Journal of Archaeological Science 69 (2016) 1–11

Contents lists available at ScienceDirect

Journal of Archaeological Science

journal homepage: http://www.elsevier.com/locate/jas

The Early Bronze Age/Middle Bronze Age transition and the aquifer geography in the Near East

Konstantin Pustovoytov [a, b, *], Simone Riehl [a, c]

[a] Institute for Archaeological Science, University of Tübingen, Rümelinstr. 23, 72070 Tübingen, Germany
[b] Institute of Soil Science and Land Evaluation, University of Hohenheim, Emil-Wolff-Str. 27, 70599 Stuttgart, Germany
[c] Senckenberg Center for Human Evolution and Palaeoenvironment, University of Tübingen, Rümelinstr. 23, 72070 Tübingen, Germany

ARTICLE INFO

Article history:
Received 19 August 2015
Received in revised form
12 February 2016
Accepted 26 February 2016
Available online 25 March 2016

Keywords:
Aquifers
Groundwater
Bronze Age
Near East
GIS

ABSTRACT

Groundwater often remains a neglected natural resource in archaeological studies in the Near East. Here we examine the potential role of aquifers in transitional phenomena in the eastern Mediterranean at the Early Bronze Age (EBA) – Middle Bronze Age (MBA) boundary using geographic relations between aquifers and archaeological settlements. As a basis for this analysis, the aquifer areas within buffers zones of 5, 10 and 20 km around the sites were used. For comparison, the total watercourse lengths within the same zones were calculated. Although no substantial changes in watercourse lengths could be found, the aquifer geography around EBA and MBA sites did show regional differences. The proportion of settlements with aquifers in upper Mesopotamia and the northern Levant doubled during the transition from EBA to MBA, whereas in the southern Levant this proportion decreased. We propose several explanatory models for these results: environmental (desiccation regional trend around 4.2 ka BP), non-environmental (changes in strategic importance, subsistence economy or hygienic requirements) and combined (human-induced transformation in the vegetation, changes in soil properties or changes in human perception of the environment followed by changes in behavioral attitudes). This study further emphasizes the potential of GIS-based spatial analysis applications in archaeology.

1. Introduction

The transition from the Early Bronze Age (EBA) to the Middle Bronze Age (MBA) represents one of the central milestones in the history of the Near East. It was accompanied by considerable changes in political, economic and cultural life. The most prominent features of this period were the decline and abandonment of urban settlements, decentralization of political power, increase in nomadism and pastoralism (Weiss, 2012; Weiss et al., 1993; Schwartz, 2007; Ur, 2010; Amiran, 1969; Parr, 2009). These changes are often considered as signs of 'collapse', not only among researchers but also in popular science literature (Diamond, 2005), although the criteria for the term 'collapse' as well as 'crisis' are still a matter of debate (Meijer, 2007; Schwartz, 2007; Yoffee, 2010). The driving forces of these processes are controversial. Increased aridity through climatic fluctuation has become the most frequently proposed explanation (Weiss, 2012; Weiss et al., 1993; Hole, 1997). This is, among others, due to the fact that paleoclimate records in the eastern Mediterranean region indicate a cyclic climate history with an aridification trend around 2 ka cal BC, amplified by several drought peaks (Bar-Matthews et al., 1997; Bar-Matthews and Ayalon, 2004, 2011; Staubwasser and Weiss, 2006; Pustovoytov et al., 2007; Kuzucuoğlu, 2007; Roberts et al., 2011; Riehl et al., 2013). Archaeobotanical data suggest considerable changes in subsistence economy (Riehl, 2008, 2012) alongside an increase in drought stress for this period (Fiorentino et al., 2008; Riehl et al., 2008, 2014). Few paleoclimate reviewers, however, question the extent and abruptness of the 4.2 ka cal BP climate event (Finne et al., 2011). Along with climate, the decline of urban civilizations in the Near East has been attributed to other external factors, such as earthquakes (Schaeffer, 1948), volcanic eruptions (Weiss et al., 1993; Zielinski, 2000) and even cosmic impact (Courty and Coqueugniot, 2013). A purely ecological shift, whatever its nature, cannot explain, however, all the features of the EBA/MBA-transition. The urban demise seems to have had a complex geographical and chronological pattern (Schwartz, 2007; Hole, 2006). An array of centers in relatively arid sectors of the Fertile

* Corresponding author. Institute for Archaeological Science, University of Tübingen, Rümelinstr. 23, 72070 Tübingen, Germany.
E-mail address: knpustov@uni-hohenheim.de (K. Pustovoytov).

http://dx.doi.org/10.1016/j.jas.2016.02.005
0305-4403/

Crescent show a continuous occupation (Abay, 2007; Marro, 2007; Mazzoni and Felli, 2007) or even expansion (Marro and Kuzucuoğlu, 2007) during the transitional period. Also at the desert margin, stable urban settlement existed for centuries at the EBA/MBA boundary (Castell, 2007). The urban "collapse" has been also explained in terms of population growth and overexploitation of landscape resources (Wilkinson et al., 2005), but only rarely have the developmental processes been addressed with a holistic approach (Hole, 2006).

The potential environmental impact on the societal development during the EBA/MBA transition, in the above citations and other works, is most frequently considered on the basis of paleoclimate archives and the geographical position of the sites in relation to isohyets and surface hydrography. By contrast, the role of groundwater is rarely taken into account (Wilkinson, 1999, 2003; Geyer et al., 2010).

