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THE SNOUT OF THE GANGOTRI GLACIER, TEHRI GARHWAL.  
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I.—INTRODUCTION.

This paper describes the observations made on the snout of the Gangotri Glacier, which I visited when on leave in October, 1935. The Gangotri glacier is situated in Tehri Garhwal State, on the north side of the Main Himalayan Range, and is the source of the Bhagirathi branch of the Ganges river. This branch is considered to be more sacred than the Alaknanda, and Gaumukh, the name given to the snout of the glacier, is visited annually by pilgrims and sadhus.

An account of the excursion I made to the region, in the company of Dr. D. G. Macdonald, occurs in the *Himalayan Journal*, Vol. 8, p. 96, for 1936.

The Gangotri glacier lies in Survey of India 4 miles to 1 inch map No. 53 N, at Lat.  $30^{\circ} 56' N.$ ; Long.  $79^{\circ} 04' E.$  The altitude of the snout is 12,770 feet. The scenery is very fine, the glacier being dominated by the Satopanth group of peaks (21,364 and 22,520), and the isolated Shivling peak (21,466), which bears a strong resemblance to the Matterhorn.

I am indebted to the Director, Geodetic Branch, Survey of India, for supplying an advance copy of a portion of Map 53 N, which is reproduced here as Plate 3.

## 1. Route.

The best route to the glacier is from Mussoorie, whence it can be reached in from 10 to 12 days. The more direct route is *viâ* Deosari and the east shoulder of Nag Tibba (53 J/N.W.), but this involves somewhat severe changes in gradient and is scenically less attractive than the slightly more circuitous path through Dhanaulti and Kanatal (53 J/S.W.). After about October 1st, the last place at which rations for porters may be obtained is at Harsil (53 I :  $31^{\circ} 02' : 78^{\circ} 45'$ ), though during the pilgrim season it is probable that supplies may be bought in the shops at Gangotri. After leaving Harsil it is necessary to use tents, and there is a good camping ground at Gaumukh, where small shrubs are available for fuel.

## 2. Historical.

The glacier has been visited, presumably for centuries, by pilgrims. It was roughly surveyed by the Survey of India in the middle of the 19th Century. Griesbach sketched the snout during the course of his geological traverses in the region [*Mem. Geol. Surv. Ind.*, XXIII, p. 27, (1891)]. The Marco Pallis expedition of 1933 was the first to climb any peaks within the Gangotri basin [*Himalayan Journal*, Vol. 6, p. 106, (1934)], although peaks and cols on the watershed between the Gangotri and Arwa drainage systems had been climbed two years earlier, by the Kamet expedition of 1931 [*Himalayan Journal*, Vol. 4, p. 35, (1932)]. Shipton and Tilman descended to Gaumukh from British Garhwal in 1934 [*Geogr. Journ.*, 85, p. 305, (1935)].

A re-survey of the region by the Survey of India was begun in 1935, and a party under Mr. J. C. Ross was on the glacier at the time of my visit. Captain C. E. Wright, in charge of this

party, arrived at Gangotri at the end of October. I am greatly indebted to him and to Mr. Ross for kindly checking the plane table sketch which I made (Plate 2).

## II.—MAPPING OF THE GANGOTRI SNOT.

The snout was mapped by plane table on the 16th and 17th October, 1935. The scale adopted was 1"=400 feet, (1 : 4,800), but the map has been reduced to a scale of 1"=800 feet (1 : 9,600) for the purpose of reproduction as Plate 2. A base line of 868 feet was made along a grass-covered moraine ridge on the north-east side of the glacier, and cairns were erected at both ends; cairns C and D of the map. They were marked with marine red paint C, 16.10.35, G. S. I. and D, 16.10.35, G. S. I. C lies at the north-west end of a slightly inclined portion of the moraine, while D is at the edge of a gully just below a buttress of granite. Subsequently Captain Wright and Mr. Ross built two more cairns four feet to the south-east of each of the cairns which I put up. On these they inscribed the marks *G.B.I./C '35* and *G.B.I./D '35*. Another cairn, No. E, was built on the south-west side of the glacier at the top of a ridge of old lateral moraine. The south-west side of this moraine is grass-covered, but the north-east side, facing the glacier, is steep and without vegetation. The cairn itself was not marked, but a flat stone immediately adjacent to it was painted *G. S. I., E. 17.10.35*. Independently of plane table sighting, directions were taken to the centre of the snout from these cairns by prismatic compass. They are given in the table below.

