly accepted (for the moment, at least) my pronouncements drawn from early editions of the *Manual of Ski Mountaineering.*

For example, those of us who compiled the book like a ski boot with a sole that will bend—not easily, but that will at least *bend.* We want bindings that will allow the heel free play in level gliding and in uphill travel; otherwise blisters are guaranteed. We'll settle for ordinary downhill skis. If there's likely to be much soft snow, our poles must have a big enough snow ring to give some thrust when we push back. A ski mountaineer must really *use* his poles, not just wave them.

Clothing need be no problem. Over the far hill there are no people to impress and to look pretty for. This is a chance to squeeze the last wear out of older ski clothes, to scrape the last thread bare. Stretch pants will get by, but impede circulation, ventilation, and insulation. The baggier the parka, the better—for the same reason. The main requirement of clothing is that it be adjustable; layers will need to be subtracted or added easily to avoid over- or underheating.

A few of the prewar axioms still hold: (1) Two light layers trap more air and insulate better than one heavy layer. (2) It is easier to *keep* warm than to *get* warm. (3) If you don't want a chill, don't work up a sweat.

"If your hands or feet get cold," I admonished the boys, "put on an extra sweater." They looked unbelieving, but I meant it and tried to explain about the body's thermostats which, when they must choose, will always shut down on circulation to the skin and the extremities if this is necessary to conserve heat for the vital organs. I wasn't too lucid, for we had shouldered our G.I. rucksacks and I found it discreet to conserve words as we started up the grade.

For a fairly long uphill stint we ordinarily would tie climbers on our skis. Plush will do but sealskins are better—they slide forward but not back, even on a thirty-per-cent slope. I let the boys know that going uphill is nothing but honest toil. They would discover toil's own good reward for themselves, and I needed to concentrate, between puffs, on hoping that I would rediscover it.

We didn't pick the warmest place for lunch. We stayed out where the view was sweeping, and the wind too. To help save weight, we carried concentrated foodstuffs—pumpernickel, cheese, bologna, nuts, dried fruit, chocolate—but took the curse off our dehydration with a can of fruit juice, brought along purely and forgivably for luxury—"instead of a canteen," I said, getting soft, knowing full well the *Manual* would not tolerate such weakness. Theoretically, we should have melted snow instead, and would indeed have done so had we really been out to make progress in all our technique of going light. Instead I chose the modified spartanism of an old friend of mine who insisted on a cold shower every morning—but explained, "I always add enough warm water to make it comfortable." We weren't going to make this trip an ordeal by hunger or by thirst.

Nor by miles. We traveled only a short distance after lunch and allowed plenty of time to make camp. Bob asked, when he saw me looking uphill for a site, "Why not camp down there in the trees?" This showed good sense but I had another purpose in mind. There must be a demonstration that our camping equipment could make us cozy in an exposed position. So I chose a spot just under the crest, well above any trees.

"Remember to keep well back of the edge," I cautioned. "It's a snow cornice with a big overhang, and all set to collapse." Indeed, we had seen a cornice collapse on our way up, and how swiftly an avalanche could start.

Safely back from the edge we set about excavating a snow platform in pseudo-Himalayan style—but without a lightweight snow shovel. The snow was wind-packed, and of just the right consistency for sawing into blocks.

"Use your ski tails as a saw and a shovel," I said, but warned, "Don't pry; just slice."

I learned this the hard way myself—harder for a friend than for me. I pried, ever so gently, and cracked a ski tail—his.

The excavating went rapidly. You push the tail straight down a foot or so in a series of stabs outlining a snow block, then diagonally slide the tail under the block and slice it out. The snow was perfect for an igloo, but Eskimo engineering and snow-cave digging could come on a later trip. We cut into the slope about three feet on the uphill side and piled our blocks below, ending up with a platform about eight feet square. Using a ski's edge as bulldozer, we leveled it. By now the platform was compacted to ice.

Our Logan-type tent—a 12-pound wonder—came out of the pack next. Ken volunteered to put up the sectional center pole—an inside job. "I know a good thing when I see it," he told Bob, and got in out of the wind. With the center pole, Ken gave the tent height; Bob and I staked it with ski poles and tied it to skis to give it semblance of shape. The inside man set to work inflating the air mattress (half length was enough for a multiple hip pad), unrolled the down-and-processed-feather sleeping bags (army surplus), and got the Primus stove set up.

Bob passed in a small foam-rubber pad to experiment with. Maybe it would be better than a shared air mattress—he who shares his neighbor's air mattress also shares his neighbor's every bounce. We should find something better. Searches for improvement, big and little, have been one of my own major ski-mountaineering pleasures and could be theirs too.

I marveled as I climbed into the Logan tent. It must have been designed by a recluse who abhorred proximity. You can even stand up in it! They call it a three-man tent but it could have held our whole family (all six of us) and leave room for a friendly guest.

Lying in the luxurious open space of this mansion-on-the-snow, I regaled Ken and Bob with the sad story of the "Home-on-the-Snow" tent I designed just before

World War II. Until I die I shall insist that this should have been the army's official mountain tent instead of the dank, impractical, inhospitable cul-de-sac the army ended up with. The Home-on-the-Snow was theoretically a two-man tent but we never had fewer than three in it and seldom fewer than four. With four, it would have an extra sag on top caused by the bulge on the sides. It was as snug and revealing as a sweater. Only one person could sit up at a time. No one could stand in it, nor need try.

All in all, this design had antifreeze advantages. It also had a built-in rest inhibitor: when it was full, you could turn over only by mutual consent.

Its minor disadvantages, I still insist, are far outweighed by its virtues, among them its lightness in weight —less than a pound per man. Another, its streamlining and low silhouette, important in high winds. Its worst feature was that it could be snowed in because it was so low. Its best feature was by all odds its cooking space, a vented floorless area in the sloping front. Here your snow mine, which is to say your water supply, is right at hand. You scoop up snow as needed for melting on the stove. If someone tips the stove over—and someone always will—you don't have to rely upon the sleeping bags' blotting up the soup. The snow in the open floor space soaks it up instead, and if you happen to scoop up a little frozen soup when melting snow for your coffee, who's the poorer?

My point isn't to argue the merit of tents, but to suggest that tent building can be fun. I experimented with paper models, then a cloth miniature, and finally the pilot project. It went on many trips before I built its successor, with different material and (let's face it) slightly larger dimensions.

"The perfect tent is yet to be invented," I told Bob, our mechanical son, "and a lot of people are going to have fun trying to invent it." Then I remembered my clincher: "Besides, that first tent only cost me $4.60 for materials."

Someone else had all the fun making the Logan—and it cost us $88.

As with tents, so with packs and stoves. Plenty of room for progress. Whatever the item, the search for a lighter, better, affordable design can be fun.

I threw the boys the epitomizing challenge as we sat there luxuriating and I remembered earlier, harder days.

"Beat our twenty-one-pound record if you can," I said. "In my heyday we could take off on a three-day trip and spend two nights out with only twenty-one pounds per man. That included the food, tents, sleeping bags, stoves, utensils, first aid for us and for our skis, and our extra clothing—for seven of us." But it didn't include what we wore, such as our skis and poles.

A pack as light as that, I could add, doesn't play hob with one's downhill ski technique. More important, it doesn't put too great a strain on the swivel muscles that are the hallmark of the chairborne.

Lightness of pack can also make ski-mountaineering coeducational, as we proved during one Easter week in Little Lakes Valley in the High Sierra. Our party of twenty-two included four women. A little more distaff over the hot kitchen Primus could do a world of good. *Anything* would help. Ski-mountaineering menus are wide open for pioneering and whatever I would like to say about the blending of foodstuffs that were never intended to be mixed in the light of day, and the resulting mayhem-in-the-pantry, is privileged information. I swiftly change the subject and claim merely that no ski mountaineer has ever starved or even gone hungry, and that no man who has done an honest day's toil *need* be a gourmet.

Continuing our honest toil, we struggled to keep the kerosene out of such food as we did have—a struggle that is always very much worth the effort—and we didn't quite succeed. The aftertaste is unforgettable; almost immortal.

I wanted to tell the boys more, but remembered in time that the less a father says to his own sons, the more they are likely to remember. Advice comes best from those who cannot command. I will just disclose to you a few of the things I should like to have told them. They will never know what is said here for they long ago made it a point never to read anything I write if there is the slightest possibility that I'd like them to.

First, I would have cautioned them, if you should ever decide to take up ski mountaineering on your own, don't go alone or with a weak party or underequipped or anywhere beyond reasonable expectation of safe retreat. Secretly not wanting them to dash too far ahead of me, I would have warned them that if they were overburdened with energy, they should save it, thus keeping the party strong if someone else's *underburden* of energy should show up; mine for instance.

Sounding even more fatherlike, I would have warned them in capital italics about *AVALANCHE HAZARD,* and would have illustrated it with a very hairy story about how four friends of mine would now be dead, their death having been brought about by a very simple-minded avalanche, had a fifth friend not had a cold that day. There I would have ended the story abruptly until they pounded me for details, which I would spoon out with liberal accompaniment of vital avalanche lore.

Finally I would have tried to explain to them what ski mountaineering had meant to me; about the peaks I had made first ascents of, for the most part on skis; of the high snow camps I had known and what it was like to be up on top in early winter morning and evening, when the world is painted with a very special light; of the kind of competence and even braveness, maybe, that one picks up from good friends and challenging peaks, up there when the storms hit and the snow pelts the fabric all through the night; of the kind of exhilaration we got when, after two winter struggles, the third put us on top of a fourteen-thousander and we were first to be there in winter and see how magnificently winter treats a high land we already knew well in summer but in a lesser beauty; of the long vibrant moments when we were back on our skis, skimming down the uncrevassed glacier on just the right depth of new powder, letting our skis go, finding that every turn worked, hearing the vigorous flapping of our ski pants even though the wind was singing in our ears and stinging our faces, sensing how rapidly the peaks climbed above us, those peaks that had dropped so reluctantly to our level in all the slow day's climb; of the care we had to take after night found us out and we sideslipped and sidestepped down into the tortuous little basins and then into the hummocky forest floor that lay in darkness between us and camp; I would have described that hot cup of soup I cuddled in my hand in exhaustion, sipping slowly to absorb its warmth and its energy at a retainable rate; and I would speak of the morning after and, not its hangover, but its glow as I looked back up to the rocky palisade above the glacier and was just pleased as hell to have got there at last—pleased with the weather, the companions, and the luck—and also forgivably pleased a little that I could do it.

But I didn't tell them all that. This is the sort of thing you find out for yourself, that comes when you escape into the reality of the wilderness and discover how amazingly well man has been designed to cope with just such reality. This is the sort of thing I would want them to find out for themselves. Maybe then, after that, we could compare notes. That would be the best reward of all!

Our Logan was really cozy now. We were in that especially blissful camping situation only the ski mountaineer or the expeditioner finds himself in. You tie the wind and the chill outside. To insulate yourself doubly against the cold, you climb into the sack, taking off only your boots. Propped on your elbows, you arrange to have dinner served to you in bed—friendly self-service—even as your breakfast will be. The Primus has a friendly roar that can outshout all but the most hostile winds and you listen to your friend. It warms your tent while it roars, but not too much, for you need to keep a circulation of fresh air coming in the tunnel entrance, and the stove exhaust going out the vent near the tent's peak.

We had the entrance tied back and were watching the shadows develop among the turrets of Castle Peak when two skiers christied to a stop at the edge of the brink below them and us.

One of them called over: "Now that really looks comfortable! When do you serve the martinis?"

"They'll be ready for your next run," I said, lying.

"Are you going to spend the night up here?"

"We're all set up to, and the boys would like to," I replied; and the boys had indeed said they wished they could. "But we're just trying this business a step at a time. We'll try for an overnight stop next trip."

They took the steep pitch below us in style, like the ski-patrol pros they were. But they never did get back for the martinis, for the lift had stopped running to the top of Signal Hill, a hundred yards above us, and there was no easy way for them to get back up. In less than half an hour we ourselves had struck camp and made out way back to the car, just as the sun left it, and were home four hours later.

On the drive home I had some more fatherly advice for my sons. "When you're old enough for martinis," I counseled, "if you do decide to take up ski mountaineering and really get back into the wilderness, remember you've got to watch your weight. 'When in doubt, leave it out,' is what we always taught them in the Mountain Troops.

"Now the way to save weight on martinis," I said, "is to take no vermouth at all."

Perhaps I should have suggested better things not to take.

* * *

And now, on to the serious work of the book—after this footnote: if you want to know all about how that one man's cold saved four men from death by avalanche, see "California Avalanche," by Kenneth D. Adam, in the 1955 Annual *Sierra Club Bulletin.* —D. R. B.

1. Warmth

THE MOST important difference between summer and winter camping is the necessity, in winter, of maintaining warmth. For a short time before the winter camper turns in, a wood fire built on green poles laid on the snow, or the small gasoline cook stove in the tent, will make available some heat; but by and large, both on the trail and in camp, the human body must produce sufficient heat to maintain normal temperature. If the interior body temperature drops two degrees, intense shivering results, further lowering of temperature produces sluggishness and coma, and finally, at somewhere between 70° and 75°, death ensues.

We must then consider the human body as a heat-producing machine and determine (1) what can be done to increase the amount of heat manufactured by the body, and (2) what can be done to conserve this heat.

Production of body heat.—A normal male adult at rest, as in sleeping or loafing, liberates approximately 50 calories of heat per hour. This can be increased appreciably by eating or by exposure to cold. The only other means by which skiers may increase heat output is muscular action.

Violent exercise will increase heat output as much as sixteen times.

Shivering, which is merely a form of muscular action, will if intense, increase heat output several times; in fact, it is nature's method of preventing freezing. The digestion of food will increase heat production. The increase is prompt but brief for carbohydrates, much prolonged and higher for proteins, slow for fats.

These facts, applied to the technique of winter mountaineering, lead to the following conclusions:

1) There is no great difficulty keeping the body as a whole warm while vigorously exercising.

2) If one is cold during the night, food is desirable.

3) Vigorous shivering, though uncomfortable, is the most effective way of getting warm inside a sleeping bag.

4) Another excellent method is to tense the muscles of the body strenuously; relaxing and tensing alternately un til heavy puffing and warmth result.

5) Hot drinks are fine only for temporary warming.

6) To prevent freezing of hands and feet, warm blood must get to them. Tight shoes and mitts restrict circula tion, and tend to induce freezing. Boots must be reason ably tight while one is skiing, but should be loosened im mediately upon arrival at camp, or before any prolonged rest.

7) Fatigue decreases the amount of heat produced by the body and should be carefully avoided. It is better to camp or bivouac before becoming excessively tired.

Conserving body heat.—Much more can be done in conserving heat than in producing it. In the first place, the body itself possesses certain mechanisms for this purpose. We are all familiar with perspiration and evaporation as a means of cooling. We are not so familiar, however, with the fact that the skin automatically shuts off surface blood circulation when exposed to cold, and that this action decreases the heat loss from the skin to one-fourth of normal. This reaction alone goes a long way toward enabling a skier to keep warm. Alcoholic drinks prevent this thermostat from properly functioning and therefore result in rapid loss of heat from the body. For this reason, the inflexible rule of ski mountaineering is that alcohol should never be drunk during or immediately previous to exposure to cold. As the body continues to get colder, the next reaction of the human system is to cut off most of the blood supply which normally goes to hands and feet and thus attempt to preserve normal temperature within the torso, where the vital parts of the body are situated. This can reduce the blood supply to the hands to as little as one-eighteenth of maximum. The danger of freezing of hands and feet as a result of such general chilling is obvious. In practice then, if danger of freezing the extremities exists, it is just as necessary for the skier to put on an extra sweater as dry mitts or socks; moreover, the sweater, unlike extra socks, cannot cramp circulation in the feet.

Wind is as important as low temperature in producing chilling. A ten-mile-an-hour wind under some conditions is equivalent to a lowering of the external temperature 60°. On increase of wind velocity above ten miles per hour produces little additional cooling effect if windproof garments are worn.

The problem of keeping warm is then primarily the providing of insulation from *both* wind and cold.

To provide insulation from wind:

1) A sheltered spot should be selected for camp.

2) The tent should be thoroughly windproof. Because of the large amount of air that filters through ordinary tent walls, coated waterproof fabrics are warmer in heavy winds than the closest woven permeable cloths.

3) In a heavy wind a snow cave is warmest because it alone can provide still air, although the snow is usually porous enough to allow adequate ventilation.

4) Clothing should consist of a thin, windproof outer shell and as many inner garments as may be required for warmth. This windproof shell usually consists of a parka, a face mask (under extreme conditions), outer mitts of leather or fabric, and windproof trousers, either wool gabardine ski pants or special trousers over usual ski pants. Ski boots complete this shell. Windproof joining of these articles of clothing should be provided: a sewed-on parka hood, adequate parka drawstrings for face and waist, straps on cuffs of outer mitts and the usual tight-bottom ski pants.

To provide insulation from cold:

1) Warmth of clothing and sleeping bags is directly proportional to thickness and independent of weight. Warmth results from small bodies of dead air enclosed by cell walls or held between numerous fibers. For this reason several layers of fluffy, loose-woven sweaters are better than hard-woven garments weighing several times as much.

2) Down, feathers, and wool, in the order named, are the best insulators. This is true for both sleeping bags and clothes.

3) Sleeping bags should be covered with tightly woven cloth to prevent warm-air permeation as well as to con tain the down. A complete hood extending over the head prevents loss of warm air around the shoulders and in sulates the neck and head. Heat loss from an unprotected head and neck exceeds that from the remainder of the body when protected by a sleeping bag. Form-fitting de sign with the outer shell cut larger than the inner shell gives most insulation for least weight.

4) Placing sleeping bags close together conserves body heat. A sheet of cloth over all the bags helps.

5) Insulation is necessary between snow and sleeping

bag; the wool, down, or feathers are crushed by body weight to a thin layer having little insulating value. Fir boughs under the tent floor shingled in the usual matter are thoroughly satisfactory. Above timberline some sort of mattress is desirable. Mattresses made of wool and kapok provide ample insulation but are bulky. Modern closed cell foam plastics are also bulky but provide much better insulation than air mattresses, where internal air movements can cause rapid heat loss. Open cell foam is also useful but must be placed in waterproof covers to prevent absorption of moisture. A mattress, air or otherwise, 18 by 36 inches, is wide enough to sleep on and long enough to extend from shoulders to hips. Food bags, boots, and clothing may be placed under the head for a pillow; a rucksack, parka, climbing rope, or other insulating material at hand can be placed under the legs and feet.

6) Damp articles of clothing, whether wet or frozen, are poor heat insulators. Every possible means should be taken to keep all of the clothes dry, especially the inner mitts and socks.

7) Oily skin is a much better heat insulator than wet skin. Too much washing and the elimination of natural skin oils is not desirable.

8) It is better to change to dry mitts at the end of the day before the hands become cold. Even though mitts which have been worn during the warmth of the day do not feel cold, they are probably quite damp from per spiration and are poor insulators. The same is true of socks.

9) Pressing the sleeping bag against the wall of a tent or pulling it very tightly over one's body decreases the thickness and resulting insulating value of the bag. This is one of the principal causes of a cold back. For the

same reason the sleeping bag should be fluffed up by shaking well before using.

10) As many layers of dry wool clothes should be worn inside a sleeping bag as are necessary to keep warm. These include shirts, sweaters, pants, and socks as well as underclothes. To keep weight to a minimum, every item must serve as many uses as possible. Thus, clothing should serve as insulation both day and night. A sleeping bag that is adequate for sleeping in the near-nude at the lowest expected temperatures is unnecessarily heavy. Even damp clothing will dry during the early, warmer part of the night if there is enough insulation to maintain warmth and if temperatures are not so low as to freeze the moisture into frost within the sleeping bag.

11) Heat loss from a small portion of the body can result in chilling the entire body. The blood acts as a circulating heating and cooling system. Therefore, it is important to cover hands and head, even when not dis tressingly cold, if there is any indication or threat of body chill.

The reverse is also true. If a sleeping bag is too hot, exposure of head, arms, and chest will provide adequate cooling for the entire body.

2. Equipment

EQUIPMENT must be kept to the lightest weight consistent with reasonable durability and adequate protection against emergencies. A light pack makes a trip more pleasant and control of skiing more certain. Even the robust man, who could easily carry much more, should always have as light a pack as possible, to maintain reserve energy for emergencies and a reserve of carrying power in case of injury or fatigue of any other member of the party. He should further consider that if *he* is injured, the party must carry *his* pack—or discard some of it.

The equipment is divided into that which is (1) worn, (2) carried in the pack, (3) included for community use, and (4) necessary for difficult climbing on rock and ice. The equipment listed first in each of the divisions is the minimum requirement for a tour of at least one night on the snow, with possibility of blizzard and temperatures down to —30° F; "optional" equipment can be added as desired. The community equipment is based on a four-man party. Variation in the number in the party using the community and climbing equipment, as well as the type of expedition, would require some changes in the items suggested. Supplementary discussion is included in the chapters on Warmth and Shelter. Refer also to the Check List of Equipment on pages 221 and 224.

Equipment for Wear

Clothing.—Inner garments are preferably all wool, of loose weave, and should consist of several lightweight layers for greater warmth and to permit adjustment of the amount of clothing under changing conditions of weather and exertion. Cotton is undesirable; it absorbs and retains moisture, and then lacks the warmth of wool for garments of equal weight. Lower underwear should be woolen and extend to the ankles. It is not easily changed, and need for protection against extremes of cold should therefore be anticipated. Overheating may then be avoided by removal of clothing above the waist. The shirt should have a long tail. Inner socks may be light wool, oversocks of heavy wool or goat hair.

Outer clothing must be close-woven, windproof, water-repellent, with a smooth finish. It need not be wool. Rough or fluffy material must be avoided, for snow will cling to it and melt. Down garments utilizing the offset seam construction provide the greatest insulation for a given weight. It is important that outer windproofs fit loosely over inner down garments to allow for full expansion of the down. Ski pants should be full at the knee and long enough to stay well inside the boot. Pockets on outside clothing should have zippers or adequate overlaps and fastening to keep out snow. A good all-metal zipper is not seriously affected by icing. Tabs should have thongs, for easier use by mittened hands. The parka should reach below the hips so that there is no gap between parka and pants, and should fit loosely. Such a parka will protect the torso better. The pull-over type is best for blizzards, but a long throat zipper is needed for ventilation. Large pockets or muff are advisable. The parka must be water-repellent but not waterproof, except possibly for the shoulders and hood. A waterproof garment can easily become soaked from within by condensing perspiration. The parka hood must have drawstrings to permit covering head and face, except eyes and nose. A cap or headband will supply necessary additional insulation for the ears. Overmitts should be large enough so that fillers will not press against the fingertips.

Ski boots.—Boots should be large enough for an additional pair of socks or for inner soles as added insulation. Lower temperatures should be expected and must be guarded against. The toe of the boot must be high enough to permit curling the toes under (to increase circulation) when worn with full set of socks and inner soles. The boot should, of course, be the best quality that can be afforded—economical in the long run since cheaper boots require earlier replacement. Rubber lug soles are desirable on two counts: they provide better traction for climbing on rock and they offer more insulation than leather. The downhill boot, with its various strata of leather, is neither light nor flexible enough for touring, where there will be little need for downhill tension and the thick sole that can take it. But the touring boot must not be so limber as to sacrifice control. Gaiters of light windproof canvas are essential for keeping loose snow out of boots and socks.

Skis.—For best results the skis should be of good quality, more flexible, and require more upturn on the tips than usually chosen for practice slopes or racing; however, any standard model will be satisfactory. Metal or plastic edges are essential to accurate control on ice or crusty slopes of high angle. A ¼-3/8-inch hole should be bored near the tip of each ski so that the pair may more easily be converted into an emergency toboggan. Bindings are listed in the check list so that those who have separate binding parts will not forget them. Release-type bindings with suitable toe attachment for walking and climbing provide a greater margin of safety during the downhill run. Ankle straps, or other positive means of tying skis to ankles, are essential to prevent possible loss of a ski in a fall. Ski poles should reach from boot to armpit, being somewhat longer than for practice-slope skiing because they must be used more, often in softer snow.

Dark glasses (see also *Snow blindness,* p. 141.—Glasses should provide side protection against glare and driving snow. They must be adequately ventilated to reduce fogging. Color should be quite dark, preferably in nonbreakable glass. Plastic lenses may not be optically correct, and may scratch easily. They weigh little, however, and do not break readily. Polaroid removes only a small portion of snow glare.

Miscellaneous.—Pocket knife should be of good steel with screwdriver and leather punch for repair and adjustment of skis. Matches should be carried in the various pockets and parts of the pack where they are most likely to remain dry. Reserve matches should always be carried in a waterproof case in the emergency kit. Matches may be waterproofed by covering them with nitrocellulose lacquer.

Optional items to wear.-—A hat with brim or visor protects against heat, snow, and overhead glare. A lightweight knapsack may be useful for short trips away from camp, or for half-day tours. A handkerchief may well be reserved for cleaning glasses, since the general utility bandanna soon becomes greasy. A lightweight watch may warn one when to turn back on a dull day.

Equipment to Carry

The rucksack.—This should be based on a rigid or semirigid frame. Center of gravity must be low and close to the body; the pack must not sway in fast turns nor go over the head in a fall. A belly strap is essential. If most of the weight is carried on the hips, shoulder muscles are relieved. The pack should also be free from contact with the back to avoid dampness from perspiration, which is particularly uncomfortable in cold weather. A pack with a rigid frame is easier and quicker to pack and heavy, irregularly shaped articles can be placed close to the body without gouging the back. The Bergans-type rucksack with frame and bellystrap fulfills these requirements. Metal frames are more durable than rattan. Packboards of the Trapper Nelson or Yukon types are preferable for loads in excess of fifty pounds, or for packs that are not easily made up in a rucksack. The army plywood packboard is excellent.

Emergency kit.—This must be more than a first-aid kit, for the ski mountaineer may often be called on for "second" aid, for building a fire in adverse weather, or for repairing equipment. The kit should be as complete as ingenuity can suggest but *must be small enough to be carried at all times* when the skier is at all removed from help. A small kit of essentials that is always carried is of far more value than a kit so complete and cumbersome that it is left behind. A suggested list of items is as follows:

Matches in waterproof case	Tincture of merthiolate
Large firemaking candle	Tannic or picric acid for burns
Compass	Antibiotic capsules
Sterile gauze pads and rolls	Codeine-aspirin capsules
Bandaids	Ammonia ampules

Two razor blades	Toilet tissue
Whistle	Small notebook and pencil
Needle and thread	Braided iron picture wire
Safety pins	Small tweezers

These items will go into a Boy Scout model first-aid case, 2 X 4 X 6 inches; total weight 19 ounces. In addition there should be 5 yards of 1½-inch adhesive tape, not waterproof.

The candle or substitute can be very helpful in starting a fire under adverse conditions. Braided iron picture wire is for repair of bindings. Two razor blades are suggested; one as a substitute for scissors, the other in its original heat-sterilized wrapping for minor surgical needs. The National Ski Patrol and other organizations have found that vocal calls for help are frequently misunderstood and disregarded. A whistle attracts attention and saves energy when it may be needed most. Three blasts signify "help!"

Other contents of pack.—Miscellaneous items in the appended check list down to and including wax should be carried on all tours, even when an overnight camp is not to be made. The map should preferably be topographical. Mittens should be loose-woven wool, and used inside of the windproof, water-repellent overmitts when low temperature requires. Gloves with separate fingers are not satisfactory since each finger radiates heat separately and cannot help to keep the others warm. A separate index finger, however, permits camp tasks to be performed without clumsiness. The index finger can be drawn into the mitt when cold. Sunburn protection is essential in spring skiing, and may be necessary even before March. The brilliant reflection from snow, particularly in the clear air of high altitudes, may cause serious burns. Tannic acid in powdered form, mixed with water in the palm of the hand at the time of use, is pleasant and satisfactory for most skiers. It may also be made up or purchased in alcohol solution. Some skins require opaque protection, such as zinc oxide. Each skier must determine his own requirements. A headband protects the ears in cold weather, particularly when windproofed by the parka hood. A light blizzard visor is desirable in severe storm. Two light sweaters of adequate length will furnish emergency protection to 0° F and will serve to insulate an injured person. One or two extra large bandannas may be carried for general use and for emergency triangle bandages—or vice versa. Climbers for the skis will ordinarily be on the skis during climbs, but must otherwise be in the pack, so the weight is listed.

For optimum insulation with least weight and bulk, a sleeping bag should be made utilizing the offset-seam principle, with a continuous layer of 100 per cent pure down surrounding the sleeper. The best design will also incorporate the differential cut which allows the inner shell to be stretched at points of contact without tightening the outer shell, thus diminishing the thickness of the insulation. Zippers, if any, should be protected with down strips. The outer cover should be water-repellent, not waterproof. The mummy design is best with hood arrangement that can be either fully open or tightly closed. With a bag designed to conserve heat most efficiently, with bags placed close together and with most of the skier's daytime clothing worn in the bag, 2½ to 3 pounds of down will be adequate down to —30° F. Such a bag will weigh from 4 to 6 pounds. Multiple sleeping bags, holding 2 to 3 people, conserve heat most efficiently and save weight and space. It is important to prevent heat loss through to the snow layer beneath. While air mattresses offer reasonable warmth, the foam plastics are better insulators (see page 20). For example, a 3/8-inch piece of ensolite 30 by 15 inches will provide ample insulation at extremely cold temperatures. Effective insulation under the sleeping bag is essential at such temperatures.

Extra clothing.—A complete change of socks should be carried. Damp or wet socks conduct heat from the feet. A long Balaklava helmet of loose-knit wool will, when worn under the windproof parka helmet, protect the throat, the back of the neck, chin, the nose, and, indirectly, the lungs.

Personal items.—These must be kept to a minimum in weight. A small hotel-size bar of soap will serve. The extra bandanna makes an adequate towel. Each man should carry a metal cup, which should be easily accessible in the rucksack.

Optional individual equipment.—Extra dark glasses may be carried, although one pair in community equipment should be sufficient. On long trips extra optical glasses should be carried if needed. Emergency food is desirable. For pitching the individual tent above timberline, three 10-inch duralumin tent stakes weighing only 2 ounces are enough. Tent stakes are not essential, however, for skis and poles serve better, and the tent need not—in fact, should not—be left pitched when one is away from it. In severe climate, windproof overpants may be essential. They should be made of material similar to that of the parka. For those using optical glasses, a case will be found useful at night.

Community Equipment

This category includes principally cooking equipment and food, with certain additional items for repair, first aid, and emergency. If a two-pound tent section is not carried by each man, the tent will of course be included in community. Most parties are strict in keeping the community to the lightest possible weight but do not exercise enough control over personal equipment. It must be emphasized again that no one should be permitted to carry an unnecessary item merely because "he wants to."

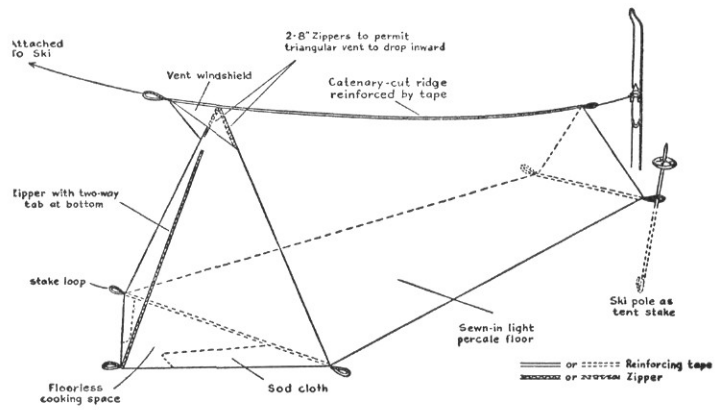


Fig. 1. Tapered tent for three men.

Tent.—Lightweight, easily pitched, but not too roomy is the two-man type of tent. The design shown (fig. 1), when made up of 5½-ounce waterproof poplin with a 3½ -ounce percale floor, weighs but 4 pounds. It will house three men comfortably, and can hold four. It may be pitched with two to four skis, two to five poles, including one under the peak of the ridge. The sod-cloth on the flaps surrounding the floorless cooking space must be weighted with packs or food bags during heavy wind. Suggested dimensions (in inches) for the tapered tent are as follows: width at front, 64, at back 30; height at front 51, at back 20; length of ridge, 88; triangular front flaps, 60 by 60 by 30, joined by 42-inch zipper; width of sod cloths, 10. The 4-man Logan-type tent with 8 by 7-foot floor plan weighs 12 pounds but provides greater ease in cooking and will be more comfortable when the party is pinned down during bad weather.

Repair kit.—Each party must be certain that it has adequate repair equipment, weeding out unnecessary duplications. Suggested items are:

Combination wrench-plier-screwdriver
Ski tip and contraction band, key or nail
Ski-pole mender (piece of light sheet metal)
30 feet 3/16G-inch line
Philips screwdriver and screws
4 slender 11/2-inch bolts with nuts and washers
2 slender 11/2-inch screws 2 heavy 3/4-inch screws
3 feet braided iron picture wire
6 feet 1/4-inch rawhide Sewing kit
Extra flashlight bulbs, proper type
Toe strap Extra matches

The contraction band (or flickzeug) is compact, light, and will repair a broken ski unless the tip is shattered or lost. To repair such a break a *sturdy* aluminum ski tip (or a plywood tip with a contraction band) is essential. A nail is advised to supplement the key (in case the soft iron of the bolt heads becomes so rounded that the key will not grip) but the bolts must be drilled for it. Miscellaneous bolts and screws are advisable for supplemental repair. Other items may of course be added, but ready portability should not be sacrificed; this kit must always be with the party. If the party has any intention of breaking into two or more units, it would be wise to have a repair kit for each unit.

Flashlight.—A headlight will serve for a party of four. It is superior to a hand light, since it will free the hands.

and the battery can be kept warm next to the body. The most efficient temperature for the cells is 70° F. Their efficiency is 50 per cent at 30° F; at 0° commercial cells will not function. The switch on any flashlight should be so designed that it cannot be accidentally turned on in the pack. Fresh battery cells should be put in the case at the start of the trip.

Cooking stoves.—A lightweight gasoline stove should be carried even for camps below timberline. One may cook over a wood fire built on the snow, but in severe weather such a procedure is most uncomfortable and it is difficult and time-consuming to make the fireplace blizzardproof. Though a variety of stoves can be recommended, the most reliable is the kerosene-burning Primus type, with roarer burner and built-in pump. One stove, half-pint or one-pint size, will be adequate for each tent. With two half-pint stoves, two courses can be cooking simultaneously; however, the pint size, with larger burner, is more efficient. If the stove is carried in a small bag of gasoline proof fabric, chance fuel leakage will not spread so easily throughout the rucksack to flavor the food. One should learn the idiosyncrasies of these stoves before planning to cook with them in the mountains.

Fuel.—The amount of fuel required will vary with the number in the party, number of stoves, and method of cooking. Far more will be required if snow—especially powder snow—must be melted for water. A reasonably safe average with one-pint stoves is a pint of fuel per stove per day (about a two-hour supply). Used conservatively this should be enough for four men at temperatures down to 0° F. Inexperienced parties should take more until their requirements are definitely known. If a Primus stove is used, alcohol will be advisable for priming. In general, the fuel should be white gasoline. *No* *ethyl* should be used because of the hazard of lead poisoning from accidental internal use, contact, or fumes; such fuel will also clog the stove. With highly volatile gasoline one must guard against fire hazard, especially if gasoline is spilled within the tent. Be particularly careful to release the stove's internal gas pressure slowly to avoid spurting of liquid fuel or ignition of the vapor. Reasonably good ventilation is required to minimize the possible danger of carbon monoxide poisoning when the stove is burning in the tent. A small funnel is needed unless fuel cans have a proper pouring spout. The closure of any can to be used for fuel should be tested by squeezing the can to see if any air is forced out.

Cooking equipment.—This must be kept to a minimum, to save weight, space, as well as time and fuel in cooking. Palatable two-course meals can be prepared, for which two nesting 21/2-quart pots *with covers* (for efficiency) will suffice. Adequate, lightweight utensils may be improvised out of 3- and 4-quart cans. The scout-type knife recommended has a can opener, but a small 1-ounce key type may be preferred. A cup and spoon per man, plus a stirring tablespoon, complete the essential equipment.

Food (see pp. 51-55).—In calculating weight of food the net of 21/4 pounds per man-day must be increased to the extent of cans or other containers that are carried. Toilet tissue and match requirements will vary with the number of man-days. At least one paper of matches a day—or preferably about 20 wooden matches—should be carried, and the waterproof matches kept in reserve.

Additional emergency equipment.—A light hand ax and sheath is considered essential by many experienced winter mountaineers, for it enables one to provide adequate shelter and fire wherever sufficient timber can be found. It is omitted from the list of advisable equipment because the tent and stove are adequate below, as well as above, timberline (see p. 76). A light shovel is convenient for making camp in addition to its emergency value for avalanche rescue; many also list it as essential. Long trips require boot wax, additional flashlight cells, and a small packet of repair parts for the stove.

Miscellaneous optionals.—These should be kept as low in weight as possible. Tact is required in limiting the number of cameras on a trip. They add appreciably to the weight carried, and it is usually possible to arrange that one camera be taken, other members of the party sharing in its use, the cost of films, and the prints. A spring scale is useful when packs are loaded at the start of a trip—but should be left there.

Equipment for Rock and Ice

As the ski mountaineer reaches terrain which is precipitous or heavily glaciated, he will find he must place less emphasis on skiing and more on mountaineering. He may reach a point where he must forsake his skis for specialized equipment to aid him on high-angle rock and ice; for while he will be able to carry ice ax, crampons, and rope in his rucksack as he skis on gentle slopes, he will probably be more than glad to leave all excess equipment, including skis, in a base camp when finally he must rely on ax and rope. Certain minimum requirements exist for the special aids the ski mountaineer will need, and these are given below. An objective study of the merits and demerits of "Modern Ice-Climbing Equipment" is given by Robert L. M. Underhill in the *Canadian Alpine Journal* for 1933, and his discussion is recommended to the ski mountaineer with ambitions.

Footgear.—First choice for ski mountaineering is a ski boot with the rubber-cleated (Bramani-type) sole. The skier thus equipped can travel on any surface but glare ice without removing the shoes he skis with. This is a great advantage, for changing of footgear in low temperatures may lead to freezing of the feet. The sole should fit the foot, and not have a wide welt.

Second choice is a well-nailed ski boot. Edge tricounis with tricouni studs in the middle of the sole and a tricouni heel provide an excellent nail combination and will not harm the binding other than to scratch the foot plate. The binding may have to be readjusted. Rubber in the center of the tricouni heel will minimize balling of snow. Edge nails should be under the edge of the foot, not beyond it.

For dry rock there is nothing better than ankle high leather boots with shallow-tread Vibram soles—the so-called Kletterschuh. Such a sole will hold well on wet rock, but not on wet moss or lichen. The shoe should fit snugly over the desired sock combination, and the sole should not extend far enough beyond the foot to roll from small holds.

Rope.—Two 120-foot lengths of 7/16-inch rope, with two men on each rope, will be best for difficult climbs that require belaying. The two ropes may be tied together for descents by rappel. A 200-foot 5/16-inch rope can be used for rappelling, and will serve the purpose of ski-mountaineering trips with mild objectives. For severe strains the rope may be doubled, but both strands must share the load equally. The 5/16-inch rope is excellent for use in slings—for rappel points, Prusik loops, and other purposes for which rope is needed. It is considered bad form for a mountaineer to misjudge his requirement of sling rope and thus be forced to cut pieces from the end of his climbing rope.

Nylon rope has four times the effective strength of raanila hemp, and will be far less affected by water and ice. It was developed for the army, and is far superior to any other climbing rope.

Improperly used, a rope can spread disaster instead of preventing it (see chapters 15—17). It is the climber's lifeline when it is needed, and should be cared for accordingly (see p. 186). Resiliency is essential, and the climber should brush up on the elementary physics affecting rope when it is subjected to the various loads that are developed in mountaineering.

Ice ax.—Choice of the varying weights and lengths of ice axes will be determined by the purpose for which the ax is intended. For those who expect to use the ax primarily as a cane—its most frequent and prolonged use—cane length is preferable; that is, about half a person's height. A ski mountaineer or rock-climber may prefer a much shorter length if he intends, most of the time, to carry the ax in his pack. In any event the shaft should be of good hickory and fit the hand well. The pick should be 7½-8 inches long, with teeth on the underside, and the adz and pick of the head should curve so as to coincide with an arc that could be drawn by the ax held at arm's length. The steel should be tough enough to hold an edge well, but not so hard as to crystallize easily. Professional guides scorn a wrist loop, but they, and particularly amateurs, run great risk of losing an ax where they need it most. The loop is secured to a ring that slides on the shaft, being stopped above the point by a round-headed screw or a ring on the ferrule. A satisfactory substitute that will not interfere with probing and is readily adjustable is a loop of rawhide tied to the shaft with a Prusik knot (see p. 187). Most rapid wear will be of the point against rock when the ax is used as a cane.

The point should protrude far enough from the ferrule to permit several resharpenings. A one-piece point does not have the resiliency of a point and ferrule. Metal parts should be protected by a thin coat of oil after each use, the stock by frequent thin coats of a good wood preservative. A leather sheath for the head will keep the point out of undesirable places when the ax is carried, but is not necessary.

Crampons.—Fitted well and tied securely to the boots, crampons, properly used with an ice ax, will hold on exceedingly steep ice slopes (80° is claimed!) without requiring that steps be cut. It follows that crampons will increase safety in steps on less severe angles. A crampon should be rugged, and the ski mountaineer should beware of rejected army crampons that may be on the market for some time, and that have received the well-deserved nickname of "folding crampons" for their utter lack of necessary sturdiness. Single articulation of the crampon is adequate. The points should be 1- 11/2inches long to permit resharpening—frequently needed if the climber wears them often on rock islands in the ice. The number of points varies from 2 to 19. The 12-point model, which has two points protruding at an angle in front of the foot, is most versatile. A 4-point crampon may serve for the skier who wishes only to wear something on his ski boots for short and infrequent pitches of ice that are not difficult. The binding when wet will tighten if of webbing and stretch if of leather, but leather is easy to tighten again and can be more easily worked at subfreezing temperatures. On any long trip a spare pair of bindings is desirable. Many methods have been devised to simplify adjustment of bindings; whichever is chosen should be so simple that the climber will remove crampons willingly when he comes to short stretches of rock. More important, however, the crampons should be held as snugly to the foot as possible without impeding circulation.

Snowshoes.—Snowshoers claim certain advantages over skiers which are seldom conceded; certainly it is not the intention of this manual to take the side of snowshoers. The bearpaw, however, has a definite function in some types of terrain a ski mountaineer may encounter, such as in an ascent where skis have necessarily been left in a base camp, yet there is deep, soft snow on slopes above. The bearpawer, moreover, can and perhaps must travel as slowly as he ought to for safety; the skier has not always been known to do this. A bearpaw with a light duralumin edge will bite better into crust and hold better on steep slopes than one with a wooden edge. The binding should allow the heel free up-and-down motion.

