This is to certify that the

thesis entitled

The Distribution of Pleistocene Proboscideans in Michigan: An Update of Records and a Co-occurrence Analysis of their Relation to Surface Saline Water

presented by

Laura Marie Abraczinskas

has been accepted towards fulfillment
of the requirements for

Master of Science degree in Zoology

Major professor

Date ~~27 February 1992~~

THE DISTRIBUTION OF PLEISTOCENE PROBOSCIDEAN SITES IN MICHIGAN: AN UPDATE OF RECORDS AND A CO-OCCURRENCE ANALYSIS OF THEIR RELATION TO SURFACE SALINE WATER

By

Laura Marie Abraczinskas

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Zoology

1992

ABSTRACT

THE DISTRIBUTION OF PLEISTOCENE PROBOSCIDEAN SITES IN MICHIGAN: AN UPDATE OF RECORDS AND A CO-OCCURRENCE ANALYSIS OF THEIR RELATION TO SURFACE SALINE WATER

By

Laura Marie Abraczinskas

Pleistocene proboscideans from Michigan are the American mastodont (*Mammut americanum*) and a mammoth (*Mammuthus* sp.). Previously published Michigan records were updated, and literature and museum records were re-examined. Duplications were consolidated and additional information on proboscidean sites was added. New or unpublished records were reported on 6 mastodont, 2 mammoth, and 6 Proboscidea Indeterminate sites. The locations of Michigan proboscidean and salt sites were mapped after proboscidean site totals were computed. These included 211 mastodonts from 41 counties, 49 mammoths from 29 counties, and 11 Proboscidea Indeterminate sites from 9 counties. A spatial analysis was conducted to examine the relationship between Michigan proboscidean and surficial salt localities. Although 35% of proboscidean sites were located within 20 miles of a salt site, statistical tests showed that the spatial arrangement of proboscidean sites is not significantly different from a random distribution.

For Marian Anna Oleksy

ACKNOWLEDGMENTS

I wish to extend my sincere gratitude to Dr. J. Alan Holman, Chairperson of my Graduate Guidance Committee, who initiated the basic concept of this research, and contributed to all phases of the project. I also wish to thank the members of my committee, Dr. Martin Hetherington and Dr. David Long for their guidance and assistance with editing this thesis. Dr. David Westjohn of the United States Geological Survey provided most of the salt locality data for the analysis.

Mr. Ron Richards of the Indiana State Museum and Memorials kindly allowed me to utilize the Indiana State Museum proboscidean collection for comparison with Michigan material. I extend my gratitude to Mark Swartz for all of his technical assistance with mapping and computer operations, as well as support and encouragement throughout this project. Thanks to Joe Henig for plotting data on the maps. I am indebted to Dr. Manfred Earl Swartz of Ferris State University for advice and assistance with the statistical tests; and to Mr. Terry Trier, of the Zoology Department, Michigan State University, for operating the SYSTAT statistical programs. Mr. Walt Peebles and the MSU Instructional Media Center provided photographic services.

I am grateful to the persons who called specific sites and information to the attention of the Michigan State University Museum: James and John Beavers,

Richard Gibson, Darrell Hughes, the late Dr. Ronald Kapp, Mildred Malkin, Steve Mathis, Charles Martinez, Walter Morrow, Theodore Sprague, and Jerry Van Horn. Library and information search assistance was provided by the staff of the Government Documents Division of the Library of Michigan, Lansing; Diana Rivera and the Staff of the Michigan State University Map Library; Diane Baclawski of the Michigan State University Geology Library; and the Science Division of the Michigan State University Library. The Zoology Department provided funds for a portion of this research. Computer facilities were provided by the Mammalogy Division of the Michigan State University Museum.

I would also like to thank the members of my family: Ray, Katherine, Diane, Carol, and David Abraczinskas; the Oleksys; and the Pischners for their love and support. Thanks to Nancy Hicks, Karen Remus Bauer, Sally and Joe Panek, Kathleen Derouin Naeger, Nicole DeGalan, Jim and Mary Smania, Richard and Dawn Kemp, Dr. Roseann Swartz, Dr. Chris Carmichael, Jamie DeWitt, and my academic siblings, Dan Brinkman and Lisa Hallock for friendship, encouragement, and for believing in me.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

LIST OF SYMBOLS AND ABBREVIATIONS

AMNH: American Museum of Natural History

BETA-(sample number): Beta-analytic Laboratory radiocarbon date, Coral Gables, Florida

ISM: Indiana State Museum and Memorials

M-(sample number): University of Michigan Memorial-Phoenix Project radiocarbon date, Ann Arbor, Michigan. (Crane and Griffin, 1958)

MSUVP: Michigan State University Museum Vertebrate Paleontology Collection

UMMP: University of Michigan Museum of Paleontology

ybp: years before present

CHAPTER I

INTRODUCTION

The goal of this research project is to determine if there is a spatial relationship between sites at which proboscidean remains have been discovered and surficial salt sites. To meet this goal, the following objectives have been set:

1) to integrate previously published proboscidean records in Michigan, and provide an update on sites as more information has become available.

2) to provide reports of new or unpublished records.

3) to map the locations of Michigan proboscidean and salt sites.

4) to examine the spatial relationship between proboscidean sites and surficial salt localities in Michigan, by utilization of a co-occurrence analysis.

The earliest recorded proboscidean find in Michigan is an American mastodont tooth found in 1834 or 1835 along Rice Creek in Calhoun County (Skeels, 1962). A few years later, mammoth remains were recovered near the bank of the Paw Paw River in Van Buren County (Lanman, 1839). MacAlpin (1940) believes this was probably a mastodont. Since the recording of these early finds, people have continued to recover bones and teeth of Pleistocene proboscideans in the area that is now Michigan. Specifically, these proboscideans are the American mastodont (*Mammut americanum*) and a mammoth (*Mammuthus* sp.).

Several researchers have published reports on locality records and the distribution of proboscideans in Michigan (Dice, 1920; Hay, 1923; MacAlpin, 1940; Skeels, 1962; Holman, et al., 1986; Holman, 1988; Holman, et al., 1988; Shoshani, 1989). All known Michigan proboscidean sites occur in the southern half of the lower peninsula below a line termed the Mason-Quimby line (Holman, 1975; Holman, 1988; Holman et al., 1988; Holman, 1991) (Figure 1). Presently, all reported records of extinct Pleistocene vertebrates from Michigan occur south of the Mason-Quimby line (Holman, 1991). Radiocarbon dates indicate that the existence of mastodonts and mammoths in Michigan was concentrated in a geologically short period of time-between 12,000 and 10,000 years before present (ybp), and it has been suggested that this concentration of proboscideans is possibly correlated with available surficial salt deposits located in Michigan's lower peninsula (Holman, et al., 1988).

Surface saline water in Michigan during the Pleistocene may have been present in the form of salt seeps or shallow pools associated with salt springs (Holman, et al., 1988). Salt deposits in Michigan originated mainly from Silurian and Devonian evaporative marine waters in the Michigan Basin. Although most of Michigans' surface is presently covered with glacial deposits, the Michigan Basin has one of the most extensive accumulations of sodium chloride and brines in the world (Dorr and Eschman, 1970). Historically, numerous salt spring and salt marsh localities existed in the southern half of Michigan's lower peninsula. This occurrence of salt springs in the lower peninsula was known to Native Americans before the coming of European settlers. Native Americans and early French settlers manufactured salt from a spring on the Rouge River in Wayne County (Hubbard, 1839). Early settlers attempted to

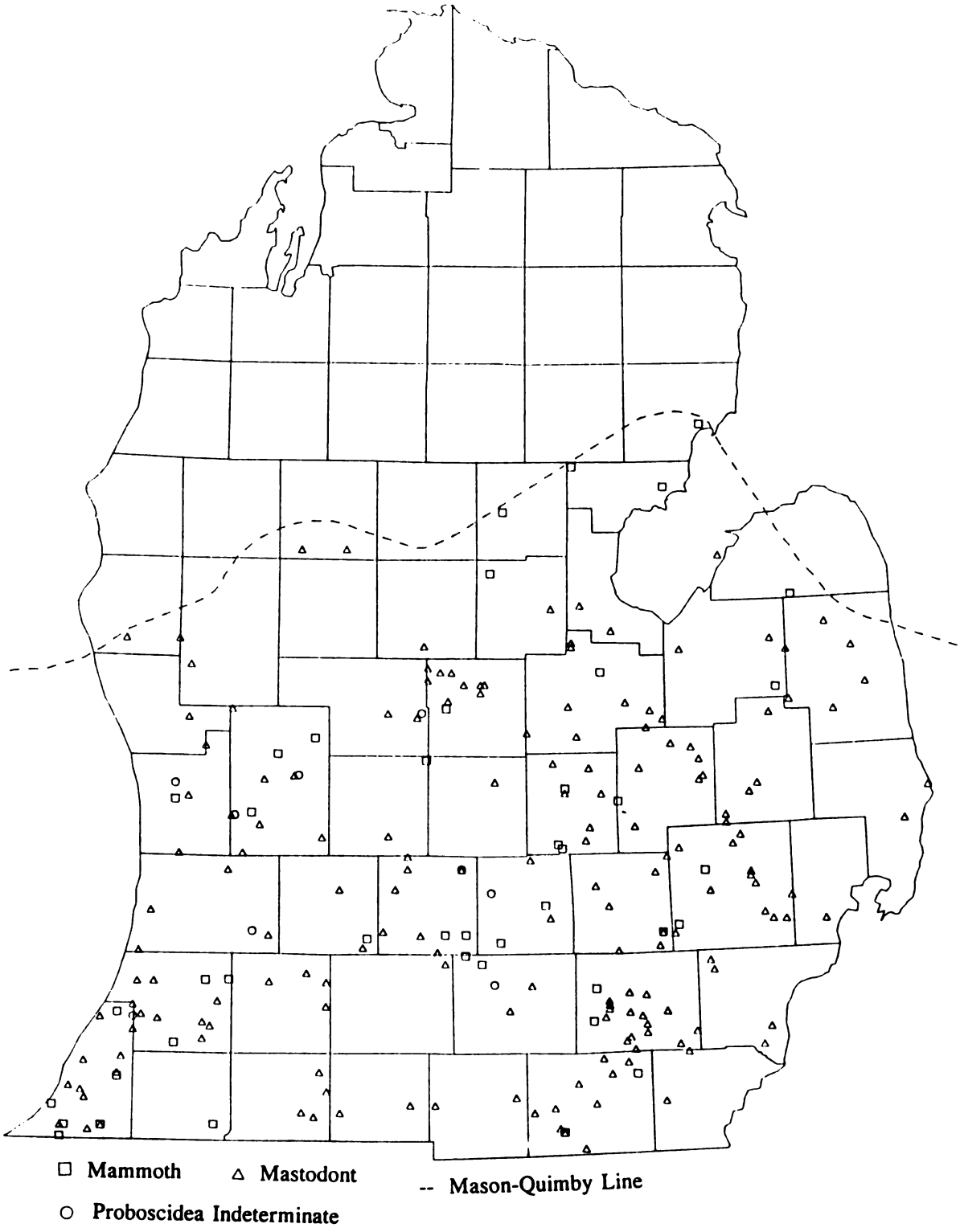

Figure 1. The distribution of Pleistocene proboscideans in Michigan

recover salt from the waters of springs near Saline in Washtenaw County, and at Salt River in Macomb County (Cook, 1914).

In 1835, the Constitutional Convention submitted to Congress a request to reserve areas with salt springs from public sale. By the 1837 Act of Congress admitting Michigan to the Union, authorities were permitted to select 72 sections of salt lands for state use. Dr. Douglass Houghton was appointed State Geologist at the first meeting of the Legislature, and immediately began to explore areas with salt springs (Cook, 1914). In 1837, Houghton devoted considerable work to the examination of brine springs in the lower peninsula. He noted important indications of saline water in five distinct areas: on the Grand River in Kent County; on the Maple River in Clinton and Gratiot Counties; on the Tittabawasee River in Midland County; in Macomb County; and on the Saline River in Washtenaw County (Houghton, 1838).

Other salt springs have been reported from the Counties of Huron (Lane, 1900); Monroe (Winchell, 1861; Sherzer, 1900); Montcalm (Douglass, 1840); Muskegon (Douglass, 1840); Saginaw (Houghton, 1838); and Wayne (Hubbard, 1839). Salt licks are known from the Counties of Huron (Lane, 1900); Lenawee (Winchell, 1864); Tuscola (Davis, 1909); and Wayne (Hubbard, 1839). Between the mid and late-1800s, many salt works were established in these areas. In 1841 a State salt well was drilled at the Grand River in Kent County, and another under construction at the Tittabawasse River in Midland County (Cook, 1912, 1914).

The salt industry was an increasingly important part of Michigan's economy in the mid to late-1800s. In 1860, only one Michigan salt company was in operation and by 1886, the number of active salt companies reached a maximum at 136 (Cook, 1914). In 1905 Michigan's salt production exceeded that of all other states, and in 1908, Michigan ranked highest for value and quantity of salt produced (Cook, 1914). Presently, the salt deposits in Michigan are important for the manufacture of chemicals.

Near-surface saline ground water presently exists in Michigan's lower peninsula (Peale, 1886; Lane, 1899a, 1899b; Long, et al., 1988). Long, et al. (1988) reported that for ground water in the East-central Michigan basin, the source of the salinity and the cause of its present distribution are unclear. The hypothesis was that the source of salinity is brines advecting or diffusing upward into near-surface water and the cause of the salinity distribution is the slow flushing of water in the argillaceous sediments by recent meteoric water. Results of their investigations indicated that the saline ground water is a mixture of modern-day meteoric water and water that recharged the aquifers at a time when the climate was much cooler.

Modern proboscideans have a physiological need for sodium, and will travel to sodium-rich areas to correct a deficit. It has been shown by Wier (1972) that the sodium budget of elephants may be precarious, and sodium metabolism in proboscideans is considered primitive (Parker and Toots, 1980). Studies of the spatial patterns of elephants have shown that their distribution is based on the availability and distribution of environmental sodium. Wier (1972) demonstrated that movements of African elephants in Zimbabwe were governed by the availability and concentration of

sodium in water holes. Numbers of elephants were higher at drinking holes with higher sodium concentrations, and smaller numbers were recorded from water holes with lower sodium content. Few elephants were found in areas lacking in sodium, even when suitable vegetation was present.

In addition to drinking water with a high concentration of sodium, elephants will also consume salt-rich soil and utilize salt licks (French, 1945). Elephants were observed removing soil from a slit in the bank of the Nile River through which sodium-rich water was seeping (Wier, 1973). Redmond (1984) studied African forest elephants who repeatedly descended into a cave to obtain salt. The elephants used their tusks scrape salt deposits from the cave walls, then used their trunks to try to catch this loosened soil before it fell to the muddy cave floor. The salt-rich soil was transferred from the trunk to the mouth, ground with the molars and then swallowed. Elephants are also known to consume food with high sodium levels (Dougall, et al. 1964; Laws, et al. 1975).

Numerous North American fossil localities provide evidence of extinct proboscideans recovered directly from salt springs or salt deposits. A Pleistocene fauna including proboscideans was excavated from sulfur and salt springs at Big Bone Lick in Boone County, Kentucky (Schultz, et al., 1963, 1967). Numerous Pleistocene mammals including proboscideans were recovered from salt spring deposits at Saltville in Smyth County, Virginia (Ray, et al., 1967). Hay (1912, 1924) reported proboscidean remains from a salt spring in Dearborn County, Indiana. Teeth of a mammoth were excavated from salt springs near the Saline River in Gallatin County, Illinois (Hay, 1923). Hartnagel and Bishop (1922) reported a mastodont found near a

salt spring at Tompkins County, New York. Hay (1924) described numerous proboscidean remains from salt works and salt deposits in Webster, Bienville, Winn, Iberia, and St. Mary Counties in Louisiana. Mammoth and mastodont bones were found in a saline marsh in Benton County, Missouri (Hay, 1924). A mastodont was discovered at Kimmswick in Eastern Missouri (Graham, et al., 1981). Saunders (1988) listed this site as a "mineral lick" with 40 identified vertebrate species. Another Missouri find is a tusk recovered from a "lick" in Jackson County (Hay, 1924).

Proboscideans living in Michigan during the Pleistocene may have utilized surficial sodium. Two operational assumptions of this project were that fossil proboscideans had a sodium budget similar to that of modern proboscideans; and that surficial salt existed during the time when proboscideans lived in the Pleistocene of Michigan.

CHAPTER II

LITERATURE REVIEW

A literature search was performed to obtain information on: Michigan proboscidean records; proboscideans associated with salt; identification of proboscidean skeletal elements; and Michigan salt sites.

Michigan Proboscidean Sites

Records of proboscidean finds in Michigan are well-documented. Early records were reported by Dice (1920), Fox (n.d.), Hay (1923), Hubbard (1840, 1841), Lane (1902, 1906), Lanman (1839), MacCurdy (1920), and Winchell (1861, 1864). MacAlpin (1940) condensed the above citations and museum records and published a census of mastodont (*Mammut americanum*) records from 1839 to 1939. Skeels (1962) updated MacAlpin (1940) and reported records of both mastodonts and mammoths from letters, news articles and museum entries. This was the first compilation of mammoth (*Mammuthus sp.*) records in Michigan. The site listings of Dice (1920), Fox (n.d.), Hay (1923), Lane (1902, 1906), Sherzer (1927), and Winchell (1861) were incorporated into Skeels' (1962) publication.

Researchers from Michigan museums and other institutions published additional records of proboscidean finds. Hatt (1965b) listed fossil Proboscidea from The Cranbrook Institute of Science. Frankforter (1966) reported new proboscidean

records from The Grand Rapids Public Museum. Wilson (1967) published records of Pleistocene vertebrates in Michigan and listed additional proboscidean finds. Holman, et al. (1986) provided an update to Wilson (1967) and added records of Pleistocene vertebrate discoveries since 1967. This comprehensive work included a wealth of information on new proboscidean sites as well as pollen spectra and radiocarbon dates. Included were updates of sites previously reported by Skeels (1962) and Wilson (1967). Shoshani (1989) provided an update to Holman, et al. (1986) and listed recently recovered material and identified a previously recorded "Proboscidea Indeterminate" specimen as that of a mastodont.

Documentation of Proboscideans Associated with Salt

In order to obtain literature on proboscideans associated with salt, a series of computer-aided literature searches was done at the Michigan State University Library. The databases Biological Abstracts (BIOSIS), Dissertation Abstracts, and Zoological Record were searched for the purpose of locating relevant information. Two searches were completed for each database. The following key words were used in the initial search: *Elephant, Proboscidea, Proboscidean, Mammoth, Mastodont, Mammuthus, Mammut, Loxodonta africana,* and *Elephas maximus*. A second search paired the above-listed key words with the terms *Salt, Sodium,* and *Saline*.

These searches were run with the Dissertation Abstracts, Biological Abstracts, and Zoological Record databases. The initial search yielded 142 sources from Dissertation Abstracts, 2396 citations from Biological Abstracts, and 1538 documents from Zoological Record. The second search yielded 1 source from Dissertation Abstracts, 35 documents from Biological Abstracts, and 4 documents from Zoological

Record. Documents and abstracts were obtained and reviewed for information pertinent to this study.

Identification of Proboscidean Skeletal Elements

An additional computer-aided literature search was carried out at the Michigan State University Library to locate information on the identification of proboscidean skeletal material. This search utilized the Dissertation Abstracts, Biological Abstracts, and Zoological Record databases. The terms *Mammut, Mammuthus, Mastodont,* and *Mammoth* were paired with the terms *Description, Determination, Morphology, Osteology,* and *Skeletal.* This search resulted in 11 sources from Dissertation Abstracts, 47 documents from Biological Abstracts, and 76 documents from Zoological Record. The documents and abstracts were located and reviewed for pertinent information.

Michigan Salt Sites

The majority of Michigan salt locality records were provided by Dr. David Westjohn of the United States Geological Survey (Holman, et al. 1988; D. Westjohn, personal communication, November 20, 1987; June 12, 1991). These records were compiled from early Michigan Geological Survey Reports and United States Geological Survey files. Additional salt locality information was obtained through literature searches carried out at the Michigan State University Library and The Library of Michigan. The Michigan Geological index of Martin and Straight (1956) provided references to publications on historical salt licks, salt springs, and State springs of Michigan. More recent publications, such as Yates (1987) provided further information on historical salt localities in Michigan. A list of surficial salt localities

used in this study is provided in Appendix D.

