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Paleoenvironmental change and settlement dynamics in the Druze Marsh: Results of recent excavation at an open-air Paleolithic site

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ABSTRACT

Large open-air archaeological sites provide a unique contribution to our understanding of the range of environments exploited by hominins and how their mobility patterns were affected by local, regional, and global environmental fluctuations. The challenge, however, is that in open-air contexts the distribution of buried and surface archaeological remains is greatly affected by geomorphic processes that acted on the landscape throughout the Pleistocene and Holocene. Deciphering the behavioural patterns of large open-air sites necessitates an approach that incorporates landscape evolution as a critical component contributing to the spatial distribution and variability in the archaeological record. We suggest that it is more appropriate to speak of open-air archaeological landscapes rather than sites in the traditional sense.

Within this framework, we present our ongoing research at Druze Marsh, a Paleolithic locale in the northwest corner of the Azraq Basin (Jordan), and an oasis that may have functioned as a desert refugium at different points during the Pleistocene. Surveys and excavations in the Azraq Basin have recovered material from the Lower Paleolithic to historical periods. Recent research by our team has identified a stratified sequence of artifacts that typologically correspond to the Late Lower, Middle, Upper, and Epipaleolithic industries. Both the surface and stratified material are the remains of prehistoric behaviour, and a full understanding of the prehistoric settlement system and land-use surrounding the Druze Marsh requires amalgamating these different contexts with the environmental history of the area, particularly accounting for the contribution of geomorphic processes on the spatial distribution of the archaeological record.

1. Introduction

Fluctuating cycles of wet and dry conditions over the past 2 million years in the eastern Mediterranean region provided windows of opportunity for hominins and other animals to move along the Levantine Corridor between Africa and Eurasia (Tchernov, 1992; Bar-Yosef, 2000; Lahr and Foley, 2003; Goren-Inbar and Speth, 2004; Belmaker, 2010; Bar-Yosef and Belmaker, 2011; Bar-Yosef and Belfer-Cohen, 2013) and/or cross into the Arabian Peninsula via a number of possible migration routes (Parker, 2009). One important route is a string of paleolake basins that follows the Wadi Sirhan depression from eastern Jordan into the north-central Arabian Peninsula. The Greater Azraq Oasis Area (GAOA), the regional focus of this paper, sits on the eastern Jordanian Plateau between the Levantine Corridor to the west and at the northern end of the Wadi Sirhan depression (Fig. 1), making it an important crossroads for hominin dispersals into Eurasia and Southwest Asia. For Levantine hominins these dispersals required adaptations to new environments through innovations in technology and changes in inter and intra-group dynamics (Rockman and Steele, 2003; Grove, 2009; Bar-Yosef and Belfer-Cohen, 2013). It is clear, however, that not all of these dispersal and colonization events were successful (Bar-Yosef and Belfer-Cohen, 2013).

While local populations can go extinct, a species will persist over time as long as the metapopulation – many local populations that are geographically separate – remains viable (Levins, 1970;

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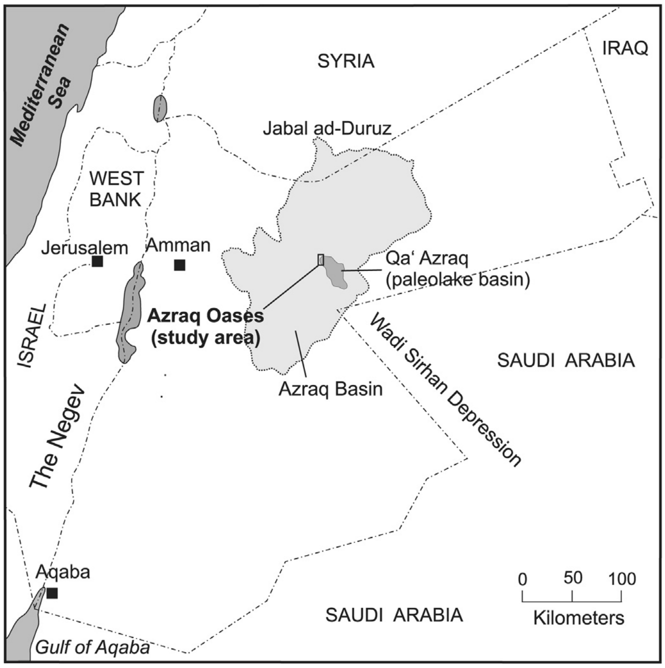

Fig. 1. Regional context of the Greater Azraq Oases Area (GAOA).

Hanski, 1999; Hopkinson, 2011). During successful times these local populations will expand into new habitats, but when under stress they contract temporarily into refugia or, when no recovery is possible, local extinction occurs (Soffer, 2009). Desert refugia are geographic areas where hominin populations subsist on the concentrated resources that are otherwise scarce in drylands (Cordova et al., 2013). Wetlands such as the Druze Marsh in the GAOA are of particular interest as they support a variety of aquatic and terrestrial plants and animals, producing concentrated areas of high biodiversity in an overall challenging landscape. In addition, when the Pleistocene environment transitioned from wet to dry conditions, the springs in Azraq would have continued to flow for several thousands of years due to recharge of the aquifer during the previous wet conditions (Noble, 1998; Jones and Richter, 2011; Cordova et al., 2013), turning the GAOA into a pocket of concentrated resources in an otherwise harsh environment. We present here the results of recent excavation and contextualize it with additional geoarchaeological research from the Druze Marsh, specifically addressing the impact of fluctuating water levels on Middle Paleolithic settlement dynamics in the region. Comparing our results with the known distribution of Paleolithic remains throughout the region demonstrates that it is best to conceive of the Druze Marsh and the GAOA in general as a large open-air archaeological landscape, and that reconstructing the settlement history and land use at such a large open-air Paleolithic site requires integrating both the buried and surface remains by reconstructing the history of landscape change and its impact on the spatial distribution and variability of the archaeological record.

2. Study area

2.1. Physical setting

The GAOA is located approximately 80 km east of Amman on the northwest part of Qa' Azraq, a 75 km^2 salt mudflat marking the lowest point of the ~12,500 km^2 endorheic Azraq Basin (Fig. 1). It sits at the contact between the Miocene-Pliocene basalt flows to the north and the Maastrichtian and Eocene limestone deposits to the south, the latter of which are blanketed by Quaternary deposits grouped into the Azraq Formation (Ibrahim, 1996). Although not fully studied or dated, a number of Pleistocene-age deposits have been described in the GAOA, such as the Middle Pleistocene sandstones (Turner and Makhlouf, 2005), upland lacustrine terraces (Abed et al., 2008), lacustrine deposits in the center of the Qa' (Davies, 2000) and near the spring-fed wetlands (Cordova et al., 2009, 2013; Jones and Richter, 2011), and terraces along a number of the ephemeral rivers – wadis – that flow into the Qa' (Besançon et al., 1989).

The present day climate in the GAOA is hot and arid. Temperatures in the summer can exceed 45 °C with an average July temperature of 27 °C. The average temperature in January is 12 °C with lows dropping below freezing (El-Naqa, 2010). The center of the GAOA receives less than 50 mm/year of highly seasonal precipitation, predominantly falling from October to April (El-Naqa, 2010). Historically, groundwater was accessible via two spring-fed wetlands, both associated with modern communities (Fig. 2B). The town of Azraq Shishan, or South Azraq, is adjacent to the Shishan Marsh and Azraq ad-Duruz, or North Azraq, is adjacent to the Druze Marsh (Fig. 2B). Water over-extraction throughout the second half of the 20th century led to dramatic drops in the local water table, causing both major wetlands to dry out by the late 1980s and early 1990s (El-Naqa, 2010). Conservation efforts by the Royal Society for the Conservation of Nature (RSCN) have reclaimed and maintained the south marsh, although the wetland area is greatly reduced in size compared to historic times (France, 2010). The Druze Marsh was less fortunate and dried out completely in the late 1980s and remains that way today (El-Naqa, 2010). The remnants of the former marsh bed cover approximately 2 km^2 (Fig. 2B) and is the primary study location discussed in this paper (Fig. 3). For a detailed overview of the historical hydrological system of the Azraq Basin and additional detail on the geologic and geographic history of the GAOA see Cordova et al. (2013), among others (Nelson, 1973; Besançon et al., 1989; Ibrahim, 1996; El-Naqa, 2010; Jones and Richter, 2011).

