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The Neolithic of the Jordanian *Badia*

Bill Finlayson and Pascal Flohr

Bill Finlayson (corresponding author), School of Archaeology, University of Oxford, Oxford, United Kingdom. E-mail: bill.finlayson@arch.ox.ac.uk
Pascal Flohr, Institute for Pre- and Protohistory and Cluster of Excellence ROOTS, Christian Albrechts University of Kiel, Kiel, Germany.[1]

Abstract

Much research has been conducted in the arid zone of Jordan, beyond the Mediterranean environments traditionally understood as the Neolithic core developmental area. The Neolithic of this arid zone has often been framed as marginal, as specially adapted to the dry environmental conditions, as maintaining hunting traditions, as providing protein to the settled communities of the core, and as made possible by new developments in pastoralism. As more evidence is discovered, an increasingly nuanced picture emerges. Not least, our understanding of the environment suggests that rather than adaptation to arid conditions much of this Neolithic expansion may relate to the exploitation of extensive areas that were better watered than today. Nonetheless, new ways of living did emerge, although typically Neolithic in their intensification of the exploitation of resources leading to the carving out of new cultural and environmental niches. The relationships between people living in these lands and those living in the core established the foundations of the economic networks that become visible in the Chalcolithic and into the Early Bronze Age.

1. Introduction

[1] Currently visiting researcher University of Oxford, School of Archaeology, Oxford, UK, and employed at Data Archiving and Networked Services (DANS), the Hague, the Netherlands.

The Neolithic occupation of Jordan's (currently) arid zone, both steppe and desert, has a long history of research (Betts 1982; Garrard et al. 1975). Not surprisingly, how this occupation is understood has undergone enormous change over time. This includes a more complex understanding of the nature of occupation, but also a considerable change in how we conceive of those arid margins in themselves. When one of the present authors (BF) first commenced work in Wadi Faynan in 1996, close to where Tom Levy's major Wadi Fidan project was to take place, the area was generally perceived of as marginal, both in terms of (early) Neolithic settlement and in environment (Goring-Morris and Belfer-Cohen 2011). After many years of work, it is now clear that in the (early) Neolithic there was nothing marginal about either.

The arid zone of Jordan, and beyond, is generally referred to as the *badia.* This term is formally used for the area receiving less than 200 mm of precipitation per year, consisting of the semi-arid and arid steppe, desert, and hyper-arid desert, which together comprise about 80% of Jordan (Betts et al. 2013; The Hashemite Fund for the Development of Jordanian Badia) (Fig. 1). These areas are generally too arid for rain-fed (or 'dry') farming and are traditionally used as grazing grounds by Bedouin, although they incorporate a number of areas with additional waters from springs or run-off from more distant rain. This is probably why the area is conceived of as environmentally marginal, but when not overgrazed many parts of the area are richly vegetated (Fig. 2). Moreover, as explored further below, the environment appears to have been wetter during the Neolithic (Jones et al. 2019). Due to the wealth of research in the Jordanian *badia* over the last decades, it is now clear that also in terms of Neolithic occupation the area was not marginal, certainly not during the Late Neolithic (c. 6500-5000 BCE[2]) for which period a wealth of evidence is now present, perhaps most remarkably from the Black Desert (e.g. Akkermans et al. 2014; Betts et al. 2013; Rowan et al. 2017).

Key research questions for the *badia* have been: In the mosaic of development paths that led to farming and pastoralism as we know them, how much was the Neolithic occupation of the *badia* the result of a more favourable environment than that which pertains today, how much may it have been based on resource needs from the more settled zones, or how much on the development of new practises in hunting and pastoralism? These traditional questions have recently been rephrased by Henton et al. (2018) as to whether the *badia* was only seasonally occupied by hunter-gatherers or hunter-herders during the Epipalaeolithic and Neolithic, or was occupied year-round by societies who had adapted to steppe

[2] All dates in this chapter are calibrated, i.e. in calendar years BCE.

conditions. It is becoming increasingly possible to move on from these questions, as we now know considerably more regarding the early stages of herd management and the movement of herd animals (Makarewicz 2017; Makarewicz and Tuross 2012), a process of domestication that appears to have been closely connected to the growth of Neolithic settlements, agriculture, and the development of a mixed farming economy (Bogaard et al. 2013). However, although the development of mixed farming is a well-known Neolithic development path, it is only one Neolithic trajectory, and in Jordan the emergence of untethered nomadic pastoralism has been a significant area of research, at least since Köhler-Rollefson used ethnoarchaeological analogy with contemporary Bedouin to argue for the development of transhumant pastoralism in PPNC 'Ain Ghazal (Köhler-Rollefson et al. 1988; Köhler-Rollefson 1992). Recent field research has focussed on a possible major colonisation of the *badia* by Late Neolithic full-time pastoralists (e.g. Rollefson 2011). An almost entirely separate strand of research has examined the technological improvements in water management during the PPNB that may have made agriculture possible beyond areas with sufficient rain, such as in the Jafr basin, and possibly even into Arabia (Fujii 2007, 2011).

In this chapter we will consider which questions have been resolved, and what new, more nuanced questions our increasing knowledge permits. Much Neolithic research focuses on the development of a mixed farming system that led to the successful spread of the Neolithic into Europe and the establishment of economies and societies that enabled the development of urbanism. We wish to explore the potential of research into understanding the exploitation of the *badia* not just as an early trajectory to forms of pastoralism that became a significant way of life in the arid lands of Southwest Asia, but also as a route that enabled a more intensive exploitation of this vast landscape and made an important contribution to early civilizations. Perhaps surprisingly, although the diversity of the *badia* has been recognised, and different regional trends noted, relatively little focus has been given to the potential presence of simultaneous multiple ways of life adapted to local conditions within the *badia* (with the exception of Miller et al. 2018).

2. Present and past climate and environment of Jordan's *badia*

The Jordanian *badia* is currently reliant on precipitation generated over the Mediterranean and Atlantic, which falls almost exclusively during late autumn, winter and early spring. Currently, rainfall ranges from around 200 mm per year (on average, fluctuations can be large) in the north and northwest to less than 50 mm in the hyper-arid southeast (Fig. 1). Fluctuations between years are large, and importantly rain in the most arid regions often falls

in one or two events only (Jones et al. 2021). Nonetheless, areas collecting runoff from wider catchments (wadis or seasonal streams, and *qe'an*[3] or seasonal lakes or mudflats) as well as those in the semi-arid (steppe) parts in the north and northwest show the potential for rich vegetation (Fig. 2) and even opportunistic growing of crops such as barley (Fig. 3). The Azraq Basin is of particular interest as water from an even larger catchment including the wetter Jebel Druze drains in this large depression towards the Azraq Oasis (Jones and Richter 2011). In this oasis, as well as in some other areas of the *badia*, especially those on the western edge of the escarpment, perennial springs are present (MWI & BGR 2019). The arid Wadi Araba also contains some locations with springs and streams, as in Wadis Faynan and Fidan. It is therefore important that the *badia* is not seen as one homogeneous area, but rather one containing a gradient from at least seasonally vegetated rainfed steppes to much less vegetated deserts, rainfed wadi courses and *qe'an*, as well as springfed, perennial wadis. Both the environmental impact and the changes in human behaviour need to be assessed in terms of these distinctions, which will in turn reveal more about what drove the decisions made.

While considerable uncertainty remains and no local high-resolution palaeoclimate records are available for the *badia*, the majority of Southwest Asian climate records indicate a wetter Early Holocene (c. 9700-6200 BCE, i.e. containing much of the Neolithic), wetter than after, including the present (Jones et al. 2019). Precipitation coming from the North Atlantic-Mediterranean system appears to have been higher: Soreq and Jeita speleothem records show more negative oxygen isotope values, which is for Southwest Asia frequently interpreted as indicating higher precipitation (Bar-Matthews et al. 1997; Cheng et al. 2015). It can be expected that this will also have affected especially the north-western edge of the *badia*, essentially moving the current rainfall zones further east- and southwards. However, it is not clear how much wetter it was exactly, and how far into the current *badia* >200 mm annual rainfall would have reached. No evidence for early Holocene standing (i.e. perennial) water has so far been found in Qa' Shubayqa, Wisad, or Qataffi in the Jordanian Black Desert (Jones et al. 2021). Nonetheless, the basins were still deeper than today and therefore had the capacity to hold more water, keeping seasonal rain available for longer periods (Jones et al. 2021). While records like Soreq, Jeita and others generally indicate an increase in precipitation from around the start of the Early Holocene, there are indications that during the Epipalaeolithic conditions in parts of the *badia*, like the Azraq basin, were at least at times also relatively wet, with soils and palaeolakes and/or wetlands, possibly

[3] As plural of *qa'*, after Jones et al. 2021.

because of lower evaporation rates (Cordova et al. 2013; Garrard et al. 1986). When this wetter period would have ended is unclear.

