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Desert kites in the Negev desert and northeast Sinai: Their function, chronology and ecology

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ABSTRACT

Desert kites are stone-built, funnel-shaped installations comprising two long and low stone-built walls ('arms') converging on an enclosure or pit at the apex. They are found in the deserts of the Near East, and are generally accepted as representing game traps to catch herds of wild ungulates. Their chronology is debated but some desert kites appear to have functioned as early as the 7th millennium BC. The largest number of these structures is recorded in the deserts of eastern Jordan where they often form chains of up to 60 km long. In contrast, in the Negev (Israel) and Sinai (Egypt) deserts, the desert kites are few in number and occur as small, individual installations.

This paper presents the results of archaeological surveys and excavations of 16 desert kites from the Negev desert and northeast Sinai. We present radiocarbon dates, infrared stimulated luminescence ages and chronology of material culture to show that desert kites in this region were established in the late 4th–early 3rd millennia BC and ceased to function by the mid-2nd millennium BC. The size, shape and location of the desert kites fits the physical conditions of the terrain and also the ethology and ecology of the prey species hunted.

1. Introduction

Desert kites (also termed hereafter, kites) are ancient funnel-shaped installations comprising long, low walls built of local field stones, with two long sides ('arms') converging on a stone-walled enclosure or pit at their apex (Figs. 1a,b). These installations were first identified by RAF pilots flying over the eastern desert of Jordan after the 1st World War who coined the term 'desert kites' due to their shape as seen from the air (Maitland, 1927; Rees, 1929). To date, kites are known from the desert regions of Jordan (Betts and Helms, 1986; Betts, 1998; Helms, 1981; Helms and Betts, 1987), Syria (Castel et al., 2005; Kennedy and Freeman, 1995; van Berg et al., 2004), Saudi Arabia (Adams et al., 1977: 35–36; Ryckmans, 1976), Israel and the Sinai Peninsula, Egypt (Avner, 1972; Meshel, 1974, 2000; Perevolotsky and Baharav, 1991).

Two interpretations of the desert kites were initially offered by the RAF pilots; Maitland (1927) suggested they served as hunting traps, while Rees (1929) explained them as devices used in the past to corral and defend domestic herds in times of danger. In an editorial note to the latter publication, Crawford (1929: 408) referred to a description by the 19th century traveller Burckhardt (1831) recounting a gazelle hunt, probably in Syria, using such an installation. The hunting interpretation proposed by Maitland, was adopted by Dussaud (1929: 151) and later by Field (1960: 129–131), but was surplanted by the herd corral theory which gained wider acceptance (Eissfeldt, 1960; Kirkbride, 1946; Ward, 1969: 208; Yadin, 1955: 5–10).

In the early 1970s, following the discovery of desert kites in the southern Negev and northeast Sinai, two researchers argued for a return to the hunting trap theory (Avner, 1972; Meshel, 1974). They based themselves on archaeological data, animal ethology as well as on the vivid, eye-witness accounts of Aharoni (1946: 31–33), Burckhardt (1831: 220–221) and Musil (1928a: 26–27), that described hunting of Persian goitered gazelle (*Gazella subgutturosa*) using such installations. These and other narratives, such as that recounted by the early 17th century traveller Teixeira (cited in Legge and Rowley-Conwy, 2000: 443), described huge gazelle herds being hunted in Syria using funnel-shaped structures with diagonal stone-built walls, or lines of parallel wooden poles hung with rows of rag pennants, that ended in an enclosure. In all instances, the gazelle herd was driven into the broad opening of the funnel along a passage created by the walls/poles, up to the walled

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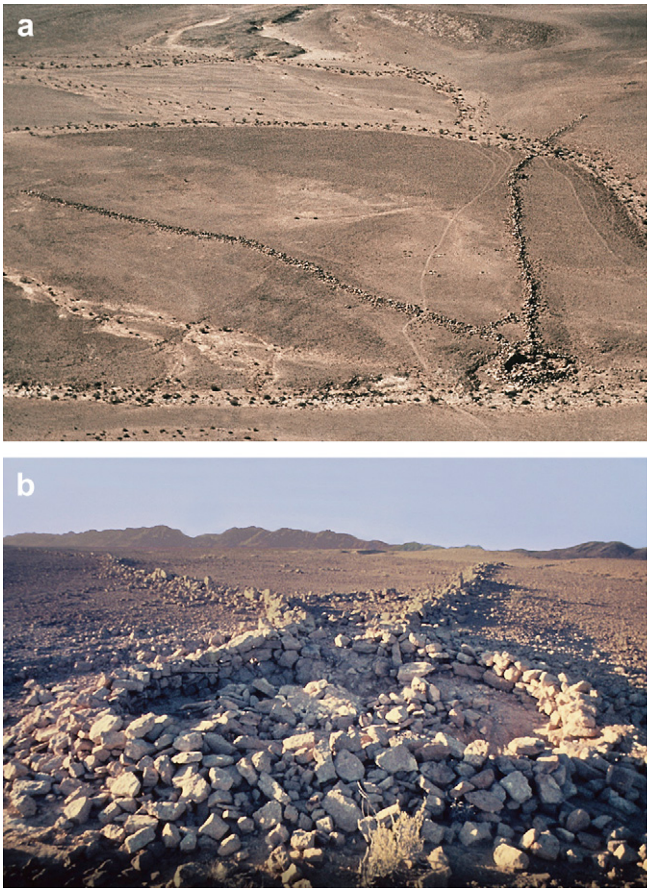

Fig. 1. (a) Jebel Hamra desert kite, southeast Sinai. (b) Close-up showing the pit of the Jebel Hamra desert kite with intersecting walls.

enclosure at the apex which was surrounded by pits, where they were trapped and killed. It should be noted that there is little if any evidence from the Jordanian deserts for such 'killing pits' surrounding the desert kites (e.g. Betts, 1998). In Syria, Wright (1895) mentions 40–50 gazelles slaughtered at a time in one killing pit, Musil (1928b: 4) notes that 50–60 gazelle were killed in this manner in half a day; Burckhardt (1831) describes the killing of hundreds of gazelles, while Aharoni (1946: 31) documents 500–600 animals slaughtered in a single kite.

During the last 80 years several other theories have been offered to account for the function of desert kites, including a role as Roman defensive lines against the Parthian or Sassanian cavalries (Poidebard, 1934: 77–78, 191–196), Neolithic corrals for capturing wild goats and cattle undergoing domestication (Echallier and Braemer, 1995), installations for channelling run-off water (Helms, 1976: 19–20) and even as cult installations (Eddy and Wendorf, 1999: 180). However, the hunting interpretation has gained wide acceptance (Betts and Helms, 1986; Betts, 1998; Betts and Yagodin, 2000; Castel et al., 2005; Fowden, 1999; Helms, 1981; Helms and Betts, 1987; Hershkovitz et al., 1987; Meshel, 2000; Perevolotsky and Baharav, 1991; Rosen and Perevolotsky, 1998; van Berg et al., 2004) and is the paradigm guiding this paper.

Extensive research on desert kites has been carried out in eastern Jordan where their number has been estimated as over 1000 by Helms (1982: 101) or as 500–600 by Echallier and Braemer (1995: 36). In the Sinai Peninsula (Egypt), some 50 such structures are known, concentrated in the south, as well as four in the northeast (Haiman, 1986; Meshel, 1974, 2000). Research on the southern Sinai desert kites has focused on their association with pasture areas (Perevolotsky and Baharav, 1991). Despite several publications on kites of the southern Negev desert (Israel) and northeast Sinai (Egypt) (Avner, 1972; Avni, 1994; Haiman, 1986; Meshel, 1974, 2000) they have not been studied in detail. New investigations are currently in progress on several Negev kites, but only preliminary results are available (Bar-Oz et al., 2009).

In this paper we present a brief survey of the 16 desert kites known to date from the Negev desert and northeast Sinai Peninsula (Fig. 2), as well as principal results of archaeological excavations of two such structures. We present radiocarbon dates and infrared stimulated luminescence (IRSL) ages from the excavated kites and discuss regional variation in kite function, location and chronology. The environmental context of the kites is discussed in relation to the ethology of the probable prey species targeted.

