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Testing for poisoned arrows in the Middle Stone Age: A tip cross-sectional analysis of backed microliths from southern Africa

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Abstract
Recent work indicated the possibility of hunting with poisoned bone arrowheads more than 60 thousand years ago in southern Africa. The interpretation rests on only a handful of bone points from Middle Stone Age contexts. Two southern African techno-complexes characterised by the knapping of backed microliths have, however, been linked to bow hunting in the past. These are the Wilton, dating from roughly 8000 years until a few centuries ago, and the Howiesons Poort dating to roughly between 67 000 and 58 000 years ago. Here I use the tip cross-sectional method to assess the likelihood of bow hunting with poisoned stone-tipped/barbed arrows for both of these techno-complexes. The results demonstrate that bow hunting with poisoned arrows was probably the preferred hunting strategy during the Holocene Wilton phase. Hunters may have introduced poisoned arrows to their arsenal during the much older Pleistocene Howiesons Poort phase, but they were probably more dependent on hunting with a combination of unpoisoned arrows and javelins (throwing spears). I also show that, during both phases, hunting with poisoned arrows may have been more frequent on the Savanna and Grassland biomes with summer and year-round rainfall regimes, instead of in the Fynbos winter-rain zone.

Keywords: Pleistocene; Howiesons Poort techno-complex; Holocene; Wilton techno-complex; bow hunting; stone-tipped arrows

1. Introduction

Backed microliths or geometric backed pieces are made on thin segmented or truncated blades or bladelets, and are often referred to as segments in southern Africa (Wadley,1986; Wadley and Mohapi, 2008) (southern Africa = the African sub-continent south of the Zambezi River; South Africa = the geopolitical republic). Similar artefacts recur globally through time and across space, and wherever populations invented or re-invented them (e.g. Clarkson et al., 2018), they represent a flexible or perhaps even a plastic techno-behaviour suited for a range of functions (e.g. Bar-Yosef, 1987; Robertson et al., 2009; Lewis et al., 2014; Groman-Yaroslavsk et al., 2020). Some of these functions consistently include cutting insets in variable hunting technologies (Clark et al., 1974;

Olszewski, 1993; Nuzhnyj, 2000; Barham, 2002; Larsson and Söström ,2011; Yaroshevich et al., 2013; Giner et al., 2017). It is on this latter aspect in the southern African context that I focus here by conducting tip cross-sectional area (TCSA) analyses on assemblages from the Wilton techno-complex of the Later Stone Age and the Howiesons Poort techno-complex of the Middle Stone Age.

Using the TCSA metric, Shea (2006) concluded that his results did not support a hypothesis of widespread hunting with spearthrowers (a.k.a. atlatls) or bows in Africa before ~40 ka (ka = thousands of years ago/old). Villa and colleagues (Villa and Lenoir, 2006; Villa and Soriano, 2010; Villa et al., 2010) supported this interpretation, but in a subsequent paper based on a slightly different approach, Shea with Sisk (Sisk and Shea, 2011) suggest dart-and-spearthrower hunting before 50 ka. Whilst there is currently no ethnographic or direct archaeological evidence for hunting with spearthrowers in sub-Saharan Africa, there is a growing body of evidence for bow hunting at >60 ka in southern Africa (Backwell et al., 2008; Lombard and Phillipson, 2010; Lombard, 2011; Bradfield and Lombard, 2011; Backwell et al., 2018; de la Peña et al., 2018). Recently, we also suggested hunting with a poisoned bone arrowhead before 60 ka at Klasies River (Bradfield et al., 2020), and based on the TCSA results of bone arrowheads spanning historical, Later and Middle Stone Age phases, I hypothesised that poisoned arrows might have been in use in southern Africa throughout the last 72 ka (Lombard, 2020). Bone points of such antiquity, are however too few to assess how widespread the techno-behaviour might have been during the Middle Stone Age.

Ethno-historical records indicate that in addition to bone arrowheads, San hunter-gatherers used microliths to tip poisoned arrowheads (Stow, 1905; Bleek and Lloyd, 1911, Dornan, 1917, Maingard, 1935; Goodwin, 1927; Walker, 1974; Clark, 1977; Deacon, 1984). If this was the case during the Stone Age, we may predict that the TCSA values of microlith assemblages will reflect their potential for such application. The two techno-complexes most strongly associated with bow hunting in the region are both characterised by backed microlith production. The youngest of these is the Wilton, starting at roughly eight thousand years ago, continuing at some sites into recent historical times. The Howiesons Poort on the other hand has considerable time depth, with most assemblages dating to between 66 ka and 58 ka (for spatiotemporal synthesis of the South African Stone Age sequence see Lombard et al., 2012). At Diepkloof Rock Shelter, a similar age range was reported by some laboratories (Jacobs et al., 2008; Feathers, 2015), but others arrived at a long-drawn-out age estimate of 104-52 ka (Tribolo et al., 2013; also see Guérin et al., 2013; but see Galbraith, 2014). To avoid either over- or under-estimating the time depth implicated for bow hunting in this study, I work with the most recent ages published for the Howiesons Poort at Diepkloof (Jacobs and Roberts, 2017).

My first aim is to assess to which extent the Holocene backed microlith assemblages of the Wilton techno-complex conform to TCSA expectations of bow hunting with poisoned and/or unpoisoned arrowheads. I then move on to the more ancient Howiesons Poort material to assess previous interpretations about deep-time bow hunting – or the lack thereof – and to compare possible variation in hunting equipment between the Wilton and Howiesons Poort phases. Before presenting the results, I briefly touch on the application of the TCSA method in the context of this study, and provide a short overview of what we currently know about the use of backed microliths from southern Africa.

2. The TCSA method as applied in this study

TCSA analyses, similar to any other metric approach, cannot demonstrate function empirically. For evidence that any ancient, haftless stone artefact was used as a weapon tip or inset, detailed and multi-stranded use-trace analyses are needed (Lombard, 2005a, b, 2006, 2011; Lombard and Phillipson, 2010; Yaroshevich et al., 2013; also see Newman and Moore, 2013; Clarkson, 2016; Hutchings, 2016). That being said, the TCSA metric is useful in terms of assessing the potential effectiveness of artefacts for weapon use, 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 in the case of poisoned weaponry for the poison to be delivered into the animal's bloodstream (Lombard, 2020). In addition, the TCSA value may influence weapon flight and penetration dynamics (Maki, 2013; Sitton et al., 2020). Regardless of artefact type, only maximum width and thickness measurements are needed for calculating the TCSA metric (0.5 x maximum width x maximum thickness = TCSA value), making it a pragmatic, easily replicated approach for analysing large sample sizes across typological and spatiotemporal boundaries, resulting in directly comparable data. The method is therefore suitable for building broad hypotheses about ancient weapon-delivery systems (Shea, 2006; Sano et al., 2016).

Shea (2006) established the TCSA standard ranges for spearthrower dart tips, arrow tips and large experimental stabbing spears (Shea 2006). These standards are now widely used in both experimental and archaeological settings (see several chapters in Iovita and Sano, 2016; Sitton et al., 2020; and discussion in Villa and Lenoir, 2006). Here I add two more TCSA ranges in an attempt to refine interpretation and hypothesis building for this study:

1. Javelin tips: Based on experimentation Rios-Garaizar (2016) suggested that if the Mousterian Levallois points from Eastern Cantabria were used as weapons, their TCSA value is best interpreted as tips of hand-thrown spears, I apply this as standard for javelin tips similar to those used today by hunters of the Kalahari in southern Africa (Lombard, 2020).
2. Poisoned arrow tips: Based on the analysis of bone arrowheads from southern Africa, I recently reported on the TCSA standard range for poisoned arrowheads (Lombard, 2020).

The suite of TCSA standards for these five weapon-delivery systems is presented in Table 1.

Table 1

Current tip cross section ranges for different weapon-delivery systems.

Weapon type	N of tools	Mean TCSA	SD	TCSA Range	Source
Poisoned arrowheads	434	11	7	4-18	Lombard 2020
Arrowheads	118	33	20	13-53	Shea 2006
Dart tips	40	58	18	40-76	Shea 2006
Javelin tips	74	88	52	36-140	Rios-Garaizar 2016
Thrusting spear tips	28	168	89	79-257	Shea 2006

In calculating the TCSA values of backed microliths, I follow Wadley and Mohapi (2008) by providing both a minimum (0.5 x maximum width x maximum thickness = TCSA value) and a maximum TCSA (0.5 x maximum length x maximum thickness = TCSA value) range/value for each assemblage. This is necessary because of the variable hafting configurations for microliths when used as weapon insets (Fig. 1). The minimum range represents hafting configurations where the segments are hafted longitudinally or almost longitudinally (Fig. 1c and f), whereas the maximum range represents them as being hafted transversely or in pairs to form a point (Fig. 1a, b, g). Diagonal hafting configurations, for example as barbs (Fig. 1d and e), will fall closer to the maximum range because they extend from the shaft.

