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MAPS:

CONTRIBUTION TO THE PHYSICS OF GLACIERS: *A paper read at the Afternoon Meeting of the Society on 8 April 1935, by*

HANS WILHELMSSON AHLMANN

GLACIOLOGY is not only important for our knowledge of present-day glaciers, but is also essential for the proper understanding of the nature and activity of glaciers existing in the Ice Ages.

The investigations, of whose results I now have the honour to speak, began in 1920 in Jotunheim, the central high mountain district in southern Norway, and were continued more especially during the summers of 1923–25 on the small Styggedal glacier. In the summer of 1931 I was the leader of the Swedish-Norwegian Arctic Expedition to North-East Land and the surrounding waters, and in the summer of 1934 I accompanied Professor H. U. Sverdrup, when we both acted as leaders of the Norwegian-Swedish Spitsbergen Expedition. Both these expeditions were made possible by grants from the Swedish Government and the Norwegian Parliament. They were carried out absolutely according to programme and by the united efforts of the Swedish and Norwegian members. The general outlines of the 1931 expedition and most of its results are published in the *Geografiska Annaler*.[1] A review of the expedition will be found in the *Geographical Journal*.[2]

The expedition of 1934 [3] undertook a more concentrated glaciological-meteorological programme than the former, and had a Swedish and a Norwegian assistant as well as the two leaders. Our headquarters were on Isachsen's Plateau, a large firn-field in lat. 79° 9′ N., long. 12° 56′ E., and 850 m. above sea-level. Here we carried out the greater part of our investigations. Besides this I devoted myself to the Fourteenth of July Glacier, which goes down to Cross Bay on the west coast of Spitsbergen. We reached this glacier as early as June 19 without having seen any pack-ice in the sea. On the journey up to the plateau, which we reached on June 23, with 17 dogs and 3 sledges, I erected 22 bamboo stakes, each $2\frac{1}{2}$ m. long, and put flags and numbers on each. During the summer these stakes were to serve as gauges for measuring the melting of the snow and ice and as signals for determining the movement of the glacier. The day after our arrival at our headquarters the sledge-drivers returned with 15 dogs to the coast and the Norwegian coalmine Longyearbyen; and they fetched us again on August 18. During our 53 days' sojourn on the plateau my assistant and I made two journeys down and up the Fourteenth of July Glacier with some light equipment specially constructed for this purpose, and this was drawn by the two dogs left with us. On the way back to the coast on August 18 the gauges were measured for the fourth and last time. On August 27 we were again in Bergen without having seen any pack-ice at all in the sea around Spitsbergen.

[1] "Scientific Results of the Swedish-Norwegian Arctic Expedition." Parts I–X (vol. i), *Geografiska Annaler* 1933. Part XI, *Geografiska Annaler* 1934. Part XIII (Vascular Plants from Northern Svalbard), Skrifter om Svalbard og Ishavet n:r 62, Oslo 1934. Part XII (Oceanography) will be published in *Geofysiske Publikasjoner* (Bergen) 1935.

[2] May 1934, pp. 420–425.

[3] The results will be published in *Geografiska Annaler* (Stockholm) and in *Geofysiske Publikasjoner* (Bergen) in 1935 and 1936.

As the Oxford Expedition in 1924 had already established, the plateaus of North-East Land are covered with typical glacier-caps. These are divided into three parts: the South Ice, the East Ice, and the West Ice. They belong to the group of glaciers which are geomorphologically characterized by extending in a continuous sheet in which the ice moves outwards in all directions. They differ from continental glaciers or inland ices in that they cover smaller areas. The second group of glaciers is characterized as confined to a more or less marked path which directs the main movement of the ice. Valley glaciers, trans-section glaciers, circus glaciers, and wall-sided glaciers belong to this group, as well as tongues afloat. As a third group I will include the movable masses of ice and firn, which spread in large or small cake-like sheets over the level ground at the foot of high glaciated regions. These glaciers, piedmont glaciers and foot-glaciers as well as shelf-ice, are not independent.

During my 350-km. sleigh journey across the three glacier caps, a pit about 2 m. in depth was dug at each camping place. Sections of three different types were thus exposed: one belonging to the ablation area, another to the accumulation area, and the third to a transition area between them. The firn-line, or climatological snow-line, which is of such great importance to our knowledge of glaciers, coincides with the boundary between the ablation and the transition areas. Such pits, which are very easy to make, thus rendered it possible to determine the altitude of this line without having to wait until it was revealed by the summer melt of the snow. On the North-East Land glacier-caps it was at altitudes varying from 350 to 550 m. above sea-level.

The area of the relatively best-known West Ice is about 2800 sq. km., 1600 of which are situated above the firn limit and 1200 beyond it. The thickness of the central parts of the three glacier-caps of North-East Land can hardly exceed 200 m., and they are probably 150–200 m. thick where they meet the sea.

The largest glacier-cap in Norway, the Jostedalsbrae (about 1000 sq. km.), is most likely much thinner. Over large areas the ice is certainly not more than 20 or 40 m. thick, and the topography of the surface of the ice sheet is influenced in detail by the rock surface underneath.

The object of my glaciological work has been to analyse the active physical processes, to investigate quantitatively the amount of snow, ice, and water passing through the glaciers, and on the basis of this knowledge to discuss the geophysical conditions of the existence and life of glaciers. In my opinion such investigations are absolutely necessary to acquire a more thorough knowledge of the geography of glaciers.

First of all I should like to treat ablation processes. While the amount and distribution of precipitation has long been carefully investigated and measured, ablation—by which I mean the joint result of the processes eating into the snow or ice surface, *i.e.* melting and evaporation—has not been made the object of any detailed study until the last few years. This is rather surprising, as ablation is obviously of as much importance in our knowledge of glaciers as are any other of the factors: accumulation, movement, etc., which have been closely studied ever since the first beginnings of glaciology.

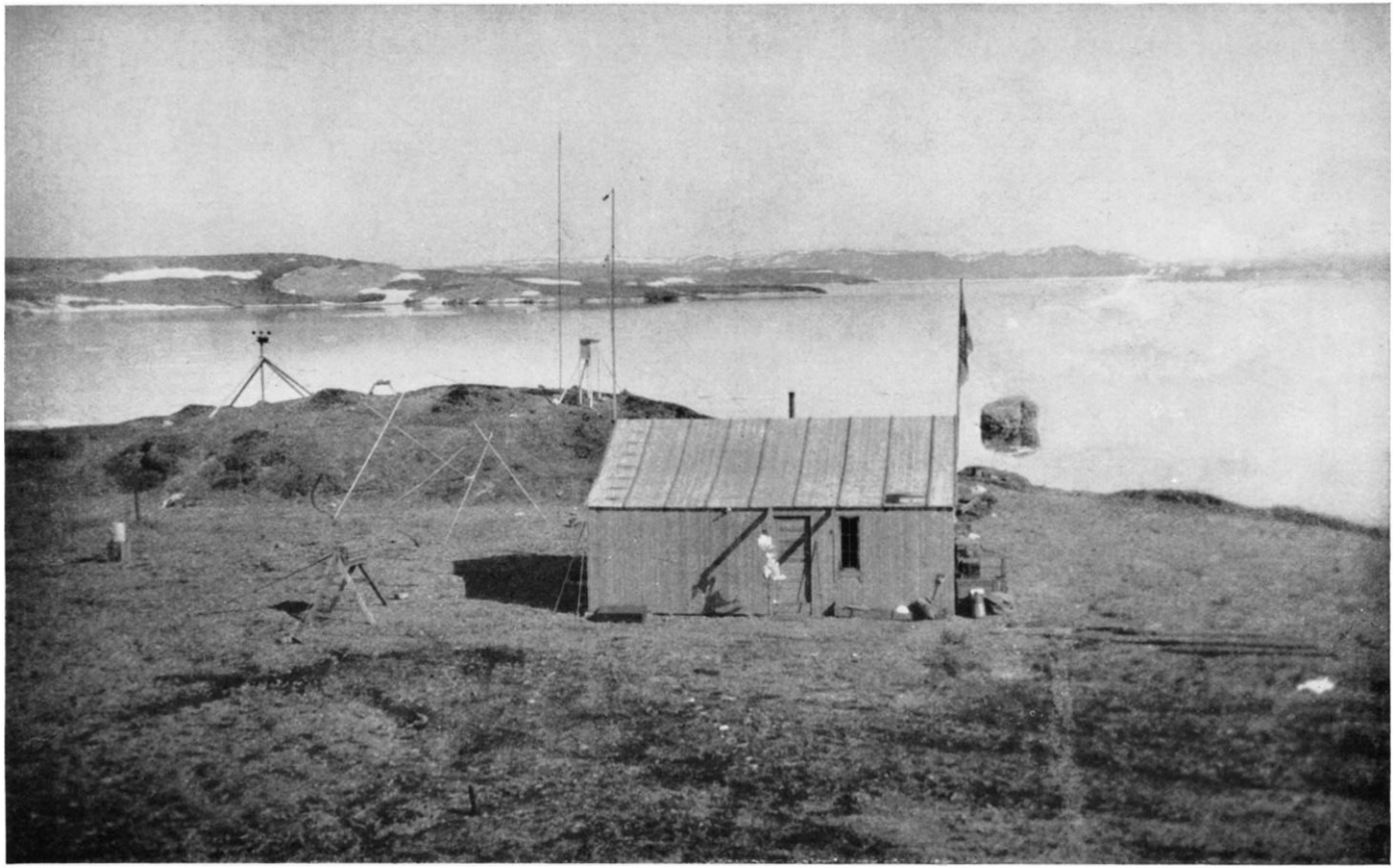

Plate 1. A view of Sveanor, headquarters of the Swedish–Norwegian Arctic Expedition in 1931

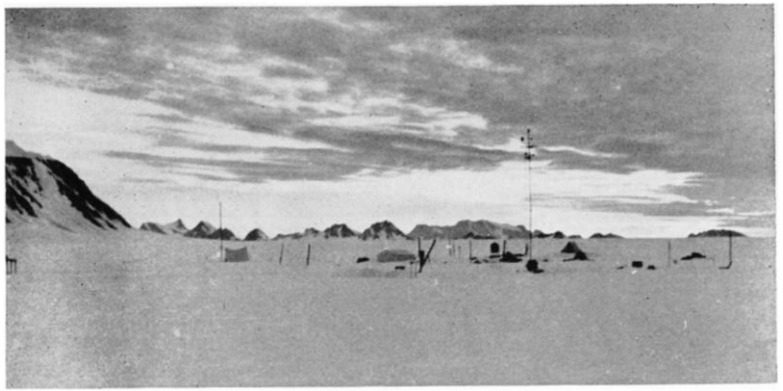

Plate 2. The headquarters of the Norwegian–Swedish Spitsbergen Expedition in 1934

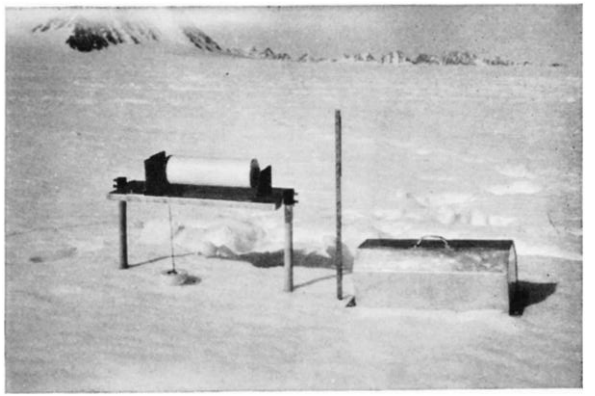

Plate 3. The ablatograph in use on Isachsen's Plateau

Plate 4. The margin of the Fourteenth of July Glacier in the fjord

For my preliminary studies[1] in the Jotunheim in lat. 60° 25′ N. and 1350 m. above sea-level I employed a first attempt at a recording instrument, an ablatograph. The amount of the ablation was determined at intervals of 8–10 hours and correlated with temperature, wind velocity, precipitation, and the values calculated of the radiation from the sun and sky. The observations covered 2515 hours. The total ablation during the whole summer at 1580 m. above sea-level was calculated for normal climatological conditions at 2000 mm. of water. During July and August the ablation amounted to a mean value of 2·3 mm. per hour for days and to 1·8 mm. for nights. The investigations resulted in a first general idea of the connection between the process of ablation and the meteorological elements. Heat convection by the air was found to have approximately twice as much effect on ablation as radiation.

A drawback to these investigations was the fact that the records of the meteorological elements had to be made some little distance from the glacier, *i.e.* about 1 km. from the ablatograph. Another disadvantage was the lack of continuous values of the radiation, which was due to the lack of a suitable actinograph.

At the headquarters of the 1931 expedition, Sveanor (Plate 1), in lat. 80° and 4 m. above sea-level, the records of the ablation were taken from June 30 to August 6 on a snowfield in the immediate vicinity of the meteorological station which was equipped with a recording actinograph of the Robitzsch's type. The observations cover 49 time-intervals aggregating 661 hours. During this time the total ablation amounted to 878 mm. of water, *i.e.* an average of 1·3 mm. per hour. I have estimated the total ablation at this place during the whole summer at 1400 mm. of water. On account of these observations A. Ångström made a preliminary equation for the relation between ablation and some of the meteorological elements most important to it: *i.e.* radiation, air temperature, and wind velocity. The result was that 40 per cent. of the ablation was due to radiation and 60 per cent. to heat convection by the air.

Even these investigations I consider have not reached the standard of necessary accuracy and completeness. The collaboration between Professor Sverdrup and myself during the 1934 expedition has now brought this problem much nearer its solution.

Professor Sverdrup's object during this expedition was a detailed study of the heat balance between the atmosphere and the snow surface. For this purpose we mounted at our headquarters an instrumental equipment to enable Sverdrup and his Norwegian assistant to determine from June 26 to August 15, for every hour of the day and the night, the meteorological elements from the snow surface to 5 m. above it with the greatest accuracy. About 20,000 readings were taken, thus giving him more extensive and accurate material than has ever been previously obtained on a glacier. At the same time Mr. Olsson, my Swedish assistant, made all radiation intensity measurements. My object was to ascertain the ablation, *i.e.* the effective result of the action of the heat, transferred to the snow surface by air and radiation.

For this purpose I employed an ablatograph (Plate 3), designed by Doctor

[1] "Physico-Geographical Researches in the Horung Massiv, Jotunheim." I *Geografiska Annaler* 1923; II–IV *Geografiska Annaler* 1927; (IV The Ablation); V–VI *Geografiska Annaler* 1928.

O. Devik in Norway at my request.[1] A recording mechanism is fixed on a firm support above the surface of the snow, and this registers the subsidence of a float resting on the snow or ice; the float is connected to the recording mechanism by a string. The support had no independent movement, the string did not stretch or slacken, and the mechanism worked perfectly. The float however had independent movement, as when the radiation was considerable it absorbed more heat than the snow and consequently melted into it. When the sky was overcast, and still more in foggy weather, the snow surface sank on the other hand more quickly than the float, if the latter had previously sunk into the snow. The level of the float in relation to the snow surface was therefore ascertained at least a couple of times a day, especially when the weather changed. Additional control was obtained too by measuring the ablation two or three times a day on a slender bamboo or other stake stuck into the surface close to the instrument. After making these corrections for the independent movement of the float, continuous curves of the subsidence of the snow surface were obtained, which permitted the determination of the ablation every two hours with an accuracy of 0·5 mm. (Fig. 1).

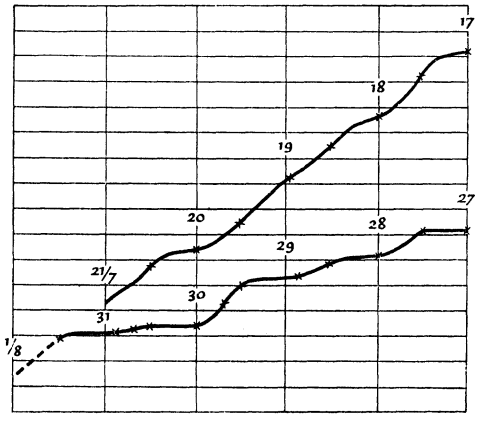

Fig. 1

The total ablation from June 26 to August 16 amounted to 415 mm. of water, or on an average 0·33 mm. per hour. The maximum for a two-hours' interval was 9 mm. of water. For the whole summer the ablation has been calculated at 480 mm. of water. Apart from this, 270 mm. of water remained of the snow accumulation from the preceding winter.

