EXPERIMENTAL USE OF CLOVIS WEAPONRY AND TOOLS ON AFRICAN ELEPHANTS

George C. Frison

Clovis projectile points and chipped-stone tools have been recovered in a number of archaeological sites in the New World, but these cannot be tested on mammoths, which we know from the archaeological evidence Clovis hunters were able to procure. Extensive culling of elephants in Hwange National Park in Zimbabwe provided the necessary animals to test replicas of Clovis tools and weaponry. The experiments leave little doubt that Clovis projectile points can inflict lethal wounds on African elephants and that simple stone tools will perform the necessary butchering tasks. The physiology of mammoths and elephants is similar enough to make positive statements on the potential of this kind of stone-tool and weaponry assemblage, but we will never be able to compare elephant and mammoth behavior directly.

Las puntas de proyectiles tipo Clovis *y las herramientas de piedra lascada han sido recobrado de varios sitios arqueológicos en el Nuevo Mundo, pero no es posible probar estas en los mamutes quê sabemôs, de los datos arqueológicos, quê los cazadores* Clovis *podrían obtener. Entresacadura extensiva de los elefantes del Parque Nacional Hwange en Zimbabwe proporcionaba lo necessario de los animales para probar unas replicas de armas y herramientas tipo* Clovis. *Las pruebas no dejan duda que los proyectiles* Clovis *podrían hacer y dar heridas mortales a los elefantes africanos, y quê las herramientas liticas sencillas realizarán las tareas necesarias de la carnicería. La fisiología de los mamutes y de los elefantes es suficiente parecida para ofrecer unas declaraciônes positivas sobre las funciones potenciales de este clase de conjunto de armas y herramientas liticas, pero nunca podríamos comprobar positivamente las maneras de los elefantes y de los mamutes.*

The data from presently known Clovis sites in North America indicate that the mammoth (*Mammuthus columbi* and possibly also *M. primigenius*) was the largest land mammal known to have been hunted there by prehistoric man. The association of Clovis type projectile points and mammoth remains in archaelogical sites that include Lehner (Haury et al. 1959), Naco (Haury 1953), Domebo (Leonhardy 1966), Blackwater (Hester 1972), Dent (Figgins 1933), Murray Springs (Haynes 1982), and Colby (Frison and Todd 1986) has convinced most Paleoindian investigators that the Clovis projectile point used on a thrusting spear and/or with atlatl and dart was the weaponry used to kill the mammoths. This does not deny Clovis hunters the use of various kinds of natural or artifical barriers, blinds, or traps that would have enhanced the effectiveness of their weaponry.

In the case of the mammoth, however, there are too many unknowns in the realm of animal behavior. Fortunately, the physiology of the species is quite well known from frozen specimens (see e.g., Herz 1902). There is a significant degree of physiological similarity between the extinct mammoth and the African elephant, particularly in size, skeletal morphology, and hide thickness. Consequently, it was proposed that should the situation ever arise to allow the right kind of experimentation on African elephants, meaningful insights into the efficiency of Clovis weaponry and butchering tools might be provided. These data could then be applied to the context of Clovis mammoth procurement to provide the investigator with some idea of the limitations imposed by the weaponry and tools used by the Clovis hunter.

During the South African winter (July and August) of 1984, the writer was able to participate in elephant-culling operations in Hwange National Park, Zimbawe (Figure 1). The purpose of the culling operations was to balance the carrying capacity of the Park with its elephant population to prevent serious damage to the ecology. The National Park director agreed to allow experimentation on nearly dead and freshly killed elephants. This appeared to be as close an approximation to the ideal opportunity to experiment with and attempt to determine the potential as well as the limitations

---

George C. Frison, Department of Anthropology, University of Wyoming, Laramie, WY 82071

American Antiquity, 54(4), 1989, pp. 766–784.

Figure 1. Map of southern Africa.

of Clovis tools and weaponry in the context of killing and butchering African elephants as could be expected.

Experimentation conducted in 1984 accumulated a worthwhile body of data on experimental stone-tool and weaponry use. However, the weaponry used was a thrusting spear with a socketed forshaft (for a detailed discussion of the thrusting spear experiments, see Frison and Todd [1986: 115–128]). The writer felt that in order to complete this project, further experimental work was needed using Clovis projectile points mounted on foreshafts socketed into mainshafts and propelled with a throwing stick (atlatl). Preparation of the necessary weaponry to be used in 1985 was started in late 1984, and the L. S. B. Leakey Foundation provided the necessary travel funds. In addition, the writer was invited by Mr. Clem Coetzee of the Wildlife Management Unit at Hwange National Park to participate in the 1985 elephant-culling operations and continue the experimental work. This was to be the last year for any major culling effort since the 1985 cull was designed to bring the elephant numbers to well within the animal-carrying capacity of the Park. This was an added incentive to complete the project in 1985, since it is unlikely that another set of circumstances would occur in the near future that would be as favorable for this kind of experimental research.

It was assumed throughout this experiment that the Clovis groups acquired the basic philosophy of true hunters and were committed to and fully capable of pursuing and killing healthy, high-quality animals. They were not forced into scavenging the old and infirm or animals that otherwise were undesirable as food. The common depiction of the Clovis hunting party throwing rocks and spears at a mammoth trapped in a bog is erroneous. True hunters would be offended deeply if they were accused of resorting to this kind of hunting strategy. Healthy animals rarely will be immobilized in a bog and, in addition, butchering and recovering the meat in edible condition from an animal mired in a bog is difficult at best. A much better hunting strategy, and also one they were fully capable of doing, would have been to drive the animals out of the bogs and kill them on dry land.

In addition, good hunting strategies extend beyond the moment the animal lies dead on the ground. Choice animals acquire this designation because they are better eating than the others. With improper handling of the dead animal, its eating qualities are impaired, so it follows that the hunter will attempt to ensure good-tasting meals by taking appropriate care of dead animals.

The archaeological evidence on the Plains and adjoining major uplifts and intermontane basins of North America indicates that by far the major part of Paleoindian hunting was limited to a few species including bison, pronghorn, deer, mountain sheep, and mammoth. The first four are still present—at least as similar subspecies—to allow close behavioral observations, but the mammoth is gone. It is argued here that reliable models of prehistoric hunting can be proposed using species-specific animal-behavior patterns, a thorough knowledge of hunting practices as they apply to each species, complete familiarity with the hunting territory, and an awareness of the limitations placed on hunting by the weaponry in use (see e.g., Frison 1978:248–276, 329–341).

CLOVIS TOOLS AND WEAPONRY

The weaponry and butchering tools used in the experiments were made to duplicate actual Clovis specimens as nearly as possible. The flaked-stone items were almost exact replicas and were manufactured by Bruce Bradley, a well-known knapper with a long-term record of replication and experimentation with Paleoindian weaponry and tools (see e.g., Bradley 1974, 1982; Bradley and Stanford 1987). Raw materials were obtained from a number of High Plains lithic sources that produce the same stone materials known to have been used in Clovis times and include cherts, quartzites, and natural glass.

