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THE TIP CROSS-SECTIONAL AREAS OF POISONED BONE ARROWHEADS FROM SOUTHERN AFRICA

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Abstract
Current hunter-gatherers from the Kalahari in southern Africa are well-known for their use of poisoned arrowheads, and it is assumed that this tradition spanned most of the Holocene in the region. Recent archaeological work, however, indicates that the techno-behaviour may have originated sometime during the Pleistocene. Tracing the use of poisoned arrowheads through time is not an easy task. Here I explore the use of the tip cross-sectional area (TSCA) metric to analyse relatively large samples of bone points that are ethno-historically associated with Kalahari San poisoned arrow hunting. I add the southern African poisoned bone arrowhead TSCA range to the previous ranges established for North American atlatl dart tips, North American arrowheads and large thrusting spears. Based on the results obtained from 445 artefacts spanning historical, Later and Middle Stone Age phases, I show that poisoned bone arrowheads may have been in use in southern Africa throughout the last 60 000 years, and that a methodical effort to trace stone-tipped poison arrowheads may be warranted.

Keywords: poisoned arrows, bow hunting, Kalahari San, Middle Stone Age, arrow morphology

Introduction

Today, the Kalahari San of southern Africa are renowned for their use of relatively small bows and light-weight poisoned arrows, and there is a plethora of ethno-historical literature on the topic (Sparrman 1785; Stow 1905; Theal 1919; Schapera 1927; Dunn 1931; Lebzelter 1934; Vinnicombe 1971; Shaw et al. 1963; Marshall 1976; Lee 1979; Wiessner 1983; Deacon 1992; Webley 1994; Nadler 2005; Wadley et al. 2015; Chaboo et al. 2016; Backwell et al. 2018; Hitchcock et al. 2019). The origin of this hunting system, is however, a matter of debate (d'Errico et al. 2012a,b; Evans 2012; Bradfield et al. 2015). The tip cross-sectional area (TCSA) metric is a ballistically significant standard that works well for discriminating between, North American atlatl or spear-thrower dart tips, North American arrowheads and large experimental stabbing spears (Shea 2006; Sisk & Shea 2010). Using this metric, Shea (2006) concluded that his results did not support the hypothesis of the widespread use of stone-tipped atlatl darts or arrows in Africa before ~40 ka – an interpretation supported by Villa and Lenoir (2006). Bone points, although plausible weapon tips, were excluded from his analysis, because at the time they were considered to be "too few and too rare to be the focus of an investigation into broader patterns of projectile point origins and variability" (Shea 2006: 824).

By now, the TCSA metric 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). The metric is 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). Regardless of point type, only maximum width and thickness measurements are needed for calculating the TCSA metric (0.5 x maximum width x maximum thickness = TCSA value). This allows for the largest possible sample sizes to be compared directly with each other, and for studies to be easily replicated.

Sisk and Shea (2011) used TCSA values in combination with the tip cross-sectional perimeter (TCSP), which they deemed a more accurate proxy of the force needed to penetrate a target to a lethal depth. The drawback of the TCSP approach (when it comes to the interpretation of archaeological material as opposed to modern experimentation), is that penetration depth is invariably also affected by the mass of the shaft and the traits of the propelling mechanism, which cannot be known for archaeological bone- or stone-tipped weapons. Also, when poison is used, depth of penetration does not have to be lethal. Instead, all that is needed, is for the hide to be cut so that the poison may enter the prey animal's bloodstream – making the TCSA metric the most relevant. The TCSP metric is furthermore limited to stone points, and cannot be applied to backed geometrics (Sisk & Shea 2010), which currently represent the earliest evidence for bow hunting with stone-tipped or barbed arrows (Lombard & Phillipson 2010; Lombard 2011). TCSA analysis on the other hand, can be applied to these backed artefacts (Wadley & Mohapi 2008; Sano et al. 2019), as well as to bone points (Bradfield 2010). Brooks and colleagues (2006) emphasised weight as the most important aspect of weapon tips, based on the prediction that lighter projectiles require greater acceleration to achieve adequate penetration. Yet, similar to the TCSP metric, the weight of a weapon tip represents only a portion of a weapon's mass, and the weight of the shaft cannot be known for archaeological material where these elements do not preserve.

I also need to draw attention to the fact that any metric approach to weapon function, whether TCSA, TCSP, penetrating angle or mass, is only able to assess the potential of artefacts to function in the context of different weapon-delivery systems. These approaches can never demonstrate such use empirically. For example, Ötzi’s well-known stone-bladed knife seen on its own, would be interpreted as a spear tip with a TCSA value of 92 (measured from the drawing of Wierer et al. 2018: 6). Yet, because it was found hafted, we know it was a knife blade instead. Two more stone points found with Ötzi have TCSA values of 40 and 45 respectively, which would fall in the lower range of North American atlatls and the higher range of North American arrows. But, because they were found hafted in arrow shafts notched to fit a bowstring, we know their explicit function. For direct evidence that any ancient, haftless stone artefact functioned as a weapon tip, detailed and multi-stranded use-trace analyses are needed (Lombard 2005, 2006, 2011; Lombard & Phillipson 2010; also see Newman & Moore 2013; Clarkson 2016; Hutchings 2016). The overlap in Shea’s (2006) dart and arrow tip categories also reveals the false sense of security in purely quantitative studies. When dealing with the human past, numbers alone can seldom reveal the nuances necessary for a deep understanding of techno-behaviours – for that a measure of qualitative assessment and interpretation is required.

