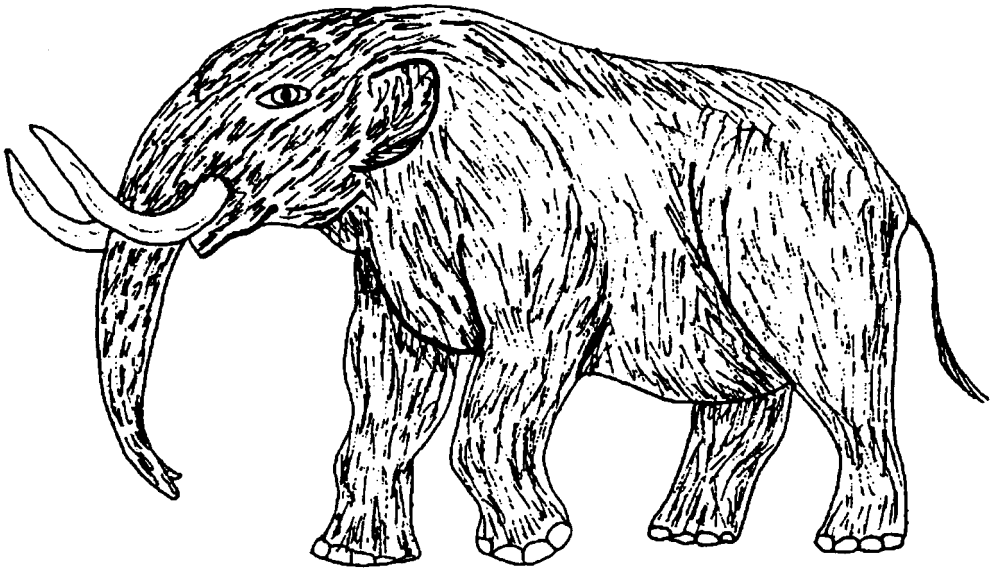
Contribution to Michigan Geology 94-01

MICHILOGIC TIME LINE

Written, compiled and illustrated by

Midwest Mineralogical and Lapidary Society of Dearborn, Michigan

As a cooperative Environmental Education Initiative Project



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This publication was written to acquaint the reader with geologic time and the history of life (fossil record) as they are known in Michigan.

GEOLOGIC TIME

A key idea that separates geology from other sciences is the concept of geologic time. Geologic time is used to describe events in the earth's history, especially those seen in the rock record. Mountain building and the emergence of a new species occur in a geologic time frame -- not the seconds -- minutes -- days --weeks -- months -- years -- decades — references of daily life.

The basic unit of geologic time is 1 ,000,000 (one million) years. A million is an incredible number. To better understand how long one million years is, we can convert it to some more familiar unit of measure. If we let one inch equal one thousand years, then one million years would equal 83.3 feet. One hundred years (longer than the average life span) would be represented by just one tenth (1/10 or 0.1) of an inch. If one goes back to the beginning of the Cambrian Period, some 570,000,000 years ago - one would need almost 9 miles to represent this part of the Earth history. To map out all of geologic time, one would need more than 72 miles.

The concept of geologic time came from work done on the fossils and physical characteristics of exposed sedimentary rocks. Sedimentary rocks are deposited in layers. The lowest layers formed first and are the oldest. As you progress up a column of rocks you progress through younger and younger layers. Early geologists used fossils as markers to correlate and thereby determine the relative ages of rocks. This led to the ability to construct a geologic column made up of rocks of different ages from different locations. This orderly succession from oldest at the bottom to youngest at the top is reflected in most time charts. Eventually a global time scale was developed. Names were standardized, commonly referring to an area where early work was done or the exposures were good. Even though this approach could help show similarities and differences with the passage of time, it could not determine how much time any strata represented.

With the discovery of radioactivity, near the close of the 19th century, geologists were given a tool to apply absolute times to rock formations. Radioactive elements change into other elements at a known rate called half-life. By carefully analyzing rocks and determining the ratios of various elements and isotopes, an absolute age range can be determined. Radioactivity is most useful for dating igneous rocks. With the addition of absolute age dating tools an even more complete interpretation of the sequence of rocks around the world has evolved.

FOSSILS

A fossil is any evidence of past life. Fossils are the remains, traces or imprints of plants or animals that have been preserved by natural processes. These plants and animals lived in the geologic past.

The process of fossilization (becoming a fossil) may be long and complex. After an animal or plant dies it must be buried by sediments before it decays or is destroyed by other forces. After it is buried, conditions must be right for it to be preserved. The rock forming processes often erase much of what could have been in the fossil record. If the encasing rock is eroded or altered by other geologic forces the fossil will be damaged or destroyed. Weathering destroys many more fossils than are ever collected.

Fossil remains are grouped or classified a number of different ways. Some fossils can be directly identified when they are found as a whole or nearly complete animal or plant, or indirectly when only a small part or only tracks or trails are found. Most commonly, only the "hard parts" of plants or animals are preserved as fossils. Some people tend to overemphasize the identification of fossils. Although identification is necessary, it is a complicated process, especially for newcomers. In order to accurately recognize and describe a fossil, one must be familiar with the classification of living plants and animals. The amount and complexity of the terminology can be staggering. Becoming

an adequate fossil identifier takes time; that is one of the reasons why paleontologists (those who study fossils) spend years in specialized training.

Only a small fraction of the plants and animals that ever lived are preserved as recognizable fossils. Estimates vary, but fewer than one percent of the previous life forms are though to have been preserved as fossils. To have been included in the rock history, and to have survived millions of years, makes all fossils remarkable.

Fossils should be collected and preserved rather than letting them erode into oblivion. However, care must be taken to accurately and completely document, identify, label and catalog specimens and localities. What is fresh in our mind today may be forgotten tomorrow. Some of the items that should be included in a catalog are: the name of the fossil (as much as is known), where it was found, when it was collected, and by whom. You will not recognize all of the fossils you find. Most earth science hobby groups and many museums can provide assistance or help you find references.

By studying geology, you can better understand the various areas in Michigan. Once you learn to interpret the geologic story and see how it affects our lives, the science of geology will take on new depth and meaning.

THE MICHILOGIC TIME LINE was conceived, compiled and written by the Paleontological Study Group of the Midwest Mineralogical & Lapidary Society of Dearborn, Michigan. Members of this group who worked on this project include: Cecilia Duluk (Chairperson), Anne Allen, Claire Boutain, Karen Goryl, Ruth Gribble, Joyce Hanschu (Secretary), Norm Hanschu, Tom Morris, Jr., Frank Nadeau, Lillian Nadeau, Pat Rutkowski, Doris Snyder and Myrna Workman. Illustrators: Karen Goryl and Norm Hanschu. Special thanks to Professor Roger Pabian, Conservation and Survey Division, IANR, University of Nebraska-Lincoln, for his help in clarifying terminology and his advice on nomenclature and interpretation of information from other authors.

MICHIGAN AND ITS GEOLOGY

The Northern and Southern Peninsulas of Michigan are geologically distinct. Michigan's vast metallic mineral resources are in the Precambrian and Cambrian rocks of the western Northern Peninsula. The Cambrian through Jurassic rocks of the rest of the State contain important resources including: gypsum, limestone, dolomite, shale, salt and petroleum.

Deposits of gravels, sands and clays have hidden much of Michigan's geology. These deposits were once part of the great variety of rocks found in Canada. The movement of the Pleistocene glaciers picked up soils and rocks, grinding them against one another. When the glaciers melted, meltwater carried the fragments and deposited them as gravel, sand, silt and clay. Glacial ice movements and meltwaters have shaped Michigan's entire land surface.

While some are abundant, our geologic resources are non-renewable. Once removed, mineral resources do not grow back. The processes that formed them however, do continue; but ever so slowly in human terms. To use or not to use non-renewable geologic resources? This is a question that has trade-offs in either case and one which we must respond to with care. As good stewards of our resources we must consider our economic needs, our quality of life, and our environment.

This publication was designed as an instructional aid. If it is printed on heavy paper it can be folded or cut and made into flashcards. Photocopies can be made so students can work with the material but not consume the original.

We Hope you find this publication useful. Any comments that would improve this product, information about how it is used, and/or suggestions for future editions or products is appreciated.

Please direct comments and suggestions to:

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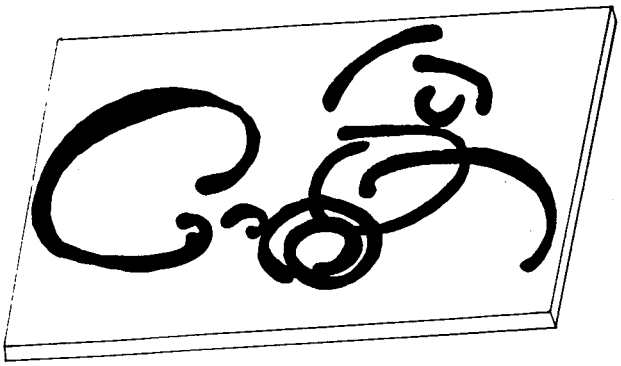
KEY TO SIZES OF KEY TO ILLUSTRATIONS:

{1x) ..... Actual size, no enlargement or reduction

{2x}, {5x} etc. ..... enlarged x number of times etc. specimen is smaller than illustration

{2r}, {5r} etc. ..... reduced r number of times specimen is larger than illustration

Illustrations of Proterozoic or Precambrian Fossils



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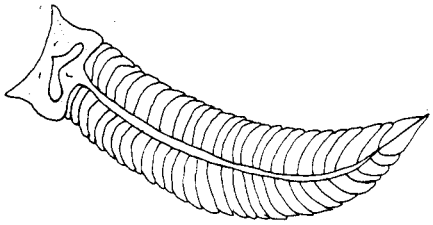

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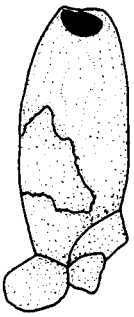

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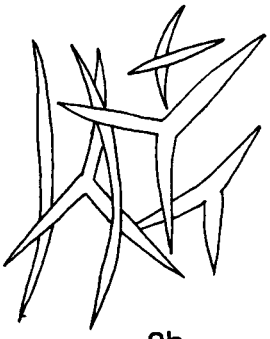

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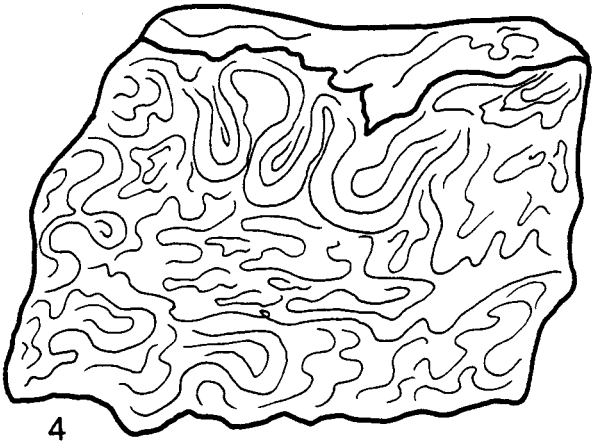

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PROTEROZOIC OR PRECAMBRIAN ERA

GENERAL SETTING

The effects of heat and pressure from widespread mountain building caused considerable alteration of rock layers during the Proterozoic, or Precambrian, Era. This was followed by extensive erosion, especially in Canada and the northeastern United States. All life was in the sea. The first evidence of life is of single celled, bacteria-like algae; the preserved forms of some colonies of these microorganisms "algae" are known as stromatolites. Algal life forms increased the amount of oxygen in the atmosphere, leading to early animal life forms. Although the majority of these animals were more highly developed, they were soft bodied and thus decayed before they could be preserved as fossils.

