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BATURA GLACIER TERMINUS, 1984, KARAKORUM HIMALAYA

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ABSTRACT

Batura Glacier in northwest Karakorum Himalaya has received considerable attention in the past decade because of some unusual characteristics and its effects on the Karakorum Highway between China and Pakistan. Chinese glaciologists found evidence that the Batura terminus would advance in the present decade and retreat in the 1990s. The predicted advance has not begun and instead the frontal ice cliff has downwasted and the cliff above the main meltwater channel has backwasted.

INTRODUCTION

The Karakorum Mountains host some of the largest and most active glaciers on Earth, yet detailed analyses of them are still sketchy, in spite of over a century of intermittant observation. This paucity of data is being remedied, however, as increasing numbers of scientists travel to the now politically and logistically more accessible area.

Several Karakorum glaciers descend into the deep mountain valleys to impinge upon the important Karakorum Highway (KKH) across northern Pakistan to China. One of these large glaciers, the Batura, has blocked the Hunza valley in the past, and in the last decade its meltwaters destroyed the road and bridges of KKH on several occasions. Continuous monitoring of the fluctuations of this glacier is useful for predicting future problems with KKH.

The 59km length of Batura glacier makes it one of the eight largest glaciers in the middle and low latitudes. The glacier flows from west to east below the north side of the peaks of Batura Mustagh (7795m) from the maximum elevation of 6200m of the western ice flow down into the transverse valley of the Hunza river at 2516m. The drainage area totals about 690km^2, with about 320km covered with ice, although the directly contiguous glaciers of the Batura proper have an area of 285km^2. The glacier consists of five main ice flows and over 20 smaller tributary glaciers. The basin is masked with heavy ice cover on higher north-facing slopes, and much less extensive glaciers on the lower south-facing side. Many of the south-facing glaciers provide only debris and meltwater to the Batura (Fig. 1).

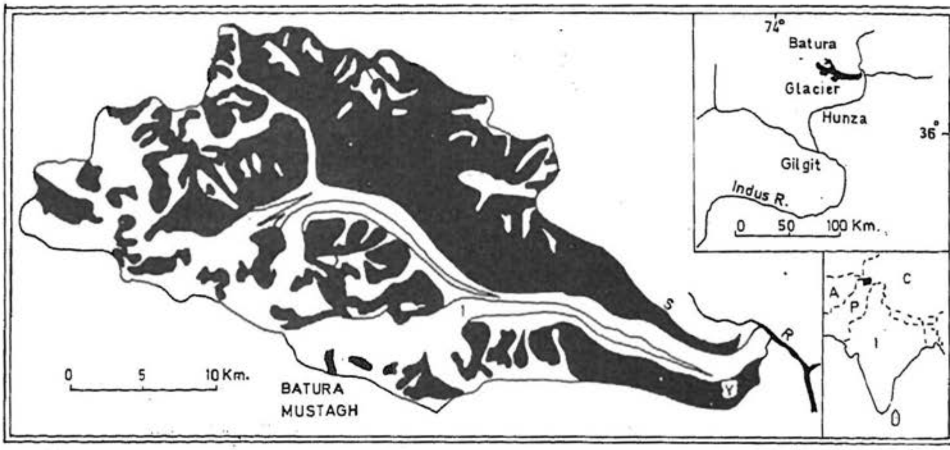

Figure 1. Location map of Batura glacier near Hunza river in Karakorum mountains of northern Pakistan, and map of overall glacial features adapted from BGIG (1979, 1980), and satellite RBV image E-2978-04342 26 Sept. 1977. A: Afghanistan; C: China; I: India; P: Pakistan; R: Hunza river; S: Shanoz; Y: Yunz; 1: first white ice stream.

The climate of the deep valleys of the Karakorum is dry, with about 100mm of precipitation on average. Measurements of annual snowfall on the upper reaches of the Batura show that precipitation there of 1000–1300mm is ten times greater (Batura Glacier Investigation Group, 1979, 1980). The glacier is notorious for large avalanches (Edwards, 1960; Finsterwalder, 1960; Shi & Wang, 1980), which contribute much to the positive side of the mass balance, as well as to the plentiful debris load so characteristic of Karakorum glaciers. The snowline occurs at about 5000m and the annual 0°C isotherm is near 4200m. The glacier is therefore a cold one in its upper reaches, and temperate in its middle and lower parts where two-thirds of the main glacier is covered with debris except for a thin (ca. 700m wide) strip of white ice that extends to within about 4km of the snout on the right (south) side of the glacier (Fig. 1).

