Early Use of Pressure Flaking on Lithic Artifacts at Blombos Cave, South Africa

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Pressure flaking has been considered to be an Upper Paleolithic innovation dating to ~20,000 years ago (20 ka). Replication experiments show that pressure flaking best explains the morphology of lithic artifacts recovered from the ~75-ka Middle Stone Age levels at Blombos Cave, South Africa. The technique was used during the final shaping of Still Bay bifacial points made on heat-treated silcrete. Application of this innovative technique allowed for a high degree of control during the detachment of individual flakes, resulting in thinner, narrower, and sharper tips on bifacial points. This technology may have been first invented and used sporadically in Africa before its later widespread adoption.

Pressure flaking is a retouching (1) technique used by prehistoric knappers to shape stone artifacts by exerting a pressure with the narrow end of a tool close to the edge of a worked piece. The earliest evidence of pressure flaking (2, 3) was thought to come from the Upper Paleolithic Solutrean industry of Western Europe dating to ~20,000 years ago (20 ka) (4–6). In later times, it was used to produce Paleolithic projectile points (7), microlithic backed tools in the

Later Stone Age of Africa (8), and bifacial arrowheads in the Holocene of North America and Australia (9, 10). Retouch by pressure provides the flintknapper with a degree of control over the final shape, regularity, and thinness of the tool edge that cannot be achieved by direct percussion.

With the exception of obsidian, Jasper, and some high-quality flint (11), few lithic materials

References and Notes
7. Information on material and methods, as well as water mass distribution, is available as supporting material on Science Online.
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can be pressure-flaked in their natural state, but heat treatment can improve the flaking quality of some of them (12). Early evidence for heat treatment of silcrete at ~164 ka comes from Pinnacle Point, southern Cape, South Africa (13).

Here, we show through experimental replication and microscopic study that silcrete artifacts from the ~75-ka Still Bay levels at Blombos Cave (14) (fig. S1) were also heat-treated before flaking and that pressure flaking was used during the final retouch phase of the Still Bay points. These bifacial points were axially hafted, and impact scars on recovered tools demonstrate that they were used as hunting weapons (15).

The manufacturing sequence of the Blombos Still Bay points can be divided into four production phases (15) (fig. S2). Direct percussion by hard hammer is used in the initial shaping (production phase 1). Advanced shaping is done by soft hammer marginal percussion (phase 2a with hard and soft hammer scars and phase 2b with only soft hammer scars). In the final phase (phase 3), retouch is applied to the edges, especially the tip. A small number of points were reworked by hard hammer percussion (phase 4). Here, we examine the finished products of production phase 3 and compare them with those from phase 2b.

Heat-treated silcrete can be recognized through the application of thermoluminescence and archaeomagnetism, both destructive methods, and maximum gloss analysis that is nondestructive (13). We used a visual method commonly used to identify heat treatment on Paleoindian and Solutrean points [supporting online material (SOM)]. After the removal of a flake from unheated silcrete, the scar surface will have a rough, dull texture. If a silcrete piece had been heat-treated first, then the scar surface will have a smooth, glossy appearance. The contrast between the two surfaces is visible at low magnification (fig. S3). The visual method is based on contrast between the two types of surfaces; thus, it can be securely identified only on pieces where surfaces flaked before heating have not been completely removed by postheating intensive flaking (table S1). Because heating precedes the advanced flaking phases of the artifacts, it must have been a phase in the knapping process, before the final phase of retouch, and not accidental.

Different knapping techniques result in flake scar patterns with characteristic combinations of attributes (16–18). Experimental replication on the local raw material is essential to recognize the distinctive markers of different techniques. We collected silcrete from outcrops located ~30 km from Blombos Cave. Some were heat-treated following the method in (13). Blanks of unheated and heated silcrete were knapped with quartzite stone hammers and a wooden billet for the first phases of reduction. A bone flaker was used during the final pressure-retouching of the points.