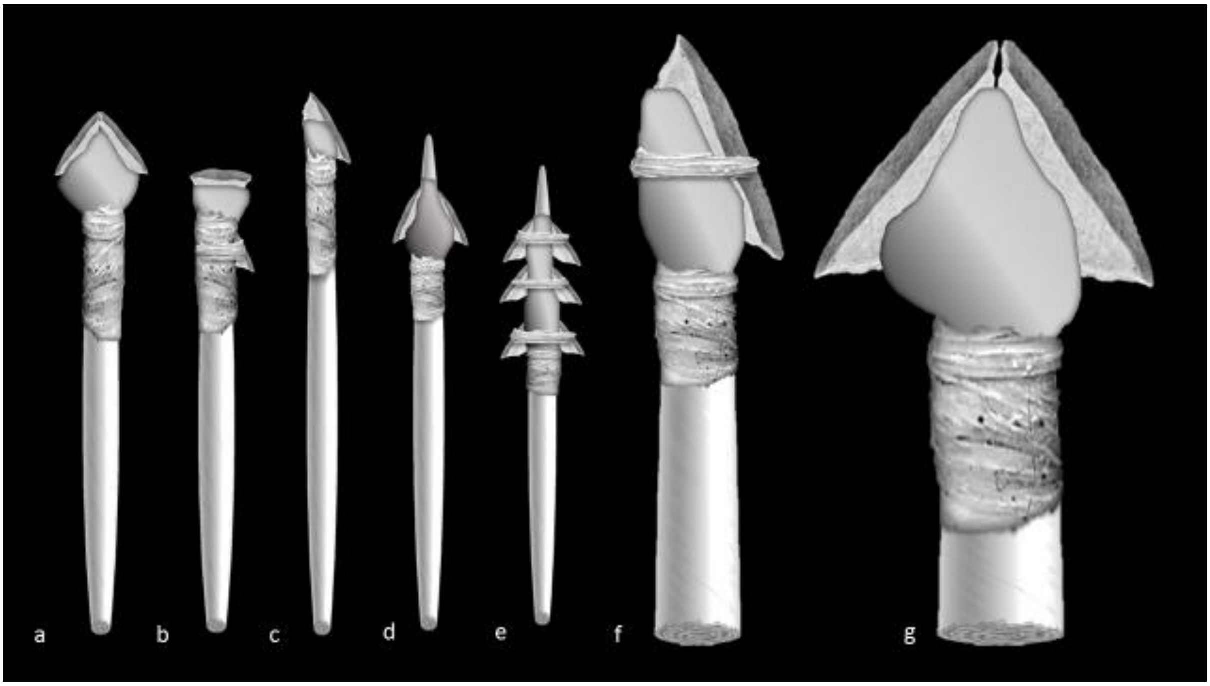


Fig. 1 [2 column fitting]. Most feasible hafting configurations for Wilton and Howiesons Poort backed microliths wherein very small pieces could serve as variable insets in arrowheads (1a-e), and larger pieces as javelin (throwing spear) or thrusting spear tips (1f-g). 1a is similar to ethno-historical and archaeological reports and reconstructions of stone tipped arrows of the Karoo region in South Africa. 1b is a reconstruction of a two-thousand-year-old arrow from an archaeological context in the Eastern Cape, South Africa, with a transversely hafted microlith and barb. 1c-g are hypothetical reconstructions based on the distribution of adhesive residues recorded on some Howiesons Poort segments from Sibudu Cave, KwaZulu-Natal, South Africa.

Thus far, TCSA values for assemblages are usually expressed as mean ± SD, but that brings with it the problem of outliers, which some researchers remove from their samples to avoid skewed data. I suggest that outliers should be included when potential variability in intra-site weapon tip application is of interest. Because not all pieces may have been intended for the same use, outliers may add interpretative value. Compensating for the outliers is however necessary, and can be achieved by calculating the TCSA median of an assemblage, which is less affected by outliers and skewed data distribution of the individual artefacts. The median statistic then represents the dominant trend within an assemblage that can be interpreted in relation to the TCSA standard ranges presented in Table 1.

3. Current understanding of backed microliths as arrow tips

Earlier I mentioned ethno-historical reports of backed microliths used as arrow insets. Although Stow (1905) reported that he and others collected many of these arrows, today there are only a few known glass- and quartz-tipped arrowheads curated in Cape Town (Walker, 1974) and the Pitt Rivers Museum, UK (Clark ,1977; Fig. 2). The origins of these arrowheads are not certain, but similar objects were made for Bleek in the late 19th century by a /Xam San informant from the Nama Karoo (Lloyd, 1889). The arrowheads each had two microliths, with their sharp ends meeting in a triangular tip (Fig. 2), fixed to a bone or wooden point with an adhesive softened by heat. It is generally accepted that backed microliths from the Wilton techno-complex were used in a similar way (Deacon, 1984; Turner, 1986; Wadley, 1987; Bousman, 2005; Villa et al., 2010).

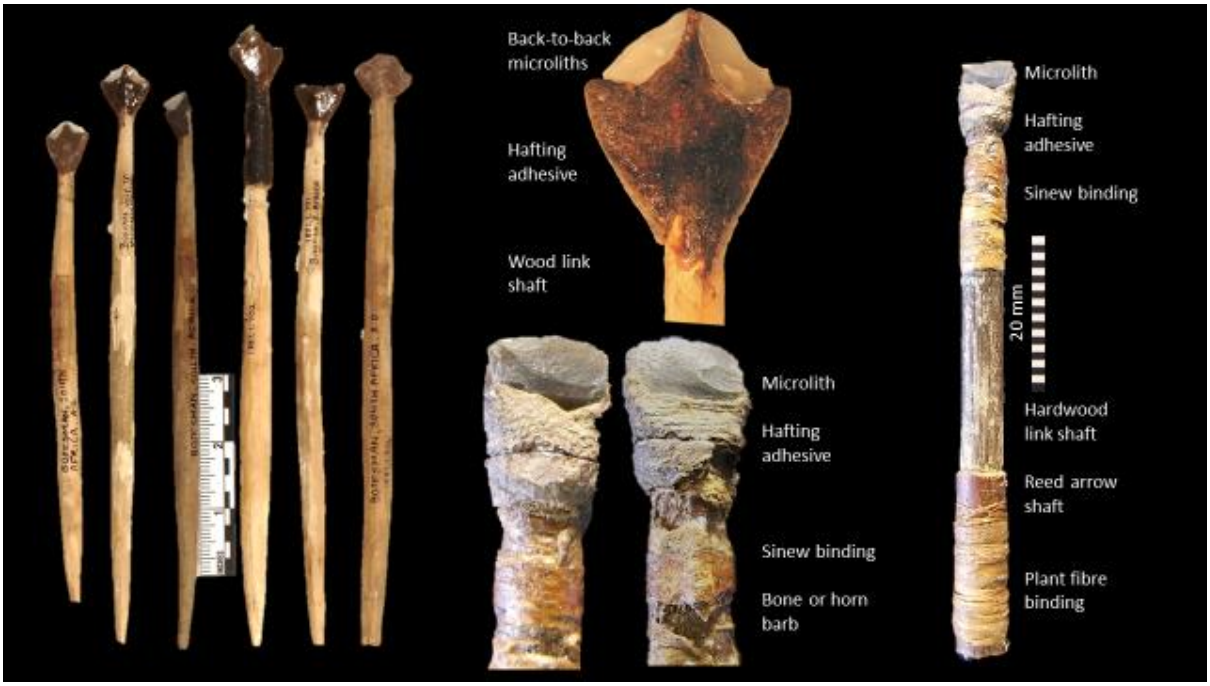


Fig. 2 [2 column fitting]. Left: Ethno-historical arrowheads with quartz microliths housed at the Pitt Rivers Museum, Oxford, UK (photo: Justin Pargeter ©). Middle top: Detail of one of the Pitt Rivers arrowheads. Right: Two-thousand-year-old arrow from Adams Kranz, South Africa, with transversely hafted tip (photo: Marlize Lombard ©). Middle bottom: Details of the Adams Kranz arrowhead.

Direct archaeological evidence of such use is, however, sparse. Some bone points from Faraoskop (Western Cape, South Africa) still have lumps of adhesive similarly shaped and positioned to the ethno-historical examples (Manhire, 1993), and one of them is notched to receive a stone inset in the way described by Stow (1905). Although these artefacts do not come from formally excavated layers, it is thought that the site was last occupied about two thousand years ago (Manhire, 1993). Binneman (1994) excavated a single, perfectly preserved, transverse arrowhead at Adams Kranz (Eastern Cape, South Africa) from a layer dating to 1760 ± 50 BP (Pta-6418) (Fig. 2). This find represents unambiguous evidence that Later Stone Age microliths were used as small, transversely hafted arrow tips, even if not all of them may have been backed.

