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Many preserved kill sites are indeed "geological oddities," as Albanese (1978:61) put it, and Folsom is no exception. To understand why and how this site was preserved where it is, and to use that information to gain insight into the form of the ancient landscape, we need to explore Folsom's geological context and stratigraphic history. Although important insights into these topics emerged from earlier work here, especially that of Anderson and Haynes in the early 1970s, there were significant gaps in our knowledge of these matters when our fieldwork began, as detailed in chapter 1.

To fill those gaps and complement the prior research at the site, we undertook our investigations with several goals in mind. First, we attempted to reconstruct the topography of the site as it was in Late Glacial times, in order to explore how the landscape appeared and may have been used by Folsom hunters to exploit their prey. It was in the course of this effort that it became apparent that a large portion of the site was situated within a paleotributary, while the remainder extended into an adjoining paleovalley (chapter 4). As a result of that discovery, a second goal of our work was to understand the depositional and erosional histories of the paleotributary and paleovalley and how these may have differed—with an eye on understanding, among other things, differences in the taphonomic history and preservation of faunal remains in these two settings (a matter also explored from the vantage of the bones in chapter 7). Finally, we sought to develop a more precise radiocarbon chronology for the site and the Paleoindian occupation than previously available.

Initial Efforts to Resolve Folsom's Age

The original investigators at Folsom had a broad sense of the site's stratigraphic history. As Figgins explained it to Oliver Hay, in reference to the now-famous photograph taken September 4, 1927, of Schwachheim and Brown next to the first in situ Folsom point (fig. 2.12):

This photo also illustrates the three strata overlying the bone layer. The lower [light-colored] member is composed of clays which Mr. Brown declares were deposited in an old stream channel, cut into Cretaceous deposits. The bones lie almost directly upon the Cretaceous. The stratum varies in thickness, as do the overlying members, but at the point shown in the photograph it is 36 inches (to the left this increases to 60 inches). The next [dark-colored] stratum is composed of clays and silt, and carries a high percentage of carbonaceous matter, together with occasional freshwater shells. At the point shown in the photograph, it is 22 inches, but increases to the left to a depth of 4 feet or more. The top [lighter-colored] layer is composed of Cretaceous clays and pieces of shale up to four or five inches in length. Also granite bowlders [sic] of equal size. You will appreciate the density of the deposit when I tell you the upper layer has been undercut fully 6 feet, the pick in the foreground being within a vertical line of the overhanging deposit. It is, of course, partially supported by roots. (Figgins to Hay, September 15, 1927, OPH/SIA)

As Brown himself observed, on the north side of the arroyo there was much more than 4 ft of the upper clay:

North side of quarry section shows 9 feet of black clay (8 thin stripes) of yellowish in local areas which merges into brownish yellow at base indistinguishable in character from that below. This dark color is probably due to the oxidation of clays by plant life, for under every large clump of scrub oak the masses of rootlets reach to about this point. Bone layer extends from 10'-12' in deepest part of deposit which was center of stream course or water holes although most of skeletons rested on sloping bank of original N X S stream course 1/2 mile
in length above quarry. A few inches above, with, and
several inches below bone layer there are irregular lime
concretions, with veinlets of pure gypsum....[?] of
ground waters through the eroded Pierre [sic] shales
which throughout most of quarry have been dissolved
into clays. (Brown, ca. September 4, 1927, Field Notes,
VP/AMNH)

While these and other descriptions (see also Cook 1927a,
1928b; Hay and Cook 1930) lack detail, all seem to agree that
there were at least three main deposits sitting atop the
Cretaceous bedrock at the site (also Cook to Hay, January 25,
1928, OPH/SIA). Embedded within their descriptions was
some hint of the paleotopography and the sloping surface
on which the bone was resting (Brown 1928b) as well as of
the stratigraphic variability across the site—or at least of the
difference in depositional histories evident in the profiles of
the South Bank and North Bank, though such differences
were scarcely remarked on or understood at the time.

There was, however, a marked difference of opinion with
regard to the depositional context of the sediments in
which the bison bone was found. Cook, on the one hand,
believed that

the fine, mucky character of the matrix (mostly clay-
silts) ... and, its freedom from coarse materials such as a
creek or stream would commonly carry, and especially in
a region where steep gradients were the rule, as here,
makes it obvious that this must have been some sort of
muck-hole, marsh, or slough at that period. (Cook to
Hay, January 25, 1928, OPH/SIA)

This interpretation was supported by the apparent presence
of freshwater invertebrates in the deposits (also Cook
1927a:244; Cook 1928b:39; Cook to Hay, December 23,
1926, OPH/SIA). For his part, Bryan (1937:141–142) saw the
deposits as a “clayey alluvium,” of a floodplain deposit. In
later years, it was generally supposed that the kill had taken
place in “an old bog or waterhole” in which the animals
were trapped in the mud (e.g., Roberts 1940:59).

On his first visit to the site in September 1927, Brown
supposed that the bonebed was situated in “a stream course
or water hole.” By the following spring, the water hole had
become a lake, formed behind a lava dam (Brown
1928a:826; also Wissler, field diary, August 2–10, 1928,
ANTH/AMNH). However, six months later, and after his
own season (1928) of excavations, Brown revised that opin-
ion, identifying the gastropods in the bonebed as “pul-
monate land shells.” He further observed that throughout
the bone-bearing stratum there were irregular “limestone
nODULES” (i.e., calcium carbonate nodules), secondary gys-
perm crystals, and fine gravel matrix, but “only one stone
was encountered during the three years’ work, a piece of
lava the size of one’s head” (Brown 1928b). Brown reasoned,
as Cook (1928b:39) had, that if these were sediments of fluv-
ial origin, boulders of all sizes would have been found.

Quite unlike Cook, however, Brown (1928b) then con-
cluded that the deposit was “of aeolian origin accumulated
during a long period of little or no rainfall.” Beyond these
general observations, there is no surviving record of any
detailed sediment or stratigraphic analysis, although
Brown’s AMNH crew was obviously interested in the matter,
given the labor they invested in clearing that 3-ft profile
along the North Bank (fig. 5.1; chapter 4).

The initial estimate of the age of the bonebed was by
Cook (1927a:244), who put it at “certainly thousands of
years” and of later Pleistocene age. This was his public posi-
tion; privately, he guessed that it might date to “some inter-
glacial stage of the Pleistocene (Cook to Hay, January 25,
1928, OPH/SIA). Yet, and as discussed earlier (chapter 2), he
never thought it “had any such antiquity as the Frederick,
Oklahoma and Colorado, Texas, evidence” (Cook to Ingalls,
January 6, 1929, HJC/AHC; Cook to Wissler, March 25, 1929,
HJC/AGFO; Cook 1928b:39).

Cook was reluctant to express an opinion of the site’s
absolute age in years, but A. V. Kidder was not (chapter 2).
He thought it indicated an antiquity of the order of 15,000
to 20,000 years ago (Kidder 1927, 1936:144). Similarly,
Brown estimated, based on observations he made on his
first visit to the site, that it would take at least 24,000 years
for the sediments lying atop the bison bone to accumulate
(Brown 1928a:828). Following the 1928 season on the site,
he would only suggest that the distinct species of bison and
the overlying sediments of “highly reworked earth” indi-
cated great antiquity, perhaps dating to the close of the
Pleistocene (Brown 1929:128). A few years later, he again
provided numerical estimates, echoing Kidder’s more con-
servative supposition that Folsom groups were on the land-
scape “15,000 to 20,000 years ago” (Brown 1932:82; also
Brown to Howard, May 16, 1935, VP/AMNH). In those pre-
radiocarbon years, such estimates were necessarily based on
general assumptions about sediment accumulation rates or
the observation that if the extinct fauna was Late
Pleistocene in age, then it would therefore be in that tem-
poral range, based on the antiquity then assigned to this
period in geological history (e.g., Antevs 1925, 1931).

Still, the co-occurrence of artifacts and bison, on which
the relative age estimates were based, was necessary but not
sufficient evidence of the site’s antiquity, since the taxon-
omy and age of the extinct bison were still in question (e.g.,
Antevs 1935:303; Bryan 1941:507; Roberts 1937:155; Romer
1933:70). Brown was confident this was a late Pleistocene
species of bison; Hay thought it earlier (Brown to Frick,
August 28, 1928, VP/AMNH; Romer to Cook, May 26, 1931,
HJC/AGFO). For others, the possibility was still open that
this species survived into the Holocene (Cook to Hay,
January 25, 1928, OPH/SIA; Simpson to Brown, July 25,
1928, VP/AMNH). As Kirk Bryan lamented, “We know so lit-
tle about the Pleistocene faunas” (Bryan to Wetmore,
August 16, 1928, USNM/SIA).

Therefore, during his Smithsonian-sponsored fieldwork
at Folsom in 1928 (fig. 2.14; chapter 4), Bryan sought
independent geological evidence of the site's antiquity. Using remnant terraces and benches in the valley (see Bryan 1929, 1937), Bryan reconstructed four main stages in the region's alluvial history—the last of which was represented by the present valley of Wild Horse Arroyo. In each successive stage, rivers and streams cut below the level of older and broader valleys, leaving behind a stair step of valley-floor remnants. The development of these “four successive stages doubtless required all of Pleistocene time” (Bryan 1937:143).

The floodplain deposits in the most recent of these valleys were dominantly comprised of younger alluvium, little different from floodplain deposits in other New Mexico streams that contained “relics of the Pueblo Culture.” But these deposits also contained a rare pocket of older alluvium, within which was the Folsom bison bonebed (Bryan 1937:142–143). If the younger alluvium was of the order of 1,000 years old, then the older alluvium “on the ordinary criteria used by geologists . . . would be considered Early Recent or very Late Pleistocene” (Bryan 1937:143; also Bryan 1929:129). Several years later, Bryan (1941:511) would round up the age of the Folsom culture (not site) to “25,000 ± years ago,” based on his work at Lindenmeier and correlating terraces and glacial deposits of the southern Rockies with continental glaciers of the Middle West (for a historical discussion of Bryan's work, see Haynes 1990, 2003; Holliday 2000b).

Many who worked at or visited the site made note of the fact that the bone-bearing deposits contained a great deal of charcoal. Yet, none of it, so far as Clark Wissler could tell,
appeared to be cultural in origin: “It is found scattered and generally, but not suggestive of a camp fire” (Wissler, field diary, August 2–10, 1928, ANTH/AMNH; also Wissler to Howarth, August 26, 1931, VP/AMNH). Although radiocarbon dating was still two decades into the future, the charcoal was nonetheless of interest. Wissler collected some while he was there in 1931 overseeing Merrill’s mapping of the site (Wissler to Howarth, August 26, 1931, VP/AMNH).

In early 1933, Cook wondered if charcoal from the site might be dated using dendrochronology. He asked Howarth if, on his next trip to the Folsom site, he would look in the arroyo a short distance downstream

to see if there is still any charcoal exposed in the bottom of it,—where that was, in those “fire pits (?)” in contact with the undisturbed Pierre,—just about the head of that little narrow wash. I’m sure you know the spot. If you find any bits big enough to show any number of annual rings,—please collect them, and send them up. I want to examine them; and will forward them to a man who is specializing on this,—Douglass,—to see if he can date them. I doubt it,—but it is interesting to try. I will give you full credit for doing it. . . . (Cook to Howarth, February 17, 1933, HJC/AGFO)

Howarth knew the spot Cook was directing him to and was sure the deposits would be “near the same age as the finds in the Folsom pit” (Howarth to Cook, February 28, 1933, HJC/AGFO). In July, 1933, Howarth finally got out there, a few days after a heavy rain had fallen and exposed charcoal in the arroyo walls—and two projectile points at the site (chapter 8). Howarth collected the points and the charcoal and sent the latter to Cook (Howarth to Cook, July 25, 1933, HJC/AGFO).

The charcoal Howarth collected must have held little dendrochronological promise, for Cook merely saved the sample. Given the limited temporal range of dendrochronology in those days, he may have realized submission of the sample was pointless, even if annual rings were visible. But soon after radiocarbon dating was invented, and at the suggestion of Frank Roberts (Roberts to Cook, October 10, 1949, HJC/AGFO), Cook submitted the sample to Willard Libby at the University of Chicago, with the following explanation:

The sample of old charcoal I collected in July, 1933, from below the Folsom bison and artifact level, in the arroyo of the type site of that cultural group. The arroyo which had cut a narrow, steep channel, down through this bison bone and artifact level, as I first saw it before any excavation work was done there, had exposed the edge of what appeared to be an old “fire pit,” just a little below, and downstream from the horizon in which the bones occurred. When I was there, at the time I collected this charcoal, a recent heavy rain had better exposed this “fire-pit. (Cook to Libby, December 7, 1949, HJC/AHC; portions in Arnold and Libby 1950:10)

That Cook reneged on his promise to credit Howarth for collecting the sample is troubling but hardly surprising. More unfortunate is the fact that he submitted a sample assuming, but not actually knowing, where it was obtained. That would prove to be a mistake.

Libby was sure the sample would provide enough carbon for dating (Libby to Cook, December 15, 1949, HJC/AHC) and, within the year, had results. Using the original solid carbon method, two ages were obtained: 4,575 ± 300 and 3,923 ± 400 14C yr B.P. These were averaged by Libby to 4,283 ± 250 14C yr B.P. (C-377).1 Libby offered the laconic observation that the age was “surprisingly young” (Arnold and Libby 1950:10).

This first radiocarbon date on a Paleindian site “caused considerable comment when [it] was released” (Roberts 1951:20; also Evans to Cook, January 20, 1951, HJC/AHC). While the charcoal sample was believed to have come from below the bonebed, the age “was entirely too low in the opinion of many archaeologists and geologists and was completely out of line with dates for other materials known to be later stratigraphically” (Roberts 1951:20). For that matter, it was far too young for either Early Holocene or Late Pleistocene.

Cook privately admitted to Glen Evans that he’d condensed “too much in the statement of where I got the charcoal,” although he never admitted that it was not so much condensed as it was simply untrue. He claimed that during the original excavations he had been so immersed in the work in the bone quarry that he had not spend enough time on the stratigraphic details, which proved to be more complex than he had originally perceived (Cook to Evans, February 7, 1951. HJC/AHC). In order to clear up this “wide-spread misunderstanding,” in June 1950, Cook revisited the Folsom site (where I had charge of the original excavations),2 for the purpose of re-examining the site. Here a condition I had suspected was clearly seen; namely, that the fire pit from which the dated charcoal came, while old, was definitely much younger than the deposit from which the original Folsom Bison and artifacts were recovered. Erosion of the past eighteen years has better exposed these beds. . . . (Cook, in Roberts 1951:20).

The stratigraphic details may well have been hard to see in 1933, and only clearer as a result of subsequent erosion. Still, much of the misunderstanding was a result of Cook’s dissembling: He reported that the charcoal came from “a narrow valley” that cut through the “original [Folsom age] deposit.” But he never specified where that fire pit was relative to the bonebed, even in his clarification note. In one paragraph, Cook put it “a few yards downstream” of the bonebed, while just a few paragraphs below he had it “some hundred feet [30 m] plus or minus,” east of the bonebed (Cook, in Roberts 1951:20). In a letter to Libby written at the same time, Cook admitted he couldn’t be certain about
the stratigraphic position of the charcoal until he could examine early photographs "to be sure just where I got that charcoal, in relation to present erosion,—I know off-hand within a very few feet,—from memory" (Cook to Libby, September 30, 1950, HJC/AHC; also Roberts to Cook, October 5, 1950, HJC/AGPO). That was a convenient excuse, of course, since he could not have had either memory or photographs of collecting the charcoal, since he had not actually collected the charcoal—Howarth had.

There is a deeply incised ravine matching Cook's instructions to Howarth (Cook to Howarth, February 17, 1933, HJC/AGPO) that enters Wild Horse Arroyo a few hundred meters downstream of the Folsom site, and high in the stratigraphic section lenses of apparently burned earth. Samples from this ravine, and from deposits upstream of the site, were subsequently investigated and sampled by Anderson and Haynes in 1970 (Haynes, unpublished field notes). Anderson (1975:39-40) suggested that the features sampled were not hearths at all but, instead, burned sediment lenses from natural forest or range fires.

Still, not knowing precisely where or from what context Howarth obtained the sample, it is impossible to say whether or not he sampled hearths. Cook himself (in Roberts 1951:20) claimed that "in size and shape the charcoal lens looks like" a hearth, but by 1950 erosion had removed "all traces" of the spot from which Howarth had collected the charcoal nearly 20 years earlier. However, there are two points worth noting: first, Cook's description of the deposit in which the charcoal was obtained—a sediment "much darker and readily distinguished" from the J2 sediments of the bonebed, and which filled a valley cut "as deep or deeper than the current arroyo bottom" and thus was below the level of the bonebed (Cook, in Roberts 1951)—easily fits what would later be designated the McJunkin Formation. The ages of the McJunkin Formation are roughly similar to the C-377 determination, as discussed below. It seems likely the sample Cook submitted came from this unit (Anderson and Haynes 1979:897). Second, there may have been anthropogenic charcoal in that stratum; one of our dated samples (CAMS-57518) from the base of the McJunkin Formation on the South Bank was obtained from a lens of charcoal that may have been a hearth, which is discussed more below. Thus, the first age on the Folsom site, although irrelevant to the Folsom Paleindian occupation, is nonetheless a usable age for marking an episode in the Holocene history of the area.

Establishing a Stratigraphic Framework: The Folsom Ecology Project

Subsequent geological and geoarchaeological fieldwork (Anderson and Haynes 1979; Haynes, Anderson, and Frazier, 1976; Haynes et al. 1992), which included a series of backhoe trenches and profiling of exposed arroyo walls, was conducted in the 1970s, primarily on the North Bank. On the basis of these investigations, Haynes named and described three major Pleistocene/Holocene formations overlying the Cretaceous shale: From top to bottom these were the Wildhorse, McJunkin, and Folsom formations, and they are essentially equivalent to the Upper, Middle, and Lower units described by Figgins, Brown, and others (above).

