

THE SNOUT OF THE BIAFO GLACIER IN BALTISTAN. BY J. B. AUDEN, M.A., F.G.S., *Assistant Superintendent, Geological Survey of India.* (With Plates 27 to 31.)

CONTENTS.

	PAGE.
I. INTRODUCTION . . . . .	400
II. PREVIOUS EXPLORATION (K. Mason) . . . . .	401
III. RECENT OBSERVATIONS . . . . .	403
IV. DISCUSSION . . . . .	405
1. Types of observation . . . . .	405
2. Ablation . . . . .	406
3. Summary . . . . .	406
V. OTHER GLACIERS . . . . .	407
VI. CLIMATE . . . . .	407
VII. APPENDIX . . . . .	411
VIII. EXPLANATION OF PLATES . . . . .	412

I. INTRODUCTION.

The following observations were made during a short excursion, when on furlough, with Captain C. E. C. Gregory, 2/18th Royal Garhwal Rifles, to Baltistan in June and July, 1933. A general narrative account of this excursion has already appeared in the *Himalayan Journal*, Vol. VI, p. 67, (1934). These notes are concerned with details of the glacier.

The snout of the Biafo glacier is situated at Lat. 35° 40' N., Long. 75° 55' E., and is included in Survey of India Degree Sheet 43 M. It has been visited by many travellers, both by those who went specifically to explore the Biafo glacier, and by those whose destination was the Baltoro glacier lying to the east, in sheet 52A.

An account of earlier observations of the Biafo glacier up to 1923 has been given by Major K. Mason (now Lieutenant Colonel) in his paper on the Glaciers of the Karakoram and neighbourhood.<sup>1</sup> This is reproduced *verbatim* in the present paper for the sake of completeness. Since 1923, there has been an Italian expedition to the Karakoram in 1929, headed by H. R. H. the Duke of Spoleto. A preliminary account of this expedition has appeared in the *Geographical Journal*, LXXV, pp. 385-411, (1930).

<sup>1</sup> *Rec. Geol. Surv. Ind.*, LXIII, pp. 254-257, (1930).

I should like here to record my thanks to Captain Gregory for the invitation to join his expedition, and also to Lance-Naik Pertap Singh for the trouble he took in preparing the sketch map of the Biafo glacier.

## II. PREVIOUS EXPLORATION.<sup>1</sup> (By K. Mason.)

*Sheet* 43M; *Type*, Longitudinal (mainly); *Length*, 37 miles (including Snow Lake); *Height of Snout*, 10,360 feet; *Fall*, 16,290 to 10,360 from edge of Snow Lake to snout, 28 miles (212 feet per mile, 4 per cent.).

The Biafo is the fifth longest glacier outside the sub-Polar regions. It descends from an enormous snow basin which has an area of some 25 square miles. This enormous reservoir, which has been described as a region 'drowned in ice', though seen by Godwin Austin, Sir Martin Conway and the Workmans, has not yet been fully surveyed, but it is believed not only to supply ice to the Biafo glacier, but to force ice over the Hispar pass to the Hispar glacier and over the main Muztagh range to the heads of the Shingshal glaciers, the Virjerab and Kburdopin. The Biafo glacier itself is fed by some ten branches on the southern side, but with the exception of the Latok glacier, there are none of any importance on its northern side. [A steep minor glacier may be seen entering the Biafo from the north, above Camp 2, in the plate, opposite page 68, of Vol. VI, *Himalayan Journal*.] The ratio of supply area to waste area is as large as 3 : 4. Near the entrance of the Snow Lake the glacier has a width of about 2½ miles, but it narrows to a mile at six miles from the snout. It is possible that this narrowing is partly responsible for the marked variations of the snout, which are unusual for a glacier of so gentle an average fall. [The longitudinal profile is broken at three places, at approximately four, nine and twenty miles from the snout. Slight ice falls occur at the first two places, but only on the south-west side of the glacier.]

The following are the most important observations that have been made regarding the snout variations of the Biafo glacier:—

1861. Godwin Austin surveyed the glacier and found the snout filling the whole Braldoh valley from one side to the other, and resting on the rocks of Mango Gusor on the left flank of the valley, in such a way that the Braldoh river, containing mainly the waters of the Punmah and Baloro glaciers, flowed in a tunnel underneath the ice. His map shows a complete block and the track is shown crossing the glacier 1½ miles from the snout.

1892. On 31st July, Sir Martin Conway found the snout a quarter of a mile away from the Mango Gusor wall of the valley, and noted that during August of that year it lost another quarter of a mile. As it withdrew, it left a wide moraine covered with earth and vegetation.

