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RECENT FLUCTUATIONS OF THE YALA (DAKPATSEN) GLACIER, LANGTANG HIMAL, RECONSTRUCTED FROM ANNUAL MORAINE RIDGES

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With 3 figures and 1 map supplement

ABSTRACT

A series of minor moraine ridges are observed on the till surface in the proglacial area of Yala Glacier, Nepal Himalaya. The till surface, which is often fluted, consists of six different till sheets. It lies present glacial margin and the bulky terminal moraine ridges. These till sheets correspond to six re-advance stages during the general retreat which followed Little Ice Age advance which formed the bulky terminal moraine ridges. Field observations and till fabric analysis suggest that the minor moraine ridges of Yala Glacier seem to be formed annually, by ice push. On the assumption that their annual character was maintained for a long time, and that the time span needed for each re-advance was proportional to the height of terminal moraine of each till sheet, the dating of Little Ice Age moraines was attempted. The results indicate that Little Ice Age advances occurred in 1815 and in 1843, roughly simultanously with those in Europe.

REZENTE SCHWANKUNGEN DES YALA-(DAKPATSEN-)GLETSCHERS IM LANGTANG HIMAL, REKONSTRUIERT AUS JÄHRLICHEN MORÄNENWÄLLEN

ZUSAMMENFASSUNG

Eine Reihe von kleineren Moränenwällen wurde im Vorfeld des Yalagletschers beobachtet. Die Oberflächenablagerungen zwischen dem heutigen Gletscherrand und den größeren Endmoränen bestehen aus sechs verschiedenen Decken, die sechs Vorstößen im allgemeinen Rückzug während der vergangenen 140 Jahre entsprechen. Beobachtungen und Gefügeanalysen deuten darauf hin, daß sich die kleinen Moränenwälle durch jährlichen Eisschub bilden. Unter der Annahme, daß diese jährliche Bildung lange nicht unterbrochen wurde und daß die Zeit, die jeder der sechs Vorstöße brauchte, um eine neue Decke abzulagern, proportional zur Höhe des entsprechenden Moränenwalls war, wurden die äußersten Moränen datiert. Dabei stellte sich heraus, daß Vorstöße um 1815 und 1843 stattgefunden haben, also etwa gleichzeitig mit denen der Alpen.

1. INTRODUCTION

The recent fluctuations of Himalayan glaciers are not well known, although several European authors have suggested that the maximum Little Ice Age advance in Khumbu Himal occurred simultaneously with that in the European Alps, namely around 1850 (Heuberger 1956, Müller 1959). Iwata (1976) recognized three moraine stages, corresponding to the Little Ice Age advances at Khumbu Glacier. The youngest moraine ridge, Lobuche I stage, was correlated with a glacial advance during the 19th and early 20th centuries. The older moraine ridges, Lobuche II and III, were regarded as earlier Little Ice Age advances, which occurred between the 15th and 17th centuries in Europe. Fushimi (1977), on the other hand, divided the recent moraine ridges in Khumbu Himal into six substages. A wood sample at the base of the moraine of the oldest substage gave a C_{14} age of 410 ± 110 y BP (Fushimi 1978). This suggests that the earliest Little Ice Age glacial advance in Khumbu Himal occurred in 16th century, roughly simultaneously with the early advance of Little Ice Age in Europe. The lack of historical records has prevented the clarification of the glacial fluctuations in the Nepal Himalaya during the Little Ice Age.

The Yala (Dakpatsen[1]) Glacier, Langtang Himal, was chosen for coring studies in the Nepal Himalaya during 1981—1982 (Higuchi 1984). Tightly spaced minor moraine ridges occur on the till surface which extends from the present glacial margin to the bulky moraine ridges corresponding to the Little Ice Age advance (cf. fig. 1 map supplement). Field observations and till fabric analyses suggest that a single minor moraine ridge is formed by periodical (annual) ice push. The till surface, itself, is divided into six superposed till sheets (till sheets A—F in fig. 1) which should correspond to re-advance phases during the general glacial retreat after the Little Ice Age maximum advance. In this paper, the dating of Little Ice Age moraines will be attempted on the assumption that the annual character of minor moraine ridges was maintained for a long time and that the time span needed for each readvance, which interrupted the general retreat of glacier, was proportional to the hight of terminal moraine of each till sheet.