CHAPTER III

SYSTEMATIC PALEONTOLOGY

The proboscideans that lived in Michigan during the Pleistocene are the American mastodont (*Mammut americanum*) and a mammoth (*Mammuthus* sp.). The vernacular name for *Mammut americanum* is "mastodont", which stems from the Greek *mast* (nipple or breast) and *odont* (tooth) and literally means "nipple or breast tooth". This term describes the paired cusps on the occlusal surface of each tooth. These paired cusps are termed lophs or ridge crests and are composed of dentine, covered by enamel. The substance cementum is found between the lophs. Many researchers refer to *Mammut americanum* as a "mastodon" but the more precise term "mastodont" is preferred and will be used throughout this paper.

Mammoth teeth are easily distinguished from those of the mastodont. They consist of a series of compressed plates of dentine surrounded by a layer of enamel and held together with cementum. Dental characteristics of the third upper molars (M^3) have traditionally formed the basis of North American mammoth taxonomy. These characteristics include thickness of enamel, lamellar frequency, and plate number. Phyletic changes in the dentition of Elephantids include: a continuous increase in the number of plates of individual teeth; an increase in lamellar frequency; thinning of enamel; and an increase in crown height of unworn molars as compared to

crown width (Kurtèn and Anderson, 1980).

Mammoths in Michigan have been given varying names in the literature: *Elephas primigenius* (Case, et al. 1935; Hay, 1923; Fox, n.d.); *Elephas columbi* (Dice, 1920; Hay, 1923); *Mammuthus columbi* (Agenbroad, 1984); *Mammuthus jeffersoni* (Frankforter, 1966; Hatt, 1965b; Holman, et al. 1986; Holman, 1988; Holman, et al. 1988; Skeels, 1962; Wilson, 1967); and *Mammuthus* sp. (Holman, 1991; Shoshani, 1989). Between 1962 and 1988, researchers in Michigan museums and institutions referred to mammoths recovered in Michigan as Jefferson mammoths (*Mammuthus jeffersoni*). Currently, the systematics of North American mammoth species is in a state of uncertainty, and researchers hold varying views on the validity of mammoth species names.

Kurtèn and Anderson (1980) provisionally recognize four North American mammoth species or "stages" (*Mammuthus meridionalis, Mammuthus columbi, Mammuthus jeffersoni,* and *Mammuthus primigenius*) as a series of successional populations. Kurtèn and Anderson (1980) refer to Osborn's (1922, 1942) *Mammuthus jeffersonii* as being the more progressive evolutionary form, *Mammuthus columbi* as an intermediate form, and consider *Mammuthus imperator* to be synonymous with *Mammuthus columbi*. They based this arrangement on the idea that Osborn's (1942) name change of *Mammuthus columbi* to *Mammuthus jeffersonii* had been ignored.

Others (e.g., Agenbroad, 1984; Graham, 1986; Maglio, 1973) recognize three North American species of mammoth- *Mammuthus meridionalis*, *Mammuthus imperator*, *Mammuthus columbi* and the Wisconsinan immigrant, *Mammuthus primigenius*, and consider *Mammuthus jeffersonii* to be a synonym of

Mammuthus columbi. Maglio (1973) described events related to the confusion surrounding the names *Mammuthus columbi* and *Mammuthus jeffersonii*, and presented a solution:

> The great confusion associated with the name *M. columbi* resulted in part from Falconer's inadequate holotype specimen and from Osborn's (1922) selection of two neotype specimens (AMNH 13707) both of which are very close to *M. imperator*, if not actually identical to it. Osborn concluded that the holotypes of *imperator* and *columbi* were probably conspecific, although in later publications he retained both names. For the more progressive elephant material that had previously been referred to *M. columbi*, Osborn proposed the specific name *jeffersonii*. Although Osborn was correct in considering Falconer's original holotype specimen as inadequate for species diagnosis, there is little evidence that his neotype accurately reflects the true characters of the original. Thus it is probably best at present to retain Leidy's name *imperator* for the more primitive of these mammoths and Falconer's name *columbi* for the more progressive stages. This also conforms with the most common usage of these names.

Mammuthus "jeffersonii" is not recognized as a valid species by Graham (1986) but merely as a chronoclinal and/or a geoclinal variant of *Mammuthus columbi*. However, it should be considered a valid biological species if contemporaneous and sympatric populations of *Mammuthus columbi* and *Mammuthus "jeffersonii"* can be documented (Graham, 1986).

Because it is difficult to designate mammoth species names to individual teeth or bones, as measurements often overlap, Kurtèn and Anderson (1980) propose that all mammoths recovered be referred to *Mammuthus* sp. until a comprehensive systematic study of mammoth taxonomy is carried out. Following Shoshani (1989) and Holman (1991), the name *Mammuthus* sp. is used for Michigan mammoths

discussed in this paper.

A problem in the Michigan proboscidean literature is that certain sites have been cited repeatedly with different names, resulting in numerous duplications. MacAlpin (1940) and Skeels (1962), for example, have duplicated reports on museum specimens. Also, failure to document original sources has resulted in the same site being counted more than once, some as many as five times! In addition, duplications occurred when localities were inexactly estimated by one researcher, and then exactly recorded by another. Thus, locality information on Michigan proboscideans needed to be re-examined and each site traced through the literature to obtain an accurate total number of proboscidean finds in Michigan. Once the locality information was corrected and brought to date, it could be used in the co-occurrence analysis.

Methods

The methods for identification of material, compilation of Michigan Proboscidean locality data, formatting of records, and classification are described in this section.

Identification of Material

Proboscidean material in the Michigan State University Museum, as well as new specimens brought in for identification were studied and all mastodont and mammoth teeth identified. Mastodont tooth placement was determined by using the methods of Hay (1912), with the symbols of Osborn (1936) to indicate specific teeth. The mastodont teeth were measured following the techniques of Saunders (1977). Mammoth teeth were measured with techniques of Maglio (1973). Skeletal elements

were identified by utilizing comparative material from the Michigan State University Museum Vertebrate Paleontology Collection (MSUVP), the Indiana State Museum and Memorials (ISM) Pleistocene Vertebrate Collections, and the publications of Hay (1912), Olsen (1972), Osborn (1936, 1942), and Warren (1852). Fragmentary skeletal material (including tusks) that could not be identified as *Mammut americanum* or *Mammuthus* sp. was designated Proboscidea Indeterminate.

Michigan Proboscidean Locality Data

Published proboscidean sites were traced through the literature. Plat books, county atlases, and historical county records were used to locate specific site data when the names of land owners were published (e.g. Hay, 1923; and Lane, 1902; 1906). Romig (1986) was used to locate names of Michigan places that have changed or disappeared from maps since the publication of early records. A database of Michigan records was compiled and duplications noted. Updates of Michigan proboscidean records and reports of new sites are presented in this chapter. Compiled lists of all known Michigan mastodont, mammoth and Proboscidea Indeterminate sites are presented in tabular form in Appendices A, B, and C, respectively.

Format of Records

The following lists of records update the summary of Shoshani (1989), and use the format established by Holman et al. (1986). In several cases, previously published proboscidean records have been re-discussed if more information has become available. Records for material in the Michigan State University Museum Vertebrate Paleontology Division, and for new specimens I have observed are fully listed. Sites with minor updated information are partially listed, with references to

the primary citations.

These records are listed under alphabetically arranged Michigan counties. The specific elements included under each heading are described below.

Site Name: When bones are discovered on public property, sites are named on the basis of an associated geographical feature, but when sites are discovered on private property, they are usually termed after the owner. Recent sites (e.g., Holman, et al. 1986; Shoshani, 1989) have been predominately named after land owners, whereas sites in earlier records (e.g., Hay, 1923; Skeels, 1962; and MacAlpin, 1940) generally were named on the basis of geographical features such as cities, towns, rivers, lakes, bogs, or islands.

Township Name: Current survey township names for Michigan Counties were obtained from *Mapbook of Michigan Counties* (Lansing: TwoPeninsula Press, 1984). In cases where townships have been incorporated into expanded city limits, and do not appear on current maps, older plat books or atlases were used to locate townships. In instances where sites were located within limits of cities, only the city name is listed.

Section Number and Coordinates: The section number follows the Township name, with quarter sections designated if available. For sites described as distance in miles from a certain town or landmark, the section number was estimated and the locality designated as "approximate". Tier (T.) and Range (R.) coordinates of the Political Land Survey System were obtained from *Mapbook of Michigan Counties* (Lansing: TwoPeninsula Press, 1984), or county atlases and plat books. These coordinates designate survey townships.

Age: The age of the site is designated on the basis of radiocarbon dates (with laboratory reference number included) or stratigraphic occurrence.

Material: Skeletal elements and teeth from each site are described, and known museum numbers are provided. Names of persons who discovered specimens, the situation in which the material was recovered, and the date of collection are included.

Remarks: Remarks include the present location of the fossils as well as any additional clarifying comments.

Literature: All known associated literature including journal papers, certain news articles, and personal communication citations are listed.

Classification

The classification presented in this paper follows Simpson (1945) and Olsen (1972) for the American mastodont, and Simpson (1945) for the mammoth.

Class MAMMALIA Linnaeus, 1758

Order PROBOSCIDEA Illiger, 1811

Family MAMMUTIDAE Cabrera, 1929

Genus *MAMMUT* Blumenbach, 1799

MAMMUT AMERICANUM (Kerr, 1792) American mastodont

Mammut americanum in North America

Remains of the American mastodont (*Mammut americanum*) have been found throughout the United States (e.g., Lundelius, et al. 1983; King and Saunders, 1984), Canada (Dreimanis, 1967; Harington, 1977; McAndrews and Jackson, 1988; Osborn,

1936), and Mexico (Irwin-Williams, 1967). Both mammoth and mastodont teeth have been recovered from the continental shelf of the Atlantic (Odale, et al. 1987; Whitmore, et al. 1967). Teeth have been dredged from submerged shorelines as deep as 120 meters. Mastodonts commonly inhabited lowland areas, but Miller (1987) reported remains of two mastodont individuals recovered from a Utah sinkhole site 2,981 meters (9,780 feet) in altitude. This is the highest elevation on record for a mastodont site.

Mastodonts in Michigan are usually recovered from low boggy areas. It is currently thought that these animals became mired after falling through the vegetation layer of quaking bogs, and their bones were preserved in the acidic sediments (Holman, 1975; 1991). Recent expansion of industrial and agricultural practices, and construction of subdivisions and highways has precipitated additional discoveries of mastodonts in Michigan.

Update of Michigan *Mammut americanum* Records

ALLEGAN COUNTY

1. *Keith Site*, near Plainwell, Gunplain Township, SE ¼, NW ¼, NW ¼ of Section 10, T. 1 N., R. 11 W. *Age*: late Pleistocene. *Material*: (MSUVP 1112) right M_1, many vertebrae, ribs, sacrum, and many fragments found at a depth of 1.68 meters (5.5 feet) in marl by Mr. Dale Keith while digging a drainage ditch in September, 1945. *Remarks*: This site was originally published by Skeels (1962) who listed an additional lower jaw with teeth and many foot bones that presently cannot be located. An extensive file, including maps and photos of the site and the lower jaw (Figure 2)

is located in the Michigan State University Museum Vertebrate Paleontology Division records. Several of the thoracic vertebrae exhibit uneven wear on the zygapophyseal facets (Figures 3 and 4). *Literature*: Skeels (1962).

2. *Fleser Site*, four miles west of Door, Salem Township, approximately Section 24, T. 4 N., R. 13 W. *Age*: late Pleistocene. *Material*: jawbone with teeth secured by Frank Fleser and others around 1900. *Remarks*: This site was reported by Hay (1923), Lane (1902) and MacAlpin (1940) as "...four miles west of Door...". According to the *1895 Illustrated Atlas of Allegan County* (Racine: Kace Publishing Co.), Mr. Fleser owned land in Section 24 of T. 4 N., R. 13 W., which is exactly four miles west of Door. Assuming that Mr. Fleser found the mastodont jaw on his property, this site is estimated to be in Section 24 of T. 4 N., R. 13 W. *Literature*: Hay (1923), Lane (1902), and MacAlpin (1940).

BERRIEN COUNTY

1. *Eau Claire*, Pipestone Township, Section 32, T. 5 S., R. 17 W. *Age*: late Pleistocene. *Material*: (MSUVP 1277) right M^2, left M_2 with part of lower left jaw ramus collected at Eau Claire by B.L. Comstock on August 17, 1896. *Remarks*: According to the State Agricultural College Museum Ledger, "...six molars, part of lower jaw, and other bones from B.L. Comstock; collected at Eau Claire, August 17, 1896". Only the two molars and part of the lower jaw remain in the Michigan State University Museum Vertebrate Paleontology Collection. The whereabouts of the four additional teeth, and the other bones is unknown. Dice (1920) stated that "...about

Figure 2. Jaws of the Keith site mastodont (MSUVP 1112)

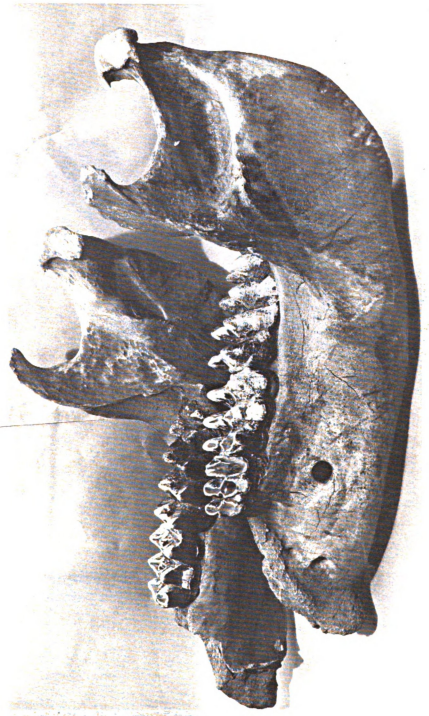

Figure 3. Posterior view of a Keith site mastodont thoracic vertebra with uneven wear on the zygapophyseal facets (MSUVP 1112)

Figure 4. Posterior view of a Keith site mastodont thoracic vertebra with uneven wear on the zygapophyseal facets (MSUVP 1112)

1897 the teeth of a mastodon were dug up by a dredge within the village limits of Eau Claire. Their disposition is unknown". Fox (n.d.) reported that "...about 1897 the teeth of a mastodon, (number unknown) were dug up by a dredge within the village limits of Eau Claire. The teeth were taken to Benton Harbor and for a time exhibited in a store there. Their final disposition is unknown". It is highly probable that MSUVP 1277 was reported by Dice (1920) and Fox (n.d.). Hay (1923), Lane (1902), and MacAlpin (1940) have briefly reported on this specimen. Hay (1923) remarked that "the teeth are extraordinarily large..." *Literature*: Dice (1920) Fox (n.d.), Hay (1923), Lane (1902), and MacAlpin (1940).

2. *Terre Coupe* (Dayton), NE ¼ of Section 7, T. 8 S., R. 18 W. *Age*: late Pleistocene. *Material*: right lower jaw ramus with a supernumerary molar (M_4) collected at Terre Coupe by A. H. Taylor in 1854. *Remarks*: This site has been reported in Hay (1923), Lapham (1855), Warren (1855) and Winchell (1864), but section and township information were not provided. Hay (1923) stated "this place has disappeared from the maps; but it is said to have been situated on the railroad, 11 miles west of Niles, not far east of Galien". Terre Coupe was located in the NW ¼ of Section 7, T. 8 S. R. 18 W. (*1929 Atlas and Plat Book of Berrien County, Michigan*. Rockford: The Thrift Press Map Makers), and was renamed Dayton between 1853 and 1860 (Fox, 1924; Romig, 1986). I believe this specimen is the same as that reported by MacAlpin (1940) as "Galien, approximately Section 1, T. 8 S., R. 19 W." MacAlpin's (1940) approximation is adjacent to the actual site location. *Literature*: Hay (1923), Lapham (1855), MacAlpin (1940), Warren (1855),

and Winchell (1864).

EATON COUNTY

1. *Narrow Lake Site*, Brookfield Township, approximately Section 33, T. 1 N., R. 4 W. *Age*: late Pleistocene. *Material*: right M_2 collected by Mr. Ozeltine in 1918. *Remarks*: The material was "...found in marl while digging a channel to Narrow Lake" (M. Malkin, personal communication). MacAlpin (1940) reported that "teeth and bones" were found at this site. Mildred Malkin of Haslett, Michigan is in possession of the right M_2, and received it from Loren Ozeltine (grandson of the person who found it) on February 6, 1968. The whereabouts of the remaining material originally reported in MacAlpin (1940) is unknown. *Literature*: MacAlpin (1940); Mildred Malkin, personal communication, May 9, 1991, when the mastodont tooth from Narrow Lake was brought to the Michigan State University Museum for identification.

2. *Cummings Farm Site*, near Bellevue, Bellevue Township, SW ¼ of Section 5, T. 1 N., R. 6 W. *Age*: late Pleistocene. *Material*: bones; including a femur, tusk, and four upper teeth. *Remarks*: Hay (1923) reported that mastodont remains were "...found on the farm of Mr. Charles Cummings. It [the animal] was a large one, the femur having a length of 3 feet 10 inches and one tusk was over 12 feet in length. Four teeth belonged to the upper jaw. The remains must have been found before 1879." The bones were found "...in 1876 in a piece of swamp near his home..." (*1891 Portrait and Biographical Album of Barry and Eaton Counties, Michigan.*

Chicago: Chapman Bros., pp. 458-459). The Cummings' farm was located in the SW ¼ of Section 5, T. 1 N., R. 6 W. (*1873 Atlas of Eaton County, Michigan.* Philadelphia: C. O. Titus Publishers). MacAlpin (1940) listed a tusk, teeth and bones of a mastodont from Bellevue, in Section 28, T. 1 N., R. 6 W. I believe these Bellevue sites reported by Hay (1923) and MacAlpin (1940) to be the same. *Literature*: Hay (1923) and MacAlpin (1940).

3. *Van Neste Farm Site*, near Mulliken, Roxand Township, NE ¼ of NE ¼ of Section 6 or NW ¼ of NW ¼ of Section 5, T. 4 N., R. 5 W. *Age*: late Pleistocene. *Material*: (MSUVP 1290) left lower jaw ramus with M_2 and M_3, with many fragments of ribs and vertebrae, found in July, 1959 by Mr. Van Neste, and excavated by R. Carroll, V. Hogg, and H. Klippell on July 9, 1959. *Remarks*: Skeels (1962) reported this specimen as Michigan State University Museum No.1130, found 2 miles west and 1 mile north of Mulliken, Ionia County. The site is located in Eaton County, not Ionia County as originally reported. The Van Neste Farm was located in the NE ¼ of NE ¼ of Section 6 and the NW ¼ of NW ¼ of Section 5, T. 4 N., R. 5 W. (*1957 Farm Plat Book, Eaton County, Michigan.* Rockford: Rockford Map Publishers). The specimen is currently on exhibit at the Michigan State University Museum. *Literature*: Skeels (1962).

4. *Parker Site*, near Mulliken, Roxand Township, SW ¼ of Section 20, T. 4 N., R. 5 W. *Age*: late Pleistocene. *Material*: (MSUVP 1269) right M^2 and proximal left humerus collected by Tom Nelson on October 31, 1966. *Remarks*: This site was

reported in Holman et al. (1986). Additional parts of the skeleton are present at the Alma College Department of Biology. The material in the Michigan State University Museum Vertebrate Paleontology Collection was received from Mr. Keith Warner on November 1, 1966. *Literature*: Holman et al. (1986).

GENESEE COUNTY

1. *Johnson Site*, Richfield Township, Section 9, T. 8 N., R. 8 E. *Age*: 12,500 ± 500 ybp (Shoshani, 1989). *Material*: Material and excavation details are listed in Holman et al. (1986) and Shoshani (1989). *Remarks*: This site was reported as Section 9, T. 7 N., R. 8 E. by Holman et al. (1986) and Shoshani (1989). The actual locality is Section 9, T. 8 N., R. 8 E. (*1979 Land Atlas and Plat Book, Genesee County, Michigan*. Rockford: Rockford Map Publishers). *Literature*: Fisher (1984b); Holman et al. (1986); and Shoshani (1989).

