Interdisciplinary Studies of the Hajny Mammoth Site, Dewey County, Oklahoma

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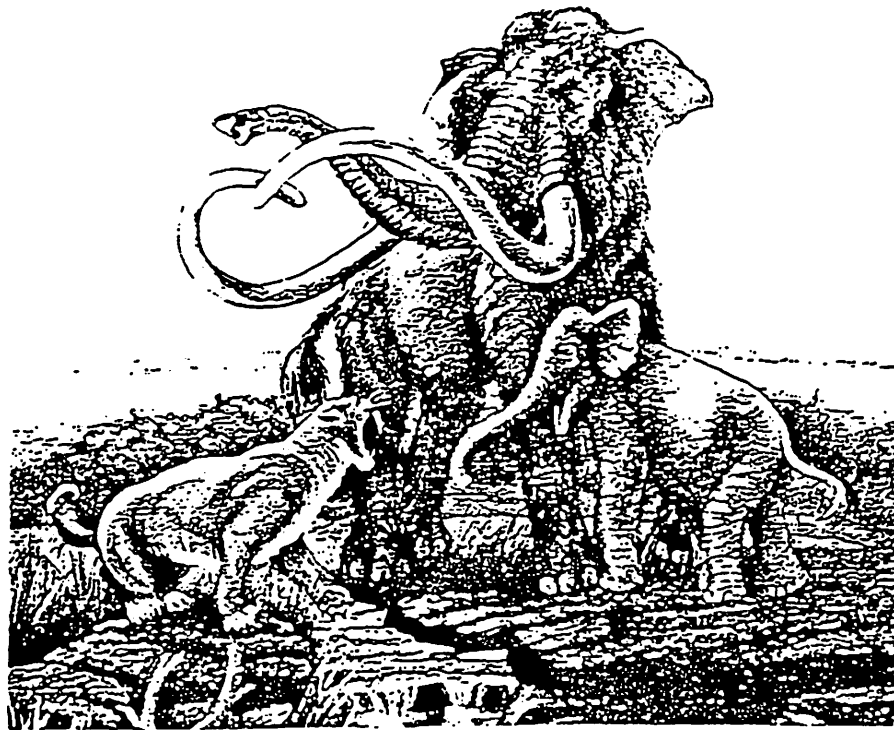
Illustration courtesy of Irene Johnson.

Frank C. Leonhardy
1935 - 1991

On August 19, 1991, Dr. Frank C. Leonhardy suffered a fatal heart attack while attending an archeological dig along the Salmon River in Idaho. If Frank could have chosen a place to die, it probably would have been there.

This volume is dedicated to Frank. Although an Oklahoma study, the Hajny mammoth study was inspired by the kind of interdisciplinary research that Frank supported and in which he participated. In 1963 he was hired as an archeologist by the Museum of the Great Plains (Lawton). While there, he was able to pull together, synthesize and publish the diverse reports of the several scholars who helped study the Domebo mammoth-kill in Caddo County. This was the first truly interdisciplinary study of Oklahoma's Pleistocene record, and thus it is appropriate to recognize Frank here.

In 1966, Frank left the Museum of the Great Plains and went to Washington State University where he received his Ph.D. in 1970. He remained there as a teacher and researcher until the late 1970s when he assumed a faculty position at the University of Idaho. As a teacher, Frank was demanding but fair. He never expected more than he himself would give. He was a dear friend to his students, to the Nez Perces of Lapwai, and the many who shared his interests in folk music, broadcasting, soils studies, ecology and archeology. We will miss him while also remembering the many good, kind things he did.

(The photo of Frank was taken in 1982 when he assisted Dan Rogers and Dr. Jim Brown in studies of the Brown and Copple Mounds at the Spiro site, LeFlore County. At the time of the photo, he was recording the microstratigraphy in the Copple Mound.)

ACKNOWLEDGMENTS

ABSTRACT

When gravel quarrying exposed mammoth bones buried deeply in a prominent terrace of the Canadian River in Dewey County, Oklahoma, controlled archeological excavations were undertaken to ascertain if the animals had been killed by Paleoindian hunters. Although no traces of humans were found, the site did yield a small, but intriguing, array of Pleistocene animals in an interesting geologic setting.

Manual stripping and extensive backhoe trenching revealed the presence of five ancient spring deposits. Located at similar elevations above the Canadian's modern course and embedded within fluvial sands and gravels, these springs formed by upwelling ground water when the river was aggrading a terrace 35 meters higher than its modern flood plain. Two springs contained bones of Pleistocene elephants, but only those around Spring #2 were uncovered and studied in detail. Portions of two mammoths and scattered bones of turtles, frogs, a water rat, a wood duck, a pocket gopher, a horse, and a pronghorn were recovered there. Along with nearly a dozen taxa of aquatic and terrestrial gastropods, these fauna attest to a marshy setting and adjacent grasslands. A few species of gastropods and the water rat are indicators of cooler summers and warmer winters than today.

The mammoth bones were arranged and damaged by large animals and subsequent chemical and fluvial processes. The springs apparently existed temporarily during a period of floodplain stability before being covered with several meters of interbedded sand and gravel, after which nearly three meters of soil accumulated. Subsequently, soil and some underlying fluvial sediments were eroded away and mass-wasting of the hillside occurred.

Dating of the site remains problematic. The mammoth molars share attributes with both *Mammuthus imperator* and *M. columbi*. Experimental uranium series dating of the teeth enamel yielded results ranging from roughly 140,000 to 165,000 years ago, but radiocarbon dated samples of gastropod shells from two different springs indicate a Wisconsinan age of some 21,500 to 34,000 years ago. The form of water rat and the elevation of the terrace seem more congruent with the late Illinoian or early Sangamon age. Resolution of the site's age awaits continued study of Pleistocene settings and fauna along western Oklahoma's Canadian River watershed.

CHAPTER 1

Introduction

Don G. Wyckoff

Between October 15, 1985, and May 1, 1986, numerous volunteers and a few professional researchers spent hundreds of hours uncovering ice age deposits and bones at a location in Dewey County of west central Oklahoma (Figure 1-1). Known as the Hajny site, this find was first thought to be one that would shed new light on the earliest people to inhabit Oklahoma. As the field work progressed, however, traces of people were not recovered. The intriguing findings increasingly indicated we had an excellent opportunity to learn about an ice age setting, animals, and environment. This opportunity necessitated studies of landforms, alluvial geology, soils and their formation, paleontology, and even dating methods. Consequently, the Hajny site became Oklahoma's first extensively studied, ice age site since the 1962 interdisciplinary research at the Domebo locality (Leonhardy 1966) in Caddo County, some 75 miles (120 km) southeast of Hajny.

Whereas the Domebo site yielded clues to people, plants, and animals in an Oklahoma setting of some 11,200 years ago, the Hajny site findings are much older. In fact, the Hajny sediments and animals bear witness to a setting that existed sometime between 140,000 and 160,000 years ago. This would have been near the end of the Illinoian glacial age, a time when a prevailing cool, moist climate helped foster one of the more recent in a series of major ice sheets that covered northeastern North America during the last 1.65 million years (Imbrie and Imbrie 1979; Richmond and Fullerton 1986a). This period is called the Quaternary and is subdivided into the Pleistocene (1.65 million to 10,000 years ago) and the Holocene (the last 10,000 years). Pleistocene glaciations apparently never covered Oklahoma, but the climates responsible for them affected North America to the extent that plant-animal communities developed which were markedly different from any known historically (Bryant and Holloway 1985; Graham, Semken, and Graham 1987; Porter 1983). Surprisingly, few Oklahoma locations (Figure 1-1) have been studied in detail for the information they could provide on Oklahoma's character during the Pleistocene. This report on the Hajny site represents a step towards improving this understanding.

Background To The Hajny Site Research

Archeological excavations were undertaken at the Hajny site with the hope that the findings would yield information on Native American hunters and foragers of some 11,500 years ago. Armed with distinctively made spearpoints, ones that archeologists classify as Clovis points, these ancient hunters explored and occupied most of the continental United States during the end of the last ice age (Haynes 1980; Hester 1966; West 1983). The environment and plant-animal communities were far different than those known today (Graham and Lundelius 1984; Graham, Semken, and Graham 1987; Guthrie 1984; Lundelius and others 1983; Watts 1983). Sites with Clovis points and associated hunting-foraging tools abound west of the Mississippi. When found in undisturbed geologic contexts, these artifacts are usually in deposits that date between 11,200 and 10,800 years ago (Haynes 1980, 1987). Frequently, Clovis spearpoints bear witness to these people's ability to successfully kill such ice-age animals as mastodons, mammoths, bison, camels, and
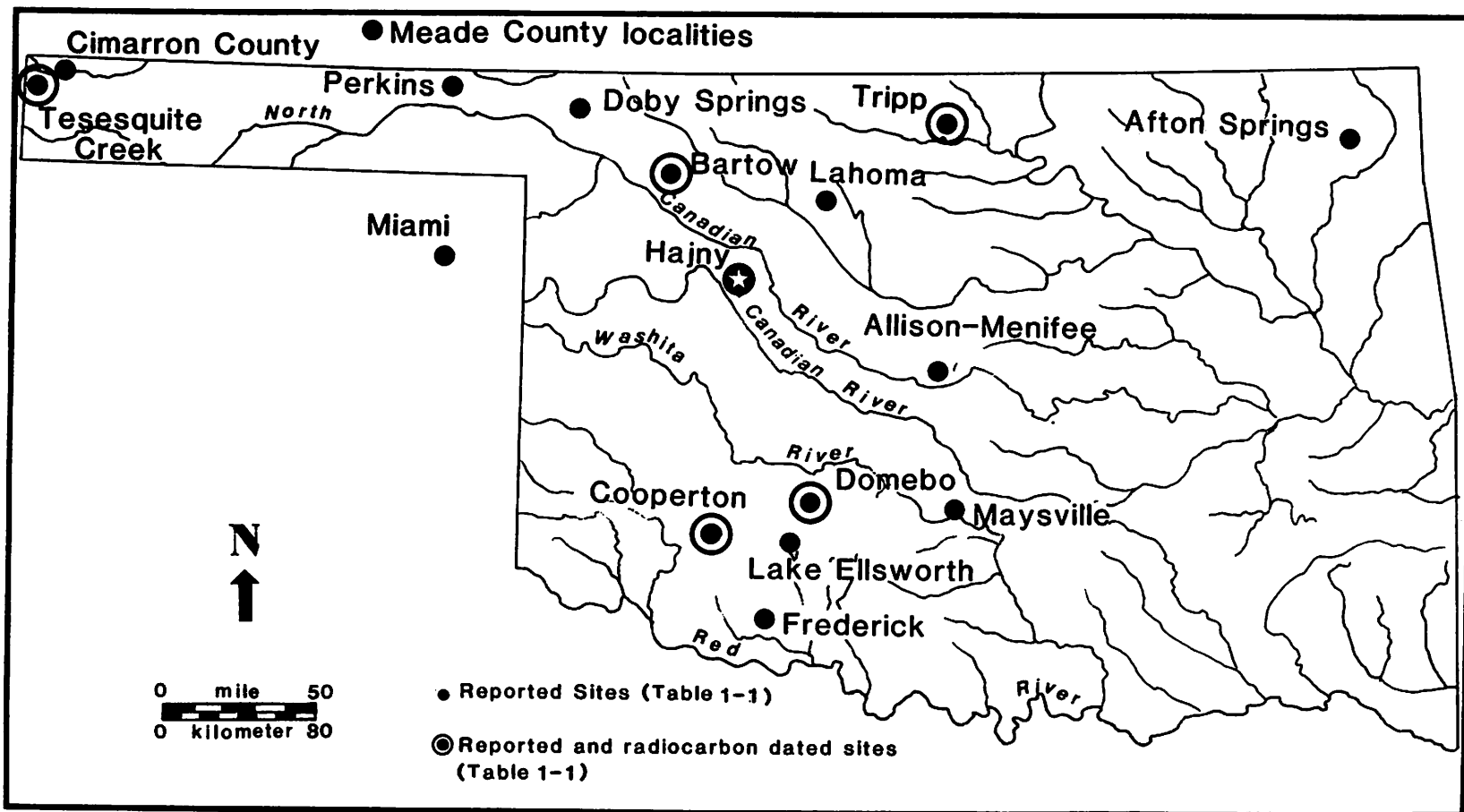
Figure 1-1.   Location of the Hajny site and other studied Pleistocene Oklahoma sites with mammoth or mastodon remains. Sites are briefly discussed in Table 1-1.

Table 1-1. Studied Sites with Mammoth and/or Mastodon Remains in Oklahoma and Adjacent Parts of Kansas and Texas. (See Figure 1-1.)

Name	County	Description	References
Afton Springs	Ottawa	Bones, tusks, and teeth of mastodon (100+ teeth) and mammoth (20+ teeth) found at least 4 feet below ground surface in spring deposit. Species identified as *Mammut americanum, Elephus columbi,* and *Elephus imperator.* Age uncertain, Corner-notched spearpoints also found in deposit but probably are not contemporaneous with mammoth and mastodon.	Hay 1924:23, 66-67, 94; Holmes 1903..
Allison-Menifee	Oklahoma	Some bones, teeth, and tusks of one mammoth found partially articulated in fluvial sands, silts, and clays. Species uncertain; age uncertain; no cultural associations. Conjectured that stream bed may be an early Pleistocene course of Cimarron River.	Neel 1985.
Bartow	Woodward	About half of disarticulated mammoth skeleton found in carbonate-bearing thin bed of clay covered by 6 feet of sand. Species not identified. Bone was radiocarbon dated at 11,990 ± 170 B.P. (A-582). An angular flintrock and couple of possible flakes found nearby might be evidence of human involvement.	Kerr 1964; Pitts 1969; Agenbroad 1984: Table 3.4.
	Cimarron	Nine finds of fossil elephants reported from various alluvial deposits, mostly along Cimarron River or its Carrizo Creek tributary. Species believed representative of *Mammuthus columbi,* but two could be *M. imperator.* Attributed to early Pleistocene or later. No cultural associations observed.	Schoff and Stovall 1943:129-131.
Cooperton	Kiowa	Disarticulated bones of a *Mammuthus columbi* in fluvial silt or clay; bones appear stacked and some are thought to exhibit green bone fractures. Radiocarbon dates derived from bones and teeth: 19,100 ± 800 B.P. (GX-1214), 17,575 ± 550 B.P. (GX-1215), and 20,400 ± 450 B.P. (GX-1216). Possible chopper and anvil found nearby.	Anderson 1975.
Doby Springs	Harper	Mammuthus tooth plate fragments found in lake deposits interpreted to be of Illinoian glacial age; snails and bones of other animals are present. No cultural associations.	Stephens 1960.
Domebo	Caddo	Bones of a single mammoth (*M. imperator?*) found in deeply buried marshy sediments. Two Clovis points, a broken spearpoint, and 3 flakes were found among the bones. Wood and bone from the marshy deposit yielded radiocarbon dates of 11,045 ± 647 B.P. (SM-695), 11,220 ± 500 (SI-172), and 11,200 ± B.P. (SI-175). Recently obtained dates on carbon fractions from mammoth bone fall mainly between 11,840 ± 420 B.P. and 10,250 ± 310 B.P.	Leonhardy 1966; Stafford 1984.
Frederick	Tillman	Mastodon and mammoth remains were among fossil mammal remains recovered from sand and gravel fill of ancient river channel on high ridge. Species identified as *Gomphotherium priestleyi, Elephus haroldcooki,* and *E. columbi.* Interpreted as Early to Middle Pleistocene in age. Association of human artifacts is questionable.	Hay and Cook 1930; Maglio 1973:63.
Lahoma	Major	Linear scatter of bones of one animal in fluvial gravel. Bones believed to be of Mammuthus, but species uncertain. Age is uncertain. No cultural associations.	Lintz 1980.
Lake Ellsworth	Comanche	Scattered bones in alluvial sediments now exposed by eroding shoreline. Species uncertain; age uncertain; no cultural association.	Leonhardy 1964.
Maysville	Garvin	Tusks and leg bone found in thin gravel lens; bones scattered and covered by clayey alluvium. Species uncertain; age uncertain; no cultural associations.	Rohrbaugh 1971.
	Meade County, Kansas	Mammuthus tooth plates and limb bone fragments found in several alluvial beds of presumed Sangamon interglacial age. Species uncertain; no cultural associations.	Hibbard and Taylor 1960; Schultz 1969.
Miami	Roberts County, Texas	Bones of 5 mammoths found buried in ponded sediments in a fossil sink; among the bones were found 3 Clovis points and a scraper. Species thought *M. columbi.* Association of Clovis artifacts would support age interpretation of around 11,200 years ago.	Sellards 1938.
Perkins	Beaver	Large tusk recovered from fluvial sands. Species and age uncertain. No cultural associations.	Wyckoff 1985.
Tesesquite Creek	Cimarron	Unspeciated tusk fragment found in brownish sand and clay above basal gravels; bones of horse and varied small mammals present along with snail shells. A date of 31,360 ± 570 (Beta-22875) obtained on shells. No cultural associations.	Dalquest and Strangl 1989.
Tripp	Kay	Disarticulated teeth and bones in dark fine sediments; bone yielded a date of 14,000 + (WSU-3353). Species uncertain; no cultural associations.	Wyckoff 1987.

horses (Haynes 1980, 1984, 1987; Hester 1972; West 1983). At least one scholar of late Pleistocene ecology and the following Holocene ecological changes argues that the Clovis-using hunters were so adept at hunting mammoths and other large mammals that they were the principal cause for these animals becoming extinct (Martin 1967, 1974, 1984; Mosimann and Martin 1975).

Since 1901, sporadic Oklahoma finds of extinct animal remains and Indian artifacts have helped fuel controversies and research on the antiquity of humans in the New World, the cultures of ancient hunters, and the character of ice-age environments (Anderson 1975; Evans 1930; Figgins 1927; Hay 1928, 1929; Hay and Cook 1930; Holmes 1903; Leonhardy 1966). However, since the 1950s' advent of improved dating and recovery techniques, few Oklahoma sites of Pleistocene age have been studied in detail. In northwestern Oklahoma's Harper County, several lake deposits dating between 17,000 and perhaps 150,000 years ago have yielded pollen, snails, and animal remains studied principally by University of Michigan researchers (Kapp 1965; Miller 1975; Myers 1959; Stephens 1960; Taylor and Hibbard 1955; Wells and Stewart 1987). In southwestern Oklahoma, the Cooperton site in Kiowa County and the Domebo site in Caddo County were the scenes of multidisciplinary research by Museum of the Great Plains (Lawton) archeologists and consulting geologists, paleontologists, and palynologists (Anderson 1975; Leonhardy 1966). Both locations contained the remains of mammoths along with varied evidence that ancient hunters were responsible for their deaths and/or dismemberment. At Domebo, Clovis spearpoints and flake butchering tools were found among the bones of a single mammoth (identified as *M. imperator*) in deeply buried marshy sediments dating 11,200 years old (Leonhardy 1966). In contrast, the shallow Cooperton site consisted of Columbian mammoth bones that bore evidence of being butchered, possibly even preparation for being worked into bone tools (Anderson 1975). Teeth and bones from Cooperton

were subjected to radiocarbon dating (of bone apatite); the resulting three dates range from 17,000 to 21,000 years ago! This age is considerably older than Clovis and older than most archeologists believe that people have inhabited North America. Little information on the prehistoric environment could be derived from the Cooperton site findings, but pollen, gastropods, other animal remains, and sediments from the Domebo site support the interpretation that the locality was marshy with more forest cover and a more moderate climate than today (Leonhardy 1966).

Since the 1961 excavations at the Domebo and Cooperton sites, numerous mammoth and mastodon remains have been reported to various Oklahoma institutions and agencies. These reports typically resulted in one-day excursions by archeology graduate students to salvage tusks and other bones threatened by erosion or construction (Leonhardy 1964; Neel 1985; Rohrbaugh 1971, 1972; Tong 1962; Wyckoff 1985). In fact, from 1961 to 1985, only two Oklahoma elephant finds received more than cursory salvage treatment. In 1963, road work in eastern Woodward County exposed the well preserved bones of a single mammoth. Known as the Bartow site (Figure 1-1), these remains were in a calcic clay overlain by 7 ft (2.12m) of sands and a caliche-bearing soil (Kerr 1964). Clear evidence of human involvement was not found, but the Bartow find yielded bone apatite that was dated at 11,990 ± 170 years ago (Arizona-582), a date slightly earlier than those associated with Clovis hunters (Agenbroad 1984a). In 1980, remains of a probable mammoth were uncovered near Lahoma in Major County (Lintz 1980). Although badly damaged by plowing and erosion, the Lahoma find consisted of ribs, a right tibia, a right femur, and a thoracic vertebra that lay in a fine clay loam thought to be deposited by sluggish water (Lintz 1980:6). No dates were obtained on the Lahoma find. The Bartow and the Lahoma finds are within 60 miles (96km) of the Hajny site (Figure 1-1).

The Hajny Site Research

The Hajny site came to the attention of the Oklahoma Archeological Survey in November of 1983. Mr. Gary Hajny, a farmer-rancher living near Oakwood in eastern Dewey County, discovered large bones being exposed during gravel quarrying on his father's land. Because of his own geological and archeological inquisitiveness, and because some bones were still in place, Gary believed the find might be of interest to someone studying Oklahoma's past. After several futile leads, he learned of the Survey and called. This resulted in a November 4, 1983, visit to the site by Survey staff archeologist Larry Neal. Nearly two hours were spent examining the already recovered bones and teeth (identified as mammoth), the remains still in situ, and the exposed geological deposits. The in situ bones were in a blue clay that was overlain by a thin, brown clay which in turn was covered with remnants of a gravel lens. The blue clay capped a very white to yellowish fine sand. The blue and brown clays appeared to contain thousands of aquatic snails. The character and sequence of these strata were thought to represent a spring deposit. Although no artifacts or traces of human involvement were observed, the blue clay appeared similar to the 11,000 + year-old Domebo Formation (Albritton 1966) that yielded Clovis artifacts in Caddo County some 75 miles (120km) to the south. This similarity, plus knowledge of reported Clovis mammoth-kills in spring deposits elsewhere (Hester 1972), led Larry to suspect the site might be a Paleoindian elephant-kill and thus merit further investigation. An archeological site survey form was completed on November 11, 1983, and the site was designated Dw-23 (the 23rd site recorded for Dewey County) in the state site files maintained by the Oklahoma Archeological Survey.

Because artifacts or other signs of human presence weren't found during the initial visit, the Hajny site's age needed to be clarified before planning and undertaking archeological research there. Consequently, samples of the recovered mammoth bone and snail shells were submitted for radiocarbon dating. We hoped these diverse materials would yield dates similar to each other and to the period that mammoths were hunted by makers of Clovis spearpoints. The bone sample consisted of several thick walled fragments collected from the blue clay. The snail sample was nearly 100 g of complete and broken shells that were washed (through a .600 mm sieve) from several liters of brown clay. Both samples were sent to the Washington State University Radiocarbon Laboratory in January 1984. At first glance, the results seemed inconsistent. The bone fragments yielded a date of 8960 ± 240 B.P. (WSU-2941), a result that is nearly a thousand years later than when mammoths apparently became extinct (Agenbroad 1984; Meltzer and Mead 1983). In contrast, the snails were dated at 27,890 ±415 B.P. (WSU-2942), or some 15,000 years before the time of Clovis-using hunters. Because freshwater snails can date older than they actually are (they can absorb carbon-14 from ancient carbonates dissolved in the groundwater; Taylor 1987:52-53), the WSU laboratory studied the sample's carbon-14 isotope ratio to its more stable carbon-13 isotope and was able to determine a corrected date (20,000 ± 415 B.P.) for sample WSU-2942. While still not overlapping, the bone and corrected shell dates fall within the late Wisconsin period and supported the conclusion that the Hajny deposit might be contemporaneous with the first appearance of human predators in Oklahoma.

Believing the Hajny site would yield maximum information if excavated by researchers better versed in Pleistocene geology and paleontology than the Survey staff, nearly 18 months were spent trying to interest other scholars in the site. Prior commitments and financial limitations prevented those contacted from taking the project. Finally, with the special encouragement and advice of Dr. Dennis Stanford (Smithsonian Institution), it was decided that the Oklahoma Archeological Survey would undertake the work. Dr. Stanford visited the site in July of 1985 and agreed

with Larry Neal's assessment that the site was a spring deposit. Dr. Stanford thought the available dates could very well mean the mammoth remains were contemporaneous with ancient hunters, and he urged us to excavate the location as if it were an archeological site. He also stressed that even if no evidence of humans was forthcoming the site would yield important information on the character and origins of a natural accumulation of bones from a little documented time during the late Pleistocene on the Southern Plains.

The actual field work began on October 15, 1985, and it continued until November 26 (when winter weather forced us to leave). During this period, a contour map was made of the location; a metric grid system was established and excavated over the area known to contain bones; backhoe trenches were dug and profiled north, south, and west of the grid; exposed bones were identified and mapped; and the exposed remains were covered with hay and polyethelene sheeting to protect them from freezing and moisture. Because remains of other mammoths were found during the first stint of field work, another 18 days were spent excavating the site between March 20 and May 1, 1986. During this period, the grid was expanded east and exposed bones mapped; extensive backhoe trenches were dug and profiled east of the grid; several soil profiles were exposed and recorded on the quarry pit walls around the grid; and the best preserved mammoth bones were jacketed in plaster and taken to the Survey laboratory for further study.

After two weeks of excavation, enough of the initially discovered mammoth was uncovered to know that it was somewhat articulated and that it was adjacent a spring vent. As more of the bones were found in roughly anatomical order, it seemed less likely that it had been killed and butchered by people. Thus, as work progressed and more of the setting was exposed, our research orientation shifted from documenting the presence of ancient hunters to recording and explaining the site's geological contexts and their paleontological contents. By mid-November we were confronted with colorful but complex sequences of waterlaid sands and gravels, by disrupting traces of spring vents and gravel-filled channels, and by bones to several mammoths and small animals. These finds stimulated questions about the ages of the spring conduits, the processes responsible for the condition and array of the bones, the origin of a gravel-filled channel that intersected one spring vent, and the age of an episode when sediments and soil were stripped from above the bone-bearing spring deposit. To answer these questions, considerable time has been spent recording in detail the character and stratigraphic relationships of the deposits, trying to obtain radiocarbon dates from diverse materials in these deposits, studying the local geomorphology, and comparing our findings with those from other late Pleistocene locations studied over the Central and Southern Plains. The following chapters present the findings and interpretations resulting from our work at the Hajny site.

CHAPTER 2

The Site's Setting and Excavation

Don G. Wyckoff

The Site And Its Setting

The fossil-bearing deposits known as the Hajny site lie in a terrace bordering the Canadian River in eastern Dewey County, Oklahoma. Pleistocene geologic and geomorphic features abound in this locality (Figure 2-1). For example, Permian bedrock uplands east of the site are mantled with extensive dunes that are thought to be leeward deposits of fine sand blown from the Canadian's bed during Pleistocene and Holocene times by prevailing south and southwest winds (Fenneman 1938:622; Fay 1959, 1962:88-93). Also, the southeast trending valley where the Hajny site occurs is believed (Dolliver 1984; Fay 1959) to be the channel of a tributary that pirated the Canadian from its original course southwest of Taloga, some 20 miles (32 km) northwest of Hajny (Figure 2-1). Because volcanic ash found in the Canadian's original channel is believed (Fay 1959:10) to be Pearlette ash, the Canadian's present valley is thought to be at least 600,000 years old. This valley is distinguished by its narrowness and by having at least five terrace levels, all interpreted to relate to pre-Illinoian, Illinoian, and Wisconsin glacial times (Fay 1959).
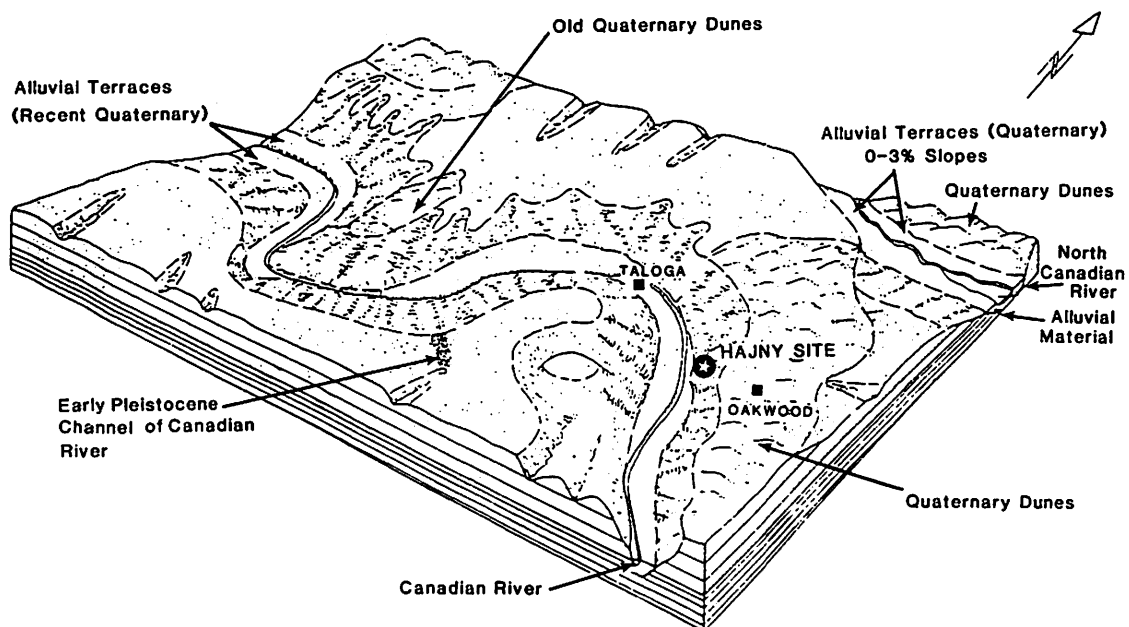
Figure 2-1. The Hajny Site (34DW-23) and other Pleistocene deposits in Dewey County, Oklahoma. (Adapted from Steers, Frie, and Grover, 1963: Figure 22).
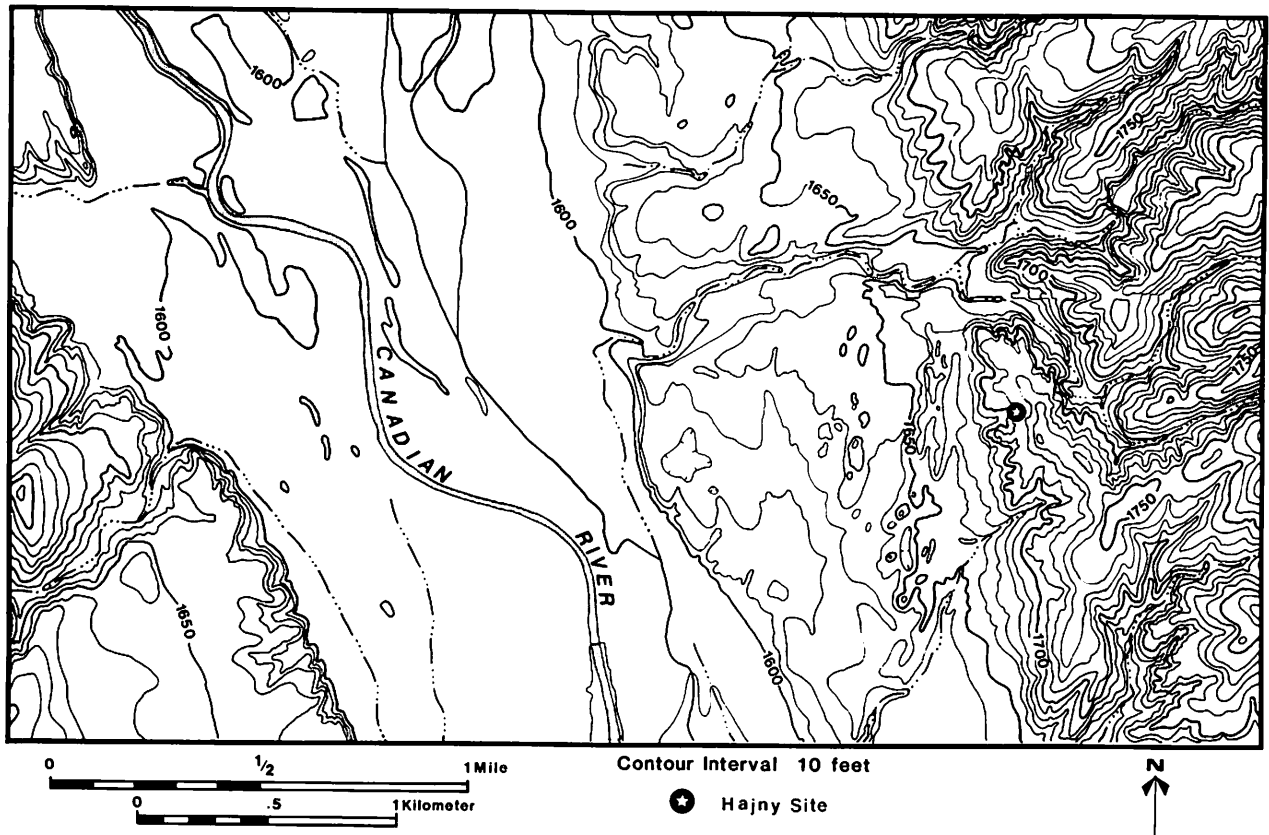
Figure 2-2. Location of the Hajny site (34Dw-23) in the Canadian River valley, Dewey County, Oklahoma.

The Hajny site is on a rounded, grass-sage-yucca covered terrace that is 115 feet (35 m) above and 1.0 miles (1.6 km) east of the Canadian River (Figure 2-2). East and north of the site this terrace is heavily eroded by an intermittent stream. This tributary joins the Canadian about a mile northwest. For several years the terrace has been quarried for gravel used on Dewey County roads. As a result, nearly 15 feet (4.57 m) of sand, gravel, and the overlying soil are missing from approximately 5 acres (2.2 ha). Except for a couple of isolated remnants, the northernmost 200 yards (182 m) of the terrace on the Hajny property have been quarried away. In the fall of 1983, county crews moved 20 yards (18.2 m) south of the quarried area and opened a new pit, one measuring roughly 130 feet (40 m) wide (north-south) and 200 feet (62 m) long (Figure 2-3). Using a bulldozer and front-end loader, they began digging into the terrace near the same elevation as the initial quarry's bottom, and they were able to trace and

recover gravel from lenses that were 7 to 14 feet (2-4 m) below the terrace slope. These lenses were in fluvial sand. Below one such lens in the north central part of the new pit mammoth bones were uncovered. The bones were in a blue-gray silt that was overlain by a snail-laden brown clay which in turn was partially covered by a densely packed gravel lens. The brown clay extended over some 10 m^3 of the quarry floor; directly south and west of this sediment was a very white sand that graded into a tan sand.

The Excavation Strategy

Because bones were observed where the brown clay was exposed, the excavation strategy entailed:
1. manually digging an exploratory trench that would extend from the white sand northward into the brown clay and that

would serve to delineate the bone distribution as well as provide a north-south profile through the bone-bearing deposit;

2. manually excavating from the west to establish its extent in that direction after the south margin of the bone bed was determined;

3. expanding the excavations from the west so that the mammoth could be fully exposed and deposition units within the bone-bearing deposit could be correlated, and

4. mechanically digging extensive trenches north, south, east, and west of the grid in order to correlate the bone-bearing
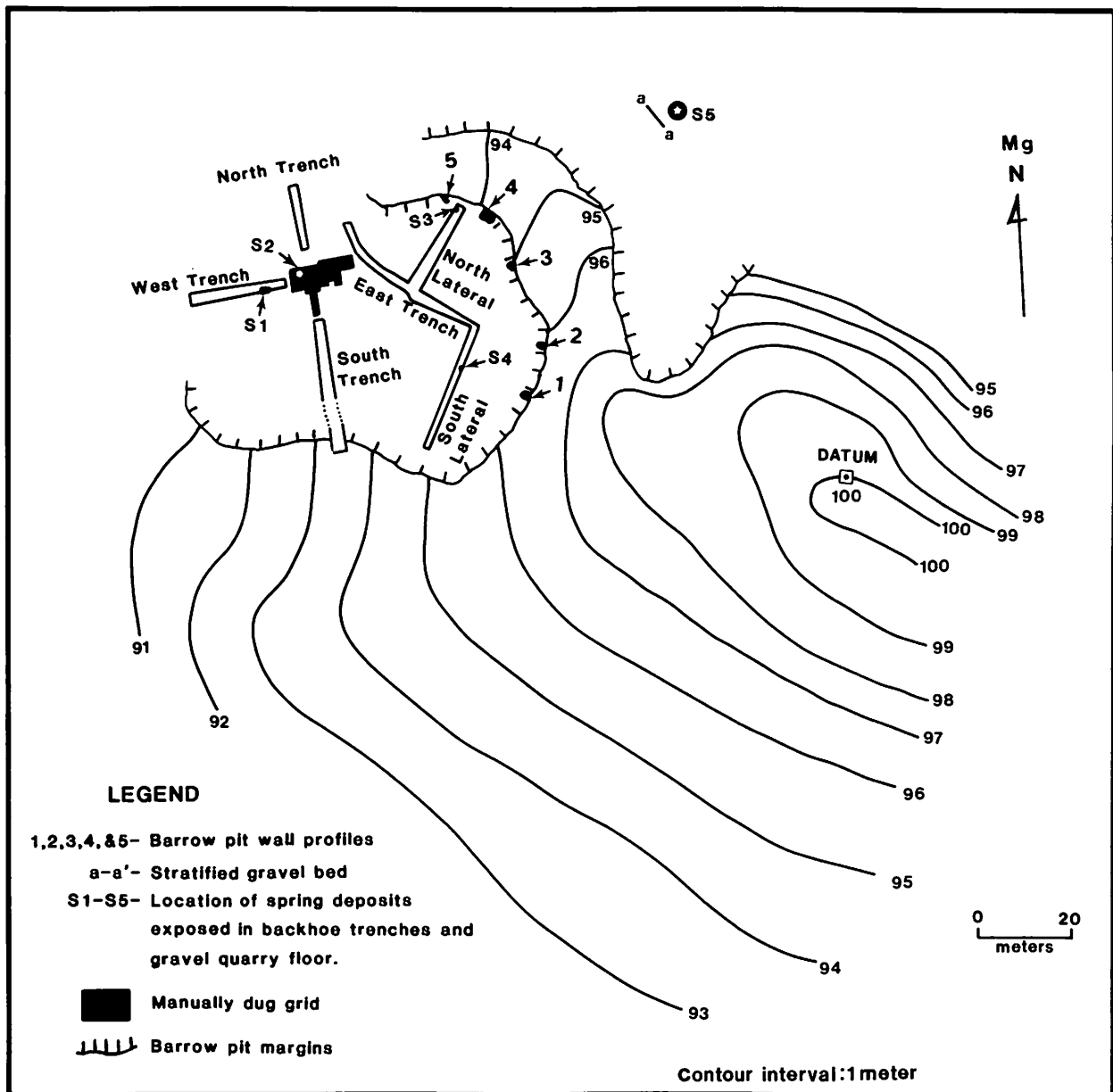
Figure 2-3. Contour map of the Hajny site (34Dw-23) and location of its excavations, profiles, and spring deposits, Dewey County, Oklahoma.

deposit with the sequence of alluvium
and soil evident on the quarry walls.

Excavation Procedures

Before any excavations were undertaken, a
datum point was established from which to
maintain vertical and horizontal measure-
ments. This datum was placed on the crest of
the terrace some 80 m east of the pit with the
mammoth remains and 40 m south of the
extensively quarried area (Figure 2-3). Be-
cause U.S. Geological Survey bench marks
(with recorded above-sea-level elevations)
were not in the neighborhood, the Hajny
datum was assigned an arbitrary elevation of
100.00 m. From this datum, a contour map
was made (using alidade, plane table, and
metric stadia rod) of the undisturbed terrace
and the margins of the quarried areas near the
fossil find (Figure 2-3). Also, elevations were
determined for selected points within the
quarry containing the mammoth.