Perishable Components of Weaponry

The perishable parts were made from plant materials that are almost certain to have been available in Clovis times. The wooden components of prehistoric weaponry have been proven experimentally to be as critical to success during use as the flaked-stone components. From the archaeological record, for example, we know that willow (*Salix* sp.) commonly was used in Archaic times for dart and arrow shafts (see Frison 1965, 1968). It is easily available in desirable lengths and diameters and, if properly processed, can be straightened easily. Willow performs satisfactorily as shaft material when used on animals up to the size of deer, elk, and even bison, but was not judged to be satisfactory under the added stress encountered in driving projectile points into even juvenile elephants, where the hide is as much as three times as thick and has an armor-like quality, in contrast to the hide of an elk or bison. The hide on a mature elephant is thicker than on a juvenile animal, which places added stress on both the stone- and wooden-weaponry components.

After testing different species of wood, the one finally chosen for both mainshafts and foreshafts was chokecherry (*Prunus virginiana*), a shrub common to the High Plains. It is relatively light, extremely tough, and is available in the proper lengths and diameters. The throwing stick, (atlatl) used in the actual experiments on elephants was made of another local shrub commonly known as skunk brush (*Rhus trilobata*), though chokecherry also would have been satisfactory. Skunk brush was chosen because of its resiliency and also because atlatls of this material of Archaic age have been recovered in dry caves in the mountain–plains area (see Frison 1965, 1968).

Proper attention to manufacture and maintenance of weaponry is critical to successful results during use. Shafts must be straightened and properly cured so that it is necessary to plan well ahead of time in order to maintain the necessary stock of usable materials. The curing process requires time and continual monitoring: Even well-cured shafts may warp and/or twist over short periods of time if not properly stored, particularly in humid weather.

For the weaponry experiments on elephants, it was assumed that separate mainshafts and foreshafts were used in Clovis times. Again, this is based on materials of Archaic age recovered in dry caves, and there is no unequivocal evidence that the same situation obtained during Clovis times. It also was assumed that the stone projectile point was joined to a nocked wooden foreshaft, in contrast to the suggestion several years ago that bone foreshafts were used with a single tapered end designed to hold the projectile point (Lahren and Bonnichsen 1974).

Different diameters and lengths of mainshafts were used and through trial and error two specimens were selected. The shafts were joined for ease in transport, which was a poor decision. With repeated use and heavy impact encountered when used on elephants, the shafts would break at the joints. This problem was solved on one of the main shafts by applying two opposing pairs of splints 25 cm in length that spanned the joints and were attached by wrapping with elephant sinew. The weight of this main shaft without splints was 365 g. The shaft with splints originally weighed 358 g, and

Table 1. Mainshaft Data.

Number	Length	Proximal Diameter	Distal Diameter	Weight	Figure Reference
1	202 cm	16.0 mm	23.5 mm	365 g	4b
2	198 cm	14.1 mm	22.5 mm	358 g 420 g[a]	6, 7, 8
3	205 cm	16.1 mm	27.0 mm	950 g	4c, 5

[a] Weight with splints added.

the splints added 72 g for a total of 432 g. It was felt that better penetration was achieved with the splinted specimen suggesting that the optimum choice would be a heavier main shaft (one with a slightly larger diameter) than the ones used. Shaft breakage of this nature would not have been a problem if they had not been jointed, as has been satisfactorily demonstrated in subsequent experiments in a different context.

Main shafts must be as straight as possible in order to function properly. Any curvature or other factor that results in the misalignment of mainshaft and foreshaft results in imparting less thrust at the proper angle to the base of the projectile point which, in turn, lessens the probability of proper penetration and also increases the probabilities of breakage. However, offsetting minor crooks and bends that do not alter shaft alignment are not seriously detrimental to performance in contrast to a continuous curvature, which is a serious matter. Mainshaft measurements and weights are presented in Table 1.

Several lengths and diameters of foreshafts were tried in order to achieve optimum performance. Six were chosen for the experiments. The smallest in diameter (see Table 2) broke in two places when used with a thrusting spear, but might have survived use with the atlatl. The next four larger diameters are regarded as of optimum size, while the largest is unnecessarily bulky and tended to inhibit penetration.

All foreshafts were originally from 28 cm to 30 cm long. However, continual experimentation with different types of mainshaft–foreshaft connections and nock-to-projectile-print bindings reduced the final lengths (see Table 2). The length of the foreshaft regulates the depth of penetration since it is smaller than the main shaft. Once the projectile point cuts the hole in the hide and it and the distal end of the foreshaft with the binding pass through, further penetration requires very little additional thrust, and forward movement usually stops only when the distal end of the larger mainshaft comes into contact with the hide.

If the foreshaft is too long, the probabilities that it will break where it sockets to the mainshaft are increased. This is particularly true if the angle of contact of projectile and target is at other than a right angle. This can result from several causes such as an improper trajectory of the mainshaft,

Table 2. Foreshaft and Projectile Point Data.

Number	Foreshaft Length	Foreshaft Diameter	Total Length	Projectile Point Length	Projectile Point Width	Total Weight	Projectile Point Material[a]	Figure Reference
1	14.9 cm	17.5 mm	18.8 cm	73.0 mm	29.5 mm	46.0 g	1	3a
2	16.9 cm	17.0 mm	20.2 cm	70.0 mm	28.5 mm	44.7 g	2	3b
3	20.3 cm	17.9 mm	25.3 cm	77.5 mm	30.8 mm	45.4 g	3	9
4	15.2 cm	22.2 mm	20.0 cm	73.5 mm	28.0 mm	69.4 g	1	—
5	19.3 cm	18.0 mm	25.2 cm	91.0 mm	33.0 mm	43.4 g	4	—
6	22.1 cm	13.9 mm	24.4 cm	52.0 mm	26.0 mm	30.1 g	5	—

[a] 1 = Spanish Point chert (northern Wyoming); 2 = Edwards Plateau chert (Texas); 3 = Spanish Diggings quartzite (southeast Wyoming); 4 = Silicified sediment (southwest Wyoming); and 5 = Phosphoria chert (northern Wyoming).

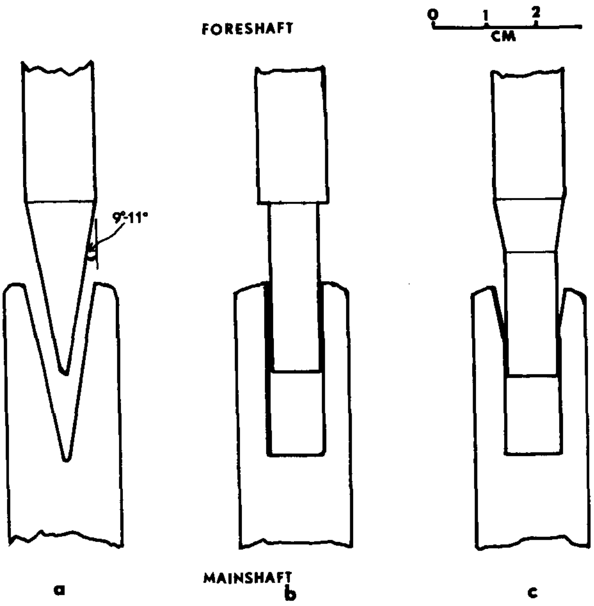

Figure 2. Foreshaft to mainshaft connections: (*a*) taper; (*b*) plug with a square shoulder; and (*c*) combination plug and taper.

for which the cause could be a faulty throw on the part of the hunter, a deflection from contact with brush, or a situation where the animal is positioned so that the desired target spot is at other than a right angle to the hunter.

