‘Discerning and explaining shape variations in Later Stone Age tanged arrowheads, southern Africa

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DIVISION OF ARCHAEOLOGY

SCHOOL OF GEOGRAPHY, ARCHAEOLOGY AND ENVIRONMENTAL STUDIES

i. DECLARATION

I, Ilan Ryan Smeyatsky, declare that this is my own original work. It has been submitted for a Master of Science degree at the University of the Witwatersrand. It has not been submitted to any other academic institution.

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Ilan Ryan Smeyatsky

ii. ABSTRACT

Over the past decade a new method of statistical shape analysis, geometric morphometrics, has been applied to the study of artefact shapes. Later Stone Age (LSA) tanged stone arrowheads, hypothesized to act as stylistic markers among prehistoric southern African hunter-gatherer groups, have been analysed with geometric morphometrics and reveal spatially coherent variations in their shape. After being tested against several variables that may have had an effect on arrowhead shape, these stylistic spatial variations could very well indicate large scale linguistic or other kinds of boundaries between different elements of prehistoric San populations. Understanding them can shed light on the social and economic organization of southern African hunter-gatherers during the later Holocene.

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- Museum of Archaeology & Anthropology, University of Cambridge (Downing)
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1. INTRODUCTION

The urge to categorise is modern human behaviour. From classifying Gods to the periodic table, humankind has exhibited categorized reality time and time again. In this thesis we are concerned with the categorisation of style in material culture, specifically that of Later Stone Age stone arrowheads made over the last few thousand years in Southern Africa.

Dunnell (1978) defined style as "forms that do not have detectable selective values" in an evolutionary sense but rather are considered 'neutral' (Lipo 2001). The central characteristic of style then is the idea that it is functionally redundant (Lipo 2001). It was thought that stylistic elements had to have some kind of cultural meaning, perhaps marking individual or group membership (Lipo 2001). In following these concepts, the work of Polly Wiessner (1983) built upon the theory of style and applied it to the material culture of the Kalahari San, specifically the style of their metal arrowheads. Wiessner formulated emblemic style as marking specific groups of hunter-gatherers (Wiessner 1983).

We will discuss Wiessner's (1983) study in more detail below because it may also apply to the antecedent of the historic San metal arrowheads. This class of artefacts is commonly referred to in the literature as the lithic tanged and barbed arrowheads, an artefact class which appeared in the later part of the Later Stone Age, dated to within the last 3500 years (Mitchell 1999). Many of these arrowheads are bifacially pressure-flaked much like the same as the class of artefacts in Europe and North Africa. Mitchell (1999) describes four variants within this artefact class, in addition to further variants identified by Close and Sampson (1999). Both of these publications acknowledge that there is a lack of understanding as to why such variation occurs within southern African LSA tanged arrowheads (Close & Sampson 1999; Mitchell 1999).

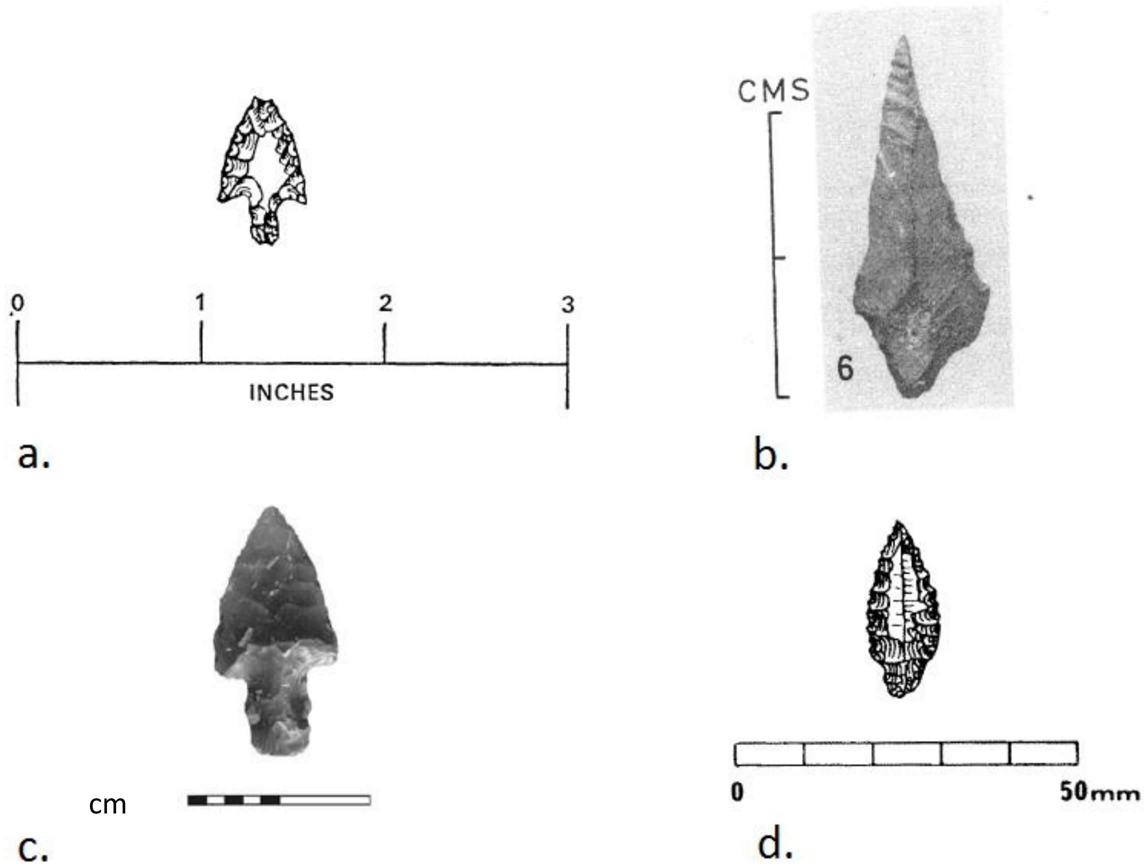


Figure 1. Examples of southern African LSA tanged arrowheads from various publications. *A.* Moshebi Shleter, Eastern Lesotho (modified from Carter & Vogel 1974, Fig 6, 2); *B.* Nelson Bay Cave, Western Cape (modified from Inskeep 1987, Plate9, 16); *C.* Holkrans, North West Province (modified from Bradfield & Sadr 2011, Fig 10, c); *D.* Rose Cottage, Eastern Free State (modified from Wadley 2000, Fig 3, 34).

It is this gap in our knowledge combined with our understanding of how metal arrowhead styles can act as group markers in the San culture that could lead one to speculate that there may be something to the stylistic variation exhibited by southern African LSA tanged arrowheads. Such a realisation spurred the initiation of a pilot study, with the aim of ascertaining whether spatially distinct stylistic clusters could be detected within this particular artefact class (Smeyatsky 2014). In following the tested methodology of several similar studies worldwide (e.g. Buchanan 2006; Cardillo 2010; Buchanan *et al*. 2014), this pilot study sought to explore the efficacy of a relatively new method of statistical shape analysis called geometric morphometrics in order to objectively investigate the existence of these spatially distinct stylistic clusters (Smeyatsky 2014). Several geometric morphometric techniques were applied to a sample of 72 published images and illustrations of LSA tanged arrowheads, where their shape coordinate data were compared and contrasted (Smeyatsky 2014). The results of the pilot study showed that our suspicions regarding the variation in southern African tanged arrowheads were not unfounded, in fact four stylistic spatial clusters exist across central southern Africa, all of which can be boiled down into two encompassing clusters (Smeyatsky 2014). We found that the shape characteristics of arrowheads from the South-Western cluster were significantly different from the arrowheads of the North-Eastern cluster (Smeyatsky 2014).

The success of the pilot study put us in a position to take this research even further and to set us up for the current thesis. Armed with the knowledge that southern African tanged arrowheads do in fact cluster according their stylistic attributes and that the ethnographies show us that style is a potentially important part of this artefact class, we can now focus on arguably more important questions. Why is this clustering occurring? Can it be purely attributed to style or are there other factors that are in play? And if they are purely attributed to style, then what could these arrowheads tell us about their makers? Before we can begin to unravel the task ahead of us, we must first understand the context of the southern African tanged arrowheads and more about the methodology that we shall see is so crucial to answering the questions before us.

1.1. ARROWHEADS IN SOUTHERN AFRICA

Returning back to what we do know about lithic tanged arrowheads in southern Africa, Peter Mitchell (1996, 1999, 2009) has been one of the most vocal authors that has attempted to address these artefacts within the framework of the southern African LSA. However, there have been many researchers over the past century who have been intrigued by these artefacts. Mitchell (1999) argued that there are four main stylistic variations in pressure-flaked stone arrowheads existing in southern Africa. However, I believe that the most important characteristic to note is that they have all been bifacially worked and can all be grouped together according to that attribute.

Additionally, we must not overlook the variants described by Close and Sampson (1999). Through their work focusing on the Seacow Valley in the Northern Cape, they describe the differences between the bifacially pressure-flaked arrowheads that have received much attention in the literature and another, lesser-known variant that they call the backed-tang arrowheads (Close & Sampson 1999). They posit that the main difference between these two types were related to the differences in the ways they had been manufactured, the one type being made with more care while the other was made in a more expedient fashion (Close & Sampson 1999). The distinction between these two arrowhead types becomes quite an important factor later on.

In terms of dating, the southern African tanged arrowheads occurred relatively ‘late’ in the LSA chronology (Smeyatsky 2014). The arrowheads fall within a range from 3500 years CalBP to approximately 150 years CalBP (Mitchell 1996; Close & Sampson 1999; Mitchell 1999; Bosc-Zanardo *et al.* 2008; Bradfield & Sadr 2011). Unfortunately, due to the lack of sufficient dating technology when many of the arrowheads were collected, compounded by the fact that many others were isolated surface finds, there is a large portion of southern African tanged arrowheads without any absolute or contextual dates (e.g. Heese 1933; Humphreys 1969; Dreyer 1975). However, the undated arrowheads only amount to about one third of all southern African specimens and the rest possess either accurate absolute dates or have been relatively dated. This is an issue which is discussed at length later on but please see Table 25 for a summary of arrowhead dates.

According to the published literature, tanged arrowhead bearing sites are known to generally occur within the Upper Orange River Basin and around the Lesotho highlands (Mitchell 1999; Bradfield & Sadr 2011). However, there are also multiple sites south of the Orange River (e.g. Close & Sampson 1999, Inskeep 1987). There is a single coastal site (Nelson Bay Cave, Western Cape) and a site as far north as the border between Zimbabwe and South Africa (Balerno Shelter, Limpopo) but these rare geographical outliers have been excluded from this study (Inskeep 1987, Van Doornum 2008). Take note, that the map displayed in Figure 2 only displays all the sites that were included in this study.

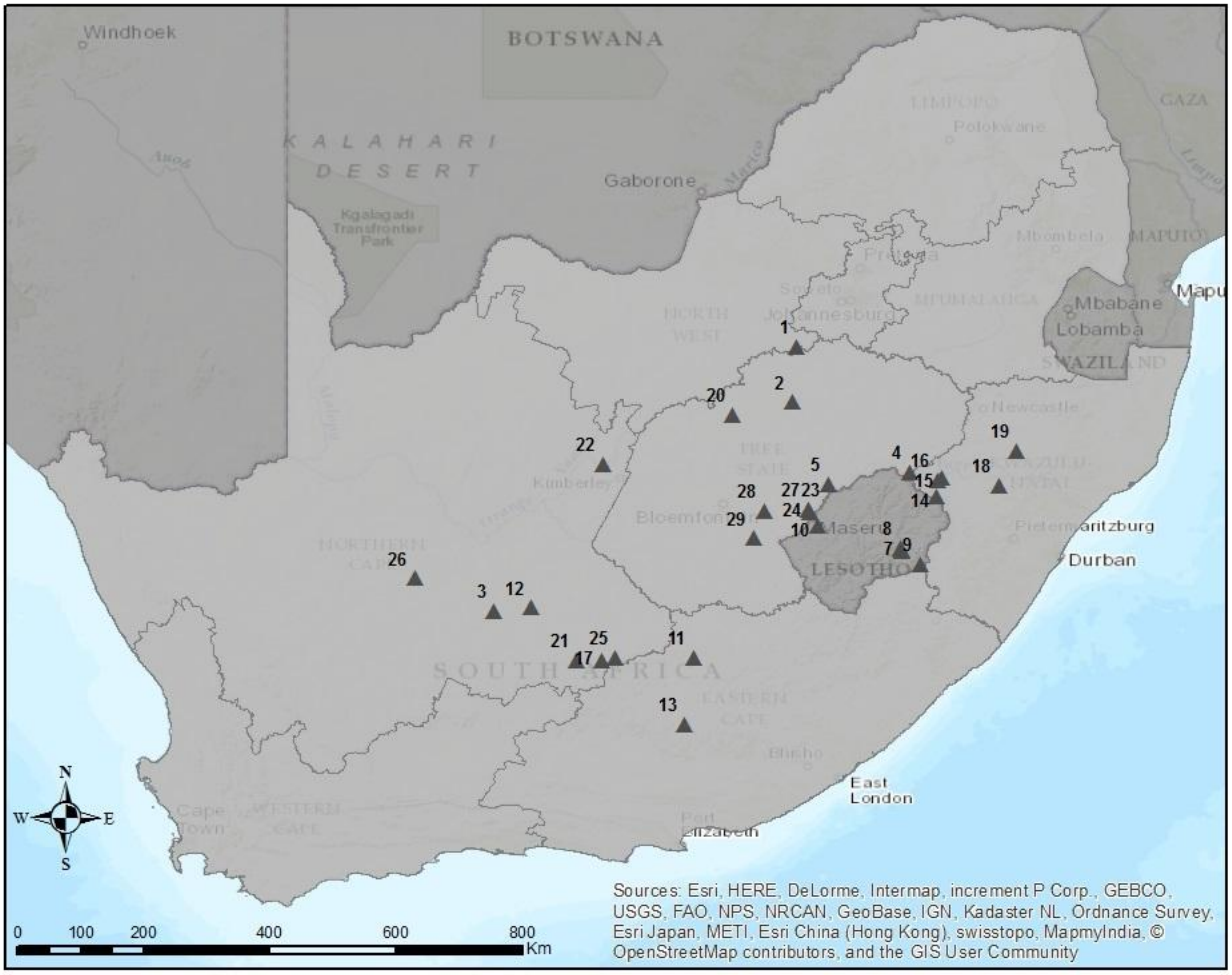


Figure 2. Map showing distribution of arrowhead bearing sites in southern Africa used in study. The dark lines indicate provincial boundaries. The numbers on the map refer to the following sites and districts: 1, Holkrans; 2, Kroonstad; 3, Keurfontein (Vosburg); 4, Dikbosch 1; 5, Roosfontein; 6, Sehonghong; 7, Lehaha-la-Masekou; 8, Likoaeng; 9, Moshebi ; 10, Leqhetsoana; 11, Steynsburg ; 12, Britstown; 13, Halesowen; 14, Poacher's Shelter ; 15, Bergville; 16, Driel Shelter; 17, Seacow Valley; 18, Esinhlonhlweni; 19, Maqonqo; 20, Wesselsbron; 21, Haaskraal; 22, Barkly West; 23, Leliehoek Shelter; 24, Rose Cottage; 25, Volstruisfontein; 26, Jagtpan7; 27, Bokpoort; 28,Thaba Nchu (De Hoop); 29, Dewetsdorp.

Going a bit further into the climatic aspects of the study area, it is clear that the arrowhead bearing sites are located within central southern Africa, mostly falling within the Nama-Karoo and Grassland biomes. The Nama-Karoo biome is characterised by an arid climate with summer rainfall fluctuating between 100-520 mm p.a. and is dominated by low-shrub vegetation (Dean & Milton 1999a). On the other hand, the Grassland biome climate is characterised by a hot wet summer season, receiving up to 625 mm of rainfall p.a., which is followed by a cooler, dry season and its vegetation mainly consisting of single layer grasses (Mucina & Rutherford 2006).

Looking at the metrics of these artefacts, the smallest bifacial tanged arrowheads in the country, with a width of 0.5 – 0.7 cm and a length of 1.2 – 1.5 cm, were recovered from the site Holkrans, North West Province (Bradfield & Sadr 2011). Whereas the largest bifacial tanged arrowheads, with a width of 1.5 – 2 cm and a length of 2.5 – 3 cm, were collected from Steynsburg, Eastern Cape (Van Riet Lowe 1947). The rest of the southern African bifacial tanged arrowheads fall within this range, with the exception of what Close & Sampson (1999) have named the "double backed tang" arrowheads, most of which are significantly larger than their bifacially pressure flaked counterparts, with a width of 2.5 – 3 cm and a length of 5 – 7 cm.

Moving on to the question of what these arrowheads were actually used for, a series of residue analyses on an arrowhead from Rose Cottage Cave found collagen and a trace of blood (Wadley 2000). This suggests that it is quite likely that the arrowhead was used for hunting or perhaps butchery (Wadley 2000). In addition, a study that assessed the micro-wear on a set of arrowheads from Holkrans indicates that they possess microscopic impact damage (De Lauriston 2014). Furthermore, just from my own observations, I have also come across several examples of possible macroscopic impact damage (Fig. 36). Some ethnographic accounts suggest that some of these arrowheads were designed to shatter on impact in order to cause more damage to the target resulting in an increased rate of bleeding (Rudner 1979). In line with these ideas, it is then entirely plausible that many of the arrowheads that were isolated surface finds may have been lost during hunting expeditions (Bradfield & Sadr 2011).

In addition, there are ethnographic sources that point towards the idea that arrowheads may have also possessed a degree of religious significance in hunter-gatherer society (Wadley 1987). San ethnography has mentioned the spiritual power of quartz linked with flight and the prediction of events (Wadley 1987). Considering that there are a number of arrowheads that were made of quartz, it is possible that the spiritual power of quartz would have been connected with arrow hunting and arrow making (Wadley 1987).

There are also several indications for non-projectile type uses for this class of artefact. Residue analysis on certain arrowheads has shown evidence of plant material and starch residues (Williamson 2000: 56) and some stone arrowheads may have been used as exchange items within a gift exchange system that is akin to the *Hxaro* gift exchange, an important point that is explored in greater detail later (Wiessner 1977; Deacon 1992).

These last few ideas point to the possibility that stone arrowheads contained social value and their distribution may correspond to emblemic styles, possibly acting as stylistic markers representing hunter-gatherer linguistic groups, much the same as metal arrowheads within contemporary San society (e.g. Wiessner 1983; Deacon 1992; Wadley 2000).

1.2. STYLE AND CULTURAL TRANSMISSION

Relating to the above, the understanding of style is fundamental and has been the subject of heated debate in the ethnoarchaeological literature since the 1970s (David & Kramer 2001). Style has been defined in many ways (e.g. Wiessner 1983; Hodder 1982; Sackett 1986; Binford 1989), yet it is important that we fully understand Dunnell's (1978) definition of style as a theoretical concept that was briefly touched upon at the start of this chapter.

The idea that style can be understood as a selection of neutral traits is central to Dunnell's (1978) explanation of style and the accounting of human behaviour in the archaeological record (Lipo 2001). Following evolutionary theory, he argued that not all traits in material culture can be seen as completely positive or negative for selective purposes, essentially meaning that those traits which "confer relatively equivalent fitness" otherwise known as neutral traits in archaeological terms, can be seen as style (Lipo 2001: 26). However, what is unclear about this model is the question of whether an evolutionary concept such as neutrality can be transposed onto cultural phenomena which are not transmitted like biological information (Lipo 2001). However, as a theoretical concept, there is no reason why the neutral model cannot be used to explain cultural traits (Lipo 2001). Thus, cultural transmission tentatively takes the place of genetic transmission when we are dealing with cultural or stylistic traits. We shall see now how cultural transmission theory fits the Kalahari San when discussing style in their metal arrowheads, which in turn can help us understand if such style could exist in the material culture of prehistoric hunter-gatherers.

Polly Wiessner's (1983) work on the San metal arrowheads of the Kalahari provides us with the case study which lays the foundation upon which this research is based. Her ethnographic study investigated the importance of arrows in Kalahari San society, focusing on how arrow style may work as a social identity marker (Wiessner 1983). It was shown that variation in the style of arrowheads related to the demarcation of social boundaries between different San language groups and even dialect groups in some cases (Wiessner 1983). Wiessner (1983) argued that this style in the Kalahari San arrows was expressed as emblemic style and assertive style. Emblemic style acts as a group marker carrying information about social groups and boundaries, while assertive style acting as an individual marker carrying information about individual identity (Wiessner 1983).

While the concepts of emblemic style and assertive style are attractive theories, David & Kramer (2001) define style as the formal characteristics of an artefact that are acquired in the course of manufacture as the consequence of the exercise of cultural choice, which is more in tune with the tenets of cultural transmission as well as Sackett's (1986) "isochrestic style".

> "Isochrestic style encompasses the idea that when artisans are presented with a broad spectrum of possible ways of designing material objects, any given group of artisans uses only a handful of those options. The choices that they make, whether conscious or not, are largely dictated by the craft traditions within which they have been acculturated as members of social groups" (Sackett 1986: 267).

This explanation of style does not rely on the assumption that the people who made the arrowheads were making them in a certain way in order to consciously or subconsciously signify to which group they belonged. In a way then, if we rely less on emblemic and assertive style, then in many ways we are able to overcome the challenges faced when transposing ethnographic observations onto the prehistoric past. However important the results of Polly Wiessner's (1983) study are to the foundations of the current study, I feel that it is safer to follow the alternative approach to style mentioned above whilst retaining our understanding of the plausibility that emblemic and assertive styles may have existed in LSA hunter-gatherer society.

In this study, we go beyond the methodologies that had been employed in the past to evaluate style among artefacts and explore more novel techniques, with the aid of geometric morphometrics.

1.3. GEOMETRIC MORPHOMETRICS

Simply put, geometric morphometrics is a method conducted through computer software that extracts shape data from cartesian landmark coordinates and then applies statistical analyses to that shape data in order to ascertain differences among complex shapes. This technique of shape analysis preserves the geometry of the landmark configurations throughout the analysis and thus permits us the representation statistical results as actual shapes or forms (Zelditch 2004). Additionally, it provides in depth visualization, interpretation and communication of statistical differences among complex shapes (Zelditch 2004).

Geometric morphometrics have a great advantage over the traditional morphometrics techniques that have been used to quantify lithic shape attributes since the 1960s (e.g. Roe 1968). Traditional morphometrics encompassed measurements of length, depth and width, and such data sets contain relatively little information about shape (Zelditch 2004). This is mostly due to the fact that many of the measurements overlap or run in similar directions (Zelditch 2004). Other issues with traditional morphometrics include the facts that its values cannot be completely independent as they are measured from a point and at times its data sets usually contains less information than could have been collected with the same effort due to the redundancy of certain measurements (Zelditch 2004). Resulting from these factors, we also find that the overlap of the measurements makes it more difficult to describe localized shape differences (Zelditch 2004). Furthermore, traditional morphometrics do not sufficiently account for the spatial relationships among measurements since whatever shape information sought after "is contained in the ratios among the lengths and it can be surprisingly difficult to separate information about shape from size" (Zelditch 2004: 5).

While this form of statistical shape analysis was originally developed for understanding the nuances among the shapes of biological species (e.g. Rholf 1990; Bookstein 1991), it has been successfully applied in numerous archaeological contexts, especially in the study of lithic shape variability (*See* Charlin & Gonzalez-Jose 2012 for further examples). These cases are best explored later within the context of the results of the thesis itself. The point here is that geometric morphometrics has been shown to be an effective tool in answering questions regarding lithic tool shape variability. We shall see in the following chapters how geometric morphometric techniques have been applied to the questions posed at the beginning of this chapter and the answers that can be extracted from the styles of southern Africa's LSA tanged arrowheads.

1.4. RESEARCH QUESTION, HYPOTHESES, AIMS & OBJECTIVES

However, we must take a brief pause at this point to set up a more structured roadmap with which we can view the direction that this thesis will be heading. Based on the results and conclusions of the pilot study (Smeyatsky 2014), as well as the current state of our knowledge regarding this topic as set out in the Introduction chapter, we can boil down the line of inquiry for this thesis into the following main research question: What do the shape clusters in South African Later Stone Age tanged stone arrowheads indicate?

To help answering this research question, it can be broken down into several relevant hypotheses that make it more manageable:

A. The spatial arrowhead clusters are temporally distinct.
B. The spatial arrowhead clusters are undermined by the effects of reduction.

C. The spatial arrowheads clusters cut across boundaries in other artefact classes and represent inter-group exchange systems.
D. The spatial arrowhead clusters coincide with natural boundaries such as biomes.
E. The spatial arrowhead clusters are replicated in other artefact classes and signify culturally distinct identities.
F. The spatial arrowhead clusters do not correlate with any other measurable variable.

My aim with this thesis is to make an attempt to improve the definition of spatial shape clusters in LSA tanged arrowheads and to explain what they might represent in social, chronological and/or economic terms. A goal which hopefully will be accomplished through the:

1. Sourcing and photographing a sample of ~100 stone tanged arrowheads from LSA contexts kept in various collections in South Africa and beyond.
2. Processing this image database for geometric morphometric analyses.
3. Examining the spatial distribution of arrowhead shape clusters in relation to natural and environmental features.
4. Examining associated artefacts such as other stone tool types, raw material preferences, ceramics, etc. in order to see if spatial arrowhead clusters are replicated in other artefact classes.
5. Examining associated dates in order to assess whether spatial arrowhead clusters can be explained in chronological terms.

2. METHOD & TECHNIQUE

2.1. METHOD

Following from the short word about geometric morphometrics in our introductory chapter, here we will go more in depth into the aforementioned statistical method, its associated techniques and how it was applied within the context of southern African tanged arrowheads. Additionally, we will explore the data collection and processing techniques as well as have a short discussion on the state of South Africa's museums and the challenges linked to museum collection based research.

To begin, we find that there are different morphometric techniques that are based on multiple geometric models that underlie the geometric morphometric method. However, Cardillo (2010) has found that Bookstein's landmark and semilandmark approximations of stone tool shape have proved to be the most effective approach in the illustration of variability in shape differences in stone tool morphology (Cardillo 2006; Costa 2010). The landmark/semilandmark based approach involves the usage of digitised x/y co-ordinates of shape which have been read from digital landmark placements in order to capture variation of contours at various levels, using different parameters or 'principal components' (Cardillo 2010). This data can then be fed into a geometric morphometric software package that can calculate the statistically significant shape data variables with which we are able to extract possible cluster patterns that we can then interpret (Zelditch 2004).

The same method of shape analysis has been implemented on lithic projectile points in several studies (e.g. Buchanan 2006; Cardillo 2010; Buchanan *et al.* 2014) and has been vindicated in its value as an effective method for extracting rich interpretations of these types of lithics from statistical shape variation data. With the above in mind, several GMM analyses were performed in order to test for the clustering of stylistic, shape variation data of southern African LSA, tanged arrowheads and to understand why this clustering may be occurring.

Using a combination of statistical and geometric morphometric software packages namely R, SPSS and MorphoJ, the digitized shape data was subjected to a series of statistical analyses such as, Principal Component Analysis (PCA) and Partial Least Squares (PLS) analysis and through this process it produced a series of helpful shape variation data. The software packages are also able to graphically visualise the results for nuanced interpretation. This method can account for more idiosyncrasies in tool form while removing the influence of size and requiring less time and effort compared to traditional morphometric techniques. In addition, to these main analyses several other analyses were performed in order to answer other important questions about the data, including Pairwise t-tests, One-Way ANOVA and Procrustes distance analysis.

2.1.1. PCA

Rather than being used to test hypotheses, Principal Component Analysis is better suited for simplifying descriptions of shape variation (Zelditch 2004). These simplified descriptions are produced in the form of linear combinations of the original shape variation data and are known as Principal Components (PCs) (Zelditch 2004). In addition, PC scores are produced from the PCA and can then subsequently be plotted in order to visualise possible clustering patterns (Zelditch 2004). PCA is sometimes misused in that the clusters found are valuable, yet they do not necessarily "represent evidence of statistically distinct entities" (Zelditch 2004: 156). However, it is still highly useful for taking complex variables such as shape and simplifying those variables, making it much easier to interpret patterns from the data (Zelditch 2004).

2.1.2. PLS

In order to 'pick up the slack' in this regard, Partial Least Squares is a method that is typically used for exploring patterns of co-variation between two (and potentially more) blocks of variables (Zelditch 2004). This means that this method can also be used for analyzing the relationship between shape and other variables which, in essence, describes it as a form of regression (Zelditch 2004). However, even though both regression and PLS explores the connection between two variables, regression assigns dependency to one variable while PLS treats both variables equally (Zelditch 2004). In other words, "PLS does not assume that one set of variables causes the other, but rather views both sets as jointly (and linearly) related to the same underlying causes" (Zelditch 2004: 262).

2.2. DATA COLLECTION

Considering that this research concerns itself with style in lithic arrowheads, the specimens had to meet specific criteria that would sufficiently classify them as arrowheads in the first place. This is paramount as the main foundation upon which this research relies is the success of Wiessner's (1983) study.

As the first criterion, they had to possess a tang or a stem, which is the most widely agreed upon morphologically diagnostic trait of an arrowhead (Close & Sampson 1999; Mitchell 1999). This morphological trait is extremely important because it separates out any flake or piece of stone that could have just as easily been used as a projectile point (Close & Sampson 1998; Pargeter 2007; Wadley & Binneman 1995), yet would not possess any latent stylistic attributes such as those proven in Kalahari San arrowheads (Wiessner 1983). And as a second more obvious criterion, they had to have been found in the geographical region of South Africa. As part of the pilot study there was a final criterion which stipulated that incomplete or damaged arrowheads had to be excluded (Smeyatsky 2014), but it was not enforced in the current study which will be explained further on.

