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VARIATIONS OF LEWIS GLACIER, MOUNT KENYA, 1978–82

With 2 figures, 1 table and 1 supplement (X)

ROBERT A. CAUKWELL AND STEFAN HASTENRATH

1. Introduction

Two earlier communications in this journal (CAUKWELL and HASTENRATH, 1977; HASTENRATH and CAUKWELL, 1979) reported on airborne mappings of Lewis Glacier in February 1974 and 1978 as part of a multi-annual field program aimed at the reconstruction of climate variations in the tropics from glacier observations. This project furthermore included determinations of ice thickness and bedrock topography by the seismological and gravimetric techniques and through numerical modelling (BHATT et al., 1980), heat budget experiments (HASTENRATH and PATNAIK, 1980), ice core analyses (THOMPSON and HASTENRATH, 1981), study of the secular variations of velocity and crevasse patterns (HASTENRATH and KRUSS, 1979, 1982; KRUSS and HASTENRATH, 1983; KRUSS, 1981, 1983a, b), as well as an inventory of East African glaciers as contribution to the UNEP/UNESCO World Glacier Inventory (Temporary Technical Secretariat for World Glacier Inventory of ICSI, 1977; International Association of Hydrological Sciences – UNESCO, 1977; HASTENRATH, 1975, 1977). Prior to our work beginning in the 1970's, the Lewis Glacier has been mapped in 1958 by tacheometry (CHARNLEY, 1958), and in 1963 *(Forschungs unternehmen Nepal Himalaya, 1967)* and 1934 (TROLL and WIEN, 1949) by terrestrial photogrammetry. Continuing the pattern established by our 1974 and 1978 mappings, further airborne mappings were carried out in February and March 1982. A new map at scale 1:2,500 is presented here along