2.2. Archaeological setting

Evidence for Paleolithic occupation of the Azraq Basin was first identified in the early 20th century (Maitland, 1927; Rees, 1929). Initial findings consisted of surface material of unknown age, but the 1956 discovery of *in situ* Lower Paleolithic artifacts during irrigation canal construction at 'Ain el-Assad, or Lion Spring (Zeuner et al., 1957; Kirkbride, 1989), solidified Azraq as an important Paleolithic landscape. The artifacts collected were almost exclusively Lower Paleolithic types, dominated by bifacial cleavers, suggesting the material dates to the Late Acheulean (Copeland, 1989a, 1989b). In the nearly 60 years since this discovery, a body of research has accumulated demonstrating that the region was occupied during every major Paleolithic time period since the Middle Pleistocene (Rollefson, 1983, 1984; Garrard et al., 1987; Copeland and Hours, 1989a; Rollefson et al., 1997; Jones and Richter, 2011; Cordova et al., 2013).

The archaeological potential of the Azraq Basin brought a multidisciplinary team of researchers led by A. Garrard to the area in the mid-1970s (Garrard et al., 1977, 1988). Their initial survey focused on three locations: Wadi el-Jilat and Wadi el-Uweinid to the west of the Azraq wetlands, and the immediate vicinity around the Shishan Marsh, specifically the area near C Spring that was identified in the 1950s (Kirkbride, 1989). Preliminary results identified surface artifacts spanning the Lower Paleolithic through the Neolithic in a variety of geomorphic contexts, although Upper Paleolithic material was scarce (Table 1) (Garrard et al., 1988). Of particular note, a 3 × 1 m sounding at C Spring encountered a Lower Paleolithic deposit with approximately 2700 pieces of worked flint (Hunt and Garrard, 1989).

Analysis of the retouched tools clearly identified the assemblage as Late Acheulean and similar to the material found at Lion Spring 25 years earlier (Copeland, 1989c). The high prevalence of bifacial cleavers led to the classification of a unique tool-kit called the Late Acheulean of Azraq facies, a designation that seems appropriate considering the high numbers of bifacial cleavers also found at the nearby Lion Spring (Copeland, 1989a, 1989b) and 'Ain Qasiya (Rollefson et al., 1997; Cordova et al., 2008).

Rattama sectors but due to the small sample size it is difficult to make any substantial conclusions. This contrasts with the data from the Enoqiyya sector that produced predominately Middle Paleolithic artifacts that typologically match the Levantine Mousterian (Hours, 1989). Despite collecting more than 7000 pieces, all finds in the Enoqiyya sector were from surface contexts. The 'Ain Beidha sector on the northeast part of the GAOA also produced surface finds from a number of time periods, but the area was not subject to a systematic study and remains a promising location for future work (Copeland, 1989d).

Table 1
Archaeological material identified in the Azraq Basin and associated geomorphic contexts.

Location (see Fig. 2)	Archaeological periods identified	Geomorphic context	References
Kharana sector	Lower Paleolithic	Surface and reworked terrace deposits	Copeland and Hours, 1989b, Maher et al., 2012, Muheisen, 1988,
	Middle Paleolithic	Surface and alluvial terrace deposits	
	Epipaleolithic	Buried (*in situ*)	
	Neolithic	Surface (*in situ*)	
Butm sector	Lower Paleolithic	Alluvial conglomerate	Copeland and Hours, 1989b, Garrard et al., 1988
	Middle Paleolithic	Surface	
	Epipaleolithic	Surface (*in situ*) and buried aeolian deposits	
Rattama sector	Lower Paleolithic	Surface and alluvial gravels	Copeland and Hours, 1989b
	Middle Paleolithic	Surface and alluvial gravels	
	Epipaleolithic	Surface and wadi bank	
Enoqiyya sector	Middle Paleolithic	Surface (wadi)	Hours, 1989
	Upper Paleolithic	Surface (wadi)	
	Epipaleolithic	Surface (wadi)	
	Neolithic	Surface (wadi)	
Lion Spring	Lower Paleolithic	Buried (sand and gray clay)	Kirkbride 1989, Copeland 1989a, Rollefson 1983
	Pre-Pottery Neolithic	Buried (grayish brown silty clay)	
C Spring	Late Lower Paleolithic	Buried (blue-gray silt)	Copeland, 1989c, Garrard et al., 1988, Hunt and Garrard, 1989
	Epipaleolithic	Buried (silty clay and silt dunes) and surface	
	Neolithic	Buried aeolian silts and silt dunes	
Wadi Uweinid	Lower Paleolithic	Surface	Garrard et al., 1988
	Epipaleolithic	Buried aeolian deposits	Rollefson, 1984
'Ain Beidha	Lower Paleolithic	Surface	Copeland, 1989d
	Middle Paleolithic	Surface	
	Upper Paleolithic	Surface	
	Epipaleolithic	Surface	
'Ain Qasiya and 'Ain Soda	Lower Paleolithic	Surface (disturbed) and buried (uncertain)	Jones and Richter, 2011, Rollefson et al., 1997
	Middle Paleolithic	Surface (disturbed) and buried (silty clay with large clasts)	
	Epipaleolithic	Surface (disturbed) and buried (*in situ*)	
	Neolithic	Surface (disturbed) and buried (*in situ*)	
Wadi Jilat	Middle Paleolithic	Alluvial conglomerate	Garrard et al., 1988
	Upper Paleolithic	Alluvial deposits	
	Epipaleolithic	Colluvial/alluvial deposits and aeolian deflation surface	
	Neolithic	Surface	

Between 1982 and 1986 Copeland and Hours undertook a detailed archaeological and geomorphological survey of four sectors along major wadi channels flowing into the central Azraq Qa' (Fig. 2A; (Copeland and Hours, 1989a). Each sector produced Lower and Middle Paleolithic artifacts on the surface but the presence of buried deposits was more variable. Although well known for the Epipaleolithic site of Kharaneh IV (Muheisen, 1988; Maher et al., 2012), the Kharana sector produced very few Lower and Middle Paleolithic artifacts in buried context, and when they were encountered they were in redeposited alluvial terraces and heavily damaged (Table 1) (Copeland and Hours, 1989b). Acheulean artifacts were ubiquitous in the Rattama sector, while Middle Paleolithic finds were less common. The Butm sector provided similar results. Although they recognized the potential long time frame represented by the Lower Paleolithic artifacts identified in the Kharana, Butm, and Rattama sectors, the considerable typological similarity, regardless of geomorphic context, led Copeland and Hours to designate the entire Lower Paleolithic collection as Desert Wadi Acheulean, specifically to separate it from the Late Acheulean assemblages found near the springs (Copeland and Hours, 1989b). The Middle Paleolithic was also identified in the Kharana, Butm, and Rattama sectors but due to the small sample size it is difficult to make any substantial conclusions.

Previous research in the Azraq Basin clearly demonstrates the importance of the region as a locus of prehistoric occupation since the Lower Paleolithic. Surface and buried remains, although in considerably different quantities, appear in every sector of the basin that has been tested (Table 1). Substantial erosion has impacted the integrity of much of this record (Bescançon et al., 1989), but it should not be dismissed, especially considering the traces of artifact bearing *in situ* alluvial deposits that have been identified (Copeland and Hours, 1989b). Integrating this record with the known Paleolithic occupations at Lion Spring, C Spring, and 'Ain Qasiya provides an opportunity to improve our understanding of prehistoric settlement and land use in the Azraq Basin since the Middle Pleistocene. Our recent research in the Druze Marsh adds to this growing body of knowledge on prehistoric occupation in the Azraq Basin (Cordova et al., 2009, 2013). Of particular importance is the buried *in situ* Middle Paleolithic occupation surface identified during our 2009 excavation, which is presented in detail in Section 4.1. Although present at a number of locations on the surface, the Middle Paleolithic is a time period for which few buried contexts are known from the Azraq Basin.

