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Why Flute? Folsom Point Design and Adaptation

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The fluting of Folsom points is an elegant technological solution to several problems faced by highly mobile hunters focused on bison procurement. The symmetrical, bifluted form allowed a split, facial-contact haft to extend nearly to the tip, thereby controlling both location and extent of fracture and allowing many cycles of point reworking. Extreme thinness achieved by fluting facilitated leading edge sharpness for enhanced penetration. The near-constant cross-section from tip to base meant no loss of leading edge acuteness upon resharpening and inter-changeability of broken segments. The high-friction, forwardly adjustable haft assured firm mounting even with shortened, reused point segments. This efficient design was critical for groups who spent weeks and maybe months away from raw material sources in pursuit of game. Short, exhausted Folsom points or "slugs" are what archaeologists most commonly find and study. In contrast, a quite long, fully fluted point made from a yet longer preform was the intended product of the Folsom knapper. The model presented here can be tested through study of preform length, finished point proportions, fracture patterns, haft element features, and use-wear analysis in archaeological specimens, as well as actualistic hunting experiments. The engine driving persistent use of snap blade, full fluted projectile technology was focused commitment to a single, highly mobile game species (bison). This specific technofunctional element in Folsom culture reveals a weapon system designed to mitigate against extreme risk regarding access to raw material. Continuing research should demonstrate that the appearance, geographic distribution, persistence, and disappearance of the Folsom fluted point relate closely to juxtapositions of climatic change, biotic change, and human population movements that occurred near the end of the Pleistocene.

Keywords: FOLSOM, FLUTED POINT, MOBILITY, TECHNOLOGICAL ORGANIZATION, PROJECTILE DESIGN, BIG GAME HUNTING.

Introduction

> There seems to be an erroneous opinion that the Folsom was made for beauty and its flutes for decoration, or due to the desire of the worker to reserve for posterity a record of his knapping skill. I do not believe the aboriginal had beauty in mind, or art for art's sake, but, rather, was designing a practical and functional tool of high quality. As a stone-worker, I consider this point to be structurally and mechanically the best designed for its purpose of any weapon produced in this period of time (Crabtree, 1966: 7).

The Folsom point is a distinctive spear or atlatl dart tip used to hunt primarily extinct forms of bison on the grasslands of North America in the period *c.* 10,900–10,200 BP (Haynes, 1993). The point is unmistakable (Figure 1), characterized by precision marginal pressure flaking and a broad channel flake scar from base to tip on each face. Since its first discovery in direct association with extinct bison in 1926 (Figgins, 1927), two questions have been asked of this artefact. First, how was it made and, second, why was it made in this fashion—why was it fluted? Satisfactory answers have so far eluded us. Two Folsom Workshops convened at the University of Texas at Austin in 1997 and 1999 (Baker, 1997*a*, 1999) each focused primarily on resolving the question of "how", through iterative cycles of replication and experimentation, collection examination, discussion, and debate. This paper focuses on the question of "why". Ideas presented here grew from deep immersion into questions about Folsom archaeology at the First Workshop. An expanded version of this paper, containing much of what follows, was presented and circulated at the Second Workshop (Ahler & Geib, 1999). If the question of "why" is being resolved, this is best considered a product of shared thinking and study spanning the last seven decades.

The above quote from Don Crabtree makes it clear that there are divergent perspectives of inquiry regarding the "why" question, and also that Crabtree had no

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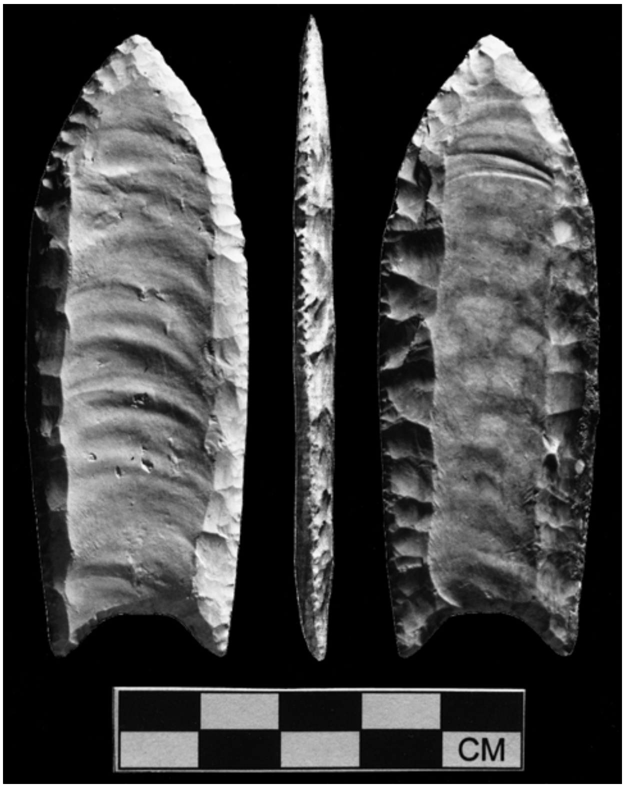

Figure 1. Folsom projectile point made of Knife River flint, from the Black Meadow site, North Dakota.

doubt regarding where the answer lay. And, as the First Folsom Workshop drew to a close 30 years later, operating assumptions or opinions from participants (see Baker, 1997*a*) underscored that this fundamental question was still unresolved. Folsom fluting:

- was related to the changing natural environment, disappearance of certain big game species such as mammoth, and specialized bison procurement, and/or
- was an ethnic symbol, or a social group marker, and/or
- was a portion of a hafting strategy related to a specific hunting strategy, and/or
- had non-functional significance, in the realm of ritual or influence of social outcomes, and/or
- ceased to be practiced when it no longer served some specific unknown purpose.

Through experimentation, cross-assemblage comparison, and ever more detailed studies of Folsom production technology, we are gaining a yet clearer picture of many features, some enigmatic, surrounding Folsom fluted point production that bear on the question of why fluting was conducted. One such feature is the extremely high level of knapping skill apparently required by Folsom technology. This observation has been the impetus for the suggestion that knapping specialists must have existed in Palaeoindian societies in general (see Bradley, 1982: 197; Bamforth, 1988: 187), and, by inclusion, in Folsom culture. If specialists existed, then their control over production of weaponry essential for group survival easily could have extended to development, control, or leadership in ritual behaviour surrounding the fluting process. People holding this "fluting shaman" viewpoint now seem clearly in the minority. Information bearing on this is the clear lack of evidence for spatial restriction of fluting behaviour. Byproducts from fluting confirm that fluting events occurred in virtually every non-kill Folsom site yet found. Where community structure can be studied (e.g. Stewart's Cattle Guard site), it appears that fluting occurred in each of several hearth-centered, individual family activity units (Jodry, 1992, 1997, 1999; Jodry & Stanford, 1992).

Another perplexing feature of Folsom technology, explainable perhaps if we knew the "why" of fluting, is the apparently high failure rate during point production. This view comes both from failure rates on the order of one in three preforms during experimental fluting replications (e.g. Flenniken, 1978: 474; Rozen, 1997) as well as studies of archaeological collections that yield comparable figures (Judge, 1973: 169–170; Winfrey, 1990). Some analysts consider it misleading to use modern experimental failure rates as an estimate of prehistoric rates (e.g. Storck, 1991: 157). Estimates of prehistoric failure rates may be exaggerated, also, because of the difficulty of making such estimates (see Crabtree, 1966: 8; Ellis & Payne, 1995; Collins, 1999: 26). The perception that prehistoric failure rates, whatever their value, were high may also be false due to lack of a suitable plane of reference. Studies of late prehistoric Plains Village arrowpoints (Ahler, 1992) indicate that in the village refuse we find approximately one failed specimen for each successfully finished point (e.g. Ahler, 1975*a*; Ahler *et al.*, 1997: 305), a failure rate higher than proposed for Folsom. We cannot deny the difference, though, in labour investment in the Folsom point versus an arrowpoint. A Folsom knapper clearly pushed the technological envelope, and knowingly risked good stone and substantial knapping time. The question of "why" remains.

A third, widely recognized feature of Folsom fluting technology is the striking uniformity across a large geographic area in the general fluted point production process (described, for example, by Roberts, 1935: 15–17; Tunnell, 1977; Frison & Bradley, 1980: 45–52; and others) and its products and byproducts (metric comparisons occur in Judge, 1973: 171–172; Wilmsen & Roberts, 1978: 176; Boldurian, 1990: 69; Tunnell & Johnson, 1991; and others). Most researchers believe that the phenomenon of production uniformity is somehow closely related to preform holding devices used during fluting or to hafting technology and haft requirements common to finished Folsom points, or to both. Understanding the haft and understanding how the fluting process relates to the haft may therefore be a central element in the quest for "why" the Folsom point was fluted.

In this paper, we hope to rectify the lack of understanding of Folsom fluting. We will (1) review several ideas and suggestions previously offered to explain Folsom fluting; (2) review technological and functional considerations relevant to effective projectile point design; (3) provide a purely technofunctional explanation for why the Folsom point was made as it was; (4) present arguments for the technological and functional advantages of this design within the context of present knowledge of Folsom subsistence and adaptive strategies; (5) suggest some tests of this model based on archaeological data, and (6) note some implications of this model, if accurate, for increased understanding of adaptive processes as well as variation in other projectile point forms in the archaeological record.

Previous Ideas

The discovery of Folsom points in 1926 in clear association with extinct bison (Figgins, 1927) not only revolutionized our thinking about human antiquity in the New World, but also focused attention on this highly distinctive projectile point type (Figure 1). Since its first recognition as a significant point form, ideas about why the Folsom point was fluted have been published. Most of these are merely intuitively appealing suggestions, and, as far as we are aware, all are offered without detailed experimental study or other analysis.

As might be perceived from the introductory quote by Don Crabtree, explanations for why the Folsom point was fluted can be broadly dichotomized as functional or technological (technofunctional) on one hand, or non-functional or non-technological (non-technofunctional or ideological) on the other. Technofunctional explanations generally present some argument linked to the mechanical relationship between projectile point and haft or foreshaft, or one linked to the killing power of the weapon system that included the Folsom point. Technofunctional explanations seem inherently subject to testing through experimentation and other analysis. Non-technofunctional or ideological explanations appeal to an idea or a culturally imposed rule as the driving force for adherence to the Folsom fluting process. In general, ideological explanations are far more difficult to test, whether through experimentation or study of the archaeological record. No explanation, in either domain, has been explicitly tested.

Roy Coffin, an early excavator of the Lindenmeier site, offered a general comment (1937: 14) that, due to its thinning, the fluted Folsom offered "more efficient mounting" or hafting than otherwise possible. Frank H. H. Roberts studied artefacts collected by Coffin and from his own excavations at Lindenmeier. Commenting briefly on the question of why fluting was used, Roberts (1935: 17–18; 1936: 19) noted a number of technofunctional ideas that had surfaced in the 8 years after the initial Folsom discovery: (1) reduction in weight; (2) improved penetration; (3) intentional fracture within the prey animal; (4) ease of removal of the point from the foreshaft; and (5) enhanced bleeding. He noted in particular that fluting facilitated hafting the point to a shaft or foreshaft, with a split haft fitting more snugly in the concavity of the flutes than it might against a more typical, convex unfluted surface. He did not elaborate on what he meant by a "split haft". Roberts (1936: 19) concluded that several purposes may have been involved in perfecting the Folsom fluting design, and that he favoured a combination of increased penetration and haft facilitation.

