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VARIATIONS OF LEWIS GLACIER, MOUNT KENYA, 1982-86

With 3 figures, 1 table and 2 supplements (I-II)

STEFAN HASTENRATH and ROBERT A. CAUKWELL

1. *Introduction*

The Lewis Glacier on Mount Kenya is now the most thoroughly studied ice body in all of the tropics, with historical documentation of the variations in ice extent dating back to the late 19th century. A continuing long-term field program initiated in the 1970's has included surveys of the ice surface and subglacial bedrock topography, investigations into the ice flow dynamics and crevasse pattern, monitoring of the ice mass budget, climatic ice core studies, and the numerical modelling of the secular climate and terminus variations (HASTENRATH 1984, p. 243-284).

An important component of this ongoing field program is the airborne mapping of the glacier at scale 1:2,500, repeated at intervals of about 4 years. The objective of these mappings is the documentation of changes in ice surface topography, and hence thickness pattern, volume, and area, as well as of alterations in the crevasse distribution. Publication of these maps at the original scale is to ensure ready access and application to future glacier research. To this end, a sequel of articles in this journal reported on the airborne mappings of Lewis Glacier in February 1974, February 1978, and March 1982 (CAUKWELL and HASTENRATH 1977, 1982; HASTENRATH and CAUKWELL 1979).

This paper continues the sequence to present the results of the mappings in January 1985 and March 1986. The motivation for two mappings in the mid 1980's, only one year apart, is as follows. At the beginning of 1985 it appeared doubtful that a mapping could be accomplished in 1986. Moreover, the 1985 datum conforms with the five-year interval stated in the international efforts at monitoring long-term glacier fluctuations (Permanent Service on the Fluctuations of Glaciers, IUGG-FAGS/ICSU 1977, 1985). The opportunity for another mapping in March 1986 was, however, seized, so as to maintain our previously established pattern of timing, and in order to resolve the distribution of crevasses, which had been obliterated by fresh snowfall in January 1985. A further mapping desired for February 1990 would thus conform to the timings of both our earlier four-year spacing and the five-year intervals of the aforementioned international program "Fluctuations of Glaciers".

2. *The mappings*

The 1974 and 1978 surveys were flown by the Kenya Air Force at flight levels of 18,000 and 18,400 feet, respectively. The survey flight by the Air Survey and Development GmbH (ASD) on 10 March 1982 was at 22,000 feet. The plotting for all three maps was accomplished on the Thompson-Watts Model II First Order Plotter of the University of Nairobi.

To the extent possible, the practice established in the earlier mappings was also followed in 1985 and 1986. As before, the control points established by the IGY Mount Kenya Expedition (CHARNLEY 1959) on

