

Société Vaudoise des Sciences Naturelles. I had hoped to supplement these before they were published—an aim which remained unachieved.

I made 14 records of crystal sizes across the glacier by a method suggested by Forel—using a glass plate as a tracing medium with copying ink and taking off “pulls.”

The results were as follows:—

Mean area of crystals, 30 m. from right margin of glacier	1.68 cm. ²
Mean area of crystals in centre of glacier	0.32 cm. ²
Mean area of crystals 25 m. from left margin of glacier	0.83 cm. ²

The answer is clear: on average the crystals at the two margins of the stream were about four times larger in area (on the exposed face) than those in the centre and about eight times as large in volume. This seems to agree with the recent researches of Mr. G. Seligman (*Journal of Glaciology*, Vol. 1, No. 5, p. 254–66).

It seemed to me that crystals at the margins owed their greater size to their being more exposed to daily fluctuations of temperature caused by radiation from the banks, and also because they had travelled for a longer time and were therefore older. If on the other hand the flow of the glacier had been the predominant factor of growth the grains ought to have been larger in the centre of the stream where the movement was more rapid.

Lausanne,
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P. L. MERCANTON

SIR, *Rate of Movement of Surface Debris in Solifluction Processes*

Little is known of the rate of development of polygonal or “solifluidal” soil patterns or of their rate of down-hill movement—subjects which are of significance to the geomorphologist and to the ecologist interested in the stability of the cover of vegetation.

In 1947, with M. Jean Michaud, I made some experimental studies at Chambeyron near Barcelonnette in the French Basses-Alpes at an altitude of 2700 metres. Selected stones were distinguished by painting them. Two years later some of the stones remained undisturbed, but others revealed clear evidence of movement. The front of the largest “rock glacier” investigated had moved a few decimeters. In another case the increase in the rate of movement from sides to centre was beautifully displayed, being very small at the sides and reaching a maximum of several centimetres at the centre.

In an experiment with polygonal soils in 1947 we intentionally destroyed the surface pattern of some small polygons (20 cm. broad). The pattern had been completely reformed into polygons by 1949. In another case painted stones were placed half-way between the centre and the side of a polygon. After two years it was found that they had moved, mainly outwards, a distance of 1–3 cm.

These experiments are being continued by Jean Michaud.

Laboratoire de Géomorphologie,
École Pratique des Hautes Études,
St-Maur (Seine).

ANDRÉ CAILLEUX

[It would be valuable if comparable experiments were made, preferably by local observers, at localities in Britain, notably the Lake District, North Wales and Scotland on the one hand and under more severe climatic conditions, such as Spitsbergen, on the other.—*Ed.*]

REVIEWS

GLACIAL-METEOROLOGICAL INVESTIGATIONS ON THE KÅRSA GLACIER IN SWEDISH LAPPLAND 1942–1948. CARL CHRISTIAN WALLÉN. Reprinted from papers in *Geografiska Annaler*, Årg. 30, Häft 3–4, 1948 and Årg. 31, Häft 1–4, 1949 and published as *Meddelanden från Stockholms Högskolas Geografiska Institut*, Nr. 75, 1948, 240 pages, tables, diagrams.

THIS work constitutes the inaugural dissertation for the author’s degree of Doctor of Philosophy presented to the Faculty of Science of Stockholm University. The investigations discussed may

be considered a link in the chain of extensive glaciological research work carried on in Scandinavia, Iceland, Spitsbergen and Greenland under the leadership or by the initiative of Professor Hans W:son Ahlmann. Ahlmann's interest has come to be more and more concentrated upon the relationship between the material balance (regime) of glaciers and the corresponding meteorological factors. Wallén's work is particularly concerned with the relationship between ablation and climatic condition. It is closely related to the pioneer work on the importance of convection and condensation in the ablation process carried out by Sverdrup and Ahlmann in Spitsbergen in 1934. He has studied in detail the distribution of wind velocity, temperature and humidity in the air stream above the glacier surface and also the insolation conditions. He has thus been able to determine quantitatively, with a considerable degree of accuracy, the heat balance on the glacier surface.

The Kårsa Glacier is a small valley glacier, only 2 km.² in area, situated in Swedish Lapland close to the Norwegian border in 68° N. and 18° E. Its height above sea level is between 800 and 1500 m.

The author first gives a comparative analysis of the climatological conditions on the glacier and at two adjacent meteorological stations. The insolation conditions are of particular interest. Especially when the sky was overcast the insolation was considerably greater on the glacier than down at Abisko at 380 m. The author explains this as being due to the reflection between the glacier surface on the one hand and the atmosphere and the clouds on the other. Wallén considers it important that the glacier is situated at a higher elevation than the meteorological station and does not accept the view that the clouds in the Scandinavian mountains are probably thinner than is generally the case in the temperate zone.