For several years, some or all of these ideas mentioned by Roberts (1935) were reiterated by others, without elaboration (e.g. Fischel, 1939: 234; Wormington, 1939: 7; see Baker, 1997*b*). In the 1960s and 1970s somewhat more explicit statements emerged regarding possible technofunctional advantages of fluting. Don Crabtree (1966: 7) assumed that the Folsom point was used on the tip of a thrusting spear, without a foreshaft, and proposed that the design allowed for deep penetration and for the hunter to repeatedly thrust and remove the weapon. Among Folsom design features, he noted the razor-sharp retouch on the leading edge, and he noted the broad-angled indelicate tip that decreased the chance of tip fracture if it struck bone. Highly important is Crabtree's concept of the haft and the role the haft played in the weapon system. He states that "the shaft was designed to fit the fluted channel in such a manner that only the cutting edge of the projectile would be exposed" and that its "design makes it one of the strongest of all projectile points" (Crabtree, 1966: 7).

Figure 2 shows a redrawing of Crabtree's (1966: figure 12(a)) original representation of a hafted Folsom point. This figure also shows two views of a replicated Folsom point made by Gene Titmus *c.* 1967 and hafted following Crabtree's design. In this arrangement, the point is seated in a deep notch cut into a single-piece wooden shaft or foreshaft such that the prongs of the haft fit snugly against the length of the flute on each face. According to Titmus (pers. comm.), who offered this specimen for illustration, cutting the notch in the haft was a demanding and time-consuming task. Sinew is used for binding, and pitch is used as mastic and to smooth the juncture between point and haft.

By "strength" it is clear that Crabtree means not the strength of the point alone, but of the whole point/haft system as measured by its resistance to breakage. He suggests that the incurvate base and tangs were designed to align the point and haft juncture, and that adhesives were probably used to make the system even stronger (as in Figure 2). He called attention to the point outline that tapers towards the base, thereby reducing drag and enhancing both thrusting as well as pulling the spear from the prey, allowing repeated stabbing. Crabtree (1966: 7) characterized the Folsom point as "structurally and mechanically the best

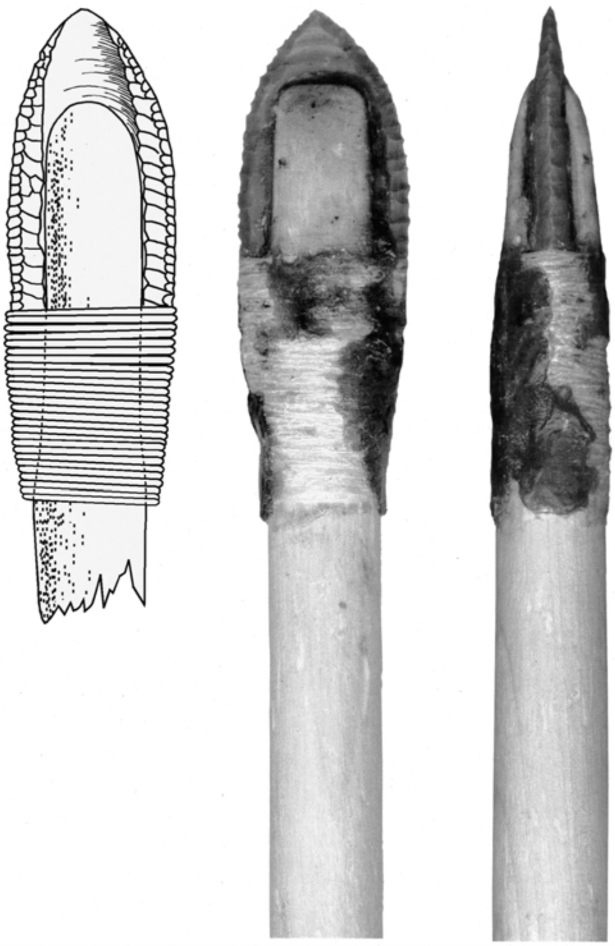

Figure 2. Left, haft arrangement for a finished Folsom point as suggested by Crabtree (redrawn from Crabtree, 1966, figure 12(a)). Centre and right, Folsom point and haft replication by Eugene Titmus, following Crabtree's design, *c.* 1967. Some pitch has flaked away due to handling over the years.

designed of any weapon produced in this period''. He called particular attention to integrated design features of a sharp leading edge, a broad tip, and a haft that provided high resistance to fracture. To Crabtree, the last feature was of greatest importance, as there was ''no stemmed point of comparable weight or size that would have had equal resistance to breakage''.

Curiously, little attention seems to have been paid to Crabtree's ideas (see Judge, 1973: 165, 174–177; Wilmsen, 1974: 52; Wilmsen & Roberts, 1978: 176–177; Bradley, 1991: 375–379; 1993: 255–256). As we note in later discussion, his explanation of Folsom fluting contains several compelling features.

Judge (1973: 165, 174–177) presents data indicating that width dimensions in the haft portions of Folsom points from the Rio Grande Valley in New Mexico are highly invariant, clustering tightly around the sample mean. From this, Judge infers that the Folsom point was built to conform to a specialized haft, and that multiple points were designed to fit interchangeably within a single, socketed foreshaft (Judge, 1973: 164, 175–176). He suggests (1973: 175) that fluting was intended to create a marked thinning at the base of the point, for purposes of haft insertion, without altering the width of the point base. He further suggests (1973: 176, 264) the use of a bone foreshaft, and, following a suggestion by Ele Baker, the possibility that a socketed bison rib served this purpose.

Several observers (see Howard, 1995: 293–294) note the advantage created by a flat, fluted surface that allows more effective bonding between point and haft—both in the Clovis point and more markedly in the Folsom point. Wilmsen (1974: 52; Wilmsen & Roberts, 1978: 176–177) gives a very specific discussion of the flat surface bonding model in relation to Folsom. He proposes that fluting, in general, was a means for increasing the strength of the haft bond by increasing contact friction where the haft met the flute scar surface. Further, he speculates that fluting arose in the context of human groups who, having just entered the continent, had little knowledge of how to secure adhesives in the natural environment, and consequently developed fluting as a compensatory mechanism in the absence of mastics. Wilmsen proposes that Folsom fluting was the epitome of this development, but that other fluted point variants in other geographic areas were simply socially conditioned (stylistic) expressions of the same technical solution.

Titmus & Woods (1991: 125, 129), focusing primarily on Clovis, emphasize both the firmness of the flat, flute surface bond as well as its fracture-resistant qualities due to dissipation of stresses across the broad point-to-haft contact area allowed by the flute. They see fluting in the Clovis point as a design that increases durability, with the portion of the point encompassed in the haft being particularly resistant to fracture. Also considering primarily Clovis points, some authors (Haynes, 1987: 91; Frison, 1989: 771; Carlson, 1991: 86) note that a flute decreases thickness at the bulge created when a split haft is attached to the proximal end of the weapon tip. For Clovis and, by extension, other fluted forms, one apparent purpose for fluting is therefore a thinner point/haft arrangement that will penetrate deeper into the target than will an unfluted haft arrangement.

Additional comments on Clovis fluting are relevant because some recent ideas serve to illustrate how the discussion about fluting has been expanded to consider broader cultural adaptive processes in addition to particular details of the point/haft arrangement. Noting the uniformity of the fluting configuration in Clovis points across contrastive micro-and macroenvironments spanning much of the continent, Kelly & Todd (1988: 256) suggest that the flute feature indicates a functional continuity among the makers of Clovis points. In direct contrast, Meltzer (1993: 304) argues that regionally distinct subsistence adaptations must have been developed by subgroups of Clovis people inhabiting this broad geographic area, and concludes that Clovis fluting is therefore either of no more functional significance than widespread use of notching in late prehistoric times, or that it perhaps is only a "stylistic" feature.

When possible technological advantages are viewed in the context of what Bradley (1993: 255) has called the "extreme complexity" of lithic production in a Folsom point, he and other archaeologists (including one of the present authors, Ahler, 1993) have expressed doubt that technofunctional motivations are sufficient to explain the existence, persistence, and uniformity of the Folsom fluting phenomenon. In general, this perspective forms the basis for other Folsom fluting explanations that are ideological in nature—i.e. that a far stronger force must have been driving the fluting process; something more than the advantages gained in projectile penetration or strength of haft bonding.

Frison and his colleagues (Frison & Bradley, 1982: 211; Frison & Stanford, 1982: 365) have called attention to: the wastefulness of the fluting process; unconvincing evidence of functional superiority in the fluted point; and the cooccurrence of fluted and unfluted points. Against this background, they suggest that fluting was either an art form or was performed in the context of ritual. Bradley (1991: 379) notes the extreme artistry expressed in Folsom and other Palaeoindian points. Baker (1997*b*) systematically reviews and finds lacking several utilitarian explanations for Folsom fluting, and concludes that it represents art expressed through mastery of medium and technique. Weighing the apparent costs and utilitarian benefits of fluting, Frison (1988: 94) reasons similarly, concluding "it may have been done as much to achieve an art form as to fulfill a functional need".

Storck (1991: 156–158) argues that we cannot really know how efficient Folsom peoples were in point manufacture, nor what standards they maintained regarding efficiency. Hence, he dismisses as unresolvable the idea that apparent waste in manufacture is a reason for seeking an ideological explanation for fluting. Nonetheless, Storck (1991: 157) accepts the assertion by Frison and others that fluting was not a functional necessity. He draws attention to the occurrence of unfluted forms in Folsom context that have the appearance of fluting, to miniature lanceolate points in Folsom contexts, and to "scaled-up" versions of Clovis fluted points in several cache contexts as evidence that fluted points did carry ideational significance that extended beyond the role of the artefact in subsistence.

Bradley (1991: 375–379; 1993: 255–256) has committed perhaps more firmly than anyone else has to a specific non-technofunctional explanation. He is most perplexed by the apparent abandonment or intentional destruction of what he judges to be usable, fully fluted preforms in several Folsom sites (Wilmsen & Roberts, 1978; Frison & Bradley, 1980: 56; Bradley, 1982: 186–195). To account for this seemingly counter-productive or wasteful artefact abandonment behaviour, Bradley suggests a supra-functional reason for Folsom fluting. He posits that the process of fluting was itself an integral part of prehunt ritual; that success or failure in the fluting process itself was a prognostication of the success of the upcoming event; and that the fluting event alone was as important as the actual production of a usable projectile point.

In conversation with one of us (SAA), George Frison called attention to the occasional occurrence of exceptionally large and well-made complete Folsom points in various contexts, primarily kill locations such as the Cooper site in Oklahoma (Bement, 1997, 1999*a*). One explanation for these is simply loss during the melee of a kill. Another is that, because of their size, these large artefacts held special importance to their makers and were intentionally deposited as offerings at the kill location (see Bement, 1999*a*: 142–143). This interpretation is closely tied to the assumption that the fluting process itself had primarily ideological rather than technofunctional significance; hence, an exceptionally long and presumably more difficult to make fluted point carried yet more power for its maker.