The sample itself (n=109) was collated from a combination of arrowhead photographs and publication arrowhead illustrations that represents a total of 28 sites across southern Africa's interior. They tend to occur within the Orange River Basin and Lesotho while a few sites also occur in the Northern Cape, Eastern Cape and KwaZulu-Natal. In addition, there are two outlying sites in the Western Cape (Nelson Bay Cave) and Limpopo (Balerno Shelter). One of the interior sites, Seacow Valley in the Northern Cape, actually comprises multiple sites and will be considered as a single site due to the close proximity of the sites within the area. The Seacow Valley, however, will be discussed later in its own right.

In terms of dating, the arrowheads were recovered from a variety of contexts, with 61 of the arrowheads found in datable assemblages, 25 were found in assemblages that have relative dates and the rest were either isolated surface finds or possessed no context at all (Smeyatsky 2014). Dating is particularly important to this research as one shall see further on.

The collation of the sample was no easy task as not only did it involve scouring through a great amount of publications, old and new, but it required an even greater amount of effort searching through South Africa's museum collections.

2.2.1. SOUTH AFRICAN MUSEUMS

A minor goal of this research has been to improve on and refine the various techniques that were implemented in the pilot study (Smeyatsky 2014). One such improvement revolved around how data collection was conducted. Taking into account previous criticisms suggesting that we do not necessarily know if publication illustrations are accurate enough to be used in GMM analyses, an issue which is addressed later on, it was decided prudent at the beginning of this study to include live arrowhead specimens in the current research.

With that decision came a challenging undertaking that took the better part of a year to complete. Considering the tremendous rarity of southern African LSA tanged arrowheads (Bradfield & Sadr 2011; Humphreys 1991; Mitchell 1999), it is quite obvious that these precious artefacts are not being excavated on a daily basis thus it is of utmost importance that the known specimens are stored properly and securely at the relevant institutions. Unfortunately, in reality the state of many of South Africa's artefactual collections leaves much to be desired.

While they are all in a generally satisfactory state with very dedicated staff and some in a better state than others, it was found that the majority of them were wrought with a common set of issues. First, government subsidy and funding of these institutions (including university collections) are at an all time low, which affects the amount of staff these institutions can hire and has a direct effect on the functionality of the museums. For instance, there is only one curator working at one of the national museums with no other staff on hand. This made it nigh impossible to contact that curator let alone to organize the release of any materials I required due to the unmanageable amount of work and number of roles she had to take responsibility for.

While at another museum, the person that had been working as that museum's only curator her whole career, was abruptly forced to retire. The municipal body did not deem it necessary to hire a replacement and as a result there is now no one to teach any future curators the system by which that museum has been run by, rendering the rich collections there all but useless. A further example relating to this problem was an experience had at another museum where they were employing interns, who without expertise in any other archaeological field besides their specialty, were tasked with sorting and classifying collection material of which they had minimal knowledge. When attempting to go through their catalogues in order to locate some arrowheads, I was left completely lost as they had created 20 classifications for a type that a professional would have given only one or two classifications.

This final point ties into the second problem which is not necessarily the museum's fault. In that, since these institutions are funded by the government, their interests have to tie in with governments interests. This is highlighted where governmental auditors have recently tasked South African museums to perform an inventory of all their collections in order to try assigning value to them. Aside from the fact that it is impossible to assign monetary value to artefacts, this forced museums to get into gear and get the work done quickly. This paves the way for mistakes to be made, objects to get lost and for inexperienced interns to make things even worse. The final example rendered that museum's Stone Age collection nearly impossible to use, if not useless until it is resorted and re-catalogued which will no doubt take years of work.

The last line above leads us into the third problem, that of cataloguing. The lack of sufficient online catalogues is probably one of the most debilitating issues at museums in South Africa. About half of the collections that were visited did not have a functioning, searchable, online database. With one of those databases having only been updated with information from when the collection was last catalogued, in 1955. This impacted my ability to search through collections greatly. For instance, I had multiple 'hits' when I queried "arrowheads" on this particular database however, when I went through those specific boxes, 80% of the artefacts that had be 'classified' as arrowheads at the time, were in fact not arrowheads at all by today's standards. This highlights one of the potential problems that can arise when collections are not re-analysed and updated. In my short time spent at the museums, I ended up re-classifying many objects; successfully assigning provenience to arrowheads which had no previous information attached to them; and successfully tracking down an odd 20 or so arrowheads to a researcher in America (which contributed to about 20-25% of South Africa's only tanged arrowheads) which were missing from their boxes when opened and had been so for the past 15 years, yet the museum had no idea they had absconded. One can only imagine the potential troubles associated with the few South African museums that still work with the original accession books from when the museums first opened. When compared to the rich, detailed online catalogues of the Pitt Rivers Museum (Oxford) or the Cambridge Collections for example, which can both be accessed and searched via the internet with ease, the difference between South African cataloguing and the international *status quo* is like the difference between day and night.

Finally, many museums have been faced with multiple curator changeovers over the years. While this is a common practice at all museums, the issue lies in contract lengths. A new curator would start implementing their own method of curation, changing the system from the previous curator and then part way into their contract, they would leave. This sadly resulted in a few museums with collections that are curated according to multiple systems, leaving the collections in disarray. Without enforcing strict contractual policies, this issue is sure to persist in certain cases.

While there are collections in South Africa that have fantastic, dedicated staff and that are generally a pleasure to work at, the remainder makes research difficult if not impossible. From my experiences, the above mentioned issues are not necessarily the fault of the museums themselves but are rooted in the governing bodies' ineptitude when it comes to understanding what is necessary for a museum to function well for general and research oriented purposes. If these essential institutions receive the funding they require, then they could hire more staff with the necessary qualifications in order to improve the state of collections as well as pay for much needed technological upgrades where is necessary. There is such a wealth of information stored in these collections and it truly heartbreaking when that information is inaccessible.

With all this said, this is not the place to take this discussion further. By delving deeper into the problems and their possible solutions, strays too far from the purpose of my highlighting of all the issues faced by South African museums. I wanted to highlight these challenges in order to emphasise the effort that was required to locate and record the specimens necessary for this research, and to give justification to the 'less than expected' number of live specimens that could actually be located.

Briefly, the process of locating and recording the specimens began with contacting the relevant museums and collections. I acquired a contact list from the Department of Arts and Culture's website which provided the contact details of hundreds of registered museums and collections throughout South Africa (and Lesotho). That list was then reduced to approximately 25 museum collections that I reasoned would possibly host Stone Age materials which could contain arrowheads. In addition, I was also guided by certain publications in which it was mentioned specifically where certain arrowheads had been stored (or should have been). I began contacting the shortlisted collections telephonically and via email, and of that list I came up with only 9 confirmed or possible arrowhead containing collections. After that it was a matter of months, in some cases, before I had received confirmed dates for my usage of the respective collections. Over a period of 8 months, I visited 7 local museums/collections and 2 international museums/collections.

Despite facing occasional problems with outdated catalogues, poorly provenienced boxes and missing/stolen arrowheads, I managed to record 94 specimens. Upon closer inspection during the data preparation stage, I found that of those 94 specimens, only 62 of the recorded specimens could be classified as Later Stone Age, tanged, arrowheads. What follows is the photography methodology I used to record the specimens.

2.2.2. PHOTOGRAPHY

In order to record the specimens from the collections, I followed a standardised photography procedure, thereby defusing the issue of possible illustration variability (an issue which is addressed later). The camera I used is a Canon SX60 HS (21mm lens, 65X optical zoom) with a Canon 430EXII wireless flash. Standardised techniques for lighting and centring of images were implemented to optimise photographic accuracy. While it was not possible to completely standardise focal length considering that the arrowheads were of different sizes and thus varying levels of optical zoom were required, the distance of the lens to the object was standardised, which did help to minimize any additional error that could have arisen from distortion.

An early issue which I considered for quite some time was that of lighting the specimens correctly in order to avoid capturing any cast shadows. It was of utmost importance that the outlines of the arrowheads were captured clearly which comes into play later on in the landmarking stage of the data preparation. After some amateur photography research, I found that in order to capture the well-lit, shadow-less images, I required a specialised lighting system occasionally referred to as a 'lightbox'. The problems with this involved the cost of such a system and that it would be difficult to travel with, especially when I had to visit the international collections. My solution, which I designed and built at a fraction of the cost, was not only easily transportable since it is foldable, but it served its purpose well and allowed well-lit images to be captured with ease.

The photographic process itself was relatively simple. I made a small makeshift stand with a scale, placed in the centre of the lightbox, on which I would secure the specimens parallel to the surface of the stand with builder's putty. This method of securing the specimens was non-destructive and it allowed me to angle the arrowheads in such a way that the outline of the specimen was always flush to the camera lens avoiding the distortion of the outline. The 430EXII wireless flash was placed facing the back left corner of the light box so that the flash was diffused resulting in no direct light creating a glare on the specimens. The camera itself was setup on a small tripod directly in front of the lightbox and the angle of the camera was adjusted according the size of the arrowhead in order to make sure that each specimen was parallel to the lens when it was captured. This process was repeated for each specimen, both on their ventral and dorsal sides. Only the images of the dorsal sides were used in this analysis. Distinguishing between the dorsal and ventral surfaces of the specimens was relatively easy in most cases where there was still distinct flaking evidence, however this was task was far more difficult on some of the bifacially worked specimens where hardly any primary flaking evidence remained.

As mentioned earlier, 94 specimens were recorded and only 62 of those photographed specimens could be classified as Later Stone Age, tanged, arrowheads. Compared to the sample size of the pilot study amounting to 72 images of published arrowheads (Smeyatsky 2014), the relatively low number of live specimens that were found is slightly distressing. This shortfall is due to a number of reasons.

First, multiple arrowheads have gone missing or have been stolen from collections over the years, which is not surprising in view of the beauty of these pieces. Many of these arrowheads have been stored since the 1930s or earlier and many different people have probably had contact with the arrowheads. Many of the published arrowheads did not have enough information as to where they were stored. And a number of arrowheads had been loaned to international museum collections which were simply inaccessible at the time of this study.

To make up for this shortfall it was decided to include partially damaged arrowheads, which were originally excluded from the pilot study, as well as all the published arrowhead illustrations that the photographs did not cover. The decision to include a portion of partially damaged pieces was made based on the successful application of manual extrapolation described in section 2.2.4 on the following page. Whereas, in an analysis that will be fully described further on in section 3.1, the shapes of photographed specimens were statistically compared to their illustrated counterparts from publications, essentially proving that the degree to which the arrowhead publication illustrations accurately represented the actual specimens was adequate for this study.

2.2.3. PUBLISHED IMAGES

Subsequently, it was then permissible to make use of published digitised images of stone arrowheads (n=41) from a series of journal articles, theses and text books to make up for the aforementioned shortfall. The published image sample mostly comprised illustrations (n=20), while a slightly smaller proportion were of scans that had been processed through graphic design software (n=18) and the remainder comprised of publication photographs (n=3). The images, together with the individual scales with which they were published, were simply lifted from their respective digital publications or scans of publications using the CorelDraw suite without any extra modification to the images themselves.

2.2.4. EXTRAPOLATED IMAGES

Of the 109 specimens that constitute the sample, a total of 21 were partially damaged with varying portions of their tips missing. However, they were considered viable enough candidates for inclusion in this study as it was possible to extrapolate their complete shapes with relative accuracy and ease. Unfortunately, arrowheads with portions of their barbs or tangs/stems could not be extrapolated with confidence and had to be excluded from the study.

2.2.5. NEWSPAPER ARTICLE

Once I had dealt with all the published literature on South African LSA tanged arrowheads, I came to various conclusions revolving around their occurrence and how they had been discovered. I found that while the majority of known arrowheads in South Africa had either been excavated or recovered from surface sites, a great number of arrowhead discoveries were simply the product of curious individuals with a very acute sense of sight. Of the known tanged specimens in South Africa, about 25-30 of those had been collected by the public and were either handed in to museums or researchers over the years (Van Riet Lowe 1947; Heese 1933; Humphreys 1969; Goodwin 1929; Peringeuy 1911; Wilson 1970).

When we know that nearly a third of South Africa's known arrowheads had been recovered by the public, this leads me to consider that there must still be a bounty of arrowheads (or similarly rare artefacts) that is held up in private collections around the country. In an attempt to contact these collectors, I decided to write to the Bloemfontein Coerant, a weekly newspaper that is distributed among city and rural dwellers alike living in the Free State (one of the known arrowhead 'hot-zones'), about writing a short article for their newspaper. This article described in basic terms: Archaeology and its goals; Archaeology in South Africa; a review of the LSA and tanged arrowheads; and a way in which I could be contacted about any information about any fugitive arrowheads.

Alas, I was not contacted by any collectors. In the end I was still considerably lucky to accumulate a sample of 109 arrowheads which would suffice in terms of statistical validity in my later analyses.

2.3 TECHNIQUE

2.3.1. IMAGE DIGITISATION

The whole digitising process is performed in a series of steps: First, the arrowhead images, be it a photograph or a publication illustration, were converted into tps or Thin Plate Splines data files using the software program tpsUtil which are part of James Rohlf's tps series (Rohlf 2006a). Doing this, allows all the images in the sample to be read as a single file that is of a preferable file type that is readable by geometric morphometrics programs (Rohlf 2006a). tpsUtil is also a highly versatile program that is essential in the manipulation of the tps files which is inevitable in any geometric morphometric analysis. It allows you to delete or reorder landmarks; to delete or reorder specimens; to convert the tps files to other file types; to append multiple tps files together if one's sample increases in size and the list goes on.

Next, these converted tps files are uploaded into another program in the tps series called tpsDig, where one is able to set all the images to the same scale and is also where the landmarking and semilandmarking will take place.

2.3.2. LANDMARKING

The landmarking process is relatively straightforward. In this study, it made use of the well designed tools within tpsDig to simply place landmarks with multiple clicks of a button. The landmarking technique in the present research differed somewhat from that of the pilot study where eight Type 1 landmarks were placed in locations on the arrowheads that the author deemed as 'stylistically significant' (Smeyatsky 2014). These points were informed by the results by the results of Polly Wiessner's (1983) study. However, it was reasoned that the choices of the location of the Type 1 landmarks were affected by a degree of subjectivity. To eliminate that subjectivity, the current study strictly adhered to the definition of Type 1 landmarks as outlined in Zelditch (2004) where it is stated that:

> "Ideally, landmarks are (1) homologous anatomical loci that (2) do not alter their topological positions relative to other landmarks, (3) provide adequate coverage of the morphology, (4) can be found repeatedly and reliably, and (5) lie within the same plane" (Zelditch 2004: 24).

When dealing with archaeological artefacts, the first condition of a Type 1 landmarks can be altered to include homologous morphological loci such as "the apex of a projectile point or other fixed point in morphology" (Cardillo 2006: 4). As such, the following locations on the arrowheads were chosen for use as Type 1 landmarks: the distal end, the most distant point of the basal end and the two points demarcating the breadth amounting to a total of n=4 Type 1 landmarks (Fig. 3).

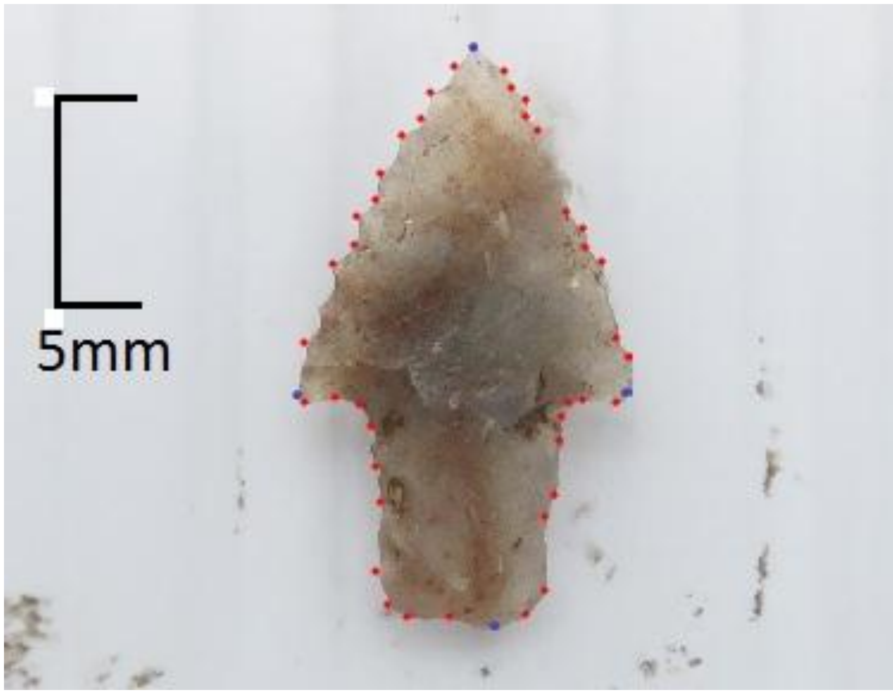


Figure 3. Digitised arrowhead image post-landmarking. Blue points indicating Type 1 landmarks and red points indicating Type 3 landmarks once they have been converted to points from drawn curves.

The semilandmarking process is slightly different and require more careful consideration in their use. While Type 1 landmarks are necessary to 'anchor down' the morphological structure of objects and in many cases, more so in biological applications, are able to capture enough shape data for geometric morphometric analysis; Type 3 landmarks or semilandmarks are able to record curvatures in shape "where there is no clear homology between points" (Cardillo 2006: 24).

2.3.2.1. SEMILANDMARKING METHODS

It is important to note that it is not as easy to analyse semilandmarks (Type 3 landmarks) representing curves in the same analytical framework as regular Type 1 and Type 2 landmarks (Zelditch 2004). In order to accomplish this "we need a way to identify points on the curve that can be treated as though they were landmarks" (Zelditch 2004: 396). One simple way of doing this "would be to select points that are at equal intervals along the curve” (Zelditch 2004: 396). Fortunately, tpsDig does possess a curve drawing tool with which one is able to record curvatures of artefact shape by clicking along said curvature, that can then be re-sampled to any desired number of landmarks with equidistant lengths in between them and when combined with the Type 1 landmarks, a highly detailed ‘image’ of artefact shape can be captured. In this study, n=10 equidistant semilandmarks were captured in between every two Type 1 landmarks, amounting to a total of n=40 semilandmarks (Fig. 3).

This program makes use of one of three ways to delimit segments of a curve “by increments along the length of the curve”, with other know methods being: “by increments along the length of a chord connecting the ends of the curve” or “by increments of an angle subtended by the curve” (Zelditch 2004: 396). All of which have pros and cons depending of the geometry of the object being sampled yet they are all acceptable techniques for landmarking a curve. However, selecting the landmarks is only part of the trouble when one needs to landmark a curve (Zelditch 2004). Due to the fact that semilandmarks are not locally defined and posses less degrees of freedom compared to regular landmarks, adjustments to the computing of their Procrustes superimposition need to be made (Zelditch 2004). It is possible to perform a Procrustes superimposition on semilandmarks without making any adjustments, however in doing so, the semilandmarks will be treated as equivalent to the landmarks which should not be the case (Zeldtich 2004). The semilandmarks would “have more influence on the result than is justified by the number of degrees of freedom they represent” (Zelditch 2004: 399). To balance this out, one is able to make use of ‘differential weighting’ methods which recognises that there is a difference between landmarks and semilandmarks (Zeldtich 2004). The problem with using this method is that we end up with a lack of information about the shape of the space that the landmark configuration delineates (Zelditch 2004).

The method that is used in tpsDig to compensate for the use of semilandmarks is the allowance of the semilandmarks to slide to minimize bending energy (Zelditch 2004). Essentially, the semilandmarks are allowed to ‘slide’ along a line tangent to their original targets to minimize the “the bending energy of the thin-plate spline describing deformation of the reference to that target” (Zelditch 2004: 400). The positions of the semilandmarks are then recomputed and compared to their previous positions and this process is repeated until a solution is reached (Zelditch 2004). This method is advantageous over the previously mentioned ones in that it does not ignore the difference between landmarks and semilandmarks and it provides clear rules for the best superimposition (Zelditch 2004).

2.3.2.2. AUTOMATED LANDMARKING VERSUS MANUAL LANDMARKING

While this particular manual landmarking technique is significantly less subjective compared to that used in the pilot study (Smeyatsky 2014), it is still not as objective as automated landmarking techniques. Automated landmarking essentially involves the use of automated landmarking software such as LAMINA (although it was designed for the analysis of leaf outlines) which is capable of scaling the inputted images, detecting the outline of the object by contrasting the object with the background and subsequently placing a pre-defined number of landmarks along that outline (Bylesjö *et al*. 2008). Even though one has to set the scale for each image individually rendering the software not completely autonomous, it is still much faster than manual landmarking in terms of landmarking speed especially when one has to deal with large sample sizes.

Even though automated landmarking does seem like the most advantageous choice between the two methods, it unfortunately had quite a significant problem that became apparent during the processing of the Photo/Illustration test which is described further on. The problem with this is that when an object is outlined by the software and that outline is converted to landmarks those landmarks will not be placed in the exact same location along the outline if the landmarking process is repeated on the same object or set of objects. This problem was highlighted during the Photo/Illustration test where there were multiple inconsistencies in pairwise t-test scores when the sample was re-landmarked and re-analysed (Table 24). When the resulting Procrustes Distances are compared between the first and second automated landmarking tests and the manual landmarking tests, one can see just how inconsistent the automated landmarking truly is. The most prominently inconsistent Procrustes Distances are underlined in Table 24. Procrustes Distances are explained in detail in section 3.1.

This issue of shifting landmarks would make for unnecessary inconsistencies if the analyses were replicated, which can simply be avoided by using manual techniques. This avenue was chosen despite it being more tedious, which is a small price to pay for the level of accuracy it provided. Until such time that automated landmarking software can be developed to address these issues, manual landmarking is definitely the superior choice out of the two.

2.3.3. REPEATABILITY TEST

Considering that the landmarking method performed was done so subjectively, it is therefore subject to a degree of human error. In order to show that the landmarking that I completed for this thesis is indeed reliable, it is necessary to perform a series of repeatability tests. These tests simply involve the manual landmarking of a set of configurations (n=3) repeated a number of times (k=5), which was done according to the same tenants that was applied to the landmarking process of the actual sample used in this thesis. Once the set of configurations has been re-landmarked, those landmarked configurations are all uploaded into MorphoJ where a Procrustes ANOVA is performed, which essentially works the same way as a regular ANOVA except it tests for the degree of similarity between all the repeated landmark configurations. Therefore, it is able to assess the accuracy of the landmarking.

	Sum of Squares	*df*	*Mean Squares*	*F*	*p-value*
Between Groups	37254.806	2	18627.403	2.222	0.109
Within Groups	5499554.256	656	8383.467		
Total	5536809.062	658			

Table 1. Results of the Procrustes ANOVA.

The Procrustes ANOVA test (Table 1), tested at a 95% confidence interval resulting in a critical score of qf = 3.00945452. Once again, since $F < qf$, we accept the null hypothesis that the repeated landmark configurations are in fact very similar showing that the landmarking method used was accurate and reliable.

2.3.4. SUPERIMPOSITION OF LANDMARKS

The next stage involves the uploading of the landmarked tps files into the statistical software platform that will be used to perform all the analyses. The tps files can still be edited before being uploaded using the tpsUtil program if need be. For instance, erroneous landmarks can be deleted or the specimens can be reordered to one's liking. The tps file format itself is also quite versatile in that it can be saved as tab-delimited text files allowing one to manually edit the landmarks or perhaps alter the specimen order using simple word processing software. In addition, it very helpfully allows other 'non-tps compatible' statistics platforms to be able to read the data.

Both the statistics software platform R as well the geometric morphometrics program MorphoJ are able to read the coordinate and scale data from the tps files, where the data is prepared for analysis by performing a Procrustes Superimposition, a method used to minimise the differences between landmark configurations of all our specimens (Zelditch 2004). In other words, this process effectively scales, rotates, and translates the raw, digitised landmarking data thereby removing all information that is unrelated to shape and allowing the subsequent pure shape data to then be analysed (Zelditch 2004). Fortunately, the Procrustes Superimposition is a basic function within R and MorphoJ that can be performed with the entering of a few lines of code or the click of a button respectively. With regards to all the analyses performed in this study, MorphoJ was used to perform the Procrustes Superimpositions.

2.3.5. CLASSIFIERS

As a crucial extra step which helps organise and give more meaning to the data, a series of classifiers were applied to the data through a relatively simple process in MorphoJ. These 'classifiers' essentially enable one to assign numerical or string based values to each of the specimens in a sample which can then be used to help interpret the results of the PCA, PLS or any other GMM analyses as we shall see further on. In addition, these classifiers can also be exported to excel or text files coupled with the shape variation data for easy manual manipulation if need be and for application in other statistical platforms such as R and SPSS. The classifiers applied to the sample including the following variables:

1. *ID* – Basic identification tag to keep track of arrowhead and its associated information.
2. *Site* – Indicates the site from which the arrowhead was excavated or collected.
3. *Major Group* – Large scale group membership tag denoted by the geographical location of sites in relation to others. (*EL* – Eastern Lesotho; *OB* – Orange Basin; *WC* – Western Cape; *MC* – Middle Cape)
4. *Date* - Numerical value indicating absolute dates. Dates were grouped into 500 yr brackets.
5. *Biome* - Indicates the southern African biome in which the site occurs.
6. *Type* – Refers to arrowhead types defined by Close & Sampson (1999). (*UBT* – Unifacial Backed Tang; *BPF* - Bifacial Pressure-Flaked)
7. *Raw Material* – Indicates raw material used to produce the specific arrowhead.
8. *Latitude/Longitude* – Numerical values indicating coordinates of site location.
9. *Scraper Ratio* – Numerical value calculated by looking at the ratio of site specific, scrapers to backed artefacts that are associated with the arrowhead.
10. *Tempering* - Indicates what type of ceramic tempering was employed at the site.

2.3.6. COVARIANCE MATRICES, PCA AND PLS

A covariance matrix is then generated which is used in a wide range of statistical and morphometric analyses (Klingenberg 2011). Covariance matrices are generated from datasets of shape data after a Procrustes superimposition has been applied to the raw coordinate data (Klingenberg 2011).

With the matrix generated, the data was ready to be subjected to multiple geometric morphometric analyses through some of the main functions of MorphoJ. Even though the statistical platform R was just as capable, it seemed prudent at the time to rather make use of MorphoJ for the main analyses as it was far simpler and faster to employ its pre-programmed functionality instead of having to manually programme the functions in R.

The entire sample of arrowheads (n=109), including the partially incomplete artefacts and extrapolated pieces were run through Principal Component Analysis (PCA), which essentially simplifies patterns of variation and co-variation among individuals within a sample that are then compared and contrasted statistically (Zelditch 2004). This analysis was performed to see if clustering is exhibited among the individual arrowheads according to their similarities in shape. The numerical results were then uploaded into the statistical platform SPSS, where the results were better visualised compared to the visualisation capabilities of MorphoJ. The classifier variables were also appropriately applied in SPSS to allow more in-depth interpretations.

As a final analysis, multiple Partial Least Squares (PLS) analyses were employed. In this respect, PLS analyses were performed to explore if there is any relationship between shape and:

- Biome;
- Raw material;
- Date;
- The geographic location of the respective site;
- The Scraper Ratio at the respective site;
- Type of ceramic tempering at the respective site.

In order to do this, one has to create a list of covariates for each variable one would like to test. These covariates need to be numerical however, for categorical variables such as raw material, those categories can just be replaced with representative numbers. For instance, the raw materials Hornfels and Cryptocrystalline Silicates (CCS) can just be replaced with the numbers 1 and 2. Next, the datasets to be explored are selected; the analysis is processed through MorphoJ and the results are then uploaded into SPSS for graphical representation. PLS analyses were also used to explore the relationship between centroid size and the aforementioned variables as well as the relationship between the shape of the point and the shape of the tang in every arrowhead.

With our newfound, comprehensive understanding of the methods and techniques that have been implemented in the present research, we will now explore the results of said research and their analysis in the following chapter.

3. RESULTS

Starting from the beginning of the GMM process, Figure 4 shows the configurations of landmarks and semilandmarks after the Procrustes Superimposition had been completed. The larger numbered points represent the average shape configuration of the 109 arrowheads in our sample while the other smaller points represent the shape configurations for each individual in the sample. As one can most likely recognise the 'typical' arrowhead shape from the configuration representing the mean from the sample, it is also quite clear from the rest of the configurations that there is a significant amount of variability among southern African LSA tanged arrowheads.

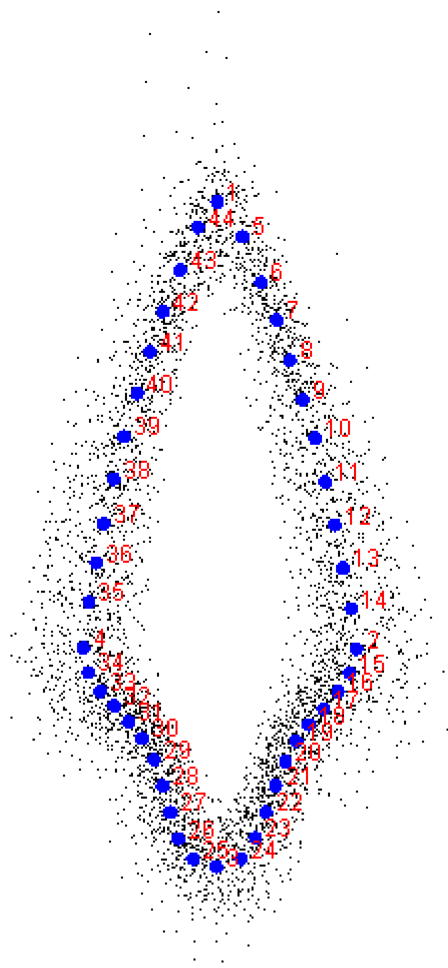


Figure 4. Variation in landmark configurations for the 109 arrowheads in the sample.

