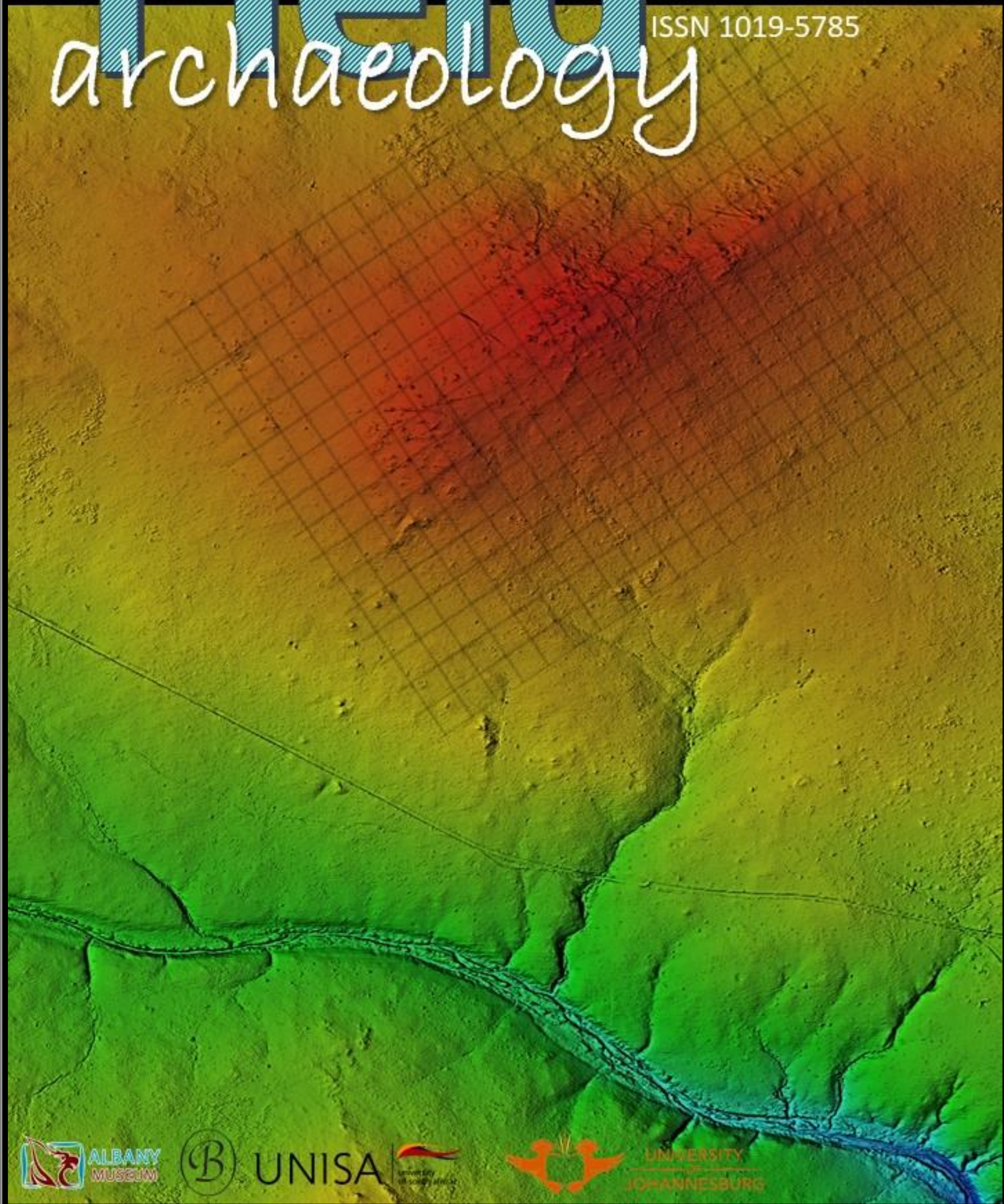
southern african

Field archaeology

ISSN 1019-5785



Variation in hunting weaponry for more than 300 000 years: A tip cross-sectional area study of Middle Stone Age points from southern Africa

Marlize Lombard

Palaeo-Research Institute, University of Johannesburg, Auckland Park, Johannesburg, South Africa

and

Stellenbosch Institute for Advanced Study (STIAS), Wallenberg Research Centre at Stellenbosch University, Stellenbosch 7600, South Africa

Abstract

Much has been written about Middle Stone Age hunting in southern Africa, yet there is no comprehensive overview for the development and use of stone-tipped hunting weapons. With this contribution, I use the tip cross-sectional area (TCSA) method to hypothesise about variation in weapon-assisted hunting strategies for the last 300,000 years or more. I assess and build onto previous hypotheses generated from similar approaches, introducing a larger sample from across the region. By also bolstering the standard TCSA ranges for javelin tips and stabbing/thrusting spear tips with more experimental and ethno-historical material, the method's interpretative robusticity is increased. The results indicate a general trend through time towards smaller weapon tips until reaching arrow-tip range during the MIS 4 glacial. Whereas light-weight javelins, similar to those used by African hunters today may have been in play since almost 200,000 years ago, it remains uncertain whether spearthrower-and-dart technology was used in southern Africa. Finally, I align the TCSA outcomes with climatic and demographic reconstructions and explain how human cognition interacts with technological adaptations such as the use of hunting weapons – demonstrating how the interplay between environment, demography, technology and cognition is integral to the development and understanding of Middle Stone Age weapon-assisted hunting strategies.

Keywords: lithics, spear hunting, javelin hunting, spearthrower-and-dart technology, bow hunting, cognitive evolution

1. Introduction

Effective weapon-assisted hunting is key to human adaptive success in terms of subsistence breadth, landscape use and cognition. Southern Africa (southern Africa = the sub-continent south of the Zambezi River, South Africa = the geopolitical republic), with its innate archaeological, fossil and DNA records, represents one of the hotspots for understanding the evolution of all these aspects. Historical and current hunter-gatherers of the Kalahari had/have a highly flexible approach to hunting and meat-getting strategies, consisting of a range of weapons and other technological props, such as nets, traps and knopkieries (knobbed throwing and clubbing sticks), to ensure access to meat. Many of these technologies consist wholly or partly of organic materials that preserve seldom or not at all.

Assuming it is also true for ancient hunting technologies, interpretations based on archaeological remains can only ever represent the minimum information about aspects of weapon use, subsistence breadth, landscape use or cognition. Here I explore possible variation in stone-tipped weapon-assisted hunting strategies in southern Africa since at least

300 ka (ka= thousands of years ago/old), using the tip cross-sectional area (TCSA) method. The aim is to assess and build onto previous hypotheses gained from the same or similar methods (i.e., morphometric approaches to hypothetical weapon use), based on a more comprehensive spatiotemporal dataset. By doing so, I provide an up-to-date hypothetical reconstruction for weapon-assisted hunting on the sub-continent that can be tested with context-specific use-trace studies, palaeo-climatic reconstructions, and faunal analyses.

2. Previous hunting-weapon hypotheses for southern Africa based on lithic morphometrics

Although morphometric approaches cannot provide direct evidence of tool function, they are well-suited for generating quantifiable and comparable data with which to assess the potential effectiveness of weapon tips and to build broad hypotheses about ancient stone-tipped weapon-delivery systems (Shea 2006; Brooks 2006; Sisk & Shea 2011; Lombard 2020a, b; but see Clarkson 2016). After experimental and use-trace studies demonstrated that Middle Stone Age points from Sibudu Cave in KwaZulu-Natal, South Africa, dating to ~50-35 ka were hafted and used for hunting (Lombard 2004, 2005; Lombard et al. 2004; Wadley et al. 2004), three influential texts using morphometric data were published on the topic in 2006.

First, Brooks et al. (2006) presented a comparative study of stone points from ‘two African regions’ (southern and eastern Africa) and the Levant. Their point-measurement system involved 25 variables, and they argued that the small size of many African Middle Stone Age points “implies the existence of a complex projectile technology rather than simple spears” (Brooks et al. 2006: 233). Southern Africa was represented by a single assemblage from ≠Gi Pan in the Kalahari dating to ~77 ka. From their table 2 (Brooks et al. 2006: 245), it seems that only 16 points from ≠Gi was included in the study, even though “points were the dominant tool class, constituting 41% of the ca. 1,500 retouched pieces” (Brooks et al. 2006: 237). There are several discrepancies between the information presented in the table and subsequent figures (Brooks et al 2006: 245-248). For example, in the figures the sample size for ≠Gi is 299 (not 16 as in the table), for Aduma 1 it is 16 (not 68 as in the table) and for Aduma 5 it is 39 (not 299 as in the table). Brooks and colleagues however reported that “[t]heir size places the points at the lower limits of ethnographically known spear armatures and within the range of ethnographically known spearthrower darts and larger arrowheads” (Brooks et al. 2006: 239).

In the second study, Shea (2006) applied the TCSA method, comparing Middle and Upper Palaeolithic stone points from Africa, the Levant, and Europe, including several assemblages from the Cape region in South Africa. Even when eliminating artefacts with TCSA values of >200 (Table 1), the results were interpreted as not supporting a widespread use of stone-tipped spearthrower darts (TCSA range = 40-76) or arrows (TCSA range = 13-53) prior to 40 ka. The main drawbacks of the study were that no javelin category was included, and that the assemblages were regionally limited to the Cape, all pre-dating 70 ka – leaving the rest of southern Africa unexplored and an unexplained 30 ka gap in terms of the argument for a lack of mechanically projected weapon use before 40 ka. Adding the tip cross-sectional perimeter statistic (again excluding possible javelin use), allowed Sisk and Shea (2011) to revise their interpretation, suggesting dart-and-spearthrower hunting with Still Bay points from South Africa dating to >70 ka in alignment with the Brooks et al. (2006) interpretation.

Villa and Lenoir (2006) followed with a study on the 'spear points' from Sibudu and Rose Cottage caves dating to ~35-50 ka (including those used in the use-trace studies mentioned above), comparing them to those from Aduma (east Africa) and Bouheben (France) – perpetuating the Brooks et al. (2006) discrepancies by calculating the TCSA values for the Aduma sites using the mean values provided in table 2 of that study. They (Villa & Lenoir 2006) found that the Sibudu point TCSA values fell within the range of 'throwing or thrusting' spears (Table 1), as given by Shea even though his experiments were "calibrated to simulate the use of thrusting spears" only with a TCSA range of 79-257 (Shea 2006: 825), and without presenting a possible TCSA category for javelin tips. For the post-Howiesons Poort points from Rose Cottage cave, they found that the TCSA values were closer to those of spearthrower dart tips (Table 1), but used statistical testing to argue that such a function was unlikely although it could be entertained (Villa & Lenoir 2006). In sum, their outcome did not favour a widespread use of spearthrower darts in South Africa before 35 ka. They did, however, draw attention to the work of Mohapi (2005) showing that the very small triangular points, dating to the final Middle Stone Age at Rose Cottage Cave by ~27 ka, may indicate the use of arrows (also see Mohapi 2007). In subsequent papers Villa with others (Villa et al. 2009; Villa & Soriano 2010) included their TCSA results for Still Bay points from Blombos – critiquing Shea's (2006, 2009) approach because it was based on an incomplete database that contained preforms, unfinished pieces, and broken pieces, yet reaching the same outcome – finding that they were best suited as tips for hand-delivered spears (Table 1).

Table 1: Previously published TCSA values and ranges for southern African point assemblages, including an approximate value for the points from ≠Gi.

Assemblage	Age estimate	TCSA	Author/s
Rose Cottage post-HP (n=47)	~35-59 ka	78±33	Villa & Lenoir 2006
Sibudu final MSA (n=21)	~37-39 ka	116±42	Villa & Lenoir 2006
Sibudu late MSA (n=71)	~46-57 ka	118± 58	Villa & Lenoir 2006
Sibudu post-HP (n=41)	~58-60 ka	139±60	Villa & Lenoir 2006
Blombos Still Bay (n=239)	~71-76 ka	143±109	Shea 2006
Blombos Still Bay points production phases 2-3 (n=64)	~71-76 ka	148±74	Villa et al. 2009
Blombos Still Bay <200 (n=190)	~71-76 ka	100±53	Shea 2006
Blombos Still Bay points production phase 3 only (n=23)	~71-76 ka	99.4±49	Villa et al. 2009; Villa & Soriano 2010
≠Gi MSA (n=320)	~77 ka	~168*	Mean data from Kuman 1989
Klasies River MSA 2 Upper (n=298)	~95 ka	170±79	Shea 2006
Klasies River MSA 2 Upper (<200; n=213)	~95 ka	131±39	Shea 2006
Klasies River MSA 2 Lower (n=545)	~100 ka	199±105	Shea 2006
Klasies River MSA 2 Lower (<200; n=328)	~100 ka	139±36	Shea 2006
Klasies River MSA 1 (n=71)	>126 ka	160±60	Shea 2006
Klasies River MSA 1 (<200; n=58)	>126 ka	138±37	Shea 2006
Kathu Pan 1 retouched points (n=69)	>464±47 ka	249±101	Wilkins et al. 2012
Kathu Pan 1 non-retouched flake (n=28)	>464±47 ka	223±90	Wilkins et al. 2012
Kathu Pan 1 nonretouched conv. blade (n=27)	>464±47 ka	201±52	Wilkins et al. 2012
Kathu Pan 1 irregular retouched pointed form (n=26)	>464±47 ka	242±64	Wilkins et al. 2012

Villa and Lenoir (2006) justified the calculation of TCSA values from the mean widths and thicknesses of point samples, suggesting a deviation of only 3-13% from the correct value skewed towards smaller values. Because ≠Gi is supposed to represent dart hunting for the southern African region (Brooks et al. 2006), and because neither the points nor their raw data were available for this study, I used the Villa and Lenoir (2006) approach to calculate their approximate TCSA value from the mean measurements of 320 points presented by Kuman (1989: 242). This resulted in a TCSA value of ~168 for the ≠Gi points (Table 1), which contradicts the previous findings in that: a) their TCSA value is considerably higher than the 40-76 range that can be expected for dart tips; and b) instead of being on the small side, the points from ≠Gi are rather large (Table 1).

Evidence for what could be the oldest known hafted spear tips currently comes from Kathu Pan 1, Northern Cape, South Africa (Wilkins et al. 2012) in the form of a macro-fracture analysis. A large sample of pointed artefacts were excavated from the site by Beaumont between 1978 and 1990, but never formally analysed or published. Wilkins et al. (2012) re-aligned these curated artefacts with a newly exposed stratigraphic context with age estimations of between 542 +140/-107 ka and 464±46 ka, directly underlying a Middle Stone Age layer with an age estimate of 291±45 ka. The TCSA values reported for the different point types in their supplementary material are all consistent with the use of heavy-duty thrusting spears (Wilkins et al. 2012; Table 1).

If we work from the hypothesis that the TCSA values of the Howiesons Poort (roughly MIS 4) backed microlith assemblages suggest both javelin and bow hunting with un-poisoned arrows as preferred weapon-assisted hunting strategies between at ~58-70 ka in southern Africa (Lombard 2020b), and that poisoned arrow use may have been introduced then represented by both backed microliths and bone arrowheads (Bradfield et al. 2020; Lombard 2020a, b), the hypothetical variation in hunting weaponry used during the Middle Stone Age in southern Africa is broad. Yet, there is currently no cohesive hypothesis for the spatiotemporal development and use of weapon-delivery systems on the sub-continent, and three questions that may be explored with the TCSA method come to mind:

1. What do point assemblages that post-date the Howiesons Poort reveal about variation in weapon choice?
2. Is there support for wide-spread spearthrower-and-dart hunting before bow hunting in southern Africa?
3. What is the time depth of hunting with light-weight javelins (Fig. 1), similar to those used by recent/current hunters in the region?

Fig. 1. Khomani-San hunter from the Kalahari with a light-weight hunting javelin (image purchased for reproduction, for details see Image ID: C01808 https://www.alamy.com/).

3. The tip cross-sectional area method in the context of this study

The TCSA metric (0.5 x maximum width x maximum thickness) is a ballistically significant standard that works well for discriminating between spearthrower (a.k.a. atlatl) dart tips, arrowheads and large experimental stabbing/thrusting spears (Shea 2006; Sisk & Shea 2011). The metric is archaeologically useful, because it represents the part of the weapon that cuts the animal's hide, creating a hole for the shaft to enter (Hughes 1998), and it may influence weapon flight and penetration dynamics (Maki 2013; Sitton et al. 2020). It has been used widely for interpreting variation in stone-tipped weapon-delivery systems and in experimental replications of such systems (see several chapters in Iovita & Sano 2016; also see discussion in Villa & Lenoir 2006). Although it cannot serve as hard evidence for real-life weapon use, it is particularly pragmatic for generating broad hypothetical scenarios because it is easily replicated, requires only maximum width and thickness measurements allowing for the largest possible sample sizes and results in directly comparable data across typological, material, and spatiotemporal boundaries (Shea 2006; Villa & Soriano 2010; Rios-Garaizar 2016; Lombard 2020a, b).