To recapitulate, technofunctional explanations for Folsom fluting are more common in both the old and recent literature. Many such lines of thought converge on the relationship between the Folsom point and haft as being of paramount importance for understanding fluting. While several modern technologists have experimented with haft arrangements for Folsom points (e.g. the frontispiece in Baker, 1997*a*, made by Bob Patten), Crabtree's (1966: 7) is one of the most specific configurations proposed in the literature, and it apparently has been largely overlooked by others. Other haft configurations have recently been proposed (Bement, 1999*b*; Osborn, 1999; discussed further below), but these are more a case of the fluted point searching for a comfortable haft than a head-on treatment of the question "why flute?" In this vacuum, and in the face of indisputable high requirements of time, skill, and raw material necessary for fluting, ideological explanations centring on symbolism, ritual power, and fluting as an artistic expression are proposed. The old, unsophisticated catchword for these explanations is "ceremonial". Frustrated by not understanding, we sometimes characterize the unknown as unknowable, just to put our busy minds at ease.

Projectile Design and Performance Characteristics

Frison (1978: 337–338) has asserted that "projectile point design was of vital concern to the hunter" and listed the two principal performance criteria as a sharp point for hide penetration and sharp distal blade edges to open a hole for passage of the binding and shaft. Design is a useful term in this context because it implies the purposeful creation of a product to meet a specific goal under various constraints (Pye, 1964; Bleed, 1986; Horsfall, 1987; Nelson, 1991; Hayden *et al.*, 1996). The design of a projectile point likely involved both a mental scheme based on hunting experience and on trials with the products of various designs.

We do not believe that there was a continent-wide or even region-wide unilineal, efficiency-driven progression in projectile point technology such as assumed by Musil (1988: 373). His assertion that "successive changes in projectile point form were made and adopted because they were functionally more efficient than designs of the preceding tradition" does not allow for mutually interacting factors that hunters likely weighed during point design. Rather than attempt to explain variation in one particular element of technology as driven by the desire for efficiency, we advocate study of variation in projectile form and technology as one aspect of a culture's organization of their technology, fully in the sense proposed by Kelly (1988). All factors have to be considered within the adaptive milieu (including mobility and access to raw materials) of the society under consideration, in this case Folsom, because this provides the essential particular context for evaluating point design.

Projectile points may well have social and symbolic roles (e.g. Weissner, 1983), but their functional role as an effective killing tool was likely of paramount concern for most past societies. Effective killing means disabling game as quickly as possible, thereby limiting pursuit time after striking prey. Prehistoric hunters designed projectile points and associated hardware (foreshafts, main shafts, etc.) with this goal in mind, but this objective was constrained or conditioned by several important factors. Our perspective is that virtually all projectile forms having persistence in the archaeological record were probably highly effective at killing, and that differences in these designs (particularly differences as dramatic as presence or absence of fluting) tell us most about changing cultural and natural contexts within which the points were used (e.g. changes in prey species, hunting behaviour, hafting systems, propulsion systems, raw material availability, and social context).

Assessing the killing efficiency or efficacy of different projectile points can be approached by experiments such as Frison's (1989) dispatching of elephants with Clovis points or by computation such as Friis-Hansen's (1990) analysis of arrowhead penetration. Both approaches have merits and bring to our attention different issues. Wound size and depth of penetration are two central performance related issues in projectile point design (Browne, 1940: 209; Friis-Hanson, 1990: 495–498). As Friis-Hansen (1990: 496) indicates, these are contradictory concerns because, while a broader point head cuts a wider wound, it carries increased drag that reduces penetration. Both factors are important to hunting success because both are connected to bleeding, which is what brings down large game in the absence of poisons.

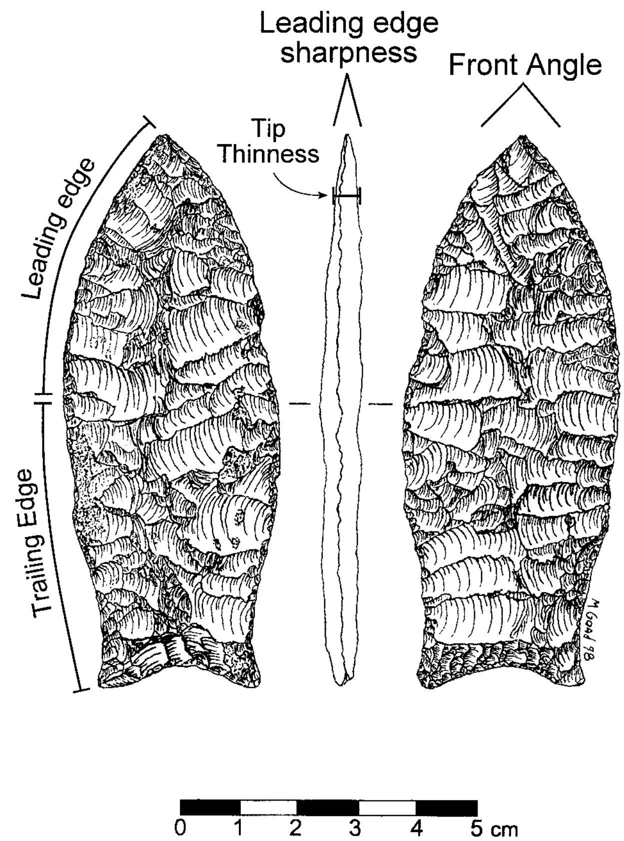

Figure 3. Illustration of the front angle and other features affecting penetration in a projectile point.

Penetration

It is perhaps useful to conceptualize projectile penetration as consisting of two parts, the initial piercing of an animal and then the depth that the projectile travels within an animal. Obviously both are interrelated, and a point designed to pierce skin should also theoretically be able to penetrate deeply, but this is not certain because of haft drag. A well-designed point is one that not only allows for easy initial penetration but also is part of a haft arrangement that minimizes haft drag so that penetration depth can be enhanced.

Although there is no consensus on the topic, we believe that Folsom points were normally used as dart point tips rather than the tips of thrusting spears (see Hutchings, 1998, for supporting data; cf. Caldwell, 1958: 13; Crabtree, 1966: 7). Holding tip or blade width constant for purposes of illustration, key factors influencing the initial penetration of atlatl dart points are tip thinness, leading edge sharpness, and front angle (Figure 3) (Guthrie, 1983; Fischer, 1985; Friis-Hansen, 1990). These notions make common sense, especially to anyone with hunting experience with bow and arrow or atlatl and dart. They are also variables under the direct control of point producers, at least initially, within the constraints of skill, raw material properties, time and other factors.

Tip thinness, leading edge sharpness, and front angle are also important variables in mathematical equations that describe initial penetration. Sperrazza & Kokinakis (1968: 163), for example, calculate penetration as projectile mass (M) multiplied by initial striking velocity (Vo) divided by cross-sectional area of the projectile (A) multiplied by a dimensional value (C). The dimensional value can be a constant, but for application to archaeological point specimens, it should account for important differences in shape, especially front angle. Cross-sectional area is that portion of a projectile point that strikes an object; it can be calculated, approximately, simply as width multiplied by thickness or more precisely by an equation that takes into account the lens-like shape of points in cross section (e.g. Friis-Hansen, 1990: figure 2, table 2; Hughes, 1998: table II). Again, note that here we are discussing primarily factors that affect initial penetration, and not so much depth of penetration.

Guthrie (1983: 282–285) concluded from experimentation that thinness was the most important variable influencing penetration with bone projectile points. His findings are predicted in the penetration equation given above, where a decrease in cross-sectional area will increase penetration. Most projectile points have a relatively narrow front angle or they would not have functioned as intended, but, archaeologically, there is a wide range of variation in this feature. In Palaeoindian points, this range is easily visualized by contrasting the relatively low front angles of Eden points (e.g. Bradley & Frison, 1987: figures 6.10, 6.13) with the greater front angles of Hell Gap points (e.g. Frison, 1974: figures 1.37–1.40). Friis-Hansen (1990: 497) states that: ''one knows from experiment that a wide broadhead with a 30°–40° front angle shows good hide-penetration and cutting qualities if the two edges are sharp, the blade thin, and the hide is not too thick''.

In stone points it seems, intuitively, that leading edge sharpness is correlated with tip thinness. Measurement data from eight fluted point sites studied by Wilmsen (1970: 51) support this idea, with significant positive correlations existing between artefact thickness and both lateral and distal retouched edge angles. In fact, the potential for sharpness or low edge angle is limited by the sectional shape (see Figure 3). Width:thickness ratios are a direct expression of transverse sectional shape, and edge sharpness or edge angle can be shown to be limited by this ratio. Simple trigonometric computations can demonstrate this relationship. For example, a symmetrical biface with a transverse width: thickness ratio of 3:1 can have an edge angle no more acute than about 37° degrees (in the absence of a hollow-ground edge effect). Similarly, a biface with a 4:1 width:thickness ratio can be flaked to no less than a *c.* 28° margin, a 5:1 ratio to no less than a *c.* 23° margin, and a 6:1 ratio to no less than a *c.* 21° margin.

Sharpness can be measured along the longitudinal axis of the point (Figure 3) and the width:thickness ratio in the longitudinal section is actually the length: thickness ratio. This ratio can be increased, and the potential for acuteness or sharpness in this direction enhanced, by increasing the length of the point. In actuality, because of geometry, an extremely acute edge angle in the longitudinal section can best be achieved only if the tip is somewhat obtuse rather than pointed. Hence, when considered from all perspectives, a point that is broad and thin, as well as long, will maximize the potential for sharpness of the leading edge.

Experiments have adequately demonstrated that a principal factor influencing depth of projectile point penetration is haft drag. The basic issue is having a point blade of sufficient width that it cuts a broad enough hole to allow the sinew binding and shaft to pass through with limited friction (Frison, 1978, 1989; Guthrie, 1983; Friis-Hansen, 1990). In Frison's (1978: 333) words, ''if the shaft and binding are too large [relative to the width of the projectile blade], it is nearly impossible to drive this bulge through the hole formed by the projectile point''. Friis-Hansen (1990: 498) argues that point perimeter is important with regard to penetration depth. A slender conical point results in more drag on the shaft while a broader head reduces this by cutting a larger hole through which the shaft passes with less drag. A broader head also has the benefit of producing a greater wound area (Friis-Hansen, 1990: 495–496). Again, a balance between wound size and haft size is required, and in wood and stone technology, this is achieved largely by the integration of the point and haft design. An optimal point is one that will create a relatively large wound and is hafted so that cross sectional area of the complete point/haft arrangement does not increase abruptly at the place where the point-to-haft connection occurs.

Breakage

With stone projectile points there is no avoiding the inevitable—they ultimately break. The primary way to design a point that will not break, or at least not easily, is to increase its thickness. However, this comes at the cost of reduced penetration. It actually might be possible to create a stone point thick enough that it did not break, but then it would kill by blunt trauma like the wooden dart bunts recovered from caves of the North American Southwest (e.g. Kidder & Guernsey, 1919: figure 92). Such points might be fine for small game such as rabbits, and this is the suggested function of the wooden bunts, but they would not work on bison. As detailed above, points with equally sharp edges and equal widths will have different penetration depths because of different thicknesses. All things being equal, thin points penetrate more easily and deeply than thick points (see Guthrie, 1983: 282–285), but they are more fragile and subject to breakage. The consequence of this is that designing effective killing points for large game requires striking a balance between ease and depth of penetration and resistance to breakage. There is no single optimal compromise to these contradictory concerns because they depend on the specific adaptive context, both environmental and social, as well as other constraints.