FOSSILIFEROUS OUTCROPS IN MICHIGAN:

Dickinson, Iron and Marquette counties

FIRST LIFE FORMS:

- Single celled bacteria-like prokaryotes
- Colonial stromatolites
- Blue green algae
- Complex eucaryotes
- Green algae
- Sponges
- Jellyfish
- Segmented worms

ILLUSTRATIONS

1. Eucaryotic algae filaments {1x}
2. Segmented worm ☸ {1.25x}

3a. Sponge ☸ {1x}

3b. Sponge spicules ☸ {4x}

4. Stromatolite colony {1x}

☸ have not been reported from Michigan

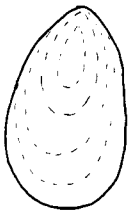
KEY TO SIZES OF ILLUSTRATIONS:

{1x} ..... actual size

{2x}, {5x}, etc. ..... enlarged x number of times

{2r}, {5r}, etc. ..... reduced r number of times

Illustrations of Cambrian Fossils



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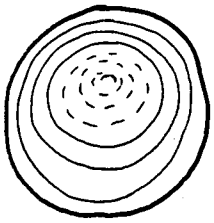

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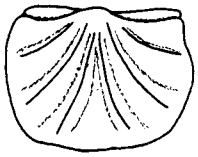

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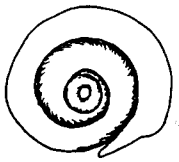

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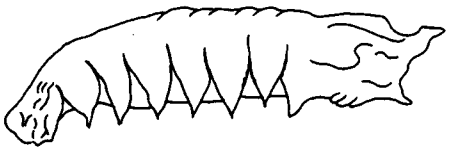

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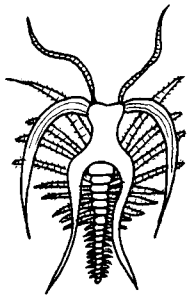

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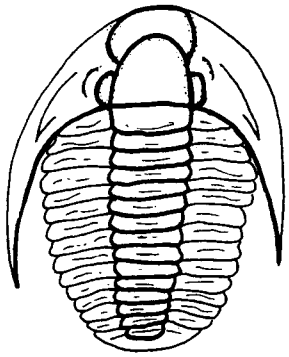


6

CAMBRIAN PERIOD

GENERAL SETTING

The beginning of the Cambrian is marked by a shallowing of the oceans and the spreading of seas over the continental platforms. The land-masses were stable, while the shallow seas became warmer and more hospitable to life. Massive stromatolites were abundant. An explosion of complex arthropods (trilobites and their kin) led to their becoming the dominant animal during this period, yet they declined in both type and number toward the close of the Cambrian, due to shrinking seas.

FOSSILIFEROUS OUTCROPS IN MICHIGAN:

Dickinson County

FIRST DEVELOPMENT OF:

- Brachiopods
- Annelid worms
- Trilobitoids
- Trilobites
- Eocrinoids
- Cystoids
- Gastropods (snails)
- Primitive clams
- Nautiloid cephalopods

SIGNIFICANT FOSSIL FORMS:

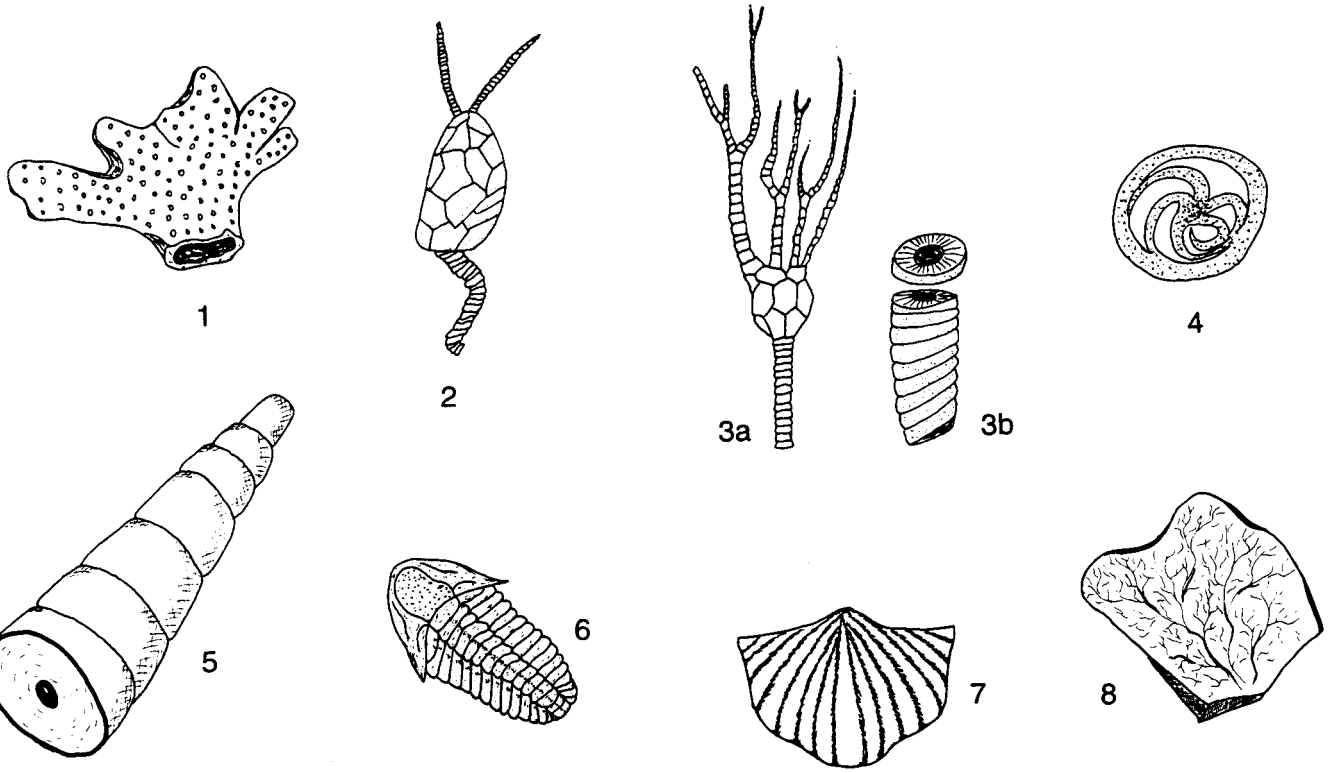
- Massive stromatolites
- Trilobites

ILLUSTRATIONS:

1a. Inarticulate brachiopod *Lingula* {1.5x}
1b. Inarticulate brachiopod *Acrothele* {2x}
2. Articulate brachiopod {1x}
3. Gastropod (snail) {2x}
4. Annelid worm {1.5x}
5. Trilobitoid ☸ {1x}
6. Trilobite {2r}

☸ have not been reported from Michigan.

Illustrations of Ordovician Fossils



ORDOVICIAN PERIOD

GENERAL SETTING

During the Ordovician Period, 70 percent of the North American continent was under water; the warm uniform temperatures resulted in expansion and greater diversification of marine invertebrates. Nautiloid cephalopods were the largest life forms of the time, sometimes reaching a length of 15 feet. These, with other mollusks, bryozoans and articulate brachiopods were the most abundant animals of the period. Plant life consisted almost completely of seaweed and algae.

FOSSILIFEROUS OUTCROPS IN MICHIGAN:

Alger, Chippewa, Delta and Menominee counties

FIRST DEVELOPMENT OF:

- Bryozoans
- Rugose corals
- Tabulate corals
- Crinoids
- Starfish
- Eurypterids "sea scorpions"
- Primitive aquatic vertebrates, including jawless fish

SIGNIFICANT FOSSIL FORMS:

- Brachiopods
- Trilobites
- Edrioasteroids
- Cystoids
- Gastropods (snails)
- Bivalves (clams)
- Nautiloid cephalopods
- Graptolites

ILLUSTRATIONS:

1. Bryozoan colony {2r}
2. Cystoid (an echinoderm) {1x}

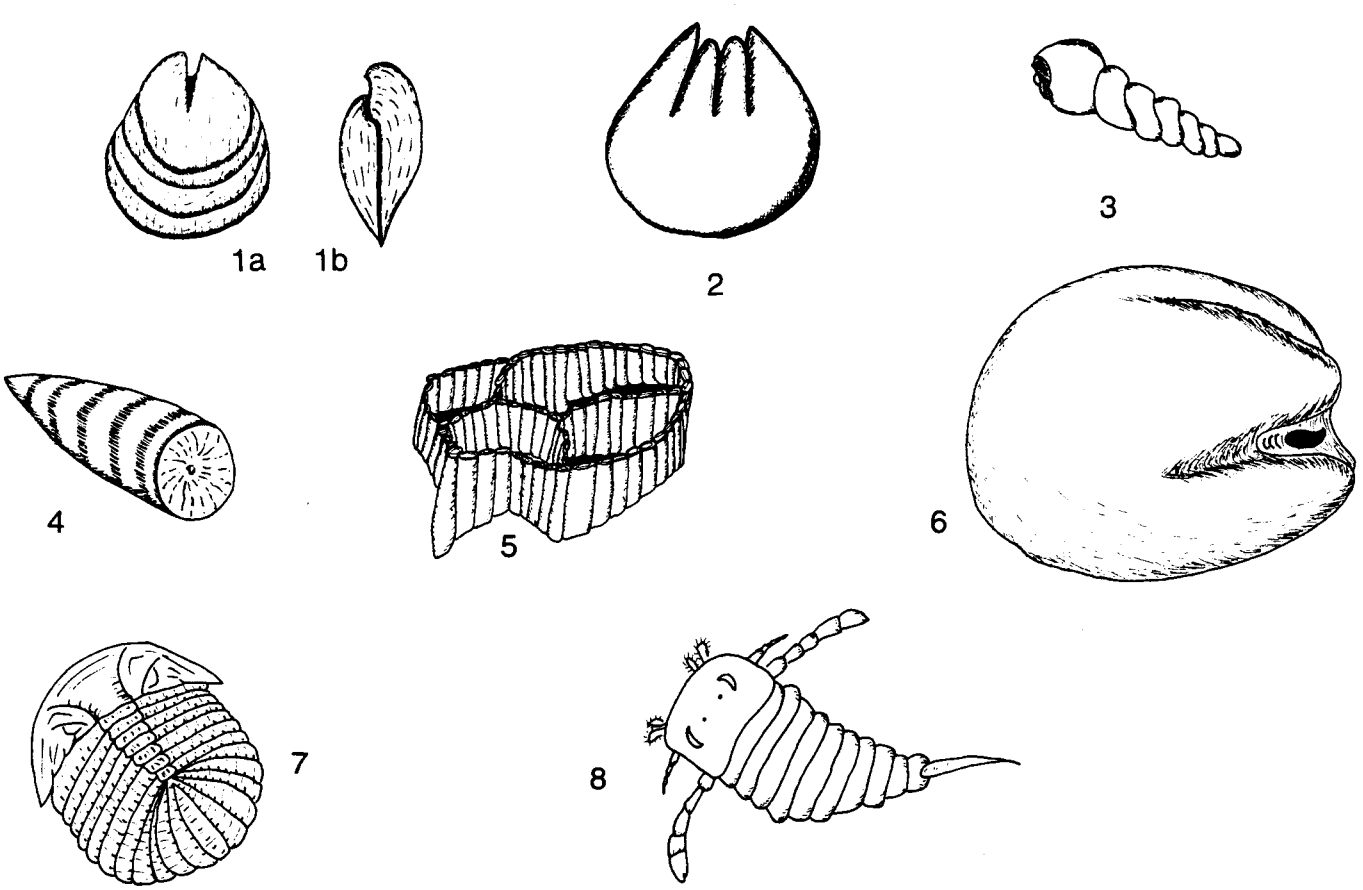
3a. Crinoid crown (complete head with arms) ☸ {2r}

3b. Sections of crinoid column {1x}

4. Edrioasteroid, an echinoderm) {1x}
5. Nautiloid cephalopod {3r}
6. *Flexicalymene* a trilobite {1x}
7. Articulate brachiopod {1x}
8. Graptolites {3r}

☸ have not been reported from Michigan

Illustrations of Silurian Fossils



SILURIAN PERIOD

GENERAL SETTING

Continental seas which covered North America during the early and middle Silurian receded during the later part of this period. An isolated, shallow sea across New York, Pennsylvania, Southern Ontario and Southern Michigan evaporated, leaving massive salt deposits. The seas abounded with reef- building corals, crinoids with root systems attached to the sea floor, mollusks and other marine life, while on land the first plants emerged.

