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The Keimoes Kite Landscape of the trans-Gariep, South Africa

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Abstract
Here we present the recently discovered desert kites of South Africa in terms of landscape-based data derived from LiDAR scanning that enable us to compare the morphometric and topographic characteristics of the individual kite funnels. We report on a least-cost-path analysis, and use both older and younger ethno-historical and ethno-archaeological observations to help understand possible animal and human interaction with the Keimoes Kite Landscape. Our results highlight the hunters' understanding of animal behaviours and migration patterns, and the minimum requirements for funnel construction. We show that all the sites were constructed within 2 km of seasonal water pans, and that elevation relative to the surrounding landscape was key to the placement of the kites. We further found that the Keimoes Kite Landscape was probably one of complex inter-connectedness, with dynamic human land-use patterns interlaced with concepts of inheritable custodianship across generations. The Keimoes kite funnels are most similar to those of the Negev Desert in the Levant, and demonstrate (against long-held opinion) that southern African hunter-gatherers in arid regions intentionally modified their landscape to optimise the harvesting of ungulates such as migrating gazelle – in this case the local, desert-adapted Springbok. Our landscape approach provides a nuanced understanding of these features within the southern African context.

Keywords
Desert kites, LiDAR, Later Stone Age, San hunter-gatherers

Introduction
Hunter-gatherer lifeways in southern Africa are seldom associated with large, enduring structures or landscape modifications. The kite-like complexes of the trans-Gariep, 24 km north of the Orange River (henceforth we refer to the river as the Gariep, its indigenous name meaning 'river'; the term 'trans-Gariep' denotes the area immediately north of the river) near Keimoes, are currently an exception (van der Walt and Lombard 2018; Lombard et al. 2020) (Fig. 1a). South of the Gariep a single, small funnel is known from Graafwater approximately 90 km south-southwest of Keimoes

(Beaumont et al. 1995), and ~550 km southeast of Keimoes, Robert Gordon (1778) described the following, whilst travelling along the Seekoei River north of the Sneeuwberg mountain range on the 19th of November 1777: "We saw low stones in long bow-like formations placed in the countryside with an opening here and there. The wild people place ostrich feathers, heavily smeared with *buchu* [a medicinal herb powder] on these stones. In these openings the hunters lie in hollows in the ground; then others chase the game upwind so that it passes through these openings". Garth Sampson (pers. comm. April 2020) was able to relocate these funnel-shaped alignments in the Seekoei River Valley area (Fig. 1a), close to where his team mapped camps associated with the Smithfield variant of the final Later Stone Age and Stone Age herder enclosures (Sampson 1984). This period dates to between 1800 and 240 years ago in the Seekoei River Valley (Sampson et al. 2015), and from ~4000 to 100 years ago in South Africa in general (Lombard et al. 2012), and is in line with our previous assessment that the Keimoes kites probably date to the last 2000 years or so based on the dated Stone Age structures of Namibia and South Africa (see Lombard et al. 2020 for discussion; and Fig. 1 bottom).

Desert kites are notoriously difficult to recognise and record in the field. Their large size, integration with natural outcrops in rugged terrain, and the use of local, unmodified boulders render them all but invisible at ground level (Arav et al. 2014; Lombard et al. 2020) (Fig. 1b). Generally, they also lack directly associated artefacts, faunal remains or datable material (Holzer et al. 2010; Nadel et al. 2010), and the Keimoes sites are no exception. In the context of their ethno-archaeological research, Hitchcock and colleagues (2019) recently reported that San hunter-gatherers who still use stone-built hunting blinds at ǂGi Pan, Botswana (Fig. 1), usually do not cook food or eat whilst laying there in ambush. What is more, apart from perhaps a quick arrow repair, the hunters rarely conduct any production activities in their blinds. Instead, when a hunt was successful, the carcass would be carried off and the butchering of the prey animal conducted away from the blinds to avoid attracting predators and scavengers (Hitchcock et al. 2019). These observations about land-use behaviour relating to ambush hunting may explain the dearth of material culture and excavatable deposits at kite sites. Another likely factor contributing to the lack of deposits is the highly mobile Kalahari sediments.

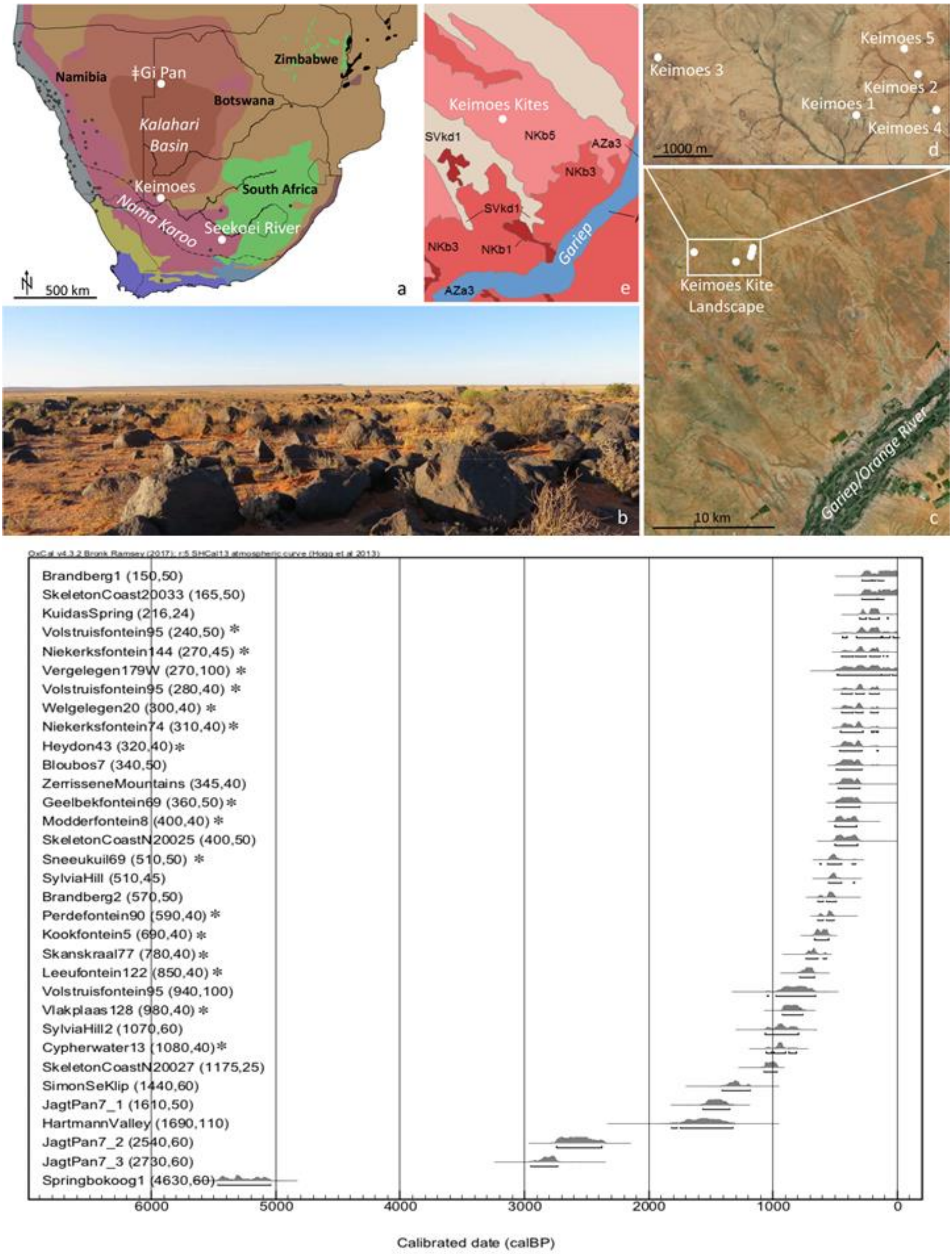

Fig. 1 Top:1a: Biome map of southern Africa with rainfall regimes (below dotted line = winter rain, between dotted and dashed lines = year-round rain, above dashed line = summer rain), Stone Age stone walling localities (black dots), and the location of Keimoes, the Seekoei River Valley and ǂGi Pan as discussed in the text. 1b: The Keimoes 3 site and landscape from eye level looking northeast (Photo: ML). 1c: Location of the Keimoes kite sites in relation to the Gariep (Orange River). 1d: The

LiDAR-scanned Keimoes Kite Landscape. 1e: Location of the Keimoes kites in relation to the surrounding veld types (NKb5 = Kalahari Karroid Shrubland, NKb3 = Bushmanland Arid Grassland, the SVkd1 = Gordonia Duneveld, AZa3 = Lower Gariep Vegetation zone [Mucina and Rutherford 2006]). Bottom: Dates for Stone Age stone structures from Namibia and South Africa (modelled in OxCal v4.3.2, using the Southern Hemisphere Cal13 calibration curve; Hogg et al. 2013; Ramsey 2017; Loftus et al. 2019). Sites with * are all in the Seekoei River Valley (see Sampson 2010; for references to the other sites please see Lombard and Badenhorst 2019).

In the Middle East, where several thousand kite sites have now been recorded (Crassard et al. 2015), these were only observed once early 20th century pilots started to fly over the Levant (Helms and Betts 1987). Thus far all the previously published Keimoes kite sites were identified through Google Earth satellite imagery – the first two sites as part of remote sensing for various renewable energy projects, and Keimoes 3 as part of remote archaeological exploration. We recently demonstrated that aerial LiDAR (light detection and ranging) scanning is an effective method for the recording and micro-topographic exploration of kite sites (Lombard et al. 2020).

Subsequently, we were able to raise funds to LiDAR scan the larger Keimoes Kite Landscape of approximately 1715 ha, on which all three known kite sites are located (Keimoes 1-3) (Fig. 1c and d). During this process, we discovered two more sites: Keimoes 4, consisting of a single funnel, and Keimoes 5, that has three loosely scattered but poorly preserved funnels with nearby circular stone structures. With this contribution, we apply the same analytical method as we did for Keimoes 3 to all the remaining kite sites, presenting data for 30 stone-built funnels on the Keimoes Kite Landscape. First, however, we provide an overview of the veld types (vegetation zones) surrounding the Keimoes kite sites. We then briefly describe the two new sites, present the morphometric details of all the funnels, and analyse funnel placement on the landscape in terms of elevation and slope. Lastly, we look at the Keimoes Kite Landscape in terms of hydrology and least-cost pathways, revisiting site-use interpretations.

Methods and approaches used in our study

We use the system of veld types (vegetation units) as published by Mucina and Rutherford (2006) to map and describe the spatial complexity of vegetation cover in the area directly surrounding the kite sites. Such floristic mapping in combination with geological, topographic and climate indicators is one of the most effective tools to describe in relatively simple terms the landscape and vegetation complexity of South Africa that currently include 435 veld types, situated in 35 bioregions, which are assembled in nine biomes (see Mucina and Rutherford 2006).