The foreshafts performed satisfactorily, except for the ones with the smallest and largest diameter, and allowed sufficient penetration to inflict lethal wounds. One foreshaft is noticeably heavy (Table 2, Number 4) because of a projectile point that is much larger than the others, and it was felt that this specimen yielded more satisfactory results on the end of a thrusting spear than with atlatl and dart.

Three different types of foreshaft–mainshaft connections were tried: one a taper (Figure 2a), another a plug with a square shoulder (Figure 2b), and the last a combination plug and taper (Figure 2c). The first functions satisfactorily if the angle of the taper is correct (satisfactory results were obtained with a taper angle of 9° to 11°). and if it matches closely the taper of the hole in the main shaft (Figure 2a). A spiral rasping (using coarse sandstone) on the tapered end of the foreshaft results in a more secure bonding, thereby lessening the chances of breakage under heavy stress. All of this is accomplished relatively easily with simple stone tools. Secure bonding of foreshaft and mainshaft is accomplished by wetting the tapered end of the foreshaft with the tongue, inserting it into the matching hole in the mainshaft, and applying a short twist in the same direction as the spiral rasping. Spiral rasping is another feature observed on Archaic Period foreshafts recovered in dry cave deposits (Frison 1965:87).

The combination of plug and taper is the most reliable, but the logistics of manufacture require extra time and care and also an expanded tool kit. The plug with square shoulder is unsatisfactory because it tends to break at the base of the shoulder on impact, leaving the plug in the main shaft hole that is extremely difficult to remove in order to insert another foreshaft. All things considered, the tapered plug is entirely adequate, provided the necessary care is taken in choosing the proper angle and matching the taper of the foreshaft to that in the hole in the mainshaft.

Bonding the stone projectile point to the foreshaft was done with sinew and pitch. Several species of trees produce pitch: Both ponderosa (*Pinus ponderosa*) and limber-pine (*Pinus flexilis*) pitch were used and both proved satisfactory. Proper alignment and seating of the projectile point in the nock is vital to achieve proper penetration. A thin piece of tanned hide or bark between the point and the wood creates a more-even contact and reduces probability of breakage on impact. The outer diameter of the shaft at the nock must be kept to the minimum and a thin, carefully applied, sinew binding reinforced with pitch (Figure 3a) will adequately bond the two elements. Care must be taken to control the bulk of the foreshaft and sinew binding so that it will pass through the hole cut by the projectile point. The flutes on a Clovis point are a noticeable aid in properly hafting the projectile point: they thin the projectile point where it contacts the nock allowing an adequate sinew binding to be applied that does not create a bulge that inhibits penetration.

Projectile Points

Clovis projectile points are distinctive, but demonstrate a wide range of variation in size and shape. Reworking of broken specimens also was common practice, as has been demonstrated in the archaeological record (see e.g., Frison and Todd 1986). Sharp distal ends and blade edges enhance penetration. Observations taken from both the archaeological record and experiments using similar weaponry on bison were used as a guide on the elephant experiments.

Seven projectile points were used over the two years of experiments on elephants. Two of these were damaged beyond any further usefulness early in the project and were discarded: one of these shattered on direct impact with an elephant rib on the first try with a thrusting spear and the other was accidentally broken before it reached the field. All but one of the remaining five survived the entire project and it broke on the last day of use. One specimen (Figure 3b) manufactured from Edwards Plateau chert went through the entire project without breakage. Each of the remaining four was damaged at least twice, but they were restored each time with no demonstrable loss of functional utility.

The two projectile points that were damaged beyond repair were made of chert and obsidian, respectively. The former purposely was made of excellent quality material, but was thinner and structurally inferior to the others in order to test its ability to withstand the stress of penetration of elephant hide. It literally was destroyed by an impact that probably would not have damaged it beyond restoration had it been of heavier construction and designed to withstand the impact. The obsidian specimen was destroyed during the hafting process and, in this case, the material itself was judged to be inferior structurally to cherts and quartzites.

The most common damage to projectile points was crushing or snapping of the tip. This was rectified easily by reshaping the distal end with an antler flaking tool while still mounted in the foreshaft. Breaks or snaps that removed more of the distal end often required extensive reworking of a large share of the point. For example, one chert specimen (Figure 3a) was rated as highly successful. It was reworked three times and was reduced over one third of its original length. It also penetrated seven elephants, causing either lethal or crippling wounds. Another chert specimen (Figure 3b) penetrated 12 elephants from juveniles to mature animals of both sexes with no damage or reworking. The sinew binding did break down after seven thrusts that penetrated elephant rib cages and had to be replaced.

Perhaps the most worrisome aspects of projectile points are hidden flaws in the material that appear only under stress. Approximately 2 cm of the tip of one point (Figure 3a) snapped upon its first thrust due to an undetected crystal pocket. After reworking, a second thrust ended in another break as the result of a second crystal pocket. After a second reworking, this same point functioned well until the sinew binding failed and it was removed from the foreshaft for reshafting. One corner of the base broke when the point was dropped accidentally, requiring the entire base to be reworked. After the three major reworkings that changed its size and shape significantly, this projectile point has been demonstrated through actual use to be every bit as functional as any of the other four specimens.

Atlatl Design

The atlatl design was a wooden spur excavated into the wood with a long trough extending toward the handle to facilitate properly engaging the spur with the cup on the proximal end of the main shaft. Proper alignment of the spur with the longitudinal center line of the atlatl and proper en-