2. *Cullen Site*, near Davison, Richfield Township, NW ¼ of Section 34, T. 8 N., R. 8 E. *Age*: late Pleistocene. *Material*: left femur collected by Mr. A. B. Cullen. *Remarks*: Hay (1923) and MacAlpin (1940) reported this site but the section and township data were not included. A. B. Cullen owned the NW ¼ of Section 34, T. 8 N., R. 8 E. (*1889 Atlas of Genesee County, Michigan*. Caro: E. R. Cookingham Publishers). Assuming that Mr. Cullen found the bone on his land, the site is estimated to be in section 34 of T. 8 N., R. 8 E. *Literature*: Hay (1923); MacAlpin (1940).

HILLSDALE COUNTY

1. *Stafford Farm, near Church*, Wheatland Township, NE ¼ of Section 27, T. 6 S. R. 1 W. *Age*: late Pleistocene. *Material*: skull, lower jaws, 1 tusk, proximal part of other tusk, 7 cervical vertebrae, 17 thoracic vertebrae, 3 lumbars, sacrum, 11 caudals, 30 ribs, part of sternum, pelvis, right forelimb, and numerous foot bones found in 1901 in a swamp, and acquired by the United States National Museum. *Remarks*: This site has been reported by Gilmore (1906), Hay (1923), Lane (1902), and MacAlpin (1940). Gilmore (1906) and Hay (1923) have referred to this site as "...the farm of Levi Wood..." Since this name does not appear on the plat maps, Wood may have been the collector of the specimen, rather than the owner of the farm. MacAlpin (1940) estimated this site to be approximately in Section 21, T. 6 S., R. 1 W. As of 1894, A. Stafford's farm was located in the NE ¼ of Section 27, T. 6 S., R. 1 W. (*1894 Plat Book of Hillsdale County, Michigan*. Chicago: The American Atlas Co.). *Literature*: Gilmore (1906); Hay (1923); Lane (1902); MacAlpin (1940).

ISABELLA COUNTY

1. *Near Mount Pleasant*, Fremont Township, SW ¼, SW ¼ of Section 24, T. 13 N., R. 5 W. *Age*: late Pleistocene. *Material*: (MSUVP 1274) left M_1 (Figure 5) collected from muck on gravel by John Gott, November 1, 1938. *Remarks*: The specimen was briefly listed by MacAlpin (1940) as "one tooth". A pelvis (UMMP 44432) was recovered from the same section of Fremont township and was reported in Holman et al. (1986). It is not known if MSUVP 1274 and UMMP 44432 are

Figure 5. Left M_1 of the Mount Pleasant site mastodont (MSUVP 1274)

from the same individual. *Literature*: MacAlpin (1940).

KALAMAZOO COUNTY

1. *Vanmiddlesworth Site*, near Climax, Climax Township, Section 1, T. 3 S., R. 9 W. *Age*: late Pleistocene. *Material*: molar tooth. *Remarks*: The site was reported in Holman et al. (1986) as T. 2 S., R. 9 W. Climax Township is located in T. 3 S., R. 9 W. (*1983 Farm Atlas and Plat Book, Kalamazoo County, Michigan*. Rockford: Rockford Map Publishers). *Literature*: Holman et al. (1986).

KENT COUNTY

1. *Dutmer Site, at Cannonsburg*, Cannon Township, SW ¼ of Section 27, T. 8 N. R. 10 W. *Age*: late Pleistocene. *Material*: left M_3 found by Henry Dutmer. *Remarks*: Hay (1923) reported this specimen to be "in the Kent Scientific Museum at Grand Rapids..." (The Grand Rapids Public Museum). MacAlpin (1940) estimated this site to be in Section 23 of Cannon Township. Henry Dutmer owned land in the SW ¼ of Section 27, T. 8 N. R. 10 W. (*1907 Standard Atlas of Kent County, Michigan*. Chicago: George A. Ogle and Co.). *Literature*: Hay (1923); MacAlpin (1940).

2. *Shaw Farm Site*, Tyrone Township, NE ¼ of Section 6, T. 10 N., R. 12 W. *Age*: late Pleistocene. *Material*: two teeth and several bone fragments were found in April of 1988 while digging a drainage ditch. *Remarks*: This site was reported by Frankforter (1991), but section and township data were not provided. The Shaw farm

is located in the NE ¼ of section 6, T. 10 N., R. 12 W. (*1988 Land Atlas and Plat Book, Kent County, Michigan*. Rockford: Rockford Map Publishers). *Literature*: Frankforter (1991).

LENAWEE COUNTY

1. *Gregg Site, at Clinton*, SE ¼ of Section 7, T. 5 S., R. 4 E. *Age*: late Pleistocene. *Material*: teeth and bones including foot bones. *Remarks*: Hay (1923) and Lane (1902) reported that "...at Clinton, Lenawee County, Mr. P. B. Gragg [Gregg] had found several teeth and bones of a mastodon." MacAlpin (1940) reported that mastodont foot bones had been found at Clinton, in Section 7, T. 5 S., R. 4 E. P. B. Gregg owned the land in the SE ¼ of Section 7, T. 5 S., R. 4 E. (*1893 Atlas of Lenawee County, Michigan*. George B. Cadwell and Co. Publishers). *Literature*: Hay (1923); Lane (1902) and MacAlpin (1940).

2. *Decker Site, Northwest of Adrian*, Adrian Township, Section 7, T. 6 S., R. 3 E. *Age*: late Pleistocene. *Material*: cranium, 5 molars, tusks, 2 caudal vertebrae, scapulae, femora, tibiae, fibula, calcanea, humeri, radius, carpals, tarsals, metacarpals, metatarsals, 3 ribs. These elements were found two feet below the surface of a small peat bog (Winchell, 1864) on the farm of Uri Decker (*1874 New Historical Atlas of Lenawee County, Michigan*. Chicago: Everts and Stewart). *Remarks*: This site was reported by Hay (1923), MacAlpin (1940) and Winchell (1864). Hay (1923) incorrectly listed the Range as 4 East. MacAlpin (1940) listed the locality as being "...7 miles *northeast*..." of Adrian but provided the correct

section and township information. Hay (1923) reported that "in the U. S. National Museum (No. 188) there a lower jaw of a mastodon found...in the same locality as the Decker mastodon..." This lower jaw and the above-listed skeletal elements probably belong to the same animal. Winchell (1864) stated that many years ago the place was known as a "deer lick". *Literature*: Hay (1923); MacAlpin (1940); Winchell (1864).

MONTCALM COUNTY

1. *Hodges Site, near Stanton*, Evergreen Township, in the SW ¼ of Section 9, T. 10 N., R. 6 W. *Age*: late Pleistocene. *Material*: teeth found in 1911 by L. C. Hodges. *Remarks*: Hay (1923) listed that mastodont teeth were found near Stanton in 1911 by Mr. L. C. Hodges. MacAlpin (1940) listed this site as being in the NE corner of T. 10 N. R. 7 W. L. C. Hodges owned land in the SW ¼ of Section 9, T. 10 N. R. 6 W. (*1921 Standard Atlas of Montcalm County, Michigan.* Chicago: Geo. H. Ogle and Co., Publishers). *Literature*: Hay (1923) and MacAlpin (1940).

NEWAYGO COUNTY

1. *Jolman Site*, Sheridan Township, Section 10, T. 12 N., R. 14 W. *Age*: late Pleistocene. *Material*: right scapula. *Remarks*: An incorrect Range for Sheridan Township was given in Holman et al. (1986). The coordinates for Sheridan township are T. 12 N., R. 14 W. (*1984 Mapbook of Michigan Counties*, Lansing: TwoPeninsula Press). *Literature*: Gilbert (1981); Holman et al. (1986).

OAKLAND COUNTY

1. *Calwell Farm Site/Fenton*, Rose Township, Section 6, T. 4 N., R. 7 E. *Age*: late Pleistocene, *Material*: In 1862, a tooth was found on the farm of D. Calwell "in a marshy place" and was described as having "two prongs with the crown of the tooth pretty well worn down" (*The Detroit Free Press*, January 9, 1862). *Remarks*: This site was listed in Winchell (1864), as being from Fentonville, Oakland County. Section and township details weren't included. This is the same site reported by Hay (1923) and MacAlpin (1940) as being from Fenton, Genesee County. MacAlpin (1940) estimated this site to be in Section 36, T. 5 N., R. 7 E. The Calwell farm was located in Section 6, T. 4 N., R. 7 E. (*1872 Atlas of Oakland County, Michigan*. New York: Beers and Co.). *Literature*: Charles H. Martinez, Michigan Archaeological Society, personal communication to J. A. Holman, January 12, 1982, with news article from *The Detroit Free Press*, page 1, January 9, 1862; Hay (1923); MacAlpin (1940); Winchell (1864).

2. *Green Site, near Eames*, Orion Township, approximately Section 33, T. 4 N., R. 10 E. *Age*: late Pleistocene. *Material*: (UMMP 60454) partial scapula, pelvis, and vertebrae (Holman et al., 1986). *Remarks*: Holman et al. (1986) listed this site as "near Eames, Pontiac Township, Section 33, T. 3 N., R. 9 E." This information is in error: Eames is located in Orion Township, not Pontiac Township, and T. 3 N., R. 9 E. coordinate with Waterford Township (*1984 Mapbook of Michigan Counties*, Lansing: TwoPeninsula Press). Essentially, information pointing to three different townships has been provided. I have been unable to find Nobi Green listed on a plat

map of Oakland County, and will assume that this site is in Section 33 of Orion Township, T. 4 N., R. 10 E. next to Eames. *Literature*: Holman et al. (1986).

OCEANA COUNTY

1. *Huls Site, near Rothbury*, Grant Township, SW ¼ of the SW ¼ of Section 12, T. 13 N., R. 17 W. *Age*: late Pleistocene. *Material*: "palate fragment with right and left M^2 plus right and left M^3 and two ribs...discovered by Adrian Huls, September 1963 in peat and mud..." (Holman et al. 1986). *Remarks*: This specimen was donated to the Muskegon County Museum in Muskegon, Michigan. It has been catalogued with Museum numbers X87.89.1 (skull) and X87.89.2-7 (photos). *Literature*: R. A. Gibson, personal communication in letter of October 20, 1988; Holman et al. (1986).

OTTAWA COUNTY

1. *Jonio Farm Site*, near Conklin, Chester Township, S ½, NW ¼ of Section 19, T. 9 N., R. 13 W. *Age*: late Pleistocene. *Material*: (MSUVP 1289) tusks, foot bones, ribs, vertebrae, humerus, pelvis, and leg bones discovered by John Jonio in May of 1938, and excavated by the Grand Rapids Public Museum. *Remarks*: All bones were reported to have been found in muck on top of light-colored till. Material was donated to the MSU Museum by the Grand Rapids Public Museum on June 10, 1947 for the purpose of "filling out" a mastodont specimen that was to be articulated and mounted for an exhibit. This specimen was listed in the mastodont census of MacAlpin (1940) as "about a hundred bones". I believe that this is the Kent County

site referred to by Skeels (1962) as "...exact locality unknown. Parts of a skeleton. Specimens at the Michigan State University Museum." A label on the bones refers to the Grand Rapids Public Museum, Kent County, but the actual site where the bones were excavated is in Ottawa County. *Literature*: MacAlpin (1940), Skeels (1962).

SAGINAW COUNTY

1. *Willis Farm*, St. Charles Township, Section 6, T. 10 N., R 3 E. *Age*: late Pleistocene. *Material*: distal tusk, lower jaw, and ribs (Lane, 1902). *Remarks*: Hay (1923) and Lane (1902) reported mastodont remains from the "Willis farm" but locality data were not provided. The Willis farm was located on Section 6, T. 10 N., R. 3 E. (*1900 Plat Book of Saginaw County, Michigan*. Rockford: W. W. Hixson and Co.). *Literature*: Hay (1923) and Lane (1902).

2. *Mauer Site*, near Frankenmuth, Birch Run Township, Section 9, T. 10 N., R. 6 E. *Age*: late Pleistocene. *Material*: mandible with right third molar collected from the Raymond Mauer farm. *Remarks*: Reported by Holman et al. (1986) as "Frankenmuth Township, Section 9, T. 10 N., R. 6 E." This site is actually located in Birch Run Township, Section 9, T. 10 N., R. 6 E. (*1974 Atlas and Plat Book, Saginaw County, Michigan*. Rockford: Rockford Map Publishers). *Literature*: Holman et al. (1986).

ST. JOSEPH COUNTY

1. *Prairie Lake*, Sherman Township, approximately Section 13, T. 7 S., R. 10 W. *Age*: late Pleistocene. *Material*: "...two bones..." (MacAlpin, 1940). *Remarks*: MacAlpin (1940) lists this site as being in the East ½ of T. 7 S., R. 10 W. (Sherman Township). Prairie Lake extends into Sherman Township in Sections 13 and 24, with the larger part being in Section 13 (*1930 Plat Book of St. Joseph County, Michigan.* Rockford: W. W. Hixson and Co.). *Literature*: MacAlpin (1940).

SHIAWASSEE COUNTY

1. *Warren Site, near Bancroft*, Shiawassee Township, Section 36, T. 6 N., R. 3 E. *Age*: late Pleistocene. *Material*: tusk, teeth, ribs, and many other bones. *Remarks*: Lane (1906) listed the remains as being found near the line between Sections 36 and 25, but did not designate the actual Section that the specimen was found in. An incorrect Range coordinate was also given. The Warren land was located in Section 36, T. 6 N. R. 3 E. (*1915 Standard Atlas of Shiawassee County, Michigan.* Chicago: Geo. A. Ogle and Co.). *Literature*: Hay (1923), Lane (1906), MacAlpin (1940).

VAN BUREN COUNTY

1. *Heuser Site*, three miles east and one mile south of Hartford, Hartford Township, Section 24, T. 3 S., R. 16 W. *Age*: late Pleistocene. *Material*: (MSUVP 792) right M^2 and M^3 and several small skull fragments with sinuses, collected by Robert Heuser from a peat bog during June, 1958. *Remarks*: specimens were briefly reported by Skeels (1962) as Michigan State University Museum number 5296. The section

number was not given. E. Heuser owned land in Section 24, T. 3 S., R. 16 W. (*1954 Farm Plat Book, Van Buren County, Michigan.* Rockford: Rockford Map Publishers). *Literature*: Skeels (1962).

2. *Near Hartford*, Hartford Township, T. 3 S., R. 16 W. *Age*: late Pleistocene. *Material*: (MSUVP 1285) a partial right scapula. *Remarks*: The specimen was said to have been found while digging a farm pond, and was reported in Holman et al. (1986) as Proboscidea Indeterminate. The specimen was compared with proboscidean material from the Indiana State Museum (ISM catalog number 71.3.39.13), and identified as *Mammut americanum*. *Literature*: Holman et al. (1986).

WASHTENAW COUNTY

1. *Kuhl Site*, near Ann Arbor, Lima Township, Section 33, T. 2 S., R. 4 E. *Age*: late Pleistocene. *Material*: a list of skeletal elements (UMMP 59936) appears in Holman et al. (1986). *Remarks*: This site was cited by Holman et al. (1986) as "...Scio Township, Section 33, T. 2 S., R. 4 E." The correct township is Lima, Section 33, T. 2 S., R. 4 E. (*1970 Triennial Atlas and Plat Book, Washtenaw County, Michigan*, Rockford: Rockford Map Publishers, Inc.). *Literature*: Holman et al. (1986).

2. *Killin Gravel Pit Site*, Ann Arbor, Scio Township, Section 25, T. 2 S., R. 5 E. *Age*: late Pleistocene. *Material*: (UMMP 61427) piece of tusk. *Remarks*: This site was cited by Holman et al. (1986) as "...Ann Arbor Township, Section 25, T. 2 S.,

R. 5 E." The correct township is Scio, Section 25, T. 2 S., R. 5 E. (*1964, 1967, 1970, 1981/82, 1985 Land Atlas and Plat Book, Washtenaw County, Michigan*, Rockford: Rockford Map Publishers). *Literature*: Holman et al. (1986).

3. *Darling Farm Site*, seven miles southeast of Ypsilanti, Augusta Township, Section 12, T. 4 S., R. 7 E. *Age*: late Pleistocene. *Material*: lower jaw with teeth, teeth of the upper jaw, parts of the cranium, vertebrae, ribs, and some limb bones found on the farm of Albert Darling, 7 miles southeast of Ypsilanti (Hay, 1923). *Remarks*: Hay (1923) listed this site, but did not include section and township information. MacAlpin (1940) estimated the location as Section 1 of T. 4 S., R. 7 E. The Darling farm was located in Section 12 of T. 4 S., R. 7 E. (*1874 Combination Atlas Map of Washtenaw county, Michigan.* Chicago: Everts and Stewart). *Literature*: Hay (1923); MacAlpin (1940); Russell and Leverett (1908).

WAYNE COUNTY

1. *Shattuck Site*, near Plymouth, Plymouth Township, approximately Section 26, T. 1 S., R. 8 E. *Age*: late Pleistocene. *Material*: tusk and teeth (Hay, 1923). *Remarks*: Both Hay (1923) and Winchell (1861) reported that Mr. Shattuck had exhumed a mastodont tusk and some teeth near Plymouth. Assuming that the specimen was found on his land, the locality of this site is Section 26, T. 1 S., R. 8 E. (*1876 Illustrated Historical Atlas of the County of Wayne, Michigan.* Chicago: H. Belden and Co.). *Literature*: Hay (1923), MacAlpin (1940), and Winchell (1861).

New Michigan *Mammut americanum* Records

BARRY COUNTY

1. *J. Beavers Site*, Assyria Township, SE ¼, NE ¼, SE ¼ of Section 28, T. 1 N., R. 7 W. *Age*: late Pleistocene. *Material*: a well-worn right M_1 (Figure 6) collected May 9, 1987 by James and John Beavers. *Remarks*: found on the surface of dredged pond matrix that was spread with a bulldozer. The specimen is currently at the Michigan State University Museum for examination.

EATON COUNTY

1. *Vermontville Site*, Vermontville Township, NE¼, SE ¼, SW ¼ of Section 14, T. 3 N., R. 6 W. *Age*: late Pleistocene. *Material*: three teeth found in the summer of 1945 by Dale Cotton and Milton Sprague. *Remarks*: Dale Cotton found one of the teeth (a third molar) while using a tractor to plow the land. Sometime later, Milton Sprague, who owns land adjacent to the corn plot where the tooth was found, recovered two additional teeth (one a second molar). The corn field is on the edge of what was once a large swamp. One tooth (the second molar) remains in possession of Theodore Sprague, who is Milton Sprague's son. One tooth was stolen and the whereabouts of the third tooth is unknown. *Literature*: Theodore Sprague, personal communication, letters of April 5, 1989, and June 21, 1989.

Figure 6. Right M_1 of the Beavers site mastodont (uncatalogued)

GRATIOT COUNTY

1. *Lentz Site*, Farm of Lee and Bertha Lentz, Pine River Township, NW ¼, NW ¼ of Section 19, T. 12 N., R. 3 W. *Age*: late Pleistocene. *Material*: left M_3 recovered in 1970 by Mr. Lentz while tiling, and a femur collected in 1941 in the same vicinity by Mr Lentz' father. *Remarks*: The femur is believed to be in possession of Anderson College, Anderson, Indiana. It was donated to them by Fred Lepperin. *Literature*: Ron Kapp, personal communication in letter of March 30, 1989.

KENT COUNTY

1. *Plainfield Heights Site*, Plainfield Township, SW ¼ of Section 33, T. 8 N., R. 11 W. *Age*: late Pleistocene. *Material*: one tooth. *Remarks*: found by Walter Morrow in August, 1989 in a peat bog. The tooth has since disintegrated. *Literature*: Walter Morrow, personal communication, March 4, 1991.

SANILAC COUNTY

1. *Ellembaum Site*, Ralph Ellembaum Farm, 10 miles south of Deckerville, approximately Section 20, T. 11 N., R. 15 E. *Age*: late Pleistocene. *Material*: (MSUVP 1268) left M_1 collected in June, 1962 by Ralph Ellembaum. *Remarks*: The tooth was turned over by a plow on the Ralph Ellembaum farm.

