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Assessing surface movement at Stone Age open-air sites: first impressions from a pilot experiment in northeastern Botswana

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ABSTRACT

Open-air sites are ubiquitous signatures on most archaeological landscapes. When they are appropriately recorded, well-preserved and are single-component occupations, they provide access to high-resolution occupation data that is often not available from rock-shelter sites. These sites are, however, commonly affected by a number of post-depositional factors that are not adequately studied in archaeology. This paper presents the results of an open-air experiment conducted in northeastern Botswana. Two surface scatters modelled on known Bushman open-air camp sites were created to investigate the taphonomic factors affecting such sites. The scattered materials at these sites included stone tools, ostrich eggshell fragments, ceramic sherds, glass beads and faunal remains. Two scatters were laid out consisting of a nested square design; one site was excavated after four months and the other after twelve. The results show little horizontal material movement at these scatters and an initial, rapid, vertical period of mobility, after which the majority of surface artefacts are protected from subsequent movement, preserving the general scatter structures. This experiment suggests that open-air sites can offer detailed spatial information relevant to human settlement structure that is often not accessible at rock-shelter sites.

KEY WORDS: Camp structure, middle-range research, open-air archaeology, post-depositional movement, Stone Age, surface experimentation.

Archaeological surface scatters and open-air sites are essential to landscape archaeology, but their importance is often downplayed in research agendas because of concerns over their contextual integrity (e.g. Lewarch & O'Brien 1981; Villa 1982; Aura et al. 2011). Such sites are valuable sources of information and in southern Africa they often contain archaeological finds not present in rock shelters (Sadr 2009; Oestmo et al. 2012). For example, open-air sites have been used to test whether forager and herder assemblages are distinct and distinguishable in the Northern Cape (Beaumont et al. 1995; Lombard & Parsons 2008; Parsons 2008), where they constitute a majority of the archaeological sites. The Namaqualand coastline lacks rock shelters and so archaeological work performed here relies entirely on open-air sites (Dewar 2007: 2). In the Limpopo province, surface scatters have been used to demonstrate that foragers used rock shelters and open-air sites differently based on the differential composition of their stone tool assemblages (Forssman 2010, 2013a). In the broader southern African region, open-air sites contain the majority of information relating to the study of pastoral camps and at times are the only source of information for the herder occupation of the subcontinent (Robbins 1986; Vogelsang 1998, 2000; Arthur 2008; also see Sadr 2003).

The archaeology of southern Africa's Stone Age foraging populations is also bolstered by excavations at open-air sites that contain a rich abundance of data for this time period (e.g. Bousman et al. 2013). Landscape archaeology and open-air excavations conducted in the Langebaan Lagoon region of the Western Cape province

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have shown that during the mid- to late Pleistocene hominids became increasingly proficient at resource provisioning and gradually became less tethered to specific resource points on the landscape (Kandel & Conard 2012). This study and others like it (e.g. Kuman et al. 1999; Steele et al. 2012; Hutson 2013) illustrate the value of open-air archaeological sites for answering questions of pre-historic population demography, landscape use, and cultural and technological change outside rock shelter contexts (also see Isaac & Harris 1975; Foley 1981; Lewarch & O'Brien 1981; Sullivan 1995; Gronenborn 1999; Mitchell et al. 2006; Vanmontfort 2008; Oestmo et al. 2012; Orton et al. 2013).

By combining archaeological data found in rock shelters with open-air assemblages, archaeologists can more effectively represent Stone Age expressions from different site types spread across a landscape, and can better observe regional archaeological signatures (e.g. Sampson 1985; Forssman 2013a, b). For example, Barham (1992) combined his finds at two open-air sites in the Siphiso Valley with finds made in Siphiso Shelter, in order to demonstrate the difficulties in distinguishing aggregation and dispersal camps in the archaeological record (cf. Wadley 1989). He criticised the ability to do so on two bases: identifying distinct occupational phases in the archaeological record relies heavily on stratigraphic integrity and a lack of overlapping occupations, possibly separated by sterile layers; and sites need to be compared intra-regionally (rock shelters and open-air sites) and not across large areas and environmental zones. Similar conclusions were suggested for Likoaeng in Lesotho, an open-air site with a large fish-bone assemblage which may be an 'aggregation' site. However, it is located in an open-air context and lacks certain artefacts indicative of aggregation, including supposed ritualistic items such as ochre and specularite (Plug et al. 2010). These examples suggest that rock shelters do not present an undistorted view of the past, and that by using open-air sites in conjunction with data from rock shelters we are able to better represent the archaeological variability in these human behaviours across landscapes.

There are a number of processes that affect the preservation and interpretation of open-air archaeological sites. These include human and animal trampling, animal burrowing, wind and water erosion, and various geological processes (Eren et al. 2010; Pargeter & Bradfield 2012). These factors have been studied independently elsewhere (e.g. Bordes 1961; Tringham et al. 1974; Gifford-Gonzalez & Behrensmeyer 1977; Keeley 1980; Villa & Courtin 1983; Behrensmeyer et al. 1986; Hofman 1986; Shea & Klenck 1993; McBrearty et al. 1998; Shott 1998; Lopinot & Ray 2007; Pargeter 2011), but no prior study has investigated the role of taphonomic processes in altering behaviourally relevant spatial patterns at open-air archaeological sites. In order to study these processes, an experiment was conducted at two replicated open-air material culture scatters designed to mimic artefact discard patterns documented at ethnographically recorded Bushman camps in the Kalahari (see Yellen 1976). At these two sites, materials were observed under natural environmental conditions in which animal trampling, wind and water erosion all played a role in their alteration and movement. The goal of this experiment was to observe changes in material-culture patterning caused by these various factors over time and not to study artefact alteration or modification. At the outset it was hypothesised that burial rate and the length of time between deposition and excavation would impact the degree of degradation at the sites, but that artefact patches relevant to the behavioural traces left behind by ethnographically documented Bushmen would still be distinguishable.

