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Distal tephras of the eastern Lake Victoria basin, equatorial East Africa: correlations, chronology and a context for early modern humans

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ABSTRACT

The tephrostratigraphic framework for Pliocene and Early Pleistocene paleoanthropological sites in East Africa has been well established through nearly 50 years of research, but a similarly comprehensive framework is lacking for the Middle and particularly the Late Pleistocene. We provide the first detailed regional record of Late Pleistocene tephra deposits associated with artifacts or fossils from the Lake Victoria basin of western Kenya. Correlations of Late Pleistocene distal tephra deposits from the Wasiriya beds on Rusinga Island, the Waware beds on Mfangano Island and deposits near Karungu, mainland Kenya, are based on field stratigraphy coupled with 916 electron microprobe analyses of eleven major and minor element oxides from 50 samples. At least eight distinct distal tephra deposits are distinguished, four of which are found at multiple localities spanning >60 km over an approximately north to south transect. New optically stimulated luminescence dates help to constrain the Late Pleistocene depositional ages of these deposits. Our correlation and characterization of volcaniclastic deposits expand and refine the current stratigraphy of the eastern Lake Victoria basin. This provides the basis for relating fossil- and artifact-bearing sediments and a framework for ongoing geological, archaeological and paleontological studies of Late Pleistocene East Africa, a crucial time period for human evolution and dispersal within and out of Africa.

1. Introduction

Fossil evidence suggests the earliest members of our species, *Homo sapiens*, first appeared in equatorial East Africa by 195 ka (McDougall et al., 2005; Brown et al., 2012). This area likely served as one point of departure for subsequent Late Pleistocene hominin dispersals across and out of Africa (Rose et al., 2011; Soares et al., 2012; Rito et al., 2013). The archaeological record and environmental context of these early *H. sapiens* populations are essential data for understanding the evolutionary success of our species (e.g., Tryon and Faith, 2013). Continental and regional syntheses of the Pleistocene African archaeological and environmental records are often characterized by mismatches in temporal and spatial scales (reviewed in Blome et al., 2012; Tryon and Faith, 2013). Deep cave sequences in northern and particularly southern Africa have provided finely resolved, rich archaeological and environmental records (e.g., Deacon, 1979; Singer and Wymer, 1982; Avery et al., 1997; Marean et al., 2000; Henshilwood et al., 2002; Jacobs et al., 2006, 2008; Wadley and Jacobs, 2006; Marean et al., 2007; Garcea, 2010; Clark-Balzan et al., 2012). However, deeply stratified cave sequences are largely lacking in East Africa, where the archaeological record consists of generally low-density open-air sites (Tryon and Faith, 2013). Demonstrating stratigraphic equivalence among these open-air sites via the correlation of tephra provides the means to assess landscape-scale spatial variation in past environments and human behaviors.

East Africa has the potential to demonstrate the equivalence among sites via tephrostratigraphy, the geochemical and lithostratigraphic correlation of tephra as widespread markers in the geological record (Lowe, 2011; Brown and Nash, 2014). Rifting along the East African Rift System (EARS; Chorowicz, 2005)

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provides the mechanisms for volcanic eruptions, rapid sedimentation and burial of archaeological and paleontological sites, as well as their subsequent exposure through continued faulting. Although there is a well-established Pliocene and Early Pleistocene tephrostratigraphic framework for paleoanthropological sites in Kenya, Ethiopia, Tanzania and Uganda that is the outcome of nearly 50 years of research (e.g., Brown et al., 1992, 2006; Feibel, 1999; Hay, 1976; McHenry et al., 2008; Pickford et al., 1991; Woldegabriel et al., 1999, 2005, 2013), comparatively few data are available for these areas during the portions of the Middle and Late Pleistocene that saw the origin and dispersal of *H. sapiens* (for published exceptions, see Brown et al., 2012; Morgan and Renne, 2008; Sahle et al., 2014; Tryon and McBrearty, 2002, 2006; Tryon et al., 2008, 2010).

We address this problem by focusing on archaeological and paleontological sites associated with tephra deposits in and around the eastern Lake Victoria basin, and develop a Late Pleistocene tephrostratigraphic and chronometric framework for the region. At 66,400 km^2, Lake Victoria is the largest lake in Africa by surface area (Adams, 1996). The habitats surrounding this lake have undergone substantial climate-driven changes throughout the Quaternary (Nicholson, 1998; Bootsma and Hecky, 2003), likely with profound impacts on human and other animal communities (e.g., Faith et al., 2011, 2015; Tryon et al., 2010, 2012). However, until recently, an understanding of environmental variation prior to the Last Glacial Maximum has been poorly constrained, and the nature of spatial variation in environments and human behavior obscured.

We present the results of 916 electron microprobe analyses to geochemically characterize and correlate 50 distal tephra deposits from 32 measured sections across Rusinga Island, Mfangano Island, and Karungu on the Kenyan mainland (Fig. 1a, b), spanning a roughly north-south oriented transect over 60 km in the eastern Lake Victoria basin (eLVB). Four tuffs: the Wakondo Tuff, the Nyamita Tuff, the Nyamsingula Tuff, and the Bimodal Trachyphonolitic Tuff are sufficiently distinct and widespread lithostratigraphic markers for correlation within and between discontinuous outcrops at distantly located paleontological and archaeological localities. Optically stimulated luminescence (OSL), Uranium–Thorium disequilibrium (U–Th) and AMS ^{14}C dates constrain the depositional history and ages of these tuffs to >33 to ~100 ka. This stratigraphic sequence of tuffs, radiometric dates, and intercalated fossil- and artifact-bearing sediments provides the fundamental framework to assess paleoecological and archaeological variation across time and space in the eastern portion of the Lake Victoria basin.

