Pre-Neolithic evidence for dog-assisted hunting strategies in Arabia

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Abstract

The function of prehistoric dogs in hunting is not readily visible in the archaeological record; interpretations are thus heavily reliant on ethnographic data and remain controversial. Here we document the earliest evidence for dogs on the Arabian Peninsula from rock art at the sites of Shuwaymis and Jubbah, in northwestern Saudi Arabia. Hunting scenes depicted in the rock art illustrate dog-assisted hunting strategies from the 7th and possibly the 8th millennium BC, predating the spread of pastoralism. Though the depicted dogs are reminiscent of the modern Canaan dog, it remains unclear if they were brought to the Arabian Peninsula from the Levant or represent an independent domestication of dogs from Arabian wolves. A substantial dataset of 147 hunting scenes shows dogs partaking in a range of hunting strategies based on the environment and topography of each site, perhaps minimizing subsistence risk via hunting intensification in areas with extreme seasonal fluctuations. Particularly notable is the inclusion of leashes on some dogs, the earliest known evidence in prehistory. The leashing of dogs not only shows a high level of control over hunting dogs before the onset of the Neolithic, but also that some dogs performed different hunting tasks than others.

Keywords

Dog, hunting, hunting strategy, domestication, prey, early Holocene, environment, Neolithic

1. Introduction

The subject of the dog's domestication and early uses has a long and complex history in archaeological research. Though it is now clear that dogs were the first domesticate and were domesticated from a grey wolf ancestor before the advent of food production (Larson et al. 2012; Vila et al. 1999; Wayne et al. 2006), questions about the timing, location, and number of domestication centers remain unresolved. Though an initial domestication period around 15,000 years ago has long been suggested by archaeological material (e.g., Clutton-Brock 1995; Davis and Valla 1978; Morey 1994) and more recent genetic findings (e.g., Axelsson et al. 2013; Freedman et al. 2014; Larson et al. 2012), some have proposed earlier domestication, up to 40,000 years ago, based on disputed canid remains and genetic analyses (Camarós et al. 2016; Druzhkova et al. 2013; Germonpre et al. 2015; Thalmann et al. 2013).

Like its timing, the geographic origin(s) of dog domestication is the focus of abundant debate. While much research has pointed to East Asia (Ding 2012; Pang et al. 2009; Savolainen et al. 2002) as the center of domestication, others have proposed Europe (Thalmann et al. 2013), Central Asia (Shannon et al. 2015), and the Middle East (vonHoldt et al. 2010). Recently, Frantz et al. (2016) suggested multiple domestication locations in both Europe and East Asia, but the resolution of the debate remains unclear.

Proposals for a domestication of dogs in southwest Asia have been made on the basis of archaeological (Clutton-Brock 1995; Dayan and Galili 2000; Lawrence 1967; Reed 1961; Scott 1968) and genetic (vonHoldt et al. 2010) research, but have not been as regularly discussed as those from East Asia and Europe. Confirmed dog remains are reported from Late Pleistocene and Early Holocene sites in Israel (Davis and Valla 1978; Dayan 1994; Dayan and Galili 2000; Tchernov and Valla 1997) and other debated remains come from Palestine (Zeuner 1958), Iraq (Lawrence and Reed 1983; Turnbull and Reed 1974), and Turkey (Lawrence 1967), though early dogs have thus far not been identified on the Arabian Peninsula. The earliest possible dog remains on the Arabian Peninsula date to the fourth millennium BC in Yemen (Fedele 2008). Later Arabian dog remains have been found in the United Arab Emirates (2300-2100 BC, Blau and Beech 1999; third millennium BC, Potts 1993) and Oman (fourth and third-millennium BC, Blau and Beech 1999; Tosi 1986).

Most research on early dogs in southwest Asia focuses on the corpus of dog remains from the Natufian Levant (beginning c. 13,000 BP), especially those from the Mount Carmel region (Davis and Valla 1978; Dayan 1994; Tchernov and Valla 1997; Valla 1988) and the subsequent Neolithic period (Dayan and Galili 2000), where they were often included in burials. Several researchers have documented Natufian dogs as morphologically distinct from southern Levantine wolves and other local wild canids, such as jackals and foxes (Dayan 1994; Maher et al. 2011; Tchernov and Valla 1997). In the Natufian Levant gazelle were heavily exploited (Tchernov and Valla 1997), likely with help of hunting dogs (Driscoll et al. 2009), as caprines continue to be hunted today in southwest Asia, including Arabia (Serjeant 1976).

In addition to the timing and geographic location of dog domestication, the use of early domestic dogs, and the extent to which humans controlled them remain open questions (Shipman 2015; Perri et al. 2015; Perri 2016). These activities leave

virtually no trace in the archaeological record and thus remain difficult to address. Moreover, skeletal remains provide only limited evidence of the phenotypic variation in a dog population. Prehistoric hunting strategies have generally been reconstructed using ethnographic data (Lupo 2017; Perri 2014; Perri 2016), but it remains uncertain to what extent observed strategies and changes in hunting productivity are applicable to prehistoric contexts. The depiction of domestic dogs in rock art, particularly in the context of hunting scenes, provides a snapshot of dog-assisted hunting activity in prehistory. While rock art will, to an extent, relate to the symbolic world of its creators, it also captures and preserves the experiences and observations of prehistoric populations in the narratives of rock art scenes and in the depicted animal species (Guagnin et al. 2016). The imagery therefore offers a unique opportunity to explore the behavior and morphology of early domestic dogs, and their use in the hunting strategies of prehistoric populations. Moreover, the engraved scenes allow us to explore to what extent hunting strategies observed in the ethnographic record are reflected in prehistoric depictions of hunting.

Here we discuss depictions of hunting dogs on Pre-Neolithic panels from the rock art sites of Shuwaymis and Jubbah in northwestern Saudi Arabia (in the absence of established terminology we adopt Fedele's (2008) term "Pre-Neolithic" here to describe the period preceding the adoption of food production). These panels represent the earliest evidence of dogs on the Arabian Peninsula, perhaps depicting dogs brought to the region from the Levant or a Pleistocene refugium, or an independent domestication of dogs from Arabian wolves. The panels predate finds of skeletal dog remains on the Arabian Peninsula by at least 2,000 years and indicate that dogs were a critical part of Pre-Neolithic hunting strategies in Arabia.

2. Regional background

On the Arabian Peninsula the archaeological record of the early Holocene remains largely unknown. Between 38,000 and 10,000 years ago a phase of hyper-aridity across the region combined with a scarcity of archaeological sites has generally been interpreted as a period of sparse occupation (Armitage et al. 2011; Magee 2014). Evidence from coastal sites in eastern and southern Arabia suggests occupation in the late tenth millennium BC, possibly in favorable zones that acted as refuges. The earliest dates from Holocene sites in the interior currently range between the mid-ninth and eighth millennium BC (Magee 2014; Uerpmann et al. 2009) and have been interpreted as a reoccupation of inland zones after a hiatus, facilitated by climatic amelioration of the Holocene Humid Phase (Magee 2014).