STRUCTURE OF THE EXPERIMENT

The experiment outlined in this paper was conducted in the Mashatu Game Reserve in northeastern Botswana (Fig. 1). This location was chosen for two reasons: 1) to create as close as possible an analogy to the environments in which ethnographic Bushman sites were recorded, and 2) because the current landscape is rich in open-air archaeological signatures (see Forssman 2013b). Establishing the two experimental sites (Surface Experiment—Short (SE-S) and Surface Experiment—Long (SE-L)) in this area therefore allowed for a direct historical analogy between the experimental site layouts and those of ethnographically documented Bushmen. The general geological context in which both the experimental sites were located was a Kalahari Sand deposit with a flat gradient profile. The actual deposit is less than 5 cm thick and is an unconsolidated unit above a hard, compact layer that appears to be a clay deposit. No micro-morphological study on the deposits was undertaken and so little more can be said about these units. In addition, there were no obvious signs of human interference in the experiment area, other than a nearby waterhole approximately 80 m to the north. No archaeological remains were noted in these specific areas.

The two site locations were chosen to best resemble those recorded at ethno-historic Bushman open-air camps. Silberbauer (1981: 191) established a set of criteria Bushmen

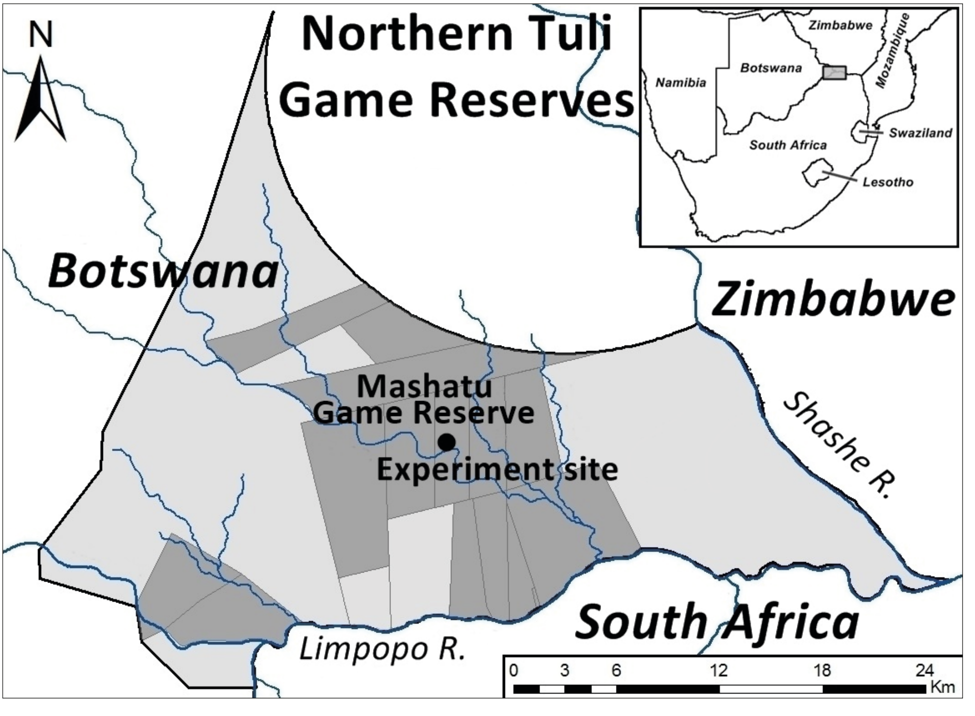

Fig. 1. The location of the experimental sites in northeastern Botswana.

considered when selecting habitation sites, which includes access to plant foods, a sufficiency of grazing and browsing for wild game, materials in the form of wood and stone, pans or other drainage lines where water could be sourced, and sufficient space to build a camp. Similar decision making was recorded amongst the Ju/'hoansi (Lee 1976), the G/wi and G//ana (Tanaka 1976), Silberbauer's (1981) study group, and the Botleti River Bushmen (Cashdan 1984). The location of the experimental sites met with all of these conditions: there was standing and flowing water, a series of rock outcrops and a large stand of mopane trees (*Colophospermum mopane*), and wild game visited the area on a regular basis.

The internal structure of the two experimental sites was established according to ethnographic data collected in the Dobe region, Botswana, by the Kalahari Harvard Ethnographic Project (Yellen 1990). Here, most activity at an open-air camp occurred around a central hearth, situated in front of a family's hut (Yellen 1976). It is around these hearth areas that the greatest accumulation of cultural material occurred, which included general debris, cooking refuse and discarded cultural items such as tools and children's toys. All rotting items were discarded behind the hut and it is in this area that activities such as the drying of skins occurred and ablution facilities were demarcated (Yellen 1976). The hearth is where the greatest activity in a Bushman campsite is located, with a decreasing density of material culture deposited as one moves away from this point (Yellen 1976; Brooks & Yellen 1987).

In accordance with these patterns, the hearth area, where the greatest amount of materials was deposited, is considered the centre of the two experimental sites, with the density of materials decreasing as one moves outward from this central point. In order to standardize this design and facilitate the accurate recording of movement data during the experiment, each site was arranged in a nested square design (Figs 2–3). Square 1 (blue), the outermost and control square, with a diameter of 8 m, was considered the limit of the experimental site and had no material placed within it. Square 2 (white), with a diameter of 6 m, was placed within Square 1 and had the lowest material density. Square 3 (orange), with a diameter of 4 m, was placed within Square 2. Square 4 (pink), with a diameter of 2 m, was placed within Square 3 and was considered the hearth area akin to those documented ethnographically by Yellen (1976). Each square was then divided, using bisecting diagonal lines, into quadrants labelled according to their cardinal orientation: north (N), east (E), south (S) and west (W). Each site was therefore composed of 16 zones (N1–4, S1–4, E1–4 & W1–4) within four squares (1, 2, 3 & 4; Table 1). This nested design allowed for the recording of material movement between each square. To further facilitate the accurate recording of this movement data, all materials were coloured according to their square, making it possible to track the movement between squares (colour zones). For example, orange-coloured stone tools in the pink square would have moved from Square 3 (orange) into Square 4 (pink). Faunal remains were also deposited at the site because, as would occur at an actual camp, their presence would have increased animal traffic over the site (Story 1958), facilitating post-depositional movement. However, all of the faunal remains had been removed within four days of deposition, and so no useable data was recorded. For this reason, we do not discuss these remains further.