The Arabian Peninsula, bordering the Jordanian *badia* to its south, is also affected by other climate systems, which appear to have been more important in the region during the Early into the Mid Holocene. The Indian Monsoon has clearly been shown to have reached further north, but still stopping well south of the Jordanian *badia* (Fleitmann and Matter 2009). In northern Saudi Arabia there is nonetheless good evidence for a wetter period between roughly 8000 and 4000 BCE (no high-precision well-dated records are available so the dating is approximate) (Petraglia et al. 2020). Modelling has shown that this was most likely driven by the African Monsoon, which, however, also did not reach as far north as Jordan (Guagnin et al. 2016). This might nonetheless be of relevance, since northern Saudi Arabia and Jordan share aquifers, with groundwater flowing northwards into southern Jordan. Southern Jordan might also have been affected by Red Sea-generated moisture (Enzel et al. 2015). If these systems indeed caused wetter conditions in Early-Mid Holocene southern, but not northeastern, Jordan, this would have further reinforced the environmental variability between different areas of the Jordanian *badia*.

The current precipitation gradients are to a large extent influenced by the topography and can therefore be expected to have been the same relatively speaking, but more south- and eastwards, with the possible exception of Red Sea precipitation plumes causing increased rainfall in southern Jordan. Potential increased available groundwater as well as large-scale drainage patterns would have further influenced the availability of water.

In any case, it is clear that the environment of the *badia* was somehow ‘wetter’ during the Neolithic compared to the present. Without the present-day, and historical, intensive grazing, and with (some) increase in annual precipitation, areas that are now parts of Jordan’s semi-arid steppe would have once been part of savannah lands that formerly likely extended further to the east and south than they do today, for example potentially placing the Wadi Jilat in the dry farming zone during the Neolithic (cereals were found at several Late PPNB Jilat sites (Colledge 2001)). Until relatively recent intensive groundwater use, the Azraq Oasis was a place of wetlands, although the Early Holocene saw flood sediments rather than evidence for marshy conditions (Jones and Richter 2011). For the Epipalaeolithic Azraq oasis the presence of palaeolakes and wetlands has been shown (Cordova et al. 2013), with evidence for soil formation in the Wadi Jilat (Garrard 1998; Richter 2020). At Shubayqa, lake or wetland environments have been attested for the Late Natufian period by the presence of ducks and rushes in the archaeological records (Yeomans and Richter 2018). Work at

Wisad Pools in the eastern *badia*, now a seasonal water resource located within the hyper-arid desert, shows this desert may have only developed in the last three or four millennia, and a lusher vegetation, including tabor oak, growing on an absorbent topsoil that was present around the transition from PPNC to Late Neolithic, while fig, a 'wet' species, has been found at Wadi Qataffi (Rollefson et al. 2015, 2018; Rowan et al. 2017). However, especially outside wetter locales, environments would have still been relatively arid, even if less so than today. Mostly steppe-adapted fauna has been uncovered from most studied Epipalaeolithic and Neolithic sites in the Azraq Basin and Black Desert (Martin et al. 2016), while arid-adapted plant species were found at Wadi Qataffi (Rowan et al. 2017). Farming in the Jafr basin, for example, would probably have required irrigation, as any eastwards increase in rainfall would not have occurred this far south (Wasse et al. 2020). The apparent discrepancy is perhaps also partly explained by a grazing effect on more recent landscapes: even today, protecting desert areas from grazing has a remarkable impact not only on vegetation, but on the development of moisture retaining soils that extend both the growing season and range of plants present (Hattough et al 1986).

3. The *badia* as resource

The *badia* is often discussed from the perspective of the settled farming lands as a resource pool, whether that be in the form of additional protein for the growing population associated with increasingly large settled populations, or the production of commodities, such as beads (or the raw materials used to make them, such as malachite), tabular flint, or wool, all helping to later underpin the development of Bronze Age urban societies. In such scenarios, it is often assumed that the people obtaining these resources were, at least in the first instance, effectively conducting expeditions into the *badia*, whether these were to mine flint or move herds. The question whether people in the prehistoric *badia* were 'local' or not is one of the most-discussed in the archaeology of this region.

3.1 Hunting in the *badia*

The debate relating to hunter-gatherer populations in the Jordanian *badia* has focused on seasonality and mobility: were 'independent' local populations present year-round in the *badia*, or did they visit the area seasonally between spending time in wetter locales? One problem we face is that we do not know where the boundaries between Mediterranean woodland and steppe zones were during any given period. Recently, Henton et al. (2018) argued, primarily from isotopic evidence, that in the better watered Eastern Desert of the Epipalaeolithic and Early Neolithic, gazelle populations did not undertake the long-distance migrations known from the recent past. This would have allowed human populations to hunt gazelle year-round in the *badia*. However, the authors also note that there were preferred

hunting seasons (winter/spring in Epipalaeolithic, summer/autumn in the Neolithic), interpreted not as the result of resource availability, but, for the Neolithic, as a result of scheduling hunting to fit within the seasonal activities relating to farming (Rollefson and Köhler-Rollefson 1993). This is important, as if correct would indicate that the people hunting gazelle in the *badia* were the same as the farmers to the west. It also still assumes that early Neolithic settlements were generally confined to our contemporary Mediterranean zone, or at least its ecotonal margins and that transhumance involved these settlements - in other words that the wetter parts of the *badia*, such as the Azraq basin, did not provide a tethering point.

A topic also relevant to the study of the people of the *badia* is whether observed changes in fauna from archaeological sites represent anthropogenic hunting pressure, selective hunting choices, or natural developments in the availability of wildlife (Martin et al. 2016), thus incorporating the key research theme of the role of climate/environment. Interestingly, throughout the Epipalaeolithic there is no sign of hunting pressure on gazelle herds, but in the PPNB there are indications for some human impact on gazelles, especially at Dhuweila during the LPPNB (Martin et al. 2016). This site, in a more arid part of the *badia*, contains no evidence for caprine herding and has therefore been interpreted as a specialised hunting site (Martin et al 2016). This would accord with the association of the site with kites first recorded by Betts, suggesting that the use of kites for mass-hunting of gazelle commenced during this time (Betts 2014; Betts 1998), perhaps by specialised hunters to gain meat and hides for exchange (Martin et al. 2016). The complete absence of caprines might suggest that these hunters were not pastoralists or farmers, but unfortunately not conclusively as the site could simply be the location for a highly specialised task. A LPPNB date for kites (and their function as hunting traps) has now been confirmed at least for a group of kites in southeast Jordan, which is of further interest as the use of these kites appears to have stopped at least by the Late Neolithic and probably before (Abu Azizeh et al. 2021).

Nonetheless, it seems hunting remained important in the *badia*, at least in the Azraq basin and the Eastern Desert, from which most of the data come, throughout the Neolithic. *Badia* sites continued to have wild animals represented in their fauna and it appears caprines are just added to the prey list, suggesting an adoption of caprines by existing populations, rather than the arrival of new herding people (Martin 1999). However, Henton et al. (2018) note that in the Neolithic gazelle were pushed away from the immediate surroundings of the main settlements in the west, possibly due to local habitat changes due to increased pastoralism still tethered to the settlements. The pattern observed may also have other causes such as keeping (domestic and wild) animals away from crops. As such, spatial patterns are also

relevant. It has for example been argued that by the Late Neolithic a difference has developed between the western *badia*, where gazelle have become less numerous due to domesticate grazing pressure, and in the eastern *badia* where they remain abundant (Henton et al. 2018). In this scenario, hunting kites are a 'response' to increased pastoralism.

While important progress has been made over the last decades, the role of climate in the various developments remains unclear. After an apparently wetter Early Holocene, it has been suggested that increased aridification post-6600 BCE shifted gazelle into long-distance migration patterns, making the kites a more viable hunting mechanism (Henton et al. 2018). However, while aridification after c. 6600 BCE has been shown in palaeoclimate proxy records from the North Atlantic (Rohling and Pälike 2005) and while more arid conditions than in the Early Holocene appear to have started at some point between 6000 and 4000 BCE, local timings and conditions are far from resolved. The above-mentioned work at Wisad Pools, for example, shows the presence of intact soil and 'wetter' vegetation during the Late Neolithic at this site.