2. ANNUAL MORAINE RIDGES

2.1 CHARACTERISTICS

Annual moraine ridges are a series of minor ridges lying on a lodgement till surface which is exposed beyond the present glacier margin. There are many kinds of "annual" moraines and various origins have been proposed (Elson 1968). It is often difficult to distinguish true annual moraines from others, but annually formed minor moraine ridges have been reported from a Norwegian glacier (Worsley 1974) and from Iceland (Sharp 1984).

In the Nepal Himalaya, Fushimi and Ohata (1980) recognised several minor moraine ridges in front of the termini of small glaciers in Khumbu Himal. They observed that a new moraine ridge was formed within one year of the destruction of a similar moraine which had been formed the previous year. This is the first observation in Nepal Himalaya that provides evidence for the annual character of these minor moraine ridges.

Minor moraine ridges, in the proglacial area of Yala Glacier, are small accumulations of till, composed of similar materials to those forming the till sheet on which they are developed. They resemble the annually formed minor moraine ridges in Khumbu Himal and, as will be discussed later, there are several reasons to regard them as true annual moraines. They are, therefore, mapped as small annual moraine ridges in fig. 1.

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[1] Langtang villagers have not named this glacier. Yala is the name of a small snow peak at the southeast end of the glacier and Dakpatsen is the name of the nearest kalka (summer village). In the following description, the author uses the names Yala Glacier and Dakpatsen Plateau.

With the exception of the most recent, the annual moraine ridges of the Yala Glacier are low and usually difficult to distinguish on the ground. They are easily recognised, however, on air-photographs and several ridges can be traced for more than 250 m. They are formed on a flat or relatively convex till surface and are absent from the valley walls and valley bottom. They are also found in an area of roches moutonnées. They form a grid-iron pattern on the till surface as they cross the flutes (Boulton 1976) which run roughly perpendicular to them (fig. 1).

2.2 GENESIS

Observations of the most recent annual moraine ridges and the marginal ice cliff of Yala Glacier were made in the middle and at the end of October 1982, at the beginning of the post-monsoon season. In this period, melting of glacier surface occurs during the day. The marginal ice cliff of Yala Glacier is about 20—30 m high and apparently has no crevasse at the snout. The ice cliff is chiefly composed of clean blue ice except for the debris-laden basal part, which is about 60—80 cm thick. This basal zone is mainly composed of till consisting of abundant fine materials and several large blocks.

As the clean blue ice exposed in the cliff face contains very few blocks, most of the till which constitutes the annual moraine ridges should originate from the debris-laden basal part of the glacier. There are no shear planes extending from the bed to the surface in the debris-laden layer, however, and it is also quite unlikely that the glacier margin is stagnant. If the annual moraine ridges are simply formed through basal melting and the release of englacial debris, the basal till fabric should be preserved in the ridges. To examine this possibility, the fabrics of the basal till and the till constituting the newest annual moraine ridge were analysed (Ono 1984). The results of measurements of a-axis orientation of gravels (cobble and boulder size) have revealed that (1) the a-axis orientation of gravels in the basal till is subparallel or oblique (about 30°) to the general direction of glacier flow while (2) their orientation in the newest annual moraine ridge is nearly perpendicular to glacier flow (fig. 2).

Field observations indicate, in fact, that the englacial gravels were gradually exposed and finally fell down to the foot of the ice cliff, as a result of melting of the glacier surface. On falling, the gravels first roll down a gently inclined short ice slope at the foot of the ice cliff and then roll along on the ground for a short distance (fig. 2). The orientation of the gravels seem to change with these movements.