2. Kites in the Negev desert and northeast Sinai Peninsula

A total of 12 desert kites are currently known from the Negev desert that together with four kites situated in northeast Sinai just over the Israeli–Egyptian border, share the same ecological niche (Fig. 2). An additional kite has recently been discovered at Ein Gedi in the Judean desert (Hadas, in press) (Fig. 2) and represents the northern-most desert kite in Israel. With this kite, the total number of these structures in the Negev–northeast Sinai is 17, which is a very low density given the size of the Negev – an area of ca. 13,000 sq km – especially when compared to the quantity of desert kites in eastern Jordan, Syria or even in southern Sinai.

2.1. Negev Highlands

Five desert kites are located in the western Negev Highlands (Nos. 1–5) (Fig. 2). The area is arid, receiving ca. 80–100 mm average rainfall per annum, while the annual potential evaporation is ca. 2700 mm. The vegetation is predominantly Irano–Turanian with some Mediterranean species. It is fairly dense in the wadis but also grows on the north-facing slopes (Danin, 1983).

Two kites (Nos. 1–2), only 1 km apart, were found on flat hilltops just above Nahal Horsha, a broad wadi used today by wild herbivores for grazing. They open to the north with their pits lying to the south on a rocky, steep slope ca. 5–10 m below the hilltop (Haiman, 1986: Nos. 145, 188). Additional two kites, also 1 km apart, are located 10 km to the south, just over the Sinai border. They are both built on flat terrain, on trails leading to an important perennial water source – 'Ein Qadis. One kite (No. 3) opens to the north with its pit below a 3 m step in the rock (Haiman, 1986: No. 370), the other (No. 4) opens to the northeast, ending on a steep slope and the pit is below a 5 m step in the rock (Haiman, 2007: No. 116). Desert kite No. 5 was built on a hillside and opens to the southeast (discovered by the late Z. Shaham; Meshel, 1974: 129–130; Meshel, 2000: 121–122).

2.2. Ramon Crater

Two desert kites are found within the Ramon Crater (Fig. 2 – Nos. 6 and 7), a hyper-arid area, much poorer in vegetation than the Negev Highlands (Danin, 1983). These installations are smaller than those of the Negev Highlands. In the Pitam kite (No. 6, Rosen, 1994: Site 168) the pit is built on the steep side of a wadi, while the Harut kite (No. 7, Avni, 1994: 147–148), is built in a wadi and utilizes a natural rock step, 2 m deep, for the pit whose walls are not preserved. The environment behind these kites is almost devoid of vegetation and it is hard to imagine, even given wetter conditions in the past, why this location was chosen for kite construction. However, both kites cut ancient paths. Kite No. 6 is an ancient trail used by both people and animals (today mainly by re-introduced

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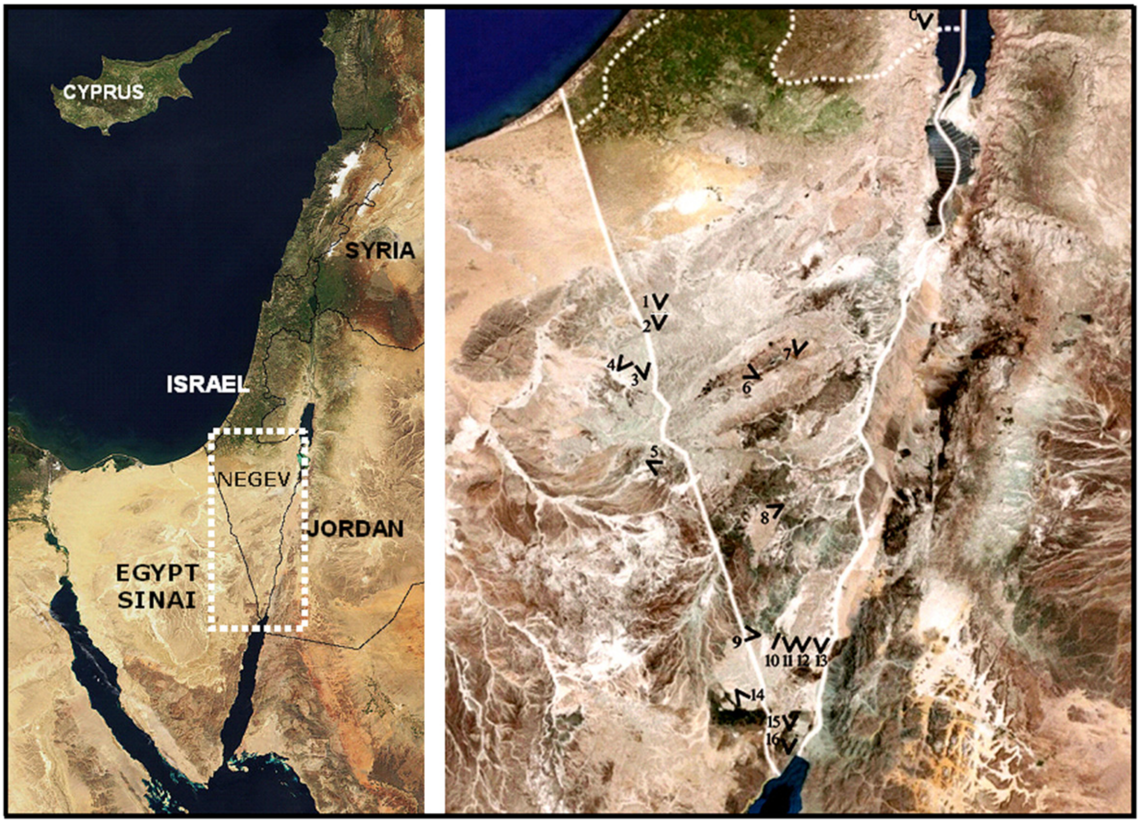

Fig. 2. (Left) Map showing location of the research area. (Right) Map showing location of desert kites in northeast Sinai, the Negev and Judean deserts. Kite numbers correspond to those in the text. *Judean Desert*: (0) Ein Gedi; *Negev Highlands and northeast Sinai*: (1) Nahal Horsha North, (2) Nahal Horsha South, (3) SW of Qa-el-Naqab at the foot of Jebel Abu Ruta (Sinai), (4) SW of Qa-el-Naqab just north of Jebel Hamra (Sinai), (5) south of Qa-el-Naqab (Sinai); *Ramon Crater*: (6) Pitam, (7) Harut; *southern Negev and northeast Sinai*: (8) Nahal Eshel, (9) Mizpe Sayarim, (10) unfinished kite, northwest of Givat Samar, (11–12) Samar West kite pair, (13) Samar East, (14) Jebel Hamra adjacent to Qadesh Barnea (Sinai), (15) Giv'at Shehoret, (16) Har Shahmon.

onagers) while for kite No. 7, the trails seem to be used only by animals. This phenomenon is also observed in two other desert kites that are discussed below.

2.3. Southern Negev–northeast Sinai

The remaining nine desert kites (Nos. 8–16) are located in the southern Araba Valley and in the Sinai, northwest of the town of Eilat (Fig. 2). This area is the most arid in the Negev, with 30–50 mm annual rainfall on average in the northern part, and only 24 mm in the southern part (Ginat and Shlomi, 2009), while potential annual evaporation is 3600 mm. The Saharo–Arabian vegetation that characterizes this region is restricted to the wadi beds (Danin, 1983).

The Nahal Eshel kite (No. 8, Avner, 1997: 133; Bar-Oz et al., 2009), and that in Sayarim West (No. 9, found by Y. Qishon and T. Kahana; listed in Avner, 1980), are both built on the edge of a plateau with almost no vegetation cover. Like Nos. 6 and 7, they cut paths that were used in the past by both animals and people while today they are only used by animals. Both kites are built on steep slopes, an important feature that will be discussed below.