Cairn number.	Cairn marks.	Prismatic compass readings to snout.
C . . . . .	C 16.10.35 G. S. I.	168°
D . . . . .	D 16.10.35 G. S. I.	190°
E . . . . .	G. S. I. E 17.10.35	60°

Cairn A lies outside the map, due east of cairn C, on the south-west side of the glacier and on a flat stone about 200 feet above Gaumukh camping ground.

Cairn B is on the same side of the valley as C and D, and a short distance to the north-west of them. It is not shown on the map as it was impossible to locate during the survey which was carried out subsequent to its erection. The photograph, Plate 5, fig. 1, was taken from this cairn and is of interest in showing the sand flat left by the recent retreat of the glacier.

### III.—RETREAT.

#### 1. Recent Retreat.

One of the most striking features of the Gangotri glacier is the obvious retreat and shrinkage which it has undergone in very recent years. In front of the snout is a sandy flat about 2,400 feet (about 730 metres) in length, which must have been occupied by the glacier within the last century. This flat is shown in the map, Plate 2, and is clearly seen in Plate 5, fig. 1, and again, though very foreshortened, in Plate 4. The decrease in thickness of the glacier is about 200 feet near the snout, but becomes less higher up, although it must persist for some way, since freshly exposed moraine, still uncolonised by vegetation, continues beyond the first lateral valley descending from the north-east (Plate 4).

#### 2. Secular Retreat.

It is often very difficult to decide to what altitude Himalayan glaciers descended during the Pleistocene Ice Age, because the original glacial features have been so often obliterated or obscured by the products of later erosion. In particular, talus fans tend to convert what were almost certainly at one time U-shaped valleys into a modified V-form (Plate 7, fig. 2).

Smooth glaciated pavements of granite are found for about a mile below Gangotri temple on the left (south) side of the Bhagirathi valley. They may occur as far down as Bhairongathi. It can be said definitely that the Gangotri glacial system once descended as far as Gangotri, down to an altitude which is now 10,000 feet, but which may have been lower during the ice age on account of the isostatic uplift which has since occurred.

Besides glaciated pavements, there are old high level moraines to indicate the height in the valley to which the glacier once rose. A bank of old lateral moraine is seen in Plate 5, fig. 1, at a height of about 400 feet above the snout. Almost certainly the same moraine extends down the valley, being seen as a slight terrace in Plate 7, fig. 2, and lying at least 1,000 feet above the valley floor about midway between Gaumukh and Gangotri.

Between Gangotri and Jangla (53 I, 31° 03' : 78° 51') the original valley, if formerly glacial, has been modified greatly by deep incision due to rejuvenation. At the foot of what may have been a U-shaped valley, there is a remarkable gorge with vertical walls which has been cut through the granite.

The extensive river flat between Dharali (53 I, 31° 03' : 78° 47') Harsil and Jala (53 I, 31° 02' : 78° 43') is due, I believe, to a catastrophic landslide at Sukhi (53 I, 31° 00' : 78° 43'), which must have blocked the valley and formed a lake. Erosion of a channel through the upper part of the landslide, and partial filling up of the valley with gravels and silts, have caused the lake to disappear. I do not think that the Sukhi barrier is a terminal moraine. It has more the appearance of a landslide which originated on the eastern slopes of Banderpunch.

Below Sukhi, the Bhagirathi valley has the typical features of river erosion, with magnificent overlapping spurs.

Summarising the evidence :—It can be stated with certainty that during the Pleistocene period the Gangotri glacier descended at least as far as just below Gangotri ; it may have descended as far as Jangla. There are no signs of glacial action below Sukhi.

