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# *Homo sapiens* origins and evolution in the Kalahari Basin, southern Africa

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**Abstract**

The Kalahari Basin, southern Africa preserves a rich archeological record of human origins and evolution spanning the Early, Middle and Late Pleistocene. Since the 1930s, several stratified and dated archeological sites have been identified and investigated, together with numerous open-air localities that provide landscape-scale perspectives. However, next to recent discoveries from nearby coastal regions, the Kalahari Basin has remained peripheral to debates about the origins of *Homo sapiens*. Though the interior region of southern Africa is generally considered to be less suitable for hunter-gatherer occupation than coastal and near-coastal regions, especially during glacial periods, the archeological record documents human presence in the Kalahari Basin from the Early Pleistocene onwards, and the region is not abandoned during glacial phases. Furthermore, many significant behavioral innovations have an early origin in the Kalahari Basin, which adds support to poly-centric, pan-African models for the emergence of our species.

## 1 | INTRODUCTION

*Homo sapiens* first emerged in Africa during the Pleistocene based on genetic, fossil, and archeological evidence (Box 1, Figure 1).

Until recently, much of the early fossil evidence for anatomically modern *H. sapiens* came from the Rift Valley in eastern Africa,[14] and much of the early archeological evidence, including early complex adaptive technologies[32,35–38] and the use of symbolic resources,[29,30,39] came from coastal regions in southern and northern Africa. Multiple models have been proposed for the emergence of humans, with one important question being whether a progenitor population emerged from a single region or multiple regions.[8] The geographic locations of fossil and archeological finds has led to a specific focus on eastern and southern Africa as critical areas of refuge during colder, arid periods in the past.[8,40] The Cape Floristic Region of coastal southern Africa, in particular, has provided a rich record of early *H. sapiens* behavior and has ecological potential for resource abundance during colder periods.[40,41] However, ongoing research in other parts of the African continent, including, for example, early *H. sapiens* fossils at Jebel Irhoud, Morocco,[13] and a continuous record of occupations at Panga Ya Saidi in coastal Kenya from ~78,000 years ago,[31] adds support to the view that there were more widespread human populations with cultural transmission and gene flow between them, best understood as a poly-centric, or Pan-African origin for *H. sapiens*.[6,13,42]

The Kalahari Basin, extending across a large area of southwestern Africa (Figure 2), has a rich archeological record of human occupation beginning in the Early Pleistocene. Formal archeological investigations began in the 1930s and 40s at the important sites of Wonderwerk Cave[110] in the Kalahari Basin, and Florisbad ~270 km to the southeast.[111] These sites continue to be investigated today by local and international research teams, with new sites continually identified. One of the earliest known fossils of the *H. sapiens* clade was found at Florisbad,[112] and the Kalahari Basin contains numerous Middle Stone

**Box 1 The African origins of *Homo sapiens***

Consistently, genetic studies show that modern African populations demonstrate the greatest amount of genetic diversity.[1,2] This means African populations had the longest time to diversify because our species first emerged on that continent. Indigenous populations in southern Africa consistently reflect the greatest genetic diversity of all African populations.[3–5] However, this may not reflect the origin centre within Africa,[6] because at that scale, population locations today are not the same as in the deep past. Populations have moved significantly, most recently influenced by colonial disruptions, and before that the spread of herders and farmers across the continent.[2,7] The process of reconstructing past population dynamics based on the genetic relationships of modern populations is complex and relies on many parameters. The default "tree-like" model generally assumes a single origin centre for *H. sapiens*, followed by dispersal and replacement of archaic populations, and then diversification. However, some researchers propose that an alternative model of semi-sub-divided populations connected by sporadic gene flow better explains the observed genetic relationships.[6–8] This model considers the potential for multiple origin centers and hybridization,[9,10] rather than replacement.

The earliest *H. sapiens* fossils are in Africa.[11–14] The earliest fossils described as belonging to "the *H. sapiens* clade"[13] are dated to ~300–200 (Figure 1). This includes the Florisbad cranium in central South Africa,[11] and several specimens at Jebel Irhoud, Morroco.[13] The earliest fossils with the full suite of modern *H. sapiens* morphologies are dated to ~195 ka at Omo, Ethiopia[15] and ~160 ka at Herto, Ethiopia.[14] New fossil finds are revealing that early *H. sapiens* coexisted with other hominins in Africa; the *Homo naledi* fossil assemblage from Rising Star Cave, South Africa, is dated to between ~335 and 236 ka.[16] A calvaria from Iwo Eleru, Nigeria dated to ~16–12 ka shows a mosaic of primitive and derived features, attesting to a complex evolutionary history involving relatively recent gene flow between archaic and modern *H. sapiens*.[17]

The earliest archeological evidence for the complex behaviors that characterize *H. sapiens* also comes from multiple regions of Africa.[18] Early models linked certain kinds behaviors exclusively to our species and proposed a revolutionary event ~50 ka for the emergence of "behavioral modernity." "Behavioral modernity" is a problematic concept for many reasons, including the observations that no traits are purely unique to *H. sapiens* and characteristic of all *H. sapiens* everywhere.[9,19,20] In opposition to a revolutionary model, the African record is more consistent with a gradual and patchy accumulation across multiple regions of new behaviors, and in particular, those traditionally associated with the concept of "behavioral modernity".[18] For example, early blade production is documented at Kathu Pan, South Africa[21] and the Kapthurin Formation, Kenya[22] ~500 ka (Figure 1). Utilized and ground pigments that may have been used to produce a powder for coloring skin, hair, and/or objects have been recovered from sites dating to more than 300 ka at Olorgesaillie, Kenya[23] and Kathu Pan, South Africa.[24] Collected non-utilitarian items are known in contexts dating to ~114–106 ka at Pinnacle Point on the south coast of South Africa (sea shells)[25] and ~105 ka at Ga-Mohana Hill North Rockshelter more than 600 km inland (crystals).[26] Geometric engravings on ochre and ostrich eggshell have been recovered from archeological contexts dating to ~100 ka in South Africa.[27,28] Beads made from seashells and dating to more than 75 ka have been recovered Grotte des Pigeons, Morocco[29] and Blombos Cave, South Africa,[30] and ~67 ka at Panga ya Saidi, Kenya.[31] Backed bladelets, which may have been components in multi-part, high-velocity hunting weapons such as the bow and arrow are known at sites in South Africa dated to more than 70 ka,[28,32,33] and in East Africa at ~50 ka.[31,34]

Age (MSA) archeological sites relevant for our understanding of the emergence and behavioral evolution of our species.

Recent discoveries from flagship sites in South Africa such as Sibudu Cave,[113,114] Blombos Cave,[27,115] the Pinnacle Point sites,[32,36,116] Klasies River Mouth,[117] and Diepkloof Rockshelter[28,118] attest to the MSA origins of the kinds of complex technological, symbolic, and social behaviors that characterize *H. sapiens*.[18,119,120] The geographic location of these sites at or near the coast has led to the dominant narrative of *H. sapiens* origins being intrinsically tied to the coast and marine resources,[40,121–124] with little or no contribution from the Kalahari Basin. However, some of the earliest evidence for MSA-type technologies in southern Africa has been recovered in the Kalahari Basin in contexts >300 ka,[21,52,70,125] coeval or earlier than MSA technologies in East Africa[23] and North Africa.[126] Furthermore, the growing MSA record in the Kalahari Basin is revealing early origins for the kinds of complex technologies and symbolic capacities that characterize our species.[21,26,70,105,127]

The last four decades have seen increasing archeological investigations in and immediately adjacent to the Kalahari Basin, resulting in the identification of numerous cave, rockshelter, and open air sites (Table 1). Investigations thus far are largely clustered within two areas; in the Middle Kalahari Basin near the Okavango Delta and Makgadikgadi Pan, and at the edge of the Southern Kalahari Basin near the Kuruman Hills. In this review, sites located within ~100 km of the edge of the Kalahari are also included to account for yearly mobility and family exchange networks, as well as past environmental change. Many excavations have targeted long stratified sequences, such as those at Wonderwerk Cave,[127] Kathu Pan,[69] Ga-Mohana Hill North Rockshelter,[63] and White Paintings Rockshelter,[101] in addition to numerous open air surface sites that contribute to broader

