Quaternary International xxx (2016) 1–18

Contents lists available at ScienceDirect

Quaternary International

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

Desert agricultural systems at EBA Jawa (Jordan): Integrating archaeological and paleoenvironmental records

Julia Meister [a, b, *], Jan Krause [a, b], Bernd Müller-Neuhof [b, c], Marta Portillo [b, d, e], Tony Reimann [f], Brigitta Schütt [a, b]

[a] Freie Universität Berlin, Department of Earth Sciences, Physical Geography, Malteserstraße 74-100, 12249 Berlin, Germany
[b] TOPOI Excellence Cluster, Hittorfstraße 18, 14195 Berlin, Germany
[c] German Archaeological Institute, Orient Department, Podbielskiallee 69, 14195 Berlin, Germany
[d] Department of Geography, Prehistory and Archaeology, University of the Basque Country, Francisco Tomás y Valiente s/n, 01006 Vitoria-Gasteiz, Spain
[e] ERAAUB, Department of Prehistory, Ancient History and Archaeology, University of Barcelona, Spain
[f] Wageningen University, Soil Geography and Landscape Group & Netherlands Centre for Luminescence Dating, Droevendaalsesteeg 3, 6708 Wageningen, Netherlands

A R T I C L E I N F O

Article history:
Available online xxx

Keywords:
Ancient agricultural terraces
Early Bronze Age
Terrace fill sediments
Multi-proxy approach
Phytoliths
OSL dating

A B S T R A C T

Located in the arid basalt desert of northeastern Jordan, the settlement of Jawa is by far the largest and best-preserved archaeological site in the region. The Early Bronze Age (EBA) settlement phase of Jawa (3500–3000 BCE) is characterized by a highly sophisticated water storage system made of a series of pools, dams, and canals. In addition, recent archaeological and geoarchaeological surveys have uncovered agricultural terrace systems in the nearby vicinity.

In this study, four of these runoff terrace systems were investigated by detailed mapping. Additionally, thirteen sediment profiles from inside and outside the terrace systems were recorded and sampled. The examined samples were analyzed for bulk chemistry, texture, phytoliths, diatoms, and dung spherulites to supply information on the environmental and depositional conditions. The terrace systems were dated using optically stimulated luminescence (OSL).

Ancient terrace agriculture was practiced on slopes, small plateaus, and valleys close to Jawa through the use of surface canals, which collected and diverted floodwater from nearby wadis or runoff from adjacent slopes. The terraced fields were usually arranged in cascades and comprised a system of risers, canals, and spillways. The terrace fills investigated yield OSL ages of around 3300 BCE, indicating that the terraces were constructed in the Early Bronze Age. The terrace fill sequences are composed of mixed unstratified fine sediments of local origin, reflecting low-energy fluvial deposition regimes. The phytolith record is dominated by Pooid grasses that include the most common Near Eastern cereals, such as wheat and barley. Increased phytolith concentrations in terrace fill sediments, as compared to samples from non-terrace deposits nearby, suggest increased plant growth and water availability within the terraces. Whether the terrace systems were used for growing food crops only or whether they were additionally used for grazing cannot be ascertained. Overall, quantitative phytolith analyses in arid environments are well suited to investigate temporal and spatial distributions of plant microfossil concentrations and their relation to human activity or paleoenvironmental conditions.

1. Introduction

The fortified settlement of Jawa, approximately ten hectares in size, is located in the basalt desert steppe of northeastern Jordan and is by far the largest and one of the best-preserved Early Bronze Age sites in the region. It may have functioned as an important trading center between the southern Levant and Mesopotamia (Müller-Neuhof, 2014a). Jawa has been partly excavated between

* Corresponding author. Freie Universität Berlin, Department of Earth Sciences, Physical Geography, Malteserstraße 74-100, 12249 Berlin, Germany. Tel.: +49 30 83870239.

