

Mini Curriculum for the Marvelous Mastodon: **Teacher Packet**



Dr. Jack Sunderman in the Geogarden at IPFW (northeast corner of Kettler Hall)

Geologist's tools (displayed on the rock from top down):

BRUNTON COMPASS (used by all field geologists to determine location and orientation of rock layers); PROTECTIVE GOGGLES (behind gloves, for use when breaking rock); HEAVY GLOVES (for work in quarries and rocky terrain); FIELD NOTEBOOK (with pencil, essential for note-taking in the field); GEOLOGY HAMMER (for breaking rocks to observe fresh rock surfaces; also used as a scale in photos); POCKET KNIFE (red, by hammer, for scratching minerals to determine hardness and type of mineral; also used as scale in photos).

Geologist's items worn or held by Dr. Sunderman:

SUN GLASSES (essential for work in bright sun, especially at high elevations); HAND LENS (for identifying rocks, minerals, and fossils under 10-power magnification); ROCK SPECIMEN (small geode, being "studied" with hand lens); usually PROTECTIVE SHOES (steel-toed boots for work in quarries; hiking boots for other work).

Mastodon americanus

A scientific description of the American Mastodon

&

Other large mammals that roamed
the Earth
during “The Age of Mammals”

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I. Introduction: The Routsong Mastodon

The name “**Mastodons**” has been adopted for IPFW (Indiana University Purdue University - Fort Wayne) sports teams because of the unique characteristics of a majestic now-extinct animal that once roamed the woodlands of northern Indiana, and whose remains have been found in several locations not far from Fort Wayne. The original IPFW mastodon, now on display in Kettler Hall, was discovered in 1968 on the Orsie Routsong farm, along I-69 just south of Angola. About two thirds of the skeleton was recovered, including most of the ribs, vertebrae, cranium and tusks. The animal probably was a medium-sized female (~8 ft. high), and may have been caring for a small offspring whose skull was found near the adult mastodon bones. The skeletons were buried in Wisconsin-age glacial silt and clay sediment, indicating that these two mastodons probably died about 10,000 years ago. Although the bones were somewhat scattered, we found no direct evidence indicating that humans or predatory animals caused their death.

The following outline gives general background information about the extinct elephant-like animals we call mastodons. Most of the data has been gleaned from the Encyclopaedia Britannica, textbooks, publications, and the Internet. (See Section XI.)

II. Time During which Mastodons Lived

A. Time units: Mastodons lived in the Cenozoic, during the middle *Tertiary* Period (Late Oligocene, Miocene and Pliocene Epochs) and into the first part of the *Quaternary* Period (the Pleistocene “Ice-Age” Epoch), but became extinct at the beginning of the modern Holocene Epoch.

B. Years: Mastodons existed from ~30 million years ago to ~8,000 years ago. In comparison, dinosaurs lived during the “Age of Reptiles.” They originated in the Triassic Period, about 100 million years ago, and became extinct near the end of the Cretaceous Period, about 65 million years ago.

C. Dating techniques. (Techniques used to determine the ages of minerals, rocks and fossils.)

1. Carbon-14 dating. The percent decay of carbon-14 isotopes after the death of carbon-bearing animals or plants yields the time of death, if between ~500 to 50,000 yrs. ago.

2. Stratigraphy (study of rock sequences, or strata). For most fossils, the age of the fossil is derived from the age of the enclosing sediments. The age of the sediments may be determined from analyses of radioactive isotopes and decay products of Carbon-14, Uranium-238, Potassium 40 and other elements, or by correlation with other sediments whose ages are known from previous studies.

The age (time of death) of the Routsong mastodon is known to be about 10,000 years ago, because it was found in unconsolidated glacial deposits of so-called late Wisconsin age. The ~10,000 year age of this sediment has been determined in previous studies, mostly by Carbon-14 dating of carbon-bearing wood fragments and animal bones. (For more information, see: VI. Methods of Age Determination.)

III. Scientific Classification of Mastodons

Below is a modern scientific classification of mastodons, showing the relations of animals, chordates and mammals to the **Order Proboscidea** and the mastodon species that once populated much of North America, including Indiana: *Mastodon americanus*.

Kingdom Animalia→ Phylum Chordata→ Subphylum Vertebrata→ Class Mammalia→ Order Proboscidea→ Family Mastodontidae (also called Mammutidae)→ Genus *Mastodon* (also called *Mammut*)→ Species *Mastodon americanus* (the American mastodon). (See IX for descriptive classification chart.)