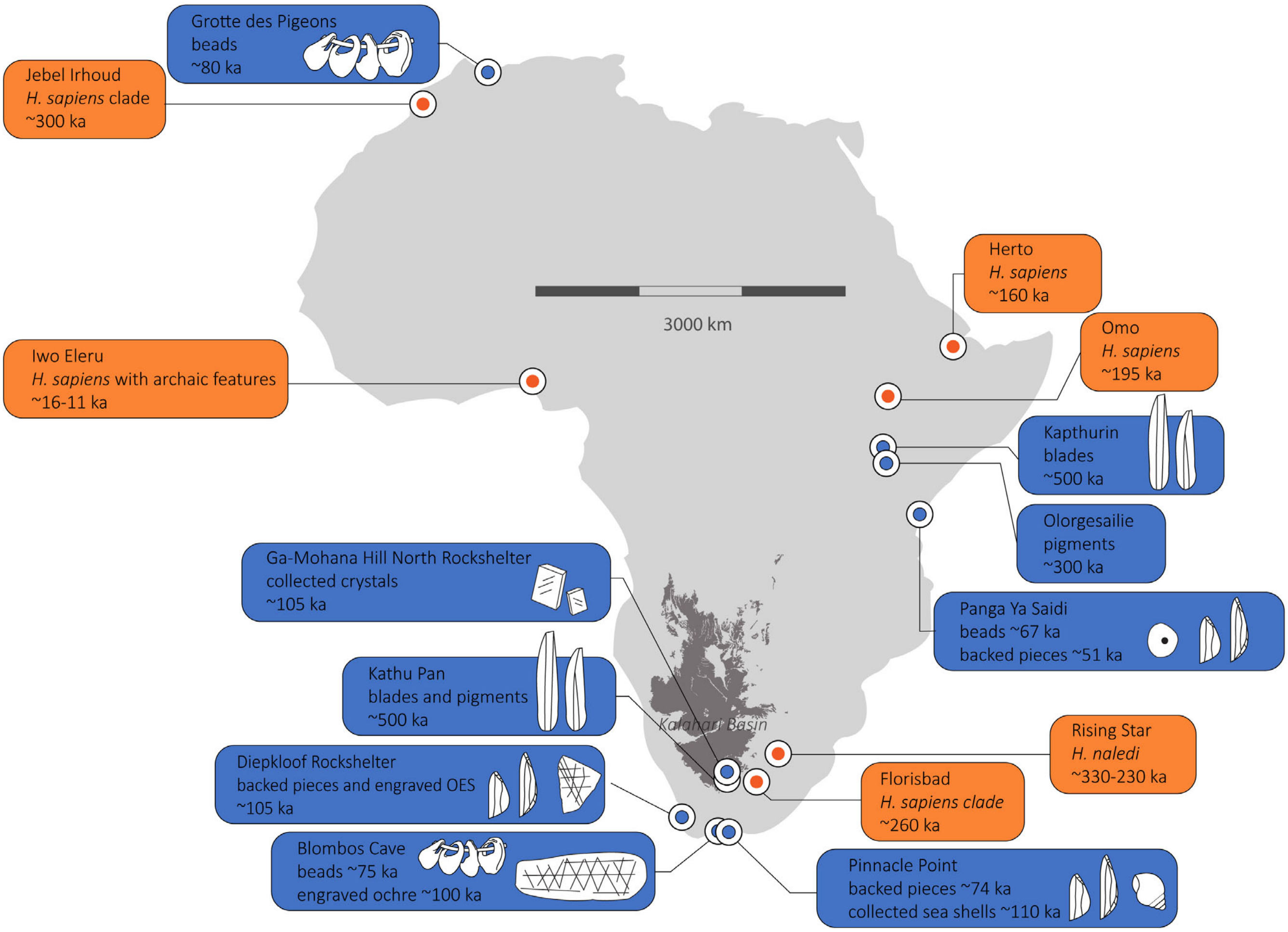


**FIGURE 1** Some key sites with fossil (orange) and archeological (blue) evidence regarding *Homo sapiens* origins in Africa

questions about landscape use. Multidisciplinary teams from many African institutions have carried out archeological work in the Kalahari Basin, including importantly the McGregor Museum, Kimberley, which houses nearly all the recovered material from the Southern Kalahari Basin, as well as the University of the Witswatersrand, University of Cape Town, Sol Plaatje University, University of the Free State, and the National Museum of Botswana. Collaborating international researchers have come from many countries, including the USA, UK, Germany, Canada, and Australia. The rich archeological record of the Kalahari Basin is key for understanding the evolution of early human behavioral evolution in Africa over the long term, and others have highlighted its significance.[26,63,95,102,105,127,128] However, a comprehensive review that brings together evidence from these diverse research programs across the whole of the Kalahari Basin has not previously been published.

The Kalahari Basin is a sand mantled landscape with an area in excess of 25 million km$^2$ in the Summer Rainfall Zone of southwestern Africa. There is a latitudinal climatic and ecological gradient ranging from the forests of Zambia in the Northern Kalahari to the deserts of Botswana in the Southern Kalahari, with mean annual precipitation exceeding 1000 mm in the north and being less than 200 mm in the south. Low precipitation and high evaporation in the Middle and Southern Kalahari results in arid and semi-arid conditions with a notable rarity of surface water today.[95] These kinds of conditions have led to a general perception that much of the interior of Africa was not suitable for early human occupation.

However, high aridity was not always the condition in the Kalahari Basin.[129] Through the Pleistocene and Holocene in the Middle Kalahari, there is extensive evidence for the intermittent existence of large lacustrine systems that are today ephemerally dry.[95,130,131] In the Southern Kalahari, Pleistocene wet periods have been identified at pan and spring sites based on sedimentary analysis.[33,68,125] At Wonderwerk Cave, multiple proxies for palaeoenvironmental conditions demonstrate shifts through the Pleistocene and Holocene,[105,128,132–135] and nearby Mamatwan Mine shows evidence for a permanent water body where none exists today.[136] At Ga-Mohana Hill, extensive tufa deposits indicate past periods of increased effective precipitation during the Pleistocene.[26] Recent research into Kalahari palaeoenvironments suggests that during some past periods, many regions within the Kalahari Basin were likely highly suitable for early human occupation and this is supported by the archeological record.