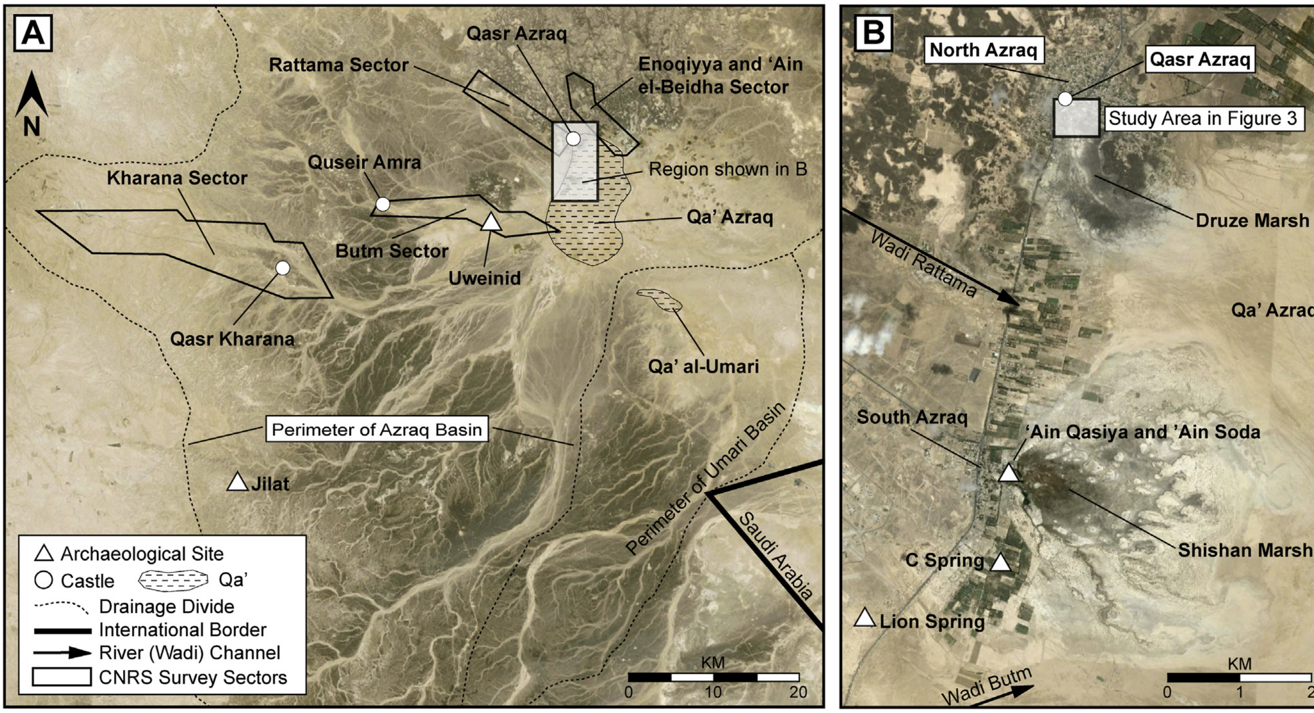

Fig. 2. Map of the central Azraq Basin (2A) and the Greater Azraq Oasis Area (2B) with locations discussed in the text (background image: Google Earth, 2012).

3. Materials and methods

The Druze Marsh Archaeological and Paleoecological Project (DMAPP) conducted three field seasons in 2008, 2009, and 2011 (Cordova et al., 2009, 2013). Our survey team initially discovered the marsh site in 2008 when the construction of a 'Cultural Centre' and 'Children's Park' exposed the stratigraphy of the historic marsh bed. Three large foundation pits (DM-1, DM-1X, and DM-1Y)

Fig. 3. The Druze Marsh study area and locations of stratigraphic profiles discussed in the text (background image: Google Earth, 2011).

presented deeply stratified deposits embedded with Paleolithic artifacts from multiple time periods (Fig. 3). Our team conducted brief salvage work to record the stratigraphy and nature of the archaeological material before the construction continued. In response to the rich record encountered, we obtained permission to open three additional geological trenches on the adjacent property (DM-7, DM-8, and DM-9) and recorded the first 40–60 cm of test pits DM-2 through DM-6. We recorded the stratigraphy, the 3-dimensional location of artifacts embedded in the profiles of the three geological trenches, and collected representative bulk sediment samples from each stratigraphic unit in DM-8 and DM-9. Based on the 2008 results, our team returned in 2009 and opened an additional geological trench close to the main road (DM-11) following the same procedure as in 2008, and recorded the stratigraphy of an open trash pit (DM-10). Our primary work during the 2009 season was a 2 × 1 m excavation extending from the south wall of DM-8, the details of which are presented in this paper. We recorded the 3-dimensional location of all artifacts >2 cm using a Leica total station, and for artifacts with an obvious long-axis we recorded both end points in order to calculate the angle of repose (Fig. 4).

Cordova and Ames recorded detailed stratigraphic properties of the excavation profile and collected sediment samples at ~10 cm intervals for laboratory analysis (Fig. 4), or at smaller intervals when necessary to ensure all sedimentary units were represented. We also recorded the sediment boundaries and sample locations with the total station in laser mode to ensure consistent depth measurements when comparing the stratigraphy and artifact assemblages. The samples were divided for sedimentological analysis at McGill University (Ames) and pollen and phytolith analysis at Oklahoma State University (Cordova) – the latter two analyses are ongoing and not discussed in this paper. Ames returned to the Druze Marsh in 2011 to complete, record, and sample the pits DM-2A, DM-2B, DM-3, and DM-5, as well as collect modern day dune samples for comparison with the buried sedimentary units.

Sedimentological analysis involved gently disaggregating each sample with a mortar and pestle as necessary, after which the samples were left to air dry in foam bowls for seven days. Once dry, 7 ml subsamples were taken for magnetic susceptibility measurement using a Bartington MS2B sensor (Dearing, 1999a, 1999b) and another 10 g for pH analysis following the procedures outlined by Hendershot et al. (1993). After completion of the magnetic

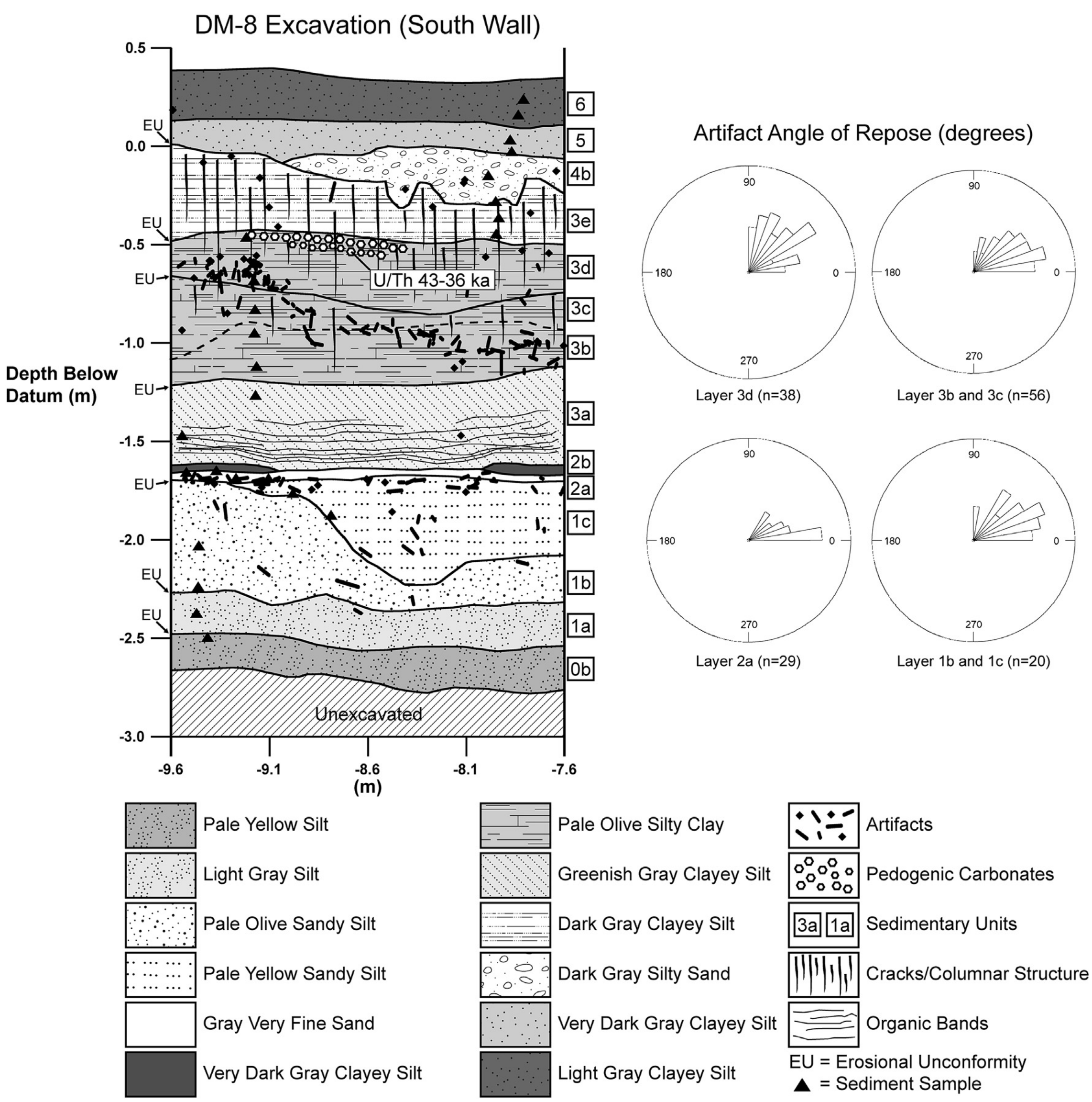

Fig. 4. Stratigraphic profile of the DM-8 excavation.