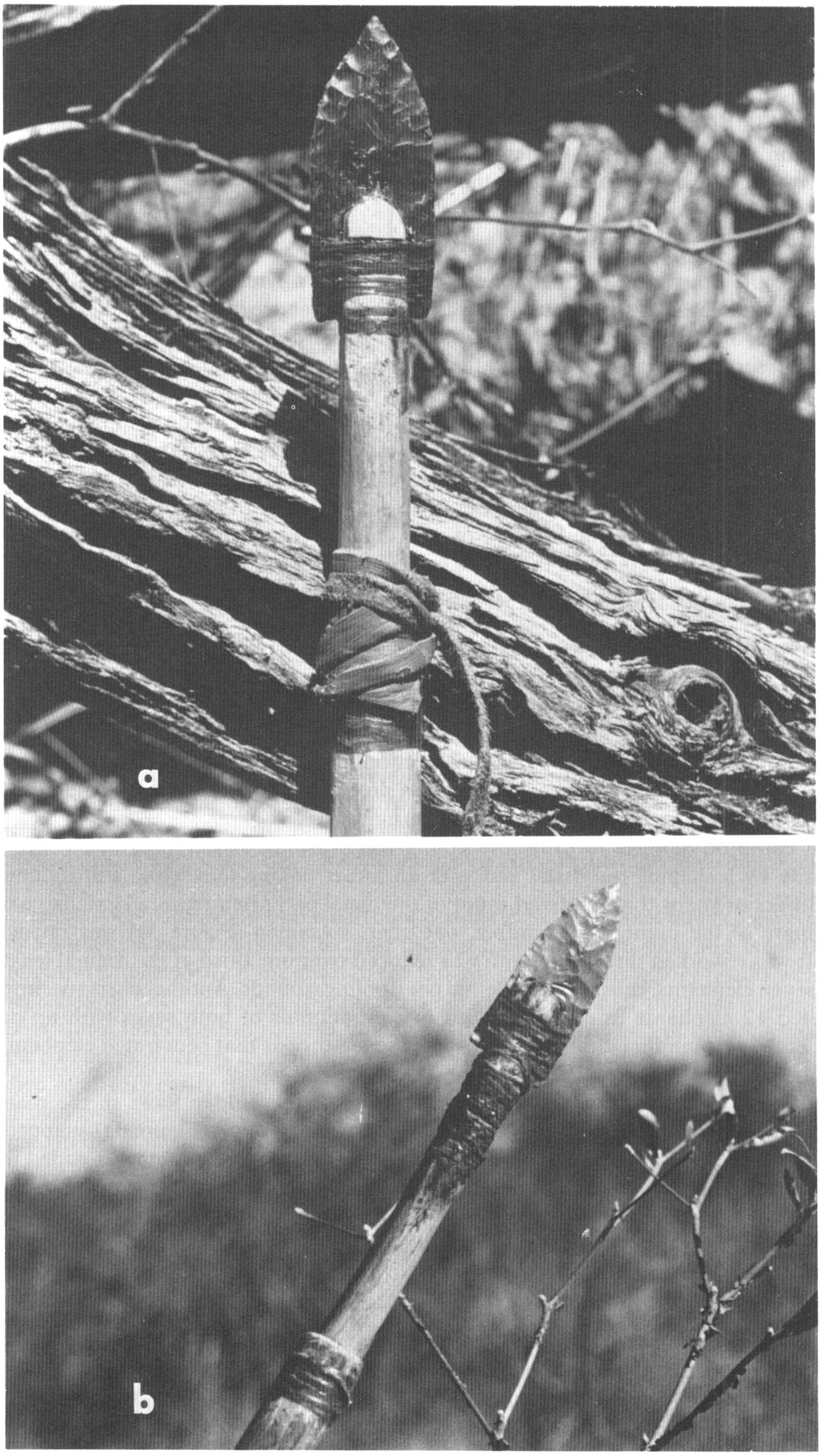

Figure 3. Two projectile points mounted in foreshafts that were used in the elephant experiments: (*a*) is 73 mm long and is made of Spanish Point chert from northern Wyoming: (*b*) is 70 mm long and is made of Edwards Plateau chert from Texas.

gagement of the spur with the center of the cup are both important to keep the mainshaft on proper trajectory. Erratic behavior of the mainshaft in flight in one series of experiments was found to be the result of the spur not being quite long enough to reach the bottom of the cup on the proximal end of the mainshaft. Instead, the outer ring of the latter was engaging with one side of the base of the spur. The problem was corrected by removal of enough wood at the base of the spur to allow it to project further and make the proper connection.

The atlatl chosen after rejection of several specimens of different diameters and lengths is 62 cm long and 3.1 cm maximum diameter with the spur placed 5 cm from the distal end (Figure 4a). It is of the rigid type and weighs 225 g. No atlatl weights were used during the experiments on elephants, nor did the addition of atlatl weights appear to improve its performance during earlier trials.

This weaponry assemblage is relatively small, which reflects confidence in its performance. Weaponry of this nature is a very personal thing, and what is optimum for one person will probably not be the same for another. There is, for example, a relation among arm length, atlatl length, and length of the foreshaft that is determined mainly by trial and error over a long period of time. The weaponry described here reflects a choice derived from more than three decades of experimentation with atlatl and dart.

EXPERIMENTAL USE OF CLOVIS WEAPONRY ON AFRICAN ELEPHANTS

The main purpose of the experiments on African elephants was to determine if a human hunter using weaponry as similar as possible to that of Clovis hunters could deliver a projectile point with sufficient velocity to regularly and predictably inflict lethal wounds on animals of all ages and both sexes. Experiments had to be limited to elephants either mortally wounded or killed in the culling operations. There was no provision for experiments on live animals nor would such activities have been allowed in any of the National Parks in Zimbabwe. With these limitations, the only time available for meaningful experiments was while the animals were being killed and the short time following while they were being skinned and stripped of flesh.

The 1985 culling operation began on July 12. A family of 22 elephants was taken in the first cull. The animals were encountered in heavy brush but two of the animals fell in an area open enough to allow shots from a distance of 15 m. One animal was a five-year-old female; the first shot was off target and hit the left hind quarter but with penetration to the mainshaft–foreshaft joint, producing what would have been a crippling but not necessarily lethal wound. The hide was approximately 9 mm thick at the point of penetration. The projectile was undamaged by impact, but the mainshaft (Figure 4b) with the plug and square shoulder (Figure 2b) snapped where it was jointed. It was obvious at this time that the mainshaft would have to be reinforced.

A try on the second animal was made using a main shaft manufactured the day before at the culling camp from a piece of unidentified wood found nearby (see Figure 4c). It proved to be much too heavy (950 g) to properly control with an acceptable level of accuracy. However, penetration of the rib cage into the stomach cavity was accomplished on the third try (Figure 5). The shaft was later shaved to a smaller diameter in order to lighten it, but it was not possible to keep it from warping and twisting, so it finally was discarded. The remainder of the daylight hours after returning to camp from the cull was spent reinforcing the broken mainshaft. Fortunately, two short pieces of chokecherry shaft were brought along in case more foreshafts were needed. Splints were made from these that were attached with sinew obtained from one of the animals killed earlier in the day. The sinew was reinforced with pitch recovered from an unidentified tree. After this treatment, the mainshaft performed without further problems during the remainder of the culling-operation experiments.

The second day's cull was not too successful because the herd split into two groups and ran in two different directions. However, one juvenile female dropped in a location that was not too brushy allowing shots at a distance of 17 m. The animal simply dropped on all fours allowing broadside shots at the rib cage. Problems developed in keeping the main shaft on proper trajectory but, after two poor throws, one penetrated the rib cage just behind the shoulder, continued deep into the lung cavity, and, in the case of a live animal, would probably have been lethal within a relatively short time. These results were encouraging, but the trajectory problems forced us to spend the rest of the day realigning and lengthening the atlatl spur, which relieved the situation.