We contracted a commercial survey company to conduct an aerial LiDAR survey of approximately 1715 ha covering the Keimoes kite sites with a Cessna 406 Twin Turbine aircraft (all Civil Aviation rules and procedures were adhered to). During the survey they flew at an altitude of 850 m above ground level, to produce an 80 mm ground sample distance pixel size and an accurate digital terrain model (DTM) of the ground. The point capture density of the LiDAR points are approximately 4 points per square metre. The relative vertical accuracy of the DTM is better than 80 mm in areas free of vegetation, and the relative horizontal accuracy of the DTM is better than 100 mm. Computer generated smoothed contours were supplied at an interval of 0.5 m. The method allowed us to map the funnel features using a geo-rectified LAS (3D point-cloud) dataset accurate to 80 mm, and therefore to list and describe the morphometric characteristics of each kite funnel. The LiDAR data were also analysed in ArcGIS 10.5, and combining this approach with orthographic photography allowed us to interpret site function based on micro-topographic placements within the immediate landscape (Lombard et al. 2020).

To generate comparable morphometric characteristics of the Keimoes kite sites, we measured each funnel's individual guiding arms, the combined arm lengths from one mouth extremity to apex to other mouth extremity, the funnel depths from mid-mouth width to apex, the funnel necks from where they narrow down to <2 m to where they end in the funnel heads, maximum diameters of the funnel heads (note that these are only approximate as the heads are collapsed), the funnel-mouth widths, the surface areas covered by each funnel and the funnel angle (see Fig. 2).

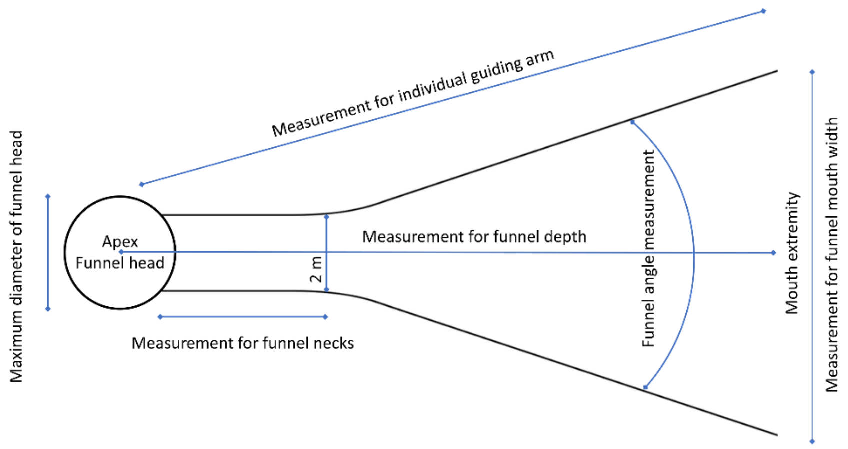

Fig. 2: Schematic representation of a kite funnel and the morphometric units as measured for this study.

We calculated the absolute measure for morpho metric standardisation in the form of the coefficient of variation (CV) values as follows: standard deviation (SD) ÷ mean x 100. Generally speaking, the smaller the SD, the smaller the CV value, and therefore the greater the standardisation of any given feature. In most cases, authors do not provide cut-off values between standardised and un-standardised artefacts or features, but Fisher (2006) used a CV value of 20 to indicate standardisation in terms of stone tools, which we also apply to this study.

With Geographic Information System (GIS) software we performed least-cost path analyses using geo-spatial datasets wherein the 'cost' is the steepness of slope, so that the analysis picks the most efficient path between any two points. This analytical technique has become part of the predictive modelling toolkit in archaeology (Whitley and Burns 2008; Williams et al. 2019), wherein models are often based on the assumption that travel passages were originally created by herbivore migration routes; hunters followed the herds and developed subsistence and settlement patterns that were linked to the animal pathways (Herzog 2016). We applied similar modelling to assess how people and animals may have used the Keimoes Kite Landscape. Given its multiple features, we ran the analysis several times to create a network of possible trails. Although hypothetical, all these trails represent the most cost-effective paths on the landscape, and as such, demarcate pathways that both humans and animals would have likely followed when moving through it.

Lastly, to help interpret the Keimoes Kite Landscape, we use ethno-historical records as described by Janette Deacon (1986) for 19th century hunter-gatherer land use of an area approximately ~120 km south of Keimoes. Her discussion was based on a sketch map and conversations in 1871 between //Kabbo of the /Xam San and Dorothea Bleek, the daughter of a German linguist fluent in the /Xam language (also see Hollmann 2004).

Veld types of the Keimoes Kite Landscape

The Keimoes Kite Landscape is situated in the summer-rainfall zone of the arid northwest region of the Nama Karoo Biome (Fig. 1a). The average rainfall for this region varies between 70 and 200 mm, and during some years the rain never comes. Rainfall usually occurs during late summer and early autumn, whilst the winters are very dry/rainless. Maximum temperatures reach ~40˚C in summer (December, January), and minimums of up to -4˚C occur in July during mid-winter. Three major veld types, i.e., the Bushmanland Arid Grassland, the Kalahari Karroid Shrubland, and the Gordonia Duneveld, interfinger on this locality (Fig. 1e). A fourth, the Lower Gariep Vegetation zone, is located ~24 km towards the south and east, and although a day's walk away from the kites, it is a dominant feature in the landscape as the only permanent green belt – just visible from the highest points on the Keimoes Kite Landscape (Fig. 1c). Here we summarise aspects of geology and vegetation for each of the relevant veld types, as described by Mucina and Rutherford (2006), and list some ungulate species that used to roam the region.

The Kalahari Karroid Shrubland, on which the kites were constructed is underlain by mudstones and shales of the Ecca Group (Prince Albert and Volksrust Formations), and Dwyka tillites, both of early Karoo age, which corresponds to the Late Carboniferous to Middle Permian in ages. About 20% of the rocky outcrops on the landscape are formed by intrusive Jurassic dolerite (diabase) sheets and dykes, which provided the kite builders with their construction material (Fig. 1b, and see discussion below). The shrubland soils are shallow Glenrosa and Mispah forms, with lime generally present and some red-yellow apedal soils; these are freely draining soils, with <15% clay and a high salt content. The landscape associated with this veld type is characterised by slightly irregular plains with dwarf shrubland dominated by a mixture of low, sturdy, spiny (sometimes succulent) shrubs and white grasses – colloquially known as boesmangras. In years of good rainfall, annuals such as botterblom (*Gazania*) and hongertee (*Leyseria*) species are abundant (see Mucina and Rutherford 2006: 337).

A note on our use of plant common names: We follow Sampson and Neville (2018) using the Afrikaans names for plant species because they mostly draw their meaning from much older indigenous languages and ancient knowledge systems. For example, 'botterblom' means butter flower referring to the buttery taste when chewing some of the indigenous daisies, and 'hongertee' means hungry tea that was used by San hunter-gatherers to still hunger pains when food was not available (also see van Wyk 2008; van Wyk et al. 2008). English common names are more recent, have not been created for all the indigenous species of the Karoo (see Powrie 2004), and are seldom used by the general population of southern Africa.

The Bushmanland Arid Grassland dominates the region south of the Gariep. About 33% of the grassland surface area is covered by Quaternary alluvium and calcrete, with outcrops of Palaeozoic diamicitites of the Dwyka Group and meta-sediments of Proterozoic age. The soils are mostly red-yellow apedal, freely draining and less than 300 mm deep. The landscape associated with the Bushmanland Arid Grassland veld type consists of extensive to irregular plains on a sparsely vegetated, slightly sloping plateau. White grasses of the *Stipagrostis* species dominate the sparse vegetation, giving the landscape a semi-desert, steppe-like character. In places, low asbos (*Salsola*) shrubs change the vegetation structure, and in years of relatively abundant rainfall the veld displays a bounty of annual herbs (see Mucina and Rutherford 2006: 335-336).

The Gordonia Duneveld, immediately to the west and southwest of the Keimoes Kite Landscape, consists of aeolian sand in the form of fixed, parallel sand dunes above plains, underlain by superficial silcretes and calcretes of the Cenozoic Kalahari Group. It is characterised by open shrubland with ridges of grassland dominated by duinriet (*Stipagrostis amabilis*), and driedoring (*Rhigozum trichotomum*) in the inter-dune straights (see Mucina and Rutherford 2006: 525). This is in sharp contrast with the Lower Gariep Alluvial Vegetation Zone, where the river cuts through a great variety of Precambrian metamorphic rocks and the surrounding surface consists of the flat alluvial terraces of the Gariep, supporting soil forms such as Dundee and Oakleaf. This alluvial vegetation zone is further characterised by riverine islands and these, in combination with the terraces, support a complex of riparian thickets dominated by blinkblaar wag-'n-bietjie (*Ziziphus mucronata*), swartebbehout (*Euclea pseudebenus*) and soutboom (*Tamarix useneoides*), as well as reed beds with *Phragmites australis* interspersed with flooded grass- and herb-lands (see Mucina and Rutherford 2006: 639).

Apart from the river, naturally occurring surface water on the trans-Gariep landscape is sparse to non-existent. Relief is brought only through sporadic thundershowers, causing waterways to develop rapidly and surface water to accumulate into pans (shallow, often seasonal water catchment planes dependent on surface runoff) – a hydro-dynamic that turns the parched grass- and shrub-lands into short-lived green pastures during rainy seasons. Before the installation of farm fences, the quick turnaround in water sources and plant biomass resulted in massive game herds migrating across the landscape to benefit from the abundance (Thompson 1827). In historic times, the following ungulate species were recorded in the Keimoes region: Black and white rhinoceros (*Diceros bicornis* and *Ceratotherium simum*), plains zebra (*Equus quagga*), warthog (*Phacochoerus africanus*), giraffe (*Giraffa camelopardalis*), grey duiker (*Sylvicpra grimmia*), steenbok (*Raphicerus campestris*), klipspringer (*Oreotragus oreotragus*), grey rhebok (*Pelea capreolus*), springbok (*Antidorcas marsupialis*), gemsbok (*Oryx gazella*), red hartebeest (*Alcelaphus buselaphus*), black wildebeest (*Connochaetes gnou*), blue wildebeest (*Connochaetes taurinus*), kudu (*Tragelaphus strepsiceros*), eland (*Taurotagus oryx*) and buffalo (*Syncerus caffer*) (Du Plessis 1969). In addition to the ungulates, migratory ducks, geese, and other waterfowl flock to the pans when full.

It is within this complex and diverse, yet arid ecosystem that the Keimoes funnels were constructed – designed for harvesting some of the wildlife that migrated across the trans-Gariep either to benefit from its short-lived abundance after rainfall, or to and from the only permanent surface water of the Gariep during spells of drought. For example, trekbokken (large springbok herds on the march), consisting of many thousands of animals, have been recorded moving south from the Kalahari Basin towards the Gariep (Shortridge 1934; Skinner 1993). The behaviour of these migrating gazelle herds would have made them ideal for kite exploitation (see discussion in Lombard and Badenhorst 2019). Springbok are also desert-adapted in their feeding and drinking habits (Nagy and Knight 1994). For example, they graze and browse selectively, feeding mostly on grass during the hot seasons when drinking water is available. Yet, during the cold dry season, they will switch to browsing on more succulent flowers, seeds, and the leaves of shrubs such as swarthaak (*Senegalia mellifera*), blougannabossie (*Monechma incanum*), driedoring (*Rhigozum trichotomum*), and karee (*Lycium*) species (Milton et al. 1992). By doing so, and by feeding early in the morning when the plants are moist from dew, they gain enough moisture to go for long spells without drinking (Nagy and Knight 1994).

