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Interglacial and glacial desert refugia and the Middle Paleolithic of the Azraq Oasis, Jordan

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ABSTRACT

A geoarchaeological study of sediments in the Azraq Oasis, in the Eastern Desert of Jordan, provides information on the fluctuations of the geomorphic and hydrologic systems in this region in relation to the local Middle Paleolithic and Upper Paleolithic occupations. The study shows that local geomorphic and hydrological environments fluctuated between marsh, lake and playa (dry lake bed with eolian activity and/or carbonate accumulation). In some instances, local wet conditions correlate with those registered in other regional paleoclimatic records, as is the case of the period comprising MIS 5a and probably early MIS 4. In other cases, however, local wet conditions represented by marsh deposits with hominin occupations are asynchronous with regional wet conditions. This suggests that the Azraq oases may have acted as desert refugia at times of regional adverse climatic conditions. The fact that Azraq represents a potential desert refugia has important consequences for understanding major issues in the Middle Paleolithic of Southwest Asia, namely (1) the arrival, survival, and extinction of populations of both Neanderthals and early modern humans. The location of Azraq at a crossroads between the Levant, the Arabian Peninsula and other regions of the Middle East, is also an important geographic aspect of desert refugia during the critical period of hominin dynamics in the Middle Paleolithic.

1. Introduction

The Azraq Basin in Jordan's Eastern Desert is known for its abundance of Paleolithic occupations purportedly associated with the presence of oases, marshes and paleolakes. The basin is located at a crossroads with other oases and former lacustrine basins in the Syro-Arabian Desert (Fig. 1). Many archaeological localities in the Azraq Basin have documented occupations spanning the Lower, Middle, and Upper Paleolithic as well as Epipaleolithic and Neolithic periods (Garrard et al., 1975, 1988; Copeland and Hours, 1988, 1989; Rollefson et al., 1997; Richter et al., 2009). Two of these localities include the former Azraq Marshes and their associated springs located in the northwestern part of the Basin (Fig. 2). Known as Azraq ad-Duruz and Azraq as-Shishan, or North and South Azraq, respectively, these areas have until recently acted as oases. Separated only by the 2-km wide alluvial fan created by Wadi Rattama, the two oases are considered a single geographic unit referred to here as the Greater Azraq Oasis Area (GAOA) (Fig. 2).

The Azraq as-Shishan area includes a cluster of springs such as 'Ayn Qasiyya and 'Ayn Sawda, the C-Spring, and the Lion's Spring, some of which have been the subject of many surveys and excavations, revealing the presence of Acheulian, Mousterian, and several Upper Paleolithic, Epipaleolithic, and Neolithic industries (Copeland, 1988, 1989; Hunt and Garrard, 1989; Rollefson et al., 1997; Rollefson, 2000; Richter et al., 2009). Likewise, the Azraq ad-Duruz area encompasses wetland, spring, and lacustrine shoreline deposits associated with similar types of industries as those in the Azraq as-Shishan area (Cordova et al., 2009).

In the early 1990s, groundwater extraction led to the drying of the marshes and a general drop of the water table. Soon thereafter the floors of the former 'Ayn Sawda and 'Ayn Qasiyya pools were dug deeper in an attempt to reach the falling water table. This

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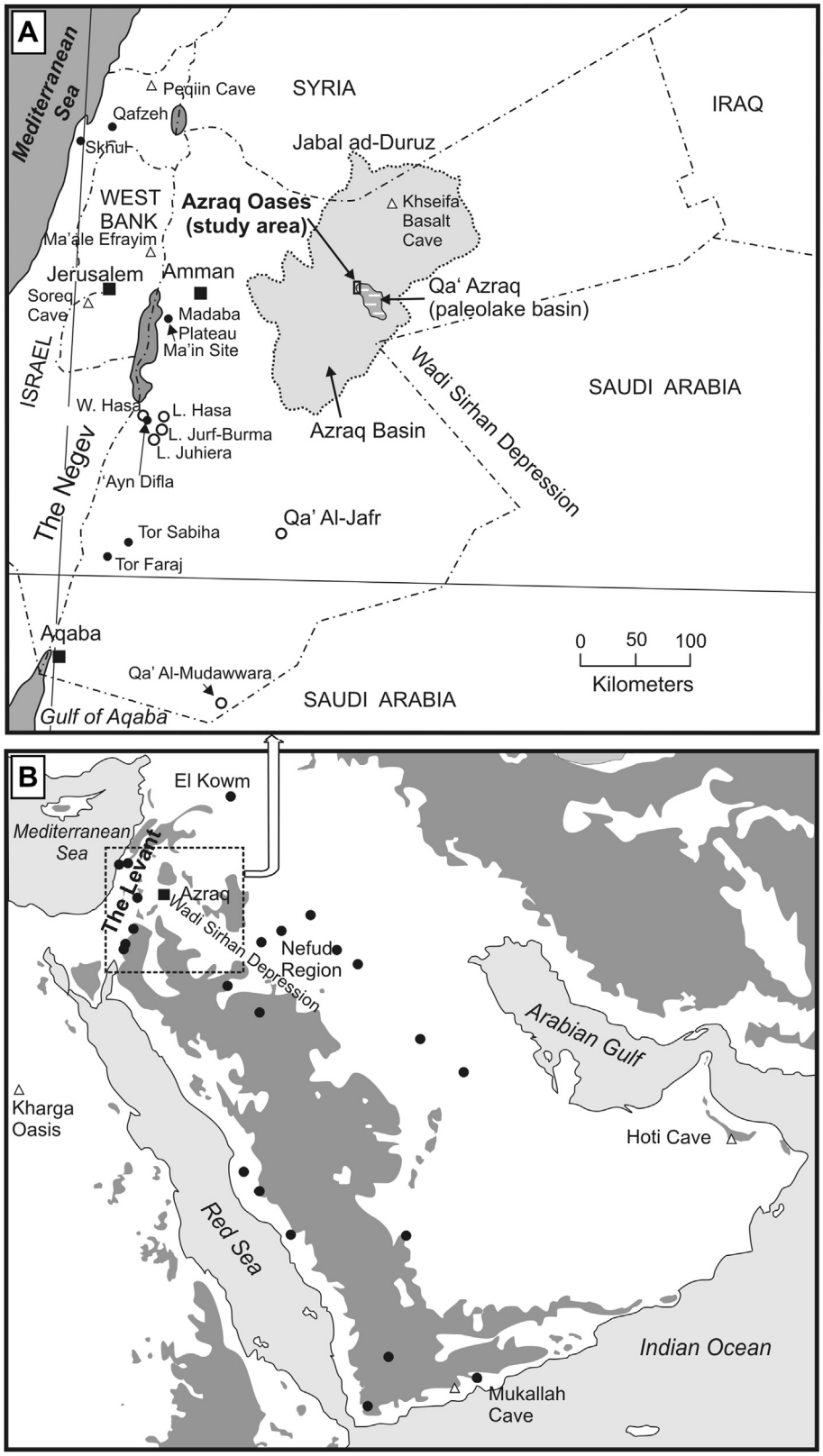

Fig. 1. (A) The Azraq Basin in the context of Jordan and the Levant. Localities referred in text: MP sites, closed circles; paleolakes, open circles; caves with speleothem records, triangles. (B) The regional context of the Levant and the Arabian Peninsula. Circles are Middle Paleolithic sites; those sites for the Arabian Peninsula are after Petraglia and Alsharekh (2003).

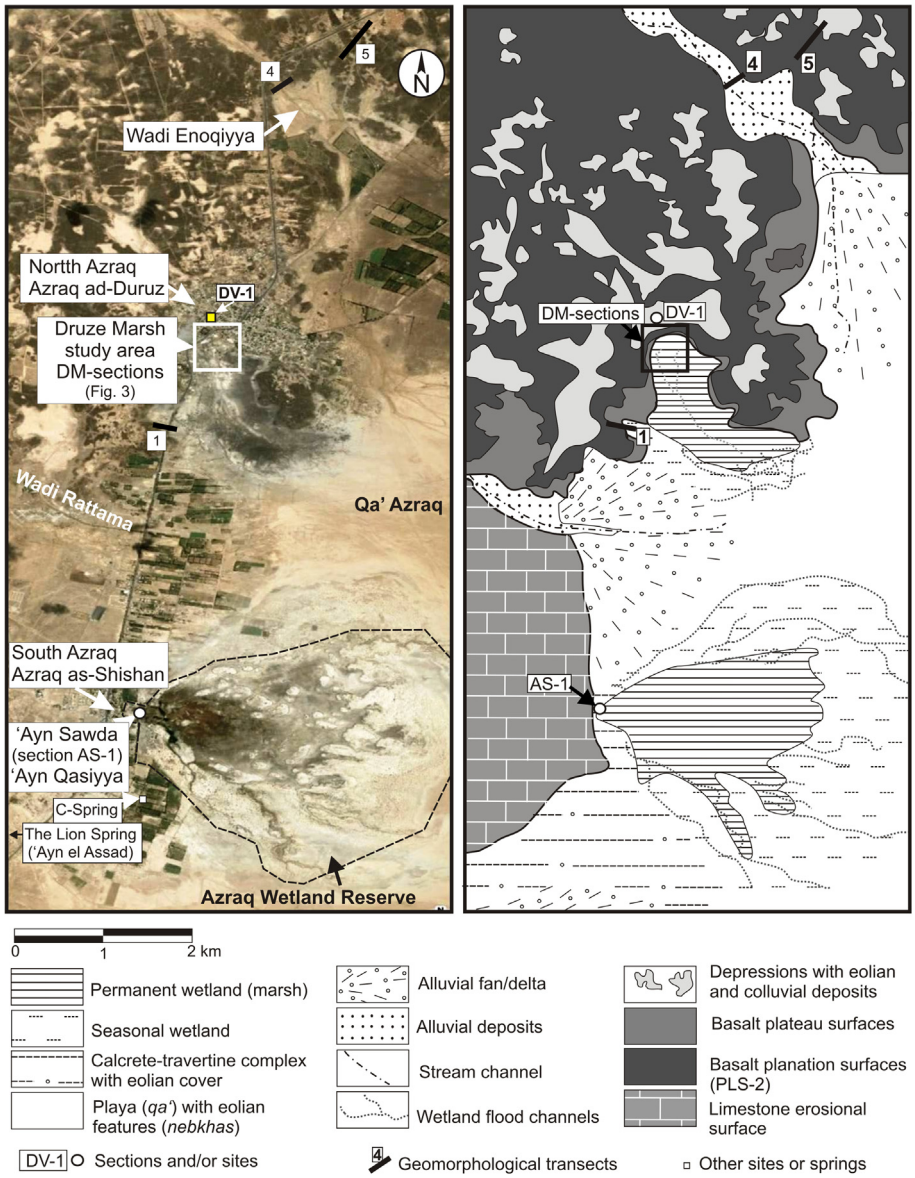

Fig. 2. The Azraq oases and marshes, study localities, profile locations, and geomorphological sketch.

process exposed a number of stratified sites in a variety of sediments (Rollefson et al., 1997). Similarly, as the water table dropped in the Druze Marsh (Azraq ad-Duruz) the local residents dug wells and trenches that also exposed deeply stratified sites (Cordova et al., 2009). Archaeological surveys in previous decades (i.e., Garrard et al., 1975; Copeland and Hours, 1988, 1989) reported numerous sites in GAOA, but at that the time no sites were visible in the Druze Marsh, since archaeological occupations were waterlogged.