WASHTENAW COUNTY

1. *Scio Farms Estates Site*, Scio Township, SE ¼, NW ¼, SE ¼ of Section 20, T. 2 S., R. 5 E. *Age*: late Pleistocene. *Material*: (MSUVP 1288) left scapula, 2 thoracic vertebrae, 1 lumbar vertebra, rib fragments, and many tusk fragments collected by Darrell Hughes in 1987. *Remarks*: The bones were collected from muck that had been spread on the surface of an area that was being paved.

Mammut americanum Tooth Measurements

Both tusks and cheek teeth develop in American mastodonts. The tusks are second incisors and are composed of dentine. Tusks from the upper jaw (maxilla) are most prevalent, although specimens are occasionally found with short tusks in the lower jaw (mandible). Hay (1912) reported that mandibular tusks were probably indicative of male mastodonts. However, Haynes (1991) found mandibular tusks in both sexes. Six cheek teeth develop in each side of the upper and lower jaws. The first three of these teeth are milk teeth or deciduous premolars, and the last three are permanent molars. Osborn (1936) used the symbols *Dp* for deciduous premolars and *M* for molars, with an upper case numeral to indicate upper teeth, or a lowercase numeral for lower teeth. The cheek teeth of the upper jaw are numerically designated as: Dp^2, Dp^3, Dp^4, M^1, M^2, M^3; and teeth of the lower jaw are: Dp_2, Dp_3, Dp_4, M_1, M_2, M_3. Some researchers utilize the scheme followed for modern elephants: M1, M2, M3, M4, M5, M6. This system makes reference to teeth according to their order of appearance, rather than their ancestry (Haynes, 1991). When referring to both upper and lower teeth, both numerical designations are included (e.g., M1/1). an R or L may be placed before the symbol to indicate a right or left tooth.

Each molar tooth has a number of paired cusps called transverse ridges, ridge crests or lophs. Dp2/2 and Dp3/3 have two ridge crests. Dp4/4, M1/1, and M2/2 have three lophs. M3/3 has four lophs and a "vestigial heel" (Skeels, 1962), or five lophs may be present. Saunders (1977) used terms to indicate specific lophs of mastodont teeth: *Protoloph, Metaloph, Tritoloph, Tetartoloph*, and *Pentaloph* indicate the first, second, third, fourth, and fifth lophs respectively. The suffix *-id* is added to indicate teeth of the lower jaw.

The measurement techniques of Saunders (1977) included the application of Simpson's (1949) definitions of length and width. For measuring teeth, Simpson (1949) defines length (L) and width (W) as:

> L= maximum length between planes tangential to the enameled crown and at right angles to the long axis of the tooth series as determined by the median sulcus.
>
> W= the maximum width between vertical planes tangential to the sides of the enameled crown and parallel to the long axis of the tooth series as determined by the median sulcus and with the tooth oriented (in the jaw or as if it were) with the tooth series horizontal.

The *Mammut americanum* cheek teeth in the Vertebrate Paleontology division of the Michigan State University Museum were examined and measured with a pair of Sylvac-Fowler electronic calipers. Tooth placement was determined using the methods of Hay (1912), and noted with Osborn's (1936) symbols. Techniques and terminology follow Saunders (1977). The tooth measurements are in millimeters and are presented in Table 1.

All *Mammut americanum* teeth in the Michigan State University Museum were determined to be permanent molars (M1/1, M2/2, or M3/3). Hay (1912) noted that occasionally the last deciduous premolar is difficult to distinguish from the first permanent molar. MSUVP 1268 and MSUVP 1274 were provisionally placed as M_1 on the basis of measurement ranges of other Michigan mastodont teeth (Skeels, 1962). Because MSUVP 1268 and MSUVP 1274 are isolated teeth, it is possible that one or both is Dp_4, and not M_1. MSUVP 1274 consists of a crown only (Figure 5). The pulp cavity is evident and no roots were preserved. Specimen MSUVP 1004 consists of a partial cranium (Holman 1979). By utilizing the descriptions of Osborn (1936), I have determined MSUVP 1004 to be a female. This is an MSU specimen that can be positively sexed on the basis of Osborn's (1936) cranial and palatal features. Because the Beavers Site tooth is not catalogued, it is unnumbered.

Class MAMMALIA Linnaeus, 1758

Order PROBOSCIDEA Illiger, 1811

Family ELEPHANTIDAE Gray, 1821

Genus *MAMMUTHUS* Burnett, 1830

MAMMUTHUS sp. mammoth

Mammuthus sp. in North America

Agenbroad (1984) studied the distribution of mammoths in the New World and reported that "...the heartlands for mammoth localities are in Alaska, the prairie provinces of Canada, and in a band of southwestern and central states in the United States". Records of finds in Mexico are apparently numerous, and the southern-most

Table 1. Michigan State University Museum *Mammut americanum* Tooth Measurements (in mm).

MSUVP#	PLACEMENT[a]	L[b]	W[b]	PROTOLOPH/-ID[c]	METALOPH/-ID	TRITOLOPH/-ID	TETARTOLOPH/-ID	PENTALOPH/-ID
1269	RM^2	112	95	92	95	94		
1277	RM^2	122	101	98e	101	99e		
1277	LM_2	124	99e	81e	99e	99e		
792	RM^2	115	98e	91e	98e	93e		
792	RM^3	171	100	100	96	98e	77	27
1272	RM^3	151	94	93	94	85	68	
1004[d,f]	RM^3	154	92	92	84	81	73	
1004[d,f]	LM^3	161	90	90	87	82	76	
1004[d,f]	RM^2	104	81	77	76	81		
1004[d,f]	LM^2	104	82	77	76	82		
Beavers	RM_1	84	69e	58e	68e	69e		
1112	RM_1	88	63e	61e	63e	57e		
1268	LM_1	90	69e	63e	69e	63e		
1274	LM_1	91	62	58	62	58		
1290[d]	LM_2	109	95	68	85	95		
1290[d]	LM_3	244+	100+	83+	100+	95+	92	76

[a]R=right, L=left, tooth placement symbols after Osborn (1936); [b]L=length, W=width after Simpson (1949); [c]loph terminology after Saunders (1977); [d]indicates a series of teeth in the jaw; [f]specimen described in Holman (1979)
+ minimum measurement; e estimated measurement

reliable record is El Salvador, Central America (Stirton and Gealey, 1949). The frequency of mammoth distribution is greatest in Alaska, followed by Texas and the central plains. Mammoths are also abundant in the Pleistocene deposits of the west coast and an area extending northeast from Arizona to Minnesota. In addition, Florida is observed as an isolated, high-frequency area (Agenbroad, 1984). As mentioned before, both mastodont and mammoth teeth have been recovered from the Atlantic continental shelf (Odale, et al. 1987; Whitmore, et al. 1967).

Mammoth sites in Michigan are found in geologic settings similar to those of the mastodont. The usual stratigraphic sequence from bottom to top is glacial sands and gravels, bluish-gray clay, marl, peat, humus and topsoil. Proboscidean bones and teeth are normally recovered between the marl and the peat (Holman, 1988; 1991). A mammoth was recently reported from an unusual stratigraphic setting for Michigan. The bones were recovered from a beach sand-blackish organic sand contact (Holman, 1991). Mammoth localities are less abundant than mastodont sites in Michigan.

Update of Michigan *Mammuthus* sp. Records

ARENAC COUNTY

1. ***Van Horn Site***, near Alger, Moffatt Township, SE ¼, NE ¼, NW ¼ of Section 8, T. 20 N., R. 3 E. *Age*: 11,280±70 ybp (Beta-32130) (Holman, 1991). *Material*: (MSUVP 1219) left M^3, found by Chris Van Horn who stepped on the tooth while wading in a pond, and the proximal end of a rib, found in a spoil bank by Jerry Van Horn, in August, 1988. *Remarks*: Specimens were found when the landowners were expanding a pond, and bulldozing the spoil. The tooth was recovered from the west side of the pond, and the rib was found on the bank near the southwest end of the

pond. On August 18, 1988, J. A. Holman, D. Parmley, and L. Abraczinskas, from the Michigan State University Museum visited the site. The Van Horn family donated the specimens to the Michigan State University Museum.

Literature: Holman (1991).

BERRIEN COUNTY

1. *E.K. Warren Site*, Two miles southeast of Three Oaks, Three Oaks Township, NW ¼ of Section 24, T. 8 S., R. 20 W. *Age*: late Pleistocene. *Material*: (MSUVP 1276) right and left M^3; right and left M_3 (Figures 7 and 8) found by Ed Ingert on the Warren farm around 1900. *Remarks*: The teeth, along with a few other bones, were recovered while digging post holes. The specimens were originally deposited in the Chamberlain Memorial Museum. Upon the closing of this Museum, the teeth were cataloged into the Michigan State University Museum Collection, and are presently located in the Vertebrate Paleontology Collection. The whereabouts of the other bones is unknown. Dice (1920), Fox (n.d.), Hay (1923), Sherzer (1927), and Skeels (1962) briefly reported this site, but section and township information were not given. The Warren farm was located in the NW ¼ of Section 24, T. 8 S., R. 20 W. (*1929 Atlas of Berrien County, Michigan*. Rockford: Thrift Press). *Literature*: Dice (1920), Fox (n.d.), Hay (1923), Sherzer (1927), Skeels (1962).

EATON COUNTY

1. *Fajnor Farm, near Eaton Rapids*, on Wilcox Road, Brookfield Township, NW ¼ of Section 11, T. 1 N., R. 4 W. *Age*: late Pleistocene. *Material*: (MSUVP 1282)

partial molar found by Milton Fajnor in 1951 in debris piled up during the dredging of a ditch. *Remarks*: The specimen had been collected from a muck field. The site was briefly listed in Skeels (1962), but no section or township data were furnished. The Fajnor farm was located in the NW ¼ of Section 11, T. 1 N., R. 4 W. (*1953 Plat Book of Eaton County, Michigan*. Rockford: Lawson's Atlases and Plat Books). *Literature*: Skeels (1962).

INGHAM COUNTY

1. *Near Leslie*, three miles west of Leslie, approximately Section 24, T. 1 N., R. 2 W. *Age*: late Pleistocene. *Material*: (MSUVP 1218) right scapula left femur, right tibia, and right ulna collected in 1960. *Remarks*: The specimen was found under peat in marl. This site was briefly reported in Skeels (1962). *Literature*: Skeels (1962).

JACKSON COUNTY

1. *Locey Farm*, southeast of Eaton Rapids, Tompkins Township, in Section 17, T. 1 S., R. 2 W. *Age*: 12,200±700 ybp (M-507) based on associated wood (Crane and Griffin, 1958). *Material*: (MSUVP 1283) lower jaws with right and left M_2 and M_3 (Figure 9), two lengths of a tusk, atlas, axis, cervical vertebrae, 7 thoracic vertebrae, 12 ribs, scapulae, proximal humerus, hyoids (Figure 10), 8 wrist or ankle bones, several fragments, and leg bones dug from a marl pit. The bones were collected by John W. Hope of the MSU Museum from November 1954 to October, 1955. *Remarks*: This specimen was reported by Skeels (1962) as Michigan State University

Figure 7. Lingual surface of the left M^3 of the Warren mammoth (MSUVP 1276)

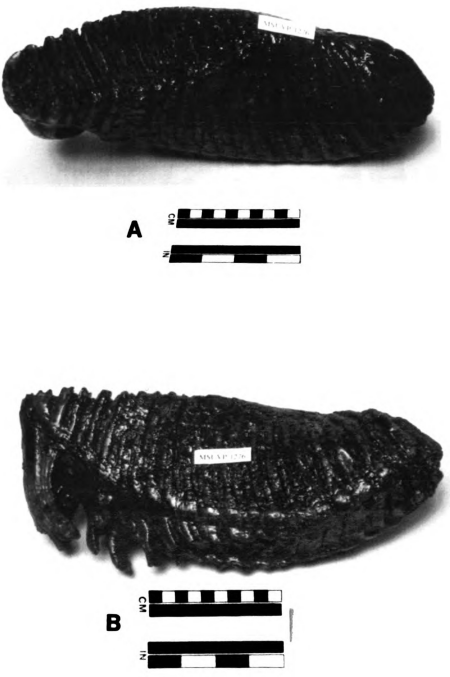

Figure 8. Left M_3 of the Warren mammoth (MSUVP 1276)
A. Occlusal surface; B. Labial surface

Figure 9. Posterior view of the Locey site mammoth jaws (MSUVP 1283)

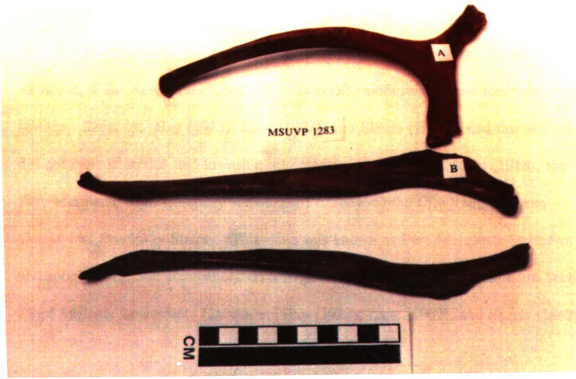

Figure 10. Hyoid bones from the Locey site mammoth (MSUVP 1283)
A. Stylohyoid; B. Thyrohyoids

Museum Number 8238. *Literature*: Crane and Griffin (1958); Skeels (1962).

SAGINAW COUNTY

1. *Père Marquette Shaft No. 2, West Saginaw*, Saginaw Township, Section 28, T. 12 N., R. 4 E. *Age*: late Pleistocene. *Material*: tooth found three feet below the surface. *Remarks*: Hay (1923), Lane (1902), and Skeels (1962) listed this site but did not include section and township information. According to Mills (1918), the Père Marquette Coal Company sunk a shaft "...beyond the City limits between Gratiot and Brockway Streets. This mine was known as Père Marquette Shaft No. 2, and soon mining was commenced on a large scale". The mine was located in Section 28 of Saginaw Township. *Literature*: Hay (1923), Lane (1902), and Skeels (1962).

SHIAWASSEE COUNTY

1. *Dysinger Farm, near Perry*, one mile away, Perry Township, Section 22, T. 5 N., R. 2 E. *Age*: late Pleistocene. *Material*: (MSUVP 1281) partial Left M_3 collected by Floyd Dysinger in September of 1953, while spreading a ridge of dirt on a field. *Remarks*: A drainage ditch which parallels the field was dredged during the winter of 1951, and it is believed that the tooth was uncovered at that time. The site was briefly listed by Skeels (1962), as Michigan State University Museum Number 8115, but section and township data were not listed. The Dysinger farm was located on Section 22, T. 5 N., R. 2 E. (*1956 Farm Plat Book, Shiawassee County, Michigan*. Rockford: Rockford Map Publishers). *Literature*: Skeels (1962)

New Michigan *Mammuthus* sp. Records

BERRIEN COUNTY

1. *Harbert Site*, Approximately ¼ mile east and ⅛ mile north of Harbert, Chikaming Township, in the SE ¼, SE ¼, SW ¼ of Section 10, T. 7 S., R. 20 W. *Age*: late Pleistocene. *Material*: (MSUVP 1275) left M_2 found 20 feet below the surface of a gravel pit, on September 5, 1925. *Remarks*: The specimen was donated to the Chamberlain Memorial Museum of Three Oaks, in December of 1925, by Mrs. J. Frankfort. When the Chamberlain Memorial Museum closed, the specimen was cataloged into the Michigan State University Museum collection in 1952. *Literature*: News article in *The Berrien County Record*, December 2, 1924.

TUSCOLA COUNTY

1. *Knight Site, near Marlette*, 2 miles north and 3 miles west, Koylton Township, SW ¼ of Section 22, T. 11 N., R. 11 E. *Age*: late Pleistocene. *Material*: (MSUVP 749) partial left scapula, rib fragments, partial fibula, pieces of tusk, and other fragments, collected by R. K. Knight on July 15, 1973. *Remarks*: The bones were said to have been collected from the surface.

Mammuthus sp. Tooth Measurements

Like the mastodont, mammoths have six teeth in each half of both the upper and lower jaws. The first three of these are milk or deciduous teeth and the last three are true molars. Mammoth teeth are composed of a series of compressed plates (called lamellae) of enamel covered dentine held together with cementum. The symbols used to denote mammoth teeth are the same as those used for the mastodont

(Skeels, 1962).

The *Mammuthus* sp. teeth in the Michigan State University Museum Vertebrate Paleontology Division were examined and measured with Sylvac-Fowler electronic calipers. Tooth placement was determined and noted with symbols (e.g. LM^3 for left third upper molar). The metrical procedure of Maglio (1973) was used to obtain measurements of length (L), width (W), height (H), plate number (P), lamellar frequency (LF), and enamel thickness (ET). The number of plates in the occluded portion of the tooth (NOP) was also recorded, after Richards (1984).

The length (L) measurement was taken perpendicular to the average lamellar plane. Width (W) was taken at the widest part of the tooth. The plate number at which this value was recorded appears as a superscript. Such references to individual plates are referred to as P1, P2, etc. when counted from the front, and PI, PII, etc. when the plates are counted from behind. The maximum crown height (H) is taken vertically along the plate from the enamel base to the highest point on its apex. The plate number is recorded as a superscript of this measurement. The plates were counted, and the lamellar frequency (LF) measured. This LF is a standard measurement of the average number of plates in a distance of 10 cm (=100mm) along the anteroposterior axis of the tooth. The most accurate LF measurement is an average of the LF's taken at the bases and apexes of the lingual and buccal surfaces of the tooth. The thickness of enamel (ET) was averaged from a series of 10 measurements from the crown. The number of plates on the occlusal surface (NOP) was counted and recorded. MSUVP 1283 consists of lower jaws with partially erupted M_3s (Figure 9), and it was not possible to take all measurements. Metrical

data for mammoth teeth in mm are presented in Table 2.

Table 2. Michigan State University Museum *Mammuthus* sp. Tooth Measurements (in mm).

MSUVP #	PLACEMENT	L	W	H	P	LF	ET	NOP
1276	RM^3	305	103^{P6}	164^{P14}	24	7.5	2	14
1276	LM^3	301	104^{P8}	183^{P15}	24	7.5	2	16
1276	RM_3	351	94^{P7}	145^{P16}	24	7	2	15
1276	LM_3	344	95^{P9}	140^{P15}	24	7	2	15
1219[a]	LM^3	270	102	165	29	9	2	14
1275	LM_2	197	71^{P10}	115^{P14}	19	10	2	17
1001	RM_3	325	99^{P9}	146^{P13}	24	8	2	19
1283[b]	LM_3	-	88^{P4}	-	-	-	3	9
1283[b]	LM_3	-	87^{P5}	-	-	-	3	10

L=length; W=width; H=height; P=plate number; LF=lamellar frequency; ET= enamel thickness; NOP=number of plates on occluded portion of tooth
[a]data after Holman (1991)
[b]partially erupted teeth in jaw
[P]plate number at which measurement was taken
-missing data

Proboscidea Indeterminate

New Michigan Records

ALLEGAN COUNTY

1. *Mathis Site*, Otsego Township, SW ¼, NW ¼ of Section 1, T. 1 N., R. 12 W. *Age*: late Pleistocene. *Material*: distal part of a femur, found by Steve Mathis in 1987 while expanding a pond; pelvic fragment; and several small bone and tusk fragments were collected by J.A. Holman, G. Larson, and L. Abraczinskas on April 15, 1988. *Remarks*: This material was found on the surface of pond matrix that was spread with a bulldozer. The femur was damaged by the bulldozer. The specimen is currently at the Michigan State University Museum for examination.

INGHAM COUNTY

1. *Wilcox Road Site*, one half mile west of Aurelius Road on Wilcox Road, Delhi Township, Section 22, T. 3 N., R. 2 W. *Age*: late Pleistocene. *Material*: one broken tusk, and 2 bones collected by Lloyd Ketchum on September 23, 1965. *Remarks*: This locality information was obtained from Michigan State University Museum files. The whereabouts of this material is unknown.