1899. The Workmans found the glacier so shrunk that it barely reached the outlet into the Braldoh valley at all. It would then have been about a mile from the Mango Gusor wall on the left bank of the river.

1902. According to Guillaumod, the glacier had advanced as far as the right bank of the Braldoh river driving before it a low frontal moraine. Dr. Pfannl, of

<sup>1</sup> Portions in square brackets are additions or omissions to Colonel Mason's summary.

the same expedition, does not mention this frontal moraine, and describes the Biafo as a mass 600 to 700 feet thick, protruding across the valley, squeezing the Braldoh into a narrow bed, and ending with a steep snout 400 feet above the river. (*Mitt. d. Geog. Ges. Wien*, 47, 1904, p. 255.)

1905. Colonel Penny records from memory in 1928, that in 1905 the low snout of the Biafo glacier was a mass of fissured broken ice 'extending to the right side of the Braldoh river and there seemed no practicable passage there'. His guides confirmed the Workman's statement of 1899 (private letter). The low fissured snout indicates that the glacier was now retreating and diminishing in volume.

1908. The Workmans on their return to the region noted that the Biafo was practically in the same position as they had found it in 1899. If this observation is correct, the glacier must have grown and shrunk again between the two expeditions.

1909. De Filippi, during the Abruzzi expedition, found the glacier projecting into the Braldoh valley, and thought at first that it blocked the river. He writes: 'It was only when on our return journey we ascended the left bank of the Braldoh valley on the Skoro La road that we clearly saw the river flowing under the open sky through a narrow gap in the valley wall and the steep front of the glacier. The latter showed no trace of frontal moraine. It is, however, possible that at some point of the left half of the glacier the ice may bridge over the river and actually reach the rock.' (*Karakoram and Western Himalaya*, p. 165.)

[1913. Desio mentions an observation made by Dainelli during the winter of 1913, who found the minimum distance between the snout and the left bank of the Braldoh river was 40 metres or 131 feet. (*Geogr. Journ.*, LXXV, p. 410, 1930). Dainelli himself writes: 'We crossed the great snout of the Biafo, scored with crevasses and rugged with needles; it flows down from its immense basin and fills up the entire width of the Braldoh valley.' (*Himalaya, Karakoram and Eastern Turkestan*, p. 86, 1932.)]

1922. Featherstone found the snout right up to the Braldoh river, and according to the natives it had been so for two years. They also said that the glacier was forcing the river to cut into the opposite bank, causing great landslides (*Geogr. Journ.*, LXVII, 1926). [It is improbable that the river is cutting rapidly into the opposite bank. The rocks are very hard ortho- and para-gneiss and showed no sign of landslipping in 1933; Plate 29, fig. 1.]

1923. Egeberg reported that the Biafo stream could be crossed below the snout of the glacier owing to the retreat of the latter (*private communication*).

[1929. Desio reports that in May the distance of the snout from the left bank of the Braldoh river was 180 metres, or 590 feet. (*Geogr. Journ.*, LXXV, p. 410, 1930.)]

*Conclusion.*—It is unusual for a longitudinal glacier with so gentle a fall to show such marked periodic or seasonal movements, and it would be well worth studying this glacier more carefully and in more detail, in spite of the fact that end erosion must to some extent vitiate the observations when the glacier actually projects into the river bed. It is inconceivable that this glacier could block the combined waters of the Punmah and Baltoro glaciers, which should always be able to maintain a channel.

The period 1861 to 1892 is too long, in view of later observations, to assume that the snout remained more or less stationary during that period; but from the latter year to 1899, there seems to have been a steady retreat. A sudden advance then set in, but by 1905 degeneration and retreat had again commenced, reaching a maximum about 1908. Another rapid advance had set in by the following year, and the glacier was in approximately the same position in 1922, though again beginning to retreat.

These movements may be considered seasonal or periodic. The fact that the snout was in approximately the same position in 1861 and in 1922 seems to indicate that there has been no secular movement of any importance during these sixty years.

### III. RECENT OBSERVATIONS.

On leaving Askoli on the 22nd June, 1933, and climbing over the promontory north of Ste Ste, the Biafo glacier suddenly comes in view, a great mass of dark ice covered with boulders. It appeared to us at first as if the glacier had retreated far away from the left bank of the Braldoh river and emerged only a short distance southwards from the conspicuous hillock west of the snout which acts as a sentinel to the Biafo valley. This hillock is called the 'Sentinel' on the sketch map, Plate 31, (*see also* Plate 28, fig. 1). This soon proved to be incorrect, because, on mounting the glacier, its snout was seen to turn away to the south-east and to approach the left wall of the Braldoh valley (north wall of the northern peak of Mango Gusor).