Rock pitons.—Various types of pitons may be driven into cracks in the rock to provide a secure point on the cliff to which the rope may be hooked through the spring gate of a carabiner (see fig. 3). If the leading climber falls, he may then be held, pulley-wise, by a man below him. Successive pitons are driven as the climber moves upward. There are four basic types for rock, of which horizontals are most frequently used, verticals least, in a ratio of about 5 to 1: (1) vertical for cracks with flush sides, preferably vertical; (2) horizontal for flush or offset cracks, horizontal or vertical; (3) angle for wide, deep cracks, offset or flush, horizontal or vertical; (4) wafer for cracks that are thin, shallow and flush or with flared opening. A good piton will have a solid head to withstand repeated pounding. Rings, if any, should be securely welded. The metal should not be too hard, thus preventing the piton from "biting" well into the rock.

Ice pitons.—There are about as many designs as there are users, most of the designs obviously being the product of little thought. The shaft should be about 1/4 X 5/8 X 7—10 inches, with real teeth—not nicks—on the thinner sides. These will hold one's weight after the shaft itself has loosened, as it will under pressure or in mild weather and sunshine. The ice piton owes its security to the soundness of the ice into which it is driven and its angle to the ice surface, but particularly to regulation after it has been driven. The smooth, hollow-tubed U.S. Army variety is light in weight, shatters the ice least, and has held a pull of 2,000 pounds parallel to the shaft at temperatures of 10-20° F. But it remains to be seen how well a toothless tube will hold in the field without freezing temperatures to help it. The recently developed ice screw is much superior to the standard designs, developing exceptional holding power parallel to the shaft.

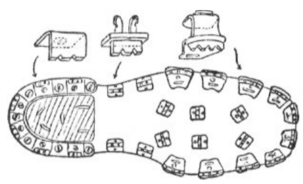
Piton hammer.—Most piton hammers have a point to aid in clearing out piton cracks or chipping ice. The point is sometimes annoying and is unnecessary. An ordinary 16-ounce mechanic's ball-peen hammer is very satisfactory for rock, and fits well, head down, in a rear pocket. A rawhide sling, anchored to a hole in the handle and long enough when around the neck to allow the hammer to be extended at arm's length, will free the hands between pitons and prevent loss of the hammer. A hammer holster is useful.

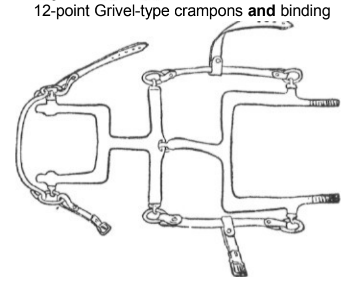
If there is to be much driving of ice pitons, a fairly long point on the hammer is useful in cutting away unsound surface ice or in chipping a recess for the piton. A geologist's pick and hammer is excellent. Greater weight—24—32 ounces—is also desired, for ice pitons must be driven much farther than rock pitons, against equal resistance.

Carabiners.—Designs of various types, oval, pear-

(Bramani-type sole) ski boot

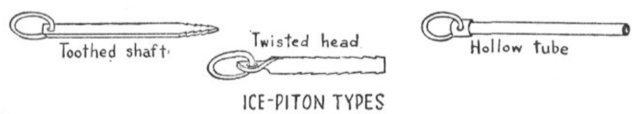
12-point Grivel-type crampons **and** binding

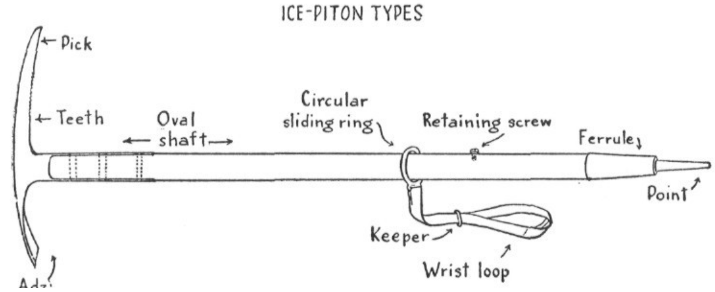




Tricount nail pattern using the heel plate, studs, and edge nails[1], sponge-rubber heel center. Nail should be spaced to fit crampons and toe Irons

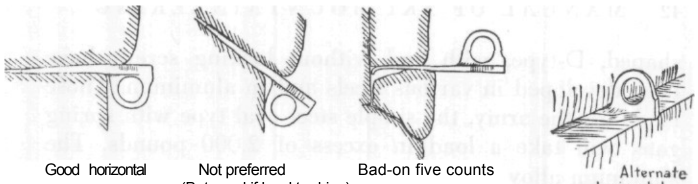
SKI-MOUNTAINEERING FOOTGEAR





ICE-AX NOMENCLATURER

Fig. 2. Ice-climbing aids for the ski mountaineer.

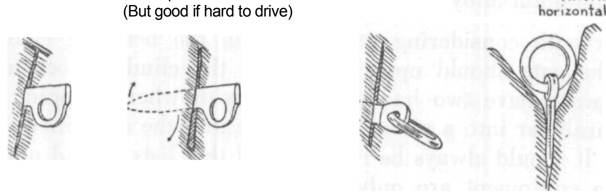


Good horizontal

Not preferred
(But good if hard to drive)

Bad-on five counts

Alternate horizontal



Good vertical

Poor

Good wafer

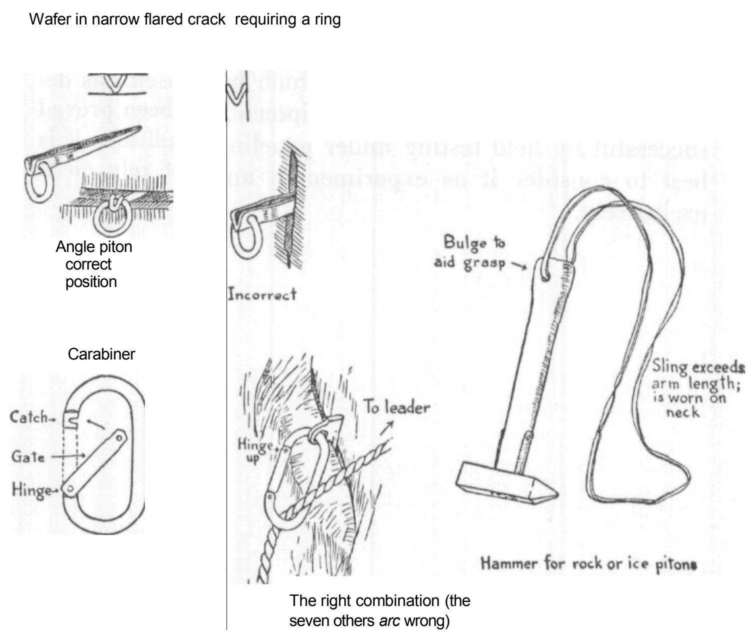


Fig. 3. Rock-climber's hardware, showing piton types in place.

shaped, D-type, with and without locking screw, have been developed in various steels and in aluminum. Those made for the army, the simple steel oval type with spring gate, will take a load in excess of 2,000 pounds. The aluminum alloy carabiners weigh only 2–2½ ounces and test from 3,000 to 4,000 pounds, more than adequate strength considering other links in the belaying chain. The gate should open freely, for the climber does not always have two hands to work with when snapping a carabiner into a piton, or the rope into the carabiner.

It should always be remembered that lists of and notes on equipment are only suggestions. There is plenty of room for both substitution and betterment. As a skier grows in proficiency and experience, one of his greatest joys will be the use of gadgets which he himself has developed. But until an item of equipment has been proved successful by field testing under grueling conditions it is best to consider it as experimental, and not rely on it exclusively.

3. Climbers and Waxes

THE RUNNING SURFACE of the touring ski is always protected from direct contact with the snow by a composite coating called, in general, wax. This coating serves a triple purpose: to protect the wood from absorbing water, to facilitate sliding, and to aid climbing. *Base wax,*—The first coating is the "base wax," and must be applied before the start of the tour. This is intended to be durable, to adhere tightly to the wood, to "take" well the running and climbing waxes later applied, and to slide well if these should be worn off. Many commercial bases are available, some of which are rapid-drying lacquers. The wood must be dry and absolutely free from wax before such a lacquer is applied. This is a minor disadvantage in repairing the coating if it is injured. A waterproof varnish is stronger but takes longer to dry. A very satisfactory base for touring can be made by melting together pine tar and flaked orange shellac, about equal parts, to give a mass that can barely be indented with the thumbnail at room temperature. A thread pulled out of the melted mass should not be too brittle, but should bend slowly. If it is soft or sticky at freezing temperature, it needs more shellac; if too brittle, more tar. This wax can be melted on to the ski with a warm—not too hot—iron, but a better coating is secured if it is dissolved in denatured alcohol, warmed by setting in a can of hot water, and then painted on to the ski with a brush, two or three thin coats. If, after it is dry, it is lightly flamed with a torch, it becomes toughened. Smooth with steel wool or fine sandpaper if desired. A good base wax such as this need be applied only once or, at most, a few times during the season of skiing.

Climbers.—A ski tourer has need of two qualities in his skis that might well seem utterly irreconcilable; he would like his skis to stick without backslipping while climbing and also to run downhill as freely as possible. Even in level going he would like them to slide only in one direction. This was achieved in the prehistoric period of skiing by fastening to one ski, the "push" ski, a coating of sealskin with the hair pointing backwards. The other and usually longer ski was the sliding ski. This method is still popular, but is now practiced by fastening long strips of sealion skin or plush to both skis, either by pasting them on with wax or by attaching them with straps or metal clips.

The waxed-on skins are much lighter, and the absence of side straps allows them to slide forward freely. Their chief drawback is that it is more of an art to apply them. That is, of course, no deterrent to a person who enjoys making an art of ski touring. If your skins have been precoated with the right wax, all you have to do is to stand the ski so that the sun can warm its under side, hook the strap over the tip—if your skis have no tips, you can equip them with short bolts with wing nuts through a hole—and stroke them down with the hand. Do not stretch them. If there is no sun, put the skins between your shirt and your own skin for a while, dry the under surface of the skis and stick the skins on quickly, one at a time. Skis so armed slide forward very freely, downhill or on the level. Of course, one cannot do any of the turns that require the skis to skid; the only turn that is feasible while sliding forward is the step turn, but this is the ski tourer's favorite.

The strap-on kind are cloth-lined and heavier. They do not slide forward very well, and, under certain conditions, ice can form between the ski and the skin. But this is the kind of skins to get if you are not ambitious to master the stick-on kind, or if you wish to run down after the climb on very fast, hard wax.

A simple makeshift is a ski sock, a canvas sack just fitting over the rear end of the ski and strapped over the toe iron.

Touring waxes.—For powder snow: The seemingly contradictory demands of high static friction for climbing and low dynamic friction for running can be reconciled by using a plastic wax just soft enough to permit the sharp crystals of powder snow to make microscopic indentations when the skis are firmly planted with no sliding motion, but hard enough to develop heat of friction when sliding to provide a film of water to serve as a lubricant. Beeswax has served as the chief constituent of such waxes. It must have the right consistency to rub thinly onto the ski and at the same time to take a polish when spread smoothly over the surface by rubbing briskly with a cork block or the ball of the hand. The colder the snow, the harder must be the wax in order for the heat of friction to produce the lubricating film. An excellent wax can be made by melting beeswax, if too hard, with just the right amount of a silicone waterproofing liquid. European waxes of this type for snow a little below freezing have been called "medium," and "mix" for colder snow.

It has been shown by a competent scientist that the lubricating water film results from friction, not from pressure. Bare metal is not suitable because it conducts away the heat of friction.

The fastest coating for skis is a fluorocarbon plastic known as "teflon," but it is suitable only for downhill running; because no wax adheres to it. It is ideal for the skis used on arctic airplanes.

Wet new snow: This is the most difficult on which to achieve both good climbing and running. "Swix" red is as good as any. It is also excellent for paste-on sealskins.

Corn snow, spring snow: The coarsely granular snow that has been repeatedly frozen hard at night and thawed loose during the day permits both climbing and running on skis coated with a relatively thick layer, about 1/8 inch, of a "Klister," composed of a sticky, stiff fluid tnat becomes indented and tough when climbing but smooths out after running a short distance. A good klister can be made by melting together pine tar and shellac, as for the base wax described earlier, but with a smaller portion of shellac. It must indent slowly after cooling in the refrigerator. The "Swix" klisters are nearly colorless, and do not stain hands and clothing. Klisters should be applied with a putty knife.

Frozen crusted snow: "Skare," a cross between a true wax and a klister, is effective.

Icing.—One of the most trying conditions the tourer encounters occurs when fresh powder snow begins to melt on the surface but is below freezing underneath. The wet snow is tramped down and freezes to the skis in the cold below. The same may occur when he goes from warm sunshine into a cold forest. When such conditions can be foreseen, it is wise to rely on sealskins for the ascent rather than climbing wax.

4. Water

THE SKI camper's water problem is much the same as that of the Ancient Mariner which caused him to lament

> Water, water everywhere,
> Nor any drop to drink . . .

The need for water varies greatly. It averages about two quarts per day, but is more than doubled by excessive perspiration or by the extreme drying effect of air at high altitudes. Unless this physiological demand of the skier for water is fully satisfied, his efficiency and even his health may be impaired. This does not mean that it is harmful to be thirsty. Since a gallon of water can be taken from the body without harm, a skier can travel a day without drinking, but at the end of the day the water should be replaced. Of course, if water can be obtained from normal sources during the day, it will save fuel required for melting snow, and, at supper time, will save space for more solid food. It should always be remembered that thirst is the best indication of need for water. To this general rule there is one exception: when one is approaching exhaustion, thirst should not be satisfied. Under such circumstances a half cup of water each quarter hour should be the maximum allowed. Salt should be added freely if the skier has perspired excessively.

Snow may be eaten safely as a source of water, provided it is eaten *slowly;* otherwise the stomach will be chilled. It is best to allow the snow to melt in the mouth before swallowing. A fruit drop or piece of fruit candy adds both flavor and sugar and dissolving it in the mouth with snow while traveling is a popular habit among experienced ski tourers.

Full advantage should be taken of all open streams as a source of drinking water. If water is sipped slowly, a pint or even more may be drunk without ill effects except a temporary slowing of pace which continues until the stomach has had an opportunity to warm the water to body temperature. Since the ski mountaineer will consume about four million small calories of food a day, it will be seen that the very small number of calories required to warm the water may be disregarded. Hot tea, however, is naturally more pleasant.

Usually, open water holes are found in the center of deep pools and if the snow pack is thick, it is a long way down to the water. Water can, however, be easily secured by tying the cup or cook pot onto a ski or ski pole. Precautions should also be taken against slipping into the pool by breaking off an insecure snow lip. It is best for the "water boy" to stay on his skis and have the basket end of one of his ski poles held firmly by a companion. These simple precautions will decrease his chances of a cold bath.

The most convenient source of running water is a small waterfall, such as is found frequently on the side walls of canyons. The water runs free except in subzero weather, and even under such conditions a small free flow may be found under the ice glaze.

During a midday halt, if the sun is shining it is possible to secure an ample supply of water by melting on a tent section. The tent section or other waterproof cloth is spread out slightly concave or dish-shaped, draining on one side into a cup or pot. Snow is spread *evenly* and *thinly* over the entire surface by sprinkling, in much the same manner as sowing seeds. The heat of the sun is absorbed by the dark tent fabric and melts the snow. The process can be hastened if the tent section is laid on insulating material, such as grass, twigs or clothing. If insulated in this manner, and out of the wind, water can be secured even though the air temperature is as much as ten degrees below freezing. A flat rock with a hollow on the top will serve as a substitute for the waterproof cloth, and cannot harm the water.

When snow is falling and a cold wind blowing, skiers crave hot drinks, not cold water. An ordinary canteen serves as an excellent thermos bottle if filled with hot coffee, tea, or other drink at breakfast, heated in the canteen until it actually boils and then stuffed quickly into the center of a rolled sleeping bag. The bag should, of course, be placed near the top of the rucksack so that the canteen can be readily reached.

On cold days the possibility of preparing hot drinks during short rests should not be overlooked. The ski stove will heat a quart of water to the boiling point in less than ten minutes. Tea and sugar should be kept in a handy part of the rucksack in anticipation of such stops.

If the day has been warm and a hot drink is prepared for a "pep up" for crossing the last high ridge to camp, salty bouillon is better than tea, since it replaces the salt lost by perspiration. The mountaineering rule is "A salt drink when you are tired in hot weather, a sweet drink when you are tired and cold."

It is well to "tank up" after meals. An extra cup of a hot drink for breakfast, a good swig or two out of a pot of water prepared while camp is being broken, and thirst will be postponed till noon. At night one's thirst will dictate that tea and more tea, or just plain water, is needed. It is better to satisfy that thirst than to deny it. There is actual danger in the practice of denying oneself—either as Spartan or Puritan—adequate water. Man can no more exist on insufficient water than on insufficient oxygen.

5. Food and Cooking

FOOD USED in winter mountaineering must meet the following requirements:

1) The food must have minimum weight for adequate food value. About 4200 kilogram calories per day are required by an active man on a mountaineering trip. Light weight is obtained primarily by using dehydrated foods and secondarily by selecting foods with a high caloric value. About 21/4 pounds per man-day of such foods are required.

2) Food used should be readily digestible and should be balanced between fat, protein, and carbohydrates (starches and sugar).

3) Good keeping qualities and easy packaging are essential. Bottles and cans are undesirable. They add weight and bulk. Food which can be placed in completely waterproof bags, tied at the top, can be carried most readily. Several items can be dry-mixed at home to eliminate extra bags and facilitate preparation at camp.

4) Food taken must be easy to prepare quickly and with simple equipment. For this reason it is desirable to take precooked foods, some of which may be eaten cold if something should happen to the stove. Because the boiling point of water decreases with the altitude, cooking time is about doubled for every 5,000-foot rise in elevation. Cooking time for some of the grains, such as rice, is reduced to less than half if they are precooked. This may be done at home by baking at 300-350° F until the first sign of browning.

5) Strenuous activity in dry, high-mountain air causes more perspiration—and attendant loss of salt—than is frequently realized. This must be replaced by extra salt ing of food. Muscle cramps and mountain sickness are often signs of salt deficiency.

6) Enough vitamins must be obtained. In the accom panying list foods particularly rich in Vitamin A are marked on the list with an asterisk (*), those with Vitamin Bi with a plus sign (+), those with B_2 with a cross (X), and those with Vitamin C with a circle (°). Vitamin C is the least readily obtained among foods which are otherwise suitable. Vitamin sufficiency for trips of only 3 or 4 days is not essential.

Food requirements may be met by food selected from the following list. Selections within each group are sub-ject to the taste of the individual, but the weight selected from each group should be approximately as indicated. The total requirement of food from each group for a given trip is obtained by multiplying the pounds per man-day, times the number of men, times the number of days.

TABLE OF FOOD REQUIREMENTS	POUNDS PER MAN-DAY
STARCHES *(Precooked)*	0.45
Oatmeal+ (for breakfast)	
Wheat germ-++ (for breakfast)	
Yellow corn meal* (for breakfast)	
Concentrated dried soups	
Dried peas or beans (for soup)	
Spaghetti, noodles, or dried potatoes (for supper, with cheese, tomato, meat)	
Brown rice+ (prepare same as noodles; takes longer)	
Rye crackers, hardtack (for cold lunches) Foil wrapped pumpernickel or rye bread	

SUGAR 0.45
Granulated sugar (put it in almost everything)
Mixed hard candies (for lunch) Sweet bar
chocolate (for lunch)

NUTS+* *(Shelled)* 0.15
Walnuts, almonds, peanuts, cashews, brazils (for lunch)

DRIED OR DEHYDRATED FRUITS AND VEGETABLES (SMALL CUT) 0.30 Apples,
apricots*, peaches, pears, prunes* (stew or mix
in mush. Use 4 parts water to 1 of fruit) Dates, figs,
and raisins (for lunch, and mixed in mush) Carrots,
beets, string beans, *tomatoes,* and *onions* (in
mulligan), spinach and cabbage flakes

FATS AND FATTY FOODS 0.15
Butter* (put in nearly everything—cocoa, mush, soup,
noodles)
Bacon (cut into mush or mulligan) Peanut
butter (on hardtack, or add to soup) Meat Bar,
3 oz. fat and protein combination

PROTEIN 0.75
Canadian bacon-}-, dried beef, and ham+ (cut into
mush, soup, or mulligan)
Salami, corned beef, liverwurst, cervelat (for lunch)
Whole milk powder* X° (in cocoa, mush, soup) Mild
cheese* X (for lunch, or melted into spaghetti) Beef
jerky, frozen-dried steaks, chops, meatballs, and
hamburger. Meat bar, as above

BEVERAGE MATERIALS .... To suit
Instant cofiee
Tea
Cocoa
Lemon powder[0] (lemonade for lunch and after dinner)
Bouillon cubes
Jello (as hot drink)

FLAVORING MATERIALS .... To suit
Salt (ample in everything)
Pepper, chili powder, onion powder, celery salt

Food preparation.—This is not a cook book, but the scarcity of equipment and fuel requires a few suggestions:

In melting snow for water, never put so much in the pot at one time that it draws the water away from the pot bottom, or the pot will scorch and give the water a flavor that cannot be disguised, even by soup.

Food must be cooked in one or two pots in order to keep to a minimum the number of utensils, the fuel consumption, and the time. The more water used in cooking, the less the chance of scorching the food. Moreover, mealtime often provides the only opportunity to obtain water. These requirements are best met by soupy dishes containing numerous food items mixed together.

Breakfast: Breakfast may consist of hot chocolate in one pot and mush in the other. The mush can be made by putting the necessary ingredients—salt, sugar, butter, diced fruits, or chipped Canadian bacon—into warmed snow water which is then stirred and brought to a boil. Oatmeal is then added and the mixture allowed to simmer 5—10 minutes; however, if you use prepared instant cereals, the meal is ready upon contact of the cereal with the boiling water.

Lunch: Lunch may be warm if the party is stormbound in camp; cold if underway. It may also be eaten at one sitting, though it is better to take smaller, more frequent snacks throughout the day's climb. A canteen of sugar-tea made at breakfast will not only slake the thirst at lunchtime, but will raise sagging spirits as well. The skiing gourmet may well produce such delicacies as smoked oysters and french bread if the car is not too distant and the pack otherwise not overloaded.

Dinner: Soup is prepared first from almost any combination of the following: powdered soup bases, butter, milk powder, onion powder, celery salt, dehydrated vegetables, minced bacon, salt, and pea flour. It is best kept thin, with few solid particles. The mulligan can be made from a base of spaghetti, noodles, powdered potatoes, or brown rice, flavored with a good quantity of cheese, tomato powder, and liberal doses of butter and salt. A fresh bell pepper or some celery sticks (chopped) will add immensely to the flavor of the mulligan if someone has been clever enough to bring them along. Meat items to be added can be: Frozen-dried hamburger or meatballs (precooked), steaks and chops (uncooked); bacon; ham; meat bars, salami, or bacon. The meat bar is precooked, weighs 3 ounces and is equivalent to about 1 pound of raw meat (513 calories per bar). Essentially a ration, it is however tasty and preferred by many ski mountaineers as a source of protein and fat. Frozen-dried meats rehydrate to about three times their dry weight and are a desirable, though more expensive, method of bringing protein to high camp. Don't waste fuel heating dish water; either wipe out the pots with snow, or allow the contents to freeze and then chip them out. These methods are fairly efficient and in any event, unless the pot is badly burned, a little carryover from one meal to the next will not be noticed and will do no harm for short periods at the low temperatures prevailing. Finally, let it be said that no skier's morale can be raised by unimaginative, ill-prepared meals. Take time to plan and prepare palatable meals but leave the experimental single-food ration for trial trips under less exacting conditions.

6. The Technique of Travel

GOOD TOURING technique will enable the skier to travel at optimum speed—farthest and fastest with the least effort and the greatest safety. It will make ski travel a sport and a pleasure. The purpose here is to follow the progress of a tour from start to finish, with a section devoted to each aspect of touring activity. Techniques which have stood the test of frequent use are suggested. This does not mean that they are the best for all time, however, and ski mountaineers should seek to perfect them. Indeed, eternal search for a better technique is the finest stimulus any sport can afford.

Organization

Leadership.—A party of ski mountaineers does not ordinarily require formal leadership. The party will usually get along best as a democracy, with the composite mind of the party, through free argument and discussion, making the decisions. When an emergency arises, however, a leader should be chosen, and should be given full authority.

The leader must be considerate of his party; those who follow must be as considerate of the leader. This manual need not apologize for the Golden Rule, preach it, or explain the ramifications of its application to mountaineering. Perhaps it can be said that the need for the rule varies directly with altitude and length of expedidon, and inversely with the number in the party. Since Mountain Craft, the mountaineer's bible, first appeared, more responsibility has devolved upon members of the party, less on the leader; only in emergency is he expected in any physical way to help his party up a climb —a natural development of the trend away from guided climbing. But Young's precepts, one of which is that no mountaineering handbook can record "genuine mountain adventure or ... attitude of human mind towards the mountains and their symbolism," still hold. Certainly it should be pointed out that no one since Young has written better of ethics in mountaineering, and his code is recommended to any ski mountaineer who has ever had or ever expects any but pleasant human relations in mountains.

Whatever the form of leadership, it should provide that the party consist of no less than three, preferably four, persons. The party should keep together, not necessarily so close that its members will feel regimented, but close enough so that the entire party strength and equipment is available for emergency. The repair outfit will not be of much help to the last man if the first man has it, and is out of sight and hearing ahead. It is particularly important that the man with first-aid equipment remain in the rear during a long descent. This may save him a long climb back to an injured skier.

The problem of keeping a party together is minimized if great disparity in stamina and temperament of the individual members is avoided. In any but a solo expedition, someone must always have the least stamina, and certainly deserves the consideration of his more robust companions; but if his stamina is far below the party average, his weakness becomes a hazard.

There are times when an unfortunate disparity of temperament cannot be foreseen, but that this is an appreciable hazard is clear. A rugged individual may veer from the chosen route, forget to help around camp, and revel in his unpredictability while the rest of the party suffers. For that reason it is well that the organizer of a trip should know men as well as materials.

Preparation.—From equipment and food lists the skier may compile an inventory of the items which he feels he must have if he is to enjoy his trip, remembering that the question isn't what he can use, but what he can do without. This list may well be framed on the closet door, or its equivalent, of the ski storeroom in the home. Thus is one certain to remember every necessary item. This may seem an inconsequential detail at first, but many is the ski trip which has been impaired by oversight, some member neglecting to bring an obvious necessity—the butter, the salt, or the emergency ski tip.

Equipment should be in good order before the trip is started. Equipment that fails can be a hazard.

Elimination.—Unnecessary articles of equipment and food should be eliminated. Enjoyment of a ski tour varies inversely with the weight of the pack. Pack weight within a party can be kept to a minimum if the group will get together just before departure and weed out all unessentials and needless duplications. Every man will want his own toothbrush, but he need not be so particular about his flashlight, ski tip, or repair kit, so long as there is one of each in the party. A good motto is "when in doubt, leave it out."

Loading the pack.—Every article has its proper place in the rucksack. When some object is needed during the tour, it saves time and temper to know exactly where it is. And at night a cold and hungry group is no happier if everyone must empty his pack to find the salt. The best time to know where everything is stored is when the pack is made up. Heavy objects should go in the bottom of the pack, and as far forward as possible. Food in penetrable bags, and fuel—even the fumes of it—should be kept far apart, preferably in separate packs. Objects that are likely to be needed on the trail, such as lunch, first aid, wax, map, mitts, dry socks, should be readily available. Sharp or pointed objects should not be placed where they can injure the skier if he falls. The belly strap should be tied snugly enough to keep the pack from swaying from side to side, or from rapping the skier on the head when he falls.

If packing can be completed well before the trip is to start—at home or in a lodge—much time will be saved. When camp is broken, every skier should pack up quickly. The morning hours are often best for travel.

Loads should be distributed equitably throughout the party, at least at the start. A strong member should not endeavor to carry a double load. His strength may be a valuable source of reserve energy should emergency arise.

Checking and adjusting equipment.—Before starting, check poles to see that basket attachment is secure, steel edges to see that all screws are tight, toe irons to see that they are secure at the proper angle. Screws that tend to work loose too readily should be shimmed, with a piece of match stick, paper, or substitute.

Fasten the ankle straps, or improvise some other means that will prevent the escape of the ski should the boot come out of the binding. A runaway ski is only a hazard to others on a practice slope. On a tour, miles from help, you may be seriously stranded if your ski escapes, to shatter against a rock, or if both skis schuss by themselves to the bottom of distant, separate canyons.

On long level or uphill stretches release the downhill tension of your bindings. If the toe irons have no touring hitch, it is sometimes helpful to run the cable direct from the forward attachment, *inside* the irons, and back to the heel. If tension is not released, an efficient stride is difficult to attain, while blisters are not.

Snug lacing of boots will allay the formation of blisters and will increase control, but laces should be loosened during long rests, or at any time when it is more important that the feet stay warm. In this respect the ideal source of downhill tension is a sturdy, resilient strip of rubber run across the instep and fastened securely well back of the heel. Boots that are more pliable may then be worn, and they need not be tied so tight.

Choice of route.—Each tour will present so many unique problems that there will be but few general rules for selection of route.

1) Do not select a destination beyond the prowess of the weakest member of the party.

2) If a route is apt to be dangerous because of storm or avalanche hazard, select alternate routes and escape routes, and predetermine how you will use them.

3) Anticipate the condition of the slopes you are to cross. Avoid, first, avalanche hazard; second, slopes that will have inadequate or poor snow cover. Take advantage of good snow surface—for instance, an early morning crust on shaded slopes.

4) Prefer the route that provides most protection from sudden storm and chilling wind. On hot days avoid, where possible, the hollows filled with stagnant air, or you may experience glacier lassitude.

5) Seek the more gradual slopes. They are safer and less tiring. The first man, in choosing a line of ascent,

should consider the gradient most easily climbed by the party. Kick-turns should be kept to a minimum.

6) Memorize the terrain as well as possible. Know your bearings and, if storm or other cause will possibly make them necessary, write them down.

Timing the tour.—Start early. Plan to make camp well before dark. If the night is going to be warm and moonlit, such precaution may not be necessary, but there are few skiers who can accurately make such a forecast. It is far easier to set up camp in daylight. Running water can be found and used before the evening chill freezes it. Night travel is usually accompanied by fatigue, as well as lower temperatures, and the chance of freezing is greatly increased. It does not make good sense to travel and camp inefficiently in the dark and then lose two or three hours of fine early-morning travel while making up for the lost sleep. No skier should be allowed to forget that he must travel with a substantial margin of safety so far as temperature is concerned. To enable him to travel freely, the weight of his items of equipment has necessarily been reduced to a minimum. He will, if properly equipped, have all the protective items that he could reasonably expect to use. But the chief danger is his own attitude, his indifference to danger. Skiing without a shirt in the afternoon sun can be most enjoyable and, when not overdone, healthful. But it should not dull the skier's alertness to the dangers inherent in high-altitude skiing in midwinter. Temperatures may drop suddenly, and with little warning. A slight accident may cause unexpected delay. Storm or wind may arise. If the skier has planned to arrive at his destination early, he will still have a margin of safety. He need only insulate himself adequately, before his temperature drops to the danger point, and proceed at whatever reduced pace conditions require. Two hours of daylight is not too much to allow for making camp if the skier is planning an overnight stand.

Technique on the Trail

Clothing.—Use of a sufficient amount of clothing is important. In anticipation of a hard climb, it is often easy to remove too much clothing before it is necessary to do so, and chilling results. It is easier to keep a warm body from chilling than to warm a chilled body. Conserve heat. For instance, when nearing a pass that is apt to be cold and windy, put on a parka *before* reaching the top. The skier who waits until his ringers are freezing before he starts to put on his wind mitts may never get them on.

On the other hand, do not wear so much clothing that overheating results. This leads to perspiration, which brings about two undesirable conditions: (1) salt is lost through the pores, and the skier doesn't always remember to replace it in his food soon enough to prevent discomfort, or even mountain sickness; (2) clothing wet by perspiration becomes too good a conductor of heat, and, in the advent of low temperature, may speed the freezing of extremities.

A pace that is too rapid can similarly produce excessive sweating and the same two undesirable results, as well as tiring the skier.

Carrying skis.—Many tours start with a portage. Roads can be blocked for cars long before they are skiable. There are several ways of carrying skis. It helps to vary the method of carrying.

1) Hand-grip fashion: Place the ski pole handle through the toe strap of the binding, and slide the pole backward until the tip of the ski enters the basket of the

pole. Grasp toe strap and pole shaft together when carrying the ski this way, to prevent the ski from escaping or the pole from slipping out of position. Carry skis with tips forward, so that pole points can be kept clear of others in the party.

2) With running surfaces tied together with toe straps, skis may be carried over the shoulder, care being taken that they always clear the man behind. The poles may be carried in the other hand, tied to the skis, or carried over the opposite shoulder. This method is most useful for rough terrain or dense timber.

3) There are various but complicated means of tying skis to the pack frame, or slipping them through shoulder straps, thus freeing both hands. Or a line may be tied to the skis, which are then towed along behind.

Trail breaking.—In soft snow, trail breaking is arduous unless the lead is frequently changed. Choose a suitable length of time, depending upon snow conditions, for each man to lead, and after which he should step aside and take place at the rear. Even if a leader prefers to think that he is an "iron man," he should not overdo his turn at breaking trail. His excess energy may be needed later.

Ski tracks should be close together, but not so close that some of the group must scrape bindings to follow the tracks. Each succeeding person should try to improve the trail for the man behind, packing it harder, rounding out the corners, not wasting his energy on a new track.

Pace.—A steady pace with a moment's rest in each step is better than many spurts and stops. Don't "race your engine and spin your wheels." Excess energy may really be needed later.

For some reason the man in front often derives a mental stimulus, perhaps from his advanced position, that tempts him to go faster than those behind, who lack this "lift." He should therefore use it sparingly, adapting his pace to that of the slowest member.

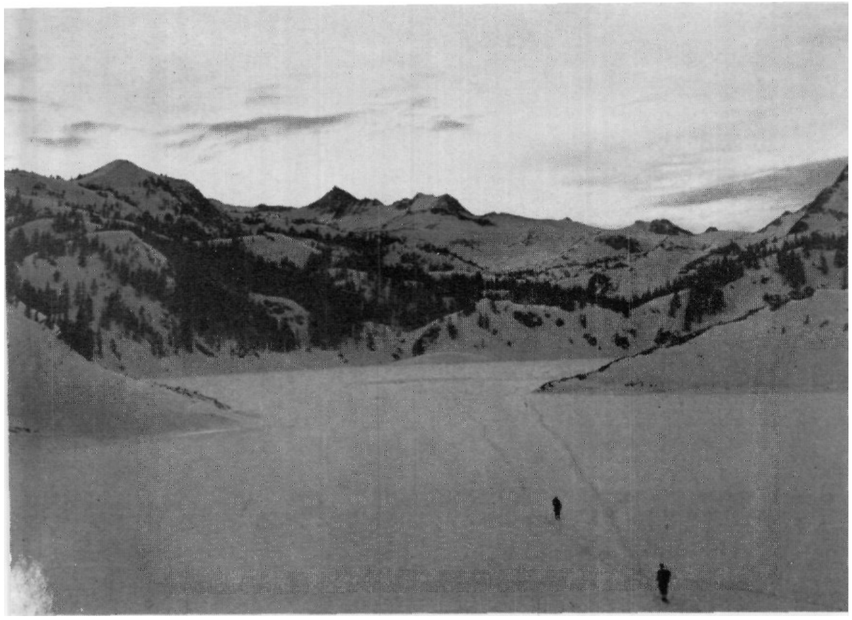
If one member of the party is chronically slow, there are four suggested courses of action: (1) If he demonstrates profound weakness at the start, suggest that he not go, but don't send him back alone. (2) Keep him well toward the front when traveling. If he is always in the rear, his brooding will further slow him. (3) Suggest changes in technique that may speed him. (4) Relieve him of some of his pack. This is a job for diplomacy, but is nonetheless often essential to party safety in preventing undue delay.

Use of poles.—Ski poles are not just outriggers to help maintain balance. They should, rather, tend to make a quadruped of the tourer, distributing the work of traveling among all the large muscles. The legs, being the most powerfully muscled, must still do most of the work, but the arms can share much of it, often, with a judiciously placed thrust, sparing the skier a spasmodic attempt to regain traction. Try to use the poles so that they will bring into play those muscles of shoulder, arm, and chest used in the push-up. This is done by keeping arms and poles close to the body, pointing and driving the poles backward with a rhythmic follow-through, enhancing propulsion by properly timing the thrust.

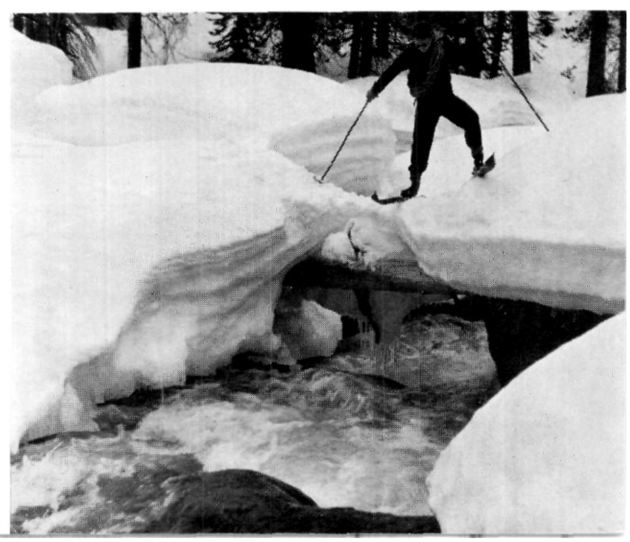
On traverses the uphill pole should be pointed farther back than the lower, and the hand should be placed over the top of the lower pole, in effect to lengthen it.

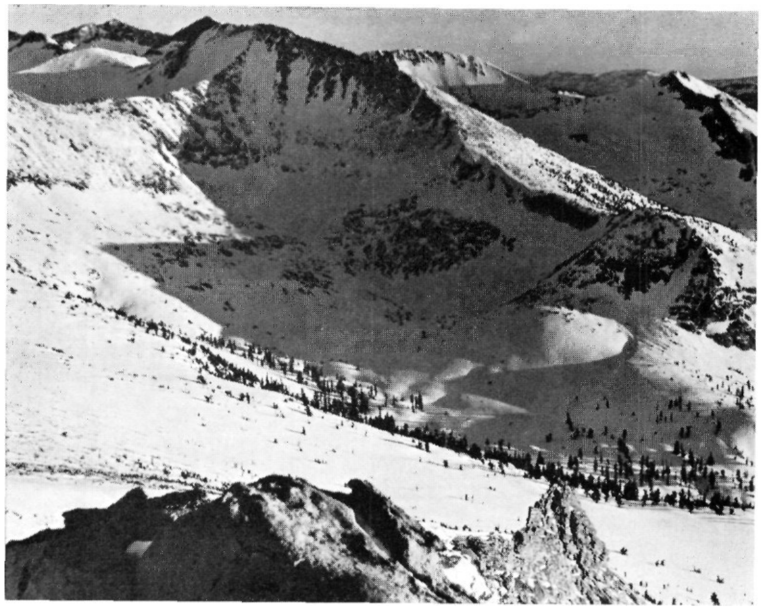
During the two-step the poles will best help to propel the glide if they are placed well forward and all the upper body muscles used in the thrust.

The skating stride is stronger and steadier if both poles are used together on a backward thrust for each glide.