It may be remarked that the glaciers of the neighbouring Saraswati-Arwa-Alaknanda system were found to have descended as far down as Badrinath, which, like Gangotri, is at an altitude of about 10,000 feet [*Rec. Geol. Surv. Ind.*, LXVI, p. 391, (1933)].

#### IV.—NOTE BY MR. J. C. ROSS, SURVEY OF INDIA.

Mr. J. B. Auden's large scale survey of the snout of the Gangotri Glacier was checked by me on the 30th October 1935. The survey appeared to be very accurate.

Some eight months later, at Mr. Auden's request, the position of the snout was rechecked by me on a tracing of his survey. This was done on the 18th and 19th June 1936. On the first day plane-

table observations were made at Mr. Auden's cairns C and D, on the right bank, and no change whatsoever in the position of the snout could be detected. On the second day cairn E was visited, on the left bank, with the same result; further the thickness of the ice at the cave did not appear to differ from that noticed by me in October 1935.

It is perhaps significant that the first observations were made a month or so after the end of the monsoon and the latter at the end of the driest part of the year, otherwise weather conditions were similar, midday temperatures rising a few degrees above freezing point, sky generally overcast with light afternoon snowfalls.

#### V.—EXPLANATION OF PLATES.

PLATE 2.—Sketch map of the snout of the Gangotri glacier. Scale 1"=800 feet (1 : 9,600). 16th and 17th October 1935. Mapped by J. B. Auden, and checked at the end of October by Capt. C. E. Wright, R.E., and Mr. J. C. Ross, Survey of India.

PLATE 3.—Map of the Gangotri area. Scale  $\frac{3}{4}$ "=1 mile.

PLATE 4.—General view of lower part of the Gangotri glacier from a height of 14,000 feet on slopes leading up to the east side of the lateral Kedarnath valley ('Bhiringpanth Glacier' of the modern map, Plate 3.) from the Bhagirathi valley. Old high level moraine in the foreground. Shrunken snout of the Gangotri glacier. Satopanth group of peaks.

PLATE 5, FIG. 1.—View of Gangotri snout and sand flat from cairn B. Direction of view south-east.

FIG. 2.—View of Gangotri snout from cairn C in the direction 155°. Satopanth massif on left; Shivling on right.

PLATE 6.—View of Gangotri snout and Shivling from cairn D in the direction 175°.

PLATE 7, FIG. 1.—View of Gangotri snout from cairn E in the direction 60°. The tip of the snout is hidden by moraine and lies to the left of the exposed cliff of ice.

FIG. 2.—View down the Bhagirathi valley towards the north-west, from the left lateral moraine of the Gangotri glacier. Top of old high level moraine seen as a slight terrace just below the twin peaks on the left of the sky-line. Modification of U-shaped valley by talus fans.