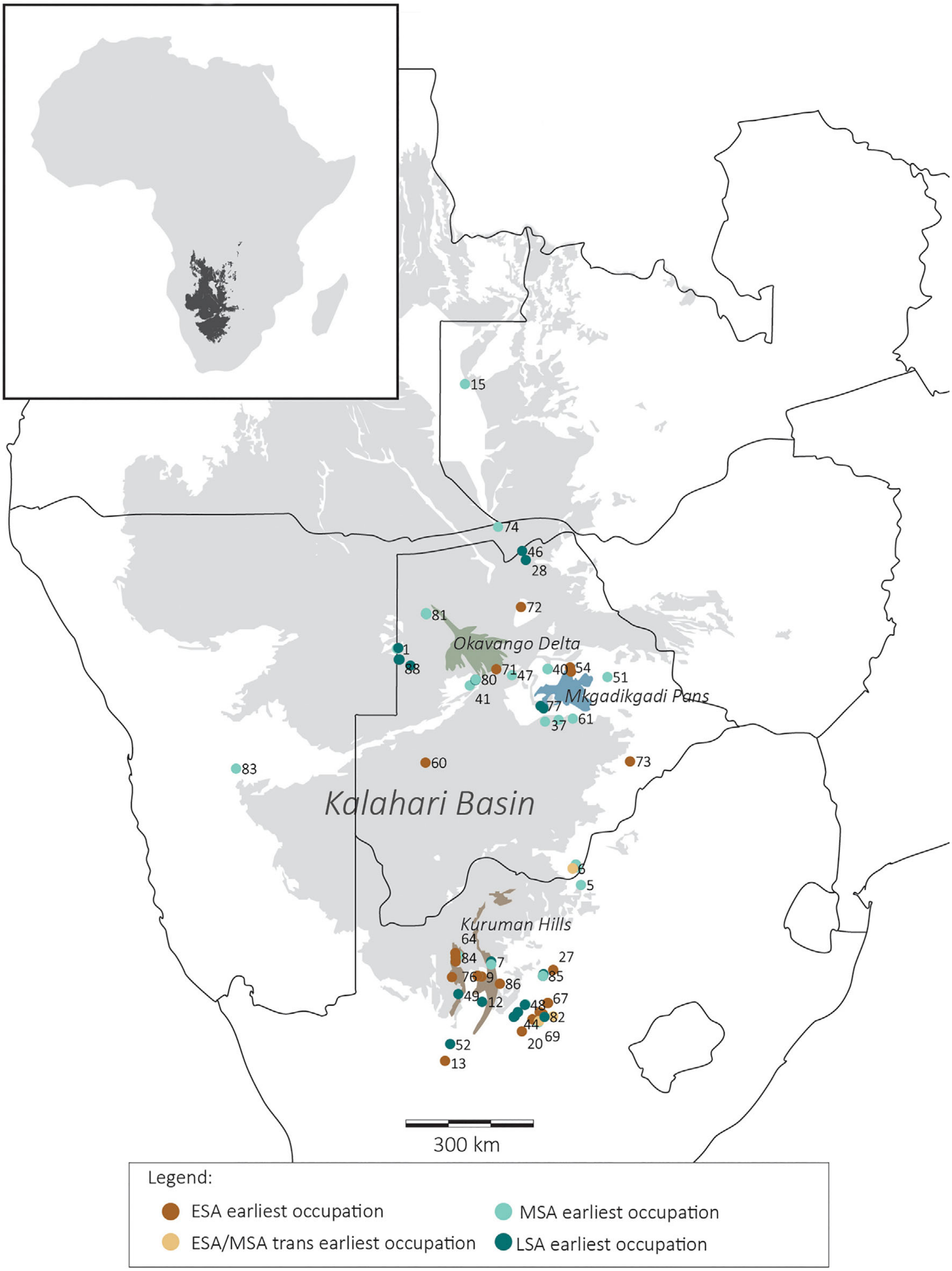


**FIGURE 2** Archeological sites in and near (~100 km) the Kalahari Basin, southern Africa. Inset: Location of Kalahari Basin (dark gray) within Africa. Main: Colored points represent sites with ESA, ESA-MSA transitional, MSA, or LSA-designation for the earliest occupation; brown = earliest occupation in ESA, beige = earliest occupation in ESA-MSA transition, light blue = earliest occupation in MSA, dark blue = earliest occupation in LSA. Numbers refer to Table 1

Here, I review and synthesize archeological information from Stone Age contexts in the Kalahari Basin. I emphasize evidence for complex technologies and symbolling capacities generally associated with "behavioral modernity" or "modern human behaviour," thereby providing a fresh assessment of the emergence of *H. sapiens*. The long chronological sequences, together with the abundance of

**TABLE 1** Archeological sites in and near (~100 km) the Kalahari Basin, southern Africa

| Site | Coordinates | Time period | Site type | Age estimate(s) | Dating method(s) | Individual ages | MIS occupations | References | # Figure 2 |
|---|---|---|---|---|---|---|---|---|---|
| ≠Gi | −19.616, 21.016 | MSA and LSA | Open air | 77, 34, 0.1 ka | TL, radiocarbon | TL 77 ± 11, radiocarbon 34 ± 1, 0.1 ± 0.05 ka | 5,3,1 | 43 | 1 |
| 45-C4-17, Ranaka | −24.935, 25.428 | ESA | Open air | n/a | n/a | n/a | | 44 | 2 |
| 45-C4-28, Ranaka | −24.993, 25.455 | MSA | Open air | n/a | n/a | n/a | | 44 | 3 |
| 45-C4-38, Ranaka | −24.918, 25.424 | MSA | Open air | n/a | n/a | n/a | | 44 | 4 |
| 45-D3-18, Ranaka | −25.424, 25.551 | MSA | Open air | n/a | n/a | n/a | | 44 | 5 |
| 55-A2-09, Ranaka | −25.016, 25.388 | ESA/MSA | Open air | n/a | n/a | n/a | | 44 | 6 |
| Batlharos 1 | −27.311, 23.345 | LSA | Open air | 0.2 ka | Radiocarbon | 0.2 ± 0.03 ka | 1 | 45 | 7 |
| Bestwood 1 | −27.682, 23.091 | Fauresmith | Open air | 366 ka | OSL | 366 ± 32 ka | | 46,47 | 8 |
| Bestwood 2 | −27.685, 23.09 | ESA | Open air | n/a | n/a | n/a | | 46 | 9 |
| Bestwood 3 | −27.675, 23.099 | ESA | Open air | n/a | n/a | n/a | | 46 | 10 |
| Biesiesput | −28.809, 24.502 | MSA | Open air | n/a | n/a | n/a | | 48 | 11 |
| Blinkklipkop | −28.301, 23.115 | LSA | Open air | 1–0.3 ka | Radiocarbon | 1.2 ± 0.04, 0.8 ± 0.05, 0.3 ± 0.05 ka | 1 | 49 | 12 |
| Bundu Farm | −29.751, 22.206 | ESA(?), MSA and LSA | Open air | >146, 146, <146 ka | ESR/U-series | 145 ± 16 ka | 6 | 50 | 13 |
| Canteen Koppie | −28.543, 24.53 | ESA, Fauresmith, LSA | Open air | 1.5 Ma, 1,2 Ma, >300, 0.4 ka | Cosmogenic, OSL, radiocarbon | cosmogenic 1.5 ± 0.08, 1.2 ± 0.07 Ma, OSL 300–315 ka, radiocarbon (cal) AD 1681–1966, AD 1436–1637, AD 1531–1955, AD 1637–1955 | 1 | 48,51–56 | 14 |
| Chavuma | −13.094, 22.688 | MSA and LSA | Open air | 75, 66, 17, 8–7 ka | OSL | 75 ± 16, 66 ± 10, 17 ± 3, 8.4 ± 1.3, 6.8 ± 1.1 ka | 5(?),4,2,1 | 57 | 15 |
| Depression Rock Shelter | −18.749, 21.74 | LSA | Rockshelter | 19–0.4 ka | Radiocarbon | 19 ± 0.2, 13 ± 0.3, 11 ± 0.4, 7.1 ± 0.09, 3.5 ± 0.12, 1.9 ± 0.09, 0.4 ± 0.08 ka | 2,1 | 58 | 16 |
| Dikbosch 1 | −28.673, 23.902 | LSA | Rockshelter | 14–2 ka | Radiocarbon | 14 ± 0.1, 8.0 ± 0.06, 3.1 ± 0.06, 1.6 ± 0.04 ka | 2,1 | 49 | 17 |
| Dikbosch 2 | −28.654, 23.918 | LSA | Rockshelter | 0.6 ka | Radiocarbon | 0.6 ± 0.05 ka | 1 | 49 | 18 |
| Doornlaagte | −28.722, 24.354 | ESA | Open air | n/a | n/a | n/a | | 59 | 19 |
| Driekopseiland | −29.018, 24.096 | ESA, MSA, and LSA | Open air | >39 ka, 5–0.8 ka | Radiocarbon | 39 ± 1 ka, 4475–3040 BP, 1220–800 BP | 1 | 60 | 20 |
| Drotsky's Cave | −20.022, 21.354 | LSA | Cave | 12–5 ka | Radiocarbon | 12 ± 0.08, 11 ± 0.06, 5.5 ± 0.09 ka | 2,1 | 61 | 21 |
| Equus Cave | −27.616, 24.63 | LSA | Cave | 8–7 ka | Radiocarbon | 7576–7270 cal BP, 8399–8050 cal BP | | 62 | 22 |
| Ga-Mohana Hill North Rockshelter | −27.387, 23.343 | MSA and LSA | Rockshelter | 105, 31, 15 ka | OSL, radiocarbon | 103 ± 7, 110 ± 6, 99 ± 8, 106 ± 7 (weighted mean 105 ± 3), 31 ± 2, 15 ± 0.8 ka | 5,3,2 | 26,63 | 23 |
| Groot Kloof | −28.35, 24.183 | MSA, Fauresmith (?), LSA | Open air | 248 ka | U-Th | 248 ± 37 ka | | 64 | 24 |
| Gweta/Ntwetwe Pan | −20.174, 25.305 | ESA(?) | Open air | n/a | n/a | n/a | | 65 | 25 |
| Gwi | −21.076, 24.629 | LSA | Open air | 0.2 ka | Radiocarbon | 0.2 ± 0.37 ka | 1 | 66 | 26 |
| Harts River Valley | −27.507, 24.864 | ESA | Open air | n/a | n/a | n/a | | 67 | 27 |
| Kandanda | −17.422, 24.196 | LSA | Open air | n/a | n/a | n/a | | 57 | 28 |

(Continues)