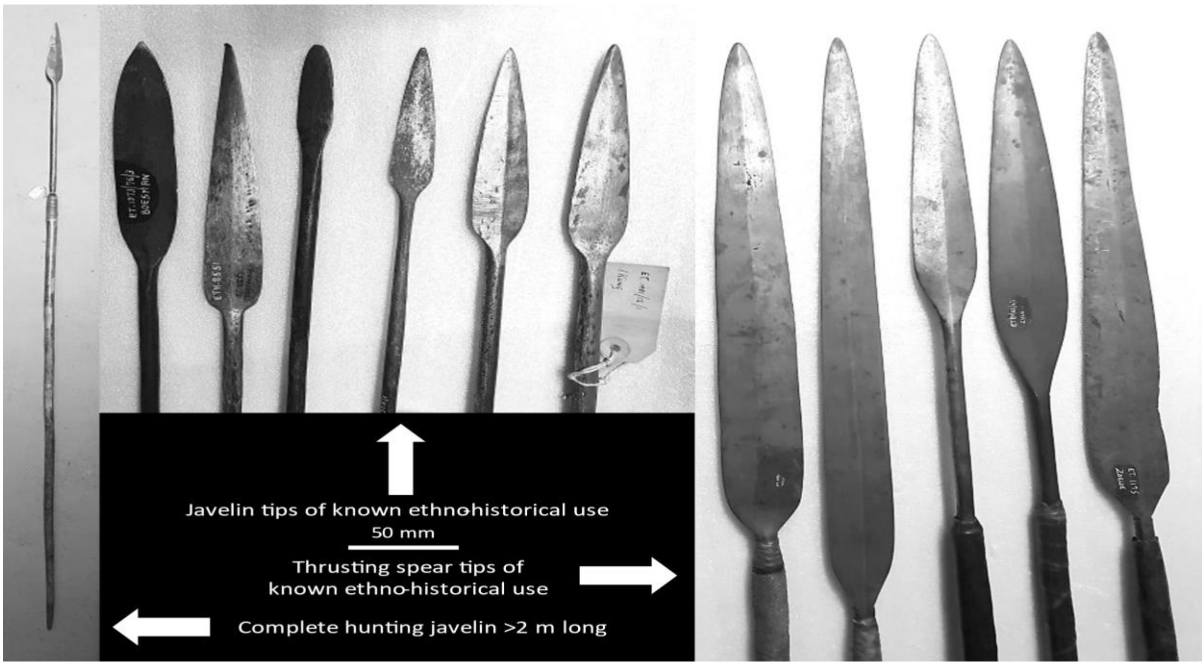
Some morphometric approaches, such as the tip cross-sectional perimeter (TCSP) or those that emphasise the mass of artefacts may also be useful (e.g., Sisk & Shea 2011; Brooks et al. 2006). These approaches are, however, more concerned with proxies of the force needed for lethal penetration depths. The drawback when it comes to the interpretation of archaeological material, as opposed to modern experimentation, is that penetration depth is largely affected by the mass of the shaft and the traits and velocity of the propelling mechanism. These factors cannot be known for archaeological stone weapon tips. Furthermore, when weapons are used to merely wound prey so that they are weakened before the kill or so that a blood spoor can be followed, or when poison is used, the penetration depth does not have to be lethal. Instead, all that is needed, is for the hide to be cut to injure, draw blood or to allow the poison to enter a prey animal's bloodstream. When all these aspects are taken into consideration, the TCSA metric with its focus on the cutting aspect remains the most relevant morphometric unit for archaeological material of which shaft masses and delivery velocity remain unknowable.

To increase the interpretative robusticity of the TCSA approach, I recently added a standard range for poisoned arrow tips (Lombard 2020a), and suggested one for javelin tips (Lombard 2020b), based on the work of Rios-Garaizar (2016), but:

1. By including a javelin TCSA category, the range for dart tips is no longer distinctive, being nested within the javelin tip category as suggested by Rios-Garaizar (2016) based on only seven experimental points with no ethno-historical backing.
2. The experimental TCSA range for thrusting spear tips is broad so that it overlaps with much of the Rios-Garaizar (2016) javelin range and remains untested with real-life ethno-historical data.

Here I provide the TCSA values and ranges of convergent flakes used to tip javelins in fracture experiments (n=23) (Lombard et al. 2004), and I measured iron javelin tips used by ethno-historical San and Bantu-speaking hunters (n=109) in southern Africa (Figs 1 and 2). I also measured the tips of stabbing spears or assegais used by Bantu-speaking warriors of the region (n=32; Fig. 2) and revisited the Shea (2006 and Shea et al. 2001) data, this time incorporating tips that only required 'minor repairs' after being used in their thrusting experiments (Table 2), because we know that some Middle Stone Age spear tips were resharpened in their shafts (e.g., Minichillo 2005), and because macro-fracture results indicate that tips used for hunting regularly undergo some damage (e.g., Fischer et al. 1984).

The resulting data represent more comprehensive experimental samples, and both the javelin and stabbing-spear categories are now bolstered by known ethno-historical use – strengthening and constraining the hypothetical ranges for these weapon-delivery systems (Table 2). Despite this refinement it remains impossible to separate out



hypothetical dart tips, because their value and range remain nested within those of both arrow (36% overlap) and javelin tips (89% overlap, Table 3), so that any interpretation for this category based on the TCSA statistic remains tentative.

Fig. 2. Iron javelin and assegai tips of known ethno-historical hunting use curated at the Ditsong Cultural History Museum, Pretoria, South Africa.

Table 2: New data for experimental and ethno-historical javelins and stabbing spears. The ethno-historical artefacts are housed at the Ditsong Cultural History Museum, Pretoria, South Africa.

Context	Mean width	Mean thickness	TCSA value	TCSA range	TCSA median
Historical iron javelin tips (n=109)	28±7	5±1	67±25	42-92	62
Rios-Garaizar experimental stone javelin tips (n=7)	25±3	7±2	94±26	68-120	92
Lombard et al. experimental stone javelin tips (n=21)	23±5	7±2	82±34	48-116	66.5
All javelins of known use (n=130)	**27±7**	**5±2**	**71±27**	**44-98**	**64**
Historical iron assegai tips (n=32)	46±6	6±1	143±27	116-170	140.5
Shea experimental thrusting spear tips (n=43)	36±10	9±3	170±89	81-259	153
All thrusting spears of known use (n=75)	**40±10**	**8±2**	**159±71**	**88-230**	**146**

The range for iron assegai tips at 116-170 (Table 2) is much narrower than suggested by Shea (2006) for thrusting spears at 79-257. Whereas both javelins and thrusting spears can be used effectively for a wide range of animals, the assegais were used specifically for close-combat warfare as one-handed stabbing and thrusting weapons against man-sized targets. Southern African bovids are prolific in Middle Stone Age fauna, so that we know they were often hunted (and those still disputing the use of stone points as weapon tips during the Middle Stone Age owe an explanation of how the animals were hunted). They are taxonomically diverse ranging in size from the tiny dikdik (*Madoqua kirki*) weighing 5 kg or less to the giant eland weighing in at >900 kg; and are therefore divided into four size classes (Brain 1974): size class I = animals up to 23 kg; size class II = animals of 23-84 kg; size class III = animals ranging between

84 and 296; size class IV = animals weighing ≥296 kg. We may thus assume that weapon tips with TCSA values similar to that of assegais would have been most effective for killing size class II bovids such as springbok (*Antidorcas marsupialis*), impala (*Aepyceros melampus*), and reedbuck (*Redunca arundinum*) and for the smaller class III species such as lechwe (*Kobus leche*) or nyala (*Tragefaphus angasi*).

Spears with smaller tips could have been used as stabbing spears for smaller prey such as blue duiker (*Cephalophus monticola*), Cape grysbok (*Raphicerus melanotus*) or steenbok (*R. campestris*), or perhaps also as 'heavier' javelins compared to the light-weight ones (Fig. 1). Ethno-historical records indicate flexible weapon use, namely that the same or similar implements could have been used as either javelins or stabbing spears (Hitchcock & Bleed 1997), depending on need and circumstance. I therefore suggest that overlapping TCSA values represent hypothetically a category in stone points that could be used effectively in both weapon-delivery systems depending on prey type and hunting strategy (Tables 2 and 3). Larger more robust spear tips may have been used for hunting size classes III and IV that include species such as kudu (*Strepisiceros strepsiceros*), gemsbok (*Oryx gazella*), nyala (*Tragelaphus agasi*), Cape buffalo (*Syncerus caffer*), eland (*Tragelaphus oryx*) and giraffe (*Giraffa camelopardalis*), or even large angulates such as elephant, hippopotamus and rhinoceros in ambush situations.

Table 3: Revised TCSA ranges used in this study to explore hypothetical variation in hunting weaponry during the Middle Stone Age of southern Africa.

Weapon type	**N of tools**	**Mean TCSA**	**SD**	**TCSA Range**
Poisoned arrowheads (Lombard 2020a)	434	11	7	**4-18**
Arrowheads (Shea 2006)	118	33	20	**13-53**
Dart tips (Shea 2006)	40	58	18	**40-76**
All javelins of known use (Rios-Garaizar 2016, Lombard et al. 2004: this study)	137	71	27	**44-98**
Thrusting spear tips (Shea 2006, This study)	75	159	71	**88-230**

By including all but the most extreme outliers, the potential intra-site and inter-regional variability in hypothetical weapon-tip application may be revealed (Lombard 2020a, b). Compensating for outliers is, however, necessary and can be achieved by calculating the TCSA median for each assemblage. This statistic is less skewed by outliers and therefore represents the predominant trend within an assemblage more accurately. The only outliers excluded in this study are individual pieces with TCSA values that exceed 415, and therefore perhaps so enormous that they required shafts too thick to carry and handle comfortably with one hand in a hunting scenario as observed amongst African hunters (Fig. 3). As a result, no more than a handful of artefacts were removed from a few of the older assemblages with one exception; 21 (8.1%) out of the 257 pieces from the Klasies River BOS layer, and I suggest that this assemblage requires future scrutiny with accompanying experimental, use-trace and faunal work to explain the anomaly.

Fig. 3. Bechuana (Tswana) men hunting a lion with one-hand over-arm delivered stabbing spears or assegais from a close-quarter range as observed and depicted by William Cornwallis Harris (1844). (This work is in the public domain in its country of origin and other countries and areas where the copyright term is the author's life plus 70 years).

Lastly, although the use of the Sorresi data by Shea for the Blombos Still Bay assemblage was criticised by Villa and Soriano (2010), I use the same data. Marie Soressi generously provided her full documentation (including fragmentation and production sequence) that was used for the study by Villa et al. (2009), enabling distinction between pieces that were finished or almost finished in their production sequence and complete enough for TCSA analysis. Use-trace analyses demonstrated that not all Still Bay points have to reach the final phase of production (as interpreted by archaeologists) before being hafted and used (Lombard 2006), I therefore include the ‘almost finished’ categories in the analysis of Still Bay points where such data are available.

4. The spatiotemporal framework of this study

No concise cultural or technical sequence or summative overview can capture the richness and variability expressed within discrete assemblages throughout the long Stone Age sequence of southern Africa. What is more, in an evolutionary context – either biological or social – “there here can be no hard and fast boundaries” between units; instead boundaries are “created in the process of study depending on what is being studied and why, and on the assumptions that are brought to bear on the study” (Davidson 2020: 36). Yet, it is possible to follow broad temporal trends in terms of techno-complexes for heuristic purposes, using the general characteristics of dated assemblages whilst acknowledging outliers and dating inconsistencies. Table 4 provides an overview of the Middle Stone Age sequence as currently understood and as used in this study. It bridges preferences for either the use of the techno-complex system or the association of assemblages with the MIS record allowing for: a) the introduction of assemblages according to their published designations (Table 5), and b) the comparison of assemblages described in terms of either their affiliation to a techno-complex or an MIS stage.

Table 4: Overview of the southern African Middle Stone Age sequence (adapted from Lombard et al. 2012) with none of the boundaries understood as finite or inflexible, but as indicating broad heuristic trends. MIS chronology according to Stewart and Jones (2016).

Techno-complex	Broad age estimate	Alternative names/designations	Approximate correlation with MIS record
Final Middle Stone Age	~25-40 ka	MSA IV at Klasies River, MSA 4	MIS 2: start date ~29 ka MIS 3: start date ~57 ka
Post-Howiesons Poort	~40-58 ka	Sibudu, late MSA, MSA III at Klasies River, MSA 3	MIS 3: start date ~57 ka
Howiesons Poort	~58-70 ka	Magosian	MIS 4: start date ~71 ka
Still Bay and pre-Still Bay	~70-80 ka	Later Sanguan, earlier Lupemban	MIS 5a: peak at ~82 ka
Mossel Bay	~80-105 ka	MIS II at Klasies River, MSA 2b, may include Pietersburg and Oragnian	MIS 5a: peak at ~82 ka MIS 5b: peak at ~87 ka MIS 5c: peak at ~96 ka MIS 5d: peak at ~109 ka
Klasies River	~105-130 ka	MSA I at Klasies River, MSA 2b, may include Pietersburg	MIS 5d: peak at ~109 ka MIS 5e: peak at ~123 ka MIS 5: start date ~130 ka
Early Middle Stone Age	~130-250 ka	MSA 1	MIS 6: start date ~191 ka MIS 7: start date ~243 ka
Earlier-Middle Stone Age transition	~250-550 ka	Fauresmith, Sangoan, late Achelean	MIS 8: start date ~300 ka Through MIS 14: start date ~563

I further situate the study within the broadly defined biomes of southern Africa (Fig. 4). Palaeo-climates in terms of rainfall and temperature would have fluctuated with the MIS record and other factors, impacting the distribution boundaries of fauna and flora. Yet, the relative locations and broad characteristics of the biomes have deep-time integrity due to ancient trends in the sub-continent's geomorphology and hydrology systems (Neuman & Bamford 2015). For example, during the Miocene lasting up to ~5.3 Mya the Cape region was characterised by subtropical forests similar to those along the eastern shore of southern Africa today (i.e., the Thicket and Coastal Forest Biomes), and southern Namibia was probably covered by a proto-savanna. The Pliocene lasting between ~5.3 Mya and ~2.6 Mya "saw the evolution of the Fynbos and Succulent Karoo biomes" (Neuman & Bamford 2015: 1), with the Savanna and Grassland Biomes developing at the transition towards the Pleistocene since ~ 3 Mya – long before the Middle Stone Age. I also include the Kalahari Desert and Basin as integral components of the ancient and contemporary hunter-gatherer landscapes of southern Africa (Fig. 4).

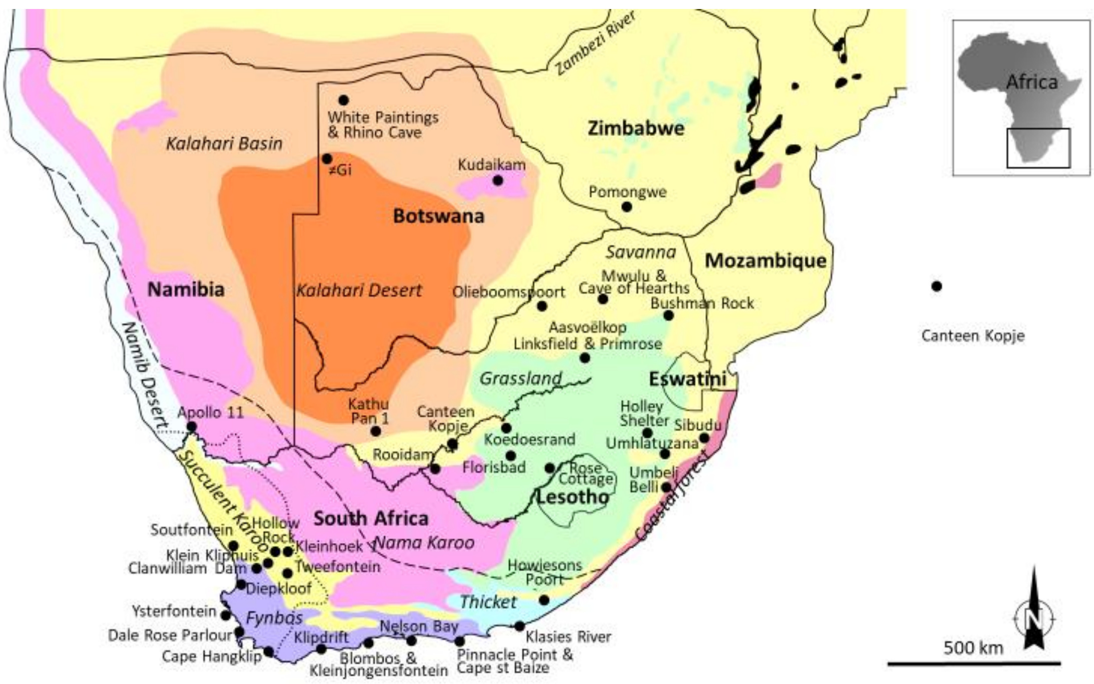


Figure 4: Map of southern Africa with archaeological sites mentioned in the text (base map by Matt Caruana, University of Johannesburg).

