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ORIGINAL PAPER

The evolution of Still Bay points at Sibudu

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Abstract
The Still Bay is a key technocomplex within the Middle Stone Age (MSA), and Sibudu, in Kwa-Zulu Natal, South Africa, provides one of the longest and richest pre-Still Bay to Still Bay sequences. It has been hypothesised that the Still Bay industry emerged through technological revolution or alternatively through gradual change. In this paper we conduct a geometric morphometric (GM) assessment of the shape differences between the pre-Still Bay and Still Bay points at Sibudu to assess their implication for technological evolution. Pre-Still Bay points are often thought of as unifacial and single-pointed, and Still Bay points as bifacial and double-pointed. Our analysis reveals a more complex and evolving pattern, lending support for the gradual change hypothesis. When the earliest pre-Still Bay points are compared with the Still Bay points, a significant difference in shape is seen. However, intermediate units provide evidence of an evolutionary continuum between those distinct ends of the continuum.

Keywords Sibudu · MSA · Stone points · Still Bay · Geometric morphometrics · Pre-Still Bay

Introduction

The rise of the Still Bay (SB) industry is a key area of research in the study of the evolution of modern human behaviour (Archer et al. 2016; Conard et al. 2012; Discamps and Henshilwood 2015; Högberg 2016; Högberg and Lombard 2016; Lombard and Högberg 2018; Mackay et al. 2014; Porraz et al. 2013; Rots et al. 2017; Schmid et al. 2019; Soriano et al. 2015; Wadley 2007; Wurz 2013). The Still Bay is considered a period of florescence during which 'the technological and behavioural repertoire of early *Homo sapiens* expanded rapidly' (Henshilwood 2012). The *fossile directeur* of the Still Bay industry is the bifoliate point. These points have been inferred to be produced through bifacial reduction and basal thinning. Soriano et al. (2015) established that the Sibudu Still Bay points were produced by 'direct percussion by hard hammer, followed by thinning and retouch by soft stone hammer'. Our study focuses on the transition from the pre-Still Bay to the Still Bay at a single, key site with the aim of assessing whether the emergence of this technocomplex at Sibudu represents continuous evolutionary change or sudden, discontinuous processes.

In this paper, we conduct a geometric morphometric (GM) and technological analysis of the points discovered in the Still Bay and pre-Still Bay layers at Sibudu, under the excavation directorship of L. Wadley. Just over half of these points are previously unpublished. The superb chronological and stratigraphic resolution of these layers allows us to analyse the degree of continuity in point form through this period. A preliminary study of some of the points in the pre-Still Bay layers BS and LBG found no evidence of a technological break between the pre-Still Bay at more than 77 ka and the final-Still Bay/early Howiesons Poort dating to 64.7 ± 2.3 ka (Lombard et al. 2019). In this study, we double the sample of complete points previously analysed from the pre-Still Bay layers and employ additional analyses, principally geometric morphometrics to assess the relationship between 'pre-Still Bay' points and Still Bay points. Our primary aim in this study is to assess whether the Still Bay emerged at Sibudu through gradual evolutionary processes or through a rapid, revolutionary transformation. To achieve this, we examine all complete points from layers BS, LBG, and RGS, Sibudu Cave, which cover the period

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of approximately 70–77 ka. We assess whether pre-Still Bay and Still Bay points were significantly different in terms of shape and how much morphological overlap existed in the points belonging to the two industries. We additionally assess whether over time there was a series of technological and shape shifts occurring within both industries, representing long-term evolution of point forms, or whether the major changes in point shapes occurred only at the boundary between the pre-Still Bay and Still Bay layers. Our expectation is that if shape change over time occurred frequently within both industries, and if points late in the pre-Still Bay were very similar to those in the earlier part of the Still Bay, then we are witnessing a continuum of changes consistent with long-term gradual evolutionary shifts akin to phyletic gradualism in biology. But if shape change over time took place predominantly at the boundary of pre-Still Bay and Still Bay industries, and points in each industry were dissimilar to the points in the other, then we are witnessing relative stasis within each industry and a very rapid transformation between industries, akin to the kind of pattern Gould and Eldredge (1977) labelled punctuated equilibria in biology. Although our analysis deals only with the Sibudu sequence establishing the chronological pattern of change in point shape at that key site will provide significant traction for future investigations into the phenomenon of the Still Bay and its antecedents. This paper establishes a quantitative way to track evolutionary change in the technology of other sites and regions in which Still Bay was present and to build robust tests of the history of innovation in the Middle Stone Age.

Background

Sibudu Cave, context, and stratigraphy

Sibudu Cave lies on the uThongathi River in KwaZulu-Natal, in north-eastern South Africa, approximately 15 km inland from the Indian Ocean. The cave is cut into a steep cliff which overlooks the river. A 3 m deep sequence was excavated by L. Wadley within a long-term excavation programme that began in 1998 and continued until 2011. This sequence captured occupational episodes from c.77 ka to the final MSA (c. 38 ka). The sequence is currently being extended by N. Conard, who now leads the excavation programme. The artefacts in this study come from the lowermost layers from the Wadley excavation, brown sand (BS), light brownish grey (LBG), and reddish grey sand (RGS).

The BS and LBG layers have been described by Wadley (2012) as pre-Still Bay, and the overlying RGS layers have been assigned to the Still Bay as they contain the signature Still Bay bifacial points (Soriano et al. 2015, 2009; Wadley 2007; Wadley and Jacobs 2006). Recent excavations by the Conard team have extended the chronostratigraphy of Sibudu back beyond 77 ka, revealing an assemblage characterised by unifacial and bifacial pieces, including serrated points and a small number of notched and denticulated tools below the pre-Still Bay layers analysed in this study (Rots et al. 2017; Will and Conard 2018). While the Still Bay layers have been extensively analysed (Backwell et al. 2018; Clark 2019; d'Errico et al. 2012; Goldberg et al. 2009; Jacobs et al. 2008a, b; Lombard et al. 2019; Soriano et al. 2015, 2009; Wadley 2007, 2013; Wadley et al. 2009; Wadley and Jacobs 2006; Wojcieszak and Wadley 2018), the pre-Still Bay layers from the Wadley excavations (c. 72–77 ka) have not yet been analysed in detail leaving a significant gap in our understanding of technological developments immediately preceding the Still Bay. Crucially, the period to which these layers belong has recently emerged as a pivotal point in the timing of innovative human developments, with abstract drawing (Henshilwood et al. 2018), the hunting of birds (Val 2016; Val et al. 2016), and projective weapons (Rots et al. 2017), all being present during this period. Further innovations like personal ornaments are also seen to emerge soon afterwards, during the Still Bay, approximately 72 ka ago (d'Errico et al. 2008; Henshilwood et al. 2004; Vanhaeren et al. 2013).

The BS to RGS sequence is approximately 80 cm deep. Stratigraphic units were divided during the excavation into sub-layers (for a complete description of the stratigraphy, see Wadley 2012; 2013. For litres of sediment in each layer, see Lombard et al. 2019). This created 16 sub-units in the BS stratigraphic unit, four sub-units in LBG, and two in RGS. This means we are examining a portion of the Sibudu sequence covering 5–10 k. OSL ages date the top of the BS layer to 77.2 ± 2.1 ka, the LBG layer to 72.5 ± 2.0—73.2 ± 2.3 ka, and the overlying Still Bay RGS layer to 70.5 ± 2.0 ka (Jacobs et al. 2008a; Wadley 2012). This is summarised in Table 1.

An occupational hiatus of approximately 5000 years has been proposed within the pre-Still Bay phase between LBG and BS (Wadley 2013), although at 1 SD, the dates overlap. This potential hiatus coincides with the Toba volcanic super-eruption that may have had affected this part of Africa. The environmental impacts associated with the Toba eruption were locally severe, but claims that it resulted in climatic cooling globally are still being explored. In eastern Africa, high-resolution climate records from Lake Malawi show

Table 1 The ages of the layers in this study and their industry classification. OSL dates from (Jacobs et al. 2008a; Wadley 2012)

Industry	Layer	Age (ka)
Still Bay	RGS	70.5 ± 2.0
Pre-SB	LBG	72.5 ± 2.0
Pre-SB	LBG2	73.2 ± 2.3
Pre-SB	BS1	77.2 ± 2.1

an unusual depositional event at ~73 ka and a particularly severe and sustained mega-drought at ~ 75 ka, which aligns with Toba super-eruption (Scholz et al. 2007).

