The Holocene Humid Period in the Nefud Desert: Hunters and Herders in the Jebel Oraf Palaeolake Basin, Saudi Arabia

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Abstract

Archaeological surveys and excavations in the Jebel Oraf palaeolake basin, north-western Saudi Arabia, have identified a well-preserved early- to mid-Holocene landscape. Two types of occupation site can be distinguished: nine small and ephemeral scatters from single occupation phases on the slopes of sand dunes and three hearth sites indicative of repeated occupation on palaeolake shorelines. In addition, 245 rock art panels, 81 cairns, and 15 stone structures were recorded. This diverse dataset provides an opportunity to reconstruct occupation patterns and changes in landscape use. A particularly important site, Jebel Oraf 2, documents two episodes of lake high stands at ca. 6500 BC and 5300 BC, flooding parts of the locality. Neolithic pastoralists likely occupied the site after the end of the wet season, when the terrain was dry. Earlier sites are located in dune embayments some 7 to 14 metres above the shore of the palaeolake. These locations are consistent with hunting strategies identifiable in the rock art that suggest wildlife was ambushed at watering places. Later rock art at Jebel Oraf also documents the hunting of wild camel in the Iron Age. The lithic industries documented in the Jebel Oraf basin support arguments of repeated contact with Levantine populations.

Key words

Neolithic; pastoralism; palaeolake; rock art; landscape; Saudi Arabia

Highlights

- Well preserved Neolithic landscape in the Nefud Desert of northern Saudi Arabia
- Evidence for changes in landscape use across the transition to herding
- Two lake high stands show seasonal use of the area by early pastoralists
- Rock art documents the presence of wild camel in the Iron Age
- Lithic industry indicative of contacts with the Levant over several millennia

Introduction

The early- to mid-Holocene wet phase in Arabia (ca 8000-4000 BC) corresponds with important cultural developments, including the expansion of Neolithic populations and the transition from hunting and gathering to herding and pastoralism (Magee, 2014; Petraglia et al., 2020). Archaeological sites along the Arabian Gulf coast indicate that domesticated cattle, sheep and goat may have been introduced from the Levant by the end of the sixth millennium BC (Crassard and Drechsler, 2013; Drechsler, 2007). However, on the basis of technological and typological similarities with lithic assemblages in the southern Levant, an initial dispersal of the Neolithic into Arabia between 6800 and 6200 BC has been considered (Drechsler, 2007; Drechsler, 2009). Indeed, lithic assemblages with similarities to Levantine industries have been found at a number of sites in the Jubbah oasis of northern Arabia (Crassard et al., 2013; Hilbert et al., 2014), but it is not yet clear if this represents the movement of ideas or people across the region. At the Epipalaeolithic site of Al-Rabyah, also at Jubbah, a lithic assemblage with similarities to the Geometric Kebaran is dated to ca. 8000 BC, several millennia younger than comparable Levantine industries (Hilbert et al., 2014). At the nearby site of Jebel Qattar 101, lithics are associated with a palaeolake dated 8000-6000 BC (Crassard et al., 2013). Here, El-Khiam and Helwan points provide links with the Pre-Pottery Neolithic A and B in the Levant, where they occur between ca. 10,500-8500 BC and 9500-8000 BC respectively, (Crassard et al., 2013; Crassard and Drechsler, 2013). In the Al Jawf region to the north of the Nefud, surface finds of naviform blade cores indicate links between northern Arabia and the Levantine PPNB (Crassard and Hilbert, 2019). The dynamics underpinning the spread of the Neolithic and in particular the question of whether the use of domesticated livestock spread together with Levantine stone tool technology remains unresolved. Moreover, the transition to herding is heterogenous in the Levant and the nature and extent of contact between prehistoric populations in northern Saudi Arabia and the Levant remains little understood.

As uncertainties increase considerably with distance from the Levant, even the terminology used to characterise Arabian sites and technologies becomes contentious. In the Levant, the Neolithic is characterised by a progression of behaviour and cultural changes that included sedentism, agriculture and herding, ground stone tools, and pottery. On the other hand, populations living on the Arabian Peninsula during the Early and Middle Holocene lack many of these cultural characteristics, and it appears that crop cultivation, sedentism and pottery did not take hold until the Bronze Age (Magee, 2014). In the absence of many characteristics that are typically used to define the Neolithic, the presence of domesticated livestock, and the considerable impact the transition to a food-producing economy would have had on society is therefore often used to define the herders of sixth millennium BC as Neolithic (Crassard and Drechsler, 2013). Following this line of argument, we use the term ‘Neolithic’ for the period following the introduction of pastoralism and ‘Pre-Neolithic’ to describe the period before the adoption of food production (Fedele, 2008). Due to the likely time lag in the adoption of herding from the Levant to northern Saudi Arabia, the ‘Pre-Neolithic’ may be at least partly contemporary with the Pre-Pottery Neolithic periods in the Levant.

At the UNESCO World Heritage sites of Jubbah and Shuwaymis, both in northern Saudi Arabia, the introduction of domestic livestock is visible in the rock art. Herding scenes with up to 20 cattle are frequently superimposed on a body of earlier rock art that exclusively shows hunting scenes (Guagnin et al., 2015). Figures of hunters were often re-engraved in this process and turned into herders. Human figures across both periods are depicted in the so-called ‘Jubbah style’, with very thin, elongated bodies, stylised heads, angular shoulders, and very thin arms held out to one side in a twist of perspective from the frontal view of the shoulders to a profile view of arms and legs. The figures are regularly shown wearing headdresses and penis sheaths. A shared cultural understanding of how a human figure is to be depicted, and a tradition of wearing headdresses and penis sheaths therefore appears to have existed across the transition to herding (Guagnin et al., 2015; Guagnin, 2018). This continuity suggests local hunters adopted herding. Hunting scenes continue to be depicted in the rock art of the Bronze and Iron Age, and hunting likely remained an important source of protein until the recent past (Guagnin et al., 2017a).

Only two sites from the Nefud Desert have thus far provided faunal remains dating to the Early or Middle Holocene. Recent excavations of two small hearths at Jebel Oraf 2 (ORF2), in the oasis of Jubbah, yielded fragmentary remains of cattle dated to around 5200 BC (Guagnin et al., 2017b). In the western Nefud Desert, remains of a caprine were found associated with hearths dated to between 5300 and 4200 BC at the site of Alshabah (Scerri et al., 2018). These remains currently represent the earliest evidence for pastoralism in the Nefud Desert, and indeed across much of northern Saudi Arabia, with the exception of the PPNB site of Wadi Sharma, close to the border with southern Jordan, which appears to form part of the Levantine Neolithic (Fujii, 2013). Considering their relatively young age, the faunal remains at ORF2 and Alshabah likely represent well-established pastoral populations in northern Saudi Arabia, though the transition to herding cannot yet be determined.

New interdisciplinary archaeological surveys and excavations have recently been conducted at Jebel Oraf (Figure 1), allowing us to trace changes in landscape use across the climatic changes of the early and middle Holocene, and likely across the transition to herding. Here we present data from rock art, stone structures, occupation sites, lithic scatters, and palaeolake deposits, which can be linked to the dated stratigraphic sequences of two Neolithic sites. This diverse data set allows the first reconstruction of a Neolithic landscape in the Nefud Desert of northern Arabia.

In turn, changes in landscape use can provide evidence for changing subsistence patterns and help to identify some of the dynamics that underpinned the Neolithic transition in northern Arabia.

Figure 1 Satellite image showing the western Nefud Desert and the location of known Epipalaeolithic, Neolithic and Chalcolithic sites in the Jubbah oasis.