In Squares 2–4, stone tools, ostrich eggshell (OES) fragments, glass beads and ceramic sherds were deposited randomly within the zones. These items of material culture were

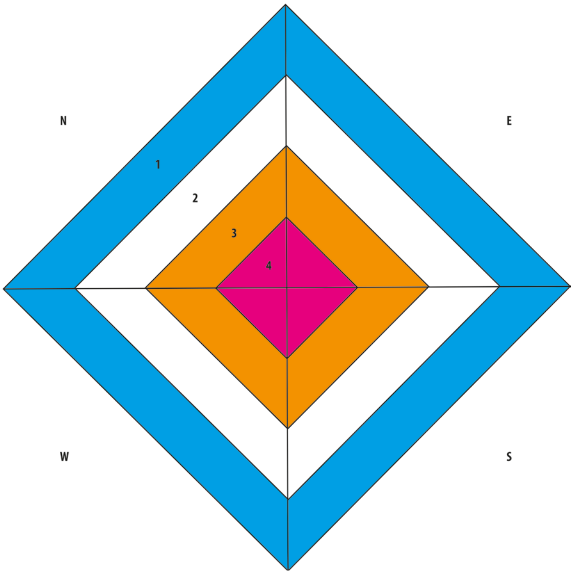

Fig. 2. Site structure of SE-S and SE-L. Quadrants labelled according to cardinal points (N, E, S, W) and squares labelled from outwards, 1: blue; 2: white; 3: orange and 4: pink.

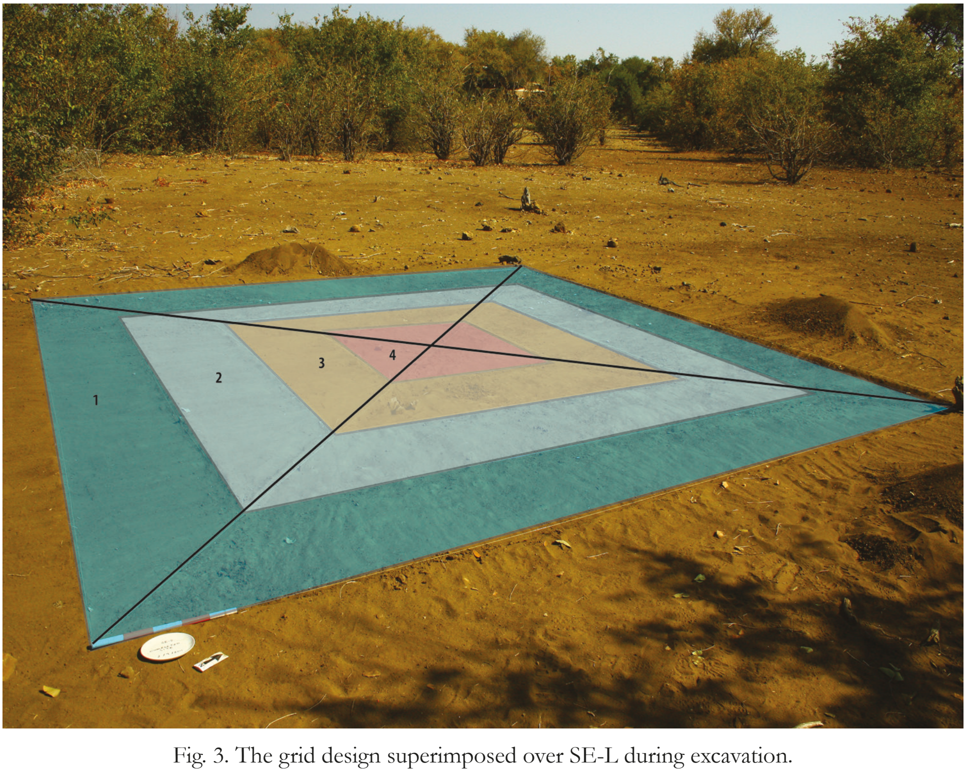

Fig. 3. The grid design superimposed over SE-L during excavation.

TABLE 1
The area of each square in the experiment sites.

Segment	Area (m²)
1	55.4
2	39.8
3	16.5
4	16.0
Total	**127.7**

chosen as they represent the most ubiquitous remains at Stone Age open-air sites in the Kalahari landscape. The number and weight of each material group, and in each square, were recorded prior to deposition (see Table 2 for counts and weights). Weight was preferred over raw counts for each material category as it was anticipated that many objects would break during the experiment and that this would then affect the final material counts. A similar weight of each material category was placed in each square so that as the area of the square increased, the density of artefacts decreased. No vegetable matter or charcoal was deposited.

The two experimental sites were monitored on a regular basis: weekly for the first month, and then monthly for an additional three months until SE-S was excavated; SE-L, although in the field for another eight months, was not monitored after the first four months since this was between field seasons. During these monitoring sessions

TABLE 2
Artefact density per square.