No more observations of the snout were made until the return journey, when camp was pitched at Korofon. The 1st and 2nd July were spent in mapping and photographing.

The production of the map, Plate 31, was carried out by Captain Gregory's orderly, Lance-Naik Pertap Singh, under my supervision, and was made by compass and tape-measure survey, on a scale of 1:9,600. It has since been reduced to a scale of 1 inch=1,600 feet or 1:19,200. Plane table work would have been very difficult with the time at our disposal, since two base lines would have been required, one on each side of the glacier. Captain Gregory had unfortunately developed malaria on the 22nd June, and had been compelled to leave on the 24th for Skardu.

The best view of the whole of the snout of the Biafo is obtained from the top of the first rise on the Korofon-Laskam path, at a height of about 11,600 feet; (*see* Plate 27). From this place, it was at once evident that the snout comes down as far as the Braldoh river and follows round the great buttress of the northern peak of Mango

Gusor<sup>1</sup>. The snout is shaped into two lobes, east and west of the buttress. If viewed from the west from any distance at river level, it gives the impression of touching the south wall, but this due to the southward overlapping of the two lobes on each side of the buttress. The closest distance to which the snout approached the south wall of the Braldoh valley on July 1st proves from the map to be 440 feet or 134 metres. Slightly to the west of this place, we measured a distance of 350 feet from the snout to the right bank of the Braldoh river and estimated a total distance of 800 feet or 244 metres as far as the buttress wall. The river was impossible to cross owing to its being in full flood, and hence the full distance to the wall could not actually be measured. The figures may be accepted as accurate within an error of  $\pm 30$  feet. They are only of significance when the date of observation is taken into account. Ablation is so strong between June and August that a month will make a considerable alteration in the southward extension of the snout; (*see* p. 406).

A less comprehensive view, because the height of observation is small relative to the distance, is obtained at a height about 11,500 on the path between Monjong and the Skoro La. This is shown in Plate 30, fig. 1 and is in the same direction as that figured by De Fillipi, (*Karakoram and Western Himalaya*, panorama between pages 158 and 159, and text photograph, page 163). There is no doubt that the west lobe of the glacier extended westwards in 1909 to close to the debouchment of the Stokpa Lungma (called by the local Baltis *Tehri Kushu*) with the Braldoh river, and as far as the level terrace of river gravels. In the map, Plate 31, may be seen from west to east: firstly, an extensive flat terrace of water-rounded river gravels, upon which the glacier has probably never overflowed since the great secular retreat after the Ice Age; secondly, a small old moraine, covered with vegetation; thirdly, a large area of new lake-covered moraine, bounded eastwards by the snout. In 1909, the west lobe of the glacier must have covered this area of young moraine. Between 1909 and 1933, approximately 750,000 square yards (0.24 square miles, 0.63 square kilometres) of this lobe has wasted away, dropping the overlying moraine. The chief portion of the snout has not, however, retreated, but curves round close to the buttress as it did in 1909.

Recent decrease in thickness of the glacier is evident from the high ice-marks seen along both sides of the Biafo valley; (*see* Plate 27 and

<sup>1</sup> See *Himalayan Journal*, VI, footnote p. 69, (1934).

Plate 29, fig. 2). The bare rock, not yet colonised by vegetation, has only recently been forsaken by the ice. This decrease in thickness is at least 100 feet near the snout, but diminishes higher up the glacier, until about 10 miles from the snout it is not noticeable.<sup>1</sup>

#### IV. DISCUSSION.

##### 1. Types of Observation.

Except for the observations of the Workmans in 1899 and 1908, other travellers have found the snout of the Biafo glacier to have remained moderately close to the south wall of the Braldoh river. In 1892, Conway noticed that during August the snout retreated one quarter of a mile.

On page 403, I stated that the impression we first had on approaching the Biafo from Askoli was that the snout appeared to penetrate only a small way beyond the Sentinel. An explanation which suggests itself is that the Workmans, anxious to move up the glacier, were misled by first appearances. The normal route from Askoli up the glacier is along the gully between the Sentinel and the north side of the Braldoh valley. If this route is followed, and not departed from, it would be impossible for anyone to find the true extension of the snout. This, I thought, might explain the somewhat anomalous observations of the Workmans. Yet both in 1899 and in 1908, the Workmans went up the Skoro La from Monjong. The Biafo snout is visible from this path, as stated on page 404, and it is difficult to suppose that they failed to see it unless the weather was abnormally hazy. It must, therefore, be allowed that their observations may perhaps be correct.

