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Variations in Arrow Technology: An Experimental Exploration of the Effectiveness of Fletching

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Abstract: *Various projectile technologies have been explored by countless archaeologists, however fletching, a critical aspect of arrow design has not received nearly the same amount of attention. A number of reasons may account for this lack of research, perhaps most notably is the fact fletching does not present well within the archaeological record. This paper gives some attention to the small amount of research done on fletching by archaeologists and then goes on to describe the production and effectiveness of fletching when added to the arrow. An experimental design was created that ultimately showed that parabolic fletching that most individuals are familiar with seems to be highly effective, in some sense showing that over time the technology was improved upon allowing for maximum efficiency and distance.*

Introduction

Projectile technology has a rich history and is an area of study for many archaeologists attempting to understand how these implements were employed as well as their role in the larger social context. However, the study of projectile technology presents many challenges to archaeologists as the materials utilized in their construction do not necessarily present well in the archaeological record. Heidi Knecht states "projectile weapons have been ubiquitous hunting implements since their Pleistocene beginnings. Under typical environmental and preservational situations, nothing remains of spears and arrows in the archaeological record except the projectile point" (1997:4). Projectile points are certainly a valuable resource for archaeologists as they offer a great deal of insight into the capabilities of groups who used them, the extent of geographic space that these groups occupied or traveled to, and other useful bits of information concerning their culture. Despite these

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facts, and because of the lack of other materials that constituted the remainder of these projectile technologies, it is difficult to fully understand how these systems functioned and the evolution of their creation.

This paper looks to focus on one of these projectile technologies: the arrow. Of course the arrow in and of itself is not very useful without the addition of the bow, the production principle Oswalt terms linkage which "refers to the manufacture of forms that are physically discrete but must be used in combination" (1986:243). Nevertheless, the arrow is the primary focus, and because much of the attention is placed on projectile points I have decided to instead look at fletching and its uses. The bow and arrow are two distinct systems used together to perform a task, and over time the arrow has evolved to meet the needs of those who employ it. An arrow consists of three basic materials—the point, the shaft, and the fletching—each of which function together to produce a whole greater than the sum of its constituent parts. It is my intent then to examine one of those components, the fletching, in hopes of gaining some insight into how one may optimally utilize such a technology. I will begin first by presenting some background on fletching and its benefits to the system that is the arrow. Subsequently I will provide a description of arrow construction and the fletching process in particular. Finally, the experimental design will be presented as well as the results and discussion.

Background on Fletching Technology

As stated earlier, very little literature exists (anthropological, archaeological or otherwise) on fletching and its evolution over time. The development of fletching seems to largely coincide with changes in the size of projectile points as George Odell notes, stating "...in some parts of the New World, the diminution of projectile points heralded not the invention of the bow and arrow, but a development of fletching techniques..." (1988:336 citing Evans 1957). Furthermore Joseph Cheshier and Robert L. Kelly argue that the entire purpose of the arrow is its ability to penetrate thus maximizing the possibility of killing the animal, and in the interest of improving range and accuracy much of the effort of arrow craft is focused on the shaft, foreshaft and fletching rather than the projectile point (2006:353). Without what might be called an effective delivery system allowing the projectile point to reach its intended target this technology would fail before it even begins; however, with all of these component parts working in conjunction with one another the ability to hunt animal resources while remaining hidden at a safe distance becomes a viable undertaking. Perhaps the best description

I have found from an academic source comes from Christopher A. Bergman who describes fletching as follows:

> The fletching on an arrow, if it is used at all, generally will consist of two to four feathers placed at the nock end. While two to four feathers are most common, some African arrowshafts, for example, are fletched with as many as eight feathers (Dr. C. E. Gray son, personal communication, 1992). The fletching helps to stabilize the arrow during flight and allows it to travel straight; at the same time, it also acts to slow the arrow down. The height and length of the fletching above an arrowshaft must be carefully balanced in order to avoid unnecessary drag. Feathers can be obtained from an almost unlimited variety of birds, and both wing and tail feathers can be used. The way in which the feathers are attached to a shaft involves the use of an adhesive and/or some sort of thread or sinew to bind them down; in some instances feathers are actually sewn onto the shaft. In the most common form of fletching, radial fletching, three or four split feathers are fastened separately to the arrowshaft in equidistant units. Another type, tangential fletching, uses two whole feathers bound back to back [1993:97]

Furthermore fletching can take a variety of shapes including triangular and parabolic as well as be of various heights (up to three + inches high) and lengths (upwards of 10+ inches long) all in an effort to maximize the balance and accuracy of the arrow (von Meissen 2001:5). This information was kept in mind when constructing the arrows for the project.

