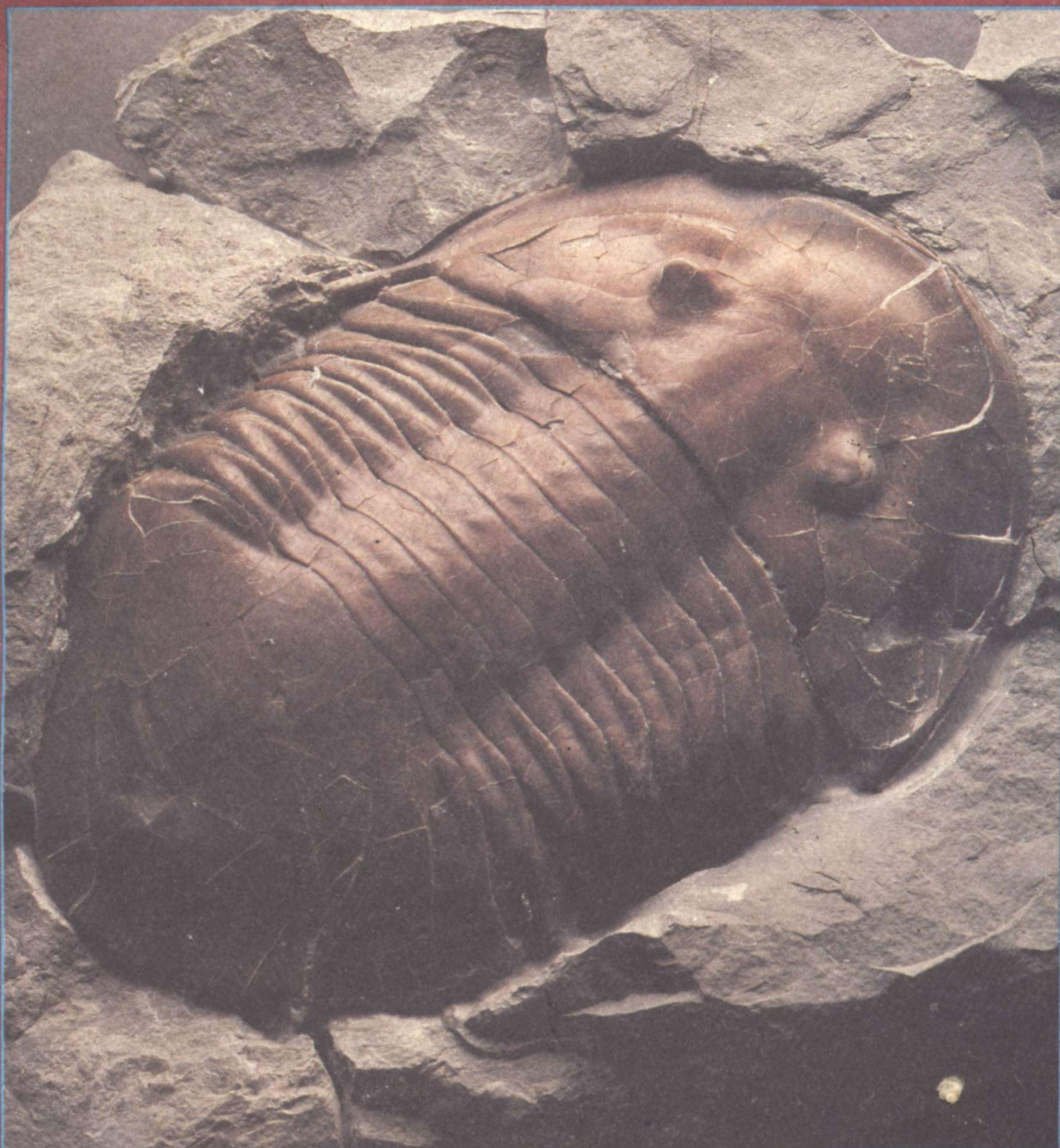
CINCINNATI FOSSILS

AN ELEMENTARY GUIDE TO THE ORDOVICIAN ROCKS AND FOSSILS OF THE CINCINNATI, OHIO, REGION



EDITED BY R.A. DAVIS

CINCINNATI MUSEUM CENTER

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EDITED BY R.A. DAVIS

CINCINNATI MUSEUM CENTERS,
1998

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PREFACE TO THE 1981 EDITION

This work has a history which spans more than four decades. In 1939 there was in use at the University of Cincinnati a mimeographed guidebook entitled "Elementary description of Cincinnatian fossils and strata and plates of commoner fossils in the vicinity of Cincinnati, Ohio". The text of this work was by Walter Bucher, with plates by Kenneth E. Caster, assisted by Stewart Jones. In 1945 the Museum entered the story with its publication of "Elementary guide to the fossils and strata in the vicinty of Cincinnati", with text by Bucher and plates by Caster and Jones. In 1955 a revised version (which had a yellow cover) appeared under the listed authorship of Kenneth E. Caster, Elizabeth A. Dalve, and John K. Pope. This was reprinted in 1961; save for a grey cover bearing a different picture and minor typographic correction the 1961 publication is virtually the same as that of 1955. Subsequently, the 1961 version was reprinted (and enclosed in a blue cover).

In the publication before you, much of the material is reprinted from Caster, Dalve, & Pope's 1955/1961 work. However, much of the text is new. Names of fossils have been updated, where taxonomic work subsequent to 1955 has made that necessary. Some of the illustrations have been revised, rearranged, or both; others have been deleted or replaced. An index has been included, as has a renovated bibliography.

The following people very kindly offered suggestions as to corrections and additions to Caster, Dalve, & Pope's 1955/1961 work: Stephen H. Felton of Cincinnati; William B. Harrison, III, of Western Michigan University; Stuart M. Kelly of Indiana University; William A. Oliver, Jr., and John Pojeta, Jr., of the United States Geological Survey; John Pope, Wayne Martin, and Roy Reinhart of Miami University, Oxford, Ohio; Raman Singh of Northern Kentucky University; Dwayne D. Stone of Marietta College, Marietta, Ohio; and Walter Sweet and Stig Bergstr^m of Ohio State University.

Amy Lamborg assisted in the preparation of the manuscript and illustrations for publication. Tom Weaver produced the cover illustration. We at the Museum are grateful for the aid of all these people.

While this edition was in the throes of preparation to go to press, Elizabeth Dalve, who originally did many of the drawings, died. She was a most talented artist who will be much missed. We at the Museum wish to dedicate this publication to her memory.

R. A. Davis
Paleontologist

Publication of this work was made possible by generous support of the J. Huston Durrell Fund.

PREFACE TO THE PRESENT EDITION

This is basically a reprint of the 1985 edition of this work. However, taxonomic revisions that have been made since then are noted. In addition, some errors, typographic and otherwise, have been corrected.

William I. Ausich and Loren E. Babcock of the Ohio State University, Richard D. Hoare of Bowling Green State University, and Michael R. Sandy of the University of Dayton very kindly offered advice on taxonomic questions. I am grateful for their help.

R. A. Davis
Paleontologist

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INTRODUCTION

The Cincinnati region is world-famous for its fossils. Virtually every natural history museum worthy of that designation anywhere on Earth has in its collections fossil specimens from the Ohio-Kentucky-Indiana Tri-State area. The rocks beneath and around Cincinnati are filled with fossils in extraordinary variety and abundance. Moreover, erosion over the last few million years has left those rocks magnificently exposed. Thus, over the generations, rock-hounds and geologists by the thousands have been able to find and collect fossils by the millions in and around Cincinnati.

It is the goal of this book to introduce you to the rocks and fossils of the Cincinnati region.

THE ROCK IN THE CINCINNATI REGION

The bedrock in the vicinity of Cincinnati consists mainly of limestone and shale. These materials were deposited at the bottom of a shallow sea which once occupied the area. Like other sedimentary rocks, those in the Cincinnati region are made up of layers, called strata (the singular is "stratum").

The limestone layers are composed primarily of the mineral calcite, a naturally occurring form of the chemical compound calcium carbonate. Here this material was derived mainly from the hard-parts of ancient sea creatures.

The shale strata consist of silt and clay derived from shores far to the east. Included in the shale are very fine calcareous shell and skeletal particles.

Both the limestone material and the clays and silts originally were deposited as soft muds and oozes. As more material was piled onto the sea-floor and as the centuries passed, the trapped water was expelled out of the once-soft sediments. Individual mineral grains gradually became interlocked with one another and cemented together. The result of these processes is our local bedrock.

The sediments which became our local bedrock were deposited toward the end of that chunk of the Earth's prehistory called the Ordovician Period, which began some 500 million years ago and ended perhaps 440 or 430 million years ago. Because the rocks and fossils of the Cincinnati area have been so well known for such a long time, the last portion of the Ordovician Period in North America is called the Cincinnatian Epoch.

When the sediments which became our local bedrock were deposited — some 450,000,000 years ago — they were laid down on the sea-floor in horizontal layers. As the millenia passed, however, there occurred changes in the crust of the Earth, so that today's Cincinnati sits on the crest of a fold in the bedrock, with the rock dipping gently to the north, east, and west. This geologic structure is the so-called Cincinnati Arch. The reason that rocks formed during the Cincinnatian Epoch are exposed in our region is that the younger rocks, which once overlay the crest of the arch, have been stripped off by century upon century of erosion.

NAMING ROCK UNITS

The science which deals with the layers in sedimentary rocks is called stratigraphy. Over the years, stratigraphers have used a number of different methods of identifying and naming bodies of rock.

One basis was time. That body of rock deposited during the Ordovician Period is called the Ordovician System. That body of rock laid down during the Cincinnatian Epoch (remember? — the last subdivision of the Ordovician Period) is called the Cincinnatian Series. And so on.

Another basis for subdividing and naming bodies of rock is lithology — the composition, size, shape, and arrangement of the particles which make up the rock. The basic lithostratigraphic unit ("lith-" means "rock") is the formation. Similar or related formations may be joined to comprise a thicker unit, called a group. And formations may be subdivided into smaller units called members.

A third basis for subdividing and naming bodies of rock is fossil content. The basic biostratigraphic unit ("bio-" is a prefix meaning "life") is the zone. The body of rock containing a particular fossil is the zone of that fossil. The particular fossil is called an index fossil.

Today it is customary to name lithostratigraphic units after some geographic locality or feature — a formation exposed in Fairview Park in Cincinnati, for example, might be named the Fairview Formation. It is also the rule nowadays to name biostratigraphic units after the fossils which characterize them — the body of rock containing the fossil *Platystrophia ponderosa* would be called the *Platystrophia ponderosa* Zone.

Unfortunately, the standard practices of today were not so standard in years past. Hence, in former times, geologists studying the rocks and fossils in many parts of the world, including the Cincinnati region, sometimes delimited so-called formations and members on the basis of their fossil content.

Because Caster, Dalve, & Pope's 1955/1961 work has become a standard reference on the stratigraphy of the Ordovician of the Cincinnati region, the following section is reprinted from pages 16-19 of that work. (Names of fossils have been updated where necessary, and some typographical corrections have been made). Following the reprinted section are two figures comparing the unit names in that section with the names of strictly lithologically defined units in use today.

THE CINCINNATIAN FORMATIONS AND WHERE TO FIND THEM

CYNTHIANA GROUP: These are the middle Ordovician rocks which underlie the Cincinnatian in our area. Near Cynthiana, Kentucky, the group consists of limestones and shales. To the north these change to the massive Point Pleasant Limestone, which is exposed near Moscow, Ohio. The lowest unit of the type-Cynthiana is the Greendale Limestone; it contains many fossils similar to those found in the lower Maysville Group.