A. Proboscideans. The mammal subdivision called **Order Proboscidea** (“long-snouted” or trunk-bearing terrestrial mammals) originated in Egypt and Northern Africa in the early Tertiary, >40 million years ago, probably from ancestors about the size of modern pigs. Proboscideans are characterized by thick “columnar” limbs, bulky bodies and elongated snouts or trunks. In modern studies, the Order Proboscidea is divided into five families (**Gomphotheriidae**, **Moeritheriidae**, **Palaeomastodontidae**, **Mastodontidae** and **Elephantidae**), with >300 species, all but 2 or 3 of which (elephants) are now extinct!

- 1. Family Gomphotheriidae.** This family includes the earliest members of the **Proboscidea**, some of which developed shovel-like lower incisor tooth structures, but it also contains shovel-toothed members that lived in South America until about 1,800 to 1,600 years ago. Some also had upper tusks common to mastodons and elephants, giving them the nickname 4-tuskers. This family contains some of the most unusual Proboscideans, but probably did not lead to development of the other families.
- 2. Family Moeritheriidae.** This family is named after fossils found in sediments of Lake Moeris, Egypt in 1904 and later found in other African sites. The animal was only 3 or 4 ft. high, about 10 ft. long, and had small ears, looking somewhat like a long, oversize pig. It had slightly elongated teeth and an elongated snout, but had no true tusks or trunk. It apparently became extinct in the Early Tertiary and did not add new members to the main line of Proboscidean mammals.
- 3. Family Palaeomastodontidae.** This family has one genus, **Palaeomastodon**, which originated >35 m.y. ago. Early members of the genus had downward-curved lower tusks but no upper tusks, and were about the size of modern Asian female elephants. Early Palaeomastodons had an elongated skull and neck, and a very short trunk, ~1 ft. long. However, later Palaeomastodons had shorter skulls, and the tusks took on the more common cylindrical shape of mastodons and modern elephants. The European species *Deinotherium gigantissimum* was about 12 ft. or more in height, and became extinct ~2.5 million years ago, at the beginning of the Pleistocene Ice Ages.
- 4. Family Mastodontidae (or Mammutidae).** This family contains a single genus, *Mastodon*, a “nipple-toothed” mammal characterized by teeth with rounded crowns. Their upper tusks were up to 7 feet in length, with a gentle upward curve, and the earliest male mastodons also had small lower tusks. Mastodons were up to 10 feet tall at the shoulder and were covered with shaggy hair, probably red-brown in color. The species *Mastodon americanus* probably originated in Africa, then migrated to North America ~15 million years ago, and became extinct ~8,000 years ago.
- 5. Family Elephantidae.** This family includes mammoths and modern elephants, with only two major genera, the **African forest** elephant and the **Asian savanna** elephant.

IV. Physical Characteristics of *Mastodon americanus*

A. Size. Average adult males of the American mastodon were about the size of modern Indian elephants. Those living in the cool climate of the last (Wisconsin) glaciation were relatively small, whereas those that lived in forests as the glaciers retreated were larger.

The females were somewhat smaller than the males.

1. **Height:** About 8 ft. at the shoulder.
2. **Length:** About 12-14 ft.
3. **Weight:** About 5 tons (10,000 lbs.)

B. Configuration.

1. **General:** Massive, with large bone structure and thick layers of fat.
2. **Back:** Large hump over the front legs (from vertebrae extensions), sloping to the rear.
3. **Legs/feet:** Sturdy “stove-pipe” legs with flat feet.

C. Flesh/surface features.

1. **Skin.** Mastodons probably had thick skin over a layer of fat several inches thick.
2. **Hair.** Mastodons probably had coats of fine “underwool,” and shaggy brown hair 2 to 7 inches long. (**Note:** Modern elephant adults are almost hairless: some have a small patch of hair on the tip of the tail, and a small amount of hair on the top of the head.)
3. **Eyes:** The eyes were small and above the tusks, possibly limiting downward vision.

D. Appendages.

1. **Tail.** The mastodon tail was relatively small, tapering at the end.
2. **Ears.** The ears were relatively small, ~1–2 ft. long.
3. **Trunk.** The mastodon trunk was an elongation of the nose and upper lip. The trunk was flexible and muscular, with no bones, but with many muscles and nerves, giving it flexibility. As in modern elephants, the mastodon trunk probably was used for drinking, placing food into its mouth, and spraying its body for cleaning and cooling.

