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MULTIDISCIPLINARY STUDY OF A LATE PLEISTOCENE
(TWO-CREEKAN) LOCALITY IN SOUTHEASTERN MICHIGAN**

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THE SHELTON MASTODON SITE:
MULTIDISCIPLINARY STUDY OF A LATE PLEISTOCENE
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Abstract.—The Shelton Mastodon Site (Oakland County, Michigan) was the subject of a five-year multidisciplinary study and yielded late Wisconsinan remains of algae, plants, invertebrates and vertebrates. The vertebrate faunule is comprised of: *Esox lucius*, *Perca flavescens*, *Rana catesbeiana*, *R. clamitans*, *Meleagris gallopavo*, *Microtus pennsylvanicus*, *Ondatra zibethicus*, *Castor canadensis*, *Canis* sp., *Alces alces*, *Cervalces scotti* (extinct), and *Mammut americanum* (extinct). The bones were derived from marginal lacustrine strata deposited adjacent to a forested moraine and show evidence of prolonged exposure and subaerial weathering. Nine radiocarbon dates (eight from Pleistocene and one from Holocene; seven conducted on wood and two on bone) were obtained. Dates on the principal bone-bearing strata range from $12,320 \pm 110$ to $11,740 \pm 175$ years before present (ybp), which corresponds to the age of the Twocreekan substage of the late Wisconsinan. Two projectile points inferred on typological grounds to be between 8,500 and 9,900 years old were found at the lower level of the Holocene bog soil overlying the Pleistocene sediments. Floral remains associated with the Pleistocene vertebrates suggest the presence of a forest dominated by conifers (mostly spruce), while the strata at a higher level contain a heterogeneous mixture of trees (mostly pine), sedges, and grasses. Some pieces of wood have gnaw marks, inferred to be those of *Castor canadensis*. Habitat preferences of the 10 molluscan and 25 diatom genera recovered from the associated lacustrine beds suggest eutrophic to oligotrophic aquatic conditions. Analysis of dentinal lamination indicates that the mastodon died in the spring; its stage of molar eruption and wear suggests that it was 13 to 17 years old. It is an unusual specimen in that only the right tusk developed. The molars and premolars of *C. scotti* are the first found in Michigan. Similarly, the remains of *E. lucius*, *P. flavescens*, *R. catesbeiana*, and *R. clamitans* are the first records for the Pleistocene of Michigan. Analyses of this site are providing detailed knowledge of the late Wisconsinan deglaciation and paleoecology of southern Michigan.

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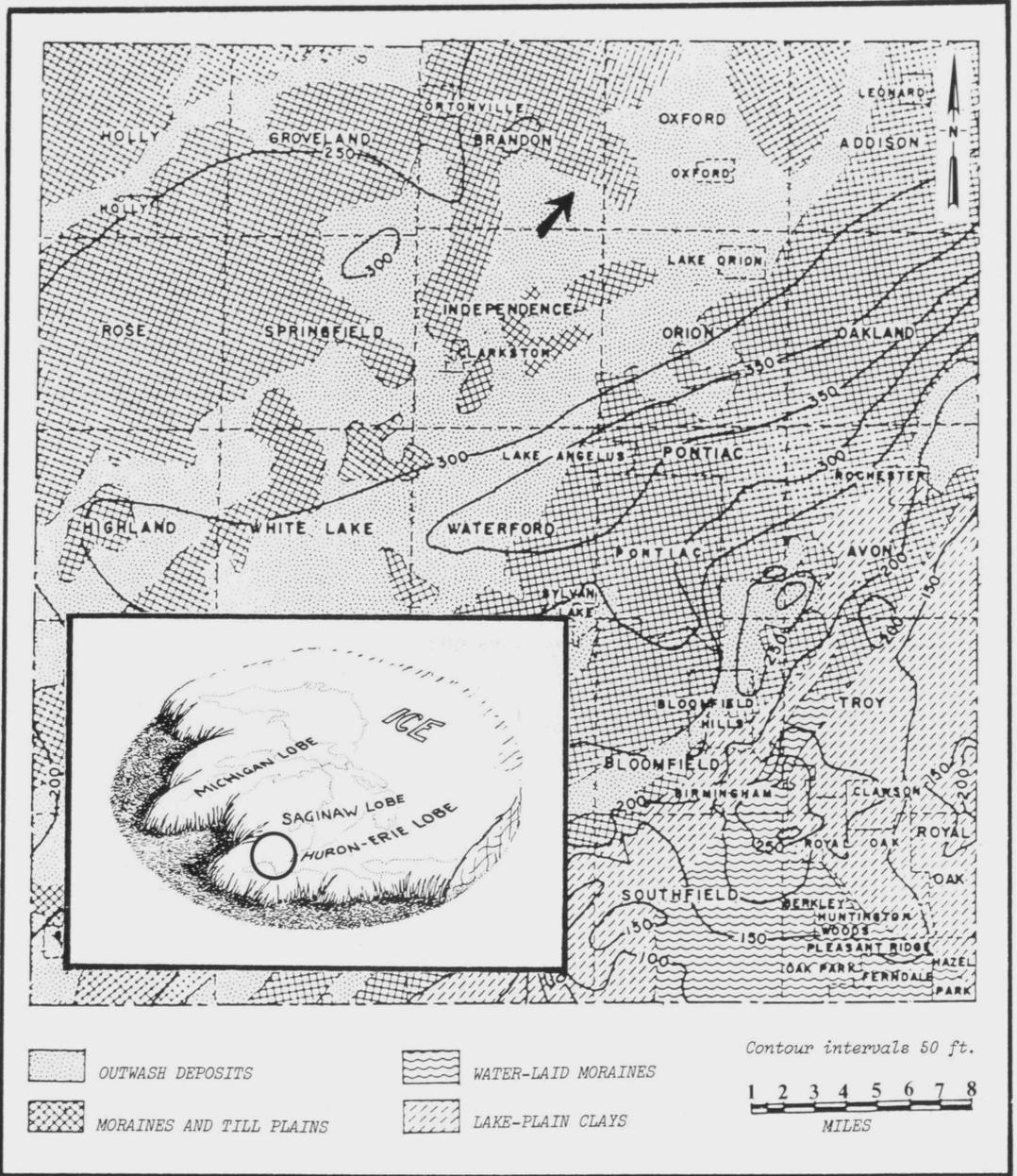


FIG. 1— Inset: the three major ice lobes that covered the Great Lakes Region at about 16,000 years ago; circle represents general area enlarged (modified after Kelley and Farrand, 1967). Enlarged area: map depicting surficial geology and drift-thickness in Oakland County, Michigan; arrow indicates location of the Shelton Mastodon Site (modified after Mozola, 1954).

INTRODUCTION

Detailed multidisciplinary studies of Pleistocene fossil vertebrate localities in the eastern Great Lakes Region are relatively rare, although Laub et al. (1988) contains notable examples of such work. The most commonly collected fossil taxon is the extinct American mastodon (*Mammuth americanum*). Other macro- and microvertebrate elements of the Pleistocene fauna are relatively poorly known. Likewise, the stratigraphy and the associated plant and invertebrate remains are often discussed in no more than cursory fashion. This has hindered attempts to understand the Pleistocene paleoecology of the eastern Great Lakes Region.

In this report we document the late Wisconsinan to Holocene transition in Oakland County, Michigan at the Shelton Mastodon Site. This includes description of a Pleistocene macro- and microvertebrate faunule, collected during five field seasons (1983-1987; analysis of the material collected in 1987 has not been completed). The ages of the bone-bearing strata and the overlying Holocene sediments were established on the basis of nine radiocarbon dates. In addition, the associated pollen, macrofloral, and invertebrate assemblages are described. The taphonomy and depositional setting of this site are also discussed. The locality is notable for the diversity of taxa documented and the variety of evidence utilized in paleoenvironmental reconstruction. Field and laboratory methods are discussed in Appendices A and B; further documentation of the site may be obtained from the senior author.

BACKGROUND AND LOCALITY INFORMATION

The Shelton Site is located on Seymour Lake Road, between the towns of Oxford and Ortonville, in Brandon Township, Oakland County, Michigan, in the SE 1/4 of the SE 1/4 of Section 26, T5N, R9E, longitude approximately 82° 20' W, latitude approximately 42° 50' N, at an elevation of 317 m (1040 ft.) above sea level. The site lies in a low meadow just west of the Paint Creek tributary of the Clinton River (Figs. 1-4).

Oakland County is covered by a complex blanket of upper Wisconsinan sediments derived, in part, from the retreat of the Saginaw and Huron ice lobes (Fig. 1). The topography is dominated by two NE - SW - oriented moraine systems, in the northern and southern parts of the county. These moraines are separated by outwash plains, and an extensive glacial lacustrine plain is present in the southeastern portion of the county (Farrand and Eschman, 1974).

The Shelton Property (Sidwell No. 03-26-400-015) was purchased in 1969. Previous owners had used the land for farming. The initial recognition of fossil material was in October, 1977, when the owner, Mr. K. Harold Shelton, was dredging a pond along an existing creekbed (Fig. 4). Two local teenagers (Todd Hattig and Randy Carson; Anonymous, 1977) found in the dredged soil part of a skull, teeth and a portion of a tusk of an American mastodon (*M. americanum*). This material was donated to Cranbrook Institute of Science (CIS) and was incorrectly named the "Hattig Mastodon." In April of 1982, a team of students and the senior author revisited the Shelton Site, and 23 small pieces of tusk were found in the same pile (later to be named Dumped Pile No. 1) where the original finds were made. An additional survey was conducted in March of 1983. After obtaining all necessary permits (state, county and township), excavations were carried out during the summers of 1983-1987, under the sponsorship of CIS, Oakland Community College (Highland Lakes Campus), and Wayne State University.

As of the end of 1987 the general area of manual excavation covered about 25 x 25 m, but most of the bones and teeth were found within an area of 21 x 15 m (Fig. 5). Within the greater area 228 square meter units were excavated on the south side of the creek and 144 on

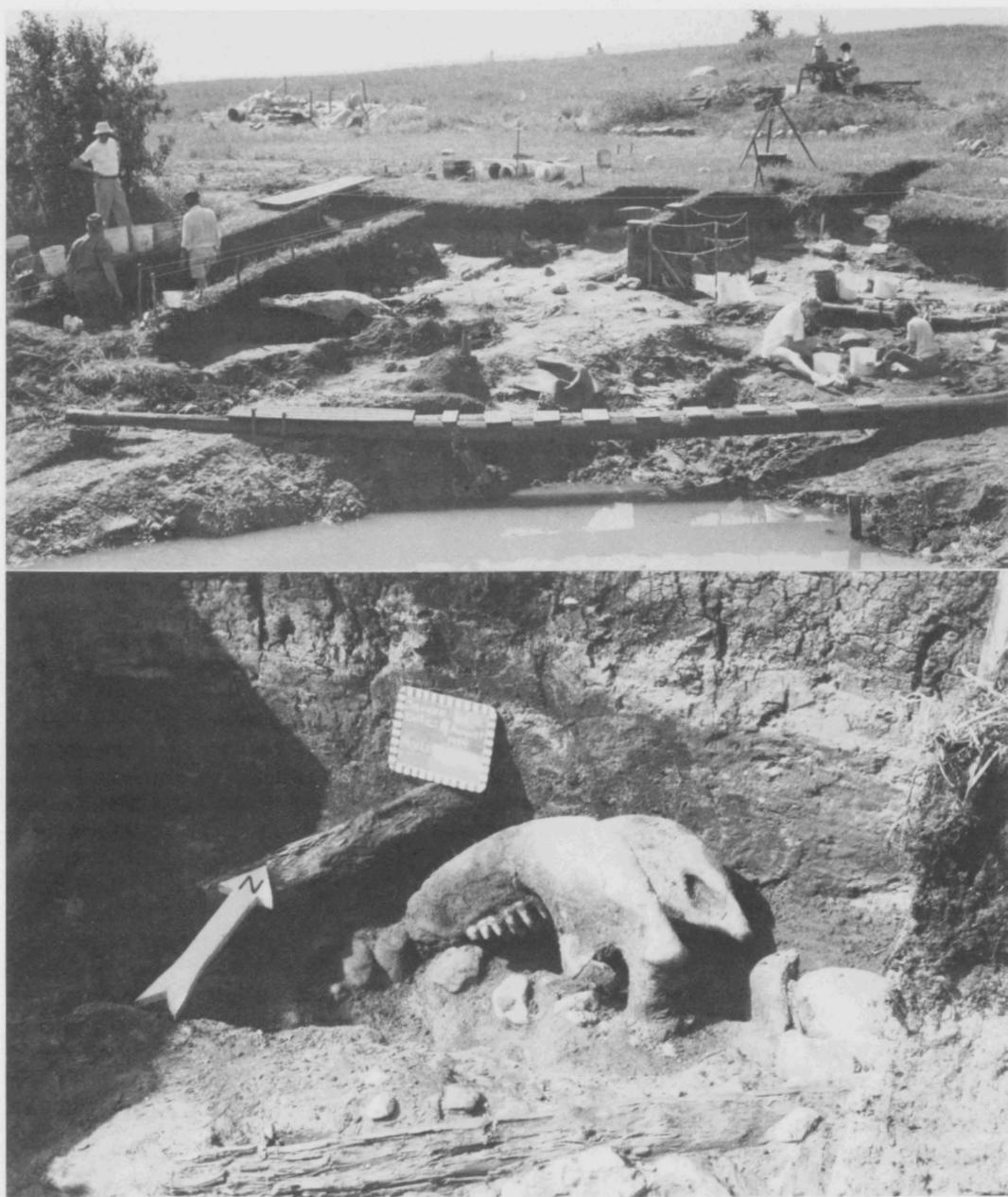


FIG. 2— The Shelton Site viewed from the north in August, 1985 (top photograph). The fenced area at the center is where a partial dentary and teeth of Scott's moose (*Cervalces scotti*) were found (Fig. 3). Bottom photograph shows the mandible of the Shelton Mastodon (*Mammot americanum*) as it was excavated in Square b1. Photographs by J. Shoshani.



FIG. 3— Cheek teeth of *C. scotti* *in situ*. Photograph by J. Shoshani.

the north side. This work was done with the help of about 70 participants every year. As of October 1989 the excavated areas were bulldozed; the entire site is now leveled. Untouched are the Datum Point (a railroad spike at the bottom of a utility pole) and the commemorative plaque (on a boulder on the hill south of the pond, which is larger than it was in 1973).

GEOLOGIC SETTING, STRATIGRAPHY, AND AGE

Leverett and Taylor (1915) and Mozola (1954) are the two most comprehensive works on the Quaternary geology of Oakland County, Michigan. Farrand and Eschman (1974) and Eschman and Mickelson (1986) provided an overview of the glacial history of the southern peninsula of Michigan and summarized its Quaternary stratigraphy.

Mozola (1954) subdivided the Pleistocene drift in Oakland County into three lithologic groups: (1) moraine and till plain deposits; (2) intermorainal outwash; and (3) glacial lake plain sediments (confined primarily to the southeastern portion of Oakland County). Muck and peat deposits also occur in local depressions on the outwash plain surface. The Shelton vertebrate faunule is derived from sediments that mantle the Oxford outwash plain. At the site, three stratigraphic units are present above the gravel and sandy outwash. General descriptions of the lithology of these units are given in Fig. 6, along with their inferred depositional environments. More detailed discussions of Shelton Site stratigraphy and depositional history are presented in Zawiskie and Shoshani (in preparation).

