The Search for Hidden Landscapes in the Shahrizor: Holocene Land Use and Climate in Northeastern Iraqi Kurdistan

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Abstract: Recent work in Slemani Province, Iraqi Kurdistan is beginning to reveal that the Shahrizor region, an intermontane valley located between Slemani (Suleymaniyah) city and Halabja, had a paleoenvironment that is very different from the region today. The region can be characterized as having active alluvial systems, with likely more perennial streams or greater hydrologic flow, surrounded by greater shrub and tree cover for long periods in the Holocene, lasting until about 2300 BP. At the site of Bakr Awa, which was a major regional center from the 3rd to 1st millennium BC, evidence of land use and water management, including possible flood farming/irrigation, is found. The immediate surroundings appear to have been ecologically diverse, suggesting agriculture may have only been one among multiple economic avenues in the region. Wetland plants, in particular, appear to have been greatly exploited. Barley cultivation was a major focus in the late 3rd millennium BC, which could be related to an economic focus on animal husbandry, as also supported by historical sources. Relatively wetter conditions in the late third and early second millennium BCE suggest the 4.2 ka year event had either unclear or minor impact in the region. At around 2300 BP or later, the hydrologic and climatic regime shifts to drier conditions with greater short-term climatic volatility, even though the general trend indicates conditions becoming more similar to today. Interestingly, some major global-scale climatic events, such as the Medieval Warm Period and Little Ice Age, do not, as of yet, appear to have direct parallels in the Shahrizor plain and perhaps wider region, emphasizing the need to collect multiple, local paleoenvironmental proxies throughout the Near East.

Keywords: Shahrizor, Kurdistan, Mesopotamia, land use, climate, phytoliths, speleothems, geoarchaeology

Introduction

The Shahrizor basin is an intermontane plain, which forms part of the Zagros fold-thrust belt. It is located between Slemani (or Suleimaniya) and Halabja, in Suleimaniya province (Figure 1). Although there has been much research on the structural geology of the region, there has been no palaeoenvironmental research undertaken until 2011 (Altaweel et al. 2012 and Marsh 2015).

To redress this, in 2011, and in conjunction with other project members conducting archaeological survey and excavations in the region, we started palaeoenvironmental fieldwork in the Shahrizor plain to better understand local change throughout the Holocene, using sedimentary, microfossil (phytoliths, diatoms and ostracods) and speleothem analyses. The main aims of the project are 1) to reconstruct the evolution of the plain during the Holocene, 2) to better understand the human-nature relationship and human modification of the environment, 3) to collect robust climate data for the Holocene, and 4) to better understand past alluvial processes and how these might impact site visibility (via erosion and burial).

An overriding theme of this project is the importance of collecting local proxy data in order to reconstruct and understand local environmental and cultural change. Although there have been some good palaeoenvironmental and palaeoclimatic studies carried out elsewhere in the Near East, far too many paleoclimate reconstructions have been attempted for Mesopotamia without using good proxies or depending on very distant proxies such as sea cores or Soreq cave in the southern Levant, reaching potentially erroneous reconstructions. The case study presented here demonstrates why it is so important to understand local environmental conditions rather than assuming more distant proxies represent what happened in the region during much of the Holocene. The Shahrizor is a case where general Near East paleoenvironmental trends seem to be followed at times, while on the other hand more regional and local variations appear to show important contrasts. Results highlight the importance of utilizing local proxies in studying past paleoenvironmental trends. Differences in the environmental record, particularly in comparison to today’s setting, should be reflected in the different economic and settlement strategies adopted by past inhabitants of the Shahrizor, including adopting different cultural trajectories and shaping the region’s geopolitical position.

In order to accomplish these goals, we are using a multidisciplinary approach that includes geoarchaeological and phytolith analyses, combined with data from speleothems, other microfossils, archaeological survey and excavations, and total station readings of topography. The geoarchaeological analysis comprised mainly of the identification and characterization of alluvial sedimentary layers, which can inform on changing hydrologies and the evolution of the alluvial plain throughout the Holocene. Phytoliths (‘plant rocks’) are cells and other plant parts, which have been infilled by silica and other minerals and which are then preserved in sediments and soils after the plant decays (see Piperno 2006 for further discussion; Figure 9). In this study, phytoliths were analyzed to complement the sedimentary data, determine vegetation change, to see if land use patterns and agricultural strategies could also be detected in the offsite and onsite samples, and to understand resource and crop use onsite. Samples were also taken for ostracod analysis. Ostracods can indicate past lacustrine environments as well as provide possible paleoclimate indicators (Horne et al. 2012).

Speleothems were also collected and analysed. Among the strongest terrestrial climate proxies available are those derived from speleothems (McDermott 2004), which are stalagmites formed in limestone caves. These records provide stable isotopes, particularly $\delta^{18}O$ and $\delta^{13}C$, used to reconstruct past temperatures and precipitation. Speleothems are generally dated using Uranium series (U-series) methods, with Uranium-Thorium being among the most common. The advantage of speleothems is that they provide highly dateable proxies, often with precision within less than a decade during the Holocene, and are independent of sea and ice core data, which are better for more general global circulation or climatic patterns (Broecker 1998).

To begin the study, we will present background information on current conditions, which demonstrates one endpoint of our study. We then present our data on past land use and climatic conditions in the region using geoarchaeological, phytolith, other microfossil, and speleothem data. These data cover different parts of the Holocene, likely spanning from the early Holocene until relatively recent. Finally, we discuss why these results are critical to understanding local paleoenvironmental conditions and their implications for understanding past cultures in the region.

General Background

The Shahrizor is a relatively large intermontane plain and forms part of the Shahrizor-Piramagroon basin (Ali 2007). Highland regions, primarily the Binzird, Baranan and Qara Dagh to the west, and the Zagros mountains to the east, bound the valley (Figure 1). The Tanjero is the major river that runs through the plain from the northwest to the southeast and drains into the Darband-i Khan lake, which is a modern dam lake. There are many seasonal streams and wadis, with a few perennial streams fed by springs (e.g., in the Khormal region and around Yazin Tepe). The plain contains Pleistocene terraces, hills, and fan deposits at the base of the slopes of the surrounding mountains (Altaweel et al. 2012).

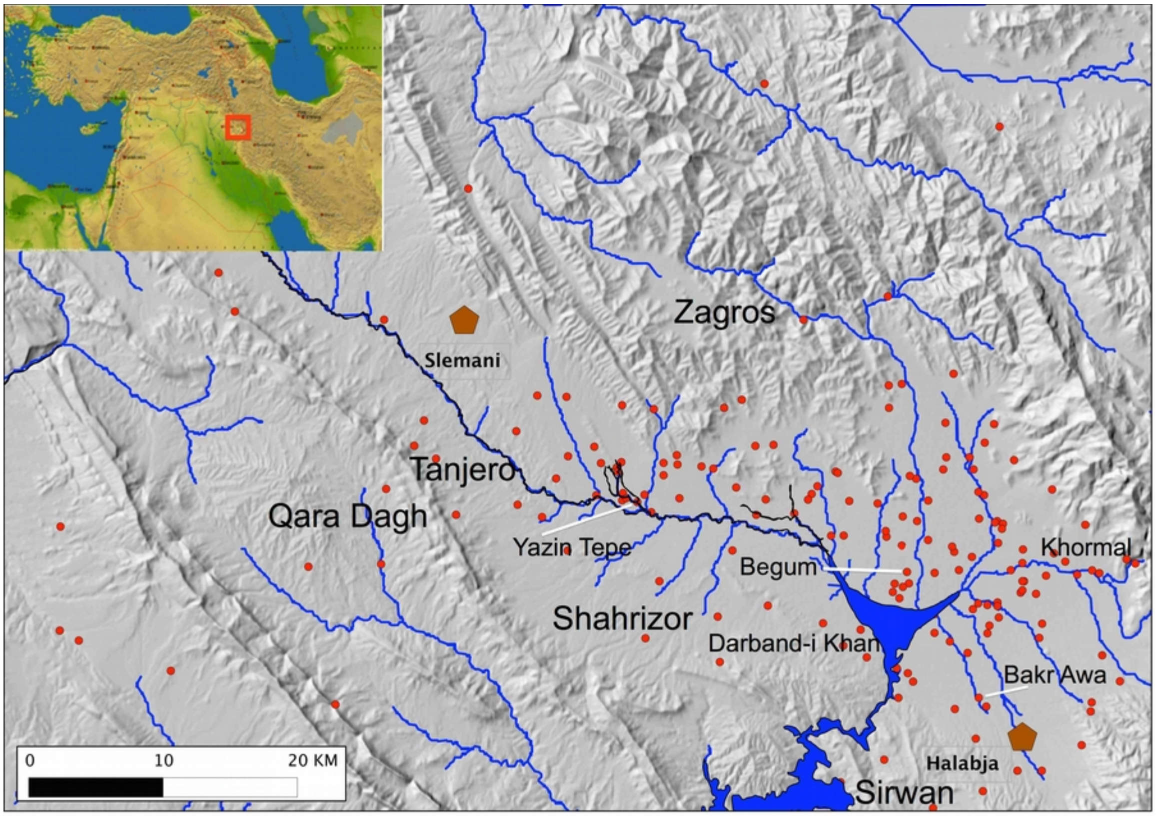

Figure 1. Map of the Shahrizor showing archaeological sites (circles), key modern cities (pentagon shapes), and geographic features. The insert shows the location of the study area in the Near East.

Modern Climate

The climate is characterized as continental Mediterranean. Mean temperature varies from 5°C in January to over 30-40°C during the summer months (Ali 2007). Precipitation generally ranges between 600-1000 mm a year, depending on the location in the basin. At the Slemani climate station, rainfall averaged 678 mm/year between 1936 to 2006 (Ali 2007; NOAA 2014).

Modern Landscape and Land use

Despite relatively high rainfall, only about 30% of the land was used for grain agriculture in the last half century, with about 50% of the land being used for grazing (Davies 1957; Sehgal 1976; Mühl 2012). Cultivated plants in the past included tobacco, rice (possibly Qush Qaya), fruits and berries. While wheat and barley are typically grown now, vegetable plots and fruit orchards can be found in arable fields as well as on the terraced hillsides. There are also small areas of riparian woodlands, mostly along the Tanjero and other perennial streams. In higher elevations, there are wild flowers, oak, pine, and Prunus trees with some naturally occurring open woodland, shrubs, and wild fruit found (e.g., wild grape observed by Fuller (2014)). The hillslopes are also in the process of being reforested, mainly to combat the problem of erosion.

Geomorphological Observations

While the hills and mountains, created through tectonic processes, are the most prominent features surrounding the valley, geomorphological processes have also shaped the valley over the millennia. These include erosion and deposition by rivers, mass wasting and slumping along the steep slopes. The foothills and mountains are highly incised, indicating past and present stream flow.