Lombard et al. (2019) report a cessation in point production which coincides with this period around 73 ka as their sample did not contain any retouched points from layers LBG4-LBG2. Our expanded sample, gained through re-analysis of the original assemblage, includes two points from these layers (see Table 2). These new data indicate that point production did not cease during this phase. In addition, there is evidence that the climatic degradation associated with the Toba eruption may not have reached Sibudu. At Sibudu, there appears to be no break in the environmental sequence.

Recent faunal and environmental studies suggest that Sibudu did not experience a dramatic environmental shift at the time of the eruption. Clark's (2019) analysis of open versus closed dwelling fauna found that the shift from the pre-Still Bay to the Still Bay (from approximately 77 to 71 ka) did not correlate with a marked change in the environment. The pre-Still Bay and Still Bay faunal assemblages were both dominated by taxa that preferentially inhabit closed forested habitats with dense underbrush. This was consistent with the analyses of avian fauna (Val 2016), charcoal (Lennox and Wadley 2019), and isotopic data (Robinson and Wadley 2018), which all indicated a persistent forest component through this period. As such, there is little local evidence for a climate-induced hiatus nor for a break in point production at this time at Sibudu.

Table 2 The sample of points showing the excavation layer, period, and number of points by type of retouch

Period	Layer	Bifacial points	Partially bifacial	Unifacial points	Total
Late Still Bay (LSB)	RGS	5		1	6
Early Still Bay (ESB)	RGS2	3		2	5
Late Pre-SB (LPS)	LBG		2		2
	LBG3			1	1
	LBG4			1	1
	BS		1	1	2
	BS6			1	1
	BS7	1		1	2
	BS10		1		1
Early Pre-SB (EPS)	BS11		1	3	4
	BS12			2	2
	BS13		1	4	5
	BS14			2	2
	BS15	1			1
Total		10	6	19	35

Materials and methods

The foundation of our comparison of the shape of the Still Bay and pre-Still Bay points is geometric morphometrics, a method which allows us to isolate shape from other factors. Here we have employed 2D images of points to calculate shape differences between the pre-Still Bay and Still Bay phases at Sibudu. Details of the samples and analytical methods are presented here.

Sample selection

The sample consists of 35 complete points from the pre-Still Bay and Still Bay layers at Sibudu (see Table 2), of which seventeen had been previously analysed, most recently by Lombard et al. (2019). We expanded the sample by re-examining the original collection boxes, a time-consuming process that is not normally undertaken by visiting scholars. We have not made any interpretation of function in selecting the sample. Our sample is constructed using a definition of "point" that references only morphological features visible on the specimen so that the specimens were congruent with the morphometric analysis we have undertaken. Only retouched specimens fitting those morphological criteria were selected for the study.

This increases the number of complete bifacial and partially bifacial points in the pre-Still Bay assemblage to eight. Two of these, including the previously published quartzite bifacial point (Wadley 2012), are completely bifacial, while the other six complete points exhibit both bifacial and unifacial edge and/or base retouch (see Fig. 1). If we had only identified a single bifacial point in the pre-Still Bay assemblage, it could perhaps be explained away by a non-manufacturing process such as trampling, but the presence of eight bifacial/partially bifacial complete points securely positions bifacial technology in the pre-Still Bay period.

Points are often employed as signature pieces in characterising archaeological sequences, but their definition has been notoriously variable (Mellars 1995:110). One approach that has been applied in Africa follows Bordes (1961) and involves defining points in terms of their use: separating hafted points, which are considered 'true' points, from hand-held pointed flakes, principally convergent scrapers. Several authors have appealed to use-wear and fracture studies to determine whether pointed-flakes were hafted 'true' points (see, for example Villa et al.'s (2009) use-wear and residue studies on the Blombos Cave Still Bay points, which suggest that they were used as hunting spear tips). However, Ahler (1971) and Greiser (1977) have demonstrated that hafted

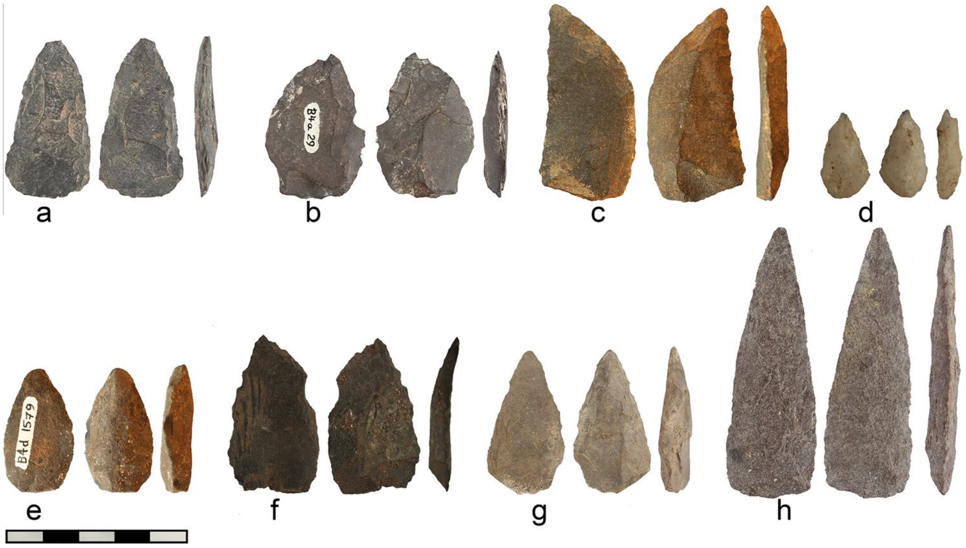

Fig. 1 The eight bifacial and partially bifacial pre-Still Bay complete points, showing ventral, dorsal, and margin. From left to right: top row: **a** 187 late pre-Still Bay (layer LBG unit C4C), one bifacial and one unifacial margin, hornfels; **b** 189 late pre-Still Bay (layer LBG unit B4A), two bifacial margins, hornfels; **c** 95 late pre-Still Bay (layer BS unit B5B), one bifacial and one unifacial margin, hornfels; **d** 107 late pre-Still Bay (layerBS7 unit B4A), all bifacial, quartz; bottom row: **e** 108 late pre-Still Bay (layer BS10 unit B4D), one bifacial and one unifacial margin, hornfels; **f** 158 early pre-Still Bay (layer BS11 unit C4C), two bifacial margins, hornfels; **g** 126 early pre-Still Bay (layer BS13 unit C4A), two bifacial margins, hornfels; **h** 132 early pre-Still Bay (layer BS15), all bifacial, quartzite

points can be multifunctional and also used in actions normally associated with scrapers such as cutting, sawing, and grooving. Similarly, fracture studies which examine breakage patterns have difficulty distinguishing points that may have been hafted tips of projectiles from un-hafted points held in the hand, because of the diversity in wear features from projectile use (Rots and Plisson 2014). In addition, crushing of the tip or snapping can also result from processes other than projectile impact, such as cutting/sawing actions and taphonomic processes (Christenson 1986:111). Tip burination, which is sometimes considered the best indicator of projectile impact, has also been shown to result from knife use (Ahler 1971; Brookes et al. 1975). Multifunctionality and equifinality in the association of tool use and tool damage lead Christenson (1986:122) to conclude that it is not possible to 'confidently distinguish knives from projectile points'. Most compelling is Lombard's (2006) study which showed that the Sibudu Still Bay points were hafted and used as both cutting knives and hunting weapons. For these reasons, we have not defined points in terms of presumed function. This means that our sample is different to previous studies because we have not made any interpretation of function in selecting the sample.

Instead, we have opted for definitions and analytical approaches that involve only readily observable artefact forms and manufacturing features. Our definitions and sample are therefore broadly in line with the inclusionary approach expounded by Conard et al. (2012), who advocated examining all pointed and convergent retouched forms. In this study, we include all convergent flakes from layers BS-RGS which were retouched on the lateral margins and were unbroken (i.e. complete), on which all our landmarks could be reliably identified.

Morphological depictions of Still Bay points were originally presented by Goodwin and van Riet Lowe (1929), who described them as being thin (≤ 10 mm), invasively retouched bifaces with lenticular cross sections, foliate or lanceolate in shape, and with semi-circular or wide-angled pointed shape at the butt. Many point specimens from Sibudu fit that broad characterisation. The earlier pre-Still Bay points are less well defined, but pre-Still Bay layers contain more points in total and most were unifacial points, while the Still Bay layers contain fewer points and most were bifacial. Throughout the sequence, most of the points (77%) are made of hornfels or dolerite, with a small percentage of quartz, quartzite, and other raw materials (see Table 3). Hence the differences we describe in this sequence are unlikely to be explained merely by engineering factors related to raw material selection (Key et al. 2020).

