AVALANCHE RESEARCH

THE very severe avalanches in the Alps in the last two winters have shown the need for intensifying the study of snow conditions which precede avalanches, and of spreading further and wider the knowledge already existing.

In the past Switzerland has been alone in organizing systematic research of this kind. In recent years, however, snow and avalanche research has begun in other European countries, and in America.

In 1948 an Avalanche Service Organization (*Lawinendienst*) was founded in Innsbruck. This originally formed a clearing station for Austrian and foreign developments in the construction of avalanche defences for road and rail, and for dwellings; but in order to carry out practical research tests in the field, a small research station was set up at Lizum in the Wattental, some 17 km. east of Innsbruck at a height of 2000 m. This is in charge of Dr. Alfred Fuchs. The whole organization, "Wildbach- und Lawinenverbauung, Lawinendienst," is under Oberforstrat Dr. W. Hassenteufel, who is also head of the Austrian Forestry Department.

The report of the 1950–51 season of the Lizum station includes work on the characteristics of the snow cover, the building of fences to form eddy-pools—large hollows in the snow cover—to intersect and weaken large areas of snow accumulation. (Experiments, said to be satisfactory, had been done in a previous year in reducing and arresting the flow of avalanches by dotting high earth mounds all over the accumulation slopes.) Improvements in testing the strengths of snow samples are noted. A method is also described for fixing snow samples by means of a solution of perspex glass in ethyl chloride—presumably on the Schaefer principle. A copy of the report is available in the Society's library.

In the Haut-Isère the Électricité de France has inaugurated an Avalanche Forecasting Department in the charge of Mons. M. Sales, which has adopted the general procedure of snow investigation in operation at the Weissfluhjoch in Switzerland. This particular service functions as a protection to the hydro-electric schemes around Brévières, but its scope will, no doubt, be extended. Details of last season's work will be found in *La Houille Blanche*, 7ème année, No. 1, 1952, p. 41–51.

In North America research on the snow cover has extended rapidly in the past few years but has been largely confined to problems occurring over the immense snow wastes of the north—traction and the like. In the mountain areas avalanche research and forecasting is beginning to be done on a modest scale. It is hoped to describe American activities later.

With so many investigators now in the field it is to be expected that some definite conclusion will be reached on the mechanism of formation of wind slab. So far as the writer is aware only one piece of detailed research work on this subject has been published, attributing the formation of slab to the effects of high relative humidity combined with drifting*. These findings have never been completely confirmed by other authorities nor disproved, although R. A. Bagnold has shown that sand *in a dry condition* can pack firm by selective deposition after drifting. With the facilities of modern snow research stations work on this subject should now be easier to carry out, and it is hoped that this will be done.

30 *April* 1952 G. SELIGMAN

CORRESPONDENCE

The Editor,
The Journal of Glaciology

SIR, *Further on the Evaporation and Melting of Snow at High Altitudes*

Supplementing Dr. Robert P. Sharp's letter in the *Journal of Glaciology*, Vol. 1, No. 10, p. 583, there is certainly melting at 12,000 ft.† and higher, but one half or more of the snow is lost by evaporation. This is what François Matthes meant in his "Ablation of snow-fields at high altitudes

* Seligman, G., *Snow Structure and Ski Fields*, London: Macmillan, 1936, Chaps. 7, 8 and 18 and *Journal of Glaciology*, Vol. 1, No. 2, 1947, p. 70–73.
† 1000 ft. = 304·8 m.

by radiant solar heat," *Trans. Am. Geophys. Union*, 1934, p. 380–85. I am glad to defend him and in support of this I quote below from a letter from myself to Oliver Kehrlein, Chairman of the Glacier Committee of the Sierra Club and the Glacier Sub-committee of the American Geophysical Union.

I also append extracts from other letters showing that final pronouncement is not easy.