The necessity should be emphasised, however, of making observations of large glaciers not only from valley level but from positions overlooking the snout. Only after obtaining a broad view can the details obtained from different places close at hand fit in without initial conflict. The map, of course, finally co-ordinates the details, but a map is made more easily if the whole layout has been grasped by a preliminary inspection from the slopes above a glacier. Such a view is to be seen from the Korofon-Laskam path.

<sup>1</sup> A very approximate idea of the loss in volume of the ice may be obtained by assuming a uniform loss in thickness of 50 feet of ice for ten miles of glacier, one mile in width. On these assumptions, the loss has been 13,940,000,000 cubic feet, or nearly 1/10th of a cubic mile (0.4 cubic kilometres).

## 2. Ablation.

The observation of Conway that the snout retreated one quarter of a mile in August 1892 is very significant. Colonel Mason was the first, I believe, to stress the importance of summer ablation in glaciers situated in low latitudes. I had myself underestimated this factor of ablation in writing the pamphlet entitled *Notes on the Study of Glaciers*, and Colonel Mason was kind enough to point this out to me by letter<sup>1</sup>. The two days that we spent mapping the Biafo snout in July 1933 fully demonstrated the importance of this factor. The day temperature was 94° F. (34° C.) in our tents, and about 118° F. (48° C.) in the open, (we had no solar thermometer). The cliffs of ice at the snout retreated almost bodily before our eyes. It seems clear that Conway's observation was not exaggerated, and that a retreat of some 400 yards may be expected during the course of a prolonged hot weather. This fact vitiates the loose comparisons of distance of the snout from the south wall of the Braldoh river. It is necessary to compare observations that are made during the same month of successive years, realising also that annual climatic conditions may not be exactly comparable. Dainelli's observation in the winter of 1913 (40 metres) should not really be compared with that of Desio in May 1929, (180 metres). This retreat of 140 metres, or 459 feet, is of seasonal magnitude, and may not indicate any periodic change.

## 3. Summary.

Apart from the observations of the Workmans, which are not entirely free from doubt, there appears to have been no secular and little periodic change in the length of the Biafo glacier since 1861. The closest position of the snout from the left or south bank of the Braldoh river on July 2nd, 1933, was 440 feet or 134 metres.

Seasonal variation in the length of this glacier is probably of the order of 400 yards.

The west lobe of the glacier has retreated eastwards since 1909 over an area of about 750,000 square yards.

There has certainly been a decrease in thickness of the glacier over its lowest 10 miles, amounting to a very approximate figure of 1/10th of a cubic mile. It is impossible to state whether or not this reduction of volume is still persisting.

<sup>1</sup> See also *Himalayan Journal*, V, p. 102, (1933).

## V. OTHER GLACIERS.

(1) On descending the Skoro La (16,664 feet ;  $35^{\circ} 34' : 75^{\circ} 49'$ ) towards Skoro village, some small hanging glaciers are seen to the west ; (see Plate 30, fig. 2). The southern glacier (left hand side) in the photograph is the same as the northern glacier (right hand side, at the margin) in the panorama between pages 340 and 341 of *Karakoram and Western Himalaya*. The snout of this glacier was at least 500 feet lower in altitude in July, 1909 than in July, 1933.

(2) Three hanging glaciers are seen from the Shigar river southwest of and overlooking the villages of Motto and Tsogo ( $35^{\circ} 37' : 75^{\circ} 30'$ ). One of these glaciers is close to a peak with an astonishing resemblance to the Matterhorn in Switzerland. They appear all to be in retreat, leaving bare polished rock below the snouts not yet blanketed with vegetation.

(3) *Machhoi glacier* : ( $34^{\circ} 18' ; 75^{\circ} 32' ;$  Sheet 43 N.). This well-known glacier is passed by every traveller who crosses the Zoji La. Neve<sup>1</sup> states that the snout may have been a little higher in the last decade of the 19th century than it was in 1910, but that upon the whole there had been little change between 1885 and 1910. He gives no position of the snout relative to the caravan path at Machhoi. A lantern slide (registered number 353) in the collection of the Geological Survey of India, probably from a photograph taken by Colonel Mason in 1910, shows the snout to have been in nearly the same position in 1910 as it was in 1933. This was approximately one-quarter of a mile from the path, though the actual distance was not measured.

De Filippi wrote as follows with reference to the glacier on 26th September, 1913<sup>2</sup> :—

' We made a single stage at Metchuhoi, beside a nameless glacier that almost touches the path with its tongue, at about 10,800 feet above sea-level.'