All three post-outwash units at the Shelton Site vary in thickness, depending on local topography, and eventually pinch out toward the south. Unit I, the blue-gray clay layer, was not usually excavated except in test pits. In one of these (Square E2), the top of the clay layer was 60 cm above the underlying gravel, and in another place (near Square H20, not shown in Fig. 5), the clay was about 2.0 m thick. Unit II had a maximum thickness of approximately 120 cm (again, pinching out to the south). Unit II was, in general, well strat-

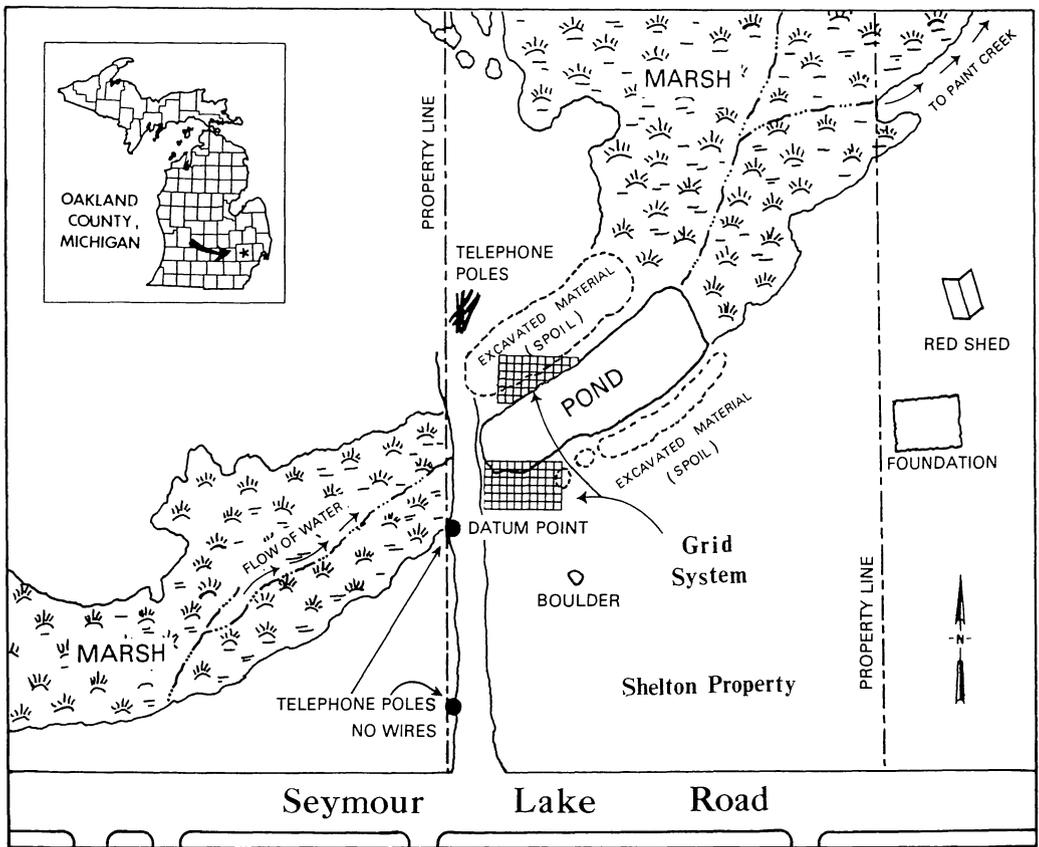
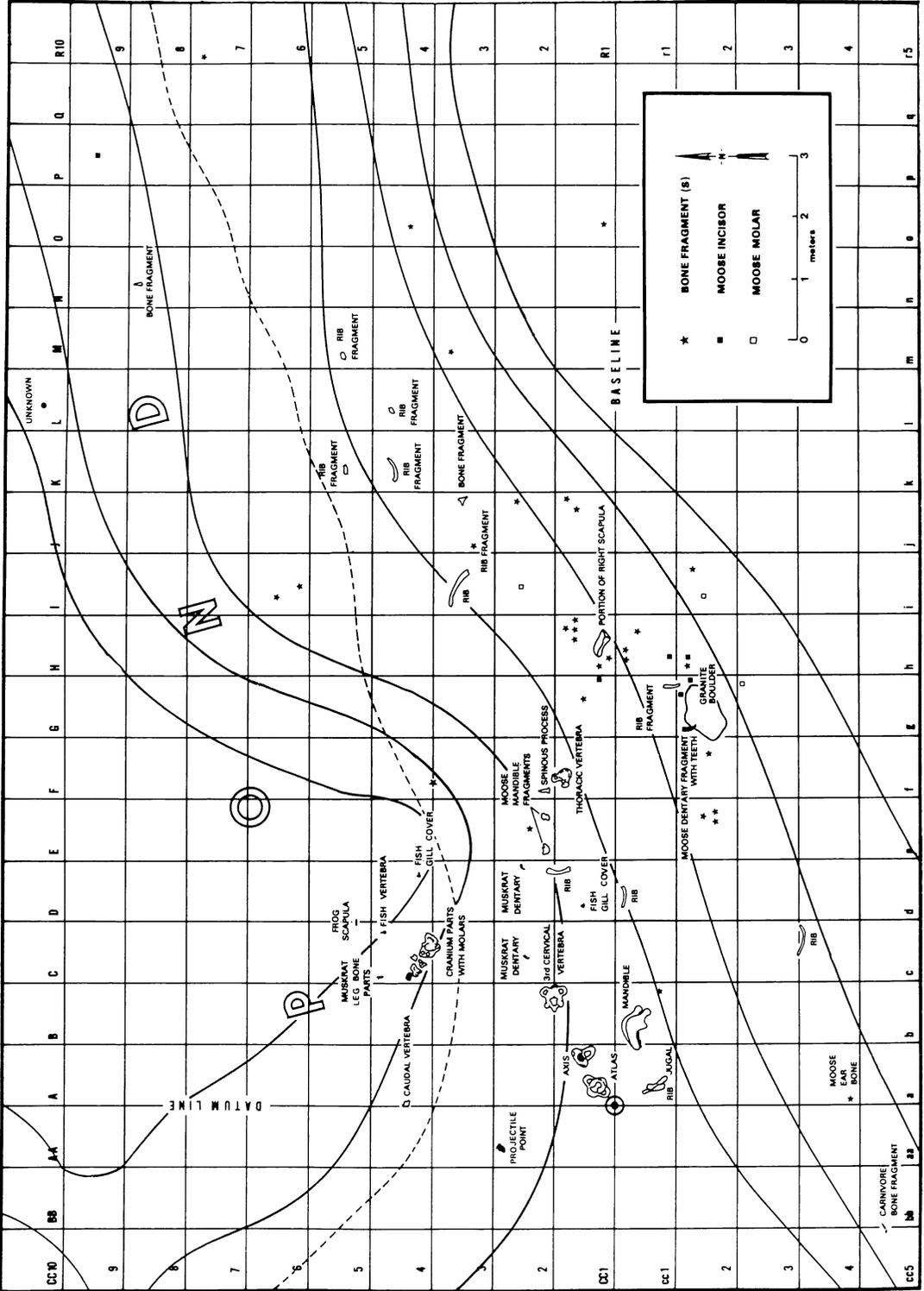


FIG. 4— Map of general features at the Shelton Site (scale: 1 cm = about 6 m). Inset: map of Michigan with an arrow pointing to Oakland County, location of the Shelton Site. Drawn by J. Grimes.

ified and sorted, especially in the deeper areas of the excavation. Its most outstanding feature was a dense, basal concentration of cobbles, boulders and abundant driftwood. Above this were interbedded sands, silts and clays, with local concentrations of peaty material. Within this sequence, distinct beds (about 5 cm thick or less) of light-colored, coarse sand (mostly quartz) could be easily traced throughout most of the excavated area. It was among the basal cobbles and wood, and within the sandy layers, that we found all the Pleistocene vertebrate, invertebrate and cone samples. One of the sand layers was clearly observed just above the mandible in Square b1 (Figs. 2 and 6). In the upper portion of Unit II, fine strata were less easily distinguished. Sediments of Unit III had a maximum thickness of about 60 cm and were coarser, looser, and darker in color than those of Unit II (Figs. 6 and 7). Although Unit III overlies Unit II, Unit III sediments descended as wedges into the lighter, lower layers of

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 FIG. 5— Grid system and vertebrate findings *in situ* on the south side of the Shelton Site (not exactly to scale; contour lines are at one-foot intervals). Unless stated otherwise, bones belong to the American mastodon (*Mammuth americanum*); see Table 4 for listing. The Kessell projectile point (in AA1) was not associated with the bone-bearing stratum. Drawn by J. Grimes.



Thickness		Unit	Lithologic Units	Inferred Environment	Macrofloristic Zones
0 - 60 cm.		III	Interbedded muck and peat sley mottles, woody fragments	BOG DEVELOPMENT	PINE-DOMINATED Jack Pine
			Network of polygonal cracks		
0 - 120 cm.		II	Interbedded sand, silt and clay, massive to faint horizontal laminations, some well-sorted sandy lenses, minor soft-sediment deformation, charcoal and woody debris, occasional pebbles, net upward increase in sand/clay ratio	OSCILLATING MARGINAL LACUSTRINE HABITAT	SPRUCE-DOMINATED Balsam Fir
			Lower part of unit contains <i>in situ</i> tree stumps and horizontal logs, many charcoaled fragments, pebbles and cobbles in sandy matrix, invertebrates, vertebrate bones		
0 - 200 cm.		I	Massive blue-gray clay, diatoms and aquatic mollusks	FOREST ZONE	White Spruce
				OPEN LACUSTRINE	

Unit II. These wedges were part of a polygonal system developed on the once-exposed surface. Most of the wedges measured 5-20 cm wide at the top and 30-60 cm vertically.

Sedimentological observations were augmented by soil analyses on six samples (the same samples used for pollen study; see Fig. 8 below). Sample No. 1 (taken from Unit III, 30 cm below ground surface) was "organic and acidic"; sample No. 2 (from Unit II, 60 cm deep) was "sandy loam to loam and acidic"; sample Nos. 3, 4, and 5 (from unit II, 83, 115, and 133 cm deep, respectively) were "sandy and alkaline," "sandy and very alkaline," and "sandy loam to loam and very alkaline," respectively; sample No. 6 (from Unit I, 167 cm deep) was "clay loam and alkaline." Additional information was provided by water analysis. Samples of pond water taken in 1983 had a total alkalinity of 135 milligram per liter (as calcium carbonate), pH of 8.09-8.27 and a conductivity of 780-840 micro-mho. Samples taken in 1985 had a total alkalinity of 223-230 micrograms per liter, 17.5-22.5 micrograms of ammonia per liter and nitrate + nitrite undetectable. The relatively high pH and total alkalinity and conductivity are typical of ground water associated with calcareous soil in southern Michigan.

The blue-gray clay (Unit I) is interpreted as having been deposited in an open lacustrine setting. The presence of many aquatic gastropods, unionids, and diatoms further suggests nutrient-rich, well-oxygenated water. This is followed by a complex sequence of interbedded sand, silt, and clay (Unit II). Unit II is inferred to have been deposited over a long period of time in an oscillating marginal lacustrine environment. The lower part of Unit II contains a spruce forest floor that developed on the lacustrine sediments following a drop in lake level. Localized charcoaled wood in this zone attests to forest fire(s) in the surrounding area. Pebbles and cobbles at the base of the unit may have been eroded from the adjacent moraines following the fire(s), as a result of the temporarily reduced binding and baffling capacity of the vegetation. Subsequent episodic sedimentation was responsible for the burial and preservation of the mastodon, along with numerous logs and other wood fragments. Sandy sediments eventually buried the entire forest zone as the lake expanded and contracted. Ultimately, the lake was infilled by clastics, and a network of prominent polygonal fissures developed on the exposed surface. This patterned surface was formed either by frost action or desiccation, probably the latter, because of the fissures' general symmetry and depth.

Geological evidence (Bay, 1938; W. R. Farrand, pers. comm.) attests that the late Wisconsinan drainage of this lacustrine system was probably toward the southwest (the Mississippi River). However, subsequent geomorphic development of this region resulted in a reversal of drainage directions such that the stream that runs across the Shelton Property today flows toward the northeast (joining the man-dug Paint Creek, which flows into the Clinton River and on toward Lake St. Clair).

Unit I, the clay, is a local aquiclude and is responsible for perched water in depressions on the outwash plain surface. Following deposition of Unit II a pine forest developed in the area and supplied abundant organic detritus. This led to the formation of interbedded muck and peat in depressions above the perched groundwater, and local bogs developed (Unit III, Houghton and Adrian mucks, after U.S. Dept. of Agri. Soil Cons. Service, 1982).

The underlying outwash and morainal till in the area are, according to Eschman and Mickelson (1986), part of the Defiance morainic system and were built during the Port Bruce Stade (ca. 14,500 ybp). The age of the Shelton Site has been established on the basis of thirteen radiocarbon dates, of which nine are relevant to this report; eight are from Unit II, and one is from Unit III. The results are listed in Table 1, and their stratigraphic sources are summarized in Fig. 7. Results confirm that Units I and II were deposited during the latest Wisconsinan. Dates from Unit II range from $12,320 \pm 110$ to $10,020 \pm 80$ ybp. The lowest part of Unit III is clearly of Holocene age ($9,640 \pm 120$). Corroborating this assignment, Early Archaic projectile points (identified by H. T. Wright as a Kessell point and a LeCroy point) from the bottom of Unit III are considered to be between 8,500 and 9,900 years old (Broyles, 1971; Fitting, 1975; Fitting et al., undated; Shoshani et al., 1989, in press).

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FIG. 6— Lithologic units, inferred environment, and macrofloristic zones at the Shelton Site.

TABLE 1 - Radiocarbon dates for nine samples from the Shelton Mastodon Site, Brandon Township, Oakland County, Michigan, USA.

Our sample number	Laboratory number ¹	Material	Radiocarbon age ²	Notes
<i>A. Holocene stratum, Unit III in Figures 6 and 7</i>				
P221/435	B-10302	Wood	9,640 ± 120	Collected 8 August 1984; fragments associated with the Kessell Projectile Point; Square AA1, lowest level.
<i>B. Pleistocene strata, Unit II in Figures 6 and 7</i>				
P224/441	B-13212	Wood	10,020 ± 80	Collected 10 July 1985; from <i>in situ</i> tree stump with roots; Square F4.
-----	GX-13099	<i>Mammot</i> bone	10,875 ± 155	Collected from the surface, in 1983; 18 samples totaling 87 cranial fragments.
P223/437	B-10303	Wood	10,970 ± 130	Collected 17 August 1984; in close proximity to <i>Cervalces scotti</i> tooth fragments; Square J2, upper level.
V161/562	AA-2315 ³	"The Unknown"	11,740 ± 175	Collected 12 August 1986; Square L10, lower level (see text for details on this specimen).
P229/482	B-14266	Wood	11,770 ± 110	Collected 3 August 1985; associated with <i>C. scotti</i> dentary fragments and teeth; Square g2, lower level.
P165/323	B-9083	Wood	11,960 ± 110	Collected 30 July 1983; associated with <i>Mammot americanum</i> rib and mandible; Square d1, lower level.
P314/617	GX-13098	Wood	12,180 ± 175	Collected 18 August 1986; from <i>in situ</i> tree stump with roots; Square DD4.
P148/303	B-9084	Charcoaled wood	12,320 ± 110	Collected 11, 13, 22 and 27 July 1983; associated fragments with <i>C. scotti</i> and <i>M. americanum</i> material; Squares D1, D2, D3, and D4, lower levels.

¹ B-numbers stand for Beta numbers of Beta Analytic Inc., Coral Gables, Florida; GX-numbers stand for Geochron Laboratories Division, Cambridge, Massachusetts.

² Ages are given as radiocarbon years before 1950 A.D.

³ Age obtained from the University of Arizona, Tucson, using electron acceleration technique; all other ages were obtained by conventional methods.