Conceivably, in an environment where excellent raw materials were ubiquitous, hunters might have less concern over point breakage because they could procure new rock nearly anywhere. The region around Austin, Texas, coinciding with the Edwards Plateau might be such an example (Banks, 1990: 58–62), or perhaps the area around the Knife River Flint quarries in North Dakota (Loendorf *et al.*, 1984; Ahler, 1986). For much of the Great Plains where Folsom hunters operated, however, high-quality raw materials are restricted in distribution (Hofman, 1992; Bement, 1999*a*). The patchy distribution of truly good raw material coupled with the distances between various sources and between them and hunting grounds (many sources occur in the mountains away from optimal bison terrain), suggests that point breakage should have been a concern for focal bison hunters.

Although breakage cannot be eliminated, loss of functionality linked to breakage can be minimized or otherwise managed by building in design features that allow more complete recovery from breakage events. Here, we are drawing a distinction between what Bleed (1986: 738–741) has called reliable tools (in the ultimate sense, ones that cannot be broken) and what he calls maintainable tools (ones that can be broken, but in which breakage and recovery from breakage are managed). A fully reliable projectile point probably does not exist, while designs can be created that have different expressions of maintainability. The latter is accomplished by combining features of managed breakage with other positive design features.

Therefore, if there is intent to reuse broken points, rather than simply discard them, an important design feature would be ability to continue to control or optimize a variety of other important design features already discussed (thinness, leading edge sharpness, front angle, haft drag) after breakage occurs. Important factors here are the length of the point and variability in cross section along the length of the point. All other factors being equal, a long primary point form will allow greater recovery from breakage because there will be more material to work with after breakage occurs. In addition, if the placement of breakage can be encouraged to occur either near the base (Musil, 1988: 382; see Flenniken, 1985; Flenniken & Raymond, 1986, for relevant experimental data) or near the tip, then the reusability of the broken pieces can also be optimized. Finally, a point with more uniform thickness along its length [for example in the extremely long and slender Agate Basin points (Frison & Stanford, 1982) and Eden points (Frison, 1978)] will also enhance recovery from breakage, because when a snap fracture occurs, a skillful knapper can more readily restore the leading edge angle and front angle that were optimized in the primary, unbroken form.

The Folsom Point and its Haft

As much of the preceding discussion suggests, our explanation for Folsom fluting is purely technofunctional in nature. We do not maintain that Folsom point production and use were devoid of elements of art, style, or ritual, but we do suggest that technofunctional elements of the Folsom point and its haft were the primary reasons for both its specific design and for most of the perplexing features associated with Folsom technology.

Designing a point for maximum penetration entails not only attention to the projectile tip itself but the haft as well; one should not be considered without the other because they are two halves of the same coin. Wilmsen & Roberts (1978: 176) stressed this aspect with regard to Folsom points in the Lindenmeier report: "in order to deliver a penetrating force with greatest efficiency, a point-shaft combination must act as a single unit". We agree; Folsom points and shafts were designed together to achieve the most desirable overall projectile system for the Folsom lifestyle. This is precisely the perspective that Crabtree (1966: 7) held in his discussion of the reason for Folsom fluting.

We concur with several of the specific features that Crabtree considered as important in Folsom point design, but we go further. We propose that the Folsom point was designed as it was for purposes of extreme conservation of raw material and for purposes of high maintainability, in contexts where these features mattered most. This situation, always planned for in Folsom technological organization, could occur when the social group found themselves very hungry, in search of game, many weeks since the last replenishing of stone, and a long distance from known raw material sources. In addition to being part of an efficient killing tool, the fluted Folsom point was designed foremost to conserve raw material and vastly extend the use-life of a given projectile tip under just these circumstances. Many other aspects of Folsom technology in addition to weaponry were designed or organized to meet this same goal. From this perspective, the Folsom point was just one part of a carefully thought out package of tool-making and tool-using behaviour designed to assure survival at a particular time and place on the landscape.

Consider Figure 4, which illustrates the concept behind the fluted Folsom point by reference to modern tools that many of us can relate to by direct experience. Two kinds of utility knives are available in most hardware stones. One (Figure 4(b)) has a simple, reversible blade. The designer of this knife has considered the near certainty of blade tip damage, and has thoughtfully incorporated a blade (Figure 4(a)) which, when worn out or broken, can be reversed and used a second time.

Consider now the utility knife in Figure 4(d). The designer of this tool, also being practical and knowing that the working end of the implement will become

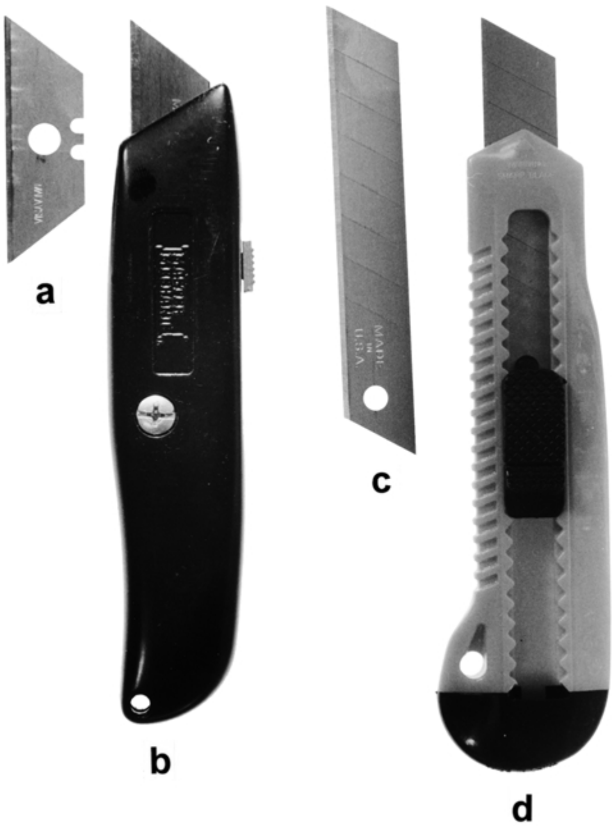

Figure 4. Two designs for steel utility knives. (a) Double-ended blade for knife shown in (b), a knife fitted with a blade having two cycles of use. (c) Blade for knife shown in (d), a knife having a forwardly adjustable snap blade with eight potential use cycles.

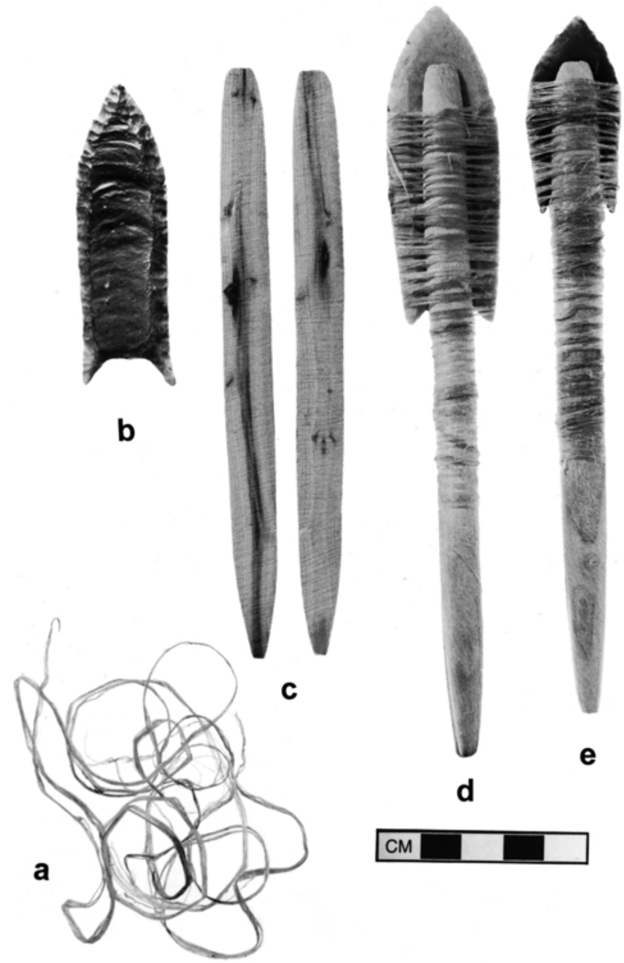

Figure 5. Suggested haft arrangement for finished Folsom points. (a–c) Disassembled parts, with (c) being the two halves of the split wood shaft. (d), (e) Hafted points showing differing degrees of resharpening. Points are casts of specimens from the Missouri River valley, North Dakota.

damaged and non-useful, offers a different mode for continued use. By designing both a longer blade, and fabricating and hafting it in such a way that a predesigned, small part of the damaged working end can be broken off, a new working end can be created, several times over, with minimal loss in blade material. Upon rejuvenation, the blade element is slipped forward in the haft, locked into place, and used again. This ''snap blade'' knife design (Figure 4(c), (d)) yields eight potential uses from a single original blade, while the former design (Figure 4(a), (b)) yields only two. To complete the analogy, note that, like virtually all Palaeoindian projectile points, both cutting elements are made from only the highest quality raw materials (''made in the U.S.A.'').

The analogy in the functional relationship between these two versions of utility knives and the functional relationship between the Folsom point and virtually all other points (including even the fluted Clovis point) could not be more precise. For both the Folsom point and the snap blade knife, key features are: (1) predesigned, controlled, and limited breakage at the tip; (2) a uniform transverse blade cross section (unchanging from end to end) that allows simple longitudinal adjustment of the blade element within the haft, without redesign or adjustment of the haft; (3) an elongated blade form that maximizes the number of cycles of use and reuse obtained from a single projectile point; and (4) a specially designed, forwardly adjustable haft that is technologically integrated with the design of the point.

Figure 5 illustrates the pieces of the haft system and how we think the Folsom point was hafted. The original, unused Folsom point (Figure 5(b)) was fitted in a split, elongated haft. The wood shaft was fashioned with nearly flat faces (Figure 5(c)) that fit snugly along the length of the flute scar. The haft could be either a partially split, single piece of wood, or two separate pieces (as we show), the essential feature being facial contact rather than basal contact with the stone point. Stone point and wooden haft were securely bound by a wrapping of sinew (Figure 5(a)). In original, unused and unbroken form, the point is overdesigned regarding both surface contact area with the haft as well as the extent of lateral haft margin available for binding (compare points of different length in Figure 5(d), (e)). Concurring with Wilmsen (1974: 52), and based on our experimental hafting, we believe that a very secure point-to-haft bonding was obtained through facial friction; contrary to Wilmsen (1974: 52), we believe that Folsom people had access to mastics. With use of a mastic, a smooth transition between the wooden and stone parts of the tool could be achieved, and the haft was yet stronger. In our example, we did not add the mastic, in order to make the fit between the point and haft easier to see. Once assembled, this configuration would appear, at a glance, little different from that envisioned by Crabtree and Titmus (Figure 2). But it differs in the critical element of a friction bond within the forwardly adjustable haft that we propose versus the basally abutted haft proposed by Crabtree and Titmus and all others who have conceptualized a specific Folsom haft configuration (e.g. Kay, 1998; Bement, 1999*b*; Osborn, 1999).

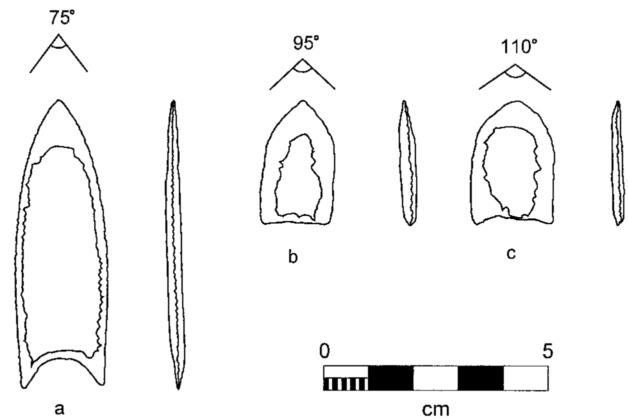

Figure 6. Plan and edge views of casts of several Folsom points from the Cooper site, Oklahoma, illustrating front angle variation, extreme thinness, and leading edge angle in transverse section and longitudinal section.

