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## **Recession of equatorial glaciers: a photo documentation**



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Cover: Kilimanjaro summit, 10 March 1974

## **Preface**

Glaciers on the high mountains of the low latitudes are sensitive indicators of climatic and environmental change. Near the Equator ice is still found in East Africa, the Ecuadorian Andes, and New Guinea. Explorations over a century have included measurements of precipitation, net balance and ice flow velocity, mappings of areal extent and surface topography, and terrestrial and airborne photography and satellite imagery. Previous and my own photographs until 1980 have been reproduced in two books, but in limited quality. More photography has been conducted since then, in part incorporated into a report on Mount Kenya. Mountain Club of Kenya, Nikunj Shah and Kazahara Mizuno sent me photographs from Mount Kenya; Konrad Steffen, Georg Kaser, Doug Hardy and Nils Wiklund gave me recent pictures from Kilimanjaro, and Bernard Francou from El Altar, Antisana and Cotopaxi in Ecuador. Bolivar Caceres sent me data on recent ice extent in the Ecuadorian Andes. Ian Allison and James Peterson contributed photographs from New Guinea. Preparation of this documentation was supported by the Variability of Tropical Climate Fund of the University of Wisconsin Foundation. I am grateful to Dierk Polzin for the electronic document processing and to Grant Petty for the publishing effort. Modern information technology has opened new possibilities for the handling and presentation of photographic evidence. This invited the present endeavour to contribute to the photo documentation of the long-term ice recession in the three glaciated high mountain regions under the Equator.

Madison, March 2008

Stefan Hastenrath

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# Part A

## A. Overview

Glaciers near the Equator are still found in three regions of the world, East Africa, the Ecuadorian Andes, and New Guinea (map 1.0.1., page C.3). Onset of glacier recession around the middle of the 19th century is borne out for the Ecuadorian Andes by the evaluation of historical sources (Hastenrath, 1981) and for New Guinea by numerical modeling (Hope et al., 1976; Allison and Kruss, 1977). By contrast, in East Africa glaciers began to recede only in the 1880's, concomitant with a climatic dislocation also manifest in the sudden drop of water level in the great lakes (Hastenrath, 1984). The cause for the onset of glacier retreat is seen in increased net shortwave radiation accompanying decreased cloudiness and precipitation associated with a drastic change of circulation over the equatorial Indian Ocean (Hastenrath, 2001, 2006). For the continuation of ice shrinkage beyond the early 20th century greenhouse forcing became effective (Hastenrath and Kruss, 1992a, b). I studied the glaciers of East Africa over three decades; I explored in the Ecuadorian Andes in the 1970s; I experienced the fossil moraines of Papua on a field trip in 1975, but never got into the glaciated mountains of New Guinea. For the three glacier regions under the Equator orientation maps are given in Part C (pages C.4 to C.26), and the photographic documentation is presented in Part D (pages D.1 to D.102). It should be appreciated that, in the sequence over a century, photographs were mostly not taken from the same location; some pictures may merely serve as reference for future comparisons. Essential publications containing photographic and map documentation are listed in Part B, separately for East Africa, Ecuador, and New Guinea.

### 1. East Africa

Fossil moraines, remnants of pleistocene glaciation, are found on other mountains of eastern Africa, but live glaciers still exist on three mountains, Mount Kenya, Kilimanjaro, and Ruwenzori (map 1.0.1.). For the broader background, including historical sources and subject literature, reference is made to a book (Hastenrath, 1984).

#### 1.1. Mount Kenya

Within the tropical half of the Earth, Mount Kenya stands out by the continuity and completeness of glaciological evidence. Historical sketches are reproduced in Maps 1.1.1. through 1.1.6. (pages C.5 to C.8). The map 1.1.7. (page C.9) offers orientation on the glaciers and their retreat. Of the 18 ice entities at the end of the 19th century, 8 disappeared altogether, and all suffered substantial loss. The glaciers are numbered clockwise starting from the North, and the photographic evidence in Part D (pages D.9 to D.43) is presented in that sequence.

Thus the Krapf Glacier (1) is shown in the sequence of photos 1.1.1. to 1.1.5., depicting the shrinkage from 1973 to 1992. For the Gregory Glacier (2), the photos 1.1.6. to 1.1.11. include a picture from 1945 and then the sequence from 1973 to 1992, as for the Krapf Glacier. For the Lewis Glacier (4) the sequence of photos 1.1.12. to 1.1.26. extends from a sketch in 1893 to a photo in 2004. For the Darwin Glacier (6) the photos 1.1.27. and 1.1.28. capture the drastic decay from 1978 to 2006. The Tyndall Glacier (10) is depicted in the sequence of photos 1.1.29. to 1.1.39., stretching from 1949 to 2004. For the Cesar Glacier (13) the photos 1.1.40. to 1.1.45. include a shot in 1911 and then a sequence from 1973 to 1994. The Joseph Glacier (14) is shown in the photos 1.1.46. to 1.1.51., including a shot from the early 1930's and then the sequence from 1973 to 1994. The Northey Glacier (16) is shown in the photos 1.1.52. to 1.1.57., again with an earliest picture from the 1930's and then the sequence from 1973 to 1994.

