with many excellent large-scale maps. Indispensable! Otherwise such maps as one can readily obtain are useless for finding one's way. I have not seen those of the General Staff. The so-called provincial maps (1 : *ca.* 500,000) are obtainable from Alberto Martin, Barcelona, Consejo de Ciento 140. And there is, of course, Baedeker's *Spain and Portugal*, or Murray, whichever may have produced the latest edition. The publications of the Club Alpino Español are full of information and suggestions.

Remember that Cantabria is only a part of the Peninsula. The whole of Spain and Portugal simply teems with secluded titbits in the way of mountains, hills and wondrous crags. They should appeal to the elderly but still romantic mountaineer who hankers after the joys of real exploration and adventure without the ice avalanches of Kangchenjunga. Even the young steeplejack with short holiday and shorter purse will find rocks worthy of his mettle, such as the weird granite spires of Las Batuecas in the Sierra de Gata. Here the dry climate would favour a students' camp. I believe Central Spain is very kind to the lover of granite, the noblest of the rocks.

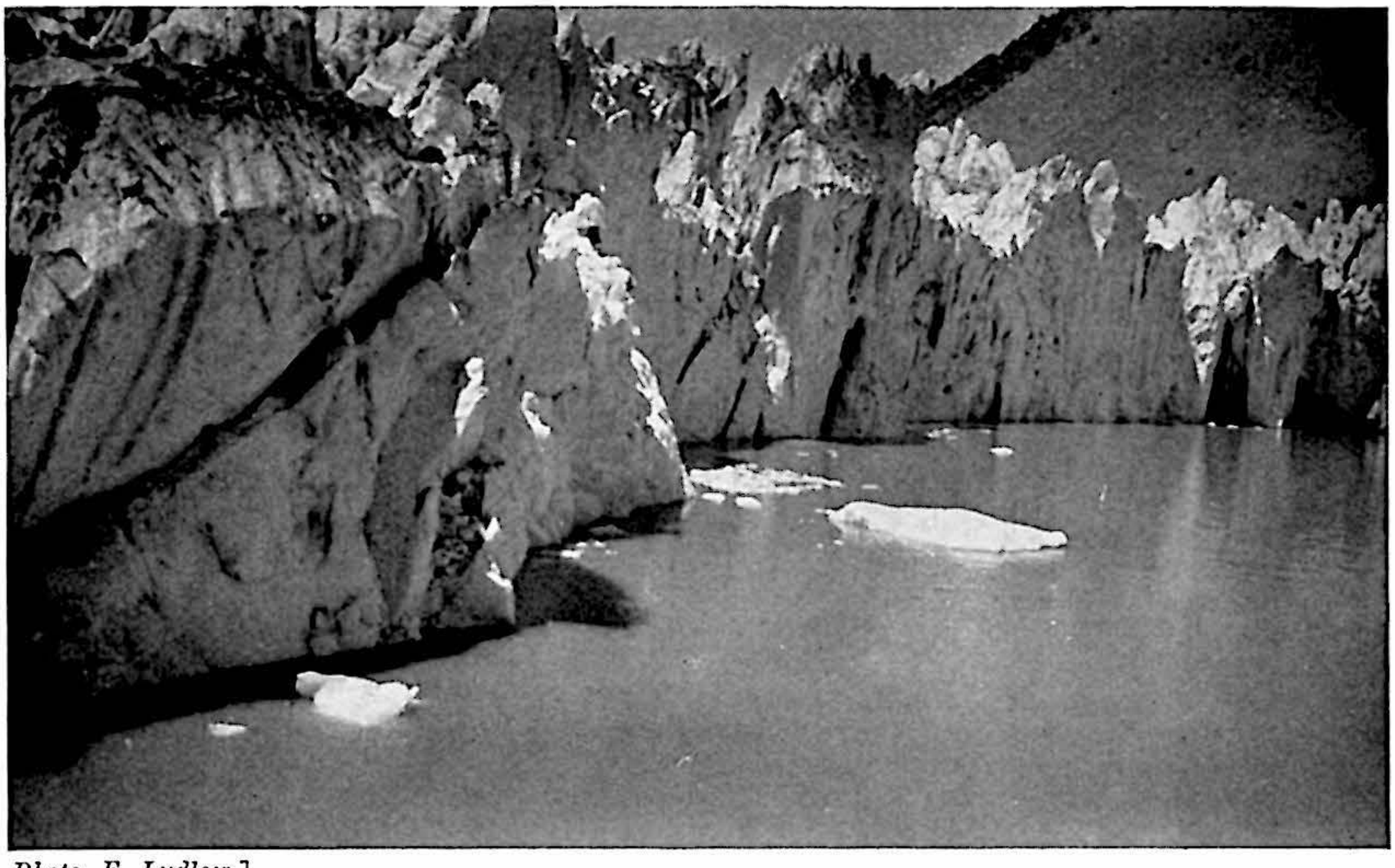
The Upper Shyok Glaciers.[1]

By KENNETH MASON.