Fluvial processes are not only active in the hills and mountains, but also in the plain itself (Figure 2). Deposition of sediments certainly affect the visibility of archaeological remains, which are also impacted by modern anthropogenic processes. Many of the Pleistocene terraces appear as low hills and are made up of mostly gravels that are now commonly excavated for building materials. These Pleistocene terrace hills represent those areas not as impacted by fluvial erosion: much of the Pleistocene terraces have been incised by Holocene period channel cutting and buried with alluvium in some areas. Archaeological sites are often found on these terraces (e.g., see Altaweel et al. 2012), as they offered likely protection from flooding, stream flow, or even conflict. The Holocene terraces are more difficult to detect, other than by coring or excavated sections, because many of the earlier terraces are eroded and covered by later sedimentation.

Holocene sedimentation is heavy in the region partly because of the increased erosion due to denuding of the hill and mountainsides, but also because of stream channel activity, as will be discussed. In some areas of the region, cores and the trenches reached 6-8 meters before encountering Pleistocene gravels; similar observations were noticed in our earlier fieldwork (Altaweel et al. 2012). There may indeed be areas where the Holocene sediments are closer to 9 meters or more. Given these depths of sedimentation, many archaeological sites are likely to have been buried. This is also suggested by the cultural materials (especially brick and pottery) that have been found in section profiles many meters below the surface.

The alluvial plain soils are described as fertile, reddish-brown in color, and having a high $CaCO_3$ content. The soils are classified as Calcisols (Ali 2007) or Calcixerolls (Sehgal 1976), with the reddish color indicative of the high iron content. These soils are also known as terra rossa, a soil which is common in the Near East and across the Mediterranean and composes much of the soils found in the lower alluvial plains (Altay 1997; Bronger and Bruhn-Lobin 1997). Rendoll and Xerorthent soils are found on the mountain slopes (Sehgal 1976; Ali

2007). The uplands generally have thinly or poorly developed soils. The soils are fairly deep in the basin; we have documented soil profiles greater than a meter (Altaweel et al. 2012). The soils generally consist of silts (50-65 %), clays (30-45%), and sands (5-10 %) (Ali 2007), and are generally homogenous. The soils are alkaline (7.5-8.2 pH), with our own geochemical analysis indicating consistently more than 8.0 pH for areas sampled throughout the valley.

Methods

Geoarchaeological survey

Sections from wadi and well cuts were recorded (drawn and photographed) across the plain. In addition, three areas (Bakr Awa, Begum and Yasin Tepe) were selected for more detailed geoarchaeological survey. Trenches were excavated, recorded and sampled. The sections were drawn and described (colour, grain size, inclusions, and other features), on forms specifically designed for this project. Bulk sediment samples were described, using parameters such as colour, grain size, plasticity, and consistence. Cores were also taken from these areas.

Phytoliths and other microfossils

The processing protocol is after Rosen (2005). Each initial sample (800mg to 5g depending on context) was sieved to remove sands. Carbonates were then removed using a 10% HCL solution. Clays were removed using the settling method (based on Stokes' Law), followed by firing in an oven at 500 degrees Celsius to burn off any organic material. The phytoliths were then separated from the remaining sediment using sodium polytungstate (SPT). The phytoliths were weighed and mounted on slides with Merck New Entellen.

The slides were examined under a transmitted light Alphashot microscope at 400x magnification. Phytoliths were identified and counted for a total of 400 for single celled examples, 100 for multi cells, if possible, as some slides had few phytoliths, then tabulated on specially designed count sheets. The total number of phytoliths per gram was calculated (i.e., using number per slide/mg mounted*total phytolith weight*total sediment weight*1000) and these figures then analysed statistically.

Speleothem analysis

In Iraqi Kurdistan, there are a number of limestone caves (Stevanović et al. 2009), many of which contain speleothems. Two caves, Kuna Ba and Gejkar, are being monitored (to properly reconstruct paleocliamte, monitoring of water and air circulation within caves is critical: Mattey et al. 2008), and speleothems have also been collected, which are currently being analysed.

Results from the 2011-14 seasons

Results from the first three years of research are presented here, including the geoarchaeological survey from Bakr Awa, Begum and Yasin Tepe areas, phytolith analysis results from offsite contexts at Bakr Awa and Yasin Tepe, and onsite data from the multiperiod site of Bakr Awa. Preliminary results from a speleothem collected from Kuna Ba cave are also presented.

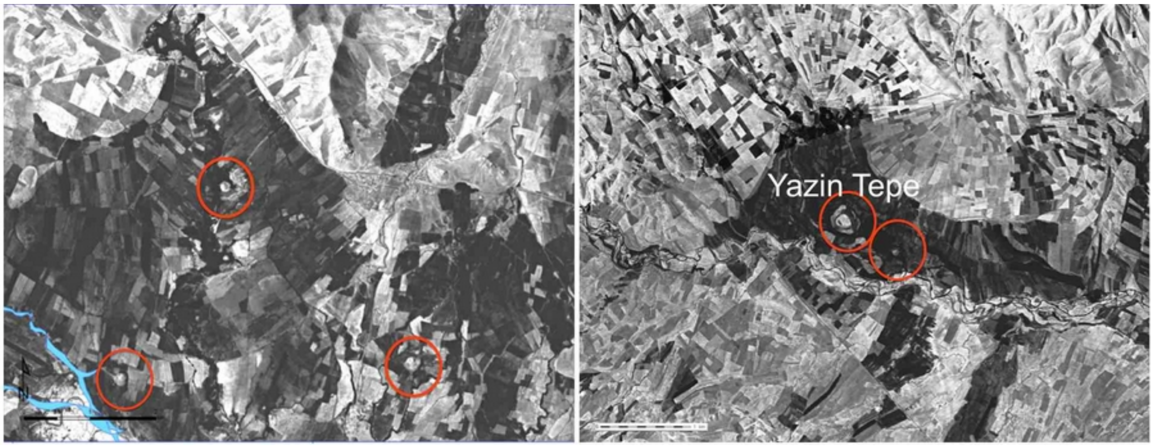

Figure 2. CORONA images showing archaeological tells (red circles) and active valley alluviation indicated by areas near the darker colors. Such alluviation in the past has contributed to diminishing visibility of archeological sites in the Shahrizor, as sites become buried over long periods.

Geoarchaeological Results

Three main regions near Bakr Awa, Begum, and Yazin Tepe (Figure 1) were studied in detail using trenches and cores. Cuts from wadi channels and wells in other parts of the plain were recorded. The following summarizes the results.

<u>Bakr Awa Region</u>

A large trench was excavated between the sites of Bakr Awa and Gurga Chiya (Figures 3 & 4). At about 6m down, a gravel layer was reached. Although gravel layers were encountered throughout the section, these differed to the base layer gravels. Firstly, the color of the base layer gravel differed, as it was pinkish rather than the blue of the gravels above, suggesting a different Cretaceous limestone source material. Secondly, there was an abrupt, erosional boundary between the base layer gravel and the clayey layer above. It is likely that this boundary marks the beginning of the Holocene sequence. A sherd of pottery was found at about 5m down, also indicating that these deposits are Holocene in age. A diagnostic sherd (Achaemenid /Hellenistic; Altaweel et al. 2012) was found above the top wadi cut in the western side of the deep sounding, about 1.8-1.95m below the surface (Figure 4: Layer OST1-5). Thus the sediments between c. 2m to 6+m represent Holocene sedimentation from c. 12,000-2300 BP.

A reddish brown clayey layer is found above the Pleistocene gravels. This layer contained iron flecks, which are flat and flexible, and a few calcium nodules (or concretions). Within this layer is a lens (Figure 4: OST1-1a), with an indistinct boundary, which was mottled and contained a higher number of calcium nodules. Above OST1-1 and 1a are two further layers, OST1-2 and 3. There is a more distinct boundary and color change from OST1-1 to OST1-2; the boundary between OST1-1/1a and OST1-3 is less distinct, but there is still a change in color to brown (7.5TR 4/4). OST1-3 cuts through OST1-2: there is a small gravel lens visible under OST1-3 in the western side of the trench (Figure 4); however, the gravel layer is much more evident on the eastern side of the trench (not pictured), so it seems the west side catches the edge of the channel. The gravels on both sides of the trench are imbricated and indicate that flow was northerly, going towards the confluence of the Diyala and Tanjero (where the dam lake is now located). OST1-3 is differentiated from OST1-2 and 3a by the presence of the calcium nodules. Boundaries between these layers are indistinct.

In the western section (Figure 4), layers OST1-2, 3 and 3a are overlain by gravel deposits. This is mirrored on the eastern side, except that OST1-3a is not present and OST1-3 shows some mottling. Again there seems to be a streambed here, and the imbrication of the gravels indicates that flow is also moving towards the old confluence.

The gravels are overlain, with a sharp boundary, by OST1-4 on the eastern side, a reddish brown (10YR 4/3) deposit consisting of mainly sands with some gravels. This is not reflected in the western section. OST1-5 (dark reddish brown: 10YR 4/2) overlies OST1-4 in the eastern section and directly on top of the gravels in the western section. This in turn is overlain by a fairly well-developed soil horizon. The soil further indicates a change in hydrology, with decreasing sedimentation and increasing plain stability, allowing for the development of soil horizons. This shift occurred in the last 2300 years.

Some of the layers were very difficult to differentiate (especially OST1-2 and 3). There were also several gravel deposits, indicating a regime of channel switching and hydrological changes, which would have eroded parts of the underlying layers and deposited new sediments over time. Although slightly different colors could be discerned (reddish to brownish), with lenses of mottling and increased calcium or iron nodule content present in some areas, the boundaries between these layers were very indistinct. These are not graded boundaries as there is no change in grain size. The boundaries seem to have been blurred, perhaps by post depositional changes. In addition, there is no trace of internal structures, (i.e., lamination).

The bulk samples taken from layers are generally crumbly in texture but also contained considerable amounts of clay. It is likely that this sediment is reworked terra rossa soil from the limestone uplands. As noted, some of the layers were mottled. This could be the result of fluctuating wet/dry periods (i.e., where the land surface was at times exposed and other times waterlogged).

The gravel cuts suggest an active floodplain where channel switching was recurrent throughout the Holocene. In some of the layers (e.g., OST1-1a and 3), there are carbonate nodules evident in varying concentrations. This could indicate warm humid conditions (Rosen 1997), where there are high temperatures combined with high rainfall and watertable. These nodules are associated with the mottling discussed above, and waterlogging may have been also caused by a higher watertable and rainfall.