That being said, TCSA analysis is a pragmatic approach for analysing considerable sample sizes across spatiotemporal boundaries in a directly comparable manner, and therefore apt for building broad hypotheses about ancient weapon-delivery systems (Sano et al. 2016). This is especially true when interpretations of the results are backed up by ethno-historical, experimental and use-trace data. Here I argue that it may also be useful for assessing a tool class’s potential to function as a poisoned arrowhead, and that the TCSA range for this category of weapon tips has yet to be established.

In the southern African context, the most secure starting point for such investigation is bone points. Kalahari San hunter-gatherers still use bone, as well as very small iron tips, for poisoned arrow hunting (Wadley et al. 2015; Alam 2019). Many museums across the world now have relatively large collections of San bow-hunting kits with quivers full of ethno-historically collected poisoned bone-tipped arrows (Fig. 1). The function of the bone points themselves is therefore incontestable. Although arrow link-shafts, needles and awls cannot be excluded from the bone point category, careful morphological and use-trace work shows that in most cases, relatively thin and straight Later Stone Age bone points served as arrowheads (Bradfield 2012, 2015, 2016). What is more, several archaeological pieces also still have visible poison remains.

Figure 1. 1a: Arrows collected from the Cape of Good Hope, South Africa, by Atherstone in 1863 now housed in the Kew Economic Botany Collection in London, UK. 1b: Bone point arrowheads that became separated from the Atherstone arrows and poison collected with them. 1c: The hunter-gatherer quiver and arrows that were collected by Sparrman in 1777 from San hunter-gatherers in the Eastern Cape, South Africa, now curated at the Ethnographic Museum in Stockholm, Sweden. 1d & e: Details of other ethno-historically collected poisoned bone arrowheads from southern Africa housed at the Ethnographic Museum in Stockholm. (All photographs by Anders Högberg©.)

Initially it was thought that poisoned bone arrowheads were used in southern Africa only after ~8 ka (ka=thousand years old/ago) (Inskeep 1987; Noli 1993). The last decade, however, saw some indication that archaeological bone points from the region, dating to more than 30 ka, may have been used to tip poisoned arrows (d'Errico et al. 2012; Robbins et al. 2012). Most recently, we reported that a bone point of >60 ka, from Klasies River Mouth in the Eastern Cape, South Africa, has a residue that may be poison based on its distribution and the interpretation of preliminary non-destructive Raman spectra (Bradfield et al. 2020). This point, as well as one from Sibudu Cave in KwaZulu-Natal, South Africa, of similar age (Bradfield & Lombard 2011; Backwell et al. 2018), also displays macro- and micro-fractures that are consistent with stresses caused by high-velocity impact, such as arrow use (Bradfield et al. 2020).

With this contribution I aim to establish the TCSA range for poisoned bone arrowheads from southern Africa to complement the set of standards currently in use as established by Shea (2006). I start with a TCSA analysis of ethno-historically collected poisoned bone arrowheads. Subsequently, I provide the TCSA range for a relatively large number of Later Stone Age bone points dating from ~40 ka to just a few hundred years ago, evaluating them against the range obtained for the ethno-historical sample.

Lastly, I assess the possibility that some of the handful of currently known Middle Stone Age bone points could have served as poisoned arrowheads.

TCSA analysis of ethno-historical poisoned bone arrowheads from southern Africa

The metrics of 128 ethno-historically collected bone points were used to determine their TCSA range (Table 1; Fig. 2). This sample size is comparable to the 118 pieces that Shea (2006) used as basis for the TCSA standard for North American stone arrowheads. The northern-most assemblage in this study is housed in the KwaZulu-Natal Museum (Pietermaritzburg, South Africa), but comes from the Caprivi Strip in Namibia (Fig. 2b), a region associated today with the Ju/hoan San group. It consists of 13 complete bone-tipped arrows with notched reed shafts. Dark poison residues are visible on some of the arrowheads (Fig. 2c). Four sets come from the Fourie Collection studied by Bradfield (2012). Louis Fourie collected these artefacts during 1916-1922 from Kalahari San hunter-gatherers who lived on the border between Namibia and Botswana (Fig. 1b). The groups from which he collected the arrows include, amongst others the ǂAon-//Ein (n=38), !Kung (n=29), Hei-//om (n=5), Naron (n=6) and Hu//Ein (n=2) (Fig. 1a). The results of the arrows representing the first four groups are presented within the context of their groups, and the two Hu//Ein arrows are included in the final count of the ethnographically-collected material (Table 1). Some arrows collected from Nama Karoo or !Xam San are currently housed at the Pitt Rivers Museum, UK, and were collected between 1815 and 1886 (Bradfield 2014, 2015), 21 of these are included in this study. Lastly, I measured and calculated the TCSA values for the arrows of a set that was found in the Drakensberg (KwaZulu-Natal, South Africa), donated to the KwaZulu-Natal Museum in 1926 (Fig. 1d). It is thought that these arrows were last used about 150 years ago, when black farmers drove the few remaining 'troublesome and thieving' Duma San hunter-gatherers deep into the mountains (Vinnecombe 1971: Schlebusch et al. 2016).