Collecting: The Greendale is well exposed near Cynthiana, Kentucky, in stone quarries and roadcuts. The area about Gratz, Kentucky, has many cliffs and quarries in the upper limestones. However, fossil-collecting at these sites is not easy. Near Moscow and Point Pleasant, Ohio, the upper limestones are exposed in the old "River Quarries". These limestones are abundantly fossiliferous, but the fossils are difficult to extract from the hard matrix.

EDEN CROUP: The main mass of the Eden sequence is blue shale with limestone partings increasing in abundance in the upper part. These deposits have traditionally been called the Latonia Formation. The fauna of the Eden Group indicates a connection of this ancient sea with the St. Lawrence Valley area. The Eden shales and limestones disappear to the south and west.

Fulton beds: These dark basal shales overlie the Cynthiana limestones. They are no longer well exposed near Cincinnati, but may be found in the Point Pleasant area. These beds contain an interesting fauna (including the trilobite *Triarthrus* which also occurs in a narrow zone at the top of the Southgate), which relates them to the Utica Shale of northwestern New York state.

Economy Shale: The Economy Member is predominantly shale. Crinoids, *Cryptolithus* ("lace-collar trilobites"), and delicate brachiopods may be found at this horizon.

Southgate and McMicken Shales and Limestones: In the Southgate and McMicken Members, thick, rippled layers of limestone (originally shell fragment sands) occur at many levels. These two members carry many bryozoans and thick shelled fossils. *Batostoma* and *Cryptolithus* are abundant in the Southgate, while *Dekayia* and *Onniella* are common in the McMicken. The limestone layers are thicker and more abundant in the upper McMicken Member. A thick limestone layer bearing ripple marks on its surface indicates the top of this unit.

Collecting: Excellent collecting localities in the Eden Group occur within the city limits: behind the Metropolitan Housing Development on Beekman Street, along the city-end of the Westwood-Northern Boulevard, the length of Columbia Parkway, and on Central Parkway opposite Central High School. Also, lower Rapid Run and Stonelick Creek are fine sites.

<u>MAYSVILLE GROUP:</u> Maysville strata are conspicuously more calcareous than the Eden sequence, although shales still predominate. The fauna is large and distinctive, indicating a re-invasion of the "Greendale fauna".

Fairview Shales and Limestones: This formation is divisible into two units, the Mt. Hope and Fairmount Members. The base of the Mt. Hope Member is marked by the appearance of new fossil forms including *Platystrophia* and *Escharopora.* The overlying Fairmount Member contains some layers of crinoidal limestone. Occasionally many fine crinoid heads occur in "pockets" of shale. Thick, massive limestones, 8 inches to 1 foot in thickness, formerly were quarried extensively on the hills around greater Cincinnati, and consequently this horizon sometimes is called the "Hill Quarry Beds". Some of the old "Hill Quarries" are still excellent collecting sites. Fairview Park, the bluffs along Clifton Avenue, the old Schlosser Quarry in Covington, the bluffs of Eden Park south of the reflecting pool, and upper Rapid Run are but a few of these old quarries.

McMillan Shales and Limestones:
Bellevue Member: The Bellevue Member marks a change from the conditions of deposition seen in the Fairmount Limestone. Muds appear, and there is evidence of much current action in the form of shell rubble and layers of edgewise-stacked shells *{Rafinesquina).* The Bellevue Member usually forms a bluff on the steep hillsides. Solution cavities in the calcareous Bellevue frequently cause sinkhole topography in the Cincinnati uplands, e.g., Burnet Woods and Mt. Airy Forest. The most distinctive feature of this member is the ponderous shells and massive bryozoans it contains. *Rafinesquina* from the Bellevue should be examined closely for Edrioasteroid remains attached to these shells.

Collecting: Good exposures of the Bellevue may be examined on the bluffs at the McMillan Street entrance to Fairview Park, Bald Knob, Galbraith Rd. north of Winton Rd., and at the small waterfall in Stonelick Creek near Newtonsville.

Corryville Member: This member is predominately shale. It occurs near the hill tops in the Cincinnati area, consequently good outcrops are seen only in excavations for roads or buildings. This is the most interesting collecting horizon in the Cincinnatian because of the splendid specimens of trilobites, *Flexicalymene,* and occasional rare fossils which have been found, e.g., jellyfish, carpoids, starfish, the only known post-Cambrian aglaspid, etc.

Collecting: The best Corryville collecting is on upper Stonelick Creek, about twenty miles east of Cincinnati. (Do not forget to get permission before entering private property.) However, occasionally there are good exposures in construction excavations on the hills within the city.

Mt. Auburn Member: The Mt. Auburn forms the general hill cap around Cincinnati. It is usually a rubbly mudstone, but in some localities, the Mt. Auburn is impure limestone. The beds are sometimes a solid mass of the large brachiopod *Platystrophia ponderosa auburnensis* (the "double-headed dutchman" of old-time collectors).

Collecting: The bluffs along the fishing lake at Dent, Ohio, and roadcuts along the Westwood-Northern Boulevard east of Montana Ave. expose the Mt. Auburn very well. The best locality is along the Baltimore and Ohio railroad cuts at Maud about five miles north of Sharonville, Ohio.

<u>RICHMOND GROUP:</u> There is no significant change in the lithological character from Maysville deposits (Mt. Auburn) to the Richmond (Arnheim). However, the base of the Richmond is defined by the appearance of the remains of many new animals even though many characteristic Maysville fossils persist to the top of the lower Arnheim Sunset Member. In the Oregonia Member of the Arnheim, the characteristic Richmond fauna becomes dominant. The Richmond fauna possibly migrated into the Cincinnati area from the south. This fauna is an evolved recurrence of the Middle Ordovician fauna and is quite distinct from the Eden and Maysville faunas. Most outcrops of Richmond strata abound in fossils.

Collecting: In Cincinnati, the Richmond is exposed only on the highest hills in the western part of the city. Many outcrops in the Richmond also may be found along the trend of a broad arc extending from Clifty Falls, Indiana, through Oxford, Lebanon, Clarksville, Sardinia, and Manchester, Ohio, and Maysville, Kentucky.

Arnheim Formation: The Arnheim is best developed toward the south, where it carries a typically shelly facies. The thickening and thinning, its rubbly nature, and the abraded condition of the fossils seem to indicate shoaling of the sea.

The **Sunset Member** in the vicinity of Cincinnati bears at its top a narrow zone of the brachiopod *Retrorsirostra.* Here also may be found the corrugated brachiopod *Leptaena* which is characteristic of the Middle Ordovician and Richmond.

The **Oregonia Member** is very reminiscent of the lumpy, wave worked Mt. Auburn. The fossils are usually poorly preserved. At the top of the Oregonia is a zone of small pelecypods and casts of snails.

Collecting: The best Arnheim collecting is found along Harrison Ave., near Dent, Ohio, and at the intersection of Boudinot Avenue and Westwood-Northern Boulevard.

Waynesville Formation: This formation is composed of repetitious, even-bedded limestone and blue shale beds. Several yellowish, clay shale beds ("butter layers") are rich in enrolled *Flexicalymene* trilobites. The lowest member of the Waynesville, the Fort Ancient Member, bears near its top the richest *Flexicalymene* layer in the Cincinnatian. The middle member, the Clarksville Member, contains an abundance of *Onniella meeki* (not restricted to this horizon). The Blanchester Member, at the top of the Waynesville, is a very fossiliferous sequence of shales. Here first appear several fossils better known to the Ordovician of the arctic region.

Collecting: Almost every collector of Ordovician trilobites has his preferred Waynesville sites. Many may be found in the Oxford-Lebanon area; an exceptional locality is the railroad cut at Weisburg, Indiana. The Boudinot Avenue locality in Cincinnati offers opportunity for rewarding "dry dredging".

Liberty Formation: This formation is distinguished from the Waynesville by the sudden abundance of *Glyptorthis.* Lithologically, this formation is similar to the Waynesville although it contains more thin limestone beds.

Collecting: Good outcrops of the Liberty are present in the Oxford, Lebanon, and Clarksville, Ohio, areas.

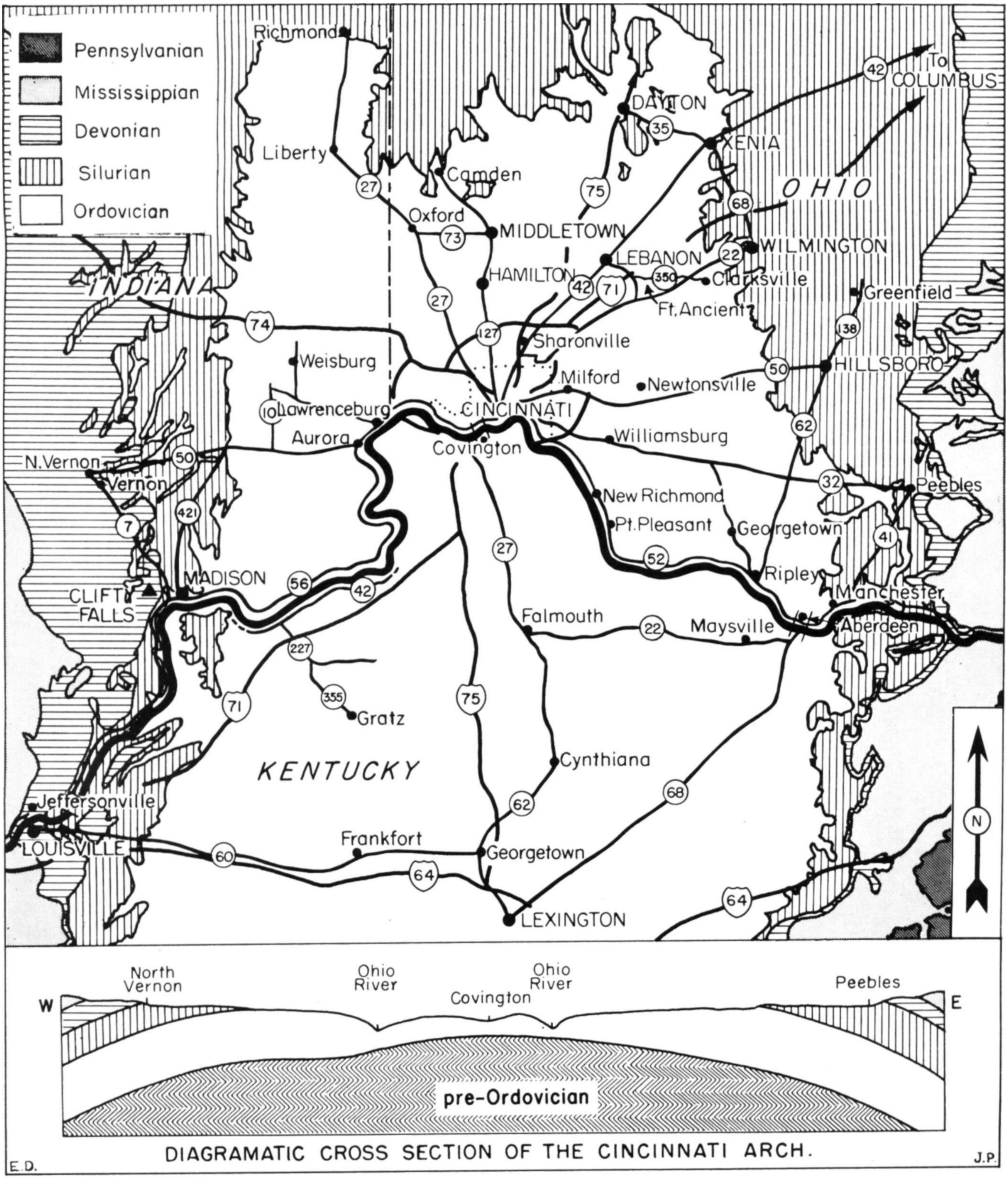
Whitewater Formation: The lower Whitewater member of the Whitewater Formation is composed largely of limestones which frequently show current eroded channels. Many large cephalopods, some coiled, and new species of bryozoa appear here. In Indiana, the middle of the Whitewater Formation is a massive limestone containing many *Tetradium* coral-heads, but in Ohio this **Saluda Limestone** is predominantly lumpy limestone and shale. The upper Whitewater member, lithologically similar to the lower Whitewater, contains an abundance of *Rhynchotrema dentatum* and delicate *Tentaculites.*

Collecting: Excellent sites for collecting Whitewater fossils are to be found in the Oxford, Ohio, area, within the city limits of Richmond, Indiana, and at Clifty Falls, near Madison, Indiana.

