THE GLACIERS OF MOUNT KENYA 1899–2004

With 1 figure, 1 table and 1 supplement (I)

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Zusammenfassung: Veränderungen der Gletscher am Mount Kenya 1899–2004

In dem vorliegenden Aufsatz wird eine Karte vorgestellt, welche die jahrhundertelange Geschichte des Gletscherrückgangs am Mount Kenya belegt. Frühe Expeditionsbeobachtungen geben Auskunft über die Eisverhältnisse vom Ende des 19. Jahrhunderts bis um die Mitte des 20. Jahrhunderts, und photogrammetrische Kartierungen der Jahre 1947, 1963, 1974, 1978, 1982, 1985, 1986, 1987, 1993 und 2004 bieten quantitative Einzelheiten für die späteren Jahrzehnte. Von den anfangs 18 Eiseinheiten mag eine vor 1926 ihr Ende gefunden haben, fünf Gletscher verschwanden nach 1926, einer nach 1978, und einer nach 1993. Alle übrigen Gletscher schrumpften auch erheblich, besonders nach etwa 1970. Mount Kenya, gleich unter dem Äquator gelegen, ist der Berg mit der besten Dokumentation des Gletscherrückgangs in den gesamten Tropen.

Summary: A map is presented documenting the century-long history of glacier recession on Mount Kenya. Observations from early expeditions provide evidence from the end of the 19th century to the 1940's, and photogrammetric mappings in 1947, 1963, 1974, 1978, 1982, 1985, 1986, 1987, 1993 and 2004, give quantitative detail for the later decades. Of the eighteen ice entities at the end of the 19th century, one glacier may have disappeared before 1926, five vanished after 1926, one after 1978, and one after 1993. All other glaciers also suffered substantial shrinkage, especially from the 1970's onward. Mount Kenya, right under the Equator, is the mountain with best documentation of glacier recession in all of the tropics.

1 Introduction

Tropical glaciers are a particularly climate-sensitive component of the environment and merit attention in relation to global change (Intergovernmental Panel on Climate Change 2001, 127–130, 647–656; WORLD GLACIER MONITORING SERVICE 1996, 1998). In that spirit the history of varying ice extent is of interest, but such sources are rare. In all of the tropics, Mount Kenya appears to be the mountain with the most extensive information. Following expedition reports since the end of the 19th century, from the middle of the 20th century onward a sequence of photogrammetric mappings have been undertaken and presented in this journal (Caukwell a. Hastenrath 1977; Hastenrath a. Caukwell 1979; Caukwell a. Hastenrath 1982; Hastenrath a. Caukwell 1987; Hastenrath et al. 1989; Hastenrath a. Rostom 1990; Rostom a. Hastenrath 1994; Hastenrath et al. 1995; Rostom a. Hastenrath 1995, 2005). All these sources have now been evaluated in context. The resulting documentation of progressive ice shrinkage is here presented in the accompanying map.

2 Background and sources

The observations of varying ice conditions on Mount Kenya from the end of the 19th century to the 1980's have been detailed in a book (Hastenrath 1984, 108–135), and a sequence of airborne photogrammetric mappings for 1947 and from the 1970's onward have been presented in this journal (Caukwell a. Hastenrath 1977; Hastenrath a. Caukwell 1979; Caukwell a. Hastenrath 1982; Hastenrath a. Caukwell 1987; Hastenrath et al. 1989; Hastenrath a. Rostom 1990; Rostom a. Hastenrath 1994; Hastenrath et al. 1995; Rostom a. Hastenrath 1995, 2005). An excellent map has been produced for 1963 (Forschungsunternehmen Nepal-Himalaya 1967) and with reference to this ice conditions in 1973–74 have been recorded in the field. A brief summary of these sources must suffice here. Figure 1 and table 1 provide an orientation on the glaciers and their names. They are numbered clockwise starting from North, as reported to the World Glacier Inventory (Hastenrath 1984, 322).

The earliest observations on the glaciers of Mount Kenya stem from the expeditions of Gregory (l894) in l893 and Mackinder (1900) in l899. The details of moraine morphology contained in Erwin Schneider's 1963 map (Forschungsunternehmen Nepal-Himalaya 1967) are essential for the quantitative evaluation of these early observations. Other early map sketches of the peak region, reproduced in the book (Hastenrath 1984, 112–115) are from Melhuish and Arthur (1921) in about 1920 and Dutton (1929) in 1926.

