A DAVID BREASHEARS FILM

KILIMANJARO

TO THE ROOF OF AFRICA

AUDREY SALKELD

INTRODUCTION BY DAVID BREASHEARS

NATIONAL GEOGRAPHIC

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Kilimanjaro
Audrey Salkeld

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Printed in U.S.A. Printed by R. R. Donnelley, Willard, Ohio; Separations by Quad Graphics, Alexandria, Virginia.

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1145 17th Street N.W.
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Library of Congress Cataloging-in-Publication Data

Salkeld, Audrey.
Kilimanjaro : to the roof of Africa / Audrey Salkeld ; introduction by David Breashears.
p. cm.
Includes bibliographical references and index.
ISBN 0-7922-6466-5 (hard)
1. Mountaineering--Tanzania--Kilimanjaro, Mount. 2. Kilimanjaro, Mount (Tanzania)--Description and travel. I. Title.

GV199.44.T342 S35 2002
796.52'2'0967826--dc21 2001052171

Major funding for
Kilimanjaro: To the Roof of Africa was provided by the

Houston Museum of Natural Science
and Omaha's Henry Doorly Zoo
Museum of Science, Boston
Denver Museum of Nature & Science
Fernbank Museum of Natural History
Fortworth Museum of Science and History

ETERNAL ICE AND SNOW?

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Crossing the vast summit crater of Kibo en route to the Northern Icefield, my oxygen-starved brain struggled to interpret environmental observations that weren't fitting together. Ahead loomed the glacier's imposing vertical wall, yet where was the snow required to nourish the glacier? Joining sun-blistered colleagues at the ice, dripping icicles quickly replenished our empty water bottles, yet we knew the fantastic ice fins, spires, and cliffs on Kibo signified the dominance of ablation processes other than melting. Our expedition's purpose was to begin a new study of glaciers and climate at Kilimanjaro's summit focusing on the recent retreat of these glaciers. As we set our packs down on the warm volcanic sand, the intellectual equivalent of warning lights were beginning to flash in my head: Don't expect any simple explanations.

Hindsight reveals that a severe drought was under way throughout East Africa in February 2000, when we joined Lonnie Thompson and his team from Ohio State University at the summit. Thompson spent four weeks there extracting six ice cores from several different glaciers, which are yielding a record of climate and environmental change spanning millennia. The history of these glaciers, provided by the ice cores, extends right up until the day each is drilled. The interface between Thompson's work and ours is here at the surface where, through automated weather, snow, and ice measurements, we are documenting how the glaciers record. Studying the past and present, we are working urgently to understand the dramatic retreat of glaciers currently underway on Kilimanjaro before the evidence—and the historical record—disappears.

Glaciers today cover a tiny fraction of Kilimanjaro relative to their extent during the last ice age. Kibo alone had probably 50 times more ice than today. There may also have been intervals with less ice than today in the roughly 20,000 years since the Last Glacial Maximum. Direct observation of Kilimanjaro's glaciers began in 1889, with the explorations and first ascent by Hans Meyer. His prolific and eloquent accounts are both fascinating and invaluable. Glaciers encircled the summit and filled much of the crater, covering an area ten times greater than today. By the time of Meyer, modern evidence indicates that the retreat, from a minor advance phase, had been underway for several decades. Continuous ice recession was documented through the 20th century by photographic mapping and satellite imagery. While we were on the mountain with Thompson in February 2000, less than one square mile of ice remained—representing 18 percent of that mapped in 1912, and 67 percent of the area covered only 11 years earlier.

The rapid decrease in glacier area during modern times (since 1889) has led many to ponder how long the ice will endure. Indeed, upon ascending the mountain nine years after his first climb, Meyer speculated that the glaciers of the Kibo crater would disappear within 20 to 30 years. The latest assessment of ice area in 2000 attracted attention and concern both within Tanzania and around the world, and very few news accounts could resist linking the retreat of Kilimanjaro's glaciers to global warming. Without adequate diagnostic evidence, however, this linkage is on thin ice; we must recognize that the mountain's glaciers have little in common with mid-latitude Alpine glaciers and accept that simple explanations are not always possible. Kilimanjaro is a mountain that defies expectations and shatters assumptions.