Elkhorn Formation: The lower shales of the Elkhorn Formation carry a sparse fauna, and fossils are hard to extract from the granular, dolomitic, upper limestones. However, the lower shales carry a beautiful and plentiful micro-fauna. Bentonite (volcanic ash) layers are found in this formation near Manchester, in Adams Co., Ohio.

Collecting: Good collecting sites in the Elkhorn are the railroad embankments at Weisburg, Indiana, and the Madison and Richmond, Indiana, areas.

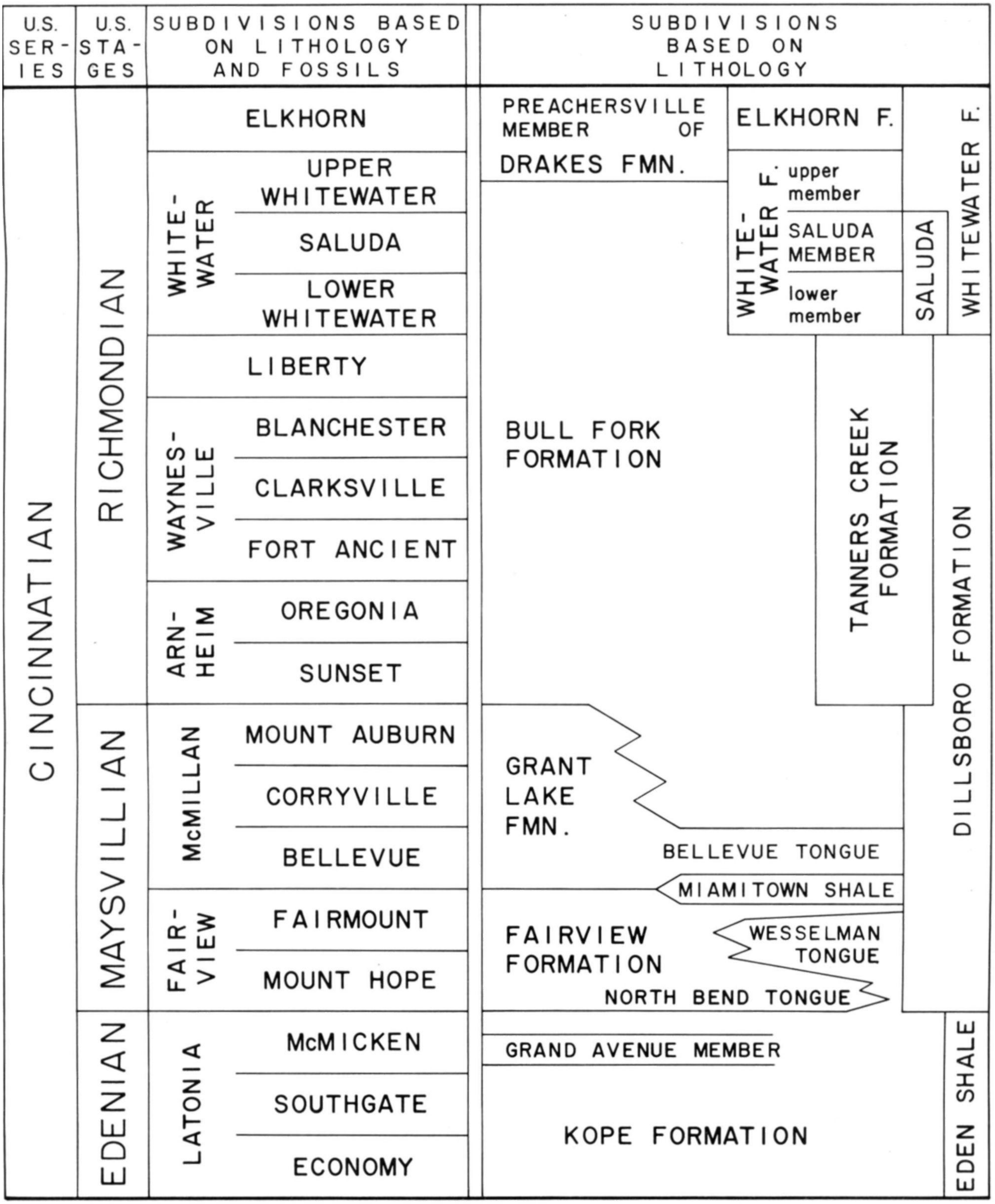
GENERALIZED GEOLOGIC MAP OF THE TRI-STATE AREA



GEOLOGIC TIME CHART

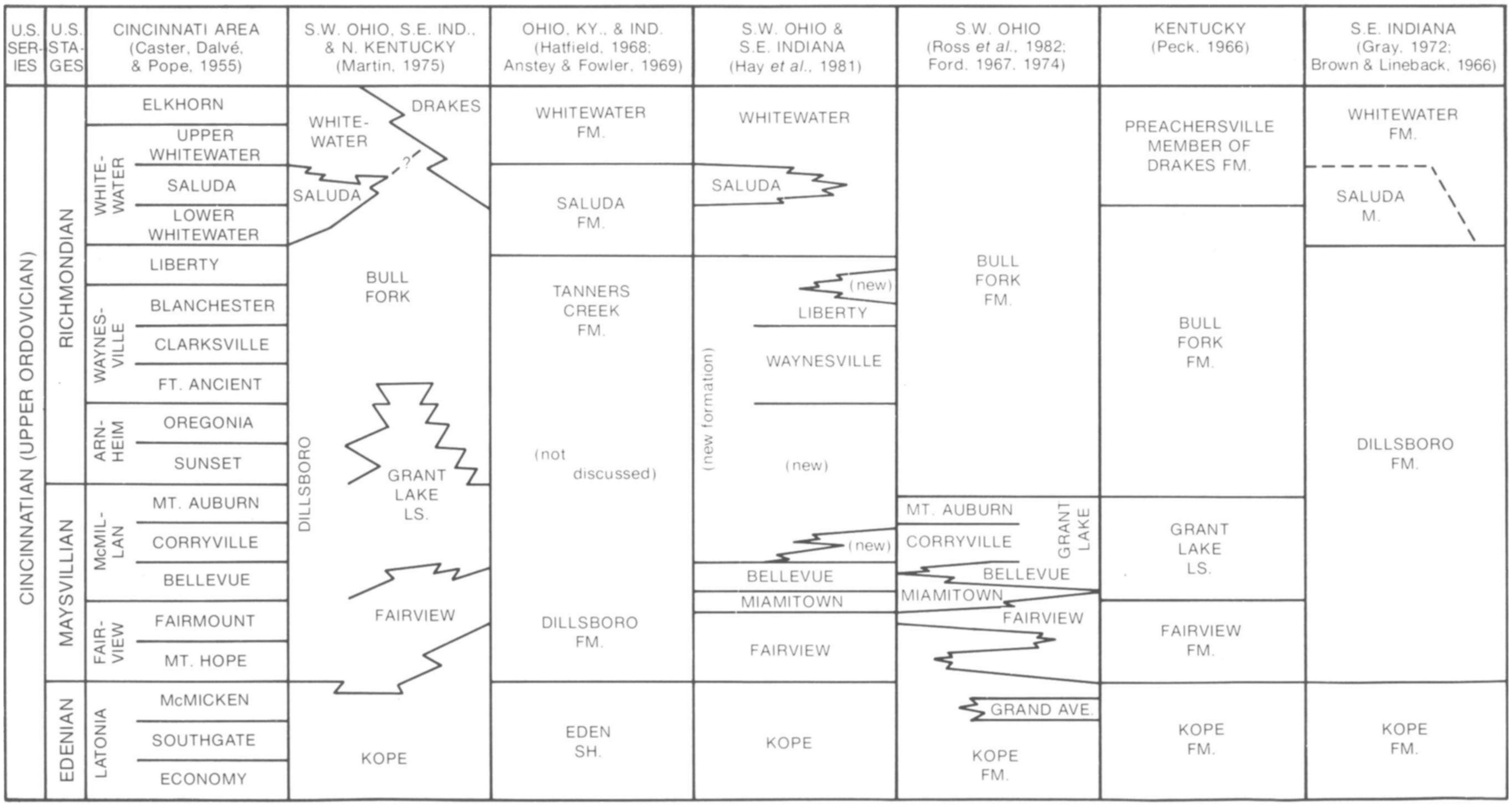
ERA	PERIOD		YEARS AGO	U.S. EPOCH
CENOZOIC	QUATERNARY			
	TERTIARY		2,500,000	
MESOZOIC	CRETACEOUS		68,000,000	
	JURASSIC		135,000,000	
	TRIASSIC		185,000,000	
PALEOZOIC	PERMIAN		225,000,000	
	CARBONIFEROUS	PENNSYLVANIAN	285,000,000	
		MISSISSIPPIAN	325,000,000	
	DEVONIAN		350,000,000	
	SILURIAN		410,000,000	
	ORDOVICIAN		440,000,000	CINCINNATIAN
				CHAMPLAINIAN
				CANADIAN
	CAMBRIAN		500,000,000	
PRECAMBRIAN			570,000,000	

STRATICRAPHIC NAMES USED IN THE TRI-STATE AREA



Those on the right are names that have been applied to rocks in the Ohio, Kentucky, and Indiana area. The different names do not necessarily represent different rock units nor their lateral relationships. (See page 14.)

STRATIGRAPHIC NOMENCLATURE OF THE CINCINNATIAN ROCKS OF THE OHIO – KENTUCKY – INDIANA AREA.



Each major column presents an interpretation of the geological situation in the area studied; its author or authors are indicated at the top of the column. The fact that the columns are not identical demonstrates that geology is an active, living science—geologists still are searching for the one system of rock nomenclature that would truly represent the geological reality in the Cincinnati area. (See the "Works on Cincinnati rocks" section of the bibliography.)

WHAT IS A FOSSIL?

Everyone would agree that a bone or shell of a long-extinct kind of animal or a piece of petrified wood is a fossil, but the term includes a good deal more than just such well-known animal and plant remains.

In some very rare instances, the soft parts of an animal have been preserved in the fossil state. The widely publicized frozen mammoths found in the Arctic would fall into this category. The word "fossil", in fact, includes all kinds of remains of plants and animals. However, the word doesn't apply only to remains; it also subsumes foot-prints, and worm burrows, and tooth marks, and objects made by creatures — traces of past life. In short, then, fossils are the remains and traces of plants and animals preserved in the geological record.