Binneman's (Binneman, 1982; Wadley and Binneman, 1995; Binneman and Mitchell, 1997) wear-pattern studies showed that Later Stone Age hunter-gatherers probably also used microliths for cutting tasks. Yet, none of these studies focussed on explicitly recognising hunting traces (e.g., Fischer et al., 1984; Lombard, 2005a, b; Yaroshevich et al., 2010). A single backed microlith with a 'pencil grip wrapping' was found at Elands Bay Cave (Western Cape, South Africa), dating to about eight thousand years ago, also interpreted as cutting tool (Charrié-Duhaut et al., 2016). Macro-fracture analyses conducted by Pargeter (2011) showed that 17.6 % of the Wilton microliths from Nelson Bay Cave, 22.1 % from Byneskranskop, and 20.9 % from Blombosfontein had fractures consistent with their use as weapon tips.

In terms of the Howiesons Poort, Wadley and Mohapi (2008) applied the TCSA method to backed microliths from Sibudu Cave according to raw material type. Below I summarise their results based on the TCSA ranges presented in Table 1 (also see Supplementary Material).

- Hafted in the minimum scenario, quartz pieces had a TCSA range of 7.7-42, so that in this position, all could have been used to tip arrows and some would have been effective as poisoned arrow tips. Hafted in the maximum positions, their TCSA range is 14.7-60, in which case some could still have been used to tip poisoned arrows, but the trend is now more consistent with hypothetical use as unpoisoned arrows. A few pieces could also have served in dart or javelin hunting contexts.
- Hornfels segments, hafted in the minimum scenario showed a TCSA range of 7-59.5, so again a reasonable portion could have served as poisoned arrow tips and almost all as arrow tips when hafted this way, with some potentially used as darts or javelin tips. When rotated into the maximum scenarios, there is a clear shift away from potential effective use as poisoned arrows with a TCSA range of 19-151. A good portion of the hornfels pieces would still be most useful as arrow tips, but now darts, javelins and hunting with thrusting spears becomes increasingly feasible interpretations.

- The dolerite backed microliths are the most robust population at Sibudu with a minimum TCSA range of 10.5-80.5, and a maximum range of 19.7-239. Again, a few pieces would have been well suited to tip poisoned arrowheads in the minimum scenario, but most lean towards the ranges of dart and javelin use. Hafted in the maximum positions, all the weapon types, apart from poisoned arrow tips, are represented.

These results are a good indication that if the backed microliths from Sibudu Cave were used as weapon tips or insets, the arsenal may well have included arrows (Wadley and Mohapi, 2008), some of which with tips or barbs so small that they would have been most effective when used with poison (Lombard, 2020).

Macro-fracture results obtained for Howiesons Poort backed microlith assemblages from Sibudu Cave, Umhlatuzana Rock Shelter, Rose Cottage Cave and Klasies River Cave show that some of the artefacts were used as impact tools, consistent with weapon tips (Lombard, 2005a; Wurz and Lombard, 2007; Soriano et al., 2007; Lombard and Pargeter, 2008). Detailed micro-residue and use-wear analyses on 53 dolerite and hornfels segments from Sibudu Cave also show that some were used as weapon tips (Lombard, 2008). Studying the small quartz segments from Sibudu and Umhlatuzana, we found that the best-fit interpretation for the observed use-trace suites and fracture patterns is that of arrow tips (Lombard and Phillipson, 2010). In a subsequent study of 13 small quartz pieces from Sibudu, at least five were found to bear use-trace sets consistent with transverse hafting, and five more of having been hafted and used diagonally as tips or barbs (Lombard, 2011). Experimental work by de la Peña and colleagues (2018) subsequently confirmed the use of arrow barbs during the Middle Stone Age at Sibudu.

An early experiment tested the effectiveness of the various hafting configurations for Howiesons Poort backed microliths and the resulting fractures (Pargeter, 2007; Lombard and Pargeter, 2008). Pargeter and colleagues (2016) showed that hafted transversely, small quartz segments make effective arrow and javelin tips. In their experimental study, Schoville and colleagues (2017) concluded that, despite similarities in shape with ethno-historical artefacts, the larger Middle Stone Age backed pieces, akin to those found at Pinnacle Point 5-6 might have been ineffective when shot from the low-powered bows used by current-day San hunter-gatherers. Instead, they suggest an as-yet-unknown weapon-delivery system with greater velocity, but fall short of proposing spearthrowers based on the lack of evidence for this technology in southern Africa. In their study, they did not consider either the use of poisoned arrows or hand-cast javelins as included in this study, which may have affected their functional interpretation. Everything considered; if Howiesons Poort backed microliths were indeed used to tip and barb arrows, the prediction is that the TCSA results will reflect their potential to do so, or that it may reveal other or additional hypothetical weapon-delivery systems that were in play at the time.

4. Tip cross-sectional area analysis of Stone Age backed microliths from southern Africa

I calculated the minimum and maximum TCSA values of backed microliths from 14 Later Stone Age Wilton assemblages (982 data points) and 11 Middle Stone Age Howiesons Poort (1064 data points) assemblages across southern Africa (Fig. 3). Although there may be spatiotemporal and functional variation regarding morphology and raw material use within each of these techno-complexes (e.g., Wadley and Mohapi, 2008), I treat them here as two broad, discrete entities to hypothesise about weapon use relating to each. Where adequate contextual integrity and data are available, future studies will seek to assess the interpretations presented here.

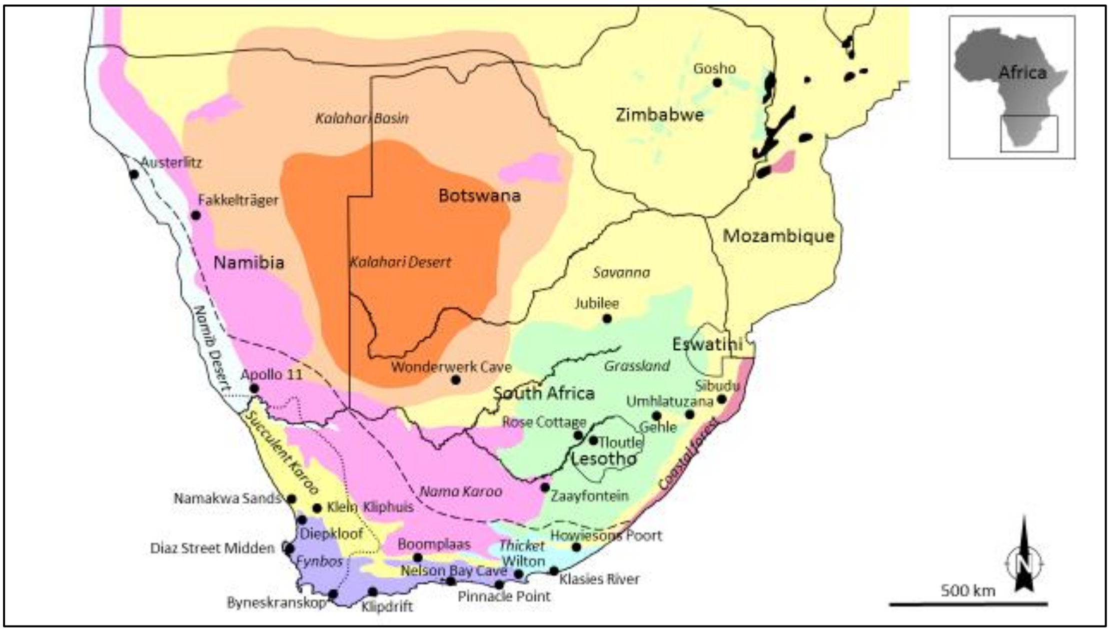


Fig. 3. [2 column fitting] Map of southern Africa with the archaeological sites from which assemblages are analysed in this study, biomes and winter (left of dotted line), summer (right of dashed line), and year-round (between the dotted and dashed lines) rainfall regimes.