5. Results of the TCSA analysis

Here I collate the TCSA data obtained for 3330 points from 53 assemblages at 32 Middle Stone Age sites in approximate chronological order – remaining mindful that age estimates are often course-grained, and that overlaps, variations and outliers may exist. However, many assemblages have relatively secure dates and/or chronological context, and I indicate those with less secure context with '?' in the second column of Table 5. Of the dated assemblages, the most problematic is the Still Bay point assemblage from Diepkloof that falls in MIS 5a according to Jacobs et al. (2008; Jacobs & Roberts 2015), but spans MIS 5c through MIS 5e according to Tribolo et al. (2013). I therefore present this assemblage in both places in the chronology, which should highlight the context in which the assemblage is an outlier (also see Högberg & Lombard 2020).

Table 5: Results of the tip cross-sectional area analysis conducted on point assemblages from across southern Africa. Assemblages with relative chronological placing are indicated with '?'. Key: × = raw data from researcher, ^ = data from publication, ^^ = data measured from published images.

MSA phase	Age estimates/relative chronology	No	Width	Thick-ness	TCSA Range	TCSA Median	Data source
Rose Cottage Cave final MSA (Grassland/summer)	~27-28 ka (Pienaar et al. 2008)	15	7±2	2±1	7±3	6	^Mohapi 2007
Umbeli Belli Rock Shelter final MSA (Coastal Forest/summer)	~29 ka (Bader et al. 2018)	19	27±7	8±3	108±55	108	^^Bader et al. 2016
Umhlatuzana final MSA (Savanna/summer)	~34-40 ka (Lombard et al. 2010)	23	27±5	9±2	125±48	108	×Mohapi
Rose Cottage Cave post-Howiesons Poort (Grassland/summer)	~35-59-ka (Pienaar et al. 2008)	35	21±4	7±2	78±33	75	^Mohapi 2007
Holley Shelter post-Howiesons Poort (Grassland/summer)	?MIS 3 (Bader et al. 2015)	45	30±6	10±2	144±49	136	×Bader
Sibudu Cave final MSA (Savanna/summer)	~37-39 ka (Mohapi 2013)	13	28±9	8±3	114±62	120	×Wadley & Mohapi
Umhlatuzana post-Howiesons Poort (Savanna/summer)	~40-60 ka (Lombard et al. 2010)	20	28±6	11±3	148±59	149.5	×Mohapi
Sibudu Cave late MSA (Savanna/summer)	~46-57 ka (Vanhaeren et al. 2019)	100	27±7	8±3	122±73	104	×Wadley & Mohapi
Sibudu Cave post-Howiesons Poort (Savanna/summer)	~58-60 ka (Vanhaeren et al. 2019)	44	28±7	10±2	147±71	140	×Wadley & Mohapi
Sibudu Cave Howiesons Poort (Savanna/summer)	~62 ka (de la Peña et al. 2013)	25	20±4	9±3	100±53	81	×de la Peña
Pinnacle Point 5-6 MIS 4 (Fynbos/year-round)	~62-72 ka (Wilkins et al. 2017)	28	26±7	8±3	110±71	90	^Wilkins et al. 2017
White Paintings Shelter MSA (Savanna/Kalahari)	≥66 ka (Staurset & Coulson 2014)	29	24±4	8±2	94±31	88	×Staurset
Rhino Cave MSA (Savanna/Kalahari)	?≥66 ka (Coulson et al. 2011)	26	23±5	7±2	89±43	71.5	^Phillipson 2007
Pomongwe Cave Magosian/ Howiesons Poort (Savanna/summer)	?MIS 4 (Wadley & Harper 1989)	67	25±7	7±2	87±55	77	^^Cooke 1963
Sibudu Cave Still Bay (Savanna/summer)	~70-73 ka (Lombard et al. 2019)	38	27±7	8±2	116±51	102	×Högberg
Umhlatuzana Shelter Still Bay (Savanna/summer)	≥70.5 ka (Lombard et al. 2010)	39	21±4	8±2	89±31	92	×Högberg
Apollo 11 Shelter Still Bay (Nama Karoo/year-round)	≥70.7 (Vogelsang et al. 2010)	15	23±4	9±2	107±42	104	×Högberg
Diepkloof Shelter Still Bay Jacobs (Fynbos/winter)	~70.8-76.5 ka (Jacobs et al. 2008)	46	25±7	10±3	128±64	115.5	×Porraz
Blombos Cave Still Bay (Fynbos/year-round)	~71-76 ka (Jacobs et al. 2020)	28	24±6	8±2	107±54	95	×Sorresi
Hollow Rock Shelter Still Bay (Succulent Karoo/winter)	~72-80 ka (Högberg & Lombard subm.)	56	27±7	10±2	132±36	119	×Högberg
Sibudu Cave Wadley pre-Still Bay (Savanna/summer)	≥77 ka (Lombard et al. 2019)	24	24±8	8±2	103±67	84	×Högberg
Dale Rose Parlour Still Bay	?MIS5/5a	92	25±6	9±3	117±54	99.5	^Minichillo

(Fynbos/winter)	(Minichillo 2005)						2005
Klein Jongensfontein Still Bay (Fynbos/year-round)	?MIS5/5a (Table x)	21	27±3	9±2	123±37	105	×Sorresi
Hollow Rock Shelter Mossel Bay (Succulent Karoo/winter)	~80-97 ka (Högberg & Lombard subm.)	30	29±7	10±3	150±72	140.5	×Högberg
Pinnacle Point 5-6 MIS 5 (Fynbos/year-round)	~81-96 ka (Wilkins et al. 2017)	86	30±8	10±3	151±78	135	^Wilkins et al. 2017
Pinnacle Point 13B LBS1, SBS-URS (Fynbos/year-round)	~90-98 ka (Jacobs 2010)	40	36±7	9±3	163±77	144	×Minichillo
Klasies River MSA II upper (Thicket/year-round)	~95 ka (Wurz et al. 2018)	293	32±7	10±3	170±79	154	×Wurz
Apollo 11 MSA 1.2/Mossel Bay (Nama Karoo/year-round)	?MIS 5/5c (Table x)	20	35±10	10±4	184±111	149	^^Vogel-sang 1998
Cape st Blaize Mossel Bay (Fynbos/year-round)	?MIS 5/5c (Table x)	25	32±6	10±2	162±61	140	×Shea
Cave of Hearths Pietersburg (Savanna/summer)	?MIS 5/5c (Esteban et al. 2020)	63	29±7	8±2	126±51	116	×Sinclair
Olieboomspoort Pietersburg (Savanna/summer)	?MIS 5/5c (Esteban et al. 2020)	79	31±8	10±3	158±75	139	×Lombard
Klasies River MSA II lower (Thicket/year-round)	~100 ka (Wurz et al. 2018)	530	35±8	11±4	199±105	176	×Wurz
Klasies River MSA II lowest SMONE (Thicket/year-round)	~100-106 ka (Brenner & Wurz 2019)	44	30±10	12±4	188±111	175	×Brenner
Diepkloof Rock Shelter Still Bay Tribolo (Fynbos/winter)	~100-113 ka (Tribolo et al. 2013)	46	25±7	10±3	128±64	115.5	×Porraz
Klasies River MSA II lowest BOS (Thicket/year-round)	~106-110 ka (Brenner & Wurz 2019)	236	31±9	12±4	189±94	183	×Brenner
Klasies River MSA II SBLS (Thicket/year-round)	>110 ka (Brenner & Wurz 2019)	48	21±9	8±3	88±79	62	×Brenner
Ysterfontein MSA (Fynbos/winter)	~120-132 ka (Avery et al. 2008)	12	29±5	9±2	127±51	125	×Lombard
Florisbad expedient MSA (Grassland/summer)	~121±60 ka (Grün et al. 1996)	70	37±8	11±3	208±85	198	×Lombard
Apollo 11 MSA 1.1/Klasies River (Nama Karoo/year-round)	?MIS5/5d-e (Table x)	25	35±10	9±3	169±108	152	^^Vogel-sang 1998
Klasies River MSA I/Klasies River (Thicket/year-round)	>126 ka (Brenner & Wurz 2019)	71	34±6	9±2	159±59	150	×Wurz
Bushman Rock Shelter 44-55 (Grassland/summer)	MIS 5 (Douze et al. 2020)	165	31±9	9±3	144±78	129	×Douze
Clanwilliam Dam East MSA (Succulent Karoo/winter)	?MIS 5 (Mackay et al. 2018)	24	29±7	11±4	168±96	131	×Mackay
Kleinhoek 1 (Succulent Karoo/winter)	?MIS 5 (Mackay et al. 2018; Ames et al. 2020)	24	33±7	13±4	223±99	216	×Mackay
Soutfontein (Succulent Karoo/winter)	? MIS 5 (Mackay et al. 2018)	32	27±6	12±2	162±58	154	×Mackay
Florisbad earlier MSA phase (Grassland/summer)	~157±21 ka (Grün et al. 1996)	76	34±7	11±3	190±71	186,5	×Lombard
Pinnacle Point 13B Upper DBS, LC-MSA Lower (Fynbos/year-round)	~159-166 ka (Jacobs 2010)	29	33±8	8±2	139±50	132	×Minichillo
Rooidam 2 early MSA/Fauresmith upper (Savanna/summer)	>174 ka (Szabo & Butzer 1979)	80	33±11	11±4	187±101	177.5	×Elzholz
Rooidam 2 early MSA/Fauresmith lower (Savanna/summer)	?≥MIS 6 (Szabo & Butzer 1979)	50	28±10	10±3	144±94	106	×Elzholz
Cape Hanghklip late Acheulean/ Fauresmith (Synbos/winter)	?>MIS 6 (Gatehouse 1953)	23	34±9	11±3	201±97	177	×Soressi
Linksfield Sangoan (Grassland/summer)	?MIS 6-8 (Tryon & McBrearty 2002; Porat et al. 2010)	46	32±7	13±3	200±73	193,5	×Lombard
Primrose Ridge Sangoan (Grassland/summer)	?MIS 6-8 (Tryon & McBrearty 2002; Porat et al. 2010)	54	31±6	13±2	210±64	195	×Lombard
Canteen Kopje Fauresmith (Savanna/summer)	>300 ka (Kuman et al. 2020)	13	33±11	11±3	189±94	190	×Lotter
Kathu Pan Fauresmith (Savanna/Kalahari)	>464 ± 47 ka (Wilkins et al. 2012)	148	38±8	11±3	219±80	207	×Wilkins

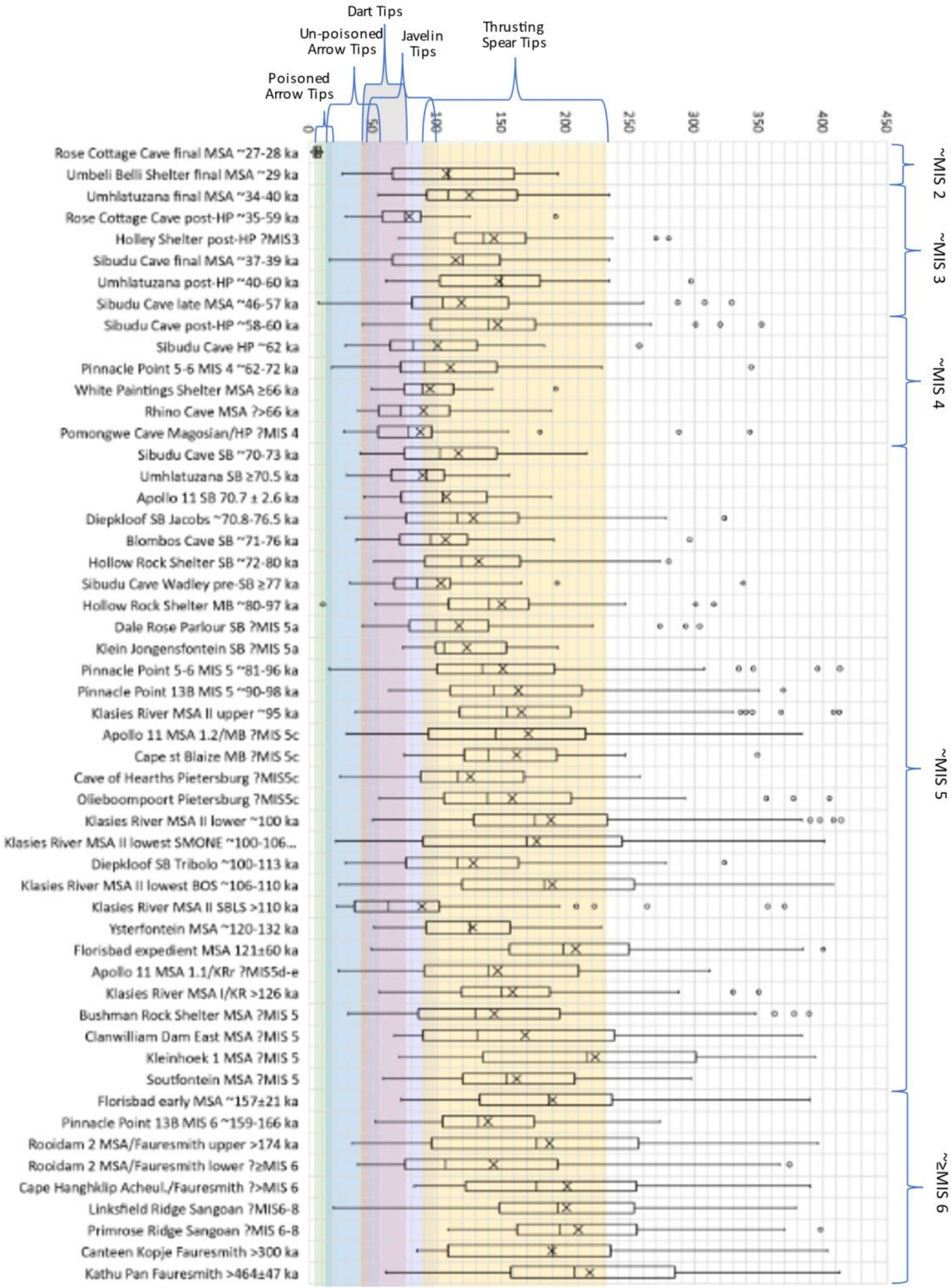
In Figure 5 the results are presented according to the TCSA ranges for the different weapon-tip types in approximate correlation with the MIS record. It demonstrates that points from the early Middle Stone Age and the Earlier-to-Middle Stone Age transition generally dating to ≥MIS 6 all have median TCSA values that fall well within that for stabbing/thrusting spears, with the exception of the older Fauresmith assemblage from Rooidam 2 whose median is close to that of javelin tips, although still within the thrusting spear tip range. The younger Fauresmith assemblage from Rooidam 2 also has a few pieces that fall within the Javelin range.

In general, the MIS 5 assemblages show much more variability compared to the older ones (Fig. 5). The median TCSA values for MIS 5b-e assemblages and those with a general MIS 5 designation (some of which remain without direct dates and/or have been collected from open-air sites without stratified context) mostly still fall comfortably within the range for thrusting spear tips, not much different from the MIS 6 assemblages. But now several more have pieces with values also consistent with the range for javelins, including points from Clanwilliam Dam East, Bushman Rock Shelter, Apollo 11 (MSA 1.1/?Klasies River), Ysterfontein, Diepkloof (Still Bay Tribolo), Klasies River (II lowest SMONE), Cave of Hearths (Pietersburg), and Apollo 11 (MSA 1.2/?Mossel Bay). We may therefore hypothesise that if the points from these assemblages were intended as weapon tips there is a trend towards including some light-weight javelins in the MIS 5 hunting arsenal.

A clear outlier in the MIS 5 group is the Klasies River MSA II SBLS assemblage with a TCSA median in the middle of the javelin and dart tip ranges. This is a well-stratified context with preserved hearths (Brenner & Wurz 2019; Brenner et al. 2020), so that there can be little doubt about the integrity of the assemblage in terms of its chronology at Klasies River. Compared to the overlaying BOS and SMONE layers, SLBS has a different shellfish composition, and the highest lithic density with pieces that are generally lighter, shorter, narrower, and thinner. The lithics from this layer also have the least amount of edge damage, indicating that hunting and butchery were not major activities during its accumulation (Brenner et al. 2020). Brenner et al. (2020) currently interpret the layer as showing elements of individual provisioning instead of residential activities such as food preparation and consumption, or as a knapping site focussed on miniaturisation and/or the maximizing of raw materials.

Figure 5: Bar-and-whisker plots for the TCSA values from Middle Stone Age points samples across southern Africa. Assemblages with relative chronological placing are indicated with '?'.

During the subsequent MIS 5a phase, the trend towards an increasing number of tips suited for javelin use becomes



patent (Fig. 5), with the median TCSA values for assemblages from sites such as Sibudu Cave (pre-Still Bay), Blombos Cave (Still Bay) and Umhlatuzana Rock Shelter (Still Bay) now falling within the range of javelin tips. Several other assemblages also have median TCSA values close to the javelin range, and contain several pieces that fall within the javelin tip range, these include points from Klein Jongensfontein (Still Bay), Dale Rose Parlour (?Still Bay), Apollo 11 (Still Bay) and Sibudu Cave (Still Bay).