Geoarchaeological research efforts in the GAOA have identified sequences of marsh, lake, playa, eolian and alluvial sedimentary facies, which provides testimony of the complex geomorphological and hydrological history of Pleistocene environments in this part of the Azraq Basin (Besançon and Sanlaville, 1988; Besançon et al., 1989; Copeland, 1989; Hunt, 1989; Kelso and Rollefson, 1989; Rollefson et al., 1997; Cordova et al., 2008, 2009; Jones and Richter, 2011). The abundance of Lower, Middle and Upper Paleolithic archaeological material in these sedimentary sequences serve not only to situate hominin occupations with local environmental changes, but also allows us to study them within the contexts of the broader Azraq Basin, the Levantine Region, and the Syro-Arabian Desert (Fig. 1).

In view of the above, the Middle Paleolithic occupation of Azraq occurs in a critical period for understanding the sequence and nature of range contraction and expansion events among both Neandertal and modern human populations in the most arid parts of Southwest Asia. For this reason, the Middle Paleolithic of the GAOA was analyzed in the context of regional climate change, local environmental change, and the regional evolutive (genetic) and migrational history of hominins in order to contribute to an understanding of Neandertal extinction and modern human survivorship in the Greater Syro-Arabian Desert, of which the Jordanian Desert is part of. In particular, this paper addresses the question of whether Azraq served as a desert refugium for hominins during the past two glacial–interglacial cycles, based on recent data collected through the Druze Marsh Archaeological and Paleoecological Project (DMAPP), as well as other past and current projects in the Greater Azraq Oasis Area.

1.1. The concept of desert refugia

The biogeographical concept of *refugium* (plural: *refugia*) in a broad sense designates a relatively small area where populations survive widespread adverse climatic conditions or ecological change. Often, the term is used in the sense of glacial refugium which has been used to refer to regions of southern and central Europe and North America, where temperate flora and fauna retreated during the coldest phases of the Pleistocene (Willis and Whittaker, 2000; Burroughs, 2005). The concept applies also to tropical refugia, which refers to patches of tropical rainforest that shrank when dry conditions took place in the tropics during glacial stages (Haffer, 1969; Willis and Whittaker, 2000), as well to desert areas where biotic populations survive in and around oases (Nichol, 1999).

The concept of glacial refugium is used in the Paleolithic of Europe to refer to localities where hominin populations retreated during the coldest phases of the Late Pleistocene, as is the case of the Neandertal refugia in southern Europe (Lahr and Foley, 2003; Stringer et al., 2004; Carrion et al., 2008; Finlayson et al., 2012) and of Upper Paleolithic populations in the Cantabrian region, southern France, and South East Europe among others (Lahr and Foley, 2003; Burroughs, 2005; Zilhão, 2009). In this sense a refugium is a location where a population should find shelter in times of adverse climatic conditions. The idea is fully transferrable to drylands, where the desert refugia are geographic areas where hominin populations subsist on the concentrated resources that otherwise are scarce in the dryland region. Accordingly, during the Middle Paleolithic various regions of the southern, southwestern and eastern part of the Arabian Peninsula have been identified as desert refugia during extremely dry events for hominin populations originating in Africa (Bailey, 2009; Parker, 2009; Rose and Petraglia, 2009; Rosenberg et al., 2011; Groucutt and Petraglia, 2012; Delagnes et al., 2013; Usik et al., 2013). These localities include areas with springs, lacustrine basins, and floodplains of large allochthonous rivers as is the case of the area now occupied by the Arabian (Persian) Gulf.

The idea of desert refugia in the Middle East transcends the Middle Paleolithic, since the idea has also been applied to Upper Paleolithic and Epipaleolithic populations concentrated around the oases related to small lakes, spring and marsh microhabitats in late glacial Wadi Hasa, Jordan (Clark et al., 1988; Coinman, 2004) and Azraq (Garrard et al., 1988), and in particular for the Azraq wetlands (Jones and Richter, 2011). In summary, it is within this conceptual framework that the DMAPP attempts to answer the question of whether Azraq functioned as a desert refugium for hominins in the Levantine interior throughout the Upper Pleistocene. If the Azraq oases acted as desert refugia during the Middle Pleistocene, then it could have also served as a crossroad point for hominin migrations between the Arabian Peninsula (and eventually NE Africa), the Levant, and other parts of SW Asia.

2. Study area

2.1. Azraq Basin overview

The Azraq Basin is an endorheic basin located in the Jordanian Plateau (Fig. 1A). At the center of the basin, where all the drainages are collected, is Qa‘ Azraq, a salt flat or playa, where sequences of Pleistocene deposits are a testimony of lacustrine bodies, eolian activity and dry periods with carbonate formation (Davies, 2000, 2005). *Qa‘* is an Arabic term that refers to a dry, seasonally flooded flat surface, which equates with the geomorphological term playa, a lake with high rates of evaporation than water input from surface or groundwater sources.

The rocks forming the Azraq Basin are predominantly limestones of Cretaceous, Eocene and Oligocene age, except for the northern third, which consists of Miocene–Pliocene basalt flows (Ibrahim, 1996). Most of the Quaternary geology has been grouped into the Azraq Formation (Ibrahim, 1996), of which distinctive units have been described, including Middle Pleistocene sandstones (Turner and Makhlouf, 2005) and lacustrine terraces (Abed et al., 2008). Other units of Pleistocene age have been broadly described by Besançon and Sanlaville (1988), Besançon et al. (1989), Hunt (1989), Davies (2000) and Macumber (2001).

Groundwater is found in three aquifers (lower, middle and upper aquifers). The upper aquifer is contained in the Tertiary limestones and basalt and is the one that feeds the springs and marshes (Dottridge, 1998). The basalt aquifer has its recharge in Jebel ad-Duruz, a volcanic range north of the Azraq Basin, in Syrian territory (United Nations Development Programme, 1966). The waters of the upper aquifer have been pumped intensively in recent years, leading to the drying of most springs and marshes (Noble, 1998). The middle aquifer is contained in the Cretaceous limestone and Triassic sandstone, and the lower aquifer is contained mainly in the Paleozoic sandstone formations (Dottridge, 1998).

The study area (i.e., the GAOA) is located at the northwestern corner of Qa‘ Azraq, practically at its contact with the Tertiary basalt (Fig. 2). Before water over-extraction, the two most prominent spring areas were the Druze Marsh (also known as North Azraq or Azraq ad-Duruz) and the Shishan Marsh (also known as South Azraq or Azraq as-Shishan). The Druze Marsh is located at an embayment of Qa‘ Azraq created by a basalt peninsula (Figs. 2 and 3). The locality is known for the Azraq Castle, located west of the marsh (Figs. 3 and 4). The as-Shishan Marsh, located within the perimeter of the Azraq Nature Reserve, corresponds to a series of springs. In historic times, a Roman settlement and a dam to contain the water of the spring existed in the area. The main settlers in later historic times were the Chechen immigrants (hence the name Shishan). The use of local aquatic resources and date palm cultivation became their important activities until the drying of the marshes. As more water was pumped from the GAOA to supply the growing population of Jordan, the marshes began to dry. By the mid-1990s the Druze Marsh dried out completely. Under the auspices of the Royal Society for the Conservation of Nature (RSCN), a pump was used to replenish the water of the marsh within the nearby nature reserve in the so-called Sirhani Pool. As a result, only

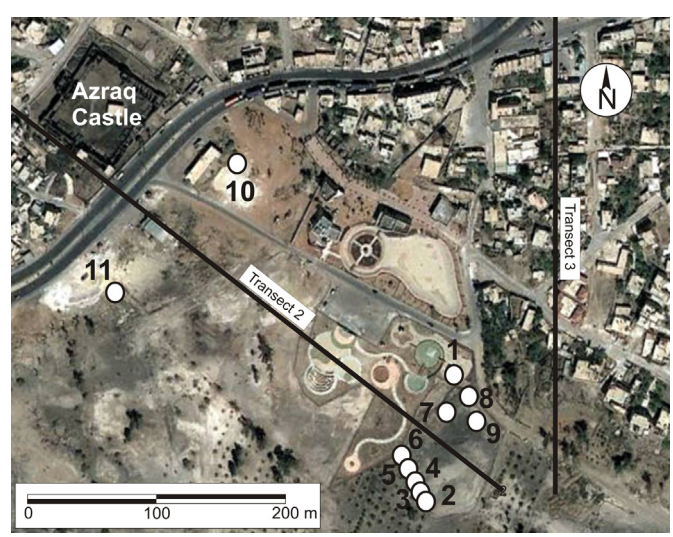

Fig. 3. The Druze Marsh. Location of stratigraphic sections and topographic profiles (2 and 3).

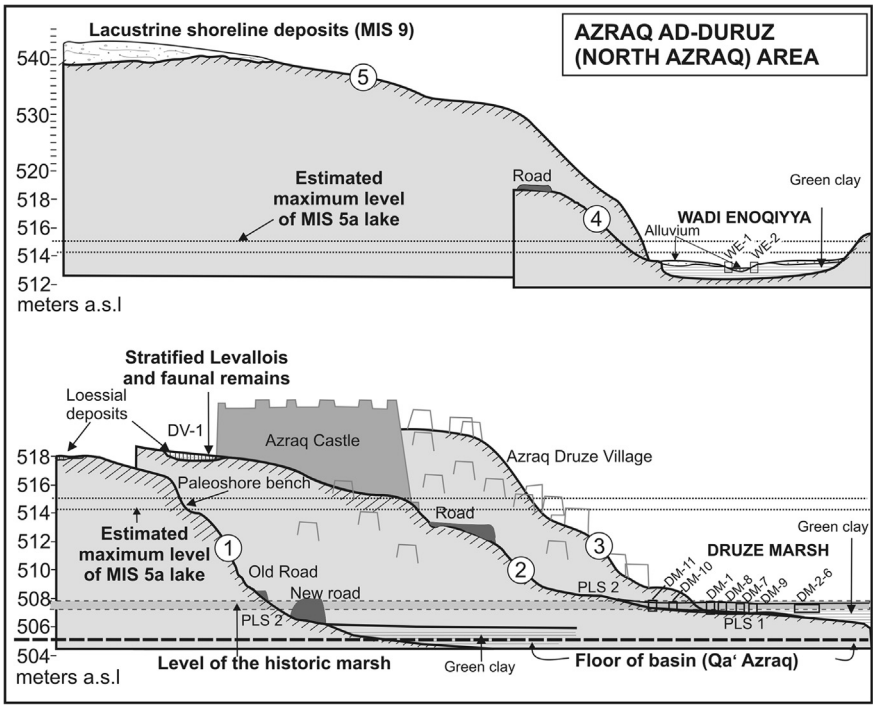

Fig. 4. Profiles and stratigraphic sections in the Druze Marsh area (see locations in Figs. 1 and 2).

about 10 percent of the original marsh was reclaimed. The Druze Marsh did not see any wetland reclamation and remains completely dry. The water table fell so low so rapidly that local settlers began to dig wells.