SE-L									
Square	**2**			**3**			**4**		
	g	m²	g/m²	g	m²	g/m²	g	m²	g/m²
Bead	10	39.8	0.251	8	16.5	0.485	10	16	0.625
Shell	29		0.729	32		1.939	36		2.25
Ceramic	602		15.13	988		59.88	606		37.88
Lithic	740		18.59	1048		63.52	1322		82.63
Total	**1381**		**34.7**	**2076**		**125.8**	**1974**		**123.4**
SE-S									
Square	**2**			**3**			**4**		
	g	m²	g/m²	g	m²	g/m²	g	m²	g/m²
Bead	10	39.8	0.251	8	16.5	0.485	10	16	0.625
Shell	32		0.804	34		2.061	32		2
Ceramic	558		14.02	658		39.88	732		45.75
Lithic	842		21.16	864		52.36	762		47.63
Total	**1442**		**36.23**	**1564**		**94.79**	**1536**		**96**

all of the materials visible on the surface in each square were counted, but not picked up or interfered with in any way, and their colour was noted. In addition, each site's condition was commented on, any animal tracks and droppings were identified (using Liebenberg 1990), and photographs were taken. As the primary goal of this paper is to discuss the movement of material culture items in space and through time, the data on specific animal activities at the sites is not presented here. While animal traffic did occur on a daily basis, humans did not interfere with the site at all. Rainfall data was also recorded, but at the time the region was experiencing a severe drought and a total of 114.5 mm fell during the twelve-month period, with no rainfall over the first four months. It was therefore impossible to determine the impact of water action; however, it would only have been possible to do so accurately if this variable could have been observed in a controlled environment. Our observations are based on findings in a natural system with multiple variables constantly at play, similar to realistic forces affecting an archaeological site. Determining the impact each variable had on the site was, therefore, not possible in this experiment. Data on the physical condition of the material culture items was not recorded in the field and will form a subsequent phase of this project.

The two experimental sites were left in the field for differing amounts of time in order to observe the effect of this variable on the movement of items and the alteration of the original site layout. Site SE-S was excavated after four months and site SE-L after twelve months. Excavations followed standard archaeological procedures and a grid was set up to ensure that each zone (N1, N2, etc.) was excavated separately. Artefacts from each zone were then bagged separately and placed into larger bags according to the squares in which they were found (1, 2, 3 or 4). All of the recovered materials were then weighed in the laboratory.

RESULTS

Surface patterns

During each monthly visit to SE-S and SE-L, all of the materials visible on the surface were counted (Table 3). At SE-S, after one month (July) 92.3 % of the visible materials were in their original square of origin, while after two months (August) 94.6 % were and after three months (September), 89.3 %. The increase in visible materials in August is likely due to mixing and movement as artefacts were being buried and re-exposed depending on animal movement or environmental factors such as rainfall. At SE-L, similar results were recorded, with 91.9 % of the visible materials in their original square of origin after the first month, increasing to just over 93 % after two and three months. Therefore, even on the surface, most materials remained within their square of origin. The combined material categories also decreased in number with each visit, suggesting either that they were being buried or had been removed from the site altogether by water action or trampling. For example, at SE-S (Fig. 4), after the first month only 45 % of the materials were visible on the surface and within the site perimeters, followed by 36 % after two months and 25 % after three. In SE-L, this decline was more apparent, with only 38 % of the materials being visible after a month, followed by 34 % and 23 % after two and three months, respectively. A similar, rapid, initial movement and burial event was noted in the Pargeter (2011) and Pargeter and Bradfield (2012) trampling experiments. In our experiment, we noted that due to the

TABLE 3

Surface counts of artefacts from July to September. P: pink; O: orange; W: white. The original deposited amount in each square was: stone tools, 340; ceramics, 50; glass beads, 100; ostrich eggshell fragments, 37.

SE-S

Square		4			3			2			1			Total	
Colour within square		P	O	W	P	O	W	P	O	W	P	O	W		
July	Bead	50	0	0	0	57	0	0	2	36	0	0	0	145	711
	Shell	29	0	0	0	22	0	0	2	18	0	0	4	75	
	Ceramic	40	0	0	2	32	0	0	4	28	0	0	18	124	
	Stone tool	149	0	0	2	87	0	0	4	108	0	0	17	367	
August	Bead	38	1	0	0	42	1	0	1	34	0	0	0	117	567
	Shell	25	0	0	0	17	0	0	2	21	0	0	0	65	
	Ceramic	36	0	0	0	31	0	0	3	29	0	2	9	110	
	Stone tool	69	1	0	3	76	1	0	3	117	1	0	4	275	
September	Bead	20	2	10	0	27	1	0	1	25	0	0	0	86	401
	Shell	15	1	7	0	11	1	0	0	23	0	0	0	58	
	Ceramic	29	0	1	2	35	0	0	0	35	0	1	2	105	
	Stone tool	62	7	0	0	26	0	1	1	50	1	0	4	152	

SE-L

Square		4			3			2			1			Total	
Colour within square		P	O	W	P	O	W	P	O	W	P	O	W		
July	Bead	30	0	0	0	41	0	0	3	21	0	0	0	95	602
	Shell	18	0	0	1	12	0	0	0	14	0	0	0	45	
	Ceramic	36	0	0	1	30	1	0	7	24	1	0	5	105	
	Stone tool	116	1	0	3	107	0	0	11	104	0	0	15	357	
August	Bead	35	0	0	0	38	0	0	3	16	0	1	0	93	542
	Shell	13	1	0	0	12	0	0	0	12	0	0	4	42	
	Ceramic	33	0	0	1	32	0	3	3	21	0	0	3	96	
	Stone tool	109	1	0	2	106	0	0	1	79	0	2	11	311	
September	Bead	25	0	4	0	25	0	0	1	16	0	3	0	74	371
	Shell	15	1	1	0	8	2	0	0	11	0	0	0	38	
	Ceramic	36	0	0	1	32	0	1	2	20	2	0	1	95	
	Stone tool	54	1	0	2	55	0	0	1	49	0	0	2	164	

Fig. 4. Site SE-S with the grid superimposed digitally over the entire site.

unpredictable patterns of trampling over the sites, such as an elephant track through a portion of the site (Fig. 5), the entire assemblage is not influenced equally by trampling, resulting in variable preservation patterns across the site. Additional studies are required to observe the impact this may have over an entire site. After four months at least 75 % of the assemblage was no longer visible on the surface of the two sites.

