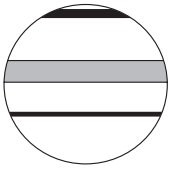

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Leaving home: Technological and landscape knowledge as resilience at pre-Holocene Kharaneh IV, Azraq Basin, Jordan

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Abstract

Humanity's relationship with the environment during the Holocene, and into the Anthropocene, is structured around our dependance on agricultural production, which has resulted in risk mitigation strategies that include intensive landscape modifications, among other tactics. However, to understand broader patterns of human resilience and the shifts in human/environment relationships, we need to look further back in time. Through this paper, we explore cultural strategies of risk management and resilience in pre-Holocene communities and how these practices allowed hunter-gatherer communities to adapt to a changing environment. For over 1000 years, the Epipalaeolithic site of Kharaneh IV was a focal point on the landscape for hunter-gatherer groups, acting as an aggregation site for Early and Middle Epipalaeolithic peoples. Located in the eastern desert of Jordan, at the time of occupation the site was a lush wetland surrounded by a rich grassland environment, providing abundant food and other resources for the site's occupants. However, over time the wetland began to dry up and by 18,600 cal BP Kharaneh IV was abandoned. In this paper, we discuss the final occupation of Kharaneh IV, linking the site's abandonment to the increasing aridification of eastern Jordan. Environmental change led to the eventual abandonment of Kharaneh IV and other nearby sites, as people relocated within the Azraq Basin in search of new water resources during the Holocene. Flexible technological strategies and knowledge of the landscape created resilient cultural practices that allowed these communities to use population movement as a risk management strategy.

Keywords

Epipalaeolithic, hunter-gatherers, landscape use, lithics, resilience, risk

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Introduction

The Anthropocene is heralded by the oversized impact of humans on the earth's ecological and environmental systems and is generally characterized as the transformation of global climate – with innumerable local impacts – through anthropogenic processes. While popular culture is most familiar with Western notions of humanity "conquering nature," this is not the only way of being (Boyd, 2004; Descola, 2013; Fuentes et al., 2010; Kimmerer, 2013; Kirch, 2002; Whatmore, 2002). Prior to recent fundamental shifts in our relationship with the rest of the planet, humans' relationship with the environment could be characterized as a system of reciprocal interactions between humans and the environment, building structures of mutual support. Through niche construction, people are equipped to deal with changing and variable climates to maintain this reciprocal relationship (Boivin et al., 2016; Laland and O'Brien, 2010; Smith, 2011; Sterelny and Watkins, 2015). This ability to adapt to, and adapt, the environment has resulted in the capacity to both explore new territories as well as stay in place as the world around us changes. In this paper, we explore the later life-history of the Late Pleistocene Epipalaeolithic site of Kharaneh IV, eastern Jordan, and hypothesize how shifting hunter-gatherer settlement and mobility during the Late Pleistocene to early Holocene shaped human-environment interactions. This is done through a broader analysis of the cultural strategies of risk management and resilience and how these practices allowed hunter-gatherer communities to adapt to a changing environment. As a hunter-gatherer aggregation locale, Kharaneh IV served as a "home" for local and non-local communities for over 1200 years. However, with a changing local habitat and the disappearance of wetland ecosystems, the people who inhabited this landscape eventually chose to leave. The nature of these environmental changes, along with changing social conditions, caused the hunter-gatherers who had aggregated at the site for generations to move elsewhere, finding new places to call home (see also Richter and Maher, 2013). Through this paper we argue that the abandonment of Kharaneh IV was not in itself a risky move, as these hunter-gatherers had the necessary strategies of resilience embedded within their cultural practices and material culture.

From the Late Pleistocene to the early Holocene there were fundamental shifts in human-environment interactions that led to the domestication of plants and animals. Domestication is also linked to cultural patterns during the Neolithic including the construction of structures, art, groundstone, and burials. Although classically described as "revolutionary," the cultural behaviors

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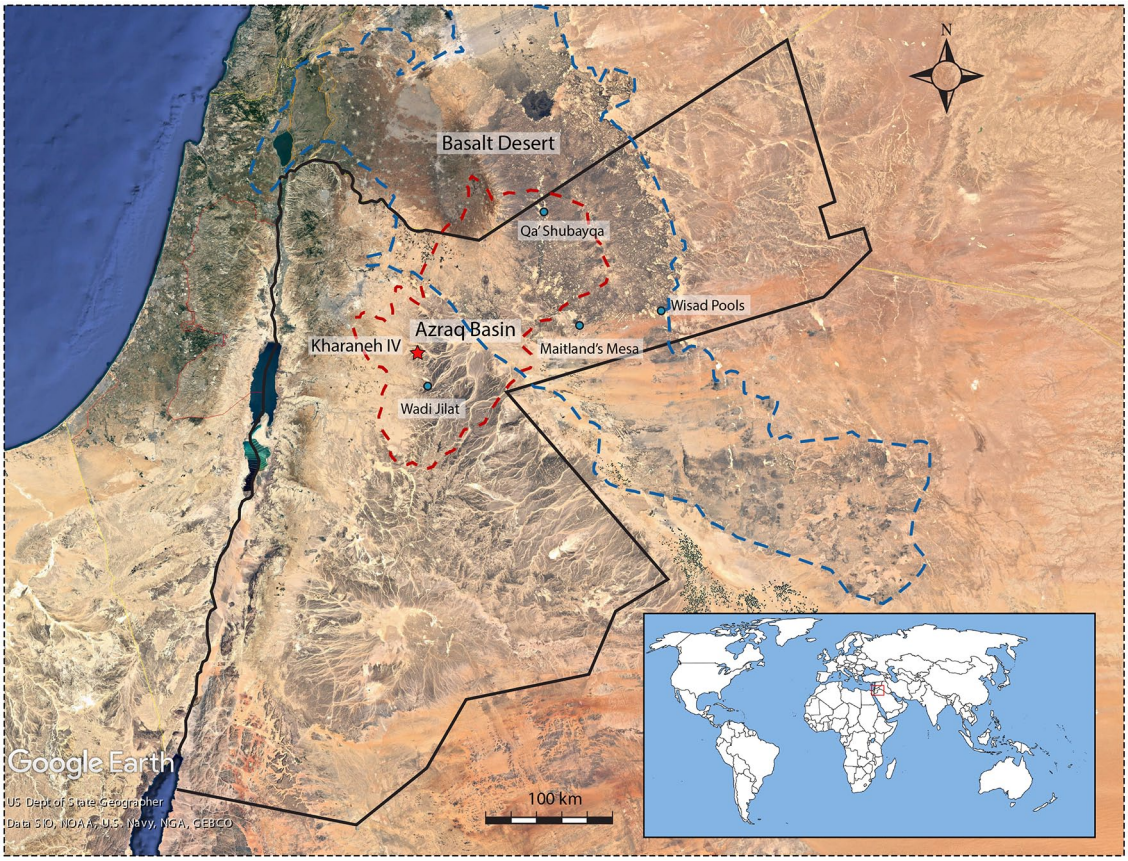

Figure 1. Map of Jordan showing key geographic regions and sites mentioned in the text. The Azraq Basin is outlined with a red dashed line. The boundaries of the Basalt Desert are demarcated by blue dashed line. Kharaneh IV is marked with a red star.

witnessed in the Neolithic were neither fast nor sudden changes, rather these cultural patterns are seen earlier in the Epipalaeolithic (Maher et al., 2012b), including at sites like Kharaneh IV (Maher et al., 2021). In keeping with this trend of long-term patterns toward domestication stretching from the Pleistocene into the Holocene, it reasons that the close interactions with nature seen in the Neolithic may have earlier roots. Thus, understanding how Epipalaeolithic hunter-gatherers mitigated risk through their interactions with the environment gives new perspectives about this pivotal period in prehistory (e.g. Ramsey et al., 2016). Using classic theories of risk buffering from Halstead and O'Shea (1989), we explore how the communities at Kharaneh IV responded to the changing environment, which in turn gives insights into broader landscape use throughout the region and into the Neolithic.