By the sixth millennium BC these groups had transitioned from hunting-based subsistence economies to mobile pastoralism; domestic cattle, sheep, and goat were probably introduced from the Levant between 6,800 and 6,200 BC (Drechsler 2007; Magee 2014). However, the occupation history of the interior of the Arabian Peninsula remains uncertain. Of the few known Neolithic sites with faunal remains, most are found along the east coast of the Arabian Peninsula and in Yemen (Drechsler 2007; 2009; Uerpmann et al 2000).

Recently, excavation of two hearth sites in the Jubbah oasis and in the western Nefud desert has yielded remains of domestic cattle and caprines dated to around

5,200 BC (Guagnin et al. 2017a; Scerri et al. 2017). These represent the first direct evidence of domestic animals in the Neolithic of northwestern Arabia, with the next closest sites as far afield as Jordan, Kuwait and Yemen. Two further sites in the Jubbah oasis have yielded early Holocene lithics, but lack faunal remains. At al-Rabyah, a lithic industry with features similar to those of the Epipaleolithic in the Levant appears to correspond to a period of lake contraction dated to 8,000 BC (Hilbert et al. 2014). At Jebel Qattar 101, El-Khiam and Helwan points similar to those known from Pre Pottery Neolithic (PPN) assemblages in the Levant were associated with a paleolake dated to 7,000-6,000 BC (Crassard et al. 2013).

While evidence for cattle, sheep, and goat is present, but sparse, on the Arabian Peninsula, so far none of the early Holocene sites have yielded remains of domestic dogs. This is likely caused by a scarcity of excavated archaeological sites and is expected to change as research intensifies. The earliest possible remains of a domestic dog come from the Neolithic site of Jebel Qutran, in southwestern Yemen, which has been dated to the fourth millennium BC (Bökönyi 1990; Fedele 2008), and sporadic remains of dogs are also known from the third millennium BC (see for example Blau and Beech 1999; Potts 1993; Tosi 1986).

The sites of Shuwaymis and Jubbah are located in northwestern Saudi Arabia (Figure 1). Jubbah is an oasis in the southern Nefud desert. Access to water and vegetation has supported human occupation in Jubbah throughout the Holocene (Guagnin et al. 2017b) and the presence of Middle Paleolithic sites attests to repeated occupation during the Late Pleistocene (Groucutt et al. 2017). During the Holocene Humid Phase a number of paleolakes formed in the oasis and likely provided fresh water and supported lush vegetation year-round (Crassard et al. 2013; Hilbert et al. 2014). The presence of cattle pastoralists in Jubbah has recently been documented at 5,200 BC (Guagnin et al. 2017a), but the timing of this transition to herding remains unknown. The early Holocene sites of Al-Rabyah and Jebel Qattar 101 have been attributed to hunters (Crassard et al. 2013; Hilbert et al. 2014) based on lithic assemblages rich in projectile points, although faunal remains are absent. Groundwater continued to support vegetation at Jubbah after the onset of aridification around 4,000 BC and is still used for agricultural irrigation today.

The Shuwaymis landscape includes relict wadi courses that branch off a main valley, flanked by sandstone escarpments. In wetter periods, wadis were active and would have supported dense vegetation along the watercourses. Even today sporadic seasonal rains lead to the development of grassland and the collection of water in ponds (Jennings et al. 2014). Analyses of the animal species depicted in the rock art showed that the area was likely characterized by a mosaic of habitats, with denser, wooded vegetation along the watercourses, and more open vegetation in the landscape around them (Guagnin et al. 2016). The rock art of Shuwaymis was first documented in 2001 (Jennings et al. 2014), but archaeological sites in this region still await survey and excavation. Occupation in this area can currently only be deduced from the rock art. Early rock art production in Shuwaymis has been dated to the Pre-Neolithic and Neolithic and shows a sequence from hunting imagery to herding. This period was likely followed by a break in rock art production. Later rock art in Shuwaymis has been dated to the Iron Age and early historic periods based on the

depiction of domestic horses and camels, and writing (Guagnin et al. 2015; 2016; Khan 2007; 2013; Olsen & Bryant 2013)