3.2 Pastoralism

Pastoralism in Southwest Asia is usually understood as a sheep-goat, and/or cattle subsistence economy, generally divided into village-based and (semi-)nomadic, but in reality on a continuum between fully sedentary to fully mobile (Abdi 2003; Bar-Yosef and Khazanov 1992; Levy 1992; Makarewicz 2013). The separation of these forms of pastoralism has been generally understood as emerging in the Chalcolithic to Early Bronze Age, but perhaps going back into the Neolithic (Abdi 2003; Cauvin 2000; Hole 1974, 1977; Levy 1983; Makarewicz 2013; Rollefson 2004). Neolithic origins have been sought through either a development arising from the Late PPNB agricultural settlements (Köhler-Rollefson 1992; Rollefson and Köhler-Rollefson 1992), or as indigenous developments with local hunter-gatherers in the arid lands adopting domesticates within their overall subsistence strategies (Baird et al. 1992; Garrard et al. 1996; Martin 1999). Pastoralists in southwest Asia are understood, when not directly tethered to agricultural settlements, to be reliant on farmers (Bar-Yosef and Khazanov 1992; Khazanov 2009), however this conception is largely based in modern ethnography of environmentally and politically marginalised pastoralists (Makarewicz 2013). Makarewicz (2013) notes that the focus of research on the origins of mobile pastoralism in the arid margins of Jordan maintains a marginalisation of nomadic pastoralism from the main trajectories of Neolithic development. The assumption that only farmers can create surplus and wealth limits the role of pastoralism in the subsequent developments of the Chalcolithic and Bronze Age, despite a clear potential for pastoralism to have created wealth

(Makarewicz 2013; Rollefson 2004). Similarly, the description of Late PPNB pastoralists as "paleobedouins" (Gebel 2010) makes tacit assumptions about past ways of life that allows for over-interpretation without analysis.

The Late Neolithic colonisation of the *badia* is generally assumed to relate to this development of new forms of pastoralism, be it transhumant or (semi-)nomadic. The central argument that increased settlement of the *badia* was linked to pastoralism is clearly made by Rollefson et al. (2014: 285): "One likely territory was a region whose climatic conditions were inimical to agriculture: landscapes that could not support perennial farming because of a lack of reliably sufficient rainfall, but whose phytogeographic cover could be converted into energy and other requirements through the agency of the herding of caprines. Substantial research effort has been expended on the nature of early pastoralism, and how caprines are introduced to the *badia* – in particular whether they are adopted gradually by indigenous hunter-gatherer populations, or by herders coming from settlements to the west. A migration of herding people has two potential routes – a relatively gradual development of transhumant pastoralism, or a more dramatic migration. Rollefson et al. (2014) have argued that the population leaving shrinking Late PPNB 'mega-sites' may have provided the impetus for this, usefully making the *badia* a potential target for Late Neolithic populations dislocated and dispersing from PPNB agricultural settlements. This arrival of new populations would mean that 'nomadic pastoralism' is not a long slow development or "timid experimentation" (Rollefson et al. 2014: 287) amongst indigenous hunter-gatherer populations, but a rapid development at the start of the Late Neolithic (Rollefson 2011; Rollefson et al. 2014). Martin (1999), however, saw more evidence for indigenous development, i.e. separate herding systems based, for example, on the percentage of caprines not being very low or very high, and when known derived from young/sub-adults. In reality, neither the faunal nor the isotopic evidence supports the idea that pre-pottery 'Ain Ghazal was involved in the development of mobile pastoralism, neither in seasonal movement of flocks to the *badia*, nor in moving from an emphasis on meat production to secondary products (Makarewicz 2014).

Increasingly the evidence appears to show that the reality was more complex, perhaps a combination of different strands. Caprine stable isotope evidence appears to show that herds both at the non-*badia* site of PPNB and PPNC 'Ain Ghazal and at the, at least currently *badia,* Early Late Neolithic (ELN; for an explanation see section 4.4) site of Jilat 13 grazed locally or at least in areas environmentally similar to where the sites are located (Mediterranean and steppe, respectively), while those at current *badia* ELN site Jilat 25 roamed into higher rainfall area(s) (Makarewicz 2014; Miller et al. 2018). The multiple strands can be seen in analyses that propose a tethered seasonal transhumant pastoralism

in PPNC (and even Yarmoukian) ‘Ain Ghazal, while by the start of the Late Neolithic, a fully separate, ‘full-time’ pastoralist population existed in the *badia* (Rollefson 2011). Tethered pastoralism may well have long-continued as an aspect of major settlements, even as pastoralists in the *badia* became more mobile.

Other important issues relating to pastoralism in the *badia* are firstly the use of dairy products, about which virtually nothing is known yet for the Neolithic Jordanian *badia* (while in contemporary northern Mesopotamia dairy products have been attested (Evershed et al. 2008). Secondly, in contrast to the Eastern Desert and Black Desert of Jordan where the focus appears to have been, as today, on sheep and goats, towards the south in Arabia cattle pastoralism was important (Makarewicz 2020). Considering this is present as well in the Levant, potential routes for expansion could have gone through the Jafr Basin and/or the Wadi Araba (Makarewicz 2020), which was perhaps better watered than the Eastern Desert at the time. This leads to the third related issue, the role of climate. It is tempting to relate the increase in settlement and pastoralism in the *badia* to either a general aridification starting around or after 6600 BCE (but see the comments above), or a more severe ‘sudden’ arid period between c. 6250 and 6000 BCE, the so-called 8.2 ka event (Alley et al. 1997; Rohling and Pälike 2005). While pastoralism was clearly present in the *badia* prior to at least the latter (Fig. 4) (Flohr et al. 2016), the potential role of intensified pastoralism as a diversification strategy is certainly of interest (Martin et al. 2013).

4. The *badia* through time

4.1 Epipalaeolithic backdrop

Early work in the Jordanian Eastern Desert encountered numerous Epipalaeolithic sites, apparently more common than in the better watered areas of western Jordan (Betts 1998). Some of this frequency is likely the result of better visibility and preservation, where flint scatter sites are more readily seen in a landscape today mostly bare of vegetation and relatively unaffected by modern development. However, the early and middle Epipalaeolithic of at least the (current) steppe zone of the *badia* were also characterised by large sites, areas of repeated occupation that appear to have drawn together different communities. Sites such as Jilat 6 and Kharaneh IV are widely understood as hunter-gatherer aggregation sites and nodes of interaction (Maher et al. 2015; Richter et al 2011). These suggest that late Pleistocene hunter-gatherer societies thrived, and that in certain favoured (and in these cases relatively wet) locations, they were able to gather in extended groups. Maher et al. (2015) have argued that given the plausible multi-season availability of resources at these locations, repeated occupation may have been long-term and multi-seasonal. Subsequently,

Natufian occupation, especially in the Azraq oasis and around Qa' Shubayqa, shows that these hunter-gatherer societies were able to flourish beyond what was once understood as the Natufian core territory of the Mediterranean woodland zone (Richter et al. 2017). It appears that this was achieved through a combination of the presence of locally rich environments, and local fine tuning of Natufian economic strategies. However, one trait of this entire Epipalaeolithic period is that the history of occupation is patchy – in time and space. There are, for example, no early or middle Epipalaeolithic sites known at Shubayqa, and the Natufian is absent from a number of likely oasis settings. Wadi Faynan has no evidence for occupation between the Palaeolithic to the Neolithic (Finlayson and Mithen 2007), although the adjacent Barqa area has clear evidence for Epipalaolithic, but no or very limited Neolithic occupation. With a palaeolake or palaeowetland present at the time, this locality might, as at Shubayqa, have been chosen for its wetland resources that helped provide the broad spectrum of subsistence that allowed Natufian communities to reduce their mobility. Nonetheless it is clear, while local environments clearly changed repeatedly over the time period under consideration, it appears implausible that the diversity of settlement patterns was driven by anything as simple as the availability of suitable locations.

