MOUNTAIN TRAINING COMMITTEE
10TH SPECIAL FORCES GROUP (AIRBORNE), 1ST SPECIAL FORCES
APO 108, US Forces

MOVEMENT ON ICE AND SNOW

The principles of travel on snow and ice are similar to those of ordinary mountain walking or of rock climbing for which you have already received training.

Walking in snow just as walking on other terrain calls for a steady pace with the body erect. If you lean forward you will find that your feet will slip back which will tire you very rapidly. Stand up straight and plant your feet firmly. Take short steps which also decreases slipping as it does not require a push with the rear foot. Each member of the party should take care to walk in the same tracks, as each succeeding person packs them down and makes them firmer. For this reason the leader should make sure that his stride is short enough to enable the smallest man in his group to move without discomfort. Breaking trail is hard work and the lead should be changed frequently. It helps if a definite time is set or a definite nember of steps is given for each man to lead, then he will step out and the next man will take over with the former leader dropping in at the rear. On deep, steep snow at high altitudes it will be found that 100 steps is a long lead.

Roping up is done in the same manner for snow and ice climbing as rock climbing. The shoulder loop, in addition to the usual chest loop should be used on glacier, because, if you do fall in a crevasse and land upside down, there is no danger of falling out of a loose loop or hanging upside down. In glacier travel three men on a rope are much safer than two, for it is very hard for one man to pull another from a crevasse. Repe length and intervals between climbers are the same as for rock climbing. It is best to move on glaciers with the rope completely extended between the men and with a small butterfly knot tied about an arm's length up the rope from you through which you pass the ice axe. This facilitates a fast belay in case of need, even with a taut rope on the man ahead. The rope should be taut enough to prevent a fall far into a crevasse and it should also be kept free from dragging in the snow as much as possible as this makes it wet, heavy and kinky, and results in frozen rope.

When it is necessary to use two men on a rope a double roping technique will be taught so that in event of a break through the man on top has two ropes immediately available.

Climbing on snow calls for application of your climbing technique to steeper terrain. As the slopes become steeper, steps must be kicked in and on steep snow just as in your ordinary mountain work, zigzag courses will be found less tiring. In climbing straight up, the ice axe driven into the snow provides a safe protection in case of a slip; in traversing, carry it across the body, or in deep snow on a steep slope drive it vertically in on the uphill side. Never carry it as a walking stick dangling on the downhill side, as it is absolutely useless in that position. If the snow is frozen hard and crampons are not resorted to, a slash step can be cut with the axe which will prove effective.

Crampons are a great help in climbing on ice and snow as surprisingly steep slopes can be climbed by using them without step cutting. When using crampons the normal forward swing of the walking foot has to be forgotten. The foot is lifted rather high and is planted cleanly on the ice without the usual forward scrape. This high, clear lift of the foot must become mechanical which you do not know as safe. You may run into a crevasse, a pile of rocks, glare ice, and unseen cliff or other dangers which cannot be seen from the top.

On glaciers, besides the task of making and using steps there is the real job of finding the best route, up and down, or of deciding if it can even be traveled on at all. If the climber has not been able to conduct a reconnaissance he has one or two rules to follow:

The shady side of the glacier usually offers the best chance of finding closed up crevasses or of locating bridges or connecting flakes which will help him through any system of open crevasses which extend right across the glacier. Also on that side there is less avalanche danger.

On a curve on a glacier the inside may appear to have steeper and rougher waves of surface ice since the movement of the glacier is more retarded on this side but actually this side will be less instricted and the crevasses more contracted.

On the outside of the curve it may appear to be easier going but the crevasses will be open and deep. Also on this side you usually find a ststem of edge crevasses caused by friction on the ice against side walls and also by uneveness of the bed. Those are in addition to the usual network of crevasses. Being on the outside of the curve they are not subject to compression and they are not only open but they stay open. It is best to avoid these by traveling towards the middle of the glacier until they run out into harmless cracks.

There are three ordinary systems of crevasses. These are marginal crevasses, tranverse crevasses, and longitudinal crevasses. I have already mentioned the marginal type and how they are formed.

The transverse crevasses are caused by the falls in the bed of the glacier. It is best to cross them on a direct line up or down the glacier. If the glacier is humped in the middle the crevasses will be less open on the side, while if it is more or less hollow they will be less open toward the center.