It is impossible to guess what distance is really implied, but perhaps some slight advance of the snout took place between 1910 and 1913, followed by a retreat between 1913 and 1933.

## VI. CLIMATE.

Many of the lateral and hanging glaciers in Baltistan appear to be in retreat. The Biafo glacier has not diminished in length since

<sup>1</sup> *Rec. Geol. Surv. Ind.*, XI., p. 343, (1910).

<sup>2</sup> *Himalaya, Karakoram and Eastern Turkestan*, 1913-1914, pp. 23, (London, 1932).



1861, but has lost in width at its snout since 1909 and in thickness and width within the Biafo valley for an unknown period of time.

It appears therefore as if the volume of ice in many glaciers in Baltistan has been diminishing. It is of interest to attempt briefly to discuss the nature of the climatic change which has been responsible for this loss in volume.

There has, of course, been a secular change in climate since the period of maximum glaciation of the Himalaya. Signs of the former extension of glaciation are to be seen throughout most regions of the higher Himalaya. With regard to historical times, Colonel Mason<sup>1</sup> has given a list of nine glaciers in the Karakoram that are suitable for the study of secular change and remarks:—

‘ Observations are as yet very scanty and incomplete and it must be remembered that those of last century were rarely made with any scientific motive. Nevertheless, as far as we can say at present, all of these are either stationary or in very slight secular retreat, except the Biafo.’

He then discusses the periodic fluctuation of the Biafo glacier, assuming as correct the observations of the Workmans. On page 257, he concludes with reference to the Biafo that ‘ there has been no secular movement of any importance during these sixty years ’ (since 1861).

Coming to the question of periodic change, Mason states that the majority of glaciers in the Karakoram which show periodic movement seem to be in retreat, though a notable exception is the Chong Kumdan, which in 1929 was at its period of maximum advance.<sup>2</sup>

The periodicities of the Minapin, Chong Kumdan, Kichik Kumdan and Aktash glaciers are given by Mason<sup>3</sup> as 48, 45, 45, and 55 years respectively, with recent maxima in 1913, 1929-1931, 1902-1914, and 1909. Other glaciers which were in a condition of maximum advance at about the same time as three of the above-noted glaciers are the Lungmo-Che A (1914), Sasaini (1912), and the Pasu (1910).

On the other hand, the Chong Kumdan, Malangutti Yaz, and Yazghil glaciers had maxima about 1929-31, 1926 and 1925 respectively. Mention may also be made of a lateral glacier in the Nubra-Shyok region, figured by Visser.<sup>4</sup> Between 1914 and 1929 this

<sup>1</sup> *Rec. Geol. Surv. Ind.*, LXIII, p. 221, (1930).

<sup>2</sup> *Loc. cit.*, p. 224.

<sup>3</sup> *Loc. cit.*, pp. 232, 271, 273, 275.

<sup>4</sup> *Zeitschr. f. Glkde.*, Bd. XX, p. 41, (1932). Visser gives no localities to his photographs.

glacier had advanced from a position well up in the side valley down into the main valley, spreading out in a great fan apparently half-way across.

It may be taken, however, that the majority of glaciers in the region were in a condition of maximum advance between about 1905 and 1915. Assuming the periodicity to be approximately 50 years, and 25 years to be the interval between the conditions of maximum advance and retreat, it follows that the glaciers should be in maximum retreat between 1930 and 1940. The data are scanty and do not allow the drawing of rigid conclusions, but it is seen that there is some agreement between the few observations that we were able to make and the conclusions as to retreat drawn from Mason's historical summary. The glaciers which were visited in 1933 did not exhibit any signs of advance ; on the contrary, most of them appeared to be in periodic and seasonal retreat.

Visser<sup>1</sup> has also studied the question of periodicity and has suggested periods of maxima for glaciers in the Karakoram in 1780, 1818-1833, 1853-1869 and 1903-1909. He considered the Karakoram glaciers to be in a condition of advance in 1922. If 1922 did mark a period of advance, it was evidently short-lived. Visser apparently did not mention those glaciers which are out of phase with his periods.

It is of interest to turn to Europe, where glacier observations have been frequent and accurate. In Europe, there was a period of maxima roughly between 1896 and 1900, the western Alps being affected earlier than the eastern.<sup>2</sup> This was followed by a general retreat over most of the Alps, Pyrenees and Norway. An exception in Norway was the Jostedalsbrae group, which showed a steady advance. About 1912-13, there were many indications in the Alps that retreat was giving way to advance, although numerically more glaciers were in retreat than in advance.<sup>3</sup> From 1921-22 to 1927-28, there has been almost universal retreat of Alpine glaciers but a general advance of Norwegian glaciers, particularly in the Folgefonn, Sogn and Olden groups.<sup>4</sup> The data subsequent to 1928 are scattered, but the yearly reports from the eastern Alps in the *Zeitschrift für Gletscherkunde* show that retreat is still continuing there.