The development towards smaller TCSA values continues into MIS 4, with all the medians now falling in the javelin tip range, some even approaching the range for dart tips. A clear exception is the Sibudu Cave post-Howiesons Poort assemblage, which is the youngest in the MIS 4 group, for which the TCSA median falls within in the range of thrusting spear tips. This tendency towards larger TCSA values is echoed in the results obtained for the subsequent MIS 3 assemblages, especially at Umhlatuzana (post-Howiesons Poort) and the post-Howiesons Poort assemblages from Umbeli Belli and Holley Shelter. The outlier amongst the MIS 3 assemblages is that of the post-Howiesons Poort from Rose Cottage Cave, with a median TCSA value within the javelin tip range, touching on the range for dart tips. It is then also here that the Middle Stone Age assemblage stretching into MIS 2 has points that are so small that they are best suited for use as poisoned arrow heads.

This course-grained reading of the TCSA results for point assemblages suggests an early use of thrusting spears during the Middle Stone Age, perhaps stretching back into the Earlier Stone Age in southern Africa. Hypothetically, the use of javelins together with thrusting spears may have started and increased throughout MIS 5, culminating to mostly javelin hunting in some Still Bay assemblages by MIS 5a. This trend is seemingly continued during MIS 4, but the analysis presented above only pertains to points and not to the backed microliths of typical Howiesons Poort assemblages. MIS 3 assemblages are, however, once again point-dominated, and here we see a probable return to the frequent use of stabbing or thrusting spears, quickly changing to bow hunting – probably with poisoned arrow tips – with the introduction of the cold MIS 2 phase at Rose Cottage Cave. Below I address more specifically the three questions listed at the end of the section on ‘previous hunting-weapon hypotheses’ above.

5.1. What do point assemblages that post-date the Howiesons Poort reveal about variation in weapon choice?

A relatively comprehensive body of work suggests bow hunting in sub-Saharan Africa since ~70 ka, specifically associated with backed microliths from the Howiesons Poort techno-complex in South Africa, but also with some younger assemblages elsewhere. Sites representing such observations include:

- White Paintings Shelter, Botswana, at ~35 ka; based on bone points, morpho-type, and morphometrics (Robbins et al. 2012; Lombard 2020a).
- Panga ya Saidi, Kenya, at ~32-45 ka; based on bone points, morpho-type, and use-notching (d’Errico et al. 2020).
- Border Cave, South Africa, at ~34-40 ka; based on bone points, morpho-type, and morphometrics (d’Errico et al. 2012, Lombard 2020a).
- Peers Cave, South Africa, at ~50-75 ka; based on bone points, morpho-type, morphometrics, and traceology (Bradfield 2010; Lombard 2020a).
- Umhlatuzana Rock Shelter, South Africa, at ~60 ka; based on backed microliths, morpho-type, morphometrics, macro-fractures, residues, blind testing, fracture and microwear experiments (Lombard &

Wadley 2007; Lombard & Phillipson 2010; Pargeter & Bradfield 2012; Pargeter et al. 2016, 2017; Lombard 2020b).

- Sibudu Cave, South Africa, at ~60-65 ka; based on backed microliths and bone points, morpho-type, morphometrics, macro-fractures, microwear, residues, blind testing, micro-CT scanning, fracture and microwear experiments, faunal assemblage (Lombard & Wadley 2007; Pargeter & Bradfield 2012; Pargeter et al. 2016, 2017; Clark 2017; Backwell et al. 2018; de la Pena et al. 2018; Lombard 2020a, b).
- Klasies River Cave, South Africa, at >60 ka; based on a bone point and backed microliths, morpho-type, morphometrics, macro-fractures, microwear, residues, micro-CT scanning, faunal assemblage (Wurz & Lombard 2007; Bradfield et al. 2020; Lombard 2020a, b).
- Blombos Cave, South Africa, at ~72-80 ka; based on bone points, morpho-type, morphometrics, microwear, fracture and microwear experiments (d'Errico & Henshilwood 2007; Bradfield 2010, Lombard 2020a).
- As well as Apollo 11 (Namibia, ~63 ka), Klein Kliphuis (~58-66 ka), Klipdrift (~59-65 ka), Diepkloof (~66 ka), Rose Cottage Cave (~62-69 ka), and Pinnacle Point 5-6 (~58-71 ka) all in South Africa; based on backed microliths, morpho-type and morphometrics (Lombard 2020b).

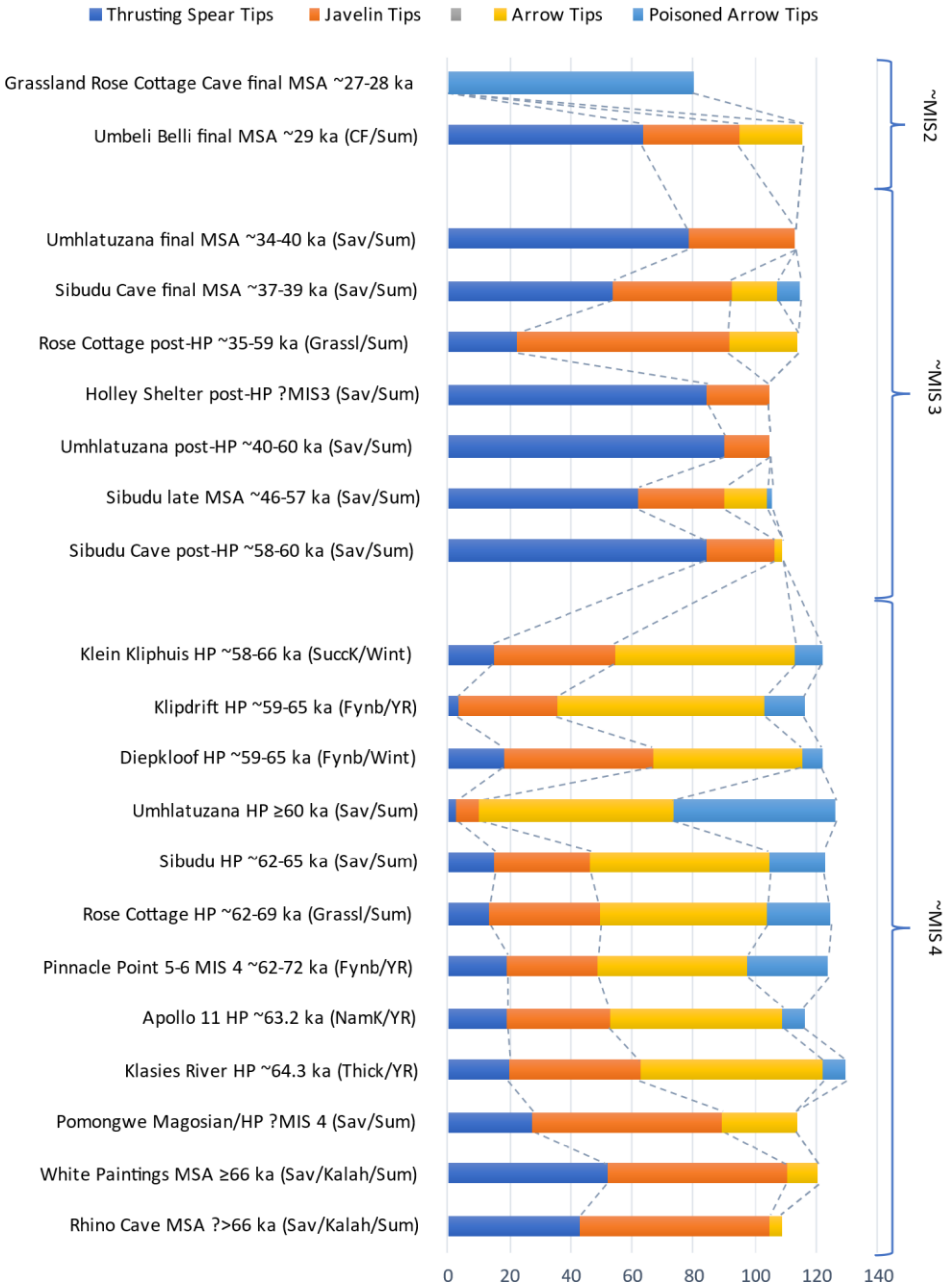


Figure 6: Variation in hypothetical weapon choices based on the distribution of TCSA values within Middle Stone Age assemblages roughly dating between MIS 4 (starting at ~ 71 ka) and MIS 2 (starting at ~29 ka). The x axis represents % of artefacts within an assemblage but adds up to more than 100 because of the overlap between TCSA ranges for different weapon-delivery types.

Thus, to assess hypothetical weapon choices based on the TCSA approach I include here the data from the Lombard (2020b) study on backed microliths (Fig. 6, Table 6). For sites such as Sibudu Cave and Pinnacle Point 5-6 that have contemporaneous point assemblages the data are collated to reflect the full range of potential stone-tipped weapon types (see discussion in Lombard 2020b). From the results presented in Figure 6, we may hypothesise that by ≥66 ka hunters from Rhino Cave and White Paintings Shelter in the Savanna/Kalahari of northern Botswana, and those from Pomongwe Cave in the Savanna of Zimbabwe preferred to hunt with javelins in combination with some thrusting spears, especially at White Paintings Shelter. At Pomongwe 24.6% of the points would also have been effective as arrow tips (Table 6). There is a marked increase in artefacts that may have been used effectively as arrow tips based on their TCSA values in all the Howiesons Poort, including the Pinnacle Point MIS 4, assemblages. At sites such as Umhlatuzana, Sibudu, Rose Cottage Cave and Pinnacle Point there are also indications for the possible use of poisoned arrow tips, but apart from Umhlatuzana where bow hunting currently stands out as a strong preference, Howiesons Poort hunters seem to have preferred combining bow hunting with javelin hunting, including the odd thrusting spear (Fig. 6, Table 6). This hypothetical pattern based on the distribution of TCSA values within the Howiesons Poort assemblages, closely resembles the composition of ethno-historical hunting kits from southern Africa. Perhaps noteworthy is that the TCSA signature for bow hunting is prevalent on the Fynbos, Thicket, Succulent Karoo, Nama Karoo, Grassland and Savanna Biomes in the summer and year-round rainfall regimes, so that it may reflect a sub-continental trend in technology-assisted hunting behaviour during MIS 4.

In stark contrast to the MIS 4 assemblages, the TCSA value distribution patterns for the MIS 3 point assemblages show a distinct preference for spear hunting with stone-tipped weaponry. During the post-Howiesons Poort phase At Rose Cottage Cave on the Grassland Biome, javelins seem to have been the weapon of choice with some stone-tipped arrows and thrusting spears. Stone-tipped arrows may also have been in use at Sibudu Cave again during its late and final Middle Stone Age phases (perhaps even with poisoned arrows), but in these instances more in combination with thrusting spears than with javelins. During the Sibudu Cave, Holly Shelter and Umhlatuzana post-Howiesons Poort phases, as well as the final Middle Stone Age at Umhlatuzana, the TCSA value distributions indicate that stone-tipped thrusting spears may have been the weapons of preference with some javelin hunting still in play. All of these sites are on the Grassland or Savanna Biomes, and currently no comparable records are available for the MIS 3 from the other Biomes. It is therefore not clear whether this may have been a regional expression of preferred hunting strategy, or whether a similar shift took place across southern Africa. The examples listed above for the use of bone arrow points during MIS 3, however, may indicate specialisation in terms of raw material use with arrow points now being made with organic materials instead of stone. The two final Middle Stone Age assemblages that fall at the beginning of MIS 2 show very different TCSA value distributions, probably reflecting variation in response to the onset of the glacial. On the Grassland Biome close to the snowy Maloti-Drakensberg, the final Middle Stone Age at Rose Cottage Cave shows a strong signature for hunting only with poisoned arrows. At Umbeli Belli, protected within a dense forest close to the warm Agulhas current of the Indian Ocean to the east of southern Africa, the TCSA value distributions indicate that hunters may have continued the MIS 3 pattern of predominantly hunting with spears.

Table 6. Frequencies of weapon tips hypothetically used between MIS 2 and MIS 4 based on the intra- and inter-assemblage distribution of TCSA values. Percentages add up to more than 100 because of the overlap in TCSA ranges for different weapon-delivery types.

Assemblage	**Thrust. spear tips**	**Javelin tips**	**Dart tips**	**Arrow tips**	**Poisoned Arrow tips**	**Spear hunting**	**Bow Hunting**
	n/%	**n/%**	**n/%**	**n/%**	**n/%**	**n/%**	**n/%**
Rose Cottage Cave final MSA ~27-28 ka (n=15)	0	0	0	0	12/80	0	12/80
Umhlatuzana final MSA ~34-40 ka (n=23)	18/78.3	8/34.8	3/13.	0	0	23/100	0
Rose Cottage Cave post-HP ~35-59 ka (n=35)	8/22.6	24/68.6	16/45.7	8/22.9	0	32/91.4	8/22.9
Holley Shelter post-HP ?MIS 3 (n=45)	38/84.4	9/20.	4/8.9	0	0	45/100	0
Umbeli Belli Shelter post-HP ?MIS 3 (n=19)	12/63.2	6/31.6	3/15.8	4/21.1	0	16/84.2	4/21.1
Sibudu Cave final MSA ~37-39 ka (n=13)	7/53.8	5/38.5	3/23.1	2/15.	1/7.7	12/92.3	2/15.
Umhlatuzana post-HP ~40-60 ka (n=20)	18/90	3/15.	2/10.	0	0	20/100	0
Sibudu Cave late MSA ~46-57 ka (n=100)	62/62	28/28	13/13	14/14	2/2.	90/90	15/15

Sibudu Cave post-HP ~58-60 ka (n=44)	37/84.1	10/22.7	6/13.6	1/2.3	0	43/97.7	1/2.3
Total data points for MIS 3 n=299	**n=200**	**n=93**	**n=50**	**n=29**	**n=3**	**n=281**	**n=30**
Tip-type percentages for MIS 3	**66.9%**	**31.1%**	**16.9%**	**9.7%**	**1%**	**94%**	**10%**
Klein Kliphuis Howiesons Poort ~58-66 ka (n=136)	20/14.7	54/39.7	49/36	80/58.8	12/8.8	68/50	82/60.3
Diepkloof Howiesons Poort ~59-65 ka (n=132)	24/18.2	64/48.5	57/43	64/48.5	9/6.8	81/61.4	66/50
Klipdrift Howiesons Poort ~59-65 ka (n=31)	1/3.2	10/32.3	11/35.5	21/67.7	4/12.9	11/32.2	22/70.4
Umhlatuzana Howiesons Poort ≥60 ka 232 (n=20)	7/3.	17/7.3	17/7.3	146/62.9	126/53.3	23/9.9	215/92.7
Sibudu Cave HP ~62 ka (n=219)	33/15.1	69/31.5	62/28.3	127/58	40/18.3	95/43.4	142/64.6
Rose Cottage Cave ~62-69 ka (n=84)	11/13.7	30/35.7	27/32.1	46/54.8	17/20.2	36/42.3	55/65.5
Klasies River Howiesons Poort ~64.3 ka (n=56)	11/19.6	24/42.9	24/42.9	33/58.9	4/7.1	34/60.7	33/58.9
Pinnacle Point 5-6 MIS 4 ~62-72 ka (n=88)	17/19.3	26/29.5	19/21.6	43/48.9	23/26.1	38/43.2	57/64.8
Apollo 11 Howiesons Poort ~63.2 ka (n=57)	11/19.3	19/33.3	17/9.8	34/59.6	4/7.	27/47.4	35/61.4
White Paintings Shelter MSA ≥66 ka (n=29)	15/51.7	17/58.6	10/34.5	3/10.3	0	29/100	3/10.3
Rhino Cave MSA ?>66 ka (n=26)	11/42.3	16/61.5	13/50	1/3.8	0	25/96.2	1/3.8
Pomongwe Cave Magosian/HP ?MIS 4 (n=65)	18/27.7	40/61.5	26/40	16/24.6	0	56/86.2	16/24.6
Total data points for MIS 4 n=892	**n=168**	**n=386**	**n=332**	**n=614**	**n=239**	**n=523**	**n=727**
Tip-type percentages for MIS 4	**18.8%**	**43.3%**	**37.2%**	**68,8%**	**26.8%**	**58.6%**	**81.5%**
Total data points for MIS 4-2 n=1257	**n=379**	**n=479**	**n=382**	**n=643**	**n=254**	**n=804**	**n=769**
Tip-type percentages for MIS 4-2	**30.2%**	**38.1%**	**30.4%**	**51.2%**	**20.2%**	**64%**	**61.2%**

Above I focussed on spear (thrusting spear and javelin) and bow hunting. Thus far there has only been one suggestion for hunting with spearthrowers and darts during these phases, namely for the backed microliths from Pinnacle Point 5-6 (Brown et al. 2012). The TCSA values for this assemblage, however, fall fully within the TCSA ranges of both un-poisoned and poisoned arrow tips (Lombard 2020b), and not in that of dart tips. Even combined with the TCSA values obtained for the point assemblage from this context that has a clear spear-hunting signature (Table 5, Fig. 5), I show here that the probability of dart hunting lies at only 21.6% as opposed to the 43.1% probability for spear hunting and the 64.8% probability for bow hunting (Table 6). Collectively, there might have been a 37.2% probability for dart hunting during MIS 4, but this pales against the probability rates for javelin hunting at 58,6% and bow hunting at 81.5% during the same period. If one then considers that 89% of all the TCSA values that fall in the dart tip category also falls in that of the javelin tip category, it is difficult to suggest any inferences about dart hunting other than, if it was practiced at all, it was not the preferred weapon-delivery system. During the subsequent MIS 3, dart hunting becomes even less of an option at 16.9% as opposed to 94% of all the pieces being able to serve as effective tips for either thrusting spears or javelins.