Ice velocities were determined by direct measurement, stereophotogrammetry and ogive displacement. Maximum rates in the ice falls are about 1300m/yr, in the ogives about 1000m/yr, in the middle reaches about 170m/yr, and at the snout about 80m/yr (Batura Glacier Investigation Group, 1980; Shi and Zhang, 1984). Velocity increases in summer, and kinematic waves have been recognized but the glacier does not appear to be a surging type. Of greatest significance to KKH, however, are fluctuations of the glacier terminus, both in terms of ice movement, as well as in terms of meltwater volume and discharge locations. To this end both the Chinese-sponsored Batura Glacier Investigation Group (BGIG) and the British-sponsored International Karakorum Project (IKP) expended considerable effort to study existing processes in order to understand more about the region in general, and the Batura glacier and other hazards in particular (Chen, 1984; Derbyshire *et al.*, 1984; Goudie *et al.*, 1984a, 1984b; Li *et al.*, 1984; Perrot & Goudie, 1984; Shi, 1984; and Zhang, 1984).

BATURA TERMINUS TO 1974

During Pleistocene at least three glaciations occurred in the upper Hunza valley, which were termed the Shanoz, Yunz, and Hunza glacial stages by BGIG (1979, 1980) after localities associated with Batura glacier. Their work is consistent with the notion of a three-fold division of glaciation (excluding stadial advances) in the Himalayas as assessed by Flint (1957, p. 422 from earlier work), and in Swat 200km to the southwest of Hunza by Porter (1970). Subsequently, Derbyshire *et al.* (1984) rejected Porter's chronology as inappropriate for Hunza and subdivided the Pleistocene glacials there into five stages; Shanoz, Yunz, Borit Jheel (?Hunza correlate), Ghulkin I and Ghulkin II. In fact their thermoluminescence dates show so little time difference between two of their last three stages that all appear to be stades. Because Porter also has three stades in his final Kalam stage for late Pleistocene glaciation in Swat, and Derbyshire *et al.* (1984) have none, their case for a quite separate chronology between Hunza and Swat is weakened. Furthermore, our recent work in the Gilgit and Indus valleys between Hunza and Swat shows a three-stage chronology to fit the stratigraphy and landforms best. During the early, middle, and late stages of Pleistocene glaciation in the western Himalaya then, the Batura glacier was one of many glacial ice masses in the Karakorum that fed a trunk glacier extending far down the Hunza valley. In the early stage (Shanoz), a major glacier extended over 250km from the Hunza valley, through Gilgit valley, and down the Indus past Chilas to produce the Jalipur diamicton (Olson, 1982; Shroder, in press). Following an interglacial, in the middle glacial stage ice readvanced down the Indus to only 475m altitude at Sazin to produce a prominent terminal moraine (Desio & Orombelli, 1971). Subsequent advances following retreats were much less extensive.

During Holocene early neoglacial age, Batura glacier advanced about 2.5km southeast down Hunza valley and deposited dark-brown moraine hills 60–70m on both sides of the Hunza river. About two centuries ago a readvance to the river formed yellowish moraine (Fig. 2). From about 1885 to 1925 the glacier terminus was at Hunza river in only one small place (Mason, 1930; Visser-Hooft & Visser, 1938). The glacier then retreated and by 1954 a prominent ice cliff in the center was 300m from the river. By 1966 the ice cliff had moved back over 500m to a new position about 800m from the river. From then until 1975 the ice cliff readvanced about 100m (Fig. 2). This advance seemed responsible for shifting the main meltwater channel at the ice-cliff to a new position on the south margin of the terminus, from which all meltwater has flowed since 1973 (BGIG, 1979, 1980).

