Late Pleistocene and Holocene Moraines in the Sagarmatha (Everest) Region, Khumbu Himal*

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Abstract

Detailed field mapping of moraines in the Sagarmatha (Everest) region of the Nepal Himalayas indicates that there are four stages of glacial advance. The Lobuche stage moraines are fresh and sparsely covered with vegetation, which contact the dirty terminus of glaciers. The Thuklha stage moraines which are covered with soil and vegetation are located just outside of the Lobuche stage moraines. Both the Periche and the Thyangboche stage moraines which show well weathered and vegetation-covered surfaces lie at the valley far down the glaciers. Comparison with Europe and North America suggests that the Lobuche and the Thuklha stages correspond to Neoglacial readvances which culminated a few hundred and also several thousand years ago. The Periche and Thyangboche stages may be of the Late Glacial and the Last Glacial Maximum. The existence of older landforms, considered to be related to glaciers, suggests that the Khumbu region was also glaciated before the Last Inter-Glacial.

1. Introduction

Only a few studies of the glaciation on the Nepalese flanks of the Himalayan mountains have been done. In the Khumbu region Heuberger (1956) observed the Late Glacial moraines and the recent moraines which correspond to the 1850 moraines in the Alps. Müller (1959) recognized the sub-recent and the Periche stage moraines in the Sagarmatha (Everest) region, and then recently he illustrated three moraine stages, Recent, Dughla (Thuklha in this paper), and Periche. Tanaka (1971) also classified the moraines in the Khumbu region into the Lobuche and the Periche stage.

The extent and patterns of all of the glacial moraines have not yet been investigated and no attempt has been made to correlate the moraine stages with those of other parts of the world.

The Imja Khola valley, the east tributary valley of Dudh Kosi, is a broad U-shaped trough and has well-developed terminal and lateral moraines. A series of well-defined moraine loops shows several stages of glacial advance. The moraines are classified into four main groups according to their relative positions, differences of their dissected forms, freshness of surface boulders, and development of soil and vegetation (Fig. 1). As air photographs were not available, mapping of the moraines was done during the field survey with the aid of ground photographs.

2. Lobuche Stage

The termini of the existing glaciers in the Khumbu region were classified into two types, debris-free termini (C-type) and debris-covered ones (D-type) (Moribayashi, 1974).

The Lobuche stage moraines are mostly clustered close to the long debris-covered glacier snouts where two or three moraine ridges were formed.

The Lobuche stage moraines of the Khumbu Glacier have three moraine ridges which show different features. The inner-most moraine has a sharp ridge and is mostly lichen-free and shows no evidence of weathering and shattering of surface boulders. Single plants occur sporadically on the outer slope but the inner slope is entirely free from vegetation. The top of the Lobuche I moraine is several meters higher than the present glacier surface except for the front.

The Lobuche II moraine of the Khumbu Glacier is the highest, standing 70-80 m above the glacier surface at the middle point between Lobuche and Gorak Shep (Fig. 2 and 6). This moraine crest at Lobuche is the one on which the base line measuring the glacial flow was set...
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The Lobuche II moraine is composed predominantly of angular boulders and soil does not develop, but grass plants occur more frequently than on the Lobuche I moraine.

The Lobuche III moraine is covered with slightly weathered boulders. Grass and shrub vegetation is low and is attached at the foot of the Lobuche II moraine. At the left bank of the Khumbu Glacier, the Lobuche III moraine appears in some places, being covered with the younger moraine (Fig. 3).

At the front, the surface of the Khumbu Glacier, covered with thick ablation moraines, keeps the same height as the Lobuche I moraine, and an ice-cored moraine is formed.

It shows the features of an active rock glacier and covers Lobuche II moraine (Fig. 4). This suggests that the front of the Khumbu Glacier is moving down slowly at present, though almost part of the ablation area is stagnant. The termina moraines of the Lobuche stage of the Ama Dablam Glacier and the Lhotse Glacier which lie east of Lhajung Station are slightly different from those of the Khumbu Glacier. The positions of the Lobuche II and III ridges are far from those of Lobuche I and their heights are low.

The Lobuche stage moraines of the small debris-free glaciers in this region form simple loops disconnected from the ice body. Surface features of these moraines show those of the Lobuche I stage, fresh and non-vegetated.

3. Thuklha Stage

The Dughla (Thuklha) stage molaines named by
Müller (unpublished) include the Lobuche II, III moraines and the moraines just outside the Lobuche stage moraines. Since there is a sharp contrast between the former and the latter, the writer excludes the former from the definition of the Thuklha stage. While some moraines of this stage are widely distributed on the flat basin of Chukhung, east of Lhajung, the Thuklha stage moraines situated in troughs, such as the Khumbu, the Lhotse, and the Lhotse-Nup Glacier have been submerged or destroyed by the subsequent moraines. They have several row ridges and smooth surfaces partly covered with loess, and permitted the development of soil and vegetation, on which the grass and the shrub have grown up completely, but a lot of weathered boulders are scatteres on them. The advances of the glaciers in this stage were almost to the same extent as those of the Lobuche stage but the surface positions were lower.