Haynes has since further subdivided some of those stratigraphic units, and/or refined those subdivisions, but the broadly defined formations remain (Haynes, personal communication, 1997). The units are shown (as best we can determine their boundaries) on the North Bank behind Kaisen in 1928 (fig. 5.1) and are listed in table 5.1, which also provides the ages from radiocarbon samples obtained during the Folsom Ecology Project, as well as from subsequent site visits—all of which comprise the radiocarbon data available at the time we began our work.

By the mid-1990s the stratigraphic history and geochronology at the site were broadly understood: The eroded Cretaceous surface was overlain unconformably by the fl sediments that began accumulating in latest Pleistocene times. The more massive overlying stratum /2, a pale brown clayey silt, contained the Folsom bison bone and artifacts in its upper part—with those remains partially coated with secondary calcium carbonate. The depositional origins of the /2 were unknown or at least unspecified. There was no "distinct surface of occupation" on which the archaeological material was resting (Haynes et al. 1992:87).

There were indications, notably in the "inclination of the cultural zone," suggesting that slope wash had contributed to the in-filled sediments (Haynes et al. 1992:87). Just how much slope wash may have occurred and, more significantly, how much of the material in the bonebed had been reworked would only become apparent following our more extensive exposure of faunal remains on the South and North Bank. Because only limited work had been done on the South Bank in the 1970s, the geological and paleographic context of the main portion of the bonebed was apparently unknown.

Haynes, Anderson, and Frazier (1976) observed that there was a knickpoint in the floor of Wild Horse Arroyo a few tens of meters upstream of the site, and inferred that it might have been an obstacle of sufficient magnitude to block the passage of bison long enough to enable them to be dispatched by the Folsom hunters. To be sure, along the present channel there is a constriction and an abrupt rise in the arroyo floor (fig. 3.5), but we suspect this channel is relatively recent (chapter 3). We do not know if there was a similar knickpoint in the bedrock within the Late Glacial paleovalley.

The top of the /2 was observed by Haynes and others to be crosscut by the coarsely laminated /3 sediments, indicating "a very shallow pond or a low gradient discharge and shallow water table during deposition" (Haynes, Anderson, and Frazier, 1976). Such may have accounted for the iron stains in the /1, the lowest part of the Folsom Formation, which implied saturation by groundwater some time after
<table>
<thead>
<tr>
<th>Stratigraphic Unit</th>
<th>Radiocarbon Age (14C yr B.P.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wildhorse Formation (w)</td>
<td></td>
</tr>
<tr>
<td>Sandy silt: dark gray, interbedded light and dark gray</td>
<td>4,470 ± 90 (TX-1272)</td>
</tr>
<tr>
<td>layers (10-20 cm thick) of clayey sandy silt with</td>
<td>4,850 ± 120 (TX-1270)</td>
</tr>
<tr>
<td>thin layers of charcoal or decayed plants near top of</td>
<td></td>
</tr>
<tr>
<td>unit and lenses of pebble to cobble gravel and shingle.</td>
<td></td>
</tr>
<tr>
<td>Unconformably overlies m2.</td>
<td></td>
</tr>
<tr>
<td>McJunkin Formation 2 (m2)</td>
<td></td>
</tr>
<tr>
<td>Clay: very dark gray to black organic clay with rootlet</td>
<td>6,060 ± 500 (TX-1452)</td>
</tr>
<tr>
<td>molds and moderate, medium, prismatic soil structure</td>
<td>6,910 ± 110 (TX-1271)</td>
</tr>
<tr>
<td>breaking to angular. Unconformably overlies m1.</td>
<td></td>
</tr>
<tr>
<td>McJunkin Formation 1 (m1)</td>
<td></td>
</tr>
<tr>
<td>Clayey silt: yellowish-brown clayey silt with</td>
<td>10,630 ± 80 (AA-7089; humates)</td>
</tr>
<tr>
<td>alternating light and dark layers and thin layers of</td>
<td>11,100 ± 130 (AA-7090;</td>
</tr>
<tr>
<td>carbonized plants. Separated from m2 by a weak erosional</td>
<td>carbon residue)</td>
</tr>
<tr>
<td>contact that truncates a black soil on m1. Unconformably</td>
<td></td>
</tr>
<tr>
<td>overlies f3.</td>
<td></td>
</tr>
<tr>
<td>Folsom Formation 3 (f3)</td>
<td></td>
</tr>
<tr>
<td>Silty clay: interbedded brown and dark grayish-brown</td>
<td>10,260 ± 110 (SMU-179)</td>
</tr>
<tr>
<td>silt clay with caliche nodules and strong, medium to</td>
<td>10,760 ± 140 (AA-1709)</td>
</tr>
<tr>
<td>coarse prismatic soil structure breaking to fine</td>
<td>10,780 ± 100 (AA-1213)</td>
</tr>
<tr>
<td>blocky. Dispersed charcoal in lower 25 cm. Unconformably</td>
<td>10,850 ± 190 (AA-1711)</td>
</tr>
<tr>
<td>overlies f2.</td>
<td>10,890 ± 150 (AA-1710)</td>
</tr>
<tr>
<td>Folsom Formation 2 (f2)</td>
<td>10,910 ± 100 (AA-1712)</td>
</tr>
<tr>
<td>Clayey silt: pale brown clayey silt with coarse</td>
<td>11,060 ± 100 (AA-1708)</td>
</tr>
<tr>
<td>caliche nodules, rootlet molds, and iron stains.</td>
<td>12,355 ± 210 (AA-7090; carbon</td>
</tr>
<tr>
<td>Interfingers with shingle colluvium adjacent to shale</td>
<td>residue)</td>
</tr>
<tr>
<td>bedrock. Contains Folsom artifacts and scattered</td>
<td>12,395 ± 90 (AA-7091; humates)</td>
</tr>
<tr>
<td>charcoal. Conformably overlies f1.</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.1: Haynes's Stratigraphic Unit Descriptions and Radiocarbon Ages for the Folsom Site

Source: After Anderson and Haynes (1979:table 1).

deposition. The top of the f3 itself was in turn eroded and subsequently buried by a younger alluvium, the McJunkin units of Middle Holocene age, and then by the alluvial Wildhorse Formation.

Samples for radiocarbon dating were collected by Haynes and Anderson from the site's exposed North Bank. These samples included bone bone fragments and charcoal from various strata, including the f2. Samples were also collected from the McJunkin Formation as exposed in Wild Horse Arroyo upstream and downstream of the site and from cut banks along the Dry Cimarron—the latter as part of an effort to assess the age of volcanic activity at Capulin (Anderson and Haynes 1979; Haynes, unpublished field notes, July 1970).

The bone fragments from the site were analyzed as part of an experiment in the efficacy of bone dating (Hassan 1975). The laboratory extraction produced good bone collagen and the first radiocarbon age for the Folsom level at the type site: 10,260 ± 110 14C yr B.P. (SMU-179; Hassan 1975:table 19; Haynes et al. 1992). This age was in close agreement with then-available ages from other Folsom sites (Anderson and Haynes 1979:896–897). Still, bone dates from the 1970s were suspect, given their potential for contamination and the state of extraction and laboratory protocols (R. R. Taylor 1980).

Haynes had also collected charcoal samples from the f2, but these were too small for dating using conventional techniques then available (Anderson and Haynes 1979:896). When radiocarbon dating by accelerator mass spectrometry (AMS dating) became available a decade or so later, these samples were submitted for analysis. Five of them were individual charcoal flecks, while the sixth was a composite of the others. The dates ranged from 10,760 ± 140 14C yr B.P. (AA-1709) to 11,060 ± 100 14C yr B.P. (AA-1708) and produced a
mean age of 10,890 ± 50 \(^{14}\)C yr B.P. (Haynes et al. 1992:84). Haynes supposed that this average age on charcoal was more accurate than the radiocarbon age derived from the bison bone collagen (Haynes et al. 1992:87). Yet, that supposition rested on the assumption that the charcoal was anthropogenic, derived from a Folsom-age hearth. Haynes admitted he could not preclude the possibility the charcoal had its origin in natural fires. Given the wide discrepancy—630 radiocarbon years—between the charcoal and the bone collagen radiocarbon ages from within the 2, ostensibly from the same event, more work on the age of the Folsom occupation was obviously necessary.

**Recent Investigations into the Geology of the Folsom Site**

As noted at the outset of this chapter, the goals of our investigation of the geology of the Folsom site were, broadly, threefold: (1) to gain a sense of the configuration of the paleotopography, in order to identify features of the landscape that may have been used by the hunters to reduce the risks of the hunt; (2) to understand the stratigraphic histories of the paleotributary and paleovalley, so as to gain insight into the depositional and erosional processes (and the climatic and environmental conditions behind them) in those different settings and derive a first approximation of the stratigraphic context and taphonomic history of the bonebed (as a prologue to more detailed analyses in chapter 7); and (3) to develop better chronological control over the site’s stratigraphic history and, of course, narrow down when the Paleoindian bison kill occurred. By gathering evidence along these several lines, we also would be in a better position to identify areas of the site where previously undiscovered intact Late Glacial deposits might occur (or ascertain such were missing) and, therefore, better assess the likelihood of finding traces of associated habitation areas. The remainder of this chapter is divided generally along those three lines, in each case first presenting the basic geological evidence, then in a separate subsection describing what that evidence implies for our understanding the archaeology of
the site. Before that discussion, however, a brief summary is provided of the geological and geophysical field methods used in these investigations.

**Geological and Geophysical Methods**

The methods in use included machine coring, hand augering, and geophysical remote sensing techniques, as well as mapping of exposed sections along the North Bank of Wild Horse Arroyo and in our excavation areas. The latter were somewhat limited in the information they provided, insofar as they occurred within the area of the bonebed, where the upper 2 m to 3 m of deposits had already been removed by the 1920s excavations and by our clearing of remaining overburden prior to excavation. Sections along the North Bank of the arroyo were relatively complete and several profiles were described in detail, although these are relevant primarily to the stratigraphic history of the paleovalley.

Therefore, the more complete picture of the stratigraphy on both the South and the North banks was obtained from machine coring and hand augering. The coring was done using a trailer-mounted Giddings soil probe during the 1997 and 1998 seasons of fieldwork. Overall, 33 soil cores were obtained, 21 of which were on the South Bank. The cores varied in depth but on average were 3.83 m (12.56 ft) deep. In general, cores were placed within a 100-m radius of the bonebed. The placement of cores did not follow a specific plan but, rather, was generally aimed at mapping the extent and occurrence of Folsom-age bone-bearing (%2)sediments, variation in the stratigraphic sequence across the site, and the subsurface depth and configuration of the bedrock in both the paleotributary and the paleovalley and, occasionally, to aid in positioning excavation units. As cores were completed and the sediment examined, the observations made would often guide the placement of subsequent cores.

Hand augering was done over three seasons. All together, 64 auger holes were put in at an average depth of 2.17 m (7.12 ft), of which the great majority (60) was on the South Bank in the area in and around the bonebed. Because augering does not produce intact sediment segments, and often cannot reach the depths that a machine corer can, the augering was mostly done in areas where it was not possible to maneuver the Giddings rig or was aimed at otherwise filling in gaps in the stratigraphic coverage. Furthermore, because it is difficult to detect fine-scale stratigraphic changes in the sediment churned up in a bucket auger, the aim of the effort was often restricted to recording the presence of particular stratigraphic units or the depth to bedrock.

All sediments brought up in core drives and augers were examined for archaeological debris. Once pulled, each core was split longitudinally and described using standard methods of field soil description (e.g., recording of horizons, depth, texture, structure, color, boundary conditions, and effervescence). More limited descriptions were obtained from sediment in the augers. Distinctive or potentially diagnostic sediments were often sampled from cores and, to a lesser extent, augers. Where relevant or of interest, charcoal from cores was collected for radiocarbon dating. The depth of the sample was determined to ±5 cm, as vertical measurements are not as precise in coring as they can be in controlled excavations. The locations of all core and auger holes were mapped by EDM/Total Station and are shown in figure 5.2.

Geophysical remote sensing work was conducted at Folsom in the fall of 1997, by advanced students from Washington University's Environmental and Exploration Geophysics course, under the direction of Drs. Roger Phillips and Douglas Wiens. Two methods—seismic reflection (fig. 5.3) and electrical resistivity—were used.

A total of six seismic lines were run, four on the South Bank and two on the North Bank of Wild Horse Arroyo (fig. 5.4). These ranged from 60 to 120 m in length; the combined length of these lines was 550 m. Geophone and shot spacing varied on each line; geophone intervals varied from 1 to 2 m; shot intervals, from 5 to 20 m. The refracted waves were analyzed, and the time delay method used to calculate the depth to bedrock for each line. There were four electrical resistivity lines run (RL1–RL4), all on the South Bank and primarily on the western side of the 1928 excavation area, and these extended over a total of 128 m. Wenner arrays were used on lines 1, 3a, and 3b; dipole-dipole arrays were used on lines 2, 3, and 4. Cathode and electrode spacing varied on the lines.

The remote sensing was done prior to the completion of the bulk of the coring, augering, and excavations on site and, thus, could not benefit from foreknowledge of the subsurface topography. Although in retrospect the lines were not ideally positioned, the methods were nonetheless well suited to mapping the interface of the bedrock and overlying unconsolidated sediment and identifying general trends in the bedrock morphology, which could subsequently be ground-truthed with coring and augering.

Resolution of the remote sensing was somewhat constrained by the lack of a sharp boundary between the Smoky...
Hill Shale and the overlying sediment. The upper surface of the shale, as is evident in exposures along the present valley wall, weathers into a gradual rubble of "shingle shale" that diffuses the stratigraphic boundary (Anderson and Haynes 1979). Hence, the modeled contact is that of the underlying consolidated bedrock. Use of the core/auger data to map the bedrock surface is also limited by the diffuse nature of the boundary between the Smoky Hill Shale and the overlying sediments, insofar as auger bucket and core barrel can be obstructed by the shingle shale rubble. However, this is likely more of a problem nearer the margins of the bonebed, where there is an added component of shingle shale from slope wash.

Moreover, where core and auger holes are close to the remote sensing lines, there proved to be good agreement, generally within 1 m, between the elevation of the top of the Smoky Hill Shale as measured in the core and auger holes and the elevation as modeled by seismic refraction, suggesting a reliability to the methods. There was, however, a much greater discrepancy—upward of 4 m—between the core and auger data and the depths modeled by electrical resistivity, likely a function of groundwater effects and the relatively coarser resolution of this technique (Roger Phillips, personal communication, 1998).

Mapping Bedrock and Reconstructing Paleotopography

It was known from the prior work of Anderson and Haynes (1979) that a thick sequence of Quaternary sediments rests unconformably on the Cretaceous-age Smoky Hill Shale bedrock, and that the Smoky Hill Shale (fig. 3.5) is the primary control on the topography of the site area today—as it presumably was in Late Glacial times. Although those sediments obscure the contours of the Late Glacial surface (also Bryan 1929), the present topography at the Folsom nonetheless provides a few clues to the form of that buried landscape.

The most obvious of those is the fact that immediately upstream and downstream of the site a high bedrock wall flanks the southern edge of Wild Horse Arroyo. However, at the site itself the bedrock wall is absent, the gap extending
over a linear reach of >30 m along the arroyo. In effect, and this must have been apparent during the 1920s investigations, the site and boneyed on the South Bank are located within a low, sediment-filled area between two bedrock uplands.

Fronting that gap is an ~32-m-wide, fan-shaped deposit of shingle shale that rests atop the Smoky Hill Shale bedrock (fig. 5.5). The shingle shale comprising this unit is not in primary context, evidenced by high inclinations of individual pieces of shingle shale. Where exposed in profile, this debris flow fan is of varying thickness, reaching a maximum of 1.70 m along the South Bank. The gap in the bedrock and the debris flow fan appear to be related features, and represent the mouth of a paleotributary that opened into the paleovalley of Wild Horse Arroyo.

A further and final surface hint of the paleotopography: There is on the surface today a shallow and subtle drainage
extending away from that debris flow fan and bedrock gap. Although it is difficult to see in the immediate site area owing to the modifications wrought by the 1920s excavations and subsequent erosion, that drainage extends south/southwest from Wild Horse Arroyo for some 30 m, then (at \(\sim N10^\circ20' E101^\circ0\) on our site grid) curves west/southwest and ultimately disappears \(\sim 100\) m from the site.

On the supposition that these several features are the expressions of a buried paleotributary, we ran one series of seismic lines along and across this area to map the contours and configuration of the underlying bedrock (fig. 5.4). Seismic line 3 (hereafter SL3), run southwest to northeast, partly overlies that modern drainage; SL4 is on a converging bearing to SL3, though it originates \(\sim 50\) m to the east and runs almost due north. On both lines, seismic data reveal that the bedrock slopes from south to north as it approaches the arroyo. There is good agreement between these two lines on the elevations of that slope: The northern and deeper end of SL3 bottoms out at a modeled elevation of \(\sim 94.7\) m, while the northern end of SL4 bottoms out at modeled depth of \(\sim 95.2\) m (Phillips et al. 1998). The overall drop of the bedrock in SL4 is greater, however, owing to the shallower depth of the bedrock at the starting point of this line.\(^4\)

Even more suggestive, along SL3 there appeared to be a steep drop in the bedrock at a point \(\sim 50\) m up from its north end (Phillips et al. 1998)—that is, slightly north of where SL3 and SL1 intersect (fig. 5.4) and, more importantly, north of the bonebed. In effect, there appears to be a bedrock sill or headcut in the paleotributary, as it extended up from the paleovalley.

Equally intriguing evidence came from SL1 and SL2, which revealed a gradual west-to-east slope across the site but then, toward the eastern ends of each line, a sharp plunge in the bedrock, which in SL1 is modeled as an \(\sim 3\)-m drop in just \(7\) m of horizontal distance, to reach a depth of \(\sim 6\) m below the present surface. An even greater dropoff was modeled for SL2 (a drop of \(\sim 4\) m across a comparable horizontal distance). SL2 also revealed a subsequent rise in the bedrock east of where it had plunged. SL4, which intersected at nearly right angles to both SL1 and SL2, showed a corresponding drop in the bedrock that corresponded closely to the position and depth of the drop off in the bedrock modeled on both these east-west lines (fig. 5.4).