There is no evidence of hunting pressure, although the number of sites examined remains small (Martin et al. 2016). Gazelle bones are dominant at all studied Epipalaeolithic *badia* sites, although in the Middle and Late Epipalaeolithic small game counts increase, like hare and birds and at Shubayqa 1 including waterfowl (Martin 1999; Martin et al. 2016; Yeomans et al. 2017). Cattle are rare except at the wet localities of Azraq 18, 'Ain Qasiyya, and Shubayqa, and steppe adapted equids are more common (Martin 1999; Martin et al. 2016; Yeomans et al. 2017). Plant evidence is limited, although Natufian Shubayqa shows an intensive use of wetland plants, with only limited use of cereals (Arranz-Otaegui et al. 2018), illustrating the ability of Natufian hunter-gatherers to tune their subsistence to local environments.

4.2 The PPNA and EPPNB

Known PPNA settlement is extremely rare in what today are the arid margins (Betts 1998; see also Richter 2020). Where present, sites were clearly in wetter environmental niches, such as in the Azraq oasis (Garrard et al 1996), Shubayqa 6 near Qa' Shubayqa (Richter 2020), or Wadi Faynan 16 on a wadi fed by perennial springs and downstream from a higher rainfall catchment area. Material culture at these sites is essentially typical of the range of PPNA material found elsewhere in Jordan. There is no sign of any PPNA 'arid' *badia* development – perhaps simply because PPNA people were only choosing to live in locales that were sufficiently wet to maintain the way of life within their normal range of activities.

Both Natufian and PPNA occupation appears within a fairly classic cultural pattern, and the simplest explanation for this is that there was very limited fine-tuning to the environment, rather settlements only developed where little change was required to the lifeways that were developing. If there was continued settlement of the drier regions, it might not be readily detected from the background of earlier hunter-gatherer flint scatter sites.

Intriguingly, the identification of Early PPNB sites in Jordan is mostly restricted to marginal zones in both Jilat and the edge of the Jafr (Jilat 7 (Garrard et al. 1986; Garrard et al. 1994); Harrat-Juhayra 202 (Fujii et al. 2019)) – possibly indicating the settlement of Early PPNB colonists in locations not exploited by indigenous PPNA communities and overlapping chronologically. Mushash 163 (8900/8800-8600/8500 BCE), located in the semi-arid steppe west of Azraq, is reported as having two phases, the first being PPNA, the later EPPNB, but both chronology and even the flint assemblage suggest it may be more EPPNB in character (Rokitta-Krumnow 2019). These EPPNB arid steppe sites appear to date from very early in the EPPNB, at least Harrat Juhayra 202 appears to represent a fully developed EPPN from its start date c. 9000 BCE, although Mushash 163 appears to grow more EPPNB in character over time. The final phase of WF16, which contains evidence for an indigenous Late PPNA, overlaps chronologically with this steppic EPPNB.

The site of Jebel Qattar 101 in Jubbah, Saudi Arabia (Crassard et al. 2013), is the first site in Arabia to show early PPN connections. It appears to have been a lakeside settlement, and in common with the Jordanian early PPN, suggests that colonisation was restricted to well-watered environments. Unfortunately, no structural evidence survives, and it is not clear if this is the result of erosion, or if the inhabitants of the site built no permanent structures. There are six el-Khiam and four Helwan points from the site, together with a flake-based assemblage that generally would accord with Jordanian PPNA and EPPNB dates. However, this flint scatter site also has 55 other points with tangs, mostly of Late Neolithic types. The argument that the PPN phase of the site represents a local adaptation is largely based on the absence of naviform technology, however, for the PPNA naviform technology would not be expected, and certainly in Jordan it is not always present even in the EPPNB. Continued connectivity with the Levant through the later projectile points suggests that the occupants of this site may have been migrants from the North, who maintained their connections.
In contrast to the continued importance of gazelle elsewhere in the PPNA, the fauna hunted at WF16 are massively dominated by caprines, although it is not certain what proportion are aegagrus (the wild ancestors of the domestic goat) and what are ibex (Carruthers and Dennis 2007). Kill patterns indicate some sophistication in wild herd management. Other animals are hunted, including cattle and rare boar, illustrating the wetter environment around

the site. There is a large assemblage of bird bones, many of them from birds of prey, with analysis suggesting that one purpose of the hunting was for feathers (White et al. 2021).

4.3 The Middle and Late PPNB

In the Middle PPNB an increasing difference appears to develop between sites in the *badia* and settlements to the west that become increasingly reliant on agriculture and domesticated herds. The evidence from 'Ain Ghazal indicates that gazelle ceased to be a significant resource by the MPPNB at this non-*badia* site. What gazelle are present appear not to come from its immediate environment, but the distances involved may be quite short (as little as 17 km) (Henton et al. 2018). The replacement of gazelle by managed caprine herds may simply indicate the end of hunting as a major subsistence activity, although if it is happening at increasing distance from the settlement, perhaps as gazelle were either deliberately kept away from fields or faced too much competition from the managed herds, then it would be reasonable to presume that greater processing of carcasses took place before meat was transported back to the site, explaining the lack of direct zooarchaeological evidence. An alternative is that transhumant pastoralism was developing, and that wherever hunting took place happened on the transhumant round.

One of the indications of how wet the region was in the Middle PPNB is the presence of domestic emmer, wild and domestic barley, and wild and domestic einkorn at Jilat 7 (Colledge 2001). While harvested cereals could have been imported to the site from the west, the more parsimonious explanation is that they were grown here. Preservation, and a focus on the development of (semi-)nomadic pastoralism, may have led to an over-focus on the exploitation of animals in the Neolithic, even if we know from Shubayqa how important wetland plants were to local Natufian diets (Arranz-Otaegui et al 2018), while Fujii's work in the Jafr at Wadi Abu Tulayha has stressed the value of cereal cropping in a more arid region (Fujii 2009). Calculations on the potential meat input from mass gazelle slaughter at kite sites to Neolithic diets based on daily consumption of 0.5 kg per day per adult (Rollefson 2021) do not fit our knowledge of the amount of meat eaten in traditional hunter-gatherer, farmer, or pastoralist diets, except in extreme latitudes.

This might appear to support Wasse et al.'s (2020) suggestion that a discrete *badia* development only begins to emerge in the northern limestone *badia* by the end of the Middle PPNB. In any case settlement density increases during this period (Richter 2020). Local lithic traditions began to develop separately from the Late PPNB into the Late Neolithic, suggesting to some that there was limited contact between the groups (Cropper 2011). However, it is equally clear that in general Late PPNB lithic assemblages in the *badia* were

similar to those on the plateau edge, and probably reflect a general PPNB expansion (Edwards 2016). Within this general Late PPNB cultural milieu, the nature of settlement of the arid lands appears increasingly specialised, such as Fujii's 'outpost' at Wadi Abu Tulayha, which he argues is a seasonal site located to take advantage of seasonal rains and grow a quick cereal crop – very much as an outpost activity relating to the permanent settlements on the plateau edge (Fujii 2009). Those permanent Late PPNB settlements on the plateau, often described as mega-sites, are generally understood as occupying a finger of well-watered landscapes that runs down the Jordanian plateau edge, reaching as far south as 'Ain Jammam. At Wadi Abu Tulayha there is evidence for a precocious water management system including a cistern and barrage, a system that allowed cereal cultivation to expand far beyond the limits of dry farming (Fujii 2007, 2008). A mixed economy is evident with carbonized seeds, some domestic sheep and goat bones, and numbers of hunted animals, dominated by gazelle. The material culture is typically PPNB, employing naviform technology and including Amuq and Byblos points. Further out into the Jafr the site of Ghuwayr 17 appears as a smaller version of the same, including the water-management features, illustrating the ability of PPNB people to move far into the desert. LPPNB Jilat 13 has a similar suite of cereals to Jilat 7, reinforcing the idea that dryland farming was possible in the Wadi Jilat at this time. However, it is notable that sickle elements are relatively rare in the chipped stone assemblage here (Baird 1993).

PPNB settlements in the Wadi Araba are relatively rare, but where found, as at Ghwayr 1 and in Tom Levy's Wadi Fidan project at Tel Tif'dan, they don't show any major signs of adaptation to an arid environment, but appear to be typical PPNB settlements with densely built predominantly rectilinear stone architecture, with fauna dominated by caprines (Simmons and Najjar 2006; Twiss 2008). One distinctive feature is the absence of suid*s* from southern PPNB sites, interesting as not only are wild suids relatively rare in these semi-arid environments (although wild boar were hunted at PPNA WF16), but there appears to be no introduction of any domesticated animals. Wild and domestic cattle are present in assemblages, but their numbers are low.