Excavated materials
Excavations were conducted at SE-S after four months and at SE-L after twelve months in order to record post-depositional weight changes in the deposited materials. Two stratigraphic units were noted during the excavations: a 3 cm thick Kalahari Sand deposit over a highly compacted clay deposit contained no artefacts. This compacted clay unit would have acted to prevent the further downward movement of materials and places a maximum limit of vertical dispersion on material remains in this environment. A comparable find was also made by Gifford-Gonzalez et al. (1985) in a trampling experiment conducted in similar unconsolidated sands.

SE-S
In total, 94.6 % of the material assemblage deposited at SE-S was recovered in the excavations in Squares 1–4 at the site (Table 4). The majority of these materials were found within their square of origin, with numbers varying according to the square in which they were placed. Of the 73.3 % of pink beads recovered, only 2.4 % were found

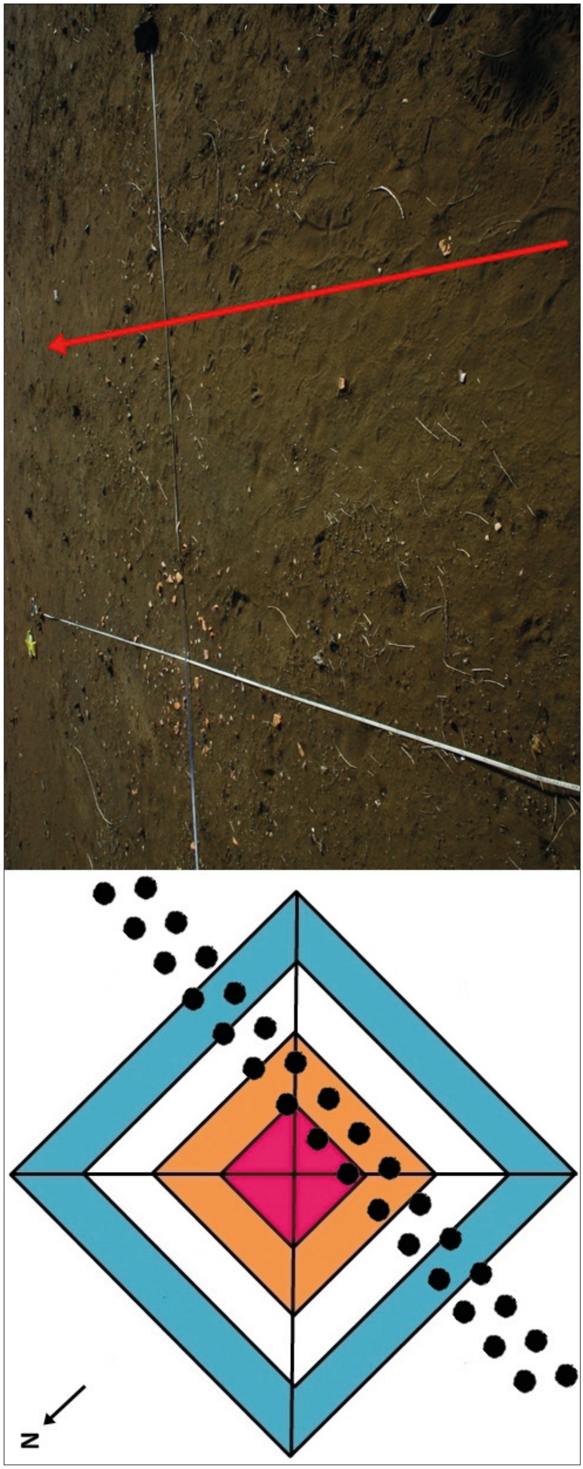

Fig. 5. A schematic diagram of an elephant track over the experimental site (left) and an image of an actual elephant path over SE-S (right).

TABLE 4

Results of excavations at SE-S (bracketed figures in grams) and amounts placed at the site.

Segment	1		2		3		4		Total	
Bead	2.7	(0)	6.4	(10)	4.2	(8)	7.1	(10)	**20.4**	**(28)**
Shell	9.9	(0)	33.1	(32)	19.9	(34)	34.3	(32)	**97.1**	**(98)**
Ceramic	423.7	(0)	400.0	(558)	391.1	(658)	578.8	(732)	**1793.6**	**(1948)**
Stone tool	292.5	(0)	753.9	(842)	736.7	(864)	600.4	(762)	**2383.5**	**(2468)**
Total	**728.8**	(0)	**1193.4**	(1442)	**1151.8**	(1564)	**1220.6**	(1536)	**4294.6**	**(4542)**

outside Square 4. This is in contrast to orange beads (a total of 72.4 % recovered) and white beads (a total of 72.9 % recovered), of which 24.3 % and 27.2 %, respectively, were found outside their original squares. This pattern was also noted for the stone tools and in the shell and ceramic categories in SE-L, discussed below. Based on the figures in Table 4, the area with the highest density of artefacts was Square 4 (96 g/m²), which experienced the least amount of material movement, followed by Square 3 (94.8 g/m²) and then Square 2 (36.2 g/m²). These results suggest that a correlation exists between the density of materials, the size of the area they were scattered across and their horizontal movement (Table 5). This is evident in the results from all Square 4 materials, the 'hearth' area, which experienced the least amount of movement.

SE-L

As with SE-S, most of the materials deposited at SE-L were recovered in the excavation (88.6 %; Table 6). Fewer materials were found at SE-L, indicating, as expected, that additional time spent in the field had resulted in the further loss of materials. Despite this extended period of exposure, most materials placed at SE-L remained in their original area of placement. An additional 2.5 % of orange and 13 % of white stone tools were recovered from site SE-L, which is likely the result of an anomaly due to the misidentification of weathered coloured materials (Table 7). It was noted in the laboratory that at times it was difficult to identify the colour of the materials due to their having faded while in the field. This anomaly does not, however, affect the frequencies of pink materials excavated from the 'hearth' area. For this reason and due to material breakages, it was not possible to place some of the excavated materials into a colour category. These were labelled as miscellaneous and were excluded from the analysis (Table 8). If these miscellaneous materials are included, 91.7 % of the materials in SE-L were recovered versus 97.3 % in SE-S.