Correlation with time-stratigraphic units in the western Great Lakes Region (Evenson et al., 1976) is complicated by the anomalously young age (10,020 ± 80 ybp) of the *in situ* tree stump in Unit II (sample No. P224/441, B-13212 in Table 1). However, the disparity between this date and the others from unit II suggests that this date may be inaccurate (possibly due to contamination by rootlets). Similarly, the age of 10,875 ± 155 ybp (GX-13099 in Table 1) on fragments of mastodon bone differs conspicuously from other dates derived from this unit. The bone fragments that gave this date were collected from the surface in 1983, where they had lain since the dredging of the pond in 1977. There is little doubt that they are the same age as the *in situ* mastodon bones, but their exposure at the surface could easily have resulted in contamination by younger carbon. We therefore suggest that this date be ignored. With these emendations, we bracket the age of the lower part of Unit II to between 12,320 ± 110 and

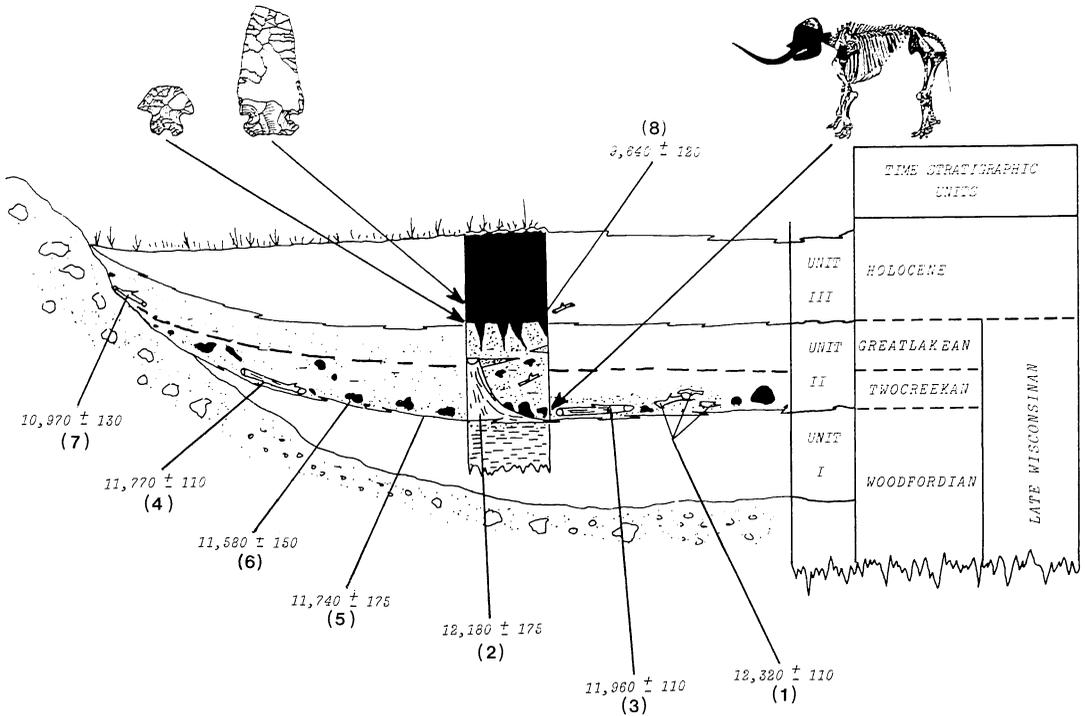


FIG. 7— Composite, generalized stratigraphic cross section (south toward left) of the Shelton Site, with associated radiocarbon dates (except for a single anomalously young date of $10,020 \pm 80$ ybp; see Table 1). Darkened bones on the mastodon skeleton are those found. Stratigraphic interpretation by J. M. Zawiskie.

$11,740 \pm 175$ ybp. This range corresponds with the Twocreekan substage, which has a lower limit of $12,300 \pm 50$ and an upper of $11,750 \pm 50$ ybp (Evenson et al., 1976; Eschman and Mickelson, 1986). The upper part of Unit II, for which we have a date of $10,970 \pm 130$ ybp (sample P223/437, B-10303 in Table 1) corresponds with the Greatlakean of Evenson et al. (1976). The pattern of ages along the base of Unit II suggests progressive onlapping of local topographic features over an approximately 1,350-year interval ($12,320 \pm 110$ to $10,970 \pm 130$ ybp; Fig. 7).

PLEISTOCENE BIOTA OF THE SHELTON SITE

Floral and faunal lists for the Pleistocene biota of the Shelton Site are provided in Appendix C. The discussions below summarize details of sampling, mode of occurrence, probable habitats, and representation of taxa.

ALGAE

The 91 algal taxa found at the Shelton Site represent 25 genera (Appendix C). All samples were collected from the topmost layer of Unit I, just below the bone-bearing layer (Unit II) and were initially identified using the keys and illustrations in Patrick and Reimer (1966),

TABLE 2 - Taxonomic breakdown of female cones (or parts of them) from coniferous trees collected at the Shelton Site during 1986 (over 30,000 identifiable female cones collected during field seasons of 1983 through 1987).

Species	Number of cones	Percentage
<i>Picea glauca</i> (white spruce)	5,687	87.95
<i>Picea mariana</i> (black spruce)	346	5.36
<i>Larix laricina</i> (tamarack)	281	4.34
<i>Abies balsamea</i> (balsam fir)	96	1.48
<i>Pinus banksiana</i> (jack pine)	37	0.56
<i>Pinus resinosa</i> (red pine)	16	0.27
<i>Pinus strobus</i> (white pine)	3	0.04
TOTAL	6,466	100.00

Vinyard (1974), and Prescott (1982). The habitats observed for extant members of these species overlap those of most of the molluscan species. According to Stoermer et al. (1988:193), the most probable habitat for the diatoms "... was the margin of a moderately alkaline (pH >7.0) and moderately productive pond which existed under arctic conditions."

PLANTS

Macroflora

Pleistocene macrofloral remains were principally coniferous and were found only in Unit II. Species-level identifications are based on thousands of cones and cone fragments collected over a period of five years. Although a few cone species usually co-occurred within single strata, the trend that emerged during excavation was that certain taxa predominated within certain levels. Unit II was a spruce-dominated zone. The vast majority of white spruce cones (*Picea glauca*) were found in the lowest part of Unit II, while cones of the black spruce (*Picea mariana*) and fragmentary balsam fir cones (spikes and a few scales; *Abies balsamea*) were found mostly in the middle and upper parts of this unit. In the uppermost layers of Unit II, in what was essentially a transition zone to Unit III, we found cones of black spruce and tamarack (*Larix laricina*). Both within Unit II and over the site as a whole, *Picea* cones far outnumber those of all other species. The association of taxa and levels held throughout the excavation area (Fig. 6). Between stratigraphic units, it was exclusive to the extent that no *Pinus* cones were found in clearly defined sediment of Unit II and no *Picea* cones, in clearly defined sediment of Unit III.

Numerous logs and wood fragments littered a large portion of the excavated area (bottom of Unit II). These logs varied in size, the largest being 8.4 m long and 25.9 cm in diameter. Five upright tree stumps with root systems *in situ* were also discovered (many other stumps with roots were found, but not in growth positions). Two of these five stumps and five other wood samples were radiocarbon dated (Table 1). L. A. Newsom examined 106 wood samples and identified nine species of trees, of which four were conifers and five, hardwoods. Seventeen specimens, representing five species, had been gnawed by beaver (*Castor canadensis*). Details of these identifications will be presented elsewhere. Preservation of plant material found in the deeper portions of the site was much better than for material collected upslope.

The taxonomic breakdown for 1986 is shown in Table 2. It is evident that the white spruce (*Picea glauca*) is the most abundant species. In addition to the evidence provided by wood

Extract of Pollen Diagram

Shelton Mastodon Site

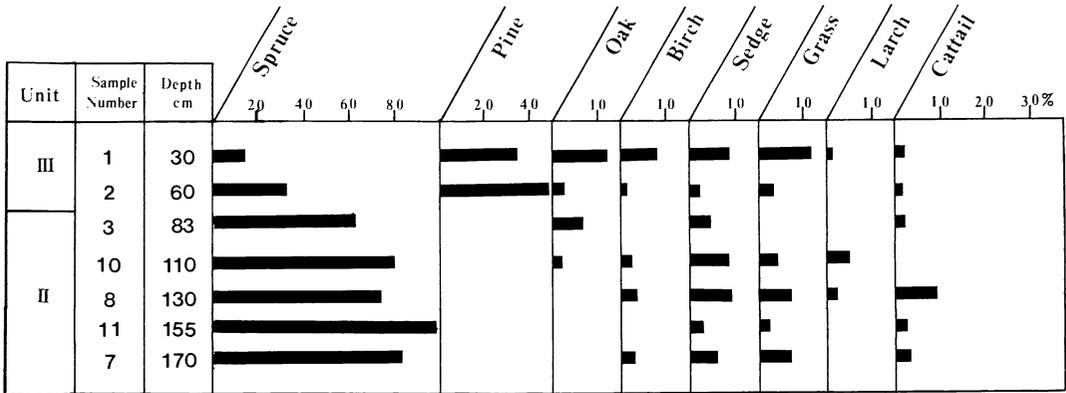


FIG. 8— Principal elements from pollen analysis conducted on seven soil samples from the Shelton Site. Percentages are based on pollen sum which included all of the taxa shown.

and cones, coniferous trees at the Shelton Site are represented by needles, spikes, and scales. All the needles were observed in the lowest level of the bone-bearing layer (Unit II), either in clumps or evenly distributed as on a forest floor. This stratum was composed of numerous needle fragments, twigs, branches and roots. The thickness of this forest floor litter varied from 1 to 15 cm or more. Comparing the outline of selected needles to the illustrations in Brockman and Merrilees (1968), and Barnes and Wagner (1981), it appears that most of the specimens are of spruce (*Picea*), but we could not further identify them as *P. mariana* or *P. glauca*. A few specimens seem to belong to tamarack (also known as American larch, *Larix laricina*), but firm identification was not possible based on needle structure alone; cones and pollen of *L. laricina* were identified, however (Table 2, Fig. 8).

Palynology

Results of pollen analysis are presented in Fig. 8. These are based on examination of seven out of twelve samples that were studied by W. S. Benninghoff, following standard methods (see Appendix B for details). These samples, derived from Units II and III, were collected in 1983 from four squares (samples 1-4 from the south wall of Square C2; 5-6 from the north wall of Square C3; 7-8 and 11-12 from the center of Square C4; 9 from Square d1; and 10 from the north side of Square C2). Sample 1 (30 cm below the ground surface) was a humified peat with a small admixture of sand; samples 2 (60 cm) and 3 (83 cm) were sand with some humus, as was sample 10 (110 cm); sample 8 (130 cm) was a mixture of marl and sand; samples 11 (ca. 155 cm) and 7 (170 cm) were very sandy peat. The sequence of sample depths do represent proper stratigraphic order, but because they were not taken from a single column, this sample series permits only a generalized record of the fossil pollen sequence. Nevertheless, it provides an interesting comparison with the sample series collected from a single column and analyzed by Snyder and Shoshani (submitted).

Results obtained by Benninghoff are summarized in Fig. 8. The sediments and stratigraphic relationships are complex and indicate nearshore deposits of a pond or small lake. Intermittent low energy currents brought in some sediment, and marsh and shallow pond margin vegetation developed from time to time. The basal portion of Unit I was deposited in a small lake that received silt- and clay-size sediments from melting ice or early eroding glacial deposits. It is

clear, however, that sedges, grasses, and cattails were on the site throughout post-Unit I time, as the herbaceous cover in the marshy habitat. The first forest to occupy the area was a spruce parkland; macrofossils of spruce suggest that trees were close to the lake margin. Next, larch (tamarack) and oak entered the area, and then pine appeared and replaced the spruce.

The pollen record obtained from four walls on this site differs from most other sites in southeastern Michigan and northwestern Ohio (Kapp, 1977) for the same time interval in that pine is entirely absent from the early spruce zone (samples 3, 10, 8, 11, and 7). This is consistent with our macroscopic findings in that no pine cones were found in Unit II, from which these samples were taken (see "Floristic Zones" column in Fig. 6). However, most pollen diagrams from sites in this region (including that obtained from a single wall profile of the Shelton Site; Snyder and Shoshani, submitted; see also Cushing, 1965) show an almost continuous presence of pine in at least trace amounts from the beginning of the post-ice pollen record. Despite this difference, the flora at the Shelton Site in most respects follows the general pattern observed in southern Michigan and northern Ohio. Corroboration of this finding has been provided by Snyder and Shoshani (submitted), based on pollen analysis of 31 new samples (collected in 1987 from the eastern wall of Square U9 by R. O. Kapp and G. Snyder). These authors state that the overall pattern at the Shelton Site is similar to nearby localities in southeastern Michigan and that spruce (*Picea*) was most abundant in Unit II and was successively replaced by pine (*Pinus*), oak-dominated mixed hardwood forest, and bog vegetation. Snyder and Shoshani (submitted) also report on pollen grains of Canada Buffaloberry, *Shepherdia canadensis*, from a soil sample collected from the alveolus of the third molar on the left side of the mandible of the Shelton Mastodon. Canada Buffaloberry is a common shrub in boreal forests and tundra of the northwest (Curtis, 1959).

INVERTEBRATES

Mollusca

The Shelton Site yielded numerous mollusc shells. Those identified comprised two species of prosobranch gastropods, seven species of pulmonate gastropods, and two species of pelecypods. Appendix C provides a list of the 11 molluscan taxa found at the site, and Table 3 indicates their habitats. All samples were collected either in the top-most layer of Unit I, or in the transition zone between Units I and II and at the lower level of the bone-bearing layer (Unit II). The gastropods were identified to species following the key provided by Burch (1982), and the pelecypods were identified using the key provided by Pennak (1978). Many specimens could not be accurately keyed due to small size, fragmentation, or lack of soft parts or radulae. Thus, the number of specimens recorded in Table 3 (222) is only a fraction of the total recovered. Additions to this collection are being made currently through processing of more recently excavated material. This expanded collection is being examined with the help of J. B. Burch, and it appears that additional taxa will be identified (Thurlow and Shoshani, in preparation).

The molluscan taxa of the Shelton Site are all limited to fresh water and are found in Michigan today. *Physella integra*, for example, prefers moving water but is often found in standing waters (Te, 1975; Clarke, 1979). *Valvata* sp. is found in both slowly moving waters and standing waters (Walker, 1906; Clarke, 1979). *Gyraulus parvus*, *Stagnicola elodes*, *Planorbella campanulata*, and *Helisoma anceps* all are typical of standing waters of varying productivities but prefer lakes and ponds rich in nutrients (Baker, 1919, 1922, 1926; Archer, 1939; Clarke, 1979). These four may be found on the dry beds of temporary ponds. In addition, *G. parvulus*, *S. elodes*, and *H. anceps* may also be found in running water (Strayer, 1987). *Ferrissia parallelus* and *Lymnaea stagnalis* are usually found in mesotrophic and eutrophic bodies of water (Clarke, 1979). *Sphaerium* sp. and *Anodonta* sp. can be found in all of the above habitats (Baker, 1926). The presence of unionids (*Anodonta*) in the lacustrine

TABLE 3 - Habitats of molluscs collected at the Shelton Mastodon Site. *N* = number of specimens complete enough for positive identification. See text for sources on which this table is based.

	Freshwater Habitat					N
	Running water	Oligo-trophic	Meso-trophic	Eu-trophic	Vernal (temporary)	
<i>Valvata sincera</i>	X	X	X	X		4
<i>Valvata tricarinata</i>	X	X	X	X		72
<i>Lymnaea stagnalis</i>	X		X	X		1
<i>Stagnicola elodes</i>			X	X	X	1
<i>Physella integra</i>	X	X	X	X		1
<i>Gyraulus parvus</i>	X	X	X	X	X	25
<i>Helisoma anceps</i>	X	X	X	X	X	84
<i>Planorbella campanulata</i>			X	X	X	25
<i>Ferrissia parallelus</i>			X	X		3
<i>Anodonta</i> cf. <i>A. grandis</i>	X	X	X	X	X	1
<i>Sphaerium</i> sp.	X	X	X	X	X	4
TOTAL						<u>222</u>

deposits at the site necessitated the presence of fish, since the former have a larval stage, the glochidium, which is a temporary but obligatory parasite on fish (Pennak, 1978:742).

Insects

Insect specimens were collected at the bone-bearing layer (Unit II, see Appendix C) and are currently being examined by Morgan et al. (in preparation).

VERTEBRATES

Pleistocene vertebrates discovered at the Shelton Site are classified and tabulated in Appendix C and Table 4. Of the twelve Pleistocene vertebrate taxa, the presence of two may be confirmed by both direct and indirect evidence. On bone fragments of *Mammut* and *Cervalces* there were indentations that appeared to have been made by carnivore teeth. Likewise, many twigs and limbs were found with well-delineated gnaw marks inferred to be of a Canadian beaver (*Castor canadensis*; see illustrations in Murie, 1974). As can be noted in Table 4, remains of *Canis* and *Castor* were also found on this site. Holocene finds are discussed in a separate section below.