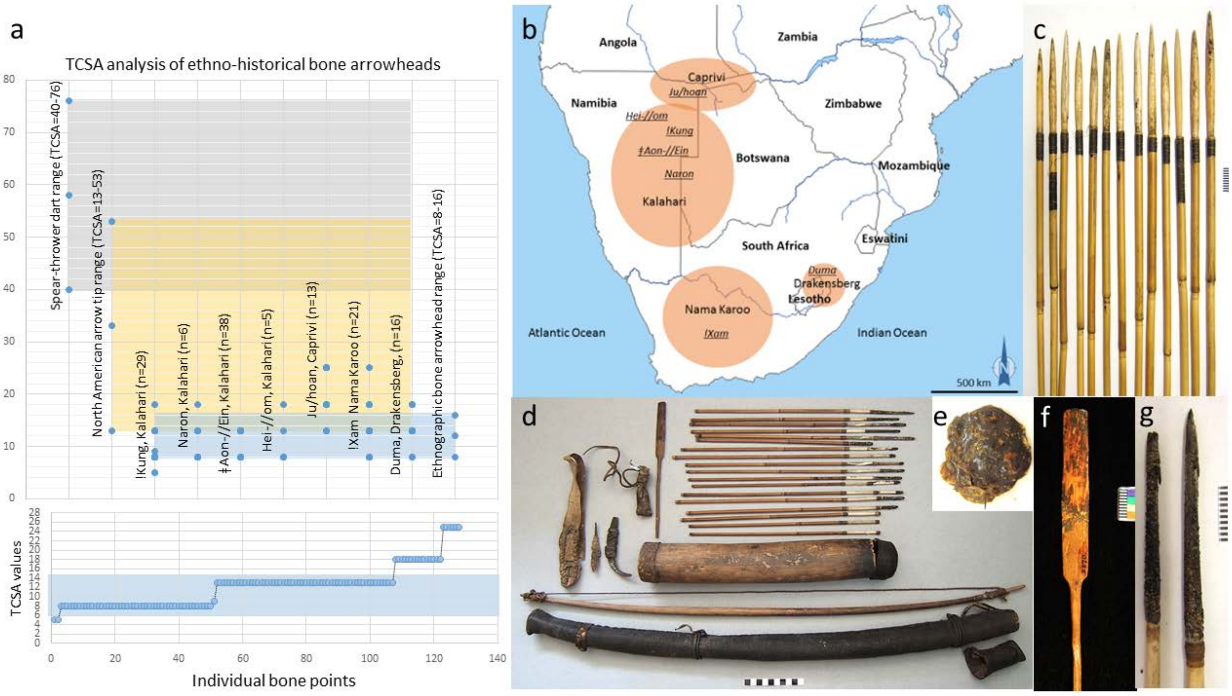

Figure 2. 2a top: Results of the TCSA analysis of ethno-historically collected bone arrowheads from southern Africa. The blue rectangle represents the range for poisoned bone arrowheads, compared with the range for North American stone arrowheads (yellow rectangle) and spear-thrower darts (grey rectangle). 2a bottom: TCSA values for each of the points showing that 105 (82%) of all the ethno-historical bone points fall within the 8-16 range for poisoned bone arrowheads. 2b: Distribution map of areas the arrows were collected from. 2c: Arrow set collected from the Caprivi region. 2d-g: The Drakensberg San hunting set with poison lump (e), poison spatula (f), and detail of poisoned bone arrowheads (g).

The Drakensberg arrows form part of a well-preserved hunting kit (Fig. 2d). Amongst other things, it contains a light-wood arrow quiver, which held a poison bag and a wooden spatula for poison application (Fig. 2f), as well as a strung bow and bow case made from sturdy hide sewn lengthwise and capped on both ends. The bow is simple, 89 cm long with a 1.5 cm diameter at the centre where it is thickest, weighing only 91 g (Vinnecombe 1971). Where the tips are intact, the arrowheads are all still covered with a thick black substance, the now-dry and crumbly remains of the poisonous paste that was used on them more than a century ago (Fig. 2g). Their shafts were identified by Vinnecombe (1971) as being common thatch grass (*Cymbopogon validus* or *Miscanfhidium capense*), but may rather be fluitjiesriet, the Afrikaans common name for *Phragmites australis*, meaning whistling reeds (Bradfield pers. comm. June 2020). The shafts have an average length of 29 cm and are un-fletched, which is a characteristic of southern African San hunter-gatherer arrows. The mean weight of the complete arrows is ~7 g (Vinnicombe 1971), thus somewhat lighter than what has been recorded for arrows from the Cape and Kalahari weighing ~10 g each (Noli 1993), and for arrows from the Fourie collection with a mean weight of ~12 g (Bradfield 2010). I provide these details because I have found that researchers working from Global North laboratory settings often seem unable to reconcile preconceived ballistic expectations of archery equipment with the delicate nature of the southern African bow-and-arrow sets. Yet, in the hands of an experienced hunter, they are perfectly accurate up to 30 m (Stander et al. 1996), and lethal when combined with poison. In Sparrman's (1785: 198) words: "Their weapons are poisoned arrows, which, shot out of a small bow, will fly to the distance of two hundred paces; and will hit a mark with a tolerable degree of certainty, at the distance of fifty, or even a hundred paces. From this distance they can by stealth, as it were, convey death to the game they hunt for food, as well as to their foes, and even to as large and tremendous a beast as the lion".

The width, thickness and TCSA ranges for each assemblage in this study consist of the average measurements (W/T) or TCSA values for the population ± the standard deviation. Most bone points are cylindrical or almost cylindrical so that their maximum widths and thicknesses are the same, i.e., the maximum diameter of the point (Table 1). Collectively, the ethno-historical bone arrowheads have a mean TCSA value of 12±4 (TCSA ± standard deviation), resulting in a TCSA range of 8-16. This range for poisoned bone arrowheads of the last few centuries from southern Africa, is considerably smaller compared to the 40-76 TSCA range for spear-thrower darts, and at the very bottom of the 13-55 TCSA range for North American arrowheads (Table 1, Fig. 2a), forming a distinct ballistic group. The median diameter and TCSA value for each assemblage as well as for the ethnographic collective are also provided. These values reflect the dominant trend for ethnographic poisoned bone arrowheads that is less affected by outliers and skewed data in the asymmetrical distribution of the individual points (Fig. 2a).

Table 1: TCSA results for ethno-historically collected bone points, generally used as poisoned arrowheads. Key: ^source for raw data, *new data.