A group of four desert kites is located in the southern Araba near Kibbutz Samar (Nos. 10–13). The installations are all built on flat land intersected by shallow, narrow wadis. They open to the north towards an area with little vegetation and dispersed acacia trees. However, 2 km to the north is the southern extent of the acacia savannah of 'Ein Ghadhian (Yotvata oasis), a locale which serves today as an important grazing area for some 200 gazelles. Given somewhat moister climatic conditions in the past, this rich pasture area may have extended further south and lain closer to the Samar kites than at present. This grouping includes an unfinished kite (No. 10), with only one arm ca. 60 m long, running from north to south

Fig. 3. Aerial photograph showing pair of linked desert kites at Samar West (bisected by numerous recent roads and paths). The desert kite entrances are marked with white arrows; the stippled circle shows where the kite arms almost touch.

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and ends on the edge of a terrace, 2 m above the wadi bed (Avner, 1972). Two additional desert kites in this group (termed Samar West, Bar-Oz et al., 2009) form a linked pair, enclosing an area 260 m wide (Nos. 11 and 12) (Fig. 3) and are somewhat reminiscent of the kite "chains" of eastern Jordan, though on a far smaller scale. They were first discovered by E. Anati in 1956 (unpublished) and later included in the Eloth Survey by Rothenberg (1967: 290). The two installations are almost connected at the tip of one arm to form a ';W', but there is a gap at this point of ca. 10 m between them which is a trail used today by gazelles (Fig. 3). The pits of both desert kites were built in shallow wadis ca. 1.5 m deep. The fourth kite, termed Samar East (No. 13), was excavated by two of the authors and is located 1 km to the east (Avner, 1972: 222) and is overlain by a later habitation unit (Figs. 4a–d; and see discussion below).

The kite near Jebel Hamra (No. 14) in eastern Sinai, 25 km northwest of Eilat (Fig. 1a), was discovered by U. Avner, H. Panet and A. Nussbaumer (Avner, 1972, also mentioned by Rothenberg, 1979: Fig. 21). It is located on a flat area intersected by shallow, narrow wadis, with little vegetation. However, the installation opens towards wadis situated 1 km to the south which are broader and richer in vegetation. This desert kite was measured and excavated by Eddy and Wendorf (1999: 173–180). The kite's arms are 137 and 125 m long and the pit is built in a wadi and is ca. 1.7 m deep (Fig. 1b). Excavation of the kite pit provided three radiocarbon dates falling in the late 4th millennium–early 3rd millennium cal BC (Table 1). The excavators (1999: 180) did not identify the installation as a kite but suggested that it had served cultic purposes.

The kite of Giv'at Shehoret (No. 15), is very small (Avner and Naor, 1978). The arms are only 20 and 25 m long. It is built on a steep alluvial slope with the pit built at the bottom in the wadi bed. The entrance opens towards a broad wadi, 1 km to the north, where gazelles still graze today. Since the width of the opening between the arms is only 17 m, it seems that this kite was never finished.

The kite of Har Shahmon (No. 16, Avner, 1980) (Figs. 5a–e) is built on the southern slope of a topographic "saddle". The findings from the excavation of this desert kite are presented below.

3. Excavation and dating of two Negev desert kites

During the 1980s and 1990s, the Samar East (No. 13) and Har Shahmon (No. 16) desert kites were excavated by the two senior authors. Aside from documenting the architecture and extent of the structures, the primary goal of these excavations was to date their initial construction and termination of use, which has been one of the major challenges facing research on kites throughout the Levant (Betts, 1998; van Berg et al., 2004). This is due to the rarity of organic matter that may be used for radiocarbon dating and the paucity of *in situ* archaeological finds. Even when the latter are

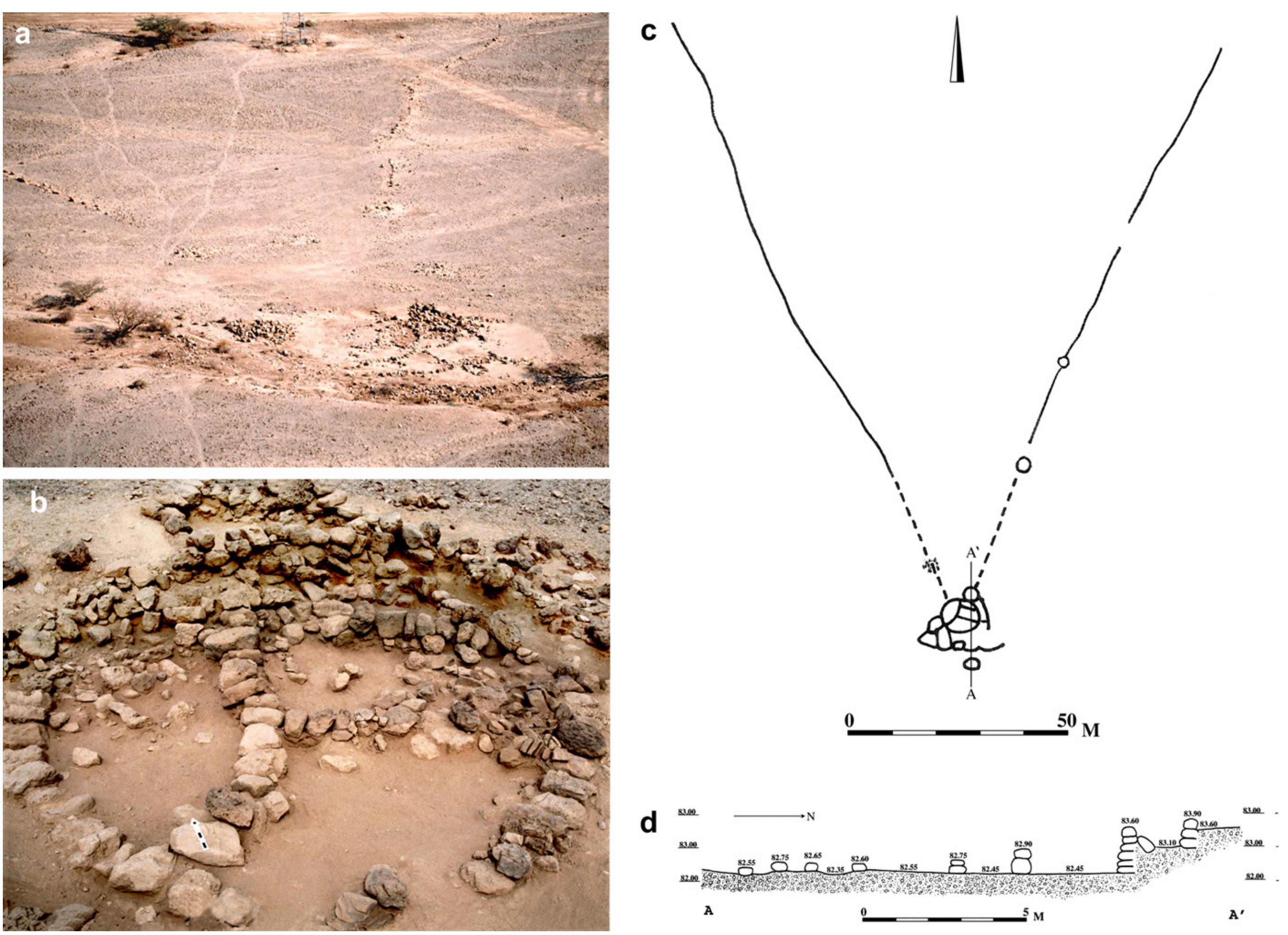

Fig. 4. Samar East desert kite: (a) aerial view. (b) Close-up showing the low, inner intersecting walls in the pit. (c) Ground plan showing location of section through kite. Numbers on the plan represent heights. (d) Section A–A' through the kite pit.

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Table 1
Summary of radiocarbon (^{14}C) dates and IRSL ages from the Negev and northeast Sinai desert kites.