After completing the contour map, a grid
system of meter squares (Figure 2-4) was es-
tablished over the bone-bearing deposit.

● The orientation of the north-south base
line was 11° west of magnetic north. Using
the still evident brown clay and white sand
on the quarry floor, the north-south base
line was set running through the center of
the brown clay exposure and extended
south five meters on the white sand.

● The east-west base line was established
perpendicular to the north-south base line.

● The intersection of the two base lines, located
near the center of the exposed clay, was desig-
nated 0-0 (Zero-Zero; Figure 2-4).

● Lines parallel to the north-south and east-
west base lines were laid at meter intervals.
Wooden stakes were drivien at each inter-
section.
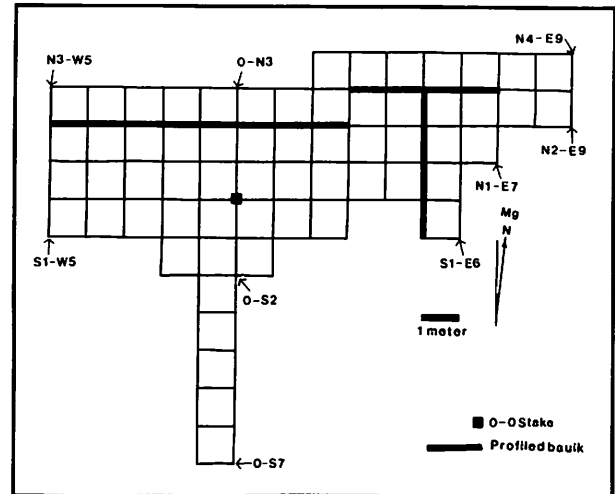
Figure 2-4. The manually excavated grid, Hajny
site (34Dw-23), Dewey County,
Oklahoma.

● Each stake was given a position name rela-
tive to the 0-0 stake. For example, a stake
three meters south and three meters east of
the 0-0 stake was called South3-East3
(written S3-E3). A stake two meters north
of 0-0 was referred to as Zero-North 2
(written 0-N2).

● Finally, each meter square was given the
same designation as the stake in the
southeast corner of the square.

The grid provided a means to maintain
horizontal control over the excavations and to
accurately map any findings. To provide a
vertical control for recording the depths of
excavation and to help stratigraphically corre-
late all findings, a principal elevation refer-
ence point was established for the grid. This
elevation reference consisted of a half-inch
rebar stake that was partially driven at 0-S2
and grooved at a point 10.4 m below the eleva-
tion assigned to datum. Although it was the
principal elevation reference for the grid,
several other elevation points eventually were
established across the grid as the excavations
were expanded west, north, and east.

The excavation procedures consisted of removing 10 cm levels (measured relative to the 10.4 m reference point) from the gridded squares. Trowels and short-handled hoes were the most efficient digging tools in the clayey, silty, and sandy sediments. The fill from each level was dry screened through quarter-inch (6.5 mm) mesh hardware cloth. All bone fragments and any interesting or problematical objects recovered on the screens were put in sacks labeled with the site number (Dw-23), the excavated square, the level being dug, the date, and the name(s) of the excavator. Once a level was dug from a square, a level form was completed whereon was recorded information about the square, the level's depth, the soil characteristics, items recovered, evidence for disturbance, and other pertinent observations.

Every effort was made to uncover bones (and any associated objects) and leave them in place. Scrapers and knives of bamboo and cane were effective in this endeavor. But skeletal elements in the west half of the grid were discovered to be badly broken from heavy machinery driving over this thinly mantled area. Consequently, preservative (Butvar B97 resin dissolved in acetone) was applied to these elements in order to hold them together for identification and thorough mapping. The few minimally damaged bones were left untreated so that they could be studied in the lab and perhaps even used for radiocarbon dating.

During the excavations, 10 cm thick walls were purposefully left between selected rows of squares (Figure 2-4). These walls were later cleaned and detailed profiles made of the stratigraphy within the manually dug area. Soil samples were also collected from the recognized strata for particle size analysis and extraction of snail shells. At other spots across the grid additional soil samples were taken from the different strata; these were used to assist with correlating deposits. Small charcoal flecks and isolated bones of small animals were found occasionally across the grid. These isolated occurrences were

plotted, their depths and strata recorded, photographed, and then they were collected and bagged individually.

The 1985 Excavations

The actual excavations began with an exploratory trench (squares 0-S7 through 0-S2). From 20 to 30 centimeters were removed from these squares, exposing a beautiful white sand that yielded occasional turtle carapace fragments. In the north half of square 0-S3, however, the brown clay and fragments of bone began to appear. Even larger segments of bone were found in 0-S2, but they were badly crushed and scraped by the quarrying machinery. With the south edge of the bone-bearing deposit now discerned, attention was directed at exposing more of its southern extent as well as its western boundary. Consequently, a series of squares (S1-W4 through N2-W4) were started four meters west of the north-south base line. In that area the brown clay was irregularly bounded by blue-gray to white loamy sand. Twenty to 30 cm were removed from these westernmost four squares, revealing they were beyond the bones but at the boundary of undisturbed spring deposits. Excavations then proceeded eastward to the north-south base line, exposing a spring (Spring #2) vent and the remains of the initially discovered mammoth. Throughout this part of the grid, squares were dug to a depth where the lower boundary of the spring deposit contacted the underlying fluvial sands. This boundary was marked by a distinctive yellow (oxidized) sand and by a discontinuous layer of lumpy limey concretions.

While the bone-bearing deposit's boundaries were being determined, access to a backhoe permitted the excavation of lengthy trenches south, west, and north of the grid (Figure 2-3). These were dug to enable learning more about the geologic setting adjacent the bone deposit and to help correlate this deposit with the alluvial and soil sequence evident in the quarry walls. Because they were dug in unconsolidated sand, the backhoe trenches were kept around 2.0 m wide and only 1.5 m deep, but they ranged from 15 to

30 m in length. These trenches served their purpose well. The west one was the first dug, and it fortuitously cross sectioned two spring vents, giving us the first confirmation of the bone-bearing deposit's suspected origin. In contrast, the north and south backhoe trenches yielded clues to previously unsuspected channel cutting and surface erosion. All backhoe trenches were mapped and their profiles recorded in detail. Also, samples were collected of all recognized strata for potential particle size and chemical analyses.

As skeletal remains were being uncovered along the north-south base line, two molars were found. Since these helped identify the position of the beast's skull, a search was begun for the tusks in squares to the east. Finally, a tusk was found in squares 0-E2 and 0-E3. But upon uncovering it, we were surprised to find its tip was toward the already exposed animal! When the butt of a second tusk was also found with the same orientation, it was obvious that remains of more mammoths lay farther east. This exciting development, and the advent of winter weather, led to the decision to continue excavations in the spring of 1986.

The 1986 Excavations

The second field work phase entailed expanding the grid eastward to uncover whatever skeletal remains lay there. Also, the origins of the gravel-filled channels (found north and south of the grid) were in question, and data was needed on the deposits in the east half of the quarry. Therefore, more backhoe trenches were planned.

The 1986 excavations began by expanding the grid six meters east of the north-south base line and excavating squares S1-E6 through N2-E6 to discover the bones' eastern extent. Nothing was found until a pelvis was encountered in N2-E6. Then, while uncovering this element's extension to the north and east, additional bones were discovered. This resulted in expanding part of the grid even

farther east in order to clarify and define what elements lay there. In the process, clues were discovered to previously unsuspected erosional processes. Eventually, the northern and eastern limits of the mammoth bones were determined, and the remains in the squares between these limits and the north-south base line were uncovered.

The 1986 backhoe work consisted of digging over 80 meters of trench east of the grid and cutting five profile pits into the quarry's walls. These pits were placed to enable Dr. Brian Carter (Oklahoma State University) to study the soil and alluvium profiles over the site. The backhoe trench was oriented to help trace two previously noted gravel-filled channels and to expose the fluvial strata lying east of the bone-bearing deposit. Both goals were accomplished. In addition, another spring vent was discovered northeast of the grid and another bone-bearing spring deposit was found to the southeast. All these depositional features were recorded on profiles made of this lengthy backhoe trench.

During the 1986 field work, several opportunities arose to inspect, photograph, and otherwise record noteworthy geologic findings made during continued gravel quarrying by Dewey County road crews. In particular, they periodically extended the major quarry to the south and east, leaving only a narrow strip of the terrace's original contour between that pit and the quarry containing the mammoths (Figure 2-3). In the process they exposed two layers of coarse gravel interbedded with sand some 70 m east and 3 m higher than the grid. Underlying these at nearly the same elevation as the bone-bearing deposit was uncovered another spring deposit (Spring #5). Samples of its greenish-brown silt were collected for extraction of aquatic snails that could be used for comparison (by radiocarbon dating and speciation) with the snail fauna from the bone-bearing deposit.

CHAPTER 3

The Hajny Site: A Geomorphic Perspective

Brian J. Carter

The study area (Figure 3-1) is located within the Rolling Red Plains land resource area (Soil Survey Staff 1981a), which is also known as the Western Sandstone Hills region (Curtis and Ham 1972). This area is marked by rolling hills of Permian sandstones capped by Quaternary alluvium and eolian sands. The bedrock exposed near the site belongs to the Permian "redbed" system and consists of the Cloud Chief Formation, Rush Springs sandstone, and Marlow Formation of the Whitehorse group (Fay 1962; Fay and Hart 1978). The Rush Springs sandstone directly underlies the Hajny site. The Marlow Formation underlies the channel of the South Canadian River west of the Hajny site while the Cloud Chief Formation caps the drainage divide between the South and North Canadian rivers to the east (Brown 1967). The beds dip westward. The Rush Springs sandstone consists of inter-bedded fine-grained sandstone, soft pack-sand, and minor amounts of gypsum and sandy shale.
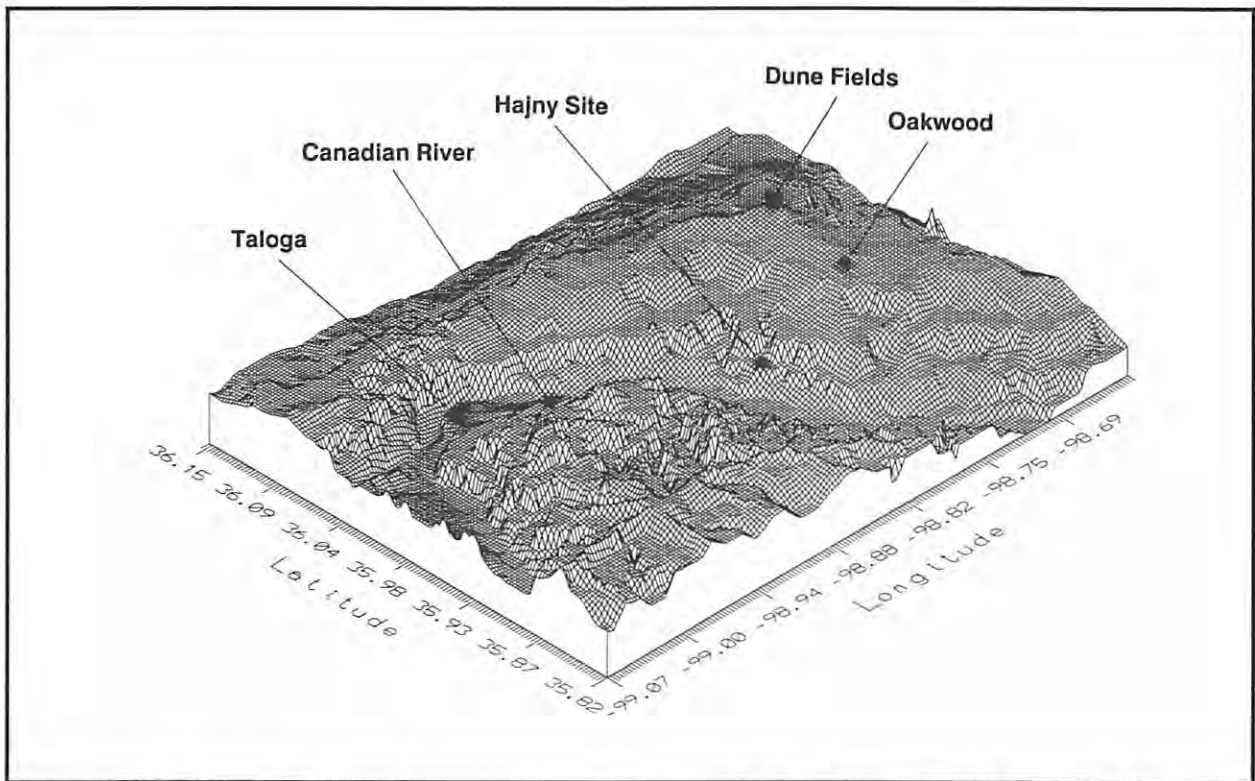
Figure 3-1. Computer-generated orthographic view of Hajny site and surrounding landscape. View is to the northeast. Illustration courtesy of J. Peter Thurmond.
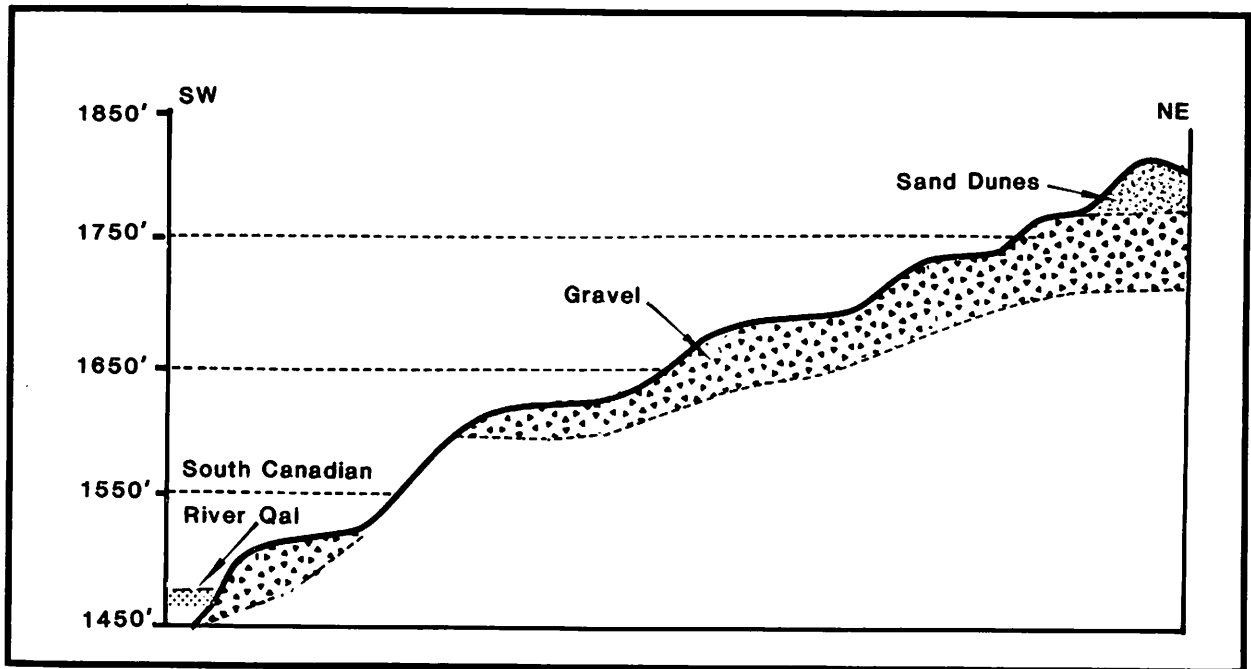
Figure 3-2. Schematic diagram of terrace levels on the northeast side of the South Canadian River in S1/2 T15N R13W., Blaine County, Oklahoma. Qt, terrace deposits; Qal, alluvium (from Fay 1959).
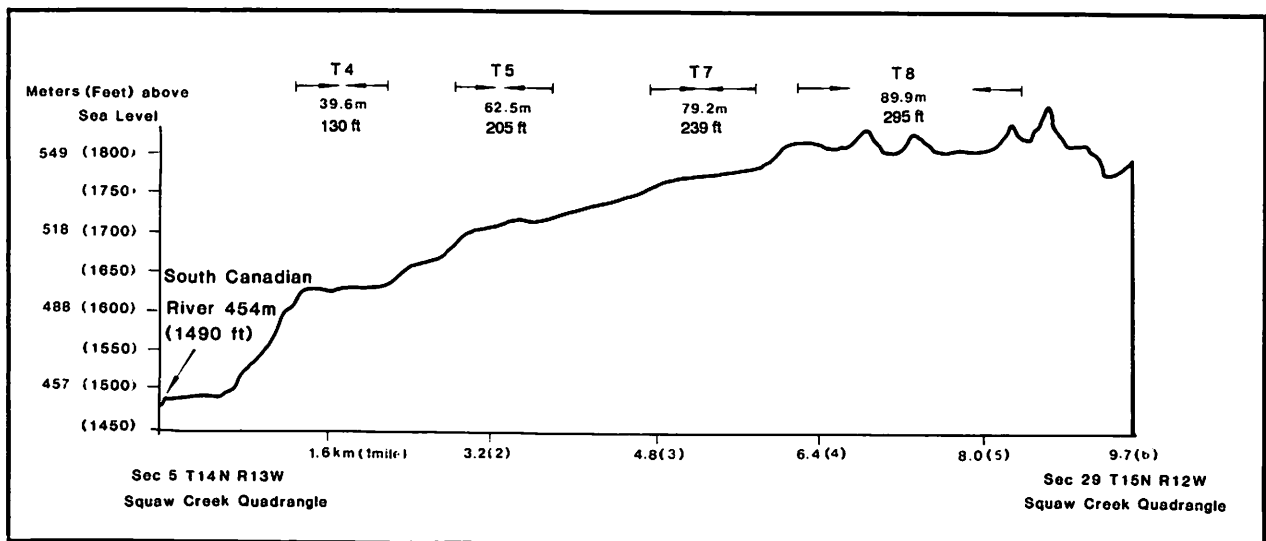
Figure 3-3. Cross section of terrace levels on the northeast side of the South Canadian River 25 km south of Hajny site.

The dominant surficial geology in the area is not residuum (soils formed from bedrock). Unconsolidated Quaternary deposits (alluvium) cover most of the bedrock near the study site. Except for the depth of Holocene alluvium (40-50 m) in the floodplain of the South Canadian River, the general thickness of these unconsolidated Quaternary deposits near the Hajny site is unknown.

Local Terrace System

Wind has modified many constructional terrace surfaces in this locality. These eolian sands occur as isolated dunes and dune fields, especially east of the site. Although recognition of terrace levels above the South Canadian River is difficult because of wind and gully erosion, five terrace levels were identified by Fay (1959; see Figure 3-2). All terrace levels are not continuous or complete throughout the study area. Figures 3-3 through 3-6 are elevational cross sections of the South Canadian's valley within the study area. These cross sections show that ten distinct terrace levels are present. These ten levels occur at 7.6-9.1 (T1), 13.7 (T2), 32.0 (T3), 39.6 (T4) 57.9-62.5 (T5), 67.1-70.1 (T6),

76.2-80.8 (T7), 89.9 (T8), 100.6 (T9), and 103.6 (T10) meters above the present river level. Four of Fay's five terrace levels seem to correlate with levels identified in these elevational cross sections. Fay's (1959:8-9) 15.2, 67.1, 82.3, and 91.4 m terraces are believed to correlate with levels 13.7, 67.1-70.1, 76.2-80.8, and 89.9 shown in Figures 3-3 through 3-6. Terrace levels within this report are numbered 1 through 10 with 1 being the lowest and 10 the highest. An underlying assumption that the river gradient has remained constant along its 37 km stretch through the area enables identification of these ten levels. If stream gradient has changed through time, then terraces recognized by relative elevation above the current river level will overestimate the number of different terrace surfaces. Current stream gradient is 1.0m/km within the study area. This river gradient has probably not changed significantly over time along the relatively short (37 km) distance under study.

The ages of the terrace levels are unknown, but the occurrence of volcanic ash in the alluvium of a high terrace on the South Canadian's west side (Figure 3-4) allows an
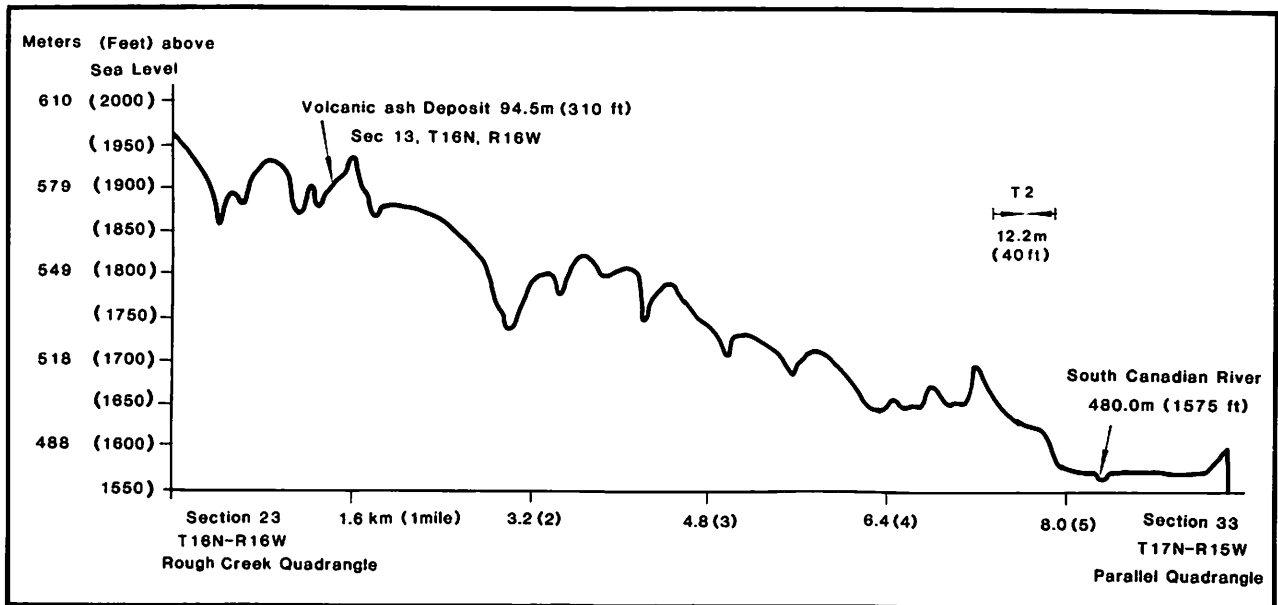
Figure 3-4. Topographic cross section of terrace levels (meters [feet] above river) west of the Canadian River and south of Hajny site (34Dw-23), Dewey County, Oklahoma.
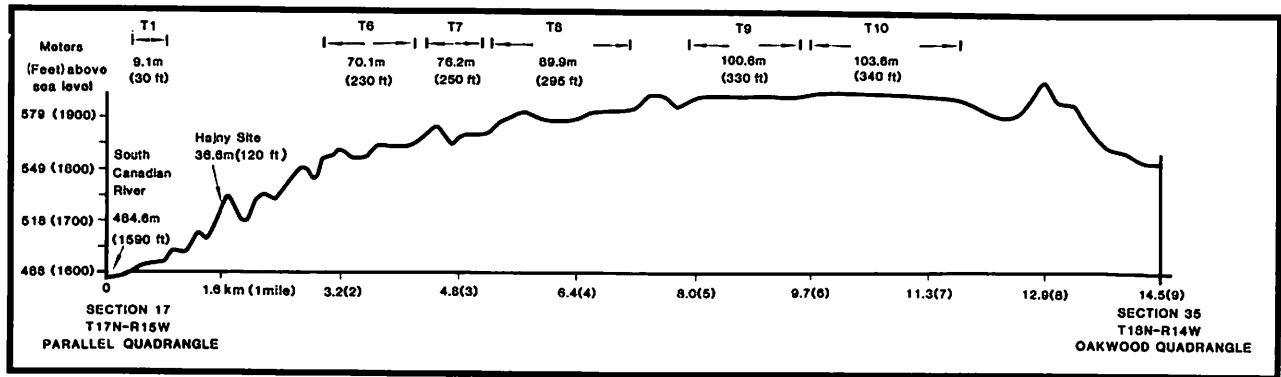
Figure 3-5. Topographic cross section of terrace levels (meters [feet] above river) east of Canadian River and north of the Hajny site (34Dw-23), Dewey County, Oklahoma.
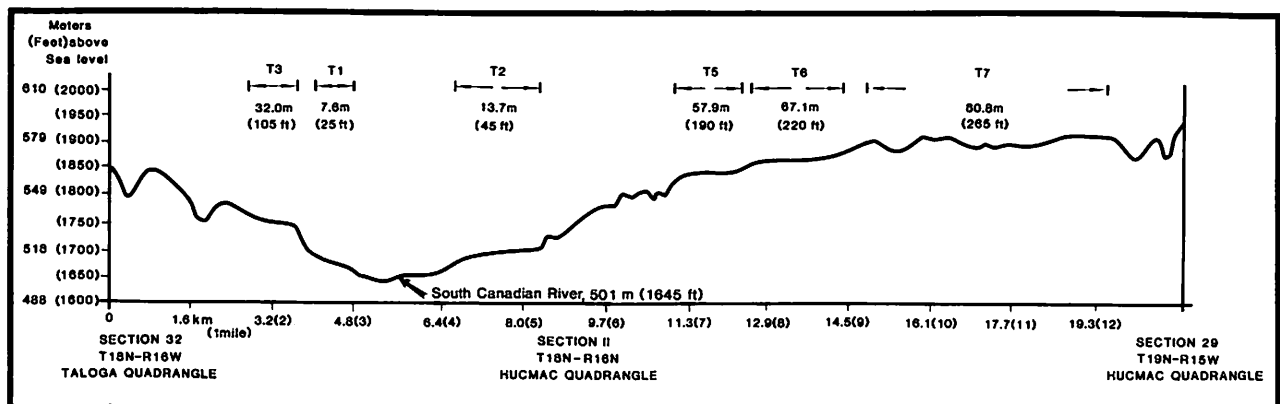
Figure 3-6. Topographic cross section of terrace levels (meters [feet] above river) southwest and northwest of South Canadian River, 12 kilometers northwest of the Hajny site (34Dw-23), Dewey County, Oklahoma.

estimated date to be assigned to the terrace sequence. The ash noted in Figure 3-4 was first assigned a late Kansan age based on the assumption that it was the Pearlette ash (Frye, Swineford, and Leonard 1948). The Pearlette ash deposits found across Nebraska, Iowa, Kansas, Oklahoma, and Texas were thought to be from one ash fall (ibid.). However, current research suggests that these ash deposits could have originated from several volcanic eruptions (Izett 1981). Although it could be different and much older, the volcanic ash and associated alluvium are probably no younger than the most widespread pyroclastic deposits found in the Southern Great Plains. This widespread ash is Lava Creek B, dates 0.61 million years

ago, and is named for the source area tephra, the Lava Creek Tuff, in Yellowstone National Park (Izett and Wilcox 1982). The ash-containing high terrace deposits are 94.5 m above the present river level. That elevation would place the ash within the ninth terrace level recognized herein. A date of 0.61 million years before present (Ward 1991) would indicate that the terrace sequence in the study area is middle Quaternary age and younger.

Geomorphic Dating of the Hajny Site

A rough estimate of the age of the sediments at the Hajny site can be made if one assumes a constant linear rate of fall in river elevation from the level of the volcanic ash-

containing terrace deposits. An estimated age of 0.24 million years before present is thus derived for sediments at the Hajny site. This estimated age is on the order of 10 times older than the radiocarbon dates on mammoth bone and aquatic snail shells buried within the Hajny site's alluvial deposits (Wyckoff et al. 1987). If the dates on bone and snails are correct, this comparison indicates that rates of absolute downcutting of the South Canadian was much slower during the middle Pleistocene than during the late Pleistocene. Similar findings are reported for the upper Trinity River and the Colorado River in Texas (Blum 1992; Ferring 1990:44-45; Madole et al. 1991:526-531).

The Hajny site lies within the shoulder to backslope hillslope position. The Hajny site also lies 36.6 m above the South Canadian River. The entire hillslope system in the site vicinity consists of rolling topography with a mean difference in elevation of 15 m. At the site, surficial geology is dominated by Quaternary alluvium modified by wind (eolian sand) and gravity (colluvium). The distribution of Quaternary alluvium approximately parallels the South Canadian River.

The Hajny site lies within the middle of two distinct terrace levels. About 1.2 km west of the site is a first terrace that is 9.1 m above the river, whereas 2.4 km east is a fifth terrace that is 70.1 m above the river. The Enterprise fine sandy loam and Canadian loam are two soils that dominate the low terrace's surface, whereas the Holdredge silt loam and Miles fine sandy loam soils are prevalent on the 5th terrace (Steers, Frie, and Grover 1963). Enterprise is a member of the Coarse-loamy, mixed, thermic Typic Ustochrept family of soils. The Canadian soil is closely related to Enterprise but is a member of the Coarse-loamy, mixed, thermic Udic Haplustoll family. These soils express moderate horizon development, and both have cambic subsurface horizons. The Canadian soil also has a thick, dark A horizon (a mollic surface horizon). In contrast, the Holdredge and Miles soils are closely related by horizon dif-

ferentiation and development. The Holdredge soil is a member of the Fine-silty, mixed Typic Argiustoll family, whereas the Miles soil is a member of the Fine-loamy, mixed, thermic Udic Paleustalf family. Both contain argillic horizons (due to clay illuviation), but the Holdredge soil has a mollic surface horizon.

In close proximity to the Hajny site, soils are formed within alluvium, colluvium, eolian sands, and bedrock. The Hajny site hillslope contains Miles and Canadian soils. Where recent hillslope erosion has eroded older colluvial and alluvial deposits (in which the Miles and Canadian soils formed), Quinlan soils are formed. The Quinlan soil is a member of the Loamy, mixed, thermic Shallow Typic Ustochrept family. They form in calcareous Permian sandstone.

Several hundred meters west of the Hajny site, and intermediate in elevation between the low (first) terrace and the site, eolian sands occur as a distinct linear dune field that parallels the low terrace. This dune field is approximately 50 m wide with dunes that are 5 m high. Pratt soils have formed in these deposits (Steers et al. 1963). The Pratt soil is a member of the Sandy, mixed, thermic Psammentic Halpustalf family.

Summary

The Hajny site is located between river terraces that show distinct differences in soils development and elevation. East of the site the landscape seems older because of the higher elevation of the constructional terrace surface and the greater soil differentiation and depth found on this surface. West of the site the constructional terrace surface (level 1) is lower with less soil horizon differentiation and depth. Using a generalized method (Harden and Taylor 1983) to estimate soil age from the degree of soil development on the terraces close to the site, a late Pleistocene age seems appropriate for the Hajny site alluvium that contains the faunal remains.

CHAPTER 4

The Hajny Site: A Soil-Stratigraphic Perspective

Brian J. Carter

Introduction

By observing the stratigraphy of sediments and soils within the Hajny site's borrow pit wall (Figures 4-1 through 4-8), the faunal remains can be placed in the context of the hillslope and Quaternary terrace system. To accomplish this, five soil profile descriptions were completed along the borrow pit wall northeast and east of the mammoth remains (Figure 4-16). Table 4-1 presents the soil morphologic information on the two major profiles manifest along the exposure.

Two types of deposits are evident in the exposure: an unstratified and poorly sorted colluvium that overlies well sorted and stratified alluvium (Figures 4-2 through 4-7). Both the colluvium and the alluvium contain well rounded rock fragments (Figure 4-7).

The Alluvial Sequence

The contact between the colluvium and alluvium paralleled the ground surface (Figure 4-16). Thus, this contact dipped at a 7% gradient to the west-northwest. The mammoth bone was initially found, and subsequent excavations begun, near the base of the colluvium and continued into the underlying alluvium. The upper part of the alluvial deposits was well exposed on the pit wall (Figures 4-1, 4-2, and 4-3). Further backhoe excavations and augering revealed three segments of alluvium that contain a total of 13 horizons (Figure 4-16; Table 4-1). The particle size distribution of the alluvium from 264 to 554 cm (Figure 4-16, description 1 in Table 4-1) ranged from sand to very gravelly sand. Cobbles 7.5 to 10 cm in diameter were common. Except from soil horizon 2C6 (437 to 554 cm; Figure 4-16, description #1 in Table 4-1), lithologies of the rock fragments were from the Ogallala Formation. Quartz was the dominant rock type. Within the 2C6 horizon, rounded Permian sandstone fragments 7.5 to 10 cm in diameter were common (Figure 4-8). This was the only layer within the alluvium that contained rock fragments (2 cm in diameter) that were from local bedrock lithologies.

The middle alluvial segment occurred at a depth of 594 to 646 cm (Figure 4-16, description 1 in Table 4-1) below ground surface. The particle size distribution ranged from silt to sandy clay loam. The sand and gravel (the upper alluvial segment) above this layer were removed for road materials prior to initiation of the study. Therefore, an extrapolation was made between the pit wall exposures, backhoe excavations, and main area yielding fossil bone. From this extrapolation the middle alluvial segment contained the majority of the faunal record. Snails (1 to 2 cm in diameter) were common throughout this segment.

Below the middle segment, starting at a depth of 694 cm, a third loamy sand to gravelly alluvial segment continued until Permian sandstone bedrock was encountered at a depth of 976 cm below ground surface.

The upper and lower alluvial deposits represent channel or near channel facies. The middle alluvial deposit represents a slackwater facies. This facies sequence developed within a past floodplain of the South Canadian River. They are now considered terrace deposits. Within the vicinity of the Hajny site, erosion has
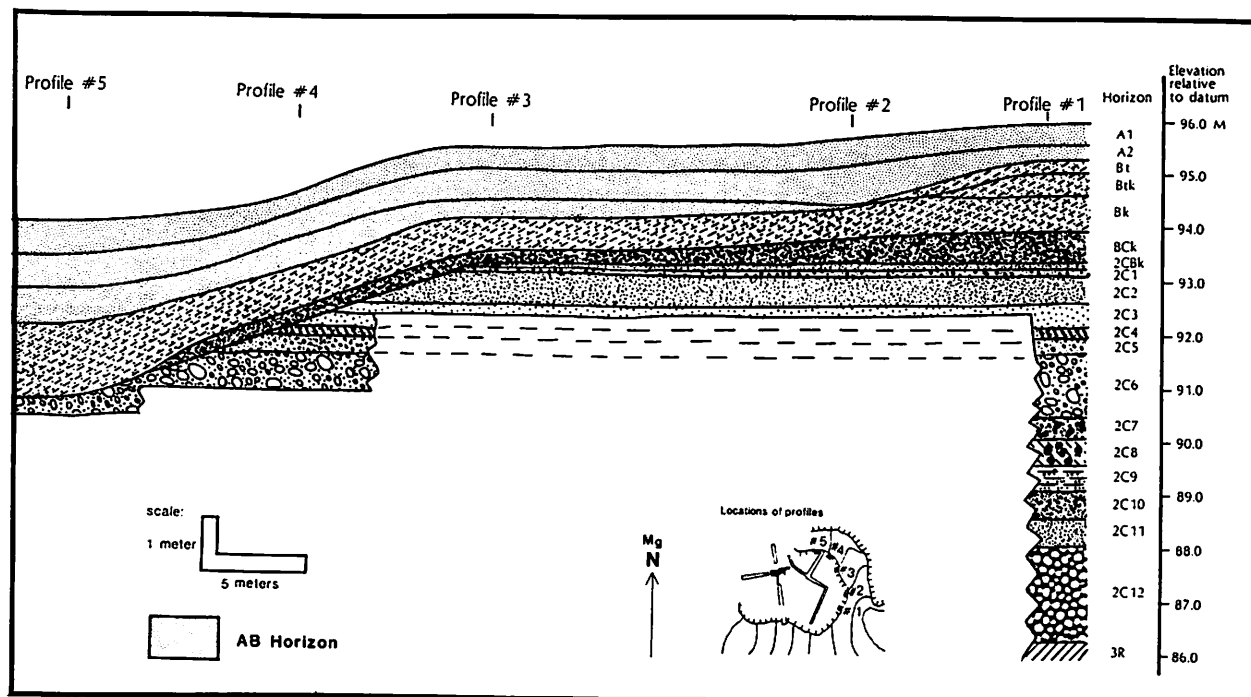
Figure 4-16. Profiles along the barrow pit wall, Hajny site (34Dw-23). Horizons are described in Table 4-1.

obscured the original terrace surface of these deposits. Not only has erosion obscured the original surface but it has highly modified the alluvial deposits. The upper alluvial segment (264 to 554 cm, Figure 4-16; Table 4-1) has been truncated by erosion and subsequent mass wasting.

The Colluvium

Some of the erosion that has shaped the landscape at the Hajny site is evidenced by colluvium which is mass wasted slope deposits that truncate the underlying bone-containing alluvium. This colluvium is also the parent material for the soils on the ground surface. The colluvium ranges from 2 to 3 m in thickness and was slightly thicker in the western segments of the pit walls. The colluvium's particle size distribution was loam to sandy loam with few rounded gravels throughout.

Often mass wasting produces colluvial deposits that occur when hillslope denudation or significant reduction of vegetation has occurred followed by increased moisture and under-cutting of slope. This instability allows soils to fail rapidly or slump slowly downslope under the force of gravity (Ritter 1986). The fact that the alluvium-colluvium boundary slopes in the same direction and degree as the 7% slope gradient of the ground surface (Figure 4-16) supports the interpretation of slope mass wasting and the identification of colluvium. The slope mass wasting and subsequent soil development in the colluvium post-dates the sedimentation of the underlying alluvium containing the fossil remains. An assessment of the relative age of the colluvium which truncates the bone-bearing alluvium can be made by evaluation of soil development within the colluvium.

Table 4-1. Descriptions of Barrow Pit Profiles #1 and #5, Hajny Site (34Dw-23), Dewey County, Oklahoma.