Type/Context	Age	Max. diam.	TCSA	Med. diam./ TCSA	Sources
!Kung, Kalahari (n=29)	<150 y	4±1*	9±3*	4/8*	^Bradfield 2012, *this study
Hei-//om, Kalahari (n=5)	<150 y	5±1*	11±4*	4/8*	^Bradfield 2012, *this study
ǂAon-//Ein, Kalahari (n=38)	<150 y	5±1*	11±3*	5/13*	^Bradfield 2012, *this study
Duma, Drakensberg (n=16)	<150 y	5±1*	13±3*	5/13*	*this study
Naron, Kalahari (n=6)	<150 y	5±1*	13±3*	5/13*	^Bradfield 2012, *this study
!Xam,Nama Karoo, Pitt Rivers (n=21)	<200 y	5±1*	13±4*	5/13*	^Bradfield 2014, *this study
Caprivi San, KZN Museum (n=13)	<150 y	6±1*	20±5*	6/18*	*this study
All ethno-historical bone points (n=128)	**<200 y**	**5±1***	**12±4***	**5/13***	***this study**

Four of the ethno-historical sets conform to the 5/13 diameter/TCSA median for all the ethno-historical arrowheads, these include the arrows of the ǂAon-//Ein and Naron from the Kalahari, the !Xam of the Nama Karoo and the Duma of the Drakensberg. The median values for points of the Kalahari !Kung and Hei-//om are smaller (4/8), whilst those from the Caprivi are larger (6/18), and several assemblages contain individual points (n=21 or 16% of 128 points) that have TCSA values larger than the 8-16 range (Table 1, Fig. 2a).

Although the ethno-historically collected points are relatively standardised (Bradfield 2010), the small variations in morphology may reflect differences in the type of animals hunted (Goodwin 1945), season and availability of poison (Bartram 1997; Hitchcock & Bleed 1997), or socio-cultural relationships amongst groups or hunters (Clark 1977; Wiessner 1983; Wadley 1987, 1993). For example, long and slender points (usually thinner than 5 mm in diameter [Smith & Poggenpoel 1988]), are often found coated in poison, whilst the more robust ones may also be used un-poisoned (Bradfield 2010, 2014; Backwell et al. 2018). Smith and Poggenpoel (1988) noted that some San bone points were thicker the further north they occur, which seems to be reflected in the Caprivi sample presented here. At the same time, some of the Kalahari and Nama Karoo San arrowheads are also more robust (Fig. 2a), even though their assemblage median conforms to the 5/13 diameter/TCSA configuration (Table 1). Both the slender and robust bone arrowheads are common in the hunting kits of all San hunter-gatherer groups of the Kalahari (Wanless 2007), and both types were found in the Drakensberg quiver where all the arrows were poisoned (Fig. 2d). Most of the Caprivi arrowheads also have poison residues, even though they represent the most robust set in the study. Whereas thicker, un-poisoned bone arrowheads may kill some small prey species, poison is mostly needed for hunting larger antelope with bone arrowheads – robust or slender. The presence of poison on some of the robust arrowheads further cautions against the notion that these invariably represent un-poisoned arrows.

TCSA analysis of Later Stone Age bone points from across southern Africa

It is generally accepted that Holocene Later Stone Age bone points were used, although perhaps not exclusively, to tip poisoned arrowheads in a similar way to the ethno-historically collected examples. Direct evidence for such application comes from a poisoned bone point with broken tip from Kruger Cave dated to 1020±70 BP (Mason 1988, Fig. 3b & c). Preliminary bio-molecular results for the residues obtained from this 1000-year-old bone point show that the poison recipe contained plant ingredients such as *Euphorbia*, *Sanseviera* and *Adenium* extracts with a small amount of animal components (Sven Isaksson pers. comm. September 2019). The plant exudates are all well-known ingredients of San hunter-gatherer arrow poisons (Shaw et al. 1963; Bradfield et al. 2015). Four more points from Kruger Cave are thought to have possible poison residues, two of which date to >8 ka. Bone points from the Sehonghong and Driel shelters spanning the Holocene have similar residues (Bradfield 2014) (Fig. 3b).