For the Krapf (1) Glacier there are observations by Mackinder (1900) in 1899, Melhuish and Arthur (1921) around 1920, and Charnley (1959) in 1957, the mapping in 1963, field observations in 1974, and our sequence of airborne mappings.

For the Gregory (2) there is evidence from Mackinder (1900) in 1899, Mittelholzer (1930) in 1930, Spink (1945) in 1944 and 1945, and then the mappings and field observations mentioned above.

For the Kolbe (3) there are observations by Mackinder (1900) in 1899, Melhuish and Arthur around 1920 (Arthur 1921), Dutton (1929) in 1926, Nilsson (1931) in 1927, Mittelholzer (1930) in 1930, and Benuzzi (1947) in 1943. Benuzzi reports the absence of a glacier in 1943, although the 1947 air photograph seems to show a snowfield in the area.

For the Lewis (4) there are observations by Gregory (1894) in 1893, Mackinder (1900) in 1899, and Dutton (1929) in 1926. In 1934, Troll and Wien (1949) mapped the glacier by terrestrial photogrammetry. Then there is an observation by Hodgkin (1941) in 1941, air photography in 1947, and the mapping by the INTERNATIONAL GEOPHYSICAL YEAR (IGY) Mount Kenya expedition in 1958 (Charnley 1959). After the 1963 mapping (Forschungsunternehmen Nepal-Himalaya 1967) came our sequence of airborne mappings in 1974, 1978, 1982, 1985, 1986, 1990, 1993, mentioned above. For the Lewis, in addition to our 1:2,500 mapping in 1982, 1985 and 1986, there is also a map for 1983 (Patzelt et al. 1984), but only at scale 1:5,000 and from terrestrial photogrammetry. For the Curling Pond area of Lewis there are observations in the 1920's, 1941 (Douglas-Hamilton 1941–42) and 1945 (Spink 1945).

The Melhuish (5) appears on photographs of 1899, 1919, 1930, 1934, 1938 (Hastenrath 1984, 125),