Complementing the terrain photos 1.1.1. to 1.1.57., the photos 1.1.58. to 1.1.63. are air photographs from 1974, 1986, 1947, 1987, 1993, and 2004.

## **1.2. Kilimanjaro**

For this highest mountain of Africa a series of maps are offered in Part C. Maps 1.2.1. through 1.2.5. (pages C.10 to C.12) are reproductions of historical maps from 1889, 1898, 1912, 1930, and the 1960's, respectively. Map 1.2.6. (page C.13) presents an orientation and nomenclature of ice entities in the 1970's, with ice entities numbered clockwise starting from the North. Map 1.2.7. (page C.14) shows the ice extent in 1912, 1953, 1976, 1989, and 2000.

The photographic documentation in Part D (pages D.44 to D.63) is presented in clockwise direction starting with the eastern sector. Thus photo 1.2.1. is an aerial shot in 1943 and photo 1.2.2. a ground picture in 1971. Photo 1.2.3. is a panorama from the Eastsoutheast in 1973. Photo 1.2.4. is from the Southeast in 2004 and 1.2.5. from the South in 2005, both taken from aircraft. Photos 1.2.6 and 1.2.7. capture the southern sector early in the 20th century. Photos 1.2.8. and 1.2.9. are aerial pictures from the Southwest in 1930 and 1941, respectively. Photos 1.2.10. through 1.2.13. and the panorama 1.2.14. are ground pictures from the West in 1901, 1930, 1948, and 1974. Further from the western sector are the ground photo 1.2.15. in 2004 and the aerial photo 1.2.16. in 1930. Photo 1.2.17. is a ground panorama from the Northnortheast in 1973. The aerial photos 1.2.18. and 1.2.19. show the Northern Ice Field and ice entity (2) in 2005. Photo 1.2.20 is a panorama of the Kibo crater from the South in 1904. Photos 1.2.21. through 1.2.24. are panoramic views of the Kibo crater from Uhuru Peak in 1929, 1973, 2002 and 2005. Photo 1.2.25. depicts the ice cliff of Furtwangler glacier in 2005. Photo 1.2.26. shows the Kibo summit from hot air balloon in 1974.

Complementing the photos 1.2.1. through 1.2.26. are the vertical air photo 1.2.27. and the satellite images 1.2.28. and 1.2.29.

### **1.3. Ruwenzori**

For this mountain range three maps are offered in Part C. Maps 1.3.1. and 1.3.2. (pages C.15 to C.16) are reproductions of historical maps from 1906 and 1938. Map. 1.3.3. (page C.17) presents an orientation and nomenclature of glaciers on the six mountains, Mounts Emin, Gessi, Speke, Stanley, Baker, Luigi di Savoia.

The photographic documentation in part D (pages D.64 to D.76) is presented successively for Mounts Speke, Stanley, and Baker. For Mount Speke, photos 1.3.1. to 1.3.3. are from 1906, 1952 and 1960; photos 1.3.4. to 1.3.6. and 1.3.9. are from 1974; and for the snout of Speke Glacier the photos 1.3.8. of 1961 and 1.3.7. of 1991 allow a comparison with 1.3.9. of 1974. For Mount Stanley photos 1.3.10. to 1.3.13. are of 1881 and 1906. For the Savoia Glacier of Mount Stanley photos 1.3.14. and 1.3.15. are of 1906 and 1960, photos 1.3.17., 1.3.18. and 1.3.19. are of 1974 and 1991. Photo 1.3.16. shows the Coronation and the lower Elena Glaciers in 1974. For Mount Baker, photos 1.3.20. and 1.3.21. are of 1974. The Moore Glacier of Mount Baker is captured in photos 1.3.22. to 1.3.25. for 1906, 1958, and 1966.

## **2. Ecuadorian Andes**

The Ecuadorian Andes have many glaciated mountains, and of these four are considered here as indicated in the map 2.0.1. (page C.18), namely Chimborazo, El Altar, Antisana and Cotopaxi. Pertinent for orientation are the maps 2.1.3., 2.2.1. and 2.3.1. (pages C.20 to C.23). For the broader background, including historical sources and subject literature, reference is made to a book (Hastenrath, 1981).