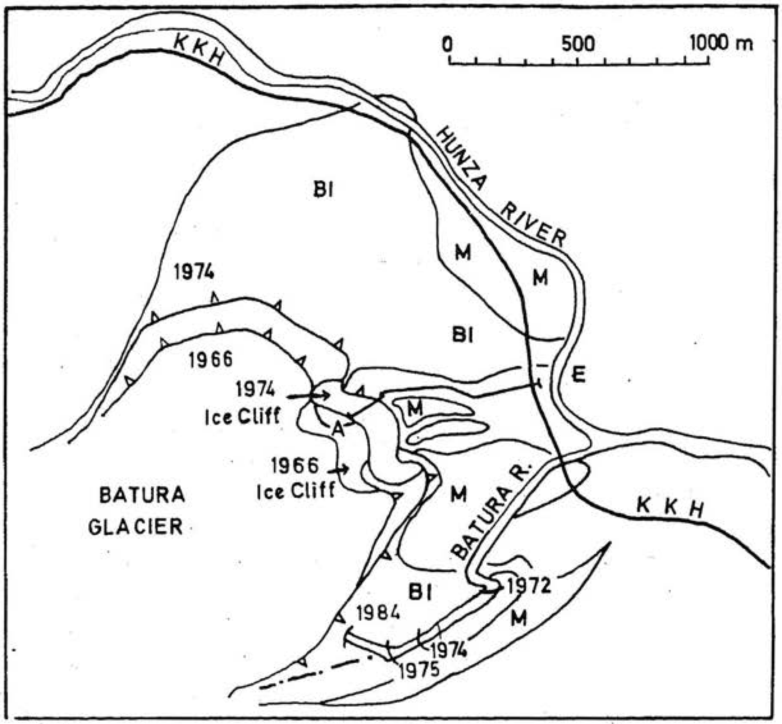

Figure 2. Terminus of Batura glacier in 1984 showing changes since 1975. A—E: line of section in Fig. 3; BI: buried stagnant ice covered with gray till (ca. 1885-1925); M: yellowish moraine about two centuries old; KKH: Karakorum Highway. The prominent ice cliff of 1966 that advanced to the position noted in 1974 is now only a steep till-covered slope. Dates on Batura river indicate former positions of main ice-cave portal; dot and dashed line indicates position of collapsing secondary cave. Map adapted from BGIG (1979, 1980), Perrot & Goudie (1984), and Zhang (1984).

Desire by the engineers of KKH to know more about potential for future change of the Batura terminus led to a series of studies of climate, tree rings, ice flux, ablation, and velocity (BGIG, 1979, 1980). Results indicated the glacier would advance some 180–240m into the 1990s to a point about 300m from the present highway and then stop advancing, with a decline thereafter for 20–30 years. The study herein was initiated to assess present configuration of the Batura terminus, and to see how predictions for change have fared. Our analysis included terrestrial stereophotogrammetry with abney level and tape traverses. The BGIG and IKP geomorphological maps were overlain with new data plotted from our 1984 ground surveys (Figs. 2 & 3). Our simplified survey techniques and locations were selected to facilitate future data collection by others, because complex and expensive survey equipment and aerial photography are not likely to be readily available in Pakistan for some time.

BATURA TERMINUS IN 1984

In June 1984 we made several trips over the front of the Batura glacier as far as the diffluent col at Yunz (Fig. 1). Two basic sets of changes from previous maps were noted: (1) the prominent ice cliff has virtually disappeared except for a few square meters of exposed ice where meltwater streams have removed overlying debris, and (2) some retreat of the small ice-cliff portal of the southern meltwater channel has occurred, and many meltwater channels and kettles are extensively developed for 2–2.5km along the southern edge of the glacier near Yunz.

Frontal Ice Slope.

The formerly prominent ice cliff has not continued to advance as predicted, but instead has downwasted and backwasted to a till-covered slope averaging about 45° through its 165m width (measured horizontally). The top of the ice cliff was about 700m from the river in 1974 (600m from cliff bottom to river). The distance from road to river is about 75m. Ten years later in 1984 the top of the ice cliff was about 740m from the road (815m from the river). The base of the ice cliff (an easier location to relocate in future years) was about 585m from the road (660m from the river). Allowing for discrepancies produced by scaling from the maps and by slopes declining through downwasting, the ice cliff has retreated a minimum of 50–100m in the intervening decade.

Meltwater Channels.

From about 1925 to 1970, the main meltwater channel of the Batura river issued from a portal at the base of the central ice cliff. Our line of section from the cliff to the road was established along the northernmost of these channels. The main channel of the Batura relocated itself in 1973 to a position on the southern edge (Fig. 2). The initial rapid rate of retreat of the portal was about 470m/yr but has slowed considerably since 1975 and retreated only a few hundred meters since then; total channel length is now about 1.4km. In the retreat process the channel curved into a topographic depression to the west and to the northwest as well as into the thicker central portion of the glacier behind the formerly prominent ice cliff. This topographic depression has existed since before 1966 and indicates probable meltout subsidence for some time prior to the establishment of the new outlet.