**TABLE 1** (Continued)

| Site | Coordinates | Time period | Site type | Age estimate(s) | Dating method(s) | Individual ages | MIS occupations | References | # Figure 2 |
|---|---|---|---|---|---|---|---|---|---|
| Kathu Pan 1 | −27.666, 23.007 | ESA, Fauresmith, MSA, LSA | Open air | >465, 465, 291, 119, 17, 10 ka | OSL, ESR/U-series | 464 ± 47, 542 + 140−107, 291 ± 45, 119 ± 7, 17 ± 1, 10 ± 0.6 ka | 5,2,1 | 21,48,68–70 | 29 |
| Kathu Pan 2 | −27.666, 23.007 | LSA | Open air | 7–2 ka | Radiocarbon | 7.4 ± 0.09, 4.4 ± 0.06, 3.0 ± 0.06, 1.8 ± 0.05 ka | 1 | 48 | 30 |
| Kathu Pan 5 | −27.666, 23.007 | MSA(?), LSA | Open air | >32, 32–20 ka | Radiocarbon | 32 ± 0.78, 20 ± 0.28 ka | 2,3 | 48 | 31 |
| Kathu Pan 6 | −27.666, 23.007 | Fauresmith, MSA, LSA | Open air | 156–75, 3 ka | OSL and radiocarbon | 156 ± 11, 121 ± 6, 100 ± 6, 75 ± 5, 3.3 ± 0.06 ka | 6,5,1 | 33,48 | 32 |
| Kathu Pan 7 | −27.666, 23.007 | LSA | Open air | n/a | n/a | n/a | | 48 | 33 |
| Kathu Pan 8 | −27.666, 23.007 | LSA | Open air | 8–1 ka | Radiocarbon | 7.9 ± 0.08, 4.6 ± 0.05, 4.7 ± 0.06, 3.7 ± 0.06, 1.3 ± 0.04 ka | 1 | 48 | 34 |
| Kathu Pan 9 | −27.666, 23.007 | Fauresmith(?), MSA | Open air | >91, 91 ka | OSL | 91 ± 5 ka | 5 | 48,68 | 35 |
| Kathu Townlands | −27.666, 23.007 | ESA | Open air | n/a | n/a | n/a | | 71,72 | 36 |
| Kedia | −21.393, 24.674 | MSA | Open air | n/a | n/a | n/a | | 73 | 37 |
| Klipback 1 | −27.161, 22.535 | ESA, LSA | Open air | n/a | n/a | n/a | | 74 | 38 |
| Klipback 2 | −27.159, 22.534 | MSA | Open air | n/a | n/a | n/a | | 74 | 39 |
| Kudiakam Pan | −20.114, 24.765 | MSA(?) | Open air | n/a | n/a | n/a | | 75 | 40 |
| Lake Ngami | −20.516, 22.816 | MSA(?) | Open air | n/a | n/a | n/a | | 73 | 41 |
| Lethakane Well | −21.354, 25.001 | MSA/LSA | Open air | n/a | n/a | n/a | | 73 | 42 |
| Limerock 1 | −28.55, 24.002 | LSA | Open air | 2 ka | Radiocarbon | 1.9 ± 0.05 ka | 1 | 48 | 43 |
| Limerock 2 | −28.55, 24.002 | LSA | Open air | 2 ka | Radiocarbon | 1.9 ± 0.05, 1.8 ± 0.05 ka | 1 | 48 | 44 |
| Little Witkrans | −27.661, 24.612 | LSA | Rockshelter | 7–1 ka | Radiocarbon | 7.5 ± 0.07, 4.7 ± 0.07, 2.1 ± 0.06, 1.9 ± 0.06, 1.5 ± 0.04 ka | 1 | 48,49 | 45 |
| Lusu (Governer's Falls) | −17.209, 24.105 | LSA | Open air | 2 ka | Radiocarbon | 2.0 ± 0.23 ka | 1 | 76 | 46 |
| Makalamabedi Drift | −20.258, 23.852 | MSA | Open air | n/a | n/a | n/a | | 77 | 47 |
| Maloney's Kloof Rockshelter A | −28.366, 24.168 | LSA | Rockshelter | 11, 5 ka | Radiocarbon | 11 ± 0.2 ka, 4.5 ± 0.2 ka | 1 | 78,79 | 48 |
| Meidekop 1 | −28.104, 22.536 | LSA | Open air | 0.2 | Radiocarbon | 0.2 ± 0.05 ka | 1 | 45 | 49 |
| Mohapa Site 1 | −19.592, 21.058 | LSA | Open air | 3–0.3 ka | Radiocarbon | 3.2 ± 0.07, 2.0 ± 0.05, 2.0 ± 0.05, 0.6 ± 0.05, 0.3 ± 0.06, 0.4 ± 0.05 ka | 1 | 80 | 50 |
| Mokape | | ESA/MSA | Open air | n/a | n/a | n/a | | 44,81 | |
| Nata | −20.304, 26.198 | MSA | Open air | n/a | n/a | n/a | | 82 | 51 |
| Nauga | −29.337, 22.333 | LSA | Open air | 2 ka | Radiocarbon | 1.7 ± 0.05 ka | 1 | 48 | 52 |
| Nchwaneng | −27.691, 22.377 | ESA, Fauresmith, MSA, LSA | Open air | >2, 2–0.2 ka | Radiocarbon | 2.4 ± 0.05, 0.8 ± 0.05, 0.2 ± 0.15 ka | 1 | 45,74 | 53 |

**TABLE 1** (Continued)

| Site | Coordinates | Time period | Site type | Age estimate(s) | Dating method(s) | Individual ages | MIS occupations | References | # Figure 2 |
|---|---|---|---|---|---|---|---|---|---|
| Ngxaishini Pan | −20.068, 25.279 | ESA, MSA, and LSA | Open air | n/a | n/a | n/a | | 81 | 54 |
| Nooitgedacht 1 | −28.605, 24.594 | LSA | Open air | 0.1 | Radiocarbon | 0.1 ± 0.05 ka | 1 | 45 | 55 |
| Nooitgedacht 2 | −28.605, 24.594 | Fauresmith | Open air | n/a | n/a | n/a | | 48 | 56 |
| Nooitgedacht 3 | −28.605, 24.594 | MSA | Open air | n/a | n/a | n/a | | 48 | 57 |
| Nooitgedacht 4 | −28.605, 24.594 | MSA | Open air | n/a | n/a | n/a | | 48 | 58 |
| Nooitgedacht 7 | −28.605, 24.594 | MSA | Open air | n/a | n/a | n/a | | 48 | 59 |
| Okwa Valley | −22.404, 21.727 | ESA | Open air | n/a | n/a | n/a | | 83 | 60 |
| Orapa | −21.322, 25.344 | MSA | Open air | n/a | n/a | n/a | | 84 | 61 |
| Pniel 1 (Power's Site) | −28.595, 24.608 | ESA, Fauresmith, MSA | Open air | n/a | n/a | n/a | | 48,85 | 62 |
| Pniel 6 | −28.609, 24.577 | ESA, Fauresmith/ MSA | Open air | n/a | n/a | n/a | | 48,86 | 63 |
| Potholes Hoek | −27.095, 22.464 | ESA, MSA | Open air | n/a | n/a | n/a | | 74 | 64 |
| Rhino Cave | −18.728, 21.734 | MSA, LSA | Cave | >5, 5,1 ka | Radiocarbon | 5.3 ± 0.16, 1.0 ± 0.08 ka | 1 | 87,88 | 65 |
| Rietputs 15 | −28.326, 24.746 | ESA | Open air | 1.3 Ma | Cosmogenic | 1310 ± 210 ka | | 89,90 | 66 |
| Riverview Estates | −28.329, 24.725 | ESA, Fauresmith, MSA | Open air | n/a | n/a | n/a | | 91 | 67 |
| Rooidam 1 | −28.775, 24.519 | Fauresmith, MSA, LSA | Open air | >174 ka | U-Th | >174 ± 20 ka | | 48,59,92 | 68 |
| Rooidam 2 | −28.774, 24.52 | Fauresmith | Open air | n/a | n/a | n/a | | 48,93 | 69 |
| Roseberry Plain | −28.643, 24.868 | Fauresmith | Open air | n/a | n/a | n/a | | 48 | 70 |
| Samedupi Drift | −20.112, 23.459 | ESA | Open air | n/a | n/a | n/a | | 77,94 | 71 |
| Savuti | −18.586, 24.071 | ESA, MSA, and LSA | Open air | n/a | n/a | n/a | | 95,96 | 72 |
| Serowe | −22.376, 26.755 | ESA | Open air | n/a | n/a | n/a | | 97 | 73 |
| Sioma M | −16.612, 23.507 | MSA | Open air | >17 ka | OSL | >17 ± 2.4 ka | | 57 | 74 |
| Tarkuni 1 | −27.31, 22.473 | LSA | Open air | n/a | n/a | n/a | | 74 | 75 |
| Tarkuni 2 | −27.31, 22.473 | ESA | Open air | n/a | n/a | n/a | | 74 | 76 |
| Toromoja | −21.012, 24.556 | LSA | Open air | >3 ka | Radiocarbon | >3.0 ± 0.05 ka | | 66 | 77 |
| Toteng 1 (Lake Ngami, Nchabe River) | −20.371, 22.955 | LSA | Open air | 5–1 ka | OSL, radiocarbon | OSL 5.0 ± 0.8, 3.8 ± 0.5, 3.7 ± 0.5, 2.1 ± 0.7 ka, radiocarbon 2.0 ± 0.04, 2.1 ± 0.04, 1.5 ± 0.04, 1.6 ± 0.06, 1.6 ± 0.03, 0.6 ± 0.03 ka | 1 | 98 | 78 |
| Toteng 3 (Lake Ngami, Nchabe River) | −20.361, 22.958 | LSA | Open air | 4–2 ka | OSL, radiocarbon | OSL 4.0 ± 1.0, radiocarbon 1.6 ± 0.04, 1.7 ± 0.04 ka | 1 | 98 | 79 |