These depth estimates are somewhat problematic, however, since they are based on data from the ends of the seismic line, where depth is estimated from only a few or just one datum point and not, as in the central portion of the line, from a series of points based on several time delay calculations (Phillips et al. 1998). Nonetheless, together these data seemingly confirmed that the paleotributary entered from the southwest, turned northeast, and emptied into the arroyo at the bedrock gap—much like the present surface drainage. They also revealed that there was possibly a second prong of the paleotributary (that plunges at the eastern ends of SL1 and SL2), coming in more or less from due south, but without any visible surface expression.

In order to ground-truth the geophysical modeled depths and test the hypothesized two-prong configuration of the paleotributary, a series of core and auger holes was strategically placed across the site (fig. 5.2). Those confirmed that there are indeed two prongs to the paleotributary. The wider and longer of the two prongs enters the site area from west of GC 98-8, then trends east/northeast toward AH 98-19 and AH 98-21, from which it continues to GC 97-10 and GC 98-2 and then north to the bedrock gap at the arroyo junction. This portion of the paleotributary is apparent from the drainage visible on the modern surface, which must have in-filled it. There is, as noted, an abrupt headcut along this segment of the paleotributary.

The head of the second prong of the paleotributary is near GC 98-10. From there, the channel runs almost due north, where it joins the other prong in the vicinity of GC 97-10 and GC 98-2. The auger and core data provided, as the seismic data from SL2 data did not, a more precise measure of the rise in the bedrock on the east side of this prong. As figure 5.6 shows, the bedrock surface rises \(\sim 5\) m, some \(12\) m west of where it bottomed out. In fact, the coring indicated that there is also a comparable rise in the bedrock close to the end of SL1 (\(5.25\) m in the \(4.5\) m separating GC 97-5 and GC 98-6)—too close to the end, apparently, to have been be detected by the seismic surveys. This second, narrower prong of the tributary is largely invisible on the present surface, although one of the trenches dug during the Folsom Paleoecology Project may have encountered it (Haynes, Anderson, and Frazier, unpublished field notes, Trench 5 profile). The two prongs of the paleotributary were separated at their upper reaches by a high bedrock peninsula (encountered in AH 01-1 and AH 01-2) and came together \(\sim 20\) m north of there and \(\sim 30\) m south of the bonebed (fig. 5.6).

The paleotributary drained into a paleovalley that was configured somewhat differently than Wild Horse Arroyo is today, which, of course, is a recent feature of the landscape and merely the latest in a series of Holocene cut-and-fill episodes (of which, more below; also Mann 2003, 2004). The thick sediments of the North Bank almost completely bury the paleovalley, but evidence of its depth and configuration emerges in SL5 and SL6 (fig. 5.4). The modeled depth-to-bedrock along the paleovalley axis is as much as \(4\) m to \(6\) m below the modern surface (Phillips et al. 1998). Coring and augering on the North Bank confirm this estimate: The deepest core reached \(6.15\) m below surface (GC 97-13), for a basal elevation of \(91.41\) m. The thalweg of the present Wild Horse Arroyo is at about the same depth.

Also apparent in SL5, as well as several cores (GC 98-12, GC 97-13, GC 97-14) and augers (AH 99-21, AH 99-20) that were put in along that same line, is that the bedrock surface rises nearly \(4\) m as it approaches the northern valley.
FIGURE 5.6 Subsurface contours of the top of the Smoky Hill Shale, as measured at Giddings core and auger hole locations. Darker areas of the map are deeper.

wall. Whether that rise in slope in Paleoindian times was gradual or more abrupt depends on how much sediment was draped over the valley margin. We suspect, based on weathering patterns observable in the Smoky Hill Shale today, that these were abrupt plunges—a vertical falling-away of the paleovalley wall—rather than steeply angled slopes.

The axis of the paleovalley thus appears to run roughly parallel to Wild Horse Arroyo but is \(~30\) m farther to the north. The portion of the paleovalley presently exposed by Wild Horse Arroyo along the North Bank is therefore the margin of the paleovalley, with a stratigraphic sequence differing in details from that in the central portion of the channel, largely as a result of its proximity to inflow from the paleotributary. Consequently, the exposures on the North Bank are a complicated record of geomorphic processes occurring close to the intersection of both the paleotributary and paleovalley—the intersection likely spanned the area now occupied by Wild Horse Arroyo. The deposits in the South Bank, along with the main area of the bison bonebed, are set squarely within the paleotributary. However, bison bone and artifacts, as noted, are also found
on the North Bank within the sediments of the paleovalley (chapter 7).

**Maneuvering for the Bison Kill**

This brings the discussion to what the seismic and stratigraphic data reveal of how the landscape may have appeared and possibly been used by the Folsom hunters. Although the majority of the bison remains that were recovered were in the paleotributary, bison remains were also found in the paleovalley. Thus, in thinking about how Folsom hunters may have used the topography to advantage, one must consider both settings.

We assume for the sake of discussion that the bison herd was initially confronted in the paleovalley. If the floor of the paleovalley was as flat as Wild Horse Arroyo is today (which drops at a rate of just 2 m vertically over a 100-m horizontal distance), and if there were exposed bedrock walls flanking the paleovalley as high and as abrupt as presently occur along Wild Horse Arroyo (fig. 3.5), which in the immediate site area are as much as 8 m above the arroyo floor, those lateral walls would have been a formidable barrier to a herd of bison looking to escape from a group of hunters who were strategically positioned to cut off the herds’ exit up or down the paleovalley.

The paleotributary, sloping down toward the paleovalley, would have presented a possible escape outlet for the herd, and some of the bison clearly took that route or were maneuvered into this landform and killed there by the hunters. There are limited data on how steep a climb the bison would have faced in scrambling out of the paleovalley up into the paleotributary. There is a 3.61-m difference in elevation between the highest point at which we encountered bison remains on the South Bank and the lowest point at which such were recovered on the North Bank (elevations = 98.07 and 94.64, respectively, across a horizontal distance of 27 m). A similar vertical difference was apparent in 1928: The highest bone on the South Bank was 1.5 m below the surface; bone on the North Bank was ~3.6 m below the surface (chapter 7). Connecting those as end points of the same surface yields a relatively steep slope from the paleovalley up into the paleotributary, which would be over three times steeper than modern arroyo gradients in the area. However, since the North Bank bones are likely not in primary context (chapter 7), their depths may not reflect the base level of the paleovalley in Folsom times but, instead, depths reached during subsequent downcutting and later emplacement of those bones with the arroyo fill of the paleovalley.

Although we cannot say how easy or difficult it would have been for a herd of bison to scramble out the paleovalley into the paleotributary, we do have data on what obstructions may have blocked their escape once in the paleotributary—leaving aside, of course, strategic positions the hunters may have taken. As noted, several of the seismic lines (especially SL1 and SL2) show that the walls of the paleotributary were high and steep, a matter subsequently confirmed by core and auger lines put in at right angles to the paleotributary. The data are shown as profiles in figure 5.7. All profiles are at the same scale; there is a 10× vertical exaggeration.

These profiles are not necessarily a precise rendering of the walls of the paleotributary as they may have appeared in Paleoindian times. After all, the upper surface of the bedrock was eroded, and portions of it were mantled in sediment by the time of the Paleoindian occupation, though the depth of that mantle, and the degree to which it modified the topography, is unknown. This makes it difficult to assess just how steep the walls of the paleotributary were at the time of the kill—and thus how difficult it might have been for the bison herd to have maneuvered in or escaped from the paleotributary.

These caveats notwithstanding, what is striking about figure 5.7 is that with the exception of Profile 3, which runs down the center of the eastern prong of the paleotributary, the side walls of the paleotributary were high and steep, with vertical dropoffs of the order of 3 m to 4 m in the span of a few horizontal meters. Profiles 1 and 2 are especially interesting in this regard, since both are close to the terminus of the larger, western prong of the paleotributary. These indicate the presence of a knickpoint at the upper end of the paleotributary, which could have been an obstacle to bison seeking escape via that route. Obviously, were hunters positioned atop the 3- to 4-m-high valley walls ringing the paleotributary, they would have been able to attack the bison while staying safely out of danger.

That the majority of the bison recovered were apparently killed in the paleotributary (chapter 7) is consistent with a hypothesis that these landscape features were used to advantage by the hunters in the kill. Of course, the herd could also have been initially confronted in this area of the site and escaped down into the paleovalley, reversing the topographic scenario discussed above. Or the hunters may have caught the animals in both areas simultaneously. Unfortunately, we have no data on how this process played out.

A final note with regard to the paleotopography and its consequences for the archaeology: The high bedrock walls on the west and northwest margin of the paleotributary effectively shielded the sediments within the paleotributary from fluvial action in the paleovalley and, thus, helped ensure the preservation of the site. Of course, those valley walls would not have protected the boneyed from erosion within the paleotributary, but there is little evidence that this occurred, and if it did, it was not on the scale of the erosion in the paleovalley. The absence of arroyo cutting within the paleotributary may also indirectly testify to the effects of the shingle shale debris flow fan (fig. 5.5) at the junction of the paleotributary and paleovalley, for by raising the base level of the paleovalley it would trigger aggradation, rather than incision, within the paleotributary. There are still other geological processes that came into play in the paleotributary that also served
FIGURE 5.7 Bedrock profile cross-sections, as measured along lines of core and auger holes on the South Bank. Lower right map, from Figure 5.6, shows location of the cross-sections lines superimposed on the top of the Smoky Hill Shale.
to protect the bonebed, discussed in more detail below (also chapter 7).

Site Stratigraphy and the Geological Context of the Bison Bonebed

As noted, the depositional environments are very different in the paleotributary and paleovalley, with the sediments in the paleovalley possibly derived from multiple processes, including alluvial, colluvial, and eolian deposition, as well as being more susceptible to cut-and-fill episodes and fluvial reworking. The sediments in the better-protected paleotributary were less subject to (and show less evidence of) fluvial deposition and erosion. Bison bones and artifacts in the two areas will, as a result, likely have very different taphonomic histories. In this section we discuss the details of the stratigraphic sequences and sediments of the paleotributary and the paleovalley, then the geomorphic processes affecting these areas, followed by a discussion of the stratigraphic position and depositional context of bison remains within them. The latter addresses in part the taphonomic history of the bonebed (explored in more detail in chapter 7).

The lithostratigraphic subdivisions and terminology for the late Quaternary fill in Wild Horse Arroyo we use generally follow the tripartite scheme developed by Haynes (fig. 5.1 and table 5.1; Anderson and Haynes 1979; Haynes, Anderson, and Frazier, 1976) though with modifications. The modifications are necessary because the sequence was developed primarily on profiles and trenches from the North Bank and thus reflects the paleovalley sequence, which as noted differs from that of the paleotributary—although there are broad similarities, reflecting their response to common climatic and geomorphic triggers.

Two additional caveats. First, as just noted the North Bank only roughly approximates the paleovalley sequence, as this wall forms the paleovalley's southern margin, not its axis. Second, and more critical, stratigraphic interpretation has been complicated by disturbances due to subsequent geomorphic processes and archaeological activities. The present arroyo has cut down to the Cretaceous bedrock, and the 1926–1928 excavations removed much of the Holocene sediment from the South Bank, which triggered erosion on both banks. The net effect has been the removal of a critical portion of the stratigraphic record, namely, the top of the section on the South Bank, and of the junction of the paleotributary and the paleovalley. We include here (table 5.2) the stratigraphic descriptions of a representative section from the South Bank from Giddings Core 97-3, which was placed on the backdirt bench immediately south of the bonebed and thus in an undisturbed area of the site, and of Profile 97-1, which describes the stratigraphic sequence of the North Bank. Although it is difficult to connect the strata between the paleotributary and the paleovalley, we can surmise some of their stratigraphic relationships based on observations made during the original work at the site and in the course of our fieldwork.

THE FOLSOM FORMATION

Stratum f rests unconformably on the eroded Smoky Hill Shale bedrock. The sediments are predominantly silt with layers of redeposited, angular shale fragments—shingle shale derived from the bedrock—more common at the base. Altogether the Folsom Formation is up to 290 cm thick, but the thickness varies significantly depending on (1) the topography of the underlying bedrock—the formation is thinner where the bedrock is higher, and (2) the amount of erosion of the Folsom Formation prior to its burial by the McJunkin Formation. The Folsom Formation is divisible into three subunits (hereafter, f1, f2, and f3). Paleoindian bison remains in the paleotributary occur solely within the f2; in the paleovalley, those remains occur in both the f2 and the f3.

In most cores and North Bank exposures the basal unit of the Folsom Formation—stratum f1—consists of 50 cm to 170 cm of shingle shale lenses interbedded with layers of silty deposits (silty clay loam and clay loam) modified by iron oxide mottling. The shingle is light olive brown (2.SY 5/4 dry) to light yellowish brown (2.SY 6/4 dry) and derived from Smoky Hill Shale bedrock. The silty interbeds typically are light yellowish brown (2.SY 6/4 dry). Stratum f1 comprises the debris flow fan and represents episodic accumulation of angular shale fragments, perhaps in rapid succession, delivered as outwash from the paleotributary as well as from erosion of the high bedrock walls of the paleovalley. There is some sorting and imbrication of the shingle shale in this unit. Between periods of shingle accumulation the valley filled with layers of silty clay. Some time after burial, these basal layers of shingle and silt were subjected to a fluctuating water table that produced the distinctive iron-oxide (FeOx) mottles.

Stratum f2 overlies f1 in most cores and sections. Stratum f2 is a massive deposit, ranging in texture from silt loam to silty clay to silty clay loam. Sedimentological data on f2 sediments, primarily from the bonebed in the paleotributary, are provided in table 5.3; the textural data on sediments from unit f2, as well as other units for comparison, are illustrated in figure 5.8. Stratum f2 is over 2 m thick in protected areas of the paleotributary (e.g., GC 98-3) but only ~1 m thick on the north wall of Wild Horse Arroyo. There is no distinctive f1/f2 contact; instead, f1 grades into the f2. Stratum f2 has a yellow to light-brown hue, typically light yellowish brown (2.SY 6/4 dry) to light brownish gray (2.SY 6/2 dry). Mottles of more neutral grayish colors (grayish brown, 2.SY 5/2 dry, to light gray 2.SY 7/2) occur locally.

Stratum f2 is calcareous (table 5.3) and commonly exhibits secondary, probably pedogenic deposits of calcium carbonate as threads, films, and fine tubules and nodules. The presence of pedogenic carbonate in f2 was noted by the original investigators (Brown 1928b; Bryan 1937:142; Cook 1928b:39), who saw it as evidence of the great age of this deposit (Anderson and Haynes 1979:897). It is unclear what duration

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### TABLE 5.2
Stratigraphic Descriptions, North and South Banks