On a global scale, glaciers are in widespread retreat. From records of area and length, recession of mountain glaciers has been documented worldwide with few exceptions. In tropical mountain areas particularly, there is abundant evidence that the retreat is accelerating. For example, Thompson has made long-term observations on one glacier in Peru where the rate in 2000 was 32 times faster than in 1978. According to the World Glacier Monitoring Service in Zurich, mountain glacier recession during the 20th century is a response to climate change, initially probably natural but which may now "...contain an expanding element of anthropogenic [human-induced] influence."

Glaciers and bank accounts are both entities that grow, shrink, and provide storage, governed by the balance between credits (accumulation) and debits (ablation). On mountain glaciers mass accumulates primarily through precipitation, while ablation is dominated by melting and sublimation – a rather mysterious process through which water molecules are transferred directly from the solid phase (snow or ice) to vapor. From measurements of accumulation and ablation, each expressed as water equivalence, we can establish a glacier's mass balance, which is intimately tied to the glacier's health. Mass balance studies are complementary to those mapping changes in area and length but remarkably, no mass balance measurements exist from Kilimanjaro prior to those we began with Thompson in 2000. Considerable debate took place within our tents that February as to whether the Northern Icefield would gain or lose mass over the next 12 months. Over the past century however, the overall net balance has clearly been negative.

Sublimation deserves further discussion, for in dry tropical areas this mechanism of ablation can result in significant mass loss. It has long been known to promote growth of *nieve penitentes* high on tropical mountain glaciers, which are strange, east-west oriented blades of ice, pointed at the sun and sometimes several meters high. Sublimation from snow and ice surfaces is a difficult process to measure, but can be calculated from meteorological measurements at the glacier surface. Recently, a French group working on Zongo Glacier in Bolivia found that nearly all the energy available was consumed by sublimation during the dry season, leaving almost none for melting. Why is this distinction between sublimation and melting important? One reason is that the process consumes tremendous energy that might otherwise be available for melting – a whooping 8.5 times more, for the same mass of snow or ice. Secondly, the balance between sublimation and melting is principally controlled by humidity. Therefore, relatively subtle changes in any atmospheric variable related to humidity (e.g., cloudiness, wind direction) will have an amplified impact on a tropical glacier's mass balance. Until now, there has been insufficient meteorological data from Kilimanjaro's summit to determine the disposition of energy (i.e., sublimation vs. melt), but we believe that sublimation is the dominant mechanism of ablation through much of the year.

Lewis Glacier on Mt. Kenya (200 miles north), the best documented glacier in the tropics, provides an analog for mass balance processes on Kilimanjaro. Although the mountain is lower in elevation, 17,058 feet (5,202 meters), and considerably smaller at high elevations, mass balance measurements and analyses made over a number of years by Stefan Hastenrath and colleagues are relevant. They attribute the initial retreat of glaciers on Mt. Kenya to a late-19th century precipitation decrease, along with an associated reduction in cloudiness; together these changes decreased accumulation and increased ablation. Warming in the 1920s caused further retreat, but temperature change alone cannot account for ice wastage since 1963. The smoking gun according to Hastenrath is held by humidity, a slight increase leading to reduced sublimation and therefore increased energy available for melting. Our new measurements and Thompson's ice-core record will help establish the degree to which these results apply to Kilimanjaro, where the mountain and its glaciers extend higher into the cold, dry tropical atmosphere.

Kilimanjaro's glaciers are situated more than halfway through Earth's atmosphere, and herein lies their great value to science. As an island in the sky, rising 19,340 feet above the East African plains, Kilimanjaro provides a unique perspective on the present and past global climate system. A better atmospheric measurement platform would be hard to design.

A great deal remains to be learned from Kilimanjaro's glaciers, and I look forward to visiting them for decades to come. But we cannot alter, within decades, the relationships between the glaciers and the global climate, and we cannot ignore that the area covered by ice is steadily diminishing. In future years, snow will continue to grace the cone of Kibo through much of the year, and the mountain will appear as Hemingway saw it: "...great, high, and unbelievably white in the sun." However, if the ice disappears, so too will the historical archive from this irreplaceable vantage point on our planet, and our chance to document how that history is recorded. We have much work to do.