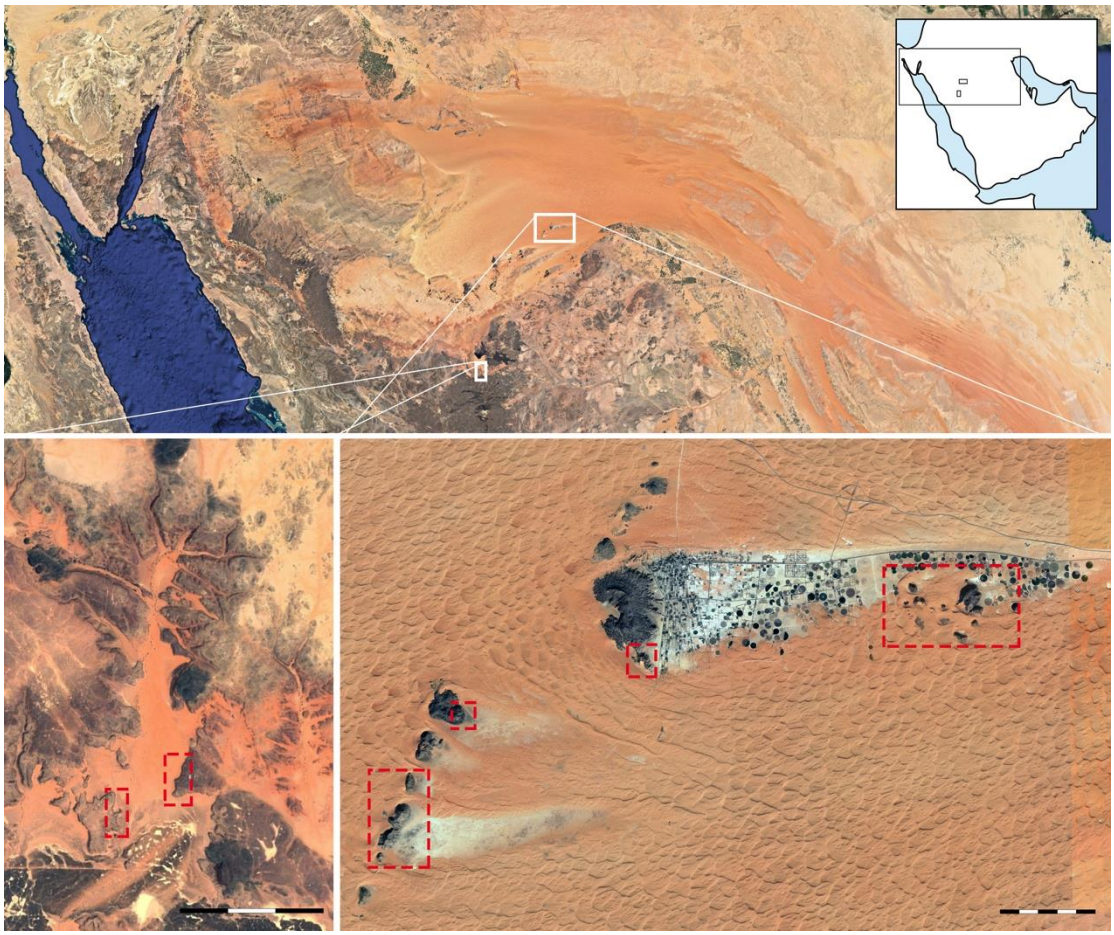

Figure 1 Satellite image showing the location and topography of Shuwaymis (bottom left) and Jubbah (bottom right). The rock art of Shuwaymis is located along the sides of a wadi on the northern edge of the lava fields of the Harrat Khaybar (only Shuwaymis east was surveyed systematically by the Palaeodeserts project). The rock art in Jubbah is found along the slopes of hills (jebels) that flank the paleolakes of this ancient oasis in the southern Nefud desert. Scales are in 1km segments.

3. Rock art at Shuwaymis and Jubbah

The rock art sites of Shuwaymis and Jubbah, in northwestern Saudi Arabia (Figure 1), are extremely rich in early Holocene imagery (Guagnin et al. 2015; 2017b; Jennings et al. 2013; 2014; Khan 2007; 2011; Olsen et al. 2013). Clear differences in content and stratigraphy allow a distinction between rock art created by Pre-Neolithic hunters and rock art created by Neolithic cattle herders. Elaborate herding scenes with domestic cattle are often superimposed on earlier depictions of hunting scenes. As part of this process earlier images are often reworked and integrated into the new scene. The apparent existence of cultural memory relating to Pre-Neolithic images and the fact that cultural markers associated with human depictions, such as headdresses and penis sheaths, continue across both periods suggest cultural continuity and an adoption of herding by indigenous hunters (Guagnin et al. 2015).

In particular, the Pre-Neolithic imagery at Shuwaymis is rich in depictions of domestic dogs, although representations of dogs are found in all periods of rock art production throughout the Holocene. Extensive rock art surveys carried out at both sites by the Palaeodeserts Project (www.palaeodeserts.com) now provide a unique dataset with 1,405 recorded panels, containing 6,618 individual animal depictions (survey results and methodologies are reported in Guagnin et al. 2015; 2017b; Jennings et al. 2013; 2014). The earliest Neolithic sites have yet to be identified in the area. However, caprine herding is documented at PPNB sites in eastern Jordan and domestic sheep have been shown to reach the southern Levant between 8,000 and 7,500 BC (see Martin & Edwards 2013 for a summary). PPNB sites have recently also been documented at Wadi Sharma in the Tabuk province of northern Saudi Arabia and may represent an extension of these early pastoralist networks into the landscapes north of the Nefud desert (Fujii 2013), although faunal remains currently still await publication. Along the gulf coast the transition to herding is dated to between 6,800 and 6,200 BC (Drechsler 2007), and herding is documented at Manayzah, in Yemen, by 6,100 BC (McCorriston 2013; McCorriston & Martin 2009). Due to the relative proximity of Jubbah and Shuwaymis to PPNB sites in Jordan, and evidence of contact between both regions in the form of shared traits in the lithic industry (Crassard et al. 2013), and in the context of the Neolithic transition in eastern and southern Arabia (Drechsler 2007; McCorriston 2013), we assume that the timing of the transition to herding along the southwestern margins of the Nefud desert similarly occurred during the 7th millennium BC (Figure 2).

Here, we focus on Pre-Neolithic and early Neolithic depictions of domestic dogs at Shuwaymis and Jubbah. Based on weathering, content, stratigraphic position, and association with “late markers” (for example, representations of domestic camels, writing, or guns), the rock art can be grouped into early Holocene (i.e., Pre-Neolithic and Neolithic) imagery and later engravings (for an overview of these methods see Guagnin et al. 2016; 2017b). While these methods cannot provide precise dates for individual images, it allows us to identify a substantial body of rock art that can be attributed to a time period before the adoption of herding with a high degree of certainty. This allows us to investigate the relationship between Holocene hunters and their dogs, the types of prey being targeted with hunting dogs, and their use in different environmental hunting strategies.