3.1. PHOTO/ILLUSTRATION TEST

Before we move onto the main results of the study, it is important to take a step back and refer to the Photo/Illustration Test, the results of which gave support to the proposal that publication illustrations were accurate enough to be used in the current GMM study. This test was originally devised in order to address a number of criticisms regarding the use of publication illustrations in the pilot study (Smeyatsky 2014). However, the test was deemed crucial when it was realised that there was just too great a shortfall in personally documented live arrowheads which most likely would have had an adverse effect on the validity of the study.

A total of 54 specimens comprising 27 arrowhead photographs and 27 corresponding arrowhead publication illustrations was included in this particular test. The sample covered a range of publication illustrations from more basic representations to ones with more artistic finesse and some that had been created from scans using CAD software. Nine different author's illustrations were assessed in the analysis.

The process by which the illustrations were assessed was relatively simple. It was during the landmarking phase of this analysis that it was discovered that automated-landmarking software such as LAMINA was inadequate for our purposes in this GMM analysis as it produced sets of landmarks that would shift when re-landmarked. Thus, manual-landmarking through tpsDig was employed in this case. The raw co-ordinates were then uploaded into MorphoJ where they were adjusted using a Procrustes Superimposition for geometric morphometric validity. The resulting adjusted co-ordinate data were then imported into the statistics platform R where they were scrutinised by paired t-test, ANOVA and Procrustes Distance analysis.

	T	***Df***	***p-value***
Paired t-test	0.4094	26	0.6856

Table 2. Paired t-test results of the comparison between the centroid sizes of the arrowhead photographs and their corresponding published illustrations.

The Paired t-test (Table 2), which compared the mean centroid sizes between the photographs and the illustrations, tested at a 95% confidence interval resulting in a critical score of qt = 2.055529. Since $t < qt$, we accept the null hypothesis that the mean centroid sizes of the two groups were in fact very similar. Centroid size, which is a measure of size that is independent of shape, is the square root of the sum of squared distances between the landmarks demarcating the shape of a form and its centre point (Zelditch 2004).

	Df	*Sum Sq*	*Mean Sq*	*F*	*Pr(>F)*
PhotoVsIllustration	1	0	0.0041	0.002	0.962
Residuals	52	94.98	1.8265		

Table 3. ANOVA test of the comparison between the centroid sizes of the arrowhead photographs and their corresponding published illustrations.

The ANOVA test (Table 3), which was used to compare individual centroid sizes between the two groups, testing at a 95% confidence interval resulting in a critical score of $qf = 4.026631$. Once again, since $F < qf$, we accept the null hypothesis that the centroid sizes of the individuals within each group are also very similar. While these two results were providing good news in terms of the illustrations' possible utility, they both only focused on size. A Procrustes Distance analysis, which focuses on shape and size, was still necessary for absolute confirmation.

Procrustes Distance analysis essentially measures the sum of the distances between the landmark configurations of corresponding individuals in two samples. The Procrustes distances from the manual landmarking process (Table 24) were then imported into SPSS for graphical representation (Figure 17). The key to interpreting Procrustes distances is their comparison to a threshold value however, there is no universal threshold value and it is calculated case by case. In this particular situation, the threshold value was calculated to be $pd = 0.2$. Therefore, if the Procrustes distance < 0.2, then that particular pair of landmark configurations can be said to be significantly similar. In addition, the closer the Procrustes distance is to 0, the more similar those particular landmark configurations are.

When inspecting the results of this analysis one can observe that all of the values fall within this threshold except for one outlier which is just over the mark. This indicates that the arrowhead publication illustrations are indeed similar enough to their photographic counterparts to be considered viable for inclusion in this study's main analyses. What is also interesting to note is that it is quite clear that Sampson's specialised technique of editing arrowhead scans using CAD software to create illustrations (Close & Sampson 1999) is the most accurate way of illustrating artefacts as all the Procrustes distances for those are extremely close to 0 and do not vary much from each other. However, it is also interesting that several examples, from multiple authors who used standard illustrations, were just as close to 0.

3.2. PCA

The results of the Principal Component Analysis were not at all surprising considering its similarity to the PCA results from the pilot study which included 72 of the 109 arrowhead landmark configurations used in the current study (Smeyatsky 2014). Figure 5 illustrates the results of one the Principal Component analyses performed in the current study where each symbol represents an arrowhead from the sample.

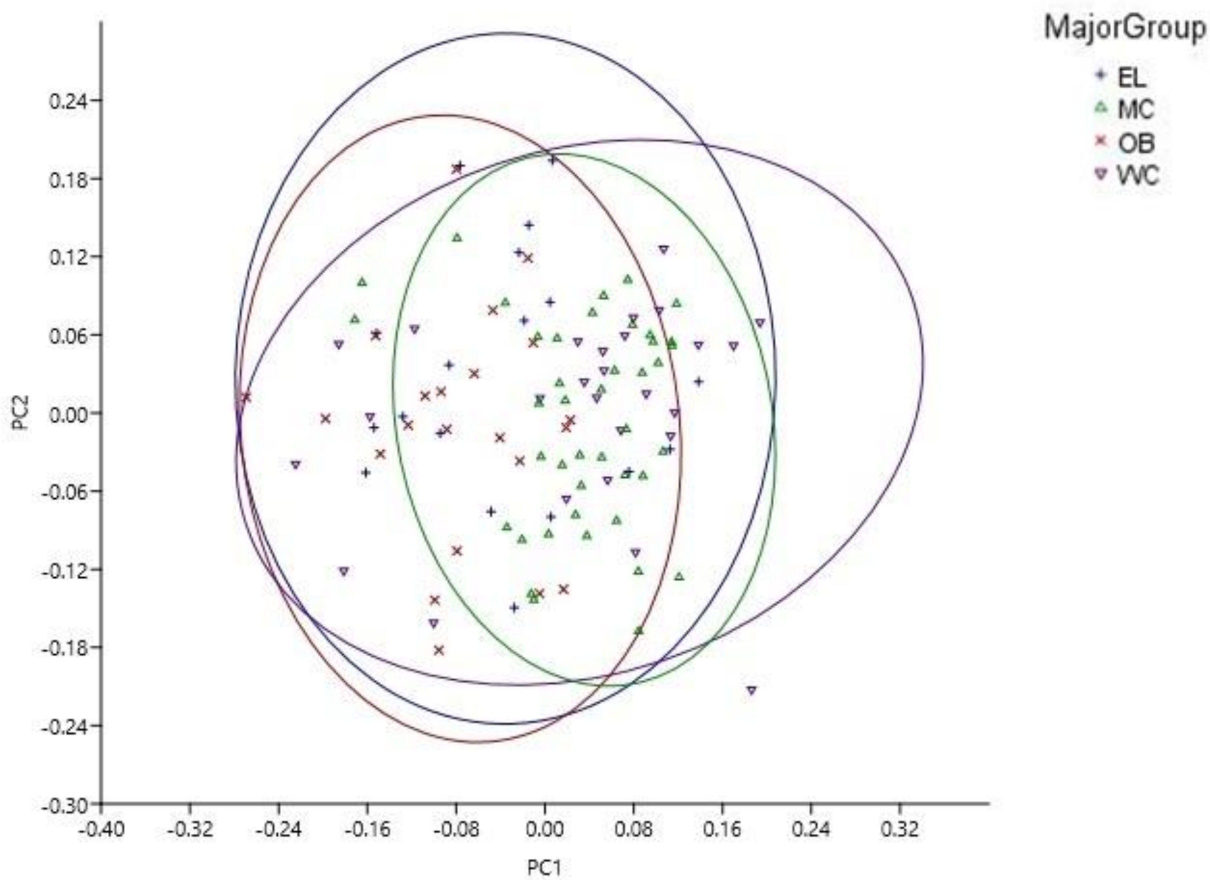


Figure 5. PCA scatter plot coloured by the Major Group variable. Ellipses at 95% confidence levels. (EL = Eastern Lesotho Group; MC = Middle Cape Group; OB = Orange Basin Group; WC = Western Cape Group).

Principal component 1 represents variation in the overall width of the arrowhead (Fig. 18) which in this analysis accounted for about 29% of the total variation. However, principal component 2 in this case represents variation in the length of the point, barbs and tang which was responsible for about 22% of the total variation (Fig. 19). The wireframe graphs helps to visualise what the variation being measured by

PC's actually represent. The light blue outline represents the mean shape of the whole sample, while the dark blue outline represents the positive deviation from the mean shape according to that particular PC. Figures 20 & 21, known as Lollipop Graphs, are just another way of representing the shape changes in PCs where the emanating lines indicate "changes in the relative positions of the landmarks as the score on the PC increases" (Zelditch 2004: 170). Table 4 shows a list of the first five associated PC loadings.

	Eigen Values	**% Variance**	**Cumulative %**
1	0.00936032	28.699	28.699
2	0.00701315	21.502	50.201
3	0.00459159	14.078	64.279
4	0.00206771	6.34	70.619
5	0.00154319	4.731	75.35

Table 4. Loadings of the first five Principal Components.

While it is not necessary to colour the data points, doing this adds on an extra layer of information that can add value to the interpretation of the PCA. In the case of Figure 5, the data points have been coloured according to the Major Group classifier that was described earlier on. One can see that by adding in this layer of information that the data is clustering to a degree according to this Major Group classifier. This classifier came about from an attempt to group sites according to a geographic context that would encompass enough arrowheads within a relatively close proximity whilst keeping the group sizes as even as possible. This was an especially difficult task considering the rarity of these artefacts and the fact that different parts of southern Africa; have received different degrees of surveying (Sampson 1988, Close & Sampson 1999).

Figure 6 shows a map of the arrowhead bearing site locations reflecting the Major Group classifier and, as can be seen in Table 5, they have been grouped to reflect relatively even groups while retaining the geographic variable. The clustering highlighted by the Major Group classifier is already showing promise in terms of understanding stylistic shape variation in these artefacts.

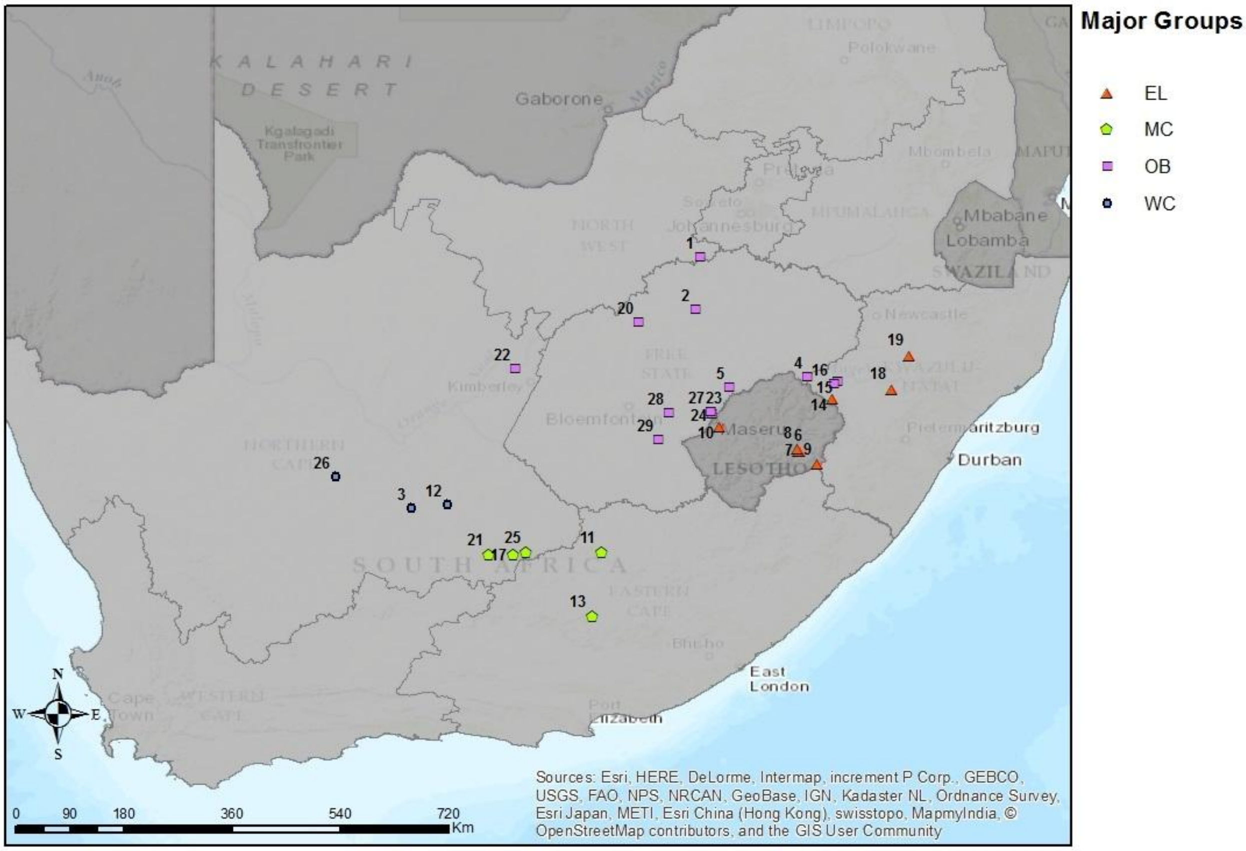


Figure 6. Arrowhead bearing sites included in study coloured according to Major Group. (EL = Eastern Lesotho Group; MC = Middle Cape Group; OB = Orange Basin Group; WC = Western Cape Group).

Major Group	No. Of Arrowheads
Western Cape Group	27
Orange Basin Group	22
Middle Cape Group	42
Eastern Lesotho Group	18

Table 5. Number of arrowheads per Major Group.

Without manipulating the PCA data yet still taking advantage of the classifier functionality, we can extract yet more information from the same analysis. Below, Figures 7 & 8 show the same PCA scatter plot from earlier, however in this case it has been coloured according to the Type and Raw Material classifiers.

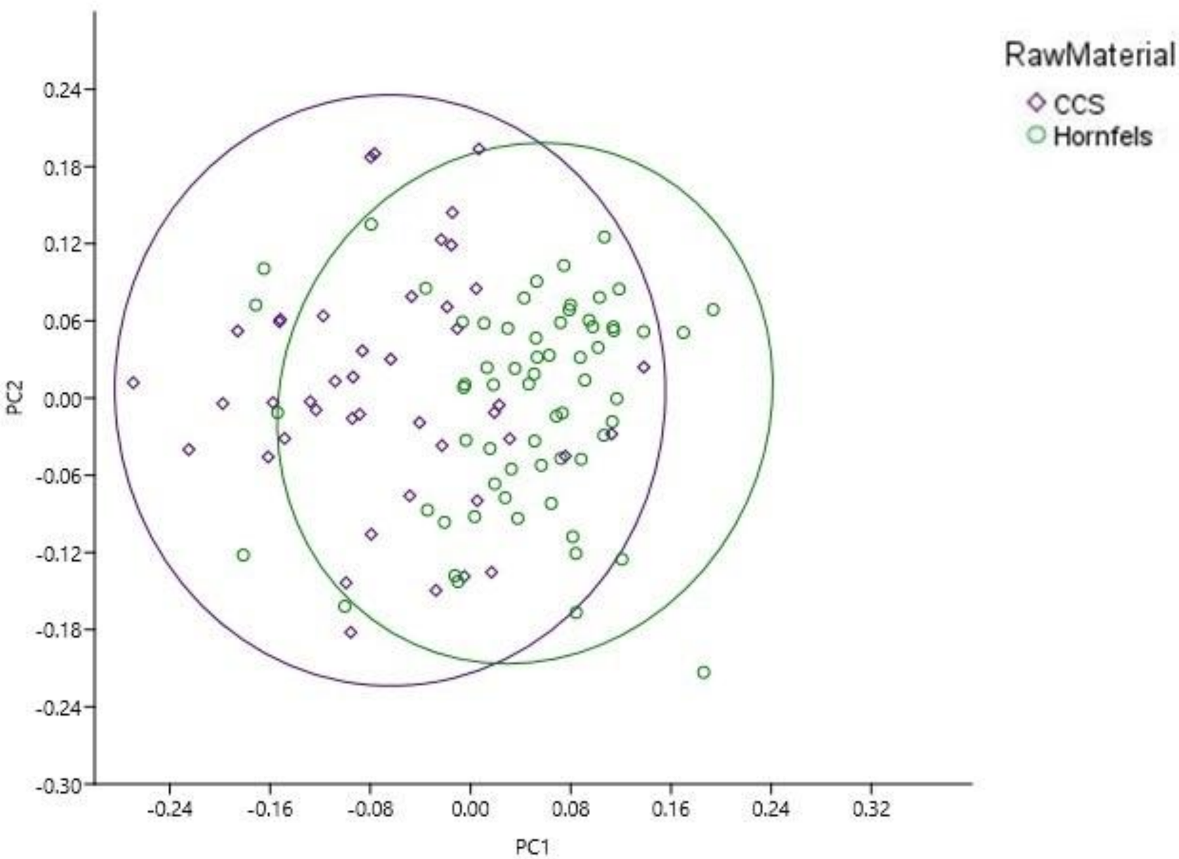


Figure 7. PCA scatter plot coloured by the Raw Material variable. Ellipses at 95% confidence levels.

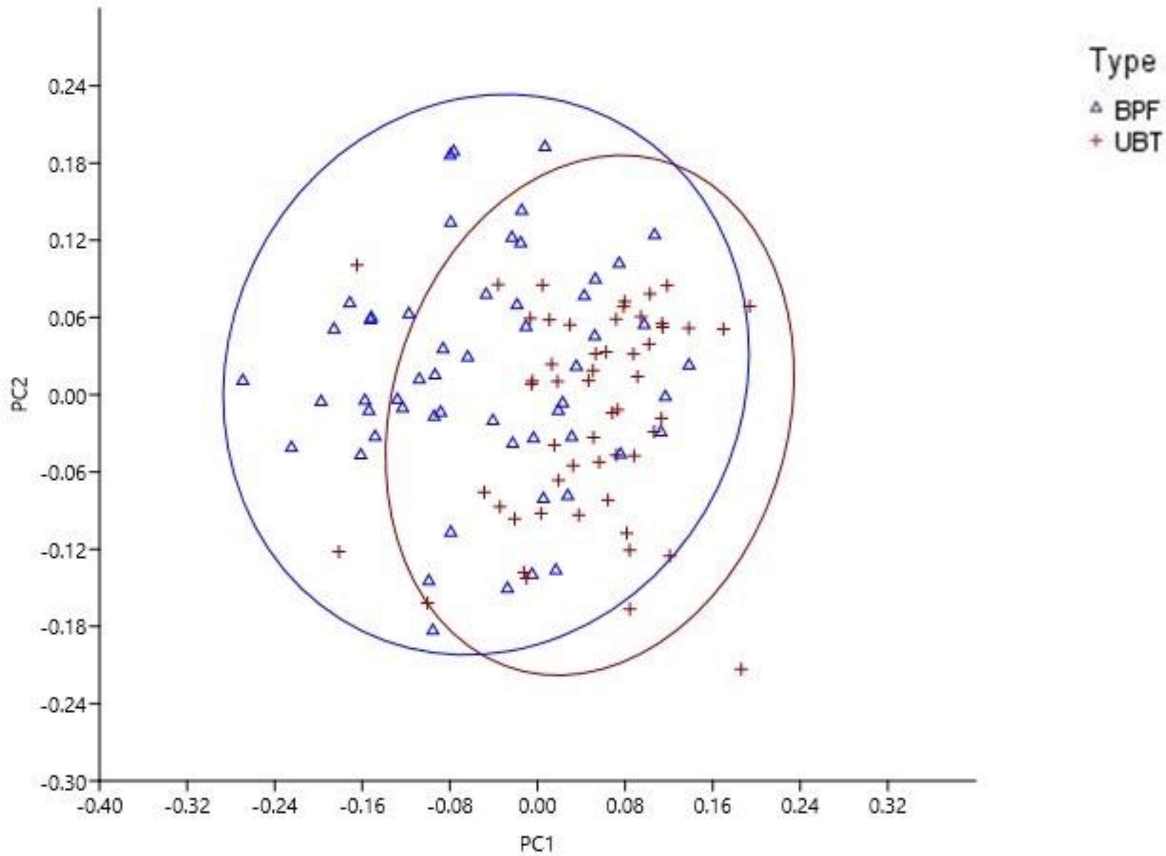


Figure 8. PCA scatter plot coloured by the Type variable. Ellipses at 95% confidence levels. (BPF = Bifacial Pressure Flaked; UBT = Unifacial Backed Tang)

Even though there is still some overlap, the clustering highlighted by these two variables is also quite clear. As explained earlier, the Raw Material classifier is denoting just that, which raw material the arrowheads were made of, either Hornfels or CCS, while the Type classifier is denoting the arrowhead 'type' as either a Unifacial Backed Tang or Bifacial Pressure Flaked arrowhead. The UBT variant, as described by Close & Sampson (1999), are formed on blade blanks, most of which are of a fine grained Hornfels and they argue that the backed tang specimens were most likely expediently produced as opposed to the curated, bifacial pressure flaked ones. The BPF variant represents all arrowheads that have been bifacially worked whether they were pressure-flaked or otherwise.

The parallels struck by this PCA coloured by these three variables are very interesting. To summarise, what we can gather from these results are the following:

1. We are definitely observing that the arrowheads from the sample are clustering to a degree according to their shape attributes or their Principal Components.
2. When coloured by the Major Group classifier, we can see that certain arrowhead styles more resemble their counterparts that are in closer proximity.
3. When coloured by the Type classifier, we can see that there is merit in the predetermined, etic classifications given to these arrowheads by past researchers.
4. When coloured by the Raw Material classifier, we can see that raw material choice plays some role in arrowhead style.
5. Looking at the PCA under the light of all 3 variables, there is a relatively clear pattern that emerges, that all these variables and arrowhead style are linked. However, we do not know how they are linked but this question will be explored further on with PLS analysis.

Before continuing with the results of the CVA and PLS analyses, we are still left with the question of how much the other 'heavily loaded' PCs have contributed to this analysis with PC1 and PC2 only contributing 29% and 22% to the overall variation respectively. As a rule of thumb, only the PCs that contribute 5% and over to the total variance are worth interpreting thus only PC3 and PC4 (at about 14% and 6% respectively) are worthwhile to inspect (Zelditch 2004: 168). Figure 22 shows the PCA of PC1 vs PC3 and one can see that we are getting similar patterns of clustering as the ones we were getting from PC1 vs PC2. When looking at the variation represented by PC3 in Figures 15 & 16, we can see that it is describing variation in the form of an asymmetrical component.

Similarly, when inspecting the PCA of PC1 vs PC4 in Figure 25, yet again we find similar patterns of clustering as compared to the previous examples. Like PC3, PC4 also represents variation in the form of asymmetry, albeit in a slightly different fashion (Fig. 26 & 27). As an aside, one can also see the differences in the magnitude of variance that each PC is responsible for as it is reflected in the range of scores for each PC on the scatter plots of scores (Zelditch 2004: 168). For example, in Figure 25 the range for PC1 is far greater than that of PC4 as it is responsible for more shape variance.

However, when inspecting the PCAs of PC2 vs PC3 and PC4 in Figures 28 & 29, there are no clear clustering patterns. The reason behind this lies in the morphometric description of what PC1 represents. Even though size is technically being extracted from the analyses when we perform geometric morphometric analyses, PC1 still reflects that size component which is embedded to a degree within the geometric form of the arrowheads. From the dispersal of this PCA we can see that PC1 is a particularly important component with regards to our clustering however, we are only getting most our dispersal from PC3 whereas PC2 does still show some relatively good clustering. This clustering along PC2 is telling us that there are significant similarities between the overall length of the arrowheads from the Eastern Lesotho group and Orange Basin group yet there is more variability in this regard among the other two groups. Since this PC2 partially represents the length of the tang, then this clustering could indicate differences in hafting techniques perhaps.

3.3. PLS

As we have seen from the results of the previous analyses, the arrowheads are clustering according to their shape attributes to a degree. What is even more interesting, perhaps, is the overlap highlighted by the Type and Raw Material classifiers. This overlap is telling us that not only is there a geographic divide between two major stylistic groups of arrowheads but that the vast majority of these groups are also characterised by their own types and raw materials. However, even though there are these patterns, we do not know why they are occurring and how they are linked with arrowhead shape. Partial Least Squares analysis seeks to clarify just that by exploring patterns of co-variation between two blocks of variables. For instance, it can ascertain the degree to which shape and say raw material choice is related in a similar way to regression analysis. Using PLS to examine the relationship between morphological variables and ecological variables is illustrated in Klingenberg & Ekau (1996). In their analysis, they sought to understand the relationship between aspects of Antarctic fish morphology and ecological factors such as diet and shift in habitat (Klingenberg & Ekau 1996). Rohlf & Corti (2000) make good work of explaining and assessing Two-Block PLS Analysis (the PLS anaylsis which is implemented in section 3.3.1). Similarly to the previous source, they discuss several case studies where animal morphology is tested against ecological variables such as diet, temperature, humidity, rainfall, soil type and vegetation (Rohlf & Corti 2000). While it is clear that biological specimens are not the same as lithic artefacts, the same principles can still apply, where instead of testing ecological variables such as diet, temperature and humidity against morphological variation, we can test variables such as type, raw material and site location. The authors explain that Two-Block PLS Analysis can "be used to analyze the covariation with shape by simply using shape variables as one of the sets of variables" (Rohlf & Corti 2000). Even though there are no direct tests of significance for Two- Block PLS, one can make use of permutation tests to test results of the PLS analyses, a feature that is already built into MorpoJ (Rohlf & Corti 2000).

Not only can it explore the relationship between two sets of variables but it can also test the relationship between two sets of landmarks within the same configuration, in other words we can test to see if there is a relationship between the shape of the point and the shape of the tang in an arrowhead.

With this in mind, most of the earlier mentioned classifiers were tested against arrowhead shape (as well as centroid size) using PLS analysis and a few PLS tests were completed “within the configuration” of landmarks.

3.3.1. TWO SEPERATE BLOCKS

3.3.1.1. BIOME PLS

The first of the PLS analyses performed were according to the Biome classifier which contained 3 South African biomes namely: Name-Karoo, Grassland and Savannah. Figure 30 describes the shape covariate of the Biome variable depicting change in the overall arrowhead shape.

Table 6 shows the results of this particular PLS. From this table, one can see the PLS extracted one dimension of covariance with a singular value of 0.03743877 explaining all of the covariance between the two blocks. The ‘golden number’, so to speak, that tells us if there is significant covariance between the two blocks is the RV Coefficient. Coming in at only 0.1180, the RV coefficient shows that there is only a very weak correlation between arrowhead shape and the biome in which the arrowhead was located.

RV coefficient: **0.1180**	Singular value	P-value (perm.)	% total covar.	Correlation	P-value (perm.)
PLS1	0.03743877	<.0001	100	0.42923	0.0012

Table 6. Overall strength of association between Biome variable and arrowhead shape.

Just as a check to see whether the correlation between shape and biome might be confounded by a correlation between shape and size, another PLS was performed using arrowhead centroid size as one of the blocks instead of arrowhead shape. The results are as follows:

RV coefficient: **0.2071**					
	Singular value	P-value (perm.)	% total covar.	Correlation	P-value (perm.)
PLS1	0.8338863	<.0001	100	0.45505	<.0001

Table 7. Overall strength of association between Biome variable and centroid size.

Once again, we are presented with an RV coefficient representing a weak correlation between centroid size and biome. These results tell us that there is simply a weak link between the shape and size of the arrowheads and the biomes in which they are located.

3.3.1.2. SCRAPER RATIO PLS

Next, a PLS was performed to investigate the possible relationship between arrowhead shape and the Scraper Ratio classifier. As explained earlier, the Scraper Ratio is simply the calculated ratio of lithic scrapers to backed tools at each individual site. This ratio has been useful in lithic studies when understanding possible cultural differences between sites (Sadr 2015). A positive or negative ratio of scrapers to backed tools would serve as different cultural indicators. Therefore, the goal with using PLS to test shape against the Scraper Ratio, where the ratio itself is used as a variable, was to ascertain if a correlation did exist in our stylistic clustering, giving evidence in support of the idea that two differing hunter gatherer cultural traditions could have been responsible for the two major clusters of arrowhead styles. Figure 31 shows the shape covariate of the Scraper Ratio variable depicting change in the length of the barbs and tang as well as an asymmetrical component.

RV coefficient: **0.1336**					
	Singular value	P-value (perm.)	% total covar.	Correlation	P-value (perm.)
PLS1	7.06376682	0.0132	100	0.53443	0.0229

Table 8. Overall strength of association between Scraper Ratio variable and arrowhead shape.