Background

Archaeology

In the southern Levant, evidence from Ayn Abu Nukhayla and Wadi Abu Tulayha suggests that Neolithic groups began herding sheep and goats as early as 7500 BC (Fujii, 2006; Henry et al., 2017). Faunal analyses also show that in the Jordan Valley and Jordan Highlands sheep and goat herding was practised by the Middle Pre-Pottery Neolithic B (PPNB, 8100-7500 BC)(Martin and Edwards, 2013). At 'Ain Ghazal, domestic goats were present from around 8500 BC. Sheep were introduced in small numbers before 7500 BC, their numbers subsequently increased rapidly, culminating in the emergence of a specialised pastoral economy by the early 7th millennium BC (Wasse, 2002). On the other hand, the marginal steppe areas in the Jordanian Badia were mostly populated by hunter-gatherers during the PPNB. Here, domesticated sheep and goats formed part of a pastoral component that was integrated into the existing hunter-gatherer lifestyle during the PPNC (6600-6250 BC) and helped local hunter-gatherer populations to extend their exploitation of the marginal environment of the Badia. Differences in tool kits and structural remains imply that a number of different subsistence strategies were in use, which helped maximize the exploitation of the Badia (Betts et al., 2013; Martin and Edwards, 2013). Following a period of extensive occupation of the Jordanian Badia in the Late Neolithic (6250-5300 BC), there was a drastic reduction in the number of sites in the Bronze Age, although Betts and colleagues (2013) suggest that this may partly be the result of a lack of characteristic artefacts.

In contrast to the heterogenous and comparatively well studied record in Jordan, research on the Neolithic period of northern Saudi Arabia is still very much at an early stage. Large-scale documentation of stone structures such as kites, clustered enclosures, gates and cairns using satellite imagery have recently identified distribution patterns across Arabia and the Levant. While kites, cairns, pendants and keyhole tombs show some regional variation, they are found in both the southern Levant and on the Arabian Peninsula (Barge et al., 2015; Kennedy, 2017; Kennedy et al., 2015), suggesting some level of contact across considerable distances. Although dating of these structures is difficult, the construction of kites appears to have begun in the Neolithic (Crassard et al., 2015; al Khasawneh et al., 2019; Rollefson et al., 2016). Gates (sometimes also known as Mustatil or stone platforms) are large rectangular stone structures of unknown purpose, that are currently only known from the Khaybar and western Nefud area of Saudi Arabia. The superimpositions of different types of stone structures suggest that 'gates', are amongst the oldest man-made stone structures in the landscape (Kennedy, 2017) with a possible temporal overlap with kites (Parr et al., 1978). In fact, a first radiocarbon date obtained from a gate structure appears to place its construction to around 5000 BC (Petraglia et al., 2020). It is thus possible that gates are associated with the early herders of northern Saudi Arabia, and their spatial overlap with rock art of the so-called 'Jubbah style' indicates that both may have been linked to the same tradition.

In the Jubbah oasis, on the southern edge of the Nefud Desert in north-western Saudi Arabia, a number of early and middle Holocene sites have been identified. The Al-Rabyah (Figure 1) lithic assemblage with its bladelets, geometric microliths, and a stone disc shows similarities to the Geometric Kebaran industries of the Levant, but optically stimulated luminescence (OSL) dating of associated sediments indicates a date of 8000 BC (Hilbert et al., 2014), several millennia younger than comparable Levantine industries. The Geometric Kebaran is perhaps the most widespread of the Levantine Epipalaeolithic industries (Bar-Yosef, 2017; Macdonald et al., 2016), with a focus on reliable wetland resources in its more peripheral manifestations (Ramsey et al., 2016). The geographically and temporally remote site of Al-Rabyah is perhaps an extreme example of this pattern.

El-Khiam and Helwan points from Jebel Qattar 101 provide links with the Pre-Pottery Neolithic A and B in the Levant (Crassard et al., 2013). Palaeolake deposits next to the site were dated to between 7000 and 6000 BC (Crassard et al., 2013). Jebel Qattar 101 is the most isolated site with PPN lithics currently known, and appears to conform to a pattern of geographical and temporal peripherality for the Jubbah Oasis in relation to a Levantine core zone. No faunal remains were recovered from Jebel Qattar 101, but the high density of arrowheads suggests a focus on hunting.

Surveys in the 1970s recorded 12 possible Neolithic or Chalcolithic sites in the main basin of the Jubbah oasis (Figure 1). These contained a range of stone tools including tanged arrowheads, blades, and hoes (Garrard et al., 1981; Parr et al., 1978). Recent fieldwork by the Palaeodeserts Project also identified numerous cairns (Jennings et al., 2013; Guagnin et al., 2017a), two of which were radiocarbon dated to the Neolithic and Bronze Age respectively (Guagnin et al., 2017a). Surveys and excavations in the Jebel Oraf palaeolake basin now substantially extend the archaeological record of the Jubbah oasis, and allow a first analysis of rock art, occupation sites and stone structures within the context of a Neolithic landscape.

Environment

Today, the Nefud is a hyper-arid desert, experiencing ~ 30-90mm of rainfall per year (Edgell, 2006). The area is characterised by the Nefud Sand Sea - the largest single area of sand dunes in northern Arabia, at around ~58,500km^2 (Breeze et al., 2017). Today, the limited rainfall the region experiences is associated with northern and western sources, in the form of the Mediterranean westerlies and Shamal, and/or the Red Sea trough (Parton et al., 2015). A variety of dune forms occur across the area, with transverse barchanoid mega-dunes that are inactive today (Edgell, 2006) the dominant form across much of the western and southern Nefud. These large dunes are up to 90m high and several kilometres long. Where rocky outcrops block and divert sand transport, this results in a 'wind-shadow' effect, that creates immense exposed basins. Coupled with deflation, this process has served to preserve basin floors that are buried in some places by shallow sand cover, and Quaternary deposits.

The Jebel Oraf basin is part of a wide complex of such basins, lying on the eastern side of a line of sandstone jebels, that repeatedly held waterbodies and palaeolakes during the Pleistocene and Holocene (Figure 1). Due to the shallow depth of the Saq aquifer in this area, recharge from increased rainfall resulted in elevated groundwater levels, which intersected the basin floors, resulting in lake and wetland formation and spring discharge during insolation maxima humid periods, including the Holocene (Engel et al., 2017; Parton et al., 2018). The largest and most well-known is the Jubbah basin in which lakes formed during marine isotope stage (MIS) 7 and MIS 5, while 1km to the north of Jebel Oraf, the Jebel Katefeh basin also held a lake during MIS 5, showing that smaller basins mirrored the situation of the main basin in Jubbah (Parton et al., 2018; Petraglia et al., 2012). This also appears to have been the case during the Holocene humid period, which coincided with the transition to herding. Dated marls, similar to those at Jebel Oraf, show elevated groundwater produced wetlands at Jubbah around 10000, 6000 and 4600 BC, with invertebrate fossils indicating that the latter period was one when vegetated marshland fringed a shallow lake (Crassard et al., 2013; Hilbert et al., 2014). Lacustrine deposits and pollen records from a palaeolake at Tayma on the western side of the Nefud Desert also show initial lake development and a spread of grasslands after 7000 BC, which peaked between 6600 and 6000 BC (Dinies et al., 2015; Neugebauer et al., 2017).

Evidence from rock art suggests that the palaeolakes and vegetation of the Holocene humid period supported a range of animal species including lesser kudu, African wild ass, onager, leopard, and lion (Guagnin et al., 2018a; Guagnin et al., 2018b). Rock art at the nearby site of Shuwaymis also allowed a reconstruction of the local ecosystem in which a wide range of carnivores found ample prey biomass. This corresponds well with the COSMOS climate model, which indicates that during the Early- to Mid-

Holocene north-western Arabia received substantially enhanced precipitation relative to today, associated with a north-ward extension of the African Summer Monsoon (Guagnin et al., 2016). Droughts were probably common along the northern reach of the African Summer Monsoon, although groundwater fed palaeolakes in the Jubbah basin may have provided water even when rains failed.