Several cores (Figure 3) were taken in 2012 between Bakr Awa and Gurga Chiya. Observations indicate that sedimentation is similar across this area, with interspersed wadi gravels and channels and silty-clay deposits; however, the main difference is the depth of sedimentation. Sedimentation appears to be deepest near Bakr Awa, while deposits are shallower near Gurga Chiya (Figure 3). One core (C1) was taken on the Pleistocene terrace on which Gurga Chiya is located. Sedimentation is relatively shallow (1.5-2.0 m) on the terrace as expected, and the sediments are a mix of colluvium and alluvial deposits. Another core, C3, contains a possible fining up sequence, starting with pebbles at about 3m below the surface, shifting into silts and then silty-clay before soil formation at 1.5m down. This is typical for river sequences and thus has been interpreted as channel deposits. C5 is closest to the deep trench and its stratigraphy resembles the deep trench: the deep trench and core seem to be reflecting one or more of the same channels, although the original channel is somewhat deeper in the core (the base layer gravels are at 7m depth). Cores C6 and C7 are progressively closer to Gurga Chiya and are at slightly more elevated positions. Core C6 has Pleistocene gravels starting at about 5.0-5.4m down, with a pinkish matrix similar to what was found in the deep trench; this is overlain by clays. A channel cut evident at about 4 meters down. While it is possible that this gravel layer is the same channel as detected in C5 and the deep trench, it is also possible that it is another branch of the stream system that flows into the confluence area. C7’s Pleistocene base starts at about 3.5 meters down, showing its position further up the original terrace. This is overlain by sandy clays and clays. This deposition would have occurred much later in the Holocene and could reflect channel movement. Before this deposition, this part of the Pleistocene terrace would have been exposed.

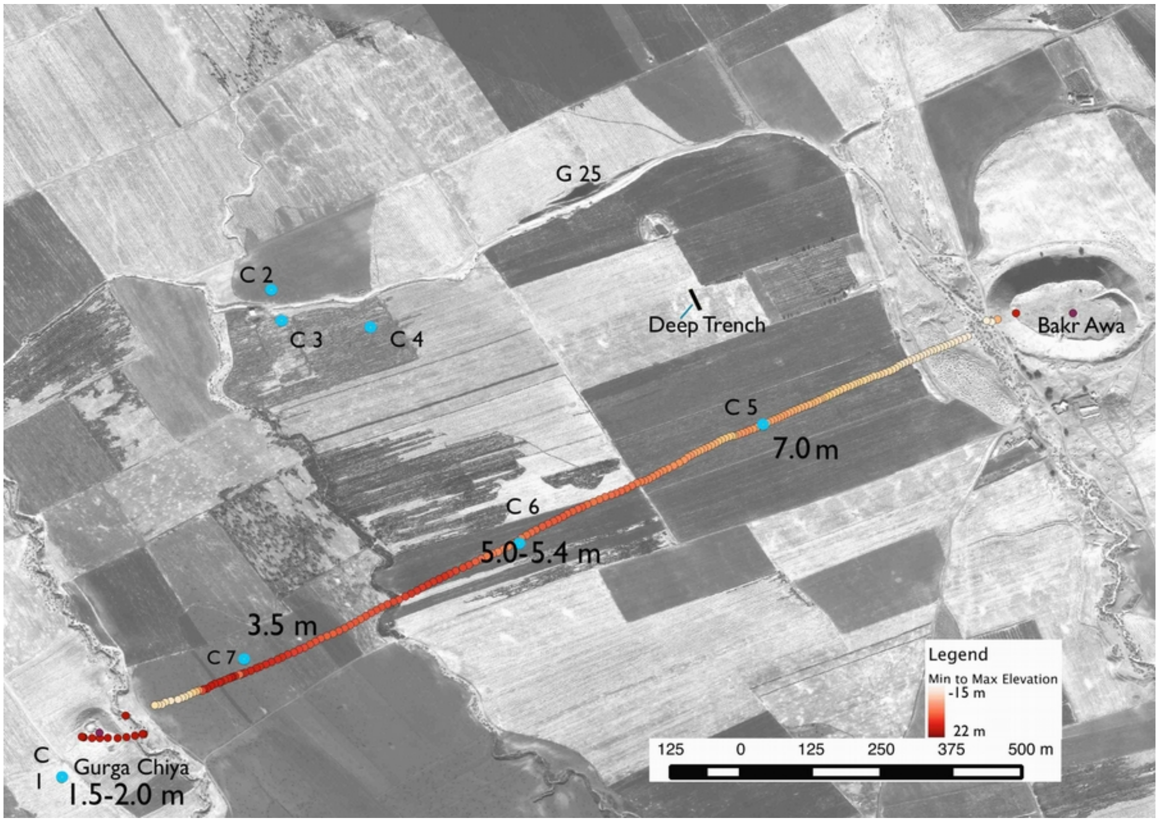

Figure 3. QuickBird November 17, 2010 image showing the Bakr Awa area investigated from 2011-2012. Points labeled as “C” are cores. Depth of sediments (in meters) before reaching Pleistocene gravels are indicated on the image.

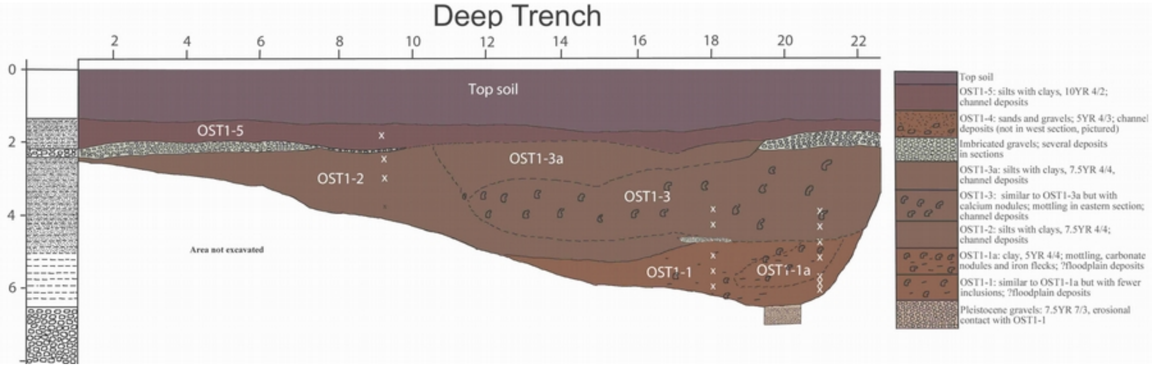

Figure 4. Reconstructed sediment profile showing the depositional sequence in the deep trench and lithology log. Measurements are in meters (Marsh 2015)

Begum Region

In the region of Begum (Figures 1 & 5), three trenches were recorded. The main issue with this area is the close proximity to the Darband-i Khan dam lake, which was created in the 1960s after the completion of the dam with the same name. Not only did this lake have a devastating effect on the archaeology now submerged, and the ecology of the river system where the Tanjero and perennial springs from the Khormal region meet, the sedimentation and buried sediments were also adversely affected. The sediments here were similar in consistency to those near Bakr Awa, in that they were mainly silts and clays, but they were mostly grey (10YR 7/2, light grey) or yellowish-brown (10YR 5/2) in color. The difference in color could of course be caused by the parent material being different; however, this seems unlikely given that there rest of the plain, as far as investigated, seems to be made up of very similar clayey-silt reddish sediments with intercalations of sands and gravels. A more likely possibility is that these sediments were originally reddish sediments derived from the terra rossa, but the dramatic rise in the water table changed the sediments’ color to a greyish hue due to reducing conditions (Wildman et al. 2010). This area under water fluctuates from season to season, with some sites becoming visible in the summer months; this seasonal fluctuation also impacts the geochemistry and stratigraphy of the sedimentary record.

As with Bakr Awa, deep sedimentation and channel cutting the Pleistocene terraces is evident. Near the site of Begum, a Halaf and later period site (Hijara 1997), which appears to be on a Pleistocene terrace, trench G35 was excavated and had a depth of around 7m or more, but the Pleistocene gravels were not reached. This area of sedimentation is deeper than that of the deep trench excavated near Bakr Awa. The exact depth was not obtained due to the fact that the watertable was high and water was rushing into the trench, making further excavation impossible. Nearer to Shamlu, where trench G31 was located, only about 3m depth was excavated, with the Pleistocene gravels again not reached because of the rising water level. Only to the east of Begum, the depth of G34 (Figure 6) reached 3.5m before the Pleistocene gravels were located. The total station results (Figure 5) indicate that the topography increases in elevation moving north and northeast of Begum towards G34. This all indicates that there is an underlying Pleistocene terrace, which was eroded by Holocene channel cutting and later covered by alluvium. The elevation dips down towards Shamlu, as it is going down towards the old confluence of the river systems. These initial channels cannot be dated, however, it is possible that they were created at around the same time as that of Bakr Awa, at the beginning of the Holocene.

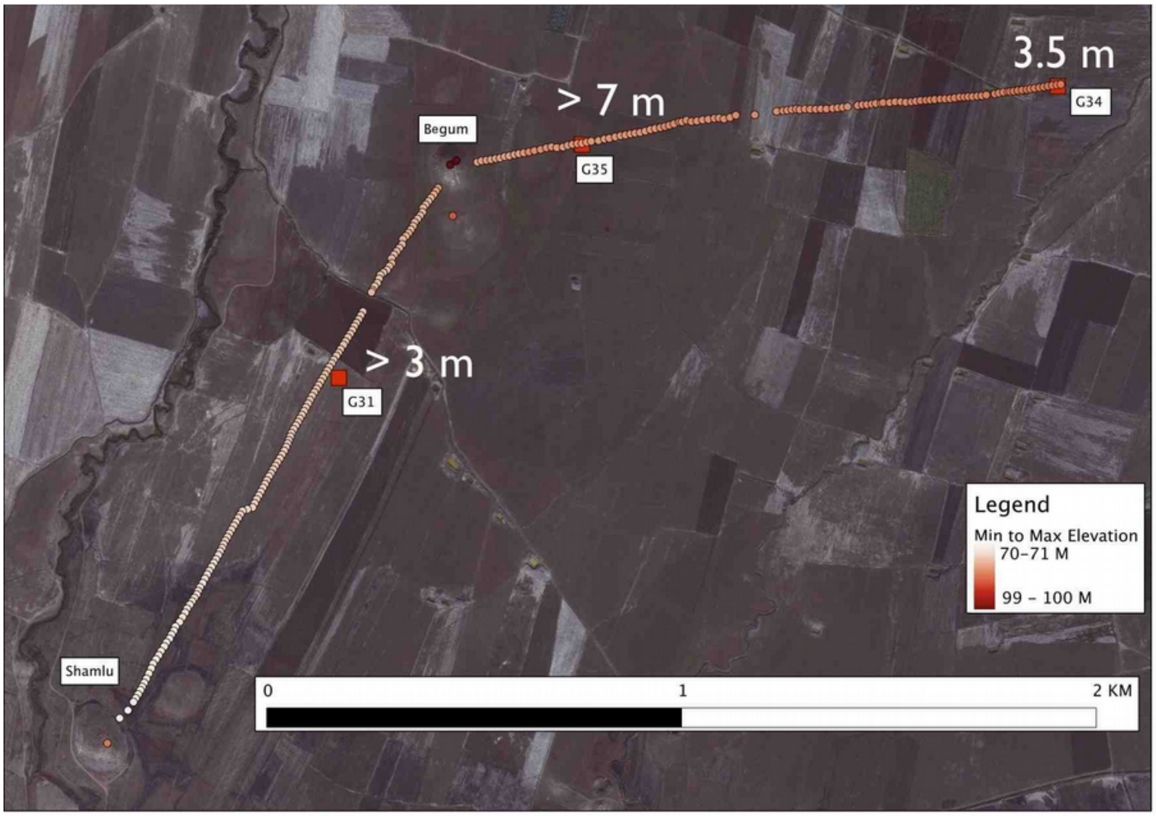

Figure 5. The region of Begum depicted in a November 17, 2010 QuickBird image with trenches excavated (G31, G34-35). The darker colors on the image reflect the high water table affecting soil colors on the image. The depths of Pleistocene gravels are indicated.