JACKSON COUNTY

1. *Near Jackson*, six miles northwest, Sandstone Township, approximately Section 11, T. 2 S., R. 2 W. *Age*: late Pleistocene. *Material*: (MSUVP 1279) poorly preserved portion of tusk and several tusk fragments collected by Leon B. Walling on September 1, 1948. *Remarks*: This specimen was reported by Skeels (1962) as a

broken mastodon tusk, Michigan State University Museum 7745. This partial tusk was identified here as Proboscidea Indeterminate due to its incomplete and fragmented condition.

KENT COUNTY

1. *Gravel Pit at Grandville*, approximately Section 17, T. 6 N., R. 12 W. *Age*: late Pleistocene. *Material*: (MSUVP 1267) poorly preserved portion of tusk uncovered by Clyde Denslow in November, 1950. *Remarks*: The specimen was uncovered with a shovel and is in the Michigan State University Museum Vertebrate Paleontology Collection.

2. *Gravel Pit in Cannon Township*, SE ¼, NE ¼ of Section 26, T. 8 N., R. 10 W. *Age*: late Pleistocene. *Material*: (MSUVP 1113) well-preserved portion of tusk excavated from sand in a gravel pit by Tom and Bernard Skipper in the summer of 1985. *Remarks*: The site was said to have been a gravel pit with a marsh next to it.

OTTAWA COUNTY

1. *Cedar Road Site*, Robinson Township, NE ¼, SE ¼ of Section 1, T. 7 N., R. 15 W. *Age*: late Pleistocene. *Material*: partial shaft of left femur (MSUVP 1286) collected by Austin Dobson in the Fall of 1966. *Remarks*: The specimen is in the Michigan State University Museum Vertebrate Paleontology Collection.

Summary of Michigan Proboscidean Records

The Michigan mammoth and Proboscidean Indeterminate records indicate that only one individual was recovered per site. For the mastodont sites, a few records indicate that more than one individual was recovered per site. These include: six specimens from Bakerstown Marsh, Berrien County (Dice, 1920; Fox, n.d.; Hay, 1923; Lane, 1902; MacAlpin, 1940); possibly two individuals from the Paw Paw River Bed, Berrien County (Hay, 1923; Hubbard, 1840,1841; MacAlpin, 1940); possibly two specimens from the Johnson site, Genesee County (Shoshani, 1989); parts of three specimens from south of Alma, Gratiot County (MacAlpin, 1940); and two individuals from Henderson in Shiawassee County (Skeels, 1962). The accuracy of these records has not been determined; some may reflect duplications of original reports, or material from one animal recovered by several persons. Until this is examined further, only one individual from each site will be counted.

After tracing the Michigan Proboscidean records through the literature, and noting the numerous duplications, new totals of Michigan Proboscideans were computed. This report includes 33 updated and 6 new mastodont sites; 7 updated and 2 new mammoth sites; and 6 new Proboscidea Indeterminate sites. The new and updated records presented this report and the list of Michigan *Mammut americanum*, *Mammuthus* sp., and Proboscidea Indeterminate sites in Appendices A, B, and C respectively, bring the total number of sites to: 211 mastodonts from 41 counties; 49 mammoths from 25 counties; and 11 Proboscidea Indeterminate records from 9 counties.

CHAPTER IV

CO-OCCURRENCE ANALYSIS

It was suggested that the large concentration of Pleistocene proboscideans in the southern part of the lower peninsula may be correlated with the occurrence of available surficial salt (Holman et al. 1988). Thus, the existence of a positive statistical correlation might enhance further research on the distribution patterns of Pleistocene proboscideans in the Great Lakes Region. Therefore, the third thesis objective was to examine the spatial relationships between proboscidean and salt sites by means of a co-occurrence analysis. Thematic maps and frequency distributions were used to show relationships between Michigan Pleistocene proboscidean sites and salt sites. The analysis involved the calculation of minimum distances from known Michigan Proboscidean sites to known salt sites. High non-random frequencies of proboscidean sites occurring near salt sites would support the hypothesis that proboscideans in Michigan utilized them.

Methods

The analysis methods include information on utilization of locality data, calculation of distances, frequency distributions, and statistical tests.

Utilization of Locality Data

Michigan proboscidean locality data from Appendices A, B, and C, and Michigan salt locality data from Appendix D were used in the analysis. This locality data exists in varying levels of spatial resolution: some sites are reported to quarter-quarter-quarter section designations, and others are only given as township names or as an unknown locality in a given county. The majority of sites reported included the section number. Because of this, the section, which is equivalent to one square-mile, was chosen as a minimum mapping unit. Sites with approximated sections were looked upon as equivalent to sites with known sections. Sites with missing section data were eliminated from the analysis. All sites were assigned code numbers.

Most of the salt locality records were provided by Dr. David Westjohn of the United States Geological Survey (Holman et al. 1988; D. Westjohn, personal communication, November 20, 1987; June 12, 1991). Only naturally-occurring salt sites that were reported as salt or saline springs, or salt licks were used in this study. Numerous records of saline wells are present in Geological Survey literature (e.g. Lane, 1899b;1900), but human-made entities such as drilled wells and borings were eliminated from the analysis, as many were drilled through layers of the bedrock and reached depths of a thousand or more feet. Because of this choice, and the fact that mastodont and mammoth sites were updated, the plotted map presented in Holman et al. (1988) and this study differ.

After selecting proboscidean sites with section data present, and omitting sites without this data, the numbers of sites used in the analysis were: 174 mastodont sites from 40 Michigan counties; 42 mammoth sites from 24 counties; 9 Proboscidea

Indeterminate sites from 8 counties; and 34 salt sites from 14 counties. These data were assigned location codes to ultimately determine the distances between proboscidean and salt sites. Data encoding maps were used to assign geographic location codes to Tier (T), Range (R), and section data from the proboscidean and salt sites. Each site was encoded with a 3-digit county code, a 2-digit political township code and a 2-digit survey township code. These codes were merged with locational information provided by the Michigan State University Center for Remote Sensing Kilometer Database. Coordinates locating the center of each identified section were determined from this database.

Calculation of Distances

Distances from each proboscidean site to each salt site were calculated from the coordinates, and the minimum distance from a proboscidean site to the nearest salt site was determined. The coordinates were transferred to the CMAP program and a thematic map was generated. The minimum distance choices were visually confirmed by comparing mapped locations with calculated distances.

Frequency Distributions

Frequency tables depicting numbers of mastodont, mammoth, and Proboscidea Indeterminate in relation to the minimum distance from salt sites were generated. There were no apparent differences between mastodonts, mammoths and Proboscidea Indeterminate groups in the separate frequency diagrams. Locality data for all Michigan proboscideans were used to generate a single frequency diagram with 5-mile increments of separation, and percentages of occurrence noted.

In order to determine if the actual Michigan proboscidean data differed from a random set of data, a set of section localities were randomly generated by the computer. The sections corresponding to these computer-generated proboscidean sites were located in the southern half of Michigan's lower peninsula, south of the Mason-Quimby line. The procedures outlined above were used to determine the minimum distances between the random set of proboscidean sites and the actual Michigan salt sites. A frequency distribution of the distances between the random proboscidean sites and the salt sites was produced. The frequency distributions of the actual and random proboscidean site distances were compared.

Statistical Tests

A statistician was consulted for recommendations on statistical methods. At first, a *t*-test on the actual and random proboscidean site distances was suggested. The *t*-test is valid for data samples from a normal distribution. After further examination of the data, it was decided that a *t*-test would be invalid because the frequency tables show the data as having non-normal distribution. Nonparametric statistical approaches are used when data do not conform to a normal distribution. Nonparametric statistical methods were explored, and it was determined that the Kolmogorov-Smirnov Two Sample and Kruskal-Wallis (Wilcoxon-Mann-Whitney Two Sample) tests are valid for these data. These tests are used for two independent samples of data (Wilkinson, 1990). The tests were carried out with the SYSTAT computer program for statistics, and the methods of Beyer (1974), Mendenhall, (1983), and Runyon and Haber (1984) for large sample sizes were applied.

The Kolmogorov-Smirnov Two Sample Test is a general test of differences between populations; it is sensitive to any differences in form or location between the groups (Campbell, 1989). This test calls for two independent samples and tests the null hypothesis that they have been drawn from the same population or from populations with the same distribution (Beyer, 1974). The data are ranked, sample cumulative distribution functions are calculated, and maximum numerical differences between them are compared (Steel and Torrie, 1980). A value (D) for the maximum difference for pairs of variables is calculated. This calculated D value is compared with a table of critical D values. The null hypothesis is rejected if the calculated D exceeds the value from the table. The SYSTAT computer program ranked the data and calculated the D value. The table of critical values of D in the Kolmogorov-Smirnov Two Sample Test for large sample sizes ($n_1 > 15$ and $n_2 > 15$) from Beyer (1974) was used to obtain the tabular D value. Tabular values at the significance levels $\alpha = .05$ and $\alpha = .10$ were obtained. The calculated and tabular D values were compared to determine rejection or non-rejection of the null hypothesis.

The Kruskal-Wallis k-Sample Test is equivalent to the Wilcoxon-Mann-Whitney U-test for $k=2$ (Steel and Torrie, 1980). This is one of the most powerful nonparametric statistical tests, since it utilizes most of the quantitative information that is inherent in the data (Runyon and Haber, 1984). It is most commonly employed as a nonparametric alternative to the t-test (Runyon and Haber, 1984). This tests the null hypothesis that the population relative frequency distributions for two samples (A and B) are identical (Mendenhall, 1983). The observations from both samples are ranked from smallest to largest and added together. These rank sums (T_A and T_B) are

used to calculate the *U*-statistic value (Mendenhall, 1983). For large sample sizes ($n_1 > 20$ and $n_2 > 20$), the distribution approaches a normal curve, and the *z*-statistic may be used to evaluate the significance of rank differences (Runyon and Haber, 1984). The *z* value is calculated and compared to a tabular *z* value. If the calculated value exceeds the tabular value, the null hypothesis is rejected. The SYSTAT computer program ranked the data, and calculated the rank sums (T_A and T_B) and the *U*-statistic value. The *T* and *U* values were applied to the *z*-statistic formula from Mendenhall (1983) to obtain the calculated and tabular *z* values. The calculated and tabular *z* values were compared to determine rejection or non-rejection of the null hypothesis.

Results

Results of the site distances, frequency distributions, and statistical tests for the co-occurrence analysis are presented.

Site Distances

The distribution of Michigan mastodont, mammoth and Proboscidea Indeterminate sites in relation to the salt sites was mapped (Figure 11). The number of calculated distances between actual Michigan proboscidean sites and salt sites was 225. The greatest distance from a proboscidean site to a salt site was 91 miles (146.42 km). The smallest distance was 0 miles (0 km). This is because there were two occurrences of proboscidean sites and salt sites in the same section.

The number of calculated distances between random proboscidean sites and actual salt sites was 225. The greatest distance from a random proboscidean site to a salt site was 90 miles (144.81 km). The smallest distance was 2 miles (3.22 km).

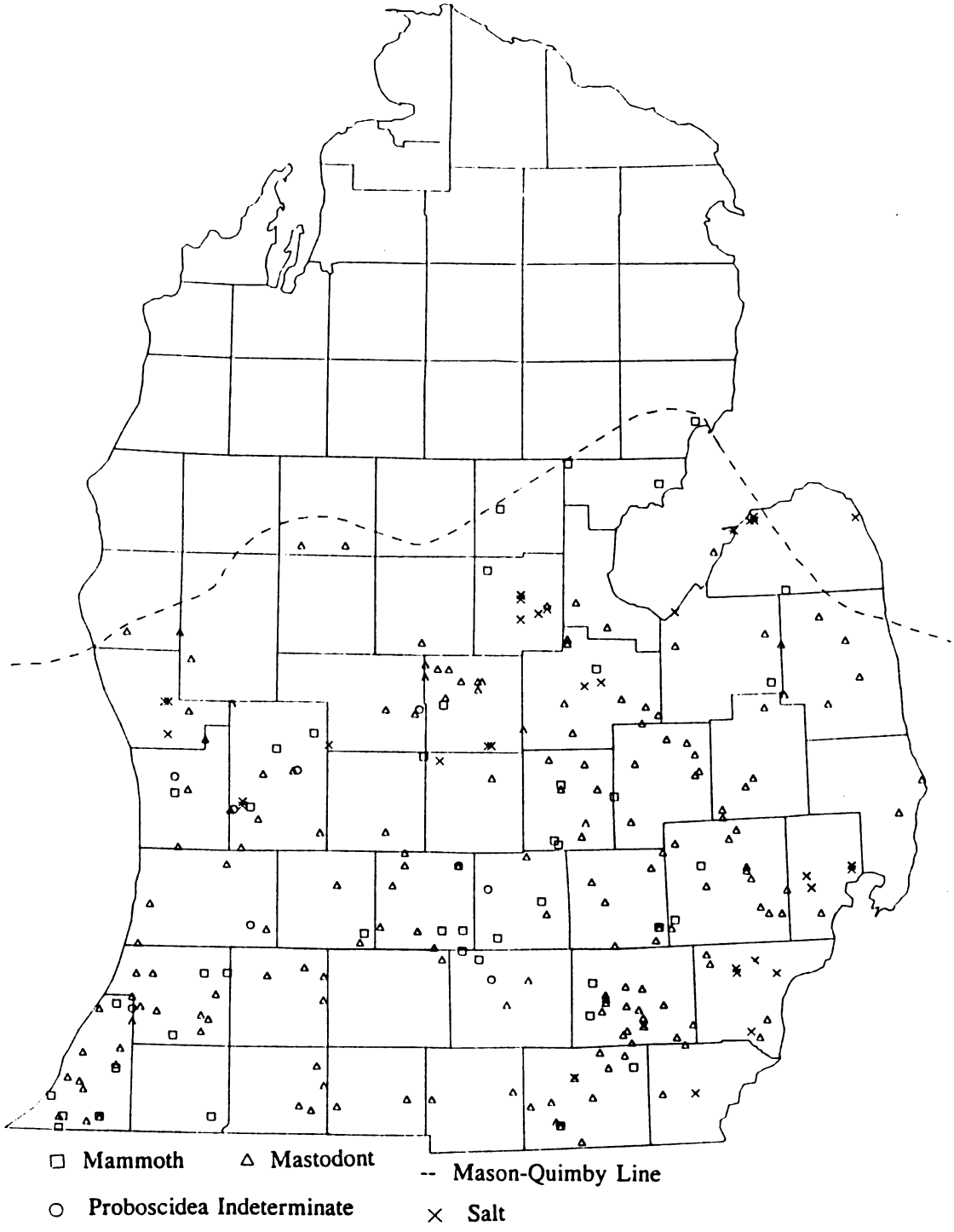

Figure 11. The distribution of Pleistocene proboscideans and salt sites in Michigan

Thirty-five percent of Michigan proboscidean sites were located within 19.9 miles of a salt site (Figure 12). Twenty-nine percent of the random proboscidean sites were located within 19.9 miles of a salt site (Figure 13).

Statistical Tests

The Kolmogorov-Smirnov Two Sample method tests the null hypothesis that the two samples come from identical distributions. The value *D* for the maximum differences for pairs of variables was calculated by SYSTAT to be .058. The tabular *D* values are .1282(α=.05) and .1150(α=.10). Since the calculated *D* value does not exceed either tabular *D* value, the null hypothesis is not rejected. The calculated values are not significant at the levels α=.05 and α=.10.

The Kruskal-Wallis (Wilcoxon-Mann-Whitney *U*) tests the null hypothesis that the frequency distributions for the two samples are identical. The rank sum values are T_A=51434.0 for the random site distances; and T_B=50041.0 for the actual site distances. The *U*-statistic is 26009.0. The calculated *z* value is .5049, and the tabular *z* values are 1.96(α=.05) and 1.645(α=.10). The tabular *z* value for α=.50 is .674. Since the calculated *z* value does not exceed any of the tabular *z* values, the null hypothesis is not rejected.

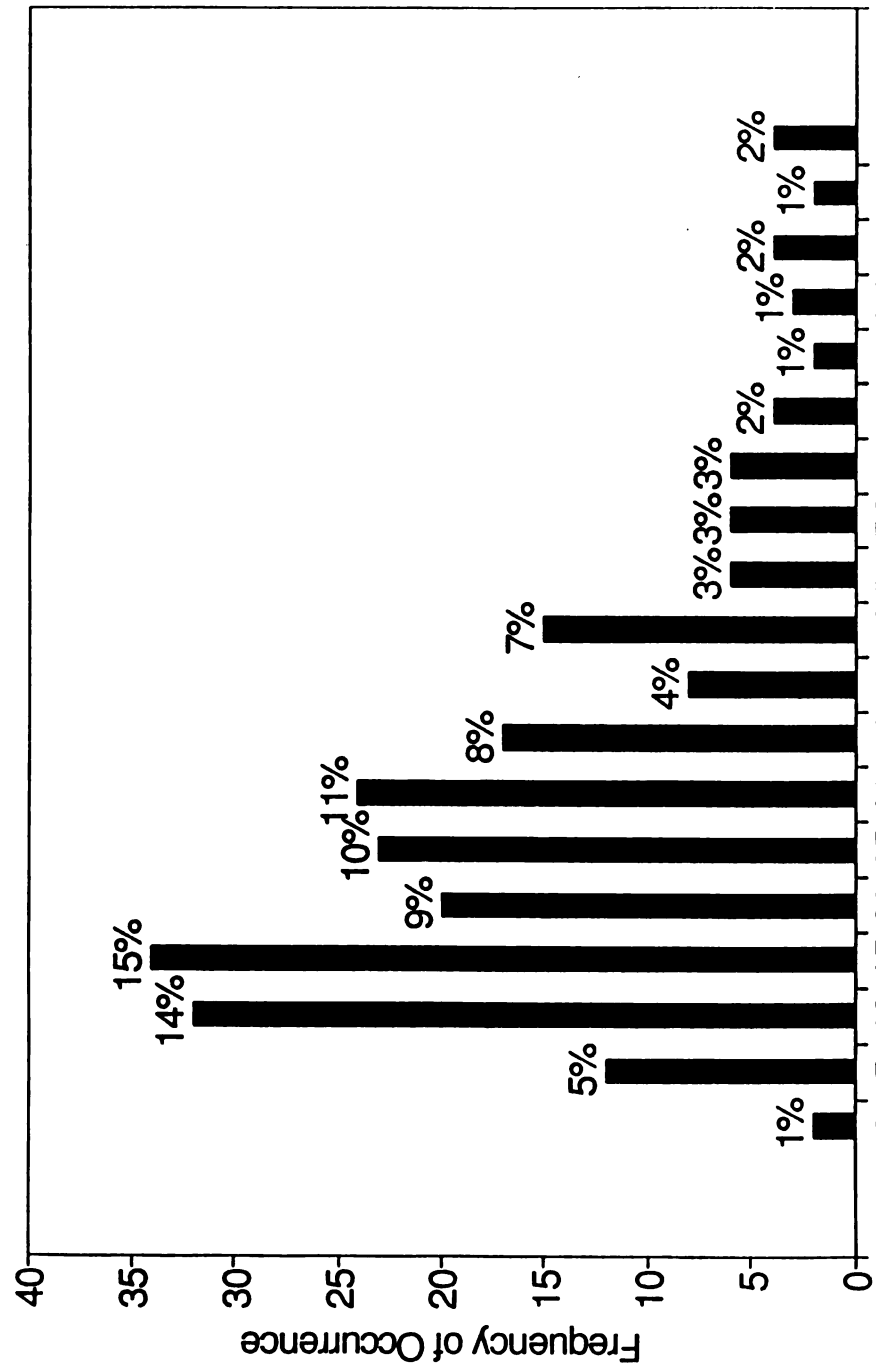

Figure 12. Frequency distribution of proboscidean sites relative to distance from salt