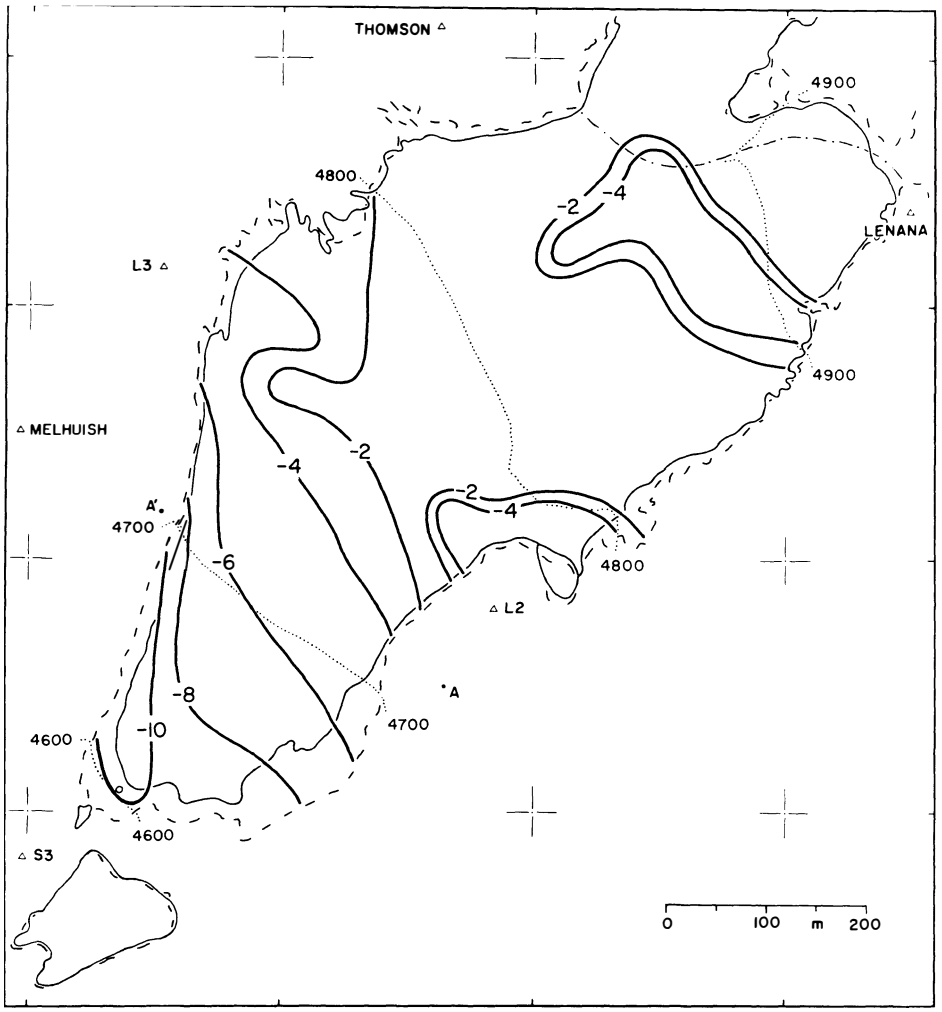

Fig. 1: Changes in ice thickness, February 1982 minus February 1978, in m. Ice rim in 1982 is shown as solid, and in 1978 as broken line. 1982 height contours are entered as dotted lines. Scale 1:7,500.

with a discussion of changes in topography and crevasse pattern over the four year interval 1978–82. Variations of net balance and velocity pattern shall be published elsewhere in due course.

2. *The 1974 and 1978 mappings*

The description in CAUKWELL and HASTENRATH (1977) and HASTENRATH and CAUKWELL (1979) is summarized here. Control points established by the IGY Mount Kenya Expedition (CHARNLEY, 1959) on rock outcrops outside the glacier were used for the 1974 and 1978, as well as the 1982 mappings. Table 1 lists the coordinates of IGY control points. In preparation for the air photography, the points were premarked in the terrain by white paint.

Both the 1974 and 1978 surveys were flown with a Caribou of the Kenya Air Force. The flight level was 18,000 feet in the 1974 flight, and 18,400 feet in the 1978 survey. On both flights Major Gathenya was in charge of the photography, and the same camera was used. Photogrammetric evaluation was performed on the Thompson-Watts First Order Plotter of the University of Nairobi.

3. *The 1982 mapping*

The practice established in the 1974 and 1978 surveys was followed as far as possible. The same IGY control points listed in Table 1 were premarked with white paint in the terrain.

Two aero-photogrammetric surveys were flown in 1982, by the Kenya Air Force (KAF) on 11 February, and by Air