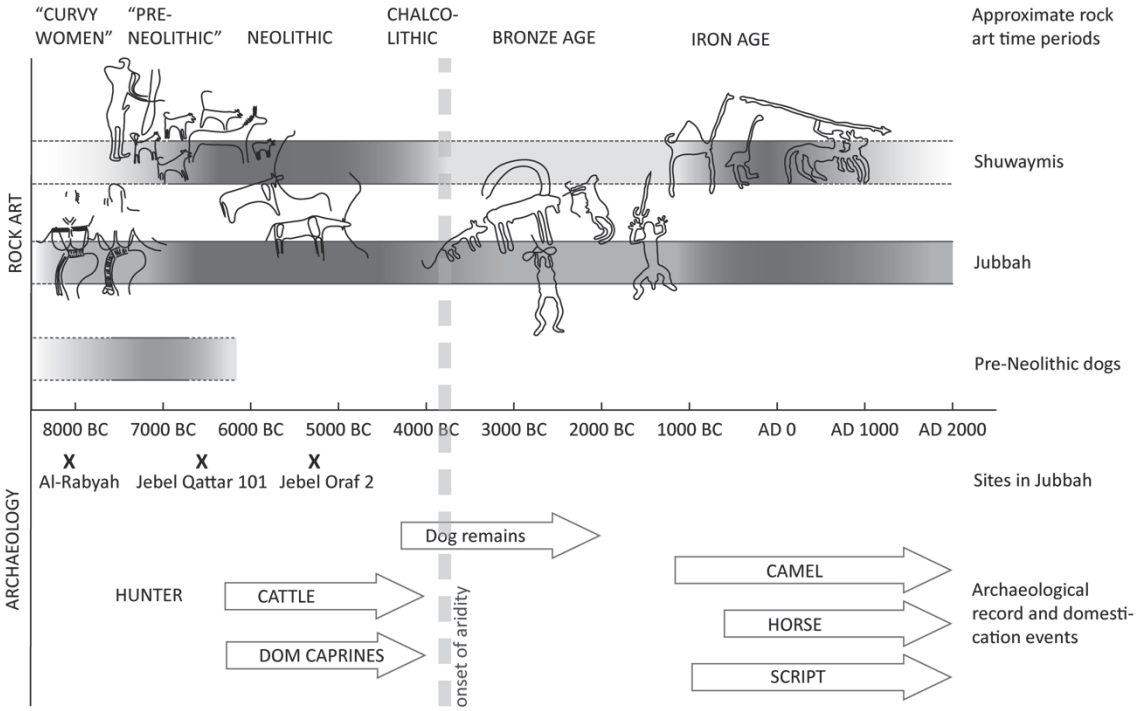

Figure 2 Comparison of chronology for rock art (top) and archaeological record (bottom). Top: Darker shading represents more intensive rock art production. Curvaceous women represent the earliest rock art in Jubbah and may relate to the occupation of Al-Rabyah (Guagnin et al. 2017b); Bronze Age rock art was only identified in Jubbah. Bottom: X marks the dates of early Holocene sites excavated in Jubbah (Al-Rabyah, Jebel Qattar 101, Jebel Oraf 2) (Crassard et al. 2013; Guagnin et al 2017a; Hilbert et al. 2014). The earliest possible dog skeletal remains currently reported are from the fourth millennium in Yemen (Jebel Qutran; Fedele 2008). 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 northwestern Saudi Arabia we have used 6,200 BC as a more conservative earliest date. 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 and Shuwaymis. The emergence of writing in northern Arabia is well documented (Macdonald 2010).

3. Dog depictions at Shuwaymis and Jubbah

At Shuwaymis dogs are found on 52 of 273 recorded rock art panels and at Jubbah on 127 of 1,131 panels. Based on the content, weathering and stratigraphy of the engravings at least 156 dogs in Shuwaymis, and 193 dogs in Jubbah can be attributed to the early Holocene. Representations of dogs are generally found in hunting scenes (see also Olsen & Bryant 2013), although occasionally dogs were re-engraved when cattle were added and superimposed onto earlier hunting scenes (Guagnin et al. 2015)

Given their distinct morphology and cultural context, it is clear the canids depicted are domesticated dogs, not wolves or jackals. Depictions of hyaenas and wolves have also been identified in the rock art and can be clearly distinguished from representations of dog (Guagnin et al. 2016; Olsen & Bryant 2013). All of the dogs display characteristic pricked ears, short snouts, deeply-angled chests, and a curled tail, appearing to be of the same "type". These phenotypic traits were also noted by Olsen and Bryant (2013). Like those authors, we suggest these canids bear a close resemblance to the modern Canaan dog (Figure 3). This Levantine dog is also proposed from archaeological (Wapnish and Hesse 1993) and historical contexts (Stager 1991) and has been identified as a basal dog breed (Larson et al. 2012;

vonHoldt et al. 2010). The previous earliest depictions of dogs in the archaeological record come from two agricultural villages in southwestern Iran, dated to around 6,000 BC (Delougaz and Kantor 1996; Hole and Wyllie 2007). Both are painted on pottery and similarly depict dogs with short snouts, pricked ears, and up-turned curled tails (Hole and Wyllie 2007).

Figure 3 Top: Canaan dogs with typical characteristics of pricked ears, short shouts, deeply- angled chest and curled tails. Both dogs also show white coloration on the chest and a spot on the shoulder ("tick"). Bottom: dog depictions in the rock art of Shuwaymis. The engraving on the left shows a dog with a shoulder "tick", and the one on the right shows a dog with chest coloration. Both dog engravings also show characteristics typical for Canaan dogs. Photos in top by Alexandra Baranova/CC (right) and xxx (left).

Though the panels appear to depict Canaan-like dogs, the potential ancestry of these Arabian dogs is unclear. Currently, the Arabian Peninsula and the Levant are inhabited by the Arabian wolf (*Canis lupus arabs*), some of which may weigh as little as 12kg (18kg on average), making them the smallest wild wolves (Dayan 1994; Tchernov and Valla 1997). Along with the Arabian wolf the Levant is also populated by the similarly small Indian wolf (*Canis lupus pallipes*), though some consider these two subspecies synonymous (Mech and Boitani 2004), while others consider them only distantly related (Bray et al. 2014). Due to the geographic range and size similarities between these wolves and Natufian dogs (~11-16kg; Tchernov and Valla 1997), some have suggested early Levantine dogs were domesticated from these wolves (Clutton-Brock 1961; Dayan 1994; Tchernov and Valla 1997). It is unclear if the Shuwaymis and Jubbah dog depictions represent non-local dogs (e.g., from the Levant) or a localized domestication on the Arabian Peninsula. While their

descending from a Natufian Levantine dog is possible, the Arabian dogs are largely depicted closer to the size of a modern Canaan dog rather than the smaller Natufian dogs, suggesting they may have another origin.

Some of the depicted dogs appear to have spots or “ticks” on the coat, produced by a dominant allele on the ticking locus. In some Canaan dogs this produces a spot on the side of the torso near the shoulder blade (Figure 3), similar to those seen on dogs in panels from Shuwaymis (see also Olsen and Bryant 2013). Some dogs also appear to have coloration called Irish spotting, which refers to white patches on the front of the chest, forehead, or lower legs. Dogs with this distinct pattern on the chest are seen on numerous panels at Shuwaymis (Figures 4-7), and are similar to modern Canaan dogs with this pattern (Figure 3). Other dogs on the panels display no distinct markings, but appear to have the same morphological features.

The panels in Figures 4-10 show that all depicted dogs subscribe to the same type of stylized depiction, which is largely static but occasionally captures elements of the movement of the animals. Despite the existence of a clear type, all dogs display individual features. Dogs are shown with differences in stance, a variety of tail positions and shapes, and coat colorations. There are also male dogs and presumably females, both of which participate in hunting. This may indicate the artists were documenting the general range of variation in local dogs or depicting individual dogs known to them. In particular, the dogs in Figure 6 show a variety of body shapes and coat coloration.

Particularly interesting is the inclusion of leashes on some dogs (also described in Olsen and Bryant 2013: 184; Olsen 2017: 114), the earliest known in the archaeological record. The leashes appear to be tethered to the waist of the hunters, leaving their hands free for the bow and arrow. Some hunters have an individual dog leashed to them and others have multiple. Figure 4 shows a Pre-Neolithic scene with two hunters and 21 dogs surrounding an equid and its young. The hunter on the right has two dogs on leashes, and the hunter on the left has one. All dogs in the scene, including those on leashes, are shown facing the equids, with the exception of those directly next to them, which appear to be corralling the equids towards the hunters. This composition reflects a general pattern at Shuwaymis where one, or occasionally two, hunters are shown with a pack of dogs surrounding prey (Olsen and Bryant 2013: 184).