The annual accumulation over the whole glacier averaged 3.70 million cubic metres of water and the ablation 3.93 million cubic metres. The difference, 0.23 million cubic metres, represents the annual loss of material. This figure is smaller than those obtained by Ahlmann, Lindblad and Schytt for the mean annual shrinkage of the Kårsa Glacier during earlier decades. The reviewer feels bound to express his view that unavoidable sources of error have contributed towards too low a value. The order of magnitude of the shrinkage of the Scandinavian glaciers during recent years has been 0.5–1.0 million cubic metres of water per square kilometre per annum, while Wallén's result gives only 0.1 million cubic metres per square kilometre for the Kårsa Glacier. The climate seems, however, to have been slightly less favourable for the shrinkage of the glacier during Wallén's years of investigation than during previous years.

Except by insolation and convective heat transport through the air ablation occurs by condensation of humidity on the cold glacier surface. The vapour pressure in the air during the ablation season is generally higher than the maximum vapour tension at the surface, so that condensation of water vapour on the glacier is more common than evaporation; during the spring however the position can, on occasions, be reversed. According to Wallén 60 per cent of the ablation is due to insolation, 30 per cent to convection and 10 per cent to condensational heating. The insolation was of far less importance on the glaciers studied by Ahlmann in Spitsbergen, Iceland and Greenland, being 10 per cent in the latter and about 30 per cent in the two former regions. It must be remembered, however, that Ahlmann's investigations only covered short periods of the ablation season, whereas Wallén's refer to the whole season. The heat supply from the air is of slightly less importance than the insolation on the Kårsa Glacier, partly because this glacier is situated so high that the air temperature is always rather low, partly because it is influenced by two different types of air masses, both supplying small amounts of convective heat. These two types consist on the one hand of continental warm air from the east with a clear sky and high temperature but with weak winds reducing the heating power, and, on the other, maritime cold air with cloudy skies and strong winds but with low temperature. In spite of the fact that the insolation is quantitatively of a greater importance than the convective and condensational factors it has been the change of the two latter factors which has resulted in the shrinkage of the glacier. Wallén shows

that the meteorological causes for the shrinkage have been increased temperature during the summer and, particularly in July, increased humidity and a prolonged ablation season.

Wallén's investigations have been criticized so far as the theoretical chapter on convection is concerned, but the agreement between calculated and observed values is so good that one must admit that the results support his assumptions. Wallén's investigations represent a most valuable complement to, and development of, the pioneer works on the importance of meteorological factors in the ablation process initiated by Ahlmann and Sverdrup. It is highly desirable that such investigations should be undertaken on other glaciers, particularly on those to which other climatic conditions apply. In addition to the meteorological and glaciological knowledge resulting from such investigations, they will help us to understand climatic variations as a whole and in the long run probably also the causes of ice ages.

*Dept. of Physical Geography,
University of Stockholm.*

O. HARALD JOHNSON

BEITRAG ZU DEN THEORETISCHEN GRUNDLAGEN DES LAWINENVERBAUS.

EDWIN BUCHER. *Beiträge zur Geologie der Schweiz—Geotechnische Serie—Hydrologie*, Lieferung 6. Bern: Kommissionsverlag Kümmerly & Frey, 1948, 113 pages, diagrams, illus. In German, English summary.

THE results of the scientific study of snow and avalanches begun at the Weissfluhjoch, Davos, under the direction of the Swiss Commission for the Study of Snow and Avalanches (Schw. Schnee- und Lawinenforschungskommission) were first summarized in the publication *Der Schnee und Seine Metamorphose* in 1938 by H. Bader, R. Haefeli, E. Bucher, J. Neher, O. Eckel, and Chr. Thams.*

In 1948, after ten more years of research, Dr. E. Bucher, now Director at the Weissfluhjoch, published a new treatise on snow for his Doctor's thesis. In this he studies snow as a structural material and finds that this mixture of air and ice is a plastic and compressible substance which, within certain limits, obeys Newton's law of viscosity. For each type of snow a coefficient of viscosity can be determined and this enables the engineer to make most of the calculations necessary for the construction of avalanche defences.

The viscosities, which vary within wide limits according to the different kinds of snow, clearly explain nearly all the observed phenomena of the snow cover, such as the varying degree of solidity of different kinds of snow deposits, the pressures and tensile stresses of inclined snow strata, the factors governing the release of avalanches and the like.

Thus, for example, since new snow is highly plastic, a deep snowfall becomes a very compact deposit, because it settles under its own weight. On the other hand a thin layer, formed in early winter and lying for a long time unprotected by a new fall, undergoes metamorphosis; the needles and stars become grains. This granular snow has little plasticity and does not settle when new strata of snow are deposited on it. On the contrary it is brittle and breaks up at the slightest jolt, so that it may at any time cause an avalanche.

The study of the slow creep of inclined snow strata has enabled the author to solve the problem of the pressure of snow against barriers and to draw simple and logical conclusions for the proper construction of avalanche defences. In the case of snow without cohesion the layers can be rendered more stable by reducing the gradient of the surface by means of walls and fences of sufficient height, behind which the snow can accumulate to form a slope of less steepness than the underlying ground. In the case of slab avalanches the downhill tensile stress can be neutralized by barriers built along the contour lines at places where the gradients increase.

In addition to excellent photographs and a large number of clear diagrams there is a very full

* Kümmerly & Frey, Bern. 1939.