ABLATION OF SNOW UNDER THE VERTICAL SUN IN HAWAII.

CHESTER K. WENTWORTH.

ABSTRACT. Late in July, 1939, snow-banks in the summit area of Mauna Kea, Hawaii, were found to be deeply pitted by ablation. The pits, or suncups, ranged to four feet deep, and with intervening spikes, were not only precisely vertical but also strikingly oriented on line with the east to west movement of the vertical sun, these attitudes being quite independent of the direction and amount of slope of the ground, or of local direction of the wind. Testimony of other observers indicates that these snow forms were produced in not over a week's time. Recorded observations are insufficient to indicate whether formation of such suncups and sunspikes is usual at a certain seasonal stage of wastage of the snow, or is exceptional.

INTRODUCTION.

IN the course of geologic studies on upper Mauna Kea in July, 1939,[1] it was the writer's rare good fortune to visit the summit of the mountain and most of the residual snow patches at just the time when the development of sun pits and of intervening spiked residuals had reached a state near perfection. In the interest of other field observations and postponement of the arduous climb until he had become better acclimated to the rarified air, the writer had refrained from visiting the summit with three earlier parties of his associates, who not only reported no such marked snow forms, but had indulged in the rare sport of tobogganing in Hawaii.[2] The feasibility of such sport is clear indication of the absence of pits and peaks at the time and place in question.

The forms observed and shown in the accompanying illustration must, therefore, have developed largely in the three or four days prior to the author's visit on July 24, and may be regarded as a somewhat ephemeral feature of the summit area, even during the last stages of wastage. From testimony of others concerning other areas, it is quite possible they may not form each year at an appropriate stage but only occasionally under especially favorable atmospheric conditions.

DESCRIPTION OF SNOW FORMS.

The summit was approached from the north after leaving a one-night camp at 10,500 feet below Puu Makanaka. The

[1] These studies were supported by a grant from Northwestern University, Department of Geology, to Dr. W. E. Powers and the writer.

[2] Larry Andrew in company with Gene Smith and the Whitman brothers on July 8, W. E. Powers on July 11, and Horace Winchell on July 20. Winchell reported incipient pitting in a few places.

FIG. 1

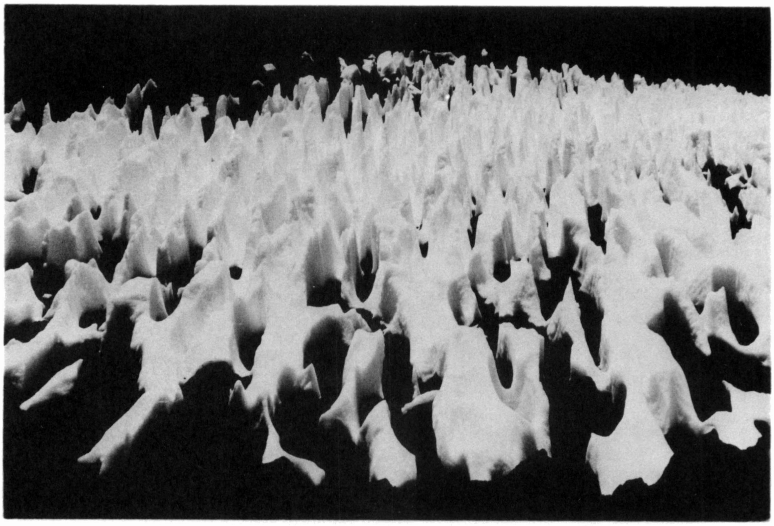

FIG. 2

FIG. 1. Sun-spikes and sun-cups at the lower end of a snow bank on the northern slope of the summit cone of Mauna Kea. The right margin of the picture is in nearly due east orientation; the largest cone in the distance is Puu Makanaka.