The longitudinal crevasses are caused by openings in the side walls in the glacier bed or to long ridges running down the bed which push up the center of the glacier. This is the most dangerous type to travel through. Crevasses must be approached for crossing at the right angle to the way they run. A party going up or down the glacier lengthways must always swing on the rope until a least two of the party at a time are approaching the crevasse at right angles. This is fairly easy on a glacier clear of snow but when the crevasses are hidden or snow covered it takes a pretty good leader to keep the party from moving along the same line as the crevasse they are going to cross or even over the crevasse itself.

In moving through ice falls you can expect to find both uneven and even falls, but near the worst part there is usually a comparatively smooth section that can be worked through. It is probably best to locate a route on the side of the glacier.

When the gergschrund is reached it is best to look for a place where a gully leads into it from above as it is most likely that a bridge will be formed here from snow avalanching down from above; otherwise you will have to descend into the gergschrund and climb the opposite wall if possible.

Cornices are one of the greatest dangers on the ridges. It is hard to judge their width and thickness from on top as they vary a good deal in a few feet. Sometimes a double cornice is formed which is particularly dangerous as otherwise the points will catch on boots or pant's leg and a bad fall may result. The firmness with which the boot is put down varies with the angle and hardness of the surface. To prevent the points working loose in the holes they make, the foot should be placed at once in the position and angle at which it will be used.

In ascending, the feet are kept pointed forward and straight as long as the angle of the slope will permit it. When it gets so steep that you can't get your heels down you can turn the toes out. Very steep slopes can be ascended by facing out and backing up, as it is much easier to flex the ankle and get the full use of the crampon.

When the slope becomes so steep that crampons are not effective, or they are not available or not used it may be found necessary to cut steps with the axe. In this work the type of ice encountered makes a difference in the method of attack. I will mention the three main types:

1. Snow, ice or firm. The most usual form found in glacial regions. It is granular and is formed by the melting and refreezing of snow. It cuts easily and makes good steps.

2. Water ice. Usually found in gullies and on rocks and is formed by freezing water. It is difficult to cut and flake off. Steps are hard to form and are not too secure.

3. Black ice. A form of water ice that is extremely hard and step making requires a lot of work.

Step cutting in snow is rather easy and is done with the edge or blade of the axe; while step cutting in ice is done with the pick and is an art which is developed through practice. Whenever possible both hands arc used on the axe, but on very steep slopes one hand will have to be used for balance. Your axe, as you have seen, is equipped with a sling and sliding ring which you will have your hand through, as the handle gets wet and slippery and then too your hand gets tired and you lose your grip and the axe is apt to slide out. Ice is always cut with the pick end of the axe. In cutting snow ice, a blow directly in and anouther diagonally toward the first will fashion a fair step. Cutting in water ice requires more blows, as the ice flakes out and you will have to make a deeper cut before you will have satisfactory steps. You shall strike the ice as near as right angle as possible to keep from flaking off the outside layer. The step should slope slightly inward and does not have to be large except on the turns.

In cutting zig-zag besides making allowance for the different size and length of step and interval needed for the men in your party, the turning step at the corner has to be made of different size and shape. It should always be larger and semicircular at the back so that you can turn around in it on your toe without difficulty. Two larger than normal steps above this will also aid in making the turn.

You will find that it is much harder cutting steps on the descent than on the ascent. Steps on a rather steep descent are usually cut with the idea in mind that the inside foot should be dropped behind the outside foot as you stand sideways on the slope and not passed in front of the standing outside foot then dropped as is done on easier angles. This system is not only easier to move in but also easier to cut.

Glassading is the fastest way to desend and very practical on moderate slopes. It is done in more or less of a crouch with the head of the axe held in one hand and the shaft in the other, using the point for balance and rudder and sliding down on the feet. A good rule is never glissade a slope the only way you can ascend is by traveling well below the crest. As the snow forming a cornice is very unstable and breaks off easily you must be very careful to keep well below the point where it is likely to break off. At times you will find it necessary to cut through a cornice from below. This is a pretty tough proposition as just below the overhang there lies a section of loose snow which slides easily and is hard to belay in. When you go to work on the cornice be sure your belayers are in a safe position and then cut as straight up as you can so as to be able to cut down the danger of larger pieces breaking off and falling on them.