(Continues)

**TABLE 1** (Continued)

| Site | Coordinates | Time period | Site type | Age estimate(s) | Dating method(s) | Individual ages | MIS occupations | References | # Figure 2 |
|---|---|---|---|---|---|---|---|---|---|
| Toteng 3A (Lake Ngami, Nchabe River) | −20.361, 22.958 | MSA | Open air | 52 ka | OSL | 52 ± 7 ka | 3 | 99 | 80 |
| White Paintings | −18.77, 21.747 | MSA and LSA | Rockshelter | 94(?), 60–8, <8 ka | TL, OSL | TL 94 ± 9, 66 ± 7, 48 ± 5, 5.7 ± 0.6, OSL 60 ± 10, 55 ± 5, 54 ± 8, 46 ± 11, 36 ± 3, 36 ± 3, 29 ± 7, 17 ± 2, 21 ± 2, 8.5 ± 1 ka | 5,4,3,2,1 | 100–102 | 81 |
| Wildebeest Kuil 2 | −28.669, 24.649 | LSA | Open air | 2–1 ka | Radiocarbon | 1.8 ± 0.06, 1.2 ± 0.08 ka | 1 | 45 | 82 |
| Windhoek | −22.56, 17.065 | MSA | Open air | n/a | n/a | n/a | | 103 | 83 |
| Witberg 1 | −27.203, 22.469 | ESA | Open air | n/a | n/a | n/a | | 74 | 84 |
| Witkrans Cave | −27.653, 24.615 | MSA | Cave/ rockshelter | 36(?) ka | Radiocarbon | 36 ± 0.7 ka | 3 (?) | 74,104 | 85 |
| Witsand | | MSA and LSA | Open air | 0.4–0.1 ka | Radiocarbon | 0.4 ± 0.05, 0.1 ± 0.06 ka | 1 | 74 | |
| Wondwerk Cave | −27.846, 23.554 | ESA, Fauresmith, MSA, LSA | Cave | 1.6 Ma (?), 1.2 Ma (?), 839–548, 238–153, 12–0.5 ka | Cosmogenic, OSL, U–Pb, radiocarbon | cosmogenic 1.7 ± 0.2, 1.6 ± 0.2, 1.4 ± 0.2, 1.2 ± 0.2, 1.3 ± 0.2 Ma, OSL 238 ± 13, 188 ± 21, 172 ± 16, 153 ± 15, U–Pb 839 ± 26, 734 ± 69 ka, 548 ± 27 ka, radiocarbon, 4.5-1.6 cal BP, 1.6-0.5 cal BP, 5.3-4.6 cal BP, 6.2-5.4 cal BP, 6.9-5.9cal BP, 9.4-6.8 cal BP, 12-10 ka cal BP, 12-11 ka cal BP | 6,1 | 105–109 | 86 |
| Xai Xai 1 | −19.883, 21.085 | LSA | Open air | n/a | n/a | n/a | | 80 | 87 |
| Xai Xai 2 | −19.878, 21.071 | LSA | Open air | 3–2, 0.6 ka | Radiocarbon | 3.6 ± 1.3, 3.6 ± 1.0, 3.4 ± 0.09, 2.8 ± 1.0, 2.5 ± 0.09, 2.4 ± 1.1, 2.3 ± 1.6, 1.7 ± 0.9, 2.2 ± 0.08, 2.6 ± 0.06, 0.2 ± 0.05, 2.3 ± 0.07, 0.8 ± 0.06, 2.0 ± 0.09, 0.0 ± 0.08, 1.8 ± 0.07, 0.64 ± 0.05 ka | 1 | 80 | 88 |

Abbreviations: ESA, Earlier Stone Age; MSA, Middle Stone Age; LSA, Later Stone Age; ESR, electron spin resonance; OSL, optically stimulated luminescence; TL, thermoluminescence.

archeological sites, provides a unique opportunity to reframe the narratives about the evolution of our species.

## 2 | OCCUPATION DISTRIBUTION AND TIMING

The Kalahari Basin has yielded a rich record of human occupation since the Early Pleistocene. More than 90 archeological sites designated as Later, Middle, or Earlier Stone Age have been identified and published (Table 1). Spatially, there are two main clusters of known sites located in the Middle Kalahari and the Southern Kalahari, but sites are not restricted to those regions (Figure 2). In the Middle Kalahari, more sites are located near large water features such as the Okavango Delta and Makgadikgadi Pans than away from them. In the Southern Kalahari, more sites are located near the edge of the Kalahari Basin, and especially near the Kuruman Hills. This distribution is influenced by geographical research bias toward areas that are inhabited and developed today, but it is reasonable to expect overlap in current and past occupation patterns.

Overall, LSA and MSA sites have more extensive distributions than ESA sites (Figure 2), though this pattern of occupation is most pronounced in the Middle Kalahari, where known ESA sites occur almost exclusively adjacent to the Makgadikgadi Pans or at the eastern edge. One known exception is the site of Okwa Valley, Botswana, which is adjacent to a feeder tributary to the Makgadikgadi Pans, where surface scatters of lithic artifacts including handaxes have been reported.[83] All other known sites in the Middle Kalahari located more than ~70 km west of Makgadikgadi Pans are only first occupied in the MSA or LSA. In the Southern Kalahari, the distribution of known ESA sites is not dissimilar from the distribution of MSA and LSA sites, mainly concentrated within the Kuruman Hills and ~150 km east on the edge of the Kalahari Basin. Of note is how common it is for LSA sites across the Kalahari Basin to also have an underlying MSA occupation. In other words, there are few recorded sites used during the LSA that had not previously been used in the MSA ($n = 28/90$, 31%), which attests to the long-term patterns of reuse of landscape features such as pans, lakes, hills, rockshelters, and caves in otherwise relatively homogenous landscapes, and potentially similar landscape use strategies in the MSA and LSA.

Forty-four sites have chronometric age estimates (Table 1). The most common method is radiocarbon analysis for deposits up to ~40–50 ka. For older deposits, optically stimulated luminescence (OSL) is the most common, but a few sites have also been dated using electron spin resonance (ESR), thermoluminescence (TL), uranium-series, and cosmogenic nuclides. The cave and rockshelter sites of Wonderwerk Cave, White Paintings Rockshelter, and Ga-Mohana Hill North Rockshelter preserve relatively long sequences dated using multiple methods. The stratified open-air sites of Canteen Koppie and Kathu Pan provide the same, but site formation history in these open contexts may be more complicated. In general, radiocarbon age estimates provide error ranges of roughly ~50–1000 years, with smaller ranges for younger estimates. OSL error ranges are roughly 1000–15,000 years, and other methods used for dating older deposits can have even larger ranges (Table 1). These are considerations to take account when evaluating the chronology of early human origins in the Kalahari Basin. However, the data available now provide a useful framework for considering occupation patterns through the Pleistocene.

