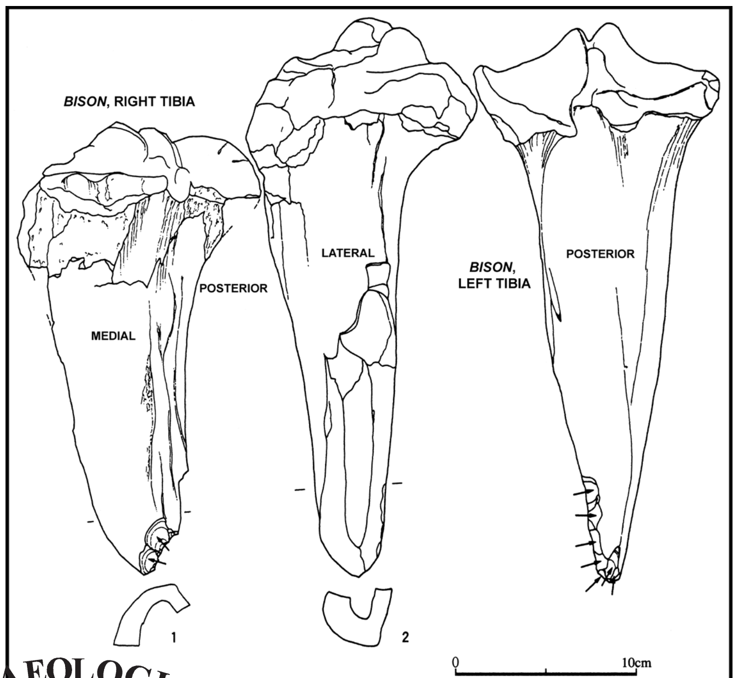
THE WYOMING ARCHAEOLOGIST



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ANOTHER ELK PETROGLYPH FROM THE GATEWAY SITE: SOME POSSIBLE FUNCTIONAL IMPLICATIONS

by
JAMES D. KEYSER
GEORGE POETSCHAT

INTRODUCTION

During a field trip in conjunction with the Fall 2006 meeting of the Wyoming Association of Professional Archaeologists (WAPA), the authors led a group to the Gateway petroglyphs (48LN348), which had been recorded two years before (Keyser and Poetschat 2005). During the site visit a combination of low-angled Fall sunlight (on September 16) and the attention of several experienced rock art researchers resulted in the recognition of a large elk figure, only parts of which (legs, antlers) had been previously recorded. In order to provide a more complete site record, we returned to the site a few days after the field trip to record this elk and improve the tracing of another elk figure at the site.

THE GATEWAY SITE

The Gateway site is a small concentration of petroglyphs incised and abraded on several faces of a distinctively-shaped sandstone outcrop perched high on a sharply rising ridge above the confluence of Fontenelle Creek and the Green River. Located on the highest point of this steep-sided ridge, the site has a commanding view to the east down Fontenelle Creek valley and out onto the Green River floodplain, now inundated by the waters of Fontenelle Reservoir. Deeply incised or abraded petroglyphs at the site are found on both surfaces within a deep cleft between two parts of the sandstone bedrock outcrop, and also outside this cleft on the outcrop's northeast facing side. The original recorders divided the site into five separate panels (Keyser and Poetschat 2005:112), the largest of which—Panel 1—is located within the cleft on its interior, south facing wall. This panel dominates the site, with more than 70 images—nearly half the site total.

THE GATEWAY ELK

Originally, single elk were recorded on panels 1-4 at the site. Panel 5 consists solely of large tool grooves. The newly-recognized Gateway elk (Figure 1) is located on Panel 1, right at the entrance to the site where one must climb over a steep pile of large sandstone boulders to enter the wide cleft in which most of the petroglyphs are carved. Due to gradual shifting and downslope movement of these boulders, which are perched right at the lower entrance to the cleft, the newly recorded elk figure is partially behind a large rock. Formed by a deeply ground out body with incised front and rear legs and large incised antlers, the animal is crossed, just ahead of the hind quarters, by a vertically-oriented arrow drawn point up and showing obvious fletching. Of the four other elk at the site, two are pierced with arrows in nearly identical fashion.

In addition to the newly recorded elk figure, we re-examined all four other elk figures at the site and made some slight changes to the tracing of the one incised on panel 4 (Figure 2). Our effort with this image was intended to delineate more clearly this animal's antlers. The other three elk at the site (Figure 3) were examined and found to be adequately traced.

ELK IN ROCK ART AND ARCHAEOLOGY

Elk, though not especially common in Northwestern Plains rock art, occur regularly—usually

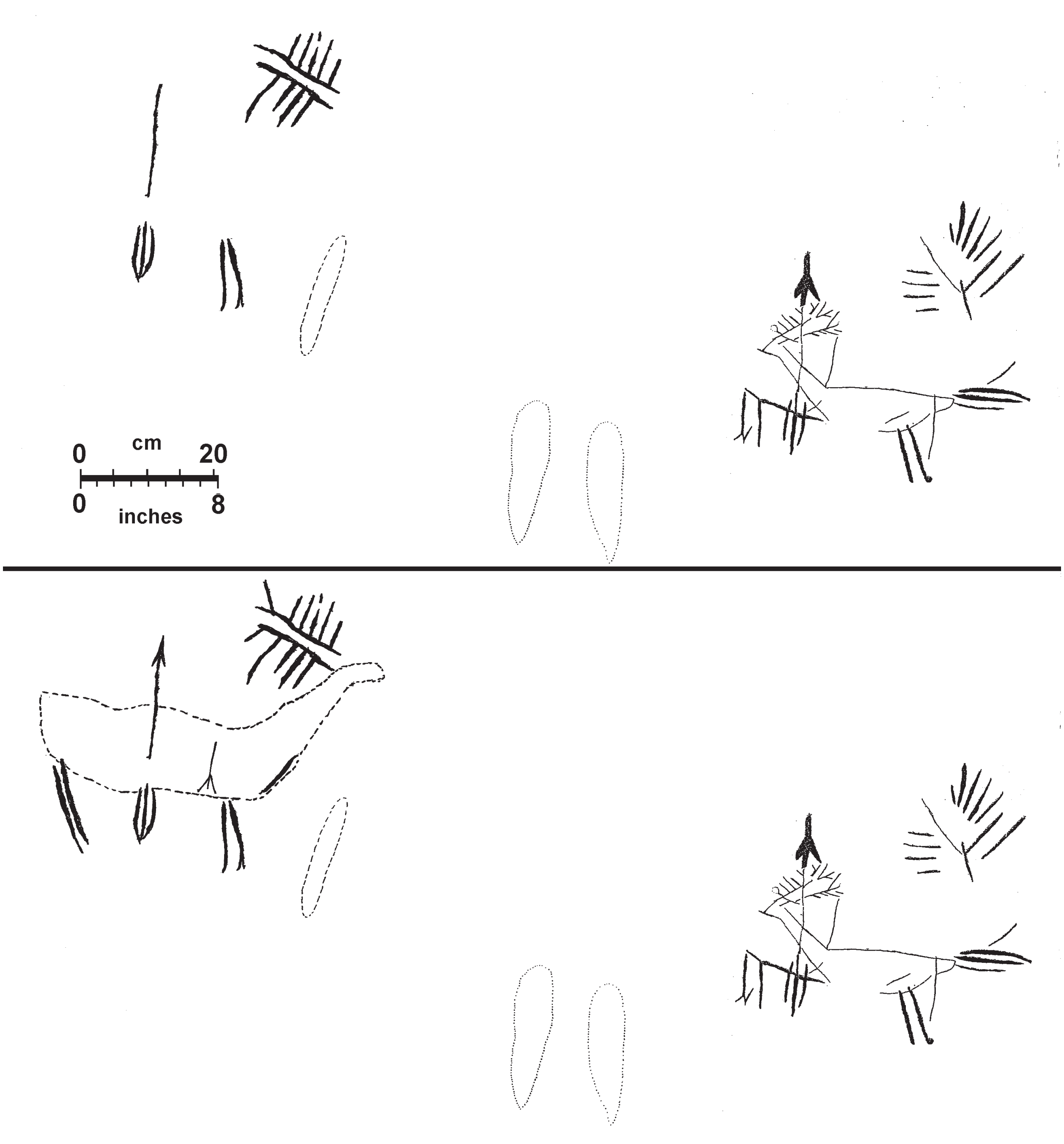

Figure 1: The newly recognized elk figure at the Gateway site. Upper portion is tracing done in 2004. Note elk's antlers, partial arrow and front legs at left. Lower portion is revised 2006 tracing, with addition of elk's body, rear legs, and arrow point. Dashed lines at left show large shallow tool groove and body of elk. Deeper tool grooves are shown in lower center by dotted outlines. Note second elk to right, originally recorded in 2004.

as single animals—at sites throughout the region (Conner and Conner 1971). For instance, more than 60 sites at Writing-On-Stone show only five elk (Keyser 1977:32-33, 75, 79), 42 sites in the North Cave Hills have five elk (Keyser 1984:11), Pictograph Cave has six elk among 21 quadrupedal

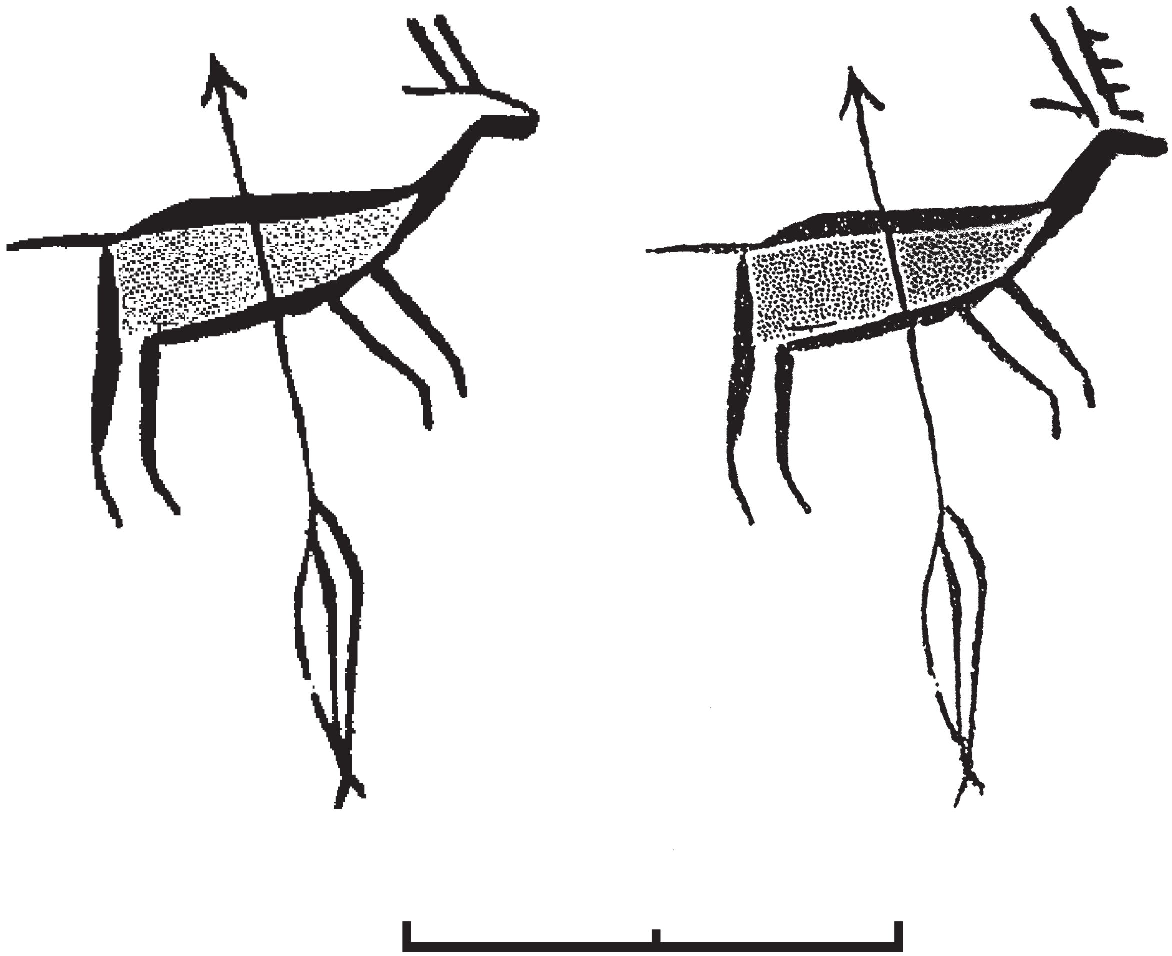

Figure 2: Revised tracing of elk on panel 4 of Gateway site. Original 2004 tracing at left; revised tracing, showing better antlers, at right. Scale bar is 20 cm.

animals (Mulloy 1958:126-139), Castle Gardens has only five elk among its nearly 30 quadrupeds (Gebhard et al 1987), and among 68 quadrupeds at Bear Gulch there are only three elk (Keyser et al 2007a). Other rock art sites and surveys show similar densities of elk representations (Buckles 1964; Francis 1991; Francis and Loendorf 2002; Fredlund 1993; Keyser 2005). The only exception to this general Northwestern Plains pattern is the Archaic period Early Hunter Tradition rock art of Whoopup Canyon and the Black Hills, where elk are commonly shown as both individuals and herds in hunting scenes (Sundstrom 1984, 1990; Tratebas 1993).

Closer to Gateway, elk are found at Cedar Canyon (Figure 4c), White Mountain (Bozovich and Bozovich 1968:14-15), Powder Wash (Keyser et al 2007b, see also Figure 4a), and LaBarge Bluffs (Keyser and Poetschat 2005:24-25). In this study we used the antler typology of Tratebas (1993:166) to differentiate elk (main beam with side tines) from deer (branching antlers), so the animal at Calpet (Francis 1991:424; Francis and Walker 2000: 41) seems most likely to be a deer. Only the four elk at LaBarge Bluffs are particularly notable because they occur in multiple animal compositions on different panels and yet all appear to have been drawn by the same hand (Keyser and Poetschat 2005:60).

Showing elk shot at or pierced by an arrow is not particularly common in Northwestern Plains

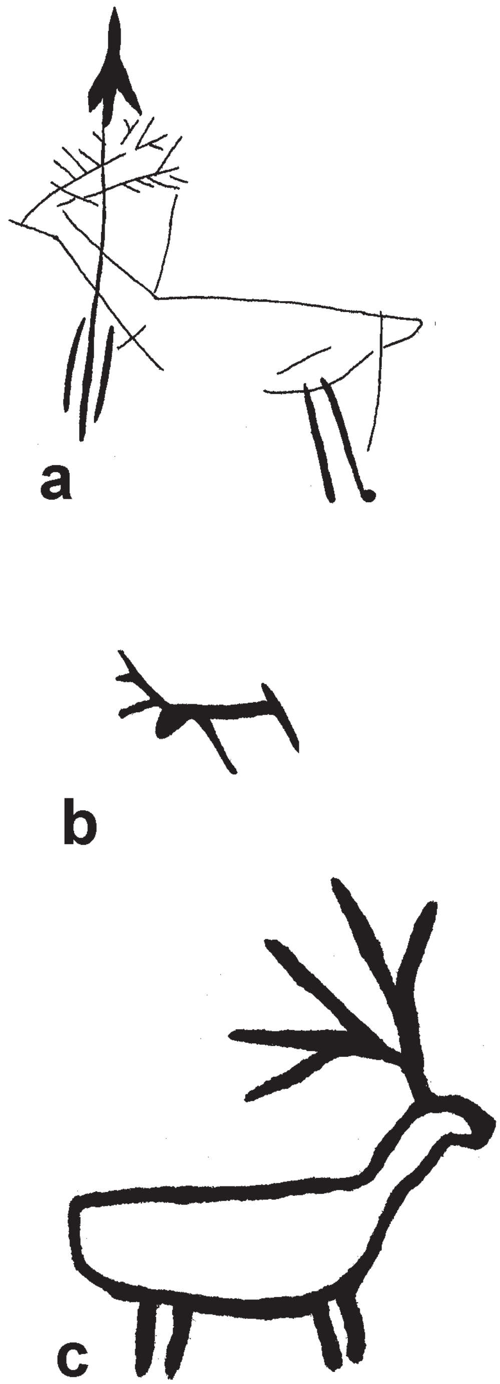

Figure 3: Elk at the Gateway site. a, also shown on panel 3 in Figure 1 (at right); b, on panel 3 on horizontal surface; c, on panel 1. Variable scale.

rock art, but a review of the literature shows it does occur at seven other sites: Pictograph Cave (Mulloy 1958:Figure 27); Davidson Microcave and Pryor Creek (Conner and Conner 1971:25, Figure 26); Medicine Lodge Creek (Francis and Loendorf 2002:159); Lander (Frison 2004:220); White Mountain (Bozovich and Bozovich 1968:14-15); and 48JO309 (Grey and Sweem 1961:6). Only rarely do elk appear in hunting scenes (Conner and Conner 1971:25). Interestingly, arrow-pierced elk are about as common as arrow-pierced bears (Conner and Conner 1971:26; Frison 2004:220; Grey and Sweem 1961; Keyser 2005). Since bears were not typically hunted for food, their being shot with arrows is usually interpreted as some sort of ritual (Conner and Conner 1971:29). In Plains biographic art bears are sometimes shown as the objects of coup counts (Keyser 2004:101) since the danger inherent in killing one was seen as equivalent to fighting a human foe. However, there is no evidence for such coup counted bears in Late Prehistoric period rock art, and in any case, elk would not have been equated with dangerous enemies in this same way. This might suggests the arrow-pierced elk had ritual significance, rather than simply being a record of hunting activity (Conner and Conner 1971:30).

Surprisingly, given their current popularity as game animals, elk food bones are conspicuously absent from the Northwestern Plains archaeological record (Frison 1991:260-263, 2004:181-186). Other than antlers, most often cut or modified for use as tools such as stone working hammers, few elk remains are found in Northwestern Plains sites. And even antlers are not particularly common, usually occurring as single tools or a few worked fragments in occasional occupation and kill sites from Paleo-Indian to Historic times (Frison 1991:261; 2004:181-183). The paucity of elk remains is true for sites found all across the Northwestern Plains, and the occurrence of so many excavations done in the last three decades of cultural resource management work makes it highly unlikely their scarcity is merely a sampling problem. Unlike the evidence for communal trapping of both bison and mountain sheep, neither corrals nor jumps are known for the communal hunting of elk. Finally, in rock art only two Northwestern Plains compositions—at Pryor Creek, Montana and Cedar Canyon, Wyoming—show elk actually being shot or chased by hunters

(Conner and Conner 1971:25, see also Figure 4). Both of these are Historic period horseback chase scenes, and the horsemen drawn at Cedar Canyon carry guns.

Thus, the archaeological record indicates elk were not extensively killed for food during the Late Prehistoric period, but they do appear regularly, though infrequently in the rock art of this time. This situation contrasts almost completely with bison, which appear by the hundreds of thousands in Late Prehistoric period kill sites and occupations across the Northwestern Plains (Frison 1991:155-237; 2004), yet are notably less common than elk in rock art (Table 1). A cursory review of the rock art literature, using essentially the same sites and surveys as previously referenced for elk, shows rock art elk outnumber bison 38 to 24. Neither bison nor elk hoofprints from Hoofprint Tradition sites are considered in this comparison.

The regular occurrence of rock art elk combined with their apparent rarity as a food resource in Plains sites begs the question of why they are drawn so regularly in rock art and, more specifically, why they are shown shot with arrows at eight sites (including three individuals at Gateway). The attribution of supernatural power to the elk is relatively common among Plains tribes (Bowers 1992:355; Lowie 1954:173; Maurer 1992). Elk are shown in several rock art scenes suggestive of the acquisition or use of supernatural power (Francis and Loendorf 2002:159-160; Keyser 1977:Figure 30), and others are shown in juxtaposed compositions that seem to reflect some sort of supernatural, rather than subsistence, importance (Keyser 1984:Figure 12e; Keyser et al 2006:57; Keyser and Poetschat 2005:24-25). One such composition at Castle Gardens includes an elk, vulvaforms, and a female human (Francis and Loendorf 2002:160). Such iconic depictions call to mind the images of various animals used as shield heraldry and iconic decoration for other Historic Plains Indian material culture items (e.g., Lowie 1935:87; Maurer 1992:125-126, 160)

One specific type of supernatural power regularly attributed to the elk, both in mythological and everyday magical contexts, was "love medicine" (Ewers 1960:163; Maurer 1992:130-131; Wissler 1905). Although this is best known for the Crow (Ewers 1960:163; Lowie 1918:192-197; 1922:424-425; Maurer 1992:131; Wildschut 1925, 1960:123-

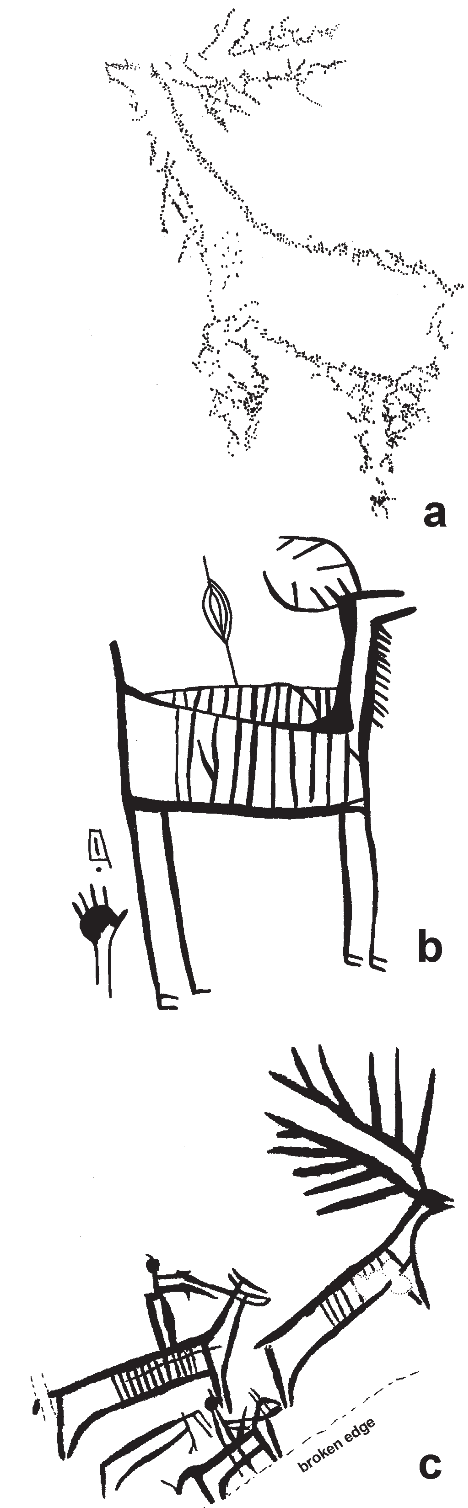

Figure 4: Other Northern Plains elk figures. a, Powder Wash, Wyoming; b, Davidson Microcave, Montana; c, Cedar Canyon, Wyoming. b is adapted from Conner and Conner (1971); note vulva and hand to left of elk, which show "vulva capture" (Keyser et al. 2006).