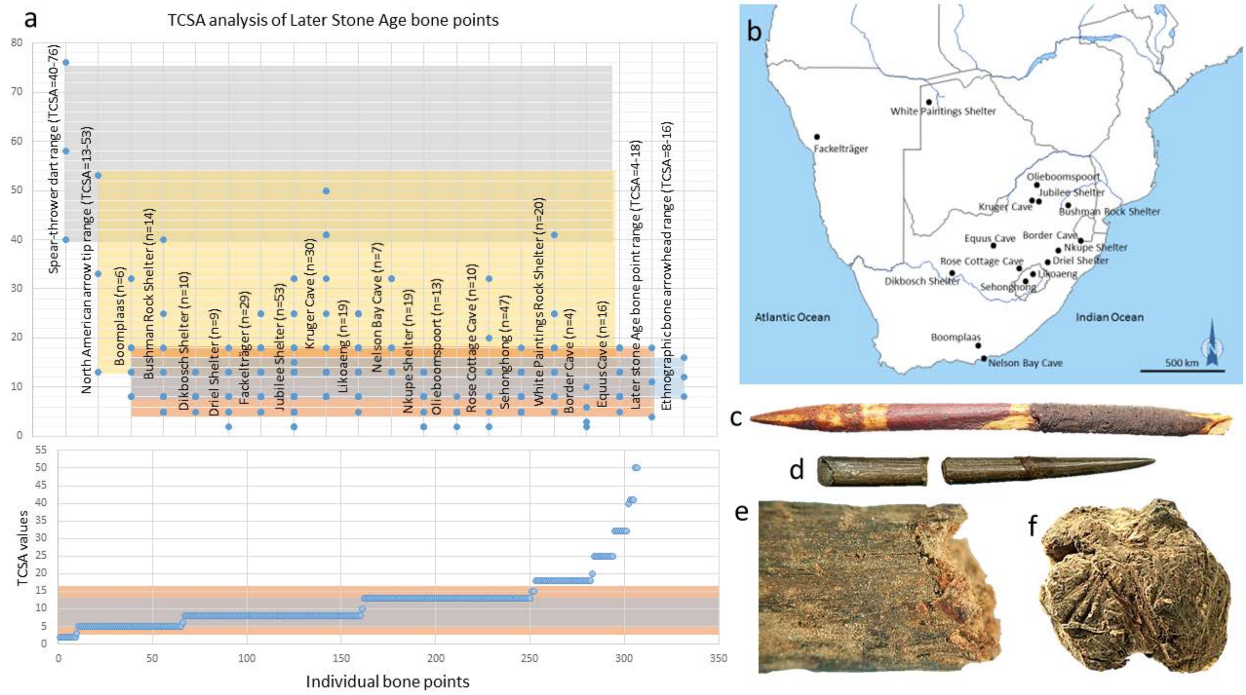

Figure 3. 3a top: Results of the TCSA analysis of Later Stone Age bone points from southern Africa. The orange rectangle represents the suggested range for poisoned bone arrowheads in general, compared with the range for ethno-historically collected poisoned bone arrowheads from southern Africa (blue rectangle), North American stone arrowheads (yellow rectangle) and spear-thrower darts (grey rectangle). 3a bottom: TCSA values for each of the points. 3b: Distribution map of archaeological sites where the artefacts were excavated from. 3c: 1000-year-old point from Kruger Cave with poison residues (with permission from Justin Bradfield©). 3d: Bone point from Border Cave dating to the Pleistocene. 3e) Tip of the poison applicator from Border Cave dated to ~24 ka, with poisonous residue. 3f) Lump of material found at Border Cave, dated to ~41 ka, containing triterpenoids derived from *Euphorbia tirucalli* resin that may have been used to poison arrows. (All images of Border Cave artefacts with permission from Lucinda Backwell© and Francesco d'Errico©.)

Direct evidence for the use of poisoned arrows during the Pleistocene comes from Border Cave in KwaZulu-Natal, South Africa. Here, a wooden poison applicator (Fig. 3e), dated to 24 564-23 941 cal BP, has residues with ricinoleic acid, originally interpreted as stemming from poisonous castor beans (d'Errico et al. 2012). Whereas ricin from castor beans might be an effective arrow poison, we could not find any southern African ethnographic reference to such use, and there is uncertainty about whether the castor bean plant, indigenous to north-eastern Africa and India, was present in southern Africa during the Pleistocene. We (Bradfield et al. 2015) did find, however, that the indigenous crab's eye creeper (*Abrus precatorius*) has been recorded as an arrow poison (Watt & Breyer-Brandwijk 1962), and that the seeds of this plant contain the toxin abrin, which is similar in molecular structure and properties to ricin (Wei et al. 1974; Van Wyk et al. 2002; Dickers et al. 2003). Thus, even if the plant species may have been misinterpreted initially, the fact remains that the 24-thousand-year-old residue was poisonous, and that it was found on a poison applicator not unlike the one associated with the 150-year-old Drakensberg hunting kit. A lump of material (Fig. 3f), dated to 41 167-39 194 cal BP, containing triterpenoids derived from *Euphorbia tirucalli* resin was also found at Border Cave (d'Errico et al. 2012). Euphorbia latex is associated with ethno-historically recorded San arrow poison recipes across southern Africa (Shaw et al. 1963; Bradfield et al. 2015).

Here I present the TCSA analysis results for 306 bone points from 16 Later Stone Age sites with deposits spanning the last 40 ka (Table 2, Fig. 3a). Of these points, 186 (61%) fall within the narrow 8-16 TCSA range that was the standard for ethno-historically collected poisoned bone arrowheads. Interestingly, 66 (21%) of the archaeological points are more slender, with a TCSA range of between 5 and 8, making them even more dependent on poison to be effective as arrowheads (Deacon 1992). Some of the points (n=55, 18%) were also more robust compared to the ethno-historical sample (Table 2, Fig. 3a). Based on the cumulative ethno-historical and Later Stone Age results, as well as the qualitative information provided above, I suggest a TCSA range of 4-18 for poisoned bone arrowheads from southern Africa.

Table 2. TCSA results for Later Stone Age points from southern Africa. Key: ^source for raw data, ^^measured from illustrations in the source cited, *new data,

