PALAEOECOLOGICAL INTERPRETATION OF POLLEN, MACROFOSSILS, POLYGONAL FISSURES, AND TAPHONOMY OF THE SHAFER MASTODONT LOCALITY, WARREN COUNTY, INDIANA

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ABSTRACT. Discovery of the jaw of an American mastodont (*Mammut americanum*) and an unusual sedimentary profile in a cornfield in Warren County, Indiana, prompted a multidisciplinary study of the palaeoenvironment of the site. Wood taken from near the base of the deposit was dated at 15,540 ybp. Stratigraphic and textural analyses of the 2.3 m sedimentary profile reveal a series of inundation and desiccation events marked by polygonal fissures. Analysis of pollen from the sediment profile indicates that a boreal flora predominated during much of the time period represented by the profile. Pollen correlation indicates that the sedimentary record was truncated by unconformities around 10,000 ybp. Macrofossil analysis indicates a local environment that began as a forest dominated by white spruce and tamarack. Later inundation of the forest was indicated by the appearance of fish (*Perca flavescens*), meadow voles (*Microtus pennsylvanicus*), and submergent aquatic macrophytes (*Myriopyllum exalbescens*, *Potamogeton pusillus*, *Ceratophyllum demersum*, and *Najas flexilis*). The aquatic environment was interrupted by periods of exposure and desiccation as indicated by the disappearance of identifiable macrofossils and by the stratigraphy. The Shafer fossil assemblage is compared with other localities, and the taphonomy and palaeoenvironment of the mastodont are discussed.

Keywords: Mastodon, polygonal fissures, paleoecology, macrofossils, pollen, Late-Pleistocene, Holocene, Quaternary biota

On 5 July 1992, while digging a trench for drainage tile in his Warren County cornfield, Larry Shafer encountered teeth and jawbone fragments of the American mastodont (*Mammut americanum*). Upon discovery of the remains, digging was suspended; and Shafer contacted Purdue University archaeologists, who referred him to the Indiana State Museum. A thorough excavation of the site (referred to as the Shafer Mastodont Locality) was then conducted by staff and volunteers of the Indiana State Museum from 17–25 September in an attempt to recover additional remains of the mastodont and other associated fossil material. Little additional mastodont or other vertebrate material was recovered. However, the complex stratigraphy encountered at the site, including well-preserved fissure fillings and a lower stratum rich in plant macrofossils, provided an opportunity to characterize the paleoenvironment of the Shafer Mastodont. The discovery contributes to palaeoecological understanding of late-glacial and post-glacial environments in Indiana. The objectives of the present paper are to 1) document the fossil biota of the Shafer Mastodont Locality, 2) describe and discuss the taphonomy of the Shafer Mastodont, 3) determine the origin of polygonal fissure fillings at the

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site, and 4) reconstruct the palaeoenvironment of the area using pollen, macrofossils, vertebrate remains, and stratigraphy.

STUDY AREA

The study area is in Section 7, T23N, R6W, Chatterton Quadrangle, Warren County, Indiana (40°27′21″N; 87°07′52″W) at an elevation of 210 m (~690 ft. asl). It occurs within shallow, marginal wetlands associated with Otterbein Bog, a glacial kettle depression with a maximum depth of approximately 13 m (Richards 1938). The site is situated on a portion of the Crawfordsville End Moraine, part of the Cartersburg Till Member of the Trafalgar Formation, created approximately 16,000 ybp (years before present) during Wisconsinage glaciation (Wayne & Zumberge 1965; Fullerton 1986). The peat in nearby Otterbein Bog originated from grass and sedge remains, and Richards (1938) reports that much of the recent vegetation of the wetland is *Phragmites* and *Calamagrostis*. The wetland surrounding Otterbein Bog is referred to on the United States Geological Survey (USGS) topographic map as "Cranberry Marsh," suggesting that the wetland may have harbored cranberry (*Vaccinium* cf. *V. macrocarpon*), a plant usually restricted to peatlands with a boreal climate or similar microclimate. The peatland is best described as a fen or sedge-meadow because it is not dominated by *Sphagnum* mosses and is extremely mineral-rich (as indicated by the predominant flora). The soils immediately around the site are mainly poorly-drained silty loams and silty clay loams of the Brenton, Drummer, and Williamstown-Rainsville series (Barnes 1990). The Shafer Mastodont Locality is situated on the southwest edge of Cranberry Marsh that formed within a kettle depression (Fig. 1).

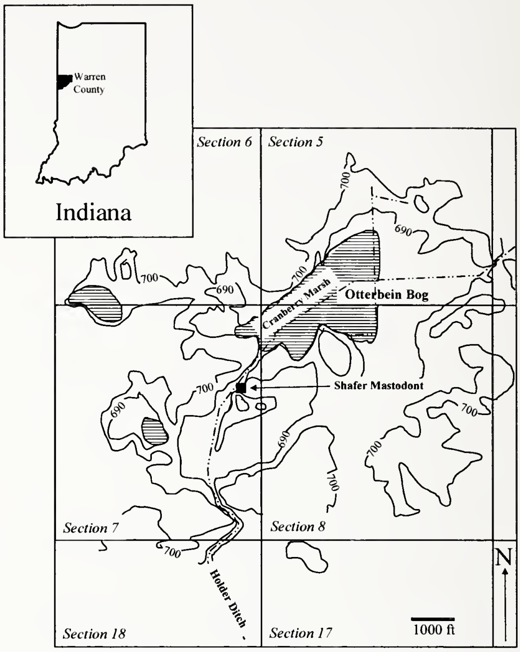


Figure 1.—Map of Otterbein Bog watershed (Sections 5, 6, 7, 8, 17 & 18, T23N, R6W, Warren County, Indiana), showing the location of the study area. Contour interval is 10 ft.(3 m) a.s.l.

METHODS

Field procedures.—Only a few fragments of mastodont bone at the Shafer Locality were found *in situ*; the remainder was disturbed by excavating. Disturbed soils were removed by shovel and trowel down to undisturbed soil. Thereafter, two intersecting trenches were excavated by shovel and backhoe near the location of the original bone fragments in an attempt to locate additional mastodont remains. Neither the 9.5 m long east-west trench nor the 10.2 m long north-south cross trench encountered any additional bone. Gasoline-powered pumps removed water that seeped into the excavation site, and also pumped clean water from adjacent Holder Ditch to wash excavated sediments for the recovery of microfauna and plant macrofossils. A site datum and baseline were established for leveling and mapping. Profiles and floor "bench" areas were created to facilitate mapping and photography of the complex stratigraphy. Bulk material from the trenches was variably washed through 1.2 mm (0.05 in) or 6.3 mm (0.25 in) mesh screens. When bulk screening from both trenches failed to yield any mastodont or other discernible biotic remains, the excavation strategy changed toward developing stratigraphic profiles, down to till if possible, to understand the geologic context of the mastodont jaw. In doing this, an organic silt, rich in conifer cones, was encountered. The soils from this "cone zone" were extensively sampled and washed through 1.2 mm mesh screen. Bulk soil samples were taken from each of the distinct strata in the profile for textural analysis and recovery of macrofossils. Additionally, small plastic canisters were driven into a freshly exposed profile at 10 cm intervals from the surface of the profile to the underlying glacial diamicton. These were capped and taken to the laboratory for pollen analysis.

During the excavation of a drainage pit at the south end of the north-south trench, the backhoe encountered a deeply-buried conifer log. This prompted eight exploratory pits and trenches several meters beyond the site perimeter. None produced any additional vertebrate material. A final widening and deepening of all the trenches and pits around the site still failed to yield bone of any kind.

Stratigraphic analysis.—Analysis of soil texture was accomplished using the Bouyoucos Procedure (Bouyoucos 1936). Percent organic carbon in the soils was determined using the loss-on-ignition method (Storer 1984).

Pollen analysis.—Extraction of pollen and spores from the sediment samples was accomplished using standard methods modified from Faegri & Iverson (1975). A 1 cm^3 sample from each level was used in processing. Palynomorph identification was based primarily on the key by MacAndrews et al. (1973), along with the aid of the pollen reference collection at the Center for Quaternary Studies at the University of Tennessee, Knoxville. Taxonomy follows Gleason & Cronquist (1963). Identification of black spruce (*Picea mariana*) and white spruce (*Picea glauca*) pollen was based on the morphometrics developed by Birks & Peglar (1980). Twenty spruce grains were measured for each level and assigned to either black spruce, white spruce, or undifferentiated spruce, following Hansen & Engstron (1985). These values were then used to assign the remaining spruce pollen to one of those categories. For each level a minimum of 300 terrestrial pollen grains was counted. Due to the existence of only a single radiocarbon date, it was not possible to calculate pollen influx rates for the profile.

Interpretation of the pollen diagram along with assignment of chronology was augmented by comparison with several studies, cited herein, which place the Shafer Mastodont Locality in a regional context. The pollen tally data are on file at the Center for Quaternary Studies, University of Tennessee, Knoxville, Tennessee 37996. Duplicate slides for each level are held by the Indiana State Museum (INSM).

Macrofossil analysis.—In addition to analysis of macrofossils obtained from bulk screening in the field using 1.2 mm (0.05 in) or 6.3 mm (0.25 in) mesh sieves, more careful analysis of the sediment was conducted in the laboratory to locate smaller or more delicate material. Subsamples of 300 cm^3 were carefully broken by hand and inspected for leaf impressions. To dissociate the soil, samples were then soaked in a 50 g per l solution of sodium phosphate for three days and rinsed through a 0.4 mm sieve. Macrofossils were identified and counted with the aid of a dissecting microscope. Excess bulk material that was not used in the quantitative subsampling was placed in a white enamel pan for recovery of large or infrequent macrofossils. Voucher specimens of macrofossils were deposited at INSM.