By looking at the results of the PLS in Table 8, it is plain from the RV coefficient that there is only a weak correlation between arrowhead shape and the scraper ratios of the sites at which the arrowheads were excavated. This result does not mean that the scraper ratio is not an effective cultural indicator, but that in this case it does not reveal any patterns even though excavated sites within the region under investigation are scraper rich. Unfortunately, due to the fact that many of the arrowheads in the sample were either collected from surface sites or brought into museums by the public, there is a substantial lack of valid scraper ratios (which would only be acquired from excavated sites) for a large portion of the sample. However, for the portion of sites for which we do have a valid scraper ratio, there is no obvious pattern occurring.

When performing a similar check as explained in the previous PLS test by examining the relationship between centroid size and the Scraper Ratio variable in Table 9, we can see an even weaker correlation between the two blocks of variables.

RV coefficient: **0.0203**					
	Singular value	P-value (perm.)	% total covar.	Correlation	P-value (perm.)
PLS1	47.24777874	0.3282	100	0.1425	0.3282

Table 9. Overall strength of association between Scraper Ratio variable and centroid size.

3.3.1.3 CERAMIC TEMPERING PLS

The Tempering variable, which accounts for the differing methods in which ceramics were manufactured (either by grit tempering or grass tempering), was employed versus shape in a similar vein to that of the Scraper Ratio. The rationale for looking at the tempering methods used at sites is much the same as that of the scraper ratio in that the type of tempering found can also be a cultural indicator (Sampson 1988; Hart 1989; Bollong *et al.* 1997). Unfortunately, just like the previous test, this PLS was also affected by the same issues. Considering that many of the arrowheads in the sample were not excavated and just collected, we can only gather tempering data from excavated sites that had recovered ceramic material. With this in mind, the PLS still produced results for both shape and centroid size versus Tempering as can be seen in Tables 10 & 11.

RV coefficient: **0.1552**					
	Singular value	P-value (perm.)	% total covar.	Correlation	P-value (perm.)
PLS1	0.0226941	0.0046	100	0.5382	0.0096

Table 10. Overall strength of association between Ceramic Tempering variable and arrowhead shape.

RV coefficient: **0.0919**					
	Singular value	P-value (perm.)	% total covar.	Correlation	P-value (perm.)
PLS1	0.31813454	0.0277	100	0.30311	0.0277

Table 11. Overall strength of association between Ceramic Tempering variable and centroid size.

It can be observed that shape and centroid size are displaying very weak correlations to ceramic tempering according to the RV coefficients. These results are not very telling as we do not have enough tempering data for whole sample to validate them. However, for the data that we do have, there are no patterns that can be observed. However, it can be added that in the region under investigation, fibre temper is common western South Africa and absent on the eastern side.

3.3.1.4. DATING PLS

For this PLS analysis, the known dates of the arrowheads were tested against the shape and centroid size of corresponding arrowheads. The dates were grouped into 500 year intervals in order to minimise the amount of statistical noise that would have occurred from the number of specific dates for individual arrowheads. While there is a greater proportion of arrowheads with corresponding dating data to test than compared to the data of the Scraper Ratio and Tempering PLS tests, there is still a proportion of arrowheads that were either surface finds or were recovered from undated contexts. In addition, a similarly sized proportion of arrowheads only possessed relative dates, each of which unfortunately covers too great a time period for them to be useful enough to be included in this analysis. Even so, the results from this analysis which are illustrated in Tables 12 & 13 are more valid than those of the Scraper Ratio and Tempering PLS tests mostly due to its larger sample size.

RV coefficient: **0.0414**

	Singular value	P-value (perm.)	% total covar.	Correlation	P-value (perm.)
PLS1	17.06116164	0.4117	100	0.4495	0.0379

Table 12. Overall strength of association between Dating variable and arrowhead shape.

RV coefficient: **0.0013**

	Singular value	P-value (perm.)	% total covar.	Correlation	P-value (perm.)
PLS1	56.38455237	0.7885	100	0.03639	0.7885

Table 13. Overall strength of association between Dating variable and centroid size.

These RV coefficients not only reveal a very weak correlation between date and shape but they reveal an almost non-exist relationship between each set of variables. This is especially true for the relationship between centroid size and date. This result points to the likelihood that the stylistic attributes of the arrowheads in the sample are not affected by development through time, an issue which will be discussed in full at a later stage.

3.3.1.5. LATITUDE AND LONGITUDE PLS

Moving on to a PLS test that is more revealing, the Latitude/Longitude PLS analysis sought to test if relationships existed between the geographic locations of arrowhead bearing sites and the overall shape and centroid size of those arrowheads. When looking back at the results of the original PCA discussed earlier in this chapter, it may seem obvious that a correlation must exist in this regard considering that we have relatively clear evidence that there is geographic stylistic clustering of the arrowheads. However, Tables 14, 15 & 16 show that this is not necessarily the case.

	PLS1	PLS2
Longitude	0.80813423	0.58899836
Latitude	-0.58899836	0.80813423

Table 14. PLS loadings associated with Longitude and Latitude.

RV coefficient: **0.1320**

	Singular value	P-value (perm.)	% total covar.	Correlation	P-value (perm.)
PLS1	0.10796899	0.0001	96.988	0.44895	0.0002
PLS2	0.01902581	0.2059	3.012	0.25358	0.3615

Table 15. Overall strength of association between Latitude and Longitude variable and arrowhead shape.

RV coefficient: **0.2128**

	Singular value	P-value (perm.)	% total covar.	Correlation	P-value (perm.)
PLS1	2.34037392	<.0001	100	0.46395	<.0001

Table 16. Overall strength of association between Latitude and Longitude variable and centroid size.

Surprisingly, the RV coefficients reveal that there is only a weak correlation between shape and site location while there is also a weak, albeit slightly stronger, correlation between size and site location. What is also worth noting is that when you look at Table 14, you will notice that Longitude holds a greater value for PLS1 at 0.81 than that of Latitude which holds a value of only 0.59, and you will notice that in Table 15 that PLS1 constitutes for 97% of the total covariance. This shows that even though the correlation between shape and site location is weak, the longitudinal position of sites plays a greater role in covariance than latitudinal position which makes sense considering that we are seeing stylistic clustering that is mostly dictated by longitude in the PCA or in other words, we are mainly seeing stylistic differences that are spread according to an easterly/western trend.

Even though we only see weak correlations in this test, it does not mean that site location is not important. It just shows that it does not have an effect on arrowhead shape or size. However, we will see further on that site location still links to style in terms of the transfer of stylistic information between groups, a point which will be followed up on in the discussion chapter.

3.3.1.6. TYPE PLS

As the discussion of the PCA results revealed earlier, when the points were coloured according to the Type classifier, a telling pattern emerged which saw the 'types' UBT and BPF overlap with the Western and Eastern sites respectively. Therefore, we would expect to see PLS results that correspond with that overlap. Yet again, Tables 17 & 18 seems to tell a different a story.

RV coefficient: **0.2089**					
	Singular value	P-value (perm.)	% total covar.	Correlation	P-value (perm.)
PLS1	0.02616549	<.0001	100	0.56221	<.0001

Table 17. Overall strength of association between Type variable and arrowhead shape.

RV coefficient: **0.2357**					
	Singular value	P-value (perm.)	% total covar.	Correlation	P-value (perm.)
PLS1	0.46729078	<.0001	100	0.48546	<.0001

Table 18. Overall strength of association between Type variable and centroid size.

The weak correlations displayed by the RV coefficients tell us that there is not sufficient evidence to show that there is a significant relationship between Type and shape and centroid size. How do we explain this anomaly? We can interpret these results as follows: Even though the etic typology that has been applied to southern African arrowheads does not influence the shape or the size of the arrowheads, the fact that we still see these types corresponding with the aforementioned pattern relating to geographic site locations in the PCA shows that these 'types' may be a stylistic choice in itself. This idea that etic typologies probably match the emic ones in this case, will be discussed later on.

3.3.1.7. RAW MATERIAL PLS

The last of the two-block PLS analyses highlights one of the most pertinent critiques of the current research, as to whether or not raw material choice could have influenced shape and centroid size in southern African tanged arrowheads. In following the PCA results that showed that the Hornfels and CCS raw materials corresponded with both the Type variable as well as the geographic grouping of sites, this would lead one to believe that Raw Material could be playing a role in the formulation of the two major stylistic groupings across southern Africa.

RV coefficient: **0.2344**					
	Singular value	P-value (perm.)	% total covar.	Correlation	P-value (perm.)
PLS1	0.02719732	<.0001	100	0.58773	<.0001

Table 19. Overall strength of association between Raw Material variable and arrowhead shape.

RV coefficient: **0.2203**					
	Singular value	P-value (perm.)	% total covar.	Correlation	P-value (perm.)
PLS1	0.44339907	<.0001	100	0.46941	<.0001

Table 20. Overall strength of association between Raw Material variable and centroid size.

However, the RV coefficients offer us a different explanation. The weak correlations indicate that raw material choice does not have a significant effect on shape and centroid size. Once again, we need to understand what this means in relation to the results from the PCA analysis. Essentially what we can take away from this is that: if raw material choice does not influence shape and centroid size then that may point to the possibility that raw material choice can be interpreted as stylistic in and of itself. This will also be discussed later on.

3.3.2. WITHIN A CONFIGURATION

'Within a configuration' PLS analyses are most commonly employed in scenarios where biological data is being tested. It simply involves splitting the landmark configuration of an object into two sets of landmarks, allowing those sets of landmarks to be tested against each other in order to ascertain how changes in their shape may or may not correlate. This kind of PLS is particularly useful in the testing of the shapes of animals within a species, where one wants to understand if changes in the shape of certain parts of the animal's form correlates with other parts. This function can be quite useful in lithics studies in that when appropriate it can be used to help us understand how the formation of certain parts of lithic artefacts can affect other parts of the same object.

3.3.2.1. POINT VERSUS SHOULDER & TANG

In following this line of thought, I considered it a worthwhile exercise to understand how the formation of the point of an arrowhead may affect the formation of its tang and vice versa. For this test the landmark configurations were split into two sets: Set 1 comprised landmarks 1, 2 and 4 as well as semilandmarks 5-14 and 35-44. Set 2 comprised landmark 3 and semilandmarks 15-34. Set 1 accounted for the shape of the point until its widest section while Set 2 accounted for the shape of the shoulders and the tang. PLS was performed on these two sets of landmarks where the results are shown in Table 21.

RV coefficient: **0.699941**	Singular value	P-value (perm.)	% total covar.	Correlation	P-value (perm.)
PLS1	0.0044011	<.001	57.597	0.92296	<.001
PLS2	0.00326004	<.001	31.603	0.89306	0.004
PLS3	0.00173931	<.001	8.996	0.7709	<.001

Table 21. Overall strength of association between Block 1 (overall shape of the point) and Block 2 (overall shape of the combination of the shoulders and the tang).

While there were a total of 42 PLS values, only the first 3 were of significant value, accounting for about 97% of the total covariance in this test. The RV coefficient in this case tells us that there is in fact quite a strong correlation between the shapes of these two parts of the arrowheads. According to the display of results of PLS1 in Figure 9, it is quite plain how true this correlation is for all of the arrowheads, despite their geographic location. In addition, the arrowheads still cluster along the geographically oriented spectrum of the Major Group variable, corroborating our results from the original PCA.

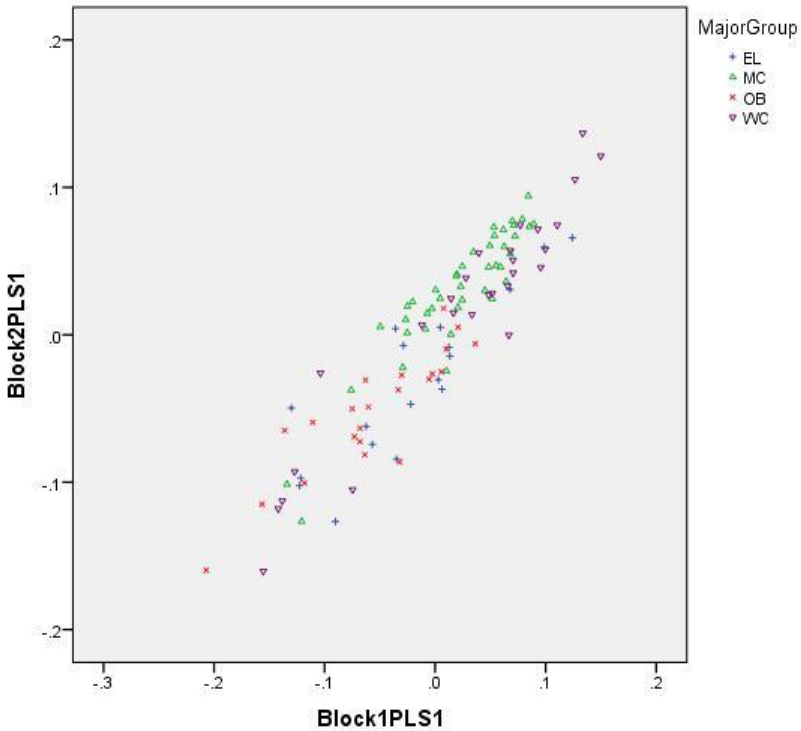


Figure 9. Point versus Shoulder & Tang PLS1 scatter plot coloured according to Major Group. (EL = Eastern Lesotho Group; MC = Middle Cape Group; OB = Orange Basin Group; WC = Western Cape Group).

Figure 10 shows the shape covariate of PLS1, where in the same image we can see how the landmark configuration was split. The shape change depicted in this image is showing that when the overall width of the point changes (red landmarks), so too does the overall width of the shoulder and tang (blue landmarks).

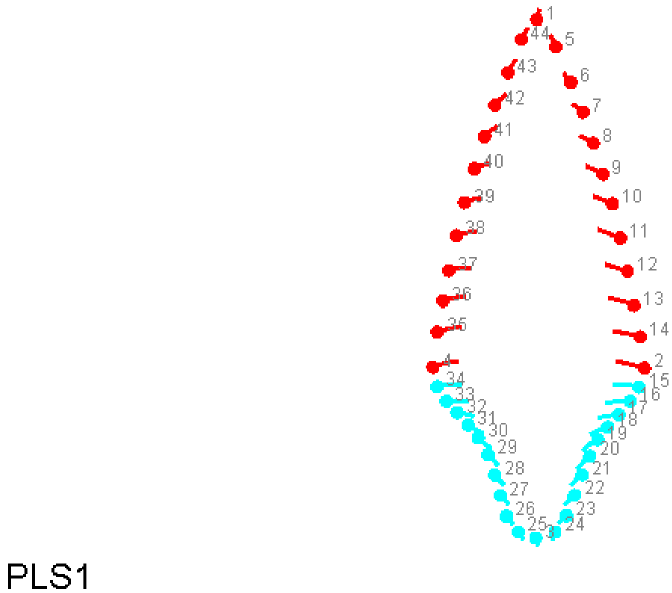


Figure 10. Shape covariate of PLS1 in Point versus Shoulder & Tang test. (Red = Block 1; Blue = Block 2).

The correlation is still true for the results of PLS2 displayed in Figure 31, however we are not seeing the same clustering we witnessed in PLS1. Figure 33 shows the shape covariate of PLS2 where change in the length of the point, correlates with change in the length of the shoulder and tang.

These results essentially show that the shape of the point is inextricably linked with the shoulder and tang. This should come as no surprise considering how the shoulder part of the arrowhead is more part of the point than the tang in that the point and the shoulder cannot be formed separately. Therefore, this PLS was retested using two sets of landmarks that grouped the point and shoulder together while separating out the tang.

3.3.2.2. POINT & SHOULDER VERSUS TANG

For this test, the two sets comprised the following landmarks: Set 1 included landmarks 1, 2 and 4 as well as semilandmarks 5-19 and 30-44. Set 2 included landmark 3 and semilandmarks 20-29. Set 1 now includes the shape of the point and the shoulder, where ‘shoulder’ is defined as the area from the point’s widest section until the end of the neck which signals the start of the tang or stem. The results for the PLS analysis performed on these sets of landmarks are illustrated in Table 22.

RV coefficient: **0.566327**	Singular value	P-value (perm.)	% total covar.	Correlation	P-value (perm.)
PLS1	0.00363426	<.001	67.445	0.9316	<.001
PLS2	0.00211986	<.001	22.947	0.80937	<.001
PLS3	0.00123315	<.001	7.765	0.7555	<.001

Table 22. Overall strength of association between Block 1 (overall shape of the combination point and shoulders) and Block 2 (overall shape of the tang).

Once again, only the 3 first PLS values were of considerable significance, accounting for almost 98% of the total covariance. While the value of the RV coefficient is not as high as that of the previous test, it is telling us that the two sets of landmarks are still relatively well correlated. The results for PLS1, as shown in Figure 11, illustrate this correlation between the point and the tang with no clustering as we saw in the PLS1 of the last analysis.

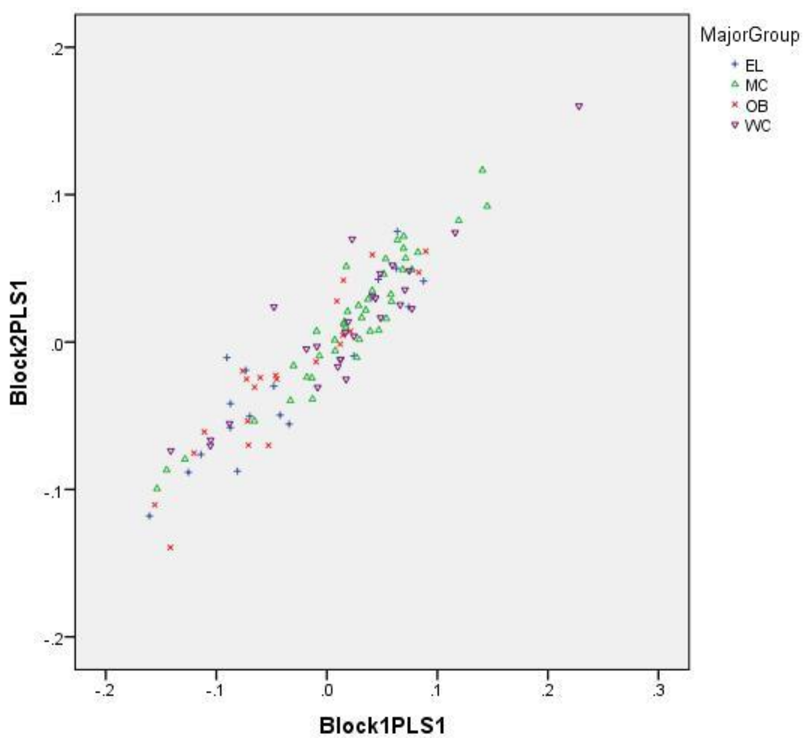
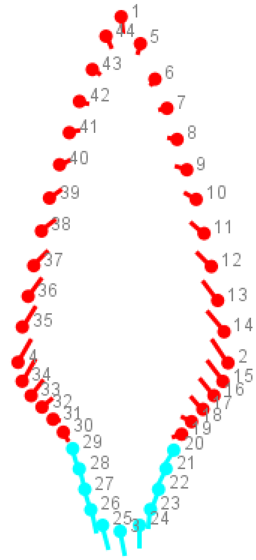


Figure 11. Point & Shoulder versus Tang PLS1 scatter plot coloured according to Major Group. (EL = Eastern Lesotho Group; MC = Middle Cape Group; OB = Orange Basin Group; WC = Western Cape Group).

Figure 12 shows the shape covariate of PLS1, where in the same image we can see how the landmark configuration was split in this particular analysis. The shape change depicted in this image is showing that when the overall width of the point and the height of the barbs changes, so too does the length of the tang.



PLS1

Figure 12. Shape covariate of PLS1 in Point & Shoulder versus Tang test. (Red = Block 1; Blue = Block 2).

Although more dispersed, the correlation is still true for the results of PLS2 displayed in Figure 34. Figure 34 shows the shape covariate of PLS2 where change in the length and width of the point, correlates with change in the overall size of the tang.

4. SUMMARY & DISCUSSION

Before we move into the current chapter, I would like to summarize the results in the previous chapter. First, the PCA confirmed the geographic shape clusters of southern African tanged arrowheads that were originally demonstrated in the pilot study. The arrowhead shapes were clustering according to the Major Group classifier. This classifier was constructed *a posteriori* in order to group arrowhead bearing sites together that were within relatively close proximity. The PCA coloured by this classifier found that arrowheads classified under the Middle Cape and Western Cape groups were more similar to one another than those classified under the Orange Basin and Eastern Lesotho groups which in turn resembled each other more. We are seeing two major clusters of arrowhead shape. One centred on Western South Africa and the other centred on Eastern South Africa. From here on these will be referred to as the South-Western Cluster and North-Eastern Cluster respectively.

In addition, it was found that when the same PCA was coloured according to the Raw Material and Type classifiers, similar patterns emerged. When coloured by the Raw Material classifier, the arrowheads made of the Hornfels raw material corresponded with the clustering observed in the Middle Cape and Western Cape groups while the CCS raw material corresponded with the clustering observed in the Orange Basin and Eastern Lesotho groups. When coloured by the Type classifier, the Unifacial Backed Tang variant corresponded with the Middle Cape and Western Cape groups and the Bifacial Pressure Flaked variant corresponded with the Orange Basin and Eastern Lesotho groups, almost mirroring the pattern displayed by the Raw Material classifier. These patterns have interesting implications which will be discussed further in this chapter.

Finally, when we inspect the results of the PLS analyses, we are perhaps presented with more questions than answers. The PLS analyses tested the correlation strength between arrowhead shape and size versus the following variables: the Biome classifier which contained 3 South African biomes, namely the Nama-Karoo, Grassland and Savannah biomes; the Scraper Ratio classifier which is the calculated ratio of lithic scrapers to backed tools at each individual arrowhead bearing site; the Tempering classifier which accounts for the differing methods of how ceramics were manufactured at arrowhead bearing sites (either by grit tempering or grass tempering); the Dating classifier which accounts for the known dates of the arrowheads in the sample; the Latitude Longitude classifier which accounts for the geographic locations of arrowhead bearing sites; the Type classifier which accounts for the Unifacial Backed Tang and Bifacial Pressure Flaked variants of arrowhead 'types'; and finally, the Raw Material classifier which accounts for the raw material choice for the manufacture of the arrowheads. The correlations between arrowhead shape and centroid size versus all of these variables were found to be too weak to be considered significant. This means that none of the above variables holds enough weight that could significantly influence the shape and centroid size of southern African LSA tanged arrowheads. This fact alone has many far reaching implications which will serve as the basis for the current chapter.

4.1. ADRESSING THE QUESTIONS

As a start we will reflect on the research question and hypotheses that were set out in the beginning of this research:

> *"What do the shape clusters in South African Later Stone Age tanged stone arrowheads indicate?"*

The results of the pilot study proved that, from a sample of 72 southern African LSA tanged arrowheads, clear patterns of stylistic clustering were occurring across the region. However, the pilot study was not able to address the question of why the clustering was occurring, I could only speculate on the answers at that stage.

The main aim of the current research was to explain what the clustering might represent in social, chronological and/or economic terms. The research question can then be framed as a series of hypotheses:

G. The spatial arrowhead clusters are temporally distinct.
H. The spatial arrowhead clusters are undermined by the effects of reduction.
I. The spatial arrowheads clusters cut across boundaries in other artefact classes and represent inter-group exchange systems.
J. The spatial arrowhead clusters coincide with natural boundaries such as biomes.
K. The spatial arrowhead clusters are replicated in other artefact classes and signify culturally distinct identities.
L. The spatial arrowhead clusters do not correlate with any other measurable variable.

It should be clear how most of the hypotheses laid out here directly relate to several of the geometric morphometric tests that were explored in the previous chapter. Each of these hypotheses will be discussed in relation to the results in turn however there will be overlap in most cases as the answers to many of the hypotheses are invariably linked in one way or another.

4.2. DATING

The first hypothesis stating that the spatial arrowhead clusters are temporally distinct can be understood to mean that the arrowheads which are associated with secure dates will be tested to see whether they define temporally separate shape clusters. In dealing with this hypothesis it is useful to begin with a case study exploring long term cultural stability in hunter-gatherers from Southern Brazil (Okumura & Araujo 2014). Okumura & Araujo (2014) employed geometric morphometrics in the study of tanged bifacial projectile points recovered from Garivaldino Rodrigues Rockshelter, Rio Grande do Sul, Southern Brazil.

Their objective was to ascertain whether tanged bifacial point style could be used as an effective chronological marker (Okumura & Araujo 2014). Traditional and geometric morphometric techniques were applied to a sample of 94 specimens, whose form was complete enough for the techniques to be considered valid and meaningful (Okumura & Araujo 2014). Splitting the sample into four groups that were dictated by stratigraphic layering at the site, PLS analysis was used to assess the relationship between point shape and layer, centroid size and layer, as well as layer and raw material (Okumura & Araujo 2014). Each layer 'group' represented a discreet period in time falling within the dates of 11,660 to 7540 cal BP (Okumura & Araujo 2014).

Their results suggested that the point 'types' (they had defined according to stylistic shape attributes) could not be considered good chronological markers as the PLS showed no significant correlation between stratigraphic position and shape (Okumura & Araujo 2014). In accordance with this, they observed that while they did find that certain point 'types' were more popular during certain time periods, there were a number of differing 'types' that happened to coexist in the stratigraphic layers (Okumura & Araujo 2014). This case study illustrates an example where there is a substantial sample size from a single site with clear stratigraphy and associated absolute dates, but there was no significant relationship between the age of points and their corresponding shape and centroid sizes.

The idea that these types of artefacts would not have changed over relatively short time periods has been demonstrated theoretically (e.g., Eerkens and Lipo, 2007; O'Brien *et al*. 2010; Shennan, 2000, 2001) and methodically tested (Okumura & Araujo 2014). However, since there is always a degree of doubt when extrapolating results from case studies to apply in worldwide scenarios, it was necessary to test the possibility for ourselves in the southern African context when addressing this particular hypothesis.

The Dating PLS analysis assessed the relationship between southern African arrowhead age and its corresponding shape and centroid size. In a similar fashion to the Okumura & Araujo (2014) study, the sample of 60 securely dated arrowheads was grouped according to 500 year intervals ranging in age from 0-499 years BP to 2500-2999 years BP. The exact ages of the arrowheads are presented in Table 25.

The results of this analysis unequivocally showed that there is no significant relationship between the age of southern African arrowheads and their corresponding shape and centroid sizes, corroborating with the results of the Okumura & Araujo (2014) study. Simply put, this means that the age of the arrowheads is a factor that does not have any meaningful impact on the shape and centroid size of the arrowheads and therefore, it has no meaningful impact on the stylistic clustering we are seeing in southern African arrowheads. While this result essentially addresses our hypothesis, sample size remains issue.

Our sample included specimens from all over the region when it would have been ideal to test this hypothesis from a single site. In an attempt to address this issue, a smaller scale PLS analysis was conducted on a sub-sample of 30 specimens originating from the Seacow Valley. These particular specimens were chosen as they were part of the largest group of dated arrowheads in South Africa that all originated from what can be a considered as a single site. Table 23 shows the results of this small scale PLS analysis. RV Coefficient shows that there is no significant relationship between arrowhead age and its corresponding shape, even when the scale is brought down from an expansive landscape to a single site.

RV coefficient : **0.0227**

	Singular value	P-value (perm.)	% total covar.	Correlation	P-value (perm.)
PLS1	8.659502	0.9624	100	0.3892	0.6177

Table 23. Overall strength of association between Dating variable and Seacow Valley arrowhead shape.

Thus, from these results which are corroborated by the case studies discussed earlier, we possess sufficient evidence to reject our null hypothesis that the spatial arrowhead clusters are temporally distinct. In order to take this question any further we would require a ‘best case scenario site’ such as that of Okumura & Araujo (2014), we can only hope that such a site will be uncovered at some point in the future.

4.3. REDUCTION

The next hypothesis regarding how the reduction of arrowheads may have an effect on arrowhead shape may be a somewhat contentious issue. There are many examples of how shape changes in certain lithic artefacts, such as scrapers and handaxes, are notable when they are re-sharpened over their use 'lifetime' (Andrefsky 2006; Buchanan 2006; Clarkson 2002; Clarkson and Hiscock 2008; Dibble 1984, 1987; Flenniken and Raymond 1986; Hiscock 1994; Hiscock and Attenbrow 2002, 2003, 2005). Needless to say, the effects of re-sharpening on point shape have also been explored in various studies.

Charlin & Gonzalez-Jose (2012) sees this as an issue in lithic morphological studies since it has become more and more apparent to them that use-life artefact reduction makes the definition of morphological types difficult. As a result, the authors sought to explore the influence of reduction on the size and shape of South American stemmed projectile points (Charlin & Gonzalez-Jose 2012). They argued that the 'tip angle' and the ratio of the blade length to stem length were reliable measures of arrowhead reduction because use related damage is concentrated to the tip of the point and therefore reduction would result in the shortening of length as well as a change in point proportions (Charlin & Gonzalez-Jose 2012). Through the employment of geometric morphometric techniques, they found that these measures of arrowhead reduction were both correlated with the 1st principal component which accounted for 77% of the total variation (Charlin & Gonzalez-Jose 2012). Interestingly, only the tip angle correlated with those arrowheads that were known to be reduced, meaning that the tip angle is more telling of reduction (Charlin & Gonzalez-Jose 2012). Finally, a regression analysis showed that only 11% variation in size is explained by reduction as opposed to 54% of variation in shape being explained by reduction in their sample (Charlin & Gonzalez-Jose 2012). Essentially, their findings suggested that reduction is an important factor to consider when analysing projectile point shape and that reduction itself is more focused on the point rather than the stem or the tang (Charlin & Gonzalez-Jose 2012).