Osteichthyes

The two fish species collected represent two families classified in two orders (identification by G. R. Smith). *Esox lucius*, the northern pike (family Esocidae), is the larger of the two, and it was identified based on two thoracic vertebrae. *Perca flavescens*, the yellow perch (family Percidae), was identified based on two opercula, from two different individuals, and one thoracic vertebra. According to Hubbs and Lagler (1958), Collins (1959), and Palmer and Fowler (1975), *Esox* is a carnivore that feeds mostly on fish but will feed on frogs and other small animals. It inhabits open waters of lakes, ponds, and streams. It winters in deep waters but spawns in the spring in shallow water and flooded marshes. *Perca* is also a carnivore, but it feeds on microscopic animals, insects, and smaller fishes. It inhabits vegetated lakes and quiet parts of streams, and it usually travels in schools. A review of the literature (Wilson,

TABLE 4 - Pleistocene vertebrates collected at the Shelton mastodon site.

Taxon	Element(s) found	Field no./Catalogue no.
OSTEICHTHYES		
<i>Esox lucius</i> (1-2) ¹	2 thoracic vertebrae	V123/443
<i>Perca flavescens</i> (2)	2 opercula, 1 thoracic vertebra	V58/163, V79/290, V81/296
AMPHIBIA		
<i>Rana catesbeiana</i> (1)	Left ilium	V187/855
<i>Rana clamitans</i> (1)	Right scapula	V33/81
AVES		
<i>Meleagris gallopavo</i> (1)	Proximal end of femur	V57/162
Aves, indeterminate	Miscellaneous fragments	V26/66, V37/104, V44/119, V59/165, V62/188
MAMMALIA		
<i>Castor canadensis</i> (1)	Tooth fragments	V176/844
<i>Microtus pennsylvanicus</i> (2-3)	Cranial fragments with teeth, 2 left dentaries	V4/10, V192/860, V20/49
<i>Ondatra zibethicus</i> (2-4)	2 left dentaries, 1 right dentary, distal right tibia and fibula	V69/221, V99/360, V137/461, V82/297
<i>Canis</i> sp. (1)	Right tibial shaft fragment	V145/478
<i>Alces alces</i> (1)	Right petrosal bone	V148/481
<i>Cervalces scotti</i> (2-4)	The Granite Moose: major dentary fragment with P2 - M3, right petrosal bone, right dentary fragments, 5 incisors and 1 canine, mandibular condyle and surrounding bone, dentary horizontal ramus fragment	V131/455, V138/462, V144/477, V112/405, V127/451, V128/452, V130/454, V140/468, V148/481, V75/273, V113/406
	Possible 2nd moose: anterior half of right upper M2	V114/407
	Possible 3rd moose: left dentary condyle and surrounding bone	V110/398
	Possible 4th moose: ? antler fragment or dentary fragment of a fetus	V161/562
<i>Mammot americanum</i> (1)	The Shelton Mastodon: cranium (incomplete) (1,250 pieces), left jugal, right tusk (incomp. 3 major pcs. and 220 minor pcs.), twelve cheek teeth, mandible (comp. in 2 pcs.), atlas, axis, 3rd cervical vertebra, right scapula (incomp.), 7th ± 2 thoracic vertebra (comp., in 2 pcs.) right 1st rib (comp.), 6 left ribs (2nd, 3rd, 4th or 5th, 12 ± 2, 13 ± 2, indeterminate, all incomp.), 1 caudal vertebra (4th ± 2, comp.)	V93/350, V95/352, V91/347, V104/384, V38/106, V85/341, V100/362, V109/397, V107/395, V108/396, V115/419, V136/460, V158/559, V92/348, V77/281, V105/385, V106/387, V120/438, V126/450, V129/453, V132/456, V133/457, V134/458, V135/459, V139/467, V411/399, V14/27,

¹ Numbers in parentheses indicate possible number of individuals for this species (a total of 16-22 individuals).

1967; Dorr and Eschman, 1970; Smith, 1981; Holman et al., 1986) reveals that *E. lucius* and *P. flavescens* are the first records for the Pleistocene of Michigan, although other representatives of their families have been reported (Wilson, 1967:201-203). Since these fish specimens were collected and identified, other bones have been found at the Shelton Site; the total fish fauna appears to consist of four genera, representing four families and three orders (Shoshani and Smith, in preparation).

Amphibia

One scapular and one ilial fragment were identified by J. A. Holman as belonging to the genus *Rana* (order Anura, family Ranidae). DeFauw and Shoshani (in press) conducted a detailed comparison with specimens in museum collections and found that the partial scapula most resembles that of *R. clamitans* (green frog), and the partial ilium resembles that of *R. catesbeiana* (bullfrog). According to Conant and Conant (1975) both frog species are generalists and tolerant of wide ranges of environmental conditions. Reports in Wilson (1967), Dorr and Eschman (1970), and Holman et al. (1986), indicate that these specimens are the only records of *Rana* for the Pleistocene of Michigan.

Aves

Eight specimens (a few of which include more than one bone) were collected. Identification by D. W. Steadman revealed that three specimens were from wild turkeys (*Meleagris gallopavo*; order Galliformes, family Meleagrididae), two from Galliformes sp. indeterminate, and three were too fragmented to identify. Of those easily identified, one (V57/162) is a proximal end of a femur. Wild turkey has been reported from the Pleistocene of Michigan (Dorr and Eschman, 1970); it inhabited woodlands.

Mammalia

Rodentia: *Microtus pennsylvanicus*, the meadow vole, *Ondatra zibethicus*, the muskrat, and *Castor canadensis*, the Canadian beaver, were the only Pleistocene rodents (Appendix C) found as of the end of 1987. These rodents represent two families, Arvicolidae and Castoridae. *C. canadensis* is represented by molar fragments, identified by comparison with museum specimens and illustrations in DeBlase and Martin (1981). In addition, seventeen wood fragments found at the Shelton Site showed gnaw marks (up to 8 mm in width) inferred to be those of the Canadian beaver (from illustrations in Murie, 1974). Of these, fifteen could be identified; four were *Pinus*, three *Picea*, three *Populus*, three *Salix*, and two *Quercus* (Shoshani and Newsom, 1989). *C. canadensis* is a semi-aquatic mammal that feeds on a variety of tree species and pond vegetation (Baker, 1983). Among Recent beaver, aspen (*Populus* sp.) appears to be a preferred food species, and conifers (e.g., *Picea* and *Pinus*) are cut mostly for lodge and dam construction and maintenance (Baker, 1983). *Microtus*, the smaller of the arvicolines, was identified based on two unassociated dentaries and two crania, all with teeth. *Ondatra* was identified based on three dentaries from individuals of three different ages and the distal end of a fused tibia and fibula (DeBlase and Martin, 1981). Hall and Kelson (1959), Burt (1972), and Burt and Grossenheider (1976) noted that *Microtus* inhabits moist, low areas with rank growth of grasses, near streams, lakes, and swamps. It feeds on grasses and sedges. *Ondatra* inhabits marshes, lakes, and streams, especially with plants such as rushes and cattails, and it feeds chiefly on stems and roots of aquatic vegetation. The presence of muskrats and beavers in close proximity is not surprising because, according to Burt and Grossenheider (1976), muskrats often make use of the ponds created by beavers.

Carnivora: A small bone fragment with a triangular cross-section and slightly twisted shaft was collected between Squares bb5 and cc5 (southwest corner of Fig. 5). This specimen (V145/478) measures 7.3 cm long, 2.1 cm wide, and 1.3 cm thick; its texture is definitely mammalian. Comparison of this fragment to mammalian bones of comparable size and shape revealed that it resembles most the tibiae of *Canis* (family Canidae). More specifically, V145/478 matches the right shaft section of either *C. lupus* (wolf) or *C. latrans* (coyote). The tibial shafts of these species are almost indistinguishable. Hall and Kelson (1959) and Burt and Grossenheider (1976) stated that wolves and coyotes inhabit forests, open woodlands,

prairies, tundra, and brushy or boulder-strewn areas. Burt (1972), however, noted that wolves are more likely than coyotes to frequent forested areas. The wolf is a hunter more than a scavenger, while the coyote is the reverse.

Proboscidea: The bones and bone fragments of the extinct American mastodon (*M. americanum*; family Mammutidae) appear to derive from a single individual. This conclusion is based on anatomical identifications of the bones, their size, the condition of the epiphyseal plates (with a few exceptions, the epiphyses were absent from the diaphyses of the bones), and the strata and locations in which they were deposited. For descriptions and/or illustrations of various aspects of mastodon anatomy, see Warren (1852), Osborn (1936), Skeels (1962), Olsen (1972), and a summary table in Shoshani (in press).

In addition to bones and molar teeth of a mastodon, we have found several large fragments and about 220 small fragments of tusk. The number of complete tusks represented by this collection might be most unambiguously determined by reassembly of the fragments, but we have found few contacts among them. In particular, the three largest fragments (or assemblies of fragments) appear not to have contacted one another directly. In the absence of such contacts, we have attempted to determine if the sizes and shapes of the three largest pieces are compatible with derivation from a single original tusk, or whether two or more tusks are represented. The longest piece (1 in Fig. 9) measures about 32 cm along its outer curvature and has a diameter of about 6.3 cm at its broken, proximal end. Cementum is present proximally, on the outer surface of this fragment. Its distal end is smoothly rounded and is easily recognized as a normally worn tusk tip. In addition, the dorsal aspect of the distal portion shows moderate abrasion such as typically develops through use of the tusks in feeding or through serving as a support for the trunk, while resting (Sikes 1971). The proximal end of piece 1, reassembled from fragments found separately, has a conical opening that is oriented appropriately to be the apical portion of a tusk pulp cavity. However, irregularities of this conical surface, such as fracture-bounded regions of dentine projecting inward from an otherwise smooth interface, make it clear that we are dealing with a fracture-parting that roughly parallels incremental laminae within tusk dentine (Fisher, 1987). Some or all of the missing 'cone' of dentine may be among the smaller fragments but has not yet been recognized. The second piece (2 in Fig. 9) is about 27 cm long and roughly cylindrical, with a diameter of about 6.5 cm at its distal end and 8 cm at its proximal end. Cementum is present over the entire outer surface of this fragment except where it has fractured away. Dentine is present all the way to the central axis (both distally and proximally), with no trace of the conical pulp cavity that should occupy the proximal portion of a complete tusk.

Pieces 1 and 2 are barely long enough for the spiral curvature typical of proboscidean tusks to be evident, but visual assessment of the subtle asymmetry that can be seen indicates that both belong to a right tusk. Although there is no contact between them, projection of their external profiles suggests that they could have been positioned as illustrated in Fig. 9, with a gap of about 3 cm. In addition, the proximal end of 2 fits just within the right tusk alveolus of the mastodon cranium found at the Shelton Site. This association is further confirmed by a fragment of right premaxilla found separate from the cranium, but which fits onto it and has an alveolar surface whose curvature matches the appropriate portion of the outer surface of tusk piece 2. On these grounds we identify pieces 1 and 2 as distal and intermediate portions of the right tusk belonging to the mastodon cranium. We shall hereafter refer to this individual as "the Shelton Mastodon," or simply, "the mastodon."

The third relatively large piece of tusk (3 in Fig. 9) is a conical mass of dentine surrounding a sediment-filled pulp cavity. The smooth and continuous surface bounding this pulp cavity is readily distinguished from the fracture-parting forming the 'pseudo-pulp cavity' at the proximal end of fragment 1. However, the outer surface of the dentine comprising fragment 3 is an exfoliated surface, defined mostly by fractures that follow incremental lamination in the dentine. The conical form of this surface is broadly reminiscent of a tusk tip, and if this interpretation were accepted, it would imply that fragment 3 is a nearly complete tusk of a juvenile. Indeed, it was identified as such in earlier reports (e.g., Shoshani,

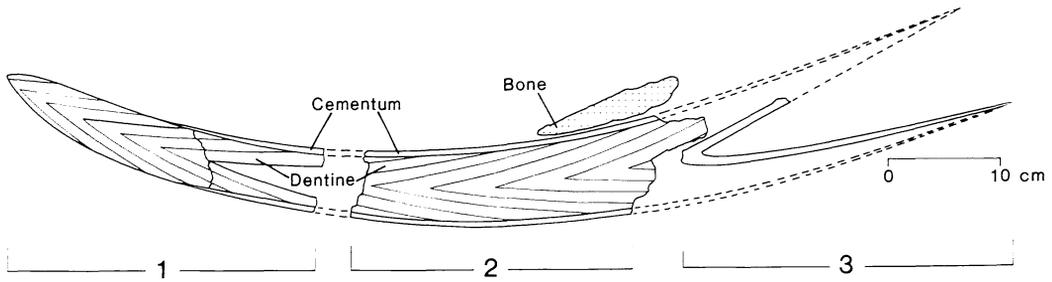


FIG. 9— Diagrammatic longitudinal cross section (medial aspect) through the three largest assemblies (1, 2, and 3) of tusk fragments and a single premaxillary fragment from the Shelton Mastodon Site, showing the arrangement proposed in the "single tusk" hypothesis (see text). Dimensions of all tissues are shown approximately to scale; approximate orientation of annual increments is shown within dentine. Drawn by B. Miljour.

1989). However, such regular, symmetrical exfoliation is uncommon at tusk tips. Furthermore, the pulp cavity appears to be too large to allow this fragment to be interpreted as a juvenile tusk. Although the proximal margin of piece 3 is incomplete, its present diameter at this end can be estimated as about 7 cm, and prior to desiccation and inward warping, it was somewhat greater than 8 cm (i.e., comparable to the basal diameter of the right tusk alveolus of the mastodon cranium). Dimensions such as these, as well as comparable patterns of exfoliation, are common for the proximal and intermediate portions of post-juvenile tusks.

A more difficult issue is whether tusk piece 3 is the proximal portion of the same tusk represented by pieces 1 and 2. It is too short and too poorly preserved to determine its left/right identity from its curvature, and as noted above, no contact with piece 2 is evident. However, when piece 2 is positioned in the tusk alveolus as determined above, the remaining depth of the alveolus is just enough to accommodate piece 3, with about 1 cm left between 2 and 3. This coincidence of fragment length and alveolar depth, together with the match between the pre-desiccation diameter of 3 and alveolar diameter, constitutes strong support for associating pieces 1, 2, and 3 as parts of a single tusk.

If piece 3 is not interpreted as part of the right tusk represented by 1 and 2, then we must be dealing with a second tusk. Ordinarily, this might be accommodated by interpreting piece 3 as part of the left tusk of the same individual, but the left tusk alveolus on the Shelton Mastodon cranium is filled with osseous material, implying that its left tusk either never developed or was injured and lost considerably prior to death. A second tusk thus requires a second individual. Since all other clearly identifiable mastodon material appears to be attributable to a single individual, it seems most parsimonious to interpret piece 3 in this manner also. This interpretation could be evaluated further by finding additional contacts and/or by analyzing growth laminae in thin section and attempting to correlate them from one fragment to another.

According to Skeels (1962), Kurtén and Anderson (1980), and Graham et al. (1981), the American mastodon inhabited a variety of habitats ranging from open woodlands to bogs, marshes, meadows and occasionally open grasslands bordering on the above habitats.

Artiodactyla: Artiodactyls were collected from both Holocene and Pleistocene sediments. The Pleistocene remains (Table 4) were those of the extinct Scott's moose, *Cervalces scotti*, and the extant moose, *Alces alces*, both classified in the family Cervidae. Analysis of the Scott's moose bone fragments (15 in total) shows that there were at least two individual *C. scotti* present at the Shelton Site. This conclusion is based mostly on the major left dentary fragment with a complete set of cheek teeth (Pm_2 - M_3 ; V131/455 and V138/462; identified by R. W. Graham and C. S. Churcher) and the anterior half of an upper molar (right M_2 ;

V114/407; identified by W. D. Turnbull). The lower teeth belonged to a subadult individual, whereas the one upper molar belonged to an adult. Their sexes could not be determined.