Horizon	Depth (cm)	Munsell color[1]	Texture	Structure[2]	Consistence	Effervescence	Rocks (%)	Roots[3]	Boundary[4]
PROFILE #1									
A1	0 - 43	7.5YR 3/2	very fine sandy loam	2mpr	firm	-	2	2f	gs
A2	43 - 71	5YR 3/3	very fine sandy loam	2cpr to 2msbk	firm	-	2	2f	gs
Bt	71 - 98	5YR 3/4	loam	2cpr to 2csbk	firm	-	2	1f	as
Btk	98 - 140	5YR 4/6	loam	2cpr to 2csbk	firm	slight	2	1f	gs
Bk	140 - 206	5YR 5/8	loam	2cpr to 2csbk	firm	slight	2	1f	gs
BCk	206 - 264	5YR 5/6 to 7.5YR 5/6	loamy sand	1csbk	very firm	slight	2	1f	ci
2CBk	264 - 278	7.5YR 6/6	sand	sg	loose	slight	15	1f	cs
2C1	278 - 288	7.5YR 4/6	gravelly sand	sg	loose	moderate	80	-	cs
2C2	288 - 341	7.5YR 7/4	sand	sg	loose	strong	-	-	cs
2C3	341 - 388	7.5YR 7/6	coarse sand	sg	loose	strong	2	-	as
2C4	388 - 406	7.5YR 6/4	gravelly sandy loam	sg	loose	strong	15	-	as
2C5	406 - 437	7.5YR 6/4 with 7.5YR 5/8 and N 2/0	gravelly sand	sg	loose	slight	15	-	as
2C6	437 - 554	7.5YR 6/4	very gravelly sand	sg	loose	-	40	-	as
2C7	554 - 594	7.5YR 6/4	gravelly sand (with bones)	sg	loose	-	15	-	as
2C8	594 - 646	7.5YR 6/4	silt (with snails)	sg	loose	-	-	-	as
2C9	646 - 694	7.5YR 6/4	sandy clay loam	sg	loose	slight	-	-	as
2C10	694 - 744	7.5YR 6/4	loamy sand	sg	loose	-	2	-	as
2C11	744 - 794	7.5YR 6/4	sand	sg	loose	-	2	-	as
2C12	794 - 976	7.5YR 6/4	gravel	sg	loose	-	100	-	as
3R	976 - 980+	5YR 4/6	Permian sandstone	m	-	-	-	-	-

Table 4-1(cont). Descriptions of Barrow Pit Profiles #1 and #5, Hajny Site (34Dw-23), Dewey County, Oklahoma

Horizon	Depth (cm)	Munsell color[1]	Texture	Structure[2]	Consistence	Effervescence	Rocks (%)	Roots[3]	Boundary[4]
PROFILE #5									
A1	0 - 61	7.5YR 3/2	very fine sandy loam	2cpr to 2fsbk	firm	-	3	2f	gs
A2	61 - 122	7.5YR 3/2 and 7.5YR 3/4	very fine sandy loam	2cpr	firm	-	3	1f	gs
AB	122 - 190	7.5YR 3/4	very fine sandy loam	1cpr	firm	-	3	1f	cs
Bk1	190 - 272	10YR 4/3	loam	1cpr/sbk	friable	strong	5	1f	gs
Bk2	272 - 329	7.5YR 4/4	loam	1cpr/sbk	friable	strong	15	-	ci
2CBk	329 - 360	7.5YR 4/6	gravelly loamy sand	sg	loose	strong	60	-	ci
2C1	360 - 383	7.5YR 4/6	gravelly sand	sg	loose	strong	60	-	aw
2C2	383 - 390+	7.5YR 7/4	sand	sg	loose	strong	-	-	-

[1]Colors recorded under moist condition.

[2]Structure code: Grade- 1, weak; 2, moderate; Size- f,fine; m, medium; c, coarse; Form- pr, prismatic; sbk, subangular blocky; sg, single grain.

[3]Roots code: Quantity- 1, few; 2, common; Size- f, fine.

[4]Boundary code: Distinctness- a, abrupt; c, clear; g, gradual; Topography- s, smooth; w, wavy; i, irregular (all as defined and discussed in Soil Survey Staff 1981b).

Soil Series on the Site

The vegetation on the hillslope around the Hajny borrow pit is native prairie. Little bluestem (*Andropogon scoparius*) is the dominant species. The soils across the hillslope (Figures 4-1, 4-3, 4-5, and 4-6) have dark surface horizons (A horizons) because of the addition of humus from the decay of organic matter, especially grass roots. The Canadian soil series (a Coarse-loamy, mixed, thermic Udic Halpustoll) contains a dark surface horizon and is the dominant soil across the borrow pit wall (Figure 4-7 and profiles 3 through 5 in Figure 4-16; profile 5 in Table 4-1) except for the highest pit area. The Miles soil series (a Fine-loamy, mixed, thermic Udic Paleustalf) is identified in the highest (east) area of the borrow pit wall (Figures 4-2 and 4-4; profiles 1 and 2 in Figure 4-16; profile 1 in Table 4-1). The Miles soil contains a distinctive yellowish red subsurface horizon with an increase of clay content from the surface to subsoil horizons. The yellowish red subsoil colors (Munsell 5YR 4/6, 5/8, and 5/6) graded to a dark brown to brown (Munsell 10YR 4/3 to 7.5YR 3/4, 9/4, and 4/6) across the pitwall (Figures 4-1, 4-3, 4-5, and 4-6). Slightly more moist subsurface conditions are probably responsible for the brown colors found in the Canadian soils within the lower slope position compared to the Miles. The yellowish red subsurface horizon and clay illuviation may reflect deeper weathering that has not been truncated by recent hillslope mass wasting. Based on the group level classification, the Halpustoll (the Canadian series) and Palenstalf (the Miles series) soils exposed on the pit wall are at least several thousand years old, and probably over ten thousand years are needed for their development (Hall, Daniels, and Foss 1982).

The Miles series is mapped on the surface of the fifth terrace level which is above and east (1.2 km) of the Hajny site (Steers, Frie, and Grover 1963). The Canadian series is mapped on the lower (first) terrace surface to the north and west of the site (ibid.).

Summary

The soils across the Hajny site are transitional between the degree of development found on the upper and lower terrace surfaces to the east and west, respectively. The Hajny faunal remains occur within the alluvial sediments that underlie the colluvium and associated modern soils. At Hajny, these alluvial deposits lie approximately 33 m above and 28 m below the lower and upper adjacent terrace surface levels, respectively. Based on the intermediate elevation above the river level and the degree of soil development in the overlying colluvium, the alluvium at the Hajny site is intermediate in age between these lower and upper terrace deposits. The alluvium may correlate to the terrace age identified by constructional surfaces found 32.0 to 39.6 (level 3) or 58.5 to 62.5 (level 4) above river level. Erosion truncated the terrace surface as the South Canadian River deepened its valley. Colluvium developed from alluvial deposits at the Hajny site. The absolute ages of the colluvium and soils development at the Hajny site are unknown, but they probably formed within the Late Wisconsin or Holocene periods based on the degree of soil horizonation.

Figure 4-1. The Hajny quarry pit wall (hillslope) looking northwest from barrow pit profile #1. Vehicles are parked just beyond the grid excavations where mammoths were uncovered.

Figure 4-2. Profile of Miles soil in colluvium above fluvial sands in barrow pit profile #1. Scale is in 20 cm increments. Profile described in Table 4-1.

Figure 4-3. Close-up of the colluvium and underlying stratified, sorted alluvium (scale is 30 cm) in barrow pit profile #1.

Figure 4-4. Miles soil, colluvium, and underlying alluvium in barrow pit profile #2. Scale is 30 cm.
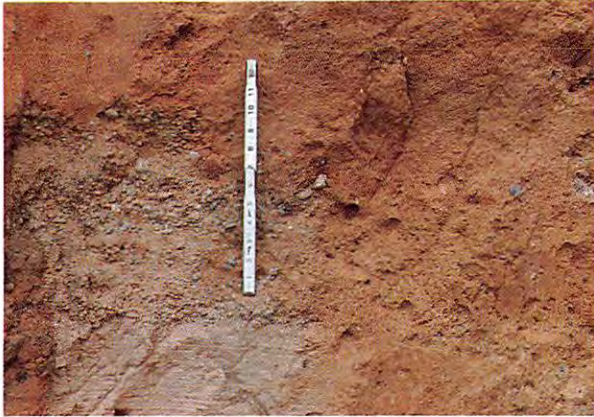
Figure 4-5. Colluvium (right of scale) within possible krotovina which truncates stratified alluvium in barrow pit profile #1. Scale is 30 cm.
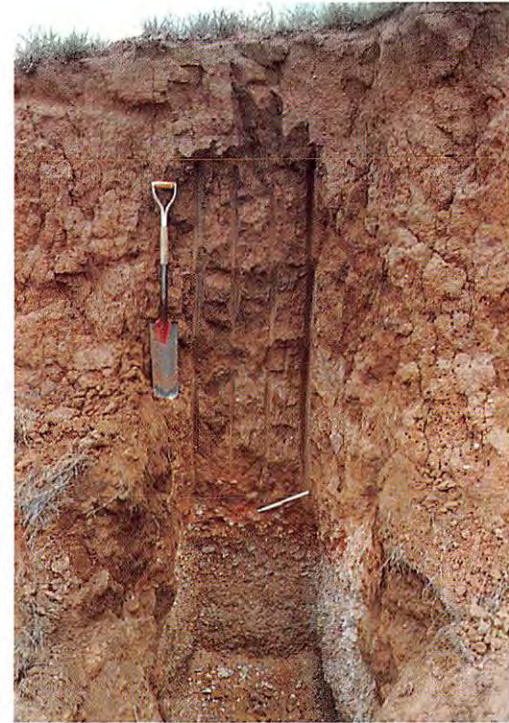
Figure 4-6. Profile of Canadian soil colluvium over alluvium at barrow pit profile #4. Scale is 30 cm.

Figure 4-7. Profile of Canadian soil in colluvium at barrow pit profile #5. Profile is described in Table 4-1.

Figure 4-8. Rounded rock fragments of Permian sandstone in alluvial layer (horizon 2C6) of barrow pitprofile. Scale is 30 cm.

Figure 4-9. Looking south at spring conduits cross sectioned in West Backhoe Trench.

Figure 4-10. View of spring conduit at north end of North Lateral to North Backhoe Trench. Note conduit's vent has been truncated by gravel scouring.

Figure 4-11. Profile of spring sediments exposed in south wall of square N2-E3. Floor is at elevation 89.2 ft (60.8 m below datum).

Figure 4-12. North wall profile of square N2-W3 showing spring conduit in cross section. Floor is at 88.5 ft (11.5 m. below datum).

Figure 4-13. Tusk with broken tip resting in brown silt loam (Unit #4) of squares 0-E2 and 0-E3. View to northwest.

Figure 4-14. Looking north at mammoth pelvis, tibia-fibula, and gravel-scoured femur in northeast corner of grid. Note south margin of gravel-filled ancient channel showing up in wall profile behind bones.

CHAPTER 5

The Alluvial Deposits and Sequence

Don G. Wyckoff

The Hajny barrow pit reveals the presence of two major deposition units: a massive colluvium that is underlain by stratified alluvial beds. These streamlaid sands and gravels merit attention because they are partially eroded and because they contain the fossil-bearing deposits. Documenting the character and stratigraphy of the alluvial beds is integral to understanding the origin, age, and taphonomy of the fossil-bearing sediments.

The sands and gravels exposed in the Hajny barrow pit represent the Canadian's channel when it was 36.6 m (120 ft) higher than now. This elevation correlates with the second of five terraces identified (Fay 1959) some 15 miles downstream. Fay (1959:10) believes this second terrace was the Canadian's active channel during Illinoian glacial times (approximately 200,000 years ago). The gravels in this terrace are predominantly metamorphic and sedimentary rocks derived from the Rocky Mountains (Fay 1959:8). A minor common constituent is Alibates agatized dolomite (Wyckoff 1989). This flint-like material was favored by prehistoric people for chipped stone tools, and it has bedrock occurrences along the Canadian's course in the Texas panhandle (Bowers 1975; Shaeffer 1958). The presence of Alibates in this terrace's gravels supports the conclusion that the terrace was deposited while or after the Canadian incised through the Alibates-bearing bedrock, which is now 150 to 200 m (490-650 ft) above the river (Bowers 1975:1-2).

The Hajny Alluvial Exposure

This site's alluvial beds manifest clues to a complex sequence of events and processes, including channel cutting and filling, the formation of springs, the entrapment of animals, and erosion. The evidence for these processes and their sequence is preserved in the profiles around the barrow pit, in the manually excavated squares, and along the 129 m (423 ft) of backhoe trenches dug around the fossil-bearing deposit (Figure 5-1). The findings at these locations are described below.

Barrow Pit Profiles

Illustrations and descriptions of the five profiles recorded around the barrow pit are provided in the preceding chapter. However, several important findings bear repeating here.

The most complete record of this terrace's alluvial beds is preserved in Profile #1 at the barrow pit's east end (Figure 5-1). Here, a 10 m (32.8 ft) profile contains 13 interbedded layers of fluvial sands, gravelly sands, gravelly sandy loams, silt, sandy clay loam, and loamy sand (Figure 4-16; Table 4-1). These fluvial deposits extend from 2.64 to 9.76 m (8.66 to 32.0 ft) below the ground surface, which at this location is 4.0 m below datum elevation (Figure 5-1). At 9.76 m (32 ft) below the surface, red Permian sandstone (of the Rush Springs Formation) was encountered. The boundary
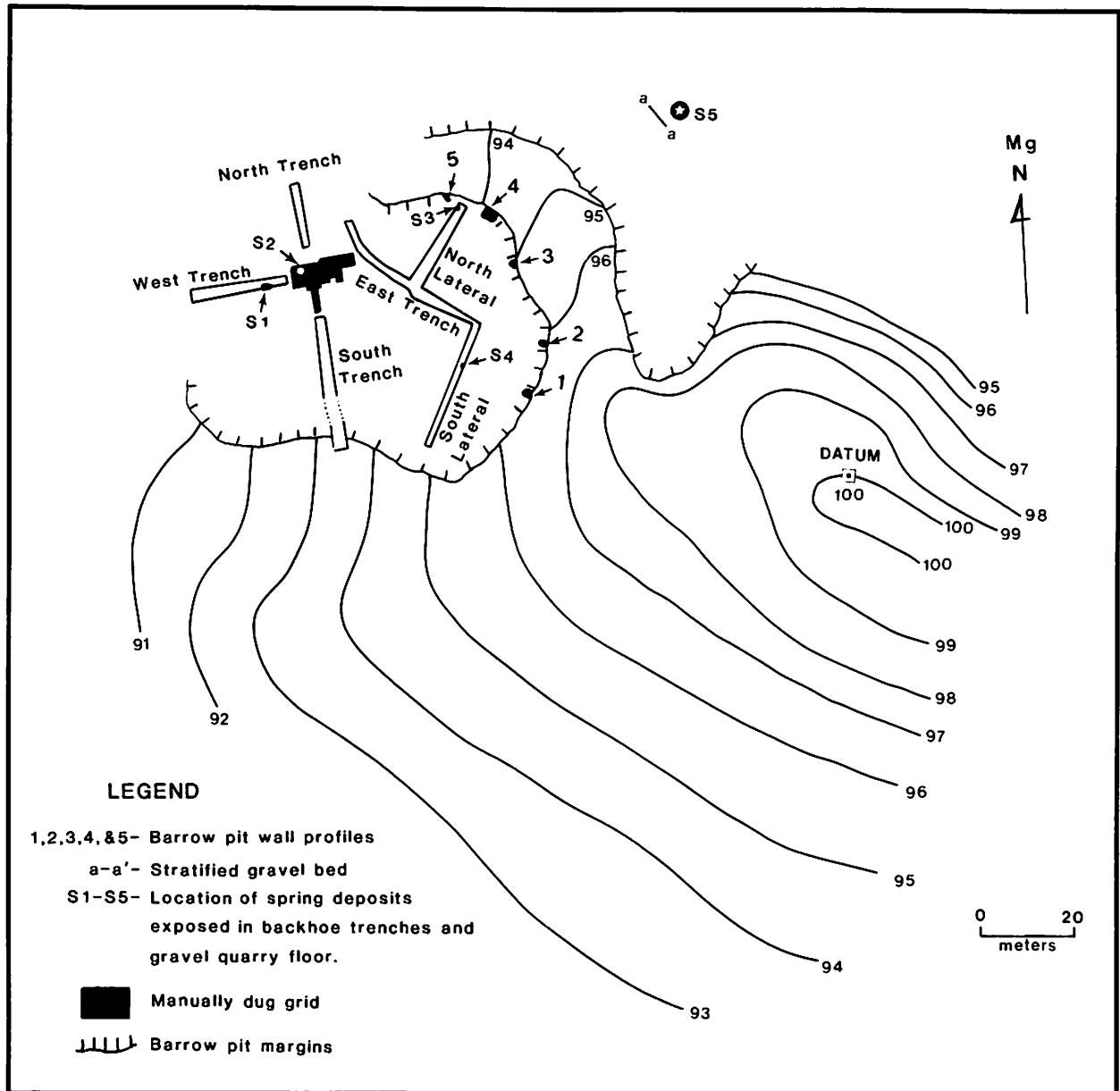
Figure 5-1. Contour map of the Hajny site (34Dw-23) and location of its excavations, profiles and spring deposits, Dewey County, Oklahoma.

between the alluvium and sandstone marks the ancient channel's bottom at 13.76 m (45 ft) below datum and indicates that 7.12 m (23.36 ft) of stream deposits are preserved here.

In contrast, just 20 m (65 ft) west of Profile #1, Profile #5 reveals that nearly 2.0 m (6.5 ft) of the alluvium are missing. This includes the uppermost six strata and much of the

seventh (Figure 4-16). The resulting slope (a 7% gradient) in the colluvium-alluvium contact between Profiles #1 and #5 is believed due to erosion.

Although not recorded in as much detail as the barrow pit wall around the mammoth remains, the profile in a nearby barrow pit merits discussion because the overall sequence resembles that of Profile #1 and be-

Figure 5-2. Interbedded sand and gravel near Spring #5 (foreground). Profile is 60 m north-northeast of barrow pit Profile #1, Hajny site (34Dw-23), Dewey County, Oklahoma. Snails from spring deposit were radiocarbon dated at 34,420 ± B.P. (corrected age; SMU-2094).

80 m (262.4 ft) southwest where the mammoth remains occur. This spring deposit is identified as Spring #5 in Figure 5-1.

Backhoe Trench Profiles

For two days during the field work, backhoes and operators were available to excavate long exploratory trenches. Radiating from the grid over the bone-bearing deposit (Figure 5-1), these trenches provided an excellent means to study and record the alluvial contexts of this find. The four trenches were designated South, North, West, and East (Figure 5-1). The East trench has two extensions, one that goes north (North Lateral) and one south (South Lateral).

cause it is adjacent a spring deposit. Located 60 m (196.8 ft) north-northeast of Profile #1 (Figure 5-1), a 6.0 m (19.7 ft) profile exhibits colluvium above two prominent layers of gravel. These are composed of well-rounded large pebbles and small cobbles, and they are separated by no less than four layers of coarse sand or gravelly sand (Figure 5-2). The lowest gravel stratum is at least a meter thick and is above a yellow (10YR 7/6, moist) sand. Just east of this profile, and approximately 10.5 m (34 ft) below datum elevation, this sand changes to a yellowish brown (10YR 5/4, moist) silt that contains numerous snail shells. Samples of this silt were collected for snail shell extraction, identification, and radiocarbon dating(Figure 5-2). This yellowish brown silt is some five meters in diameter and marks the location of a former spring like the one

South Backhoe Trench (Figures 5-1, 5-3, and 5-4). This 27.5 m (90.2 ft) long trench extends from grid square 0-S7 into the barrow pit wall south-southeast of the grid. The trench was 1.5 m (4.9 ft) wide and from 1.5 to 1.75 m (4.9 - 5.7 ft) deep along most of its length. Where the trench was cut into the barrow pit wall, this depth increased to 3.7 m (12.1 ft). Relative to datum elevation (100.00), the trench floor varied from 88.3 to 88.8 m. This elevation corresponds to a loamy sand (Horizon 2C10 in Table 4-1 and Figure 4-16) that was 2.75 m (9.0 ft) above Permian bedrock in barrow pit Profile #1. Detailed drawings (Figures 5-3 and 5-4) were made of all but 4.0 m (13.12 ft) (where the backhoe sat while digging into the barrow pit wall) of the South Trench profile.

For its first 13 meters, the South Trench profile is predominantly small and large scale cross-bedded sand (Figure 5-3). Most of the cross-bedding is trough-fill cross-stratification, but
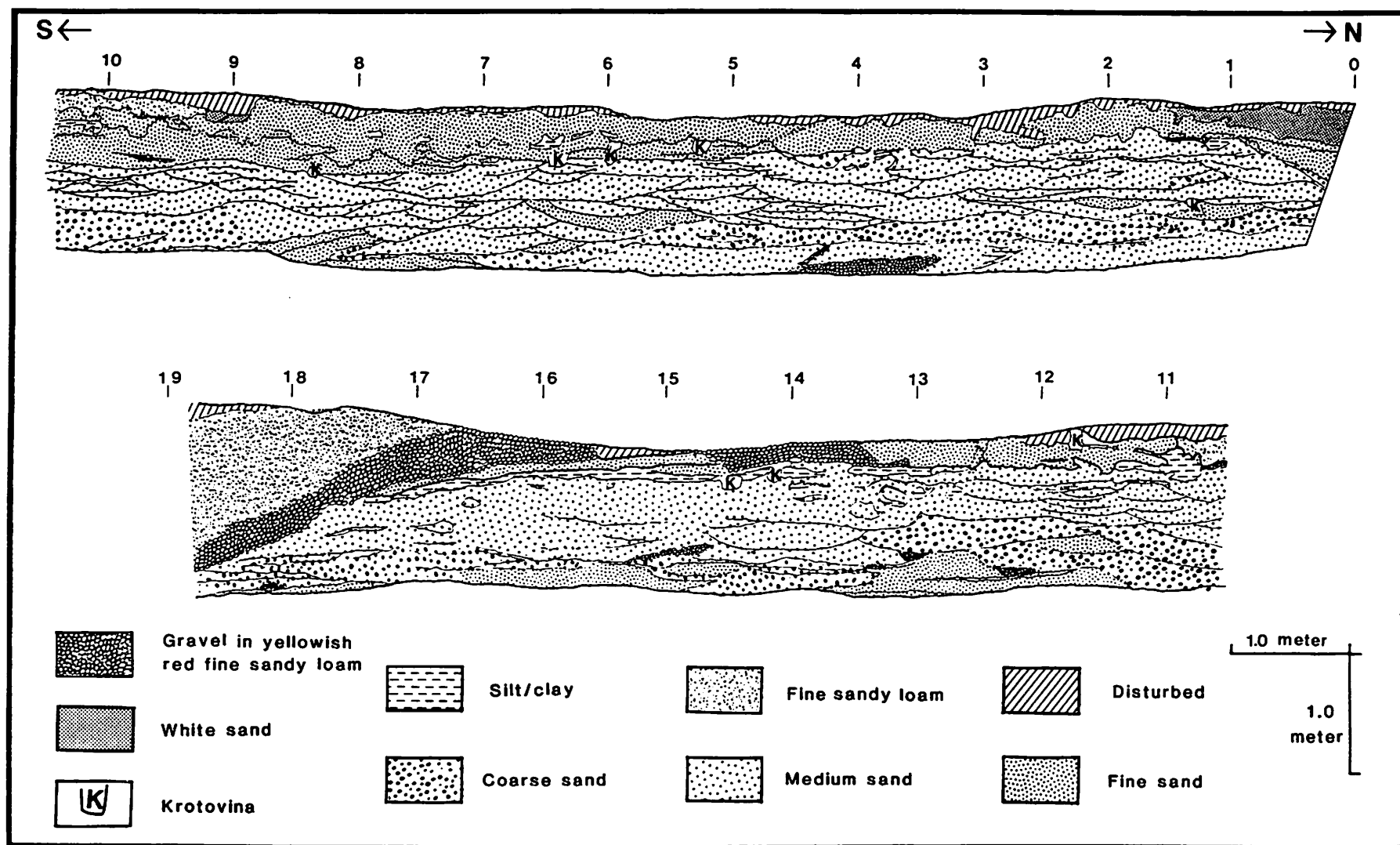
Figure 5-3. West wall profile of the South Trench (backhoe), Hajny site (34Dw-23), Dewey County, Oklahoma.
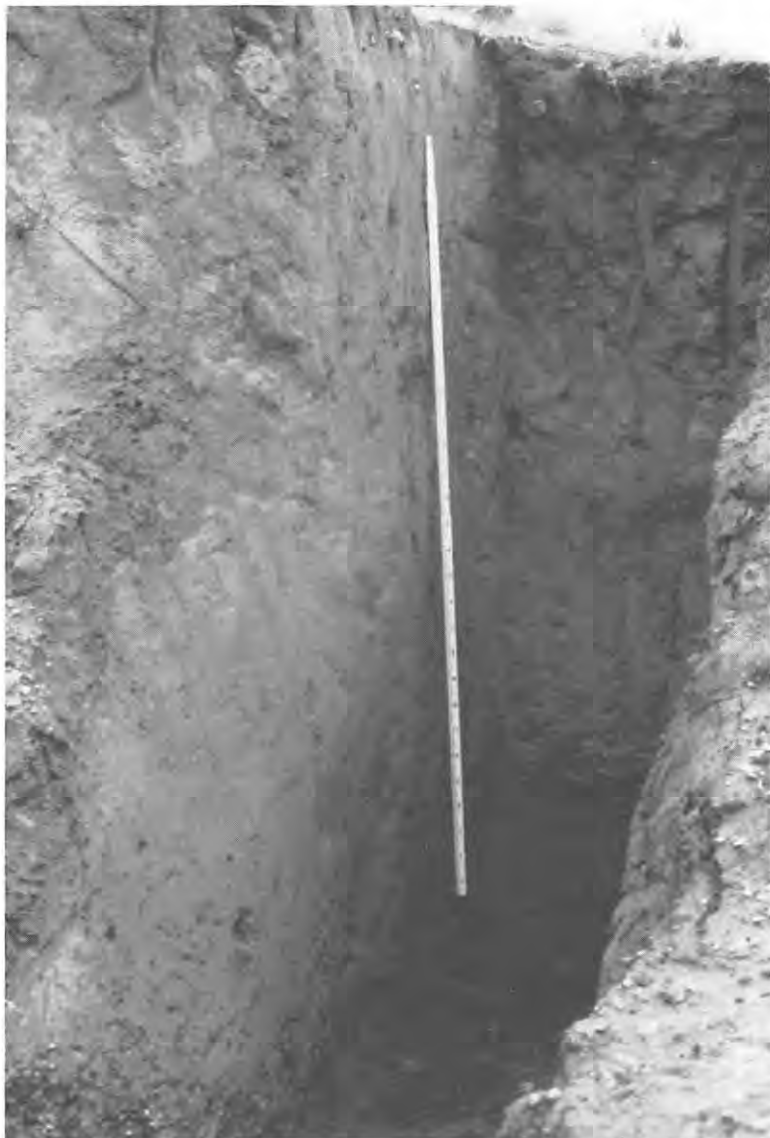
Figure 5-4. Looking south at south end of South Backhoe Trench at the Hajny site. A slightly melanized surface horizon caps nearly 3.0 meters of slightly reddish, loamy to loamy sand colluvium that overlies fluvial gravels. Scale is in centimeters.

laminae of reddish brown to black sediment. This latter is sometimes silt or clay and sometimes black-coated sand grains. At the northern end the profile is mantled by a lens of white very fine sand; this is the fluvial material that was washed and even redeposited by water from the spring that entrapped the mammoths. From meter 6 to meter 17 (Figure 5-3), a discontinuous clay stratum is manifest at 25 cm (10 in) below the surface. From meter 14 to 17.5, this clay stratum is red (rather than gray green), carbonate rich (reacts strongly to 10% HCl), and begins to dip (9% slope) to the south.

Between meter 13 and meter 19, the generally horizontal beds of sand are interrupted by a south-dipping (23% slope), 25-38 cm (10-15 in) thick layer of gravel (Figure 5-3). The clasts are well-rounded pebbles and cobbles (to 15 cm in maximum dimension) that are tightly packed in a yellowish red (5YR 4/6, moist) fine sandy loam. From meter 17 southward, this gravel is overlain by a yellowish red to reddish brown (5YR 4/4, moist) fine sandy loam that has been identified as colluvium. The southernmost 4.5 m (14.76 ft) of the South Trench profile show the gravel in a depression but beginning to rise at meter 27 (Figure 5-4).

minor amounts of foreset cross-stratification are evident at scattered segments of the profile. The prevailing color is yellowish brown (10YR 5/4, 5/8, 6/3, 6/4, and 6/6, moist). Although this sand tends to grade from fine at the top to coarse near the bottom, this sequence is broken by lenses of fine to medium sand and pebbly gravel in the lower 50 cm (19.68 in; Figure 5-3). Throughout the profile, the lens boundaries are marked by more yellow or reddish sand, or by very thin

West Backhoe Trench (Figures 5-1, 5-5, 5-6, and 5-7). A 16.5 m (54.1 ft) long trench was dug in a west-southwesterly direction from just west of grid square S1-W4 (Figure 5-1). This trench ended near a pile of overburden removed while digging the barrow pit. Like the South Trench, this one averaged 1.5 m (4.9 ft) in width, but it was more shallow. Varying from 1.25 to 1.6 m
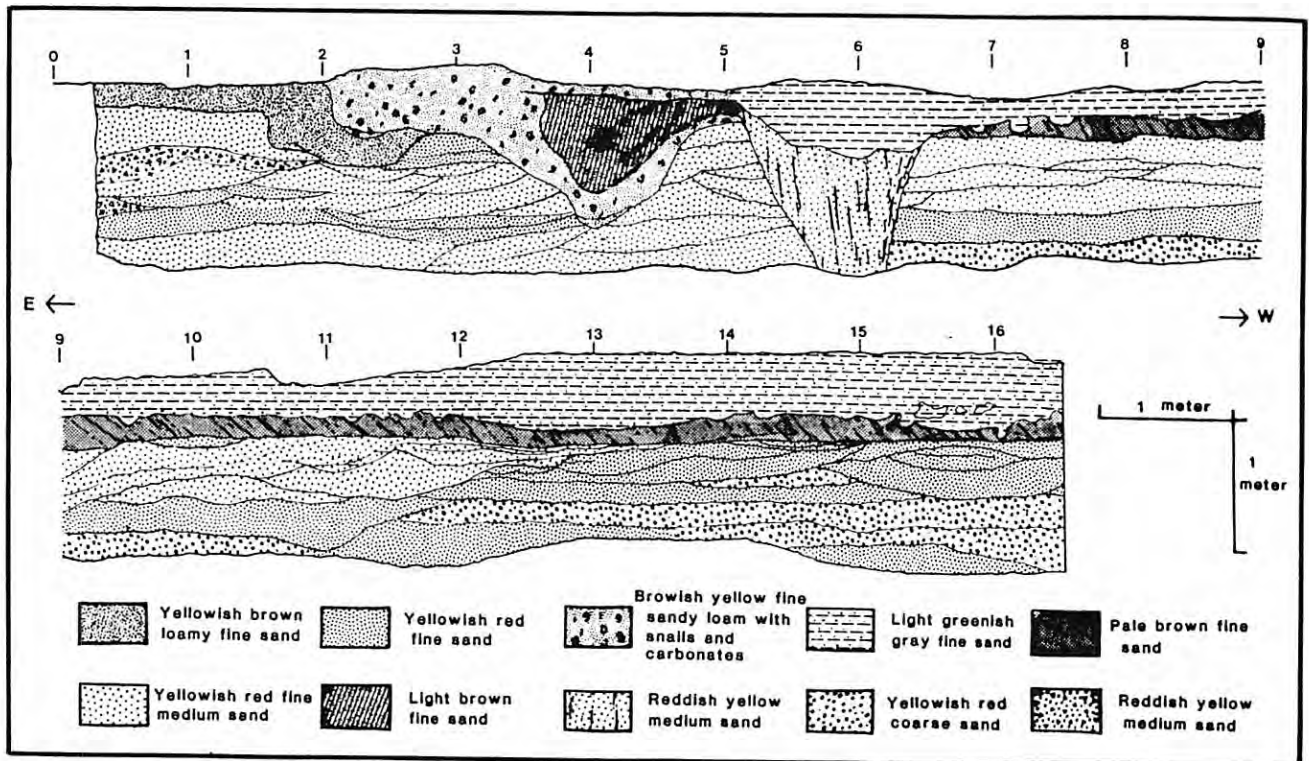
Figure 5-5. South wall profile of West Backhoe Trench, Hajny site (34Dw-23), Dewey County, Oklahoma.

Legend:
- Yellowish brown loamy fine sand
- Yellowish red fine sand
- Browish yellow fine sandy loam with snails and carbonates
- Light greenish gray fine sand
- Pale brown fine sand
- Yellowish red fine medium sand
- Light brown fine sand
- Reddish yellow medium sand
- Yellowish red coarse sand
- Reddish yellow medium sand
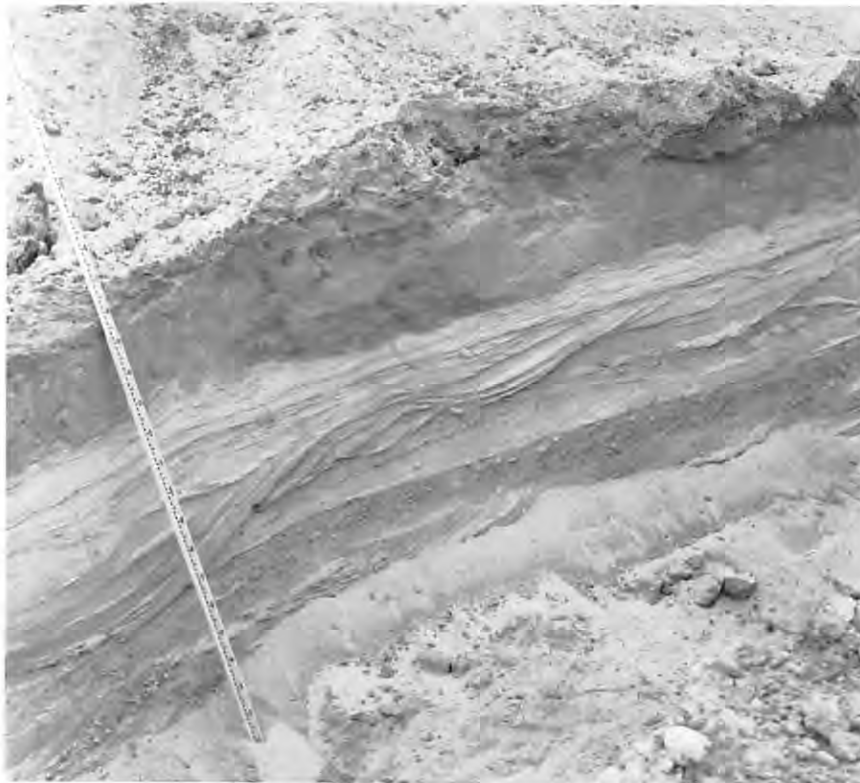
Figure 5-6. Cross-bedded fluvial sands overlain by silt loam spring sediment in West Trench. View of south wall; scale is in 10 cm increments.

Figure 5-7.   Conduits to Spring #1 as cross-sectioned in West Trench.   View looking south; scale is in 10 cm increments.

(4.1 to 5.2 ft) below the barrow pit's surface, this trench's floor was between 10.95 m (35.92 ft) and 11.3 m (37.07 ft) below datum elevation. Thus, its floor varied between 88.7 and 89.05 m. This depth corresponds to a light brown loamy sand unit (Stratum 2C10 in Figure 4-16 and Table 4-1) in Profile #1, the most complete stratigraphic record known for the site.

The West Trench profile is dominated by the small and large scale cross-bedded sand (Figure 5-6) of the same color range that was seen in the South Trench. However, this sand appears to manifest more mixing, and less stratigraphic gradation, of the fine, medium, and coarse textures than recorded in the South Trench. Foreset cross-strata prevail in the lower 25 to 30 cm (10-12 in) of the profile, whereas trough-fill cross-strata are prevalent elsewhere. Capping the western 10 m (32.81 ft) of the profile is a horizontal bed of fine gray sand.

The West Trench is distinguished by its having cross sections of two spring conduits (identified as Spring #1 in Figure 5-1) and sediments washed by these springs. These sediments include a mantle of yellowish brown (10YR 5/6, moist) to light greenish gray (5GY 7/1, moist) loamy fine sand. In the western 10 m (32.81 ft), this is underlain by a pale brown (10YR 7/3, moist) fine sand that is nearly white when dry.

Exposed at meter 4.0, the easternmost spring conduit is represented by a portion of its sediment-filled mouth (Figure 5-7). Most of this fill is a brownish yellow (10YR 6/6, moist) fine sandy loam that contains aquatic snail shells. This sandy loam effervesces strongly with dilute (10%) hydrochloric acid due to the presence of the snail shells and due to carbonates. Also present in this spring's mouth is a very noticeable cone-like deposit of light brown (7.5YR 6/4, moist) fine sand. Segments of this sand's boundaries consist of vertically-oriented red clay (Figure 5-7). This easternmost conduit is essentially 3.0 m (9.8 ft) wide.

A second spring conduit (Figure 4-9) was cross sectioned 2.0 m (6.5 ft) west of the first. Its mouth is about 1.5 m (4.9 ft) wide and narrows to a 50 cm (1.64 ft) wide neck at the floor of the backhoe trench (Figure 5-7). Vertical lenses of very pale brown (10YR 7/4, moist) fine sand fill this neck. This sandy fill was clearly extruded through the fluvial sands, and it also truncates and overlaps sediment from the east spring conduit (Figure 5-7). Capping the western spring's mouth is the light greenish gray fine sand (Figures 4-9 and 5-7). Subsequent to profiling the western spring conduit, a meter wide square was dug in the backhoe trench to further expose the conduit's neck. This square was dug to approximately 40 cm (or to 88.3 m relative to datum 100.00) below the backhoe trench floor, exposing the vertical neck where it eminates from coarse sand and small boulders of Permian sandstone. Because these may be basal gravels in the ancient channel, it appears the spring's bottom was uncovered. The neck at this point contains vertical lenses of white and black-stained (manganese?) sand. The plan view of the neck shows irregularly concentric bands of yellow (oxidized) sand.

North Backhoe Trench (Figures 4-10 and 5-8). A 11.0 m (36.1 ft) long trench was excavated north-northwesterly from the grid (Figure 5.1). This trench's southern end was 2.5 m (8.2 ft) north of grid square 0-N2; its northern extent was well into a bed of gravel (Figure 5-8). It was 1.5 m (4.9 ft) wide, and its depth ranged from 1.28 to 1.57 m (4.2 to 5.1 ft) below the barrow pit floor. These depths correlate with 88.9 and 89.19 m relative to the site's datum elevation. Such depths correspond with sandy clay loam and loamy sand fluvial deposits (units 2C9 and 2C10 in Figure 4-16 and Table 4-1) exposed in barrow pit Profile #1.

Preserved in the North Trench profile is a record of spring and river-laid sediments that were interrupted by a north-dipping (10°) bed of gravel (Figures 4-10 and 5-8). This gravel bed actually is composed of two units. The uppermost consists of a dark reddish brown (5YR 3/3, moist) fine sandy loam that contains some pebble-sized clasts. The dipping lower unit is a dark reddish brown (5YR 3/4, moist) loamy fine
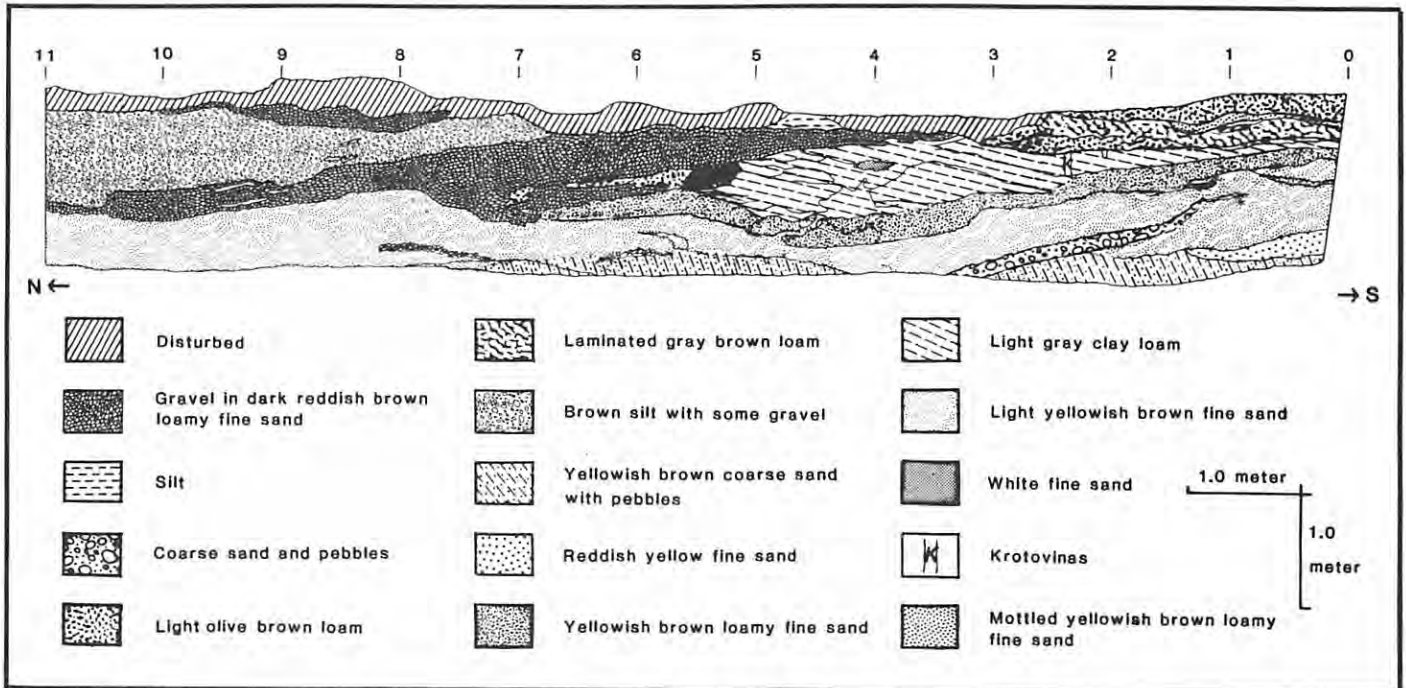
Figure 5-8. East wall profile of North Backhoe Trench where spring deposits are intersected and eroded by gravel-filled channel, Hajny site (34Dw-23), Dewey County, Oklahoma.

sand with tightly packed pebbles and small cobbles. Along its southern boundary, this second gravel deposit occasionally contains angular blocky chunks of light olive brown (2.5Y 5/6, moist) very fine sandy loam (Figure 5-8). This material has the same oxidized appearance and sometimes contains aquatic snails like observed at this site's spring vents. The chunks appear to be segments of spring deposits that sloughed off and were incorporated into the gravel as it washed downstream.