Silcrete in its natural state can be flaked by hard hammer and can be trimmed by soft organic or soft stone hammer. However, during our experiments we found that the final phases of retouch (phase 3) observable on the Blombos bifacial points cannot be executed on unheated silcrete. For pressure flaking to be successful, the silcrete needs to be heat-treated. Regularity and parallelism of scars is considered the main trait of pressure flaking (12) (fig. S4). On flint, pressure will produce subparallel and rectilinear retouch scars with 10 to 15 mm of maximal length and up to 4 to 5 mm wide (19). However, the technical features described for flint are different from those observed on the Blombos bifacial points. It was on the basis of the flint features that we previously rejected the hypothesis of pressure retouch on the Blombos points (15).

Our experiments showed that wider flakes (up to 10 mm wide) can be detached by pressure retouch on heated silcrete and that the resultant scars are not always subparallel and rectilinear.
Our analysis also provided a number of criteria to distinguish between pressure and soft hammer flaking (Table 1, Figs. 1 and 2, and figs. S5 to S7). Three of the attributes in Table 1 (a prominent bulb, no lip on the bulb, and hackles on the bulb) occurred in high proportions on pressure flakes, in contrast to flakes made by soft hammer. \( \chi^2 \) values are high (\( P < 0.001 \) in all cases; SOM). Two other features (small platforms and regular ridges) seem less useful for discriminating between the two techniques. Intermediate frequency values in the Blombos flake sample show that both techniques were used by the tool makers.

The distinctiveness of the two flaking modes is also seen in the frequency distribution of scar dimensions (table S2). The mean width and length of scars on Blombos production phase 3 points are similar to those of experimental scars by pressure, whereas the scars of phase 2b points are more similar to the scars of our experimental soft hammer percussion points. To identify the flaking technique used on the Blombos bifacial points, we calculated the frequencies of five attributes (Table 2). Four of these were observed on experimental pressure scars and flakes (deep bulb negative, hackles on the bulb negative, scars \( \leq \) 10 mm, and regular ridges; Figs. 1 and 2). Another attribute (V-shaped tips with straight edges) is based on expectations of rectilinear edges made by pressure (fig. S4, E and F). Two attributes, V-shaped tips with straight edges and hackles on the bulb negative, do not occur at all on phase 2b points made by soft hammer. Thus, those two features discriminate between the two techniques. On phase 3 points, these features are consistently associated with two other distinctive attributes (deep bulb negative and regular ridges). We conclude that at least half of the production phase 3 points were

Table 2. Frequencies of attributes for the identification of flaking techniques and tip measurements of the Blombos Still Bay points compared to unifacial points from the post-Howiesons Poort of Sibudu (database of P. Villa).

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Phase 2b</th>
<th>Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scar width ( \leq )10 mm</td>
<td>24/50</td>
<td>55/55</td>
</tr>
<tr>
<td>Deep bulb negative</td>
<td>10/24</td>
<td>50/55</td>
</tr>
<tr>
<td>Regular ridges</td>
<td>7/24</td>
<td>43/55</td>
</tr>
<tr>
<td>V-shaped tip with straight edges</td>
<td>0/15</td>
<td>21/43</td>
</tr>
<tr>
<td>Hackles on the bulb negative</td>
<td>0/24</td>
<td>17/55</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tip angle (degrees)</th>
<th>Mean</th>
<th>SD</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 3 points</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V-shaped tip with straight edges</td>
<td>51.2</td>
<td>6.8</td>
<td>21</td>
</tr>
<tr>
<td>Arched tip with curved edges</td>
<td>63.2</td>
<td>6.5</td>
<td>20</td>
</tr>
<tr>
<td>Phase 2b points</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tip with irregular or asymmetrical edges</td>
<td>65.4</td>
<td>7.0</td>
<td>11</td>
</tr>
<tr>
<td>Unifacial points from post-Howiesons Poort (HP) layers at Sibudu (RSp-MOD ( \sim )47 ka)</td>
<td>65.9</td>
<td>11.1</td>
<td>83</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tip thickness (mm)</th>
<th>Mean</th>
<th>SD</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 3 points</td>
<td>3.7</td>
<td>0.7</td>
<td>44</td>
</tr>
<tr>
<td>Phase 2b points</td>
<td>4.5</td>
<td>1.0</td>
<td>11</td>
</tr>
<tr>
<td>Unifacial points from post-HP layers at Sibudu (RSp-MOD ( \sim )47 ka)</td>
<td>5</td>
<td>1.4</td>
<td>84</td>
</tr>
</tbody>
</table>