Toward the end of the 1986 season, a small piece of porous, bony material (measuring 5.3 x 3.4 x 1.1 cm and weighing 7.9 grams) was found in the bone-bearing layer (Unit II). It is brown in color and possesses narrow parallel streaks on a flat area. The radiocarbon date on this piece was $11,740 \pm 175$ ybp. Initially it was thought that this "Unknown" specimen (V161/562) was part of a toenail structure of a mastodon. Comparisons to bones and other tissues of mastodon and other species showed otherwise. X-ray diffractometry indicated that the mineral phase present was hydroxyapatite, as expected for bone. The odor emitted upon burning a small piece of the specimen indicated the presence of organic material, as is common in bones from comparable geological contexts. The results of histological, biochemical, immunological and elemental analyses are also consistent with an identification as bone. The most useful results from a taxonomic standpoint were from immunological tests by J. M. Lowenstein, which indicated that albumin extracted from V161/562 is most similar to cervid albumin. Based on its distinctive, porous texture, the "Unknown" may be part of an antler of a *Cervalces* or other cervid species. Alternatively, as C. S. Churcher suggested, this fragment may be part of a dentary (the area of the angular process) of a fetus or newborn *C. scotti*.

One almost complete right petrosal bone (V148/481, Table 4) was found *in situ* in Pleistocene sediments "in sandy layer about 1/2 way between muck and clay" in the southwest corner of Square a4 (see Fig. 5). This specimen was compared by the senior author to material in the osteological collection at the American Museum of Natural History (AMNH) in New York. The specimen differed in size and/or shape from petrosals of *Canis*, *Ursus*, *Odocoileus*, and *Cervus*. It closely resembled the petrosal size and shape of adult *Alces alces* (e.g., AMNH 173562, a male, and AMNH 13794, a female). R. H. Tedford of the AMNH concurred with this identification. In view of the presence of two cervid species from Pleistocene strata, the "Unknown" (V161/562) specimen may belong to either one, or perhaps to some other cervid.

Literature on the extinct Scott's moose (*C. scotti*) indicates that it inhabited a similar environment to that of the modern moose (*Alces alces*). These habitats were limited to forest and wooded areas with lakes, swamps, and/or marshes (Scott, 1885; Hall and Kelson, 1959; Burt and Grossenheider, 1976; Dorr and Eschman, 1970; Kurtén and Anderson, 1980).

HOLOCENE BIOTA OF THE SHELTON SITE

Included in this section are specimens that were found within Unit III at the Shelton Site. We have, however, excluded material that appeared to derive from mortality within the past few decades. In some circumstances, as when excavating in disturbed sediments, stratigraphic control was inadequate for determining the source of specimens. In such cases we relied on the predominant nature of surrounding sediment (e.g., the dark, Houghton-Adrian muck of Unit III vs. lighter colored sands of Unit II) to attribute specimens to one of the principal stratigraphic units.

PLANTS

Macroflora

Unit III contained a varied flora, but most specimens were conifers of the genus *Pinus*; we thus consider it a pine-dominated zone (Appendix C and Fig. 6). Representatives of the family Pinaceae found in unequivocal sediments of Unit III included *Pinus banksiana* (jack pine), *P. resinosa* (red pine), and *P. strobus* (white pine). *Larix laricina* (tamarack, or American larch) was found both in the transition zone with mixed sediments of Unit II and Unit III, and in the

bottom-most layer of Unit III. Similarly, fragments of *Abies balsamea* (balsam fir) cones (i.e., spikes and a few scales) were found both in the uppermost layer of Unit II and in the transition zone. Wood and bark samples of *Betula* sp. (probably *B. alleghaniensis*, the yellow birch) were collected at the top of Unit II, occasionally at the interface between Units II and III, and at the lowest level of Unit III. In this interface or transition zone, we sometimes found cones of jack pine and black spruce (*Picea mariana*). Specimens were identified by comparisons with collections in herbaria of the University of Michigan and Cranbrook Institute of Science, and by consultation of keys and descriptions in Brockman and Merrilees (1968) and Barnes and Wagner (1981).

Throughout the entire excavation area in the Houghton and Adrian mucks of Unit III, we encountered tiny brown or tan-colored spherical objects which were suspected to be of plant origin. Most of them appeared to have a single hole in them; they were very brittle and crumbled easily. In a collection of over 50 specimens found at various depths (between 30 and 67 cm below ground surface, from nine squares), the average diameter was 2.9 mm, with a range of 2.5 to 3.4 mm. Specimens were studied by S. P. Dudas, and with the help of M. Thele (Cooperative Service, St. Clair County Extension Office) and R. E. Taggart (Department of Botany and Plant Pathology, Michigan State University) they were identified as seeds belonging to the aquatic plant genera *Potamogeton* and *Alisma* (order Najadales, family Najadaceae, and order Alismales, family Alismaceae; see Appendix C). *Potamogeton* is known as pondweed and has about 45 species distributed in the United States; *Alisma* is known as water plantain. Both genera have worldwide distribution and are commonly found in fresh water habitats, in shallow waters, and quiet parts of streams. They are eaten by birds and various aquatic or semi-aquatic animals; e.g., *P. natans* is eaten by muskrats (Palmer and Fowler, 1975; Prescott, 1980).

Palynology

Fig. 8 depicts a summary of results from pollen analysis on sediments derived from Holocene layers (Unit III), and Appendix C provides additional information. Except for *Abies* all other tree genera mentioned in the previous section were also identified microscopically. Taxa isolated as pollen grains (and not as cone, wood, or seed samples) included *Quercus* sp. (oak; family Fagaceae), cattails (family Typhaceae), grasses (family Gramineae), and sedges (family Cyperaceae). These results were obtained by W. S. Benninghoff and are based on examination of seven out of twelve samples, following standard methods (Appendix B). These findings were discussed in conjunction with those obtained from Pleistocene sediments.

VERTEBRATES

Amphibia

A fused right calcaneum and astragalus (V193/861; measuring 19.8 mm long and 5.4 mm wide) was found *in situ* in square C19 on the north side of the pond. This was compared to bones of seven Michigan amphibian species and was identified by G. Schneider (of the University of Michigan) as belonging to *Rana* sp. It resembled comparable elements of the green frog (*R. clamitans*; order Anura, family Ranidae; see Table 5). A partial scapula of this species was also found in Pleistocene sediments and was described in detail by DeFauw and Shoshani (in press). Conant and Conant (1975:341-342 and map 299) noted that *R. clamitans* is found in maritime habitats of most of eastern United States and is a generalist species (see also under Pleistocene Biota).

TABLE 5 - Holocene vertebrates collected at the Shelton Mastodon Site.

Taxon ¹	Element(s) found	Field no./Catalogue no.
AMPHIBIA		
<i>Rana</i> cf. <i>R. clamitans</i> (1) ²	Fused right calcaneum and astragalus	V193/861
REPTILIA		
<i>Clemmys guttata</i> (1)	Possible second right costal scute	V124/444
<i>Sternotherus odoratus</i> or <i>Chelydra serpentina</i> (1)	Ventral scute	V52/143a
<i>Clemmys guttata</i> (1)	? right femoral scute	V52/143b
AVES		
<i>Meleagris gallopavo</i> (1)	Right ulna	V214/1006
<i>Agelaius phoeniceus</i> or <i>Euphagus carolinus</i> (1)	Right humerus	V212/1002b
MAMMALIA		
<i>Sorex</i> cf. <i>S. cinereus</i> (1)	Almost complete cranium	V213/1004
<i>Ondatra zibethicus</i> (4-6)	Assorted bones	V179/847, V212/1002c
<i>Sylvilagus floridanus</i> (1)	Partial right dentary with teeth	V184/852
<i>Alces alces</i> (1-2)	Patella and proximal phalanx	V203/871, V171/839
<i>Cervus canadensis</i> (1)	Partial left scapula	V185/853
<i>Odocoileus virginiana</i> (1)	Partial upper third right molar	V157/544
<i>Rangifer tarandus caribou</i> (1)	Partial left antler of a juvenile	V202/870

¹ Not included in this list are specimens of Mollusca, Pisces, and Amphibia because many of them live in the area today. We also found remains of domestic animals (see text for details).

² Numbers in parentheses indicate possible number of individuals for this species (a total of 16-19 individuals).

Reptilia

Three chelonid scutes (V52/143a, V52/143b and V124/444) were initially identified by J. A. Holman, and subsequently compared to museum specimens and the key provided by Conant and Conant (1975). They were collected in the lowermost portion of Unit III and thus are of Holocene rather than Pleistocene origin. Specimens V52/143a and V52/143b were identified as ventral and (?) right femoral scutes. The ventral scute belonged either to *Sternotherus odoratus* (stinkpot turtle) or *Chelydra serpentina* (snapping turtle), while the (?) right femoral scute belonged to *Clemmys guttata* (spotted turtle). V124/444 was identified as a second right costal scute of *Clemmys guttata* (see Appendix C and Table 5). All four turtle species are found in the lower peninsula of Michigan in marshy meadows, bogs, swamps, and small ponds; they feed on aquatic insects and other animals including carrion and dead fish, and on vegetable matter (Conant and Conant, 1975; Palmer and Fowler, 1975).

Aves

One right ulna, V214/1006, of wild turkey (*Meleagris gallopavo*; order Galliformes, family Meleagrididae; Table 5) was collected from disturbed soil at the Shelton Site. It was identified with the help of P. C. Chu, using comparative material at the University of Michigan, Museum of Zoology. A specimen of this species was also noted in the Pleistocene Biota. Wild turkeys generally inhabit woodland areas (Dorr and Eschman, 1970).

Specimen V212/1002b, a right humerus measuring 27.7 mm long, 8.5 mm wide at the proximal end, and 7.0 mm wide at the distal end, was found in soil derived from dredging, on the north side of the pond. It was identified by P. C. Chu and R. W. Storer (of the University

of Michigan) as belonging to an icterid species (meadowlarks, blackbirds, and orioles; order Passeriformes, family Icteridae; Palmer and Fowler, 1975). Comparison with bones of a variety of icterids and members of related families showed that V212/1002b most resembles the humeri of red-winged blackbirds (*Agelaius phoeniceus*) and rusty blackbirds (*Euphagus carolinus*). It was not possible to give it a specific designation since the humeri of these two species are almost identical. According to Palmer and Fowler (1975), both *A. phoeniceus* and *E. carolinus* inhabit marshy and swampy habitats; the former is found in North America from Canada to the southern United States and occasionally winters in the Great Lakes region, and the latter species breeds in Canada and migrates to the southern United States during winter. No records of Pleistocene or Holocene icterids were given for Michigan (Dorr and Eschman, 1970; Holman et al., 1986).

Mammalia

Insectivora: *Sorex* cf. *S. cinereus* (order Insectivora, family Soricidae) was identified based on an almost complete cranium (V213/1004) collected from dredged, disturbed soil. Using the mammal collection at the University of Michigan, Museum of Zoology (UMMZ), the senior author and P. Myers compared this specimen to specimens of four local and extralimital soricid species as follows: *S. cinereus* (e.g., UMMZ 126615), *S. fumeus* (e.g., UMMZ 106569), *S. dispar* (e.g., UMMZ 100824), and *S. arcticus* (e.g., UMMZ 103512). Our conclusion is that the cranium found at the Shelton Site most resembles that of *S. cinereus*. In the Great Lakes region, this species is the most common of those considered; it frequents moist, grassy, and woodland habitats with logs and litter on the forest floor, and it is found in the northern United States and over most of Canada (Burt, 1972; Burt and Grossenheider, 1976).

Rodentia: Most of the specimens of *Ondatra zibethicus* (order Rodentia, family Arvicolidae) were recovered from disturbed Holocene sediments. It may be noted, however, that the minimum and maximum number (4-6) of individual muskrats is the highest of the Holocene species (Table 5).

Lagomorpha: Specimen V184/852 (partial right dentary with teeth) represents the only lagomorph found at the Shelton Site. Unfortunately it was recovered from dredged soil, and thus it is not possible to determine its geological context. Based on the good preservation of this specimen and its off-white color (unlike Pleistocene specimens, which are mostly brown or patinated), we conclude that it is of Holocene age. Comparison with museum specimens indicates that V184/852 belongs to *Sylvilagus floridanus* (order Lagomorpha, family Leporidae), the eastern cottontail, commonly found in Michigan and other Great Lakes states today (Burt, 1972). According to Burt and Grossenheider (1976), *S. floridanus* is distributed in most of the southern and eastern United States, and its range in Michigan is limited to the lower peninsula. It inhabits a variety of terrains but prefers brushy areas, edges of swamps, open woodlands, and weed patches. There are no records of Pleistocene lagomorphs in Michigan (Dorr and Eschman, 1970; Holman et al., 1986).

Artiodactyla: Five specimens of this order were collected from Holocene sediments at the Shelton Site; they represent four artiodactyl species, all classified in the family Cervidae (Table 5). These cervid species are: *Alces alces* (common moose; identification based on a patella and a proximal phalanx), *Cervus canadensis* (elk; based on an almost complete left scapula), *Odocoileus virginiana* (white-tailed deer; based on an upper third right molar), and *Rangifer tarandus caribou* (woodland caribou; based on a partial left antler of a juvenile). *Odocoileus* was discovered *in situ* within the Holocene stratum (Unit III); all other species were found in disturbed black soil similar to that in Unit III. According to Burt and Grossenheider (1976), and Baker (1983) *O. virginiana* is the only one of these four species that inhabits southern Michigan today, though all inhabited this part of the state in historic times (Baker, 1983). The other three taxa are either found in northern Michigan (*Alces* and

Cervus— the latter reintroduced in 1909), or north of Lake Superior in Canada (*Rangifer*). According to Burt (1948), the last native elk (*C. canadensis*) died in 1870. The records of moose, *A. alces*, in Michigan extend as far south as Oakland County in historic time. Both elk and moose specimens have been recovered as fossils in Michigan (Dorr and Eschman, 1970). The woodland caribou, *R. t. caribou*, on the other hand, has not been recorded from the lower peninsula of Michigan in historic time (Burt, 1948, 1972) but only as a Pleistocene species (Dorr and Eschman, 1970). Burt (1942:214), reported on a caribou from Michigan and concluded that "This, as far as I am aware, constitutes the first authentic record of caribou from the mainland of the Lower Peninsula of Michigan." The same antler (UMMZ 48108) was identified by Hibbard (1951; see also Dorr and Eschman, 1970:413) as belonging to barren ground caribou (*Rangifer tarandus arcticus*), whose distribution is more northern than that of the woodland caribou (*R. t. caribou*; Burt and Grossenheider, 1976; Jackson, 1989). Based on comparison to material in osteological collections of the University of Michigan, the antler discovered at the Shelton Site was identified as belonging to *R. t. caribou*. Taking these records into consideration and the palynological results obtained from soil associated with the antler (see details later), it is entirely possible that the woodland caribou recovered at the Shelton Site dates to late Pleistocene or very early Holocene. It may be noted that the five cervid species for the Holocene and Pleistocene combined (total of ten possible individuals) are the largest group of any mammalian order or family found at the Shelton Site.

As mentioned above, specimen V202/870 was recovered from disturbed soil and was later identified as a partial left antler of a juvenile woodland caribou, *R. t. caribou*. This specimen piqued our interest more than any other cervid material discovered out of context, because of the lack of records of this species in the lower peninsula of Michigan in historic times (Burt, 1948, 1972). Thus we suspected it was at least a few hundred years old. More reliable data were obtained from pollen analysis conducted on sediment that was associated with the antler. The results were compared to a pollen profile based on 31 soil samples (at approximately 5 cm intervals) from a single column of Square U9 at the Shelton Site. According to Snyder and Shoshani (submitted), the most prevalent pollen grains in the caribou-associated soil sample were spruce (*Picea*, 40%), oak (*Quercus*, 14%) and pine (*Pinus*, 9%). These results suggest that the caribou antler came from sediments in the transition between the spruce- and pine-dominated zones, possibly closer to Unit II than to Unit III. The radiocarbon date on wood from the bottom-most layer of Unit III was 9640 ± 120 ybp. One antler fragment from Genesee County in Michigan is reported by Dorr and Eschman (1970) to have yielded a radiocarbon date of 5870 ± 400 ybp. Considering all the above information and records, we cautiously assign an earliest Holocene date to the caribou antler, though we realize that it may be of a younger age. A radiocarbon date on the bone itself would be desirable.