In short, the vegetation on the plains directly surrounding the pans and kite sites reported here is a mixture of veld types that sustain several species of grazing grasses and browsing shrubs. Some of the grasses, such as bloubuffelsgras (*Cenchrus ciliaris*), are high in protein, and others such as perennial rooigras (*Eragrostis nindensis*) and twaboesmangras (*Stipagrostis brevifolia*) are drought resistant (Fish et al. 2015). Thus, even during normal dry seasons, there would have been springbok and other ungulates on the Keimoes Kite Landscape – although not in the large numbers associated with migrating herds – as some grazing would still be available, and the open water of the Gariep within range.

Site descriptions for Keimoes 4 and Keimoes 5 and comparative funnel morphology

All the Keimoes kite sites are constructed and/or shaped by organising local dolerite boulders and stones into the various formations (Fig. 1b). The method of construction differs slightly depending on the location and distance of the walling from the funnel apices or funnel heads. For example, the portions of the guiding arms most distant from the funnel heads generally consist of large, roughly packed, single-tired boulders, sometimes incorporating natural dolerite outcrops. The walls become slightly higher in the neck areas (elongated tube-like passages) that taper towards the funnel heads. Where the necks are not completely collapsed, they appear to have been more deliberately constructed through vertical stacking. Some funnels have enclosures at their apices (Van der Walt and Lombard 2018), and some have additional protrusions or screens adjacent to their guiding arms (Lombard et al. 2020 figure 4).

Keimoes 4 is located 1.3 km east of Keimoes 1 and consists of a single funnel, with the funnel head towards the west and the funnel arms opening towards the east. It is a relatively large kite with its northern arm measuring 60.73 m and the southern one 93.69 m, covering a surface area of >1400 m² (Table 1). It has a collapsed enclosure or head at its apex, but no screens protruding from its guiding arms.

Using aerial LiDAR data for the first time to record kite-like structures, we previously provided the details for Keimoes 3 (Lombard et al. 2020), the largest and most complex of the kite sites with its three funnel chains comprising 14 funnels that stretch over a small hill of ~13 ha (Fig. 3). We also described Keimoes 1 and 2, based on conventional field recording and drone observations (Van der Walt and Lombard 2018), and thus do not repeat the published particulars for those sites here. Instead, we describe the newly located Keimoes 4 and 5 sites (Fig. 3), and present comparative morphometric details for all the funnels in the Keimoes Kite Landscape (Table 1).

Keimoes 5 is a more complex site (Fig. 3), which we do not fully understand yet. It has three, seemingly independent kite remnants all with collapsed enclosures at their apices, and 5b has screens protruding from both its guiding arms close to the funnel neck. They all display different directional orientations; 5a opens towards the southwest, 168 m to the south 5b opens towards the south-southwest, and a further 144 m south-southeast Funnel 5c opens towards the east. The arms of all three funnels, especially 5a and 5c, are substantially shorter than any of the guiding-arm sets recorded on the other four sites (Table 1). The only other funnels with notably short arms are 3m and 3n. We have previously interpreted these features as funnel remnants based on their poor condition, and we see the Keimoes 5 funnels, especially 5a and 5c, in a similar light. In the case of funnel 5c, only the neck and head remain, and in the case of 5a the arm remnants are so short that they could hardly be functional in any hunting scenario.

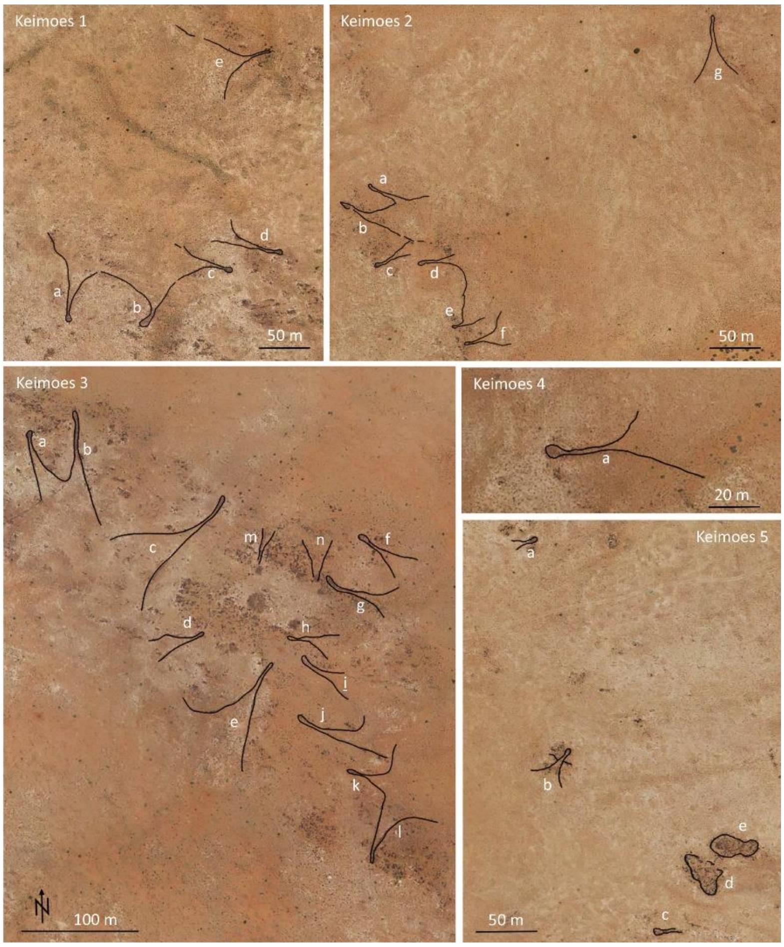

Fig. 3 Orthographic/aerial photographs of the Keimoes kite sites with the individual structures highlighted in black. Sites and funnel characters correspond to Table 1

About 25 m to the northeast of the 5c funnel remnant there is evidence of a different type of structure, two of which occur with rounded walling and internal divisions (Fig. 3); structure 5d measures ~34.6x19 m and structure 5e ~30x18 m. It is our preliminary impression that these structures may post-date the funnels, and that their builders harvested material from the nearby kite guiding arms (5a-c) to construct them, leaving the funnels in their current shortened state. Below we focus only on the funnel structures on the Keimoes Kite Landscape, but we hope to revisit these newly discovered circular structures at a later stage to establish their significance and purpose.

Table 1 Morphometric characteristics of the Keimoes kite sites. For each funnel, we measured the individual guiding arms, the combined arm lengths from one mouth extremity to apex to other mouth extremity, the funnel depths from mid-mouth width to apex, the funnel necks from where they narrow down to <2 m to where they end in the funnel heads, maximum diameters of the funnel heads (note that these are only approximate as the heads are collapsed), the funnel-mouth widths, the surface areas covered by each funnel and the funnel angle (length, depth, width and diameter measurements in metres, *tentative due to incompleteness). Funnel characters correspond to Figure 3

Funnel	**Short arm length**	**Long arm length**	**Combined arm length**	**Funnel depth**	**Neck length**	**Approx. head diameter**	**Mouth width**	**Surface area (m^2)**	**Angle**	**Opening cardinal direction/degrees**
Keimoes 1 (5 funnels, with a total of 655.46 running metres of walling covering 7044.56 m^2)										
1a	59.85	90.28	150.13	66.61	15.5	4.29	61.63	1731.68	45.34°	NNE/15°
1b	52.94	78.16	131.10	50.14	14.76	8.09	68.85	1601.64	72.38°	N/4°
1c	50.55	51.09	101.64	44.64	13.67	3.59	36.57	811.54	44.75°	WNW/283°
1d	58.58	62.98	121.57	56.66	21.59	4.24	26.03	678.07	24.85°	WNW/290°
1e	63.90	87.11	151.02	61.05	13.76*	4.69*	79.29	2221.63	66.13°	WSW/252°
Keimoes 2 (7 funnels, with a total of 606.73 running metres of walling covering 3001.21 m^2)										
2a	28.72	51.37	80.09	30.21	14.05	3.42	26.76	286.82	25.68°	ESE/120°
2b	47.83	68.65	116.48	51.12	15.72	4.32	35.10	647.03	26.83°	E/86°
2c	27.20	35.20	62.40	31.55	11.43	3.53	13.38	160.18	19.22°	ENE/59°
2d	29.66	57.49	87.15	31.71	12.72	2.61	21.88	288.15	26.45°	E/86°
2e	28.48	33.84	62.32	24.54	7.08	3.01	25.53	319.12	52.89°	NE/37°
2f	38.10	39.33	77.43	32.80	17.52	2.86	26.13	458.82	40.81°	ENE/74°
2g	59.72	61.15	120.86	52.45	14.46*	3.82*	30.81	841.09	31.51°	S/176°
Keimoes 3 (14 funnels, with a total of 1764.12 running metres of walling covering 8661.24 m^2)										
3a	45.59	48.93	103.52	48.89	11.48	5.66	22.30	374.07	24.8°	SSE/154°
3b	65.08	106.18	171.26	72.06	39.13	4.54	55.11	860.46	24.4°	S/188°
3c	113.76	128.42	242.18	108.13	24.00	4.22	67.58	2355.40	32.5°	WSW/242°
3d	48.30	49.55	97.85	45.30	13.48	3.00	18.99	390.82	23.4°	WSW/255°
3e	99.18	112.22	221.40	85.24	17.85*	NA	85.52	1599.03	54.2°	SW/218°
3f	42.89	57.97	100.86	48.04	14.56*	3.72*	25.70	339.06	25.3°	ESE/120°
3g	59.68	65.51	125.19	56.24	22.98	4.27	25.35	393.44	18.3°	ESE/104°
3h	40.33	47.81	88.14	31.50	18.23	3.45*	24.17	301.73	30°	ESE/104°
3i	40.08	55.45	95.53	40.57	15.23	2.94	27.09	267.50	30.1°	ESE/106°
3j	70.33	94.92	165.25	65.22	22.82	2.62*	44.13	834.42	24.6°	E/93°
3k	41.75	54.12	95.87	39.36	15.85	3.84	25.42	273.92	37.7°	ESE/104°
3l	65.36	72.89	138.25	58.32	13.47	3.89	43.36	78.48	39.3°	NNE/26°
3m*	27.88*	33.23*	61.11*	30.10*	NA	NA	9.35	124.99	58.4°	NNE/24°
3n*	28.60*	29.11*	57.71*	36.20*	NA	NA	26.13	467.92	58.5°	N/0°
Keimoes 4 (1 funnel, with a total of 154.42 running metres of walling covering 1410.11 m^2)										
4a	60.73	93.69	154.42	70.19	19.08	5.56	53.11	1410.11	33.60	E/81°
Keimoes 5 (3 funnels, with a minimum total of 127.94 running metres of walling covering 357.37 m^2)										
5a*	14.47*	15.58*	30.05*	14.14*	7.11	4.62	7.18	51.70	27.79	SW/254°
5b*	30.45*	32.07*	62.52*	26.94*	9.69	4.68	22.68	305.67	45.53	SSW/216°
5c*	17.48*	17.89*	35.37*	NA	11.97	4.42	NA	NA	NA	E/86°
Standardisation metrics for all the funnels on the Keimoes Kite Landscape, excluding deteriorated funnels (3m, 3n, 5a-c)										
SD	20.46	24.85	44.76	19.15	6.60	1.20	20.21	656.24	14.14	

Mean	53.54	68.17	122.48	52.10	17.13	4.16	38.79	780.97	35.00	
CV	38.21	36.45	36.54	36.76	38.53	28.76	52.1	84.03	40.4	

Whilst the construction method of all the funnels is similar, the five sites on the Keimoes Kite Landscape are highly variable in their funnel numbers, grouping, sizes, angles and orientations (Table 1, Fig. 3). For example, Keimoes 1 consists of five funnels, with a total of 655.46 running metres of walling covering 7044.56 m² between the funnel arms. Four of its funnels form a chain, with the fifth being isolated to the north. Keimoes 2 has seven funnels, with a total of 606.73 running metres of walling covering 3001.21 m². Here, six funnels form a chain, and similar to Keimoes 1, a single funnel is situated to the north. Keimoes 3 is massive compared to the other sites (Table 2, Fig. 3). It has 14 funnels arranged in three separate chains, and a total of 1764.12 running metres of walling that covers 8661.24 m² between the funnel arms. Keimoes 4 on the other hand, consists only of a single large funnel, and Keimoes 5 of three separate small funnel remnants (Fig. 3).