E. Skeleton. (Measurements are from the Routsong Mastodon, probably a female.)

1. **Leg bones.** The mastodon leg bones were thick, massive and relatively straight. The animal probably could walk about 5 miles per hour, for long periods of time.
2. **Ribs.** Mastodons had ~24 pairs of ribs, which were slightly curved and ~2 in.-5 ft. long.
3. **Vertebrae.** The vertebrae varied from ~3-10 in. in width and from ~1-23 in. in length.
4. **Skull.** The mastodon skull was massive, with two holes for the tusks in the lower front.

F. Teeth. (Descriptions mostly from the Routsong Mastodon.)

1. **Mouth teeth.** Mastodons had ~8-12 teeth, each with 6-8 tapered roots shaped like ice cream cones, and with “ice-cream”-shaped crowns on the eating surface. Instead of erupting and moving up vertically as in humans, the mastodon teeth erupted in the back of the jaw and moved laterally forward, toward the front of the mouth. The oldest teeth thus were in the front of the mouth and were more worn than those in the back.

Mastodon remains are easily distinguished from woolly mammoth remains by the appearance of their teeth. Woolly mammoth teeth consist of numerous vertical plates that are worn into shallow parallel grooves and ridges across a flat eating surface.

- 2. Tusks.** Mastodon tusks were “extended teeth” that developed from the position of their upper incisor teeth. In the most recent mastodons, they were cylindrical, curved gently upward, ~6-8 inches thick at the skull, and up to 7 ft. long in males.

The tusks of excavated, now-extinct mammoths have been much used by modern humans in the ivory trade, and modern elephants currently are being driven toward extinction by illegal killing of the animals for their tusks.

G. Comparison with humans.

- 1. Weight:** Adult mastodons weighed ~100 times as much as a 100 lb. human.
- 2. Height:** Adult mastodons were taller than most adult humans (~8 ft. at the shoulder).
- 3. Sight:** The mastodon’s eyes were situated to the side of its skull and above its trunk.
- 4. Life span:** The average life span of mastodons probably was similar to that of humans.
- 5. Teeth:** Mastodons had 2-3 pairs of teeth in each jaw, whereas humans have ~8 pairs.
- 6. Toes:** Mastodons had 20 digits (all toes); humans have 20 digits (10 toes, 10 fingers).
- 7. Food:** The mastodon diet was entirely herbaceous (all plants, no meat). Mastodon adults probably ate ~100 times that of an adult human (~500 lbs. per day vs. ~5 lbs.).

H. Special characteristics.

- 1. Tusks:** Mastodons were browsers (not grazers). Their tusks probably were used to clear forest undergrowth, to dig for edible roots, and to break small branches for food.
- 2. Trunk:** The mastodon trunk probably was used to lift and move objects, to bring food to its mouth, and to shower its body with water for cooling.
- 3. Attacks by Mastodons:** Mastodons and mammoths may have had habits. When modern elephants charge at an enemy, they usually fan their ears and hold their trunks out of the way.
- 4. Attacks against Mastodons.** Mastodons probably were nearly immune to attacks by most other animals, due to their large size and thickness and toughness of their skin. However, very young mastodons probably were subject to attack by aggressive carnivores, and some adults apparently became mired in swamps or ponds, rendering them virtually helpless to attack.

Eventually, early humans solved the problem of overcoming mastodons and mammoths by inventing sharp, narrow arrows (some called Clovis points) and spears that would penetrate the heavy skins of the animals. The animals then became major sources of food for the humans. Unfortunately, this activity and environmental changes that took place at the end of the Pleistocene probably led to the extinction of the mastodons and mammoths.

V. Life of the Mastodon

- A. Characteristics of *Mastodon americanus*.** The following “probable” characteristics are based on reported studies of mastodon remains and observations of modern elephants.

- 1. Life span.** Mastodons probably lived an average of ~80 years, but possibly lived as long as ~120 years.
- 2. Maturation age.** Mastodons probably reached full growth at about age 25.