TAPHONOMIC ANALYSIS

GENERAL COMMENTS

The taphonomic issues we have addressed at the Shelton Site concern mainly the vertebrates of Pleistocene age. Remains of small vertebrates are too scanty to warrant taphonomic discussion, and we therefore focus on the two largest species, the Scott's moose (*C. scotti*) and the American mastodon (*M. americanum*). Only small portions of skeletons of each of these were recovered—less than 5% for the former and about 15% for the latter. Soon after the first *in situ* discovery of mastodon bones it became apparent that the skeleton was disarticulated and that bones were scattered on both sides of the creek and pond (Figs. 5 and 7). The largest concentration of mastodon bones was limited to an area of 5 m². The moose bone fragments were likewise disarticulated. All other vertebrate bone discoveries were made either in the

squares where *Mammot* and *Cervalces* were found or in adjacent areas. An exception was the tibial fragment of *Canis* sp. that was collected in the wall between Squares bb5 and cc5.

To aid in a general taphonomic interpretation, it is noted that the original land surface where the bones were found had a gradual slope of about 14°, with the highest elevation on the south side of the excavated area (Figs. 5 and 7). It was also observed that large bone fragments (over 10 cm in length) were found resting against rocks or wood.

BONE BREAKAGE

Except for the three cervical vertebrae, one caudal vertebra, and the first right rib of the Shelton Mastodon, all other bones of mammals were broken. Those of the Scott's moose (*C. scotti*) consisted of the major left dentary fragment with a complete set of cheek teeth, plus 15 bone pieces and 9 tooth fragments. The only recovered remains of the modern moose (*Alces alces*; V148/481, Table 4) consisted of a right petrosal bone that was slightly damaged. The cranium of the mastodon was broken into many pieces. The mandible was fractured at the symphysis, and the cranium was broken into about 25 large and small fragments, plus numerous scraps. There were also 20 pieces of ribs, one partial thoracic vertebra, a portion of the right scapula, and two possible limb fragments.

The many mastodon cranium fragments that were found *in situ* (in Square C4) and in Dumped Pile No. 1 raised some question as to the mechanism of fracturing. The bucket of the drag-line which was used to excavate the pond in 1977 may have crushed the cranium. Alternatively, it may have already been fragmented before it was picked up. Freezing and thawing of water and soil are known to affect objects in them. To study this phenomenon, we placed a large mastodon cranium piece that was found *in situ* and a similar piece from an Asian elephant (*Elephas maximus*) in buckets packed with mud from the site and subjected these buckets to 23 freezing and thawing cycles. As expected, the freezing of the water in the air pockets (diploe) of the cranium caused the bones to crack and break. The *Mammot* sample showed considerably more fragmentation than the *Elephas* sample, presumably as it was older and less sturdy. The number of pieces broken would probably have increased if we had allowed the experiment to continue. Guillien and Lautreidou (1970) found that fragmentation of stones increased as the number of cycles of freezing and thawing increased. It is possible that freezing and thawing played a role in cracking the Shelton Mastodon's cranium.

Most of the mammalian bone at the Shelton Site shows a high incidence of longitudinal cracking that is generally indicative of subaerial weathering. Behrensmeyer's (1978) stages 1-4 are represented, with variation in degree of weathering both within and among individuals. Weathering tends to be more extreme on the bones of larger-bodied taxa, apparently indicating a more protracted preburial history. Fracturing has occurred in association with various stages of bone weathering and may be attributed to a variety of mechanisms, including postmortem weathering itself, transport (either by current action or trampling), or post-burial compaction.

One bone fragment (V153/529; found in Square K3) is distinctive enough to warrant separate description. Its overall shape is trapezoidal, and it is about 10 cm wide, 17 cm long, and up to 2 cm thick (Fig. 10). Based on its texture and dimensions, we identify it as a cortical fragment of the diaphysis of a proboscidean long-bone (probably a humerus or femur). It may have been derived from the Shelton Mastodon, but this cannot be verified. Most edges of this fragment are relatively smooth and rounded in comparison to those of other bones found at the site, but one edge, formed by the intersection of a spiral fracture and the original outer surface of the bone, is smoother than the rest. In these respects, this fragment shows some resemblance to previously described "bone tools" thought to have been used by Paleoindians during butchery (e.g., Stanford et al., 1981). Indeed, some individuals consulted have favored this interpretation (A. R. Pilling, pers. comm.; W. N. Irving, *in litt.*).

Since the overall shape of this fragment did not allow conclusive interpretation of its origin, we examined microscopic features of the "polish" evident on its surface. If this fragment had been used as an "expedient bone tool" (i.e., derived from and used in butchering the Shelton

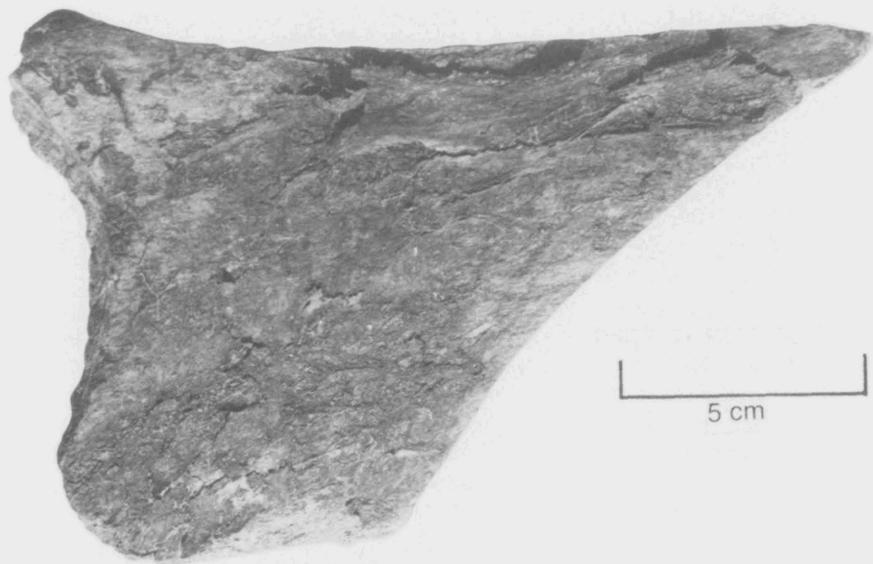


FIG. 10— External view of V153/529, a cortical fragment of the diaphysis of a proboscidean long bone that was initially interpreted as a bone tool. Photograph by J. Shoshani.

Mastodon), the polish should predate any weathering features. However, scanning electron micrographs reveal at least two generations of fine-scale fracturing subsequent to the production of the fragment itself (Fig. 11). The polish clearly *postdates* the first generation of fractures, rounding their edges as well as those of the original fragment. Furthermore, the polish is sufficiently coarse that it cannot be distinguished from sedimentary abrasion. The second generation of fractures transects the polish sharply, thus indicating an origin after the interval of abrasion. Both generations of fractures appear to relate to subaerial weathering and the attendant desiccation and loss of organic material from the bone. Since a period of weathering thus seems to have intervened between the formation of the fragment and the development of polish, the "expedient bone tool" interpretation is not corroborated. While some alternative mode of human association remains conceivable, the most cautious interpretation is that this fragment was produced and modified through nonhuman processes. This interpretation was also supported by G. Haynes (*in litt.*).

PATTERN OF BONE DISPERSAL

Cervalces scotti

The *Cervalces* remains in Fig. 5 were, with few exceptions, confined to about 3 m². The exceptions were small bones or tooth fragments that could have been easily transported by water and/or animals. The concentration of teeth and bone fragments in the vicinity of the large granite boulder in Square g2 was apparently natural; it can be explained by local fragmentation of a small number of skeletal elements and the retention of these fragments by deposition among "obstacles" (stones and driftwood) on the substrate. The largest of the den-

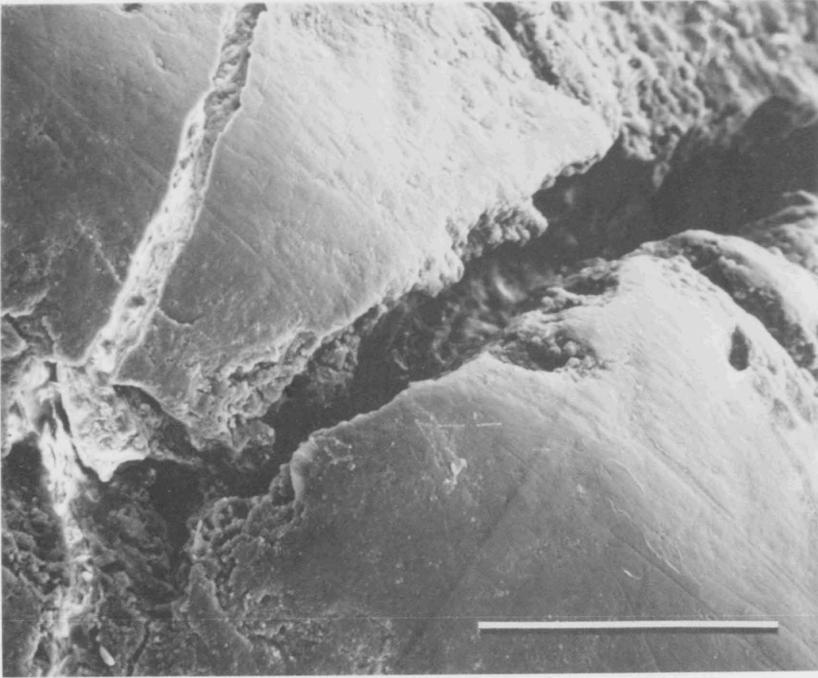


FIG. 11— SEM photomicrograph of a region near the polished edge of this bone fragment (see discussion in text); scale bar = 0.1 mm. Photograph by D. C. Fisher.

tary fragments was found on top of the sloping granite boulder. Given the instability inherent in half of a moose dentary (approximately 350 grams) resting on a rock with an inclination of about 21° , it seems likely that most of the boulder was buried, with only a portion of it exposed when the dentary was deposited. It may also be noted that of the 15 bone fragments (excluding teeth) collected in the vicinity of the granite boulder, 10 were identified as parts of the *Cervalces* mandible, and one of these had indentations which may be tooth marks of a carnivore (see illustration in Haynes, 1983). It thus seems likely that the moose was preyed upon or scavenged by a carnivore(s).

Mammot americanum

Comparing the dimensions of a carcass of a subadult *M. americanum* (body length about 3.5 m, excluding trunk and tail; height about 2 m) to the pattern of bone scatter in Fig. 4, it is apparent that the area of bone distribution for the Shelton Mastodon is at least 20 times larger than it would have been if the bones had remained articulated. Considering that this calculation ignores the likelihood that parts of the skeleton not recovered at all may have been dispersed over an even wider area, it becomes clear that bone dispersal was a major factor in the formation of this site. It would be interesting if the condition and/or distribution of bones within the excavated area could be used to reconstruct aspects of the death or early postmortem history of the Shelton Mastodon. However, even the simplest of such inferences are complicated by the multiplicity of causal factors that need to be considered. For instance, a mastodon rib fragment located to the northeast (Square K5) of the main bone concentration has indentations that appear to be carnivore toothmarks (confirmed by L. D. Agenbroad and J. I. Mead, pers. comm.). This seems to be a clear indication of carnivore activity, and it is

possible that the present position of this rib fragment, and perhaps other bones as well, results from that activity. Nonetheless, this does not rule out other mechanisms of bone dispersal (for this and other fragments). One such alternative interpretation is that other mastodons could have displaced bones. This can happen either inadvertently, through trampling or kicking, or intentionally, through manipulation (mostly using the trunk) of bones of dead conspecifics, as has been observed in African elephants (Douglas-Hamilton and Douglas-Hamilton, 1975; Frison and Todd, 1986; Haynes, 1988). Such behavior could accomplish displacements of even the largest skeletal elements recovered at the Shelton Mastodon Site, and yet we are aware of no physical attributes of single bones or bone assemblages that would be diagnostic of such events.

Another mechanism of bone dispersal is transport by moving water. This has been investigated by a number of previous workers (e.g., Voorhies, 1969; Behrensmeyer, 1975), but the observations most relevant to the behavior of mastodon bones are those of Todd and Frison (1986) on transport of bones of the Asian elephant (*Elephas maximus*). Judging from the fluvial transport indices calculated by Todd and Frison (1986), the mastodon bones recovered at the Shelton Site include easily transportable elements (e.g., a caudal vertebra), elements of intermediate transportability (e.g., ribs), and elements that are difficult to transport (e.g., the mandible). Likewise, the parts of the skeleton that were not recovered represent all levels of transportability (from foot bones to pelvis). Such a pattern makes it extremely unlikely that transport by moving water was the sole mechanism responsible for presence and absence of bones at the Shelton Site. That is, the assemblage is neither a lag deposit from which all easily transportable elements have been winnowed, nor a grossly allochthonous suite washed in from a distant death site. Between these extremes, however, lies a broad range of possibilities that are much more difficult to evaluate.

In the course of their work, Todd and Frison (1986) noted that dried elephant bones sometimes float for a short time, until a sufficient amount of the air contained within internal cavities is replaced by water. The duration of flotation (or indeed of any interval of reduced density; Behrensmeyer, 1975) is clearly a determinant of susceptibility to transport. In order to explore this aspect of the problem further, we conducted several simple flotation experiments in the pond now present at the Shelton Site. These experiments used bones of Asian elephant (Wayne State Univ. Mus. Nat. Hist. 4544), African elephant (*Loxodonta africana*; WSU-MNH 4543), and the Shelton Mastodon itself. Of the 14 bones or bone complexes tested, only a large cranial fragment of *E. maximus* floated for an appreciable interval (2 hrs, 30 min, 18 sec). Brief flotation was observed for a complete cranium of a young *L. africana* (30 sec), a sternum (16 sec) and two ribs (4 sec for the left second rib, and 15 sec for the right nineteenth rib) of *E. maximus*, and a cranial fragment of *Mammot* (3 sec). Other bones tested (a small cranial fragment, mandible, articulated atlas and axis, four other articulated cervical vertebrae, lumbar vertebra, right scapula, right humerus, right cuboid, left pelvis, left femur, left patella, right astragalus, left first rib, and left eighth rib) sank immediately. These observations leave many issues untouched, such as the effects of residual soft tissues, in various stages of desiccation, on the transport behavior of proboscidean bones. Nonetheless, they do tend to support the possibility that transport by moving water could have been involved in the displacement of some bones of the Shelton Mastodon (e.g., the cranium or cranial fragments).

A different approach to interpreting bone dispersal is to consider the pattern as a whole, rather than on a bone-by-bone basis. For instance, Fisher (1984b) described two contrasting categories of distributional patterns, based on differences in the evident timing of particular instances of bone disarticulation, dispersal, and burial. "Disarticulation" is here used to signify loss of anatomical attachment, without reference to mechanism, and "dispersal" refers to displacement beyond what could be interpreted as a gravitational response to disarticulation. The two categories of patterns were typified by the "Pleasant Lake mastodon" and the "Johnson mastodon," both of which are from sites in Michigan. The first of these showed tightly articulated sequences of bones, displaced appreciably from one another. This indicated that the displaced units had been separated from other such units prior to any general disarticulation (such as would follow soft tissue decomposition) of the skeleton. The Johnson mastodon, on

the other hand, was completely disarticulated, but retained most of its bones in approximate anatomical relationship. This indicated that burial was delayed long enough for general disarticulation to occur, but that there was little disturbance of the carcass during this interval. The Pleasant Lake pattern was interpreted as suggestive of butchery, while the pattern at the Johnson site seemed to indicate lack of human association (Fisher, 1984b).