Table 1: Frequency of Elk and Bison in Plains Rock Art.

Site/Area	N sites	N Quadrupeds*	Elk	Bison	Other Game	Non-Game	Not Identified**
Writing-On-Stone	60	75	5	11	11	8	27
Pictograph Cave	1	21	6	2	2	7	4
Bear Gulch	1	68	3	3	9	17	36
Ashland	17	7	2	--	1	4	--
Castle Gardens	1	29	5	2	9	3	10
North Cave Hills	42	31	5	5	2	2	17
Upper Green River***	4	23	9	1	--	1	12
Recognition Rock	1	7	3	--	2	2	--
	127	261	38	24	36	44	106

* Horses excluded in total number of quadrupeds
** Quadrupeds without sufficient detail to identify to species.
*** Includes Gateway site.
References for these sites are: Writing-On-Stone (Keyser 1977); Pictograph Cave (Mulloy 1958); Bear Gulch (Keyser et al 2007a); Ashland (Keyser 2005); Castle Gardens (Gebhard et al 1987); North Cave Hills (Keyser 1984); Upper Green River (Keyser and Poetschat 2005); Recognition Rock (Fredlund 1993).

132), it also occurs among the Sioux (Ehrlich 1937:310; Ewers 1960:163; Maurer 1992:130; Sundstrom 2004; Wissler 1905), Assiniboine (Ewers 1960), Cheyenne (Maurer 1992:132), Mandan and Hidatsa (Ewers 1960:163), and possibly other groups as well.

Such medicine could be acquired directly by the person using it, from their own visionary experience, or it could be borrowed from someone else who had obtained it in their vision and then successfully used the particular charm. Such charms could include human or elk effigy figures, hides painted with elk images, flutes called “elk whistles,” an elk antler headdress, or a belt made from the leg skin of an elk (Wildschut 1960:123-132). Notable among all of these are the elk images, which still retain their popularity in today’s Crow culture (Tim McCleary, personal communication, 2006).

McCleary (personal communication 2006) also notes:

> “This idea of the elk as metaphor for masculine sexual prowess persists to this day. Some years ago the State of Montana started offering a license plate with an image of an elk—funds [collected from those who buy this special ‘vanity’ plate] go to support the Rocky Mountain Elk Foundation. It is the second most popular plate on the reservation—after the official Crow Tribal plate. Now you can’t tell me that Crow people are that interested in supporting the Rocky Mountain Elk Foundation.”

Crow men saw the bull elk, with his distinctive bugling to acquire and maintain a harem of cows, as the supernatural personification of power for the seduction of women. In one Crow vision, described by Wildschut (1925:211-215), a bull elk transforms into a man wearing an elk skin robe painted with an elk image and then parades in front of the supplicant saying “I am the medicine elk; whenever I want a woman, I can make the one I love best come to me.” In this vision, the medicine elk also instructs the supplicant to “parade in front of the woman you want [wearing the painted elk skin robe]. Sing the song I have just given you, and she will come to you.” The supplicant, a man named Fog, was said to have made an elk robe like the one worn by his visionary spirit and used it successfully. He is also reported to have lent it to many other men who were equally successful (Wildschut 1925:213-214; 1960:125-126).

In addition to Fog’s elk robe, painted with an elk image, numerous other bull elk images are known to have been used as love medicine. Wildschut (1960:123-125) illustrates a second love medicine robe originally belonging to Travels, who painted it sometime in the mid 1800s. On this elk skin robe is a painted scene in which a bull elk, with head up in the bugling posture, closely pursues a cow elk, who looks over her shoulder as if she cannot resist her suitor. Other, similar robes with paintings of bull elk, are reported to have been owned and used by legendary love charmers (Lowie 1918:196-199; Wildschut 1960:126-129). Finally, there is another elk effigy fetish, made from rawhide, in the form of a bugling elk, with head thrown back and mouth open, that was part of the medicine bundle of Long Tail (Wildschut 1960:130).

Furthermore, the Crow believe elk medicine designed to attract women can be "shot" as a magical arrow, to infect the intended object of a lover's interest. Again according to Tim McCleary (personal communication 2006), "The Crow word for the act of 'infecting' someone with love medicine is *duskua*. The term literally means 'to shoot somebody, or something,' metaphorically referring to 'shooting' somebody with the spell causing agent." Lowie (1922:424-425) reports essentially this same word—his transcription is *duck uo* (with the c sounding like sh)—used in casting a spell, either for love charming or sorcery.

Among the Crow, both men and women employed elk love medicine, often in the form of a medicine bundle or charm (Lowie 1922; Wildschut 1960). It seems men most often used various bull elk symbols (effigy figures, painted images of the animal, elk antlers) while women tended to use botanical materials (pine pitch, odorous herbs, or a special plant used as incense) in employing such love medicine (Lowie 1922:424-425; Wildschut 1960). However, both men and women received their medicine in visions where bull elk played the central role (Wildschut 1960:124, 125, 131).

Among the Sioux, Elk were also strongly associated with "love medicine." Elk spirits were thought to give men power over the sexual passions of women (Wissler 1905), and a variety of flutes, pipes, and magic talismans were decorated with elk imagery (Maurer 1992:130-132). In these societies, it was felt Elk Dreamers (those who had seen elk in their visions) could attract any woman they wanted (Berlo 2000:56-58, Sundstrom 2004:181-185).

Given the strong and widespread Plains Indian belief that elk embody love medicine, it seems reasonable to suggest — as have previous rock art scholars (Conner and Conner 1971:30; Francis and Loendorf 2002:158) — that many of the rock art elk are portrayed not for their importance as food, but for their supernatural seductive power. Furthermore, showing them shot at or pierced by an arrow may reflect not the killing of these animals, but instead the idea of shooting the love power they embody into an intended target.

Aside from simply asserting the connection between elk and love medicine, the known Northwestern Plains rock art elk representations show several hints some or all of them were drawn to invoke just such "love power." Six of the eight Northwestern Plains sites with elk shot by an arrow are centered in the country of the Crow—the tribe most strongly associated with the belief in elk love medicine, and the other two sites—White Mountain and Gateway—are located less than 50 miles southwest of the southern extent of Crow territory (Voget 2001:696).

In addition to the several examples of arrow-shot elk, compositions at four other sites have an obvious sexual theme. At Pictograph Cave, one of the sites located in the center of Crow territory, the six painted elk (one of which is shot at with arrows or spears), share the shelter walls with two obvious sexual intercourse scenes (Mulloy 1958:131, 134). At LaBarge Bluffs, two bull elk, each with their neck outstretched and head up in a characteristic bugling posture (Figure 5), are pursuing a cow elk (Keyser and Poetschat 2005:24) in a scene mimicking the rutting behavior of rival bull elk vying for control of a cow (Keck 2006). This scene is also notably similar to one painted on Travel's love medicine robe (Wildschut 1960:Figure 51). At Castle Gardens, a more symbolic composition shows a human female, with prominent vulva, juxtaposed with several vulvaforms and a bull elk with four short lines issuing from his muzzle in what appears to be a representation of the bugling call (Francis and Loendorf 2002:160).

Additionally, the shot elk at Davidson Microcave (Figure 4b) is associated with a stylized hand print reaching up to touch a rectangular vulvaform. This composition is the sexual "capture" hand that illustrates another instance of "vulva capture" in Plains Biographic rock art (Keyser et al 2006). Associating this obvious sexual sign that graphically and symbolically stands for the sexual capture of a woman, with the shot elk is strong support the elk itself represents love medicine.

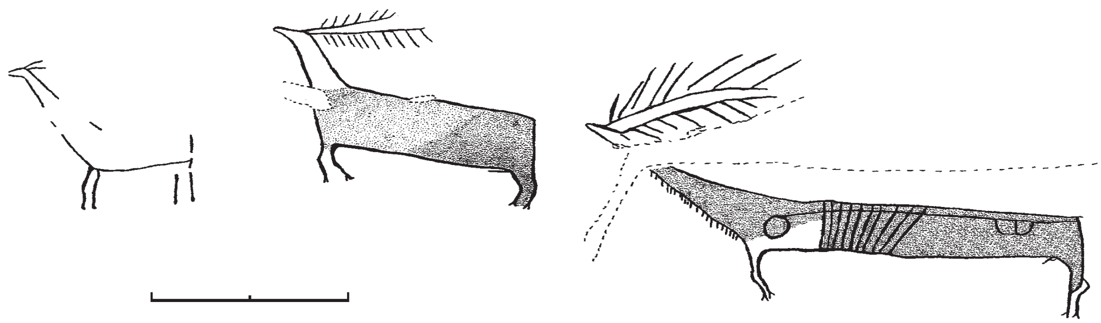

Figure 5: Three elk at LaBarge Bluffs. Dashed lines indicate eroded areas on middle animal and large fracture separating head from neck on animal to right. Scale bar is 40 cm.

Finally, there is the Gateway site itself. The prominent cleft atop the ridge has an obvious vulvaform shape (Figure 6), and at the site there are nearly 40 large, wide, shallow tool grooves, several of which have narrower, deeper median grooves strongly suggesting vulvaforms. Added to this vulva symbolism are the five elk figures, three of which are shot with arrows.

The vulva symbolism of the site itself and the numerous tool grooves carved there originally led us to propose the site had been a place of women's power at some point in its history. The earliest art clearly has a male-gendered warfare theme, focusing on simple, Seedskadee style shield bearing warriors and their weapons, and a few other images. Based on one key superimposition of a large tool groove over one spear-carrying Seedskadee style warrior (Keyser and Poetschat 2005:123), it appears the Plains Groove tradition art at the site is later than this warfare art. This Plains Groove art also appears to be different from warfare art, both structurally and functionally.

Basing our interpretation on a Plains-wide association of such large tool grooves with the ritual

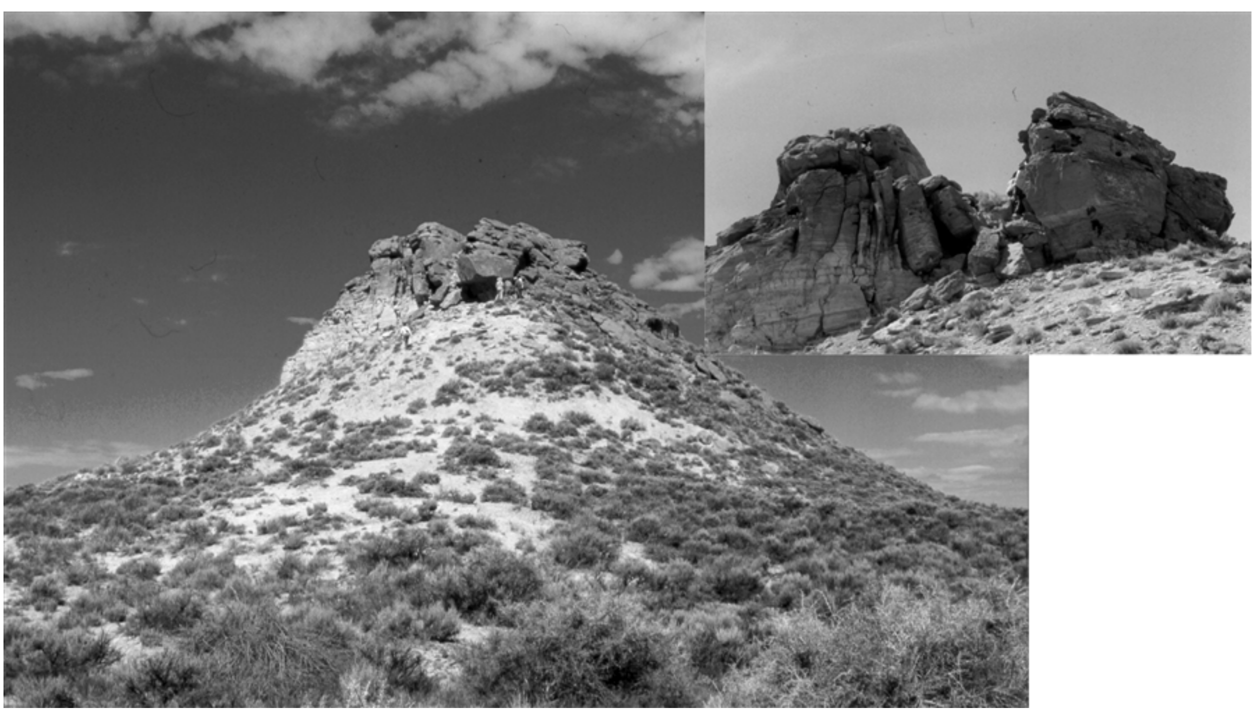

Figure 6: Location of Gateway site atop steep ridge. Inset shows vulva-shaped cleft in sandstone outcrop.

sharpening of women's tools, we suggested this art indicated the site was later used as a place of power associated with women (Keyser and Poetschat 2005:164). The basic distinction between these two suites of rock art imagery is further supported by the distinctly separate physical locations of the various images in the site, since 20 of the 21 large tool grooves are found on panels other than the main "warfare scene" panel, which is located deep within the cleft (Keyser and Poetschat 2005:119). Instead, a few of these grooves are found at the entrance to the cleft, significantly below the warfare panel, but most are found on two panels outside the cleft on the northeast-facing cliff surfaces above Fontenelle Creek. Although the chronological relationship of the elk to any of the other art cannot be conclusively demonstrated, the spatial relationships clearly associate the elk with the grooves and not with the warfare scene.

Now, with the discovery of a fifth elk at Gateway, and the recognition three of them are pierced by arrows, we suggest the site may also have served as a place to obtain elk "love medicine," thought by members of several tribes to assist in the sexual seduction of women and felt by Crow women to help restore the fidelity of a "wandering" husband (Lowie 1922; Wildschut 1960). Like the tool grooves, the elk at the site also occur on panels other than the main warfare panel, although two of them are carved within the cleft—one on the left side of the cleft, facing the warfare panel and the other (the sketchiest example) on a horizontal surface below and to the right of the main panel. The three other elk, and all of those pierced by arrows, are strongly associated spatially with the large tool grooves.

Thus, it seems likely the site functioned in three ways. Initially it was a proto-narrative battle scene, extolling an actual event—a fight between opposing forces. Associated with this are several symbolic images, including several comb-like forms and a long "arm" with hand extending above the battle (Keyser and Poetschat 2005:115). This long arm is positioned in such a way that it appears to be influencing the fight in some way—possibly as spiritual protection or a portent of victory for one side or the other. Similar protective symbolism is known for a particular Late Prehistoric period shield design at Bear Gulch, which shows a human arm and hand reaching out from a darkened half of the shield which likely represents a cloud (Keyser et al 2007a).

Following this war oriented art, the site may well have been a place where women obtained power, as suggested by large shallow tool grooves, some of which resemble vulvaforms. That these were women's petroglyphs was inferred from the likelihood the tools being sharpened were women's bone hide-working tools such as awls, quill flatteners, or hide fleshers. Several wide tool grooves on a panel at DgOv-2 at Writing-On-Stone are so wide they were attributed to the sharpening of "utilitarian tools" (Keyser 1977:47). Based on their width and depth these grooves seem most likely to have been made by shaping the blades of bison metapodial hide fleshers—another example of women's tools being shaped or sharpened at rock art sites. Fewer male-oriented tools are known that would require sharpening and leave grooves such as those at tool groove sites. Finally, the detailed ethnographic analysis of similar grooves associated with vulvas has identified such Plains Groove tradition sites as women's vision quest art elsewhere on the Northern Plains (Sundstrom 2002a, 2002b, 2004, 2006).

The third function of the site appears to have been a place where supplicants came to obtain love medicine to aid in their seduction of the opposite sex. Because the depictions at the site are antlered bull elk, one could interpret them as men's charms for seducing women, if Crow practices can be assumed to have structured this site. However, we know Crow women dreamed of bull elk that gave them love medicine (Wildschut 1960:131), so these images need not necessarily represent male rock art. At present we cannot say what sex was responsible for the elk petroglyphs at the site.

Could three such apparently widely different functions actually reflect the site's use? Such a switch in gender function (from men's warfare, to women's power, and then possibly back to men's seductive power) would not be unreasonable, given the different ethnic groups with access to this site over the last few centuries when the petroglyphs were carved. In fact, just such a shift, from a women's place to a young men's place, has been recently recognized for a prominent petroglyph site in the Italian Alps (Fossati 2006:268-270). Likewise, having both women and men recognize the site's obvious vulvaform morphology, and then carve both male and female art there would not be contrary to Plains Indian beliefs as expressed at other rock art sites showing a gendered mix of images and offerings (Keyser 1984:7; Sundstrom 2002b, 2004).

CONCLUSIONS

Despite Campbell Grant's (1967:32) assertion that most rock art animal images, and especially those pierced with arrows or spears, were hunting related, little Late Prehistoric and Historic period Northwestern Plains rock art imagery shows a hunting theme. Instead, most animals and humans are drawn as iconic images, apparently associated with supernatural themes and activities (Francis and Loendorf 2002; Keyser 1977, 1984, 2004; Keyser and Klassen 2001; Sundstrom 2004). In this period, only the Biographic art tradition, whose primary function was to illustrate narratives of personal glory, do hunting scenes regularly occur, and even these are not particularly common. We are well aware the Early Hunting Tradition art shows many scenes of trapping and killing animals, but this rock art dates several thousand years prior to the Late Prehistoric and Historic periods.

The images at the Gateway site not structured around a warfare theme are exactly such iconic images. Of these, five are elk — one of the largest concentrations of such animals in Plains rock art — despite the fact that this is a relatively small site, with fewer than 150 images. These elk appear to have been carved at the site as "love medicine," and document a change in site function from both the warfare imagery and the probable women's imagery found at the site.

We cannot determine what ethnic group(s) may have been the artists responsible for the elk carved at Gateway, but such arrow-pierced elk are strongly correlated with Crow territory, and the site is not unreasonably far from the southern extent of Crow country in the period when it was used. Possibly it is an example of Crow rock art love medicine.

ACKNOWLEDGMENTS

We thank the Wyoming Association of Professional Archaeologists for the opportunity to revisit the Gateway site. Sam Drucker provided us a place to stay for the meeting. On the field trip, it was Julie Francis who suggested the possibility these elk might represent love medicine—a comment that spurred us to record the newly discovered elk and undertake this research. As he has previously, Bill Current provided financial support to our research efforts. Our friend, Phil Adolf, assisted with recording the newly discovered elk image.

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FRACTURE PATTERNS OF BONES IN ARCHAEOLOGICAL CONTEXTS: SIGNIFICANCE OF THE CASPER SITE MATERIALS

by
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MATERIAL CONDITIONS

The original objects for zooarchaeological analyses are specimens excavated in Paleolithic and later sites, although there are many arguments in the discussion of bone modification regarding human or non-human origin. The breakage principle for large mammal cylindrical bones is a model suggested either from excavated bones from these archaeological sites or from breakage experiments. Before I discuss the worldwide examples of animal bones from Paleolithic sites (see Ono 2001), we have to discuss another topic. The reason for this is there are many unclear aspects and gaps between the theoretical principle of bone breakage and actual bone specimens. Although these gaps cannot be filled completely, we need to discuss about some critical points.

In the study of Paleolithic flaked bone tools, the most important criteria are the quality of preservation and completeness when we are trying to elucidate details of fracture on cylindrical bones. There are virtually no examples which adequately satisfy these criteria. We must use specimens which are as close to the ideal conditions. The close-to-the-ideal conditions are: 1) the bones are from sites where hunting of large mammals was carried out; 2) the site is considered or close to Paleolithic in age; 3) the curated collections are in good order; and 4) there is good preservation of the bone specimens.

For criteria 1, 2, and 3, the Tategahana site, a Japanese site at the shore of Lake Nojiri is appropriate (see Ono 2001). For all four criteria, the Bilzingsleben site in Germany is fairly appropriate (Ono 2001). However, when criteria 4 takes precedence over the other criteria for close observation and the other criteria are adequately satisfied, the Casper site (Frison 1974) in Wyoming is the best. At the Casper site, there are many exceptionally well-preserved specimens from a sand dune site scattered among more weathered bone specimens. These examples allow close investigations and examination, just like experimental specimens. Moreover, the completeness of the assemblage is exceptionally excellent, and the relationships between bone and other archaeological specimens can be analyzed.

The Casper site provides a bridge between Paleolithic materials which are not preserved well and the principle of cylindrical bone breakage. To discuss aspects of bone breakage and give a guideline for the understanding of bone specimens from other sites, I am going to discuss details of bone breakage in the Casper site examples before we move on to flaked bone tools worldwide (Ono 2001).