susceptibility measurements the same subsamples were used for sequential Loss-on-Ignition (LOI) to estimate the proportions of organic and inorganic carbon (Dean, 1974; Heiri et al., 2001; Santisteban et al., 2004). Approximately 1 g subsamples were placed in clean, dry ceramic crucibles and the combined weight recorded to 4 decimal places using a Mettler Toledo AB104-S digital balance. The samples were placed in a muffle furnace at 105 °C for 12 h to remove all remaining moisture then cooled in a desiccator and reweighed before returning to the muffle furnace at 550 °C for 4 h. Again they were cooled and weighed. The percentage weight loss after this ignition (LOI_{550}) is an estimate of the organic carbon content. The final ignition was at 950 °C for 2 h after which the samples were cooled and weighed for the final time; the percentage weight loss (LOI_{950}) is proportional to the inorganic carbon content, whose source we can assume is from $CaCO_3$ (Dean, 1974; Jones and Richter, 2011). Values are presented as percentage weight loss. Finally, we determined the particle size distribution (PSD) for each sample using a HORIBA Laser Scattering Particle Size Distribution Analyzer LA-920. Prior to the PSD analysis carbonates were removed from each sample using a 3 M HCl treatment as was organic matter using successive cold and heated H_2O_2 treatments (Sheldrick and Wang, 1993) Proportions of clay (<4 μm in diameter), silt (from 4 μm to 62.5 μm in diameter), and sand (>62.5 μm) were calculated using the size class divisions established by Wentworth (1922).

Artifacts were classified using the typology outlined by Debénath and Dibble (1994). The technological (Bisson, 2000) and taphonomic attributes of each specimen were also recorded. In addition to the artifact angle of repose, other taphonomic variables considered include condition and alteration. Condition refers to post-depositional damage of the edges and/or surface of the artifact. Undamaged specimens have sharp edges and flake-scar ridges that appear fresh and exhibit no microflaking, crushing, or abrasion. Moderately damaged pieces show evidence of microflaking, abrasion, or edge crushing that is discontinuous but extensive, as opposed to slightly damaged pieces that only show traces of these features. The heavily damaged category refers to pieces with substantial damage on all edges. Rolled specimens are characterized by extensive crushing and abrasion on all edges and surfaces, while wind-abraded pieces may have intact edges with polished and rounded flake scar ridges. Alteration refers to patination and other chemical alterations to the artifact surface color. Slightly patinated pieces have an altered surface color but the natural color is still evident, although patchy. Moderate patination refers to a color change on the entire surface of the piece; while heavy patination means the artifact is bleached white. De-silicified pieces show evidence of chemical dissolution of the artifact surface, leaving a chalky texture and appearance.

4. Results

4.1. The DM-8 excavation

4.1.1. Stratigraphy

The stratigraphy of the DM-8 excavation is similar to the geological trench profile described in Cordova et al. (2013), however the details of the DM-8 excavation have yet to be published and the additional laboratory data elaborate upon and clarify previous descriptions of the Druze Marsh stratigraphy (Figs. 4 and 5; Table 2). The stratigraphic unit designations developed by Cordova et al. (2009, 2013) will continue to be used in order to maintain consistency with previously published reports. The DM-8 excavation stratigraphic sequence is characterized by thick deposits of lacustrine and palustrine silts and silty clays intercalated with erosional unconformities, aeolian deposits, and pedogenic carbonate development (Fig. 4). The lower portion of the profile is dominated by silts with the proportion of sand increasing upward until the erosional unconformity at the contact between layers 1c and 2a (Fig. 5). This represents a transitional period from a marsh or lake environment in unit 1b to arid conditions and the accumulation of aeolian silt in 1c, ultimately leading to a period when erosion dominates the Druze Marsh (Table 2). The erosional episode ends with the accumulation of unit 2a, which is aeolian silt. The basal age of the DM-8 section and the length of time represented by this erosional unconformity at the boundary of layer 1c/2a are currently unknown. Attempts to date quartz grains from layers 0b and 2a using optically stimulated luminescence (OSL) produced saturated age estimates of >38 ka and >29 ka respectively. The deposits contain an unusually high concentration of uranium and have high dose rates, resulting in rapid saturation of the quartz samples. The saturated estimates provide 'older than' dates. We expect that the lower deposits are much older due to the Lower and Middle Paleolithic artifacts they contain (see Section 4.1.2). Also, a uranium series age estimate from the pedogenic carbonates at the top of layer 3d suggests the onset of carbonate formation, indicating a local transition from wet to dry conditions with increased evapotranspiration, occurred between 43 and 36 ka (Cordova et al., 2013). It also implies that the greenish gray silty clays of layer 3d – and all

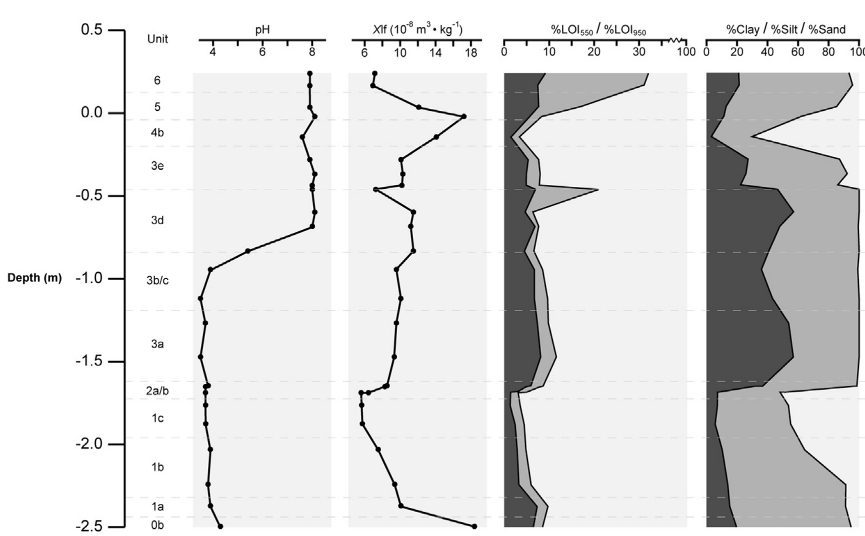

Fig. 5. Sedimentological data from the DM-8 stratigraphic profile (*X*lf is the low frequency magnetic susceptibility measurement).

layers below – were deposited prior to the carbonate formation ca. 43–36 ka. It is possible that the depositional hiatus at the 1c/2a boundary correlates with the accumulation of pedogenic carbonates in DM-2A, which produced a U-series age estimate of 151–140 ka (Cordova et al., 2013). Current attempts to date feldspar grains from the lower layers in the Druze Marsh are in process but at present radiometric age estimates are unavailable for the basal deposits at DM-8.

according to the sedimentary unit in which they were found (Table 3). When plotted against the stratigraphic profile, and in conjunction with field notes, the artifacts clearly cluster into four major groups. Artifact clusters occur in layer 3d, layers 3b and c, layer 2a, and scattered throughout layer 1b and 1c (Fig. 4). Artifacts are sparsely scattered in layer 5 and 3e but the sample sizes are too small to warrant detailed analysis. Throughout the Druze Marsh, layers 5 and 6 consistently produced Epipaleolithic and Neolithic material mixed with Roman-Byzantine period ceramic and glass. Our test pits suggest that layer 3e dates to the Upper Paleolithic/Epipaleolithic (Cordova et al., 2009), but a larger sample and better chronological control is needed to confirm this hypothesis.

Table 2
Description of sedimentary units in the DM-8 excavation and associated depositional environments.