Nevada Agricultural Experiment Station,
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J. E. CHURCH

26 January 1952

"Dear Oliver,

I shall not let you surrender too easily Dr. Matthes' theory that at high altitudes the evaporation of snow and ice exceeds the melting. You have started too low and have confined your measurements to mid-summer when temperature is strongest. Dr. Matthes' theory should also be applied where wind accelerates evaporation and cold retards melting. The season should include winter as well as summer and the altitude chosen should depend upon latitude. Thus at 10,000 ft. on Mount Rose of the Central Sierra Nevada the snow accumulation supplies a timberline tundra basin with a steady flow thruout the summer. But on the crest at 10,800 ft. ice feathers 4 ft. in length seen projecting from the cairn and boulders in winter have vanished without runoff. Again in Greenland near sea-level the snow- and ice-melt from the edges of the Inland Ice has made gorges tremble with its impetus while the snow dome in its center at 8,000 to 10,000 ft. is compacted into glacial ice by its own weight without appreciable melting.

I like the directness of your method and your pioneer spirit. But if the altitude is great enough, the high mountain crests receive smaller precipitation than their windward slopes and the precipitation that falls on them is subjected to greater evaporation. At Mount Rose, for example, the evaporation about 9,000 ft. is more than twice that in the open meadow at Lake Tahoe at 6,000 ft. However, the average monthly rate above 9,000 ft. was found to be only 2·759 in.* water equivalent. Yet for 6 months January–June, the total would be 16·554 in. as compared with the average snow cover of 31·1 in. water equivalent at 9,000 ft. on April 1. Since there was no melting during January–March, the loss during this period by evaporation was 35 per cent but during the melting period of April–June was 50 per cent or practically equal to the melting.

On the exposed southern face of the summit of Mount Rose (10,800 ft.) in early March with average wind at 20 miles an hour, an evaporation rate has been measured of practically one-fifth inch water daily with only a film of melting visible. On the Inland Ice of Greenland at a time when wind velocity, temperature and friction have been high, ice even in February and March has been evaporated at daily rates of 0·206 to 0·703 in. water equivalent. The ice, being moistened by the wind, even acquires a rippled surface. However, the phenomenon is not continuous. The summer melt of the ice, though limited to 9 a.m. to 4 p.m. daily, probably exceeds it greatly.

In the central Andes where the climate is arid and precipitation can in no case equal evaporation, glaciers have been found at approximately 16,000 ft. completely stagnant with no trace of runoff except possibly sub-surface, and deeply pitted in the form of *nieve penitente*, some ice pinnacles being even 30 ft. high.

Pinnacled glaciers like these have been photographed by Dhar and Nigudkar at 18,000 ft. in eastern Himalaya, indicating possibly that toward the crests of the Himalaya the evaporation exceeds the precipitation and the glaciers are becoming stagnant. However, ice plumes that seem from the distance to deck the rocks with dazzling white may be the direct product of cloud condensation, though in the Andes fields of dry powder snow have been found so light that a staff would sink out of sight in it. . . .

It is possible that the sun cups and pits mentioned by Matthes may be due to melting as well as to sublimation, for they occur at all altitudes though the largest and deepest are associated with deep snow and long melt seasons. . . . The penitent glacier ice, however, is the residue from the pitting of glacier ice for many years and bears the stratification marks of the accumulation of the original ice. Ultimately it melts or evaporates beneath the soil where it lingers as fossil ice. The penitent snow may be sufficiently deep to survive until covered by the following season's snow but usually does not outlast its own season.

Snow cups or pits do not seem to be exclusive evidence of either evaporation or melting but rather of acceleration in both. My article "Perennial Snow and Glaciers" (*Scientific Monthly*, Vol. 56, 1943, p. 211–31) contains abundant evidence of accelerated ablation due to moderate overlay of opaque material and of retarded ablation by an excess of covering. Fuchsine dye on a weathered surface would indicate the descent of snow-melt. Likewise, the drainage rivulets on mountain ranges might indicate the relative efficiency of the snow at high altitudes except that the crest snow-melt may sink beneath the talus and appear as surface flow much lower down.

Some problems as suggested also by Matthes could be carried much further, as for example (1) the relative decrease in precipitation on windward slopes with increase in altitude (by snow surveys), (2) the relative size of high areas in basins, (3) the efficiency of stream sources at high altitudes (by stream gaging).

Very high areas by their low temperature will retard snow-melt at least a month and by their wind movement will accelerate evaporation. Their total water catch by area and altitude will therefore be relatively small though more efficiently released. Their altitude may even be too great for melting but the Sierra Nevada have almost no area of this extreme character. They do, however, have 50–50 snow in fair abundance and evaporation even more active than melting. J. E. CHURCH."

* 1 in. = 25·4 mm.