DESCRIPTION OF THE CASPER SITE

The Casper site is located at the west end of the city of Casper, Natrona County, Wyoming in the United States. The site is on a sand dune river terrace on the west bank of the North Platte River. The site elevation is 1590 meters or 36 meters above the modern riverbed and about 1.1 km northwest of the river (Figure 1). There are five terraces, the lower two formed during the Holocene, while the upper three were formed during the Pleistocene. The Casper site is located on the fourth terrace from the bottom and in a Pleistocene sand dune. The sand

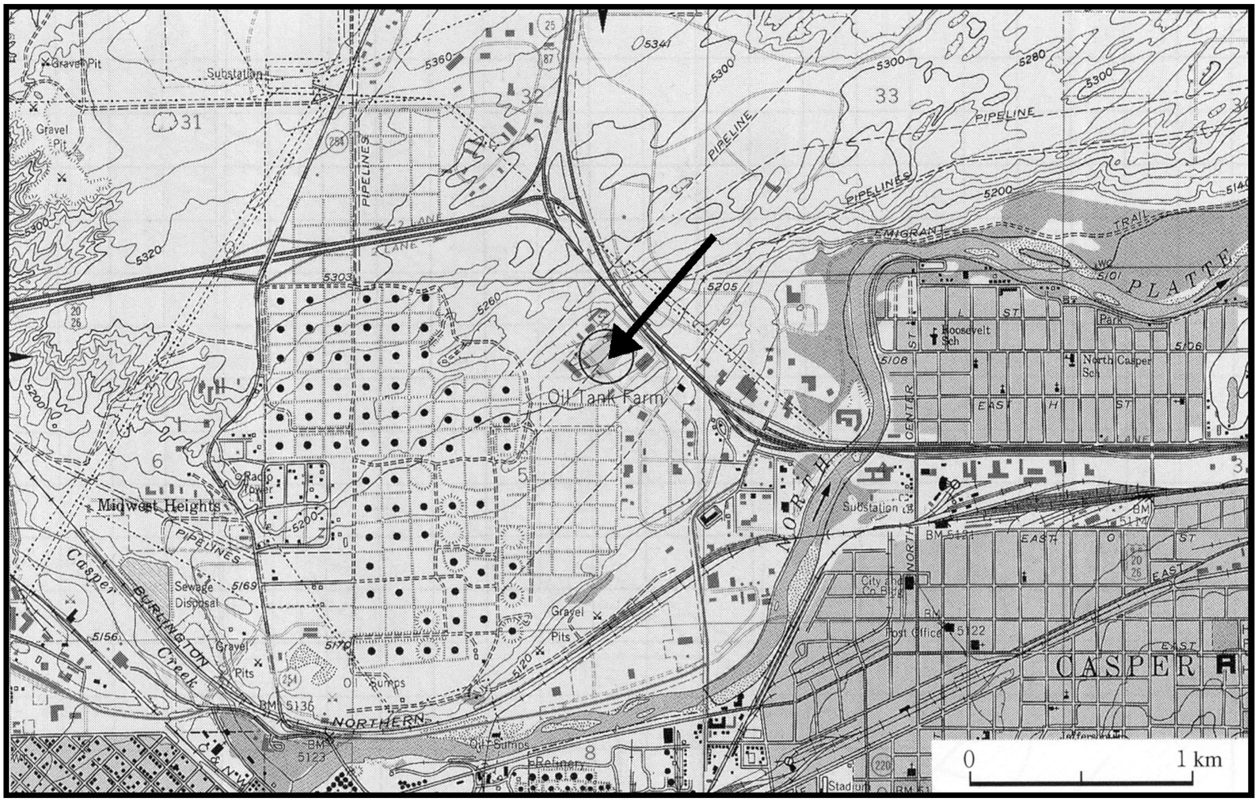

Figure 1: The location of the Casper site (circle, O).

dune is parabolic and its longer side ranges from N65°E to N75°E. This orientation corresponds to the prevailing southwest wind, which comes from N-60° to N-70°. There are four strata of old sand dunes, A, B, C, and D, on a Pleistocene gravel stratum. Stone tools, bone tools, and bones are found in unit B (at the beginning of the Holocene). Unit B partially covers the gravel stratum (Albanese 1974a, b). At the time of occupation, the site terrain was a sand dune depression, U-shaped in cross-section and parabolic in its plane. The extent of the site is approximately 20 m in width and slightly more than 90 m in length. Remains of about a hundred individual bison were found.

In 1971, G. C. Frison (1974) carried out the first excavation as an emergency investigation following construction of an oil pipeline. In 1976, a second investigation adjacent to the first was conducted (Frison *et al*. 1978; Figure 2). The archaeological age was established as the Hell Gap culture complex of the Paleoindian period. Radiocarbon dating yielded two dates of 9830 ± 350 (RL-125) yr BP and 10060 ± 170 (RL-208) yr BP.

Recovered artifacts include 59 Hell Gap type projectile points (spear points), five scrapers, 19 hammer stones, and many flakes (Figures 3 and 4). The Hell Gap projectile points consist of 19 complete specimens out of 59. However, 11 of the 19 were broken in two pieces, with the pieces found at a distance and refit. The longest distance between broken pieces of a single projectile point was 33 m. The raw material was mostly quartzite, with jasper the next most abundant material. There were only a few stone tools made of flint and shale. Nineteen projectile points have breaks at their tips due to impact fractures. Although the variation in maximum widths and basal lengths of finished tools is small, the length variation is large, from a maximum of 13.7 cm to a minimum of 5.0 cm (Figure 3). This large variation in length is explained by resharpening of the tips, broken by impact, while still hafted. When this behavior repeated several times, the tip of a point was likely to be short. Although resharpening flakes were excavated, there is no evidence projectile points were made at the site. The archaeological and circumstantial evidence suggests the hunting and butchering of bison. It has been inferred the losses of the tips were due

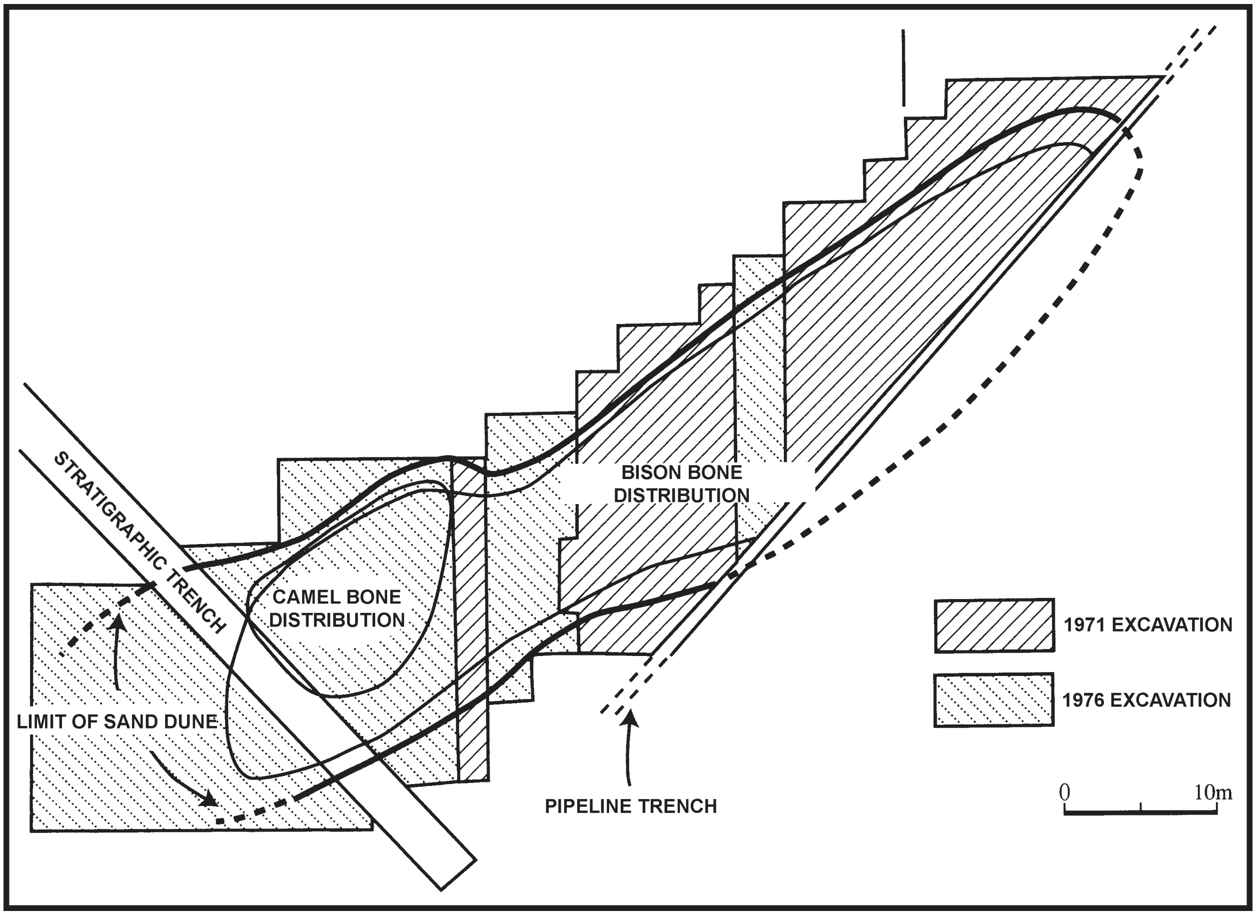

Figure 2: Excavation area of the Casper site.

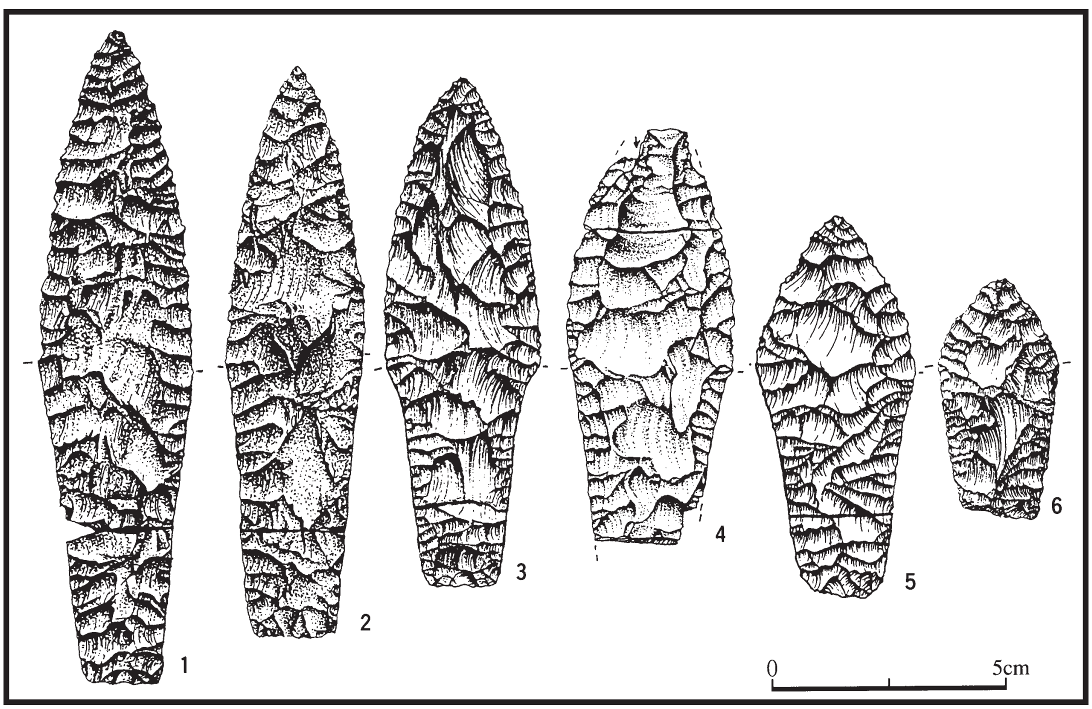

Figure 3: Hell Gap projectile points found in the Casper

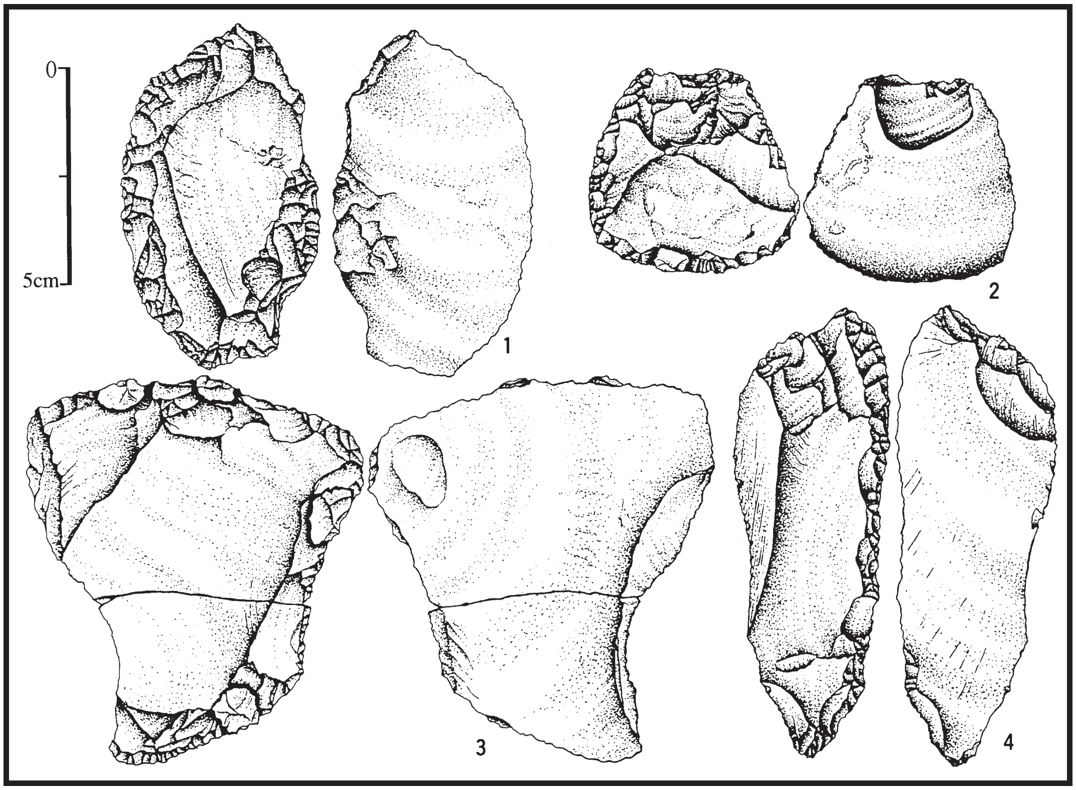

Figure 4: Scrapers from the Casper site.

to hunting use, not to production of the stone tools (Bradley 1974).

There are many bone flakes and one bone scraper that can be compared morphologically with stone tools. The fauna is simple and almost completely represented by bison (*Bison bison antiquus*) [1]. However, there were other animals at the site including, white-tailed jackrabbits (*Lepus townsendii*), ground squirrel (*Spermophilus sp.*), pocket gopher (*Thomomys sp.*), coyote (*Canis latrans*), fox (*Vulpes sp.*), lynx (*Lynx sp.*), and pronghorn (*Antilocapra americana*) (Wilson 1974). Bone of a single camel (*Camelops*) was discovered in the 1976 excavation. It is inferred the camel was hunted and butchered in the same period and with the same method as the bison because the camel bones are found at the same stratum as bison bones (Frison *et al.*1978). However, it is unclear whether the camel bones are associated with the bison bones or not. [2]

The Casper site is a good example of a typical short-term hunting station in which a Paleoindian group drove bison into the sand dune and followed by accompanying butchering of the animals.

SPECIMENS STUDIED

In 1971, the bones of approximately 100 individual bison were found at the Casper site, with a minimum number of the individuals based on lower mandibles being 77 animals (Wilson 1974). Including adults, calves, and fetuses, the number of identified complete and broken bone was 5,385. Among these, 2319 specimens can be divided into 231 articulated units (Frison 1974:51-64). The age characteristics of animals recovered from the Casper site when compared to a normal age distribution of *Bison* are displayed in Figure 5.

Among the 8,000 bone specimens from the 1971 and 1976 excavations, some bones are suitable for examination of the degree of preservation and bone cylinder breakage, including femora, tibiae, and radii of adult bison.[3] Therefore, to make these the fundamental specimens for comparison, impact flakes and spiral flakes are chosen based on the quality of preservation, and on the easiness for observation and measurement of important aspects, such as traces of fracture.

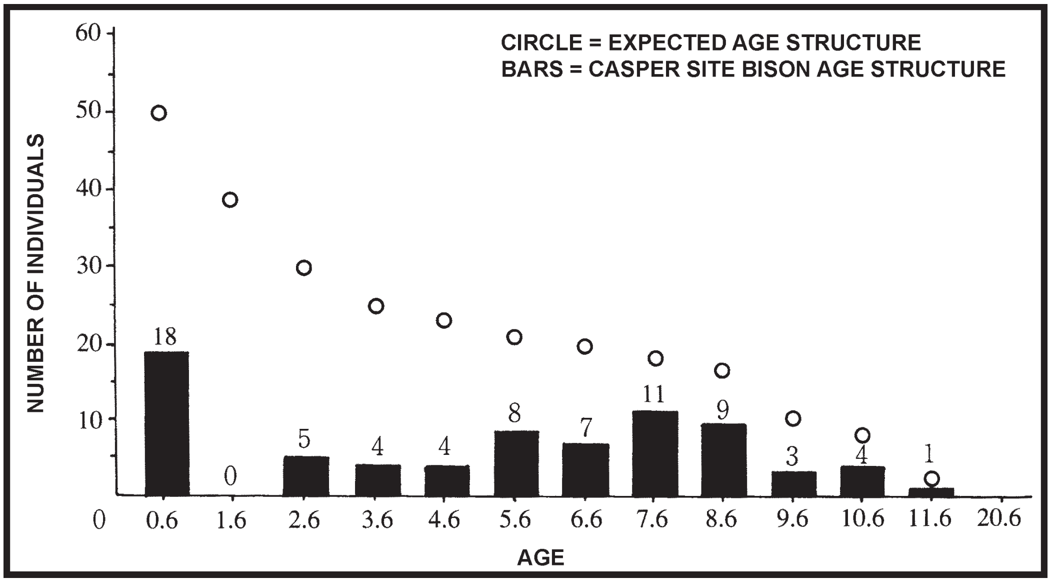

Figure 5: The age distribution of bison (Reher 1974, modified). Open circles are the expected age structure, black bars are the age structure at the Casper site.

ASPECTS OF BONE FRACTURE

Though the bone breakage varies at the Casper site, the pipe-shaped bones, that is the cylindrical bones (long cylindrical bone), are the object of analysis here, because bone artifacts of flaked bone tools found in Paleolithic archaeological sites are mostly made of long cylindrical bones.

SPIRAL FRACTURE AND SMALL FLAKES FROM AN IMPACT POINT

On spiral flakes, which were flaked off by the blow to the diaphysis of cylindrical bones, the shape around the impact contains some distinctive features. This is found not only on the spiral flakes, but the same features can also be seen on the remaining diaphysis. Ono (2001, Chapter 3; Fracture of Long Bones by Pointed Percussion) discussed the importance of the recognition of these bone modifications near the impact point. Why is this so important? In many cases, the form of the bone near the percussion (impact) points can show whether the cause is cultural or non-cultural (such as deposition and burial, chemical modification, effect of plants, activities of animals other than human, etc.). Here materials excavated from actual sites will be examined for aspects of spiral fracture and associated small flakes, and I will establish the foundation for much more unambiguous evaluation of flaked bone tools and bone artifacts from other Paleolithic sites (see Ono 2001). The following four items will be examined here: 1) features seen near the impact points on cylindrical bones diaphyses, 2) features of detached spiral flakes from the impact point on cylindrical bones, 3) features of small flakes which are assumed to have scattered from the impact point of spiral flakes, and 4) features of the small flakes which are assumed to have scattered when a secondary impact was performed on the edges of diaphysis of long-cylindrical bones which were already split and opened.

Small Flakes Emerging at the Percussion Point on Cylindrical Bones. Because of the pinpoint blow on a cylindrical bone diaphysis, the crushing of the bone at the point of impact usually forms a depression. Several cracks are then formed in the shape of concentric circles around the depression, and a part of the bone breaks off as small bone flakes (Figures 9-4 to 9-7). Figure 9b shows the model of this flaking event. Although, theoretically, the depression of the impact point is close to a circle (Ono 2001: Figure 3-7-2), the actual shapes vary (Ono 2001: Figure 3-11). However, exceptional discoveries are occasionally made, such as a cylindrical cone of flaked bone in which the compact bone was not broken (Figures 9-1 to 9-3; Figure 10a). Figure 9a shows a model of this case.

I am going to give a more concrete explanation. There is one bone artifact from Casper with a spiral-shaped piece flaked off from a percussion blow on a left *Bison* femur posterior side. The bone at the percussion point was broken, a hole made and

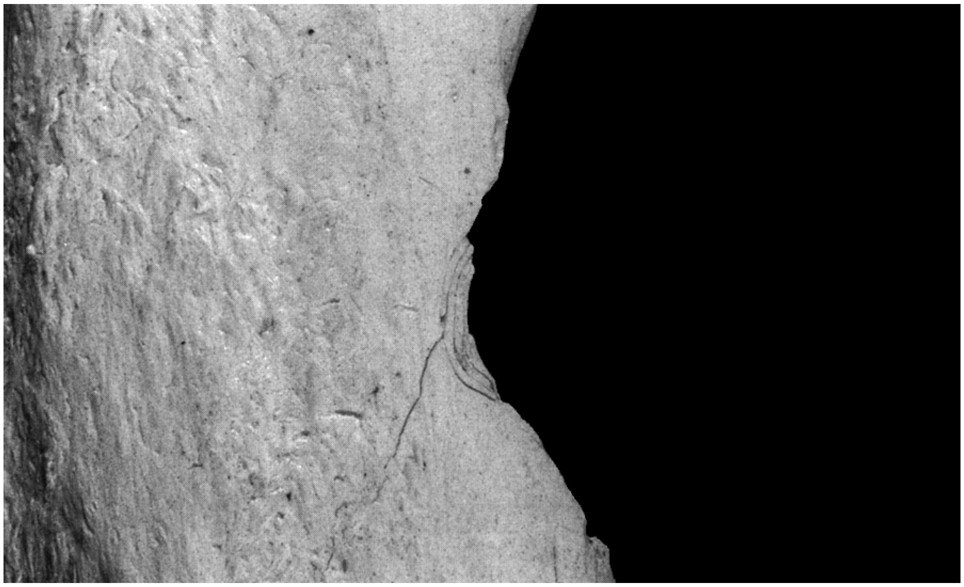

Figure 6: Enlargement of the percussion point on long cylindrical bone.