WITH the bursting of the Chong Kumdan Glacier dam in the early morning of July 11, 1932, it is interesting to review the information now available concerning the upper Shyok glaciers and to deduce some lessons from the floods of the last few years.

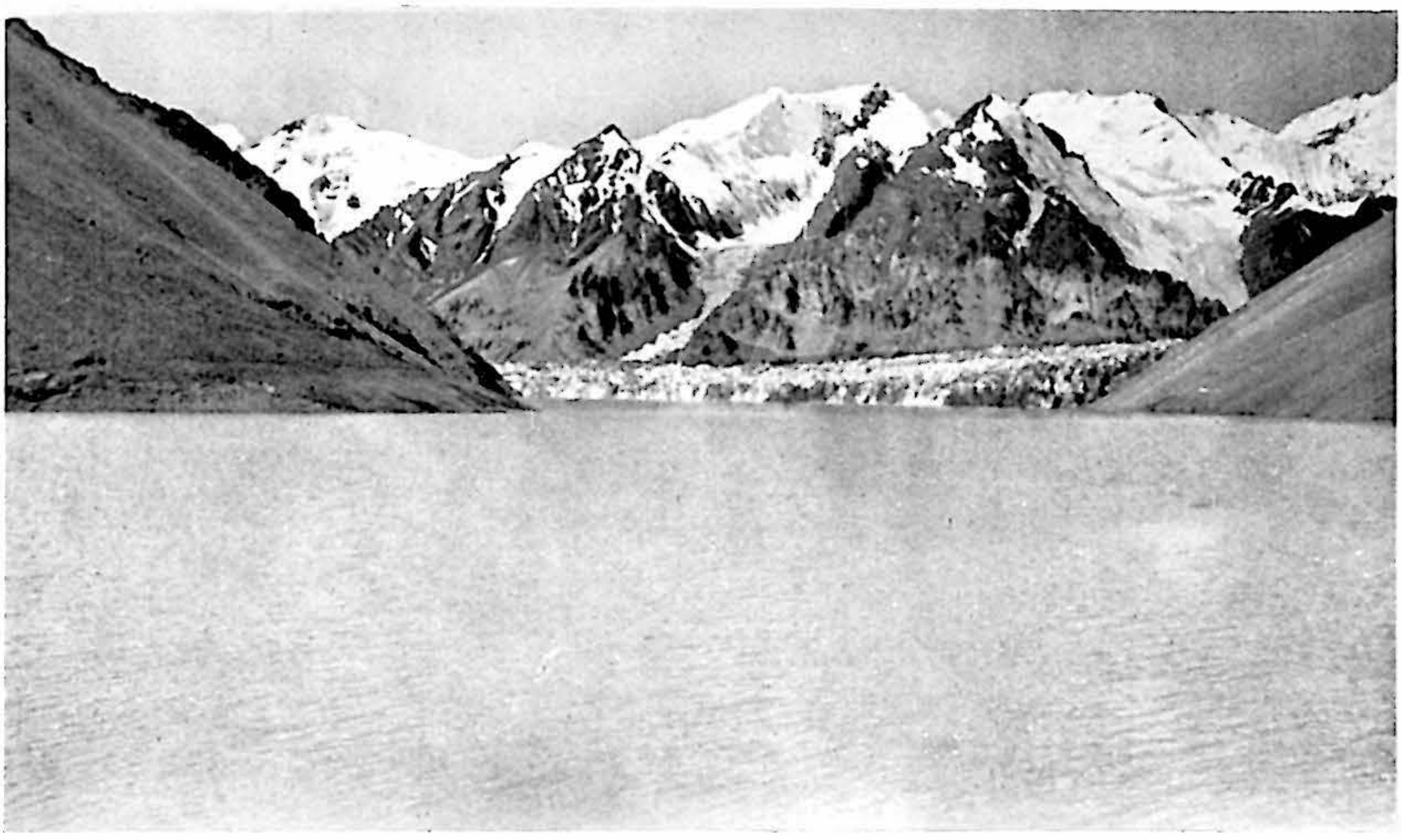
The upper Shyok glaciers lie in the heart of the Karakoram, and drain the north-eastern flank of the Muztagh range. The northernmost glacier, the Rimo, is a compound one with three large tributaries, the northern of which throws a tongue over the Central Asian watershed to form one source of the Yarkand River. By far the greater part of the Rimo drainage, however, feeds the Shyok River and is the main source of it. The stream from the Rimo Glacier flows in a broad flood-plain south-eastwards for about 9 miles to meet the Chip-chap River, of small dimensions and carrying little water from the barren

