[Supplementary material]

The Keimoes 3 desert kite site, South Africa: an aerial lidar and micro-topographic exploration

Marlize Lombard[1], Matthew V. Caruana[1], Jaco van der Walt[1] & Anders Högberg[1,2,*]

[1] *Palaeo-Research Institute, University of Johannesburg, South Africa*

[2] *School of Cultural Studies Archaeology, Linnaeus University, Sweden*

[*] *Author for correspondence (Email: anders.hogberg@lnu.se)*

Table S1. Newly calibrated age ranges for all the ^{14}C-dated Stone Age stone structures from Namibia and South Africa (calibrations based on Hogg *et al*. 2013; Loftus *et al*. 2019).

Site	Radiocarbon date	Calibrated range at 95.4%	Pottery	Metal	Source/s
Brandberg (date 1)	150±50 BP (Pta-3891)	AD 1670 and younger	Yes	Not stated	Kinahan 1991
Skeleton Coast N2003/3	165±50 BP (KIA-21033)	AD 1660 and younger	Yes	none	Eichhorn & Vogelsang 2011
Kuidas Spring	216±24 BP (OxA-27897)	AD 1650-1880	Yes	Present	Veldman *et al.* 2017
Bloubos 7 (Spit 2)	340±50 BP (Pta-7730)	AD 1450-1670	Yes	None	Parsons 2004
Zerrissene Mountains	345±40 BP (Pta-1577)	AD 1470-1660	Yes	Present	Carr *et al.* 1978
Skeleton Coast N2002/5	400±50 BP (KN-5565)	AD 1440-1640	No	None	Eichhorn & Vogelsang 2011
Sylvia Hill (date 1)	510±45 BP (Pta-3294)	AD 1390-1610	Yes	Not stated	Shackley 1983
Brandberg (date 2)	570±50 BP (Pta-3873)	AD 1310-1460	Yes	Not stated	Kinahan 1991
Sylvia Hill (date 2)	1070±60 BP (Pta-3295)	AD 890-1160	Yes	Not stated	Shackley 1983
Seacow River Valley	1080±40 BP (Beta-230584)	AD 890-1150	Yes	Not stated	Sampson 2010
Skeleton Coast N2002/7	1175±25 BP (KIA-18993)	AD 880-990	Yes	None	Eichhorn & Vogelsang 2011
Simon se Klip	1440±60 BP (GX-32343)	AD 540-770	Yes	None	Jerardino & Maggs 2007
Jagt Pan 7	1610±50 BP (Pta-4300)	AD 380-600	Yes	None	Parsons 2008
Hartmann's Valley	1690±110 BP (UtC-9880)	AD 130-640	Yes	Present	Eichhorn & Vogelsang 2011
Springbokoog 1	4630±60 BP (Pta-4091)	3520-3090 BC	No	No	Morris 1988; Beaumont & Vogel 1989; Beaumont *et al.* 1995