Avalanche precautions are to be observed at all times when traveling in the mountains in winter. You should figure that any slope over 20 degrees is dangerous and under certain conditions will avalanche, then too, flatter slopes lying beneath steep ones are risky as the outflow of the avalanche from above will pour across them.

If you have to cross a slope that you think may slide, cross as high as possible, don't cross the base of a steep slope but keep well out from it.

A slope may be quite safe, as long as the sun isn't hitting it, and can be crossed quite safely. You should never stop on a slope that may possibly slide. Sometimes the snow can be made to slide before you get on to it, making a crossing safe. You can ascend an avalanche slope by going straight up as this makes no line for the avalanche to start from. When a party has to cross a suspected avalanche slope members should be well separated, at least 100 yards apart so that if the slope does slide it will catch few and leave others to start rescue work. You will be issued avalanche cord, which is a red line that will be tied to you and will aid in finding you if caught in an avalanche. If you are ever caught in an avalanche try to stay on top. According to the manual you should use a swimming motion. If you are wearing a rucksack get it off if possible. Once an avalanche stops it packs solid.

In high mountains work it is the usual procedure to mark your route with wands or trail markers. In the Army these are small dowels about 36 inches long with one end painted bright orange. They are placed within a ropes length of each other so that in case of a blinding storm or fog one can be picked up from another by by sweep of the rope.

GLACIER CHARACTERISTICS

The glacier normally affords the best route of advance to high mountains and to the connecting ridges. This statement is probably surprising to most of you who have no contact with mountains except from what they have seen from some pulp magazine which shows glaciers as great messes of tumbling ice moving at a tremendous rate of speed. There is no doubt the glacier is dangerous, however after becoming familiar with the characteristics one respects it but does not necessarily fear it.

The glacier is a characteristic of a certain Alpine Zone, its existance depends more on the latidude of the mountain range than on its height. For example, in the artic the ice fields are at sea level, in Alaska the glaciers decend to the sea, in the Northwest the ice desends to approximately 4000feet. In Colorado 14,000 feet mountains are too low to support anything except small snow fields, the same holds true in Mexico where mountains of 18,000 feet hold only thin snow caps.

Another influence is the amount of snowfall and the average temperature. For example again, the glacier regions in Alaska we have great snowfall and a mean temperature of 38 degrees, in the Northwest the snowfall is also great, about 24 feet level, the average temperature being 52 degrees in Colorado the snowfall in the mountains is 12 feet, its average temperature being 68 degrees. At one time entire sections of the United States contained extensive glaciers. The location of these can be noted by the carving action resulting in great canyons.

For all practical purposes glaciers are great self maintaining rivers of moving ice, which follow the line of least resistance. The glacier is maintained by piling up of snow from one year to the next. This snow reforms into ice by partial melting and refreezing and by the pressure of the upper layers.

The movement of the glacier plus its great weight wears away the surrounding terrain resulting in the canyon mentioned previously. Rock and dirt removed from the sides is carried on the edges of the glacier as the moraines. These may be listed as the terminal moraine, at the end of glacier where the deposit is made; the lateral moraines formed by the juncture of 2 or more glaciers resulting in the joining of the inside lateral moraines of each. Where we had two glaciers with one moraine on each side , we now have one glacier with 3 moraines. The outside being the lateral and that down the center caused by the joining of the two inside lateral moraines being called the medial moraine. These moraines are characterized by dirt and rock on and in the ice. That ice containing the dirt and silt is usually extremely hard and rather dark or black.