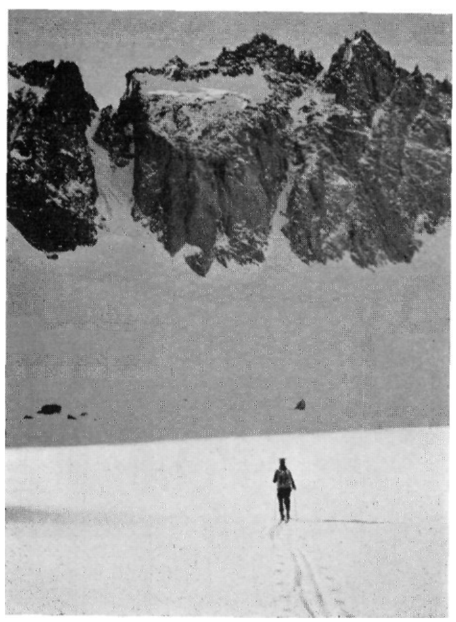


Lakes make the ***best*** *boulevards, streams the poorest.* Rush Creek lakes lead a ski mountaineer in toward Mount Ritter. Illilouette Creek crossings can be tricky on the way to Mount Starr King, in Yosemite. *(20,21)*

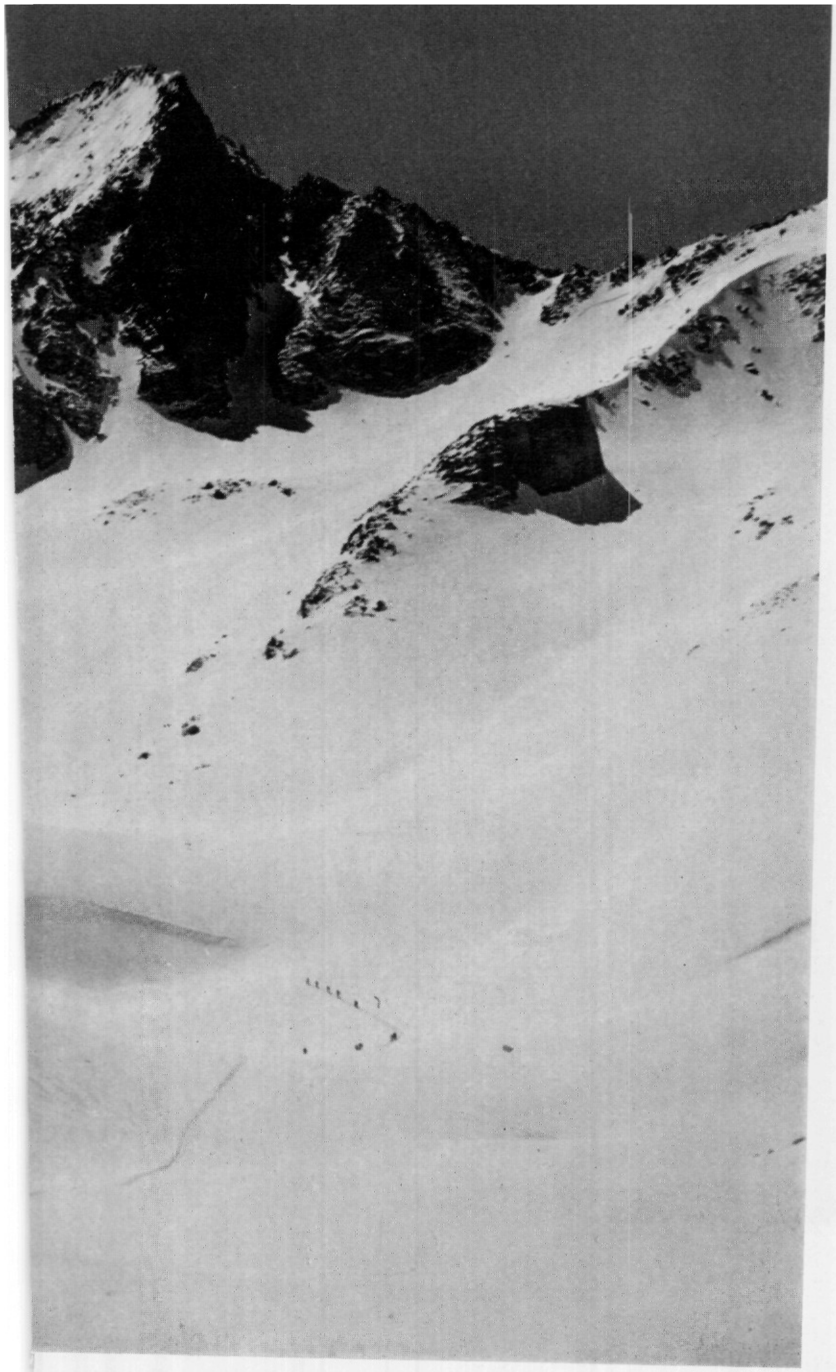


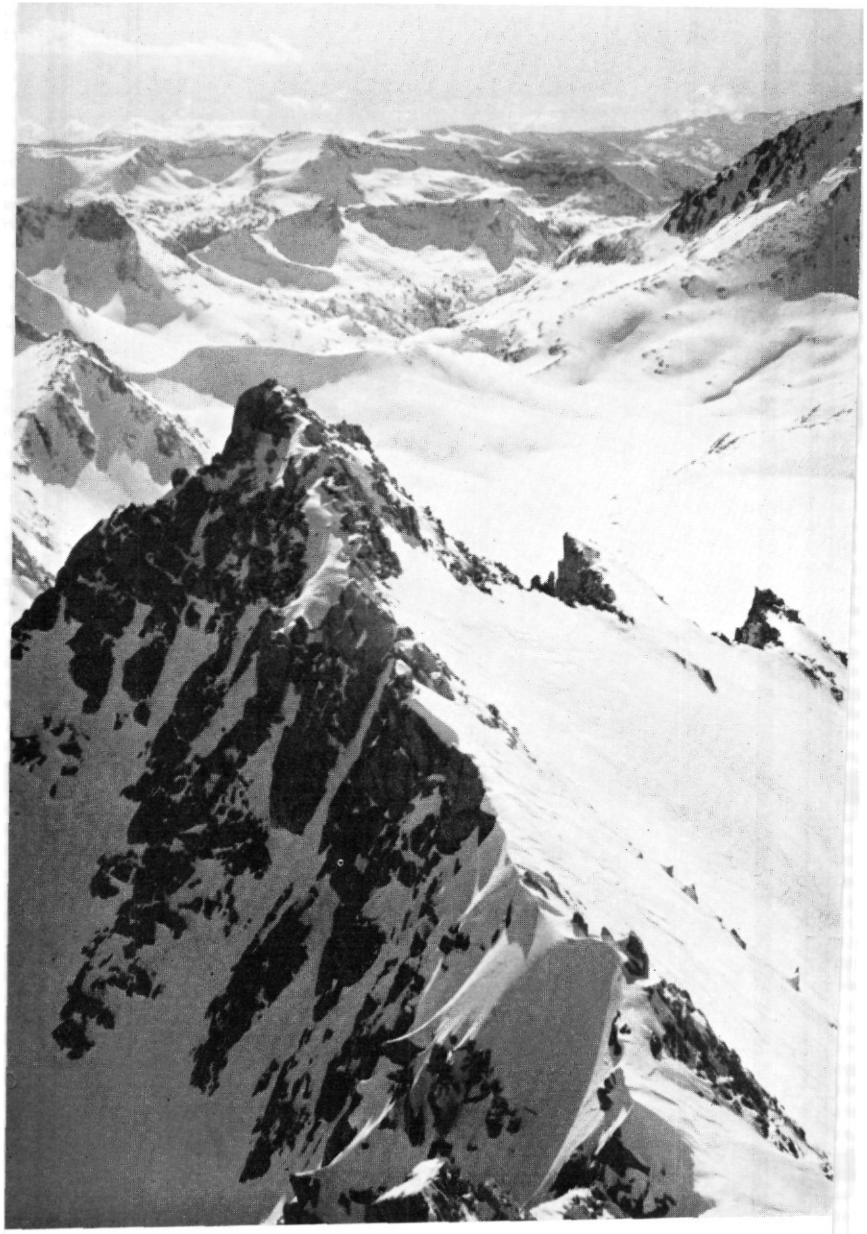


Sometimes you make the top, and look out at afternoon light along the Clark Range. Sometimes you don't, and merely look up at North Palisade and wait 'til next year . . . *(22,23)*

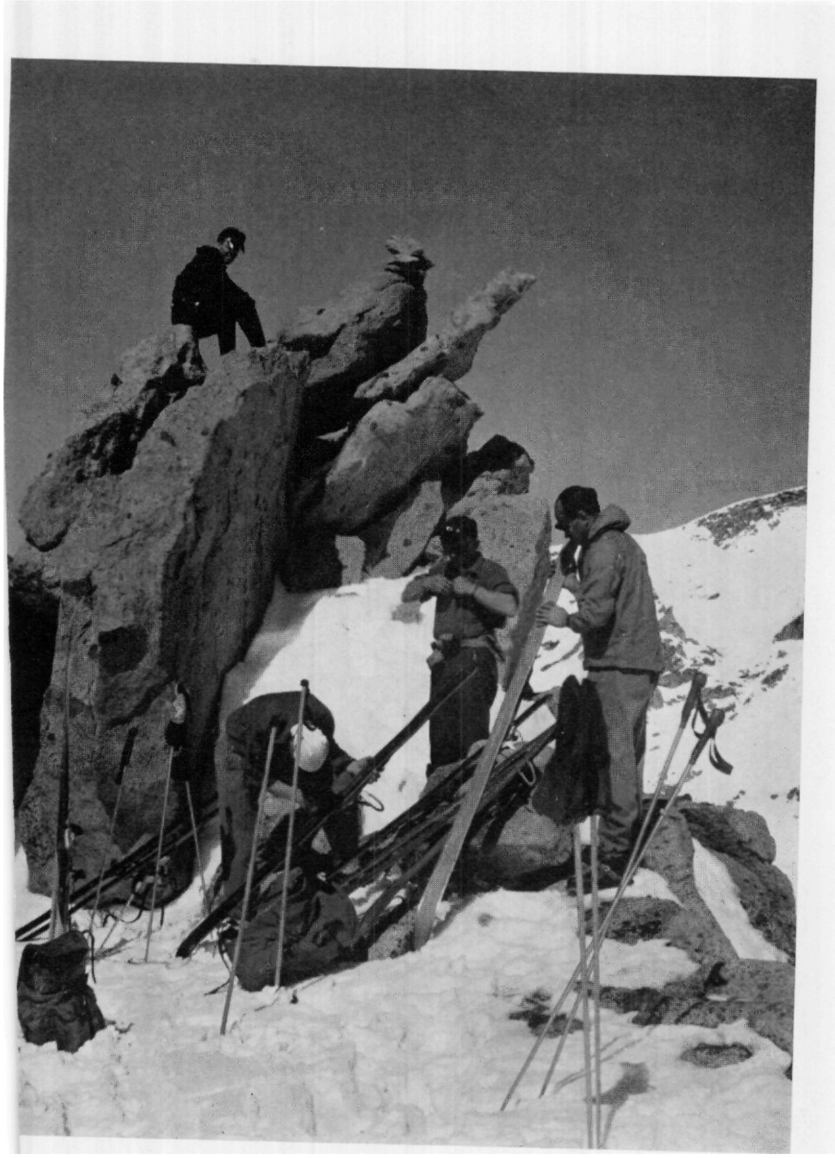


. . . and find *that* too stormy, the murk not clearing until time has run out and you're on the way down. If you are one ski mountaineer in a thousand, you'll get in a few pretty turns like this one. Eventually, breakable crust will throw you. But not discourage you. You'll be back again another year, but in the great country *(24, 25; 26 following)*

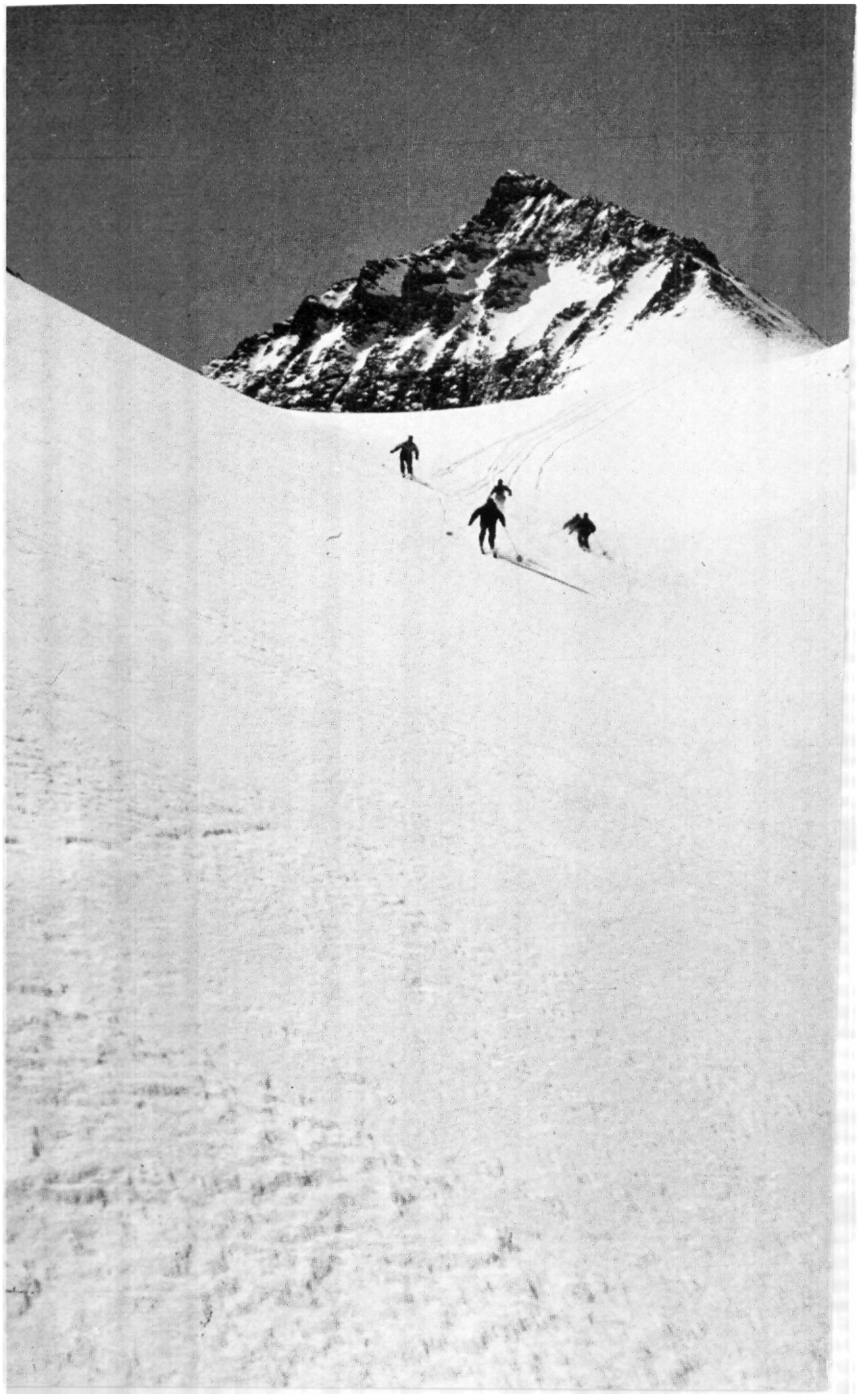




And if you make the top of Bear Creek Spire, which dominates that great country, you can look west to Lake Italy and its untouched basin —all of it supreme wilderness, even in summer. *(27)*



Then back to where you parked your skis, to roll up the climbing skins and get everything set for the run back to camp in Little Lakes Valley. *(28; 29 following)*



Pole christies and jump turns can be made upon shorter notice if the pole is held in the same way as for ordinary gliding, with the hand through the strap, grasping the pole top, only one pole being used at a time. In both maneuvers the pole serves indirectly to swing the body, driving the turn to completion.

Use of wax and climbers.—Skiers should not become so dependent upon climbing aids that they forget how to climb without them. Proper use of wax, edging, poles, and route will enable the skier to cover rapidly the rises or dips of a few hundred feet which characterize rolling terrain. Much time can be lost if there are repeated stops for applying and removing skins. On the other hand, much energy can be wasted in the attempt to climb too long a grade without the aid skins can give.

Wax is adequately covered in a separate chapter; the skier is here merely reminded that a properly waxed ski climbs when placed, slides when pushed—all, of course, within the limitation of the slope. In climbing, then, each step should be preceded by a definite downthrust that will impress the crystalline pattern of the snow on the wax, and thus increase traction. A firmer thrust, if needed, will result if the front of the ski is lifted for each step. The harder the downthrust, the better the traction—except, however, as the exertion leads to exhaustion.

On cold sunny days avoid the damp spots which usually exist under trees, or the skis will ice up as soon as they again enter cold, dry snow. Snow will also clog on skis when the snow surface is wet and the lower snow is dry. Such slopes may sometimes be avoided by proper choice of route. If no choice is possible, the ice must be scraped from the running surface, and paraffin applied over the running or climbing wax.

One-step.—This is the most used touring maneuver.

It is simply walking, or rather gliding, on skis, and its mastery is the essence of touring. Every extra pound of energy the skier puts into a step is multiplied thousands of times before the day is over. Thus, wherever possible, the skis should be slid, not lifted; downhill tension should be released to permit this. Poles must be functional, not ornamental. The angle of ascent should not be so great that it unduly tires the ankles. Other than for these suggestions, this manual cannot attempt to teach the skier to walk. Particular and continued attention to efficient use of his own physical equipment must give each skier his own individual stride.

Two-step.—One of the most useful maneuvers for attainment of speed on the level or on slight downhill gradients is the two-step, which uses the gliding ability of skis. If the two-step is to be used for long, it must be deliberate and rhythmic, slow enough to let the skier relax during the glide between thrusts.

Take a short step for propulsion, lean well forward from the waist, placing the poles well ahead, and lunge into a glide on the opposite ski by shifting the propelling thrust smoothly from the driving ski to a strong follow-through with the poles. Slowly bring the driving ski alongside the gliding ski in preparation for the next short step. Occasionally two consecutive short steps are taken to change the glide from one ski to another (this constitutes the three-step), and to tire out a new set of muscles.

A two-step taken as the skier enters a dip will speed him through and help him up the other side. Opportunities for such use of the step are frequent.

Skating.—A pleasant variation for gradual descents in suitable snow, and most useful for rapid and accurate changes of direction in dense wood-running, is the skating stride. This stride should not be a spasmodic picking up of alternate skis and subsequent struggle for balance.

Edge one ski sharply on the inside edge and strike off briskly from that ski at an angle of about 30° on the other ski, first giving a thrust with the edged ski and following through smoothly and immediately with a strong backward thrust with both poles. Strive for a long glide, with the weight well over the gliding ski. Near the end of the glide, slowly edge the gliding ski in preparation for the next stride. The skier will soon learn not to overshift the weight onto the outside edge of the gliding ski, because he will probably fall when he does so; but, on the other hand, he will never know the full effectiveness of the stride if he doesn't shift his weight far enough over the gliding ski.

The ability to ride confidently on one ski is well worth attaining, for the skier may often find himself momentarily and unexpectedly on one ski, and might as well feel at home there.

Telemark position.—Much controversy may exist with respect to the merits of the telemark as a turn, but it is generally agreed that the telemark position, with one ski well advanced, is the soundest position to assume when a sudden checking of forward speed is imminent. The position should be used when running from fast snow to slow, or to increase forward-backward stability in running across dips in the course, or in leveling out after a descent. Lateral stability is of course reduced, but the skier would do better to fall to one side than to fall forward when he buries both ski tips in the opposite side of a dip.

Herringbone.—Chief fault of the herringbone for the tourer is its inefficiency: the position, being unnatural, calls for an unordinary use of muscles; skis must be lifted too far; a track must be packed for the entire length of the ski with each step; traction is often uncertain. A deliberate herringbone, executed with rhythm, is nevertheless necessary for some short bits of climbing.

For traverses the half-herringbone is useful. Both skis are edged into the hill. The lower ski half side-steps, half traverses up the hill, at the highest angle at which it will hold. The upper ski slides ahead at a slightly higher angle. The grade of ascent is thus steeper than a simple traverse would permit. The upper ski will hold while the lower is picked up and placed higher. It would not hold if the lower ski were slid ahead in a parallel track.

Edging.—Proper use of edges provides a simple means of directly ascending short, narrow avenues. Both skis are edged in the same direction—to the right, for instance, by bending both knees forward and to the right. As a skier knows from his herringbone and many of his unsuccessful turns, skis edged too far will not run; they will, however, climb. Direction of edging should be changed from time to time so that the ankles and knees are not always bent in the same direction. This method of climbing develops the leg muscles required for christianias. The harder the edging, the steeper the slope that can be climbed.

Side-stepping.—On steep, soft slopes, to avoid floundering—bringing the slope down to you instead of climbing it—leave as much space as possible between each pair of steps. This space usually provides enough support for the snow to keep it and the skier on the slope. Placing the lower pole just next to the lower binding will also help.

On steep hard snow, use of the lower pole next to the lower binding will prevent sideslipping down an otherwise hopelessly steep and hard crust. The same technique will assist hard-snow traverses. Better purchase on the hard crust will be attained if the skis are swung sharply sidewise into the slope with each step.

Resting.—Skiers sometimes fail to realize they are overtiring themselves; more often they are reluctant to admit it, and will press on, subjecting themselves to the hazards of fatigue. The ill-effects of such a tendency are threefold: (1) In tiring himself, the skier loses skiing proficiency, and is more apt to fall and injure himself. (2) The person who is fatigued is predisposed to freezing. (3) The party that goes the limit of its endurance in good going has no margin of safety left when an emergency arises. One may experience a feeling of self-satisfaction at playing the iron man, but such heroics are better saved for the practice slope. On a ski-mountaineering trip, just as in a military campaign, the man who gets injured is a hazard, no matter how much sympathy he may deserve.

Accordingly, it is essential that the members of any touring party watch themselves for signs of fatigue, and plan for periodic rests. If a member of the party feels he should rest, he should not be too proud to say so. He'll cause the party less trouble if he rests before it is too late. Particularly important, a skier should rest efficiently when a stop is made—take off his pack to relieve shoulders and back, sit down on a convenient rock, log, or on his pack, and relax. He should at the same time avoid chilling, either by seeking shelter or by providing shelter with extra clothing. If the skis can be kept on, the feet will be kept warmer. On a sunny day it is easier to stop in a mixture of sun and shade and to control one's temperature by moving a yard or so than to add and remove clothing.

At times the party may need only stop for breath, each man leaning forward and supporting much of the weight of his pack on his poles.

Rests should not be too long. "The longer the rest, the harder the start."

Eating on the trail.—A skier can do no more on an empty stomach than a soldier. There are some, who, under the unaccustomed exertion of a ski climb, are famished to a point almost of illness after four hours without food. It is better to use food for energy than to rely upon stored energy in the body.

A mountaineer may often be using so much energy that he cannot, or at least should not, eat enough at conventional mealtimes to provide that energy. But he can eat oftener. Two lunches, of easily digested foods, can be the solution. Dextrose foods are quickly assimilated. Dried beef and fruits (in limited amounts) are good for munching along the trail. When possible, lunch places should be near some supply of liquid water; the more the skier drinks during the day, the less will he have to melt snow and use fuel when he makes camp. Furthermore, if he is not so thirsty at dinner time, he can use more space for the solid food he needs to restore energy and tissue.

Stream crossing.—Ordinarily the ski tourer can cross the smaller high-mountain streams on a snow bridge, taking care that the bridge is substantial, that his weight is evenly and gradually applied, and that only one skier at a time try to cross.

Failing to find a snow bridge, the skier should look for a log crossing, take off his skis, and proceed cautiously. As a last resort, it may be necessary to rig a raft of some sort. The buoyancy of air mattresses should not be overlooked. Also dead, dry logs may be cut with the lightweight saw blade (see p. 78).

Particularly toward the end of the day, when there is little chance to dry out and get warm easily, the skier should not take chances of falling into a stream. The danger of freezing afterward is serious.

The mountaineer may devise a Tyrolean traverse (see p. 203) if suitable anchor points are available. If the stream must be forded, he should:

1) Search for the ideal ford—where the stream fans out and flows shallow and slowly over a smooth grave) bed.

2) Remove socks, to keep them dry and warm, but wear boots to protect feet.

3) Select good footing for each step, step on the up stream side of submerged obstacles, and move each foot forward under water (not lifting it above the surface).

4) If the current is swift, use a ski or long pole as a third leg, braced farther upstream the swifter the current, and move only one leg at a time.

5) Where the channel is deep and boulder-filled, cross below a bend that best facilitates an upstream belay. The leader should use a pole brace and cross above emerged boulders that can serve as intermediate belays. A sub merged rope can have a pronounced undertow on the leader.

Downhill touring.—To travel safely in rough mountain terrain, far from the rescue crews of a ski patrol, requires conservative skiing. Caution must be the ski mountaineer's watchword. It is easy enough to break a leg on a practice slope, where the position and texture of every bump, and the angle of every turn, have been memorized. It is far easier to get into trouble on a long trip in new country, where not only is the topography unknown, but also the snow conditions vary remarkably. In a run of several thousand feet off a high peak the skier may, in addition to perfect open slopes, encounter wind-cut snow, ice, the two combined at intervals of a few feet, deep powder, heavy snow, wind and sun crust that is breakable at times, wet snow, thin snow, sticky snow, and slush. Visibility may be superb, it may be zero. Character of the snow may be indistinguishable in the flat light of a muggy day.

This variety of conditions is the skier's curse. But it is more. It is his challenge. It becomes as fascinating as it is important to learn how to handle these handicaps, and to like them. There is some pleasure in executing a series of beautifully linked christianias on a practice slope, but that satisfaction is diminished by the fact that, in this day of proficiency, nearly every other practice-slope skier can execute them as well. But to make, with few falls, a descent of the myriad snow surfaces the ordinary high mountain provides is more than a satisfaction. It is a triumph. It is the ski mountaineer's meat.

No manual can explain the techniques necessary for each snow condition. Each skier must learn the hard way; surely he would rather do this. But a few suggestions may give direction to his experiments, and spare him bodily harm. The imperatives are:

1) Ski no faster than you can judge in advance the snow texture you are about to hit. In descending a mountain, follow where possible the general route of ascent. Even though the interim hours will doubtless have changed the snow, you will at least have a hint of what to expect.

2) The worse the snow, the more evenly should the skis be weighted, and the more sure you should be that

both skis are doing the same thing—going in the same direction.

3) Do not start a descent without first fixing your ankle straps so that there is a reliable emergency connection between you and the ski should you fall and the binding release. A runaway ski may strand you disastrously.

4) One of the most useful ski-mountaineering turns is the short-radius, lifted stem-christiania with the aid of the inside pole. It is accomplished at low speed, and the combined thrust of the inside ski and the inside pole will serve to drive the outside ski through any but the heaviest snow.

5) Keep skis together. Consider the photographers in your party and don't leave a "railroad" track. A narrow track, besides looking better, indicates safer skiing. Balance, if upset, can be restored with the shoulders and ample bending of knees and ankles; if worst comes to worst and a bump throws you, at least the bump will have affected both skis equally. Most damage is wrought when a fall, in and of itself, stops only one ski.

6) When in doubt, traverse and kick-turn. An open christy into the hill, with the aid of the upper pole and body swing, can with little practice be made in any snow conditions. This is true of no other turn but the kick-turn, which will reverse the direction in preparation for another traverse and open christy into the hill. Stem-christies away from the hill at thirty miles per hour are prettier to watch and more thrilling to execute than are kick-turns, and should be attempted, though perhaps at lower speed, when conditions warrant; but a fall with a pack, in poor snow that may thinly conceal a sharp rock, may not be thrilling.

7) It saves time and energy to use a prolonged and

gradual route of descent, rather than to make a quick and steep descent, thereafter having to pole on the level.

The purpose here is not to urge that every ski mountaineer be an alarmist, nor that he establish a copybook code of skiing morals. The instinct of self-preservation will, after all, tend to protect even a skier. He should merely take care that this instinct does not become atrophied.

"Don't schuss in where angels fear to stem."

Storm, Night, and Fire

Travel in storm.—Travel in a snowstorm requires special care. Visibility is poor, and although air temperatures usually are not so low as they often are in fair weather, wind, clouds, and snow will chill the skier much sooner. It is difficult to get warm again, and opportunities for rest are greatly reduced or absent, so that danger from fatigue is increased. The skier should therefore wait out the storm in camp, where he can be both comfortable and safe.

If it becomes essential to travel in storm, the following precautions should be taken:

1) Set up an "autocratic" leadership. Choose a com petent leader and adhere to his decisions. Keep together. When the route is in doubt, no good will result if the party scatters in all directions looking for it. Confusion follows, sometimes chaos; at best, much time is lost. If search for the route requires separation, members of the party should keep within calling distance of each other—and keep calling.

2) Analyze the route of escape, the dangers of new-snow avalanches. Develop some plan, with alternatives, for using that route.

3) Locate your position. Take immediate bearings.

and record your bearings as you travel so that you can backtrack if you have to. The last man, with compass, should direct the party's route, taking care not to be misled in judging direction by the optical illusion brought about by swirling clouds.

4) Keep warm. There is little chance to warm up if you become cold. If there is climbing to do, put on climb ing skins before it becomes too cold. Chilled fingers are almost useless. In very cold weather keep a scarf or facemask over the nose and mouth to prevent freezing of the lungs, or draw the parka hood across the face and breathe the air that has been warmed by the body. Don't over exert.

5) Keep dry. Don't so burden yourself with clothes that you perspire and get wet from the inside (this is easy to do). Keep the pack waterproof. Chances are it will be heavy enough without being soaked.

6) Don't go hungry. Food is a source of necessary heat. Too often the discomfort of stopping to eat in a storm is apt to result in the skier's eating too little. Rely on quick-energy foods that can be eaten quickly, and eat them frequently, on the trail if you prefer not to stop. A simple rule is, eat sugar for energy, protein for heat.

7) Ski slowly and cautiously. At best visibility is so much poorer during storm, as well as in some storm-bred flat light conditions, that it is most difficult to determine snow texture and topography well enough in advance to permit speedy travel. Any accident is doubly serious during storm. Don't protect the eyes so adequately that you in effect blindfold yourself; better, slow down, lower the head, and look through the eyelashes.

Travel at night.—Night travel has most of the disadvantages of travel in storm. Although the weather may be more agreeable, visibility, even during brilliantly moonlit nights, is much poorer and travel should be slower. The precautions are the same as for storm travel; in addition, each group of four should be equipped with a headlight, and the battery should be worn so that the cells will be kept warm. The life of the cells will be longer if the light is used intermittently, and small portions of the route remembered until it is necessary to use the light again. The man with the light should remember the handicap of those behind, and that the farther behind they are, the greater is their handicap.

In descending steep slopes at night it is safest to side-slip.

Uniform distress signal.—A man or party who, beyound question of doubt, requires aid should give three signals (=SOS) of any sort, audible or visual, at frequent intervals. A yell is perhaps the least satisfactory signal, because it will soon tire the vocal cords, and, unfortunately, is often mistakenly assumed not to be a call of distress. The call for help is acknowledged by two signals (=0K) and an immediate attempt to help.

The skier who is lost should follow the maxim, "stay warm and keep cool." He must waste no effort. He should:

1) Sit down and think, carefully plan a way out of his predicament.

2) Try to retrace his steps to the last familiar land mark, seek a good point of vantage, and reconstruct the proper route from there.

3) Failing in this, he should stay put, build a fire, sig nal for help, and prepare to bivouac.

Fire building.—To build a fire in the snow quickly, in stormy weather or at low temperatures, is sometimes a major problem. The fire may serve only as a convenience during a noonday stop, or it may be essential in case of accident. Where warmth is urgently necessary, however, the ski mountaineer should remember his tent and sleeping bag, in which he can keep warm and dry, and his stove, on which he can prepare hot, stimulating drinks.

If the skier wishes to, or must, build a fire, he should choose a spot sheltered from wind and falling snow. This may be in the lee of a rock, in the shelter of a large conifer, or in a small grove of saplings which break the wind.

After a prolonged, wet snowfall, or in regions where the forests are always wet, even the standing dead trees may hardly burn at all. Dead birch is often worthless; the wood is wet and punky within the bark. The bark, however, is excellent for starting a blaze. Dead hemlock is also likely to be rotten and wet, even though standing. Where oak is available, the dead branches offer the first choice for fire, and most oaks carry some dry, dead branches. Resinous, dead branches of most conifers burn well. These may be broken into small kindling material and, if wet, may be peeled off the soaked surface and ignited by use of a fire-making candle or a small amount of gasoline from the fuel supply. Or tinder may be shaved or split from the dry interior of branches. Small, standing dead maples which have not become rotten make good firewood after the blaze is well started if they are first dried out over the blaze. It is sometimes necessary, in storm, to pile the wood on the fire tepee-wise to protect the fire inside from snow and to dry the wood to the point where it will burn. Don't underestimate the quantity of wood that an all-night fire will require.

Ordinarily, dry, dead trees which have not been denuded of limbs and "squaw wood" (the small dead limbs under the live crown of a tree) are the most desirable. A few green poles four feet long laid side by side make an excellent hearth for a roaring and welcome campfire.

Small trees can frequently be broken off by rocking, either by repeated pushing or by use of a rope. Some mountaineers carry a small ax despite the undesirability of increased weight. Far better for those who anticipate the need of cutting green poles and dry firewood is a thin saw blade 36 inches long, 1 inch wide, and weighing 3 ounces, which is commercially available. Two four-inch nails are the handles. It rolls into a four-inch circle, yet can be used effectively to cut trees over a foot in diameter. The simplest method is to use it as a two-man drag saw, although a bucksaw can be improvised with a bent green pole four feet long, split at each end, with the ends of the blade made fast by the nails as pins.

Expedients for Steep Terrain

High-angle climbing on snow, ice, or rock, with its requirements of advanced rope technique, ice ax, crampons, and pitons, is beyond the scope of this chapter. A ski tourer should ordinarily be able so to select his route that he avoids steep terrain requiring advanced technique. In no event should a party go beyond the limit set by its ability or equipment. Below are suggestions of ways by which the ski tourer can improvise from his ordinary equipment and technique the means to cope with moderately rough terrain. (See chapters 2, 15, 16, 17 for mountaineering equipment and technique.)

Avalanches.—The skier must bear in mind that the steeper the terrain, the greater the avalanche hazard to be considered.

Climbing without skis.—Among the precautions taken against avalanches, or when slopes become too steep, is removal of skis. At such times the most expert climber takes the lead, kicking a series of good steps straight up the slope, or as nearly straight as possible. Those who follow should try to improve the steps, at no time using the outer edges, which tend to collapse easily. The steps will hold best if the climber stands vertically in them, rather than leaning into the slope.

In a skiless descent of a steep slope, backing down is often the safest method. If this is known not to be necessary, one may descend facing out, driving the heels hard down and back into the snow. The skis should be held securely lest they be lost. The ski tails may be driven back into the snow as a brake.

When skis are cached and the climb continued on foot, skins should be removed at once; otherwise they will likely be frozen to the skis on the skier's return.

A substitute alpenstock can be improvised from two ski poles if the baskets are removed and the two shafts lashed together, side by side, for reinforcement.

Use of skis and poles.—When putting on skis on a high-angle slope, put the lower ski on first. It will then serve as a barracade for the other ski and other equipment which might otherwise escape.

Do not put the hands through the pole straps. In a fall one must be able quickly to slide the hand down the shaft in order to use the pole to brake the fall.

In falling, the skier should become adept at swinging the skis below the body and across the slope. A slide can seldom be stopped otherwise.

When standing upon or traversing a hard and steep surface, insert the lower pole in the snow beside the lower ski to prevent a surprise slip.

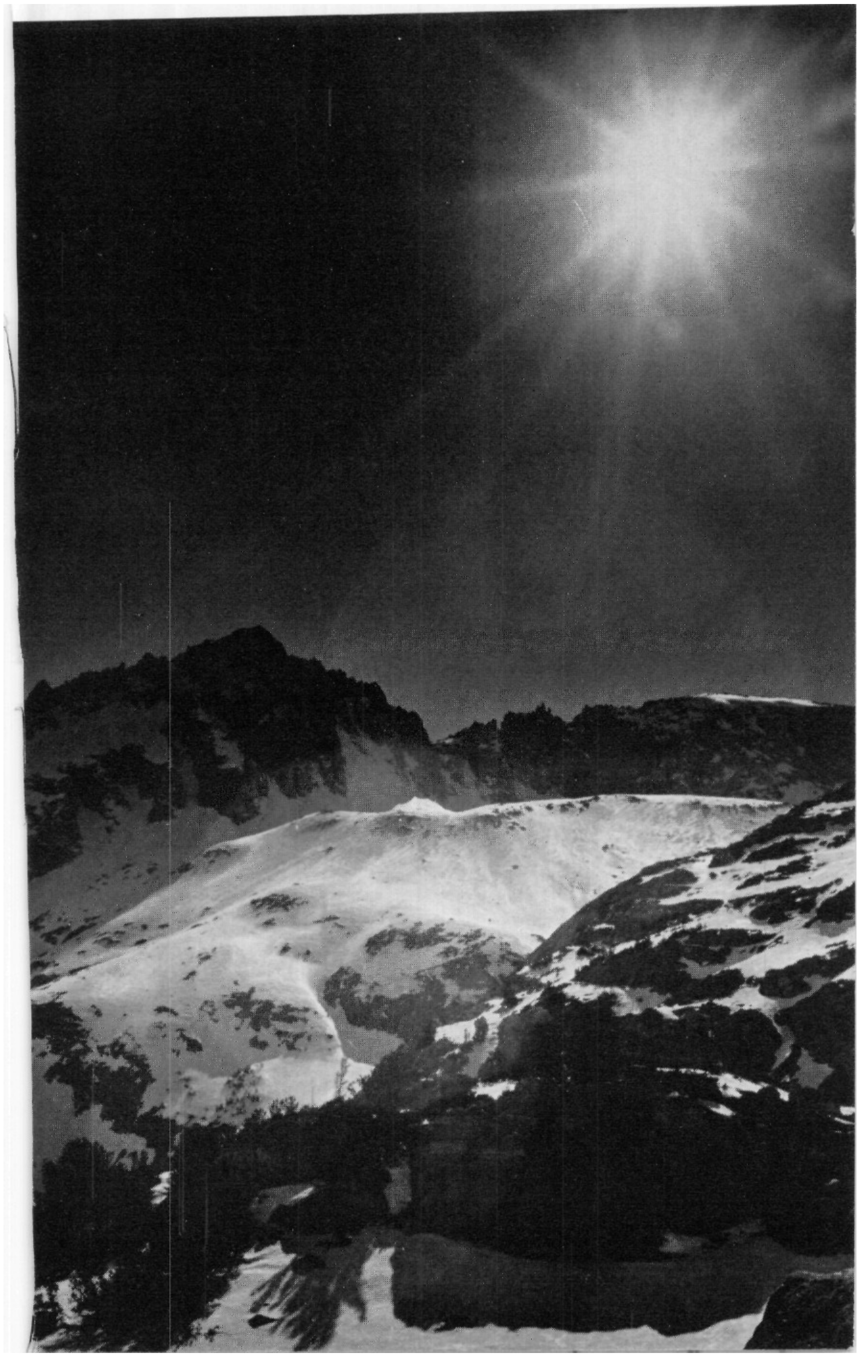
Cornices.—Owing to their potential avalanche hazard, cornices should wherever possible be avoided. If they cannot be, they must be cut or tunneled through. From above, one of the party, belayed, should approach the edge afoot and select the region of lowest angle for the break-through. If the overhang is severe, the tunnel should emerge well back from the lower part of the cornice, so that it will clear the skier should it collapse. The party should remain afoot until reaching slopes of low and safe angle, well below the cornice—but few slopes below a cornice can be truly safe.

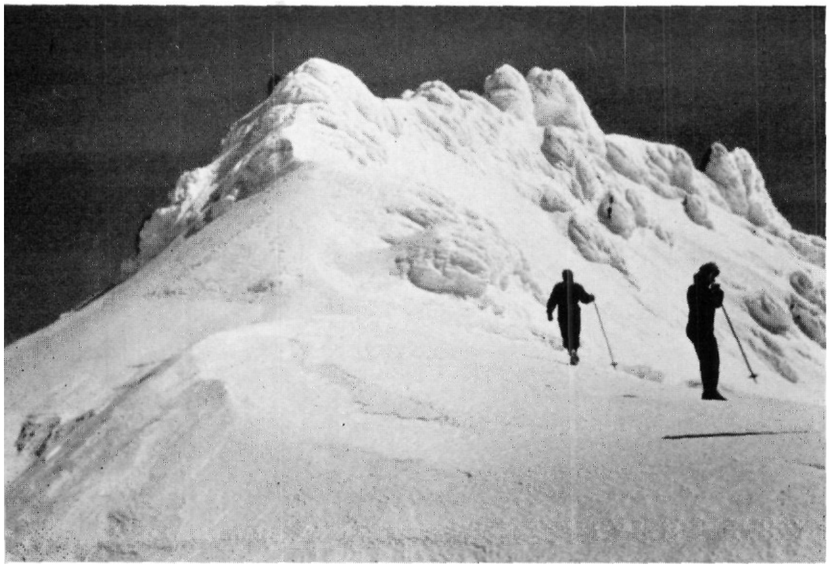
From below, the procedure is reversed, with the exception that it is easier to select the spot for the attack, and harder to make it, or to tell how secure the cornice will be. Accordingly, it is all the more essential that the leader start tunneling well in past the overhang. Ordinarily the ski will serve as a digging tool.

Occasionally a ladder of skis and poles can be made up a vertical cornice by driving them into the compacted, steep face. Particular care must be taken to see that the skis, if loosened, do not escape.

Fielding.—Most frequent use to which a ski mountaineer will put his rope is fielding, in the descent of slopes steeper or more exposed than should be descended without safeguard of some kind. In fielding, the most expert climber anchors to his ice ax, alpenstock, or skis that have been driven well into the slope, and pays out rope until the members of his party have descended its full length. Then, with the protection of his ice ax he descends to his party and repeats the process. If he is certain that he can check a long free slide with proper use of the rope, he may continue a full rope length below his party before anchoring and belaying its descent. The party should tie into the rope with a bowline (for the end men) and a butterfly (for those in the middle) ; these knots will not jam or cinch up.

Rappelling.—Ability to slide down a doubled rope and to recover the rope afterward provides an invaluable



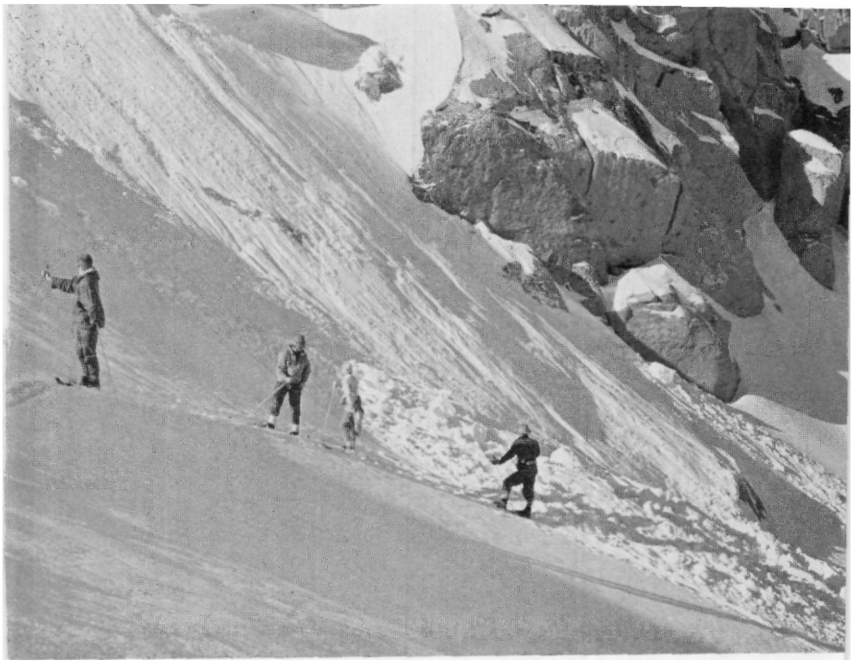


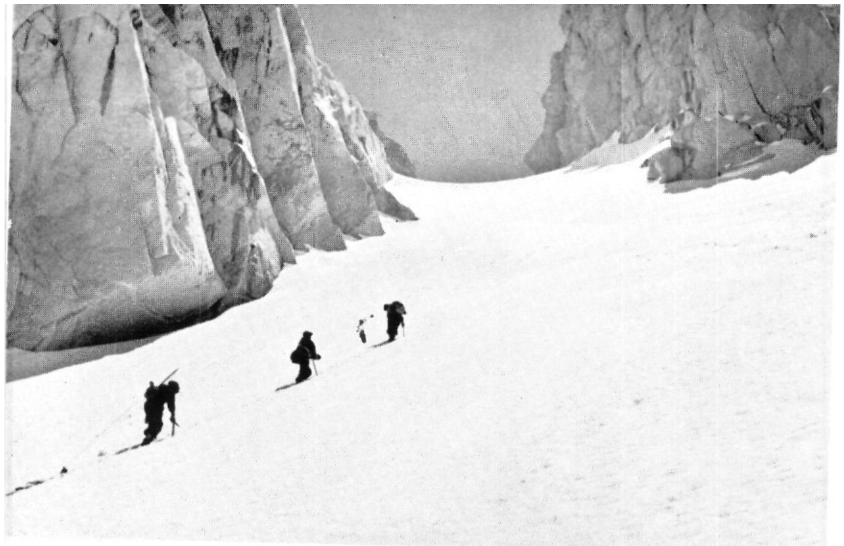
Mountain blend. In the Alps it is commonly understood that the seasons are marked by a man's putting away his skis and taking out his rope, and vice versa. Ski mountaineers can take pleasure in confusing this nice distinction—they can take ropes on winter climbs and skis in summer. Mount Lassen, for example, will serve a skier nicely well into July. But he had better park his skis below the summit ridge when it is covered with ice feathers.