Here we applied standardisation metrics to the Keimoes funnels to assess whether any of their features were standardised, and therefore key to their construction and function. Applying the same principle as Fisher (2006) to the Keimoes funnels, we see no clear evidence of standardisation as none of the CV values are ≤20 (Table 1). The least variable feature is the diameter of the funnel heads, with a CV value of 28.76. Compared to the funnel mouth widths (CV=52.1) and angles (CV=40.4), funnel arm and neck lengths are less variable with CV values between 36.45 and 38.53, respectively. The surface areas of each funnel show the greatest degree of variation, with a CV value of 84.03 (Table 1).

From the morphometric data accumulated for the most complete funnel features (n=25, funnels without * in the first column of Table 1), we can hypothesise that the minimum construction criteria for effective funnel function were at least 24.5 m for funnel depth, 13 m for the width of the funnel mouth, a surface area of at least 78.5 m², and an angle of no less than 18.3˚. These minimum criteria are, however, in stark contrast with that of the largest funnel (Funnel 3c), which stretches over a surface area of 2355.4 m², and for which 242.18 running metres of walling was put in place to create a funnel that is 108.13 m deep from mouth to apex. Funnel necks, from where they narrow down to <2 m up to where they end in the funnel heads, needed to be at least ~7 m long, and all the funnel heads are between about 3 and 5 m in diameter. It is therefore clear that apart from a relatively constrained dimension for the funnel heads, which is similar to that of other Stone Age stone-built circular structures (Sadr 2012), and the minimum dimensions required for functional purposes, funnel morphology alone was not a key consideration in the construction of the Keimoes Kite Landscape.

Site topography

All the Keimoes funnels, however, have three things in common regarding their micro-topography.

1. They are on higher ground relative to the surrounding landscape even though it is a rather flat landscape in general (Fig. 4, Table 2).
2. Their elevation provides them with clear vantage points overlooking nearby pans and/or waterways, as well as the plains in-between.
3. Even though some funnel heads may be slightly lower than their necks, the necks and heads are almost all upslope from the orientation of their guiding arms (Fig. 5, Table 2), which open towards the plains that lie between the funnels and water sources.

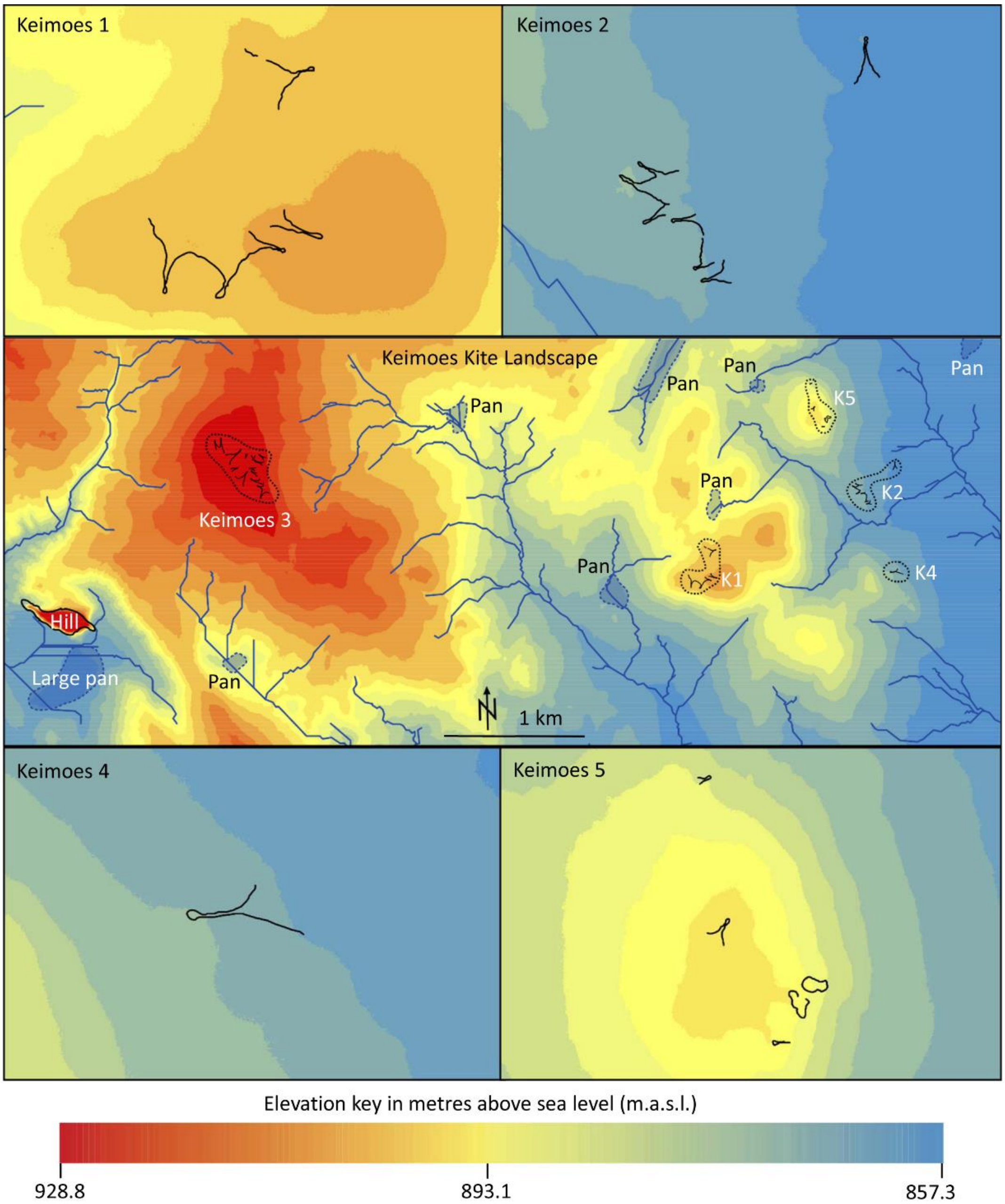

Fig. 4 Elevation map/s of the Keimoes kite sites and landscape (scale applies only to landscape, for sizes of individual sites see Fig. 3)

Keimoes 1 was constructed on an area of medium elevation, at an average of 878.9 m.a.s.l.. The heads of the funnel chain towards the south (Funnels 1a-d) are all on slightly higher ground than the funnel mouths (openings), and generally lower than the highest points of each funnel. The highest points are all in the funnel necks, and between ~0.6 and 6.2 m away from the heads (Table 2, Fig. 4). All the funnels open up towards an area with minimal slope change, with the greatest slope changes mostly behind the apices. It seems that this site complex was intentionally built on a generally high-lying area where the slope then drops off behind and beyond the circular funnel heads. In the case of the single, isolated funnel north of the chain (Funnel 1e), the neck of the funnel was constructed on the most intense slope (Table 2; Fig. 5), and this is also the only funnel where the head is lower than the mouth and the distance between the funnel head and the highest point is relatively long (18.96 m), so that the highest point does not fall within the funnel neck. From both locations, hunters would have had clear views to two pans, one 630 m east-southeast of the funnel chain, and the other 290 m north of the single, isolated funnel. From both locations the flat grazing plains between these two pans can be observed (Fig 4).

Compared to Keimoes 1, Keimoes 2 was built on a relatively low-lying area at an average of 867.6 m.a.s.l. (Fig. 4). It follows the same general slope pattern as observed for the funnel chain of Keimoes 1. Also similar to Keimoes 1, all the funnels open up towards an area of the landscape with minimal slope change, and the funnels are specifically placed on the steepest rising parts of the slope in their immediate landscape. In some instances, the greatest slope changes occur within the individual funnel catchments (shown by the yellow and red areas located within the funnels). In other words, as one enters the Keimoes 2 funnels, the slope change is more drastic relative to the surrounding landscape, but still rather gentle (i.e., 7%) from the highest point to the mid-width of the funnel mouths where they open on the surrounding landscape (Table 2, Fig. 5).

Table 2 Micro-topographic data for each funnel, recorded in metres (heights and distances) and degrees (slope). Funnel characters correspond to Figure 3. Kites 3m and 3n have no discernible heads, due to degradation, and thus cannot be measured according to these metrics (slope calculated as rise ÷ run x 100).

Funnel	Highest point	Height: mid-head	Height: mid-mouth	Distance: highest point to mid-head	Distance: highest point to mid-mouth	Slope: highest point to mid-head	Slope: highest point to mid-mouth
Keimoes 1: average height above sea level = 878.9 m							
1a	878.24	878.24	878.15	0.66	50.25	0.00	0.30
1b	878.65	878.61	878.39	6.23	25.74	0.64	1.01
1c	880.12	880.11	879.00	0.95	46.01	1.05	2.43
1d	880.11	880.08	879.35	3.16	49.05	0.95	1.55
1e	878.27	877.75	877.95	18.96	26.42	2.74	1.21
Keimoes 2: average height above sea level = 867.6 m							
2a	869.86	869.8	869.08	1.09	25.85	5.50	3.02
2b	870.60	870.58	869.14	1.74	38.67	1.15	3.93
2c	869.85	869.69	868.45	1.01	27.32	15.84	5.12

2d	868.66	868.67	867.93	0.82	26.43	1.22	2.76
2e	869.08	868.92	867.88	1.27	17.55	12.60	6.84
2f	868.71	868.41	866.99	3.05	30.28	9.84	5.68
2g	864.97	864.87	864.67	5.15	43.45	1.94	0.69
Keimoes 3: average height above sea level = 891.4 m							
3a	891.85	891.28	891.84	45.01	0.43	1.42	2.33
3b	892.18	890.96	891.97	61.63	7.19	1.98	4.73
3c	893.05	892.15	892.70	72.10	34.74	1.25	1.01
3d	894.96	894.94	893.38	0.55	43.89	3.64	3.60
3e	894.84	894.12	892.84	20.37	61.33	3.53	0.00
3f	890.02	890.01	887.90	1.06	45.06	0.94	4.70
3g	891.76	891.70	887.89	0.97	54.65	6.19	7.08
3h	893.67	893.47	891.01	2.46	42.14	8.13	6.31
3i	892.59	892.59	890.58	0.38	31.29	0	6.42
3j	893.03	893.03	889.37	1.14	66.29	0	5.52
3k	891.28	890.97	888.82	1.64	37.81	18.90	6.51
3l	891.59	891.59	888.92	1.23	53.04	0	5.03
Keimoes 4: average height above sea level = 876.7 m							
4a	876.88	876.74	876.58	5.44	14.43	2.57	2.08
Keimoes 5: average height above sea level = 875.4 m							
5a*	873.98	873.79	873.90	4.63	7.34	4.10	1.09
5b*	876.98	876.78	876.55	15.23	9.16	1.31	4.69
5c*	875.98	875.86	875.35	1.96	12.94	6.12	4.87
Standardisation metrics for all the funnels on the Keimoes Kite Landscape, excluding deteriorated funnels (3m, 3n, 5a-c)							
Mean	881.85	881.63	880.59	10.00	33.17	4.06	3.59
SD	10.18	10.08	9.71	18.65	17.42	0.93	0.42
CV	1.15	1.14	1.10	186.60	52.51	22.88	11.66

This placement strategy holds true for both the funnel chain (Funnels 2a-f), as well as for the single, isolated funnel (2g) of Keimoes 2, and also applies to the funnels at Keimoes 4 and 5. The Keimoes 2 funnels afford clear views of the grazing flats located between them and one of the main waterways that feeds into the Gariep, when flowing. The aerial aspect reveals that towards the south and east of Keimoes 2, this waterway may form relatively wide floodplains during wet spells. For Keimoes 4 at an average of 876.7 m.a.s.l., these same floodplains are visible towards its north and east. The Keimoes 5 (average 875.4 m.a.s.l.) funnels are located so that they provide views over at least four pans towards the southwest, west and north east of the site, and to the grazing areas between the funnels and the pans (Table 2, Fig. 4).