The site of Kharaneh IV is situated in the Azraq Basin in the eastern Jordanian desert (Figure 1). Dating to between 19,830 and 18,600 cal. BP (Richter et al., 2013), there is evidence for multiple phases of occupation at the site spanning the Early and Middle Epipalaeolithic (Macdonald et al., 2018; Maher et al., 2012a). Initially excavated in the 1980′s (Muheisen, 1983, 1988a, 1988b), renewed excavations at Kharaneh IV since 2008 have detailed the site's occupational history in relation to the changing environment (Jones et al., 2016a, 2016b; Maher et al., 2022). Kharaneh IV is an exceptionally large Epipalaeolithic site, approximately 21,000 m^2, and the deflated surface of Kharaneh IV has created a palimpsest of lithics capping the site, protecting the fragile subsurface deposits from erosion. Beneath the surface is evidence of intensive occupation with several stratified, dense accumulations of cultural material, including chipped stone and groundstone, fauna, ochre, incised stone, bone tools, and marine shell. Well-preserved features include floors, hearths, post-holes, brush hut structures, and human burials. The site's large size and dense artifact accumulations, in addition to ongoing research into the material culture, indicate that Kharaneh IV was a hunter-gatherer aggregation locale during occupation and a focal point for interaction in the region during the Early to Middle Epipalaeolithic. However, this continual and intensive occupation came to an end around 18,600 years ago, when the hunter-gatherers who had previously called Kharaneh "home" stopped returning. To understand why returning to Kharaneh IV become too "risky" for these communities, we explore the final stages of occupation at the site in relationship with the shifting environment at the end of the Pleistocene and hypothesize where these populations may have migrated to during the early Holocene.

Final phases at Kharaneh IV

Excavations at Kharaneh IV

Excavations at Kharaneh IV have concentrated in several key areas of the site, including the highest peaks of the mound. Two of our largest excavation areas, Area A and Area B, were placed on these high points to gain a better sense of the stratigraphy of the deposits (Figure 2). The stratigraphy recorded in Area B (and small soundings around this area) indicates there were several phases of Early Epipalaeolithic occupation covering much of the eastern side of the site (Maher, 2019; Maher et al., 2016), while the stratigraphy in Area A documents two main phases of Early Epipalaeolithic occupation overlain by Middle Epipalaeolithic occupations (Macdonald et al., 2018), suggesting extensive and expansive use of the site since its earliest occupations. Some of the more notable finds from the Early Epipalaeolithic in Area B include the oldest hut structures in Jordan, one with a human burial placed inside on the floor of the structure prior to its conflagration (Macdonald and Maher, 2020; Maher et al., 2012a, 2021). While the Early Epipalaeolithic deposits shed valuable insights

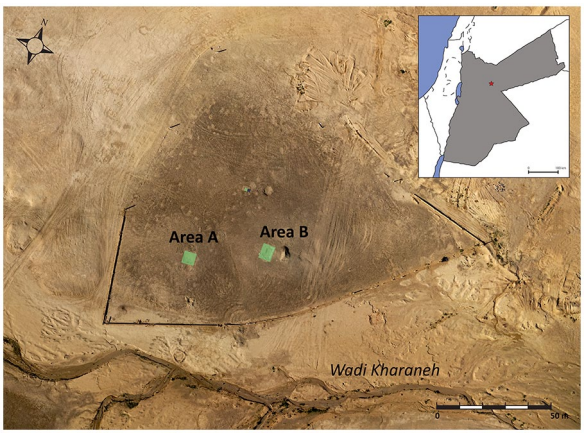

Figure 2. Aerial image of Kharaneh IV showing the location of excavation areas A and B. Inset image in the top right shows the location of Kharaneh IV, marked with a star, within the broader region.

into the intertwined symbolic and domestic worlds of Epipalaeolithic peoples, it is the end of occupation that we will focus on here. Our discussion of the final phases of Kharaneh IV occupation will center on the material culture from the Middle Epipalaeolithic deposits of Area A, where the final inhabitants of Kharaneh IV lived prior to abandoning the site, and how these traces of human life relate to the changing environment. It is important to note that the artifacts on the deflated surface of Kharaneh IV are composed of Epipalaeolithic material culture, suggesting that no other later cultural groups inhabited the site after the people of Kharaneh IV left.

Middle Epipalaeolithic stone tool assemblage

As archeologists, we gain access into the lives of past people through the objects that they leave behind. Furthermore, the technologies that people use, whether in the past or the present, act as mediators between humans and the environment, and thus technologies themselves can be part of a larger cultural strategy of resilience and risk management. The Middle Epipalaeolithic artifact assemblage at Kharaneh IV is dominated by stone tools, and thus, our discussion will focus on these objects. However, we acknowledge that these chipped stone materials represent only a small fraction of the material lives of these people and our interpretations are, as a result, incomplete. Several million lithics have been excavated from Kharaneh IV, and over 100,000 lithics from the Middle Epipalaeolithic occupation areas alone have been analyzed. This wealth of material allows us to better understand the activities and actions that the hunter-gatherers at Kharaneh IV participated in during their final years at the site. Chert raw materials are abundant in the local landscape with three distinct chert formations within 15 km of the site, one of which has outcrops <5 km from Kharaneh IV (Sánchez de la Torre et al., 2019). All three outcrops produce a range of different colors and textures of chert, and much of this is fine-grained, high quality material. In addition, secondary sources of nodular chert are abundant adjacent to the site as they litter the ground surface and can be found in the wadi beds. Comparing the choice of raw material type between the Early and the Middle Epipalaeolithic phases, we see more diversity in raw material selection toward the Middle Epipalaeolithic, with knappers choosing both elongated and rounded nodules, as well as a wider range of chert colors (Macdonald, 2013; Maher and Macdonald, 2013). Interestingly, although there is abundant raw material surrounding the site, during the Middle Epipalaeolithic phases we see the use of more varied and, rarely, more distant chert in small amounts, coming from sources >15 km away (<4% of the analyzed assemblage), including pink, purple, white with pink spots, and translucent cherts (Macdonald, 2013). Although the pink and purple chert outcrops are located approximately 25 km from the site (Sánchez de la Torre et al., 2019), it is not clear where the white with pink spots chert source is located, suggesting that it might be coming from further afield. Shifting technological practices from the Early to the Middle Epipalaeolithic meant that there was less constraint on core shape, thus, making it possible for Middle Epipalaeolithic knappers to explore the use of new materials, perhaps for the esthetic properties of these cherts (Macdonald, 2013; Macdonald et al., 2018; Maher and Macdonald, 2013). In addition, these choices might reflect more movement and mobility of the hunter-gatherers at Kharaneh IV toward the end of the site's occupation, as they encountered different chert sources on their travels. Alternately, the knappers of Kharaneh IV may have just chosen any available material, not constrained by nodule shape, since there were fewer constraints on the blank shape for making microliths.