Radiocarbon dating.—A single radiocarbon date was obtained from a piece of spruce wood located at a depth of 2.1 m ("cone zone"), approximately 1.8 m below the level from which the mastodont molars and jaw fragment were found and approximately 20 cm above the glacial till. The wood sample, sent to Beta Analytic, Inc., was processed for a standard radiocarbon age determination (Beta-62640). An attempt was made to date the mastodont, but mandible fragments failed to produce recognizable collagen for dating (Beta Analytic, pers. commun.).

RESULTS & DISCUSSION

Stratigraphy.—The Shafer Mastodont Locality, like most of the other lakes and bogs that have yielded mastodonts in Indiana, is a shallow deposit of aquatic sediments that was truncated early in the Holocene. In this case, the profile represents a time period of approximately 5000 years, beginning just after deglaciation nearly 16,000 ybp. Four major divisions of sediments were identified in Profile 4 and designated as A through D, oldest to youngest (Fig. 2). Division A has also been designated the "cone zone" (as well as Unit XI in Fig. 2). This unit consists of wood and plant remains in a matrix of silt loam. A piece of wood from this zone yielded a radiocarbon age of 15,540 ± 70 ^{14}C ybp (Beta-62640), which provides a minimum age for deglaciation of the site and a maximum age for all other sediments above. Division B consists of interbedded silt and clay that is gray at the

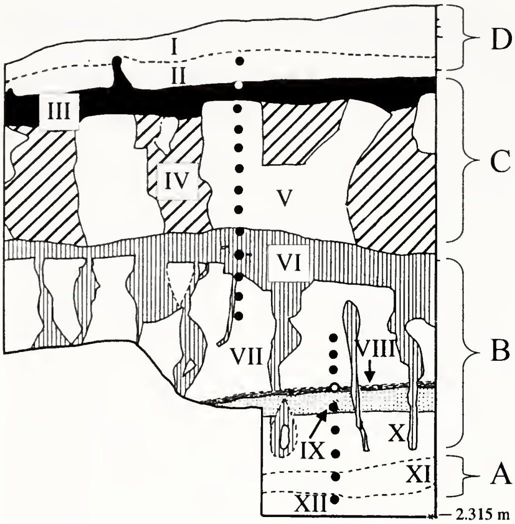


Figure 2.—Diagram of Profile 4, showing sediment divisions (capital letters) and units (Roman numerals). Dots represent the location of pollen samples taken from the profile at 10 cm intervals (see Table 1 for sedimentological details).

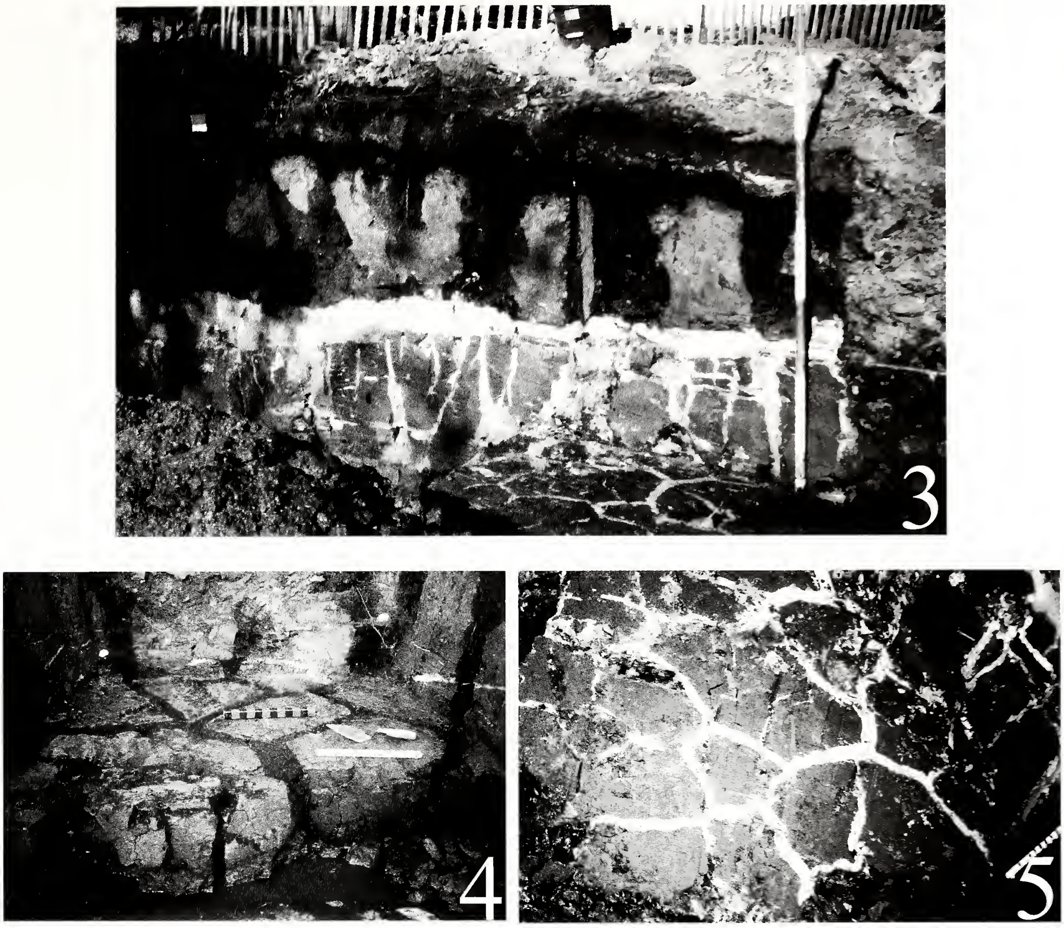
base (Unit X) then changes upward to blue-green (Unit IX), dark brown (Unit VIII), and brown (Unit VII) overlain by pure sand (Unit VI). This sand also in-fills fissures (Figs. 3, 5) that may extend downward into Unit X. Besides a thickness of up to 1 m of this sand as fissure in-fillings, there is another 5–25 cm as a blanket over younger units (Fig. 3). The unit both blankets the older deposits and fills the fissures within them. Sediments in Division C are similar to those below it and consist of brown silt (Unit V) that was buried, and fissures that were in-filled with brown silt loam (Unit IV) (Fig. 4). Unit IV of Division C is the source of the mastodont mandible. Division D consists of a cap of brown loam (Unit III), gray loam (Unit II), and black humus (Unit I). The oldest sediment reached in the excavation was late Wisconsinan till of the Wedron (?) Formation. This deposit of unknown thickness presumably underlines the entire basin of Otterbein Bog. It was not described at the Shafer Locality. Two samples were taken from below the cone zone, apparently from the matrix of till (Fig. 2), for laboratory analyses (Table 1, Fig. 2). The texture of these samples is silt loam. Loss-on-ignition averages 3.5%.

The sediments of the Shafer Locality are only about 2.3 m deep (Fig. 2), yet changes in the paleoenvironment are indicated by both the sediments themselves and the plant macrofossils and pollen they contain. The area appears to have been in a relatively shallow fringe zone, or shelf, around the margin of a much deeper kettle at the south end of the Shafer site. Back-hoeing well below the cone zone exposed clay and logs. Based on the topography of the area, it is likely that the Shafer Site was on a shelf, and erosion of the hillslopes (including sand and allochthonous organic matter such as wood, cones, and bones) may have transferred debris to the shelf. Waves and currents probably moved some of the debris to the deeper kettle.

As the landscape became less of a direct source of sediment for the kettle, sand percentages in the sediment declined from more than 10% in the cone zone (Unit XI) to only a few percent in the younger sediments (except for Unit VI). The size of the organic matter also declined, and the finer sizes characteristic of the younger sediments were more disseminated throughout the matrix rather than being concentrated as in the cone zone. The textures of Sediment Division B are silt loam, silty clay loam, and silty clay, textures common among glacio-lacustrine sediments. Mean organic carbon content was relatively low at 15%.

Delivery of organic sediments ceased temporarily during deposition of the sand of Unit VI. The extremely high percentage of sand in this unit (96%) and the fine to very fine sand size suggest eolian deposition during an episode of aridity. A backhoe pit dug north of the original excavation revealed a meter of massive sand and may be part of a sand dune. However, it is not known whether this eolian sand is the same age as Unit VI.

Organic deposition then resumed during the formation of the deposits of Sediment Division C. These younger sediments have about the same grain size, but have considerably more organic matter than those of Sediment Division B (Fig. 2, Table 1). Resumed deposition in a quiet-water lacustrine or wetland environment seems likely. The youngest sediments of Sediment Division D are probably the result of erosion in the drainage basin after European settlement. Sand percentages increase, but organic content is very high with a loss-on-ignition value of 50% in Unit III.



Figures 3–5.—Photographs of fissures encountered in sediment divisions B and C. 3. Profile; 4. Cross section of sediment division C; 5. Cross section of sediment division B.

Origin of the fissure in-fillings.—Three main hypotheses for the origin of the fissure in-filled polygons at the Shafer Locality were considered (periglacial, desiccation, and sand-blown mechanisms). Any reasonable hypotheses must include an explanation of two events: 1) what opened the vertically oriented fissures, and 2) how and when they were filled. Moreover, there is the possibility that the upper and lower sets of fissure in-fillings were formed by different mechanisms.

