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Reprint of Glass compositions and tempo of post-17 ka eruptions from the Afar Triangle recorded in sediments from lakes Ashenge and Hayk, Ethiopia

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ABSTRACT

Numerous volcanoes in the Afar Triangle and adjacent Ethiopian Rift Valley have erupted during the Quaternary, depositing volcanic ash (*tephra*) horizons that have provided crucial chronology for archaeological sites in eastern Africa. However, late Pleistocene and Holocene tephras have hitherto been largely unstudied and the more recent volcanic history of Ethiopia remains poorly constrained. Here, we use sediments from lakes Ashenge and Hayk (Ethiopian Highlands) to construct the first <17 cal ka BP tephrostratigraphy for the Afar Triangle. The tephra record reveals 21 visible and crypto-tephra layers, and our new database of major and trace element glass compositions will aid the future identification of these tephra layers from proximal to distal locations. Tephra compositions include comendites, pantellerites and minor peraluminous and metaluminous rhyolites. Variable and distinct glass compositions of the tephra layers indicate they may have been erupted from as many as seven volcanoes, most likely located in the Afar Triangle. Between 15.3–1.6 cal. ka BP, explosive eruptions occurred at a return period of <1000 years. The majority of tephras are dated at 7.5–1.6 cal. ka BP, possibly reflecting a peak in regional volcanic activity. These findings demonstrate the potential and necessity for further study to construct a comprehensive tephra framework. Such tephrostratigraphic work will support the understanding of volcanic hazards in this rapidly developing region.

1. Introduction

1.1. Geological setting

The Afar Triangle of northern Ethiopia represents one of the best examples of an active rifting system on Earth, marking the juxtaposition of the Arabian, Somalian and African plates above a mantle plume (Schilling, 1973; Mohr, 1978). During the Quaternary, explosive eruptions occurred at many volcanoes in the Afar Triangle and the adjacent Ethiopian Rift Valley (Pyle, 1999). Volcanic ash (*tephra*) ejected by explosive eruptions may be dispersed over ranges of hundreds or thousands of kilometres, forming widespread chronostratigraphic markers in sedimentary archives. Pleistocene tephras have been correlated throughout Ethiopia, Kenya and the Gulf of Aden and have been crucial in providing chronological control for regional palaeoanthropological sites (e.g. Brown, 1982; Pickford et al., 1991; WoldeGabriel et al., 1999; Katoh et al., 2000; Clark et al., 2003; Brown et al., 2006; Haile-Selassie et al., 2007; Campisano and Feibel, 2008; DiMaggio et al., 2008; Saylor et al., 2016).

Regional volcanic activity has continued into the Holocene. However, of the ~40 Holocene volcanoes in the Afar Triangle, very few have recorded historical eruptions (Siebert et al., 2011). Recent explosive volcanism has occurred from the Nabro Volcanic Range

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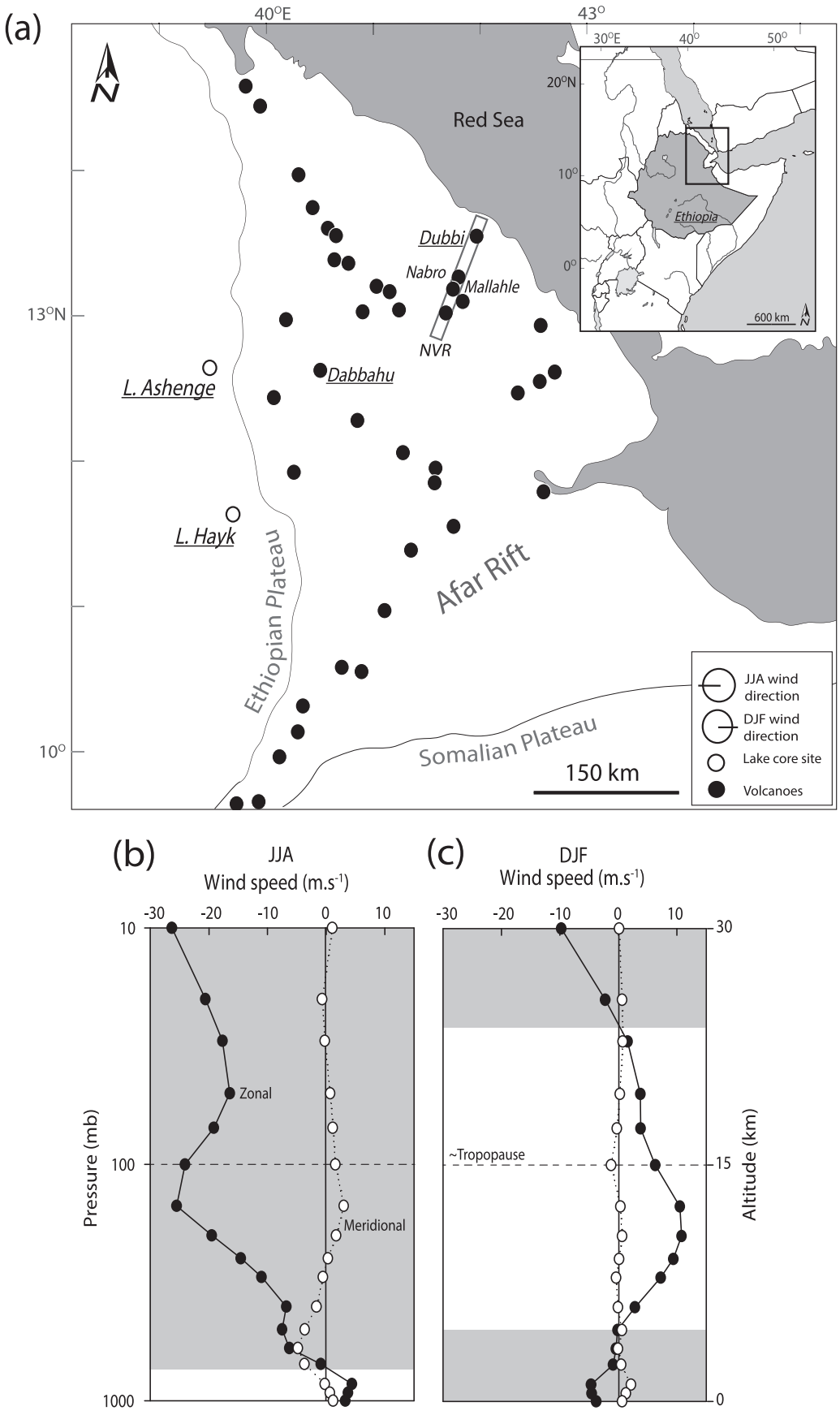

Fig. 1. (a) Map of the Afar (N Ethiopia) showing the location of lakes Ashenge and Hayk and Holocene volcanoes (Siebert et al., 2011). Volcanoes referred to in the text are labelled, NVR = Nabro Volcanic Range. (b) Profile through atmosphere showing the speed of zonal and meridional winds during the summer and (c) winter monsoon months, after Feakins et al. (2007). Wind velocities are from the NOAA NCEP CDAS-1 monthly pressure level climatology dataset spanning January 1949–January 2016 (Kalnay et al., 1996), averaged over 40–45°E, 10–15°N. Favourable wind directions for transporting tephra to the Ethiopian Highlands are shaded in grey, negative (positive) wind speed values indicate easterly (westerly) flow of zonal winds and southerly (northerly) flow of meridional winds.