As the glacier moves uneveness in the bed affects the condition of its surface. If for example as shown on the chart the bed tilts downward the glacier will crack causing transverse crevasses. As the bed returns to a lesser gradient the crevasses narrow or even close again. When the tilt is not abrupt but quite steep and ice fall occurs. The ice fall may be compared to the rapids of a great river with all the tumbling water frozen-magnify this a hundred times and you have the fall as it appears in the glacier. When a glacier pulls away from the upper portion which is anchored to the rock a bergshrund occurs. The bergschrund appears as a crevasse with the lower lip dropped down and away from the upper lip, and extends above a cliff. Below this the glacier may continue. The glacier, in that case, moves really as two separate sections, the upper part breaking off as it moves over the cliff edge, the avalanche dropping off into the lower part. The lower part of course moves independently of the upper section however, it is maintained by the avalanche from above and terminates in the snout and terminal moraine. In the bed of longitudinal crevasses. Another type of crevasses is the marginal, which is formed by the friction of the glacier against the side walls. On occasion a curved crevasse may be found. These are caused by the joining of marginal and transverse crevasses or where one of the sides of the glacier unsupported by a wall falls away at its edge, this falling away may also be a cause of longitudinal crevasses. It can be seen that the crevasses system of a glacier may become so intricate as to create a series of ice islands with crevasses on all four sides. When these occur near a place where the glacial bed begins to flatten out the movement of the glacial and the pressure caused by the flattining of the glacier and they will become ice towers. Where the glacier has pulled away from the upper end of the cirque, or where extreme melting has occured along the edge a gap is formed between the glacier and the rock wall. This is called the moat. This moat may be as much as 30 feet wide and extend to the bottom of the glacier.

A glacier is made of many types of ice, deep in the glacier is a hard ice caused by the pressure of the upper section of the glacier. The surface of the glacier usually consists of snow ice or firn. This is granular and quite crystalline and is formed by the melting and re-freezing of the snow. Another type is water ice, which is found on the surface of the glacier where there has been extreme melting, to the extent that water actually flows over the glacier. Another form of water ice is the black ice found in couleirs and under the moraines. This is extremely hard and its black color is due to the dirt and silt it contains. An unusual type of ice very seldom found is pressure formed, an ice of concrete-like density upon which and ice axe will bounce. This is also found at the point where tow glaciers join under the medial moraine.

As most of you know pressure will cause ice to melt, this action causes a particular phenomenon on a glacier. There may be a river underneath the glacier itself which you may hear roaring when standing on the edge of the deep crevasse. The surface melting of a glacier may cause a regular drainage system to occur. This will be made up of main river on the surface plus many contributing streams. The river and its tributaries have all the characteristics of a normal drainage system. The river will disappear into the glacier at a mill which is a hole formed in the glacier by the movement of the water. These mills are tremendous whirlpools of water and extend to the botton of the glacier. They are as great as 20 feet across.

During the winter movement of the glacier is retarded by the cold weather, however this does not cause the crevasses to close but rather to become bridged with snow or if shallow to fill partially. Thus in the winter and early spring the glaciers appear as a great smooth white expanse. As spring comes and melting occurs these bridges become thin and melt out. This process continues until September and early October when the glacier and its crevasses are sharply outlined. Also at this time of year since most of the melting has already occured the avalanche danger is relatively small.

Glaciers vary from year to year, due to the difference in yearly snowfall and warmth of the summers. Glaciers even change slightly from week to week, since during one week melting may be greater and the next week it may be limited. There may be no movement of the snout of the glacier, even in the heat of the summer, although the center of the glacier may move along at 10 to 15 inches a year. In Alaska, where there is a great glacial movement the ice may move at the rate of 15 feet a day, and in Greeland there is a glacier that moves 99 feet per day.

It may be seen from this description of glacier characteristics that the ice fields are dangerous. However, again they are not something to fear if you have proper knowledge of how to move on them. One major caution might be to never let familiarity with mountain problems lead you to contempt. The purpose of this course is to give you as much knowledge as possible in the limited length of time provided, so that you will have a general picture of what to expect and how to act when moving on glaciers and ice fields.

CAUSES AND TYPES OF AVALANCHES

An avalanche is any mass of rock, ice or snow moving down a mountain side. The danger of avalanche is greatest in alpine terrain because the depth of the snow and the angle of the mountain-side are so extreme. The avalanche may be just a trickle of snow down a gully or the movement of hundreds of tons of snow and rock. One example of the danger of avalanche is the loss of 10,000 men and officers in one day during the First World War in the Alps. The European Armies consider the importance of avalanche knowledge so great that they have established boards of scientists who do nothing but work, in stations established in the mountains, on avalanche and snow structure.

Our study of avalanche is based upon six point rules of the thumb written by a famous mountain soldier and scientist Colonel Belgeri. His points consist of 3 rules that apply to the mountain side and 3 that apply to the snow.

