Quaternary Research 85 (2016) 147–158

Contents lists available at ScienceDirect

Quaternary Research

journal homepage: www.elsevier.com/locate/yqres

Geochemical "fingerprints" for Olduvai Gorge Bed II tuffs and implications for the Oldowan–Acheulean transition

Lindsay J. McHenry [a,*], Jackson K. Njau [b,c], Ignacio de la Torre [d], Michael C. Pante [e]

[a] Department of Geosciences, University of Wisconsin-Milwaukee, 3209 N. Maryland Ave., Milwaukee, WI 53211, USA
[b] Department of Geological Sciences, Indiana University, 1001 E 10th Street, Bloomington, IN 47405, USA
[c] The Stone Age Institute, 1392 W. Dittemore Rd., Gosport, IN 47433, USA
[d] Institute of Archaeology, University College London, 31-34, Gordon Square, WC1H 0PY London, United Kingdom
[e] Department of Anthropology, Colorado State University, 1787 Campus Delivery, Fort Collins, CO 80523, USA

ARTICLE INFO

Article history:
Received 27 June 2015
Available online 7 December 2015

Keywords:
Olduvai Gorge
Tephrostratigraphy
Tephrochronology
Pleistocene
Acheulean
Oldowan

ABSTRACT

Bed II is a critical part of early Pleistocene Olduvai Gorge, Tanzania. Its deposits include transitions from humid to more arid conditions (with associated faunal changes), from *Homo habilis* to *erectus*, and from Oldowan to Acheulean technology. Bed II (~1.8–1.2 Ma) is stratigraphically and environmentally complex, with facies changes, faulting, and unconformities, making site-to-site correlation over the ~20 km of exposure difficult. Bed II tuffs are thinner, less evenly preserved, and more reworked than those of Bed I. Five marker tuffs (Tuffs IIA–IID, Bird Print Tuff (BPT)), plus local tephra, were collected from multiple sites and characterized using stratigraphic position, mineral assemblage, and electron probe microanalysis of phenocryst (feldspar, hornblende, augite, titanomagnetite) and glass (where available) composition. Lowermost Bed II tuffs are dominantly nephelinitic, Middle Bed II tuffs (BPT, Tuff IIC) have basaltic components, and upper Bed II Tuff IID is trachytic. The BPT and Tuff IID are identified widely using phenocryst compositions (high-Ca plagioclase and high-Ti hornblende, respectively), though IID was originally (Hay, 1976) misidentified as Tuff IIC at Loc 91 (SHK Annexe) in the Side Gorge. This work helps establish a high-resolution basin-wide paleolandscape context for the Oldowan–Acheulean transition and helps link hominin, faunal and archaeological records.

Introduction

Bed II (~1.8–1.2 Ma) is the most laterally extensive and paleoecologically varied of the Olduvai Gorge Beds, and is famous for its well-preserved record of Pleistocene hominin behavior and evolution (Leakey, 1971). Like underlying Bed I, Bed II preserves artifacts, fossils, and paleoecological indicators in a variety of depositional contexts, including saline–alkaline lake and lake margin, fluvial, freshwater wetlands, and alluvial and volcaniclastic fans. Bed II also documents environmental change over time, with a shrinking lake and an apparent change from more humid-adapted to more arid-adapted species (Leakey, 1951, 1965, 1971; Gentry and Gentry, 1978). These changes are coupled with changes in the hominin record, with the disappearance of *Homo habilis* and appearance of *Homo erectus* along with the end of the Oldowan lithic technology and the emergence of the Acheulean. The strata of Bed II also contain layers of both primary and reworked tephra derived from the nearby Ngorongoro Volcanic Highlands (NVH; Fig. 1). However unlike in Bed I, these tephra are often contaminated, discontinuous, or even absent in addition to being highly altered, making correlation between sites more difficult. Post-depositional faulting, erosion, and alteration make it difficult to correlate across the basin.