E-mail addresses: j.meister@fu-berlin.de (J. Meister), jan.krause@fu-berlin.de (J. Krause), bernd.mueller-neuhof@dainst.de (B. Müller-Neuhof), marta.portillo@ehu.eus (M. Portillo), tony.reimann@wur.nl (T. Reimann), brigitta.schuett@fu-berlin.de (B. Schütt).

http://dx.doi.org/10.1016/j.quaint.2015.12.086
1040-6182/

1972 and 1976 by S. Helms (Helms, 1981; Betts, 1991). The pottery remains indicate two occupation periods: the earlier and largest occupation phase, in which Jawa may have up to 5000 inhabitants, dates to the end of the Late Chalcolithic and beginning of the Early Bronze Age (Levantine Early Bronze Age IA, c. 3500–3000 BCE, as verified by radiocarbon dating, see Müller-Neuhof et al., 2015). A later and much smaller reoccupation of the site dates to the transition from the Early Bronze Age IV to the Middle Bronze Age I (around 2000 BCE).

The Jawa region is located in transition zone between the semi-arid southern Levant and the arid Syrian Desert, where these climatic conditions roughly prevailed since the Mid-Holocene aridisation (Robinson et al., 2006; Rambeau, 2010; Finné et al., 2011; Roberts et al., 2011). While the Dead Sea area has been extensively studied (e.g. Bar-Matthews et al., 1997, 1998, 1999; Frumkin et al., 1999; Migowski et al., 2006; Neumann et al., 2007; Bar-Matthews and Ayalon, 2011), there is a lack of high-resolution proxy records in northeastern Jordan (Rambeau, 2010; Finné et al., 2011). Therefore, detailed reconstructions of paleoenvironmental conditions during the Late Pleistocene and Holocene for Jawa are missing. According to isotopic compositions of speleothems from the Soreq Cave in Israel (Bar-Matthews et al., 1998, 1997), annual rainfall rates during the second half of the fourth millennium BCE are estimated to have been temporarily ~100 mm higher than today (Issar and Zohar, 2004). However, this does not necessarily mean that the Jawa region shared the same temporal and intense precipitation conditions (Rambeau, 2010).

The seemingly unfavorable environmental conditions in the region necessitated water management strategies to supply Jawa's inhabitants with local food and water (Roberts, 1977; Helms, 1981). The site's highly sophisticated water storage system appears to be one of the earliest hydraulic system of its kind in the world (Roberts, 1977; Helms, 1981; Viollet, 2007; Whitehead et al., 2008). Combining a series of pools, dams, and canals to utilize surface and wadi runoff, it could probably meet the water demand of a population of 6000 and their livestock, at least during predicted wetter times of the Early Bronze Age (Whitehead et al., 2008).

For subsistence, the inhabitants of the Early Bronze Age settlement relied on agropastoralism with some hunting; animal remains at the site are dominated by sheep and goat (86.7%), followed by cattle (8.5%) and gazelles (2.3%) (Köhler, 1981). Evidence of farming is shown in the large number of grinding stones and sickle blades (Helms, 1981) as well as plant remains, including several cereal seed taxa such as six-row hulled barley (*Hordeum vulgare*), einkorn (*Triticum monococcum*), bread wheat (*Triticum aestivum sensu lato*), and emmer (*Triticum dicoccum*) (Willcox, 1981). Apart from a few small areas, however, evidence of arable land in the vicinity of Jawa has been scant until this study (Mithen et al., 2008).

Recent archaeological and geoarchaeological surveys have revealed the well-preserved remains of several abandoned complex runoff terrace systems in the vicinity of Jawa (Müller-Neuhof, 2014a, 2014b, 2012). Runoff terraces are one of the various types of agricultural terraces (reviewed in e.g. Frederick and Krahtopoulou, 2000; Spencer and Hale, 1961; Treacy and Denevan, 1994) typical for the southern Levant (e.g. Evenari et al., 1982; Beckers et al., 2013b). They are usually built across channel beds and floodplains of ephemeral rivers (*wadis*) or on hillslopes. The terraces consist of stone walls (commonly called *risers*) which retain and collect water and sediments of episodic flash floods and runoff events, gradually silting up the fields in a self-filling process. When the terrace surfaces are sufficiently leveled and large enough, they are cultivated (commonly known as *tread)*. The sediment body referred to as *terrace*- or *tread fill* (Fig. 5a). Once the terrace is filled, the farmer can easily enlarge its sediment storage capacity by adding a new row of stones on top of the riser (Beckers et al., 2013b).