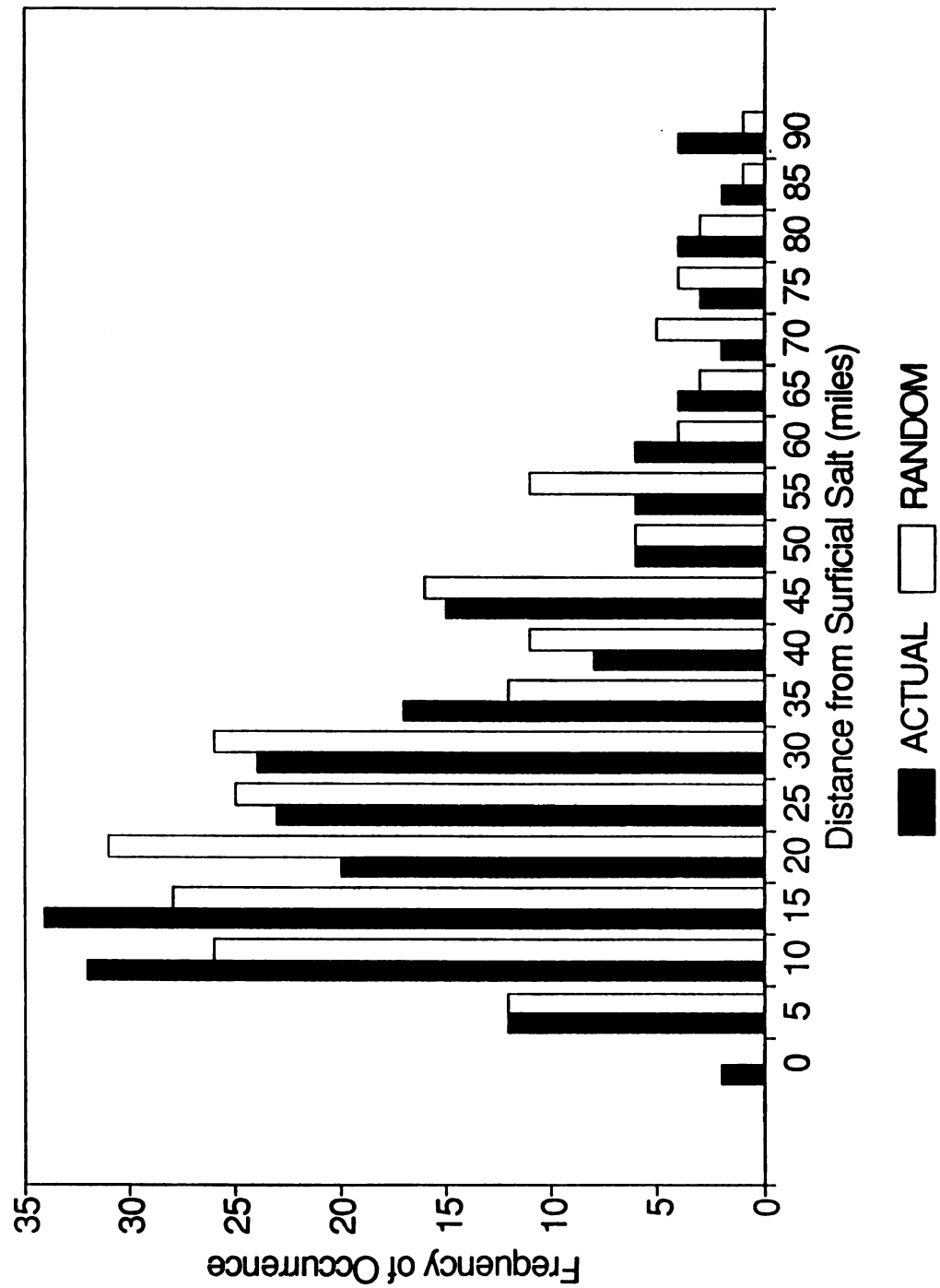

Figure 13. Frequency distributions of actual and random proboscidean sites relative to distance from salt

CHAPTER V

DISCUSSION

The goal of this project was to determine the spatial relationship between surficial salt sites and sites where proboscidean remains have been found. Four objectives were met in pursuit of this goal:

1) Previously published Michigan proboscidean records were updated. The literature and museum records were re-examined, duplicated records were consolidated and additional information on 33 mastodont and 7 mammoth sites was added.

2) New or unpublished records were reported on 6 mastodont, 2 mammoth, and 6 Proboscidea Indeterminate sites. These sites were compiled from older Michigan State University Museum records, and from persons who notified the Michigan State University Museum upon discovering proboscidean remains.

3) The locations of Michigan proboscidean remains and salt sites were mapped after proboscidean site totals were computed. These include 211 mastodonts from 41 counties, 49 mammoths from 25 counties and 11 Proboscidea Indeterminate sites from 9 Michigan counties. All of the salt and proboscidean sites are located in the southern half of Michigan's lower peninsula, below the Mason-Quimby line.

4) A spatial co-occurrence analysis was conducted to examine the relationship between Michigan proboscidean sites and surficial salt localities. Although thirty-five percent of Michigan proboscidean sites were located within 20 miles of a salt site, the results of the co-occurrence analysis show that the spatial arrangement of proboscidean sites and surficial salt sites is not significantly different from a random distribution.

Although these results do not support the idea that the concentration of proboscideans in Michigan is related to surface salt sites, they do not invalidate it. Moreover, the idea that the primitive sodium metabolism in proboscideans may have been related to their high rate of extinction during the Pleistocene is worthy of further study. The validity of this idea and need for continued study is emphasized by Parker and Toots (1980), who stress the importance of utilizing trace elements in skeletal components as paleobiological indicators:

> Evolution of physiological adaptations does not necessarily parallel evolution of skeletal parts and dentition. Proboscideans are highly advanced in the evolution of their dentition but are primitive in their sodium metabolism. Because of the latter fact, distribution of elephants in modern Africa is closely correlated with high environmental sodium levels (Weir, 1972), and elephants are known to depend on food that is particularly rich in sodium (Dougall et al. 1964; Laws et al. 1975). This is also reflected in the high sodium levels of fossil proboscideans (normalized mean Na percentage = 0.68) and may be a factor in the unusually high rate of extinctions of proboscideans during the Pleistocene. One should keep this factor in mind when theorizing about the extinction of such high sodium groups of mammals as titanotheres or oreodonts, as an animal with a poorly developed sodium metabolism would be more vulnerable to environmental stress, and at a disadvantage in competition with better-adapted animals (Parker and Toots 1976).

Analytic Limitations and Suggestions

There are limitations to this analysis that relate to both the proboscidean sites and the salt sites. An obvious restriction in studies involving extinct animal remains is the absence of observable living animals. In essence, this spatial analysis was based on localities where the animals died and became preserved; which for various reasons might be rather remote from their salt-procuring areas.

The number of utilized sites may have restricted this analysis, as only 34 salt sites and 225 proboscidean sites were considered valid. A conservative approach was taken in considering the validity of the salt sites as only sites reported as salt or saline springs, or salt licks were used and many human-made borings and drilled wells were not considered. Thus, the salt localities plotted in Holman et al. (1988) and this analysis differ. Moreover, 46 proboscidean records were not used because they could not be accurately assigned to the proper section.

The early work of State Geologist Douglass Houghton included documenting 72 sections of land exhibiting evidence of surface saline water (Cook, 1914). Some of these sections are documented in early state geological reports (Houghton, 1838; Hubbard, 1839; Douglass, 1840) but a comprehensive list of these could not be located. A continued search for these salt sites and a re-examination of the salt data may provide additional valid salt localities, and possibly different results.

Repeating this analysis with additional salt and proboscidean sites may give more supportive evidence relative to the distribution of proboscideans around salt sites. An analysis that incorporated Douglass Houghton's list of 72 salt sections, and re-examined salt data would be worthwhile. Also, the elimination of approximated

and estimated sites from the analysis could remove error and may produce different results. The completed co-occurrence analysis included only one randomization that was compared with the actual data and tested for significant differences between the groups. A comparison of several randomizations with the actual data would be interesting and also may produce different results. Hopefully, more proboscidean and salt sites will come to light and additional analyses can be made.

APPENDICES

APPENDIX A

MICHIGAN MASTODONT DATA

COUNTY	SITE NAME	1/4	1/4	1/4	SECTION	TIER	RANGE	MIN#	REFERENCES
Allegan	Keith Site/Plainwell	SE	NW	NW	10	1N	11W	1	Skeels(1962),LA thesis
Allegan	Gun River				–	1N	11W	1	MacAlpin(1940)
Allegan	N of South Haven				32	1N	16W	1	Skeels(1962)
Allegan	SW of Fennville				11*	2N	16W	1	MacAlpin(1940)
Allegan	Fleser Site/W of Door				24	4N	13W	1	Hay(1923),MacAlpin(1940),Lane(1902),LAthesis
Barry	Beavers Site	SE	NE	SE	28	1N	7W	1	LA thesis
Barry	Hastings				16*	3N	8W	1	MacAlpin(1940)
Barry	Possibly Carlton Township				–	4N	8W	1	MacAlpin(1940)
Bay	Frankenlust			SW	1	13N	4E	1	Lane(1902),MacAlpin(1940)
Bay	Auburn/Williams Township			SW	3	14N	3E	1	Hay(1923),Lane(1902,1906),MacAlpin(1940)
Berrien	Watervliet Site		NW	NE	1	3S	17W	1	Skeels(1962)
Berrien	Hager Township Site		SE	NE	22	3S	18W	1	Skeels(1962)
Berrien	SE of Watervliet				1*	4S	17W	1	MacAlpin(1940)
Berrien	Adams Farm				9*	5S	17W	1	Skeels(1962)
Berrien	Eau Claire				32	5S	17W	1	Dice(1920),Fox(nd),Hay(1923),Lane(1902),MacAlpin(1940),LAthesis
Berrien	Berndt Site				13	5S	19W	1	Holman et al.(1986),Wilson(1967)
Berrien	Baroda		NE	SE	17	6S	19W	1	MacAlpin(1940)
Berrien	S of Baroda/Beebe Farm				23*	6S	19W	1	Dice(1920),Fox(nd),Hay(1923),MacAlpin(1940)
Berrien	Snow				36	6S	19W	1	Dice(1920),Fox(nd),MacAlpin(1940)
Berrien	Bakerstown Marsh/Buchanan				3	8S	18W	6?	Dice(1920),Fox(nd),Hay(1923),Lane(1902),MacAlpin(1940)
Berrien	TerreCoupe/Dayton/E of Galien			NE	7	8S	18W	1	Hay(1923),Lapham(1855),MacAlpin(1940),Warren(1855), Winchell(1864),LA thesis
Berrien	E of Three Oaks/Avery Marsh				1*	8S	20W	1	Dice(1920),Fox(nd),MacAlpin(1940)
Berrien	Paw Paw River Bed				–	–	–	2?	Hay(1923),Hubbard(1840,1841),MacAlpin(1940)
Branch	Quincy,in a Marl Lake				–	6S	5W	1	MacAlpin(1940)
Branch	Archer's Lake Site				5*	7S	5W	1	MacAlpin(1940)
Branch	Bronson Site				16	7S	8W	1	Holman et al.(1986)
Calhoun	Heisler Site	SE	NE	NE	14	1S	4W	1	Bearss and Kapp(1987),Holman et al.(1986),Shoshoni(1989)
Calhoun	Along Rice Creek				–	–	–	1	Skeels(1962)
Clinton	Avery Road Site				2*	7N	2W	1	Skeels(1962)

MICHIGAN MASTODONT DATA (CONTINUED)

Eaton	Narrow Lake/Ozeltine Site				33*	1N	4W	1	MacAlpin(1940),LA thesis
Eaton	Northeast of Olivet			NW	11	1N	5W	1	Hay(1923),Lane(1902),MacAlpin(1940)
Eaton	Bellevue/Cummings Farm			SW	5	1N	6W	1	Hay(1923),MacAlpin(1940),LA thesis
Eaton	Vermontville Site	NE	SE	SW	14	3N	6W	1	LA thesis
Eaton	NW of Millet			SW	21	4N	3W	1	MacAlpin(1940)
Eaton	Van Neste Farm Site		NW	NW	5	4N	5W	1	Skeels(1962),LA thesis
Eaton	Parker Site			SW	20	4N	5W	1	Holman et al.(1986),LA thesis
Genesee	Ray Road Site				35	6N	5E	1	Holman et al.(1986), Wilson(1967)
Genesee	Cole Site				–	6N	5E	1	Holman et al.(1986)
Genesee	Davison				4	7N	8E	1	MacAlpin(1940)
Genesee	Flushing Site			NE	24	8N	5E	1	Skeels(1962)
Genesee	Johnson Site				9	8N	8E	2?	Fisher(1984b),Holman et al.(1986),Shoshani(1989),LA thesis
Genesee	Cullen Site/Near Davison			NW	34	8N	8E	1	Hay(1923),MacAlpin(1940),LA thesis
Genesee	Richfield Township				–	8N	8E	1	Skeels(1962)
Genesee	Taylor Site				20	9N	7E	1	Fisher(1984b),Holman et al.(1986)
Genesee	Otisville				30	9N	8E	1	MacAlpin(1940)
Genesee	Unknown locality near Flint				–	–	–	1	Skeels(1962)
Genesee	Unknown locality near Davison				–	–	–	1	Skeels(1962)
Gladwin	Unknown locality near Beavertown				–	17N	1,2W	1	MacAlpin(1940)
Gratiot	St. Louis, 3 mi SE				4*	11N	2W	1	Skeels(1962)
Gratiot	Ruskovic Site/N of Ithaca			SW	5	11N	2W	1	Holman et al.(1986),Skeels(1962)
Gratiot	Smith Site		SW	NE	17	11N	2W	1	Hay(1923),Holman et al.(1986),MacAlpin(1940),MacCurdy(1920), Oltz and Kapp(1963),Skeels(1962)
Gratiot	South of Alma		NE	NE	3	11N	3W	3?	Hay(1923),MacAlpin(1940),MacCurdy(1920)
Gratiot	Shaffer Site				25	11N	4W	1	Holman et al.(1986)
Gratiot	Lentz Site		NW	NW	19	12N	3W	1	LA thesis
Gratiot	Thaller Site	SE	NE	NE	18	12N	4W	1	Held and Kapp(1969),Holman et al.(1986)
Gratiot	Pitt Farm Site			NW	22	12N	4W	1	Hay(1923),MacAlpin(1940),MacCurdy(1920),Oltzand Kapp(1963)
Gratiot	Riverdale				31	12N	4W	1	Hay(1923),MacAlpin(1940)
Hillsdale	Church/Wood-Stafford Farm			NE	27	6S	1W	1	Gilmore(1906),Hay(1923),Lane(1902),MacAlpin(1940),LAthesis
Hillsdale	Near Hemlock Lake				5	7S	4W	1	Skeels(1962)
Huron	Island near Sebewaing				10*	16N	9E	1	MacAlpin(1940)
Ingham	Sheathelm Site				19	2N	2E	1	Holman et al.(1986),Holman(1986)
Ingham	Gulick Road Site				9	4N	1E	1	Holman et al.(1986)
Ingham	Unknown locality W of Fowlerville				–	–	–	1	Skeels(1962)
Ionia	Crandell Site				9	5N	6W	1	Holman et al.(1986)
Isabella	Near Mt. Pleasant/Fremont Twp		SW	SW	24	13N	5W	1	MacAlpin(1940),LA thesis
Isabella	Near Winn				24	13N	5W	1	Holman et al.(1986)
Jackson	Root State Prison Farm				8	2S	1E	1	MacAlpin(1940)

MICHIGAN MASTODONT DATA (CONTINUED)

Jackson	Unknown locality on Portage Creek			–	2S	1W	1	MacAlpin(1940)
Jackson	Unknown locality near Jackson			–	2,3S	1W	1	MacAlpin(1940)
Jackson	Near Jackson			9	3S	1W	1	MacAlpin(1940)
Kalamazoo	West end of Sherman Lake			30or31	1S	9W	1	Skeels(1962)
Kalamazoo	Fort Custer Military Reservation			1or2	2S	9W	1	Skeels(1962)
Kalamazoo	Kalamazoo			3	2S	11W	1	MacAlpin(1940)
Kalamazoo	Valley Flat of Kalamazoo River			–	2S	11W	1	MacAlpin(1940)
Kalamazoo	Vanmiddlesworth Site			1	3S	9W	1	Holman et al.(1986),LA thesis
Kent	NE Part of Bowne Township			11*	5N	9W	1	Skeels(1962)
Kent	Ross/Zuidema Farm			34	5N	12W	1	Hatt(1965b),Lambie(1933),MacAlpin(1940)
Kent	Kramer/Buck Creek Drainage Ditch			29	6N	11W	1	Frankforter(1966),Wilson(1967)
Kent	Smith Site			18	6N	12W	1	Shoshoni(1989),Fisher(1990)
Kent	Cannonsburg/Dutmer Site		SW	27	8N	10W	1	Hay(1923),MacAlpin(1940),LA thesis
Kent	Plainfield Heights Site		SW	33	8N	11W	1	LA thesis
Kent	Shaw Farm Site		NE	6	10N	12W	1	Frankforter(1991),LA thesis
Kent	Unknown, N of Grand Rapids			–	–	–	1	Skeels(1962)
Lapeer	Hadley			21	6N	9E	1	MacAlpin(1940)
Lapeer	Big Fish Lake			33	6N	9E	1	MacAlpin(1940)
Lapeer	Southeast of Lapeer			14	7N	10E	1	Skeels(1962)
Lapeer	Van Sickle Site			28	7N	10E	1	Fisher(1984b),Holman et al.(1986)
Lapeer	Rappuhn Site	NE	SW	21	10N	11E	1	Hatt(1965b),Holman et al.(1986),Kapp(1985),Skeels(1962), Wittry(1965)
Lapeer	Possibly near Clifford			–	10N	11E	1	MacAlpin(1940)
Lenawee	Gregg Site/Clinton		SE	7	5S	4E	1	Hay(1923),Lane(1902),MacAlpin(1940),LAthesis
Lenawee	Tecumseh			33	5S	4E	1	MacAlpin(1940)
Lenawee	NE of Tecumseh			18	5S	5E	1	Skeels(1962)
Lenawee	Decker/NW of Adrian			7	6S	3E	1	Hay(1923),MacAlpin(1940),Winchell(1864),LAthesis
Lenawee	Cadmus Road Site			17	7S	1E	1	Holman et al.(1986)
Lenawee	Clayton		SE	7	7S	2E	1	Hay(1923),MacAlpin(1940)
Lenawee	Adrian			2	7S	3E	1	MacAlpin(1940),Winchell(1864)
Lenawee	Seneca Township			5	8S	2E	1	Skeels(1962)
Lenawee	Seneca			9*	8S	2E	1	MacAlpin(1940)
Lenawee	S of Weston			32	8S	3E	1	MacAlpin(1940)
Livingston	Putnam Township		SW	36	1N	4E	1	Skeels(1962)
Livingston	Green Oak			11*	1N	6E	1	Hay(1923),MacAlpin(1940),Winchell(1861,1864)
Livingston	Four Lakes Drive Site			27	1N	6E	1	Holman et al.(1986)
Livingston	SW of Howell			3*	2N	4E	1	Hay(1923),MacAlpin(1940)
Livingston	Adams Site			7	3N	4E	1	Holman et al.(1986),Holman(1979)
Livingston	Shiawassee River/Howell Twp			–	3N	4E	1	Hay(1923),Lane(1902),MacAlpin(1940)

MICHIGAN MASTODONT DATA (CONTINUED)