Professor Sverdrup's treatment of his meteorological observations is not yet completed,[2] but from what has hitherto been ascertained, it may be said that the results from the 1931 expedition have been confirmed concerning the much greater effect on ablation[1] of heat convection by air than of radiation. The air temperature was as a rule lowest at the surface of the snow and increased upwards. Consequently, a transference of heat generally took place from the air down to the snow, even when the temperature was negative. These observations also rendered it possible to determine in detail the importance of the humidity of the air for ablation. This is necessary for calculating the quantity of moisture condensed on the snow, when warm and humid air passes over it,

[1] The instrument, its technical use and the necessary corrections that must be made to its records are treated in: H. W:son Ahlmann, "Determination of the Ablation of Snow and Ice; Hyllningsskrift till Sven Hedin," 19 febr. 1935," *Geografiska Annaler* 1935.

[2] A preliminary report, "Varmeutvekslingen mellem en sneflate og atmosfaeren," is published in *Beretninger fra Chr. Michelsens Institutt*, Bd. V, Bergen 1935. The definitive treatise will be published in *Geofysiske Publikasjoner*, Bergen.

and the amount of evaporation when the air is dry. Professor Sverdrup has found that ablation is greatest in periods with warm and humid air, especially when wind velocity is great; in periods with warm and dry air ablation is much less. It will be remembered in this connection that the melting of 1 mm. of snow requires only one-eighth of the heat necessary for the evaporating of the same quantity. On the whole evaporation plays an unimportant rôle in ablation as compared with melting.

For studying the firnification of snow and the recrystallization of firn into ice we dug seven pits at our headquarters, five of which were 4–5 m. in depth. In the largest of them we bored another 10 m. with an auger specially constructed for this purpose.

In Figure 2 the sections of five pits are placed side by side and refer to the snow surface on June 25 at 8 p.m. We see that the firn is well stratified, which is due to the presence of a great number of horizontal ice layers in the sections marked in black. From this figure the following facts are obvious: firstly, even if an ice layer varies considerably in thickness, its base is horizontal; secondly, some ice layers are thicker and more continuous than others. The first circumstance is due to the fact that the ice layers are first established as relatively thin crusts, which have subsequently been increased by material from above. The second circumstance is due to the ice layers making the boundary between two accumulation periods, *i.e.* these layers have their origin in the ice crusts, which freeze on the snow surface during the autumn, after the summer melting, and are then covered by snow during the winter following. The correctness of this opinion is fully proved by facts, upon which I cannot however enter here. Thus the firn mass is very clearly laminated in annual layers, and I have marked the boundaries in question with the respective years during the autumns of which they were established as an ice crust on the snow surface. The profiles are therefore calendars, comprising the years 1924–34, in which every annual layer corresponds to the accumulation surplus of one year, *i.e.* the total accumulation of precipitation in solid form during the winter minus the ablation during the summer following. This surplus varies in the seven pits between 95 and 300 mm., the mean being 200 mm. of water. These numbers also represent the very important values of the yearly contribution of nourishment to the glaciers in this district of Spitsbergen.

The boring from 5 to 15 m. in depth showed that the same conditions prevail in that part of the firn mass as in the uppermost 5 m., *i.e.* during the period 1899–1934 the glaciers from Isachsen's Plateau have received an annual average of 200 mm. of water in the form of snow or firn.

I found exactly the same conditions in the accumulation area of the North-East Land glacier-caps. In these districts however the annual surplus of snow and firn was only 63 mm. of water on an average. This fact is closely allied to the circumstance that these glacier-caps are nearly dead or have at least only a very small activity.

Besides this I have systematically made microscopic investigations of the structure of the firn, determinations of its specific gravity, and its permeability of radiation. These investigations are not as yet completed.

Sverdrup determined the temperature and its variations every day in the

firn masses in several places at our headquarters, by means of electrical resistance thermometers. In consequence of the facts established in North-East Land in 1931 we had expected to find on Isachsen's Plateau, where the mean annual temperature is about −12° C., frozen firn down to a considerable depth. As early as on June 25, when the largest pit was dug and the melting had just begun, I found however that at 3 m. the temperature was the lowest (−6° C.) and from there it rose to zero at 10 m. Sverdrup's systematic records have led him to the following conclusions about the thermal conditions in the snow and firn.[1] When the ablation water penetrates down into the firn, it freezes when it reaches the depth where the firn temperature is negative; it gives off its freezing heat and makes the temperature rise lower down. Exactly the same process occurs when a frozen fish for instance is put in water to thaw: an ice-shell forms round the fish. On August 1 every trace of the winter cold had disappeared and the whole firn masses were at zero.

Sverdrup has calculated that 145 mm. of water freezes in this manner in the first 10 m. when the annual surplus of snow is 400 mm. The rest of the ablation water passes down through the firn and runs off.

In consequence of these processes the ice crusts become thicker and the specific gravity of the annual layer of firn rises the lower we go. My measurements show that the density of the annual layers regularly increases from 0·54 in the layer 1933–34 to 0·64 in the layer 1924–25. This freezing process does not occur lower than 10 m., and Sverdrup believes that the transformation of the firn into glacier ice does not begin until the depth is so great that the pressure becomes the decisive factor. As a consequence of this freezing process a slow recrystallization of firn crystals will take place.

All these processes are of the greatest importance to our knowledge of glaciers. On the basis of the temperature observations made during my sledge journey over the glacier-caps of North-East Land in 1931 it has been calculated that under certain assumptions these glaciers are frozen to a depth of 270 m. at least. The glaciers with negative temperature, so important in the study of glaciology, were first discovered by Colonel J. P. Koch and A. Wegener in East Greenland during their expedition in 1912–13. The German Greenland Expedition Alfred Wegener continued these investigations at the station Eismitte in 1930–31. The results of these expeditions, our knowledge of Alpine glaciers, and various statements as regards the structure of glaciers in other parts of the Earth led me to classify glaciers geophysically as follows:

I. *Temperate glaciers* consist of crystalline ice formed by fairly rapid recrystallization of the annual surplus of solid precipitation. Throughout these glaciers the temperature corresponds to the melting-point of the ice, except in the winter time, when the top layer is frozen to a depth of not more than a couple of metres. The glaciers of Scandinavia and the Alps are included in this group.

II. *Polar glaciers* consist, at least in their higher and upper parts, of hard crystalline firn formed by slow recrystallization of the annual surplus

[1] H. U. Sverdrup, "The Temperature of the Firn on Isachsen's Plateau"; will be published in *Geografiska Annaler* 1935.

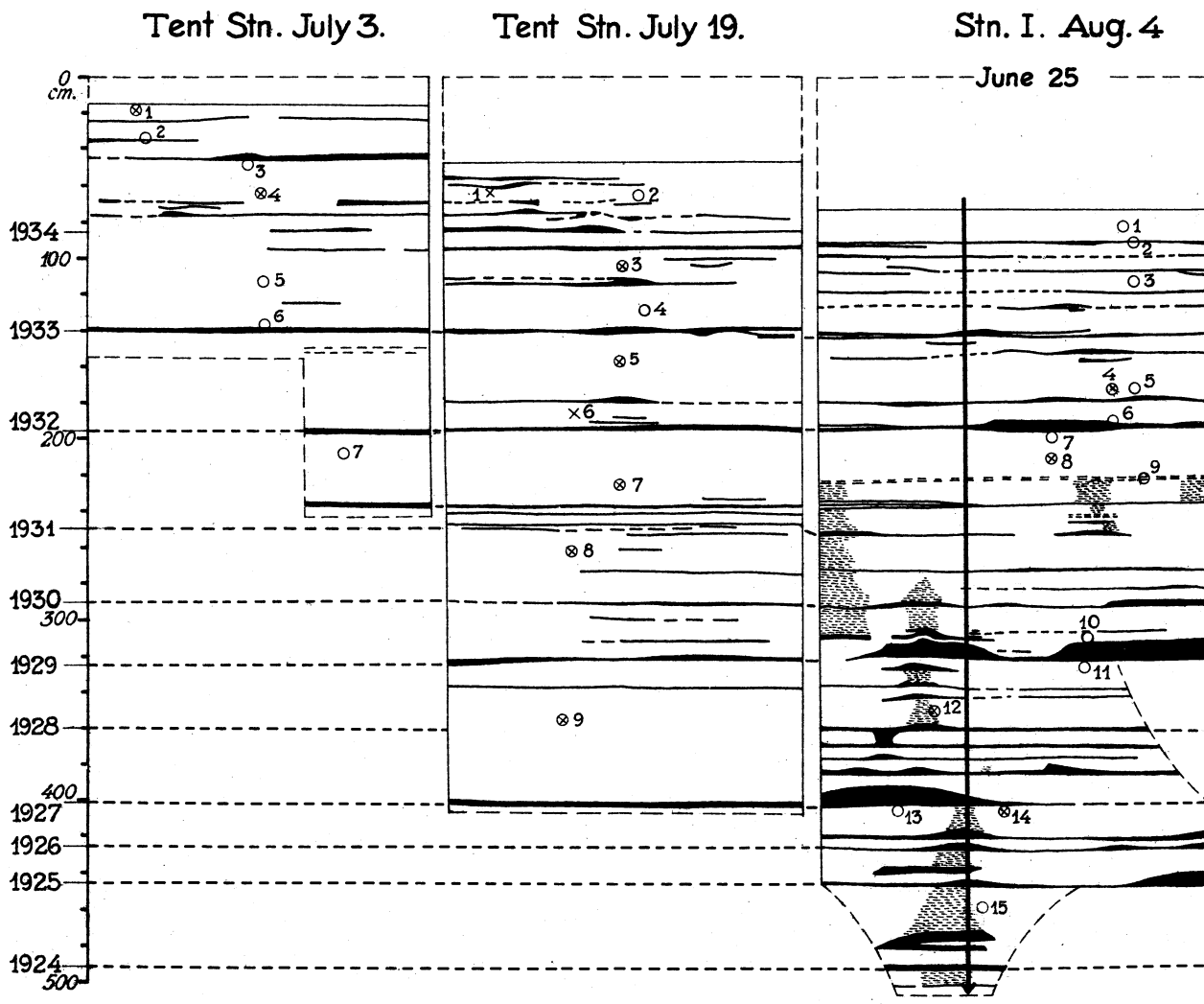
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Fig. 2.

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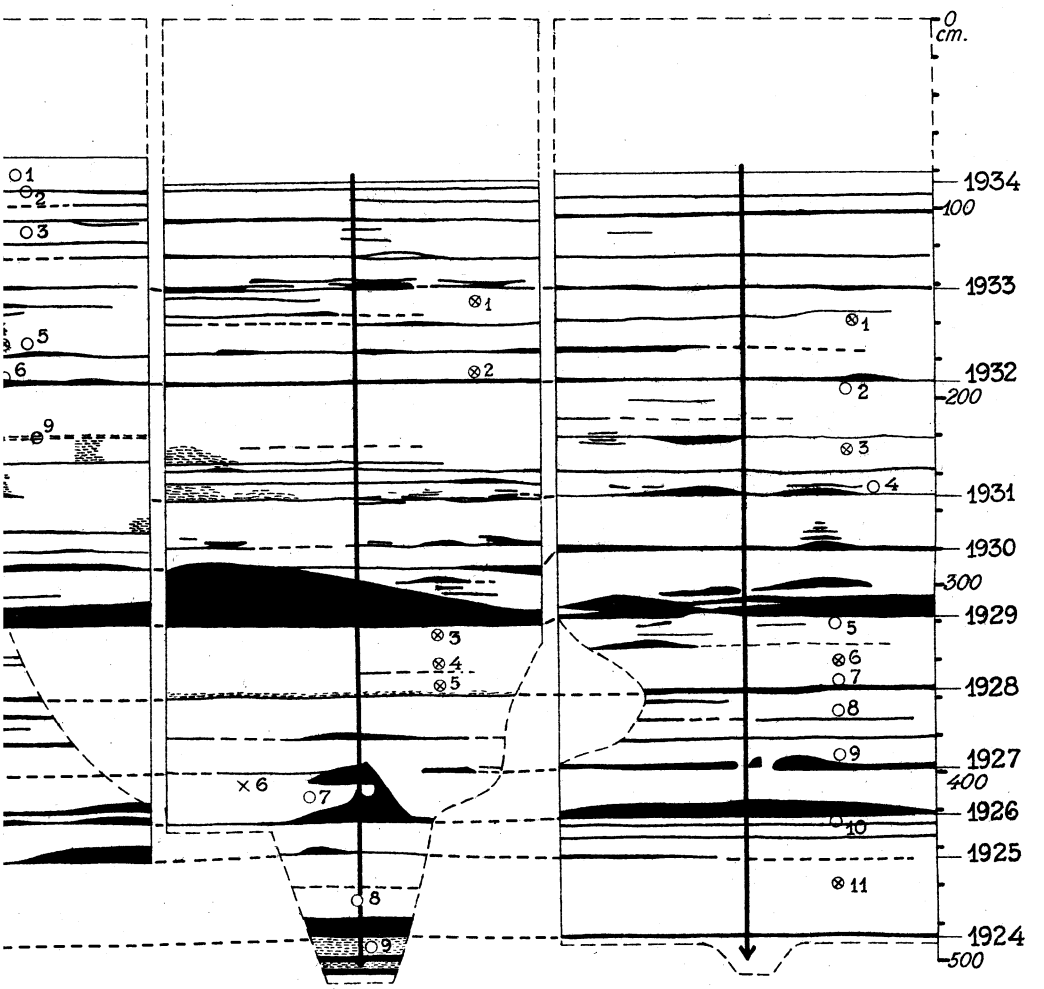

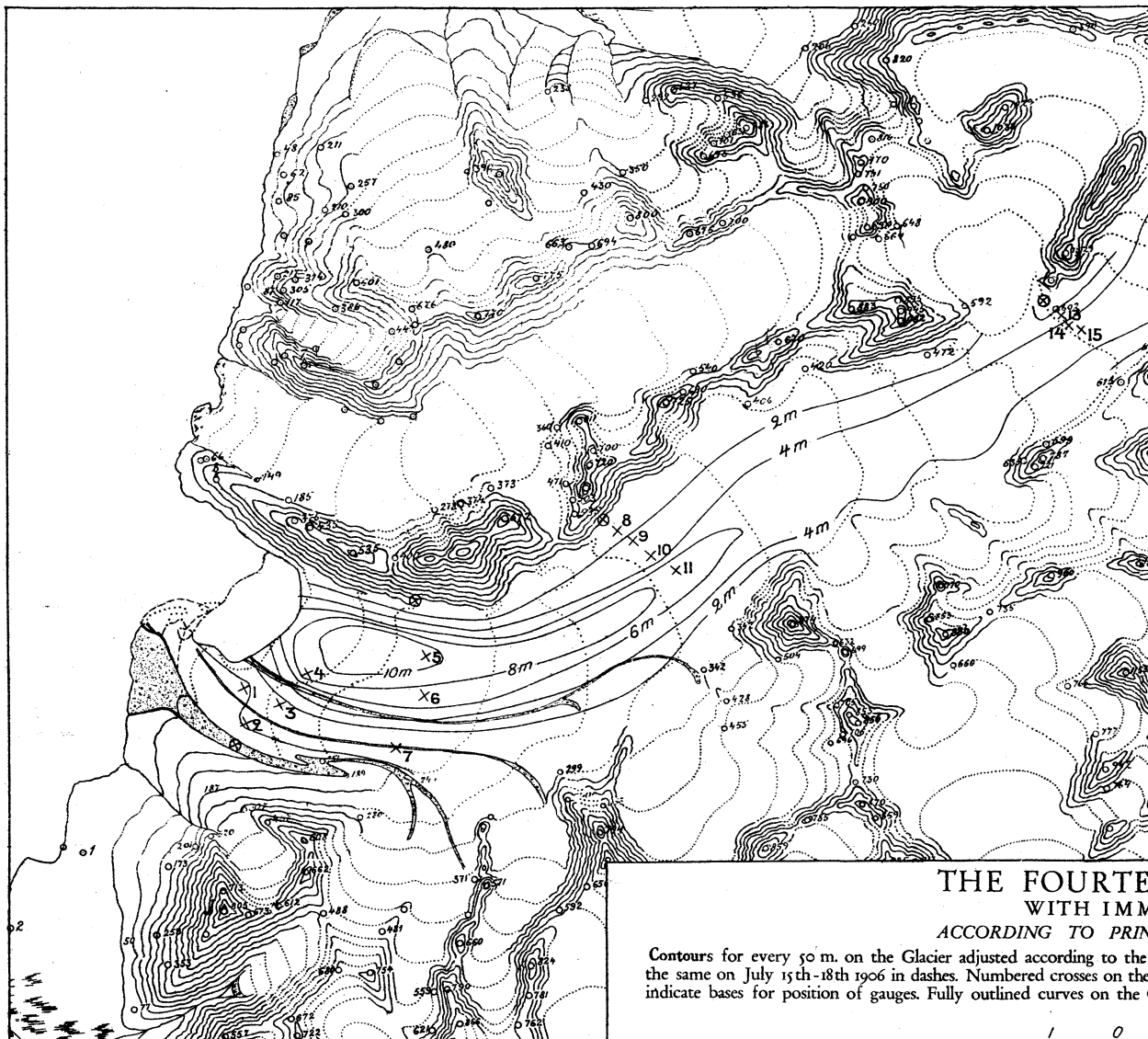
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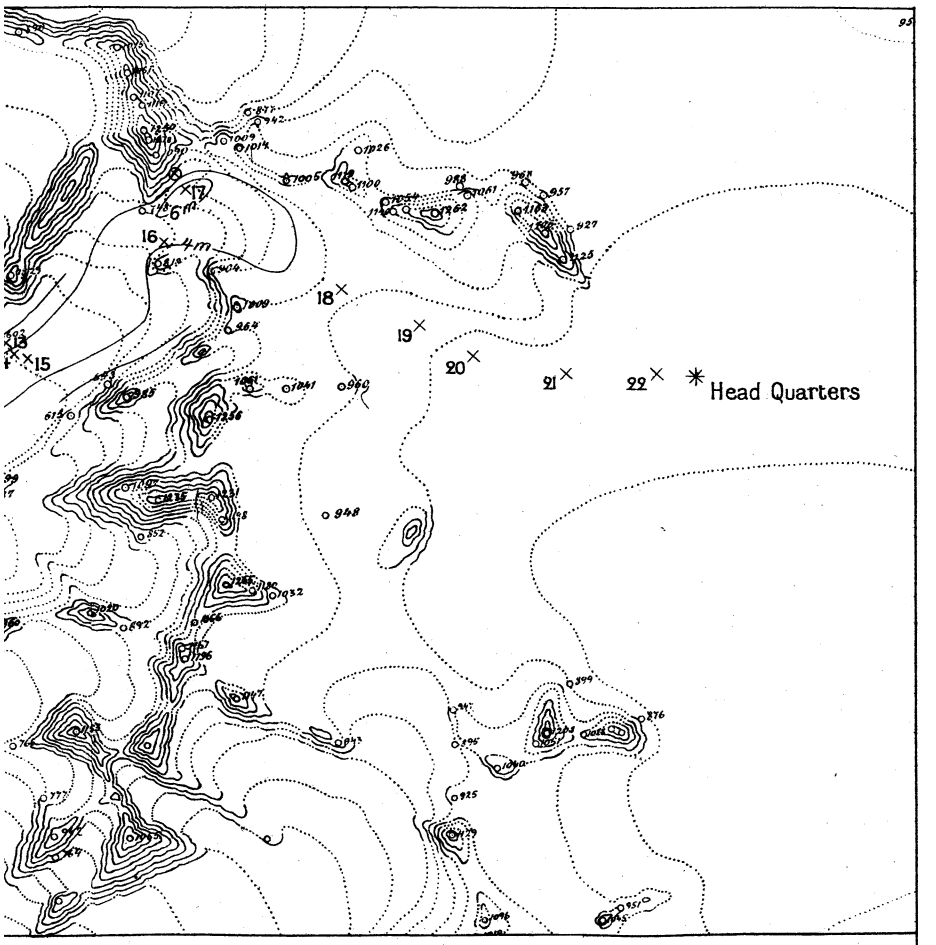
the same on July 15th-18th 1906 in dashes. Numbered crosses on the
indicate bases for position of gauges. Fully outlined curves on the