Excavation 1 at Wonderwerk Cave has yielded the earliest age estimate based on cosmogenic nuclides and palaeomagnetic data with the basal deposit, Stratum 12, dated to ~1.6 Ma.[137,138] The lithic assemblage in Stratum 12 is characterized by an Oldowan-like flake-based technology that lacks handaxes.[106] The overlying Stratum 11 contains handaxes and is dated by cosmogenic nuclides to ~1.2 Ma.[106,138] These early age estimates by U–Pb analyses of buried speleothems that point to a younger chronology for the Excavation 1 deposits starting ~1 Ma.[109] Cosmogenic nuclide analyses at Canteen Koppie have provided preliminary ages estimates for ESA assemblages there; the unit containing handaxes and organized core technology may date to ~1.5 Ma and the overlying unit containing handaxes and Victoria West-type technology may date to ~1.2 Ma.[53] At Rietputs 15, the deposit dated to ~1.3 Ma based on cosmogenic nuclides contains handaxes and organized core technology.[89,139] The only other chronometrically-dated Early Pleistocene deposits are at Wonderwerk Cave; U–Pb analysis of Stratum 10 that contains an Acheulean-type lithic assemblage gave an age estimate of ~839 ka.[109] Dated Early Pleistocene deposits are not known in the Kalahari Basin beyond the Southern Kalahari, but handaxes and Acheulean-type assemblages that may date to similar time periods occur across much of the Kalahari Basin (Figure 2).

Several sites have deposits that chronometrically date to the Middle Pleistocene. At Kathu Pan 1 and Wonderwerk Cave, deposits containing lithic assemblages designated as Fauresmith with blades, points, Levallois technology, and rare handaxes have yielded age estimates of ~500 ka[69] and ~548 ka,[109] respectively. The earliest MSA-type assemblages lacking handaxes are dated to between ~300 and ~200 ka at Kathu Pan 1 and Groot Kloof.[64,69] Other assemblages with chronometric age estimates in the Middle Pleistocene include Bundu Farm[50] and Kathu Pan 6.[33]

Twelve sites have deposits chronometrically dated to the Late Pleistocene (Table 1), including the Kathu Pan sites,[33,48,68] Ga-Mohana Hill North Rockshelter[26,63] in the Southern Kalahari and ≠Gi,[43] White Paintings,[100–102] and Toteng 3A[99] in the Middle Kalahari. The Late Pleistocene documents many significant shifts in early human technological and symbolic behaviors, as will be detailed further below. The earliest LSA-type assemblage in the Kalahari Basin dates to ~36 ka at White Paintings Rockshelter in the Middle Kalahari.[101,102] Known as the Lower Fish deposit, this unit provides evidence for fresh water fishing in the form of abundant fish bones and bone harpoons, as well as ostrich eggshell beads.[101] Another early LSA assemblage in excess of ~20 ka includes Kathu Pan 5[48] in the Southern Kalahari.

Many of the dated deposits can be assigned to a Marine Isotope Stage (MIS) between MIS 6 and MIS 1 (Figure 3). MIS are defined based on a combined marine oxygen isotope record of 57 deep-ocean

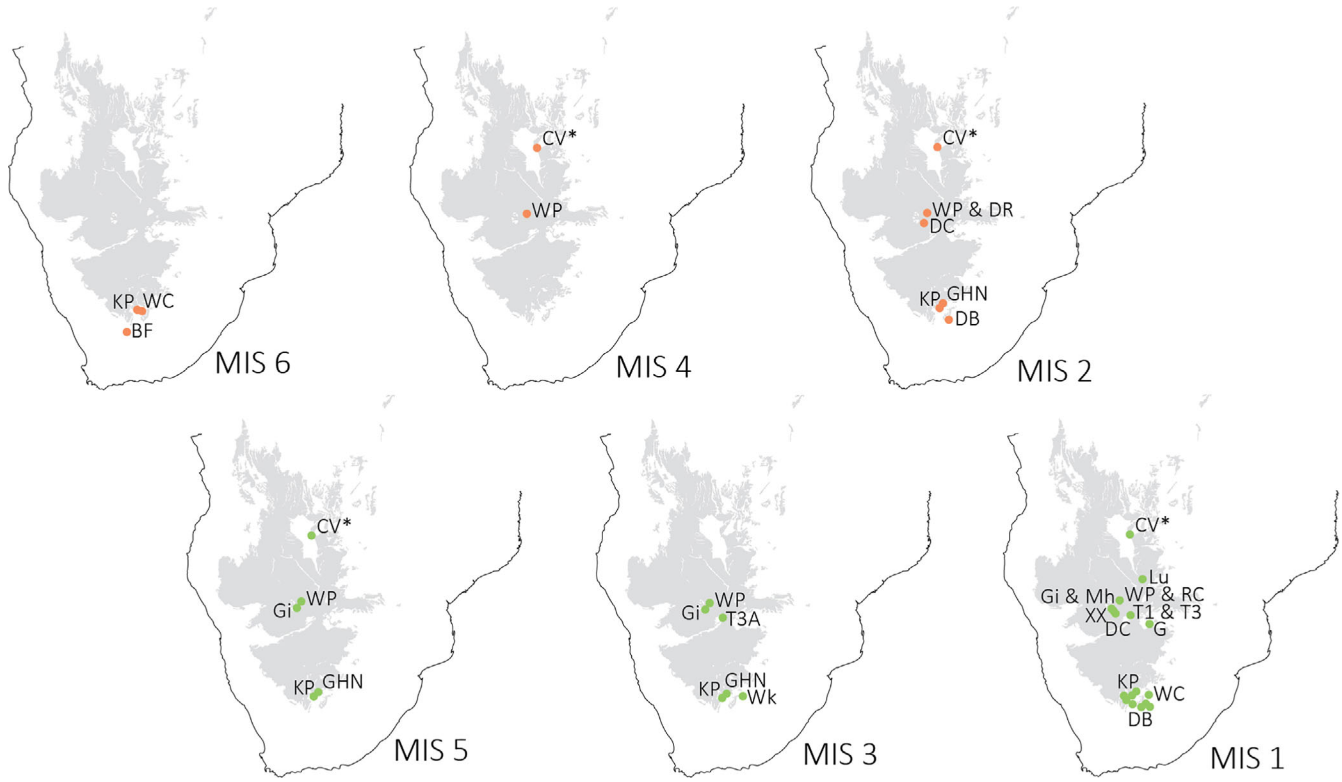


FIGURE 3 Archeological sites in and near (∼100 km) the Kalahari Basin (light gray), southwestern Africa with chronometric age estimates by Marine Isotope Stage (Lisiecki & Raymo, 99). Site details in Table 1. BF, Bundu Farm; CV, Chavuma; DB, Dikbosch; DC, Drotsky's Cave; DR, Depression Rock Shelter; GHN, Ga-Mohana Hill North Rockshelter; G, Gwi; Gi, ≠Gi; KP, Kathu Pan; Lu, Lusu; Mh, Mohapa 1; RC, Rhino Cave; T1 &T3, Toteng 1 and Toteng 3; T3A, Toteng 3A; WC, Wonderwerk Cave; Wk, Witkrans Cave; WP, White Paintings; XX, Xai Xai 2. * indicates that age estimate is not directly associated with artifacts. For MIS 1, sites not labeled here are listed in Table 1

sediment cores, which provide a nearly continuous record of global ice-volume and global sea-levels through the Pleistocene.[140] For some regions of Africa, glacial periods (i.e., MIS 2, 4, 6) correspond to cooler, drier conditions and interglacials (i.e., MIS 1, 3, 5) with warmer, wetter conditions, but other regions have shown evidence that they are in antiphase with this general expectation.[141] This includes parts of the Middle Kalahari Basin.[95,142] While MIS may not be great representations of climate for all regions of southern Africa, they are frequently used by researchers to temporally structure the archeological record, and in the development of models for early human behavioral change. The general perception is that glacial periods posed more challenges to hunter-gatherers than interglacial periods, with influences on population size and distribution, inter-connectedness, and technology.[8,143–149]

In general, there are more Kalahari sites during interglacial phases (MIS 5, 3, and 1), consistent with general expectations for more suitable conditions for hunter-gatherer occupation. There are also more sites deeper into the Kalahari Basin and away from the margins during interglacial phases than glacial phases. Of note, however, is the presence of sites dated to MIS 6, 4, and 2. While potentially less populated based on the fewer number of sites, based on current evidence, the region is not abandoned during glacial phases.[102,105]

## 3 | TECHNOLOGY

Technologies with multiple components and complex manufacturing processes reflect accumulated knowledge and social learning.[150,151] The MSA record of the Kalahari Basin documents early origins for many technologies that are generally associated with the emergence of our species and the complex technological behaviors that we uniquely display.