As the glacial melting continues, the fallen gravels accumulate in front of the glacier margin. As the glacier snout retreats continuously due to melting, however, no marked accumulation of fallen materials is created. A minor glacial advance, or ice push, is necessary to cause accumulation forms such as the annual moraine ridges. The gravels and fines left on the proglacial ground are bulldozed into ridge, when a minor advance of the glacier occurs. The fallen gravels do not seem to be incorporated into the glacier ice during this advance, but only pushed forward by the advancing glacier front. The orientation of the gravels, which is already perpendicular to the glacial flow, should not be badly distorted during the ice push.

In the Nepal Himalaya, glacier ablation and accumulation occur simultaneously during the summer monsoon season. Ageta et al. (1980) established that the summer temperature decisively influences the mass balance of small glaciers in Khumbu Himal, because it determines whether the monsoon precipitation falls as rain or snow. Small glaciers, such as the Yala, are in a delicate steady state, therefore, in which the

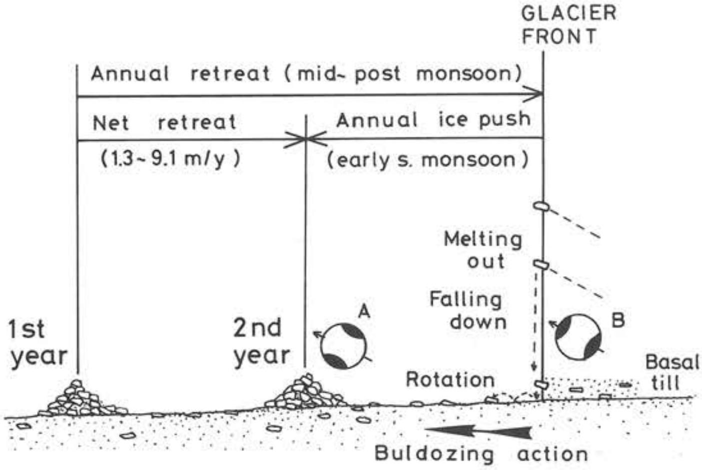

Fig. 2: Genesis of annual moraine ridges of Yala Glacier. A, B: Concentration of a-axis of gravels in annual moraine ridge (A) and in basal till (B). Arrow indicates the general direction of glacial flow (from Ono 1984)

annual change of mass balance is controlled by a slight difference of air temperature in the summer monsoon season. Ageta (1983) concluded that the maximum mass balance usually occurs in late May in such glaciers, although, when there is abundant snowfall at the end of summer monsoon, it can also occur during September or October.

Glacial flow rates, on the other hand, are acceralated at the beginning of the summer monsoon season, while the ablation rate exceeds flow rates in the middle of the season (Kodama & Mae 1976). In fact, Fushimi and Ohata (1980) observed that a new annual moraine ridge had been formed by July 1976, following the partial destruction of a similar ridge which had existed in November 1975. This suggests that a short advance or ice push of a smaller glacier in the Nepal Himalaya is most likely to occur at the beginning of the summer monsoon season.

3. DATING OF THE LITTLE ICE AGE MORAINES

The minor moraine ridges of the Yala Glacier seem to be formed by an ice push which occurs annually depending on delicate annual changes in mass balance, glacier flow rate and ablation rate. Although there is no evidence that such annual ice pushes occurred over a longer time span, there are several reasons to regard these minor ridges as true annual moraines:

(1) If these ridges are true annual moraines, then the time span of continuous retreat can be measured by counting their ridges. The mean intervals of each minor moraine (table 1) thus indicate the mean speed of retreat of the glacier. The values range from 1.3—9.1 m/year, which are of the same order as measured rates of retreat of several of the small glaciers in Khumbu Himal (Fushimi & Ohata 1980).