FOSSILIFEROUS OUTCROPS IN MICHIGAN:

Chippewa, Delta, Luce, Mackinac and Schoolcraft counties

FIRST DEVELOPMENT OF:

- Land plants
- Barnacles
- Arachnids (spiders)
- Blastoids
- Jawed fish

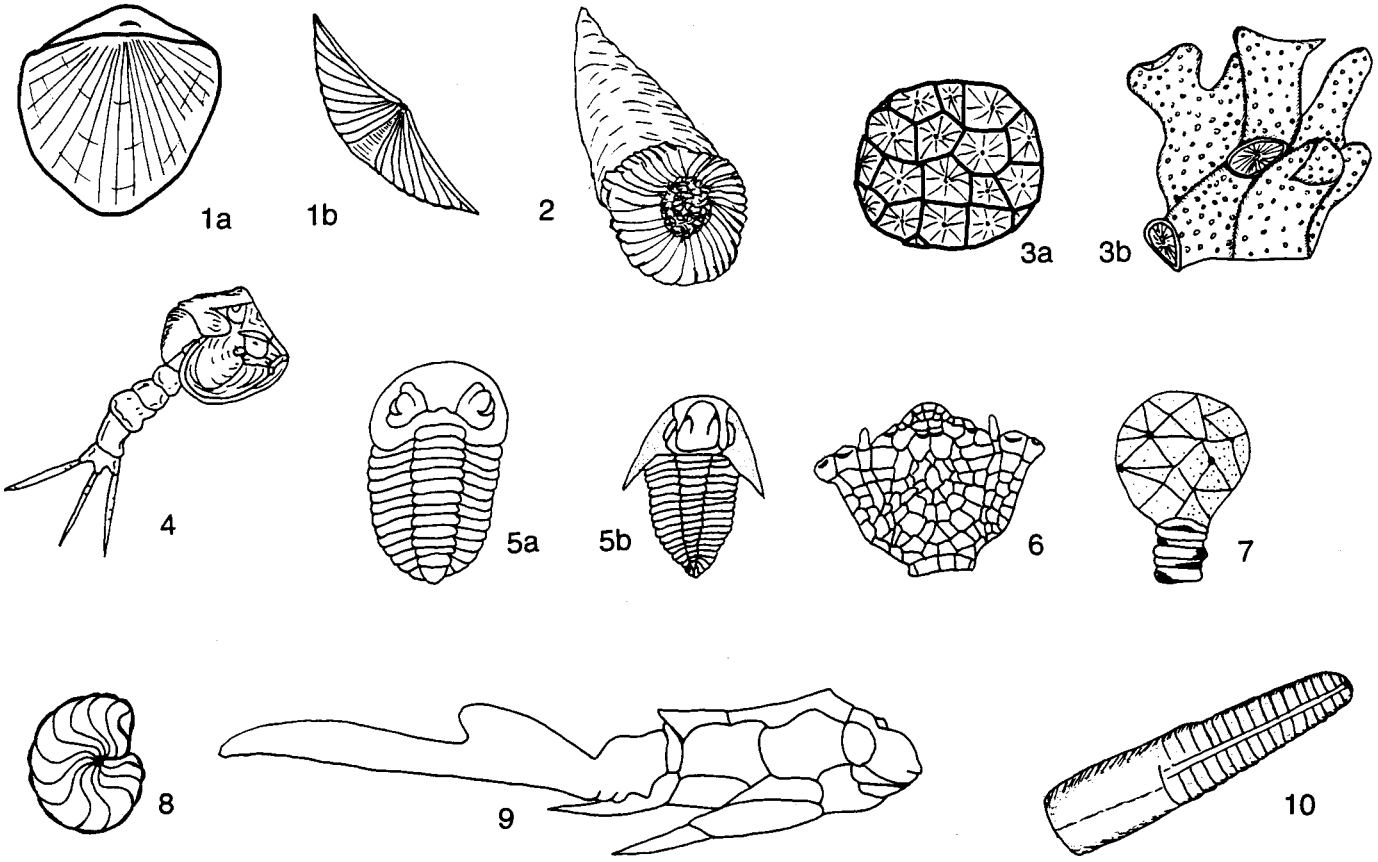
SIGNIFICANT FOSSIL FORMS:

- Sponges
- Solitary or "horn" and colonial corals
- Large inarticulate brachiopods
- Crinoids with root systems
- Trilobites
- Marine eurypterids
- Gastropods (snails)
- Bivalves (clams)

ILLUSTRATIONS:

1a. Articulate brachiopod, view of pedicale valve {1x}
1b. Articulate brachiopod, view of both valves {1x}
2. Internal mold of large inarticulate brachiopod {2r}
3. Gastropod (snail) {1x}
4. Solitary or "horn" coral {range 1x to 2r}
5. *Halysites* a colonial coral ("chain coral") {2r}
6. *Megalomus* an internal mold of bivalve (clam) 2r}
7. Trilobite {2r}
8. Marine eurypterid or "sea scorpion" {range 1x to 12r}

Illustrations of Devonian Fossils



DEVONIAN PERIOD

GENERAL SETTING

The sediments from which the basins of the Lower Great Lakes formed were laid down during this period of alternating raising and lowering of sea levels. These deposits are the most fossiliferous outcrops in Michigan. Fish underwent great evolutionary development during the Devonian, with specialized forms such as the placoderms (fish with hard bony plates covering their skin) reaching lengths of 15 to 40 feet. Other sea life included the corals, bryozoans, mollusks, arthropods and echinoderms.

FOSSILIFEROUS OUTCROPS IN MICHIGAN:

Alcona, Alpena, Antrim, Charlevoix, Emmet, Leelanau, Monroe, Presque Isle, St. Clair, Washtenaw and Wayne counties

FIRST DEVELOPMENT OF:

- Land plants (large, tree-like)
- Horse-tail rushes
- Gymnosperms
- Primitive hexapods
- Ammonoid cephalopods
- Sharks
- Amphibians

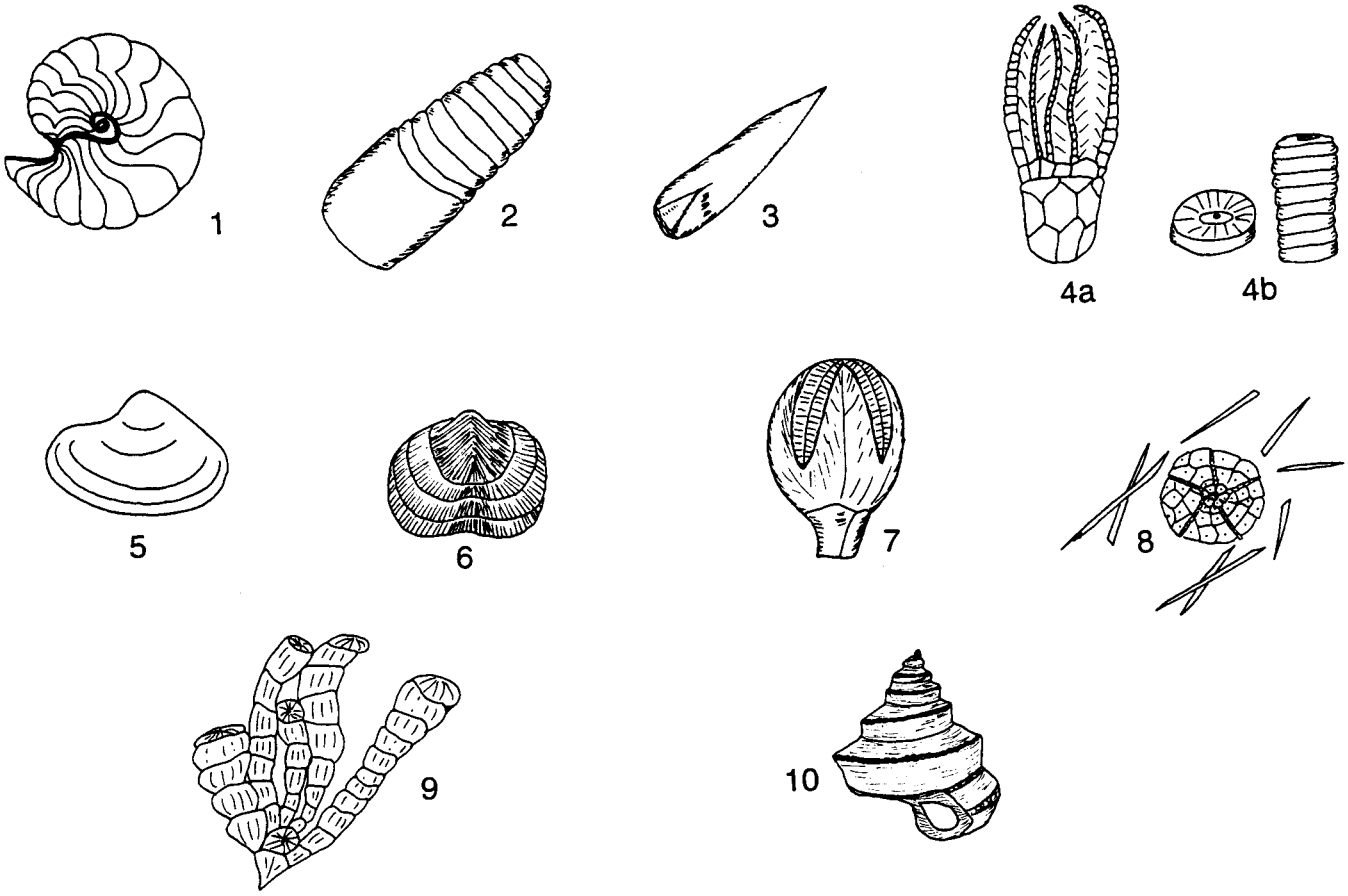
SIGNIFICANT FOSSIL FORMS:

- Stromatoporoids
- Brachiopods (inarticulate and articulate)
- Phyllocarid crustaceans
- Echinoderms (blastoids, cystoids, crinoids)
- Bivalves (clams)
- Nautiloid cephalopods
- Placoderms or armored fish

ILLUSTRATIONS:

1a. *Atrypa* an articulate brachiopod {1x}
1b. *Mucrospirifer* an articulate brachiopod {1x}
2. Solitary or horn coral (range 1x to 3r}
3a. *Hexagonaria* a colonial coral; as the "Petoskey Stone", has been designated Michigan's State Stone
3b. *Favosites* a colonial coral {range 1x to 3r}
4. Phyllocarid crustacean {2r}
5a. *Phacops* a trilobite {range 1x to 2r}
5b. *Dechenella* a trilobite {1x}
6. Crinoid calyx {1x}
7. Cystoid, an echinoderm {1x}
8. Ammonoid cephalopod {2x}
9. Placoderm or armored fish {30r}
10. Internal mold of nautiloid cephalopod ("steinkern") {2r}

Illustrations of Mississippian Fossils



MISSISSIPPIAN PERIOD

GENERAL SETTING

Warm Shallow continental seas covered most of the central portion of North America, providing the perfect habitat for the proliferation of echinoderms, especially the crinoids and bastoids. However, conditions in the Michigan area were more arid, resulting in the deposition of extensive gypsum beds. By the end of the Mississippian Period the retreat of the continential seas caused a restriction of the marine environment, resulting in a reduced invertebrate populations. In particular the trilobites were decimated both in numbers and species diversity.