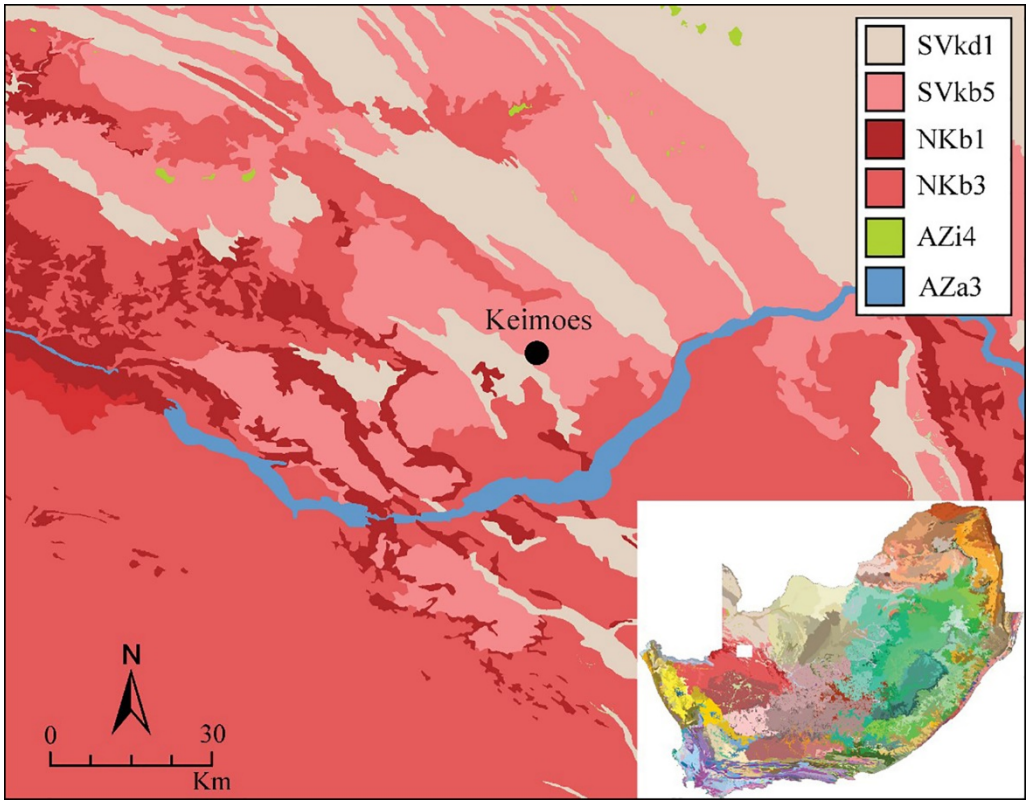

Figure S1. South African vegetation map and detailed veld-type map of the area surrounding Keimoes 3 including Lower Gariep Broken Veld (NKb1), Bushmanland Arid Grassland (NKb3), Kalahari Karroid Shrubland (NKb5), Gordonia Duneveld (SVkd1) and Lower Gariep Alluvial Vegetation (AZa3). AZi4 indicates saltpans of the southern Kalahari (map adapted from Mucina & Rutherford 2006).

Table S2. Geology, soils, climate and vegetation overview within a 20km radius of Keimoes 3, according to bioregions and their vegetation units as identified and discussed in Mucina and Rutherford (2006).

Geology and soils	Climate	Altitude, features and vegetation
NAMA-KAROO BIOME: BUSHMANLAND BIOREGION		
Lower Gariep Broken Veld: NKb1 (Mucina & Rutherford 2006: 333–34)		
The geology here is complex. Banded iron formation and amphibolites of the Asbestos Hills Subgroup are Vaalian and the carbonates and cherts of the Campbell Group are of the same era. Metamorphic rocks of the Mokolian Erathem include quartzites and gneisses of the Korannaland Supergroup as well as the Riemvasmaak gneiss. Metamorphosed clastic sediments of the Uitdraai formation are also Mokolian. Remaining areas are composed of the multiplex Namaqualand Metamorphic Complex. Soils are shallow and skeletal, typically of Ib, Ic and some Fb land types.	The mean annual precipitation ranges from ~77mm in the west to ~240mm in the east. Summers are hot with mean maximum temperatures for January reaching 41°C in January, and mean minimum temperatures -2°C in July for Kakamas. Frost varies from less than 10 days per annum in the west to around 30 days in the east.	Altitude ~400–1200m. Hills and low mountains characterise this region, plains are slightly irregular but with some rugged terrain (e.g. downstream of the Augrabies Falls). The sparse vegetation is dominated by shrubs and dwarf shrubs, with annuals (especially in the spring), and perineal grasses and herbs. Groups of widely scattered low trees such *Aloidendron dichotomum*, (previously *Aloe dichotoma*) and the drought-resistant *Vachellia karroo* (previously *Acacia mellifera*) occur on slopes of outcrops and on the sandy soils of foot slopes respectively.
Bushmanland Arid Grassland: NKb3 (Mucina & Rutherford 2006: 335–36)		