3. **Mating.** Mastodon mothers probably could give birth from about age 10 to age 60. Mastodon males probably fought to acquire females, and then protected them.
4. **Gestation and birth.** Mastodon young probably spent ~20 months in the mother's womb. The newborn mastodon probably was ~3 ft. high and weighed ~200 lbs. After about two hours' time, the baby mastodon probably could stand by itself and nurse from its mother. The mother and her newborn probably were surrounded by adults of the herd, to give protection,
5. **Number of offspring.** Mastodon females probably could have one young about every 4 years, so each female could produce about 10-12 offspring during her lifetime.
6. **Migration.** The Family Mastodontidae originated in North Africa ~30 million years ago and spread to Eurasia. *Mastodon americanus* then migrated into North America about 15 million years ago across the Bering Strait, now a shallow sea that became a dry land connection between continents during the Pleistocene Ice Ages. Mastodons and woolly mammoths probably traveled in small herds, as modern elephants do.
7. **"Intelligence."** Mastodons probably were about as intelligent as modern elephants, which are intelligent enough to work together in herds, to establish herd leaders, to protect their young from carnivores, and to adopt lost young. Modern elephants also are intelligent enough to be trained by humans to do heavy lifting or push-pull work, to transport humans during hunting, and to do "tricks" in carnivals.
8. **Special senses.** Mastodons and mammoths may have been able to detect weak sound vibrations. Some observers believe that modern elephants *may* be able to detect ground vibrations associated with earthquakes and related tsunamis, partly because of their great weight and their flat feet, which are in contact with a large ground surface area.
9. **Strength.** Mastodon strength probably was similar to that of elephants, which can lift heavy trees and other objects with their trunks and can carry, push, or pull heavy objects. Because of their strength, size, weight and thick skin "armor," elephants have been used by humans in ancient wars, and still are being used in some parts of the world as a substitute for machinery in heavy construction and clearing projects.

B. Environments of the mastodons.

1. **Enemies.** The major enemies of mastodons probably were carnivorous wild animals, and humans. When not protected by adults, very young or injured mastodons probably were captured and eaten by carnivorous (flesh-eating) animals. Probably more significant was the hunting and killing of large numbers of adult mastodons and woolly mammoths by Paleolithic humans, for food. Intermingling of mastodon remains and human artifacts show that these early humans developed spears made of long arrowheads (some called "Clovis points") attached to wood stalks, making a weapon capable of penetrating the tough skins of both mastodons and mammoths.
2. **Diseases.** The long reign of the Family Mastodontidae (~30 m.y.) and the *Mastodon americanus* (~15 m.y. in America) suggests that mastodons probably were very resistant to most diseases.
3. **Habitats.** Mastodons probably were best adapted to conifer forests, forest margins and marshlands. During the Pleistocene ice ages, they probably adapted to somewhat cooler climates, for which their thick skin and shaggy hair partly prepared them.
4. **Climate.** During the Pleistocene Ice Ages, the climate was relatively cool, but before and after the Pleistocene, the climate probably was similar to today's climate.

5. Contributions to the environment. Mastodons probably dug roots and shrubs at or near the forest floor and browsed up to 15 ft. above it. Mastodons thus cleared the forests for travel by other animals, increased the amount of sunlight reaching the floor, and aerated the forest soils. This in turn allowed new plants and shrubs to flourish and provided new plant food for both the mastodons and other animals. Some mastodons apparently frequented shallow ponds to eat pond plants and wallow in the mud. As a result, the mastodons also fertilized the pond areas with their excrement.

C. Mastodon food.

1. **Diet.** Mastodons were herbivores, or plant-eaters. They probably ate shrubs, roots, leaves and twigs of trees, mainly in open forests and along the edges of forests. They also probably ate water-loving plants in nearby marshes and ponds. An adult mastodon probably ate ~500 lbs. of solid food per day, all plants, making new and plentiful supplies essential. At some times other animals probably competed with the mastodons for food supplies.
2. **Evidence.** Some mastodons have been preserved well enough in clay-silt pond sediment, and woolly mammoths in frozen sediment, that plant remains inside their stomach areas have been used for the study of the plant types and for carbon-14 (radiocarbon) age dating of the plants and animals. (See **VI, Methods of Age Determination.**)

D. Mastodon relatives. Mastodons have no close *modern* relatives, only distant ones.

1. **Elephants.** Elephants are the closest modern relatives of mastodons, but their common ancestors probably lived more than 30 millions years ago.
2. **Woolly mammoths.** Mammoths were present in Europe, northern Asia and North America during the time mastodons were, and became extinct at about the same time.
3. **Palaeomastodon.** The oldest mammals that had elephant-like characteristics were members of the Genus Palaeomastodon, which probably first developed about 35 million years ago.

