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Holocene stages of tufa deposition/erosion in Ethiopia: the role of climate fluctuations and human impact

Francesco Dramis and Giandomenico Fubelli
Department of Sciences, Roma Tre University, Italy (giandomenico.fubelli@uniroma3.it)

The geomorphological-stratigraphic study of the backfill deposits of two tufa dams, May Makden and Tsabati Mariam, supported by 14C dates, has provided a detailed description of the depositional/erosional stages of tufa and the related environmental changes during the Holocene.
The 14C dates of the Tsabati Mariam dam backfill span from the Early Holocene 9510±100 14C yrs BP (11,046-10,675 cal) to the Late Holocene 2380±50 14C yrs BP (2592-2367 cal). The time interval covered by the May Makden dam backfill is shorter but more continuous and much better exposed. The backfill deposit includes: a) 8 m thick swampy-lacustrine sequence of organic-rich levels and peaty layers spanning from 7630±80 14C yrs BP (8521-8382 cal) to 6510±70 14C yrs BP (7485-7346 cal) and affected by desiccation cracks indicating the disappearance of the swampy-lacustrine water body due to a prolonged drought period; b) a sequence of thin alternating layers of phytoclastic travertine, alluvial gravels and buried soils dated from 5610±70 14C yrs BP (6472-6333 cal) to 3450±50 14C yrs BP (3808-3656 cal). The last evolution stage of the dam after 4710±70 14C yrs BP (5552-5355 cal), is characterized by alternating phases of tufa aggradation and erosion. Subsequently, the tufa dam was completely incised by the May Makden stream. The finding of a large number of artifacts and charcoal fragments above the top surface of the backfill indicates the presence of human settlements and the practice of clearing fires in the surrounding area.
The Holocene evolution of the investigated tufa dams points out the occurrence of some century-scale stages of tufa deposition (10.9-9.3; 8.4-7.4; 6.6-5.5 kyrs BP) interrupted by intervals with lower or absent deposition and dam incision (9.3-8.4; 7.4-6.6 kyrs BP). Since 5.5 to 2.5 kyrs BP, the deposition rates of tufa progressively declined until stream erosion incised the dams down to the underlying bedrock. The 8.2 cooling event, recorded at the global level, is not well recognizable in Tigray unless a short hiatus in the sequence of tufa between 7310±90 14C yrs BP (8328-7969 cal) and 7310±90 14C yrs BP (8328-7969 cal) is considered.
The sequence of tufa events in Tigray seems to be parallel to the record of lake level fluctuations in the Ethiopian Rift with high stands corresponding to the main deposition stages of tufa and low stands corresponding to the non-deposition/erosion intervals. Interesting, in this context, is the progressive lowering of the lake levels after ca. 5.5 kyrs BP. The tufa record of Tigray also shows some correlation with the cooling-warming stages of the Mediterranean Sea and, more in general, with the main peaks of the Holocene global temperatures.
The above relationships emphasize the primary role of rainfall and temperature as controls of tufa deposition. This does not exclude human impact as an additional negative factor for the deposition of tufa. Man-made deforestation could have significantly favored the decline of tufa deposition in Tigray where widespread forest clearing for farming started around the IV century bC, in the pre-Axumite period.