Figure 4. Atlatl of ***Rhus trilobata*** (*a*), mainshaft of ***Prunus virginiana*** (*b*), and mainshaft of unidentified African wood (*c*) used in the elephant experiments.

In addition to this, one of the projectile points broke transversely about 1.5 cm from the point at the time of impact into the distal end of one of the anterior ribs. The shot was too low and hit the animal near the bottom of the anterior part of the rib cage where the ribs are relatively wide and flat. Furthermore, the armour-like quality of elephant hide was beginning to remove the pitch from several of the projectile-point bindings, allowing animal body fluids to penetrate the sinew and loosen the projectile points. Getting the weaponry back into a functional condition required a good share of the night as well as the daylight hours.

Figure 5. Penetration of stomach cavity of a juvenile elephant using the heavy mainshaft (Figure 4c) and foreshaft (Figure 3b).

The third cull was especially satisfying because a presumed-dead, mature female actually was only crippled and managed to get back on her feet while the shooters were pursuing part of the group that had split and run away. This provided a broadside shot at the rib cage. The animal was hit at the right elevation and far enough forward so that the projectile had to pass through some of the fleshy part of the front quarter. Even so, penetration was to the distal end of the mainshaft and into the lung cavity, producing a potentially lethal wound. At this point, the animal dropped on all fours (Figure 6).

With most of the particularly bothersome problems with weaponry corrected, the next cull allowed more freedom of action on more animals. The location of the next kill was less brushy, allowing for several throws at three different animals including two juveniles and an adult. Throws were made at the adult female from a distance of 20 m. The rib cage was penetrated three times in succession to the length of the foreshaft (Figure 7 and Figure 8c–e); another throw was too high and the projectile point penetrated near the top of the back. In doing so, it cut a long slit through the hide (Figure 8a). It would not have been either a crippling or lethal wound, but it did demonstrate the cutting effect that a properly thrown Clovis projectile point can have on elephant hide 12 mm thick. The last throw was still too high but low enough so the entire length of the foreshaft was buried in the flesh along the back (Figure 8b). These throws were made using a single projectile point (Figure 3b) without damage other than the sinew binding needed replacement. This same projectile had also survived seven penetrations of both juvenile and mature elephants on the end of a thrusting spear without damage in 1984.

Several throws were made at the second animal, which was a juvenile female, using each of the four remaining foreshafts, and each one successfully penetrated into the rib cage. One quartzite projectile point snapped just distal to the sinew binding (Figure 9), but it still continued into the rib cavity and produced a wound of lethal quality. The snap apparently was due to a sudden change

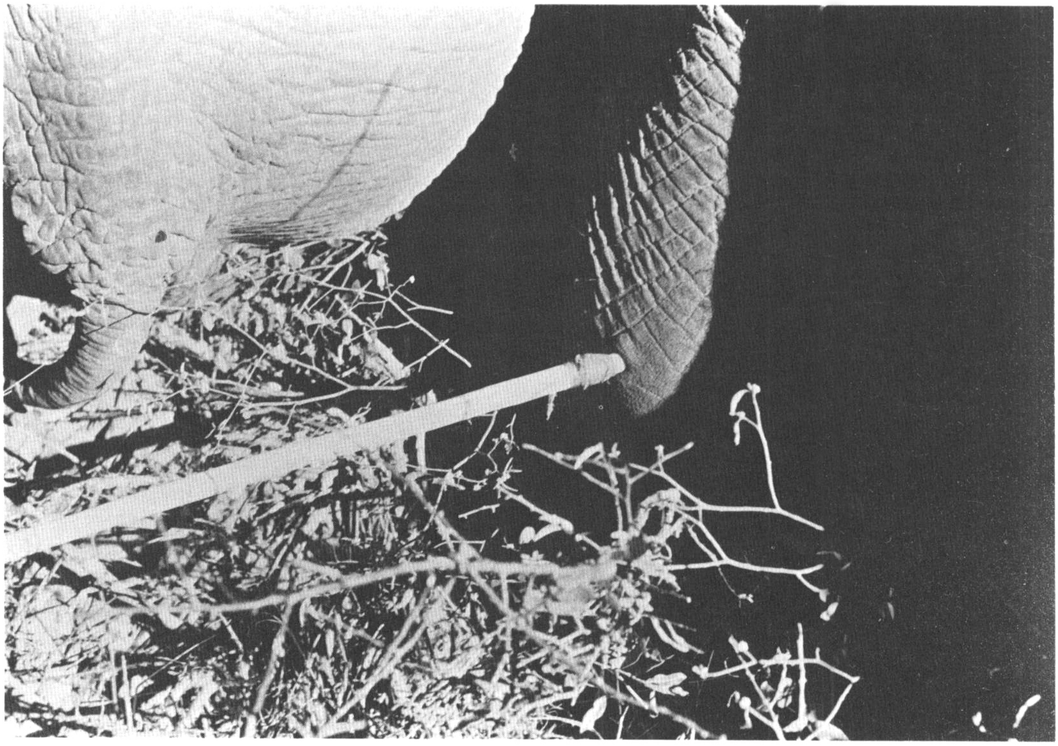

Figure 6. Penetration of front leg and anterior rib cavity of mature female elephant. The animal collapsed and died in the position shown alongside a dead younger female in the same position.

of direction as the point hit the edge of a rib. The break (Figure 9) is remarkably similar to those on Paleoindian projectile points recovered in High Plains bison kills and which are now identified regularly as diagnostic of heavy impact.

USE OF THE ATLATL AND DART

Proper use of the atlatl and dart requires considerable movement on the part of the hunter. In these experiments, the darts were thrown from a standing position with feet in place, and a considerable amount of body movement was required in order to obtain the necessary velocity. In the case of actual hunting, this movement very likely would attract the attention of the animal whose subsequent reactions would not always be entirely predictable. The same would be true of an animal who was watching the hunter. The body movement of the latter could evoke a number of responses from the animal. The atlatl and dart can be very effective at short range when used on a moving animal. In a situation where the animal is aware of the hunter and is committed to a path of movement, the experienced hunter need only lead the animal the proper distance and expect satisfactory results. In addition, good accuracy can be obtained from a standing position.

The atlatl may also be used by taking a few steps to add to the velocity of the dart (Stanford 1979). However, this increases both the amount of movement by the hunter and the time required to complete the throwing operation. This in turn allows further reaction by the animal. This may not be detrimental if the animal already is committed to a direction of movement. On the other hand, the extra steps by the hunter can cause a startled animal to resort to erratic behavior, which nearly always results in a poorer target. Animals that do not see the hunter or are already committed to a direction of movement provide the best target.

The cooperation of two or more hunters would add to the probabilities of success using any

Figure 7. Penetration of rib cage of mature female elephant.

weaponry system. In the case of elephants, one person could keep the animal's attention allowing others to use the weapons without the animal's knowledge. These kinds of basic principles of hunting are gained only by experience but are necessary in any human economic system based on hunting.