The first point is the "angle of the slope". Generally speaking the steeper the slope the greater the avalanche danger. A slope of 25 degrees or greater should be suspected. This angle should not be regarded as a borderline above which everything is dangerous and below which everything is safe. Advanced firm snow rests with safety on angle of 50 degrees yet wet snow has avalanched at 15 degrees. In the early spring when the rains come, the snow, when wet, normally slides at 20 to 25 degrees. A consideration the mountineer must make is not only to note the angle of the terrain upon which he is climbing or skiing but to note the angle of the terrain above him. An avalanche may start above and sweep across perfectly flat country. The rule is to at least suspect slopes of 25 degrees. This has been found to be the most reliable criteria.

"The terrain" is the general shape of the mountain-side over a large area disregarding local irregularities in the ground. The bigger the area of a slope the greater the danger of avalanche. Concave slopes of a given steepness are safer than those of any other shape. The convex slope on the other hand is the most dangerous type.

The last consideration for the mountain-slide is the"Nature of the Ground" surface since the ground underlayer is the basic anchorage for the snow. If freezing weather comes before the first snowfall and continues during the fall of the snow will be dangerous because it has no anchorage. The ground will have been frozen hard and the snow will be hard crystals, powdery and loose on the surface. Just like sugar on a dance floor. If there has been warm weather or a rain before the snowfall and the weather cools to freezing during the snow anchorage will be firm. The snow will freeze to the ground and be well anchored. Smooth rock such as slab will not hold snow on an angle greater than 10 degrees while other types of rock such as scree, talus and moraines will form good anchorage because of the uneven surface. Green slopes are very poor anchorage because the long blades of grass mat and provide a smooth, slick surface for the snow. Close dense woods are a hinderence to avalanches, and they will provide a barrier for any but the largest slides. On the other hand open woods are as dangerous as open slopes. In Europe a wind slab avalanche occurred on a slope of 20 degrees which was wooded by trees about 20 yards apart.

The first consideration of the snow is number 4 on the list "The Depth of the Snow". Obviously the thicker the layer of snow the greater the probability of its avalanching and the more dangerous the resulting avalanche. If the anchorage is good the thick layer will flow while if the anchorage is bad the entire slope will slip.

"The consistency of the Snow" is the major point to be considered in this study, new snow that is dry will hold together immediately after falling since the rays of the flakes are interlocked and have not begun to shrink. As the snow settles the rays disappear or break off. After this has happened the snow loses its trapped air and packs becoming settled snow. It is during this settling period that dry snow avalanches occur and are most dangerous. You see that the avalanches danger is not immediately after the snowfall but between 6 and 24 hours later. Remember we are referring to cold, dry snow. There have been cases north slopes where the snow has been dangerous for as long as 2 weeks due to continued cold slowing the settling process. A general rule is the higher the temperature after a snowfall the quicker the slope becomes settled in safe from dry snow avalanches. After the snow has settled it may remain safe as long as it is not wetted by rain or warm wind. If this happens the snow again becomes unsafe. The water in the snow drains through it acting as a lubricant so that wet snow avalanches occur.

The final point is the "anchorage". We have already spoken of the ground anchorage, however, the snow anchorage is of greater importance. The surface of the first layer may eventually become hardened if exposed to wind, rain, sun or thaw. If the new snow falls on the hardened surface the result is exactly the same as though it had fallen on frozen ground--if the snow is dry no anchor will be formed, the upper layer will not bind the layers to gether. A most dangerous type of avalanche occurs when the anchorage is destroyed or lubricated by water. The water will flow down the crust destroying the anchorage and lubricating it so the layers will slide. This water action has caused wet snow avalanches on slopes as flat as 15 degrees. Wind slab of course is always dangerous. First because no anchor exists below the slab and second because new snow can fall on the slab and be anchored to it yet the danger is not gone due to the lack of anchorage of the original slab.

The six points do not complete the avalanche picture. Though slopes slide of their own accord they are often in such a delicate balance that while they do not slide along, any outside influence will set them off. Man or animals crossing a slope will do the job. The falling of a cornice, rock, snow off trees or ice towers will start an avalanche moving.

A knowledge of past weather conditions is necessary for movement in high alpine terrain. The surface may appear safe yet be extremely unstable. Warm weather followed by a freeze then snow will cause a dangerous condition. Weather bureau reports may be consulted or a more practical system used. This is merely to cut down through the layers and see the previous anchors and layers for yourself.