[1] See the late Major Minchinton's sketch map, *A.J.* **39,** facing 210.



Photo, F. Ludlow.]

A CLOSE VIEW OF THE DAM THREE DAYS BEFORE IT BURST, AUGUST 1929.



Photo, F. Ludlow.]

THE CHONG KUMDAN ICE-DAM FROM ONE MILE DISTANT, AUGUST 1929.

[*To face p.* 237.

highlands in the neighbourhood of the Karakoram Pass and plateaux to the E. After the junction, the Shyok River turns southwards and penetrates an ever-narrowing gorge. On the E. weathered-red limestone walls, supporting the Depsang plateau, fall steeply to the river; on the W. a high buttress of the Muztagh ends with a scree slope reaching almost to the valley bottom. Immediately S. of this buttress lies the Chong Kumdan Glacier, descending on the W. side of the Shyok valley, its upper basin surrounded by heavily ice-clad mountains rising to over 22,000 ft. above sea-level.

The upper basin of the Chong Kumdan is unexplored in detail, but from distant observation the head of the glacier seems to be divided into two portions by a ridge, the highest point so far known of which is at 23,200 ft., while across the upper southern branch of the glacier is the great peak, K^{31}, 24,690 ft. N.W. of this peak there appears to be a large snow reservoir lying across the Muztagh watershed and feeding the Chong Kumdan as well as a long glacier tributary of the Nubra on the W.

On the S. of the Chong Kumdan Glacier another long rocky buttress of the main Muztagh separates the Chong Kumdan from the Kichik Kumdan Glacier, which is similarly isolated by another buttress from the Aktash. Further S. is the insignificant Kichik Aktash Glacier, which is of little importance.

There are thus four glaciers on the right bank of the upper Shyok above Saser Brangsa, and a fifth at the main source. As far as we can ascertain, for at least the last hundred years, and probably for very much longer, the snout of the Rimo has lain in its broad flood-plain; those of the Chong Kumdan, Kichik Kumdan and Aktash have always ended in the neighbourhood of the main Shyok river, and that of the Kichik Aktash has always been distant from it. Only the Chong Kumdan, the Kichik Kumdan and the Aktash have therefore been in a position to block the main valley. The lengths of these three glaciers are 12, 7, and 5 miles approximately; the heights of their snouts, 15,470 ft., 15,250 ft., and 15,000 ft. above sea-level; their slopes, as measured roughly from the available surveys, approximately 350, 500, and 400 ft. per mile.

It is well to be quite clear concerning the normal causes of glacier snout variation. The snout of a glacier is that point at which the ablation caused by the increased temperature of lower altitudes balances the supply of ice from above. It will therefore be readily understood that the position of a glacier snout is balanced by these two factors, temperature and ice-

supply ; and that a change in either may upset the balance and lead to a change in the snout position. Minor variation of snout position is of little consequence in glaciers such as the Rimo, where the snout lies in a broad valley with no obstacle to expansion ; but when a glacier, such as the Chong Kumdan, emerges into another valley, such as the main Shyok, whose walls are of immovable rock, an advance of the snout means that the ice will be crushed against that wall. The glacier then lies across the valley as a great dam, and any water draining into the main valley above the dam may be held up by it and a lake may form. Such dams are more likely to occur near the heads of valleys than lower down, where the drainage of a large basin and many tributaries increase ablation by snout erosion to such an extent that a channel is kept clear.