We have previously described the micro-topography of Keimoes 3 in detail (Lombard et al. 2020), and as mentioned before, it is located on the highest rise in the larger Keimoes Kite Landscape at an average elevation of 891.4 m.a.s.l., apart from the steep hill 1.6 km to its southwest at 902.3 m.a.s.l. with a maximum height of 928.8 m.a.s.l. (Fig. 4). With our slope analysis (Fig. 5), we can now show that this site represents both slope trends as discussed for the Keimoes 1 and 2 sites above. That is, the funnels opening up towards the southwest (Funnels 1a-e) generally show an increase in slope behind them, whilst the slope change within them is relatively gradual. Conversely, the funnels opening towards the east show more considerable changes in slope within the guiding arms, where the gradual blue slopes give rise to steeper yellow and red slopes (Table 2, Fig. 5). Funnels 3a-c follow the pattern of Keimoes 1e, where the funnel head is lower than the funnel mouth and the highest points within these funnels are also the furthest away from the heads or apices and closer to the funnel mouths. Keimoes 3 is the furthest away from potential water sources, but, because of its elevation it affords clear views of at least three pans and the grazing zones in-between. The two smaller pans are 1.48 km due east and 1.3 km due south of the site. Towards the southwest the largest pan on the Keimoes Kite Landscape is located 1.9 km from the site.

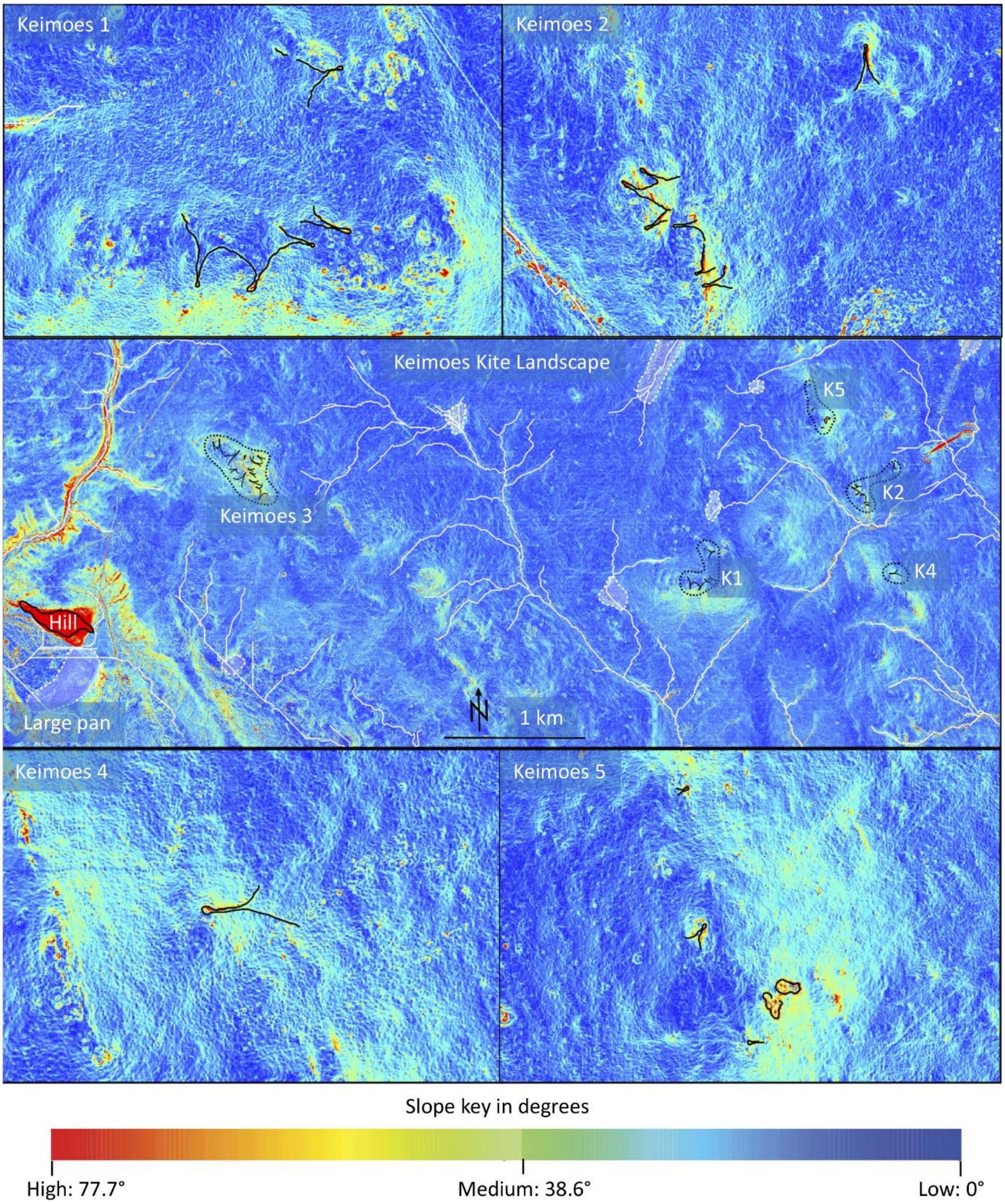

Fig. 5 Orientation of the funnels relative to slope. Darker blue shows a flatter gradient whereas the lighter colours show increased slope angles. The middle image shows that all the sites occur in areas where there are considerable slope changes relative to the surrounding landscape (scale applies only to landscape, for sizes of individual sites see Fig. 3)

Taking the larger Keimoes Kite Landscape into consideration (Fig. 4 middle), it shows a west to east decrease in elevation, especially evident in the southeast where the main drainage lines head towards the Gariep Valley. What is immediately apparent is the high position of Keimoes 3 relative to the other kite sites, and its proximity to the only steep hill and the largest, deepest pan formation on the landscape. These may all have been instrumental in choosing this location for building such a large and costly installation stretching over 130 340 m² of the high ground.

We also analysed the standardisation metrics for variation in funnel elevation and slope (Table 2). For these data we see that in terms of elevation, the funnels are highly standardised (highest point CV=1.15, height in the middle of the funnel heads CV=1.14, height at the middle of the mouth widths CV=1.10). From this we conclude that their elevations, even though only slightly higher than the surrounding areas, and the vistas they afford across grazing zones and water sources, were key to their construction and use. Slope values are also relatively standardised, especially in terms of highest point to mid-mouth (CV=11.66), and to some degree concerning highest point to mid-head (CV=22.88), which further supports a relationship between the placement of kite structures and the topography of the landscape (Table 2).

In sum, the kites are strategically positioned to take advantage of high points on the landscape, where the structures were blanketed over topographic rises, often hiding narrowing necks and enclosed kite heads from approaching animal herds. The slope map (Fig. 5 middle) also shows that all sites are located in areas where there are considerable slope changes relative to the surrounding landscape. This probably relates to their elevation, which seems to have been a determining factor for their respective placements. Other aspects in our elevation and slope analyses, such as the distance between the highest point within a funnel and the funnel head and the distance between the highest point within a funnel and the middle of its mouth width, are highly variable (Table 2). Thus, the distance of the highest point from the funnel heads or mouths are not considered to be guiding factors for site construction or use.

Topographical implications for site-use interpretation

The funnels on the Keimoes Kite Landscape share characteristics with examples from the Negev (Israel) regarding size, general layout and placement (van der Walt and Lombard 2018). Bar-Oz and colleagues (2011) describe several Negev kites, demonstrating that they are all strategically placed relative to their environmental settings, some opening towards adjacent grazing areas while others were positioned along game trails. They argue that all the Negev kites were built and used for hunting purposes, concluding that: “The topographic position of each kite suggests that animals were approached while grazing in a pasture area or migrating along animal trails. Once driven and frightened between the arms, the animals gained speed with no opportunity to escape [see Holzer et al. 2010; Lombard and Badenhorst 2019 for discussion on gazelle/springbok behaviour towards low barriers]. The low location of the enclosure prevented the fast-moving animals from seeing the trap until it was too late. The vertical drop in all kites (natural or artificial) ensured the injury of prey, which facilitated their slaughter by hunters hiding around the enclosure" (Bar-Oz et al. 2011: 214). The only marked difference in this description is that the Keimoes funnels do not show steep vertical drops at the funnel apices. Our slope analysis showed an average percent change in elevation of 4.06 between the highest points within the funnels and the middle of the funnel heads (Table 2), and even though areas just behind some of the funnel heads may be more rugged (Fig. 5), the slopes all remain relatively gentle.

Whilst funnel direction for the Keimoes kites might seem random at first glance (Table 2, Fig. 3), above we have demonstrated that, similar to the Negev kites, their arms all open towards the surrounding plains and occasional water sources where game would have gathered for grazing and drinking during wet seasons. All the Keimoes kite sites are located within 2 km of pans (Fig. 4), which are known to be the choice aggregation areas for large herds of springbok (Cain et al. 2004; Lombard and Badenhorst 2019).

Using visibility-path and viewshed analyses, we have previously demonstrated that the Keimoes 3 funnels were topographically placed so that most of the funnel apices or heads would have been hidden from oncoming game (Lombard et al. 2020 figure 6). Using this same analytical method here, the visibility-path analysis for the other four kite sites shows that the same placement applies to most of the funnels on the Keimoes Kite Landscape (Fig. 6). Thus, we can now be certain that, notwithstanding the relative flatness of the landscape, the builders of the Keimoes sites purposely placed their funnels to conceal their dead-end ambush traps. Although our slope analysis (Fig. 5) showed no marked drops within the kites (Table 2), the fact that the funnels were constructed on areas where there are considerable slope changes relative to the surrounding landscape suggests that natural topographic features may have been used deliberately to trip already-confused prey animals when they moved within the kite arms.

From these results we are able to hypothesise that the use of low walling at the funnel mouths, which open towards the plains, would not have alarmed the animal herds congregated on the Keimoes Kite Landscape. Their intentional and careful topographic placement that conceal higher apex walling and hunters from the animals, and the occasional use of human drivers as described for ambush hunting springbok herds (Gordon 1778; Bleek and Lloyd 1911), would have helped to coax the animals towards the funnels. Ultimately, they would be forced into the narrow funnel necks from where they could be easily picked off by hunters concealed safely behind the stacked walling or screens.