Methods

A systematic interdisciplinary archaeological survey was carried out along the slopes of Jebel Oraf, in the Jubbah oasis, in 2016. Cairns, stone structures, and rock art panels were documented with photographs, GPS coordinates, and detailed field descriptions. A sample of 14 cairns was targeted for more detailed recordings of size, condition and construction methods, and any archaeological remains visible on the surface of disturbed pits were collected for further analysis. In addition, further archaeological sites in the wider Oraf basin were recorded during targeted survey. Local museum staff in Jubbah led the team to several known locations where arrowheads or grinding stones had been found, and additional areas were surveyed based on the local topography and proximity to palaeolake deposits.

Erosional processes appear active on the slope of the dunes in the basin, in the form of the deflation of the loose aeolian sand substrate upon which sites were emplaced. As a consequence, sites in dune locations appear to have been subjected to some movement, resulting in surface scatters of lithics on wind-blown sand. However, although their original substrate has deflated, clear concentrations of material are still visible. The spatial preservation of small ephemeral sites indicates that effects of dune movement and erosion are relatively minor over the Holocene timescale. In contrast, ground surfaces on the jebel slopes and on the edge of the palaeolake in the vicinity of the ORF2 site appear stable, likely due to the water lain and consolidated substrate being substantially less friable and free for mobilisation than the surrounding sands, and having been shielded from deflation, lying close in the lee of the dunes and jebel. The excellent condition of excavated and visible hearths suggests good preservation and thus it appears the topography on the edges of the Jebel Oraf basin has remained largely unchanged since the middle Holocene. Further towards the basin centre appears to be a different story however, as scattered upstanding small mounds of palaeolake deposits on the rocky floor indicate the majority of their contemporaneous deposits have been removed by subsequent deflation.

Any archaeological assemblages visible on the surface were logged and collected for further analysis. At the hearth site of ORF2, the extent of visible lake deposits along the edge of the palaeolake was recorded, and lake deposits were also excavated in two small test areas. In Trench 7, the original excavation of Hearth 2 (Guagnin et al., 2017b) was extended to obtain a better understanding of site formation process and stratigraphy, in particular the distinction between lake marls, lake marls with remains of destroyed hearths, and intact hearths. Where possible, deposits in Trench 7 were also sampled for radiocarbon and OSL dating. Organic remains were recovered from four contexts (Context 702, 703, 704, and 708). In addition, the stratigraphic sequence of Context 709, 708, and 704 was sampled for OSL dating in the section of Trench 7 at depths of 46 cm, 25 cm, and 8 cm, respectively. An additional small trench (Trench 11) was placed on the edge of the visible palaeolake deposit to investigate its depth and OSL samples were taken at depths of 18 cm and 25 cm. Sample locations were also recorded using a total station, allowing a comparison of absolute depth within an arbitrary grid (see Table 1).

OSL dating was carried out by the Luminescence Laboratory at the University of Sheffield. Sample dose-rates were determined from elemental analysis from ICP-MS measurements attenuated for grain-size and present-day moisture (with uncertainties of 5% to encompass past changes) combined with calculated cosmic contributions (as per Prescott and Hutton, 1994; Table 1). OSL dating at the single aliquot level (aliquots had a 5 mm diameter) was applied to cleaned and extracted coarse-grained (180-250 µm) quartz grains from five samples taken from ORF2. Preparation followed that of Bateman and Catt (1996). Samples were measured using a Risø DA-15 luminescence reader using the single aliquot regenerative (SAR) approach (Murray and Wintle, 2000; Murray and Wintle, 2003) and an experimentally derived preheat of 180°C for 10 seconds. Samples responded well to OSL measurement displaying a strong fast component and good growth with laboratory irradiation. For each sample palaeodoses (De) were measured for 24 replicate aliquots. All but one sample showed broadly normal distributions De and overdispersions lower than 30% when outliers were removed (Figure 2). These samples are considered to have been sufficiently bleached prior to burial and as such the De used for age calculation purpose was calculated using the Central Age Model (Galbraith and Green, 1990). One sample (Shfd17036) showed skewed and scattered replicate De data and is assumed to not have been fully reset prior to sediment burial. Data for this sample is therefore based on the Minimum Age Model (Galbraith and Green, 1990).

Radiocarbon dating was carried out by the Radiocarbon Dating Laboratory at the University of Waikato (sample code Wk) and by the Centre for Applied Isotope Studies at the University of Georgia (sample code UGAMS). All contexts with preservation of organic materials were sampled for radiocarbon dating although in many cases carbon content was not sufficient for dating and samples had to be abandoned. All contexts with sufficient depth were also sampled for OSL dating. Given the nature of the sites and the deflation in the Jebel Oraf basin, most contexts were found on the surface and were thus not suitable for OSL dating.

Figure 2 Replicate De data for the OSL samples measured for this study. All data shown within Abianco plots with aliquots considered as outliers and removed from subsequent analysis shown in red.

All recorded rock art panels were entered into a database, where each animal engraving was recorded separately, and species identification, evidence for domestication, and the level of preservation were noted. In addition, engravings associated with 'late markers' such as writing, firearms, domesticated horses or camels with riders were marked (for a more detailed description of this methodology see Guagnin et al., 2017a). This allows a distinction of engravings that can be securely dated to the Iron Age and historic periods from earlier rock art. However, this method is not suitable to identify all late engravings, and a small percentage of late imagery will be included in the remaining body of 'earlier' rock art, particularly where engravings have been exposed to erosion, and lack association with clear markers. For example, a highly eroded camel engraving may look similar to other late camel engravings, but without associated script, riders or visibly fresh peck marks it cannot be securely identified as 'late'. Although the distinction has a degree of imprecision, in separating securely identifiable late engraving, we can analyse changes in distribution between early and late rock art. The majority of the rock art at Jebel Oraf can be attributed to an early period of rock art production. It shows an advanced degree of weathering and patination, larger and more naturalistic representations of animals, and frequently depicts species that are associated with the Holocene humid period (such as cattle, African wild ass or kudu). Early rock art is also frequently associated with hunting scenes and Jubbah-style human depictions, which can be linked to the hunters and early herders of the area (Guagnin et al., 2015; Guagnin et al., 2018a; Guagnin et al., 2017a; Khan, 2007; Nayeem, 2000). This relative chronology is also confirmed in XRF measurements of the rock varnish (Macholdt et al., 2018).

Results

Dune sites

Along the northern and southern edges of the Jebel Oraf lake basin, sand dunes gently rise up to a height of about 40m. A number of relatively small sites were found on these dunes, either at the base of a dune or some way up the dunes, overlooking the palaeolake basin. The main characteristic of these dune sites, apart from their location, is that they are small surface scatters of lithics and occasionally grinding stones or fragments of charcoal and bone that apparently result from single occupation phases. No hearths or structural remains were visible on the loose sand. This is in contrast to hearth sites found on the edge of the palaeolake, where agglomerations of up to 170 hearths attest repeated occupation of the same location over several millennia (Guagnin et al., 2020).