4.1. TCSA results for the Later Stone Age Wilton backed microlith assemblages

The TCSA median values for backed segments hafted in the minimum scenario from 11 out of the 14 sites, fall exclusively within the range for poisoned arrow tips (Table 2, Fig. 4), for two more sites the values fall in the overlap between poisoned and unpoisoned arrows. Only the backed microliths from Diaz Street Midden hafted in the minimum configuration has a median TCSA value that falls outside that of poisoned arrowheads. Hafted in maximum configurations, the backed microliths from Gehle Shelter, Jubilee Shelter and Tloutle also have median TCSA values exclusive to poisoned arrow tips. We may therefore hypothesise that ecological, socio-technical or socio-economic circumstances (or a combination of any/all of these factors) made bow hunting with poisoned arrows the most feasible hunting strategy for hunters from these three sites. This may also have been the case for Gosho, Namakwa Sands and Wonderwerk Cave where the median TCSA values of the maximum scenarios lies at the lower end of the standard range for unpoisoned arrows (Table 2, Fig. 4). At all the other sites, the maximum median TCSA values fall within the range for unpoisoned arrowheads. From these results, it is clear that if Later Stone Age Wilton backed microliths were used for hunting, they would be ballistically most suited as arrow tips (poisoned and unpoisoned). Only at Diaz Street Midden does the median TCSA value overlap with the standard ranges for unpoisoned arrows, darts and javelins (Fig.4). Cumulatively, the dominant trend represented by the median TCSA values for the Wilton backed microliths in southern Africa is that of bow hunting with poisoned arrows.

Table 2 [2 column fitting]

TCSA results for Later Stone Age Wilton backed microlith assemblages from southern Africa. Key: nd = not dated, source for age estimate[a], *new data, ^source for raw data, ^^measured from scaled illustrations, ˣraw data provided by researcher.

Site, biome, rainfall regime (data source)	Age estimate	Thickn.	Hafting scenario	Width/ Length	TCSA (mean ± SD)	TCSA Median
Austerlitz, Namib Desert, year-round rain (^^Richter 1991[a])	~9.4-0.9 ka	3±1*	Min n=27	8±2*	13±6*	12*
			Max n=27	15±3*	23±11*	19.5*
Boomplaas, Succulent Karoo, year-round rain (^^Deacon 1982[a])	6.4-1.5 ka	2±1*	Min n=26	6±2*	8±5*	7*
			Max n=26	15.4*	19±12*	19*
Byneskranskop, Fynbos, winter rain (ˣPargeter; Schweitzer and Wilson 1982[a])	~6.3-0.2 ka	3±1*	Min n=104	8±3*	15±10*	13.5*
			Max n=104	15±5*	29±19*	26*
Diaz Street Midden, Fynbos, winter rain (ˣOrton; Orton 2009[a])	~6-0.2 ka	4±1*	Min n=21	10±3*	23±12*	24*
			Max n=21	18±4*	42±19*	45*
Fackelträger, Nama Karoo, Summer rain (^^Richter 1991[a])	~3-0.3 ka	4±1*	Min n=36	8±2*	16±9*	14*
			Max n=36	15±4*	30±15*	26*
Gehle, Grassland, summer rain (ˣLombard; Mazel 1984[a])	~5.7-4.3 ka	3±1*	Min n=20	7±2*	10±6*	8*
			Max n=20	10±3*	14±8*	11*
Gosho, Savanna, summer rain (^^Burrett 2003[a])	~8.5-0.5 ka	2±1*	Min n=27	7±2*	8±4*	7*
			Max n=27	13±3*	15±7*	13*
Jubilee, Savanna, summer rain (^^Wadley 1987[a])	~6.5-3.1 ka	2±1*	Min n=31	5±2*	6±4*	5*
			Max n=31	12±4*	14±9*	11*
Namakwa Sands, Succulent Karoo, winter rain (ˣOrton)	nd	3±1*	Min n=89	6±2*	8±4*	7.5*
			Max n=89	12±2*	16±6*	15*
Nelson Bay Cave, Fynbos, year-round rain (^Inskeep 1987[a])	6-0.5 ka	3±2*	Min n=37	7±4*	14±17*	8*
			Max n=35	17±7*	30±35*	21*
Tloutle, Grassland, summer rain (^^Mitchell 1990[a])	~9-5 ka	2±1*	Min n=16	4±1*	6±3*	5.5*
			Max n=16	12±4*	15±9*	11.5*
Wilton Shelter, Fynbos, year-round rain (^^Deacon 1972[a])	~8.2-2.2	3±1*	Min n=12	5±1*	7±3*	7*
			Max n=12	14±5*	19±9*	19*
Wonderwerk Cave, Savanna, summer rain (^^Humphreys and Thackeray 1983[a])	~6-3 ka	2±1*	Min n=23	6±2*	8±5*	5*
			Max n=23	20±9*	26±19*	15*
Zaayfontein Shelter, Nama Karoo, summer rain (^^Sampson 1967[a])	>730±75	3±1*	Min n=23	6±2*	9±5*	7.5*
			Max n=23	15±6*	22±13*	19.5*
LSA Wilton 982 data points			**Min n=492**		**11±9***	**8***
			Max n=490		**23±17***	**18***

However, I argue that when thinking about backed microliths in the context of hunting flexibility or plasticity, it is most fitting to do so in terms of a continuum of possible weapon systems, instead of in an 'either-or' way. To facilitate such thinking in terms of TCSA, I added the minimum data points to the maximum ones, hypothetically covering the full spectrum of potential effective weapon tip ranges at the Wilton sites included in this study (Table 3, Fig. 5). When the frequencies for each weapon-delivery system are calculated, 67 % of the Wilton pieces could have been used to tip poisoned arrows and 64.9 % unpoisoned arrows. Collectively, 95.1 % would have been suitable for bow hunting. Possible effective use as javelin tips is represented by 10.1 % of the data points, which include 7.6 % potentially suitable as dart tips. Only 0.7 % indicate possible use as effective thrusting spears (Table 3, Fig. 5). This analysis further demonstrates that, if Wilton backed microliths were intended for hunting use, the dominant hunting strategy using lithic insets in southern Africa since at least ~8 ka was bow hunting, mostly with poisoned, but also with unpoisoned arrows. In addition, hunters would have relied on bone arrow tips (e.g. Lombard, 2020), Knopkieries (knobbed sticks that serve as clubs and throwing sticks), as well as a range of net and trap hunting strategies (e.g. Imamura and Akiyama, 2016).

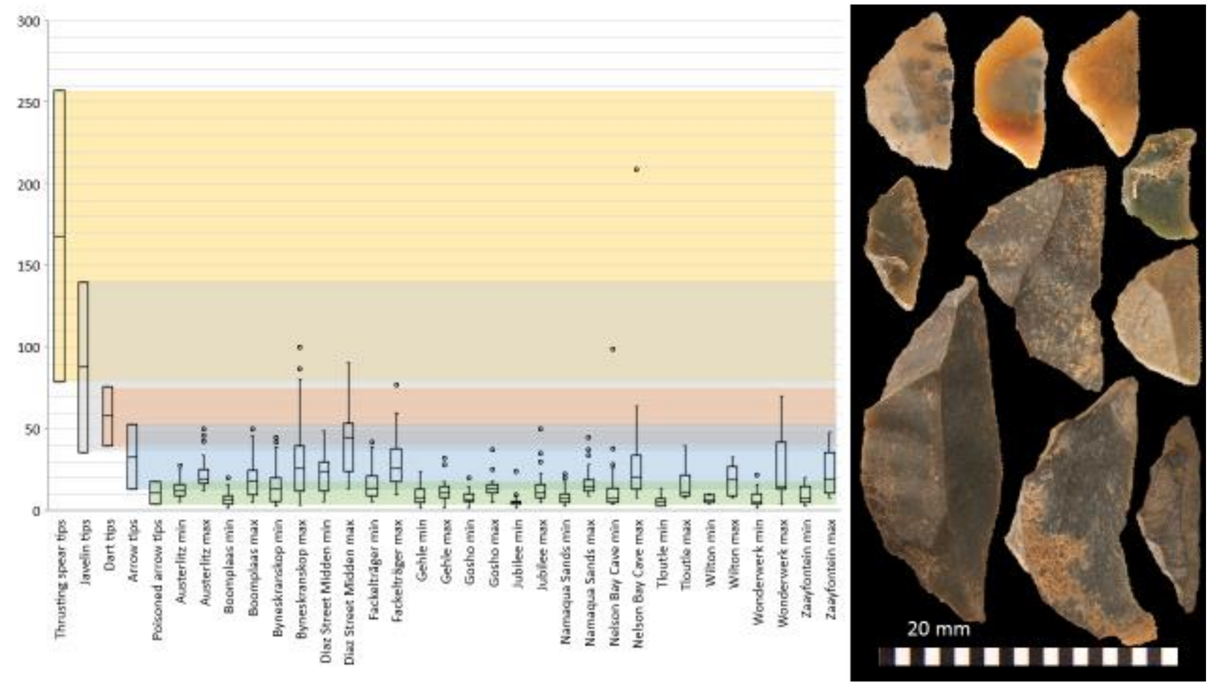


Fig. 4 [2 column fitting]. Left: Bar and whisker plots for the minimum and maximum TCSA values calculated for 14 Later Stone Age Wilton backed microlith assemblages. The horizontal line in each bar indicates the median TCSA value of the assemblage. The standard TCSA ranges for the different weapon-delivery systems are indicated at the left of the graph with the range for poisoned arrows tips in green, unpoisoned arrow tips in blue, drat tips in orange, javelin tips in grey and thrusting spear tips in yellow stretched across the graph. Right: Examples of backed microliths from Gehle Shelter dated to ~5.7-4.3 ka, showing variation in size, shape and material.