Sedimentary unit	Description	Depositional environment
6	Light gray clayey silt high in carbonate content with a slightly basic pH	Drying of the historical/Holocene marsh
5	Very dark gray sandy silt with a slightly basic pH	Historic/Holocene marsh with permanent water
4b	Dark gray silty sand with a neutral pH	Channel fill, mudflow
3e	Dark gray clayey silt with numerous large vertical cracks, columnar structure, and a slightly basic pH	Shallow marsh with permanent water
3d	Pale olive silty clay with high carbonate content at its upper boundary, vertical cracks and columnar structure, and a slightly basic pH	Deep marsh or lake with perennial water
3b and 3c	Dark greenish gray to olive gray clayey silt with a few vertical cracks and an acidic pH	Marsh or shallow lake with dry episodes, perhaps seasonal drying
3a	Dark greenish gray silty clay with an acidic pH and organic bands visible at the bottom of the unit	Deep Marsh or lake with perennial water
2b	Thin layer (<5 cm) of very dark gray clayey silt with an acidic pH	Transition from playa to marsh
2a	Thin layer (<5 cm) of gray silty sand with an acidic pH	Playa with aeolian accumulation
1c	Pale yellow sandy silt with a sugary consistency and an acidic pH	Aeolian accumulation, perhaps a lunette
1b	Pale olive silt with an acidic pH that grades upward to a silty sand	Deep marsh or lake, transitioning to arid conditions
1a	Light gray silt with orange stains similar to 0b and an acidic pH	Aeolian accumulation
0b	Pale yellow silt with an acidic pH and orange mottles	Aeolian accumulation, oxidation of underlying basalt

The accumulation of aeolian silt in layer 2a is conformably overlain by a light brownish gray clayey silt deposit (2b) that is associated with an increase in organic matter content (Fig. 5). This layer represents the onset and transition to wet conditions in the Druze Marsh, as evidenced by the thick accumulation of silty clays that lie immediately above. These silty clays were deposited by standing permanent water. The absence of artifacts in layer 3a and the presence of artifacts in 3d being explained by post-depositional disturbance (see Section 4.1.2) suggests these deposits are culturally sterile and produced by a perennial deep marsh or shallow lake. The slight reduction in clay content in layers 3b and 3c and the embedded artifacts (Figs. 4 and 5) lead us to conclude that at least the upper portion of this deposit represent a seasonal deep marsh or shallow lake that allowed Paleolithic populations to exploit the area for part of the year. The silty clay deposits of 3d are capped by substantial pedogenic carbonate development, verging on a K horizon. The transition to this dry period likely began ca. 43–36 ka and continued for an unknown length of time until a dark gray clayey silt, layer 3e, from a shallow and probably seasonal marsh is deposited. This is a return to moist conditions but not nearly as wet as the previous thick clay deposits of 3a through 3d, which is evidenced by the reduced clay content and small proportion of fine aeolian sand in the particle size distribution (Fig. 5). This shallow marsh is truncated by a channel flow deposit, likely laid down in a single mudflow event (Cordova et al., 2009). The corresponding spike in magnetic susceptibility may represent increased fluvial influx and watershed erosion, as was suggested by Petraglia et al. (2012) for deposits surrounding the Jubbah paleolake in the Nefud Desert in the north-central part of the Arabian Peninsula. This interpretation is consistent with a mudflow event. The top two deposits, layers 5 and 6, are associated with the historic wetland and its gradual drying, demonstrated by the increase in carbonate content towards the surface (Fig. 5).

4.1.2. The artifacts

A total of 193 artifacts >2 cm were recovered, recorded, and analyzed from the DM-8 excavation. Artifacts were grouped

Table 3
Summary of artifacts recovered from the DM-8 excavation.

Artifact type	Sedimentary unit						Total
	1b & 1c	2a & 2b	3b & 3c	3d	3e	5	
Levallois flake	1	1	0	0	0	0	**2**
Levallois point	0	2	2	0	0	0	**4**
Mousterian point	0	1	2	0	0	0	**3**
Endscraper	0	0	1	0	0	0	**1**
Endscraper on blade	0	0	0	1	0	0	**1**
Burin	0	0	0	0	1	0	**1**
Perçoir	0	0	0	1	0	0	**1**
Naturally-backed knife	0	1	0	0	0	0	**1**
Notch	1	0	0	0	0	0	**1**
Denticulate	1	1	0	0	1	0	**3**
Miscellaneous	0	1	0	0	1	0	**2**
Flake and flake fragments	9	16	18	18	5	5	**44**
Blade and blade fragments	0	1	32	20	5	2	**87**
Twisted bladelet	0	0	1	0	0	0	**1**
Levallois blade	0	4	0	0	0	0	**4**
Angular fragment	3	3	2	4	0	0	**12**
Biface retouch flake	1	0	0	0	0	0	**1**
Double backed bladelet	0	0	1	0	0	0	**1**
Single platform core	0	2	3	2	0	0	**7**
Polyhedral core	0	0	1	0	0	0	**1**
Levallois core	1	1	0	0	0	0	**2**
Blade core	0	0	3	2	0	0	**5**
Bladelet core	0	0	1	1	0	0	**2**
Bladelet core tablet	0	0	0	0	1	0	**1**
Discoid core	1	0	0	0	0	0	**1**
Core fragment	1	0	0	0	0	0	**1**
Handaxe and handaxe fragments	2	0	0	0	0	0	**2**
Azraq cleaver	1	0	0	0	0	0	**1**
Total	**22**	**34**	**67**	**49**	**14**	**7**	**193**

The predominance of blades, blade cores, the endscraper on a blade, the twisted debitage, and the absence of Levallois technology in layer 3d suggest that the assemblage dates to the Upper Paleolithic (Table 3). This attribution is also suggested by the Uranium series date of 43–36 ka from the pedogenic carbonate that caps the deposit. The majority of artifacts were found resting at angles greater than 45° from horizontal (Fig. 4). We suspect that this cluster originated as an Upper Paleolithic occupation on the surface of layer 3d and when the environment transitioned to arid conditions the clayey silts of layer 3d dried out and shrank causing the artifacts to fall through large vertical cracks. This arid transition would also cause the precipitation of pedogenic carbonates, suggesting an approximate age for the assemblage. This post-depositional scenario provides an explanation for why the cluster appears embedded in the bottom half of layer 3d, which is a thick silty clay deposited by a perennial deep marsh or shallow lake. Moreover, the angle of repose suggests a heavily disturbed assemblage (Fig. 4) but nearly all of the artifacts are in pristine condition (Table 4), meaning whatever disturbed the orientations must have been a relatively gentle process. Although the vertical cracks in the DM-8 profile become less dramatic and less frequent in layers 3c and 3b they still occur, meaning there is a chance some artifacts from 3d have fallen below the 3c/d boundary and are incorporated into the underlying cluster of artifacts. However, the artifacts in layers 3b and c are predominantly tilted at angles less than 45°. If artifacts have been incorporated into the 3b and c cluster from above it appears to have been very few, as we would expect them to show up as severely tilted artifacts in the distribution of angles of repose (Fig. 4).

Table 4
Condition of artifacts from the DM-8 excavation.

Artifact condition	Sedimentary unit						Total
	1b & 1c	2a & 2b	3b & 3c	3d	3e	5	
Undamaged	14	26	61	48	8	4	**161**
Slightly damaged	6	2	1	0	5	2	**16**
Moderately damaged	0	2	2	2	1	1	**8**
Heavily damaged	1	4	1	0	0	0	**6**
Rolled	1	0	0	0	0	0	**1**
Wind abraded	0	0	1	0	0	0	**1**
Total	**22**	**34**	**66**	**50**	**14**	**7**	**193**

As described in Section 4.1.1, layers 3b and c were deposited by a fluctuating marsh or shallow lake that could be exploited by prehistoric populations when the marsh or lake bed was exposed for short periods of time, perhaps seasonally. The general tilting of artifacts between 0 and 45° can be explained by artifacts sinking or being trampled into the soft clayey silts or perhaps slight disturbance as the clayey silts experienced seasonal cycles of shrink and swell. If this is the case, it is possible that hominins occupied the Druze Marsh at the unit 3c/3d transition and not during water level fluctuations during the deposition of 3b and 3c. Ongoing sedimentological research will hopefully resolve this issue. Nevertheless, the relatively pristine condition of the assemblage implies gentle disturbance (Table 4). Typologically the 3b and c assemblage is difficult to classify. It is dominated by blades and blade fragments but the presence of a Levallois flake, two Levallois points, and a Mousterian point clearly indicate Middle Paleolithic technology. Because the deposit represents either a seasonally fluctuating marsh over an unknown length of time or an occupation on an erosional unconformity, it could be a palimpsest of Middle and Upper Paleolithic occupations. This assemblage has two prominent types of patination, whereas all others are dominated by one particular category (Table 5). However, because the carbonates at the top of layer 3d date to ca. 43–36 ka, the assemblage must be older, perhaps dating to the latter part of the Middle Paleolithic near the transition to the Upper Paleolithic, which could account for the combination of tool types observed.