Fig. 3.



)URTEENTH OF JULY GLACIER

ΓH IMMEDIATE SURROUNDINGS

TO PRINCE ALBERT I (MISSION ISACHSEN) 1906-1907

rding to the present conditions. The margin of the Glacier in the fiord on Aug. 19th 1934 in full outline, rosses on the Glacier and on Isachsen's Plateau mark the gauges. Encircled crosses on side of the Glacier ves on the Glacier mark its movement in m. for 60 days from middle of June to middle of Aug. 1934.

0 1 2 3 4 5 km

of accumulated solid precipitation. The temperature of the glacier, at least in the accumulation area, is negative even in summer down to a depth of at least 100 m. or more. These Polar glaciers can be subdivided into:

A. *High-Polar glaciers*, which consist, at least in their accumulation areas, of crystalline firn to a depth of a couple of hundred metres or more. Even in summer the temperature in the accumulation area is so low that as a rule there is no melting accompanied by formation of water.

B. *Sub-Polar glaciers*, which in their accumulation areas consist of crystalline firn down to a depth of some 10 or 20 metres. In the summer the temperature allows melting accompanied by the formation of some water. This group includes the North-East Land glacier-caps.

This geophysical classification of glaciers is of course only a preliminary one, and it is only a first attempt to gain a broader and more rational survey than the morphological one, which principally refers to their external qualities and says very little about their most important characteristics, that is the physical ones.

It is undoubtedly correct that a close relation exists between the two essential physical qualities of the glaciers and the proportion of firn to ice, *i.e.* their temperature and their composition of firn and glacier ice. The temperature of the air, especially during the summer, is of great importance, not directly however, as this depends upon the quantity of ablation water, which it determines. In districts where the ablation water is sufficient to raise the negative winter temperature in firn and ice to zero, the glaciers are temperate and consist mostly of ice. In districts where the ablation water is not sufficient to make the winter cold disappear, glaciers are polar and consist mostly of firn. In these latter regions we must first mention the Antarctic, in which pure blue ice is very rare; in the second place we have Greenland, the inner and larger parts of which consist mostly of firn with very low temperature. Those portions of the Greenland inland-ice which consist of ice can also have a negative temperature, which is due to the ice being formed in the deeper parts of the central districts where the temperature is low; carried forward to the peripheral districts with ablation, it is difficult for the melt-water to penetrate the ice in the same manner as it can the porous firn, thus increasing its temperature to zero.

The investigations carried out at headquarters on Isachsen's Plateau formed the basis for the quantitative determinations of the material that pass through the Fourteenth of July Glacier, these being necessary in order to form an opinion of its character and life; the same holds good for every glacier.

Figure 3 is a copy of part of the excellent maps of N.W. Spitsbergen of the Isachsen Mission, 1906–07. Only the contours on the glacier have been changed in order to suit present conditions; the margin of the glacier in the fjord on 19 August 1934 and in August 1906 has been drawn as well as the curves showing the rapidity of the movement of the glacier during sixty days

from the latter part of June to the middle of August 1934 and from a maximum of 10 m. to zero.

The ablation determinations on the 22 gauges placed at different altitudes on the glacier and on Isachsen's Plateau, showed that ablation decreases with rising altitude and falling temperature, but that this decrease does not occur continuously. At the firn-line it drops, thus giving the curves the courses seen on Fig. 4. Ablation is much greater on snow-bare ice below the firn-line than on snow above this line, this being due to the fact that ice utilizes much more radiation heat than snow. This difference almost corresponds to the unequal albedo of ice and snow. The consequence is that ablation on a glacier, which has been long in recession or is dying and therefore comprises large areas of snow-bare ice, is more dependent on radiation than a glacier which advances or is in a stage of equilibrium and is thus covered by snow over at least two-thirds of its area.

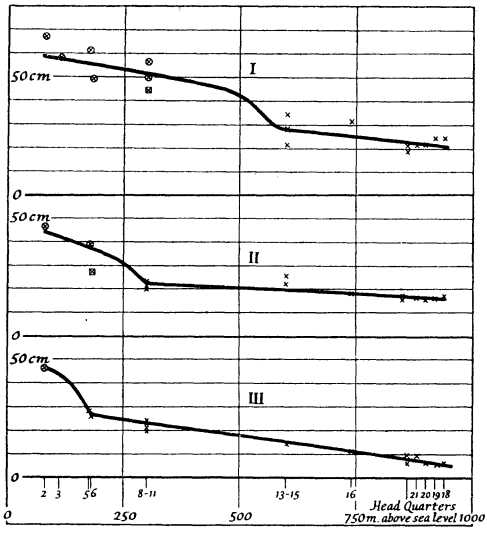


Fig. 4

After the last measures were taken on August 18 the ablation continued on the lower parts of the glacier right to the end of September, which was due to the exceptional heat of this month. For this period the ablation has been calculated with sufficient accuracy from the observations at the Norwegian Meteorological Station on Cape Linné. On August 18 the firn-line was at 550 m. above sea-level, but during the latter part of August it rose to 600 m., which is 150–200 m. higher than its normal position.

As a consequence of the determinations of the depth of the snow during the journey up to Isachsen's Plateau on June 20–23, and as a result of additional calculations, the accumulation of snow has also been determined on the whole glacier from the autumn of 1933 to the autumn of 1934. The curve representing this accumulation from sea-level to 1000 m. above it differs considerably from that of the precipitation. The reason of this is that during the winter the wind sweeps away large quantities of snow from the higher parts of the glacier and this accumulates on the lower and more sheltered portions. The quantity of material thus shifted is estimated at about 9,000,000 cubic m. of water.

In the same way, *i.e.* with the aid of the figures of the areas between the different contours, I have calculated the excess of accumulation above the firn-line and the excess of ablation below it. The result of this is that during the last season, 1933–34, the ablation surplus was about $4\frac{1}{2}$ times as much as the accumulation excess. The preliminary value of the former is about

53,000,000 cubic m., and of the latter 12,000,000 cubic m. of water. This incongruity between the accumulation and the ablation is so considerable that it cannot but prove disastrous to the maintenance of the glacier at its present size. These facts are not at all impossible, as last summer was characterized by such meteorological conditions that the firn-line, as has already been said, rose 150–200 m. above its normal position, and therefore an additional 13·5 sq. km. were exposed to the great ablation which always occurs on snow-bare ice. This also shows the very great importance of every change in the position of the firn-line, the decisive rôle of the ablation factors in these changes, as well as their effect on the whole life of a glacier. Most of the Spitsbergen glaciers have been receding for many decades and the conditions of last summer even brought this to a culmination.

The following data also confirm that the Fourteenth of July Glacier is at present in a very bad condition. Its margin has receded about 1000 m. since 1911 (Plate 4), the thickness of the ice had diminished 25–40 m. in the lower part, the movement of the whole glacier is slow, and some of its peripheral parts are dead or dying (Fig. 3).

As I have said before, warm humid air with a strong wind greatly contributes to ablation. Spitsbergen receives its supply of such air from the winds which blow from the northernmost part of the Atlantic Ocean, called the Norwegian Sea, the heat capacity of which is regulated by the Gulf Stream. The investigations of this stream, which Fr. Nansen and B. Helland-Hansen began and the latter continued, have shown[1] that its variations of heat quantity are so great, that these correspond to the unequal climatological conditions regulating the ablation on the Spitsbergen glaciers. When the capacity of heat increases in the Norwegian Sea, the frequency and force of the warm humid south-west winds on Spitsbergen also increase. The activity of the atmosphere connected with the heat conditions in the northern Atlantic may possibly explain the recession of glaciers, not only on Spitsbergen but also on Franz Josef Land and in Scandinavia; the very remarkable gradual death of inland ice on the northern island of Novaya Zemlya may also be attributed to this fact. If the continued analysis of last summer's observations can prove this, it may be possible to form a basis for a general discussion of the present glaciation on the Earth and its fluctuations.

It must be remembered however that the observations hitherto published by U. Monterin[2] on the ablation on the Lys Glacier on the southern side of Monte Rosa, lat. 45° N. and 2300–2500 m. above sea-level, most likely show that in this place radiation is more important than heat convection by the air.

It may be assumed that the variations of the heat capacity in the Gulf Stream are connected with the general circulation of the atmosphere of the Earth. In this case we come to a question similar to that which G. C. Simpson[3] has

[1] Björn Helland-Hansen: The Sognefjord Section. "Oceanographic Observations in the Northernmost Part of the North Sea and the Southern Part of the Norwegian Sea," James Johnstone Memorial Volume. Liverpool 1934.

[2] U. Monterin: "Recerche sull' ablazione e sul deflusso glaciale nel versante meridionale del Monte Rosa," *Bollettino del Comitato Glaciologico Italiano*, N. 11, 1931. Torino 1931–IX.

[3] G. C. Simpson: "World Climate during the Quaternary Period." *Quarterly Journal of the Royal Meteorological Society*, vol. lx, October 1934.

recently discussed theoretically. If the radiation from the sun increases, then the general circulation of the atmosphere as well as the activity and heat of the Gulf Stream will also increase; the south-west winds from the northern Atlantic will increase in strength, and ablation on glaciers will be greater in districts where melting is principally due to this heat supply by air, as well as in districts where it is mainly due to radiation.

This series of theoretical possibilities must however be regarded as only an hypothesis. We must first secure detailed glaciological material of the same character as this I have now mentioned from Spitsbergen and the North-East Land, in different climatological regions and on different heights round the Earth. In conclusion I should like to express the hope that the Royal Geographical Society has been sufficiently interested in my lecture to wish to support my suggestion.

Additional Notes

(1) After I had delivered this lecture my attention was called to an article by G. Slater ("Studies on the Rhone Glacier, 1927. The Relationship between the Average Air Temperature and the Rate of Melting of the Surface of the Glacier," *Quart. Journal of the Royal Meteorological Society*, vol. lv, October 1929). Concerning this article I only wish to say that analyses hitherto made (such as G. Slater, "Observations on the Nordenskiöld and neighbouring Glaciers of Spitsbergen, 1921," *Journal of Geol.*, vol. xxxiii, Spitsbergen Papers 1–32) between ablation and average *temperatures* cannot give any answer to the question of the dependance of ablation on the *meteorological* elements. First and foremost wind velocity, turbulence, and air humidity play such an important rôle that one must make the same consideration to these factors as to the air temperature. Further, it is not the mean air temperature but the high temperature during some hours or days that is most decisive for the amount of ablation. I am glad to see that Mr. Slater (on p. 392) has come to the same conclusion as I have concerning the necessity of locating the meteorological station, the records of which might be correlated with the ablation, right on the glacier. This was one of the objects of my expedition in 1934 and it was also fully realized.

(2) In 'Scientific Results of the Swedish-Norwegian Arctic Expedition in the Summer of 1931,' Part VIII: C (1933) I proposed that the glaciers from a geophysical point of view should be divided into *temperate glaciers*, *high-arctic*, and *sub-arctic glaciers*. These names have been changed in my lecture to *temperate glaciers*, *high-polar*, and *sub-polar glaciers*. When I wrote my treatise in 1932 I did not know the article of M. Lagally ("Zur Thermodynamik der Gletscher," *Zeitschrift für Gletscherkunde* 1932, 4–5). In this article he writes: "Man hat also für weitergehende Untersuchungen verschiedene Typen von Gletschern zu unterscheiden. 1. einen *kalten Typ*, der nirgends Schmelztemperatur hat; 2. einen *Warmen Typ*, der überall, von einer Oberflächenschicht mit schwankender Temperatur abgesehen, Schmelztemperatur hat; 3. einen *Übergangstyp* mit einer mehr oder minder dicken Schmelzschicht." It is with great pleasure that I have established that the principles of Lagally's classification fully agree with mine, and I think that they are of such a significant character that they will be of lasting value. Another question is the suit-

ability of the terms proposed, which subject can be decided by international discussion. My account of the relation between the fundamental thermal conditions and the different proportion between firn and ice in the formation of glaciers is also of only a preliminary character. I am convinced of the great importance of these circumstances for our knowledge of the nature of glaciers, but considerable additional investigations must certainly be achieved before the problem is solved.

(3) Professor Sverdrup emphasizes that, when discussing the relative importance of melting and evaporation, it must be borne in mind that the temperature of the snow (or ice) surface cannot rise above 0° C., and that the air which is in contact with the snow (or ice) has a temperature of 0° and contains an amount of water vapour which corresponds to saturation at the given air pressure. Furthermore, it must be remembered that the processes of evaporation and condensation do not depend upon the relative humidity of the air, but upon the specific humidity, the content of water vapour in unit volume. If the air is warm and wet, the content of water vapour increases rapidly with increasing distance from the surface, and, since the air motion is turbulent, water vapour is conveyed towards the surface where it condenses and the liberated heat is used for melting the snow. A snow surface will nevertheless appear almost dry since the melting water rapidly trickles down through the snow, but an ice surface will appear wet. If the air is warm and dry similar processes take place, unless the air is very exceptionally dry. At an air temperature of 10° the relative humidity must be less than 50 per cent., and at an air temperature of 15° the relative humidity must be less than 36 per cent., if the content of water vapour is to decrease with increasing distance from the surface. Even when evaporation takes place the effect on the ablation is small, since 680 gram calories are needed in order to evaporate 1 gram of snow or ice, but the effect of condensation on ablation is considerable, since condensation of 1 gram of water liberates 600 gram calories which are sufficient for melting 7·5 grams of snow or ice.

DISCUSSION

Before the paper the PRESIDENT (Major-General Sir PERCY COX) said: The paper this afternoon is a "Contribution to the Physics of Glaciers," and is to be read by Professor Ahlmann, Professor of Geography in the University of Stockholm. This study of glaciers he has made specially his own, and I am glad to see that there are present several who are specially interested in glaciology, so that we hope to have an interesting discussion after the paper.