The cores at Kharaneh IV are heavily focused on the production of blades/bladelets, with only a few cores targeting flake removals (Macdonald, 2013). Of the analyzed assemblage, the most common cores are narrow-faced bladelet cores on tabular chert ($n=126$, 41.0%) that produce narrow, gracile bladelets. Broad-faced bladelet cores, manufactured on rounded chert nodules, are also very common in the assemblage ($n=69$, 22.5%), producing slightly wider and less standardized bladelets (Macdonald, 2013). There is evidence of both core preparation and core maintenance during the Middle Epipalaeolithic at Kharaneh IV and the generalized reduction sequence can be reconstructed through the core-trimming elements present at the site. Reduction is initiated through the removal of an initial spall across the core to prepare a striking platform. This was followed by the preparation and removal of a crested blade from the core face. Lateral core-trimming elements were removed from the sides of the core, thinning, and removing some of the cortex. There was minimal core shaping after the removal of the crested blade and some minor core thinning. Most of the core-trimming elements are related to maintenance ($n=2035$, 79.5%), removed during the knapping sequence to fix problems instead of changing the shape of the core. The most common maintenance elements are profile correction blades ($n=648$, 25.3%). These blades remove knapping errors from the face of the core, such as hinge terminations or bulges, while still maintaining the parallel arrises needed for further blade removals. Thus, the Middle Epipalaeolithic reduction strategy is more heavily focused on corrective removals rather than preparation (Macdonald, 2013). This focus on maintenance, rather than preparation, allowed for a flexible microlith technology that could be easily adapted to new chert nodule shapes and sizes. This flexibility in raw material choices and technological production may have provided a measure of adaptability to these Middle Epipalaeolithic groups as the local habitat around Kharaneh IV was drying. Here, a flexible technology to produce a diversity of microliths may have equipped these hunters and foragers with a resilient set of subsistence tools (and other types, of course) and allowed them to constantly re-strategize in a changing landscape. Indeed, it is possible that the increase in gazelle numbers in the Kharaneh IV faunal assemblage over time (Martin et al., 2010) may relate to intensified exploitation of these prey with the drying of wetlands and expansion of grasslands, both of which disappear into the Holocene. Finally, once the area around the site was no longer favored, or considered habitable, this technological flexibility may have aided these groups as they left the site and explored new territories.

Here we present the results from a sample of 823 microliths which were analyzed in detail with attribute analysis (for full results, see Macdonald, 2013). These microliths were randomly chosen from the Middle Epipalaeolithic deposits at the site. Like

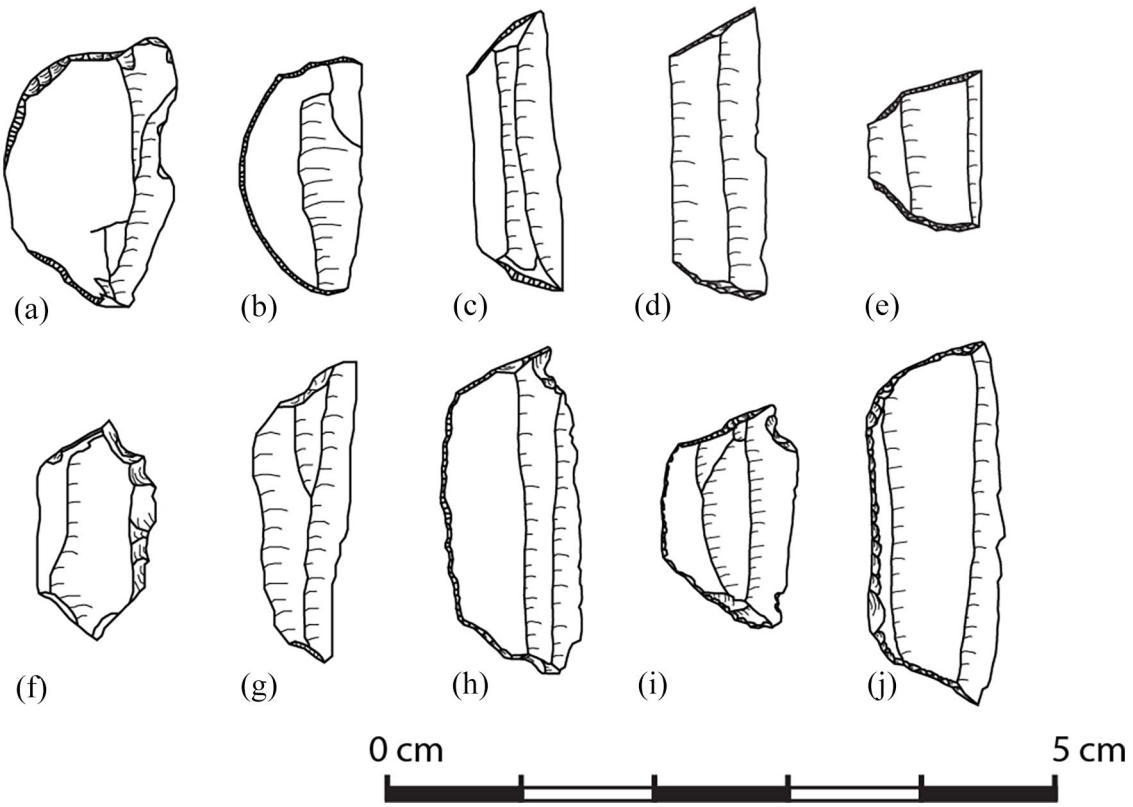

Figure 3. Examples of geometric microliths from the Middle Epipalaeolithic occupation of Kharaneh IV: (a and b) lunates, (c–e and g) unbacked trapezes, (f) varia, and (h–j) trapeze rectangles.

all Epipalaeolithic sites, the Middle Epipalaeolithic tool assemblage at Kharaneh IV is dominated by microliths at >80% of the analyzed retouched tool assemblage (Macdonald, 2013), including both geometric and non-geometric microliths. The geometric forms tend toward trapeze-rectangles, which are the *fossile directeur* of several Middle Epipalaeolithic cultural entities; however, at Kharaneh IV both backed and unbacked trapeze-rectangles are present, the latter unusual for these assemblages (Figure 3). In addition to various types of trapeze-rectangles, there are numerous other geometric types present in the assemblage including lunates, parallelograms, and triangles (Table 1). There is considerable variability in form within the trapeze-rectangle typological class. Some are very wide, with rounded corners, while others are narrower with more angular edges. There are also several trapeze-rectangles with large notches or denticulations on the cutting edge (Macdonald, 2013). Although there is great flexibility in microlith types during the Middle Epipalaeolithic at Kharaneh IV, there are consistent patterns in retouch style among the microliths. All microlith classes, including both non-geometric and geometric microliths, are marginally, non-invasively, or invasively retouched with unidirectional backing, suggesting that the Middle Epipalaeolithic knappers were using similar mental templates for how to retouch microliths, regardless of form (Table 2 and Figure 4) (Macdonald, 2013). Despite the similarities in retouch patterns between the geometric and the non-geometric microliths, the metrics suggest that trapeze-rectangles were being produced from different blanks than the unbacked trapezes and the non-geometrics, indicating different *chaîne opératoire* for these microlith types (Macdonald, 2013). The diversity of geometric microlith forms during the Middle Epipalaeolithic suggests that there was a wide range of ways that the inhabitants of Kharaneh IV envisioned the final product of microliths. This range may reflect different knapping preferences, traditions, or communities, where groups of knappers learned to produce distinct microlith types and brought these traditions with them when they aggregated at Kharaneh IV.