<sup>1</sup> *Zeitschr. f. Glkde.*, Bd. XVI, p. 226, (1928).

<sup>2</sup> Hess: *Die Gletscher*, p. 259, *et seq.*, Braunschweig, (1904).

<sup>3</sup> *Zeitschr. f. Glkde.*, Bd. X, pp. 137, 138, (1917).

<sup>4</sup> *Rapport pour 1914-1928*, Commission des Glaciers: Section d'Hydrologie de l'Union géophysique et géodésique internationale, Venice, (1930).

The data are so consistent over a number of years that it is impossible to assume that seasonal factors are responsible for their interpretation. It is almost certain that some periodic climatic change is involved though modified in certain regions by local conditions. In Europe, it is usual to assume that Brückner's cycle of 35 years is responsible, though this has not been accepted by all glaciologists. Brückner's periods of damp and cold weather are thought to correspond more or less with those of glacier maxima.

This consistency in Europe leads to the hope that some measure of consistent behaviour will be found to obtain in the Himalaya, and makes it seem permissible, in spite of the inadequacy of the data, to suggest the conclusions as to advance and retreat given above. Apart from purely local factors of mountain topography that may govern exceptions to the general behaviour in any given region, it is not perhaps to be expected that the glaciers of different regions along a chain so great as the Himalaya will show identical periods of advance and retreat. What may be expected is that the variation from region to region will be in some orderly sequence, based, for instance, on an interplay between world-wide climatic cycles and the local conditions obtaining at the different latitudes through which the Himalaya pass.

Coming to India, Visser<sup>1</sup> has drawn up the following table:—

Glacier maxima in Karakoram.	Brückner Cycles.	
	Damp.	Cold.
1780 . . . . .	1771-1780	1766-1785
1818-1833 . . . . .	1806-1825	1806-1820
1853-1869 . . . . .	1841-1855	1836-1855
? . . . . .	1871-1885	1876-1890
1903-1909 . . . . .	..	.
1922 growing.		

The Brückner's cycles are deduced from observations of climate in Europe. While it is very probable that weather cycles are of world magnitude, and that those of Europe are applicable to India, yet local conditions are also important, and are certainly influential in governing local glacier growth in India. It is desirable therefore to undertake a study of rainfall and climatic conditions in India, and attempt a correlation with the behaviour of Indian glaciers.

<sup>1</sup> *Zeitschr. f. Glkde*, Bd., XVI, p. 226, (1928).

Little correlation appears to have been done in India in connection with climatic variation. Walker<sup>1</sup> has shown that in north-west and central India the monsoon rainfall showed a tendency,

- (1) to increase to a maximum between 1892 and 1894,
- (2) to sink to a minimum in 1899,
- (3) to improve slowly until 1908, the last year of data analysed in his paper.

He has also shown a strong degree of correlation between the Nile floods in Egypt and the monsoon rainfall in north-west India. Examination of the graphs on Plate I of his paper shows that a period of low monsoon rainfall occurred between 1864 and 1871, followed by increased rainfall between 1872 and 1894 and a further decrease from 1895 to 1905. In a later paper, the data are carried on to 1921, and it is seen that there were peaks of high rainfall in 1908 and 1917.<sup>2</sup> It may be remarked that the period of increased monsoon rainfall in north-west India, 1872-1894, corresponds roughly with Brückner's damp cycle of 1871-1885 in Europe, and that the period of glacier maxima in the Karakoram between 1905 and 1915 similarly corresponds with that of increased monsoon rainfall 1908-1917. The period of glacier minima believed to exist in parts of Baltistan at the present time may perhaps correspond with one of minimum monsoon rainfall, but the data of rainfall are so numerous and unwieldy, when not collected together in graph form, that it is not practicable to deal with them at the present time. It would be unwise at this juncture to do more than suggest that some correlation may be possible between monsoon rainfall and glacier advance and retreat. The problem has been put forward to Professor Mahalanobis, Presidency College, Calcutta, and it is hoped that analysis of rainfall data, together with further observation on glaciers, will produce something of value.

## VII. APPENDIX.

After this paper had already gone to the press, there has appeared an important paper by H. de Terra and G. E. Hutchinson on recent climatic changes shown by the Tibetan Highland lakes.<sup>3</sup> These authors have proved that the recent rise in water level of the Pangong Tso, the Tso

<sup>1</sup> *Mem. Ind. Meteorol. Dept.*, XXI, Pt. 1, p. 5, (1910).