Assessing Folsom Point Design and Performance

As noted previously, several elements—thinness, leading edge sharpness, front angle, and cross-sectional area at the point-to-haft juncture—are essential features controlled by the technologist that determine the penetrating power of the projectile design. These features are not necessarily independent of one another, and the Folsom fluting and hafting design allows manipulation of all toward the goal of optimized penetration. As noted, a final design factor controlled by the technologist is fracture characteristics. The Folsom design maximized use-life in the same manner as the snap blade utility knife. It is only when this last feature is considered in combination with all the others that the true balance between production costs (skill level, time, raw material, and fluting failure) and utility becomes fully understandable. We will discuss each of these features in turn.

Thinness and leading edge sharpness

The Folsom point is widely recognized as one of the thinnest stone points for its overall size made anywhere in the world (Figures 1 & 6(a)). This extreme thinness is directly achieved by fluting. Thinness enhances penetration, so fluting is directly related to increased penetration. For finished specimens from Lindenmeier (Wilmsen & Roberts, 1978: table 43), one may compute a (weighted) mean ridge thickness of 3·66 mm (N=30), a channel scar or flute thickness of 3·18 mm (N=22), a maximum width of 18·60 mm (N=31), for a width:thickness ratio of 5·1:1 based on ridge thickness or 5·8:1 based on flute thickness. The Agate Basin point is one of the thinner unfluted Paleoindian forms. Mean dimensions for 14 nearly complete specimens illustrated in figure 2.48 in Frison & Stanford (1982) are width 21·32 mm, thickness 6·69 mm, with a width:thickness ratio of 3·2:1. Most pertinent perhaps are data for Goshen points, which in form, size, and haft arrangement are perhaps most similar to Folsom points. Data from Mill Iron (Bradley & Frison, 1996: table 4.1) are mean width 23·10 mm (N=20), thickness 5·10 mm (N=20), with a width:thickness ratio of 4·5:1.

In direct thickness, Folsom points are 28% thinner than Goshen points and 45% thinner than Agate Basin points. Fluting in the Folsom point creates perhaps a 13% increase in relative thinness (W:T ratio) over its closest technological equivalent (Goshen) and as much as 59% over the Agate Basin point. As noted in previous discussion, the width:thickness ratio can be directly related to minimum possible edge angle. For the Folsom, the minimum possible lateral edge angle is *c.* 22°, for the Goshen it is *c.* 25°, and for the Agate Basin it is *c.* 35°.

In the central part of the point, the Folsom point is even thinner (where flute thickness is measured). Because the point tip is created along the central axis of the point, it is in this area that the thinness created by fluting could most enhance initial penetration into the target. In addition, channel thickness becomes most relevant to penetrating power after the original point is fractured and resharpening invades the flute scars. When channel thickness is considered as a meaningful measure of thinness, the Folsom point is 38% thinner than the Goshen, and 52% thinner than the Agate Basin point. This is certainly relevant when invasive pressure flaking encroaches on the flute scars, as is almost always the case in resharpened specimens. A leading edge angle in the longitudinal section, measured at the minimum thickness created by fluting along the centerline of the Folsom point, could be as low as 19°.

Creating and maintaining extreme tip thinness and therefore extreme leading edge sharpness are highly significant features made possible by fluting in Folsom points. Full length fluting as conducted in the Folsom point created a uniformly thin section from tip to base. This enabled continuous removal of the tip by breakage, followed by resharpening, resulting in virtually no changes in tip cross section and long section. Thus, the point lost no penetrating efficiency, even if on its fourth or fifth cycle of rejuvenation. This cannot be fully achieved in any unfluted point, having a lenticular cross section, in which thickness increases from either tip to centre, edge to centre, and base to centre. The goal of constancy in cross section from tip to base was apparently sought in other elongated forms such as the Goshen, Agate Basin, and Cody complex types, but it was only achieved in combination with extreme thinness by the use of full fluting.

Precisely the same combination of ideas involving sharpness due to thinness, constancy in edge angle, and constancy in sharpness is played out in ultrathin bifaces, also produced (invented?) by Folsom knappers. These are a large, apparently specialized bifacial cutting tool (Jodry, 1998; Collins, 1999: 21–22), usually shaped by opposed diving biface thinning (Bradley, 1982: 207), to create an extremely thin and flat, even biconcave, cross section. The Folsom ultrathin biface was continuously resharpened along all margins without decreasing edge acuteness; this is possible because one is always flaking into the same tool thickness. The same principle is put into effect with Folsom points, but with only the longitudinal direction of resharpening, from the tip back towards the base or from base to tip, being important.

Front angle

Folsom point front angles (see Figure 6) are almost always much greater than the 30° to 40° optimal range of effectiveness recorded by Friis-Hansen (1990: 497). For example, the well-fluted lengthy, complete specimen from the Cooper site (Figure 6(a) and Bement, 1999*a*: figure 43FF) has a front angle of about 75° and shorter, apparently reworked specimens from this site have angles of *c.* 85°–110° with a mean of 101° (N=13) (data from points illustrated in Bement, 1997: 90). Some specimens appear to actually have rounded but unfractured tips (Figure 6(c) and Bement, 1997: 90, figure 5R,S,Z). Front angles for Folsom points from other sites consistently approach 110° on the upper end of the range (e.g. Wilmsen & Roberts, 1978: figures 104,105). A pattern exists in which the longest whole points or most lengthy distal tip fragments appear to have the most acute front angles [see lengthy tip specimens from the Folsom type site in Howard (1935: plate XXXIII)] and points of shorter length usually have 90° or greater front angles. Why the high front angles?

This pattern apparently reflects two things, both related to fluting. First, because the point is thinnest along the central axis within the flute scars, invasive pressure flaking can be applied in this central part of the tip, into the flute, even with a rounded tip, while achieving an extremely acute edge angle and great edge sharpness directly at the tip of the point. Thus, with fluting, a longer, more acute front angle (associated with greater stone loss upon breakage) could be traded off against a lower front angle and less protruding tip while maintaining edge sharpness, thereby minimizing the amount of stone lost during tip fracture and resharpening. Second, the haft pieces were basically fitted to the flute scar, and in a fully fluted point or in a partially resharpened point in which leading edge pressure flaking invaded the flute scar surface, virtually the entire tip except for the most distal leading edge was protected directly by the haft. Thus, the front angle could be made to conform to the shape of the leading part of the haft, while still not loosing leading edge sharpness because of its extreme thinness.

Cross-sectional area and haft drag

It has long been accepted that Clovis points are designed to reduce haft drag by being basally thinned so that the haft bindings will not project much above the surface topography of the point. Frison (1989: 771) found that Clovis flutes to be 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 thick bulge that inhibits penetration". This aspect can be appreciated by looking end on at a hafted Clovis point. This is a good design feature, one that Folsom points incorporated and improved upon by creating a point that is roughly twice as thin as a Clovis point. Less thickness means that Folsom points have less cross-sectional area, thus greater penetration potential. Increased penetration was not gained by an increased chance of catastrophic breakage because the flute scars allowed almost the full length of the point to be encased within the haft.

In outline, Folsom points have straight or slightly convex lateral margins that expand slightly from the base to a place of maximum width at least half way up the point, and then the margins converge to the tip. The portion of the point forward of its maximum width is the leading edge, that part which cuts and enters the target. The portion behind is the trailing edge, serving only as a purchase for hafting. Typically, the entire leading edge, however long or short, is flaked with low-angle pressure retouch, while the trailing edge, no matter its length, is shaped by steep and abrupt retouch and is intentionally dulled. This boat-shaped outline is essential to penetration. Because of the flutes and facial-contact haft, the trailing part of the point (behind the place of maximum width) has a cross sectional area that is less than that at the place of maximum width. Just as the flute allows the stone point to have a continuous cross-sectional area along its entire length, the flute also allows a haft to be

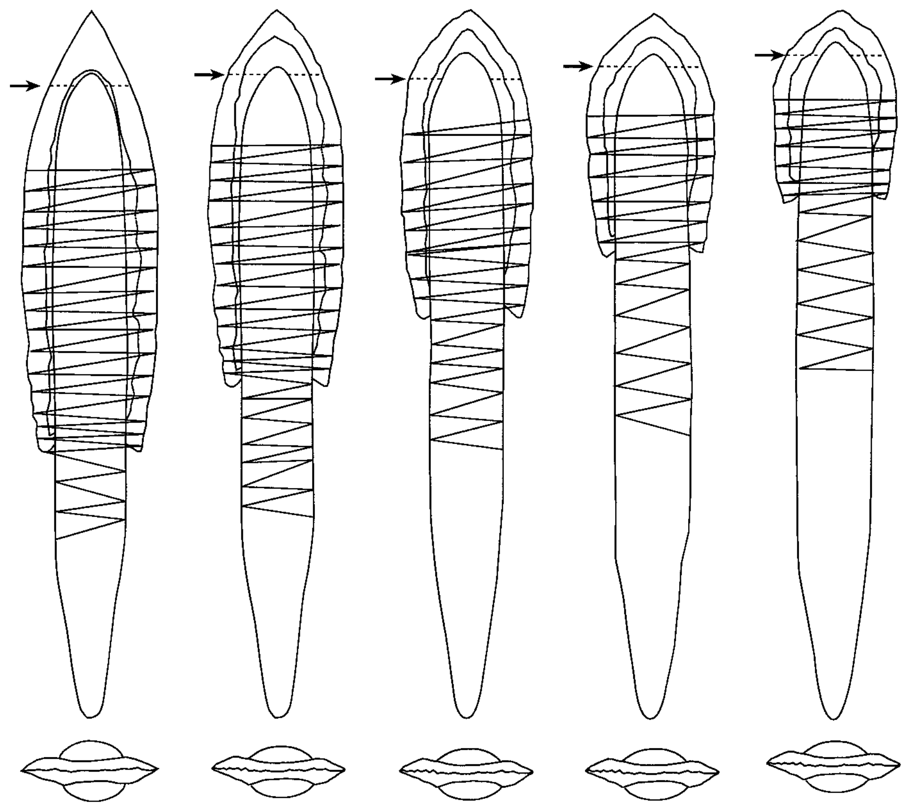

Figure 7. Reconstruction of several cycles of reuse in a hafted Folsom point based on fracture at different places near the tip (arrows), subsequent resharpening at the tip, and repositioning of the point farther forward in the haft. (a) Primary point form with acute front angle. (b)–(d) Resharpened forms with high front angles. (e) Slug on last cycle of use.

applied without creating a hafting bulge behind the leading edge of the point. This in turn ensures that the blade will cut a hole large enough for the point and haft to enter without excessive shaft drag.

Managed fracture and refurbishing

Coffin (1937: 15) concluded, as many of us have after him, that the "Frugal Folsom" person was very interested in conserving stone and reusing broken points, frequently building new tips and bases on broken specimens. Certainly, the excellent studies in recent years (e.g. Hofman, 1992; Amick, 1995) that link tool use and conservation behaviour to Folsom mobility verify that Folsom peoples were concerned with loss of raw material when operating at some distance from stone sources. The reworking process is nowhere more clearly illustrated than in the Cooper site points (see Figure 6) (Bement, 1999*a*: 139–141, figure 43). Therefore, it is logical that conservation of stone was a central issue in the design of the Folsom point. As the thinnest of all dart or spear points, the Folsom was inherently subject to fracture, but again, the fluting design features in combination with the haft allowed a high degree of fracture management.