Some people would insist that fossils must be "prehistoric". However, the word "prehistoric" is a problem, because it means different things in different places. "Prehistoric" literally means "before history", which, in turn, means "before written records". The difficulty is that writing appeared in different places on Earth at different times. For example, writing arrived in our area with the first European explorers, say about AD1650, but the Egyptians were writing more than 4,000 years before that. Moreover, from time to time there are discovered in remote areas of our planet, groups of people who lack written records even today. Hence, inserting the word "prehistoric" into our definition of the word "fossil" just might be confusing.

In former times many people wouldn't have included remains and traces of human beings as fossils. They would have argued that humans are not animals. Nowadays we all recognize that we belong in the Kingdom Animalia, along with dogs, cats, lizards, frogs, jellyfish, and the whole variety of the Earth's animal world.

So fossils are the remains and traces of plants and animals somehow preserved in the geological record. What is this "geological record"? "Geology" means "the study of the Earth", and the "geological record" is the stuff the geologist studies — the materials of which our planet is made — the rocks, the soils, the sand and gravel, the ice, etc.

To a fossil, the key word is "preservation". To be a fossil, a plant or animal must be preserved. When an organism dies, a whole host of destroyers are waiting to wipe away all trace of that creature. First off, a hungry animal might eat the would-be fossil; or it might be destroyed by rotting. Or battered to pieces by waves. Or broken apart by being carried along by a river or stream. Or chemically disintegrated.

Becoming a fossil is a really chancy business, even if you are equipped with a sturdy shell or other preservable hard parts. The best way to be preserved is to be buried quickly — this will lessen the likelihood of destruction by waves, or streams, or hungry animals. The material in which burial occurs should be very fine-grained and impervious to the passage of underground water — this will retard chemical destruction. Cold or salt or drying, for example, will slow down or even stop rotting.

The study of fossils is called "paleontology". In the course of everyday work, the paleontologist may well encounter fossils preserved in various ways:

Unaltered remains — in which the substances of the plant or animal essentially are as they were in life. In very rare instances soft parts may be preserved, and maybe even stomach contents, etc. Less rare is preservation of unaltered hardparts; good examples of this are the bones of the Ice Age animals which have been found at Big Bone, Kentucky, and at Rancho La Brea, in Los Angeles, California.

Compression — in which the plant or animal is smashed flat.

Carbonization — in which the volatile substances in the organism (water, nitrogen, hydrogen, etc.) have been driven off, leaving a carbon residue. Coal is a good example of carbonization of plant remains. (Another name for carbonization is **"distillation".)**

"Petrification" — in which the remains of the plant or animal literally are "turned to stone". "Petrification" (or "petrifaction") actually refers to two different kinds of preservation:

Infiltration (or **permineralization)** — in which the empty spaces in an organism are filled with mineral matter. For example, the mineral quartz may fill up the myriads of small spaces of wood.

Replacement (or **mineralization)** — in which the actual substance of an organism is removed bit-by-bit and mineral matter is left in its place.

"Petrifaction" may involve any of a number of minerals; quartz (silica), pyrite, and calcium phosphate are, perhaps, best known. An important aspect of "petrifaction" is that the internal structure of the bone, shell, or whatever is preserved.

Impressions and **molds** — in which the actual substance of an organism may be gone, but there is a replica, in reverse, remaining. For example, if you press the outside of a clam shell down into some clay and then remove it, you've made a mold of the outside of the clam shell — an **external mold.** If, on the other hand, you press the clay down into the inside of the clam shell, you've made an **internal mold.**

Cast — in which some mineral substance fills up a mold, resulting in a positive replica of the original organism. Making a cast is a two-step process; first a mold is made from the plant or animal, and then a cast is made from the mold. A cast differs from a "petrifaction" in that no internal structure is preserved in the cast; all that remains is the overall shape of the original creature. (Note that when a physician puts a so-called "cast" on a broken arm or leg, in fact, what is being made is an external mold of the arm or leg.)

The kinds of preservations we have discussed in the last several paragraphs all produce what we might call "body fossils", in that they involve the remains of organisms or replicas of remains. **Trace fossils,** on the other hand, show us that the animal or plant existed, but these fossils lack actual remains. Also called **ichno-fossils** or **lebensspuren,** trace fossils include a wide variety of fossils: tracks, trails, burrows, buffalo wallows, beaver dams, nests, tooth marks, etc. One variety includes things called **coprolites**; they are fossil excrement.

In the years before they were recognized as trace fossils of animals, some of the burrows and trails in our local rocks were thought to be the remains of ancient seaweeds. They were called "fucoids", after the well-known group of modern seaweeds, *Fucus.*

Artifacts are objects made by organisms (especially humans) — tools, weapons, items of clothing, and so on. Archaeologists, those scientists who study the remains and artifacts of ancient humans, commonly wouldn't include artifacts as fossils. However, tools, weapons, etc., certainly are traces of past life (albeit human).

The preceding paragraphs list a number of different categories of fossils. They are treated as though they were completely separate, easily differentiated groups. Actually, that's not always the case. For example, a given fossil specimen, say a **compressed** fish, might include **infiltrated, replaced** bone, **carbonized** soft-parts, and, if removed from the rock, leave an **external mold** — all in one specimen.

In conclusion, fossils are the remains and traces of plants and animals preserved in the geological record. Preservation may have been accomplished in a number of ways, but it involved the exclusion of biological, physical, and chemical destruction. The best way to have done this was by rapid burial in fine, impervious material.

NAMING AND CLASSIFYING FOSSILS

When people from a number of different countries endeavor to communicate with one another, eventually there is a problem, namely language. Different peoples have different names for the same animal; for example, felix, gatto, gato, chat, and katze all refer to the animal we call a cat. Moreover, the same word may be used to designate more than one kind of animal; for instance, we use the word "cat" when talking about the house cat, the lion, the tiger, the bobcat, the mountain lion, etc.

Well over two centuries ago it was recognized that, if scientists around the world were to communicate with one another successfully, each kind of plant and animal must have its own unique name, and that each name must refer to one and only one kind of plant or animal. At that time all educated Europeans knew Greek and, especially, Latin, so it was suggested that these plant and animal names be in one of these classical languages; that way no one modern language would be favored. For simplicity, however, it was decided that Greek letters wouldn't be used; hence, only Roman letters were employed in these scientific names.

The basic name for each kind of plant and animal consists of two words; the common house cat, for example, is *Felis domesticus.* This is called a species name, because each kind of organism is called a species. The first word, in this case *Felis,* is the generic name; the second word is called the specific or trivial name. The species name, consisting of the generic and trivial name, is called a "binomen", literally "two names". Commonly the species name of an organism is called its "scientific name".

Note that the species name is in italics. This was agreed to by scientists: each binomen is to be put in a form which stands out from the writing around it. Generally this is done with italics, although sometimes with underlining or by setting the name all in capital letters. Remember, the species name must be in Roman letters, so that in a Russian or even in a Chinese scientific work Fe//s *domesticus* will leap out of the paper at you.

The generic name of an animal always is capitalized. If the species name is printed using both upper case and lower case letters, then the trivial name is always lower case throughout.

In some scientific works, you may see a scientific name followed by a person's name and date, for example, *Felis domesticus* Linnaeus, 1758. This means that it was Carolus Linnaeus who named the species in the year 1758. (It turns out that it was Linnaeus — also called Carl Linne — who invented the binomial system of naming organisms, and his landmark work was published in 1758. Because of the great scope and importance of that work, it is common to abbreviate Linnaeus, 1758 to L. Hence, you might see *Felis domesticus* L.)

Actually, the regularization of biological nomenclature (the science of naming organisms) was only one of the contributions of Linnaeus. He also was the inventor of the system according to which we classify organisms.

The basic kind of organism is called a species. Related species are joined together in a larger unit, the genus (plural is "genera"). Related genera are grouped into an even larger unit, the family. In short, Linnaeus invented what is called the Linnaean Hierarchy, a system of categories in which smaller related groups of organisms are joined to form larger, more inclusive groups. Take the house cat, for example. *Felis domesticus* is the name of the species. *F. domesticus* and other, related cats belong in the genus *Felis. Felis* and other cat genera are assigned to Felidae, the cat family. Cats, dogs, bears, skunks, *etc.,* make up the order Carnivora. The orders Carnivora, Insectivora (shrews, moles, hedgehogs, and their kin), Primates (monkeys, apes, humans, and their relatives), and all the other orders of hairy creatures comprise the class Mammalia. Mammals, birds, reptiles, amphibians, fishes, etc., comprise the phylum Chordata. The chordates, coelenterates (corals, etc.), sponges, and more than twenty other phyla comprise the kingdom Animalia.

Let's summarize this in tabular form, using the house cat as an example:

Category

Kingdom	Animalia
Phylum	Chordata
Class	Mammalia
Order	Carnivora
Family	Felidae
Genus	*Felis*
Species	*Felis domesticus*

The purpose for the Linnaean Hierarchy is to join together related creatures and to simplify describing them. Imagine if you had to describe a house cat completely; it would take reams of writing and many months. Because of the Linnaean Hierarchy, by saying *Felis domesticus* you convey to your listener all the characteristics of the species, genus, family, etc., without having to use up paper and time in vast quantities.

There are seven levels of categories in the Linnaean Hierarchy. When doing detailed work with a group of creatures, one commonly finds a need for more levels. As a result, extra ones have been invented. For example, several related families may be grouped into a superfamily. Or, going in the other direction, a family may be composed of several related subfamilies, and a subfamily may be composed of several infrafamilies. Analogously, above the class level there can be superclasses, and below it can be subclasses and infraclasses. And so on for the other levels of the hierarchy. You don't have to use all the levels of the expanded hierarchy, however, just the ones necessary best to classify the creatures being studied.

One of the most commonly used levels of the expanded Linnaean Hierarchy is the subspecies (commonly called "variety"). *Platystrophia ponderosa auburnensis,* for example, is a subspecies of *P. ponderosa,* along with *P. ponderosa ponderosa.* Note that the subspecific name appears in print in exactly the same style as the specific name.

In some instances one thinks that a given fossil belongs in a particular genus, but one isn't entirely certain — perhaps thin-sections are needed to be sure of the identification. In such cases one puts a question-mark before the generic name, for example: *^.Platystrophia.*

Sometimes one knows that a given fossil belongs in a particular genus, but it's not certain into which species it should be placed — maybe the fossil is less than perfectly preserved. In such a case, one would give the name as, for example, *Platystrophia* species or *Platystrophia* sp., with the "sp." standing for "species". Note that neither the "sp." nor the "species" is italicized or underlined; this is because it is not the formal specific name.

Other times a fossil may be well preserved, but doesn't seem to fit exactly into any particular named species. The specimen may closely resemble fossils which have been assigned to a given species, but there are some differences. Perhaps the specimen is just an unusual individual of the known species, or maybe it is the first-found specimen of a hitherto unknown species. Commonly such an individual would be given a name in the form: *Platystrophia* sp. *cf. P. ponderosa.* This says that the specimen definitely belongs in the genus *Platystrophia* and that it compares favorably with *Platystrophia ponderosa* (the *cf.* is an abbreviation of the Latin "conferre", meaning "to compare").

So every kind of organism has a name. But sometimes names get changed. Now, amateur fossil-collectors commonly get more than a little aggravated at paleontologists for changing the names of fossils. Rest assured that this is not done for frivolous reasons.