Sites ORF206 - ORF209 occupy successive dune embayments on the northern edge of the palaeolake (Figure 2). These sites are located approximately 7 - 14m above the edge of the palaeolake, and observations during fieldwork suggest that their location may have been chosen to offer some protection from wind, while at the same time affording a view over the palaeolake basin. Lithics collected from the surface include Helwan and Jericho points and blades with continuous marginal retouch similar to sickle inserts known from the Levant (Figure 3). The materials used for these tools include local yellow silcrete with a known source on the southern tip of Jebel Umm Sanman, and exotic dark chert from an unknown source which was also being exploited in the Epipalaeolithic (Hilbert et al., 2014). Fragmentary and complete grindstones occur at these sites. In addition to the sickle blades, some of the arrowheads also appear to have been made on blades. A bidirectional scar pattern on at least one of the blades (Figure 3) indicates that these may have been produced using the same naviform core system evident at PPNB sites in Al Jawf (Crassard and Hilbert 2019), however no blade cores were found to test this hypothesis. No absolute dates are available for these surface sites, but the presence of Helwan and Jericho points suggests these sites represent an earlier occupation than the hearth sites on the edge of the palaeolake such as ORF2 and ORF115, where ha-Parsa and Nizzanim arrowheads appear to show links with the Levantine Pottery Neolithic (PN) (Guagnin et al., 2020). In the southern Levant Helwan and Jericho points are characteristic for the early PPNB (Gopher et al., 1994; Henry and Nowell, 2007; Shea, 2013), although their chronological context in the Nefud Desert may differ and remains unresolved.

Five additional sites were found along the base of the dunes, four along the northern edge (ORF202-ORF205) and one along the southern edge of the basin (ORF201) (Figure 2). Most of these sites were very small and a lack of diagnostic lithics prevents attributions to archaeological periods. Charcoal fragments sampled for radiocarbon analyses from ORF205 provided a calibrated age of AD1667-1948 (Table 2), and therefore clearly represent a recent intrusion to the site, unsurprisingly given the relatively common occurrence of modern campfire remains observed in the Jubbah oasis and in the wider Nefud Desert.

Site ORF200 on the southern edge of the basin appears to consist of an accumulation of hearths, similar to ORF2. Charcoal collected from one of the hearths provided a radiocarbon date of 3353-3104 BC (Table 2) and thus attests to occupation into the Bronze Age.

Figure 3 Top: Jebel Oraf palaeolake basin showing the location of dune sites with PPN characteristics (yellow), undiagnostic dune sites (green), partially excavated hearth sites with PN characteristics (large turquoise) and stone structures (blue, pink, and maroon). The extent of the palaeolake (826m contour) is modelled based on the height of lake deposits observed in Trench 7 and represents the highest observed lake level. An alternative lake extent is modelled for a height of 824m to indicate how the lake would have contracted when less water *was available. Bottom: Google Earth view across the palaeolake basin showing hearth sites ORF2 and ORF115 in turquoise and dune sites with PPN characteristics in yellow.*

Figure 4 Arrowheads and sickle blades recovered from ORF207. A: silcrete Helwan point (made on a blade); B & C: dark chert Byblos points; D: dark chert blade with use-wear nibbling along the entirety of both edges; E & F: silcrete sickle blades with marginal edge nibbling retouch along the right dorsal edge (extent indicated by arrows). Note the distal scar on the chert blade.

Oraf palaeolake

At hearth site ORF2 (Figure 3), grey lake marl deposits are visible along the edge of the former palaeolake. The marl is composed mainly of gypsum and anhydrite minerals demonstrating a high evaporation rate during its formation and deposition. To date 10% (17) of the 170 hearths documented at the site have been excavated (Guagnin et al., 2020). The lake marl can now be shown to extend some way underneath the site; many of the hearths sit directly on top of the lake marl deposit and therefore post-date it, also perhaps indicating the preferential use of this firmer substrate immediately below the loose sand as a base for the hearths. The excavations at ORF2 can therefore give valuable new insights into the middle Holocene environment and landscape of the Jebel Oraf basin.

In the initial test excavation in 2015 (Guagnin et al., 2017b), the exposed area was too small to allow a distinction between Hearth 2, a layer of sand mixed with ash (Context 701), and the marl immediately below, which contains fragments of charcoal and bone (Figure 5, Context 704). Further excavation around Hearth 2 now reveals that Context 704 is separate from Hearth 2. Context 704 continues to stretch beyond the fireplace, forming part of the lake sequence (Figure 4). In this area, earlier fireplaces appear to have been washed into the lake deposit, creating a high content of ash, charcoal and bone, thereby making its distinction from later hearths difficult.

A section in the south-eastern corner of Trench 7 (Figure 4, lower right) shows that the marl (Context 704) below Hearth 2 sits on top of a layer of sand (Context 708), with a further, thicker layer of marl below (Context 709). All three layers were sampled for OSL dating (Table 1). Results show extremely high uranium concentrations, particularly in the upper marl and sand layers (Contexts 704 and 708), which are well above 3 ppm uranium, which has been reported as a maximum level typical for the Nefud Desert (Clark-Balzan et al., 2018; Rosenberg et al., 2013). Recent analyses of luminescence chronologies in the Jubbah basin reported high levels of uranium in all samples, possibly due to high radioisotope levels in the groundwater of this region. This leads to a luminescence age underestimation that can at present not be quantified (Clark-Balzan et al., 2018). In combination with site formation processes observed in Trench 7, a rise in groundwater, possibly as a result of rainfall events linked to the Holocene humid period (also reported in Parton et al., 2018), may have led to hearths being washed into the lake sediments. OSL dates obtained from exposed marls slightly further towards the centre of the basin, at the southern edge of the site, confirm that the layer to which Context 709 belongs continues across a wider stretch of the lake and formed approximately 8000 years ago, although marl deeper in the section is substantially older (Table 1).

Radiocarbon ages obtained from charcoal fragments in the marl below Hearth 2 (Context 704), and from the sand layer (Context 708) between both marl layers suggest that sand, marl and hearths accumulated in relatively short succession. Based on the stratigraphy and overlap of radiocarbon ages, the formation of the upper marl (and perhaps the last lake high stand of the Jebel Oraf basin) probably occurred shortly after 5300 BC, and Hearth 53 was in use some time before 5200 BC (Table 2). Hearth 2 belongs to a later occupation of the site in the mid 5th millennium BC.

Lake levels in Figure 2 were modelled based on the height of the upper lake marls in Trench 7 (Context 704), using Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) data with a 30m horizontal resolution. The contours can only give an approximate indication of shorelines given reports of typical vertical accuracies for this DEM of <8m. Moreover, contours are modelled based on the modern terrain, which may have been altered by both deflation and redeposition of wind-blown sand since the Neolithic period. Nonetheless, given the fact that the lake extent estimated from the altitude of the deposits observed in the field matches that indicated by earlier independent analyses (Breeze et al., 2015) using remote detection of lake sediments elsewhere in the basin on satellite imagery; we are confident that the 826m contour gives a good approximation of palaeolake shorelines during the 5300 BC lake high stands. Since lake levels were likely subject to fluctuations (Parton et al., 2018), in addition to this maximum extent, an arbitrary contour 2m below the high stand was modelled to indicate changing lake shores during drier periods. The fragmented nature of the hypothetical lake produced by the 824m contour highlights the shallow terrain in the ORF basin, which probably experienced high rates of evaporation resulting in the formation of gypsum as a lacustrine deposit. A differentiation between groundwater or precipitation and their seasonal variation as the major water sources for the basin is currently elusive. However, the basin likely supported vegetation and would have attracted wildlife providing opportunities for hunting, as well as pasture for livestock.

Figure 5 Excavations and contexts in Trench 7, revealing a stratigraphic sequence of: Hearth 2 & Hearth 53 – C701 – C704 – C708 – C709. Left: main photograph showing the excavation carried out in 2016, including the re-excavation of the original test trench. The white dashed line outlines the edge of the lake marl, which appears to continue northwards under the sand and is also visible in patches on the southern edge of the trench (context

704). The black dotted line shows the outline of the charcoal rich remains of Hearth 2, sitting on top of a deposit rich in ash, and the charcoal rich remains of Hearth 53. The outline of the trench is marked with a blue dashed line. Upper right (red border): photo showing the original test excavation from 2015; Hearth 2 can be seen in the section. Lower right (yellow border): photo showing the section in the south-eastern corner of Trench 7, which was excavated to retrieve OSL samples. Two layers of marl (Contexts 704 and 709) are clearly separated by a layer of sand (Context 708). Although the lake marl is not continuous across the area of the trench, the marl in the south-eastern corner appears to belong to the same layer as the marl in the north-west of the trench (Context 704), measurements with the total station across Context 704 were all within a range of 2.5cm.