Climate in the area is arid, with precipitation less than 50 mm/year, most of which falls between October and April as a result of cyclones developed over the Mediterranean (El-Naqa, 2010). The average temperatures for January and July are 11.6 °C and 26.6 °C, respectively (El-Naqa, 2010). The highest temperatures in July and August usually surpass 45 °C, while the lowest in January can be a few degrees below zero. Over the Azraq Basin (Fig. 1B) the precipitation average is 87 mm/year, but its lowest amount around 50 mm in the eastern and center of the basin. At the western margin of the Azraq basin annual precipitation reaches 100 mm/year. At the northern end of the basin, in the Jebel ad-Duruz, it fluctuates between 200 and 500 mm (El-Naqa, 2010). Some of the wadis feeding the basin originate in the west and southwest. Elsewhere wadis are shorter, except for Wadi Rajjil, which originates in the basalt plateau known locally as the al-Harrah in the northeastern part of the Azraq Basin.

2.2. Hydrology of the Azraq Marshes

Before their drying, the marshes experienced a seasonal cycle characterized by rising water levels and the exchange of water with Qa' Azraq (United Nations Development Programme, 1966; Nelson, 1974). During the winter, rain water would be poured into the Qa' Azraq basin by the incoming streams (Fig. 5). As the qa' filled up, water flowed through channels into the marshes, changing not only the level of the water, but also its salinity. As rains diminished and waters evaporated from the qa', the excess of water in the marshes flowed back into the qa' through the same channels. Then, throughout the dry season (summer), the water in the marshes turned fresher, since the only sources were the springs.

This seasonal hydrological pattern was observed during historical times. Evidence in the stratigraphy suggests that this might have been the pattern throughout the late Holocene (Ames and Cordova, in press). No evidence of deposition exists for the early and middle Holocene. The lengthy gap between the Neolithic and Roman periods, with only a few Early Bronze materials supports the idea that during the Middle Holocene at least the marshes were not significant, although water in the springs was probably still available.

In the mid-1950s, the discharges of the Azraq ad-Duruz and Azraq as-Shishan springs were measured as 3.5 million and 22.8 million m^3/year, respectively (Dottridge, 1998). Because several methods have been used to estimate aquifer recharge rates, a number of values have been obtained, of which 34 million m^3/year is the average (Noble, 1998). Under conditions of no agriculture and no water pumping, a portion of the spring water output would evaporate in the marshes and the Qa' Azraq. The remaining water would seeps again into the ground, hence contributing to the balance of the aquifer in the lowest part of the basin.

It is difficult to estimate how much water is stored in a year given the current pumping conditions (which in some cases is not measured in clandestine wells) and the high loss through agriculture. However, a broad idea of water storage at a millennial scale can be estimated by considering the date that Noble (1998) obtained from ^{14}C dissolved in water in the aquifer in the center of Qa' Azraq, where the water has been residing for a period between 12,000 and 25,000 years. This long storage time suggests that even after climatic desiccation water may still flow out of the springs for a few millennia.

3. Methods

The stratigraphic sections in the Druze Marsh were obtained from 11 test pits (Fig. 3), of which only DM-1, DM-8 and DM-11 are described in detail (Figs. 6–8). Of these, only section DM-8 was fully excavated by opening a 1 × 2 m unit. Individual artifacts were recorded in situ using a Leica total station with both infrared and

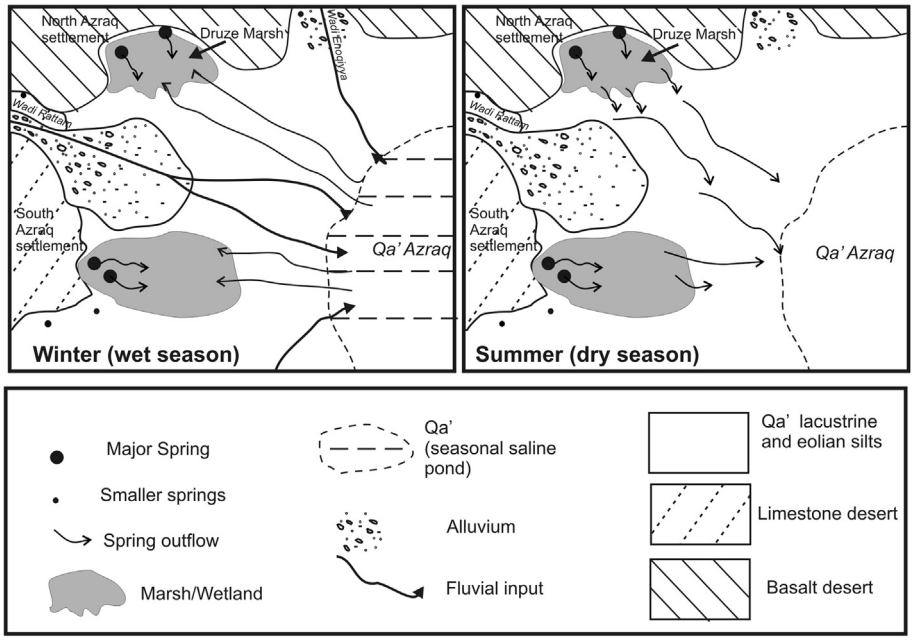

Fig. 5. Seasonal hydrology of the Azraq marshes before drying in the early 1990s.

red laser modes, in conjunction with a portable TDS Recon data logger. The sediments from each unit were dry-sieved for additional lithic and bone recovery. Artifacts were analyzed, photographed and labeled. Layer boundaries and depths of occupation surfaces were also recorded using the total station.

After excavation was completed, samples were taken for microfossils (pollen and phytoliths), grain-size analysis, organic carbon, and soil micromorphology. The results of these analyses are part of theses and dissertation projects and are not yet available for this paper. Soil and sediment descriptions followed the methodology

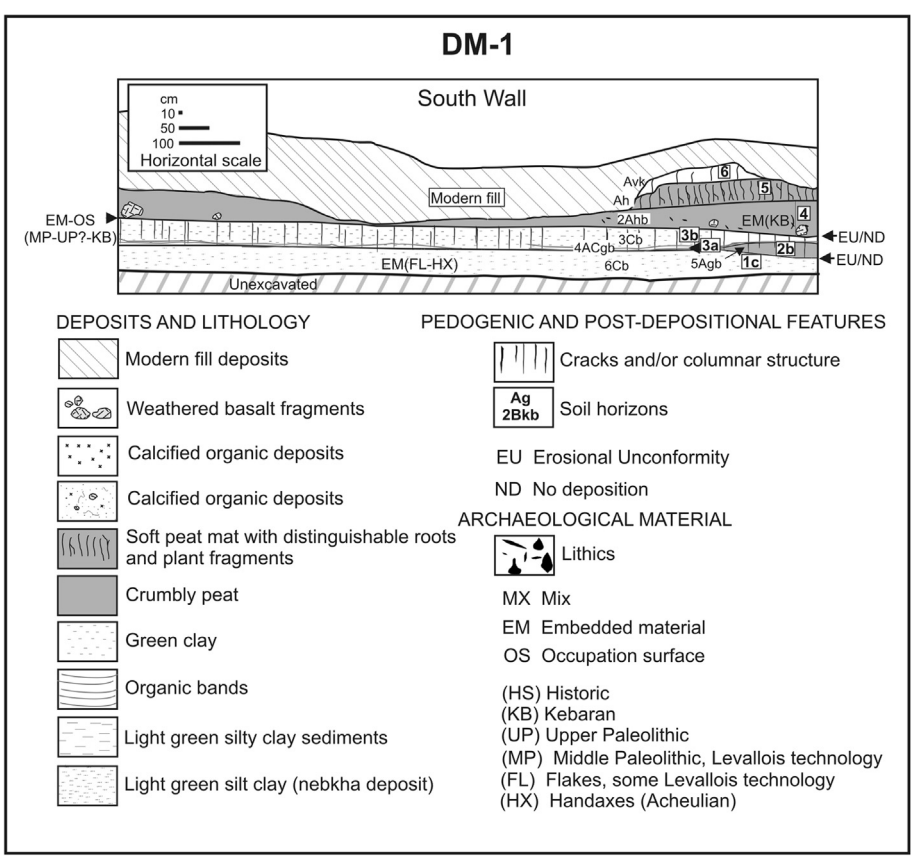

Fig. 6. Section DM-1.