Professor Ahlmann then read the paper printed above, and a discussion followed.

The PRESIDENT: I will call first upon Dr. Sandford, who was a member of the Oxford Arctic Expedition to North-East Land, 1924.

Dr. K. S. SANDFORD: Professor Ahlmann is one of those who are engaged in making glaciology an exact and precise science, and he is doing it at the right moment, because our ordinary observations are beginning to lead us into some difficulty. There have been many classifications of ice forms, and I think one of the last, that of Wright and Priestley, was highly satisfactory and stood us in good stead for many years, but now we see this very precise work coming along and supplementing the early classifications, which in part at least have served

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their purpose. Like many others, I have very much enjoyed listening to Professor Ahlmann's dissertation. I reviewed his first volume of results for the *Journal*, and perhaps it might be of interest to you to know that it took me three months to digest it, which gives some idea of the work comprised in that volume, and now there are other volumes in process of coming out. I congratulate Professor Ahlmann on his journey. The Oxford Expedition of 1924, by bad luck, got into North-East Land a little late in the season and encountered certain difficulties. Professor Ahlmann got in a little earlier, and performed a really amazing journey. I should like to offer my congratulations on that remarkable performance.

As to the question of wind, which is mentioned once or twice in the paper, the blizzards are very severe perhaps in winter, but certainly in summer, and clearly there must be an appreciable loss to the surface by blizzard removal throughout the whole year, but probably in certain months especially so. I am not quite sure how that would be represented in such sections as he was showing us. Some of the snow of course is entirely lost to the whole system. A second point which particularly interested me, especially in relation to North-East Land, was the reference to ice crusts. When we were at the highest part of North-East Land we noticed blue ice, and all three of us who were there formed the impression that it was blue ice to a considerable depth. That is of great importance to the expedition going up to North-East Land this year. If they are superficial blue ice layers they are merely incidental and probably of no great thickness underneath; otherwise it may be impossible to dig it into blocks to obtain shelter.

I should like to ask Professor Ahlmann how he overcomes the direct rays of the sun shining on his ablatograph. We saw a photograph of that instrument which he has himself invented and constructed, and it seems to me that there will be some reciprocal effect from the instrument from such rays. I have no doubt he has some method of allowing for that in making his calculations. It would certainly cause, I should think, an addition of ablation in the immediate vicinity. I congratulate Professor Ahlmann and thank him for the lucid and extremely interesting account to which I have just listened.

The PRESIDENT: I will ask Mr. Gerald Seligman to speak. Mr. Seligman is the author of a paper on "Properties of Ice and Snow" in a Ski Club Year-book.

Mr. GERALD SELIGMAN: I have listened to Professor Ahlmann with the greatest interest. It is no small achievement to deal with so complex a subject in a foreign language. It is like heaping Pelion upon Ossa and climbing them both. We have just heard from Dr. Sandford that it took him three months to digest Professor Ahlmann's earlier work, so that for you, Sir, to call upon me to give an opinion on a lecture of this character at short notice is to expect a great deal of me. I, personally, was immensely interested in it as being of the greatest help in the work that some of us are trying to do in the Alps to elucidate certain of the snow problems we are meeting there.

I have one question to ask. In his paper Professor Ahlmann states that the greatest ablation takes place with a humid wind of high speed. I can very easily understand that wind of high speed containing a great deal of moisture would deposit much of that moisture on the snow, and in doing so would generate heat. That, no doubt, is one of the reasons why it helps the ablation. What I do not quite understand is why the moisture should assist, as it were, the wind in respect to the ablation, because evaporation must be taken into account, and evaporation, although it has been said that it is of not so great importance, is cut out altogether by raising the humidity of the wind. If we take the extreme case of wind containing 100 per cent. moisture we should get no evaporation taking

place under those conditions. I am sure there is some explanation, and I should like to know what it is. A point entirely new to me is that in Antarctic regions we get very little blue ice. If that is the case it is most interesting, and would, no doubt, be accounted for by the great altitudes from which the ice is derived in Antarctic regions, where melting cannot take place.

The PRESIDENT: Dr. Fritz Loewe, one of the party at the Central Ice Station of Wegener's expedition to Greenland, will make a few remarks.

Dr. FRITZ LOEWE: I must, in the first place, apologize for my poor English. Nevertheless I wish to congratulate Professor Ahlmann on his very important new "Contribution to the Physics of Glaciers."

It is astonishing that our knowledge of glacier conditions in the accumulation area is much greater in polar regions than in the Alps, which afford easier facilities for an intensive study of glaciers. For instance, no systematic measurements of the temperature of alpine névés exist, a fundamental necessity if we are to understand the likewise unknown way in which in the highest alpine regions snow is transformed into firn and firn into ice. It is to be hoped that the knowledge gained by Profesor Ahlmann and his companions with regard to polar and Scandinavian glaciers will stimulate the study of the corresponding alpine conditions.

Professor Ahlmann mentioned Alfred Wegener as one of his predecessors. Unfortunately, on Wegener's last expedition two of the three glaciologists were unable to do scientific work. One died, and the other got seriously frostbitten. We made a thorough study of the mass balance and heat balance at the Ice-Cap Station under high polar conditions, the results of which will, I hope, be published soon. There, melting as a factor in transport of mass and energy is entirely absent and conditions are therefore relatively simple. We gained however little knowledge in regard to the condition in the transitional zone where melting takes place in summer, but nevertheless accumulation preponderates over ablation, as it does on the Isachsen Plateau. This gap Professor Ahlmann has filled. I was interested to hear that ablation is higher in periods of warm and humid air than in those when the air is warm and dry. If other conditions are the same, that can hardly be understood. Is it because humid air is connected with greater cloudiness and consequently the outgoing radiation is diminished? Thus the layer of cold air covering the snow surface is easily disturbed, and the heat convection at the surface is consequently greater. That the ice crusts separating the layers of different years are formed in the autumn confirms the somewhat uncertain hypotheses of De Quervain and Wegener and the estimates of annual accumulation on the Greenland Ice-Cap based thereon.

One component of the accumulation of polar ice-caps is hoar-frost with clear sky due to direct sublimation by cooling through outward radiation. It has been suggested that this kind of deposit is the most important component in the accretion of the central inland ice regions. I do not agree with that suggestion, but it would be highly interesting to know whether the measurements in Spitsbergen gave any hint as to the relative importance of this component. It is most interesting to know that on the Spitsbergen Ice-Cap there is a large surplus of ablation over accumulation which corresponds so well to the external appearance and behaviour of the front of many Spitsbergen glaciers. We have not yet a very clear idea of what happens in Greenland; but it seems that there the conditions are inverse to those found in Spitsbergen: that the accumulation, in the mean, exceeds the ablation.

As far as I understand, Professor Ahlmann makes temperature conditions the touchstone in his classification of glaciers, calling "temperate" such glaciers which are at melting-point throughout, and "polar" those which, at least in the

accumulation area, are frozen to a certain depth. In that I agree completely with him. As Professor Ahlmann found, the Isachsen Plateau shows temperate conditions. But the additional qualities given by Ahlmann's definition to the temperate glaciers do not seem to exist there. Their snow and firn should form a rather thin layer, whilst in Sverdrup's opinion the firn reaches down to a considerable depth, which in Professor Ahlmann's classification is a quality of a polar or even high-polar glacier. Also the "slow" recrystallization of firn crystals mentioned by the lecturer means rather " polar glacier" conditions. Thus his last studies seem to show that slight alterations in his "Geophysical Glacier Types" of 1933 would make his classification more valuable still.

In conclusion, I wish once more to emphasize what a lot of valuable new information Professor Ahlmann has laid before us this afternoon.

The PRESIDENT: We should like to hear Mr. Glen, the leader of the forthcoming Oxford Expedition to North-East Land. I may say that the lecturer is the only man who has visited the district where Mr. Glen proposes to make his base camp.

Mr. ALEXANDER GLEN: I may point out that it was largely due to my good fortune in meeting Professor Ahlmann in King's Bay during the summer of 1934 that the first idea of this North-East Land Expedition came into my mind, and I should like to record how very grateful I am to Professor Ahlmann for the help he has given us on every possible occasion. It is our intention to establish two winter stations on either the East or West Ice of North-East Land. The reason for two stations is that part of our programme covers the investigations of wind conditions as well as of general meteorological conditions, an interesting study of which ought to be possible from one inland station on the ice summit (about 2400 feet), another at perhaps 1200 feet or lower, and from observations at the base station in Rijps Bay, at sea-level. In addition we hope to carry on investigations on the precipitation and to continue Professor Ahlmann's work on ablation. This last will be done by one of the above two stations over the whole year, and the change over from winter to summer conditions should prove especially interesting. Professor Ahlmann is coming to Oxford in a day or two to give us his advice on our plans, and we are very grateful to him for the assistance he has given us.

The PRESIDENT: Mr. John Wright, of the Hagavtn Expedition, Iceland, 1934, and a member of Glen's expedition, may like to add something to what has been said.

Mr. JOHN WRIGHT: I do not feel at all qualified to express any opinion of Professor Ahlmann's lecture since I have had practically no experience of glaciological work, but I have two points which I should like to raise in comparing his observations with those that we made in Iceland. We were not making a detailed investigation of glaciology, but chiefly doing survey work, and endeavouring to discover the general physical régime of this lake. In the light of this lecture however I cannot say whether our observations support Professor Ahlmann's theories or not. In one or two cases they certainly do. First of all, he said that radiation was very much greater on snow-free areas of ice, and our observations certainly confirm that, because where the snow had been melted off the ice-cap on the edge of which we were working, the importance of radiation was clearly shown by the usual phenomena of ice-dirt cones, in which the dirt blown on to the glacier protected the glacier from radiation, and so raised a cone which might be anything up to 4 or 5 feet high; also by ice wells in which dust sinks into the ice because of the increased heat due to radiation. We were fortunate enough to be shown photographs of the ice-cap on which we were working taken nine years previously, and these showed that there had been a

retreat of something like a kilometre of the ice. It has been mentioned that in the 1934 Expedition the air temperature was measured and the ordinary meteorological phenomena taken at the snow surface and also at heights up to 5 metres. I believe that some difficulty in measurement was encountered, and I should like to know how they obtained accurate readings.

The PRESIDENT: A Fellow who could not be present this afternoon has sent a request that the lecturer would offer some suggestion as to the cause of that very disturbing and even terrifying noise which he heard occasionally upon the ice-pack in the middle of Greenland.

Professor AHLMANN then made the following reply: As regards Dr. Sandford's question about the effect of strong winds on the glaciers, there is beyond doubt a great drifting of snow especially in winter from one place to another on the North-East Land glacier-caps as well as on the other ice- and firn-plateaus in Spitsbergen. Concerning the Fourteenth of July Glacier, as I have just said, the amount of this transport of loose snow can be calculated at about 9 millions of cubic m. The quantity that the accumulation area thus loses will be represented in the sections of the ablation area. This drifting can be so great that the whole quantity of precipitation in solid form will be swept away from large parts of the accumulation areas. According to M.M. Ermolajeff such conditions prevail on the northern island of Novaya Zemlya. During my sledge journey across the central parts of the North-East Land glacier-caps I did not find any snow-bare ice and the pits showed more than 2 m. stratified firn.

It is quite correct that the radiation from the sun has some effect on the float of the ablatograph. In my description of this instrument, mentioned in my lecture, I have given an account of the corrections necessary for these "independent movements of the float." The examples here given represent exceptionally great values of the independent movements. In general they are much less and on ice they are of very little importance.

I am very glad to have had the opportunity of giving Mr. Glen some advice about his expedition to North-East Land this summer and I am looking forward with great interest to a more detailed discussion with him about the glaciological programme; at the same time I should like to wish the expedition every success.

In answer to Dr. Loewe's question about the hoar-frost, I should like to say that its formation plays an important rôle in the alimentation of glaciers in districts with maritime climates. In Norway I have proved this in the highest part of Jotunheim, and my assistant in 1934, Mr. Olsson, measured very great quantities of hoar-frost on Mount Nordenskiöld in Spitsbergen during the Polar Year 1932–33. Most of the "snow" accumulated on this mountain is not snow fallen but hoar-frost. In districts with continental climates, as for instance Central Greenland, I cannot believe that hoar-frost plays any really great rôle.

Concerning the application of my geophysical classification of glaciers to the Isachsen's Plateau and the Fourteenth of July Glacier, it is obvious that they must be regarded as "temperate." I also refer to my note about this classification, added to my lecture.

Mr. Wright's question about the temperature measurements on Isachsen's Plateau can only be answered by Professor Sverdrup's treatise on his investigations, the methods and instruments employed being of such new and exact types that they require a detailed description.

Concerning the important and complicated problem of the relative importance of melting and evaporation, I shall take the liberty of asking Professor Sverdrup for a short account (see above, p. 107, Additional Notes no. 3).

The PRESIDENT: I am sure you will have appreciated, as I have, the lucid and practised way in which Professor Ahlmann has delivered his paper. Some of the

uninitiated among us, including myself, have no doubt found that in the more technical parts of his address he has been to some extent speaking over our heads, but we can all appreciate the interest and importance of his subject and admire the skill which enabled him to deal with it effectively in a language not his own. As you are all aware, we have constant reason to be grateful to our Scandinavian friends for cooperation in connection with exploration in the north polar regions; and, as you have just heard, Professor Ahlmann has already been giving Mr. Glen the benefit of his cooperation and will continue to give it in connection with the latter's coming expedition to North-East Land.

It has been a great pleasure to us to welcome Professor Ahlmann and his wife, and we hope that during their stay in England it will not be all work and no play for him, but that they will have time to see something of our countryside.

Mr. N. E. ODELL *sends the following contribution to the discussion:* Professor Ahlmann has made a long series of observations upon the glaciers of Scandinavia and of Spitsbergen, and it was a pleasure both to hear the lecture upon his important conclusions and to have the opportunity later to discuss some of those conclusions, as well as the deductions that may be made from them.

His studies with those of Professor Sverdrup, upon ablation processes, and the determination of heat-convection as opposed to radiation, and the evaluation of these relative to melting, are of the greatest importance, not only for their explanation of the way in which glaciers of the regions studied are at present so fast wasting away, but for the emphasis they lay on the value of such observations in countries and districts which derive their water supply in large part from mountain snows and glaciers. Some studies with this end in view have recently been begun on the western slopes of the Cascade Range and the Sierra Nevada of western U.S.A., and from my friend Mr. François Matthes, Chairman of the Committee on Glaciers of the American Geophysical Union, I have lately received a small paper[1] treating of ablation on snowfields. Under the conditions prevailing in those parts, Matthes has shown that so great is the ablation by evaporation from the upper snowfields that the latter must be excluded from any estimates of run-off based upon "snow surveys." On the glaciers of Mount Rainier, for instance, surficial melting in sufficient quantities to produce rills and rivulets on the ice does not extend above an altitude of about 7000 feet. "On warm days," Matthes states, "these streamlets form miniature river-systems, with miniature waterfalls, lakes, and canyons in the ice. They are truly impressive for the volume of water they carry off, but far more impressive, if one stops to consider it, is the fact that from this low level upward to the summit of the peak (14,408 feet), through an altitude range of some 7000 feet, the snow and névé extend with dimpled, sun-cupped, sun-pitted surfaces (due to evaporation) that are perpetually dry." Matthes considers that any quantities of water that may be released by the warmth of the mountain or by pressure melting from the basal layers of these névé-fields are probably so small for all practical purposes as to be negligible. It is therefore from the lower portions of the glaciers, and those alone, that the great floods of melt-water in summer are derived, the function of the névé-fields being the indirect one of supplying water only in the solid state to the glaciers. Observers taking part in the "snow-surveys" in the Sierra Nevada are now engaged in trying to find the level of the zone of maximum snow-precipitation and of melt-water yield.

As to the important rôle played by melting as opposed to evaporation which

[1] François Matthes, "Ablation of Snow-Fields at High Altitudes by Radiant Solar Heat," *Transactions of the American Geophysical Union*, Fifteenth Annual Meeting, 1934.