In the Karakoram ablation begins in earnest in July. Melting of ice and snow reaches a maximum in August, and the main rivers, the Shyok and the Indus, rise rapidly to summer flood level in the latter month. It is at this period that the glacier ice is most weakened by every factor of ablation—the direct rays of the sun, radiation from barren rocky walls, erosion by rapidly flowing water, conduction of heat through moraine material, contact of warm air and radiation from moist air and low clouds, evaporation, and rain. The combined effect of all these factors working together in the latitude of the Karakoram is enormous, and tributaries as well as main rivers become impassable. It is therefore at this period that glacier dams are most likely to burst, especially when the ice is in an active state of advance ; and it is at this period that a burst is most dangerous, for the river below is also in summer flood and the addition of more water may be disastrous. By October, in the Karakoram, frost occurs every night at these altitudes ; water, which has percolated into the wounds caused by summer ablation, freezes ; and gradually the ice becomes compacted and healed during the winter.

I would enter here a warning to observers of snout phenomena in the Karakoram. Ablation is so fierce in the month of August that it is easy to note signs of so-called retreat of the snout during this month, which are in reality only evidence of seasonal degeneration. I have often noticed that observers have recorded their opinion that a glacier is retreating in July or August because the ice is apparently more flattened than it was in April. This is almost inevitable in the Karakoram. The normal pieces of evidence that can be employed in higher latitudes must be used with extreme care in the Karakoram :

only if a glacier is more degenerate in April than in the previous August or in the previous April is it possible to interpret periodic degeneration and 'retreat.'

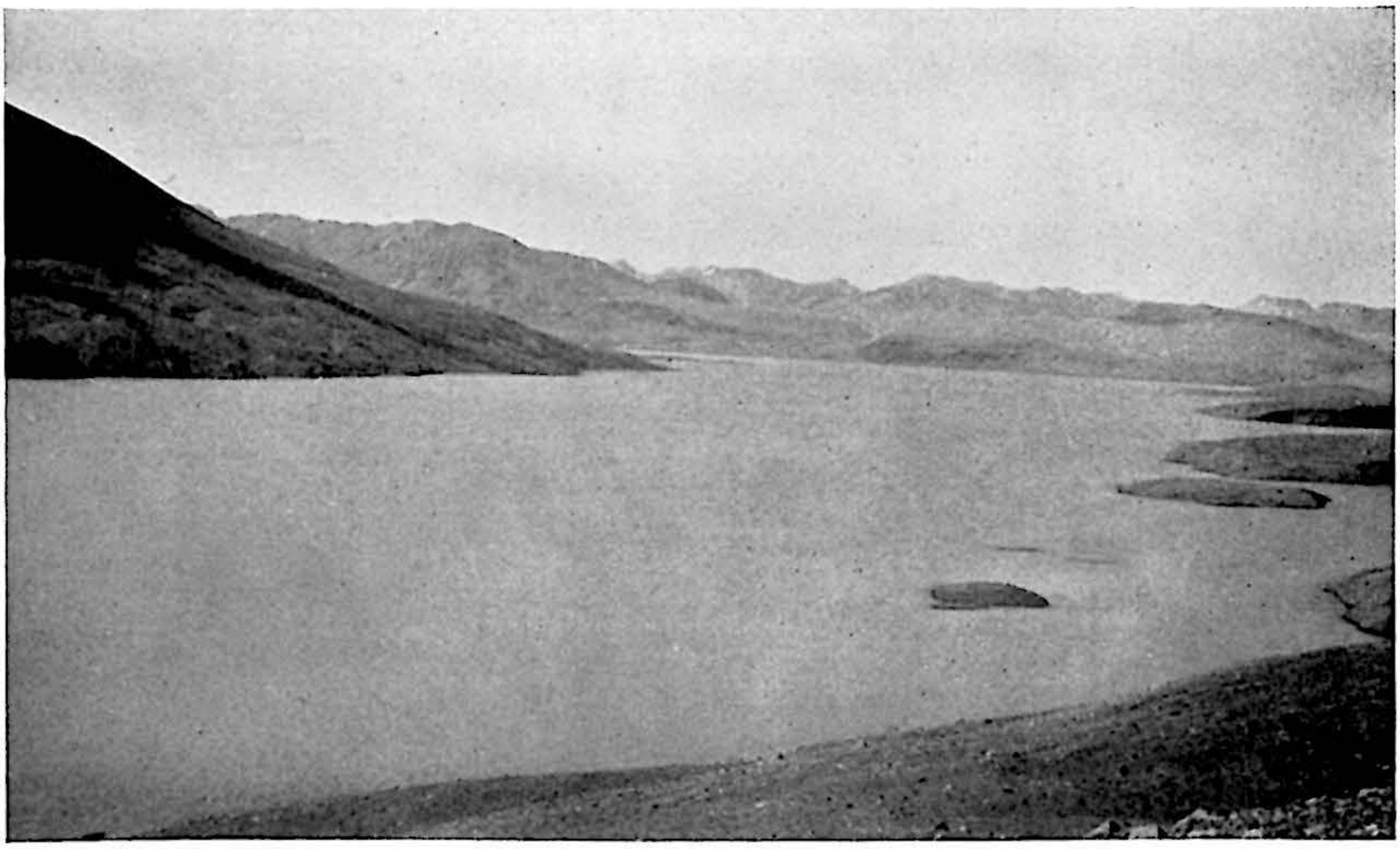
I have said that the Chong Kumdan, the Kichik Kumdan and the Aktash are the only three glaciers in a position to block the upper Shyok. The large glaciers S. of Saser Brangsa, though they occasionally project into the main valley, are not dangerous, because enough water always enters the valley above to keep a channel clear. The Chong Kumdan is, however, almost ideally suited to form a dam. It has a considerable basin with a comparatively narrow exit valley. The normal flow of ice is therefore constricted through this exit, and any abnormal change in volume in the ice will be accentuated at the snout. Should the advance be sufficient to carry the snout across the main valley to the cliffs opposite, a block is almost certain to occur the following winter, and there is only one feeder of any consequence—the Rimo—above it to erode a channel. Incidentally the valley bottom here is almost impervious to water percolation; further down the valley the soil becomes more porous, and generally a good deal of percolation, both through the Kichik Kumdan and under it, takes place when this glacier is across the valley.