While this study does certainly compel one to appreciate the affect of reduction on lithic arrowhead shape, there are other examples in the literature that prove otherwise. Azevedo *et al* (2014) sought to disprove previous misconceptions about Patagonian arrowhead types. They posited that when you separate out the shapes of the point and stem/tang into modules, that those modules should be integrated as "they are conceived to accomplish a given, specific function" and thus are made together to accomplish that goal (Azevedo *et al.* 2014: 298). Therefore, if reduction was to occur on the arrowhead, then evidence of its re-sharpening would be plain in only one of the modules (the point) and not the other (Azevedo *et al.* 2014). The authors made use of the Factor Model to explore this idea since using this geometric morphometric method, one can separate out external factors affecting variation (raw material, biome, geography etc) from internal factors, signifying the relationship between the modules of the arrowhead (point and stem/tang) (Azevedo *et al.* 2014). While it was found that the shape differences between the two arrowhead types being tested were largely due to stylistic differences and not necessarily due to reduction factors, it was still observed that reduction differences were mostly observed in the point module (Azevedo *et al.* 2014). Other studies investigating the affects of reduction on point shape have produced similar results suggesting that re-sharpening was not a major cause of variation in their samples (Flenniken & Raymond 1986; Buchanan & Collard 2010; Buchanan *et al.* 2014).

When we turn our eye to the southern African lithic arrowhead literature, we find that there are hints scattered throughout which echo the above sentiments that these artefacts were never re-sharpened throughout their use-life. For instance, authors have shown that stone arrowheads are designed to break-off once they have entered their target (Bosc-Zanardo *et al.* 2008) and that there are also ethnographic accounts of how southern African tanged arrowheads in particular were designed to shatter on impact (Rudner 1979). It is then entirely plausible that many of the complete arrowheads that were isolated surface finds might have been lost during hunting expeditions and therefore, have not been used at all (Mitchell 1999; Bradfield & Sadr 2011). Additionally, a micro-wear analysis conducted on LSA tanged stone arrowheads from Holkrans (North-West Province) found evidence of microscopic impact damage, implying that even though most of these arrowheads were designed to shatter on impact, there still remains the possibility that they also could have been used without incurring any noticeable damage (Law de Lauriston 2014).

Even if there was no evidence in the literature to back up the argument that these arrowheads were not reduced over their ‘use-life’, one could allow for an argument based on common sense. When we consider the level of difficulty with which these incredibly tiny artefacts must have been made, it almost becomes unreasonable to try understanding how they could have been re-sharpened in any case. The brittle nature of the raw materials that these arrowheads are made of, compounded with their minute size, would make it nearly impossible for any re-sharpening to be done without breaking off a barb or tang, rendering the arrowhead useless. Instead of being re-sharpened, the idea that the damaged arrowheads were simply discarded seems more plausible, as is further evidenced by the arrowheads exhibiting macroscopic impact damage in Figure 36.

One last line of evidence arguing against reduction in southern African tanged arrowheads, was cultivated as a by-product of the ‘within a configuration’ PLS analyses that were discussed in the previous chapter. While not directly related to the original hypotheses of this research regarding stylistic variation in LSA tanged arrowheads and why the stylistic clustering is occurring, the results of the ‘within a configuration’ analyses in section 3.3.2, afford us some valuable insight into how these artefacts were formed by their makers. In the first analysis, we explored the relationship between the shape of the point and the combined shape of the shoulders and the tang, finding that the correlation between the two blocks was in fact quite high. In hindsight, this result did not tell us anything new as the shoulders are technically also part of the tang so the high correlation between the two blocks should have come as no surprise.

However, with regards to the second analysis where we explored the relationship between the shape of the point (including the shoulder area) and the shape of tang, we gathered a more interesting result. Even though the correlation between the blocks was not as strong as the one from the previous analysis, it was still significant and it could mean one of three things:

1. Either the correlation exists because the only way the point could have been formed into a specific shape was to keep the tang in a specific form or shape. In other words, the tang had to be in a form that would facilitate the formation of the point. For instance, in terms of handling the lithic while it was being knapped.
2. Or the correlation exists because depending on the shape of the point, the shape of the tang had to correlate with it in one way or another in order to fulfil its functional purpose as a hafting mechanism. For example, an inadequately small or flimsy tang would not be able to support a robust point once hafted and used as an armature.
3. Or, as a more speculative possibility, the correlation exists because it was part of a stylistic choice. Even though it makes more sense that the point would be the centre of stylistic expression as it would be the only exposed part of the arrowhead if it was hafted, it could still be possible that the shape of the tang was a stylistic choice which matched or complimented the style of the point.

The reasoning behind this correlation is not entirely clear however, I believe it would be a worthwhile question to explore through some experimental research at some point in the future. Regardless of this point, when looking back at Tables 21 & 22, we can see from the RV Coefficients that we have a strong correlation between the point shape and the shoulder/tang shape and a relatively strong correlation between the point/shoulder shape and the tang shape. This means that the point module and tang module (irrespective of which module is combined with the ‘shoulder’) were formed during the same shaping process or at the same time. Although not entirely conclusive, it implies that these arrowheads could not have been reduced as that would only have been able to occur once the whole arrowhead had been formed, allowing us to reject the null hypothesis that reduction affects the spatial arrowhead clusters. If the arrowheads were indeed reduced then we would only see weak to no correlation between the modules.

4.4. EXCHANGE NETWORKS

The hypothesis that spatial arrowhead clusters cut across boundaries in other artefact classes and represent inter-group exchange systems is an interesting one as there is a sizeable amount of evidence in the literature that seems to support this particular scenario.

From the discussion in the introductory chapter on arrows in San ethnography, the importance of these cultural objects in San society should come as no surprise. In line with this, many authors have made a link between the ethnography of the San and the lithic tanged arrowheads in southern Africa. Wiessner (1983) takes the foreground in terms of San arrow ethnography with her seminal work as we have seen in the introductory chapter. I would like to highlight some of the most prominent points from her research that revolve around arrows as exchange items in San society. Wiessner explains that in San society, arrows play an important role in their gift exchange system known as *hxaro*, which “underwrites relationships of mutual sharing, assistance, and extended visiting” (Wiessner 1983: 10). All of the San groups interviewed during her study had explained that they had either exchanged arrows themselves and/or had been given arrows from exchange partners (Wiessner 1983). Interestingly, with regards to the !Kung, the greatest percentage of arrows received from exchange partners were from those within a 1-20km range, a sharp drop in percentage from those partners living within 20-60km, then a sudden increase from partners living 60-100km away and finally a tiny percentage from partners living 100-200km away (Wiessner 1983). The higher percentage of arrows from exchange partners within a 60-100km range possibly indicate a greater importance to the San to exchange with partners in areas with complementary resources (Wiessner 1977, 1981).

In another seminal paper on San arrow ethnography, Deacon (1992) explores arrow beliefs within the /Xam Bushmen cosmology as discussed earlier. As she explains with reference to the Bleek & Lloyd ethnography, a similar exchange system was also practiced by the /Xam Bushmen; however it was also described as a means for making peace among rivals (Deacon 1992). Helping us bridge the gap between San metal arrowheads and their stone antecedents, is further ethnographic commentary, pulled from the Bleek and Lloyd archives, of a /Xam informant who expresses his preference for stone arrowheads over metal ones (Deacon 1992). This titbit provides us with some much needed confidence over our analogous transposition of San metal arrowheads onto the lithic tanged pieces that this study concerns itself with. While the ethnographic analogies can provide valuable insight into the past, especially with regards to the

San and prehistoric hunter gatherers, it is still overwhelmingly important to query the archaeology before coming to conclusions.

Mitchell (2003) addresses this issue by exploring the evidence of a gift exchange system akin to *hxaro* that has been revealed in the LSA archaeological record. He argues that our ability to transpose contemporary San gift exchange to a similar gift exchange system between hunter gatherers during the LSA, is actually quite limited (Mitchell 2003). Unfortunately, most of the evidence employed to create the connection has been through doing just that:

> "…drawing of formal analogies between items favoured by Ju/'hoansi for exchange (ostrich eggshell beads; arrows) and others found in archaeological excavations (ostrich eggshell beads; bone points), assuming that the social context can be mapped on that of the other." (Mitchell 2003: 38)

Mitchell (2003) highlights several problems with this. The one I think is relevant in the context of this thesis is when he makes the meaningful point that ostriches are found over almost all of southern Africa therefore the raw material for OES beads are by no means in short supply and can be made by any hunter gatherer group across the country (Mitchell 2003). He does mention a special case where, through ethnographic sources, it was known that the 'Flat Bushmen' did not make beads but instead would trade for them from other groups, which has been evidenced by a lack of bead-making debris at 'Flat Bushmen' sites (Mitchell 2003). This point is relevant to LSA tanged arrowheads because it undermines the only archaeological link we know of between lithic tanged arrowheads and LSA hunter gatherer gift exchange. OES beads were found in the same context with a few lithic tanged arrowheads that were recovered from Sehonghong Shelter (Lesotho), which signifies by extension that the arrowheads could have been associated with some sort of gift exchange system (Mitchell 1996). Luckily there is no evidence of on-site bead manufacture at Sehonghong, further strengthening this position (Mitchell 1996). An additional example exhibiting a similar scenario has also been observed at Holkrans, North-West Province (Bradfield & Sadr 2011).

An additional avenue of inquiry into evidencing the exchange of these arrowheads could be sought through the sourcing of the raw materials used to make them. However, one would require the mapping of all local raw material outcrops, a monumental task that until completed makes this route nigh impossible to tread.

While there is reasonable evidence from the ethnography and the archaeology pushing the idea of LSA tanged arrowheads being popular exchange items among Holocene hunter gatherers, I thought it may be possible to find further evidence of their application as such in the results from the geometric morphometric analyses. Unfortunately, this proved to be a tall order to accomplish from the available data. One way of assessing this issue would be to analyze the outliers we find in our PCA distribution as highlighted in Figure 5.

For instance, when we see specimens from one cluster (Middle Cape and Western Cape Groups) among specimens in another cluster (Orange Basin and Eastern Lesotho Groups) that should be firmly located among their peers, one might interpret that as evidence of exchange. However, when investigated thoroughly, there simply is not enough evidence to confirm this. A more likely explanation for the distribution of these outliers is the mere coincidence that a few happened to be more similar in shape to those in their opposing arrowhead clusters. Coincidence can be the only option as any other explanation would conflict with the other confirmed results of this study (the raw material and 'type' correlations) as well as the limitations imposed by territorial boundary limits, which will be discussed shortly.

Mitchell (2003) explains that in order to track how exchange items moved across space (when referring to OES beads), one would need a large number of sites with consistent variation in the concerned exchange item distributed over a large area. While we do possess a thorough site distribution, the sample is simply not fine grained enough to draw anything substantial from the geometric morphometric results. To be successful in this regard, we would need sample sizes that are at least as robust as the entire sample used in this study, to be present at individual sites. However, our inability to detect lithic arrowhead exchange on a macro scale does not mean it does not exist. In fact, gift exchange provides us with the perfect mechanism with which stylistic information could be spread within language group territories. Thus, gift exchange may help us explain the distribution of our shape clusters as we shall see.

4.5. BOUNDARIES

4.5.1. BIOMES

It should be apparent that the ultimate goal of this study seeks to prove that LSA tanged arrowheads are emblems of different archaeological cultures and could possibly point to the limits of their territorial boundaries. Hence, the formulation of the hypothesis that the coinciding of spatial arrowhead clusters with natural boundaries could help to push us towards this ultimate goal. Referring back to the previous chapter, the possible impact that the biome had on arrowhead shape was investigated as a means of addressing this particular hypothesis.

As you may recall, the Biome PLS analysis found that there was a very weak correlation between biome and arrowhead shape meaning that the biome in which an arrowhead occurred does not influence that arrowhead's shape in a significant way (See page 48). However, when we look at a PCA distribution that is coloured by the Biome variable in Figure 13, we are presented with an interesting pattern (See pages42, 45 and 46 for comparisons). When you compare Figure 13 with the other PCA distributions coloured by the Major Group, Raw Material and Type variables, that pattern of overlap displayed across all four is quite clear.

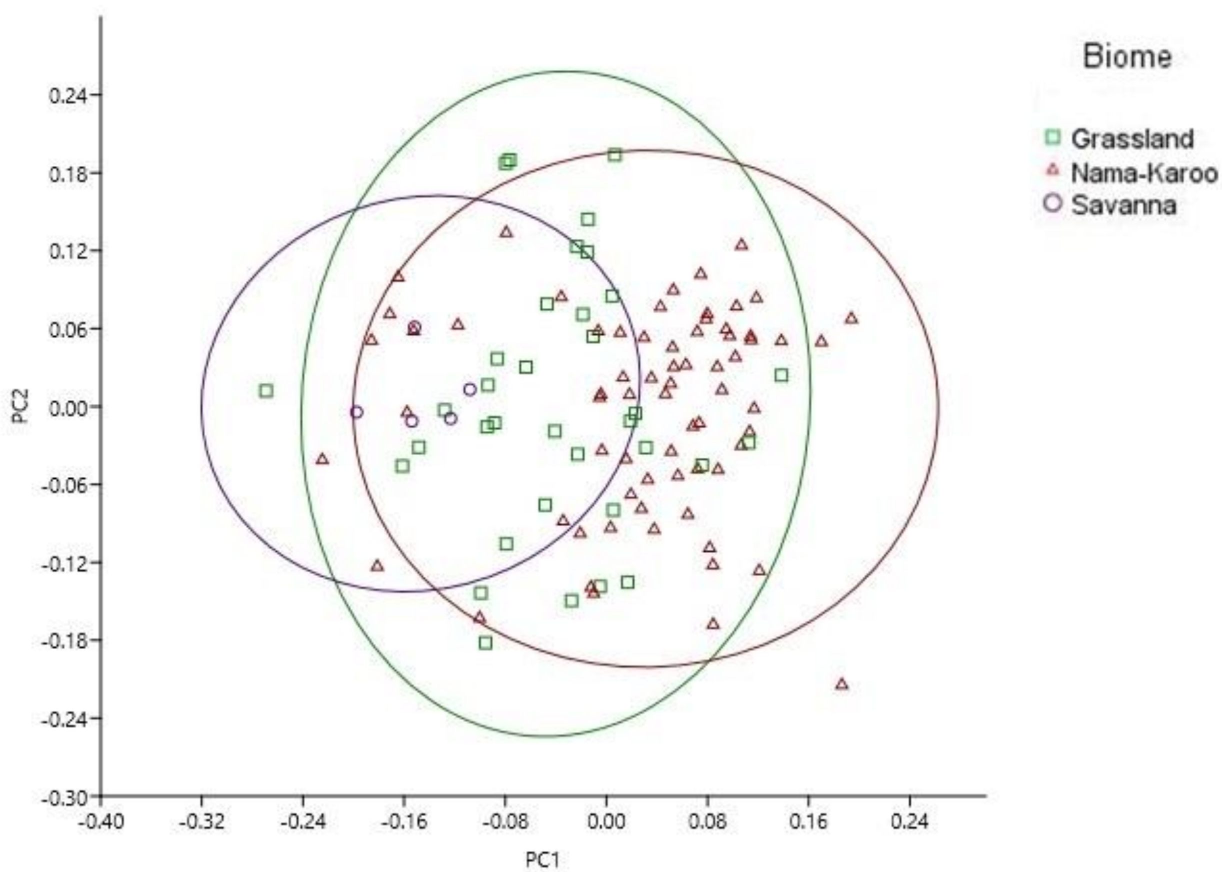


Figure 13. PCA scatter plot coloured by the Biome variable.

While we are seeing parallels from this PCA, there is still some overlap meaning that we are not seeing specific styles that are solely relegated to certain biomes. However, just like the other patterns that have emerged from this PCA coloured by different variables, this graph hints at the possibility that the pattern exhibited by the biome variable is worth exploring.

The literature exploring the relationship between hunter-gatherer toolkits and their respective biomes, have tended to revolve around environmental determinism over the years. They generally follow similar lines of argument that differences in lithic toolkits were sometimes determined by variation in the types of fauna that were being exploited in those biomes inhabited by those particular hunter-gatherers. Geometric morphometrics studies on point shape such as Buchanan *et al* (2014) have used such arguments to explain their results among Clovis points. In this case, as a possible explanation for shape variation found among Clovis points from clusters in the Western and Eastern United States, they argue that the eastern Clovis points were tailored for hunting caribou or deer whereas the western points were tailored for much larger game, such as mammoth and bison (Buchanan *et al.* 2014). This idea they based off the results of their previous study comparing the shape and size between Clovis points and Folsom points, associated with both bison and mammoth remains (Buchanan *et al.* 2011). While they did find significant differences in size and shape between Clovis-mammoth points and Folsom-bison points; Clovis-mammoth points and Clovis-bison points were almost indistinguishable, and Clovis-bison points were significantly different from Folsom-bison points (Buchanan *et al.* 2011). This does not bode well for the environmental prediction of arrowhead shape but the authors do mention that the tailoring of points for specific game is just a hypothesis as they do not have sufficient arrowhead assemblages with associated fauna nor experimental studies to test which point types are suited best for certain types of fauna (Buchanan *et al.* 2014).

Taking a word of caution from the Paleo-Indian points of North America, we now turn our gaze back to tanged arrowheads from South Africa and their relationship with South African biomes. Fortunately, all the arrowheads in this study were dated from 3500 BP to historical times, lining up with the late Holocene characterised by a moist, stable climate in which faunal species also remained fairly stable in their respective biomes. Considering that the Grassland biome and the Nama-Karoo biome were represented by the vast majority of arrowheads, they are the only ones worth discussing. In terms of hunted faunal species in the Grassland biome, as evidence by faunal remains at multiple sites, we find that they mainly comprised of ground game, small and small-medium bovids, multiple species of buck as well as large grazers (Mitchell 2002). The hunted faunal species of the Nama-Karoo biome comprised mainly of ground game, smaller bovids and large-medium grazers (Mitchell 2002). By Buchanan *et al*'s (2011, 2014) route of argument, we would expect the Grassland biome arrowheads to be significantly larger than the Nama-Karoo arrowheads in order to deal with the larger game that are known to occur in the

Grassland biome. However, this is not the case at all. In fact, we find that the majority of the Nama-Karoo arrowheads are significantly larger than their Grassland counterparts.

Why do southern African tanged arrowheads differ in such a way to Palaeo-Indian points? I believe the answer lies in how each of these armatures were intended to kill their prey. While the Palaeo-Indian points relied purely on stopping power combined with the penetrative effects of their physical design to take down large prey (Buchanan *et al.* 2011), the southern African tanged arrowheads were employed in combination with strong poisons, rendering a robust physical design largely irrelevant (Bradfield *et al.* 2015: 22). Thus, even though we are finding that the pattern exhibited by the Biome variable in the PCA results parallels that of the previously mentioned variables, it does not necessarily mean that southern African tanged arrowheads will fall into the ecology model. Additionally, the results of the Biome PLS analysis confirm that southern African tanged arrowhead size and shape is not related to the biome from which they were recovered.

4.5.2. NATURAL BOUNDARIES

We have ecological boundaries such as biomes that coincide with our major stylistic clusters, yet they do not have any impact on the arrowhead styles themselves. However, considering that there is evidence of variation in the rest of the assemblages across the different biomes (Mitchell 2002), the biome boundaries could act as an indicator of the toolkit requirements for each particular biome which points to the possibility that it would also act as an indicator of the territorial boundaries of the hunter gatherers responsible for those assemblages. While on its own this theory is relatively weak, when we take into account other natural boundaries that may coincide with the biomes and the stylistic arrowhead clusters, this position is somewhat bolstered.

Hilary Deacon was one of the first authors to comment on the topic for the southern African Holocene context (Deacon 1976: 170). In discussing the resolution with which we can detect the different scales of hunter-gatherer groups via archaeological remains, he suggests that ‘boundary zones’ which coincide with major ecological divisions may also provide us with the means to detect territorial boundaries on a scale of the dialect or language group level (Deacon 1976: 170). He provides the example of the Cape Folded Mountain Belt acting as an ecological boundary (the border between two biomes), where to the North lays the Name-Karoo biome and to the South lays the Fynbos biome which is cut off by the Indian Ocean coastline, acting a physical boundary (Deacon 1976). Across this ecological boundary, he states that “there are distinct typological differences in hafted tool preferences” (Deacon 1976: 170). He suggests that in the case of differing linguistic groups occupying the areas on either side of a physical and/or ecological boundary, the communication barrier itself could be seen as a correlate of typological differences (Deacon 1976). This last sentiment is echoed by Garth Sampson in his study on hunter-gatherer stylistic boundaries (Sampson 1988: 20).

With this in mind, turn your attention to Figure 14 which illustrates the distribution of our arrowhead localities and sites, overlaid with South Africa's biomes. As you can see, we have the North-Eastern groups (Orange Basin and Eastern Lesotho) falling neatly within the Grassland biome and the South-Western groups falling almost as well within the Nama-Karoo biome. While the locations of the Nama-Karoo localities are not sitting right on the ecological boundary between the biomes, the distance of the "dead ground" (Sampson 1988: 20) sitting between the closest North-Eastern and South-Western localities actually gives an advantage to the argument as you shall see soon. Looking at Figure 14 you may also notice that the Orange River not only separates the two biomes but also separates the two major stylistic clusters. Armed with the knowledge that watercraft are absent from the archaeological record over almost all of the southern African interior, the breadth of the Orange River combined with relative impassability of the Southern part of the Drakensberg Mountains (see Figure 37 for elevation of study area), these obstacles may very well have served as the physical boundaries preventing the transmission of stylistic information as proposed by Hilary Deacon (Deacon 1976; Mitchell 2002).

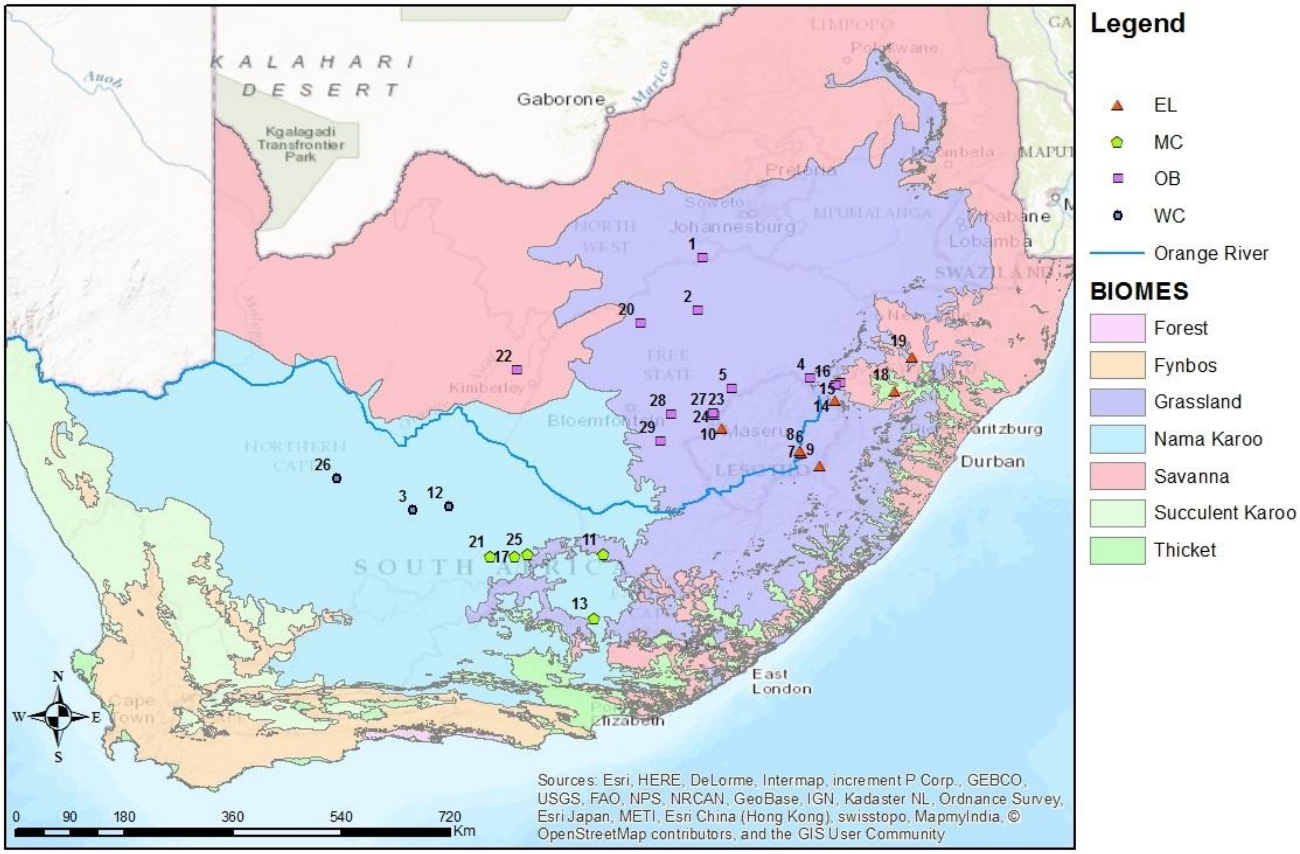


Figure 14. Map showing biomes and major groups. (EL = Eastern Lesotho Group; MC = Middle Cape Group; OB = Orange Basin Group; WC = Western Cape Group).

Thus, not only does Deacon's (1976) ecological and physical boundary model fit quite well in our case, but his suggestion that sites within the Karoo and Fynbos Biomes fall within different style zones corroborates with my data exactly. Even though his specific sites were not included in my study, one can see that my results echo his conclusion that "the differences in the artefact styles between the Highlands and Melkhoutboom occurrences in equivalent time ranges represent some major divisions in social and linguistic terms", as is evidenced by a lack tanged stone arrowheads south of the Cape Fold Mountain Range (Deacon 1976: 169). Even though we understand that a particular biome will not have an effect on the arrowhead shapes in our sample, it still has implications for typological differences between other artefact classes that could possibly be linked to differing hunter-gatherer linguistic groups. By looking at the patterns derived from the ecological and geographic evidence, it may well be sufficient to address our hypothesis posed at the beginning of this sub-chapter that it seems as if natural boundaries coincides with our spatial arrowhead clusters. However promising this may seem, we still need to delve further into the complicated nature of hunter-gatherer territorial boundaries and the implications of style before we can reach any conclusions.

4.6. CULTURAL IDENTITY

4.6.1. STYLISTIC BOUNDARIES

While the delineation of hunter-gatherer territorial boundaries has long been a heated topic in anthropological and archaeological circles alike, I will focus mainly on what I believe to be a seminal work that grapples with this particularly complicated topic, that of Garth Sampson's (1988) work on the stylistic boundaries of the hunter-gatherers from the Seacow Valley, South Africa. Sampson (1988) headed a massive surveying project within the Seacow Valley, Northern Cape, which procured a wealth of archaeological materials and detailed geographic knowledge of the area (raw material outcrops etc.). He used decorated ceramics from multiple sites within the Seacow Valley combined with a slew of statistics in order to attempt to map out, using style theory as a foundation, hunter-gatherer territorial boundaries within the Valley (Sampson 1988).

In line with our recent discussion on ecological and physical boundaries, Sampson brings up an important critique that those researchers who may integrate physical boundaries such as those imposed by rivers, mountain ranges and the like, with hunter-gatherer territorial boundaries, must take heed that those 'enclosed' areas may have been "crisscrossed by territorial lines mutually agreed upon by its former inhabitants" or for some other reason (Sampson 1988: 14). From this statement alone, we should surmise that the task of delineating hunter-gatherer boundaries will be no easy task. However, what works in our favour in terms of being able to delineate boundaries is that for the most part, we possess a requirement that Sampson deems crucial in the process of delineating boundaries:

> "…a sufficiently large and complete archaeological map of the distribution of some non-functional stylistic element, produced by systematic survey, in a region where hunter-gatherers have recently lived" (Sampson 1988: 15).

While Sampson does seem to agree that Polly Wiessner's (1983) emblemic and assertive style theory serves as a sufficient framework with which we can work from in terms of delineating boundaries, he argues that most case studies have only shown their utility in determining boundaries between language groups and not individual bands because of small sample sizes (Sampson 1988). This interpretation suits our purposes in this study, but it is also important for us to understand hunter gatherer territorial boundaries at the band level for reasons that will become clear further on.

Sampson begins his discussion of band-level territorial boundaries with the example of the Dobe !Kung, band located in Namibia (Sampson 1988). He shows that almost all of the neighbouring territory boundaries overlap with one another and that a percentage of the boundary lines are defined by drainage channels (a point to note in lieu of our recent discussion regarding physical boundaries) (Sampson 1988). Additionally, he explains that even though these band-level territorial boundaries existed, many families would act as their own entities and wander well out of their band territory's ranges, some wanderings extending 100-150km which intersected with other band territories (Sampson 1988). Using this example as an analogue, he argues that even though families did wonder outside of their territories, they would have still spent most of their time within the boundaries of their band's territory (Sampson 1988). Far less time was spent visiting other territories and they would rarely venture even further when heavy draught would force greater need for resources sharing (Sampson 1988). (*See Sampson 1988: 19 for an illustration of this model.*)

The reasoning behind this explanation follows that different discard rates of stylistic elements can be detected in each zone (Sampson 1988). While this point is not relevant for our purposes, it illustrates a model with which we can more or less detect band-level boundaries at the frontier where certain stylistic elements are most concentrated and where they start petering out (Sampson 1988). He also discusses the influencing factors on boundary changes during times of resource abundance and scarcity, and how territories may shrink with firmer boundaries or become larger with more diffuse boundaries respectively (Sampson 1988). He was able to show that stylistic boundaries did exist in the Seacow Valley, but he suggests further investigations as to whether or not those boundaries are socio-political or otherwise (Sampson 1988).