Unfortunately, the Shelton Site offers no simple correspondence to either the Pleasant Lake or the Johnson pattern. No synovial articular relationships are preserved at the Shelton Site, and in the small suite of bones recovered, there are only rather tenuous approximations of anatomical order (the best being the association of the atlas, axis, and third cervical vertebra; Fig. 5). The Shelton pattern is perhaps more similar to Johnson than to Pleasant Lake, but it is better accommodated by a third category discussed by Fisher (1984b). This third category is represented by the New Hudson site, where disarticulation is complete, dispersal has disrupted all anatomical organization, and bone loss (either by *in situ* destruction or dispersal out of the area of excavation) has been extensive. This third pattern is easily recognized as a later stage (than either Pleasant Lake or Johnson) in the cumulative process of disarticulation and dispersal. It is characterized by bone dispersal that has progressed to a sufficiently advanced state that very little can be deduced concerning the relative timing of particular disarticulation and dispersal events. In both the Pleasant Lake and Johnson patterns, burial (and stabilization of pattern) occurred after certain disruptions of anatomical relationship, but before all anatomical order was lost, and it was the character of the residual anatomical order that made these sites interpretable. In contrast, at the Shelton Site, little order is retained, and consequently, there is little basis for making comparable determinations regarding postmortem history. It is even difficult to determine whether the greater disorder observed at the Shelton Site results from more rapid accumulation of dispersal events or from a more prolonged interval prior to burial, though the relatively advanced states of weathering of many bones at the Shelton Site tend to favor the latter interpretation.

The factors discussed above militate against any detailed, deductive reconstruction of the postmortem history of the Shelton Mastodon. Nonetheless, it is important to address the issue of whether there is any evidence of human involvement with this individual. As noted above, many agents of skeletal modification may have operated on the Shelton Mastodon, but signs of their action appear to have been largely overridden by subsequent events. We cannot rule out human involvement, but neither is there any positive evidence to support it. Under these circumstances, the most cautious approach is to treat the Shelton Mastodon as a natural death that was not subsequently disturbed by humans. To illustrate that all aspects of the pattern of bone distribution can be accounted for by nonhuman processes, we offer the following, admittedly speculative, interpretation of postmortem history. We emphasize that we cannot defend the details of such a picture against many comparable scenarios, but our intent is only to show that human involvement is not required.

Given the relatively low transportability of the mandible (Todd and Frison, 1986) and its close association with the atlas, axis, and third cervical vertebra, we suggest that the Shelton Mastodon may have died with its head in the vicinity of the origin of our grid system ("Bull's eye" in Fig. 5). Since most of the bones lay generally to the east of this point, this may have been the direction in which the rest of the body was oriented. The only other hints concerning the original death posture involve the laterality of bones recovered. The jugal is from the left side and is also located near what we have suggested as the original position of the skull. In an individual of this age, the jugal is not yet firmly synostosed with the zygomatic process of the maxilla. This, together with its exposed position on the side of the cheek region, means that it is easily detached from the zygomatic arch and is frequently lost from proboscidean skulls, both fossil and Recent (J. S. and D. C. F., pers. obs.). Both its preservation and its apparently minimal displacement could reflect derivation from the lowermost side of the Shelton Mastodon, giving it an opportunity for early burial and stabilization. Likewise, six of the seven ribs represented at the site are from the left side. If the left side was lowermost, and the head and body were located as suggested above, then the limbs must have extended downslope, to the north. The only other clear instance of asymmetrical preservation is the

presence of the right scapula. While this may seem at odds with the interpretation that the left side was lowermost, scapulae are larger and more "three dimensional" (with the spine oriented roughly at a right angle to the blade) than ribs or jugals (which present a lower profile on a planar substrate). This may make scapulae less easy to bury and more susceptible to dispersal events such as trampling or kicking.

Working within the framework of this suggestion for the carcass position, the implied displacements of other skeletal elements can be readily accommodated. The location of the palate and partial braincase implies that the cranium was moved downslope several meters, which is not incompatible with some combination of gravitational processes, trampling, or "intentional" movement by other mastodons. Although tusk material was not found *in situ*, its location on the piles of sediment dredged from the pond indicates that it probably came from the area of the present pond, perhaps just offshore from the cranial fragments in Squares C4 and C5. The mandible must have been displaced to some degree, if only to explain its upside down orientation. This too could be the result of trampling, however. The mandibular symphysis is broken, but this could have occurred during or after displacement, possibly even as a result of sediment compaction.

Locations of most of the smaller bones and bone fragments can be easily explained by either the activity of nonhuman scavengers or in some cases, by water movement. These same processes could also be responsible for many absences of medium to small bones (vertebrae, ribs, foot bones), either by removal or local destruction. Bones recovered from more southerly portions of the excavation, where Units II and III became thinner in an onshore direction, were generally less well preserved. This presumably relates to lower rates of burial and thus more prolonged subaerial exposure (see also Webb et al., 1989). The absences of many large elements, such as limb bones, are harder to ascribe to weathering, water transport, or destruction by scavengers, but displacement out of the excavation area by bears, wolves, or other mastodons remains a possibility. This also raises the possibility, counter to the suggestion of the above scenario, that the elements recovered were displaced into an area of potential preservation, rather than the unrecovered elements being displaced out of one. While this alternative may be less likely in view of the apparent association shown by the cranium, mandible, and cervical vertebrae, it seems difficult to rule out.

AGE AND SEX

Cervalces scotti

Examination of the molars and premolars of the moose found on the granite boulder reveals that it was a subadult. Its sex could not be determined. Since other Scott's moose molars of a different age were discovered *in situ*, we know that there were at least two individual *Cervalces* at this site (C. S. Churcher, pers. comm.). If the "Unknown" specimen (V161/562) found at the end of the 1986 field season proves to be a piece of *Cervalces* antler, then it would further imply the presence of at least one male.

Mammot americanum

The chronological age of the Shelton Mastodon is estimated to be 15 (\pm 2) years. Following Saunders (1977), this estimate is based on examination of the cheek teeth and comparisons with dental wear patterns and age estimates for the African elephant (*Loxodonta africana*; see Laws, 1966, and Sikes, 1971), and the Asian elephant (*Elephas maximus*; see Roth and Shoshani, 1988). On the Shelton Mastodon, molars one and two were in use (dentine was exposed on the first molar but not on the second), and the third molars were just erupting and were still without roots.

Sex determination in mastodons is based on sexual dimorphism in body size and tusk dimensions (Osborn, 1936). If we have correctly associated the three largest tusk fragments

with the Shelton Mastodon, the total length (ca. 90 cm) and basal diameter (ca. 8.4 cm) of this tusk may be judged relative to the state of molar eruption and wear. Preliminary comparisons suggest that this tusk is shorter and more slender than most male tusks of this molar-age, but well within the range of variation for females. However, on an individual as young as the Shelton Mastodon, dimorphism is not as pronounced as in older individuals. Until more comparative data are available, our determination will therefore remain somewhat uncertain. It may be noted that the mandible of the Shelton Mastodon lacked incisors, which are considered indicative of males (Osborn, 1936). In their position were apparent alveoli filled with osseous material.

PALEOECOLOGY

Stratigraphic and topographic features at the Shelton Site provide evidence for lacustrine habitat. Corroborative evidence for this environment was provided by the finding of remains of extinct and extant species whose habitat may be inferred from knowledge of their extant relatives. Except for the American mastodon (*M. americanum*) and the Scott's moose (*Cervalces scotti*), all species found at the Shelton Site are present in Michigan today (the elk, *Cervus canadensis* was reintroduced into the state at the beginning of this century). Information on the ecology of extant relatives was obtained from Barnes and Wagner (1981) for plants, Pennak (1978) for molluscs, Hubbs and Lagler (1958) for fish, Conant and Conant (1975) for amphibians and reptiles, and Burt (1972) for mammals. Inferred habitats for *M. americanum* were given by Warren (1852), Bearss and Kapp (1987), Garland and Cogswell (1985), Graham et al. (1981, 1983), and Saunders (1977), and for *C. scotti* by Scott (1885). This information was summarized by Dorr and Eschman (1970), Kurtén and Anderson (1980), and in articles in Martin and Klein (1984). The types of habitat in which bones of *Mammut* were found are, in the majority of cases, wooded areas with coniferous and/or deciduous trees, bogs, swamps, and meadows in post-glacial topographies. *Cervalces* habitats were more restricted and included forested/wooded regions with lakes and swamps, similar to habitats in which *Alces alces* is observed (Baker, 1983).

The habitats of the cervid species (*Alces alces*, *Cervus canadensis*, *Odocoileus virginiana*, and *Rangifer tarandus caribou*) should also be considered in the overall reconstruction of the environment of the Shelton Site, although their relevance is principally to the Holocene phase of its history. The habitats of all the cervid species can be found in close proximity in some parts of their ranges (Burt and Grossenheider, 1976). Taken *in toto*, the cervids may allow us to narrow our reconstruction of environmental conditions beyond what would be possible using any one species alone.

Based on the evidence provided in previous sections of this paper, ecological interpretations for the Shelton Site appear to lead in one primary direction--a wetland habitat. The environmental tolerance of most of the vertebrate species is wide, and thus a number of habitat types are possible. However, a wooded area with open clearings and adjacent wetlands seems most likely. Supportive evidence for such a habitat are the plentiful wood, cones, and other plant remains, and the *in situ* tree stumps and forest litter. Forest fires also require a substantial amount of dead wood in the area. The clay deposits (Unit I) and the mollusc fauna (Appendix C) indicate the presence of a lake.

Female cones provide more reliable evidence of the nature of immediately surrounding vegetation than does pollen, because pollen is wind-blown and can easily travel from other localities, meters or kilometers away (Faegri and Iversen, 1975). Additionally, based on the available literature (Benninghoff and Hibbard, 1961; Oltz and Kapp, 1963; Stoutmire and Benninghoff, 1964; Held and Kapp, 1969; Garland and Cogswell, 1985; Kapp, 1986; Bearss and Kapp, 1987; Kapp, pers. comm.), the Shelton Site is the only locality in Michigan where cones of seven Pinaceae species (3 *Pinus*, 2 *Picea*, 1 *Larix*, and 1 *Abies*; see Appendix C) have been discovered. One cone (*Pinus resinosa*), collected in the lower portion of Unit III

and therefore probably of early Holocene age, is believed to be the earliest record of its species in Michigan (Kapp, pers. comm.).

The two northern pike (*Esox lucius*) and the two yellow perch (*Perca flavescens*) were undoubtedly part of larger populations of fish; perch, in particular, generally travel in schools (Collins, 1959). Comparing our specimens to museum skeletons of known age and size (G. R. Smith, *in litt.*), the larger of the two pikes was at least 8 years old and 68 cm long. The larger of the two yellow perch was about 4 years old and 13 cm long. Both *E. lucius* and *P. flavescens*, according to Hubbs and Lagler (1958) and Scott and Crossman (1973), are fish of open waters; both are carnivorous (though *Esox* is a top carnivore) and spawn in the spring, in water of 4.4-11.1° C, for *Esox*, and 8.9-12.2° C, for *Perca* (Scott and Crossman, 1973).

A brief overview of the present day fauna and flora at the Shelton Site in particular and southeastern Michigan in general reveals that about half of the late Pleistocene trees no longer grow in this area. Specifically, among the coniferous tree types we collected, three out of the seven species have had their distribution shifted northwards (Brockman and Merrilees, 1968; Barnes and Wagner, 1981); these species are *Pinus strobus*, *P. resinosa*, and *Abies balsamea* (see Appendix C for other species found). Among the eleven vertebrate species that were present at the Shelton Site during the late Wisconsinan, seven (*Esox lucius*, *Perca flavescens*, *Rana catesbeiana*, *R. clamitans*, *Meleagris gallopavo*, *Ondatra zibethicus*, and *Microtus pennsylvanicus*) occur in southeastern Michigan today.

The former presence, in Michigan, of species that today favor a more boreal climate implies that the overall annual temperatures in southern Michigan have increased, making it unfavorable habitat for certain animals and plants. This general trend of warming has been given ample discussion by Dorr and Eschman (1970).

Climatic changes have been cited as a principal cause of late Pleistocene extinction (Skeels, 1962; Dreimanis, 1968; Olsen, 1972; Kurtén and Anderson, 1980). Other factors may include competition with species having similar ecological requirements, and hunting by man. Because of the longer generation times and smaller population sizes in larger species (e.g., elephants; Laws et al., 1975) compared to smaller ones (e.g., rodents; Hall and Kelson, 1959), the effect of any of these possible factors would be greater on the megafauna than on the microfauna. Ample discussion of Pleistocene extinction is available in the literature (Meltzer and Mead, 1983; King and Saunders, 1984).

SEASON OF DEATH OF THE SHELTON MASTODON

Season of death is routinely determined for cervid dental remains through analysis of cementum annuli, using techniques reviewed by Grue and Jensen (1979). This has not yet been undertaken for the *Cervalces* material recovered at the Shelton Site. However, we have determined the season of death for the Shelton Mastodon. The method of analysis (Fisher, 1984b, 1987) involves counting incremental lines that are formed on an approximately fortnightly cycle within tusk and molar dentine. The winter-spring boundary is marked within the annual cycle of dentine accretion by a series of especially thin fortnightly increments, a band of darker-colored dentine, and a compositional shift to dentine that is depleted in ¹⁸O relative to ¹⁶O (Koch and Fisher, 1986; Koch et al., 1989). Using a hand-held grinder, small samples of dentine abutting on open pulp cavity were removed from the developing left and right M³s of the Shelton Mastodon. Thin sections of both samples showed that dentine formation ceased during the fifth fortnight following the last winter-spring boundary. This individual appears to have died during the spring.

Season of death has recently been reported for a series of seventeen other mastodon sites from southern Michigan and surrounding areas (Fisher, 1987). All sites that showed evidence of butchery (eight, based on cutmarks and disarticulation marks on bones, burned bone, and patterns of bone disarticulation and dispersal) involved individuals that had died in the autumn or earliest portion of winter. In contrast, all deaths of non-butchered individuals (nine, not

counting Shelton) took place between late winter and early summer, and most of these, near the winter-spring boundary. These probably represent deaths by natural causes associated either with poor physical condition after enduring a long winter, or with the heightened probability of accidental death posed by spring flooding or thawing of ice-cover on bogs, ponds, and lakes. As noted above, the Shelton Mastodon shows no compelling evidence of butchery and thus would be classed with other non-butchered individuals. We do not propose using season of death as direct evidence of butchery or non-butchery, but it is notable that the Shelton Mastodon died at roughly the same time of year as other non-butchered individuals. While there remains some possibility that Paleoindians were involved with the death of the Shelton Mastodon, or that they butchered it after death, the most cautious and internally consistent interpretation of these data is that it died and decomposed without human intervention.

SUMMARY AND CONCLUSIONS

The Shelton Mastodon Site is unusual among Michigan's Pleistocene localities for the multidisciplinary character of the studies focused upon it. The mastodon recovered from Brandon Township, Oakland County, is one of 219 found in Michigan (Shoshani, 1989). As index fossils *Mammuth americanum* and *Cervalces scotti* are integral parts of the fossil assemblage of the late Wisconsinan at this site. This assemblage consisted of at least twelve vertebrate species (with 16 to 22 possible individuals) discovered in association with invertebrates (over 100 taxa) and plants (about 20 species) in a well documented stratigraphy.

Data accumulated over five excavation seasons reveal a complex ecosystem of a woodland of coniferous and deciduous trees adjacent to a body of water and marshes. Within the context of the overall geology of southeastern Michigan, the following scenario for the Shelton Site is hypothesized. Roughly 14,500 years ago the last ice fronts withdrew from Oakland County leaving behind morainal tills, till and outwash plains. A nutrient-rich, oxygenated lake formed on a depression on the Oxford outwash plain and supported a diverse molluscan and diatom community. This lake was progressively infilled by clastic sediments. A spruce forest initially surrounded the lake and was inhabited by a variety of vertebrates. Forest fires followed by episodic sedimentation events buried some elements of the vertebrate fauna along with numerous logs and charcoaled wood fragments. The lake continued to expand and contract, probably over a 2,000 year interval ($12,320 \pm 110$ to $10,970 \pm 130$ ybp). Holocene bogs developed in low-lying areas by at least 9,640 ybp, along with dense pine forest in better-drained areas. Early Archaic human occupation of the area is represented by about 10,000 ybp, judging from the Kessell and LeCroy projectile points in the bog deposits above the bone-bearing layer.