A use-wear study on the microliths from Kharaneh IV indicated that these tools had a range of functions. In a sample of 200 microliths, randomly selected from the sample of 823 chosen for attribute analysis, 48.5% ($n=97$) showed evidence of use. The tools with use-wear indicate that the microliths at Kharaneh IV functioned primarily as projectile inserts (56.7%), suggesting that these tools were an important part of the hunting tool kit. Analysis of the diagnostic impact fractures shows that the microliths functioned as both projectile tips and barbs, with the geometric microliths functioning primarily as barbs, while non-geometrics were more likely to be used as projectile tips. For the remainder of the microlith assemblage, 21.6% functioned as cutting tools, with the remainder functioning as scraping or drilling tools. Non-projectile functions include cutting meat and hide, butchering activities with bone contact, and working hard materials. Analysis of microlith function by typological group did not show a clear pattern between form and function, with each typological group being used for a range of different functions.

The remainder of the retouched tool assemblage are tools typical for the Middle Epipalaeolithic, including endscrapers on blades, multiple tools (usually combining endscrapers with burins or truncations), burins, backed blades, notches/denticulates, and retouched pieces. In addition to these tools, there is also evidence for the manufacturing and use of groundstone implements in the Middle Epipalaeolithic assemblages at Kharaneh IV, including fragments of bowls, mortars, and pestles made from locally-sourced limestone or basalt from the east. Notably, a very large, breached basalt mortar fragment was found on the surface of the site. This mortar would have taken community cooperation to move from the nearest basalt fields 25 km to the east of Kharaneh IV and would have been a semi-permanent feature for the Kharaneh IV community. The mortar was used until the bottom was completely worn through and was left at the site, either by the residents of Kharaneh IV when they

moved to a new locale or by later populations reusing the mortar (although there is no clear evidence for Late Epipalaeolithic or later occupations at the site, there is a scatter of Neolithic artifacts on the terrace on the other side of the wadi, less than 100 m away).

Table 1. Microlith types from the Middle Epipalaeolithic assemblage of Kharaneh IV.

Tool type	Count	Percent
Geometric Microliths		
Asymmetrical trapeze A	6	0.7
Asymmetrical trapeze B	3	0.4
Lunate	6	0.7
Parallelogram	2	0.2
Scalene bladelet	1	0.1
Trapeze-rectangle	70	8.5
Trapeze-rectangle with one convex end	4	0.5
Triangle	2	0.2
Unbacked trapeze	88	10.7
Unbacked trapeze with one end pointed	3	0.4
Geometric Microlith Subtotal	185	22.5
Non-Geometric Microliths		
Alternating retouch bladelet	1	0.1
Arched backed bladelet	3	0.4
Completely backed	16	2.0
Curved pointed bladelet	13	1.6
Inversely retouched bladelet	1	0.1
Micropoints	2	0.2
Notched bladelet	5	0.6
Obliquely truncated	37	4.5
Obliquely truncated and backed	2	0.2
Partially backed	48	5.8
Pointed bladelet	14	1.7
Pointed and retouched on both sides	4	0.5
Retouched on both sides	4	0.5
Varia	12	1.5
Non-Geometric Microlith Subtotal	162	19.7
Fragmentary Microliths		
Backed bladelet fragment	60	7.3
Convex truncation	1	0.1
Curved pointed bladelet	19	2.3
Obliquely truncated	326	39.6
Obliquely truncated and backed	70	8.5
Fragmentary Microliths Subtotal	476	57.8
Total	823	100.0

Other middle Epipalaeolithic material culture

In addition to the stone objects at Kharaneh IV, other types of materials have survived (Figure 5). There is a rich assemblage of marine shells, coming from the Mediterranean and Red Seas, which may have traveled with the hunter-gatherers aggregating at Kharaneh IV or perhaps traded through communities, being passed from person to person until they arrived on the site (Richter et al., 2011). This shell is generally perforated and most show evidence of ochre-staining and having been strung, perhaps worn as personal ornamentation or used as decoration. It is possible that this shell served as important markers of identity or affiliation for hunter-gatherer groups coming from afar and aggregating at Kharaneh IV. It may have also served as a valued trade item, or as currency in exchanges between individuals or groups. As well, there are several pieces of notched bone, with patterns of notches that resemble counting or record keeping notations (e.g. D'Errico et al., 2018). Otherwise unmodified, these bones are found primarily in the later phases of the Kharaneh IV occupational sequence, with only a few coming from the Early Epipalaeolithic occupation. Finally, a small, incised stone plaquette was discovered in the Middle Epipalaeolithic deposits. This incised plaquette is one of the oldest pieces of art found in Jordan and bears an incised ladder pattern similar to those found on contemporaneous plaquettes from Israel (Macdonald and Maher, 2022). The presence of marine shell, notched bones, and incised stone highlights the knowledgeable and novel uses of materials from the local landscape to express aspects of identity, affiliation, and symbolism and to mark or keep track of other facets of daily life and worldviews now lost to us.

Middle Epipalaeolithic faunal assemblage

The landscape around Kharaneh IV supported a wide range of different animal species. However, the faunal assemblage from the final phases of occupation at Kharaneh IV shows that the inhabitants of the site preferentially hunted gazelle over other locally available species. While this focus on gazelle is typical for the period, during the final stages of occupation at Kharaneh IV there is a marked increase in the use of gazelle, representing >90% of the faunal assemblage (Martin et al., 2010). Furthermore, the mortality profiles of the gazelle assemblage, with an increased number of individuals and a higher present of juveniles, suggest that the increase in gazelle hunting is linked to a change in hunting strategies, where larger groups were participating in communal hunting (Martin et al., 2010). Despite this focus on gazelle, the remainder of the faunal assemblage is remarkably diverse, with evidence of hunting hares, tortoises, canids, foxes, birds, wild cattle, wild ass, and other species which would have been available in the local environment (Macdonald et al., 2018; Martin et al., 2010).

Table 2. Retouch type on microliths from the Middle Epipalaeolithic deposits of Kharaneh IV.

	Geometric Microliths		Non-geometric Microliths		Fragmentary Microliths	
Type of retouch	Count	Percent	Count	Percent	Count	Percent
Total	0	0	0	0	1	0.2
Combination	9	4.9	1	0.6	1	0.2
Invasive	14	7.6	16	9.9	28	5.9
Marginal retouch	50	27.0	76	46.9	270	56.7
Non-invasive	24	12.9	69	42.6	176	37.0
Unbacked	88	47.6	0	0	0	0
Total	185	100	162	100	476	10
Direction of retouch	Count	Percent	Count	Percent	Count	Percent
Unidirectional	185	100	162	100	475	99.8
Bidirectional	0	0	0	0	1	0.2
Total	185	100	162	100	476	100

The focus on gazelle hunting would have produced a large amount of meat, perhaps more than could be consumed after the kill. Archeological evidence from the later phase of occupation at Kharaneh IV presents the first evidence for food preservation and storage at the site. A series of small post-holes were discovered circling two hearths – postholes that are too small to support an architectural structure. Due to the postholes' proximity to heaths, we interpret these be the remains of meat drying racks used to smoke meat over the fire (Spyrou et al., 2019). The preservation of meat would allow communities to pack food for travel across the landscape, bringing with them a reliable source of protein as they moved.