Spring deposits and fluvial sands affected by spring discharge are prevalent in the southern half of the North Trench profile. The lowest three strata are horizontally-bedded fluvial deposits: a light yellowish brown (10YR 6/4, moist) fine sand, a reddish yellow (5YR 6/6, moist) fine sand, and a yellowish brown (10YR 5/4, moist) gravelly coarse sand (Figure 5-8). The light yellowish brown fine sand extends throughout the profile and underlies the extensive gravel deposit that dominates the northern

half of the profile. Between meters 1 and 3, this fine sand (and the underlying gravelly coarse sand) is intersected by a lens of coarse sand and pebbles (Figure 5-8).

The uppermost 55 to 110 cm (1.8 to 3.6 ft) of the profile's southern half consist of loams, clay loams, and loamy fine sands that originate from, or were markedly affected by, the spring that entrapped the mammoths. The lower boundary of the affected sediments is a carbonate enriched (reacts slightly to dilute HCl), colorfully oxidized (yellowish brown; 10YR 5/6, moist) loamy fine sand that dips (9°) northward, forms a shallow depression, and is truncated by the gravel bed (Figures 4-10 and 5-8). Above this deposit lie slightly dipping (9° north) to horizontal beds of light gray (2.5Y 7/2, moist) clay loam, light olive brown (2.5Y 5/4, moist) laminated loam, light gray (2.5Y 7/2, moist) laminated loam, light yellowish brown (2.5Y 6/4, moist) loamy fine sand, and a light olive brown loam (Figure 5-8). Some carbonates and snail shells are

present in this latter. The light gray clay loam is carbonate-enriched (reacts strongly to dilute HCl), whereas the underlying yellowish brown loamy fine sand is slightly enriched. The laminated gray loam in this profile is the feathering north edge of the principal spring deposit that yielded mammoth and other animal bones.

East Backhoe Trench (Figures 5-1, 5-9, and 5-10). A 35 m (114.8 ft) long trench was dug with backhoe from a point north of the grid's east end to a point well southeast of the grid (Figure 5-1). Although diagonal and generally oriented northwest to southeast, this exploratory trench is referred to as the East Trench. The major deposition units exposed along
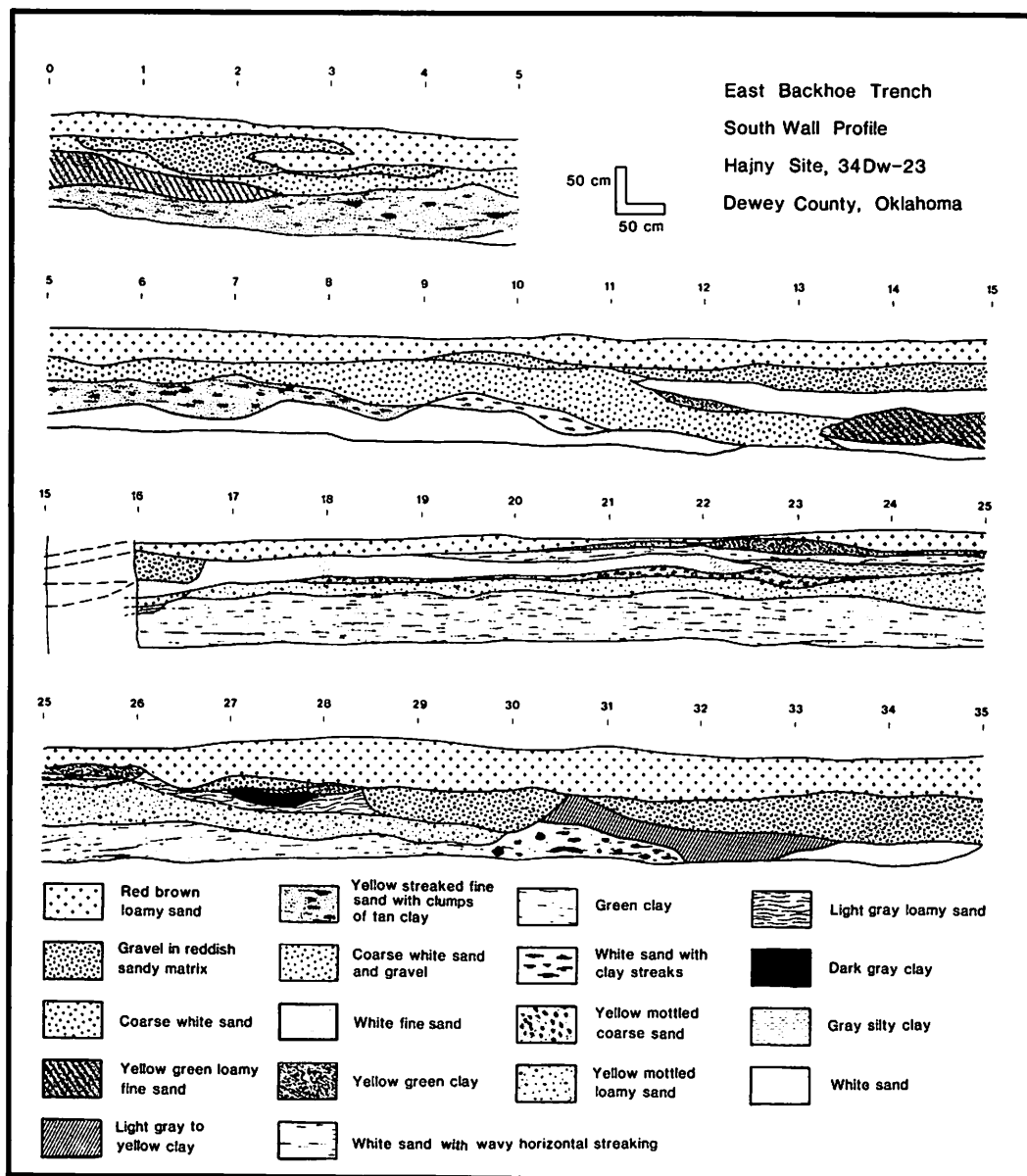
Figure 5-9. South wall profile of East Backhoe Trench, Hajny site (34Dw-23).

Figure 5-10. Sand and gravel-filled channel in north wall of East Trench just east of the manually dug grid.

its profile are illustrated in Figure 5-9. Its floor varied from 1.1 to 1.3 m (3.6 to 4.3 ft) below the barrow pit surface. These depths correspond to elevation 89.4 (relative to datum elevation) which correlates with a sandy clay loam (unit 2C9 in Figure 4-16 and Table 4-1) in the stratigraphic sequence recorded in Profile #1.

The sequence manifest in the East Trench is composed predominantly of fluvial sands occasionally interrupted or truncated by lenses of gravel or spring deposits. The prevailing sandy strata include light yellowish brown (10YR 6/4, moist), reddish yellow (5YR 6/6, moist), or pale brown (10YR 7/3, moist) sands of coarse, fine, or loamy fine texture (Figure 5-9). These strata display small and large scale trough-filled cross-

stratification and little to no particle size gradation from top to bottom. Sometimes, subangular to rounded clumps of light olive brown (2.5Y 5/4, moist) fine sandy loam or silt loam are incorporated in these otherwise sandy strata. Capping the profile is a 10 to 20 cm (4 to 8 in) thick layer of yellowish brown (10YR 5/8, moist) loamy fine sand. Some of this is mixed from machinery treads, and some of it appears in situ. The latter looks like the base of the colluvium.

Cross and longitudinal sections of gravel lenses are recorded between meters 0.3 and 3.0, 11.0 and 16.0, 28.5 and 30.5, and 30.7 and 35.0 (Figure 5-9). The gravel is typically well rounded pebbles and cobbles. These are tightly packed in a matrix of light brown (7.5YR 6/4,

dry) loamy fine sand. These gravel lenses appear to be remnants of a fan and gravel-filled channel that are oriented east to west. Within 35 m (114.8 ft), the base of one channel drops 0.5 m (1.6 ft) to the west.

One sand and gravel-filled channel was cross-sectioned between meters 28.5 and 30.5 (Figure 5-9) which is directly east of the manually dug grid. This channel is runs west-northwest, where it lies just north of grid squares N3-E6, N3-E7, N3-E8, and N3-E9. The gravel fill in this channel shows at the top of the north wall profiles in these squares (Figure 4-14). This same gravel-filled channel is believed to be the one that begins at meter 3.0 and extends northwesterly in the North Trench (Figure 5-8).

Figure 5-11. Conduit to Spring #3 in west wall of North Lateral Backhoe Trench. Note truncation by gravel that dips north(right). Scale is in 10 cm increments.

The North Lateral Trench. At meter 15.0 in the East Trench a 20.0 m (65.6 ft) long trench was dug in a northeasterly direction (Figure 5-1). Called the North Lateral, this trench was 1.1 to 1.3 m deep (3.6 to 4.3 ft below the barrow pit floor); it was dug to the base of the barrow pit wall. Except for its northern end, the North Lateral profile has trough-filled, cross-stratified and minor amounts of foreset cross-stratified fluvial sands overlain by 20 to 30 cm (8 to 12 in) of eroded and historically mixed colluvium. But at the very northern end, the fluvial sands are interrupted by a rather narrow (60cm; 1.96 ft) spring conduit filled with light brown (7.5YR 5/4, moist) fine sand (Figure 5-11). Identified as Spring #3 (Figure 5-1), this conduit is truncated by a 30 cm (11.8 in) thick layer of gravel that appears to dip north and that may be fill in another channel.

The South Lateral Trench. A 27.5 m (90.2 ft) long trench was dug south perpendicular to the eastern end of the East Trench and was called the South Lateral. This trench varied from 1.15 to 1.45 m (3.8 to 4.75 ft) in depth below the barrow pit floor. The backhoe trench floor was maintained close to 11.4 m below datum elevation (or 89.6).

The southern 12 meters of the South Lateral Trench contain the profile of a channel filled with a layer of coarse sand and pebbles above a lens of coarse gravel in a light brown (7.5YR 6/4, dry) loamy fine sand (Figure 5-12). This channel profile is directly east of the gravel-filled channel cross-sectioned in the south end of the South Trench (Figure 5-3). Because of this alignment and because the channel depth is deeper in the South Trench, the two cross sections are believed to be of a west draining channel that became filled with gravel.
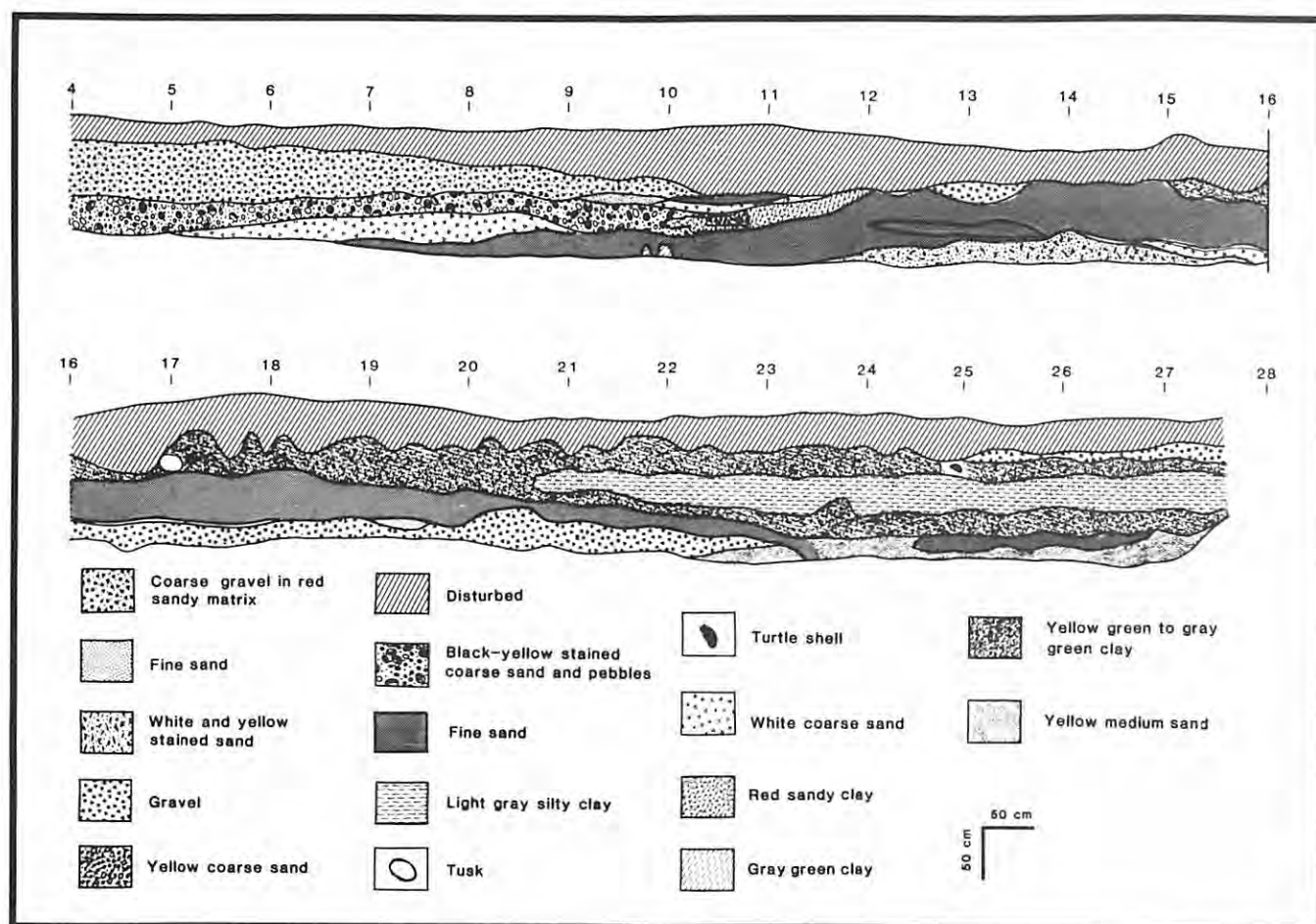
Figure 5-12. Partial profile of west wall of South Lateral backhoe trench, Hajny site (34Dw-23).

In the northern 15.5 m (50.85 ft) of the South Lateral, the profile has white to reddish yellow trough-fill cross-stratified fluvial sands overlain by lenses of gray loam and a brownish yellow (10YR 6/6, moist) loam (Figure 5-12). This latter contains numerous complete and broken snail shells. In addition, a tusk was cross-sectioned in this stratum at meter 17.0 and part of a turtle carapace was exposed near meter 25.0 (Figure 5-12). These two lenses of loam closely resemble those in the manually dug spring deposit, and they are believed to represent the margin of another spring deposit (identified as Spring #4 in Figure 5-1).

The Manually Dug Grid

Most of the time and effort at the Hajny site was spent in uncovering and recording mammoth bones in 61 hand-dug 1x1 meter squares (Figure 5-13). A total of 18.1 m³ (23.67 ft³) of spring sediments was removed from these squares. This was done by using trowels, knives, hoes, and, occasionally, picks to excavate 10 cm (3.93 in) thick levels that were correlated with the datum elevation. Relative to this elevation, 22 squares were dug to 89.3, 16 to 89.4, 13 to 89.2, 7 to 89.1, 2 to 88.5, and 1 to 89.6 (Figure 5-13). The depth where excavations were stopped was usually determined by exposing in-

Square Designations in Grid

							N3-E3	N3-E4	N3-E5	N3-E6	N3-E7	N3-E8	N3-E9
N2-W4	N2-W3	N2-W2	N2-W1	O-N2	N2-E1	N2-E2	N2-E3	N2-E4	N2-E5	N2-E6	N2-E7	N2-E8	N2-E9
N1-W4	N1-W3	N1-W2	N1W1	O-N1	N1E1	N1-E2	N1-E3	N1-E4	N1-E5	N1-E6	N1-E7		
O-W4	O-W3	O-W2	O-W1	O-O	O-E1	O-E2	O-E3	O-E4	O-E5	O-E6			
S1-W4	S1-W3	S1-W2	S1-W1	O-S1	S1-E1	S1-E2	S1-E3			S1-E6			
			S2-W1	O-S2	S2-E1								
				O-S3									
				O-S4									
				O-S5									
				O-S6									
				O-S7									

☐ 1985 Excavations
▨ 1986 Excavations
■ 0-0 Stake

Mg N

1 meter

Floor Depths (Below Datum) of Excavated Squares

							89.1	89.2	89.3	89.4	89.3	89.2	89.2
89.3	89.2	89.1	89.2	89.2	89.4	89.3	89.3	89.3	89.4	89.4	89.4	89.4	89.4
89.2	88.5	88.5	89.3	89.3	89.3	89.4	89.4	89.4	89.4	89.4	89.4		
89.2	89.3	89.3	89.3	89.3	89.3	89.3	89.3	89.4	89.4	89.6			
89.2	89.1	89.2	89.3	89.3	89.3	89.3	88.2			89.3			
			89.3	89.2	89.4								
				89.2									
				89.1									
				89.1									
				89.1									
				89.1									

Mg N

1 meter

■ 0-0 Stake

Figure 5-13. Designations and depths of squares in manually dug grid, Hajny site (34Dw-23).

Figure 5-14. West-east profile along North 2 line through spring conduct exposed in squares N1-W2 N1-W3, Hajny site (34Dw-23), Dewey County, Oklahoma.

dividual bones, ascertaining whether or not they inclined through strata, and excavating at least 10 cm (3.93 in) below their lowest point. Nowhere were mammoth bones discovered below the lowest spring deposit. This boundary was easily traceable because the spring's lowest deposit was a light gray laminated clay loam immediately underlain by a colorful (yellowish brown, 10YR 5/6) fluvial sand that contained a discontinuous layer of lumpy carbonate nodules.

Squares N1-W2 and N1-W3 were dug 70 to 80 cm deeper than surrounding squares (Figure 5-13). This was done because the mammoth bone exposed here dipped sharply to the west. Upon tracing these bones and the silty sediment containing them, it was dis-

covered they were in the mouth of the principal conduit for the spring deposits manifest here. By excavating squares N1-W2 and N1-W3 to a depth of 88.5 (11.5 m below datum elevation) it was possible to obtain a profile and plan view of this conduit and its mouth (Figures 4-12 and 5-14). A second possible conduit may exist in square S1-E6 where spring sediments were exposed deeper (and show a pronounced dip; Figure 5-17) than anywhere else in adjacent squares.

As the grid excavations progressed, it became apparent that gravel quarrying had removed most of the spring deposits from the southwestern third of the grid. There, mammoth bones were scraped by the heavy machinery (bulldozer or front-end loader) or lay badly crushed just below the graded surface. Fortunately, north of the North 1 base line
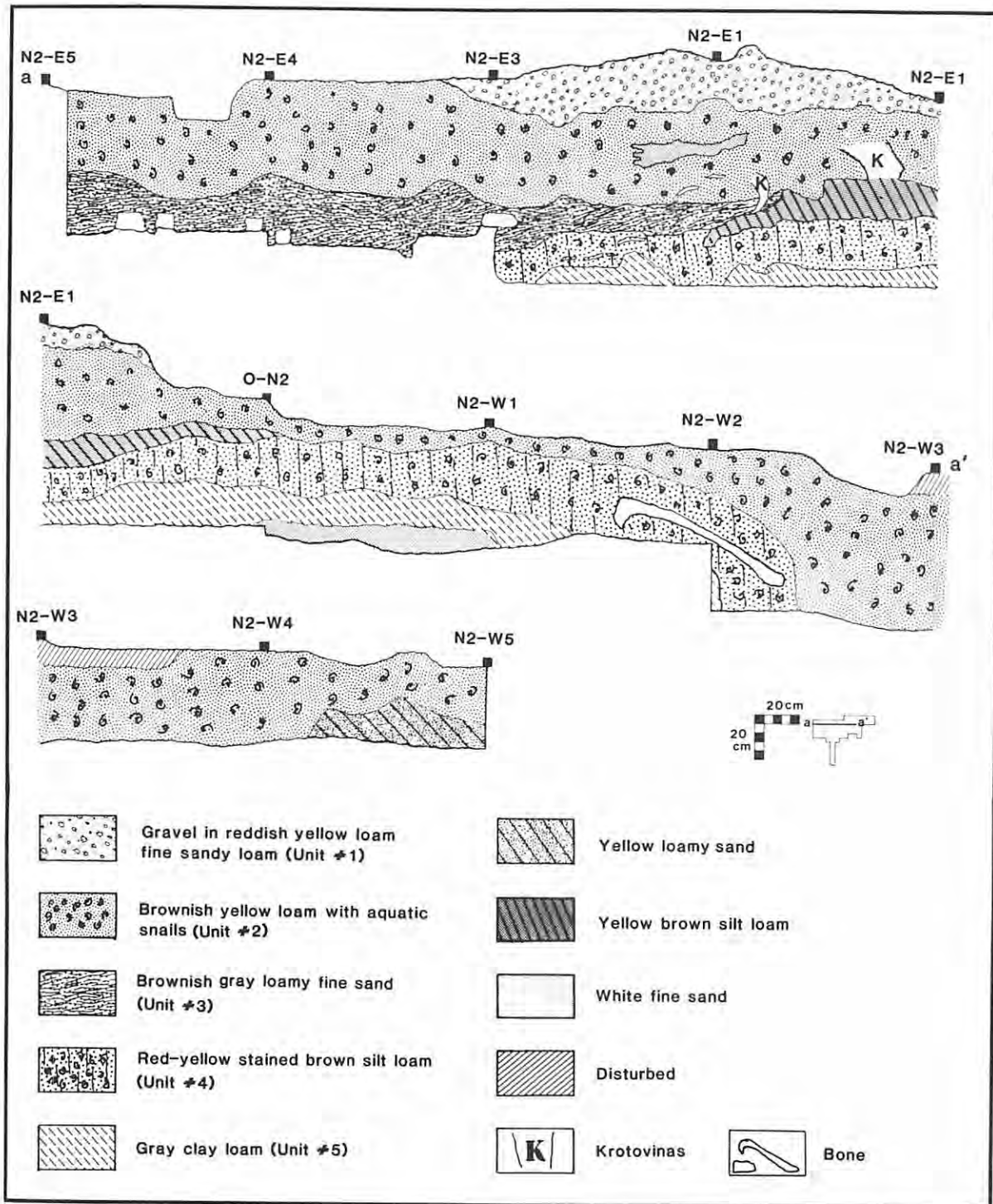
Figure 5-15. East-west profile of spring deposits along North 2 line, Hajny site (34Dw-23), Dewey County, Oklahoma.
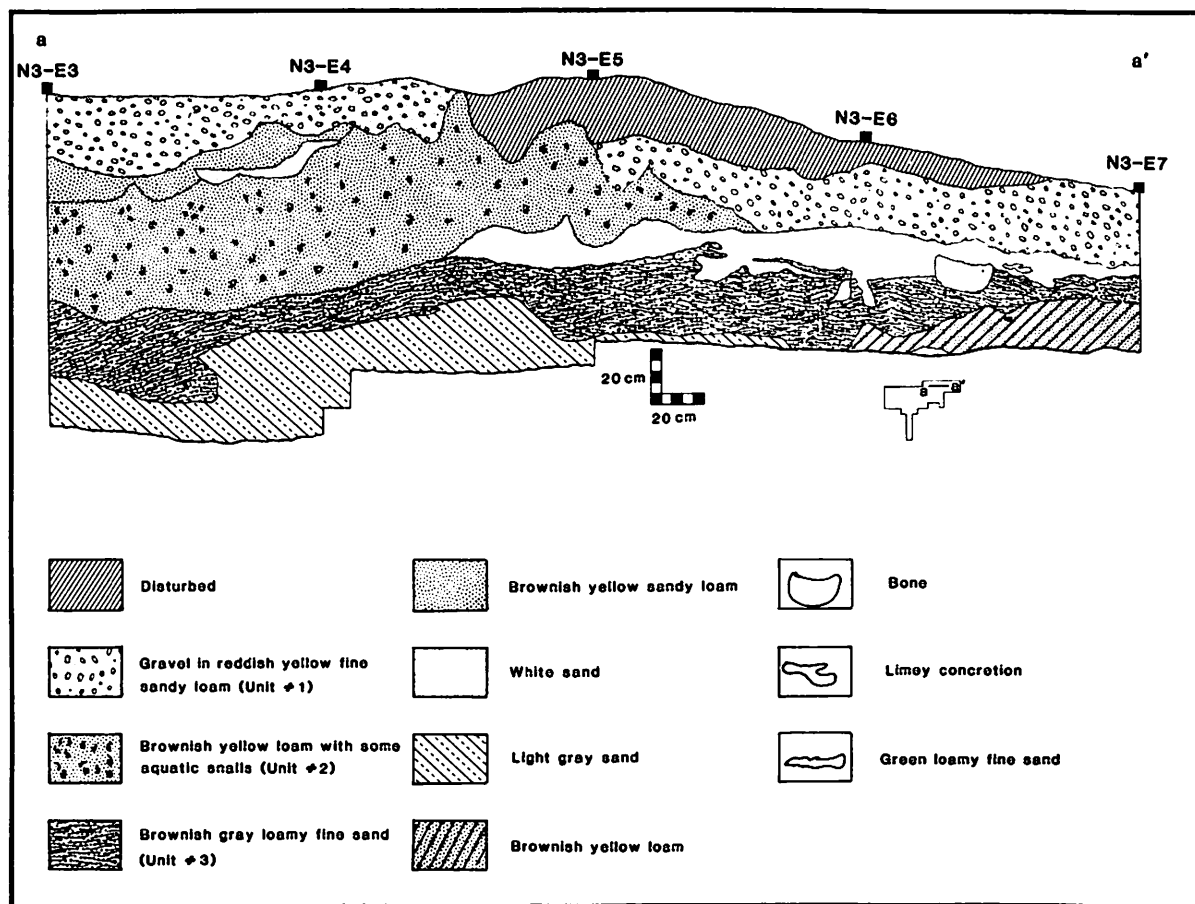
Figure 5-16. Profile of spring and other sedimentary deposits between grid stakes N3-E3 and N3-E7, Hajny site (34Dw-23). Dewey County, Oklahoma.

and east of the East 1 line, the stratigraphic record was more complete. Consequently, profiles were made along the grid lines north and east of stake N1-E1 (Figures 5-15 through 5-17).

Stratigraphy Within the Grid

Two different stratigraphic records are manifest within the grid. Most squares contain at least part of a stratified sequence of five deposition units. Four are believed to relate to spring discharge, sedimentation, and weathering. Capping them is the fifth unit, one that attests to gravel scouring and accumulation some time after spring discharge had stopped. In the northeasternmost seven squares, however, the overall profile is markedly different due to the spring deposits having been reworked by erosional and fluvial processes.

The Spring Stratigraphy. Four strata originate as sediments discharged from the spring conduit exposed in squares N1-W2 and N1-W3, and possibly from another vent suspected in square S1-E6. The sequence and variable thicknesses of these four strata are shown in several east-west and north-south cross sections (Figures 5-15, 5-16, and 5-17). Colors and other characteristics of these strata (and the overlying gravel deposit) are given in Table 5-1. From the top down, the stratigraphy includes:

Unit #1: a reddish yellow fine sandy loam with many pebbles and occasional small cobbles. This was the gravel deposit that was being quarried when the mammoth bones were discovered; the deposit was entirely scraped away west of a diagonal line between squares 0-N2 and 0-E5 (Figure 5-13). Where present, Unit #1 has an abrupt, very irregular wavy boundary due to scouring of the underlying stratum.

Table 5-1. Stratigraphic Units Recorded at 30 Centimeters West of Stake N2-E3, Hajny site (34Dw-23), Dewey County, Oklahoma.

Unit	Thickness (cm)	Munsell colors	Distinguishing characterics
1	0 - 9.5	7.5YR 6/6, dry 7.5YR 5/6, moist	Reddish yellow fine sandy loam with many pebbles and occasional small cobbles; massive structure; abrupt wavy boundary.
2	9.5 - 32.5	10YR 5/8 to 10YR 6/8, dry; 10YR 6/6, moist.	Brownish yellow loam with weak medium platy structure; contains occasional pebble-size carbonate concretions, occasional small pebbles, and numerous snail shells (complete and broken); abrupt wavy boundary.
3	32.0 - 40.5	10YR 6/1 to 10YR 7/2, dry; 10YR 6/2, moist	Light brownish gray loamy fine sand with reddish yellow stains; weak medium platy structure; abrupt wavy boundary.
4	40.5 - 46.25	10YR 6/1, dry; 10YR 5/3, moist	Brown silt loam with reddish yellow stains; massive structure; abrupt wavy boundary.
5	46.2 - 50.25 +	10YR 6.3, dry; 10YR 7.2, moist	Light gray clay loam with weak thin platy structure; contains occasional small concretions of crystaline material; abrupt wavy boundary.

Unit #2: a brownish yellow loam containing aquatic snail shells (broken and complete) is the uppermost spring deposit and mantled most of the excavated area where gravel wasn't present. In some places, this unit is nearly 25cm (9.8 in) thick; the tusks and some thick bones extend up into it (Figures 4-13). Weak platy structure and small carbonate concretions attest to this unit having undergone some pedogenesis (Figure 5-18).

Unit #3: a light brownish gray loamy fine sand with reddish yellow stains. It has a weak medium platy structure and ranges from 5 to 12cm (.05 to 4.72 in) in thickness. East of the north-south base line, some bones were resting in this unit.

Unit #4: a brown silt loam with reddish yellow stains. Although massive in structure, this stratum appears laminated. It varies from 10 to 15cm (3.93 to 5.90 in) in thickness. The mammoth bones lying west of the north-south base line and many east of this line are in this unit. It is the principal deposit traceable to the spring conduit in squares N1-W2 and N1-W3 (Figures 4-12 and 5-14). Snails are concentrated in a few spots, including the conduit area in square N1-W3; a sample of these was radiocarbon dated.

Unit #5: a light gray clay loam with weak thin platy structure; typically around 5cm (1.96 in) in thickness. It contains occasional very small spar-like concretions that could be gypsum or selenite. This is the lowest sedimentary unit of the spring deposit, and it overlies yellow oxidized fluvial sands. At irregular points across the grid, lumpy sandy carbonate concretions (up to 10 cm long and 3 cm thick) were encountered between Unit #5 and the fluvial sands.
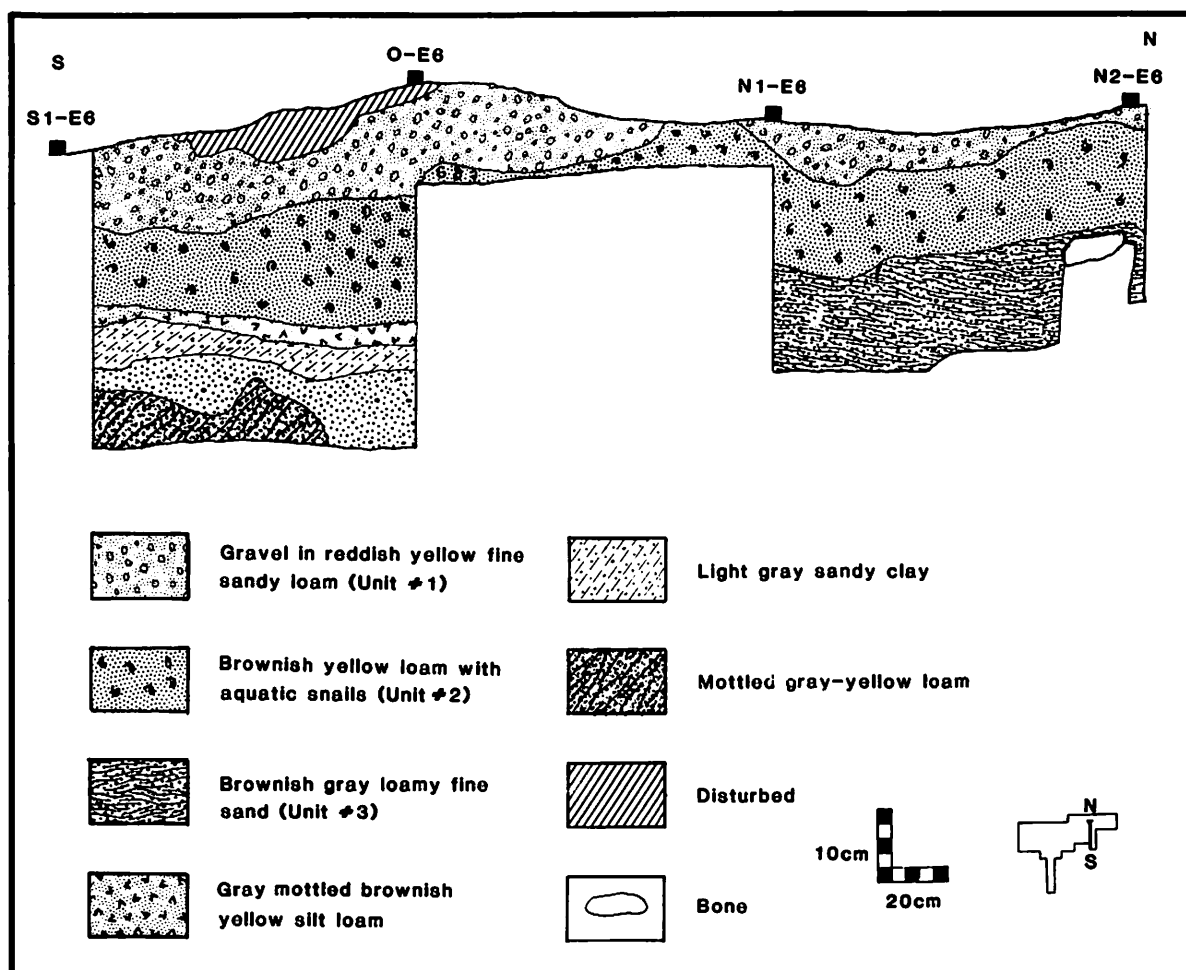
Figure 5-17. South-north profile of spring deposits along East 6 line, Hajny site (34Dw-23),
Dewey County, Oklahoma.

The Modified Spring Stratigraphy. Partially due to post-depositional processes, the spring deposit stratigraphy begins to change in the northeastern corner of the grid. Although several of the recognized spring deposits continue, they occur with new or altered strata in squares N2-E7, N2-E8, and N3-E5 through N3-E9. In these squares, Units #2 and #3 of the recognized spring sequence are present, but in somewhat modified form. Both thin and feather out as they extend east and north, and their stratigraphic relationship is changed because they become separated by a lens of white sand (Figure 5-16). Moreover, Unit #3 no longer has Units #4 and #5 directly

underneath. Instead, a lens of brownish yellow loam now underlies the easternmost meter exposure of Unit #3, whereas a light gray sandy loam underlies the rest (Figure 5-16).

As observed over much of the grid east of the north-south base line, the gravel deposit identified as Unit #1 mantles the profile in the grid's northeastern corner. But even with Unit #1, as with Units #2 and #3, its stratigraphic relationship isn't always the same as recorded elsewhere. Northward from the northern part of N2-E4, for example, lenses of white sand and brownish

Figure 5-18. South wall profile of square N2-E3 showing gravel stratum (Unit #1) over weakly laminated loam (Unit #2) that contains aquatic snails and pebbly carbonate concretions. Units #3, #4,and #5 underlie the laminated loam. Scale is in 10 cm increments.

yellow sandy loam lie between Unit #1 and Unit #2 (Figure 5-16). In squares N3-E6 and N3-E7, Unit #1 lies above another lens of white sand, which in turn is above Unit #3 (Figure 5-16).

The latter white sand lens seems an important marker in this part of the grid. Where this lens occurs there is also evidence of channel cutting, bank sloughing, vertical cracking, and/or gravel scouring. The white sand lens extends from the southern margin of square N3-E4 eastward to the midpoint of square N2-E6's northern boundary. From there, the lens angles across that square's northeastern corner and then goes east across the northern three-quarters of N2-E7, N2-E8, and N2-E9. Along its southern and western margins this white sand interfingers with the gray loamy fine sand of Unit #3 (Figures 5-16, 5-19, 5-20, and 5-21). In squares N2-E6, N2-E7, N3-E5, and N3-E6, this white sand thinly covers a mammoth's ribs, pelvis, left femur, and right tibia and fibula, all of which were seated in Unit #3 (Figure 5-21). The white sand thickens to the north (Figure 5-21) and is extensively mixed with Unit #3-like material in squares N3-E7, N3-E8, and N3-E9.

Along the northern edges of these three squares, jumbled concentrations of broken and abraded (by water and sand) mammoth and other bones lay in the mixture of white sand and gray loamy fine sand (Figures 5-22). At floor depth 89.2 in N3-E8 and 89.6 in N3-E9, sand and gravel filled cracks were

recorded (Figure 5-23) in the gray sandy loam that lies beneath the mixture of white sand and gray loamy fine sand.

Although sand or gravel filled cracks were not observed, squares N2-E7 through the western half of N2-E9 contained abundant broken bone below the white sand lens. Per- haps most intriguing as far as evidence of post-deposition reworking of the spring deposits is the mammoth left femur in square N2-E7. For nearly its entire length, the up- permost quarter to a third of this femur's head, shaft, and lateral condyle have been abraded away by gravel movement (Figure 5-24).

Figure 5-19. South wall profile at stake N3-E6 showing gravel over white sand that is interbedded with gray loamy fine sand (Unit #3). Partially exposed femur head rests in Unit #3. View to south.

Figure 5-20. South wall profile of square N3-E4 with
white sand interfingering with gray
loamy fine sand (Unit #3) that contains
mammoth ribs. Scale is in centimeters
and inches. View to south.

Figure 5-21. Looking southwest at square N3-E6 with exposed
mammoth tibia and fibula. Note white sand lens in
profile and how it thickens to the right (north) while
interfingering with underlying gray loamy fine
sand (Unit #3).

Figure 5-22. Looking west at a jumble of broken and stream-abraded bones lying in white sand with gray loamy fine sand in north edges of squares N3-E7 and N3-E8. Scale points north and is in 10 cm increments.

Figure 5-23. Sand and gravel filled crack in floor of N3-E9 at elevation 89.4. Scale points north and is in 10 cm increments.

Figure 5-24. Gravel-scoured mammoth femur in square
N2-E7. Floor shows mixing of white sand with
gray loamy fine sand (Unit #3). Top is north.