Table 5
Alteration of artifacts from the DM-8 excavation.

Artifact alteration	Sedimentary unit						Total
	1b & 1c	2a & 2b	3b & 3c	3d	3e	5	
Unpatinated	0	0	0	0	1	2	**3**
Slightly patinated	0	0	18	41	6	3	**68**
Moderately patinated	0	0	3	6	5	2	**16**
Heavily patinated	2	2	2	0	1	0	**7**
Double patinated	1	1	0	2	0	0	**4**
De-silicified with thermal damage	0	0	1	0	0	0	**1**
Patinated with thermal damage	5	5	3	0	1	0	**14**
Black and white patina	0	1	32	1	0	0	**34**
Black patina	14	25	7	0	0	0	**46**
Total	**22**	**34**	**66**	**50**	**14**	**7**	**193**

The cluster of artifacts found in layer 2a is a Middle Paleolithic occupation surface in primary context. The artifacts are lying horizontally in nearly pristine condition (Fig. 4; Table 4) on the aeolian silts of layer 2a at the transition with layer 2b, which marks the return to moist conditions in the Druze Marsh. The length of time represented by the 1c/2a erosional unconformity and the 2a aeolian deposition is unknown. However, the elongated Mousterian point and the prevalence of laminar Levallois technique in the layer 2a–b assemblage match well with other early Levantine Mousterian assemblages in the Near East (Fig. 6; Table 3) (Shea, 2008).

In layers 1c and 1b artifacts are scattered and diffuse (Fig. 4). They constitute a very small assemblage, but it includes large handaxes and a bifacial cleaver (Table 3), which are typical of the Late Lower Paleolithic. Until a larger sample is obtained we preliminarily classify the basal deposits at DM-8 as Late Acheulean, likely to be contemporaneous with the Late Acheulean of Azraq facies deposits identified in the Shishan Marsh to the south (Copeland, 1989a, 1989b, 1989c; Rollefson et al., 1997). Taphonomically the artifacts are undamaged or only slightly damaged (Table 4) and the pattern of the angle of repose matches the 3b and c assemblage. Layer 1b represents a similar depositional marsh or lake environment as layers 3b and c, although the reduced clay content suggest it was slightly shallower water (Fig. 5), and layer 1c is an aeolian sandy silt. We suspect this collection of artifacts accumulated slowly and was gently buried by seasonal marsh and aeolian deposits, possibly the remains of a lag deposit that has since been reburied. The slightly different pattern of patination for artifacts from layers 1c and b compared to those from the thick clays suggests a different post-depositional environment (Table 5), perhaps a longer exposure on the surface during the aeolian accumulation. Although only speculation at this point in time, the only other assemblage with a similar breakdown of patination categories is layer 2a that is also an aeolian accumulation.

5. Discussion

5.1. The DM-8 excavation in broader context

Despite poor chronological control of the Druze Marsh stratigraphic sequence at present, it is clear that there are traces of Lower through Upper Paleolithic occupations buried beneath the

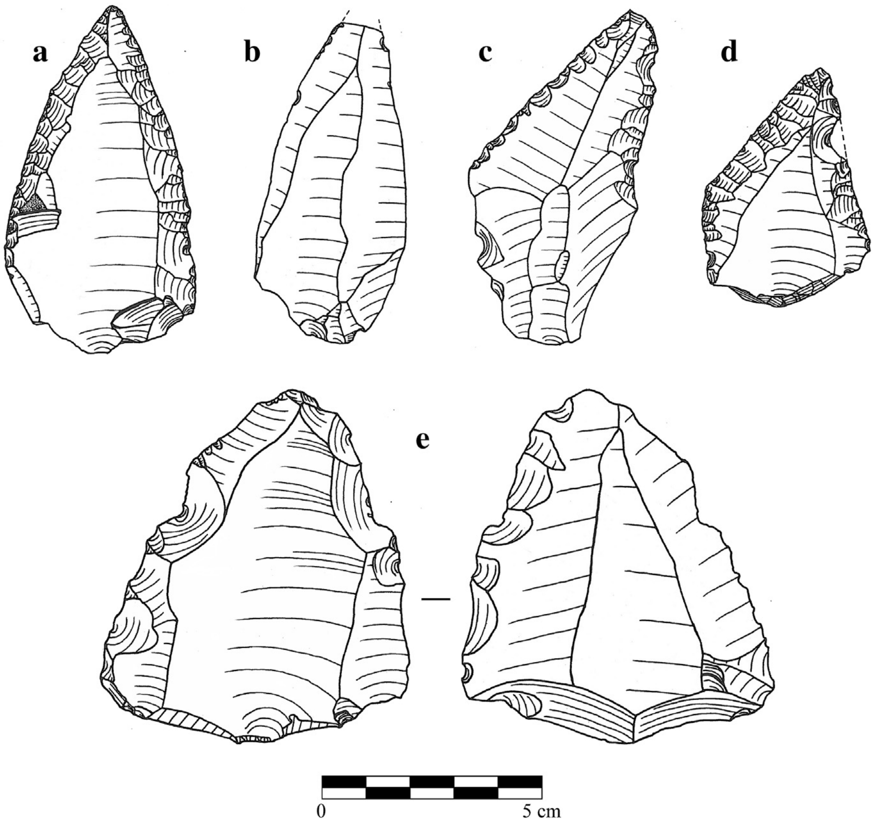

Fig. 6. Example of MP artifacts from Druze Marsh: (a) Mousterian point; (b) elongated Levallois point (tip broken in antiquity); (c) convergent scraper-denticulate or atypical Mousterian point (tip broken in antiquity); (d) retouched Levallois point (notch is excavation damage); (e) Nubian type 2 preferential Levallois core (Van Peer, 1991) with a dihedral striking platform. The support for the Levallois core appears to be a very large pointed flake in which the interior face was prepared for product removal. Specimens a, b and e are from layer 2a; specimen c from Level 3bc; specimen d from layer 3d.

bed of the historic Druze Marsh. The occupations correspond to relatively dry paleoenvironments when the wetland area was reduced in size. Separating these occupations are extended periods of time when the wetland increased in size and depth, perhaps becoming a deep marsh or shallow lake and drowning the land previously available for hominin occupation. Although DM-8 is at present our only detailed excavation, the stratigraphic and archaeological sequences recorded from various test pits throughout the former marsh bed (Fig. 3) confirm the general occupation sequence identified in the DM-8 excavation (Fig. 7). The most striking observation is that the Middle Paleolithic occupation surface identified by layers 2a and 2b appears in almost all test pits examined, suggesting there is a buried, well preserved and *in situ* Middle Paleolithic occupation surface beneath most of the bed of the former Druze Marsh, at least across the 1–1.5 km^2 area tested thus far (Fig. 7). Lower Paleolithic occupation below this stratigraphic marker is also confirmed throughout the area by numerous large bifaces found in DM-1 and DM-11, and a >20 cm long Azraq cleaver found in DM-2B in 2011. It is thus possible that the Lower to Middle Paleolithic transition is documented in the Druze Marsh stratigraphy. The Upper Paleolithic occupations are slightly more difficult to correlate but the deposits are present in numerous profiles (Fig. 7). At present it is unclear if the Middle to Upper Paleolithic transition is well documented here.

The correlation of stratigraphic sequences across the Druze Marsh also sheds light on the paleotopography of occupation surfaces (Fig. 7). In some test pits (DM-2B, 3, and 11), the erosional unconformity prior to the deposition of layers 2a and 2b contains an additional set of layers designated layers 1d and 1e. Layer 1d is a light gray silty sand of aeolian origin that is overlain by layer 1e, a grayish brown silt or sandy silt with a slight increase in organic matter that we believe represents an interdunal pond during relatively arid conditions. Moreover, there is a facies transition from north to south that sees the greenish gray and pale olive clayey silts and silty clays in units DM-8 and 9 become coarser grained greenish gray and pale olive sandy silts or silty sands in DM-2 through 6 (Fig. 7). We suspect this change is related to the proximity of the stratigraphic profile to the paleoshore of the marsh or lake, with coarser sediments being deposited closer to the shoreline and higher concentrations of clay in the deeper parts. These local paleotopographic variations have a significant influence on the potential areas available for hominin occupation and exploitation at various times in the past (Ames and Cordova, in press), a full understanding of which can only be attained through a detailed study of the local landscape evolution.