Arrow Fletching Process

The actual process of fletching can be a quite time intensive undertaking, the basic outline of which is described in Figure 1. The arrow shaft provides the solid foundation upon which the remaining components are mounted. A notch, otherwise known as the nock, was first placed on one end which in turn denotes where the fletching should be located. For this experiment 36 inch hardwood poplar dowels were used and subsequently notched using a standard hacksaw. As for the adhesive, an industrial grade glue was employed that in the

Description of Fletching Process for Three Feathers

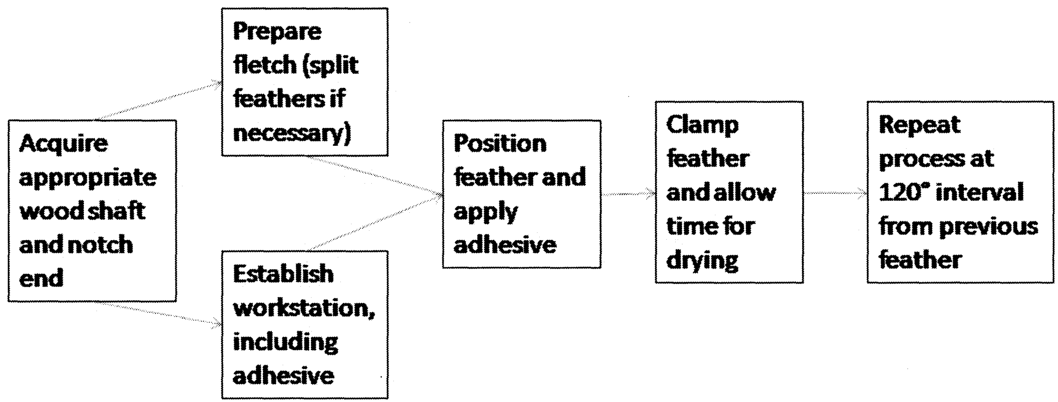

Figure 1

presence of water foams and hardens around a surface. This was ideal when applying the feathers because the adhesive attached to the shaft and formed around the base of the feather providing a solid hold with the expectation that these arrows would be fired in a number of experimental trials.

Two types of fletching were used in this experiment: the first being a modern, parabolic style feather roughly one inch in height and four inches in length as well as larger turkey feathers roughly two inches in height and four inches in length. The parabolic feather required little preparation as they were already cut and formed, however the turkey feathers need to be split down the center. This involved cutting a notch in one end and pulling the respective halves apart by hand, monitoring for any deviations from the center of the feather. Furthermore the larger turkey feathers need to be trimmed down to the four inch length ultimately taking an angled shape.

Five arrows were prepared for the experiment which included:

- one inch high parabolic fletching placed one inch from the nock
- one inch high parabolic fletching placed three inches from the nock
- three inch high turkey fletching placed one inch from the nock
- three inch high turkey fletching placed three inches from the nock
- A control without fletching

Three feathers were used for this replication and a radial fletching style was employed wherein each of the three feathers were placed at equidistant points at 120 degree angles from the initial feather. The shaft of the arrow was placed in a vice to create a secure workstation and the points that the feathers would be placed were marked. As mentioned earlier the adhesive used reacts to water to create a foam therefore prior to the application of the adhesive a thin layer of water was spread the length of the feather (four inches) along the shaft. A liberal amount of adhesive was then applied and the parabolic feather was placed roughly one inch from the nock so as to allow room for the fingers when firing the arrow. As the feather was held in place wire clamps were placed around the shaft and secured to both ends of the feather to hold it securely in place. As the adhesive was left to dry the next shaft was prepared in the same manner, however the parabolic feather was placed three inches from the nock. The same is also true for the three inch tall turkey feathers placed one inch from the nock and three inches from the nock on their respective arrow shafts. The arrows were then turned 120 degree and the fletching process was continued until each of the four shafts had three feathers attached.

Experimental Design

When designing this experiment I kept a number of elements in mind and was particularly inspired by Susan S. Hughes who discusses balance as

> keeping the center of pressure behind the center of gravity. Two design options place the center of pressure behind the center of gravity: (1) increasing forward mass to shift the center of gravity forward and (2) adding lightweight surfaces to the rear of the shaft (Cundy, 1989; Hayes, 1938; Hickman, 1929). A heavy stone tip will accomplish the first (Hill, 1948; Van Buren, 1974), while fletching will accomplish the second (Burke, 1954; Cundy, 1989; Hamilton, 1982; Lambert, 1929; Rausing, 1967). Fletching creates more surface area at the rear of the shaft, and by increasing rear drag, creates a spin that keeps the projectile tangent to the flight path (Higgins, 1933; Klopsteg, 1943). The increased surface area and reduced mass also increase the lift component (Tennekes, 1996). Using lightweight hindshafts, such as cane, a phenomenon frequently observed in the archaeological record, may also contribute to projectile balance [1998:366].