Professor Ahlmann has shown takes place on the low altitude, "Sub-Polar," glaciers of Spitsbergen and North-East Land, I am able to bear him out if only from qualitative observations made during two sledging journeys (1921 and 1923) in Spitsbergen. Nothing is more striking than the vast amount of melting and the resulting rivers and lakes of melt-water which form during the summer, even under prolonged conditions of saturated atmosphere and thick fogs. With regard to the general recession and shrinkage of glaciers and snow-fields, to which Professor Ahlmann makes reference, I can fully support him with quantitative field evidence from southern New Friesland and Garwoodland. In the latter region of eastern Spitsbergen certain higher peaks now project above the highland ice-covering some 1000 to 1500 feet. On many of them, owing either to similar adjacent formation, intensive frost-splitting, or other causes, there is no definite evidence from erratic perched blocks of an earlier and higher level occupied by the ice. But in one instance at least, on the great mountain-nunatak, at the head of the Nordenskiöld Glacier, Mount Ferrier, there was unequivocal evidence—and a minimum measure of the amount—of the former much higher stand of ice in these parts. On the eastern ridge of that limestone mountain were found granite blocks at 1000 feet above the general level of the highland ice-sheet lying eastward of it, their composition arguing their derivation from the Chydenius Mountains to the north-east, and their elevated position proves that the ice in this region was formerly far more inundated. Only future exploration and observation can determine what the maximum "glacierization" of Spitsbergen amounted to and whether it ever entirely enveloped all the highest peaks or not, apart from the question as to when it last occurred, and if its incidence has been cyclical and entirely due to the variable heat capacity of the North Atlantic Drift, as Professor Ahlmann supposes.

Although Professor Ahlmann puts forward his geophysical classification of glaciers purely as a preliminary one, I think it is definitely to be welcomed, since its basis emphasizes a side of glaciological study that has been singularly neglected. Morphological studies of glaciers, which have been pursued for so many years, have really done little to advance our knowledge of the real constitution of glaciers, their mode of motion, and the question of their potency as erosive or merely abrading agents. The intensive physical examination of the kind that Professor Ahlmann and his collaborators are carrying out seems therefore to afford new hope for the immediate future of glaciology as a whole. What is clearly wanted now is a series of similar observations upon the glaciers of other regions, and particularly at the highest altitudes, where a peculiar combination of arctic and tropical external conditions are to be found. If systematic and detailed observations of the kind that Professor Ahlmann has made with such admirable enterprise in high latitudes, could be extended by some of the projected expeditions in the near future to the high altitudes of the Himalaya, and especially perhaps the coming Mount Everest Expedition, we should be going some way in our support of the suggestion of cooperation made by him to the Society.

Professor AHLMANN: After reading Mr. Odell's contribution to the discussion I am very glad to acknowledge the importance of his observations in Spitsbergen. I should also like to call special attention to the advisability of physico-glaciological investigations on glaciers at the highest altitudes. In my opinion these observations are now the most important contributions to glaciology. Special methods can be worked out and instruments constructed for climbing parties on the highest parts of the Himalayas or Karakoram. I should feel more than pleased if my lecture could bring this about.

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A JOURNEY IN BHUTAN: *A paper read at the Evening Meeting of the Society on 27 May 1935, by*

C. J. MORRIS

BHUTAN is an independent state in the Eastern Himalayas. On the north and east it is bordered by Tibet; on the west by the Tibetan district of Chumbi, the scenery of which has been made familiar by successive expeditions to Mount Everest; and on the south by the British Indian Provinces of Assam and Bengal. Its extreme length from east to west is 190 miles, and its breadth, which varies considerably, extends to 90 miles at the widest point. The area is about 18,000 square miles, and the population has been estimated at about 300,000.

Communication between the hills of Bhutan and the plains of Bengal and Assam takes place through a series of mountain passes, known locally as Dooars, a word derived from the Hindustani *dwār*, meaning gate or entrance. This name is nowadays used also to denote the level tracts upon which these passes open. The Dooars, which contain much rich and fertile soil capable of high cultivation, are divided into two by the Sun Kosh river, which also forms the boundary between Assam and Bengal. The western or Bengal Dooars are for the most part now covered with tea gardens; but the eastern or Assam Dooars are still to a great extent covered in virgin forest and are not at all unlike the Nepal Terai. The present southern boundary of Bhutan runs along the foothills, and thus the country contains practically no flat land beyond a narrow strip only a few miles broad which has been retained in places. Prior to the war in 1865 the whole of the Dooars belonged to Bhutan. Geographically the country does not differ greatly from Nepal and Sikkim, and forms an extension eastwards of the latter countries. It possesses similar deep valleys and high mountain ridges, and suffers equally from a lack of communications.

The original inhabitants of Bhutan are believed to have been subjugated about two centuries ago by a band of military colonists from Tibet. In 1774 the East India Company concluded a treaty with the ruler of Bhutan; but repeated outrages on British subjects committed by the dwellers in the hills led from time to time to punitive measures, usually ending in the temporary

or permanent annexation of various parts of the Dooars. In November 1864 the eleven western or Bengal Dooars were thus annexed, and in the following year a treaty was concluded under the terms of which Bhutan was granted an annual subsidy on condition of good behaviour. Many years later, in 1910, this treaty was amended and by its terms the British Government undertook not to interfere in the internal administration of the country. On its part the Bhutanese Government agreed to be guided by the advice of the British Government in regard to its external relations.

The form of government in Bhutan, which existed from the middle of the sixteenth century until 1907, consisted of a dual control by the clergy and the laity as represented by Dharma and Deb Rajas. In 1907 however the Deb Raja, who was also Dharma Raja, resigned his position, and the Tongsa Penlop, or Governor, Sir Ugyen Wangchuk, was thereupon elected as the first hereditary Maharaja of Bhutan. He died in 1926 and was succeeded by the present ruler, Sir Jig-me Wangchuk, K.C.I.E.

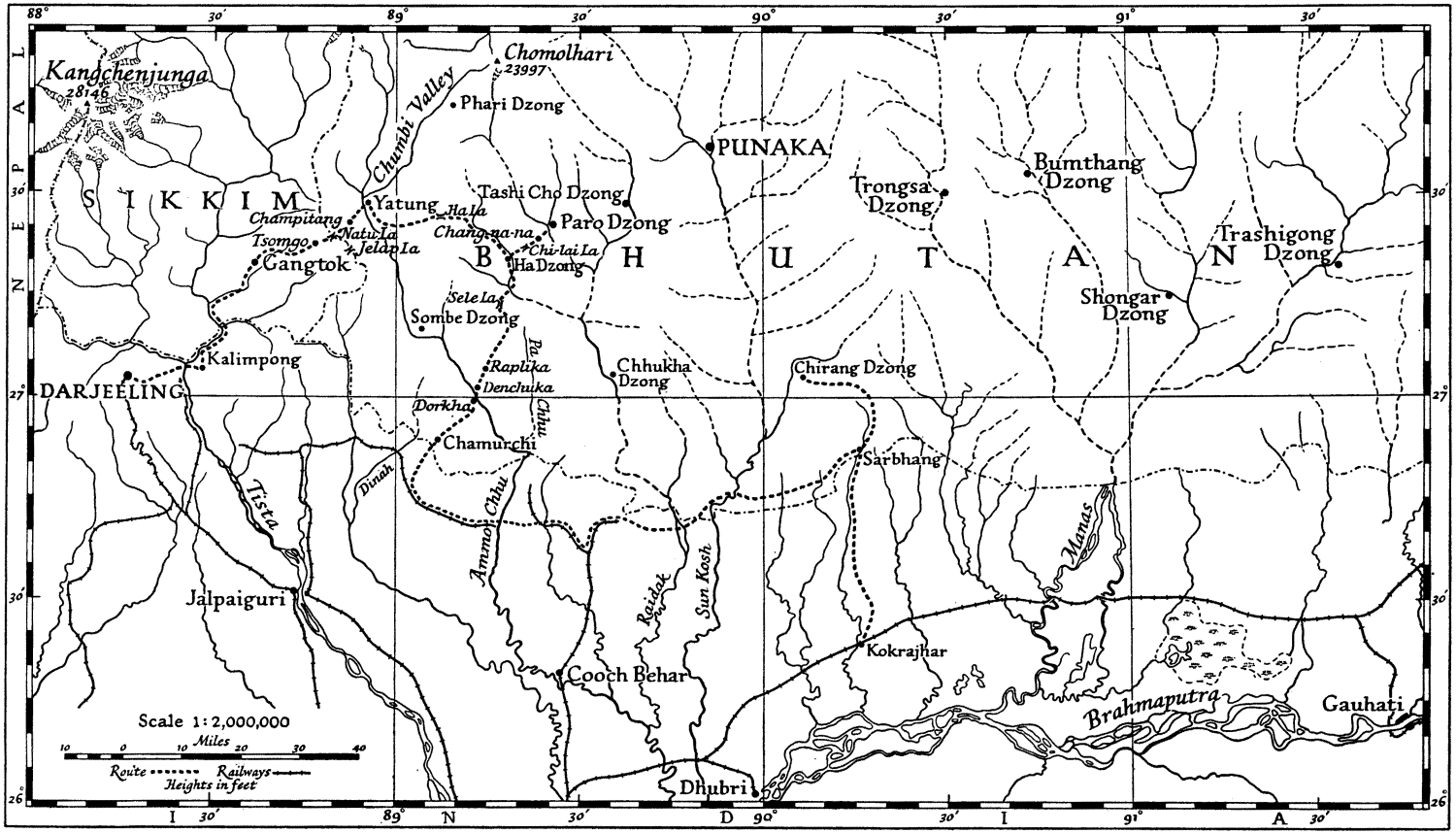
The people of Bhutan are closely akin to the Tibetans and speak a Tibetan dialect similar to that spoken in Sikkim.[1] Anthropologically they are closely allied to the Mongoloid tribes of Nepal, such as for instance the Gurungs, Rais, and Limbus; but whereas the latter are now Hindus the Bhutanese are Buddhists. A very large number of people spend most of their lives in monasteries or nunneries, and probably in no other Buddhist country is such a large proportion of the population so segregated. These religious institutions vary in size from diminutive wayside chapels housing no more than a bare half-dozen monks to the great Lamasery at Tashi Cho Dzong, which contains some three hundred.

Beyond the guards for the defence of the various castles there is no army, but some parts of the country are famed for the manufacture of muzzle-loading guns and swords of highly-tempered steel.

His Highness keeps an agent at Kalimpong, who is also assistant to the Political Officer in Sikkim for Bhutanese affairs. This is at present Raja Sonam Tobgay Dorji. He it was who made the detailed arrangements for my journey and he also gave me much valuable information about the country. I cannot sufficiently thank him for all that he did on my behalf.

Bhutan is probably the most closed country in the world at the present day, and beyond occasional ceremonial visits to the Capital by the Political Officer in Sikkim very few Europeans have been allowed to enter the country. I visited Bhutan in 1933 at the request of the Government of India and at the invitation of the Maharaja. It was originally intended that I should confine my travels to the southern parts of the country, now almost exclusively occupied by Gurkha settlers from Nepal. I was however extremely anxious to see Ha and Paro. There seemed at one time little chance of this: but Mr. F. Williamson, the Political Officer, mentioned my desire to Raja Dorji, with the result that I was given permission to visit both these most interesting places. Part of my route has been previously traversed, but in the opposite direction, by Lord Zetland (then Lord Ronaldshay) when he was Governor of Bengal. "The greater part of the route we followed," he later noted, "was said never before to have been traversed by a European. It provided little of

[1] See *e.g.* 'Linguistic Survey of India,' vol. 3, part 1, pp. 129 *et seq.*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Chomolhari 23997
Chumbi Valley
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Trashigong Dzong
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Natu La
Jelap La
Tsomgo
Gangtok
Tashi Cho Dzong
Ha La
Chang-na-na
Paro Dzong
Chi-lai La
Ha Dzong
Sele La
Sombe Dzong
Kalimpong
DARJEELING
Raplika
Denchuka
Dorkha
Pa Chhu
Chhukha Dzong
Chirang Dzong
Chamurchi
Sarbhang
Tista
Dinak
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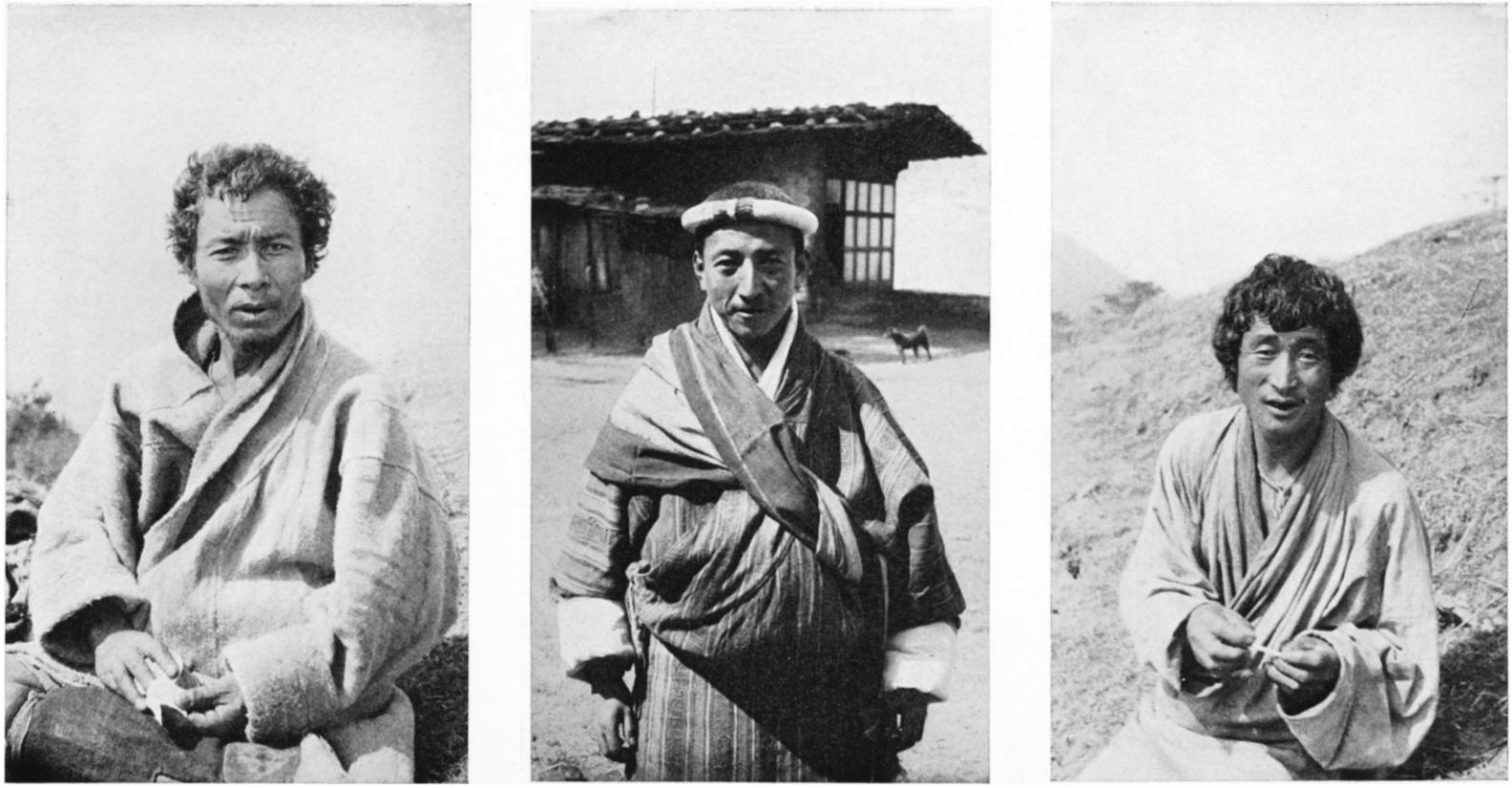
interest, however, climbing up and down heavily wooded mountain sides sparsely populated for the first few days, but colonised by Nepalis as we got nearer to the plains." [1] I have quoted his words as a warning of what follows, since the remainder of this paper is principally concerned with the question of Nepalese settlement in Bhutan. I must also make it quite clear that since my time in Bhutan was fully occupied I had no opportunity, nor had I the means, of making detailed investigations. The journey occupied in all only a few weeks, and I was almost constantly on the move. I would, then, ask the reader to receive my comments in the spirit in which they are offered: that is to say, as the superficial impressions of a very hurried and brief visit.

It is said that until some sixty years ago the foothills about Sarbhang were peopled by Bhutanese. About 1870 however the Bhutanese are believed to have begun a gradual movement farther into the hills. Until a few years before the Great War the district, which consisted for the most part of dense jungle, appears to have been practically uninhabited; but about 1910 the first of the Gurkha settlers arrived. Prior to this however many Gurkhas used to make annual visits to the district, but they never stayed more than a few months in the hot weather. They came in order to tap the rubber trees, of which there is still a large number, but for the rest of the year they remained at their homes in Nepal. This rubber tapping went on for some years, but eventually the Government of Assam commenced to plant on a large scale, after which it was no longer profitable to the Gurkha owing to lack of proper equipment and ignorance of scientific methods. The systematic settlement and commencement of agriculture by Gurkhas in this part of Bhutan appears to date from this time.