Desert kite	Material	Lab No.	^{14}C date BP	Calibrated date BC	Average & error BC	Context
(a) Radiocarbon dates						
Samar East	Charcoal	Rt-2716	4080 ± 25	2696–2567	2630 ± 65	Hearth-habitation unit
Samar East	Charcoal	Rt-2715	3775 ± 40	2310–2118	2215 ± 95	Hearth-habitation unit l
Samar East	Charcoal	Pta-3627	3940 ± 60	2581–2277	2430 ± 150	Top of living floor-habitation unit
Har Shahmon	Charcoal	Rt-1956	3220 ± 50	1615–1411	1515 ± 100	Below lowest burial
Har Shahmon	Charcoal	Rt-1954	585 ± 25	1303–1366[a]	1335 ± 30[a]	From uppermost burial
Har Shahmon	Charcoal	Rt-1955	375 ± 50	1443–1636[a]	1540 ± 100[a]	From uppermost burial
Jebel Hamra[b]	Charcoal/burnt bone	Gd-7953	4420 ± 80	3341–2907	3124 ± 215	Kite pit
Jebel Hamra[b]	Charcoal/burnt bone	Gd-7948	4530 ± 60	3375–3079	3225 ± 150	Kite pit
Jebel Hamra[b]	Charcoal/burnt bone	Gd-11317	4390 ± 110	3370–2860	3115 ± 255	Kite pit
Wadi Jenah-Wadi Marra[c]	Charcoal	Rt-1850	3750 ± 45	2280–2040	2160 ± 120	Kite pit
Desert kite	**Material**	**Lab No.**	**Age (before 1996)**	**Age (BC)**	**Context**	
(b) IRSL ages, also shown as Age (BC), rounded to the nearest 10 years (recalculated from Table 2)						
Samar East	Sediment	SAM-1	4620 ± 570	2620 ± 570	Infill between stones in pit	
Samar East	Sediment	SAM-2	5000 ± 200	3000 ± 200	Under a stone at the base of pit	
Har Shahmon	Sediment	SHAH-1	3710 ± 170	1720 ± 170	Under a stone at the base of pit	
Har Shahmon	Sediment	SHAH-2	3090 ± 60	1090 ± 60	Base of wall postdating pit	

Notes: ^{14}C dates from the studied desert kites were measured in Pretoria (Pta) and the Weizmann Institute (Rt).
[a] = AD.
[b] The Jebel Hamra dates were measured in Gliwice (Gd) and were published in Eddy and Wendorf (1999: 278–281; Table 17-1: 173–178). All dates were calibrated using OxCal 4.0, errors given with ±2 sigma.
[c] Segal and Carmi (1996: 103).

recovered, they can seldom serve as *fossile directeurs* since their use in the region often spans long periods of time.

As a solution to this problem, we have applied here luminescence methods to establish a numerical chronology for desert kites since they date sediments associated with archaeological remains. In addition, radiocarbon dating was applied to date habitation units or burials overlying the kites, and these offer minimum ages for the end of kite use.

3.1. Infrared stimulated luminescence (IRSL) dating

The luminescence methods (e.g. Aitken, 1998) date the last episode in a mineral's history of exposure to sunlight and use signals that are acquired by mineral grains such as quartz or feldspar from exposure to natural environmental radiation. The magnitude of the infrared stimulated luminescence (IRSL) signal is related to the total radiation dose that the sample received and hence to its age. Since the IRSL signal is sensitive to sunlight, exposure to the sun during transport and deposition of the sediment will reduce any previously acquired IRSL signal to zero ("bleaching" the signal), and after burial it will grow again.

Human activities during site construction and use do not necessarily result in sedimentation. However, once a site is abandoned, sediments accumulate and fill the interstices between stones making up the walls and installations. This sediment is often wind-blown, comprising both local and far dust sources, and is expected to have been sufficiently exposed to sunlight. The two kites, Samar East and Har Shahmon that were selected for IRSL dating following excavation, are both built on abandoned alluvial fans comprising gravel onto which Reg soil developed. To constrain the age of the structures, two types of sediments were selected: (1) sediments underlying the stones used for construction. These surface sediments were exposed to the sun prior to placement of stones over them, providing a maximum luminescence age for the initial construction of the structure; and (2) trapped sediments filling the spaces between construction stones, that accumulated after construction or abandonment of the installation (e.g. Porat et al., 2006). These would provide a minimum age for the use of the desert kite.

Two samples were collected from each kite (Online Appendix A): at both sites one sample was taken from under the lowermost course of stones in the walls of the pit (SAM-2; SHAH-1). In Samar East the second sample was collected from the infill between the pit stones (SAM-1), whereas in Har Shahmon the second sample was the infill of a wall postdating the pit (SHAH-2). The samples were placed directly in a black bag under an opaque cover without exposure to sunlight and all further laboratory work was carried out under subdued orange-red light. Alkali feldspars (KF) were selected for measurements as the quartz from the Har Shahmon site proved to have poor luminescence properties. KF were separated from the sediments using standard procedures (Porat, 2002). The equivalent dose (De) was determined using the single aliquot added dose protocol (Duller, 1994) on six to 12 aliquots from each sample. Dose rates were calculated from the concentrations of the radioisotopes in the sediment and the extracted feldspars (Table 2). Averages and errors were calculated using the central age model. Ages were rounded to the nearest 10 years and are also given in years BC (Table 1). To facilitate comparison between the radiocarbon and IRSL ages, both are presented as age ± error in years BC, with the radiocarbon dates rounded to the nearest 5 years (Table 1).

3.2. Excavations

The *Samar East kite* (Figs. 4a–d) (No. 13), was excavated in three, week-long seasons; two seasons by Avner in 1982 (Avner, 1982) and one in 1996 by Holtzer and Avner (Holzer, 2002). Prior to excavation, it was clear that a later habitation unit had been built on top of the pit. This was attested to by additional walls around the pit and missing sections in the arms near the kite's apex, most probably the result of secondary use of stones for construction of the overlying habitation. In the first season, the 10–15 cm thick upper sediment crust was excavated all over the habitation unit to the top of a living level. This deposit contained artifacts, including flint debitage, pottery sherds of hole-mouth jars, some Red Sea shells, shell beads, fragments of ostrich egg shell, animal bones and one square-sectioned copper awl (113 mm long and 4 mm thick). All these finds were associated with the habitation unit. In the following excavation seasons, the