Summary of the final phases at Kharaneh IV

The material culture record in the final phases of Kharaneh IV shows a Middle Epipalaeolithic community of hunter-gatherers who had flexible technological practices in their raw material choice, *chaînes opératoires*, and microlith typology that suggest that the site was populated by different aggregating communities, but also by knappers who were adaptable to change. The diversity exhibited in tool-making strategies allowed for risk mitigation and resiliency, allowing these communities to exploit a range of different resources and manufacturing techniques. The presence of large groundstone objects on the surface of the site suggests that these communities were invested in Kharaneh IV as an important place on the landscape, somewhere where they could return to again and again. Beyond stone, the material culture in the final phase of the site highlights the rich symbolic world of these hunter-gatherers. This leaves us with the question of why these communities stopped returning to Kharaneh IV, somewhere that had held a sense of "home" for over 1200 years. To answer this question, we need to turn to the environment in which these hunter-gatherers dwelled.

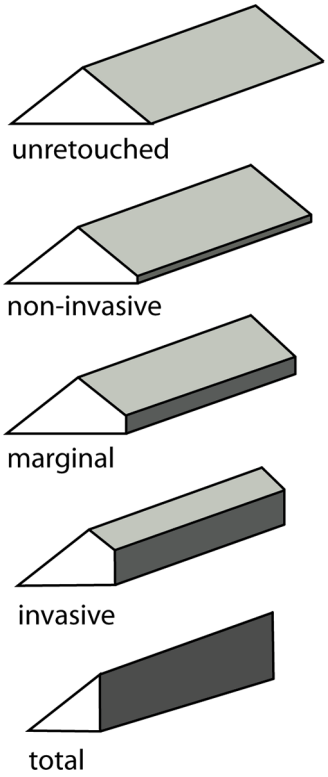

Figure 4. Microlith backing retouch types (adapted from Christensen and Valentin, 2004).

The paleoenvironmental context of Kharaneh IV

Previous work around the site environs

The first published mention of Kharaneh IV was in 1959, when Lankester Harding (1959) described it in his book *The Antiquities of Jordan* as "a magnificent Upper Paleolithic-Mesolithic site, where the ground is covered with thousands of flint implements and flakes." This early characterization – which also included his musings about how a local dog could possibly survive in the present-day desert – led many to wonder how such an archeologically-rich site was created and why in this particular location. In other words, what kind of prehistoric activities led to the formation of such a site, and what post-depositional processes led to its preservation in such an arid and deflated environmental context?

Garrard et al. (1975) provided the first detailed description of the site as part of their survey of prehistoric sites in the larger Azraq region. Expanding on this work in the 1980s, Garrard conducted the first geomorphological work around the site's environs as part of a larger project to investigate Paleolithic, Epi, and Neolithic sites throughout the basin and reconstruct paleoenvironmental conditions during these phases of occupation. Garrard et al. (1985) characterized the generalized stratigraphy around Kharaneh IV as Pleistocene gravel deposits containing Middle (?) and Upper Paleolithic artifacts, overlain by massive clays, possibly of lacustrine origin, forming a series of low terraces upon which Kharaneh IV sits. These well-drained gravels suggested the

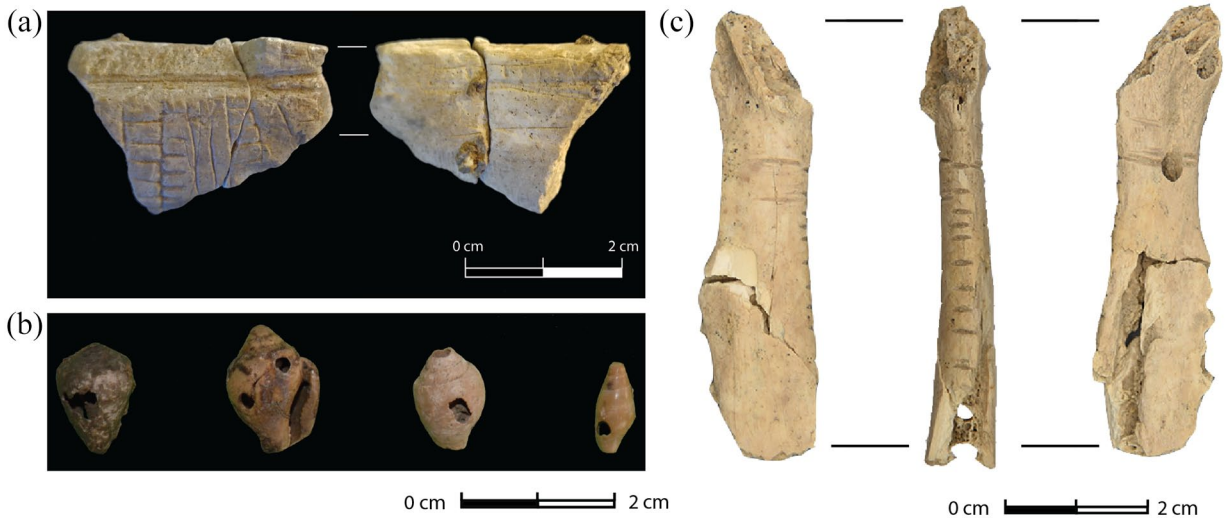

Figure 5. Incised stone (a), perforated shells (b), and notched bone (c) from the Middle Epipalaeolithic occupation of Kharaneh IV.

regular presence of flowing water, but there was no indication of what might have caused the shift to deposition of lacustrine clays after the Upper Paleolithic. Garrard et al. (1985) also reported a homogenous sandy loam above the clays that might represent loess deposition similar to that identified in association with Epi and Neolithic occupations in nearby Wadi Jilat. They interpreted this sequence as representing an initial wet period depositing lacustrine-like clays, followed by increased aridity marked by the onset of loess accumulation that coincided with the occupation of Kharaneh IV. After the abandonment of Kharaneh IV, they suggested the area became increasingly arid and characterized by local wadi incision and deflation of terrace surfaces.

Further geomorphological work by Besancon et al. (1989) identified three distinct terrace sequences for the Wadi Kharaneh: an upper Pleistocene terrace, a middle terrace with Acheulian artifacts, and a more recent lower terrace containing Epi and Neolithic material and including the site of Kharaneh IV. The lower terrace stratigraphy is described as fine, light brown silt overlying a clay layer containing root traces and greenish-white calcareous concretions. Both the silt and clay contain Epi artifacts, which are similar to the depositional sequence documented at Kharaneh IV (Maher et al., 2021). Underlying the clay is a pebble layer containing unpatinated Middle and Upper Paleolithic flints. Besancon et al. (1989) describe only minimal downcutting of the Wadi Kharaneh – approximately 20 m below adjacent bedrock exposures at Qasr Kharaneh – over the last ~18,000 years. They attribute this minimal downcutting to both low annual rainfall in the region at end of the Pleistocene and throughout the Holocene and a low gradient in this part of the Azraq Basin. Here, it seems, the wadi has moved extensively laterally and experienced multiple depositional and erosional phases.

Ongoing work at the site: Evidence for initial occupation and later abandonment of the site

In 2008 we (the authors), along with colleagues, initiated our first full excavation season at Kharaneh IV, paired with geoarchaeological investigations off-site. The details of this ongoing work have been published elsewhere (Jones et al., 2016a, 2016b; Maher, 2019; Maher et al., 2022) and so are only summarized here. We began by re-opening Muheisen's two main excavation areas (Areas A and B) and extending horizontally and vertically from these to re-locate and document the range of archeological features described by Muheisen and to examine the site's stratigraphy. In subsequent years, we opened several new excavation areas, especially designed to correlate stratigraphic features and the chronology of occupation of the site between Areas A and B. We also dug several deep soundings and geological trenches off- and on-site, including Geotrench2009 and Geotrench2018, to connect the deposits documented on-site with those of the adjacent wadi and surrounding low terraces.