If we contextualize the Druze Marsh Middle Paleolithic occupation surface with other known MP finds in the region, it becomes clear that a changing paleolandscape in response to fluctuations in water availability had important ramifications for Middle Paleolithic settlement and land use in the Druze Marsh. During a period of regional aridity when the Druze Marsh spring pools were substantially reduced, hominins moved into the Druze Marsh proper to exploit the concentration of resources around a limited water source in what would otherwise be a very dry, harsh regional environment. This likely relates to the end of the MIS 6 glacial, which also produced arid conditions around the Jubbah paleolake in the Nefud desert (Petraglia et al., 2012). This time period agrees with an early Levantine Mousterian attribution for the *in situ* occupation we identified in layers 2a-b, which Shea (2008) places

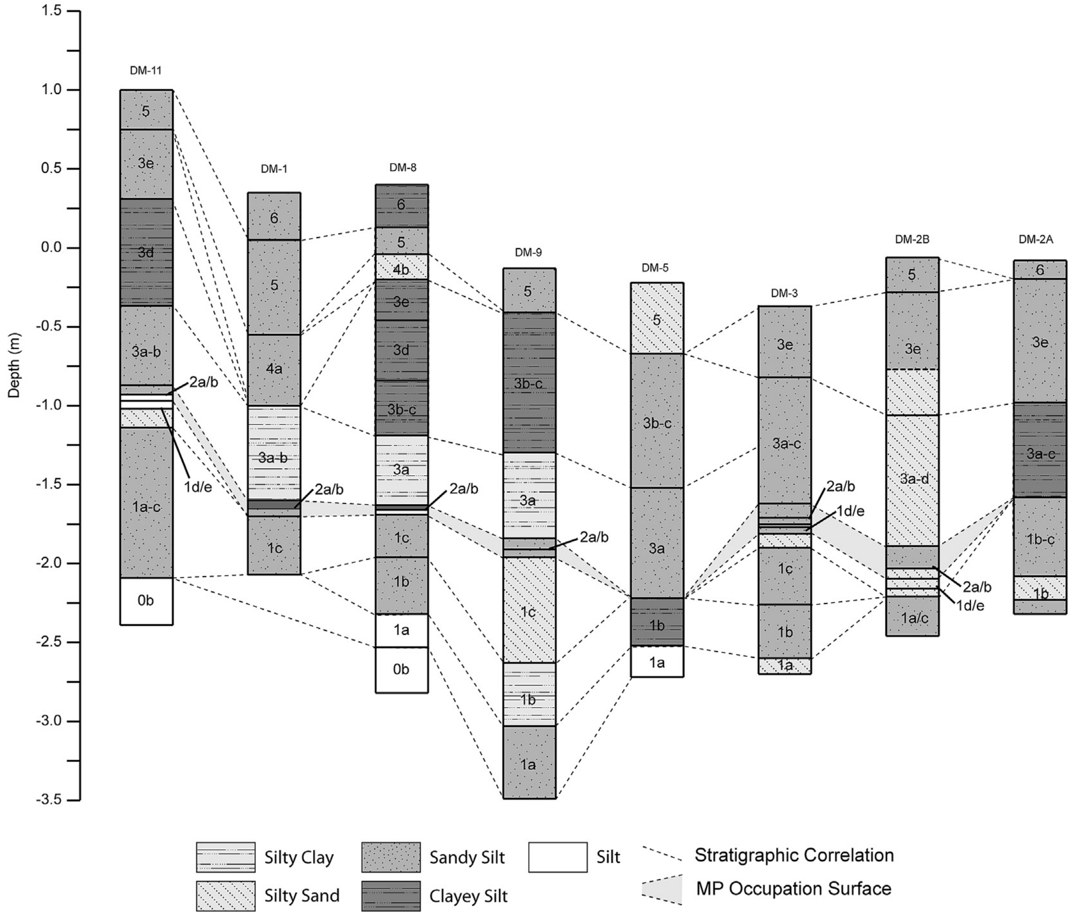

Fig. 7. Stratigraphic correlation of the Druze Marsh sequences.

between 250 and 130 ka. This occupation surface most likely corresponds to the end of MIS 6 or the early part of MIS 5e. As conditions improved during MIS 5c and 5a in the Druze Marsh, the spring sites were inundated with deep marshes and shallow lakes. The wetter conditions were not limited to the two historic spring sites in Azraq. Green clayey silts, similar to those observed in the Druze Marsh stratigraphy, were identified in the banks of Wadi Enoqiyya to the north. The clays were capped by carbonate nodules that formed sometime between 118 and 93 ka (Cordova et al., 2009), suggesting the open water deposits accumulated during MIS 5e or 5c. It is during this wet period that the MP occupation of Wadi Enoqiyya documented by Hours (1989) most likely occurred. As the region returned to arid conditions, erosion and deflation left the traces of MP occupation on the surface as part of a lag deposit. There is also evidence to suggest that during wetter conditions MP hominins occupied the uplands that are now behind the Azraq Castle (Cordova et al., 2013). MP artifacts were observed lying above a pedogenic carbonate horizon that correlates with a similar layer exposed in another section of the Druze Village from which the carbonates were dated to between 137 and 126 ka (Cordova et al., 2009, 2013). The MP occurred on top of this horizon, and is therefore more recent. It may correspond in time to the Wadi Enoqiyya occupation during MIS 5e or 5c, but it could also relate to MIS 5a. The timing of speleothem deposition to the northwest of Azraq suggests that MIS 5a was a regionally wet period in the eastern desert (Frumkin et al., 2008). Although the full timing of events is still unclear, the result of our excavation at DM-8 and research in the surrounding areas demonstrate that paleoenvironmental fluctuations had a substantial influence on the land available for hominin occupation and played a key role in how settlement patterns changed throughout the Middle Paleolithic. Only with continued research on the timing of hominin occupation and paleoenvironmental change, as well as the size and location of water sources, will we be able to fully understand what the specific impacts were for MP hominins.

The importance of understanding the location and size of water sources is highlighted by layer 4a, which only appears in DM-1, DM-1X, DM-1Y, and DM-10 (Figs. 3 and 7). Layer 4a is a black, organic-rich deposit that grades upward from a silt loam to a silty sand. During only a few short days of salvage work in DM-1, wall scrapings from layer 4a produced a >5000 piece Epipaleolithic assemblage. The assemblage is dominated by chipping debris (>3700 pieces), blades ($n = 610$), bladelets ($n = 692$) and backed, diagonally truncated bladelets ($n = 200$) (Cordova et al., 2009). It is typologically Early Kebaran and is reminiscent of assemblages recovered from 'Ain Qasiya to the south that date between 24 and 17 ka (Richter et al., 2007; Richter, 2009; Jones and Richter, 2011). The deposit represents a spatially isolated marsh edge environment that is at least partially contemporaneous with the shallow marsh deposits of layer 3e in DM-8. This means that DM-8 was not occupied during the Epipaleolithic because it was under water, whereas the marsh edge only a dozen meters away to the north and west was heavily exploited. This example, combined with the MP example above, can be projected back in time to ask what part(s) of the Azraq Basin were the Lower, Middle, and Upper Paleolithic inhabitants occupying while the deep marshes and shallow lakes were depositing layers 1b, 3a, 3b and c, and 3d. We have some possibilities established, but a full understanding of the prehistoric settlement and land use in the Druze Marsh cannot be separated from the larger Azraq Basin settlement history.

In addition to understanding the paleotopography and landscape evolution of the Druze Marsh, piecing together the prehistoric settlement history and land use of the area depends on identifying and accounting for a variety of post-depositional alterations. Artifact assemblages documented in the DM-8 excavation, although mostly in pristine condition (Table 4), ranged from an *in situ* occupation surface to substantially displaced assemblages due to the shrink-swell of clayey sediments (Fig. 4). It can be assumed that similar phenomena occur across the Druze Marsh paleolandscape and most likely the pattern of disturbance is spatially variable, at best it is correlated with paleotopographic variations.