Livingston	Tyrone			27	4N	6E	1	MacAlpin(1940)
Livingston	Unknown locality in Tyrone Twp			–	4N	6E	1	MacAlpin(1940)
Livingston	Unknown locality Near Fowlerville			–	–	–	1	Skeels(1962)
Macomb	S of Mt. Clemens			33*	2N	13E	1	MacAlpin(1940)
Macomb	Clinton R Valley/Leech Farm/Utica		NE	31	3N	12E	1	Hay(1923),MacAlpin(1940),Winchell(1864)
Macomb	Unknown locality in Macomb Co.			–	–	–	1	Hubbard(1841),MacAlpin(1940)
Midland	Midland Country Club			9	14N	2E	1	Skeels(1962)
Midland	Near Midland			–	14N	2E	1	Holman et al.(1986)
Midland	Unknown locality in Midland Twp			–	14N	2E	1	MacAlpin(1940)
Monroe	Oakville			3	5S	7E	1	MacAlpin(1940)
Monroe	Petersburg			3*	7S	6E	1	Hay(1923),MacAlpin(1940),Winchell(1864)
Montcalm	Eldridge Site		SW	15	10N	5W	1	Shoshani(1989)
Montcalm	Stanton/Hodges Site		SW	9	10N	6W	1	Hay(1923),MacAlpin(1940),LA thesis
Montcalm	Unknown Locality near Stanton			–	–	–	1	Skeels(1962)
Muskegon	Unknown locality Fruitport Twp			–	9N	16W	1	MacAlpin(1940)
Muskegon	N of Moorland/McKay Site	NE	NE	16	10N	14W	1	Frankforter(1966),Hay(1923),Lane(1906),MacAlpin(1940),Wilson(1967)
Newaygo	Jolman Site		SW	10	12N	14W	1	Gilbert(1981),Holman et al.(1986),LA thesis
Newaygo	Unknown locality near Whitecloud			–	13N	12W	1	MacAlpin(1940)
Newaygo	NW of Fremont			7*	13N	14W	1	Skeels(1962)
Oakland	Near New Hudson			8	1N	7E	1	Fisher(1984b),Holman et al.(1986)
Oakland	Bloomfield Hills Mastodont			24	2N	10E	1	Case and Stanley(1935)
Oakland	Birmingham			32*	2N	11E	1	MacAlpin(1940)
Oakland	Troy Township		NW	35	2N	11E	1	Hatt(1965b)
Oakland	Troy Juvenile (CIS 892)			–	2N	11E	1	Holman et al.(1986)
Oakland	Groleau-White Lake Site			23	3N	8E	1	Holman et al.(1986),Dorr et al.(1982)
Oakland	Mastodont of Pontiac			4	3N	10E	1	Hatt(1963,1965b),Stoutamire and Benninghoff(1964)
Oakland	Pontiac Twp Juvenile	SW	NE	15	3N	10E	1	Hatt(1965a,b)
Oakland	Calwell Farm Site/Fenton			6	4N	7E	1	Hay(1923),MacAlpin(1940),Winchell(1864),LAthesis
Oakland	Green Site/Near Eames			33*	4N	10E	1	Holman et al.(1986),LA thesis
Oakland	Near Holly			27or32	5N	7E	1	Skeels(1962)
Oakland	Shelton Site	SE	SE	26	5N	9E	1	Holman et al.(1986),Shoshani(1989),Shoshoniet al.(1989)
Oakland	Mosher Site	SW	NW	18	5N	10E	1	Shoshani(1989)
Oceana	Huls Site	SW	SW	12	13N	17W	1	Holman et al.(1986),LA thesis
Osceola	Near Evart			23	17N	8W	1	Holman et al.(1986)
Osceola	Hersey		NE	24	17N	10W	1	MacAlpin(1940)
Ottawa	E of Holland			31*	5N	14W	1	Skeels(1962)
Ottawa	Allendale		SW	21	7N	14W	1	MacAlpin(1940)
Ottawa	Jonio Farm Site/Conklin		NW	19	9N	13W	1	MacAlpin(1940),Skeels(1962),LA thesis
Saginaw	NE of Elsie	SE	SW	4	9N	1E	1	Hay(1923),MacAlpin(1940)

MICHIGAN MASTODONT DATA (CONTINUED)

Saginaw	Unknown locality in Chapin Twp		--	9N	1E	1	MacAlpin(1940)
Saginaw	Chesaning		9*	9N	3E	1	MacAlpin(1940)
Saginaw	Willis Farm		6	10N	3E	1	Hay(1923),Lane(1902),LA thesis
Saginaw	Mauer Site		9	10N	6E	1	Holman et al.(1986),LA thesis
Saginaw	NE of Birch Run		24*	10N	6E	1	MacAlpin(1940)
Saginaw	Frankenmuth	SW	32	10N	6E	1	Skeels(1962)
Saginaw	S of Bridgeport		33*	11N	5E	1	MacAlpin(1940)
Saginaw	NW of Saginaw		20	13N	3E	1	Hay(1923),Lane(1902),MacAlpin(1940)
Saginaw	Near Freeland	NW	29	13N	3E	1	Skeels(1962)
Saginaw	Unknown locality near St. Charles		--	--	--	1	Skeels(1962)
St. Claire	N of St. Claire		2	5N	16E	1	MacAlpin(1940)
St. Claire	Lake Huron Shore at Port Huron		35*	7N	17E	1	MacAlpin(1940)
St. Claire	Unknown Locality on Huron Shore		--	--	--	1	MacAlpin(1940)
St. Joseph	Blake Site		27	5S	9W	1	Holman et al.(1986)
St. Joseph	SE of Colon		24	6S	9W	1	MacAlpin(1940)
St. Joseph	Zeller Site		21or22	7S	9W	1	Holman et al.(1986)
St. Joseph	Prairie Lake		13*	7S	10W	1	MacAlpin(1940),LA thesis
Sanilac	Marlette		5	10N	12E	1	MacAlpin(1940)
Sanilac	Elk Township Site		19	10N	14E	1	Holman et al.(1986)
Sanilac	Ellembaum Site		20*	11N	15E	1	LA thesis
Sanilac	NE of Kingston		6*	12N	12E	1	MacAlpin(1940)
Sanilac	Bryce Site		2	12N	14E	1	Holman et al.(1986),Weston and McMillion(1973)
Sanilac	Argyle Township Site		2	13N	13E	1	Holman et al.(1986),Skeels(1962)
Sanilac	Unknown locality near Crosswell		--	--	--	1	Skeels(1962)
Sanilac	Unknown Locality		--	--	--	1	MacAlpin(1940)
Shiawassee	Vanagon Site		14	5N	3E	1	Holman et al.(1986)
Shiawassee	Unknown locality near Byron		--	5N	4E	1	Skeels(1962)
Shiawassee	Warren Site/Bancroft		36	6N	3E	1	Hay(1923),Lane(1906),MacAlpin(1940),LAthesis
Shiawassee	Owosso		24*	7N	2E	1	MacAlpin(1940)
Shiawassee	Venice/Johnson Site		21	7N	4E	1	Hay(1923),MacAlpin(1940)
Shiawassee	Henderson		16	8N	2E	2?	Skeels(1962)
Shiawassee	Near Corunna		24	8N	3E	1	Skeels(1962)
Tuscola	Gilford		26	13N	7E	1	MacAlpin(1940)
Tuscola	S of Cass City		21*	13N	11E	1	MacAlpin(1940)
Tuscola	Unknown Locality near Cass City		--	14N	11E	1	MacAlpin(1940)
Van Buren	Almena Township		33	2S	13W	1	Skeels(1962)
Van Buren	Shine Site		2	2S	16W	1	Holman et al.(1986)
Van Buren	NW of Hartford		6*	2S	16W	1	MacAlpin(1940)
Van Buren	Lawton		31*	3S	13W	1	MacAlpin(1940)

MICHIGAN MASTODONT DATA (CONTINUED)

Van Buren	Paw Paw River valley flat				26*	3S	14W	1	MacAlpin(1940)
Van Buren	Pine Creek Site				17	3S	16W	1	Holman et al.(1986)
Van Buren	Heuser Site				24	3S	16W	1	Skeels(1962),LA thesis
Van Buren	Near Hartford				--	3S	16W	1	Holman et al.(1986),LA thesis
Van Buren	Powers Site		NE	SW	14	4S	14W	1	Garland and Cogswell(1985),Holman et al.(1986)
Van Buren	Unkn locality near PawPaw Lake				--	--	--	1	MacAlpin(1940)
Van Buren	Unknown locality in County				--	--	--	1	MacAlpin(1940)
Washtenaw	Kuhl Site				33	2S	4E	1	Holman et al.(1986),LA thesis
Washtenaw	Scio Farms Estates Site	SE	NW	SE	20	2S	5E	1	LA thesis
Washtenaw	Killin Gravel Pit Site				25	2S	5E	1	Holman et al.(1986),LA thesis
Washtenaw	Freedom Township			NE	4	3S	4E	1	Skeels(1962)
Washtenaw	Rogers Corners				9	3S	4E	1	MacAlpin(1940)
Washtenaw	Pleasant Lake Site				20	3S	4E	1	Fisher(1984a,b),Holman et al.(1986),Shipman et al.(1984)
Washtenaw	Lodi Township		SW	SW	17	3S	5E	1	Skeels(1962)
Washtenaw	Lodi Township				23	3S	5E	1	MacAlpin(1940)
Washtenaw	Saline				36*	3S	5E	1	Hay(1923),MacAlpin(1940)
Washtenaw	Sakstrup Site				14	3S	6E	1	Holman et al.(1986)
Washtenaw	S of Saline				12*	4S	5E	1	MacAlpin(1940)
Washtenaw	SW of Saline				17*	4S	5E	1	MacAlpin(1940)
Washtenaw	W of Saline				19*	4S	5E	1	MacAlpin(1940)
Washtenaw	NE of Macon		SW	SE	33	4S	5E	1	MacAlpin(1940)
Washtenaw	SE of Ypsilanti/Darling Farm				12	4S	7E	1	Hay(1923),MacAlpin(1940),Russell and Leverett(1908),LA thesis
Washtenaw	Near Milan				29	4S	7E	1	Skeels(1962)
Wayne	Hollis Site				15	1S	8E	1	Holman et al.(1986)
Wayne	Near Plymouth/Shattuck Site				26*	1S	8E	1	Hay(1923),MacAlpin(1940),Winchell(1861),LAthesis
Wayne	Unknown Locality in T3S R11E				--	3S	11E	1	MacAlpin(1940)
Wayne	Trenton/Vreeland Farm/Monguegon		NW	NE	12	4S	10E	1	Hay(1923),MacAlpin(1940),Skeels(1962)
Wayne	East of Flat Rock				34*	4S	10E	1	Hatt(1965b)

* Approximate Locality
-- Missing Data
LA thesis: Site information listed in this document

APPENDIX B

MICHIGAN MAMMOTH DATA

COUNTY	SITE NAME	1/4	1/4	1/4	SECTION	TIER	RANGE	MIN#	REFERENCES
Arenac	N of Au Gres				1*	19N	6E	1	Skeels(1962)
Arenac	Van Horn Site	SE	NE	NW	8	20N	3E	1	Holman(1991),LA thesis
Barry	N of Assyria			NW	15	1N	7W	1	Skeels(1962)
Berrien	Near Watervliet			NE	17	3S	17W	1	Holman et al.(1986),Wilson(1967)
Berrien	Prillwitz Site				5	6S	17W	1	Green(1967),Holman et al.(1986),Wilson(1967)
Berrien	SW part of Lake Twp				--	6S	19W	1	Skeels(1962)
Berrien	Harbert Site	SE	SE	SW	10	7S	20W	1	LA thesis
Berrien	Bakerstown Marsh				3	8S	18W	1	Hay(1923),Skeels(1962)
Berrien	Beeson-Holden Farm/Galien Twp			NE	6	8S	19W	1	Dice(1920),Fox(nd),Skeels(1962)
Berrien	Warren Site			NW	24	8S	20W	1	Dice(1920),Fox(nd),Hay(1923),Sherzer(1927),Skeels(1962),LAthesis
Berrien	Berrien Co., Unknown Locality				--	--	--	1	Dice(1920),Fox(nd),Skeels(1962)
Cass	Jones/Chapel Hill School			NW	32	7S	13W	1	Case et al.(1935),Skeels(1962)
Eaton	Eaton Rapids/Fry Site				10*	1N	3W	1	Hay(1923),Lane(1906),Sherzer(1927),Skeels(1962)
Eaton	Fajnor Farm/Near Eaton Rapids			NW	11	1N	4W	1	Skeels(1962),LA thesis
Eaton	N of Grand Ledge/Tabor Site				--	--	--	1	Hay(1923),Lane(1902),Skeels(1962)
Eaton	Unknown locality near Charlotte				--	--	--	1	Skeels(1962)
Genesee	Lennon/Flint Site				31	7N	5E	1	Holman et al.(1986),Oltz and Kapp(1963)
Gladwin	Unknown locality near Gladwin				6*	18N	1W	1	Sherzer(1927),Skeels(1962)
Gratiot	W of Ithaca				2	10N	4W	1	Skeels(1962)
Huron	Sweeney Site				33	15N	12E	1	Holman et al.(1986),Weston and McMillion(1973)
Ingham	Near Leslie				24*	1N	2W	1	Skeels(1962),LA thesis
Ingham	Mead Site		NW	NE	1	2N	1E	1	Holman(1979),Holman et al.(1986)
Ionia	Hubbardston/Bed of Fish Creek				12*	8N	5W	1	Skeels(1962)
Iosco	Henry Site				18	22N	8E	1	Holman et al.(1986)
Jackson	Locey Farm				17	1S	2W	1	Crane and Griffin(1958),Skeels(1962),LA thesis
Jackson	Betz Site				3	1S	3W	1	Holman et al.(1986)
Jackson	Northern Part of Jackson County				--	--	--	1	Sherzer(1927),Skeels(1962)
Kent	Plaster Creek/S of Grand Rapids				12*	6N	12W	1	Skeels(1962)
Kent	NE Grand Rapids, 15 mi.				9*	9N	9W	1	Skeels(1962)

MICHIGAN MAMMOTH DATA (CONTINUED)

Kent	Rockford		36*	9N	11W	1	Skeels(1962)
Kent	Nine Mile Road/Grand Rapids		--	--	--	1	Skeels(1962)
Lenawee	E of Ridgeway		33*	5S	5E	1	Skeels(1962)
Lenawee	Seneca Twp Site		9	8S	2E	1	Holman et al.(1986)
Livingston	American Aggregates Gravel Pit		11*	1N	6E	1	Holman et al.(1986)
Macomb	Unknown locality		--	--	--	1	Hay(1923),Lane(1902),Skeels(1962),Winchell(1861)
Midland	Bailer Site	SW	22	16N	2W	1	Kapp(1970),Holman et al.(1986)
Oakland	N of New Hudson		33*	2N	7E	1	Sherzer(1927),Skeels(1962)
Oakland	Andersonville Gravel Pit		27*	4N	8E	1	Hatt(1963,1965b)
Ottawa	Bass River Pit Site		25	7N	15W	1	Frankforter(1966)
Saginaw	Pere Marquette Shaft #2		28	12N	4E	1	Hay(1923),Lane(1902),Mills(1918),Skeels(1962),LAthesis
Shiawassee	Dysinger Farm/Near Perry		22	5N	2E	1	Skeels(1962),LA thesis
Shiawassee	Three Miles S Morrice		26	5N	2E	1	Skeels(1962)
Shiawassee	Owosso 1895 City Limits		13	7N	2E	1	Skeels(1962)
Tuscola	Knight Site	SW	22	11N	11E	1	LA thesis
Van Buren	S of Mentha		1	2S	13W	1	Skeels(1962)
Van Buren	Johnson Site		1	2S	14W	1	Holman et al.(1986)
Van Buren	W of Decatur		22*	4S	15W	1	Skeels(1962)
Washtenaw	Chelsea/Sylvan Twp		13	2S	3E	1	Skeels(1962)
Washtenaw	Near Pleasant Lake Drain		26	3S	3E	1	Shoshani(1989)

* Approximate Locality
-- Missing Data
LA thesis: Site information listed in this document

APPENDIX C

MICHIGAN PROBOSCIDEA INDETERMINATE DATA

COUNTY	SITE NAME	1/4	1/4	1/4	SECTION	TIER	RANGE	ELEMENT(S)	REFERENCES
Allegan	Mathis Site		SW	NW	1	1N	12W	Femur shaft	LA thesis
Berrien	Carmichael Site				25	3S	17W	Tusk	Holman et al.(1986)
Eaton	I-96 Site				21#	4N	3W	Rib	Holman et al.(1986)
Ingham	Wilcox Road Site				22	3N	2W	Tusk	LA thesis
Jackson	Near Jackson				11*	2S	2W	Tusk	Skeels(1962),LA thesis
Kent	Grandville Gravel Pit				17*	6N	12W	Tusk	LA thesis
Kent	Cannon Twp Gravel Pit		SE	NE	26	8N	10W	Tusk	LA thesis
Montcalm	Zamarron Site				11	10N	5W	Femur	Holman et al.(1986)
Oakland	Michaelson Site				--	3N	11E	Tusk	Hatt(1965b)
Ottawa	Cedar Road Site		NE	SE	1	7N	15W	Femur shaft	LA thesis
Unknown	CIS P.879				--	--	--	Tusks	Hatt(1965b)

* Approximate Locality
\# MacAlpin (1940) lists a mastodont from this section
-- Missing Data
LA thesis: Site Information listed in this document

APPENDIX D

MICHIGAN SALT SITE DATA

COUNTY	SITE NAME	SECTION	TIER	RANGE	REFERENCES
Clinton	Lebanon Twp Salt Marsh	15	8N	4W	Houghton(1838)
Gratiot	Washington Twp Saline Marsh 1	26	9N	2W	Houghton(1838)
Gratiot	Washington Twp Saline Marsh 2	27	9N	2W	Houghton(1838)
Huron	Caseville Twp Salt Spring	16	17N	10E	Lane(1900)
Huron	Chandler Twp Brackish Spring	5	17N	11E	Lane(1900)
Huron	Chandler Twp Salt Spring	6	17N	11E	Lane(1900)
Huron	Lake Twp Salt Lick	32	18N	11E	Lane(1900)
Huron	Rubicon Twp Salty Water	4	17N	15E	Lane(1900)
Kent	Grand Rapids Saline Springs 1	3	6N	12W	Houghton(1838)
Kent	Grand Rapids Saline Springs 2	10	6N	12W	Houghton(1838)
Lenawee	Adrian Twp Deer Licks	7	6S	3E	Winchell(1864)
Macomb	Shelby Twp Brackish Marsh	13	3N	12E	Houghton(1838)
Macomb	Macomb Twp Brackish Marsh	31	3N	13E	Houghton(1838)
Macomb	Chesterfield Twp Saline Springs 1	2	3N	14E	Houghton(1838),Lane(1899b),Winchell(1861)
Macomb	Chesterfield Twp Saline Springs 2	11	3N	14E	Houghton(1838),Lane(1899b),Winchell(1861)
Midland	Lee Twp Salt Spring	24	14N	1W	Yates(1987)
Midland	Midland Twp Salt Spring 1	16	14N	2E	Yates(1987)
Midland	Midland Twp Salt Spring 2	19	14N	2E	Yates(1987)
Midland	Jerome Twp Saline Spring	24	15N	1W	Houghton(1838)
Midland	Jerome Twp Saline Springs	25	15N	1W	Houghton(1838),Lane(1899b),Winchell(1861)
Monroe	Ida Twp Salt Spring	1	7S	7E	Winchell(1861),Sherzer(1900)
Montcalm	Eureka Twp Saline Springs	30	9N	8W	Douglass(1840)
Muskegon	Sullivan Twp Saline Springs	15	9N	15W	Douglass(1840)
Muskegon	Engelston Twp Saline Springs 1	3	10N	15W	Douglass(1840)
Muskegon	Engelston Twp Saline Springs 2	4	10N	15W	Douglass(1840)
Saginaw	Swan Creek Twp Brine Springs	13	11N	3E	Houghton(1838)
Saginaw	Spaulding Twp Brine Springs	10	11N	4E	Houghton(1838)
Tuscola	Wisner Twp Salt Licks	14	14N	7E	Davis(1909)
Washtenaw	Saline Twp Saline Spring	12	4S	5E	Houghton(1838),Lane(1900),Sherzer(1900)
Wayne	Nankin Twp Brine Springs	11	2S	9E	Hubbard(1839)
Wayne	Nankin Twp Saline Spring	2	2S	9E	Houghton(1838)

MICHIGAN SALT SITE DATA (CONTINUED)

Wayne	Redford Twp Saline Spring	27	1S	10E	Hubbard(1839)
Wayne	Brownstown Twp Salt Spring	29	4S	10E	Hubbard(1839)
Wayne	Springwells Twp Licks	16	2S	11E	Hubbard(1839)

REFERENCES CITED

REFERENCES CITED

Agenbroad. L. D. 1984. New World Mammoth Distribution. IN: P. S. Martin and R. G. Klein, (eds.), *Quaternary Extinctions: A Prehistoric Revolution.* Tucson: University of Arizona Press.

Bearss, R. E. and R. O. Kapp. 1987. Vegetation Associated with the Heisler Mastodon Site, Calhoun County, Michigan. *Michigan Academician* 19:133-140.

Beyer, W. H. (ed.) 1974. *Handbook of Tables for Probability and Statistics.* Cleveland: The Chemical Rubber Co.