AVALANCHE RESCUE TECHNIQUE

When we speak of avalanche rescue technique we refer to the system of marking the slope, probing and digging for the victim.

There is a high probability of the victim being retained on a shelf in the avalanche slope, however unless the shelf is visable on the surface of the avalanche its probability need not be considered. In other words if the shelf is so small that its location can not be noticed by inspection of the surface of the avalanche after it has stopped it should not be considered as a possible location. The chances of being pushed out to the edges of the avalanche are relatively high. The third probable location of the victim is at the fan or end of the avalanche.

It can be seen then that the proper method of marking the slope when searching for a victim is to first inspect the slope for his probable location, looking for shelves, and along the edges and the fan.

After possible locations have been marked, the next procedure is to start probing. This may be done with any pole. In the Army a special probe is issued for just such purposes. The searchers work the marked areas, probing every eight inches. After the first fifteen minutes 1 or 2 members of the party should be sent to the valley or base for a properly equipped rescue party and medical officers. The probe should not be driven into the snow, but pushed down firmly. When a resistance is felt the searchers attempts to discover other resistance by continuing his probing for several more strokes. If the resistance continues he calls his companions and they dig vigorously for the victim, being careful not to injure him with the edges of the shovels.

If after probing the marked areas the victim has not been found and additional procedures is introduced. Starting at the foot of the avalanche the searchers dig channels up the slope about three feet wide and nine feet apart. They then probe through the sides of the channels until the victim is found. If there is only 1 survivor and help is 3 or 4 hours away he should search at least 1 hour before going for assistance. If there is a reasonable chance of finding the victim alive, as in the case of a large shallow avalanche tip on a slope with no shelves, it would be well to search for several hours before going for help.

When the victim is found, warm blankets, sleeping bags and warm drinks will assist him in his recovery. Do not under any circumstances take him into a warm tent or a warm room immediately, he must be gradually warmed until the greatest amount of the chill is gone from his body. It may be that artificial respiration is necessary. This should be applied through the blankets rather than removing them to get at the mans back. When applying artificial respiration do not give up after a mere hour or so. An example of avalanche rescue occurred on Mt. Rainer. The avalanche was of wet snow. It was six hours before the three victims were found, one half alive, the other two dead. It required a little more than three hours of artificial respiration to revive the one survivor. There is a famous avalanche rescue that occured in Italy that was performed in fresh snow. The victim was two days in the avalanche, and when he was found he was still alive.

SNOW CLASSIFICATION AND FORMATION

Snow is the name that has been given to precipitation in the form of ice crystals. The snow falls in a variety of shapes, the crystals may be flat and flake like, small hexagonal bars or any one of the four thousand other designs that have been photographed. A general consideration is that the lower the temperature, the smaller the flakes and the more solid its shape. The snow we have just spoken of is falling snow, since the structure begins to change immediately upon its striking the ground.

Once the snow has reached the ground it is referred to as fallen snow and the process of firnification, or change from snow to ice is begun. The main types are powdered snow and old snow. This classification does not take into consideration wet snow, since snow may become wet at any time. In addition when snow becomes wet it assumes characteristics or another type.

Avalanches are probably the greatest danger to the inexperienced, or the experienced for that matter, that exist in the mountains. During the winter of 1916-17 the Italian Army had 200,000 casualties due to mountaineering accidents alone in the northern campaign, these accidents were largely caused by avalanches or really by the lack of experienced personnel to control movement of troops in avalanche areas. A knowledge of snow types and conditions is essential before avalanches can be understood and discussed.

To go back to snow types, powdered snow may be divided into new snow, which is snow immediately after it has fallen and still possesses the fluffy, feathery or flemy nature due to its not having changed from the flake condition to any great extent; settling snow, which is an intermediate stage between new snow and settled snow, is feathery as is new snow, however the crystals have begun to lose their points and to lose their identity; and settled snow which is the next step in aging of snow and is composed of crystals that have interlocked and united, the crystals becomming more globular. In this process the air spaces in the snow have decreased so that it is very firm.