Figure 5 shows a similar scene with fewer dogs. Here one, or possibly two, hunters are shown approaching an equid with its young. Of their five dogs, two are on leashes, and all dogs are facing the prey. While only a small number of hunting panels depict dogs on leashes, they all subscribe to the same pattern, whereby a small number of dogs on leashes forms part of a larger group of dogs. Dogs may be leashed to, for example, protect valuable scent dogs from being injured or to keep dogs near a hunter for protection. They may also represent young dogs being trained to hunt or older dogs more susceptible to injury. This suggests not only are some human populations controlling their hunting dogs by the Pre-Neolithic, but that some dogs may perform different hunting tasks than others. Some may be used only to track prey scents, while others are used to corral and attack prey, protect human hunters, or help haul meat back to camp. This variation in hunting dog skills is well-

documented among ethnographic reports of dog-assisted hunting groups (e.g., Nobayashi 2006; Perri 2014).

Later depictions of hunting dogs are also seen in pre-Islamic rock art across the Arabian Peninsula and nearby regions, and the use of hunting dogs is frequently reported in ancient inscriptions (Maraqten 2015). Hunting dogs with similarly pricked ears and curled tails are also seen on leashes hunting wild goats, lions and leopards in 4th millennia BC rock art from Armenia (Manaserian and Antonian 2000).

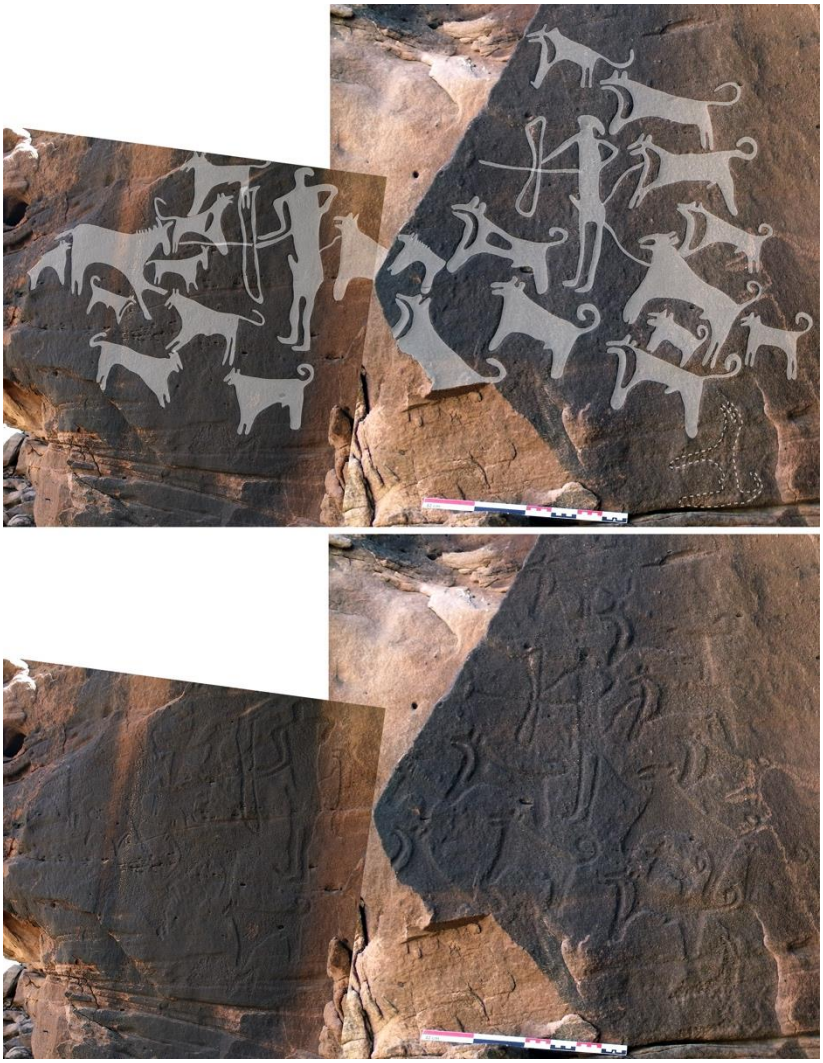

Figure 4 Composite photograph of Panel 16 at Shuwaymis. The panel is damaged in the center, and excessive water flow has removed some of the ancient patina. The right side of the panel shows a hunter with 13 dogs, the left side of the panel shows a hunter, a large equid and 8 dogs. The above picture shows the engravings traced in white, an unfinished dog engraving is traced with dotted lines.

Figure 5 Panel 134 at Shuwaymis, showing a hunter with two dogs on a leash and three further dogs hunting an equid and its young. Two examples of the so-called "Hanakiyah tool" can be seen in the center. Note that the panel is damaged on the top left, bottom right, and in the center, and may originally have contained a further hunting figure.

Figure 6 Detail photograph of a panel in Shuwaymis west showing a complex stratigraphic sequence with dog engravings and human figures superimposed with multiple cattle. To aid visibility only clearly identifiable engravings of dogs, cattle and human figures were traced.

4. Targeted prey

The prey pursued by dogs in the panels mirrors prey targeted by Arabian wolves. Wolves are primarily predators of medium-bodied mammals, specifically ungulates (Gazzola et al. 2005). Gazelle and ibex are particularly targeted by modern Arabian wolves (Hefner and Geffen 1999; Hosseini-Zavarei et al. 2013; Shalmon 1986), as are

vulnerable juvenile oryx (Price 1989). Some have documented Arabian wolves specifically targeting individual males when they are weak during the post-rut period (Hosseini-Zavarei et al. 2013), which may be echoed in the targeting of males in the rock art. For example, several panels depict the hunting of male ibex with their tails raised, a sign they are in the rut. Similarly, the panel depictions of equids defending their young reflect equid adaptive responses to carnivore predation in the wild (Feh et al. 1994). In the case of large-bodied adult ungulates, like equids, this often leads to only the death of the offspring by carnivore predators, but in dog-assisted human hunting this maternal response may lead to the targeting of both adult and juvenile.

The species spectrum depicted in the rock art of Shuwaymis is extremely narrow, with only four wild ungulate prey species (oryx, ibex, gazelle and equid) (Guagnin et al. 2016). In Jubbah, three further species (kudu, aurochs, and wild camel) have recently been identified in Pre-Neolithic rock art (Guagnin et al. 2017c). To date, the Pre-Neolithic rock art dataset only shows the use of dogs with ibex, gazelles and equid; oryx are only shown with dogs in Bronze Age rock art, where they are a recurrent motif (Guagnin et al. 2017b). However, this may to some extent be a result of sample bias, as oryx, gazelle, aurochs, and wild camel are only rarely depicted. A number of panels in Shuwaymis also appear to show lions and leopards being hunted with the help of dogs (Figure 10; see also Olsen & Bryant 2013).