Our sample of points has been organised into four periods which correspond with the stratigraphic division of the site (see Table 2). We distinguish two pre-Still Bay units: early pre-Still Bay (EPS) and late pre-Still Bay (LPS). We identify two Still Bay units: early Still Bay (ESB) and late Still Bay (LSB). This division differs slightly from that of Lombard et al. (2019) who combined the stratigraphic layers LBG and RGS2 into a single unit, whereas we place one in LPS and

Table 3 Raw material numbers and percentages within each layer

Period	Dolerite		hornfels		quartz		quartzite		other		Total (n)
LSB	3	50%	1	17%		0%	1	17%	1	17%	6
ESB	4	80%	1	20%		0%	1	0%	1	0%	5
LPS	1	10%	5	50%	2	20%	1	10%	1	10%	10
EPS	5	36%	7	50%		0%	1	7%	1	7%	14
Total	13	37%	14	40%	2	6%	3	9%	3	9%	35

the other in ESB. This aligns more closely with Wadley's previous subdivision (Wadley 2012).

Data acquisition

Our analysis employed photographs of the dorsal face of each specimen. For fully bifacial points, the dorsal surface was determined by longitudinal curvature. Specimens were consistently positioned so that the camera focal plane was parallel to the plane formed by the average junction of the two main faces of each point. This was not always the optimal angle with which to view retouch and other features, but since we were studying only the plan shape of specimens and not features within the outline our images are appropriate. Photographs were taken with a DSLR camera to give images between ~2146×2264 pixels and 4000×3000 pixels, typically at over 300dpi. This provided considerable details when landmarking. A scale was placed in each image so that size could be input.

Definition and digitising of landmarks

The practice of GM is founded upon the procedure of landmarking. One important principle in conceptualising and selecting of landmarks is usually expressed as a requirement for landmarks to be 'homologous' as the mathematical propositions of GM presume and demand the correspondence of every landmark with conceptually equivalent landmarks on other specimens (Lele and Richtsmeier 2001). The key characteristic of landmarking is simply that each landmark should represent the same point on each specimen in the analysis. To fulfil this requirement, we have defined 12 structurally corresponding landmarks on each specimen (Fig. 2). This number of landmarks is also mathematically conformable with the small sample size available from the site.

The points analysed here are simple leaf-like shapes. They vary from what would be classified as acute/lanceolate or ovate to deltoid or even slightly cordiform (see Hasim et al 2016). These simple shapes have very gently curving lateral margins that can effectively be represented by a small series of straight lines (see Fig. 2). They contain few distinctive, 'functional' features, such as notching, tangs, or other structures that relate to hafting and that have been employed to orient other unifacial and bifacial point classes in different places and times. Additionally, many specimens had platforms removed by retouching, and so platform features were not able to be consistently used as a baseline. Since these points are differentiated from other classes of retouched flake by the systemic retouching of the piece to form converging margins, we aligned all specimens along their long axis, from the tip of the point to the most protruding portion of the base. This alignment is shown in Fig. 2. We positioned landmarks on repeatable, corresponding locations, based on the procedural rules listed in Table 4. Landmarking was facilitated by superimposing a 'centre line' from tip to base and placing a rectangle around the boundary of the specimen and parallel to the centre line (using a drawing programme). These lines and frames are shown in Fig. 2. On the photograph of each specimen, landmarks were digitised and scaled as shown in Fig. 2 (upper row) (Rohlf 2004a; b). Note that where the butt or tip was formed as a flat line the relevant pair of landmarks (1 and 2 or 3 and 4) will be separated whereas when the butt or tip was formed as the point of converging margins the pair of landmarks are co-located, as shown in Fig. 2. The effectiveness of this landmarking system is illustrated in Fig. 2 (lower row), which shows the landmarks for one specimen from the pre-Still Bay and one from the Still Bay. On those specimens, lines joining the landmarks closely resemble the outline shape of the points. Given the adequacy of this landmarking system and the low sample sizes, we are employing that high dimensional morphometric approaches are neither warranted nor necessary.

Computation of shape differences

Our GM analysis was carried out with Klingenberg's MorphoJ programme (2011, 2013) and proceeded through the standard statistical manipulations: generalised Procrustes analysis (GPA), compilation of a covariation matrix, regression to remove allometric effects, followed by principle component analysis (PCA). Each of these steps plays a critical role in isolating shape and understanding the structure of shape variation. Briefly, the Procrustes superimposition removed size, orientation, and position information to transform raw landmark coordinates to Procrustes coordinates that depict shape variation. Creating the covariation matrix yields a dataset describing the relationship of all coordinates with each other and formats these data to allow us to employ

Fig. 2 Examples of landmarking on pre-Still Bay (left) and Still Bay (right) points from Sibudu. The images are wireframe graphs of the average point shape for each of the industries, based on the GM analysis presented in the paper

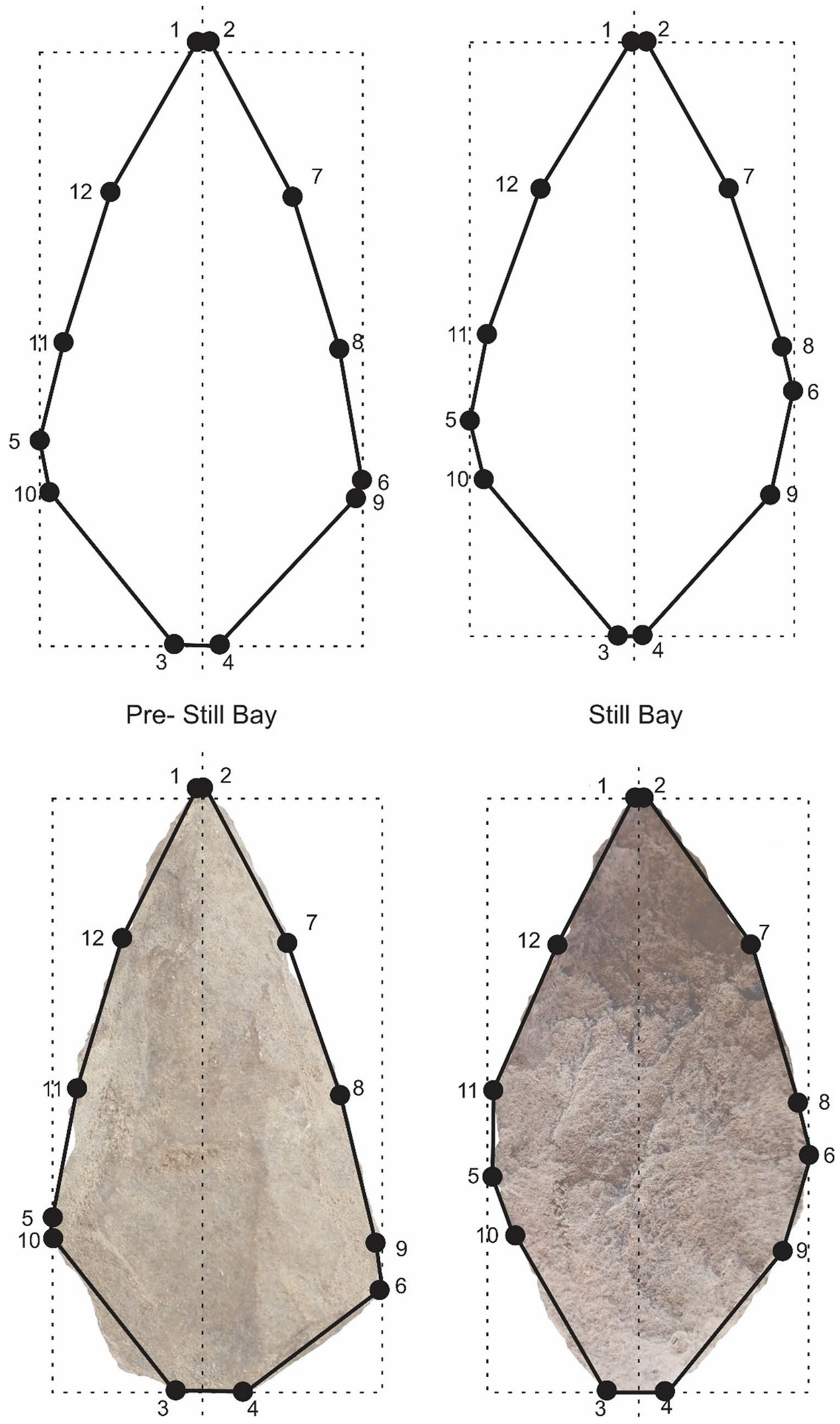

Table 4 Definition of landmarks used in the study

Landmark	Location
1	Left hand side of the 'tip'
2	Right hand side of the 'tip'
3	Left hand side of the 'butt'
4	Right hand side of the 'butt'
5	Point on the left margin most distant from the centre line
6	Point on the right margin most distant from the centre line
7	Location of the right margin 3/4 way along the centre line from the butt
8	Location of the right margin 1/2 way along the centre line from the butt
9	Location of the right margin 1/4 way along the centre line from the butt
10	Location of the left margin 1/4 way along the centre line from the butt
11	Location of the left margin 1/2 way along the centre line from the butt
12	Location of the left margin 3/4 way along the centre line from the butt