Criteria from several sources by which the periglacial, desiccation, and sand-blow mechanisms may be compared, both to each other and to the observations and data from the polygonal in-fillings at the Shafer Locality, are presented in Fig. 6.

Periglacial hypothesis: The primary sources of information about the periglacial origin of polygonal fissure-fillings used in the present study include Lachenbruch (1962), Bertouille (1974), Nissen (1985), Mears (1987), Nissen & Mears (1990), and Johnson (1990). The periglacial hypothesis requires temperatures cold enough to maintain permafrost. As the temperature drops, the permafrost-laden soil will crack. Meltwater will enter the crack and freeze, increasing the volume by 9%. Cracking may occur again and again, gradually building up an ice wedge. When the climate warms, the ice wedge melts, and sediment begins to fill the fissure. Most of the sediment is derived from the walls of the crack. Some small amount of material may be washed or blown in. The most critical condition for this hypothesis to be valid is temperatures cold enough to first form permafrost, then contract and crack it. The time of the

Table 1.—Field and laboratory data for Profile 4 at the Shafer Mastodont Locality, Warren County, Indiana. [1] SIL = Silt loam; SICL = Silty clay loam; CL = Clay loam. [2] NA = Not available.

Sediment division	Unit	Depth (cm)	% Sand	% Silt	% Clay	Soil texture[1]	% Org. C	Notes
D	I	0–15	NA[2]	NA	NA	Humus	NA	
D	II	15–30	NA	NA	NA	SIL	NA	Field texture
D	III	30–40	12	65	23	SIL	50	Overlies Units IV and V
C	IV	40–100	2	71	27	SICL	16	In-fills Unit V
C	V		23	47	29	CL	39	Grap sample near top
			12	58	30	SICL	21	7 samples, 10 cm apart
			7	59	34	SICL	18	
			9	61	29	SICL	20	
			6	60	34	SICL	19	
			1	64	35	SICL	14	
			2	55	43	SIC	17	
			9	49	42	SIC	13	
Mean (Unit V)			6.6	58.0	35.3	SICL	20.1	
B	VI	100–120	96	2	2	Sand	0.6	In-fills Units X-VII
B	VII	120–175	1	70	29	SICL	16	6 samples, 10 cm apart
			1	57	42	SIC	14	
			7	81	12	Silt	17	
			2	63	35	SICL	14	
			6	82	12	Silt	16	
			3	89	8	Silt	13	
Mean (Unit VII)			3.0	77.0	20.1		15.0	
B	VIII	175–180	1	97	2	Silt	10	
B	IX	180–185	1	68	31	SICL	7	
B	X	185–205	1	68	31	SICL	12	
			2	93	5	Silt	12	2 samples, 10 cm apart
A	XI	205–215	16	71	13	SIL	5	
			9	74	17	SIL	6	Sampled for ^{14}C dating
TILL		215+	6	79	15	SICL	4	Matrix of Late-Wisconsin till
			15	64	20	SIL	3	

Observation or Criterion	**Peri-glacial hypothesis**	**Seismic Sand-blow Hypothesis**	**Desiccation and In-filling Hypothesis**	***Shafer Mastodont Locality, Lower Set***	***Shafer Mastodont Locality, Upper Set***
1) In-fills occur as wedges, tapering with depth	Yes, active ice wedges taper with depth	Usually dike-like, with mushrooming if surface is reached. Usually widen with depth	Crack should propagate downward, thus be wider at the surface	*Almost all in-fills are wedges tapering with depth*	*Some in-fills taper with depth; many do not*
2) Map-view polygons	Yes, as shown by numerous active areas	Not likely, unless injection occurred along older fissures	Yes, widely known mudcracking is polygonal	*Well-defined polygons present*	*Well-defined polygons present*
3) Dimensions of polygons: a. Diamter b. Depth c. Thickness at junction with land surface	Diameters of 3 to 20 m, but mostly <1 m. Depths of 1 to 3 m. Thickness at the surface may average about 50 cm	No polygons. Depths of several meters. Thickness of < 1 cm to > 60 cm.	Very little data available.	*Diameters of about 30 cm, depth of about 1 m, thickness at land surface about 15 cm.*	*Diameters of about 75 cm, depth of about 90 cm, thickness at land surface about 30 cm*
4) Timing of in-filling vs. fissuring	If buried, ice wedges can melt slowly, perhaps over 2000 yrs. Sediments would replace ice as it melts	Sediment injected simultaneously with fissuring unless fissures formed previously by periglacial activity or desiccation.	With fissuring occurring during drying, cracks may develop very quickly and may remain open for many centuries.	*Formation of fissures estimated at 12,000 ^{14}C y BP, based on pollen assemblage.*	*Climate too warm to form periglacially. May have formed in last few decades after ditching.*
5) Temperature conditions	-6 to -8 deg. C	Any temperature.	Any temperature as long as drying can occur.	*Probably too warm to form periglacially after ~ 14,000 ^{14}C y BP*	*Definitely too warm to form periglacially.*
6) Composition of in-filled sediments vs. adjacent sediments	Similar to sediments surrounding the wedges; delivered by slumping from walls of fissure.	Sand-injected from below; host usually fine-grained	Almost always eolian silt or, more frequently, sand (few impurities)	*Nearly pure sand.*	*Organic sediments very similar to those adjacent.*
7) Presence of blanketing layer	Can be deposited once fissures are filled.	Only locally if surface is reached; mushrooming.	Can be deposited once fissures are filled	*Sand filling the fissures also blankets older sediments.*	*Sediment filling fissures does not blanket, but younger sediments do.*
8) Structure of in-fillings	Layering parallel to the wall and horizontal layering both possible, but may also be massive.	Usually massive, but may be vertical, stress-produced banding.	Probably rather massive, may locally be laminated.	*None noted.*	*None noted.*
9) Effects on adjacent material	Often deformed as ice takes up space.	None.	Cracking can cause deformation in host material.	*None noted.*	*None noted.*

Figure 6.—Observations and criteria of three hypotheses to explain the polygonal fissure fillings at the Shafer Mastodont Locality, Warren County, Indiana.

cracking is estimated at about 13,000 ^{14}C ybp based upon pollen correlation.

When the characteristics of periglacially-produced fissure in-fillings (i.e., ice-wedge casts) are compared with the observations and data at the Shafer Locality, there are both similarities and differences (Fig. 6). Periglacial in-fills are wedge-shaped; at the Shafer Locality, the lower fissure fills are, too, but some upper in-fills are tapered and some are not. Ice-wedge casts are usually polygonal; both upper and lower fissure fillings at the Shafer Locality are polygonal. The dimensions of the wedges and polygons are within the range expected for ice wedges.

Other differences between ice-wedges and the fissure in-fillings at the Shafer Locality include a very different sediment for lower in-fillings (pure sand) compared to the much finer surrounding materials, the lack of layering in the in-fillings at the Shafer Locality, and the lack of deformation in the adjacent materials. The periglacial origin for the upper set of fissure fillings at the Shafer Locality can likely be dismissed because the late Pleistocene and Holocene climate was much too warm to support permafrost. The possibility of a periglacial origin for the lower sequence remains. Such a case is supported by the wedge-shaped in-fills, their polygonal patterns, and range of dimensions for the in-fills, but these characteristics are not unique to periglacial mechanism. If the periglacial origin hypothesis is considered for the lower fissure fillings, then the permafrost would have to be present at a time after all the silt, sand, wood fragments, bone fragments, cones and other organic debris were washed into the lake; then organic sediment accumulated under boreal forest conditions for about three millennia (i.e., by about 13,000 ^{14}C ybp). By that time, it seems quite unlikely that permafrost was around in Indiana. Mean annual temperatures were probably warmer than $-6°$ to $-8°$ C.

Seismic sand-blow hypothesis: Primary sources of information about sand-blow phenomena used in the present study are Morris 1983, Gohn et al. (1984), Obermeiere (1987), Selley (1988), Munson et al. (1993), and Tuttle & Barstow (1996). Sandy sediments can be mobilized at the time of an earthquake through a liquification process. The sand is squeezed upward as a dike. The pressure will cause fissuring of older silty and clayey material as the sand is forcefully injected toward the land surface. If it reaches the surface, the injected materials will spread laterally for a short distance, forming a mushroom.

Although the seismic sand-blow hypothesis was considered as an origin for the fissure fillings at the Shafer Locality, it was noted immediately that seismic fissure in-fillings are not wedge-shaped and do not occur as polygons (Fig. 6). The seismic sand-blow origin can be considered only as part of a complex mechanism in which injection followed fissuring by one of the other mechanisms. Other aspects of seismic sand-blows that do not fit the Shafer Locality are the tendency of dikes to widen with depth, the apparent lack of a sand source with depth, and lack of structure in the fissure infillings. Some criteria for sand blows do match the conditions at the Shafer Locality. These include dimensions and lack of internal structure. Considering all the criteria for seismic sand-blows in Fig. 6, this mechanism is not likely the source for either set of in-fillings at the Shafer Locality.

Desiccation and in-filling hypothesis: The third hypothesis relies on drying and cracking, followed by in-filling with eolian sand at a later date. Primary sources of information about desiccation phenomena used in the study were Conybeare & Crook (1968), Calabresi & Burghignoli (1977), Haigh (1978), and Selley (1988). This hypothesis is not contradicted by any of the criteria in Fig. 6. Similarities between desiccation-caused in-fillings and both sets of fissure fillings at the Shafer Locality include the wedge shape, although this is more convincing in the case of the lower set. Similarly, both sets form polygons. We have found very little data on the size of desiccation polygons, but ordinary mud cracks are examples, and they seem to have dimensions that sometimes match those at the Shafer Locality.