ELEPHANT BUTCHERING

Butchering experiments with stone tools were carried out on the last two culls that the writer was able to participate in during 1985. These were continuations of experiments that began in 1984 and were limited by unexpected delays in the 1985 culling operations that limited the time in the field. On the other hand, the 1985 butchering experiments mainly served to further confirm most of the results of the 1984 efforts and added little in the way of new data.

The tools used in butchering experiments were large biface-reduction flakes that were similar to those recovered in the Sheaman Clovis site in the Agate Basin site locality in eastern Wyoming (Frison and Stanford 1982:Figure 2.92). A biface tool patterned after one from the Sheaman site (Frison 1982:Figure 2.91a) was somehow lost and was never recovered during a long chase after a small family of five elephants. This may someday come as more than a small surprise to someone, because there are no known artifacts of this nature in this part of Africa. It was made of quartzite from the Spanish Diggings quarries in the Hartville Uplift in southeastern Wyoming. The loss was unfortunate, because one of the objectives of the 1985 project was to compare the efficiency of biface-reduction flake tools against that of biface tools on fresh elephant carcasses.

The results of both years' butchering experiments can be summarized in the following manner (see also Frison and Todd 1986:128–134). Quartzite tools tend to hold an edge better than chert tools. This is thought to be due to the graininess of quartzite that tends to wear unevenly, while the chert, which does wear evenly, loses its keen edge more rapidly. The main effort in elephant butchering is cutting the hide (Figure 10). A quartzite biface-reduction-flake tool performs adequately

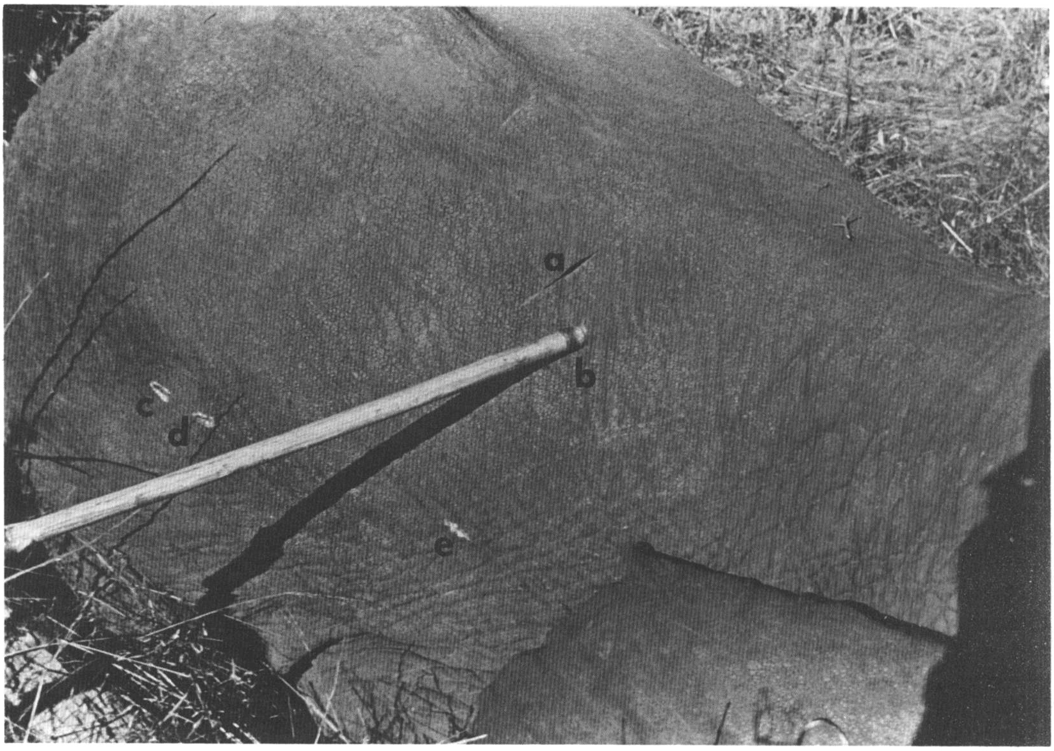

Figure 8. Penetration of back (points *a* and *c*) and rib cage (points *c–e*) of mature female elephant.

in this task but not with the efficiency of a metal knife, and the tool must be resharpened regularly in order to cut the hide. For example, the tool in Figure 10, manufactured of Spanish Diggings (Wyoming) quartzite was used on a young (6–7-year-old) male elephant. The section of hide between the front and hind quarters and from the centerline of the back to about three-fourths of the distance from the centerline of the back to the centerline of the belly was cut, which required four sharpenings of the tool. The edge angle was maintained at 45°–47°, and there was 52 mm of cutting edge on the tool. However, once the necessary cuts are made in the hide, the removal of the hide is relatively easy on a freshly killed elephant, and no resharpening of the tool was required even though it was approaching a condition where resharpening was needed if cutting the hide was to be continued.

Stripping the flesh from the carcass is relatively easy, and the same quartzite biface-reduction-flake tool that was too dull to cut hide efficiently was used to strip a good share of the flesh from the hind quarter without resharpening. Disarticulation of the major long bones of the elephant carcass also is relatively easy, because the great weight of the elephant does not allow the amount of angular movement of the joints as in the case of smaller mammals such as the horse or bison, and the resulting, deep-seated muscles are not present. Once the thick joint capsule is cut through, which was done with the same quartzite reduction flake used in cutting the hide and stripping the meat, the joints literally fall apart. This can be done leaving no cut marks on the bone. Cooperation of two or more butchers greatly enhances skinning, stripping, and carcass dismemberment.

In the case of a freshly killed elephant, there is an urgency to remove the hide covering the back of the animal (Figure 11) to allow heat to escape and slow the process of intestinal-gas formation that can cause rapid spoilage of the meat. A young elephant in good condition produces a large quantity of tender meat of excellent flavor. If mammoth meat was comparable to that of the African elephant, it should have been sought eagerly by Clovis hunters.