In contrast, Neolithic settlement around the Azraq oasis has generally been interpreted as continuing the nomadic lifeways of hunter-gatherer groups, although there is some (limited) evidence for plant cultivars and domestic sheep and goat from about 7000 BC (Garrard and Byrd 2013). Occupation of the *badia* has been interpreted as simply providing additional protein to the large populations of these sites (Bar-Yosef 2001). Interpretation of desert kites as mass-kill gazelle hunting traps that have their origins at the end of the Late PPNB provides further support to the idea of a relatively arid *badia* occupied, probably seasonally,

by people pursuing specialist roles that helped support the large settlements on the plateau edge (Abu-Azizeh and Tarawneh 2015; Helms and Betts 1987*)*. However, the lithic assemblage from settlements near the kites in Jibal Khashabiyeh is markedly different from both Late PPNB or PPNC assemblages elsewhere, suggesting this occupation may belong to a different technocomplex (Crassard and Hilbert 2019).

One southern Jordanian site that may be critical to the transition to pastoralism is the site of ‘Ayn Abu Nukhayla, located in the Wadi Rum world heritage site. This site, excavated in the 1990s by Henry, has produced some interesting but conflicting data (Henry and Beaver 2014). Henry’s current interpretation of the site is that it is largely Middle PPNB in date, and represents an early instance of sheep management, with herds being moved between ‘Ayn Abu Nukhayla and the plateau edge on a transhumant seasonal basis. The Amuq points which dominate the diagnostic elements of the flint assemblage, however, suggest that the settlement might be later, dating to the Late PPNB/PPNC. This chronology would also fit better with the introduction of sheep this far south. ‘Ayn Abu Nukhayla does provide evidence for developments in mobile pastoralism, still within the framework of a society employing the material culture of the settled communities to the west. (The retention of circular architecture appears typical of the most southern PPNB/C sites, such as Nahal Issaron (Carmi et al. 1994)). As such, ‘Ayn Abu Nukhayla may be a critical site in the development of Late Neolithic nomadic pastoralism, critical for understanding both the settlement of the Jordanian *badia* and a new wave of settlement in Arabia. In fact, the recently excavated site of Wadi Sharma 1 in Saudi Arabia has many strong parallels with Ayn Abu Nukhayla, and is clearly dated to the LPPNB with a predominance of Amuq points (Fujii et al. 2021). The fauna and any plant remains have yet to be examined, but the presence of sickle elements and grinding stones suggests cereal cultivation. Doorways are sealed, suggesting the site was only seasonally occupied. With the exception of Jebel Qattar 101 this is the furthest south manifestation of the PPNB, and the site’s Late PPNB date confirms that this is the start of expansion into this more arid zone, not yet representing fully nomadic pastoralists, but another form of seasonal migration.

Wadi Sharma 1 has a very limited lithic repertoire and no naviform cores, although some blades may have been produced by naviform technology and imported. To the East there is a small cluster of PPNB sites with naviform technology at Dumat al-Jandal in the al-Jawf province - at a similar latitude to ‘Ayn Abu Nukhayla although far removed from the main concentration of Jordanian sites (Cressard and Hilbert 2019). However, the naviform technology is not standard, but appears to have local adaptations, raising questions over its relationship with the Levantine PPNB.

4.4 PPNC and Early Late Neolithic (ELN)

In the arid margins/current steppes and deserts the PPNC (often called the Early Late Neolithic (ELN) in the eastern *badia*) is mostly known from Wadi Jilat 13 and 25 although the limited radiometric dating evidence that gives a broad range of 6900-6300 BCE includes both the PPNC as well as start of Pottery or Late Neolithic (Garrard et al. 1994).

By the PPNC there is a shift in settlement patterns across Jordan. Unfortunately, many of the Late PPNB 'mega-sites' are poorly known and poorly published, but it appears from 'Ain Ghazal, that their permanent populations may decline after the LPPNB and there may be an increase in seasonal mobility (Rollefson and Köhler-Rollefson 1989). This has been interpreted as the consequence of overexploitation of the land around the mega-sites, leading to developments in mobile pastoralism, and a decreased tethering of pastoralists from the major settlements (Rollefson 2011; Rowan et al 2020). This interpretation is not uniformly accepted, and it is notable that western sites such as Beisamoun and Motza may reach their peak in the PPNC. However, it is clear that occupation does continue into the Late Neolithic at both 'Ain Ghazal and Basta, although at a reduced scale (Gebel et al. 2006). The presence of massive anthropogenic rubble deposits at several sites implies considerable human activity. The PPNC appears to be a southern Levantine reflection of a wider set of changes to the Late Neolithic, in the northern Levant generally associated with the adoption of ceramics.

This period is when apparently herded sheep and goat herding in the *badia* first appear, as seen at Jilat 13 and 25 (Martin 1999: 94-5; Miller at al. 2018) (Fig. 4). The change in settlement pattern to the west has been argued to be part of the same innovation, with a large part of the population at sites such as 'Ain Ghazal becoming transhumant herders (Rollefson 2021). The possibility has been raised that these transhumant herders may have made it as far as the Eastern Desert. An alternative hypothesis is that herding was adopted by indigenous hunters, who rather than become transhumant, moved directly to fully mobile pastoralism (Miller et al. 2018). The evidence used, combining the animal remains, stable isotopes and chipped stone, suggests a complex pattern, where the inhabitants of Jilat 13 may be indigenous mobile pastoralists, while those at close-by Jilat 25 are more likely to be part of a tethered, transhumant pastoralist network (Miller et al. 2018).

Martin (1999: 94) also notes that the *badia* sites continue to have considerable numbers of wild animals represented in their fauna (Martin 1999: Table 4, based on MNE counts 6-30% gazelle and 24-35% hare) – suggesting there is no grazing pressure from herded caprines,

which would also suggest people simply did not have any/many caprines with them. Martin argues for continuity in faunal assemblages from the PPNB to the Late Neolithic with caprines just added to the mix, suggesting an adoption of caprines by existing populations, rather than the arrival of new herding people. She also notes that different kill patterns in the steppe suggest a distinct local herding system. Martin's analysis of *badia* faunal assemblages does not suggest the development of nomadic pastoralism in the PPNC/ELN, but she also argues for strong local continuity. Martin argues that given it is clear wild animals remained a good source of meat in steppe, caprines were most likely adopted as part of a social process. In turn, they (especially sheep) have different requirements in terms of water and pasture, therefore may have in themselves created new mobility patterns.

In the Jafr, the abandonment of water management systems may reflect a drying environment, but may also illustrate a change in adaptation to the area, no longer based on agro-pastoralist economies of the PPNB, but on an increasingly nomadic pastoralism (Fujii 2013).

Rollefson et al. (1992), and Martin and Edwards (*2013*), have argued that nomadic or transhumant pastoralism may have emerged in the *badia* in the ELN, contemporaneous with the PPNC, or perhaps the very end of the Late PPNB. Rollefson's initial argument was based on evidence from 'Ain Ghazal that part of the population became seasonally nomadic. The same evidence has been used to support the idea that the burin Neolithic was associated with pastoralism, with a suggestion that the burin spalls were used to make combs for collecting wool from moulting sheep within a single settlement system in the Late PPNB and PPNC/Early Late Neolithic. Mixed sheep and goat herds, as well as secondary products would have been essential for the development of pastoralism and a tethered pastoralist system connecting the steppe and desert with the western settlement (Quintero et al. 2004; Wasse et al. 2020). However, as noted by Makarewicz (2014) and Martin (1999), there is no faunal or isotopic evidence for pastoralism based on secondary products, nor for a mobile system linking the desert and the plateau edge. Furthermore, there is good evidence that whenever the burin spalls are found, they show signs of use as drills, both microscopically and macroscopically, and by association with bead manufacture waste (e.g. Finlayson and Betts 1990; Baird in Garrard et al. 1994). The burins begin to appear in Middle PPNB contexts, suggesting that they are not a marker of sheep pastoralism (Baird 1993).

As noted above, recent excavations in the south-eastern *badia* have confirmed a hunting function for the kites, and have produced dates from the very end of the PPNB and start of the ELN (Abu-Azizeh et al. 2021), indicating a highly specialised hunting economy.