The older set of fissures probably formed by 13,500 ^{14}C ybp (based on estimations derived from the pollen profile) as a result of desiccation. In-filling with eolian sand (Unit VI) must have followed quickly after fissuring because no other sediments are present in the fissures. The upper set of fissures may have formed by desiccation following ditching and lowering of the water tables in the early 1900's. Such fissures were filled with reworked organic sediment (Unit VI) before the site was blanketed with sediment resulting from cultivation of the surrounding landscape. Fissures of the upper set are still forming as witnessed by some fissures that were not filled with sediment. The fact that the upper fissures do not extend deeper is probably controlled by the level of the lowered water table.

All the observations and data at the Shafer Locality seem to be consistent with the conclusion that both sets of fissure fillings are the product of desiccation. Neither the periglacial hypothesis nor the seismic sand-blow hypothesis is a viable alternative to the desiccation hypothesis.

Both desiccation events (represented by Units V & VII) resulted in deep cracks (~80 cm) in the sediment. This suggests a nearly complete loss of the wetlands water source.

Because the entire profile represents a time when lobes of the Laurentide ice-sheet were still retreating from Indiana, it is possible that these successive water fluxes and desiccation events were driven by glacial meltwater dynamics. Beaver (*Castor canadensis*) may have also played a role. The oldest fissures (> 13,000 ybp) quickly filled with eolian sand. The sand, being fine and pure, likely originated from an area relatively devoid of vegetation, favoring erosion and transport by wind. Because macrofossils and pollen confirm a well-established forest community in the area, the sand must be from a relatively local source, perhaps redeposited from a beach/dune environment or a patch of land devegetated by fire. The decrease in spruce and the increase in ash correspond with the sand layer and the desiccation. The organic-rich silty clay loam that fills the youngest set of fissures may have been deposited during reinundation of the area (evidenced by the aquatic alga *Pediastrum*). It is at this time that the jaw of the Shafer Mastodont was washed into the cracks of Unit V.

Pollen analysis.—The pollen diagram along with the stratigraphy of the profile, vegetational zonation, and chronology is presented in Fig. 7 and is divided into three pollen zones (SML-1, 2, and 3).

SML-1 (210–85 cm): (15,540–ca. 13,000 ybp).—The deepest level in which pollen was found was 210 cm within the cone zone. Radiocarbon dating of wood from this level gave a date of 15,540 ± 70 ^{14}C ybp (Beta-62640). *Picea* (both black and white spruce) dominates the pollen record within this zone (> 80% arboreal pollen), with herb pollen making up between 5–10% (total pollen). Other conifer taxa include *Abies*, *Larix*, *Pinus*, *Tsuga*, and Cupressaceae (all less than 5%). *Quercus*, *Carya*, and *Fraxinus* occur in low quantities and were likely blown in from outside the local area. Other deciduous taxa that occur sporadically within this zone in trace amounts include *Ulmus*, *Ostrya-Carpinus*, *Betula*, *Salix*, *Juglans*, *Acer*, *Fagus*, *Platanus*, and *Populus*. The pollen from these taxa was likely blown in from outside the area. Herbaceous taxa are present at low levels (< 5%) throughout this zone. These taxa include *Ambrosia*-type, *Artemisia*, *Chenopodium*-type, Cyperaceae, and Poaceae. The upper-most portion of this zone exhibits a rise in herbaceous pollen (*Ambrosia* (ragweeds), Cyperaceae (sedges), Poaceae (grasses) from trace amounts to 5%. Aquatic taxa in this zone are limited to *Typha latifolia* (cattail) and *Pediastrum* colonies (aquatic algae). *Pediastrum* colonies were present in greatest abundance at the base of the profile, suggesting aquatic conditions early in the development of the soil profile. A gap in the pollen record occurs at 110 cm due to the sand layer (Unit VI) in which there was no pollen preserved.

SML-2 (85–45 cm): (ca. 13,000–11,000 ybp).—This zone is marked by the decline of *Picea* (from 80% to < 20%) and a rise in *Fraxinus* (from < 5% to > 40%). While it was not possible to identify *Fraxinus* to species at this site, it was probably almost entirely *Fraxinus nigra* (black ash) which grows in wet, poorly drained sites and has been identified at other locations in Indiana during this same period (Whitehead et al. 1982; Jackson et al. 1986). *Quercus* also increases to > 20% by the end of this zone. *Ostrya-Carpinus* pollen peaks at 17% in this zone and the profile for *Carya* becomes continuous. Other taxa with records that become continuous in this zone include *Ulmus*, *Betula*, *Salix*, *Juglans cinerea*, and *Acer*. Trace amounts of *Fagus*, *Celtis*, *Platanus*, *Populus*, and *Tilia* pollen also occur in this zone. Herbaceous pollen rises to > 20% in this zone, suggesting a closer proximity to, or expansion of, prairie vegetation to the west, or a more open woodland created by the dramatic decline in *Picea*. There are also small amounts (< 1%) of the aquatic taxa, *Nuphar*, *Sphagnum*, and *Typha latifolia*, suggesting the presence of aquatic vegetation, perhaps dispersed from nearby Otterbein Bog. The occurrence of *Pediastrum* colonies suggests at least periodic inundations with standing water. The sedge pollen could be an indication of a marsh environment during this time with cattails surrounding the edge of the site.

SML-3 (45–20 cm): (ca. 11,000–10,500 ybp).—The upper 25 cm is marked by a large increase in *Quercus* (from 20% to > 40%), *Carya* (from < 5% to > 20%), and *Ulmus* (from 6% to 20%), and a slight increase in *Picea* (from 10% to 20%) and *Pinus* (from < 2% to 7%). Additional temperate deciduous taxa that are present at low levels include *Betula*, *Juglans*, *Acer*, *Fagus*, *Celtis*, *Populus*, and *Tilia*. *Ambrosia* pollen rises to greater

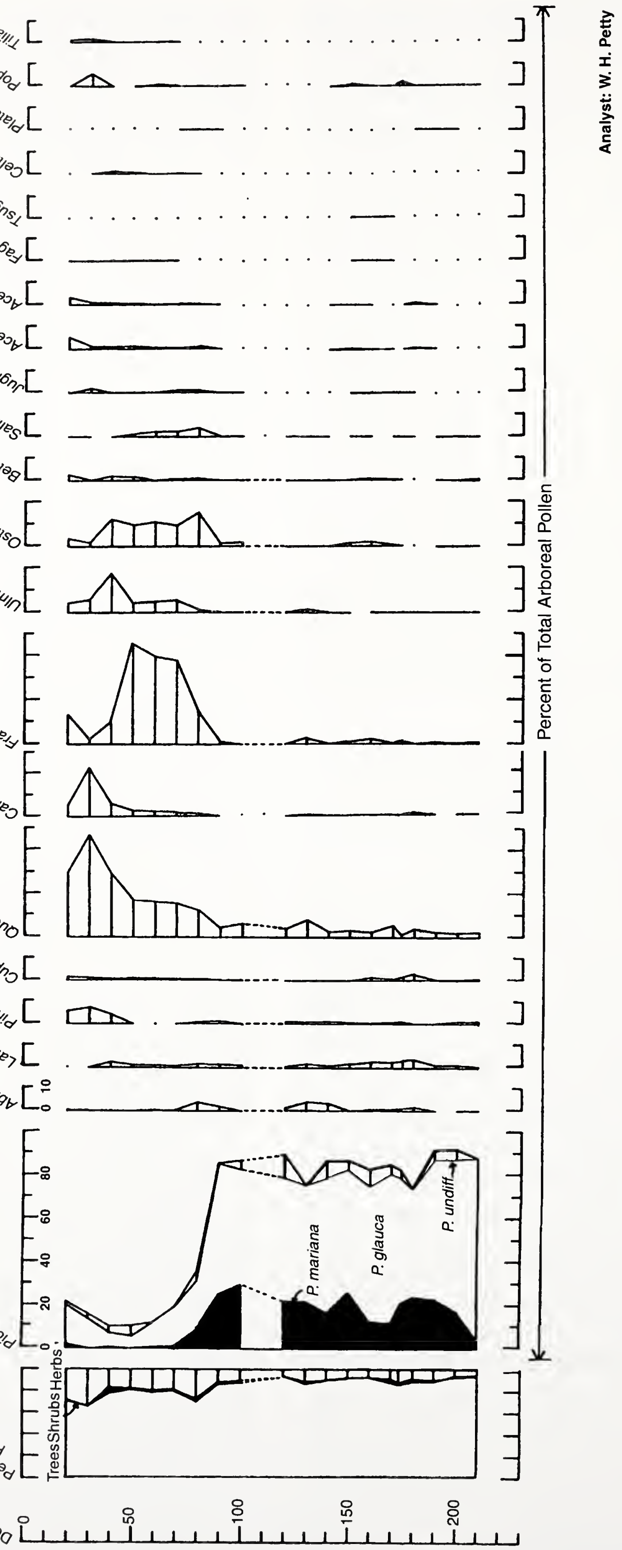


Figure 7.—Pollen diagram for the Shafer Mastodont Locality, Warren County, Indiana.