Recall again that the ultimate goal of the naming system is to assure that each kind of creature has its own, unique name. It follows that all creatures with the same species name belong in the same species, and all organisms with the same generic name belong in the same genus.

In 1859 a paleontologist named J. H. McChesney assigned a particular kind of fossil to a species of the genus *Orthoceras.* Its official name was *Orthoceras knoxense* McChesney, 1859. In 1911 another paleontologist, George Girty, upon careful study of the species, decided that it actually belonged in a different genus, which he called

Pseudorthoceras. The name of the species thus became *Pseudorthoceras knoxense* (McChesney, 1859) Girty, 1911. This name still is the full official name of the species, although, to save space, generally it would be listed as *Pseudorthoceras knoxense* (McChesney), or, even, just *Pseudorthoceras knoxense.* (But pay attention to parentheses around people's names after the scientific names of organisms; they tell you that the species in question originally was assigned to a different genus.)

So, one reason for changing a name is that further study has revealed that a species originally assigned to one genus actually belongs in another. The same thing could happen at the species level. Let's say that a paleontologist assigns a number of specimens of fossils all to one species. Then further study reveals that actually several species are represented amongst the lot of specimens. Because each species must have one, unique name, it is necessary to assign some of the specimens to several newly named species.

On occasion it becomes obvious that someone has been overzealous in naming new species, that specimens assigned to a number of separate species actually all belong in one species. It then is necessary to abandon the extraneous names in favor of the original, first-named species. This also could happen at the generic level.

In conclusion, then, sometimes paleontologists are obliged to change the names of fossils. The goal, however, is living up to the principle that every kind of animal should have one, unique name and that each name should refer to one, unique kind of animal.

HOW TO MAKE A FOSSIL COLLECTION

People who live in the Cincinnati area are very lucky with respect to fossils. The rock of the area is abundantly supplied with well preserved fossils, and, because of the many hillsides, the rocks containing the fossils are well exposed.

The great abundance of beautifully preserved fossils sometimes is bad for local collectors. They become so used to finding essentially perfect specimens that they ignore fossils that aren't complete and fully eroded from the rock. That's really sad, because commonly it is the broken or incomplete specimen which can tell us most about the original animal. Such a specimen might give clues about the soft-part anatomy of the creature or tell us how the animal constructed its shell. Such a specimen might even provide evidence as to how the creature met its death long ago. Moreover, there are fossils, some of which are very rare, that almost never are found free of rock matrix.

Whenever collecting fossils you should keep fossils from different localities carefully separated from one another. Even fossils from the same locality but from different layers at that locality should be kept separated by layer. Each fossil or group of fossils from a given locality and stratum should have a label telling just exactly where and when it was collected. This can make the specimen or group of specimens scientifically valuable, because the paleontologist armed with fossils, complete with accurate and precise collecting data, can add significantly to our understanding of the past of our Earth. Fossils without such information are just so many rocks — pretty maybe, interesting perhaps, but generally worthless scientifically. (A good way to keep fossil and data together is to enclose the collecting information inside the newspaper or whatever you use to wrap the fossil to keep it safe in the journey home from the field.)

A couple of practical notes about fossil-collecting are in order here. Firstly, be a good citizen: obtain the landowner's permission before going on to private property; if a gate is closed, leave it closed behind you; if the gate is open, leave it that way; don't throw unwanted rocks onto streets, sidewalks, or driveways; don't bother others with your noise. Second, be safety conscious. No fossil is worth risking life or limb — either yours or anyone elses's. Use proper clothing, equipment, and procedures; and, above all, "use your head".

Okay, so you've got your fossils and data safely home; now what?

Probably some or all of the specimens need cleaning. Alas! There is no miracle chemical which will strip away rock matrix. Oh! water and a tooth-brush might work on some fossils, but all too often one must scrape and pick away the matrix oh-so-carefully with a needle, or dental tool, or tiny chisel. And you can't hurry or become overly enthusiastic, because delicate features of many fossils are very easily destroyed. It's better to leave some rock matrix than to ruin the specimen.

Stay away from coating specimens with shellac or lacquer. Don't glue everything to cardboard or mount them in plaster, either. All these substances can be very difficult to remove, when later you wish to look at the specimen as it originally was. (In cases where specimens need repair, reinforcement, or protection from deterioration, seek some good advice from a paleontologist or in books.)

Always bear in mind that a specimen without locality data is virtually worthless to the scientist. Keep that information with each and every fossil you have. A good way to do this is to put a number on each specimen with India ink and keep a card-file or note-book with the locality data meticulously recorded by number. And always keep that file or note-book associated with your collection. If you do, your collection truly can be a valuable scientific tool.

Which brings up another point: Suppose you find an especially rare fossil or one which is better preserved than any other of its kind? Such unique specimens should be made available to the scientists studying the group concerned. Your specimen may provide the key to unlock some important paleontologic problem. It may give an unequalled glimpse at a major aspect of our planet's past. Who knows? More than one amateur fossil-collector has had a fossil named after him. In other words, don't "hog" the fossil for you alone. Share it with everyone. After all, that's what fossil-collecting is all about — knowledge. And knowledge hidden is knowledge wasted.

WHERE TO LEARN MORE ABOUT FOSSILS

This book is an elementary guide. There are many fossils found in the local Cincinnatian rocks which are not illustrated or discussed in it. Luckily there are many other sources of information on our fossils.

The Cincinnati Museum of Natural History has exhibits which feature local fossils. So also does the University of Cincinnati Geology Museum. A bit further afield from Cincinnati, there are exhibits of fossils at the Geology Department, Miami University, Oxford, Ohio, at the Ohio Historical Center in Columbus, at the Department of Geology and Mineralogy, Ohio State University, also in Columbus, and at the Joseph Moore Museum, Earlham College, Richmond, Indiana. In fact, natural history museums the world-over have fossils from the Cincinnati area.

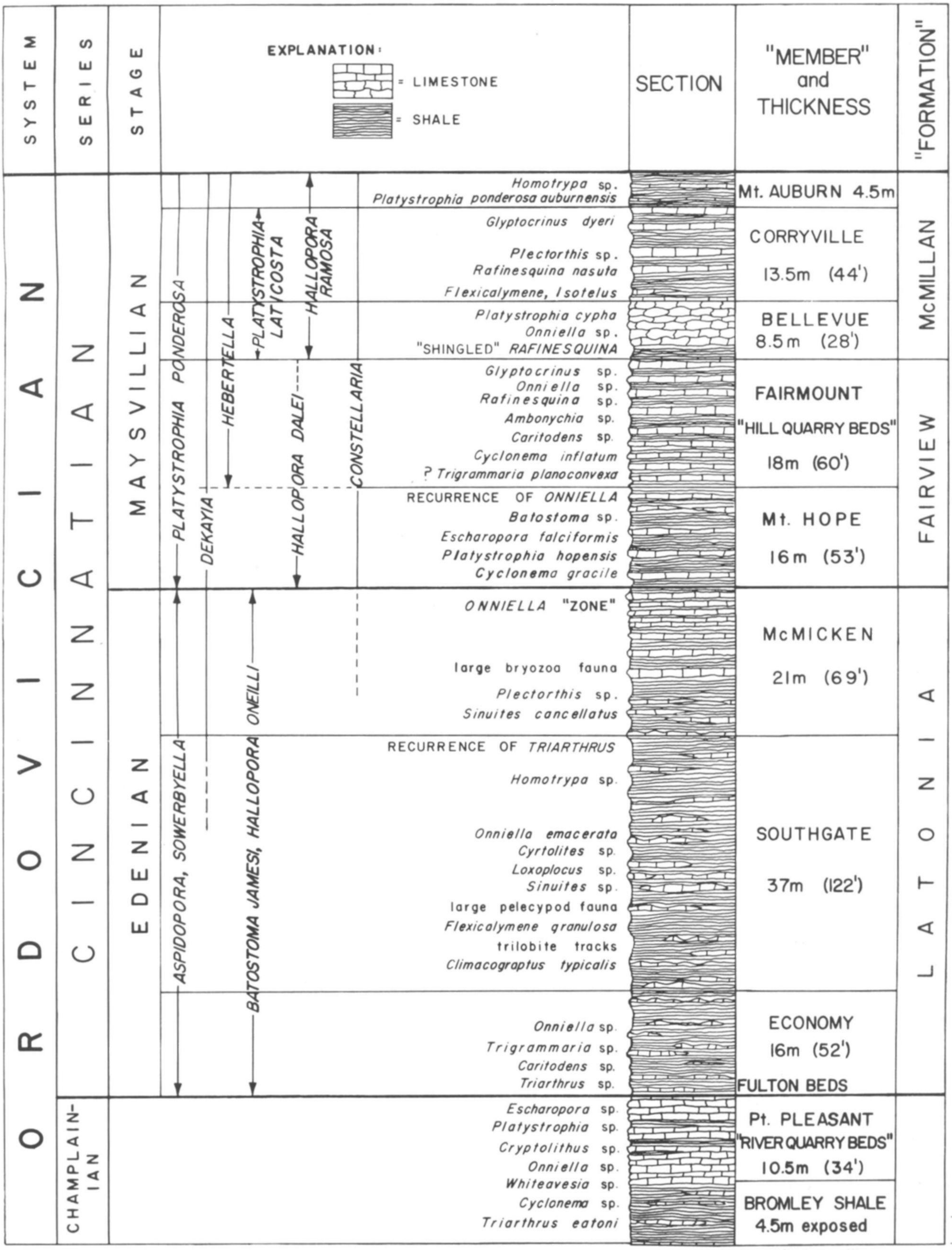
Other places to learn about fossils include the various amateur fossil-collecting groups. For example, the Cincinnati Dry Dredgers have met at the Geology Department at the University of Cincinnati since 1942. The Cincinnati Mineral Society sponsors a yearly rock, mineral, and fossil show in Cincinnati. There are other shows in Columbus and Dayton, Ohio, and other not-too-far-distant cities.

More serious fossil-collectors might want to join one or more of the scientific organizations which concern themselves with fossils. In the U.S., these include the Paleontological Society, the Paleontological Research Institution, and the Society of Economic Paleontologists and Mineralogists. The Geological Society of America deals with all geological subjects, including paleontologic ones.

Books and periodicals offer masses of information about fossils, too. The main library and the various branches of the Public Library of Cincinnati and Hamilton County are good places to start. The Geology Library at the University of Cincinnati, and other college and university libraries also are good sources of paleontological reading material.