In this paper, we address the role of aquifers as potential contributors to the phenomena observed at the end of EBA and the beginning of MBA in the eastern Mediterranean sector of the Near East. An aquifer is defined as 'a water-bearing or saturated formation that is capable of serving as a groundwater reservoir supplying enough water to satisfy a particular demand, as in a body of rock that is sufficiently permeable to conduct groundwater and to yield economically significant quantities of water to wells or springs' (Poehls and Smith, 2009). One of the essential features of aquifers is that they can accumulate precipitation water and release it back, conducting within a very broad range of velocities, depending mostly on the depth below the land surface but also other factors (Domenico and Schwartz, 1998). In arid to semiarid regions, the turnover time of water within an aquifer from the recharge to the discharge zone may be as long as tens or even hundreds of millennia (Alley et al., 2002; Scanlon et al., 2006; Gholam et al., 2006; McMahon et al., 2011; Gassiat et al., 2013). In the Near East, early Holocene to mid-late Pleistocene ages have been shown for groundwater on the basis of ^{3}H, ^{14}C, U/Th dating techniques and the stable isotope composition (Bajjali and Abu-Jaber, 2001; Dabous et al., 2002; Kazemi et al., 2006; Avrahamov et al., 2010; Burg et al., 2013).

Aquifers represent an essential terrestrial water resource in arid regions (FAO, 2003). With allowance for aquifer geography, the picture of potential regional water availability can substantially deviate from what can be expected from the distribution of modern precipitation and surface water bodies alone (BGR & UNESCO, 2008). Furthermore, groundwater is a relatively conservative water resource. Although the productivity of an aquifer may vary in time, its geographical configuration obviously remains stable as long as the principal geological structure of the landscape does not change. As long-term buffer stores of rainfall water, aquifers usually are less sensitive to climate fluctuations than the patterns of atmospheric precipitation (Clifton et al., 2010; Treidel et al., 2011). Specific responses of an aquifer to climate change depend on the aquifer type (Rosenberg et al., 1999; Scibek et al., 2008; Barron et al., 2011).

Today, aquifers frequently become a political issue both at the national (Weinthal et al., 2005; Barron et al., 2011; Tanji and Kielen, 2002) and international level (Foster and Loucks, 2006; GWP INBO, 2009; Foster, Ait-Kadi, 2012; Jarvis, 2013). Likewise, it appears reasonable to assume that their importance has been similarly paramount, if not greater, in the past. The goal of this paper is to compare the distributional patterns of the Early and Middle Bronze Age sites in the eastern Mediterranean with the geographical location of major aquifers in the region. This analysis further should provide an insight into the potential role of groundwater in the economic and political transformations at the EBA/MBA boundary.

2. Materials and methods

This work analyses the interrelation between the locations of archaeological sites from the EBA and MBA periods and the substantial aquifer areas in the Near East and eastern Mediterranean. The data on archaeological sites were taken from ADEMNES, the archaeobotanical database of eastern Mediterranean and Near Eastern sites (www.ademnes.de). The database currently embraces 1206 data sets from 352 archaeobotanically investigated sites covering a time sequence between the Epipalaeolithic and the Medieval periods. Although these are obviously not all sites known to archaeologists, the sites in the database are provided with a detailed occupation history and an established chronology. Attribution of the sites to either the Early or the Middle Bronze Age is according to typology and absolute chronology as provided by the excavators. For a rough orientation, calendar chronology used in the database for the EBA and MBA periods is c. 3200–2000 BCE and c. 2000–1500 BCE respectively. A total of 96 EBA and 46 of MBA sites were taken into consideration. The site locations are presented in Fig. 1A.

The localization of aquifers is based on the hydrogeological map of the Tubingen Atlas of the Near East (Schöler et al., 1990). For analysis, extensive and highly productive aquifers, both intergranular and fissured, were taken into consideration (Fig. 1B). Additionally, for comparison purposes, the watercourses for the same territory were displayed (Fig. 1C). No differentiation between perennial, periodic or episodic water flows was made.

In a GIS application (ArcGIS 10), concentric buffer zones with distances 5, 10 and 20 km around the point symbols of archaeological sites were created (Fig. 2). These sizes of buffer zones were chosen according to the radiuses of 5 km and 10 km around settlements used in site catchment studies (Bailey, 2005). Distances of order of 20 km may have been common between neighboring urban settlements in densely populated areas of the Bronze Age Near East (Wilkinson, 2003; Wilkinson et al., 2010).

Subsequently, the intersection of these zones, with the aquifer polygons (Fig. 2a–c) and the clip of the watercourses by the buffer zones were generated (Fig. 2d–f). The total area of the intersection shape features and the total length of the clipped watercourses around the sites for every buffer zone were calculated.

3. Results

3.1. Aquifer distribution around the Early Bronze Age sites

All results of the site counting and area quantification are presented in Table 1. Fig. 3 displays the total of aquifer areas within the buffer zones around the sites. For reasons of detailed comparison, the map fragment for the Levant and upper Mesopotamia with site-related diagrams is presented in Fig. 4: top for EBA and bottom for MBA. Among all the EBA settlements under consideration, 28 (21%) sites were located directly on principal aquifers or in their vicinity, whereas 68 (79%) were beyond the 20-km aquifer proximity (Table 1, Fig. 4, top). Considering all the EBA sites, the averages of 16, 59 and 194 km^2 were found for the aquifer areas within the 5, 10 and 20 km buffers respectively. For the sites with aquifers only, the same parameter increases to 54, 203 and 665 km^2 respectively. Around the aquifer-related sites, the total aquifer area varied between 2 and 79 (5 km buffer), 34 and 315 (10 km buffer), 129 and 1257 km^2 (20 km buffer). It stands out that an aquifer, if available at a site, is present in all three buffer zones. The rest of the sites do not have any aquifers closer than 20 km to a site at all. By contrast, every settlement showed water flows within the buffer zones (Fig. 3d). The total water flow length was on average 9, 30 and 109 km inside the 5, 10 and 20 km buffers respectively. If only sites