*Table 1 Summary of dosimetry related data, single aliquot palaeodose data and ages. De data based on minimum age model. Total dose is attenuated for grain size, density and moisture. Overdispersion (OD) is shown with values in parenthesis indicating value once outliers were removed. *The De distribution of Sample Shfd17036 is skewed, indicting partial bleaching. A minimum age model has been used for this sample.*

Lab Code	Description and depth	Absolute height in arbitrary grid	K (%)	U (PPM)	TH (PPM)	Moisture (%)	Dose rate (Gy/ka)	De (Gy)	OD (%)	Age (ka)
Shfd17032 (Context 704)	Lake marl, 0.08m	98.92m	<0.1	19	1.0	6.1	4.6±0.26	9.3±0.59	32 (28)	2.02±0.17
Shfd17033 (Context 708)	Sand and organic material, 0.25m	98.75m	0.3	21	1.0	6.9	5.2±0.29	14.5±0.63	36 (19)	2.78±0.20
Shfd17034 (Context 709)	Lake marl, 0.46m	98.54m	0.2	4.13	2.6	2.1	1.6±0.07	13.3±0.66	29 (22)	8.46±0.56
Shfd17036 * (Trench 11)	Lake marl, 0.18m (OSL2)	98.45m	0.4	6.34	3.3	0.4	2.4±0.11	19.1±1.5	41 (37)	8.05±0.73
Shfd17035 (Trench 11)	Lake marl, 0.25m (OSL1)	98.38m	0.4	6.21	4.7	0.4	2.5±0.11	75.8±4.3	30 (27)	30.8±2.3

*Table 2 AMS Radiocarbon ages obtained from hearth sites, dune sites, cairns, and from palaeolake deposits in the Jebel Oraf basin, calibrated using OxCal calibration programme. Radiocarbon ages are listed in reverse chronological order. *radiocarbon age originally associated with Hearth 2 (Guagnin et al. 2017). #calibration with marine curve Marine13 (Reimer et al., 2013)*

Lab code	Site	Trench	Context	Material	Description	AMS date (bp)	Calibrated date (2 sigma)
Wk-44941	ORF205		Dune site	Charcoal	Charcoal fragment collected from surface	148 ± 20	1667-1948 AD
UGAMS 44678	ORF200		Hearth site	Charcoal	Charcoal fragment collected from surface	4520 ± 25	3353-3104 BC
UGAMS 44684	ORF108 cairn A		Cairn, 4m diameter		Bioapatite, bone fragment from robbed cairn	4780 ± 25	3639-3522 BC

UGAMS 44685	ORF2	7	702	Charcoal	Fill of Hearth 2	5520 ± 25	4447-4333 BC
Wk-43212*	ORF2	7	704	Charcoal	Hearth materials washed into upper lake marl	6242±23	5310-5070 BC
Wk-44958	ORF2	7	708	Charcoal	Sand between upper and lower lake marl	6255±20	5301-5214 BC
Wk-44957	ORF2	7	703	Charcoal	Fill of Hearth 53	6278±20	5306-5220 BC
UGAMS-36030	ORF125B		Cairn	Bioapatite	Human remains in partially disturbed cairn	6270±25	5306-5216 BC
UGAMS 44682	ORF132A		Double cairn 4m & 3m diameter	Shell	Shell fragment collected from robbed cairn	7900 ± 30	6372-6060 BC[#]

Cairns

A total of 81 cairns was recorded on the slopes of Jebel Oraf. Almost all showed signs of having been robbed, many in antiquity, although some show signs of recent disturbance. The majority of cairns were small, circular mounds of rocks between 3m and 7m in diameter; in some cases, cairns were elongated in shape or consisted of two cairns joined to each other. Cairns were generally visible as irregular, partially collapsed features, but in some cases the internal corbelling and courses of stones which comprise the original cairn were relatively well-preserved and regular. We also recorded one pendant tomb (a cairn with a 'tail' of small cairns: ORF108B), and six 'bull's eye' tombs (a cairn encircled by a ring of stones; Figure 2). Overall, the cairns are evenly distributed along the eastern slope of Jebel Oraf, facing the palaeolake basin (Figure 3, top), and there is no apparent correlation with the location of rock art panels.

A sample of 14 cairns in the vicinity of rock shelter ORF115, on the southern part of Jebel Oraf was recorded in more detail with the aim of investigating possible spatial and chronological links between archaeological features in this area. Of these 14 cairns, at least 13 were robbed, with apertures measuring 1-2m in diameter. Cairns were not excavated, but construction method, preservation and location were noted, and the robber pits were examined for archaeological remains. In three of the cairns intact capstones were noted, suggesting that some of the content may be undisturbed and would benefit from further investigation. Of the 13 disturbed cairns, seven had visible human bone fragments on the surface. The majority of these remains were heavily degraded and it was not possible to obtain radiocarbon dates from them. Over half of the examined cairns were elongated and on average 50% longer along their N-S axis. With few exceptions, cairns were built on the lower slope of the jebel and in some cases appear to be aligned with other cairns in the vicinity. The location of one cairn in the centre of the palaeolake basin suggests that the construction of cairns continued after aridification had led to the permanent desiccation of the lake. A bone fragment from cairn ORF108A was radiocarbon dated to the Early Bronze Age, and thus post-dates the Holocene humid period. On the other hand, a shell fragment from cairn ORF132 was radiocarbon dated to the late 7th millennium BC and confirms that cairns were constructed over the course of several millennia (Table 2), as has been documented at the eastern end of the Jubbah basin (Guagnin et al., 2017a).

Cairn ORF125B was investigated in more detail, as there were signs of more recent disturbance including relatively well-preserved human bone. This cairn is built against a small cliff, ca 20m above rock shelter ORF115 and many of the stones that made up the original structure have been displaced downslope. The cairn appears to have been initially built in two rings; an outer ring with a diameter of ca 8.0m and an inner ring with a diameter of ca 2.2m. Skeletal remains were exposed on the surface and included a human humerus. Human skeletal remains and an arrowhead similar to Levantine Pottery Neolithic types (Shea 2013) were found inside the cairn (Figure 5), with a radiocarbon age of 5306-5216 BC obtained from bioapatite (Table 2).

Figure 6 Cairn ORF125B, with a Neolithic arrowhead and human remains. Left: Neolithic quartzite arrowhead similar to some Herzliya points from the Levant. Right: top of the skull found in situ.

Other stone structures

During the survey, 15 stone structures were identified, mostly circular arrangements of medium sized rocks. The stone structures observed at Jebel Oraf are generally similar in size to the cairns, with a diameter between 3m and 7m. The largest enclosure measures 17m in diameter, and was recorded in the palaeolake basin, approximately 300m from the base of the jebel (Figure 6). No archaeological remains were visible on the surface inside and around the enclosures, and their function cannot be identified. Given the differences in their size, shape, and construction, these structures probably had various purposes. Some appear to have been constructed as temporary shelters against larger boulders, while others may have been used as animal pens. It is possible that some may represent structures similar to the so-called open sanctuaries documented north of the Nefud Desert (see for example Fujii, 2016), or perhaps unfinished cairns. Similarities with water management structures, dwellings, and standing stone structures observed in north-eastern Jordan (Müller-Neuhof and Abu-Azizeh, 2018) were not observed. In general, the structures recorded in Jebel Oraf are singular structures, more circular in shape than the camps reported by Kennedy (2011) or the clustered enclosures reported from eastern Jordan (Meister et al., 2017). Walls are generally also lower and less compact than either the Neolithic houses known from eastern Jordan (Rowan et al., 2015; Rowan et al., 2017), or similar structures reported from the fringes of the western Nefud Desert (Breeze et al., 2017). It is thus unlikely that the structures were used for longer-term habitation, but further fieldwork is required to determine their function and age.

