Geophysical Research Abstracts, Vol. 8, 04767, 2006
SRef-ID: 1607-7962/gra/EGU06-A-04767


# Quaternary glaciation of the Bale Mountains, Ethiopia

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One of the most noticeable records of Quaternary climate change within tropical mountains is the geomorphological record of former glacial events. Although Ethiopia does not currently have any glaciers, there is evidence for the former existence of glaciers on many of the highest part of the extensive plateau that occur on either side of the East African Rift Valley. This paper reports recent fieldwork in the Bale Mountains (39˚45˚ E 6˚52˚N) on the southern side of the rift where there is a range of geomorphological evidence indicating former glaciation.

The Sanetti plateau forms the upper part of the Bale Mountains reaching a maximum elevation of 4400 m asl in the peak of Tullu Dimtu. Across the plateau there is a moraine composed of large ($>$ 5m diameter) angular erratic boulders and smaller ridges which can be traced for c. 15 km and interpreted as a boulder limit defining the former extent of an ice field that covered $>$30 km$^2$. Other evidence of former glaciation has been encountered on the northern flank of the Bale Mountains with glacial modification of the major valleys. There are also a number of lateral moraine ridges which occur both within these valleys such as the Tagona and also on the interfluve areas. The elevational range of these landforms suggests that they relate to different events with the open slope and higher moraines associated with an earlier glaciation before the valleys were incised and within which are found recessional moraines associated with a later glacial event.

Total glaciated area for the Bale Mountains is estimated at $<$ 190 km$^2$ with Equilibrium Line Altitudes (ELA) based on THAR (toe-headwall-altitude-ratio) ranging from 3750 m to 4230 m for the different glacial units and aspects. These estimates accord with those of other Ethiopian mountains. Lack of any present glaciers makes calculations of change in ELA from the last glaciation difficult; however, it can be estimated

as being as little as 120 m and due to a temperature change of $< 1^{\circ}$ C (assuming an environmental lapse rate of $6\ ^{\circ}$ k $\mathrm{m}^{-1}$) which is considerably less than other East African mountains.

The age of the moraines is presently unknown. Radiocarbon dates from key sites within the area show that they were ice-free by 14000 $^{14}$C yr BP and suggest that the last glacial event can be correlated to the Last Glacial Maximum. Samples from boulders from the Big Boulder Moraine and one of these moraine ridges at the edge of the Tagona valley have been submitted for cosmogenic dating. It is hoped to be able to report these dates at the meeting.