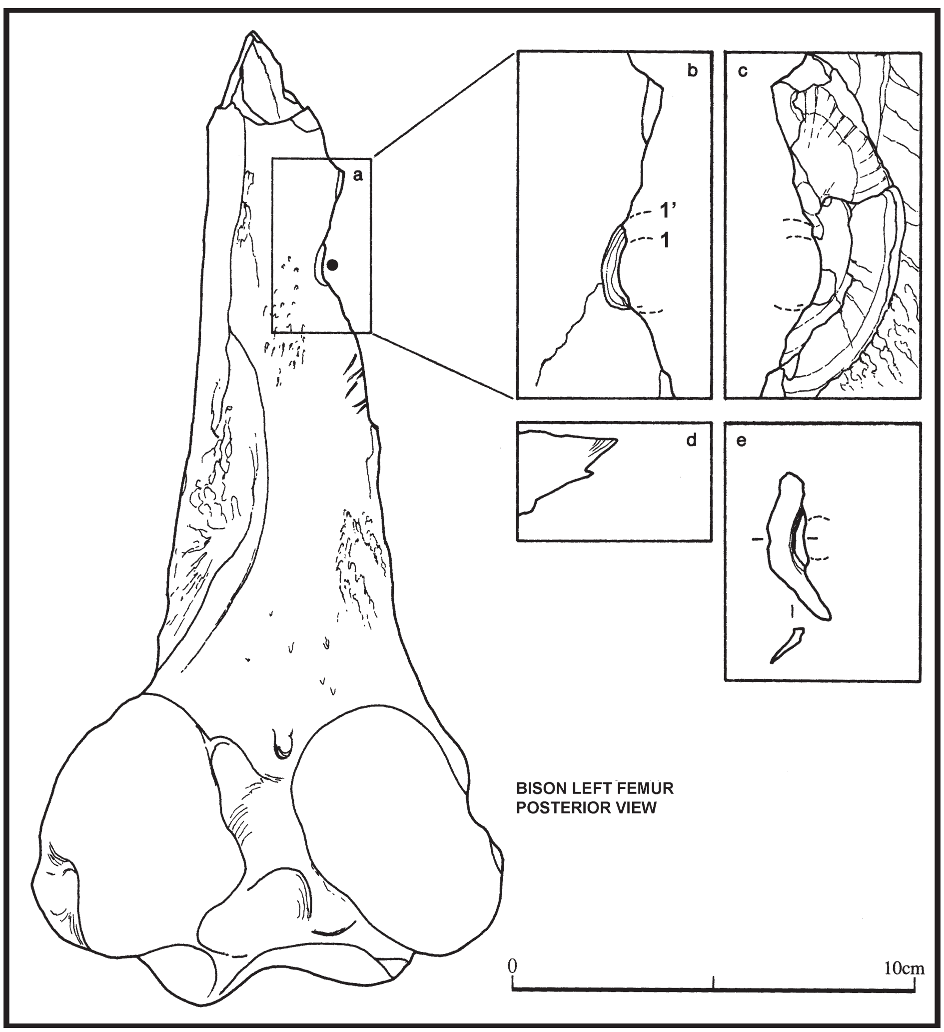

Figure 7: Percussion point on long cylindrical bone and impact flakes. Posterior left bison femur.

several concentric circles are now visible around the hole (Figure 7). The several cracks between 1 – 1' of Figure 7b are the concentric circles. Figure 6 shows that portion of Figure 7b in a photograph. Figure 7c is the interior of the bone where several facets of flaking due to one blow can be seen. Figure 7e is a diagram from the measurements and restoration of the small flake, which is assumed to have separated from the bone. This was not actually recovered, but is replicated here from Figure 7c. Figure 7d is the cross-section of the impact point.

Binford (1981) clearly explained the existence of "the impact notches" and "the impact chips formed at the impact point of a cylindrical bone" from flaking scars on cylindrical bones and from evidence of blows for extraction of bone marrow, based on the ethnographic record of the Nunamiut Eskimo (Binford 1981). He used the terms "impact notch" and "impact chip(s)." After Binford's study, there is another study by Johnson (1983, 1985). Although Johnson's morphological study closely examined the crushing of cylindrical bones, she did not mention "the impact notches" and "the impact chips formed at the blow point of a cylindrical bone." Johnson only mentioned the impact points and the flakes from the backside of the impact point (inside of the bone). Later, there is a study which says these kinds of impact flakes may be formed by hyena chewing. This hyena study implies these flakes themselves cannot be used as evidence for artificial/cultural modification. However, the study only pertains to "small flakes of bone" and does not talk about impact notches or impact flakes closely (Potts 1988; Hill 1989). Lyman (1994) mentions the circular and semi-circular depressed hole at the impact point, but he just mentions the existence of bone "chips" and there is no further description (Lyman 1994).

Thus, Binford explained the most concrete evidences of artificial percussion, but there are no morphological observations and records of "the impact chips formed at the blow point of a cylindrical bone" in his study. Other researchers have tried to clarify the difference between artificial impact and bites of carnivorous animals by morphological and statistical methods (Capaldo and Blumenshine 1994). They tried to show the notch caused by animal chewing was deep and half-circular shaped and the human impact notch was shallow and wide. However, they hypothesized about the morphology of the notches for the keying of the human/natural modifications and did not consider the entire shape of the flakes. Therefore they collectively discussed the notches on the diaphysis and the notches on the flakes. They did not mention the impact flakes from the impact point. It is dangerous to decide whether the notch is artificial or not only from the morphology of the notch at the impact point. The real artifacts from the

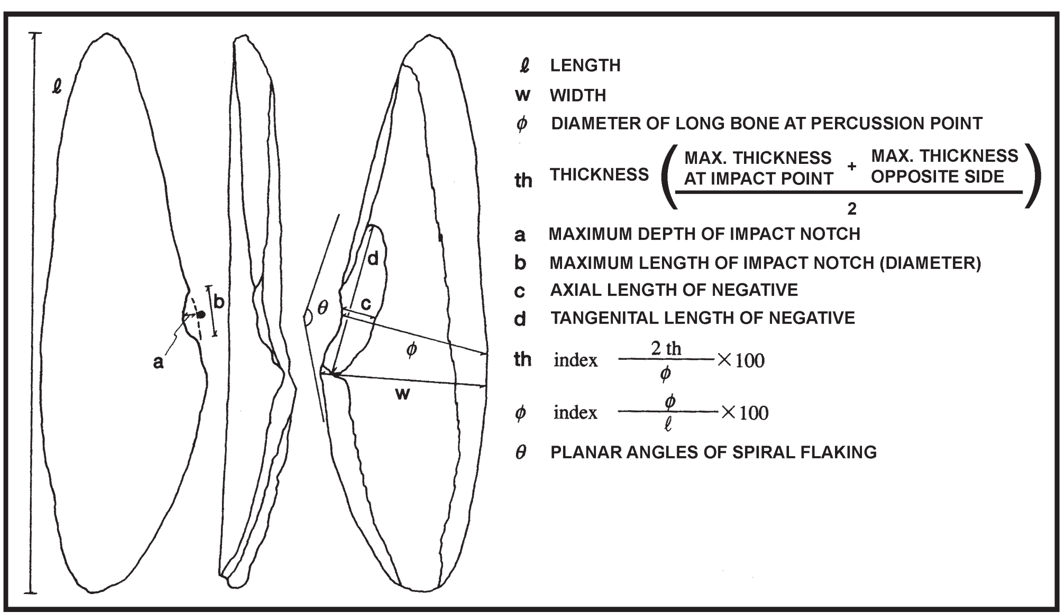

Figure 8: Attributes of spiral flakes and measurement locations. a) maximum depth of impact notch; b) maximum length of impact notch (diameter); c) axial length of negative scar; d) tangential length of negative scar.

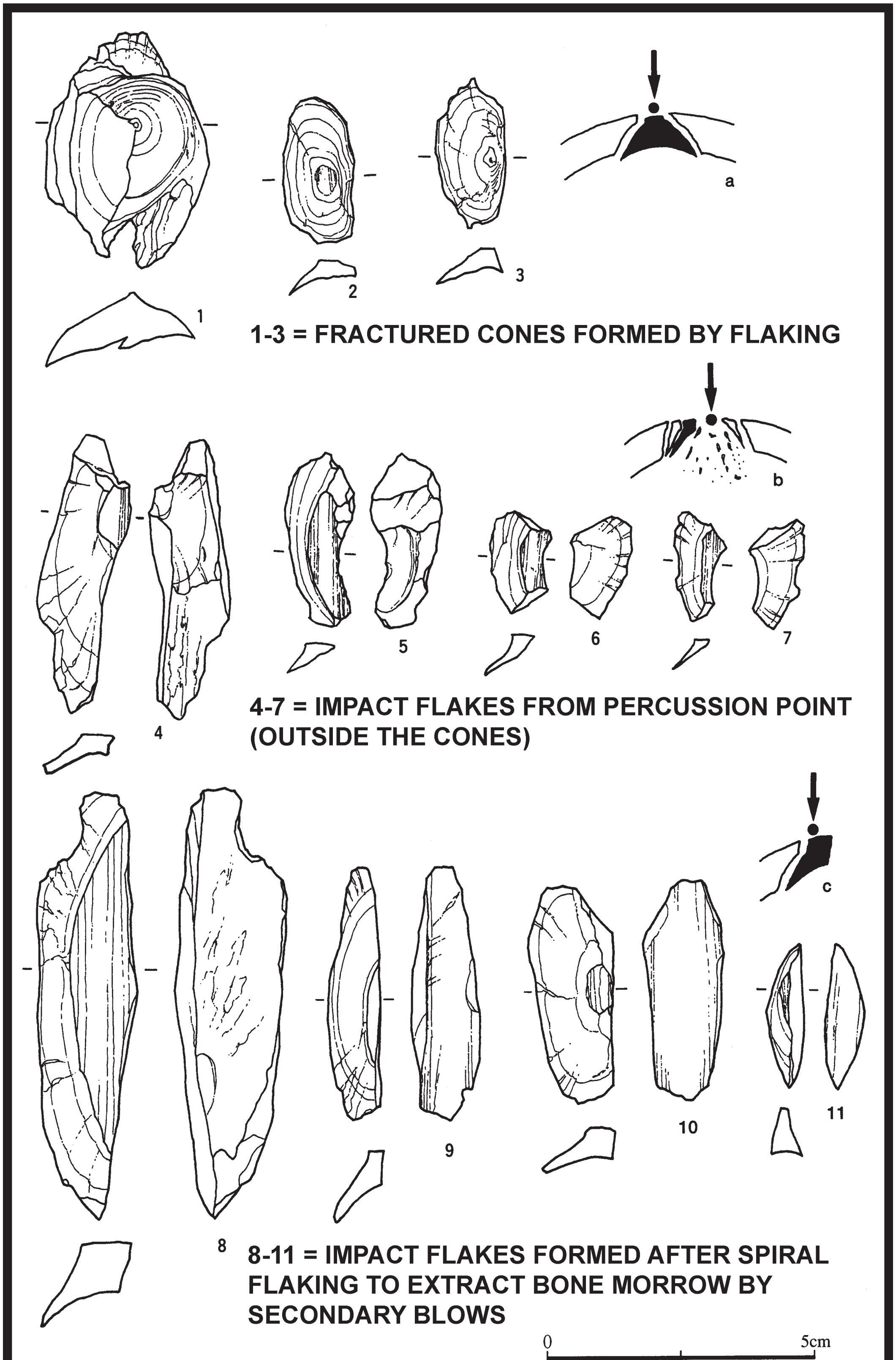

Figure 9: Three types of impact flakes at the percussion point. 1-3 fracture cone formed by percussion (usually crushing into powder); 4-7 impact flakes from percussion point (outside of the cones); 8-11 impact flakes formed after spiral flaking by secondary impacts to extract bone marrow.

Table 1: Measurements of impact flakes from the impact points of spiral flakes. LB=long bone. a, b, c, and d are the same as in Figure 8.

	CATALOG # 48NA304-	BONE	(cm) a	(cm) b	(cm) c	(cm) d
1	7000	LB	0.6	1.2	0.9	5.1
2	8164	LB	0.5	3.8	0.9	5.1
3	4626	LB	0.3	1.7	1.2	4.9
4	3829	LB	0.7	2.9	0.8	4.8
5	4629	LB	0.2	0.8	0.9	4.5
6	1034	LB	0.7	2.7	1.3	4.5
7	4088	LB	0.4	0.9	1.1	4.3
8	3376	LB	0.3	1.0	1.4	4.0
9	4881	LB	0.4	3.2	1.2	4.1
10	5559	LB	0.4	1.6	1.2	3.9
11	913	LB	0.5	1.4	1.1	3.4
12	905	LB	0.4	1.0	1.1	3.6
13	3476	LB	0.3	1.5	1.4	3.2
14	3399	LB	0.5	0.7	1.0	3.3
15	4887	LB	0.6	2.2	0.9	3.2
16	4886	LB	0.4	0.6	1.1	3.3
17	1598	LB	0.7	2.0	0.9	2.0
18	3337	LB	0.3	1.1	1.2	3.1
19	8163	LB	0.3	1.0	0.7	3.3
20	4627	LB	0.7	2.9	0.7	3.1
21	3477	LB	0.3	1.5	1.0	3.6
22	7936	LB	0.4	1.6	1.2	2.7
23	8082	LB	0.4	1.2	1.1	1.8
24	7938	LB	0.5	1.2	1.0	1.9
25	3390	LB	0.2	1.4	0.7	2.0

LB = long bone. A, b, c, and d are same as in Table 4.

Casper site also tell us the danger of the excessive generalization of the results.

Now that I've discussed the characteristics of an impact point on a femur diaphysis, next, I will discuss similar characteristics of the impacted area of spiral flakes, which have been removed from a diaphysis. Figure 8 is the model of Figure 12-2. The black circle in Figure 8 is the impact point. The bone structure directly under the impact point is crushed, and a scar is formed. In relation to this modification, an impact flake (Figure 9-4 to 9-7) is formed. Table 1 shows the measured values of 25 typical examples of such impact flakes (including Figure 9-4 to 9-7). In the right figure (inside the bone) of Figure 8, closest to the impact point, there is evidence for detachment of the impact flake. Thus, the same impact notch and impact flake can be observed both on the impact flake and on the diaphysis of a cylindrical bone. However, this estimation has a condition; the impact has to be placed exactly perpendicular to the surface of the bone when the impact on the diaphysis is created and the spiral flake is detached. If the angle of the percussion is not exactly perpendicular, the hole due to the crushing by the blow is not a perfect circle but biased toward one side; the actual forms of the circles vary.[4)]

Small Impact Flakes from Already-Opened Diaphysis. When a blow is added on a cylindrical bone, and an impact flake is driven off, the morphology of the spiral flakes varies and is not always restricted to the model of the flake in Figure 8. Moreover, there are examples of diaphyses which show the occurrence of a secondary blow at the already-opened fracture to enlarge the open area to more easily extract bone marrow, as well as examples in which just one blow allowed immediate extraction of the bone marrow. In the case of the secondary percussion, there is a scar of detachment for a wide flake. In fact, a real example of this flake was recovered at the Casper site.

Neither the terms "impact chip(s)" coined by Binford nor small "bone flakes" by Potts and Hill differentiate flakes formed near the impact point of the first blow on the cylindrical bone from those formed by the secondary blow added to the already-

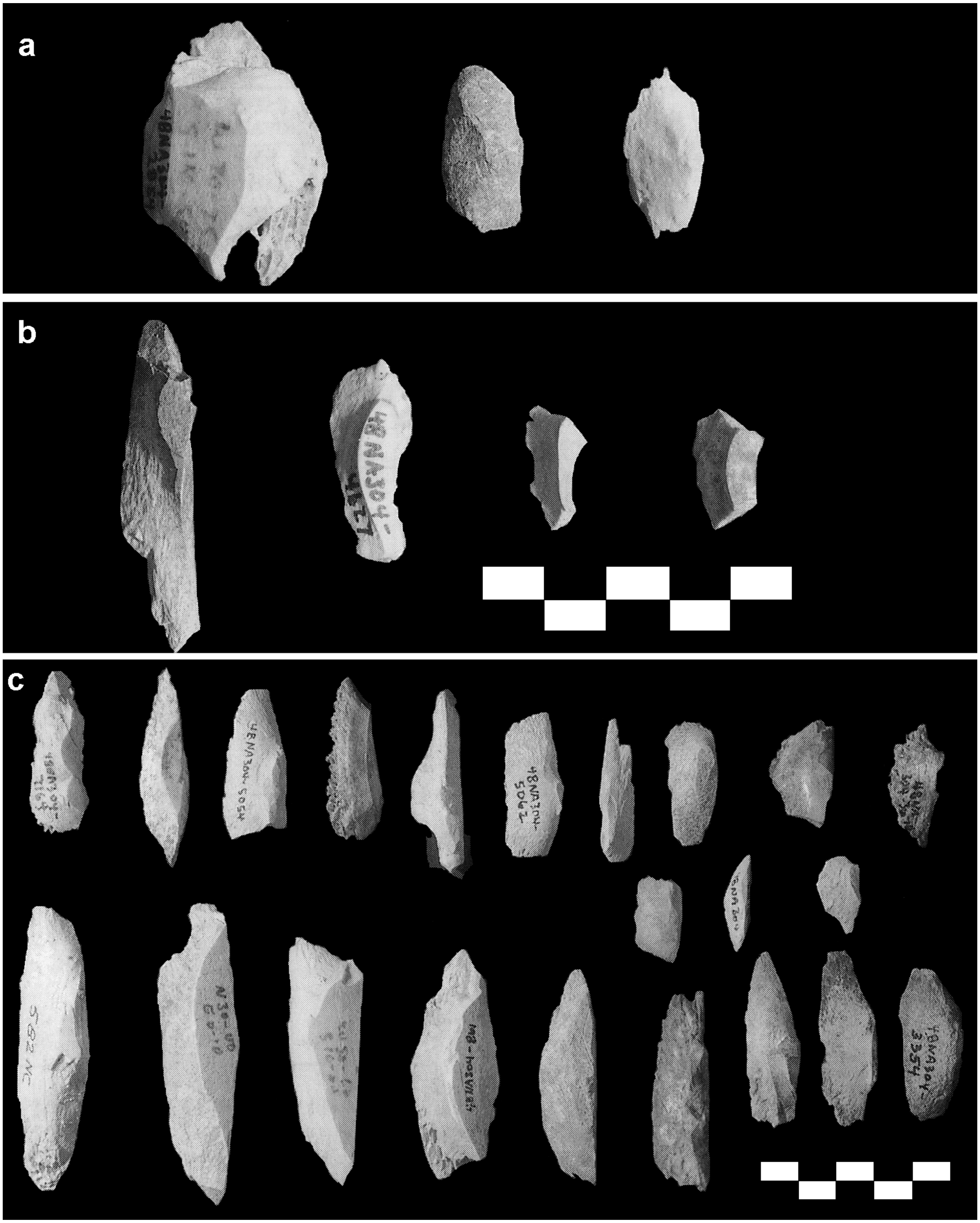

Figure 10: Three types of impact flakes. a) 1-3 of Figure 9; b) 4-7 of Figure 9; and c) 8-11 of Figure 9.

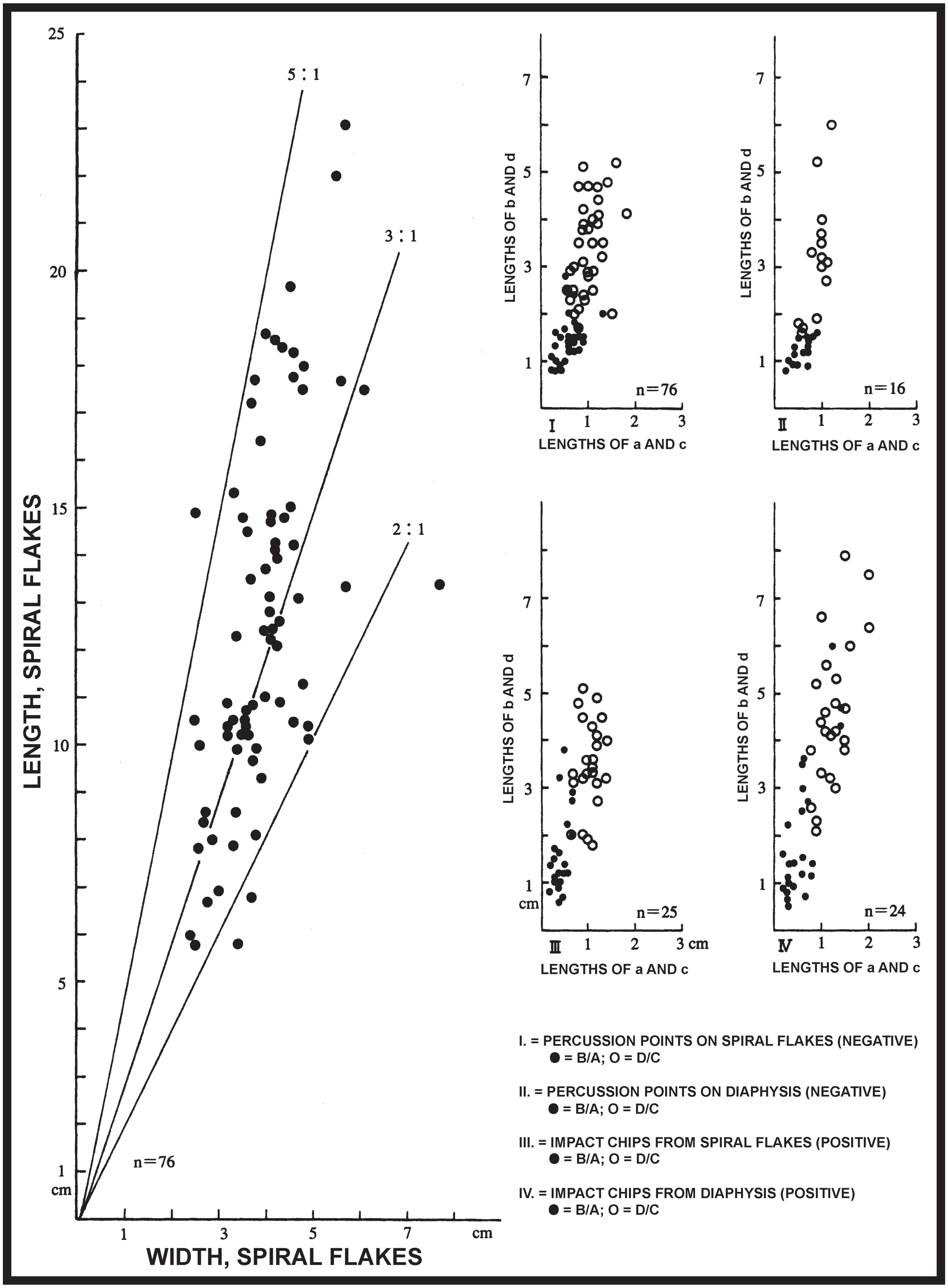

Figure 11: Spiral flakes and impact flakes. Left: distribution of the ratios of length:width of spiral flakes. Correlation of spiral flakes and impact flakes (right I to IV). I) percussion points of spiral flakes (negative) (solid dot=b/a, open circle=d/c); II percussion point on diaphysis (negative) (solid dot=b/a; open circle=d/c); III impact flakes from spiral flakes (positive) (solid dot=b/a; open circle=d/c); IV impact flakes from diaphysis (positive) (solid dot=b/a; open circle=d/c).