PCA as a data reduction procedure. However, these data may still retain allometry, and so we regressed shape data (Procrustes coordinates) against size data (centroid size) to determine the effect of allometry. We then removed allometry by employing regression residuals as data for subsequent PCA calculations. With those PCA, we are able to characterise the magnitude and dimensionality of shape variation observable within the sample. We tested the strength of separation in shape space between our predefined groups using canonical variate analysis (CVA). In presenting the results of these statistical treatments, we emphasise wireframe graphs, as discussed by Klingenberg (2013).

Relationship between shape differences and retouch variables

We then examined the relationship between shape changes and variation in retouch location and extent. This allowed the layer and extent of retouch to be compared. One concern is to establish whether manufacture occurred throughout the life history of each specimen and if so whether the phase of manufacture at discard was an important factor in creating shape differences, as proposed by Villa et al. (2009). A second, related concern is to evaluate whether increasing layers of bifacial flaking was partly responsible for the alteration of point form from the pre-Still Bay to the Still Bay. We evaluate the relationship of shape changes and reduction process with conventional significance tests of the invasiveness index (Clarkson 2002) and specimen size.

Results

Geometric morphometric results

Allometry was not strong in this collection of points. Regression revealed a positive but not strongly linear increase in coordinate values as centroid size increased. The regression indicated that about 5.6% of shape variation changed in response to size change, and a permutation test yielded indicated this was not significant ($p = 0.0954$). Nonetheless we removed that allometric effect, and all results reported here are based on 'size-corrected' data. A PCA of those data yielded twenty components, the largest three of which explained 84.2% of variations: PC1 = 39.4%, PC2 = 23.9%, and PC3 = 20.9%. Here we explore only these three principal components to examine the shape differences in Still Bay and pre-Still-Bay points.

The nature of shape differences represented by those three components is shown in Fig. 3. By definition, each component represents different and independent shape traits. PC1 primarily expresses shifts in the location of maximum point width, from near the centre of the length for negative values to very close to the base for strongly positive values. This largely measures differences between acute/lanceolate (bi-pointed specimens) and deltoid-shaped specimens with rounded or squared butts. PC2 primarily expresses shifts in the elongation and relative width of points, from relatively squat specimens for negative values to more elongate specimens for strongly positive values. PC3 primarily expresses shifts in the bilateral symmetry of the points, from specimens with greater mass on the lower right hand for negative values to specimens with greater mass on the lower left hand side for strongly positive values, with symmetrical values being close to 0. In combination, these three principal components depict many of the shape differences that have been recognised in traditional studies of these points. However, while these quantitative descriptions of independent elements of shape differences cover the kinds of differences noted in conventional typological discussions, they also additionally allow us to evaluate the differences between Still Bay and earlier points in Sibudu.

The outlines we used in Fig. 2 to show landmarks are the average shapes for pre-Still Bay and Still Bay points

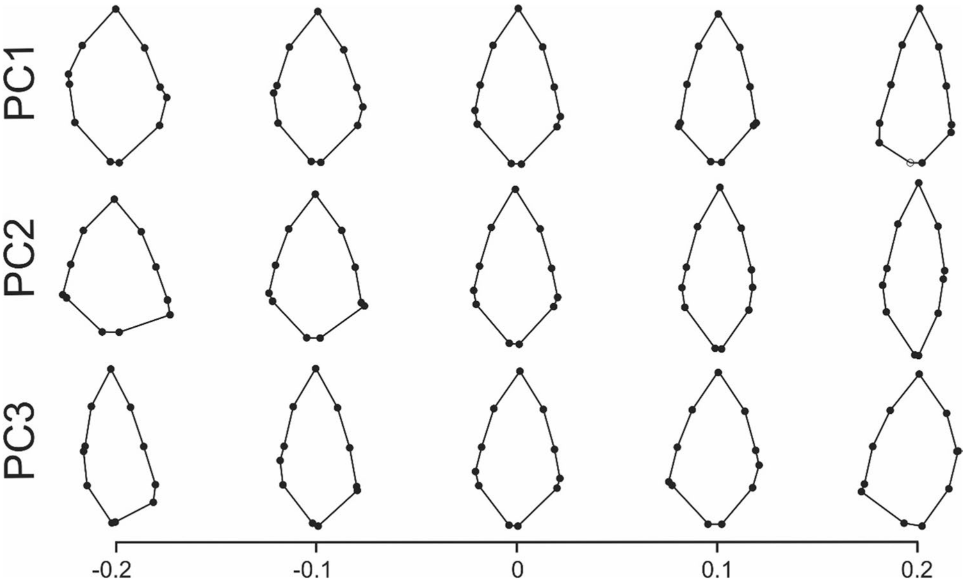

Fig. 3 Shape differences in PC1-3 for Still Bay and pre-Still Bay points from Sibudu

and reveal a difference between the average shapes of points from the two phases, on average. However, such normative depictions of difference between the points in each industry hide considerable variation in point form within each industry and the extent of overlap between the industries. This can be seen in Fig. 4, which shows bivariate plots of PC1 against PC2 and PC3. We make two observations about the pattern in both plots. First is that the points from both phases show similar morphological variation, and consequently there is significant overlap in the morphospace being occupied by points from the two industries. There is more separation between the industries on PC3 (symmetry) than on the other components, and we will target this shape difference in analyses below, but even for PC3, there is significant overlap. However, the second observation is that across the morphospaces shown in Fig. 4, the two industries display differences in the densities within the graph. Still Bay points frequently occupy more negative spaces on PC1 and more positive space on PC3 than many pre-Still Bay points, reflecting the pattern for Still Bay points to more commonly have acute/lanceolate shapes with mass protruding on the lower left hand side. For example, 73% of Still Bay points are negative on PC1, whereas only 40% of pre- Still Bay points are negative on PC1. These data indicate a shift over time in common point shapes, from less to greater emphasis on bi-pointed forms. Additionally, if measures of symmetry can be reliably compared given the differences in proportions of uni- and bifacial specimens, and the identification of the dorsal surface on bifacial points using longitudinal curvature can be relied upon, then these data also indicate a shift over time from right side to left side departures from bilateral symmetry. That shift, in conjunction with the increasing emphasis on bi-pointed forms, could be interpreted as consistent with a gradual evolutionary transition and raises questions about how sharp the technological boundary between the Still Bay and preceding industry may have been.