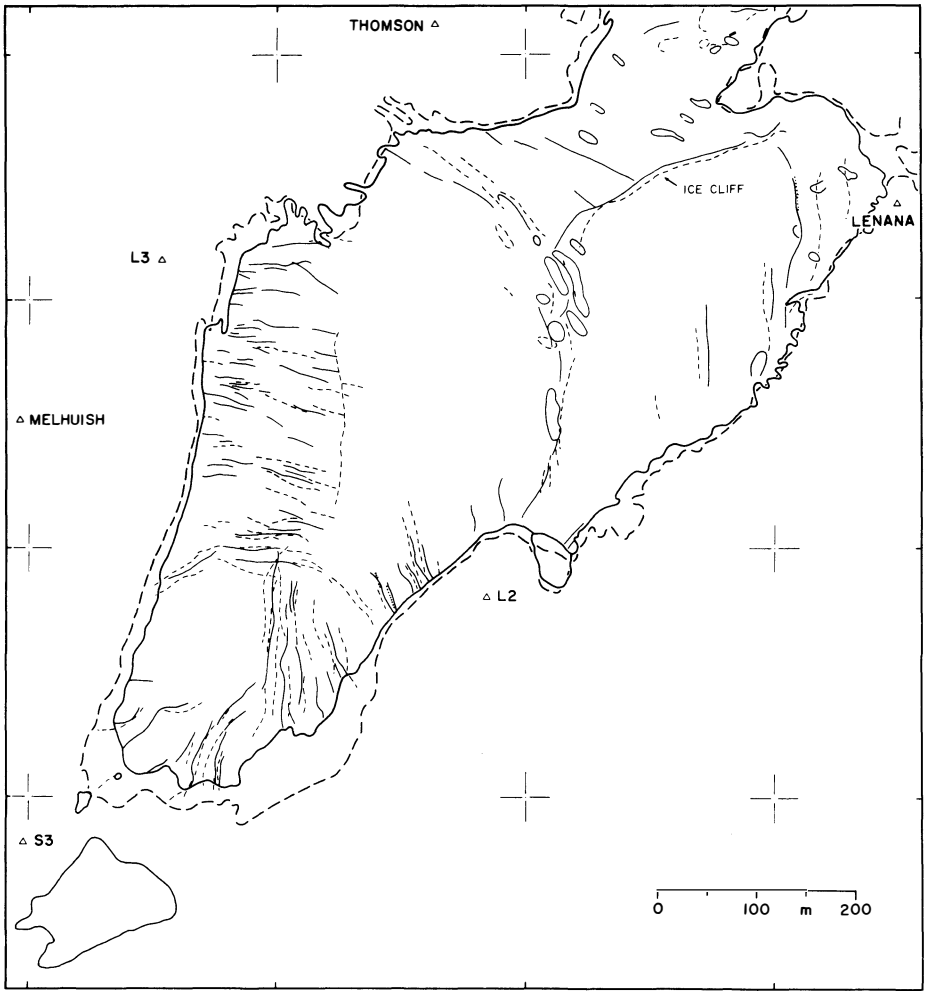

Fig. 2: Changes in crevasse pattern, 1982 solid and 1978 broken lines. Scale 1:7,500.

Table 1; IGY control points in the vicinity of Lewis Glacier. Marks not identified and not used in the survey are indicated by asterisk. South-North (+ Y), West-East (+ X) coordinates, and elevation (h) in m

	+ Y	+ X	h
L 1*	1,508.0	3,373.9	4,823.1
L 2	1,450.4	3,210.6	4,797.2
L 3	1,791.8	2,884.0	4,792.7
Little John*	1,306.1	2,577.7	4,628.4
Lenana	1,847.9	3,622.1	4,985.0
Melhuish	1,630.6	2,742.2	4,876.5
S 3	1,206.3	2,745.5	4,600.6
Thomson	2,031.0	3,159.7	4,955.1
Top Hut*	1,361.4	3,177.5	4,809.4

Survey and Development GmbH (ASD) on 10 March. Maps were produced of both surveys at the Department of Surveying and Photogrammetry of the University of Nairobi. The KAF flight was just under 19,000 ft, with four frames covering the whole glacier. However, only the middle overlap contains full control, so that the snout and Lenana areas had to be controlled by bridging out on common points of detail on the photos. This required use of the Wild A 8 Autograph. The ASD flight was at 22,000 ft, with two frames providing fully controlled coverage of the entire glacier. Plotting was accomplished on the Thompson-Watts Model II First Order Plotter, as for the 1974 and 1978 maps. The 10 March 1982 flight resulted in the superior map. Only this map is presented here.

The 1978 map (HASTENRATH and CAUKWELL, 1979) shows the array of 31 stakes laid out on the glacier for purposes of net balance measurements and the monitoring of surface ice

movement by repeated surveying of these poles. In the course of 1978–82, the network was repeatedly refurbished, but various stations were lost.

A thorough new installation was accomplished in December 1981. The position of stations in January 1982 is plotted in the map. These stations were surveyed from IGY control points "L2" and "L3" using optical theodolite (LIETZ T-60 D) and electronic distance measuring equipment (Beetle 500 of Precision International, USA). Stations 1, 3, 12, 4 A, 6, 7, 10, 11, 81, 71, consist of a bamboo pole, stations 2 and 4 B of a wooden stake, stations 51 and 13 each of two 2 m stakes linked together. Stations 22 and 25 are made up of four 2 m segments, thus totalling each a depth of 8 m. Five such segments of 2 m were inserted at stations 31, 32, 33, 42, 41, 43, which thus reach to a depth of about 10 m. The position was accurately surveyed for all stations except 1, 2, 51, and 4A.

4. *Changes in ice thickness*

The enclosed map at scale 1:2,500 for 10 March 1982 continues the historical documentation on varying glacier topography provided by the February 1974 and 1978 maps. Differences between the 1978 and 1982 maps were evaluated in separate maps at scale 1:2,500, reproduced in Figs. 1 and 2 at scale 1:7,500.

Fig. 1 shows an ice loss for all areas of the glacier, but a particularly drastic thickness decrease in its lower portion. The terminus has receded some 30 m and a second small pond has formed above Lewis Tarn. The two large ice caves that developed between 1974 and 1978 have in large part collapsed. The slope in the snout region continues to be comparatively gentle. Together with the recession of the ice front, Curling Pond appears displaced towards the North.

The decrease in ice thickness during the 1978–82 interval (Fig. 1) is particularly large in the low southwestern portion of the glacier where values around 10 m are reached; the approximately North-South orientation of the lines of equal thickness change being similar to the 1974–78 interval (Hastenrath and Caukwell, 1979, Fig. 1). Thickness decrease is less than 2 m in most of the middle and upper glacier, but values exceeding 4 m are found above Curling Pond and in the plateau-like region below Point Lenana.