<sup>2</sup> *Op. cit.*, XXIII, Pt. 2, graph Pl. II, (1922).

<sup>3</sup> *Geogr. Journ.*, LXXXIV, pp. 311-320, (1934), *Nature*, Vol. 134, p. 741, (1934).

Morari and other lakes in Ladakh is not connected with increased melting of glaciers, since the local glaciers appear to be in a stationary condition, and the rise in water level has been recorded also in lakes which have no glaciers in the immediate neighbourhood. They conclude that the rise is due to increase in rainfall, and mention that such an increase has been established by Brooks for the period 1880-1910 for the temperature zone of the Eurasian continent. De Terra and Hutchinson also compare their own observations with those of the Karakoram glaciers, mentioning Mason's historical survey of the Chong Kumdan glacier as supporting their own conclusions. This comparison is misleading, because the evidence as discussed in my paper indicates that, in spite of exceptions such as the Chong Kumdan glacier, there has been retreat rather than advance of the Karakoram glaciers during the last 25 years. It may be noted that the rainfall fluctuations at Leh (fig. 4 of their paper) correspond approximately with those of monsoon rainfall in northern India. The rise in lake level of the Pangong Tso between 1890 and 1905 took place during an interval of time when the rainfall was first high, then low and finally on the increase, and before most of the glaciers in the Karakoram had reached their maximum. Further, between 1905 and 1932 there appears to have been no change in lake level or in the condition of the Ladakh glaciers, but there has been a definite change in the Karakoram glaciers. It seems, therefore, that while rainfall may be one of the prime factors governing the secular and greater periodic variations of the Ladakh lake levels and of the glaciers in the Karakoram, its influence must be modified by other factors, peculiar to those areas, which prevent an exact parallelism of short-time behaviour. The discrepant results arrived at in Baltistan and Ladakh only serve to show the complexity of the problem.

### VIII. EXPLANATION OF PLATES.

PLATE 27.—General view of snout of Biafo glacier, from Korofon-Laskam path. Direction of view  $267^{\circ}$ . Biafo glacier emerges from its own valley and forms the right bank of the roughly east-west Braldoh river. On right wall of glacier may be seen a high ice-mark, forsaken by shrinking ice.

PLATE 28, FIG. 1.—Biafo glacier emerging from its valley, past Sentinel rock. View  $15^{\circ}$  from C. The photographic point lies on river gravels, over which the ice has probably not been since the great secular retreat. The Sentinel rock lies in the left-centro of the photograph, humped on the side adjacent to the glacier and *roche moutonnée* in form. The route up the Biafo glacier is through the gully on the west side of the Sentinel.

FIG. 2.—Snout of Biafo glacier. View 55° from hill of dead ice B. Paiju peaks in distance. Possible recumbent fold in paragneisses on the Laskam spur.

PLATE 29, FIG. 1.—Northern peak of Mango Gusor and east side of east lobe of glacier from A. The true Mango Gusor is possibly the peak in clouds lying next to the south from that so labelled in the panorama between pages 158 and 159, *Karakoram and Western Himalaya* (London, 1912).

FIG. 2.—High ice-marks along lowest four miles of Biafo glacier, which is completely covered with moraine.

PLATE 30, FIG. 1.—Braldoh river and Biafo glacier. View east from Skoro La path. Figured also in panorama between pages 158 and 159, *Karakoram and Western Himalaya*.

FIG. 2.—Hanging glaciers. View west from south-west of Skoro La. Figured in panorama between pages 340 and 341, *Karakoram and Western Himalaya*.

PLATE 31.—Sketch map of snout of Biafo glacier ; July 1st and 2nd, 1933.



*J. B. Auden, Photo.*

*G. S. I., Calcutta.*

GENERAL VIEW OF SNOUT OF BIAFO GLACIER FROM KOROFON-LASKAM PATH. DIRECTION OF VIEW 267°.



FIG. 1. BIAFO GLACIER EMERGING FROM ITS VALLEY, PAST SENTINEL ROCK. VIEW 15° FROM C.



*J. B. Auden, Photos.*

*G. S. I., Calcutta.*

FIG. 2. SNOOT OF BIAFO GLACIER. VIEW 55° FROM HILL OF DEAD ICE B.





FIG. 1. NORTHERN PEAK OF MANGO GUSOR AND EAST SIDE OF EAST LOBE OF GLACIER FROM A.



*J. B. Auden, Photos.*

*G. S. I., Calcutta.*

FIG. 2. HIGH ICE-MARKS ALONG LOWEST FOUR MILES OF BIAFO GLACIER.