FOSSILIFEROUS OUTCROPS IN MICHIGAN:

Branch, Calhoun, Eaton, Huron, Jackson and Ottawa counties

FIRST DEVELOPMENT OF:

- Belemnoids

FURTHER EVOLUTION OF:

- Ferns
- Insects
- Bony fish and sharks
- Amphibians

SIGNIFICANT FOSSIL FORMS:

- Reef-building corals
- Bryozoans
- Brachiopods
- Echinoderms (crinoids, blastoids, echinoids ansd starfish)
- Gastropods (snails)
- Bivalves (clams)
- Cephalopods

ILLUSTRATIONS:

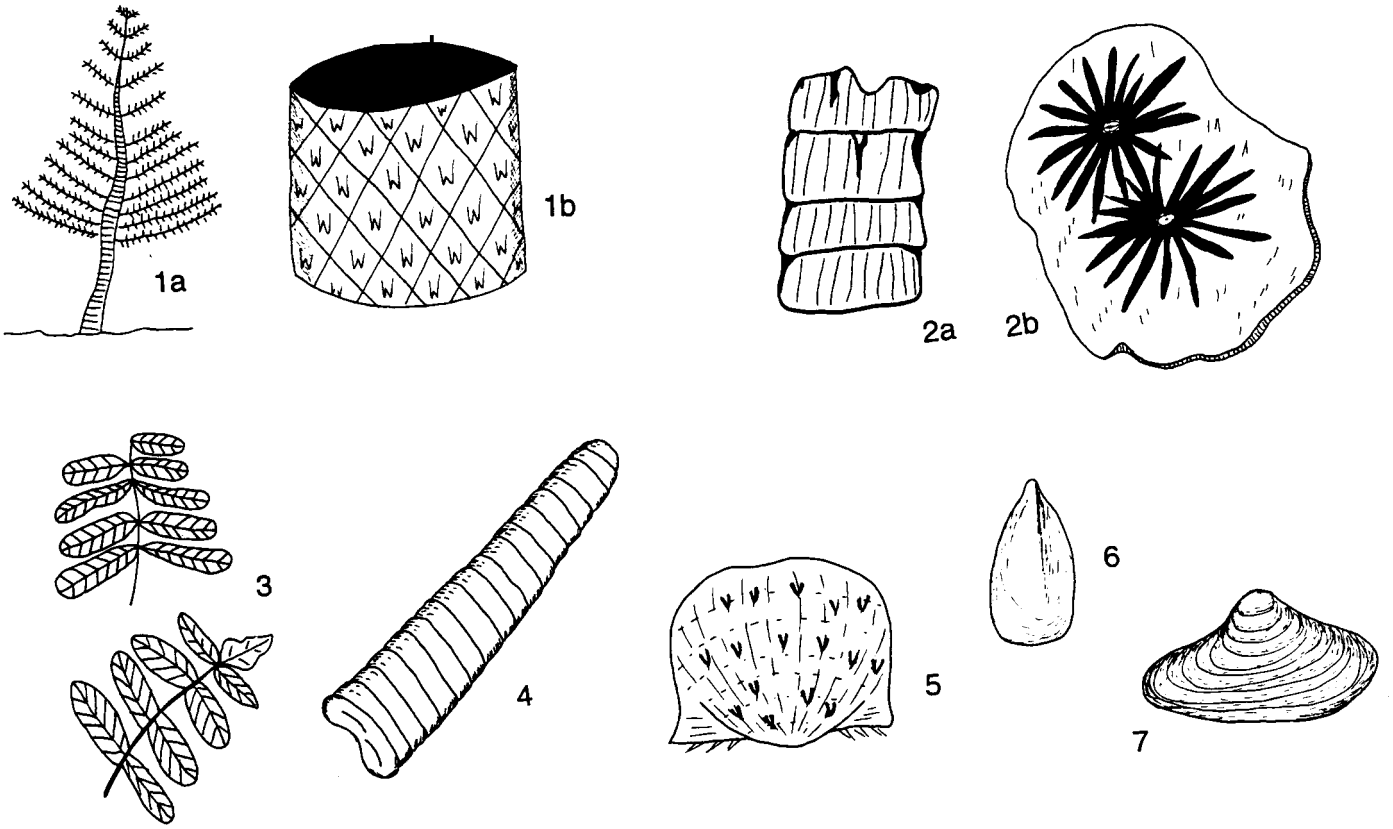
1. Ammonoid cephalopod with goniatite sutures {2r}
2. Nautiloid cephalopod {range 1x to 3r}
3. Beleminoid ☸ {2r}

4a. Criniod crown ☸ {1x}
4b. Crinoid columnal and column section {range 2x to 2r}

5. Bivalve or clam {2r}
6. Articulate brachiopod {1x}
7. Blastoid, an echinoderm {range 3x to 2r}
8. Echinoid or sea urchin {2r}
9. Colonial coral {2r}
10. Gastropod or snail {1x}

☸ have not been reported from Michigan.

Illustrations of Pennsylvanian Fossils



PENNSYLVANIAN PERIOD

GENERAL SETTING

The retreating seas of the Mississippian Period left extensive deltas. increased temperatures and rainfall, combined with poor drainage, turned the deltas into swamplands. Plants became so abundant in these swampy areas that their decayed remains formed thick deposits of peat. Over geologic time these peat beds were converted to coal by heat and pressure, while individual leaves, stems and roots were preserved in the mud which turned to shale. In the seas, shallow water forms such as trilobites and crinoids declined, while deeper-water animals such as sharks and cephalopods continued to flourish.

FOSSILIFEROUS OUTCROPS IN MICHIGAN:

Calhoun, Clinton, Eaton, Ingham, Jackson, Saginaw, Shiawassee and Tuscola counties

FIRST DEVELOPMENT OF:

- Ancestral conifers
- Dragonflies
- Cockroaches
- Spiders
- Shrimp
- Reptiles

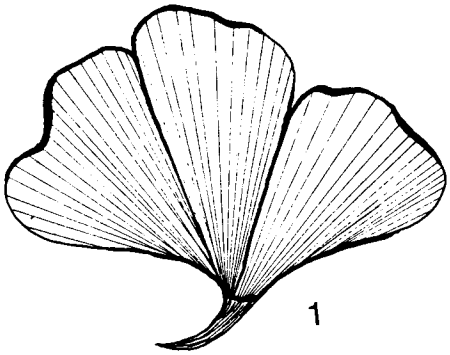
SIGNIFICANT FOSSIL FORMS:

- Scale Trees
- Giant horsetails
- Tree ferns
- Large foraminifera
- Brachiopods (inarticulate and articulate)
- Gastropods (snails)
- Bivalves (clams)
- Cephalopods
- Sharks
- Amphibians

ILLUSTRATIONS:

1a. Reconstruction of Scale tree {ranges up to 95r}
1b. Scale tree trunk cast {ranges up to 50r}
2a. *Calamites* a pith cast of giant scouring rush {range 1x to 6r}
2b. Leaves of scouring rush {range 1x to 2r}
3. Leaves of tree fern {range 1x to 2r}
4. Nautiloid cephalopod showing suture markings {range 1x to 3r}
5. Articulate brachiopod {1x}
6. Inarticulate brachiopod {1x}
7. Bivalve (clam) {1x}

Illustrations of Permian Fossils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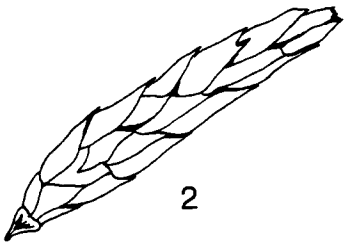
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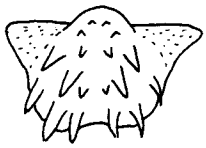
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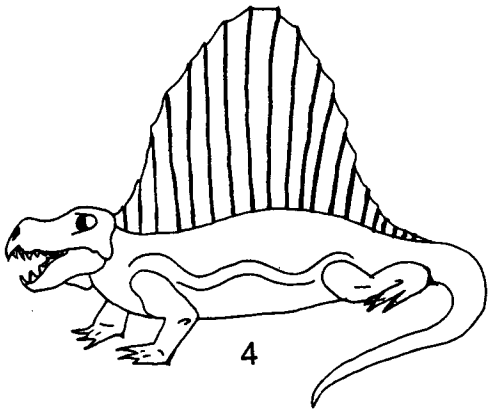
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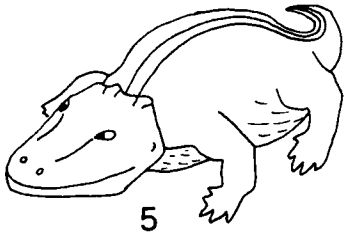
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PERMIAN PERIOD

GENERAL SETTING

The continental seas shrank even further. Giant scale trees, conifers and insects dominated the land. Climatic and geographic changes at the end of the Permian, combined with extensive mountain building, resulted in the extinction of over 90 percent of all animal species, including *ALL* trilobites, blastoids and rugose corals. Reptiles then developed, as well as the first reptile with mammal-like features, *Dimetrodon*.