Planimetering of Fig. 1 yields a 1978–82 decrease in area of 34×10^3 m^2, in average thickness of about 3.6 m, and in total volume of $1{,}067 \times 10^3$ m^3. The March 1982 area is about 261×10^3 m^2, and the volume is estimated at $7{,}400 \times 10^3$ m^3. The volume decrease during the four year period 1978–82 amounts to about 15 percent of the presently remaining ice mass.

5. *Crevasse pattern*

The location of crevasses in 1978 and 1982 is compared in Fig. 2. The regions of prominent crevasse formation in the upper glacier appear favored by the bedrock topography, although the exact location of crevasses differs between the 1974 (Hastenrath and Caukwell, 1977), 1978, and 1982 maps. Large ice holes are more prominent in 1982 than at the earlier epochs. The Southwest to Northeast oriented ice cliff in the upper glacier has moved northwestward since 1978.

In the middle to lower glacier the transition from transverse to longitudinal crevasse orientation occurs in a location similar to 1978. However, the large longitudinal crevasse in the middle glacier shown by the 1978 map has disappeared.

6. *Concluding remarks*

As a result of the continuity of historical sources since the end of the 19th century and our field program since the early 1970's, the Lewis is now the glacier with the most complete documentation in all of the tropics. Glaciers are an extremely sensitive environment component, that reflects climatic variations which may be too small to detect by conventional sensing techniques. In this perspective, the Lewis Glacier appears as a prime candidate for a continuous monitoring program of net balance, velocity and crevasse pattern, and topography. Regular mappings at about four year intervals – following the pattern set by our 1974, 1978, and 1982 surveys – are an important part of these efforts.

Acknowledgements:

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BERICHTE

MESOFORMEN DES HEUTIGEN PERIGLAZIALRAUMES

Bericht über ein Geomorphologisches Symposium in Göttingen

Peter Höllermann

Vom 3. bis 7. Oktober 1982 fand in Göttingen ein von der Akademie der Wissenschaften ausgerichtetes Geomorphologisches Symposium zum Thema „Mesoformen des heutigen Periglazialraumes" statt, an dem 22 Wissenschaftler aus der Bundesrepublik, aus Belgien, Polen, Schweden, Kanada und den USA teilnahmen. Die unter der Gesamtleitung von H. Poser stehende, von ihm langfristig und sorgsam vorbereitete, als Klausurtagung besonders arbeitsintensiv organisierte Veranstaltung stand in enger Verbindung zu den Aufgaben und Zielen der Akademie-Kommission „Geomorphologische Prozesse, Prozeßkombinationen und Naturkatastrophen in den Landschaftszonen und Höhenstufen der Erde" (Kurztitel „Morphodynamik"). Nachdem bei einem 1976 in ähnlichem Rahmen durchgeführten Symposium mehr die Kleinformen, deren Vergesellschaftung und Untergrenzen in den heutigen periglazialen Höhenstufen zwischen Arktis und Äquator im Mittelpunkt standen (vgl. dazu den Bericht in Erdkunde 30, 1976, 300–302), war es folgerichtig, eine weitere Veranstaltung den bislang weniger systematisch untersuchten Geländeformen mittlerer Größenordnung des aktuellen Periglazialbereiches zu widmen. Die 23 straff gestalteten Referate nebst einigen Paper-Vorlagen dienten vornehmlich als formulierte Diskussionsbeiträge, d. h. als Zubringer von Material und Anregungen für die als

LEWIS GLACIER

Scale 1: 2 500

Plotted from photographs taken

10 th March 1982

Nos 3800 – 3801

PT. THOMSON
4955.1

PT. LENANA
4985.0

L 3
4792.7

PT. MELHUISH
4876.5

L 2
4797.2

(L 1)
4823.1

Curling Pond

Top Hut
4809. 5

M. C. K. Huts

(LITTLE JOHN)
4628.4

S 3
4600.3

Lewis Tarn

Glacier edge

Principal crevasses

Ice cliffs

I. G. Y. survey stations used in mapping

(I. G. Y. survey stations not used in mapping)

Tachy stations not used in mapping

Net balance and motion stakes

Net balance stakes, not surveyed

0 50 100 150 200
metres