Table 1: Maximum number of annual moraine ridges and mean intervals between each ridge on different till sheets

Till sheet	Little Ice Age Max. advance	A	B	C	D	E	F	Total
Length of till sheet (m)	50—55	65	45—85	70—90	115—150	20—60	10—20	425—475
Maximum number of ridges	6	8	16	18	30	15	6	99
Mean intervals (m)	8.3—9.1	8.1	2.8—5.3	3.8—5.0	3.8—5.0	1.3—4.0	1.6—3.2	4.29—4.79

(2) Fushimi and Ohata (1980) have recognized distinctive glacial advances of Gyajo Glacier, Khumbu Himal in 1970 and in 1976. These two advances were of nearly the same magnitude and the annual moraine ridge of the 1976 advance partially destroyed the 1970 ridge. If till sheet F, the most recent re-advance stage of Yala Glacier, is correlated with the 1976 advance of the Gyajo Glacier, then the continuous retreat since the 1960's is marked by fifteen tightly spaced minor moraine ridges on till sheet E of Yala Glacier. A small till sheet, almost covered by till sheet F, should correspond to the short re-advance of 1970 (fig. 3).

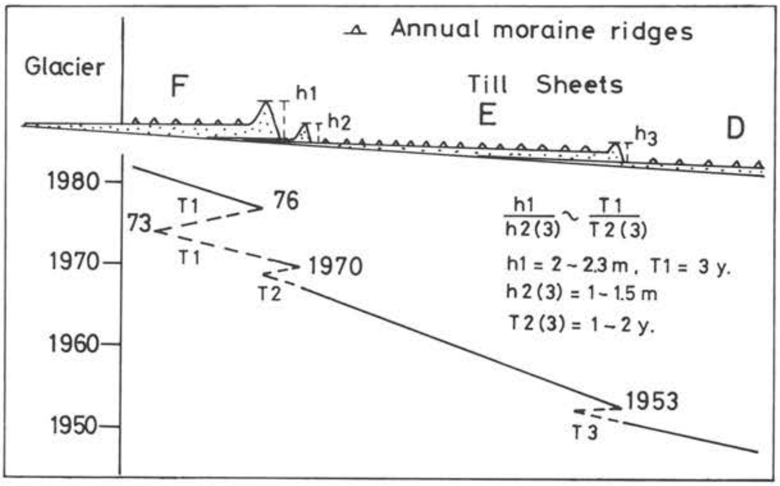

Fig. 3: Calculation method of time spans (T) for continuous glacial retreat and re-advance of Yala Glacier. 1 year was adopted for T2 (3) in figs. 3 & 4

On the assumption that the minor moraine ridges of the Yala Glacier have kept their annual character over a long period and that the most recent re-advance corresponds to the 1976 advance of the Gyajo Glacier, the dating of the Little Ice Age moraines was attempted using the following procedures (fig. 3):

(1) The time span of continuous glacial retreat from the outer to the inner edge of each till sheet was calculated by counting the maximum number of annual moraine ridges left on the till sheet (solid line in figs. 3 and 4).