Combined with their ethological knowledge about trekbokken (Lombard and Badenhorst 2019), these large structures would have provided the hunters with the infrastructure to maximise springbok harvesting when the herds accumulated around the pans after they were filled with thunderstorm runoff, or when herds moved south towards the Gariep during dry spells when the grazing further north became depleted.

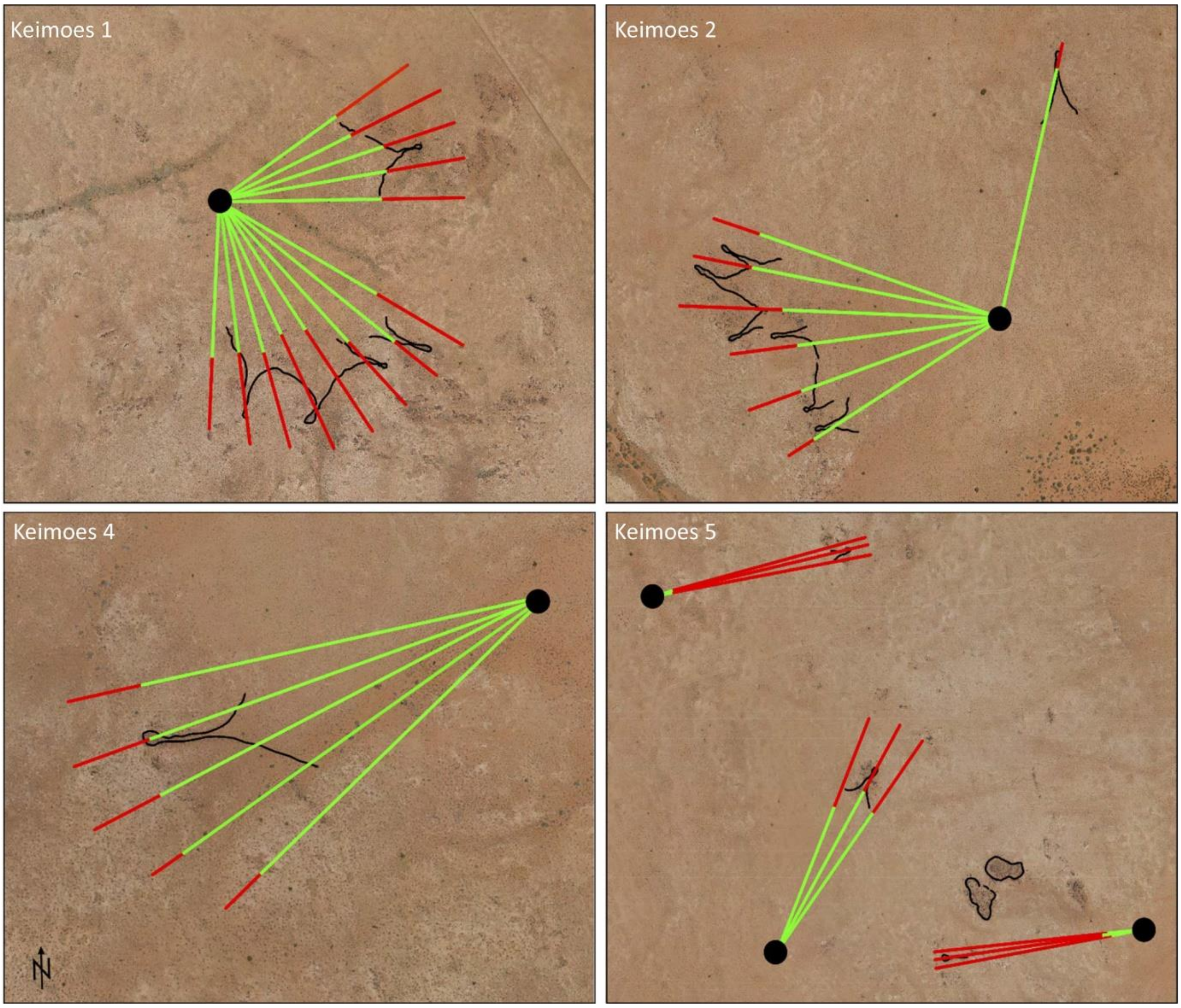

Fig. 6 Line of sight maps for Keimoes 1, 2, 4, 5 (see Lombard et al. 2020 figure 6 for the Keimoes 3 line of sight analysis). The green lines indicate in-sight areas from ~150 m away from the funnels, at a height of 1 m (~maximum springbok eye height)

Least-cost path analysis across the Keimoes Kite Landscape

Our ability to hypothesise about ancient pathway systems has the potential to open up discussion about possible networks of interconnectedness between archaeological sites, activity areas, and other phenomena in ways that are not necessarily apparent in the archaeological record (Phillips and Leckman 2012). Reconstructing pathway systems through archaeological landscapes could reveal patterns in the habitual movement of people and animals, and their associated activities (Tilley 1994).

They could also shed light on the meaning that people may have vested in particular features on any given landscape, and indicate socio-political boundaries (Snead 2009). Such pathways, however, usually do not preserve, so it may be difficult or impossible to identify them with conventional methods.

When investigating the movement of humans and animals through a landscape, these usually occur in a manner that offsets energy expenditure against the distance covered. Depending on the species or context, such behaviour might be instinctive (natural predisposition without conscious thought) in the context of self-learnt experience, be the result of social learning or social convention, or be consciously considered. In general, movement is economised to cover the greatest possible distance whilst maximising energy saving (Browne and Wilson 2011). An example of this would be a contour walk from point A to B on the side of a mountain; one would follow the contours as much as possible because they are horizontal, and they require minimal effort to walk along (Wilson 2007). When walking along a contour, slope is negligible.

Applying such modelling to the Keimoes kite landscape, we found that the most energy efficient routes (solid red lines; Fig. 7) between the drainage lines and pans on the one hand, and the kite sites on the other, would have been used by humans and animals alike. These pathways consistently lead into central areas in front of the funnels where animal herds would most likely have gathered. It is conceivable that sometimes the animals would have drifted into funnel arms of their own accord by following these energy-efficient paths. After such a drift, hunters could move in to close off the funnel mouths and slaughter the animals captured within. When humans would have attempted to coax animals towards the kites, they would have nudged the prey herds onto the paths indicated by the red-stippled lines, veering off of the least-cost paths as a result of deliberate human interference during hunting roundups.

Keimoes 3 shows three coaxing/drifting directions originating from the southwest, south and east (Fig. 7). The route from the south shows that animals could have been coaxed or drifted either to the west or the east upon approaching the site. This route thus provides two possible directions for funnel exploitation. It demonstrates the efficiency of the site's configuration, which was set up for maximum harvesting of approaching herds from multiple directions. The Keimoes 2 and 4 least-cost paths show that herd coaxing or drifting would have occurred primarily from the east, generally originating from the large drainage line and the pan further to the north (Fig. 7). Keimoes 1 is situated close to the only major north-south/west-east 'crossroads' on the Keimoes Kite Landscape, so that animals may have entered the general area from several directions, which may also relate to the central location of this site within the kite landscape. It is, however, most likely that the predominant herd coaxing or drifting for this site would have occurred from the west given the orientation and typography of the funnels

(Figs. 4-7). Two of the Keimoes 5 funnel remnants have herd coaxing or drifting directions from the west and the southwest respectively, in which case the animals may have approached from the two pans to the west, or from the drainage line directly opposite the funnels. A third funnel remnant opens to the east, which would have attracted animals from the pan to its northeast and from the floodplains to its southeast (Fig. 7).

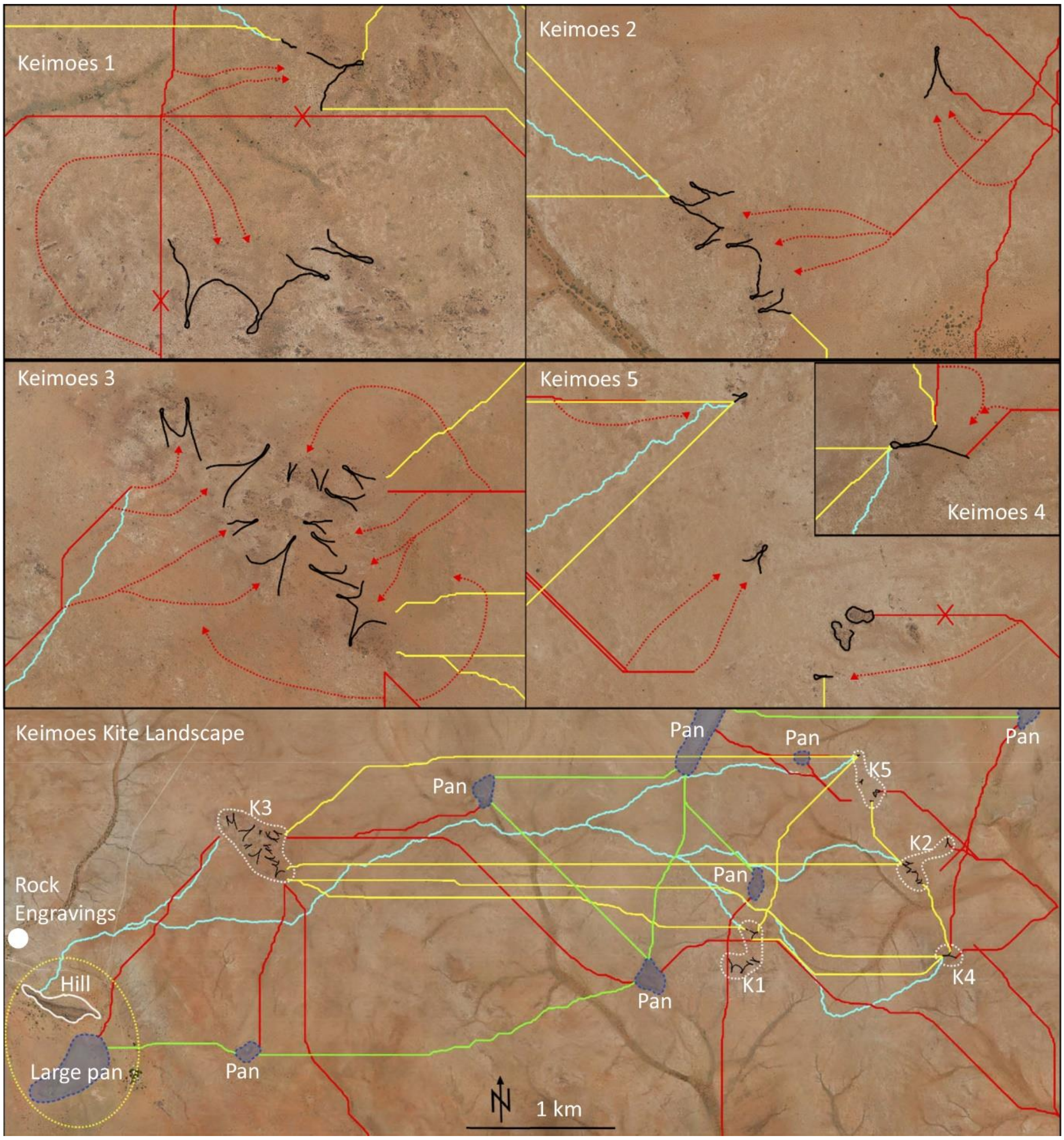

Fig. 7 Least-cost paths map. Paths linking the hill to the kite sites are shown in light blue. Paths that link pans to pans are in light green. Paths that link the kite sites are in yellow, and those that link the pans and the drainage lines to the kite sites are in red (with crosses – Keimoes 1 and 5 – indicating trajectories that were likely avoided due to their proximity to the funnel arms).