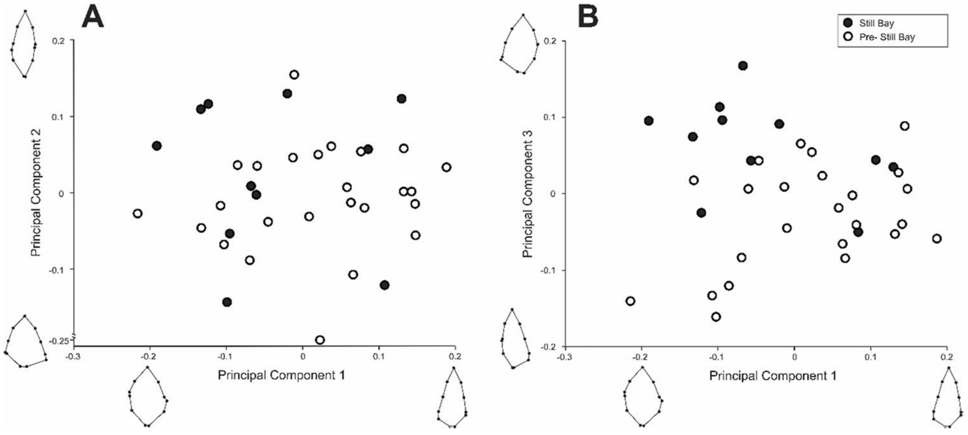

Fig. 4 Bivariate plot of principal components 1 and 2 for the shape of Still Bay (solid) and pre-Still Bay (hollow) points at Sibudu

We evaluate the proposition that our data documents an evolutionary shift from pre-Still Bay to Still Bay forms by looking in detail at the relationship of PC3 to PC1. In Fig. 5A, we plot PC3 against PC1 and show equal frequency ellipses ($p = 0.9$) for each industry. This reveals a different relationship between PC1 and PC3 in each of the two point industries, implying different chronological trajectories. While pre-Still Bay points show a positive relationship, Still Bay points show an inverse relationship. The result is a pattern in which the two industries have a significant overlap on the right of the graph, where all specimens with positive PC1 values share similar shapes (between −0.1 and 0.1 on PC3), but on the left hand side of the graph, where Still Bay points commonly have positive PC3 values and pre-Still Bay points have negative PC3 values, the industries are well separated. PC3 expresses bilateral symmetry of the points, and these data show that many of the pre-Still Bay points had protruding right hand sides, whereas chronologically later Still Bay Points often had protruding left hand sides. However the clustering of data points on the right of Fig. 5A represents a number of leaf-shaped symmetrical forms which have very similar shapes even though some are from Still Bay layers and others from pre-Still Bay layers.

Chronology is strongly associated with these patterns of shape difference. We place an arrow in Fig. 5A to show the general chronological pathway that exists within these industries. Over time, there was initially a trend from asymmetrical lanceolate shapes towards bilaterally symmetrical deltoid shapes but subsequently a shift back to asymmetrical lanceolate shapes, although the pattern of the asymmetry was different from at the start of the sequence of point production. One way to depict the chronological shifts is presented in Fig. 5B where we show that sequence of shape change by subdividing both Still Bay and pre-Still Bay points into either 'early' or 'late' to create four temporal groups, each of which is bounded by convex hulls and numbered in chronological order from earliest (1) to latest (4). The earliest pre-Still Bay specimens (chronological group 1) span the full range of PC1 (lanceolate to deltoid shapes), but most specimens are negative on PC3, indicating mostly right margin asymmetry. Late pre-Still Bay points (chronological group 2) are more symmetrical, showing a distribution shifted upward on the y axis in comparison to group 1. Early Still Bay points (chronological group 3) cover a similar range of PC1 values as the underlying late pre-Still Bay but show some specimens that have even higher PC3 values than were present in the late pre-Still Bay. In other words, the early Still Bay has much the same range of lanceolate/deltoid shapes as the late pre-Still Bay and differed primarily by having some specimens with greater asymmetry than is observed in the late pre-Still Bay. Late Still Bay points (chronological group 4) also occupy a broad range of

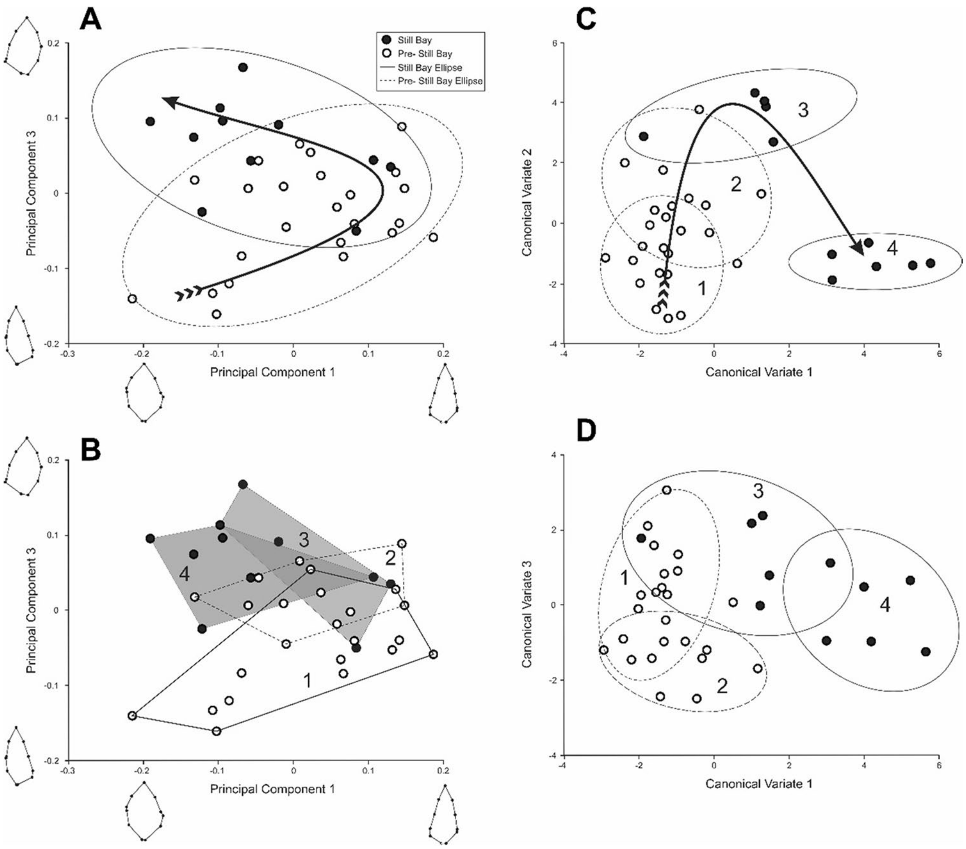

Fig. 5 **A** Bivariate plot of principal components 1 and 3 showing the $p = 0.9$ ellipses for each industry; **B** bivariate plot of principal components 1 and 3 showing convex hulls and chronological order from earliest (1) to latest (4) for the four temporal groups; **C** bivariate plot of canonical variate 1 and 2 showing the four temporal groups with an arrow indicating our proposed evolutionary trend; and **D** bivariate plot of canonical variate 1 and 3 showing overlap between the four temporal units

shapes PC1, but the majority are lanceolate in shape, indicated by low PC1 values, and most show right side asymmetry. Graph 5B reveals that there is substantial overlap in the shape spaces represented by all four chronological groupings spanning both pre-Still Bay and Still Bay. The evidence does *not* show that points within each industry are similar or are unlike points from the other industry. Instead, the evidence is best understood as an evolutionary continuum in which the points in each time period show an overlap with shapes found in the preceding period but also points occupying adjacent shape space that had not previously been exploited. Again we see a non-directional trend towards the upper left of the morphospace described by PC1 and PC3, and the trend begins in at least the late pre-Still Bay, consistent with an evolution of Still Bay from pre-Still Bay point production technology. Furthermore, by showing convex hull boundaries around the specimens from each of these four chronological groups, it is clear that both early and late Still Bay points at Sibudu are spread across approximately the same area of morphospace as the late pre-Still Bay, which means that Still Bay points were not more standardised than points from at least the final stage of the pre-Still Bay. Examples of pre-Still Bay and Still Bay points from Sibudu are shown in Fig. 6.

We examined these patterns further by performing CVA on the same four stratigraphically defined groups, to diagnose the degree and pattern of separation between the chronological units. Permutation tests on Procrustes distances among groups were performed (permutation 10,000 rounds), and the only statistically significant difference found was between the two ends of the chronological sequence, between the early pre-Still Bay and the late Still Bay (Table 5). Adjoining phases were not significantly different, a result consistent with our proposition that there were only small differences from one layer to the next as could be expected from a sequence of gradual evolution. Relationship between CV1 and CV2, which represents 88.3% of total variance, is shown in Fig. 5C. In that graph, the early Still Bay does not separate from the pre-Still Bay, but the later Still Bay is clearly separated from all earlier points produced at Sibudu, including ones from the early Still Bay. Again we indicate the chronological trend with an arrow, to visually emphasise the non-linear shape shift represented by the late Still Bay, where points again became asymmetrical, as they were at the start of the sequence. When we plot CV1 and CV3, together accounting for 61.9% of the total variance, we see the four chronological units overlapping, with data points continuously arrayed and with our predefined groupings displaying difference, but none of the units or industries show clear separation from chronologically adjacent ones (Fig. 5D). These analyses do not discriminate two morphologically distinct industries and provide quantitative evidence of the Sibudu points displaying a continuum of gradual morphological shifts consistent with evolutionary modification over time.