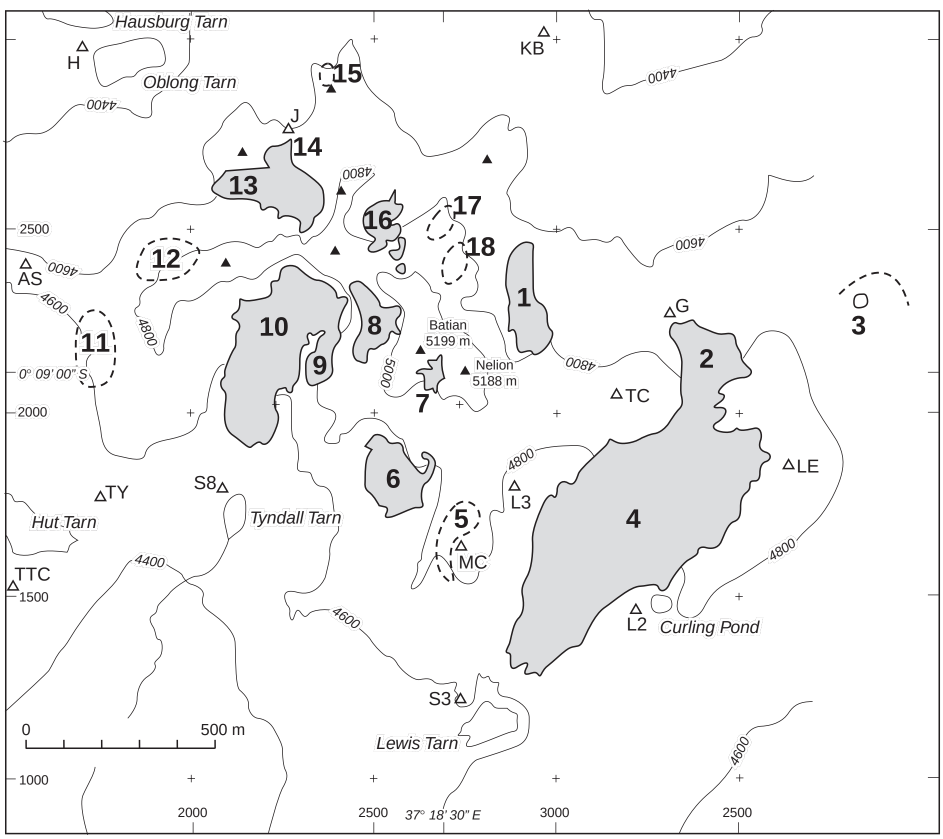

Fig. 1: Orientation map of the glaciers on Mount Kenya. Shading and solid lines refer to September 1987, and dashed lines indicate glaciers that disappeared earlier. Large numbers denote glaciers listed in table 1. Contours are at 200 m intervals. Scale 1:20,000

Orientierungskarte der Gletscher des Mount Kenya. Durchgezogene Linien und Schattierung beziehen sich auf September 1987 und gestrichelte Linien auf Gletscher, die früher verschwunden sind. Grosse Ziffern bezeichnen die in Tabelle 1 aufgeführten Gletscher. Höhenlinien haben einen Abstand von 200 m. Maßstab 1:20.000

Table 1: Nomenclature and ice extent of Mount Kenya's glaciers. Asterisks indicate glaciers that have disappeared

Nomenklatur und Ausdehnung der Gletscher am Mount Kenya. Sterne bezeichnen die Gletscher, die verschwunden sind

	glacier	disappeared after	area (10^3 m^2) 1899	1947	1963	1987	1993	2004
1	Krapf		85	43	43	23	21	14
2	Gregory		290	94	91	45	35	12
3	* Kolbe	1926	100	–	–	–	–	–
4	Lewis		603	400	351	243	203	139
5	* Melhuish	Feb 1978	(5)	5	5	–	–	–
6	Darwin		90	40	42	26	23	12
7	Diamond		(7)	7	6	3	3	3
8	Forel		(37)	37	25	16	15	12
9	Heim		(25)	25	18	16	15	5
10	Tyndall		165	101	90	78	65	51
11	* Barlow	1926	6	–	–	–	–	–
12	* NW Pigott	1926	5	–	–	–	–	–
13	Cesar		100	49	40	24	18	16
14	* Joseph		63	34	25	10	6	–
15	* Peter	1926	2	–	–	–	–	–
16	Northey		50	39	29	11	9	3
17	* Mackinder	1899	2	–	–	–	–	–
18	* Arthur	1926	2	–	–	–	–	–
	total		(1637)	874	765	495	413	267

remnants persisted into the 1970's and it disappeared after February 1978.

The Darwin (6) appears on photographs of 1899, 1913, 1919, 1930, 1938, and the 1940's (HASTENRATH 1984, 125), and is captured by the sequence of later mappings and field observations mentioned above.

The hanging Diamond (7), Forel (8), and Heim (9) glaciers are depicted on photographs of 1899, 1908, 1919, and the 1940's (HASTENRATH 1984, 125). They appear to have essentially maintained their areas until 1963 (Forschungsunternehmen Nepal-Himalaya 1967) and the 1970's. Since 1978 the connections between the Forel (8), Heim (9), and Tyndall (10) glaciers have broken up. The sequence of mappings mentioned above shows the further shrinkage of the Diamond (7), Forel (8), and Heim (9) glaciers.

Tyndall (10) is the second largest ice body on the mountain. Changes since the end of the 19th century are fairly well documented (HASTENRATH 1984, 126). Thus GREGORY's report for 1893 shows the ice tongue close to the large moraine situated below the present-day Tyndall Tarn, a similar state of affairs is indicated by MACKINDER for 1899, and there are photographs of 1908 and 1919. By February 1926 (DUTTON 1929) Tyndall Tarn had formed, but was still in contact with the ice. There are further photographs from the 1940's (HASTENRATH 1984, 126), and from 1947 onward follows the sequence of photogrammetric mappings and field observations mentioned above.

The now defunct Barlow (11) Glacier was located to the North of Tyndall and on the Southwest side of Point Pigott. As detailed in the book (HASTENRATH 1984, 126), it is evidenced on photographs of 1908, 1912, around 1920, and DUTTON's (1929) map for 1926. This glacier has since disappeared.