A final thought on butchering elephants is that experimental efforts on animals that either were frozen (Stanford 1979:120) or had lain and deteriorated for several days (Weaver 1985:611) can

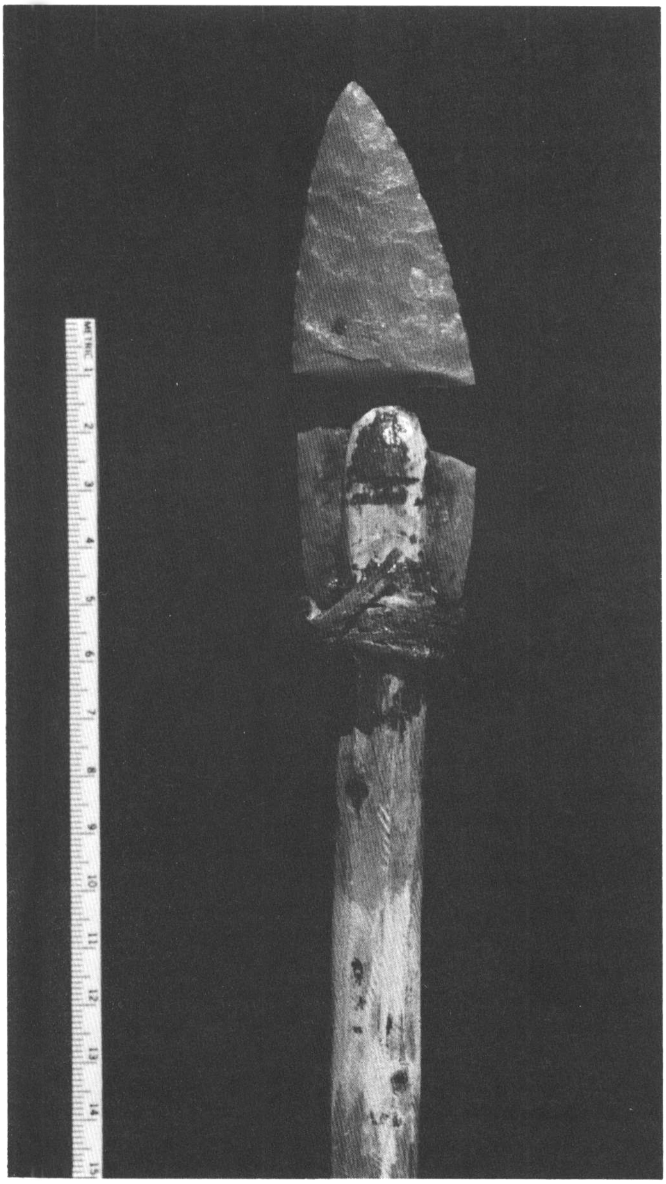

Figure 9. Transverse impact break on a quartzite projectile point.

provide a range of information that is useful and valuable as a guide to more realistic conditions. However, an elephant that has been dead for several days or even hours is considerably more difficult to butcher than a freshly killed animal.

OBSERVATIONS ON ELEPHANT BEHAVIORAL CHANGES FROM 1984 TO 1985

As already mentioned, animal behavior plays a major role in any animal-procurement strategy that changes with age and sex of the animal and external conditions such as weather, vegetation, availability of water, time of year, time of day, and many other more subtle factors. Ecological changes from one year to the next can be of considerable magnitude and require subsequent changes

Figure 10. Biface-reduction flake made of Spanish Diggings quartzite used to cut the hide of a juvenile male elephant. The tool is 81.3 mm long, 40.0 mm wide, and 8.3 mm thick at the center. The cutting edge is toward the front and the opposite edge is steeply backed to protect the hand during use. The cut is on top of the left shoulder where maximum hide thickness is 8.7 mm.

in procurement strategy. Observations on elephant behavior were made during both 1984 and 1985 trips to Zimbabwe, even though their application to actual Clovis mammoth hunting can only be tentative at best. The emphasis here is that year-to-year ecological changes do occur, and animal behavior changes accordingly, so that any proposed animal-procurement strategy must adapt to these changes. The following is presented only to illustrate one way in which short-term climatic changes can alter elephant hunting.

Drought conditions were severe in southern Africa in 1984, and had been so for several years

Figure 11. Hide removed from the back of freshly killed, mature female elephant to prevent meat spoilage. Stripping of meat from the hind quarter has begun.

previous to this. Consequently, water and vegetation were becoming more scarce each year. This worked to the advantage for elephant-culling operations, because the animals reacted to these drought conditions by aggregation of smaller family groups into larger ones. These larger groups were easier to locate for culling purposes. This also was aided by the decreased vegetative cover, and the fact that they foraged within predictable distances of the remaining water sources.

Drought conditions were alleviated in 1985 and, with better forage and widely scattered, dependable water sources, the animals were in smaller family groups, which were more widely dispersed and difficult to locate. Even when it was possible to bring several smaller families (8–15 animals each) together into larger groups, they tended to fragment again on initial contact with culling personnel. The different climatic conditions observed for two summers required adjustments in the elephant hunting strategy. Similar kinds of changes in the past undoubtedly affected mammoth procurement from year to year.

CONCLUDING REMARKS

Two seasons of participating in the elephant-culling operation in Hwange National Park in Zimbabwe and experimenting with replicas of Clovis tool and weaponry assemblages on dead and dying elephants can aid in building one possible model of mammoth procurement and carcass treatment during Clovis times in North America, if we assume that the matriarchal structure of African elephant families applied to mammoths. Unfortunately, the model cannot be tested on mammoth populations. On the other hand, Clovis groups were accomplished hunters and would have been able to develop a procurement strategy based on mammoth behavior in whatever way it was manifested.

Statements on tool and weaponry efficiency in a mammoth context based on experiments on African elephants is on much firmer ground. The physiology of mammoths is relatively well known from frozen specimens preserved from the Late Pleistocene (see e.g., Herz 1902), and direct com-

Figure 12. Typical elephant family with the matriarch and submatriarchs in position to meet any possible threat.

parisons can be made with the physiology of modern elephants. These comparisons indicate a remarkable degree of similarity in things such as size, musculature, and hide thickness, which can be used to test both tools and weaponry. The small ears and heavy coat of hair on the mammoth may have affected the use of Clovis weaponry. The large ears on the African elephant can deflect a thrusting spear or dart thereby limiting the exposed area on the neck. This would not have been the case with mammoths. The coat of hair should not have been seriously detrimental to penetration of the Clovis projectile point, unless the entry deviated to a large extent from a right angle.

With regard to elephant behavior, the writer feels confident that Clovis weaponry could be used to inflict crippling and/or lethal wounds on members of African elephant families on a regular and predictable basis. However, a strategy of procurement based on direct confrontation of a family of elephants with Clovis weaponry seems highly improbable. Clovis weaponry cannot be depended on to drop quickly and reliably a charging matriarch or even younger and smaller elephants as can be done using high-powered rifles. The umbrella of protection provided by the matriarch is not to be regarded lightly by anyone attempting to harm any family member (Figure 12). On the other hand, if a strategy of eliminating the matriarch was developed by Clovis groups, the remainder of the family could then have been killed.

Individual members of an elephant family continually wander away from the protection of the matriarch and the family. Careful stalking of such animals eventually would put the hunter in a favorable spot to inflict crippling or lethal wounds that would eventually lead to their deaths without arousing the suspicion of the matriarch and bringing to bear the umbrella of protection offered by the family. This kind of procurement strategy involves careful stalking, a minimum of noise and excitement, and patience once a spear has inflicted a wound on the animal. It involves also taking of single animals within a family rather than entire families at one time. A similar procurement strategy also would work on the mature males who spend their lives outside the family structure.

This strategy also negates the commonly pictured, artist-conceived event of the mammoth deep in a bog, bristling with spears, with noise, confusion, and dead and/or crippled hunters being helped from the scene. These conceptions violate the rules of successful hunting strategies.