E. Mammal neighbors of the mastodon.

1. **Extant Mammals.** Modern horse, deer, buffalo, rhinoceros, fox, and at least 40 other modern mammal species (including humans) lived during the same time and in the same environments as the latest mastodons. Some of these “neighbors” may have competed for food and water sources, aiding in the extinction of the mastodons.
2. **Extinct Mammals.** At least 10 species of now-extinct mammals also lived with and possibly competed with mastodons for food and water. They include the woolly mammoth, a long-horned bison, a lion-like cat, and the saber-tooth tiger, which lived from the Oligocene to the Pleistocene (~30 m.y. ago to ~1 m.y. ago).
3. **Nebraska Ashfall fossils.** At about the same time the Routsong mastodon lived in northern Indiana (~10 m.y. ago), a volcanic eruption in Idaho similar to those of Mt. St. Helens produced ash clouds that traveled eastward, burying animals as far east as northeastern Nebraska. The resulting fossil assemblage contains rhinoceros skeletons preserved in three-dimensions by the ash, five types of horses, camels, and other fossils. The Ashfall Fossil Beds State Historical Park has been established at the site, where visitors can see the rhinoceros remains still in their original positions.

4. **The Clovis people.** Another neighbor of the mastodons were humans called the Clovis people that settled in the American Midwest and southwest ~10,000 years ago. (See additional information below, under: **F-2 - Just before extinction.**)
5. **Northern Indiana Early Pliocene fossils.** Fragmental fossils of mammals and other animals of early Pliocene age (~5 m.y. ago) have been found recently in a small sinkhole complex south of Marion, Indiana. The fossils and enclosing sediments are the only ones of this age known in the East-Central U.S. Large mammals found there include giant camel and bear. Although remains of mastodons have *not* been found at the site, mastodons could have lived in this area at this time. Evidence at the sinkhole suggests that a relatively dry climate existed in this area at this time, possibly forcing the water-dependent mastodons to migrate to other areas. (See **XI**, Gray Fossil Site.)

F. Distribution of Mastodons and association with humans

1. **The past.** Mastodon remains have been found throughout the world, but during the Pleistocene Ice Ages they lived primarily in North America, in Central and Eastern U.S. and southern Canada. U.S. sites include: Indiana ~10, Missouri ~10, Illinois ~35 and Michigan ~40. At the end of the Pleistocene, both mastodons and mammoths declined rapidly in numbers and soon became extinct in all parts of the world.
2. **Just before extinction.** Humans and mastodons existed together for only a relatively short period of time. However, remains of numerous mastodons and woolly mammoths have been found with scrape marks on their bones and/or with arrowheads embedded in them or found nearby, indicating that the animals were hunted and killed for food by early humans. *Mastodon* remains have been found associated with Clovis Indian artifacts in the so-called Kimmswick Bone Beds near St. Louis, Missouri, and similar human/*mammoth* bone associations have been found at other sites.
3. **Today.** Mastodons and mammoths possibly could live in environments where elephants live today, in Africa and Asia, or in colder environments of Canada or Russia.

VI. Extinction of the Mastodon

A. The nature of “extinction.”

1. Extinction means that all existing representatives of a given species or higher group of plants or animals have died, with no living animals or plant parts (seeds, roots, etc.) to reestablish them. The term usually is applied to complete extinction on planet Earth, but is sometimes applied to extinctions of organisms on isolated continents or islands.

B. Causes of extinction

1. **Short-term catastrophes.** Short-term events, such as large meteorite impacts, earthquakes, tsunamis and volcanic eruptions may cause isolated changes in local environments that affect food and water supplies. Animals that live on islands may become locally extinct, but usually survive the events by migrating to nearby areas or by later returning to the affected.
2. **Long-term environmental changes and loss of food supply.** Long-term events such as continental drift, mountain-building, glaciation, sea-level changes and climatic changes may affect both regional and continental environments, bringing about drought and changes in temperature that affect food and water supplies, forcing the animals to either migrate or become extinct. These are “natural” extinction processes.

4. **Competition from other wild animals.** Mastodons and woolly mammoths may have competed for food supplies during the late Pleistocene ice ages. Also, young or wounded mastodons may have been killed and eaten by packs of hungry, fast-moving wild animals (tigers, lions, etc.), just as elephants are affected today.
5. **Competition from humans.** The Clovis Indian artifacts found associated with large numbers of mastodon remains, and similar associations with mammoths elsewhere, suggest that hunting by humans was a major factor in the extinction of the North American mastodons and mammoths. Modern humans are bringing other species to extinction for their own monetary benefit, perhaps *not* “natural” extinction process.

VII. Methods of age determination

Geologists use two types of age descriptions for rocks and fossils: **relative age** and **absolute age**. For example: you are younger than your parents (relative ages), whereas if someone is known to be exactly 15 years old and their parents are exactly 40 years old, these numbers would be called absolute ages.