Likewise long defunct is the Northwest Pigott (12) Glacier, formerly located to the Northwest of Point Pigott. Observations exist of 1920 and 1926 (HASTENRATH 1984, 126, 133).

The Cesar (13) is shown on MACKINDER's (1900) map for 1899 reaching to within 150 m of Oblong Tarn, and a 1908 photograph (MCGREGOR ROSS, 1911) indicates a similar snout position. For February 1919, ARTHUR (1921) describes the snout of the Cesar (13) as being just l7 m above the upper one of two little lakes, evidently Oblong Tarn. Unless ARTHUR's estimate is in error, this would indicate an advance of the glacier snout. From 1947 onward follows the sequence of photogrammetric mappings and field observations mentioned above.

The Joseph (14) is shown on MACKINDER's (1900) map for 1899 reaching close to Oblong Tarn. Photographs from the 1930's and 1940's are referenced in the book (HASTENRATH 1984, 134). The photogrammetric mappings bear evidence of the evolution from 1947 onward; it vanished after 1993.

The Peter (15) Glacier was a small ice entity on the West face of Point Peter shown on DUTTON's (1929) map for 1926. It has since disappeared.

The Northey (16) appears on the map of MACKINDER (1900) for 1899, map sketches from the 1920's and photographs from the 1930's and 1940's (HASTENRATH 1984, 134). The changes from 1947 onward are captured by the sequence of photogrammetric mappings and field observations.

The Mackinder (17) and Arthur (18) Glaciers, are shown on MACKINDER's (1900) map for 1899. The Arthur (18) still appears on a map sketch of around 1920 (HASTENRATH 1984, 35) and on DUTTON's (1929) map of 1926. These ice bodies have since disappeared, although the January 1963 map (Forschungsunternehmen Nepal-Himalaya 1967) shows a snow or firn field in the realm of the defunct Arthur (18).

These sources summarized here form the foundation for the century-long documentation of ice recession on Mount Kenya .

3 Documentation of ice shrinkage

The accompanying map documents in context the recession of Mount Kenya's glaciers in the course of the past century.

Some smaller ice entities, the Kolbe (3), Barlow (11), NW Pigott (12), Peter (15) and Arthur (18) disappeared after 1926. The Mackinder (17) may have vanished before that. Remnants of the Melhuish (5) persisted until after February 1978. The other, more persistent glaciers shall be considered in clockwise sequence starting from the North.

The Krapf (1) Glacier is well documented by the sequence of photogrammetric mappings from 1947 onward. The map shows a greater extent for 1963, which may reflect an advance or temporarily larger snow cover. Overall there is a drastic recession, and by 2004 the remnants had broken up into separate patches.

The Gregory (2), beyond the earlier observations, is well documented by the sequence of photogrammetric mappings from the middle of the 20th century onward. Towards the Northwest the map shows larger extent for 1963 than 1947, possibly temporarily larger snow cover. Overall the mappings bear out continuous and progressive recession.

The recession history of the Lewis (4) is particularly well documented. From the end of the 19th to the middle of the 20th century the terminus retreated from near the innermost large moraine to above a steep rock precipice and the southern tip of the present-day Lewis Tarn. This terminus retreat was accompanied by substantial lateral shrinkage especially at the radiationally more exposed western flank. In 1963 the ice was still in contact with the lake. By the 1970's a substantial swath of rock became bare between the ice margin and the lake, and the area also decreased in the Northwest. Shrinkage continued into the later decades.

Darwin (6) is captured by photographs in the 1910's and 1940's, which indicate a larger ice extent than borne out by the later mappings. Again, the 1963 map shows a larger extent than that of 1947, reflecting either an advance or temporarily larger snow cover. The area decreased drastically into the 1970's, to shrink further somewhat in the later decades. Feeding into the Darwin (6) through the Diamond Couloir was the Diamond (7) Glacier. The connection started to break in the 1970's. By the 1987 mapping, the Diamond Couloir was ice-free and the Diamond (7) Glacier isolated. It continued to shrink drastically.

The Forel (8) shrank drastically from the 1947 to the 1963 mapping, lost connection with the Heim (9) and Tyndall (10) glaciers in the 1970's, with some further shrinkage in later decades. The area of the Heim (9) also progressively decreased somewhat since 1947.