Ski mountaineers most likely to attain great competence are those who learn their craft in time to avoid crossing trails with an avalanche. Allen Steck, who took these photographs, will agree; he was buried by an avalanche, and survived only because a friend had a cold that day. If you insist on getting caught, wear a magnet and hope an untrapped friend has a portable magnetometer!

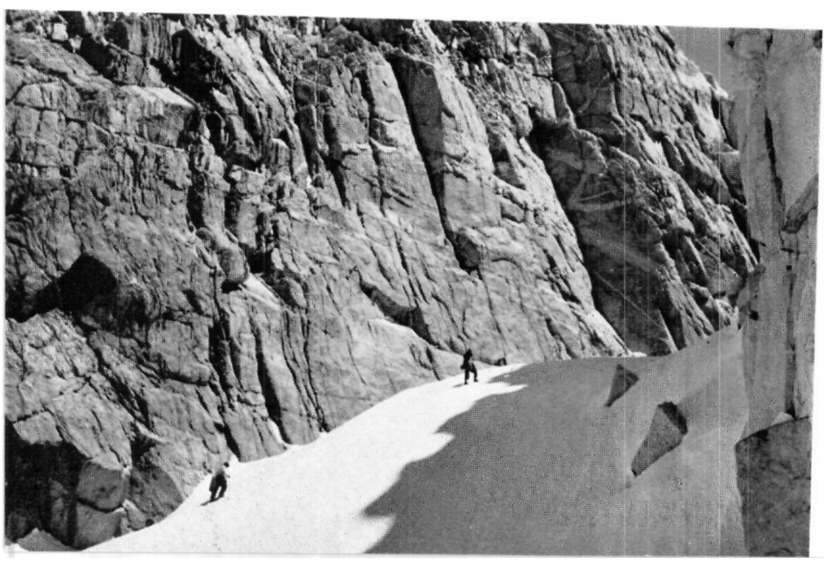
Best way to assure a long ski-mountaineering life is to learn to turn back in time. As of this writing, Mount Darwin has not yet been climbed in winter, but there was a very satisfactory first winter rappel *{lower right)* to its glacier, a safe retreat from a gathering storm, and a chance to try again another day.

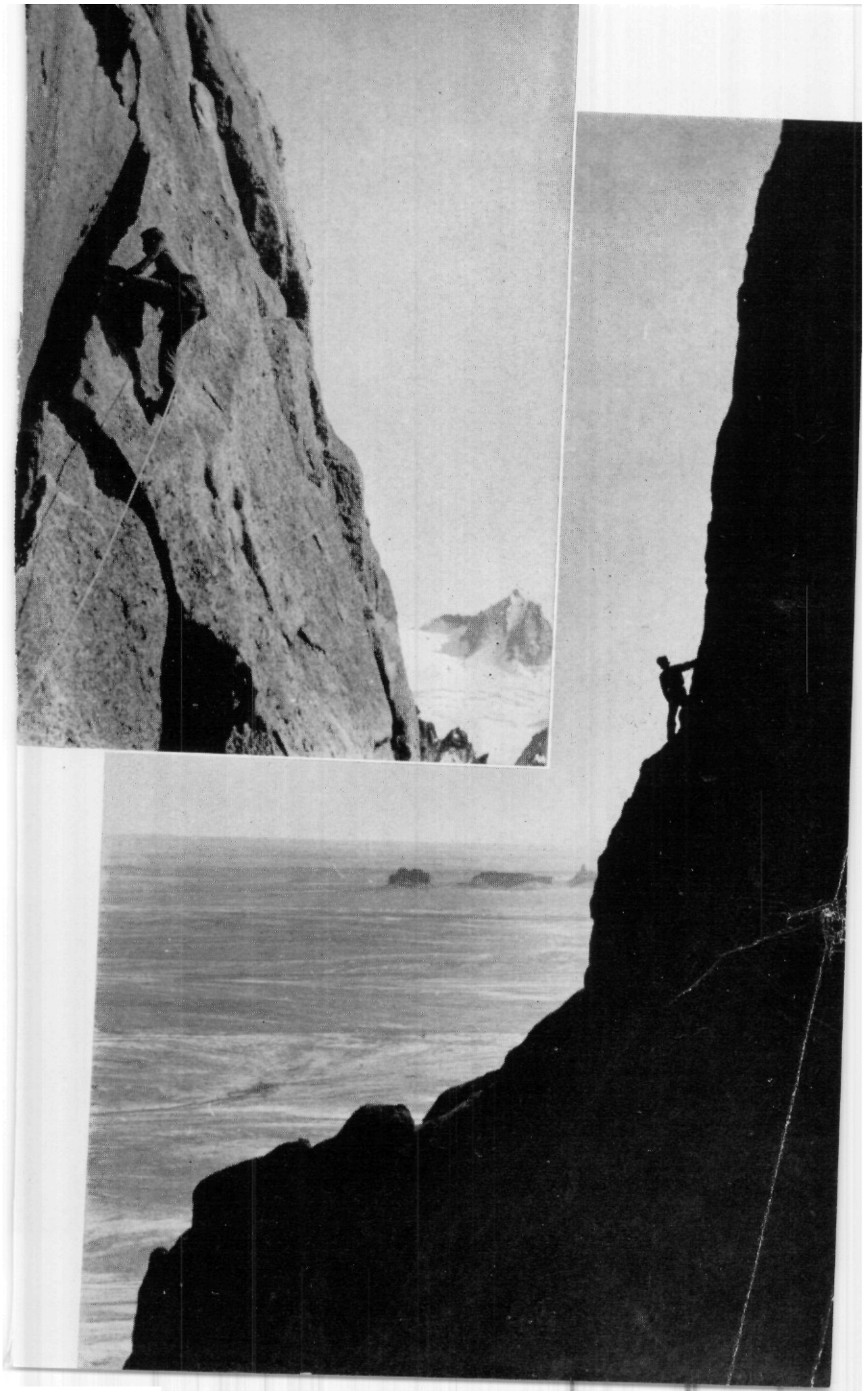
(31-33; 30 preceding)

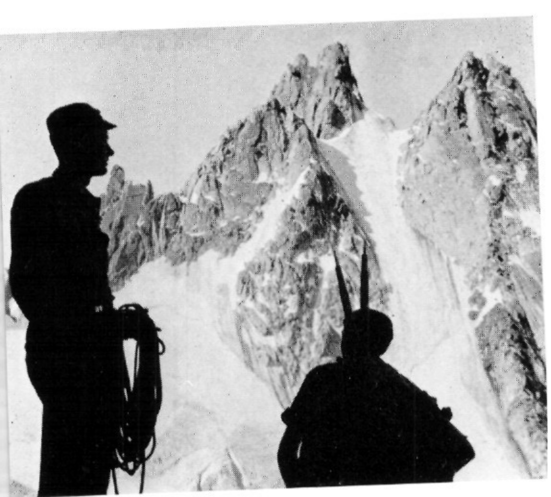




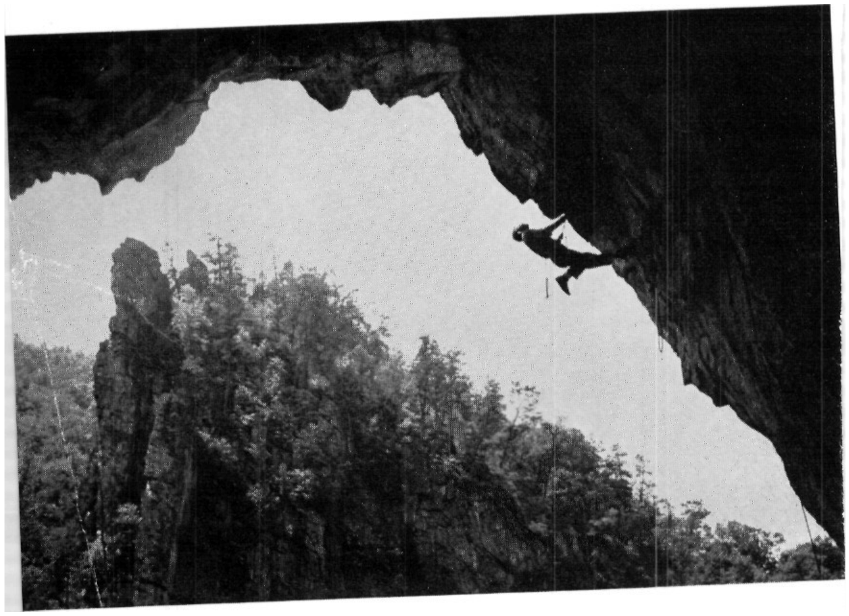
Transition, continued. A do-it-yourself ski tow was discovered one day on the approach to Sawtooth Ridge, part of Yosemite's northern boundary. Ski there just once, look at that superb granite, feel it, test it, look out from **its** sides and down from its top, and you will know why a mountaineer is. II Look the world over for more granite like that. You'll find it on the Grepon, in France, but not on the mainmast of Shiprock, in New Mexico. But you'll still find things you were looking for as you climb there. *(Note:* See chapters **15-17** before looking.) *(34-37)*



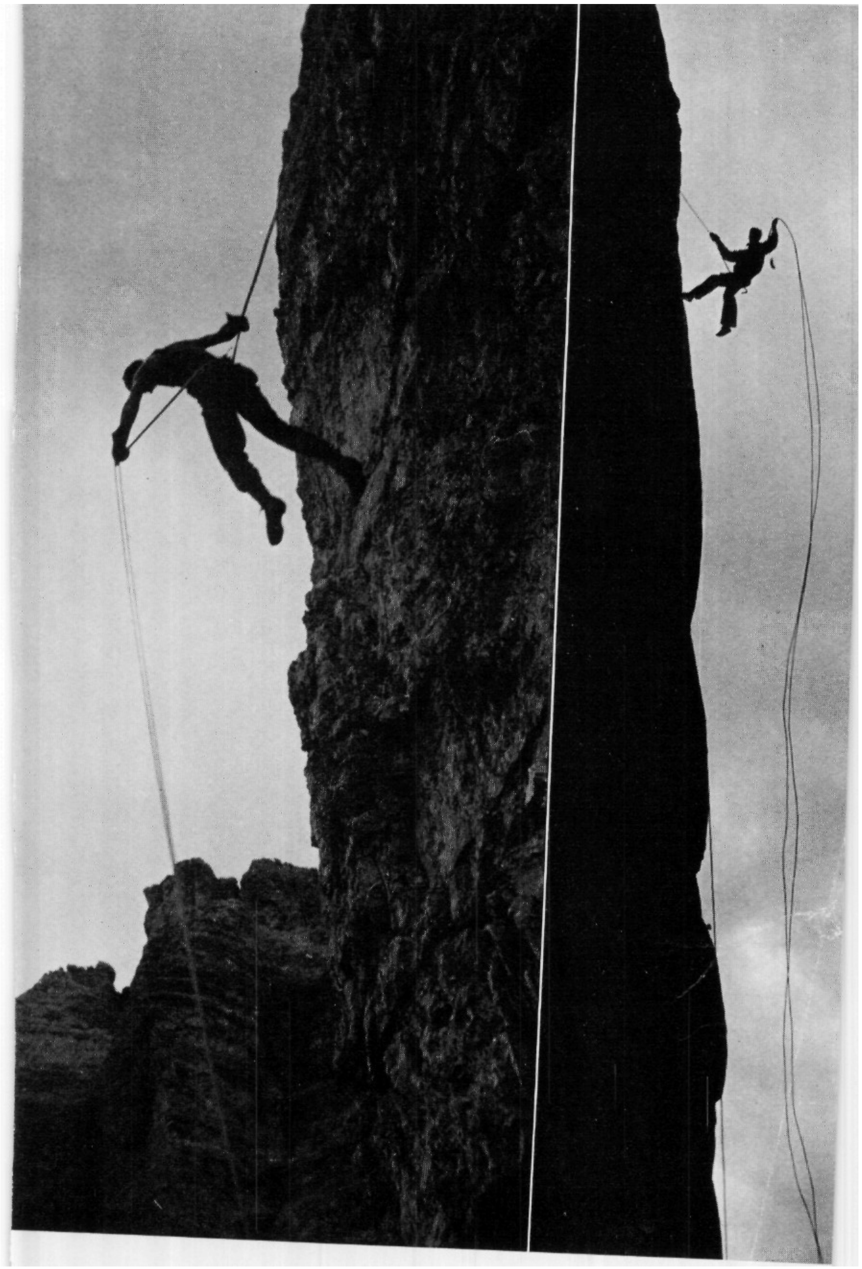




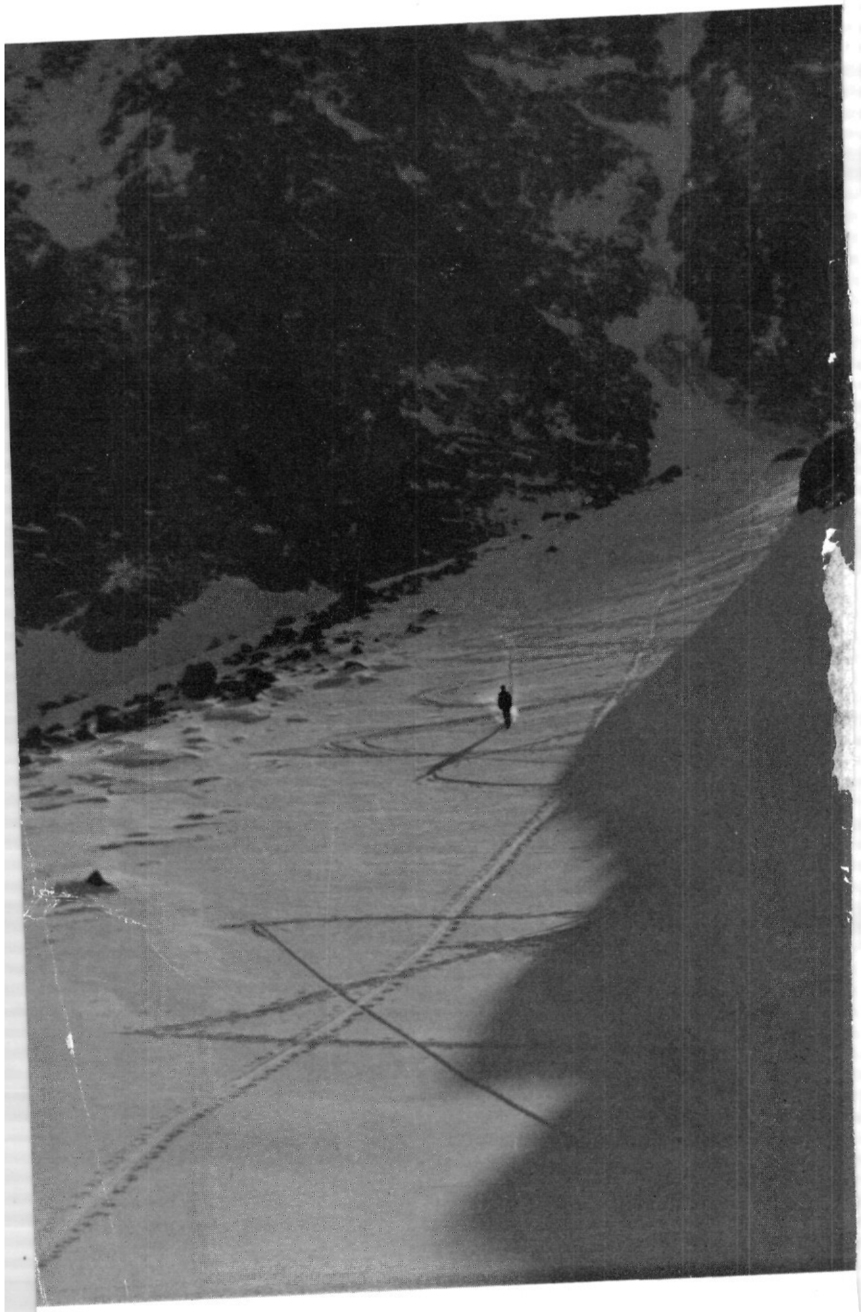
You will find exciting places to rest, whether a Chamonix aiguille in France or Seneca Cave in West Virginia—and great, airy places to rappel from, whether a Piccola Cima in the Dolomites or a Lower Spire in Yosemite. But nothing will ever beat what happens when the shadows reach out for your morning tracks and you point your skis down over the powder. . . .



(38,39; 40,41 facing; 42 following)



... That's when you come **closest** to knowing how a bird feels »



route of escape from steep and exposed summits in any weather. The mountaineer's method of sliding down the rope is the safest and most comfortable yet devised, and can be practiced at home (see p. 189).

High-angle climbing.—This, in itself, is the subject of later chapters. The novice not wishing to pursue the subject further should remember at least three rules:

1) Select the easiest, safest route; plan and remember how to use it.

2) Maintain an adequate margin of safety; don't rely upon a single hold, but use two or three at a time.

3) Make the legs and feet do most of the work; leg muscles are far stronger than arm muscles, and a one-inch hold will support a foot; arms and hands should be saved for balance and emergencies.

7. Selecting a Campsite

It is not possible arbitrarily to lay down a controlling set of specifications for an ideal campsite. Much depends on terrain, climate, and type of shelter to be used. The importance of each factor will vary with conditions; for instance, if danger of avalanche exists, it may be that every other consideration will have to be sacrificed in order to find a spot free from this all-important danger. There are, however, certain factors which a ski mountaineer should weigh in determining the selection of a place to camp:

1) Freedom from objective danger: The chapter on mountaineering routes should be consulted for detail. A rocky bench on a ridge or the middle of a windswept, flat-bottomed valley may have to be selected if the party is above timberline.

2) Availability of liquid water: Snow takes time and fuel to melt.

3) Protection from wind: Timber is the best protec tion, but a tent immediately under large trees may be wrecked by the dumping of heavy masses of snow from the branches overhead.

4) Firewood: Daring comfortable weather a fire will add cheer to a campsite, and will save fuel in cooking, so that the party may prefer to camp near a good source of firewood (see *Fire building*—).

5) Warmth of location: Lowest temperatures usually

come on clear, quiet nights. On such nights flat valleys are the coldest spots in the mountains. A sheltered bench one hundred or more feet above the valley floor will frequently be ten to fifteen degrees warmer.

The perpendicular side of a large rock or small cliff acts as a good reflector for a fire. Placing the tent between such a rock face and the fire is excellent.

6) Routes of retreat: Since a storm may suddenly arise, it is well to be sure that a safe route of retreat exists. Don't put a dangerous pass between your camp and safety.

7) Time: The most ideal campsite, if it has to be pre pared in the dusk or dark, will not compare with a camp set up in daylight, completely cozy, with fire crackling or primus stove purring, supper steaming, and sleeping bag ready when night falls. Pleasures of a trip will be enhanced if camp-making is started early.

8) Scenery: Despite all the ominous rumblings in this manual about freezing and avalanches, it should never be forgotten that the purpose of ski mountaineering is to make available the scenic and recreational values of mountains in winter. Surely no one should miss the op portunity of letting his soul and fancy soar to new heights as he looks at great peaks rising above snowy ridges that are bathed by starlight or moonlight. The ef fect is not decreased by having the entire body, except for eyes and nose, snugly encased in a warm, down-filled sleeping bag.

8. Shelter

Before starting on a tour the ski mountaineer should provide himself with the means of constructing a shelter adequate to protect him against the strongest wind, the worst snowstorm, and the lowest temperature he may encounter. Requirements will obviously vary with terrain and climate. Types of shelter range from the simplest bivouac caves and brush huts to complete igloos, tents, and multi-room caves. The competent ski mountaineer will not only familiarize himself with each type, but also will construct all of them in order to have the knowledge and experience necessary to meet all conditions.

Brush for shelters may not be securable, snow may not be deep enough for caves nor sufficiently compacted for igloos, time may be needed for touring rather than for constructing shelters out of locally available materials. Any or all of these causes warrants the carrying of some sort of a tent.

Tent Requirements

No single type of tent can truly be described as best. Each has distinct advantages. The small, two- to three-man tent with a tapered floor plan and sloping ridge is the most popular model. There are also the tried and proved mountaineering tents, such as the Mead, Logan, and Whymper.

Design of tents.—Whatever model is selected, certain factors are important:

1) Weight should be kept to about two to three pounds per man. This compels the elimination of many poles required by some types. Skis at front and rear, skis or ski poles for pegs, should fully satisfy all require ments. The tent is dropped if left all day, and its location marked.

2) Tents that require numerous guy lines to support the various edges and walls have no place in winter mountaineering.

3) Tents with perpendicular walls will catch the wind and should be avoided wherever possible. Slop ing walls, on the other hand, spill the wind, particularly if the guy lines which hold up the peak or ridge are supported by rubber bands.

4) A sewed-in bottom is indispensable. The tent will then be held down in heavy wind by the weight of the occupants even though all stakes and anchorages fail. If it is planned to use a tent primarily in timber, a permeable floor of two-or three-ounce percale is better than a waterproof floor. Laid over fir boughs it is warm (no air mattress is necessary), dry, and at the same time never allows puddles of water to form from melted snow or from condensation of breath, insensible perspiration, or steam from cooking. If the tent is to be used much above timberline, a light waterproof sheet may be laid over the percale floor or a waterproof floor of regular tent fabric substituted. The separate sheet, although heavier, has the advantage of permitting the condensa tion on the inner walls to run down through the per meable floor into the snow without wetting the contents of the tent.

5) Provision should be made, either by the tent design

or by zippers on the tent floor, to cook on snow rather than on the floor itself. Water is then available inside the tent, and a toppling pot of soup is not a disaster.

6) The tent must be made of lightweight fabric in order to come within the rigid weight restrictions re quired for comfortable ski mountaineering. Fabrics weigh ing two to four ounces per square yard have tensile strengths of forty to eighty pounds per inch and in a properly designed tent are rugged enough for the most violent storms. Excellent lightweight nylon fabrics weigh ing from 11/2 to 21/2 ounces per square yard are now being made. Coated fabrics have not proved acceptable owing to the excessive condensation on tent walls, which cannot be effectively controlled by ventilation, particularly in stormy weather.

7) It is apparent that tents should be barely large enough to provide room for sleeping. Any additional size increases weight, requires the use of heavier fabric and stronger anchorage to resist winds, and decreases warmth because of the increased volume of air required to be warmed by the cook stove or body heat.

Pitching tents.—An area large enough for the tent is leveled if necessary by using a ski as a scraper. The snow is then compacted by vigorous stamping with skis. The floor of the tent is laid out with the entrance away from the direction of the prevailing wind. At each corner the snow is stamped hard by the boots, then more snow is kicked into the holes and similarly stamped in order to provide a firm anchorage. Skis and ski poles are usually used as pegs, although locally secured poles and sticks may serve. Tent pegs one foot long, made of sheet duralumin, bent longitudinally into a right-angle section, are sometimes carried. If the snow is fluffy or sloppy, these short pegs can serve as a dead-man anchor; the guy line is tied around the middle of the peg, which is then buried horizontally at least one foot below the snow surface at right angles to the guy line. The overlying snow is tamped thoroughly.

If fir boughs are used as a floor, they should, if tent design permits, be laid after the tent is pitched, but with an adequate supply along the sides of the tent. This eliminates the tendency to roll off the edge of a fir-bough mattress.

Other Shelter

Under ordinary circumstances ski mountaineers should use a tent for shelter. But tents may be destroyed by fire or storm, and skiers may be separated from the member of the party carrying the tent. Therefore, every ski mountaineer should know how to construct certain basic types of shelters from field materials. In addition, snow caves and igloos are more comfortable in heavy winds and under conditions of intense cold than are tents, and if time permits will be constructed out of preference. In the spring when the snow is deep and well packed, some experienced snow campers travel without a tent, relying entirely upon bivouacs.

There are infinite variations of the basic types here described. Every man may well indulge his ingenuity.

Open bivouac.—On calm nights or in areas protected from the wind when no storm is threatening, there is no necessity for the construction of any shelter. A fir-bough bed laid on the snow for insulation and to keep the bag dry (or ground sheet and a mattress as a substitute) is all that is necessary. The deep snow hole under a dense drooping fir is an excellent spot for a one- or two-man bivouac. A low snow wall or a line of branches stuck in the snow will reduce snow drifting should a wind arise during the night.

If several persons are bivouacking together the quantity of boughs required for a mattress is reduced and considerable body heat is conserved. Two feet in width should be allowed for each person. A waterproof sheet may be thrown over all the sleeping bags for increased warmth. This will not condense excessive moisture because ventilation is provided between the sleeping bags.

Brush shelter.—If the snow is not deep enough for a snow bivouac a brush shelter can be constructed, in the heart of the densest thicket available and well out of the wind. The design is unimportant provided the walls are interlaced densely for windproofing, and the entire shelter is made no larger than necessary. Covering the brush with bark, snow, or sod will aid windproofing and better retain air warmed by body heat.

Trench and wall bivouacs.—By shoveling a trench or building walls of snow blocks, using skis or field-cut poles for rafters, and a waterproof sheet or fir boughs for a roof, a satisfactory shelter can be produced. There are many designs, each with its vociferous advocates. Some prefer a lean-to, others a flat roof; some prefer a rectangular shape, others a hallway with alcoves accommodating two skiers each; some prefer complete enclosure, others insist on an opening with a fire in front. Whatever the design or method of construction, these points should be borne in mind:

1) Provide adequate rafter strength to support a snow load should a snowstorm arise during the night.

2) If a waterproof sheet is used, be sure it slopes for drainage and is well anchored with snow blocks or other means to prevent the wind's ripping it away.

3) If a brush roof is used, cover it with snow if the weather is cold to keep in the warm air; but if the air temperature is near or above freezing do not do this as otherwise melting snow will drip, drip, drip.

4) If an open-front shelter is used be sure an all-night supply of wood has been gathered. And just in case you get tired of stoking the fire, or a storm douses it, have enough brush or snow blocks handy to close the entrance completely.

5) Trench bivouacs can be constructed in any size. The simplest is the one-man type, 31/2 by *21/2* by 7 feet, which can be stamped or kicked into the snow and lined and covered with fir boughs in about half an hour.

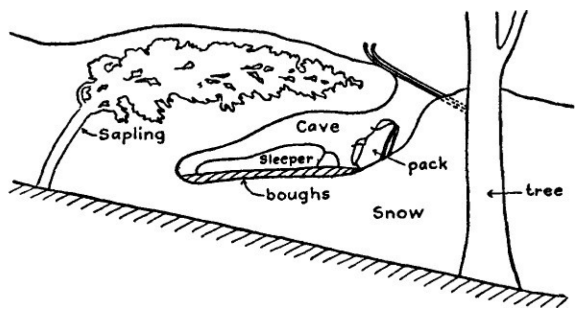


Fig. 4. Snow cave for one man.

One-man snow cave.—The simplest bivouac for a lone skier provided with a sleeping bag and a waterproof outer cover is the one-man cave. In the shelter of an overhanging conifer or beside a rock or log, or best of all, under a bent-over sapling, a cave can be kicked into unconsolidated snow with the boots, or dug out of packed snow with a cup or cooking pot in a few minutes. The cave should be just large enough to squeeze into after the lining of fir boughs or the air mattress has been inserted. If a slope is not available a pit can be dug 31/2 feet deep and the cave dug as a drift from the pit. For greater warmth the top of the pit should be covered with boughs and snow blocks.

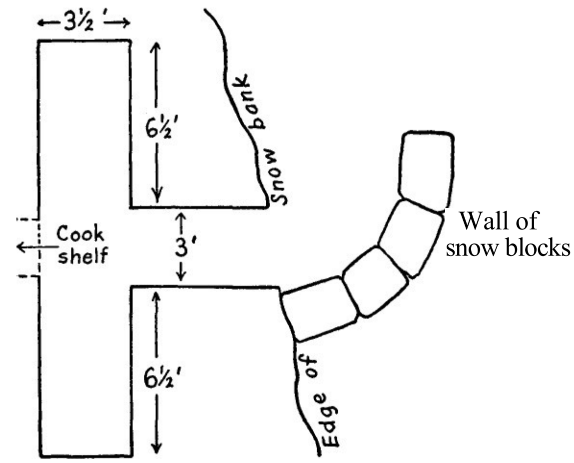


Fig. 5. Plan for a four-man snow cave.

Snow caves.—Here again there is an opportunity to choose from an infinite number of designs. For simplicity the standard four-man cave only will be described. Its layout is shown in the accompanying illustration. A compacted snow slope at least six feet in depth is selected, preferably a steep bank or drift. A tunnel with arched roof, about three feet wide and four feet high is dug directly into the bank. A small shovel, such as the army trench shovel, or a lighter duralumin substitute, is the best tool for the purpose, but a satisfactory job can be done with a long knife, or the heel of the ski (but do not pry hard with it). The face of the tunnel is cut into blocks, the lowest layer chipped out and the successive upper layers pried down. These blocks, remaining intact, can be removed by hand and the better ones used for the construction of the wing wall shown in the diagram. Broken blocks can be scraped out of the cave with hands or cooking pots.

Side alcoves holding two men each, 31/2 feet wide, 4 feet high, and 61/2 feet long, are constructed at right angles to the entrance hallway. A shelf 18 inches above the floor is cut at the end of the hall and used for cooking-

If the snow is too shallow or inadequately compacted, the same design may be constructed in the form of a ditch and roofed with local poles and branches, or with skis and waterproof sheet, the roof covered with snow.

Igloos or snow houses.—There is no mystery about this structure, nor any particular difficulty. Four men, after an afternoon's practice, should be able to build a snow house, large enough to hold them, in from 45 minutes to an hour. The only thing needed is snow packed firmly enough (not simply crusted over) to support a man without his sinking in more than enough to leave a slight footprint. Probing with the handle end of a ski pole will help decide whether the snow is right all the way through, or only crusted.

A flat-bladed shovel, or the heel-end of a ski may be used for cutting the snowblocks. They should be cut in the shape of a domino, at least 4 inches thick, a foot and a half wide, and 2 or 3 feet long. Undercutting, in addition to cutting around the edges, is necessary to secure well-shaped blocks. If four men work as a team, it will be well to have one cut blocks, another carry them to the building site, a third (standing inside the structure) put them into position, and the fourth caulk the joints with loose snow, or aid the builder. If blocks are cut from inside the structure, the necessary height of wall to be constructed is greatly reduced.

The floor plan may be oval or circular, but not rectangular. It is well to make an outline first, by standing in the center, grasping a ski at the desired radius, and sketching with the point the course to be followed with the first row of blocks. An inside diameter of eight feet will provide adequate quarters for four men.

Depending upon whether the house is to be high or low, each block of this first row is undercut along the lower edge. So beveled, the block will lean inward at the desired angle. Later rows will be similarly beveled.

When the first row has been completed, the next row may be built on top. But a better system is to provide for a continuous spiral in the following manner. Choosing any block in the first row, cut away a diagonal half —from the top of one side to the bottom of the other. Begin the second row of blocks by placing the first in this space. Then build continuously around and around in smaller and smaller diameters until space remains for only one more block at the top. This final block will act as a keystone, and the igloo as it stands will be satisfactory, if caulked with loose snow. But added strength will be provided, and the brushing off of snow at contact prevented, if a little time is taken for icing the interior. This is done by lighting a stove (or woodfire) inside the igloo, sealing the door, and leaving until the snow becomes sufficiently moist inside to form ice when the fire is extinguished and the cold air from outside let in.

The temperature inside such a house may easily rise to 70° or 80° while the stove is in operation. If this results in undue softening of the roof, it is only necessary to go outside and, with a ski, scrape down the thickness of the structure until the heat can be dispersed. If, on the other hand, hoarfrost begins to form and drop off the roof inside, it means that the structure is not thick enough to give adequate protection from the weather. The remedy here is to pile loose snow on the outside. Cooling may also be secured by increasing the number or size of vent holes.

In thawing weather igloos cannot be used because the blocks will shrink, causing the roof to sag and eventually to collapse.

Even in the coldest weather, once the temperature inside an igloo has been brought to 60° and kept there a while, mere body heat will ordinarily suffice to keep it comfortable thereafter.

An igloo which has been iced over inside by the method indicated is strong enough to hold the weight of several men standing on its roof, although a sharp blow at one point will puncture it. Igloos are also nearly soundproof. But a man sleeping on the floor will feel, in a manner akin to hearing, any footsteps or vibrations coming from an appreciable distance. If the slope of the snow permits, the entrance can be made *below* the level of the floor. This prevents the escape of warm air except through the vent hole at the top and results in a much warmer igloo. Brush or a rucksack will serve as a door and permit control of ventilation. Lining the floor with fir boughs will provide additional warmth for sleeping.

9. Miscellaneous Notes on Camping

Snow is an excellent heat insulating material, comparable to leather and asbestos. The heat of the body quickly warms a small snow structure to the freezing point of water (32° F), provided the snow walls are thick enough (at least one foot), and that all ventilation which is not necessary is excluded.

The amount of fresh air needed for a human being at rest is usually overestimated. Under resting conditions only 0.01 cubic foot of oxygen is consumed each minute. One cubic foot of air per minute for each man is then more than ample. This amount will permeate the unpacked snow around a bivouac. There is then no danger of suffocation from being completely "snowed in" so long as the cave is not glazed with ice.

A small stove consumes more oxygen than twenty men at rest. It may also produce poisonous carbon monoxide. Common prudence requires adequate ventilation while a stove is in operation.

If snow is too loose to cut into blocks for constructing bivouacs and igloos, it can frequently be consolidated by thoroughly tramping an area, first with skis, then with boots. But this is hard work.

Fir and pine boughs are an excellent substitute for air mattresses and even sleeping bags in emergencies. They can be used, not only on the snow floor, but also as a lining on the sides and roof. The thicker and denser the mat of boughs, the better the insulation and springiness. If evergreen boughs are not available, twigs from deciduous trees, dry moss from trees or tundra, dry grass and brush may be substituted.

A good place for the boots is in a hole under the sleeping bag. The hole should be lined with boughs, extra clothing or other insulating material, except on top. If this is done carefully, the boots will not freeze during the night. Equally effective, but more uncomfortable is to take your boots to bed with you—but take them off. Boots can also be thawed over the cook stove—but don't get the leather hot.

Warm air rises. The best way to keep it in a tent, cave, or other shelter, is to take care that the upper portion of the shelter does not provide excessive opportunity for warm air to escape. Where practicable with caves or igloos, construct the entrance below the level of the main floor area; that is, tunnel up to the floor. Where a low entrance is impracticable, improvise a door of brush, cloth, or snow blocks sealed at the top, leaving the air opening near the bottom.

However, during cooking operations adequate ventilation should be provided especially in impermeable tents for the reasons previously stated. Also, reasonably controlled ventilation from the top of a tent prevents excessive condensation of moisture and is desirable not only during cooking, but also while resting and sleeping if the need for conserving warmth is not imperative.

Overinflated air mattresses are hard and uncomfortable. Skiers with big hips should dig a hip hole whether or not it is overlain by fir boughs or an air mattress.

Wet socks and innersoles can be dried on a good day by tying them outside the rucksack. On bad days they may be dried against the belly, a method which can also be used at night if necessary; however, it increases the moisture which will be condensed in the bag or tent. Because of the low rate of blood circulation when one is lying down, socks should not be dried on the feet.

Sleeping too warm is undesirable. Even though one is not conscious of perspiring, water is always being evaporated from the skin surface. In extremely cold weather this moisture will condense as frost in the outer layer of the sleeping bag, impairing its insulating value and necessitating frequent drying.

Drying the sleeping bag by hanging it on a branch or rock during the noontime stop, whenever the sun is shining, is the best method of insuring a warm sleeping bag at night. This should be routine, since even moisture that cannot be felt will decrease the warmth of the bag.

An excellent method of having water ready for a hurried breakfast is to dig a hole in the snow, line it with grub bags and just before turning in at night place a full pot of boiling water in this lined hole. Cover pot with more bags and snow for insulation. In extremely cold weather at least a foot of snow cover is needed.

Never leave articles scattered around the snow. They should be either in the tent or in the rucksack. An extra waterproof bag or two is excellent for miscellaneous small articles.

To expedite the work of making camp, members of the party should be given certain duties, such as cooking, collection of firewood, or preparation of tent sites. Time and effort spent in preparing for a good rest and sleep is time well spent. Camp is the best place for the repair of both personal and community equipment. It is also the best place for recuperation of any member of the party who has shown signs of weakening. Timely attendance to his rest and warmth may save the party trouble later.

10. Snow Formation and Avalanches

CONSIDERING THE excellent sliding surface that snow affords, the skier might well wonder, "Why doesn't this snow avalanche?" instead of "Will it avalanche?" Any rugged snow terrain demonstrates that the avalanche is the rule, not the exception. Almost as soon as snow falls, it slides from the steeper cliffs and rock faces. What kind of ground or rock surface, then, will hold it? Once it is held by the ground, what will hold each succeeding snowfall to the snow layer it falls upon? Indeed, what holds one snow crystal to another? These are basic questions, and there are three more: What precautions should be taken in avalanche territory? What should one do if caught in an avalanche? And what can one do for others who are trapped?

Much of this chapter, which endeavors to answer these questions, will seem unduly technical and dryly scientific. Yet the tragic toll of human life taken every year by snow avalanches makes it necessary that every man who ventures onto steep snow slopes be capable of telling when danger exists. He must be able to say with assurance that "this slope is safe," "this slope is unsafe," or "this slope will be safe if we cross it one hour after the sun has left it."

There is no short cut, no easy rule of thumb to determine whether a snow slope is in danger of avalanching. Experience alone is not enough. There may be no chance for a second experience. Required is an accurate knowledge of the internal structure of snow, why it is sometimes packed as hard as concrete, at other times is as fluffy as down, as gritty as sand, as sticky as pie dough, or as slushy as mud. The crystalline structure and texture of snow is in a continual process of change from the time the snow flake is first formed until it either melts or compacts to solid ice. Thorough knowledge of the causes and results of this change underlies an understanding of the causes—and results—of an avalanche.

Snow Texture

Crystalline structure of fresh snow.—There are many forms of snow crystals (see fig. 6), all of which are hexagonal, consisting of plates, prisms, star-shaped designs, or a combination of these forms. In general simple

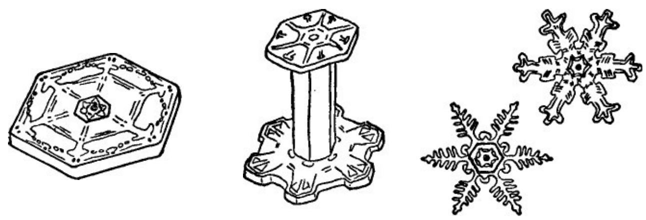


Fig. 6. Typical forms of new snow crystals.

crystals are formed when the temperature is low. The range of size is, roughly, from 1-4 mm. in diameter. A snowflake frequently consists of a cluster of interlaced snow crystals. Snow crystals of the simple plate form accumulate loosely compared to the branched type of crystal. The points of the branched crystals interlace and cohere within a mass of new-fallen snow. An avalanche is, therefore, less likely to occur immediately after a snowfall made up of branched crystals. Snow made up of the simpler type of crystals will flow more readily.

Consolidation of crystals.—As soon as snow has fallen a transformation begins. If the temperature is above freezing, the branches of the crystals begin to melt, destroying the interlocking bond. Even if the temperature is below freezing, these branches will still, although more slowly, disappear because the vapor pressure of the ice particles, and consequently evaporation, is greatest at the points. This evaporation will take place even though

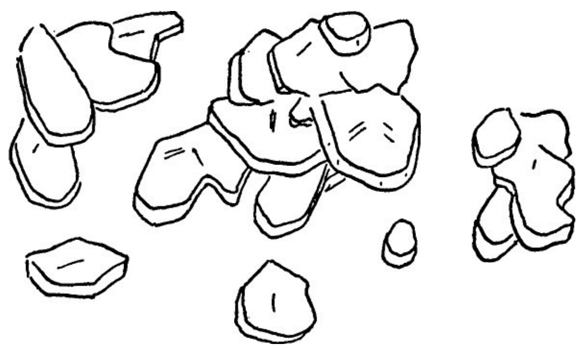


Fig. 7. Crystals of "spring" or corn snow.

the humidity is such that no net evaporation results, since the difference in vapor pressure will cause ice to evaporate from the points and attach itself to flatter portions of the crystals. The result is a gradual transformation from branched or thin-edged snow crystals to larger hexagonal crystals. The smaller crystals in turn tend to consolidate with larger crystals. By this basic process new-fallen snow is converted gradually to the "spring snow," which every skier knows (fig. 7). The rate and manner of change will depend on the weather, but the process is always going on, and accounts for variations in the internal cohesion of the snow. Cohesion is at first reduced by the loss of the interlocking crystal branches, but as the process continues, the large crystals which are finally formed pack more closely, so that the snow settles and cohesion again increases. But when temperature and humidity produce wet crystals, the film of water, acting as a lubricant, reduces internal cohesion.

Effect of wind on texture.—The effect of wind on fallen snow is varied and difficult to predict accurately. The primary effect of a dry wind is evaporation of the snow. A humid, or wet wind nearly always causes packing of the surface snow (assuming that the snow is not already hard-packed), and simultaneously causes erosion (wind-cut snow) and drifting. Wind packing sometimes forms a *crust* which is well bonded to the underlying snow; however, if there is simultaneous deposition of fresh or drifting snow, a *wind slab* is apt to form. This is poorly bonded to the underlying snow, and may break up when disturbed, sliding away in blocks. Therefore, wind *slabs* are likely to be on lee slopes; a wind-cut surface is usually a safe crust and not a slab. Frequently, soft snow under a wind slab will settle unevenly, leaving spaces under the slab. Owing to the lack of continuous support the slab breaks easily under the weight of a skier.

The rate of consolidation to "spring snow" is appreciably accelerated by wind. The acceleration is due to the greater rate of evaporation of the branches and edges of the snowflakes. If the wind has a low humidity, there may be a large net evaporation from the snow field, but wind with a high humidity may actually deposit moisture or ice. If the moisture freezes immediately, an icy crust or a hoarfrost is formed, depending on the temperature. If it remains wet it may make the snow very unstable and subject to avalanche until frozen.

In summary, the effect of wind varies considerably, depending on whether it is above or below freezing, and has a high or low humidity. If the temperature and humidity are both low, no crust need be expected; if the temperature is low, but the humidity is high, wind crust or wind slab will be formed (or hoarfrost); and if the temperature and humidity are both high, the snow will become quite wet.

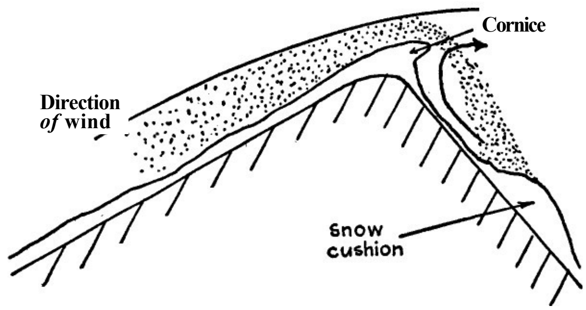


Fig. 8. Formation by wind of cornice and snow cushion.