Summary of the excavations

Overall, 52.6 % of the materials found in SE-L came from their original squares, compared with 59.7 % in SE-S (see Tables 4 & 6). Between the two sites, an average of 56.2 % of the recovered materials did not move beyond their square of origin. However, not all material categories were equally affected by post-depositional movement and variability exists within the material categories at the two sites. At SE-L in the bead category, 13.4 % of pink beads were found outside Square 4, which increases to

TABLE 5
SE-S: Recovery of materials from within their original square.

	SE-S: Bead						**SE-S: Shell**				
	Original (g)	**Recovered (g)**	**% of actual**	**% elsewhere**	**Total % found**		**Original (g)**	**Recovered (g)**	**% of actual**	**% elsewhere**	**Total % found**
Pink	10	7.1	70.9	2.4	73.3	**Pink**	32	26	81.4	0.8	82.2
Orange	8	3.9	48.1	24.3	72.4	**Orange**	34	16.6	48.8	45.3	94.1
White	10	4.6	45.7	27.2	72.9	**White**	32	21.1	66	37.8	103.9
Total	**28**	**15.5**	**55.4**	**18**	**73.3**	**Total**	**98**	**63.8**	**65.1**	**28**	**93.1**
	SE-S: Ceramic						**SE-S: Stone tool**				
	Original (g)	**Recovered (g)**	**% of actual**	**% elsewhere**	**Total % found**		**Original (g)**	**Recovered (g)**	**% of actual**	**% elsewhere**	**Total % found**
Pink	732	543.1	74.2	14.7	88.9	**Pink**	762	593	77.8	18.3	96.2
Orange	658	241.8	36.8	60	96.7	**Orange**	864	630.3	73	22.1	95.1
White	558	114.4	20.5	53	73.5	**White**	842	558.8	66.4	29.2	95.6
Total	**1948**	**899.4**	**46.2**	**42.6**	**88.7**	**Total**	**2468**	**1782**	**72.2**	**23.2**	**95.4**

27.6 % with orange beads and to 24.9 % with white beads in relation to their respective squares (Table 9). This result indicates that the central 'hearth' area was the most resilient to post-depositional material movement. At SE-S a similar change occurs in which more beads were found outside their original square in the larger Squares 2 and 3. At both SE-S and SE-L the percentage of beads found outside Squares 2 and 3 was relatively similar, while the percentage of beads found outside Square 4 is noticeably lower in SE-S (2.4 %) than in SE-L (13.4 %). A similar pattern is noted with regard

TABLE 6
Results of excavations at SE-L (bracketed figures in grams) and amounts placed at the site.

Segment	**1**		**2**		**3**		**4**		**Total**	
Bead	2	(0)	4.5	(10)	5.4	(8)	7.7	(10)	**19.5**	**(28)**
Shell	1.9	(0)	12.3	(29)	18.2	(32)	21.3	(36)	**53.8**	**(97)**
Ceramic	176.7	(0)	343.3	(602)	724.3	(988)	437.2	(606)	**1681.5**	**(2196)**
Stone tool	596.1	(0)	410	(740)	1042.1	(1048)	1010.6	(1322)	**3058.8**	**(3110)**
Total	776.7	(0)	770	(1381)	1790	(2076)	1476.8	(1974)	**4813.5**	**(5431)**

TABLE 7

SE-L: Recovery of materials from within their original square.

	SE-L: Bead						SE-L: Shell				
	Original (g)	Recovered (g)	% of actual	% elsewhere	Total % found		Original (g)	Recovered (g)	% of actual	% elsewhere	Total % found
Pink	10	6.9	69.2	13.4	82.6	**Pink**	36	14.5	40.4	0	40.4
Orange	8	3.9	49	27.6	76.6	**Orange**	32	17.1	53.5	16	69.5
White	10	2.6	26.2	24.9	51.1	**White**	29	10.7	37	21.6	58.6
Total	**28**	**13.5**	**48.1**	**22**	**70.0**	**Total**	**97**	**42.4**	**43.7**	**12.5**	**56.2**
	SE-L: Ceramic						**SE-L: Stone tool**				
	Original (g)	Recovered (g)	% of actual	% elsewhere	Total % found		Original (g)	Recovered (g)	% of actual	% elsewhere	Total % found
Pink	606	333.6	55	1.8	56.8	**Pink**	1322	933.4	70.6	15.6	86.2
Orange	988	628.7	63.6	13.8	77.4	**Orange**	1048	816.4	77.9	24.6	102.5
White	602	213.9	35.5	33	68.6	**White**	740	366	49.5	63.5	112.9
Total	**2196**	**1176**	**53.6**	**16.2**	**69.7**	**Total**	**3110**	**2116**	**68**	**34.6**	**102.6**

to the other material categories. This result suggests that the integrity of the central hearth area does diminish as the time of exposure is increased.