In addition to artifact displacement, a second challenge presented by the Druze Marsh stems from the fact that no faunal material was recovered from stratified context during our test pits or the DM-8 excavation. The highly acidic pH of the deposits in the Druze Marsh makes the preservation of bone and teeth highly unlikely. The pH profile from the DM-8 excavation demonstrates the general pattern for the entire Druze Marsh (Fig. 5). Deposits close to the surface and near layers capped by pedogenic carbonates, such as layer 3d, have a relatively neutral or slightly basic pH. All other sedimentary units, especially the deeper deposits, have a pH between 3.0 and 4.0. A set of pH samples from 'Ain Soda in the Shishan Marsh (Pokines et al., in press) show a similar pattern of neutral values near the surface and highly acidic deposits at depth. The one exception is that the deepest tested deposit at 'Ain Soda, approximately 2.75 m below the surface and associated with the Late Acheulean (Rollefson et al., 1997; Cordova et al., 2008), has a pH between 6.0 and 7.0 (Pokines et al., in press). This difference is probably related to the underlying bedrock of North Azraq being basalt, whereas in South Azraq it is limestone (Ibrahim, 1996). As a results, the Late Acheulean layers at C Spring and 'Ain Soda have produced a rich faunal record, including extinct rhinoceros specimens (*Dicerorhinus hemitoechus*) that date from the Middle to Late Pleistocene (Clutton-Brock, 1989; Rollefson et al., 1997). Pollen has also been obtained from deposits in South Azraq, at both Lion Spring (Kelso and Rollefson, 1989) and 'Ain Soda (Cordova et al., 2008). The degradation of recovered pollen from the Druze Marsh has made identifications difficult, but phytoliths are well preserved. Both pollen and phytoliths studies are underway.

The results of our excavations to date suggest that even during the driest periods the Druze Marsh would still have had seasonal ponds similar to the center of the modern Qa' Azraq in winter (Cordova et al., 2013). Hominins and other animals would have continued to congregate near these ponds as they would have represented the only water source on the landscape. During more humid periods, abundant rains would have resulted in high lake levels and large amounts of spring water. During these periods it appears that hominins moved to higher elevations or upriver along the banks of the many surrounding wadi channels. At other times, when there was an intermittent drying of the lake, hominins reoccupied the Druze Marsh proper in order to continue to access this source of water, plants, and animals. This suggests that while hominins experienced range contractions and local population extinctions throughout the Levant, populations in this area may have been less vulnerable.

5.2. Future directions: reconstructing the Paleolithic settlement history of the GAOA

Combining the previously known Paleolithic finds in the Azraq Basin with the new results from the Druze Marsh produces a spatially continuous, but compositionally heterogeneous distribution of artifacts across the GAOA landscape, at least for the parts tested to date (Fig. 2; Table 1). Paleolithic artifacts from all time periods are known from a variety of geomorphic contexts in both buried and surface contexts. Reconstructing a history of prehistoric settlement and land use in the region, therefore, requires establishing methodological and analytical techniques that can integrate the archaeological remains found in different geomorphic contexts and account for post-depositional alterations similar to those observed in the Druze Marsh.

Traditionally, the reconstruction of Paleolithic settlement patterns has relied on site distribution data from large scale survey with only minimal excavation. Sites are identified based on flexible criteria of artifact densities, assigned to temporal periods spanning millennia using diagnostic features of stone tools, and their spatial distribution is correlated with various landscape features to determine prehistoric settlement patterns through time. However, the applicability of the site concept for the open-air Paleolithic archaeological record has been heavily criticized (Thomas, 1975; Foley, 1981; Binford, 1992; Dunnell, 1992; Ebert, 1992) and the relationship between landscape variables (e.g. slope, geology, etc.) and the distribution of surface artifacts is known to change through time and space, requiring more sensitive spatial analyses that consider multiple scales of analysis (Bevan and Conolly, 2009). In reality, the Pleistocene open-air archaeological record is a constellation of material culture interspersed throughout a 3-dimensional space of sedimentary history (Foley, 1981; Butzer, 1982: 198; Stafford, 1995; Goldberg and Macphail, 2006), making the distribution of artifacts on the contemporary landscape a product of the spatial distribution of artifact discard, the length of artifact accumulation, as well as sedimentary deposition, erosion, and land surface stability (Foley, 1981; Bailey, 1983, 1987, 2007, 2008; Schiffer, 1987; Rossignol and Wandsnider, 1992; Stein and Linse, 1993; Stern et al., 1993; Stern, 1994; Holdaway and Wandsnider, 2008). In this respect, we suggest that deciphering the settlement patterns and behaviours associated with large open-air sites, such as the Azraq Basin, necessitates an approach that incorporates landscape evolution as a critical component contributing to the spatial distribution and variability in the archaeological record.

The temporal resolution at which landscape change unfolds, however, places constraints on the interpretation of regional settlement history and land use (Binford, 1981; Foley, 1981; Bailey, 1983, 1987, 2007, 2008). For example, in northwest Jordan, Edwards (2004) observed that both rolled and fresh Middle Paleolithic artifacts occur in the same stratigraphic context. This suggests that some small stone tool scatters were buried quickly, preserving them in primary context, while other scatters were left exposed for long periods of time before being buried. The temporal resolution in this stratigraphic unit is variable, meaning some artifact occurrences represent relatively brief moments in time, but others could theoretically span the entire Middle Paleolithic. In addition, research in central Australia (Fanning and Holdaway, 2004; Fanning et al., 2008, 2009; Holdaway and Fanning, 2008) demonstrates that surface geomorphology in arid and semi-arid environments is surprisingly discontinuous; and that artifact clusters which appear very similar can be substantially different in age and can have accumulated over significantly different lengths of time. Together, these and other case studies (Stern et al., 1993; Barton et al., 2002; Bettis and Mandel, 2002; Rech et al., 2007; Fanning et al., 2009; Maher et al., 2011; Sitzia et al., 2012) demonstrate that the spatial distribution of artifacts across the landscape, whether buried or on the surface, is not a simple proxy for prehistoric behavior, but one filtered and interpretively constrained by the history of landscape change. Therefore, a robust understanding of the Paleolithic settlement history of the Azraq Basin, and subsequently its importance as a desert refugium along a possible migration corridor, can only be achieved by reconstructing the regional history of landscape change and evaluating its influence on the visibility, integrity, and spatial distribution of the archaeological material. Only then can the remains from diverse archaeological contexts be incorporated into a unified history of settlement and land use.

Although a number of impressive cave and rockshelter sites exist in the eastern Mediterranean region (see Hovers, 2009: 247–249 for a thorough list), buried or stratified open-air contexts are rare, making their investigation at locations such as the Druze Marsh and throughout the Azraq Basin landscape critical for broadening our knowledge of Pleistocene hominin behaviour and dispersal, and the range of environments they exploited. Nevertheless, both buried and surface contexts are remnants of prehistoric behavior and are thus crucial for deciphering regional settlement histories. We must acknowledge that surface accumulations are not second-rate datasets. Most buried and stratified open-air sites started as surface deposits, meaning they were subject to the same suite of post-depositional processes that are often used to argue for the second-rate nature of surface data (Dunnell, 1992). Regional investigations of settlement patterns therefore require integrating both lines of evidence, something Butzer (2008) sees as a primary challenge confronting the future contribution of geoarchaeology to palaeoanthropological research. Our conception of the Pleistocene archaeological record in the Druze Marsh as a 4-dimensional system of artifact discard, artifact accumulation, sedimentary deposition, erosion, and stability, provides an opportunity to develop novel methodological and analytical techniques capable of integrating the seemingly disparate sources of surface and buried archaeological data.

6. Conclusion

Recent excavation and geoarchaeological research at the Druze Marsh in northeast Jordan have produced Late Lower Paleolithic through Epipaleolithic occupation horizons embedded in a stratigraphic sequence characterized by cyclical aggradations of lacustrine or palustrine silts intercalated with erosional unconformities and aeolian deposition suggestive of drier environments. Evidence of substantial Lower, Middle, and Upper Paleolithic occupation at times when the Druze Marsh was reduced in size suggests that the GAOA functioned as a desert refugium for hominins at times of adverse climatic conditions, with important implications for regional population continuity, turnover, and extinctions at critical times during the Pleistocene. In contrast, Middle and Late Pleistocene humid periods caused substantial increases of the water level in the GAOA, forcing hominins out of the central basin into areas along wadi channels. Positioned at the northern end of the Wadi Sirhan depression between the Levantine Corridor and the Arabian Peninsula, this observed relationship between fluctuating paleoenvironments and hominin settlement dynamics makes the GAOA a potentially important location for the dispersal of hominins between Africa, Eurasia, and the Arabian Peninsula. Evaluating the importance of the GAOA at critical points in human prehistory, however, requires reconstructing a detailed history of Paleolithic settlement and land use by integrating the large body of archaeological remains distributed across varying geomorphic contexts and subject to inconsistent post-depositional alterations. Deciphering the behavioural patterns of such a large open-air landscape necessitates an approach that accepts landscape evolution as a critical component contributing to the spatial distribution and variability in the archaeological record, making it more appropriate to speak of open-air archaeological landscapes rather than sites in the traditional sense.

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