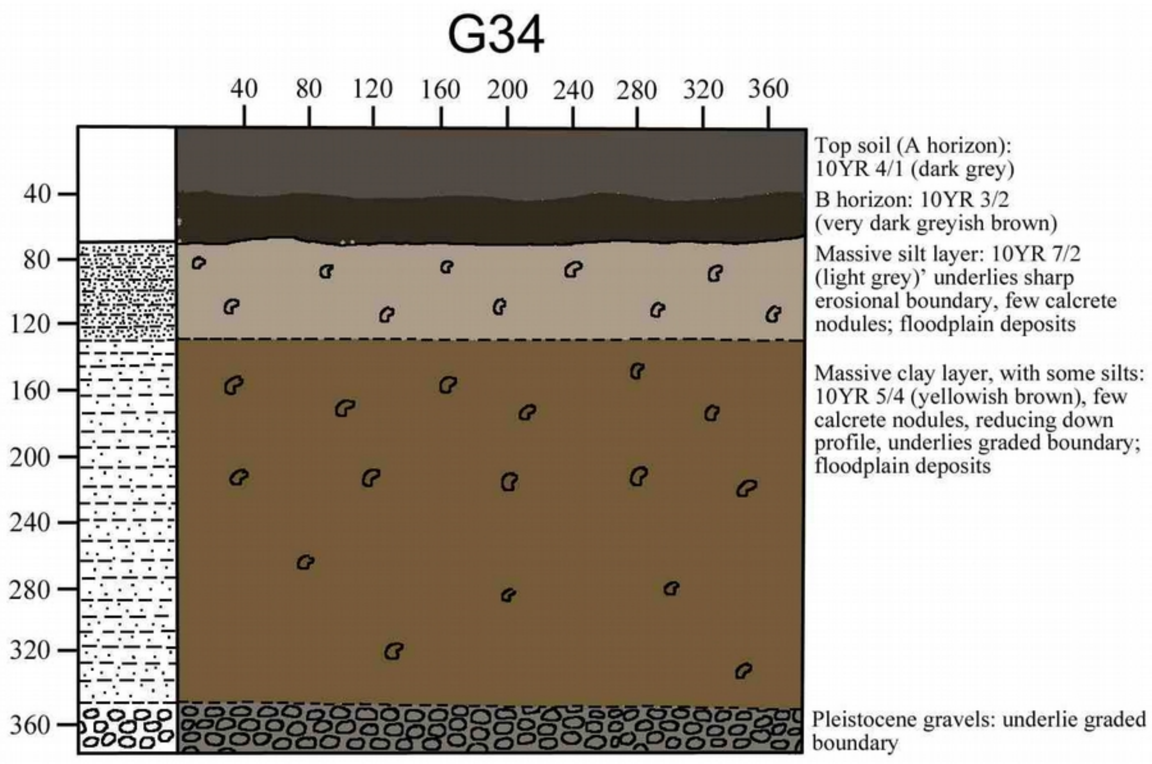

Figure 6. Sediment profile and lithology log of G34 in the Begum region (Marsh 2015).

<u>Yasin Tepe Region</u>

Yasin Tepe (Figure 1) is slightly different in that it sits on an outcrop rather than a Pleistocene terrace. The movement of the channels are also somewhat constrained by the underlying hard rock lithology. Unlike Bakr Awa, there are no channel cuts, instead there are more typical floodplain deposits, which change in grain size slightly, indicating channel migration across the plain. In 2011, a riverbed section near Yasin Tepe (Figure 7:G14) was photographed, drawn and sampled for phytoliths. On top of Pleistocene (blue and pink layered) gravels were small layers of alternating silts and sands, with charcoal throughout. This is a Holocene period terrace, but it has not been dated as of yet. This is an area that may have been farmed, with the relatively large charcoal deposits found indicating perhaps field burning. The layers alternate between clays/silts and fine-grained sands, but towards the top, there are minor layers of coarser sand, possibly indicating minor flash flooding episodes. The sediments are much greyer here, falling in the 10YR range, and are more typical alluvial sediments.

In 2013, we returned to the Yazin Tepe region and three trenches were excavated, drawn, and sampled (Figures 7 and 8), going along a transect from Yasin Tepe to the Tanjero. A total station was used in this transect to record the topography. Looking at the elevation results, a small increase in elevation near G32 is noticeable because a small archaeological site is located near G32 (Altaweel et al. 2012). The major dip in elevation is reflecting a stream channel, whose source is a spring located near the site. G32 (Figure 8) and 33 were excavated to about 4.5m before hitting Pleistocene gravels, the depth of G30 only reached about 3m as the excavator was not big enough to go further. No Pleistocene gravels were seen in this trench. The sedimentation is not as deep in this region as it is near Begum and Bakr Awa. The sediments in G32 are mainly yellowish brown (10YR 6/4) and different to those at Bakr Awa, with less evidence of terra rossa influence. The sequence coarsens upwards: the first layer above the Pleistocene gravels is composed of mainly massive clays, and the layer above is composed of massive silts. Above this layer is brown soil, with a depth of about one meter. In G32, there is a channel cut into the topsoil and going into the top sedimentary layer. Limestone rubble, bricks, and pottery sherds, with diagnostics dating to the Late Bronze Age, found in this cut, which may be associated with the nearby archaeological site. The cut is likely a more modern irrigation channel, given its location in the G32 profile, but this has not been confirmed by a radiocarbon date.

Trench G30 is very similar, although the full extent of the Holocene sedimentation could not be exposed. At the bottom of the trench, there is a clay layer, overlain by sands with some clays. Both have massive structures. The colors of the sediments do differ somewhat from G32, being more in the 7.5YR range (brownish) and thus more similar to those at Bakr Awa. The sedimentation may be a bit shallower in this trench than G32: gravels were seen at the bottom, which could have been the top of the Pleistocene layer. G33 again had similar sedimentation to the other two trenches, a massive clay bed overlying the Pleistocene gravels, and which in turn is overlain by a massive silt bed. The colors appear to be lighter here, and more yellowish (10YR 8/3: very pale brown and 10YR 5/4: yellowish brown). There is also an area in the second layer (the massive silt layer) and below the soil horizon, which is a lens of clayey silt and is a slightly different color. The boundary was indistinct. This may have been a more waterlogged area in the floodplain.

The sediments in the three trenches likely represent floodplain deposits, the increasing grain size reflecting either a shift in stream power or location of the channel.

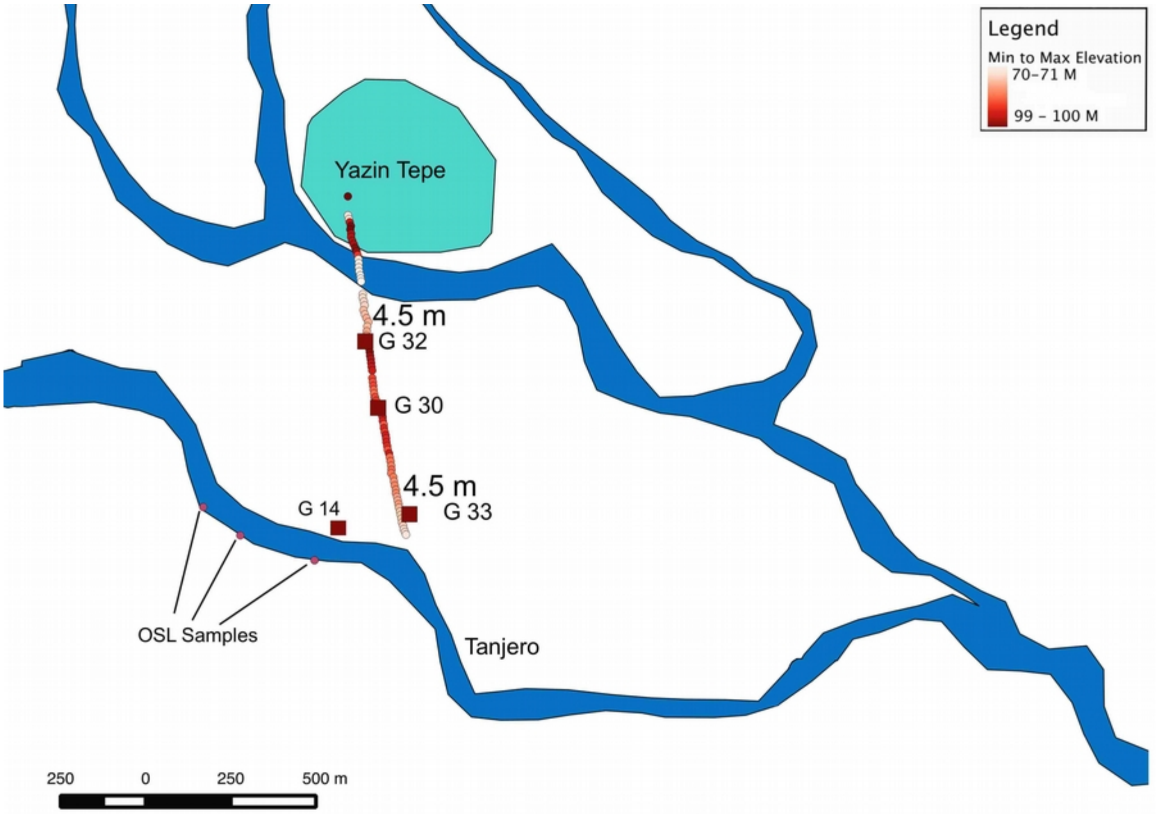

Figure 7. Trenches (G30, 32-33) and elevation transect in the region of Yazin Tepe with a sedimentary exposure (G14) investigated in 2011.