Given below are the highlights of our findings and concluding statements on subjects discussed in this paper:

1. The Shelton Mastodon site (Michigan Archaeological Site File Number 20-OK-394) is a late Pleistocene locality, with most of the vertebrate faunule representing the Twocreekan substage of the late Wisconsinan. This conclusion is based on radiocarbon dates for the bone-bearing layer (Unit II) ranging from $12,320 \pm 110$ ybp to $11,740 \pm 175$ ybp (Table 1 and text for details).
2. The wooded/forested zone associated with the bones was spruce-dominated (probably white spruce, *Picea glauca*), and the strata at higher levels contained a heterogeneous mixture of trees (mostly pines), sedges, and grasses. The Holocene sediments included three *Pinus* species (Fig. 6 and Appendix C). Cones of the red pine (*Pinus resinosa*) may be the earliest record of the species in Michigan.
3. Among the twelve vertebrate species (Table 4 and Appendix C), the American mastodon (*Mammuth americanum*) and the Scott's moose (*Cervalces scotti*) are the focal points, and three of the remaining nine species (*Esox lucius*, *Perca flavescens*, and the two *Rana* species) are the first Pleistocene records for Michigan.

4. It appears that the Shelton Mastodon and the Scott's moose may have died of natural causes and were subsequently subjected to scavenging by carnivores. Bone weathering, scattering, and trampling indicate that the skeletons were subjected to a prolonged period of subaerial exposure. The mastodon was 13 to 17 years old and probably died in the springtime. It is an unusual specimen in that only the right tusk developed. The molars and premolars of the Scott's moose (*C. scotti*) are the first such find in Michigan.
5. Although there is no direct evidence for the preferred habitats of the extinct species (*M. americanum* and *C. scotti*), ecological inferences can be made from the sediments in which they were found and the niches of associated, extant species. In this case we suggest an open boreal spruce forest with adjacent wetlands and clearings.

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APPENDICES

APPENDIX A. FIELD METHODS

GENERAL

Soon after Todd Hattig and Randy Carson found the tusk and cranium fragments, Todd's father, Herman Hattig, came to investigate the newly excavated pond and noticed bones sticking out of the water. He marked the south shore of the pond at that point with a large rock. Later that year when the water level rose and covered the marking stone, H. Hattig placed a piece of drainage tile on the shore of the advancing water south of the marking stone. Hattig's foresight in marking the spot proved to be very helpful and saved us much valuable time.

We employed paleontological and archaeological techniques as described by Kummel and Raup (1965), Rixon (1976), and Joukowsky (1980), and used standard surveying equipment. Our datum point is a railroad spike that was driven into a utility pole west of the dirt road and 22 meters south of the culvert which drains the marsh west of the Shelton property into the Shelton pond (Fig. 4). This datum point is 2.8 km northwest of the closest Bench Mark located at the intersection of Indian Wood and Eston roads in the center of Section 1, T4N, R9E, at an elevation of 319 m (1048 ft.) above sea level.

After pumping water from the pond and clearing the dense vegetation, we positioned the east-west baseline and the north-south datum line at 13 m south of, and 10 m east of the datum point (these two reference lines intersect at the "Bull's eye" at the corner joining Squares AA1, A1, aal, and a1 in Fig. 5). Using surveying stakes driven at the southwest corners of the squares, a 1-meter grid system was then laid out to the northeast of the "Bull's eye," with the numbers increasing northward and the letters eastward. We concentrated our efforts northeast of the "Bull's eye" because, according to H. Hattig, the marking stone was in the vicinity of Square C4. Later we found bone fragments outside the boundaries of the single uppercase letter system, and it became necessary to expand the grid system in all cardinal directions (see Fig. 5).

The marking stone was found in Square C4, and thus we began excavating downhill from the stone (in Square C5) and proceeded uphill toward the baseline. During the first field season we used no shovels; only trowels were employed because we were uncertain of the exact location and depth of the bones. Thin layers of soil (of about 3-5 cm thick) were removed with much care to prevent damage to bones. A standard masonry level was used as a guide so that floors and walls of the squares were level and vertical. After the first year, when it became evident that all the mastodon and the other Pleistocene animals were found above the clay (Unit I) in sandy strata among wood and rocks, we used shovels to excavate the topmost layer (Unit III) and resorted to trowels in the bone-bearing layer (Unit II). Once a bone was discovered, more delicate tools were used; these included metal spatulas, dental picks, wooden tongue depressors, and brushes.

We excavated one meter square at a time and then joined the squares into long trenches of one or more meters wide, separated by walls. These walls were left intact to retain a representative sediment profile for future studies.

DOCUMENTATION

A daily field log of the Shelton Site was kept. In this journal we recorded general events, which squares were excavated by whom, and notes on all finds. Data sheets and catalogue cards were filled out for each specimen or group of specimens given the same field number. These data sheets and catalogue cards were formatted after Joukowsky (1980) and included provenances and all pertinent information. A sketch of the specimen was often made. The provenances were taken from the southwest corner of each square. Using a line-level, we measured depths of specimens from the ground surface as well as from a stake whose height relative to the datum point was known. In most instances we also recorded the degree of inclination (dip) and the compass orientation of a specimen.

The rule of thumb was not to remove any specimen from its original location until all data were collected, sketches were made and/or photographs *in situ* were taken. Small specimens with no associated objects were removed soon after data collecting. Large bones were kept in place (covered with moist cloth), allowing them to serve as additional reference points for other finds.

We photographed and drew wall profiles and floor maps of specimens including associated wood, stones and rocks, following standard techniques (Joukowsky, 1980). In addition, we measured the aerial distance of all major discoveries (e.g., large and important bones, tree stumps with roots) from one fixed point--the center of the granite boulder upon which the *Cervalces* teeth were found.

Specimens were given field and catalogue numbers; the former were grouped according to five major categories, each of which had a code letter, whereas catalogue numbers were assigned continuously. Field number categories were: A, for artifacts; I, for invertebrates; P, for plant material and soil samples (since some were used for pollen analysis); S, for stones; and V, for vertebrates.

SCREENING

Every bucket of soil excavated was screened, regardless of the layer in which it originated. Three screen sizes were employed: coarse (12 mm openings), medium (6 mm), and fine window screen (1 mm). As we became more familiar with the wall profiles and the bone-bearing layers, we sifted the topmost muck (Unit III) with the coarse screen and the underlying stratum (Unit II) with medium screen. The fine window screen was often used when washing with water in search of small molluscs, insect parts, or coniferous needles.

Screening was also conducted on the soil excavated by the drag-line (in 1977). Dumped Pile No. 1 (the original pile where parts of the cranium and tusks were discovered in 1977 and 1983) was carefully divided into quadrants and layers. The layers were clearly delineated (due to striking differences in color and texture) and could be identified as being from Unit I, II, or III. By keeping track of the matrix surrounding specimens in disturbed soil, finds could be traced tentatively to Holocene or Pleistocene deposits.

SAMPLE COLLECTING

General

Bones that were discovered in the uppermost layer (Unit III) are of Holocene rather than Pleistocene origin. These specimens were labeled and separated from the Pleistocene specimens.

Samples from the waterlogged bone-bearing layer started to crack and deteriorate if allowed to dry quickly. This was true for any plant material, bones, and teeth. For this reason, objects

of importance had to be covered and kept damp, or allowed to dry slowly, depending on the nature of the specimens.

Water samples

The creek that passes through the site is dry during the hottest months of the year (July - September), but the water level at the pond is relatively constant, being fed by underground springs. Samples were bottled in 1983 and in 1985 from standing water in the pond before pumping it and were refrigerated prior to testing.

Plant material and soil samples

Wood samples were kept moist in plastic Ziploc bags or in containers with ethylene glycol, commercial antifreeze. An entire tree stump with root system was preserved by this method. Dry wood samples were also collected in Ziploc bags. Wood samples for radiocarbon dating were collected in aluminum foil. Female cones of coniferous trees were usually kept in plastic containers in the excavated square or trench for a few days before sorting, counting and recording. All identifiable cones or cone parts were counted, and thus we obtained yearly and total counts. A few exceptionally preserved cone specimens were placed in a 50:50 solution of glycerine and distilled water. Needles of conifer trees were collected in the same manner.

Soil samples for pollen analyses were collected in newly purchased plastic containers (2.5 cm long and 2.0 cm in diameter) from wall profiles at given intervals. To minimize contamination, the surface of the wall was shaved with a trowel, and the containers were then pressed against the wall. Sediments for pH determination and diatom sampling were also collected from fresh wall surfaces.

Vertebrate and Invertebrate materials

Special care was taken in collecting invertebrate material such as molluscs and clams because of our close proximity to a natural water source and thus the concern that these specimens might be from Holocene rather than Pleistocene sediments. For this reason all questionable specimens were discarded. The same general procedure was applied to insect parts.

All bone fragments were collected and counted; those that were too small to keep and identify were employed as "practice" pieces for new participants at the site. Most large (20 cm and longer) bone fragments were collected together with associated soil and/or wood samples. All bones were kept in protective containers, labelled, and allowed to dry slowly. When needed, a dilute solution of Glyptal was applied on the bones to prevent further deterioration. Occasionally, we used a solution of Formvar. Broken bones were mended with Duco cement. We did not need plaster jackets.

Artifacts and Non-artifactual Lithic Materials

In addition to clearly recognized artifacts, we kept many lithic fragments (mostly chert) that might be interpretable as artifacts or debitage. We also kept samples of non-cultural pebbles and cobbles found at the site.

APPENDIX B. LABORATORY METHODS

Soil analysis and radiocarbon dating were performed by commercial laboratories. Analyses of water, diatoms, pollen, dentine and bone microstructure were conducted at non-commercial facilities. Radiocarbon dates were obtained by three laboratories as given in Table 1. The soil was analyzed by the Cooperative Extension Service (Michigan State University, U. S. Department of Agriculture & Counties Cooperating, Oakland County).

Water samples were studied at R. A. Hough's laboratory (Department of Biological Sciences, Wayne State University, WSU) following procedures described by Wetzel and Likens (1979). Diatoms were isolated at the Geology Department, WSU, as described by Patrick and Reimer (1966).

Pollen analyses were conducted at W. S. Benninghoff's laboratory (Department of Biology, University of Michigan, UM). Techniques followed were those of Faegri and Iversen (1975) and Moore and Webb (1978), whereby samples were first treated with hydrochloric acid and hydrofluoric acid to remove carbonates and silicates. This treatment was followed by the Erdtman acetolysis technique to remove cellulose and lignin.

Dentinal lamination on the molars and tusks was studied in D. C. Fisher's laboratory (Museum of Paleontology, UM) following procedures described by Fisher (1984b). A bone fragment showing smooth edges was also examined in D. C. Fisher's laboratory. In order to obtain a sample for scanning electron microscope study, the bone surface was replicated with a high-resolution molding compound and cast in epoxy resin as explained by Shipman et al. (1984).

X-ray diffractometry was employed by P. L. Koch (Dept. Geol. Sci., UM) and D. F. Sibley (Dept. Geol., Michigan State Univ., MSU) to better understand the nature of the "Unknown" (V161/562; see discussion of artiodactyl material in the section on the Pleistocene biota). An odor-sensitivity experiment on the "Unknown" was conducted by J. A. Holman (The Museum, MSU) by burning corners of different samples (the "Unknown", bones, antlers, and hooves) and comparing the degree of pungency on a scale from 1 to 10, with 10 being the most pungent.

APPENDIX C. SPECIES LIST FOR THE SHELTON SITE

Classification of fresh water diatoms is given following Vinyard (1974), of plants following Scagel et al. (1965), and Barnes and Wagner (1981), of insects following Borror et al. (1976), of molluscs following Barnes (1980) and Burch (1982), and of vertebrates following Romer (1966). Pleistocene [P] and Holocene [H] designations are given at the highest taxonomic rank for which a single designation is applicable; the designations are used together only when the lowest ranking taxon available was found in both stratigraphic units.

Kingdom Protista [P]

Phylum Crysophyta

Class Bacillariophyceae

A total of 91 diatom taxa, representing 25 genera, was identified. The most abundant species found (after Stoermer et al., 1988) are: *Achnanthes biasoletiana*, *A. exigua*, *Amphora perpusilla*, *Cymbella diluviana*, *Fragilaria brevistriata*, *F. construens*, *F. lapponica*, *F. pinnata*, *Navicula graciloides*, *N. minima*, *N. modica*, and *N. subrotundata*.

Kingdom Plantae

Division Coniferophyta

Class Gymnospermae

Order Coniferales

Family Pinaceae

Abies balsamea, based on parts of cones [P and ?H]

Larix laricina, based on cones (for species) and pollen (for genus) [P and H]

Picea glauca, based on cones (for species) and pollen (for genus) [P]

Picea mariana, based on cones (for species) and pollen (for genus) [P]

Pinus banksiana, based on cones (for species) and pollen (for genus) [H]

Pinus resinosa, based on cones (for species) and pollen (for genus) [H]

Pinus strobus, based on cones (for species) and pollen (for genus) [H]

Division Anthophyta

Class Dicotyledonae

Order Fagales

Family Betulaceae

Betula sp. probably *B. alleghaniensis*, based on wood, bark, and pollen [H]

Family Fagaceae

Quercus sp., based on pollen [P and H]

Class Monocotyledonae

Order Pandanales

Family Typhaceae

Cattails, based on pollen [P and H]

Order Najadales

Family Najadaceae

Potamogeton sp., based on seeds [H]

Order Alismales

Family Alismaceae

Alisma sp. based on seeds [H]

Order Graminales

Family Gramineae

Grasses, based on pollen [P and H]

Order Cyperales

Family Cyperaceae

Sedges, based on pollen [P and H]

Kingdom Animalia

Subkingdom Metazoa

Phylum Mollusca [P]

Class Gastropoda

Subclass Prosobranchia

Order Mesogastropoda

Superfamily Cyclophoracea

Family Valvatidae

Valvata sincera

Valvata tricarinata

Subclass Pulmonata

Superorder Basommatophora

Order Limnophila

Superfamily Lymnaeoidea

Family Lymnaeidae

Subfamily Lymnaeinae

Lymnaea stagnalis

Stagnicola elodes

Superfamily Ancyloidea

Family Physidae

Subfamily Physinae

Physella integra

Family Planorbidae

Subfamily Planorbinae

Tribe Planorbini

Gyraulus parvus

Tribe Helisomini

Helisoma anceps

Planorbella campanulata

Family Ancyliidae

Subfamily Ferrissinae

Ferrissia parallelus

Class Pelecypoda

Subclass Paleoheterodonta

Order Unionoida

Family Unionidae

Anodonta sp. (probably *A. grandis*)

Subclass Heterodonta

Order Veneroida

Family Sphaeriidae

Sphaerium sp.

Phylum Arthropoda [P]

Subphylum Mandibulata

Class Insecta

Order Coleoptera

Further identification needed; specimens are being studied by Morgan et al.
(in preparation).

Phylum Chordata

Subphylum Vertebrata

Class Osteichthyes [P]

Order Clupeiformes

- Family Esocidae
 - Esox lucius*
- Order Perciformes
 - Family Percidae
 - Perca flavescens*
- Class Amphibia
 - Order Anura
 - Family Ranidae
 - Rana catesbeiana* [P]
 - Rana clamitans* [P and ?H]
- Class Reptilia [H]
 - Order Testudines
 - Family Chelydridae
 - Chelydra serpentina* or
 - Family Kinosternidae
 - Stenothernus odoratus*
 - Family Emydidae
 - Clemmys guttata*
- Class Aves
 - Order Galliformes [P and H]
 - Family Meleagrididae
 - Meleagris gallopavo*
 - Order Passeriformes [H]
 - Family Icteridae
 - Agelaius phoeniceus* or
 - Euphagus carolinus*
- Class Mammalia
 - Order Insectivora or Soricomorpha [H]
 - Family Soricidae
 - Sorex* cf. *S. cinereus*
 - Order Rodentia
 - Family Arvicolidae
 - Microtus pennsylvanicus* [P]
 - Ondatra zibethicus* [P and H]
 - Family Castoridae [P]
 - Castor canadensis*
 - Order Lagomorpha [H]
 - Family Leporidae
 - Sylvilagus floridanus*
 - Order Carnivora [P]
 - Family Canidae
 - Canis* sp. (possibly *C. lupus*)
 - Order Proboscidea [P]
 - Family Mammutidae
 - Mammut americanum*
 - Order Artiodactyla
 - Family Cervidae
 - Alces alces* [P and H]
 - Cervalces scotti* [P]
 - Cervus canadensis* [H]
 - Odocoileus virginiana* [H]
 - Rangifer tarandus caribou* [?P or H]