(A) Profile 97-1, North Bank

<table>
<thead>
<tr>
<th>Unit</th>
<th>Soil Horizonation</th>
<th>Depth Below Surface (cm) and Description of Color, Texture, Structure, Boundary</th>
<th>% Sand</th>
<th>% Silt</th>
<th>% Clay</th>
<th>USDA Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>w</td>
<td>A–C</td>
<td>0–40 cm: light yellowish-brown (2.5Y 6/4 dry) to olive brown (2.5Y 4/4 moist) silty clay; A = 0–10 cm, v. weak subangular blocky, C = 10–20 cm, weak subangular blocky; 20–40 cm, dense coarse gravel; abrupt lower boundary</td>
<td>13</td>
<td>47</td>
<td>40</td>
<td>SiC</td>
</tr>
<tr>
<td>m2</td>
<td></td>
<td>40–74 cm: light olive brown (2.5Y 5/4 dry) to olive brown (2.5Y 4/4 moist) clay with some mottling and few faint carbonate threads; moderate angular blocky; clear lower boundary</td>
<td>10</td>
<td>59</td>
<td>31</td>
<td>SiCl</td>
</tr>
<tr>
<td></td>
<td>ABb1</td>
<td>74–100 cm: grayish-brown (2.5Y 5/2 dry) to dark grayish-brown (2.5Y 4/2 moist) clay, prismatic to angular blocky, faint olive mottling; gradual lower boundary</td>
<td>5</td>
<td>69</td>
<td>25</td>
<td>SiL</td>
</tr>
<tr>
<td></td>
<td>Btgb1</td>
<td>100–136 cm: grayish-brown (2.5Y 5/2 dry) to dark grayish-brown (2.5Y 4/2 moist) clay; subangular blocky; v. dark-gray clay films (organs?) on ped faces; abrupt lower boundary</td>
<td>7</td>
<td>69</td>
<td>24</td>
<td>SiL</td>
</tr>
<tr>
<td>m1</td>
<td>ABb2</td>
<td>136–175 cm: dark grayish-brown (2.5Y 4/2 m) to v. dark grayish-brown (2.5Y 3/2 moist) clay with common films and threads of carbonate; prismatic and angular blocky common clay films (probably pressure faces?) on ped faces</td>
<td>4</td>
<td>74</td>
<td>22</td>
<td>SiL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>175–235 cm: laminated zone with grayish-brown (2.5Y 5/2 dry) to dark grayish-brown (2.5Y 4/2 moist) silt loam; subangular blocky; and dark grayish-brown (2.5Y 4/2 moist) to v. dark grayish-brown (2.5Y 3/2 moist) clay; angular blocky; the blocky clay has continuous clay films (probably pressure faces); abrupt lower boundary</td>
<td>7</td>
<td>93</td>
<td>23</td>
<td>SiL</td>
</tr>
<tr>
<td>f3</td>
<td>Bkb3</td>
<td>235–250 cm: light brownish-gray (2.5Y 6/2 dry) to dark grayish-brown (2.5Y 4/2 moist) clay with some lighter olive mottles; common threads of carbonate; common flecks of charcoal; common fragments of rock, especially in lower 10 cm; clear lower boundary</td>
<td>4</td>
<td>66</td>
<td>30</td>
<td>SiCL</td>
</tr>
<tr>
<td></td>
<td>Bk1b4</td>
<td>250–300 cm: dark grayish-brown (2.5Y 4/2 moist) to v. dark grayish-brown (2.5Y 3/2 moist) clay, strong angular blocky with common threads and films of carbonate; clear lower boundary</td>
<td>11</td>
<td>62</td>
<td>27</td>
<td>SiCL</td>
</tr>
<tr>
<td>f2</td>
<td>Bk2b4</td>
<td>300–330 cm: grayish-brown (2.5Y 5/2 dry) to dark grayish-brown (2.5Y 4/2 moist) silt loam with rock fragments common; subangular blocky; common threads and films of carbonate; common flecks of charcoal; clear lower boundary</td>
<td>6</td>
<td>67</td>
<td>27</td>
<td>SiL</td>
</tr>
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<td></td>
<td></td>
<td>330–360 cm: light brownish-gray (2.5Y 6/2 dry) to dark grayish-brown (2.5Y 4/2 moist) silt loam; weak olive-gray mottles; strong subangular blocky; clear lower boundary</td>
<td>5</td>
<td>59</td>
<td>36</td>
<td>SiCL</td>
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(continued)
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<tr>
<th>Unit</th>
<th>Soil Horizonation</th>
<th>Depth Below Surface (cm) and Description of Color, Texture, Structure, Boundary</th>
<th>% Sand</th>
<th>% Silt</th>
<th>% Clay</th>
<th>USDA Texture</th>
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<tr>
<td>f1</td>
<td></td>
<td>360–440 cm: light yellowish-brown (2.5Y 6/4 dry) to 2.5Y 5/4 moist silt loam; heavily mottled; common Fe-ox stains, especially near bottom; strong angular blocky; few threads especially and films of carbonate; common shale fragments, in lower half</td>
<td>9</td>
<td>60</td>
<td>31</td>
<td>SiCL</td>
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<td></td>
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<td>440–540 cm: covered</td>
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<td></td>
<td>Bedrock</td>
<td>540+ cm: shale</td>
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<td></td>
<td></td>
<td>(B) Giddings Core 97-3, South Bank</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1920s fill</td>
<td>A</td>
<td>0–20 cm: back dirt from berm</td>
<td>5</td>
<td>69</td>
<td>26</td>
<td>Si.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20–27 cm: dark gray (10YR 4/1 dry) to v. dark gray (10YR 3/1 moist) silt loam; weak angular blocky to granular; clear boundary</td>
<td></td>
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<td>27–50 cm: v. dark gray (10YR 3/1 dry) to black (10YR 2/1 moist) silt loam; weak prismatic and strong subangular blocky; thin, continuous clay films on ped faces; clear boundary</td>
<td>6</td>
<td>70</td>
<td>24</td>
<td>Si.</td>
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<td>50–80 cm: dark gray (10YR 4/1 dry) to v. dark gray (10YR 3/1 moist) silty clay loam; strong prismatic and strong angular blocky; thin, continuous clay films on ped faces; clear boundary</td>
<td>8</td>
<td>62</td>
<td>30</td>
<td>SiL</td>
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<td></td>
<td>80–125 cm: dark gray (10YR 4/2 moist) silty clay; thin continuous clay films on ped faces; strong prismatic and strong subangular blocky; clear boundary</td>
<td>4</td>
<td>48</td>
<td>48</td>
<td>SiC</td>
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<tr>
<td></td>
<td>Bt1</td>
<td>125–157 cm: light yellowish-brown (2.5Y 6/4 dry) to light olive brown (2.5Y 5/4 moist) silty clay loam; moderate subangular blocky; carbonate and shale “shingle” at 153157 cm; clear boundary</td>
<td>5</td>
<td>69</td>
<td>26</td>
<td>SiCL</td>
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<td></td>
<td></td>
<td>157–203 cm: light yellowish-brown (2.5Y 6/4 dry) to light olive brown (2.5Y 5/4 moist) silty clay loam; moderate subangular blocky; clear boundary</td>
<td>4</td>
<td>48</td>
<td>48</td>
<td>SiC</td>
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<td></td>
<td></td>
<td>203–285 cm: light brownish-gray (2.5Y 6/2 dry) to dark grayish-brown (2.5Y 4/2 moist) silty clay loam; moderate subangular blocky; black clay lens at 203–204 cm; clear boundary</td>
<td>9</td>
<td>59</td>
<td>32</td>
<td>SiCL</td>
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<tr>
<td></td>
<td></td>
<td>285–343 cm: light yellowish-brown (2.5Y 6/4 dry) to dark grayish-brown (2.5Y 4/2 moist) silty clay loam; moderate subangular blocky; common faint Fe-ox mottles; distinct Fe-ox lenses 298–305 cm; clear boundary</td>
<td>9</td>
<td>59</td>
<td>30</td>
<td>SiCL</td>
</tr>
<tr>
<td></td>
<td>f3</td>
<td>343–370 cm: light gray (2.5Y 7/2 dry) to light olive brown (2.5Y 5/4 moist) silty clay loam; moderate subangular blocky; common distinct Fe-ox mottles; distinct Fe-ox concentration 365–370 cm; abrupt boundary</td>
<td>12</td>
<td>54</td>
<td>34</td>
<td>SiCL</td>
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<tr>
<td></td>
<td></td>
<td>370 cm: shale</td>
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**Note:** See figure 5.2 for location. Soil horizon notation provided only where pedogenic modifications present. We subdivided the section of Core 97-3 from 125 to 203 cm after sampling and laboratory analysis and, therefore, do not have separate textural data for the two units within that section. Sand, silt, and clay percentages rounded to the nearest whole number v., very.
<table>
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<td>&lt;1</td>
<td>1</td>
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<td>3</td>
<td>4</td>
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<td>45</td>
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<td>&lt;1</td>
<td>7</td>
<td>9</td>
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<td>52</td>
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<td>Silty clay</td>
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<td>0.83</td>
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<td>42</td>
<td>Silty clay</td>
<td>0.48</td>
<td>0.83</td>
<td>15.39</td>
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NOTE: Particle size percentages rounded to the nearest whole number. Trace amounts are <0.5.
FIGURE 5.8 Textural triangle of Folsom site sediments from Folsom formation 2 (f2), Folsom formation 3 (f3), McJunkin (mcj), and Wildhorse (wh).

of surface stability is indicated by these features of weak pedogenesis: Observations of modern Entisols developing in overbank settings along streams in the area suggest that under the present climate the accumulation of diffuse secondary carbonates, clay illuviation, and the development of prismatic structure occur rapidly, perhaps in a matter of centuries or less (Mann 2004). Other pedogenic modifications of f2 include formation of subangular and prismatic soil structure with coats of illuvial clay on ped faces. Distinct Bk, Bt, and Btk horizons were observed in some but not all cores and exposures, making them difficult to trace through the site. Some finely divided gypsum is also present in f2, as noted by Brown (1928b; unpublished field notes, September 4, 1927, VP/AMNH) and in thin section (Goldberg and Arpin 1999).

Since the bison bonebed in the paleotributary occurs in the upper portion of stratum f2 and is covered thinly by more f2 sediments, the origin of this unit and what it may reveal of environmental conditions at the time of deposition are of considerable interest. We previously (Meltzer, Todd, and Holliday 2002) called attention to the similarity of stratum f2 displays to the physical characteristics of loess. Loess is not widely reported for the region, but as noted, Brown (1928b) also inferred an aeolian origin for this unit. Loess was observed in a study of volcanic rocks of the area: Collins (1949:1023) remarks that on some of the basalt mesas “quaternary loess has been added to the decomposition products” but does not elaborate. Allen (1959), in examining soils formed on the basalt uplands, observed that loess (and volcanic ash) is an important component of the parent material of some soils. Similarly, the soils of Johnson Mesa, mapped as the Borela Series, and the Capulin series down in the valleys, “formed in . . . residuum derived from basalt and other volcanic debris that were modified by mixed eolian material” (G.G. Anderson et al. 1982:15). Loess would not be out of place in the region given the site’s proximity to glacial and periglacial processes in the southern Rocky Mountains during the Late Glacial. The late glacial timing of f2 deposition would also be appropriate for loess accumulation. Of course, as recent work has shown, not all North American loess is glacigenic (Aleinikoff et al. 1999; Busacca et al. 2004; Mason 2001).

Alternatively, Mann (2004; personal communication, 2003) points out that the Smoky Hill Shale underlying the site is a source of abundant silt through physical and chemical weathering, and that fine sand, silt, and clay are the predominant sediments in valley fills. He observed deposits of silts and clays that closely resemble stratum f2 elsewhere in the Upper Dry Cimarron area, dated to the early and middle Holocene, when regional-scale loess deposition seems less likely than during the Late Glacial. He notes, further, that
although these are similar deposits, their distribution is patchy. Loess ought to form widespread "blankets" of sediment, since it is carried so high in the air column. In the absence of other indicators of aeolian activity—e.g., sand sheet sediments—and given the distance of Folsom from retreating ice sheets, outwash rivers, or other obvious sources, Mann argues that the f2 was derived not from airborne loess, but primarily by colluvial deposition or slope wash from a local bedrock source.

To be sure, the Smoky Hill Shale is a ready source of fine-grained sediment, but evidence against the supposition that Stratum f2 was largely derived from colluvium or slopewash includes the following.

- In places within the paleotributary the f2 is several meters thick and largely devoid of any particles coarser than fine sand. Were the f2 sediments derived from the Smoky Hill Shale, we should see lenses of shingle shale and a greater contribution of coarse particles throughout—as we do in the f3 (below). The coring data further indicate that there was massive silt deposition inset against bedrock; the only coarse material is immediately adjacent to bedrock, even where there was 3 m to 4 m of relief over a distance of just a couple of meters—that is, even where steep slopes were present.

- Although weathering of the shale would produce fine sediments similar to f2, it would also produce more clay than is indicated by the textural analysis (table 5.3 and fig. 5.8). Also, in order to derive sufficient silt from the shale there would have to have been very rapid weathering, exceeding the weathering of the f2—and we see no soils or other weathering zones buried in f2.

- Silt deposits have been detected on the uplands and in the lowlands by us and others (above) and an airborne source accommodates this. Folsom is downwind from the Sangre de Cristos, which, while not subjected to massive glaciation, were and still are subject to periglacial processes that could produce silt.

- Those sources are not likely to produce massive quantities of silt, and though such silt would initially cover upland and lowland areas, given the regional topographic relief it would probably get quickly redeposited in lowland areas.

Examination of thin sections from stratum f2 sheds some light on the matter. Goldberg and Arpin (1999) found that the f2 consists of domains of quartz silt in which the fine fraction appears to have been elutriated, interspersed with finer, calcareous clay bands. In places the sediments are finely bedded, but they are commonly disrupted. There are occasional, coarse clay coatings, some of which are very thick. Calcium carbonate is present in four forms: (1) within the clay, (2) in precipitated hypocoatings around voids, (3) as grains in the sand and silt fraction, and (4) as shell fragments. The carbonate is therefore both primary and secondary. A thin section across the boundary at the top of the Bk horizon just below the bonebed (discussed below) shows that it is much finer grained than other f2 samples and is more porous. The sample also contains gypsum precipitated in large chambers and voids at its base. Gypsum formation disrupted the structure of the sediments resulting in the higher porosity.

What these thin sections indicate is that the f2 may not be primarily airfall loess, however, but rather remobilized or redeposited silts derived from airborne loess. The thin sections display fine bedding with stringers of clay, indicating syndepositional reworking (Goldberg and Arpin 1999). Nevertheless, the absence of coarse clastics or pronounced bedding in the f2—except for several widely separated lenses of shale gravel—suggests that the loess was not extensively reworked by fluvial/colluvial runoff or sheetflow before it began to accumulate in the paleotributary.

Evidence for pedogenesis within the f2 unit further complicates interpretations and indicates that the sediments accumulated there episodically. Anderson and Haynes (1979:897) note evidence for pedogenesis in f2 in the form of "calcareous root molds and carbonate coating on ped surfaces" but propose that these pedogenic features suggest "aggradation at a rate rapid enough to prevent clear differentiation of soil horizons." The presence of distinct buried soils in f2 in some cores indicates, however, that aggradation ceased or slowed significantly for substantial amounts of time. Further, because distinct buried soils seem to be discontinuous through f2, this unit may have been subjected to several cycles of erosion as it aggraded.

If the f2 was ultimately aeolian in origin, it must have once been much more extensive than it is at present. Examination of the exposed walls along Wild Horse Arroyo, as well as along that portion of the Dry Cimarron valley from the base of Johnson Mesa to its downstream junction with Wild Horse Arroyo, reveals that deposits like those of the f2 are exceedingly rare (also Bryan 1937:142–143). Sections of fine-grained silts are visible in the walls of Wild Horse Arroyo in a few areas upstream and downstream of the site and in a few spots along the Upper Dry Cimarron (Mann 2004). Unlike the situation at the site itself, these silts contain a higher concentration of platy and angular fragments of Smoky Hill Shale, indicating deposition in higher-energy settings.

At the Folsom site, f2 sediments occur in both prongs as well as throughout the main portion of the paleotributary: essentially, all of the 1920s excavation areas, as well as our excavation blocks (fig. 5.2). The unit also occurs in most of the core and auger placed on the North Bank. Assuming that the f2 at one time more or less draped the region, its present scarcity on the landscape is testimony to subsequent widespread erosion.

Within the paleotributary, f2 is capped by unit f3, which consists of angular, platy fragments of Smoky Hill Shale, generally <5 cm in maximum length. The shingle shale
tends to be imbricated, poorly sorted, angular, and primarily from a single source—downslope movement of the Smoky Hill shale off the bedrock walls flanking the paleotributary. The shingle shale for the most part flowed across the top of the f2, and in the area of the bonebed it formed a lens—sometimes sets of lenses—between 10 and 30 cm in thickness. In the upper reaches of the paleotributary the shingle thins and altogether disappears. The distribution of shingle shale in the M17 and M15 excavation blocks is discussed in more detail in chapter 7, as it pertains to the taphonomic history of the bonebed. Here we note that in just a few places in the paleotributary the f3 came to rest directly on bison bone; overall the f3 deposit played an important role in the preservation of the site, for it effectively armored and protected the underlying bonebed from subsequent disturbance (e.g., erosion, rodent burrowing).

In contrast to the relatively homogeneous shingle shale capping the bonebed in the paleotributary, the clasts comprising stratum f3 in the paleovalley tend to be more rounded (i.e., gravel), show more size sorting, and occur in multiple, complex lenses of gravels, which include secondary carbonate nodules that may have been transported as well (as also observed by Anderson and Haynes 1979). These clasts are embedded in sediments that appear to represent continued deposition of fine-grained silt; while these silts bear a strong resemblance to those of the f2, and presumably result from the same depositional mechanism, they are stratigraphically defined as the fine component of the f3.

The f3 deposits in the paleovalley are of variable thickness, ranging from 70 to 232 cm, the variation a consequence of the slope of the channel both downstream and from the margins to the axis of the channel, the irregular surface it filled, and the erosion that subsequently took place across the f2/f3 contact. The f3 here also has more complex layering and fine laminations than in the paleotributary. The laminated interbeds of silty clay contain scattered fragments of shale, all of which mark repeated episodes of low gradient fluvial erosion and redeposition. The size of the gravels, packets of which range from coarse to very fine (i.e., <8 mm), suggests that water velocity and turbidity here on the edges of the valley were irregular, as was stream competence. There is also, overall, a fining upward through this unit, from the complex lenses of sand, gravel, and occasional faunal materials lower down into laminated brown and dark grayish-brown silty clay loam and silt loam lenses higher up.

Although the f3 looks different in the paleotributary and the paleovalley, and the depositional mechanisms in those two areas are likely also different (colluvial vs. fluvial), we nonetheless suspect that the deposition of f3 across the site was essentially penecontemporaneous and that depositional processes in both areas were responding to the same underlying geomorphic/climatic trigger.

THE STRATIGRAPHIC CONTEXT OF THE FOLSOM BISON. In both the paleotributary and the paleovalley the bison bone occurs near the top of stratum f2, but not atop the f2. In the paleotributary, where the stratigraphic context of the bone is more straightforward, there is no unconformity or other stratigraphic indicator of the surface on which the bonebed rests; the Folsom site may be rather unusual in this regard (Frison 1991; Hofman 1989, 1996; Holliday 1997).

Although there is no well-defined stratigraphic surface on which the bonebed is resting, the bones in the paleotribu-
tary were apparently deposited on a relatively level and well-defined surface, as they are distributed across a very narrow vertical span (chapter 7). There is a subtle change in soil texture and chemistry just below the bonebed: There is an increase in carbonate content (table 5.3) and a pronounced Bk horizon (fig. 5.9), which coincides with a change in texture and porosity of f2. The sediments below the bonebed are finer-grained and more porous than those associated with the bone. Bk horizons can be formed by such textural changes (Birkeland 1999:17; Gale 1975) and, more importantly, may be indicative of activity surrounding the kill and butchering. The actions of humans and their large prey could result in the introduction of coarser sediment from the valley walls and uplands and also reduce porosity through trampling.

The absence of a stratigraphic break marking an occupation surface, and the apparent rapidity with which the skeletal material in the paleotributary was buried (based on the very slight weathering of the bone surfaces; chapter 7), implies that f2 deposition continued essentially uninterrupted through Folsom times, almost completely blanketing the bonebed soon after the carcasses were deposited. This further substantiates the inference that airfall loess alone might not have been the sole mechanism of f2 deposition, unless one assumes that there was a substantial amount of dust falling out of the atmosphere and a very large and nearby donor source, which we do not. However, there is no evidence to suggest that the bison carcasses within the paleotributary, once deposited, were moved appreciably by fluvial action associated with either stratum f2 or stratum f3. Indeed, there are several lines of evidence, detailed in chapter 7, to indicate that the faunal remains here are in primary context.