In this particular case the balance created by the addition of fletching to the shaft was of particular interest as well as variation in balance through changes to the fletching. To that end, as described above, I placed one inch tall parabolic fletching both one inch and three inches from the nock on their respective arrow shafts. I further tested variations in height of fletching by using three inch tall angular turkey fletching placed one inch from the nock and three inches from the nock on the other two arrow shafts. A control was also employed that had nock, but lacked any fletching to further get a sense of the effectiveness of the addition of fletching to the arrow. The weight of the projectile point was also controlled for using a three inch bolt weighing three grams that screwed into the tip of the arrow shaft opposite the nock, and the angle at which the arrow was fired was consistently parallel to the ground and fired straight forward.

A 50-meter tape measure was stretched along the length of a grassy field with the archer standing at the zero meter mark employing a standard, roughly four foot long recurve bow. Each of the five arrows underwent five firing trials with each arrow being fired in succession starting with the control followed by the parabolic fletching one inch from the nock (Style A), the parabolic fletching three inches from the nock (Style B), the three inch tall angular fletching one inch from the nock (Style C), and finally the three inch tall angular fletching three inches from the nock (Style D). The distance of each of the five shafts was measured to the tip of the shaft using the tape measure and recorded.

Results

The results of each of the trials are listed in Figure 2 as well as a bar graph to visually illustrate each of the trials. Furthermore the averages for distance traveled by each of the five arrows is recorded in Figure 3 as well as visually represented by the bar graph. The experiment provided some very interesting results as each of the five arrows are compared with one another. The most notable aspect being that the control flew a substantially greater distance than those arrows with fletching. As was noted in the background on fletching, the addition of feathers creates drag on the arrow causing it to decrease in speed. The control arrow lacked that drag and was much lighter in weight, and it was observed during the firing that the control arrow flew in a chaotic manner often being caught by the wind causing it to veer from the intended path.

Fletching Style	Trial 1 (m)	Trial 2 (m)	Trial 3 (m)	Trial 4 (m)	Trial 5 (m)
A	15.20	18.50	15.30	13.40	17.70
B	14.30	16.80	17.20	11.60	15.30
C	12.70	12.40	13.90	11.40	15.20
D	10.70	12.00	11.20	11.60	14.30
Control	18.80	19.30	20.50	25.70	22.00