Table 3 [2 column fitting]

Comparative frequencies of potential effective weapon tip ranges of backed microliths from Wilton sites in southern Africa. Percentages do not add up to 100, because categories overlap, and a few pieces are so small or so large that their individual TCSA values fall outside any of the weapon categories.

Site = data points	**Poisoned arrow tips**		**Arrow tips**		**Dart tips**		**Javelin tips**		**Thrusting spear tips**		**Bow hunting**		**Spear hunting**	
Later Stone Age backed segments														
	dp	**%**	**dp**	**%**	**dp**	**%**	**dp**	**%**	**dp**	**%**	**dp**	**%**	**dp**	**%**

Austerlitz = 53	35	66	35	66	4	7.5	4	7.5	0	0	53	100	4	7.5
Boomplaas = 52	33	63.5	19	36.5	2	3.8	2	3.8	0	0	47	90.4	3	3.8
Byneskranskop = 208	106	51	123	59.1	28	13.5	37	17.8	3	1.4	195	93.8	37	17.8
Diaz Street = 42	10	23.8	30	71.4	13	31	16	38.1	1	12.2	37	88.1	16	38.1
Fackelträger = 72	35	48.6	48	68.1	8	11.1	12	16.7	0	0	69	95.8	12	16.7
Gehle = 40	33	75	14	35	0	0	0	0	0	0	38	95	0	0
Gosho = 54	47	87	18	24.3	0	0	1	1.9	0	0	52	96.3	1	1.9
Jubilee = 62	55	88.7	13	21	1	1.6	1	1.6	0	0	61	98.4	1	1.6
Namakwa Sands = 178	153	86	68	38.2	1	0.6	2	1.1	0	0	177	99.4	2	1.1
Nelson Bay Cave = 72	46	63.9	34	47.2	6	8.3	9	12.5	1	1.4	67	93.1	10	1.4
Tloutle = 32	21	65.6	9	28.1	1	3.1	1	3.1	1	0	27	84.4	1	3.1
Wilton = 24	18	75.1	7	29.2	0	0	0	0	0	0	24	100	0	0
Wonderwerk = 46	35	73.9	20	43.5	7	15.2	8	17.4	0	0	41	89.1	8	17.4
Zaayfontein = 46	32	69.6	22	47.8	4	8.7	6	13	0	0	45	97.8	6	13
Total LSA= 982	**658**	**67**	**461**	**64.9**	**75**	**7.6**	**99**	**10.1**	**7**	**0.7**	**934**	**95.1**	**100**	**10.2**

Real-life observations show that the poison of a Kalahari bow hunter's arrow could take up to 12-15 hours to affect large game enough so that it can be finally killed with a javelin, knife or assegai (broad-tipped stabbing spear) without the hunter being in any danger (e.g., Silberbauer, 1965). With this knowledge in mind, hunters would memorise the direction in which their prey fled and the characteristics of its footprints before returning to camp. There they may gather extra gear (such as spears) and a companion or two before setting out to track the prey, which if still alive when found they kill with a stab through the aorta (Schapera, 1929; Imamura and Akiyama, 2016). I suggest that the TCSA results for the Later Stone Age Wilton backed segments reflect similar hunting strategies and behaviours. Such an interpretation is consistent with observations of each bow hunter carrying an array of different arrows in their quivers, along with a single light-weight javelin, and that amongst a family or group of bow hunters there may be a single assegai to share (e.g., Sparrman, 1785; Stow, 1905).

Inter-site variability in preferred hunting strategies is also reflected in the TCSA frequencies (Table 3; Fig. 5). These variations may indicate ecological considerations, socio-technical or socio-economic processes at work, or a combination of factors. Looking at ecology, the trend seems to be towards a greater preference for hunting with poisoned arrows in the summer rain regime and in Savanna and Grassland biomes (Fig. 5), with the Namakwa Sands and Wilton assemblages being outliers to this trend. Hunting with unpoisoned arrows seems to have been preferred for animals in the Fynbos biome and winter and year-round rain regimes. Even though still coarse-grained, these interpretations represent the first attempt to understand variation in hunting behaviours across southern Africa during the Later Stone Age Wilton phase. For now, I speculate that the reliable availability of suitable arrow poisons may be one of the most important factors in this distribution, but the inference requires future testing. Other explanations may be found in preferred or available prey types, or variation in aspects of site use in combination with reigning socio-technical and socio-economic dynamics.

The outcome of the TCSA analysis of Later Stone Age Wilton backed microliths is consistent with ethno-historical records of the last few hundred years for southern Africa, reporting their use as poisoned arrow tips. It is also consistent with the TCSA results of bone arrowheads that point to the use of bow hunting with poisoned arrows throughout the last 40 ka in southern Africa (Lombard, 2020). I therefore suggest that these assemblages represent an appropriate middle range for interpreting older backed microlith assemblages in terms of their suitability for bow hunting with poisoned arrows.

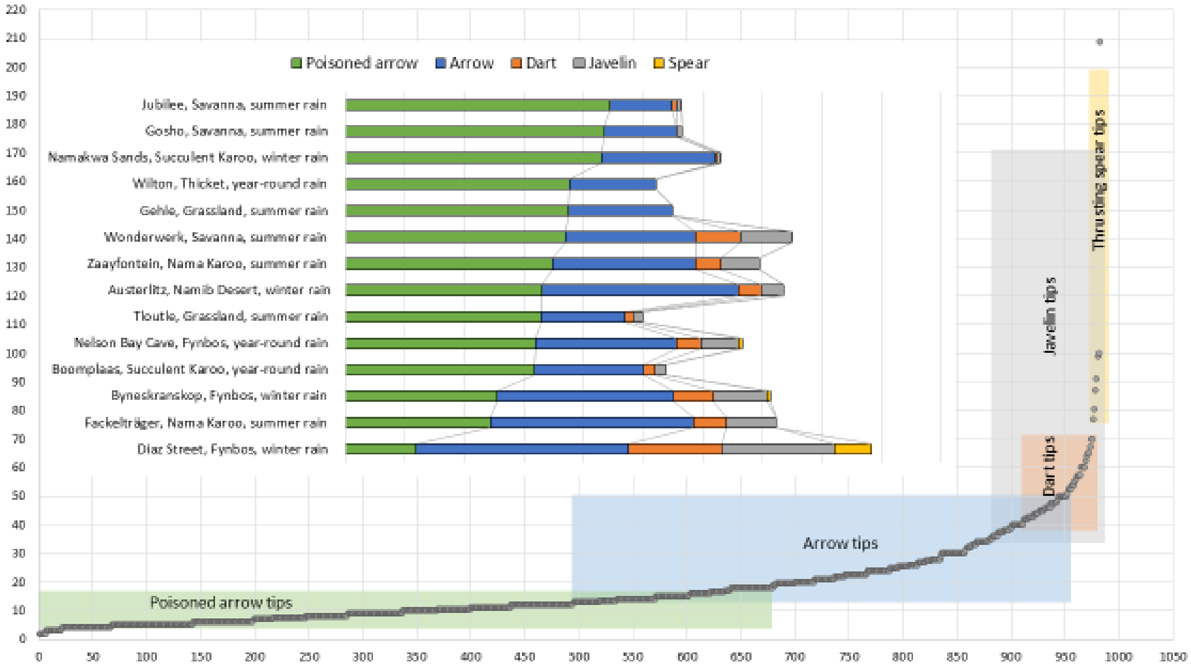


Fig. 5 [2 column fitting]**.** The background graph shows the individual data points on the X axis (minimum and maximum TCSA values = 2 grey dots for each piece) and their respective TCSA values are reflected on the Y axis. The rough proportional distribution of hypothetical effective weapon tip coverage for backed microliths of the Holocene Wilton techno-complex as a whole are reflected in the coloured blocks. The inserted bar chart shows the percentages of hypothetical effective weapon tip coverage for backed microliths from each of the sites included in the study, together with their biomes and rainfall regimes. Note that in each instance the total adds up to more than 100 because of the overlap between weapon-tip TCSA values.

4.2. TCSA results for the Middle Stone Age Howiesons Poort backed microlith assemblages

In contrast with the Wilton assemblages, none of the TCSA median values for the Howiesons Poort assemblages falls exclusively in the range for poisoned arrow tips (Table 4, Fig. 6). However, hafted in their minimum scenarios, the assemblages from Pinnacle Point 5-6 and Umhlatuzana fall well within the range for poisoned arrow tips, and at the lower end of the range for unpoisoned arrow tips, and at the Howiesons Poort site the median TCSA value is 19, just outside the range for poisoned arrow tips. Thus, at all three these sites bow hunting with arrow tips too small to have been effective without poison is a reasonable scenario. Hafted in their minimum arrangements, the median TCSA values of all 11 Howiesons Poort backed microlith assemblages fall within the range of arrow tips.