Sampson's (1988) work provides valuable insight into southern African hunter-gatherer territorial boundaries and how his findings may help us understand our stylistic clustering. Before continuing, we need to take note that in order to delineate boundaries at the resolution that Sampson was capable of, we would have needed a far larger sample as in his own words when referring to Wiessner's (1983) study, our sample is "only large enough to determine boundaries between language-groups" (Sampson 1988: 16). This does not mean that his study was irrelevant to our case; on the contrary, there is much to glean from his work in terms of a mechanism by which stylistic information would have been able to travel around the research area, forming the stylistic clusters we have been able to detect.

First, we now know that the sizes of known Kalahari San band territories, the largest of which sits at approximately 40km^2, would allow for multiple band territories to fit well within the space where each major stylistic cluster occurs (Sampson 1988: 174). This approximation also allows for the inclusion of the "dead space" in between band territories. Thus, making it clear that the stylistic arrowhead clusters are by no means representative of band territories but since they are large enough to encompass multiple band territories, they could only be representative of hunter-gatherer language groups (Sampson 1988: 15; Wiessner 1983).

When we look at how hunter-gatherer territorial boundaries operated and the fact that we have multiple bands represented within each of our clusters, we can establish a mode by which stylistic information was able to move throughout the possible language group areas. There are a number of ways in which this could have happened. First, the ways in which family units would stray from their band territories, with their yearly ranges sometimes intersecting with other band territories, could have been a vehicle for the transport of stylistic information. Whenever they would enter into another territory, they could have interacted with its members and possibly spreading ideas about their particular arrowhead styles. This interaction could have spurred intentions by either party to copy an arrowhead style or to adopt elements of that style. Alternatively, that style could have been rejected outright by the recipient and that recipient may have attempted to make something completely different however, elements of that particular design could still remain, even without intention by the recipient. Another characteristic of band-level boundaries in which similar stylistic information transferring scenarios could have occurred may have been in the shifting of the boundaries themselves. As mentioned earlier, periods of resource scarcity would cause territories to become larger with more diffuse boundaries and result in more resource sharing strategies (Sampson 1988). This increased contact between bands would serve as another mode within which the above mentioned stylistic information transference mechanisms could have taken place. These processes would obviously have a knock-on effect whereby stylistic information travelling to adjacent band territories, would eventually spread throughout an area the size of say the North-Eastern or South-Western site clusters.

Alternatively, a gift exchange system akin to the *hxaro* gift exchange system of the San could also have been a viable candidate for the transfer of stylistic information across space. Stylistic information could have been gleaned off arrows received via gift exchange in a similar manner to the mechanisms explained above and then possibly incorporated (knowingly or unknowingly) into future arrowhead designs. Knowing that *hxaro* exchange partners were limited to those within a maximum distance of 100-200km (Wiessner 1983), allows this explanation to fit with what we see on the ground.

Referring to Figure 15 we can see that the maximum distances for exchange partners, family ranges and band-level territorial sizes all fit within the boundaries of our over-encompassing site clusters. And considering that there is about 250km separating the nearest South-Western and North-Eastern sites together with the Orange River (and the southern end of the Drakensberg Mountain Range) forming a natural boundary between the two groupings, the characteristics of the maximum gift exchange distances and family ranges allows the possibility that arrowhead stylistic information would thus not have been able to cross over from the South-Western to North-Eastern cluster. Therefore, the arrowhead styles would have been relegated to their respective groups, an indication that those styles could have been indicative of hunter-gatherer language groups. If so, a language barrier would serve as a further boundary disallowing stylistic information to travel between the two groups.

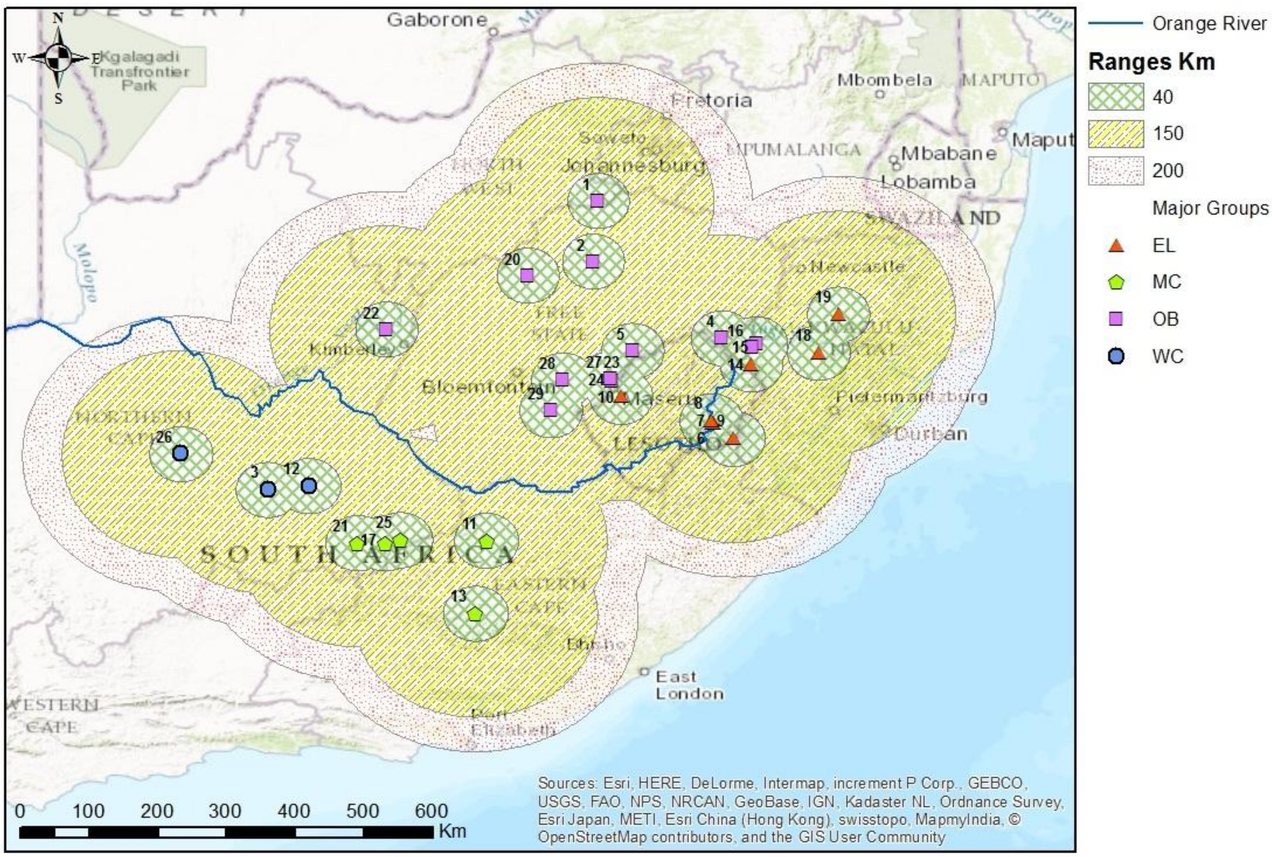


Figure 15. Hypothetical territorial ranges surrounding arrowhead bearing sites. Green cross hatching: Band territorial range; Yellow diagonals: Family wandering range; Red stippling: Maximum exchange partner range. (EL = Eastern Lesotho Group; MC = Middle Cape Group; OB = Orange Basin Group; WC = Western Cape Group).

It should be clear that from what we understand about hunter-gatherer territorial boundaries and exchange networks, it is entirely plausible that our arrowhead shape clusters may be representative of hunter-gatherer territorial boundaries at the language group level during the late Holocene in southern Africa. However, in order to come to firmer conclusions about the meaning behind our arrowhead clusters, we still need to address the hypothesis of whether or not the spatial arrowhead clusters are replicated in other artefact classes and thus could signify culturally distinct identities. The correlation between the arrowhead shape clusters and clusters of other lithic types, raw material choices, ceramics, rock art, etc, will help support or refute the idea that they are emblems of different archaeological cultures.

4.6.2. SCRAPER RATIO & CERAMIC TEMPERING

In an attempt to address this hypothesis, the Scraper Ratio and Ceramic Tempering variables were tested for their relationship with arrowhead shape. As a reminder, the first variable is the calculated ratio of lithic scrapers to backed tools at each individual site. This ratio has been useful in lithic studies when attempting to understand possible cultural differences between sites (Sadr 2015). In his study of how the first livestock reached southern Africa, Sadr (2015) explains that retouch may be considered as stylistic choice. He argues that "the difference in the proportion of types of formal (that is to say retouched) tools is culturally patterned" (Sadr 2015: 9). Through this line of reasoning, it was shown that scraper rich sites represented southern San groups and sites that were rich in backed tools represent northern San groups (Sadr 2015). Thus we sought to test if any such pattern existed in the assemblages that were directly associated with the arrowheads from our sample.

Unfortunately, it was clear from the PLS results testing this variable that the proportion of scrapers to other backed formal tools among our sites bore a very weak, non-significant relationship to arrowhead shape. Adding fuel to this fire, I was hardly able to detect any pattern geographically either. This very weak result could be due in part to the fact that we had lack of data available for this particular test because a total of 60 arrowheads from the sample were collected without any excavated material. In any case, the fact that all my sites already fall within Sadr's (2015) southern San scraper rich zone, may mean that a pattern will not be able to be detected even with a preferential sample size. While a pattern could not be detected with this sample, a significant pattern may still exist but we are simply not able to detect it. Hopefully future excavations may be able to deal with this issue.

When looking at the Ceramic Tempering variable, a similar picture is painted. Once again as a reminder, this variable accounts for the differing methods of how ceramics were manufactured (either by using grit tempering or grass tempering) at arrowhead bearing sites and it is useful in a similar way to the scraper ratio in that the type of tempering can also be seen as a cultural indicator (Sampson 1988; Hart 1989; Bollong *et al.* 1997). The criterion referenced here dictates that the presence or absence of fibre tempering would distinguish between Khoi and Bushman pottery (Sampson 1988; Hart 1989; Bollong *et al.* 1997). Once again while this variable would have normally proven to be a valuable asset to our argument, it seemed to have almost no relationship to arrowhead shape and I could not detect any geographic patterns relating to it. However, it should be noted that no fibre tempered sherds have been found in South Africa's grassland biome, once again implying that a pattern may very well exist (Sadr 2008). Regrettably, I believe that just like with the failure of the Scraper Ratio variable, there were far too few ceramic assemblages associated with arrowheads in our samples for this particular variable to be valid and useful.

4.6.3. TYPE

When we look back at the PCA results and the parallels struck between the Type and Raw Material variables with the spatial arrowhead clustering in Figures 5, 7 & 8, there is an obvious pattern that emerges which tells us that while these variables do not have a significant effect on arrowhead shape (this we know from the relatively poor results of the PLS analysis), the remaining patterns may hint at something else that is going on. First, we will discuss the Type variable. This variable is not so much an objective one such as the raw material and age variables, but it is a subjective variable extracted from the etic classifications of southern African tanged arrowheads.

The first of the types proposed in the literature, the bifacial pressure-flaked, tanged and barbed arrowheads, are also the most common and have been given a tremendous amount of attention in lithic studies over the years. While there have not been any experimental studies trying to re-create southern African bifacial arrowheads as yet, we can assume that they were made in a similar way to their European counterparts. Via the reduction of a preferential flake through bifacial percussion and then shaped via pressure-flaking (Inizan *et al.* 1999). Mitchell (1999) believes that this class of arrowhead exhibits further variants in the form of bifacially retouched and bifacially pressure-flaked barbed and tanged arrowheads. However, I have decided to group these variants under the class of bifacially pressure-flaked tanged and barbed arrowheads following my test results confirming that these variants do not differ much in overall shape (Smeyatsky 2014).

The second southern African tanged and barbed arrowhead type, as proposed by Close & Sampson (1999) when discussing the arrowheads of the Seacow Valley, is the double-backed tang arrowhead. They explain how they are formed on blade blanks, almost all of which are of a fine grained hornfels. They argue that the backed tang specimens were most likely expediently produced as opposed to the curated bifacial pressure flaked ones. Close & Sampson (1999) argue that there are also multiple variants within this class namely the unifacial tanged and double-backed tang variants. Once again, through my previous testing, I found that there were not enough shape differences between these variants to warrant separate terminology and henceforth I have grouped them under the umbrella term of double-backed tang arrowheads (Smeyatsky 2014).

So, even though we are dealing with a variable that is etic, having been assigned to the arrowheads after the analyses were completed, it begs the question why we are seeing such patterns in the results as observed in Figure 8. Taking into consideration the fact that there is some overlap between the two spatial clusters, we find that a few bifacially pressure-flaked specimens occur in the South-Western cluster and only a single double-backed tang specimen occurs in the North-Eastern cluster. That is to say the vast majority of arrowheads from the South-Western cluster comprise double-backed tang specimens which are all of the Hornfels raw material, while the North-Eastern cluster comprised almost entirely of the bifacial pressure-flaked variant with a single double-backed tang specimen of the CSS raw material. The importance of the raw material distinction will become clear soon enough.

Since we know that the arrowheads from the two clusters were used in the same way, if we assume that they were used as hunting projectiles in the first place, then it can be said that just as the shape of the arrowhead can be seen as a stylistic attribute, the ways in which these arrowheads were made that gave rise to these etic variants, could also be seen as a stylistic choice. The concept that artefact styles or types have been viewed as 'calling cards' for particular groups of prehistoric peoples is as old as the discipline of Archaeology. While this angle is wrought with issues, the fact that the age of the arrowheads in our sample is spread over a relatively short time period and the bifacial pressure-flaked and double-backed tang variants overlap relatively neatly with our stylistic clusters, then perhaps this concept is not too farfetched in the case of southern African tanged arrowheads. This possibility is undoubtedly an attractive one, but it is not quite enough just yet to push us to claim that each arrowhead cluster is representative of a hunter-gatherer language group.

4.6.4. RAW MATERIAL

The second variable that revealed interesting parallels with the spatial arrowhead clustering exhibited in the PCA graphs in Figures 5 & 8 was the Raw Material variable (Fig. 7). And as the name suggests, it simply recorded the raw materials that were used to construct the arrowheads in the sample.

We find that there is almost an even split in raw material choice for southern African LSA lithic tanged arrowheads. One portion having been made on a group of very fined grained materials such as jasper, chert, chalcedony, and agate (Humphreys 1969; Dreyer 1975; Bradfield & Sadr 2011). These raw materials have been commonly grouped under the term CCS (cryptocrystalline silicates) and they tend to share similar physical properties. The rest were made on Hornfels, which is a relatively fine grained metamorphic rock (Heese 1933; Inskeep 1987; Close & Sampson 1999). Interestingly, there is only a single quartz example that has been found in the assemblage, but it was excluded from this study due to its degree of incompleteness (Bradfield & Sadr 2011).

Certain authors argue that raw material preferences probably reflect geological opportunity and that people exercised choice within the raw material availability depending on the kind of artefacts they wanted to make (Mitchell 2009). We shall see shortly how this may be true, however it has also been shown that raw material choices may have had gender (Mazel 1989) and cosmological implications (Deacon 1992) or may have helped construct social boundaries among hunter-gatherers (Sampson 1988; Hall 2000).

Simon Hall (2000) brings up this particular issue when discussing the hunter-gatherers of the Fish River Basin at around 5000BP. He explains that after 5000BP there was a dramatic shift away from locally sourced raw materials to the use of 'exotic' raw materials sourced from 40 to 50km from the excavated site in question as well as the same phenomena occurring regionally (Hall 2000). He argues that the facts that this shift happened regionally and that these raw materials were sourced from such distances by choice, could be interpreted that raw material choice in this case could be considered as stylistic (Hall 2000). Hall refers to the example of the /Xam Bushmen of the Northern Cape who were observed to use different raw materials in their arrowheads, namely metal and quartz, as distinguishing stylistic group markers (Deacon 1986: 151, as cited in Hall 2000). He believes that at the local level specific raw materials could have acted as an identity marker that tied groups to quarries that held special significance however, at a regional level, it most likely would have more of a link to a "social risk-pooling network", or, in our case, to a hunter-gatherer language group (Hall 2000: 143).

When looking back at the PCA distribution pattern coloured by the Raw Material variable in Figure 7, we find that the spatial clustering almost mirrors the one exhibited by the Type variable. Essentially, the arrowheads made on CCS raw materials are almost entirely relegated to the North-Eastern cluster (only 2.6% are of Hornfels) and the arrowheads that are made of Hornfels, make up the vast majority of the distribution within the South-Western cluster (only 7.7% are of CCS). Fortunately, from the results of the PLS analysis regarding this variable, we find that there is no significant correlation between raw material choice and arrowhead shape and centroid size. This result is particularly important because it challenges the widely assumed notion in lithic studies that raw material choice will have an effect on the morphology of stone tools whereas, in the case of southern African tanged arrowheads, we find that this is not necessarily the case. Whether an arrowhead was made of CSS or Hornfels did not predetermine the shape or overall size of the arrowheads, presumably due to the fine-grained characteristics of both materials we find in the southern African arrowhead assemblage. Therefore, I believe that the above ideas put forward by Hall (2000) could serve as a plausible explanation why we are seeing such a juxtaposition of raw material choices between the two clusters.

However, it is still important to heed a word of caution from Mitchell (2009) in that the raw material choice of the arrowheads may just reflect geological opportunity. Taking a snapshot from our sample, we find four specimens from Keurfontein Farm (Vosburg) that are all of the CSS raw material as exhibited in Figure 39. These particular specimens are highlighted because they are located well within the South-Western cluster, the cluster that is mostly characterised by Hornfels arrowheads yet these specimens are clearly made of CCS. Interestingly, we find that arrowheads from surrounding sites around Vosburg exhibit similarly shaped arrowheads except they are all of Hornfels. So, how can we explain this abnormality? Well, perhaps the maker of these pieces was taking advantage of a particular geological opportunity, or maybe there is a geological source nearby that holds cosmological significance. Another option is that these specimens may exhibit an example of Wiessner's (1983) 'assertive style' in that the maker's choice to use CCS was a statement of individualism.

While there does seem to be evidence supporting the idea that the almost complete characterisation of each of the major arrowhead clusters by either CSS or Hornfels, there are still some examples that do not neatly fit this explanation. A way to further refine this position would be a recommendation found in Sampson (1988) which reads in the context of delineating hunter-gatherer territorial boundaries that:

> "The recommended approach is to combine the distribution maps of distinctive stone artefact styles with the distribution maps of distinctive flakable rock types from solitary outcrops" (Sampson 1988: 15).

Following this recommendation would be paramount in order to strengthen the position that the raw material choices could be stylistic in and of itself; however, such a task would be a massive undertaking. This project would most likely span many years of thorough fieldwork, a task that is well beyond the scope of this research. With that said, the parallels that are struck between raw material, type and morphology are still particularly strong lines of evidence that could indicate the existence of boundaries between hunter-gatherer language groups.

4.6.5. ROCK ART

As a smaller investigation, the question of the existence of a correlation between arrowhead and rock art styles was probed to a lesser degree compared to the other patterns discussed in this chapter. This was mostly due to a lack of GIS information that we have for southern African San rock art. As Sam Challis explained, southern African rock art studies have made massive leaps and bounds in terms rock art interpretation, however we have a severe lack of reliable GIS information about rock art sites (Challis, personal communication, April 2016). This problem is currently being addressed through large rock art mapping projects across the country.

While this work is ongoing, it is not yet in a state that will be of much use to us. This is unfortunate because it has been demonstrated how some rock art depictions can be seen as analogous for groups of people living in a certain time and place (Challis 2012). Such a line of evidence would have proven to be extremely valuable. While we do not have any high resolution distributions of San rock art styles, we are fortunate enough to at least have a distribution map of rock paintings versus rock engravings in South Africa, being the culmination of the University of the Witwatersrand Archaeological Survey in 1952 (Fig. 16) (Van Riet Lowe 1952).

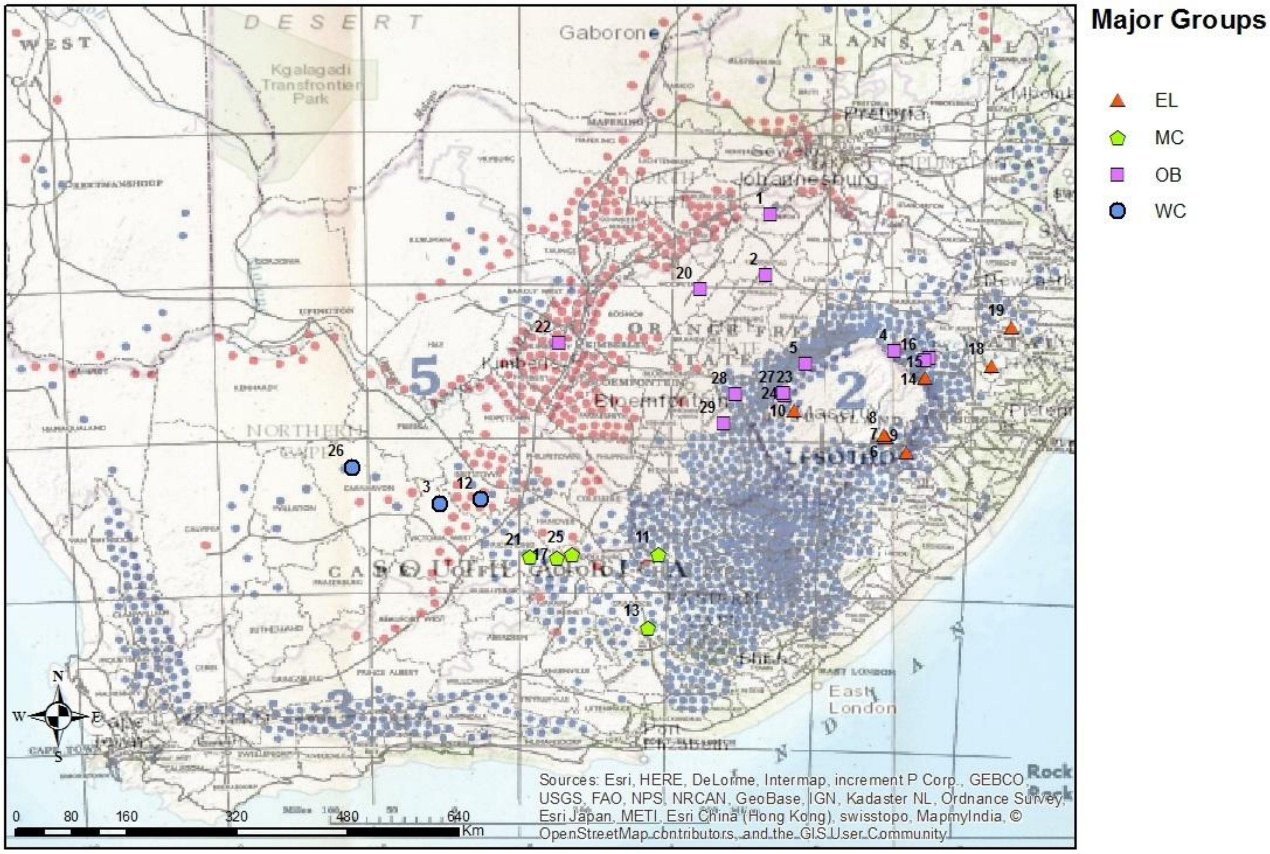


Figure 16. Rock art map with site localities and their Major Groups. Red dots: Rock Engravings & Blue dots: Rock Paintings. (EL = Eastern Lesotho Group; MC = Middle Cape Group; OB = Orange Basin Group; WC = Western Cape Group).

When we translate arrowhead-bearing site locations onto this distribution, there are no significant patterns that parallel the previously discussed patterns that we have seen in this chapter. This does not mean, however, that there are no patterns to be found. There is a possibility that patterns may exist within the distribution of rock art styles, whether they are engraved or painted. To detect such a pattern would require an amount of fieldwork that is also well out of the scope of this research but perhaps sometime in the future, once southern Africa's rock art record has been fully mapped in detail, then this question may be readdressed.

4.6.6. HUMAN ERROR

In what one could call an afterthought, human error may also be seen as another possible variable in the explanation of stylistic variation in LSA tanged arrowheads. Eerkens (2000) considers the effect of human error on lithic production and its accountability in lithic shape variation.

Eerkens (2000) tested the Weber fraction for length estimation, a constant which shows that when humans are producing artefacts of a particular size, the closest they can get is within 3% of the original, without an independent scale or ruler (Eerkens 2000). His study found that even with the compounding factors of errors in visual perception, "accuracy in memory, the ability to convert a mental template into a physical object, and motor control during production", would have only contributed 2-3% to artefact variation (Eerkens 2000: 664).

While this concept is hardly enough to provide an explanation for the major stylistic variation we are seeing among the main arrowhead clusters, it is possible that it could be an influencing factor in the more subtle stylistic variation we find on the band level within the major stylistic clusters possibly representative of hunter-gatherer language groups. This possibility fits in particularly well with our previous discussion on the mechanisms with which stylistic information was transferred on the band level.

5. CONCLUSIONS

The pilot study upon which this research was based showed that among a moderately sized sample of southern African tanged arrowheads, there was a degree of stylistic clustering according to arrowhead morphological attributes (Smeyatsky 2014). These stylistic clusters are located in the central region of South Africa, with one cluster positioned to the South-West and the other positioned to the North-East. This was uncovered in the pilot study through the application of Principal Component Analysis and Canonical Variate Analysis, two geometric morphometric methods equipped to detect nuances in the differences and similarities in morphological data.

The aim of the current study was to further investigate the stylistic clusters themselves and understanding why southern African tanged arrowheads are clustering according to their morphological attributes. The first task of reinvestigating the stylistic clusters was done in much the same way as the pilot study except with a larger sample size. This was made possible through the inclusion of photographs of previously unpublished specimens. Unsurprisingly, very similar clustering patterns emerged with the Eastern Lesotho and Orange Basin groups (North-Eastern cluster) being more similar in shape to each other while collectively being dissimilar to the Middle Cape and Western Cape groups (South-Western cluster) who share shape similarities between themselves. Having confirmed the existence of the stylistic clusters, we moved onto the meaning behind the clustering.

Through a geometric morphometric method known as Partial Least Squares analysis, we were able to test the relationship between external variables and arrowhead shape and centroid size. Variables associated with the arrowheads such as dating, biome, site location, raw material and type were tested in the PLS analyses and it was found that none of these variables held any statistically significant relationship with arrowhead shape and centroid size, in contrast to what is known in the literature. The first being chronology, the fact that there was no significant correlation with dating agrees with the literature pointing towards similar conclusions: it implies that there was no significant morphological change through time in these arrowheads. Thus, time is a variable that can be disregarded when searching for meaning behind the stylistic clusters. Second, the poor result from the PLS analysis showed that raw material does not have a significant impact on southern African arrowhead morphology. Additionally, the "within a configuration" PLS analysis, which tests the significance of the relationship between sets of landmarks within a configuration of landmarks, helped to prove that lithic rejuvenation did not have a significant impact on arrowhead shape.

While these variables may not specifically have had any significant influence on arrowhead shape, patterns observed in other geometric morphometric results and GIS data combined with ethnographic knowledge may hold the answers we seek to help us understand the stylistic clustering. The first was Biome. We find in the literature that ecological boundaries such as biomes and physical boundaries such as coastlines, major rivers and mountain ranges, have been to shown to act as territorial boundaries. When we add in the spatial distribution of our stylistic clusters in southern Africa, we find that not only do they correlate with ecological boundaries such as biomes, but also separating those biomes and their arrowhead clusters are physical boundaries in the form of the Orange River and part of the Drakensberg Mountain Range. In following the ecology model (Deacon 1976: 170), there seems to be more than mere coincidence behind the location of our clusters in that they may be indicative of hunter-gatherer territorial boundaries.

There are two raw materials that in their distribution almost mirror the stylistic clusters and the biome membership of those clusters. The same phenomenon is observed when referring to the Type variable describing the etic classification of southern African tanged arrowheads, which also encompasses two main arrowhead types, once again mirroring the spatial, biome and raw material patterns. That is to say that we are observing two stylistic clusters of arrowheads: one that is located in the Nama-Karoo biome, made on the Hornfels raw material and including the Unifacial Backed Tang type; while the other is located in the Grassland Biome, made on the CSS raw material and including the Bifacially Pressure-Flaked type. And with our understanding of how artefact types and raw material choice can be stylistic in and of themselves, they may be working together with the arrowhead morphological style that we are finding in the spatial clusters, thus adding to the position that these clusters are representative of hunter-gatherer territorial boundaries.

The scale of the stylistic arrowhead clusters could be representative of hunter-gatherer language groups. The same characteristics of those band level territorial boundaries regarding band ranges, familial entity ranges and the “dead space” in between those territories serves to further explain how stylistic information, in the form of arrowhead styles, could have spread throughout the areas large enough to be considered language group territories but not far enough to spread into other linguistic group territories. The related phenomenon of hunter gatherer gift exchange may also have served as a possible mechanism by which stylistic information could have travelled within language group territories.

Even though we unfortunately did not possess the added evidence for cultural identification from the Scraper Ratio and Ceramic Tempering variables, I believe that there is still sufficient evidence to address the second last of our hypotheses, that these arrowhead clusters may represent culturally distinct entities. And these entities may very well have been Holocene hunter-gatherer linguistic groups.