A. Relative ages.

1. **Rock sequences.** Relative ages of rocks and unconsolidated sediments can be determined by observing the following relations of rock sequences:
 - a. **Superposition** of rock layers (in an undisturbed rock sequence, the oldest rocks are at the bottom, the youngest at the top),
 - b. **Cross-cutting relations** (an igneous dike that cuts across other rock is younger than the rock it cuts across);
 - c. **Unconformable relations** (rocks with eroded surfaces are older than rocks that rest on the eroded surface).
2. **Correlation** of rock units. If rock units can be traced from one place to another, even over hundreds of miles distance, the rocks are said to be **correlated**, and are assumed to be of about the same age.

B. Absolute ages.

1. **Decay of radioactive isotopes** in rocks, minerals and fossils. The procedures make use of the time for decay of half of the radioactive isotope, called its “half life.”
 - a. **Young ages.** Rapid isotopic decay of **radioactive carbon-14** (radiocarbon) to non-radioactive carbon-12 gives ages of up to ~50,000 or 60,000 years ago, with an uncertainty of about $\pm 2,000$ years or less. This type of analysis is much used to determine the ages of archaeological samples of bone, cloth, wood and plants, and for determining the ages of Pleistocene (ice-age) carbon-bearing bones and food of Woolly Mammoths and Mastodons.
 - b. **Older ages.** A large number of other elements have radioactive isotopes whose decay rates are slow enough that their analysis can be used to determine the ages of much older rocks, minerals and fossils. Over the past few decades, the refinement of analytical techniques and instrumentation has resulted in the ability to determine the ages of rocks that are billions of years old, most with age uncertainties of $\pm 1-2$ million years.

The isotope analysis equation used to determine the ages of rocks and minerals, called the “age equation,” is shown below. Also shown is a partial list of radioactive elements and their decay products currently being used for age determinations.

- c. The age equation:** $t = 1/\lambda \times \ln (1+D/P)$, where,
 t = age of rock or mineral specimen.
 λ = decay constant for the parent isotope.
 \ln = natural logarithm (logarithm to base e).
 D = number of atoms of daughter isotope today.
 P = number of atoms of parent isotope today.

d. Radioactive elements currently used in age determinations.

Parent isotope		Daughter isotope	Half-life	Age dating limit
Carbon-14	->	Carbon-12	5730 yr.	50,000 – 60,000 yrs.
Uranium-235	->	Lead-207	704 Ma.	7.04 Ga
Potassium-40	->	Argon-40	1.25 Ga.	12.5 Ga
Uranium-238	->	Lead-206	4.5 Ga.	45.0 Ga
Thorium-232	->	Lead-208	14.0 Ga.	140 Ga
Rubidium-87	->	Strontium-87	48.8 Ga.	488 Ga
Samarium-147	->	Neodymium-143	106 Ga	1,060 Ga

Note: yr. = years; Ma = millions of years; Ga = billions of years. Also note that the *age dating limit* for all but Carbon-14 isotopes goes far beyond the age of any dated earth rocks or minerals.

Some of the oldest rocks and minerals on earth currently dated by isotopic age analysis are metamorphic gneisses found near Great Slave Lake in northwestern Canada (~4 Ga), rocks of western Greenland (~3.8 Ga.), and zircon mineral grains found in sedimentary rocks of west-central Australia (U-Pb ages of ~4.4 Ga).

- 2. Magnetic reversals.** The earth’s magnetic poles have reversed N-S directions several times, as demonstrated by measurements of the polarity of magnetic rocks and minerals, on both the continents and the ocean basins. The magnetic reversals and intermediate intervals have been dated through use of radioactive element decay ages of the magnetic rocks and minerals. Thus the magnetic reversal sequence can be used as a secondary tool to determine absolute ages of rocks, sediments and fossils.
- 3. Varved lake sediments.** In some lakes, differences in summer and winter deposition produce a couplet of coarser summer sediment (silt) and finer winter sediment (clay), called **varves**. Counting of the varves gives the number of years it took for the sediment to be deposited, and correlation of the varves with lake sediments of known age can be used as a secondary tool to determine an absolute age.

VIII. The Nature of Fossils

Human remains and associated materials (**relics**), usually not more than a few thousand years old, are studied primarily by archaeologists in their investigation of past human lives and cultures. The term **fossil**, as used is used in geology, refers to the remains, traces, or imprints of any formerly living plant or animal that is more than a few thousand years old. Fossils may be embedded in solid rock, usually limestone, shale or chalk that formed as ancient marine, stream or lakebed sediments. They also may be preserved in more unusual materials such as lava, volcanic ash or hot spring deposits. Fossils may consist of original materials, but most often the original bones or plant material have been replaced or partly replaced by other mineral matter.