In their maximum hafting configurations, the assemblages from several sites, including Howiesons Poort, Klipdrift, Pinnacle Point 5-6, Sibudu Cave and Umhlatuzana also have median TCSA values consistent with effective use as arrow tips. At four of these sites (Howiesons Poort, Klipdrift, Pinnacle Point 5-6, Sibudu Cave), their values overlap with the dart/javelin tip ranges, but not at Umhlatuzana, where the median TCSA values fall exclusively within the arrow range (poisoned and unpoisoned; see Supplementary Material). At Apollo 11, Diepkloof, Klasies River, Klein Kliphuis and Rose Cottage Cave, the median TCSA values for backed microliths hafted in their maximum positions fall outside the arrow tip range, being consistent with use as effective dart/javelin tips. In this hafting configuration, the assemblage from Nelson Bay Cave is the only one that falls in the javelin category also overlapping with the range for effective use as thrusting spear tips. Taken as a whole, the backed microliths from the Middle Stone Age Howiesons Poort context hafted longitudinally reflect their potential use as arrow tips. On the other hand, hafted in pairs or transversely, their collective median TCSA value is more consistent with use as dart or javelin tips (Table 4, Fig. 6).

Table 4 [2 column fitting]

TCSA results for Middle Stone Age Howiesons Poort backed microlith assemblages from southern Africa. Key: nd = not dated, *new data, ^source for raw data, ^^measured from scaled illustrations, ˣraw data provided by researcher.

Site, biome, rainfall regime (data source)	**Age estimate**	**Thick -ness**	**Hafting scenario**	**Width/ Length**	**TCSA (mean ± SD)**	**TCSA Median**
Apollo 11, Nama Karoo, all-year rain (^^Vogelsang 1998; Vogelsang et al. 2010[a])	63.2±2.3 ka	5±1*	Min n=32	13±3*	30±13*	26*
			Max n=25	37±9*	89±47*	74*
Diepkloof, Fynbos, winter rain (ˣMackay; Jacobs and Roberts 2017[a])	65.9 ± 3.0-59.2 ± 2.7 ka	5±1*	Min n=66	17±4*	41±19*	37*
			Max n=66	33±6*	75±30*	73*
Howiesons Poort, Thicket, year-round rain (^^Deacon 1995)	nd	3±2*	Min n=23	15±2*	25±12*	19*
			Max n=23	34±10*	56±34*	45*
Klasies River Wurz excavation, Thicket, year-round rain (ˣWurz, Jacobs et al. 2008[a])	~64.3±2.5 ka	5±1*	Min n=28	15±3*	36±12*	37.5*
			Max n=28	35±10*	83±37*	74.5*
Klein Kliphuis, Succulent Karoo, winter rain (ˣMackay; Jacobs et al. 2008[a])	~66-58 ka	5±2*	Min n=68	16±4*	40±25*	34*
			Max n=68	27±7*	66±39*	58*
Klipdrift, Fynbos, winter rain (^Douze et al. 2018; Henshilwood et al. 2014[a])	65.5±4.8-59.4±4.6 ka	4±1*	Min n=17	14±3*	30±14*	27.5*
			Max n=14	26±8*	56±29*	53.5*
Nelson Bay Cave, Fynbos, year round rain (^^Volman 1980)	nd	5±2*	Min n=18	19±4*	51±29*	47.5*
			Max n=18	41±10*	112±64*	98*
Pinnacle Point 5-6, Fynbos, year-round rain (^Brown et al. 2012[a])	71.1±2.3-58±4 ka	3±1*	Min n=30	11±4*	16±9*	13*
			Max n=30	28±8*	47±30*	41*
Rose Cottage Cave, Grassland, summer rain (^^Lewis 2015; Jacobs et al. 2008[a])	68.7± 2.7-62.5±2.9 ka	4±1*	Min n=42	12±3*	26±14*	21*
			Max n=42	30±6*	68±32*	64*
Sibudu Cave, Savanna, summer rain (ˣWadley and Mohapi, Jacobs et al. 2008[a])	64.7±1.9-61.7±1.5 ka	4±1*	Min n=105	12±4*	27±18*	22*
			Max n=89	29±11*	65±45*	52*
Umhlatuzana Level 24, Savanna, summer rain (ˣLombard; Lombard et al. 2010[a])	≥60.0±3.5 ka	3±1*	Min n=128	10±3*	16±10*	14*
			Max n=22	20±9*	33±27*	24*
MSA Howiesons Poort = 1064			**Min n=557**		**28±19***	**24***
			Max n=507		**62±41***	**51***

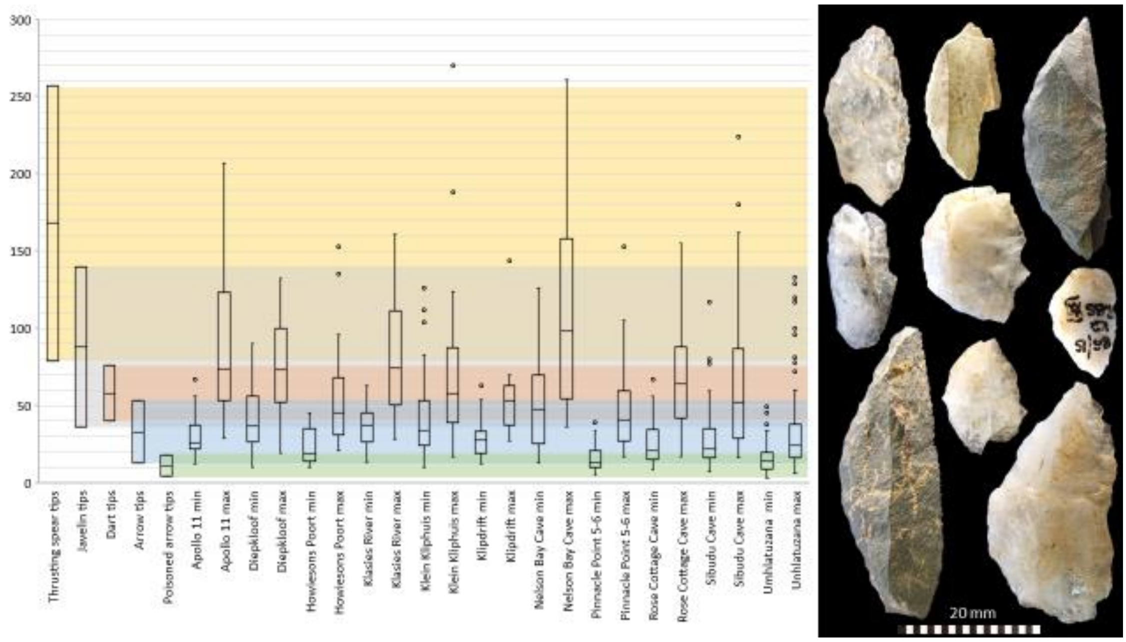


Fig. 6 [2 column fitting]. Left: Bar and whisker plots for the minimum and maximum TCSA values calculated for 11 Middle Stone Age Howiesons Poort backed microlith assemblages. The horizontal line in each bar indicates the median TCSA value of the assemblage. The standard TCSA ranges for the different weapon-delivery systems are indicated at the left of the graph with the range for poisoned arrows tips in green, unpoisoned arrow tips in blue, drat tips in orange, javelin tips in grey and thrusting spear tips in yellow stretched across the graph. Right: Examples of backed microliths from Umhlatuzana Rock Shelter dated to ≥60.0±3.5 ka, showing variation in size, shape and material. Some of the pieces also have fractures consistent with arrow use.

However, when considering these artefacts in the context of a hypothetical continuum in variable weapon tip configurations, collectively 23.4 % could have been used effectively as poisoned arrow tips, 59.9 % as unpoisoned arrow tips, 27.4 % as spearthrower dart tips, 46.9 % as javelin tips and 13.4 % as thrusting spear tips. When the TCSA frequencies for poisoned and unpoisoned arrows are combined, 71.3 % of the backed microliths would have been effective in bow hunting scenarios. When the same is done for javelin and thrusting spear frequencies, 49.4 % of the artefacts would have been effective in spear hunting scenarios (Table 5, Fig. 7). These results provide strong quantitative support to use-trace interpretations suggesting that some of the backed microliths from Howiesons Poort contexts functioned as arrow tips or barbs (Lombard and Phillipson, 2010; Lombard, 2011; de la Peña et al., 2018), perhaps also poisoned. The data presented here, however, also back suggestions of javelin use (e.g. Villa and Lenoir, 2006). Notwithstanding differences, and even though many millennia apart, there is a similar trend for the Howiesons Poort as for the Wilton, wherein hunting with poisoned arrows seems to be expressed stronger for Savanna and Grassland biomes with summer and year-round rainfall regimes (Fig. 7), compared to the Fynbos winter-rainfall zone.