CHAPTER 6

Absolute Dates for the Hajny Site

Don G. Wyckoff

With the discovery of several mammoths in different deposits that were eroded or buried by diverse sediments, dating the Hajny site's finds became increasingly important. Finding something datable became an even more pressing problem. As the manual excavations progressed, the main spring's deposits yielded only occasional smears of charcoal, none in quantities favored by most radiocarbon laboratories. Consequently, Hajny site dating has had to rely on less suitable materials and more unusual techniques than are preferred.

Samples of mammoth bone, mammoth teeth, aquatic snail shells, and organic-looking sediments were eventually submitted for dating. All samples but one are from Spring #2. The exception (SMU-2094) is from Spring #5. These samples yielded highly variable results (Table 6-1).

Bone Dates

A date of 8960 ± 240 B.P. (WSU-2941) was obtained by radiocarbon dating mammoth bone. In this instance the organic fraction collagen was chemically isolated and subjected to regular β-decay counting.

The result is totally inconsistent with a uranium/thorium derived date (McKinney 199E1 in Table 6-1) from a molar of the same animal. The date is also a millenium too recent for mammoths in general. No reliable dates support the contention that mammoths persisted later than 10,000 years ago (Mead

and Meltzer 1984; Meltzer and Mead 1983, 1985). Moreover, notable problems arise in dating Pleistocene animal bones (Meltzer and Mead 1985:160-161). As they weather in the open air and especially as they are incorporated into sediments or soils, bones begin to undergo chemical changes. These can affect both inorganic and organic compounds in the bone, causing the loss of some potentially datable compounds or their replacement with contaminants (Stafford et al. 1987, 1988). Under certain conditions, however, datable organic fractions, may be preserved and can be extracted and radiocarbon dated by accelerator mass spectrometry (Stafford et al. 1991). Contamination was clearly a problem with the second Hajny bone sample (Table 6-1) and more than likely figured in the early Holocene result obtained for the first submitted bone samples. For these reasons, and because many bones looked chemically degraded and/or altered, it was decided to forego accelerator dating organic fractions from any additional bone samples.

Mammoth Teeth Dates

Fossil bones and teeth have long been known to absorb uranium isotopes and their related elements (Cherdyntsev 1956a 1971; Rosholt 1958). Although uranium series dating of bone has tended to provide results congruent with archeological, geological, and/or radiocarbon estimates, uranium series dating of fossil teeth has yielded unsatisfactory results (Szabo 1979, 1980, 1982; Szabo, Stalker, and Churcher 1973).

Recently, Southern Methodist University graduate student Curtis McKinney has been endeavoring to refine and improve the application of uranium series dating to fossil teeth. By focusing only on teeth enamel, he believes the derived thorium/uranium ratios provide more consistent results than previous efforts that used enamel, cementum and dentine (McKinney 1978; Szabo 1982). Because he was already working with mastodon teeth from Missouri, Curtis readily agreed to perform uranium series dating on the Hajny site's mammoth teeth.

Single molars from both mammoths found around Hajny Spring #2 were taken to Southern Methodist University. Both molars appeared to be well preserved and manifested no signs of chemical degrading. Mr. McKinney thin-sliced segments of interior enamel from each molar, ground each sample, and used heavy liquids (2.85 density) to separate enamel particles from those of potentially contaminating dentine and cementum. With his procedures, the derived enamel sample is believed 99.9% pure. The subsequent procedures closely followed those described by Szabo (1979, 1982) and McKinney (1978). During the fission track analysis, the results did not indicate any unusual uranium distributions, an observation that again suggests the teeth were not contaminated. From his uranium/thorium findings, Mr. McKinney determined that the second or third lower molar of the west mammoth was roughly 143,000 years old (Table 6-1), whereas an upper third molar from the east mammoth was approximately 166,000 years old (Table 6-1).

Both dates are far older than the age indicated by a radiocarbon determination on bone from the west mammoth. Moreover, both uranium series dates implicate at least a late Illinoian glacial or early Sangamon interglacial age for the animals, the spring deposit, and the terrace. While these uranium series results seem congruent with the Hajny site's position in a terrace sequence, it is important to remember that this dating technique is still in an experimental stage. Earlier applications

to fossil teeth from other locations have led to results inconsistent with their stratigraphic and geomorphic situations (Szabo 1979, 1980, 1982). Despite McKinney's belief that these inconsistent results can be eliminated by focusing on teeth enamel, his uranium series dating of other Oklahoma fossil teeth has not resolved questions of the technique's reliability. For example, a bison tooth from a late Pleistocene/early Holocene deposit at site 34Cd304 in Caddo County (some 40 miles south of Hajny) yielded a date of 276,000 ± 16,000, and a bison tooth from a Burnham site (in Woods County, some 80 miles northwest of Hajny) deposit radiocarbon dated no older than 26,800 B.P. yielded a uranium/thorium date of 98,000 ± 4,500 B.P. Clearly, much remains to be learned about uranium series dating of fossil teeth before it is widely accepted as a reliable technique.

Snail Shell Dates

Three samples of aquatic snail shells were radiocarbon dated, and all yielded results indicative of a late Wisconsin age (Table 6-1). Two samples (SMU-2093 and WSU-2942) came from Spring #2 sediments and attest to a period of 21,000 to 27,000 years ago. The third sample (SMU-2094) comes from Spring #5 and dates to slightly more than 34,000 years ago. Large statistical deviations are shown (Table 6-1) for the two samples analyzed by Southern Methodist University and are, in part, due to small sample sizes (0.24 g and 1.2 g).

Freshwater snail shells are among the most problematical materials for obtaining consistent, reliable radiocarbon dates (Meltzer and Mead 1985:Table 2; Taylor 1987:52). Gastropod shells typically yield wide ranging ages, apparently because they are susceptible to carbon contamination from more diverse processes than marine shells (Rubin and Taylor 1963; Tamers 1970). Most serious is contamination from ancient carbon dissolved from eons-old limestone into ground water that eventually reaches habitats where snails live, grow, and reproduce. Consequently, snail shells typically date older than they actually are (Evin, Marechal, Pachiaudi, and

Table 6-1. Radiocarbon and Uranium/Thorium Dates for the Hajny Site (34Dw-23), Dewey County, Oklahoma.

MATERIAL Sample number	Date (uncorrected)	Provenience	Discussion
BONE			
WSU-2941	8960 ± 240 B.P.	Spring #2: brown silt loam resembling "blue clay" of other western Oklahoma late Pleistocene sites; sample collected during first visit; exact stratum uncertain but probably Unit 4.	Sample was thick-walled fragments of mammoth bone; β-decay count run on collagen.
WSU-3390	No result due to contamination	Spring #2: brown silt loam (Unit 4) of square 0-W3; elevation 89.8.	Mammoth ulna segment; β-decay count run on collagen; despite being repurified, sample was still contaminated.
MAMMOTH TEETH ENAMEL			
McKinney 199E1	143,026 ± 5500 B.P.	Spring #2: tooth resting in brown silt loam (Unit 4) at elevation 89.4 in northeast corner of square 0-S1.	U-234/Th-230 ratio manifest in interior enamel of mammoth molar (left $_{2-3}$?M); process performed by Curtis McKinney at Southern Methodist University.
McKinney 200E1	166,045 ± 6500 B.P.	Spring #2: tooth resting on light brownish gray loamy fine sand (Unit 3) at elevation 89.4 in north-central part of square N1-E4.	U-234/Th-230 ratio manifest in interior enamel of mammoth molar (left ^{3}M); process performed by Curtis McKinney at Southern Methodist University.
SEDIMENT			
Beta-19949	No result due to inadequate carbon	Spring #2: light brownish gray loamy fine sand (Unit 3) around tip of tusk at elevation 89.3 in square 0-E1.	Most organic looking sediment was submitted for β-decay counting process of radiocarbon dating; sample did not contain sufficient carbon for process.
SNAIL (Aquatic) SHELLS			
SMU-2093	21,587 ± 2364 B.P.	Spring #2: brownish yellow loam (Unit 2) at elevation 89.0 in square N1-W3; unit is next to last fill in spring conduit.	β-decay count corrected for isotope 13/12C fractionation makes this sample date to 21,830 ± 2360 B.P.
SMU-2094	34,169 ± 2378 B.P.	Spring #5: yellowish brown silt that is principal fill of deeply buried (under colluvium, sand, and gravel) spring conduit some 80 m east-northeast of Spring #2.	β-decay count corrected for isotope 13/12C fractionation makes this sample date to 34,420 ± 2380 B.P.
WSU-2942	27,890 ± 415 B.P.	Spring #2: collected from "blue clay" (which is probably Unit 4, a brown silt loam) during first visit to site.	β-decay count corrected for isotope 13/12C fractionation makes this sample date to 20,000 ± 415 B.P.

Puissegur 1980; Taylor 1987:52-53). Because they can fix carbon depleted of C-14, and because their shells can be contaminated or recrystalized after death, freshwater snails may also date younger than they actually are (Yates 1986).

CHAPTER 7

Interpreting the Hajny Site Geology

Don G. Wyckoff and Brian J. Carter

Gravel quarrying and archeological excavations at the Hajny site revealed an intriguing series of fossil-bearing spring sediments and fluvial deposits affected by erosion, mass wasting, and soil development. Preceding chapters have described the site's setting, stratigraphy, and absolute dates. Our purpose here is to synthesize these findings into a credible explanation of the processes and events that created the Hajny site as we found it.

Understanding of the Hajny site increasingly changed as the excavations uncovered more and more of the geologic contexts. At first, the site was thought to be a spring that formed in a swale eroded on a hillside and that entrapped a mammoth sometime between 10,000 and 27,000 years ago. This age was based on the initially derived bone and snail shell dates provided by Washington State University. With excavation of the first backhoe trenches, gravel-filled channels found north and south of Spring #2 appeared to be later erosional (cut and fill) features. The reddish brown sandy loam incorporated into these channels was considered to be derived from the similarly colored soil manifest in barrow pit profiles east of Spring #2, so the erosional features were believed to be gulleys filled with gravel and soil eroded from the prehistoric hillside.

The above interpretation prevailed until midway through the 1986 field work. Then, as the east backhoe trench was dug, the foundations of this interpretation began to crack. The east backhoe trench exposed the gravel-filled channels farther east and still incised through the cross-bedded fluvial sands, but now in fluvial deposits well below the reddish brown sandy loam soil profiled in the barrow pit's east wall. This occurrence clearly indicated that the reddish brown, gravel-filled channels were not erosional features cut after that soil had developed. Our initial interpretation crumbled rapidly as fresh backhoe cuts along the barrow pit wall revealed that extensive erosion (slope wash or gulleying) had removed nearly 3.0 m (9.84 ft) of fluvial sands originally overlying the spring deposits. Our understanding changed markedly when more gravel quarrying in a separate pit to the east uncovered Spring #5 under stratified fluvial sands and gravels and a thick mantle of soil (Figure 5-2). Based on all these findings, the several spring deposits were definitely features that developed during one stable phase in the Canadian's aggrading a channel at this elevation. Consequently, we offer the following revised interpretation of the Hajny site geology.

The Hajny Site And Canadian River History

Geologist Robert O. Fay (1959, 1962) has described an interesting Pleistocene history for the Canadian River through Dewey, Custer, and Blaine counties. In part, the Canadian's past has been structurally controlled by a broad, north-northeast oriented syncline and by west dipping, southeast
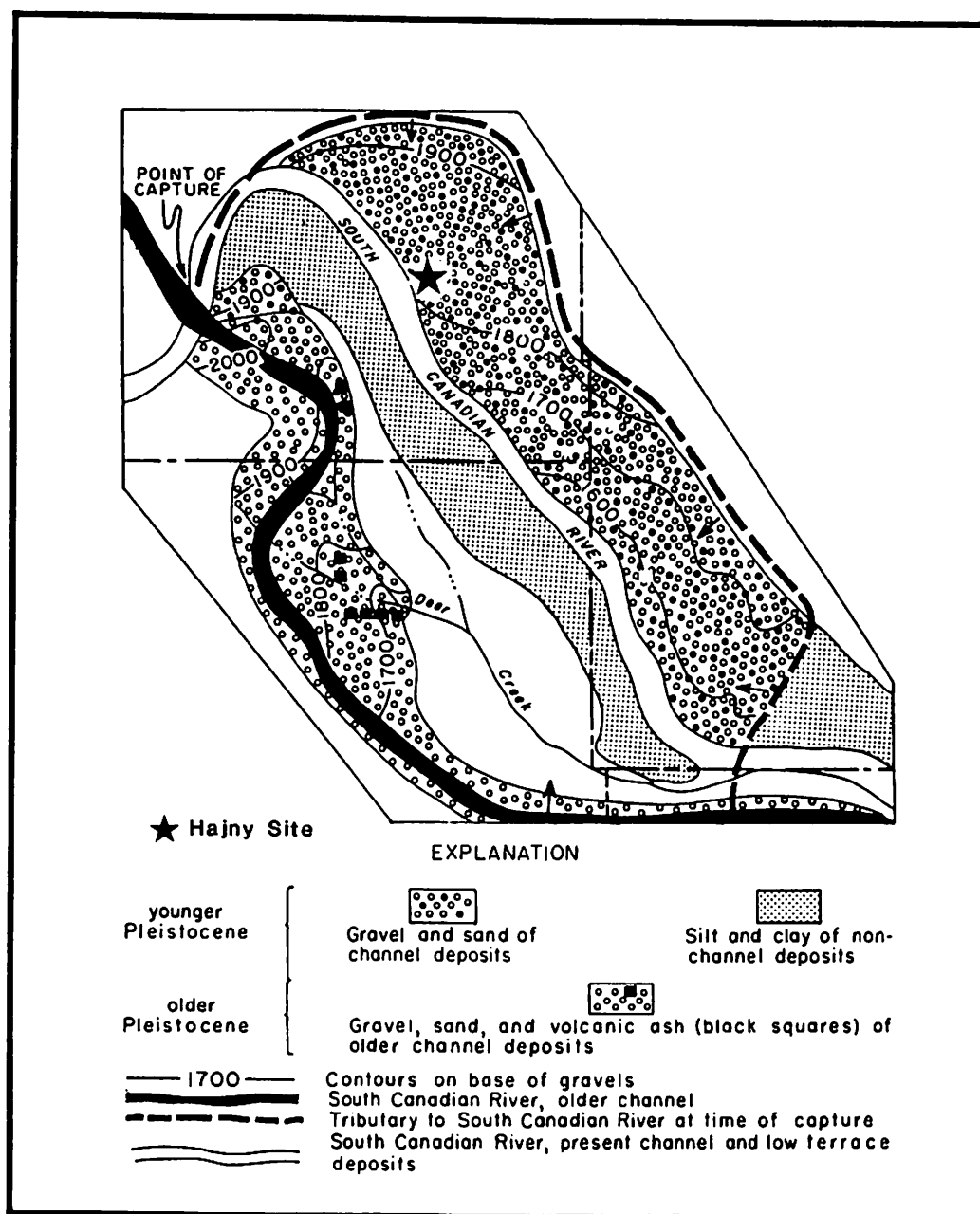
Figure 7-1. The Hajny site in relation to early Pleistocene course of Canadian
River, its former tributary and its subsequent piracy. Arrows show
direction of shift of channels after piracy.
(Adapted from Fay 1959:Figure 4.)

striking beds of moderately resistant Per-
mian sandstones and shales (Fay 1959:3-5).
Some 19 km (12 miles) west of the Hajny site,
Pleistocene gravels mark a former Canadian
course southeasterly across an area now
drained by the underfit Deer Creek. When
the Canadian occupied this western course, the

Hajny locality was drained by another stream,
one which eventually pirated the Canadian
about 32 km (20 miles) upriver from the
Hajny site (Figure 6-1). Based on probable
Pearlette volcanic ash deposits found on the
Canadian's original course and on its present
highest terrace, this stream piracy is thought

(Fay 1959:10) to have occurred before or during during what used to be called Kansas glacial times, or some 600,000 years ago.

Once ensconced in its new valley, the Canadian began cutting laterally to the west (due to Permian bedrock dip), leaving five progressively lower terrace levels bordering the present course (Fay 1959:8-9). In the Hajny vicinity, ten terrace levels are evident

(Carter, this publication). Situated nearly 36 m (120 ft) above the Canadian's present floodplain, the Hajny site is on the second lowest terrace, one which Fay (1959:10) thinks might be of late Illinoian glacial age, or roughly from 198,000 to 132,000 years ago (Richmond and Fullerton 1986a:Figure 2; 1986b:189-190). Fay's identification of this second terrace as being of late Illinoian age appears to be correct.
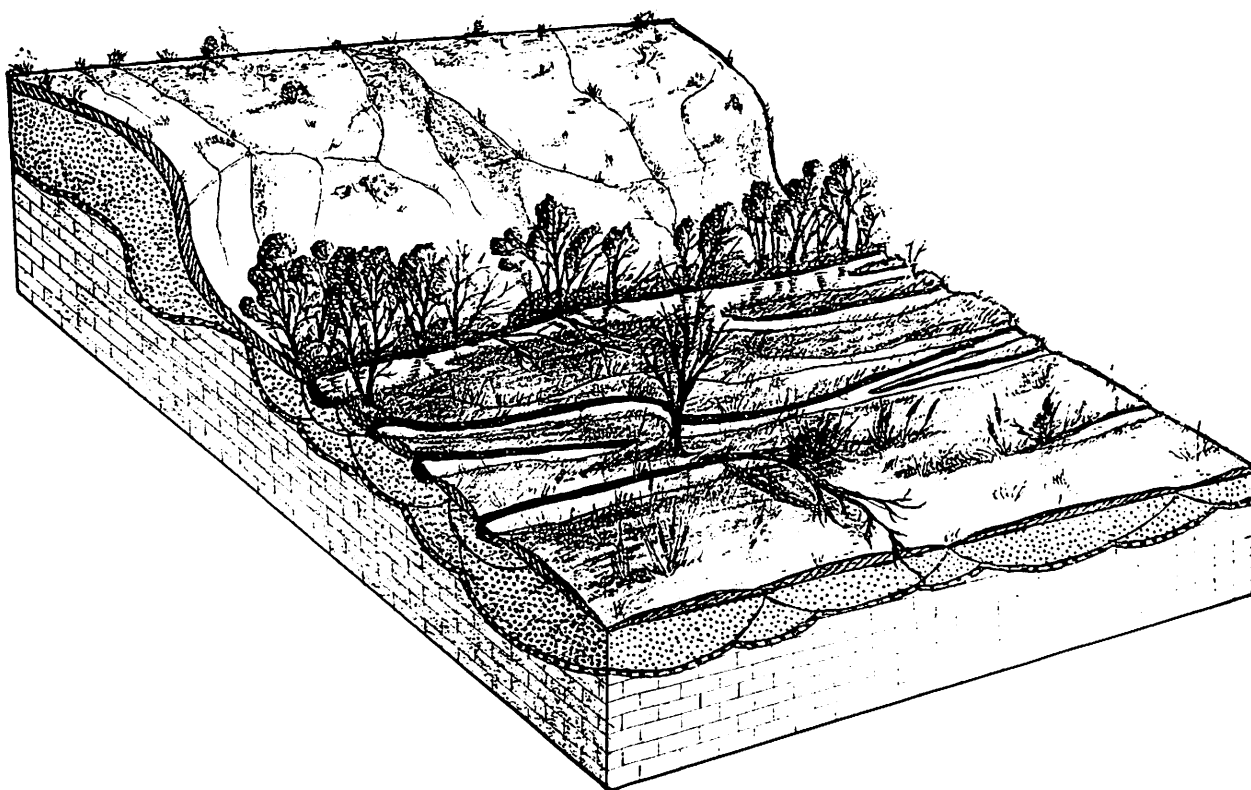
Figure 7-2. Artist's depiction of Hajny site locality during early Illinoian floodplain development. Profiles show basal gravels covered by cross-bedded sandy strata deposited by low energy, short duration peak flow stream. View to southeast. Illustration by Irene Johnson.

Uranium/thorium dates on the Hajny mammoth teeth indicate they are from 143,000 to 166,000 years old. We believe these dates are the most reasonable of the several chronometric results obtained for the site.

The Canadian River In Late Illinoian Times

Floodplain Development (Figure 7-2). Between 198,000 and 132,000 years ago, pronounced glacial activity is evidenced by oxygen isotope changes in deep-sea cores and by dated glacial tills in the Sierra Nevadas, the Rocky Mountains, and the Lake Michigan lobe in Illinois (Richmond and Fullerton 1986a, 1986b). With changes in base level and increased effective moisture, the Canadian River began downcutting. In the Hajny locality, this involved the river shifting westward as it eroded a channel in the west-dipping Rush Springs (Permian) sandstone. The channel's contact with the Rush Springs sandstone was exposed at elevation 86 (14 m below datum) in Barrow Pit Profile #1 (Figure 4-16). This elevation is approximately 36 m (120 ft) higher than today's channel. As exposed in the Hajny gravel pit, the late Illinoian channel was at least 120 m (393 ft) wide, almost a third wider than today's channel. Arroyos located 400 m (1320 ft) east of the Hajny pit manifest fluvial sands at an elevation near those exposed in the pit and may be traces of the late Illinoian floodplain. Its full width is unknown since subsequent cutting and lateral shifting have destroyed whatever Illinoian deposits lay west of the Hajny pit.

As manifest at the Hajny gravel pit, the Canadian's Illinoian channel accumulated 6.98 m (22.98 ft) of fill before it was abandoned. The lowest 3.8 m (12.4 ft) of this fill consists of upward fining strata: basal gravels (including rounded clasts of Permian sandstone), sand, loamy sand, sandy clay loam, and silt (Table 4-1). This sequence was best evidenced from elevation 86.0 to 89.8 in Barrow Pit Exposure #1 (Figure 4-16 and Table 4-1) and in the West Backhoe Trench (Figures 4-9 and 5-5).

Sand is the principal constituent filling this ancient channel. The sand is predominantly quartz, usually medium to coarse in texture, and clear to occasionally slightly frosted. Depositionally, the sand displays mainly small scale foreset and trough cross-bedding (Figures 5-3, 5-5, 5-6, 5-7, and 5-10). The latter is prevalent in the South Backhoe Trench, whereas east dipping foreset beds are evident in the West Backhoe Trench. The relative locations of these features are interpreted to show that the stream channel ran southwesterly with a point bar along its north margin. In the West Backhoe Trench, trough cross-bedding truncates the foreset beds, indicating a period when the channel had shifted north. The stratification types and physiographic features (McGowen and Garner 1975) of this ancient sand-choked channel are believed to resemble those of today's low energy, short duration peak flow, braided Canadian stream bed (Figure 7-3).

Floodplain Stability (Figure 7-4). With the accumulation of a silty unit (horizon 2C8 in Figure 4-16) at elevation 89.54, the Canadian's Illinoian floodplain seems to have stabilized temporarily near the Hajny site. Based on uranium series dating of mammoth teeth this apparently occurred sometime between 140,000 and 165,000 years ago. During this period, at least five spring vents formed when ground water welled upward through the gravel and sand, often carrying red fine sand up from flow along the alluvium's contact with the underlying Permian bedrock. While these springs flowed, the river's active channel was elsewhere.

None of the exposed spring deposits showed evidence that river-carried sediments were moving laterally across them while they were flowing. Just how contemporaneous these springs were is not well understood. All occur near the same stratigraphic position; thus, they are generally contemporaneous. Differences among the snail shell dates from Springs #2 and #5 or between the uranium series dates on mammoth teeth from possibly coalesced deposits at Spring #2 may implicate that the springs are not exactly

Figure 7-3. Modern braided stream channel of Canadian River directly west of the Hajny site. View downstream; channel lined with willows and young cottonwoods. Photo taken in July 1990 by Don G. Wyckoff.

contemporaneous. However, it seems unlikely the springs are as much as 10,000 to 20,000 years apart as is suggested by the differences among radiocarbon dates or between the uranium series dates.

Judging from the kinds and amounts of accumulated sediment, these springs were of variable flow and duration. For example, Spring #3 has a narrow, sinuous conduit containing fine to medium red sand; its mouth contains red sand and no snail shells (Figure 5-11). Spring #3 bears witness to ground water oozing towards the surface. In contrast, the two adjacent conduits called Spring #1 (Figures 4-9 and 5-7) have a straight neck with vertically aligned sandy fill and v-shaped mouths lined or partially filled with red sand. These mouths collected sandy loam (which oxidized and in which aquatic snails thrived and small carbonate nodules formed) or win-

nowed fine sand (which gleyed slightly in a reducing atmosphere). The fluvial sand adjacent Spring #1 is also gleyed slightly. The gleying evident in Spring #1's west conduit and the adjacent sand indicates both areas were buried when saturated with water. This spring's open pool lay directly east where it collected a silt enriched unit wherein snails floresced and small nodules of carbonate formed.

Springs #2, #4, and #5 are believed to have flowed longer than the others because they developed sizeable pools that collected oxidized silty sediments, aquatic snails, and occasional animals. All three settings have silty and/or clayey deposits which are at least 30 cm (12 in) thick and 6.0 m (19.6 ft) in diameter. The exposed (but not cross sectioned) fill of Spring #5 was a yellow green to gray green clay that con-

tained many aquatic snails (Theler, this report). No fossil bones were observed there. The Spring #4 cross section (Figure 5-12) revealed a gleyed silty clay embedded in a yellow to gray green clay that contained aquatic snails, a turtle shell, and at least the tusk of an elephant.

The longest, perhaps most complex, spring history is represented at Spring #2 (the manually dug area). Here, hints exist for coalesced deposits from possibly two spring vents. Over all, a snail-rich, brownish yellow loam caps stratified silty sediments. In their eastern extent these sediments cover the disarrayed, incomplete remains of a mammoth and the scattered bones of a horse and a few small mammals, reptiles, and birds (Larry Martin, this volume). In their western extent, gleyed silty sediments cover the generally articulated remains of another mammoth. These bones rest near and partially in oxidized and reduced fine sediments that fill a circular spring conduit. This feature is lined with oxidized reddish yellow sand and filled with brown to
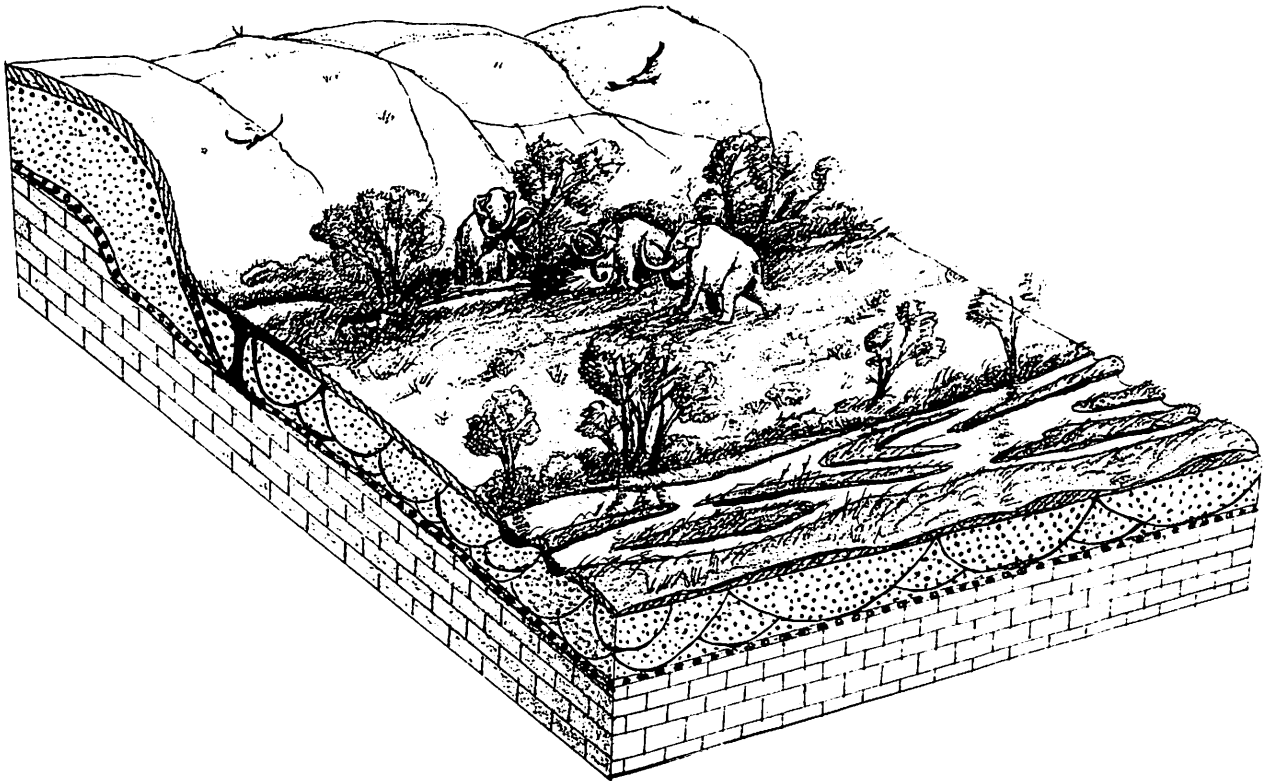
Figure 7-4. Artist's depiction of Hajny site locality during floodplain stability in the Illinoian period. The active stream has shifted west, and high water table has created a spring-fed marshy habitat . The Hajny mammoth site may have formed when droughty conditions adversely affected the locality. View to southeast. Illustration by Irene Johnson.

(south of Spring #2) a channel was eroded deeply into the Illinoian alluvium. This channel is lined with gravel that is embedded in reddish loamy sand. This same material fills the channel and merges with colluvium.

This erosion was closely followed by mass wasting wherein 2.0 to 3.0 m of loam and sandy loam units were moved downslope over the eroded area. The timing and cause of this mass wasting are uncertain. Perhaps the erosion undercut the terrace in such a way that, under different temperature and/or moisture regimes, the loamy mantle began to slump or creep downslope. This colluvium contains occasional redeposited gravel clasts, but stone lines and paleosoils are not evident. A dark (organically enriched) surface horizon is visible in the colluvium and probably formed over the past 10,000 years.

The Canadian River Valley in Post-Illinoian Times

After aggrading the floodplain in which the Hajny mammoth site was incorporated, the Canadian River has continued to cut deeper while also shifting west-southwest. This deeper, lateral cutting are responses of the Canadian as it adjusts to the southwest dip of the underlying Permian sandstones and shales (Fay 1959; Dolliver 1984:76-80). Because of this bedrock controlled adjusting, the Canadian's modern bed is some 36 m lower than, and 1.5 km west of the Hajny site. A 9.1 m (30 ft) first terrace is well represented along the river's west side (Figure 7-7), whereas on the east side this terrace is less evident, being more dissected and eroded by numerous small streams that drain off the uplands to the east. This conspicuous first terrace was earlier recognized by geologist

Figure 7-7. Looking south at prominent first terrace on west side of Canadian River directly west of the Hajny mammoth site. Trees are growing on slope and at foot of terrace. Photo taken January 17, 1992.

R.O. Fay (1959:10 and Figure 5) as probably Wisconsinan in age. Although undated as yet, this first terrace contains at least one buried (2.5 m), gastropod-bearing, black silty stratum. Located west of the Canadian (in SW1/4, NW1/4, SW1/4 of Section 20, T17N-R15W), this deposit merits further study of its potential for studying the environment and age of the Canadian's alluvial history in this segment of the watershed.

Northwest-southeast trending sand dunes (some attaining heights of 6.0 m) are common geomorphic features between today's river and the Hajny site. East of the site, dune fields parallel the Canadian's valley, extending up to 11.3 km (7 miles) east of the river's modern course. While many of these have steep slopes and sharp crests (Figure 7-8), some are low and rounded. Differences in dune morphology may attest to different ages, but apparently their distance from the river does not. An organically enriched soil horizon buried nearly 2.0 m by eolian sand and located 8.85 km (in SW1/4, SW1/4, SW1/4 of Section 8, T17N-R14W) east of the river has been radiocarbon dated at 6960 ± 150 B.P. (Beta-37701). While one radiocarbon date does not provide a chronology for the Canadian's dune fields in Dewey County, the location of this low, rounded dune makes one wonder if all of these eolian erosional features are mid-Holocene in age.

Figure 7-8.   Looking north-northwest at large dune deposit in Section 11, T17N-R15W, 3.6 km east of the Hajny mammoth site. Photo taken September 13, 1991.

CHAPTER 8

The Mammoth Bone Bed: Character and Taphonomy

Don G. Wyckoff

As the Hajny excavations progressed and no evidence of human predators was found, attention increasingly focused on dating the site and understanding the various processes that created the prehistoric bone bed. Knowledge about these processes is important. When chipped stone artifacts are not found and unequivocal traces of human butchering are lacking, claims that ice age animals were killed by people become questionable (Binford 1981, 1983:33-76; Dixon and Thorson 1984). One reason for this is that archeologists long have lacked sufficient information to distinguish between natural and human accumulations of animal bones. Fortunately, this void is being filled. A growing body of literature exists on the age and sex profiles of calamitously killed elephant and bison herds (Haynes 1985, 1988a), the natural decomposition and dispersal of animal remains (Coe 1978), the natural accumulation and breakage of African elephant bones at drought-stressed watering places (Conybeare and Haynes 1984; Haynes 1988b), bone weathering (Behrensmeyer 1978; Lyman and Fox 1989), and the sorting and breakage manifest in bone beds produced by prehistoric human hunters (Bonnichsen and Sorg 1989; Fisher 1984; Gilbow 1981; Todd 1987a, 1987b; Todd and Rapson 1988). Finally, as opportunities have arisen, more attention is being paid to carefully recording plan views, orientations, and breakage in bone beds that are clearly too old for human involvement or that accumulated from entirely natural processes, including water transport (Behrensmeyer 1987; Behrensmeyer et al. 1989; Koster 1987). In fact, several published studies already document Pleistocene elephant bone beds that accumu-

lated naturally in spring deposits (Agenbroad 1984b; Saunders 1977, 1988). Because its bone bed is arranged differently than previously reported spring-associated bone deposits, and because its bone bed displays the effects of some unusual fluvial processes, the Hajny site is believed to offer additional taphonomic information on bone beds that accumulated at spring settings without human intervention.

Undoubtedly, the Hajny site findings could have provided more information than presented herein. Although all bones were carefully uncovered, mapped, and photographed, systematic procedures for recording bone weathering, orientation, dip, strike, etc., such as those espoused by Todd and Rapson (1988; Todd 1987b), were unknown to us during the Hajny field work. Thus, while we tried to responsibly record pertinent information, some details were overlooked or not considered that, if available today, would enhance this site's contribution to taphonomic understanding.

The Hajny Bone Bed

While tusks and other bones were occasionally exposed in the several backhoe trenches, the Hajny bone bed is considered hereafter to consist of the remains uncovered and recorded in the 61 manually dug 1x1 meter squares (Figure 8-1). Nearly 500 bones were exposed here. Some were fragments too small to attribute to a particular element or species. Many were small platy pieces from deteriorated tusks. Nearly 70 bones are attributable to two mammoths, (these bones are inventoried in Appendix B), whereas 52
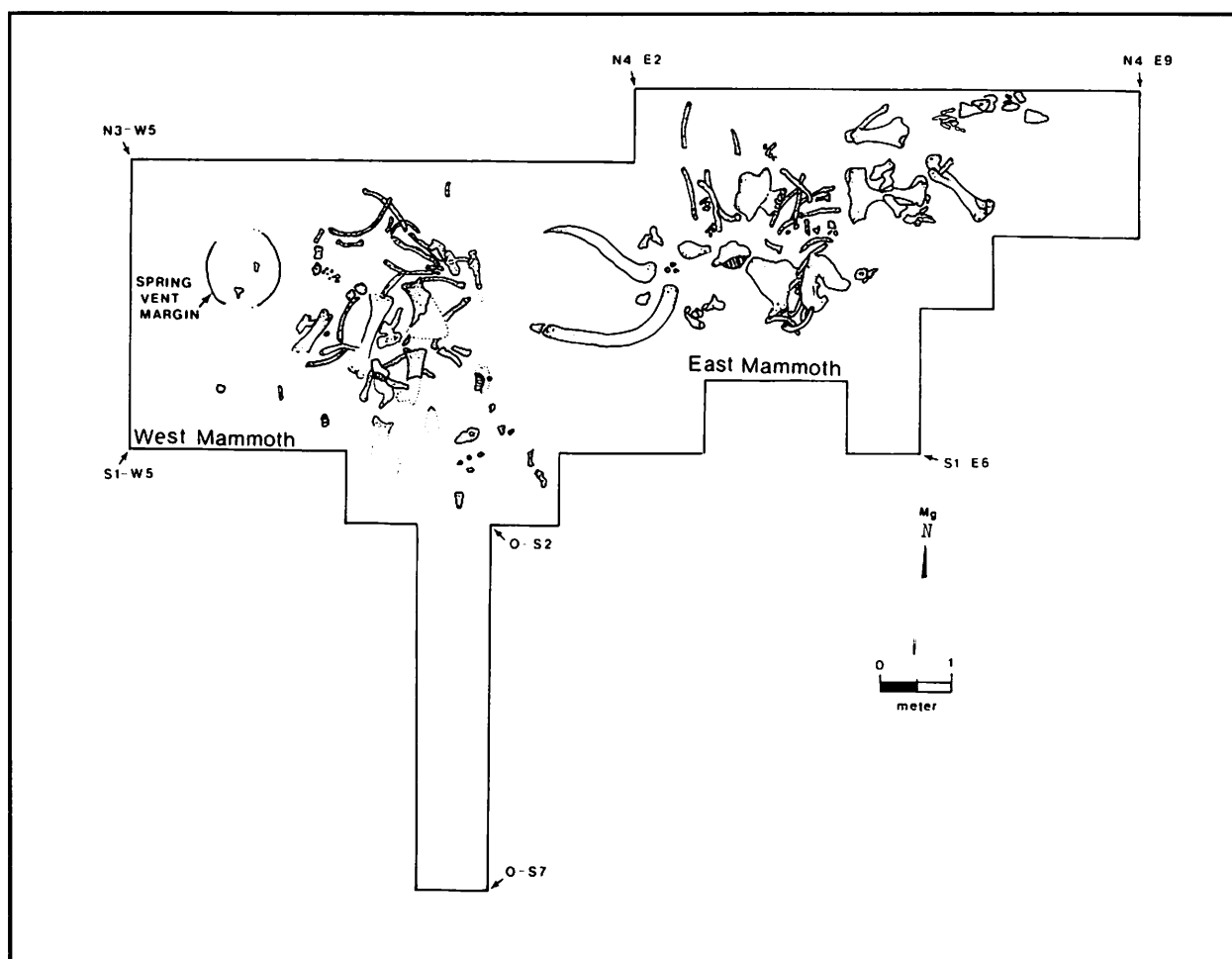
Figure 8-1.   Plan view of mammoth bones exposed during manual excavations around Hajny Spring Vent #2.

bone or teeth fragments comprise a small assemblage of other mammals and several reptiles. The remains and distributions of these other animals are discussed in Chapter 10 by paleontologist Larry D. Martin. Here, however, we focus attention on the mammoths.

A TAPHONOMIC MODEL

The Hajny mammoths provide clues to an interesting history of deposition and decomposition. This history is most evident when the exposed skeletal remains are studied in terms of their individual distributions and modifications. To facilitate a systemic approach to studying and documenting a bone's taphonomic history, D.G. Steele (1990) recently formalized a model (Figure 8-2) of the potential pathways leading to a bone's condition in its final resting place. First

applied in a comparative study of mammoth bones from northwestern Canada's Old Crow Flats and the Duewall-Newberry site in central Texas, this model is useful for examining and explaining the sequence of events affecting the mammoths' bones uncovered in Hajny Spring #2.