The Routsong Mastodon bones are considered *fossil bones*. Even though the original bones, teeth and tusk materials are well preserved, the animals from which they came lived ~10,000 years ago. Very different fossils found in much older rocks in northern Indiana can be seen in quarries such as those along Ardmore Avenue and Yohne Road in southwest Fort Wayne. The fossils found there are millions of years old, and the organisms they represent lived in a warm, shallow sea that covered this area during the so-called Silurian Period, about 410 Million years ago. The fossil organisms (marine brachiopods, clams, snails and ancient sponge-like animals called stromatoporoids) built a large reef, the Fort Wayne Bank. The fossils consist of calcite and dolomite minerals.

IX. Geology – Study of the Earth

Geologists work in the largest laboratory in the world: *the entire Earth!* It is the goal of geologists to unravel the characteristics and natural history of the earth - and for some geologists, even those features of nearby planets. We hope that you will share in this never-ending search for knowledge. Even the smallest rock outcrops and the tallest mountains retain secrets not yet discovered or explained. Perhaps you will be the person who discovers and explains their features! We hope that your study of the now-extinct *Mastodon americanus* will stir within you an interest in science, both the science of your local environment and that of the geologic world around you.

The following three pages show data that I hope will help you in a continued study of *Mastodon americanus* and related ancient and modern animals.

Jack Sunderman

X. Classification Chart for Mastodons

Species: *Mastodon americanus* (Mastodons that lived in America.)

Genus: *Mastodon* or *Mammut* (Mastodons, whose name means “elephant-like animals with nipple-shaped teeth.”)

Family: **Mastodontidae** or **Mammutidae** (Elephant-like Proboscideans whose teeth had several rounded, nipple-shaped crowns.)

Order: **Proboscidea** (Mammals with trunks.)

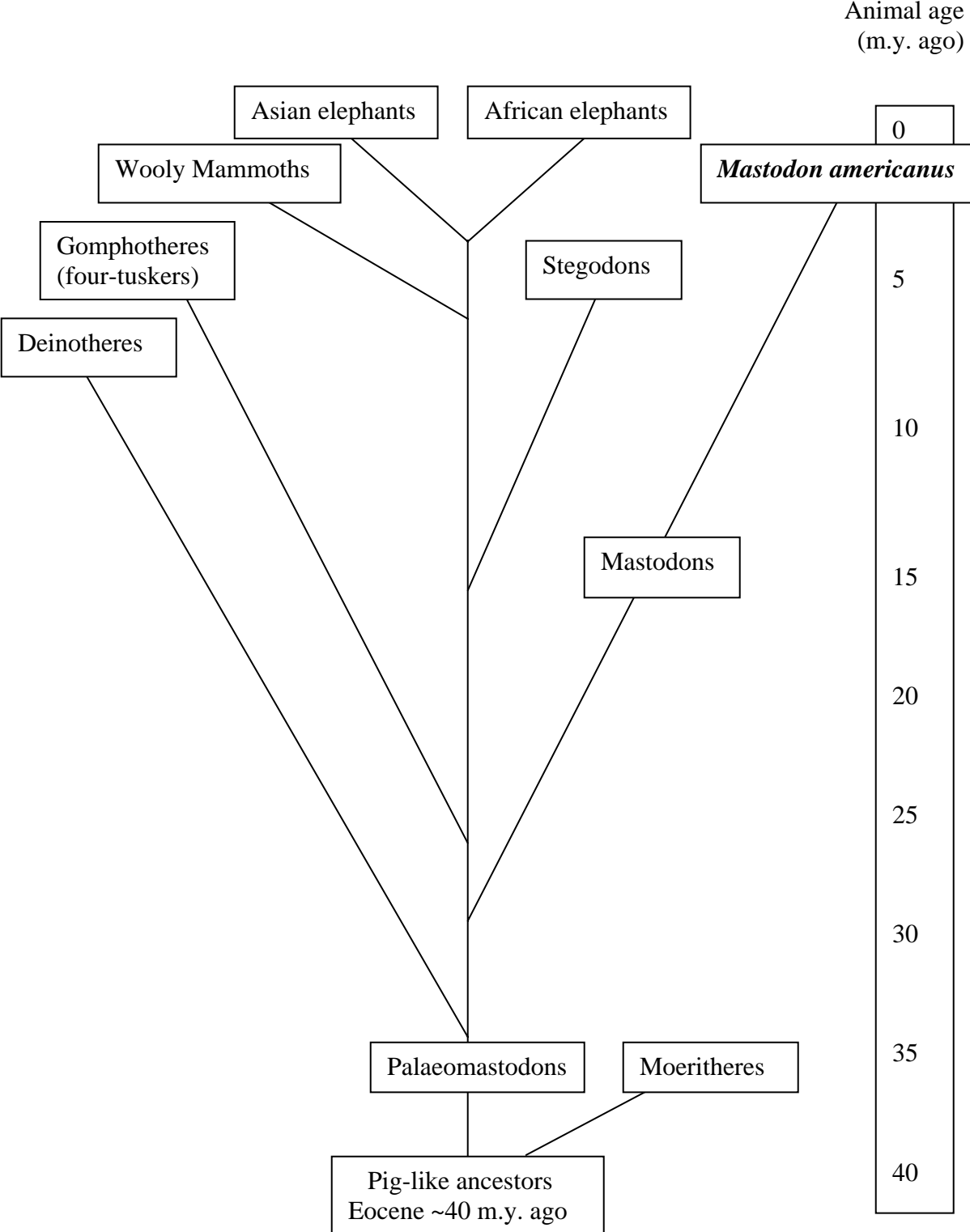
Class: **Mammalia** (Vertebrates whose young drink milk from the mother’s mammary glands.)