It is unfortunate that the upper Shyok glaciers lie so far from permanent habitation that it is not possible to keep them under continual observation, but we can learn much of their general behaviour during the last hundred years from the fact that the regular Central Asian trade-route passes up the main Shyok valley whenever *all* the glaciers are clear of the river bed. When the valley route is blocked traders cross the Shyok at Saser Brangsa, some 10 miles lower down, and make a long détour to the E. of the valley over the high, desolate and inhospitable Depsang plateau. The détour, besides being a most unpleasant substitute, is longer and more expensive, for there is no fuel or grass; and the track bears witness to the increased expense by the litter of bones of pack animals that have died of exposure or starvation by the way. It may, therefore, be safely assumed that the valley route is taken when practicable, and it is possible to deduce from travellers' accounts whether the valley has been blocked in the particular year of their journey.

Another source of light on the past is the information gleaned by travellers down the Shyok and Indus valleys. Some of these travellers have observed the effects of recent floods, and have been told by natives that they were caused by the bursting

Photo, F. Ludlow.]

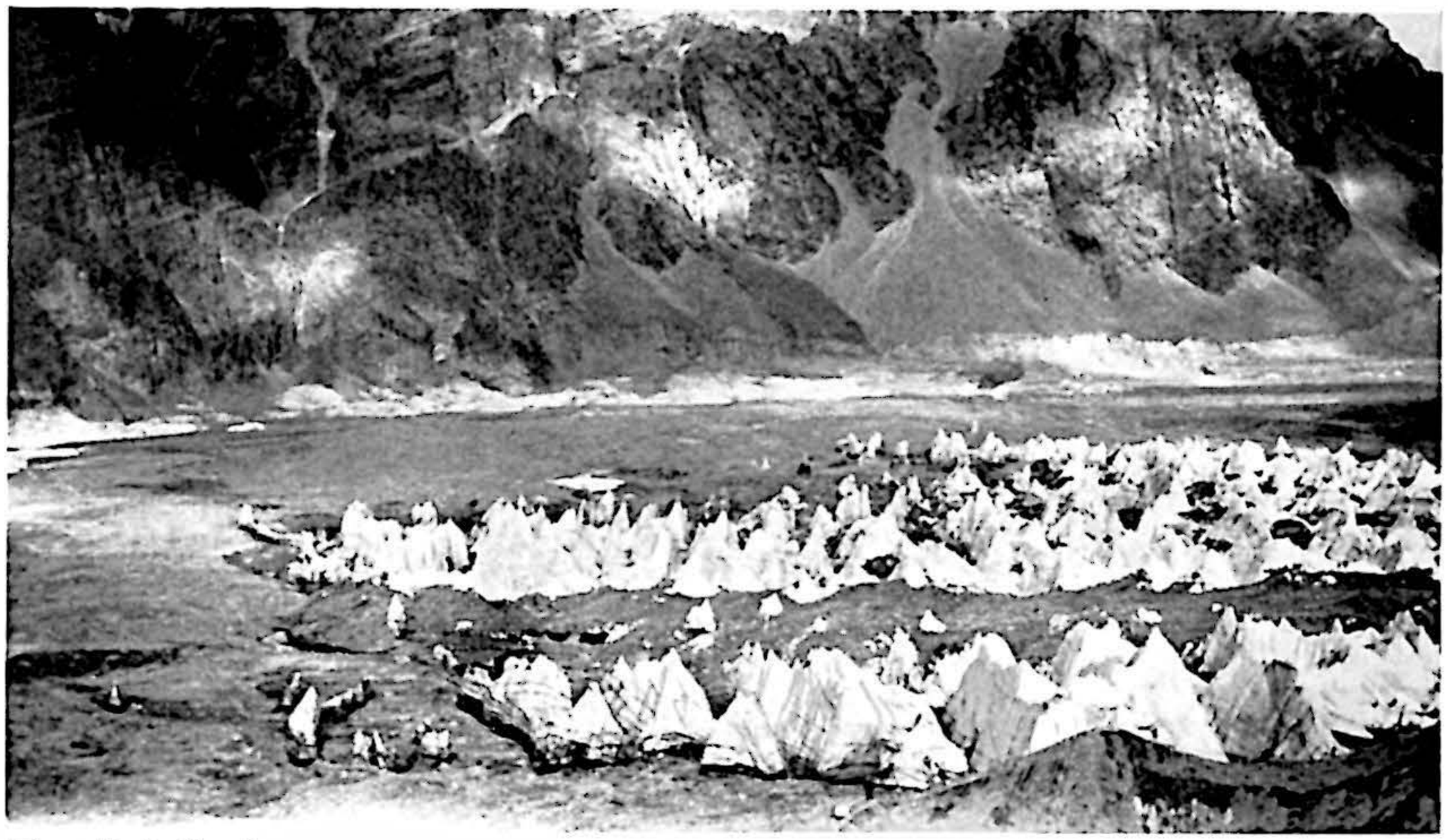
THE CHONG KUMDAN DAM, AUGUST 1929, WITH THE IMPOUNDED LAKE IN THE BACKGROUND.



Photo, F. Ludlow.]

THE SUBMERGED VALLEY OF THE UPPER SHYOK IN 1929 BEFORE THE DAM BURST.

[*To face p.* 240.



Photo, F. Ludlow.]

DEGENERATE ICE AT SNOUT OF KICHIK KUMDAN GLACIER, SEEN FROM LEFT LATERAL MORAINE, 1929.

Photo, Capt. C. E. C. Gregory.]