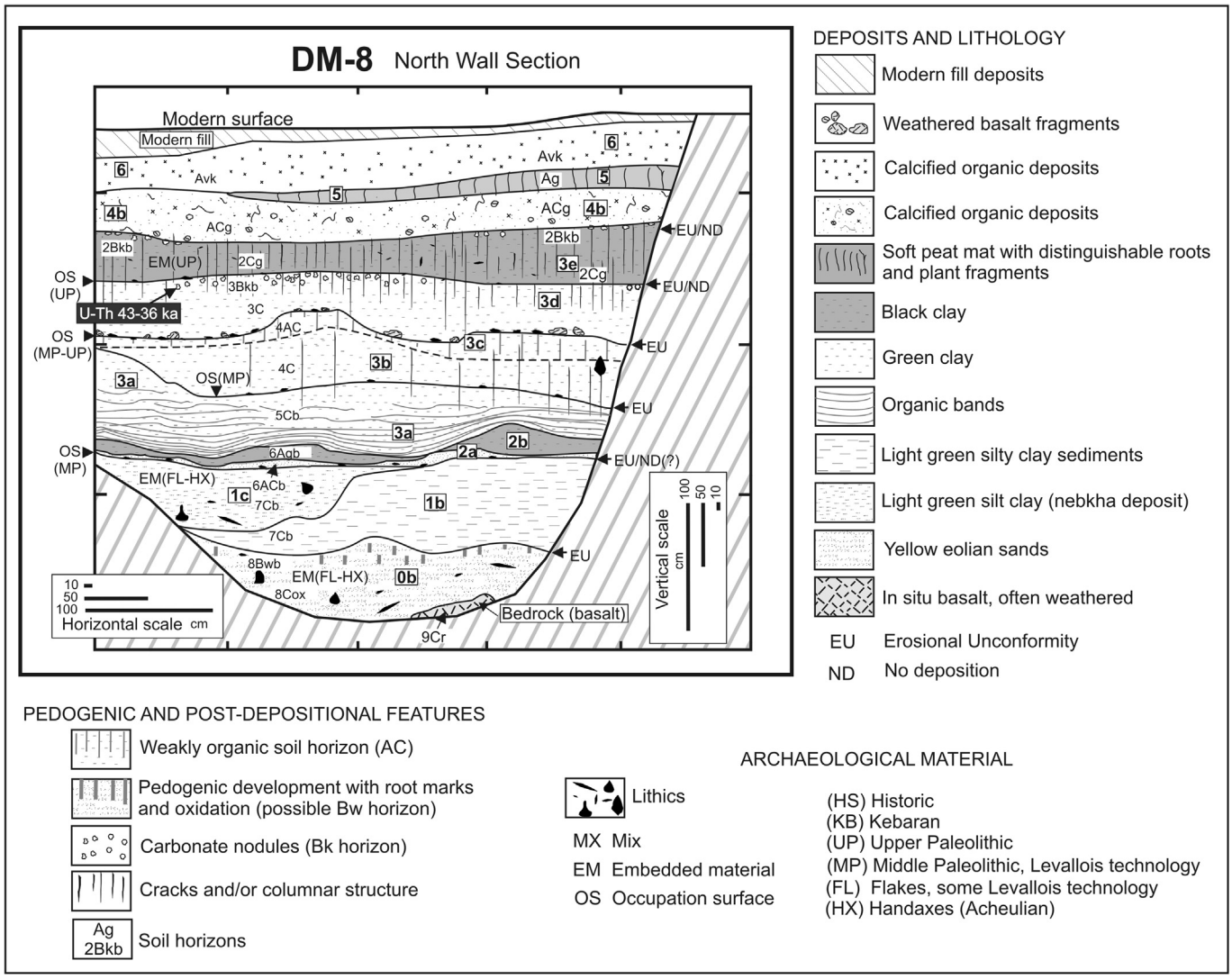

Fig. 7. Section DM-8.

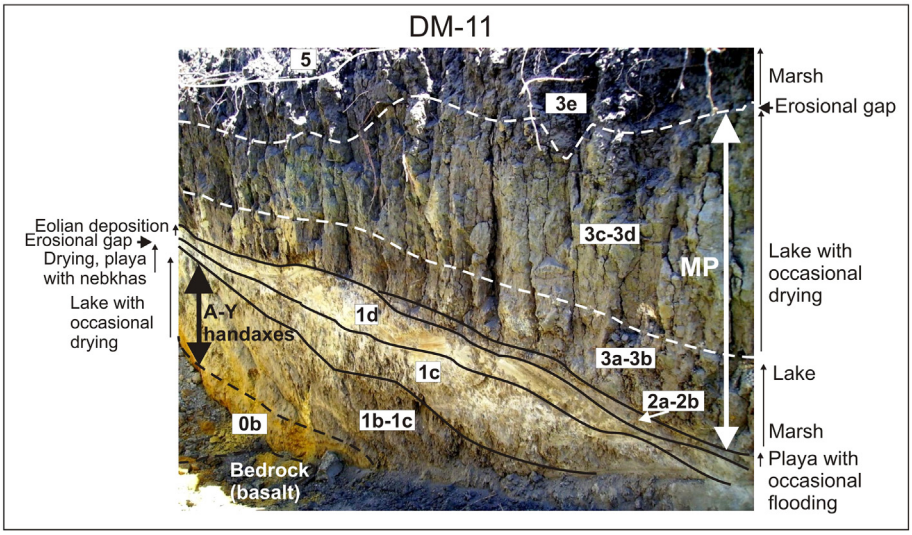

Fig. 8. Section DM-11. The Middle Paleolithic is above the eolian sediment (unit 1e) deposited on a dry lake floor (units 1 and 1 d). Areas with Middle Paleolithic are indicated. Unit 2b marks an improvement in conditions evident throughout most stratigraphic sections in the Druze Marsh.

used by Cordova et al. (2011), which is based on the pedogenic horizon classification of the United States Department of Agriculture (See references in Birkeland, 1999 and Holliday, 2004). Description of pedogenic carbonate stages in Bk horizons follows the scheme proposed by Gile et al. (1966) and modified by Birkeland (1999).

Thus far the only dates available in the sections of Azraq ad-Duruz are Uranium–Thorium (U–Th) assays. They were obtained from pedogenic carbonate nodules and were processed by Bassam Ghaleb at the GEOTOP lab of the Université du Québec à Montréal. The samples were corrected for detrital content. They are reported here as ranges between the errors. OSL dates were only obtained from section AS-1 in Azraq as-Shishan (See Cordova et al., 2008). The section at the Druze Village is DV-1, was described and samples were taken for further sediment, soil and microfossil analyses. Sedimentary units and dates from sections Wadi Enoqiyya (Cordova et al., 2009; Ames and Cordova, in press) are also referred to in this paper. In the Azraq as-Shishan area, sections previously published by Cordova et al. (2008) and Jones and Richter (2011) also contributed some information to this analysis. Section AS-1 in 'Ayn Sawda, which was described, sampled and dated by Cordova et al. (2008) is presented and discussed in detail here. The information of all the sections mentioned above plus sections published by Jones and Richter (2011) were used to reconstruct the phases of hydrological and geomorphological phases of the GAOA at least since MIS 5e.

4. Results

4.1. Stratigraphic units and paleogeographic reconstruction

The stratigraphy of the Druze Marsh presents several units with numerous occupations spanning the Late Lower, Middle, Upper and Epipaleolithic, and a few traces of Neolithic, Early Bronze Age and Roman. Although the stratigraphy seems very uniform throughout the 11 sections in the Druze Marsh, some layers are restricted to a few areas. However, the lacustrine sediment layers indicated by the green clays of units 1b, and 1c and 3c-3d (Figs. 6–8), are widespread throughout the GAOA, including the Azraq as-Shishan area, at the bottom of the 'Ayn Sawda section (Fig. 10) and 'Ayn Qasiyya (Jones and Richter, 2011), as well as in the C-Spring (Besançon et al., 1989; Copeland, 1989), the Lion's Spring Area (Kelso and Rollefson, 1989; Rollefson, 2000), on the eastern edge of the Shishan marsh (Hunt, 1989), and in the center of Qa' Azraq (Davies, 2000).

Section DM-8 has the most complete sequence of pedo-stratigraphic units and occupation surfaces, which is the reason why the description of sedimentary deposition and occupations was based on this section (Fig. 7). Sections DM-1 and DM-11 (Figs. 6 and 7) are used to describe pedo-stratigraphic units and occupations absent in DM-8. The overall chronology of Quaternary

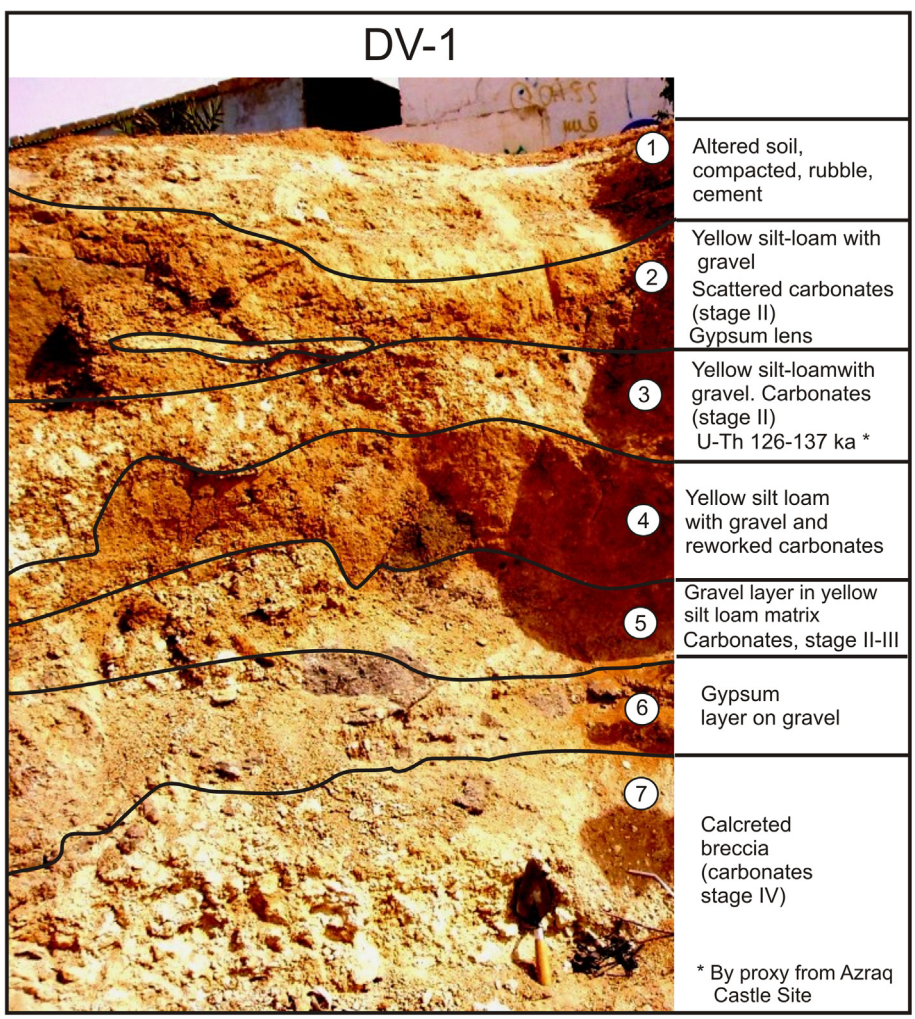

Fig. 9. Section DV-1. The U-series date is a proxy from a similar layer below the Azraq Castle.