2. Pleistocene distal tephra deposits, fossils, and artifacts in the eastern Lake Victoria basin

The Lake Victoria basin formed in the depression between the eastern and western branches of the EARS, probably within the last few million years (reviewed in Danley et al., 2012). The northeastern part of the Lake Victoria basin (Fig. 1c) is unlikely to have been volcanically active since the cessation of rifting and volcanism associated with the failed Nyanza Rift in the Early Miocene (e.g., Van Couvering, 1972; Peppe et al., 2009). During the Pleistocene, the eLVB formed a repository for sediments, including volcaniclastic deposits from eruptions originating from sources outside of the basin. Tephra input appears to be from multiple sources of the central and southern Kenyan Rift in the eastern branch of the EARS (Fig. 1b), demonstrated by tephra deposits from Kenyan and Tanzanian volcanoes mapped in areas as far west as ~35°10′E (see Fig. 1b; Dawson, 2008; Peters et al., 2008; Tryon et al., 2010; Williams, 1991). Pleistocene tephra in the eLVB west of 35°10′E have been previously reported from Rusinga Island (Tryon et al., 2010; Van Plantinga, 2011; Garret et al., 2015) and from sediment cores near Buvuma Island (Kendall, 1969: 139) within Lake Victoria, but are poorly documented due to a focus on economic geology or igneous and metamorphic suites in the region (e.g., Le Bas, 1977).

Localities with Pleistocene tephra, fossils and artifacts attributed to the Early Stone Age (ESA), Middle Stone Age (MSA), and Later Stone Age (LSA) archaeological technocomplexes are known from the eLVB in Kenya as discussed below (Tryon et al., 2010, 2012, 2014; Faith et al., 2015), as well as from Loiyangalani (HcJd-1) in the ash-rich Serengeti Plain of the eLVB in Tanzania (Fig. 1b, Anderson and Talbot, 1965; Bower et al., 1981, 1985; Pickering, 1959; Thompson, 2005). A number of these western Kenyan sites occur ~80–100 km east of Lake Victoria's Winam Gulf, and are associated with at least two widespread marker tuffs considered useful for local field correlation. Pickford (1982, 1984) termed these the “Nyando Ash” or “Nyando Ashes” (Fig. 1). From the area of mapped exposures of the “Nyando Ashes,” McBrearty (1981) excavated lithic artifacts and fossils from within reworked Pleistocene tephra at Songhor near the head of the Nyando River (Fig. 1b, c). McBrearty (1991, 1992) also described a sequence of twelve tuffaceous deposits at the site of Simbi in an area mapped as Nyando Ashes (Fig. 1b, c) and reported a preliminary ^{40}Ar/^{39}Ar age range of ~50–200 ka (McBrearty, 1992). These preliminary dates appear to confirm the Pleistocene age of the Nyando Ashes, but the number of tuffaceous deposits documented at Songhor, Simbi and Rusinga (McBrearty, 1991, 1992; Tryon et al., 2010; Van Plantinga, 2011; Garret et al., 2015) indicates that there are more than the two tephra deposits originally suggested by Pickford (1982, 1984).

Here we couple the first geochemical investigation of the “Nyando Ashes” with geological, archeological, and paleontological data developed during our field program investigating Pleistocene tephra, fossils, and artifacts along the margins of Lake Victoria on Rusinga Island, Mfangano Island and Karungu on the Kenyan mainland (Tryon et al., 2010, 2014, 2014; Van Plantinga, 2011; Beverly et al., in press; Garrett et al., 2015).

3. The Wasiriya beds of Rusinga Island, the Waware beds of Mfangano Island and the Pleistocene exposures of Karungu

3.1. The Wasiriya beds

The Wasiriya beds are exposed over an area of approximately 10 km^2 on the hill slopes around Rusinga Island (Fig. 2, Tryon et al., 2010). These sediments were informally named by Pickford (1984, 1986) based on previous mapping and descriptions (Kent, 1942; Van Couvering, 1972). The first measured sections, sedimentary lithological descriptions and geochemical characterizations and correlation of tephras from the Wakondo and Nyamita localities on Rusinga Island were reported by Tryon et al. (2010). These are shown in Fig. 2, supplemented by new data from the Nyamsingula locality.

The Wasiriya beds are exposed in sections that are ≤15 m at their thickest points, and are comprised of three primary recognized lithologies: 1) poorly sorted coarse sand and gravel channels cemented by carbonate representing episodic channel erosion and deposition, 2) fine grained mudstone, siltstone, and silty sandstones preserving evidence of incipient soil development indicating a slightly more stable landscape, and 3) tephra that has undergone varying amounts of reworking and incipient pedogenesis (Tryon et al., 2010, 2012). AMS ^{14}C dates of gastropod shells primarily from tuffaceous sediments at the Nyamita 2 and Nyamita 3 localities (Tryon et al., 2010) indicate a minimum age of 33 ka for these and underlying deposits (Tryon et al., 2010, 2012). These dated