In sharp contrast, some of the bison bones recovered in the paleovalley were resting at very high angles (up to 79°). These bones are situated in and among multiple lenses of gravel in the f3, while other bone elements (or portions thereof) are found within small packets of fine-grained sediment (fig. 5.10). Some of those packets may, in fact, be noneroded “islands” of stratum f2 surrounded by f3. Other packets, however, are clearly part of the f3 fine component; in one particular instance, two ribs were found in proximity to one another, lying at high angles (37° and 49°) within fine-grained sediments sandwiched between lenses of fine gravels. Sitting directly atop the upper fine gravel lens was a large cervical vertebra, coated with calcium carbonate, amid fine-grained sediments. This evidence, in turn, hints that the deposition of f3 took place over a relatively long period of time or that there were separate episodes in which bison bone was plucked from primary context upstream and then transported and deposited downstream.

The bone found in clean and gravel-free sediments in the paleovalley, that is, within those f2 islands, or f3 fine sediments, tended on the whole to be in better condition than the bone found within the gravel lenses. None of the bone in the paleovalley was articulated, and much of it from the f3 experienced relatively greater amounts of breakage on the articular ends and surface attrition in comparison to the bone in the paleotributary, presumably from being rolled by water.

As a result, faunal remains in the paleovalley do not form—as they do in the paleotributary—a discrete archaeological horizon or even a recognizable bonebed. Furthermore, they are not solely within f2 sediments or protected by an overlying shale shingle armor. Instead, they tend to occur as isolated elements in secondary context at high angles indicative of fluvial transport, sometimes jutting upward in the lowest levels of the f3 (anchored in f2 islands) or within the f3. The f2 in the paleovalley has an irregular, erosional upper contact.

Despite these differences in stratigraphic context, we infer that the bison bones in both the paleotributary and the paleovalley are from the same event. The evidence supporting that inference is straightforward.

1. There is no stratigraphic evidence that more than a single kill took place in any area at this site.
2. The bison dental age cohorts are tightly grouped (chapter 7).
3. Radiocarbon ages on bison bone from both the paleotributary and the paleovalley are virtually identical, as discussed in more detail under Radiocarbon Dating and Geochronology, below.

All of this suggests that the postdepositional history of the faunal remains in the paleovalley was very different from the history of those in the paleotributary, and that divergence began soon after the original deposition of the bison carcasses. In both settings, the bones were deposited on top of, and in turn were buried by, F2 silt. Slope wash in the paleotributary relatively soon thereafter carried in shingle shale that sealed the faunal remains in place, while fluvial action in the paleovalley dispersed and redeposited skeletal elements. In the paleovalley, erosion and redeposition likely continued at intervals throughout the Holocene.

Although the bison bones in the paleovalley were obviously transported and in a secondary context, and the remains in the paleotributary were in primary context, it is important to stress that it is not the case that the bison remains in the paleovalley were necessarily washed out from the paleotributary. Indeed, it may well be that some, perhaps even a majority, of the bison remains in the paleovalley were originally deposited there, as suggested by the following evidence.

1. Bison remains in the paleovalley have been found at least ~35 m upstream of the mouth of the paleotributary and, thus, could not have been redeposited from that source.

2. In 1928 projectile points were found in association with bison bone, and in 1972 an intact and well-preserved bison cranium was recovered from within the paleovalley. Either of these finds could have been in a secondary context; unfortunately, no records exist to indicate their precise depositional contexts, angles of orientation and inclination, etc. Yet, their condition opens the possibility that they are in a primary context. That inference is not incompatible with the observation that reworking has been extensive in the paleovalley. Fluvial action need not have affected all of the carcasses deposited in this area.

3. Finally, although F2 sediments were eroded by flow down the paleotributary in Early and Middle Holocene times (as discussed below), there is little corresponding evidence that bison elements in the paleotributary were moved or otherwise influenced by fluvial action (chapter 7). If this area was a significant feeder source of the bone in the paleovalley, there ought to be more evidence of movement in the paleotributary than is otherwise present. Admittedly, however, the absence of faunal disturbance is known only from our excavations on the west side of the paleotributary; we have no data on the east side of the paleotributary.

The possibility that bison were killed in both the paleotributary and the paleovalley raises several intriguing but likely unanswerable questions: Were the bison attacked in the paleovalley and sought the paleotributary to escape the hunters? Or was the kill in the paleotributary, and the animals tried to flee down the paleovalley? Or were bison dispatched—and processed—in both areas? If the main activities of the kill took place in the paleovalley, that might account for why the density of carcasses in the paleotributary is lower than that seen in other Folsom sites (e.g., Bement 1999b; Hofman 1999a). And if the bison remains in the paleovalley were deposited as partial carcasses, that raises the question of whether processing and habitation areas were once located in the paleovalley and might still be preserved under the thick overburden of the North Bank.

THE MCFUNKIN FORMATION (m1–m2) AND HOLOCENE CUTTING AND FILLING

Following the deposition of stratum F3, there was a series of cut-and-fill episodes, producing stratum m, the McJunkin Formation. We place the boundary between the Folsom and the McJunkin formations at the appearance of the laminated and bedded dark-gray and dark-brown layers above the F3 shingle. The McJunkin Formation deposits filled and ultimately obscured the paleovalley and the paleotributary.

Stratum m covers stratum f throughout the South Bank and the North Bank and in all observed exposures along Wild Horse Arroyo. Stratum m is largely fine-grained silts and clays and is typically 200 cm to 300 cm thick (and up to 350 cm thick in places). Layers of shingle and gravel are common. Visually, stratum m is quite distinct from stratum f, because m is stratified and is generally much darker in color. The very low chromas and values and the relatively high organic carbon content of stratum m suggest deposition of fine sediments from dust, or slopewash in a heavily vegetated or wet environment, the latter inferred from the presence of gleying and motting. Analogous slackwater deposits are common in the area today in tributary arroyos when the Dry Cimarron backfills its tributaries (Mann, personal communication, 2003).

The most distinctive and obvious stratification in stratum m is in its lower half on the North Bank, a zone identified as stratum m1. This subunit consists of layers of silt loam, silty clay loam, and silt clay, each a few centimeters to a few decimeters thick, with a few sandy interbeds and thin shingle and gravel layers. Dry colors of the layers are variable and include dark grayish brown (2.5Y 4/2), grayish brown (2.5Y 5/2), light olive brown (2.5Y 5/4), light brownish gray (2.5Y 6/2), light yellowish brown (2.5Y 6/4), and dark gray (10YR 4/1). The laminated zone of m1, though distinctive along the North Bank exposure (Profile 97-1), does not extend north of the arroyo to any significant degree, based on our coring. The presence of the laminations only in exposures opposite the paleotributary raises the possibility that these lighter-brown and yellowish-brown silts may be
re-deposited $f_2$ or $f_3$ flushed out into the paleovalley. The absence of the laminated zone along the axis of the paleovalley may be due to subsequent downcutting, or simply because these sediments were never deposited that far out from the mouth of the paleotributary.

Stratum $m_2$, like $m_1$, is stratified with layers of silt loam, silty clay loam, and silty clay. In $m_2$, however, the individual strata are thicker (decimeters) and coarse clastics (i.e., shingle) are less common except in proximity to the bedrock valley wall. Stratum $m_2$ also is generally darker and duller in color than $m_1$; the layers are black (10YR 2/1), very dark gray (10YR 3/2), dark gray (10YR 4/1), grayish brown (2.5Y 5/2), and dark grayish brown (2.5Y 4/2) (all dry colors).

The silty and clayey layers comprising stratum $m$ contain lenses of shingle and gravel, typically along the valley margins. Sections toward the valley axis have little or no shingle or gravel. This may be a simple facies change—shingle and gravel are more common lithologies in proximity to the bedrock valley walls—but this characteristic may also indicate that fine-grained valley-axis units are cut into the bedded deposits. Cores from the center of the North Bank contain thick deposits of $m$ over a deeply eroded surface of $f_2$. For example, the top of the $f_2$ is at an elevation of 94.138 in core 98-13 along the valley axis but at an elevation of 98.084 in Profile 3 on the valley margin. Moreover, the laminated deposits of stratum $m_1$ (discussed above) are not found in the valley axis, suggesting that they may have been cut out.

Some of the silty layers within unit $m$ exhibit sharp, irregular upper boundaries and several of these are capped by shingle or gravel, which is suggestive of cut-and-fill episodes. Earlier investigators also observed cut-and-fill sequences along the vertical walls of Wild Horse arroyo below the site (Anderson and Haynes 1979; Cook, in Roberts 1951). The most obvious stratigraphic evidence for McJunkin-age channel cutting was exposed during excavation of the L23 block, where a well-defined channel ~2 m deep was discovered. The incision of this channel completely removed the $m_1$, $f_3$, and $f_2$ units and eroded the surface of the $f_1$, which was then buried in $m_2$ fill. This channel was visible only in cross section, so its upstream and downstream course is uncertain. It appears to have come in from the northwest, where a part of it may be visible ~40 m to 50 m upstream, pivoted against the Smoky Hill Shale bedrock on the South Bank, and then turned east/northeast back toward the valley axis. There is no evidence that the bonebed in the paleotributary experienced any such significant Middle or Late Holocene erosion; it was buried and well armored by the time these processes took place.

Evidence for postdepositional and probably some postburial alterations of stratum $m$ is common (Anderson and Haynes 1979:897 [including their $f_3$, now part of our $m_1$]). Pedogenesis is marked by the accumulation of organic matter in some zones within $m$ (indicated by the very dark colors and relatively high organic carbon content; table 5.2), the development of prismatic structure, the slight reddening (10YR hues, in contrast to dominantly 2.5Y hues in the Folsom Formation strata), and the presence of films and threads of carbonate in ped faces in some horizons (e.g., Profile 97-1: AB-2Tg horizon in $m_2$ at 74-136 cm and AB horizon in $m_1$ at 136-175 cm; Bk horizon in $f_2$ at 250-330 cm; and in Giddings Core 97-3, A-Bt horizon at 20-125 cm; table 5.2). Some horizons also were subjected to gleying (e.g., Big horizon in Profile 97-1 at 100-136 cm; table 5.2). The evidence for soil formation within unit $m$ in turn indicates episodes of landscape stability during the evolution of the deposit.

THE WILDHORSE FORMATION (w)

Stratum $w$ is the youngest layer in the late Quaternary stratigraphic sequence at the Folsom site. The distinctive characteristics of $w$, according to Anderson and Haynes (1979:897, table 1), and in contrast to $m$ and $f$, are that the unit consists of “sandy silt” in layers ranging in color from dark gray (10YR 4/1) to grayish brown (2.5Y 5/3) interbedded with cobbles, gravel, or crystalline rock and shingle shale. Limited laboratory data plus field textures from cores indicate that the fines are lithologically similar to the silty clays of $m$ and $f$. Weak soil development is apparent in some layers within the Wildhorse Formation. The principal difference between stratum $w$ and stratum $m$, therefore, are the multiple layers of shingle and gravel in stratum $w$. In the absence of the coarse clastics, therefore, $w$ is very similar to some facies of $m$.

Stratum $w$ is best expressed in the North Bank arroyo exposure opposite the paleotributary. This hints that perhaps some of the gravel in $w$ came down the paleotributary. The profile for trench 5 of Haynes, Anderson, and Frazier (1976) is relevant here: It shows a very thin and gravel-free stratum $w$ resting unconformably on $m$, further hinting that $w$ is related to the paleotributary. That said, other source areas are clearly indicated, given that there are gravels in $w$ that in places are much larger than the clasts in the paleotributary and, in fact, occur upstream of the mouth of the paleotributary.

Stratum $m_2$ is at the surface in many parts of the site, suggesting that $w$ may be a channel fill inset against $m$, and it is so indicated by Haynes et al. (1992:fig. 3.1). Such crosscutting relationships were not observed. The only relevant data we have come from an ~3-m section exposed in an excavation unit in the M23 block on the North Bank, where a 30- to 40-cm-thick lens of cobbles and coarse gravel, the base of a channel cut, was exposed ~1.5 m below the surface and subsequently topped with very dark-gray silty clay (10YR 3/1). While this zone of large clasts was deposited, it was not necessarily associated with an erosional event, and it may well be a pulse of gravel interrupting otherwise quiet and ongoing deposition of mud (McJunkin). In effect, stratum $w$ may simply be a facies of $m$ that, within the main valley, contains large clasts.
In any case, accounting for the relatively common presence of crystalline gravel is somewhat problematic. The source is likely gravel from high Pleistocene strath terraces of Wild Horse Arroyo and the Upper Dry Cimarron, which is dominated by basalt but also includes gravel from the Ogallala Formation, which outcrop around the area (chapter 3). Why the gravel is more common in W than in any of the older units is still unclear. It should be considered for redeposition in stratum f or m. Perhaps deposits of gravel were only available for erosion and redeposition following a unique combination of climatic, floral, and geomorphic processes.

Radiocarbon Dating and Geochronology

All together, there are 49 radiocarbon ages available from the Folsom site and nearby sampled sections along Wild Horse Arroyo. These vary in their precision and accuracy in providing age control over the stratigraphic sequence and the age of the Paleoindian bonebed. A comprehensive list of all radiocarbon dates obtained from the site, from 1950 to the present, is provided in table 5.4, along with provenience, context, and other information.

Ten of those ages are separately dated fractions from the same sample of charcoal (e.g., AA-7088 and 7089, AA-7090 and 7091, CAMS-57513 and 57514, CAMS-57518 and 57519, CAMS-57520 and 57521). Where charcoal and humic acid fractions from a single charcoal sample were separately dated (the CAMS pairs), the charcoal fraction is used, on the assumption that it is less likely to be contaminated. Where carbon residue and humate fractions from a single sample were separately dated (the AA pairs), the carbon residue fraction is used, again on the same assumption. We further assumed that radiocarbon ages from charcoal as opposed to bone bone represent maximum-limiting ages for sediments in which it is contained.

The four radiocarbon ages listed at the end of table 5.4 are unacceptable based on stratigraphic and/or other evidence and are not considered further. Thus, a total of 40 radiocarbon ages form the basis of the discussion that follows.

Radiocarbon ages from the laboratories at the University of Arizona (AA), Southern Methodist University (SMU), and the University of Texas Radiocarbon Facility (TX) were obtained by C. V. Haynes (Haynes et al. 1992). All but one of the samples with a CAMS designation were prepared by T. Stafford of Stafford Research Laboratories; the other CAMS sample (CAMS 96034) was prepared by P. Matheu at the Alaska Quaternary Center, University of Alaska.

METHODS

Charcoal samples received standard acid/base pretreatment using hydrochloric acid (HCl) decalcification and potassium hydroxide (KOH) cycles to removed humates (Stafford 1998). The SMU sample of bone bone was prepared by A. Hassan, using then-experimental techniques, as described in detail by Hassan (1975). The laboratory protocols for all other bison bone samples followed the procedure developed by Stafford (see Stafford et al. 1987:fig. 1, 1988, 1991), which is also used by Matheu (1997:appendix 2). In general, that procedure involves a series of steps to separate the collagen and mineral (bioapatite) portions of the bone, which is accomplished by repeated soaking of the sample in weak HCl at low temperatures until the sample is demineralized. Once the sample is rinsed to neutralize the HCl, it is soaked in KOH to partially remove humic and fulvic acids. The collagen is then gelatinized to separate it from other proteins and organic compounds in the demineralized bone and given a final “filtering” via liquid chromatography using nonionic, hydrophobic, styrene (XAD) resins to remove fulvic acids (Matheu 1997; Stafford, Brendel, and Duhamel 1988). All CAMS sample targets were run at the Lawrence Livermore National Laboratory Center for Accelerator Mass Spectrometry (CAMS).

Calibration of radiocarbon ages was done using both OxCal Version 3.9 (Ramsey 2003) and CALIB Version 4.4 (Stuiver, Reimer, and Reimer 2000). The OxCal results are used in table 5.4 and the figures because they provide more illustrative graphical results. We note that OxCal and CALIB returned slightly different calibrated ages for the same 14C age, but the discrepancy does not appear to be significant. Assessments of statistical contemporaneity and averaging of ages are based on chi-square analysis using an SPSS algorithm developed by H. Fietala (1989). Ages are rounded to the nearest decade.

The 1σ errors on half of these radiocarbon ages—which includes all of the f2 ages—fall between 13,200 and 11,260 cal yr B.P., thus overlapping the Younger Dryas Chronzone, with its multiple radiocarbon plateaus and reversals (Beck et al. 2001; Delaygue et al. 2003; Hajdas et al. 1998; Hughen et al. 2000; Kigawa and van der Plicht 1998; Leuvenberger, Siegenthaler, and Langway, 1992; Monnin et al. 2001; Taylor, Stuiver, and Reimer 1996). Hence, the calibration and precision of radiocarbon ages from this period are hardly straightforward, since a given radiocarbon age can correspond to an unusually wide range of calibrated calendar ages (table 5.4). The ages are discussed in stratigraphic order.