FIG. 2. View of much pitted, small snow field in saddle west of summit peak of Mauna Kea. View looking due west. Parallel lines of orientation are shown in perspective lines converging in the distance.

first residual snow seen lay in several small patches at elevation 12,200 feet to 12,500 feet about a mile northeast of the summit. These and other patches up to 13,000 feet showed no notable pitting; the snow consisted of granules 2 to 3 millimeters in diameter, had an icy layer at the bottom, and at the edge and around imbedded rocks, was melted one to two inches away from the rock. In general the snow patches visible on approaching the mountain were much smaller than they had been when first photographed from a distance during the early part of July.

Deeply pitted and spiked snow was first seen at about 13,250 feet on the north rib of the mountain (Plate I, Fig. 1). Additional snow-banks, ranging from 100 to 500 or more feet across, large portions of which showed notable pit and spike development were seen slightly higher and farther west on the north slope, at several points along the high ridge enroute to the summit, on the east slope of the summit mass, on the northeast-facing inner slope of the summit ring, and at several points visible to the northwest. Several of these are shown in accompanying figures.

At the time of encountering these features in the field the writer had no recollection of literature on the subject, though the form and occurrence of sastrugi came to mind and were dismissed as being something quite different. Observations made were therefore entirely without reference to any previous descriptions. The most conspicuous of the features seemed to be the spikes; this is probably in part due to the fact that travel was on the surrounding bare ground and spikes were more notable at the margins of a given bank, the pits less so and more difficult to see from the margin of the field. The spikes were variable in form but tended in their upper portions toward a blade-like shape, with quite striking orientation of the longer axes of the horizontal section. They were from one to four feet high and six to 24 inches long and two to six inches wide at the base. The rows were somewhat continuous, but showed considerable *en echelon* shifting of axis. The appearance of orientation and the contrast between the vista along the rows and that across it was very striking. The view of the field across the rows gave the appearance of an assemblage of projected profiles of rounded summits; no bare ground or deep pits would be visible.

At the margin of a pitted bank the spikes were well isolated, many of them standing alone, and each of them quite symmetrical in form, with no indication of leaning either along the rows or to one side or the other. Farther from the edge, the spikes were merged at their bases, most commonly along the rows but also laterally. The amount of bare ground was less and there was commonly no bare ground at distances of 50 feet or more from the margin. In the inner parts of the largest banks one could see the nearly intact, smooth upper surface of the snow, broken only by a few pits.

Between the partly merged spikes and progressively more symmetrical and conspicuous toward the interior parts of the snow field were deep pits of elliptical cross-section (Plate I, Fig. 2). Both pits and spikes were strikingly oriented with their long transverse axes in an east-west direction and seemed as a whole precisely vertical. Despite the prominence of the spikes around the margins of the snow fields, which impressed the writer first, it is clear from all the evidence and scrutiny of the photographs of the larger fields that, as Matthes and others have recognized, the pits or suncups are the fundamental and initial forms.[3]

The verticality of the pits and spikes, as well as their east-west orientation, was quite independent of the amount or direction of exposure of the slope on which they occurred. Most of the banks of snow were on slopes from 20 to 30 degrees, with exposures toward every quarter of the compass. The east-west path of the practically vertical sun appeared to be the controlling cause.

The location of the snow-banks is a product both of depth of original accumulation and of effectiveness of preservation. From these brief observations it appears that the former is most important and probably the banks which survive the longest are those accumulated just over the crest from the prevailing easterly winds and where snow precipitation and drifting is at a maximum. However, there were some large banks on windward exposures and there were doubtless local factors, as well as special circumstances in controlling periods of heavy snow fall. Several of the banks with crescentic ground plan changed from one end to the other by as much as 90

[3] Matthes, F. E.: Ablation of Snow Fields at High Altitudes by Radiant Solar Heat, Amer. Geophysical Union, Transactions, Fifteenth Annual Meeting, Part II, pp. 380-385, 1934.

Nichols, R. L.: Nieves penitentes near Boston, Massachusetts, Science, Vol. 89, pp. 557-558, 1939.

degrees in direction of slope. In spite of such changes the east-west orientation persisted.

FACTORS CONTROLLING FORMATION OF PITS AND SPIKES.