Key was the small amount of the Folsom projectile blade tip exposed beyond the haft (see Figure 5), the part most vulnerable to breakage during use. By creating flutes that run most of the length of the tool, then extending the split haft along most of the length of the flutes, nearly the entire point was strengthened against bending fracture [as pointed out by Crabtree (1966: 7)], and the potential for fracture was concentrated in the forward part of the projectile protruding beyond the haft pieces. Thus, fracture was expected but was highly controlled and limited in extent. This concept is discussed by Titmus & Woods (1991: 125) for the Clovis point, but is executed in a different manner for the Folsom point.

Successive stages of fracture, resharpening, and reuse are shown in Figure 7. We believe that the primary form (primary meaning finished and not reworked, Bradley & Frison, 1996: 45) for most Folsom points resembled the outline shown in Figure 7(a), with an extended narrow tip and acute front angle. This tip was created if fluting did not carry completely to the end of the preform (and therefore the point) and if the full length of the preform was utilized. Examples of this primary tip form occur at the Folsom type site (Howard, 1935: plate XXXIII). Because the haft did not extend far beyond the flutes, most of this slender tip was vulnerable to fracture and was probably lost during the first fracture cycle (Figure 7(b)). After the first fracture cycle, the tip was resharpened with a much broader front angle, and the point was slipped forward in the haft and remounted (Figure 7(b)). From this time onward in the use and fracture history of the point, the front angle was intentionally kept high, and the tip was sharpened to a broad and even curving margin in order to minimize the amount of tip stone exposed beyond the haft (see Bement, 1999*a*: 139). This strategy was made possible by the extreme thinness between the flute scars that now extended completely to the tip, allowing maintenance of an extremely sharp, razor-like leading edge, even on a point with a broad front angle.

The long, complete point from the Black Meadow site in North Dakota (Figure 1; Ahler *et al.*, in preparation) is the direct model for the point outline in Figure 7(b). We believe this particular artefact was fractured and resharpened at least one time. Successive tip fractures resulted in minimal loss of stone, due to the protection of most of the point in the haft, and the cycle of fracture, resharpening, and rehafting was repeated several times (Figure 7(c)–(e)). This figure gives a hypothetical example of how the system should have worked in an ideal situation. In reality, the point might have suffered a major break during initial use, perhaps moving directly from Figure 7(a) to 7(d). The extent to which small fragments from more severe fractures would be put to use was likely context-specific and principally related to anticipated time of return to a raw material source.

The excessive thinness of the point tip as well as the manner of flaking promoted fracture at the tip. Tips were shaped by flaking on an angle towards the base. In plan, this results in an abrupt change in lateral margins where the slightly expanding haft element margins abruptly converge toward the tip. In transverse cross section, there is a transition from a biconcave section created by the flute scars, to a flat or slightly convex but very thin section of the tip. The contrast in the two sections we believe is another important aspect of Folsom point design because the biconcave section is less prone to breakage than the lenticular section of the tip. The contrast between the two sections promotes fracture at the location of the change in flaking.

Tip portions that snapped transversely at the approximate location where the thinned tip meets the body of the point are common at Folsom sites. There are of course other types of fractures including some that ruin the entire point. Examples include points that split longitudinally from impact. Edge burination from impact is not necessarily deleterious because steep retouch can be used to recentre the flutes on a newly fashioned tip.

Yet one more advantage regarding conservation of raw material can be attributed to fluting in Folsom points. The uniform transverse cross section of Folsom points not only allowed a simple sliding arrangement during rehafting, as in the snap blade utility knife, but it also allowed for virtually any segment of the broken point above a critical length (tip, medial segment, basal fragment) to be transformed into a useable point as necessity dictated. This feature was made possible by the high-friction haft contact enabled with fluting, which meant that a shorter point segment could be reworked and firmly secured in the haft than might otherwise be possible. Of all Palaeoindian point forms, Folsom is therefore the one design that most allowed small fragments to be recycled as killing projectile tips. Large stemmed points and Clovis points could be reworked after small tip fractures, but these point forms do not easily allow for a portion amounting to as little as one-fourth of the original point size to be resharpened and hafted for use if necessary.

Clearly, the number of cycles of controlled breakage and reuse available in a projectile point is directly related to the original point length. A long point, on the order of specimens that occur rarely but consistently in Folsom contexts throughout the Plains (Figures 1, 6(a)), probably offered four, five, or more cycles of controlled breakage before the point was reduced to a slug (Figures 6(b), (c), 7(e)). The slug was discarded, even if unbroken, when the opportunity for resupply and refurbishing of equipment was opportune.

Reliability and maintainability

Folsom hunters took point thinness to the extreme limit for a large dart tip, and did so with a point that is, by almost any standard, one of the most costly in time and materials to produce. This runs counter to Guthrie's (1983: 290) argument that points made thin to maximize penetration should result in designs that can be produced rapidly and cheaply because thin points will easily break.

Bleed (1986) has discussed the terms reliable and maintainable in archaeological context, and has noted that both features may be expressed in a weapon or tool system. In the Folsom case, and in the sense we use it here, reliable means (1) effective killing of bison during hunts; and (2) that the tool can be counted on for more cycles of killing after the first one. In the present context, we see maintainable as meaning that, when dysfunction occurs, the tool can be altered, refurbished, modified as necessary to bring it again into a functional state. We therefore see maintainability as a subfeature of reliability, in the case where a tool is subject to fracture. If fracture is accepted as part of the picture, then it can be made most reliable by either minimizing the possibility of fracture, minimizing the cost of fracture, or maximizing the potential of the tool to be brought again into a workable state following fracture.

We believe the Folsom point was one of the most reliable big game hunting tips ever made. Regarding point (1) (above), it was reliable because its design ingeniously combined features of thinness, extremely sharp leading edge, and low haft drag to create a weapon with deep cutting and penetration capabilities. Regarding point (2), it was highly reliable because it had built into its design many inter-connected features that ensured the greatest ease in rehafting without need to modify the haft arrangement and the greatest number of cycles of reuse with no measurable loss in functionality. Together, these latter features characterize the Folsom point as highly maintainable, as well.

Suggested Archaeological Tests

If this postulated design for the haft arrangement for a Folsom point is correct, then the reason for fluting in the Folsom point is primarily that it was an elegant technofunctional solution to the challenge of conservation of raw material and reliable maintenance and redeployment of critical yet complex hunting equipment. This model should be tested in several ways. We can briefly discuss some tests that come to mind.

Preform and point length

If the Folsom point system is operating in the manner we propose, and if extended use-life of the point is in fact a fundamental aspect of this design, then Folsom points in primary form will have been manufactured so that length (and therefore the number of use cycles) was maximized. Long, complete Folsom points do in fact occur in the archaeological record, although rarely, and some researchers have suggested (see discussion in Bement, 1999*a*: 142–143) that their rarity is an indicator of special artistic or ritual meaning attached to such artefacts. We propose something very different: that the long slender points were the normal production target [see Geib & Ahler (1999) for more extensive discussion regarding length in replication experiments and Collins (1999: 26) for related discussion]. If this can be demonstrated, then the hafting and recycling model proposed here will be supported. If studies of point length demonstrate that a short or medium sized finished point was in fact all that Folsom knappers were seeking, then the explanation we offer must be reconsidered. Of course, size constraints imposed by raw materials must be factored in.

The length dimension can be studied both in finished points and in preforms. Each approach has its special complications, due to resharpening in finished points and fracture in preforms. The measurement "length" has played a curious role in previous archaeological studies. Some extensive studies of Folsom point metrics omit data on finished point length (Judge, 1970: 150,165) or preform length (Tunnel & Johnson, 1991: 26–27). Roberts (1935: 15,16) noted that most finished Folsom points were very short and had rounded tips, while a few were much longer with more acute tips. On this basis, he proposed two subtypes (those that we would call "slugs", versus others discarded for other reasons). Titmus & Woods (1991: 120) also suggest that Folsom points occur in two length groups. We think these proposals derive from studies of small samples in combination with the pervasiveness of resharpening. Further study should document a continuum in length in finished Folsom points, with nearly all unresharpened examples being markedly longer than most resharpened specimens.

Unbroken preforms for which we can directly measure total length are uncommon in the archaeological record. In rare instances [e.g. at Agate Basin; Bradley (1982: 190–191)], they occur without apparent technological flaws, and their mere existence in this form is suggested by some to be an indication of ritualistic value attached to Folsom fluting (Bradley, 1982: 186–195). In light of the model presented here, we would suggest that some of these unbroken preforms must be reconsidered as also being flawed—i.e. flawed by simply being too short for production of a fluted point having several potential use cycles.

Preform length should be assessed in several samples, and ideally in contexts such as Adair Steadman in Texas (Tunnel & Johnson, 1991), Hanson in Wyoming (Frison & Bradley, 1982; Ingbar, 1992), and Lake Ilo in North Dakota (Ahler, 1995), where raw material is readily available and the true target of the Folsom knapper may be determined in a situation relatively free of influences from previous transport, use, and retooling events (Hoffman, 1991, 1992; Ingbar, 1992). Because whole, unbroken, and reconstructable preforms are relatively rare, this test should involve some means for estimating total length (perhaps through regression analysis) from data available on more common broken preforms. Controlled experiments may also prove helpful in this regard. If continuing experimentation with the "how" of Folsom fluting reaches some consensus on the likely methods used, and if a large series of failed preforms can be generated in experiments by the probable fluting method(s), then perhaps the fracture and dimensional characteristics in the replicated specimens can be used to estimate preform length for fractured preforms in archaeological context.

Under the explanatory model proposed here, we predict that mean original preform length will be highly distinct from, and perhaps twice as great as, the mean length of finished points recovered archaeologically. The model in Figure 8 characterizes this relationship. In general, the length distribution of preforms should have normal properties, with perhaps a truncation to the right reflecting mechanical constraints imposed by fluting technology or raw material variation. The length distribution for unbroken abandoned points will have a markedly different distribution, with a mode occurring far to the left of modal preform length, and with a strong skew to the right (see Wilke *et al.*, 1998, and Ahler, 1975*b*: 531–542, figure N-5 for

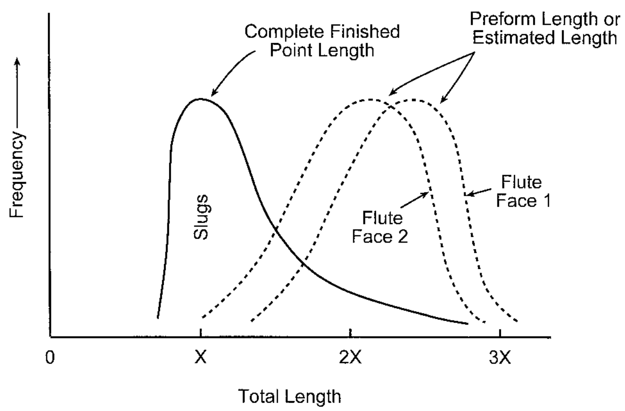

Figure 8. Graphic representation of predicted frequency distribution of length of finished Folsom points found in archaeological sites and estimated length of Folsom preforms.

similar models for resharpened end scrapers made on blades and elongated flakes).