THE ICE-DAM FROM THE LEFT BANK OF THE IMPOUNDED LAKE, 1931.

of the Shyok glaciers. The more recent the flood the more accurate the information is likely to be ; and the further down the valley the information is obtained the less accurately is the cause of the flood known. Owing to the fact that the floods of 1835 and 1839 were known to have been caused by the Shyok glaciers, the two great Indus floods of 1841 and 1858, both of which did immense damage right down the Indus, were immediately attributed to a similar cause. There is not the slightest doubt that both these floods were due to great landslips : the first was caused by a fall of the hillside on the W. side of the Leychar spur of Nanga Parbat, which dammed the Indus for six months and caused a lake a thousand feet deep and forty miles long to form above it ; the second, in 1858, was caused by a similar landslip about nine miles above Baltit on the Hunza River, which was blocked for nine months. Neither of these blocks nor the subsequent floods had anything to do with the Shyok ; but mistakes once made and repeated are difficult to correct, and newspapers still quote the bogey of the 1841 disaster when the Shyok glaciers come into prominence in the news to-day.

A third source of information is the study of the river gauges. Of these the only one that has been established for any length of time is at Attock. Abnormal rises must have some cause, and it may be possible to assign the cause by a careful comparison of gauge readings.

I have been investigating on these lines for some years, and of thirty-four glaciers in the Karakoram that I have studied, the Chong Kumdan and the Kichik Kumdan yield the most interesting results.