In Hawaii, because of its position south of the Tropic of Cancer, there is a period of several weeks, dependent on latitude, when the sun is north of the zenith at noon, and for each place there are two days, one before and one after the summer solstice, when the sun is nearest vertical at noon. Because of the lag of the time of maximum temperature of ocean water and other controlling maxima, the hottest season in Honolulu, on the average, comes early in September.[4] This condition, taken together with the fact of greater wastage of snow-banks, appears to favor the development of vertical and oriented wastage forms at a time near the second period of vertical sun. Indeed, it appears on consulting the tables, that the solar declination equalled the latitude of Mauna Kea, 19°-50′, on the day of the writer's visit, July 24.

While such coincidence cannot be taken as of great significance, it is evident that the development of oriented forms, arranged in rows, by cumulative, self-shading, would be most effective where the motion of the sun near noon is practically in a vertical plane with only slight movement in azimuth. Only on the equator at the equinoxes does the sun follow a vertical plane path through all the daylight hours, but it may be presumed that solar action on these vertical forms is most important near noon.

Besides the marked arrangement in east-west rows, which seems to the writer to inherently require a nearly vertical noon sun, the spikes or blades themselves are here perfectly vertical and symmetrical with reference to the east-west line. Such symmetry greatly favors stability of these slender spikes on rather narrow bases, the latter often supported on a 20 to 30 degree slope. It is supposed that stability would here be greater than in most higher latitudes. Here, certainly, the spikes may be "nieve" but not the "nieve penitentes" of other climes.[5]

The general conditions of origin of these forms has been well set forth by Matthes.[6] Each point in his exposition takes on extraordinary significance in such a situation as Mauna Kea at the season of vertical solar incidence at noon, and nearly

[4] Palmer, H. S.: Personal communication, based on unpublished study.

[5] Matthes, F. E.: Op. cit., pp. 380-381, 1934.

[6] Matthes, F. E.: Op. cit., pp. 382-385, 1934.

plane east-west motion for some time before and after noon. From the few observations made on Mauna Kea, it had been concluded by the writer that deepening of initial pits and preservation of intervening spikes must be responsible for the features shown. Moreover, the initial irregularity must be that shown on many snow fields, but which to the present writer's knowledge has not been clearly explained. Many somewhat similar, rhythmic forms are developed on rock surfaces abraded and etched by various agents and lead to interesting speculation.

In the snow-banks seen on Mauna Kea, the residual spikes seemed more notable as units than did the earlier developed pits, and despite their exposure appeared to be capable of enduring for at least several days. The range of elevation of snow survival was not sufficient to trace the transition upward from the feebler to the stronger development of pits, as described by Matthes for Mt. Rainier but the lowest banks seen did not show notably deep pitting. Neither do temperature conditions on Mauna Kea match those described as ideal by Matthes. Noon temperatures at 13,000 feet on Mauna Kea in late July average about 52 degrees[7]; there must be a moderate amount of melting, but the terrane is so permeable that there is no visible runoff. Condition of the pits and the snow surface generally, substantiates the interpretation that the bulk of the wastage is by evaporation which is especially active in the very dry air of upper Mauna Kea. That so much ablation can take place in a few days and in such strongly controlled fashion is amazing.

It is impossible to say how common or usual is the formation of strongly accentuated suncups or sunblades on Mauna Kea or on adjacent Mauna Loa, where snow falls, but probably less abundantly than on Mauna Kea. At present, probably not over 10 to 20 persons visit the summit area within any summer month and no other testimony has come to light concerning observation of such forms. But few of those reaching the summit area, even on giving casual attention to the forms, would be likely to make any permanent record of their observations. With a growing interest in the recreational possibilities of this peak, with its freezing night temperatures even in summer, it may be possible in the future to collect additional observations on this and other characteristics of the snow-banks.

[7] Raine, C. T.: Meteorological Reports of the Mauna Kea Expedition, 1935, Bull. Am. Met. Soc., Vol. 20, p. 101, 1939.

HONOLULU, HAWAII.