The other main type of snow is old snow-that's snow which has passed beyond the settled or loose lying powder stage. This snow has become granular. The earliest form of this is new, firm snow, which lies with the grains fairly loose, as it grows older it becomes more solid and is called advanced firn snow. This greater solidity due to the freezing, thawing and refreezing which causes it to be firmly held together by a cement of ice which originates from the firm of thaw water caused by the melting. This advanced firm snow is found in the late spring and through the summer. The new firm snow, by the way, includes sun and rain crusts, which are caused by the warming and melting of the surface and its freezing.

All the snow forms except the advanced firn snow are affected by the wind. Snow thus affected is called wind packed and forms either a wind slab or a wind crust. This wind packed snow may be varying hardness, from a slightly toughened condition to a hardness on which nail boots will leave no impression. It is more important from an avalanche consideration to note the difference between the two types of wind packed snow, wind slab and wind crust.

Wind slab is a snow deposit which has been packed to any degree of consistency by a wind agency. It may lie over the ground over soft snow, or over an older slab, but will never lie over ice. It appears as a dull, lusterless, chalky expanse quite different from the crisp, brilliant aspect of powdered snow. This may be understood when you remember that the powdered snow crystals have more reflecting surface whereas, wind slab crystals are largely of a regularely rounded type and do not reflect so much light. A slab may be a few feet to a hundreds of square yards in area, and an inch it several feet in thickness. Its essential feature is that it is not anchored to the surface below. On occasions the lack of anchorage is so marked that an air space of $\frac{1}{4}$ inch to several inches exist below the slab. This slab is held together not by friction with lower surfaces but rather by surface tension, the adhering of the crystals of the slab to each other, You can see the great avalanche danger of wind slab, since when it is fractured the whole slab will break loose.

Wind crust is generally found to be very hard deposit. It essential difference from wind slab is that when fractured it breaks locally and the fractures neither spread nor break across the whole area. For this reason wind crusts are a perfectly safe formation and as we have said wind slab is extremely dangerous.

The conditions under which each type of wind packed snow is formed are as follows: If, during the wind packing, the snow drifts and is being moved from one place to another by the wind, a wind slab will form. On the other hand if no drifting or displacement of the snow is taking place a crust is formed.

You have probably noticed that we have not discussed the conditions of advanced firn snow to any great extent, and we shall not, since in reality there is no reason to consider it further in this discussion; however, do not forget its existance, as it will come up again in our avalanche discussion.

It might be well for us to cover processes of firnification again in a few words. This process is a simple one. Owing to the feathery nature of snow flakes they will in calm weather float gently to earth and remain touching at a few points. In this way a great deal of air is imprisoned among them. But immediately after coming to rest they start melting, especially at the sharp points. As these evaporate the snow sticks. The pressure of overlying snow tends to fracture the delicate plumes of the flakes, and in this way also causes a consolidation of the snow. At the same time, the grains become more globular and also larger, thus decreasing the spaces between the grains and reducing the air content of the snow. This packing and the reduction of the air content of the snow proceeds through the whole process of firnification from the earliest new snow stage to the latest firn snow stage. It must be remembered that once the old snow condition has set in, time required for the snow to reach the most advanced stages is much larger than that required for the snow to reach the advanced stages of the powdered type. Snow may fall, reach the ground, pass through the stages of new snow, settling snow, and settled snow in a matter of three days; however the length of time required for snow to move from the settled snow stage to the advanced firn stage may be several weeks or even as long as one month. Let us go back to the wet snow. As was said, snow may become wet at any stage. It may fall when the air temperature is above freezing. Snow may become dampened by the sun, warm winds, rain, fog or mist or even a damp atmosphere. The wet flakes are the largest type, as you will remember the lower the temperature the smaller the flake and the more solid its shape. These large flakes, however break and melt as they reach the ground, and since the temperature is not freezing when they fall, the water created by the melting does not freeze and hold snow together but rather melts on through the snow resulting in an extremely unstable condition. This snow that has become damp on the ground from the conditions I mentioned, sun, warn wind, etc. also goes through the same process of that which has fallen wet. In other words, the plumes of the flakes are melted off, the resulting water does not freeze and again we have an extremely unstable condition.