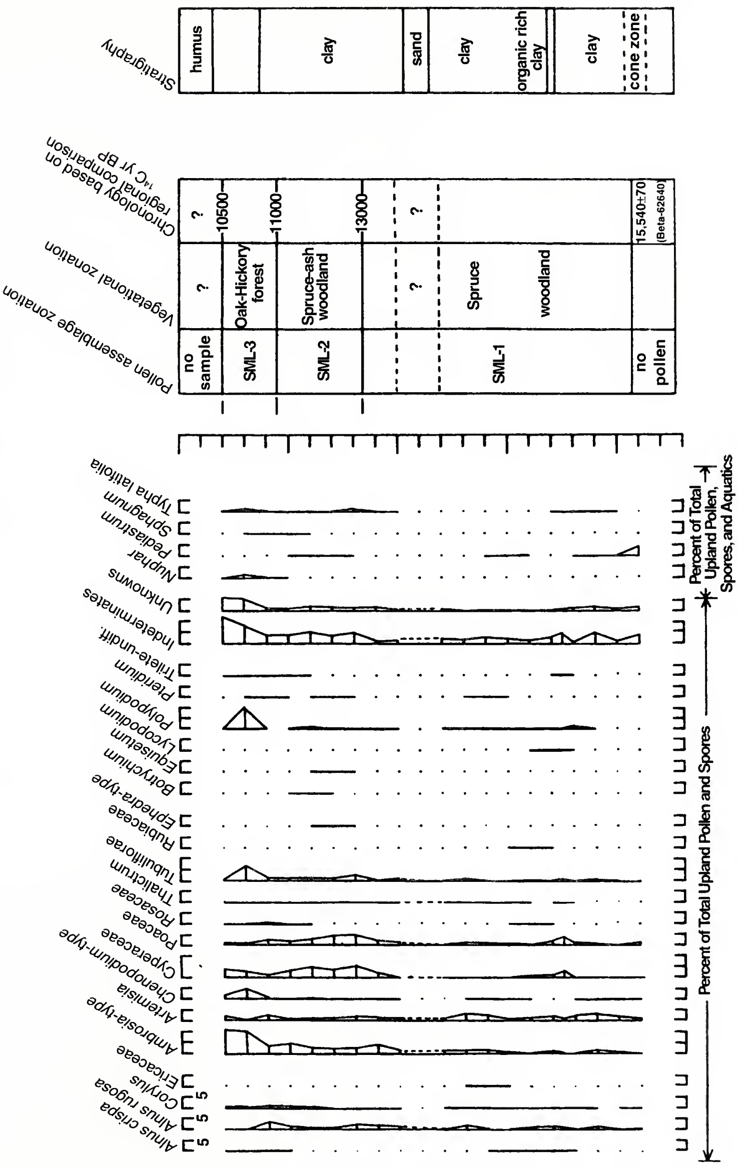


Figure 7.—Continued

than 10% within this zone, indicating that post-settlement pollen has been incorporated into this zone. Aquatics within this zone include *Nuphar*, *Sphagnum*, and *Typha latifolia*, all < 2%.

Macrofossil analysis.—Recognizable macrofossils were found in sediments between 150–230 cm below the surface, although they were relatively infrequent where found. The organic matter above this level was so highly decomposed that only minute, taxonomically indistinguishable plant remains were recovered.

The most distinct stratum in terms of macrofossil remains was a layer, at a depth of 200–230 cm (Div. A, Unit XI), that was characterized by numerous *Picea glauca* (white spruce) cones (Fig. 8). Radiocarbon dating of spruce wood from the unit revealed a date of 15,540 ± 70 ybp. A total of 0.36 m^3 of the cone-bearing stratum was washed through a 1.2 mm mesh screen in the field. Approximately 16% (by weight) of the strained material was wood fragments larger than 4 mm (mean oven dry weight of 3.7 grams dry organic weight per liter of sediment). The remaining 84% was small particulate material including wood, seeds, leaves, and other organic remains between 0.4–4.0 mm in size (mean oven dry weight of 22.4 g/l).

Eighty-six white spruce cones were recovered. In addition to cones, spruce leaves were also abundant, comprising 4–6% of the unstrained sediment. Large fragments of conifer wood, numerous conifer seeds, and bark were also recovered. *Larix laricina* (tamarack) was represented by spurs with leaf scars (Fig. 9) that numbered approximately 25 per liter of unstrained material. Seeds determined to be of the family Juncaceae, possibly *Luzula spicata*, were also present in similar numbers. The wetland moss *Drepanocladus aduncus* was found to have a mean density of 17 fragments per liter. Aquatic plants, *Potamogeton pusilus* (pondweed) (Figs. 10, 11) and *Najas flexilis* (bushy pondweed) (Fig. 12) were present, but extremely infrequent. Several head capsules, pronota, and elytra of coleopterans were also recovered.

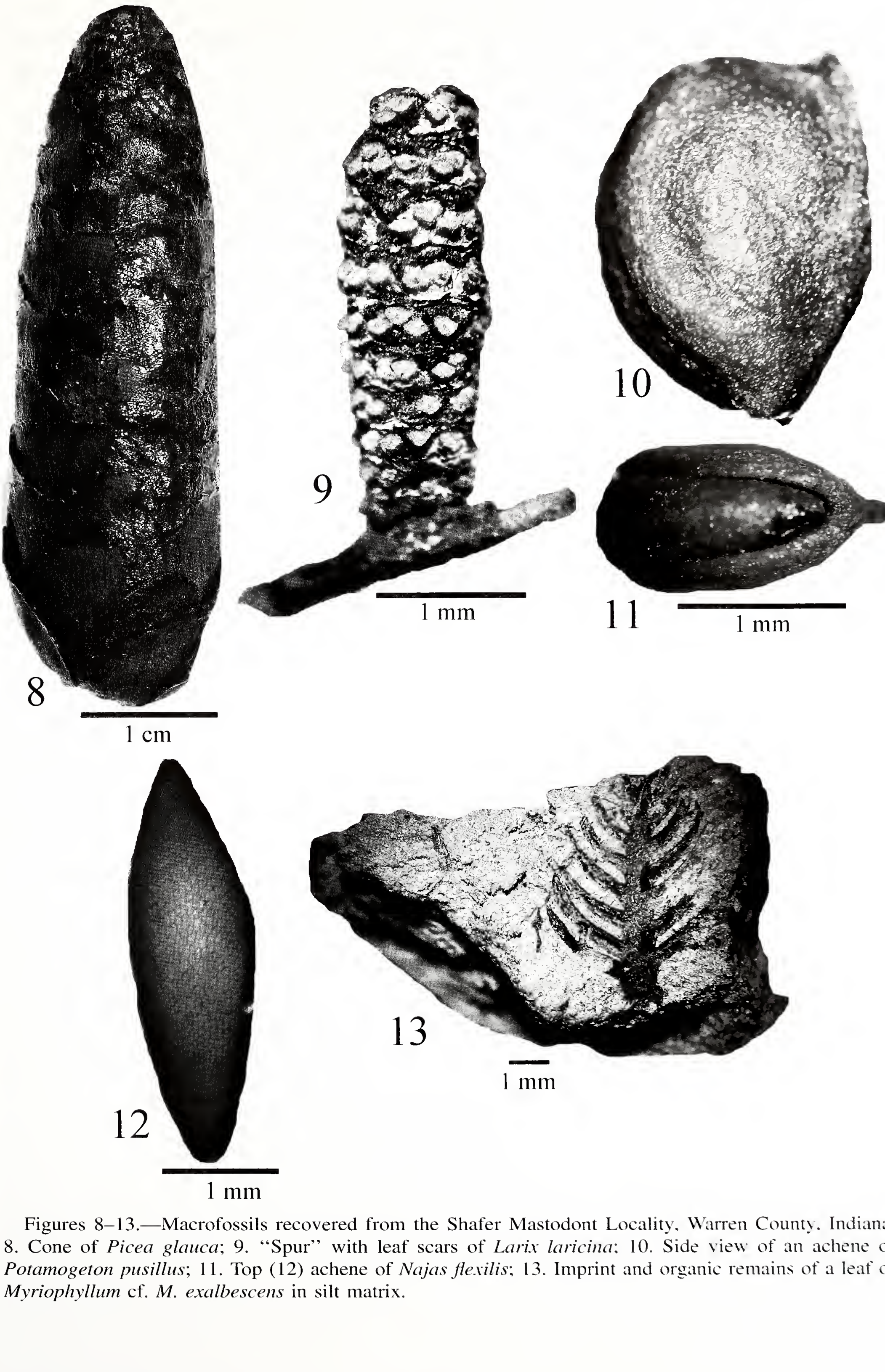
Unit X of Division B was marked by an increase in remains of aquatic macrophytes and a sharp decrease in conifer remains. *Myriophyllum exalbescens* (milfoil) leaves were found as carbonized imprints in the silt (Fig. 13), and as discrete fragments. The fragments comprised approximately 10% of the unstrained sediment. *Najas flexilis* achenes numbered 12 per liter. Both *Drepanocladus aduncus* and Juncaceae were absent from this stratum.

Unit IX of Division B marks the disappearance of conifer and other remains of terrestrial origin and the appearance of *Ceratophyllum demersum* (hornwort) leaves. *Myriophyllum exalbescens* remained in similar quantity. Identifiable macrofossils were essentially absent from most of Units I–VII.