Table 5 [2 column fitting]

Comparative frequencies of potential effective weapon tip ranges of backed microliths from Howiesons Poort sites in southern Africa. Percentages do not add up to 100, because categories overlap, and a few pieces are so small or so large that they fall without any of the weapon categories.

Site = data points	Poisoned arrow tips		Arrow tips		Dart tips		Javelin tips		Thrusting spear tips		Bow hunting		Spear hunting	
Middle Stone Age backed segments														
	dp	**%**	**dp**	**%**	**dp**	**%**	**dp**	**%**	**dp**	**%**	**dp**	**%**	**dp**	**%**
Apollo 11 = 56	4	7.1	34	60.7	16	28.1	28	50	11	19.6	35	62.5	31	55.4
Diepkloof = 132	9	6.8	64	48.5	57	43	98	74.2	30	22.7	68	51.5	98	71.2
Howiesons Poort = 46	11	23.9	35	76.1	16	34.8	20	43.5	3	6.5	43	93.5	21	45.7
Klasies River = 56	4	7.1	33	58.9	24	42.9	42	75	13	23.2	33	58.9	54	80.4
Klein Kliphuis = 136	12	8.8	80	58.8	49	36	92	67.6	24	17.6	82	60.3	94	69.1
Klipdrift = 31	4	12.9	21	67.7	11	35.5	14	45.2	1	3.2	22	71	15	48.4
Nelson Bay Cave = 36	1	2.8	14	38.9	11	30.6	25	69.4	15	41.7	14	38.9	30	83.3
Pinnacle Point 5/6 = 59	21	35.6	37	62.7	12	20.3	17	28.8	4	6.8	51	86.4	18	30.5
Rose Cottage = 84	17	20.2	47	56	27	32.1	43	51.2	9	10.7	55	65.5	45	53.6
Sibudu = 193	40	20.7	126	65.3	52	26.9	81	42	25	13	141	73.1	85	44
Umhlatuzana = 232	126	54.3	146	62.9	17	7.3	35	15.1	8	3.4	215	92.7	35	15.1
Total MSA n=1064	**249**	**23.4**	**637**	**59.9**	**292**	**27.4**	**495**	**46.5**	**143**	**13.4**	**759**	**71.3**	**526**	**49.4**

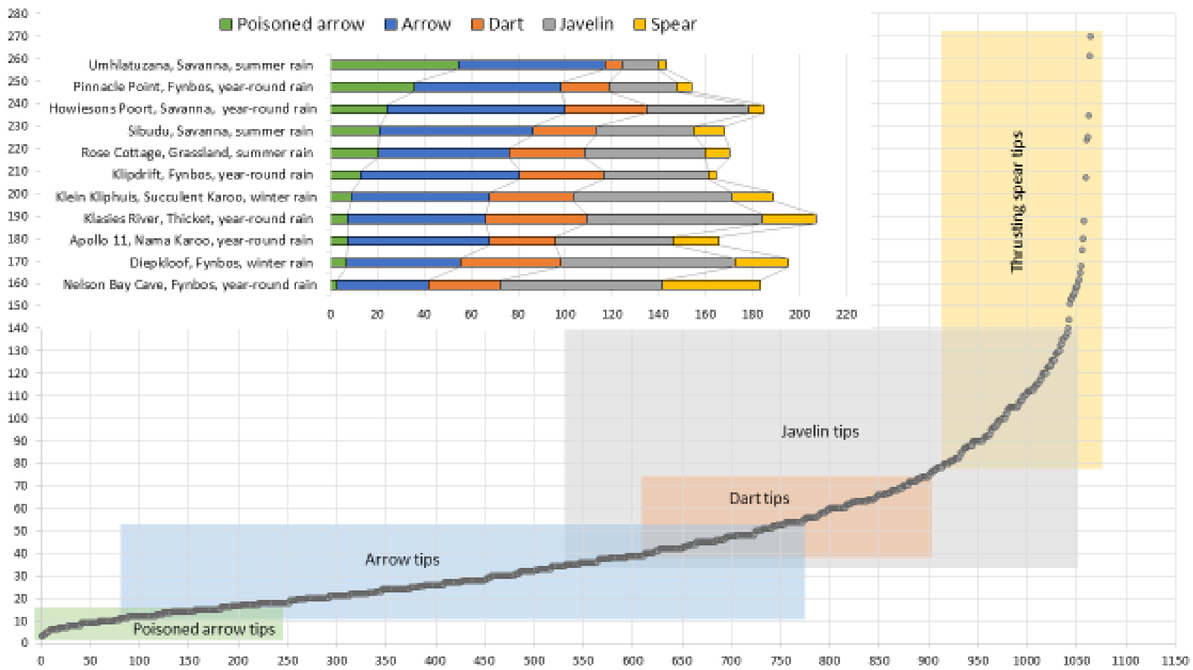


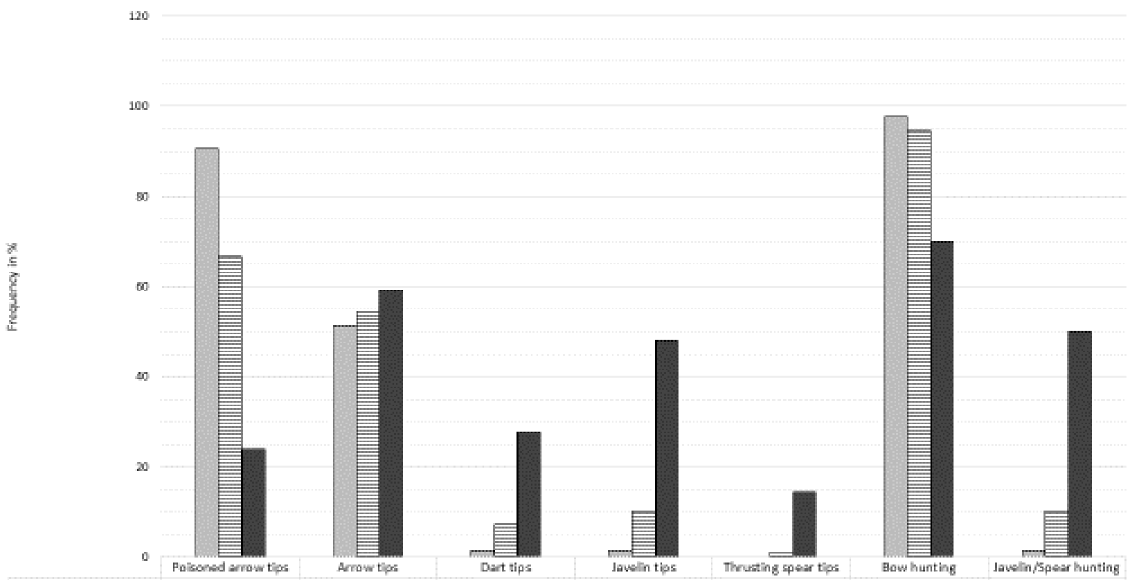
Fig. 7 [2 column fitting]. The background graph shows the individual data points on the X axis (minimum and maximum TCSA values = 2 grey dots for each piece) and their respective TCSA values are reflected on the Y axis. The rough proportional distribution of hypothetical effective weapon tip coverage for backed microliths of the Pleistocene Howiesons Poort techno-complex as a whole are reflected in the coloured blocks. The inserted bar chart shows the percentages of hypothetical effective weapon tip coverage for backed microliths from each of the sites included in the study, together with their biomes and rainfall regimes. Note that in each instance the total adds up to more than 100 because of the overlap between weapon-tip TCSA values.

4.3. Comparative results

With this paper, I set out to test for the hypothetical use of poisoned arrows during the Howiesons

Poort in southern Africa using the TCSA method on backed microliths. Poisoned bone arrowheads from historical and Later Stone Age contexts of the region, many of which still have poison residues on them, and are therefore of known use, set the TCSA standard for bow hunting with poisoned arrows (Lombard 2020; Table 1). Collectively, 90.5 % of these artefacts fall within the TCSA range for poisoned arrows, demonstrating that bow hunting with poisoned bone arrowheads was a deliberate hunting strategy during the last 40 ka or so (Fig. 8). Later Stone Age Wilton backed microliths show a frequency of 66.7 % hypothetically being effective for use as insets for poisoned arrows. This result implies that, even though bone points may have been the preferred poison carriers during Later Stone Age bow-hunting forays, there is good reason to suggest that hunters also deliberately knapped and used backed microliths for this purpose during most of the Holocene. The frequency of 24 % for Pleistocene Howiesons Poort backed microliths consistent with poisoned arrow hunting is comparatively low, implying that if it was practiced, it was not the preferred hunting strategy at the time. Yet, the hypothetical frequency is high enough to speculate about the introduction of poisoned arrows by more than 58 ka in southern Africa.