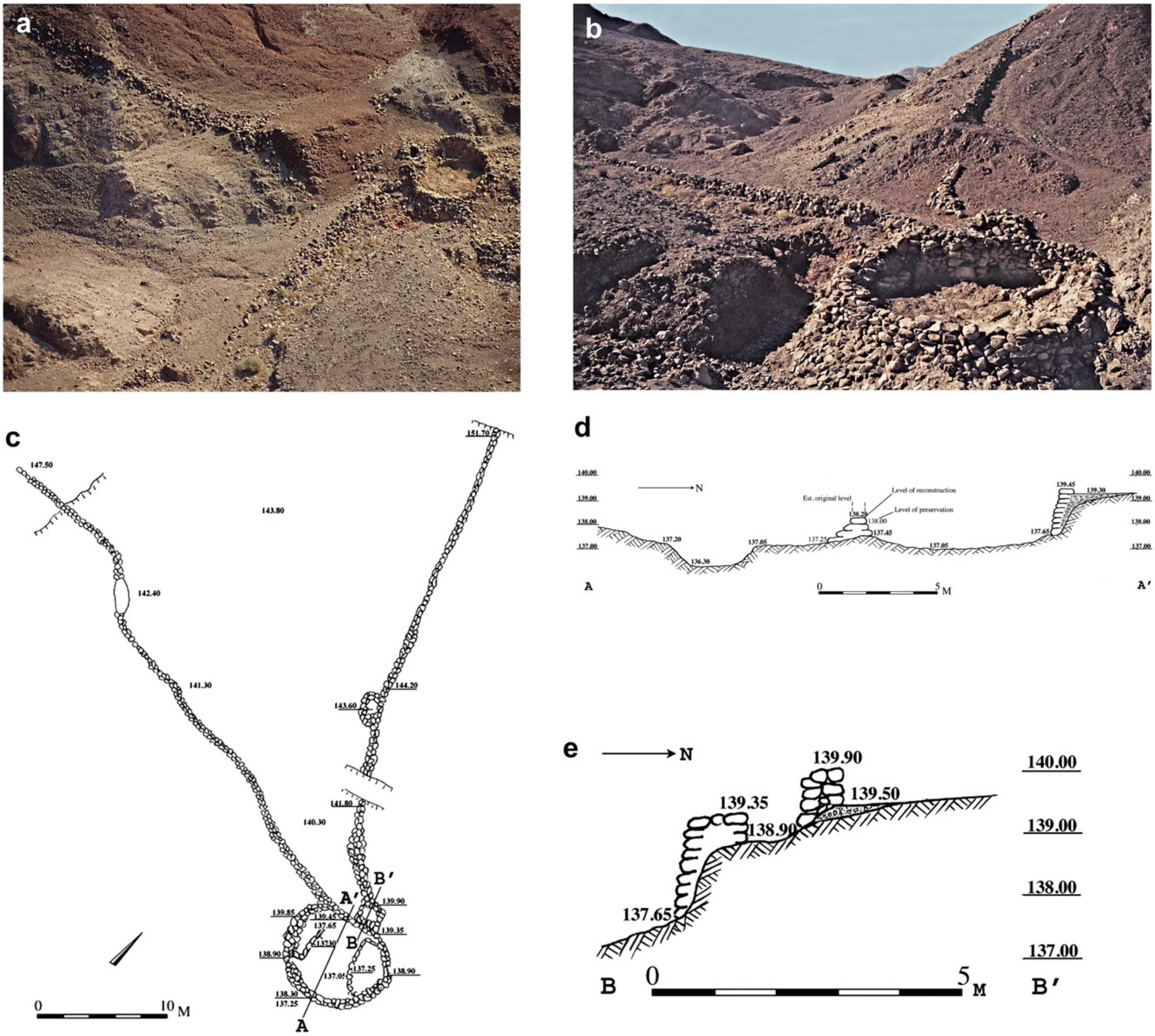

Fig. 5. Har Shahmon desert kite: (a) aerial view. (b) Close-up showing the pit encircled by stone walls restored to establish their original height. (c) Ground plan showing location of two sections through the kite. (d) Section A–A′. Numbers on the section represent heights. (e) Section B–B′ through the cell adjacent to the kite pit. Numbers on the section represent heights.

occupation level itself was excavated over the entire area of the habitation unit down to virgin soil (solid, rich with gravel and small rocks, reached at a depth of 25–80 cm from the surface). The occupation level deposit comprised fine silt mixed with varying amounts of ash and with rock debris from the walls. Aside from pottery sherds and flint debitage, notable finds were three micro-lunates and two olive stones. All these finds belong to the habitation unit and none of these items could be safely attributed to the underlying kite.

The stratigraphic situation clearly indicates that the habitation unit post-dates the kite. The stone-built pit at the apex of the kite, 6 m across, was situated in a small wadi bed, 1.2 m lower than the surrounding landscape. The pit's step was preserved to its full height (1.2 m), while in most of the perimeter, only one course of stones remained ca. 30 cm high. The inner area of the pit was intersected by three low curving walls, with heights preserved up to 50 cm (Fig. 4b), a phenomenon documented in other Negev desert kites (see below).

The *Har Shahmon kite* (Figs. 5a–e) (No. 16) is located at the northeast foot of Mount Shahmon, just north of Eilat. It is situated in a saddle between the mountain slope and a small hill (Fig. 5a); the arms open northward toward the wide Wadi Roded, rich in acacia trees and other plants grazed by gazelles.

The kite was excavated in two short seasons, in 1993 and 1994 by Holzer and Avner (1998; Holzer, 2002). It comprises two arms, respectively 42 and 50 m long, converging on a round enclosure. In the first stage of the excavation a large amount of stone debris was removed from the built pit (8 m in diameter), and a north–south trench excavated, 1 m wide and ca. 1 m deep, down to bedrock. The dry-stone walls comprising the arms had collapsed. However, following excavation, the arms were restored using the existing stones in order to assess their original height which was up to 60 cm. The eastern arm was constructed on a nature rock outcrop that protrudes above the ground surface, while the southeastern arm meets the mountain slope (Figs. 5a,b).

The pit was 2 m deep and built in a wadi. The pit wall was preserved on its northern end to its full height ca. 2 m, i.e. at the drop, and ca. 1.5 m around the remaining perimeter (Figs. 5b–e). The amount of stone debris indicates that the latter wall was nearly 1 m higher. The kite had been built at the base of a natural step in

Table 2
Infrared stimulated luminescence ages for the desert kites Samar East (SAM) and Shahmon (SHAH).

Sample	Location	Burial depth (m)	Grain size (μm)	U sed (ppm)	Th sed (ppm)	K sed (%)	K KF (%)	Dose rate (Gy/ka)	De (Gy)	Age (years before 1996)
SAM-1	Infill between stones in pit	0.5	149–212	1.02	2.00	0.40	4.21	1.31 ± 0.05	6.2 ± 0.9	4620 ± 570
SAM-2	Under a stone at the base of pit	0.5	149–212	1.23	1.88	0.23	5.18	1.25 ± 0.05	6.16 ± 0.2*	5000 ± 200*
SHAH-1	Under a stone at the base of pit	1.0	177–212	1.97	3.10	2.50	6.12	4.15 ± 0.16	8.4 ± 0.4	3470 ± 160
$SHAH\text{-}1_M$							6.7	4.18 ± 0.16	9.5 ± 0.6	3980 ± 280
								Weighted	Average	3710 ± 170
SHAH-2	Base of wall postdating pit	1.5	177–212	2.58	4.18	1.90	5.6	3.48 ± 0.07	8.9 ± 0.3	3090 ± 100
$SHAH\text{-}2_M$							6.3	3.52 ± 0.07	8.8 ± 0.2	3090 ± 60
								Weighted	Average	3090 ± 60

Notes: Samples were collected and measured in 1996. De was determined on alkali feldspar separated from the sediment, using the infrared stimulated luminescence (IRSL) signal and the single aliquot added dose protocol (Duller, 1994). Dose rates were calculated from the concentrations of the radioelements U, Th and K, and from the contribution of the cosmic dose. For sample SHAH-1 the cosmic and gamma dose rate was also measured in the field using a gamma scintillator. Water contents were estimated at 2 ± 0.5%. An alpha efficiency value of 0.2 ± 0.05 was used for age calculations. Average De and errors were calculated using the central age model. * – the lowest De obtained for this sample out of 6 measurements, used in age calculations. M – the alkali feldspar fraction after removing mica flakes by passing the sample on an rough surface. The De was re-determined using the same protocol and the K-contents re-measured. As the two sets of measurements provided average De values within errors, the two data sets were combined.

the bedrock and was constructed to exploit the natural topography; abutting a saddle through which animals passed from Wadi Roded situated to its north.

At the bottom of the excavation of the pit, within the first 4 cm above bedrock, two olive stones were found and several coarse, handmade and poorly fired ceramic sherds (Online Appendix B). Further excavation of the entire pit area revealed two low, curving walls that intersected it and three later burials-one on top of the other. An additional, even later intrusive burial was found during excavation of the stone cell located adjacent to the apex, just above the drop into the pit.

4. Discussion

4.1. Architecture

The Negev–northeast Sinai desert kites share many characteristics suggesting that they should be considered a single group, corresponding to ‘Type E’ kites as defined by Helms and Betts (1987). These are small and occur as isolated installations with only one instance of a kite pair (Nos. 11 and 12, Fig. 3). All are built of locally occurring field stones and have a similar layout resembling a keyhole (Fig. 1a). Located at the apex is a circular-oval enclosure (ca. 6–10 m in diameter), that is built up to ground level from a natural drop such as a cliff edge, a step in the bedrock or a wadi (Fig. 1b). Converging onto the enclosure are two diagonally oriented stone-built arms. Their length varies between kites, ranging from tens of meters to a few hundred metres, depending upon the local topography. Despite the observed variation in the height of the walls, none were more than 60 cm high. The apex enclosure in which the animals were trapped consistently lies at a low point in the topography. The drop down into the pit can be as low a 1.7–2 m (Nos. 7 and 14), 3–5 m as in Nos. 3 and 4, or as high as 10 m as in the cliff drop found in kites Nos. 1 and 2. In kites located in open, relatively flat landscapes (e.g. Nos. 12–14), the sunken pit at the apex would not have been discerned by animals until they had entered it, with the enclosure entrance appearing as a gap in the walls of the arms (Fig. 6). In other instances, kites (such as Nos. 6, 8, 9 and 16) were constructed on steep slopes using a natural drop in the topography such that the pit would only have been visible to the animals once inside the funnel. However, they could not avoid entering it due to the steep incline on which the kite arms were built, their speed while running and probably by being impelled forward by animals running behind.

