

Unravelling the Plio-Pleistocene history of the paleontologically significant Turkana Basin, Kenya

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The Omo-Turkana Basin in Kenya and Ethiopia is renowned for fossil-rich, Plio-Pleistocene sedimentary sequences that have yielded spectacular hominin specimens. These discoveries afford remarkable insights into the antiquity (>4.3 Ma) and complexity of human evolution, under changing paleoclimate and paleoenvironmental conditions. Importantly, the region contains abundant interbedded volcanic units, which provide critical time markers. Advances in our understanding of the Basin rely on the integration of diverse scientific fields and analytical/modelling tools. Geochemical methods are crucial for establishing a high-resolution timeframe for human evolution, robust stratigraphic correlations across the Basin, time anchors for paleoclimate proxy models, and insights into source magma dynamics.

We studied numerous Turkana Basin silicic tephra units (termed tuffs) and their contained pumice clasts, using combinations of field mapping, petrography, major and trace element analyses, radiogenic isotopic analyses and ultra-precise $^{40}\text{Ar}/^{39}\text{Ar}$ geochronology. Geochemical fingerprinting is essential for correct unit designation and correlations across the Basin. Although major element data from tuff and pumice glass are sufficient for fingerprinting some units, other deposits also require trace element and/or radiogenic isotope data for unique identification. To reveal key characteristics of individual units, we have developed innovative sampling and analytical methods to enhance precision and accuracy.

Recent ultra-high precision $^{40}\text{Ar}/^{39}\text{Ar}$ analysis of feldspar crystals extracted from tuff pumice clasts reveals an array of ages within individual pumice clasts, a feature not apparent from previous work. Tuff eruption times are determined from the youngest age populations using either a custom weighted mean or Bayesian estimation approach. These statistical methods yield high-precision ages, with uncertainties on the order of $\pm 1\text{--}3$ ka, allowing improved age constraints for Turkana hominin fossils. As our $^{40}\text{Ar}/^{39}\text{Ar}$ results have been calibrated to the astronomical timescale, key tuff ages can also be used to test Pleistocene paleoclimate reconstruction models based on geochemical proxy records (e.g. C and H isotope leaf wax data and $^{87}\text{Sr}/^{86}\text{Sr}$ data from marine fossils); these reconstructions are critical for testing potential paleoclimate drivers of human evolution. Furthermore, our combined petrographic, geochemical and $^{40}\text{Ar}/^{39}\text{Ar}$ datasets provide new insights into the magma dynamics of source volcanoes to the Turkana Basin tuffs.