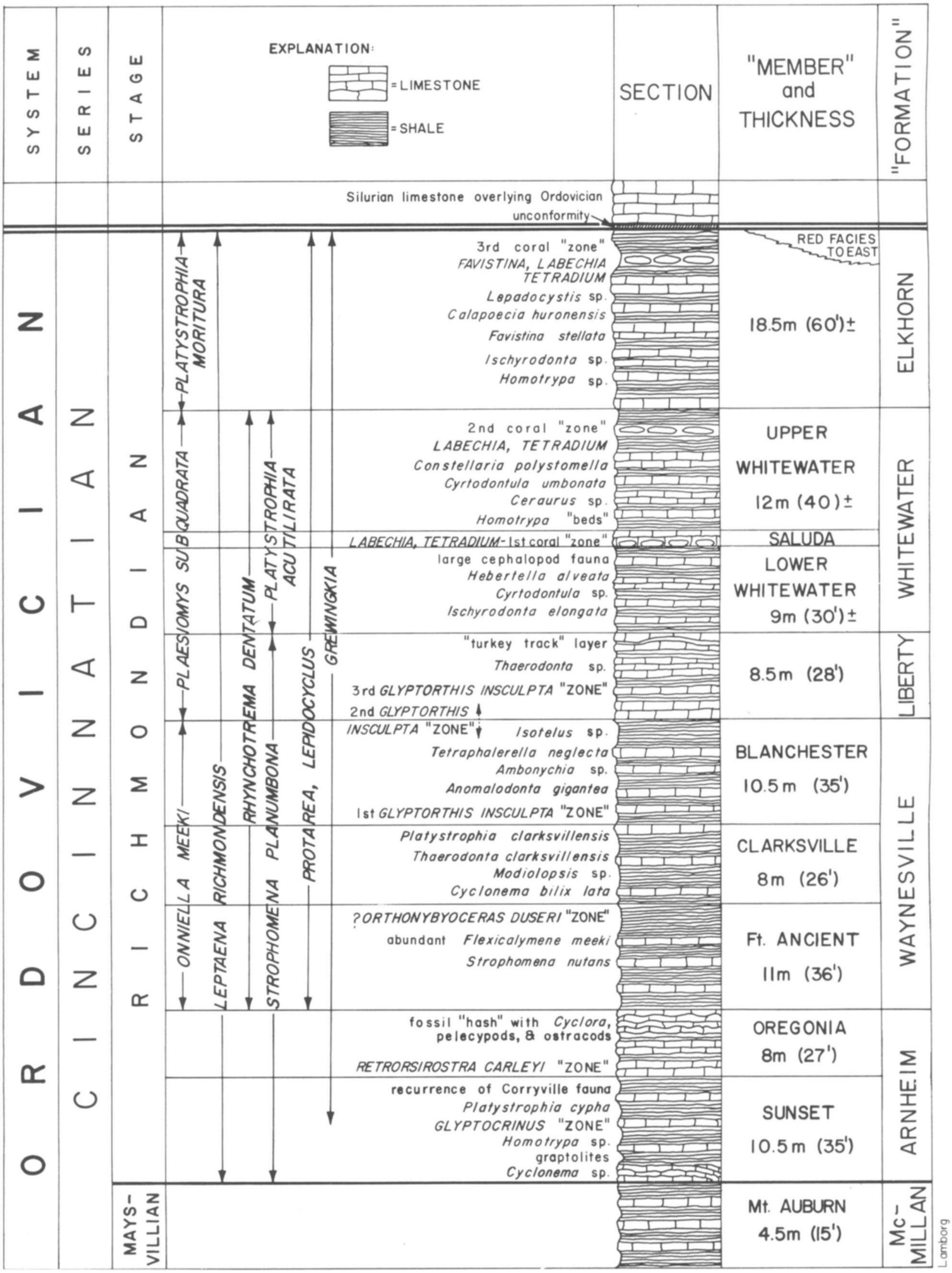
To begin your study, consult the bibliography.

FOSSIL-RANGE CHART: EDENIAN AND MAYSVILLIAN



Local *Hallopora* have been referred to as *Parvohallopora* by Singh, 1979; the specific name *oneilli* should be spelled *onealli*. *Glyptocrinus dyeri* now is referred to as *Pycnocrinus dyeri*.

FOSSIL-RANGE CHART: RICHMONDIAN



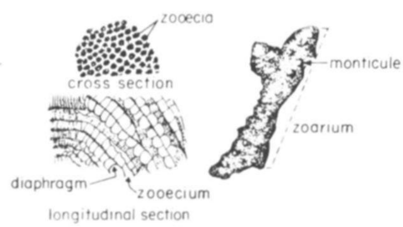
Lepidocyclus capax capax has been referred to *Hiscobeccus* by Amsden, 1983.

SUMMARY OF FOSSIL CROUPS FOUND IN THE CINCINNATIAN

BRYOZOA

Bryozoa, or "moss-animals", are perhaps the most common fossils in the local rocks. They are known from the Late Cambrian to the present, and, although exclusively aquatic, inhabit both fresh and marine waters.

Specimens collected in this area have the appearance of twigs, branches, flattened unsymmetrical masses, or crusts on shells or other bryozoans. What is found is actually a colony (zoarium) made up of the calcareous living tubes (zooecia, sing, zooecium) of numerous individuals, which give the zoarium a porous appearance on close inspection. Although a zooecium may have the diameter of a pin or less, zoaria sometimes reach many inches in length.



A bryozoan colony ***(Monticulipora).***

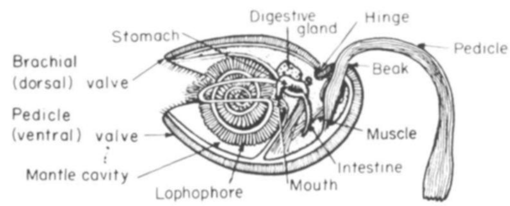
The amateur may confuse bryozoans with corals. Close observation will show that the bryozoan's zooecium is much smaller than a corallite and has great structural differences. Few bryozoans may be identified accurately by surface features, since their classification is based on their greatly variable internal features. Accurate identification is possible only through microscopic study of thin-sections of the zoarium.

Because of their variability and abundance, bryozoa usually are good index fossils. Unfortunately for the amateur who cannot make the thin-sections, many of the original index fossils differentiating local stratigraphic horizons are bryozoans. However, substitute index fossils usually serve adequately for the purpose.

BRACHIOPODA

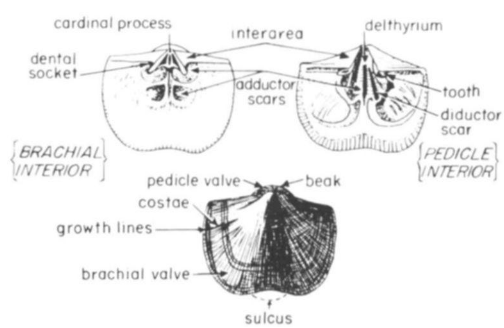
Brachiopods, or "lamp shells", are exclusively marine to brackish water bivalves which have survived from the Early Cambrian to the present. The Paleozoic seas abounded in brachiopods, which were at their apogee at that time. During almost every subsequent period new major types made their appearance.

However, many major groups disappeared at the beginning of the Mesozoic, and since then brachiopods have held a position of steadily declining importance until now they are very inconspicuous in our seas.



General anatomy of a living brachiopod.

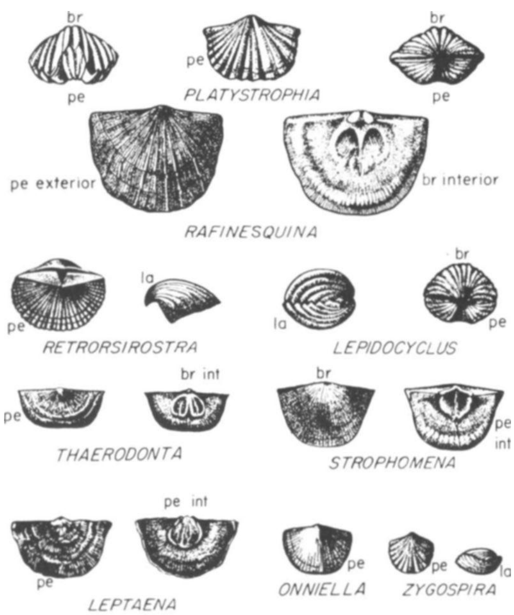
Only the hard brachiopod valves are commonly preserved as fossils. While the external features of a shell may sometimes serve to identify a specimen, the interior of the brachial valve is far more important for this purpose.



Shell morphology of the brachiopod *Hebertella.*

The two major divisions of the brachiopods, the articulates and the inarticulates, are known from the Cincinnatian and are still present in the oceans. The articulates, by far the more important division, are found in great abundance in all local members.

They are too numerous to describe here but may be easily identified from the plate illustrations. Some of these are our most useful index fossils.



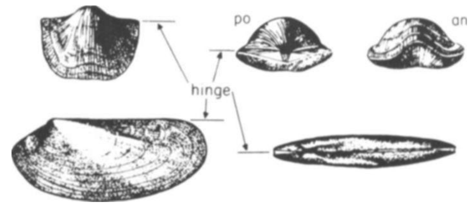
Articulate brachiopods from the Cincinnatian (pe = pedicle valve; br = brachial valve; la = lateral view).

The inarticulate brachiopods are distinguished from the articulate forms by the absence of a hinge, a different musculature, and shells of calcium phosphate-chitin rather than calcium carbonate. In the Cincinnatian these frequently may be seen as thin, oval shells adhering to larger brachiopod shells *{Petrocrania, Schizocrania),* as chalky shells with minute punctae (pores) in the valves *{Trematis),* or as glossy, triangular shells *(Pseudolingula).* Since the inarticulates appeared in the Cambrian before the articulates, they are considered the evolutionary precursor of the articulates.

Inarticulate brachiopods from the Cincinnatian. (Note that the *Petrocrania* are shown attached to the shell of an articulate brachiopod, *Rafinesquina.)*

Brachiopods all live in shallow water. According to their species, some lived attached by a pedicle to the bottom or other hard surface, some burrowed in the mud, and some were free upon the bottom.

Brachiopods may be distinguished from the pelecypods, which are also bivalves, by their distinctive symmetry. The valves are not mirror images of each other; rather, an imaginary plane extended from the umbo through the center of the anterior margin, bisects each valve into two symmetrical halves.



A brachiopod (top) compared with a pelecypod (bottom). The brachiopod is *Hebertella;* the pelecypod is *Psiloconcha.* (an = anterior view; po = posterior view).

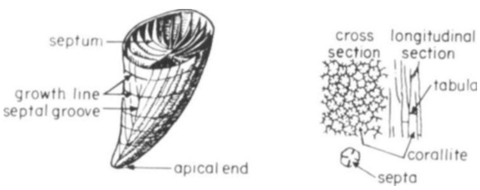
COELENTERATA

Corals, which are one type of coelenterate, occur in great abundance and variety in marine rocks ranging in age from Cambrian to present. This phylum presents representatives of all of its three major classes in the Cincinnatian.

Most important in local rocks, are members of the class Anthozoa. This class includes the simple "horn corals" or "cup corals" which resemble the modern sea-anemones but had a thick calcium carbonate skeleton. Corallites — the horn minus the flesh, all that remains as

Lepidocyclus capax capax has been referred to *Hiscobeccus* by Amsden, 1983.

a fossil — of this type of anthozoan are found in great abundance in all members of the Richmondian above the Arnheim. Also in the Richmondian, comprising zones in the Saluda, upper Whitewater, and Elkhorn, are colonial anthozoans. This type of coral has the individual corallites fused into a solid "head" called a corallum. The cups of the colonial coral resemble horn corals in structure, but may be more slender, even angular in section, and longer. Anthozoa are not known in the Edenian or Maysvillian.