5.2 Is there support for wide-spread spearthrower-and-dart hunting before bow hunting in southern Africa?

Whilst the results presented above indicate a possibility for dart hunting contemporaneous with bow and javelin hunting during MIS 4, it has been invoked for southern Africa during ~MIS 5 by both the Brooks et al. (2006) and Sisk and Shea (2011) studies. Sahle and Brooks (2019) even sees the notion that dart hunting preceded bow hunting as 'consensus view' for the whole of Africa. Here I test these suppositions, using a much larger sample than any of the previous studies, sub-dividing MIS 5 in three broad phases (roughly corresponding to MIS 5a, MIS 5b-c, MIS d-e+bulk MIS 5 assemblages) (Table 7).

An obvious observation is that different from the MIS 4 assemblages, all those roughly aligned with MIS 5 (or at the very beginning of MIS 4) indicate bow hunting as the least probable strategy, and that tips with TCSA values that fall in the poisoned arrow category is all but absent (Table 7). The only obvious outlier is the Klasies River MSA II SBLS assemblage wherein 36.6% of the points would have been effective in a bow hunting scenario, and I have discussed this anomaly above. From the totals provided at the bottom of Table 7, it is evident that if practiced, dart hunting at 10.1% was the least likely option for the duration of this period, with javelin hunting at 20.2% twice as likely, and hunting with thrusting spears four times as likely as javelin hunting at 82.7%.

Table 7. Frequencies of weapon tips hypothetically used during MIS 5 based on the intra- and inter-assemblage distribution of TCSA values. Percentages add up to more than 100 because of the overlap in TCSA ranges for different weapon-delivery types.

Assemblage	**Thrust. spear tips**	**Javelin tips**	**Dart tips**	**Arrow tips**	**Poisoned Arrow tips**	**Spear hunting**	**Bow Hunting**
	n/%	**n/%**	**n/%**	**n/%**	**n/%**	**n/%**	**n/%**
Sibudu Cave SB ~70-73 ka (n=39)	27/69.2	15/39.5	10/25.6	3/7.7	0	37/94.9	3/7.7
Umhlatuzana SB ≥70.5 ka (n=39)	23/59	21/53.8	10/25.6	6/15.4	0	36/92.3	6/15.4
Apollo 11 SB 70.7 ± 2.6 ka (n=15)	11/73.3	6/40	4/26.7	1/6.6	0	14/93.3	1/6.6
Diepkloof SB Jacobs ~70.8-76.5 ka (n=46)	32/69.7	16/34.8	10/21.7	1/2.2	0	45/97.8	1/2.2
Blombos Cave SB ~71-76 ka (n=28)	17/60.7	12/42.9	7/25	4/14.3	0	26/92.9	4/14.3
Hollow Rock Shelter SB ~72-80 ka (n=56)	45/80.4	18/32.1	7/12.5	2/3.6	0	56/100	2/3.6
Sibudu Cave Wadley pre-SB ≥77 ka (n=24)	11/45.8	12/50	7/29.2	4/16.7	0	22/91.7	4/16.7
Dale Rose Parlour SB ?MIS 5a (n=92)	59/64.1	44/47.8	20/21.7	4/4.3	0	91/98.9	4/4.3
Klein Jongensfontein SB ?MIS 5a (n=21)	17/90	5/23.8	1/4.7	0	0	21/100	0
Total data points for ~MIS 5a n=360	**242**	**149**	**76**	**25**	**0**	**348**	**25**
Tip-type percentages for ~MIS 5a	**76.2%**	**41.4%**	**21.1%**	**6.9%**	**0**	**96.7%**	**6.9**
Hollow Rock Shelter MB ~80-97 ka (n=30)	26/86.7	5/16.7	2/6.7	1/3.3	1/3.3	29/96.7	1/6.7
Pinnacle Point 5-6 MIS 5 ~81-96 ka (n=86)	72/83.7	17/19.8	10/11.6	5/5.8	1/1.2	83/96.5	5/5.8
Pinnacle Point 13B MIS 5 ~90-98 ka (n=40)	35/87.5	8/20	3/7.5	0	0	40/100	0
Klasies River MSA II upper ~95 ka (n=293)	258/88.1	41/14	19/6.5	7/2.4	0	290/99	7/2.4
Apollo 11 MSA 1.2/MB ?MIS 5c (n=19)	18/94.7	4/21.1	1/5.3	1/5.3	0	18/94.7	4/21.1
Cape st Blaize MB ?MIS 5c (n=25)	24/96	1/4.	1/4.	0	0	25/100	0
Cave of Hearths Pietersburg ?MIS 5c (n=63)	47/74.6	21/33.3	7/11.1	3/4.8	0	61/96.8	3/4.8
Olieboompoort Pietersburg ?MIS 5c (n=79)	69/78.3	13/16.5	6/7.6	0	0	79/100	0
Klasies River MSA II lower ~100 ka (n=530)	498/94	49/9.2	17/3.2	3/0.6	0	530/100	3/0.6
Klasies River MSA II lowest SIM. ~100-106 ka (n=44)	33/75	8/18.2	7/15.9	5/11.4	0	41/93.2	5/11.4
Diepkloof SB Tribolo ~100-113 ka (n=46)	32/69.7	16/34.8	10/21.7	1/2.2	0	45/97.8	1/2.2
Klasies River MSA II lowest BOS ~106-110 ka (n=236)	202/85.6	28/11.8	18/7.6	18/7.6	0	221/93.6	18/7.6
Klasies River MSA II SBLS >110 ka (n=48)	15/31.3	22/45.8	16/33.3	19/39.6	0	34/70.8	19/39.6
Total data points for ~MIS 5b-c n=1539	**1329**	**233**	**117**	**63**	**2**	**1496**	**66**
Tip-type percentages for ~MIS 5b-c	**86.4%**	**15.1%**	**7.6%**	**4.1%**	**0.1%**	**97.2%**	**4.3%**
Apollo 11 MSA 1.1/KRr ?MIS 5d-e (n=23)	18/78.3	4/17.4	4/17,4	2/8.7	0	21/91.3	2/8.7
Ysterfontein MSA ~120-132 ka (n=12)	10/83.3	5/41.7	2/16.7	1/8.3	0	12/100	1/8.3
Florisbad expedient MSA 121±60 ka (n=70)	65/92.9	6/8.6	4/5.7	0	0	70/100	0
Klasies River MSA I/KR >126 ka (n=71)	65/91.5	10/14.1	3/4.2	0	0	71/100	0
Bushman Rock Shelter MSA ?MIS 5 (n=165)	119/72.1	45/27.3	23/13.9	16/9.7	0	153/92.7	16/9.7
Clanwilliam Dam East MSA ?MIS 5 (n=24)	20/83.3	9/37.5	2/8.3	0	0	24/100	0
Kleinhoek 1 MSA ?MIS 5 (n=24)	21/87.5	3/12.5	2/8.8	0	0	24/100	0
Soutfontein MSA ?MIS 5 (n=32)	30/93.8	4/12.5	1/3.1	0	0	32/100	0
Total data points for ~MIS 5d-e n=421	**348**	**86**	**41**	**19**	**0**	**407**	**19**
Tip-type percentages for ~MIS d-e	**82.7%**	**20.4%**	**9.7%**	**4.5%**	**0**	**96.7%**	**4.5%**
Total data points for MIS % n=2320	1919	468	234	107	2	2251	110
Tip-type percentages for MIS 5	82.7%	20.2%	10.1%	4.7%	0.1%	97%	4.7%

When the results are considered according to assemblage and within the three broad phases used here for MIS 5, it is possible to gain more detailed insight. For MIS 5a, we see the highest probability for spearthrower use with 21.1% of the points having TCSA values that indicate potential effective use as dart tips. This trend is consistent through assemblages from the Savanna/summer-rain, Nama Karoo/year-round rain, and Fynbos/year-round/winter rain areas (Fig. 7). The pre-Howiesons Poort assemblage from Sibudu Cave dated to ≥77 ka has the highest percentage of points that would have been effective as dart tips at 29.2%, but javelin hunting and hunting with thrusting spears predominate with 50% and 45.8% respectively. Thus, 91.7% of the pre-Still Bay points at Sibudu were made with dimensions suited for spear hunting strategies – this TCSA signature is stronger in all the other assemblages in this block (Fig. 7), so that even if dart hunting was practised during MIS 5a, it was always the least preferred strategy (or the least amount of weapon tips were produced suited for use as dart tips). On the other hand, the TCSA values for ~MIS 5a show a strong probability that javelin hunting was habitually practiced with the frequent use of thrusting spears. For the Still

Bay assemblages at Umhlatuzana (Still Bay), Blombos Cave (Still Bay) and Dale Rose Parlour (?Still Bay) this dual spear-hunting strategy seems most evident (Table 7, Fig. 7), whereas during the pre-Still Bay at Sibudu javelin hunting at 50% just about outranks hunting with thrusting spears at 45.8%.

For the preceding MIS 5b-c phase (excluding the Klasies River MSA II SBLS anomaly) the highest frequencies for both possible dart tips at 21.7% and javelin tips at 34.8% are observed for the Tribolo Still Bay assemblage from Diepkloof, which is more consistent with the other ~MIS 5a assemblages than with those dating to ~MIS 5b-c (Fig. 7). Only 7.6% of all the points manufactured during this phase would have been effective to use as dart tips. In stark contrast spear-hunting strategies seem to have been preferred with a combined 97.2% of the points manufactured with dimensions suited for use as javelin tips (15.1%) or most likely as thrusting spear tips (86.4%). Thus, if dart hunting was practiced at all in southern Africa it was probably done contemporaneous with bow hunting during MIS 4, and perhaps during MIS 5a at less than ~85 ka, but almost certainly not before.

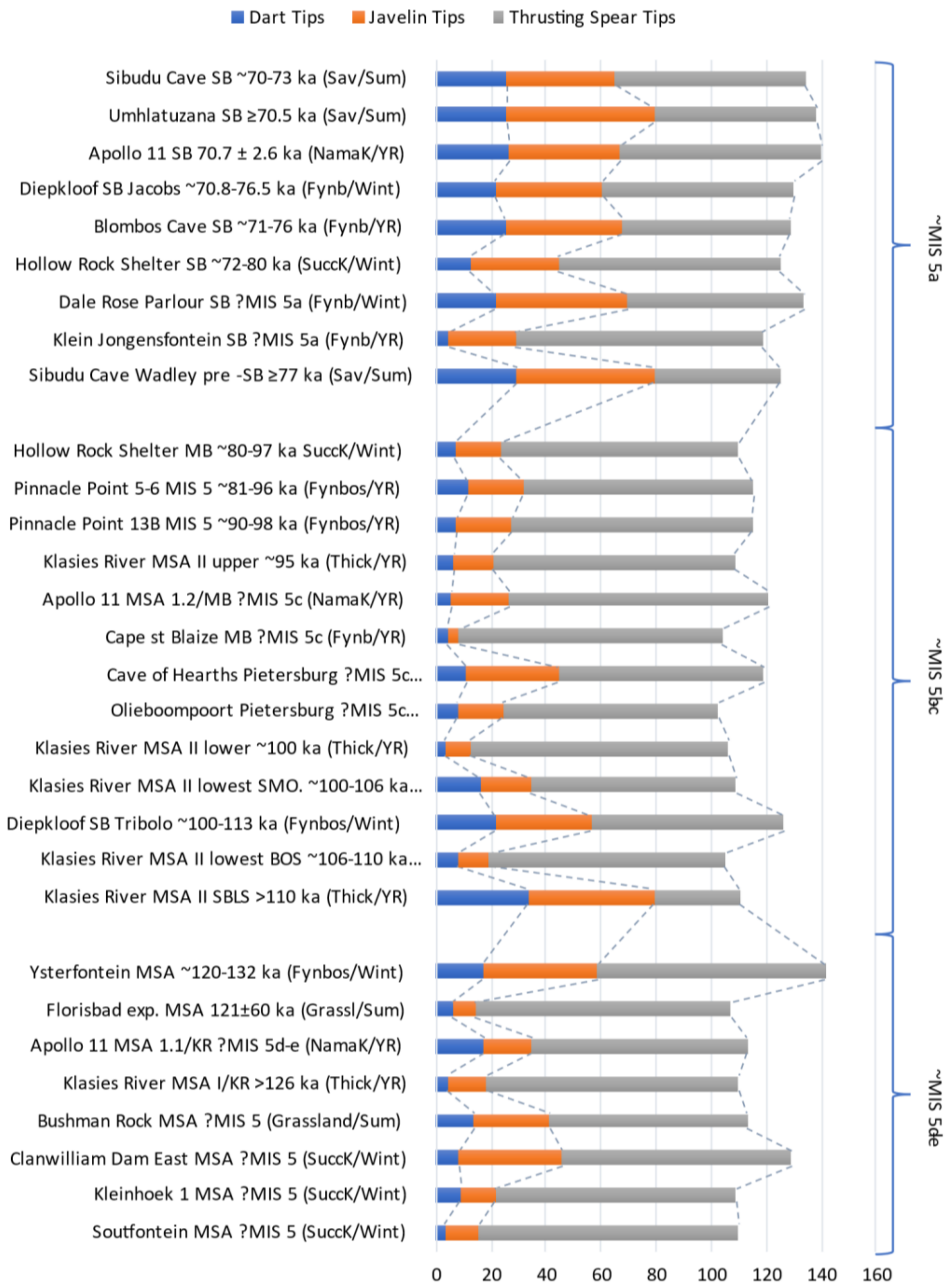


Figure 7: Variation between hypothetical dart, javelin and thrusting-spear tips based on the distribution of TCSA values within Middle Stone Age assemblages roughly dating to MIS 5 (starting at ~130 ka). The x axis represents % of artefacts within an assemblage, but adds up to more than 100 because of the overlap between TCSA ranges for different weapon-delivery types.

Apart from the Klasies River (MSA II SBLS) and Diepkloof (Tribolo Still Bay) assemblages, the Cave of Hearths Pietersburg assemblage with 33.3% of its points potentially suited for tipping javelins stands out for the ~MIS5 b-c phase. Other assemblages with frequencies of >15% for points with javelin tip TCSA values include Apollo 11 (MSA 1.2/?Mossel Bay) with 21.1%, Pinnacle Point 13B (MIS 5) with 20%, Pinnacle Point 5-6 (MIS 5) with 19.8 %, Klasies River (MSA II lowest SMO.) with 18.2%, Hollow Rock Shelter (Mossel Bay) with 16.7%, and Olieboomspoort (Pietersburg) with 16.5%.

The likelihood of dart hunting during the preceding MIS d-e phase seems a fraction higher at 9.7% of its points falling into the TCSA range suited for such use, but again it is overshadowed by a more than double likelihood for javelin hunting at 20.4% and a four times again likelihood for the use of thrusting spears at 82.7%. It is therefore unlikely that spearthrowers armed with darts were used in southern Africa during MIS 5d-e, whilst assemblages with frequencies of >15% for tips potentially suited for light-weight javelins include those from Ysterfontein with 41.7%, Clanwilliam Dam East with 37.5%, Bushman Rock Shelter with 27.3%, and Apollo 11 (MSA 1.1/?Klasies River) with 17.4% (Table 7, Fig. 7).

5.3 What is the time depth of hunting with lightweight javelins in southern Africa?

Tracing the early use of javelins is not an easy task in southern Africa, because we do not have the conditions that usually preserve wooden artefacts beyond the Holocene. There is one exception, namely the piece of wood described as part of an ancient throwing stick from Florisbad (Clark 1955), which could date to anything between ~125 ka and 259 ka (Bamford & Henderson 2003). This find suggests the existence of wooden throwing implements used during the Middle Stone Age on the southern African Grassland Biome perhaps as far back as MIS 8. Currently, the earliest known javelins are the wooden ones from Schöningen, Germany, dated to ~300-400 ka (e.g., Thieme 2000; Schmidt et al. 2005), where they were probably cast from a short distance to wound horses before killing them at close-quarters in an ambush scenario (Voormolen 2008). The reality therefore is that we know almost nothing about African Middle Stone Age wood-based hunting technologies and that lithics can tell only a partial story.

Above I have shown that, based on the TCSA method, we may hypothesise that at least since MIS 5a southern African hunters habitually used lightweight, stone-tipped javelins in addition to their heavier thrusting spears. I have also highlighted contexts during the preceding MIS 5 sub-stages during which hunters may have used javelins in combination with their thrusting spears (Fig. 7), which suggests that this option was available at least since about 130 ka in southern Africa. Here I test whether a hunting strategy that included stone tipped javelins in the region may be more ancient.

Table 8: Frequencies of weapon tips hypothetically used during and before MIS 6 based on the intra- and inter-assemblage distribution of TCSA values. Percentages add up to more than 100 because of the overlap in TCSA ranges for different weapon-delivery types.