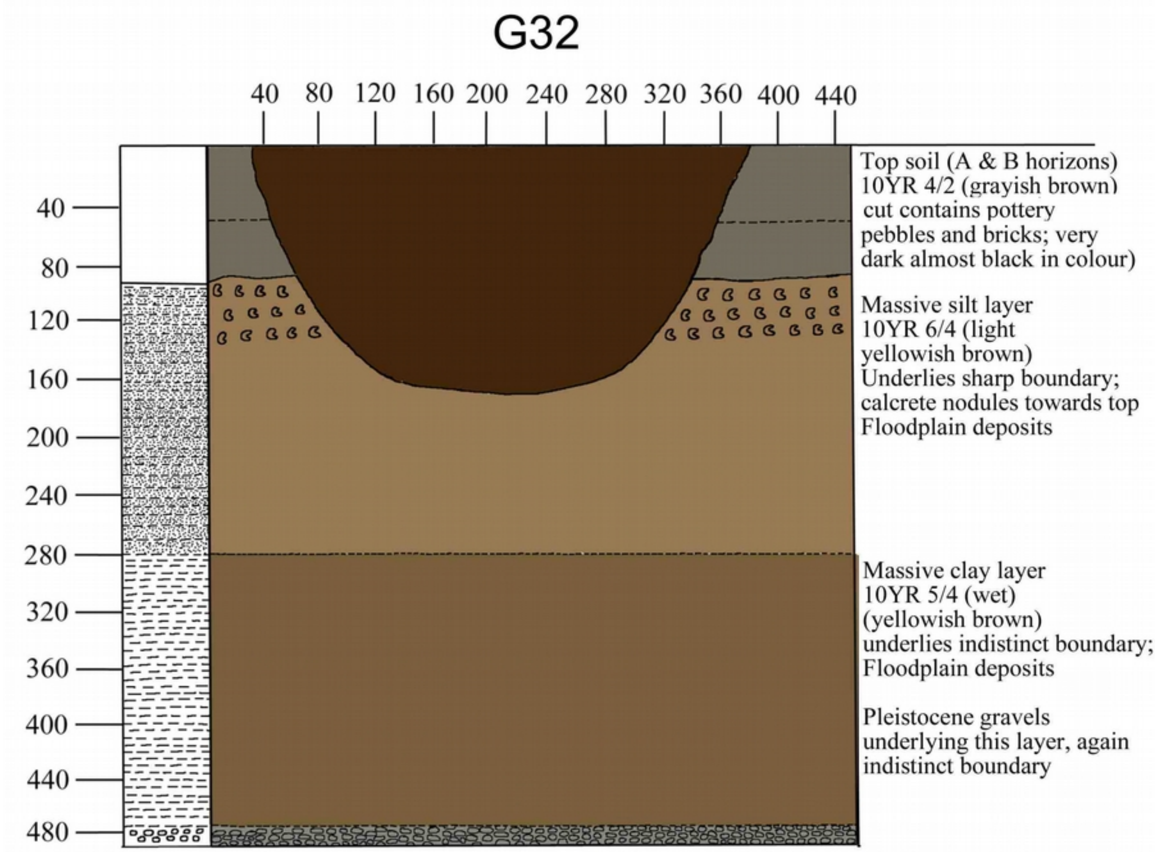

Figure 8. Sedimentary profile and lithology log of G32 from the Yazin Tepe area.

Phytolith Results

Phytolith samples were taken from the multiperiod site of Bakr Awa (Miglus et al. 2013) and from the deep trench near Bakr Awa and section G14 at Yazin Tepe (Table 1).

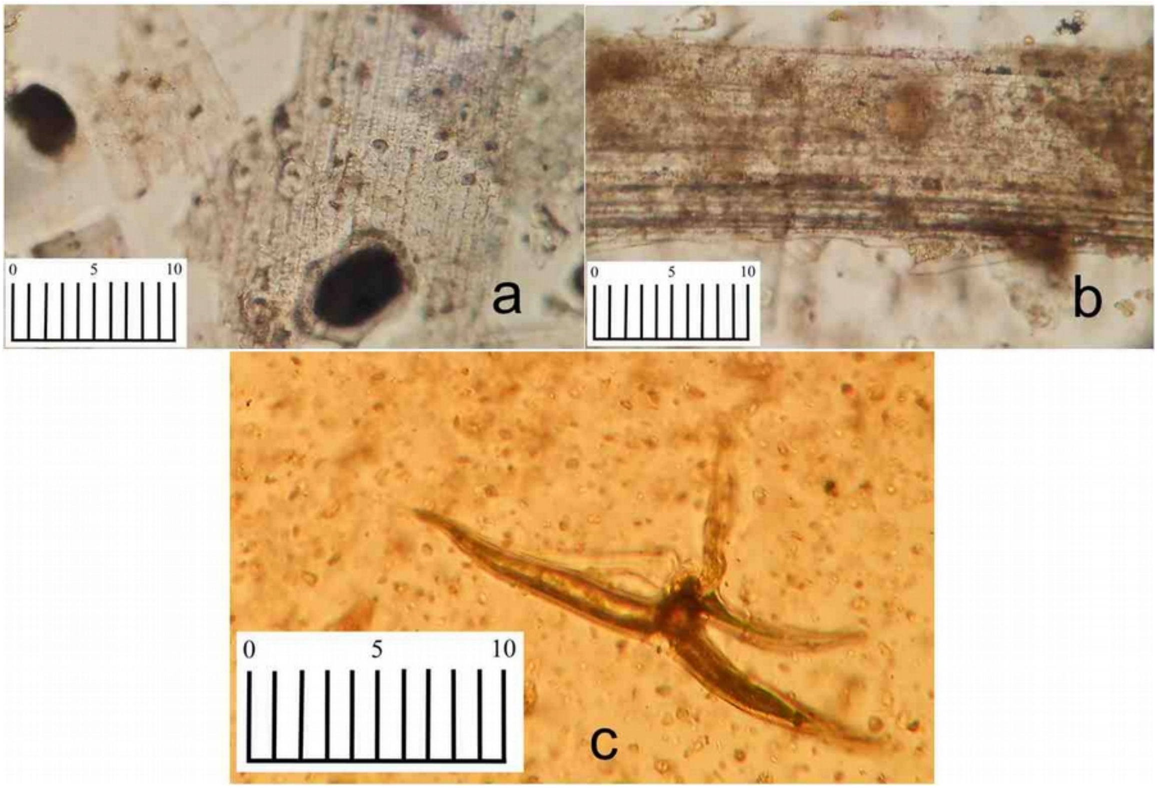

Figure 9. Images of microfossils from Bakr Awa samples (a: cereal husk multicell, b: grass stem multicell) and offsite samples (c: sponge spicule).

Offsite Samples

The samples (Table 1) taken from the deep trench are not dated, although all predate 2300 BP, as the samples came from near or below the Achaemenid/Hellenistic sherd found in the deep trench and above the Pleistocene-Holocene boundary. Attempts were made to date the sediments from the trench, but all AMS dates were found to be Pleistocene, indicating the sediments are reworked soil with older organic matter contained within. This also has implications for some, although not all, of the phytoliths that were found in the samples.

Total silica content of offsite samples is very low, all falling below 0.5%, which is expected as preservation is less in offsite contexts, mainly due to soil formation processes which can break down silica (Alexandre et al 1997). Phytolith abundance was, thus, almost universally low. Counts (that is 400 for single cells and 100 for multi-cells, see above) were not reached for the majority of samples, with whole slides scanned; however, there was one exception, sample P023 (taken from OST1-5), which had a very high number of phytoliths, comparable to onsite samples from Bakr Awa. In many of the samples, there were fragmented and weathered phytoliths. The fragmenting could be related to transport, and weathering could be related to soil formation and other geochemical processes (see Marsh 2015 for a fuller discussion on taphonomy). Dissolution is also exacerbated by fragmentation. Figure 10 shows a summary of monocotyledon (grasses and sedges/reeds) versus dicotyledon (trees and shrubs) phytoliths. Figure 10 indicates that there are relatively high ratios of dicotyledon phytoliths in the samples. This could indicate increasing deforestation around 2300BP. The values range between 20-75% in recovered phytoliths from samples. There do not seem to be any significant temporal trends, although towards the top of the deep trench section dicotyledons do decrease, at nearer to the time when the Achaemenid/Hellenistic sherd was deposited. There is also an apparent hydrological shift at this time (see above).

Sponge spicules and diatoms are present in most of the samples in small numbers, indicating the presence of water. The diatoms are mainly pennate, with some *Nitsczhia sp.*, but mainly undetermined due to size and magnification restrictions; two samples do contain centric forms (P024 and P026). While centric diatoms tend to be more planktonic, thus indicators of deeper water, without proper identification, nothing very significant can be said of their presence. Sponge spicules were generally more abundant. In some samples (P014, P025), there are burnt phytoliths, and charcoal was present in most of the samples.

The comparative values of rondels, bilobes and saddles (short cells from different monocotyledons with different climate/environmental requirements) show that, for the most part, rondels (from C_3 grasses, including cereals) dominate, indicating a temperate climatic regime for much of the Holocene sequence. There are some fluctuations in the numbers of bilobes (panicoids) and saddles (chloridoids), which may indicate climate change.

Several indices, based on specific single cell morphotypes were also calculated and include: tree coverage (Delhoun et al 2003; Alexandre and Meunier 1999, Alexandre et al 1997, Bremond et al 2005); Ic climate index (Burrough et al 2012, Twiss 1992, Barboni et al 2007) and the Fs water stress index (Barboni et al 2007). Some caution with the results, though, should be taken because of the sample size recovered. The tree coverage values indicate that, broadly speaking, the region was forested, in the uplands and the alluvial plain, but coverage may have varied throughout the Holocene. The jigsaw-shaped phytoliths, which are formed in tree leaves, are present in several samples, most notably P023, but also in P025, P026, and a few in P010 and P024. These could either be an indication of wetter forest conditions or irrigation/water management (Tsarstidou et al. 2007); in essence, their presence indicates increased water availability. There are also possible fruit phytoliths as well, which could indicate horticulture in the plain or in the uplands.

While we should be cautious with interpretation due to low sample counts, the Ic (climate index) values show some variation across time but conditions are generally stable and C_3 plants dominate, indicating a temperate regime. The Fs (water stress) index reflects high water availability throughout the Holocene, but with some variation across time; water stress increases in more recent periods (Figure 11).