Zooming out onto the Keimoes Kite Landscape, access to water and vegetation would have been the most important criteria for animals, and they would have moved on the plains between the drainage lines and pans from where these resources could be accessed (Fig. 7 bottom). The green lines indicate the most energy-efficient pathways between the Keimoes pans, hypothetically modelling animal movement on the landscape during the wet season when the pans had water, or during drier times when the pan basins provided grazing and mineral- and saltlicks (Fig. 7 bottom). Human least-cost paths to water access during the wet season from the kite sites can also be reflected by the solid red lines on the landscape map (Fig. 7 bottom). Presumably, humans would have also moved between the different kite sites, either in a socio-economic context between groups on the landscape, or to hunt with specific funnels when herds gathered in their vicinity. The yellow lines indicate the most likely pathways for people moving between the sites.

Two natural features that stand out on the Keimoes Kite Landscape are the steep-sided hill (white polygon towards the southwest corner of the landscape), and the large pan immediately to the south of the hill (both shown within the yellow stippled oval, Fig. 7). The hill provides a vantage point overlooking the vast, mostly flat landscape in all directions, and the pan is the largest one in the area. It would have held water for considerable periods in the past, long after other water sources may have dried up. There are no other similar settings on the Keimoes Kite Landscape. Interestingly, it is also just to the northwest of the hill, right on the edge of the scanned landscape, where we found a rock engraving site on a pavement of gneiss in the main drainage line that feeds into the pan (Hollmann and Lombard in prep) (Fig. 7 bottom). Rock art sites are part of the San hunter-gatherer landscape in which "…water supply and its location, the plant food supply and its location, the meat animals and their movements, are pressing absolutes around which cultural life is organised" (Biesele 1993: 9).

Nineteenth 19th century /Xam San ethnography, collected from people who used to live in the Nama Karoo south of the Gariep, describes how image-making hunter-gatherers perceived environmental features as relational entities (Bleek and Lloyd 1911; Deacon 1997; Morris 2002). Working from such records, Deacon (1988: 131) suggested that: "The long-lasting quality of the engravings and their placement […] can be seen as a deliberate attempt to mark the landscape. […] suggest[ing] that the choice of a site for engravings was purposeful and therefore held some meaning". People thus changed landforms into landscapes by marking living sites and other important localities with imagery that reflected their understanding of the world (Parkington et al. 2008). Whilst we cannot know whether the engraving site was made and/or used at the same time as the kite sites, their presence is a clear indication that the hill-pan locality on the Keimoes Kite Landscape had power of place during the Later Stone Age. The light blue pathways represent the most likely routes people took when visiting this place from the different kite sites (Fig. 7).

Considering these hypothetical pathways, we suggest that the following is noteworthy in terms of the Keimoes Kite Landscape:

1. One would assume that walking alongside a riverbed would be easier compared to taking alternative routes, yet, the visible drainage lines seem to have little influence on the modelled path trajectories.
2. In multiple instances, the different pathways intersect and/or follow a similar trajectory.
3. The Keimoes Kite Landscape was therefore one of dynamic inter-connectedness, with the movement of people and animals forming an intricate set of paths across the whole area.

Discussion

Janette Deacon's (1986) discussion of 19th century hunter-gatherer use of the Bitterputs (bitter wells) landscape (~120 km south of Keimoes), based on a sketch map from 1871 made by Bleek from his conversations with //Kabbo (one of his /Xam San informants), may help to interpret aspects of land use on the Keimoes Kite Landscape. She explains that each location annotated on the map is invariably next to a water source, and that from the top of the three steep-sided, flat-topped dolerite hills that form the Strandberg, one has an excellent view of the vast, flat plains with patches of clay where water pans form after sporadic rainstorms. From here, //Kabbo and his people must have watched "the endless herds of migrating springbok so beloved" to them (Deacon 1986: 136).

There are scratched rock engravings on all three of the Strandberg hills. These hills play a prominent role in /Xam mythology, as captured in the 'The Death of the Lizard' song (Bleek and Lloyd 1911: 214-17; Deacon 1986). Several sites on the larger Bitterputs landscape have boulders with engravings, demarcating the places as important landmarks for the local /Xam San. Three engraving styles have been identified for the region, the oldest of which are weathered fine outlines, followed by pecked designs and figures, with the most recent and least weathered the scratched motifs most likely made by the immediate ancestors of the Bleek and Lloyd informants (Deacon 1988). The Bitterputs landscape thus roughly replicates that of the Keimoes Kite Landscape in the sense that it is located amongst pans, has a steep-sided dolerite outcrop from where the plains with animal herds can be scouted, and has a place with pecked engravings where the hunter-gatherers marked their landscape.

//Kabbo, when asked where he came from answered: "My place is the Bitterputs" (Bleek and Lloyd 1911: 299). His son-in-law, /Han#kass'o, described a white boulder standing in the dry riverbed as marking this location that belonged to his father-in-law, and that he possessed a water pool with everything that came with it. /Han#kass'o goes on to describe how //Kabbo dug very effective pitfalls with which to trap game such as ostrich on his Bitterputs grounds (footnote in Bleek and Lloyd 1911: 307). Less than 15 km to the west of Bitterputs is Blouputs (blue wells) and Oud Bastard's Puts (Old

Bastard's wells), with a rock engraving site halfway in between. Oud Bastard was //Kabbo's uncle on his father's side, and it would seem that he was co-owner of Bitterputs. He also owned, amongst other things, a small hill, large trees along a watercourse, a spring and a green shrub. /Han#kass'o, on the other hand, owned the great Brinkkop (probably a mispronunciation of bruinkop [brown hill], a general description for all the iron-rich brown dolerite hills on the northern Nama Karoo), the only hill in the Bitterputs vicinity providing scouting for springbok, with several rock engravings (Deacon 1986).

The map, in combination with the recorded knowledge of the informants, shows that different inter-generational members of the same hunter-gatherer family had custodianship over specific features and landforms on a shared landscape. In the case of //Kabbo's uncle and son-in law, their total area extended to ~30x20 km and included at least three waterholes (Deacon 1986). //Kabbo and his uncle lived relatively close to each other along the same watercourse, moving frequently and freely between Bitterputs, Blouputs and Oud Bastard's Puts, but each 'possessed' their own water source and other natural resources and landmarks. Deacon (1986) highlights that contrary to assumptions of San hunter-gatherers generally moving across environmental zones following seasonal patterns, there is no mention of such relocation or migration by the Bleek informants when discussing the Bitterputs landscape. Instead, although they were clearly knowledgeable about food source seasonality and roamed fairly widely, the places they regarded as home were all within a day's walk. These insights suggest that where resources were adequate, and socio-political circumstance allowed, families of hunter-gatherer groups would stay on the same landscape for generations. As individuals, they identified with specific landforms of which they had custodianship.

Hitchcock and colleagues (2019) reported more recent ethno-archaeological observations about current ambush hunting from stone-stacked blinds at ǂGi Pan in the Kalahari basin on the border between Botswana and Namibia ~650 km north of Keimoes (Fig. 1). Here the San hunter-gatherers did not build kites, but rather a complex of small, round hunting blinds by stacking stones up to ~ 50 cm high, from where they would lie in wait with their bows and arrows, spears and knopkieries (knobbed sticks used as clubs and throwing sticks). Hitchcock and colleagues (2019) also comment on the fact that constructing the hunting blinds would require a reasonable amount of effort, seeing that many rocks were so large that they would require at least two people to shift, and that the stacked walls were up to 3 stones high. These construction methods, as well as the reported sizes of the ǂGi blinds, are similar to the enclosures at some of the kite apices at Keimoes.

The Ju/'hoansi San (a.k.a. !Kung San) hunters at ǂGi explained that knowledge about wild animal behaviour is critical for ambush hunting success (Hitchcock et al. 2019). They carefully chose the spots for blind construction after assessing wind directions, as well as the track patterns of potential prey and predators, so that the building happens in areas where wind will not carry the smell of humans to either prey or predator. Ambush strategies would be carefully planned and precisely executed by two or three hunters manning a single blind, and several blinds in the complex manned simultaneously to increase the chance of hunting success (Hitchcock et al. 2019). The blind complex at ǂGi therefore represents a form of co-operative and co-ordinated effort in both construction and ambush hunting. The structures are maintained and re-used across generations, similar to other places of resource or meaning in the landscape. In addition to hunting activities, the Kalahari pans form focal points for hunter-gatherer land-use systems in terms of where the groups camped and the general foraging territories of each group. The largest pans also serve as meeting places for groups coming from further afield "to trade, dance, and arrange marriages" (Lee 2013: 19). These resource hubs in the Dobe region, where the ǂGi pan and other similar ones are located, are still being handed down from one generation to the next as places that 'belong' to them (Hitchcock et al. 2019).

On the Keimoes Kite Landscape people arranged at least 3.5 running km of rock to form numerous funnels, cumulatively covering more than 20 ha between the funnel arms. Their construction with thousands of stones and boulders, some of which would have required several people to move, would have demanded a substantial investment in co-operative labour. Smith (2011, 2013) suggested that ungulate-drive structures, such as kites, represent communal landscape-altering endeavours aimed at increasing the annual productivity of an ecosystem in the context of arid-landscape niche construction. Seen in this context, the Keimoes kite sites represent costly, lasting and multi-generational landscape modifications that required the participation and co-ordination of builders, game drivers, hunters and butchers (e.g., Smith 2013). The effort involved in constructing and maintaining the kites would have been well worthwhile, considering the potential for bountiful springbok harvests (Lombard and Badenhorst 2019). Another trade-off against the investment is that the ambush method reduces search time and energy expended in looking for and tracking prey (Hitchcock et al. 2019), as is necessary during non-ambush bow hunting forays.

Although evidence of such costly and enduring infrastructure is thus far relatively rare in the southern African Stone Age context, it defies the notion of mostly small, isolated bands of hunter-gatherers incessantly moving across the landscape as described by Parkington and colleagues (2008) – leaving little or no evidence of their presence and activities as they follow seasonal resources. Even when there is evidence that they occupied caves or shelters, these sequenced sites are often associated with seasonal aggregation phases (Wadley 1987; 1989). This hypothesis builds on the notion that the default behaviour for all Later Stone Age hunter-gatherers was that they were structured in small, mobile family bands or extended households, who congregated occasionally amongst related households. Such gatherings are thought to only have taken place during the 'public phases' of their band life "for visiting, socialising, making and exchanging gifts, marriage brokering and intensified ritual" (Wadley 1992: 52). Deacon's (1986) work on the Bitterputs landscape and the ethno-archaeological records of the ambush hunters at ǂGi (Hitchcock et al. 2019), however, show that this was/is not necessarily the case for the all hunter-gatherer societies when permanent water may have been available within a day's walk.