Assemblage	**Thrust. spear tips**	**Javelin tips**	**Dart tips**	**Arrow tips**	**Poisoned Arrow tips**	**Spear hunting**	**Bow Hunting**
	n/%	**n/%**	**n/%**	**n/%**	**n/%**	**n/%**	**n/%**
Florisbad early MSA ~157±21 ka (n=76)	73/96.1	4/5.3	1/1.3	0	0	76/100	0
Pinnacle Point 13B MIS 6 ~159-166 ka (n=51)	45/88.2	11/21.6	6/11.8	1/2.	0	51/100	1/2.
Rooidam 2 MSA/Fauresmith upper >174 ka (n=80)	66/82.5	21/26.3	9/11.25	4/5.	0	77/96	4/5.
Rooidam 2 MSA/Fauresmith lower ?≥MIS 6 (n=50)	34/68	19/38	11/22.	3/6.	0	48/96	3/6.
Total data points for ~MIS 6 n=257	**218**	**55**	**27**	**8**	**0**	**252**	**8**
Tip-type percentages for ~MIS 6	**84.8**	**21.4**	**10.5**	**3.1**	**0**	**98.1**	**3.1**
Cape Hanghklip Acheul./Fauresmith ?>MIS 6 (n=23)	20/87	3/13	0	0	0	23/100	0
Linksfield Ridge Sangoan ?MIS6-8 (n=64)	63/98.4	0	0	1/1.6	0	63/98.4	1/1.6
Primrose Ridge Sangoan ?MIS 6-8 (n=54)	54/100	0	0	0	0	54/100	0
Canteen Kopje Fauresmith >300 ka (n=13)	12/92.3	1/7.7	0	0	0	13/100	0
Kathu Pan Fauresmith >464±47 ka (n=148)	143/96.6	9/6.1	3/2.	0	0	148/100	0
Total data points for ~≥MIS 7 n=302	**292**	**13**	**3**	**1**	**0**	**301**	**1**
Tip-type percentages for ~≥MIS 7	**96.7**	**4.3**	**1**	**0.3**	**0**	**99.7**	**0.3**

Total data points for MIS 6->8 n=559	**510**	**68**	**30**	**9**	**0**	**553**	**9**
Tip-type percentages for MIS 6->8	**91.2**	**12.2**	**5.4**	**1.6**	**0**	**98.9**	**1.6**

Based on the data presented in Table 8, the first observation is that in general these older assemblages are dominated by points that are hypothetically suitable for tipping heavy-duty thrusting spears, and that the collective frequencies for potential dart and arrow points are very low at 5.4% and 1.6% respectively, practically ruling out the use of mechanically projected weapon systems in southern Africa >130 ka. The only possible anomaly is the MSA/Fauresmith lower assemblage from Rooidam 2 where up to 22% of the points have TCSA values that fit the dart category. But here too, 96% of the points are suited for tipping spears or javelins, and it is the assemblage with the highest frequency of points suited for light-weight javelin tips at 38% (Table 8). This assemblage was estimated to date to ≥MIS 6, which may indicate that stone-tipped javelins, similar in tip dimension to those used today, were used on the Southern African Savanna Biome before ~191 ka. The overlaying Rooidam 2 (MSA/Fauresmith upper) assemblage dated to >174 ka contains 26.3% points that would make effective tips for such light-weight javelins, and also at Pinnacle Point 13B in the Fynbos Biome hunters may have used stone tipped javelins together with their heavier thrusting spears during MIS 6 seeing that 21.6% of the points from that assemblage have TCSA values that would conform to such use.

However, at Florisbad on the Grassland Biome a strong preference for stabbing or thrusting spears are indicated as 96.1% of the points from the ~157±21 ka context could be used effectively for this purpose (Table 8). This pattern is perpetuated at the other two Grassland Biome sites of Linksfield Ridge and Primrose Ridge where their Sangoan assemblages contain pointed tools with TCSA values only falling in the thrusting spear range. At Cape Hangklip in the Fynbos Biome, and the Fauresmith sites on the Savanna Biome, namely Canteen Kopje dated to >300 and the assemblage from Kathu Pan that may date to >464±47 ka the probability of light-weight javelin hunting is also very low. I therefore suggest that we may hypothesise about habitual light-weight stone-tipped javelin hunting in southern Africa since ~MIS 6, but that currently there is little indication for the use of this hunting strategy before ~191 ka. This observation does not exclude the possibility that heavier stone-tipped spears were sometimes thrown, only that light-weight javelins reinforced with hard tips, such as those used by the Kalahari San hunters today (Fig. 1), were probably not used before MIS 6.

6. Concluding discussion

This study currently represents the most comprehensive TCSA study conducted on Middle Stone Age assemblages from southern Africa with the purpose to generate a hypothetical spatiotemporal reconstruction of variation in the use of stone-tipped hunting weaponry. The results are course-grained, intended to highlight the most probable trends, but it also reflects potential changes in weapon-assisted hunting strategies at sites with long sequences and adequate dating resolution such as Klasies River and Sibudu Cave. Apart from a few outliers, the general trend since at least ~300 ka (the approximate start date of MIS 8) is towards greater frequencies of smaller TCSA median values for stone points until the medians of backed microlithic assemblages reach TCSA values that fall in the arrow-tip range during the MIS 4 glacial (Fig. 8).

The greatest variation in median TCSA values occur during MIS 5, but during the final MIS 5a sub-stage most assemblages have TCSA median values falling within the javelin range. Whilst this is the long-term 'big picture', the possible intra-assemblage variation in weapon choices presented in Tables 6, 7 and 8 agree with Mackay's (2016: 49) finding that "rather than a series of discrete packages of innovation, technological change […] is better understood in terms of the differential persistence of continually generated variation. The resulting picture is one of technologically flexible groups adapting rapidly and in some cases dramatically to changing circumstances through the Late Pleistocene". It is also my view that once a hunting technology has been developed, its potential use remains an option for subsequent hunters, and that the choice to 'use or lose' a technology depends on socio-economic circumstance (see Lombard 2016 on weapons and the evolution of human technological, behavioural and cognitive flexibility; as well as Haidle et al. 2015).

Previous broad reconstructions of human hunting strategies during the Middle Stone Age rest on the interpretation of faunal assemblages and range from obligate scavenging (e.g., Binford, 1981, 1984), to ineffective exploitation (e.g., Klein and Cruz-Uribe, 1996, 2000), to elevated meat yields and diet breadth resulting from effective hunting (e.g., Faith 2008; Dusseldorp 2010). If our reconstructions of Middle Stone Age hunting strategies are to be robust, multiple lines of evidence should come together in a simultaneously strengthening and constraining narrative. Recently, Clark and Kandel (2013) argued that, although fluctuation in environmental conditions seemed to affect the shaping of the faunal data, factors such as demography, technology, and cognition also need to be considered. They predicted "that the observed expansion of dietary breadth from MIS 6 to MIS 4 is related to an increase in population pressure caused by either expanding population sizes or the concentration of existing populations" (Clark & Kandel 2013: S282). They battled to reconcile the general variation and diet breadth observed in the faunal data during MIS 4 with technological change, and concerning cognition, they start from a bias of stagnation, namely that all people between roughly 29 ka and 191 ka "likely shared the same cognitive capacity and behavioral capabilities" (Clark & Kandel 2013: S284).

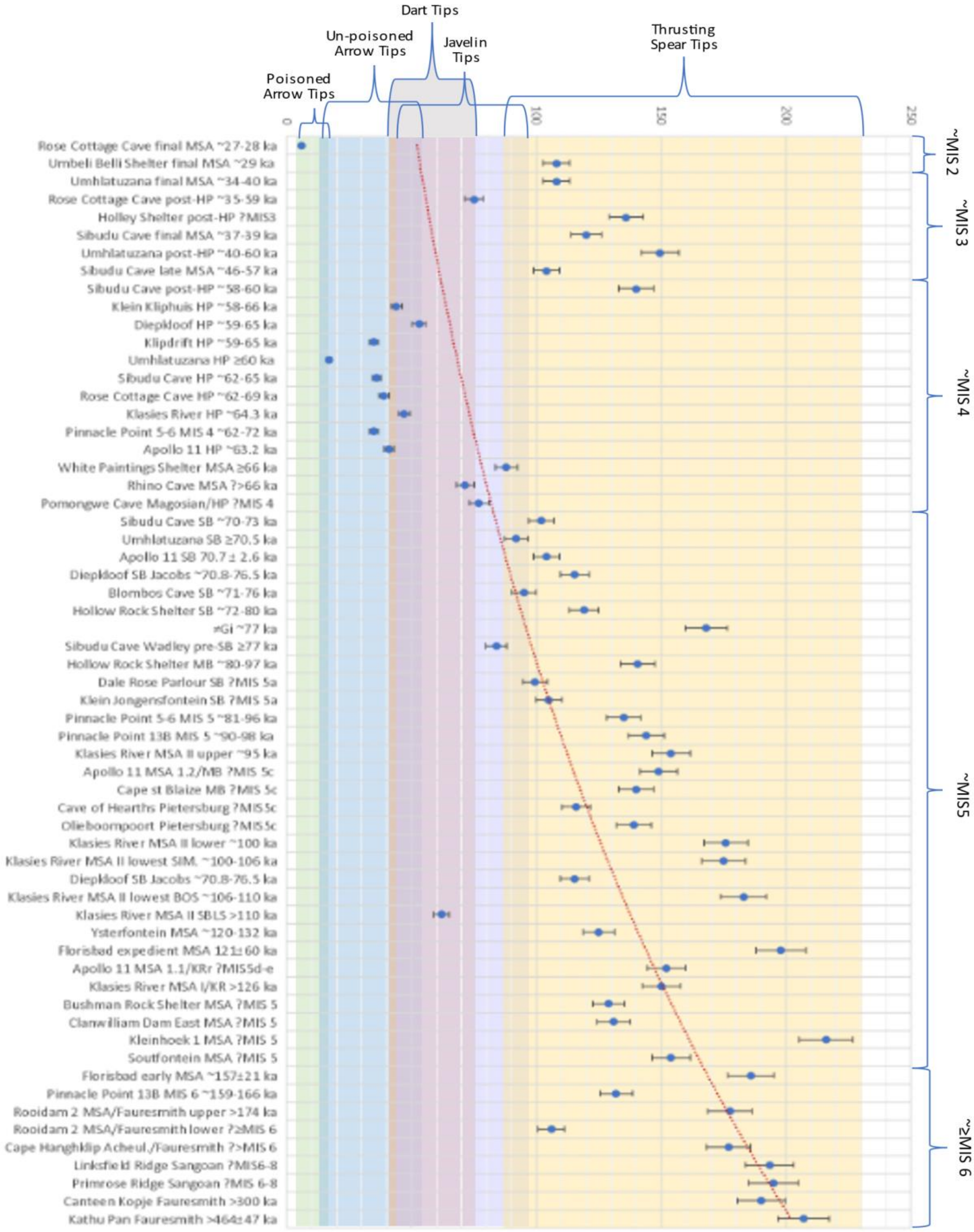


Figure 8: Overview of trends and variations in median TCSA values for the complete Middle Stone Age of southern Africa including point and backed microlith assemblages, set generally against the MIS record.

I cannot fully unpack all four topics raised by Clark and Kandel (2013) in the context of this paper, but I do agree with their co-evolutionary relevance for understanding variation in Middle Stone Age animal exploitation strategies (see Lombard & Högberg 2021). I therefore provide only a brief overview of how some recent datasets for climate and demography may link to the TCSA results obtained during this study. By integrating the TCSA results with the MIS record (isotopic values from Cohen & Gibbard 2019; sea-surface temperatures just off the east coast of southern Africa from Caley et al. 2018) as broad climatic indicator, we may hypothesise that the use of stone-tipped thrusting or stabbing spears came into play at least since the cold phase of MIS 12 (Fig. 9). Based on the reconstructions of ancestral population sizes based on modern and ancient-DNA from southern African Khoe-San compared with other African and non-African populations (Schlebusch et al. 2017, 2020), the human ancestral population at the time was somewhere between 21,000 and 26,000 (Fig. 9).

Javelin hunting with stone tipped weapons may have been introduced during the initial cold spell of MIS 6 at ~190 ka, when ancestral Khoe-San and other African groups reached their maximum population sizes at between about 28,000 and 35,000. Based on the trend in TCSA values (Fig. 8), we may hypothesise that since then javelin hunting became increasingly popular until it reached its pique as weapon of choice during MIS 5a, in tandem with a decrease in population sizes, reaching the lowest numbers during MIS 5a and the beginning of MIS 4 (Fig. 9). Bow hunting may have been introduced during a cold phase in MIS 4, when we see an increase in the populations of some ancestral Khoe-San groups and a decline in others – a trend that is continued through MIS 3 with the return to a preference for hunting with stone-tipped thrusting or stabbing spears (for discussion see McCall 2011; Parsons & Lombard 2011), perhaps in combination with bone-tipped arrows for bow hunting).

Thus, on a rudimentary level, cold phases seem to stimulate greater variation in human weapon-assisted hunting strategies. What stands out, however, is that in contradiction to previous theorising and speculative modelling – suggesting that increases in cultural complexity = increases in population, and decreases in cultural complexity = decreases in population size (e.g., Shennan 2001; Henrich 2004; Powell et al. 2009; Kline & Boyd 2010; but see Collard et al. 2016) – the florescence in cultural complexity and increased variation in hunting weapons associated with the Still Bay and Howiesons Poort techno-complexes in southern Africa during MIS 5a and MIS 4 (e.g., Henshilwood 2012, Wadley 2015), can now instead be aligned with DNA evidence for a decline in population sizes (Schlebusch et al. 2017, 2020; Fig. 9).

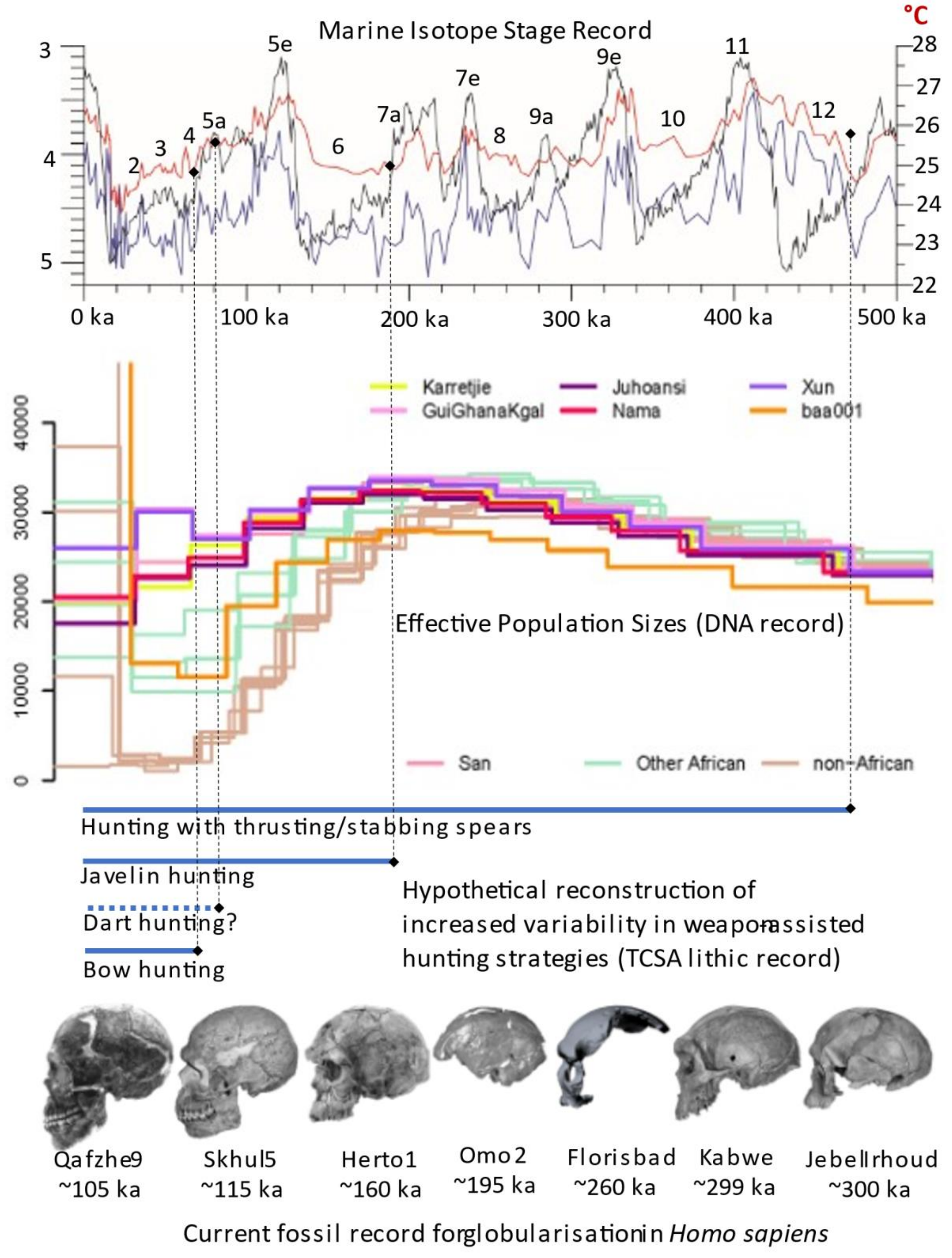


Figure 9: Summary of the marine isotope stage record: red line = temperature, black line = oxygen isotope fractionation, blue line = Mg/Ca (isotopic values from Cohen & Gibbard 2019; sea-surface temperatures just off the east coast of southern Africa from Caley et al. 2018), ancestral population sizes based on modern and ancient-DNA (Schlebusch et al. 2017, 2020), the lithic TCSA record, and the early fossil record for *Homo sapiens*.