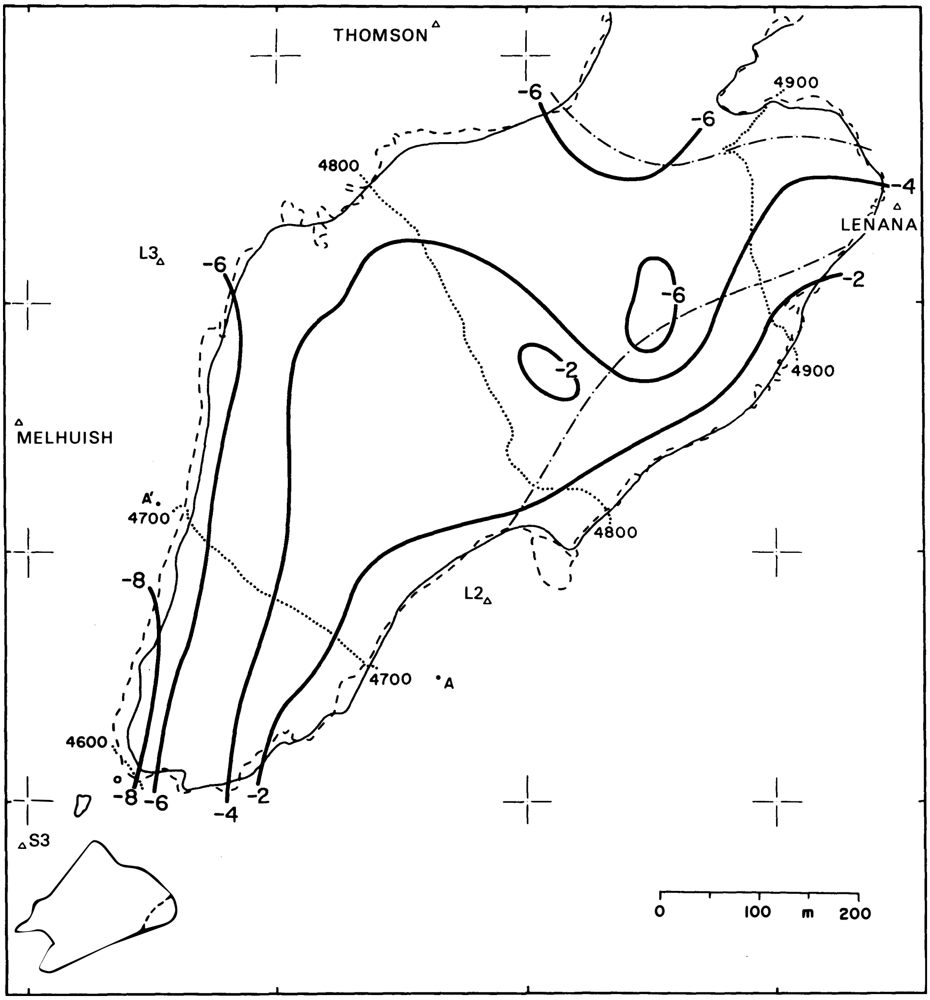

Fig. 1: Changes in ice thickness, January 1985 minus March 1982, in m. Ice rim in 1985 is shown as solid, and in 1982 as broken line. 1985 height contours are entered as dotted lines. Scale 1:7,500

Table 1: IGY control points in the vicinity of Lewis Glacier

	+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

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

rock outcrops outside the glacier were used. The coordinates of the IGY control points are listed in Table 1. In preparation for the air photography, the points were premarked in the terrain with white paint.

On 31 January 1985 Geosurveys Ltd., Nairobi, flew a survey at approximately 22,000 feet, with two frames providing fully controlled coverage of the entire glacier. Geosurveys also flew the 13 March 1986 survey at the same altitude and with coverage again by two frames. For both the 1985 and 1986 maps, plotting was accomplished on the Wild A8 First Order Plotter of the University of Nairobi by the same photogrammetrist. The 31 January 1985 flight happened to take place after light snowfall; this may have compromised the contouring especially for the