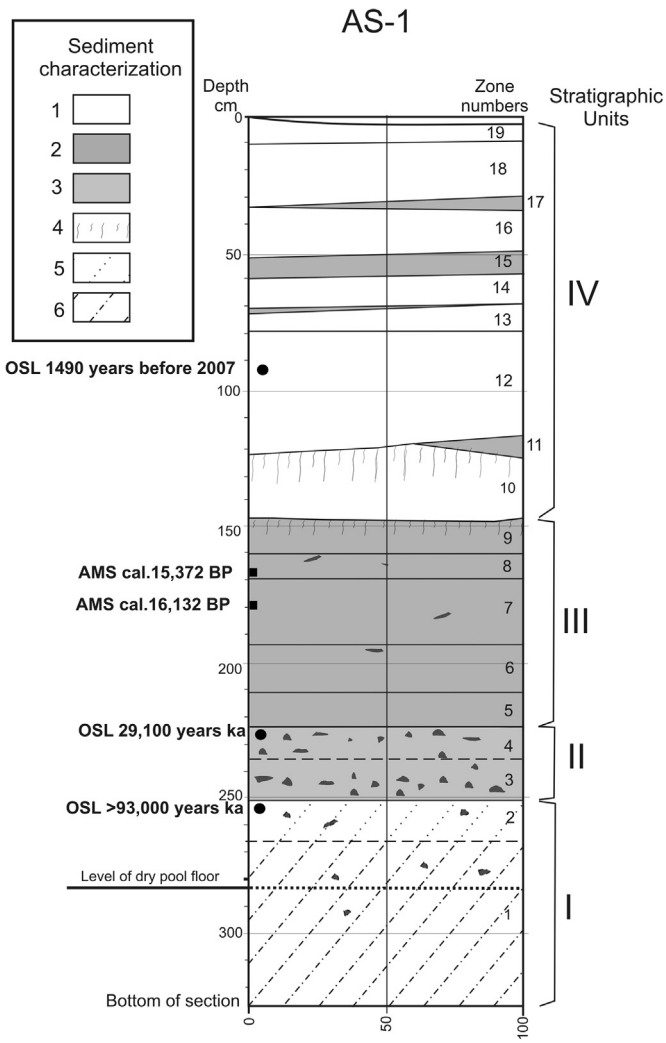

Fig. 10. AS-1 section in 'Ayn Sawda (modified from Cordova et al., 2008). Sediment characterization: 1, carbonated hard silt deposit; 2, dark organic deposit; 3, grayish organic deposit; 4 pedogenic development; 5, eolian and altered lacustrine clays; 6, green lacustrine clays.

deposits overlying the basaltic bedrock in the Druze Marsh begins with a yellowish-green sandy material of unknown age (unit 0b). This one is overlain by layers of green clay, differentiated into four different units: 0b (sand material and basalt regolith sediment), 1b (lacustrine clay), and 1c, an eolian silt deposit formed by sand-size pellets of the green lacustrine clay, and 1d, an eolian deposit of fine silt and sand. Unit 0b yielded material identified as the Acheulo-Yabrudian cultural complex. Unit 1b is a lacustrine green clay deposit that is practically sterile, except for a few small pieces of debitage. Unit 1c is a deposit of sediment of a sugary consistency formed by sand-size clay pellets similar to the modern clay dunes in Qa' Azraq identified as nebkhas or lunettes. This unit contains several handaxes and other materials of the Acheulo-Yabrudian complex, several Levallois flakes and points, and a few Mousterian points. In DM-7 and DM-11 two Micoquian elongated handaxes were found in this same unit. Although no numerical dates have been obtained from the deposit associated with the findings, carbonate nodules in a layer correlative with 1c and 1b in DM-2 provided a U-series age ranging between 151 and 140 ka (Cordova et al., 2009). These dates seem to mark the youngest dates for the deposit. This is consistent with the fact that the Acheulo-Yabrudian material in the Levant is no younger than 200 ka (Stiner et al., 2009). The material in 1c, however, seems to be in a secondary context, where most likely the primary sediment matrix was deflated and the material embedded in younger eolian material. Therefore, no clear occupation layers or seriation can be studied at the moment.

The top of unit 1c represents an erosional surface, which in some places has carbonate nodules (DM-2 and DM-4). In section DM-11 a layer of fine eolian sand (unit 1d) caps this erosional surface (Fig. 8). It is on the erosional surface of unit 1c two silt layer units (2a and 2b) overlie in association with the earliest Middle Paleolithic (Mousterian) occupation (Fig. 11). The lithic assemblage of this occupation surface included 44 tools and flakes as well as abundant (562 pieces) small chipping debris. Over 85% of artifacts were fresh or only slightly damaged, and most of the damage was heat fracturing. The artifacts in this layer included retouched flake tools (notch, denticulate and scraper), two points (Levallois and elongated Mousterian) and a Levallois point core. Given the presence of both cores and formal tools, this assemblage may represent one or more brief episodes of hominin occupation during which both tool manufacture and hunting/butchering activities were taking place.

The overlying deposits are an organic-rich clay deposit (unit 3a) that grades into a green clay unit (3b–3c). Unit 3a has been identified as a marsh deposit and units 3b and 3c a transition into a deep lacustrine environment. Middle Paleolithic artifacts are scattered throughout layers 3a, 3b and to a lesser degree in 3c (Fig. 7). Presumably this low density is due to the fact that the green clays were deposited under a relatively permanent lake, which hindered any occupations. However, in section DM-8

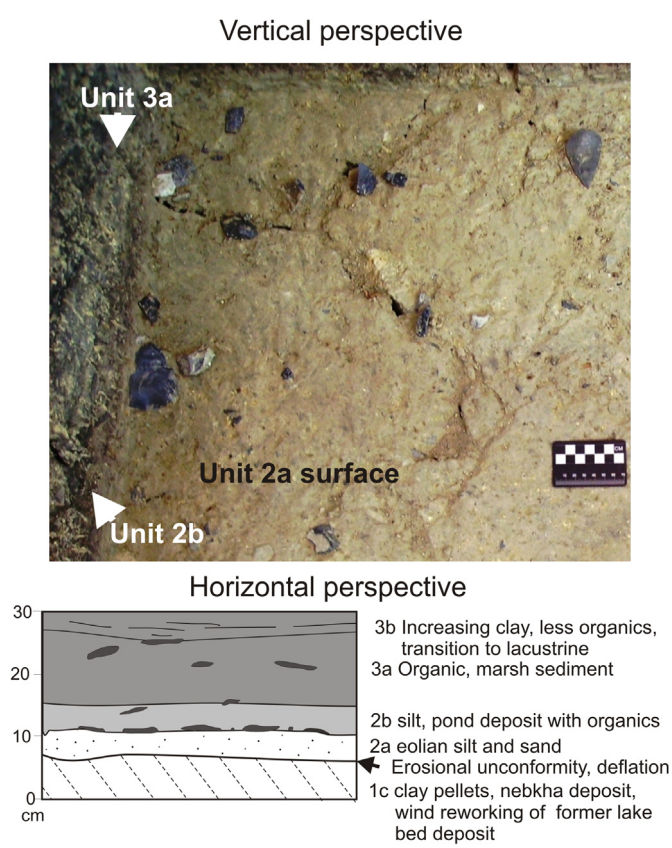

Fig. 11. Middle Paleolithic occupation surface on dry lake bed in units 2a and 2b and subsequent marsh build up (unit 3a) in section DM-8 (Fig. 7).

a series of occupation layers are apparent on erosional unconformities in the green clay deposits of Units 3c and 3d, suggesting that the lake dried out several times (Fig. 7). It is hypothesized that the Middle Paleolithic material found at the Castle Site and DV-1 correspond to hominin populations moving to higher areas when the lake was deeper. It is still not clear when exactly the lake was high, but brackets in dates suggest that probably this high lake stand occurred during MIS 5c to 5a, and probably into early MIS 4 (Cordova et al., 2009).

The top of unit 3c represents another erosional unconformity that has an occupation surface associated with Middle Paleolithic material and a number of basalt stones (Fig. 7). On top of the unconformity, unit 3d represents another lacustrine green clay deposit ending in an erosional unconformity capped by a layer of carbonate nodules. U-series dating of the carbonates provided an age between 40 and 36 ka. Lying flat on this surface Upper Paleolithic material was found. From this surface the material included 861 artifacts including 13 cores and 9 retouched tools. The retouched tools include 4 endscrapers (including a large endscraper on a retouched flake fragment found in the upper horizon), one borer on a blade, and three double-backed bladelets. The cores include informal cores (6), blade cores (4) and bladelet cores (3). Blades and blade fragments (147) outnumber bladelets and bladelet fragments (108). One noteworthy characteristic of the blade debitage is the presence of "twisted" forms. 14 of the 27 whole blades, and all 6 of the whole bladelets have twisted profiles.

A dark organic-rich clay deposit (Unit 3e) that contains Upper Paleolithic lies immediately above the layer of carbonate nodules capping unit 3d. Some artifacts in this unit were only slightly patinated (brown), but many were heavily patinated, partially desilicified and heat damaged, suggesting a harsh depositional environment including strongly acidic groundwater. Artifacts were dispersed in this layer, with no evidence of distinct occupation horizons. The formal tools from this layer included an atypical burin, a denticulated large blade and a borer on a large blade. The only core was a normal blade core. Among the technological elements, blades and blade fragments outnumbered bladelet fragments 27 to 21. Striking platforms were always either plain or cortical.

Unit 4 is a peat deposit with signs of burning. It only appears in sections DM-1 and DM-10. Most of the diagnostic material was recovered from DM-1 (Fig. 6), where the lithic assemblage is clearly Early Kebaran, and broadly similar to the Early Epipaleolithic artifacts recently recovered in areas A, B and D at 'Ayn Qasiyya, Azraq ash-Shishan, where dates put it sometime between 19 and 18 cal ka (Richter et al., 2009). The sediments show a marsh-side environment similar to that at 'Ayn Qasiyya, and suggest a common pattern of Kebaran subsistence in the Azraq area concentrating on aquatic resources. However, it is unknown why this wetland was so small in the Druze Marsh in comparison with the Azraq ash-Shishan area.

Unit 4b is a mudflow deposit bearing a mixture of artifacts of various ages, including Epipaleolithic, Neolithic and Early Bronze Age (unit 4b). The top units 5 and 6 are historical marsh and carbonate units associated with historic material, mainly Roman ceramics. According to the aerial photographs and pictures of the former marsh, unit 5 corresponds to the areas that are underwater throughout the year, while unit 6 corresponds to islands and areas flooded only during the winter.

The top of the basalt plateau in the Azraq ad-Duruz area has several sequences of loess-like deposits filling in depressions, some of which contain high shoreline deposits with *Cardium* shells, which have been studied and dated to the MIS 9 by Abed et al. (2008) (Fig. 4, profile 5). On the edge of the basalt in our study area two localities with Pleistocene sediments have been identified, one on them at the southwest corner of the Azraq Castle and another in the Druze Village (Fig. 4, profiles 2 and 3). The section exposed during restoration work of the castle's western wall consisted of loess-like sediments with gravel and pedogenic carbonates and gypsum nodules. The material on top of the deposit consisted of a Middle Paleolithic tool assemblage and teeth identified as a subspecies of *Equus caballus* (Pokines et al., in press). The presence of *E. caballus* in the Levant is consistent with other findings in association with Middle Paleolithic sites in the Levant (see Davis, 1980; Stiner et al., 2009). Unfortunately, bureaucratic formalities impeded the proper description of the deposit and classification of the lithic material, leaving it only determined as Middle Paleolithic. A U–Th date of the carbonates immediately at the bottom of the findings provided an age between 126 and 137 ka (Cordova et al., 2009).