A third of the area is covered by recently (Quaternary) alluvium and calcrete. Superficial deposits of the Kalahari Group are present in the east. There are outcrops of Palaeozoic diamicitites of the Dwyka Group and metasediments of Mokolian age. The soils of most of the area are red-yellow apedal soils, freely drained, with a high base status and mostly < 300 mm deep, typical of Ag and Ae land types.	Rain falls largely in late summer/early autumn and varies annually, with a mean annual precipitation varying from 70mm in the west to 200mm in the east. At Kenhardt, mean maximum and minimum temperatures are 40.6°C for January and -3.7°C for July. The Middle Orange river, mostly surrounded with this regime experiences about ten days of frost per annum.	Altitude vary between 600 and 1200m. The landscape consists of extensive to irregular plains on a slightly sloping plateau, sparsely vegetated by grassland. It is dominated by white grasses (*Stipagrostis* species) giving this vegetation type the character of a semi-desert 'steppe'. In places, low *Salsola* shrubs change the vegetation structure. In years of abundant rainfall, the veld experiences rich displays of annual herbs.
Kalahari Karroid Shrubland: NKb5 (Mucina & Rutherford 2006: 337)		
Mudstones and shales of the Ecca Group (Prince Albert and Volksrust Formations) and Dwyka tillites, both of early Karoo age, dominate. About 20 per cent of rock outcrop is formed by Jurassic intrusive dolerite sheets and dykes. Soils are shallow Glenrosa and Mispah forms, with lime generally present in the landscape (Fc land type), and some red-yellow apedal, freely drained soils with high base status usually <15 per cent clay (Ah and Ai land types). The salt content in these soils is very high.	Rainfall occurs in late summer/early autumn with mean annual precipitation 100–200mm. Mean temperatures for January are ~40°C and for July ~ -3°C.	Altitude ~800–1200m. Slightly irregular plains with dwarf shrubland dominated by a mixture of low sturdy, spiny (and sometimes also succulent) shrubs and white grasses characterises the landscape. In years of good rainfall, annuals such as *Gazania* and *Leyseria* species are abundant.
SAVANNA BIOME: KALAHARI DUNEVELD BIOREGION		
Gordonia Duneveld: SVkd1 (Mucina & Rutherford 2006: 525)		
Aeolian sand underlain by superficial silcretes and calcretes of the Cenozoic Kalahari Group. Fixed parallel sand dunes, with almost exclusively Af land type.	Summer and autumn rainfalls with very dry winters. MAP 120–260mm. Frost fairly frequent to frequent in winter. December mean maximum temperature is ~40°C, and the mean minimum for July ~ -4°C.	Parallel dunes ~308m above plains. Open shrubland with ridges of grassland dominated by duinriet (*Stipagrostis amabilis*) and driedoring (*Rhigozum trichotomum*) in the inter-dune straiten.
FRESHWATER WETLANDS		
Lower Gariep Alluvial Vegetation: AZa3: (Mucina & Rutherford 2006: 639)		
Recent alluvial deposits of the Orange River supporting soil forms such as Dundee and Oakleaf. The river cuts through a great variety of Precambrian metamorphic rocks. Ia land type. Subject to floods in summer.	Details as above for different regions.	Altitude 1–1000m with flat alluvial terraces and riverine islands supporting a complex of riparian thickets dominated by *Ziziphus mucronata*, *Euclea pseudebenus* and *Tamarix usneoides*, reed beds with *Phragmites australis* as well as flooded grasslands and herblands populating sand banks and terraces within and along the river.

Table S3. Synthesis of the micro-topographic features of some Negev kite sites as discussed by Bar-Oz *et al.* (2011: 109–211).

Kite	Micro-topographic features (natural and/or constructed)
Samar West-A kite	The kite is located on a plain, facing north towards a rich grazing pasture and marshland oasis 3km south of it. Its right arm reaches the apex from the northwest, its arms create a narrow neck near the apex. Excavation revealed that the apex of the trap was built above a shallow wadi bed, to take advantage of the small topographic difference that is needed to hide the enclosure. The head itself is circled by a wall made of massive stones. A large, round pit was dug before the construction of the enclosure wall. In addition, a stone ramp was built where the arms meet the apex, to increase the vertical difference between the running plane of the hunted game and the bottom of the trap's head. Both operations created a change in depth from ~0.6–0.7m to more than 1.5m (Nadel *et al.* 2010).

Samar West-B kite	The kite is adjacent to the Samar West-A kite and together they form the shape of a W open to the north. The right arm of Samar West-B starts at the foot of a steep hill. Together the two kites block the southern exit from the rich pasture area of the oasis. The arms of Samar West-B were built on a flat area, running south into a shallow wadi, where the apex was constructed. The head of the kite was surrounded by a massive wall preserved up to 1.2m. The excavated trench clearly indicates that, before construction, the builders dug a wide, shallow pit, approximately 1m deep, including a vertical cut into the wadi bank and a ramp on the terrace, just above the enclosure, to enhance the depth of the vertical fall and to hide the trap from the driven game. Later the kite's enclosure was turned into a corral.
Sayarim kite	The kite is located on a slope facing east with its arms open to a plain on the west, dropping steeply towards the apex, built within a small wadi.
Pitam kite 4	The kite is built on an east-facing slope, opening to a plateau on the west and curves steeply into a small wadi on the east, where the apex is built. The lack of vegetation to the west can explain the kite's location, and it blocks ancient trails used by ungulates. A massive barrier of large rocks forms the enclosure that was originally built within the small wadi, diverting it with a few metres.
Har Harut kite	This is a small kite located within a crater. Like the Pitam and Sayarim kites, its setting indicates that it was carefully placed within a narrow pass on ancient animal trails.
Nahal Eshel kite	The kite is built on the edge of a plateau. The arms open to the west toward a wide plain, while they converge to the apex on a steep, rocky slope. The natural slope was utilised for the kite's design and the construction of the enclosure.
Nahal Horsha North and South	These two kites are located above and to the west of a broad wadi that runs to the north. They are approximately 600 m away from each other on flat hilltops. The arms of both kites are open to the plateau. One of the arms was built along a natural cliff. In both kites, the apex was set below a cliff ~5 m deep that faces east (northern kite) and southeast (southern kite), and both are opened to the west and northwest. At the bottom of the cliff, a massive rampart created a round enclosure.
Giv'at Shehoret kite	A small kite situated on a plain intersected by west-east wadis. The arms run on a steep slope, while the apex is in the wadi.
Har Shahamon kite	The arms of this small kite located at a topographic saddle run from the north and west, capturing the animals driven from a broad wadi to the north. The apex is massively built in a wadi.