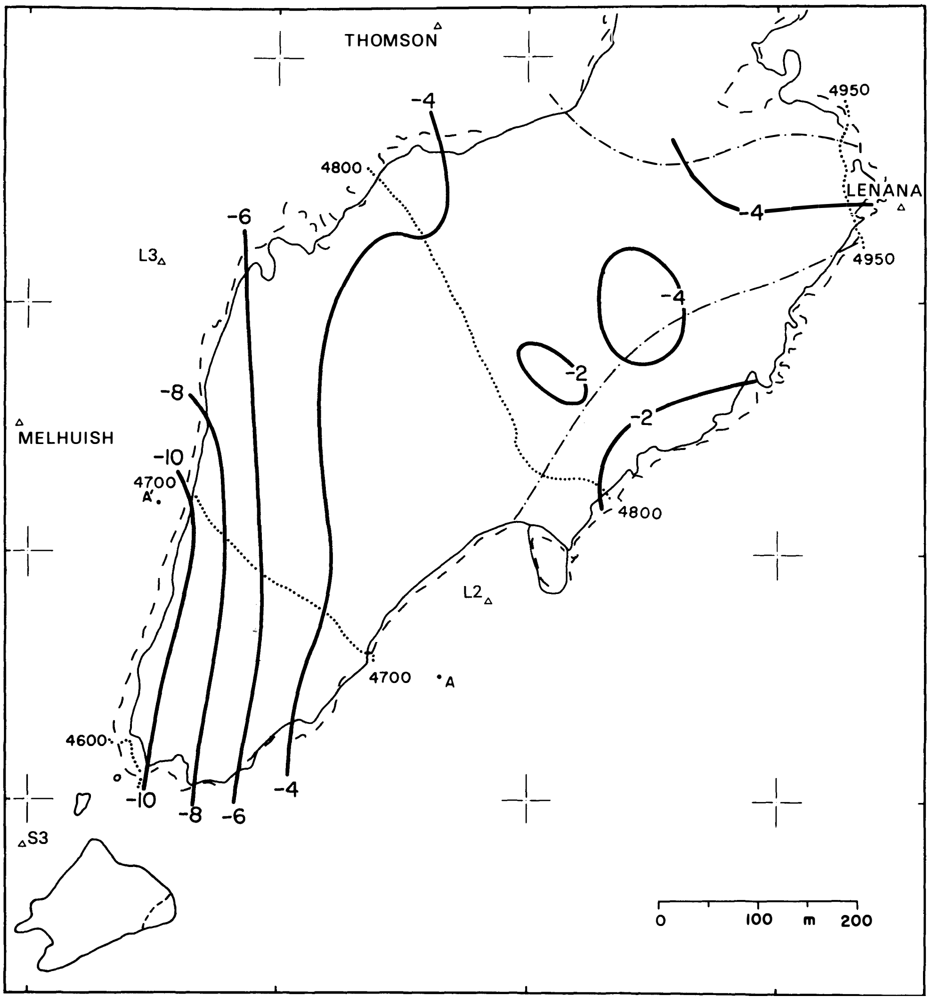

Fig. 2: Changes in ice thickness March 1986 minus March 1982, in m. Ice rim in 1986 is shown as solid, and in 1982 as broken line. 1986 height contours are entered as dotted lines. Scale 1:7,500

upper glacier. In fact, for the 1985 mapping the photogrammetrist had more difficulty than usual with relative and absolute orientation of the stereoscopic model due to the fresh snow interfering with the definition of the higher pre-marked ground control crosses. The misclosures in the vertical and horizontal planes across the model were larger than usual although still within acceptable tolerances for photogrammetric mapping at this scale. Contouring the smooth new snow was also difficult, and small lateral displacements of the lines as a result of both causes are quite possible. In contrast, the March 1986 photographs show the glacier as almost entirely bare grey ice, with very little snow even in the upper section of the glacier.

3. Changes in ice thickness

The enclosed maps at scale 1:2,500 for 31 January 1985 and for 13 March 1986 (supplements I a. II) extend the historical documentation on variations in glacier surface topography established by our maps for February 1974, February 1978, and March 1982. Differences of ice surface topography in January 1985 and March 1986 were evaluated against the March 1982 datum. The resulting 1:2,500 maps of ice thickness change are reproduced in Figs. 1 and 2 at a scale of 1:7,500.

Fig. 1 depicting the difference in ice thickness February 1985 minus March 1982 shows an ice loss for all areas of the glacier, with largest differentials in