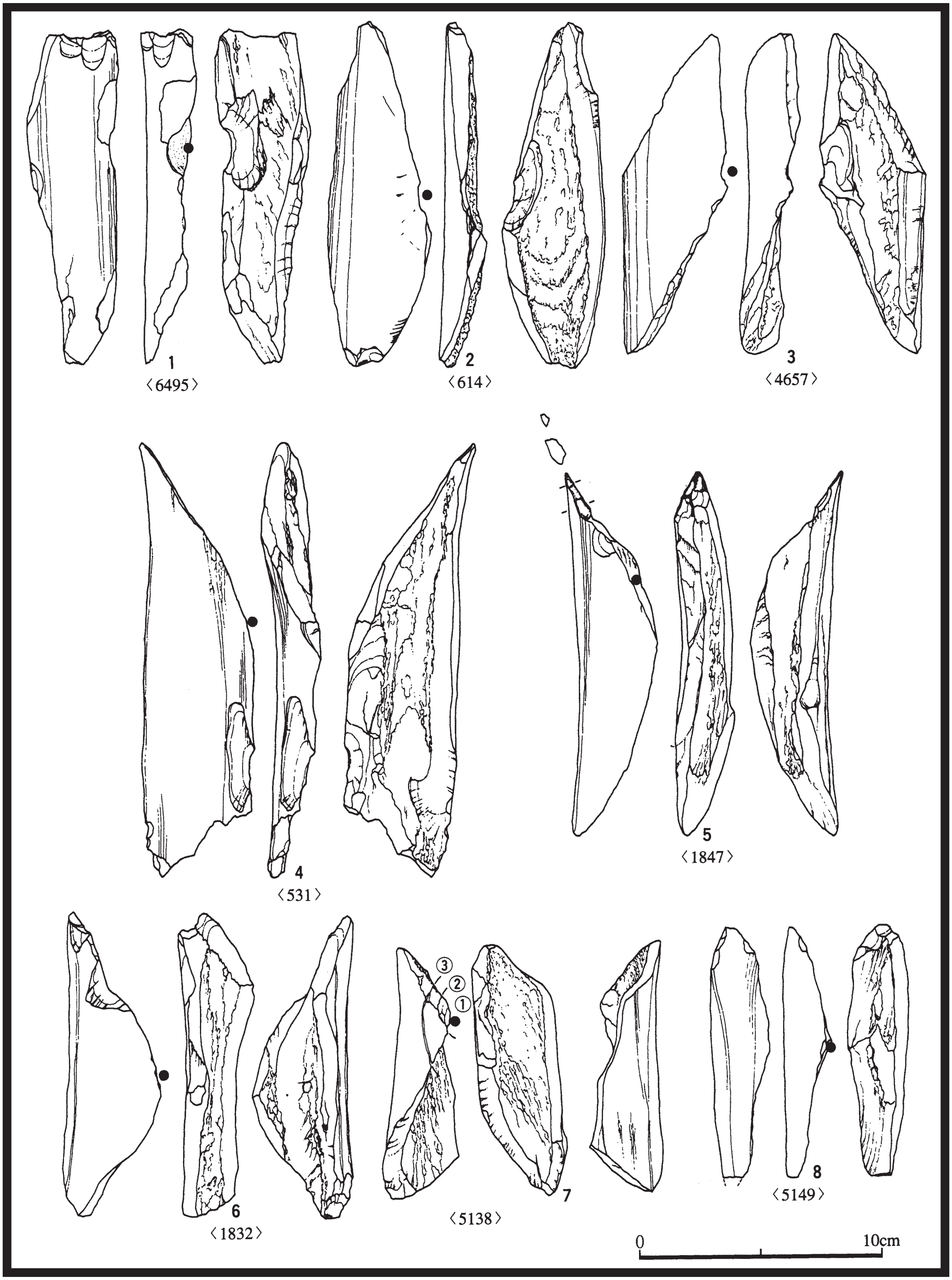

Figure 12: Variations in spiral flakes. Black dots (.) are expected percussion points, brackets (<>) indicate specimen number. 1: Table 4-8; 2: Table 4-1; 3: Table 4-2; 4: Table 4-7; 5: Table 4-5; 6: Table 4-4; 7: Table 4-6; 8: Table 4-3.

Table 2: Measurements of impact flakes formed by secondary percussion after the spiral fracture. LB=long bone flake. a, b, c, and d are the same as in Table 8.

	CATALOG # 48NA304	BONE	(cm) a	(cm) b	(cm) c	(cm) d	NOTES
1	1893	LB	1.2	6.0	1.5	7.9	Figure 9-8
2	7853	LB	0.8	1.4	2.0	7.5	
3	2306	LB	1.4	4.7	1.0	6.6	
4	2231	LB	0.8	1.1	2.0	6.4	
5	861	LB	1.4	4.3	1.6	6.0	
6	2237	LB	0.6	3.6	1.1	5.6	
7	5560	LB	0.6	3.5	1.3	5.3	
8	7533	LB	0.6	2.5	0.9	5.2	
9	7362	LB	0.4	1.4	1.3	4.8	
10	6810	LB	0.2	1.6	1.5	4.6	Figure 9-9
11	6812	LB	0.7	0.7	1.1	4.6	
12	7535	LB	0.6	3.0	1.0	4.4	
13	7164	LB	0.7	2.7	1.1	4.2	
14	3354	LB	0.4	0.9	1.2	4.1	Figure 9-10
15	5062	LB	0.3	0.8	1.5	3.8	
16	1532	LB	0.3	2.2	1.3	4.2	
17	5054	LB	0.3	1.1	1.5	4.0	
18	6618	LB	0.6	1.5	1.0	3.3	
19	5068	LB	0.3	1.4	0.8	3.8	
20	7549	LB	0.6	1.2	1.3	3.0	
21	3678	LB	0.3	0.6	1.2	3.2	
22	5027	LB	0.3	0.5	0.9	2.3	
23	2434	LB	0.3	1.0	0.9	2.1	
24	5418	LB	0.2	0.9	0.8	2.6	Figure 9-11

LB = long bone. a, b, c, and d are same as in Table 4.

Table 3: Measurements of percussion scars on long cylindrical bones. TA=tibia, FM=femur.

	FIGURE NUMBER	BONE	MATERIAL # IN FIGURES	(cm) a	(cm) b	(cm) c	(cm) d
1	Figure 18	TA	7	0.3	1.0	0.8	3.3
2	Figure 18	TA	8	0.7	0.9	0.9	5.2
3	Figure 18	TA	9	0.7	1.4	1.2	6.0
4	Figure 15-1	TA	4	0.5	0.9	0.6	1.7
5	Figure 15-1	TA	5	0.4	1.3	1.0	3.0
6	Figure 14	TA	4	0.3	---	1.0	4.0
7	Figure 14	TA	5	0.5	1.5	1.0	3.5
8	Figure 15-2	FM	5	0.4	0.9	0.6	1.6
9	Figure 15-2	FM	6	0.7	1.5	0.9	2.9
10	Figure 7	FM	1	0.2	0.8	0.5	1.8
11	Figure 7	FM	1’	0.8	1.5	1.0	3.7
12		FM		0.6	1.2	1.0	3.2
13		FM		0.7	1.2	1.1	3.1
14		FM		0.4	1.1	1.1	2.7
15		TA		0.9	1.6	1.2	3.8
16		TA		0.7	1.3	1.0	4.2

TA = tibia; FM = femur; a, b, c, and d are same as in Table 4.

opened diaphysis. To identify carefully whether the fractures on an animal cylindrical bone are human or non-human caused, we need to differentiate "the small flakes formed around the impact point of the cylindrical bone" from "the flakes from an already-opened diaphysis." The latter has no relationship to spiral fractures. In other words, this case can be expressed by detachment of oblong small flakes that are restricted by the thickness of the compact bone. In an analogy to stone tools, it can be expressed by the flaking of oblong small flakes from a thin stone core.

The following is an explanation of this process of breaking bones to extract marrow initiated by an impact to the diaphysis, then enlarging the cavity by secondary impacts to the remaining diaphysis. The bone flakes created by the latter process are the flakes discussed below. The morphology of these flakes includes the negative scar of previous percussion. The already-opened side of the diaphysis looks flat, while the overall shape is likely to be an inverted-D shape. To emphasize the difference, you can compare the secondary flakes to the morphology of flakes created from the primary impact point (Figure 9-4 to 9-7). The most important thing here is the position of the percussion. When the bone surface remaining on the small flake is set as the reference, the impact point is not on the side of fracture of the opened-diaphysis area, but on the opposite (deep-inside) region. Figures 9-8 to 9-11 are examples of these flakes (positive), and the position of percussion is shown on Figure 9c. Table 2 summarizes 24 cases of impact small flakes from already-opened diaphysis.

Next, I looked at the relationships between the impact flakes (positive) and the flaking scars on the diaphysis (negative). The relationship of the impact flakes and the flaking scar (on the long cylindrical bone core) cannot be simply determined, unless an attached specimen is found. Therefore, to assume the relationships, the measurements of both the impact flakes and the diaphysis flaking scar for attributes a, b, c, and d in Figure 8 can be used. To measure the diaphysis percussion scars, I chose the 16 examples which have clear flaking scars for easy measurements. Each of the numbers in Table 3 (material numbers in Figures) corresponds to the numbers in Figures 18, 15-1, 14, 15-2, and 7. Especially, attribute "a" cannot be measured unless the impact notch is relatively deep. The bone thickness at the percussion point and the corresponding impact flake (positive) are difficult to measure. Because I take this difficulty into account, I did not measure every flaking scar on the examples, but only selected some specimens for measurement.

The above is the discussion of morphology and measurement of the flakes (positive) scattered by impacts on the remaining diaphysis after the spiral fracture and the percussion point (negative) remaining on the diaphysis. Now, let us discuss the correlation of these two measurements.

It is reasonable to think about the correlation between positives and negatives. Attributes of impact flakes considered to be flaked from the diaphysis, those of the impact points on diaphysis (negative), and the dispersion patterns of b/a and d/c are shown on II and IV of Figure 11-2. However, there are two examples that exceed seven cm in length, in the d/c dispersion patterns (IV), which deals with the impact flakes. One of these is Figure 9-8. Morphologically, this specimen is an impact flake which was flaked by percussion on the diaphysis. However, there are no negative scars (the flake scars on the diaphysis) corresponding to this flake in the investigated materials.

The criteria for differentiating human from non-human fracture on long cylindrical bones of large mammals, both "impact flakes created from the blow point of spiral flakes" (Figures 9-4 to 9-7) and "impact flakes created by the additional blow on the remaining diaphysis, after the spiral fracture" (Figures 9-8 to 9-11) have characteristics of artificial modification. The identification of the former (formed by the first percussion on cylindrical long bones) and the latter (formed by the secondary percussion added to the already-opened diaphysis) as human induced bone breakage types helps in identification of artificial blows to cylindrical bones. However, the report from the Amboseli Basin, in Kenya says impact flakes similar to figures 9-9 and 9-11 can be formed by chewing activities of the spotted hyena (Potts 1988; Hill 1989). You may want to be careful when the group of animals found in the site contains hyena.[5)]

Spiral Fracture/Spiral Flakes. The fracture that forms spiral flakes when a blow is delivered to a long cylindrical bone is called a spiral fracture, but the resulting flakes vary greatly. Early in the

Table 4: Attributes of spiral flakes. Specimens with solid dots are depicted in Figure 12. Legends are the same as the Figure 8. Underlined numbers are estimated values. FM=femur, TA=tibia, RA=radius, LB=long bone flakes.

	CATALOG # 48NA 304	BONE	(cm) ℓ	(cm) ϕ	(cm) th	(%) th index	(°) θ	(cm) w	(cm) a	(cm) b	(cm) c	(cm) d
1	● 614	LB	14.1	3.7	1.00	54.1	140	4.2	0.3	1.3	0.9	3.9
2	● 4657	LB	13.1	4.1	1.10	53.6	150	4.1	0.4	1.5	1.1	3.5
3	● 5149	RD	10.5	2.4	1.05	87.5	150	2.5	—	—	—	—
4	● 1832	TA	12.4	4.0	0.90	46.3	150	4.0	—	—	0.74	2.9
5	● 1847	TA	14.8	3.1	0.95	61.3	—	3.5	—	—	0.9	3.9
6	● 5138	TA	10.5	3.2	0.80	50.0	120	3.3	—	—	—	—
									0.6	0.7	0.9	2.4
									1.2	2.5	0.9	3.8
7	● 531	TA	17.8	4.3	1.25	58.1	—	4.6	—	—	1.0	4.6
8	● 6495	FM	13.5	3.5	0.85	48.6	—	3.7	0.8	1.7	1.1	3.9
9	100	FM	13.3	4.6	0.85	37.0	130	5.7	0.8	1.5	1.0	2.9
10	2050	TA	18.4	4.3	1.00	46.5	—	4.3	0.5	2.8	1.2	4.7
11	518	TA	12.3	3.3	0.90	27.3	155	3.4	0.5	—	0.9	3.1
12	609	TA	17.5	5.0	1.00	20.0	—	6.1	—	—	—	—
13	587	FM	18.3	4.1	0.70	34.1	—	4.6	1.3	2.0	1.0	4.0
14	1822	FM	15.0	4.5	0.85	37.8	—	4.5	0.6	1.2	1.1	2.9
15	1841	FM	11.3	4.8	0.80	33.3	—	4.8	0.3	1.6	1.1	2.5
16	6031	TA	18.0	4.8	1.30	54.2	—	4.8	0.8	1.2	1.8	4.1
17	593	TA	17.5	3.9	0.95	48.7	120	4.8	0.3	0.8	1.0	2.8
18	8424	TA	14.2	4.1	0.90	43.9	120	4.6	0.2	0.8	0.8	2.1
19	1828	TA	13.4	6.1	0.75	24.6	—	7.7	0.6	—	1.3	3.2
20	1838	TA	10.9	4.0	0.95	47.5	120	4.3	—	—	—	—
21	5130	TA	14.8	4.3	0.95	44.2	150	4.4	—	—	—	—
22	2928	TA	12.1	3.2	1.05	65.6	—	4.2	—	—	—	—
23	6498	TA	10.2	3.4	0.85	50.0	130	3.5	—	—	—	—
24	1864	LB	8.6	2.6	0.80	61.5	—	3.35	0.7	1.8	0.8	4.7
25	1858	TA	8.4	2.7	0.90	66.7	—	2.7	—	—	—	—
26	774	TA	8.6	2.4	1.00	83.3	150	2.75	0.4	0.8	0.7	2.5
27	2170	TA	6.0	2.4	0.75	62.5	160	2.4	—	—	—	—
28	2881	LB	12.6	4.1	0.80	39.0	—	4.3	—	—	—	—
29	2966	LB	17.7	3.7	0.90	48.6	140	3.8	0.6	1.3	0.8	3.5
30	4222	LB	16.4	3.9	0.85	43.6	160	3.9	—	—	—	—
31	828	LB	14.2	3.9	0.95	48.7	—	4.2	0.2	1.1	0.6	2.5
32	2299	LB	14.7	4.0	0.75	37.5	140	4.1	—	—	—	—
33	3364	LB	13.9	3.9	0.70	35.9	130	4.2	0.4	0.8	0.7	2.5
34	4653	LB	10.1	4.8	1.05	43.8	120	4.9	—	—	0.8	1.7
35	1869	LB	5.8	3.3	1.05	63.6	110	3.4	—	—	—	—
36	5144	RD	14.5	3.6	0.70	38.9	140	3.6	0.4	0.9	0.6	2.9
37	119	TA	10.0	2.5	1.10	84.0	140	2.6	—	—	—	—
38	2898	LB	10.4	3.6	0.90	50.0	130	3.6	—	—	—	—
39	1823	RD	23.1	4.2	1.10	50.0	—	5.7	0.6	1.2	1.2	4.1
40	827	RD	22.0	4.1	0.90	41.5	—	5.5	—	—	—	—
41	2301	LB	17.2	3.6	0.70	36.1	160	3.7	0.3	1.0	0.8	2.1
42	1827	RD	12.2	4.0	0.70	35.0	140	4.1	—	—	—	—
43	4651	RD	6.7	2.7	1.00	70.4	150	2.8	—	—	—	—
44	7209	TA	19.6	3.4	0.90	52.9	—	4.5	0.9	1.5	1.2	4.1
45	4226	TA	18.7	3.6	0.90	47.2	—	4.0	—	—	—	—
46	6030	TA	18.5	3.2	1.00	62.5	—	4.2	0.9	1.4	1.0	4.7
47	534	TA	14.8	3.9	0.90	46.2	160	4.1	—	—	—	—
48	2955	TA	13.1	4.4	0.80	36.4	140	4.7	0.7	1.5	1.0	3.8
49	4603	TA	9.9	3.2	0.90	53.1	—	3.4	0.5	1.0	0.9	3.1
50	831	TA	10.5	3.0	0.90	56.7	—	3.6	0.3	—	0.7	2.0
51	4934	TA	10.8	3.2	0.90	53.1	—	3.7	0.5	1.7	1.1	4.4
52	1831	TA	10.2	3.5	0.90	48.6	120	3.6	—	—	—	—
53	6502	TA	6.9	3.0	0.70	46.7	140	3.0	—	—	—	—
54	536	TA	8.1	3.8	1.10	55.3	—	3.8	—	—	—	—
55	1862	TA	8.0	2.9	0.90	62.1	110	2.9	—	—	—	—
56	2866	TA	5.8	2.3	0.70	56.5	130	2.5	—	—	—	—
57	7835	TA	5.8	2.5	0.70	52.0	100	2.5	—	—	—	—
58	1846	TA	13.7	3.4	0.90	50.0	140	4.0	0.2	0.8	0.6	2.3
59	7210	TA	11.0	3.6	0.60	33.3	150	4.0	—	—	—	—
60	1826	TA	9.7	3.7	0.50	27.0	140	3.7	—	—	—	—
61	2922	TA	12.8	4.1	0.80	39.0	130	4.1	—	—	—	—
62	1839	TA	9.9	3.2	0.80	50.0	150	3.8	0.6	1.5	0.9	4.2
63	1851	TA	10.4	3.2	1.00	59.4	130	3.2	—	—	—	—
64	707	TA	10.7	3.6	0.90	50.0	140	3.6	—	—	—	—
65	4647	TA	6.8	3.7	1.00	54.1	120	3.7	—	—	—	—

Table 4: (continued).

66	1859	TA	7.9	3.3	0.90	51.5	120	3.3	—	—	—	—
67	2887	FM	12.4	3.3	0.90	51.5	—	4.1	0.6	—	1.1	4.0
68	2969	LB	14.9	2.5	1.00	76.0	—	2.5	0.7	2.4	1.4	4.8
69	2875	LB	10.5	3.9	0.90	46.2	160	4.6	0.6	2.5	1.6	5.2
70	7951	LB	15.3	2.7	0.90	66.7	—	3.3	0.6	2.0	0.9	5.1
71	7746	LB	9.3	3.5	0.80	45.7	—	3.9	0.7	1.2	1.2	3.9
72	7742	LB	10.2	3.1	1.00	64.5	—	3.2	—	—	—	—
73	2958	LB	10.9	2.6	0.70	53.8	—	3.2	0.6	1.2	1.5	2.0
74	586	LB	10.4	4.7	1.00	42.6	—	4.9	0.7	1.4	1.3	3.5
75	843	LB	7.8	2.6	0.90	69.2	110	2.6	—	—	—	—
76	312	FM	17.7	4.2	0.80	38.1	—	5.6	0.6	1.4	0.9	2.3

Legends are the same as Figure 8. Underlined numbers are estimated values
FM = femur. TA = tibia. LB = long bone. RA = radius. Black marked specimens depicted in Figure 12.

study of bone breakage, spiral flakes were thought to be the evidence of human breakage. However, later it became evident spiral flakes can also be formed by natural forces (Agenbroad 1984, 1989; Lyman 1989; Haynes 1991). What kinds of spiral flakes can be identified as flaking due to human forces, when general spiral flakes cannot be thought to be only a human phenomenon? Artifacts at the Casper site are special because they represent the emergence of intensive kill-butchering activities of bison in the Paleoindian Period. Therefore, the site has good conditions for archaeological studies of breakage of animal bones. Although there is a long history of controversy concerning spiral flakes and spiral fractures, here I limit my argument within the present recognitions of human/non-human origin of spiral flakes.

I chose 76 specimens and measured their attributes (Table 4). I chose various kinds of materials, including typical spiral flakes and morphologically significantly different spiral flakes. Figure 8 shows the legends for the attributes which should be used as the standard for my specific measurements.

l: maximum length of spiral flakes, parallel to the length of long cylindrical bones.

w: maximum width of spiral flakes.

ϕ: diameter of long cylindrical bones that are impacted (maximum diameter). Since cross-sections of cylindrical bones (femur, tibia, and radius) are not exactly circular, I use the distance from the impact point to the opposite side of the bone as an approximation.

th: thickness of compacta. This is an averaged value of the maximum thickness at the impact point and the thickness of the opposite side of the cylinder.

a: maximum depth of impact notch.

b: maximum length (diameters) of impact notch.

c: axial length of negative scar.

d: tangential length of negative scar.

th index: twice the thickness is divided by ϕ and then multiplied by 100.

ϕ index: ϕ divided by *l* and multiplied by 100.

θ: planar angles of spiral flakes. When so-called "cracking destruction" occurs, the open angle of the spiral flake from the impact point is defined as θ. "Cracking destruction" occurs when a cylindrical bone is impacted, creating an X-shaped fissure, the adherent force among the compact bone disappears, and then the resistance against modification is completely eliminated.