Known archaeological examples appear to support the contention that long preforms were the norm during Folsom point production. In Figure 9 we show early stage preforms ranging in length from 87 to 108 mm recovered from the Beacon Island (Ahler *et al.*, in preparation), Moe (Schneider, 1982: 19), and Big Black (William, 1995: 118) sites in North Dakota, and from the Agate Basin site in Wyoming (Bradley, 1982: figure 3.7a). All these preforms are made of Knife River flint. Also shown is the exceptionally long (77 mm) complete, finished point of Knife River flint from the Black Meadow site (Figure 1; Ahler *et al.*, in preparation), also in North Dakota. Production failures are apparent in all these preforms, and all were designed to accommodate production of a completed specimen at least as long as that from Black Meadow.

When a method for estimating original length in broken preforms is developed, we expect to learn that these preforms are not the exception but the rule.

If estimation of preform length proves too challenging, then we suggest investigating means for estimating the total length of channel flakes, a logical surrogate or close correlate for preform length and finished Folsom point length. Ellis & Payne (1995: 465) have explored this approach in their study of channel flake or flute scar lengths in Barnes points that occur in the northeast.

Control of blade length

A second test has to do with study of the distributions of length measurements for the discrete blade element and haft element parts of the finished Folsom point. We can identify the blade element as the part that extends distally beyond the limits of intentional dulling on the lateral margins. Similarly, the haft element is the portion of the finished point demarcated by dulling on the lateral margins (see Ahler, 1971: 21, 23). In the hafting and resharpening model we propose, the tool user minimized fracture by controlling the length of the blade element so that just a small amount extended beyond the full support of the bindings and adjustable haft. In this model, the haft element in the primary point form was actually much longer than needed for a secure binding, and the length of the haft element encased within the haft was therefore less closely controlled by the tool user, allowed to gradually diminish as the tool was fractured and resharpened. This behaviour—of rigid control of blade element length, and free flow in the haft element length—should lead to predictable relationships between certain variables recorded in large samples of finished Folsom points.

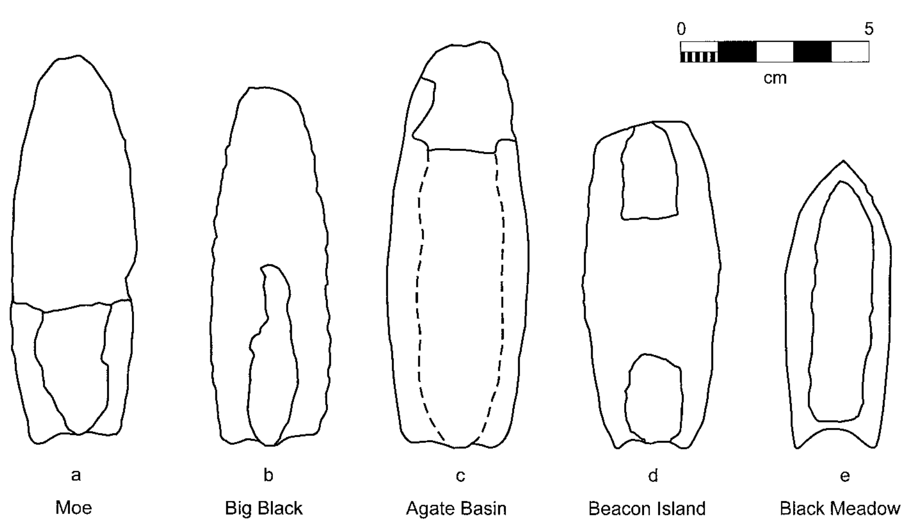

Figure 9. Length in Folsom points. (a)–(d) Folsom point preforms made of Knife River flint from sites in North Dakota (a), (b), (d) and Wyoming (c) illustrating what is considered to be typical length of preforms (range 87–108 mm); specimen (a) failed on the second face flute, and the others show the first face flute. (e) Finished Knife River flint Folsom point from the Black Meadow site in North Dakota, illustrating typical length (77 mm) of a finished point that has experienced perhaps no more than one cycle of tip fracture and resharpening.

We suggest at least two specific relationships: (1) that haft element length measurements should be much more variable than the blade element length measurements in finished points. (Importantly, data can be obtained from fractured specimens.) This can be tested by comparing the coefficients of variation for these two length measures. In a large sample from many contexts (in which variation due to vagaries of fracture and situational constraints will tend to even out), we expect the coefficient of variation for haft element length to be significantly (and meaningfully) greater than the coefficient of variation for blade element length. (2) The second relationship is that, again in a large sample, haft element length will be highly correlated in a positive manner with total point length in complete points, and that blade element length will be significantly less highly correlated with total point length in complete points.

Fracture location

In the model of fluting and hafting we propose, fracture is (ideally) confined to the small portion of the point extending beyond the haft, and the forward limit of the haft is marked by the extent of lateral margin dulling on the point. If this haft arrangement is in fact used, rather than one in which a larger portion of the point extended beyond the haft, then a patterned relationship between fracture location and the extent of lateral margin dulling should prevail. We predict that careful study of archaeological specimens will indicate a strong tendency for breakage to have occurred in close proximity to the place where lateral dulling terminated on the point. This relationship should be observable on both distal and proximal fragments. Some analysts point out that the lengths of snapped basal fragments of Folsom points appear to cluster tightly about a single mode, and that this indicates that points of various lengths were inserted in a fixed haft of constant length, with fracture occurring near the distal end of this haft. We would predict that more careful analysis will indicate that the majority of these fractures occurred near the termination point of lateral dulling—and therefore, that most of these artefacts were already very short specimens. These fractured and discarded basal fragments therefore reflect simply the terminal cycle of fracture in what was already a slug (rather than a lengthy point), unsuitable for further use.

Basal margin treatment

Several investigators have recently offered detailed suggestions about how the Folsom point was hafted, and following Crabtree (1966) and others before them, have proposed basally abutted configurations. In a paper at the Second Folsom Workshop, Bement (1999*b*) proposed a two-piece haft with pieces asymmetrical in length, and with the base of the stone point firmly fixed against a raised abutment built into one face or side of the haft. Bement (1999*b*) proposed, largely as a consequence of basal abutment, that when tip fracture occurred the distal end was resharpened without removing the proximal part of the point from its fixed haft. This in turn required that the distal end of the wood haft be periodically sawed off or whittled away as fracture and resharpening occurred, and as the remaining part of the point diminished in length.

In a study of use-wear and other features of Folsom points from Stewart's Cattle Guard site in Colorado, Kay (1998: 6) has suggested, we think correctly, that as successive cycles of fracture and resharpening occurred, the smaller and smaller points were fitted into hafts of unchanged proportions. To accommodate this changing relationship between point length and haft length, Kay proposed that shims of increasing length were used to recreate a fixed basal abutment in the haft, as the point became progressively shorter.

Osborn (1999: 204–205) suggests that the Folsom point was placed in a "clamp-like" antler foreshaft without use of sinew binding. The foreshaft Osborn envisions is made in a single piece, with the stone point fitting into the prongs of the foreshaft with firm abutment against the base of the slot in the foreshaft. The idea for this model comes from weaponry of Arctic whale and walrus hunters in which detachable ground slate, ivory, and bone points were fitted to slotted toggle harpoon heads of antler or ivory (Osborn, 1999: 203).

The basally fixed abutment aspects of these and other models can be tested by careful study of basal margin treatment and use fractures. We believe archaeological data will support the sliding haft arrangement with facial friction and lateral marginal binding that we propose. Because the hafting model proposed here calls for the point to have been continually slipped forward between the haft pieces as fracture and resharpening occurred, we suggest that the finished point basal margin (the portion that lies between the projecting ears of the point) will have played a different and far less significant role in the haft arrangement than did the lateral haft margins. The basal margin was not butted against a solid part of the haft, and was not intended to absorb impact forces directed into the tip of the point. Rather, such forces were absorbed by (1) the high friction contact between haft and flute scar surface in combination with (2) the bindings against the lateral haft element margins that taper slightly toward the base, creating a self-tightening, wedging effect similar to that in a socketed haft. Study of basal margin treatment and fractures at the basal margin should confirm the non-functional role of this margin in the haft arrangement. As another archaeological test, we therefore expect studies to reveal that the basal margins of Folsom points will be less consistently dulled than the lateral margins, and when dulled, basal margins will often be treated in a manner different from the lateral margins. Further, because of the lack of firm contact between basal margin and haft, we expect few impact or use fractures in finished specimens to initiate at or propagate through the basal margin.

A small amount of data has already been collected that supports this idea. Titmus & Woods (1991: 124–126) note that lateral haft dulling occurs on 14 of 15 Folsom specimens they studied, while basal margin dulling occurs on only four of eight observable specimens. In a study of specimens from the Missouri River valley in North Dakota (Ahler *et al.*, in preparation), only 2 (10%) of 21 finished specimens had a basal margin dulled across its extent and in the same manner that lateral margins on the same point were dulled. Eight specimens (38%) lacked basal dulling of any kind, nine (43%) had dulling confined to the margin area just interior to the ears, and one (5%) had remnant dulling clearly related to platform preparation for flute removal. Additional, focused study along these lines with larger artefact samples should prove informative.

Use-wear

Bement's (1999*b*) tip resharpening model, an integral part of his proposed fixed haft arrangement, brings to the forefront a powerful kind of archaeological test for this problem—use-wear analysis on finished Folsom points. During use of a Folsom point, we expect high velocity contact and movement to have occurred between the exposed functional part of the stone weapon tip and bone or other external materials, and also between the haft element of the point and its haft. Use-marks from these two sources should have in common striations having an orientation approximately parallel to the long axis of the point. These two sources of use-wear will be clearly distinguishable, however, by the direction of motion between the stone point and the external material. Movement between the point and the target or environment will leave striations on the point that have a tip-to-base direction of motion. Movement of the point against the haft, in an impact situation, will have a base-to-tip direction of motion embedded into the stone surface. Further, the extent and distribution of these contrastive use-traces should provide direct information about the parts of the stone point that were enclosed within the haft, and the parts that were exposed to impact contact with target material. Finally, if the resharpening model suggested by Bement (1999*b*) was practiced, evidence should be clear in the form of transversely directed saw marks created while the distal end of the wood haft was whittled away.

Under the hafting model we propose, lacking fixed basal abutment, we believe it to have been common for the point to have shifted backward in the split haft upon severe impact. Haft bindings may have ruptured in instances of high impact forces, but this may in fact have been a built-in, breakaway design feature intended to minimize breakage in the stone point. From this model, we predict that in archaeological specimens striations from movement of the point in the haft (base-to-tip directionality) will be common, due to the absence of fixed basal margin abutment, and that such striations will occur over all parts of the flute surface, from the base to the tip of the point (indicating nearly complete encasement of the point in the split two piece haft). Striations from contact with the target (tip-to-base directionality) should occur almost exclusively forward of the termination point for lateral margin dulling—that is, only on the portion of the point we define here as the blade element. We further predict little evidence of contact that is not parallel to the long axis of the point, and a lack of use-wear evidence for cut marks associated with the distal end of the haft, as proposed in Bement's (1999*b*) resharpening model.