Perhaps the most fruitful of these deep soundings was the West Section of R/S2/60 in Area B, representing an expansion from Muheisen's sounding here where he documented several pit features, a floor, and two human burials (Muheisen, 1983, 1988a). Not only were we able to re-expose several of these features and discover several additional surfaces and hearths, but we excavated two extensive brush hut structures and one additional burial from this area (Maher, 2019; Maher et al., 2012a; Maher and Conkey, 2019; Maher et al., 2021). Most notably, we were able to provide a high-resolution chronology for the complex sequence of the Early Epipalaeolithic occupations in this portion of the site (Richter et al., 2013). After excavating 1.7 m of artifactually-dense silts in the 2 × 2 m deep sounding we reached a very hard, brown clay devoid of artifacts. While we continued to auger down another 70 cm in this clay, it remained sterile and we did not reach its base. This clay is extremely compact, with a well-developed prismatic soil structure and little to no evidence of secondary carbonate features. Of particular note, this is the only location on-site where we have discovered this brown clay or reached sterile deposits. Elsewhere, deposits underlying the loose silty artifact-rich layers consist of a carbonate-encrusted, greenish marl that still contains low densities of Early Epipaleolithic artifacts and faunal material. Ongoing analysis of micromorphological and bulk sediment samples from these deposits offers insight into the significant lateral variation documented between Area B and other deep excavation areas and trenches across the site.

To the west, in Area A, extensive lateral excavations of a series of activity areas focused on gazelle meat processing and drying (Spyrou et al., 2019) were paired with a deep sounding 1 × 1 m Square AS42 in order to (a) explore whether Early Epipalaeolithic occupation layers could be found underneath the Middle Epipalaeolithic levels here (and they were; Macdonald et al., 2018), and (b) articulate these deep deposits with the clay noted from Area B. Square AS42 was excavated to a depth of 2.3 m below the surface and its full stratigraphic sequence is described in Macdonald et al. (2018). At ca. 70 cm below surface, the loose silty artifact-dense occupational deposits end abruptly with an unconformity and are replaced by a series of green and gray marl deposits similar to those documented from Epipalaeolithic Ayn Qasiya in the Azraq Shishan wetlands (Jones and Richter, 2011). It is at this unconformity that we witness a shift in the proportion of geometric to non-geometric microliths, with a sharp decrease in geometrics in the green and gray marl deposits, representing the transition from Early Epipalaeolithic to Middle Epipalaeolithic occupations at the site (Macdonald et al., 2018). The greenish marl is extremely well-sorted and compact, with some rust-colored iron staining, and contains abundant freshwater ostracods (Jones, personal communication, 2010), representing deposition of fine sediments within a former wetland habitat. Iron-stained clay layers below the greenish marl suggest fluctuations in water levels here that coincide with the earliest episodic occupations of the site and may represent episodic drying of the wetlands (see below). Early Epipalaeolithic microliths and faunal remains continued to be found here and sterile deposits were never reached. This square was closed and backfilled at 2.3 m depth due to danger of collapse.

Several other deep soundings were placed in between Areas A and B (Area C) and to the north (Area E) and east (Area F), as well as a 9 m long geological trench running from just south of Area B to the edge of the site. In each of these, a similar greenish marl containing Early Epipalaeolithic artifacts was documented. For example, in Area C, Square AZ51 was excavated to a depth of 1.2 m; 50 cm deeper than the base of the Area B deep sounding, but still 1 m above the level of the modern terrace surface just off-site. Here, Middle Epipalaeolithic features were excavated within the loose silts, while after 60 cm depth the greenish marl was encountered. Artifacts and fauna dropped off significantly in frequency, but these marls are not sterile here and still contain Early Epipalaeolithic material. High densities of freshwater ostracod shells indicative of shallow water conditions, at least episodically, were also identified here (Jones, personnel communication 2010). A sterile, hard white clay at the bottom of this square suggests a period of severe aridity preceding occupation of the site. This sequence suggests that early occupation of the site in the Early Epipalaeolithic may have occurred adjacent to a small, fluctuating freshwater source.

Jones conducted a geomorphological survey of the area around Kharaneh IV in 2008–2009 to document local hydrological patterns, past and present, and excavated five small geological trenches in the surrounding low terraces to correlate their stratigraphy across the landscape. He collected bulk sediment samples for sedimentological analyses and OSL dating (Jones et al., 2016a, 2016b). Jones documented two main depositional units in these sections: an upper Holocene wadi fill and lower Pleistocene

wetland deposit (greenish marl), with both showing extensive lateral variation. OSL dates from the upper Pleistocene marls suggest these palaeo-wetlands appear to start drying up between 23,000 and 19,000 cal BP (Jones et al., 2016a). Geochemical analyses of bulk samples from these trenches show lower percentages of SiO_2 and MgO but higher percentages of CaO and carbonate content than samples from Geotrench (2009) (see below), which Jones et al. (2016a) used to interpret off-site terrace deposits as carbonate-enriched wetland marls, formed as groundwater discharge deposits, that existed at Kharaneh IV prior to and overlapping with the beginning of the site's occupation.

Geotrench 2009 is a 9×1 m long geological trench excavated from the southern extent of Area A to the southern edge of the site where it tails out to the modern wadi bank (Maher et al., 2022). This trench allowed us to define the edges of the subsurface occupation of the site and to assess the articulation of on- and off-site deposits as the site meets the lower terrace sediments. Through much of the trench we found dense subsurface deposits of in situ lithics and fauna, including the discovery of a small knapping area containing cores, debris, and retouched tools that are currently undergoing refit analysis. Therefore, although the size of the site might be slightly exaggerated as deflation exposes artifacts and they are washed downslope at the edges of the mound of the site, this effect is minimal and most of the large mound of the site contains intact subsurface deposits. We were also able to confirm that Early Epipalaeolithic occupations underlie Middle Epipalaeolithic occupations at several locations across the site, suggesting that much of the site's area was in use, albeit perhaps episodically, throughout both the Early and Middle Epipalaeolithic periods. The site was laterally extensive in the Early Epipalaeolithic and in the Middle Epipalaeolithic, over approximately 1200 years of use. However, several episodes of inundation (marked by the deposition of greenish-gray marls) and drying (marked by three separate horizons of carbonate deposition) in Geotrench 2009 mark variation in water levels and wetland extent prior to and during the initial occupation of the site. A similar sequence was noted in Geotrench 2018 (Maher et al., 2022). Here, several marl layers display different thicknesses, colors, and contacts with underlying deposits, emphasizing significant lateral variation across the site in these wetland deposits.

Sedimentological and geochemical evidence, alongside the presence of freshwater ostracod shells, indicated that the lower carbonate-enriched, greenish marls at Kharaneh IV and in the surrounding terraces formed in a wetland environment. Initial occupation of the Kharaneh IV area was episodic, with fluctuating wetland boundaries causing periodic abandonment of the site during high water levels and settlement during low water levels. This created an initial occupational sequence of alternating and interfingered artifact-bearing and sterile marls that likely resulted from a fluctuating wetland environment that supported a range of wetland plant resources (Ramsey et al., 2016, 2018). Sustained occupation of the site in the Early Epipalaeolithic was only possible once the wetlands were already receding substantially, providing a dry elevated terrace upon which Early Epipalaeolithic hunter-gatherers built and lived in brush huts and buried their dead ca. 19,800–19,100 cal BP. The Kharaneh IV wetland was a mosaic of vegetated and differentially submerged lands that provided habitat for a diverse range of water-dependent and dryland species at various times (Bode et al., 2022; Martin et al., 2010; Ramsey and Rosen, 2016; Ramsey et al., 2016, 2018), much like that reconstructed for the Epipalaeolithic occupation of Ayn Qasiyya (Jones and Richter, 2011), and the more recent Azraq Shishan (Nelson, 1973).