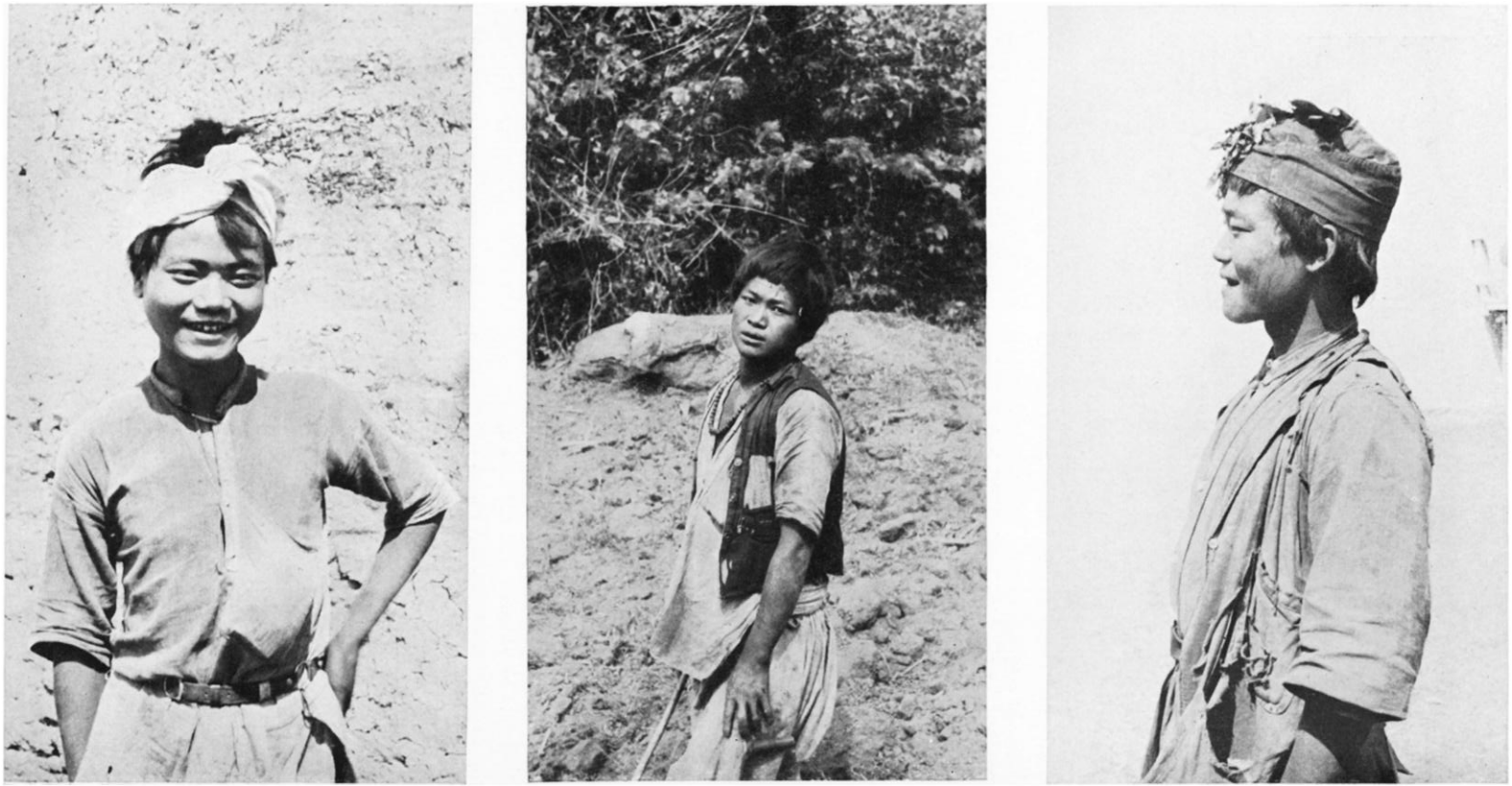
There are several reasons for this immigration into Bhutan. Some men for instance told me that in 1914 there was a very serious landslide in the Yangrup district of Eastern Nepal. Large numbers of people lost their entire property in this calamity, and hearing that there was good land to be obtained for the asking in Bhutan they decided to emigrate. Nepal however is undoubtedly over populated in its more fertile parts, and it appears always to have been difficult to arrange for sufficient land in the hills to support the needs of the people. Until comparatively recently the Nepal Terai was of little use as a settlement area owing to the difficulty of providing a sufficiency of pure water and to the danger of malaria throughout the greater part of the year. Thanks however to modern methods of research and to the efforts and expenditure of vast sums of money on the part of successive Maharajas of Nepal, large tracts of this once ill-famed stretch of country have been made habitable and numbers of the early settlers have now been able to return to their own country.

Gurkha settlement in Bhutan is at the present time confined to two main areas: firstly, the eastern area known as Chirang, which lies immediately to the north of the eastern or Assam Dooars; and secondly, the western area, which lies to the north of the Western or Bengal Dooars. This is known to the Bhutanese as Samchi, and to the plains-dwellers as Chamurchi. The two areas are roughly separated by the Sun Kosh river. I decided first to visit the eastern area.

[1] 'Lands of the Thunderbolt—Sikkim, Chumbi, and Bhutan,' London, 1923, p. 246.



Typical Bhutanese



Typical Nepalese settlers

Chirang is reached *via* Kokrajhar, a flag-station on the Lalmanir Hat–Gauhati section of the Eastern Bengal Railway, and here I found myself towards four o'clock of a morning in March 1933. It was hardly the most suitable hour to arrive at even the most civilized of places, nor was I feeling disposed to hunt for a guide. There was nothing to be done beyond spreading our bedding on the cement platform and waiting—one could hardly sleep—for the day to dawn. Later on we learned that the Bhutanese authorities had most kindly sent porters for our onward journey, and soon after daybreak we set off over the dusty and scorched plains: far away in the distance the outline of the foothills was just visible.

Along the whole of the southern border of Bhutan and extending for some miles south into British territory runs a dense belt of forest. This is strictly comparable with the Nepal Terai and is equally famed for the quantity of big game to be found within its secluded glades; and also for the numbers of particularly malicious mosquitoes which make the area uninhabitable for a great part of the year. There are clearings in this forest belt, many of them very large, and before reaching the foothills we passed through a number of villages, occupied mostly by a tribe known as Mechi. The Mechis are of Mongoloid appearance, and except for the very dark colour of their skin, not greatly different from Gurkhas. Many of the men indeed spoke Nepali, but I was told that the women never learn this language. Unlike the Gurkhas, the Mechis carry their loads slung from a pole across the shoulder and do not use the head-strap—the universal method of carrying loads in Nepal. We saw also a few villages inhabited by Santals. These people are small of stature, very dark-skinned, and of somewhat Negroid appearance, but for lack of a common language I was unable to converse with them.

We were forced to spend one night in the forest, where there was a tiny rest-house and a few wretched huts. The people here looked emaciated and fever-ridden. It was a hot and airless night and the glade was filled with the myriad lights of fireflies. Soon after leaving this little clearing of Patgaon the forest becomes denser, and for the last 18 miles or so consists of almost impassable sal jungle. It is crossed only by a few rough tracks, and there is water at only one place. Shortly before reaching the Bhutanese frontier the forest becomes thinner and there is again a number of clearings. During the monsoon rains this forest belt becomes almost impassable, but the journey down from the hills is at all times a fairly arduous one. It is important to note these facts, for they have done much in preventing culture contact with the plains of Bengal and Assam, and have enabled the Nepalese to live a life in conditions not dissimilar to those prevailing in their own country. The Nepalese settlements are equally segregated from the north, as will be noted in a later paragraph.

A mile or so beyond the frontier is a big clearing in the forest, and here is Sarbhang, the principal and indeed the only market for the people living in the Chirang district. It consists of about forty thatched huts, all occupied by Nepalese. The inhabitants live here throughout the year and rice is grown in the surrounding fields. Every Sunday throughout the year a *Hāt*, or market, is held and practically the entire adult population of the district regularly attend. They bring down oranges, potatoes, mustard, and a certain amount

of rice from the hills. These they sell or exchange for salt, which is unobtainable in the hills. I also saw many stalls where cheap cotton goods, necklaces, and mirrors could be obtained, and there was a brisk sale in umbrellas. Oranges are obtainable here at one hundred for eleven annas (about one shilling), and the market rate for rice at the time of my visit was 36 lb. for one rupee (one shilling and sixpence). Most of the oranges are exported by Bengali traders who either visit or have agents in these various markets. Chirang, which gives its name to the district, is about 5000 feet above sea-level. It is only one of many villages, but the name is used to denote the whole of the settlements in this area. There are said to be about one thousand houses in Chirang, exclusively occupied by Nepalese, and beyond the Bhutanese official who accompanied me I saw none but Gurkhas in the whole area.

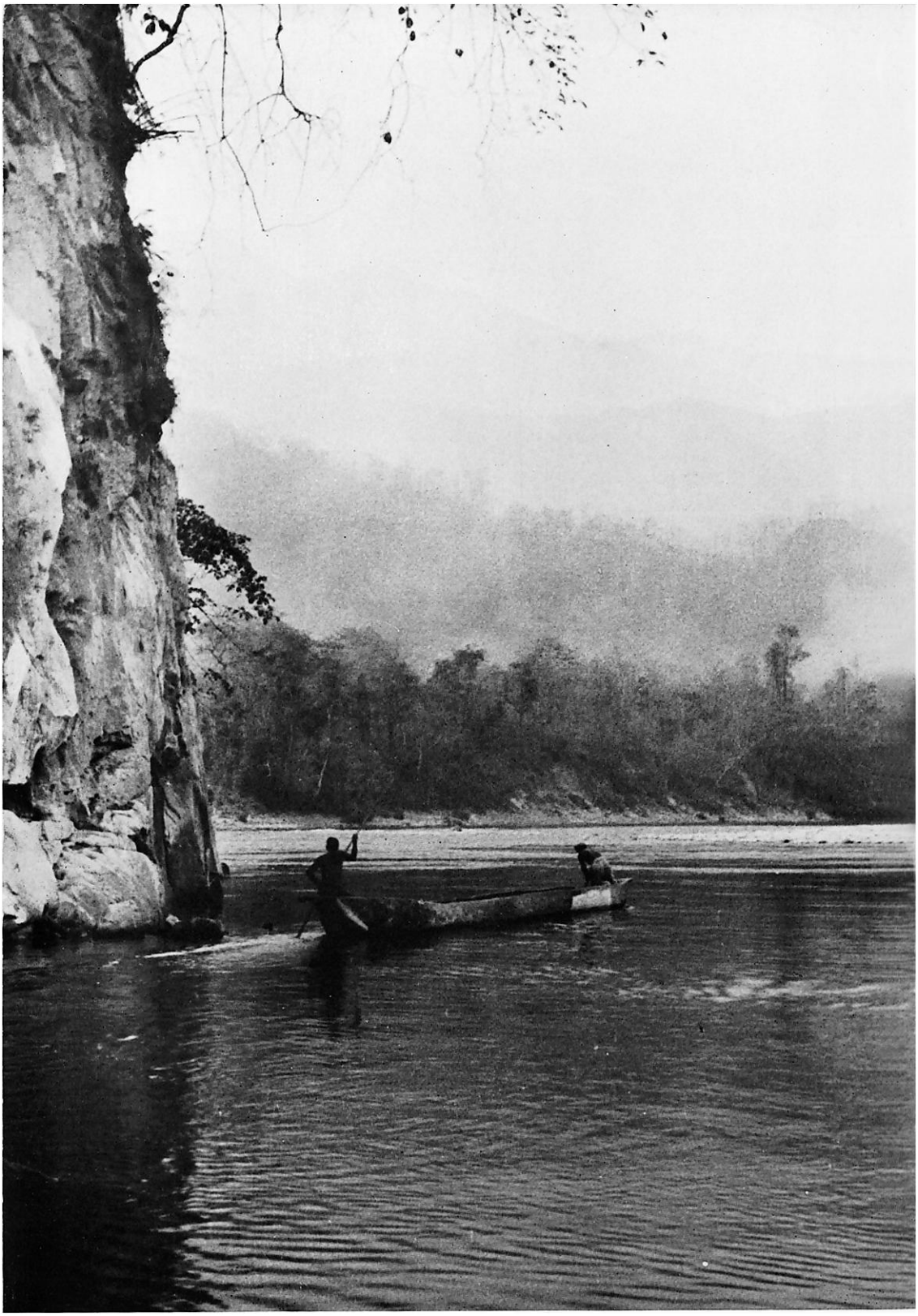
The Bhutan Government does not in any way interfere with its Nepalese settlers, and provided they pay their taxes they are entirely free to live as they wish. It follows therefore that the system of village administration which has gradually come into being is based on that existing in Nepal, only slightly modified to suit local conditions. Each group of villages has an official known as *Mandal* (in Nepal *Mukhiyā*). The Mandal is selected by the villagers themselves and is then recognized by the Bhutan Government. He receives no official remuneration, but, on the other hand, he is not required to pay any taxes. The occupants of each house are required to pay him a tax of one rupee and four annas yearly, or in lieu provide six days' labour. Most people provide the labour and the cash is seldom paid. When labour is required by the Government it must be provided, but is paid for at the rate of four annas a man each day. Each house is assessed at a rate varying between six and nine rupees a year according to the number of male occupants. Buffaloes are taxed at the rate of two rupees a year; cows at twelve annas; and sheep at two annas. All other animals are free. The rent for land under rice cultivation is three rupees per acre yearly; but ground used only for the cultivation of maize is free of tax. All lands are held in perpetuity.

Except in the rice fields the system of cultivation known in Assam as *jhuming* is carried out. In this method a piece of ground is cleared of jungle, used for one season, and then allowed to revert to jungle again for the next four or five years. Large areas are thus being gradually deforested, and much valuable timber destroyed; but it is probably not economically possible under present conditions to carry out scientific timber cutting. Mr. J. P. Mills informs me that it is now generally considered that the custom of jhuming as carried out in Assam is no longer harmful owing to the fact that virgin jungle no longer exists in that district. The same cannot be said at present of Bhutan. It is of course a difficult matter to control; but the Bhutanese Government has made a start by prohibiting all cultivation in the actual valley of the Sun Kosh where jhuming operations on the banks, resulting in some places in almost complete deforestation, had already caused considerable damage during times of flood.

The area in the foothills nearest to the plains is occupied for the most part by a floating population of Nepalese. These grow rice and maize: a few people, those who are able to afford cattle, also grow a little jute, for this cannot be satisfactorily grown without manure. The inhabitants of this district usually

A typical example of Nepalese terraced cultivation

A typical example of jhuming cultivation



Crossing the Sun Kosh river

stay only long enough to make a little money, generally two or three years, and then move on elsewhere. It is from this area that many people have recently returned to the newly opened districts in the Nepal Terai. The whole of this district is very malarious and the people looked ill and under-nourished. One effect directly attributable to the custom of cultivation by jhuming is that the people do not trouble to build themselves proper houses and live in very primitive shelters of bamboo and grass. These last only a short time, but can be easily constructed without cost each time the family moves to a fresh area. The land here is good for rice and maize, but the people suffer greatly from the depredations of wild elephants, which are numerous in the surrounding forests, as also are tigers. I was told that every year four or five people are killed by elephants. Each field has a very high machan in the corner in which people sit up all night when the crop is ripening. It is their custom to discharge a gun at intervals throughout the hours of darkness in order to scare away elephants. In this district there are many so-called salt springs, which are actually large patches of very damp greyish-black earthy sand. The salt is of no use for human consumption, but the places are much frequented by animals as salt licks. We passed by one which contained all about it the footprints and droppings of many kinds of animals, including elephants. I was told that on dark nights elephants can always be heard at the salt licks, but they are said never to come when there is a moon.

The early emigrants from Nepal settled almost entirely in this foothill area owing to the fact that it was the most convenient for their rubber-tapping operations. It was only when the rubber tapping ceased to be profitable and the need for agricultural land arose that they started to penetrate farther into the hills. I do not think the question of the Bhutanese being pushed back by the Nepalese has ever arisen. Raja Dorji himself told me that the Bhutanese have been consistently decreasing in numbers for a very long time. He considered this to be due to the fact that an unduly large proportion of both sexes enter religious institutions and do not therefore marry, and also to syphilis, which is said to have increased greatly during recent years. When the Nepalese settlers started to penetrate into the hills they found them already uninhabited or at least deserted, and even at the present day there is still a fairly wide strip of practically uninhabited land between the two peoples, which both however use as a grazing ground.

One interesting social fact may be briefly noted. When the early settlers arrived from Nepal they left their wives at home, as seems usually to be the case with emigrants. In the course of time however women settlers also arrived, and from amongst these many of the earlier arrivals selected wives. Later on, the original wives, finding that their husbands did not return, decided to join them in Bhutan, and thus it is common for the Nepalese settlers to have several wives. Polygamy is of course permitted in Nepal, but in actual practice amongst the peasantry monogamous marriages are by far the more common, except where there have been no children by the original marriage.