The reconstruction and interpretation of Olduvai's diverse and dynamic paleoenvironments requires accurate chronological and stratigraphic control, provided in part by Hay's (1976) composite stratigraphic sections. Geochemical fingerprinting of individual tephra has led to a detailed tephrostratigraphic framework for Bed I (McHenry, 2004, 2005, 2012; McHenry et al., 2008), which helped correct the relative stratigraphic placement of western gorge fossiliferous deposits in relation to the better-known sites in the eastern gorge (Blumenschine et al., 2003). Since volcanic glass alters readily to clays and zeolites in many Olduvai depositional environments (McHenry, 2009, 2010), useful "fingerprints" rely on phenocryst compositions (feldspar, augite, hornblende, and titanomagnetite) as well as minimally altered glass.

This paper extends this approach to the Olduvai Bed II tuffs. The objectives are to: (1) Geochemically and mineralogically characterize the major Olduvai Bed II marker tuffs, (2) document and recommend geochemical type and reference sections in different environments across Olduvai to help characterize the tephra record across the basin, and (3) identify geochemical "fingerprints" for key marker tuffs that can be used to support local stratigraphic correlation. This technique can provide tight stratigraphic control for paleoanthropological contexts for Bed II, which provides the resolution needed to conduct detailed

* Corresponding author.
E-mail address: lmchenry@uwm.edu (L.J. McHenry).

http://dx.doi.org/10.1016/j.yqres.2015.10.005
0033-5894/

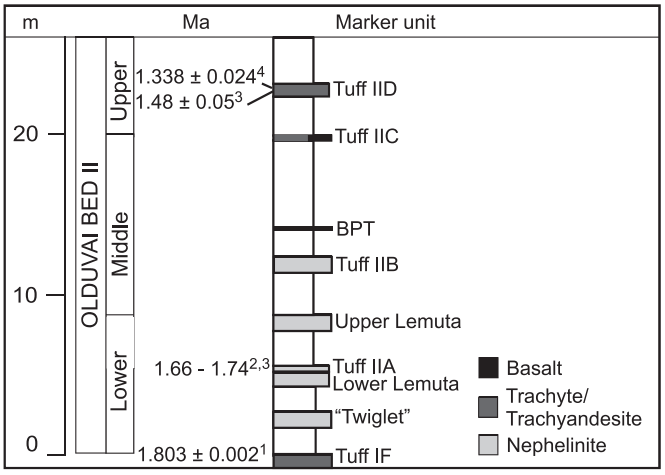

Figure 1. Olduvai Bed II tephrostratigraphy, composite section. Note that Bed II tuffs are not preserved at most sites and differ significantly in thickness and tuffaceous content; this figure provides their relative stratigraphic positions and general compositions based on the results of this study and Hay (1976). The division of Bed II into Lower, Middle, and Upper parts is based on Leakey (1971). Dates from [1]Deino (2012); [2]Curtis and Hay (1972); discussion in Torre et al. (2012); [3]Manega (1993); and [4]Domínguez-Rodrigo et al. (2013).

investigations into the nature and timing of the Oldowan–Acheulean transition. This work also helps establish a basin-wide paleolandscape context for the Oldowan–Acheulean terminus and ties together hominin, faunal, and archaeological records, providing high-resolution evolutionary context.

Background

The sediments of the Olduvai basin are exposed by the ~20-km-long and deeply incised (up to 100 m deep) Olduvai Gorge, between the Serengeti Plains to the west and Ngorongoro Volcanic Highlands (NVH) to the east (Fig. 2). Exposed strata include non-volcanic sediments as well as tuffs, lavas, and ignimbrites. The two main branches of the gorge (the Main and Side Gorges) meet at the "Junction," about 9 km west of where the Olduvai river seasonally discharges into the Olbalbal drainage sump. Hay (1976) provides a detailed introduction to the Olduvai beds. His nomenclature for sites (Localities, or "Locs") and tuffs will be used throughout this paper. It should be noted that for Bed II, Hay (1976) uses the term "Tuff" to describe both primary volcanic ash units and reworked and contaminated sedimentary units of varying volcaniclastic content.