Compared to other Late-Pleistocene and Holocene aquatic sediments studied in Indiana, the diversity of macrofossil remains at the Shafer site is very low. Mean macrofossil species richness for 15 other Late-Pleistocene and Holocene deposits studied by Swinehart (2002) was 15.6 (min. = 8; max. = 25, S.D. = 4.4). However, with the exception of *Myriophyllum*, the taxa that were recovered at the Shafer Locality are common in other deposits in Indiana, including sites harboring mastodonts and other ice-age megafauna (Whitehead et al. 1982; Jackson et al. 1986; Swinehart & Richards 2001; Swinehart 2002). *Myriophyllum* has been reported at the Christiansen Mastodont Locality in central Indiana by Whitehead et al. (1982), in central Michigan by Oltz & Kapp (1963), and recently in Late-Pleistocene and Holocene sediments at Tamarack Bog, north of High Lake, in Noble County, Indiana, and the Buesching Mastodont Locality in Allen County, Indiana (Swinehart unpubl. data).

Reconstruction of the palaeoenvironment.

Extra-local & regional palaeoenvironment.—The vegetation record from the Shafer Mastodont Locality extends back to 15,540 ybp, beginning perhaps only 500 years after deglaciation, and is summarized in Fig. 14. Based on the radiocarbon dates, known glacial chronology, and presence of boreal flora (including black and white spruce, tamarack, pine, and possibly fir and cedar), the climate of the Shafer Locality during the time of the mastodont (lowermost portion of the pollen record) likely had similarities to that which predominates in the modern coniferous forest biome in northern Michigan and southern Canada. While black spruce was not found in the macrofossil assemblage it is likely that



Figures 8–13.—Macrofossils recovered from the Shafer Mastodont Locality, Warren County, Indiana. 8. Cone of *Picea glauca*; 9. "Spur" with leaf scars of *Larix laricina*; 10. Side view of an achene of *Potamogeton pusillus*; 11. Top (12) achene of *Najas flexilis*; 13. Imprint and organic remains of a leaf of *Myriophyllum* cf. *M. exalbescens* in silt matrix.

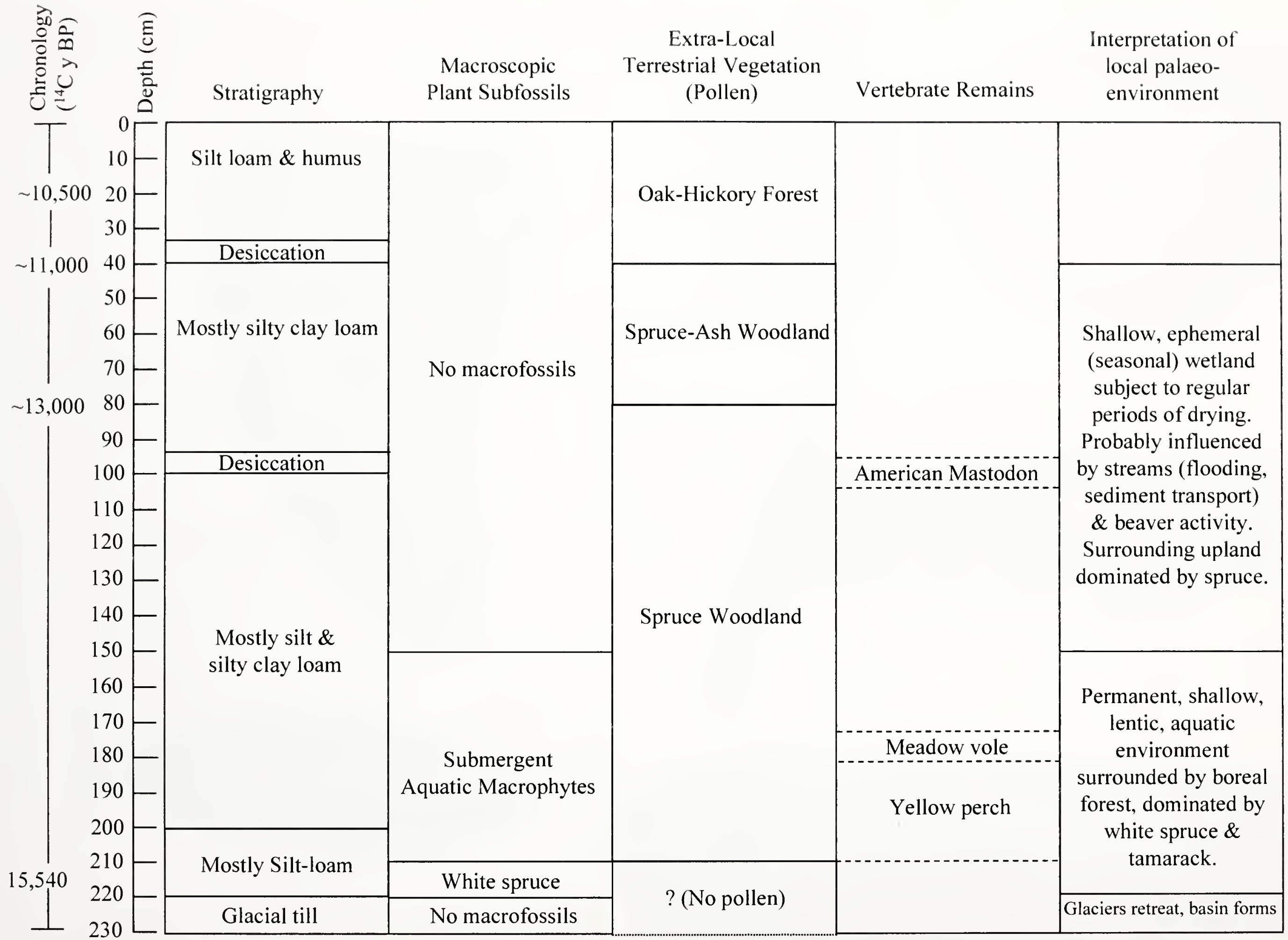


Figure 14.—Diagram summarizing the chronology, stratigraphy, macrofossils, pollen, vertebrate remains, and interpretation of the palaeoenvironment of the Shafer Mastodont Locality, Warren County, Indiana.

black spruce was growing locally since it has been shown to be present elsewhere in the region during late-glacial time (Whitehead et al. 1982; Jackson et al. 1986; Swinehart 1995).

The herbaceous pollen is low without any indication of tundra taxa (e.g., *Dryas*). From the pollen diagram it is clear that the bulk, if not all, of the Holocene record is missing. The top of the record is estimated to be 10,500 ybp based on the persistence of the spruce in the record. This truncation of the sequence is not uncommon for this region or time period (Whitehead et al. 1982; Jackson et al. 1986). In the case of the Shafer Mastodont Locality the basin might have filled in by 10,000 ybp or the water table may have dropped at this time or later. One scenario is that the water table dropped at the beginning of the Hypsithermal between 9000–8000 ybp and that subsequent erosion resulted in the loss of the most recently deposited sediments.

Interpretation of the sand layer is aided by the pollen stratigraphy and by comparison to records from Chatsworth Bog (King 1981). Based on these sources, the sand layer at the Shafer Mastodont Locality would likely date to greater than 13,000 ^{14}C ybp and less than 15,000.

As has been noted in other studies (i.e., Whitehead et al. 1982), *Fraxinus* pollen has been misidentified as *Salix* in some earlier studies. This was likely the case by Richards (1938) in her study of Otterbein Bog. In the pollen diagram from Otterbein Bog, *Salix* is shown to peak immediately following the decline of spruce. A similar peak is present in more recent studies and is correctly identified as ash (King 1981; Whitehead et al. 1982; Jackson et al. 1986; Shane 1987). Ash pollen is distinguished from willow by the lack of a psilate furrow margin, present in willow pollen. This rise in ash is most likely attributed to black ash, which is typical of wetlands and has been identified in other studies.

The slight rise in *Ambrosia* pollen at 90–100 cm depth might indicate an opening of the forest canopy associated with the decline of spruce (perhaps by fire after the desiccation event) and prior to the expansion of ash. An alternative explanation is that the *Ambrosia*, Cyperaceae, and Poaceae pollen are from long-distance transport from an expanding grassland to the west.

With the addition of palynological analysis of the sediments above the cone zone it is possible to place the section and lithologic transitions into a regional chronology. The upper 25 cm of the profile is difficult to interpret due to conflicting signals within this zone. First, the rise of *Quercus* and *Carya* records the development of a post-glacial oak-hickory forest, however, at the same time there is a rise in *Picea* and *Pinus*, as well as *Ambrosia*-type, typical of both late-glacial and post-settlement records. The rise in *Picea* at the surface may be 1) "antiquing" of the sequence due to erosion from surrounding older sediments, 2) a "climatic reversal" suggested by Shane (1987) in Ohio at the Pyle and Stotzel-Leis Sites, or 3) contributions from extremely local sources such as peatlands, which often provide microhabitats for northern conifers.

Finally, the decline of spruce at 13,000 ybp as determined by Shane (1987), and King (1981) correlates with a dramatic positive shift in the ^{18}O isotope curves (equates to warmer temperatures) from Greenland ice cores and Switzerland lake sediments (Paterson & Hammer 1987).