4.5 Late Neolithic (c. 6500-5000 BCE)

The first Late Neolithic developments in the *badia* predate the so-called 8.2 ka event (Flohr et al. 2016, Rowan et al. 2020), suggesting that they are not a response to climate change, although these developments could have been reinforced by adaption to increased aridity. There are other changes in climate, but the data is not very clear, and at present connecting the uncertain impacts of climate change with our limited archaeological knowledge remains difficult.

A considerable amount of research has taken place on the Late Neolithic in the *badia*, especially in the Eastern Desert and around Azraq and Jilat (e.g., Betts et al. 2013; Rollefson 2011, 2021; Rollefson et al. 2014; Rowan et al. 2017). Late Neolithic sites appear abundant in all types of *badia* regions: the (current) steppe, oases, (seasonal) lakes, and more clearly than before in areas with lower rainfall, although still with water resources such as at Wisad Pools, Wadi Araba and south-eastern Jordan (see also the map in Flohr 2022). Not only do there appear to be more (or more visible) sites in more areas, they are also more diverse and include temporary camps such as Jebel Naja, and Jilat 13, longer-lived sites such as Wadi Qataffi and Wisad Pools, and funerary sites with cairns in SE Jordan (Rowan et al. 2020), and kites may continue into this period, although they have not yet been directly dated (Akkermans et al. 2014). Late Neolithic Dhuweila continues to be dominated by gazelle hunting (at 90% of the faunal remains) and still only a very low caprine presence (Martin 1999). In other places, caprines form a more substantial part of the assemblage, like at Burqu 27 (38%) and Jebel Naja (50%); but with continued hunting (gazelle 10% and 25% respectively, hare 16% and 25%) (Martin 1999: 94, Table 4). It is possible that hunting is now assisted by domestic dogs. Dog as aids to hunting have been attested from the PPNA onwards in the *badia* (Yeomans et al. 2019) and domesticated dogs have been found at Late Neolithic Wisad pools (Rollefson et al. 2014).

It has been proposed that by the Late Neolithic a difference has developed between the western *badia*, where gazelle have become less numerous due to domesticate grazing pressure, than in the eastern *badia* where they remain abundant (Henton et al. 2018). This would provide further support for Rollefson et al.'s suggestion that pastoralism had become a major activity in the *badia* by the Late Neolithic (Rollefson et al. 2014). In this scenario, kites are therefore a 'response' to increased pastoralism, although Abu-Azizeh et al.'s (2021) new excavation results suggest that kites may emerge before this, at the end of the LPPNB/ELN.

A further argument to explain continued hunting of gazelle, is that this was a response to dairying, where caprine herds are increasingly kept 'live'. Meat is provided by hunting gazelle, who are separated from herding lands by the kite systems. Keeping caprine herds 'live' is used to explain why caprine bones are rare from faunal assemblages left by people who are assumed to have been at least semi-nomadic herders: the herds were not being culled (Henton et al. 2018; see also Martin 1999). However, evidence for dairying in the Late PPNB and ELN remains limited, with no zooarchaeological evidence for dairying as kill patterns of caprines in the *badia* suggest they are kept for meat and not being culled to enhance dairy production (Martin 1999). Martin argues that Late Neolithic assemblages suggest that caprines are just hunted in the same way as gazelle – no specialisation, nor different treatment between caprines and gazelle. She also notes that the kill-off of prime animals at *badia* sites does not support the idea that herds were fattened in the *badia* before return to the plateau edge for eating. Evidence from the *badia* is that very few caprines were being killed for any reason. Either all culling took place to the west, or in a possibility rarely mentioned, caprines were still rare in the *badia*, a difficulty for arguments that fully untethered pastoralism had developed by the Late Neolithic.

It has been suggested that cattle pastoralism may have been introduced to Arabia from the Jordanian *badia*, however, as described above, it appears that early pastoralism in the *badia* was based on caprine herding making the *badia* an unlikely source (Makarewicz 2020). Cattle, including wild aurochsen, require open water to drink, and this might have been available in wetter early Holocene Arabia. However, there is no clear evidence for wild aurochsen, making local domestication unlikely (Makarewicz 2020). The best examples of cattle on rock art appear to have horn shapes that suggest they are domesticated (Guagnin et al. 2015). Cattle may have been introduced along the Gulf from southern Mesopotamia. However, evidence appears to be mounting that domesticated cattle were present at Late PPNB settlements in the South of Jordan, including at Basta (Becker 2002), and at Tel Tif'Dan in the Wadi Araba (Makarewicz 2020; Twiss 2008). It is possible that rather than via the northern *badia* and the Wadi Sirhan, cattle may have reached Arabia either through the Late PPNB in the Jafr Basin, or down the Wadi Araba (Makarewicz 2020). This appears to match emerging evidence of PPNB connections.

The Jafr sequence has been interpreted to indicate that the isolated cemetery and ritual sites of the Late Neolithic may indicate early nomadic pastoralism, but fully nomadic pastoralism may not appear until the EBA when it is visible in the large-scale cairn fields that appear without associated settlements (Fujii 2013).

5. Development in the margins

After an initial phase of Neolithic exploitation of the savannah lands during the PPNA that appears to have been limited and restricted to locations where there was no need for any significant adaptation to a different environment, adaptation in the PPNB appears to commence. Where dryland farming could be achieved, as in Jilat, it was. Where some additional water-management allowed for farming at least of a seasonal nature, as in the Jafr margins, that was also implemented. More marked local adaptations appear in the later course of the Neolithic, and the changing nature of Neolithic settlement patterns and landscape occupation continues from the PPNC into subsequent Late Neolithic phases. Several dramatic developments appear to occur at around the same time.

The first is the establishment of so-called desert kites. These, most plausibly interpreted as hunting traps for mass killing of migrating gazelle, are known from an extensive system that runs predominately north-south down desert margins of the *badia*. Very few have received even exploratory excavation, but so far what is known suggests a date around the end of the PPN, and confirms their role in gazelle hunting (Abu-Azizeh et al. 2021). It appears that they continued to be used over time, and it is not clear if the appearance of a system of kites emerged rapidly, or consists of a long development of addition. It is conceivable that their construction follows a shift in gazelle migratory patterns, following increasing pressure on grazing lands to the west, but equally plausible that it represents a new exploitation of migratory gazelle once their less mobile western populations were reduced. Suggestions have been made that they were constructed to provide protein for settled communities to the west or to feed a herder population who kept their sheep and goats alive while in the east (Bar-Yosef 2001; Henton et al. 2018). Both suggestions are problematic, partly as they both reflect an assumed relationship between pastoralist and farmer, where the *badia* serves to provide food to the settled population. The distances some kites are from the settled world also make provisioning implausible. Further, if the kites appear after the major settlements are abandoned or reduced in size, who would they provision? Equally, it appears unlikely that a population of nomadic pastoralists would have either required meat on this scale, nor been unable to obtain protein from their own herds through both diary and culling practices.

The second development is the emergence of an entirely new form of Neolithic settlement. Known from locations such as Wisad Pools and the ‘Mesas’ these comprise Late Neolithic structures including enclosures and structures. Markedly different from the preceding LPPNB densely built settlements, these spread out over extensive areas of land. Although frequently discussed in the context of arid lands, a growing body of evidence suggests that

when occupied their environment supported a fertile topsoil and woodland (Rowan et al. 2020). Settlement patterns hint that this environment may have been more extensive than what could be described as oasis settlement. However, interpretation still leans towards one of seasonal pastoralism, taking advantage of seasonal bounty. Notably the Late Neolithic here is still described as “The Black Desert Neolithic” (Rowan et al. 2020), perhaps unintentionally emphasising its relationship to arid margins. Faunal assemblages that are dominated by wild taxa, and flint assemblages characterised by arrowheads, have both been used to argue that these herders were depending substantially on wild resources, and reserving the domestic herds they are assumed to have kept, for exchange with western settled populations (again, problematically if the mega-sites are now abandoned). In contrast, if these sites can be related to processes where the tethers to western settlements are finally broken, it is interesting that such a marked change in architecture and settlement organisation appears. Does this reflect a major social change, triggered by new relationships to the landscape? If so, is this similar to other Late Neolithic landscape changes – where farmers appear to live closer to their fields – as argued in both Dhra’ and the Wadi Ziqlab (Banning et al. 2013; Kuijt et al. 2007)? Without the ritual and social constraints holding the densely occupied mega-sites together, were people able to reduce social stress by reducing their demographic density, at the same time as living more closely to their subsistence resources? For the Late Neolithic pastoralists did this represent a pastoralist escape from settled constraints?