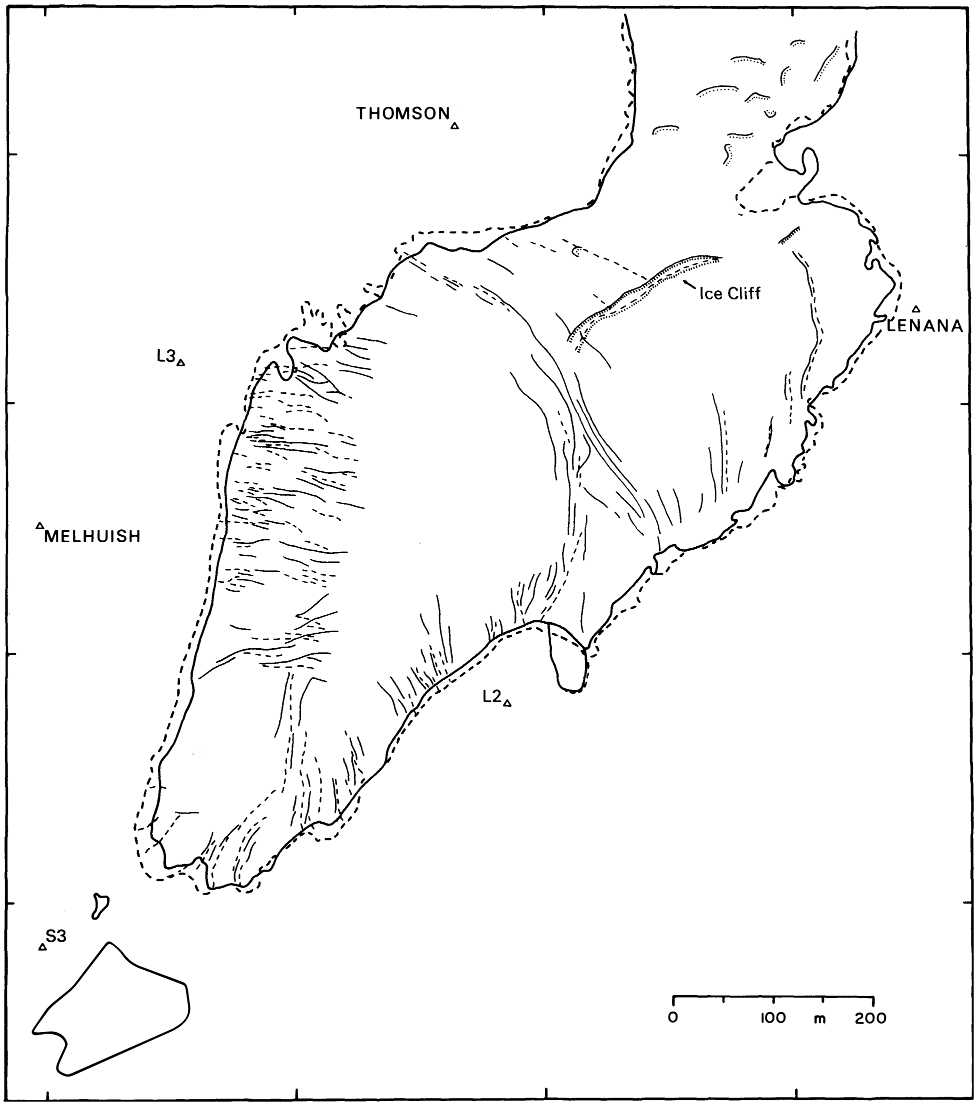

Fig. 3: Changes in crevasse pattern, 1986 solid and 1982 broken lines. Scale 1:7,500

its lower portion. The terminus receded by horizontal and vertical distances of 13 and 3 m, respectively, and some decrease of area is apparent. Continuing a pattern apparent in the comparison of the 1978 and 1982 maps, the Curling Pond appears displaced further northward.

Fig. 2 exhibiting the topography change from February 1982 to March 1986 is qualitatively similar to Fig. 1, in showing the large ice loss expecially in the lower glacier, a terminus retreat from the 1982 datum by horizontal and vertical distances of 18 and 6 m, respectively, an a further decrease in area. Apart from the overall somewhat larger negative values in Fig. 2, the two maps differ particularly in the upper glacier. It is conjectured that this discrepancy is due to the somewhat less satisfactory contouring in the upper glacier for the 31 January 1985 datum, as explained in section 2.

Planimetering of Fig. 1 yields a 1982–85 decrease of 74×10^2 m^2 in area, of 4 m in average thickness, and of $1{,}059 \times 10^3$ m^3 in total volume. Similarly, planimetering of Fig. 2 yields a 1982–86 decrease of 140×10^2 m^2 in area, of 4.6 m in average thickness, and of $1{,}193 \times 10^3$ m^3 in total volume. At the March 1986 datum the total area is about 247×10^3 m^2 and the total volume is estimated at $6{,}200 \times 10^3$ m^3.

The volume decrease during the four year period 1982–86 thus amounts to about 22 percent of the presently remaining ice mass.

4. Crevasse pattern

Fig. 3 compares the location of crevasses in 1982 and 1986. As in the various earlier mappings a region of prominent crevasses stands out in the upper glacier, extending broadly from Point Thomson towards the rock ridge West of Curling Pond and Austrian Hut. This seems favored by the subglacial bedrock topography. Large ice holes in this general band appear less prominent than in 1982. The Southwest to Northeast oriented ice cliff in the upper glacier has continued its northwestward displacement as compared to the 1978 and 1982 epochs. Of particular interest in our earlier mappings has been the transition from prevalently longitudinal crevasses in the lower glacier to predominantly transverse crevasse orientation in the middle and upper glacier. Comparison of the 1982 and 1986 patterns reveals a weak tendency for this transition zone to shift glacier upward.

5. Concluding remarks

The systematic observation of glaciers is recognized as an important component of climate and environment monitoring. The World Glacier Monitoring Service (formerly Permanent Service on the Fluctuations of Glaciers) in particular coordinates such efforts on a global scale and compiles observations regularly over five-year intervals. Within the tropical belt, systematic reports are scarce. The Lewis Glacier on Mount Kenya is a notable exception in that quantitative documentation of varying ice extent reaches back to the past century, and detailed mappings of ice surface topography have been performed since 1974 at four-year intervals. In perspective with its important role in global environment monitoring, it is intended to repeat the aero-photogrammetric survey of Lewis Glacier in 1990.