Within Steele's model (Figure 8-2), **primary taphonomic provenience** refers to the location where bones first became disarticulated and modified. **Secondary taphonomic provenience** (Figure 8-2) represents those places where bones come to rest after they have undergone movement and modification (by animals, water, ice, or air, for example) from where they first became disarticulated. A key element to distinguishing between primary and secondary taphonomic proveniences is the capability to

demonstrate that a bone was moved by some agency from where it first separated from the skeleton. In Taphonomic Pathway #1 (Figure 8-2), bones are buried where the animal died and became disarticulated, whereas in Pathway #2 (Figure 8-2) the animal dies, its body and bones are scavenged by predators, and all remains then become buried at the place of disarticulation. With Pathways #3, #4, and #5, however, there are increasing amounts of bone modification and movement away from the initial point of disarticulation (Steele 1990:90-93). Each time and place a bone undergoes a different modification process, they constitute a new **taphonomic context** for that bone (Steele 1990:91). Thus, a bone in Pathway #5 (Figure 8-2) could have had many taphonomic contexts prior to its being uncovered and recorded.

Applying The Model

The West Mammoth

The bones that first attracted everyone's attention were those of a single adult mammoth eventually uncovered in the manually

dug grid's west half (Figure 8-1). Unfortunately, the gravel quarrying that led to these bones' discovery also damaged them far more than first suspected. As the exploratory trench (squares 0-S7 through 0-S3 in Figure 8-1) was extended northward, we determined that the quarrying machinery had scraped away all but the lowest 3 to 5 cm of the spring deposits in the southern third of the grid. Consequently, bones once present were shaved, and sometimes crushed, down to fragments. Occasionally, specific elements could be identified from large, but thin, segments that retained key articular surfaces.

However, as the excavations progressed northward the spring sediments thickened and the mammoth bones were more intact. They frequently did exhibit transverse cracks and breaks. Some of these resulted from compression by the heavy machinery being driven over them, whereas others (with weathered breaks) are attributable to prehistoric compression from the weight of fluvial sediments and soils that eventually accumulated over them. All in all, uncovering the initially discovered (west) mammoth required much

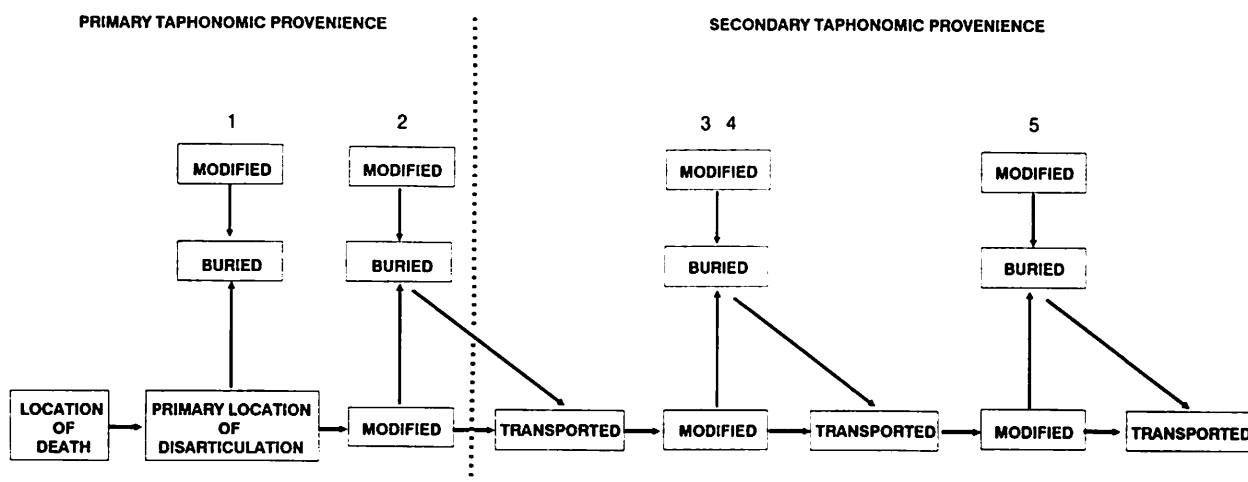Figure 8-2. D.G. Steele's model showing the various pathways and points of modification a bone can take through its taphonomic history. (Adapted from Steele 1990: Figure 5.2.)
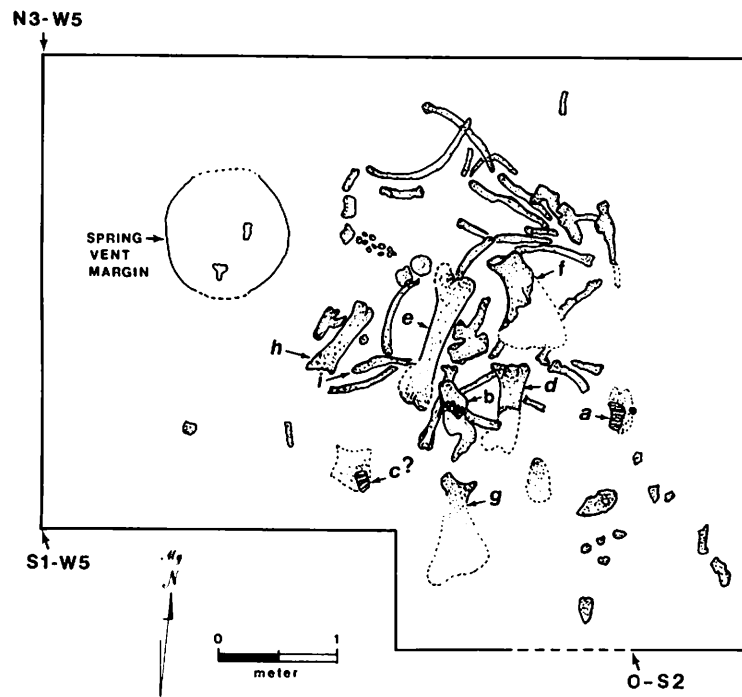
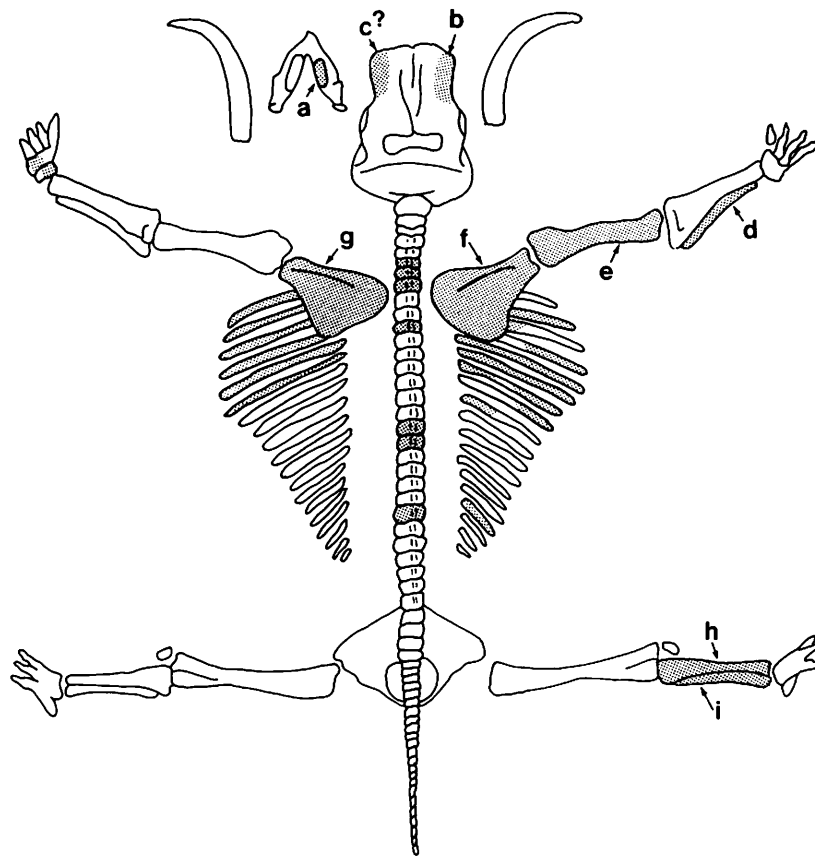Figure 8-3. Plan view of the west mammoth's remains, Hajny site, Dewey County, Oklahoma.

Figure 8-4. Identified elements of the west mammoth at the Hajny site, Dewey County, Oklahoma. (Adapted from Martin 1987: Figure 5.)

tedious manual labor and double checking for bone landmarks that would enable us to identify the element, its proximal and distal ends, and its medial and lateral sides.

Twenty-nine identifiable bones and 24 unidentifiable fragments are attributable to the west mammoth. Their in situ locations are shown in Figure 8-3. The identified elements are depicted in Figure 8-4. The 29 identifiable bones comprise only 14% of all the elements associated with a single mammoth. Most obviously lacking are many of the vertebrae, the pelvis, many long bones of the fore and hind legs, the bones of the fore and hind feet, the skull, the mandible, and the tusks (Figure 8-4). Several clues implicate some missing elements were removed during gravel quarrying. A molar was among the bone fragments found where the gravel was being spread along the township road. Tusk fragments were observed in the disturbed spring sediments before our excavations, and a few tusk-like fragments were found in the disturbed sediments of square 0-S2. Finally, the few remaining leg bones and molars are in the southern part of the bone bed where crushing and scraping by the machinery were most evident (Figures 8-5, 8-6, and 8-7).

At the time of death and initial soft-tissue decomposition, the west mammoth apparently lay on its left side with its head to the southeast. The clues to this orientation are the molars and tusk fragments which are among the most southeasterly extending elements. The best clues to the position are the right scapula and right humerus which lie atop ribs and vertebrae in squares 0-W1 and N1-W1 (Figure 8-3).

Other than the absence of certain bones, some of which undoubtedly were removed during gravel quarrying, direct evidence is lacking that the west mammoth was bothered by predators or scavengers. In fact, bones that were still well buried, and thus least damaged by the machinery, don't even display the kinds of longitudinal cracking, outer layer flaking, or deep cracking and splitting that taphonomists

associate with open air weathering (Behrensmeyer 1978; Coe 1978; Conybeare and Haynes 1984; Lyman and Fox 1989). These bones do display cracks from compression by heavy machinery and/or the formerly overlying sediments and soils.

Despite the west mammoth's bones being little weathered and not degraded by animal scavenging, the skeleton is obviously disarticulated and rearranged (Figure 8-3). Not only are normally articulated elements separated, but they are often overlying bones from other parts of the skeleton. In these instances, the maximum inclination is 15°. Otherwise, the west mammoth's bones usually lie at a common elevation (89.3) that is just above the limey concretions found along the boundary between the spring deposits and the underlying fluvial sand. A notable exception occurs, however, in squares N1-W2 and N1-W3. Here, a unciform and a magnum lie in the slopping mouth of Spring Vent #2 (Figure 8-8), and a broken lumbar vertebra is at elevation 88.5 inside the spring conduit (Figure 8-9).

A final observation regarding the west mammoth is that the long axes of different weight bones tend to display diverse orientations. Heavy elements like the humerus, the tibiae, and scapulae are aligned roughly with magnetic north, whereas many of the ribs and some vertebrae lie almost perpendicular to that direction (Figures 8-3 and 8-8).

The East Mammoth

While trying to define the eastern limits of the west mammoth's remains, a tusk was discovered in square 0-E2. Because it was pointing towards the west mammoth, this tusk was the first clue that a second mammoth was present. To uncover this second animal, the manually dug grid was expanded eastward. Eventually, 29 1x1 meter squares were dug. These eastern excavations revealed that in situ gravel still covered the spring sediments and that gravel quarrying had not crushed, scraped, or removed bones of this second mammoth. Thus, as the tusks were uncovered, everyone expected that a complete skeleton would be found. This expectation was being fulfilled as the upper molars, a right

Figure 8-5. Looking north at ribs and right tibia segment of west mammoth in square 0-W2, Hajny site, Dewey County. Scale in centimeters.

Figure 8-6. West mammoth's right molar, right humerus, right radius, and ribs in square 0-W1, Hajny site. Scale is in centimeters and points north.

Figure 8-7. West mammoth's ribs, right humerus, and right scapula in squares 0-W1 and N1-W1, Hajny site. Scale is in centimeters and points north.

Figure 8-8. Looking south at west mammoth's disarticulated skeletal remains and those elements on slope into mouth (right foreground) of Spring #2. Scale is in centimeters.
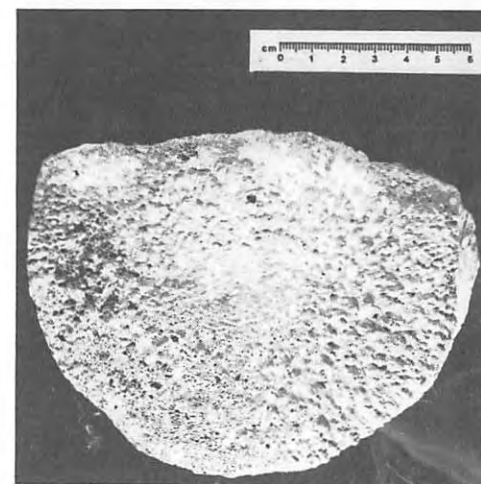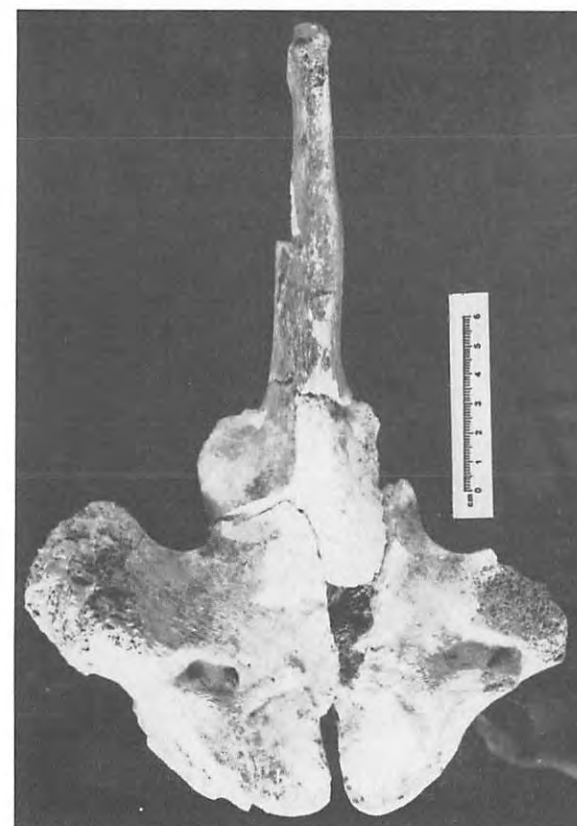
Figure 8-9. Left: Three sections of the west mammoth's broken
lumbar vertebra lying within the conduit of Spring #2, Hajny site.
View to the east. Right: The vertebral process and centrum recovered
from the conduit.

scapula, the mandible, and ribs were found east of the tusks. But as additional squares were dug eastward, many skeletal elements were not found, and those that remained showed the effects of some unusual taphonomic processes.

Thirty-four identifiable and 15 unidentifiable bones were uncovered and plotted for the east mammoth (Figure 8-10). The identifiable elements are listed and shown in Figure 8-11. The 34 identified bones represent 15.7% of a single adult mammoth's skeleton. Notably, the left tusk is nearly twice the length of the right (Figures 8-12 and 8-13). Given the tusks' parallel orientations and the nearly articulated positions of the left pelvis and left femur, this beast was in one of two positions at the time of death. It could have been on its left side with its head to the west-northwest. Haynes (1988b:140-142) also reports that African elephants are known to collapse straight down, finally resting on their tusks, jaws, and bellies, when they die suddenly from heat stroke during droughts. Thus, the east mammoth could represent a sudden death posture where the body was aligned generally east-west. After soft tissue decomposition, its skeleton became very disarranged and incomplete.

The left tusk lacks nearly 10 cm of its tip; this segment was lying directly west of the main tusk (Figures 8-10 and 8-12). About a meter north was found the shorter, right tusk (Figure 8-13). Many minute (1-2 cm) bone fragments found around the tusks' proximal ends attest to the skull's former presence. The two upper molars (each retaining maxillary remnants) became separated, eventually to rest between the tusk and the mandible (Figures 8-14 and 8-15). This mandible is overturned, resting on ribs, partially covered by ribs, and has the right scapula between it and the tusks (Figure 8-15). Within a meter north of the mandible occur broken ribs, and the skull's occipital condyles, whereas to the northeast are a few broken ribs and vertebrae, the left pelvis, the left femur, and the left tibia and fibula (Figures 8-10, 8-16, 8-17, and 8-18). While the left femur is almost articulated with the left pelvis, the left tibia and fibula are nowhere near where they should occur. Instead, they are north of the pelvis with their proximal ends toward the proximal end of the humerus. Notably missing are most vertebrae, some ribs, the bones from both front legs, the right pelvis, and many bones from the hind legs (Figure 8-11). Some of these latter may be represented among the many thick bone fragments found east of the left tibia (Figures 8-11 and 8-19).

Taphonomic History Of The Hajny Mammoth Bone Bed

Hajny Spring #2 contains the remains of two adult mammoths, both represented by incomplete and noticeably rearranged skeletons. Obviously, both skeletons have undergone a sequence of taphonomic processes before attaining their documented in situ states. Despite uranium series dating of their teeth indicating the two mammoths might be 20,000 years apart in age, both animals are believed to have been incorporated into this spring's deposits at roughly the same time. This conclusion is based on their teeth being representative of the same species (Chapter 9). Also, the spring deposit's stratigraphy lacks clues that the spring was active 20,000 years or that interbedded deposits are present from two springs of such diverse ages. Consequently, while they may involve different processes, the sequences of events affecting these skeletons are believed to be of comparable length.

Because they are represented by large (heavy) and small (light) skeletal elements, the two mammoths are believed to have become disarticulated around Spring #2. This spring's sediments thus comprise the **primary taphonomic provenience** for the recorded bones. Lacking traces of root etching and seldom exhibiting open air drying cracks, these bones must have become submerged in active spring sediments as tendons, muscles, and other soft parts decomposed.
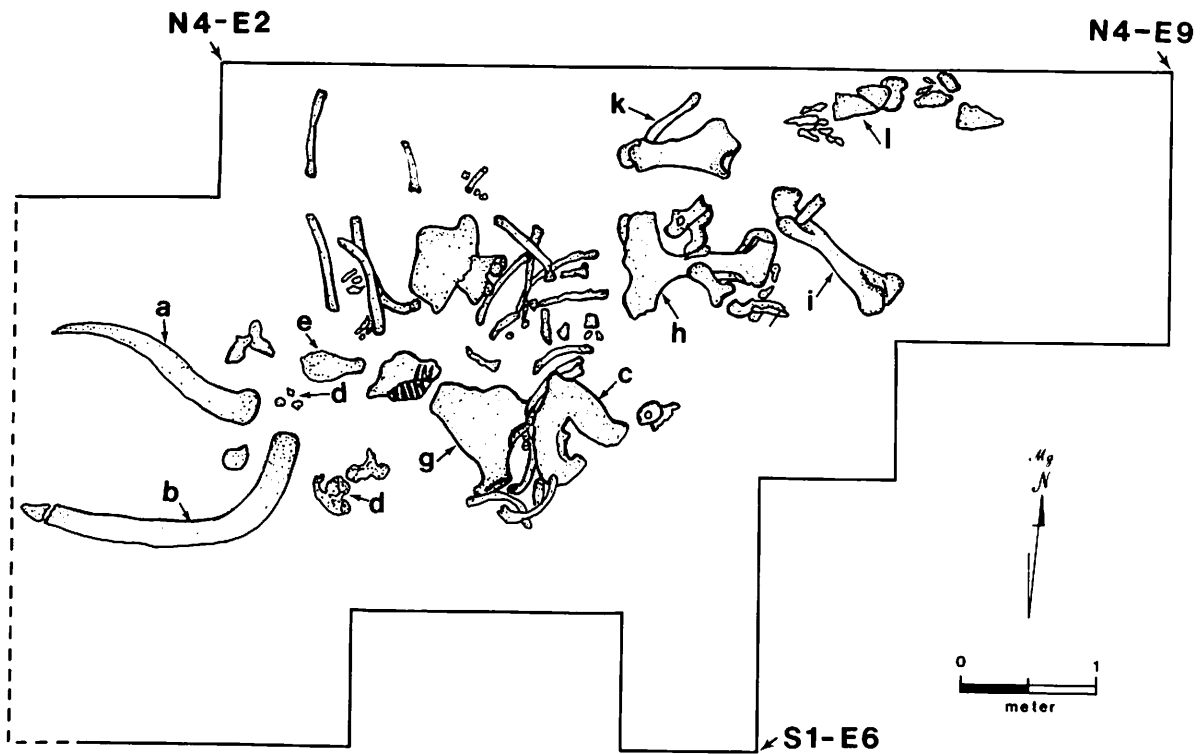
Figure 8-10. Plan view of east mammoth's skeletal remains, Hajny site, Dewey County, Oklahoma.
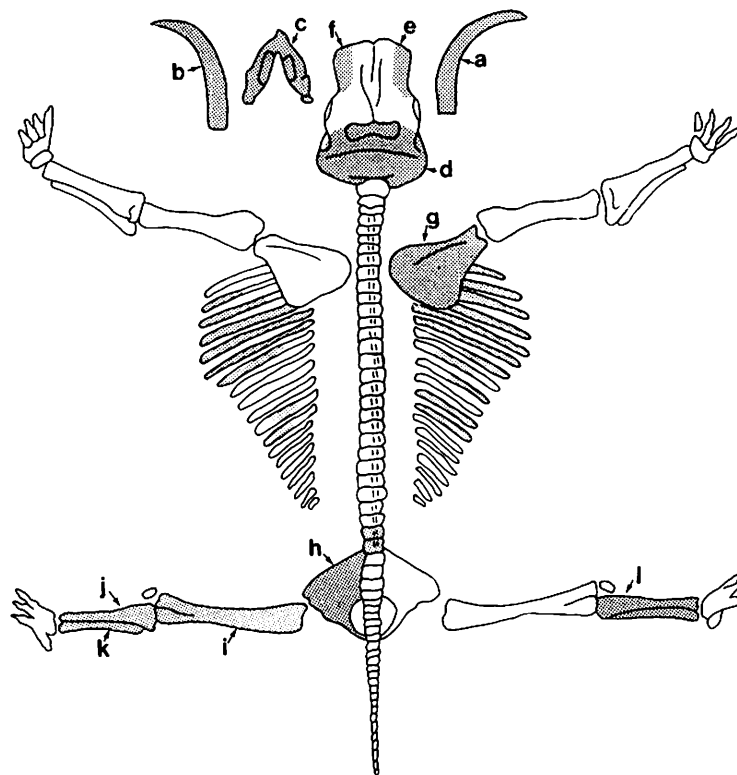
Figure 8-11. Identified elements of the east mammoth, Hajny site, Dewey County. (Adapted from Martin 1987: Figure 5.)

Figure 8-12. Looking northwest at the east mammoth's left tusk. The distant end is broken off and lying almost perpendicular in the gray loamy sediment of Unit #4. Scale is in centimeters, and its metallic end points north.

Figure 8-13. The east mammoth's short, right tusk exposed in squares N1-E2 and N1-E3, Hajny site. Rib fragments are in left foreground. Scale is in centimeters, and its metallic end points north.
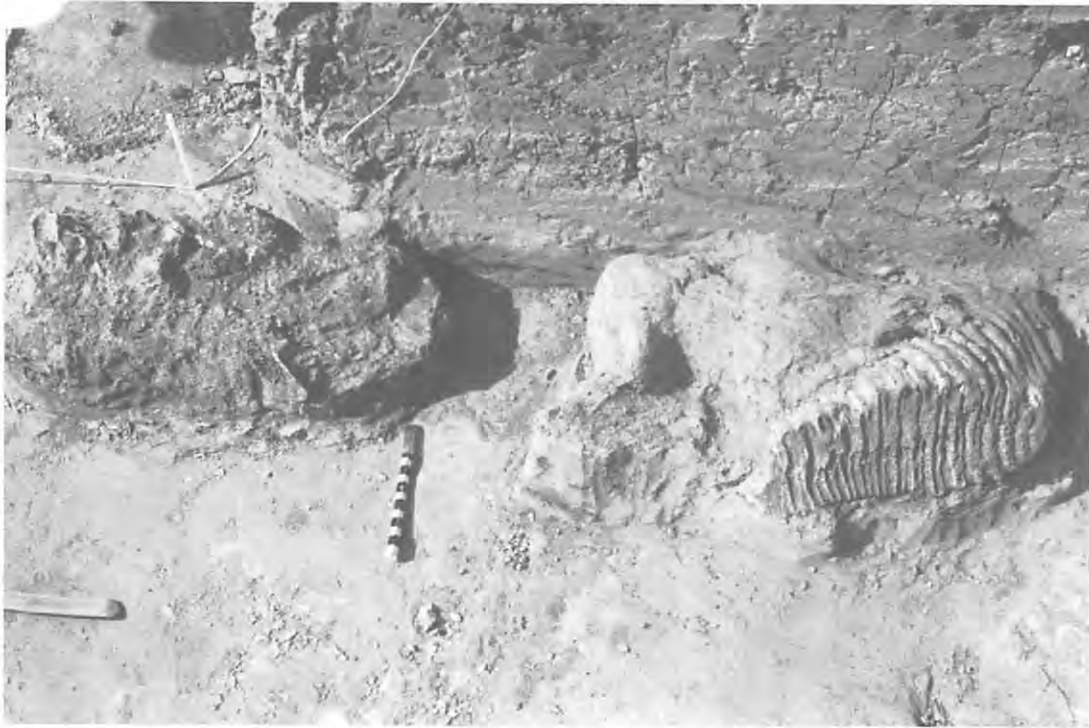
Figure 8-14. Looking north at the east mammoth's two upper molars in square N1-E4, Hajny site. To the left is the very worn right upper molar, while the slightly worn left upper molar is to the right. Scale is in centimeters, and its metallic end points north.

Spring Fluvial Taphonomic Processes. During this period of decomposition and disarticulation, different processes altered each skeleton's anatomical order and damaged some bones. Spring flow may have aligned some bones. Both skeletons manifest separation and reorientation of lighter from heavier elements. This separation and reorientation is most evident for the west mammoth, but the east mammoth's ribs are somewhat aligned and distributed as if moved by flowing water (Figures 8-10 and 8-18). Light weight bones of both skeletons appear to have drifted and aligned to the north-northwest, the direction the spring's sediments dip (as seen in the North Backhoe Trench profile; Figure 5-8). Moreover, some heavy bones tend to be aligned in the same direction (Figure 8-1). This subtle linear alignment contrasts sharply with the annular pattern for proboscidian bones reported for springs with substantial discharge (Saunders 1977, 1988).

Biogenic Taphonomic Processes. Light weight bones from both mammoths also are sometimes overlapping, occasionally even with large, non-articulating elements. Likewise, some non-articulating heavy elements are mixed together. These distributions are interpreted as evidence that more than spring flow was moving bones.

Carnivores such as lions and hyenas are known to gnaw and scatter the carcasses of elephants that die around failing waterholes in Africa (Conybeare and Haynes 1984; Haynes 1980, 1988a, 1988b). While carnivore scavenging may be responsible for some elements missing from the Hajny bone bed, carnivore marring and breakage are not evident on the remaining bones. In fact, few bones even manifest green bone breakage. For the west mammoth, a lumbar vertebra recovered from the spring conduit (Figure 8-9) was found in three pieces. Its spinous and transverse processes were broken off the

Figure 8-15. Looking northwest at east mammoth's mandible overturned on ribs and adjacent the right scapula. The slightly worn left upper molar is in the background.

behavior (Haynes 1987, l988b, 1990; Saunders 1980, 1990). Recent studies in drought-stricken Zimbabwe reveal much about modern African elephant behavior during times of environmental stress (Conybeare and Haynes 1984:195-196; Haynes 1987, l988b). During these times, elephants expend much energy digging for shallow ground water and contesting for water at drying waterholes. While jostling for water, tusks on living individuals get broken. Even more importantly, the bones and tusks of animals that died earlier get trampled and broken (ibid.). Not only are skeletons trampled, but modern elephants also try to move carcasses and even kick and toss bones. The end results are diverse watering places with bone assemblages that are highly variable in terms of the number of elephants represented (but usually many young ones), the proportions of broken and missing bones, and the extent of mixing and dispersal (Haynes 1988a, l988b). Where environmental stress is not as severe, only a few elephants may die around a waterhole, but many bones may be broken, buried, or lost (Haynes 1988b:148-149).

centrum before all three settled into the viscous fill of a low discharge, spring mouth. For the east mammoth, the centrum and spinous process of a vertebra lie just north of the pelvis, segments of broken ribs occur near the right tusk; and the 10 cm tip of the left tusk is snapped off and lying perpendicular to the tusk's broken end.

The displacement, mixing, and breakage of bones around Spring #2 are believed due to animal activity. Given the 10 cm diameter of the broken tusk, it must have been a heavy animal. There is some basis for believing it was another mammoth.

As anatomically distant relatives of modern African elephants (*Loxodonta*), North American mammoths are assumed to have had similar herd structure and social

Two of the Hajny site's five spring deposits contain the remains of three adult mammoths as well as the scattered bones of a few other animals, notably aquatic birds, mammals, and reptiles (see L.D. Martin, this volume). While there is little that conclusively indicates the Hajny site was a late Illinoian analogue to southern Africa's drought-affected failing waterholes, the bones around Hajny Spring #2 exhibit some of the mixing, removal, and breakage patterns like those caused by modern elephants. Perhaps Hajny's few

Figure 8-16. Looking south at east mammoth's left femur and pelvis in squares N2-E7 and N2-E6, Hajny site. The upper (lateral) surface of the femur was scoured away by water-swept gravel. Both the femur and pelvis are in the gray loamy fine sand designated as Unit #3. Note mixing of gray and white sand in lower left corner.

undergo both reduction and oxidation, creating the brown and yellow mottling that characterizes loamy Unit #2 (see Chapter 5). This alternating dry and wet environment also initiated development of small (< 1.0 cm) carbonate concretions and a weak platy structure.

These pedogenic processes diversely affected the east mammoth's skull, tusks, mandible, and several ribs. Due to their thicknesses, curvatures, and/or overlapping positions, these elements projected from Unit #4 up into Unit #2. Hundreds of yellow-stained skull fragments found between the tusks' proximal ends attest to the skull disintegrating (perhaps due to open air weathering?) and being coated with iron oxide during repeated drying and wetting of this last spring sediment. Where they extended into oxidized Unit #2, portions of the tusks, the overturned mandible, and three ribs overlying the mandible likewise exhibit yellow staining, and occasional small (1-2 cm) patches of iron oxide are encrusted on the mandible and ribs. This mineral buildup is not apparent in the cracks of these elements, but the cancellous interior of the mandible is thoroughly stained yellow. Bone surfaces in Unit #2 do seem to be more cracked, pitted, and decomposed than surfaces encased in the lower spring sediments. Some of this differential surface preservation can be seen on the left tusk in Figure 8-20 and the overturned mandible and overlying ribs in Figure 8-21. The longitudinal nature of some

broken bones and mammoths are related to the short duration the springs were active. Their shallow deposits certainly attest to their not flowing very long.

Pedogenic Taphonomic Processes. After being moved by the spring's flow and by animals, a few east mammoth bones were modified chemically and and physically. This happened as the uppermost (and last) Spring #2 deposits underwent some soil-forming processes. Specifically, Unit #2 in this spring's stratigraphic sequence was repeatedly subjected to drying and extreme wetting. This fluctuating water content caused these highest spring sediments to

Figure 8-17. The east mammoth's left tibia and fibula in square N3-E6, Hajny site. Splotchy floor is at boundary between gray loamy fine sand (Unit #3) and underlying white sand. Marker is in 10 centimeter increments and points north.

of this cracking probably bears witness to these surfaces being exposed periodically to open air weathering.

Riverine Fluvial Taphonomic Processes. One of the most unusual attributes of the Hajny bone bed was the unmistakable evidence that it was disturbed by river channel changes and renewed aggrading. These processes definitely damaged bones, undoubtedly removed some, and probably rearranged others.

The flood plain dotted with springs dramatically changed when a channel was cut and then filled with gravel along the north edge of Spring #2. This channel's formation signaled the end of the once-stable flood plain. The channel's accumulation of gravel seems linked to the process of renewed flood plain aggrading. Both processes affected the Spring #2 deposits and the Hajny bone bed in several ways.

Channel cutting caused bank sloughing that altered some of the spring's northeastern deposits. Here (in squares N3-E8 and N3-E9), large cracks formed (due to undercutting?) and were filled with sand and gravel (Figure 5-23). Also, complete and broken bones (of mammoth and other animals; see Martin, this volume) were washed from the spring deposit (their **primary taphonomic context**) and were redeposited in small

Figure 8-18. East mammoth's overlapping ribs in square N2-E5, Hajny site. Marker is in centimeter increments and its metal tip points north.

Figure 8-19. Broken thick-walled bones and drying cracks in square N3-E7 of the Hajny site. Marker is in 10 centimeter increments and points north.

Figure 8-20. East mammoth's left tusk as it was being uncovered. Note its upper surface was encased in pedogenically developed Unit #2, whereas the better preserved lower surface was in Unit #4, the gray loamy sediment. View to northwest.

Figure 8-21. Looking north at east mammoth's overturned mandible which is lying on ribs and which has rib segments draped over it. The mandible and overlying ribs are encrusted with iron oxide, whereas the right scapula (center and lower than mandible) was not encrusted but displays compression cracks. Scale is in centimeters.

pockets in the underlying fluvial sands. Examples of these winnowed bone features were exposed in squares N3-E6 and N3-E7 (see Figure 5-22). Although situated only a short distance and slightly deeper than where they were first deposited, these small concentrations of bones are now in a **secondary taphonomic context** according to Steele's model (Figure 8-2).

When gravel was deposited in the channel, it also swept across at least the exposed northeast edge of the Spring #2 deposits. While this occurred, chunks of oxidized spring sediments (Unit #2) were incorporated in the channel's gravelly fill (Figure 5-8). This gravel's deposition may have been part of the aggrading episode that laid down the gravel being quarried when the site was discovered. As this gravel swept across the Spring #2 location, it scoured away portions of the uppermost sediments. Gravel scouring may have totally destroyed some of the east mammoth's bones. It clearly eliminated the upper half of the east mammoth's left femur (Figure 8-16). No evidence exists for gravel scouring that damaged or destroyed any of the west mammoth's elements.

The land owner and the county workers recollect that the gravel being quarried covered all of the recorded springs. Thus, with the deposition of this extensive gravel unit, the Hajny bone bed was sealed from any further open-air disturbances. However, subsequent aggrading of sands and gravels must have comprised times when water could have resoaked the spring sediments. In these instances, chemical reduction processes might have continued on both mammoths' remains. Finally, the accumulation of sand, gravel, and, eventually, soil over the site added considerable compressive forces on the bones. The results vary from the extensive cracks visible on all bones to the warping and breakage of some bones, such as the east mammoth's overturned mandible.

Summary

Since their deposition in spring sediments, perhaps some 140,000 years ago, the bones of two mammoths and a few other mammals, reptiles, and birds have been subjected to several interesting taphonomic processes. In terms of their distributions, most bones are in the same deposit that covered the animals at the time they died and became disarticulated. When evidenced, bone movement was partially by spring flow, primarily by other animals (probably mammoths). In terms of their condition, none of the bones manifested traces of carnivore scavenging. The mammoth bones do, however, show limited breakage by a large animal (probably mammoth), considerable breakage from compressive forces (from the overburden and from quarrying machinery), and some chemical alterations and degradation (due to oxidation and pedogenesis of the uppermost spring sediments). The most unique taphonomic process that affected the Hajny bone bed was that produced when stream-carried gravel swept across the spring sediments and scoured away much of the east mammoth's left femur.

CHAPTER 9

The Hajny Mammoths: Age Profiles And Species

Peggy Flynn

The purposes of this chapter are to determine the relative and chronological ages of the Hajny site's mammoths and to assign them to their proper taxa. Fossil elephant molars are common elements preserved and recovered from Pleistocene sites. As a result, most studies involving the identification of mammoth age groups and species have focused on variables involving the cheek teeth. Meaningful morphological attributes (that is, attributes which display change within evolving lineages) associated with mammoth molars have been identified through studies on larger samples of both fossil and living elephants (Haynes 1991; Laws 1966; Maglio 1973; Osborn 1942). By
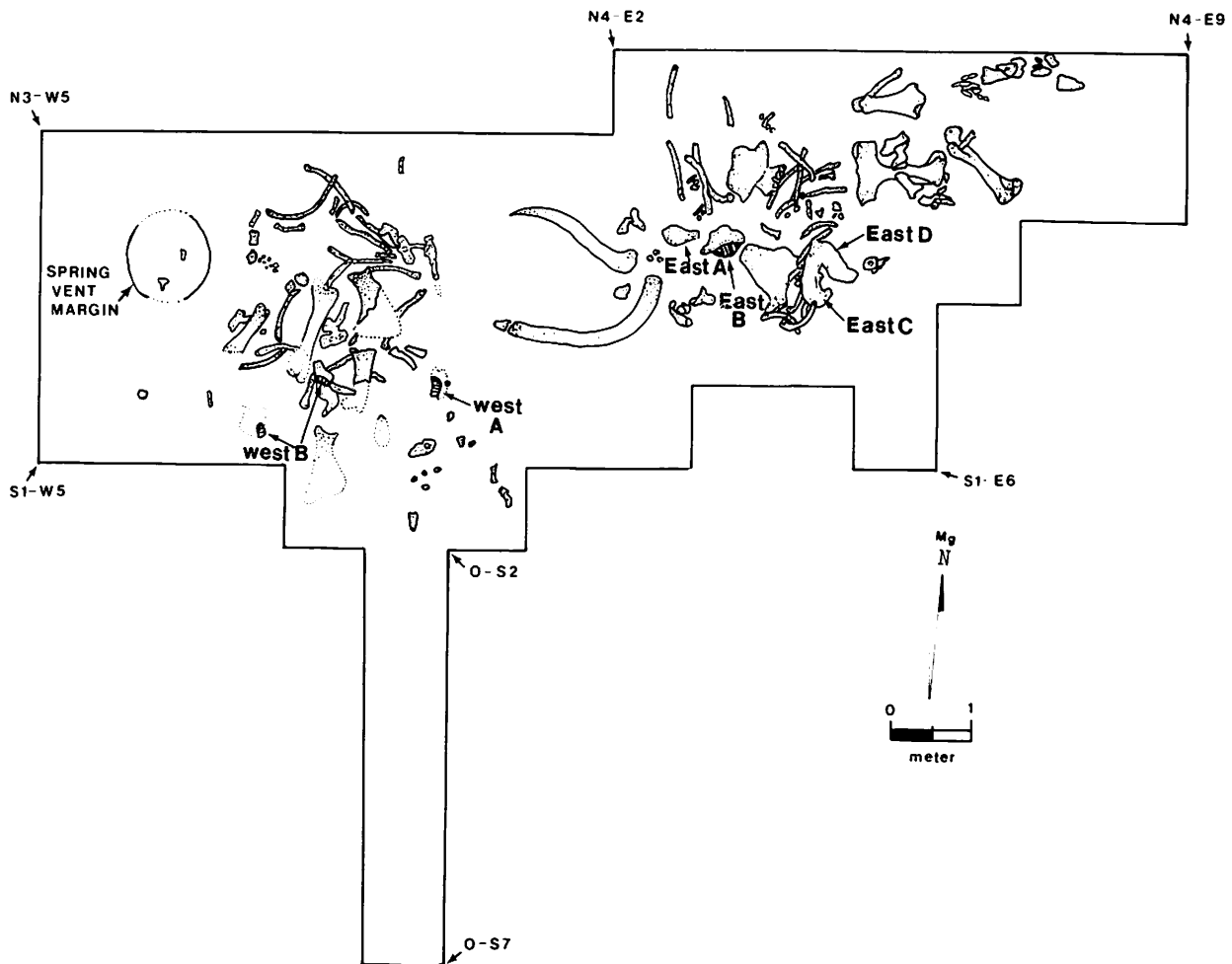
Figure 9-1. Locations and designations of studied mammoth teeth, Hajny site, (34Dw23), Dewey County, Oklahoma.