Table 5 P-values from permutation tests (10,000 permutation rounds) for Procrustes distances among groups

	Early pre-Still Bay	Late pre-Still Bay	Early Still Bay
Late pre-Still Bay	0.2918		
Early Still Bay	0.0700	0.6475	
Late Still Bay	**0.0024**	0.0853	0.2514

Retouch analysis results

With that evolutionary sequence of shape changes established, we turn to the technological shifts that may have been associated. Villa et al. (2009) argued that the shape of the Still Bay points from Blombos was a product of their

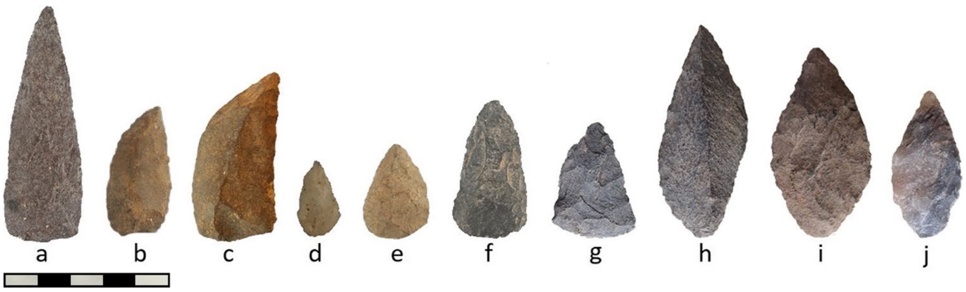

Fig. 6 Examples of pre-Still Bay to Still Bay points, **a** 132 early pre-Still Bay (layer BS15 unit B4), all bifacial, quartzite; **b** 118 early pre-Still Bay (layer BS12 unit C4C), unifacial, hornfels; **c** 95 late pre-Still Bay (layer BS unit B5B), partly bifacial, hornfels; **d**107 late pre-Still Bay (layer BS7 unit B4A) all bifacial, quartz; **e** 135 late pre-Still Bay (layer LBG4 unit B5D), unifacial, hornfels; **f** 187 late pre-Still Bay (layer LBG unit C4C), partly bifacial, hornfels; **g** 504 early Still Bay (Layer RGS2 unit B4D), all bifacial, hornfels; **h**509 early Still Bay (layer RGS2 unit B5A), all bifacial, dolerite; **i** 501 late Still Bay (layer RGS unit B4C), all bifacial, dolerite; **j** 511 late Still Bay (layer RGS unit C5C), all bifacial, quartzite scale = 50 mm

manufacturing stage, with shape varying along a trajectory from 'initial' to 'advanced' shaping and ultimately 'recycling/modification'. As shape changes are predicted to accompany this progression of artefact life history, they argued that chronological shifts in typical point shapes would be a consequence. We tested this possibility by inferring extent of retouching using two measures: the extent of margin retouched and the invasiveness index of retouch, with the assumption that initial shaping would modify only part of the surface of the point, while advanced shaping would extend onto both ventral and dorsal surfaces as reduction continued. Since our GM analysis above showed an evolution of shape change over time, we explored the reduction indices for temporal shifts between phases to see if shape change was broadly associated with intensity of reduction.

A shift over time in amount of retouch was clearly present (see Fig. 7). The intensity of retouch is extremely variable in each phase, but both measures display a consistent trend in central tendency, a pattern displaying in inverted U, with substantial increase in the level of retouching throughout the pre-Still Bay and then decrease in the level of retouching during from the early Still Bay. The two measures peak at similar points in the stratigraphic sequence in the late pre-Still Bay. This graphical pattern does not indicate a systematic difference between Still Bay and pre-Still Bay in levels of retouch and reveals non-directional evolutionary trends in retouching across the industrial boundary. We tested that interpretation with a multivariate analysis of variance (MANOVA) which compared GM shape values for the two measures of retouch intensity: extent of margin retouched and invasiveness of retouch. The multivariate result did not show statistically significant differences at the $p < 0.05$ layer in shape for the two measures of retouch (invasiveness: Pillai = 0.09, $F = 1.72$, $df = (2.34)$, $p = 0.19$, and extent of margin retouched: Pillai = 0.11, $F = 2.02$, $df = (2.34)$, $p = 0.15$). Thus no statistically significant effects were found for level of retouch on point shape, and we therefore conclude that there is no capacity for variation in retouch intensity to explain the chronological changes in point shape between pre-Still Bay and Still Bay industries at Sibudu.

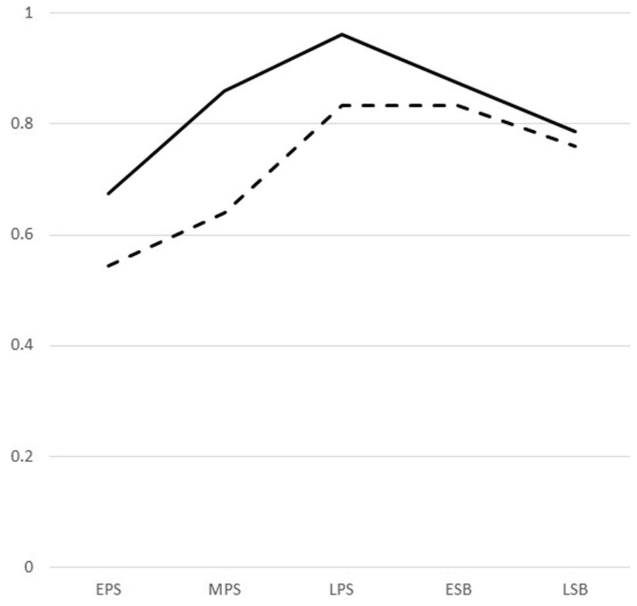

Fig. 7 Line plot showing the average level of retouch in each phase. The solid line describes the mean percentage of total margin retouched in each period, with 1 = retouch around the entire perimeter and 0 = no retouch. The dashed line describes the invasiveness of retouch as a percentage of the point surface, with 1 = both faces completely removed through retouch and 0 = no retouch

While a statistically significant correlation was not found between shape and *extent* of retouch, it was found between shape and *location* of retouch. By location we refer to the number of sides that were retouched and we document a trend from unifacial to partly bifacial to bifacial over time. In the early pre-Still Bay, unifacial retouch accounted for 79% (n = 11) of the assemblage, with smaller numbers of bifacially (n = 1) and partly bifacially retouched points present (n = 2). An intermediate point form that displayed bifacial retouch along one margin and unifacial retouch along either the other margin or the base was present in early to late pre-Still Bay phases. This intermediate form disappeared in the two Still Bay phases, with bifacial points dominating, although unifacial points remained present in the final Still Bay phase (n = 1). The implication was an increasing preference for bifacial retouch in the Still Bay especially on the base of the point, which helped make the points more bi-pointed. This increase in bifacial flaking through time was statistically significant. Kendall's rank correlation tau found retouch form and phase to be strongly correlated, $r(34) = 0.44$, $p < 0.003$. A multivariate analysis of variance also showed a statistically significant difference at the $p < 0.01$ layer in shape and retouch form: Pillai = 0.24, $F = 5.01$, $df = (2,34)$, $p < 0.01$. We interpret this to show that shape differences were affected by the location of retouch, even though the subsequent intensity of retouch had little effect on shape. We argue that knappers changed the location of their retouching blows to produce the point shapes typical of each phase.

Finally, the GM analysis presented earlier removed size and allometric effects. Hence the shape differences we tracked over time in Fig. 5 were independent of size variation between specimens. As such, we can say that the evolution of shape is not a product of chronological shifts in the sizes of artefacts being produced. As we have also observed that the temporal shape shifts are not explained simply by reference to raw material or extent of retouching, we argue that the shape evolution we have identified is not a consequence of raw material economics or levels of resharpening. The implication is that people occupying Sibudu over time shifted from a preference for unifacial to bifacial flaking and made points that were on average slightly different shapes.