The retreat history of Tyndall (10), the second-largest ice body on the mountain, is particularly well documented. At the end of the 19th and the beginning of the 20th century, the ice was close to the innermost large moraine. By 1926 the terminus had retreated drastically, the Tyndall Tarn had formed, with which the ice was still in contact. Rapid recession continued to the 1940's. In the terminus region a somewhat larger ice extent is indicated by the 1963 as compared to the 1947 mapping, reflecting advance or temporarily larger ice cover. Continued shrinkage is borne out for the later decades, near the terminus, the western side, and the upper edge of the glacier.

The Cesar (13) and Joseph (14) form a contiguous ice entity. For the Cesar (13) a far northerly terminus position is documented for the end of the 19th and the beginning of the 20th century. A report of an even far northerly terminus in 1919 may be an error, or else would reflect a drastic advance not paralleled by the other glaciers of Mount Kenya. The Joseph (14) is also reported to have been much longer at the end of the 19th century than from the 1940's onward. The 1963 as compared to the 1947 mapping shows a somewhat longer albeit narrower glacier, similar to the comparisons for other glaciers. A drastic recession took place to the 1970's, with some further shrinkage in later decades. After 1993 the Joseph disappeared completely.

The Northey (16), entrenched in its steep rock groove, had a long ice tongue in 1947 and still in 1963, but then shrank drastically to the 1970's, and further decay followed in the later decades

In context, evidence from a variety of sources bears out a large ice extent at the end of the 19th century and a drastic recession to the 1940's. From then onward developments are in quantitative detail documented by a sequence of photogrammetric mappings. Table 1 lists the areas of the various glaciers in 1899 and the years with photogrammetric mappings from 1947 onward. Apart from the apparent discrepancies in some terminus areas between the 1947 and 1963 surveys, the synthesis map documents consistently for all glaciers a continuous and drastic recession.

Complementing the present documentation for Mount Kenya, here is a brief summary of our assessment for nearby Kilimanjaro. The total ice cover on the Kibo summit during 1912, 1953, 1976, and 1989, amounted to 12,058, 6,075, 4,171, and 3,305 x 10^3 m^2, respectively (HASTENRATH a. GREISCHAR 1997). Air photography (THOMPSON et al. 2002) indicates a further decrease to 2,170 x 10^3 m^2 in 2000. Drastic ice shrinkage is also apparent on other tropical high mountains (WORLD GLACIER MONITORING SERVICE 1996, 1998), thus in the Ruwenzori of East Africa (HASTENRATH 1984; KASER a. NOGGLER 1996), in New Guinea (HOPE et al. 1976), and in the Ecuadorian (HASTENRATH 1981; SEMIOND et al. 1997) and Peruvian Andes (KINZL 1942, 1949; AMES 1988; HASTENRATH a. AMES 1995; HASTENRATH 1998), but the evidence is much less abundant and continuous than for Mount Kenya.

4 Concluding remarks

Within the tropical half of the Earth, Mount Kenya and particularly Lewis (4) Glacier stand out by continuity and completeness of glaciological evidence, thanks to the expeditions since the end of the 19th century and our later work. Indeed, for over a decade the Lewis Glacier has been the only tropical glacier with continuous monitoring of precipitation, net balance, and ice flow velocity (WORLD GLACIER MONITORING SERVICE 1996). While in the other glaciated mountain regions under the Equator, the Ecuadorian Andes and New Guinea, the onset of recession is dated around the middle of the 19th century, the glaciers of equatorial East Africa began to recede only in the 1880's. The climatic and general circulation causes of this peculiar behavior of glacier recession have been progressively elucidated (KRUSS 1983; HASTENRATH 1997, 2001). Given the location under the Equator and the long history of glaciological observations, Mount Kenya and Lewis Glacier deserve particular attention in the global monitoring of climatic and environmental change. The synthesis of documentation presented in the accompanying map may serve as reference in such endeavors.