Three phytolith samples (PO42, 043, and 045) were analyzed from the Yazin Tepe region, taken near the banks of the Tanjero (Figure 7:G14), mainly to see if there is a difference in preservation in this area as compared to the Bakr Awa area. At this point, without dating, there is no way to correlate this with the Bakr Awa sediments. Two of the samples came from sandy contexts and one from silt. The phytolith abundance was generally better than that of Bakr Awa, but the absolute numbers were still not very high, ranging from about 1000-8000 phytoliths per sample. There were very few multicells. The sandy deposits contained more diatoms and spicules, perhaps a reflection of overbank deposition; it should be noted that there were very few of these present in any case. Monocotyledons dominated the assemblage with more than 87%. Some jigsaw-shaped phytoliths were found, indicating that wetter forest conditions were present at some point, likely upstream. Sedges dominated the samples, with some grasses, possibly wild. Only one unidentified cereal multicell was found in the three slides.

As mentioned previously, samples were also taken from bulk sediments to search for the presence of ostracods. Unfortunately, none were found.

Region	**Sample**	**Number**	**Depth (meters)**	**Location**	**Relative date**
Bakr Awa	P021	1	5.4	Deep trench	Early-Mid Holocene
Bakr Awa	P014	2	5.2	Deep trench	
Bakr Awa	P004	3	5.1	Deep trench	
Bakr Awa	P020	4	5	Deep trench	Pottery Neolithic or later
Bakr Awa	P013	5	4.9	Deep trench	
Bakr Awa	P003	6	4.9	Deep trench	
Bakr Awa	P012	7	4.6	Deep trench	

Bakr Awa	P019	8	4.5	Deep trench	
Bakr Awa	P002	9	4.5	Deep trench	
Bakr Awa	P011	10	4.3	Deep trench	
Bakr Awa	P018	11	4.2	Deep trench	
Bakr Awa	P026	12	3.8	Deep trench	
Bakr Awa	P001	13	3.4	Deep trench	
Bakr Awa	P025	14	3	Deep trench	
Bakr Awa	P010	15	2.7	Deep trench	
Bakr Awa	P024	16	2.5	Deep trench	
Bakr Awa	P009	17	2	Deep trench	
Bakr Awa	P023	18	1.8	Deep trench	Before or near Achaemenid/ Hellenistic period (c. 2300 BP)
Yazin Tepe	P045	19	1.4	G14	
Yazin Tepe	P043	20	1.25	G14	
Yazin Tepe	P042	21	1.05	G14	

Table 1. Offsite phytolith samples and their given depths and location.

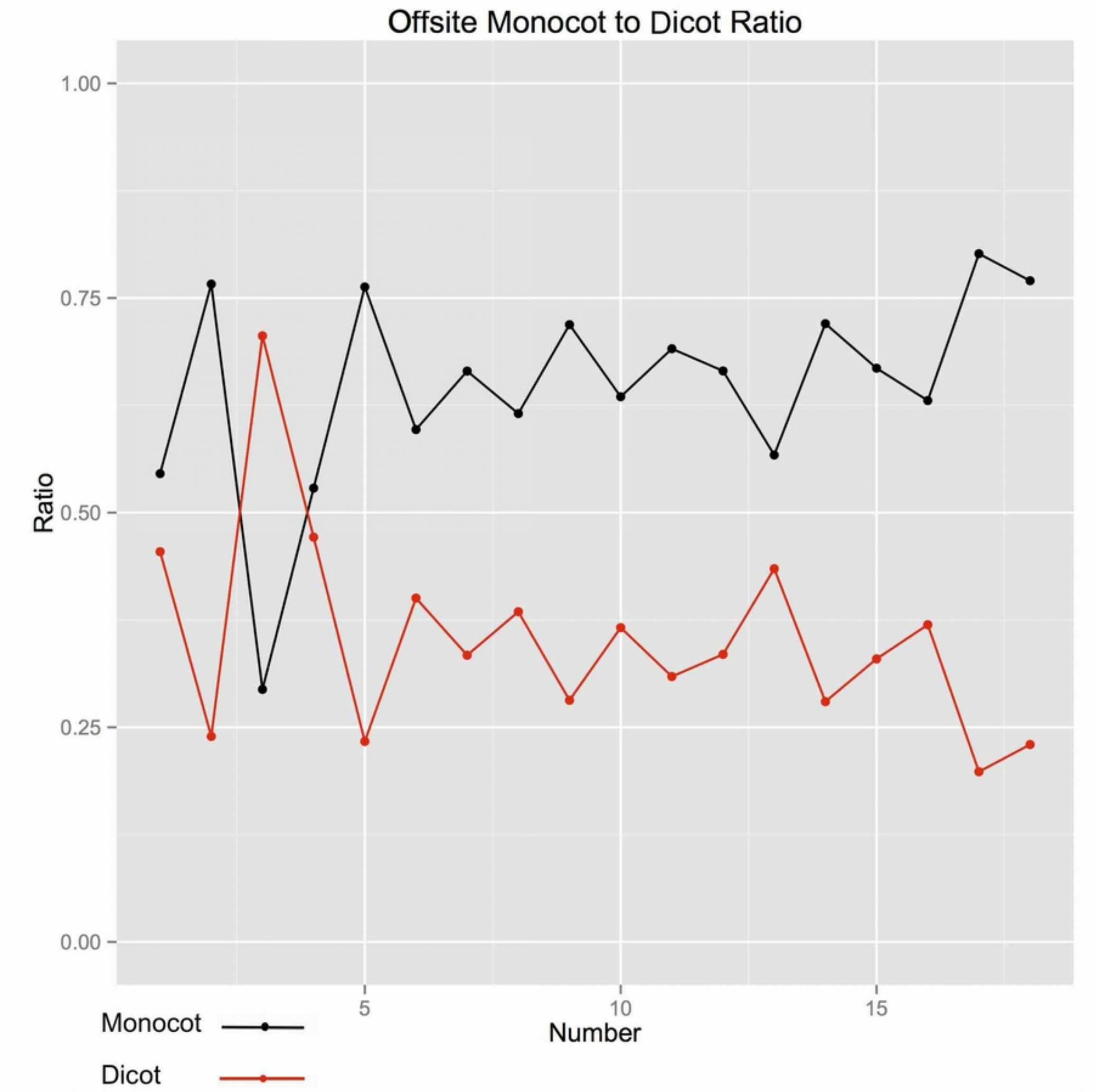

Figure 10. Ratio of monocotyledons (grasses and sedges/reeds) to dicotyledons (trees and shrubs) from offsite samples. The number indicates the sample number corresponding to Table 1 (e.g., P021 is Number 1, etc.).

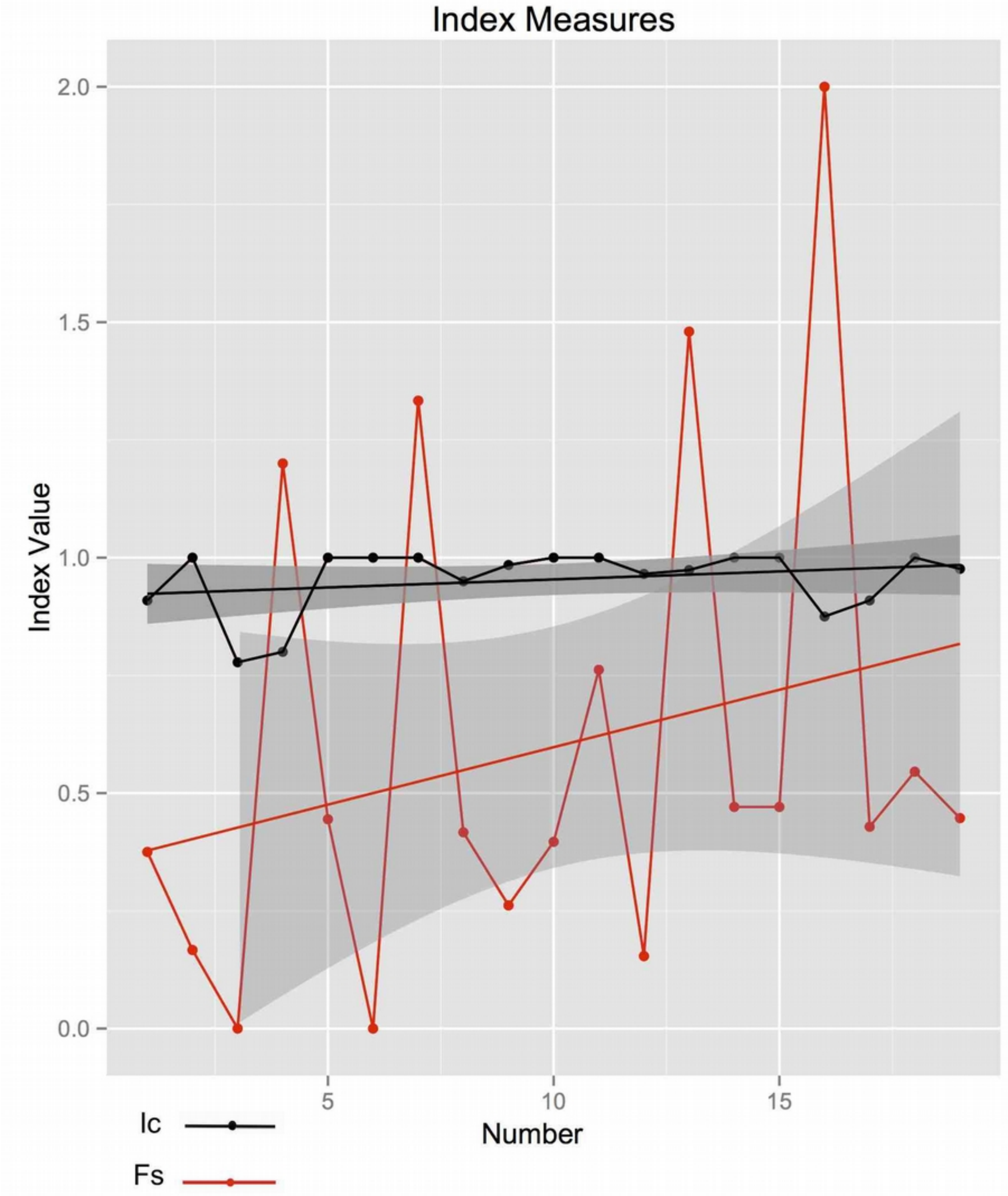

Figure 11. Ic and Fs indices showing climatic and water stress over time along with regression trend lines. Generally, we see more drying conditions occurring at the top of the trench and near the Achaemenid/Hellenistic sherd. The number indicates the sample number corresponding to Table 1 (e.g., P021 is Number 1, etc.).