Subphylum: **Vertebrata** (Chordates with segmented spinal columns and brains encased in a cranium or skull of bone.)

Phylum: **Chordata** (Animals with a tubular nerve chord.)

Kingdom: **Animalia** (All animals.)

XI. Generalized Evolution Tree for Proboscideans



XII. Data Sources and Background Reading

1. Encyclopaedia Britannica, Chicago, London, etc. [Excellent for general background information on characteristics and classification of Proboscideans, mammoths and mastodons.]
2. Farlow, J.O., Sunderman, J.A., Havens, J.J., Swinehart, A.L., Holman, J.A., Richards, R.I., Miller, N.G., Martin, R.A., Hunt, R.M. Jr., Storrs, G.W., Curry, B.B., Fluegeman, R.H., Dawson, M.R., and Flint, M.E.T., 2001, The Pipe Creek Sinkhole Biota, a Diverse Late Tertiary Continental Fossil Assemblage from Grant County, Indiana: The American Midland Naturalist, v. 145, p. 367-378. [Background on the only Tertiary fossils known from North-central U.S. The site is a paleosinkhole south of Marion.]
3. Graham, Russell W., et al., 1981, Kimmswick: A Clovis-Mastodon Association in Eastern Missouri: Science, Vol. 213, No. 4512, pp. 1115-17.
4. Gray Fossil Site. Websites on this Late Miocene (?) site, discovered in northeastern Tennessee in 2000, describe fossils similar to those of northern Indiana's sinkhole site. R. Gardner's website states that *mastodon* tusk fragments have been found there.
5. Illinois State Museum Website: [Information about the Clovis People and the close association of their weapons with the remains of Mastodons - evidence for hunting.]
6. Matsch, C.L., 1976, North America and the Great Ice Age: McGraw-Hill Earth Science Paperback Series. 131 p. [Old, but good description of Pleistocene glaciation.]
7. Stanley, S.M., 1986, Earth and Life Through Time: W. H. Freeman and Company, 690 p. [Excellent introduction to earth history and the development of life on Earth. Some treatment of plants, but emphasis is on animals. Later editions may be available.]
8. Sunderman, J.A., Farlow, J.O. and Havens, J.J., 1997, Preglacial Sinkhole, Pipe Creek Jr. Quarry, Northern Indiana: Geology and Geomorphic History: Indiana Academy of Science 113h Annual Meeting Programs and Abstracts, p. 78, 79. [Early stratigraphy indicated the sediments were Tertiary, but critical fossils had not yet been dated.]
9. Sunderman, J.A., Farlow, J.O., and Havens, J.J., 1998, Tertiary sediments and fossils from northern Indiana Pipe Creek Jr. Sinkhole site: Geological Society of America Abstracts with Programs, v. 30, no. 2, p. 74. [Age of dated fossils (~5 m.y.) agreed with Tertiary age predicted by stratigraphic relations.]
10. Voorhies, M.R. and others, 1994, The Cellars of Time, Paleontology and Archeology in Nebraska; originally published in NEBRASKAland Magazine, by Nebraska Game and Parks Commission, Ken Bouc, Coordinator, v. 72, no., 1 162 p. [Excellent descriptions of some of the world's most unusual assemblages of Tertiary fossils.]