The TCSA data supports a hypothesis wherein hunters preferred to use backed microliths for hunting with unpoisoned arrows during the Howiesons Poort phase (Fig. 8). Although the frequencies for bone arrowheads (51.3 %) and Wilton backed microliths (54.5 %) are also relatively high, the frequency for the Howiesons Poort is the highest with 59.2 % of its backed microliths suitable for unpoisoned arrow tip use. The Later Stone Age bone and backed microlith frequencies for unpoisoned arrow use are somewhat lower than for poisoned arrow use, which is consistent with ethno-historical reports that indicate hunters carrying an array of arrowheads for different purposes in their quivers. The TCSA data show that during the Howiesons Poort, bow hunters were potentially less reliant on poisoned arrows than on their unpoisoned counterparts. Thus, if backed microliths were used to tip or barb arrows – as use-wear studies have indicated – bow hunting with unpoisoned arrows was habitually practiced between about 70 ka and 58 ka in southern Africa, while poisoned arrows may have been used occasionally.



	Poisoned arrow tips	Arrow tips	Dart tips	Javelin tips	Thrusting spear tips	Bow hunting	Javelin/Spear hunting
LSA Bone arrowheads	90.5	51.3	1.4	1.4	0	97.7	1.4
LSA Backed microliths	66.7	54.5	7.2	10.3	1	94.5	10.3
MSA Backed microliths	24	59.2	27.7	48	14.5	70.1	50

Fig. 8 [2 column fitting]**.** TCSA weapon tip frequencies compared for Later Stone Age bone arrowheads, known to have functioned as arrow tips, Later Stone Age Wilton backed microliths and Middle Stone Age backed microliths.

This is however not the full story. The comparative analysis also shows that bone points played an almost negligible role in hunting with darts and javelins, and not at all in hunting with thrusting spears (Fig. 8). For the Wilton backed microliths, some dart/javelin hunting is indicated. This is in contrast to the frequencies for these weapon tips during the Howiesons Poort phase, which are relatively higher. When the frequencies for arrow hunting are combined (poisoned + unpoisoned), we see that 70.1 % of the Howiesons Poort backed microliths would have been suitable for bow hunting and 50 % for spear hunting with either light-weight javelins (48 %) or heavy thrusting spears (14.5 %). These data show that Howiesons Poort hunters probably equipped themselves habitually with both arrows for bow hunting and javelins to throw at prey, and sometimes also with stabbing spears to optimise their hunting success. The possible introduction of poisoned arrows, may herald hunting traditions that would ultimately develop into the variety of hunting equipment encountered in, for example, the hunting kits of Kalahari bow hunters today.

5. Concluding discussion

There are two key outcomes for this study. First, I suggest that the median TCSA values of eight for the minimum and 18 for the maximum hafting scenarios of the Wilton backed microliths provide a robust standard for such artefacts used as insets for poisoned arrows. Secondly, the study shows that hypothetically, bow hunters introduced poisoned arrows, tipped or barbed with backed microliths, into their hunting kits during the Howiesons Poort phase in southern Africa. According to this interpretation, poisoned arrows were used occasionally (not habitually), which is in contrast with the Later Stone Age Wilton phase during which hunters preferred bow hunting with poisoned arrows using either bone or stone tips. During both phases, however, there is inter-site variability in the configuration of hypothetical weapon tip types, with poisoned arrowheads perhaps used most often in the Savanna and Grassland biomes with summer and year-round rainfall regimes, and least often in the Fynbos biome with winter rain.

Finding and identifying ancient traces of poison is not easy (e.g. Carlin et al., 2015; Wooding et al., 2017), but results obtained from organic artefacts, demonstrate that it is not impossible. For example:

- We were able to obtain chemical signatures of plant-based toxins from small samples of San arrow poisons mixed more than 90 years ago (Wooding et al., 2017);
- Shaw and colleagues (1963) found material of protein structure, alkaloids and their chemical combinations with glycosides in residues removed from San hunter-gatherer poisoned arrows used more than 100 years ago;
- Preliminary biomolecular results for the residues obtained from a 1000-year-old bone point show that the poison recipe contained *Euphorbia*, *Sanseviera* and *Adenium* extracts with a small amount of animal components (Sven Isaksson, pers. comm. September 2019; Lombard, 2020);
- d'Errico and colleagues (2012) reported residues containing ricinoleic acid found on a wooden poison applicator of ~24 ka;
- The same team also found a lump of material of ~40 ka containing triterpenoids derived from *Euphorbia tirucalli* resin, an ingredient often used in San arrow poisons (d'Errico et al., 2012);
- Lastly, we reported that a bone point from a Howiesons Poort context dating to ≥60 ka has a residue that may be poisonous based on preliminary Raman spectra (Bradfield et al., 2020).

Based on the results presented here, and permitting adequate preservation, the prediction is that the best possibility for poison residues used during the Wilton phase may be found on backed microliths from Jubilee Shelter, Gosho Shelter, Namakwa Sands, Wilton Shelter, Gehle Shelter, Wonderwerk Cave and Zaayfontein. For the Middle Stone Age Howiesons Poort, scrutinising the backed microliths from Umhlatuzana Rock Shelter, Pinnacle Point 5-6, Howiesons Poort Shelter, Sibudu Cave and Rose Cottage Cave for poisonous residues seems warranted.

The TCSA frequency for hypothetical dart hunting during the Howiesons Poort phase is 27.7 %, compared to 70.1 % for bow hunting (with either poisoned or unpoisoned arrows), and 50 % for spear hunting (with either thrown javelins or thrusting spears). Thus, even though the least probable technology, the frequency is high enough to raise again the question of spearthrower use during the African Middle Stone Age. Some North American scholars working on aspects of the evolution of hunting weapons in Africa assume that spearthrowers must have preceded bow hunting (e.g. Brooks et al., 2006; O'Driscoll and Thompson, 2017; Sahle and Brooks, 2019), probably because it represents weapon chronology in the Americas and Eurasia (e.g. Cattelain, 1997; Knecht, 1997; Bingham et al., 2013). Yet, the archaeological record of sub-Saharan Africa does not necessarily follow the timing or chronological patterns observed elsewhere, so that this assumption may be out of place. From a technical evolution perspective, spearthrower-and-dart technology and bow-and-arrow technology are based on two very different mechanical principles (Wittacker, 2006, 2013; Bingham et al., 2013), so that the one is not technologically ancestral to the other. Instead, a more appropriate candidate for the technical predecessor to bow hunting is the tensile energy stored in the cords and bent branches of spring traps (Lombard and Phillipson, 2010), for which there is proxy evidence in southern Africa at >70 ka (Wadley, 2010).

In the absence of any ethno-historical or direct archaeological evidence for spearthrower use in southern Africa, and considering the fact that the current TCSA range for javelin tips embraces that of dart tips, I suggest that the appropriate way forward is to apply the law of parsimony. According to this principle, the best interpretation of the data is the simplest explanation, requiring the fewest possible assumptions. It is therefore most feasible to interpret the Howiesons Poort TCSA data that fall in the overlap between the dart and javelin ranges as pointing towards javelin use – until evidence to the contrary comes to the fore.

In summary, the TCSA work presented here supports a hypothetical scenario of habitual bow hunting robustly supplemented by the use of lightweight javelins or throwing spears in southern Africa before ~58 ka, and that backed microliths probably played a substantial role in the manufacturing and use of both these hunting technologies. The results are also suggestive of the occasional use of poisoned arrows, but more work is required to strengthen this hypothesis. Today, few if any known hunter-gatherer groups rely solely on a single way of hunting. Instead, they use multiple weapon types, complemented with different forms of throwing implements and net and trap hunting. Based on the TCSA ranges, it is reasonable to suggest that Howiesons Poort hunters too were not dependent on a single weapon-delivery system during hunting forays, but that they regularly used at least two stone-tipped strategies to optimise their hunting success.

The work presented here is course-grained, aimed at generating broad impressions of potential variation in Stone Age hunting strategies associated with backed microliths across southern Africa within two discrete time slices. Yet, as Wadley and Mohapi (2008) pointed out: "a segment is not a monolith". In both the Wilton and Howiesons Poort techno-complexes spatiotemporal variation in morphology and raw material use is expected, and by focussing on these aspects in the future, fine-grained intra- and inter-site understanding may be gained about aspects that affected the invention and use of poisoned arrows in southern Africa.

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