Results from Bakr Awa

Evidence presented here will elucidate on resource use and site economy, with some background environmental signals, which can be compared with the offsite samples. The preservation of the phytoliths is generally very good. Some samples, however, did have some dissolved, melted or weathered specimens, and some of the cereal husks are difficult to identify to genus/species levels as a result. Samples range in date from the Early Dynastic (ED; 2900-2300 BC) period to the Late Bronze Age (LBA; 1600-1200 BC) and were sampled from a variety of contexts. Further information on absolute dates from Bakr Awa, including those used for the periods discussed here, can be obtained from Miglus et al. (2013).[1]

Figure 12 indicates ratios of different plants present on the site and their estimated dates, based on AMS values and ceramic finds. There do not seem to be any obvious temporal trends in these samples. Generally speaking, cereals, weeds, wetland plants, and dicotyledons are all present throughout the different periods, and variance seems to be more dependent on archaeological context in which they were found rather than indicating specific environmental conditions or changing resource use. Monocotyledons (grasses) outnumber dicotyledons (shrubs and trees), which is expected as monocotyledons produce more phytoliths than dicotyledons (Piperno 2006). The dicotyledons range between 5-15%. There may be some tapering off of dicotyledon numbers in the later LBA levels; however, this is likely context related as all samples came from floors in the later LBA. Rondels (C_3 plants) also dominate the record, in all periods, and reflect the trends of the offsite samples. These likely reflect the presence of cereals on site. There are some increases in the number of saddles and bilobes in certain contexts and all periods, probably signifying context-specific use (i.e., use of wetland plants for baskets and mats). At any case, it is difficult to determine climatic signals with any certainty from onsite materials, as the phytolith record reflects material that is mostly, although not completely as in the case of weeds, intentionally brought on to the site.

Wetland plants are found throughout the existence of the site, and consist mainly of sedges, although some reed phytoliths were

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[1] The ED interpretation is based on an AMS date to around 2620-2570 BC, but the full range of possible dates and ceramics could push this date back to roughly the late 29th century BC (i.e., near the end of the ED I period). Another date, ranging between 2270-2040 BC, is suggested for an Akkadian/Post-Akkadian structure, with the 22nd century BC being a likely range. An occupation gap might be present at around 1600-1400 BC in the east part of the site where samples were taken, while the site of Bakr Awa likely becomes smaller during this period (Altaweel et al. 2012; Miglus et al. 2013), but otherwise the area appears to be continuously occupied during this time.

identified in a few samples, specifically a late third millennium floor level (where the reeds may have been used for floor mats). Wetland plants were (and still are) used for baskets, bedding, mats and/or roofing material. Overall, the relatively high presence of wetland plants indicates exploitation of these resources that were most likely found very near Bakr Awa, given the results of the offsite samples.

Dicotyledons were also found throughout the samples, but were especially high in one sample from an unidentified “white layer” of pure silica, on an Akkadian/Post-Akkadian (i.e., roughly 22^{nd} century BC) shrine pavement. The fireplace, located in the shrine, also contained wood and dicotyledon leaves and cereal and weed phytoliths, possibly indicating the use of both charcoal (wood) and dung or leaf and cereal/weeds as fuel types.

Single cells and multicells are both found in the samples and the multicells ranged between 5-50% of the total, with most ranging between 15-25%, which is far higher than in the offsite samples. Throughout samples from the ED to LBA, there are large multi-cells, mainly 10+ conjoined cells, but in some cases they are larger, with over 100 conjoined cells. Due to taphonomical issues, such as crop processing, sampling, and laboratory procedures, large multicells such as these are very rare and their presence could indicate flood farming/irrigation (Rosen and Weiner 1994), or high water availability. This further suggests the region’s relatively high water abundance. It is likely, given the geoarchaeological evidence, hydrologic conditions, as well as the index results on the offsite samples for high water availability, that flood farming/irrigation was practiced from at least the early third millennium BC until roughly 2300 BP.

As Figure 13 shows, only barley is found in the ED period; however, this could be because the overall sample is relatively low for the ED. Wheat and barley are then found throughout the Akkadian period, but by the late third millennium BC, again there is only barley. During the Old Babylonian (2000-1600 BC; OB), which was the best-represented period in the samples, both barley and wheat are present, with only wheat represented in LBA samples. In general, barley dominates most samples. The results could be biased because of sample size and poor preservation of multi-cells. There appears to be no covariance between straw and cereal husks. Barley appears to covary with agricultural weeds especially from the ED to the OB, and there is also fairly strong positive correlation between the two (r=0.93), possibly indicating that it is a weed or a wild type being used as fodder (Ryan 2009). Additionally, it seems that only the barley came in together with weeds, showing that less effort may have been taken to remove weeds from barley. There is a weak correlation between wheat and weeds (r=0.69), which may suggest separation of weeds from wheat, as well as between wheat and barley (0.78). Straw was also found in most of the floor contexts. These come from different floors and might be indicating domestic activity revolving around the processing/storage of cereals.

Similar to the offsite samples, diatoms are present in small numbers in most of the samples, and sponge spicules are found in one of the samples. Most of the diatoms are pennates, in many cases *Hantzschia amphyoxis*, which is a terrestrial species found on mosses. In two samples there are centric forms. The diatoms are most abundant in one sample, which comes from an Akkadian/Post-Akkadian period (22nd century BC AMS date; Miglus et al. 2013) fireplace near the shrine. There is very little covariance between wetland plants and diatoms, and no correlation (r=0.28), which probably indicates that they did not come into the record together. There was very little charcoal in the samples; however, there were some burnt and even melted phytoliths in many samples, indicating burning and high temperatures in the vicinity of those contexts.

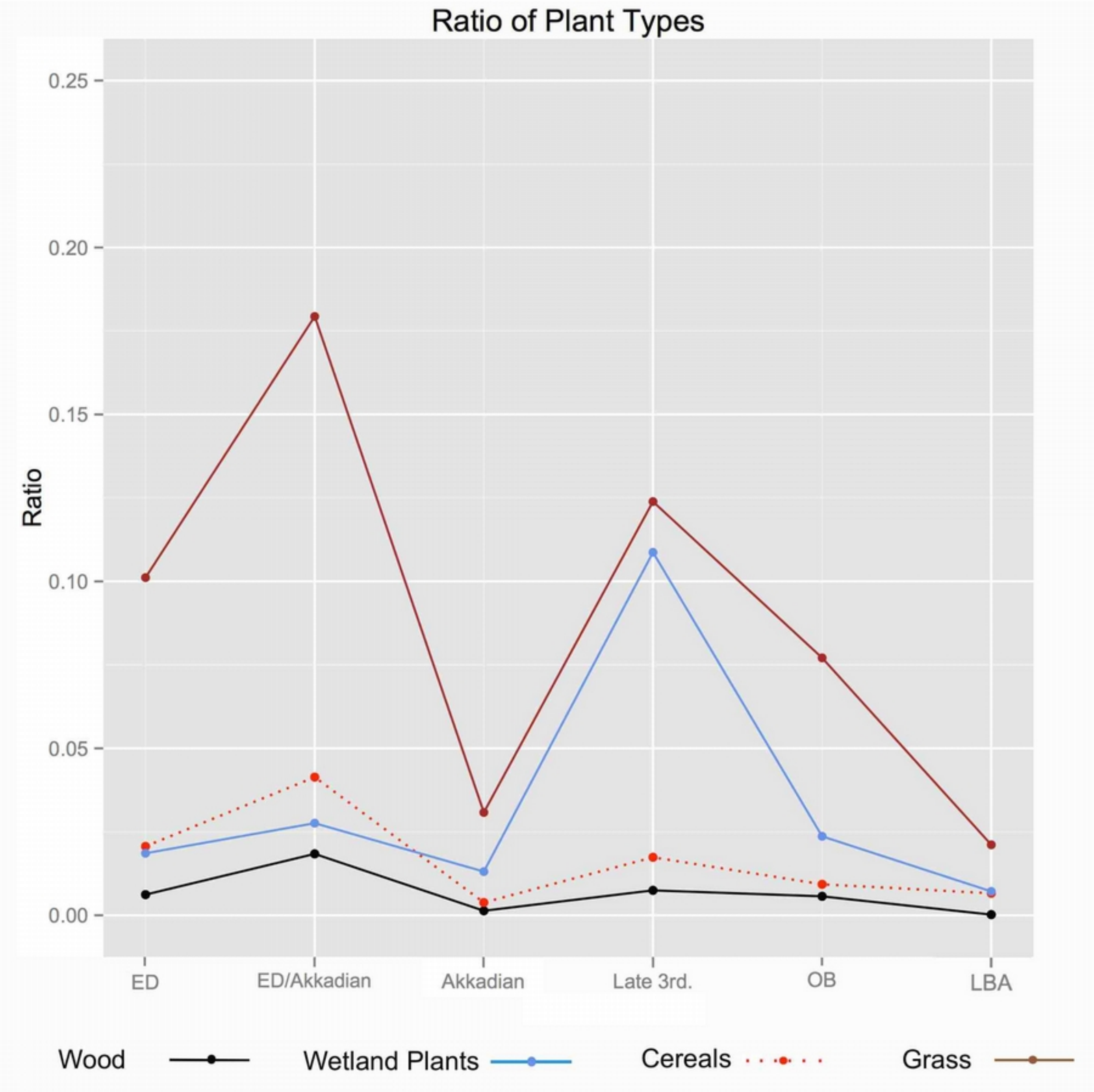

Figure 12. Ratios of different types of plants found at Bakr Awa and in different periods. Sample number of phytoliths range between 329,511-27,734,675.