Kharaneh IV was inhabited for at least 1200 years, most likely through a series of prolonged and repeated occupations, although there may have been phases within this time span where hunter-gatherer settlement at the site could be considered permanent. As discussed above, the shift from intermittent to intensive use of the site appears correlated to the initial drying of the local wetland, providing a reliable (and dry) "persistent place" for settlement, but within an otherwise well-watered and lush environment (Maher et al., 2022; Ramsey et al., 2016). Indeed, we suggest that one of the reasons Kharaneh IV was such an attractive locale for settlement was access to both reliable wetland resources and more risky adjacent grassland resources. Intensive occupation of the site is evident through the Middle Epipalaeolithic, where hunter-gatherers engaged in communal gazelle hunting and processing and long-distance trade and exchange with groups from throughout the region (Maher, 2019; Spyrou et al., 2019). However, ongoing regional desiccation in the late Pleistocene, evidenced through evaporite precipitation, oxidation stains, and a decline in organic content, indicated the wetlands were shrinking and their resources disappearing (perhaps aided by over-exploitation by the site's inhabitants). By 18,600 cal BP the local landscape was arid enough that large settlements like Kharaneh IV could no longer be sustained or were no longer attractive for aggregation (Maher et al., 2022) – with the disappearance of the wetlands, the risks were too great. At this point, the site was abandoned, not to be re-occupied. Indeed, this trend toward aridity continued throughout the Holocene and the entire area is not occupied again with the same intensity, highlighting the clear link between water and life in this now-desert environment. Water availability played a key role in the establishment of Kharaneh IV, and water scarcity played a key role in its abandonment.

Discussion: Beyond Kharaneh IV

Understanding cultural practices of resilience and risk management necessitates the integration of cultural and environmental data to identify how people dwelled in past landscapes and how these patterns of landscape use changed over time. Paleoenvironmental reconstructions show that during much of its occupation, Kharaneh IV was a rich environment that provided the necessary water, flora, and faunal resources for groups of aggregating hunter-gatherers. The earliest levels of occupation of the site were episodic and related to brief periods of drying of the extensive surrounding wetlands. As drying continued and the site area was no longer regularly inundated, people settled here repeatedly and for prolonged periods and, indeed, aggregated at the site from potentially far and wide. Ongoing aridity and its impact on these shrinking wetlands eventually led to the abandonment of the site. The surrounding landscape may have been too arid to support the flora and fauna necessary to sustain returning populations at Kharaneh IV. Alternately, the shrinking wetlands may have altered the landscape in other ways that made it unattractive to hunter-gatherer communities at the time. The abandonment of the site is linked to broader regional trends of Late Pleistocene and Holocene aridification, with the nearby Ayn Qasiyya spring drying up (Jones and Richter, 2011). This drought is also reflected across the region in Lake Lisan deposits and paleoclimate data from Soreq Cave (Enzel and Bar-Yosef, 2017 and references therein). The abandonment of Kharaneh IV is not an isolated event; nearby Epipalaeolithic sites such as Wadi Jilat 6 and Ayn Qasiyya (Figure 1) were also abandoned at this time, suggesting a broader shift in landscape use as water availability changed throughout the basin. One of the closest parallels to the abandonment of Kharaneh IV comes from the site of Wadi Jilat 6, located to the south. Like Kharaneh IV, Wadi Jilat 6 was a large hunter-gatherer aggregation site, occupied around the same time as Kharaneh IV. The lowest geological phases of the site are composed of playa-marsh sediments, likely accumulated from a spring with a high water table in an otherwise riverine environment (Hunt and Garrard, 2013). Over time, the environment around Wadi Jilat 6 increased in aridity, even as the occupation

intensified. The final phase of occupation at the site coincided with the aridest period, perhaps related to persistent water in the Wadi Jilat, but leading to the site's eventual abandonment at 18,600 cal BP (Hunt and Garrard, 2013), around the same time as communities left Kharaneh IV. However, unlike Wadi Kharaneh, there continue to be occupations of Wadi Jilat through the Late Epipalaeolithic, and again later in the Pre-Pottery Neolithic B (Garrard and Byrd, 2013).

It is during the shift to a more arid climate that the risk of returning to Kharaneh IV becomes too great, and the communities move to new regions. However, this abandonment was not in itself a risky move, as the hunter-gatherers at Kharaneh IV have the necessary strategies of resilience already embedded within their cultural practices. Using a model of hunter-gatherer reliance strategies and risk buffering developed by Halstead and O'Shea (1989), and explored further by Rosen (this volume), hunter-gatherers engage in four primary strategies to ensure resiliency: (1) mobility and knowledge of landscape water resources, (2) diversification of resources and tools kits to allow for flexibility, (3) capacity for storage, and (4) exchange. At Kharaneh IV, these key strategies are evident throughout the Middle Epipalaeolithic phases of occupations, building on the knowledge and skills of generations to ensure a robust, diverse, and flexible set of strategies to "leave home."

Each of these resiliency and risk buffering strategies are found in the archeological record at Kharaneh IV. Mobility and knowledge of landscape water resources are essential for the management of risk in hunter-gatherer communities. The ability to move away from areas with dwindling resources to others with plentiful resources is often predicated on the knowledge of the wider landscape (Bender, 2001; Holdaway et al., 2008; Ramsey et al., 2016; Rockman, 2013; Rosen, 2011). Once the Azraq Basin is (mostly) abandoned by hunter-gatherer communities, including those at Kharaneh IV, we begin to see the proliferation of sites to the east in the foothills of Jebel Druze in the basalt desert (Figure 1), where water would have been more stable during the early Holocene (Richter and Maher, 2013). This movement to a new region hints at the broader landscape knowledge held by hunter-gatherer communities at the end of the Pleistocene and highlights their ability to move to a new place (Rockman, 2013). Evidence for interaction with the broader landscape is also evidenced by the presence of marine shells in the assemblage. These shells are from both the Mediterranean and Red Seas and may reflect either long-distance movement to collect these resources, or the maintenance of long-distance trading partners (Richter et al., 2011). In addition to trading shells, these sorts of trading partnerships are useful for the exchange of information and knowledge about the landscape and may have provided additional risk buffering to the people at Kharaneh IV.

Diversification, the second risk buffering strategy identified by Halstead and O'Shea (1989) is witnessed in both diet and, relatedly, material culture repertoires. Although the bulk of the faunal assemblage is composed of gazelle during the Middle Epipalaeolithic, where it makes up an even greater percentage of the faunal assemblage than in the Early Epipalaeolithic, a wide breadth of taxa were also exploited, including wild ass, wild cattle, wild boar, canid, fox, hare, hedgehog, amongst others (Martin et al., 2010). When removing the dominating taxon of gazelle, the final phase of Kharaneh IV has the greatest faunal diversity of any phase of occupation at the site (Martin et al., 2010), suggesting that even while intensifying their exploitation of gazelle, the inhabitants of the site were comfortable exploiting a range of different resources. In addition, the paleobotanical assemblage shows that starch-rich plant life was readily available at the site including knotweed, sedges, and *Chenopodiaceae*, as well as some wild cereals (Bode et al., 2022). This knowledge of a wide range of resources in the natural environment allowed these communities to explore new regions with a diversity of flora and faunal, as the communities already had the knowledge needed to exploit a range of different foodstuffs.