A third development is the apparent growth of specialist industrial sites on the *badia* edge. This so-called ‘burin’ Neolithic – associated with the presence of large numbers of burins, burin spalls, and sometimes bead manufacture, has been seen as another activity developed by mobile pastoralists to produce commodities for exchange with settled populations. Indeed, either of the main interpretations of the burin Neolithic – that the burins are used for combing wool, or that the spalls are used as drill bits, would have the same role in producing commodities. In that sense they possibly serve as a precursor of Chalcolithic flint mining activity and Bronze Age wool trade. If this is the beginning of extensive patterns of trade, perhaps it would become easier to accept the idea of quantities of dried meat being moved within a ‘global’ exchange system.

6. Conclusion - the diverse desert

It is perhaps important to note that amongst the reasons that researchers have been drawn to these areas is that the absence of substantial development in the last few thousand years has created landscapes of survival (cf Akkermans 2020), as well as the romantic pull of the

desert landscapes (e.g. Bell 1907). Neither may be relevant to Neolithic occupation of course, as both relate to the contemporary environment.

The historical context of human occupation of the *badia* appears to start with societies who take advantage of periods of increased moisture, and who largely maintain the societies and subsistence systems of populations in areas of greater rainfall to the west. Such adaptations, such as the use of tubers at Natufian Shubyqa, are fine-tuning of contemporary Natufian lifeways (and in this case fine-tuning to a wetland environment, not a desert). PPNA lifeways seem to have followed a similar route, with locations such as WF16 taking advantage of local water availability. It may not be until the PPNB, and probably not until the Late PPNB, that adaptation of emerging Neolithic economies to an arid landscape can begin to be seen, most notably in the outposts identified by Fujii in the Jafr, with their barrages and cisterns. By the end of the LPPNB and into the Early Late Neolithic, this process appears to extend with the appearance of the extensive system of kites and mass hunting of gazelle. By the Late Neolithic this specialised hunting adaptation is joined, or perhaps replaced if the kites are no longer used, by a transhumant system seen in the extensive settlements of the Eastern Desert.

Work over the past decade/s, especially at Wisad Pools and Wadi Qataffi, has illustrated an expansion of population and settlement in the Late Neolithic. Rowan et al. (2020) outline possibilities for Late Neolithic settlement of the Eastern Desert as being a single community of *badia* adapted hunter-herders, or separate communities of migrant pastoralists coming from the west meeting indigenous 'hunter-forager-herders' coming from well-watered eastern niches. These possibilities encapsulate a wider range of issues that both go back in time and require an improved understanding of the wider geographical context.

All of this unprecedented activity suggests a complete re-adjustment of human-landscape interaction. There is at present no reason to assume a dramatic improvement in the environment that allowed this to happen at this time, indeed the Late Neolithic is more associated with a phase of drying and the 8.2 k event. Equally, if the environment was so productive, why did the nature of settlement construction change so much – to these new and relatively dispersed sites? Our knowledge of the precise effects and chronology of climate change makes correlation between human behaviour and environment difficult (Contreras and Makarewicz 2016; Flohr et al. 2016; Makarewicz and Tuross 2012; Stein 2014; Torfstein et al. 2013; Richter et al. 2017*).* It is vital to understand the environment through time if we wish to understand when a new technology is required to exploit new landscapes, or when increased rainfall, or a raised water table, may permit an extension of

existing technologies to new areas, and equally necessary to understand why reduced rainfall may not have the catastrophic impact that might be expected.

Even in the Late Neolithic, the evidence for the development of mobile pastoralism is still largely circumstantial - if the *badia* west of the Black Desert was greener, why develop pastoralism rather than extend the nascent PPNB mixed farming system at locales such as Wadi Qataffi? How good is our evidence that these people depended on pastoralism, in the absence of significant caprine domestic faunal remains, is the argument for pastoralism based largely on the presence of possible animal enclosures at the sites? The animal management systems that developed into pastoralism arose as part of the process of domestication occurring around increasingly settled sites - perhaps best illustrated by the transhumant practises of the PPNB (Makarewicz 2017), which are presumably the foundation of more distant movements. It seems implausible that these management systems, built up over many generations and incorporating skills, the establishment of social territories, and ownership of domesticated species, could be easily picked up by desert hunter-gatherers and translated into a sophisticated mobile pastoralist system. Equally, the new systems of kites, possibly relating to new gazelle behaviours, and perhaps only relevant within a system of exchange that included large populations to create demand, appear unlikely to have appeared from nothing. The people who begin to experiment with new ways of exploiting the *badia* are those in the Jafr outposts, coincidentally the same people who start to build long low wall systems to create their barrages to guide water.

To understand these changes, our concern is not solely with the Eastern Desert, but with all of the *badia* lands. This includes the semi-arid areas most likely affected by climate change. The *badia* is not the same everywhere but a ‘diverse desert’, with different environments, different uses, and different communities. The human presence has not been dependent on favourable climate change, people have been present in *badia* at least from the Epipalaeolithic during times of increasing aridity *(*Maher et al. 2011*).* Emergent evidence, perhaps best seen from the Jilat assemblages, suggests that different communities are present, some possibly still tethered to more settled communities to the west, others perhaps becoming less tethered - but still linked to sites with agricultural potential.

We still need to improve our understanding of the impacts of both climate change and increased grazing. We also need to improve our understanding of the relationship between these populations and those who inhabit lands suitable for dry farming. In particular, does the *badia* simply become a resource for settled communities - providing resources such as protein, flint, and increasingly importantly, wool, with much of its occupation restricted to

seasonal expeditions and migrations? Alternatively, is this when increasingly mobile pastoralism first becomes an independent lifestyle, no longer tethered to the settled communities? These are vital issues for our understanding of the development of early urbanism, where control over wool appears to have played a major role in the development of trade and wealth. Finally, and often assumed to be part of the development of mobile pastoralism, it appears that there is a new wave of outward migration – in particular into the Arabian peninsula. Similar questions apply regarding how and why this jumps off, how much its early phase may relate to the increased water availability in this area.

Unfortunately, our contextual knowledge of this period in the 'core' region is relatively poor. Evidence from a number of the mega-sites suggests that occupation continued, although in an altered and probably reduced form. The substantial layers of rubble that appear in some cases appear to be largely anthropogenic, indicating continued activity. Other sites appear to become more diffuse than preceding PPN activity, such as the Late Neolithic occupation at Dhra'. There are, as again visible at Dhra', indications of an increasingly managed landscape (Kuijt et al. 2007) – and while there are lacunae in our knowledge, it does appear that while settlement patterns change, people don't vanish. The focus on large-scale settlement in the PPNB, and even the initial interest on whether this was an early expression of urbanism, has drawn attention away from indications that Late Neolithic settlement patterns may have been more scattered, but quite possibly more consistently present throughout the landscape than ever before, just harder to find (Banning et al. 2013). In some ways, the Late Neolithic settlement systems, more dispersed, more closely located adjacent to resources - be those fields or pastures, may be as much a social reaction to the controls required to maintain the densely populated intensive settlements of the Late PPNB. People chose increasingly mobile pastoralist lives not because they had to, but as a choice

One explanation of this is that the transition to the Late Neolithic involves many of the major changes in human-environment relations often assumed to occur earlier in the process. Locally appropriate methods for exploiting the environment start to come of age, with mixed farming, tethered pastoralism, and nomadic pastoralism (potentially including seasonal crop growing) all representing viable ways of life. Neolithic exploitation of the *badia* sets the ground for subsequent use, the presence of mobile pastoralists and people using water management techniques to live in fortified settlements farming and herding (Betts and Tarawneh 2010; Müller-Neuhof 2017). It is possible that the kites, at least in Jordan, go out of use as there is no evidence connecting them to Chalcolithic or Bronze Age use (Betts and Burke 2022). Connections between these diverse systems doubtless helped promote

regional networks, trade, and an increasingly intensive use of the landscape for other resources, such as tabular flint, or indeed copper mining in Wadi Faynan.

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Figure Captions

Fig. 1: Map of Jordan and surroundings with current mean annual precipitation gradients (in mm) and locations of main sites and areas mentioned in the text. The *badia* is the <200 mm red-yellow zone. Precipitation from WorldClim 2 (Fick and Hijmans 2017).

Fig. 2: Shaumeri Nature Reserve, near Azraq, showing the contrast between vegetation present inside the fence (a) and land outside under grazing pressure (b), in June 2017.