Two additional features deserve attention. One is the presence of short intersecting walls within the pit (e.g. No. 13 – Fig. 4b; No. 14 – Fig. 1b), a feature that has been observed in several kites. In addition to the limited diameter of the pit, these intersecting walls may have been constructed in order to slow the animals down and so prevent them from gaining sufficient speed to leap over the pit wall. The second feature is the presence of small stone-built cells, ca. 1 m across, situated beside the entrance of some of the pits (Nos. 13, 14 and 16 – Fig. 5c). These cells were probably constructed as a hiding place for a ‘gate-keeper’ whose function was to prevent animals from turning around and running back into the funnel, or for hunters responsible for killing the trapped animals.

4.2. Chronology

One of the main objectives of this study was to date the duration of the Negev kites. To this end, two radiometric dating methods (radiocarbon of charcoal and IRSL of associated sediments) were applied, along with examination and analysis of material culture associated with the kites or overlying constructions, burials (tumuli) and habitation units. It should be borne in mind that despite the large standard errors for the IRSL ages from Samar East,

Fig. 6. Samar West desert kite taken from an ungulates view-point from the entrance looking towards the pit. Note that there is an illusion of a gap in the walls where the pit lies ahead.

the internal consistency between the IRSL ages and radiocarbon dates has led us to accept the IRSL ages as reliable (Tables 1 and 2).

The IRSL ages for the Samar East kite (No. 13) are analytically sound. Sample SAM-2, from under a stone at the base of the pit, had a large scatter, probably due to mixing with older material from the underlying terrace on which the pit was built. The youngest age calculated from this sample, 5000 ± 200 years BP (3000 ± 200 BC; Table 1), constrains the construction of this kite to the late 4th–early 3rd millennia BC (Early Bronze Age I–II). Sample SAM-1, from infill between stones used in the construction of the walls of the pit, gave an IRSL age of 4620 ± 570 years BP (2620 ± 570 BC–Early Bronze Age II–III) (Table 1).

Three radiocarbon dates on charcoal recovered from the habitation unit overlying the Samar East kite, fall between 2630 ± 65 and 2215 ± 95 years cal BC (Table 1), while cultural finds recovered from this habitation span a lengthy time period; the pottery sherds represent hole-mouth jars which span the 5th–3rd millennia BC (i.e. Late Neolithic–late Early Bronze IV) (Avner, 2002: 66–68, and references therein). Likewise, the single square-sectioned copper awl recovered here, spans the 4th–3rd millennia BC (Chalcolithic–Early Bronze Age; Avner, 2002: 59 and references therein). Of the flint artifacts, the micro-lunates recovered from the habitation unit first appear towards the end of the Late Neolithic and, according to Rosen (1997: 41, 47), may continue into the Early Bronze Age II (early 3rd millennium BC). The latter contention awaits further confirmation (Avner, 2002: 19, Note 19 with references).

Overall the IRSL ages for the Samar East kite show good internal consistency despite large standard errors and agree with the radiocarbon dates of the overlying habitation unit. The radiocarbon dates, IRSL ages and archaeological artifacts indicate that the kite was used between ~ 3000 and ~ 2600 years BC while the common date for the radiocarbon dates and artefacts for the overlying habitation unit is ~ 2600–~ 2000 BC.

For the Har Shamon kite, the IRSL age from the base of the pit wall (sample SHAH-1) is 3710 ± 170 years BP (1720 ± 170 BC) which is a minimum date for the construction of the kite. However, the pottery sherds and olive stones (Online Appendix B) found in fill within the pit just above the bedrock and are associated with the construction and/or use of the kite, are slightly earlier, having been attributed to the 4th millennium BC (Chalcolithic) (Ram Gophna pers comm., 2001; cited in Holzer, 2002). Given that the IRSL is a minimum age may account for the lack of concordance.

Sample SHAH-2, from the base of a wall postdating the construction of the pit, is 3090 ± 60 years BP (1090 ± 60 BC; Table 1). This supports the three radiocarbon dates on charcoal for intrusive burials overlying the desert kite. The lowermost burial gave a radiocarbon date of 1515 ± 100 cal BC while the uppermost burial gave two radiocarbon dates of 1540 ± 100 and 1335 ± 30 cal AD (Table 1). The radiocarbon and artifactual evidence from the intrusive burials show good correspondence and indicate that at least from ~ 1500 cal BC onwards the kite ceased to function as a hunting trap.

The chronological framework for the two Negev kites studied here can be compared with the scanty radiocarbon determinations available from other desert kites in the region. Three radiocarbon dates on charcoal/burned bones retrieved from inside the pit of a desert kite at Jebel Hamra in northeast Sinai (kite No. 14 on Fig. 2; Table 1), span from 3230 ± 150 to 3120 ± 260 cal BC, i.e. late 4th millennium BC–early 3rd millennium BC, and are therefore slightly earlier than the radiometric ages reported here for the Negev installations (Eddy and Wendorf, 1999: 176–177, 278–281). During excavation of a desert kite in Wadi Jenah–Wadi Marra in southern Sinai, a single radiocarbon date on charcoal gave an age of 3750 ± 45 uncal BP (2280–2040 cal BC) (Segal and Carmi, 1996: 103) pointing to the use of kites in this area as late as the end of the 3rd millennium BC. Finally, radiocarbon dates for a tumulus built on top of one of the Samar West kites (Nos. 11 and 12 on Figs. 2 and 3), located adjacent to the Samar East kite in the Negev studied here, place the construction of the latter to the first half of the 3rd millennium BC, denoting the last use of this desert kite as a hunting trap (Bar-Oz et al., 2009).

Based on the radiometric dates presented here, it appears that the Negev–northeast Sinai kites were first established during the late 4th millennium BC, with most intensive use during the 3rd millennium BC, followed by with cessation in their use towards the late 3rd millennium BC. All in all, this is a very short time scale when compared to desert kites in eastern Jordan and Syria, which appear to have been in use already in the late 7th millennium BC and continued to be exploited into the early 20th century AD (Aharoni, 1946; Buckhardt, 1831; Helms, 1981: 47; Helms and Betts, 1987: 54–55; Legge and Rowley-Conwy, 2000; Musil, 1928a,b; Wright, 1895). Thus, the dates presented here for the Negev–Sinai desert kites demonstrate that they were a relatively late and probably short-lived phenomenon. Whether this technology was imported from areas to the east still needs to be investigated, as do the reasons for the cessation of kite use in the Negev–northeast Sinai. Factors that may have been responsible include climate change, overkill of prey, reduced population density and changes in social structure of local communities, to name but a few.

4.3. Animals hunted

Avner (1972), Mendelssohn (1974) and Meshel (1974) were the first to account for the observed differences between kites in eastern Jordan and those in the Negev and northeastern Sinai, based on the ecology and ethology of the prey species trapped. They suggested that the large and dense kite complexes identified in the deserts of Syria and Jordan were constructed along migration routes to exploit the enormous numbers of migrating Persian goitered gazelle (*Gazella subgutturosa*). In contrast, the smaller individual desert kites of the Sinai and Negev deserts were primarily intended for hunting dorcas or acacia gazelle, that live in small groups.