Type/Context	Age	Max. diam.	TCSA	Med. diam./ TCSA	Sources
Olieboomspoort (n=13)	~1.4-0.7 ka	3±0*	5±1*	3/5*	^Bradfield 2014, *this study
Border Cave (n=4)	~34-40 ka	4±1*	7±5*	3.5/6.5*	^d'Errico et al. 2012, *this study
Bushman Rock Shelter (n=14)	~12.5-9.5 ka	4±2*	12±10*	4/8*	^Bradfield 2010, *this study
Dikbosch Shelter (n=10)	~1.5 ka	4±1*	9±2*	4/8*	^Bradfield 2014, *this study
Driel Shelter (n=9)	~0.4-0.2 ka	4±1*	9±5*	4/8*	^Bradfield 2014, *this study
Equus Cave (n=16)	<6 ka	5±1	11±4*	4/8*	Stammers et al. 2017, *this study
Fackelträger (n=29)	~3-0.3 ka	5±1*	12±5*	5/13*	^^Richter 1991, *this study
Jubilee Shelter (n=53)	~8.5-1.3 ka	4±1	11±6*	4/8*	Bradfield 2010, *this study
Nkupe Shelter (n=19)	3-0.4 ka	4±1*	9±4*	4/8*	^Bradfield 2014, *this study
Sehonghong (n=47)	<12 ka	4±1*	9±4*	4/8*	^Bradfield 2014, *this study
Rose Cottage Cave (n=10)	~27-0.5 ka	5±2	12±6*	4.5/12*	Bradfield 2010, *this study
Kruger Cave (n=30)	≤10 ka	6±2*	17±13*	5/13*	^Bradfield 2014, *this study
White Paintings Rock Shelter MSA-LSA (n=20)	≤35.70±3.33 ka	5±2*	15±9*	5/13*	^^Robbins et al. 2012, *this study
Boomplaas (n=6)	~21-1.5 ka	6±1*	17±8*	5.5/15.5*	^^Deacon 1982, *this study
Likoaeng (n=19)	~1.7 ka	5±1*	16±6*	6/18*	^Bradfield 2014, *this study
Nelson Bay Cave (n=7)	~18.6-0.5 ka	6±1*	21±8*	6/18*	^^Deacon 1982, *this study
All Later Stone Age bone points (n=306)		**5±1**	**11±7**	**4/8**	

The TCSA values for a handful of robust Later Stone Age bone points fall within the range that Shea (2006) suggested for spear-thrower dart tips, but Bradfield (2010) interpreted the large points from Nelson Bay Cave as spear tips. In this context it is necessary to highlight that although North American scholars have suggested the use of spear throwers for some stone points from southern

Africa (perhaps because it represent the chronology of weapon use in North America [e.g. Brooks et al. 2006; Sisk & Shea 2011]), to date, there is no ethno-historical nor direct archaeological evidence for the use of such a weapon system in sub-Saharan Africa. Instead, small, lightweight spears are known be part of every San bow hunter's kit (Sparrman 1786). In historical times such spears are fitted with iron tips (Fig. 4), which are so small that they may fall into the American dart or arrow tip ranges, as is the case of some of the Later Stone Age bone points in this study (Fig. 3a). The San spears are mainly used for the final killing (cutting the aorta) of a prey antelope hit with a poisoned arrow and weakened by tracking. These spears are also used as throwing spears to hunt smaller antelope, especially when arrow poison is not available (Hitchcock & Bleed 1997). Although some examples exist (Sampson 1974; Bradfield 2014), bone spear tips are not widely known from the Later Stone Age, and configurations of hafted flaked stone artefacts or un-tipped wooden spears may have been used for the same purposes instead.

Figure 4: Khomani-San hunter from the Kalahari with a light-weight spear – note the small dimensions of the artefact. (Image purchased for reproduction from Alamy, photographer: Fabian von Poser©.)

TCSA values of Middle Stone Age bone points from South Africa

It seems that where there is good bone preservation at Middle Stone Age sites, there may also be bone artefacts, sometimes including bone points (d'Errico & Henshilwood 2007; Backwell et al. 2008; Bradfield et al. 2020). Backwell and colleagues (2018) have suggested that the bone point from Sibudu Cave (KwaZulu-Natal, South Africa), from a context dated to 61.7±1.5 ka, is morphologically similar to un-poisoned bone arrowheads used by Kalahari San hunter-gatherers in the twentieth century (Fig. 5f left). The macro- and micro-fractures of this point are consistent with what can be expected to develop during arrow use (Bradfield & Lombard 2011; Backwell et al. 2018). At the same site, a more slender bone point fragment was found in a context dating to 64.7±2.3 ka (Fig. 5f right), these artefacts are interpreted as fitting a hypothesis of bow hunting at the site since ~65 ka (Backwell et al. 2008).