Clovis projectile points used with either atlatl and dart or thrusting spear will penetrate elephant hide and inflict lethal wounds on African elephants of all ages and both sexes. A hunting strategy based on cooperation of two or more hunters, with one or more using an atlatl and dart, and at least one using a thrusting spear, would seem to be the optimum plan. Once the wound affects the animal enough to cause it to drift away from the herd, it is then removed from the protection of the family and the hunters need only play the waiting game.

Raw-material procurement, manufacture and maintenance of weaponry, and continual practice are more time consuming than most investigators realize, but their importance cannot be minimized in hunting societies. African elephants are considered as dangerous game, and mammoths probably fell into the same category. Failure of Clovis hunters to maintain weaponry in top condition would have negatively affected not only the economic process but would have increased the probabilities of self injury and/or death.

The African elephant-butchering experiments indicated that these animals could be skinned, dismembered, and stripped of meat with simple tools of the kind recovered in Clovis sites. As with the hunting strategy, close cooperation of two or more persons in the butchering process increases efficiency. A purely biased observation is that if mammoth meat was of the quality of elephant meat, it is quite easy to understand why Clovis cultural groups were hunting the animals.

Further experimentation along these same lines would appear at present to be redundant unless specific problems of interpretation arise that need to be clarified. It is tempting to attempt the actual procurement of an African elephant in its natural habitat to further test various aspects of the hunting strategy described here. However, hunting of this nature requires the agility and strength of individuals in their physical prime. Investigations at this level should be pursued by younger, physically fit persons.

Acknowledgments. The writer thanks D. Cumming and C. Coetzee for allowing the elephant experiments in Hwange National Park, Zimbabwe. C. Coetzee and his wife, E. Coetzee, generously provided food and lodging during the 1985 stay in the field. G. Haynes was instrumental in arranging the two seasons of fieldwork in Zimbabwe. The L. S. B. Leakey Foundation provided overseas airfare for the 1985 season, and the University of Wyoming provided domestic airfare for both the 1984 and 1985 summers of research.

REFERENCES CITED

Bradley, B. A.
1974 Comments on the Lithic Technology of the Casper Site Materials. In *The Casper Site: A Hell Gap Bison Kill on the High Plains,* edited by G. C. Frison, pp. 191–197. Academic Press, New York.
1982 Lithic Technology. In *The Agate Basin Site: A Record of the Paleoindian Occupation of the Northwestern High Plains,* edited by G. C. Frison and D. J. Stanford, pp. 181–208. Academic Press, New York.
Bradley, B. A., and D. J. Stanford
1987 The Claypool Study. In *The Horner Site: The Type Site of the Cody Cultural Complex,* edited by G. C. Frison and L. C. Todd, pp. 405–434. Academic Press, New York.
Figgins, J. D.
1933 A Further Contribution to the Antiquity of Man in America. *Proceedings of the Colorado Museum of Natural History* 12(2):4–8. Denver.
Frison, G. C.
1965 Spring Creek Cave, Wyoming. *American Antiquity* 31:81–94.
1968 Daugherty Cave, Wyoming. *Plains Anthropologist* 13:253–295.
1978 *Prehistoric Hunters of the High Plains.* Academic Press, New York.
1982 The Sheaman Site: A Clovis Component. In *The Agate Basin Site: A Record of the Paleoindian Occupation of the Northwestern High Plains,* edited by G. C. Frison and D. J. Stanford, pp. 143–157. Academic Press, New York.
Frison, G. C., and L. C. Todd
1986 *The Colby Mammoth Site: Taphonomy and Archaeology of a Clovis Kill in Northern Wyoming.* University of New Mexico Press, Albuquerque.
Frison, G. C., and D. J. Stanford
1982 *The Agate Basin Site: A Record of the Paleoindian Occupation of the Northwestern High Plains.* Academic Press, New York.

Haury, E. W.
1953 Artifacts with Mammoth Remains, Naco, Arizona: 1. Discovery of the Naco Mammoth and Associated Projectile Points. *American Antiquity* 19:1–14.
Haury, E. W., E. B. Sayles, and W. H. Wasley
1959 The Lehner Mammoth Site, Southeastern Arizona. *American Antiquity* 25:2–30.
Haynes, C. V.
1982 Were Clovis Progenitors in Beringia? In *Paleoecology of Beringia,* edited by D. M. Hopkins, J. V. Matthews, Jr., C. E. Schweger, and S. B. Young, pp. 383–398. Academic Press, New York.
Herz, O. F.
1902 Frozen Mammoth in Siberia. *Bulletin of Imperial Academy, St. Petersburg,* Fifth series, Vol. 16, No. 4.
Hester, J. J.
1972 *Blackwater Locality No. 1: A Stratified Early Man Site in Eastern New Mexico.* Publications of the Fort Burgwin Research Center No. 8, Taos, New Mexico.
Lahren, L. A., and R. Bonnichsen
1974 Bone Foreshafts from a Clovis Burial in Southwestern Montana. *Science* 186:147–150.
Leonhardy, F. C. (editor)
1966 *Domebo: A Paleo-Indian Mammoth Kill in the Prairie-Plains.* Contribution No. 1. Museum of the Great Plains, Lawton, Oklahoma.
Stanford, D. J.
1979 Bison Kill by Ice Age Hunters. *National Geographic* 155:114–119.
Weaver, K. F.
1985 The Search for Our Ancestors. *National Geographic* 168:560–623.

Received September 28, 1987; accepted December 9, 1987

STEREOLOGICAL IDENTIFICATION OF OPAL PHYTOLITH POPULATIONS FROM WILD AND CULTIVATED *ZEA*

John C. Russ and Irwin Rovner

Reported criteria for distinguishing wild Zea *varieties (teosinte) from cultivated primative maize using plant opal phytolith morphology were tested using computer-assisted image analysis. Results showed current criteria to be effective but inconsistent. A straightforward stereological algorithm was derived from image analysis data providing high-confidence statistical assignment of the* Zea *phytolith populations in this study to wild or cultivated categories.*

Analisis estereológico y estadístico fue ejecutado por computadora para evaluar los métodos de análisis morfológico de fitolitos opalinos sugeridos en la literatura y utilizados para diferenciar las variedades de Zea *silvestres (teosinte) de las cultivadas (maíz). Dicho análisis produjó un algoritmo estereológico que indica que el método estereológico computadorizado propuesto en este estudio es más efectivo como los métodos analizados, es más simple y consistente, y ofrece mayor certeza estadística.*

For some time phytolith taxonomy has been used as a means of distinguishing members of the grass family, Gramineae. Silica bodies and a variety of silicified cells have been used for their taxonomic value both in grass systematics itself (Metcalfe 1960; Prat 1932, 1948) and as a repository

John C. Russ, Materials Science and Engineering Department, North Carolina State University, Raleigh, NC 27695
Irwin Rovner, Research Associate, Materials Science and Engineering Department, North Carolina State University, Raleigh, NC 27695

American Antiquity, 54(4), 1989, pp. 784–792.