Fig. 2. Replicates of Still Bay bifacial points done by pressure (C and D) compared to Blombos points of production phase 3 (A and B) and diagnostic attributes of pressure scars on replicates (E to H). (A) and (B) Points P54 and PVN 66. (C) and (D) Replicates with pressure retouch. (E) Deep bulb negative. (F) and (G) Regular ridges. (H) Hackles (black arrow) on the bulb negative. Scale bars: (A) to (D), 1 cm; (E) to (H), 1 mm.
Fitness Correlates of Heritable Variation in Antibody Responsiveness in a Wild Mammal

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A functional immune system is important for survival in natural environments, where individuals are frequently exposed to parasites. Yet strong immune responses may have fitness costs if they deplete limited energetic resources or cause autoimmune disease. We have found associations between fitness and heritable self-reactive antibody responsiveness in a wild population of Soay sheep. The occurrence of self-reactive antibodies correlated with overall antibody responsiveness and was associated with reduced reproduction in adults of both sexes. However, in females, the presence of self-reactive antibodies was positively associated with adult survival during harsh winters. Our results highlight the complex effects of natural selection on immune responsiveness and suggest that fitness trade-offs may maintain immunoheterogeneity, including genetic variation in autoimmune susceptibility.

Immune systems of different individuals are notoriously heterogeneous in the strength, specificity, and efficacy of responses to infection, and much of the variation is under genetic control (1, 2). Individuals likewise vary in their genetic susceptibility to generate self-targeted immune responses (autoimmunity) (3–7). The challenge is to explain why natural selection has failed to eliminate alleles that confer susceptibility to infection (2) or promote autoimmunity (8). One hypothesis is that individuals with strong immune responses experience fitness benefits of immunity (e.g., clearance of infection to promote survival or provision of maternal antibodies to promote offspring survival) but are also likely to suffer its costs (e.g., energetic drain and/or autoimmune disease) (9, 10). Although wild rodents have autoimmune susceptibility genes (3) and higher standing antibody concentrations than their laboratory counterparts (11), autoimmunity is known only in people and laboratory, domestic, or captive mammals (7, 8, 12–14). Here, we assess the associations among antibody responses, survival, and traits associated with reproductive success in the wild.

The unmanaged population of Soay sheep (Ovis aries) in Village Bay, Hirta, St. Kilda, has been monitored since 1985, yielding detailed longitudinal information on both individual life histories and population dynamics (15). Using blood plasma samples collected during August of 11 years (1997 to 2007), we measured the concentration of antibodies that bind mammalian nuclear and cytoplasmic antigens (hereafter, antinuclear antibodies, or ANAs) (16). Using silicate heating and helping us in the experiments. We thank K. Brown for sharing information about silicate heating and helping us in the experiments. V.M. thanks N. Schlanger for assistance. The Iziko Museum in Cape Town provided space and working facilities.

Supporting Online Materials

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Materials and Methods

Figs. S1 to S7

Tables S1 and S2

References

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References and Notes

1. The use of pressure to remove blades and bladelets from a core is a more complex technique that appears in Northern Asia at about 25 ka (12).

2. Possible evidence of heat treatment and pressure retouch has been suggested (9) for the Early Upper Paleolithic Stretletskayan bifacial points of Kostienki 1.


17. J. Pelegrin, in L’Europe centrale et septentrionale au Tardiglaciaire, B. Valentin, Ph. Bodu, M. Christensen, Eds. (Mémoire du Musée de Préhistoire d’Ile-de-France, Nemours, 2000), pp. 73–86.


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