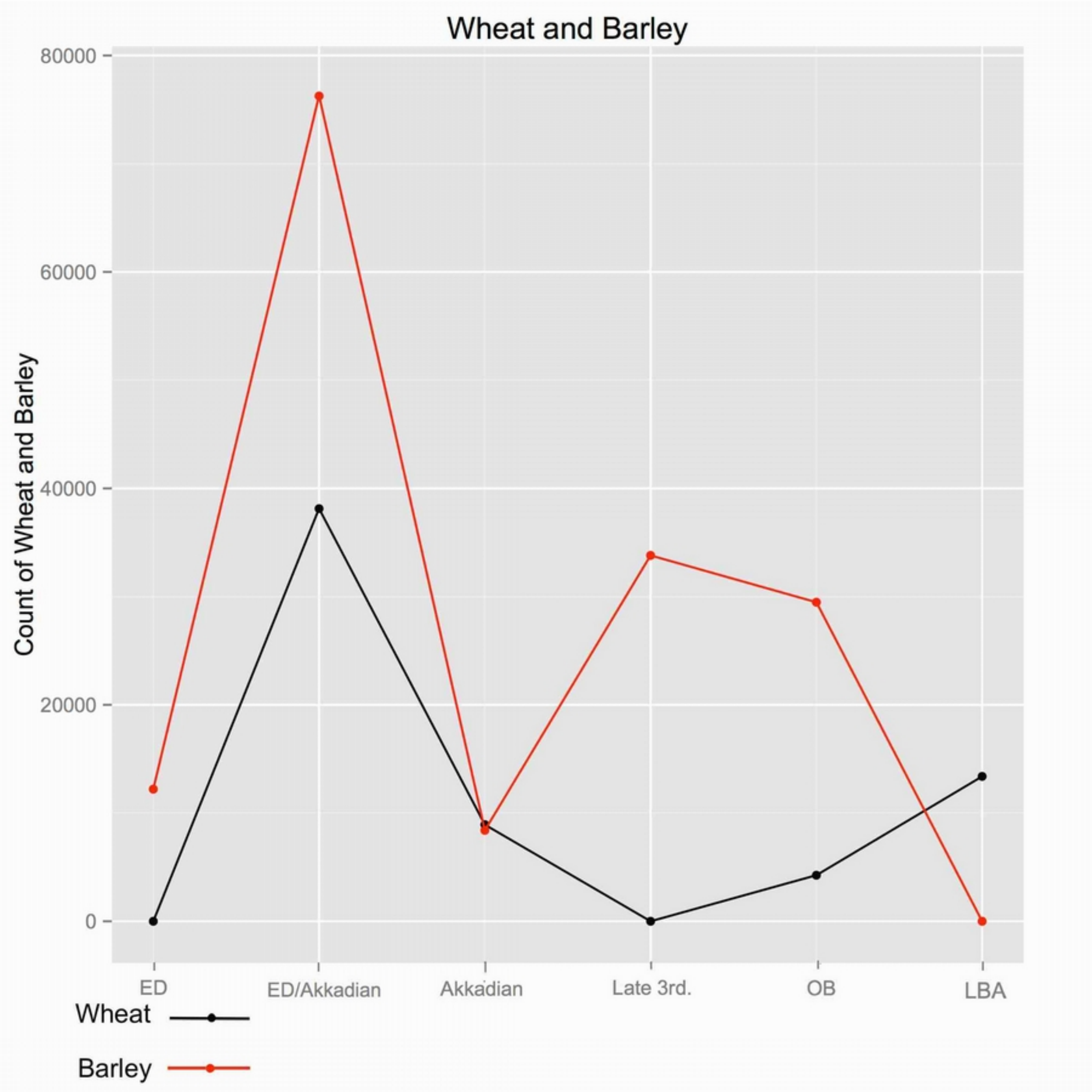

Figure 13. Number of wheat and barley phytoliths from samples and different periods.

Speleothems

While speleothem studies have mostly focused on northern Turkey (Badertscher et al. 2011), the Levant (Bar-Matthews et al. 1997), and the southern Arabia Peninsula (Fleitmann et al. 2003), work in Iraqi Kurdistan, specifically from Kuna Ba cave near Darband-i Khan village and lake with the same name, has begun to use these proxies to reconstruct climate (Reuter et al. 2012). The speleothem record begins from 1500 BP and shows that there has been a general trend of desiccation for longer periods, with the years between AD 700-900 and 1100-1700 in particular being relatively dry. Additionally, the signals do not correspond well to the Little Ice Age (LIA) and Medieval Warm

Period (MWP), or North Hemisphere temperature anomaly, indicating that local conditions could have been different from larger climatic trends and emphasizing the importance of local climate proxies rather than those that are distant. Considerable precipitation variability from year to year is evident, specifically in 5-20 year cycles, even though the long-term trend is not drastically different than today's conditions, with only 1.3% variability from proxy records. These results generally agree with what is found in the sedimentary record that shows soil formation happening during the later parts of the Holocene (i.e., after 2300 BP) and until recently, as alluviation, and thus hydrologic flow into the Shahrizor valley, diminished in areas we have investigated. This likely indicates generally less discharge and wadi or small river systems diminishing and becoming more seasonal as the climate has become drier over the last 2300 years.

Discussion and Conclusion

We have presented information on current and past Holocene environmental conditions. To summarize, the sedimentary sequence suggests that alluviation and increased hydrologic flow, relative to today, once characterized the Shahrizor region, particularly from the earlier parts of the Holocene to before 2300 BP. Large alluvial channels once cut across the landscape, carving out much of the Pleistocene topography, leaving some parts of the terraces more elevated and exposed, where archaeological sites, including Bakr Awa, are commonly seen today. The sedimentary record also indicates that many sites, which did not occupy the more elevated Pleistocene terraces, might be buried under meters of sediments. Generally, our sections in the Bakr Awa and Begum region indicate an area of frequent channel cutting and erosion, followed by deposition of fine-grained sediment. The modern topography reflects, for the most part, the deposition patterns followed during the Holocene. There also appears to be multiple channels active at possibly the same time in these regions, suggesting water flow abundance, where anabranching stream systems, that is composed of multiple active channels which avulse across a section of the plain, being characteristic of part of the region (i.e., Bakr Awa). In addition, because the sediments often contain a large percentage of clay content and do not exhibit the usual fining up sequences found in channel deposits, it is possible that these channels are cut off chutes, or channels created during flooding events, which were then cut off shortly after creation, filling up subsequently with silts and clays (Brown 1997), as floodplain deposits. The sediment colors, including the mottling present in some of the layers, indicate that the sediments went through periods of dryness and waterlogging. This supports the idea that the channels seen in the deep trench for instance were more likely cut off chutes or flood channels, secondary to a larger channel elsewhere. At Begum and Yazin Tepe, sediments are more similar to overbank deposits, and seem to reflect changing channel positions, representative of more meandering river systems.

After about 2300BP, there is a hydrological change, which is also reflected in the speleothem record, indicating increasing aridity in the region. While the Shahrizor is still a relatively wet region, the implication of this on local cultures and economies is that there may have been changes in agricultural and husbandry strategies; for instance, a switch from flood/irrigation farming (e.g., seen at Bakr Awa in 3rd to 2nd millennium BC) to more reliance on dry farming and certain crops requiring less water. In addition, deforestation in the region would also have influenced the water budget, sedimentation, and microclimate in the region, exacerbating any possible drying trends after 2300 BP.

A mosaic of landscapes and vegetation are likely to have existed for much of the Holocene in the Shahrizor. We see strong evidence of wetland plants in many phytolith samples, both at Bakr Awa (on and off site) and Yazin Tepe, from different parts of the Holocene. Most of the early to late Holocene vegetation, in fact, suggests a region with riparian woodlands and wetlands, alluvial plains and upland forests, with only a minor remnant of the forested areas remaining today. In fact, much of the Holocene was relatively temperate, given the evidence of C_3 grasses. Phytolith data suggest, in general, a high presence of water, continuing until at least until the late 1st millennium BC. However, considering the presence of large alluvial channels, only parts of the plain, specifically the better drained areas along the upward slopes of Pleistocene terraces, would have been more ideal for longer-term grain agriculture. Additionally, both charcoal and dung resources were utilized for cooking and other fire-related activities, with wood likely to have been used as building material. Wetland plants, such as reeds and sedges, appear to have been exploited at Bark Awa, utilizing local resources. Fluctuations in crops in the region are suggested by the phytolith results, but this does not appear to correspond to any clear climatic signals and could just be a result of limited sampling or crop preference. Interestingly, greater or exclusive use of barley in the late third millennium BC period from Bakr Awa does parallel events in southern Mesopotamia, where barley was also becoming the grain of choice (Jacobsen 1982; Maeakawa 1984). This could reflect an economic focus toward barley used for animal fodder, rather than climatic change, as the Shahrizor was possibly very important for wool production and animal husbandry in the late 3rd millennium BC and Ur III period (Stone 2014). The presence of weeds in barley at Bakr Awa suggests its use for animal fodder rather than human consumption. Plant exploitation also appears to utilize weedy barley, which further highlights the possible use of these grains for fodder or there was some general preference for such grains that may have required less agricultural input for production. For other sampled periods, excluding the ED, we see mixed use of wheat and barley or exclusive use of wheat, specifically in the LBA. Fruit cultivation is also evident in samples taken on- and offsite.

While the change in the landscape over the last 11,000 years has been undoubtedly affected by anthropogenic activity, climatic shifts are also evident. Continued and long-lived sites in the Shahrizor (Directorate General of Antiquities 1970; Altaweel et al. 2012) during the 3rd to 1st millennium BC suggest favorable climatic conditions for the mid to late Holocene, but there does seem to be a cultural transition or some level of site abandonment by around 1600 BC with the arrival of the Shamlu culture. Any climate relationship to this is not currently evident.

Overall, long-lived cultural trends suggest that the region likely had favorable climate conditions. We would characterize that much of the Neolithic through the mid-first millennium BC as a period of relatively stable and greater water abundance in contrast to today, possibly suggesting no major or long-term drying episode during that time. In fact, major temperature or climate anomalies that agree with larger global trends, including the 4.2 kiloyear event (i.e., often associated with the collapse of the Akkadian Empire; Kerr 1989; Kaniewski et al. 2012), MWP, and LIA, have yet to be evident in the Shahrizor. While dated samples from Bakr Awa do not suggest the 4.2 ka event had a major impact in the region or even wider region, the results emphasize the need for collection of local and multiple proxies rather than assuming other, distant or singly proxies are indicative of regional environmental trends. Speleothem proxy results and dates provided show that global climate trends did not necessarily have major effects on the immediate region. For later periods, sometime during the last 2300 years, and particularly by 1500 BP, there is strong evidence of increased drying and long-term drying phases, which indicate soil formation and decreased alluviation, indicated from the deep trench at Bakr Awa, and the speleothem from Kuna Ba cave. This increased drying does not indicate any catastrophic desiccation, as conditions may have simply become relatively drier but sufficient for rainfed agriculture. However, dependence on wetland and woodland plants could have diminished during the longer drier phases within the last 2300 years. Year to year volatility in rainfall is seen in the speleothem record, but the millennial trend is somewhat similar to today’s conditions. The presence of Parthian through late Islamic sites does not suggest any major settlement abandonment in the region (Altaweel et al. 2012), but the site survey record is not yet complete. More precise dating is also needed from sites for any shorter-term abandonments.

Certainly more work is needed to refine our understanding of past land use and climate in the region, with particular focus on more refined and better dated contexts. This has begun by the collection of phytoliths from dated contexts or at least datable contexts, while our speleothem work is currently monitoring two caves (i.e., Kuna Ba, located near Darband-i Khan village, and Shelli cave (35° 8'47.70"N 45°17'47.28"E), where a more continuous Holocene climate record appears to be available. Other caves, particularly Shalaii Cave cave just south of Chamchamal, also show great promiss as paleoclimate proxies. Additionally, sedimentary collection and geophysical analysis will allow us to reconstruct the relatively early Holocene topography and have a greater understanding of alluvial change in the region during most of the Holocene. This could also give us a sense of the location of paleochannels and places where likely agriculture would have taken place.

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