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PLEISTOCENE GLACIATION IN ETHIOPIA: NEW EVIDENCE

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Abstract. Geomorphological evidence indicates that Mount Badda, Ethiopia, had a Pleistocene ice cap of at least 140 km². Altitude of the snow line was probably about 4 000 m, only 350 m below the summit, suggesting that glaciation occurred during the Würm glacial maximum.

Résumé. *Glaciation pleistocène en Ethiopie: nouveaux indices.* Des preuves géomorphologiques indiquent que le Mount Badda, en Ethiopie, a porté une calotte glaciaire d'au moins 140 km². L'altitude de la ligne de névé était probablement d'environ 4 000 m, 350 m seulement en-dessous le l'altitude du sommet, ce qui laisse à penser que la glaciation s'est produite au moment du maximum glaciaire du Würm.

Zusammenfassung. *Pleistozäne Vergletscherung in Äthiopien: Neue Beweise.* Geomorphologische Zeugnisse beweisen, dass Mount Badda in Äthiopien eine pleistozäne Eiskappe von mindestens 140 km² trug. Die Schneegrenze lag bei etwa 4 000 m, nur 350 m unterhalb des Gipfels, was auf eine Vergletscherung während des Höchstandes der Würm-Eiszeit schliessen lässt.

Introduction

The recognition of Mount Badda, Ethiopia, as a center of alpine glaciation is significant because it enlarges what is known of the very limited extent of African Pleistocene glaciation. Only a few very high mountains in eastern Africa (peaks generally over 3 500 m) are known to have been glaciated during the Pleistocene (Flint, 1971). Alpine glaciers are still extant on the Ruwenzori Range (Whittow, 1959), Mount Kenya (Baker, 1967) and Mount Kilimanjaro (Downie, 1964). Evidence for a more extensive Pleistocene glaciation has been found on these peaks, but also on some lower peaks now ice-free: the Aberdare Range, Kenya; Mount Elgon, Uganda (Nilsson, 1940); and the Simien Mountains of Ethiopia (Fig. 1A).

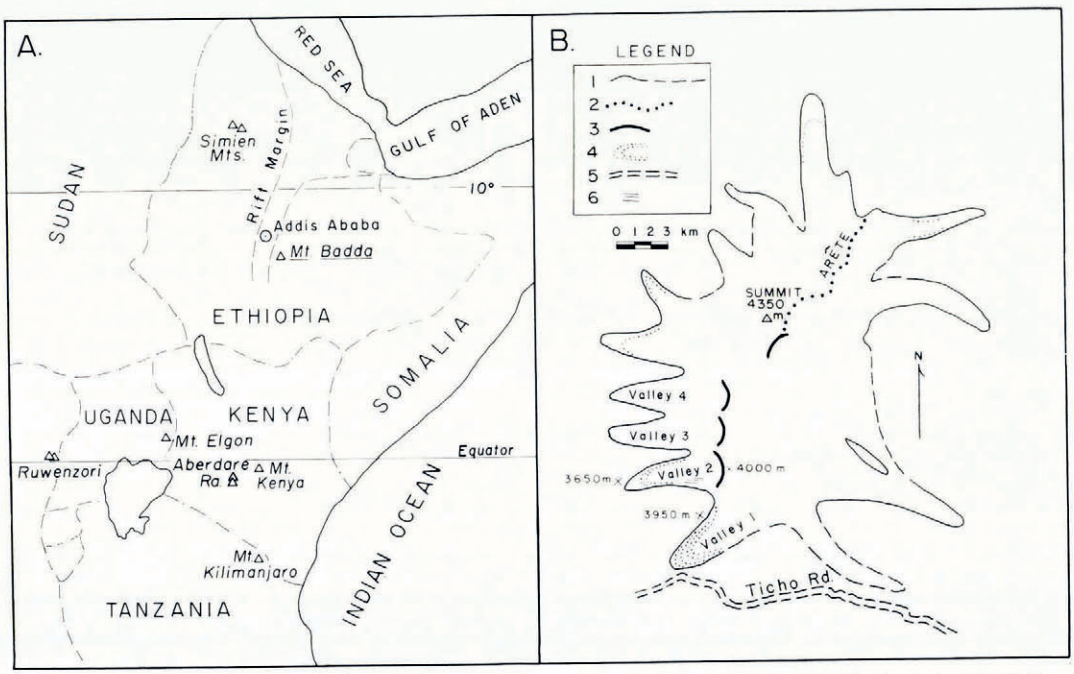

Fig. 1. A. Locality map of eastern Africa showing known centers of Pleistocene glaciation (small triangles). B. Features resulting from glaciation near the summit of Mount Badda, as determined from field work and analysis of 1 : 60 000 scale air photographs. 1, limit of ice-contact features, generally moraines and lowest portions of distinctly U-shaped valleys, dashed where inferred; 2, main arête; 3, major cirques not associated with the arête; 4, end moraines; 5, land-rover track to Ticho villaage from the Asella area to the west; 6, schematic representation of location and azimuths of striations.