On the north-eastern side of Jebel Oraf, a 'gate' structure with a length of 150m runs down the slope of the jebel. The gate is associated with at least three cairns: two were found inside the gate; a third abuts the northern wall, and all look like they were at least partly built using stones from the walls of the gate. The cairns thus appear to postdate the construction of the gate. No archaeological remains were found associated with the gate, and the site requires further investigation.

Figure 7 Two types of stone structure recorded at Jebel Oraf. Top: large stone circle in the centre of the palaeolake basin, 17m diameter (ORF3). Bottom: sub-circular feature (ORF126A).

Figure 8 Gate structure (ORF45). Left: Google Earth satellite image. Right: The long sides of the gate can be seen to continue some way up the slope and are intersected by at least two cairns.

Rock art distribution and content

At Jebel Oraf, 245 rock art panels containing 1075 animal engravings were recorded. Of these, 31% (336 animal engravings) were clearly associated with 'late markers', while 69% (739) of engravings predominantly date to early rock engraving periods. In comparison, 52% of the engravings previously documented in Jubbah were associated with 'late markers' (Guagnin et al., 2017a). This suggests that the landscape of Jebel Oraf was more heavily targeted for rock art creation during the Holocene humid period rather than after the onset of aridification. This approximate age distribution of the rock art also closely reflects the radiocarbon dates obtained in the basin (Table 2), which suggest increased activity in the late 6th millennium BC, a pattern that was also observed in the western Nefud Desert (Scerri et al., 2018).

The spatial distribution of early rock art (not associated with 'late markers') shows the highest densities on the southern part of Jebel Oraf (Figure 8), particularly around rock shelter ORF115, in which stratified deposits attest to short-lived but regular occupation concentrated in the period in between 6000 and 5000 BC (Guagnin et al., 2020).

The distribution of rock art with 'late markers' also shows highest densities around ORF115, although this is in part due to the depiction of larger hunting scenes with multiple riders on camel back targeting Arabian oryx (*Oryx leucoryx*) with hunting dogs. Unlike the rock art associated with earlier periods, engravings with late markers show considerably higher densities along the northern end of Jebel Oraf, perhaps indicating a shift in the use of the landscape after the end of the Holocene humid period.

Figure 9 Comparison of rock art density distribution for rock art with 'late markers' (below) and rock art without late markers (above). Early rock art locations are indicated with green dots and late rock art with red dots. Dune sites and hearth sites are marked with white circles.

The early skew in the age distribution of the Jebel Oraf rock art is visible in its content. Of 1075 individual animal engravings, the species was identifiable in 743 (69%). Animal engravings at Jebel Oraf show lower frequencies of domesticated horse and camel, than the rock art in the rest of the areas surveyed in the Jubbah oasis (Guagnin et al., 2017a). This observation is consistent with the majority of rock art at Jebel Oraf falling into the 'early' period which predates the domestication of both species. The engravings show high frequencies of ibex (*Capra ibex*) (Figure 9). The identification of a comparatively large number of African wild ass (*Equus africanus*), depicted in herds, is particularly striking. African wild ass can only be distinguished from engravings of other wild equids, such as onager (*Equus hemionus*) where their characteristic shoulder stripe is depicted, a trait that is extremely rare in the rock art of Arabia (Guagnin et al., 2018b). To date, the 17 securely identifiable African wild ass recorded at Jebel Oraf are the only ones identified in north-western Saudi Arabia.

The majority of the rock art with late markers depicts the typical motifs of domesticated camels associated with writing, and riders on horses hunting oryx or ibex. An interesting depiction was recorded on panel ORF16B, on the northern end of Jebel Oraf, and shows a camel being hunted by two human figures with bows and arrows (Figure 10). The associated Ancient North Arabian script dates this engraving to between 800 BC and AD 400. The wild dromedary likely became extinct towards the end of the Iron Age, and its distribution may already have been very limited by the end of the Bronze Age (Almathen et al., 2016; von den Driesch et al., 2008). Rock art scenes showing the actual hunting of camels, as opposed to the raiding of domesticated camels, are therefore extremely rare. The few known scenes have generally been attributed to the 3rd millennium BC and clearly pre-date representations related to inscriptions (Macdonald, 1990). The camel hunting scene on panel ORF16B is the first recorded evidence suggesting that in the Jubbah oasis wild camel may have survived into the Iron Age.

Figure 10 Comparison of animal species identified from rock art at Jebel Oraf (blue) and other survey areas in the Jubbah oasis (yellow), based on Guagnin et al. (2017a).

Figure 11 Camel depiction on panel ORF16B, showing a camel being targeted by two hunters with bows and arrows. The legs of the camel may be hobbled, although the peck marks of this trait appear coarser than the rest of the depiction and may relate to an earlier engraving episode. The inscription above the camel belongs to the Ancient North Arabian scripts and identifies the engraver. Peck marks and engraving technique visible on *the camel engraving (particularly the head and neck), the hunters, and the inscription suggest it was probably carved by the same person and with the same tool.*

Rock art chronology

The high density of rock art around shelter ORF115 documents numerous superimpositions, which give some insight into the time depth of the engraving tradition at Jebel Oraf. Panel ORF112D shows medium sized ibex engravings superimposed by a large ibex being hunted by a dog, which in turn is superimposed by five 'Jubbah style' human figures and a sheep (Figure 11). This sequence is repeated in numerous other panels in this cluster, some of which also include cattle engravings superimposed over 'Jubbah style' human figures. We note that ibex engravings are generally relatively basic and show the outline of the body as well as large backward curving horns. Some ibex are clearly shown with the bossed horns typical for the Nubian ibex (Figure 11), although other representations show more stylised representations of the horns. However, there are clear stylistic differences between depictions of ibex and other caprines such as domesticated goats (Guagnin et al., 2017a: Figure 6) which allow a distinction between both species.

Figure 12 Panel ORF112D showing multiple engravings and superimpositions. A large ibex engraving in the centre is being followed by a dog on the left, and an earlier engraving of an ibex with bossed horns can be seen beneath the hind of the large ibex. Superimposed over both ibex is an engraving of a sheep with short horns curving back on either side of the head. On the right of the panel five 'Jubbah-style' human figures are engraved over the large ibex. Engravings have not been traced to allow better visibility of the superimpositions of individual engraved lines.

Figure 13 Top: Panel ORF115B showing a herd of nine African wild ass being hunted by stick figures with bows and arrows. Bottom: tracing highlighting the older engravings of the panel, including African wild ass and human figures. Later, superimposed engravings of camels and horses with riders are not traced. Inset: Engraving of an African wild ass on an adjacent rock surface (ORF115C) traced in white, a later engraving of an ibex is traced in grey; two further ibex and a human figure with bow and arrow are superimposed over the scene and are shown in black.