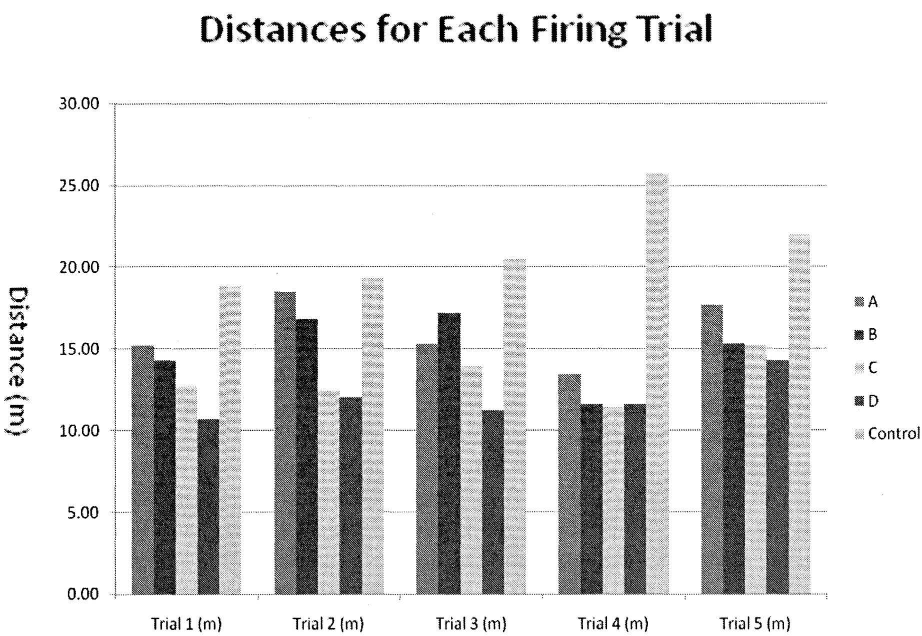

Figure 2

Fletching Style	Average (m)
A	15.47
B	14.70
C	13.50
D	12.37
Control	22.73

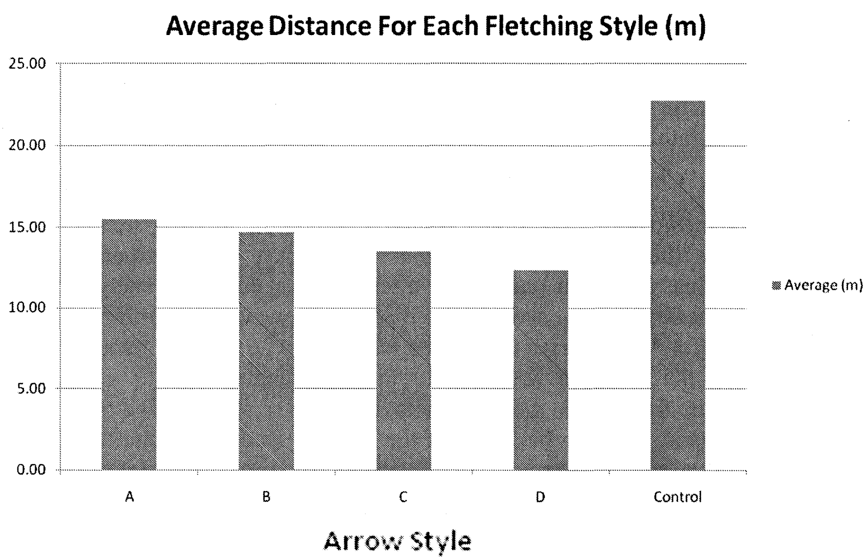

Figure 3

However, it was also noted earlier that fletching provides stability and this was certainly observed when the fletched arrows were fired. It can be seen in both Figure 2 and Figure 3 that the Style A arrow flew a greater distance than the other three fletched arrows. It was also observed that this arrow flew in a highly balanced manner and almost consistently flew parallel to the 50-meter tape. Furthermore, when the Style A arrow is compared with the Style C arrow it can be noted that the Style C arrow flew a much shorter distance on average despite both shafts having fletching one inch from the nock. This can perhaps be accounted for by the much greater drag on the three inch tall fletching that ultimately causes it slow and fall at a shorter distance, as opposed to the Style A arrow which has much less drag and excellent balance.

Figure 2 and Figure 3 also illustrate that the arrows with fletching three inches from the nock did not perform nearly as well as those with fletching much closer to the nock. As Hughes (1998) states fletching provides rear drag which in turn causes the shaft to spin and remain along its intended trajectory. However, it would seem that some of that rear drag is lost as the fletching is moved further up the shaft and as a result these arrows do not perform as well as the other two arrows with fletching closer to the nock. This fact was also observed as the arrows were being fired as the shafts with fletching further forward on the shafts did not remain straight along their path, but rather had a tendency to angle upwards as they flew.

Discussion and Conclusion

As the experiment was designed it was noted that a number of elements have the potential for error, as is the case in all experimental designs. In this particular case, the attempt was made at using some quantitative measurements, specifically distance, however determining how the arrows performed in terms of balance was largely an observational study. Some of the human error involved in the observation was to a degree mitigated by the fact that as the archer shot each arrow an objective observer was also on hand to view the flight of the arrows. Both the archer and the observer had unique perspectives on the arrows' trajectory and stability and after each trial the observed findings were discussed at length.

Furthermore, the angle at which the arrows were fired was controlled for as much as possible by having the arrow parallel with the ground as it rested in the bow. Also, in this case the objective observer was on hand to ensure the archer was meeting this requirement as well as standing at the zero meter mark on the measuring tape. Of course, in an experiment such as this one there are many opportunities for human error, however these issues were carefully monitored to ensure that the experiment was done in a controlled manner.

Nevertheless, the results were ultimately very rewarding and interesting. They provide a valuable insight into the fletching process and the effects it has on the arrow as a whole. It would appear that placing the fletching closer to the nock as well as using slightly shorter fletching provides an optimal means of balancing the arrow during its flight. Processes such as this would have been employed by people who utilized the bow and arrow system and wished to maximize its effectiveness as its intended use was the acquisition of animal resources. With the addition of a projectile point and the bow as a means of launching the arrow, the overall combination results in a hunting and/or military technology that would make its mark on history and be of a great deal of interest to archaeologists and anthropologists.

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