Acknowledgements

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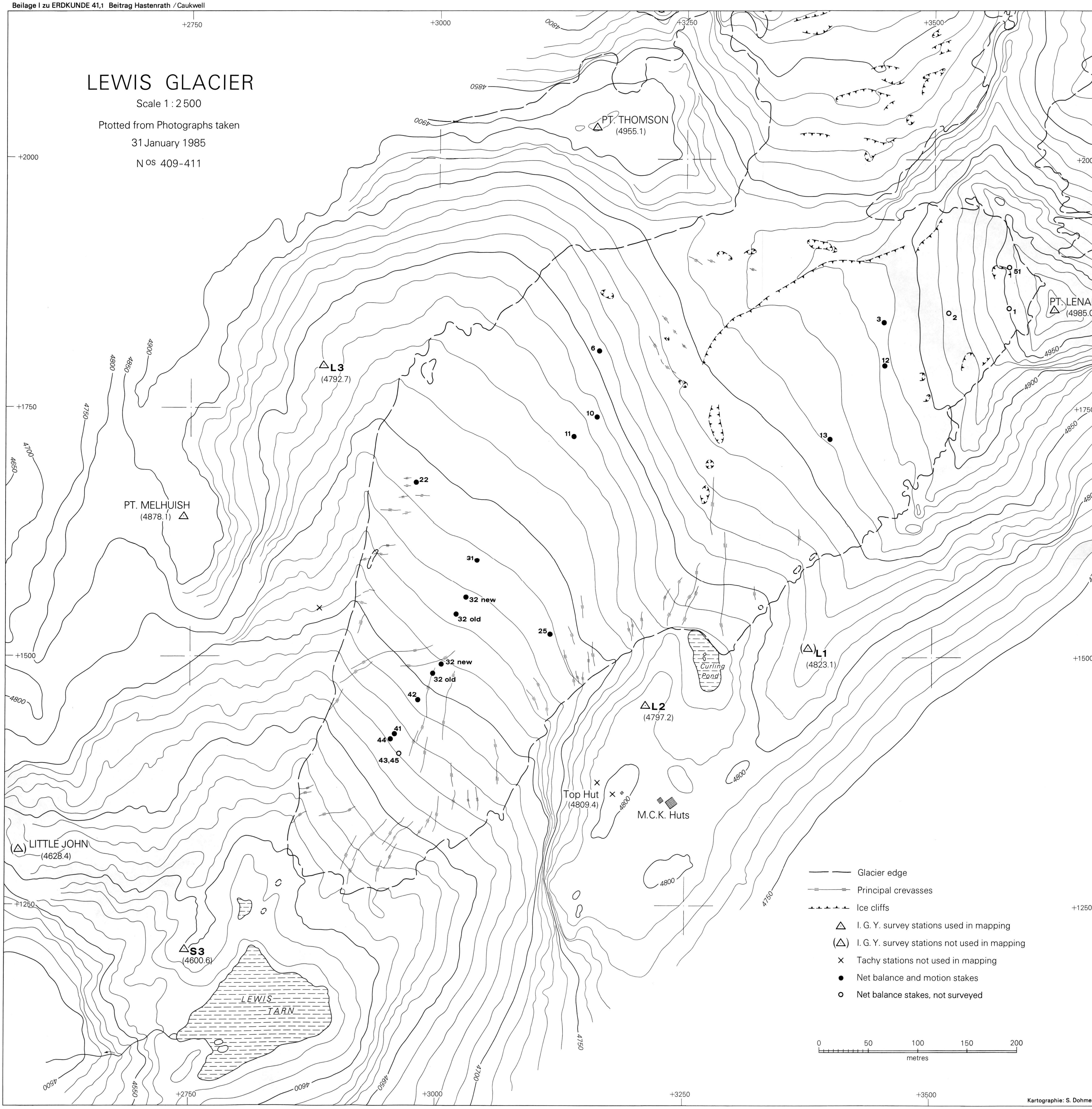
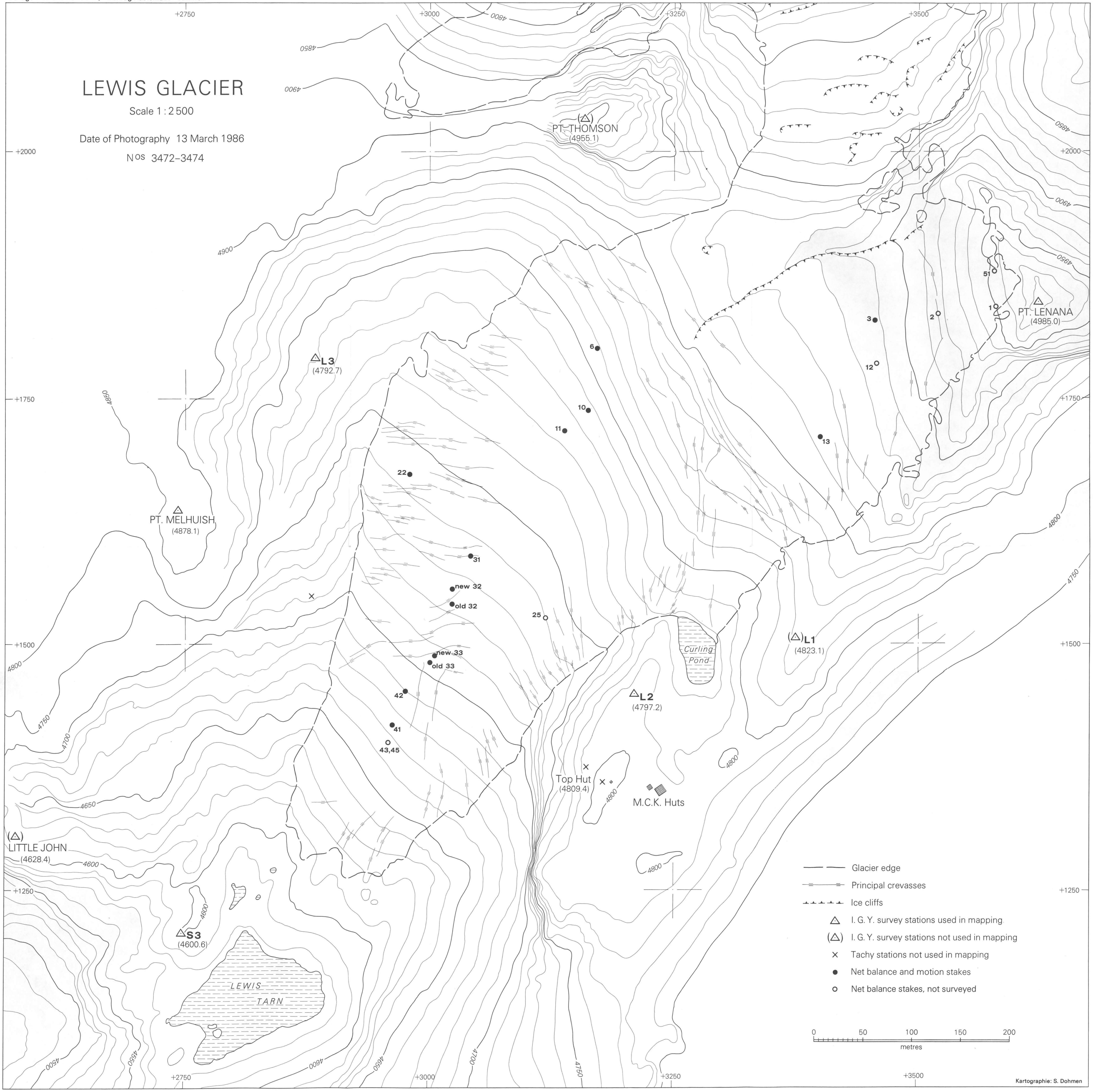
Beilage I zu ERDKUNDE 41,1 Beitrag Hastenrath / Caukwell



Kartographie: S. Dohmen



LEWIS GLACIER
Scale 1 : 2 500
Date of Photography 13 March 1986
Nos 3472–3474
PT. THOMSON (4955.1)
PT. LENANA (4985.0)
L3 (4792.7)
PT. MELHUISH (4878.1)
L1 (4823.1)
L2 (4797.2)
Curling Pond
Top Hut (4809.4)
M.C.K. Huts
LITTLE JOHN (4628.4)
S3 (4600.6)
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
Kartographie: S. Dohmen