Systematic use-wear studies of points from single contexts should prove most fruitful regarding the predictions made here. A high-magnification use-wear study of 22 points from the Stewart's Cattle Guard site, partially reported (Kay, 1998), promises very interesting results. A low-magnification use-wear study of Folsom points from North Dakota (Ahler *et al.*, in preparation) is in progress, and particularly revealing data for one specimen can be reported here (Figure 10). The artefact is No. MRND-10, an unusually long, finished point of Knife River flint that because of its size, we have illustrated elsewhere (Figure 1) and used as a model for an finished, unbroken artefact. Even with its great length, discontinuities in marginal flaking near the tip indicate that this artefact was actually damaged and resharpened at the tip at least one time. Wear from use is confined to the channel flake surfaces on both faces. On Face 1, wear occurs in three diffuse areas of gloss on elevated undulations in the proximal half of the point (Figure 10(a)), in five discrete patchy areas (also slightly elevated) with polish and clear directionality or striations parallel to the long axis (Figure 10(b)), and in three narrow polish streaks with distinct directionality (Figure 10(c)). On face 2, use-wear occurs as an interrupted linear polish streak in the distal one-third of the point (Figure 10(d)). On both faces, details of striations (most clearly, Figure 10(b), (c)) indicate that the material in contact with the point moved from base-to-tip, consistent with movement of the point backward within the haft. The fact that use-wear in this direction extends off the end of the flute surface on face 1 and nearly to the distal end of the flute surface on the opposite face suggests nearly complete encasement of the point within the haft. We interpret all of this wear as consistent with backward movement of the point upon impact within a non-abutted, split haft. The basal margin of the point is undamaged, and not even dulled, clearly indicating lack of fixed basal abutment. In all respects, features on this point directly support the haft model and functional role of fluting we propose here.

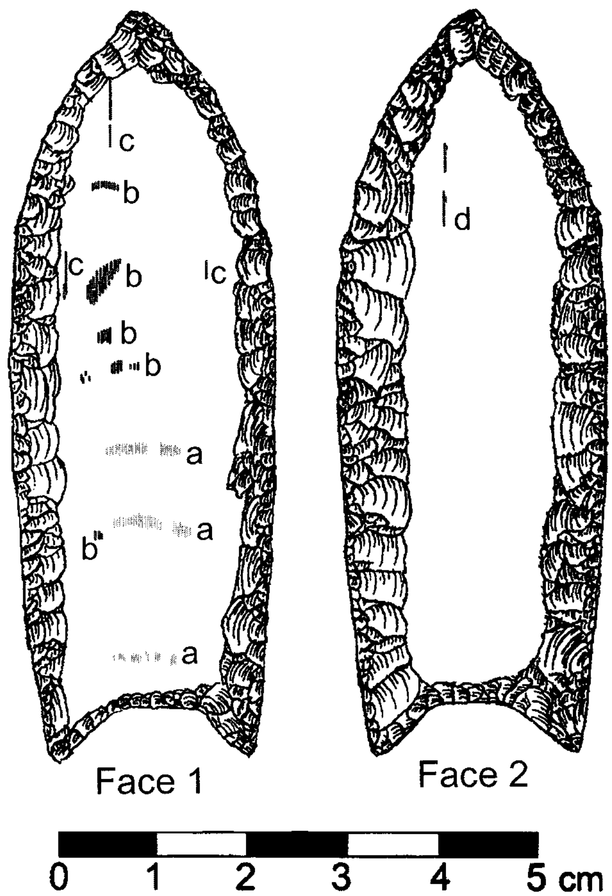

Figure 10. Use-wear on the Folsom point shown in Figure 1: (a) raised areas with diffuse polish; (b) raised areas with discrete patches of polish with striations parallel to long axis; (c), (d) flat or slightly concave surfaces with discrete linear polish streaks. At (b) and (c) it is clear that movement with contact material was from the base to the tip of point.

Finally, in the realm of tests, we must note the important role that actualistic tests and experimental studies of the proposed haft model should play in future research (see Flenniken, 1985; Flenniken & Raymond, 1986; Frison, 1989). Specifically, fluted points similar in size to specimens illustrated here (Figures 1 & 10) should be fabricated and hafted in the manner we propose, then used for big game hunting with a hand-held spear or atlatl. Through such experiments, limitations or refinements in various hafting models and fluting roles can be identified, and our understanding of Folsom technology greatly improved.

Discussion and Conclusions

Many recent studies have focused on variation in Folsom stone technology as a means for understanding highly inter-related factors of resource use and mobility patterns. There is little doubt from even a cursory understanding of Folsom stone technology, site types, site locations, and faunal assemblages that a heavy commitment to (specialization in) hunting of extinct forms of bison was the central element in their survival (Bamforth, 1988: 155; Frison, 1988). A high level of residential mobility was probably an accepted part of this commitment. Many studies of Folsom stone technology that deal with tool production, use, re-use, and conservation activities and strategies indicate that behaviour in these domains was organized to conform to the demands that come from a commitment to mobility (Judge, 1970: 190–193; Hofman, 1991, 1992; Ingbar, 1992; Amick, 1995, 1999: 2–5; Collins, 1999: 30).

We believe that the Folsom point hafting arrangement and lithic material conservation model proposed here fits well with available information regarding Folsom subsistence, mobility, and position in the surrounding cultural and natural landscape. More specifically, we believe that a high level of mobility, combined with unpredictability in scheduling of stone procurement, were the dominant circumstances that caused the Folsom point to be invented and used over a relatively long period of time [700 radiocarbon years (Haynes, 1993), or perhaps 1000 to 1500 calendar years (Kitagawa & van der Plicht, 1998)]. When either of these circumstances changed (mobility level or predictability in stone procurement), we anticipate that adherence to full fluting and the particular haft arrangement for Folsom points would have changed as well. That is, persistence through time in Folsom point production is predicated on both of these factors remaining constant, while a shift from fluted point production to another point form (reflecting different haft configuration and fracture management strategies) may reflect decreased mobility and/or increased predictability in access to raw material. Space does not allow treatment of these concepts here (see Ahler & Geib, 1999, in preparation), but it is clear that understanding the origin, dispersion, persistence, and disappearance of Folsom fluting is a complex issue involving timing of extinctions of all megafauna except bison within the Folsom range (see Graham, 1998), detailed understanding of calendrical dates for Folsom and other Palaeoindian complexes (see Kunz, 1998), relative chronology of Folsom sites throughout their broad geographic range, changes in human population densities, and the rapidly evolving biotic landscape at the close of the Pleistocene (see discussion of forage production during this critical period in Jodry, 1999).

The explanation for Folsom fluting offered here has bearing on some enigmatic aspects of Folsom point production noted at the beginning of this paper. If the purely technofunctional motivation for fluting we propose is accurate, then the purpose of fluting is removed from the "mystical" domain, and we may be less inclined to see need for a "fluting shaman" in Folsom culture. We do not deny that a high level of skill is required for making a Folsom point, but full resolution of the question of knapping specialists and fluting shamans now probably lies more in the realm of understanding how the point was fluted. The authors believe that through continued experimentation one or more simple methods yielding a high degree of success in full fluting—a procedure within the capacity of any Folsom knapper able to make a suitable preform—will soon be confirmed, and the apparent need for the knapping specialist/shaman will largely disappear.

We believe the broad explanation of Folsom fluting offered here makes the apparently high failure rate linked to the fluting process more understandable. The key to the fully functional Folsom point lay both in its complete fluting from base to tip (allowing use of the forwardly adjustable friction haft) as well as in its extreme thinness. Extreme thinness allowed fairly precise control of tip fracture (again, conserving stone) and tip resharpening without loss of penetrating and killing ability. If a thicker point were produced, front angle would have to be decreased in resharpened specimens to maintain penetrating ability, and this more extensive reworking would in turn diminish the number of use cycles in any given point. So, increased thickness worked against weapon conservation in the context of a hunt at some distance from raw materials. It is clear that Folsom knappers chose extreme thinness, with its concomitant failures and loss of material in the context of the knapping event, as a suitable tradeoff for a higher level of maintainability and higher weapon use-life when the cultural group was beyond predictable reach of stone sources.

If one accepts as reasonable and satisfying the technofunctional explanation of Folsom fluting offered here, it gives cause to reconsider the meaning of morphological variation among all Palaeoindian projectile point forms. One must ask if there is predominantly technofunctional meaning, rather than stylistic meaning, behind variation in clearly discrete types. In an obvious example, both the unfluted Midland point (Wendorf & Kreiger, 1959: 67; Amick, 1995) and the enigmatic "pseudo-fluted" forms common in Folsom sites (e.g. Wilmsen & Roberts, 1978: 111–113) are now fully understandable as direct technofunctional equivalents of the fully fluted Folsom form. These artefacts bear their form, not because their makers wished them to mimic the fluted Folsom point in appearance (as suggested by Storck, 1991), but because they were designed to fit the same sliding, friction haft as the fluted Folsom point.

A fruitful avenue of investigation, again beyond the scope of this paper, is careful and systematic reconsideration of the haft element treatment, fracture patterns, resharpening patterns, and probable haft arrangement (basally abutted versus forwardly adjustable, friction haft) in several recognized Palaeoindian point types that precede and post-date Folsom artefacts (see Ahler & Geib, 1999, in preparation). Such studies, in which point morphology is perceived as intimately linked to subsistence, mobility, and predictability of access to stone raw material, should prove enlightening regarding topics such as multiple cultural co-traditions within Plains Palaeoindian complexes (Stanford, 1998). Similarly, the fully fluted point forms in eastern North America such as Cumberland, Gainey (Morrow & Morrow, 1996), and Barnes (Ellis & Payne, 1995) bear re-examination in light of the functional link between fluting and broader cultural adaptive features offered here.

The primary conclusions one should draw from the foregoing treatment are as follows.

(1) Although elements of art, ritual, ceremony, and religion may have been involved in the production and use of the fluted Folsom point, a purely technofunctional explanation linked to hafting configuration and raw material conservation offers a satisfying answer to the question that has intrigued archaeologists and others for decades.
(2) Previous scholars have all suggested that the Folsom point was mounted in a fixed, basally abutted haft. We conclude that the Folsom point was designed to fit in a split or two-piece, forwardly adjustable friction haft.
(3) The haft arrangement for the Folsom point offered strength and confinement of breakage to the extreme distal tip, greatly reducing loss of stone from fracture and extending the working use-life of the tool. By minimizing fracture and slipping the point forward for remounting in the haft, many cycles of use could be obtained from a single point.
(4) Full fluting and extreme thinness in the Folsom point were designed for high penetration as well as a high degree of maintainability through resharpening, even in severely fractured specimens, with virtually no loss of penetrating ability.
(5) The high maintainability and extreme stone conservation design features built into the Folsom point reflect the central elements of specialized bison hunting, commitment to high mobility, and unpredictable access to stone raw material that pervaded the Folsom lifeway.
(6) The explanation for Folsom point fluting, hafting, and design offered here is fully compatible with other more comprehensive studies of the organization of Folsom stone technology in which mobility, staged tool production, and high concerns for material conservation play important roles.
(7) The explanation of Folsom fluting offered here can be tested and refined through studies of finished point and preform length, artefact proportions and fracture patterns, basal margin treatment, use-wear in archaeological specimens and through actualistic studies of experimental point/haft arrangements.
(8) If one accepts the importance of technofunctional concerns in the design and manufacture of the Folsom point, then similar factors should be

considered relative to several other morphologically and technologically distinct Palaeoindian projectile point forms common to the Great Plains, Upper Midwest, and Northeast. Such new considerations may alter our perceptions of early cultural group relationships and adaptations as well as properties of the natural landscape at the close of the Pleistocene across a large part of North America.

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