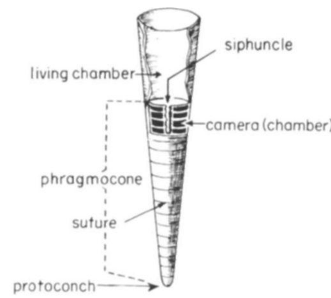
A solitary or horn coral (left) compared with a colonial coral (right). The horn coral is *Grewingkia;* the colonial coral is *Tetradium.*

Class Scyphozoa includes the true medusae or jellyfish. Most corals have a jellyfish-stage in their cycle of generations, but the scyphozoan medusae have no restive stage. All modern scyphozoans lack hard parts, but an extinct group, found from the Cambrian to Triassic possessed a pyramidal, hard cover to the jellyfish-bell. Although rare, this group occurs throughout the Maysvillian and Richmondian, represented by the species, *Conularia formosa.*

MOLLUSCA, CEPHALOPODA

Class Cephalopoda, whose few remaining representatives include the squid, octopus, and pearly nautilus, belongs to the phylum Mollusca. This phylum is immensely important in our modern seas and in the geologic past, for other classes within it include the gastropods (snails) and pelecypods (clams, oysters, etc.). Although molluscs in general are found on land and in fresh and marine waters, the cephalopods are exclusively marine. Cephalopods first appeared in the Cambrian and reached their maximum diversity in Late Paleozoic and Mesozoic. However, by Ordovician times they already had evolved into many genera and had become extremely abundant. All Early Paleozoic cephalopods belong to the sub-class called the Nautiloidea, whose only survivor is *Nautilus* of the western Pacific area.

Some Cincinnatian nautiloids became quite large, as much as twelve feet maximum length. They probably were capable of rapid movement and may have had powerful grasping tentacles, strong beaks, good eyesight and strong shells. They were very likely the largest and most numerous predators of their time.



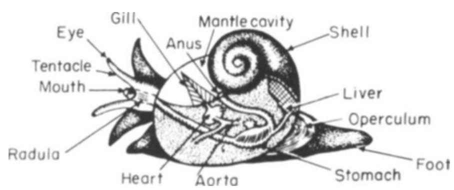
Shell morphology of a generalized orthoconic nautiloid cephalopod.

Most Cincinnatian nautiloids had straight, conical shells, a shell-form called an orthocone. However, in the Richmondian, arcuate shell-forms, gyrocones, and coiled shell-forms are occasionally found. Generally, only the internal mold of the shell is found (Pl. I, 24-25), but rare external molds show a surface ornament of raised longitudinal and transverse ridges.

Unfortunately, cephalopods may not be accurately identified by their external characteristics. Different genera, even different families, may have somewhat similar external features. This and tradition has led many collectors to the unfortunate habit of calling every Cincinnatian cephalopod by the generic name *"Orthoceras". "Orthoceras",* as the generic name of a cephalopod, is invalid and should be abandoned. The true genus and species of most local cephalopods may be determined only by thin-section analysis.

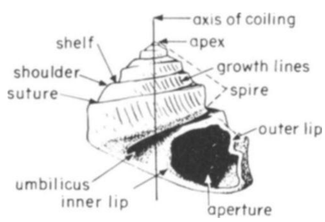
MOLLUSCA, GASTROPODA

The snails belong in the class Gastropoda (gastros, stomach; podos, foot) of phylum Mollusca. They are second in the Animal kingdom in total number of species only to the insects of phylum Arthropoda. The earliest snails known are from the Early Cambrian; since then they have slowly but continuously increased in variety and importance until the present.



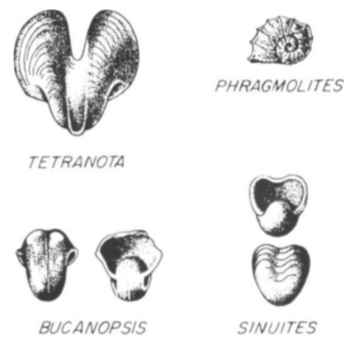
General anatomy of a living gastropod.

Certain forms show remarkable adaptions to their environment. The most remarkable are those which, alone among the molluscs, have become adapted to terrestrial life. However, the majority, by far, are aquatic. They are known to exist from between depths of three miles in the oceans to heights of over three miles above sea level.

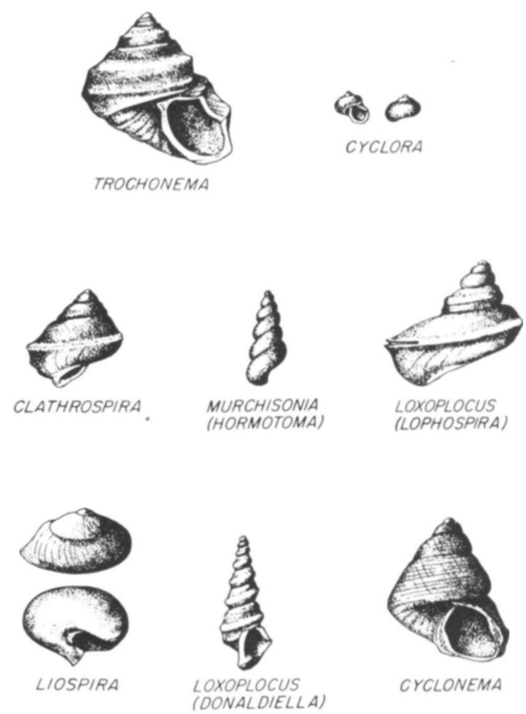


Shell morphology of the gastropod *Trochonema.*

In the Cincinnatian, only a few genera of snails are common. Strangely, the shells of certain genera, for example *Cyclonema,* are usually found complete; whereas only the internal molds of other genera, e.g. *Loxoplocus,* are found commonly. This undoubtedly reflects an original difference in the physical structure or chemistry of the shell.



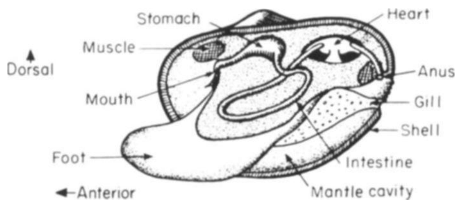
Planispirally coiled gastropods from the Cincinnatian. (Planispiral refers to coiling in a single plane.)



Conispirally coiled gastropods from the Cincinnatian. (Conspiral refers to coiling in which the overall shape of the spiral is a cone.)

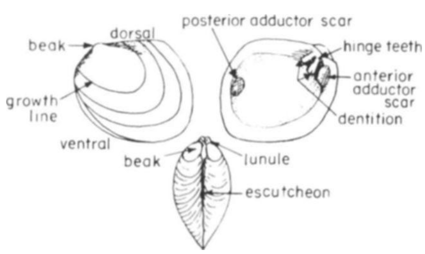
MOLLUSCA, PELECYPODA

Class Pelecypoda of phylum Mollusca is well known to everyone, for it includes the clams, scallops, oysters, and mussels. Members of this class are, in general, sluggish bottom-dwellers, inhabiting marine or fresh waters. Throughout their geologic, history, the pelecypods have undergone many remarkable environmental adaptions. This class has had a long geologic history. Beginning in the Ordovician, they reached their greatest diversity in the Mesozoic and have slightly declined until the present.



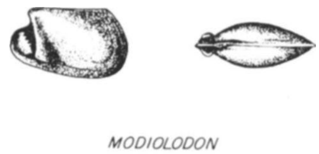
General anatomy of a living pelecypod.

Pelecypods have two valves, a right and a left, joined by a hinge. If the viewer holds a specimen so that he is looking at the hinge line, with the beak forward, the right valve will be on the right, the left on the left. These valves externally are mirror images of each other, the plane of symmetry passing between the two valves.



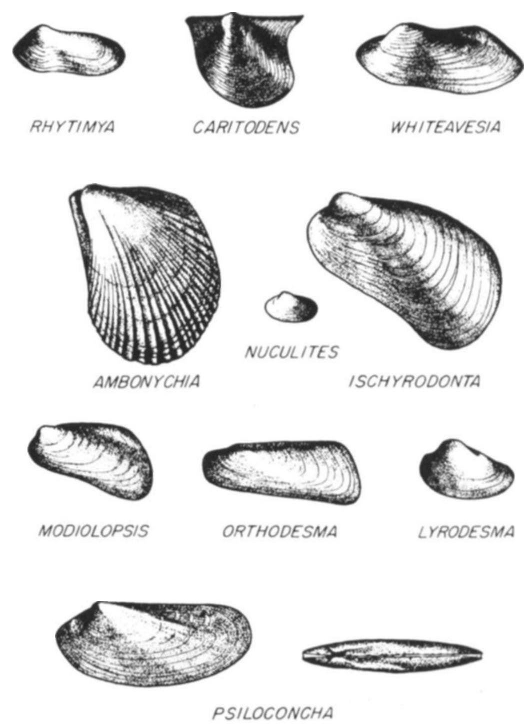
Shell morphology of the pelecypod *Ischyrodonta.*

In the Cincinnatian, there are only a few common pelecypods, and good specimens of these 'are unusual. Three general types of preservation are encountered, internal or external molds, carbonaceous films on rock layers, and, rarely, except for the genu' *Caritodens,* the replaced shell itself.



Internal mold of a pelecypod.

The external ornament and form of pelecypod valves is of generic and specific significance. Of far greater importance are the teeth and socket structures on the inside of the shell along the hinge line. Only by study of these features may the higher systematic position of the species be determined.



Pelecypods from the Cincinnatian.

MOLLUSCA, MONOPLACOPHORA

The molluscan class Monoplacophora is not very well known to the General Public. The name means "one shell bearing"; this refers to the fact that the animal has a single shell. That one shell looks like that of a snail, but the soft parts are different indeed. The identification of a fossil monoplacophoran as such depends on study of muscle scars on the inside of the shell — features so rarely preserved and observable that it's been only recently that some Cincinnatian fossils, long believed to be gastropods, have been reassigned to the Monoplacophora by paleontologists.

The Monoplacophora were long believed to have been extinct for hundreds of millions of years. Then in the 1950's some living specimens were dredged up from the deep ocean floor. This modern form, *Neopilina,* gave paleontologists their first real understanding of the fossil monoplacophorans which had been known for a long time.

Cincinnatian monoplacophorans of the genus *Cyrtolites.*

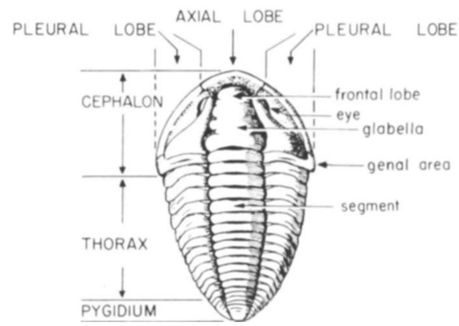
MOLLUSCA, CRICOCONARIDA

There are in the local Cincinnatian rocks some small, conical shells called tentaculites (Pl. VI, Fig. 14). They bear transverse ridges, which give the group its name — Cricoconarida means "ringed small cone". The general shape of the shell is that of a narrow, straight cone closed at the tip. In addition to the rings, there may be growth-lines parallelling the rings and striations running the length of the cone. There may be transverse partitions inside the shell, too.

The cricoconarids are extinct, and we do not know what their soft parts were. Nor do we know for certain what their way of life was. The shell is composed of the mineral calcite; this and the microstructure of the shell suggest that the cricoconarids belong in the phylum Mollusca.

ARTHROPODA, TRILOBITA

The exclusively marine trilobites, related to the crabs, spiders, and insects (Phylum Arthropoda) abounded in the Paleozoic seas. They are found among the oldest well preserved fossils in the Lower Cambrian (Waucobian) and up into the Permian, although numbers diminished after Devonian times. The Cincinnatian rocks are filled with trilobite fragments, and good specimens of the common genus *Flexicalymene* are abundant. Two other genera, *Isotelus* and *Cryptolithus,* somewhat rarer than *Flexicalymene,* and fragments of extremely rare genera may be found here.