FOSSILIFEROUS OUTCROPS IN MICHIGAN:

NO KNOWN OUTCROPS IN MICHIGAN

FIRST DEVELOPMENT OF:

- Cycads
- Ginkgoes
- Reptiles with mammal-like features

SIGNIFICANT FOSSIL FORMS:

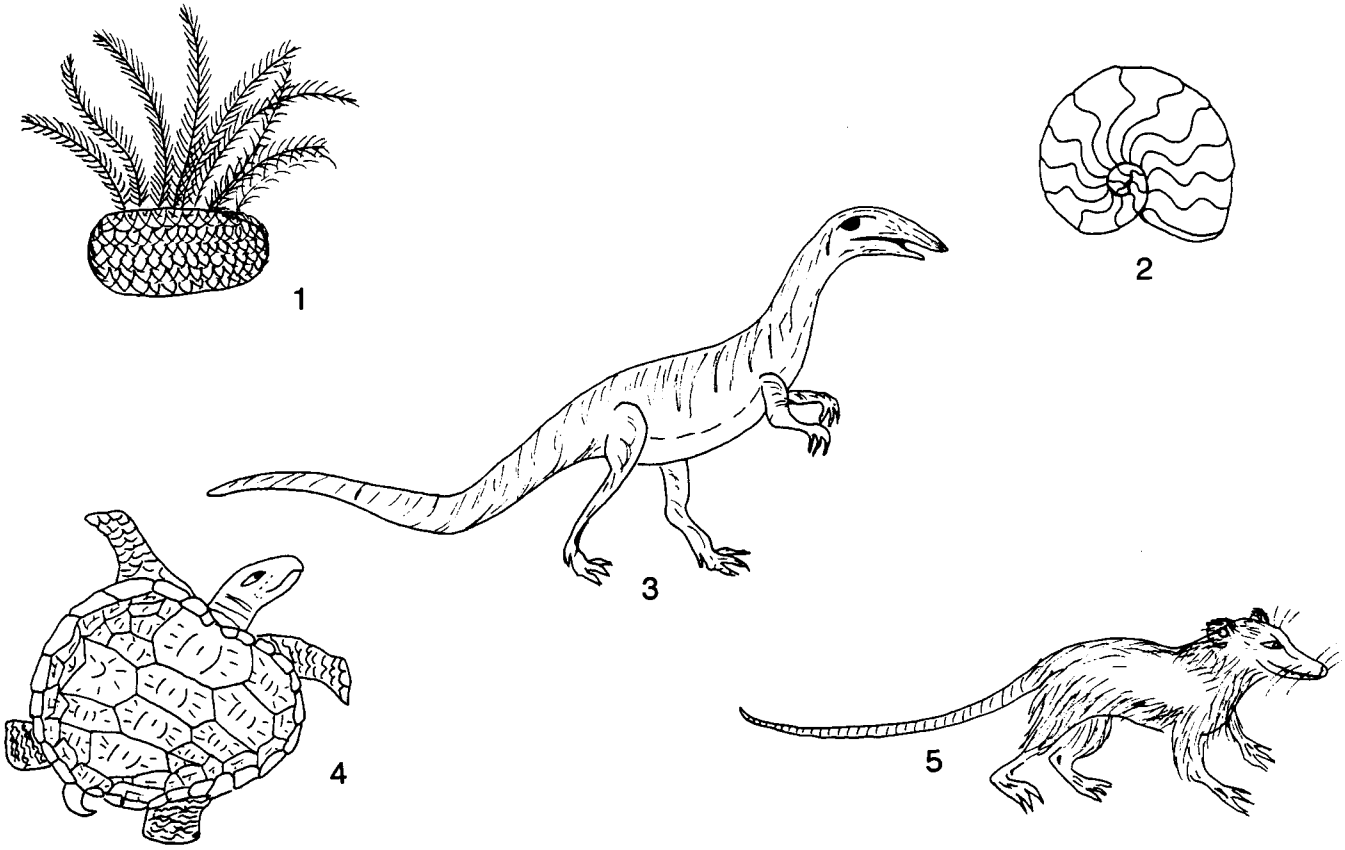
- Conifers
- Large foraminifera
- Spiny brachiopods
- Insects
- Cockroaches
- Amphibians
- Reptiles

ILLUSTRATIONS:

1. *Ginkgo* leaf ☸ {2r}
2. Pine cone ☸ from a conifer {1x}
3. Spiny brachiopod ☸ {1x}
4. *Dimetrodon* ☸ a reptile with mammal-like features {40r}
5. Amphibian ☸ {24r}

☸ have not been reported from Michigan.

Illustrations of Triassic Fossils



TRIASSIC PERIOD

GENERAL SETTING

During the Triassic, there was considerable volcanic activity in eastern North America and shallow seas in the west. Ammonites, gastropods and pelecypods flourished in these waters, while brachiopods, crinoids and nautiloid cephalopods declined. Reptiles established their dominance on the land, giving rise to the "Age of Dinosaurs".

FOSSILIFEROUS OUTCROPS IN MICHIGAN:

NO KNOWN OUTCROPS IN MICHIGAN

FIRST DEVELOPMENT OF:

- Hexacorals (present day corals)
- Oysters
- Lizards
- Turtles
- Marine reptiles
- Dinosaurs
- Primitive mammals

SIGNIFICANT FOSSIL FORMS:

- Cycads
- Ginkgoes
- Conifers
- Gastropods (snails)
- Bivalves (clams)
- Ammonoid cephalopods
- Lung-fish
- Reptiles

ILLUSTRATIONS:

1. Cycad plant reconstruction☸ {80r}
2. Ammonoid cephalopod☸ {range 1x to 3r}
3. Primitive saurischian dinosaur☸ {19r}
4. Turtle☸ {72r}
5. Primitive mammal☸ {2r}

☸ have not been reported from Michigan.

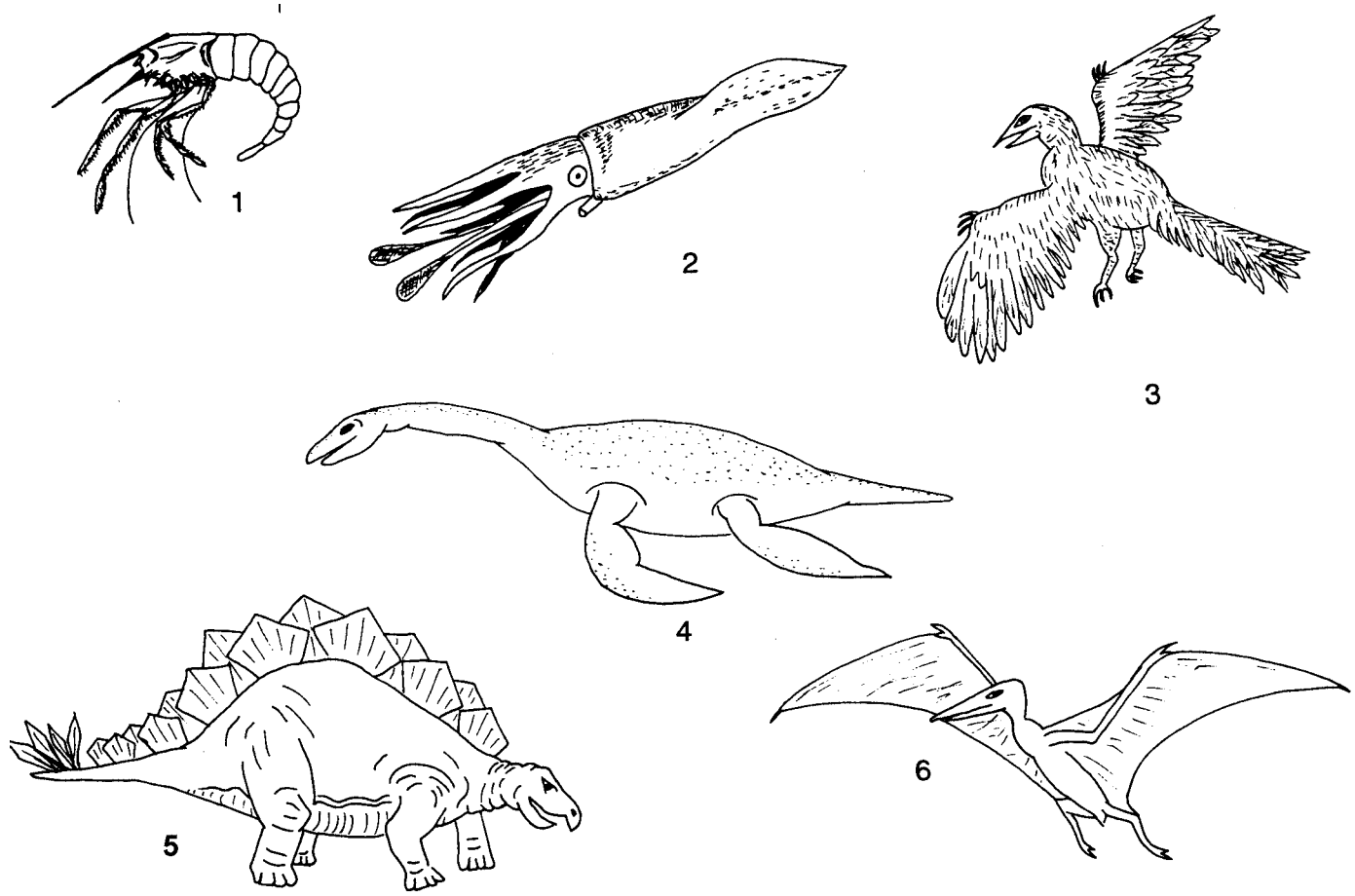
KEY TO SIZES OF ILLUSTRATIONS:

{1x} ..... actual size

{2x}, {5x}, etc. ..... enlarged x number of times

{2r}, {5r}, etc. ..... reduced r number of times

Illustrations of Jurassic Fossils



JURASSIC PERIOD

GENERAL SETTING

The seas in Jurassic times covered only limited portions of North America and the climate was mild and humid. On land, the dinosaurs continued to dominate while conifers, cycads, ferns and ginkgoes thrived. The first mammals and birds appeared. In the seas, reef-building corals, mollusks, ammonites and sea urchins flourished. At the close of the Jurassic the extensive uplifting and volcanic activity in western North America created the Sierra Nevada range.

FOSSILIFEROUS OUTCROPS IN MICHIGAN:

NO KNOWN OUTCROPS IN MICHIGAN, drill cores show Jurassic strata with fossil spores and pollen

FIRST DEVELOPMENT OF:

- Squids
- Frogs
- Salamanders
- Crocodiles
- Small mammals

SIGNIFICANT FOSSIL FORMS:

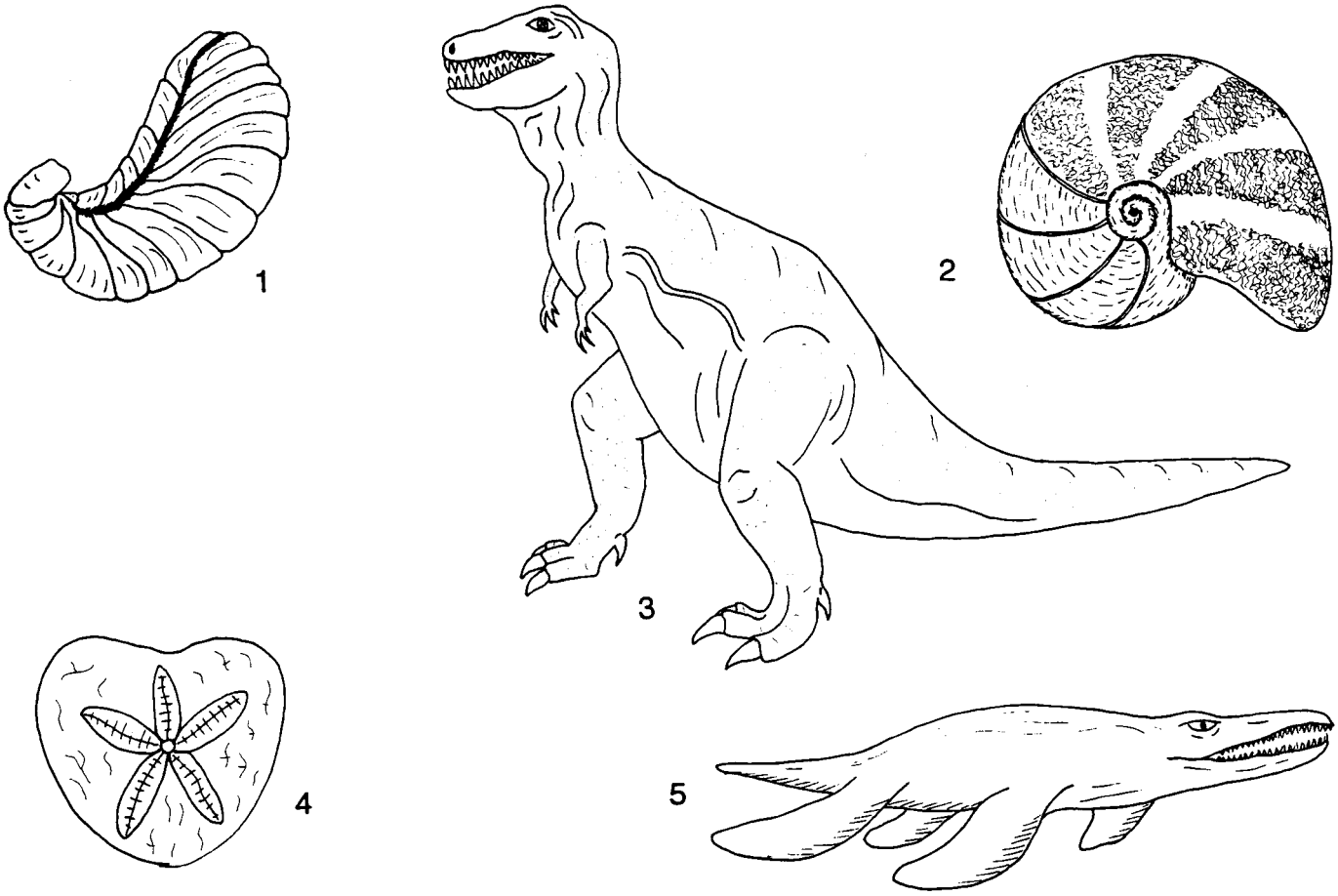
- Cycads
- Ginkgoes
- Ammonoid cephalopods
- Belemnoid cephalopod
- Lobsters
- Shrimp
- Crayfish
- Dinosaurs
- Flying reptiles
- Reptilian "bird" with feathers

ILLUSTRATIONS:

1. Shrimp ☸ {1x}
2. Belemnoid cephalopod ☸ (related to squid) {range 1x to 2.5r}
3. *Archaeopteryx* ☸ a primitive bird {9r}
4. Plesiosaur ☸ a marine reptile {range 30r to 60r}
5. *Stegosaurus* ☸ a dinosaur {range 67r to 93r}
6. *Pterodactylus* ☸ a pterosaur or flying reptile {3.5r}

☸ have not been reported from Michigan.

Illustrations of Cretaceous Fossils



CRETACEOUS PERIOD

GENERAL SETTING

The Cretaceous Period saw an advancement of the continental seas causing the last major submergence of North America. The climate was still mild, favoring the development of the first flowering plants and insects that pollinate them. The evolution of dinosaurs and other reptiles peaked during the Early Cretaceous but declined swiftly toward the end of the period. This last period of the Mesozoic Era ended with major uplifts and volcanic activity through most of North America. The resulting catastrophic changes in the climate contributed to the extinction of dinosaurs, marine and flying reptiles, ammonoid and belemnoid cephalopods, and a decimation of two-thirds of the other marine invertebrates.

FOSSILIFEROUS OUTCROPS IN MICHIGAN:

NO KNOWN OUTCROPS IN MICHIGAN

FIRST DEVELOPMENT OF:

- Angiosperms (flowering plants)
- Bees
- Butterflies
- Ancestral bird-like forms
- Marsupials

SIGNIFICANT FOSSIL FORMS:

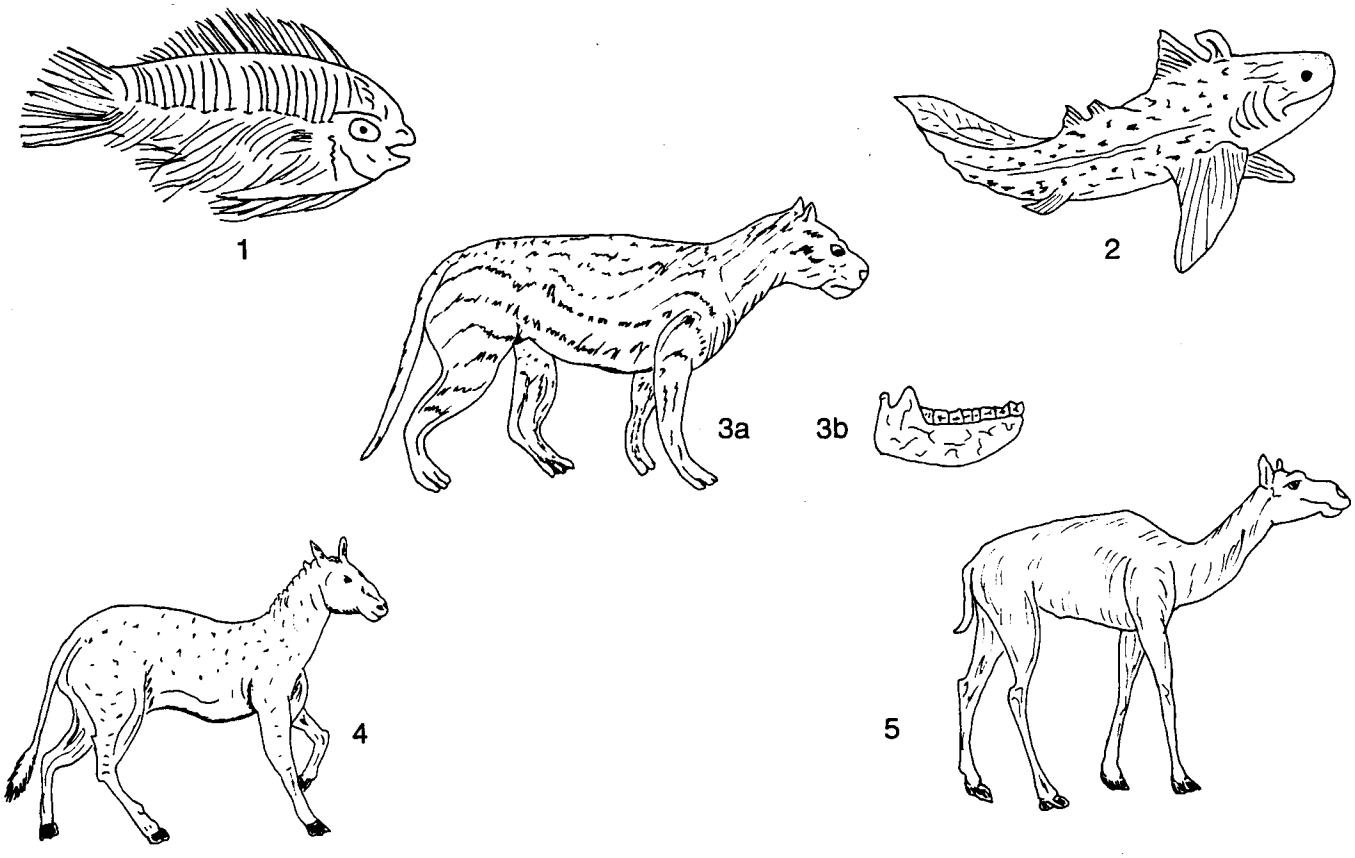
- Bivalves (clams and oysters)
- Nautiloid and ammonoid cephalopods
- Echinoids (sea urchins)
- Dinosaurs
- Mosasaurs
- Turtles
- Small mammals

ILLUSTRATIONS:

1. Oyster ☸ {1x}
2. Ammonoid cephalopod with ammonite sutures ☸ {range 1x to 6r}
3. *Tyrannosaurus* ☸ a dinosaur {164r}
4. Echinoid ☸ or sea urchin {range 1x to 2r}
5. Mosasaur ☸ a marine reptile {81r}

☸ have not been reported from Michigan.

Illustrations of Early Tertiary Fossils



EARLY TERTIARY PERIOD

GENERAL SETTING

The Early Tertiary Period (called Paleogene in European references) consists of the Paleocene, Eocene and Oligocene epochs. Land plants and animals became the primary forms of life and remain so today. Mammals increased dramatically in both number and type with the widespread prairies supporting a variety of horses, camels and other larger animals. Carnivores such as saber-toothed cats and ostrich-like birds reached an unusually large size. Marine invertebrates such as snails, clams and oysters were much like modern forms.

FOSSILIFEROUS OUTCROPS IN MICHIGAN:

NO KNOWN OUTCROPS IN MICHIGAN

FIRST DEVELOPMENT OF:

- Prairie grasses
- Birds
- Elephants
- Horses
- Saber-toothed cats
- Bears
- Whales
- Rodents
- Pigs and peccaries
- Camels

SIGNIFICANT FOSSIL FORMS:

- Gastropods (snails)
- Bivalves (clams and oysters)
- Bony fish
- Sharks
- Oreodonts
- Early horses
- Insects

ILLUSTRATIONS:

1. Bony fish ☸ {range 2r to 8r}
2. Shark ☸ {29r}

3a. Oreodont ☸ {28r}
3b. Oreodont jaw with teeth ☸ {26r}

4. *Mesohippus* ☸ an early horse {20r}
5. Primitive camel ☸ {13.5r}

☸ have not been reported from Michigan.