The lithic tool assemblage also highlights a level of diversity and flexibility not seen in the earlier phases of occupation. During the Middle Epipalaeolithic, the choice of raw material was flexible both in the shape of the nodule, as well as the source of the material. The use of raw material from outside the immediate vicinity of the site, and potentially some raw materials not local to the region, indicates that the people at Kharaneh IV were exploring the landscape and bringing some of their preferred raw materials with them back to the site. Many of these materials from further afield are high quality and esthetically striking, including white opaque chert with hot pink spots, suggesting that they may have been curated based on their visual appeal. This flexibility in raw material choice was possible because microlith tool manufacturing was centered on secondary modification with heavily retouched blanks, rather than initial core preparation with minimally retouched blanks as seen in the Early Epipalaeolithic assemblage. These strategies for tool manufacturing were excellent at minimizing the risk of raw material access; small nodules of chert could be carried with people as they moved and allowed for the use of new sources.

It is also during the later phases of occupation that we have the first evidence for food preservation and storage at the site. Faunal remains of gazelle associated with clusters of small post-holes surrounding hearths are interpreted as the remains of racks that were used to dry and smoke meat over the fire (Spyrou et al., 2019). The mortality profiles of gazelle in these contexts and the scale at which processing occurred also suggests that hunting and food processing was likely a communal activity (Maher et al., 2016; Martin et al., 2010; Spyrou et al., 2019). The preservation of meat is an important risk mitigation strategy that would allow communities to pack food, knowing that they would have a reliable source of protein if game was uncertain in new environmental contexts (Rowley-Conwy and Zvelebil, 1989).

Site use intensification is also witnessed during the final phases of occupation. Alongside the above-mentioned evidence for communal working spaces, the increased abundance and proliferation of incised bones, marine shell, and the stone plaquette – much of which occurs in these communal spaces – contributes to a picture of more communal and community-based living for hunter-gatherer groups at Kharaneh IV. The marine shell was clearly brought to the site, either through long-distance travel of regular site inhabitants or, more likely, through networks of trade and exchange as groups traveled throughout the landscape, some of whom stopped temporarily at Kharaneh IV. Intensification of gazelle hunting and meat drying may reflect increasing cooperation among groups at the site. As an aggregation site, this intensification may reflect new trade and exchange partners among communities coming to Kharaneh IV. The increase in personal ornamentation made from shells from the Mediterranean and Red Seas also shows that exchange networks were intensifying during this period (Richter et al., 2011) and as noted above, the development and maintenance of personal networks is essential for hunter-gatherer resiliency as reliance on neighbors and other communities is key for knowledge and resource exchange.

Around the same time that Kharaneh IV was abandoned, new sites appear in the eastern and northern parts of the basin, marking a shift in settlement into the Holocene, rather than basin-wide abandonment. This includes a proliferation of Natufian and Early Neolithic sites in river systems of the northern basalt desert, including the area around Qa' Shubayqa (Figure 1) (Richter and Maher, 2013). The basalt desert landscape is composed of fields of basalt boulders, rearranged by humans for millennia to create houses, burial cairns, animal pens, and other enigmatic structures. Some of the earliest occupations of this landscape date to the

Early Natufian, after the abandonment of Kharaneh IV had already taken place (Maher et al., 2012b). The basalt desert is interspersed with expansive wadi systems and seasonal playa lakes that clearly sustained these hunter-gatherer populations in small and large stone-built villages. Indeed, the earliest evidence for grain exploitation to make bread comes from these sites (Arranz-Otaegui et al., 2018). Although it is hard to trace the movement of the communities from Kharaneh IV through the material culture record, it is possible that some of these hunter-gatherers moved to the eastern basalt desert once the marshland of Kharaneh IV receded. By the Neolithic, we witness a return of populations to the area around Kharaneh IV. Directly to the south of Kharaneh IV, approximately 100 m away, is a small Late Neolithic site that remains unexcavated. Although small and seemingly ephemeral, the presence of this site indicates that people eventually returned to the area to make Wadi Kharaneh their home once again.

Providing further evidence for long-term settlement of the basin, sustained occupation of the eastern desert during the Holocene is documented at several locations. This runs in contrast to early models of desert settlement that assumed the small surface lithic scatters, described as burin sites, were the most representative type of early Holocene occupation of the eastern desert (Goring-Morris et al., 2009; Kuijt and Goring-Morris, 2002). These sites were generally interpreted as short-term, ephemeral hunting camps of highly mobile groups (perhaps pastoralists connected to larger permanent villages in the west) who could not sustain more intensive occupation in this harsh desert environment. Yet, recent work at Maitland's Mesa and the Wissad pools (Rowan et al., 2011, 2015, 2020), both east of the Azraq Wetlands, shows a very different picture. Here, hundreds of Late Neolithic cairn burials at Maitland's Mesa indicate a strong connection to this desert "place," returned to over generations to bury and commemorate the dead (Rowan et al., 2011). At Wissad pools, stone-built houses, re-used, maintained, and renovated for generations, show persistent, intensive, and long-term use of this landscape (Rowan et al., 2015). Like the sites around Maitland's Mesa and Wissad Pools, the area of Wadi Jilat has evidence of long-term sustained occupations. Sites persist from the Early to Late Epipalaeolithic, even after the abandonment of Wadi Jilat 6. After a brief hiatus after the Epipalaeolithic, populations return to Wadi Jilat in the Pre-Pottery Neolithic B, with several sites containing stone architectural structures appearing during this period (Garrard and Byrd, 2013; Garrard et al., 1994). These locations, as well as those mentioned above (including Kharaneh IV), remind us that despite dramatically changing climatic regimes and local landscapes, prehistoric peoples in eastern Jordan were resilient. While settlement locations may have changed over the millennia, the ties to place established while living in the Azraq Basin persisted from the early Pleistocene through the Holocene and continue with modern communities in the present (Ames and Cordova, 2015; Cordova et al., 2013).

Conclusion

The final phases of occupation at Kharaneh IV provide a glimpse into the lives of the people who lived at the site. This final occupation dates to approximately 18,600 BP, at which point the area was abandoned until later Neolithic communities returned to the region during the Holocene. However, due to the deflated surface of Kharaneh IV, some of the details of the end of the site's life-history have been lost, indicating that occupation might have continued at Kharaneh IV for a short period of time after the last radiocarbon dates currently indicate. Despite this, the material culture record in the final phases of Kharaneh IV shows a Middle Epipalaeolithic community of hunter-gatherers who had flexible technological practices in their raw material choice, *chaîne opératoire*, and microlith typology. This flexibility and adaptable technology would have afforded them the resiliency strategies they needed to explore new areas and move to new places as the landscape around Kharaneh IV changed. And, move they certainly did – there is no evidence of Late Epipalaeolithic or subsequent occupation of the site and its immediate surroundings. Subsequent Holocene communities to the east of Kharaneh IV show the continued occupation of the larger landscape and region over time, highlighting how strategies of resilience practiced during the Epipalaeolithic may have continued into the Holocene. Thus, the abandonment of Kharaneh IV indicates the resilience of Epipalaeolithic hunter-gatherers, embedded in their cultural practices and material culture, allowed them to move across the landscape to find new places to call home.

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