The species targeted in hunting scenes may reflect the prey species for which hunting dogs are most useful. Ibex, gazelle, and equids are all medium-large prey that live individually or in small family groups; ideal for dog-assisted hunting strategies (Perri 2014). On the other hand, aurochs and wild camel are megafauna and oryx form large herds, two factors that can limit or negate the usefulness of hunting dogs (Perri 2014; Perri et al. 2015; Perri 2016). Additionally, innate prey selection in dogs may lead to the targeting of vulnerable individuals – the old, the sick and injured, lone males, and females with young. Indeed, the panels from Shuwaymis and Jubbah overwhelmingly depict prey from these groups, particularly lone or small groups of males and mothers with their young. This prey selection by dogs may have significant implications for how we interpret the faunal record not only in Pre-Neolithic Arabia, but in any location where dog-assisted hunting strategies are utilized.

Figure 7 shows a scene in which two ibex are being attacked by dogs (a third was added into the scene later). Both original ibex are shown with dogs biting their necks and their heads turned backwards, possibly to indicate that the animal is dying. A further dog is shown biting the belly of the ibex on the left. The ethnographic record suggests the hunting of ibex is both difficult and dangerous, challenges mitigated by hunting dogs which chase down the quick animals or corner them on cliff ledges, barking to alert their handlers or holding them so the human hunters can make a kill (Hobbs 1989; Musil 1928).

Similarly, the gazelles in Figure 8 are shown with a dog biting the neck of each. Ibex and particularly gazelle are extremely quick prey. Human hunters use dogs to mitigate the disparity in speed between them and these animals (Smith 1978). The typical way of hunting swift ungulates is to send dogs after them, who then chase them into exhaustion, pulling them down by their necks and holding them until humans arrive to dispatch them (Allen and Smith 1975; Clark 1995). This technique

of hunting dogs pulling quick ungulates down by the neck has long been documented in the Middle East (Hole and Wyllie 2007), including at Shuwaymis and Jubbah. Moreover, this technique is likely the reason dogs are largely depicted alone with gazelle and ibex on the Pre-Neolithic panels, while hunters with bow and arrows are prominent in hunting scenes with equids, lions and leopards.

Figure 9 shows a hunting scene from Shuwaymis where an equid and its young are surrounded by 11 dogs. While the larger equid is only encircled (see also Figures 4 and 5) by the dogs, the juvenile is shown being attacked on the neck, similar to the gazelle and ibex in other panels. This reflects the equid response to defend their young against predators instead of fleeing (Feh et al. 1994). In the wild this may only lead to the taking of the juvenile by predators, as the adults are too large and dangerous, but in Figure 9 this response appears to lead to the targeting of both the juvenile and adult, as the human hunter seemingly aims his bow at the adult animal.

At Shuwaymis there is also one scene that shows a lion being hunted. Here, a hunter with two dogs is shown facing the lion (Figure 10), while a group of five dogs is engraved behind the lion. It is not clear if this scene portrays the actual hunt of a lion or if the panel shows a symbolic scene, but the hunting of lions with dogs is not uncommon in the ethnographic and historical literature (e.g., Mors 1953; Stager 1991). Similar rock engravings of hunting lions with dogs are found in Armenia from the 3rd or 2nd millennium BC (Schnitzler 2011).

It is also important to note that in Figure 7 one ibex appears to be held in some way, perhaps tethered with a rope and staked to the ground. Researchers have previously suggested humans experimented with managing wild goat populations as early as 8,000 BC (Makarewicz and Tuross 2012), and that domestication may have occurred independently in three locations in southwest Asia (Fernandez et al. 2006; Horwitz et al. 1999; Luikart et al. 2001; Zeder and Hesse 2000). In the southern Levant this process appears to have taken place during the Late PPNB (~7300-6700 BC) (Makarewicz and Tuross 2012). The Shuwaymis depiction may represent a Pre-Neolithic attempt at caprine control dating to around the same time as goat domestication in other parts of southwest Asia. The inclusion of dogs in the scene suggests they may have participated (e.g., capture, herding, guarding) in the initial phases of goat domestication.

Figure 7 Section of Panel 82 in Shuwaymis showing two ibex (center and left) being attacked by eight dogs. One of the ibex appears to be held by a tether. A third ibex (right) was added to the scene at a later point.

Figure 8 Scene from the western embankment in Shuwaymis depicting three gazelles being hunted by four dogs.

Figure 9 Panel 105 at Shuwaymis, showing a hunting scene with an equid and its young, surrounded by dogs.