The NVH erupted diverse volcanic materials into the Olduvai basin. The focus of the current study is on Bed II, the second oldest and most extensive of the Olduvai Beds; a composite stratigraphic section is provided in Figure 1. Its tuffs are typically silica undersaturated, ranging from nephelinites to trachytes with some basaltic ash. Bed II can be subdivided into Lowermost Bed II, which is dominated by a saline–alkaline lake and lake margin similar to that of Upper Bed I; the Lemuta Member, an eolian tuffaceous unit in the eastern gorge at the transition between Lowermost and Middle Bed II, and Middle to Upper Bed II, with its much smaller lake. A significant (but not well dated) disconformity separates the Lemuta Member from overlying deposits. Important marker tuffs include Tuff IF (uppermost unit of Bed I), Tuff IIA (within the Lemuta Member), Tuff IIB (a mappable unit in the Junction and Side Gorge with a limited volcaniclastic component), the Bird Print Tuff (BPT, locally preserved in the Junction, Side Gorge, and lake center), Tuff IIC (only a primary tuff locally on the south side of the eastern gorge), and Tuff IID (widespread trachytic tuff in upper Bed II).

Paleoanthropology

The nature and timing of the transition from *H. habilis* to *H. erectus* and Oldowan to Acheulean traditions is a longstanding debate in human origins research (e.g., Leakey et al., 1964; Leakey, 1966, 1971; Antón, 2003, 2012; Lordkipanidze et al, 2013; Wood, 2014). Bed II contains a more varied – and contentious – archaeological record than Bed I, which is only associated with Oldowan technology (Leakey, 1971). Lowermost Bed II assemblages are similar to those of Bed I, and are widely attributed to the classic Oldowan (Leakey, 1971; Blumenschine

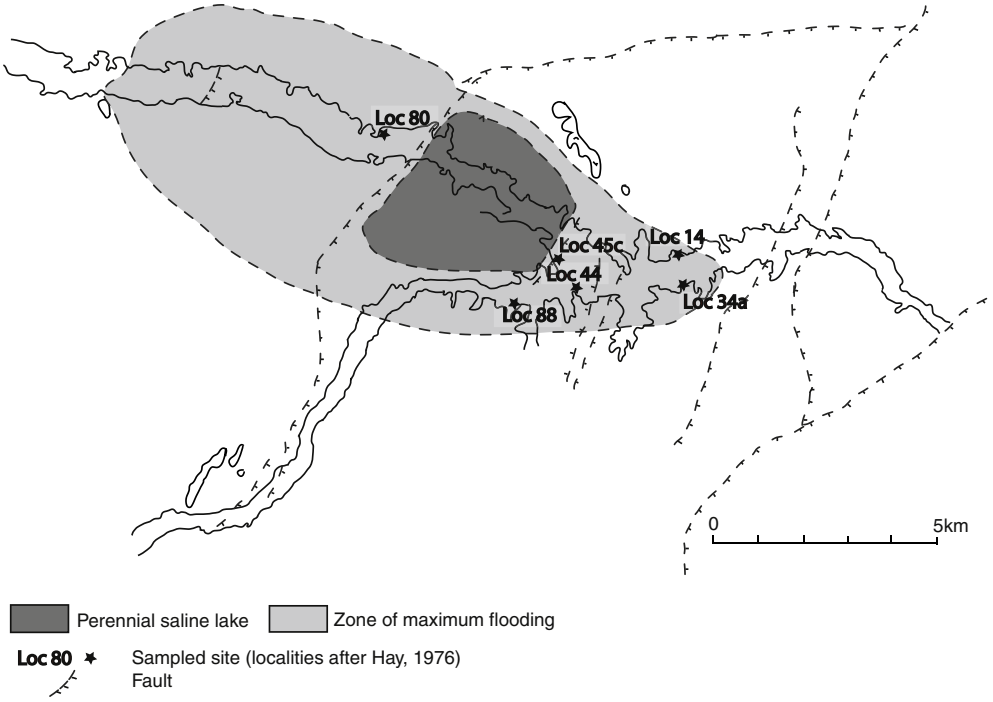

Figure 2. Map of the Olduvai basin, showing the outline of the modern gorge, and the extent of the paleo-lake at the time of deposition of the Bird Print Tuff (Middle Bed II) as reconstructed by Hay (1976). Locations of sampled and measured sections along with other sites mentioned in the text are indicated, using Hay (1976) locality names.