With the Chong Kumdan we have definite information of a block period from about 1834 to 1842, succeeding a period of at least twenty years when the glacier was clear of the river bed.[2] Floods caused by the bursting of the Chong Kumdan dams are recorded by various travellers to have occurred in 1835, 1839 and 1842, after which there are no further native accounts of any, and the danger seems to have been forgotten.

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[2] I can only here give the results of my investigations. I have dealt in more detail with the observations and the discrepancies in dates in *Himalayan Journal*, vol. i. pp. 10–29, and in *Records, Geological Survey of India*, vol. lxiii. part 2 (1930), pp. 215–78. Current observations by various travellers to the Shyok glaciers during the last few years have been recorded in the *Himalayan Journal*, i. (1929), 4–10 ; ii. (1930), 35–47, 176–8 ; iii. (1931), 155–7 ; iv. (1932), 67–74.

The next evidence that I can find is from a study of the gauge readings at Attock. Abnormally high floods were recorded there in mid-August 1879 and on July 29, 1882. The summer normal flood at Attock is at about 894 ft. above sea-level. In August 1929 the river rose to 922·75, owing to the bursting of the Chong Kumdan dam in that year. In August 1879 the river rose to 922·72, and in July 1882 to 927·82— that is, there were abnormal rises of about 29 and 34 ft. in those years. Rises due to the bursting of other glacier dams, such as the Karumbar, in the Gilgit Agency, or of landslide dams, such as those of 1841 and 1858, are entirely different in character, for the blocks are much further down, and the level of the Indus at Attock was affected before the dam burst.[3] But though these abnormal rises in 1879 and 1882 are not definitely traced to their source, there are many arguments that prove almost conclusively that they were caused by the bursting of the Chong Kumdan Glacier during one of its periodic advances across the river. Thus we know that Colonel Gordon of the Forsyth Mission to Yarkand recorded that both the Chong Kumdan and the Kichik Kumdan protruded into the Shyok river bed in 1873, and we know of no other traveller passing up or down the river till 1889. Nor is there any other recorded abnormal high level of the river at Attock during this period other than those of 1879 and 1882.

We have now the data of the last phase during which the Chong Kumdan Glacier has been across the Shyok valley since the winter of 1924–25. The dam burst in October 1926, healed the following winter, burst again on the morning of August 15, 1929, healed again during the winter of 1929–30, and burst again on the morning of July 11, 1932. It is extremely interesting to compare the floods of the three block periods :

1*st Period :*
1835, serious ; 1839, serious ; 1842, small.
2*nd Period :*
Mid-August 1879, serious ; July 25, 1882, serious.
3*rd Period :*
October 1926, serious ; August 15, 1929, serious ; July 11, 1932, small.

The total period between the middle burst of the first of these periods and the middle burst of the last is ninety years.

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[3] The Indus at Attock before the bursting of the Leychar dam in 1841 is said to have been fordable.

We do not know whether there were two or three bursts during the middle period, but it is possible that a smaller flood may have occurred towards the end of the block period as in the other two periods, and that this occurred before or after the period of high summer flood and so passed unnoticed at Attock. From analogy of the other two periods it is tempting to suggest that a third minor burst occurred in 1885, probably in June, when the Indus would not have attained its flood level.

Many people will say that all this is guessing. As a matter of fact, after the burst in 1926, from a study of the available history of the glacier and from photographs taken during recent years it was possible to forecast with an astonishing degree of accuracy what would happen, and with the accumulation of further reports of travellers during the last three or four years it has not been necessary to modify the forecast to any appreciable extent. The latest photographs of the snout seem to indicate that ablation has now definitely got the upper hand, and I do not believe that the ice will again completely heal during the coming winter.[4] If we place the block periods as 1834 to 1842, 1878 to 1886, 1924 to 1932, and if these previous cycles are repeated—both big 'ifs,' no doubt—we may anticipate another block period of about eight years commencing about the year 1968, and no inconvenience from the Chong Kumdan in the meanwhile.

It is not so easy to investigate the snout movements of other glaciers, owing to lack of observations over a sufficiently long period; but some remarks may be of interest, particularly concerning the Kichik Kumdan. This glacier seems to have had two periods of advance during the last hundred years. During these periods its ice has been across the Shyok valley approximately from 1856 to 1869 and from 1902 to 1915.[5]

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[4] Since the above was written, I have received a note from Captain C. E. C. Gregory, written from Leh on August 16, 1932, which states that the Public Works overseer who visited the glacier after the burst in July records that the lake emptied through a tunnel under the ice. The tunnel was about 450 ft. wide. Captain Gregory considers that the lake took 14 hours to empty. In 1929 the lake cut a breach *through* the glacier. I believe that this tunnelling is a further confirmation that the glacier has definitely entered on a period of degeneration.