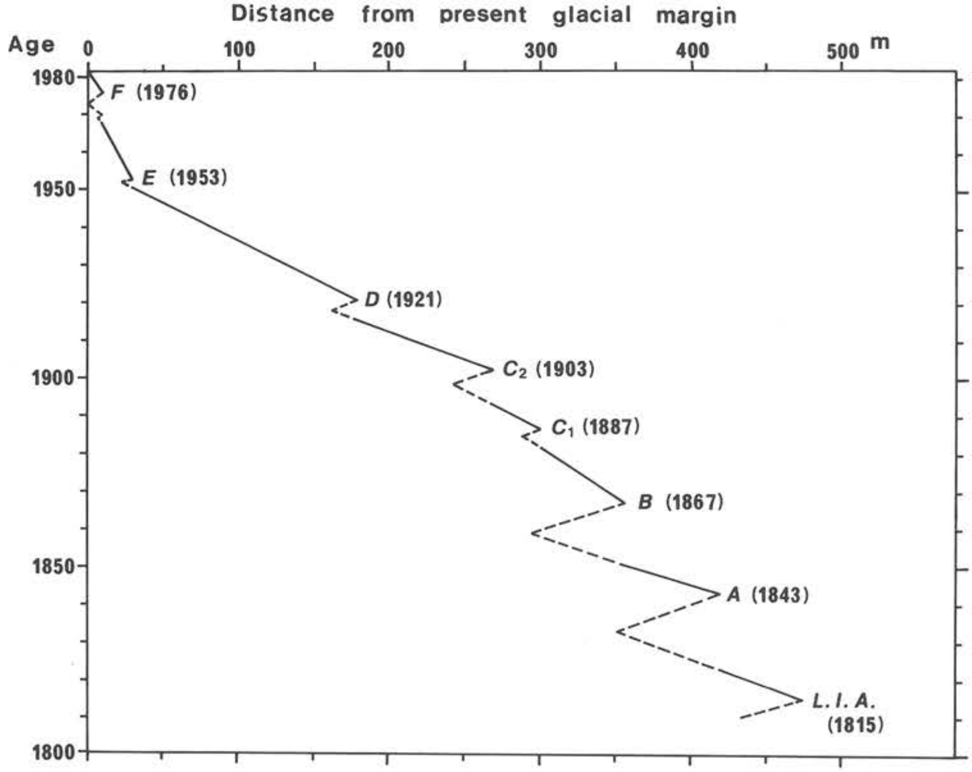

Fig. 4: Recent fluctuation of Yala Glacier reconstructed by annual moraine ridges
Solid line: time span of continuous retreat represented by annual moraine ridges, Broken line: time span of continuous retreat not represented by annual moraine ridges and time span of re-advance estimated by the hight of terminal moraine of each till sheet

(2) The time span of continuous retreat which would have occurred upglacier, until the onset of the next re-advance, beyond the position of the terminal moraine of the next re-advance, was hypothesized to be equal to the time span of the re-advance (broken line in figs. 3 and 4).

(3) The time span needed for a re-advance of each till sheet was estimated by the height of the terminal moraine limiting it. If the genesis of annual moraine ridges is as suggested, the height of the annual moraine ridge should reflect the volume of till left on the proglacial area during the retreat. When the glacier advances for a longer distance, it should bulldoze more material to form higher ridges. The height of the terminal moraine ridge which limits each till sheet should therefore be proportional to the distance of glacial advance which is, again, proportional to the time span of the advance, assuming the speed of advance is constant.

The time needeed for the building of the terminal moraine of each till sheet was calculated as shown in fig. 3, by assuming that the terminal moraine of till sheet F, which is about 2 m high, was formed by a re-advance of three years (1973—76, Fushimi and Ohata 1980). The time span of each re-advance stage, is thus calculated as follows: till sheet A: 11 years; B: 8 years; C1: 2 years; C2: 5 years; D: 3 years; E: 1 year and a small till sheet covered with F: 1 year.

Fig. 4 shows the result of these calculations. Although these calculations are based upon many assumptions, this figure indicates that the Little Ice Age maximum advance occurred in 1815, roughly simultaneously with the maximum advance in Little Ice Age in Europe (e. g. Le Roy Ladurie 1967). Furthermore, the first re-advance of the glacier after the 1815 advance is dated as 1843, which is also roughly synchronous with the glacial advance around 1850 in Europe. In fig. 1, the moraine ridge of till sheet A is classified as a recessional moraine. In reality, till sheet A should be included in the Little Ice Age advances in the European chronology. The younger re-advance stages also correspond roughly to several re-advance stages known in Europe, although there are some differences. These are probably the result of the inaccuracies involved in the adopted calculation method. As far as the assumptions adopted in this paper allow, it can be concluded that the recent fluctuations of small glaciers in the Nepal Himalaya are roughly parallel to those of other glaciers in the high mountains of the Northern Hemisphere.

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