Local palaeoenvironment.—Reconstruction of local conditions may be best aided by the study of macrofossils because they are less likely than pollen to have traveled long distances. A summary of the interpretation of the local paleoenvironment is provided in Fig. 14. The presence of abundant macrofossils of white spruce and tamarack in the lowest strata of the Shafer locality suggests a nearby terrestrial environment, initially. The presence of two small fish vertebrae within the floral debris suggest possible deposition in water. White spruce are boreal trees common in well-drained uplands and lakeshores. Black spruce (*Picea mariana*), on the other hand, are more common in poorly-drained lowlands. Although pollen of black spruce was found at the Shafer Locality, macrofossil remains were not recovered, suggesting relatively well-drained conditions locally. The poor diversity and preservation of macrofossils at the site might be further indication of well-drained soils. The abundance of tamarack macrofossils could be viewed as evidence for poorly-drained wetland soil, but similar boreal environments of today harbor tamarack in a wide range of soil conditions. Potzger and Wilson (1941) hypothesize that *Larix* may have been sub-dominant to spruce even though not evident from pollen assemblages (due to the tendency of *Larix* pollen to decompose readily in water). The abundance of *Larix* macrofossils in both the Shafer sediments as well as the Kolarik and Christensen sites (Whitehead et al. 1982; Jackson et al. 1986) may be evidence of this, and might represent a regional rather than a local association. The infrequent achenes of *Potamogeton pusilus* and *Najas flexilis* and the fragments of *Drepanocladus aduncus* in the cone zone may have been deposited and incorporated after subsequent inundation of the site.

Strata superceding the cone-bearing layer are successively more indicative of submergent conditions. Conifer remains become scarce while the richness and abundance of aquatic macrophytes increase. The early aquatic environment was characterized by permanent standing water, as evidenced by the presence of fish bones and macrofossils of submergent aquatic plants (*Myriophyllum*, *Potamogeton*, *Najas*, and *Ceratophyllum*) and algae (*Pediastrum*). The presence of fish so early in the sedimentary record suggests that the water-body was in contact with, or in close proximity to, an aquatic system (possibly lotic) which acted as a migration route or as a transport medium for carcasses. However, despite extensive screen-washing of the sediments there were few elements of individual fishes. This suggests that entire animals did not remain buried *in situ*, but rather were either dispersed along the fringe zone ("shelf") around a deeper kettle or transported into the site by lotic systems or floodwaters. The lack of fishes in middle and upper strata may suggest little subsequent "seeding" of the basin by connecting waterways. Although streams may have influenced the subfossil assemblage, the aquatic macrophyte taxa recovered suggest that the prevailing conditions in the basin were lentic rather than lotic.

The transition to more aquatic conditions suggests a marked rise in the local or perhaps regional water table. Three possible explanations for this transition are proposed: 1) aquatic conditions could have prevailed from the beginning, and the white spruce and tamarack remains were deposited in the water from the surrounding upland, 2) the cone layer could represent a terrestrial forest that existed on overburden of a buried ice-mass that later melted and created a water-filled depression with associated aquatic flora, and 3) the cone layer could represent a terrestrial environment that was later subject to paludification from increases in meltwater from the retreating glacial ice to the north or from beaver activity. The first hypothesis would suggest that boreal trees retreated locally because their macrofossil remains were restricted to a narrow stratum at the base of the sedimentary profile. The second hypothesis seems unlikely because the depth of the sedimentary profile is only 2.3 m, and therefore, it is unlikely that the overburden could have sufficiently insulated such a thin ice mass long enough to allow a forest to colonize above it. The third hypothesis seems most likely and is consistent with other biotic and abiotic phenomena encountered higher in the profile (see below).

Identifiable macrofossils became rare and ultimately absent in successive strata, yet deposition of organic sediments characteristic to wet environments continued through most of the profile. The elimination of identifiable macrofossils is attributed to increased oxidation during and/or subsequent to the deposition of the sediments, facilitating decay. Such conditions can occur in extremely shallow waters where oxygen diffusion at the surface is sufficient to oxidize sediments, or when standing water becomes only seasonal, and dry periods expose sediments to the atmosphere. Two hypotheses are proposed to explain the eventual increase in oxidation of the sediments at the Shafer Locality: 1) autogenic factors such as filling of the basin with sediment reduced water depth, or 2) allogenic factors depleted the water source (reduction of glacial meltwater, stream diversion, beaver activity, etc.), but irregular or seasonal fluxes maintained wetland conditions.

SYSTEMATIC PALAEOBIOLOGY OF VERTEBRATES

Phylum Chordata
(Subphylum Vertebrata)
Class Osteichthyes
Order Perciformes
Family Percidae

Perca flavescens
(Yellow Perch (INSM Cat # 71.3.224.1))

Material: Left dentary (Fig. 15). *Occurrence:* NW bench, 20–30 cm above cone zone (Unit XI). Recovered from 1.2 mm mesh screen washing of bulk sediments. *Comments:* The jaw represents a small individual of perhaps 140 mm standard length. Its detail closely matches details of three reference specimens, particularly on the lingual face, bony boss on the supero-anterior rim of the jaw, details of foramina on the buccal surface, and midline lateral angularity along the jaw length. *Habitat:* The yellow perch is most common near vegetation in clear waters of lakes, ponds, pools of creeks and small to large rivers (Page & Burr 1991). It has a relatively northern distribution.

Fish, sp. indet. INSM Cat #71.3.224.2)

Material: Two partial vertebral centra. *Occurrence:* NW bench, Cone Zone (Unit XI). Recovered from 1.2 mm mesh screen washing of bulk sediments. *Comments:* One partial vertebral centrum (Fig. 16) represents a fish similar in size to the above perch, and the other is from a smaller fish.

Class Mammalia
Order Rodentia
Family Cricetidae

Microtus pennsylvanicus
(Meadow Vole) (INSM Cat # 71.3.224.3)

Material: Upper R molar 3, lacking portion of anterior loop (Figs. 17, 18). *Occurrence:* NW bench, 20–30 cm above Cone Zone (Unit XI). Recovered from 1.2 mm mesh screen washing of bulk sediments. *Comments:* The tooth enamel pattern consists of an anterior crescent, three alternating closed triangles, and two posterior lingually-directed loops that are confluent laterally. This pattern is shared by *Microtus pennsylvanicus* and *M. xanthognathus*, though the latter lacks cementum in the posterior-most lateral re-entrant angle (Hallberg et al. 1974). The cementum has been leached from most of the re-entrant angles of the Shafer fossil, but its size is relatively small (1.9 mm + in length). Semken (1984) showed that M3's of *M. pennsylvanicus* in Peccary Cave, Arkansas, did not exceed 3.2 mm, while those of *M. xanthognathus* exceeded 3.55 mm in length. *Habitat:* The meadow vole frequents low moist areas or high grasslands with rank growths of vegetation and is found near streams, lakes, swamps and occasionally in forests with little ground cover (Burt & Grossenheider 1964).

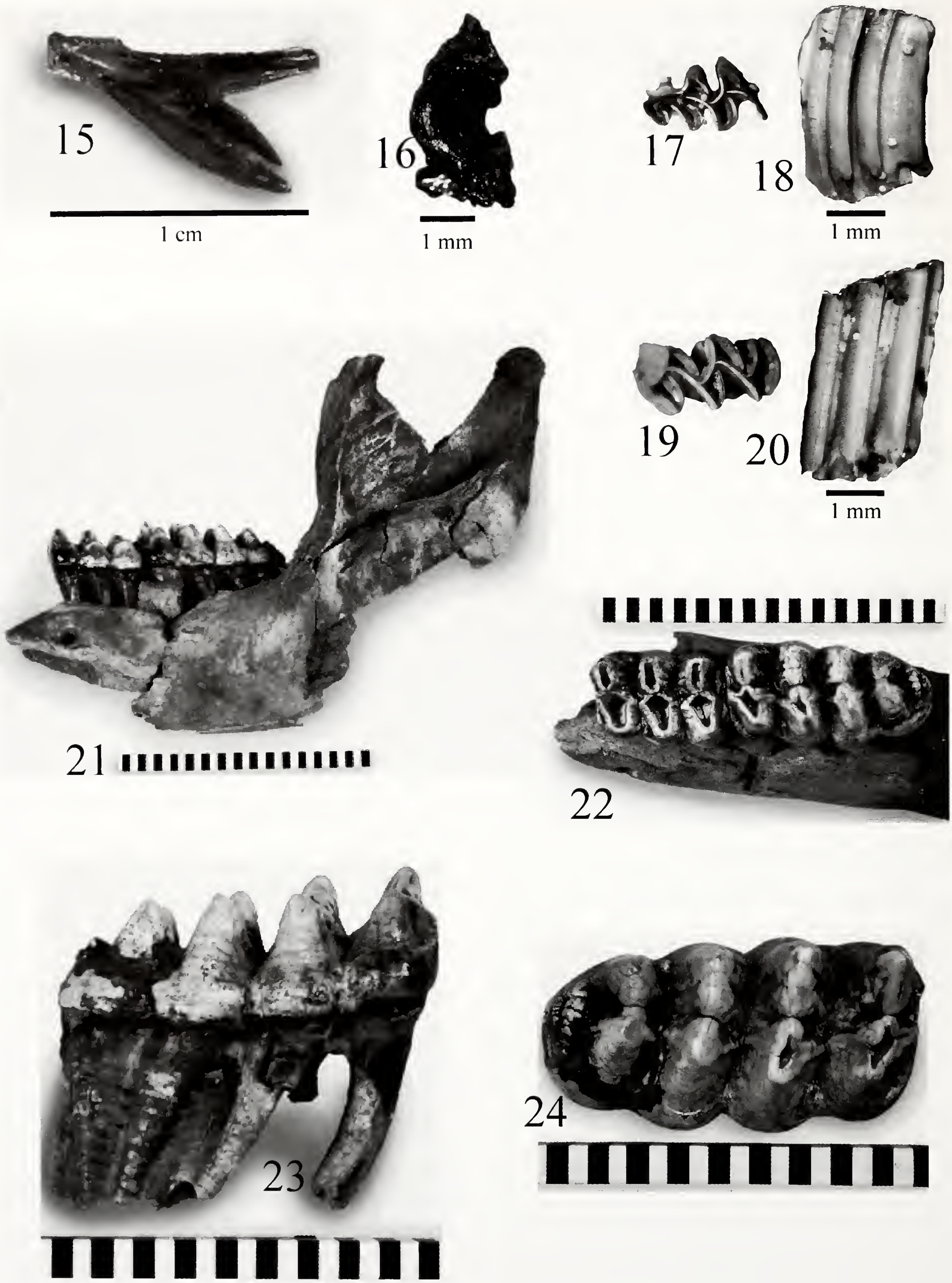
Microtus, sp. indet.
(Vole (INSM Cat # 71.3.224.4))

Material: Left upper M1 (Figs. 19, 20) and R upper M1, and partial upper tooth (3 triangles). *Occurrence:* NW bench, 20–30 cm above Cone Zone. Recovered from 1.2 mm mesh screen washing of bulk sediments. *Comments:* These teeth are undiagnostic to species, and could well represent the same individual of *M. pennsylvanicus*.