Levallois reduction methods, which extract predetermined lithic end products from bifacial hierarchical cores,[152] are the hallmark of the MSA. The MSA is associated with early *H. sapiens* fossils at some sites in southern Africa,[18] including Florisbad, South Africa,[11,125] and Mumbwa, Zambia.[153] Levallois reduction methods date to >300 ka in the Kalahari Basin, with evidence for that antiquity at the sites of Kathu Pan 1 and Canteen Koppie. At Kathu Pan 1, Levallois methods occur in the Stratum 4a deposit dated to ~500 ka based on combined ESR/U-series data,[21,69,154] and the capping Stratum 3 dated to 300 ka provides a secure minimum age estimate for the underlying Stratum 4a.[69] At Canteen Koppie, Levallois methods occur in the assemblages found at the base of the Hutton Sands, which have been dated to ~300 ka and provide a minimum age estimate for the basal assemblage. Other MSA-type technologies associated with these assemblages are blade and point production,[21,69] and evidence for hafted hunting weapons.[70,155,156]

Organized core technologies that some view as precursors to Levallois reduction methods occur prior to this in the Kalahari Basin at Rietputs 15 in an Acheulean deposit dated to ~1.3 Ma and Canteen Koppie in Acheulean deposits dated to ~1.5 Ma.[53,139,157] These earlier expressions of organized core technologies are consistent with continuity and in situ cultural change in or near the Kalahari Basin. Alternatively, they demonstrate technological convergence. Either way, they attest to the technological capacities of Early Pleistocene humans in this region.

A technological behavior that has received minimal attention in the MSA thus far is the exploitation of anisotropy in stone raw material. Anisotropy is a difference in properties when measured along different axes due to the presence of bedding planes, and planar anisotropy influences technological decisions about stone tool manufacture.[158] Knappers at Kathu Pan 1 beginning ~500 ka (or at least >300 ka) exploited the anisotropic properties of banded ironstone to detach blades and elongated blanks.[159]

The origin of container technology was a significant milestone for early humans,[160] but preservation issues challenge our capacity to identify it. Ostrich eggshells, when emptied of their nutritional contents, make excellent storage containers and are known as such ethnographically, and from many LSA archeological contexts of southern Africa. The earliest known support for ostrich eggshell container technology comes from MSA contexts at Diepkloof Rockshelter on the west coast ~105 ka[118] and Ga-Mohana Hill North Rockshelter in the Southern Kalahari Basin at roughly the same time.[26] This is based on the presence of human-collected (not carnivore-collected) ostrich eggshell remains in those deposits, and the relative abundance of sites after that time showing similar kinds of evidence.[26] At a few MSA sites beyond the Kalahari Basin, ostrich eggshell containers were engraved with geometric patterns.[118,161,162]

Bladelets and backed pieces date to ~98 ka at Kathu Pan 6 based on OSL analysis,[33,68] which is roughly coeval with similar technologies at Diepkloof Rockshelter on the west coast.[163] Backed pieces at other southern Africa sites sometimes show evidence of having been used as armature tips for high-velocity projectiles.[37,164,165]

Thus far, the earliest bone points have been recovered from LSA deposits at White Paintings Rockshelter in the Middle Kalahari. They are barbed, and recovered from deposits that also preserve abundant fish bones (mainly *Clarius sp*. and tilapia). The lowest deposit with barbed bone points (Lower Fish Deposit) has yielded an OSL age estimate of ~36 ka.[101]

## 4 | SUBSISTENCE

*H. sapiens* is characterized by our capacity to access a wide range of food resources within a broad and flexible adaptive niche. Shellfishing and fishing are often considered markers of this and evidence for these strategies extend back to ~60 ka in the Kalahari Basin. Fresh water mollusk (bivalve) shell fragments are reported at White Paintings in the Lower Fish deposits (~36 ka) and the MSA deposits that are dated to ~60 ka.[102] The LSA deposits at White Paintings also preserve abundant fish bones (mainly *Clarius sp*. [catfish] and tilapia) in association with probable fishing technologies (barbed bone points). The lowest of these LSA units (Lower Fish Deposits) has an OSL age of ~36 ka.[101] Nearby lacustrine carbonate deposits have provided a similar age estimate, suggesting that at the time of occupation of the Lower Fish Deposits, Tsodilo Hills were adjacent to a permanent body of water.[102] A low frequency of fish remains have been also recovered in the underlying transitional LSA/MSA deposit, which is dated to ~45 ka.[102]

Researchers have used the frequency of retouched pieces versus artifact density at archeological sites as an indicator of land-use strategies.[166] These data can shed light on whether the mobility system is based more on collection (bringing people to resources) or logistical forays (bringing resources to people). Based on MSA and LSA survey data from the Southern Kalahari, data are more consistent with logistical foraging, but based on published results at White Paintings Rockshelter in the Middle Kalahari, data are more consistent with collecting.[167] This diversity implies that early humans in the Kalahari Basin had flexible responses to resource distribution.

## 5 | LONG-DISTANCE TRANSPORT

A distance of more than ~100 km has been proposed as evidence for long-distance transport of stone raw materials.[168,169] The Middle Kalahari sites have offered some evidence for long-distance transport in the MSA. At White Paintings Rockshelter, silcrete may have been transported from the Boteti River (~295 km distant) and Lake Ngami (~220 km distant) in the MSA levels (units 8–11), which date to ~94–45 ka.[170] The Boteti River source appears to have also been accessed during the MSA occupations at Rhino Cave (undated, >250 km distant), Corner Cave (undated, >250 km distant), and ≠Gi (~77 ka, >250 km distant); and the Lake Ngami sources (~220 km distant) were accessed during the MSA occupations at Corner Cave.[171] However, these results may be problematic due to the formation processes of Kalahari silcrete and the resulting challenges with provenience studies (Webb and Nash 2020). At Rhino Cave, in the MSA levels, it is reported that there are high levels of "non-locally acquired" raw materials such as chert, jasper, chalcedony and silcrete,[87] though a detailed sourcing study has not been carried out.

At Canteen Koppie in the Southern Kalahari, some jaspelite artifacts dated to >300 ka contain round white macrofossils similar to jaspelite exploited at the Late Acheulean quarry site of Kathu Townlands ~175 km to the northwest.[24,172] The closest known primary outcrops of formations containing jaspelite are ~90 km west. Specularite, which is a type of hematite known for its glittery visual display properties, outcrops ~170 km to the west of Canteen Koppie; two specularite pieces were recovered from deposits dated to >300 ka at the site, and it is suggested that there is no known alluvial system that could have transported the material east toward Canteen

Koppie.[24] Further work is required to confirm this potential evidence for long distance transport. At Kathu Pan 1, raw materials in the ESA and MSA assemblages were locally-acquired.[159]

## 6 | SYMBOLS AND RITUAL

Pigments are known from many MSA contexts,[18] and recent research places the earliest evidence for pigment use in the Kalahari Basin. Modified specularite and other ferruginous pieces were recovered from deposits dated to ~500 ka at Kathu Pan 1.[24] At Canteen Koppie >300 ka, specularite may have been transported ~170 km from its original source as discussed above. Modified pigments have also been recovered from Fauresmith, MSA, and LSA-designated deposits at Wonderwerk Cave.[24,127] In the Middle Kalahari, specularite is associated with potential grinding slabs at Rhino Cave in MSA deposits.[87]

In the Kalahari Basin, there is early evidence for the collection of non-utilitarian objects. Calcite crystals have been recovered from ~105 ka deposits at Ga-Mohana Hill North Rockshelter, and natural processes (i.e., falling from ceiling, washing into the shelter) do not explain their presence.[26,162] Earlier evidence for collected quartz crystals, banded ironstone slabs, and small chert pebbles comes from Wonderwerk Cave,[105,173] but the interpretation of non-utilitarian is less secure because those material types are also used for knapping. Furthermore, Tryon[174] has suggested that some of the small rounded stones reported by Beaumont and Vogel[127] could be ostrich gastroliths, rather than collected objects. Many unused points with evidence for smashing and/or burning have been recovered in undated MSA deposits at Rhino Cave in association with ground pigment, perhaps pointing to non-utilitarian or ritual behavior.[87]

The LSA units at Wonderwerk Cave contain engraved slabs of dolomite and hematite, with the oldest coming from a deposit dated by radiocarbon to ~10 ka.[175] These engravings included geometric cross-hatched patterns, as well as figurative forms (including a rump of a zebra), and represent the region's earliest known engraved art. In Fauresmith-designated deposits at Wonderwerk Cave, banded ironstone slabs were collected and modified as simple cores, and some have linear marks on them with potential behavioral significance.[127,173] However, based on neutron tomographic assessment many of the marks appear to be due to natural fracturing in the stone.[176] Though, Watts et al.[24] suggest that some of the linear marks may have served to produce pigment powder.