Drifting and erosion.—Wind is of great importance in determining snow conditions. It tends to pack and erode the snow on windward slopes, simultaneously depositing drifted snow on lee slopes. These drifts may become very deep and sometimes have a steep lee side. Since the friction and evaporation during movement of the snow tends to remove the branches from the crystals, the cohesion of these drifts initially is usually low, and dry-snow avalanches may result if the snow is not wind packed. Wind slabs may be formed, however, if the snow is drifted by humid wind and collects at a point where the wind velocity is reduced, but is not calm.

In traveling over the crest of a ridge, drifting snow frequently forms cornices (see fig. 8). These occur in the calm triangular region between the air current flowing over the top of a ridge and the eddy current drawn up the lee side of the ridge by the main current of air. Drifting snow carried by the main current settles, in part, into this comparatively calm region, and builds out the cornice, either by the interlocking of the crystal branches, or by formation of a wind slab. Snow carried past this calm region before dropping out of the main air current falls below the cornice and forms a drift, generally known as a snow cushion.

The formation of a large cornice is favored by a windward slope which is 15-30° and a leeward slope of about 52°. Cornices can be formed, however, with windward slopes from level to about 45°, and with lee slopes from perpendicular to 30° or less.

Cornices are often unstable, their collapse the frequent cause of avalanches. The snow cushion in itself is frequently an avalanche hazard. Where possible, routes should be so planned that cornices are avoided. Moreover, skiers should bear in mind that a flat and innocent-looking ridge crest may in reality be a cornice that is overhanging several feet and is on the verge of collapse.

Stratification of Snow Deposits

The stability of a given layer of snow depends not only upon its texture and internal cohesion, but also on the cohesion between the snow layer and the underlying surface. For when a vertical section is cut from the topmost surface of the snow to the ground, it is seen that each successive snowfall forms a separate and distinct layer of snow. In general, the lower layers have larger, better consolidated crystals. The difference between the layers is due to the difference in weather during and between successive snowfalls, and to the greater age of lower layers.

Bond between layers.—A new layer will be well bonded to the previous layer if it falls when the previous layer is wet, or if the falling snow itself is somewhat damp. This is particularly true if the temperature falls after the snowfall has commenced, thereby freezing the new snow to the old snow. If, on the other hand, the old snow is-fairly well packed and the temperature is well below freezing, the bond is likely to be very poor until the new layer has also settled. The bond is particularly poor if the new snow falls on crusted snow. The crust may be due to wind, but is even worse if it is due to thawing; and then refreezing to form a smooth icy surface. In other words a layer of loose, unconsolidated snow lying on a smooth crust is apt to avalanche.

Flow of water through strata.—The stratification of snow has further effects during a thaw. If the snow i& melting, or if water is running down through it because of thawing conditions higher up the slope, then one layer of snow may become wet while other layers remain unaffected. In filtering through snow, water tends to saturate a densely compacted layer such as a wind crust, in preference to traveling through a looser snow texture, and it may rise up through the layer from the bottom rather than flowing down from the top. This is because the water motion is governed primarily by capillary attraction, which tends to make it flow along the crystal surfaces, just as kerosene flows up a lamp wick, or ink into a blotter. Water in a snow layer not only reduces the internal cohesion, but also tends to provide a water-lubricated upper surface over which an overlying snow layer may slide.

If a solid ice crust is present, any water formed above this crust cannot flow down through it, and when the snow above becomes saturated, additional water will, therefore, run down over the surface of the ice crust. This results in a very wet surface on the ice crust providing a particularly well lubricated surface on which the next higher layer of snow may slide.

Thus, where several layers of snow are present, one layer may be wet without the others being wet, and the wet layer is not necessarily the upper layer. It is therefore not enough merely to know that the upper layer of snow possesses good internal cohesion, since it may be lying either on a loose lower layer or on a lubricated lower ice crust, either of which may permit the upper layer, or several layers, to slide away.

The skier must accordingly consider whether there exists on any suspected slope a lubricating snow layer, either dry or wet, below the surface. Avalanches caused by the yielding of several layers are particularly dangerous because of the depth of the snow released.

Effect of Slope and Ground Surface

Steepness of slope.—Generally speaking, the steeper the slope, the greater the danger of avalanche. Avalanches are not likely to occur on slopes less than 22°, but can occur on lesser slopes if other conditions are unusually favorable. Much steeper slopes than this are entirely safe if snow texture and snow bondage are good.

Ground surface.—Inequalities in the ground surface, such as rocks, mounds, or terraces, tend to give a firm anchorage to the lowest snow layer, and whenever numerous firmly placed rocks are protruding above the snow, the avalanche danger will be negligible. Rounded, downward-sloping ledges give little support to snow, but angular, upward-tilted ledges give considerable support. Grass usually forms a poor bond with the lowest snow layer since the grass bends downhill and is matted into a slippery surface. This is sometimes also true of the more flexible types of brush, but shrubs with fairly rigid stems give a good bondage. Trees growing in a close wood serve both as a good bondage and as an indication that avalanches have not recently swept through the region. Avalanches can fall, however, from a sparsely wooded slope, and even dense woods are sometimes swept out by avalanches starting above the wood. Water-saturated soil is obviously a slippery surface.

It should be borne in mind that the ground surface and vegetation affect only the snow layers into which they protrude. After the ground and vegetation is completely covered and a smooth snow slope is formed, each succeeding snow layer must be bonded to lower layers in order to obtain any support from the original surface.

Contour.—The general contour of the mountainside also affects the bondage of the snow. On a concave slope, the snow in the lower, flatter portion of the slope tends to support the snow higher up, whereas on a convex slope the steepest portion is at the bottom, and it consequently provides less support for the snow on the flatter portion at the top.

The effect of contour is relatively important if the principal cause of an avalanche is a lack of bondage between the sliding layer and the next lower layer, which may be the ground. The snow then *slides,* to a certain extent as a blanket. The effect of contour is less important when the danger of avalanche is due to lack of internal cohesion within a snow layer so that the snow *flows* downhill. A wind slab on a convex slope is more likely to be under some initial internal tension than a wind slab on a concave slope. A slab on a convex slope, therefore, should tend to fracture more readily.

Most avalanches fall in chutes or gullies (or couloirs); indeed, in high mountains, these chutes owe their existence primarily to erosion by frequent avalanches. These avalanches are mostly of the flowing type, however, and are frequently started by snow falling off the headwalls. Obviously, then, when a skier crosses an avalanche chute, it is not enough that he merely know the character of the snow in the chute. The imminent danger is in the slopes high above, the structure of which is usually entirely different from slopes in the chute.

Avalanche Types

Avalanches may be placed in four classifications: those of ice, dry snow, wet snow, and wind slab. Combinations of several types may occur; for example, an ice avalanche may start several layers of snow, both wet and dry, old or new, on their way down a mountainside.

Ice avalanches.—In any precipitous region undergoing heavy glaciation, ice avalanches are frequent, and often of tremendous proportions. Hanging glaciers high on a mountainside will move beyond their support and collapse, sweeping everything before them. In the Himalaya, avalanches started in this manner have been known to travel fully a mile across a level valley floor before spending themselves. Where the course of a glacier is less precipitous, a cliff may be entirely covered with ice, being indicated only by the heavily crevassed and chaotic surface of the glacier, known as an icefall. Here the seracs, or pinnacles of ice, often collapse to cause avalanches of large proportions.

For the purpose of this chapter, it will be presumed that the skier who travels in terrain that spawns such avalanches will be fully prepared, by study and experience acquired elsewhere, for the problems that will confront him. But a milder hazard from falling ice is frequently encountered in any rugged ski terrain. Water from melting snow will freeze on cliffs during the night, or whenever the temperature is low enough, and will break loose with the first thaw. The breaking loose of large accumulations of ice may cause a snow avalanche on the slopes below. It is usually easy to see where such bombarded areas exist, and to plan a route that avoids them, or to time the trip so the party passes beneath the cliffs when the ice is frozen.

Dry-snow avalanches.—New snow: This is the most frequently encountered avalanche. The primary cause is a loss of internal cohesion soon after a snowfall, owing to evaporation or transformation of the branches of the snow crystals. This eliminates the bond initially provided by the interlacing of these branches, and permits the snow to flow. Avalanches of this type may occur during or soon after a snowfall, wherever the slope is steep enough. If the snow has fallen on a frozen crust, or even on settled snow when the temperature is well below freezing, the likelihood of avalanche is increased since the poor bond may permit slippage as well as flow, and more gradual slopes are apt to avalanche. If the layer of new snow is only a few inches thick, the likelihood and seriousness of an avalanche is slight, but if the fall has been very deep, or has been collected in large drifts, the likelihood of avalanche, and the possible damage from it, is great.

The length of time between the start of a snowfall and danger of avalanche, and the further length of time before the snow will have settled sufficiently to become safe again, depends on the weather conditions and slope exposure. If the slope is exposed to sunshine soon after the fall, dry new-snow avalanches may occur within a few hours, and if the sunshine continues, the danger from avalanche will be over within two or three days, and will be greatly reduced after one full day of warm sunshine. If the temperature is very low, however, and if the snow is not exposed to sunshine, the period before avalanches may occur is extended, and it may be two or three weeks before safe conditions are reestablished. Danger from this type of avalanche should therefore be suspected from almost any time during a heavy snowfall until not less than two or three days later, and the length of time that danger should be suspected is governed by the exposure of the slope and the weather conditions known to have existed subsequent to the fall of snow. Generally speaking, south and west slopes will avalanche first and become safe again first, whereas north and east slopes, receiving less radiation from the sun, will remain dangerous for a longer period. This period may be affected, however, by wind. Wind may pack the new fall of snow sufficiently to remove the hazard; if the wind is humid, it may form a wind slab, which introduces the hazard of a different type of avalanche; wind may form large snowdrifts which may be hazardous. A humid wind above freezing temperature may make the snow wet and introduce the hazard of a wet avalanche.

Settled snow: This type of avalanche is rare and is only likely to occur when the support of the snow is removed. This may result either from loss of bond with the underlying snow, resulting, for example, from water seepage over an underlying crust, or from loss, perhaps by avalanche, of support derived from snow on the lower part of a very steep slope, the upper portion of which is covered with settled snow.

Wet-snow avalanches.—New snow: A wet new-snow avalanche may occur when the snow becomes damp because of sun, rain, warm humid wind, or high air temperature, and may well be expected whenever the snow becomes sticky or sloppy. Here again, the likelihood of an avalanche will depend not only on the wetness of the snow, but also on the gradient and contour of the slope, and the bondage to the underlying snow or ground layer. The extent to which a wet new-snow avalanche will slide as a blanket or roll in huge balls will depend on how wet the snow is. Water in small quantity increases cohesion, but reduces cohesion when present in a large quantity, just as is true with dry, damp, and very wet sand.

Old snow: Wet old-snow avalanches usually fall because the snow has become so heavy from water that its weight cannot be held by internal cohesion or its bond to underlying snow or ground. This type of avalanche usually falls in the same tracks each year. Abnormal avalanches may occur in years of heavy snowfall or warm spring. The snow in such an avalanche is wet and slushy, and flows very much like mud.

Wind-slab avalanches.—Wind-slab avalanches may occur at any time after formation of a wind slab, until the slab has settled and is once more bonded to the underlying snow. The ease with which a slab slides after being broken depends on the character of the underlying snow and the gradient of the slope, and the ease with which it breaks depends on the toughness of the slab, on its thickness, on its size, and on the depth of the space between the slab and the underlying snow. The thickness of slabs varies from a few inches to two or three feet. It should be borne in mind that a snow slab may be formed and then covered by a later fall of snow which completely conceals it. The presence of a snow slab which is broken by the weight of a skier as he travels can be detected by the dull thud occasioned by the settling of the slab, and when the slab is not covered, the lines of fracture can be seen to run off some distance from the point of breakage. This extension of the fracture is one of the visible points of distinction between wind *slab* and wind *crust.* The effect of breakage of wind crust is quite local, with no tendency to break up the crust to any distance from the point of fracture. Hoarfrost is sometimes formed between a wind slab and the underlying snow. Since the internal cohesion of hoarfrost is very low, this increases the likelihood that the wind slab, lubricated by the hoarfrost, will avalanche after breakage. The avalanche consists of large blocks of wind slab, which may subsequently break up during the fall, and is especially dangerous if the blocks are large. Skiers caught in such avalanches are usually crushed by the blocks.

Detection of Snow Condition

With respect to the methods of determining that avalanche conditions exist, no amount of discussion can replace experience; but the skier can be cautioned to take advantage of certain classes of available information.

The most complete knowledge of snow conditions at a given point can be obtained by cutting a section through the snow from the surface to the ground and examining the texture of the snow in each layer and the firmness of the bond between layers. This method is usually too laborious to be practical, and normally requires the use of a shovel. An approach to such an examination can be obtained, however, by prodding the snow with a pointed stick, such as a ski pole with the basket removed, with a reversed ski pole, or with the heel of a ski. Although this does not permit visual examination, it will indicate any hard crust or probable wind slab below the surface within a depth corresponding to the length of the pole. The skier must remember, however, that ski-pole detection will not go far enough to disclose the most dangerous avalanche hazard—that of several feet of surface snow avalanching on a deeply buried but poorly bonded underlayer.

Frequently it is desirable to know the probable condition of snow at so distant a point that it cannot be directly examined. This, and the condition of underlying snow which cannot be readily examined, is best learned by study of past weather conditions. Records of weather must be used with caution, as local variations due to slope exposure, wind, and altitude, may make notable difference. Weather reports may serve, however, to a limited extent. For example, if temperatures well below freezing are reported to have prevailed prior to and during a snowfall, there will be a greater danger of avalanche following the snowfall than if the temperature is known to have been above freezing prior to and during the first stages of the snowfall, followed by lower temperatures during the balance of the storm. Or, if rain or a heavy thaw were followed by a freeze and then by additional snowfall, an impermeable ice crust would probably have formed, which would provide poor bondage for overlying new snow, and over which water from the thawing snow might collect as a lubricant for a subsequent avalanche.

The skier on one slope may judge the snow on a nearby slope by considering its relative exposure. Thus, if the slope on which he stands is wet from the sun, or is covered with a sun crust due to wet snow being refrozen, he can probably obtain better skiing conditions by crossing to an unexposed north slope, although in this event he must assure himself that the snow there has settled sufficiently to be past a point of danger from new-snow avalanche. Similarly, if the skier knows the direction of the prevailing wind or of the wind which is reported to have existed in the recent past, he can predict where wind crust may have formed and where drifts are likely to be found. He can judge of the probability of wind slab or wind crust if he knows the humidity of the wind which took place.

A thermometer and to a slightly lesser extent a hygrometer can be of considerable value in determining the changes which are likely to be taking place in snow condition. An experienced mountaineer can determine temperature and humidity fairly well, however, by "feel" and by telltale signs.

Summary of Avalanche Causes

An avalanche occurs whenever the pull of gravity on a snow mass is sufficient to overcome anchorage or internal cohesion. To determine the probability of an avalanche on any suspected slope the skier should consider the following factors:

1) Steepness of slope.
2) Shape of slope.
3) Anchorage to ground surface and bond between snow layers.
4) Possible existence of a buried snow slab.
5) Internal cohesion of visible *and buried* snow layers.
6) Recent weather as affecting the last three factors.
7) Evidence of prior avalanches.
8) Depth of snow.

Precautions in Avalanche Territory

Safest part of slope.—Careful study of dangerous slopes should always be made, if possible, in conjunction with others. The party should give thought to the time of day and its probable effect upon the chances of an avalanche. It will always be preferable to avoid any slopes which appear to be in danger of avalanche. This is not always possible, however, and some consideration must be given to the least dangerous method of traversing dangerous slopes. In general, a dangerous slope should be crossed as near the top as possible. An exception to this rule, however, must be made when the slope is considerably concave, so that the upper portion is steepest. An exception should also be made when the slope is surmounted by a cornice, since there is the double danger that the cornice may fall, thus starting an avalanche, and that a deeply drifted snow cushion may exist just below the cornice.

The advantage of crossing high is that the skier will then be above most of the sliding mass of snow if an avalanche does occur, and he is therefore less likely to be dragged down by the avalanche or buried in it if he should be carried down. It is usually much safer to travel along ridges than in gullies, a flat-topped ridge being ideal. The skier should, of course, be sure that what looks like a flat ridge top is not an overhanging cornice.

The skier should be careful to observe and consider not only the snow on which he is skiing, but also the snow above and below him, since an avalanche falling from below may undermine the snow on which he is skiing, and an avalanche starting above him may sweep across his path. The bottom of a narrow valley is dangerous if either slope is in danger of avalanche.

Precautions when danger exists.—Having selected the safest place to travel, if danger still exists, the following additional precautions should be taken:

1) The members of the party should travel at a sufficient distance apart, so that an avalanche would carry away only one of the party, leaving the others available for search. This frequently means a spacing between members of not merely a few yards, but of one or two hundred yards or more. Occasionally this rule of separation may have to be abandoned when visibility is poor, owing to the danger, possibly greater, that some of the men may lose the route.

2) In getting off a dangerous slope, it is safer to go either straight up or straight down than to go across, since a vertical track does not cut the slope and reduce the snow bondage so much. It is usually wisest to travel on foot if possible. If it is necessary to go up with skis on, climbing skins should preferably be used, and in traveling straight down, it may be well to remove the skis unless the skier can take the steep course without danger of a fall.

3) Any necessary steps should be taken to permit quick removal of skis, poles, and pack, for reasons which will be explained later. This may necessitate loosening any ski bindings which cannot be removed by the flip of a single catch. Pole straps should be removed from the wrists and the belly strap on the pack unhitched.

4) If there is danger of avalanche from above, it is desirable to have one member of the party watch the dangerous slope while the lower slope is being crossed by the other members, one by one, in order that the watching member can give immediate warning if an avalanche starts.

5) The probability of being found when caught in an

avalanche is greatly increased if each individual attaches to himself a 3/16-inch colored cord 30 yards or more in length. This is a greater precaution than the average person wishes to take, but it is of marked value in searching for victims. A somewhat shorter cord of approximately this diameter should normally be carried anyway, for use in making rescue toboggans and for other emergencies.

6) Occasionally a rope may be used in crossing a narrow gully or small wind slab. One member of the party crosses the dangerous portion while holding on to a rope which is being anchored by another member of the party who is on safe snow. Dangerous slopes should never be crossed, however, by skiers tied together by a rope, since they will become badly entangled if an ava lanche occurs.

7) If the danger is from a light powder-snow ava lanche, it is desirable to cover the mouth and nose with a cloth to avoid suffocation from the snow cloud which always accompanies such an avalanche.

8) It is important that mittens be worn in order to avoid frozen hands in the event of an avalanche.

9) Silence should be maintained in order to hear warning shouts or the first sounds of an avalanche.

10) Before crossing a dangerous slope, the leader of the party should make certain that all members under stand how to conduct themselves during an avalanche.

Conduct During an Avalanche

When actually caught in an avalanche, it is vitally important that one avoid becoming buried. This can best be done by lying on the back (or stomach according to some authorities) with feet downhill and by maintaining a powerful swimming motion, being careful to keep the feet high, to avoid being tripped and rolled over head foremost. To accomplish this, it is obvious that one must have first removed his skis, poles, and pack before becoming caught in the full sweep of the avalanche. The importance of removing this equipment cannot be overemphasized.

In a wet-snow avalanche, it is particularly important to exert every ounce of strength to get one's head above the snow, or failing this, to obtain a space around one's head and chest as the avalanche comes to rest. This is because a wet avalanche frequently freezes solid as soon as it stops.

If an avalanche starts above a skier, he may be able to ski away from it if it is a wet-snow avalanche which moves slowly, but a wind-slab avalanche or dry-snow avalanche usually travels far too fast for escape by this method, and if such an escape it attempted and fails, the skier is caught with his skis on.

Avalanche Rescue Work

Marking victims' position.—If one or more members of a party are caught in an avalanche, other members in safe positions should carefully observe the path of those being swept away, in order to ascertain where they may be found when the avalanche comes to rest. Then, unless there is extreme danger that the undermining effect of the first avalanche will cause another, the members who best observed the probable position of the victims should remain in place to direct others, who should place markers at the position.

Probing for victims.—The party must then immediately probe the snow where the victims are thought to be. This should not be done in a haphazard fashion, but should be well organized under a leader. The area to be probed should be carefully but quickly laid out and the probing done systematically to cover each square foot of snow surface. Long poles are best for this purpose, but it is frequently necessary to use ski poles with the baskets removed, or reversed with the wrist-straps removed; or skis may be used. If the victims are not located in the anticipated position, the same systematic search should be extended, either moving from the initial point outward in all directions or starting from the top or bottom of the avalanche tip—whichever seems most likely to succeed quickly.

The searchers can usually best be arranged in a line, about 3 or 4 feet apart. This line is moved slowly forward, keeping in perfect alignment, with each member sounding with his pole or ski from left to right, making his soundings one foot apart in each direction. If the avalanche is quite deep and the victims are not found by this method, it is necessary to dig trenches about 9 feet apart, which permit probing horizontally through from one trench to the next.

If there are a large number of survivors, it may be desirable to send one or two for additional help, but if the number of survivors is small and help is some distance away, they should search for at least an hour before going for assistance. The site of an accident should never be left without first carefully marking the place with markers that will not be obliterated by a storm.

Victims will rarely survive very long in a wet-snow avalanche, and may have been crushed immediately by large blocks in a wind-slab avalanche; however, men have been known to survive for days when buried in light dry snow.

11. Compass and Map

MANY ARE the tales of successful escape from disaster by storm, made possible by reliance upon a so-called sense of direction, or upon the legend that moss always grows on the north side of trees. The skier, however, should bear in mind that there are perhaps many more tales of failure to escape disaster which never have been told, and, indeed, never can be. Bearing this in mind, he should acquire an adequate knowledge of the proper use of compass and map, and rely on this knowledge—and not on superstition—when he is required to travel with visibility poor or in country that is new.

Magnetic declination.—The angle between the direction in which the compass needle points and true geographic north is known as the magnetic declination. The needle is aligned with the strongest lines of magnetic force affecting it. In the absence of such magnetized objects as a knife, ice ax, steel pole, or local beds of magnetic ore, the needle will always point approximately toward the north magnetic pole of the earth. This is on Boothia Peninsula, about 1300 miles south of the geographic north pole. Consequently, at about Cincinnati, magnetic north and true north will be in line. East of Cincinnati the compass needle will point west of true north; west of Cincinnati it will point east. A clear understanding of this will show how declination varies, and why one cannot rely upon declination marked upon a compass, which may be made in France but used in British Columbia.

Conversion of compass readings.—The amount and direction of declination is nearly always shown on better maps. To obtain a true map reading where there is an east declination, *add* the amount of the declination to

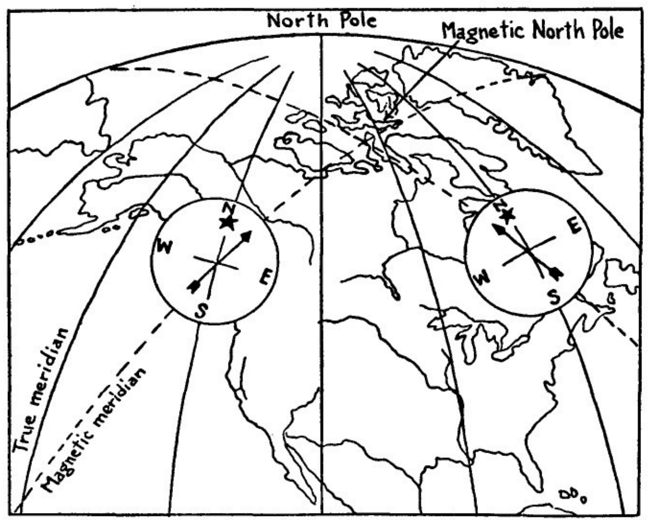


Fig. 9. Relation of magnetic north to true north (simplified).

the compass reading; in localities having west declination, *subtract* the amount. In the field it is usually simplest to use magnetic bearings throughout, since no conversion is then necessary.

If the magnetic declination is not known, it can be determined as accurately as the compass will read by taking a bearing on Polaris, the North Star.

Determination of compass bearings.—A compass bearing is simply the angle between the direction of an object and that of magnetic or true north or south. By determining on the map the bearings of several points of a chosen route, the skier may plot his course of travel. To facilitate accurate readings, north, east, south, and west should be marked on the compass case so that the pivot of the needle can be placed accurately over a particular point on the map. With the compass centered over the point on the map from which the bearing is to be taken, and with the map oriented, the bearing can be read directly from the compass by use of a line from the center of the compass to the object whose bearing is desired. The reading where the line crosses the divisions of the compass is the bearing.

Compasses are marked according to two major systems. Easiest to use, and standard with the United States armed forces, is the azimuth system, by which bearings are specified in degrees up to a circle of 360°, in a direction clockwise from north. Compasses graduated on that system usually have the case marked counterclockwise, so that if the north—south line of the case is directed toward the object, the north end of the needle will read directly in degrees of azimuth. Thus a northwest bearing would be given as 315°.

Most civilian surveying in the United States is based upon four segments of the circle, graduated respectively from north and south 90° in each direction to east and west; a northwest bearing is given as north 45° west.

Plotting of compass bearings.—This is merely the reverse of determining the bearings from a map. With a compass centered over the point on the map from which the bearing was taken, and with the map properly oriented, a line can be projected through the graduation on the compass which corresponds to the bearing. The point to which the bearing is taken will be on that line if the reading and plotting are accurate. If one is using his own bearings, it will be simpler to keep them all magnetic to avoid conversion errors.

Use of a compass in storm.—A storm provides the vital justification for carrying a compass at all times in ski mountaineering, for visibility in storm is greatly reduced. One *must* rely upon the accuracy of the compass, taking care to eliminate local magnetic influence. If such influence is suspected, several readings on a distant object should be taken on a straight course at intervals of about 400 yards. If uniform, the readings will eliminate the possibility of local attraction. One's sense of direction may, under stress, sometimes be completely off—as much as 180°. To avoid this, mark the compass case to show which end of the needle is north.

A storm may require a party to retreat in poor visibility, so it may be well to record distances traveled in each direction as well as compass bearings of prominent landmarks along the route. Then, knowing the bearing, locate a landmark as far away as visibility will permit, and proceed toward that landmark for the distance required. If the chosen landmark is likely to be obscured for any reason, an intermediate landmark should be chosen on the same line before the distant one is lost.

Visibility may be so poor that no landmarks are seen. The last man in the party should then direct the travel by compass, sighting ahead on the other two men and thus maintaining a straight line. In turning to pass such an obstacle as a cliff or open stream, one can return to the original line by carefully recording the new angle of direction and the distance traveled. Easiest to use is a series of right angles. A shorter but slightly less accurate method is to diverge from the original course at a diagonal to clear the obstacle, returning to the course by the same angle on the opposite side of the obstacle and with the same number of paces (see fig. 10).

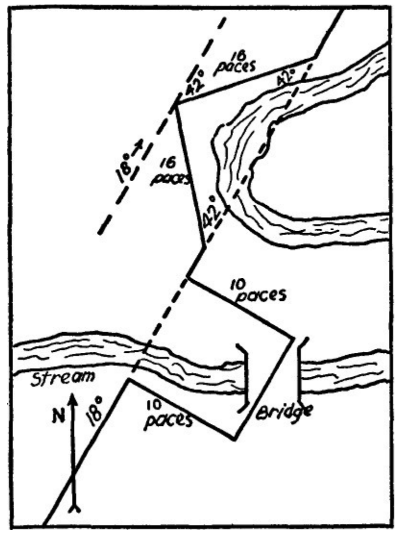


Fig. 10. Two methods of maintaining a compass course around obstacles.

Orienting the map.—The compass is necessary if landmarks cannot be identified. Keeping the north—south line of the compass case parallel to any north-south grid on the map, rotate the map and compass until the north end of the compass needle coincides with the local declination. All directions on the map will then coincide with those on the ground.

A map is most satisfactorily oriented by use of a known location on the map and a known landmark. Placing matches or pine needles vertically on the map at the location and landmark, rotate the map until the matches align with the known landmark. The map is thus oriented, more accurately than by compass.

A map may be oriented with three known landmarks, but with one's own location unknown. Place a match near the center of a thin sheet of paper and sight across it to another match which is lined up with one of the known landmarks. Draw a line on the paper in that direction. Without moving the paper, sight across the center match to the other landmarks and draw similar lines. The landmarks should be as diverse as possible. Placing this sheet over the unoriented map, move it to a position in which all three lines will, on the map, pass through the three known landmarks. The center point from which the lines were drawn will then be the position of the observer, and the map can be oriented with any one of the three landmarks.

A rough way to determine south and thus orient the map is by use of a watch and the sun. If the hour hand is pointed directly toward the sun, a line drawn halfway between the hour hand and 12 will point approximately south. This method, while not accurate, may be much better than nothing at all. Use local standard time.

Determining one's unknown position.—This is possibly the most valuable use of a map in emergency. Every effort should of course be made to keep so well acquainted with the map and country that one's position will always be known. Nevertheless, prolonged travel under restricted visibility may bring one to a position which cannot be determined by simply glancing at the map. If landmarks shown on the map can be recognized in the distance, choose two whose direction is separated approximately by a right angle (for greater accuracy). Orient the map by compass, place a match vertically on the map above the position of one of the known landmarks, move another match along the near edge of the map until it aligns with the landmark, and draw a light line between the two vertical matches. Then repeat the

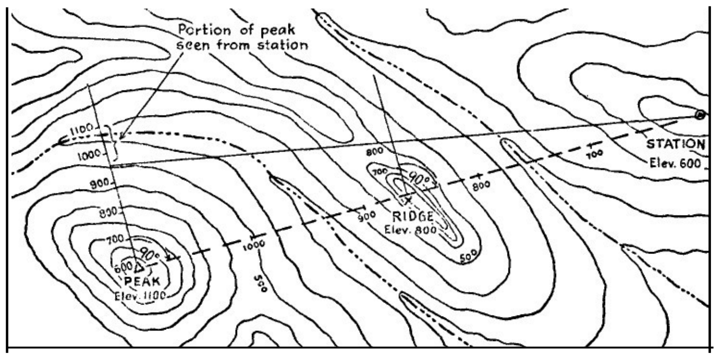


Fig. 11. Method of determining intervisibility.

process for the other known landmark. The intersection of the two lines thus obtained will be near your position. A more precise determination can then be made by sighting on additional known landmarks.

If a compass is not available, one's position can be determined by sighting three known landmarks.

To identify unknown landmarks reverse the procedure for identifying position. With only one line of sight, the exact position of the landmark can only be determined if one has enough knowledge of the country and of maps to know how distant the feature is, its shape, and its position with reference to intervening ridges.

Determining intervisibility.—Experience in reading topographic maps can usually show approximately whether any two points should be intervisible. This may be checked by a procedure such as follows:

Draw a dotted line between the observation station and the peak whose visibility is to be tested and determine their difference in elevation. Draw a line from the higher point at right angles to the dotted line, and, if the difference in elevation is, for example, 500 feet, mark five equal divisions on the right-angle line. Checking along the dotted line, draw a second right-angle line to represent the ridge that might obstruct the view. Using the same divisions as before, mark on this second line the difference in elevation between the station and the ridge. A line drawn from the "summits" of the right-angle lines representing the station and obstruction is then extended as far as the peak. If the peak line is high enough to rise above the extended line, the peak can then be seen from the observation station.

An easy variation is to substitute for the dotted line a rubber band upon which the equal divisions of the difference in altitude have been marked. By stretching the rubber band between the station and the peak, one can easily determine whether the elevation of any intervening obstruction is higher or lower than the elevation division marked on the rubber band at that point.

If a distance of more than a few miles exists between the station and the peak, allowance must be made for curvature of the earth and refraction of light by the atmosphere.

Contour topography.—The most accurate method of representing land forms upon a map is provided by contour topography, the method used throughout the United States in maps of the Geological Survey. On the back of most of these maps is an excellent diagram showing a landscape in relief drawing and in contour topography.

A contour is a line every point of which is at the same elevation. The shore line at mean low tide is the zero contour for all United States surveys and maps. If the coast has a ten-foot tide, the water will follow up each inlet and cross each beach to establish, in effect, a new contour line, ten feet higher. Ten feet would then be the contour interval. The interval between contours usually varies according to the scale of the map and roughness of the country, but is uniform throughout a particular map.

In land forms resulting from water erosion, contours along stream channels are normally V-shaped, the V pointing upstream; shoulders and ridges are usually U-shaped, the U pointing downhill. An understanding of the main drainage system will make it easier to understand the relation of ridges and minor valleys and gullies to the main canyons and mountain systems.

A contour line cannot end except on itself (or at the edge of the map). If it ends on itself, it will form a closed circuit which usually indicates a peak or ridge crest, the interior portion of the circuit being higher than any portion along its edges. Such contours may also show a depression. For that use, they are usually marked with short, right-angle lines inside the closed circuit. In desert regions, depressions may be on such a vast scale that such a method of marking is not practical. They may then be recognized by the form of the rest of the topography and a careful check to determine which contours are higher than others.

Contours are close together when the land surface is steep, far apart when it is gradual. A vertical cliff is indicated by many contours converging to form a single line. Contours cross only when they represent an overhanging cliff. It is rare to find maps which are of such scale and accuracy that they will show the fine detail of an overhang.

Adequate knowledge of contour topography is difficult to obtain from any manual. It is suggested that the skier first become familiar with the United States Geological Survey map of his home locality or usual skiing area. Recommended for further study are: Yosemite Valley Special Sheet (for detail of cliff sculpture), Mount Rainer National Park (for glaciers), and the Wabuska or Carson Sink sheets of Nevada (for desert forms).

The map and the ski tour.—A skier makes good use of his ability to visualize terrain by reading a good topographic map, correlating this information with his knowledge of the region and basic ski-mountaineering requirements. The slope can be determined roughly by the spacing of the contours. The height of the slope can be told at a glance. The experienced map reader will recognize which slopes are so long and of such high angle that they will be especially subject to avalanches. The exposure of the slope, readily seen on the map, will suggest what will be the effect of sun upon the snow. The skier may thus be able to plan his trip on north slopes to take advantage of powder snow; in spring he may choose north slopes at certain times of day to take advantage of frozen crust, or south slopes to avoid it. Angle and direction of slope may determine wind exposure, to be avoided in storm, or sought on a hot day. The map will suggest where cornices are formed, and where wind-slab avalanches are most likely; it may tell, indirectly, where a timberline camp may be made, which slopes will be open, which heavily forested. The campsite can be chosen with regard to distance that the party will best travel in a day over the terrain as disclosed by study of the map. Choice of campsite may be affected by the availability of "liquid" water to save fuel in cooking. Sites near lakes and streams, which may be open in part, will be selected. The map may show which campsite should have reasonable protection against storm and freedom from the avalanche hazard which would exist at the base of long, high slopes or steep chutes.

Nor should the skier overlook the pure enjoyment a thorough knowledge of his maps can give him, either while he plans and anticipates his trip, or, after it is over, when he traces the trails over which his skis have taken him.

12. First Aid

THE SKI MOUNTAINEER, when called upon for help in case of accident, must often give more than first aid, for he may be far from organized medical assistance. In addition to a thorough knowledge of first aid he should therefore be familiar with a few of the simpler medical procedures—so-called "second" aid. For the usual first-aid work, publications of the American Red Cross should be carefully studied. This chapter will go a bit beyond first aid, but the procedures should be within the ability of ski mountaineers well-trained in first aid.

Not fewer than three persons, preferably four, should undertake any ski-mountaineering trip. If, in a party of four, one member is injured, a second member stays with him while the other two proceed for help. The injured man should never be left alone, and only in dire emergency should anyone ski alone.

Shock.—When any but a minor accident happens, shock develops, more severely in ski accidents than usual because of the ever-present cold. The injured man should be laid down, head lower than feet, and should be kept as warm as possible, special care being taken to see that there is abundant insulating material between him and the snow. Extra clothing will serve, supplemented by branches, pack, tent, or air mattress. As every first aider knows, the victim must be moved little, and then only with caution, so that he will not be injured further.

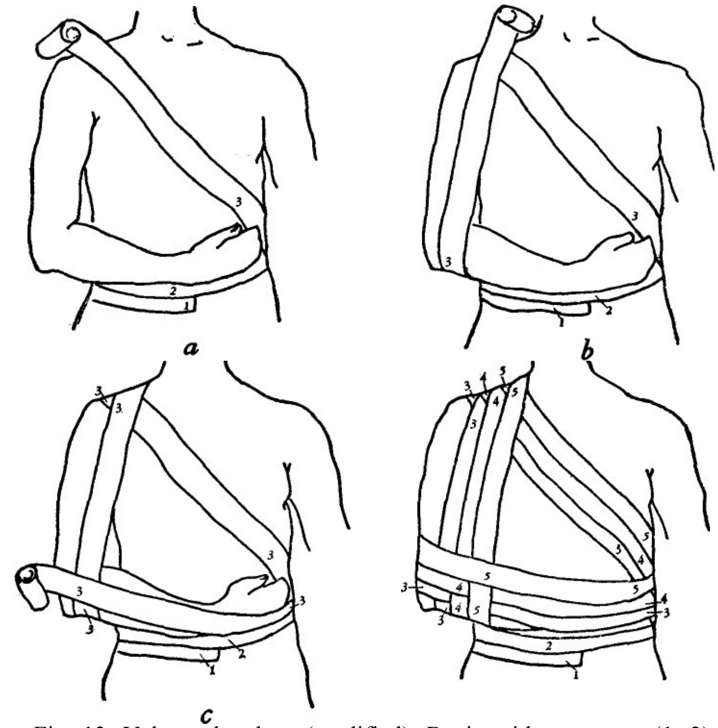


Fig. 12. Velpeau bandage (modified). Begin with two turns (1, 2) around waist, rolling toward affected side; bring third turn upward across chest, down behind shoulder and arm, upward over shoulder, across the back, and horizontally across forearm (3). More turns can be applied (4, 5), depending on desired stability of arm and length of bandage roll.

Heat should be applied. This may require that one member of the party build a fire or start a stove and heat water, coffee, or tea; hot-water bottles may be improvised from canteens or extra fuel cans. Avoid overheating the patient until he perspires. Although such a condition can hardly be attained outside in the snow, room temperature, blankets, and hot-water bottles may cause the patient to perspire after he has been brought indoors. He is then subject to being chilled later; moreover, the blood is brought to the skin and thereby is lost to the general circulation and to more important organs, where it is badly needed.

To minimize shock, pain must be relieved. Capsules of codeine sulfate, 1 grain, and aspirin, 5 grains (obtained on prescription), will help relieve pain, and should be carried by all ski mountaineers. Aspirin may cause perspiration and should be used with caution, not more often than once every four to six hours. It is hoped that the morphine syrettes used extensively by the armed forces, or an equivalent product, will be available on prescription. The morphine solution is injected under the skin and is used when pain is severe, as in fractures; it should not be given more often than once every four hours.

When a serious accident occurs on a trip, make camp at the spot immediately. Pitch the tent, get the victim into a sleeping bag, start the stove, and perform the necessary treatment.

Hot tea, coffee, or chocolate is helpful when the patient is able to take and retain it; but *avoid too much fluid,* for it is then sometimes necessary for the patient, soon afterward, to empty his bladder—an extremely difficult feat if he is supine, and especially if he has a traction splint on his leg.

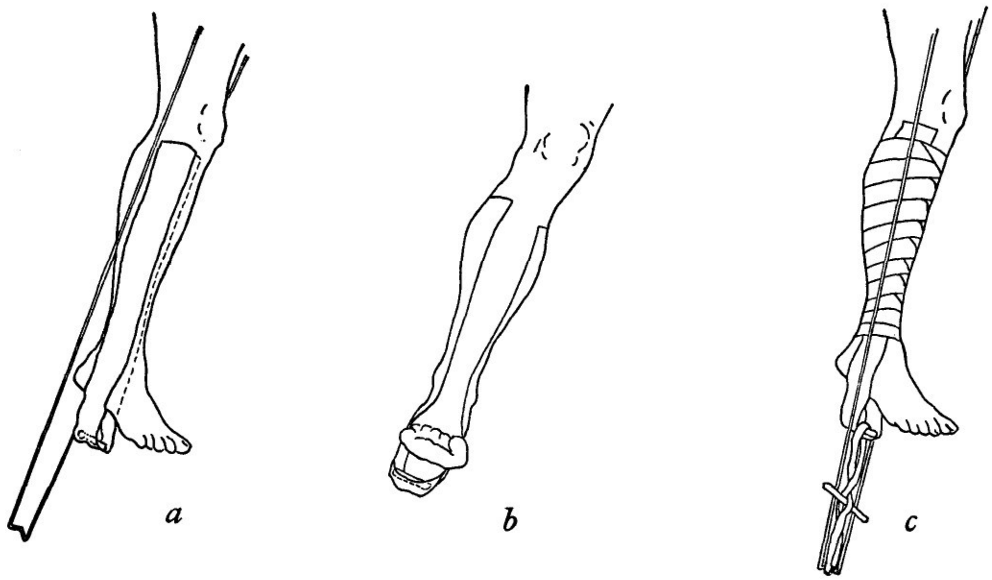


Fig. 13. Adhesive traction for fractured leg or thigh. Three-inch adhesive tape is applied along side of leg, beginning just below knee. Tape is extended three inches below sole of foot and is brought back up other side of leg the same distance. A spreader is put across the stirrup. Adhesive is then anchored by a spiral reverse from ankle to knee. Traction is applied by the usual windlass **be**tween stirrup and end of leg splint.

Fractures.—Fractures of the extremities must be immobilized with splints. Traction splints are absolutely necessary for thigh fractures and are preferable for lower leg and ankle fractures. The Velpeau bandage (fig. 12) is considered preferable for upper arm and shoulder immobilization and padded board splints for forearm fractures. Such splints may be used for lower leg and arm fractures if it is more convenient to do so. It is better to use a good padded wooden splint than to use a poorly improvised traction splint. In using any splint — especially the traction type—care must be taken not to restrict the blood supply and thus increase the susceptibility of frostbite. When applying a traction splint, leave boot and sock on; loosen the laces and straps. If the socks are wet, however, a change to dry must be made first. The entire body of the patient—including his injured arm or leg—must be kept warm. For other details of splinting, see the Red Cross publications.

In transporting an injured man who is wearing a traction splint, continually check the injured extremity to see that it does not become cold. If it should, traction must be released gently and the extremity warmed until the danger of frostbite is over; the traction may then be reapplied.