[5] I can find only one flood definitely attributed to the Kichik Kumdan Glacier. This occurred in 1903. Almost always the drainage into the valley above escapes through or under the Kichik Kumdan when the latter is across the valley.

It will thus be seen that the Kichik Kumdan Glacier is roughly at its maximum advance when the next glacier to it, the Chong Kumdan, is at its maximum degeneration—a point which is well shown by the similarity between the photographs of the degenerate Chong Kumdan taken by Professor Giotto Dainelli in 1914, and those of the degenerate Kichik Kumdan taken by Mr. Ludlow in 1928. In both, the dead pinnacles appear isolated by masses of exposed moraine. But it will be noted that the periodicity of the two glaciers is approximately the same, forty-five years. From these two facts it seems to me safe to deduce that the cause of the advance is certainly not due to any change in temperature at the snout, but most probably to a variation in volume of the ice supply in the upper regions of the two glaciers.

It is easy to understand how a considerable excess of snow above normal in the basins of two adjacent glaciers in a few consecutive years may reach their snouts at widely different periods, owing to the different lengths of the glaciers, their different bed-slopes and different topography. And it is equally obvious that such general observations as one occasionally sees in print, as ' the snouts of all glaciers in such and such an area are advancing,' are nonsense. For not only may a glacier snout be advancing while its neighbour is in full retreat, but we have instances in the Karakoram of one side of a glacier snout advancing while the other side is retreating. One of the chief causes of this phenomenon is the compound structure of a glacier, two tributaries entering near the snout, which are out of phase with one another.

A very great deal of observation and investigation is necessary before the movements of glaciers are fully understood. The Chong Kumdan and the Kichik Kumdan seem to have a periodicity of about forty-five years. This periodicity *may* be related in some way to weather cycles, such as Brückner's. But we must be careful. Observations of other glaciers are incomplete : the period of the Aktash seems to be more in the neighbourhood of fifty-five, while it seems possible that the Karumbar has a periodicity as low as sixteen. The Minapin, on the other hand, one of the Hunza glaciers first marked by the late Sir Henry Hayden, and carefully observed since, seems to show a periodicity of about forty-eight years. But none of the observations have yet been carried through two whole periods.

Of the thirty-four glaciers that I have investigated in the Karakoram, only six appear to show any periodicity at all, and

many definitely are so subject to accidental influences that they never can show any. Considering the complexities of a glacier's topography, considering how small are the amplitudes of all the different periods of climatic variation compared with the haphazard variations of weather, it is indeed surprising that the snout movement of any glacier should reveal the phases of climatic variation of its basin, such as that of the Chong Kumdan would appear to do.

The Ennstaler Alps, Styria.

By J. W. WYATT.

THE Ennstaler Alps of North Styria consist of five isolated groups of limestone peaks which rise abruptly above both banks of the River Enns. This river is an important tributary of the Danube, having its source in the western end of the Niedere Tauern, and joining the Danube just below Linz. Between the towns of Admont and Hieflau the river has cut its way through a narrow gorge for a length of about 12 miles, known as the 'Gesäuse,' and is flanked on either side by the different groups. They date from the Triassic period and rest on a foundation of dolomitic limestone.

Although they do not exceed 7800 feet in height, the valleys separating the different groups are so deeply cut, down to an average of only 1700/2000 feet above sea-level, and are so precipitous that they give the effect of a much greater elevation. They are not dolomitic in character, so far as the texture of the rock is concerned, but are certainly so in appearance. The arêtes and ridges are weather-worn and broken up into a series of imposing peaks, pinnacles and needles often almost fantastic in appearance; this is especially so up the Johnsbachtal, a subsidiary valley running up to Johnsbach.

Besides the main gorge of the Enns, each tributary, rivulet and torrent has cut its way so deeply into the heart of the mountains that they have formed a succession of remarkable gullies or clefts with very precipitate sides, almost approaching the nature of miniature canyons, which give a very distinct feature to the rock scenery. Owing also to heavy wastage and denudation, each gully is filled with a mass of scree and boulders; in one case, in the Johnsbachtal, where gullies from opposite sides meet, the river gets blocked up and has