Most research on the subject of alpine glaciation in Ethiopia has centered on the Simien Mountains, Ethiopia's highest massif (Nilsson, 1940; Scott, 1958; Mohr, 1963). However, there is evidence of glaciation in another mountain area of Ethiopia. Nilsson (1940, p. 56 and 57) noted moraines on Mount Badda (lat. 7° 56′ N., long. 39° 24′ W.), but he had to cut short his studies because of the impending rainy season. 3 days of field observations made in the spring of 1973, combined with air photographic study, permit a more detailed description of evidence of glaciation on Mount Badda.

Mount Badda's summit lies at the northern end of a 70 km long, north–south trending ridge (Sagatu Ridge) composed of dikes, plugs and volcanic flows of Pliocene–Pleistocene age. The terrain is ideal for studies of geomorphology because of the views afforded by the lack of tall vegetation.

Evidence of glaciation on Mount Badda

Deep valleys with U-shaped profiles are the most obvious features of glacial origin on the mountain. Below the lower limit of glaciation, the valley profiles become markedly narrower and more irregular.

Two of the south-westernmost valleys (Fig. 1B) were studied in detail and they contain several end moraines, which vary in height from 3 m to 9 m and can be distinguished on 1 : 60 000 scale air photographs. The relief of the moraines has been subdued by weathering and erosion. Plant colonization of the moraines is the same as that of the adjacent ground. The flora consists mostly of heathers, everlasting (*Helichrysum*) and occasional giant lobelias (*Lobelia wollastonii*).

Valley 1 lacks a cirque but contains five end moraines with the lowest at the 3 800 m level. Three end moraines are present in valley 2. The altitude of the lowest terminal portion is 3 650 m. Moraines in each valley are sub-parallel to one another and have similar relief.

The distinct U-shaped valley cross-section continues down-valley about 1 km beyond the end moraines in valley 2 and in several valleys to the north. This suggests that older glaciers, whose moraines have been removed by erosion, extended beyond the observed moraines. Evidence of an older glaciation on Kilimanjaro, Mount Kenya and the Simien Mountains has been described; on Mount Kenya (Baker, 1967) and in the Simiens (Nilsson, 1940) this consists of isolated erosional remnants of moraine material.

There are several exposures of distinct glacial striations on dike-rock outcrops near the 3 930 m level in valley 2. Striations have not previously been reported from Ethiopia, perhaps because of the susceptibility of volcanic rocks to tropical weathering. Their preservation of Mount Badda is almost certainly due to the excavation of a resistant trachyte dike-swarm by the glaciers.

Striations trending across the upper end of the divide between valleys 3 and 4 suggest that adjacent glaciers diverged there, having descended from a common ice cap. Support for the existence of an ice cap is also found in valley 1, where end moraines indicate that a glacier once occupied the valley, but an accumulation zone, in the form of a cirque, is absent.

Extent of glaciation

Figure 1B shows the lower limit of features produced by ice contact. Valleys 1, 2, 3 and 4 were examined in the field by the writer and P. A. Mohr. The remainder of the figure was constructed by interpretation of air photographs. The total area glaciated is more than 140 km². Nilsson (1940) estimated a minimum extent of 440 km² of Pleistocene glaciation in the Simien Mountains. Thus the total glaciated area in Ethiopia (Mount Badda plus the Simien Mountains) is more than 580 km² and is significant compared to the total area (1 900 km²) of known Pleistocene glaciation in Africa (Flint, 1971).

Terminal moraines (valley 2) indicate that glaciers descended to an altitude of 3 650 m on the west side of the peak. This is notably lower than the 4 100 m minimum reported for the Simien Mountains, 5° of latitude farther north (the claims of Hovermann (1954) that moraines exist down to 3 000 m in the Simien Mountains have been treated with some scepticism by Scott (1958)).

Age of glaciation

The glaciation of Mount Badda cannot have been pre-Pleistocene, because the K-Ar ages obtained by P. A. Mohr (personal communication, 1975) show that the volcanic rocks which form Mount Badda are late Pliocene to early Pleistocene in age. The glaciation was not recent, as shown by the subdued relief of the moraines. By comparison, the moraines of the historic re-advance on Mount Kenya are

very fresh in appearance; fine details, such as 1 m high minor ridges, are preserved. In addition, recent moraines of Mount Kenya are devoid of living plants, whereas the Mount Badda moraines support a varied flora.

An estimate of the climatic snow line at the glacial maximum can be made, assuming that it coincides with the upper limit of the lateral moraines. In valleys 1 and 2, this altitude is approximately 4 000 m. This is comparable to the Pleistocene climatic snow lines of glacial maxima on Kilimajaro (4 400 m) and on Mount Kenya (3 900 m) (Baker, 1967). The estimated snow line on Mount Badda is only 350 m below the summit. This suggests that the glaciation responsible for the moraines occurred during the Würm maximum.

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