NOTES ON PETROLEUM TECHNOLOGY IN BURMA DURING 1936  
WITH SPECIAL REFERENCE TO THE PROTECTION OF OIL AND  
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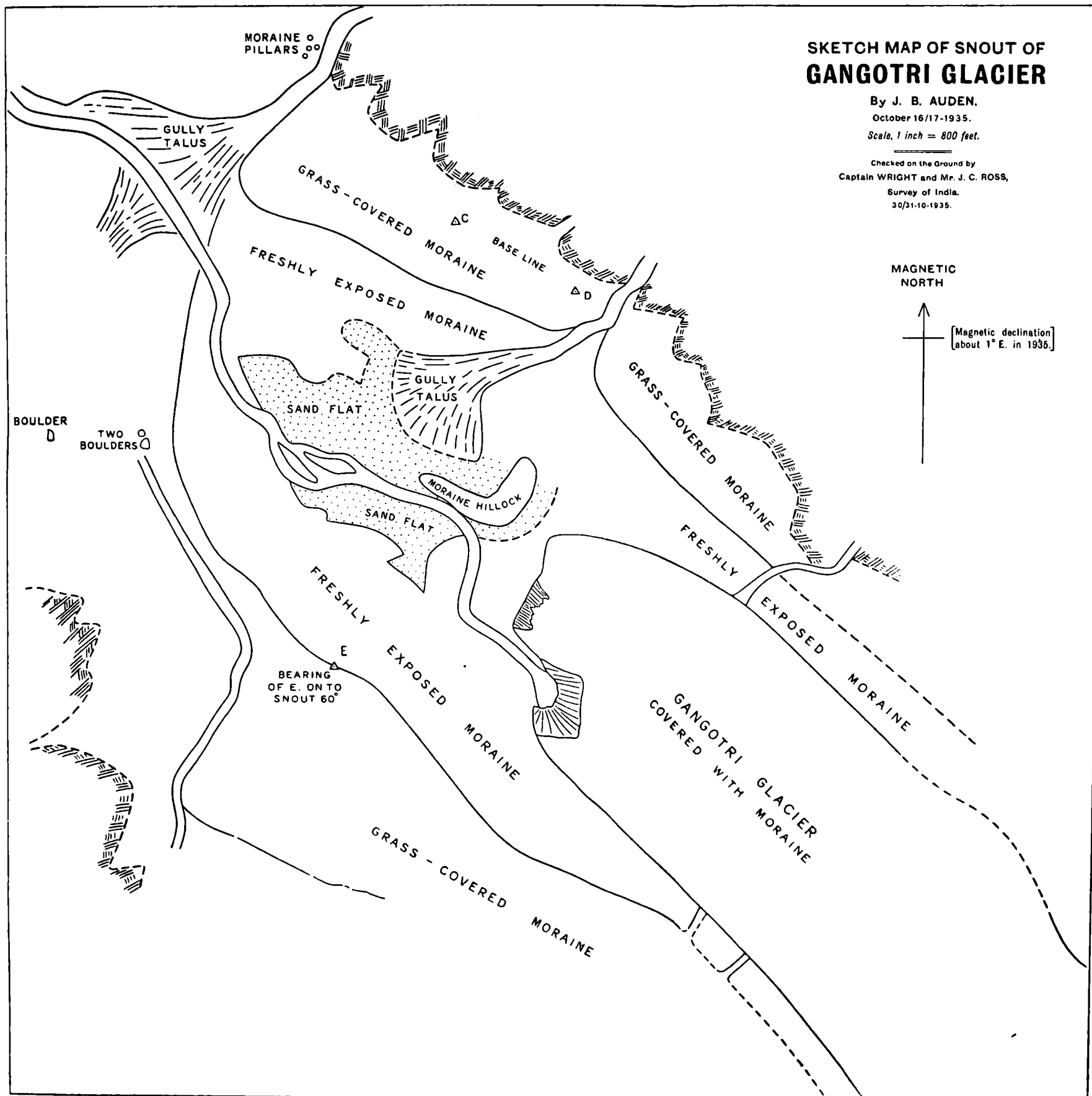
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The Warden, Burma Oil Fields, who is an officer of the Indian Civil Service, is advised on technical matters relating to drilling in competitive areas by two Advisory Boards, at

**Introduction.** Yenangyaung and Chauk respectively. The oil companies nominate members of their technical staffs to membership of the Advisory Boards, on each of which the Resident Geologist, Burma Geological Department, Yenangyaung, is the Government representative. The Yenangyaung and Chauk Advisory Boards normally meet once a week to discuss, and advise upon, technical operations in the oil fields. Besides routine business the Boards are frequently called upon to advise on problems which are of general interest to oil field operators, and the purpose of this paper







By permission of the Surveyor General of India.

G. S. I., Calcutta.

### MAP OF THE GANGOTRI AREA.

Scale:  $\frac{3}{4}$  inch = 1 mile (1: 95,040).



*J. B. Anden, Photo.*

GENERAL VIEW OF GANGOTRI GLACIER, WITH SATOPANTH PEAKS.