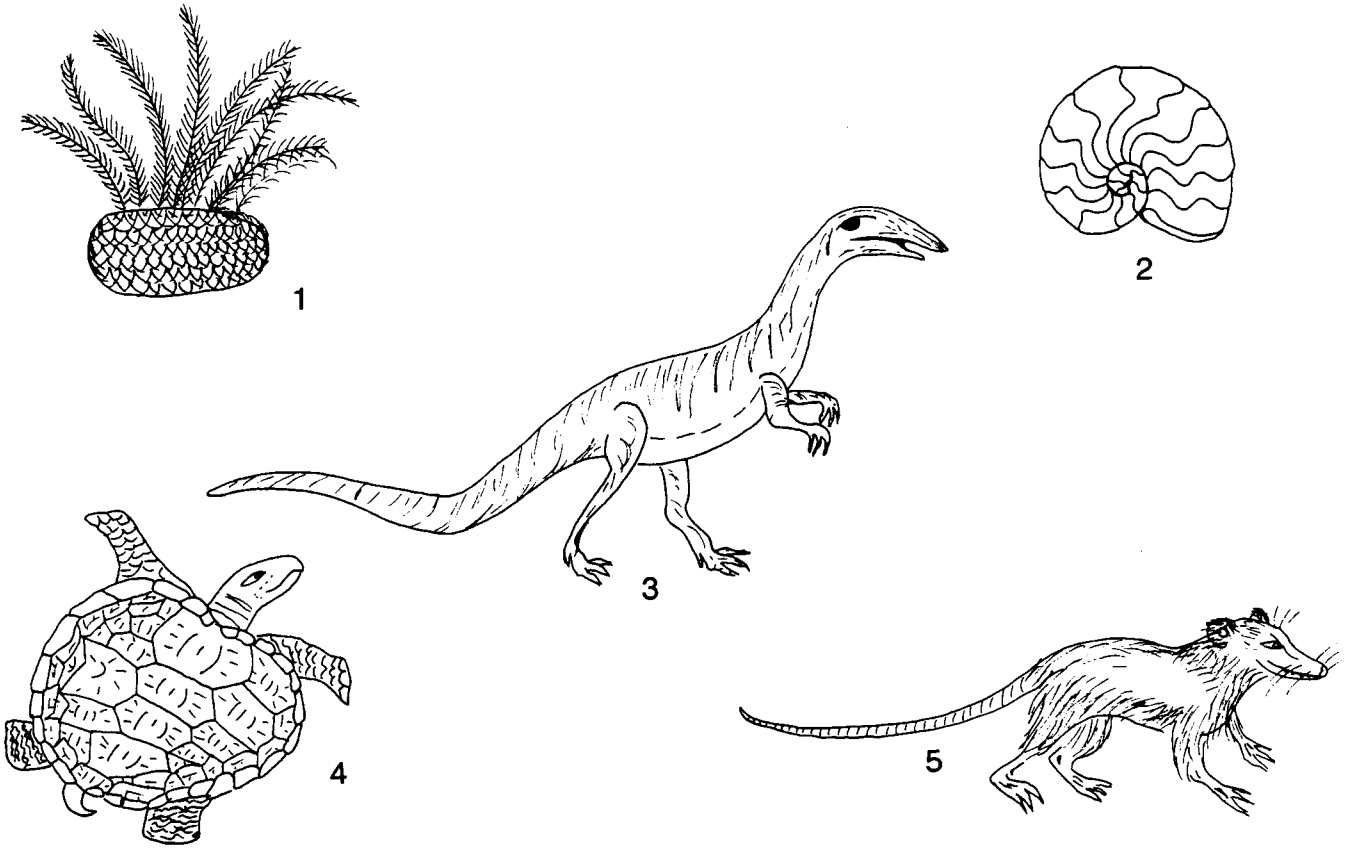
KEY TO SIZES OF ILLUSTRATIONS:

{1x} .....actual size

{2x}, {5x}, etc. .....enlarged x number of times

{2r}, {5r}, etc. .....reduced r number of times

Illustrations of Late Tertiary Fossils



LATE TERTIARY PERIOD

GENERAL SETTING

The Late Tertiary Period (called Neogene in European references) consists of the Miocene and Pliocene epochs. Continued gradual continental uplifting produced a drier climate and vast grasslands. During this time many mammals and birds evolved into their modern forms: horses and deer developed hooves; dogs, cats and related families developed canine teeth. Amphibians and land reptiles increased in numbers. The first man-related hominids appeared.

FOSSILIFEROUS OUTCROPS IN MICHIGAN:

NO KNOWN OUTCROPS IN MICHIGAN

FIRST DEVELOPMENT OF:

- Mastodons
- Camels
- Dogs
- Wolves
- Bears
- Modern cats
- Antelopes
- Raccoons
- Pedapods (seals and walruses)
- Hyenas
- Modern horses
- Man-related hominids

SIGNIFICANT FOSSIL FORMS:

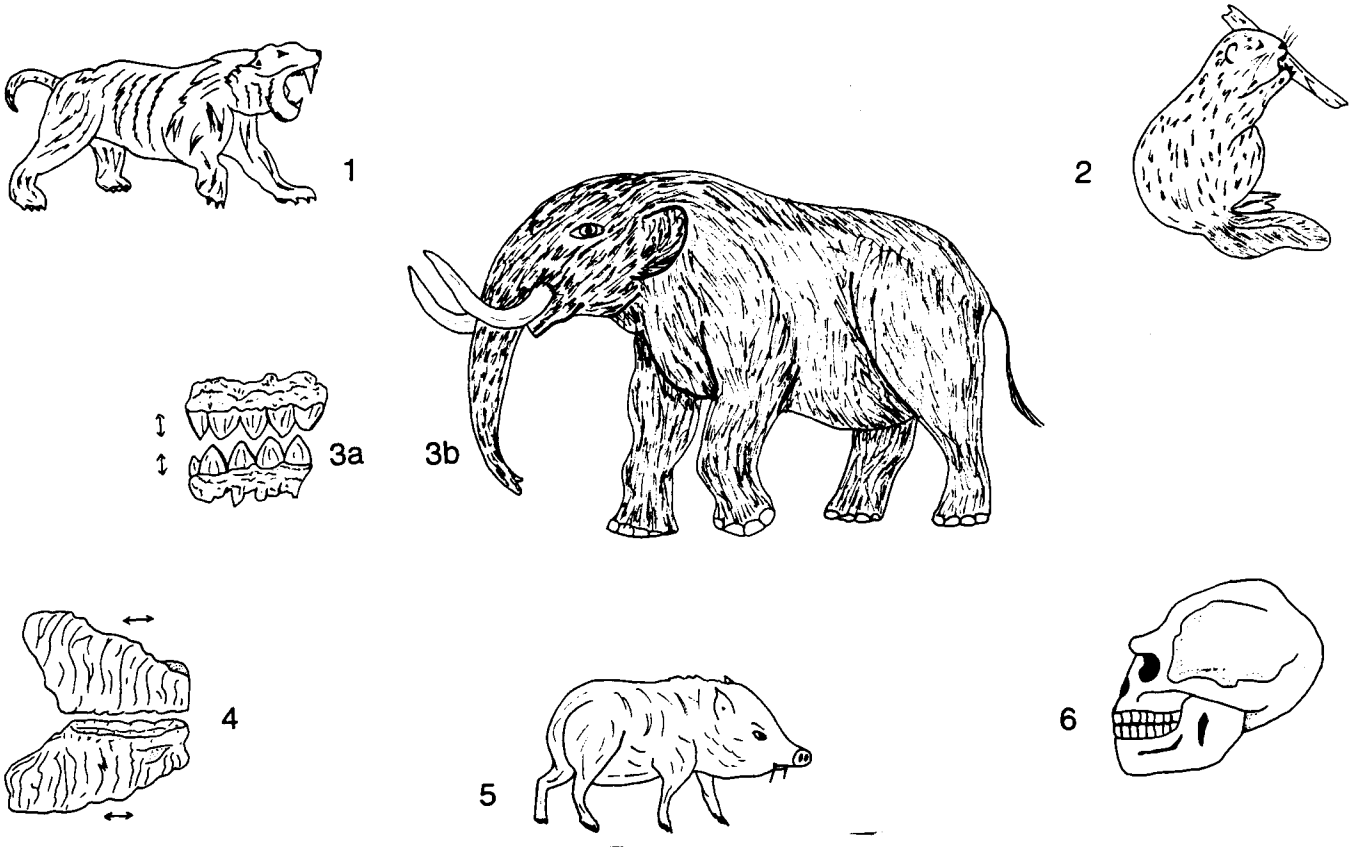
- Bivalves (clams oysters)
- Gastropods
- Barnacles
- Sharks
- Frogs
- Insects
- Rats & mice
- Rhinoceros

ILLUSTRATIONS:

1. *Pecten* ☸ a bivalve{2r}
2. Gastropod ☸ {1x}
3. Barnacle ☸ {1x}
4. Shark tooth ☸ {range 2.5x to 4.5r}
5. Antelope ☸ {15r}
6. Mouse ☸ {5r}
7. Rhinoceras ☸ {range 23r to 72r}

☸ have not been reported from Michigan.

Illustrations of Quaternary Fossils



QUATERNARY PERIOD

GENERAL SETTING

The Quaternary Period consists of the Pleistocene and Holocene epochs. During the Pleistocene Epoch great continental ice sheets several thousands of feet thick spread over most of the northern hemisphere at least four different times. As the ice advanced, some animals were driven to warmer climates while others adapted to the cold by developing thick, furry hides. The term Holocene is used to denote the last 11,000 years when human beings became the dominate life form by domesticating animals and cultivating the land.

FOSSILIFEROUS OUTCROPS IN MICHIGAN:

Numerous locations throughout Michigan

FIRST DEVELOPMENT DURING PLEISTOCENE

- Giant ground sloths and
- other giant land mammals
- Armadillos
- Skunks
- Foxes
- Hominids (ancestral humans)

FIRST DEVELOPMENT DURING HOLOCENE

- Cultivated grasses (wheat, barley etc.)
- Domestic animals
- Humans beings

SIGNIFICANT FOSSIL FORMS:

- Leaves, seeds & cones of trees
- Mollusks
- Insects
- Whales
- Saber-tooth cats
- Mastodon & Mammoth
- Peccaries
- Giant beavers
- Bones of early humans

ILLUSTRATIONS:

1. *Smilodon* ☸ a saber-tooth cat{40r}
2. Giant beaver {68r}

3a. Mastodon molars {9r}

3b. Mastodon {31r}

4. Mammoth molars {10r}
5. Peccary (relative of pig) {26r}
6. Early human skull ☸ {3r}.

☸ have not been reported from Michigan.

READINGS AND REFERENCES

The following are available from the - Michigan Department of Environmental Quality, Geological Survey Division, P. 0. Box 30256, Lansing MI 48909-7756. A complete listing of publications and maps is available on line at ***www.deq.state.mi.us/gsd***

- Bulletin 4 - **Glacial Lakes Around Michigan**, 1988 W. R. Farrand; A general introduction ad description of Michigan's glacial geology. *Available on line www.deq.state.mi.us/gsd*
- Chart 1 - **Stratigraphic Succession in Michigan;** Generalized representation of the rocks found in Michigan, black and white. Available on line www.deq.state.mi.us/gsd
- Pamphlet 6 - ***Collecting Rocks Minerals and Fossils in Michigan:*** 1976; S. E. Wilson; An illustrated introduction to the hobby.
- Poster - ***Michigan Fossils:*** Black and white photographs of 16 common Michigan invertebrate fossils.

The following are recommended for additional information about evolution as well as identification of fossil genera.

- ***The Audibon Society Field Guide to North American Fossils.*** 1988; Thompson, Alfred A. Knopf, Inc., New York, New York.
- ***Contributions to the Museum of Paleontology, University of***
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- ***Nebraska: A Field Guide,*** Educational Circular Number 9, 1991; Pabian & Diffendal, Conservation & Survey Division, University of Nebraska-Lincoln, Lincoln, Nebraska.
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GLOSSARY

AMMONOID — An extinct, usually coiled, shelled cephalopod whose chamber divisions had saddles and lobes (GONIATITE and CERATITE sutures), or were crinkled and ornate, resembling leaves (AMMONITE sutures).

ARCHEAN — Rocks of the Archeozoic, the earlier part of the Precambrian representing the geologic record from 3,800 MYBP. known in Michigan from outcrops in the western northern peninsula. See also Proterozoic.

ARTHROPODS — A group of invertebrate animals with segmented bodies, jointed legs and, in most cases, a chitinous exoskeleton (outer shell) which is molted for growth. Extinct arthropods include TRILOBITES and PHYLLOCARIDS. Modern arthropods include SPIDERS, INSECTS, CRUSTACEANS and horseshoe crabs.

AZOIC — The first part of the geologic record that constitutes the longest interval of time yet does not have any significant fossil record, representing the geologic record from 3,800 MYBP to the beginning of time. No known Michigan outcrops. See also Proterozoic.

BELEMNOID — A cephalopod with a tapered, unsutured shell that is internal except for an elongated external shield which helps protect the head. Its modern relative is the SQUID.