There may be other possible explanations related to tool use, such as temporal shifts in hafting procedures which led to selection for different point shapes suited to the hafting procedure employed in each period. We have no independent evidence of use with which to test relationships between shape and use/hafting, but it would be valuable for the existence or absence of relationships to be explored. However, invoking tool use or hafting is a limited form of explanation for the evolutionary trend we have found. One difficulty with such explanations is that we have shown a long-term incremental transformation in shape, a sequence of transformations that are not linear but begin as asymmetrical shapes that gradually become more bilaterally symmetrical before trending back to asymmetrical (see Fig. 4). Invoking tool use or hafting mechanisms as an explanation for such a trend may require long-term, incremental change in hafting techniques and patterns of use to be demonstrated. Long-term trends in tool use of this kind have not been widely discussed, but in suitable sites, their existence could be tested. One complexity of proposing evolution in tool use as the explanation for the long-term evolution of MSA point shapes is that it implies tight synching of form and function, which as we note above has not been demonstrated for MSA points. It seems that in any phase throughout the Sibudu, MSA sequence point shape was variable and point use was also varied, and so coevolution of the two phenomena would have been an elaborate process. A second issue with explanations referring to use/hafting is that even if they represent proximate effects, they leave us with questions about why shapes changed at all in response to functional shifts and why they changed in the ways they did? Below we explore different possible explanation for the evolution of point shape in the MSA.

Discussion

At Sibudu, we have an evolutionary continuum in point shape on display. Our results reveal that while there is a significant difference between the ends of this continuum, between early pre-Still Bay and late Still Bay points, there is an incremental shift throughout the Sibudu sequence. We find a shift from early symmetrical and leaf-shaped points, to the late Still Bay forms that are typically asymmetrical and bi-pointed. In our four phase sequence, there is substantial shape overlap and no statistical differences between adjoining phases, which is consistent with a gradual local evolution in technology. It is especially relevant to note that the point assemblage from the final pre-Still Bay phase (LPS) overlaps to a large degree with the first Still Bay phase (ESB). We propose that the incremental sequence of shape changes we document represents the evolution of Still Bay point forms at Sibudu from slightly different point varieties that were manufactured in the period immediately prior to the recognised onset of the Still Bay. This continuity in traditions, which seems to have resulted from a long series of small technological changes through time, is in line with Kandel et al. (2016: 644) finding that ‘contrary to the idea that the MSA represents a time of sudden increases in complex behaviour, on the macro-scale we just see slow and steady change’.

The mechanisms underlying those evolutionary shifts, including the direction of asymmetry in the different phases, are difficult to define. We evaluated a number of factors, such as raw material shifts, intensity of retouch, technological choices to retouch points unifacially or bifacially, and size differences. Only technological choices (location of retouch, from unifacial to bifacial) were associated with the temporal sequence of point shape changes we established at Sibudu. In a southern African context, our results sit in opposition to the findings of Villa et al. (2009) who saw a correlation between shape and manufacturing stage. We find no support for that proposition at Sibudu.

Instead we emphasise that the shape variation in points during the Still Bay is approximately the same as the variation visible in the pre-Still Bay. It is a noteworthy inference that we can state no evidence for increased standardisation in the Still Bay. These results support the recent questioning of the integrity of the Still Bay technocomplex (Soriano et al. 2015; Archer et al. 2016). They do not support an interpretation of the Still Bay as a period in which there were altered learning patterns, such as heightened training and greater craft specialisation, nor does the observation of equal levels of variation support models of stronger social cohesion later in the sequence that reveals altered levels of social networking or cohesion mediated by more standard public signalling in the Still Bay.

We present data from only one site and cannot comment on the shape similarity of Sibudu points across the different regions of southern Africa. However, our depiction of the Sibudu evidence provides a useful sequence of the evolution of common shape norms for Still Bay points and yields information about how that evolution occurred. One implication of our data is that the Sibudu technological sequence is not stadial but shows a pattern of evolution that may have been continuous or near continuous. This means that the neither the Still Bay nor the pre-Still Bay is monolithic entities; they display internal change. Whether a sharp break exists between the pre-Still Bay and what came before requires examination in future studies.

Our data also raises the question of whether norms were shared over wide geographic areas for only one portion of the Still Bay, such as those of the early Still Bay. There are already indications of regional differentiation as well as broad similarities within Still Bay point shapes that may imply coordination was short term and preceded by and/or followed by some divergence in norms (Archer et al. 2016:68; Soriano et al. 2015 Wadley 2007). If that was the case, it could imply that a super-network of shared norms and perhaps coordinated public signalling was relatively short lived, while before and after that phase point shapes were not as strongly coordinated and hence varied regionally. The alternative is that coordination was much more prolonged and that in multiple regions there was parallel evolution of point shape, comparable to what we see at Sibudu, so that coordination was maintained in spite of evolution of shape norms. Those alternatives of how widespread coordination operated can be evaluated in future studies, as should the possibility that there was far less similarity and hence coordination than has been thought. Geometric morphometric studies similar to ours across southern Africa should be able to test these competing propositions.

Conclusion

In this study, we quantified variation in MSA point shape through time at Sibudu, examining the shape shifts that accompanied the transition from the pre-Still Bay c.77 ka to the Still Bay, c.72 ka. We found an incremental evolution of average point shapes through the Sibudu sequence, from asymmetrical leaf-shaped forms in the early pre-Still Bay points to more symmetrical and leaf-shaped points in the late pre-Still Bay and early Still Bay and finally to asymmetrical and more bi-pointed shaped points in the late Still Bay. Change over time within the pre-Still Bay assemblages shows evolution of point shapes progressively towards the forms common in the early Still Bay. Shapes in the final pre-Still Bay and early Still Bay were not significantly different, and the differences that exist are best attributed to small evolutionary change. On this basis, we conclude that the Sibudu evidence reveals incremental evolution of point shape throughout this long period, changes that cannot be represented as stadial and which do not support claims of the Still Bay being a dramatic break with previous technology. This recognition of gradual evolutionary change in point form complicates visions of the Still Bay as a period of shared norms across vast portions of Southern Africa and calls for the incorporation of the nature of evolution before and within the Still Bay into such models. The questions we have raised about models of MSA point evolution and regional connectivity can be addressed with further use of the GM methods we employed here.

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Author contribution AW conceived of the project, formulated the sample, photographed specimens, and undertook the conventional technological analysis. PH landmarked the points and carried out the geometric morphometrics analysis. Both AW and PH contributed to writing the paper.

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Availability of data and material Subject to review.

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Declarations

Conflict of interest The authors declare no competing interests.

References

Ahler SA (1971) Projectile point form and function at Rodgers Shelter. College of Arts and Science, University of Missouri, Missouri

Archer W, Pop CM, Gunz P, McPherron SP (2016) What is Still Bay? Human biogeography and bifacial point variability. J Hum Evol 97:58–72

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

Bordes F (1961) "Typologie du Paléolithique ancien et moyen. Mémoires de l'Institut Préhistorique de l'Université de Bordeaux

Brookes SO, Gray BJ, Inmon B, Rodrigue A (1975) Greenbriar projectile points: a discussion of form and function. Q Bull Archaeol Soc Virginia 30:97–100

Christenson AL (1986) Projectile point size and projectile aerodynamics: an exploratory study. Plains Anthropol 31(112):109–128

Clark JL (2019) The Still Bay and pre-Still Bay fauna from Sibudu cave: taphonomic and taxonomic analysis of the macromammal remains from the Wadley excavations. J Paleolithic Archaeol 2(1):26–73

Clarkson C (2002) An index of invasiveness for the measurement of unifacial and bifacial retouch: a theoretical, experimental and archaeological verification. J Archaeol Sci 29(1):65–75

Conard NJ, Porraz G, Wadley L (2012) What is in a name? Characterising the post-Howieson's poort' at sibudu. S Afr Archaeol Bull 67(196):180–199

d'Errico F, Backwell LR, Wadley L (2012) Identifying regional variability in Middle Stone Age bone technology: the case of Sibudu Cave. J Archaeol Sci 39(7):2479–2495

d'Errico F, Vanhaeren M, Wadley L (2008) Possible shell beads from the Middle Stone Age layers of Sibudu cave, South Africa. J Archaeol Sci 35(10):2675–2685

Discamps E, Henshilwood CS (2015) Intra-site variability in the Still Bay fauna at Blombos cave: implications for explanatory models of the Middle Stone Age cultural and technological evolution. PLoS One 10(12):e0144866

Goldberg P, Miller CE, Schiegl S, Ligouis B, Berna F, Conard NJ, Wadley L (2009) Bedding, hearths, and site maintenance in the Middle Stone age of Sibudu cave, KwaZulu-Natal. S Afr Archaeol Anthropol Sci 1(2):95–122