Engraved OES fragments exhibiting a diversity of geometric patterns occur in the LSA deposits of Wonderwerk Cave, going back to ~6 ka.[49,107]

Ostrich eggshell beads are common at LSA sites across southern Africa, including the Kalahari Basin.[49,63,101,177] Early ostrich eggshell beads in the Kalahari Basin are known at White Paintings, directly dated to ~31 ka.[101] OES beads also reported in the Stratum 2, Early LSA deposit at Kathu Pan 5 with radiocarbon ages dating them to around 30 ka.[48,178,179] Small bone beads also occur in Kalahari LSA deposits at Wonderwerk,[48,49] and Powerhouse.[48,178,179]

## 7 | DISCUSSION AND CONCLUSIONS

This review of the long-term archeological evidence in the Kalahari Basin indicates significant presence of humans from the Late Pleistocene onwards, especially near the Okavango Delta and Makgadikgadi Pans/paleolakes in the Middle Kalahari and the Kuruman Hills at the southeastern edge. This is based on an abundant record, with 90 sites published in the literature and more than 40 with chronometric age estimates. Based on these chronometric age estimates and their corresponding MIS, global-scale shifts in climate roughly correlate with the number and location of sites. While glacial phases have fewer sites with more restricted distributions, they do not appear to represent periods of abandonment in the Kalahari Basin. MIS 6 is of particular importance in current debates about the emergence of *H. sapiens*. In single-origin centre and coastal models for the origins of *H. sapiens*, environmental degradation during MIS 6 restricted populations to more productive refugia on the African continent (including coastal regions), with trickle down effects on adaptation, innovation, and sociality in what became the founding human population.[8,121,145] Against expectations of these models, humans appear to be present in the Southern Kalahari Basin during MIS 6 at Wonderwerk Cave, Kathu Pan 6, and Bundu Farm (refs in Table 1), and at nearby Florisbad 157 ± 21 ka,[11,180] with a subsequent fluorescence across the region during MIS 5. It is important to acknowledge here that the error ranges for some of these age estimates are large (11–21 ka), and in some cases the site formation processes and dating methodologies are complex or under-reported. Based on these considerations, and the higher frequency of sites, evidence for MIS 2 occupation is stronger than for MIS 4 and 6. However, while the current evidence is limited in its ability to either support or refute a single-origin or coastal model, the data reviewed here point to the critical role the Kalahari Basin plays in evaluating debates about the origins and evolution of *H. sapiens*. Future work focused on increasing dating precision and accuracy, understanding local environmental change, and investigating the more under-studied areas of the Kalahari Basin will undoubtedly lead to important new insight.

Many advancements have been made in the last few decades in identifying the timing for the origins of the behavioral and social complexities that characterize *H. sapiens*, with significant new data from coastal zones.[31,124,181] Despite traditionally being considered marginal to the development of landmark human innovations, the Kalahari Basin exhibits long chronologies for many innovative technologies and symbolic behaviors that were reviewed here. In their landmark paper titled "The Revolution the Wasn't," McBrearty and Brooks[18] disrupted the then dominate paradigm that the whole suite of traits that define us appeared simultaneously. Visually, this was represented in what has become an iconic figure with time on the x-axis, and bars representing the timing of the first appearance for significant behavioral innovations. Here, the Kalahari Basin data are presented in the same manner (Figure 4), and similarly indicate non-concurrent origin times for key behavioral innovations in the Kalahari Basin. Based on current evidence, some behavioral innovations occur earlier in the Kalahari Basin than other

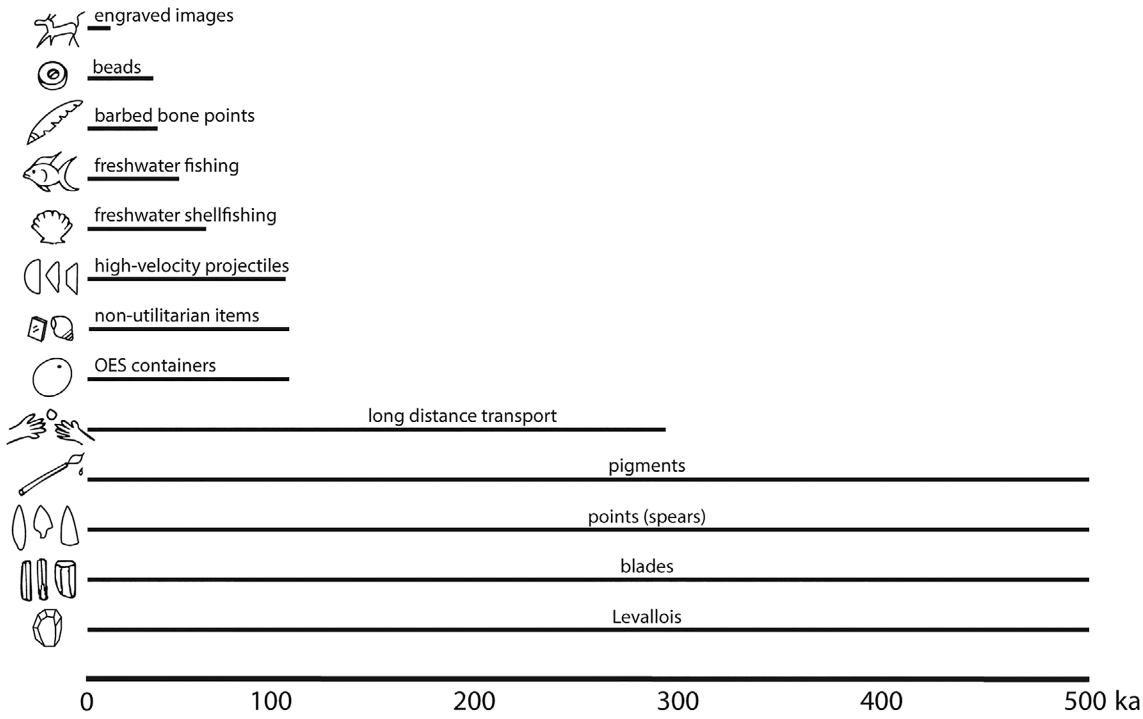


**FIGURE 4** Behavioral innovations in the Kalahari Basin and their time depths, modeled after figure 13 in McBrearty and Brooks[18]

regions in Africa (e.g., Levallois, hafted points, blades, pigment processing), some may be later (e.g., engravings, painting, beads). However, the extent to which the latter is true is potentially limited by geographic research bias and preservation bias, which are issues that can only be addressed through continued investigation in the Kalahari Basin. Current evidence in the Kalahari is most consistent with a patchy, non-linear accumulation of behaviors through time, as is witnessed across Africa.[18] Thus, the archeological record better supports a poly-centric, or Pan-African origin for *H. sapiens*[6,13,42] that includes the Kalahari Basin.

The coastal and Kalahari Pleistocene records of southern Africa are not the same, but that does not necessarily mean that technological and symbolling capacities differed between populations occupying those regions. One of the defining characteristics of *H. sapiens* is extreme behavioral flexibility and adaptability,[182] and thus one would expect differences across an extensive, environmentally- and resource-diverse area like southern Africa. An obvious example is that humans in the Kalahari will never exhibit a coastal adaptation, but will rather adapt to the periodically arid and semi-arid environments in which they live. An additional example is the practice of heat-treatment for improving the knappability of stone raw materials, which was practiced by early humans in MSA coastal contexts,[36,183] but so far appears to be absent in the Kalahari. This behavior is dependent on the underlying geology of southern Africa; silcrete is not available in Southern Kalahari landscapes, and Middle Kalahari silcretes are not improved through heat-treatment.[184]

Environmental variability in the Kalahari Basin makes it a particularly important region for understanding early human adaptations to environmental change, and several avenues (dune fields, palaeolakes, carbonate formations, fauna, OES, micro- and macro-botanicals) are available for palaeoenvironmental investigations at sites and on the landscape.[59,68,95,128,129,132,135] Current research teams are leveraging this record of high-amplitude variability to better understand the nature of Pleistocene human-environment interaction in the Kalahari. These regional records for the Kalahari are critical given the reality that a glacial/interglacial dichotomy is an oversimplification, and climate change across the continent was asynchronous.[95,141,142]

In sum, the Kalahari Basin preserves a rich archeological record with high potential. Rather than being peripheral to debates about the origins of our species, this review highlights the active role that Kalahari Basin archaeology can and should play in these debates. Multiple inter-disciplinary research teams are actively scrutinizing this record today with cutting-edge excavation and dating methods, and generating critical new data for further understanding the emergence of *H. sapiens*.

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## CONFLICT OF INTEREST

The author declares no competing interests.

## DATA AVAILABILITY STATEMENT

The data that supports the findings of this study are available within the article.


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