BIVALVES — A group of marine mollusks whose soft, unsegmented bodies are protected by two calcified valves, or shells. They include CLAMS, OYSTERS and mussels.

BLASTOID — An extinct, short-stalked echinoderm with five deep food grooves folded over a bud-shaped body. Simple, fine brachioles (armlets) extend from the edges of the grooves and help with food-gathering.

BRACHIOPODS — A group of soft-bodied marine animals that secrete a shell consisting of two unlike and unequal valves. The body has muscles, a digestive tract, nerves, glands and a fleshy stalk, or pedicle, by which it can attach itself to objects on the sea floor. INARTICULATE BRACHIOPODS have shells held together by muscles alone, while ARTICULATE BRACHIOPOD shells have hinges and teeth as well, to hold the valves together.

CAMBRIAN — The earliest period of the Paleozoic named after Cambria, the Roman name for Wales, where the rocks were first studied. Known in Michigan from outcrops in the central northern peninsula.

CARBONIFEROUS — A term for the both the Mississippian

and Pennsylvanian periods.

CENOZOIC — The era of geologic time from the end of the Mesozoic up to and including the present. Includes the Quaternary and Tertiary periods. See also Paleozoic, Mesozoic, Proterozoic.

CEPHALOPODS — Marine mollusks with a well-developed head, eyes and strong tentacles, which may have either an external or internal shell. The pearly ***Nautilus*** is a modern shelled cephalopod; the octopus is a cephalopod which has lost all trace of a shell.

CONIFERS — A group of cone-bearing trees and shrubs with leaves that are generally needles or scales. The pine tree is one example.

CRETACEOUS — The last period of the Mesozoic, named from the latin word for chalk because of the chalk beds of this age in Great Britain, represent the geologic record from 144 to 65 MYBP. No known Michigan outcrops.

CRINOID — An echinoderm with a crown consisting of a cup-like body (sometimes covered on top by a leathery tegmen) and well-developed, movable arms. The crown is held upright on a plated, somewhat flexible stalk or column in most cases; however, some crinoids became stalkless as adults.

CYCADS — A group of palm-like trees and shrubs with large, elongate or squat, fleshy trunks and singly-growing, unbranched leaves. The modern Sago Palm is a cycad.

CYSTOID — An extinct, short-stalked echinoderm with an egg-shaped or spherical, plated calyx (body) which has a few armlike brachioles.

DEVONIAN — Period in the Paleozoic that is after the Silurian and before the Mississippian. Named after Devonshire County, England where rocks of this age were first studied, representing the geologic record from 408 ±5 to 360 ±5 MYBP. Known in Michigan from outcrops in the northern & southeastern southern peninsula.

DURATION IN MILLIONS OF YEARS — How long a geologic interval lasted..

EARLY PROTEROZOIC — Representing the geologic record from 2,800 to 800 MYBP. Known in Michigan from outcrops in the western northern peninsula.

EARLY TERTIARY — The first three epochs of the Tertiary period, called Paleogene in European references. It includes Oligocene, Eocene and Paleocene epochs. No known Michigan outcrops.

ECHINODERMS — A group of plated, spine-bearing marine animals with bulbous bodies and a water-vascular system that helps with feeding and locomotion. Echinoderms may grow on a flexible stalk, or column, of doughnut-shaped plates CRINOIDS, CYSTOIDS, BLASTOIDS, EOCRINOIDS) or be stalkless (EDRIOASTEROIDS, starfish, .SEA URCHINS and sand dollars)

ECHINOID — a stalkless echinoderm with a modified spherical shape, and,short to long, movable spines. Examples are SEA URCHINS and sand dollars.

EDIACARAN — A term for part of the upper Precambrian named for the Edicaran fossils from Austrailia, representing the geologic record from 600 to 570 MYBP. No known Michigan outcrops.

EDRIQASTEROID — A small, extinct, stalkless echinoderm which has five food grooves which resemble the arms of a tiny starfish, attached to a button-shaped calyx, or body.

EOCRINOID — A very ancient, extinct “dawn crinoid” with an elongate stalk (column), a vase-shaped body and a few simple arms.

ERA — A major division of geologic time made up of more than one period.

EUCARYOTIC (or eukaryotic) PROTISTS — single-celled organisms whose cells have one or more nuclei surrounded by a well-defined nuclear membrane with DNA arranged in long strands along chromosomes. Eucaryotic protists include radiolaria, FORAMINIFERA, brown, red, yellow-green and grass green algae; diatoms and the unique fungi. Many algal eucaryotic protists have attributes of both plant and animal in symbiotic association.

EURYPTERID — An extinct aquatic arthrapod which breathed through gills and had seven pairs of jointed appendages, one pair of which served as paddles for swimming. Also called a sea scorpion, its modern relative is the horseshoe crab.

FORAMINIFERA -Eucayotic protists which secrete a test (“shell”) composed of calcium carbonate. The most common fossil foraminifera resemble grains of rice.

GRAPTOLITES — Shallow-water marine organisms consisting of tube-like branches or interlaced mats which have an a floating mode of life; tentatively Considered hemichordates.

HEXAPOD — A group of arthropods with a head composed of six fused segments, a pair of antennae and unjointed, whole-limbed mandibles. Each of the three segments of a hexapod’s thorax, or mid-section, has a pair of jointed walking legs. INSECTS form the largest group of living hexapods.

IGNEOUS — Any rock that has solidified from molten or partially molten material. See also sedimentary, metamorphic.

JURASSIC — Period in the Mesozoic that is after the Triassic and before the Cretaceous. Named after the Jura Mountains between France and Switzerland where rocks of this age were first studied, representing the geologic record from 208 to 144 MYBP. Known in Michigan from subsurface well drilling samples only.

LATE TERTIARY — Period in the Cenozoic that is after the early Tertiary and before the Quaternary, called the Neogene in Europe. No known Michigan outcrops.

MACROSCOPIC — Able to be seen without the aid of magnification.

MESOZOIC — The era of geologic time from the end of the Paleozoic to the begining of the Cenozoic. Includes the Cretaceous, Jurassic and Triassic periods. See also Cenozoic, Paleozoic, Proterozoic.

METAMORPHIC — Any rock derived from pre-existing rocks undergoing change in essentially a solid state. Change is caused by changes in heat, pressure and/or chemically

active fluids, usually at depths below the weathering zone on the earth~s surface. See also sedimentary, igneous.

MIDDLE PROTEROZOIC — Representing the geologic record from 2,000 to 1,100. Known in Michigan in the western northern peninsula.

MISSISSIPPIAN — period in the Paleozoic that is after the Devonian and before the Pennsylvanian, about the same as the Lower Carboniferous of European usage. Named after the Mississippi River Valley where rocks of this age are exposed and studied, representing the geologic record from 360 ±5 to 320 ±5 MYBP. Known in Michigan from outcrops in the central southern peninsula.

MYBP — Millions of Years Before Present. How far back in time a geologic interval started. See also duration in millions of years.

NAUTILOID — An externally-shelled straight, curved or loosely coiled cephalopod which has straight or gently curved membranes (sutures) separating the inner chambers. The only living nautiloid is the pearly *Nautilus.*

ORDOVICIAN — Period in the Paleozoic that is after the Cambrian and before the Silurian. Named after a Celtic Tribe called the Ordovices, representing the geologic record from 505 ±5 to 435 ±5 MYBP. Known in Michigan from outcrops in the central northern peninsula.

PALEOZOIC — The era of geologic time from the end of the Precambrian to the begining of the Mesozoic. Includes the

Permian, Pennsylvanian, Mississippian, (Carboniferous), Devonian, Silurian, Ordovician and Cambrian periods, see also Cenozoic, Mesozoic, Proterozoic.

PENNSYLVANIAN — Period in the Paleozoic that is after the Mississippian and before the Permian, about the same as the Upper Carboniferous of European usage. Named after the State of Pennsylvania where rocks of this age are exposed and studied, representing the geologic record from 320 ±5 to 285 ±5 MYBP. Known in Michigan from outcrops in the central southern peninsula.

PERIOD — A subdivision of an era, sometime called the fundamental unit of geologic time. See also era, epoch.

PERMIAN — The last period in the Paleozoic after the Pennsylvanian. Named after the province of Perm, Russia, where rocks of this age were first studied, representing the geologic record from 285 ±5 to 245 ±5 MYBP. No known Michigan outcrops.

PHYLLOCARID — The oldest, most primitive form of malacostracan arthropod characterized by a large, bivalve carapace (exoskeleton) that encloses the head and thorax of the animal. Malacostracans includes crabs and shrimp.

QUATERNARY — Second period of the Cenozoic which is further divided into the Holocene and Pleistocene. This is a more general term often used for the glacial deposits that are found statewide.

SEDIMENTARY — Any rock resulting from the consolidation of loose sediment, typically forming layers or from the precipitation from solution or from organic processes. See also igneous, metamorphic.

SILURIAN — Period in the Paleozoic that is after the Ordovician and before the Devonian. Named after a Celtic Tribe called the Silures, representing the geologic record from 435 ±5 to 408 MYBP. Known in Michigan from outcrops in the eastern northern peninsula.

STROMATOPOROID — Extinct, marine colonial organisms that formed calcareous skeletons of closely spaced, concentric layers (thus the name meaning “layer-pored”), joined by radial pillars. Its massive or sheet-like colonies sometimes spread out upon the sea floor, or formed large lumps of fossilized cells. In Michigan they helped form great marine reefs. Stromatoporoids have been classified as sponges or algae, but they are presently considered to be a sub class of coelenterates (corals).

TERTIARY — The first period of the Cenozoic. No known Michigan outcrops.

TRIASSIC — The first period in the Mesozoic before the Jurassic. Named because of its threefold division of the rocks in Germany, representing the geologic record from 245 ±5 to 208 MYBP. No known Michigan outcrops.

TRILOBITE — An extinct marine arthropod with a three-lobed, oval or elliptical outer skeleton consisting of a head, thorax and pygidium (posterior part or tail piece). Some fossil arthropods which resemble trilobites but have not been assigned to the class trilobita have also been placed in the superclass or subphyllum TRILOBITOMORPHA.

PLEISTOCENE — An epoch of the Quaternary period before the recent (or Holocene), representing the geologic record from 2.0 0.4 to .011 MYBP. Pleistocene glacial deposits are found statewide.

PRECAMBRIAN — All of the geologic record before the beginning of the Paleozoic. The Precambrian represents close to 90 percent of geologic time. The Precambrian has been divided into many diffent groupings.

PROCARYOTE (or prokaryote) — A primitive unicellular organism whose cell does not have a nuclear membrane, so that the DNA is scattered throughout the protoplasm. Bacteria and BLUE-GREEN ALGAE are procaryotic monerists (neither fully plant nor animal). A separate KINGDOM, the Monera, established for organisms which include bacteria and cyanophytes (blue-green algae), because the show very little relationship to other organisms, plant or animal.

PROTEROZOIC — “Late Precambrian”, the more recent subdivision of the Precambrian, representing the geologic record from 2,800 to 570 MYBP. Known in Michigan from outcrops in the western northern peninsula. See also Cenozoic, Paleozoic, Mesozoic.

Some of the biological terms used are from Pabian & Diffendalls *“Late Paleozoic Cyclic Sedimentation in Southeastern Nebraska: A Field Guide”*, Educational Circular No. 9, Conservation & Survey Division, University of Nebraska-Lincoln, 1991. Used with author’s permission.