If it becomes apparent that the time between injury and admission to a hospital will be more than eight hours, some means of obtaining traction on the leg must be resorted to other than the hitch over the ski boot, for long-continued traction will cause severe damage to the tissues and circulation of the foot. To prevent this, adhesive-tape traction is applied (fig. 13). After the shoe and sock are removed, the leg shaved (if possible), dried, and warmed, a strip of 3-inch tape is started just below the knee on one side and continued down the side of the

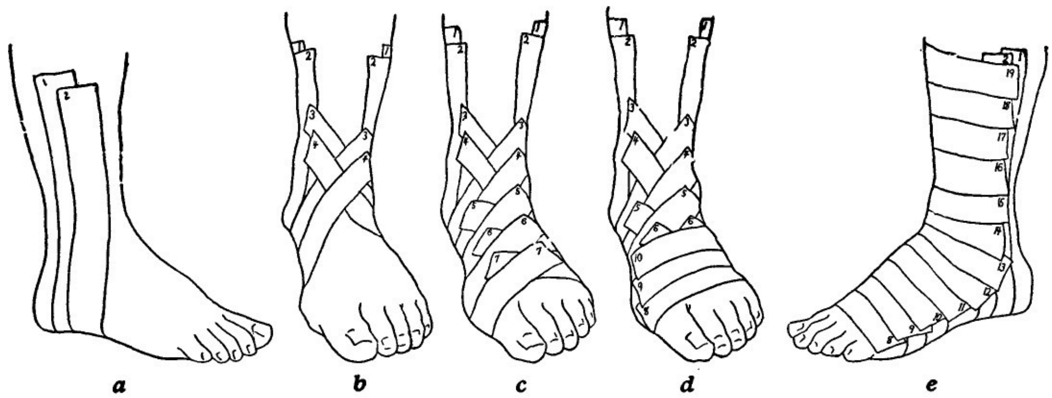


Fig. 14. Taping an ankle (see text), *(a)* Two adhesive stirrups are applied, extending one-third the way up each side of the lower leg. *(b)* Stirrup-like strips are continued forward down the foot, crossing over ankle and instep, (c) Strips are continued down to the base of the toes on the sole, *(d)* Layer of strips is applied over the top of the foot, starting at the base of the toes, crossing from side to side, (e) The strips are continued up the foot, ankle, and leg to the top of the first two stirrups.

leg below the sole of the foot by 3 inches, and in stirrup fashion around the foot and up the other side of the leg to the starting level. The adhesive strip is anchored by a spiral reverse bandage from ankle to knee. A spreader must be put in the stirrup below the sole to prevent constriction of the foot.

Compound fractures.—If possible, carefully wash the wound with soap and water; at least two quarts of clean water, to which two level teaspoons of ordinary salt per quart have been added, should be poured onto any exposed bone and into the wound. Dirt from the outside must never be washed into the wound. The skin around the wound, but not the wound and bone, should be painted with a skin antiseptic (e.g., 2 per cent tincture of iodine or the commercially prepared mercurial antiseptics in alcoholic tinctures. These freeze at about —37° F). If there is going to be a delay of more than twelve hours in getting to medical care, the use of broad spectrum antibiotic is advisable. Ask your physician what you should take. The wound should finally be covered with sterile gauze, bandaged, and traction applied.

Injuries to joints.—It is often not possible to distinguish a sprained from a fractured joint without X-ray examination. It is only permissible to tape a joint and to allow further skiing when the injury appears so slight that the additional support of tape would allow the skier to travel without undue discomfort. If there is any question about the severity of the injury, the skier should be transported on a toboggan or ski sled. With *all* joint injuries, a doctor should be consulted as soon as possible to avert any permanent disability which might otherwise result.

The accompanying drawing (fig. 14) illustrates the taping of the ankle. Recommended tape width is 11/2 inches. Note that in taping an ankle the tape is extended on the foot to the base of the toes, both on the sole and top, to prevent swelling of the foot and cutting of the sole by the tape.

Dislocations should be considered fractures until proved otherwise; splint the same as simple fractures.

If a shoulder is dislocated by a victim who knows the injury is recurrent, the dislocation may be reduced as follows: place the injured man in a horizontal position on a ledge so that his arm can hang down and free below him. Tie a weight of about ten pounds to the arm. In 30—45 minutes the shoulder muscles should tire enough to permit the dislocation to reduce itself. If not, treat as a simple fracture and seek medical aid as soon as possible. A Velpeau bandage is recommended to immobilize a dislocation of the shoulder.

Lacerations.—Lacerations that occur in skiing are rarely severe enough to need a tourniquet, and only as a last resort should one be applied, inasmuch as frostbite may develop quickly when the blood supply is shut off. All effort should be directed to stopping the flow of blood by pressure of a compress over the wound. This can almost always be done. Then sterilize the skin with the skin antiseptic; apply sterile compress and take the injured person to medical aid. If medical aid is not available within six hours, the following procedure should be performed: Wash out the wound with clean salt solution (see p. 135). Apply skin antiseptic to the skin only; if laceration is large, antibiotic capsules are recommended (see *Compound fractures).* Press the skin edges together and fasten as adequately as possible with adhesive "butterflies" (see fig. 15); apply sterile gauze dressing and bandage firmly but not too tightly.

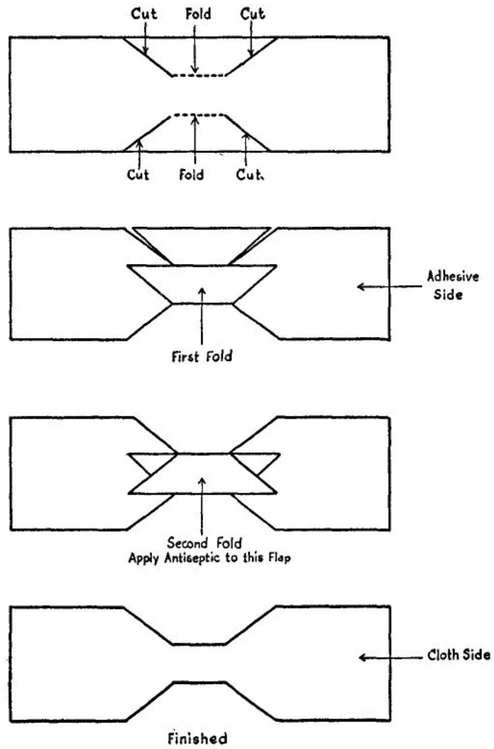


Fig. 15. The butterfly bandage with
11/2-inch adhesive tape.

In working on any open wound, the worker's nose and mouth should be covered, because on a ski trip more harmful bacteria enter the wound from these sources than from any other. A bandanna will serve as a cover, used as a highwayman would use it.

Treatment of lacerations and compound fractures as outlined here does not replace proper surgical care. But the ski first-aider *can* delay or prevent infection by proper use of procedures described above.

Frostbite (freezing).—Frostbite is usually of quick onset. The sensation of cold dies away and all sensation in the affected part is lost. At this stage the skin is white; the part becomes stiff. Three possible results of frostbite are:

1) Complete recovery.

2) Apparent complete recovery, but with loss of sensation, especially to temperature, in the affected parts and the predisposition of these parts to be more readily frozen. Neuralgic pains occur, especially in affected joints of the fingers and toes. Use of these joints is very painful.

3) Gangrene, with the gradually developing line of •demarcation of normal and gangrenous tissues; these gradually separate from the body, but may be held by bone.

Causes: The essential change that occurs in frostbite is damage to the blood vessels, causing hemorrhage and liberation of plasma from the blood into the tissue. This causes swelling and blisters.

At high altitudes less oxygen reaches the tissues, and the warming effect of oxygen is reduced, thereby predisposing the tissue to frostbite. Undernutrition, physical exhaustion, general illness, especially heart trouble, diabetes, and diseases of the blood vessels in the arms and legs—these are other recognized predisposing causes. Previous attacks increase the susceptibility.

The general condition of the individual as well as his protection at the time of exposure also determines the degree of tissue damage. As the circulating blood is the primary heating system in the body, any decrease in this volume which might occur at high altitude, where severe dehydration exists, would accentuate the process. It is sometimes difficult to tell how much tissue is affected. Dead tissue may merely appear slightly discolored and have a feeling of warmth imparted to it from the adjacent normal tissue. This is misleading, as one is sometimes overly optimistic about the damage only to observe later that the gangrene has extended.

Treatment: Of course the best treatment is prevention with adequate clothing, gloves, boots, oxygenation, food, fluid intake, and minimizing of fatigue and perspiration. Military experiences in the Korean War and research have resulted in the modern concept of rapid thawing of frozen tissue and abstinence from incurring further tissue injury by brisk rubbing or prolonging the thawing process. Large damaging crystals are prevented from forming in the tissues by rapid thawing, and a marked vaso-dilatation in the extremity is demonstrated proximal to the injury. This method is carried out by immersing the affected area in a water bath of 45 degrees Centigrade, or 115 degrees Fahrenheit. This procedure can usually be performed without difficulty at a high camp with the available equipment of cooking pots and Primus stoves. It should be done promptly.

The treatment may be painful, but pain can be controlled with narcotics. Following this, sterile moderate-compression dressings should be applied to control the edema before it develops. Some authorities advise no dressings. However, some form of sterile protection should be afforded while the patient is being transported. Antibiotics are begun immediately, and the patient should not be allowed to walk if a foot is involved. Certain circumstances may make it expedient for a climber to descend under his own power to a more appropriate camp with feet still frozen rather than to attempt to thaw them on the trail, thereby becoming totally a litter case. Less damage comes from walking on the feet or toes that are frozen than walking on them after they have thawed.

Additional methods of treatment, such as dilatation of blood vessels by oral medication of nerve (sympathetic ganglion) blocks and the use of anticoagulants, have not proved especially valuable. The gangrenous area will become fully demarcated after about a month, and no attempt at amputation should be performed earlier.

In summary, frostbite is better prevented by proper clothing and footwear and by adequate food and liquid intake. Should it occur, turn back early before extensive damage results. Treatment should be instituted in an appropriate camp rather than on the trail and should include rapid thawing; the gentle handling and cleansing of tissues to prevent further damage and infection; the prophylactic use of antibiotics; and general supportive measures determined by the patient's condition, shock, and other injuries. Walking on thawed frostbitten feet and premature "surgery" must be avoided. If nothing can be done, at least protect the part from further cold and allow it to thaw slowly by itself.

Snow blindness.—The temporary diminution or loss of sight of varying degree, occurring when unprotected eyes are subjected to the intense light reflected from the snow, is known as snow blindness. It may occur on cloudy days as well as clear, and is particularly apt to occur on brilliant days in the spring, when the sun is high and the days are long. More harmful rays exist at high altitudes because there is less in the air to absorb them.

The action of reflected light from the snow is threefold. Ultraviolet light causes "sunburn" of the conjunctiva and cornea. The dazzling visual rays cause squinting and, finally, spasm of the muscles surrounding the eye. The infrared rays may coagulate the protein of the structure of the eye. The effect of light on the eye is cumulative to the extent that many short, repeated exposures in one day are about as damaging as one longer continuous exposure.

The onset of snow blindness may be immediate or delayed as much as twelve hours, and the condition may last several days. The symptoms are burning or smarting of the eyelids, sometimes a sensation akin to sand in the eyes, spasm in the muscles surrounding the eye, pain in the eyes or forehead, sensitivity to light, and profuse watering of the eye. Sight may be unaffected or definitely increased. The affliction is usually temporary, although for some time afterward there may be pain in the eyeball, "weak eyes," or headache.

To prevent snow blindness proper dark glasses must be worn, such as Calobar, Rayban, or Fieuzal. They absorb ultraviolet rays, some infrared, and diminish the intensity of the reflected light so that it ceases to be dazzling. Spare glasses should be carried. Should a skier lose or break his, he may protect his eyes by improvising shields with the use of adhesive tape. A horizontal slit not wider than 1/8 inch is made by stretching strips of adhesive tape across the eyeglass frames or improvised frames. A refinement of a crossed slit helps the skier to look up and down as well. He may help protect his eyes by keeping them nearly closed or not looking at bright surfaces.

A blue sky, trees, his own shadow or companions, will tend to alleviate the dazzling glare. Optical quality in dark glasses is needed to prevent eyestrain.

First aid consists of relieving the local irritation and spasm. This may be accomplished by cold compresses over the closed lids for 15-20 minutes at a time. Instillations of bland oils, such as castor oil and mineral oil, are good first-aid measures. Irrigations of boric or salt solutions several times daily also give relief. Local anesthetics may be used if pain is severe. Ophthalmic pontocaine (1/2 per cent in ointment form) is recommended. Others which may be substituted are 2 per cent butyn, 4 per cent metacaine, or 2 per cent holocaine. These may be used in either solution or ointment. Too frequent use of these drugs is to be avoided; one or two applications a day should be sufficient. Patients should be cautioned against rubbing the eyes when anesthetic agents are used. Dark glasses are indispensable for relief of the sensitivity to light. Several pairs may be worn if one is not enough.

If pain is severe and not relieved by the use of local anesthetics, aspirin, or even the codeine compound referred to under *Shock,* should be used.

Though the above-named methods may prove beneficial the most dramatic relief is obtained with the use of one of the many ophthalmic Cortisone preparations. As this steroid hormone inhibits inflammatory processes and fibrous tissue proliferation, it is a logical choice in such a condition where the main pathological reaction is inflammation of the cornea from a photochemical burn. With one or two applications of the ointment placed on the retracted lower eyelid, the symptoms are dramatically relieved in eight to ten hours. Though snow blindness is not seen frequently, when it does occur it can be totally disabling, and this method of treatment is excellent. Of course, adequate eye protection from the glare is of utmost importance and should be provided for all directions around the eye.

General Considerations: Though knowledge of the foregoing First and Second Aid measures have pertained particularly to injuries, there are other misfortunes that may be encountered. Such may be a severe respiratory infection or pneumonia or a heart failure or to a lesser degree a heart strain.

In recent years a condition called *High Altitude Pulmonary Edema* has been described. It is probably a form of heart failure that is brought on by rapid exposure to high altitude and oxygen lack. It is characterized by the rapid onset of extreme fatigue and shortness of breath usually occurring within a day or two after ascending to altitudes above 10,000 feet. Symptoms progress rapidly to include a dry cough and difficulty in sleeping, especially in the flat position. The individual may want to sit up because his breathing becomes noisy and bubbling and his cough productive of frothy sputum. Usually the pulse is rapid, the temperature is normal, and the patient appears acutely ill. The skin color may be pale or have a bluish tinge. In this condition the patient has often been considered to have a pneumonia and the true diagnosis has only recently been recognized.

Treatment must be prompt and the patient gotten to a lower altitude as quickly as possible. Oxygen if available should be given by mask. Antibiotics are indicated as the diagnosis can not readily be distinguished from a pneumonia and secondary infection can be controlled. Other drugs and methods of treatment are best reserved for the discretion of a physician.

In general, mountaineers should be aware of this condition and adequate time should be taken in gradual ascent to allow the process of acclimatization to occur. The possibility of one of these problems occurring depends basically on the general condition of the individual prior to his participation on an outing. Preliminary conditioning should be taken seriously in order to prevent extreme exhaustion which may otherwise occur. Any preliminary respiratory infection should contraindicate participation in any extended mountaineering adventure. Routine physical examinations are advised and in this way serious problems may be avoided. Sufficient rest, even if the common sleeping capsules are needed, and adequate fluids, amounting to at least six pints a day, are two very important measures for good health. Needless to say, for these serious problems prevention is easier than treatment, which for all practical purposes is transportation to medical care.

13. Transportation of the Injured

SKI ACCIDENTS are difficult to deal with because of the cold, the delay in reaching a doctor, and the necessity for transporting the injured over snow. Fortunately, these difficulties can be overcome by the trained ski mountaineer. When the extent of an injury has been determined, shock treated, and any necessary splints placed, then—and only then—the patient is ready for transportation.

Do not underestimate the physical effort required to transport an injured person, no matter what type of rescue sled is used. It is better to make camp and send for help than to start transporting an injured man without adequate manpower. Rescuers and rescued may all be overtaken by fatigue, night, and cold.

The ready-made toboggan.—An eight-foot, flat, wooden, ready-made toboggan is by far the best method of transportation for the injured. Before starting any long haul of an injured man, the party should consider skiing out to get such a toboggan, with a crew of several skiers to handle it.

A sled with runners is drier and warmer than a flat toboggan, but is too high for stability on difficult terrain and is of no use in soft snow. Metal toboggans are too cold unless covered. A rigid toboggan should *never* be used as a splint for a broken pelvis, back, or neck. Such an injury must be splinted with skis (see p. 151).

A rigid toboggan is best for transportation even when separate splints are used, but, because the splints are then independent of the bending of the toboggan, its rigidity is not essential. Severe injuries should, therefore, be transported on a rigid toboggan if possible, but the flexible type is usually quite satisfactory and is much easier to pull over rough terrain. If a long trip must be made over rough ground, guard rails may be constructed by tying the skis of the patient on edge along the toboggan sides.

If an air mattress is available it will add comfort to the toboggan. It should not be inflated too much. Sweaters should be placed on the toboggan before the victim is lifted on so that they will be under as well as over him. In long hauls the injured man should be put in a sleeping bag. Narrow down bags are best and may be put on over splints if first turned inside out and then drawn up over the body from the feet. A wind- and snowproof cover, such as a tent, may be put on last if necessary. The injured man should be tied to the toboggan to save him muscular effort and anxiety and to hold wraps in place, unless the trip is to be short and along the level. The importance of keeping him warm cannot be overemphasized.

The victim should usually be carried in a reclining position, unless the injury is slight. Ordinarily he will wish to have his feet at the front of the toboggan so he can see where he is going. If a leg has been broken, care must be taken that it does not press against the upturned end of the toboggan. If shock is severe, the victim should be placed so that his head will be downhill. Injured limbs must be well supported and must not be subjected to strain from cords used to tie the man to the toboggan, from pulling ropes, or from the weight of heavy covering.

At least eight good skiers are needed to handle the toboggan properly unless the snow is hard and the distance short. In the interests of efficiency, one of them should be designated as leader of the group. Ropes for pulling should be tied to all four corners and an additional line may be rigged to the middle of the front of the toboggan. The corner lines must not be longer than necessary or they will render wood-running very difficult. At least one man should be stationed behind the toboggan as brake and rudder. If the snow is not deep, those doing the pulling should tie their skis to the toboggan and walk on the snow. This is particularly important for the men in the rear. If it is necessary to wear skis, rope or cord may be tied around them to prevent sliding. Plush skins will help.

In crossing roads, rocks, or steep slopes the toboggan may be lifted as a stretcher, six men carrying it so that a slip by one will not be disastrous. Bandannas tied around the shoes may increase traction on icy slopes.

The victim of an accident will thank his rescuers for using the greatest care in pulling the toboggan. They should work smoothly, and unless it is very cold or darkness is coming on there is no need to rush. They should pick their course carefully to avoid bumps, steep slopes, and traverses. They should avoid jerking and should never go fast. Everything that can be done to make the victim comfortable and warm will reduce pain, anxiety, and shock.

Four-ski improvised toboggan.—If a ready-made toboggan is not available, the improvised four-ski toboggan is best. Materials used in its construction are four skis, a pair of ski poles, two braces 18-20 inches long, and 8—10 feet of cord or thongs. The skis are placed side by side on the snow. They must be staggered a little so that the projecting toe irons do not interfere with one another. If one pair of skis used is 3 or 4 inches shorter than the other, and the long and short skis are alternated, the toe irons may be staggered without bringing the ski tips out of line. This will facilitate tying the forward brace in place just behind the upturned points. The tying of this brace is also easier if small holes have been bored through the ski tips. These holes do not weaken or disfigure the skis. If a ski has been broken by the fall causing the injury, it can be repaired with a tip or contraction band and used in the toboggan.

The second brace is placed across the toboggan just ahead of the toe irons and is tied firmly to them. If saplings or squaw wood are not available for braces, a ski pole broken in two at the middle will furnish suitable pieces. The value of a good pair of ski poles is, however, not lowered by an injury to their owner, hence this should be done only as a last resort. If the patient can safely be allowed to sit up, the pack frame of a Bergans-type rucksack may be used for the rear brace. The sack itself serves as a backrest.

Diagonal braces from the ski points on one side of the toboggan to the toe irons on the opposite side are necessary to give rigidity. Ski poles, firmly tied in place, will serve for these braces. Cord will also serve this purpose; rawhide thongs stretch too much. Braces must not project beyond the sides of the toboggan. If all cords are pulled tight, this toboggan will prove to be very strong. If there is a shortage of tie ropes, the toe straps may be used to hold the rear brace in place by passing each toe strap around the brace and one ski. However, if the snow is crusted, it is better to avoid passing cords or straps under the skis, as they would be cut by the ice. In any event straps or cords on the running surface of the skis greatly increase the friction in pulling. The exact relations of skis, braces, and lashings must, of course, be worked out in each toboggan.

The four-ski improvised toboggan is handled, so far as possible, in the manner described for the ready-made toboggan.

Two-ski rescue sled.—The improvised four-ski toboggan has one serious fault. If an accident occurs so far from a ski center that a ready-make toboggan cannot be had, it is usually not possible for an able skier to sacrifice the second pair of skis necessary for its construction. For this reason ski mountaineers should place most emphasis upon the two-ski toboggan. It can be used for any injury, but is most satisfactory for injuries which permit the victim to sit up while being transported.

Two basic types of sled are described, requiring different materials for their construction and serving under different conditions.

The first type of two-ski rescue sled is made of 1 pair of skis, 1 pair of ski poles, 2 braces 18-20 inches long, and cord or thongs—the materials used in the four-ski rescue toboggan, minus a pair of skis. The skis are placed in the snow about 18 inches apart, cross braces are tied ahead of the bindings and behind the ski points, and diagonal braces (ski poles) are tied across the frame from the point of one ski to the binding of the other. It will be noted that the construction of the two-ski rescue sled is the same as that of the four-ski sled, and that they are the same width.

A mattress of sweaters or boughs is more important with the two-ski toboggan. This sled is a little harder to

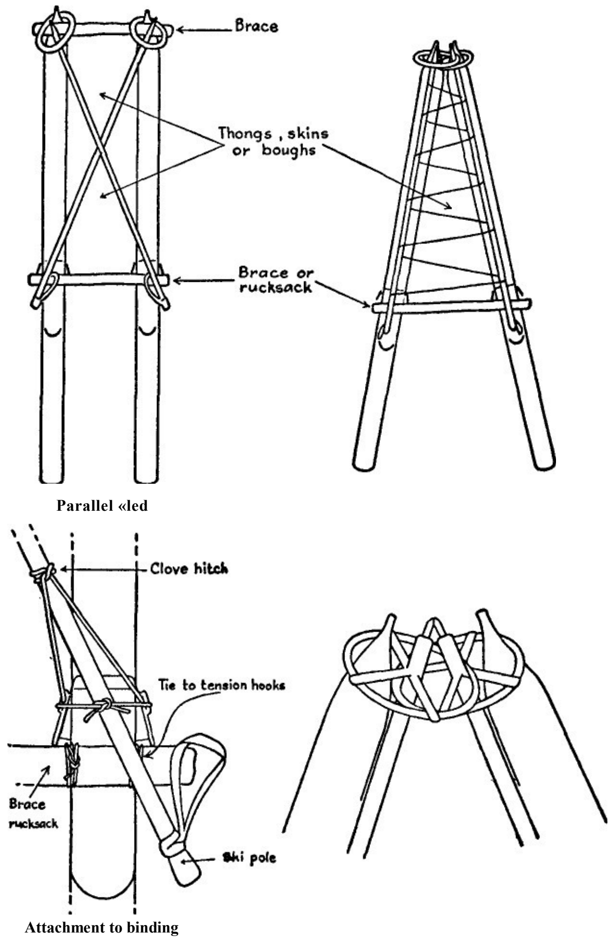


Fig. 16. Parallel and snowplow types of two-ski rescue sleds.

pull than the other toboggans described because it sinks deeper into the snow; however, the method of handling is essentially the same. If soft snow tends to come up between the skis, this can be prevented by running cords, sealskins, or canvas climbers back and forth between the ski poles.

Two-ski sled as a splint.—A frame which is identical to this toboggan, except that skis are placed only 6 inches apart, serves as a splint for a broken back, neck, or pelvis. The victim is tied to the bottoms of the skis—face *down* for a broken *back;* face *up* for a broken *neck* or pelvis—and is transported in those respective positions.

Snowplow sled.—This two-ski rescue sled needs only one brace and fewer cords. No "emergency" equipment at all is needed if the skis, poles, pack frame, and boot laces of the injured man are used in its construction. If no Bergans-type pack frame is available, one wooden brace must be secured. The wedge shape of this sled, however, makes it the hardest type to pull—an asset on steep descents or icy slopes, but a serious drawback elsewhere.

The skis are placed in a snowplow position, points together and bindings 18 inches apart. The handle of one ski pole is run through the basket of the other so that the poles are united at the baskets. The points of the skis are fitted into the webs of the baskets and one pole is placed on top of each ski so that the handles lie between the toe irons. Now a cord (a rawhide boot lace is excellent) is tied around each ski pole about 6 inches in front of each toe iron. The thongs must be tied with a clove hitch because other knots will not hold. The knot is tied in the middle of the thong leaving two long ends. These ends are passed through the toe-strap holes in the toe irons, pulled very tight and their ends tied together across the toe irons with a square knot. This method of tying pulls the poles back along the skis, thus tightening the ski tips in the baskets at the front end of the toboggan. No cords are needed at the front of the sled. A brace must be placed at the toe irons.

If no pulling ropes are available, the handles of two ski poles may be passed through the baskets at the front of the toboggan so that their handles extend forward. These poles are held in place by their baskets and may be used in place of pull ropes.

14. The Ski-Mountaineering Test

THE SKI-MOUNTAINEERING TEST is a measure of the ability required for safe ski mountaineering. This manual comprises as much of the technique of the art as can be briefly explained by the printed page. To indicate the parts of the technique which are most important to requirements of the test, the test itself, and the suggested interpretation, are given here. They may serve as an informal examination on the manual for those who have no opportunity to take a formal test. It is suggested that the parts of a formal test not be taken too soon after instruction. For it is not the purpose of the test, or of its detailed interpretation, to encourage memorizing. It is intended, rather, to bring out the resourcefulness and to weigh the judgment inherent in every skier, and vital to the meeting of frequent challenges to ingenuity that ski mountaineering so happily provides.

The formal wording of each test part is below in italics, and is followed by explanation of the aspects which require emphasis. Chapter references are in parentheses.

The candidate must prove to the satisfaction of the judges that he has: (1) Passed the third-class test (3, 6).

The purpose of this test is to stimulate and measure the ordinary touring ability every skier should be ambitious to attain in order to enjoy all-day tours over mountain terrain. Fluency, assurance, steadiness are required, rather than speed. The demonstrations required are:

a) Four linked stem turns on a slope of 15-20°, de pending on snow conditions, executed slowly under com plete control and separated by traverses with skis paral lel, upper ski leading.

b) A right and left christiania to a standstill from a direct descent, starting the turns at a speed of at least 10 miles per hour. Stem, open, or pure christianias may be used; inside ski must not be lifted.

(Parts *a* and *b* may be on either hard or soft snow, but must be on such character of surface and must be executed with such stability and assurance that they indicate clearly an ability to execute these turns on either hard or soft snow. Judges may require execution on both types of snow.)

c) Sideslipping to right and to left down a smooth slope, traveling far enough in each direction to demon strate control of sideslip and speed by edging and weight shifting.

d) Kick-turns to right and left, both uphill and down hill, on a slope of at least 30°.

e) Good form and effective propulsion on the level with the one-step and two-step. Rhythm and glide should be emphasized.

/) Step-turns to right and left at speed of approximately 15 miles per hour.

g) Ascent and descent of a standard course of approximately 1,000 vertical feet if available, but in any event not less than 800 feet. Climbing aids other than appropriate waxing are not permitted, and the candidate must demonstrate a knowledge of appropriate waxing. The course must include the variety of slope and terrain encountered in ordinary touring.

Alternative (for gradual terrain): Cross-country, continuous three-hour tour over variable terrain, with enough climbing and downhill running to test the stamina and steadiness of the candidate. Rest periods must be restricted to bare minimum required for terrain, altitude, and snow conditions encountered. Climbing aids other than appropriate waxing are not permitted, and the candidate must demonstrate a knowledge of appropriate waxing. Tour must be made at a steady and reasonably aggressive pace throughout.

2) Ability to use properly a topographic map and compass (11).

To demonstrate use of map and compass, the candidate should be able to:

a) Understand the fundamentals of magnetic declination; convert magnetic readings to true readings, and vice versa.

b) Determine on a map compass bearings of several courses of a route and explain the use of this information in a storm; plot on a map a given set of compass bearings.

c) Explain how to hold a compass course around impassable obstacles such as cliffs or streams.

d) Orient a map: by compass; by a known location on the map and a known landmark; by three known landmarks; by sun and watch.

e) Locate position on a map by intersection of lines from known landmarks.

/) Identify unknown landmarks with the aid of the map; determine intervisibility of two points on a map.

g) Understand the fundamentals of contour topography; draw simple forms; recognize and explain forms of topography shown on selected United States Geological Survey maps.

h) Plan a week's ski tour from selected maps of high-mountain ski terrain, with particular reference to angle of slope, sun and wind exposure, avalanche hazard, probable timber conditions, showing campsite objectives, with alternate plans in case a severe storm or accident occurs at any point.

3) Knowledge of first-aid rescue technique, including the treatment of freezing, and the ability to construct and use a two-ski rescue sled (12, 14).

To demonstrate ski-mountaineering rescue requirements, the candidate should:

a) Know the first-aid measures taught in the Standard (20-hour) Course of the American Red Cross, with par ticular reference to shock, bandages, and splints.

b) Demonstrate an understanding of precautions that must be taken when caring for a man injured while ski ing.

c) Demonstrate resourcefulness in improvising splints and bandages.

d) Explain the principles of "second" aid that would be used in caring for a man injured far from medical help.

e) Understand the first aid care of freezing.

/) Know the prevention and care of snow blindness.

g) Construct a two-ski rescue sled which is rigid enough to stand the strains of use. Knots and braces must be tight and efficient.

h) Explain the procedure of using a rescue sled, with particular reference to the means of keeping the victim warm and comfortable.

4) Knowledge of the basic principles of snowcraft, with special reference to avalanches (10).

The candidate should:

a) Explain the structure and hazard of wet snow, dry snow, and wind slab; the relation of anchorage and slope to avalanche danger; the basic effect of sun, wind, temperature, humidity, and time of day on snow in its relation to texture and avalanches.

b) Describe the precautions to be taken when travel ing on slopes which may avalanche, including the respon sibilities of the leader; review recommended conduct dur ing an avalanche.

c) Show an understanding of the method of rescuing avalanche victims.

5) *Toured on skis two full days during the winter sea son, with at least one overnight camp on snow, carrying an appropriate share of total equipment during the en tire tour* (1-9).

The candidate, on the tour, should:

a) Demonstrate ability so to use his energy that at the end of each day he has enough reserve to make and care for camp. He should show proper rhythm and stride, and should avoid loss of energy through chilling or over heating.

b) Show a knowledge of selection, preparation, and use of the campsite.

c) Know a few basic ski-mountaineering menus and be able to prepare meals in camp.

d) Show a degree of stamina that will enable him to carry his share of equipment and food and to keep up with an average party.

6) Knowledge and demonstrated ability to use equip ment necessary for safely undertaking a ski tour of sev eral days' duration (2, 6, 7, 8).

The candidate is expected to be able so to select and use his equipment on a ski tour that he can tour in safety and relative comfort. He should use properly: clothing, pack, skis, bindings, skins, tent, sleeping bag, stove, cooking utensils, first-aid and repair equipment.

7) Completed the ascent and descent on skis of ap-

proximately 1500 feet of elevation, preferably on a peak, demonstrating a knowledge of proper equipment (2, 6, 10).

The candidate should demonstrate an ability to climb efficiently, to handle himself safely in steep terrain, and to select a route of ascent and descent which will take advantage of snow texture and slope, thus making the best use of his energy.

8) Demonstrated ability on tour to cope with an average variety of snow conditions (6).

Steadiness in skiing should be shown throughout the two-day tour; the candidate should be able to recognize and maintain control in several types of snow, such as hard crust, breakable crust, powder, wind-cut, heavy, and wet. He need not show marked speed, but should not delay the party.

15. Mountaineering Routes

THE STEEPER and higher a mountain becomes, the more severe are the forces of nature that serve to tear it down. Wind, running water, changes of temperature, swift avalanches, slow-moving glaciers, ricocheting falling rocks—these elements are ever at work taking a mountain apart, reducing it to low-lying sediments which, in ages to come, will rise again to new heights. Much of the skill of the mountaineer is devoted, during the specific acts of tearing apart, to being somewhere else at the time. He must know the objective dangers of mountains—those which the mountain thrusts upon him; knowing them, he may avoid them. The better he knows their exact limits, the broader the routes of safe travel between them will seem to him, and the greater may be his accomplishment in mountains; more important esthetically, in an absence of unnecessary worry, he can enjoy his mountains immeasurably more.

It is assumed that the skier has already followed the principles of leadership, preparation, timing, and choice of route laid down in a preceding chapter, has thus been able to reach the base of a high mountain, and that he is now wondering what to do next. He may very well wonder what got into him to bring him to such a state of affairs; but that question cannot be answered here, and indeed has not been answered adequately in all mountaineering literature.

Mountain Structure

Description of each major type of high-mountain structure and its relation to objective danger will assist the skier's search for a route that will best lead him past a mountain, or to its summit.

Gentle slopes: the valley and foothill.—A ski tourer knows the problems of gentle terrain full well. It is mentioned here merely because it provides a final good perspective of the mountain. From the valley the mountaineer can make his final careful appraisal of:

1) The prospective weather. If prospects are bad he may well ask "Is this trip necessary?" There is little point in climbing in storm today to a summit that will be in sunshine tomorrow.

2) The size of the mountain—its over-all height, the height of individual pitches, its remoteness.

3) The map. He can study his map and notes as they relate to the mountain he sees.

4) The route. He can make a general outline of his course, remembering that on the mountain proper he, like persons who can't see the forest for the trees, may not see the route for the rock. A sketch may help.

5) The time. An average yardstick: 21/2 miles per hour for horizontal, and 1,000 feet per hour for vertical distance. The time may be cut; on the other hand, horizontal and vertical speed drops to zero on Mount Everest. A good margin of safety contains a generous margin of time.

6) The equipment—mechanical and physical. A final check should be made in gentle terrain. Once the party is on difficult ground, failure of an ax may result in turn ing back; failure of a man must so result.

Corridors: steep-walled valleys, canyons, ravines.—The steepness of corridor walls, as well as their height, accentuates a danger discussed more fully under Avalanches. Snow slopes along many streams may be perfectly free of avalanche danger, but the walls may extend up to where possibility of avalanche is great indeed. The skier must weigh the danger, study the canyon walls for signs of past avalanches, and see that his route skirts those signs if the danger is believed appreciable. If the wall is forested, there may be avalanche swaths cut through the forest, and piles of avalanche debris may fan out on the floor. Above timberline there may be cornices or hanging glaciers poised above the route, their threat just as real even though clouds conceal them. The threat may vary from that of a few thawing and falling icicles in a mild Western canyon to such Himalayan cataclysms as fall from 10,000-foot escarpments to sweep a mile out onto level glacier. If trouble is expected, the party has three choices: It can select a safe route variant. Failing in that it can travel the safest existing route at the safest time of day, and as quickly as possible to minimize the time of exposure. Finally, the party can turn back, realizing that retreat can be fully as much an indication of good mountaineering as the achievement of a summit. On Kangchenjunga, third highest peak in the Himalaya, an expedition that in two successive endeavors had spent 105 days cutting its way from camp to camp on the final tremendous ice ridge, was at last confronted by a snowfield looking as if it might slide—and turned back.

The corridor is also the habitat of streams and torrents. The mountaineer should not underestimate the power of a mountain stream, nor overestimate its temperature and the ease of getting warm and dry after faulty attempts to cross.

Couloirs: the chute, chimney, and crack.—Beyond the canyon, and tributary to it, are the gully formations that owe their existence largely to falling snow, ice, and rock, and are still avenues for the same falling bodies. In high mountains chutes are usually filled with ice at high angle, sometimes snow-covered and often not. They are normally to be avoided as dangerous territory, but the hazard varies greatly. In the mild summer climate of Yosemite Valley one rarely hears falling rock in the chutes, which are usually the chosen route. In such severe weather as that of the Alps there may be many couloirs as evil as one on the Aiguille du Blatiere, which is rarely quiet. The detritus at the base of a chute, or the color of the snow or ice in it, may suggest the extent of danger. If the route must be taken, either wall of the chute should be preferred to the middle, which is directly in the firing line and provides least defilade from flying fragments. The best time to pass is in early morning, before the sun has released the seal that holds icicles and rock to the couloir walls.

When the walls of a chute are so close together that the climber may touch both, the chute becomes a chimney. The defilade has improved, but there is less chance of dodging anything that falls into the chimney. The depth of shadow may allow ice to persist long after it has cleared from the rest of the mountain. Moreover, if a climber can reach both sides, it follows that some of the larger rocks falling into the chimney can do the same. Once a chockstone has jammed in the chimney, smaller rocks often collect behind, closing all but the overhanging passage in front of the original block, which, to add final insult, may be loose enough to launch itself and its collected debris when disturbed.

If the walls of a chimney are too close together to admit a climber, the chimney becomes a crack. This is normally a cleavage of the rock, is not due to erosion, and is exposed to no unusual objective danger. The tendency of an inexpert climber, however, is to try to escape exposure to height by getting every possible bit of his body into the crack. The result is that he all but blocks his progress, and tires himself needlessly.

Immediately below the chutes of lower mountains are the talus or debris slopes, often seemingly interminable. They are more stable than moraines, because the rocks have usually fallen and rolled into place, instead of being balanced in place by melting ice. Some blocks do, however, roll when stepped upon. The climber can avoid them by stepping on rocks held in place by other surrounding rocks. He will eventually develop an aplomb that permits him to move swiftly over talus, never pausing on any block long enough to care whether it rolls or not. His self-assurance should not, however, be careless; nor should others follow so closely as to be imperiled by blocks that do roll.

The largest blocks—the "big-jump" talus—are at the bottom of the slope; the gravel at the top, which slides underfoot, is known as scree. Climbing it is arduous, but downhill scree running is enjoyable so long as one does not step on a thin veneer of scree overlying smooth, massive rock.

Ridges: the buttress, rib, arete, knife-edge, and gendarme.—A buttress is a main bulwark of a peak. A rib separates the flutings in a wall having shallow avalanche chutes or chimneys. An arete is a sharp ridge, either between deep couloirs, or in a position where it is a principal support of a peak. A knife-edge, as the term implies, is sharper still and usually will be ragged, sections of the ridge having dropped away. If the clefts between sections are deep and sharp enough, the tower in between becomes a gendarme—a policeman who is all too often signaling the climber to stop. A ridge often owes its lofty, exposed position to a rock structure sounder than that which once surrounded it. Sound rock is steepest, requires the best handholds—and has the fewest. The ridge route is usually devoid of falling rock and ice, but devoid as well of an even gradient toward a summit. The sharper the ridge, the more it is broken by notches and towers, and the more numerous are the detours that will have to be made onto its walls. Ridges are particularly exposed to wind, storm, and lightning. If an electrical storm is approaching it is advisable for a party to be off the skyline before rocks hum and hair stands on end, to give too ominous a display of the discharge of static electricity. (See *Lightning and the Mountain,* pages 175-180.) Ridges in high mountains will have cornices to leeward of prevailing winds; if the winds of the region are too whimsical, there may be cornices on both sides—double cornices, both collapsible. If the ridge is exposed, roped travel is of course in order, and consecutive belays may be necessary.

Cliffs: the face, wall, or precipice.—Between the couloirs and ridges are high-angle slopes for which the names are interchangeable. If the slope is very steep, subtended by ridges, and broken only by cracks, chimneys, shallow chutes, and ledges, it is either a face or a wall. The precipice is more the poet's word than the mountaineer's—but it is perfectly permissible for a man to be both. The climber is prone to consider not the entire cliff, but its separate faces, overhangs, bulges, slabs, flakes, or offset cracks; and whether he is on a cliff, a ridge, or in a gully, the portion of route between belay positions is a pitch. Cliffs are subject only to sporadic fall of rock or ice, provided there is no hanging glacier or chute overhead; a route which exists on a face will usually be quickly perceivable and one of the safest on the mountain. Ledges are necessary breaks on any face, welcome as long as they are neither concealed too heavily with snow, nor too sloping and covered with loose, rolling scree.

The pass, saddle, col, and notch.—In general usage the pass is lowest and broadest; the notch is the other extreme. Any of the forms of passes may be the goal of a ski mountaineer who is seeking a route through a region rather than to the top of it. The dangers inherent in the chute, face, and ridge end here, but rarely, in high mountains, without a final battle with a cornice and the wind that made it.

Summit, peak, crest, spire, dome, pinnacle, needle.—The ski mountaineer can choose his own appropriate name for the top. Here the prime objective danger, provided the top is not too pointed a pinnacle or needle, is the weather. But here the mountaineer can best observe the weather coming his way, and can hurry or linger accordingly. If the mountaineer is fortunate he may bask in such weather as described by Mummery on the Matterhorn, when he held out a match and the flame did not waver. His thoughts may swagger with Halliburton's on the same summit ("At last I can spit a mile"), or he may feel, with Young, the need of the "ability to smoke, and consequently to sustain his part in the effortless silence which characterizes the true comradeship of mountaineering." Solitude may affect him as it did Samivel's mountaineer: how much more beautiful it is if there is someone to talk to about it. Perhaps the climber will have none of the published reactions, and will prefer his own. If the weather forbids him to remove a mitt to get a match, much less try to light it, he is likely not to be really happy about the top until he can say, "How nice it is to have been there," and meanwhile fervently hopes that in his fatigued condition the descent will not seem too much steeper than the ascent, that the weather will not get any worse, and that some of the snow bridges he used in the morning will still exist in the evening. But the skier who has achieved his difficult summit with sound technique, and has equally well achieved the valley again, may now consider himself a true ski mountaineer.

Glaciers

The name *glacier* has been applied to ice bodies varying from small residual glaciers in Colorado, moving a few inches a year, to a valley glacier in Greenland which races along at 99 feet per day. Few are the mountains really deserving of the name that have not been severely modified, and made beautiful, by glaciers. Even the ski mountaineer who never expects to see glaciers would do well to know a little of them so that at least he can recognize their effect on the mountains he travels.

Wherever more snow accumulates every year than can melt in place, it forms permanent snowfields *(neve),* compacts into ice, breaks away from the mountain (at the *bergschrund)*, and flows slowly downhill. Irregularities in its course may break the surface into roughly parallel cracks *(crevasses),* confluence with other glaciers may buckle it *(pressure areas),* and the glacier bed may break it up badly *(icefalls* with their ice-block *seracs),* or drop it over cliffs *(hanging glaciers).* Tributary glaciers may join it, either by means of icefalls, by dropping from hanging glaciers, or by simple confluence, and a lake of ice may form *(icefield),* from which the main glacier descends far below the peaks *(valley gla-*

der). On its surface will be the sand and rock debris that has avalanched from the mountains (lateral moraines at the sides, medial moraines down the middle, formed of lateral moraines where two glaciers join), and which is piled up where melting equals the flow, at the end of the glacier (terminal moraine at the terminus or snout). Also on the surface is the surface-drainage system, consisting of ice marshes, of small lakes in pinched crevasses, streams and waterfalls that finally disappear in crevasses or glacier mills (moulins), to join the main stream that flows beneath the glacier or subsidiary streams along the sides. Where the glacier flows past cliffs the edge will be melted back (the moat, or randkluft). But the ski mountaineer ascending a mountain will meet these features in reverse order. Certain considerations should be given each:

The terminus.—This may be so covered with morainal material—even forest and lakes in Alaska—as not to be recognizable. During the present climatic cycle, however, most glaciers have retreated far, and are approached by rock-strewn valleys which forests have not yet had time to claim. The terminus may be an abrupt ice cliff that the climber will have to cut his way up, or may even thrust itself into a fjord, with icebergs being launched at irregular intervals.