Order Proboscidea
Family Mammutidae
Mammut americanum

American mastodont
(INSM Cat # 71.3.131.1–71.3.131.5)

Material: Major portions of mandible, including lower L and R molars 2 and 3 (Figs. 20–24). *Occurrence:* Because the mandible was disturbed by the backhoe, its original location is uncertain. It would have occurred somewhere above the floor of the original backhoe trench that extends 150–160 cm below the surface on Profile 4. However, dark loam impacted into the cancellous bone of the mandible suggest burial in the brown silty clay loam (Unit IV) which fills the fissures in the clay loam (Unit V) of Sediment Division C. In addition, jaw fragments, thought to be *in situ*, were encountered just above floor #1, approximately 74 cm below the surface at an interface where dark loam penetrated fissures in the clay near the east end of Profile 1. The mandible appears to be part of Unit IV fill, deposited into the fissures of silty clay loam of Unit V. Whether the jaw was intact and moved as a unit, or whether spalled fragments worked down into the fissured Unit V at different rates is uncertain. It is less probable that the mandible was deposited in Unit V clay, and was intercepted by a fissure that afterwards filled with the dark loam of Unit IV from above. In either case, the mandible was deposited relatively late in the stratigraphic sequence. *Comments:* The jaw was likely deposited after the formation of Unit V lake sediments. This would correlate with a time later than the pollen sample at 40 cm (Unit V), dominated by oak-hickory and estimated to be just under 11,000 ybp, and earlier than the pollen sample at 30 cm (Unit III), with a stronger oak-hickory component, and estimated age of well over 10,500 ybp. In the event



Figures 15–24.—Vertebrate fossils from the Shafer Mastodont locality, Warren County, Indiana. 15. *Perca flavescens* (yellow perch), left dentary (71.3.224.1); 16. Fish, sp. indet., partial vertebral centrum (71.3.224.2); 17, 18. *Microtus*, sp. indet. (vole), left upper M1 (71.3.224.4, occlusal and lingual views, respectively); 19, 20. *Microtus pennsylvanicus* (meadow vole), right upper M3 (71.3.224.3, occlusal and labial views, respectively; 21, 22. *Mammut americanum* (American mastodont), partial mandible, left ramus with M2 and M3 (71.3.131, left lateral and occlusal views, respectively), scale in cm; 23, 24. *Mammut americanum*, lower right M3 (71.3.131.5; labial and occlusal views, respectively), scale in cm.

Table 2.—Tooth measurements (mm), Shafer Mastodont, Warren County, Indiana.

Catalogue # / Tooth placement	71.3.131.3 L molar 3	71.3.131.5 R molar 3	71.3.131.2 L molar 2	71.3.131.4 R molar 2
Greatest length	184.5	184	112	114
Greatest width	96.5	96.3	8	88.5
Width across protolophid	85.7	85.5	75.6	73.9
Width across metalophid	96.1	95.4	84.2	83.9
Width across tritolophid	92	92	84.3	82.6
Width across tetralophid	78.1	76	n/a	n/a

that the jaw did occur in the silty clay loam of Unit V, the spruce-ash woodland would have been dominant, with an age up to slightly over 13,000 ybp. The lowermost sediments of Unit V, however, were dominated by spruce woodland.

Tooth wear suggests age class XX (Laws 1966), indicating a middle-aged mastodont of 34 ±2 African elephant years of age. Tooth measurements (Table 2) follow the terminology of Saunders (1977). The teeth of the Shafer Mastodont are small when compared to those from Michigan (Skeels 1962). They are less than the average size of the Bony Spring, Missouri, sample (Saunders 1977), yet are larger than the Trolinger Spring, Missouri, average (Saunders 1977). The teeth of the Shafer Mastodont share the small size of the Christensen (Graham et al. 1983) and Aker (Richards et. al. unpubl. data) mastodonts from Indiana, and contrast with the larger Dollens (Richards et al. 1988) and Lewis (Hunt & Richards 1993) specimens. Characters of the skull used to differentiate sex in the mastodont (Osborn 1936) suggest that the Christensen materials were female (Graham et al. 1983). Male mastodonts were of greater stature than females (Kurten & Anderson 1980), suggesting that the Aker mastodont, of small adult stature, was a female (Richards et al. unpubl. data). Although the large sample of teeth from Missouri are not bimodal in size and do not readily demonstrate sexual dimorphism (Saunders 1977), the small size range of the Shafer Mastodont teeth compared with those of probable Christensen and Aker females, suggest that the Shafer mastodont is likely a female.

The fractured mandible produced only two standard measurements: Greatest transverse width, L condyle, 164 mm; greatest anteroposterior length, L condyle, 64.5 mm. *Habitat:* The mastodont is thought to have inhabited open spruce woodlands and spruce forests (Kurten & Anderson 1980).

TAPHONOMY OF THE SHAFER MASTODONT

Like many mastodonts recovered from the region, the Shafer specimen died over 10,000 ybp and was deposited in shallow aquatic sediments of lentic origin. Unconformities in the sedimentary record occur just above the stratum where the mastodont element was recovered, and the profile was ultimately truncated around 10,000 years ago. The unconformities in the upper portions of the profile are likely a combination of the disappearance of the wetland in the early Holocene by both autogenic and allogenic factors and eventual alteration of the soil by human activity in the nineteenth and twentieth centuries.

The isolated mastodont mandible (with teeth) was the only mastodont element recovered at the locality, despite extensive exploration with heavy equipment. There is no obvious macroscopic evidence of gnawing or scavenging on the mandible that could suggest exposure before burial. Hill (1979) related that the mandible is usually one of the earliest elements to separate from the skeleton of the African antelope *Damaliscus*, and that the vertebrae, separating last, are the bones that remain longest at the death site. This same disarticulation sequence was confirmed with several other African mammal taxa (Hill & Behrensmeyer 1984). Experimenting with bone movement in running water, Voorhies (1969) related that such items as ribs, vertebrae, and sometimes scapulae, ulnae and phalanges (transport Group I) were removed first by flotation or saltation. His group II bones included the pelvis, humeri, radii, femora, tibiae, metapodials, and sometimes scapulae, mandible, ulnae, and phalanges, which moved slowly by traction. Group III included the cranium and sometimes the mandible as lag deposits. Hill's scenario could suggest that the mandible of the Shafer Mastodont had separated from and moved away from the main skeleton, perhaps leaving vertebrae nearer the original site of deposition. Voorhies' scenario might indicate that the skull of the Shafer Mastodont, and perhaps mandible, would remain as lag at the site of deposition, with the other elements dropping into the kettle basin by moving water. The relationship of disarticulation and scattering was noted by Hill (1979), who related that the bones that separated first are among the most difficult to remove by running water—as is the case with the mandible of the Shafer Mastodont. The lack of the massive skull or tusks that should accompany the mandible as lag on the "shelf" does not support a scenario where the remaining skeleton had washed into the deeper kettle basin, particularly since the extensive deep trenching of the backhoe failed to recover a single mastodont bone. It seems more likely that: 1) the mandible, separated early from the skeleton, moved onto the shelf from an upland source where the remaining skeleton was scattered, and perhaps unburied, thereafter disintegrating, or 2) the mandible detached from a floating carcass during a temporary flood event. It is speculation that the mandible could have been moved to position by other animals, as African elephant skeletons have been scattered up to 50 m from the death site by trampling, scavengers, and elephants which are known to carry bones and tusks for some distance (Coe 1980). As the wetland sediments of Unit V dried, the dark silty clay loam soils carried the mastodont mandible as part of the fill into the desiccation fissures. Less probably, the mandible was earlier deposited into the wetland sediments on the shelf, and later penetrated by dark loam seams from above as the surrounding sediments dried and cracked. A similar lack of smaller elements and suggested upland skeletal source was proposed for the Dollens Mastodont (Richards et al. 1988).

ACKNOWLEDGMENTS

Property owner Larry Shafer thoughtfully suspended the laying of drainage tile when the mastodont bone was uncovered, contacted authorities, participated in daily excavations with his backhoe, and donated all materials to the Indiana State Museum. R. Criss Helmkamp, Purdue University, reported the discovery to the Indiana State Museum and aided with the benchmark survey. Indiana State Museum staff and volunteers provided field labor, supported by Randy Patrick and students from Southmont High School, Luke Hunt and students from Whitko High School, and students from Purdue and Ball State Universities.

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