At one place we were shown a Limbu cemetery. There were no longer any survivors of these particular settlers from eastern Nepal. The Headman pointed out that the people had made a particular point of burying their dead with the faces turned in the direction of Nepal, whence they had originally

come. He also told me that if the deceased had been a heavy drinker or smoker it used to be the custom to place a little spirit or tobacco by the side of the grave; but with the death of the last of this particular colony the custom had not survived. Each grave was marked by a pile of stones, but there was no indication of any names.

After crossing the Sun Kosh river I re-entered British territory; but the subsequent journey across to the western or Chamurchi area, carried out by various means of transport, does not merit description here.

The Chamurchi or Samchi district of Bhutan lies directly to the north of the tea-growing district of Jalpaiguri. Unlike the eastern district this area is not approached through dense forest as the land was cleared and turned into tea plantations many years ago. It was indeed on account of the ease with which work could be obtained on the tea gardens that the early Nepalese settlers came to this part. Amongst the earlier arrivals was one with considerably more foresight than his fellows. He discovered that there were vast quantities of lime to be obtained with ease in the surrounding foothills of Bhutan; and in course of time he obtained the sole right to deal in this commodity. His enterprise flourished considerably until later on he was able to obtain a concession for practically the whole of the western area now occupied by Nepalese. No actual boundaries have been fixed, but the concession appears at present to be bounded on the east by the Pa Chhu river and on the west by the Dinah. The southern boundary is of course the British Indian frontier; and the northern extends as far as Raplika, a grazing camp one march beyond Denchuka. The present holder of the concession is a grandson of the original owner. He holds his title on the authority of the Maharaja's *lāl mohor*, which has been granted to him and his successors in perpetuity. Since he has been invested with full judicial powers, excluding only the power to award a sentence of death, and is required to remit only a portion of his revenues to the Bhutan Government, his position is somewhat analogous to that of a tributary raja to the Maharaja of Bhutan. The system of administration does not differ greatly from that in force in the eastern area; but if a settler wishes to leave the district his land and houses lapse to the owner of the concession, who is at liberty to sell them to any one he wishes. Taxes are rather higher than in the other district; but since the area has been settled for a longer period the land is probably much more valuable. This corner of Bhutan is said to be much used as a refuge by Nepalese criminals when they are able to get away before the discovery of their crimes. Incidentally, it may be of interest to note that in Bhutan the death sentence is carried out by sewing the criminal up in a bullock skin and throwing him thus into the nearest river: it is said to be most efficacious in preventing crime!

In the Samchi district there are now many Brahmans, mostly of the Jaisi sub-caste. The Brahman is as a rule thrifty, and neither drinks nor gambles. The Mongoloid tribes, on the other hand, have no such scruples, and are extremely improvident: when they have any money they like to spend it. The result of this state of affairs is that most of the Gurkha settlers are heavily in debt to the Brahmans, whose position in Bhutan, unlike Nepal, is no longer that of spiritual leader but of money lender. Their position is analogous to that of the Marwaris in the plains of India. Cash advances are usually given

against a lien on the harvest, and the rate of interest is high. Brahmans, on account of their superior social status, used formerly to receive homage from every one, as indeed they still do in Nepal. In Bhutan however this custom has entirely dropped out and they are not now treated differently from any one else. Many Bhutanese also advance money to Nepalese settlers for grain. The rice and other crops grown in the Dorkha–Denchuka area is much more than is required for the people's own consumption, and large quantities are therefore sent up into the interior of Bhutan, notably into the Ha district, where, on account of its elevation and consequent cold climate, rice cannot be grown. Some of the Nepalese in the areas nearest the plains have now taken to breeding pigs on quite a large scale. These they dispose of at the weekly markets where there is a big demand for them by the agents of the various Calcutta hotels.

It was my intention after visiting Samchi to continue north to Ha, and then, after visiting the Governor of Western Bhutan at Paro, to return to India *via* the Chumbi Valley and Sikkim. I stayed some days at Samchi both in order to pay my respects to Kaji Hemraj Gurung, the present owner of the concession, and also to make arrangements for the onward journey into Bhutan proper. It was a characteristic kindness of the Paro Penlop to send me a letter of welcome to this place: he told me that all arrangements had been made for my visit, but gave me no hint of the part I was expected to play.

We set off towards the end of March: it was already almost unbearably hot in the plains, and I was glad, in spite of the roughness of the track, to be making for the inner heights. Along the whole of the southern border of Bhutan the foothills rise very steeply and suddenly out of the plains, and there is not such a gradual ascent as in other parts of the Himalaya. It follows therefore that the valleys are narrow and steep and the rivers in consequence swift. To these facts are due the peculiar Dooar formation to which reference has already been made, and which makes it difficult to enter the country except through these various narrow valleys. The Chamurchi Dooar, through which we now entered, is formed by the valley of the Ammo Chhu and is a remarkable natural gateway and a very strong defensive position. It was in this area that the operations against the Bhutanese took place in 1865, and it is not difficult to realize what a very great advantage must have been possessed by the defenders.

There is no proper road up the valley of the Ammo Chhu, but we were easily able to pick our way along the boulder-strewn banks. I had been given a mule to ride and was told that his name was *Gyamo*, or "The brown one." His master, a Nepali-speaking Bhutanese, kept up a running commentary as the mule picked its way carefully amongst the rocks. "Now then, Gyamo, go carefully!" he would say, "don't stumble; go round that rock; go slowly, don't throw the gentleman off!" and so on. But in spite of these careful injunctions Gyamo, who was a quiet and tractable beast, did manage on one occasion to pitch me over his head, but without any damaging result. As we descended the hill towards Dorkha, the chief stronghold of the Nepalese settlements, we were met on the path by a party of Damai musicians, who played us into the village. Every now and again the band would halt while the leader, who carried an enormous jointed instrument, blew a sort of

fanfare. Occasionally he would execute a brief *pas seul* in front of the band. In this manner we proceeded at a slow pace for the last mile or so.

I found on arrival at Dorkha that my visit had been made the occasion for a general gathering of the surrounding villagers. The place had been gaily decorated and I found that I was expected to make a speech to the assembled headmen. It was a great pleasure to meet them; but since I was travelling very lightly and quite unprepared for anything of the sort, the official part of the gathering was a trifle embarrassing. I hoped that there would be nothing of the kind at Paro; but in any case there was now nothing to be done, since I was quite out of touch with India and could make no further additions either to my following or my wardrobe.

Dorkha is largely populated by Rais: Denchuka, on the other side of the river, by Limbus, both these being eastern Nepalese tribes. All the rice fields here were beautifully terraced and the houses well built of stone with thatched roofs. Jhuming is not the custom here, and there is therefore more incentive to build permanent houses. The people were very cheerful and seemed prosperous, and everywhere I was greeted with the greatest kindness and attention. When the rice is cut it is all collected in one spot, known as *Khali*. Both Rais and Limbus spread the sheaves all over the ground in this place and then both boys and girls dance on it in order to separate the straw from the rice. This is a time of great feasting, and singing and dancing go on throughout the night.

In Nepal, although at one time most of the Mongoloid tribes were in the habit of burying their dead, the custom of cremation is now becoming usual owing to the spread of orthodox Hindu ideas. In Bhutan however both Rais and Limbus still bury their dead and there is a small cemetery outside each village. Only very occasionally are bodies cremated, in spite of the fact that fuel is plentiful here: this is only one of many possible examples which might be quoted to show how the customs of an emigrant people persist in spite of changed geographical conditions.

In addition to the Nepalese there are also in this district a number of Lepchas, some of whom are Christians, and a very few people calling themselves Daoya. The Daoyas, of whom I saw only one or two, are of very Mongoloid appearance. Some of them speak Nepali, but their own language almost certainly belongs to the Tibeto–Burman group, as I found some words to be almost identical with those used in other languages of this group with which I am familiar. The Daoyas eat elephants, which they kill by means of poisoned arrows. They make their clothes from the fibre of nettles. They have apparently no caste restrictions and no organization beyond that of the family, as in Tibet and Bhutan. They are said to intermarry to some extent with the Bhutanese. The Daoyas never burn their dead but place them in very shallow graves, which they cover with large flat stones: offerings are made at the graveside from time to time. These people do not recognize the Brahmans in any way nor have they any priesthood of their own. I have been unable to find any mention of them in works of reference. They seemed somewhat similar to the Naga tribes of Assam, whence they may possibly have originally come.

We left Dorkha as we had entered it, with a musical accompaniment. The

band turned back after a mile or so and almost at once the country became less thickly inhabited. The last Nepalese settlements are at Raplika, north of which the Samchi concession does not extend; but beyond the Bhutanese hamlet of Shektina the area between Raplika and the Ha valley is practically uninhabited. It is thickly forested and contains some good grazing alps. It is used by both the Bhutanese from Ha and the Nepalese from Dorkha and Denchuka as a grazing ground, and I noticed a number of temporary shepherds' huts scattered about on the hillsides. This practically uninhabited tract serves as a buffer or "no-man's land" between the Bhutanese and the Nepalese, and segregates the latter from the north in the same way that the Terai forest does in the south of the eastern settlement area.

Although the hamlet of Shektina contains no more than a dozen or so Bhutanese shepherds it is at once apparent to the traveller that he has entered an area of a different culture. In place of the Nepalese wood and thatch we have here two-storeyed houses with roofs of matting, weighted down with large rocks. The method of cultivation too is different from that practised by the Nepalese, for the millet fields surrounding the houses are not terraced, as they certainly would be were they Nepalese.

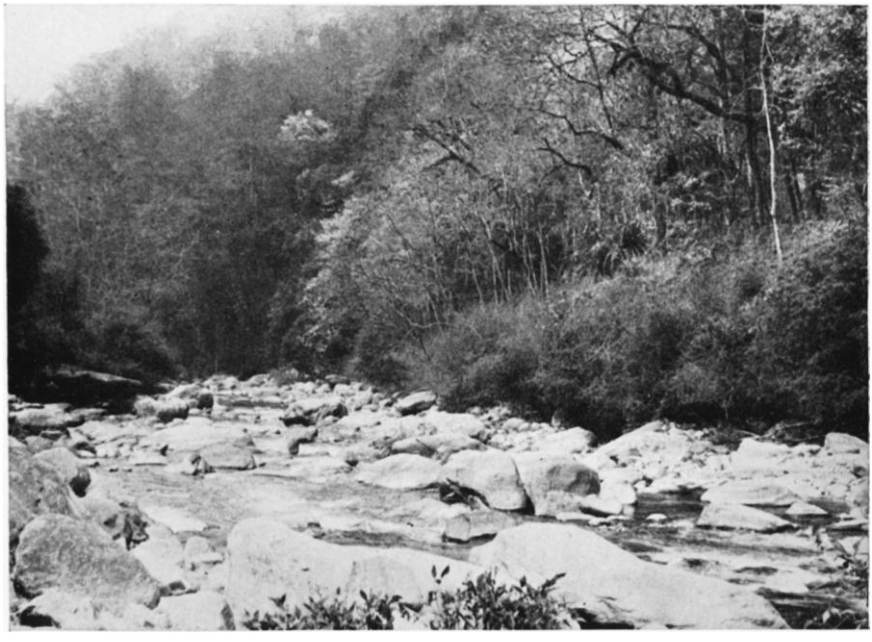
Before entering the Ha Valley we had first to cross the Sele La, an easy pass 10,900 feet above sea-level. We climbed up through pastures deeply carpeted with purple primulas and soft green bracken: it was a strange contrast to the steamy forest through which we had passed only a few days previously. There was fresh snow on the top of the pass and a cold wind blew: we halted only long enough to check the height and then ran rapidly down the snow-covered track that leads into the Ha Valley. This valley lies at an average height of 8000 feet above sea-level, and is therefore never hot. The surrounding hillsides are high and steep, so that the valley loses the sun in the early afternoon. During these days of early April it was pleasant when walking about in the sun, but bitterly cold in the early mornings and evening. I have never seen any Himalayan valley that so reminded me of Switzerland—of the road up to Zermatt for instance—and the impression was heightened by the very chalet-like appearance of many of the houses.

Any doubts I might have had concerning the nature of my visit were now finally resolved, for I noticed with considerable apprehension that the path leading up to Raja Dorji's house, which he had most kindly placed at my disposal, was lined with local officials and schoolboys, who had erected a large banner with an inscription of welcome over the door. I felt that I had come out of the ordeal of speech making rather badly, and my sombre garments compared most unfavourably with the magnificent brocades of my hosts. The Dzongpon however was a man of great charm. He had been educated at the University of Calcutta, and it soon became apparent that the opportunity to exercise his considerable knowledge of English made up for some of the stranger's other deficiencies. Since the Bhutanese are Buddhists and therefore free from the restrictions of caste, we were able to dine together, and thus a degree of intimacy was possible such as would be quite out of the question in most other parts of the Himalaya. The Ha Valley forms part of the personal estate of Raja Dorji, the Bhutanese Agent at Kalimpong, and to him is principally due a remarkable educational experiment which has been

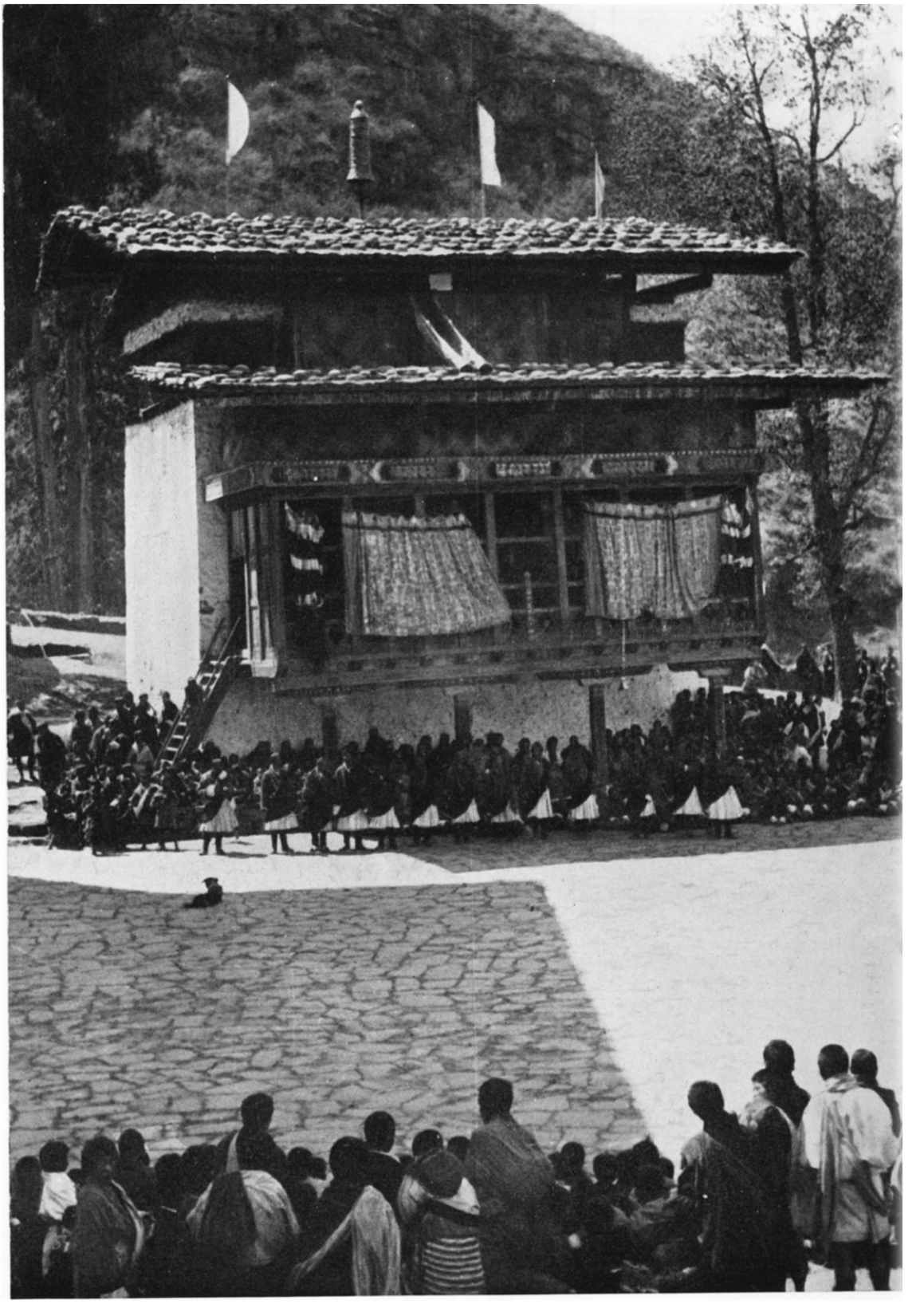
proceeding with the very greatest success for some years. He himself was educated at St. Paul's school in Darjeeling, but he early realized that although Bhutan has need of men with modern western education, it must be an education adapted to the special needs of the country and given primarily through the medium of the people's own tongue. There were some thirty boys in residence at the school, where they are given instruction up to the university matriculation standard. It is hoped that eventually they may be trained to the various professions of which the country has need, such as medicine, forestry, and agriculture. With great foresight the number of pupils has been strictly limited to the number of trained men the country can at present absorb, and during their early training the boys are always in intimate touch with the lives of the people amongst whom their work will eventually lie. It is in this matter in particular that the school gives such a much better education than any provided in British India. The Dzongpon of Ha, who, as I have already noted, was extremely well educated, fully realized that he would have been of more value to his country had his own preliminary training been carried out on similar lines. "I can draw from memory a map of Africa," he told me, "but of what use is this in Bhutan, where my ignorance of agricultural methods is a great handicap?"