Today, only a limited range of ungulates inhabit the Negev and northeast Sinai – dorcas and acacia gazelles (*Gazella dorcas* and *Gazella gazella* cf. *acaciae* respectively), Nubian ibex (*Capra ibex nubiana*) and onager (*Equus hemionus*), the latter was recently reintroduced (Mendelssohn and Yom-Tov, 1999). However, until the early 20th century, faunal diversity was greater and included, in addition, wild asses *Equus africanus* (African) and/or *Equus hemionus* (Asiatic), hartebeest (*Alcelaphus buselaphus*) and possibly also Arabian oryx (*Oryx leucoryx*) (Bodenheimer, 1958; Jarvis, 1941: 187–214; Yom-Tov and Mendelssohn, 1988). Establishing the identity of prey species hunted in the Negev kites is problematic due to the paucity of animal remains from excavated structures, probably due to poor bone preservation. Alternately, as documented in historical accounts of hunts using kites in eastern Jordan and Syria, entire prey carcasses were transported away from the installations to habitation or processing sites, with limited or no butchery taking place at the desert kites themselves (Aharoni, 1946: 33; Burckhardt, 1831: 220–222). This pattern may be reflected in the archaeological record of the 7th millennium BC occupation at the prehistoric site of Dhuweila (eastern Jordan) which has been interpreted as representing an early summer hunting camp focused on gazelle exploitation (Betts, 1998; Martin, 1994) based on the proximity of the site to desert kites; high frequency of arrowheads; inflated number of adult male gazelles in the faunal assemblage; presence of remains of juvenile gazelle; presence of all body parts of the carcass; and the presence of rock engravings depicting gazelles in and around the site. However, Dhuweila is an exception and in the case of the Negev desert kites, we can only extrapolate based on the limited osteological data available from contemporaneous habitation sites in the Negev coupled with information on animal behaviour. Archaeozoological assemblages from Late Neolithic to Early Bronze Age settlements in both the Negev and Sinai deserts coeval with the kites are dominated by domestic goats and to a lesser extent sheep (e.g. Grigson, 1987, 2006; Horwitz et al., 2001, 2002; Horwitz, 2003). Although rare, remains of wild ruminants – notably gazelle and ibex – attest to their having been sporadically hunted, while small mammals and carnivores further demonstrate trapping of wild taxa (e.g. Grigson, 1987, 2006; Horwitz et al., 2001, 2002; Horwitz, 2003).

4.3.1. Gazelle

G. subgutturosa, the main prey species hunted in the desert kites of eastern Jordan and Syria (Betts, 1998; Legge and Rowley-Conwy, 2000), never inhabited Israel or the Sinai Peninsula (Harrison and Bates, 1991: 203; Kingswood and Blank, 1996: 3; Mendelssohn, 1974: 722). Until the early Holocene, *Gazella gazella* inhabited the Sinai and Negev deserts, with *Gazella dorcas* a late migrant into the southern reaches of the region (Tchernov et al., 1986/1987). *G. dorcas* is the most common wild ungulate in the Negev today (ca. 1500 animals in 1985 – Mendelssohn and Yom-Tov, 1999; and approximately the same number in 2008 – B. Shalmon pers comm., 2008), while *G. g. acaciae* inhabits a small area in the southern Araba Valley and represents an isolated sub-species (ca. 12 animals in 1996 – Mendelssohn and Yom-Tov, 1999; and ca. 30 animals in 2008 – B. Shalmon pers comm., 2008). They feed mainly on Acaccia tree leaves and pods as well as on leaves and young twigs of several shrub species. Little has been published on their behaviour but it appears to resemble *G. dorcas* (Mendelssohn and Yom-Tov, 1999). In the Negev and Sinai, neither of these species is known to migrate but they do move extensively in search of forage. In both gazelles, adult males are territorial and herds typically comprise one to four females, their young and one adult male. Bachelor herds may comprise two to five young males (Mendelssohn and Yom-Tov, 1999; Yom-Tov et al., 1995). The latter represent the most logical group to trap since their slaughter will have the least impact on the reproduction potential of the population, thereby ensuring an ongoing supply of animals.

The dorcas gazelle is not an obligate drinker and prefers lush green herbaceous vegetation. In the Negev desert, the dorcas gazelle primarily subsists on *Accacia* leaves, flowers and pods in addition to bushes and geophytes that are usually found in the beds of the broad wadis (Mendelssohn and Yom-Tov, 1999).

Over the years 1992–2002, observations by A. Holzer of free-ranging dorcas gazelle herds at 'Ein Ghadhian (Yotvata oasis) in the Negev desert showed that they preferred to move along defined paths and although they have the ability to jump over obstacles (up to 2 m in height) they avoided doing so if there was an alternative. Moreover, when disturbed in their grazing area they tended to stay close to the pasture area by escaping towards the lower slopes of the wadi edge (up to 45 degree incline).

The rock engraving from the 'Cairn of Hani' (Jordan), dating to the 1st century BC–2nd century AD based on the presence of Safaitic inscriptions (Harding, 1953; MacDonald, 2005), depicts a structure resembling a desert kite with a human figure driving horned animals into this enclosure. This scene has been interpreted as depicting gazelles being hunted using a kite (e.g. Meshel, 1974) although some researchers (e.g. Harding, 1953; MacDonald, 2005), have suggested that it may depict corralling of domestic animals. Another engraving from Burqu', Jordan (MacDonald, 2005: 339–341) convincingly depicts gazelles inside a trap recalling the late 19th–early 20th century eye-witness accounts, i.e. Burckhardt, Musil and Aharoni. Although it has been proposed that these traps differ from kites (Echallier and Braemer, 1995), these depictions establish a clear association between kites/traps and gazelle hunting in the region.

An interesting feature of many rock engravings from the Levantine deserts is that dogs are often portrayed accompanying human and animals figures (Anati, 1979; Hershkovitz et al., 1987; MacDonald, 2005; van Berg et al., 2004) sometimes together with a trap or kite as on the 'Cairn of Hani'. Indeed, ethnographic accounts of gazelle hunting in the Near East commonly cite the use of dogs to herd, harass and rundown prey (Hobbs and Tregenza, 1992; Musil, 1928a).

4.3.2. Oryx and hartebeest

Skeletal remains of *Oryx leucoryx* have never been positively identified from the Negev or northeast Sinai, although this species has been identified in rock engravings from this region (Horwitz et al., 1999). While rare, remains of hartebeest (*Alcelaphus bucelaphus*) occur in archaeological sites in the Negev and Sinai, with the latest finds dating to the Late Bronze Age and Iron Age (Davis, 1982; L.K. Horwitz, unpublished data). As such, this species would undoubtedly have inhabited the region when the kites functioned.

4.3.3. Equids

Skeletal remains of equids have been reported from Late Neolithic to Early Bronze Age archaeozoological assemblages in the Negev and Sinai, but all have been identified as domestic donkey (e.g. Grigson, 1987, 2006; Horwitz, 2003). During excavations of a 3rd millennium BC desert kite in Wadi Jenah – Wadi Marra in southern Sinai, several teeth of an equid were recovered (Bar-Yosef, 1986–1987). Furthermore, rock engravings from Sinai and Jordan depict animals identified as equids being hunted using a desert kite-like structure (Hershkovitz et al., 1987: Fig. 7; MacDonald, 2005). The Levantine rock engravings recall accounts of equid hunting in Uzbekistan that describe the use of kite-like traps for this purpose (cf. Betts and Yagodin, 2000: 37). In some of the Negev and Sinai kites, the pit is built under a deep step in the rock (Nos. 1, 3, 4 and 7) or under a steep or cliffy slope (Nos. 8and 9). The latter locations seem unsuited and unnecessary for hunting gazelles, but can be better understood if the kites were constructed specifically to catch larger more robust animals such as equids, that would have been unable to stop themselves from entering the pit as they ran down the incline.

Gazelles and wild asses (*Equus africanus* and/or *Equus hemionus*) that may have inhabited the Negev are social herbivores that live in same-sex groups while adult males are territorial. Research on habitat selection in the re-introduced animals in the Negev desert (Henley et al., 2007) has shown that under drought conditions, the abundance of asses in the study area was primarily correlated with forage (richness and cover) and less so with distance to water or woody cover, such that their occurrence in the study area was less localized than that of dorcas gazelle. However, they are obligate drinkers and require access to freshwater every few days. These traits may have contributed to their extinction in the region since herds could easily be ambushed or trapped especially en route to, or at, water sources (Mendelssohn and Yom-Tov, 1999). In fact, some of the Negev kites are not built near natural pasture areas, but on animal trails (Nos. 3, 4 and 6–9).

4.3.4. Ostrich

Although bones of ostriches (*Struthio camelus*) are rare in Late Neolithic–Early Bronze Age habitation sites from the Negev and Sinai, eggshell is commonly found (Horwitz et al., 2001; Horwitz, 2003). Ostriches are also commonly depicted in rock engravings in the Levantine deserts, in some cases apparently being hunted using a kite, for example in an engraving from eastern Jordan (Betts and Helms, 1986; MacDonald, 2005), or in an engraving from Sinai that depicts ostriches, ibex and possibly oryx being driven by people with raised arms near the walls of what has been interpreted as a kite (documented in Hershkovitz et al., 1987).