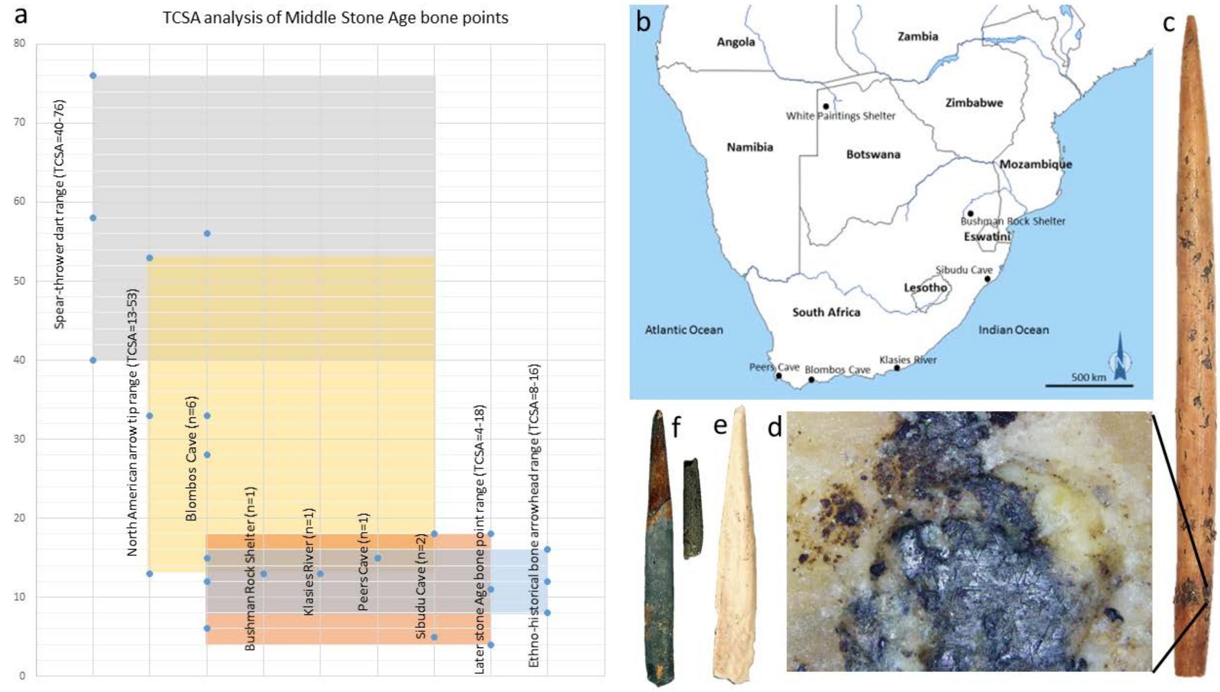

Figure 5: 5a) Results of the TCSA analysis of Middle Stone Age bone points from southern Africa. The orange rectangle represents the suggested range for poisoned bone arrowheads in general, compared with the range for ethno-historically collected poisoned bone arrowheads from southern Africa (blue rectangle), North American stone arrowheads (yellow rectangle) and spear-thrower darts (grey rectangle). 5b) Distribution map of archaeological sites where the artefacts were excavated from. 5c) The bone point from Klasies River Mouth that is older than 60 ka. 5d) Micrograph of the residue dotted over the surface of the Klasies river point that may be poisonous (with permission from Justin Bradfield©). 5e) The bone point from Peers Cave (with permission from Justin Bradfield©). 5f) The point and point fragment from Sibudu Cave older than 60 ka (with permission from Lucinda Backwell & Francesco d'Errico©).

From the same contexts as the bone points from Sibudu, small quartz backed pieces have also been interpreted as arrow tips and barbs used at the site (Wadley & Mohapi 2008; Lombard 2011; de la Peña et al. 2018). A similar interpretation applies to quartz artefacts of comparable age from Umhlatuzana Rock Shelter, also in KwaZulu-Natal (Lombard and Phillipson 2010). Rots and colleagues (2017) suggested that starchy residues on serrated stone points from Sibudu Cave, dated to >77 ka, my represent poison. Here I show that the TCSA values for both of the Sibudu bone points fall within the range of Later Stone Age bone points that were most likely used as poisoned arrowheads (Table 3, Fig. 5a). Measuring them against the ethno-historical TCSA range, the younger point from Sibudu is more robust, and the older one more slender. This thin point, if used to tip an arrow, would only have been effective with poison. The more robust of the two artefacts falls within the lower TCSA range of North American arrowheads, which is markedly smaller than the TCSA range for spear-thrower dart tips. Thus, if these two bone points were used as weapon tips, they represent bow hunting at >60 ka in KwaZulu-Natal, and perhaps also hunting with poisoned arrows.

The bone point from Klasies River is also older than 60 ka (Fig. 5c), and the distribution and orientation of use-wear on it show that the point was hafted, probably in a reed shaft (Bradfield et al. 2020). The artefact also has micro-cracks with characteristics that are in line with that of arrow use (Guthrie 1983; Bradfield & Lombard 2011). A black residue that is dotted over most of the point's surface (Fig. 5d), is especially concentrated in a circumferential band close to the proximal end of the point, immediately adjacent to the discoloured section where it was fitted into the shaft or shaft binding. This substance may represent remains of an adhesive that was used to glue the point into its shaft, but its distribution is also consistent with that of poison application (Bradfield et al. 2020). These two functions for pastes (i.e., adhesives and poisons) applied to southern African arrowheads are not mutually exclusive (Wadley et al. 2015), so that it may have served both purposes on the Klasies River point. Micro-morphologically, the residue on the bone point from Klasies River is similar to poisons used on twentieth century arrows and poison applicators (Bradfield et al. 2020), and to residues interpreted as adhesives found on quartz arrow tips/barbs from Sibudu Cave and Umhlatuzana Rock Shelter (Lombard 2007, 2011; Lombard and Phillipson, 2010; also see Charrie-Duhaut et al. 2013). This point also has the 5/13 diameter/TCSA ratio that is identical to the ethno-historical median for poisoned bone arrowheads, and lies at the lowest margin for North American arrowheads (Table 3, Fig. 5a).

Table 3. TCSA results for Later Stone Age points from southern Africa. Key: ^source for raw data, ^^measured from illustrations in the source cited, ˣraw data provided by researcher, *new data.

Type/Context	Age	WxT	Diam.	TCSA	Sources
Sibudu Cave (PGS)	64.7±2.3 ka		3	5*	^Backwell et al. 2008, *this study
Sibudu Cave (GS)	61.7±1.5 ka		6	18*	^Backwell et al. 2008, *this study
Klasies River (MSA HP)	>60 ka		5	13*	^Bradfield et al. 2020, *this study
Blombos Still Bay (8940)	~80-72 ka	6x2		6*	^Henshilwood et al. 2001, *this study
Blombos Still Bay (8949)	~80-72 ka	8x3		12*	^Henshilwood et al. 2001, *this study
Blombos Still Bay (8954)	~80-72 ka	6x5		15*	^Henshilwood et al. 2001, *this study
Blombos Still Bay (8947)	~80-72 ka	8x7		28*	^Henshilwood et al. 2001, *this study
Blombos Still Bay (8964)	~80-72 ka	13x5		33*	^Henshilwood et al. 2001, *this study
Blombos Still Bay (tanged)	~80-72 ka	14x8		56*	^^d'Errico & Henshilwood 2007, *this study
Bushman Rock Shelter MSA	nd		5	13*	^Bradfield 2010, *this study
Peers Cave MSA	~75-50 ka		6	15*	ˣBackwell, *this study