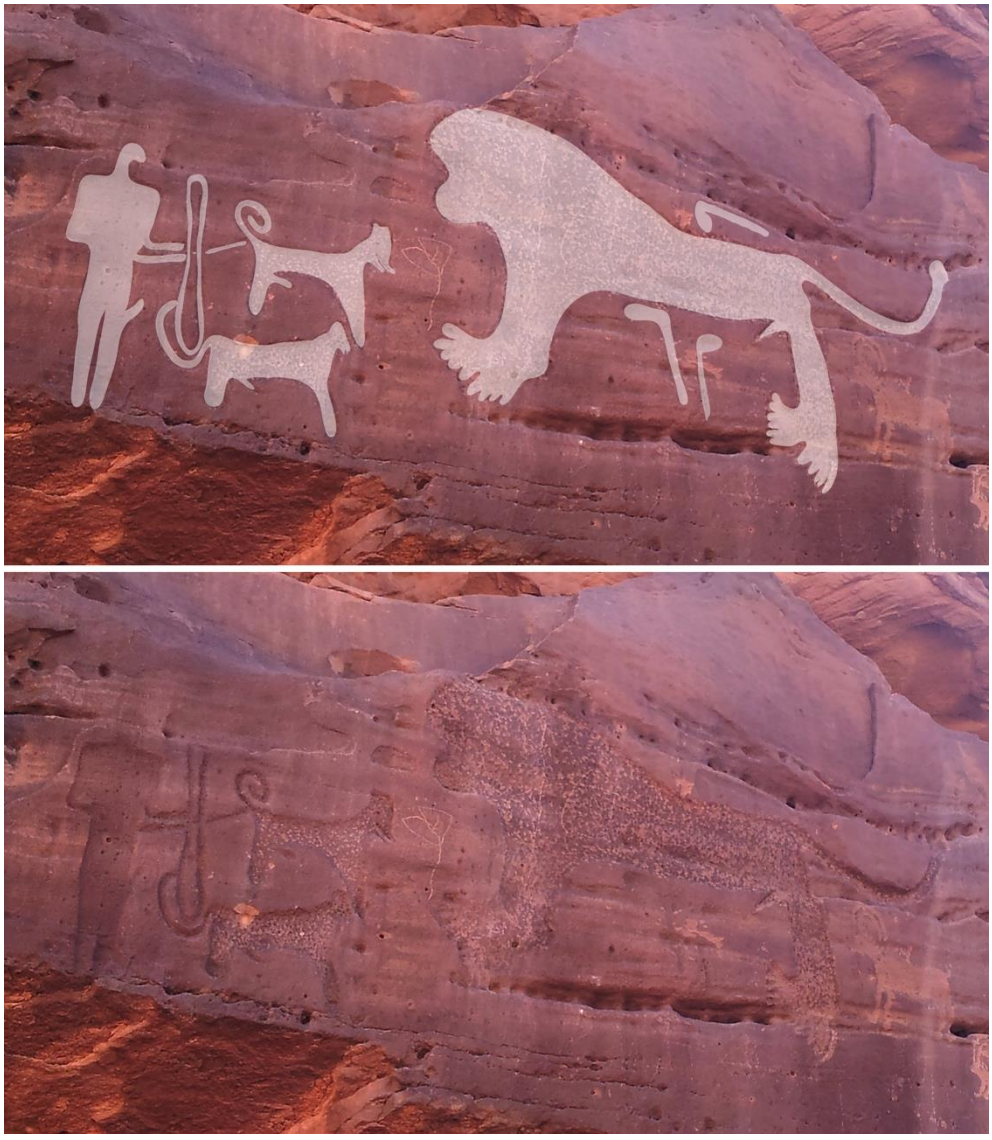

Figure 10 Shuwaymis Panel 144, hunting scene with lion and two dogs (a further five dogs are engraved behind the lion, not visible on photograph). "Hanakiyah tools" are engraved below the belly and above the back of the lion and may represent at type of tool used to butcher or skin animals.

5. Landscape-tailored hunting strategies

Our case studies above focus on Shuwaymis, where dog representations are more common and include larger numbers of dogs per scene. Our dataset from eastern Shuwaymis contains a total of 204 dog depictions. Of these, 156 dog engravings, depicted in 39 individual scenes, can be attributed to the early Holocene. Of the early dogs in Shuwaymis, 45% (71) are depicted in groups of over seven individuals (Figure 11), with up to 21 individual dogs in one scene. This is in strong contrast to dog depictions at Jubbah. Here, a total of 193 early Holocene dog engravings were recorded from at least 108 individual scenes (Figure 11). In Jubbah, dog representations are predominantly depicted in small groups, with a maximum group size of seven.

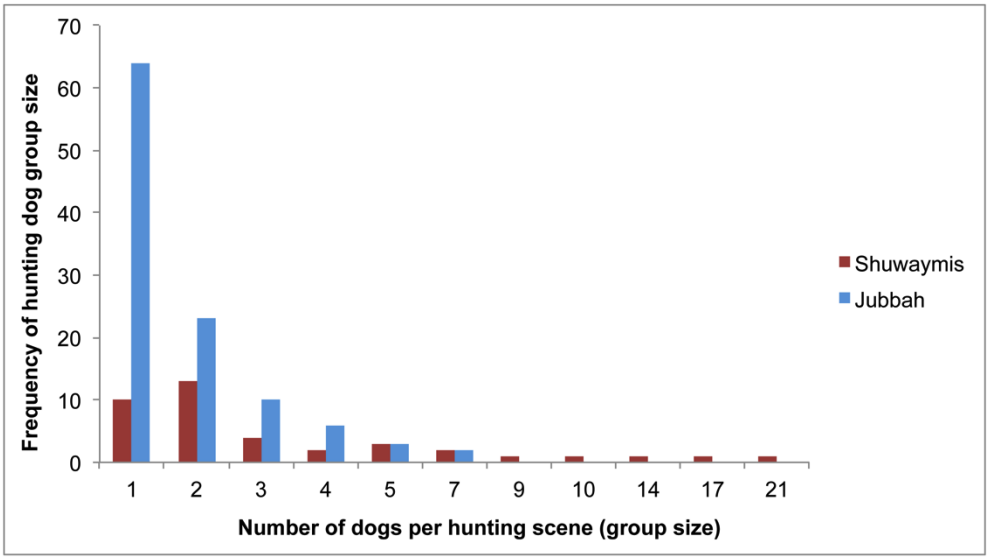

Figure 11 Graph comparing the number of early Holocene dog representations per scene in Jubbah and Shuwaymis. While small groups of dogs are common in Jubbah, large groups are typical for Shuwaymis.

Although the frequency with which species are depicted in an overall body of rock art is driven by cultural considerations (Guagnin et al. 2016), we propose that the consistent difference in the number of dogs shown involved in a hunt reflects landscape-tailored variation in the hunting strategies used at each location. This variation was likely driven by the substantial differences in early Holocene environments and topography at Jubbah and Shuwaymis.

Shuwaymis is a wadi flanked with sandstone escarpments, on the northern edge of the lava fields of the Harrat Khaybar, and on the southern margins of the Nefud desert (Figure 1). The area around Shuwaymis lacks paleolakes and would have been an unpredictable environment during the early Holocene Humid Phase. Climate data simulated by the Community Earth System Models (COSMOS) show that Shuwaymis was positioned at the northern extent of the African summer monsoon. Consequently, although seasonal rainfall would have been substantially higher than today, droughts were probably common (Guagnin et al. 2016).

In contrast, the landscape around the Jubbah oasis is much more open; satellite imagery shows the remains of a large paleolake as well as a number of smaller paleolakes (Figure 1, white deposits). These would have provided a source of

permanent freshwater during the early Holocene (Crassard et al. 2013; Hilbert et al. 2014). Prey species likely congregated at drinking places along the edge of these paleolakes, and would have been easy targets for Pre-Neolithic hunters. Whereas the Jubbah paleolakes offered a beneficial environment for predators, including humans, to target prey species year-round, the site is an open desert environment with no natural features to trap prey, nor is there evidence for the building of desert kites. In contrast, at Shuwaymis the wadi would have provided numerous locations suitable for the trapping of prey.

The pattern visible in the rock art, where large groups of hunting dogs characterize hunting panels in Shuwaymis, and small groups of dogs are typical for the rock art of Jubbah, may therefore relate to local hunting strategies. While large groups of dogs could have been used to drive game into narrow segments of the wadi at Shuwaymis, prey in Jubbah could be ambushed with only few dogs. In addition, the oasis of Jubbah likely supported year-round occupation, and small human groups would have hunted regularly. Hunters in Shuwaymis on the other hand were almost certainly constrained by frequent droughts and may have aggregated more seasonally, using large groups of dogs to minimize hunting risk and maximize hunting returns during short seasonal wet periods.