4.3.5. Ibex

In terms of their ethology, gazelles, wild asses, ostriches and possibly also oryx are taxa well suited to trapping in a desert kite since they live in groups, follow each other and use regular trails. Most importantly, under conditions of stress the animals react instinctively by escaping in the same direction. Although ibex fits many of the criteria outlined above, the suitability of this species to trapping in kites raises some difficulties.

Ibex preferentially inhabit rugged cliffs while the majority of desert kites in the Negev–northeast Sinai are located in open country with only a few installations (Nos. 6, 8, 9 and 16) constructed on mountain slopes. Secondly, ibex tend to flee uphill, into the high cliffs rather than escape out into the open, which would complicate their being driven into a kite. Finally, unless snared in a net (El Mahi, 2000), it is highly likely that ibex would evade trapping by jumping over the low walls of the structure. Ethnographic accounts of ibex hunting by the semi-nomadic Beja (Red Sea hills, Eastern Sudan), indicate that for this purpose a well camouflaged stone-built enclosure is constructed with one entrance "in an area where ibex frequently visited or passed through" (El Mahi, 2000: 40). One group of hunters drives the animals from behind towards the enclosure while another group is placed at strategic points along the route to prevent animals from escaping. Once the ibex have entered the stone enclosure, they are set upon and killed by the hunters using knives and throwing sticks. In some cases the animals are caught in nets and then dispatched. Another trapping technique reminiscent of desert kites, was to ambush the ibex at water localities (Bartlett, 1845; Jarvis, 1941: 193). Here the stone enclosure was usually replaced by nets. As the animals approached the water they are chased by hunters towards the nets in which they got entangled as they tried to escape. Only two of the kites described here (Nos. 3 and 4) lie on trails leading to a water source ('Ein Qadis), but their location in the local topography makes them unsuitable for trapping ibex in this fashion.

4.4. Recent attempts at trapping gazelle

In 1970/1971, hundreds of mountain gazelle (*Gazella gazella*) were trapped by the Israel Nature Reserves Authority using a kite-like structure in order to transport them from the Lower Galilee to the Golan Heights. After unsuccessful attempts to trap them using a 2.5 m high metal fence as arms, these were 'constructed' from 10 cm wide, white plastic strip laid on the ground, one 2 km long and the other 0.5 km long. This was sufficient to direct the gazelles into the enclosure which was made of fish net stretched at 2–3 m height. Herds of up to 200 animals were created and trapped in this fashion, totalling 700 animals (G. Ilani pers comm., 1997; Ilani, 2004: 73–74).

In 1997, Holzer further demonstrated how gazelles could be efficiently trapped using a kite. During the annual count of *G. dorcas* at the Yotvata Nature Reserve, near Eilat, the animals were rounded-up to form a herd and driven forward by a spaced line of vehicles. At some point the gazelles turned around and escaped through the spaces between the vehicles, at which point they were counted. The day before the gazelle count, the author prepared the terrain by placing on the ground in the area where the round-up would take place, three plastic pipes each 100–125 m long and only 16 mm wide. Two pipes formed the outline of the arms of a kite while the third formed an additional line. Observations of gazelles grazing in the area prior to the round-up demonstrated that they did not cross the plastic pipes but moved alongside, avoiding crossing. During the round-up, despite their evident stress, none of the gazelles attempted to jump over the desert kites 'arms'. From these reports we may conclude that gazelles tend to run parallel to obstacles such as low walls/fences rather than traversing them. Both instances demonstrate that the low stone arms of the ancient kites would have been efficient in directing animals, thereby contradicting arguments of several scholars that the kite's arms were too low for hunting but good enough to conduct domesticated herds (e.g. Echallier and Braemer, 1995). Indeed this is borne out by the description given in Wright (1895: 42) of gazelles entering a desert kite: "The gazelles, led by curiosity and guided by the little walls, march boldly into the field".

4.5. Environment

Desert kite architecture and location clearly demonstrate that their builders were cognizant of the ethology and ecology of their intended prey. Thus, the evident variation in the topographic and environmental conditions the desert kites occupy was intentional and suited for trapping different prey.

(i) The kites were built of local field stones and hence, as noted by Aharoni (1946: 33), camouflaged and unnoticed by the animals from a distance.
(ii) The low arms of the kite did not dissuade the animals (especially gazelle) from entering between the walls, but at the same time offered a clear path directing their movement forward within the funnel.
(iii) As noted below, desert kites occur in three different ecological and/or terrain settings, although some combine these traits. The most common group (e.g. Nos. 1–4 and 12–14) (Fig. 2) are located in flat, relatively open terrain. The entrance is oriented towards locations rich in vegetation, such as wadi bed, that are preferentially grazed by gazelles even today. The long arms of the kites near wadi beds would have helped to funnel animals for long distances as they were driven from behind, into the structure. Some of the kites exploited the gazelle's instinct to run to the wadi edge or uphill when escaping (No. 11), such that the arms rise above the wadi bed to exploit the flight path (Figs. 5a,b).

These types of desert kites exploited topographic 'blind points' in the landscape, with the pit at the apex recessed so that it was obscured. Indeed, the pit would have appeared to the animals in the funnel as an opening in the boundary walls of the kite through which they could flee (Fig. 6). This kite type may have been specifically tailored to hunt small herds of dorcas or acacia gazelles.

In a second group of desert kites (e.g. Nos. 6–10), the installation was located in an area void of vegetation but cutting an animal trail. This would have facilitated driving and ensnaring animals as they moved through the landscape.

A third group of desert kites were built on steep slopes or ridges below a plateau or shoulder (e.g. Nos. 5, 15 and 16) such that animals driven over the ridge/plateau would suddenly be confronted by the installation before and below them. Although the apex and pit would have been visible, due to the steep incline they would not have been able to stop themselves from entering the pit. These kites may have been used for hunting large ungulates, such as wild asses, since driving them down-slope would facilitate their being trapped or injured.

5. Conclusions

This paper summarizes available information on desert kites from the Negev and northeast Sinai deserts. It describes findings based on excavation of two such installations, including the date of their construction and the cessation of their use as hunting traps. Finally, the two kites are placed within the context of other such

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installations from the region in terms of their architecture, chronology, location in the landscape and the prey species hunted. Based on our research we have reached several general conclusions that are listed below.

1. Despite the large territory covered by the Negev–northeast Sinai and extensive surveys, only 17 desert kites are known from this region to date.
2. They all conform to the same general design; they are of small size and occur singly, unlike kites in other Near Eastern deserts. These inter-regional differences appear to be associated with targeted prey species, although other factors cannot be excluded such as population size of the kite builders or the extent of their annual use.
3. Based on iconography and ethology a range of wild ungulates, all occurring in small groups, could have been trapped in the Negev–northeast Sinai kites: dorcas and accacia gazelles, wild ass, onager, oryx, hartebeest and ostrich.
4. The Negev–northeast Sinai kites occur in three main locations, each suited to trap animals in a different manner: (i) desert kites with long arms found in flat locations adjacent to wadi beds which funnelled animals from the wadi pasture into the kite – primarily used to trap gazelles; (ii) kites located on paths routinely used by animals that would intercept them as they traversed the landscape – mainly used to trap gazelle but also equids and other ungulates; and (iii) desert kites built on slopes abutting a natural drop in the topography – used to trap large ungulates, primarily equids.
5. Although there is some evidence that the Negev–southeast Sinai kites were first constructed in the late 4th millennium BC, they were mainly used during the 3rd millennium BC (Early Bronze Age I–II) and then ceased to function by the mid-2nd millennium BC (Early Bronze Age III–IV). This means that they were a relatively late and short-lived phenomenon compared to desert kites in other parts of the Near East.
6. The fact that the kites in the Negev–northeast Sinai region were few in number, usually isolated in the landscape and of small size, indicates that hunting did not play an important role in the local subsistence base at this time. This is supported by the archaeozoological record of coeval habitation sites that shows that communities relied on domestic herds for food.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jaridenv.2009.12.001

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