### **2.1. Chimborazo**

For this highest mountain of the Ecuadorian Andes a series of maps are presented in Part C. Maps 2.1.1., 2.1.2., and 2.1.4. (pages C.19 and C.22) are reproductions of historical maps of Chimborazo from 1892, 1907 and 1971, respectively. Map 2.1.3. (pages C.20 and C.21) presents an orientation and nomenclature of ice entities in the 1970's, with glaciers numbered clockwise starting from the North.

The photographic documentation in Part D (pages D.77. to D.82.) consists of ten photos taken in 1974, namely 2.1.1. to 2.1.3. from the South, 2.1.4. and 2.1.5. from the Southwest, 2.1.6. from the West, 2.1.7. and 2.1.8. from the Northwest, and 2.1.9. and 2.1.10. from the Northeast.

### **2.2. El Altar**

The map 2.2.1. in Part C (page C.23) provides an orientation. Part D (pages D.83. to D.90) presents the long history of pictorial documentation for the West side of the mountain. Largely consistent in vantage point are the photos 2.2.1. to 2.2.5., beginning with a painting in 1872, continuing with a photo in 1902, a painting in 1903, and photos in 1978. Photos 2.2.6. and 2.2.7. were taken inside the caldera in 1978. Photos 2.2.8. to 2.2.10. are from 1999, and photo 2.2.11. is from 2000.

### **2.3. Antisana**

The map 2.3.1. in Part C (page C.23) provides an orientation. Part D (pages D.91 to D.95) presents the photos 2.3.1. to 2.3.8., most taken in 1975, with a comparison to two shots from 1903. Photos 2.3.1. and 2.3.2. show the mountain from the Southwest. The photos 2.3.3., 2.3.5. and 2.3.6. capture the snout of glacier (12) at Antisana (Great West Glacier, Los Crespos), to be compared with the conditions in 1903 documented by photo 2.3.4. Similarly, photo 2.3.7 of the North side of this glacier should be compared with photo 2.3.8., taken in 1903. For further comparison, photos 2.3.9. and 2.3.10. capture the conditions in 2007 and 2006.

### **2.4. Cotopaxi**

The map 2.3.1. in Part C (page C.23) provides an orientation. Page D.96 presents photos from Antisana in the Northeast. Photo 2.4.1. shows the mountain in June 1975, and photo 2.4.2. was taken from the summit of Antisana in July 2000.

## **3. New Guinea**

The map 3.0.1. (page C.24) offers an orientation. Fossil moraines, remnants of Pleistocene glaciation, are found also in the eastern part of the island, Papua New Guinea, but the recent glaciation is limited to the western part, the Irian Jaya province of Indonesia. Ice disappeared on Puncak Trikora (Wilhelmina, 4,730 m) around the middle of the 20th century, and on Ngga Pilimsit (Idenburg, 4,717 m) and Puncak Mandala (Juliana, 4,640 m) in recent decades (A. Klein, personal communication). The best historical documentation has been collected for the region of the highest peak, Puncak Jaya (Mount Carstenz, 4,884 m). The map 3.1.1. (page C.24) presents a summary of retreat history. As referenced in the literature account in Part B, evidence stems from expeditions by Wollaston in 1913, by Colijn and Dozy in 1936, by Harrer in 1962, the Australian Universities team in 1971-73, a photo flight in 1942, and satellite imagery in 1987 and 2002.

The photographic documentation in Part D (pages D.97 to D.102) consists of ten frames. Photos 3.1.1. and 3.1.2. show the Northwall Firn, Meren and Carstenz Glaciers in 1936 as compared to 1972. Photos 3.1.3. and 3.1.4. offer a view to the Southeast in 1936 as compared to 1991. Photo 3.1.5. is an aerial view to the South of 1942. Photo 3.1.6. compares the view to the North in 1913, 1936, and 1973. Photo 3.1.7. offers a broad view to the South in 1936. Photo 3.1.8. shows the lake at the foot of the Carstenz Glacier in 1936. Finally, photos 3.1.9. and 3.1.10. are shots of the cairns built at the terminus of Carstenz Glacier in 1936 and 1962, respectively.

## **4. Time series diagrams**

A quantitative appraisal of the long-term changes of glaciated area is presented in Fig. 1.0.1. for East Africa, in Fig. 2.0.1. for the Ecuadorian Andes, in Fig. 3.0.1. for New Guinea, and Fig. 4.0.1. offers a synopsis for the three glaciated mountain regions under the Equator (pages C.25 to C.28). In compact form, these diagrams show the drastic and sustained recession of the equatorial glaciers.



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