5.1. LIMITATIONS, FUTURE DIRECTIONS AND CONCLUDING REMARKS

While the results of this research have definitely proved to be of value in furthering our understanding of southern African LSA arrowhead style, its ability to act as a vehicle for signalling group membership and how style could have been used by Holocene hunter-gatherers, there are still variables that need to be reigned in before we can conclusively say that we have mapped out the territorial boundaries of Holocene hunter-gatherer linguistic groups. First, we simply need more arrowheads to take these results further. With larger sample sizes, accrued through systematic excavation, we would be able to see if this model would still hold. If so it is likely that we are seeing two major linguistic clusters and with a larger sample size we would also be able to investigate the question of whether we would also be able to detect stylistic differences at the band level. The added benefit of the systematic excavation that would go along with the new found specimens would be the more complete excavation data that could be used to employ the Scraper Ratio and Ceramic Tempering variables more efficiently, thereby allowing us another avenue of evidence to prove existence of the linguistic and band level groups alike.

Second, as mentioned in the previous chapter, Sampson (1988) put forward the recommendation that if the spatial distributions of stone artefact styles could be mapped onto the spatial distributions of outcrops of specific rock types, then the boundaries where those two distributions coincided would then reflect the territorial boundaries of the groups that those artefact styles represent. Such an undertaking, while ambitious, would prove to be an invaluable asset in confirming the limits of the possible linguistic territorial boundaries we have detected in this study. However, it would be a massive undertaking that could only be accomplished through foot-on-ground surveying on a large enough scale to encompass hunter-gatherer linguistic groups and could serve as a worthwhile project for a PhD perhaps.

Finally, extra layers of data that are known to act as group membership markers, such as rock art style distributions and ceramic style distributions, would have added to the strength of our argument. Unfortunately, the one could not be fully explored in this study due to the simple fact that we do not posses that information at the necessary resolution. While our interpretation of southern African rock art is of an extremely high quality, our knowledge about the distribution of southern African rock art styles is comparatively meagre therefore leaving us incapable of utilising this layer of data to its full potential. In the case of using ceramic style distributions, which has been utilised in the identification of cultures time and time again, we may find that it has tremendous potential as has been exemplified in Sampson (1988).

However, once again the task of mapping out the potentially complex spatial distribution of hunter-gatherer ceramic decoration styles would be well beyond the scope of this thesis and such an undertaking could only be recommended for future research endeavours.

To conclude, the intention of this thesis was not only to try and grapple with the complicated nature of Holocene hunter-gatherer territorial boundaries and their identity but it also sought to showcase a relatively new and powerful method that is now being applied to material culture. It has been shown that when geometric morphometric methods are applied to lithics, a wealth of new information can be extracted from old collections, begging the question of what else can be extracted from old collection materials that have been thought to have spent their utility in archaeological research. Geometric morphometrics should be seen as a way to reinvigorate collections of all types of material culture and to spark new lines of inquiry that once were not possible.

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7. APPENDICES

Arrowhead Pair ID	Author	Site	1st Auto Proc. Dist.	2nd Auto Proc. Dis.	Manual Proc. Dist.
1	Mitchell	Sehonghong Area	<u>0.850</u>	<u>0.850</u>	0.183
2	Mitchell	Likoaeng	0.067	0.064	0.086
3	Mitchell	Likoaeng	0.044	0.044	0.139
4	Mitchell	Likoaeng	0.061	0.053	0.120
5	Mitchell	Likoaeng	<u>0.544</u>	<u>0.051</u>	0.096
6	Mitchell	Likoaeng	0.103	0.105	0.157
7	Wilson	Bergville	0.070	0.057	0.114
8	Maggs & Ward	Driel Shelter	0.041	0.044	0.128
9	Wilcox	Poacher's Shelter	0.085	0.088	0.082
10	Van Doornum	Balerno	0.053	0.058	0.071
11	Humphreys	Keurfontein Farm	<u>0.070</u>	<u>0.903</u>	0.155
12	Humphreys	Keurfontein Farm	0.058	0.048	0.148
13	Humphreys	Keurfontein Farm	0.053	0.057	0.155
14	Humphreys	Keurfontein Farm	0.063	0.063	0.105
15	Sampson	Hass Kraal Shelter	0.050	0.051	0.071
16	Sampson	Hass Kraal Shelter	<u>0.725</u>	<u>0.030</u>	0.099
17	Sampson	Hass Kraal Shelter	0.086	0.031	0.070
18	Sampson	Hass Kraal Shelter	0.023	0.046	0.079
19	Sampson	Hass Kraal Shelter	<u>0.831</u>	<u>0.726</u>	0.056
20	Sampson	Hass Kraal Shelter	<u>0.661</u>	<u>0.072</u>	0.096
21	Sampson	Hass Kraal Shelter	0.027	0.099	0.075
22	Inskeep	Nelson Bay Cave	0.032	0.030	0.061
23	Inskeep	Nelson Bay Cave	<u>0.039</u>	<u>0.643</u>	0.061
24	Inskeep	Nelson Bay Cave	0.071	0.034	0.133
25	Morris	Jagtpan 7	0.050	0.033	0.115
26	Morris	Jagtpan 7	0.034	0.043	0.214
27	Morris	Jagtpan 7	0.031	0.077	0.176

Table 24. Procrustes distances from comparison between arrowhead photographs and their corresponding illustrations.

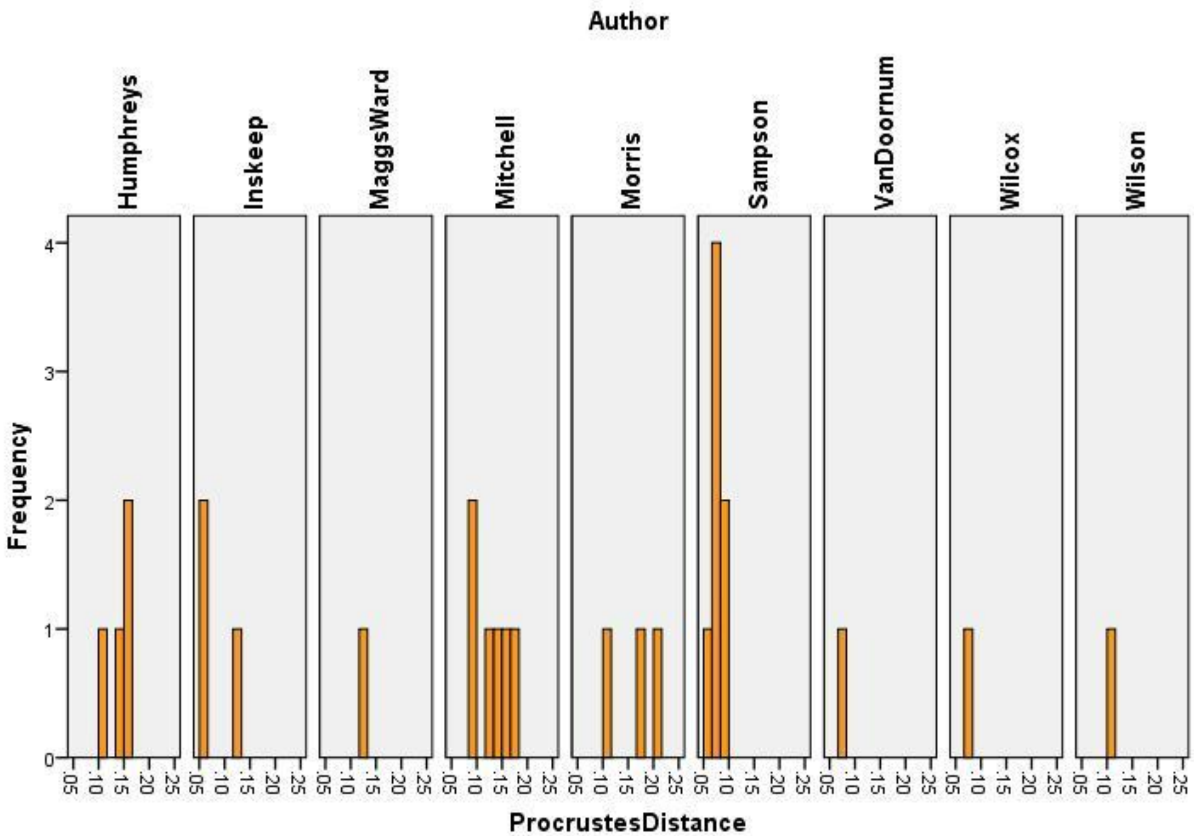

Figure 17. Procrustes Distance histogram sorted by published illustration author. The closer the Procrustes distance is to 0, the more accurate the illustration. 0.2 is the acceptable accuracy threshold.

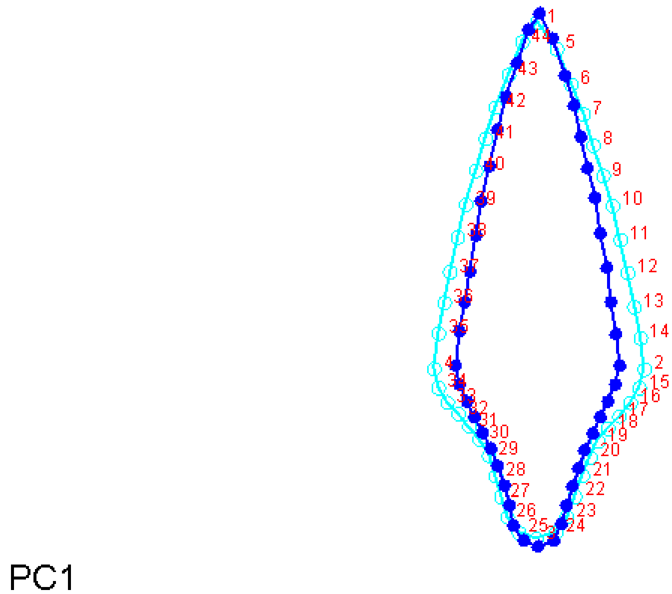

Figure 18. Visualisation of shape changes represented by Principal Component 1.

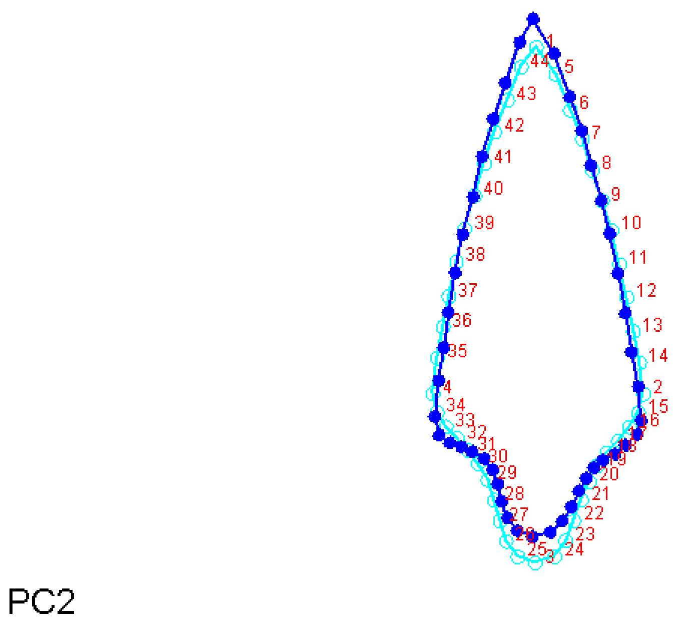

Figure 19. Visualisation of shape changes represented by Principal Component 2.

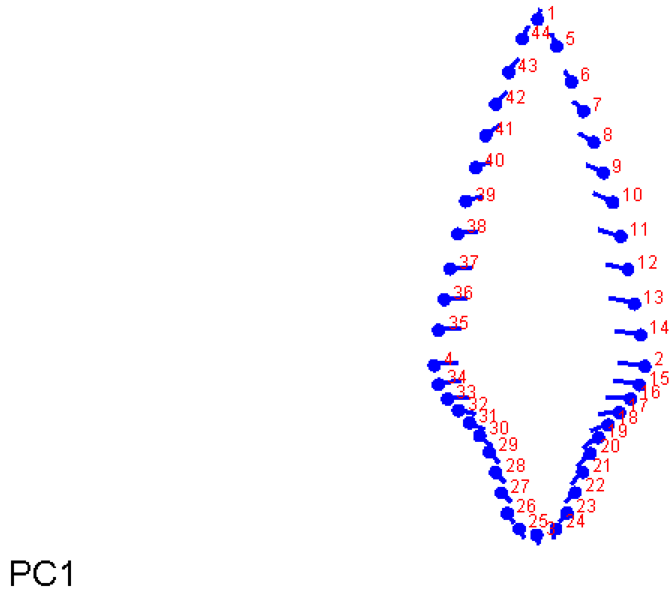

Figure 20. Lollipop graph visualising shape change represented by Principal Component 1.

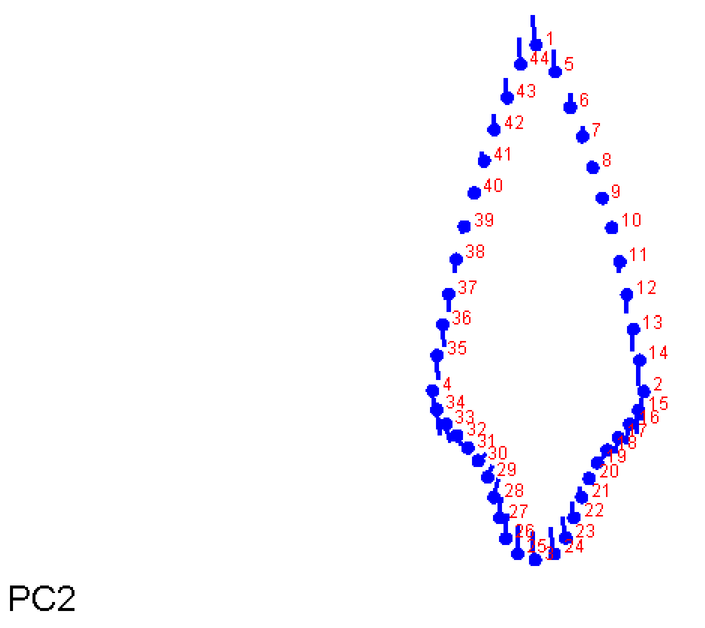

Figure 21. Lollipop graph visualising shape change represented by Principal Component 2.

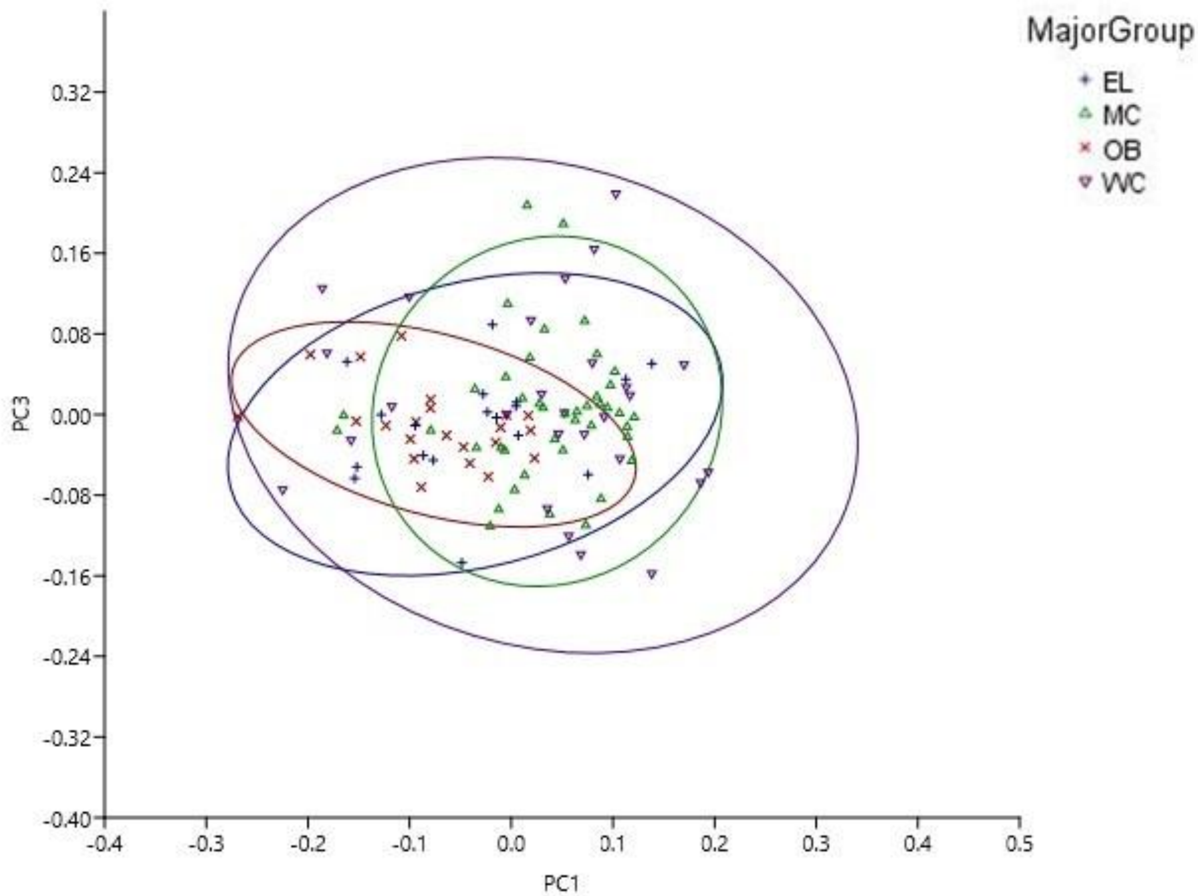

Figure 22. PC1 vs PC3 scatter plot coloured by Major Group. Ellipses at 95% confidence levels. (EL = Eastern Lesotho Group; MC = Middle Cape Group; OB = Orange Basin Group; WC = Western Cape Group).

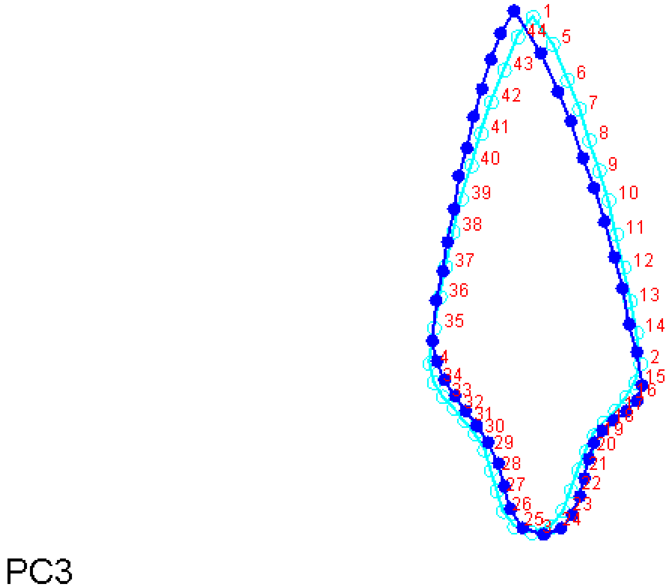

Figure 23. Visualisation of shape changes represented by Principal Component 3.

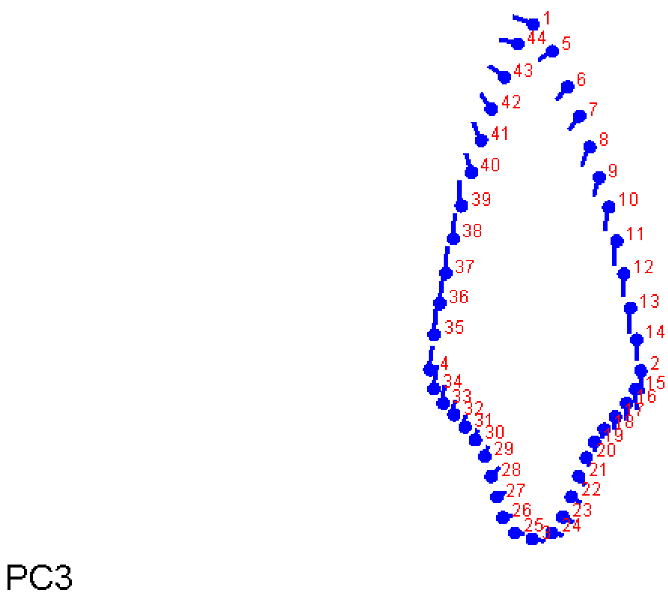

Figure 24. Lollipop graph visualising shape change represented by Principal Component 3.

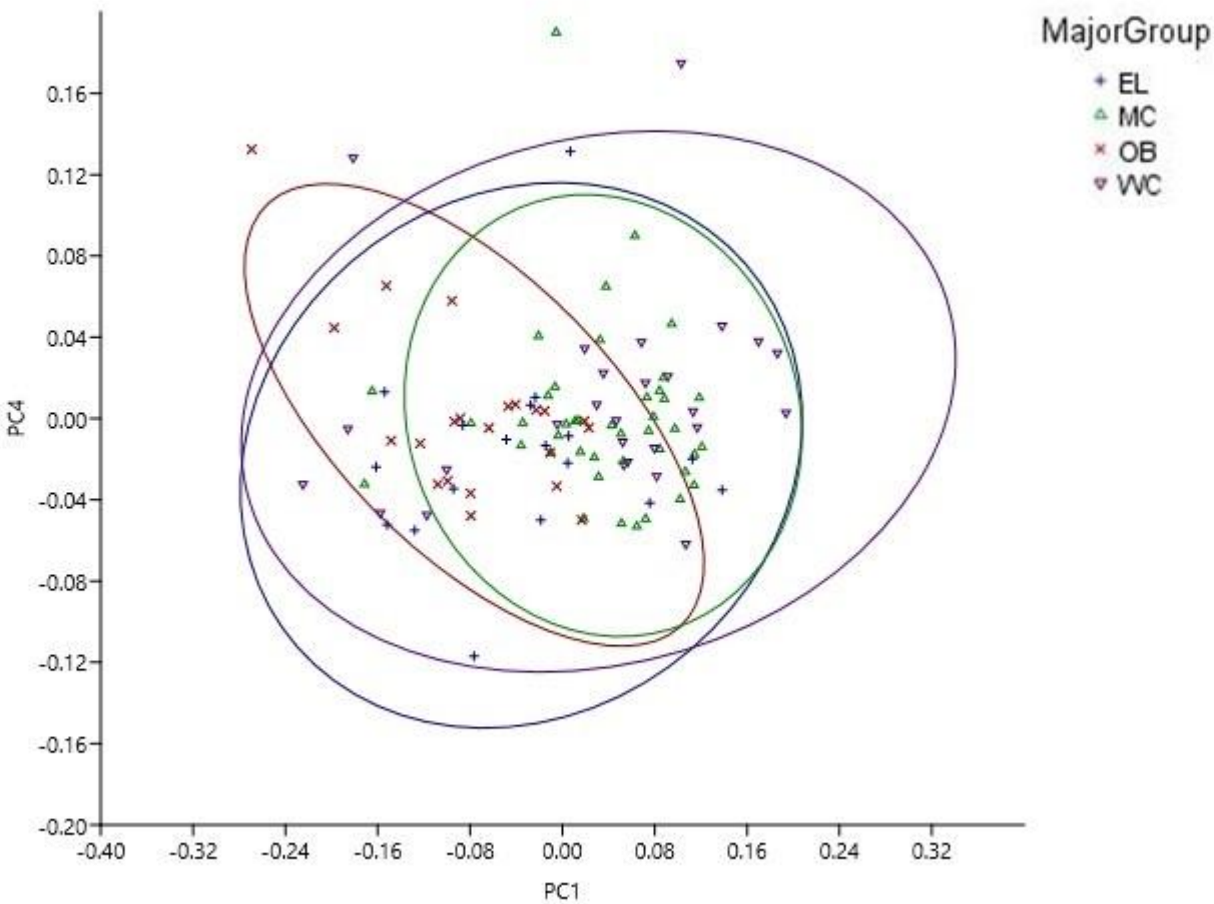

Figure 25. PC1 vs PC4 scatter plot coloured by Major Group. Ellipses at 95% confidence levels. (EL = Eastern Lesotho Group; MC = Middle Cape Group; OB = Orange Basin Group; WC = Western Cape Group).

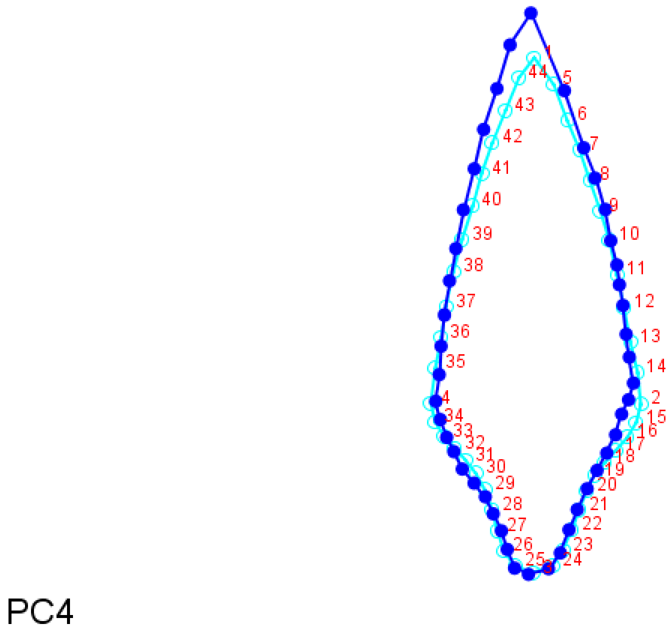

Figure 26. Visualisation of shape changes represented by Principal Component 4.

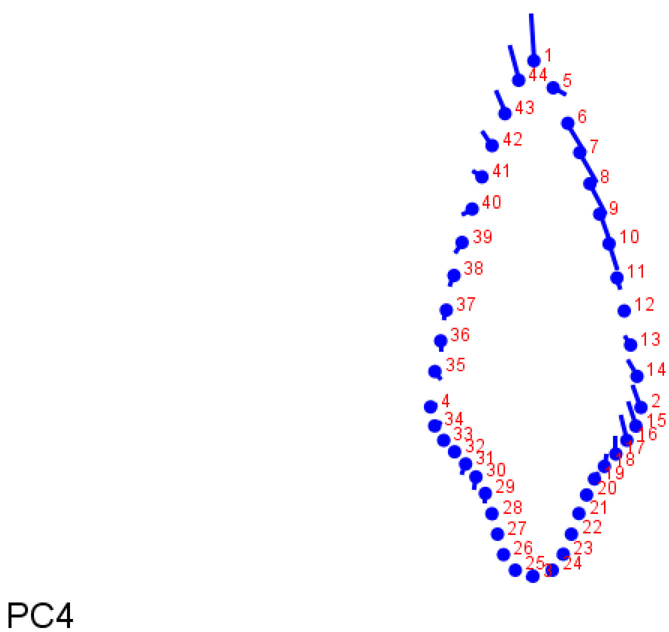

Figure 27. Lollipop graph visualising shape change represented by Principal Component 4.

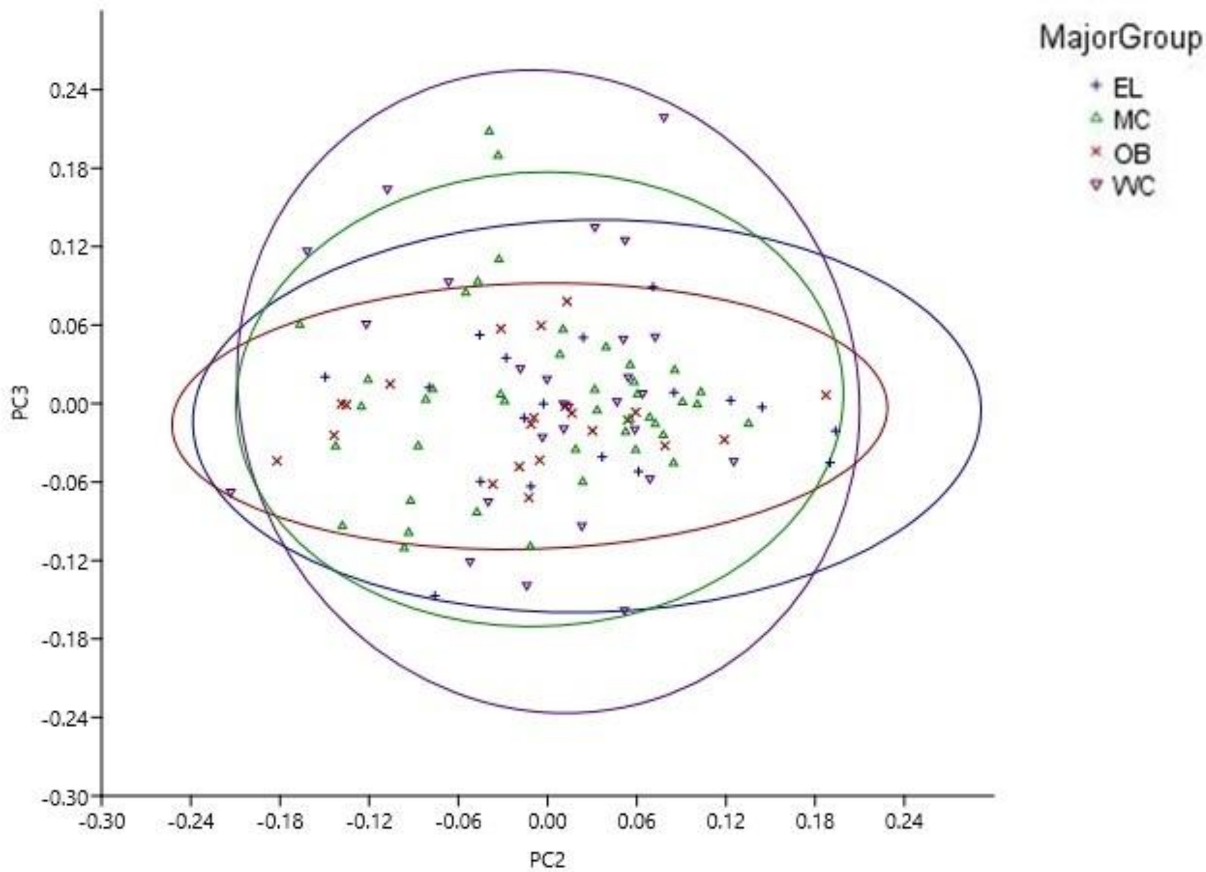

Figure 28. PC2 vs PC3 scatter plot coloured by Major Group. Ellipses at 95% confidence levels. (EL = Eastern Lesotho Group; MC = Middle Cape Group; OB = Orange Basin Group; WC = Western Cape Group).