Campbell, R. C. 1989. *Statistics for Biologists.* Cambridge: Cambridge University Press.

Case, E. C., I. D. Scott, B. M. Badenoch and T. E. White. 1935. Discovery of *Elephas primigenius americanus* in the Bed of Glacial Lake Mogodore, in Cass County, Michigan. *Papers of the Michigan Academy of Science, Arts and Letters* 20:449-454.

Case, E. C. and G. M. Stanley. 1935. The Bloomfield Hills Mastodon. *Cranbrook Institute of Science Bulletin* 4:1-8.

Cook, C. W. 1912. The Salt Industry of Michigan. IN: Allen, R. C. (ed.), *Mineral Resources of Michigan with Statistical Tables of Production and Value of Mineral Products for 1910 and Prior Years.* Michigan Geological and Biological Survey Publication 8 (Geological Series 6), Lansing: Wynkoop Hallenbeck Crawford Co., State Printers.

Cook, C. W. 1914. The Brine and Salt Deposits of Michigan: Their Origin, Distribution, and Exploitation. *Michigan Geological and Biological Survey* 15:1-188.

Crane, H. R. and J. B. Griffin. 1958. University of Michigan Radiocarbon Dates II. *Science* 127:1098-1105.

Davis, C. A. 1909. Report on the Geology of Tuscola County, Michigan. *Report of the State Board of Geological Survey of Michigan for the year 1908.* Lansing: Wynkoop Hallenbeck Crawford, Co., State Printers.

Dice, L. R. 1920. The Mammals of Warren Woods, Berrien County, Michigan. *Occasional Papers of the University of Michigan Museum of Zoology* 86:3-20.

Dorr, J. A. and D. F. Eschman. 1970. *Geology of Michigan.* Ann Arbor: The University of Michigan Press.

Dorr, V., N. Goebel, J. Haslock, K. Lehto, J. Shoshani, P. Sujdak, M. A. Vaerten, F. Zoch, and P. Zoch. 1982. *A Guide to the Groleau-White Lake Mastodon.* Oakland Community College Press: 1-19.

Dougall, H. W., Drysdale, V. M., and P. E. Glover. 1964. The Chemical Composition of Kenya Browse and Pasture Herbage. *East African Wildlife Journal* 2:86-121.

Douglass, C. C. 1840. Report of C. C. Douglass, Assistant Geologist. Third Annual Report of the State Geologist. *1840 State of Michigan Senate Document Volume II(7).*

Dreimanis, A. 1967. Mastodons, their Geologic Age and Extinction in Ontario, Canada. *Canadian Journal of Earth Sciences* 4:663-675.

Fisher, D. C. 1984a. Mastodon Butchery by North American Paleo-Indians. *Nature* 308:271-272.

Fisher, D. C. 1984b. Taphonomic Analysis of late Pleistocene Mastodon Occurrences: Evidence of Butchery by North American Paleo-Indians. *Paleobiology* 10:338-357.

Fisher, D. C. 1990. Age, Sex, and Season of Death of the Grandville Mastodont. IN: T. J. Martin and C. E. Cleland, (eds.), Pilot of the Grand: Papers in Tribute to Richard E. Flanders, Part 1. *The Michigan Archaeologist* 36:141-160.

Fox, G. R. 1924. Place Names of Berrien County. *Michigan History Magazine* 8:6-35.

Fox, G. R. (no date). Mammoth and Mastodon Remains in Berrien County. Unpublished paper from the possession of Judge Ira Butterfield of Bay City. A copy of the paper is present in the Michigan State University Vertebrate Paleontology Division.

Frankforter, W. D. 1966. Some Recent Discoveries of Late Pleistocene Fossils in Western Michigan. *Papers of the Michigan Academy of Science Arts and Letters* 51:209-220.

Frankforter, W. D. 1991. On the Trail of the Mighty Mastodon. *Museum (Public Museum of Grand Rapids)* 1:43.

French, M. H. 1945. Geophagia in animals. *East African Medical Journal* 22:103-110; 152-161.

Garland, E. B. and J. W. Cogswell. 1985. The Powers Mastodon Site, Van Buren County, Michigan. *Michigan Archaeologist* 31:3-39.

Gilbert, S. 1981. The Jolman Mastodon Site. *Coffinberry Bulletin of the Michigan Archaeological Society* 28:32.

Gilmore, C. W. 1906. Notes on Some Recent Additions to the Exhibition Series of Vertebrate Fossils. *Proceedings of the U. S. National Museum* 30:607-611.

Graham, R. W. 1986. Taxonomy of North American Mammoths. IN: G. C. Frison and L. C. Todd (eds.), *The Colby Site: Taphonomy and Archaeology of a Clovis Kill in Northern Wyoming*. Albuquerque: University of New Mexico Press.

Graham, R. W., C. V. Haynes, D. L. Johnson, and M. Kay. 1981. Kimmswick: A Clovis-Mastodon Association in Eastern Missouri. *Science* 213:1115-1117.

Green, A. R. 1967. Paleo-Indian and Mammoth were Contemporaneous. *Michigan Archeologist* 13:1-10.

Harington, C. R. 1977. *Pleistocene Mammals of the Yukon Territory*. Doctoral Dissertation. University of Alberta, Edmonton, Canada.

Hartnagel, C. A. and S. C. Bishop. 1922. The Mastodonts, Mammoths and Other Pleistocene Mammals of New York State. *New York State Museum Bulletin* 241-242:1-110.

Hatt, R. T. 1963. The Mastodon of Pontiac. *Cranbrook Institute of Science Newsletter* 32:62-64.

Hatt, R. T. 1965a. The Littlest Mastodon. *Cranbrook Institute of Science Newsletter* 35:20-23.

Hatt, R. T. 1965b. Fossil Proboscidea at Cranbrook. *Cranbrook Institute of Science Newsletter* 35:24-25.

Hay, O. P. 1912. The Pleistocene Period and its Vertebrata. *Indiana Department of Geology and Natural Resources, 36th Annual Report.* 1911:540-784.

Hay, O. P. 1923. The Pleistocene of North America and its Vertebrated Animals from the States East of the Mississippi River and from the Canadian Provinces East of Longitude 95 Degrees. *Carnegie Institute of Washington* 322:1-499.

Hay, O. P. 1924. The Pleistocene of the Middle Region of North America and its Vertebrated Animals. *Carnegie Institute of Washington* 322A:1-385.

Haynes, G. 1991. *Mammoths, Mastodonts, and Elephants: Biology, Behavior, and the Fossil Record.* Cambridge: Cambridge University Press.

Held, E. R. and R. O. Kapp. 1969. Pollen Analysis at the Thaller Mastodon Site, Gratiot County, Michigan. *The Michigan Botanist* 8:3-10.

Holman, J. A. 1975. Michigan's Fossil Vertebrates. *Publications of the Museum, Michigan State University, Educational Bulletin* 2:1-54.

Holman, J. A. 1979. New Fossil Vertebrate Remains from Michigan. *Michigan Academician* 11:391-397.

Holman, J. A. 1986. The Dansville Mastodont and Associated Wooden Specimen. *National Geographic Research* 2:416.

Holman, J. A. 1988. Michigan's Mastodonts and Mammoths Revisited. IN: G. L. Larson and G. W. Monaghan (eds.), *Wisconsinan and Holocene Stratigraphy in Southwestern Michigan.* East Lansing: Department of Geological Sciences, Michigan State University, *one-time publication only.*

Holman, J. A. 1991. New Records of Michigan Pleistocene Vertebrates With Comments on the Mason-Quimby Line. *Michigan Academician* 23:273-283.

Holman, J. A., L. M. Abraczinskas, and D. B. Westjohn. 1988. Pleistocene Proboscideans and Michigan Salt Deposits. *National Geographic Research* 4:4-5.

Holman, J. A., D. C. Fisher, and R. O. Kapp. 1986. Recent Discoveries of Fossil Vertebrates in the Lower Peninsula of Michigan. *Michigan Academician* 18:431-463.

Houghton, D. 1838. First Annual Report of the State Geologist. *1838 State of Michigan House of Representatives Document 24.*

Hubbard, B. 1839. Report of Bela Hubbard, Assistant Geologist. Second Annual Report of the State Geologist. *1839 State of Michigan House of Representatives Document 23.*

Hubbard, B. 1840. Report of Bela Hubbard, Assistant Geologist. Third Annual Report of the State Geologist. *1840 State of Michigan Senate Document II(7).*

Hubbard, B. 1841. Report of Bela Hubbard, Assistant Geologist. 1841 Annual Report of the State Geologist. *1841 State of Michigan Joint Documents I(11).*

Irwin-Williams, C. 1967. Associations of Early Man with Horse, Camel, and Mastodon at Hueyatlaco, Valsequillo (Puebla, Mexico). IN: P. S. Martin, and H. E. Wright, Jr., (eds.), *Pleistocene Extinctions: the Search for a Cause.* New Haven: Yale University Press.

Kapp, R. O. 1970. A 24,000-Year-Old Jefferson Mammoth from Midland County, Michigan. *Michigan Academician* 3:95-99.

Kapp, R. O. 1985. Late-Glacial Pollen and Macrofossils Associated with the Rappuhn Mastodont (Lapeer County, Michigan). *American Midland Naturalist* 116:368-377.

King, J. E. and J. J. Saunders. 1984. Environmental Insularity and the Extinction of the American Mastodont. IN: P. S. Martin and R. G. Klein, (eds.), *Quaternary Extinctions: A Prehistoric Revolution.* Tucson: University of Arizona Press.

Kurtèn, B. and E. Anderson. 1980. *Pleistocene Mammals of North America.* New York: Columbia University Press.

Lambie, A. S. (editor) 1933. *Cranbrook Institute of Science Newsletter* 3:5.

Lane, A. C. 1899a. Water Resources of the Lower Peninsula of Michigan. *United States Geological Survey Water Supply Paper* 30:1-97.

Lane, A. C. 1899b. Lower Michigan Mineral Waters: a Study into the Connection between their Chemical Composition and Mode of Occurrence. *United States Geological Survey Water Supply Paper* 31:1-97.

Lane, A. C. 1900. Geological Report of Huron County, Michigan. *Geological Survey of Michigan* 7(part 2):1-329.

Lane, A. C. 1902. *Report of the State Board of Geological Survey of Michigan for the Year 1901.* 3:252-253.

Lane, A. C. 1906. *Report of the State Board of Geological Survey of Michigan for the Year 1905*. 7:553.

Lanman, J. H. 1839. *History of Michigan, Civil and Topographical in a Compendious Form; with a View of the Surrounding Lakes*. New York: E. French Publishers.

Lapham, I. A. 1855. *Proceedings of the Boston Society of Natural History* 5:133.

Laws, R. M., Parker, I. S., and R. C. B. Johnstone. 1975. *Elephants and their Habitats*. Oxford: Clarendon Press.

Long, D. T., T. P. Wilson, M. J. Takacs, and D. H. Rezabek. 1988. Stable-Isotope Geochemistry of Saline Near-Surface Ground Water: East-Central Michigan Basin. *Geological Society of America Bulletin* 100:1568-1577.

Lundelius, E. L. Jr., R. W. Graham, E. Anderson, J. Guilday, J. A. Holman, D. W. Steadman, and S. D. Webb. 1983. Terrestrial Vertebrate Faunas. IN: Wright, H. E. Jr., (ed.), *Late-Quaternary Environments of the United States, Volume 1: The Late Pleistocene*. Minneapolis: University of Minnesota Press.

MacAlpin, A. 1940. A Census of Mastodon Remains in Michigan. *Papers of the Michigan Academy of Science, Arts, and Letters* 25:481-490.

MacCurdy, H. M. 1920. Mastodon Remains found in Gratiot County, Michigan. *Annual Report of the Michigan Academy of Science* 21:109-110.

Maglio, V. J. 1973. Origin and Evolution of the Elephantidae. *Transactions of the American Philosophical Society* (New series) 63:1-149.

Martin, H. and M. T. Straight. 1956. An Index of the Geology of Michigan, 1823-1955. *Michigan Geological Survey Publication* 50:1-461.

McAndrews, J. H. and L. J. Jackson. 1988. Age and Environment of Late Pleistocene Mastodont and Mammoth in Southern Ontario. IN: R. S. Laub, N. G. Miller, and D. W. Steadman (eds.), Late Pleistocene and Early Holocene Paleoecology and Archeology of the Eastern Great Lakes Region. *Bulletin of the Buffalo Society of Natural Sciences* 33:161-172.

Mendenhall, W. 1983. *Introduction to Probability and Statistics*. Boston: Duxbury Press.

Miller, W. E. 1987. *Mammut americanum*, Utah's First Record of the American Mastodon. *Journal of Paleontology* 61:168-183.

Mills, J. C. 1918. *History of Saginaw County, Michigan.* Vol. 1. Saginaw: Seemann and Peters Publishers.

Odale, R. N., F. C. Whitmore Jr., and J. R. Grimes. 1987. Elephant Teeth from the Western Gulf of Maine and Their Implications. *National Geographic Research* 3:439-446.

Olsen, S. J. 1972. Osteology for the Archaeologist: The American Mastodon and the Woolly Mammoth. *Papers of the Peabody Museum of Archaeology and Ethnology, Harvard University* 56:1-47.

Oltz, D. O. and R. O. Kapp. 1963. Plant Remains Associated with Mastodon and Mammoth Remains in Central Michigan. *American Midland Naturalist* 70:339-346.

Osborn, H.F. 1922. Species of American Pleistocene Mammoths: *Elephas jeffersonii*, new species. *American Museum Novitates* 41:1-16.

Osborn, H. F. 1936. *Proboscidea: a Monograph of the Diversity, Evolution, Migration and Extinction of the Mastodons and Elephants of the World.* Volume 1. New York: American Museum of Natural History.

Osborn, H. F. 1942. *Proboscidea: a Monograph of the Diversity, Evolution, Migration and Extinction of the Mastodons and Elephants of the World.* Volume 2. New York: American Museum of Natural History.

Parker, R. B. and H. Toots. 1976. Sodium in Teeth of Fossil Vertebrates as a Paleobiological Tool. *Journal of the Arizona Academy of Science, Proceedings* 11:87.

Parker, R. B. and H. Toots. 1980. Trace Elements in Bones as Paleobiological Indicators. IN: A. K. Behrensmeyer and A. P. Hill, (eds.) *Fossils in the Making*. Chicago: University of Chicago Press.

Peale, A. C. 1886. Lists and Analyses of the Mineral Springs of the United States. *Bulletin of the United States Geological Survey* 32:1-235.

Ray, C. E., Cooper, B. N., and W. S. Benninghoff. 1967. Fossil Mammals and Pollen in a Late Pleistocene Deposit at Saltville, Virginia. *Journal of Paleontology* 41:608-622.

Redmond, I. 1984. Underground Elephants. *Animal Kingdom* 87:30-37.

Richards, R. L. 1984. The Pleistocene Vertebrate Collection of the Indiana State Museum With a List of the Extinct and Extralocal Pleistocene Vertebrates of Indiana. *Proceedings of the Indiana Academy of Science* 92:483-504.

Romig, W. 1986. *Michigan Place Names: the History of the Founding and the Naming of More than Five Thousand Past and Present Michigan Communities.* Detroit: Wayne State University Press.

Runyon, R. P. and A. Haber. 1984. *Fundamentals of Behavioral Statistics.* New York: Random House.

Russell, I. C. and F. Leverett. 1908. *United States Geological Survey Folio* 155:9.

Saunders, J. J. 1977. Late Pleistocene Vertebrates of the Western Ozark Highland, Missouri. *Illinois State Museum Reports of Investigations* 33:1-118.

Saunders, J. J. 1988. Fossiliferous Spring Sites in Southwestern Missouri. IN: R. S. Laub, N. G. Miller, and D. W. Steadman (eds.), Late Pleistocene and Early Holocene Paleoecology and Archeology of the Eastern Great Lakes Region. *Bulletin of the Buffalo Society of Natural Sciences* 33:127-149.

Schultz, C. B., L. G. Tanner, F. C. Whitmore, Jr., L. L. Ray, and E. C. Crawford. 1963. Paleontologic Investigation at Big Bone Lick State Park Kentucky: A Preliminary Report. *Science* 142:1167-1169.

Schultz, C. B., L. G. Tanner, F. C. Whitmore, Jr., L. L. Ray, and E. C. Crawford. 1967. Big Bone Lick, Kentucky-A Pictoral Story of the Paleontological Excavations at this Famous Fossil Locality from 1962 to 1966. *University of Nebraska Museum Notes* 33.

Sherzer, W. H. 1900. Geological Report on Monroe County, Michigan. *Geological Survey of Michigan* 7(part 1):1-240.

Sherzer, W. H. 1927. A New Find of the Woolly Elephant in Michigan. *Science* 65:616.

Shipman, P., D. C. Fisher, and J. J. Rose. 1984. Mastodon Butchery: Microscopic Evidence of Carcass Processing and Bone Tool Use. *Paleobiology* 10:358-365.

Shoshani, J. 1989. A Report on the Shelton Mastodon Site and a Discussion of the Numbers of Mastodons and Mammoths in Michigan. *Michigan Academician* 21:115-132.

Shoshani, J., D. C. Fisher, J. M. Zawiskie, S. J. Thurlow, S. L. Shoshani, W. S. Benninghoff, and F. H. Zoch. 1989. The Shelton Mastodon Site: Multidisciplinary Study of a Late Pleistocene (Twocreekan) Locality in Southeastern Michigan. *The University of Michigan Contributions from the Museum of Paleontology* 27:393-436.

Simpson, G. G. 1945. The Principles of Classification and A Classification of Mammals. *Bulletin of the American Museum of Natural History* 85:1-350.

Simpson, G. G. 1949. A Fossil Deposit in a Cave in St. Louis. *American Museum of Natural History Novitates* 1408:1-46.

Skeels, M. A. 1962. The Mastodons and Mammoths of Michigan. *Papers of the Michigan Academy of Science, Arts, and Letters* 47:101-133.

Steel, R. G. D. and J. H. Torrie. 1980. *Principles and Procedures of Statistics: A Biometrical Approach*. New York: McGraw-Hill Book Company.

Stirton, R. A., and W. K. Gealey. 1949. Reconnaissance Geology and Vertebrate Paleontology of El Salvador, Central America. *Geological Society of America Bulletin* 60:1731-1754.

Stoutamire, W. P. and W. S. Benninghoff. 1964. Biotic Assemblage Associated with a Mastodon Skull from Oakland County, Michigan. *Papers of the Michigan Academy of Science, Arts, and Letters* 49:47-60.

Warren, J. C. 1852. *Description of a Skeleton of the* Mastodon giganteus *of North America*. Boston: John Wilson & Son.

Warren, J.C. 1855. Supernumerary Tooth in *Mastodon giganteus*. *American Journal of Science* 19:349-353.

Weston, D. and K. McMillion. 1973. Elephant Hunting in Michigan. *Michigan Natural Resources* 42:18-21.

Whitmore, F. C. Jr., K. O. Emery, H. B. S. Cooke, and D. J. P. Swift. 1967. Elephant Teeth from the Altantic Continental Shelf. *Science* 156:1477-1481.

Wier, J. S. 1972. Spatial Distribution of Elephants in an African National Park in Relation to Environmental Sodium. *Oikos* 23:1-13.

Wier, J. S. 1973. Exploitation of Water Soluble Sodium by Elephants in Murchison Falls National park, Uganda. *East African Wildlife Journal* 11:1-7.

Wilkinson, L. 1990. *SYSTAT: The System for Statistics*. Evanston: SYSTAT, Inc.

Wilson, R. L. 1967. The Pleistocene Vertebrates of Michigan. *Papers of the Michigan Academy of Science Arts and Letters* 52:197-257.

Winchell, A. 1861. *First Biennial Report of the Progress of the Geological Survey of Michigan, 1860.* Lansing: Hosmer and Kerr.

Winchell, A. 1864. Notice of the Remains of a Mastodon Recently Discovered in Michigan. *American Journal of Science* (2nd Series) 38:223-224.

Wittry, W. L. 1965. The Institute Digs A Mastodon. *Cranbrook Institute of Science Newsletter* 35:14-19.

Yates, D. L. 1987. *Salt of the Earth: A History of Midland County, Michigan.* Michigan: Midland County Historical Society.