CREVASSE RESCUE

Due to the conformation of crevasses, a special technique is required to rescue those who have fallen in. A crevasse does not normally have vertical lips, but overhangs at the upper edges and the walls are slick and overhanging or vertical. Snow bridges over a crevasse most generally do not entirely collapse when the climber breaks through, rather he makes a hole in them. It can be seen that these characteristics causes several difficulties in crevasse rescue work: First, the rope cuts back into the lip of the crevasse or hole in the bridge, causing the rescuers difficulty by binding the ropes. Second, the walls being steep causes the climber to hang on the rope rather than to swing in against the wall and to hold on. This of course makes him unable to help himself.

The systems of crevasse rescue may be described as follows: These should be followed by the numbers so that no step is missed and so that the rescue may be accomplished with the utmost speed, since the longer the man hangs on the rope the more helpless he becomes. When the leader falls in # 2 belays him by thrusting the point of his axe into the slope and moving on the downhill side by it. A caution is to belay with the rope as low on the axe as possible preferably next to the snow, so the axe will not be pulled out. This is accomplished by dropping the loop down the shaft as the axe is thrust into the snow. #3, as soon as he is sure #2 is secured, moves up to the edge of the crevasse on bridge. The leader if he is conscious removes the sling from his pocket, passes it between his legs, around the calf of one and places his toe in the loop. By alternately standing in the sling loop, while #2 and #3 pull up on the loose rope, the leader climbs up to the crevasse lip. He must then either grasp the ropes and walk himself out over the lip, or more normally, he must chop his way through the lip.

When #3 falls, the action of the leader and #3 are reversed.

When the middle man falls he is assisted by #1 and #3 who will pull on the opposite sides of the rope, assisting him out of the crevasse.

If the person who has fallen in to the crevasse has been injured or is unconscious, a member of the party will have to go into the crevasse to assist him. In that case the rescuer must lash the victim on to the rope in such a manner that the victims weight does not hang under his armpits, and assist the belayer in pulling him up.

When double roping, the procedures are essentially the same. #2 will belay the fallen leader with his axe. The leader will place his weight on the sling rope as we have previously mentioned which by the way is attached to the rope to the ice axe. He will them move out of the crevasse alternately stepping on the loop of the rope to #2, who takes it in whenever there is no resistance, and moving up the prussik knot. If the leader is strong enough, he will pull himself up the fixed rope attached to the ice axe, assi ted by #2 who pulls up the rope attached to his waist. It may seem that double roping merely makes a poor best of a bad situation since in the case the leader is injured he can do very little to help himself, and since, in any case the ropes become easily tangled and jammed as they cut into the lip of the crevasse. Remember, for safety, move either in one rope of three or two ropes of two persons each, in which case the leader of the second rope follows closely behind #2 man of the first rope. Are there any questions?

ROPE MANAGEMENT

With regard to roping there are several differences between the methods used in Rock and those used in Snow and Ice work. Initially the system of tying in differs. While in Rock work most climbers tie in around the waist, in Ice work the tying in is done around the chest. The knot used is the bowline, made with a long running end, which can be dropped over the shoulders and tied to the chest loop, thus forming a suspended keeping the rope high on the chest, the bowline on a bight may also be used since one loop may be used as suspender. After tying in each climber should tie a small butterfly on the rope about an arm length ahead of him. This loop is carried on the ice axe during movement.

Moving on snow slopes where belaying is not necessary climbers may be spaced as they wish, however, the ropes should not be permitted to drag in the snow, To prevent this each climber is responsible for the rope ahead of him, and carries the slack in coils in his hand. In crevassed areas the climbers move th full length of the rope apart, again keeping if off the snow and ice, by carrying one or two small loops.

For a party of two a double roping technique is used. Number two ties on the rope at one end in normal fashion. He then ties and ice axe loop in the other end of the rope holding it at arms length. The leader then pulls both rope snug, and ties in at the bight thus formed.

When a man falls into a cravasse he normally hangs free and can do little to help himself since his weight is all in his chest loop which is under his arns. A simple method used to assist a climber to put his weight on his feet is a sling rope about 12 feet long tied to his climbing rope. The sling is made about 6 feet long and it is fastened to the climbing rope in front of the chest knot, is passed through the chest loop and put into the climbers pocket. When the climber has fallen he merely removes the loop from his pocket, and stands in it, removing the weight from his chest loop. The fact that the sling runs through the chest loop prevents the climber from falling backward off the rope.

Other than the differences just mentioned the knots and systems used in ice climbing are the same as used in rock climbing.