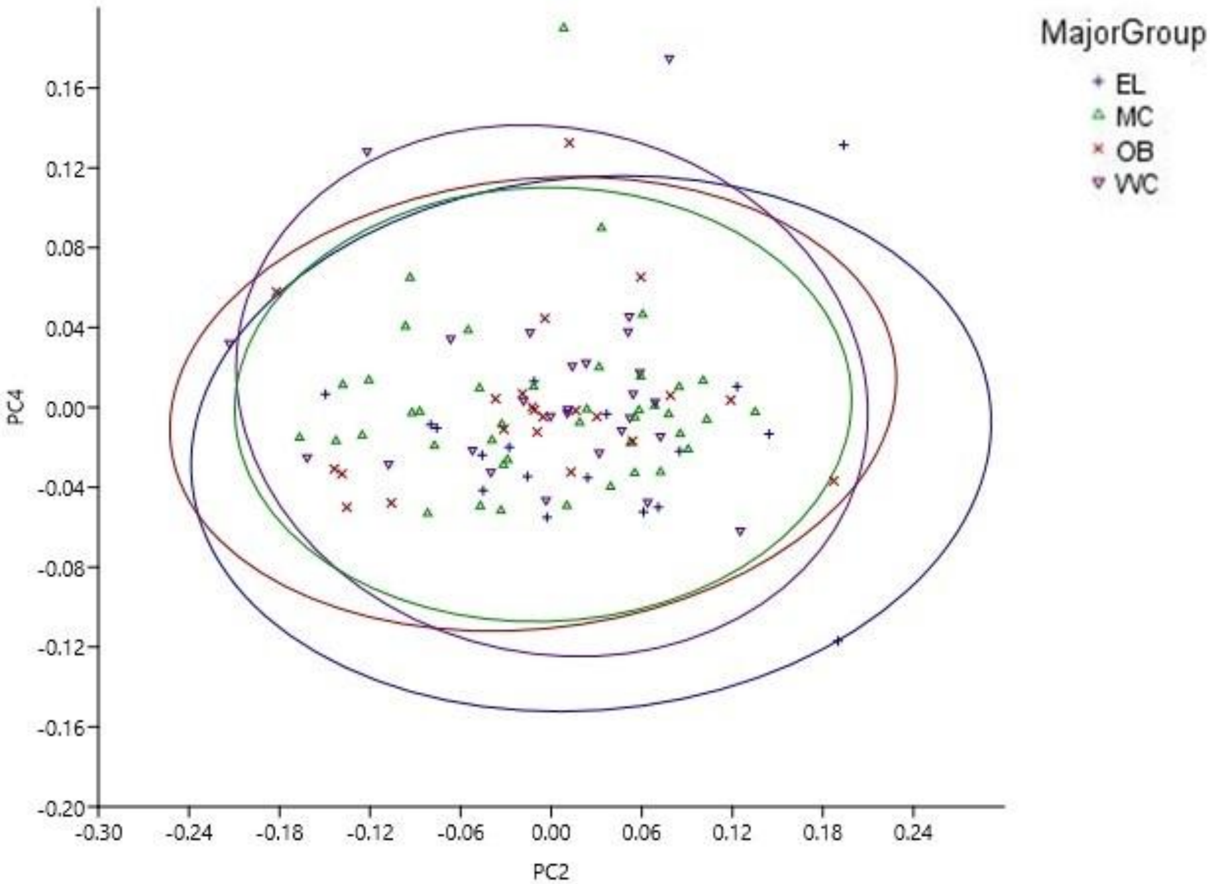

Figure 29. PC2 vs PC4 scatter plot coloured by Major Group. Ellipses at 95% confidence levels. (EL = Eastern Lesotho Group; MC = Middle Cape Group; OB = Orange Basin Group; WC = Western Cape Group).

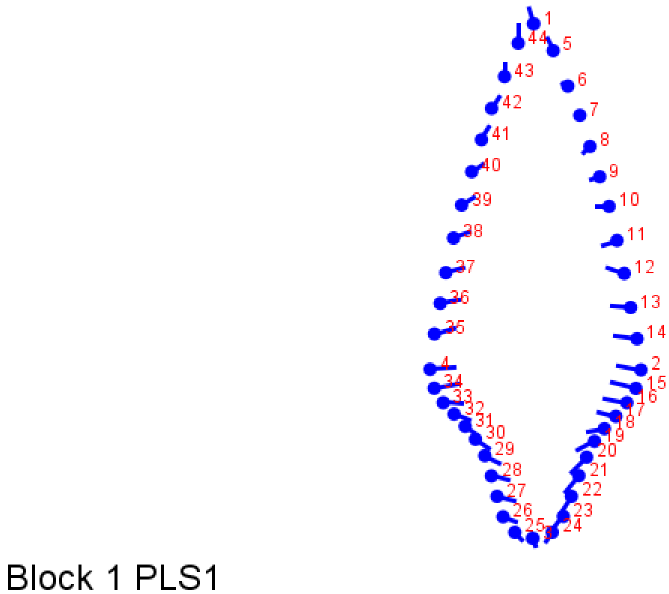

Figure 30. Shape covariate of the Biome variable.

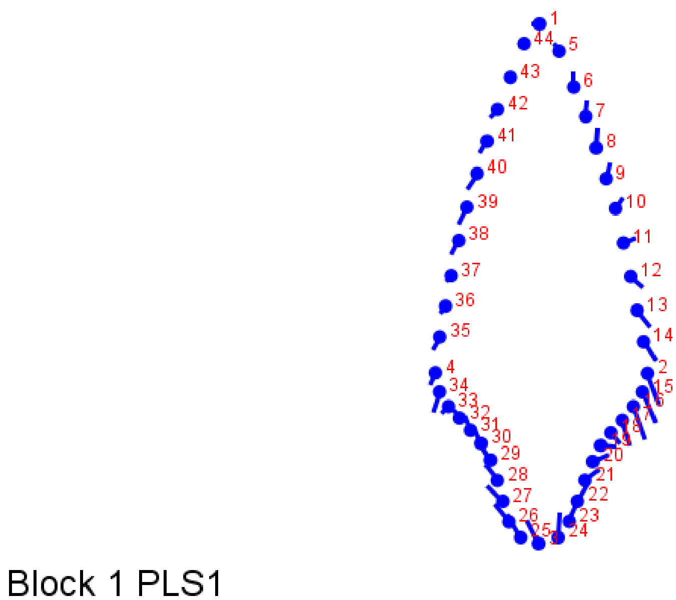

Figure 31. Shape covariate of the Scraper Ratio variable.

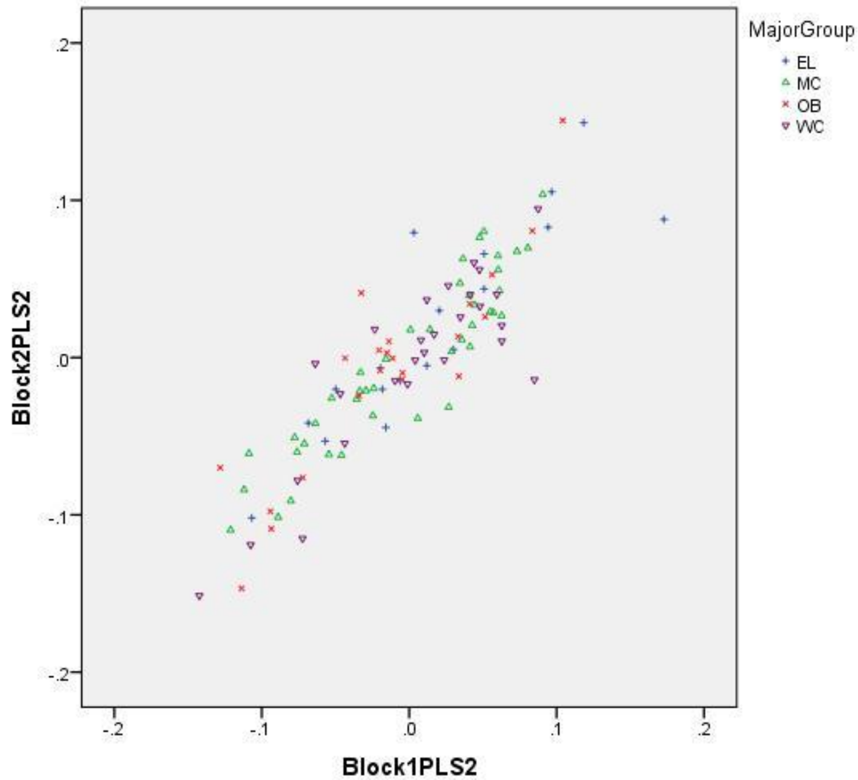

Figure 32. Point versus Shoulder & Tang PLS2 scatter plot coloured according to Major Group. (EL = Eastern Lesotho Group; MC = Middle Cape Group; OB = Orange Basin Group; WC = Western Cape Group).

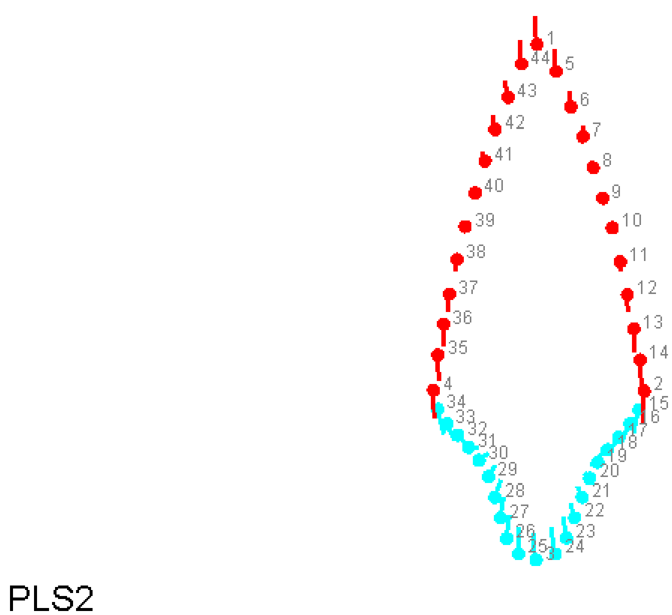

Figure 33. Shape covariate of PLS2 in Point versus Shoulder & Tang test. (Red = Block 1; Blue = Block 2).

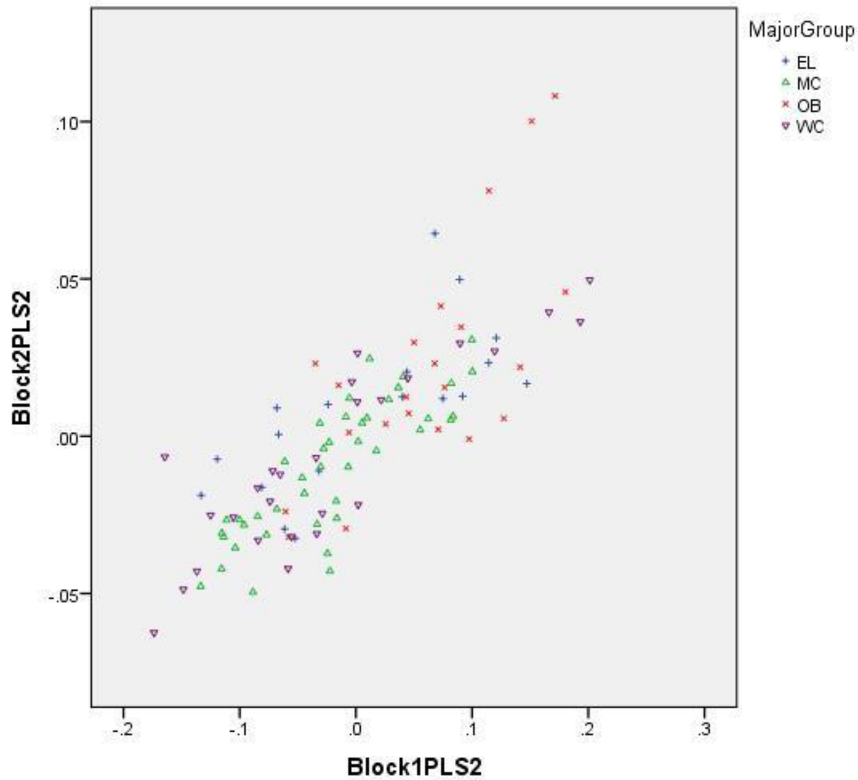

Figure 34. Point & Shoulder versus Tang PLS2 scatter plot coloured according to Major Group. (EL = Eastern Lesotho Group; MC = Middle Cape Group; OB = Orange Basin Group; WC = Western Cape Group).

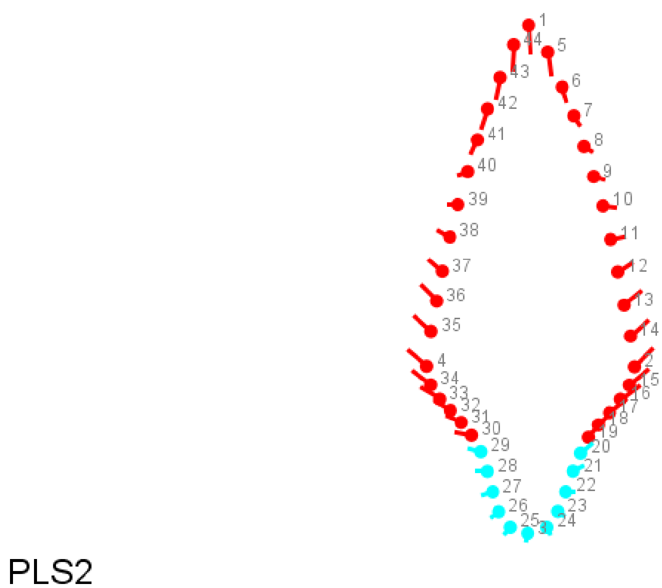

Figure 35. Shape covariate of PLS2 in Point & Shoulder versus Tang test. (Red = Block 1; Blue = Block 2).

Table 2'5 · Arrowheads included in study with associated dates.

Authors	Site	Dates					
		3000-2500 BP	2499-2000 BP	1999-1500 BP	1499-1000 BP	999-500 BP	499-0 BP
Beaumont 1989	Jagtpan 7	1 < 2730+- 60		2 at 1415+- 50			
Bradfield & Sadr 2011	Holkrans						3 at 200+- 23 BP
Carter & Vogel 1974	Moshebi		1 at 2180 BP		2 < 1500 BP		4 at 260 BP
Dreyer 1975	Kroonstad			1 SURF			
Heese 1933	Britstown			3 SURF			12 < 499 BP
Hewitt 1934	Thaba Nchu			1 Smithfield			
Humphreys 1969	Vosburg (Keurfontein)			4 SURF			
Humphreys & Thackery 1983	Dikbosch 1			1 at 1570+- 40 BP			
Inskeep 1987	Nelson Bay Cave		1 at 2450+- 60 BP; 1 at 2540 +- 50 BP; 1 at 2500 +- 50 BP				
Klatzow 1994, 2000	Roosfontein			3 > 1500 BP			
Maggs and Ward 1980	Driel Shelter			1 < 1775 +- 40 BP			
Mazel 1986, 1994	Esinhlonhlweni						1 < 350 BP
	Maqonqo						1 < 350 BP
Mitchell 1996, 1999, 2009	2928DB51			1 SURF			
	Lehaha-la-Masekou (2928DD22)			1 SURF			
	Likoaeng			4 at 1830 +- 15 BP; 1 at 1850+-40 to 2000+-70 BP			
	Sehonghong				2<1240+- 50 BP; 2 > 1400+- 150 BP		

Table 25:- Arrowheads included in study with associated dates continued.

Authors	Site	Dates					
		3000-2500 BP	2499-2000 BP	1999-1500 BP	1499-1000 BP	999-500 BP	499-0 BP
Sampson 1999							
	Abbots Cave				1 at 760+- 50 BP	1 at 500+- 40 BP	1 at 100 +-45 BP
	Bloubos Overhang			1 (with brass clothing hook)			
	Boundary						3 at 190 +- 40 BP
	Driekoppen			1 at 1530+- 45 BP			
	Haaskraal	3 Ceramic (1/2); 3 Smithfld (+ 2 Aceramic); 4 Int. Wilton; 2 SURF			1 at 1140+- 60 BP	2 at 544+- 43 BP	
	Halesowen			2 Strandloper			
	Heydon			1 Smithfield			
	Kookfontein			1 Int. Wilton			
	Kragga Kamma			1 Int. Wilton			
	Lame Sheep			1 (with iron fencing wire)			
	Leopard's Vlei			1 Int. Wilton			
	Meerkat				2 at 1102 +- 62		
	September's Kraal			1 Smithfield			
	Sneeukuil			1 Smithfield Aceramic			
	Vergelegen			2 Int. Wilton			
	Volstruisfontein			1 Smithfield		1 at 560+- 170 BP	
	Zoetvlei			1 Smithfield Aceramic			
Van Doornum							
	Balemo					1 at 1100+- 60 BP	
Van Riet Lowe 1947							
	Matielele			1 SURF			
	Steynsburg			2 SURF			
Wadley 2000							
	Rose Cottage		1 at 2240+-60 BP				
Wilcox 1970, 1971							
	Poacher's Shelter			1 UNKNOWN			
Wilson 1955							
	Bergville			1 SURF			
	Olivierhoekspass			2 SURF			
Unknown							
	Bergville			1 SURF			
	Bokpoort			1 UNKNOWN			
	Dewetsdorp			1 SURF			

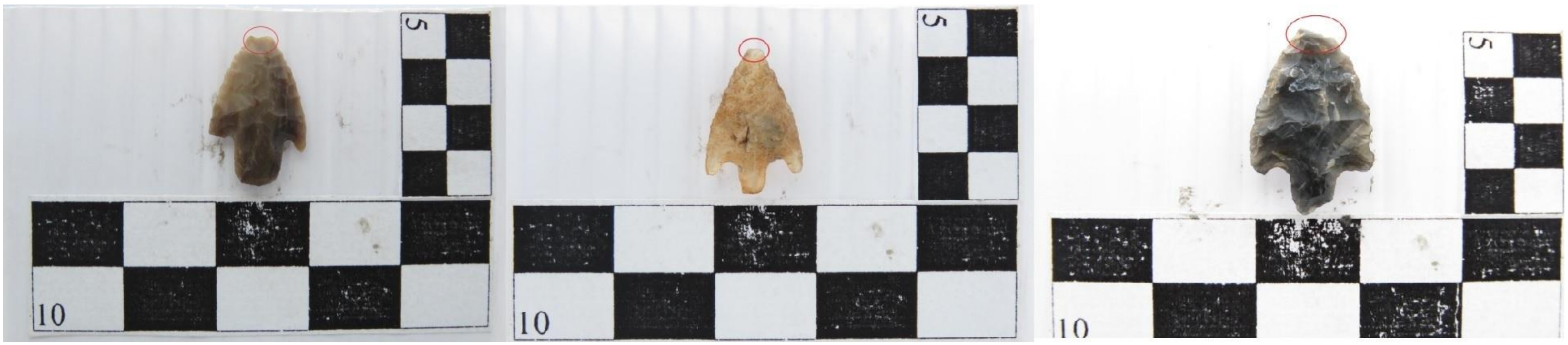

Figure 36. Examples of possible macroscopic impact damage on LSA tanged arrowheads. wheads.

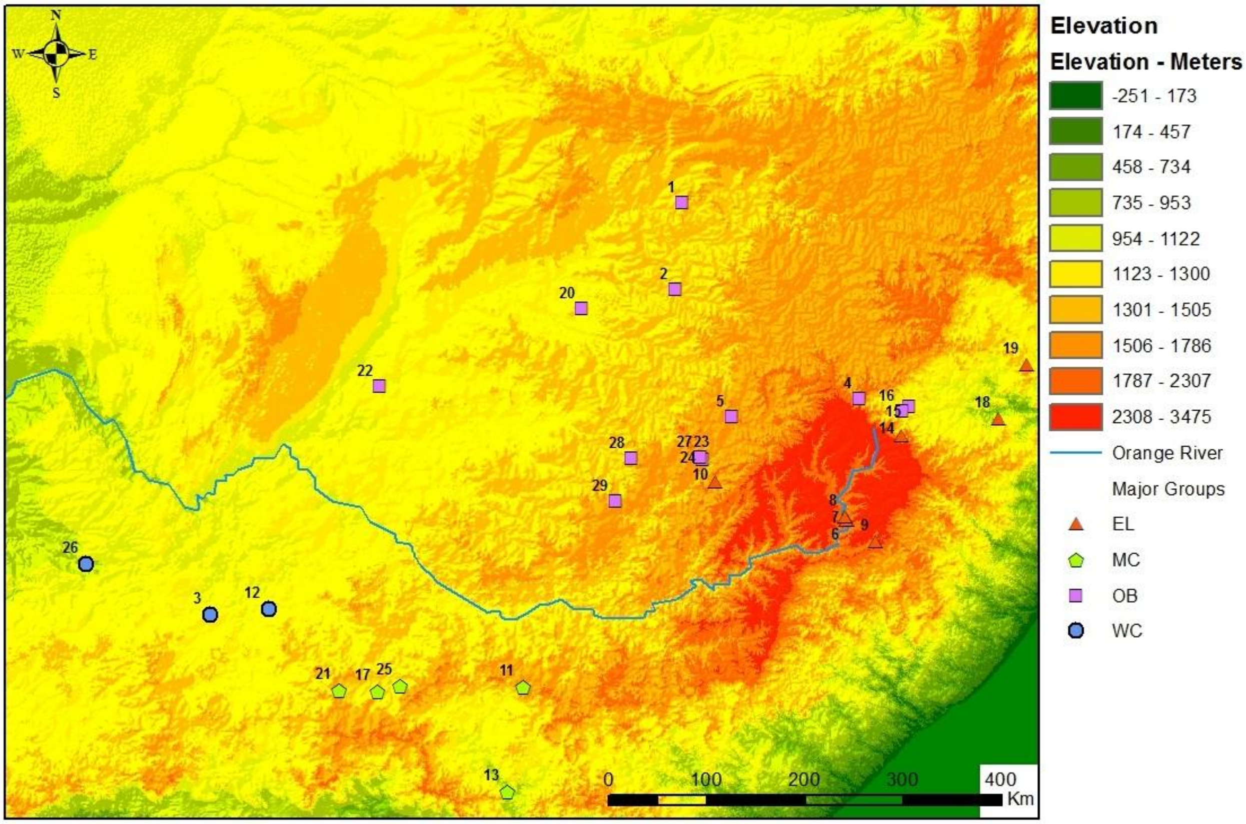

Figure 37. Elevation map of study area. The southern part of the Drakensburg Mountains is signified by the highest elevations. (EL = Eastern Lesotho Group; MC = Middle Cape Group; OB = Orange Basin Group; WC = Western Cape Group).

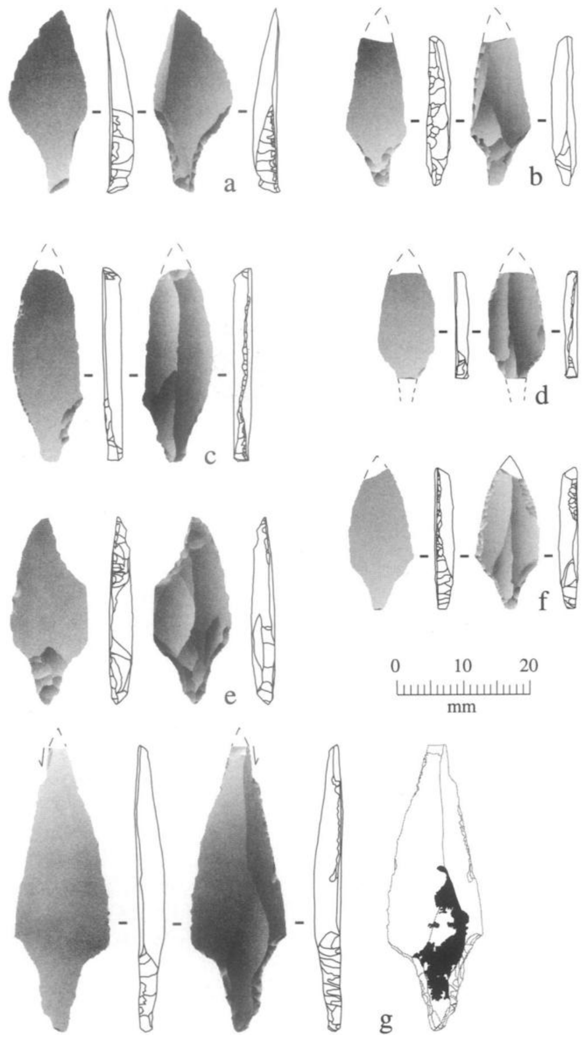

Figure 38. Examples of Double-Backed Tang arrowheads as seen in Close & Sampson (1999: fig. 6).

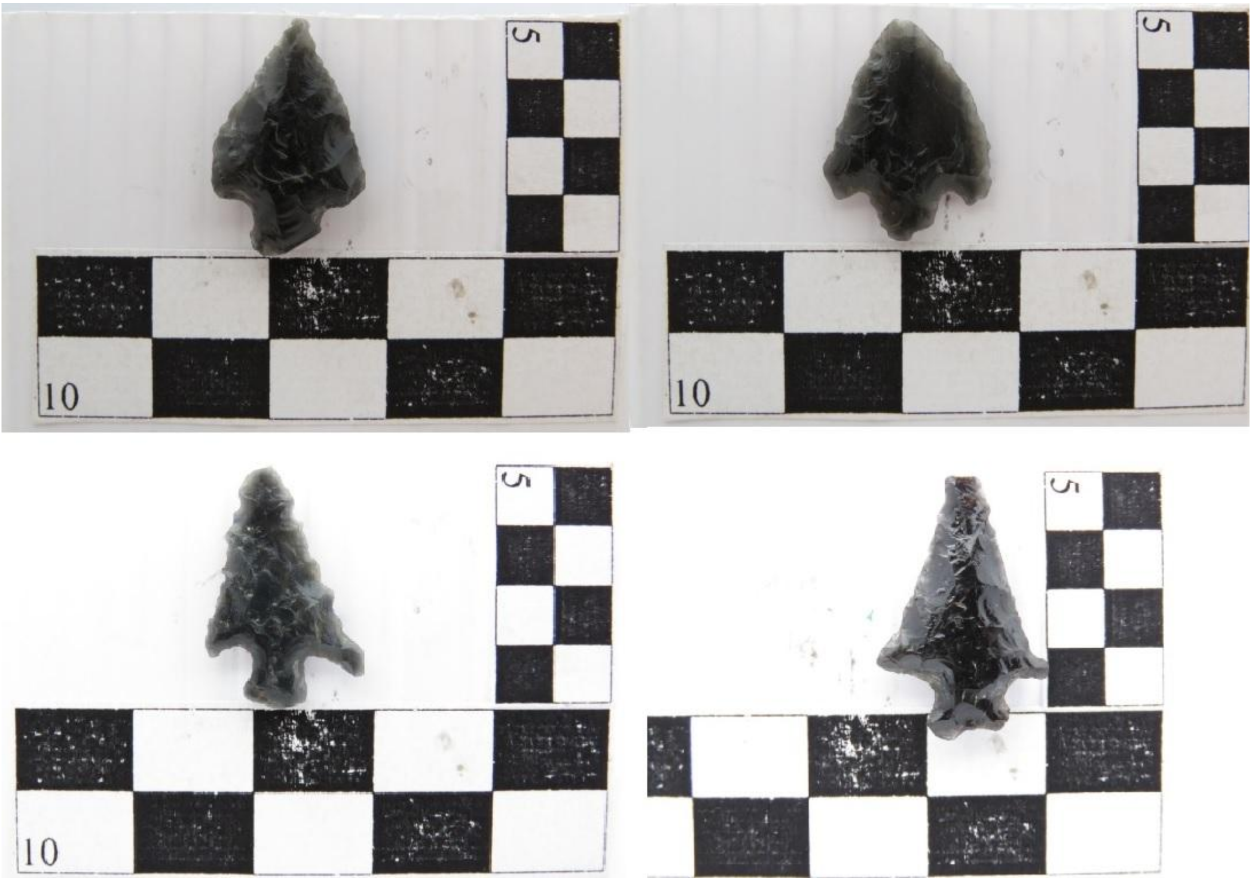

Figure 39. Keurfontein Farm arrowheads of the CCS raw material.