Six older bone points, dating to ~80-72 ka, come from Blombos Cave along the southern coast of South Africa (Henshilwood et al. 2001, d'Errico and Henshilwood 2007). Three of them were initially interpreted as 'projectile points', based on their trend towards having cylindrical shapes with almost-circular cross-sections, similar to some Kalahari San and Later Stone Age bone points (Henshilwood et al. 2001). In subsequent papers they are called 'spears' (d'Errico & Henshilwood 2007; Backwell et al. 2008). Backwell and d'Errico (2016) acknowledge that it is difficult to demonstrate spear use for bone points, because relatively large bone arrowheads are known ethno-historically and archaeologically (Guthrie 1983; Bosc-Zanardo et al. 2008; Bradfield 2012; Zhilin et al. 2014). Yet, they go on to suggest that "the interpretation of the Blombos bone artefacts as spear points is none-the-less consistent with most ethnographic and recent archaeological stone point dimensions, which show spear tips to be 5 times larger than arrowheads" (Backwell & d'Errico 2016: 20).

Bradfield (2010) identified four points (one only a fragment and not included here) and two possible spearheads in the Blombos collection, but found that collectively they are morphologically more similar to robust bone arrowheads from the Fourie collection than to the presumed bone spear tips from Nelson Bay Cave. Here I show that three of the bone points from Blombos Cave have TCSA values consistent with Later Stone Age bone points with a TCSA range of 4-18 that could have been used as poisoned arrowheads. Two of these points fall within the narrow poisoned bone arrowhead range for ethno-historically collected arrows (TCSA 8-16), and one is smaller, which if used as an un-poisoned arrowhead would have been ineffective. Two of the Blombos Cave bone points fall in the range of North American arrowheads, and the tanged bone point in the range of spear-thrower darts or light-weight Kalahari San throwing spears (Table 3, Fig. 5a).

Concluding discussion

With this study, I added a new TCSA metric standard for poisoned bone arrowheads from southern Africa (TCSA=11±7) to complement the existing standards for North American stone arrowheads (TCSA=33±20), North American atlatl dart tips (TCSA=58±18), and experimental thrusting spears (TCSA= 168±89) as set by Shea (2006). Most Later and Middle Stone Age bone points fall within the poisoned bone arrowhead TCSA range, but there are also several that are more robust, falling within the range of North American arrowheads. I suggest that these are the best candidates for having been used as un-poisoned arrowheads at sites such as Boomplaas, Bushman Rock Shelter, Fackelträger, Jubelee Shelter, Kruger Cave, Likoaeng Shelter, Nelson Bay Cave, Rose Cottage Cave, Border Cave and Blombos Cave, in combination with the poisoned arrowhead category from all of these sites. Such an interpretation would be consistent with ethno-historical observations of southern African bow-hunting kits containing a range of arrow types to suit hunting needs and the availability of ingredients for making arrow poison. Potential bone tips for light-weight spears may be represented by the bone points that fall in the TCSA range for atlatl dart tips and its overlap with North American arrowheads.

These would include the Middle Stone Age tanged bone point from Blombos Cave (Fig. 5a), a Later Stone Age bone point each from Bushman Rock Shelter and Border Cave, and two of the Later Stone Age bone points from Kruger Cave (Fig. 3a).

Based on the results of the TCSA analyses presented here, it seems that if southern African Stone Age bone points were produced for hunting purposes, most of them would have been morphometrically and ballistically suitable for use as poisoned arrowheads, and there is good reason to suggest that this tradition may have deep-time roots – perhaps spanning more than 70 ka. Whereas bone points are always less numerous in Stone Age archaeological assemblages compared to stone artefacts, this analysis of 445 artefacts, in combination with previous work by Backwell and Bradfield on bone points (Backwell et al. 2008, 2018; Bradfield & Lombard 2011; Bradfield 2012, 2015, 2016; Backwell & d'Errico 2016; Bradfield et al. 2020), demonstrate their potential to contribute to lithic research that argue for bow hunting in southern Africa at >60 ka (Lombard & Pargeter 2008; Wadley & Mohapi, 2008; Lombard and Phillipson, 2010; Lombard, 2011; Brown et al. 2012; de la Peña et al., 2018).

Whereas, Shea (2006) found a lack of support for the widespread use of stone-tipped atlatl darts or arrows in Africa before ~40 ka, I suggest that in southern Africa bow hunting was habitually practised since ~65 ka. The southern African Middle Stone Age bone point sample is too small to assess how widespread this techno-behaviour was before 40 ka. Our results for the Klasies River bone point, however, expands the possible distribution for early bow hunting, previously limited to archaeological sites in KwaZulu-Natal, to include the Cape (Bradfield et al. 2020). The limited number of deep-time bone arrowheads is probably partly due to poor bone preservation in these older contexts (see Robbins et al. 2012), but more work is required to unravel the role of stone in tipping Pleistocene arrows in southern Africa. Where such work has been conducted systematically, use-trace evidence of arrow tips and barbs has been found (Lombard & Phillipson, 2010; Lombard, de la Peña et al., 2018), backed up by morphometric interpretations (Wadley & Mohapi, 2008; 2011; Brown et al. 2012) and experimental work (Pargeter 2007; Lombard & Pargeter 2008; Pargeter et al. 2016; Pargeter et al. 2018).

I suggest that the Shea (2006) conclusion was based on too narrow an understanding of how arrowheads may manifest in southern Africa. My prediction is that with dedicated, continued investigation, including TCSA analyses of more comprehensive lithic samples from the region pre-dating 40 ka, the body of evidence for deep-time bow hunting will increase exponentially. Because it is well-grounded both in the ethno-historical and Later Stone Age records of southern Africa spanning the last 40 ka, the TCSA standard range for poisoned bone arrowheads as set in this contribution could serve as middle range for such future investigation,

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