A schematic transverse profile of these moraines is shown in Fig. 3.

4. Periche Stage
The Periche stage moraines are located conti-
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continuously along the left bank of the valley below the Khumbu Glacier, but are intermittent in the other valley of the studied area. Some lateral moraines attached to the middle of the valley slopes are considered to belong to this stage.

Occurring as a distinct terminal and lateral moraine in Periche, the moraine ridges are impressive landforms up to 200 m high from the bottom of the valley. They are completely overgrown by grass and shrub vegetation, and large boulders are scattered.

It was observed that there is a thin buried soil layer consisting of organic material at a depth of 20 cm beneath the surface and it covers the loess deposit (Fig. 5).

5. Thyangboche Stage

There is a subdued lateral moraine of the

Thyangboche stage on which the Lhajung Station is established. Some blocks over 3-5 m in size lie on the surface which is covered with loess, buried soil and vegetation.

The Thyangboche stage moraine is found along the valley intermittently covered with subsequent moraines, talus, and fluvial deposits. The lateral moraine of the Thyangboche stage was covered with the moraines pushed out from the Mingbo and the Omoga valleys, 3 km down from Periche. According to the moraine profiles along the valley (Fig. 6), the moraine continues to the huge terminal moraine on which the monastery of Thyangboche stands.

6. Platform topography

Flat platforms are formed on the middle of the back slopes behind the junctions of the valleys, such as north of Chukhung and Pibre, behind Lobuche, and on Kala Pattar (Fig. 2).

The surface is completely subdued and covered with soil and vegetation. No boulders, blocks, or bed rock can be found on the surface. The platforms occur at about the same level over 5000 m in altitude. But to be exact, their altitude becomes higher along the valleys. This suggests that the platforms are caused by glacial erosion or deposition, though it is not confirmed yet whether they consist of bed rock or till.

7. Chronology

In this region, none of the ages of construction of moraines have been obtained by any method,
including absolute dating and historical record.

Glacial histories in many high-mountain chains have been revealed recently by intensive studies with $^{14}$C dating. The fluctuations of alpine glaciers since the Late-Glacial show the same sequence in Europe as in North America (Porter and Denton, 1967; Denton and Porter, 1970; Denton and Karlén, 1973; Heuberger, 1974). The results of meteorological observations indicate that recent climatic fluctuations over the Northern Hemisphere are controlled by the polar air mass.

In the recent past, for example, some glaciers in Central Asia advanced corresponding with the advance of the Alpine glaciers (Kick, 1962).

The features of the moraines of each stage in this region are very similar to those of Europe and North America reported already.

These facts suggest that it is possible to correlate the Himalayan glacial sequence with those of Europe and North America.

The Lobuche stage moraines coincide with glacial advances occurred during the last few centuries. According to the vegetation-free and fresh surface features, the moraines of Lobuche I stage were formed by the recent readvance which corresponds to that in the Alps and the North American Cordillera during the nineteenth and early twentieth centuries.

According to the recent glacial advance in the Karakoram (Kick, 1962), Moribayashi (1974) concluded that the advance in the Khumbu Himal occurred at the middle of the nineteenth century. Afterwards the debris-free glaciers receded to the present positions rapidly, but the debris-covered parts of glaciers remain as stagnant ice.

While the thick moraine cover of the glacial terminus prevents the ice from ablating, at the upper part of the ablation zone the glacier ice covered with less debris become thin.

The old Lobuche III moraines are identified with the early stage of the so called "Little Ice Age", dated at fifteenth to seventeenth centuries.

In terms of the degree of weathering, modification, and vegetation cover, the sharp contrast between the Lobuche stage and the Thuklha stage moraines suggests that the stages are clearly of different ages. Tentative correlation with dated moraines having similar features and relative positions in North America and Europe would date them at 2000-6000 years B.P. The neoglacial readvance in this sequence is separated into two stages in North America, Arctic, (Denton and Karlén, 1973) and Patagonia (Mercer, 1968; 1970), but it is not clear to which of them Thukla stage belongs.

The Periche and the Thyangboche stage moraines were formed when glaciers had advanced to very far down below from their present limits. The buried soil which covers the above-mentioned moraines would have been formed in the Hypsithermal time which was warmer than the present.

The huge terminal moraine at Thyangboche preserves its original form and beyond it there is no apparent terminal or lateral moraine down the Dudh Kosi valley. These facts suggest that the Periche and the Thyangboche stages correlate with the readvance and the maximum of the Last Glacial Period, respectively.

The difference of the deterioration of the forms between the Periche and the Thyangboche stage moraines is not so great that the Thyangboche stage cannot coincide with Pre-Interglacial stages.

From the conspicuously subdued forms of the platforms, it is assumed that they were built in the Pre-Interglacial Glaciation.

The glacial chronology mentioned above is insufficient in aspects of regional correlation and age determination. The complete glacial fluctuation will not be known until detailed field work is extended throughout the Himalayas.

References


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of Science, 269, 1-25.