The scale of the Keimoes Kite Landscape also seems to be in contrast with other known Stone Age structures, including those at ǂGi, that are mostly in the form of small (2-4 m in diameter) stone circles. Similar circles and half-circles in South Africa and Namibia are located along game trails and were used as hunting blinds from which to ambush game (Alexander 1838; Moffat 1858; Shackley 1985; Badenhorst et al. 2015, 2016), whereas others served as hut bases (e.g. Parsons 2004; Veldman et al. 2017). Some Stone Age pastoralists in southern Africa constructed larger complexes (Kinahan 1986, 1996), as well as livestock enclosures (Jerardino and Maggs 2007; Sampson 2010). In all these instances, even though morphologically different, the general construction method is similar to that of the Keimoes funnels.

Our re-calibration of dated Stone Age sites with stone structures in South Africa and Namibia (Fig. 1 bottom) shows that, with the exception of Springbokoog (Morris 1988; Beaumont et al. 1995) and perhaps Jagt Pan 7 (Parsons 2008), all sites post-date the arrival of herders on the landscape at about 2000 years ago; this suggests a relative age for the Keimoes kite sites of ≤2000 years (see discussion in Lombard et al. 2020). That being said, the Keimoes landscape in terms of human use is an ancient one. For example, the dating of archaeological deposits at Zoovoorbij Cave (Smith 1995), located ~15 km to the south of the Keimoes Kite Landscape (Fig. 8), shows hunter-gatherer presence since at least 4000 years ago, but the site also contains artefacts of Middle Stone Age character, which indicate much older occupation.

The records resulting from Cultural Resource Management (CRM) surveys (reflected in the South African Heritage Resources Information System managed by the South African Heritage Resources Agency), indicate human presence during the Earlier, Middle and Later Stone Ages (Fig. 8). The recorded points do not necessarily represent archaeological 'sites', because deflation and sheet erosion in the region sometimes produce cumulative palimpsests resulting in widespread low-density lithic scatters (Bailey 2007). Yet, they bear witness of the human footprint on the landscape for more than 300 thousand years, and further land-use patterns may emerge with future exploration of high-density scatters in association with landforms such as dunes, hills and water sources. The records also show a few more sites with stone walling east and south of the Keimoes kite sites (Fig. 8), but these are not funnel sites and will form part of a forthcoming research project (Jaco van de Walt pers. observ.).

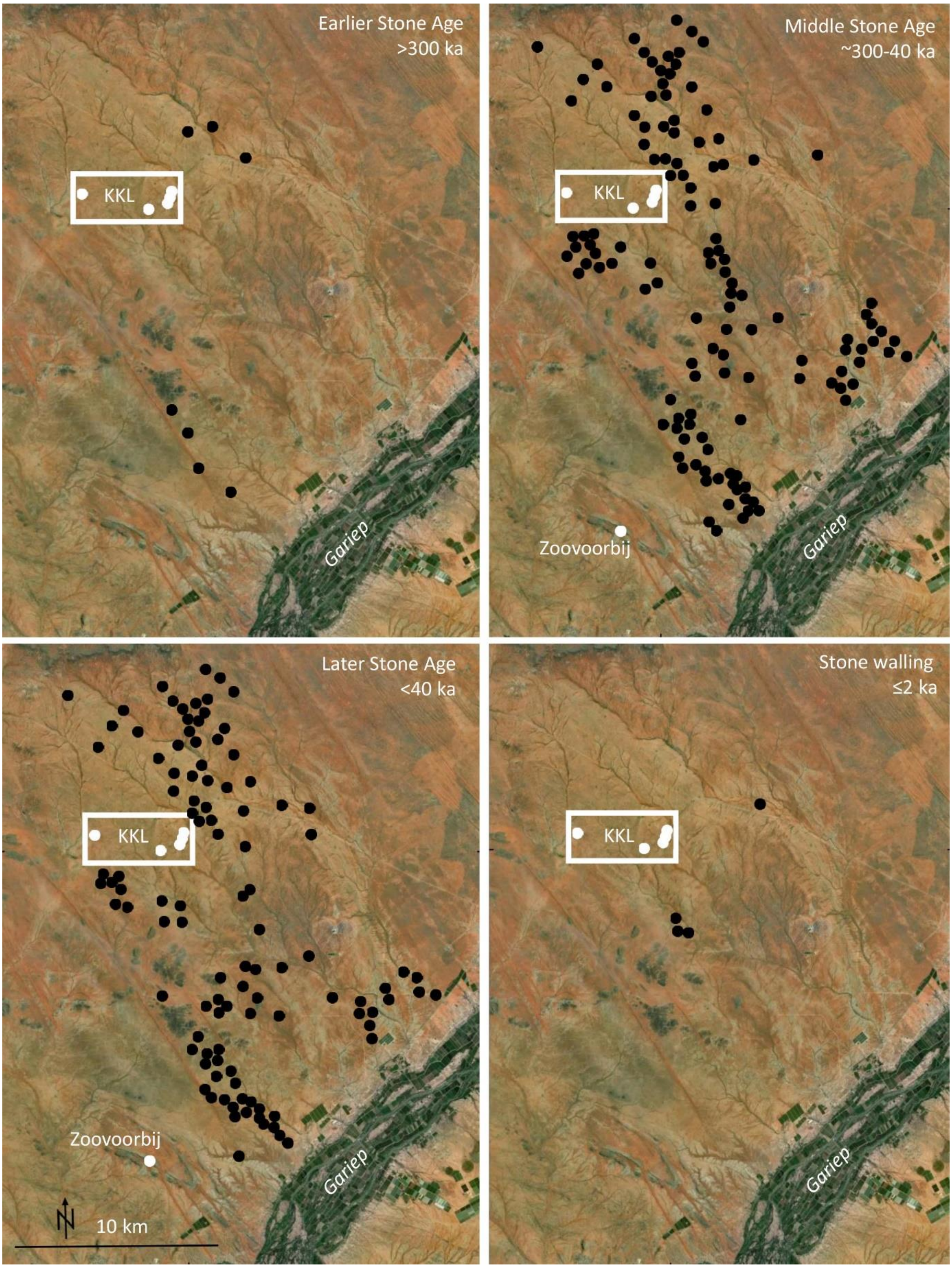

Fig. 8 Distribution of recorded Earlier, Middle and Later Stone Age observations, as well as sites with Stone Age stone walling (KKL = Keimoes Kite Landscape).

Both the archaeological and ethno-historical records indicate that the region around Keimoes was a complex socio-economic landscape for at least the last 2000 years, where several societies with a wide range of subsistence economies lived or roamed the terrain (Gordon 1778; Mossop 1935 [Coetsé 1760; Wikar 1779 ; Van Reenen 1791]; Parsons 2004; 2008; Penn 1995; Smith 1995). Whilst the hinterlands north and south of the Gariep were hunter-gatherer terrain at the time, Khoekhoe herders settled on the banks and islands of the river. By the late 1770s, some of the islands in the Gariep around Keimoes housed up to about 100 Einiqua Khoekhoe pastoralists in villages of 20-30 huts each (Wikar 1779 [in Mossop 1935]; Penn 1995).

Herding communities, originating from East Africa, admixed with local San groups to form the Khoekhoe population (Breton et al. 2014; Lombard and Parsons 2015; Parsons and Lombard 2017; Schlebusch et al. 2017). The herders who initially arrived from east Africa, however, would have brought with them experience in handling and corralling animal herds, and possibly the habit of shaping structures on the landscape for their management – desert kites have been reported from Neolithic Sudan and Egypt (Hobler and Hester 1969). On the other hand, the local hunter-gatherers had age-old knowledge systems about the rhythms of the landscape, and of when and where resources such as springbok herds would become plentiful and how best to hunt them (Lombard and Badenhorst 2019). The Gariep, as the only permanent open water source in the region, thus brought together people and animals in a vibrant socio-economic environment where co-operation, feasting, ritual, inter-marriage, the exchange of resources and familial/group skirmishes were all part of everyday life (Penn 1995; Smith 1995).

In conclusion

Based on our analyses, we proposed some minimum requirements for the construction of funnels to be effective during hunting (i.e., funnel necks of <2 m at least ~7 m long, and funnel heads between about 3 and 5 m in diameter), but found that other morphological aspects are highly variable. We determined that topographic differences, relative to the surrounding landscape, from where hunters could overlook ungulate grazing and drinking areas, was a critical aspect for the location of funnel construction. Variation in slope may have been used to slow down herd movement in some of the funnels, but slope variation in general is not substantial – which is different from the Negev kites where sudden natural or human-made drops were used to debilitate prey animals. All the Keimoes funnels were constructed within 2 km of pans, and all the funnel arms open towards the surrounding plains and occasional water sources where game would have gathered for grazing, salt/mineral licking and drinking when water was available. These plains also represent the preferred aggregation areas for large springbok herds. We further found that the Keimoes Kite Landscape was probably one of dynamic inter-connectedness, with human land-use and ‘ownership’ systems perhaps not much different from those described for Bitterputs.

Whereas globally the debate of a herding *vs* hunting use for desert kites continue (Malkinson et al. 2018; Barge et al. 2018), the reality around these structures may prove not to be an either-or scenario (Rosen 2019). Currently a hunting function for the Keimoes kites is the best-fit interpretation based on their morphology, topography and similarity to the kites of the Negev (Lombard and Badenhorst 2019; Lombard et al. 2020). The presence of pecked hunter-gatherer engravings near Keimoes 3, depicting wildlife such as giraffes, elephant, ostriches and lizards (Hollmann and Lombard in prep), and the CRM-recorded material culture scatters indicate hunter-gatherer use of the landscape through time. Most ethno-historical accounts of structured ambush hunting also point to the practice as being an integral part of hunter-gatherer animal exploitation in southern Africa (Gordon 1778; Wikar 1779 [in Mossop 1935]; Moffat 1858; Bleek and Lloyd 1911; Hitchcock et al. 2019). It is therefore reasonable to argue that the funnels were built and used by a hunter-gatherer group or groups, whose members had custodianship over the pans, the hill-pan locality as well as the funnel-hunting infrastructure across generations. Subsequent or simultaneous co-operative use by Stone Age herding communities can, however, not be excluded at this stage. Regardless of who built, used and owned (or co-built, co-used or co-owned) the Keimoes funnels, such a co-operative investment that brings with it “a kind of ownership or right of use” (Rosen 2019: 72), indicates a distinct adaptation in the structure of the Keimoes Kite Landscape and the societies who inter-acted with it.

For example, in the greater Keimoes region, Dunn (1931: 30) linked one of the two great San hunter-gatherer festivals with the time “when the travelling springbok passed by” and “thus fell an easy prey to the Bushman’s arrow”. This would indicate that mass killing of springbok was shared by several different groups on the landscape when they feasted, and when they ‘visited each other’ when springbok was plentiful (Bleek and Lloyd 1911). Such feasts could also have resulted in surplus meat, hide, horn and sinew, which could have been traded with the Khoekhoe on the river or hunter-gatherer groups with fewer resources further north. The generated surpluses and associated trade networks would have impacted on economies and socio-political power relationships across the trans-Gariep region.

The Graafwater and Seekoei River Valley records mentioned in the introduction to this paper could mean that Stone Age kite sites and associated behaviours may have been more widely distributed throughout southern Africa. If the sites were primarily constructed for the funnel hunting of migrating springbok herds, then their wider distribution may potentially be linked with regions known for trekbokken. They may also be linked to intense interaction between hunter-gatherer and herding groups, as has been recorded in different contexts for both the central Gariep near Keimoes and the Seekoei River Valley.

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