These results also suggest that there is a correlation between the size of the material item and its likelihood to migrate post-depositionally. Beads measuring 4 mm in diameter moved less, on average, than shell fragments between 12 and 34 mm, and still less than ceramics and stone tools, both of which varied in size between > 10 mm to 100 mm in length (Figs 6, 7). This result contrasts with the lack of size-orientated

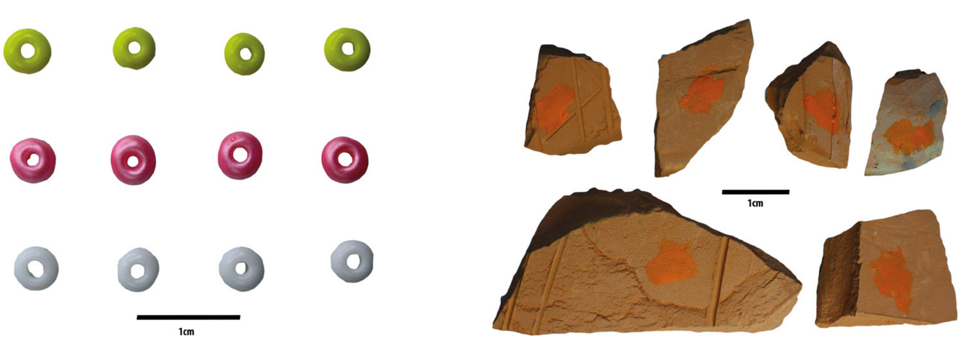

Fig. 6. Examples of imaterials used in the experiment. Left: glass beads; Right: ceramic sherds.

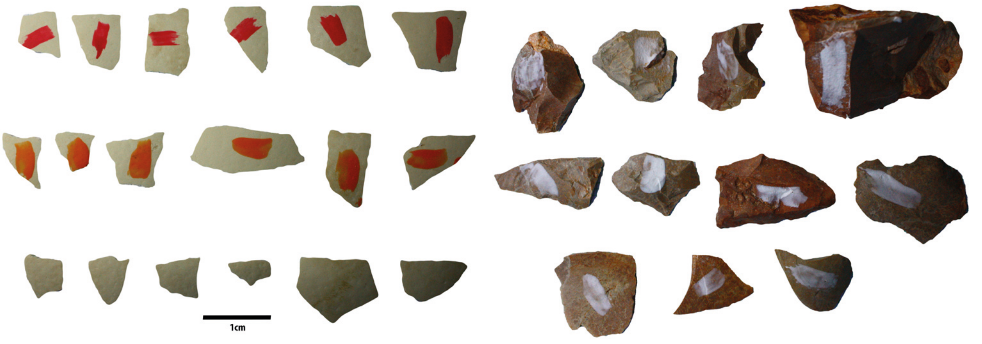

Fig. 7. Examples of imaterials used in the experiment. Left: OES fragments (bottom row = white, hence no marking); Right: stone tools.

movement recorded in previous trampling experiments and may have to do with the unique Kalahari Sands context of this experiment (see Villa & Courtin 1983; Eren et al. 2010; Pargeter & Bradfield 2012). There are, however, exceptions to this pattern, such as the shell and ceramic remains in SE-S, Square 3, which occur in considerably higher frequencies than in Square 2, and the stone tools in SE-L, Square 2, which are also present in a much higher frequency than elsewhere at this site. Overall, it appears that the general structure of each site remained intact throughout these experiments despite the fact that variation within the different material categories was noted and some vertical dispersion of materials also took place.

TABLE 8

Miscellaneous materials from SE-L and SE-S.

SE-L					
Segment	**1**	**2**	**3**	**4**	**Total**
Bead	0	0	0	0	0
Shell	0	0	0	0	0
Ceramic	15.7	22.5	46.7	74.8	159.8
Stone tool	5.8	1.2	0	1.8	8.7
Total	**21.5**	**23.7**	**46.7**	**76.6**	**168.6**
			% of total:		**3.1**
SE-S					
Segment	**1**	**2**	**3**	**4**	**Total**
Bead	0	0	0	0	0
Shell	0	0	0.8	4.8	5.53
Ceramic	19.0	24.7	41.8	10.7	96.2
Stone tool	0	0.9	22.1	1.3	24.3
Total	**19.0**	**25.6**	**64.7**	**16.8**	**126**
			% of total:		**2.8**

TABLE 9
Total percentage of material categories found outside their square of origin.

Square	4		3		2		Total		
Site	SE-L	SE-S	SE-L	SE-S	SE-L	SE-S	SE-L	SE-S	**Combined**
Bead	13.4	2.4	27.6	24.3	24.9	27.2	22	18	**20**
Shell	0	0.8	16	45.3	21.6	37.8	12.5	28	**20.3**
Ceramic	1.8	14.7	13.8	60	33	53	16.2	42.6	**29.4**
Stone tool	15.6	18.3	24.6	22.1	63.5	29.2	34.6	23.2	**28.9**
Average	**7.7**	**9.1**	**20.5**	**37.9**	**35.7**	**36.8**	**21.3**	**27.9**	**24.6**

DISCUSSION

This experiment has shown that in a thin Kalahari Sand deposit, materials remain at or near their point of origin over extended periods of time in an open-air context. Our results show that just over 50 % of the experimental materials moved less than one meter in a period of between four and twelve months. Areas where increased material deposition occurred in the past, such as around a hearth, should be observable in the open-air archaeological record and these are likely to be the most visible traces in an open-air archaeological survey. In addition, the high recovery rate of materials at both of our experimental sites is promising and suggests that open-air sites may not be as degraded as is commonly thought, provided that their context is amenable to preservation between the time at which they were deposited at the site and its excavation.

One of the most important findings is the relative lack of horizontal mobility at both of these sites. Most of the recorded movement occurred on the periphery of the sites (Squares 1–3), whereas the central 'hearth' areas remained largely intact. This result is likely to be related to the experimental sites' structure where the hearth area, Square 4, was in a small area in the centre of the site whereas Squares 1, 2 and 3 were spread out over a larger, more exposed area due to their greater size and distribution (Square 4, for example, is isolated in the centre but the zones in Squares 1–3 are distributed around the site). This structure was, however, derived from ethnographic observations of Bushman campsites in the Kalahari, and therefore approximates the site structures likely to be found in this region. Any trampling activity, such as elephants walking over the site, might have less of an effect on the hearth area because it is smaller in area and so less likely to be trampled on (Fig. 5). These results, and studies elsewhere (see Foley 1981; Oestmo et al. 2012), indicate that by focusing on artefact scatter patterns at open-air sites, it may be possible to isolate zones of increased human activity. In so doing, it is probable that one could identify single-use camps at open-air sites (e.g. Orton 2012), a task more difficult to achieve at rock-shelter sites (cf. Sadr 2009). Ethnographic Bushman campsites, and forager campsites in general, are fluid and dynamic structures, fluctuating between small, single-family structures and larger conglomerations (Wilmsen 1970, 1974; Cashdan 1984; Wiessner 2002). Careful documentation and understanding of the factors that affect the preservation and recording of these open-air patterns is therefore a crucial first step in interpreting these malleable traces of human behaviour.