AGE OF THE f1

There is but a single age available on unit f1: 12,355 ± 210 14C yr B.P. (AA-7090; the humate split from this sample [AA-7091] is statistically indistinguishable). The precise provenience of this sample is uncertain. It is reported only as having come from "a 0.5 cm thick carbonaceous band ca. 40 cm below 1 Folsom 90" (Haynes, unpublished field notes, July 18, 1990). It is unclear whether the chronological gap between this sample and the oldest of the ages from the f2 (~11,500 14C yr B.P.) is indicative of a depositional hiatus or stratigraphic unconformity that has been otherwise overlooked or whether the sample is minutely contaminated.
<table>
<thead>
<tr>
<th>Stratum</th>
<th>Provenience</th>
<th>Material</th>
<th>Laboratory No.</th>
<th>$^{14}$C Age, yr B.P.</th>
<th>Cal Age, yr B.P.: 68.2% Probability</th>
<th>Cal Age, yr B.P.: 95.4% Probability</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>$w$</td>
<td>North Bank, collected July 1999, from M23 profile (M23-NAP-29; 99-29) (N1063.792 E997.491 Z99.561)</td>
<td>Oak charcoal</td>
<td>CAMS-74651</td>
<td>700 ± 40</td>
<td>560–590 (19.1%)&lt;br&gt;640–680 (49.1%)</td>
<td>550–610&lt;br&gt;620–710 (65.1%)</td>
<td>From possible hearth in-fill in a secondary channel; analyzed using solid carbon method; see discussion in text</td>
</tr>
<tr>
<td>$m2^?$</td>
<td>North Bank (?), collected by F. Howarth, July, 1933, “some hundred feet, plus or minus,” east of the site (Cook, in Roberts 1951:20)</td>
<td>Charcoal</td>
<td>C-377</td>
<td>4,575 ± 300&lt;br&gt;3,923 ± 400&lt;br&gt;average = 4,280 ± 250</td>
<td>4,450–5,300&lt;br&gt;(68.2%)</td>
<td>4,150–5,650&lt;br&gt;(95.4%)</td>
<td>From gravels at the base of the McJunkin arroyo; dates the onset of filling in the arroyo</td>
</tr>
<tr>
<td>$m2$</td>
<td>North Bank, collected July 1998, 98-479 (N1065.567 E998.177 Z94.732)</td>
<td>Charcoal</td>
<td>CAMS-57517</td>
<td>4,460 ± 50</td>
<td>4,970–5,080&lt;br&gt;(25.9%)&lt;br&gt;5,100–5,130&lt;br&gt;(6.6%)&lt;br&gt;5,160–5,280&lt;br&gt;(35.6%)</td>
<td>4,870–4,940&lt;br&gt;(7.3%)&lt;br&gt;4,960–5,300&lt;br&gt;(88.1%)</td>
<td>Haynes, unpublished field notes, July 13, 1970</td>
</tr>
<tr>
<td>$m2$</td>
<td>North Bank, collected by C.V. Haynes July 1970, from &quot;charred log and reddened silt&quot; in &quot;Loc. upstream from type site&quot; (CS 70-9)</td>
<td>Charcoal</td>
<td>TX-1272</td>
<td>4,470 ± 90</td>
<td>4,970–5,290&lt;br&gt;(68.2%)</td>
<td>4,850–5,350&lt;br&gt;(95.4%)</td>
<td>Core taken close to north valley wall, on presumed edge of paleovalley. Sample from 3.92–3.93 m below surface. Date indicates $m2$ fills this portion of paleovalley</td>
</tr>
<tr>
<td>$m2$</td>
<td>North Bank, collected July 1997, from Giddings Core 97-14 (97-49F) (N1074.134 E1072.558 Z 93.649)</td>
<td>Pine charcoal</td>
<td>CAMS-74644</td>
<td>4,640 ± 60</td>
<td>5,300–5,470&lt;br&gt;(68.2%)</td>
<td>5,050–5,200&lt;br&gt;(7.1%)&lt;br&gt;5,250–5,600&lt;br&gt;(88.3%)</td>
<td>Haynes, unpublished field notes, July 13, 1970; same location as TX-1271 and TX-1452</td>
</tr>
<tr>
<td>$m2$</td>
<td>North Bank, collected by C.V. Haynes July 1970, from &quot;charcoal with red band, downstream from confluence (car park)&quot; (CS 70-14)</td>
<td>Charcoal</td>
<td>TX-1270</td>
<td>4,850 ± 120</td>
<td>5,480–5,510&lt;br&gt;(14.3%)&lt;br&gt;5,580–5,660&lt;br&gt;(53.9%)</td>
<td>5,460–5,710&lt;br&gt;(95.4%)</td>
<td>(continued)</td>
</tr>
<tr>
<td>Stratum</td>
<td>Provenience</td>
<td>Material Dated</td>
<td>Laboratory No.</td>
<td>$^{14}$C Age, yr B.P.: 68.2% Probability</td>
<td>Cal Age, yr B.P.: 95.4% Probability</td>
<td>Comments</td>
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<tr>
<td>$m_2$</td>
<td>South Bank, collected July 1998, Feature 1, upper half of $m_2$ (M17-3-1; 98-304) (N1030.301 E997.608 Z98.242)</td>
<td>Pine charcoal (from same sample as CAMS-57519)</td>
<td>CAMS-57518</td>
<td>4,910 ± 50</td>
<td>5,590–5,670 (61.4%)</td>
<td>Average of CAMS-57518 and -57519 = 4,880 ± 35 $^{14}$C yr B.P.</td>
<td></td>
</tr>
<tr>
<td>$m_1$</td>
<td>North Bank, collected by C.V. Haynes July 1970, from a “meter down in this unit, where exposed 300 m downstream from the site” (Haynes and Anderson, unpublished); (CS 70-13)</td>
<td>Charcoal</td>
<td>TX-1452</td>
<td>6,060 ± 500</td>
<td>6,350–7,450 (68.2%)</td>
<td>Haynes, unpublished field notes, July 13, 1970; same location as TX-1270 and TX-1452</td>
<td></td>
</tr>
<tr>
<td>$m_1$</td>
<td>North Bank, collected by C.V. Haynes July 1970, from “charcoal in fire pit in [stratum] Qy in main draw” “downstream from type site and forks” (CS 70-16)</td>
<td>Charcoal</td>
<td>TX-1271</td>
<td>6,910 ± 110</td>
<td>7,610–7,640 (4.1%)</td>
<td>Haynes, unpublished field notes, July 13, 1970; same location as TX-1270 and TX-1452</td>
<td></td>
</tr>
<tr>
<td>$m_2$?</td>
<td>North Bank, collected June 1997, from Profile 97-1 (97-7f) (N1051.445 E1021.947 Z96.937)</td>
<td>Charcoal—humic acid fraction</td>
<td>CAMS-57511</td>
<td>7,500 ± 40</td>
<td>8,200–8,270 (27.2%)</td>
<td>Sample from lower portion of $m_2$, 20 cm above $m_1/m_2$ contact. Date seems too old for $m_2$ but would fit with $m_1$</td>
<td></td>
</tr>
<tr>
<td>$f_3$</td>
<td>North Bank, collected July 1998, Bison carpal. Bone from stratigraphically above $f_2/f_3$ contact and just above Bison humerus (element L23-8-10; see below) (L23-8-9) (N1061.742 E992.593 Z96.558)</td>
<td>Bone (XAD-gelatin &amp; KOH collagen)</td>
<td>CAMS-74654</td>
<td>9,220 ± 50</td>
<td>10,260–10,350 (28.9%)</td>
<td>Bone not from Paleoundian bison kill</td>
<td></td>
</tr>
<tr>
<td>Sample</td>
<td>Location</td>
<td>Date</td>
<td>Description</td>
<td>Carbon</td>
<td>Radiocarbon Dates (95.4%)</td>
<td>Other Carbon Dates (95.4%)</td>
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<tr>
<td>Bone</td>
<td>North Bank, collected July 1999, antilocaprid femur (N22.3-1) (N1055.797 E1002.889 Z95.857)</td>
<td>Bone (XAD-gelatin &amp; KOH collagen)</td>
<td>CAMS-74934</td>
<td>9,270 ± 50</td>
<td>10,280-10,300 (3.9%)</td>
<td>10,240-10,580 (95.4%)</td>
<td></td>
</tr>
<tr>
<td>Pine charcoal</td>
<td>North Bank, collected July 1998, in f3 immediately (5 cm) above Bison carpal (see L23-8-9 above) (L23-8-21; 98-489) (N1061.802 E992.633 Z96.608)</td>
<td>Pine charcoal—humic acid fraction</td>
<td>CAMS-57515</td>
<td>9,340 ± 50</td>
<td>10,420-10,450 (5.0%)</td>
<td>10,390-10,700 (95.4%)</td>
<td></td>
</tr>
<tr>
<td>Pine charcoal</td>
<td>North Bank, collected July 1999, from auger hole 1.55 m below floor of M23 unit; 4.75 m below present surface. Sample from f3 ~5 cm above f2. (M23-NAP-45; 99-45) (N1064.47 E997.944 Z95.434)</td>
<td>Pine charcoal</td>
<td>CAMS-74653</td>
<td>9,440 ± 50</td>
<td>10,570-10,750 (68.2%)</td>
<td>10,500-10,850 (82.0%)</td>
<td></td>
</tr>
<tr>
<td>Charcoal</td>
<td>North Bank, collected July 1998, in f3 immediately (4.7 cm) below Bison carpal (see L23-8-9 above) (L23-8-20; 98-488) (N1061.752 E992.543 Z96.511)</td>
<td>Charcoal—humic acid fraction</td>
<td>CAMS-57516</td>
<td>9,780 ± 40</td>
<td>11,170-11,205 (61.1%)</td>
<td>11,140-11,235 (95.4%)</td>
<td></td>
</tr>
<tr>
<td>Pine/conifer charcoal</td>
<td>South Bank, collected July 1999, from bedrock surface atop bedrock wall immediately west of the bonebed (J19-4-10; 99-58) (N1040.479 E983.502 Z99.971)</td>
<td>Pine/conifer charcoal</td>
<td>CAMS-74647</td>
<td>9,820 ± 40</td>
<td>11,190-11,230 (68.2%)</td>
<td>11,160-11,260 (94.4%)</td>
<td></td>
</tr>
</tbody>
</table>

In same area of the North Bank where Howarth reported finding “deer” bones, which he believed came from Folsom bison bonebed. If this is the same individual, it indicates the animal is not from Paleoindian bison kill.

(continued)
<table>
<thead>
<tr>
<th>Stratum</th>
<th>Provenience</th>
<th>Material Dated</th>
<th>Laboratory No.</th>
<th>$^{14}$C Age, yr B.P.</th>
<th>Cal Age, yr B.P.: 68.2% Probability</th>
<th>Cal Age, yr B.P.: 95.4% Probability</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>f3</td>
<td>North Bank, collected June 1997, from basal portion of f3, 8 cm above f2/f3 contact, Profile 97-1. (97-12F) (N1051.445 E1021.947 Z95.155)</td>
<td>Charcoal—humic acid fraction</td>
<td>CAMS-57512</td>
<td>10,370 ± 50</td>
<td>11,950–12,050 (4.9%)</td>
<td>12,100–12,400 (40.4%)</td>
<td>12,450–12,650 (23.4%)</td>
</tr>
<tr>
<td>f3</td>
<td>North bank, collected July 1999, from amid gravels in paleovalley (Q21-8-16; 99-61) (N1051.534 E1017.803 Z94.623)</td>
<td>Charcoal</td>
<td>CAMS-74648</td>
<td>10,420 ± 140</td>
<td>11,950–12,050 (3.3%)</td>
<td>12,100–12,650 (61.5%)</td>
<td>12,700–12,800 (3.4%)</td>
</tr>
<tr>
<td>f2</td>
<td>South bank, collected July 1998, from above bone bed (N17-21-18; 98-170) (N1034.158 E1000.160 Z97.620)</td>
<td>Conifer charcoal</td>
<td>CAMS-74645</td>
<td>10,010 ± 50</td>
<td>11,260–11,280 (2.4%)</td>
<td>11,290–11,450 (37.7%)</td>
<td>11,460–11,570 (26.2%)</td>
</tr>
<tr>
<td>f2</td>
<td>North Bank, Bison bone (radius) collected by C. V. Haynes July 1970) (CS-70-11)</td>
<td>Bone—collagen</td>
<td>SMU-179</td>
<td>10,260 ± 110</td>
<td>11,650–12,350 (68.2%)</td>
<td>11,350–12,850 (95.4%)</td>
<td></td>
</tr>
<tr>
<td>f2</td>
<td>South Bank, collected July 1998 from M15 block. (M15-24-43) (N1024.051 E998.593 Z97.733)</td>
<td>Charcoal</td>
<td>CAMS-57520</td>
<td>10,380 ± 50</td>
<td>11,950–12,050 (2.6%)</td>
<td>12,100–12,400 (38.7%)</td>
<td>12,450–12,650 (26.9%)</td>
</tr>
<tr>
<td>Sample ID</td>
<td>Description</td>
<td>Radiocarbon Dates</td>
<td>Measurement</td>
<td>Precision</td>
<td>Percent Error</td>
<td>Notes</td>
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<td>f2</td>
<td>South Bank, collected July 1998 from M15 block. (M15-24-43) (N1024.051 E998.593 Z97.733) Charcoal—humic acid fraction CAMS-57521 (from same sample as CAMS-57520)</td>
<td>10,600 ± 40</td>
<td>12,380–12,480</td>
<td>24.3%</td>
<td>12,300–12,550 (32.3%) Same as CAMS-57520 (above)</td>
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<tr>
<td>f2</td>
<td>South Bank, collected July 1998, <em>Bison</em> (right) humerus (M17-19-106) (N1033.091 E998.899 Z97.627) Bone (XAD-gelatin &amp; KOH collagen) CAMS-74656</td>
<td>10,450 ± 50</td>
<td>12,150–12,250</td>
<td>4.5%</td>
<td>11,950–12,850 (95.4%)</td>
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<tr>
<td>f2</td>
<td>South Bank, collected July 1999, <em>Bison</em> (right) tibia (M17-24-310) (N1034.312 E998.220 Z97.538) Bone (XAD-gelatin &amp; KOH collagen) CAMS-74658</td>
<td>10,450 ± 50</td>
<td>12,150–12,250</td>
<td>4.5%</td>
<td>11,950–12,850 (95.4%)</td>
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<tr>
<td>f2</td>
<td>North Bank, collected June 2002, <em>Bison</em> thoracic vertebra (R20-14-5) (N1047.760 E1023.113) Bone (XAD-gelatin &amp; KOH collagen) CAMS-96034</td>
<td>10,475 ± 30</td>
<td>12,320–12,550</td>
<td>44.9%</td>
<td>12,050–12,850 (95.4%)</td>
<td></td>
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<tr>
<td>f2</td>
<td>South Bank, collected July 1998, <em>Bison</em> (right) mandibular molar (M17-24-141) (N1034.765 E997.992 Z97.567) Bone (XAD-gelatin &amp; KOH collagen) CAMS-74657</td>
<td>10,500 ± 40</td>
<td>12,330–12,530</td>
<td>43.1%</td>
<td>12,050–12,900 (95.4%)</td>
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<tr>
<td>f2</td>
<td>South Bank, collected July 1999, from test unit in upper portion of tributary headcut, ~65 m south of the southern edge of the bonebed (F8-6-20; 99-68) (N986.460 E960.999 Z99.789) Pine charcoal CAMS-74649</td>
<td>10,510 ± 50</td>
<td>12,330–12,530</td>
<td>41.4%</td>
<td>12,100–12,900 (95.4%) Indicates sediments of Folsom Paleoindian age present in this area of the site, although no archaeological traces were found</td>
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</table>

(continued)
<table>
<thead>
<tr>
<th>Stratum</th>
<th>Provenience</th>
<th>Material Dated</th>
<th>Laboratory No.</th>
<th>$^{14}$C Age, yr B.P.</th>
<th>Cal Age, yr B.P.: 68.2% Probability</th>
<th>Cal Age, yr B.P.: 95.4% Probability</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>f2</td>
<td>North Bank, collected July 1998, <em>Bison</em> (right) humerus from below f3/f2 contact (L23-8-10) (N1061.474 E992.465 Z96.289)</td>
<td>Bone (XAD-gelatin &amp; KOH collagen)</td>
<td>CAMS-74655</td>
<td>10,520 ± 50</td>
<td>12,730–12,820 (13.7%)</td>
<td>12,100–12,250 (6.6%)</td>
<td></td>
</tr>
<tr>
<td>f2/f3</td>
<td>North Bank, collected July 1999, <em>Bison</em> (left) tibia in reworked sediments (Q21-8-52) (N1051.620 E1017.792 Z94.587)</td>
<td>Bone (XAD-gelatin &amp; KOH collagen)</td>
<td>CAMS-74659</td>
<td>10,520 ± 50</td>
<td>12,330–12,520 (40.6%)</td>
<td>12,100–12,250 (6.6%)</td>
<td></td>
</tr>
<tr>
<td>f2</td>
<td>South Bank, collected July 1998, associated with <em>Bison</em> metatarsals. (M17-25-102) (N1034.518 E999.652 Z97.425)</td>
<td>Charcoal—humic acid fraction</td>
<td>CAMS-57525</td>
<td>10,670 ± 50</td>
<td>12,630–12,760 (31.2%)</td>
<td>12,350–12,500 (13.8%)</td>
<td>As age predates bone dates, indicates not all charcoal in f2 sediment is anthropogenic</td>
</tr>
<tr>
<td>f2</td>
<td>North Bank, collected by C.V. Haynes July 1970; part of a sample of “single lumps or flecks widely dispersed throughout the [f2] zone, 10–30 cm thick, as it was exposed in scraping the arroyo wall (CS-70-7.3)</td>
<td>Pine charcoal</td>
<td>AA-1709</td>
<td>10,760 ± 140</td>
<td>12,400–12,500 (1.4%)</td>
<td>12,300–13,150 (95.4%)</td>
<td>Haynes et al. (1992:87) average AA-1708 to AA-1712 plus AA-1213 together. As age predates bone dates, indicates not all charcoal in f2 sediment is anthropogenic</td>
</tr>
<tr>
<td>f2</td>
<td>North Bank, collected by C.V. Haynes July 1970, as above AA-1709 (CS-70-7.0)</td>
<td>Charcoal</td>
<td>AA-1213</td>
<td>10,780 ± 100</td>
<td>12,650–12,740 (17.5%)</td>
<td>12,400–12,500 (3.9%)</td>
<td>This sample is a composite of fragments from AA-1708 to AA-1712.</td>
</tr>
</tbody>
</table>
North Bank, collected by C.V. Haynes July 1970, as above AA-1709 (CS-70-7.4)

Juniper charcoal AA-1711 10,850 ± 190 12,650–12,740 (11.5%) 12,800–13,140 (56.7%) 12,150–13,450 (95.4%) As above, AA-1709

North Bank, collected by C.V. Haynes July 1970, as above AA-1709 (CS-70-7.3)

Juniper bark or hard-wood charcoal AA-1710 10,890 ± 150 12,820–13,140 (68.2%) 12,350–12,500 (3.0%) 12,600–13,200 (92.4%) As above, AA-1709

North Bank, collected by C.V. Haynes July 1970, as above AA-1709 (CS-70-7.5)

Juniper bark or hard-wood charcoal AA-1712 10,910 ± 100 12,860–13,050 (55.0%) 13,060–13,130 (13.2%) 12,600–12,750 (10.8%) 12,800–13,200 (84.6%) As above, AA-1709

South Bank collected July 1998, from M15 block, which marks southern margins of bonebed (M15-24-55) (N1024.495 E998.236 297.682)

Charcoal—humic acid fraction CAMS-57523 10,970 ± 50 12,910–13,050 (50.6%) 13,070–13,140 (17.6%) 12,660–12,720 (4.8%) 12,840–13,160 (90.6%) Although older than the age of the kill, the lack of any overlying stratigraphic unconformity or truncation of f2 in this area indicates sediments of Folsom Paleolithic age likely present here; absence of bone is evidence of absence.