At present there are two main meltwater sources; the main portal system from within the central ice mass behind the formerly prominent ice cliff, and a second system of kettles and discontinuous supra- and sub-glacier meltwater streams that flow close to the southern margin of the glacier before remerging

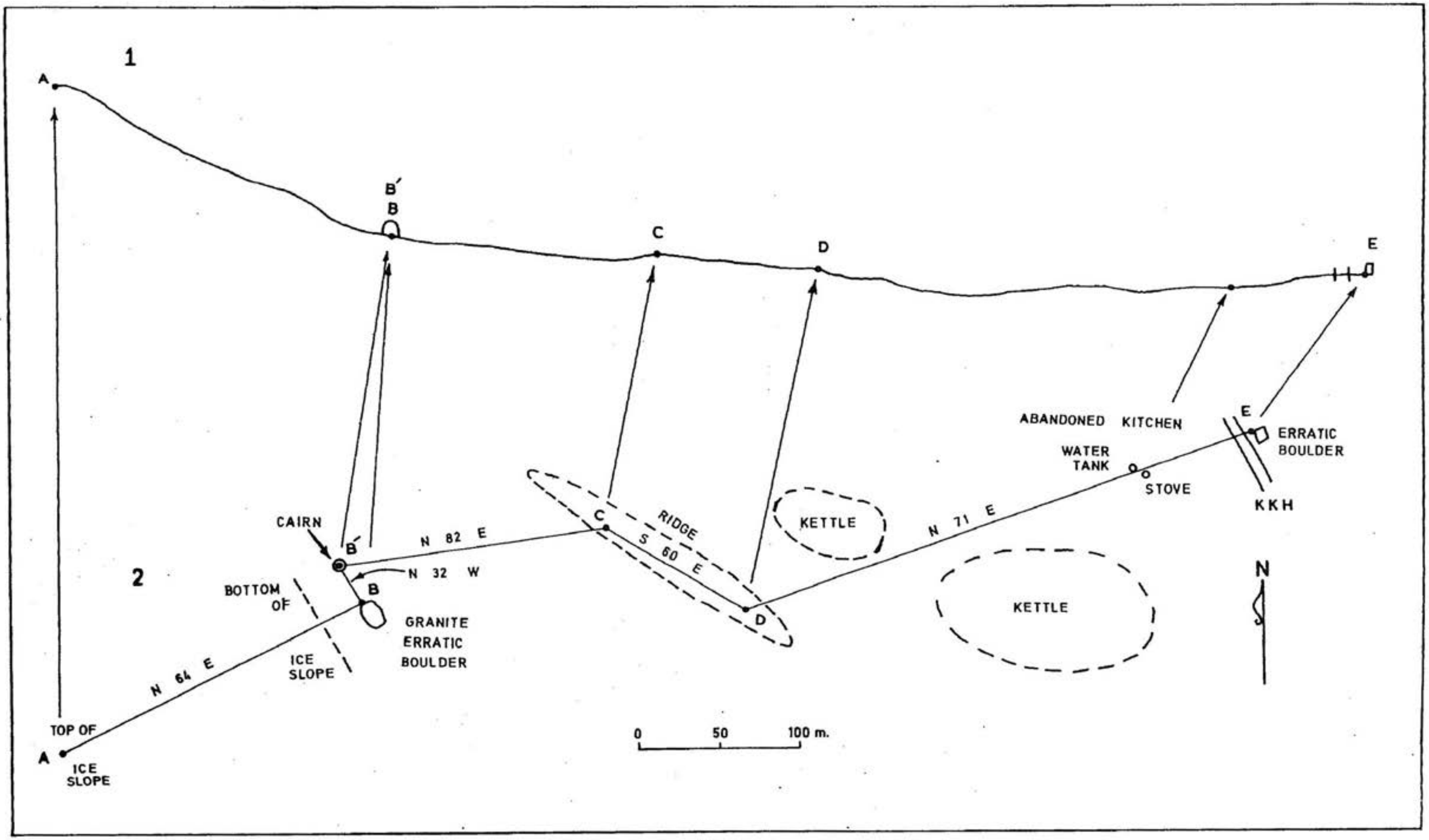

Figure 3. (1) Profile in 1984 from top of formerly prominent ice cliff of Batura glacier terminus to Karakorum Highway. (KKH).
(2) Map of line of 1984 profile (see (Fig. 2 for location).

from a collapsed portal about where the main portal was in 1975. If these lateral channels continue to develop through roof collapse and meltout enlargement then in a few more years a secondary channel will be exposed as a new ablation valley for upto 3.5km along the south margin of the glacier.

CONCLUSION

Neither the formerly prominent ice cliff nor the meltwater channel of the Batura river have changed appreciably in the last decade since the intensive study by BGIG. The predictions for further forward movement of the prominent ice cliff were never viewed as especially hazardous anyway, with the result that the original predictions combined with these latest observations reinforce each other that little potential problem exists into the foreseeable future for the KKH. Nevertheless, short surveys of a few days time can be made periodically to maintain a reasonable data base for further forecasting. In addition, the relative ease of access and the large size of the Batura glacier make a useful natural laboratory to assess long-term glacial trends in the Karakorum.

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