In order to reach Paro we had first to cross the Chi Lai La. This pass is 12,200 feet above sea-level, but the ascent is very gradual and presents no difficulty of any kind whatsoever. A number of domestic yak were grazing on the upper slopes, but they resented all efforts to approach them closely. A little way down on the Paro side of the pass the Penlop has constructed a little bungalow at Chang-na-na, and at his special request I arranged to spend the night in this delightful little forest clearing. No sooner had I arrived than the Penlop's representatives were announced. They brought with them a letter and scarf of welcome and a considerable quantity of liquor and oranges, all in heavily sealed containers. We set off early the next morning, the Penlop's retainers making a picturesque addition to my humble retinue. Hardly had we covered a few miles when I found a meal spread out for me by the wayside and a further supply of spirit and oranges. This remarkable display of hospitality was repeated at intervals along the route. I had now sufficient oranges to last me for several months, and the spirit, which I had on each occasion distributed to the assembled company, had put them all into a distinctly Jubilee mood. I was by now so embarrassed by this lavish display of welcome and my lack of ability to make any adequate return that I was quite unperturbed by the state of my following, for, truth to tell, the Penlop's special brew was no fit drink for the hours of the hot mid-day sun! The culminating point however had by no means yet been reached, for a short distance outside Paro itself the Penlop's private bodyguard awaited us. They brought with them a magnificently caparisoned mule for me to ride and also a small portable cannon. We proceeded at a slow pace, the size of our party being increased at each house we passed. At intervals the whole cavalcade was halted while some of the retainers performed a short dance and the ancient piece was primed. I was preparing to dismount before the explosion, but I was told that the mule was well used to the performance: and so it proved to be. I was now taking, so far as I could see, the principal part in a mediaeval

The valley of the Ammo Chhu, showing the entrance to Chamurchi Dooar



The upper reaches of the Ammo Chhu



Lama dance at Paro Dzong

pageant; but by some mischance I was dressed in the inappropriate mufti of the twentieth century, and I felt that some sort of fancy dress would be more suited to the occasion. With some such feelings as these I dismounted by the banks of the river, where I found that a most comfortable camp had been prepared and laid out on a lavish scale.

I decided to call on the Penlop at once in order to thank him for his welcome. Some word of my intention must evidently have reached him, for with true oriental grace he decided to forestall me and pay his visit first. He was perfectly charming and all doubts as to my reception were finally set at rest. He appeared genuinely pleased to meet some one from the outside world, and stayed talking for a considerable time. Before he left we arranged that I should dine with him on the following day and then witness a performance of the dance which annually takes place at this time of the year.

The big dance of the year at Paro is held in the early Spring and usually lasts for three whole days. It is carried out entirely by parties of monks who live in the monastery attached to the Dzong at Paro and must, I imagine, necessitate many months of arduous practice throughout the year, for there did not seem to be the slightest hesitation or mistake throughout the entire performance. Very early in the morning people started to arrive from all the surrounding villages. Most were dressed in their gala clothes in which brilliant reds and yellows predominated; many, with a view to staying throughout the entire three days, carried supplies of food and drink with them. The performance was timed to begin at ten o'clock, and shortly before this hour I was escorted to my place beside the Penlop. The dance took place in an inner court of the Dzong, where was a paved court surrounded on all four sides by many-storeyed buildings, the ground floors of which were built in the form of large verandahs opening on to the court. Privileged spectators and some of the monastic dignitaries were accommodated in some of these verandahs, others were used as dressing-rooms for the performers. There was a dense mass on all four sides and the crowd was in holiday mood. It was probably the first occasion that many of the spectators had ever set eyes upon a European; but it was a relief to be treated with no more attention than an Englishman receives in Piccadilly.

Punctually at ten there was a crash of cymbals and a faded yak-hair curtain was pulled aside. There then entered in slow procession the various officials of the Penlop's court and all the elders of the monastery. All were dressed in magnificent robes of brocade and silk and many of the priests carried large drums which they beat rhythmically as the procession moved slowly round the court. Following them came the dancers, all of them monks or novices, some fifty or so in number. Some were dressed in peacock blue brocades and wore large-brimmed black hats surmounted with a single peacock's feather; others were garbed in costumes of various colours and wore the most fantastic masks. One series for instance represented human skulls; another yaks and cows; and there was one series consisting of the most nightmarish of farmyard animals: one almost expected Alice or the White Knight to appear at any moment. Soon the court was filled to overflowing and all but the actual dancers then withdrew.

We saw first the Black-hat dance. This has been many times described by

travellers to Tibet, where it may be seen in many of the monasteries. It was carried out by the monks in robes of peacock blue. The dance consists in slowly circling round the arena with the addition of a very intricate gyration at every few steps. By means of certain hip movements the dancers are able to keep the very ample folds of their robes standing well out from the body, and there is much graceful play with the long ribbon streamers with which each performer is adorned. This and indeed the other dances too were extremely interesting to watch for a short time; but since each separate movement is performed for about two hours without a break of any sort the spectacle becomes a little wearisome after a time. One would imagine these dances to be extremely exhausting, but in actual fact none of the performers appeared to be in the least tired after dancing in the hot sun for two hours without a rest.

All the dances were carried out to the accompaniment of the monastery band. In addition to several kinds of drums and flute-like instruments there were several very long trumpets. These were not sounded continuously, and their notes appeared often to be in rhythmic opposition to the rest of the music. Their note was extremely deep and more of a pulsating vibration than an actual musical sound. These long trumpets produce only one note: they are said to be difficult to play, and only a man with exceedingly strong lungs is able to produce any sound out of them. In front of the band sat all the novices, many of whom were quite small boys, not more than seven or eight years of age. They were clearly enjoying the performance; but lest they lose sight of the more serious religious significance of the play an elderly monk occasionally brandished a knotted whip in their faces in order to restore their wandering attention. For a little while they would watch the dance with rapt attention, but soon their gaze would be wandering and before long they would once again be laughing and talking amongst themselves.

Other dances followed the Black-hat dance, but there is no space here to describe them. In some the performers were completely masked, in others they wore a head-dress almost exactly similar to the head-cloth universally worn in Arabia. One dance in particular appeared to be connected in some way with the idea of Spring, although none of the people actually offered this interpretation. In this dance, which was free from the stereotyped movements considered essential in the more ritual dances, the performers all wore wreaths of fresh green leaves.[1] The dance was continued without a break until the late evening, and many of the villagers camped in the Dzong for the night.

On the following day the whole performance was repeated. This time it took place in an open space outside the fort in order to allow a greater number of spectators than was possible inside the Dzong to watch the celebration. It was preceded by a dignified procession consisting not only of the Penlop's Court officials but also of the entire population of the monastery; all wore Lama's robes of deep maroon. The purpose of this procession was to do honour to a visiting prelate from Tibet and to escort him in state to the performance. I had no opportunity to talk with him, but he gave me the friendliest of smiles as he passed to his seat in the upper storey of a neighbouring house. From this point of vantage he watched the dances from behind a thin gauze

[1] Cf. *e.g.* 'The Golden Bough' by Frazer, abridged edition, ch. 28, pp. 296–323, inc.

screen. Once more the dance was continued throughout the day, and only when the sun had already sunk behind the distant hills did many of the spectators set off towards their homes. Late that night I went for a last turn along the banks of the river. The walls of the Dzong gleamed white in the cloudy moonlight, but there was no lamp in any of the windows. From somewhere far above in an upper gallery I could hear the piercing vibrations of the longest trumpets: evidently the last office of the day was being celebrated. Soon there was no further sound, only the plash of the water against the stones in the river-bed. I turned and went back.

After leaving Paro I retraced my path to Ha and from the latter place crossed over the Ha La (13,900 feet) to Chumbi. Although it was now mid-April it was bitterly cold in Yatung and a little snow fell. I decided to push on into Sikkim, waiting only long enough in Chumbi to collect transport. The road from Chumbi over the Natu La to Sikkim is almost a tourist track, and has been traversed by hundreds of travellers. It was raining when we left Yatung and still exceedingly cold. Very soon the rain turned to snow, and it was only with difficulty that we reached Champitang late that evening. It continued to snow, and by the next night there was about 4 feet all round the bungalow. It seemed impossible to go on, but after two more days we decided to try the pass, as the supply of food for the transport mules was running low. We set off in almost a gale, and it was impossible to see for any distance in front. My diary for April 16 notes: "Over the Natu La: left at 6.30 and reached Tsomgo at 5.30 in the evening. Snowstorm most of the way: a tiring day." The following evening we arrived at Gangtok, whence I continued by motor to Darjeeling.

DISCUSSION

Before the paper the PRESIDENT (Major-General Sir PERCY COX) said: My Lords, Ladies and Gentlemen,—Major Morris, who is going to read the paper to-night on "A Journey in Bhutan," is no stranger to us. He lectured to us twice in the Aeolian Hall: in 1923 on "A Journey in Nepal," and in 1928 on "A Journey in Hunza-Nagar Territory," while at the opening of this hall he was one of those, as a member of the Second Mount Everest Expedition, to speak on the platform here. He is a practised lecturer and a highly skilled photographer, so you may be sure that we are going to have an interesting evening. The journey he will describe was undertaken in March 1933. He is shortly going back to India, to Nepal, and the Himalayas, so we may look forward to hearing him again later on. To-night, as I have said, he is going to talk about Bhutan.

Major Morris then read the paper printed above, and a discussion followed.

The PRESIDENT: Lord Zetland, the lecturer has made reference to your connection with the region: I hope you will favour us with some observations on the expedition undertaken by you in the tract of country he has been discussing, during your service as Governor of Bengal.

The MARQUESS OF ZETLAND: I need hardly say that I have listened to Major Morris's paper with very acute interest, for I have travelled over much of the ground which he has described to us to-night. I have witnessed those remarkable corybantic performances at Paro Dzong of which he has shown a number of most admirable pictures. I have taken part in those ceremonial processions which the hospitable people of Bhutan insist on organizing in honour, if I may

say so, of distinguished visitors, and I have drunk, as Major Morris drank, the wine of the country.

Those of you who have visited Sikkim will perhaps remember that the wine of the country, known as *marwa*, is made by pouring hot water into a vessel containing fermented millet. The hot water can be poured into the same vessel of millet more than once, and at first sight it might be mistaken by the novice for a temperance drink. The question whether indeed it did come within that category or not was settled rather unexpectedly one day for me and my companion—an ardent teetotaller, by the way—who were drinking *marwa* provided by the hospitable headman of a Sikkim village. We got into conversation and asked: "How many times may the vessel of millet be replenished with hot water?" and they replied, "Oh, many times." We then asked, "What is done with the millet when it is finished with?" and we were told that it was given to the pigs, and our informant, looking at us reflectively, added musingly and, if I may say so, quite gratuitously, "And the pigs get drunk too."

Major Morris has spoken of the unhealthiness of the Dooars, that undulating country which runs along the borders of Bengal and the mountain States, including Bhutan; and it is, indeed, a fever-infested land. In the plains of Bengal the malaria carrier is the mosquito known as *Anopheles fuliginosus*. The *Anopheles fuliginosus* breeds only in stagnant water. One might have hoped therefore that when one came to the undulating tracts of the Dooars where water is not stagnant but where there are running streams, one would have got beyond the range of the malaria-carrying mosquito; but, unhappily, there is another mosquito, the *Anopheles listoni*, which also carries the malaria parasite, and by an unhappy dispensation of Providence this mosquito breeds not in stagnant but in running water! Hence the malarious nature of the Dooars.

But it was not by the Dooars that I myself entered Bhutan. I actually entered the country by a route which lies a good deal north of the Ha La by which Major Morris told us he left Bhutan to enter the Chumbi valley. I actually branched off from Phari on the Phari table-land and crossed into Bhutan by a pass known as the Tremo La, some 16,500 feet in altitude, dominated in its turn by a magnificent snow-clad peak known to the Bhutanese as Cho-tra-ké, "The Lord of the Cleft Rock," and proceeding down the Pa Chhu, that is to say, the Pa river, I came to Paro.

Now there are two things that immediately strike one in Western Bhutan. The first of these things has been well brought out by Major Morris in the course of his paper, and particularly by his photographs. That is the solidity and the massive character of the chief buildings of Western Bhutan. The first time that I crossed the Pa Chhu I did so by a substantial covered-in roadway similar to the one of which Major Morris showed a photograph, flanked by stone towers at either end and constructed with great engineering skill, as it seemed to me, on the cantilever principle.

Some way down the Pa Chhu I came across that which is reputed to be the oldest of the great feudal castles of Bhutan known as Duggye Dzong, and I found structures which corresponded very closely to the barbican, the gateway, the bailey, and the keep of feudal castles of the twelfth century of our own country.

And that brings me to the second point which immediately, I think, strikes the traveller, and that is the existence in Western Bhutan of a social system which corresponds very closely, as far as I was able to judge, with the feudal system which was characteristic of a well-known epoch in our own history. The Duggye Dzong itself is a vast building, but even Duggye Dzong pales into insignificance before the immense dimensions of Paro Dzong, of which you have seen photographs this evening, a really stupendous quadrilateral of whitewashed stone,

with the great eaves of a penthouse roof surmounting it. At the time of my visit I was informed that the actual population of the castle of Paro Dzong itself was three hundred persons. The impression that I had stepped back in time to the twelfth century in our own country was heightened by an archery contest which was ordered by the Penlop, or governor, of Western Bhutan in my honour. Locksley had his counterpart in a skilled bowman who had come from a distant part of Bhutan to take part in the contest. The targets were set up at each end of a pitch about 120 paces in length, and it was the practice of the archers, as soon as they had discharged the arrows from their bows, to shout after them wildly adjuring them to fly true to the mark. I soon noticed that this practice was very necessary, though on this particular occasion it, unhappily, did not prove to be very effective. However at last one archer did succeed in getting a bull's-eye, much to the delight, and I think the surprise, of the vast audience which had gathered round, and the proceedings came to an end with the falling of dusk.

From Paro I traversed the same route as has been described by Major Morris this evening, only of course in the reverse direction, spending some time at Ha, the Bhutanese home of Raja Sonam Tobgay Dorji, the admirable Bhutanese Agent, through whom passes all the official correspondence between the Government of Bhutan and the Government of India. I should like to join Major Morris in the tribute which he paid both to the charm and the ability of Tobgay Dorji.

I was delighted to hear what Major Morris said with regard to the educational experiment which Tobgay Dorji was actually initiating at the time of my visit, and I remember well the enthusiasm with which the scheme was conceived and with which its details were worked out, on the advice of Drs. Graham and Sutherland of Kalimpong.

From Ha I crossed back down the route across the Nepali inhabited part of Southern Bhutan over the same route as that by which Major Morris entered, returning to Bengal once more by, I think, the same Dooar—at least judging by the photograph it appeared to be the same—the Chamurchi Dooar, of which you saw a picture.

May I say once more how very much I have enjoyed listening to the lecture which has brought back to me so many memories of a happy kind.

The PRESIDENT: Ladies and gentlemen, we have been indeed fortunate in that Lord Zetland has been able to be with us to-night. I am sure I am voicing your feelings when I say what a great pleasure it has been to us to see him on this platform. We only wish that we saw him oftener.

There is one question I would like to ask the lecturer. He said that the masks shown in his pictures seemed to be of Chinese origin. I do not know whether he has been on the Leh side of Tibet, and, if he has, whether he regards them also as being of Chinese origin. I have always regarded them as Tibetan.

Major MORRIS: I think they are rather different.

The PRESIDENT: I take it the local idea is that the masks came from China. I do not know that we have any other speakers present to-night who know the country that we have been hearing about; in that case I can only ask you to join me in thanking the lecturer. It has been of very great interest to listen to him and see his fine photographs, especially the different types met with. They must be of very great value. Major Morris' bent is in the direction of anthropology, and during his journeys in Nepal or, as in this case, Bhutan, he devotes himself especially to anthropological work among the natives. I ask you to join me in thanking him exceedingly for his excellent paper and his very fine photographs.