A further panel in the same cluster (ORF115B) shows a herd of African wild ass being hunted. The presence of wild ass in the Jubbah oasis was recently documented for the first time (Guagnin et al., 2018b). The fact that they are shown in a hunting scene provides further evidence that the rock art shows African wild ass, rather than early domestic donkey. Of the nine engraved African wild ass on this panel (seven adults and two young), six are shown with the characteristic shoulder stripe, and in five the upright mane is also shown (Figure 12). The herd is being hunted by stick figures with bows and arrows. In addition, the panel shows a series of very unusual human depictions, which are highly eroded but appear to show fingers and toes in an unusual level of detail. An additional, similar engraving of an African wild ass was found on an adjacent rock surface (Figure 12, inset). The latter is superimposed by a number of medium and large ibex engravings. The stratigraphy visible at ORF112D, ORF115B and ORF115C is thus indicative of a considerable time depth and appears to show a sequence of engravings that begins with depictions of African wild ass, followed by multiple phases of ibex engravings, all of which appear to predate engravings of Jubbah-style human figures that are associated with the transition to herding in the region. This chronological sequence matches observations at other rock art sites in northern Saudi Arabia. Previous research at Jebel Umm Sanman has shown that engravings of wild equids are often associated with some of the earliest engraving periods in Jubbah (Guagnin et al., 2017a). Similar engravings of ibex are also known from Kilwa, one of the oldest rock art sites in Saudi Arabia, where engravings clearly predate the introduction of domesticated livestock (Khan, 1993; see also Horsfield et al., 1933; Khan, 2007). Stratigraphy and content of the rock art at Jebel Oraf thus document multiple phases of engravings that predate the introduction of domesticated livestock (Figure 14). We also identified numerous engravings of domesticated animals, including 30 cattle, 12 goats, and 13 sheep. These provide a link to cattle remains dated to 5200 BC at ORF2 (Guagnin et al., 2017b) and reflect the presence of herders in the 6th millennium BC.

Figure 14 Comparison of the chronology at Jubbah and Shuwaymis (top) with the specific engravings from Jebel Oraf that are mentioned in the text (middle). Tracings show the approximate timing of the engraving based on observations of stratigraphic relationships in the field. Bottom: introduction of domestic livestock based on current archaeological data. Domestic cattle and caprines were introduced to the Arabian Peninsula between 6,800 and 6,200 BC (Drechsler, 2007); in the absence of dated early Neolithic sites in north-western Saudi Arabia, we have used 6,200 BC as a more conservative earliest date. Earliest evidence for domestic donkeys in the Levant currently dates to 3,000 BC (Marshall, 2007). Early dates for the presence of domestic camel and horse were documented in eastern Arabia (Magee, 2014; Uerpmann & Uerpmann, 2012), and we assume similar timing in Jubbah, Shuwaymis and Jebel Oraf.

Discussion

Archaeological survey and excavations in the Jebel Oraf basin document the preservation of an early- to mid-Holocene landscape and highlight changes in landscape use that appear to be associated with two key environmental and economic shifts: the shift from the Holocene humid period to aridification and the incorporation of herding into a hunter-gatherer economy.

Two types of occupation site can be distinguished in the wider Jebel Oraf basin, i.e., small scatters of lithics and bone on the slopes of dunes that apparently result from single occupation phases, and more substantial hearth sites on the shores of the palaeolake where the same location was repeatedly visited for short periods over centuries and even millennia. A total of four ephemeral dune sites contained a small number of stone tools typical for the PPN in the Levant, including Helwan and

Jericho points. Direct dating of these sites has not yet been possible. However, radiocarbon dates place the main occupation of hearth sites ORF2 and ORF115 in the 6th millennium BC (Guagnin et al., 2020; Guagnin et al., 2017b). Differences in lithic assemblages suggest that the dune sites predate these hearth sites. Given that in the Jordanian Badia herding was not wide spread until the late 7th millennium BC (Betts et al., 2013), and considering the comparatively slow spread of livestock recorded in the southern Levant (Martin and Edwards, 2013) it is possible that these dune sites predate the introduction of domestic livestock in the area.

Although faunal remains were not recovered from dune sites, their landscape context and position relative to hearth sites allow a cautious interpretation of their economic context. Dune sites with PPN arrowheads were found in successive dune embayments, at elevations between 7 and 14m above the palaeolake, in locations apparently chosen to offer protection from wind while also providing a view over the palaeolake basin. The hearths of ORF2 are found directly on the shores of the palaeolake, and their location corresponds to highest known Holocene lake levels in the Oraf basin. The location of earlier dune sites is thus not related to higher lake levels, but to occupants choosing elevated positions, perhaps because they afford a good view over the basin. This is consistent with locations that are advantageous to hunting, facilitating the spotting, tracking and ambush of wildlife congregating on the edge of the lake to drink or graze. This observation corresponds with Pre-Neolithic depictions of dog-assisted hunting strategies that are visible in the rock art. While hunting scenes in Shuwaymis depict large numbers of dogs, which were likely used to trap prey in narrow wadis, engravings in Jubbah show small groups of up to three hunting dogs. Ethnographic studies suggest that in more open landscapes such as the terrain of the Jebel Oraf basin, hunting strategies using few dogs to ambush prey would have been most advantageous (Guagnin et al., 2018a).

At the hearth site ORF2, two flooding events (one radiocarbon dated to around 5300 BC and one OSL dated to the 7th millennium BC), appear to have destroyed earlier hearths, leading to substantial amounts of charcoal, bone fragments and lithics being washed into the lake sediment. High uranium concentrations in these deposits indicate that flooding may have been caused by rising groundwater (Clark-Balzan et al., 2018), probably related to heavy rainfall episodes. Lake high stands must have softened the ground sufficiently for hearths to dissolve completely and become mixed into the lake deposit. Neolithic pastoralists subsequently returned to the site and built further hearths on top of newly formed lake deposits. The ground must have been sufficiently dry when the site was in use, after the lake had receded (see Figure 2) and occupation must have coincided with drier seasons or years. It appears that it was the lake edge itself that was attractive for visiting groups, perhaps because vegetation provided pasture for livestock; access to water – either from the lake itself, or via high groundwater levels – was probably also an important factor.

Modelling of the lake shores highlights the shallow terrain of the Oraf basin, and sedimentary analyses suggest that the palaeolake or wetland likely had high evaporation rates. Water may have been brackish for at least part of the year, and the basin may even have dried up seasonally. It is not yet clear if pastoralists visited the area to provide for their herds, or to supplement their subsistence with hunting. Vegetation around the palaeolake would have undoubtedly attracted wildlife, even during the dry period. For example, wild camel rely on halophythic plants that typically grow in waters of high salinity, and both camel and African wild ass require drinking water during the summer months (Gauthier-Pilters and Dagg, 1981) – both species are depicted in hunting scenes in the Jebel Oraf basin.

The fact that high lake levels at Jebel Oraf were dated to around 6500±500 BC and 5300 BC, while in the Jubbah basin lake expansions date to as early as 10,000 BC, suggests that the shallow Oraf basin only filled with some delay, perhaps once groundwater was fully re-charged. This is consistent with the relatively higher elevation of the Oraf basin in relation to Jubbah. Only when higher lake levels occurred in the Jubbah basin would lake formation commence in Jebel Oraf. Following the end of humid conditions, the Jebel Oraf basin also probably dried up relatively quickly. Today, a small garden in the centre of the basin still persists but is reliant on water pumped from the now deeper aquifer (Figure 2).

The occupation of dune and hearth sites appears to have been ephemeral and seasonal, as our survey did not record any substantial dwellings or architectural features. A total of 15 unidentified (non-funerary) stone structures were recorded, some of which may have been used as wind breaks or temporary shelters, although lithics or other material remains were not observed at any of the structures. The survey also documented a gate structure and 81 cairns. Many of these cairns have been robbed in antiquity and in the more recent past. Of the 14 cairns that were targeted for more detailed investigation, approximately 50% had visible bone fragments in the robbers' pits and were thus clearly used as burials. This raises the question of how the individuals came to be buried in this area. The age of many of these cairns remains unknown, but our sample from the slopes of Jebel Oraf now more than doubles the number of dated cairns in the Jubbah oasis (Table 2). Excavations at Tayma suggest that cairns and circular tombs were in use throughout the Bronze Age and into the Iron Age (Hausleiter and Eichmann, 2019). We can now add three dated cairns with radiocarbon ages ranging from over 6000 BC, to 5200 BC and 3500 BC (Table 2) to the archaeological record of the region. In addition, two cairns on the eastern end of the Jubbah oasis were dated to around 5200 BC and 2800 BC respectively (Guagnin et al., 2017a). The construction of simple cairns thus stretches across at least four millennia, and possibly longer. More elaborate tomb constructions such as a pendant tomb, and a bull's eye tomb have been associated with the first millennium BC in Arabia (Kennedy, 2011) but the structures remain undated at Jebel Oraf. We recorded a higher density of cairns on the slopes of Jebel Oraf than in other areas of the Jubbah oasis. However, considering the fact that the 81 cairns recorded at Jebel Oraf may have been constructed over the course of 5000 years, burial activity must have been sporadic or limited to specific individuals.