I chose four examples to show the variation in the 76 specimens (Figure 12, Table 4).

I. Notches at the impact points of 1, 2, and 3 of Figure 12 are created by one of the following processes: (1) the break of the impact point itself; (2) secondary flakes created by the force of impact; or (3) formation of a cracking cone of bone (rare case). Therefore, around the impact points, clear impact notches are observed. There are clear flake scars inside the bones, as well as notches on the surface of compacta.

II. Numbers 4 and 5 of Figure 12 are linear rather than notched, but fissures and rings are seen around the impact point on compacta, especially around that of 5.

III. Figure 12-7 is an example which does not have a notch around the impact point, but has two cracks. Impact flakes are not flaked off from the diaphysis. If the power of the percussion were

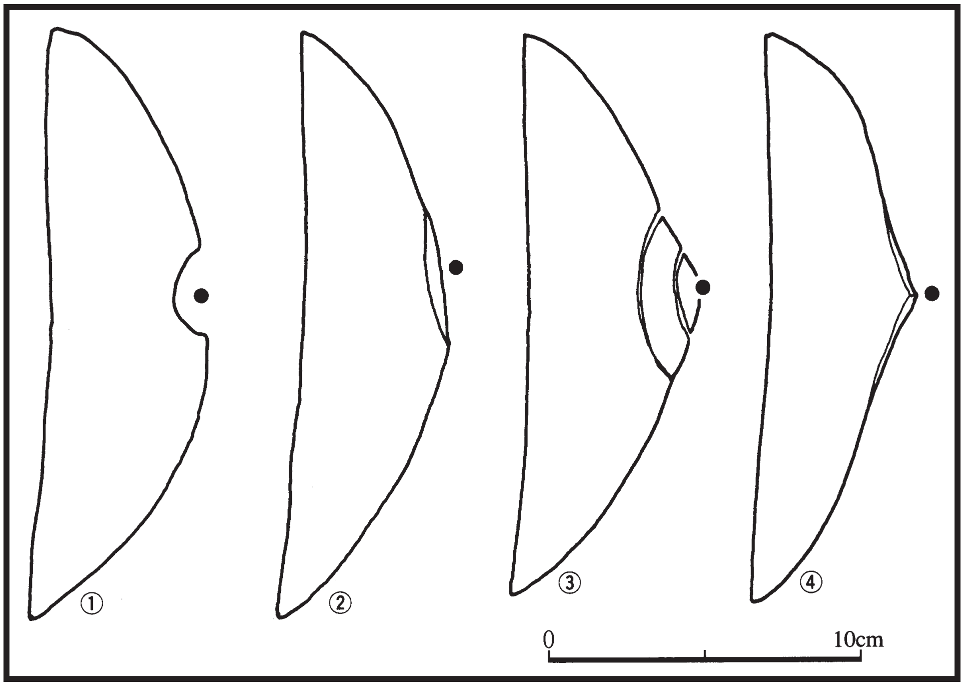

Figure 13: Models of spiral flake variation.

stronger, the impact point would be notched, just like specimens 1, 2 and 3.

IV. Numbers 6 and 8 of Figure 12 are examples of pointed impact points, instead of notches. However, in 6, there is evidence for a very thin impact flake having been flaked off. This is suggested by a 2.5 cm long, thin, exfoliation scar along the break. Even with that, the overall shape around the impact is pointed. Pointed impact points may be an appropriate criterion for artificial modification because materials with pointed regions near the impact points are often formed in percussion experiments, and because there are examples which have impact flake like 7 attached to the diaphysis.

Examples I, II, and III (1-5 and 7 in Figure 12) are appropriate criteria for recognizing human caused modification for three reasons: 1) they are not found on dry bone breaks, which will be discussed later; 2) they are not found on carnivore chewed bones; and 3) they cannot be formed by external natural forces, such as overlying soil pressure. It may be appropriate to conclude the rank of certainties of artificial modification is I, II, III, and, IV, respectively.

For IV, one should not conclude conclusively the examples are human modifications when the only evidence is the area of impact being pointed, unless other additional evidence, such as 6 or 7 of Figure 12, are found close to the impact point. For example, Lyman (1989) shows an example of a pointed spiral flake from a long cylindrical bone diaphysis of elk killed by the explosion of the Mt. Saint Helens, in May 18, 1980.

Furthermore, Figure 14 shows an example of the misconception of a pointed area as an impact point. This figure is an example of a case in which a spiral flake was exfoliated from the outside of a bison tibia by the first percussion, and secondary fractures occurred intensively on the inside of the bone. The spiral flake happened to be attached to the diaphysis nicely. On the side view of the center Figure 14, the flaking scar of a thin impact flake can be seen from the posterior of a tibia. The impact point is shown as a black circle, and the white circle just above it is the resulting pointed region. In this example, the mechanism of flaking was clearly determined because of the refitting of the spiral flake to the diaphysis. If this hadn't happened, the assumption of the position of the impact would be difficult to ascertain.

The above discussion is my explanation for variations in spiral flakes, though it is somewhat complicated. Figure 13 is a model of variation in spiral flakes. The period in which we were arguing about human/non-human origin of general spiral

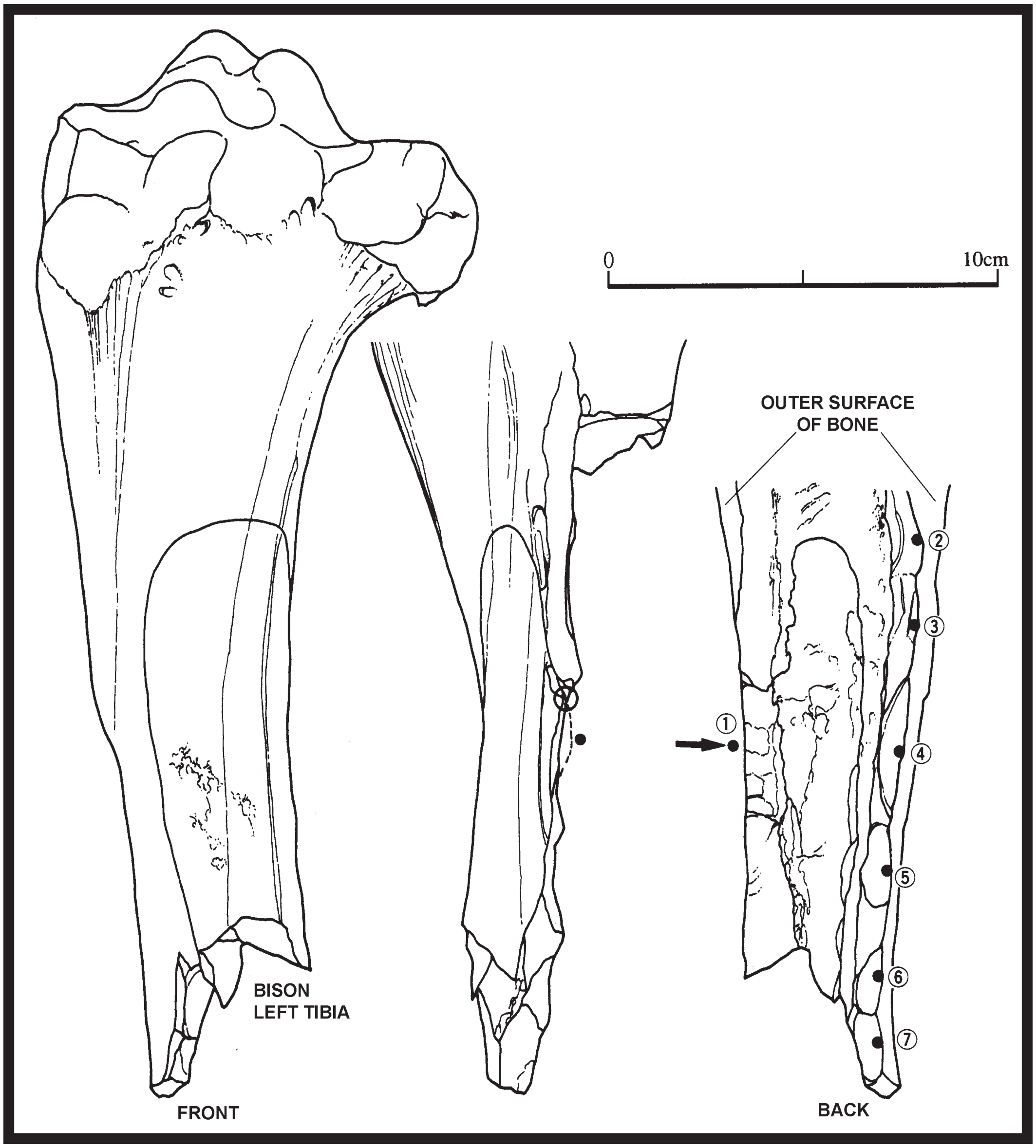

Figure 14: Spiral fracture and secondary fracture of diaphysis (1). Left bison tibia: anterior view on left, inner surface of bone on right.

flakes has passed. My conclusion for the model of variation with high probability of artificial modification is derived from cylindrical bison bones at the Casper site.

Lastly, we are going to observe the dispersion of the ratios of the length to the width of the 76 spiral flakes. There is one specimen which has longer width than length (Figure 11-1 and Table 4-19; specimen number 48NA304-1828). For the others, it can be roughly concluded the width of cylindrical bones (cross-sectional diameters of cylindrical bones) determines the length of spiral flakes. There is a good correlation between Figure 11-2-I (the negative of the impact point of a spiral flake) and 11-2-III (the positive impact flake from the spiral flake). Thus, it is permissible to admit the impact flakes in Figure 9-4 to 9-7 are created at the same time the percussion made the spiral fractures.

Spiral Fractures and Extraction of Bone Marrow. What is the purpose of spiral fractures? Although the term "spiral fracture" has been discussed with special attention, actually, this is an inverted question. A distorted, lozenge flake is formed when a blow on a long cylindrical bone breaks the diaphysis. The piece of bone is called a spiral flake. Therefore, the question can be converted to "for what purpose

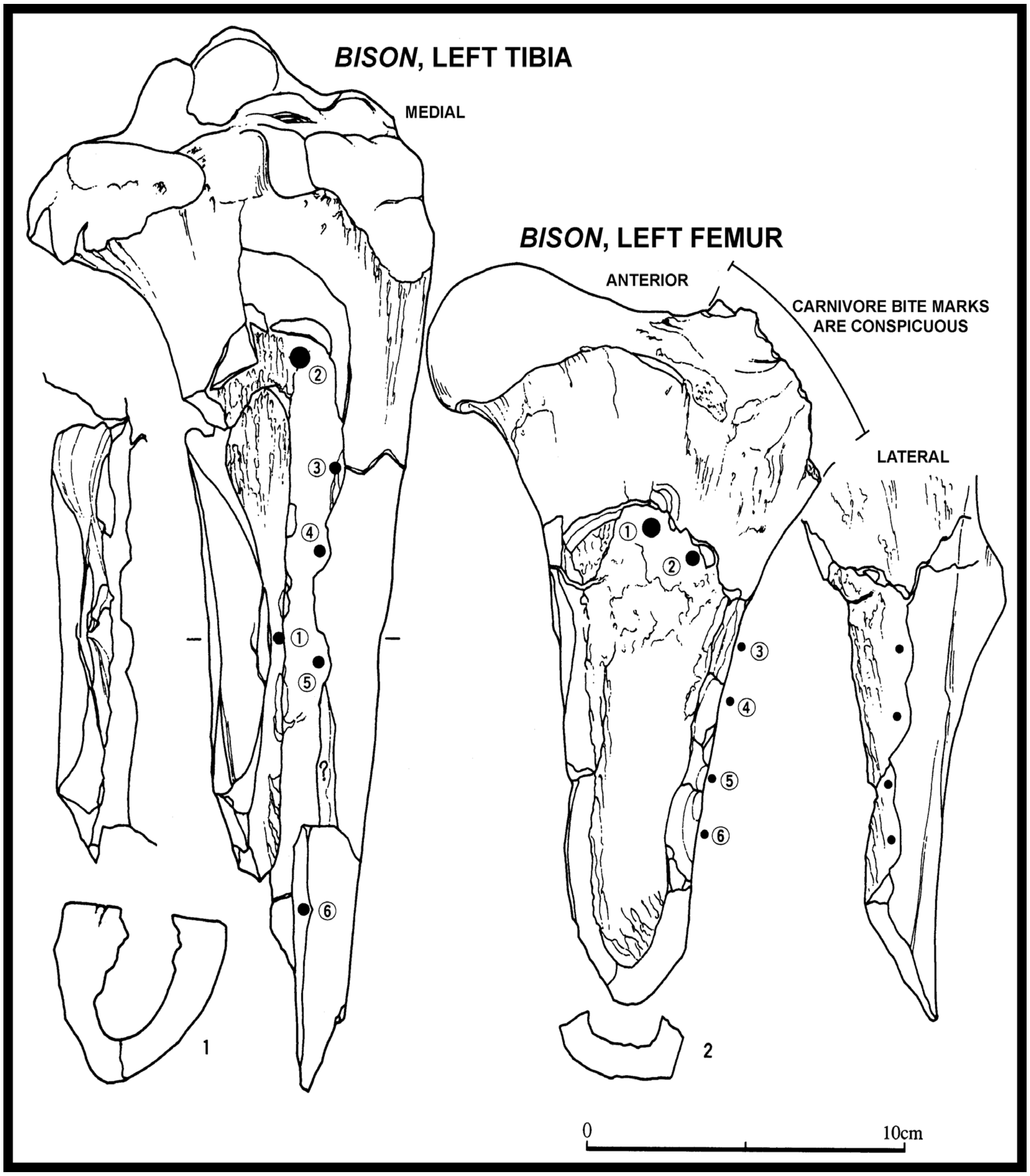

Figure 15: Spiral fracture and secondary fracture of diaphysis (2). Left bison tibia (on left); bison femur (on right) showing carnivore chewing.

has the cylindrical bone been broken?" The main purpose for breaking bones in the extraction of bone marrow, and the secondary purpose is making bone tools from the bone flakes formed by the break. There is no chronological limitation for extraction of bone marrow by a blow on cylindrical bones of mammals of large or intermediate sizes. Evidence of this activity has been observed from FxJj 50 (Bunn *et al*. 1980), a site of early hominids in Kenya, to modern Inuit (Binford 1981).

What is the specific significance of the artifacts found in the Casper site, since the breakage of cylindrical bones is universal? The answer is they give a reference point for interpretation of percussion scars and fracture on bone artifacts from the Paleolithic and Paleoindian periods. Here, I am discussing the Casper site materials. The important fact to remember is the concurrent occurrence of "spiral flakes," "clear scars of broad fracture by bluntly-pointed hammer stone on the flat regions of cylindrical bones," and "the existence of the scar of repeating secondary small fractures along the already-opened crack on a cylindrical bone" in a single bone specimen. Moreover, it is convenient to understand the

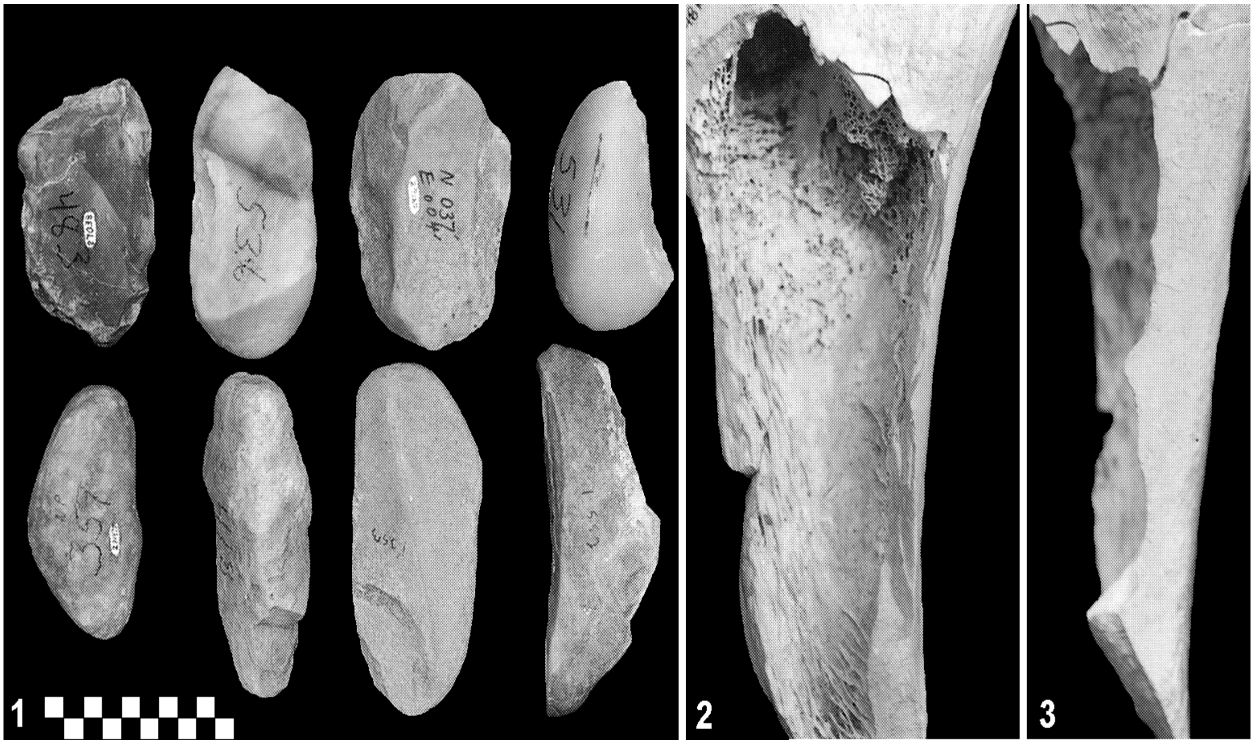

Figure 16: Hammerstones and secondary fracture of diaphysis (enlargements of Figure 15-2).

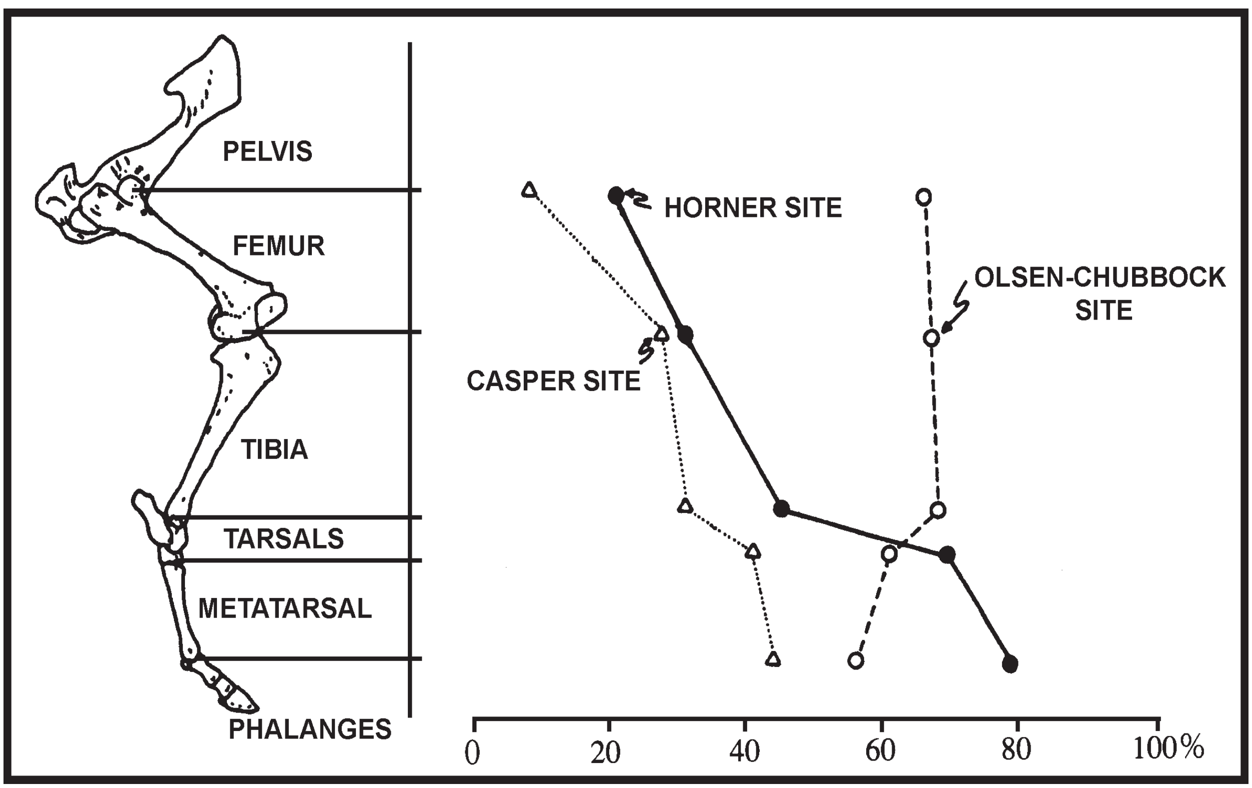

Figure 17: Frequency of bison lower extremity articulations in Paleoindian kill-butchery sites (Todd 1987). Casper site dotted line on the left, Horner site solid line, Olsen-Chubbock site dashed line.

Table 5: Measurements of hammerstones and other materials. HS=hammerstone.