Moat and moraine.—A moat may have to be reckoned with if the glacier is approached from the side. Steps may have to be cut, but usually a bridge of debris from a side canyon will provide easier access. Moraines provide a hazard only in their instability. Melting ice leaves many of the blocks precariously perched. When disturbed, they may roll on the man who is following the disturber too closely.

Valley glacier.—A smooth valley glacier is the best avenue of approach to a heavily glaciated region. In 1942 the United States Army's Columbia Icefield Detachment used such a glacier, with only slight modification, as a truck route. During most of the summer season the surface is free from snow, is granular, and provides excellent footing for nailed or Bramani-soled boots. Crevasses are easily seen, and may often be avoided altogether if the climber selects a route along the inside corners of the glacier's turns, where the crevasses are closed by pressure. The ice in the mills and surface-stream channels is very smooth, and is best avoided. The primary hazard is that of avalanche from slopes high above the glacier.

Icefield.—Two problems are provided by an icefield: Its crevasses are usually snow-covered and difficult to detect. Wherever this situation exists, the party must be roped, with a good interval between men, and should follow a route perpendicular to the crevasse system so that no more than one man will be, unsuspectingly, over the same crevasse. The second problem is that of maintaining route when, as frequently happens, a fog or blizzard settles down on the icefield. If weather threatens, route markers (willow wands 36 in. X 1/4 in. with red flag on which back azimuth may be marked) should be placed along the route, each succeeding wand being retrieved on the return as soon as the next one has been found. The skier should remember that a cloudless sky does not necessarily mean a fogless icefield later in the day, and that tracks may be either quickly melted in wet snow or quickly covered by windblown powder.

Hanging glacier.—An active hanging glacier can threaten a broad area beneath it, and should be given a wide berth. Its first sign of activity may be an ice avalanche.

Icefall.—An icefall is to be avoided where possible. It is not static. Seracs may topple as the glacier moves, but they are often stable for long periods of time. If passage is necessary and seracs appear unstable, it should be swift, to minimize time of exposure, and silent, so that sounds of moving or falling ice may be heard and heeded. Members of the party should keep a weather eye on the ice cliffs above them.

Crevasses.—These are the classical bugaboo of glaciers, and while often very interesting and beautiful, deserve their bad reputation. Even when not snow-covered, they may present a maze that requires time-consuming search for a zigzag route. In a gentle icefall they can close unpredictably, and, in an area under pressure that was supposed to keep them closed, one was known to open with an alarming report just three feet from a pitched tent. On snow-covered glaciers they may be too broad to be bridged and require long detours; snow bridges may be unsturdy-looking and adequate or deceptively the exact opposite; a bridge reliable in the morning may have softened and be ready to slough into its crevasse in the afternoon; the crevasse may be completely covered by snow, which may have settled into a hollow barely perceptible in poor light, or there may be so fresh a snow cover that the crevasse cannot possibly be detected, even by careful probing with the ice-ax shaft, until the curses are heard of the leader who has fallen into it (and who, if his curses are to be heard, must be roped and belayed).

Bergschrund.—This crevasse is often a welcome sight, because it is the highest and last crevasse encountered on the ascent of a glacier; conversely, it is a discouraging sight if, as can happen, its upper lip is 40 feet high and overhangs (see the final page). It is usually crossable on a bridge formed by frequent snow slides from the neve above. Close watch must be maintained for falls of additional bridging material. A shoulder stand may provide all the leader needs to find purchase on the upper lip. The 40-foot, overhanging type might be climbable with the aid of ice ax, crampons, ice pitons, and a tension belay; chances are, however, it was the wrong route.

Snow curtain.—On this slope the mountaineer sighs with relief because the bergschrund is below, but he is mindful of the step-cutting job on the steep slope above him, and of the frequency of the recent avalanches needed to build and maintain his snow bridge over the bergschrund.

Weather and Rock

Weather hazards.—As important as a mountain's surface of rock and ice is the mood of the atmosphere enveloping it. Big mountains make their own weather, using various formulas, a common one being that air drops in temperature 3-5° for every 1,000-foot rise in elevation. Clear air over a sunny valley may thus be chilled, its moisture condensed into a cloudcap, precipitated in a violent blizzard on a high crest. Steep slopes can create wind, or accelerate balmy zephyrs into chilling gales. The effect of bad weather on a climbing route obviously merits special consideration by the mountaineer.

1) On long routes weather changes for the worse must be anticipated. Wet or icy rock can make an easy route almost impassable: cold may reduce climbing efficiency, snow may cover holds, a cloudy night may be too dark to travel, an enshrouded glacier too foggy to cross.

2) Smooth rock slabs become treacherous when wet, or iced after a freeze and rain. Holds may be hidden in the rime that has condensed from an icy mist.

Wind and Barometer Indications for the United States

Wind	Barometer (inches at sea level)	Weather indicated
SW to NW	30.1 to 30.2, steady	Fair, with slight temperature changes, for 1 to 2 days
SW to NW	30.1 to 30.2, rising rapidly	Fair, followed within 2 days by rain
SWtoNW	30.2 or above, steady	Continued fair, with no decided temperature change
SWtoNW	30.2 or above, falling slowly	Slowly rising temperatures and fair for 2 days
StoSE	30.1 to 30.2, falling slowly	Rain within 24 hours
StoSE	30.1 to 30.2, falling rapidly	Wind increasing in force, with rain within 12 to 24 hours
SE to NE	30.1 to 30.2, falling slowly	Rain in 12 to 18 hours
SE to NE	30.1 to 30.2, falling rapidly	Increasing wind, and rain within 12 hours
EtoNE	30.1 or above, falling slowly	In summer, with light winds, rain may not fall for several days. In winter, rain within 24 hours
EtoNE	30.1 or above, falling rapidly	In summer, rain probable within 12 to 24 hours. In winter, rain or snow, with increasing winds, will often set in when the barometer begins to fall and the wind sets in from the NE
SE to NE	30.0 or below, falling slowly	Rain will continue 1 to 2 days
SE to NE	30.0 or below, falling rapidly	Rain, with high wind, followed, within 36 hours, by clearing, and in winter by colder
StoSW	30.0 or below, rising slowly	Clearing within a few hours, and fair for several days
StoE	29.8 or below, falling rapidly	Severe storm imminent, followed, within 24 hours, by clearing, and in winter by colder
EtoN	29.8 or below, falling rapidly	Severe northeast gale and heavy precipitation; in winter, heavy snow, followed by a cold wave
Going to W	29.8 or below, rising rapidly	Clearing and colder

3) Tufts of vegetation that might appear firm (but are dangerous substitutes for holds at best) may have their root systems soaked and ready to give.

4) Gullies otherwise dry and quiet may rapidly be come waterfalls, with rocks falling as well as water.

5) In electrical storms the climber near a lone tree, or on a peak, ridge, or pinnacle, is especially vulnerable. (See *Lightning and the Mountain,* pages 175—180.)

6) During heavy snowfall crevasses will be well but flimsily hidden, avalanches may occur, or may soon fol low.

Weather signs.—It is not always possible to obtain a timely professional weather forecast to cover a climb or expedition, nor is such a forecast always the final word about what the weather will do. The ski mountaineer, aided by a pocket aneroid barometer and a thermometer should, with additional study, understand many of the immediate weather signs that prevail in his area. The United States Weather Bureau's table of wind and barometer indications gives further assistance (see table on facing page).

Following is the very general behavior of a traveling storm in the Northern Hemisphere. All probably's and if's, although deleted, should be understood.

1) The storm consists of a humid mass of air of low barometric pressure, that travels from west to east, over rides the cooler mass of air in front of it, cools to pro duce clouds, and cools still more to precipitate them. Wind blows spirally inward and counterclockwise about its center.

2) As the storm approaches, the temperature rises, the barometer falls, the wind backs (e.g., from west to south), cirrus clouds (mare's-tails) and alto-cumulus (mackerel sky) appear in the vanguard, storm warnings

in the form of cloudcaps fly from the peaks, progressively lower clouds follow, the wind and the temperature increase further, the barometer continues to fall, and precipitation begins.

3) As the center of the storm passes, precipitation diminishes, the wind veers (e.g., shifts from south to northwest), its velocity drops, the clouds break, the barometer begins to rise, the mountain storm is reduced to flurries, then to isolated cumulus clouds (sheepbacks) and finally to cloudcaps and snow banners on the high peaks. Temperature and wind drop. The barometer returns to high—unless the storm is followed by others in its family.

4) The slower the transition between stages, the longer the storm will last.

Exceptions to any prescribed rules of storm behavior probably, in total, outnumber the rules. Some of the exceptions:

1) The barometer will record a daily variation, lowest near noon, having nothing to do with storms. Readings will decrease with altitude far more than with storm:

Pressure (inches)	30	27	24	21	18	15	12
Elevation (feet)	0	2,871	6,080	9,718	13,918	18,886	24,966

2) Mountains usually distort the wind; a mountaineer's camp may be so sheltered by a ridge that an ominous shift in the wind's direction goes undetected. The direction of local air currents may be opposite to that of the prevailing wind. High clouds are the best weather vane.

3) Slope and daily temperature change affect wind, which tends to blow up the slope by day, down by night.

4) The down-by-night wind, carrying cold air into

canyons and basins, often produces a temperature inversion, and higher elevations are warmer.

5) The daytime wind will tend to produce clouds independent of traveling storms, for humid air, when raised by convection, condenses into clouds—often thunderheads—by early afternoon. Hence with a red sky in the morning, that is, with some clouds present, moun taineers as well as sailors may take warning.

6) Conversely, the evening reversal of wind and tem perature disperses clouds, and thus if a storm has broken enough to permit a red sunset, the continuing reversal (not the full moon) will clear it.

Loose and jailing rock.—Just as avalanches are the most common mountain danger for the skier, falling rock is most common for the rock-climber. Weather is a frequent cause of rock fall; rocks are brought down by changes of temperature and resultant splitting action of intermittent freezing and thawing, as well as by heavy rain. Rock falls occur on all steep slopes, particularly in gullies and chutes. Areas of frequent rock falls may be indicated by abundant fresh scars on the rock walls, fine dust on the talus piles, or lines, grooves, and rock-strewn areas on snow beneath cliffs. A more immediate cause of rock fall is carelessness in climbing by both man and beast.

Warning of a rock fall, if detected, should be a vigorous cry, "Rock!" Other warnings: a whistling sound, a grating, a thunderous crashing, or sparks where the rocks strike at night.

Immediate action is to seek cover—if one can move, and cover is available. If not, the climber should watch the falling rock, present his narrowest profile, and not commit himself until he knows he is in direct peril.

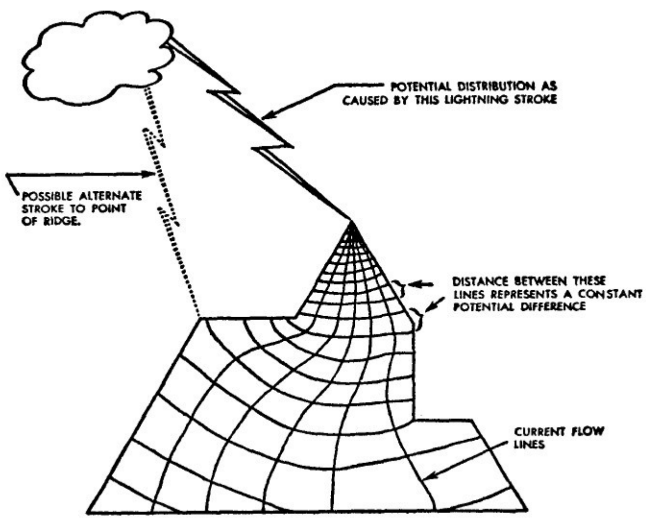
Otherwise he might move into the path of a falling rock by blindly or prematurely trying to avoid it.

Rock-fall danger is minimized by judgment in choice of route; clean and careful climbing will reduce it further. Holds should be tested before use by striking with the heel of the hand or the foot, but not with such vigor or indirection as to launch loose rock on the party below. Careful appraisal will prevent many an insecure rock's being stepped on or grasped. Many insecure rocks should deliberately be moved into safe positions to avoid accidental fall due to action of the rope or to careless movement. The body will not brush rock loose if it is properly balanced—away from the rock. The rear foot is a bad offender, and the climber should know, as he brings it forward, that it will not kick rocks.

Lightning and the mountain.—The urge to know more concerning the effects of lightning becomes stronger when one is on a peak with the static charge beginning to make its power felt. When every projection in the vicinity, and finally the climber himself, begins to spark and the air is filled with ominous hissing, the desire to be in camp becomes overwhelming. Since this desire cannot always be satisfied, it is well to know what to do at this time.

The reasons behind the classical warning to be off the summit and ridges in a lightning storm can be seen when the mechanics of the lightning discharge are studied. Owing to rising currents of air and various other disturbances in the atmosphere, the clouds in cold-front and line-squall weather obtain high charges of static electricity. When these charges build up to such magnitude that they can overcome the resistance of the air, they tend to join their counterparts on the ground. This is similar to the action of a spark plug in the automobile engine, magnified millions of times. The discharge between cloud and ground is accompanied by currents which dissipate themselves over the ground surface.

A study of static electricity reveals that the cloud charge prefers to discharge to a sharp pointed object rather than to other shapes. This, coupled with the rela-



Idealized thin-plate two-dimensional mountain.

tive closeness of the summit of a mountain to the cloud, is the reason for the danger at the top of the mountain. However, where there are low clouds and a ridge, discharge is likely to occur to points on the ridge rather than to the summit. This can be seen in the figure. Once discharge has occurred, the current flows over the surface of the rock toward the base of the mountain. It flows perpendicular to the lines of equal potential. These lines and their distribution are shown in the figure. The closer the potential lines are together, the greater is the current flow. Near the summit the lines are very close together, while near the base, they are relatively far apart; the ground currents are strong near the top and weak near the base. Also, the lines are close together on vertical walls, while on the horizontal ledge they are far apart. Similarly, it is found that the current flow is greater on the face of a mountain than on its ridges.

The two types of danger from lightning consist in a direct strike and in a subsidiary danger from the ground currents. Anywhere but on the summit or very near to it the chance of being the victim of a direct bolt is small and the probability of being killed is almost certain. In contrast, the chance of meeting ground currents is almost certain, while with a few precautions the probability of being injured by the currents is small.

The precautions to be taken against a direct strike consist in getting away from the summit or ridges, and, if this is impossible, to get as close to the rock as possible without lying down. A squatting position with head low is ideal. Any pinnacle in the vicinity that is five to ten times the height of the squatting position will give lightning-rod protection.

From a study of potential distribution on an idealized mountain (see figure) several important theoretical conclusions may be reached.

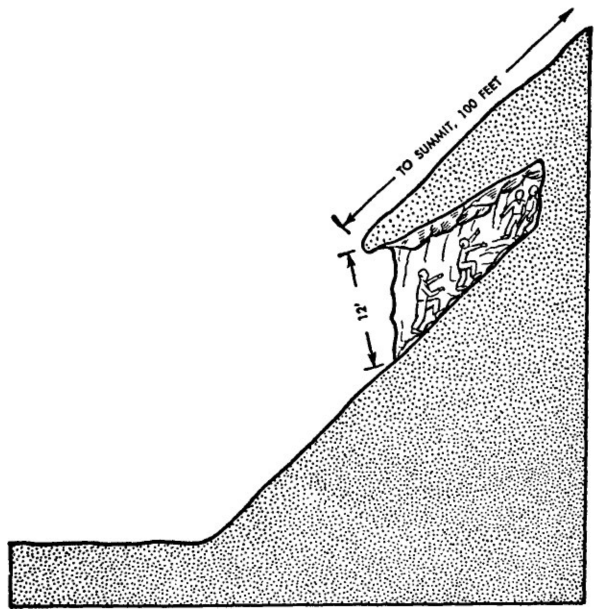
Since the potential lines are farther apart near the base, it is apparent that it is safer near the base. The long ledge is safer than the sloping ridge near it. The vertical portion of the ridge conducts large currents. Thus, one may conclude that the steeper the rock, at any given height above the base, the more dangerous its ground current.

The protection from ground-current injury should consist of getting on rock with the least slope available. The climber should be sure that he stays as far from the wall as possible to minimize the danger of a discharge from the wall to the body. One point of contact with the rock should be the maximum. The danger of rappelling is immediately apparent, as it automatically gives the climber two points of contact with a very great potential difference.

Combining the precautions against both ground currents and a direct strike, we find that the best position would consist of squatting with the head down and feet together in the middle of a wide ledge or as gentle a slope as is available. Ice ax, crampons, pitons, and other sharply pointed objects should be some distance away. Possibly the ice axes could be placed ferrule up to form crude lightning rods (especially if the handle is wet or its conductivity is otherwise improved, e.g., by wire).

The cave shown is similar to the one in which an accident on Bugaboo Spire took place in which lightning indirectly caused the death of two climbers and nearly killed two others. The potential gradient is seen to be high in the vicinity of the cave, owing to the steepness of the floor and sides. It is presumed that this is the reason for the injury and deaths, inasmuch as a direct strike inside the cave is highly unlikely. All were leaning against the rock at the time of the discharge, which would account for the burns that they suffered on the back and legs. From an analysis of this situation, it would seem that a position on the somewhat level portion of the ridge would have been safer.

In general, shelter should be taken in a cave only if it is deep in comparison with the vertical height. Again, the body should not touch the sides and the head should be as far from the top as possible. In a similar situation during the same storm, a party on Pidgeon Spire was subjected to numerous shocks and noted discharges between the head and the roof of a cave.



Representation of the cave on Bugaboo Spire.

Seldom will there be similar situations from one mountain to the next and from one storm to the next, so some ingenuity will have to be applied, and the merits of one position weighed against those of another at the time. *The isolated squatting position should be used in one form or another, as it affords the maximum protec-*

tion. And even though one should be far from the summit he should not overlook the possibility of lightning's striking some distance down the ridge with resultant danger from ground currents.

These suggestions for positive action were brought forth in the light of previous experiences and from an analysis of the behavior of electricity. They are not to be regarded as guaranteed safeguards, but more as enlightened guesses. Further work should be done on the subject, and any suggestions and experiences should be reported to the Mountaineering Committee, Sierra Club.

16. Rock-Climbing

Reasonable ability on rock comes first in progressive schooling in the art of climbing in rugged terrain. Technique is easier to acquire on rock than on ice because rock is more comfortable to work on, requires little equipment, is far more abundant, and demands less judgment. Rock-climbing does not make a mountaineer, any more than does skiing, but it is a substantial start.

Ski mountaineers will be grounded while applying advanced climbing technique. Difficult summits or passes are rarely accessible to a man on skis. At best, it is recommended that the ski mountaineer not try to climb any but short roped pitches, on rock or ice, if he must carry or drag his skis.

Training

A rock-climber can't afford such peril as that to which the unskilled skier—speeding down, happily out of control without knowing it—subjects himself if he tries the Nosedive. On rock, a subjective danger is more serious, for if there should be snow for a climber to fall on when he is out of control, it is often too far below. His safety, then, lies in controlled climbing, an ability derived in turn from progressive study of what his body is able to do. Once he has learned his limitations, his further safety lies in knowing how to correct the mistake of going beyond the limit of his ability.

Control can be learned on easy ridges and rocks. With no risk, a skier can assay his coordination and develop his ability by climbing at the base of a cliff, on progressively higher angles and tinier holds, where he is never so far above a landing strip that he cannot safely jump if something happens to his controls. Competition afforded by a follow-the-leader process will speed his early progress and that of his friends. Without increasing his exposure to difficulty he can learn the function of the rope, carabiner, piton, and footgear. Finally, and still without exposing himself to great height until he is ready, he can learn how his control and his climbing aids are combined to provide corrective measures and to build a team.

While learning to control himself and his rope the student will raise the limits of his agility, strength, and endurance. Agility will enable him to use more efficiently the strength he builds. The actual exercise will ease his acclimatization to high altitude. When his muscles and vital organs are in tone, and he has finally become smart enough to hoard his fund of energy, spending it only when necessary, he will have endurance. It is endurance that gets mountaineers up big mountains, endurance so distinct from the flash energy used in downhill racing or football that it has been said that the ideal age for those who would attempt to climb Mount Everest is 25 to 35. Younger men spurt too much.

Climbing Control

On steep slopes the climber uses a combination: the balanced movement of a tightrope walker and the unbalanced climbing of a man ascending a tree or ladder. The climber must travel with his weight in poise over his feet or just ahead of them as he moves. His feet, not his hands, carry his weight, except on the steepest cliffs. His hands are for balance. Feet will not hold well when the climber leans in toward the rock. With his body in balance and his eyes leading the way, the climber moves in a rhythmic slow motion. He uses three points of support (two feet and one hand, for example, but never knee, elbow, and seat) whenever possible, and prefers handholds that are waist- to shoulder-high. He relaxes, because tensed muscles tire quickly; when he rests, it is with his arms low, where circulation is not impaired. He uses small intermediate holds rather than stretching and clinging between widely separated big holds. He avoids the spread-eagle position, in which a man stretches so far he can hardly let go. He climbs sidewise to the rock where he can, rather than hug it too closely. In descents he faces out where the going is easy, sidewise where it is hard, and faces in where it is difficult, looping his rope momentarily over rock points that can serve as intermediate belays; he uses the lowest possible handholds, and never jumps down.

Types of holds.— (1) Pull holds are those that are pulled down or out upon and are the easiest holds to use. They are also the most likely to break out.

2) Push holds are pushed down upon, help the climber keep his arms desirably low, rarely break out, but are more difficult to hold to in case of slip. A push hold is often used to advantage in combination with a pull hold.

3) Friction holds are those dependent solely on the fric tion of hands or feet against a smooth surface. They are difficult to use because they give a feeling of insecurity, which the climber tends to try to correct by leaning closer to the rock, thereby only increasing his insecurity. They often serve well as intermediate holds, some of which will give needed support while the climber moves over them, but would not hold him were he to stop.

4) Cross-pressure holds do not exist as useful single

holds, but must be used in combinations by exertion of opposing pressure between hands, arms, and legs. There are several types: *(a)* The pinch hold—the pinching of a protruding part between the fingers, *(b)* Pressing outward or pulling inward with the arms, (c) The lie-back—a lying back to one side of an offset crack, with the hands pulling and the feet pushing against the offset side, *(d)* Inverted pull or push holds, sometimes called underholds—permitting opposing pressure between hands and feet, (e) Chimney climbing—exertion of cross pressure between the back and the feet or hands or knees.

5) Footholds will usually be the same as handholds, sooner or later, depending upon which way the man is climbing, and are normally used as push holds. A Bramani or sneaker rubber sole will hold on slabs up to about 45°. On such steep slopes the body should be kept vertical, or should lean out, with use being made of small irregularities in the slope to aid friction. Footholds less than half an inch wide can suffice for intermediate holds, even when they slope out.

6) A shoulder stand will overcome a short, holdless pitch. The top man should decide where and when he is going before, not after, he is standing on the somewhat sensitive tissue padding the low man's shoulder.

Use of holds.—A hold need not be large to be good, nor need it be solid, so long as the pressure is in the direction that holds it to the mountain. Experienced climbers can use holds which are scarcely seen. The climber must roll over his holds, not try to skip or jump from one to another. It is, however, often desirable in traverses to use the hop step, in which the climber changes feet on a small hold, replacing his outside foot with his inside foot so that he may move sideways more easily. A slight upward hop, followed by precise footwork, accomplishes this useful step.

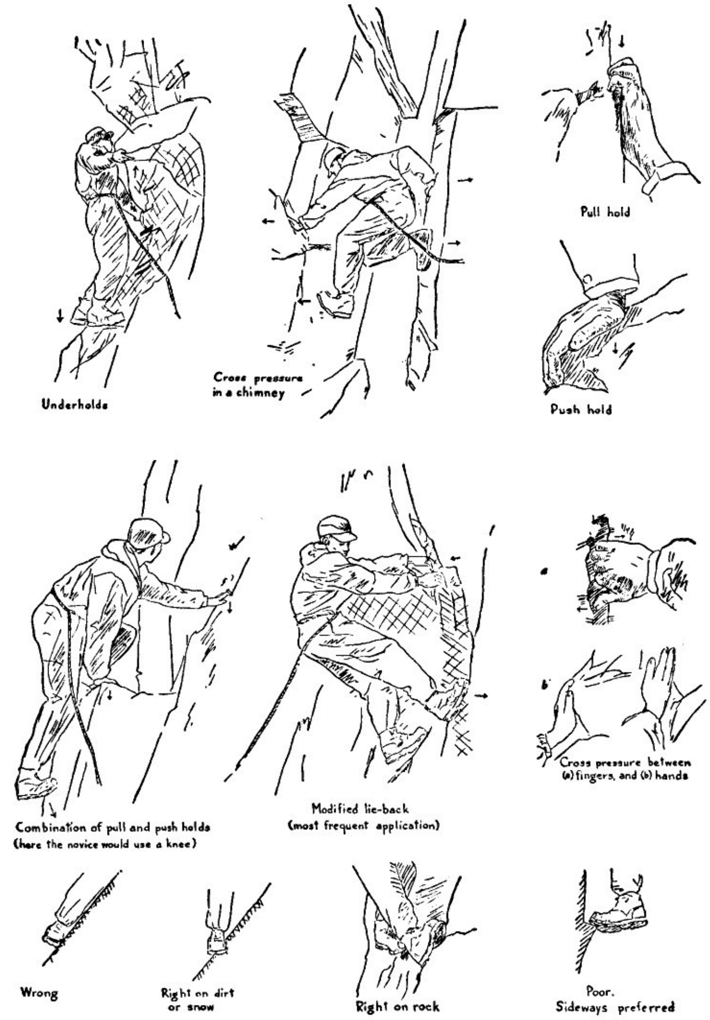


Fig. 17. Some frequent combinations of holds.

Margin of safety.—A margin of safety is the protective buffer a climber keeps between what he knows to be the limit of his ability and what he actually tries to climb. He bases his margin of safety on experience gained with little or no risk in training, where he learns to calculate his ability. Close to the ground or tied to a rope belayed by a trained man above, he climbs on progressively harder pitches until he reaches the limit of his ability—and falls. When climbing thereafter, exposed, he leaves a margin, which can become smaller as he learns to calculate better. This margin should be calculated not only for the pitch immediately ahead, but also for the entire climb. The climber should plan his route and movement so far ahead as never to find himself in difficulties beyond his ability.

Climbing Aids

Rope.—Much climbing in ski mountaineering may be free climbing; that is, without rope. However, on some steep unbroken cliffs, where exposure is great, the rope is necessary in party climbing. When rope is needed it is the climber's lifeline, and it should be cared for accordingly. When not in use, the rope should always be coiled in an approved manner. It should never be stepped on. For long carries, it may be placed over the neck and one shoulder in a diagonal chest carry, or twisted into a figure-eight and folded over in the pack. The climber cannot always know that the rope he is to use has been properly cared for. If being put to any demanding use, rope should be new or nearly new, resilient, and free from serious cuts or abrasions. Serious cuts should be finished with a knife at once; a mountaineering rope is never spliced.

Knots.— (1) The bowline is used for either end man on a rope. It is one of the easiest knots to untie after it has held a heavy load.

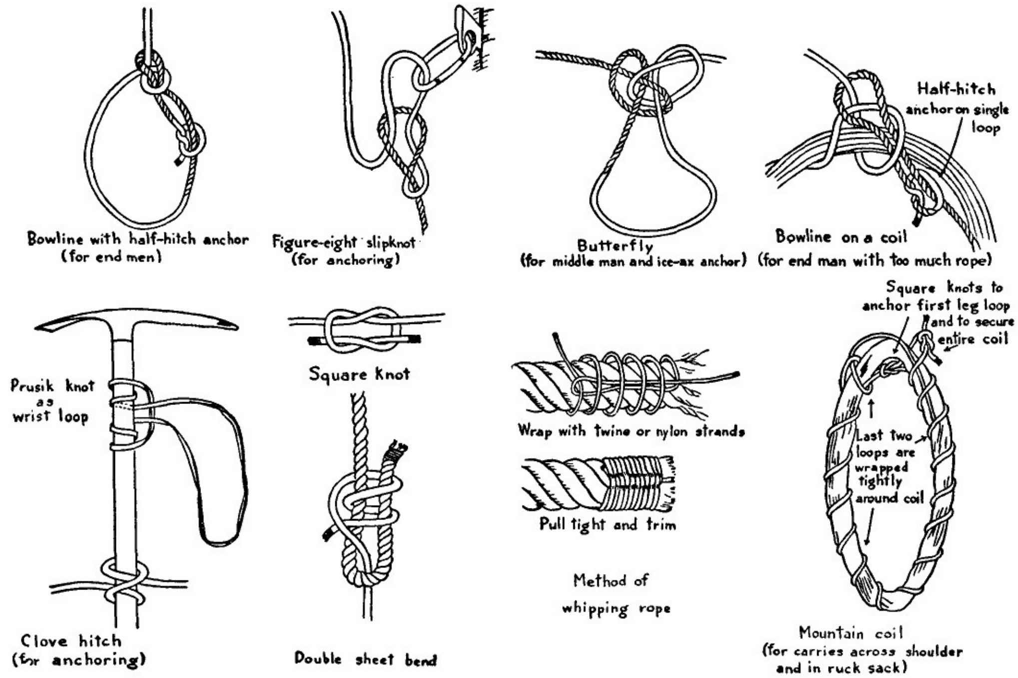


Fig. 18. Climbing knots and the mountain coil.

2) The bowline on a coil is used to take up extra rope around the climber's body, to relieve strain around the waist in tension climbing, and is used by the faller in practice belaying.

3) The butterfly knot is used in tying men in to the middle of a rope. This knot reduces the strength of the rope less than other knots.

4) The sheet bend is used in tying two ropes together.

5) The clove hitch is thrown around a pole or ice ax to provide a nonsliding anchor.

6) The Prusik knot will hold under stress, and slide when the stress is removed. It may be tied with a loop or on a bight. Its ratchet effect has many uses.

Placing of pitons.—Pitons are placed to reinforce the climber's judgment. If well placed (see fig. 3) they will limit his fall to twice the distance he is above the piton plus the amount of slack the belayer lets run. In placing pitons the climber should:

1) Study the rock to see that driving of a piton will not weaken it. Test rock for soundness by tapping with ham mer. Select a crack that is wide enough to take one-third to one-half the piton shaft before hammering. Select the right piton—one that the rock will support best and that the snap-link can be hooked into after the piton is driven.

2) Drive the piton. While driving watch the rock to see that it is not being weakened by further cracking. Watch the piton to see that it goes in smoothly and to notice if the point hits a dead end. Listen to the piton's sound at each blow; good verticals and horizontals usually go in with a rising pitch; wafers and angles will have no noticeable pitch so long as the ring is swinging free. Drive the piton hard, until the head begins to change shape. The greater the resistance overcome in driving the piton, the firmer it

will be. A well-driven piton will withstand a direct outward pull of 1,000-2,000 pounds.

3) Test the piton. Pull up several feet of slack, snap rope into carabiner, grasp doubled rope at least 2 feet from the carabiner. Jerk vigorously outward, downward, and to each side, observing the piton meanwhile, repeating if the test is questionable. Tap the piton. If the pitch has changed much, drive the piton in as far as possible; if the sound regains its original pitch the piton is good. If not, the crack has been enlarged and the piton should be treated with sus picion. This test alone should not be relied upon if the piton does not look good. Nor should the tester rely on the piton he is testing.

4) Check the carabiner to see that it will not cause unnecessary friction as he climbs beyond it, and that the gate is not likely to open accidentally owing to pressure against rock, rope, or piton.

5) Beware of pitons that have been used, removed, bent, and straightened. Pitons already in place should seldom be trusted; weathering will loosen them in time, and only the man who has just driven a piton has adequate knowledge of how good it is.

Rappels.—The climber with a rope can descend quickly by means of a rappel—sliding down a rope which has been doubled around such rappel points as a tree, projecting rock, or two firm pitons tied together. Procedure for rappelling:

1) In selecting a route the climber should be sure the rope reaches the bottom or a place from which further rappels will reach the bottom.

2) The rappel point should be tested carefully for soundness, and inspected to see that the rope will run around it when one end is pulled from below.

3) If a sling rope must be used for a rappel point, it should be tied double; if around a rock, it should sag a little, rather than be taut. Use several loops of nylon or Manila sling, keeping all loops of the same dimensions- Avoid parachute cord. If any lowering under tension is contemplated, use a descending ring or sacrifice a carabiner; running a climbing rope directly over slings will lead to disaster.

4) The first man down should: (a) Choose a smooth route for the rope, free of sharp rocks, *(b)* Place loose rocks, which the rope might later dislodge, far enough back on ledges to be out of the way. Always use an upper belay for all but the last person, who should be protected by a lower belay if possible, (c) Prevent the doubled rope from twisting by placing the index finger of the braking hand between the two ropes (see below), *(d)* See that the rope will run freely around the rappel point when one end is pulled from below.

5) Each man down signals "Off rappel" (by pulling alternately on each end of the rope so that the rope runs across the rappel point).

6) When the last man is down, the rope is recovered. The climber should pull it smoothly, to prevent the rising end from whipping around the down-moving rope, and he should stand clear of falling rope or the rocks it may dis lodge.

Several rappelling techniques may be used; only the body rappel is given here: The climber should face the rappel point and straddle the doubled rope. From the rappel point the rope goes between the legs, under the left buttock, up and in front of the left hip, across in front of the chest, over the right shoulder, and across the back to the left, or braking hand. The right hand grasps the rope running to the rappel point at about shoulder height. It

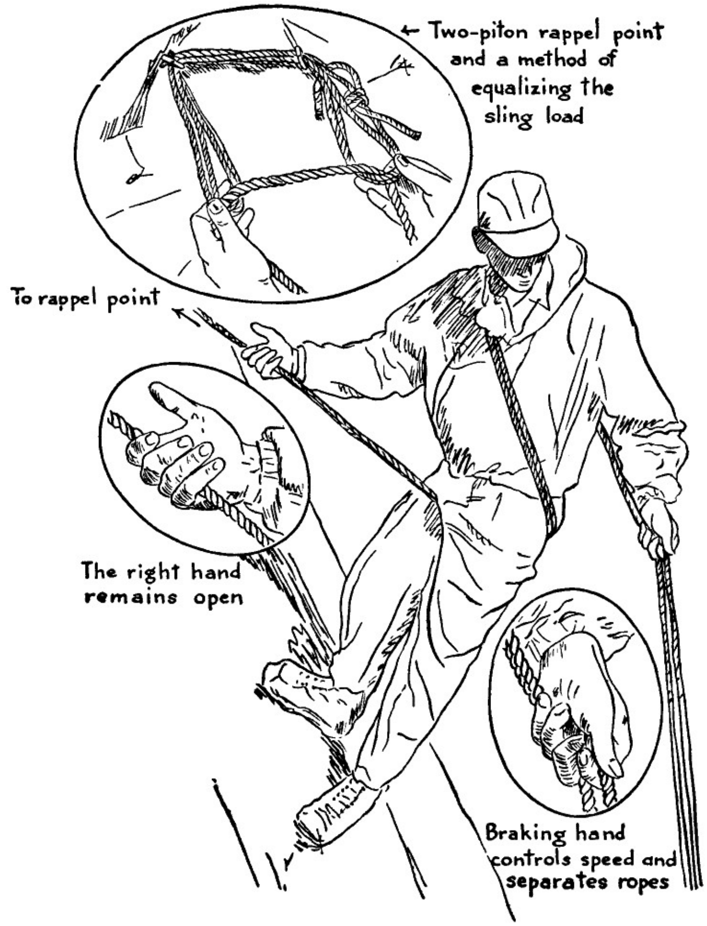


Fig. 19. The body (Dülfer) rappel and a two-piton rappel point.

is used only to steady the body and hold it in the desired position. Trying to support the weight with the right hand will result in a rope burn. The left hand can be held to the rear wherever comfortable, so long as the arm is nearly straight. Friction can be increased if the hand is moved forward, reduced if moved backward. Control of speed will be learned more easily, however, if the hand itself is used as a brake. The climber then leans away from the rock just far enough for his feet to hold, with his weight supported by the rope, and descends slowly, leading with the left leg to make certain that the rope stays in place. He soon learns to rappel in longer and longer bounds, and to use insulation against heat on the shoulder and under the buttock.

Corrective Measures

Belays.—In party climbing, two or three men tie in to a 120-foot length of rope. Belaying provides the necessary safety factor or tension, enabling the leader to climb. Without belaying skill the use of rope in party climbing is a hazard, not a help. When any one man is climbing, he is belayed from above or below by another man, who may use any one of several belay positions.

Procedure for all positions.—The belayer should perform the following duties, and will obviously have his hands full:

1) Select a position that will best protect the leader if he falls. Where possible, the position should permit watching the climber.

2) Run the rope from the climber through his feeling hand (which tests slack), around the hips to his braking hand (which will serve as brake), and make certain the rope will slide readily.

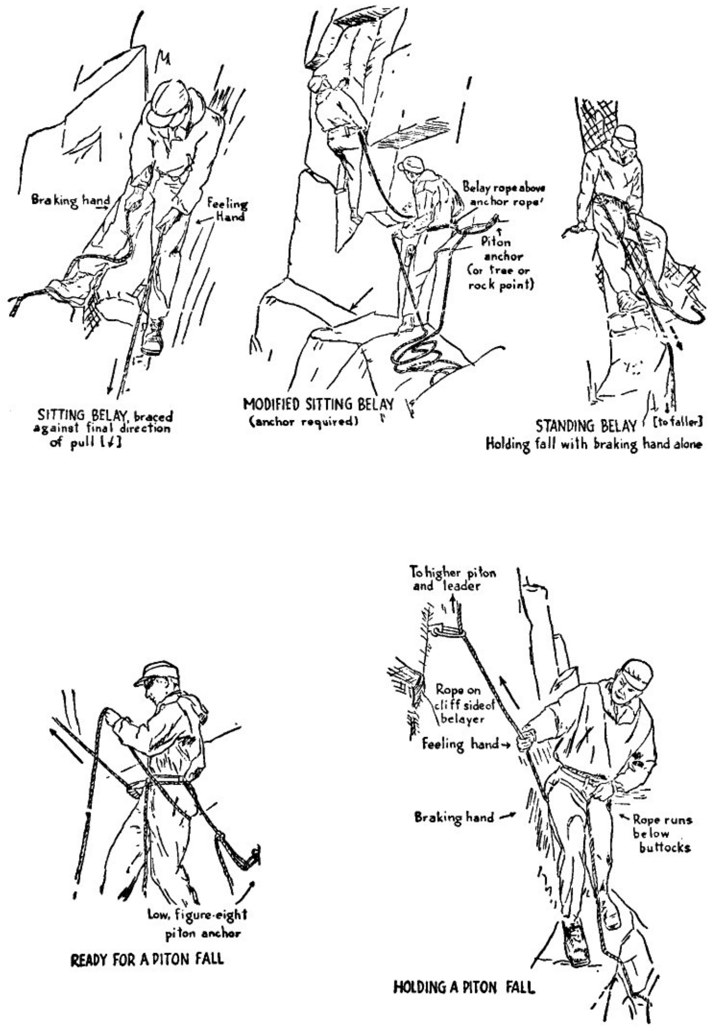


Fig. 20. The three most reliable climbing belays.

3) Anchor himself to the rock with a portion of the climbing rope if his position is doubtful.

4) Be ready to move the braking hand close in front of the body so that body friction can help check the rope in a fall.

5) Make sure remainder of rope is so laid out as to run freely through the braking hand.

6) See that rope does not run over sharp edges of rock.

7) Avoid letting too much slack develop in the rope through constant use of the feeling hand, except where this hand is used as an anchor. Gently tug the line running to the climber, thus sensing his movement. Avoid taking up slack too suddenly and throwing the climber off balance.

8) Brace well for the final direction of a fall, so that the force of the fall will, whenever possible, pull the belay man more firmly into position.

9) Be able, in case of fall, to perform the following movements automatically: (a) Relax feeling hand and move braking hand in toward body for friction. (6) Let the rope slide enough to let braking action be applied gradually, (c) Hold belay position, even if this means let ting the rope slide. No one profits if the belayer holds the rope so firmly that he is pulled from his belay position.

Sitting belay.—This is the preferred position when pi-tons are not in use. The belayer should attempt to get good triangular bracing between his two legs and buttocks. Wherever possible, legs should be straight. The rope should run around the hips at belt level or lower and be above anchoring rope, and braking and feeling hands should be held inside the thighs. If the belay spot chosen is back from the cliff edge, friction of rope over rock will be greater, and will simplify holding of falls, but the direction of the pull on the belayer will be directly outward, and the leader is less easily watched. If the belay spot chosen is at the very cliff edge, friction will be much lower, but a fall will pull the belayer directly down into his position. Such a spot will require the belayer to hang his feet over the edge, and should not be taken unless the sitting position slopes back and down into the cliff.

Standing belay.—This weak belay position with the rope running around the hips, although far stronger than the frequently advocated but wholly inadequate shoulder belay, is never preferred to the sitting belay (except as varied in the piton belay). An anchor is almost always essential.

Piton belay.—As soon as the leader has placed a reliable piton, the direction of pull when he falls will be forward and up on the belayer, who should therefore have a low anchor directly in line with this direction of pull, and should run the belay rope just below his buttocks. Both knees should be bent, to prevent the rope from sliding up above the buttocks. The braking arm should be extended; when a fall occurs the arm is brought in, with steadily increasing resistance, to a position in front of the hip where as much rope as necessary is then allowed to slide through the hand. A fall is easier to hold with a piton than without, especially through several pitons, because of the added friction between rope, rock, and carabiner. For this reason it is imperative that the belayer keep enough slack in the line to prevent the fall from jerking to a stop; likewise, he must not resist the fall too much when its impact first hits him.

Tension belay.—This is used when the leader, having placed a piton, wishes to lean back on his belay rope, either to rest or to drive in a higher piton. The piton belay position is used, except that the belayer, to support the leader, sits back into the rope and brings his key hand close in to his body to provide all possible friction.

Rock or tree belay.—Where possible, the leader passes his rope behind rock projections or trees, which can serve the same protective purpose as pitons. *Precaution:* he should avoid passing the rope over sharp edges, or in crevices where the rope could jam or cause too much friction as he climbs beyond. When a rock or tree belay has been definitely established, the belayer should assume the piton-belay position.