The presence of Ancient North Arabian scripts and the depiction of domesticated horse and camel allow the rock art to be separated into engravings associated with 'late markers', dated to the Iron Age and historic periods, and a body of earlier rock art. The distribution patterns of both rock art groups highlight changes in landscape use through time. Early period rock art was concentrated along the southern end of Jebel Oraf, whereas rock art of the later period was more abundant along the front and northern end of the Jebel. The boulders around the shelter of ORF115 have the highest rock art densities throughout all rock art periods, potentially because it is also the area with the highest density of surfaces suitable for engraving, while at the same time affording a view over the palaeolake basin.

The content and stratigraphic relationships observable in the rock art suggest considerable time depth in the early rock art period (Figure 14). At Jebel Oraf, the rock art sequence appears to have begun with the depiction of African wild ass, often shown in hunting scenes and in large herds. Subsequent engraving periods depict ibex of varying sizes, before content of the Neolithic period, including representations of cattle, sheep and goats were placed over this earlier body of rock art. The rock art of Jebel Oraf thus reflects a full sequence of prehistoric occupation of the basin that ranges from the hunting scenes of the 'Pre-Neolithic', to the livestock of early herders and to the use of domesticated camel, horse and Ancient North Arabian Scripts.

Equids are also depicted in the rock art of Dhuweila, which pre-dates the Late PPNB/late 7th millennium BC (Betts, 1987; Betts, 1998). However, the rock art in Dhuweila is substantially different from the rock art in northern Saudi Arabia, and particularly Jubbah. Representations in Dhuweila are made with thin incisions that show great detail in the animals' outlines and often include the hair of the mane and tail. The incisions also depict a variety of activities with animals bending their necks down to drink or looking back over their shoulder. The rock art in Jubbah is much more stylised with simpler, engraved outlines and a more standardised depiction that generally shows animals in profile with the neck up – even animals that are being hunted are normally shown completely static (Figure 13). The rock art in Dhuweila also mostly shows gazelles, while at Jebel Oraf only 3 of 743 identified animal engravings showed gazelles. Moreover, human depictions follow different conventions in both areas and differ in stance, proportions of body and legs, and the length of the neck. The rock art thus appears to show clear cultural differences between the southern Nefud (at sites such as Jubbah and Shuwaymis) and the Jordanian Badia.

Frequent depictions of African wild ass and ibex being hunted suggest that the Jebel Oraf basin may have been attractive for hunting. In the rock art of northern Saudi Arabia, wild equids are generally depicted on their own or in pairs, generally a mother with her young. The fact that two panels at Jebel Oraf show 10 and 11 wild equids respectively, with a further panel of 4 wild equids documented at the neighbouring Jebel Katefeh, suggests that this area may have been associated with the hunting of equids. Perhaps the environment at Jebel Oraf with a shallow water body, likely fringed with vegetation, and likely less populated than the main lake basin in Jubbah, provided a suitable habitat for wild equids and other wildlife that were targeted by hunters. The discovery of the only known Iron Age depiction of a wild camel being hunted in the Jubbah oasis may indicate that the area continued to act as a refuge for wildlife even after the onset of desert conditions. However, representations of domesticated livestock are also common in the rock art of Jebel Oraf and together with evidence for the presence of cattle from faunal remains (Guagnin et al., 2017b) show that pastures around the edge of the palaeolake were exploited during the Holocene humid period. The location, lithic industry and characteristics of dune and hearth sites suggest a change in landscape use from loosely scattered sites in dune embayments to the repeated visit of specific locations on the lake edge, possibly from around 6000 BC onwards. This shift may correspond to the transition to pastoralism, but subsistence practices now need to be confirmed through analyses of faunal remains.

Asynchronicity in the transition to the Neolithic has been well documented in the Levant and neighbouring regions (Goring-Morris and Belfer-Cohen, 2011). Where dates are available, the lithic typologies represented at Jubbah tend to be younger than equivalent types in the Levant. This is true for the ~8000 BC Epipalaeolithic (cf. Geometric Kebaran) site of Al-Rabyah; the PPNA points from JQ101 which are presumed to be associated with the filling of the nearby Palaeolake from between 7000 and 6000 BC; and dates of ~5200 BC from two sites with late Neolithic type arrowheads (ORF2 and ORF125B). This suggests that while contact between Jubbah and the Levant was repeated, it was not regular enough to produce concurrent changes. Moreover, it seems plausible that repeated similarities in lithic typologies are not merely the result of repeated, uni-directional population movements but reflect a complex picture in which local populations and their interaction spheres played a significant part.

Conclusion

Lithic assemblages at various sites within the Jubbah oasis provide evidence of Levantine influences across more than three thousand years, stretching from the Geometric Kebaran to the Pre-Pottery Neolithic and the Pottery Neolithic, with a time lag between the Jubbah sequence and that of the Levant indicating slow diffusion. On the other hand, the rock art in Jubbah is part of a wider cultural expression that is unique to northern Saudi Arabia and appears to overlap spatially with the phenomenon of 'gate' structures. Moreover, the ephemeral nature of Early- to Middle Holocene sites in the Nefud Desert and the apparent absence of architectural features suggest that pastoralists in northern Saudi Arabia followed different mobility patterns than their Levantine neighbours. The context of these obvious cultural differences raises the question of how similarities in the lithic industry are to be interpreted and how they might relate to the introduction of domesticated livestock. Was domesticated livestock introduced to Arabia during the Levantine PPN, when the earliest evidence for the use of livestock is available in Jordan, or was the spread of pastoralism a gradual process that arrived in Jubbah with some delay?

The scarce data currently available from northern Saudi Arabia suggests that the timing of the lake high stands at ORF2 at the end of the 6th millennium BC coincides with Neolithic activity in Jubbah and in the wider Nefud Desert – hearth sites are at the peak of their use, there is evidence for the use of domesticates, and stone structures are being built. Based on the changes visible in the rock art of Jebel Oraf, and the wider change in the use of the landscape in the basin, we suggest that dune sites with PPN lithics correspond to the earliest phases of rock art production with African wild ass and ibex hunting scenes; these are then succeeded by lakeshore hearth sites corresponding to early herding communities, and to depictions of Jubbah style human figures, cattle, sheep and goats. The dune and hearth sites recorded in the Jebel Oraf basin may therefore bracket the introduction of domesticated livestock in this region.

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Author contributions

M.G. designed the research and wrote the manuscript with contributions from P.B. (palaeolake modelling), C.S. (lithic analysis), F.O. (sedimentary analyses), M.S.

(Neolithic cairn), M.B. (OSL dating), L.G. (cairns), L.M. (fauna), A.M.A. and M.P. All authors collected data in the field and contributed to data interpretation. A.O. organised logistic support in the field, and A.M.A. co-directed the project with M.P. and facilitated collaboration with Saudi institutions. M.P. is the grant holder and PI of the Palaeodeserts project and secured research permits and collaboration with the Saudi Commission for Tourism and National Heritage.

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