*G. S. I., Calcutta.*



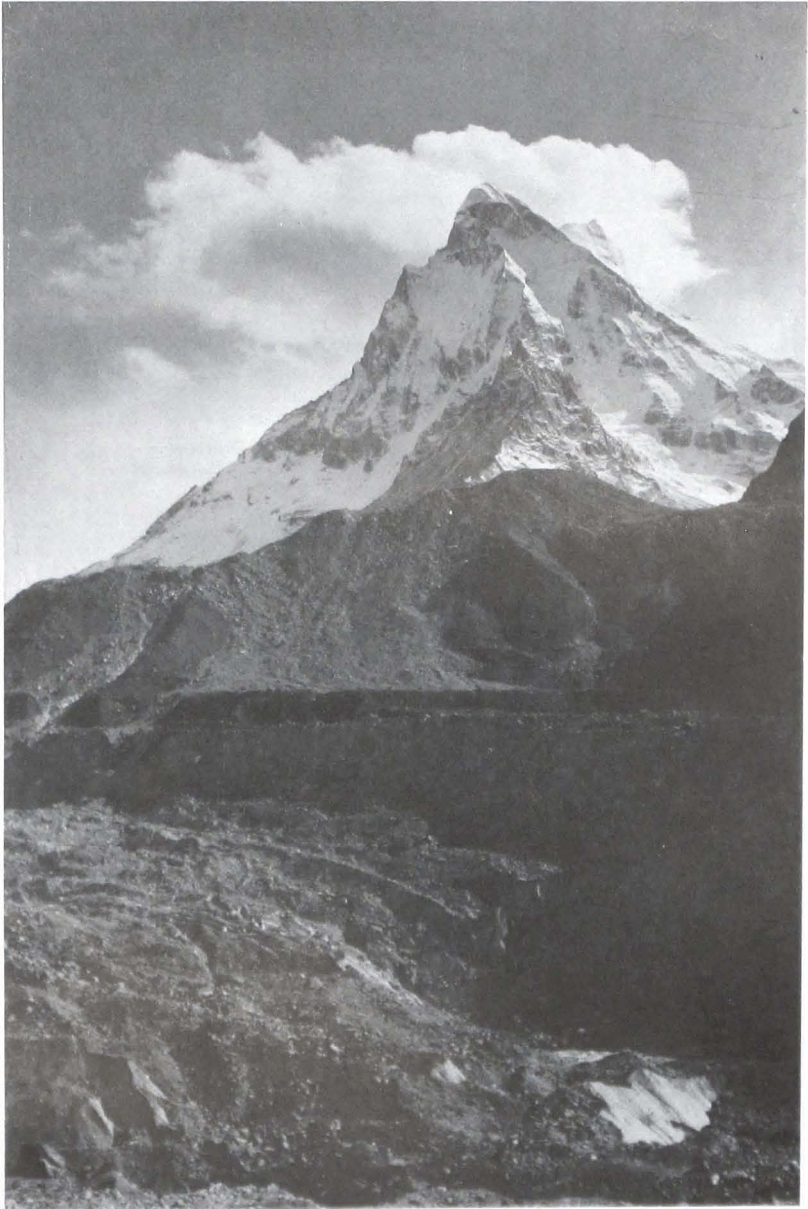
FIG. 1. VIEW OF GANGOTRI SNOT AND SAND FLAT FROM CAIRN B,  
LOOKING SOUTH-EAST.



*J. B. Auden, Photos.*

*G. S. I., Calcutta.*

FIG. 2. VIEW OF GANGOTRI SNOT FROM CAIRN C, LOOKING TOWARDS 155°.



*J. B. Auden, Photo.*

*G. S. I., Calcutta.*

VIEW OF GANGOTRI SNOUT AND SHIVLING FROM CAIRN D,  
LOOKING TOWARDS 175°.



FIG. 1. VIEW OF GANGOTRI SNOUT FROM CAIRN E, LOOKING TOWARDS 60°.



*J. B. Auden, Photos.*

*G. S. I., Calcutta.*

FIG. 2. VIEW DOWN BHAGIRATHI VALLEY SHOWING HIGH LEVEL MORAINE AND TALUS FANS.