	CATALOG NUMBER	(cm) l	(cm) w	(cm) th	(g) w	CATEGORY	PERCUSSION SCARS, ETC.	MATERIAL TYPE	NOTES
1	27147	11.49	6.08	3.53	357.8	HS		quartzite	circular stone
2	27135	13.00	6.65	4.82	536.1	HS		quartzite	circular stone
3	27156	15.50	7.74	6.30	1173.2	HS+PS		quartzite	circular stone
4	27?44	8.94	5.14	4.60	249.2	HS		quartzite	semi-circular stone
5	27161	10.26	7.30	4.85	516.9	HS		quartzite	semi-circular stone
6	27138	14.64	5.54	4.62	417.1	HS		quartzite	semi-angled stone
7	27039	15.60	6.58	4.10	538.6	HS		novaculite	semi-angled stone
8	27??2	20.00	8.06	6.37	1207.0	HS		quartzite	semi-angled stone
9	27154	11.70	10.05	7.70	1250.4	HS+PS		quartzite	circular stone
10	27160	12.05	8.65	6.25	639.8	HS		quartzite	semi-angled stone
11	27142	15.37	6.56	5.38	760.9	HS		quartzite	semi-angled stone
12	27155	15.41	8.43	5.10	501.2	HS		quartzite	semi-angled stone
13	27159	16.70	5.90	5.36	509.5	HS		quartzite	semi-angled stone
14	27157	16.60	9.50	6.90	1229.2	HS		quartzite	semi-angled stone
15	27148	17.40	10.09	7.37	1321.0	HS		quartzite	semi-circular stone
16	27163	11.16	6.47	6.10	529.8	HS		quartzite	circular w/fracture
17	27145	9.36	5.97	4.73	362.7	HS		quartzite	circular w/inclusion
18	27038	12.10	7.34	5.20	487.7	HS		flint	semi-angled stone
19	27143	9.57	6.20	4.90	305.0	HS		quartzite	angled stone
20	27158	12.20	8.26	2.80	376.7	pebble		novaculite	semi-angled stone

HS + hammerstone; PS =

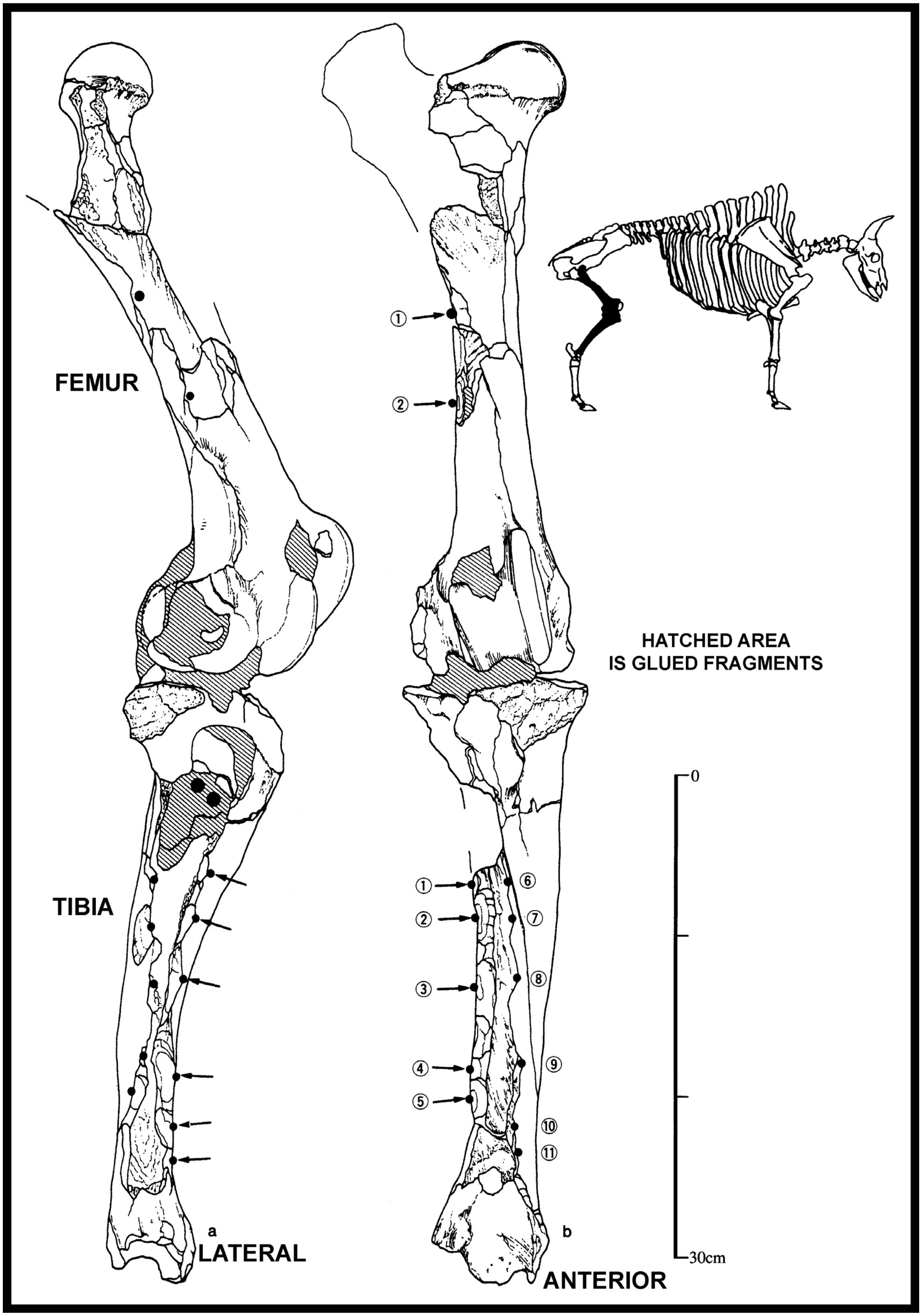

Figure 18: An example of bison right femur and tibia articulation.

Figure 19: Fractures from extraction of bone marrow. 1) diaphysis to proximal epiphysis front view of bison femur; 2) diaphysis to distal epiphysis, front view of bison tibia (enlargement of Figure 18b).

relationship of these three factors because of the existence of the conjoined materials of a spiral flake and diaphysis (Figures 14 and 15). Differing from many other American scholars, Binford presented line drawings in addition to the photographs of fractured bones, resulting from customary acquisition of bone marrow by the Inuit (Binford 1981, p. 155). However, the sketches are not accompanied by measurements, and details of the fracture(s) cannot be discerned. Here, practical conditions of fracture aspects related to bone marrow extraction will be discussed with measurements to describe the assemblage as accurately as possible.

Figure 14 shows the exfoliation of a relatively large spiral flake from the outer diaphysis of a left bison tibia by a single percussion. Probably, at least six more successive blows were added from the backside to open the diaphysis.

Figure 15-1 is also an exfoliation of a spiral flake by a single blow to a left bison tibia. Furthermore, a blow close to the proximal end caved the bone, and four or five successive small fractures enlarged the fissure. Around the circled “2,” a refitting of the flake to the diaphysis despite the break can be observed.

Figure 15-2 is an example of two blows on the proximal end of a left bison femur (circled 1 and 2 in the figure) and four secondary blows from the outside. Spiral flakes are unknown. A refitted flake to the diaphysis despite the crack can be seen as well (Figure 15-2 and 16-2). On this femur, there is evidence of a blow to extract bone marrow on the anterior, regardless of being left or right (Figure 19-1), because the posterior side of femur has a large tuberosity for muscle attachment and is not suitable for fracture.

Next, the characteristics of hammerstones for cracking bison femora and tibiae at the Casper site are discussed. Twenty hammerstones were recovered, with the stone material mainly quartzite. These hammerstones can be classified in two clusters: about 570 grams and about 1190 grams (Frison 1974). Table 5 shows the results of re-measurement by this author. One of the stones is flat, and it is doubtful it was a hammerstone. Figure 16-1 shows a selection of hammerstones.

For the stone materials, some novaculite and flint were used as well as quartzite. Quartzite and granite are thought to be obtained from the nearby gravels and cobbles of the North Platte River and its terraces (Frison 1974). Minor scars and slight use wear can be clearly described on some pieces. Among the hammerstones are specimens with relatively pointed edges as well as those with rounded edges. Both were probably used for various methods of breaking bone.

BONE ARTICULATIONS

Bone articulation refers to skeletal segments found in their original anatomical positions. Bones can be disarticulated from each other by carnivores even if human butchering activities removed meat from the articulated bones without disturbing the joint. Excavated articulations at the Casper site show the bones have not experienced such carnivore action.

Rear limb articulations at the Casper site consist of o*s coxae* (pelvis, hip bone) and femora (8 percent of the total articulations), femora and tibiae (a little less than 30 percent), tibiae and tarsals (a little more than 30 percent), tarsals and metatarsus (40 percent), and metatarsus and proximal phalanx (43 percent) (Figure 17). In comparison to other kill-butchering sites, the proportional patterns of the articulation composition is about the same, except for a high frequency of the tarsals, metatarsus, and phalange articulations at the Horner site, compared to the Casper site. On the other hand, the Olsen-Chubbock site has a different articulation pattern. The o*s coxae* and femora to the tibiae and tarsus articulations exceeds 60 percent of the total articulated units. What caused this difference? One interpretation is the different functions of the butchering sites. That is, at the Casper and the Horner sites, the kill-butchering activities were carried out in the open, while the Olsen-Chubbock site butchering occurred in a narrow arroyo (a deep canyon). Because of limited space, disarticulation of skeletal units was difficult to carry out in an arroyo, resulting in a high frequency of articulated material (Todd 1987).

Next, the conjoined specimens and specimens retaining flake scars of spiral flakes and secondary impact flakes are discussed. Articulations provide more information for reconstruction of butchering patterns than individual bones. An example is provided by the articulation of a bison right femur and tibia (Figure18). On the femur, a blow near the proximal end from the exterior removed a spiral flake. There is also a scar from another blow. There are no small secondary fractures on this bone (Figure 18). On the tibia, at least five secondary impacts from the lateral side and six secondary impacts from the anterior produced impact flakes. There is no evidence of spiral flake removal on the tibia. I can imagine the two impact events (two large black circles on the figure) on the lateral side initiated a crack and produced an impact scar, and that at least eleven blows for extraction of bone marrow on the diaphysis (small black circles) produced impact flakes. Figure 19-2 is the enlargement of percussion points 1 to 11 from the outside.

At which stage of bison butchering were the articulated units processed to obtain bone marrow? This question can be answered from the articulated units, although it is difficult to answer from single percussion scars on disarticulated bones. Figure 18 shows the skeletal structure of an entire bison, including location of the articulated units. Because the impacts on the femora and tibiae originated on the lateral and anterior sides, it was impossible to extract bone marrow without the disarticulation of bones from the right lower limb from the pelvis with the bison lying with the right side on the ground. Conversely, if the bison lay on the left side, it was impossible to extract bone marrow, unless the right femur and tibia were disarticulated from the pelvis because of the instability of the bone to be processed. Therefore, it can be inferred the impacts on the femur and tibia diaphysis occurred after the kill, skinning, disarticulation of right femur and tibia from pelvis, and stripping the meat from them. The femur and tibia are thought to be impacted with their medial side on the ground for stability, and the blow was directed to the lateral side of the bones. Moreover, for the tibia, it can be inferred that additional impacts from the anterior side of the bone were executed to extract bone marrow.[6)]

DRY-BONE BREAKAGE

Bone fractures can be formed by weathering and destruction in addition to artificial and deliberate percussion. Behrensmeyer (1878) has made a useful table for describing degrees of bone destruction (correlation between weathering of animal bones and years from death) from archaeological sites. In her research, she also defined weathering as a process in which the original compositions of organic and inorganic material in bone are destroyed and disturbed from the original function by physical and chemical forces. The description does not specify whether the bone is exposed on the ground surface or buried (Behrensmeyer 1978:153).

My purpose is not to discuss the general aspects of weathering and destruction of Casper site bones, but to discuss human/non-human induced fractures of bone found in Paleolithic sites. Frison emphasizes the excellent preservation of bone at the Casper site (Frison 1991:176). However, a broad range of weathering and destruction is also seen on Casper site bone.

I selected eleven specimens of both left and right femora and arranged the bone in ascending order in terms of the degrees of weathering and degradation (Figure 20). Missing portions and exfoliations are shown by hatches. For the Casper site, Frison says the occurrence of carnivore chewing is relatively scarce compared to other kill-butchering sites (Frison 1991), but among the assemblage in Figure 20, 16 specimens out of 22 have evidences of some form of damage. Thus, among the specimens I chose for examples of weathering and destruction, carnivore damage is relatively common. However, it is may be possible prolonged exposure of these particular animals resulted in more frequent occurrence of animal chewing.[7)]

Here is an explanation of bone anatomy and structure. The bone matrix, composed of both organic and inorganic materials, is the element of bone without bone cells. Osteoblast cells produce collagen filaments and materials between filaments, and hydroxyapatite (consists mainly of calcium and phosphorus) attaches to the filaments and becomes a hard structure, which supports the body (Masumi 1995; Tsukamoto 1995). When the metabolic activities of bone stop due to death, the bone experiences various mechanisms of weathering and destruction during the exposure of hard structures of bone to the atmosphere or burial in the soil. Unlike green-bone breakages, dry-bone cracks and dry-bone breakages have particular characteristics which reflect the structure of the hard bone. Specimens of bison femora are appropriate to investigate the conditions of weathering on diaphysis and articular surfaces, although many of the specimens have missing portions due to carnivore destruction.

The first noticeable characteristic is the many cracks run parallel to the long cylindrical bones (Figure 20-8, 20-9, 20-10, 20-15, 20-19, and 20-21). This is because the Haversian system, the osteon of compact bone, runs through the diaphysis in a concentric structure of pillars, and because the outer lamella (see figure 3-1-2), which surrounds the Havasian system, cracks lengthwise due to drying. The second characteristic is cracks tangential to the long bones, especially in well-weathered bones (Figures 20-3, 20-5, 20-9, 20-11, 20-17, 20-18, 20-19, and 20-22). The longitudinal cracks are caused by contraction due to drying, due to the effects of Volkmann canal (Volkmann canals run parallel to the bone long axis). However, there is still no clear explanation for perpendicular cracks. There is an example showing the flaking off of part of the outer lamella, due to the advances of both longitudinal and transverse cracks deep into compact bone (Figure 21-2). In one specimen, due to more weathering, the longitudinal and transverse cracks reached the inner basic lamella of the compact bone, and part of the diaphysis surrounded by cracks subsided (Figure 21-3; this is an enlarged photograph of the diaphysis seen in Figure 20-22).

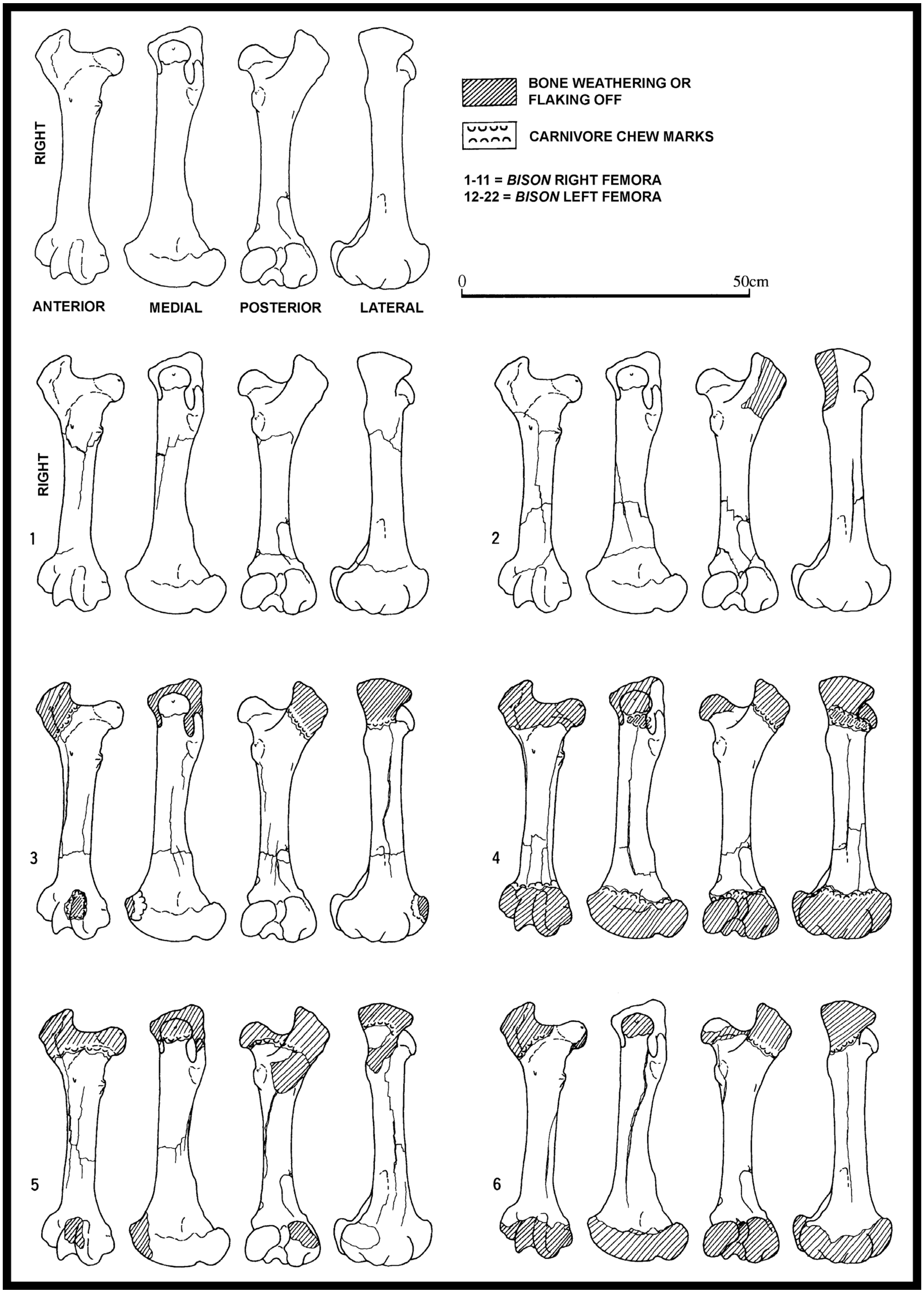

Figure 20: Variation in "dry bone cracks" of bison femur due to weathering and degradation (1). Anterior, medial and lateral views. Hatched represents missing or flaked off portions. Scalloping represents carnivore chewing. 1-11 right bison femur, 12-32 left bison femur.

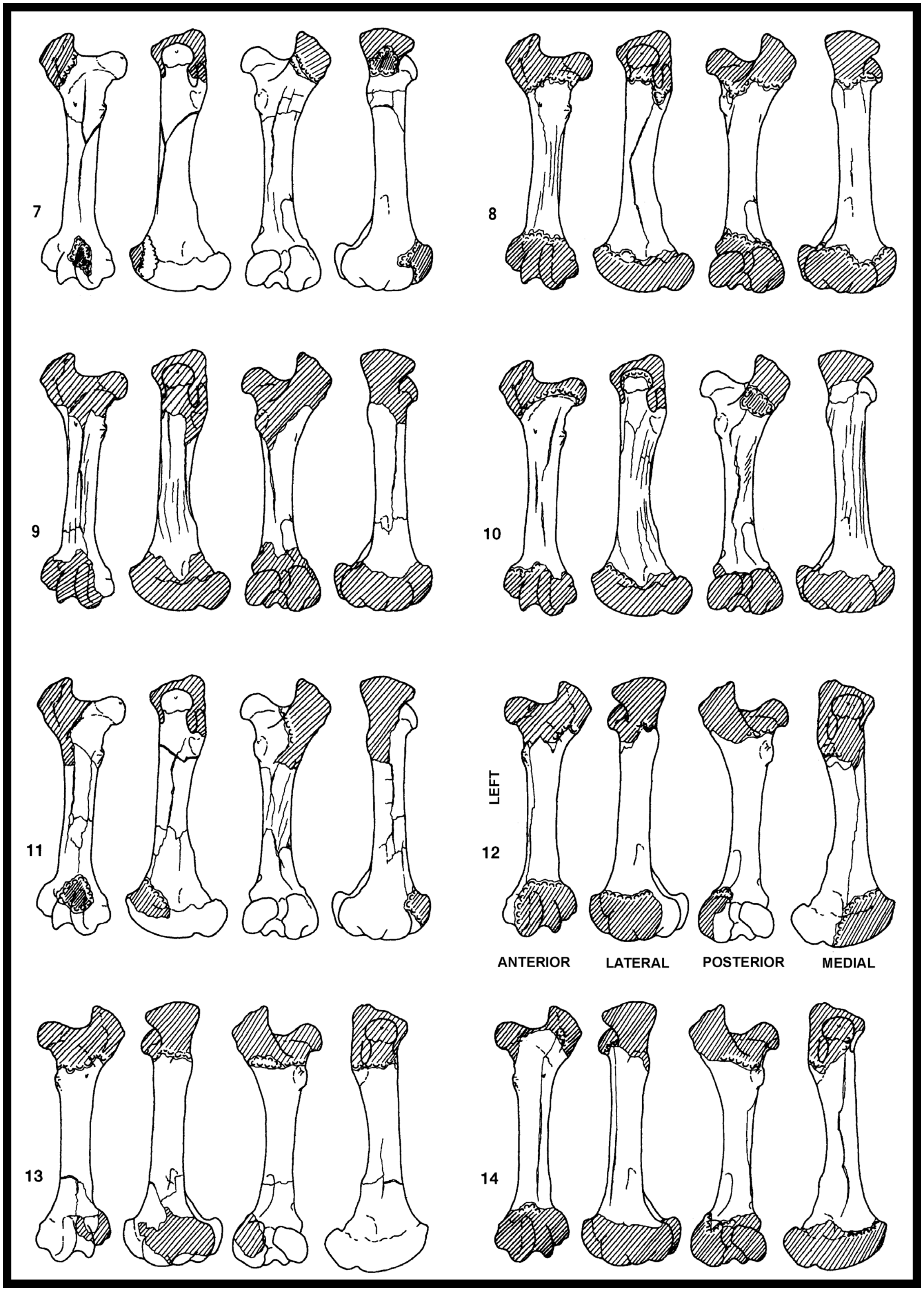

Figure 20: (continued).