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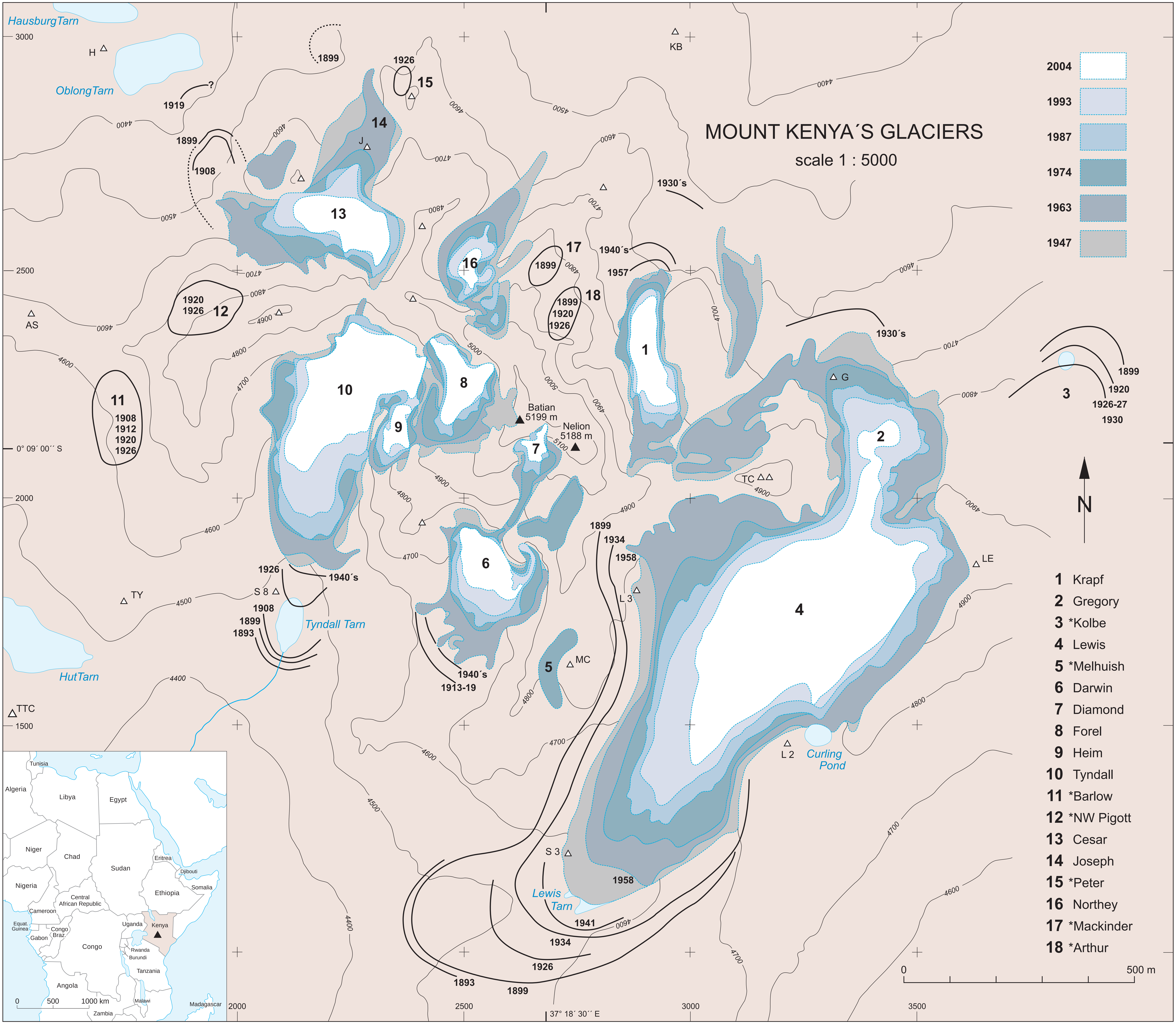
MOUNT KENYA´S GLACIERS
scale 1 : 5000
2004
1993
1987
1974
1963
1947
1 Krapf
2 Gregory
3 *Kolbe
4 Lewis
5 *Melhuish
6 Darwin
7 Diamond
8 Forel
9 Heim
10 Tyndall
11 *Barlow
12 *NW Pigott
13 Cesar
14 Joseph
15 *Peter
16 Northey
17 *Mackinder
18 *Arthur
Batian 5199 m
Nelion 5188 m
HausburgTarn
OblongTarn
Tyndall Tarn
HutTarn
Lewis Tarn
Curling Pond
N
0 500 m
0° 09´ 00´´ S
37° 18´ 30´´ E