The other upland section was located in an empty lot cleared for construction in the Druze Village. This section, described as section DV-1, is situated exactly at the same elevation as the Azraq Castle section (519 m). The DV-1 section consists of a top unit altered by modern fill (unit 1) and a series of units of yellow silt loam with gravel and carbonates (units 2–5). Most carbonates are in stage II, which is common in most Late Pleistocene soils in Jordan (See Cordova et al., 2011 for details). By their structure and pedogenic characteristics, units 2 and 3 were correlative with the layers observed in the Azraq Castle locality. These units lie on undated layers of carbonates and gypsum on gravel of unknown age (units 6–7) (Fig. 9). The two localities, Azraq Castle and DV-1 lie at an elevation slightly above the cut-benches observed in profile 1 (Fig. 4). Thus, it is assumed that this Middle Paleolithic occupation may have occurred near the lakeshore of the presumed high lake stand. It is important to emphasize that U–Th dates refer to the age of the carbonate, which is a post-depositional feature. Therefore, the date marks the youngest age of the deposit.

Wadi Enoqiyya is an area with abundant Middle Paleolithic material, based on the survey by Hours (1989). Our team carried out a stratigraphic reconnaissance of the layers, most of which are lacustrine, with layers of spring and marsh deposits. In addition to the large number of embedded Levallois flakes, horse and camel teeth are abundant. Most of the material seems to be associated with the green lacustrine clay with carbonate nodules. U–Th from the carbonates produced a date between 118 and 93 ka (Cordova et al., 2009). Evidence of springs in the area exists in the stratigraphy and in the modern landscape (Cordova et al., 2009). However, further study of the area will provide more information to the rich lithic, faunal, and micro-floral material in this area and its relation to the rest of the Azraq Oases.

In the south marsh area (Azraq ash-Shishan) in the 'Ayn Sawda area, section AS-1 is located next to the unit originally carried out by Rollefson et al. (1997). AS-1 (Fig. 10) includes some dates previously reported by Rollefson et al. (1997) and Cordova et al. (2008). This section presents a stratigraphic sequence similar to those of the Druze Marsh. First, the bottom of the section has the green lacustrine clay (unit I), which seems correlative with units 1b and 1d (Figs. 6 and 7). The green clay seems to be only a clay wedge resting on bedrock and gravel of unknown age. It seems that it was partially eroded when the lake dried out. This unit is subdivided into two zones; zone 1 is a sterile green clay deposit; zone 2 is unaltered clay, most probably a re-deposited silt deposit mixed with a few pieces of debitage. The OSL date from the top of this zone is 93.2 ka (Cordova et al., 2008). This suggests a Middle Paleolithic occupation of a dry lake bed that later develops into a marsh, very similar to the occupation layers in units 2a–2b–3a in DM-8 (see Fig. 11).

Unit II at AS-1 contains Middle Paleolithic occupations in association with a rich assemblage of faunal remains (Rollefson et al.,

1997; Dirks et al., 1998). However, given the date span (92 ka–29 ka) and the thickness of the unit (48 cm) it seems that it may have been a series of occupations where material was mixed, or partially deflated. The thickness of this unit varies throughout the area. Outside the section, the occupation extends into other areas where hearths with bones were discovered (Cordova et al., 2008). The fauna associated with this unit included elephants (*Elephas namadicus*/*Elephas hysudricus*), aurochs (*Bos primigenius*), and European ass (*Equus hydruntinus*) (Dirks et al., 1998).

Unit III constitutes a series of organic marsh deposits with Upper Paleolithic and early Epipaleolithic materials. The bottom zone of this unit (zone 5) is predominantly Upper Paleolithic. No absolute dates were obtained from this unit, but given the dates of the layers above (zones 8 and 7), it is suggested that the unit may correspond to sometime around the Last Glacial Maximum. Jones and Richter (2011) report a correlative unit of organic sediments nearby in 'Ayn Qasiyya dated to the LGM. It seems that this unit is also correlative with the top of unit 3e in DM-8 (Fig. 7). The rest of the zones in unit III seem to represent the late LGM and early Deglaciation period; this is indicated by the two radiocarbon dates and by the presence of early Epipaleolithic materials. The unit is also present in 'Ayn Qasiyya (Jones and Richter, 2011) and it seems correlative with unit 4 in DM-1 (Fig. 6).

It seems that around the Pleistocene–Holocene transition and in most of the early and middle Holocene, dry conditions led to the development of a playa environment with carbonates and no deposition of organic material. Hunt (1989) and Besançon et al. (1989) report several units of early Holocene age bearing carbonates, but overall in the study area the Pleistocene–Holocene transition is missing. The 'Ayn Qasiyya deposits also suggest dryness at this time (Jones and Richter, 2011). Marsh environments returned at the end of the Holocene, indicated by unit 5 in DM-1 and DM-2 in the Druze Marsh, where Roman ceramics are often found. The Late Holocene pollen record from the Sirhani Pool, in the Azraq Wetland Reserve (Woolfenden and Ababneh, 2011), indicates moisture climatic improvement during the Roman period.

4.2. Environmental change and Paleolithic occupation in the Azraq Oases

Each of the layers studied in the Druze Marsh in North Azraq and the 'Ayn Sawda section in South Azraq can be directly associated with particular depositional environments, referred to as geomorphic/hydrologic environments (Table 1). At least seven main environments are evident in the deposits of the sections studied in the Druze and Shishan marshes. Each environment is the result of a combination of hydrological and climatic characteristics (Table 2).

Table 1
Classification of sedimentary units at the studied sections in relation to geomorphic/hydrologic environments.

Environment	Units in Druze Marsh	Units in 'Ayn Sawda
Marsh with permanent water	3a, 3e, 4, 5	
Dry marsh with carbonates	6	Top unit
Lake	1b, 3b, 3c, and part of 3d	II zone 1
Playa with eolian accumulation	1b, 2a	
Playa with deflation	1d–2a transition	II zone 2
Playa with pedogenic carbonate	3d	IV zone 10
Transitional playa-marsh	2b	III zone 1

Table 2
Suspected primary and secondary causes of each geomorphic/hydrologic environment.

Environment	Hydrological	Climatic
Marsh with permanent water	Primary (aquifer discharge)	Secondary (aquifer recharge and/or low evaporation)
Dry marsh with carbonates	Primary (aquifer diminishing)	Primary (low or no aquifer recharge, high evaporation)
Lake	Irrelevant as aquifers input is minimal	Primary (Pluvial input directly, via streams)
Playa with eolian accumulation	Secondary (aquifer dry or minimally functional in season)	Primary (reduced rain and high evaporation)
Playa with deflation	Secondary (aquifer dry or minimally functional	Primary
Playa with pedogenic carbonate	Primary (high water table, suggesting minimal recharge)	Primary (Atmospheric dryness, high evaporation
Transitional playa-marsh	Primary (increasing aquifer input after dry period)	Primary (increasing rainfall and/or low evaporation)

Marsh conditions are represented by peat and organic-rich clay deposits, which are similar to those in the modern and historic marshes. Lacustrine conditions are represented by the green clays. Playa with eolian accumulation are represented by deposition of silt dunes similar to the ones currently found on the east of Qa' Azraq as well as sandy and sandy-loam eolian deposits. Playa with deflation is represented by erosional unconformities; and playa with carbonate deposition is represented by playa conditions with influence of strong evaporation and probably high water.

Based on the scheme developed for paleoenvironmental reconstruction (Table 2) the interpretation of geomorphic/hydrological environments in relation to Paleolithic occupations can be summarized in seven phases (Fig. 12). Of these, Phase 1 should be considered still undetermined given the low availability of dates and information for MIS 6. Although clay lacustrine layers are associated with it, some sections do have silt-dune deposits and erosional unconformities, which suggest the presence of a lake that subsequently dried out. Other records in neighboring areas suggest the presence of wet conditions and lakes during MIS 6. High level stands in Qa' el-Mudawwara are reported for the period between 170 and 152 ka (Abed et al., 2000; Petit-Maire et al., 2002, 2010). The speleothem records in the rainshadow area of the Judean Highlands show also some fast development, but not in the Khseifa Cave in the Jawa basalt plateau (Frumkin et al., 2008). Similar dry phases and wet periods with paleolake formations are reported in the Arabian Peninsula (Parker, 2009). One of these is the speleothem record at Hoti Cave in Oman, where a wet period between 180 and 200 ka has been identified (Fleitmann et al., 2003). Interestingly, this period of wet conditions extends throughout all latitudes of the Greater Arabian Desert. The existence of a wet and then dry period is diffusely reflected in our records in Azraq. The few U–Th dates from North Azraq, DM-2, DV-1 and WE-2 (W. Enoqiyya) suggest that at least two lacustrine bodies of water may have existed, one before 160 ka and the other one shortly before 130 ka (Fig. 12). Lake levels and late LP occupations during the MIS 7–MIS 6 transition are one of the targets of our next research phase.

A clearer picture of environmental change in Azraq emerges only at the end of Phase 1 during MIS 5e–d stages, when conditions seem to be dry, as evidenced by the U–Th dates of pedogenic carbonates at the Castle Site (DV-1 as proxy) and Wadi Enoqiyya. These carbonates and the lack of lacustrine and marsh deposits suggest that during MIS 5e it was dry in Azraq. In most sections of