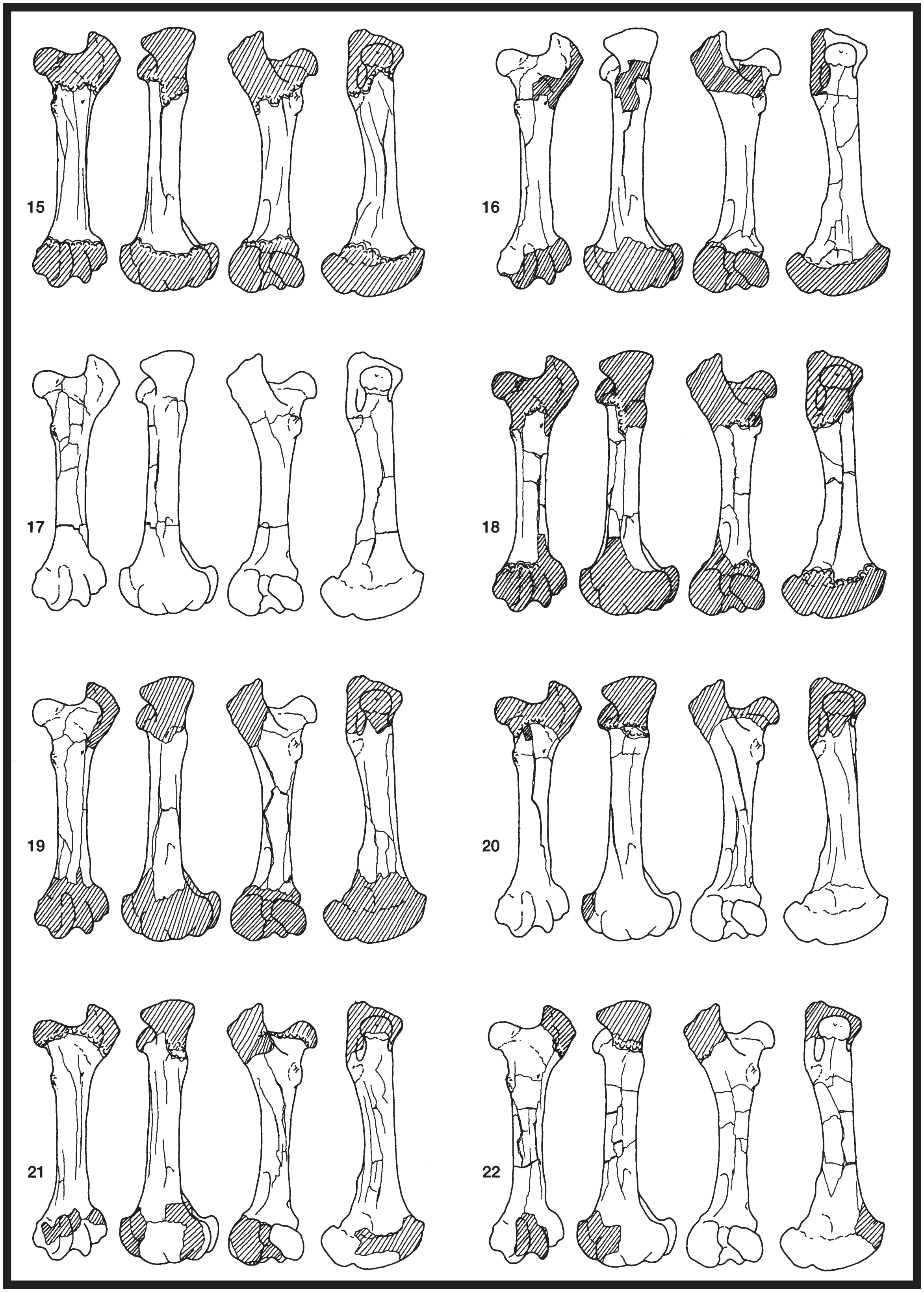

Figure 20: (continued).

In addition to the tangential and parallel drying cracks, some slanting cracks are observed as well (Figures 20-6, 20-7, 20-8, 20-14, 20-20, and 20-21). The slanting cracks are a problem because studies suggest slanting cracks are difficult to produce on dried bone and provides evidence for butchering (see Figure 20-7).[8] Based on the models of variation in spiral flakes I developed earlier (Figure 13, circle 1 to 4), this specimen shows no impact notches and thus cannot be evidence of butchering. However, there are other weathering processes resulting in cracks on the femur that may be confused with evidence for butchering. In this case, the flakes resemble model 4, in Figure 13. Therefore, to demonstrate model 4, observations of fractures on compact bone are necessary.

When Behrensmeyer's five-stage classification chart is applied to the degrees of weathering, Figure 21-1 is the first stage, 21-2 is the second or third stage, 21-3 is the fifth stage. However, I do not find an exact correspondence. For modern ungulate bone specimens exposed in the ground of Amboseli National Park, Kenya, there is a correlation between the degree of weathering and years from death, but the condition of weathered bone buried in sand dunes (for almost 10,000 years in the case of the Casper site) is different from bones exposed on the ground for several decades.[9]

FLAKED BONE TOOLS AND BUTCHERY ACTIVITIES

There is a wide range of variation in flaked bone tools, for example: elaborate bone tools, bone tools with little secondary modification, bone tools without any modification but repeated uses evident by a polished surface on the bone, and bone tools which morphologically resemble stone tools. Like flaked stone tools, flaked bone tools can also be classified as curated or expedient. This dichotomy made by Binford is especially useful for flaked bone tools because of possible frequent uses of bone flakes from breakage of long cylindrical bones (Binford 1977). The classification of flaked bone tools is still untouched worldwide; we are uncertain our classifications capture either the emotional or experiential thoughts of people in the Paleolithic. In comparison to stone tools, bone tools are generally expedient. There are a few curated flaked bone tools, although

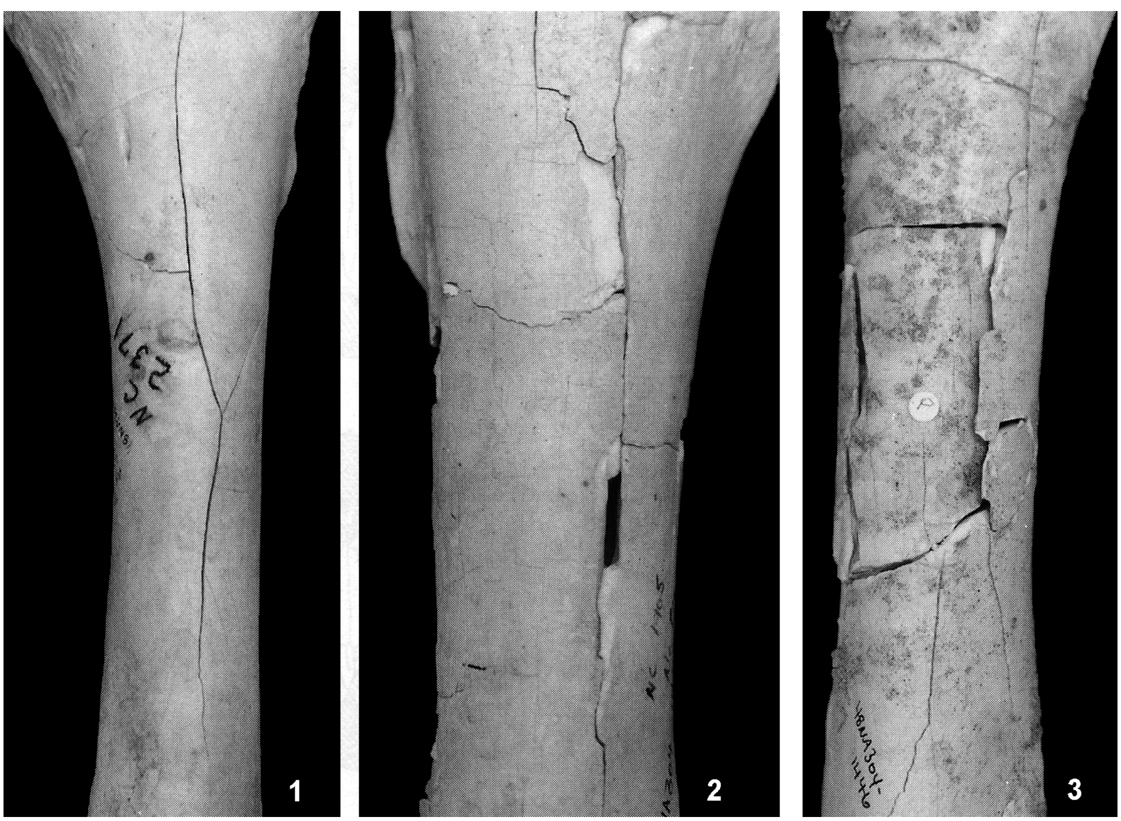

Figure 21: Variation in fracture due to weathering and degradation (bison femur).

the number of these tools is scarce. To be analyzed by morphological analogy to flaked stone tools, curated bone tools are meaningful because they were made for repeated use and transportation, compared to on the spot use of expedient tools. Of course, my assumption is not universal among scholars, and my standard of classification is detailed elsewhere (Ono 2001:Chapter 5).

Among 8,000 bone specimens from the Casper site, only one is analogous to the morphology of a stone tool, a scraper (Figure 22-2). This scraper was made of a flake of bison long bone, measures 7.2 cm long, 4.2 cm wide, 0.8 cm thick, weighs 15.6 g, and has an edge angle of 70^{o}.

Another specimen (Figure 22-1) has one of the edges of a spiral flake secondarily modified to a point, although no comparable stone tool type exists (the same specimen in Figure 12-5). In this artifact, a glass-like shiny surface due to repeated use is observable. This is an artifact made from a left bison tibia diaphysis and measures 14.8 cm long, 3.5 cm wide, and 0.95 cm thick (for other measured values, see Table 4-5). I assume this artifact was made of a spiral flake from a hammerstone blow on tibia to extract bone marrow with added secondary modifications. The tip of this flaked bone tool was used so repeatedly it shines. The particular use of the tool is not certain. Recent studies of polish and striae on compact bone, are unfortunately still in the experimental stage (LeMoine 1994). This kind of study has not yet been done on the Casper specimens.

Another significant bone specimen that contains secondary modification is made on a bison tibia flake formed by extraction of bone marrow. This specimen is a proximal tibia and approximately one half of the diaphysis with secondary modification at the distal end. It has been suggested to have functioned as a chopper (Figure 23-1 and 23–2). This specimen should be called "tibia with a trace of secondary modification at its end." Because this specimen is significant for identification and classification of bone tools, it must be mentioned, although the subject of the present chapter is limited to the identification of human/non-human modification of flaking surface.

Frison (1974) reports items 1 and 2 in Figure 23 as choppers. The term "chopper" is not derived from a morpholo-typology of stone tools. Frison probably used this term according to his func-

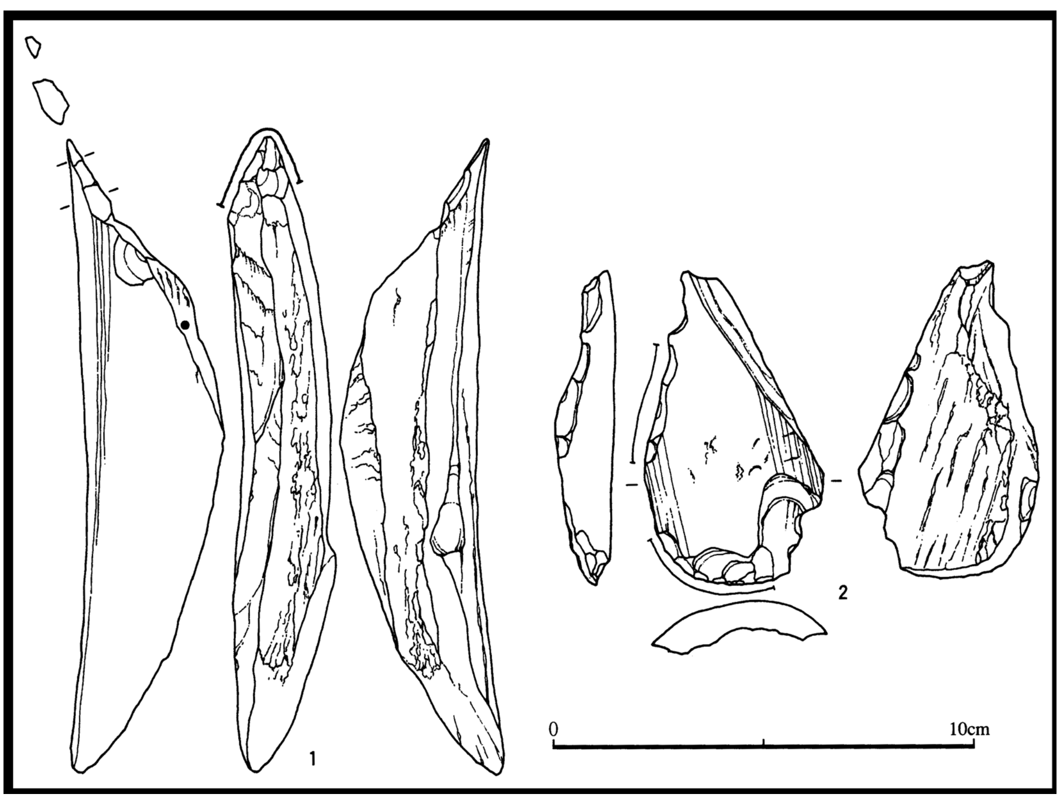

Figure 22: Spiral flake and scraper, both contain scars of secondary fracturing.

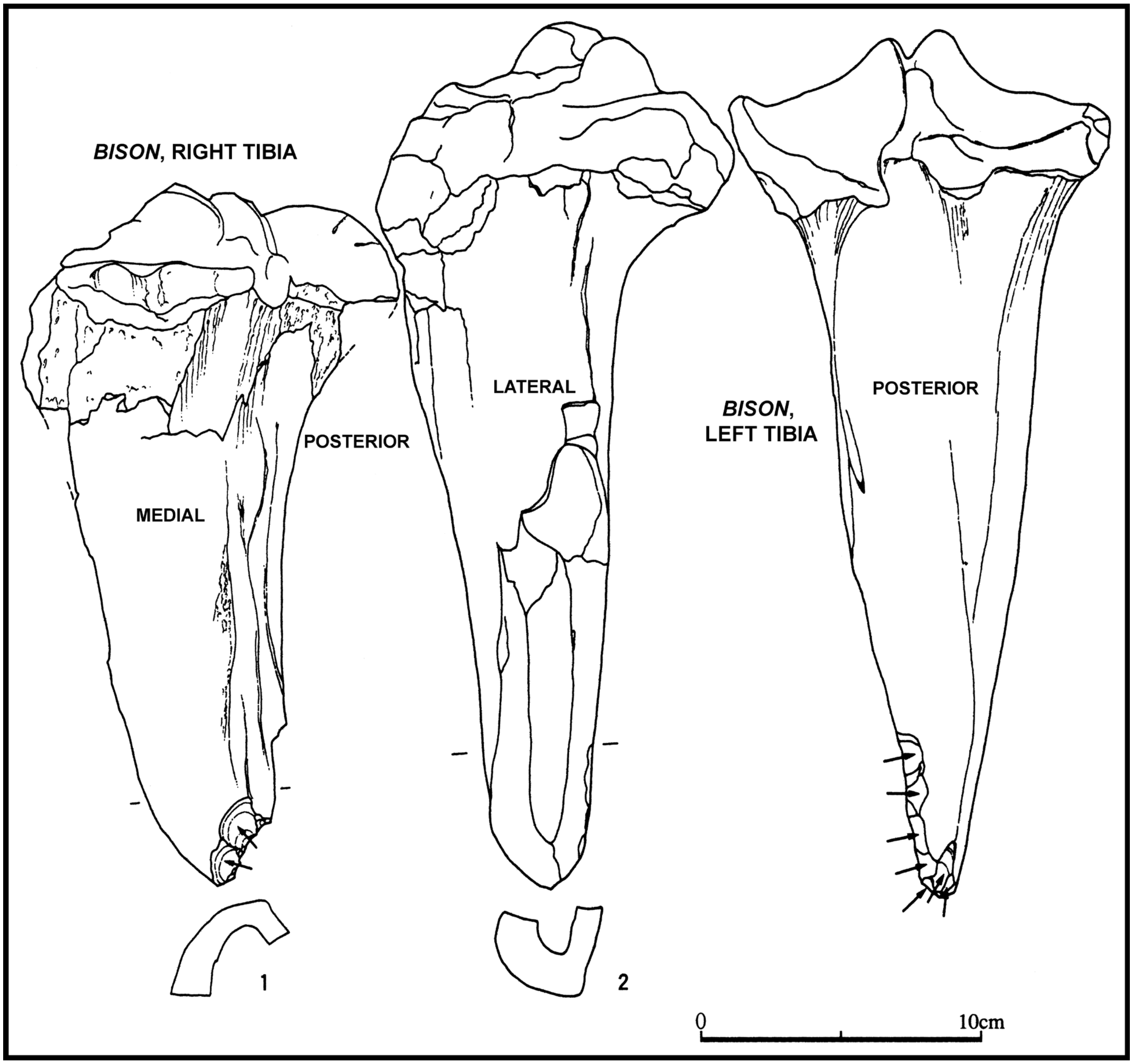

Figure 23: Tibia with secondary modification. Left tibia, posterior-medial view on the left, lateral view in center, posterior view at right.

tional and morphological observation in butchering experiments. He also used the expression, "tibia was the most important bone used as choppers" (Frison 1974:42). Later, however, he does not restrict these specimens to choppers, but changes the classification to "expedient tools" (Frison 1991: 302-308). In Frison's butchering experiment of an adult female bison, pointed green bones and flakes from large bones made excellent tools for disjointing muscles and breaking small bones (Frison 1991:302-303) [10]. Here, I would just mention the experimental evidence showing the usability and versatility of expedient bone tools, such as large bone flakes, randomly-shaped flakes, and diaphyses with secondary modification at its end. Although the shapes of these bone tools are not standardized, they are useful for disarticulating extremities or other joints from the body and for the first incision of animal skin.

This discussion was designed to understand the processes of bone breakage and to introduce a standard for interpretation of bone specimens excavated from Paleolithic sites. I used the bone materials from the Casper site for the purpose of interpreting Paleolithic bone tools. The subjects here can be applied universally to other Paleolithic bone artifacts. These subjects include: flakes formed at the impact point of a cylindrical bone, impact flakes made by secondary flaking on already-opened diaphysis, characteristics of negative scars from which flakes were formed, spiral fracture and extraction of bone marrow, conjoined specimens, and variations in breakage of dry bones. Another reason for the concrete discussion of morphological aspects of bone specimens is that observation of bone specimens is still insufficient, even in the United States where discussion about general and specific characteristics of bone modification are being carried out.

NOTES

1) An area of 622.45 square meters was excavated in 1971 and 446 square meters in 1976. Frison (1974) reported the materials from his 1971 research. Although the main report for the excavations in 1976 has not been published yet, 8,000 bison bone specimens were recorded from both excavations, according to Dr. L. C. Todd.
2) Although the bones were excavated from the same stratum, it is unclear the camel was killed and butchered at the same time as the bison, according to Dr. L. C. Todd (personal communication, August 1992).
3) These results are based on my observation in the Department of Anthropology at the University of Wyoming, from July 26, 1992 to September 14, 1992.
4) My experiments of bone breakage (Ono 2001: Figures 3-11-3; 3-12-3 and 3-8) are examples of intentional impact scars; the scars are not circular or semi-circular when observed from the upper sides.
5) Both Potts (1988) and Hill (1989) were discussing using the same three bone specimens from a den of a spotted hyena. Concrete aspects of these specimens are not known because they show only photographs and not measurements and morphological description. I have not investigated the flakes formed by chewing of spotted hyena. For impact flakes from diaphyses, I imagined the percussion in which a person struck the bone with an accelerating speed. For chewing activities of hyena, on the other hand, I think the chewing is just like pressure flaking with a fang-shaped tool placed on the diaphysis. The bone flakes from the studies of Potts (1988) and Hill (1989) do not include the shapes of Figure 9-4 to 9-7. This problem of human or non-human agency in bone modification should be studied further.
6) It can be difficult to restore the initial condition of butchery from flake scars on bone specimens from a site. When we think about butchery, we have to consider various positions of the body and procedures, such as: the butchering was carried out with or without disarticulation of extremities from the body, the angle of the percussion on the diaphysis, a stable position of the bone on the ground either with or without soft body structures, and whether the elements are single bones or conjoined.

   In 1992, when I was observing the Casper site assemblage, I had an opportunity to discuss with Dr. Lawrence Todd, at Colorado State University, about this problem. His major studies are mammoths in the Colby site (Frison and Todd 1986) and a taphonomical study of bison bones at the Horner site (Frison and Todd 1987). My idea here is from Dr. Todd.

   The problems are these: on which position (anterior, posterior, lateral or medial) of cylindrical long bones are the flake or fracture scar, and whether the scars have influence from singularity/jointing of bones. In other words, the question is that a particular type of impact (in respect of angle of the percussion, position on bone, etc.) has a relationship with disarticulation of a particular joint. For example, the stable positions on the ground for femur and tibia are determinate. If the bone was struck on the top with the bones placed stably on the ground, this means that the extraction of bone marrow was carried out on a disarticulated bone. Inversely, if bone was struck in its unstable position, this means that the elements were articulated at the time of extraction of bone marrow. Moreover, if bone was struck to the articulated elements in their unstable position, it means that the opposite side of percussion had original soft materials (such as meat) attached at the time of extraction of bone marrow (the side from which the bone was struck was free from soft body materials).
7) I chose the materials for examples of breakage and cracking of dry bones of bison femur at the Casper site, but the models and measurements were not made by the complete examination of femur materials. Therefore, the correlation among the degrees of degradation and weathering, the speed of processes of burying, and the frequencies of animal chewing is not certain.
8) In the report about the Casper site, the spiral fracture on this specimen (especially on Figure 21-1, the enlarged photograph) was interpreted as the position of the blow with a pointed tool to disconnect the muscle from the femoral trochanter (Frison 1974:38-39).
9) Behrensmeyer says the study of weathering is just in its beginning, and the standard and identification table she constructed for the stages of weathering are just hypotheses which will be tested from

perspectives of modern and fossilized materials (Behrensmeyer 1978:162). I think, after her study, no systematic study of bone weathering has been carried out. However, the table and stages proposed by Behrensmeyer are often used, even if a site has a different climate and/or latitude from her study. Some studies slightly modify Behrensmeyer's tables and standards (Todd 1987:123; Todd et al. 1987:64).

10) Other than this study of Frison, I had an opportunity to observe the material made by repeated experiments of Dr. Frison. He made ice-ax-like bone tools from tibia, tarsus, and metatarsus of modern bison. The same kind of cloudy-glass-like polish on the material of Figure 22-1 was observed. Although these specimens suggest the use of this kind of bone tools, I do not want to discuss this further because of the lack of observed data.

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