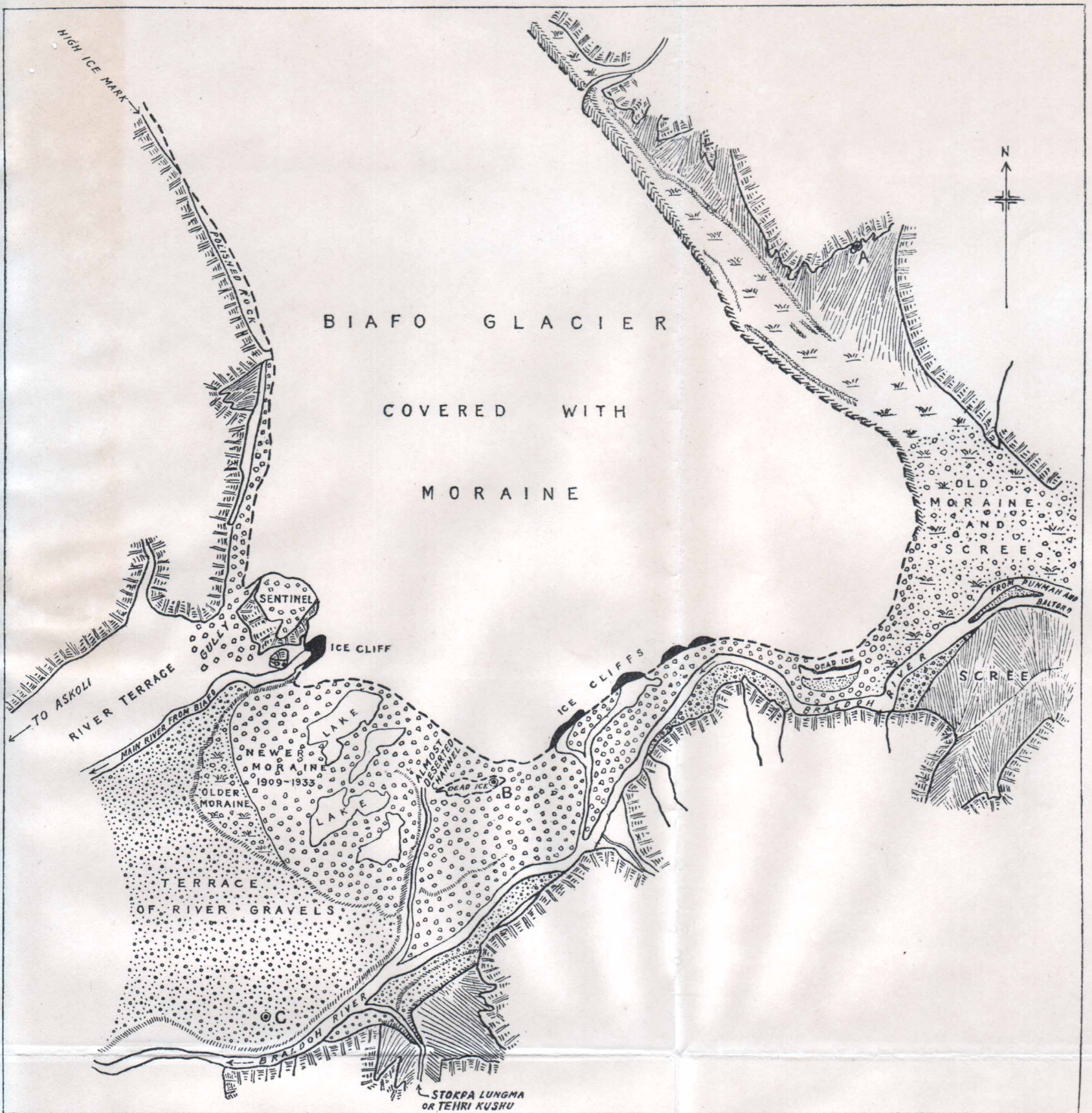
FIG. 1. BRALDOH RIVER AND BIAFO GLACIER. VIEW EAST FROM SKORO LA PATH.



*J. B. Auden, Photos.*

*G. S. I., Calcutta.*

FIG. 2. HANGING GLACIERS. VIEW WEST FROM SOUTH-WEST OF SKORO LA.



Mapped by Pertap Singh & J. B. Auden. A. K. Ghosh, del.

G. S. I., Calcutta.

SKETCH MAP OF SNOUT OF BIAFO GLACIER, JULY 1st & 2nd, 1933.

Scale, 1 inch = 1,600 feet. 1:19,200.