Fig. 3: Barley growing in the Qa' Shubayqa, June 2017.

Fig. 4: Summed probability plots showing 14C-dated Neolithic sites in the Jordanian Eastern Desert and the presence or absence of sheep and goat (i.e. pastoralism) at these sites (after Flohr et al. 2016: Fig. 7; Martin in Garrard et al. 1994; Martin in Betts 1998; Martin 1999; Rollefson et al. 1999; Betts et al. 2013; Rollefson et al. 2014). Dark blue lines show sites without evidence of sheep/goat pastoralism, yellow lines

indicate sites that do have evidence.

Figures

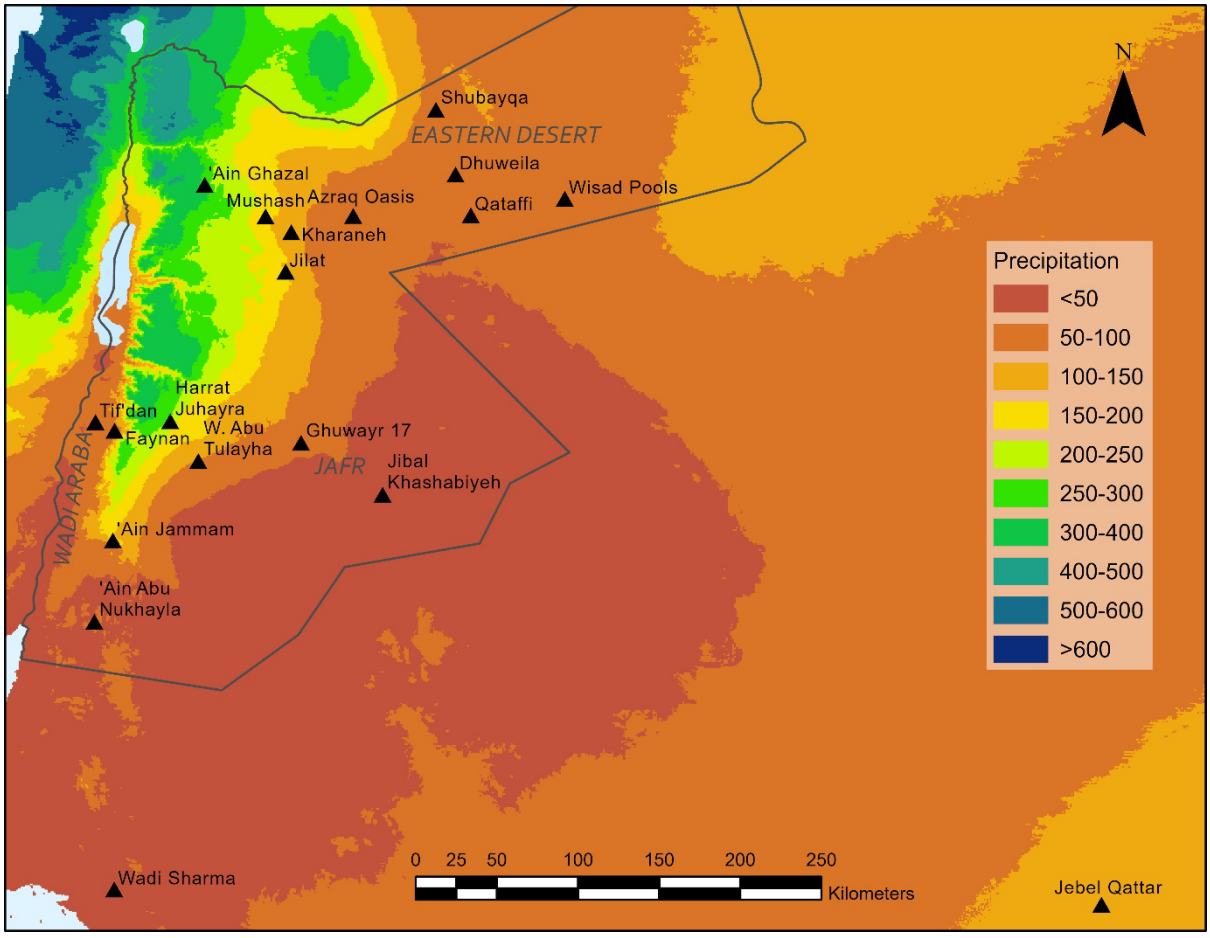

Figure 1: Map of Jordan and surroundings with current mean annual precipitation gradients (in mm) and locations of main sites and areas mentioned in the text. The badia is the <200 mm red-yellow zone. Precipitation from WorldClim 2 (Fick and Hijmans 2017).

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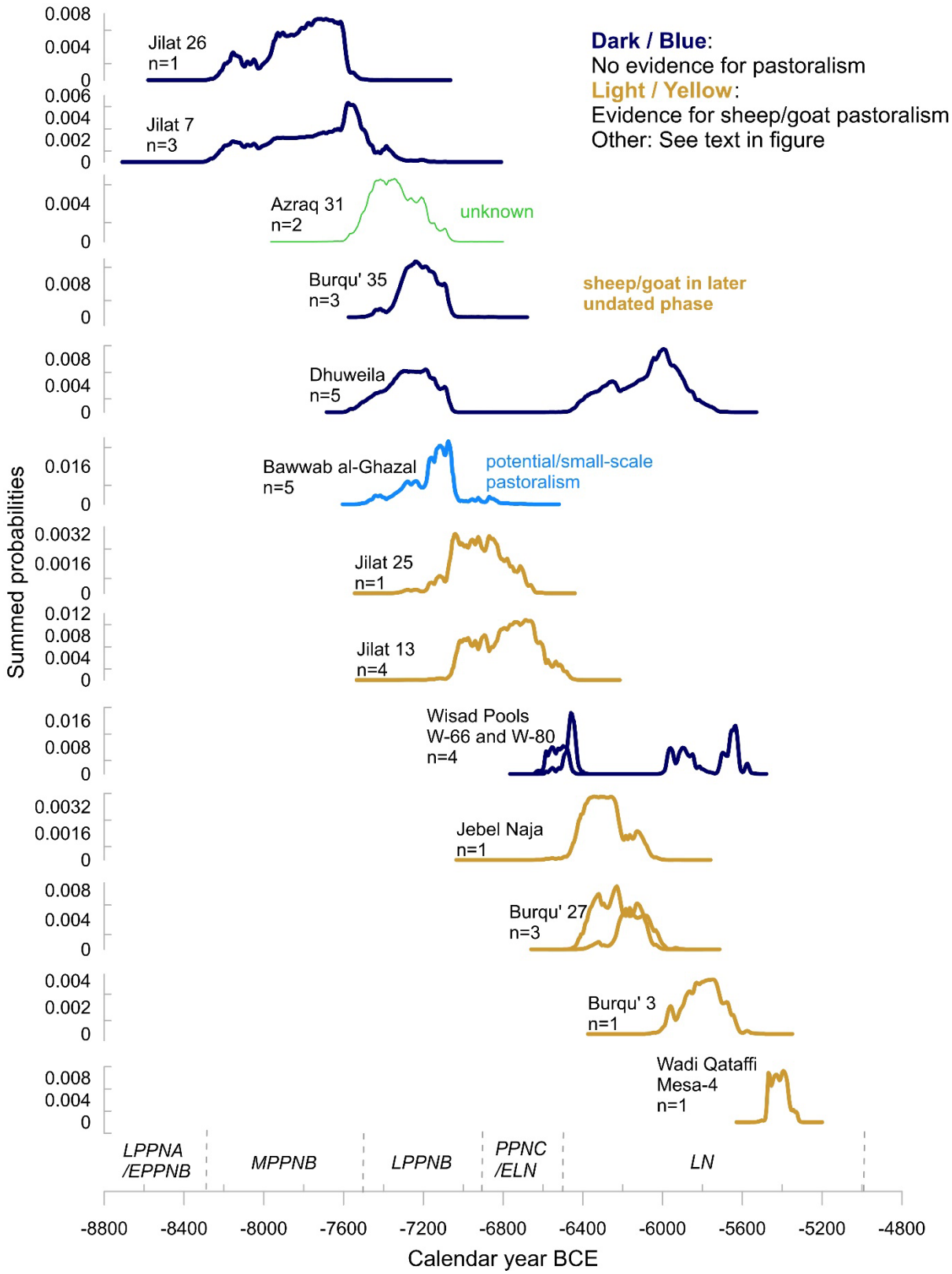

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