Anchors.—Experience in knowing how heavy a shock a good belay position will withstand will tell the belayer when he should take time to anchor, and when he need not. Until he has that experience, he should not belay a leader. He may anchor either to a rock, piton, or tree, and should ordinarily use two half hitches on a bight around the anchor. Small bushes may serve well if the anchor rope is passed completely around the base. The anchor should be tied with a portion of the climbing rope next to the belayer, and should be tied snugly enough to keep the belayer in position and not allow him to be jerked against the anchor in case of fall. Given a choice between anchoring to a rock point or belaying around it, the belayer should prefer to anchor.

Party Climbing

The rope converts two or three men into a team; they tie together whenever by so doing they increase their mutual safety and ability on difficult slopes. Although the rope is rarely used to pull on, it is, strangely enough, something to lean on. A leader who knows that his team, through proper rope handling, can stop his fall, will have moral support that materially raises his ability to lead. Before rope management can be adequate all members of the team must know the theory and have practiced so thoroughly that the rope is at no time a nuisance. The rope cannot boss the team; rather, the team should be able to dominate the rope, and more, to do so subconsciously. Three men who, roped together, can ascend a mere 500-foot slope of talus mixed with brush, moving at varying speeds, varying distances apart, jumping now and then from block to block; who can avoid dragging the rope on the ground, snagging rock points, or involuntarily throwing clove hitches around occasional branches; who at last reach the top with no snarls in their rope, having not once uttered "Wait a minute!" nor suffered any feeling of irritation, or are for that matter still on speaking terms—these three have achieved a good basic technique in the management of the rope. Should they learn belaying and rappelling as expertly, then moral support derived from their rope, if it is a good rope, will be based on a deserved confidence.

Continuous climbing (or roped walking).—Following is the procedure for dangerous, but not difficult climbing, in which an unchecked slip would be disastrous, but where a slip can easily be checked with a rope without use of a standing belay. The procedure also serves for easy going between difficult pitches, to save time of unroping, and is always used, with variations discussed later, on snow-covered glaciers.

1) Party ties in to rope. *A,* the leader, carries one loose coil of rope to be paid out if the rope is jerked suddenly. He climbs slowly enough to minimize the effort of *B,* the weakest man, who carries the rest of the rope. He selects a route behind trees or smooth rock points, so that these can serve as belay points in case of fall. On short, tough pitches he may gather in rope from *B* after he is up.

2) *B* and *C* watch the rope ahead, prevent its snagging in brush or loosening rocks, and keep it just taut enough to prevent dragging. They carry extra rope in neat coils in

one hand, take up or pay out coils if they go faster or slower than the man ahead, and climb as well as they can with the free hand.

3) If there is any chance of a dangerous slip by one or the other, each man continually anticipates the stances he must assume quickly and effectively in order to stop the fall.

Rope of two.—In very difficult climbing, where only one man can move safely at a time, while the other belays, the best man goes up first, down last, and is the leader. The least experienced man does the opposite. When only two men are on a rope they can move about three times as fast as three men on the same rope. Two ropes of two men each are the strongest party that can travel a given route quickly. Vocal signals given clear and loud serve best as communication between leader and belayer. If wind is high, a code using high pitched "screams" has proved successful. Rope signals are inadequate if the route is circuitous and pitons vary the attitude of the rope. Nevertheless, rope signals included below can be used for communciation when storm or angles of the mountain muffle oral signals which would normally be given. Procedure for two:

1) *A,* the leader, ties in, plans route, and awaits signal from *B,* the belayer.

2) *B* ties in, assumes belay position, anchors if neces sary, belays, and motions *A* to climb.

3) While *A* climbs, *B* watches him, the rope, the route, and the rock, and begins to put resistance on the rope grad ually when there is 20 feet of slack left, or calls out the number of feet.

4) *B* anticipates and is prepared for the final direction of pull of any fall.

5) When new belay position is reached, 10 feet or more

from end of rope, A signals "Off belay" (two jerks on taut rope), takes in slack rope, assumes belay position, anchors if necessary, signals "Climb" (two jerks). Whatever belay position A chooses is normally used by B when A continues, and should be strong enough to hold a 10-foot fall —the probable minimum if A slips.

6) B meanwhile replies "Off belay" (two jerks), takes off belay, answers "Climbing" (two jerks), follows A's route, climbing no faster than A takes up rope, signaling "Slack" (three jerks) when he wants him to pay out slack, or "Rope" (repeating two jerks) when he takes up rope too slowly.

7) If B is a proficient enough climber, he becomes the leader for the next pitch to be climbed; if not, he assumes A's belay position, and painstakingly avoids snarling the rope.

8) For rope signals the rope must be taut. To signal "Tension," climber places his weight on the rope (or one jerk) and belayer holds; belayer allows rope to run only on signal for slack, whereupon he pays out only as much as is pulled in by the climber at that time.

9) With two ropes of two men on the same route, the second leader follows B closely, accepting his upper belay if the pitch is severe and its ascent should be speeded, and anchoring B's belay of A if he is otherwise idle.

Rope of three.—(1) A climbs to the first belay position, brings up B, the second best climber, then continues to the second belay position, anchoring while B brings up C and follows A.

2) C anchors B when not climbing. On traverses, if C is the weakest climber, and A will not require B's better belaying, then C should be in the middle.

Pitons for safety.—The leader uses pitons for protection whenever he feels and before he knows that he is dangerously high above his belayer and is likely to fall. He also uses them for holds if they are needed to speed up and safeguard climbing, but does not use them in preference to natural handholds which are usually far quicker to use. The leader using pitons should:

1) Select, if possible, a route that will probably not require pitons, as it takes a great deal of time to drive them in and manage the rope when they are used.

2) Carry enough pitons and carabiners to take himself over the pitch, allowing for bending and loss; they should be carried, hooked into carabiners, on a sling placed over the shoulder and under the opposite arm.

3) Place and test pitons carefully.

4) Choose a route for the rope that will reduce friction—the worst hazard in pitoncraft—where the rope bends around carabiners, binds over rock between pitons, or runs around the belayer's body. The greater the friction, the more the leader must pull on the rope to secure enough slack for each step, and the more likely is his injury if he falls. If he foresees that friction will be too great, he may lead with two ropes, snapping one into the carabiners until friction is high, tying the first rope into the top piton, and freeing himself and the second rope, now snapped into the top carabiner, for further leading, *B* tending the second rope.

5) Establish a well-planned belay and anchor that *B* can take over quickly and securely if the position is cramped. It may be better for *B* to assume the lead.

6) In a difficult position, snap into a piton as soon as it is driven far enough to be of any possible value, and test it later.

7) Have the last man recover the carabiners and remove the pitons unless time is short.

Removing pitons.—The piton hammer is not strong enough for prying pitons. The climber should pound them back and forth in the crack with a hammer or rock, and when they are loosened, pull them out by repeating the procedure for testing. It is advisable to be well braced, as they often come out very suddenly, and to see that no one is close enough to be struck by the flying piton.

Tension climbing.—The belayer, in tension climbing, holds the leader to the rock by means of rope and pitons, the carabiner in each piton serving as a pulley. Thus the leader may be above or to one side of his belayer and still be able to climb, driving pitons successively higher for tension, even though natural holds are absent. Tension climbing is necessary when an easier route cannot be found or used. Often it is used in one or more short, difficult pitches in an otherwise easy route. The tension climber should follow this procedure:

1) Drive pitons no closer together than necessary for safety. The piton need not be so secure for holding body weight as for holding a fall.

2) Never hook a finger in a piton, but put in a carabiner and climbing rope, and hold on to them.

3) Use rope slings for foot and hand holds only when tension from the belayer will not hold him, through his highest piton, high enough on the rock to place a higher piton, or when the downward moment of the pull of ten sion on the piton is the safest.

4) Rely on the belayer's tension, keeping both hands free for the work above.

5) Use alternate (two-rope) tension for the most diffi cult pitches. Two belayers are desirable to slack off and hold the two ropes alternately as the leader, held by a taut rope, snaps a slack rope in successively higher pitons.

6) The belayer should anticipate the leader's needs so that few signals need be given.

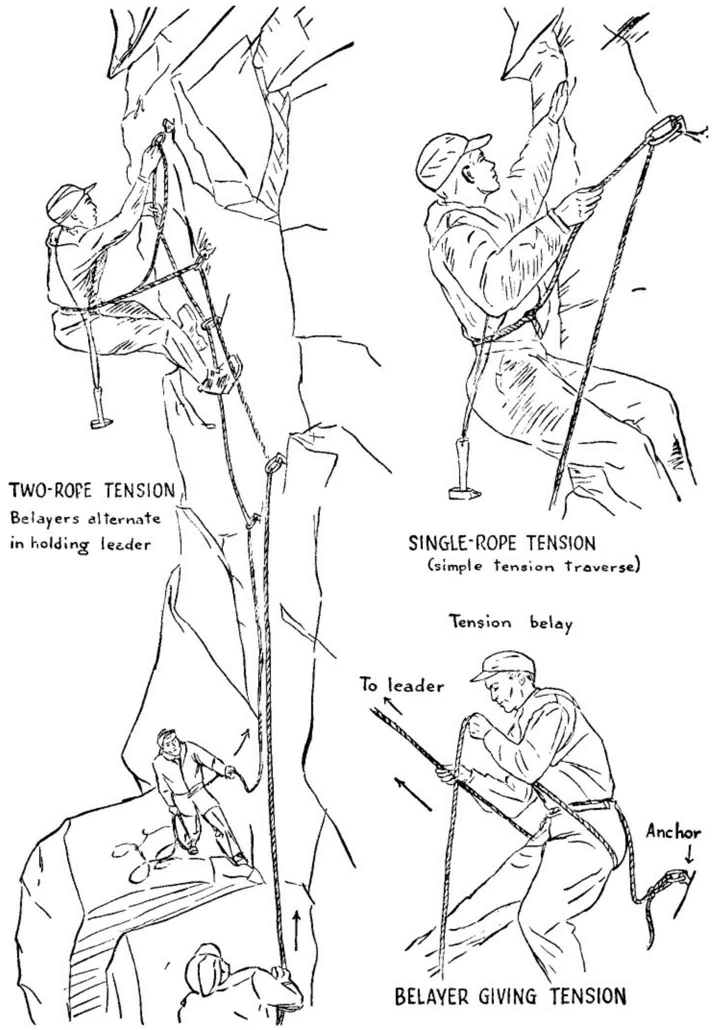


Fig. 21. Tension (direct-aid) climbing.

7) When the leader requires tension, the second man will need assistance on that pitch. Any necessary rope slings should be left for him, or a second rope afforded as hand line while the leader gives tension.

Rope traverses.—The rope, used either for tension or as a rappel, may further aid the climber in traversing or swinging from a blind route across a holdless face to better climbing. The party should be assured of a means of return before retrieving the rope.

Isolated pinnacles may be reached or gaps crossed by means of a Tyrolean traverse—a single-rope suspension bridge. The primary problem is anchoring the far end of the rope, which may be accomplished by:

1) Holding both ends of a doubled rope and throwing the looped middle across the gap to the far anchor point, securing it by judicious flicking around the anchor.

2) Tying to the intended far end some object which will securely jam in a crevice or tree crotch on the far side, thus serving as dead man.

3) Belaying one man across.

The near end is then anchored and cinched, with care, to prevent excessive sag. There should be a sag of more than 1 foot per 100 of unweighted line, and the rope must not be cinched repeatedly after loading or it will be seriously and cumulatively weakened through loss of resiliency. The rope is then crossed in a slothlike manner, each man, for security, hooking a carabiner through his waistloop and to the line.

Fixed ropes and hauling lines.—Passage of a difficult route that must be traveled often, perhaps by heavily loaded persons, may be simplified with fixed ropes and hauling lines. The rope is most helpful if anchored with figure-eight slipknots to carabiners or rope slings at frequent intervals. A better rope is installed if the climber works up from the bottom, belayed from above, and cinches each section as he goes. The line should be close to the rock, so that the hand may be used as a hook, rather than as a clutch. Loads are best hauled in the climbers' packs. If a pitch is too difficult for a heavily loaded man to climb unaided, an endless upper belay loop may be contrived from a second climbing rope and carabiners (2 to diminish friction) that have been anchored above the pitch to serve as a pulley. The loaded climber ties in, then is belayed, or perhaps hauled, from below. All lines should be removed, both to keep the mountain clean and to avoid enticing inexperienced persons who might otherwise try to use them.

Rescue.—Fixed ropes, hauling lines, and the Tyrolean traverse are readily adapted to mountain rescues. Details of the use of mountain equipment for this work, as well as for the use of field expedients, were perfected by the Mountain Training Group of the U.S. Army, and are dealt with fully in the field manual, *Mountain Operations.* See also: "Neuzeitliche Bergretungstechnik," pages 199-200.

17. Ice-Climbing

CLIMBING on ice and rock requires the same niceties of balance, of avoiding objective danger, of maintaining a margin of safety. But ice adds a few complications. The margin must be greater—the dangers are different, as are the mechanical aids, whereas methods of correcting errors in judgment are less sure. And where the rock-climber must rely on nature's fortuitous placing of holds and ledges, hoping that he can put the jigsaw pieces together into a complex route, the ice-climber needs only the proper surface; if his technique is good enough, he can cut holds, belays, even bivouacs where he needs them.

Training.—Control that has been learned on easy ridges and rocks can be applied to ice; if easy glaciers and snow slopes can now be added to the training grounds, so much the better. A procedure parallel to that given for early training for rock can then be followed as the skier learns control, the use of equipment, and acquires endurance on ice.

Ice and snow walking.—A climber walking with nailed boots should select his foothold, place his foot on it accurately, and leave his foot as placed, without twisting or turning, until he moves it to a new hold. Pace and stride should be moderate. Weak surface crust that will break if the heel strikes first may hold if the foot is placed flat. If deep tracks are made, each man should follow in the

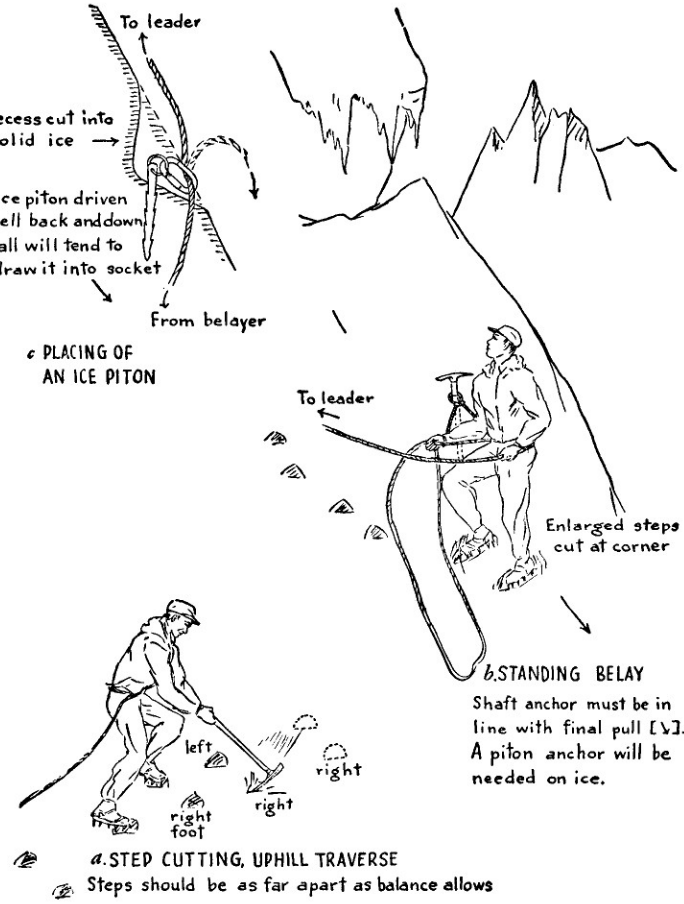


Fig. 22. (*a*) Step cutting; (*b*) body belay on snow; (*c*) diagram of ice piton in place.

leader's footsteps, spelling him off after a prearranged tour of duty at the arduous job of breaking trail. (See also *Pace.)*

Climbing Aids

Use of the ice ax.—(1) When the climber is skiing, the ax is placed head down in the rucksack, the pick preferably resting against something more substantial than the sugar bag.

2) During an ascent on rock the ax may be suspended by the wrist loop, inserted through the belt behind the hip, placed like a sword through a loop of rawhide tied where the left shoulder strap meets the rucksack, or placed head down in the pack. No method is satisfactory, but any is better than leaving behind an ax that may be needed badly

3) Easy glacier walking. The ax is used primarily as a cane, and is held with the hand over the shaft and the pick out or forward. It may be carried horizontally, with the point forward, so that the user can choose whom it sticks, and the pick down, where he won't fall on it. A third posi tion is under the armpit, the pick curving up behind the shoulder, the point forward and down. In traverses of gentle slopes the ax is held in the uphill hand.

4) Steep slopes. When steps are kicked and the slope is steep enough to require additional assurance, the shaft should be driven vertically and deep into the snow to serve as a secure handhold for each pair of steps. Steps will break out if the climber leans in too far to grasp the ax.

5) Probing. Here the ax is used for safety, testing for each step the consistency of questionable snow, searching for hidden crevasses. Resistance to the ax is being com pared, and only experience will tell the climber what the comparison means. A simple rule, not wholly adequate, is: if the ice ax stops, the snow may hold your weight; if the ax

doesn't stop, you had better. If probing is necessary at all, the party should be roped.

6) Glissading. The ice ax serves as a rudder, outrigger, and brake for the climber who wishes to descend snow slopes quickly by sliding on his feet or seated. If the snow surface is right, christiania swings will work passably well without skis. Skiers should take care, however, that they develop a thorough respect for high-mountain snow slopes, which take a heavy toll of the ignorant. Once sliding has started it is not always possible to stop, should the snow slope turn out to have a surprise ending, such as a talus pile, crevasse, or cliff. If the shape and consistency of the slope are not fully known, glissading should be attempted only by a roped party, one man moving at a time. The sitting glissade is swifter than the standing position, but less graceful, wetter, harder to control, and the climber is vulnerable to rocks hidden, but not padded, by snow.

7) Self-arrests. The point of the ax has been shown to be useful in controlling a voluntary glissade. It will also assist in controlling involuntary glissades if the snow is soft and the slope gradual. But fall face down and check with the toes. The heels are a better catapult than brake. To arrest falls on steep snow or ice: the ax is grasped with one hand around its head at the shaft, pick down and adz over the same shoulder; the other hand grasps the shaft about 18 inches lower; the climber falls face down and smoothly grinds the pick into the snow until he has secured enough braking action to stop himself, but not so far nor so abruptly that he loses control on the ax. For soft snow the adz may be down. Should the fall begin on the back, the climber rolls over onto his stomach toward the ax head and begins the arrest. Self-arrest is no contribution to safety until the user has tried it out several times, with various snow conditions, on slopes with a safe outrun.

Gloves are recommended for practice arrests on hard snow and ice.

8) Traverses on steep slopes. Snow texture and the self-arrest technique it requires will dictate how the ax should be held in traverses, so long as the climber bears in mind that an ax held on the downhill side may be fallen on before it can be controlled, and an ax head held too high above him on the uphill side may be out of reach if he suddenly falls. The most used position on a traverse: point to the slope, shaft nearly horizontal, inside hand on middle of shaft, outside hand on head at shaft, pick down. For still steeper traverses the shaft is driven deep into the slope for each step, and the ax head is held by both hands while the next step is kicked.

9) Balance. As on rock, the climber's center of gravity should be over his feet, even when he is holding the ax in the traverse position described above. The horizontal position of the ax is a great aid in permitting one to touch the slope for better balance without leaning in.

Use of crampons.—Crampons should be tied securely and used confidently. On most snow texture they may merely be placed, but on hard ice they must be stamped into position. That position is then held until the foot is moved to the next step, without being slid or twisted. Ankles and knees do all necessary bending; the body must remain vertical. The crampon is not edged into the slope, but placed flat on the surface. To avoid tripping, the foot must be lifted farther than normal off the snow and swung a little wider of the other leg. Running in crampons is possible, but is frowned upon. Easy slopes are ascended directly, moderate slopes are traversed, steep slopes are backed up, and the steeper they are the lower the crouch and the greater the reliance on the ice-ax point.

Extreme danger arises when snow balls between the crampon points so that little or no traction is obtained. Many fatal acidents have resulted. Since crampons are usually needed and used only on high-angle slopes of ice or very hard snow, full precautions against the event of a fall should be taken. To climb with crampons "instead of" an ice ax is like climbing with pitons instead of a rope or motoring with a steering wheel instead of a brake.

Step cutting.—Perhaps there is no finer example of mountaineering than that afforded by the climber who can swiftly and precisely cut and use steps on a steep ice slope. Many are the complaints, in mountaineering literature, of those who have been forced to follow the lead of such a man, who would seem with few strokes to have cut many imperceptible steps and to have moved over them skillfully, hardly seeming to have poised in one long enough to ascertain that it would hold him. The ski mountaineer, however, would do well to start with steps that are more bucketlike.

At least two horizontal strokes with the pick will determine the slightly inward-sloping floor of the step, and should be followed by enough vertical strokes to clear room for at least the inside of the ball of the foot, and often for the entire foot and lower leg, if the slope is very steep. The adz levels the floor of the step. The wrist loop must be worn. If quarters are cramped, the shaft may be choked, but then the point can easily stab the climber. The ax should be held in both hands if possible, to spread the fatigue. One hand is usually all that is available.

Fair handholds may be cut in the ice. They are apt to break out if cut with too pronounced an inward slope, and are hard to hold if not.

The conformity of slope and climber will govern the placing of steps. Ordinarily they will be cut in pairs from each stance; that for the outside foot is lower, and for the inside foot is diagonally back and about 10 inches higher.

To step from pair to pair, the climber balances himself with a handhold or the pick of his ax, and moves the outside foot first, following with the inside foot, which is then used in the most comfortable manner to balance the stance from which he will cut the next pair of steps. Pairs should not be so far apart as to impede balance. A series of zigzagging diagonals provides the most desirable route up the slope—and also requires that the climber be able to cut equally well with either hand. An extra-large step will facilitate "kick turns" at the end of each traverse and when sufficiently enlarged will help establish the belay positions for the second man as he moves up.

Steps may, of course, be cut straight up a slope with more difficulty; this, however, subjects the belayer to the minor hazard of falling ice chips and the major hazard of a falling leader, who would probably sweep him out of his belay position. The leader may use tension when cutting down a slope; his reach will still be too limited for him to cut the steps excessively far apart.

The devices to keep him from slipping—the ice ax, nail patterns, crampons, ice pitons, ropes, carabiners—have become rather highly developed. How to use these tools properly on steep ice and snow seems to have been an elusive problem and for a while the techniques in use were apt to be inadequately formulated even though used on actual climbs. In the Northwest where the glaciers are more readily accessible for the weekend practice session, belay experience has progressed to the point where choice of the best belay technique can be made and detailed with some degree of confidence. Mere discussion of these techniques is not enough; the climber who belays successfully on ice and snow is the one who has thoroughly practiced the use of the belaying tools and knows their limitations well. For a more detailed discussion of the techniques that follow, the reader should see *Mountaineering: The Freedom of the Hills.*

Body belay.—As on rock, it is better to interpose the resilient and well-positioned frame of the belayer between the climber and the belay anchor wherever possible. Anchors are best achieved through the use of ice bollards or ice pitons, never by means of an unattended ax. A third man may anchor the belayer by using an ax belay. The techniques for belaying will be as described for rock. Remember that sharp ice will abrade a rope as quickly as sharp rock.

Boot-ax belay.—The only effective way to anchor the ax is to drive the shaft as far as possible into the snow. The depth of penetration and the snow conditions will directly affect the value of the belay. Ideally, the ax will be driven in to the hilt at the back of a small platform stamped into the snow, pick pointing into the slope. The belayer stands below the ax with the well-weighted uphill boot placed solidly against the shaft. The ax is also braced with the uphill hand. The rope from below crosses the toe of the boot, bends around the shaft and then continues around the boot heel, where the downhill hand controls it. The steeper the slope becomes, the more difficult to operate this belay, in which case (one hopes) ice will be present in which to place a secure ice piton.

On steep ice, a belay over the pick, the latter having been driven as far as possible into the ice with shaft flush against the slope, will give some support as an upper belay. In such cases, a boot-crampon spike belay is probably better. A fair sized step is cut and the crampon is stamped into the flat part of the step as deeply as possible and heavily weighted. The spike of the ax is forced into the step behind the boot (with pick also driven into the slope) and provides some additional holding power. The rope leads through the belay as with the boot-ax belay. The belay is at best still not suitable as a lower belay and an ice piton should be placed.

For a summation on belaying that comprehends classical experience, the lessons learned in half a million man-hours of army rock-climbing, and strength of materials as documented by the National Bureau of Standards as well as other authorities, see Belaying the Leader: An Omnibus on Climbing Safety, by Leonard, Wexler, et al., Sierra Club.

Use of ice pitons.—Considerable experience is required in driving ice and rock pitons to determine when they are sound. Both may provide excellent security, or may be equally weak. One must drive his own and chop them out, again and again, on practice slopes. Ice pitons have a definite advantage over rock pitons in that they can usually be driven wherever needed. Their weight and expense, however, plus the difficulty of getting them in and out, means that they must be used less lavishly. Many excellent ice-climbers believe that the piton belay alone is justifiable on high-angle ice. The record of casualties in using other types of belay certainly indicates, at least, that something better is desirable. Much further study is needed.

Rotten ice should be cleared away with the point of the hammer before the ice piton is driven. Much better support is given the piton if a recess for it is cut into the solid ice. High air temperatures or sun may leave the piton a loose pin in a socket; consequently, the piton should be placed well back in the recess and driven down into the ice at such an angle that a fall will help pull it down into its socket. The piton is more secure at subfreezing temperatures ; therefore shade, storm, or early morning hours may work to advantage. If the piton is frozen in its socket, it will, like a tent stake, hold a direct outward pull better than a pull at right angles to the shaft. If the pitons are used for tension, it must be remembered that the climber's weight serves to melt the ice around the piton shaft. A toothed edge should hold, however, while the climber's weight is on it—provided his weight is not on it too long.

Ice screws have exceptional holding power even on direct pulls. They take more time to place, but do not require the use of a hammer and are easy to remove. A carabiner placed into the ring serves as an effective handle; more leverage is needed if ice screws are placed in fairly hard ice. In such ice this type of anchor may be the only one that can be placed.

Party Climbing

In travel on snow-covered glaciers the rope is always on —for all practical purposes whenever the party is outside of sleeping bags. A party of two men is too weak on any ski-mountaineering trip, let alone travel on a crevassed glacier. Three should be the minimum; two ropes of two, both following the same route, provide maximum speed and security. The four will preferably tie in to the same rope if continuous roped travel is possible. Each climber attaches a Prusik sling to the rope taking care that it is drawn down behind his bowline or butterfly and tucked into a pocket. The rope should be kept taut between members of the party at all times. Should one man of a three- or four-man team fall into a crevasse, his companions can all contribute to the "belay" by falling into self-arrest position. Experience has shown that the frantic attempts at belaying after the fall has begun are usually inadequate; there is not normally enough time to arrange an effective shaft belay and generally the surface of the glacier is such that the shaft will not penetrate far enough to be of much use. After a fall is thus arrested, those persons not directly holding the climber may unrope and assist in retrieving the absent member. *(Precaution:* there may be another crevasse, still to be discovered.) In all probability the leader, if he fell, should have probed better with his ice ax, and if he suspected unstable snow should have changed his route, or have asked for a belay and then crawled, better to distribute his weight.

If there is a crevasse to be jumped, each man should use the broad-jumper's technique, landing with both feet forward, and should continue to roll forward to plant his pick, holding the ax as in a self-arrest. He should not have neglected to secure enough slack rope before the jump. At other times the rope should be held taut enough to prevent unnecessary dragging in the snow and to preclude deep falls into crevasses.

The rope must be so snug at the waist as not to be pulled down over the hips in an upside-down fall. If the rope is long enough, a bowline on a coil or a double-loop butterfly will, in event of fall, provide a more comfortable distribution of weight than a single loop. An additional loop over the shoulder will keep the rope high, but is not advisable for that very reason. A man who has fallen will be unable to get the loop down and constriction of his chest may suffocate him—unless he can contrive a foot sling, quickly get into it while awkwardly suspended, and relieve that constriction.

Roped skiing.—Speed and broader distribution of weight provided by skis will diminish the probability of the skier's dropping into hidden crevasses. But he can still drop in, especially if he falls, and should be roped. The self-arrest is aided by the anchor man's falling and placing his skis at right angles to the direction of pull. Hands should be out of the wrist loops of the poles, so that if there is a break-through the anchor man may grasp the lower part of the pole for a self-arrest.

The route should lie at right angles to the crevasse system so that no two skiers will be over the same crevasse. This suggestion assumes that the skier will perceive or know the direction of the crevasses; the assumption is optimistic indeed when the glacier is heavily snow-covered and its edges cannot be seen. If occasional large crevasses are open, they will provide a clue. Otherwise it must be deduced—and hoped—that the crevasses are perpendicular to the direction of flow of the glacier at its center where that flow is most rapid, and curve progressively farther upstream the nearer they are to the edges, where the flow is least rapid. Each man then follows the leader's tracks to avoid excessive cutting of the snow surface and to take advantage of snow cover that has at least demonstrated it will hold somebody. The speed of descents should be governed by that of the poorest skier; turns should be made by all men on the rope at the same time, on signal of the first man, so that the rope can be kept properly taut. A rope that is intermittently slack and taut will protect the skier too little and too much.

Rescue

Odd indeed is the glacier traveler who hasn't fallen into at least one crevasse, and who has not suffered the indignities of being jeered for his clumsiness by his companions, who photograph and push a little snow on him before they help him out. The victim takes this lightly, for he knows he will have his day before the trip—or even that day—is over. The usual rescue is casual. The faller's pack or ice ax prevents his dropping much more than waist-deep into the crevasse, or he is able, when he feels the snow give, to fall forward and bridge the crevasse. The rope quickly becomes taut enough to hold him where he is, and a little tension gets him out.

Self-rescue.—Chances are the victim will still have his ice ax; the wrist loop he presumably was wearing will have saved it. If conditions are right he may be able to climb out utilizing the configurations of the crevasse to his advantage. If they are not right, he may be able to use the Prusik method of ascending the rope, if he has taken the precaution of attaching the slings before taking his fall. Three 6-foot slings are needed: two for the feet and one for the chest, all three being tied onto the anchor rope with the Prusik knot. The knots will hold when weighted, slide when unweighted. The weight is placed onto the feet as quickly as possible to relieve constriction of the chest. The three loops are consecutively unweighted and with great effort slid by hand up the wet rope as the climber ascends. Difficulty will be encountered in getting up over the lip where the rope bites deep into the snow. A single rope of two, however, will not usually be able to extricate itself if one of the team is down.

Team rescue.—Assuming again that one member of a three- or four-man team is down and the fall arrested, one or two persons will immediately be available to begin the rescue. A conscious person can be raised by the Bilgiri method (fig. 25), whereby one belayer above alternately raises one foot sling while the fallen climber slides his own Prusik sling along his anchored climbing rope to provide purchase for the other foot. An ax or heavy clothing placed under the rope at the lip will prevent deep penetration by the moving rope.

If the victim is unconscious, a good first-aid procedure would require that the nature of the injury be learned before he is moved. After an assistant has descended to the victim and prepared him for the evacuation, a pulley system is installed (see "Mountaineering") and the lifting begins.

Pulley system.—Set the main anchor far enough back from the crevasse lip to allow work space. An ice ax or ice bollard will suffice, but do not leave the anchor unattended. Presumably, the fallen climber is already being held on anchor and precaution has been taken to prevent the rope's biting into the crevasse edge. Attach a long sling with carabiner to the main anchor. Attach a short Prusik sling to the climbing rope near the edge and a longer Prusik sling just below it. Tie the longer sling onto the original anchor and ease the load over to this sling. The climbing rope is then snapped into the main anchor, brought back and snapped into the short sling (all with carabiners, or preferably, wheeled pulleys), then led up to those doing the hauling. As the rope is pulled up, the short sling moves toward the main anchor carabiner. The hauling stops while the alternate anchor sling takes the load. The short sling is loosened and moved back down the climbing rope for the next haul. This process is repeated until the victim reaches, and is brought over, the top of the crevasse. The pulley system operates much the same on rock terrain except for the differences in anchoring and rope-protection problems.

Two persons can raise 180-200 pounds; four can raise two climbers, the injured and the assistant, if necessary. Additional ropes and slings may be required depending on the location of the victim.

One-man rescue.—The brute strength required to pull a man directly from a crevasse is nonexistent, or rare at best. Friction of a rope that has cut deep against the snow is prohibitive. The rescuer must have some means of freeing himself from the rope so that he can work. The

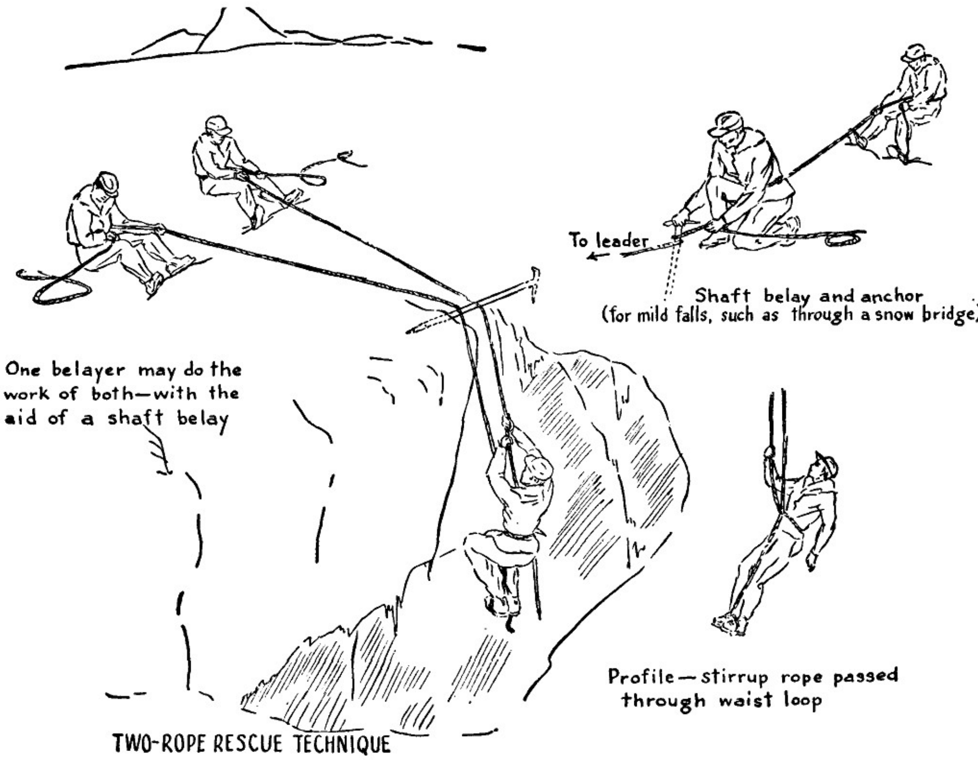


Fig. 23. Two-man crevasse rescue and the anchored shaft belay.

anchor butterfly in his climbing rope provides this. With the victim anchored by the butterfly, the rescuer unties, places whatever smooth object he can find under the rope near the crevasse lip to prevent the rope's digging in any farther, places a short Prusik loop around the belay rope and anchors it to the ice ax to serve as a ratchet, and then hauls with all he has, using his leg muscles and hip belay as much as possible, meanwhile sliding the Prusik knot along the rope to hold all he gains and permit the frequent rests he will need. He may meanwhile take a very dim view of his prospects of success. Prospects would have been much brighter with two ropes between the two men and a conscious victim.

Two-man rescue.—If the victim is unconscious, a good first-aid procedure would require that the nature of his injury be learned before he is hauled anywhere. It may further be desirable to tie a second rope or portion of rope to him. The assistant may rappel to the victim for these purposes, climb back up the rappel by methods suggested above, and then assist in the hauling. If the hauling rope is passed through a carabiner in a waist loop on the victim, and one end of the hauling rope is anchored to an ice ax on the far side of the crevasse, the other end may be pulled and the victim raised with a theoretical mechanical advantage of two. He is also much freer of the overhanging lip of the crevasse. Another rope will be needed to get him finally up and out.

L'envoi.—Perhaps we should end the book on a pleasant, positive note: for more enjoyable ski mountaineering, simply avoid stumbling into predicaments where you need to be rescued—and urge your friends to do the same. We don't mean to suggest that you stay home. Statistics prove that *there* is where most accidents happen.

To be safe, ski!

Appendix: Check List of Equipment

THE SKI MOUNTAINEER would do well to peruse this list before each trip, to be certain that he has omitted no essential item, as well as to ascertain which items among his equipment he need not carry. Weights, where given, are in ounces, and represent a minimum which the skier should strive to attain—or to better.

EQUIPMENT TO WEAR

ADVISABLE

Underwear	Ski boots	Matches
Shirt	Parka	Pocket knife
Socks	Mittens	Skis
Ski pants	Bandanna	Bindings
Belt	Dark glasses	Ski poles
Hat or cap	Gaiters	Watch

OPTIONAL

Knapsack	Notebook and pencil	Handkerchief

EQUIPMENT TO CARRY

ADVISABLE

Rucksack or pack frame 56-76
Emergency kit........... 18
Adhesive tape 4
Outer mits .. 3
Sunburn protection 1

Headband ..1
Blizzard visor....1
Sweaters or down jacket with hood . 18-'. 2
Waxes 1
Bandanna .. 20
Skins ....

Air mattress or foam insulation .. 26
Sleeping bag 32,80
Compass, small 2
Flashlight .. 2
Undersocks . 3

Equipment to Carry *(continued)*

ADVISABLE

Oversocks .. 5
Cup 3
Map
Toothbrush, soap, and comb ----- 2
Extra matches 1
Total (pounds). 14

OPTIONAL

Air mattress ... 32
Extra glasses ... 1
Case for above . 2
Balaklava helmet 5
Innersoles 4
Emergency food 12
Camera and film 30
Windpants........... 14
Cigarettes 4

Community Equipment for Three or Four

ADVISABLE

Tapered tent .. 64
Repair kit 18
Headlight 22
One stove, funnel, and container 34
Two nesting pots 16
Five spoons 4
Extra glasses, case 3
Food and containers (per man-day) ... 40
Fuel and containers (per stove-day) ... 16
Toilet tissue
Matches
Two flasks 8

OPTIONAL

200 feet 5/16" rope 100
Hand ax, sheath 29
Emergency food 32
Snow shovel .. 8
Extra laces ... 1
Can opener ... 1
Ace bandage ..2
Boot wax........... 8
Extra battery cells 10
Stove parts ... 1
Milk whip 4
Playing cards 3
Aneroid barometer 3
Therometer ... 3
Light saw blade 3
First-aid extras 16
Putty knife ... 2

Equipment for Rock and Ice (for Four)

Crampons, 2 to 4 88-176
1 ice hammer 44
1 to 3 ice axes ____40-120
Carabiners, 12 24
1120-foot 7/16$_6$ nylon climbing rope 96
1100-foot % nylon climbing rope 96
Hammer 24
Pitons: 4 for ice 32
16 for rock 90
80 feet 5/16" sling rope 40
16 route markers 16

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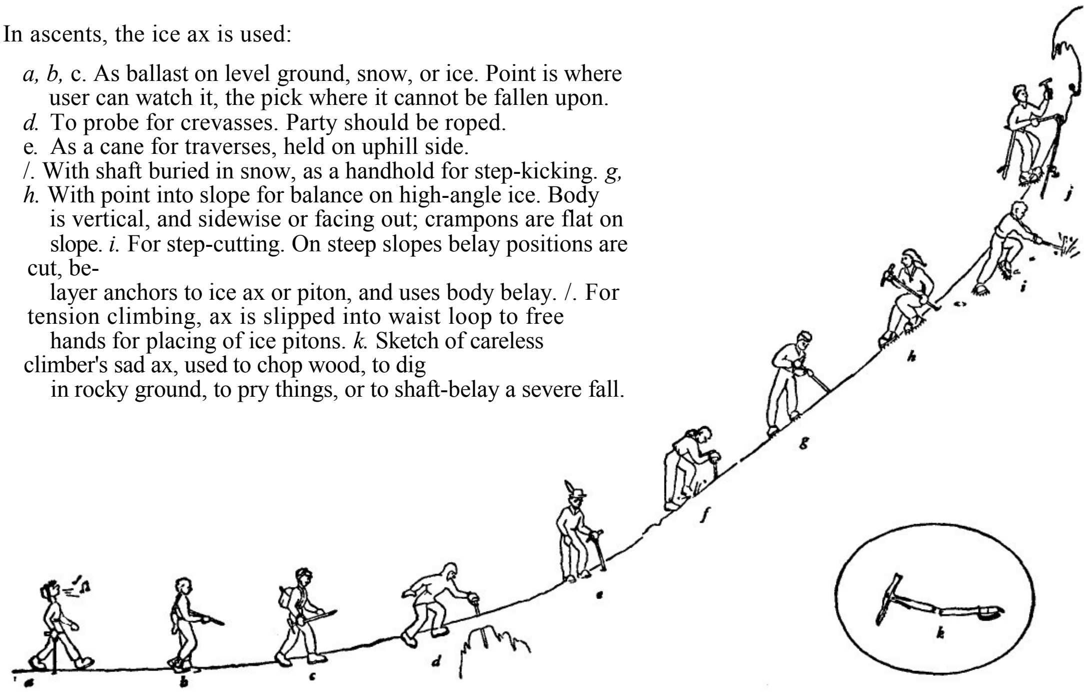
In ascents, the ice ax is used:

a, b, c. As ballast on level ground, snow, or ice. Point is where user can watch it, the pick where it cannot be fallen upon.
d. To probe for crevasses. Party should be roped.
e. As a cane for traverses, held on uphill side.
/. With shaft buried in snow, as a handhold for step-kicking. *g, h.* With point into slope for balance on high-angle ice. Body is vertical, and sidewise or facing out; crampons are flat on slope. *i.* For step-cutting. On steep slopes belay positions are cut, be-
layer anchors to ice ax or piton, and uses body belay. /. For tension climbing, ax is slipped into waist loop to free hands for placing of ice pitons. *k.* Sketch of careless climber's sad ax, used to chop wood, to dig
in rocky ground, to pry things, or to shaft-belay a severe fall.



In descents, the ice ax is used:

a. As a rappel point—but not for the last man except as last resort; rope must be low on buried shaft of ax, as in the shaft belay.
6. For downhill step-cutting. Tension given from above aids reach.
c. For support in steep, direct descents with crampons, which must be kept flat on slope and ever clear of balling snow.
d. For self-arrests. One hand on head, the other on shaft. Pick is a brake—if turned into ice gradually.
e. As a handhold during backward step-kicking.
/. As a cane when heels are driven into snow.
g, h. As a rudder and support in standing and sitting glissades. *i.* For balance in crevasse jumps, held ready for self-arrest. ;. To complete the tripod for a standing "blow." *k.* Sketch of careless, sad climber, whose ax is deep in the crevasse because he used it without wearing the wrist loop.