North Bank, collected by C.V. Haynes July 1970, as above AA-1709 (CS-70-7.1)

Pine charcoal AA-1708 11,060 ± 100 12,950–13,160 (68.2%) 12,650–12,750 (3.1%) 12,800–13,400 (92.3%) As above, AA-1709


Conifer charcoal—humic acid fraction CAMS-57524 11,070 ± 50 12,980–13,150 (68.2%) 12,650–12,750 (1.9%) 12,850–13,200 (93.5%) Bison mandible is M17-24-146

North Bank, collected by C.V. Haynes July, 1990, precise provenience unknown. “Collected at base of dark unit (? in buff (yellow) loess?” (1 Folsom 90A)

Charcoal—carbon residue AA-7088 (from same sample as AA-7088) 11,100 ± 130 12,900–13,200 (68.2%) 12,650–12,750 (2.3%) 12,850–13,450 (93.1%) Sample was plotted by Haynes as occurring at the base of f3; field description matches f2 sediments.

North Bank, collected by C.V. Haynes July, 1990, precise provenience unknown. “Collected at base of dark unit (? in buff (yellow) loess?” (1 Folsom 90A)

Charcoal—humates (from same sample AA-7088) AA-7089 10,630 ± 80 12,390–12,480 (17.8%) 12,620–12,680 (11.5%) 12,700–12,880 (39.0%) 12,150–12,250 (1.1%) Sample plotted by Haynes as occurring at the base of f3; field description matches f2 sediments.

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<table>
<thead>
<tr>
<th>Stratum</th>
<th>Provenience</th>
<th>Material Dated</th>
<th>Laboratory No.</th>
<th>$^{14}$C Age yr B.P.</th>
<th>Cal Age yr B.P.: 68.2% Probability</th>
<th>Cal Age yr B.P.: 95.4% Probability</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>f2</td>
<td>North Bank Profile 1, collected June 1997, Profile 97-1. Sample from −28 cm below f3/f2 contact and below level of bonebed (97-2F) (N1051.445 E1021.947 Z94.8)</td>
<td>Charcoal</td>
<td>CAMS-57513 (from same sample as CAMS-57514)</td>
<td>11,370 ± 150</td>
<td>13,140–13,490</td>
<td>12,950–13,850</td>
<td>Average of CAMS-57513 and -57514 = 11,500 ± 40 $^{14}$C yr B.P.</td>
</tr>
<tr>
<td>f2</td>
<td>North Bank Profile 1, collected June 1997, Profile 97-1. Sample from −28 cm below f3/f2 contact and below level of bonebed (97-2F) (N1051.445 E1021.947 Z94.8)</td>
<td>Charcoal—humic acids</td>
<td>CAMS-57514 (from same sample as CAMS-57513)</td>
<td>11,510 ± 40</td>
<td>13,200–13,250 (1.5%)</td>
<td>13,150–13,550 (66.6%)</td>
<td>Average of CAMS-57513 and -57514 = 11,500 ± 40 $^{14}$C yr B.P.</td>
</tr>
<tr>
<td>fl</td>
<td>North Bank, collected by C.V. Haynes, July, 1990; precise sample position and elevation unknown. From &quot;0.5 cm thick carbonaceous band ca. 40 cm below 1 Folsom 90&quot; [AA-7088/AA-7089] (2 Folsom 90A)</td>
<td>Charcoal—carbon Residue</td>
<td>AA-7090 (from same sample as AA-7091)</td>
<td>12,355 ± 210</td>
<td>14,050–15,050 (68.2%)</td>
<td>13,750–15,550 (95.4%)</td>
<td>Average of AA-7090 and -7091 = 12,390 ± 80 $^{14}$C yr B.P.</td>
</tr>
<tr>
<td>fl</td>
<td>North Bank, collected by C.V. Haynes, July, 1990; precise sample position and elevation unknown. From &quot;0.5 cm thick carbonaceous band ca. 40 cm below 1 Folsom 90&quot; [AA-7088/AA-7089] (2 Folsom 90A)</td>
<td>Charcoal—humates</td>
<td>AA-7091 (from same sample as AA-7090)</td>
<td>12,395 ± 90</td>
<td>14,100–14,500 (35.5%)</td>
<td>14,050–15,450 (95.4%)</td>
<td>Average of AA-7090 and -7091 = 12,390 ± 80 $^{14}$C yr B.P.</td>
</tr>
<tr>
<td>Stratum</td>
<td>Provenience</td>
<td>Material Dated</td>
<td>Laboratory No.</td>
<td>$^{14}$C age, yr B.P.</td>
<td>Comments</td>
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<tr>
<td>$m1$</td>
<td>North Bank, collected July 1999, from M23 profile (M23-NAP-24; 99-24) (N1064.198 E997.093 Z97.983)</td>
<td>Oak charcoal</td>
<td>CAMS-74650</td>
<td>$840 \pm 50$</td>
<td>Date younger than expected, based on stratigraphic position</td>
<td></td>
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<tr>
<td>$f3$</td>
<td>North Bank, collected July 1999, from M23 profile (M23-NAP-44; 99-44) (N1063.887 E998.617 Z97.526)</td>
<td>Pine charcoal</td>
<td>CAMS-74652</td>
<td>$820 \pm 40$</td>
<td>Date younger than expected, based on stratigraphic position, and because it was thought to come from $f3$ (compare age from sample 99-45)</td>
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<tr>
<td>$f2$</td>
<td>South Bank, collected July 1999, in close proximity to Bison crania (M17-23-69; 99-11) (N1034.269 E997.429 Z97.602)</td>
<td>Conifer charcoal</td>
<td>CAMS-74646</td>
<td>$14,800 \pm 2,500$</td>
<td>Sample was only 5 µg and was evidently contaminated</td>
<td></td>
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</tr>
<tr>
<td>$f2$</td>
<td>South Bank, collected July 1998, in close proximity to Bison rib, upper part of bonebed (M17-25-50; 98-24) (N1034.348 E999.389 Z97.709)</td>
<td>Charcoal</td>
<td>CAMS-57522</td>
<td>$55,500 \pm$</td>
<td>Sample was not especially small but may have been minutely contaminated by carbonaceous material eroding out of Smoky Hill Shale</td>
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</tbody>
</table>

Note: Arranged by stratum and chronologically within stratum, except in the case of paired fractions from a single sample, which are listed together, with the age that is used listed first. See text for discussion. Calibrations were done using OxCal version 3.9 (Ramsey 2003).
AGE OF THE F2

Leaving aside for the moment the half-dozen radiocarbon ages obtained directly from bison bone, radiocarbon ages derived from charcoal samples from the F2 on both the South and the North banks range from 10,010 14C yr B.P. (CAMS-74645) to 11,370 14C yr B.P. (CAMS-57513) (fig. 5.11). The combined 1σ errors of these ages span the interval from 9,960 to 11,520 14C yr B.P. (11,260 to 13,490 cal yr B.P.). Taken as a group, these ages suggest that the deposition of this unit took place over a relatively long period of time, some 1,560 radiocarbon years (2,230 cal years). Combined with the absence of stratigraphic unconformities and the evidence for pedogenesis and buried soils (above), these ages suggest that F2 accumulation was uninterrupted through much of the Late Glacial.

That general picture becomes more complicated, however, when radiocarbon ages from the paleotributary and paleovalley are separately examined. The ages on the F2 in these two areas overlap for a span of 500 years (both 14C and cal), but the maximum and minimum ages of the F2 from the paleovalley are older than the corresponding ages from the paleotributary. The difference in the mean 14C ages between the two areas is significant, as measured by t-test (t = 2.267, P = 0.043). In effect, it appears as though F2 deposition began earlier and ended earlier in the paleovalley. That the ages of the paleotributary and paleovalley are out of phase, however, should not be taken at face value, as the offset is clearly a by-product of both sampling and erosion. In terms of the former, we did not excavate significantly below the bonebed in the paleotributary, so F2 ages from the South Bank do not date the onset of F2 deposition. In contrast, deeper and older portions of stratum F2 were visible in the North Bank profiles and sampled for radiocarbon. Moreover, on the North Bank erosion within the paleovalley may have stripped away the upper portion of the F2 and, with it, any of the younger charcoal that might have represented the final period of deposition of that unit in that area. In the higher, more protected paleotributary, the upper portion of the F2 remains intact and, not surprisingly, yields younger ages.

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While these ages bracket the \( f2 \) deposition, they do not pertain directly to Paleoindian activities at the site. The charcoal that produced these ages commonly occurs as small fragments throughout stratum \( f2 \) and, to a lesser degree, in the lower reaches of the \( f3 \). No hearths, burned areas, or other discrete anthropogenic features were found within the \( f2 \) in the paleotributary or in the paleovalley. The ubiquity of the charcoal and the absence of any cultural features lead us to conclude that charcoal in the \( f2 \)—and the \( f3 \), for that matter—is a result of natural fires in the area (also Bryan 1937:142; Wissler, field diary, August 1928, ANTH/AMNH). The wooded slopes of Johnson Mesa today produce abundant charcoal in slope wash due to frequent forest fires. Thus, the ages from charcoal collected site-wide from the \( f2 \) can be used only to bracket, not pinpoint, the age of the Paleoindian occupation. From that, and the erosion of \( f2 \) sediments in the paleovalley, it also follows that the previously reported ages from charcoal sampled from the North Bank provide, at best, only a ballpark figure for the Folsom kill (cf. Haynes et al. 1992).

Two of the \( f2 \) charcoal ages are nonetheless of particular interest: CAMS-57520, which yielded an age of 10,380 ± 50 \(^{14}C\) yr B.P. (CAMS-57520), came from the M15 excavation block. Bison bone was virtually absent from this block, prompting the question of whether this part of the site was simply beyond the margins of the kill, or whether bone had once been present but had degraded in place, or whether bone-bearing sediments of the proper age had simply been removed. This radiocarbon date indicates that sediments of the appropriate age are present. The question of whether the bone disappeared as a result of erosion or weathering, or was simply not deposited here in Paleoindian times, is taken up in chapter 7.

CAMS-74569 came from a charcoal sample in \( f2 \) sediments 1.5 m below the surface in a test pit (N986 E960) dug in the upper reaches of the western prong of the paleotributary, and yielded an age of 10,510 ± 50 \(^{14}C\) yr B.P. (CAMS-74649). This unit was excavated to assess whether traces of a habitation area associated with the Paleoindian kill could be detected—the spot being some 65 m south of the bonebed—and as a check to assess whether sediments of the right age are present in this area. No trace of habitation debris was found, save for an enigmatic rhyolite cobble (described in chapter 8). However, this radiocarbon age also indicates that sediments of the right age are present.

The age of the Folsom bison kill. As Haynes et al. (1992:87) anticipated, the best solution for determining the age of the bison kill would be bone dating using “technological improvements allowing the isolation of specific amino acids for dating.” We have now done this: Six samples from various bison bone elements (long bones, primarily)—three from the paleotributary and three from the paleovalley—were radiocarbon dated.

The resulting ages are statistically indistinguishable and provide a mean age of 10,490 ± 20 \(^{14}C\) yr B.P. (CAMS-74655 through CAMS-74659, and CAMS-96034). The two right humeri that were dated, one from the paleotributary and the other from the paleovalley, were obviously from different individuals. We cannot rule out the possibility that the remainder of the specimens were from the same two animals, but the likelihood that five bison bones scattered over such a large area and separated by topographic barriers that preclude transport between the paleotributary and the paleovalley areas makes that possibility remote. Of course, if the three North Bank specimens are from the same individual, this provides additional support for the stratigraphic evidence of reworking, for these specimens were found 27 m apart, with one coming from \( f2 \) sediments only a few centimeters below the \( f3/f2 \) contact, while the other two came from amid reworked gravels in the \( f3/f2 \).

This mean age of these six ages is older than the single age obtained by Hassan on bison bone collagen several decades ago (10,260 ± 110 \(^{14}C\) yr B.P.). Although this may attest to the unreliability of that bone collagen age, as Haynes et al. (1992) anticipated, it must also be observed that the \( 1\sigma \) calibrated age for this sample (11,650–12,350 cal yr B.P.) has at least a 200-year calendar year overlap with the \( 1\sigma \) calibrated age range for the other dated bone (12,150–12,820 cal yr B.P.). Its \(^{81}C\) value also corresponds with values obtained on the other bison bone (chapter 6), suggesting that the then-experimental efforts of Hassan (1975) to extract collagen were reasonably reliable.

The mean age on the bison bone is also several hundred years younger (fig. 5.12) than the age of the Paleoindian occupation previously inferred from charcoal dates, which produced a mean age of 10,890 ± 50 \(^{14}C\) yr B.P. (Haynes et al. 1992). This substantiates the suspicion that the charcoal came from natural fires, but also the fact the charcoal represents a maximum limiting age of a deposit—it can be older than the sediments in which it was embedded. Thus, we put the age of the Paleoindian bison kill at the Folsom at ~10,500 radiocarbon years ago, based on the direct dating of the bison bone.

That \( f2 \) deposition continued after the kill, as observed stratigraphically, is confirmed by several younger radiocarbon ages on charcoal. Precisely how long deposition continued is unclear, at least in the paleovalley, where erosion removed the upper portion of the \( f2 \). The latest age on the \( f2 \) here, if one excludes the bone dates, is only 10,760 ± 140 \(^{13}C\) yr B.P. (12,400–13,000 cal yr B.P.). The latest age for \( f2 \) deposition on-site is likely that from the paleotributary, where the \( f2 \) yielded an age of 10,010 ± 50 \(^{14}C\) yr B.P. (11,260–11,630 cal yr B.P.).

AGE OF THE \( f3 \)

The complications of erosion within the paleovalley predictably carry over into the assessment of the age of stratum \( f3 \). Further complicating matters, there are no radiocarbon ages on the \( f3 \) in the paleotributary. The majority of the ages on the \( f3 \) postdate 10,000 \(^{14}C\) yr B.P. Yet, several of the oldest overlap chronologically with (or are
older than) the youngest of the \( f/2 \) ages (fig. 5.13). The oldest of these, \( 11,100 \pm 130 \) \(^{14}\text{C} \) yr B.P. (AA-7088), was from a sample Haynes collected from the base of a "dark unit(?) in buff (yellow) loess." Although no further provenience information is provided, we suspect that the sample may come from the base of the dark band we observed at 250 cm to 300 cm in Profile 97-1 (table 5.2), which would put the sample immediately above the \( f/2/f/3 \) boundary at 300 cm. Because the age of this sample clearly overlaps that of the \( f/2 \), there is a strong possibility that this particular sample was reworked from older sediments and came to rest on the stratigraphic contact. The other two older ages, \( 10,420 \pm 40 \) \(^{14}\text{C} \) yr B.P. (CAMS-74648) and \( 10,370 \pm 50 \) \(^{14}\text{C} \) yr B.P. (CAMS-75512), come from fine gravels in the \( f/3 \) and from silts 8 cm above the \( f/2/f/3 \) contact, respectively. Also in the \( f/3 \) on the North Bank, of course, are radiocarbon dates on redeposited bison bone that dated to \( \sim 10,500 \) \(^{14}\text{C} \) yr B.P. All of this, of course, is in keeping with the observation that stratum \( f/3 \) includes older reworked material.

Excluding those radiocarbon ages >10,000 yr B.P., the oldest of the ages on \( f/3 \) in the paleovalley is \( 9,780 \pm 40 \) \(^{14}\text{C} \) yr B.P. (CAMS-75516), this from a charcoal sample immediately above the \( f/2/f/3 \) contact in a topographically higher portion of the \( f/3 \) in the paleovalley. Perhaps not coincidentally, this date is statistically identical to one of \( 9,820 \pm 40 \) \(^{14}\text{C} \) yr B.P. (CAMS-74647) obtained \( \sim 23 \) m away on charcoal resting directly atop the Smoky Hill Shale bedrock (in block J19-4). The latter sample was not from \( f/3 \) sediments per se, and hence is not included in figure 5.13, but instead was on the Smoky Hill Shale bedrock surface on top of the valley wall immediately west of the paleotributary. This was the source area from which the shingle shale was washed out over the bonebed, and thus the date on this fragment of charcoal, deposited on an exposed bedrock surface, then blanketed in sediment, marks the maximum age at which sediment deposition began on this surface, after it served as a shingle shale source.

It is significant that two radiocarbon dates from widely separated areas of the site and from very different strati-
graphic and topographic contexts yield statistically identical ages for the onset of \( f_3 \) deposition. If we are correct in the inference that \( f_2 \) deposition ceased \( \sim 10,010 \) \(^{14} \)C yr B.P., and that following a brief episode of incision a period of deposition and greater landscape stability began again around 9,800 \(^{14} \)C yr B.P., then clearly the most active period of shingle shale movement in the paleotributary, and erosion of the \( f_2 \) within the paleovalley, took place during the intervening \( \sim 200 \) radiocarbon years. It was likely at this time that bison bone in the paleovalley, first deposited half a millennium earlier, was reexposed, transported, and reburied. There is emerging evidence that a similarly timed cycle of Late Glacial and Early Holocene deposition-erosion-deposition occurred in other drainages in the Upper Dry Cimarron (Mann 2004), at Bellisle Lake (chapter 6), and elsewhere on the Great Plains and Rocky Mountains (Mayer et al. 2005), suggesting panregional geomorphic and climatic controls on arroyo filling around the Pleistocene/Holocene boundary.