Located on small plateaus or on the valley floor of Wadi Rajil and its tributaries, the runoff terrace systems at Jawa were only partly recognized during earlier surveys or were interpreted as animal pens (Helms, 1981). According to lithic evidence, the initial construction of these systems most presumably dates to the Late Chalcolithic/Early Bronze Age. If so, they would be the oldest example of its kind known to date (Müller-Neuhof, 2014b).

However a detailed description of these systems is missing and the dating is still being debated. In this study we document these terrace systems through detailed mapping in order to gain a better understanding of their function. We also take a multi-proxy approach for studying sediment records of different terraces. By investigating bulk chemistry, texture, phytoliths, diatoms, and dung spherulites we aim at characterizing their environmental and depositional conditions. Furthermore, we clarify whether the sedimentary record and the paleoenvironmental proxies analyzed are suitable for identifying former land use (crops or pasture), especially in this nowadays desert environment where organic remains are often rare. In order to establish a chronology of the terrace systems we applied optically stimulated luminescence (OSL) dating on sediments from two selected terraces.

2. Regional setting

The ancient settlement of Jawa (32.336 N, 37.002 E, 1002 m asl) is located on Wadi Rajil in the basalt desert steppe (Arabic *al-harra*) in northeastern Jordan, close to the Syrian border (Whitehead et al., 2008; see Fig. 1a, b). Geologically, the region is part of the north Arabian volcanic province of Harrat Ash Shaam, which extends from southern Syria to Saudi Arabia and is composed of Quaternary and Neogene basalt lava flows extruded from widespread volcanic centers (Bender, 1968; Taqieddin et al., 1995; Allison et al., 2000). There are numerous small volcanoes and fissures in the Jordan territory (Bender, 1968), and the relief gradually declines from north to south, with elevations ranging between c. 1200 and 400 m asl (Allison et al., 2000). The topography is dominated by a gently undulating plain riddled by low hills. Slopes are generally slightly inclined and concavo-convex in shape. Between the basalt hills, depressions filled with fine-grained sediment deposits are common, locally called *Qa'a* (Al-Homoud et al., 1996). Apart from these topographic lows, the entire surface area is covered with extensive stone pavements formed by basalt boulders of varying size and shape from the weathering of the volcanic rocks (Allison et al., 2000).

As for climate, this region is located in the transition zone between the Mediterranean climate and the fully arid zone that predominates in northeastern Jordan (Al-Homoud et al., 1996). Following the Köppen-Geiger classification, the area around Jawa is classified as a hot desert climate (BWh) (Kottek et al., 2006), characterized by marked seasonal variations: hot, dry summers and cool, moist winters (Allison et al., 2000). The average summer temperature reaches 28 °C, while the mean winter temperature is 10 °C. Under present-day conditions, the mean annual rainfall is less than 100 mm and occurs mainly between November and March (see the climate diagram for the nearby Safawi station, shown in Fig. 1a, c). The mean annual temperature is about 19 °C and potential evaporation rates are high, ranging from 1500 mm*a^{-1} to 2000 mm*a^{-1} (Allison et al., 2000). Strong winds occur frequently, in the summer coming mostly from the northwest and in the winter prevailing from the northeast, caused by cyclonic disturbances from the Mediterranean Sea (Al-Homoud et al., 1996).

In the absence of natural springs, the only natural water sources are ephemeral river systems (Arabic *al-wādī*) and groundwater aquifers