References

BAR-OZ, G., D. NADEL, U. AVNER & D. MALKINSON. 2011. Mass hunting game traps in the Southern Levant: the Negev and Arabah "desert kites". *Near Eastern Archaeology* 74: 208–15. https://doi.org/10.5615/neareastarch.74.4.0208

BEAUMONT, P.B. & J.C. VOGEL. 1989. Patterns in the age and context of rock art in the Northern Cape. *The South African Archaeological Bulletin* 44: 73–81. https://doi.org/10.2307/3887648

BEAUMONT, P.B., A.B. SMITH & J.C. VOGEL. 1995. Before the Einiqua: the archaeology of the frontier zone, in A.B Smith (ed.) *Einiqualand: studies of the Orange River frontier*: 236–64. Cape Town: UCT Press.

CARR, M.J., A.C. CARR & L. JACOBSON. 1978. Hut remains and related features from the Zerrissene mountain area: their distribution, typology and ecology. *Cimbebasia* 2: 235–58.

EICHHORN, B. & R. VOGELSANG. 2011. *Under the Mopane tree: Holocene settlement in northern Namibia* (Africa Praehistorica 24). Köln: Heinrich Barth Insitut.

HOGG, A.G. *et al*. 2013. SHCal13 Southern Hemisphere calibration, 0–50 000 years cal BP. *Radiocarbon* 55: 1889–1903. https://doi.org/10.2458/azu_js_rc.55.16783

JERARDINO, A. & T. MAGGS. 2007. Simon se Klip at Steenbokfontein: the settlement pattern of a built pastoralist encampment on the west coast of South Africa. *South African Archaeological Bulletin* 62: 104–14.

KINAHAN, J. 1991. *Pastoral nomads of the central Namib Desert: the people that time forgot*. Windhoek: Namibia Archaeological Trust and New Namibia Books.

LOFTUS, E., P.J. MITCHELL & C. BRONK RAMSEY. 2019. An archaeological radiocarbon database for southern Africa. *Antiquity* 93: 870–85. https://doi.org/10.15184/aqy.2019.75

MORRIS, D. 1988. Engraved in place and time: a review of variability in the rock art of the Northern Cape and Karoo. *South African Archaeological Bulletin* 43: 109–20. https://doi.org/10.2307/3888623

MUCINA, L. & M.C. RUTHERFORD. 2006. *The vegetation of South Africa, Lesotho and Swaziland*. South African National Biodiversity Institute: Pretoria

NADEL, D., G. BAR-OZ, U. AVNER, E. BOARETTO & D. MALKINSON. 2010. Walls, ramps and pits: the construction of the Samar Desert kites, southern Negev, Israel. *Antiquity* 84: 976–92. https://doi.org/10.1017/S0003598X00067028

PARSONS, I. 2004. Stone circles in the Bloubos landscape, Northern Cape. *Southern African Humanities* 16: 59–69.

– 2008. Five later Stone Age artefact assemblages from the interior Northern Cape province. *The South African Archaeological Bulletin* 63: 51–60.

SAMPSON, C.G. 2010. Chronology and dynamics of later Stone Age herders in the upper Seacow River valley, South Africa. *Journal of Arid Environments* 74: 842–48. https://doi.org/10.1016/j.jaridenv.2008.11.001

SHACKLEY, M. 1983. Human burials in hut circles at Sylvia Hill, south-west Africa/Namibia. *Cimbebasia 3*: 102–106.

VELDMAN, A., I. PARSONS & M. LOMBARD. 2017. Kuidas Spring 1, Namibia: first impressions of a Later Stone Age site complex. *South African Archaeological Bulletin* 72: 60–70.