Although reconstructing ancient cognition is a daunting task. One way to reconcile the continuous evolution of our human minds with the archaeological record is through Material Engagement Theory wherein "[o]ur most habitual actions (psychical or physical) are experienced and become constituted where brain, body and [material] culture conflate" (Malafouris 2019: 1). Thus, not only the size and shape of our brains and bodies, but also the ways in which we think and socialise are deeply rooted in how we use things – so that making, working with, and playing with things shape how we perceive and understand each other and the world (our cognition), and may even have helped to shape our brains and bodies (e.g. Debarnot et al. 2014; Walls 2019; Chakrabarty 2019; Malafouris 2019, 2021; Barona 2020; Lombard & Högberg 2021). Bruner and Lozano (2014), for example, argue that without technology it would be impossible for the human mind to do what is does or to be what it is.

Whereas an increase in brain size probably played a role in early hominin evolution in terms of the social brain hypothesis (e.g., Dunbar 1998; Pérez-Barbería et al. 2007), this aspect was less distinct between the later populations (Galway-Witham et al. 2019; Lombard & Högberg 2021). *Homo sapiens* is known for the bulging of the parietal profile and a more rounded skull shape compared to all other hominins – partly caused by the enlargement of the precuneus (e.g., Bruner et al. 2018; Bruner 2021). Although other brain regions such as the cerebellum and thalamus also seem to be unique to the *Homo sapiens* brain (e.g., Boeckx & Benítez-Burraco 2014; Neubauer et al. 2018), it has been demonstrated that: a) the precuneus serves as connective hub between brain regions (e.g. Margulies et al. 2009); b) it developed to its current dimensions only in *Homo sapiens* becoming visible in the fossil record from ~100 ka (e.g., Bruner 2021; Lombard & Högberg 2021; Fig. 9); and c) it can be neurologically linked to modern archery and Stone Age bow-and-arrow use (e.g., Kim et al. 2008, 2014; Chang et al. 2011; Williams et al. 2014; Lo et al. 2019; Lombard 2019).

Bruner (2018) explains how the frontal region of the precuneus mostly facilitates body cognition, whereas its posterior region deals with visual cognition, and the middle portion serves as integrative hub for signals received both bodily and visually in a process called 'visuo-spatial integration'. This process helps to facilitate understanding the 'body-environment physical coordination', as well as assimilating visual images with conscious, self-centred episodic memory recall that provides the necessary scaffolding for mental experiments or imagination (also see Fletcher et al. 1995). I argue that the evolution of increasingly efficient visuo-spatial feedback was key in terms of developing and choosing between and/or increasing variability in the use of different weapon-delivery systems.

This short discussion serves to highlight that climate, demonography, technology, and cognition are inextricably linked in ways that we do not yet understand fully, and that all these aspects (both separately and cumulatively) require our future attention. The TCSA analysis at the centre of this paper, although only a partial record considering that organic artefacts did not preserve equally, enables hypothesis building both in terms of long-term developments in weapon-assisted hunting strategies across the southern African landscape, as well as in terms of spatiotemporal variation. The question about the possible invention and use of spearthrower-and-dart technology prior to bow hunting in the region remains unresolved. For now, there is more convincing TCSA data for dart use contemporaneous with bow hunting than prior to it. But, by including a TCSA category for javelin tips, representing a hunting strategy that is ethno-historically well-known in Africa, the dart-tip category lost its identity, so that other methods are needed to explore this topic. The points from ≠Gi and some Still Bay assemblages, previously suggested as representing dart hunting in southern Africa, do not conform to TCSA expectations for the preferential use of this technology. Instead, the collective data presented here indicate that even if practiced, dart hunting was never the hunting strategy of choice.

Currently, there exists no supporting use-trace nor ethno-historical evidence for the use of the spearthrowers in southern Africa, nor does the invention of the one lead to that of the other (e.g., Lombard & Phillipson 2010; Whittaker 2014). It is therefore conceivable that dart hunting was never practiced here especially considering that versions of all the other 'Stone Age' hunting technologies are still in use.

Although course-grained, this study shows that it is increasingly reasonable to hypothesise about bow hunting across the region since at least MIS 4 from ~70 ka. Together with supporting use-trace and experimental outcomes as introduced above, these results counter previous hypotheses based on lithic morphometric studies suggesting a lack of support for the widespread use of mechanically projected weaponry before ~35-40 ka. Here I also explored, for the first time, the probable time-depth of hunting with light-weight stone-tipped javelins in southern Africa. The TCSA results show that this hunting technology and strategy, that is akin to iron-tipped javelins used by African hunters today, may have been an option since MIS 6 at almost 200 ka, and was probably practiced habitually between roughly ~80 ka and 70 ka. The implications of this outcome require further exploration against the faunal record in terms of subsistence breadth, as well as in terms of landscape use and cognition.

Acknowledgements

To be completed upon acceptance.

References (to be formatted upon acceptance)

Ames, C.J., Chambers, S., Shaw, M., Phillips, N., Jones, B.G. and Mackay, A., 2020. Evaluating erosional impacts on open-air archaeological sites along the Doring River, South Africa: methods and implications for research prioritization. Archaeological and Anthropological Sciences, 12(5), pp.1-15.

Avery, G., Halkett, D., Orton, J., Steele, T., Tusenius, M. and Klein, R., 2008. The Ysterfontein 1 Middle Stone Age rock shelter and the evolution of coastal foraging. Goodwin Series, pp.66-89.

Backwell, L., Bradfield, J., Carlson, K.J., Jashashvili, T., Wadley, L. and d'Errico, F., 2018. The antiquity of bow-and-arrow technology: evidence from Middle Stone Age layers at Sibudu Cave. antiquity, 92(362), pp.289-303.

Bader, G.D., Cable, C., Lentfer, C. and Conard, N.J., 2016. Umbeli Belli Rock Shelter, a forgotten piece from the puzzle of the Middle Stone Age in KwaZulu-Natal, South Africa. Journal of Archaeological Science: Reports, 9, pp.608-622.

Bader, G.D., Tribolo, C. and Conard, N.J., 2018. A return to Umbeli Belli: new insights of recent excavations and implications for the final MSA of eastern South Africa. Journal of Archaeological Science: Reports, 21, pp.733-757.

Bader, G.D., Will, M. and Conard, N.J., 2015. The lithic technology of Holley Shelter, KwaZulu-Natal, and its place within the MSA of southern Africa. The South African Archaeological Bulletin, pp.149-165.

Bamford, M.K. and Henderson, Z.L., 2003. A reassessment of the wooden fragment from Florisbad, South Africa. Journal of Archaeological Science, 30(6), pp.637-650.

Barona, A. M. (2020). The archaeology of the social brain revisited: rethinking mind and material culture from a material engagement perspective. Adaptive Behavior, 1059712320941945.

Binford, L.R., 1981. Bones: Ancient Men and Modern Myths. Academic Press, New York.

Binford, L.R., 1984. Faunal Remains from Klasies River Mouth. Academic Press, New York.

Boeckx, C. A., & Benítez-Burraco, A. (2014). The shape of the human language-ready brain. Frontiers in Psychology, 5, 282.

Bradfield, J., 2010. The evolution of bone points as hunting weapons in South Africa. Unpublished PhD thesis. Johannesburg: University of the Witwatersrand.

Bradfield, J., Lombard, M., Reynard, J. and Wurz, S., 2020. Further evidence for bow hunting and its implications more than 60 000 years ago: Results of a use-trace analysis of the bone point from Klasies River Main site, South Africa. Quaternary Science Reviews, 236, p.106295.

Brain, C.K., 1974. Some suggested procedures in the analysis of bone accumulations from southern African Quaternary sites. Annals of the Transvaal Museum, 29(1), pp.1-8.

Brenner, M.J., Ryano, K.P. and Wurz, S., 2020. Coastal adaptation at Klasies River main site during MIS 5c-d (93,000–110,000 years ago) from a southern Cape perspective. The Journal of Island and Coastal Archaeology, pp.1-28.

Brenner, M.J. and Wurz, S., 2019. A high-resolution perspective on MIS 5c-d lithic assemblages from Klasies River main site Cave 1. Journal of Archaeological Science: Reports, 26, p.101891.

Brooks, A.S., Nevell, L., Yellen, J.E. & Hartman, G. 2006. Projectile technologies of the African MSA. In Transitions before the transition (pp. 233-255). Springer, Boston, MA.

Bruner, E. (2018). Human paleoneurology and the evolution of the parietal cortex. Brain, Behavior and Evolution, 91, 136–147.

Bruner, E., 2021. Evolving human brains: paleoneurology and the fate of Middle Pleistocene. Journal of Archaeological Method and Theory, pp.1-19.

Bruner, E., Amano, H., Pereira-Pedro, A. S., & Ogihara, N. (2018). The evolution of the parietal lobes in the genus Homo. In E. Bruner, N. Ogihara, & H. C. Tanabe (Eds.), Digital endocasts (pp. 219–237). Tokyo: Springer.

Bruner, E., & Lozano Ruiz, M. (2014). Extended mind and visuo-spatial integration: three hands for the Neandertal lineage. Journal of Anthropological Sciences, 92, 273–280.

Caley, T., Extier, T., Collins, J.A., Schefuß, E., Dupont, L., Malaizé, B., Rossignol, L., Souron, A., McClymont, E.L., Jimenez-Espejo, F.J. and García-Comas, C., 2018. A two-million-year-long hydroclimatic context for hominin evolution in southeastern Africa. Nature, 560(7716), pp.76-79.

Chakrabarty, M. (2019). How stone tools shaped us: Post-phenomenology and material engagement theory. Philosophy & Technology, 32(2), 243-264.

Chang, Y., Lee, J. J., Seo, J. H., Song, H. J., Kim, Y. T., Lee, H. J., ... & Kim, J. G. (2011). Neural correlates of motor imagery for elite archers. NMR in Biomedicine, 24(4), 366-372.

Clark, J.D., 1955. A note on a wooden implement from the level of Peat I at Florisbad, Orange Free State. Navorsinge van die Nasionale Museum: Researches of the National Museum, 1(6), pp.135-140.

Clark, J.L., 2017. The Howieson's poort fauna from Sibudu cave: documenting continuity and change within middle stone age industries. Journal of human evolution, 107, pp.49-70.

Clark, J.L. and Kandel, A.W., 2013. The evolutionary implications of variation in human hunting strategies and diet breadth during the Middle Stone Age of southern Africa. Current Anthropology, 54(S8), pp.S269-S287.

Clarkson, C. 2016. Testing archaeological approaches to determining past projectile delivery systems using ethnographic and experimental data. In Multidisciplinary approaches to the study of Stone Age weaponry (pp. 189-201). Springer, Dordrecht.

Cohen, K.M. and Gibbard, P.L., 2019. Global chronostratigraphical correlation table for the last 2.7 million years, version 2019 QI-500. Quaternary International, 500, pp.20-31.

Collard, M., Vaesen, K., Cosgrove, R. and Roebroeks, W., 2016. The empirical case against the ‘demographic turn’in Palaeolithic archaeology. Philosophical Transactions of the Royal Society B: Biological Sciences, 371(1698), p.20150242.

Cooke, C.K., 1963. Report on excavations at Pomongwe and Tshangula caves, Matopo hills, southern Rhodesia. The South African Archaeological Bulletin, 18(71), pp.73-151.

Coulson, S., Staurset, S. and Walker, N., 2011. Ritualized behavior in the middle stone age: evidence from Rhino Cave, Tsodilo Hills, Botswana. PaleoAnthropology, 2011, pp.18-61.

Davidson, I. 2020. "Inventing modern human origins." In Interrogating human origins: Decolonization and the deep human past edited by Porr, M. and Matthews, J. 35–55. New York: Routledge.

Debarnot, U., Sperduti, M., Di Rienzo, F., & Guillot, A. (2014). Experts bodies, experts minds: how physical and mental training shape the brain. Frontiers in human neuroscience, 8, 280.

de la Peña, P., Taipale, N., Wadley, L. and Rots, V., 2018. A techno-functional perspective on quartz micro-notches in Sibudu's Howiesons Poort indicates the use of barbs in hunting technology. Journal of Archaeological Science, 93, pp.166-195.

de la Peña, P., Wadley, L. and Lombard, M., 2013. Quartz bifacial points in the Howiesons Poort of Sibudu. THE SOUTH AFRICAN ARCHAEO LOGICAL BULLETIN, pp.119-136.

d'Errico, F., Backwell, L., Villa, P., Degano, I., Lucejko, J.J., Bamford, M.K., Higham, T.F., Colombini, M.P. and Beaumont, P.B., 2012. Early evidence of San material culture represented by organic artifacts from Border Cave, South Africa. Proceedings of the National Academy of Sciences, 109(33), pp.13214-13219.

d'Errico, F. and Henshilwood, C.S., 2007. Additional evidence for bone technology in the southern African Middle Stone Age. Journal of human evolution, 52(2), pp.142-163.

d'Errico, F., Martí, A.P., Shipton, C., Le Vraux, E., Ndiema, E., Goldstein, S., Petraglia, M.D. and Boivin, N., 2020. Trajectories of cultural innovation from the Middle to Later Stone Age in Eastern Africa: Personal ornaments, bone artifacts, and ocher from Panga ya Saidi, Kenya. Journal of human evolution, 141, p.102737.

Douze, K., Igreja, M., Rots, V., Cnuts, D. and Porraz, G., 2020. Technology and function of Middle Stone Age points. Insights from a combined approach at Bushman Rock Shelter, South Africa. In Culture History and Convergent Evolution (pp. 127-141). Springer, Cham.

Dunbar, R. I. (1998). The social brain hypothesis. Evolutionary Anthropology: Issues, News, and Reviews, 6(5), 178–190.

Dusseldorp, G.L., 2010. Prey choice during the South African Middle Stone Age: avoiding dangerous prey or maximising returns?. African Archaeological Review, 27(2), pp.107-133.

Esteban, Irene, Curtis W. Marean, Richard M. Cowling, Erich C. Fisher, Dan Cabanes, and Rosa M. Albert.

"Palaeoenvironments and plant availability during MIS 6 to MIS 3 on the edge of the Palaeo-Agulhas Plain (south coast, South Africa) as indicated by phytolith analysis at Pinnacle Point." Quaternary Science Reviews 235 (2020): 105667.

Faith, J.T., 2008. Eland, buffalo, and wild pigs: were Middle Stone Age humans ineffective hunters?. Journal of human Evolution, 55(1), pp.24-36.

Fischer, A., Vemming Hansen, P.&Rasmussen, P. 1984. Macro and micro wear traces on lithic projectile points: experimental results and prehistoric examples. Journal of Danish Archaeology 3: 19–46.

Fletcher, P. C., Frith, C. D., Baker, S. C., Shallice, T., Frackowiak, R. S., & Dolan, R. J. (1995). The mind’s eye: precuneus activation in memory-related imagery. Neuroimage, 2(3), 195–200.

Galway-Witham, J., Cole, J., & Stringer, C. (2019). Aspects of human physical and behavioural evolution during the last 1 million years. Journal of Quaternary Science, 34(6), 355–378.

Gatehouse, R.P., 1953. The origin of the Cape Hangklip shell beds. South African Journal of Science, 50(1).

Grün, R., Brink, J.S., Spooner, N.A., Taylor, L., Stringer, C.B., Franciscus, R.G. and Murray, A.S., 1996. Direct dating of Florisbad hominid. Nature, 382(6591), pp.500-501.

Haidle, M.N., Bolus, M., Collard, M., Conard, N.J., Garofoli, D., Lombard, M., Nowell, A., Tennie, C. and Whiten, A., 2015. The nature of culture: an eight-grade model for the evolution and expansion of cultural capacities in hominins and other animals. Journal of Anthropological Sciences.

Harris, W.C., 1844. The wild sports of southern Africa: Being the narrative of an expedition from the Cape of Good Hope, through the territories of the chief Moselekatse, to the Tropic of Capricorn. Pelham Richardson.

Henrich, J., 2004. Demography and cultural evolution: how adaptive cultural processes can produce maladaptive losses: the Tasmanian case. American antiquity, pp.197-214.

Henshilwood, C.S., 2012. Late Pleistocene techno-traditions in southern Africa: a review of the Still Bay and Howiesons Poort, c. 75–59 ka. Journal of World Prehistory, 25(3-4), pp.205-237.

Högberg, A. and Lombard, M., 2020. ‘I Can Do It’Becomes ‘We Do It’: Kimberley (Australia) and Still Bay (South Africa) points through a socio-technical framework lens. Journal of Paleolithic Archaeology, pp.1-31.

Högberg, A. and Lombard, M., Submitted. Was there a gradual shift from Levallois to Still Bay point knapping between about 90 000 and 70 000 years ago in South Africa? Hollow Rock Shelter as a test case. Azania.

Hughes, S.S. 1998. Getting to the point: Evolutionary change in prehistoric weaponry. Journal of Archaeological Method and Theory 5: 345-408.