The age obtained from the charcoal sample resting on the Smoky Hill Shale bedrock surface above the bonebed is significant for another reason. It provides an important clue as to why no associated Folsom camp was found in this area of the site. This was the source area for the \( f_3 \) shingle shale that washed out across the bonebed. If Paleoindian activities had taken place on that surface, their traces would have been removed along with that shingle shale, for it appears that surface was largely swept clean of clasts between 10,000 and 9,800 \(^{14} \)C yr B.P. For the record, no Paleoindian artifacts have been found mixed in with the \( f_3 \) shingle shale armor ing the bonebed, but it should be added that this unit was not systematically searched or even screened.

The youngest age from the \( f_3 \), a date of 9,220 \( \pm 50 \) \(^{14} \)C yr B.P. (CAMS-74654) was obtained from a bison carpal above the \( f_2/f_3 \) contact. It is well bracketed by charcoal dates from just above and below the specimen (CAMS-57515 and CAMS-57516), and younger by 1,300 years than a bison humerus resting 27 cm below (CAMS-74655). Thus, this bison carpal is not a reworked element from the Paleoindian kill but is, instead, from an unrelated animal. This finding raises the cautionary flag that not all bison remains in the paleovalley, and even near the \( f_2/f_3 \) contact, can be
assumed to be reworked elements from the Folsom occupation.

Similarly unrelated to the Paleoindian kill, and of particular significance for Folsom subsistence, is the radiocarbon age of 9,270 ± 50 \(^{14}\)C yr B.P. (CAMS-74934) obtained on a femur of an artiodactyl found on the North Bank. Its significance derives from the fact that Howarth found in 1926 what he identified as deer bones at the site (see Howarth to Cook, May 18, 1928, HCP/AFNM; see also Brown 1928b; Hay and Cook 1930:30; see the discussion in chapter 7). Howarth's taxonomic identification cannot be confirmed and the specimen cannot be relocated (chapter 7), but this recovery of a deer (or whatever species it might be) has long held open the possibility that other prey species may have been part of the assemblage at Folsom. Yet, because the precise stratigraphic position of the material Howarth found was unknown, that possibility could not be resolved. Howarth, did, however, leave a very rough sketch map showing where the remains were found, placing them on the North Bank just upstream of a large overhanging mass of oak roots—still present at the time of our excavations—that marks the upstream end of the 1920s clearing (see Howarth to Cook, May 18, 1928, HCP/AFNM).

Test excavations in this same area in 1999 yielded the proximal shaft of a femur from an unidentified species, but one that more closely resembles an antilocaprid than a cervid (chapter 7). Importantly, this element was found not in the J2 sediments, but in the overlying J3 stratum. Assuming, for the sake of discussion, that this artiodactyl specimen comes from the same animal Howarth found in this same area, its Early Holocene radiocarbon age negates the claim that deer were exploited at the site by Folsom hunters.

**AGE OF THE HOLOCENE STRATA**

There is a series of dates now available on the McJunkin units, including the one obtained by Harold Cook in 1950. With one exception (CAMS-57518), all of the samples are from deposits on the North Bank, but not necessarily from the site.

Ages on the m1 range from ~6,000 to ~7,500 \(^{14}\)C yr B.P.; two of those (TX-1271 and TX-1452) are not from the site proper but from some distance downstream. There is a 2,000-year gap in the chronology above the m1, which roughly correlates with the Middle Holocene/Altithermal period. This, as well as the stratigraphic unconformity seen in Profile 1, suggests erosion or lack of deposition during this period; however, as that unconformity is seen only in Profile 1, this evidence is not conclusive.

The m2 dates to the later Middle Holocene: The ages from this unit fall within a relatively brief and well-defined interval from ~4,900 to ~4,200 \(^{14}\)C yr B.P. The oldest age on the m2—4,910 ± 50 \(^{14}\)C yr B.P. (CAMS-57518)—came from a small concentration of charcoal, possibly the remnants of a hearth, found in the sidewall of the M17 block on the South Bank.\(^8\) This is not where one would expect the oldest age for stratum m2. Initially the m2 in-filling would have taken place in the deepest part of the paleovalley, and then the deposits would have reached up into the paleotributary. And yet charcoal from gravels at the base of the McJunkin channel within the paleovalley, 3.5 m lower than the possible hearth, was dated at 4,460 ± 50 (CAMS-57517). There is a 420-radiocarbon year difference in age between these samples and they do not overlap, even at 2σ. These samples are nonetheless from the same stratigraphic unit, which is multiaged and time-transgressive and represents sediments from discretely different alluvial events. The onset of deposition of m2 clearly begins sometime around the older of the two ages. That the charcoal collected from gravels at the base of the McJunkin channel is younger than the charcoal higher up in the stratum may mark minor episodes of erosion within the paleovalley or vagaries of sampling.

There is only one radiocarbon date available on the uppermost part of the stratigraphic sequence at the site: An age of 700 ± 40 (CAMS-74651) was obtained on charcoal from the Wildhorse Formation on the North Bank. The charcoal came from sediments ~80 cm above the thick lens of cobbles and coarse gravel in the M23 block, just 50 cm below the present surface. It provides an approximate age for the last major pulse of deposition in the valley.

Obviously, there is a large gap in the chronological sequence between stratum m2 (late Middle Holocene) and stratum w (Late Holocene). This gap may in part reflect a lack of sampling, rather than a depositional hiatus. Therefore, we do not know the age for the onset of deposition of the Wildhorse Formation and, thus, have little chronological help in addressing the question of whether the Wildhorse Formation was simply a facies of the McJunkin Formation. More work is required to resolve this matter.

**Summary: The Quaternary Geology of the Folsom Site**

The Folsom bonebed is within Late Glacial sediments that fill the lower portions of a small, two-pronged paleotributary and the adjoining paleovalley—the ancestral Wild Horse Arroyo—into which it drained. Both the paleovalley and the paleotributary are incised into Smoky Hill Shale, and in each area this Cretaceous unit is overlain unconformably by late Quaternary sediments. It is not known precisely when these bedrock valleys were incised or when the landscape began to take on the topographic appearance it had when Paleoindian groups entered the area. Given the erosion of latest Tertiary and early Quaternary basalt flows, as well as the very spotty distribution of Ogallala formation gravels throughout the region, it appears that a considerable amount of erosion took place in post-Tertiary times, perhaps beginning in the early Quaternary and continuing through much of that period (see also Bryan 1937).

In-filling of stratum m1 sediments onto the Cretaceous surface began after 12,400 \(^{14}\)C yr B.P. By the time of the Folsom occupation, ~1 m to 2 m of fluviol and colluvial deposits had filled the lower reaches of these channels. Beginning
some time after 11,500 14C yr B.P., the paleotributary and the paleovalley began to fill with sediments of stratum J2, fine-grained, calcareous, light yellowish-brown silts, similar in physical characteristics to loess and deposited through a combination of airfall and redeposition of silts derived from airborne loess. Evidence from thin sections shows fine bedding with stringers of clay, indicating syndepositional reworking. Still, and as noted earlier, the absence of coarse clastics or bedding suggests that the loess was not extensively reworked by fluvial/colluvial runoff or sheetflow.

Deposition of the J2 took place during a geologically brief period of time. The slight degree of pedogenesis in the sediments of the J2 and the absence of any visible erosional breaks are consistent with a single episode of aggradation in which the surface never stabilized for more than several years to several decades. That deposition appears to have been continuous through the time of the Folsom kill. The top of the bison bone within the paleotributary is covered, thinly in spots, by J2 sediments.

Around 10,500 14C yr B.P. Paleoindian hunters killed a herd of at least 32 bison, dropping the animals in both the paleotributary and the adjoining paleovalley. The kill was made on a ground surface that was essentially dry underfoot, at least within the paleotributary. The J2 within the adjoining, topographically lower paleovalley may have had more moisture, but unfortunately we cannot be certain, as we have virtually no evidence that speaks to this matter. The iron-oxide motting of the J1 clearly indicates that water flowed in the paleovalley after that unit was deposited, but we do not know how long afterward or whether that rise in the water coincides with the time of the Paleoindian occupation. In neither area of the site do the bison bones occur on a distinct stratigraphic surface or unconformity; the ground on which the animals were killed was not long exposed. However, a backplot of the bones in the paleotributary shows that there is a well-defined archaeological surface on which they are resting (chapter 7), and there are subtle differences in soil texture and chemistry just below the bonebed.

There is no stratigraphic or paleontological evidence for more than a single Paleoindian kill taking place at this site, though the bones on the North Bank suggest that the kill was spread out over a large area and may have taken place within the paleotributary and the paleovalley. The statistically identical radiocarbon ages on bison bone from these different parts of the site substantiate this inference, within the limits of radiocarbon dating. We believe, all evidence considered, that these bison were killed at the same moment in real time.

The most precise age for that event comes from the dates run directly on the organic fractions of bison bone, which yield a mean age of 10,490 ± 20 14C yr B.P. The majority of the charcoal ages from stratum J2 are as a group slightly—but consistently—older than the ages from the bison bone in that same unit (fig. 5.12), and the bison bone ages are more tightly constrained in age. However, the calibrated ages of both groups overlap at 1σ, suggesting geological contemporaneity, granting the inaccuracies of the radiocarbon timescale during the age plateaus of the Younger Dryas Chronozone and the fact that there is a considerable amount of natural charcoal here.

Although the J2 deposits may at one time have blanketed much of the area, they are today relatively rare, being limited to the immediate area of the site and a few spots up and downstream of it. The scarcity of J2 deposits, particularly within the paleovalley, could be the result of one or more of the subsequent cut-and-fill episodes of the Holocene, the last following the 1908 flood that exposed the bison bone for George McJunkin to later discover. That a sizable portion of the bonebed was protected from these later erosional episodes is partly a consequence of many animals having been killed within the confines of the paleotributary, where their skeletal remains were protected from fluvial processes in the paleovalley by the flanking Smoky Hill Shale bedrock walls.

The geomorphic process that had the most impact on the archaeological deposits was the erosional and depositional cycle that began soon after the kill. Erosion started sometime after 10,100 14C yr B.P. and was followed by deposition of the J3, which began before −9,800 14C yr B.P. and lasted until −9,200 14C yr B.P. The effects of this cycle played out in different ways between the paleotributary and the paleovalley. Soon after the deposition of the bison carcasses, shingle shale washed off the nearby bedrock uplands and paleotributary walls. The shingle shale was deposited onto the bonebed in a thick lens—sometimes sets of lenses (chapter 7)—that rode across the top of the J2 and effectively armored and protected the underlying bonebed. It is not known how much of the J2 was removed in the process. This slope wash of shingle shale testifies to a scarcity of vegetation on the landscape: If the bedrock walls had been anchored by a vegetative groundcover, it would have been unlikely that the shingle shale could have moved so readily and en masse downslope.

In the paleovalley, the geomorphic processes that triggered the deposition of stratum J3 had a detrimental impact on the bison remains. The bison bones in this area show evidence of having been dispersed by fluvial action, occur at high angles and largely as isolated elements, and are found jumbled amid channel gravels of varying size, all of which is indicative of fluvial transport and a secondary depositional context. These bison bone elements are not capped by a protective shingle armor, nor do they constitute an integrated and distinctive bonebed. Although much of the bone that we examined in the paleovalley was subject to transport and redeposition, not all of the bone from this area was similarly impacted, as we infer based on meager records of an earlier excavation of a bison cranium in the 1970s.

Importantly, the bison bone found in the paleovalley could not have simply washed out from the paleotributary: the bone was recovered well upstream of the intersection of the two. Thus, the kill must have extended over a large
area, and was not restricted to either the paleotributary or the adjoining valley. How many animals may have been dropped in either area is unknown, as is the larger question of whether the hunters' strategic objective was to maneuver and kill the bison in the paleovalley, the paleotributary, or perhaps both. Although the greatest concentration of bison bone was recovered from the paleotributary, this could be an artifact of preservation, and not necessarily the main locus of the kill. Indeed, it is conceivable that the kill was centered in the paleovalley and that a comparable or greater number of animals were dropped there, and their traces were either moved or removed by subsequent erosion or still remain buried and archaeologically invisible beneath the deep Holocene fill of the paleovalley. A kill extending over this large an area would not be off-scale for hunter-gatherers (O'Connell, Hawkes, and Blurton-Jones, 1992).

In either setting, the hunters could have maneuvered, trapped, or otherwise disadvantaged the animals, by using the high bedrock walls of the paleovalley and the paleotributary and, perhaps, a knickpoint within the paleotributary, to reduce the risks of the hunt. Subsequent sedimentation in the area, including colluvial movement of shingle shale off the valley walls, has obscured the precise configuration of the land surface at the time of the kill.

The F3 erosion and reworking of older F2 sediments further complicate efforts to tease apart the precise chronological relationship between these depositional units, given the admixture of charcoal throughout, the removal of an unknown amount of F2 sediment from the paleotributary and the paleovalley during the erosional episode, and the overlap in radiocarbon ages between the top of stratum F2, which ranges in age from −11,500 to as recent as −10,010 14C yr B.P., and the base of stratum F3, at −10,420 14C yr B.P. (fig. 5.13).

Deposition of stratum F3 continued into the early Holocene. The stratigraphy of the early Holocene and the onset of the middle Holocene is somewhat obscure, admittedly because less investigative effort focused on this portion of the sequence. Stratum F3 itself was eroded sometime after −9,200 14C yr B.P., Filling of the valley appears to have been episodic after F3 deposition; there was deposition of bedded muds and silts (m1) from −7,500 to −6,000 14C yr B.P. The gap in the chronological sequence from 9,200 to 7,500 14C yr B.P. may overestimate the period of erosion, as far fewer radiocarbon dates are available for this part of the sequence.

Stratum m1 was, in turn, eroded sometime between −6,000 and −4,900 14C yr B.P. and was followed by deposition of organic rich muds (m2) from −4,900 to −4,200 14C yr B.P. Again, there appears to be a chronological gap—this time from −6,000 to −4,900 14C yr B.P.—between stratum m1 and stratum m2. Unlike the earlier gap, this one is better expressed stratigraphically, and better controlled chronologically, since the onset of m2 deposition is securely dated. The ages from the Folsom site of this stratigraphic and chronological hiatus, and subsequent deposition, roughly correlate with the Alithermal erosional-depositional sequence on the Great Plains (Holliday 1995; Meltzer 1999). While we suspect that this marks a local expression of Alithermal climatic changes, we recognize that more work and more radiocarbon ages would be necessary to resolve the matter.

The youngest sediments of the valley are those of stratum w, with a single Late Holocene age of −700 14C yr B.P. Stratum w is characterized by muds and interbedded gravel lenses. We were unable to determine whether this deposit was inset into m2 or just a late Holocene facies thereof. The gravel that characterizes stratum w contrasts with the fine-grained sediment devoid of gravel in the underlying Mcjunkin strata. This textural difference may simply reflect whether the exposed sections mark channel axis as opposed to channel margin deposits.

In the American Southwest arroyo cutting in the late Holocene is interpreted as evidence for cycles of drought, although the environmental significance of erosion and deposition in arid and semiarid environments has long been debated (Bryan 1922, 1925, 1940; Bull 1991; Butzer 1980; Knox 1983; Miller 1958). That late Holocene cycles of erosion and deposition in the Folsom region may be related to cycles of drought is supported by data from the High Plains, where reactivation of dunes due to aridity after −1,000 14C yr B.P. is widely reported (Forman and Maat 1990; Forman, Oglesby, and Webb, 2001; Holliday 2001; Madole 1995; Muhs et al. 1996, 1997).
96.15, which puts it ~1.5 m below the average level of the bone in the M17 block some 21 m distant.

6. There are pre–Late Glacial episodes of massive reworking of these large cobbles and gravels in the form of terrace deposits along the Dry Cimarron River.

7. Some comments on the rejected radiocarbon ages follow.

a. The dated charcoal samples that yielded ages of 840 ± 50 yr B.P. (CAMS-74650) and 820 ± 40 yr B.P. (CAMS-74652) were from strata m1 and f3, respectively. Thus, not only are they far younger than they ought to be (ages on these units ought to be Early to Middle Holocene, not latest Holocene), but they are not even in proper stratigraphic order—despite being vertically separated by 45 cm of deposits. Moreover, despite being recovered from very different strata at different depths, the two ages are statistically identical. It appears, therefore, that younger, penecontemporaneous charcoal worked its way down into older deposits.

b. It was suspected even during pretreatment that sample 99-11 (M17-23-69) might not yield a suitable age, since the amount of available carbon was extraordinarily small, even for AMS dating, and it was therefore highly susceptible to contamination (T. Stafford, personal communication).

That it ultimately produced an age of 14,800 ± 2,500 yr B.P. (CAMS-74646) confirmed those suspicions.

c. The still older age, 55,000 ± 5 yr B.P. (CAMS-75522), run on charcoal from the bonebed came as a complete surprise. The sample was of suitable mass for dating and came from a secure context relatively high up within the Folsom bonebed on the South Bank (that is, not from any stratigraphic context that would be even close to that antiquity). There are several factors that might account for this "pre-Clovis" date from the Folsom site, most obviously the minute inclusion of geologically ancient carbon, which has since been identified within the Cretaceous-age Smoky Hill Shale (chapter 6). Contamination may have occurred via particulate matter or, perhaps, via groundwater percolating through the shingle shale that caps the bonebed. Such contamination, fortunately, was not a chronic problem at the site, given the otherwise good agreement between ages run on charcoal and on bone from the same stratigraphic unit.

8. This feature was spotted in the western wall of the M17 excavation block, and was photographed and profiled, but could not be excavated to examine the top or nearby surface; it remains in the ground.