Table 9-1.   Attributes and Measurements of the Hajny Site's Mammoth Molars.

Specimen	Provenience	Element	Pl	A	L	W	Ht	En	C
West A	O-S1	LM/2 or M3	12+	+9	+226+	87	93	2.9	20
West B*	O-W1	?	-	-	-	-	-	-	-
East A	N1-E3	RM3/	+6	5	161	87	-	2.7 - 3.0	3.0
East B	N1-E4	LM3/	21	16	367	114.6	190	2.7 - 3.0	2.7
East C	N1-E5	RM/3	9+	9	**	77	**	. 2.6	-
East D	N1-E5	LM/3	17	11	363	102.2	**	2.7	2.7

NOTE: A plus sign (+) indicates the specimen is fragmented anteriorly, posteriorly, or both.

*   No measurements due to poor preservation.

**   Specimen encased in mandible.

Table 9-2.   Lamellar Frequency (LF) of Hajny Mammoth Molars.

Specimen	Occlusal surface			1/2 distance to base			Base		
	lin	lab	med	lin	lab	med	lin	lab	med
West A	6	8	7	5	6	-	4.5	5.5	-
West B	-	-	-	-	-	-	-	-	-
East A	-	-	3.5	-	-	-	-	-	-
East B	6	5.5	6.5	6	5.5	-	6	5.5	-
East C	6	6.5	6	-*	-*	-*	-*	-*	-*
East D	3.5	4	4	-*	-*	-*	-*	-*	-*

*   Unmeasureable due to being encased in mandible.

applying some of these criteria to the Hajny specimens, I hope to clarify the character and taxonomy of the Hajny mammoths.

The Hajny Sample

A total of six mammoth molars were recovered from the Hajny site. Two were associated with the west mammoth, and four were with the east mammoth (Figure 9-1). The correct identification of individual molars is necessary to determine both relative and chronological ages as well as to properly place the animals within a taxa. Molars were identified from the shape and curvature of their occlusal basins, the curvature of their individual plates or lamellae, and their overall size and appearance. As will be discussed later in this chapter, the advantage of initially studying these molars in the field where they were near other elements proved to be very helpful in correctly identifying them and insightful about the shortcomings of identifying molars in the lab solely on the basis of the aforementioned characteristics.

Tables 1 and 2 present attributes and measurements observed on the Hajny mammoth molars. The variables presented herein follow those outlined by Maglio (1973). These include:

1. the number of plates preserved (Pl);
2. the number of plates abraded by wear (A);
3. length of the specimen (L);
4. height of the deepest plate (Ht);
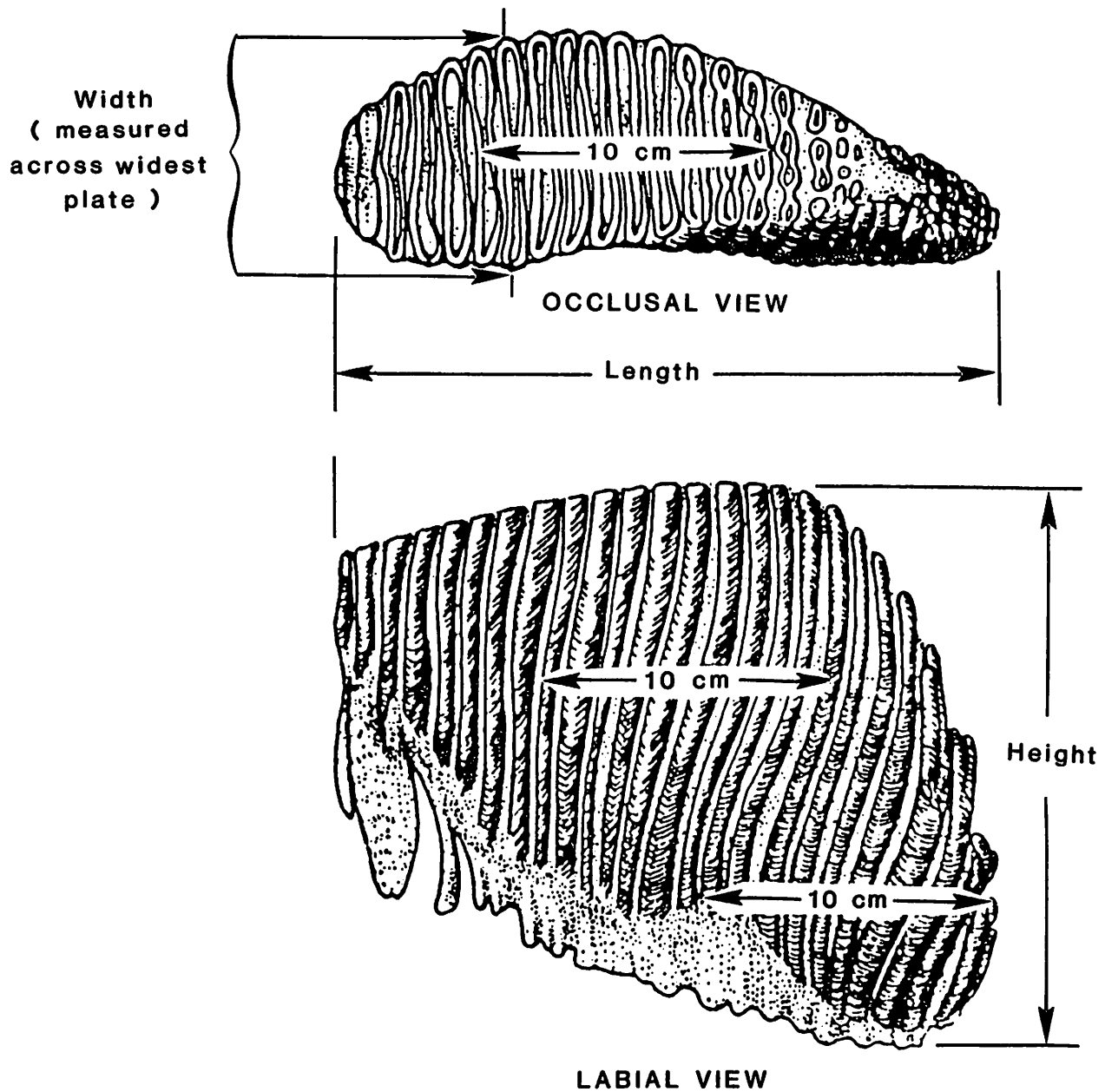
Figure 9-2.   Measured variables on Hajny mammoth teeth.
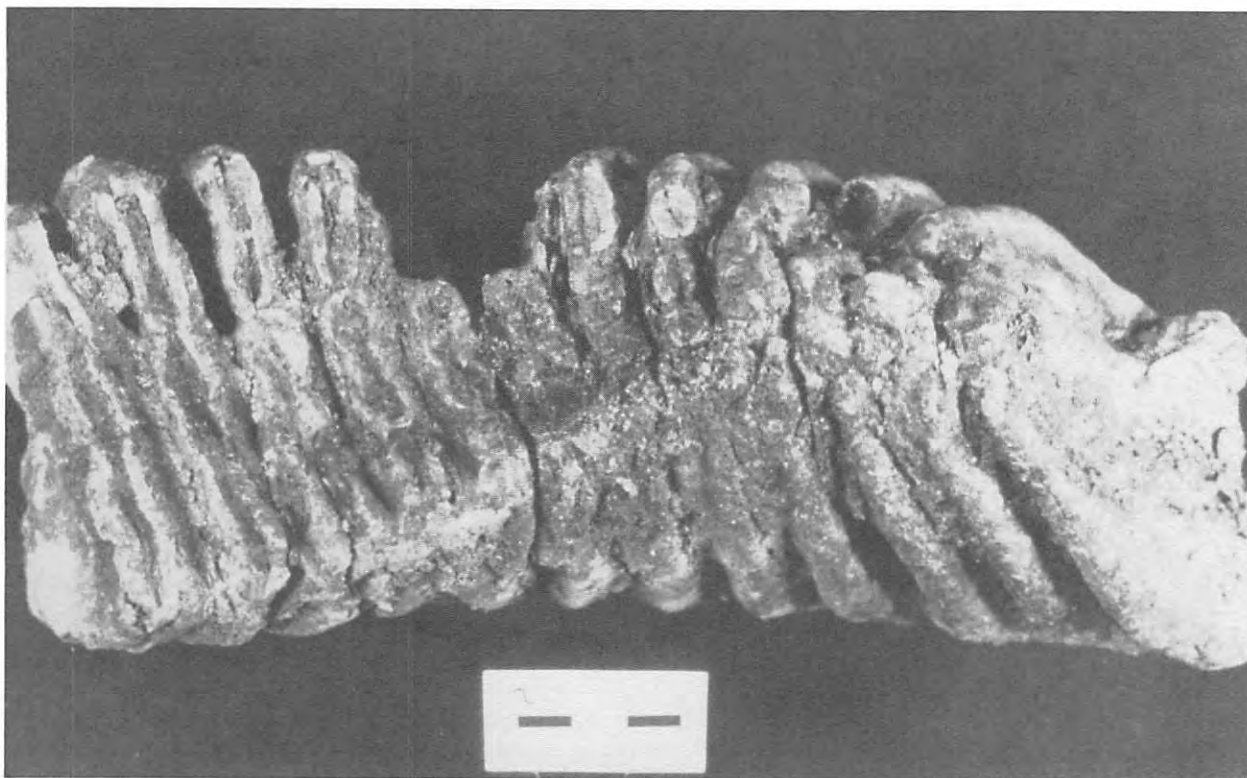
Figure 9-3. Occlusal view of LM/2 or M/3 of west mammoth (found in square 0-S1). Scale is centimeters.
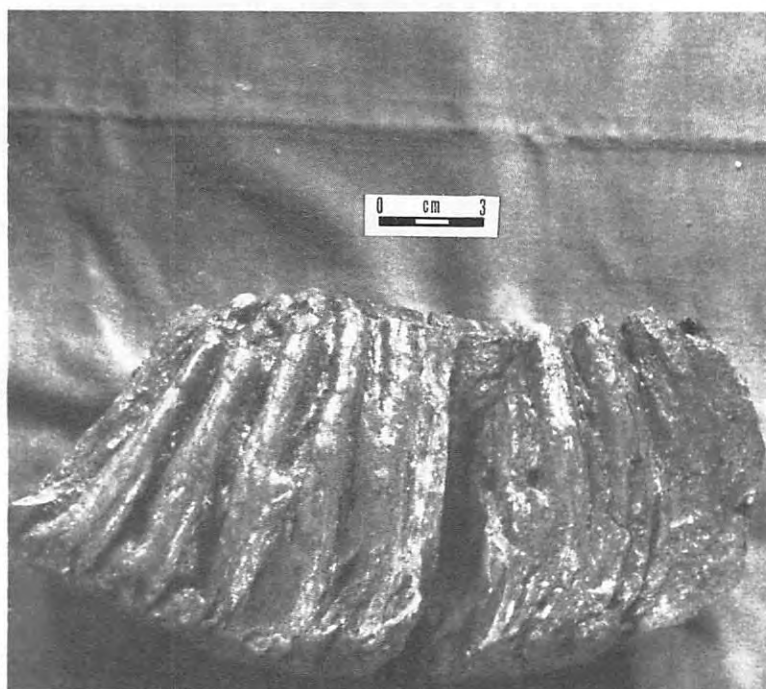
Figure 9-4. Lingual view of west mammoth's LM/2 or M/3
(found in square 0-S1). Scale is in centimeters.

5. width (**W**) followed by a number in parentheses that refers to the plate number from which the value was taken;
6. thickness of enamel evident on worn occlusal surfaces (**En**);
7. thickness of cementum at occlusal surface (**C**);
8. lamellar or plate frequency (**LF**) measured on the lingual (**lin**), labial (**lab**), and medial (**med**) surfaces and taken at points on the occlusal surface, one-half distance to the base, and at the base.

Figure 9-2 illustrates the measurement parameters for the Hajny specimens. Measurements were taken following those used by Maglio (1972) and Saunders (1970). Since the thickness of enamel and cementum varies from one part of a plate to another, measurements for these variables (shown in Table 9-1)

represent ranges where possible. Measurements were taken at subjectively chosen areas along the occlusal surface. Care was taken not to take measurements on enamel and cementum areas that had been worn at an angle.

The West Mammoth

The first molar found was exposed in square 0-S1 during the 1985 field season. This specimen is incomplete, missing both the anterior and posterior plates. It is identified as a left, lower molar and is designated as either a M/2 or M/3 based on overall size and lamellar frequency. Exact identification is not possible. It is well worn, nine of the 12 enamel loops present being complete. The occlusal and lingual views are provided in Figure 9-3.

Figure 9-5.   East mammoth's RM3/ found in square N1-E4. Molar still has maxillary bone adhering to it. Scale is in centimeters.

The remaining molar associated with the west mammoth was in square 0-W1. This specimen was in such a poor state of preservation that it could not be removed from the field. As noted in Chapter 8, this molar occurred in the southern part of the bone bed (Figure 9-1) where damage by machinery was most apparent. Due to its broken, scattered state, no measurements were obtained.

The East Mammoth

As noted earlier, four molars are associated with the east mammoth. The specimen recovered from square N1-E3 (Figure 9-1) is identified as a right, upper third molar. It is incomplete anteriorly, exhibiting only six plates and displaying extreme wear. This specimen remains partially encased in maxillary bone (Figure 9-4).

A relatively complete left, upper third molar (LM3/) comes from square N1-E4 (Figure 9-1). This specimen was identified in the lab as a lower molar due to the basin shape of the occlusal surface. However, upon review of the field notes and slides, it became evident this molar was partially encased in maxillary bone when first uncovered in the field. The condition of the bone was extreme-ly poor and could not be retained. The mated lower left molar (discussed below) has a raised platform area along the first four plates which match the basin-shaped occlusal surface of this molar. There is some anterior erosion of this specimen, and approximately 75% of the plates are worn (Figure 9-5).

The remaining two specimens come from square N1-E5 (Figure 9-1) and consist of the lower left and lower right third molars (LM/3; RM/3). Both are still in a nearly complete, but badly crushed and twisted, mandible (Figure 9-4). Because of this, not all measurements were possible. The left M/3 is a long, wide specimen which is well worn and exhibits slight anterior erosion (Figure 9-7). Its first three enamel loops are contiguous, and seven enamel loops are complete with a tendency to be concave anteriorly. As noted above, the occlusal outline of this molar is such that the first four plates form a raised platform followed by a basin-like surface. The right M/3 appears much less worn than its bilateral mate (Figures 9-6 and 9-8). No enamel loops are complete; there is no anterior erosion; the M/2 has been eliminated; and there is approximately 50% wear. These attributes show that this molar is in an entirely different stage of wear than its bilateral mate.

Table 9-3.   Mammoth Age Groups at the Hajny Site.

Provenience	Element	Laws' Age Group	Equivalent African Elephant Years (AEY)
WEST MAMMOTH			
West A - - S1-E0	Left M/2 or M/3	XVII	28 years
EAST MAMMOTH			
East A - - N1-E3	Right M3/	XXVIII	55 years
East B - - N1-E4	Left M3/	XXIII	43 years
East C - - N1-E5	Right M/3	XXII/XXIII	41 years
East D - - N1-E5	Left M/3	XXII/XXIII	41 years

Age Groups

The Hajny mammoth molars have been placed into relative and chronological age groups following the method outlined by Laws (1966). Age groups are determined by characteristics of wear and the progress of eruption of cheek teeth described in Tables 9-1 and 9-2. Table 9-3 summarizes the findings for the Hajny site's two mammoths.

The only molar available for the west mammoth is tentatively placed in Laws' Age Group XVII. As already noted, this is an isolated molar that is missing both anterior and posterior plates. As a result, identification as M/2 or M/3 is unclear. However, placement of this molar in Age Group XVII means the west animal had attained a minimum age of 28 African elephant years (AEY).

The remaining four molars are associated with the east mammoth. As can be seen from Table 9-3, characteristics observed on these molars indicate a wide range of age groups.

These age groups range from 41 to 55 AEY. Placement of the right M3/ (from square N1-E3) in group XXVIII provides a maximum age, because this molar appears to be nearly a waste fragment. Its bilateral mate (the left M3/ from square N1-E4) is a much larger tooth that exhibits the beginnings of anterior erosion. A total of 75% of the plates are worn, and the M2/ has been eliminated. Thus, this molar has been assigned to age group XXIII (43 AEY). If these right and left upper molars represent a single elephant, as is interpreted here, then we have significant variation of molar size, wear, and/or replacement within an individual animal.

This variation is further evidenced by characteristics observed in the east mammoth's lower third molars, both of which are still encased in the mandible. The assignment of the right M/3 to age group XXII/XXIII is possible only because it is known that the M/2 is eliminated. If this molar was examined as an isolated tooth, then most likely it would be

Figure 9-6. Posterior view of east mammoth's twisted broken mandible. Scale is in centimeters.

Figure 9-7. Occlusal view of east mammoth's LM/3 molar. Scale is in centimeters.

assigned to age groups XXI/XXII (37.5 AEY) due to its lacking anterior erosion and to 50% of its plates being worn.

Characteristics observed on the left M/3 indicate that this molar is in a totally different stage of wear than its bilateral mate. Indeed, had these left and right molars been recovered without the surrounding mandibular bone, they surely would have been considered to come from two different animals! The fact that both molars are still in the mandible provides unquestionable evidence of the degree of variation possible in one individual's tooth eruption and wear. While such extreme bilateral asymmetry could attest to tooth damage, it may merely reflect delayed molar eruption (J. Saunders, personal communication). According to Haynes (1991), however, upper molars wear differently than lower molars and often result in asymmetrical wear on both sides of the lower jaw.

Figure 9-8. Occlusal view of east mammoth's RM/3 molar. Scale is in centimeters.

In summary, both mammoths at the Hajny site appear to be mature adults. At the time of its death the west mammoth was at least 28 AEY. In contrast, the east mammoth (represented by right and left, upper and lower third molars) was between 41 and 55 AEY. This wide range possibly results from tooth damage but more likely is due to the variation in molar wear and elimination possible within an individual animal.

Mammoth Species at the Hajny Site

At least 25 species of *Mammuthus* have been identified for the North American continent (Anderson 1984:83-86; Kurten and Anderson 1980:343-354; Madden 1981; Maglio 1973; Osborn 1942). It is not the intent of this chapter to review the literature on mammoth taxonomy, nor to necessarily attach a taxonomic label to the Hajny sample. It may be more useful, as suggested by Maglio (1973:62), to discuss placement of the Hajny mammoths within an evolutionary sequence. In so doing, I follow the evolutionary scheme of Maglio (1973). Briefly, he outlines four specific taxa of mammoths for North America. These include *Mammuthus meridianalis*, *M. imperator*, *M. columbi*, and *M. primigenius*. The first three represent successional populations exhibiting progressive evolutionary changes. The latter represents a Eurasian immigrant during the Wisconsinan glacial stage.

The earliest, and only, form of mammoth in North America during the early Pleistocene was *M. meridianalis* (Maglio 1973). This robust, "primitive looking" species displayed the following M3 dental characteristics: 10 to 13 plates, a lamellar frequency of 4.0 to 4.5, and enamel thickness of 2.5 to 3.0mm (Maglio 1973:61-63). By middle Pleistocene times, *M. meridianalis* grades into an intermediate stage known as *M. imperator* (ibid.). With this stage there is an increase in the number of M3 plates (16- 19) and an increase in the lamellar frequency (now 4.0-6.0). Later forms of *M. imperator* morphologically grade into the late Pleistocene mammoths known as *M. columbi*. In this taxon there is a general increase in the number of plates (20 +) as well as an increase in the lamellar frequency (5.0-7.0) and a thinning of the molar enamel (ibid.). Later examples of *M. columbi* third molars exhibit up to 20 or 24 plates and have lamellar frequencies of 7.0 to 12.0.

In comparing the Hajny sample to the evolutionary scheme proposed by Maglio (1973:61-63), and described above, several factors must be considered. Graham (1986) discusses three processes which can affect the determination of mammoth species identification. Not only must the evolutionary stages (as evidenced by dental characteristics) of the species be considered but the stage of tooth wear (which affects these characteristics) must be examined. Thirdly, geographical clinal variation should be reviewed. In North America, the latter becomes especially important in distinguishing later forms of *M. columbi* from *M. primigenius* (as discussed by Maglio 1973:62).

Of the six molars recovered from the Hajny site, only two are complete. Specimen East B (LM3/ from N1-E4) exhibits 21 plates and has a lamellar frequency of 5.5-6.5, falling within the range described by Maglio (1973:61-63) for *M. columbi*. The other complete molar is specimen East D (LM/3 from N1-E5). It displays 17 plates and a lamellar frequency of 3.5-4.0, thus falling within the range of *M. imperator* (ibid.). As noted previously, these two molars are believed to be from the same individual!

Lamellar frequency values from the remaining broken specimens range from 6.0-8.0, indicating possible relationships to *M. columbi*. The exception is specimen East A (RM3/ from N1- E3) which exhibits a lamellar frequency of 3.5, a value more closely associated with *M. imperator*.

Graham (1986) has illustrated, from his study of the Domebo mammoth, that values for dental characteristics such as the number of plates, lamellar frequency, and enamel thickness may differ within the same individual as a result of varying degrees of tooth wear. Specifically, "...as mammoth teeth wear

the number of plates is reduced, the spacing between plates is increased, and the enamel thickness is greater" (Graham 1986:169). Hajny specimen East A has been described herein as exhibiting extreme wear. Perhaps, then, the low lamellar frequency value (3.5) for this molar is more reflective of the stage of wear than an evolutionary stage.

Somewhat varying degrees of wear are indicated on the remaining specimens. The complete molar for N1-E4 (Specimen East B) indicates 75% of the plates are worn. As described earlier, this molar has 21 plates. Given the degree of wear, this may argue more firmly for placement with the *M. columbi* taxon. The lower mate (East D) to this specimen displays only 17 plates and appears less worn (50%). This may strengthen its placement within *M. imperator*.

The degree of variation, both in dental characteristics and in stages of tooth wear, exhibited in molars from the same individual makes taxonomic assignment of the Hajny mammoths tenuous at best. Perhaps the intermediate nature of the Hajny sample reflects an evolutionary stage between *M. imperator* and *M. columbi*? If this is the case,

then it would tend to support the late Illinoian or early Sangamonian age for the site.

Very little post-cranial evidence is available from the Hajny mammoths to help resolve their species identification. Length and width measurements for the east mammoth's femur and tibia fall within the ranges reported (Madden 1981) for both *M. imperator* and *M. columbi*. The femur measures 1230 mm in length which is toward the higher end of the *M. columbi* range (980-1295 mm; $\bar{x}$ = 1145 mm) while being in the middle of the *M. imperator* range (1086-1468 mm; $\bar{x}$ = 1357 mm). Measuring 760 mm in length, Hajny's east mammoth tibia also compares favorable with sizes recorded for both species.

Summary

The Hajny mammoths bear attributes and dimensions common to both *Mammuthus imperator* and *M. columbi*, and they possibly represent an intermediate evolutionary stage between the two species. However, the small and broken nature of the Hajny samples precludes precise speciation at this time. The incredible variation in dental characteristics and wear serves to illustrate problems inherent in any classification system.

CHAPTER 10

The Hajny Local Fauna

Larry D. Martin

The Hajny Local Fauna

A small collection of vertebrates was found at the Hajny site as accidental discoveries while troweling through the sediments during excavation of the mammoths (Figure 10-1). A higher yield of small vertebrates could probably have been achieved through underwater screening. In most cases the remains were scattered and very fragmented.

The vertebrate taxa recovered from the site (Figure 10-1) include: *Rana* sp. (grass frog); *Terrapene* cf. *carolina* (large boxturtle); *Aix* sp.(wood duck); *Geomys* sp. (pocket gopher); *Neofiber leonardi* (Leonard's water rat); *Mammuthus* (mammoth); some form of pronghorn; and *Equus* sp. (extinct horse). The horse, pronghorn, mammoth, and pocket gopher all indicate grassland habitat, and in the case of the pocket gopher, these grasslands would need to be close to the site of deposition unless the remains were brought to the site by a raptorial bird.

The wood duck, if a resident, would require trees adjacent to water for nesting, but trees need not have been close if only an occasional visit occurred. All the rest of the vertebrates can be associated with a marshy environment. The absence of fish and the rarity of amphibian remains suggests the absence of permanent standing water.

Two of the recovered taxa deserve detailed attention: the boxturtle (Figure 10-2) and the extinct water rat (Figure 10-3). The boxturtle *Terrapene* was the most commonly recovered small vertebrate, but even the turtle remains were scattered and fragmentary. The presence of boxturtles, which prefer marshy

areas to open water, and the absence of pond turtles is consistent with the habitat reconstruction given above. The fossil turtles are relatively large with the largest individuals estimated to have a carapace length approaching 170 mm.

Large size is also characteristic of early boxturtle populations in the Central Great Plains (Auffenberg 1958), and large turtles have also been associated with interglacials.

The excavations produced several fragmentary specimens of a large arvicoline rodent (Figure 10-3) that can be separated from the muskrats *Pliopotamys* and *Ondatra* on the basis of unrooted teeth with dense crown cementum. The teeth are a little larger than those of the living round tailed water rat, *Neofiber alleni* True. They also differ from the living form in having the external re-entrant angles on m1 broader and more turned anteriorly. The m3 of the fossil has two labial re-entrant angles while the living form usually only has one. In all of these respects the fossils resemble the extinct water rat *Neofiber leonardi* which Hibbard (1943) described from the Rezabek Local Fauna of Kansas, and they can be assigned to that species.

The Hajny record of *Neofiber leonardi* is an important one. The species was described from the Rezabek Local Fauna of Lincoln County, Kansas, and was later reported from the Kanopolis Local Fauna of Ellsworth County, Kansas (Hibbard et al. 1978).

Both of these sites were regarded as Yarmouthian by Zakrzewski (1975). The present record, however, appears late Illinoian in age and

Figure 10-1. Distribution of faunal remains, other than mammoths, recovered from the Hajny site.
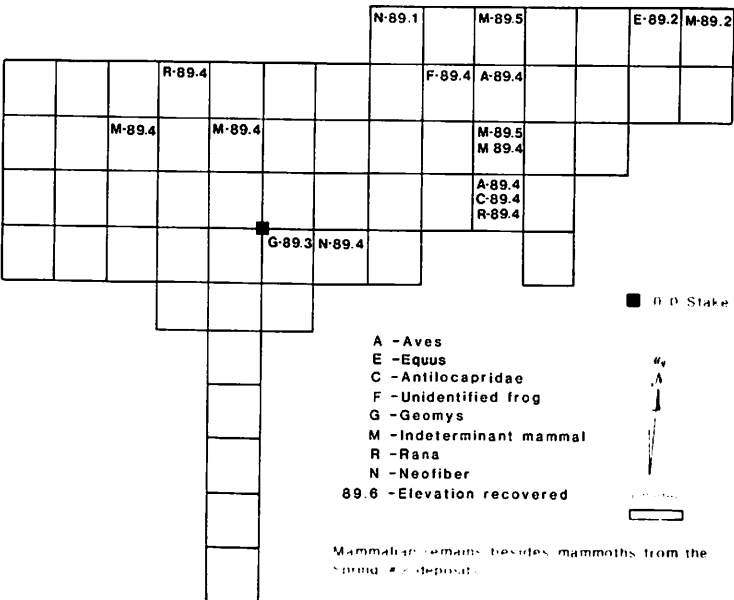
thus significantly extends the known temporal range of *N. leonardi*. Resting in the lowest spring deposit, this animal's mandible was broken but did not appear waterworn as if redeposited. This is the first record of a fossil water rat from Oklahoma. The living species, *Neofiber alleni*, is restricted to Florida and southern Georgia (Figure 10-4). It is possible that the living form is restricted in range by an intolerance to freezing temperatures, perhaps due to temporary losses of its food supply during the winter (Frazier 1977:372).

Neofiber leonardi is found together with *Ondatra* in both Kansas localities, but no *Ondatra* has been recovered from the Oklahoma site which may have been south of the southern limit of *Ondatra* at the time of deposition of the sediments at the Hajny site.

Figure 10-2. Posterior view of carapace fragment of *Terepene* cf. *carolina* found in the South Lateral backhoe trench.

Birkenholz (1972) suggests that *Neofiber* is restricted to regions that are largely frost free because it feeds on marshy vegetation throughout the year. A similar factor may limit the distribution of cotton rats (*Sigmodon*) which needs a year-round supply of food that may be interrupted by ice storms. In any case, the presence of *Neofiber* indicates warmer winters than presently occur in this part of Oklahoma. Because all other records of *Neofiber leonardi* are Irvingtonian in age, the most logical stratigraphic assignment would have been the Yarmouthian interglacial. However, the stratigraphic position indicates an Illinoian age. Wisconsinan sites in southern Oklahoma and Texas (Slaughter 1967; Lundelius 1967) contain armadillos (*Dasypus*) and giant tortoises (*Hesperotestudo*). Both of these animals are also thought to be intolerant of freezing temperatures, but these animals are not evident at Hajny.

Summary

The presence of *Neofiber* in Oklahoma may be taken as further evidence of climatic equability (cool summers coupled with warm winters) during the Illinoian glacial stage. As pointed out by Martin and Martin (1986:126), equable Pleistocene climates are often cited as a difference between Wisconsinan and Holocene environments. The Hajny site findings seem to indicate that Illinoian climates were also warm in Oklahoma.

Acknowledgments
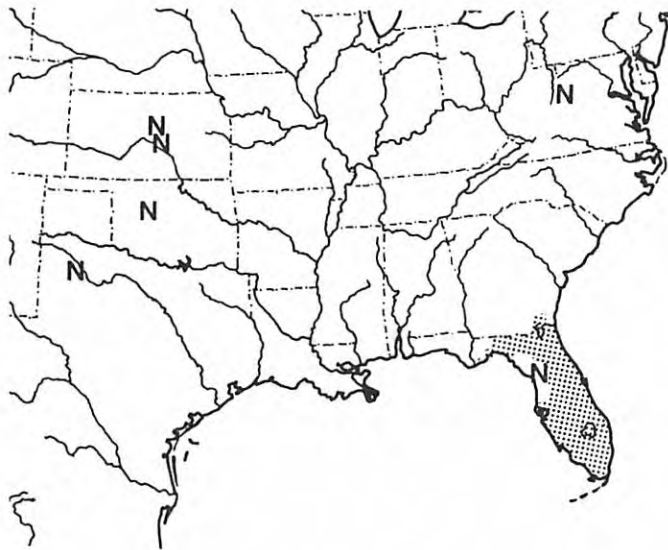
Figure 10-3. TOP: Right lower dentition of *Neofiber leonardi* from the Hajny Spring #2 deposit. BOTTOM: Drawing of *Neofiber leonardi* dentition and distribution of *Neofiber* (N = extinct occurrences; stippled area is modern distribution). Adapted from Frazier 1977: Figure 2.

CHAPTER 11

Gastropods from the Second Spring Deposit, Hajny Mammoth Site

Branley A. Branson

Six samples of sediment were collected from the four strata and single lens of spring deposits exposed in the south wall of square N2-E3 (Figure 11-1). These were bulk matrix samples of approximately 2.0 liters each; they were collected in as large, intact pieces as possible. All six samples were used for extraction of identifiable gastropods. Each sample was dissolved in water and passed through a set (from 0.088 to 2.0 mm) of graduated sieves. Each sample was then air dried and segregated by hand.

The samples and recovered gastropods are listed below. Catalogue numbers (EKU #) were assigned to the identifed species from each sample. These catalogued specimens are housed at the Department of Biological Sciences at Eastern Kentucky University, Richmond, Kentucky.

Sample A1
Collected November 18, 1985, from the upper part (see Figure 11-1) of field-identified horizon A, 4 to 34 cm east of the N2-E2 stake:
  many white nodules, but no mollusks or parts thereof.

Sample A2
Collected November 18, 1985, from the lower part (see Figure 11-1) of field-identified horizon A, 12 to 33 cm east of the N2-E2 stake:
  3 *Hawaiia minuscula* (Binney) (terrestrial), EKU-13410

1 *Gastrocopta tappaniana* (Adams) (terrestrial), EKU-1340

11 *Vertigo rugosula* Sterki (terrestrial), EKU-13408

2 *Gastrocopta contracta* (Say) (terrestrial), EKU-13407

3 *Vertigo ovata* Say (terrestrial), EKU-13406

9 *Gastrocopta pentadon* (Say) (terrestrial), EKU-13405

7 *Gastrocopta cristata* (Pilsbry and Vanatta) (terrestrial), EKU-13404

243 *Promenetus kansasensis* (Baker), EKU-13402

345 *Lymnaea (Stagnicola) caperata* (Say), EKU-13398

260 *Lymnaea (Stagnicola) reflexa* (Say), EKU-13399

2 *Quickella* cf *vermeta* (Say) (terrestrial), EKU-13402

2 *Oxyloma decampi gouldi* Pilsbry (terrestrial), EKU-13400

162 *Physa virgata anatina* (Lea), EKU-13401

296 *Gyraulus circumstriatus* (Tryon), EKU-13397

748 *Gyraulus parvus* (Say), EKU-13396

Sample B
Collected November 18, 1985, from a thin, white sandy lens (designated horizon B) within horizon A (see Figure 11-1), 4 to 34 cm east of N2-E2 stake:
  much sand (resorted?) and broken shell (unidentifiable) only.
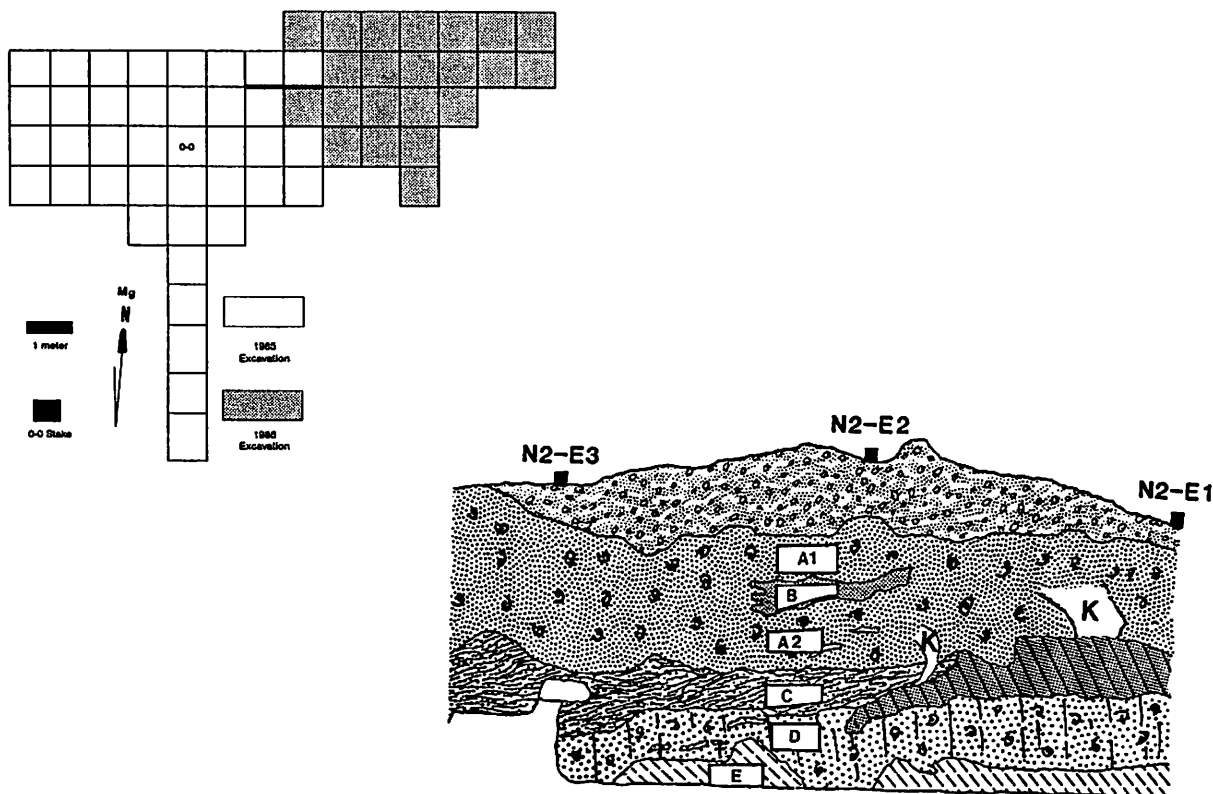
Figure 11-1. Location and stratigraphic position of Hajny Spring #2 sediment samples from which gastropods were studied. For detailed profile description see Figure 5-15 in Chapter 5.

Sample C

Collected November 18, 1985, from field-identified horizon C (see Figure 11-1), 12 to 33 cm east of N2-E2 stake:

5   *Lymnaea* (*Stagnicola*) *reflexa* (Say), EKU-13393

3   *Lymnaea* (*Stagnicola*) *caperata* (Say), EKU-13392

27   *Gyraulus circumstriatus* (Tryon), EKU-13391

5   *Physa virgata anatina* (Lea), EKU-13395

2   valve of *Sphaerium transversum* (Say), EKU-13394

plus many unidentifiable shell fragments

Sample D

Collected November 18, 1985, from field-identified horizon D (see Figure 11-1), 10 to 30 cm east of N2-E2 stake:

4   *Gyraulus parvus* (Say), EKU-13389

1   *Physa virgata anatina* (Lea), EKU-13390 plus some unidentifiable shell debris

Sample E

Collected November 18, 1985, from field-identified horizon E (see Figure 11-1), 23-42 cm east of N2-E2 stake:

no mollusks of any sort, nor any shell fragments.

Summary

The species involved and their percentage compositions are in keeping with a Wisconsinan faunule that lived in a temporary to semi-permanent, relatively shallow body of water that was well vegetated. Such setting could have included a pond, a marsh, or a back-water area of a sluggish stream.

CHAPTER 12

Paleoenvironmental Reconstruction From Gastropods At The Fifth Spring Deposit, Hajny Mammoth Site

James L. Theler

Introduction

The subfossil shells of aquatic and terrestrial snails (gastropods) are abundant in many Quaternary deposits of the Great Plains. In most cases, the shells can be attributed to living taxa, the distribution and ecology of which are understood to some degree. Gastropod taxa represented in Quaternary deposits are compared with data derived from extant populations of the same species and used as a source of proxy information in the reconstruction of paleoenvironments (Hibbard and Taylor 1960; Miller 1966; Taylor 1960; Wells and Stewart 1987). The abundant gastropod shells from the fifth spring deposit at Hajny are used to assess the local habitat and regional environment.

Methods And Materials

A one liter matrix sample from the fifth spring deposit at the Hajny mammoth site (Figure 2-3) was processed specifically for the recovery of subfossil gastropod shells. The matrix was subjected to a watersceening procedure with all material larger than .425 mm retained in a Tyler #40 geologic sieve. The abundance of gastropod shells resulted in subdividing the processed material with a Humboldt sample splitter to obtain an unbiased .25 liter subsample. From this subsample all complete and potentially identifiable shell fragments were isolated and removed from non-shell sediment with the aid of a low power (10X) binocular microscope. Shells (Figure 12-1) were sorted to taxon with reference to Baker 1928; Burch 1962, 1982, 1988; Burch and Tottenham 1980; Clarke 1981; Franzen 1947; Leonard 1943; Hibbard and Taylor 1960; Pilsbry 1948; Taylor 1960; and others. Following identification, shells were counted, catalogued by taxa and stored in glass vials containing individual labels with pertinent taxonomic and provenience information. The taxonomic nomenclature used here is that presented by Turgeon et al. (1988).