Iovita, R. & Sano, K. (eds). 2016. Multidisciplinary approaches to the study of Stone Age weaponry. Dordrecht: Springer.

Jacobs, Z., 2010. An OSL chronology for the sedimentary deposits from Pinnacle Point Cave 13B—a punctuated presence. Journal of Human Evolution, 59(3-4), pp.289-305.

Jacobs, Z., Jones, B.G., Cawthra, H.C., Henshilwood, C.S. and Roberts, R.G., 2020. The chronological, sedimentary and environmental context for the archaeological deposits at Blombos Cave, South Africa. Quaternary Science Reviews, 235, p.105850.

Jacobs, Z. and Roberts, R.G., 2015. An improved single grain OSL chronology for the sedimentary deposits from Diepkloof Rockshelter, Western Cape, South Africa. Journal of Archaeological Science, 63, pp.175-192.

Jacobs, Z., Roberts, R.G., Galbraith, R.F., Deacon, H.J., Grün, R., Mackay, A., Mitchell, P., Vogelsang, R. and Wadley, L., 2008. Ages for the Middle Stone Age of southern Africa: implications for human behavior and dispersal. Science, 322(5902), pp.733-735.

Kim, J., Lee, H. M., Kim, W. J., Park, H. J., Kim, S. W., Moon, D. H., ... & Tennant, L. K. (2008). Neural correlates of pre-performance routines in expert and novice archers. Neuroscience letters, 445(3), 236-241.

Klein, R.G., Cruz-Uribe, K., 1996. Exploitation of large bovids and seals at Middle and Later Stone Age sites in South Africa. J. Hum. Evol. 31, 315-334.

Klein, R.G., Cruz-Uribe, K., 2000. Middle and Later Stone Age large mammal and tortoise remains from Die Kelders Cave 1, Western Cape Province, South Africa. J. Hum. Evol. 38, 169-195.

Kline, M.A. and Boyd, R., 2010. Population size predicts technological complexity in Oceania. Proceedings of the Royal Society B: Biological Sciences, 277(1693), pp.2559-2564.

Kuman, K.A., 1989. Florisbad and not equal to Gi: The contribution of open-air sites to study of the Middle Stone Age in southern Africa.

Kuman, K., Lotter, M.G. and Leader, G.M., 2020. The Fauresmith of South Africa: A new assemblage from Canteen Kopje and significance of the technology in human and cultural evolution. Journal of Human Evolution, 148, p.102884.

Lo, Y. C., Chen, C. M., Shen, W. C., & Shih, Y. L. (2019). Cerebellar contributions to tactile perception in people with varying sensorimotor experiences: Examining the sensory acquisition hypothesis. Human movement science, 63, 45-52.

Lombard, M., 2004. Distribution patterns of organic residues on middle stone age points from Sibudu Cave, Kwazulu-natal, South Africa. The South African Archaeological Bulletin, pp.37-44.

Lombard, M., 2005. Evidence of hunting and hafting during the Middle Stone Age at Sibudu Cave, KwaZulu-Natal, South Africa: a multianalytical approach. Journal of human evolution, 48(3), pp.279-300.

Lombard, M., 2006. First impressions of the functions and hafting technology of Still Bay pointed artefacts from Sibudu Cave. Southern African Humanities, 18(1), pp.27-41.

Lombard, M., 2016. Mountaineering or ratcheting? Stone Age hunting weapons as proxy for the evolution of human technological, behavioral and cognitive flexibility. In The nature of culture (pp. 135-146). Springer, Dordrecht.

Lombard, M. (2019). On the minds of bow hunters. In F. L. Coolidge, K. A. Overmann, & T. Wynn (Eds.), Squeezing minds from stones: cognitive archaeology and the evolution of the human mind (pp. 473–496). Oxford: University of Oxford Press.

Lombard, M., 2020a. Testing for poisoned arrows in the Middle Stone Age: A tip cross-sectional analysis of backed microliths from southern Africa. Journal of Archaeological Science: Reports, 34, p.102630.

Lombard, M., 2020b. The tip cross-sectional areas of poisoned bone arrowheads from southern Africa. Journal of Archaeological Science: Reports, 33, p.102477.

Lombard, M. and Högberg, A., 2021. Four-field co-evolutionary model for human cognition: variation in the Middle Stone Age/Middle Palaeolithic. Journal of Archaeological Method and Theory, pp.1-36.

Lombard, M., Högberg, A. and Wadley, L., 2019. Temporal perspectives on Still Bay point production at Sibudu Cave, KwaZulu-Natal, in the context of southern Africa. Azania: Archaeological Research in Africa, 54(2), pp.141-176.

Lombard M, Phillipson L. 2010. Indications of bow and stone-tipped arrow use 64 000 years ago in KwaZulu-Natal, South Africa. Antiquity 84(325): 635-648.

Lombard M, Wadley L. 2007. The morphological identification of micro-residues on stone tools using light microscopy: Progress and difficulties based on blind tests. Journal of Archaeological Science 34(1): 155-165.

Lombard, M., Wadley, L., Deacon, J., Wurz, S., Parsons, I., Mohapi, M., Swart, J. and Mitchell, P., 2012. South African and Lesotho Stone Age sequence updated. The South African Archaeological Bulletin, 67(195), pp.123-144.

Lombard, M., Wadley, L., Jacobs, Z., Mohapi, M. and Roberts, R.G., 2010. Still Bay and serrated points from Umhlatuzana rock shelter, Kwazulu-Natal, south Africa. Journal of Archaeological Science, 37(7), pp.1773-1784.

Mackay, A., 2016. Technological change and the importance of variability: The Western Cape of South Africa from MIS 6-2. In Africa from MIS 6-2 (pp. 49-63). Springer, Dordrecht.

Mackay, A., Hallinan, E. and Steele, T.E., 2018. Provisioning responses to environmental change in South Africa’s winter rainfall zone: MIS 5-2. In Lithic technological organization and paleoenvironmental change (pp. 13-36). Springer, Cham.

Maki, J.M. 2013. The Biomechanics of Spear Throwing: An Analysis of the Effects of Anatomical Variation on Throwing Performance, with Implications for the Fossil Record. Doctoral Thesis. Washington University: St. Louis.

Malafouris, L., 2019. Mind and material engagement. Phenomenology and the Cognitive Sciences, 18(1), pp.1-17.

Malafouris, L., 2021. Mark making and human becoming. Journal of Archaeological Method and Theory, 28(1), pp.95-119.

Margulies, D. S., Vincent, J. L., Kelly, C., Lohmann, G., Uddin, L. Q., Biswal, B. B., et al. (2009). Precuneus shares intrinsic functional architecture in humans and monkeys. Proceedings of the National Academy of Sciences, 106(47), 20069–20074.

McCall, G.S. 2011. Progression, regression, or adaption: further thoughts on the post-Howieson’s Poort Middle Stone Age of South Africa. South African Archaeological Bulletin 66: 89–92.

Minichillo, T.J., 2005. Middle Stone Age lithic study, South Africa: an examination of modern human origins. University of Washington.

Mohapi, M., 2005. Middle Stone Age Rose Cottage Cave Lithic Points: Does Technological Change Imply Change in Hunting Techniques? (Doctoral dissertation, University of the Witwatersrand).

Mohapi, M., 2007. Rose Cottage Cave MSA lithic points: does technological change imply change in hunting techniques?. South African Archaeological Bulletin, 62(185), pp.9-18.

Mohapi, M., 2013. The Middle Stone Age point assemblage from Umhlatuzana rock shelter: a morphometric study.

Southern African Humanities, 25(1), pp.25-51.

Neubauer, S., Hublin, J. J., & Gunz, P. (2018). The evolution of modern human brain shape. Science Advances. https://doi.org/10.1126/sciadv.aao5961.

Neumann, F.H. and Bamford, M.K., 2015. Shaping of modern southern African biomes: Neogene vegetation and climate changes. Transactions of the Royal Society of South Africa, 70(3), pp.195-212.

Pargeter J, Bradfield J. 2012. The effects of class I and II sized bovids on macrofracture formation and tool displacement: Results of a trampling experiment in a southern African Stone Age context. Journal of Field Archaeology 37(3): 238-251.

Pargeter J, Bam L, De Beer F, Lombard M. 2017. Microfocus X-ray tomography as a method for characterising macro-fractures on quartz backed tools. The South African Archaeological Bulletin 72(206): 148-155.

Pargeter J, Shea J, Utting B. 2016. Quartz backed tools as arrowheads and hand-cast spearheads: Hunting experiments and macro-fracture analysis. Journal of Archaeological Science 73: 145-157.

Parsons, I. and Lombard, M., 2011. The multi-disciplinary landscape of mid-late Upper Pleistocene archaeology. The South African Archaeological Bulletin, 66(194), pp.178-181.

Pérez-Barbería, F. J., Shultz, S., & Dunbar, R. I. (2007). Evidence for coevolution of sociality and relative brain size in three orders of mammals. Evolution. https://doi.org/10.1111/j.1558-5646.2007.00229.x.

Phillipson, L., 2007. Reassessment of selected Middle Stone Age artefacts from Rhino Cave and from White Paintings Rock Shelter, Tsodilo Hills, Botswana. The South African Archaeological Bulletin, pp.19-30.

Pienaar, M., Woodborne, S. and Wadley, L., 2008. Optically stimulated luminescence dating at Rose Cottage Cave. South African Journal of Science, 104(1-2), pp.65-70.

Powell, A., Shennan, S. and Thomas, M.G., 2009. Late Pleistocene demography and the appearance of modern human behavior. Science, 324(5932), pp.1298-1301.

Rios-Garaizar, J., 2016. Experimental and archeological observations of Northern Iberian Peninsula Middle Paleolithic Mousterian point assemblages. Testing the potential use of throwing spears among Neanderthals. In Multidisciplinary approaches to the study of Stone Age weaponry (pp. 213-225). Springer, Dordrecht.

Robbins, L.H., Campbell, A.C., Brook, G.A., Murphy, M.L. and Hitchcock, R.K., 2012. The antiquity of the bow and arrow in the Kalahari Desert: bone points from White Paintings Rock Shelter, Botswana. Journal of African

Archaeology, 10(1), pp.7-20.

Sahle, Y. and Brooks, A.S., 2019. Assessment of complex projectiles in the early Late Pleistocene at Aduma, Ethiopia. Plos one, 14(5), p.e0216716.

Schlebusch, C.M., Malmström, H., Günther, T., Sjödin, P., Coutinho, A., Edlund, H., Munters, A.R., Vicente, M., Steyn, M., Soodyall, H. and Lombard, M., 2017. Southern African ancient genomes estimate modern human divergence to 350,000 to 260,000 years ago. Science, 358(6363), pp.652-655.

Schlebusch, C.M., Sjödin, P., Breton, G., Günther, T., Naidoo, T., Hollfelder, N., Sjöstrand, A.E., Xu, J., Gattepaille, L.M., Vicente, M. and Scofield, D.G., 2020. Khoe-San genomes reveal unique variation and confirm the deepest population divergence in Homo sapiens. Molecular biology and evolution, 37(10), pp.2944-2954.

Schmitt U, Singh AP, Thieme H, Friedrich P, Hoffmann P (2005) Electron microscopic characterization of cell wall degradation of the 400,000-year-old wooden Schöningen spears. Holz als Roh-und Werkstoff 63:118-122

Shea, J.J. 2006. The origins of lithic projectile point technology: evidence from Africa, the Levant, and Europe. Journal of Archaeological Science 33: 823-846.

Shea, J.J., 2009. The impact of projectile weaponry on Late Pleistocene hominin evolution. In The evolution of hominin diets (pp. 189-199). Springer, Dordrecht.

Shea, J., Davis, Z. and Brown, K., 2001. Experimental tests of Middle Palaeolithic spear points using a calibrated crossbow. Journal of Archaeological Science, 28(8), pp.807-816.

Shennan, S., 2001. Demography and cultural innovation: a model and its implications for the emergence of modern human culture. Cambridge archaeological journal, 11(1), pp.5-16.

Sisk, M.L. & Shea, J.J. 2011. The African origin of complex projectile technology: An analysis using tip cross-sectional area and perimeter. International Journal of Evolutionary Biology 2011: 968012.

Sitton, J., Story, B., Buchanan, B & Eren, M. 2020. Tip cross-sectional geometry predicts the penetration depth of stone-tipped projectiles. Scientific Reports 10:13289

Staurset, S. and Coulson, S., 2014. Sub-surface movement of stone artefacts at White Paintings Shelter, Tsodilo Hills, Botswana: Implications for the Middle Stone Age chronology of central southern Africa. Journal of human evolution, 75, pp.153-165.

Stewart, B.A. and Jones, S.C., 2016. Africa from MIS 6-2: the florescence of modern humans. In Africa from MIS 6-2 (pp. 1-20). Springer, Dordrecht.

Szabo, B.J. and Butzer, K.W., 1979. Uranium-series dating of lacustrine limestones from pan deposits with final Acheulian assemblage at Rooidam, Kimberley district, South Africa. Quaternary Research, 11(2), pp.257-260.

Thieme, H., 2000. Lower Paleolithic hunting weapons from Schöningen, Germany—the oldest spears in the world. Acta Anthropologica Sinica, 19, pp.140-147.

Tribolo, C., Mercier, N., Douville, E., Joron, J.L., Reyss, J.L., Rufer, D., Cantin, N., Lefrais, Y., Miller, C.E., Porraz, G. and Parkington, J., 2013. OSL and TL dating of the Middle Stone Age sequence at Diepkloof Rock Shelter (South Africa): a clarification. Journal of Archaeological Science, 40(9), pp.3401-3411.

Tryon, C.A. and McBrearty, S., 2002. Tephrostratigraphy and the Acheulian to Middle Stone Age transition in the Kapthurin formation, Kenya. Journal of Human Evolution, 42(1-2), pp.211-235.

Vanhaeren, M., Wadley, L. and d'Errico, F., 2019. Variability in Middle stone age symbolic traditions: The marine shell beads from Sibudu Cave, South Africa. Journal of Archaeological Science: Reports, 27, p.101893.

Villa, P. & Lenoir, M. 2006. Hunting weapons of the Middle Stone Age and the Middle Palaeolithic: Spear points from Sibudu, Rose Cottage and Bouheben. Southern African Humanities 18: 89-122.

Villa, P., Soressi, M., Henshilwood, C.S. and Mourre, V., 2009. The still bay points of Blombos cave (South Africa). Journal of Archaeological Science, 36(2), pp.441-460.

Villa, P. and Soriano, S., 2010. Hunting weapons of Neanderthals and early modern humans in South Africa: similarities and differences. Journal of Anthropological Research, 66(1), pp.5-38.

Vogelsang, R., 1998. Middle-Stone-Age-Fundstellen in Südwest-Namibia (Vol. 11). Heinrich-Barth-Institut.

Vogelsang, R., Richter, J., Jacobs, Z., Eichhorn, B., Linseele, V. and Roberts, R.G., 2010. New excavations of Middle Stone Age deposits at Apollo 11 Rockshelter, Namibia: stratigraphy, archaeology, chronology and past environments. Journal of African Archaeology, 8(2), pp.185-218.

Voormolen B (2008) Ancient hunters, modern butchers: Schöningen 13II-4, a kill-butchery site dating from the northwest European Lower Palaeolithic. Leiden University, Leiden

Wadley, L., 2015. Those marvellous millennia: the Middle Stone Age of southern Africa. Azania: Archaeological Research in Africa, 50(2), pp.155-226.

Wadley, L. and Harper, P., 1989. Rose Cottage Cave revisited: Malan's Middle Stone Age collection. The South African Archaeological Bulletin, pp.23-32.

Wadley, L., Williamson, B. and Lombard, M., 2004. Ochre in hafting in Middle Stone Age southern Africa: a practical role. World Archaeology, 26, pp.19-34.

Walls, M. (2019). The bow and arrow and early human sociality: An enactive perspective on communities and technical practice in the Middle Stone Age. Philosophy & Technology, 32(2), 265-281.

Whittaker JC. 2014. Atlatls are levers, not springs. Bulletin of Primitive Technology 48: 68-73.

Wilkins, J., Brown, K.S., Oestmo, S., Pereira, T., Ranhorn, K.L., Schoville, B.J. and Marean, C.W., 2017. Lithic technological responses to late pleistocene glacial cycling at Pinnacle point site 5-6, South Africa. PloS one, 12(3), p.e0174051.

Wilkins, J., Schoville, B.J., Brown, K.S. and Chazan, M., 2012. Evidence for early hafted hunting technology. Science, 338(6109), pp.942-946.

Williams, V.M., Burke, A. and Lombard, M., 2014. Throwing spears and shooting arrows: preliminary results of a pilot neuroarchaeological study. The South African Archaeological Bulletin, pp.199-207.

Wurz, S., Bentsen, S.E., Reynard, J., Van Pletzen-Vos, L., Brenner, M., Mentzer, S., Pickering, R. and Green, H., 2018. Connections, culture and environments around 100 000 years ago at Klasies River main site. Quaternary international, 495, pp.102-115.

Wurz, S., & Lombard, M. 2007. 70 000-year-old geometric backed tools from the Howiesons Poort at Klasies River, South Africa: were they used for hunting?. Southern African Humanities, 19(1), pp.1-16.