This experiment has also produced a useful body of information regarding the recording of ephemeral surface finds at open-air localities. These results suggest that it is not the minute sub-centimetre accuracy of excavation techniques that is important when working in the Kalahari region, but rather the broader context in which material remains are found. While post-depositional forces have moved the materials within each site, these would not affect the site's interpretation, but may affect the way archaeologists record and identify such sites, and structure their excavations. Our results also indicate that in such contexts piece plotting may not be useful because obtaining the general context of the artefacts, perhaps within a 25 cm square, is accurate enough, considering their movement.

In spite of this, the evaluation of so-called ephemeral open-air scatters must be done with caution as these experiments indicate that material remaining on the surface is not an accurate indicator of that which has entered the deposit (see Orton 2007: 75). Recent finds in the area support this conclusion. Excavations were carried out at two ephemeral, open-air LSA sites. One contained no artefacts below the surface, whereas the other produced a high density of stone tools within a shallow deposit (Forssman 2013b, 2014). The preservation of such sites may be due to the rate of burial: the more rapidly artefacts are buried, the less likely they are to disappear (Eren et al. 2010), and possibly, as our experiment suggests, to leave their point of origin. Thus, where burial rate is high, the integrity of the open-air site is better preserved.

Although these experiments were conducted within obvious time limits and do not approach the chronological scales of the archaeological record, they do nonetheless provide guidelines for estimating rates of artefact loss at more ancient sites. In four months a total of 247.5 g of material was removed (meaning that it could not be recovered within Squares 1–4) from site SE-S, while at SE-L, 617.5 g was removed over the twelve months (Table 10). Extrapolating from these results, the monthly rate of loss at SE-S was 61.3 g (1.3 %) whereas at SE-L it was 52 g (1 %). This is unexpected as it was initially hypothesised that greater loss of material would be observed at SE-L, since it was in the field for a longer period. However, the initial rapid removal and movement of materials at the two sites, followed by a gradual decrease in the rate of purging over time, meant that eventually the process of artefact removal reached equilibrium. Using an exponential decay formula ($y = a\,(1 - b)^x y = (1 - b)^x$) where a is the initial amount, b is the decay rate and x is the time interval) it is possible to calculate the amount by which an assemblage will decrease over a set period, but also the initial amount at deposition ($a = y/(1 - b)^x a = (1 - b)^x$). For example, a 500-year-old open-air stone tool assemblage of 1000 artefacts, which decreased by 1 % annually (based on SE-L) was originally made up of over 150 000 stone tools. As mentioned above, it may be that most artefacts are lost during an initial, rapid mobility episode, after which an asymptote is reached, thus reducing the yearly loss of artefacts.

These experiments have also shown that larger material categories, such as ceramics and stone tools, are less likely to disappear, even though in this experiment they were observed to be more mobile than smaller materials, such as beads and shell. This indicates that while larger artefacts are more susceptible to processes such as trampling, as well as wetting and drying cycles, they remain at or near to the site and have a greater chance of being recovered in excavations. Testing the impact this has on preserving micro- versus macrolithic archaeological assemblages would warrant

TABLE 10
Material category values missing from the experimental sites.

	Bead		Shell		Ceramic		Stone tool		Total	
Site	g	%	g	%	g	%	g	%	g	%
SE-S	7.6	27.1	0.9	0.9	154.4	7.9	84.5	3.4	247.4	5.4
SE-L	8.5	30.4	43.2	44.6	514.5	23.4	51.2	1.6	617.5	11.4
Total:	**16.1**	**28.7**	**44.2**	**22.7**	**668.9**	**16.1**	**135.7**	**2.4**	**864.9**	**8.7**

future experimental work. It would also be worthwhile to establish experimental sites that incorporate vegetable remains, actual hearths, camera traps to observe animal movements and weather stations set up in different locations and run over an extended period measuring variables such as rainfall, wind and changes in the deposit due to processes such as wetting and drying cycles. Lastly, the Kalahari Sand deposit that this experiment was conducted in is especially unconsolidated and prone to churning. It is expected that in different deposits, such as on consolidated surfaces, the assemblages would preserve differently. Future work should assess these differences in order to test whether comparing open-air archaeological assemblages from different geological backgrounds is possible since different components of an otherwise similar assemblage may be preserved.

CONCLUSION

The role of open-air archaeological sites in the interpretation of southern African prehistory is often not adequately taken into account owing to a poor understanding of the various post-depositional factors that affect their preservation. As a result, most of the archaeology of this region is based on excavated materials from rock-shelter sites. In this experiment two open-air experimental sites, modelled on ethnographic Bushman camps recorded in the Kalahari Desert, were created in order to test their long-term retention of materials. The majority of the deposited materials remained at the site, with more than half remaining at or near where they were initially placed. The least movement was recorded at the centre of each site, modelled on an ethnographic hearth area, and in the smaller material categories (beads and OES fragments), even though a greater proportion of the larger categories (ceramics and stone tools) were recovered. The low degree of mobility observed in this study indicates that by studying dense patches at open-air sites we may be able to identify single-occupation sites and possibly nuclear-band site structures more accurately. The information derived from studies of well-preserved open-air sites can supplement data from rock shelters and in certain cases provide levels of detail not possible at sites where space is recycled and multiple occupations are often superimposed directly over one another.

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