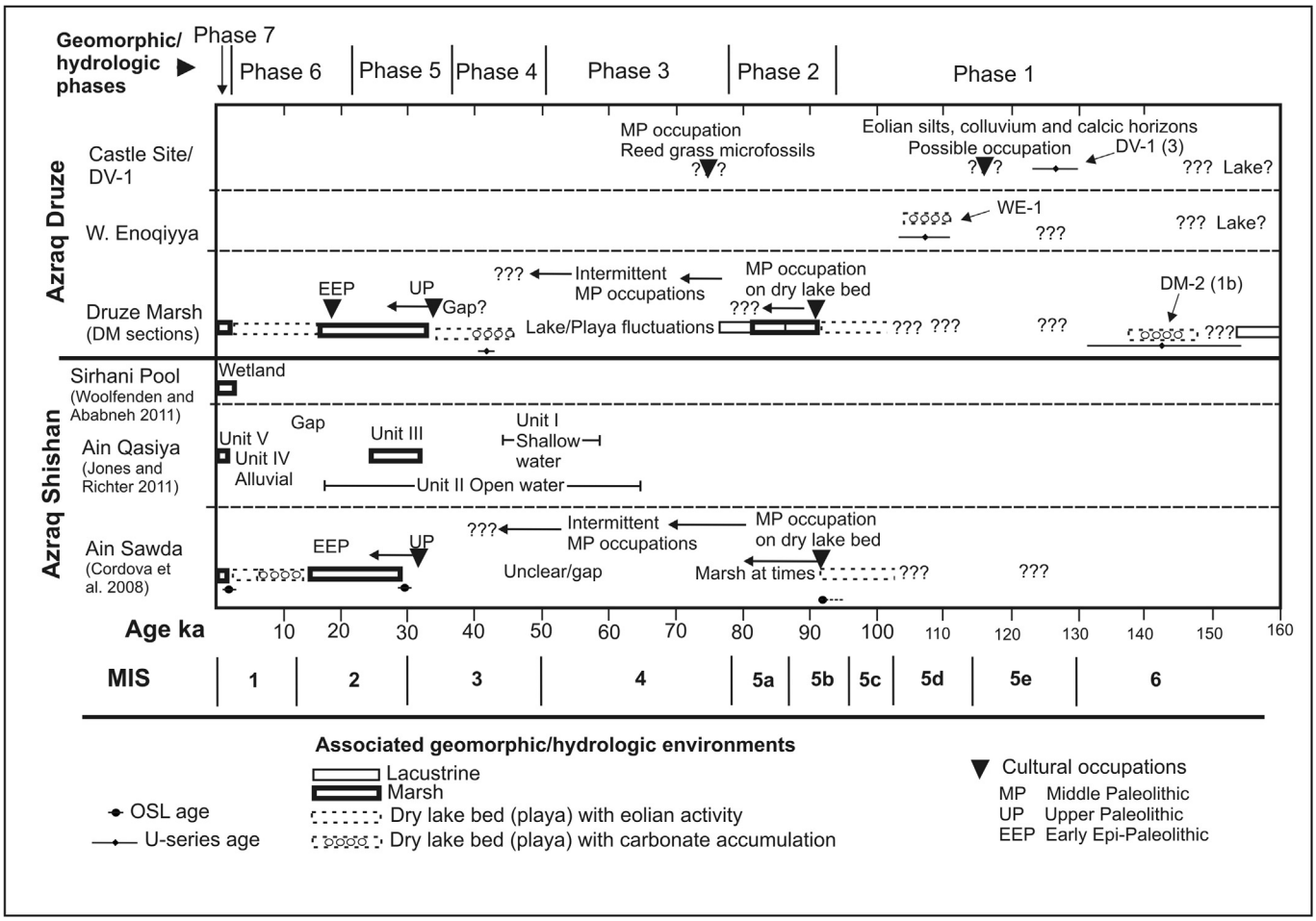

Fig. 12. Transitional environments diagram for the Druze Marsh and Shishan Marsh areas.

the Druze Marsh there is an erosional unconformity, and in some (e.g., DM-11) a veil of eolian sediment. Therefore, it is apparent that conditions of a playa, similar to the center of the modern Qa' Azraq existed prior and during the deposition of unit 2a. Speleothem records at the same latitude in the western Levant (Vaks et al., 2007, 2010; Frumkin et al., 2011) and the nearby Khseifa Cave (Frumkin et al., 2008) suggest hyperarid conditions. A similar dry phase during MIS 5e was also recorded in the deposits of the Ma'in site and other localities of the Madaba Plateau (Cordova et al., 2011).

The beginning of Phase 2 represents local wet conditions, represented first by darker silts (unit 2b), and followed by the organic lacustrine clay, which suggests a transition from marsh to lake. As conditions of moisture became available in the springs and wetlands, hominin populations with Mousterian technology appear, first occupying the dry lake bed in the Druze Marsh (units 2a–2b) and 'Ayn Sawda (unit I, zone 2). As conditions became wetter, a lacustrine body engulfed the area, producing the deposits of units 3b and 3c. Due to the impoundment of the area by the lacustrine body, hominin occupations moved to uplands on the lakeshore, perhaps to locations in the area of the Castle and DV-1 sections (Fig. 9). Meanwhile, in the 'Ayn Sawda area (Fig. 8), the lake levels that were responsible for the development of units 3b–3d were not high enough to cover this area, but conditions of lakeshore and marsh attracted hominin populations and megafauna. Ongoing palynological research provides information on this environment, not only with the presence of aquatics (i.e., Cyperaceae, Typhaceae and Juncaceae, and *Phragmites*-type grass pollen), but also large amount of non-reed grasses, pistachio and even Kermes oak (Cordova, unpublished data).

Phase 3 is characterized by fluctuations between dry and wet conditions, all of which are undated, but probably occurred between 70 and 40 ka. Occasional drying of the lake may have brought populations closer to the location of DM-8 and DM-1, where a few lithics were discarded. A drying event of unknown age brought an end to the lake and dry playa conditions ensued, although the springs did not dry out completely given the presence of MP lithics on the erosional surfaces of units 3c and 3d (Fig. 7). The lake developed again and conditions similar to the ones above returned. The process of lake development and drying may have happened several times, but no dates exist yet to date these events.

In Azraq ash-Shishan, conditions for this period are unclear, although there is evidence of dry and wet periods, as shallow waters have been identified in 'Ayn Qasiyya (Jones and Richter, 2011). Alluvial deposits reported by Jones and Richter (2011) in 'Ayn Qasiyya may be related to alluvial influence from Wadi Rattama (See Fig. 2). It is possible also that the flow of Wadi Rattama, located in between the two marshes, may have eroded the lacustrine deposits or created a deltaic deposit that expanded into the Azraq ash-Shishan area.

In the Druze Marsh, the lake dried out sometime before 40 ka and playa conditions with carbonate deposition returned. Some time passed before conditions became a marsh again (unit 3e) at the time when an Upper Paleolithic occupation took place sometime after 36 ka. This marsh seems to have persisted throughout

the Last Glacial Maximum. Unit II in 'Ayn Sawda (Fig. 10) represents a deposit associated with an Upper Paleolithic occupation with a similar component in 'Ayn Qasiyya (Jones and Richter, 2011).

Phase 5 corresponds to the deglaciation period, i.e., towards the end of MIS 2. Unit 4 in DM-1 and unit III in the AS-1 section are deposits of peat associated with early Epipaleolithic (Early Kebaran) material. Similar deposits are also reported in 'Ayn Qasiyya (Jones and Richter, 2011). A preliminary study of phytoliths and pollen (unpublished data held by the authors) suggest that this is a wetland composed mainly of *Phragmites* grass, very similar to the reeds in the modern wetlands in the reserve. Signs of frequent fire are evident, which is one characteristic that differentiates this phase from previous marsh environments (Cordova, unpublished data). Phase 6 represents drying throughout the Younger Dryas and early–middle Holocene. Phase 7 represents the return of marshes, a period that continued until the modern drying of the wetlands.

5. Discussion

5.1. Regional climate in relation to the Azraq refugia

The climatic conditions associated with each of the geomorphic/hydrologic environments in Azraq are difficult to assess, but it is possible to infer them given the geomorphic situation of the lacustrine basin under conditions of increased or reduced rainfall, as well as increased or reduced evaporation (Table 2). This assumption is based on the fact that the hydrology of the two main oases is based on the recharge of the aquifers. This idea has been put forward by Jones and Richter (2011) to explain the discrepancies between the local sediments and the regional climatic developments when analyzing the Late Glacial stage (MIS 2) deposits of 'Ayn Qasiyya in Azraq ash-Shishan. This suggests that recharge of the aquifers feeding the oasis springs may have not be in synchrony with those of climatic fluctuations. As suggested by Noble (1998), water in the aquifer has been residing longer than 12,000 years, which suggests that springs may be fed by stored water for several millennia. This allowed the spring waters to flow and form a wetland at a time when conditions in the desert became harsher. If this was the case during extremely cold conditions, that is to say during glacial stages, then it is possible that under low summer insolation evaporation from the wetlands may have been minimal. This same phenomenon has been a debate associated with the high levels of Lake Lisan to the relative dryness of the last ice age (Waldmann et al., 2009; Stein et al., 2010). Although Mediterranean cyclogenesis seems to have been important in this area during the LGM (Enzel et al., 2008), low evaporation made conditions in the desert less arid. In this context, wetlands are significant, as they form important resource bases for hunting and gathering groups around the world (Jones and Richter, 2011).

Overall, the sequence of hydrological–geomorphological environments in the GAOA suggests that interglacial climatic conditions such as MIS 5e and most of MIS 1 are of extreme dryness. In contrast, times of abundant water and lacustrine conditions occurred apparently during the transition from the last interglacial to the last glacial, as is the case during MIS 5c–5a and possibly early MIS 4. Presumably a similar lacustrine environment existed prior to 150 ka, which may have led to the formation of the lacustrine clay of units 1b in DM-1 and DM-2, which could have been the transition from interglacial MIS 7 to MIS 6, but the lack of dates allow no further details as to when this wet period occurred. In between these extreme conditions, aquifers produced enough discharge to produce marshes at least during the MIS 3–2 transition and at the end of MIS 2.

Paleoenvironmental data from 'Ayn Qasiyya suggest a concentration of flora and fauna during the late LGM, associated with the Kebaran occupation (Richter et al., 2009; Jones and Richter, 2011). Examples of similar desert refugia have been suggested for the Wadi Hasa, where permanent springs and lakes occurred during the Upper Paleolithic and early Epipaleolithic (Clark et al., 1988; Coinman, 2004) and Wadi al-Jilat, a southwestern stream of the Azraq Basin (Garrard et al., 1988).

Another aspect of Azraq oases to consider with regards to its role as desert refugia for hominins is the fact that within the Azraq region occupations shifted depending on where the watercourses, shorelines, and marshes were located (Jones and Richter, 2011). The differences of occupation timing between the North and South Azraq, the Druze Marsh and the upland basalt sites, and Wadi Enoqiyya exemplify this situation. As shown above, while the Kebaran occupation is substantial in South Azraq, it is barely noticeable in the Druze Marsh, suggesting changes within the same oasis area, perhaps linked to spring output (see Section 2.2 above) or perhaps geomorphological changes that imply blockage or differences in surface water flow.

5.2. The Azraq refugia in the regional paleoclimatic context

From the paleogeographic point of view, the Azraq Basin occupies a key location in the Levant and Southwestern Asia as it is situated at the northern end of the Wadi Sirhan Depression which can be seen as a corridor of paleolakes and springs linking the Levant with the north-central part of the Arabian Peninsula, namely the an-Nafud Region (Sanlaville, 1992; Petraglia et al., 2011) (Fig. 1B). Furthermore, Azraq is connected to the east with the Levantine Corridor (i.e., along the Mediterranean coast) via streambeds, valleys, more vegetated highlands (Fig. 1). The number of Paleolithic sites and Pleistocene paleontological localities in the Azraq Basin indicates the importance of this corridor, which may have served two purposes: as a migration corridor and desert refugia for populations during adverse regional climatic conditions.

The Azraq refugia drew substantial faunal and hominin populations at the end of the Last Glacial Maximum (ca. 22–20 ka), when conditions became drier (Jones and Richter, 2011). But in other times, when lakes existed, as was the case of Phase 2 (Fig. 12), it also attracted populations. But with many lakes in the area these groups were less dependent on the Azraq region. This may have been the case of the exceptionally wet period that caused high lake level stands in the Jordanian Plateau between 100 and 70 ka, with concentration between 85 and 78 ka (Fig. 13).