Results

Aquatic Gastropods

The .25 liter Hajny sample contained 3118 individual gastropod shells. The majority (98.7%) of these are shells of aquatic species with 3076 specimens of 11 taxa (Table 12-1). The most abundant snail is referred to *Promenetus exacuous* (Say) with 1249 individuals representing 42.1% of the aquatic assemblage. In assemblages of pre-Sangamon age this taxon has been frequently classified as *Promenetus kansasensis* (Baker) based on a surface sculpture of riblets (Hibbard and Taylor 1960:105-110; Taylor 1960:60). It has been suggested that by post-Sangamon times riblets on this taxon were for

Table 12-1.   Gastropods Recovered from Fifth Spring Deposit, Hajny Mammoth Site (34Dw23).

	Number Of Individuals	Percentage
Aquatic Gastropods		
Taxa		
Stagnicola caperatus (Say)	2	.1
Fossaria dalli (F.C. Baker)	178	6.0
Fossaria obrussa (Say)	12	.4
Fossaria parva (Lea)	55	1.9
Gyraulus parvus (Say)	324	10.9
Gyraulus circumstriatus (Tryon)	148	5.0
Gyraulus sp. (juveniles)	706	23.8
Planorbella sp. (juveniles and adult fragments)	24	.8
Promenetus exacuous (Say)	1249	42.1
Ferrissia fragilis (Tryon)	3	.1
Ferrissia sp.	3	.1
Physella virgata (Gould)	64	2.2
Physella gyrina (Say)	59	2.0
Physella sp. (juveniles)	139	4.7
Subtotal	2966	100.1
Juveniles	110	
Aquatic Total	3076 (98.7%)	
Terrestrial Gastropods		
Taxa		
Carychium exiguum (Say)	2	
Hawaiia minuscula (Binney)	1	
Deroceras laeve (Muller)	1	
Succineidae	6	
Strobilops labyrinthicus (Say)	1	
Strobilops sp.	3	
Gastrocopta pentodon (Say)	4	
Gastrocopta cristata (Pilsbry and Vanatta)	4	
Vertigo ovata Say	2	
Subtotal	24	
Terrestrial sp. (juveniles)	18	
Terrestrial Total	42 (1.3%)	
Sample Total	3118	

NOTE: Sample volume was .25 liter.
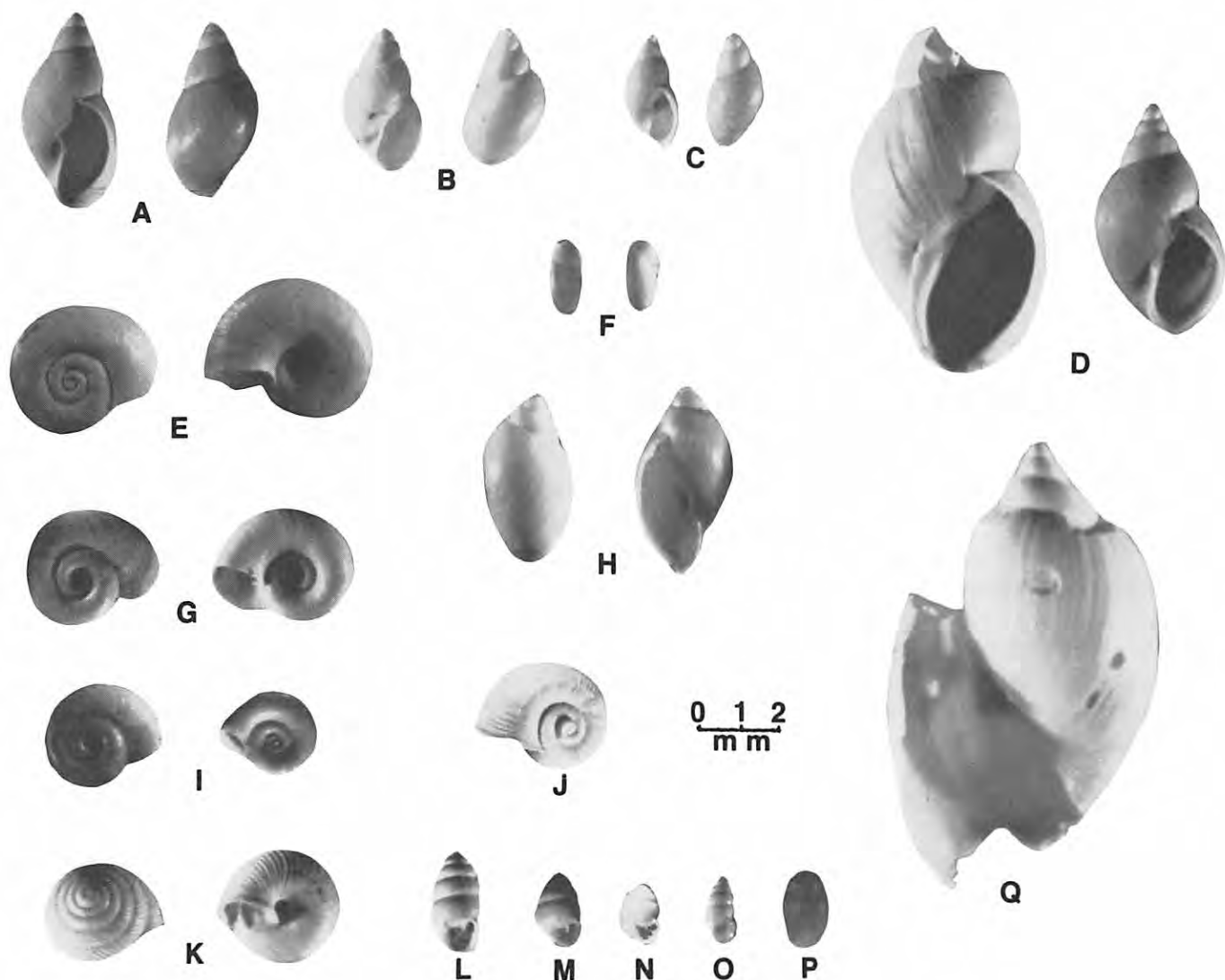
Figure 12-1. A. *Fossaria dalli*   B. *Fossaria parva*   C. *Fossaria obrussa*
D. *Stagnicola caperatus* E. *Promenetus exacuous* F. *Ferrissia fragilis*
G. *Gyraulus parvus*   H. *Physella gyrina*   I. *Gyraulus circumstriatus*
J. *Planorbella*   K. *Strobilops labyrinthicus* L. *Gastrocopta cristata*
M. *Gastrocopta pentodon* N. *Vertigo ovata*   O. *Carychium exiguum*
P. *Deroceras laeve*   Q. *Physella virgata*
(*Hawaiia minuscula* and Succineidae are not shown.)

the most part replaced with less well defined growth lines. This transition possibly took place during the Sangamon. The evolved, post-Sangamon form is then referable to the extant species *Promenetus exacuous* (Hibbard and Taylor 1960:106). The Hajny *Promenetus* appear to be intermediate in riblet sculpture, perhaps indicating a late Illinoian or Sangamon temporal position following the reasoning of Hibbard and Taylor (ibid.). However, research by Miller (1966:234-235) has shown that a chronologic separation of *P. kansasensis* from *P. exacuous* based on riblet sculpture or other morphological characteristics is not evident for a series of High Plains *Promenetus* recovered from Pleistocene deposits. The Hajny *Promenetus* listed by B. Branson (preceding chapter) are perhaps identical to the specimens I have assigned to *P. exacuous*.

Promenetus exacuous is known to live in a wide range of quiet, shallow water habitats, including marshes, vernal and permanent ponds, lakes and low energy stream pools, often in association with aquatic vegetation or detritus on a mud substrate (Baker 1928:262; Clarke 1981:186; Pip 1986:58). Approaching the southern margin of its modern range, this species was found in vernal ponds and quiet creek pools in the Sand Hills of western Nebraska (Taylor 1960:42-44). In the Ozark Plateau of eastern Oklahoma, *P. exacuous* has been recovered "in a boggy area near a creek" (Branson 1961:57). A rare species in Kansas today, *P. exacuous* was recovered on aquatic vegetation in a cool water pond in Meade County (Leonard 1959:67). A population of *P. exacuous* has been located adjacent to the West Fork Trinity River in Terrant County, Texas. The setting for this disjunct population is a vernal pond having a clay rich substrate covered with fallen leaves (Pratt 1983:73-74). Pratt (ibid.) believes that this Texas population may represent a relic community surviving since the late Pleistocene, favored by a cool, shaded mesic habitat.

Next in abundance in the Hajny sample are members of the genus *Gyraulus*. *Gyraulus parvus* (Say) with 324 specimens represents 10.9% of the aquatic assemblage. This is widespread and common aquatic snail that is found on aquatic vegetation in a variety of temporary and permanent waters having a mud substrate (Baker 1928:376; Clarke 1981:180; Leonard 1959:61). *G. parvus* is a widespread species on the Plains today (Fullington 1982:63; Leonard 1959:64, Figure 28). *G. parvus* was the most common gastropod identified by B. Branson (preceding chapter) in the lower portion of Horizon A at the Hajny Spring #2.

The fifth spring deposit subsample also produced 148 shells of *Gyraulus circumstriatus* (Tryon), representing 5.0% of the aquatic assemblage. This species is characteristic of small seasonal ponds with aquatic vegetation and a mud substrate (Baker 1928:378; Clarke 1979:40, 1981:176; Strayer 1987:24, 47, Table 2). Although a common species in many late Pleistocene deposits on the Plains (Hibbard and Taylor 1960:98; Miller 1966:230, 1975:10, Table 1), *Gyraulus circumstriatus* is not known to be living today in Texas or Oklahoma and is rare and sporadic in Kansas and Nebraska (Fullington 1982:66, Table 2; Leonard 1959:64 and Figure 28; Taylor 1960:42-44).

In addition to *G. parvus* and *G. circumstriatus*, 706 individuals or 23.8% of the aquatic assemblage are specifically unidentifiable *Gyraulus* juveniles.

Fossaria dalli (Baker) is represented at Hajny by 178 individuals that equal 6.0% of all aquatic snails. *F. dalli* along with the less abundant *Fossaria obrussa* (Say) and *Fossaria parva* (Lea) are recorded as usually living on the wet ground at the margins of ponds or in shallow water, typically on mud or detritus (Clarke 1981:106; Franzen and Leonard 1943:406; Leonard 1959:51-52, 54-57).

Two Physidae, *Physella virgata* (Gould) and *Physella gyrina* (Say) together total 29 specimens and represent 0.9% of the aquatic forms. Additionally, there are 233 juvenile *Physella* that were not specifically classifiable and account for 7.9% of all aquatic snails. *Physella virgata* and *P. gyrina* are species that

can be found in a broad spectrum of aquatic habitats, but they typically occur in shallow, low energy regimes associated with aquatic vegetation (Clarke 1981:152; Leonard 1959:46-47).

Terrestrial Gastropods

The 42 land snails of eight taxa in the Hajny subsample comprise 1.3% of the entire gastropod assemblage. Although this number seems small in proportion to aquatic snails, a projected total of 168 terrestrial snails per liter can be considered a relative high density for paleontological sites (Wells and Stewart 1987:131).

Carychium exiguum (Say), a species usually found living in moist settings near creeks and ponds or among the detritus in woodlands (Leonard 1959:194), is represented by two shells. No extant populations of *C. exiguum* are known to be living in Oklahoma today (Hubricht 1985:59, Map 19), but it has been recorded at a few locations in Kansas (Leonard 1959:191, 194, and Figure 85).

Vertigo ovata Say is represented by two specimens in the Hajny sample. This species is widespread in the Plains region today, inhabiting riparian environments (Franzen 1947:355; Leonard 1959:186).

Other land snail species recovered at Hajny, all occurring in low numbers, include *Hawaiia minuscula*, (Binney), *Strobilops labyrinthicus* (Say), *Gastrocopta cristata* (Pilsbry and Vanatta), and *Gastrocopta pentodon* (Say). These species are usually found living in somewhat drier terrestrial locations than *Carychium exiguum* and *Vertigo ovata*. I have followed Bequaert and Miller (1973:88-89) in grouping the *Gastrocopta* forms that might be classified as *Gastrocopta tappaniana* (C.B. Adams) under *G. pentodon*.

Discussion

The snails found at the Hajny mammoth site may be used as proxy indicators of local habitat conditions when they lived at the site. A combined assessment for the habitat

preference of the aquatic gastropod *Promenetus exacuous* and the recovered species of *Gyraulus*, *Fossaria*, and *Physella* indicates a setting with marshy areas adjacent to quiet, relatively shallow ponded waters containing aquatic vegetation (see Martin, this volume) rooted in a clay rich substrate. This interpretation is consistent with the surface expression of an active spring conduit (Wyckoff et al. 1987). The terrestrial snails include the riparian taxon *Vertigo ovata* and the moist habitat associated *Carychium exiguum* in addition to species that would be found in grassy meadows, perhaps with some woody vegetation, including *Hawaiia minuscula*, *Deroceras laeve*, the Succineidae, *Strobilops labyrinthicus*, *Gastrocopta pentodon*, and *Gastrocopta cristata*. The land snails probably lived in the immediate vicinity of the fifth spring conduit.

The presence or absence of certain gastropod species can provide some indication of past climatic conditions. Today, the principal range of two abundant species at Hajny, *Promenetus exacuous* and *Gyraulus circumstriatus*, is to the north of Oklahoma, with only sporadic occurrences in Kansas and Nebraska. The southwest spread of some aquatic snail species appears to be controlled by warmth of summer water temperatures, although other factors such as available moisture are critical. The presence at Hajny of *P. exacuous* and *G. circumstriatus* implies cooler summer temperatures than those for modern Dewey County, but perhaps not as cool as during the Wisconsinan and Illinoian glaciations when the northern aquatic snails *Valvata tricarinata* (Say), *Physa skinneri* Taylor and *Gyraulus crista* (Linnaeus) were widespread in Kansas and Oklahoma (Devore 1975:21; Miller 1975:15 and Table 4). For example, *Valvata tricarinata* requires cool summer water temperatures, perhaps no greater than 15° C (59° F) (Taylor 1960:48). The boreal-alpine terrestrial snail species, *Pupilla blandi* E.S. Morse, *Pupilla muscorum* (Linnaeus) and *Vallonia gracilicosta* Reinhardt often considered (Miller 1975:5, Table 4; Pilsbry 1948:XLII; Wells and Stewart 1987) characteristic of cooler summer temperatures are

absent from the Hajny deposits. While the presence of *P. exacuous* and *G. circumstriatus* seems to indicate that summer temperatures were cooler than today, the absence of certain aquatic and terrestrial forms seem to indicate it was not so cold as during the maximum of the Wisconsinan glaciation.

Absent from the Hajny sample are a number of terrestrial species that seem to be controlled in their northward distribution by the "length and severity of the winters" (Miller 1975:14). Among these are *Gastrocopta procera* (Gould), *Gastrocopta pellucida* (Pfeiffer), *Helicodiscus singleyanus* (Pilsbry), and *Vallonia perspectiva* Sterki. Since *G. procera* and *G. pellucida* are present today in northern Oklahoma and portions of Kansas, it may be that winters during the period of Hajny spring deposition were more severe

than those of modern Dewey County. However, availability of habitat cannot be discounted in distributional considerations, because both *G. pellucida* and *G. procera* are associated with xeric vegetation communities that may not have been present in the vicinity of the Hajny site.

Summary

The snail fauna indicates that the fifth spring conduit at Hajny produced a shallow seasonal or perennial pool of water that supported aquatic vegetation growing from a mud substrate. Margins of the spring pool were marshy, with nearby higher, somewhat drier ground. The species composition of both aquatic and terrestrial snail assemblages may indicate somewhat cooler or shorter summers than those of present.

CHAPTER 13

DATING AND SUMMARIZING THE HAJNY MAMMOTH SITE

Don G. Wyckoff

When gravel quarrying uncovered bones of ice age elephants in a terrace high above the Canadian River, the find was perceived as an opportunity to see if these animals were hunted and killed by Oklahoma's earliest people. Initially obtained radiocarbon dates indicated the find was between 9,000 and 20,000 years old. These dates suggested the site might be contemporaneous with the first dispersal of humans across North America.

Controlled excavations began in October of 1985. They soon revealed that the remains of two mammoths were buried in spring sediments. Backhoe trenching in the vicinity revealed the fossil-bearing sediments were one of five spring locations that had formed along a prehistoric course of the Canadian River. This geological context and a continual lack of evidence for human involvement increasingly convinced us that the Hajny site was older than the arrival of humans in North America. Consequently, our research interest in the site shifted from one with an anthropological focus to one centering on paleontology and paleoecology. In essence, we gave up expecting evidence that people had killed these ice age beasts. Instead, we began compiling evidence that might allow us to explain what processes formed the springs, when they were active, what the setting and environment were like when they were flowing, what kind of animals were there, and what processes created the bone layout that we found.

Uncovered near the middle of nearly 10 meters of river-washed, interbedded sand and gravel, the Hajny site's five springs are unquestionably part of the geologic record left when the prehistoric Canadian was aggrading and forming this 36 meter (120 ft.) terrace. Because these springs occur at the same elevation, they probably formed at the same time, a period when the river's flood plain was relatively stable. More than likely, these springs were ancient sand boils created by up-welling ground water that had flowed west along the contact between the river alluvium and the underlying, west dipping bedrock (the Permian age, Rush Springs Formation). Because they contain thin accumulations of sediments and few animal remains, these springs probably flowed only a short period, perhaps only a season.

While these springs were active, thousands of fresh water snails flourished in their waters. Among the aquatic species, *Promenetus exacuous* is most abundant, but varieties of *Gyraulus* and *Fossaria* are also common. These aquatic forms attest to shallow pools that supported aquatic vegetation which grew on mud substrates. The occasional terrestrial snails recovered in the spring deposits are species that would have been common to moist habitats adjacent the springs and to grassy meadows nearby. Collectively, the aquatic and terrestrial gastropod assemblages bear witness to cooler, shorter summers than are normal in the region today.

Based on the recovered findings (which perhaps were limited due to the recovery techniques), vertebrate animals living at or frequenting the springs were few. Those residing at the springs included Leonard's water rat (*Neofiber leonardi*), the grass frog (*Rana* sp.), and box turtles (*Terrapene* cf. *carolina*). Of these, the water rat is an extinct form related to the modern *Neofiber alleni* which is restricted to Florida and southern Georgia today. The Hajny box turtles are also noteworthy because they are much larger than modern forms. The frog and box turtles are species that prefer marshy habitats, a setting already implicated by some of the aquatic gastropods. Whether it was residing there or a visitor, wood duck is represented in the Hajny fauna and constitutes further evidence to a marshy habitat around the springs.

From the extensively excavated Spring #2 deposits also come traces of horse (*Equus* sp.), pronghorn (Antilocapridae), and pocket gopher (*Geomys* sp.) and segments of two mammoth skeletons. All of these animals are forms that lived in grassland habitats nearby. The horse, pronghorn, and pocket gopher are represented by single bones or teeth. For this reason, these elements may have been dropped here by scavengers rather than originating from animals that actually died by the springs.

That is not the case for the mammoths. Represented by tusks, teeth, ribs, some vertebral elements, and a few heavy limb bones generally disarticulated and somewhat disarranged around Spring #2, these huge beasts clearly died by and were incorporated into that spring's sediments. Their cause of death is not known. Their sex could not be determined. Both were adult animals, the easternmost being slightly older. Occasional green bone breakage of this east individual's bones and one tusk and the incomplete nature of both animals' skeletons sort of resemble African elephant bone beds that acccumulate around drought-stressed waterholes. But these modern scenes typically contain many young animals, none of which are manifest at Hajny.

Low-charge spring flow may have slightly dispersed the mammoth bones, but they were principally moved and altered by a large animal (probably another mammoth) and by chemical, pedogenic, and highly destructive fluvial processes. This latter consisted of channel cutting and gravel deposition which cut away a portion of the spring's deposits; broke, tumbled, and roiled bone fragments; and literally abraded away sizeable segments of large bones.

This episode of channel cutting and gravel deposition marked the resumption of stream aggrading, a process that eventually covered the ancient springs with three to four meters of interbedded sands and gravels. These were covered, in turn, with fine sand to loamy calcic soils that underwent erosion and mass wasting much later in prehistory (during some episode[s] of the Wisconsinan glacial period?).

Despite the Hajny site's colorful spring deposits, intriguing snails and vertebrate animals, complex record of fluvial aggrading and soil accumulation, and subsequent erosion, two key questions about the site have not been clearly answered. What kind of mammoths are these? How old is this site?

The mammoth teeth share attributes and measurements that suggest they could be *Mammuthus imperator* or *Mammuthus columbi.*

M. imperator generally has an older record of existence in North America, dating roughly from over a million years ago to perhaps a hundred thousand years ago (Maglio 1973:61-63). But *M. columbi* is closely related and apparently overlaps the existence of *M. imperator* (ibid.). Given this situation and the ambiguous character of the Hajny mammoth teeth (which even show much variation within one individual), the Hajny mammoths can only be identified as *Mammuthus* sp.

Dating the Hajny Site

Direct and indirect dating permit two interpretations of the Hajny site's age. Before presenting these, the diverse evidence for the site's age is reviewed briefly.

Radiocarbon Dating. Regular radiocarbon dating was undertaken on two samples of mammoth bone, three samples of gastropod shells, and one sample of organic-looking sediment. This latter did not contain enough organic matter to be radiocarbon dated (Table 6-1). Both submitted bone samples came from the west mammoth at Spring #2. One bone sample was contaminated; its collagen failed to yield any results, even after repurification. A collagen sample from one of the west mammoth's initially discovered bones was radiocarbon dated at 8960 ± 240 B.P. (WSU- 2941). Two gastropod samples from Spring #2 were submitted, and they provided uncorrected results of 21,587 ± 2364 B.P. (SMU- 2093) and 27,890 ±415 B.P. (WSU-2942). The third dated gastropod sample was from Spring #5, and it yielded a result of 34,169 ± 2378 (SMU-2094). After correcting for isotope 13/12C fractionation (see Table 6-1), these gastropod samples date from 20,000 to 34,400 years ago. If correct, Spring #5 is some 13,000 years older than Spring #2.

Uranium Series Dating. Single molars from the east and west mammoths at Spring #2 were subjected to what must be considered an experimental dating technique. They were taken to Southern Methodist University where graduate student Curtis McKinney extracted interior enamel from each molar, established the uranium/thorium ratio for each, and used that ratio to determine the ages of each. As a result, the west mammoth's molar yielded a date of 143,026 ±5500 B.P., whereas the east mammoth's molar was dated at 166,045 ± 6500 B.P. (Table 6-1).

Terrace Sequence Dating. Five different terraces are believed (Fay 1959) evident along the Canadian in Blaine County, just 20 miles (32.2 km) downstream from Hajny.

The lowest terrace is 50 ft (15 m) above the present flood plain, and Fay (1959:10) interprets it to be Wisconsinan in age. Terraces at 150 ft (45.7 m) and 220 ft (67 m) are thought to be of Illinoian age (ibid.)

A relative age for the Hajny site can be estimated from the site's position within the Canadian's local terrace system. In the Hajny site vicinity, Brian Carter (Chapter 3) discerns as many as 10 distinct terrace levels. The lowest is 30 ft (9.1 m) above the present channel, whereas the highest is 340 ft (103.6 m). If one assumes a constant rate of fall in river elevation, and assuming that the volcanic ash in a terrace at 310 ft (94.5 m) is about 610,000 years old, Carter (ibid.) estimates the terrace sediments containing the Hajny site are around 240,000 years old. If so, they would be early Illinoian in age.

Carter's estimated geologic age may be roughly correct. The Hajny site is on the first prominent terrace above the very evident first terrace, and the site's elevation above the river is closest to downriver terraces identified (Fay 1959:10) as Illinoian.

Invertebrate Biostratigraphic Dating. The Hajny site's aquatic and terrestrial snails comprise assemblages that can be compared with dated assemblages from other paleontological sites in the region. Among these latter are seven gastropod assemblages from southwestern Kansas and northwestern Oklahoma (Miller 1975). Each of these assemblages has been radiocarbon dated; collectively, they provide a record from 10,700 to 29,700 years ago (ibid.). Another dated gastropod record is available for the 11,500 to 26,800 year-old deposits at northwestern Oklahoma's Burnham site (Wyckoff et al. 1991). Finally, paleontologist Barry Miller's (1991) recent application of aminostratigraphy for six gastropod taxa from 14 southwest Kansas-northwest Oklahoma sites provides at least a relative chronology that extends the regional record back to more than two million years ago.

Similar taxa of aquatic snails dominate the gastropod samples from Hajny Springs #2 and #5, but different species are most prevalent in each spring's inventory (see Chapters 11 and 12). For Spring #2, the five most abundant aquatic species are (in order of abundance): *Gyraulus parvus*, *Lymnaea* (*S.*) *caperata*, *G, circumstriatus*, *L.* (*S.*) *reflexa*, and *Promenetus kansasensis*. For Spring #5, the five most abundant aquatic species are *Promenetus exacuous*, *Gyraulus* sp., *G. parvus*, *Fossaria dalli*, and *G. circumstriatus*. The diverse compositions of the more abundant aquatic gastropods from these two springs may be further evidence (along with their nonoverlapping radiocarbon dates) that these two springs are not contemporaneous.

The Hajny springs' gastropod assemblages do share some species with assemblages reported for regional sites that are radiocarbon dated between 10,700 and 29,700 B.P. (Miller 1975:Tables 1 and 2; Wyckoff et al. 1991:Table 4). However, the greatest similarities appear to be with such Illnoian assemblages as those reported for the Berends, Doby Springs, Adams, Butler Spring, and Mount Scott sites (Devore 1975; Miller 1966). Most of the assemblages from these sites have every one of the predominant species recovered from Hajny Springs #2 and #5.

Vertebrate Biostratigraphic Dating. Correlating the Hajny site's faunal assemblage with those from dated sites in the region is done with caution. One reason for this is the Hajny faunal assemblage's limited size and diversity (although it does contain several interesting species). Another reason hinges on the problem of circular reasoning. Namely, because the geologic records for some species may not be known entirely, using only dated finds to correlate undated ones runs the risk of incorrectly restricting that species' record to what is known. Thus, it seems best to use more than one species when trying resolve questions of geologic age.

For Hajny, however, few of the recovered vertebrates can be speciated with any assurance: the box turtles and the water rat.

The box turtles (*Terrapene* cf. *carolina*) at Hajny are large, having carapace lengths of nearly 170 mm. This length only slightly exceeds that of modern northern versions of the species (Milstead 1969:33-35) while being nearly 30% smaller than Texas and Kansas finds dated to Illinoian and Sangamonian times (Milstead 1969:Table 5). In contrast, the water rat found at Hajny is believed representative of *Neofiber leonardi*, a species previously only known from Yarmouthian deposits in north-central Kansas (L. Martin, Chapter 10).

While the evolution of mammoths in North America is known in broad outline, but perceived differently by several scholars (Kurten and Anderson 1980:348-353; Madden 1981; Maglio 1973), the Hajny mammoths do not easily lend themselves to speciation. As noted by Flynn (Chapter 9), the Hajny mammoths exhibit surprising individual variation in tooth wear while manifesting characteristics attributable to both *Mammuthus columbi* and *M. imperator*. Maglio (1973:61-63) believes these two species are related, *M. columbi* developing from *M. imperator* perhaps as late as 100,000 years ago.

Interpreting the Hajny Site's Age

As a preface to discussions of the Hajny site's age, it should be noted that my use of formal glacial and interglacial stages relies on the time ranges recognized by Richmond and Fullerton (1986:Figure 2). As one project of the International Geological Correlation Programme, the recent correlation of northern hemisphere Quaternary glaciations (Sibrava, Bowen, and Richmond 1986) provides the most current thinking about (and standardization of) the timing and duration of North America's glacial periods.

Interpretation #1: Wisconsinan Springs and Fauna in an Illinoian Terrace. Without question, the sands and gravels exposed in the Hajny gravel pit bear witness to alluvial deposition during an ancient stage of river flow. An Illinoian age for this terrace deposit

seems entirely appropriate, especially given the terrace's relative position within the locally manifest series of terraces and its elevation above the Canadian's present bed. But are the five spring deposits found in this Illinoian terrace as old? A few clues can be interpreted to indicate they are not.

In particular, radiocarbon dated aquatic snails from Springs #2 and #5 attest to their being roughly 20,000 and 34,000 years old. Because the snail shells exhibit no breakage and abrasion (indicative of redeposition), these gastropods are believed to have thrived in those springs when they were active.

Stratigraphic evidence exists for at least two meters of alluvial sand and gravel being eroded from this terrace. Perhaps the snail shell dates are telling us that this erosion occurred prior to 34,000 years ago and that subsequent more effective precipitation (during the onset of the last Wisconsinan glaciation?) increased ground water flow, causing springs to form in arroyos. Then, as these springs began drying, they attracted late Pleistocene animals which we found there?

This interpretation was prevalent during most of the field work as we tried to reconcile the radiocarbon dated mammoth bone and snail shells with our findings. But as the field work ended, stratigraphic clues indicated something was amiss. The profile at Spring #3 showed that erosion had truncated the spring deposit (Figure 5-11). Thus, the spring was there prior to the major erosion. This conclusion was even more dramatically evidenced when Spring #5 was discovered after being uncovered during gravel quarrying. Despite dating some 14,000 years older than Spring #2, Spring #5 is at the same stratigraphic position as the other four springs, but it has nearly three meters of interbedded fluvial sands and gravel over it (Figure 5-2). This is not sand and gravel redeposited by some ephemeral drainage. Clearly, the river aggraded this much after Spring #5 ceased flowing.

All of these findings were made during the final days of field work, and they forced considerable rethinking of the site and its age. It became difficult to believe that the river aggraded an additional 2-3 m over the springs, then incised itself nearly 37 m, then aggraded a 9 m first terrace, and finally incised itself to its modern course in the 34,000 years indicated by the shell date from Spring #5. While spectacular late Pleistocene erosional rates are known to have occurred elsewhere in North America (Blum 1992; Bretz 1969; Madole et al. 1991:530-531; Waitt 1985), this segment of the Canadian drainage wasn't affected by flooding from broken ice dams, and evidence is lacking for orogenic changes that might have accelerated river cutting. In essence, the geological context of the Hajny springs is incongruous with the radiocarbon dates derived from snail shells.

Interpretion #2: Illinoian Faunal and Springs in an Illinoian Terrace. As noted, the bulk of the geomorphic evidence supports the conclusion that the Hajny site's terrace setting is of Illinoian glacial age (Carter, Chapter 3; Fay 1959:10). Experimental uranium series dating of the Hajny mammoth teeth indicates they are from 143,000 to 166,000 years old, a period currently considered (Richmond and Fullerton 1986:Figure 2) as being late Illinoian glacial age. These teeth come from one (possibly two coalesced) spring deposit, one of several that formed about the same time on a relatively stable floodplain. Eventually this floodplain was covered with two to three meters of fluvial sand and gravel. Thus, the fossil-bearing spring deposits were embedded within alluvium left by the Canadian when it was flowing at this elevation. Given the spring deposit's position slightly above the midpoint of the aggraded channel fill, the deposit and fauna probably date to one of the later substages of the Illinoian glacial stage.

Among the Hajny site's animal bones are remains of a species previously found in early Illinoian and even older Pleistocene contexts on the Plains. *Neofiber leonardi*, ancestor of today's water rat (*N. alleni*), is identified at

Hajny and is recorded in pre-Illinoian deposits in Kansas and Illinoian deposits in west Texas (Dalquest 1967; Hibbard 1943, 1955). Based on these finds and late Pleistocene occurrences of *Neofiber alleni* in Georgia and Florida, Frazier (1977:372) believes *N. leonardi* was grading into the present-day variety by late Illinoian times. While *N. leonardi's* occurrence at Hajny may make its duration on the Plains longer than thought, its presence is congruent with the Illinoian age attributed to the spring deposits and terrace.

Summary

The Hajny springs lie at a common elevation within river-aggraded sands and gravels that comprise a 37 meter terrace of western Oklahoma's Canadian River. This terrace compares favorably with one that geologist R.O. Fay (1959) identifies as being of

Illinoian glacial age. Experimental uranium series dating of Hajny mammoth molars also attests to late segments of this glacial stage. Little confidence is placed on late Pleistocene radiocarbon dates derived from aquatic snail shells. Like the mammoth bones, these shells must have undergone diagenesis after deposition. The character of such diagenesis is only now beginning to be understood (Stafford 1984; Stafford et al. 1987, 1988, 1991; Yates 1986).

In summary, attributing the Hajny mammoth site to the late Illinoian glacial stage is considered the most reasonable interpretation. Hopefully, opportunities will arise in the future to study archeological, paleontological, and geological finds that will further clarify the antiquity and changes along this segment of the Canadian River.

APPENDIX A

Lithic Clasts From The Hajny Spring #2 Deposits

Don G. Wyckoff

Few stones were recovered during the manual excavations around the mammoths at Spring #2. In fact, only eight stone clasts are recorded for the 18.1 cubic meters of spring sediments removed from the 61 1x1m squares. Although two of these clasts are flakes, none are believed the result of human knapping. However, to assure thorough documentation of everything that was found, all of the recovered clasts are described briefly below.

Pebbles

Table A-1 provides the provenience, measurements, and some descriptive notes for six waterworn clasts recovered during the manual excavations. None exceed 6.4 cm in

Table A-1. Variables and Attributes of Stone Clasts from Hajny Spring #2, Hajny Mammoth Site(34Dw23), Dewey County, Oklahoma.

Provenience	Elevation	Length	Width	Thickness	Weight	Comments
N1-W2	89.3[1]	3.87[2]	2.57[2]	1.16[2]	13.5[3]	black quartzite, very rounded pebble
N1-E1	89.5	4.25	3.34	3.13	78.3	quartz, very rounded pebble
N1-W1	89.4	4.44	2.90	2.20	39.7	quartz, very rounded pebble
N2-E3	89.5	0.88	0.37	0.20	0.5	angular pebble, blue-black chert
S2-E1	89.4	2.04	1.54	1.15	4.7	angular pebble of Alibates agatized dolomite
N2-E1	89.5	2.97	2.08	1.22	8.8	angular pebble of Alibates agatized dolomite
N2-E5	89.7	1.80	1.33	0.27	1.1	flake of Alibates agatized dolomite
N1-E2	89.5	0.56+	1.22	0.2	0.5	fragment of Alibates agatized dolomite flake

[1] Meters relative to datum elevation 100.0.

[2] Measured in centimeters.

maximum dimension, so all are classifiable as pebbles. Two very rounded, patinated pieces are yellowish quartz, a material probably derived from the Rocky Mountains at the Canadian's westernmost extent. Another very rounded, patinated pebble is a black, fine grained quartzite like that sometimes seen in nearby Pleistocene and earlier gravel deposits. Although knappable, this black quartzite seldom appears to have been used by prehistoric people residing in western Oklahoma.

Three other pebbles are of cherty material. One very small, elongated, triangular piece is a blue-black flint that could have eroded from the Alibates Formation, an agatized dolomite (Permian) with bedrock exposures along the Canadian River in the Texas panhandle (Bowers 1975). The remaining two pebbles are small, waterworn (but angular) pieces that are clearly Alibates agatized dolomite.

Flakes

Two flint flakes were recovered from the Spring #2 deposits. Both are of Alibates agatized dolomite. The largest (Figure A-1) has a battered, very patinated, cobble cortex

dorsal face, whereas the smallest represents the distal end of a flake which has cortex and other flake scars on its dorsal face. The ventral faces of both faces are the fracture surfaces of these flakes, and these surfaces exhibit a lot of polishing due to water- carried fine sediments.

The largest flake has a narrow, cobble cortex platform and a readily visible bulb of force (Figure A-1). These attributes are believed to result from a blow, probably from a gravel cobble being swept along during episodic flooding.

Summary

Clearly, stone clasts are rare within the spring sediments around the Hajny mammoths. Their rarity, in part, must be due to the weak flow of Spring #2. Cobbles and pebbles do occur in the river-laid gravels several meters below this spring's mouth, but the water force was not strong enough to move these clasts upward.

Although two flint flakes were recovered, both are of lithic material common to Canadian River gravels (Wyckoff 1989). Neither show platform preparation and/or patterned flake removal as is common to flakes produced by human knapping. Both most probably were struck off as cobbles were swept along the river during periods of flooding.
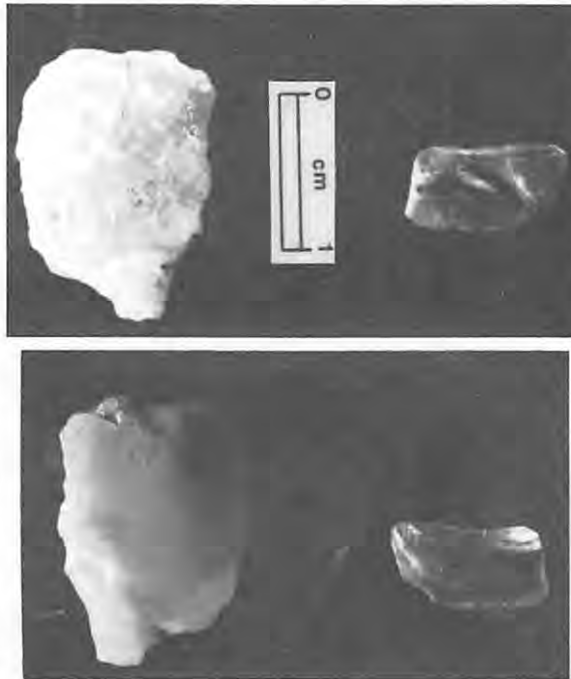

Figure A-1. Dorsal (top) and ventral (bottom) of two nature-produced flakes recovered from excavations around Hajny Spring #2. Specimen on left is Alibates agatized dolomite from elevation 89.7 of square N2-E5. Specimen on right is distal end of Alibates agatized dolomite from elevation 89.5 of square N1-E2.

APPENDIX B

Inventory Of Mammoth Bones At Hajny Spring #2

Don G. Wyckoff

In Chapter 8, Figures 8-3, 8-4, 8-10, and 8-11 illustrate the mammoth elements uncovered and recorded around Spring #2. To facilitate comparisons, these elements are inventoried here along with occasional field or lab observations. Those bones marked with an asterisk (*) were recovered and returned to the Survey's laboratory for preservation and potential inclusion in an interpretive exhibit.

Elements of the West Mammoth, Hajny Spring #2

» *lower right 2nd or 3rd molar; segment submitted to Southern Methodist University student Curtis McKinney for uranium series dating; result - 143,026 ± 5500 B.P.

» upper right molar; badly crushed in field by machinery (see Figure 8-6)

» upper left molar; fragments found in square S1-W2

» glenoid cavity and proximal anterior border of left scapula

» six left ribs

» proximal half of right scapula (remainder was scraped away)

» anterior half of right humerus

» right radius; badly crushed

» nine sections of right ribs

» *six vertebrae

» anterior half of right tibia

» right fibula; badly crushed

Elements of the East Mammoth, Hajny Spring #2

» *left tusk; has prehistorically snapped tip

» *right tusk; about half length of left with worn rounded tip

» *mandible containing both lower molars

» occiptal condyles

» *upper right third molar; very worn

» *upper left third molar; slightly worn; submitted to Southern Methodist University student Curtis McKinne;y for uranium series dating; result - 166,045 ±6500 B.P.

» complete right scapula; not recovered because inadequately reinforced plaster jacket broke when being lifted in the field

» eight left rib segments

» 11 right ribs and segments

» *two lumbar vertebrae

» left pelvis

» *left femur; lateral side largely abraded away by gravel

» *left tibia

» *left fibula

» *proximal right tibia; badly broken by channel cutting

» * right unciform

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