6. Discussion

A key challenge in the use of archaeological evidence from rock art is the lack of direct dating methods. However, the stratigraphies of the Shuwaymis and Jubbah engravings clearly show a Pre-Neolithic phase of rock art production that only depicts wild animals and hunting scenes with dogs (Guagnin et al. 2015). These scenes are frequently directly overlain by depictions of Neolithic cattle herding. In Jubbah, the Pre-Neolithic rock art is preceded by an even earlier phase of rock art production from which only a small number of representations of curvaceous women and life-sized depictions of wild camel and aurochs are currently known (Guagnin et al 2017b; 2017c; Figure 2). While the regional transition to the Neolithic remains undated, the stratigraphy of the rock art allows us to attribute the majority of the depictions of hunting dogs to the Pre-Neolithic period. These depictions from Shuwaymis and Jubbah reveal that dogs were used to hunt gazelle, ibex and wild equids as early as the 7th and possibly the 8th millennium BC.

This earlier timing of dogs in Arabia is an important part of understanding not only the presence of dogs in the region and possible dog domestication in southwest Asia, but the movement of human populations on the Arabian Peninsula in the Pre-Neolithic. The rock art depictions of hunting dogs predate previous faunal evidence for the earliest dogs on the Arabian Peninsula by over 2,000 years, suggesting domesticated dogs have been present in the region for much longer than previously suspected. Other early dogs in southwest Asia include those from the Levantine Mount Carmel region (c. 12,000 BP; Davis and Valla 1978; Tchernov and Valla 1997), which predate the Arabian rock art, and various contested material from Palegawra Cave (c. 12,000 BP; Turnbull and Reed 1974), Jericho (~9,000 BC; Zeuner 1958), and Çayönü (~7,000 BC; Lawrence 1967).

The elaborate depictions of such sizeable hunting dog groups on the Arabian Peninsula, up to 21 animals in some panels, suggests a sustained, and perhaps managed, breeding population, instead of one-off traded individuals. The phenotypic conformity seen in the depicted dogs alludes to a fairly isolated population with little outside introgression. The archaeological record of southern and eastern Arabia suggests that Pleistocene hyper-aridity in the region kept human populations in coastal refugia until the interior was repopulated around the mid-ninth and eight millennium BC, following the Holocene Humid Phase (Armitage et al. 2011; Magee 2014; Uerpmann et al. 2009). The human populations bringing dogs into the interior in the Pre-Neolithic may have originated in the Levant, where dogs are found beginning in the Natufian period, or from refugia on the coast or in oases, though earlier dog remains have not been found elsewhere on the Arabian Peninsula. Alternatively, they could represent an independent domestication of dogs from the small Arabian wolf that inhabits the Arabian Peninsula (e.g., Dayan 1994; vonHoldt et al. 2010).

The rock art imagery shows characteristics of the Arabian Peninsula dogs that are difficult or impossible to identify in the archaeological record; phenotypic traits such as pricked ears, curled tails, and coat patterning. These traits bear a remarkable resemblance to the modern Canaan dog, a breed associated with the Levant, but which may have a more ancient ancestry than previously assumed. Canaan dogs are a basal breed (Larson et al. 2012; vonHoldt et al. 2010) recreated from isolated individuals living with Bedouins in the Negev desert of the southern Levant (Menzel and Menzel 1960; Shiboleth 2001). The Arabian Peninsula dog depictions and modern Canaan dogs may represent a case of convergent evolution; or two unrelated groups of dogs adapted to harsh, arid environments. Alternatively, the Arabian dogs may be ancestral to the modern Canaan breed, having been moved into the Levant during a later period. The Arabian dogs and Canaan dogs may also be independent lineages descended from earlier Natufian dogs, though Canaan dogs are much larger (and the Arabian dogs appear so) than the 11-16kg weight range of Natufian dogs (Tchernov and Valla 1997).

The depictions also indicate that dogs were utilized as important hunting tools by Pre-Neolithic populations for a variety of prey in diverse environments, though they appear to be used differently in each. Our data clearly show that the number of hunting dogs used and the likely hunting strategies employed correspond closely with the topography and environment at each site. At Shuwaymis the layout of the wadi provided ample opportunity to trap prey with the use of hunting dogs and rock art panels frequently show large groups of hunting dogs with up to 21 individual animals. In the more open environment surrounding the paleolakes of the Jubbah oasis, dogs were presumably used in smaller numbers to ambush prey at watering holes. Here, dogs are generally depicted individually or in small groups.

Hunting dogs can be an important factor in minimizing subsistence risk and maximizing hunting returns in unpredictable environments (Mitchell 2008; Perri 2014; 2016), such as those with extreme seasonal fluctuations. Perri (2016:1175) suggested increasing numbers of prehistoric dog burials reflected increasing use and importance of hunting dogs as adaptive technology in seasonal hunting regions. The depiction of large numbers of dogs in both Shuwaymis and Jubbah may indicate a

similar importance of Pre-Neolithic hunting dogs in the Arabian Peninsula, and particularly in areas of high-risk seasonal fluctuations.

The hunting dog depictions at Shuwaymis and Jubbah represent the earliest evidence of dogs on the Arabian Peninsula, predating the first faunal evidence for dogs by thousands of years. Depictions of leashes, the earliest known from the archaeological record, demonstrate how early Holocene hunters controlled their dogs, potentially utilizing different dogs for different tasks. This suggests complex dog-assisted hunting strategies on the Arabian Peninsula began in the Pre-Neolithic and may have been a critical part of successfully repopulating the interior after a long hiatus. In the future, archaeologists should consider the effects of hunting dogs on cost-benefit analyses and prey choice models (Koster 2008; Koster and Tankersley 2012; Perri 2014; 2016). For example, the targeting of male prey species may be less about human intentionality of conserving females and more about innate prey choices by hunting dogs. Similarly, high numbers of young or very old animals may be related to hunting dogs targeting weaker individuals.

Our study clearly highlights the potential of rock art in providing evidence for the control and use of early domestic dogs, as well as providing phenotypic information such as behavior and coat color. The prehistoric hunting scenes of Jubbah and Shuwaymis also reflect hunting strategies, such as the leashing of only a few selected dogs, and the targeting of prey for which hunting dogs have been documented as most useful in the ethnographic record. The prehistoric documentation of hunting strategies, which survives in the rock art, therefore provides an ideal dataset to evaluate ethnographic datasets. Moreover, the ancestry and distribution of ancient dogs is key in our understanding of the population dynamics that underpinned the early Holocene occupation of the Arabian interior. More fieldwork is now needed to identify Pre-Neolithic and early Neolithic sites throughout the Arabian Peninsula and to secure early Holocene domestic dog remains. Comparative ancient DNA analyses, for example between Pre-Neolithic Arabian dogs and Natufian dogs, may further clarify the relationship between the Levant and interior Arabian Peninsula populations and provide insight on the possibility of dog domestication on the Arabian Peninsula.

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