The paleoenvironmental records from Azraq seem to be in close parallel with Levantine records at the same latitude, roughly 31° 30′–33° N and with some records in latitudes 29°–31° 30′ N, but there is little parallel with records at lower latitudes (Fig. 13). The inter-latitudinal comparison of wet and dry phases obtained from cave speleothem isotopic composition and growth has suggested the alternation of wet conditions between south and north through the period of late MIS 6 to MIS 4 (Vaks et al., 2006, 2007, 2010; Frumkin et al., 2011). These studies pose the suggestion that while the interglacial MIS 5e was wet in the lower latitudes (i.e., the southern Arabian Peninsula and the Eastern Sahara) due to monsoon intensification, the northern part of the Levant was drier (Vaks et al., 2007, 2010). However, as conditions changed to glacial (i.e., MIS 5c–e to MIS 4), the southern part of Southwest Asia and Northwest Africa became drier (Vaks et al., 2010; Frumkin et al., 2011). This slow northward migration of moisture may have aided the modern human passage from Northeast Africa to the Levant and other parts of Southwest Asia (Vaks et al., 2007, 2010; Parker, 2009; Rose and Petraglia, 2009; Armitage et al., 2011; Frumkin et al., 2011; Rosenberg et al., 2011).

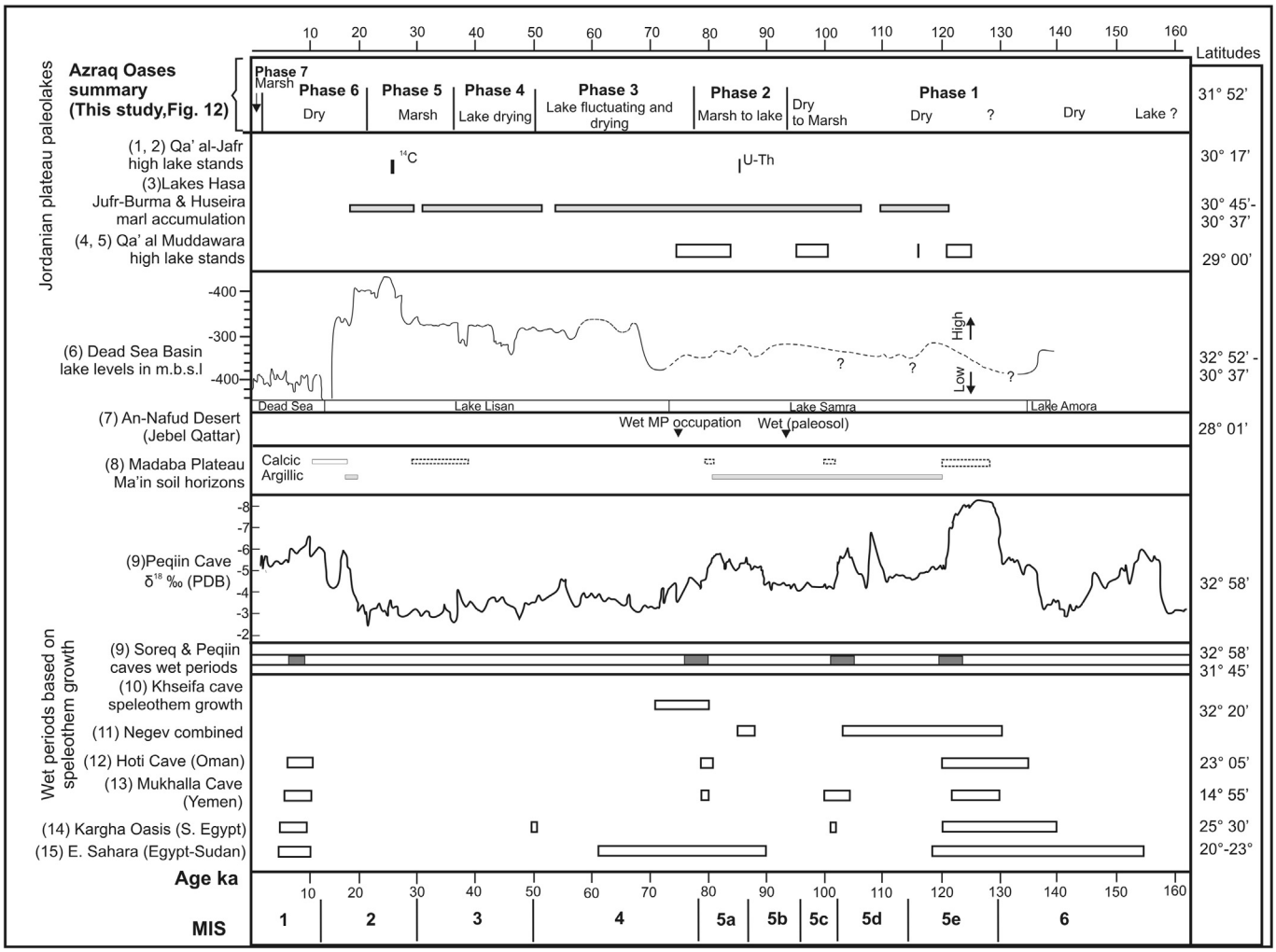

Fig. 13. Regional paleoclimatic chronology. References: 1, Huckriede and Wieseman (1968); 2, Macumber (2001); 3, Moumani et al. (2003); 4, Abed et al. (2000); 5, Petit-Maire et al. (2010); 6, Waldmann et al., 2009; 7, Petraglia et al., 2011; 8, Cordova et al., 2011; 9, Bar-Matthews et al., 2003; 10, Frumkin et al., 2008; 11, Vaks et al., 2010; 11, Fleitmann et al., 2003; 12, Fleitmann et al., 2011; 13, Smith et al., 2004, 2007; 14, Szabo et al., 1995.

5.3. The Azraq desert refugia in the paleoanthropology of broader Southwest Asia

For several periods of the Pleistocene the Levant acted as a biogeographic corridor between Africa and Eurasia, facilitating the migration of plants and animals, including Neandertals and early modern humans, between these regions (Tchernov, 1992; Bar-Yosef, 2000; Belmaker, 2010). The general picture of biogeographic, paleoclimatic and paleoanthropological knowledge in recent publications shows that in terms of hominin survival and movements during the Middle Paleolithic there is a transient pattern of wet and dry climates that provide windows of opportunity for northward migration of modern humans into the Levant (Vaks et al., 2006, 2007, 2010; Frumkin et al., 2008, 2011; Rose and Petraglia, 2009).

At the other geographic end, the more recent knowledge on the Middle and Upper Paleolithic of the Arabian Peninsula (Petraglia and Alsharekh, 2003; Maher, 2009; Parker, 2009; Rose and Petraglia, 2009; Armitage et al., 2011; Rosenberg et al., 2011; Groucutt and Petraglia, 2012) as well as the numerous paleontological and Paleolithic sites in the northern area of the Arabian Desert (Sanlaville, 1992; Petraglia and Alsharekh, 2003; Petraglia et al., 2011) provide an important geographical dimension of Neandertal and modern human populations. Geographically, many of the Middle Paleolithic sites of the northern Arabian Peninsula and the Jordanian Plateau occupy areas of oases associated with springs and paleolake basins including not only Azraq, but also Qa Al Mudawwara, and the other former depressions (Fig. 1A). In other dry parts of Jordan, sites such as 'Ayn Difla (Clark et al., 1997) lie near a series of lakes linked to former Lake Hasa; Tor Faraj and Tor Sabiha (Henry, 1997), occupy similar locations in proximity to Al-Hisma Basin paleolakes (Fig. 1A). At the very north end of the Syro-Arabian Desert, the oasis locality of El-Kowm proves the important of springs, marshes and paleolakes in attracting hominid populations during the Lower and Middle Paleolithic (Le Tensorer et al., 2007; Hauck, 2011). Similarly, desert refugia localities existed in the Wadi Sirhan Depression, the an-Nafud region, and many other areas of Arabian Peninsula (Garrard et al., 1981; Sanlaville, 1992, 2002; Petraglia and Alsharekh, 2003; Petraglia et al., 2011). When these localities, most of which qualify as desert refugia, are placed on a map they show patterns that allude to potential geographic connections over time (See Fig. 1B). Azraq and El-Kowm exemplify the potential crossroads for connecting other refugia in the Arabian Peninsula, the Levant the Sinai and other regions of

Africa and Southwest Asia. It has been hypothesized that the latitudinal changes in moisture between 130 and 45 ka are important for the migration of modern humans from Africa via various routes along the Red Sea Coast, the Sinai, and Southwestern Arabia (Rose and Petraglia, 2009; Vaks et al., 2010; Armitage et al., 2011; Frumkin et al., 2011). It is within this broader context that research was undertaken at the Greater Azraq Oasis Area. Wet conditions between 90 and 75 ka in the GAOA and other basins (i.e., Al-Mudawara and Al-Jafr), were likely to make these areas more attractive than in the Arabian Peninsula. The presence of marshes in Azraq during the Last Glacial Maximum with abundant evidence of Upper Paleolithic and Epipaleolithic may have also served as a refugium for human populations at the time when areas to the north and west were drier (Van Zeist and Bottema, 1991). As more research emerges from the multidisciplinary work in the GAOA, more detailed information in relation to these changes should emerge.

6. Conclusions

Wet and dry phases in regional paleoclimatic records across the Levant and the Syro-Arabian Desert show north-to-south timing differences, marked on the one hand by the influence of Atlantic–Mediterranean cyclogenesis in the north, and the summer monsoon influence in the south. These latitudinal timing differences have recently been pointed out as a catalyst for modern human migrations from Africa to the Levant and to other parts of Southwest Asia (Vaks et al., 2006, 2007, 2010; Frumkin et al., 2011). However, at the same latitude, records vary in timing, suggesting that while some regions remained dry, others stayed locally wet, hence suggesting the existence of desert refugia for hominin populations. Under wet conditions, lakes occupied the former basins, making the possibility of higher mobility and long distance migration.

In this respect, the Azraq Oases seem to have played an important role in hominin population dynamics in the northern Arabian Desert because of its location at crossroads along thoroughfares of paleolakes and springs connecting the Levant and Arabian Peninsula via the Wadi Sirhan Depression–Greater an-Nafud corridor facilitating the diffusion of hominin populations and technologies.

Ongoing research has provided the basis for studying the Azraq Oases as desert refugia in the Jordanian Desert. But thus far, geoarchaeological record in the Greater Azraq Oases Area shows that an important regional wet period occurred between MIS 5c to early MIS 4 attracting hominin populations making Middle Palaeolithic tools. During this time many other basins in the region contained lakes, facilitating movement of populations across the vast Syro-Arabian Desert. At later times, such as late MIS 4, MIS 3 and MIS 2, marshes existed in Azraq when other records show regional dry and cold conditions.

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