Goodwin AJH, van Riet Lowe C (1929) The stone age cultures of South Africa: AMS Press

Gould SJ, Eldredge N (1977) Punctuated equilibria: the tempo and mode of evolution reconsidered. Paleobiology 3:115–151

Greiser ST (1977) Micro-analysis of wear-patterns on projectile points and knives from the Jurgens site, Kersey. Colorado Plains Anthropologist 22(76):107–116

Hasim A, Herdiyeni Y, Douady S (2016) Leaf shape recognition using centroid contour distance. IOP conference series: earth and environmental science 31:012002

Henshilwood C, d'Errico F, Vanhaeren M, Van Niekerk K, Jacobs Z (2004) Middle stone age shell beads from South Africa. Science 304(5669):404–404

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

Henshilwood CS, d'Errico F, van Niekerk KL, Dayet L, Queffelec A, Pollarolo L (2018) An abstract drawing from the 73,000-year-old layers at Blombos Cave. S Afr Nat 562(7725):115–118

Högberg A (2016) A lithic attribute analysis on blades from the middle stone age site, hollow rock shelter, western Cape Province. S Afr Lithic Technol 41(2):93–113

Högberg A, Lombard M (2016) Still Bay point-production strategies at hollow rock shelter and Umhlatuzana rock shelter and knowledge-transfer systems in southern Africa at about 80–70 thousand years ago. PLoS One 11(12):e0168012

Jacobs Z, Roberts RG, Galbraith RF, Deacon HJ, Grün R, Mackay A, Mitchell P, Vogelsang R, Wadley L (2008a) Ages for the Middle Stone Age of southern Africa: implications for human behavior and dispersal. Science 322(5902):733–735

Jacobs Z, Wintle AG, Roberts RG, Duller GA (2008b) Equivalent dose distributions from single grains of quartz at Sibudu, South Africa: context, causes and consequences for optical dating of archaeological deposits. J Archaeol Sci 35(7):1808–1820

Kandel AW, Bolus M, Bretzke K, Bruch AA, Haidle MN, Hertler C, Märker M (2016) Increasing behavioral flexibility? An integrative macro-scale approach to understanding the Middle Stone Age of southern Africa. J Archaeol Method Theory 23(2):623–668

Key A, Proffitt T, de la Torre I (2020) Raw material optimization and stone tool engineering in the Early Stone Age of Olduvai Gorge (Tanzania). J R Soc Interface 17:20190377. https://doi.org/10.1098/rsif.2019.0377

Klingenberg CP (2011) MorphoJ: an integrated software package for geometric morphometrics. Mol Ecol Resour 11(2):353–357

Klingenberg CP (2013) Visualizations in geometric morphometrics: how to read and how to make graphs showing shape changes. Hystrix, Italian J Mammal 24(1):15–24

Lele SR, Richtsmeier JT (2001) An invariant approach to statistical analysis of shapes: Chapman and Hall/CRC

Lennox SJ, Wadley L (2019) A charcoal study from the Middle Stone Age, 77,000 to 65,000 years ago, at Sibudu, KwaZulu-Natal. Trans R Soc S Afr 74(1):38–54

Lombard M (2006) First impressions of the functions and hafting technology of Still Bay pointed artefacts from Sibudu Cave. S Afr Humanit 18(1):27–41

M Lombard, Högberg A, Wadley L (2019) Temporal perspective on Still Bay point production at Sibudu Cave, KwaZulu-Natal, in the context of southern Africa. Azania Archaeol Res Afr 54(2):141–176

Lombard M, Högberg A (2018) The Still Bay points of Apollo 11 rock shelter, Namibia: an inter-regional perspective. Azania Archaeol Res Afr 53(3):312–340

Mackay A, Stewart BA, Chase BM (2014) Coalescence and fragmentation in the late Pleistocene archaeology of southernmost Africa. J Hum Evol 72:26–51

Mellars PA (1995) The Neanderthal legacy: an archaeological perspective from Western Europe. Princeton University Press, Princeton, New Jersey

Porraz G, Parkington JE, Rigaud JP, Miller CE, Poggenpoel C, Tribolo C, Archer W, Cartwright CR, Charrié-Duhaut A, Dayet L, Igreja M (2013) The MSA sequence of Diepkloof and the history of southern African Late Pleistocene populations. J Archaeol Sci 40(9):3542–3552

Robinson JR, Wadley L (2018) Stable isotope evidence for (mostly) stable local environments during the South African Middle Stone Age from Sibudu, KwaZulu-Natal. J Archaeol Sci 100:32–44

Rohlf F (2004a) TpsDig. State University of New York, Stony Brook, NY, Department of Ecology and Evolution

Rohlf FJ (2004b) tpsUtil, file utility program, version 1.26. Department of Ecology and Evolution, State University of New York at Stony Brook

Rots V, Lentfer C, Schmid VC, Porraz G, Conard NJ (2017) Pressure flaking to serrate bifacial points for the hunt during the MIS5 at Sibudu Cave (South Africa). PloS one 12(4):e0175151

Rots V, Plisson H (2014) Projectiles and the abuse of the use-wear method in a search for impact. J Archaeol Sci 48:154–165

Schmid VC, Porraz G, Zeidi M, Conard NJ (2019) Blade technology characterizing the MIS 5 DA layers of Sibudu cave. S Afr Lithic Technol 44(4):199–236

Scholz CA, Johnson TC, Cohen AS, King JW, Peck JA, Overpeck JT, Talbot MR, Brown ET, Kalindekafe L, Amoako PY (2007) East African megadroughts between 135 and 75 thousand years ago and bearing on early-modern human origins. Proc Natl Acad Sci 104(42):16416–16421

Soriano S, Villa P, Delagnes A, Degano I, Pollarolo L, Lucejko JJ, Henshilwood C, Wadley L (2015) The Still Bay and Howiesons Poort at Sibudu and Blombos: understanding Middle Stone Age technologies. PLoS One 10(7):e0131127

Soriano S, Villa P, Wadley L (2009) Ochre for the toolmaker: shaping the Still Bay points at Sibudu (KwaZulu-Natal, South Africa). J Afr Archaeol 7(1):41–54

Val A (2016) New data on the avifauna from the Middle Stone Age layers of Sibudu Cave, South Africa: Taphonomic and palaeoenvironmental implications. Quatern Int 421:173–189

Val A, de la Pena P, Wadley L (2016) Direct evidence for human exploitation of birds in the Middle Stone Age of South Africa: The example of Sibudu Cave, KwaZulu-Natal. J Hum Evol 99:107–123

Vanhaeren M, d'Errico F, van Niekerk KL, Henshilwood CS, Erasmus RM (2013) Thinking strings: additional evidence for personal ornament use in the Middle Stone Age at Blombos Cave, South Africa. J Hum Evol 64(6):500–517

Villa P, Soressi M, Henshilwood CS, Mourre V (2009) The Still Bay points of Blombos cave (South Africa). J Archaeol Sci 36(2):441–460

Wadley L (2007) Announcing a Still Bay industry at Sibudu cave, South Africa. J Hum Evol 52(6):681–689

Wadley L (2012) Two 'moments in time' during middle stone age occupations of Sibudu South Africa. Southern African Humanities 24(1):79–97

Wadley L (2013) MIS 4 and MIS 3 occupations in Sibudu, KwaZulu-Natal, South Africa. S Afr Archaeol Bull 41–51

Wadley L, Hodgskiss T, Grant M (2009) Implications for complex cognition from the hafting of tools with compound adhesives in the Middle Stone Age, South Africa. Proc Natl Acad Sci 106(24):9590–9594

Wadley L, Jacobs Z (2006) Sibudu Cave: background to the excavations, stratigraphy and dating. S Afr Humanit 18(1):1–26

Will M, Conard NJ (2018) Assemblage variability and bifacial points in the lowermost Sibudan layers at Sibudu South Africa. Archaeol Anthropol Sci 10(2):389–414

Wojcieszak M, Wadley L (2018) Raman spectroscopy and scanning electron microscopy confirm ochre residues on 71 000-year-old bifacial tools from Sibudu South Africa. Archaeometry 60(5):1062–1076

Wurz S (2013) Technological trends in the Middle Stone Age of South Africa between MIS 7 and MIS 3. Curr Anthropol 54(S8):305-S319