Morphology of the trilobite *Flexicalymene.*

Only the hard outer skeletons of trilobites are commonly found. These skeletons may be either enrolled into a ball like that of the related pill-bug, found under stones and logs in the woods, which enrolls when disturbed, or may be extended in the natural life-position.

In addition to the animal itself, trilobite tracks are frequently found on the surface of shale layers. Molds of the hollows where trilobites dug into the mud *(Rusophycus)* are also known in the Cincinnatian.

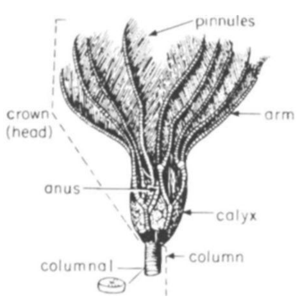
RARE CINCINNATIAN ARTHROPODA

Two very rare, extinct groups of fossils, related to the spiders, crabs, and insects, are known from local rocks. The Eurypterida, related to the horse-shoe crab, are occasionally found as fragments in the Richmondian, and a locality in the Elkhorn near Manchester in Adams County, Ohio, has yielded several good specimens. Only one post-Cambrian specimen belonging to the group called the aglaspids is known. This specimen came from the Corryville of Stonelick Creek, in Clermont County, Ohio.

The Cincinnatian aglaspid *Neostrabops.*

ECHINODERMATA, CRINOIDEA

The crinoids or, "sea lilies", are a class of the more general group of marine animals called the Echinodermata, which also includes, for example, the starfish, sand dollars, and sea cucumbers of the modern seas. Crinoids first appear in rocks of Early Ordovician (Canadian) age and have persisted to the present. The more specific groups to which the Cincinnatian crinoids belong disappeared at the end of the Permian. Crinoid fragments, in particular the doughnut-shaped or pentagonal columnals, are abundant throughout the Cincinnatian, even composing complete limestone layers. Good specimens, showing the calyx and arms, are rather rare (some species very rare), although sometimes many are found in very localized "pockets". This indicates that they probably preferred an exacting environment and, thus, lived grouped together.

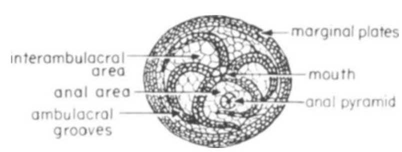


Morphology of the crinoid *Pycnocrinus.*

The crinoids of the Cincinnatian lived attached to the bottom by a long, flexible column and a root-like base. The main part of the body, the calyx, at the upper end of the column, bore arms which channeled food into the mouth on the upper surface of the calyx. The hard structure of the animal was composed of plates of crystalline calcium carbonate, a distinctive feature of all echinoderms.

ECHINODERMATA, EDRIOASTEROIDEA

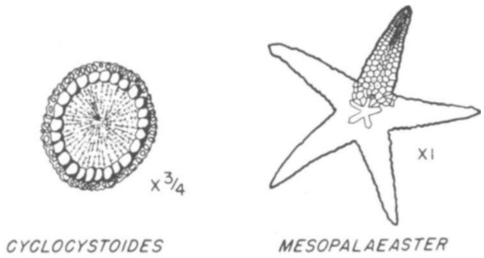
The edrioasteroids are another class of animals belonging to the marine echinoderms. They range in time from the Early Cambrian to the Mississippian. These animals are rather rare in the Cincinnatian but occasionally may be found by diligent search of the Bellevue and Corryville Members. The mode of life of the edrioasteroids was dominantly sessile; that is, they generally lived on the bottom or attached to a suitable hard object. The outside surface of the pedicle valve of *Rafinesquina* seems to have been their favorite site of attachment and consequently should always be carefully studied. Because of their rarity and beauty, good edrioasteroids are always prize finds.



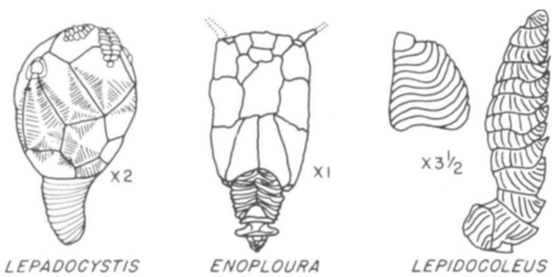
Morphology of the edrioasteroid *horophus.*

RARE CINCINNATIAN ECHINODERMATA

Several groups of fossils found in the Cincinnatian are indeed of great rarity. The amateur collector cannot be assured of ever seeing even fragments of these fossils (in some cases even fragmentary specimens are of great importance) but should be sufficiently acquainted with them for chance field recognition.



A Cincinnatian cyclocystoid (left) and asteroid (right).



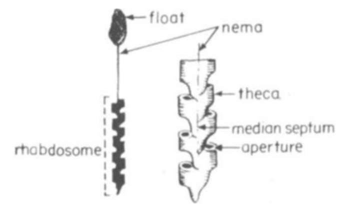
A Cincinnatian cystoid (left), carpoid (middle), and machaeridian (right).

The Machaeridia, Carpoidea, Cyclocystoidea, Asteroidea, and Cystoidea are all echinoderms. Many hundred specimens of asteroids (starfish) and cystoids are known, but good specimens are both hard to find and are very beautiful fossils. Much rarer are good cyclocystid specimens (thought to be related to the Edrioasteroids). There are very few good carpoids and machaeridians.

GRAPTOLOIDEA

The graptoloids, known from the lower Ordovician through the Silurian, belong to a little known phylum called Hemichordata. This phylum is represented in modern seas by a few obscure genera. Prior to 1948 when the true position of the graptoloids was first recognized, they were considered coelenterates by some authors, bryozoans by others.

The graptoloids were colonial animals with many minute individual living tubes (thecae) grouped together into a colony called a rhabdosome. The rhabdosome frequently looks like a single, two-sided, forked, four-pronged, etc., jigsaw blade. In life, the rhabdosome was suspended from a float by a slender thread called a nema.



Morphology of the graptolite *Climacograptus.*

The walls of the rhabdosome were composed of tough, flexible chitin, much like a beetle wing. However, the fossil colony is generally seen as a black, carbonaceous film on the surface of dark shale layers, very rarely in limestone. Usually the colony is crushed flat, but occasionally specimens retain the "inflated" form the colony had in life. Inflated rhabdosomes are known from the Cincinnatian.

Graptolites floated and, thus, were capable of wide distribution and preservation in toxic bottom muds prohibitive to bottom-dwelling life. Graptolites rapidly evolved in the Ordovician and Silurian. Thus, they provide excellent index fossils for long distance correlation of stratigraphic units of these two periods.

FOSSIL CROUPS OF MINOR IMPORTANCE TO BEGINNERS

Sponges

The phylum Porifera includes the sponges. The name means "hole bearing", a reference to the system of holes and canals whereby the animal circulates water through itself.

Sponges are primitive creatures. They are multicellular, but the cells are not organized into tissues. Members of the phylum are characterized by specialized cells which cause water to flow through the animal by means of beats of whip-like structures termed "flagella" (sing., flagellum).

Many sponges have hard parts composed of calcium carbonate or of silicon dioxide, but most of those which occur in our local rocks appear as non-descript, rounded masses. Although abundant at some localities, they generally are difficult to recognize as sponges, let alone identify, without study of thin-sections.

Sponges are aquatic creatures. Some present-day forms are marine, and others live in fresh-water.

One group of poriferans which is represented in the local rocks includes specimens not so non-descript as the more standard sponges. These are the members of the order **Stromatoporoidea.**

The name stromatoporoid means "layered place". This name is appropriate because the skeleton of these colonial creatures most often appears distinctly layered, especially in thin-section. The surface of the colony commonly is marked by bumps (see, for example, *Labechia* on pi. VI). Generally there is a hole in the center of each bump; this is the opening of a canal feeding down into the mass of the colony. In many types of stromatoporoids there is a pattern of shallow grooves radiating from each canal opening. Stromatoporoids can be identified only after study of thin-sections of the colonies.

For many years it was thought that stromatoporoids were long extinct, and there was much question as to just what kind of creatures they were. Then in the mid-1960's some animals were discovered in the Caribbean which exhibited many of the characteristics of the ancient stromatoporoids. These "new" animals were found to be sponges.

Conodonts are small tooth-like fossils composed of calcium phosphate found in most Paleozoic rocks. They are usually quite abundant and variable; therefore, they make good index fossils. The type of animal which bore these structures is unknown, although affinities with many groups of animals have been proposed.

"Worms"

There are many worm-like animals alive today. But the various long, thin, soft creatures commonly lumped together under the term "worms" are not all closely related; in fact, there is quite a number of different phyla with worm-like representatives.

Because "worms" are basically soft-bodied organisms, they don't fossilize too well, in general. They leave trace-fossils, but commonly it's tough to identify just what creature produced a given burrow, tube, or groove in the once-soft sediment we now see as rock. Some kinds of "worms" do produce identifiable fossils, however.

Some annelid worms have tooth-like jaw structures called scolecodonts (PI. II, Fig. 26). These are composed of a complex organic material similar to your fingernails. They appear shiny black or dark brown as fossils. Scolecodonts are so small that a microscope is needed to study them. They are common in our local rocks.

Some worms construct tubes in which they live. In some instances these tubes are composed of calcium carbonate and, hence, can be preserved as fossils. These tubes, while the worms are alive, are fastened to the sea floor or to other objects, for example, snail shells, brachiopod shells, or bryozoa.

The relatively common worm tube in the local Cincinnatian rocks is called *Cornulites* (PI. III, Fig. 16). It looks rather like the shell of the cricoconarid mollusc *Tentaculites,* but in *Cornulites* generally the conical tube is less straight, and the transverse rings, less regular. The microstructure of the tube wall of *Cornulites* includes vesicular tissue *(i.e.,* loaded with small cavities), whereas the shell of *Tentaculites* is multi-layered and lacks vesicles. Commonly *Cornulites* tubes occur in bunches of a half-dozen or more in the local rocks.

Ostracods are minute, bivalved crustaceans found in great abundance and variety throughout the Cincinnatian. They are actually of great stratigraphic and economic importance not only in this region but also throughout most sedimentary rocks. Their many species make them excellent index fossils, and their small size enables them to be removed intact with the chips brought out of oil wells. They are not considered here, because, although important, their size and variety makes them difficult to detect and identify by the amateur collector.

CINCINNATIAN ENVIRONMENTAL CONDITIONS

The sediments of the Cincinnatian Series were deposited in a shallow, marine sea which covered much of North America in late Ordovician times. All of the major fossil groups known in Cincinnatian rocks which have survived to the present are exclusively marine or have marine representatives. Most of these animals lived on or near the bottom. Few bottom dwelling animals in the modern seas live below 180m (600 ft.) deep, the maximum depth to which light penetrates. Some of the rocks found in the local area show ripple marks, channel fillings, and reworked "hash" zones. These are the effects of wave action and currents, which also are not found in the present oceans to any great extent below 180m (600 ft.) depth. From these two general lines of evidence it is concluded that the Cincinnatian sediments were deposited in a shallow continental sea.

In late Ordovician times, a mountain chain known as the "Taconics" bordered the eastern shore of the Cincinnatian sea along the present-day eastern edge of the United States. Weathering and erosion on this land supplied the sands, silts, and clays which were reworked by the currents of the sea. Beds containing volcanic dust (bentonitic muds) occur in the Cincinnatian as the result of occasional volcanic activity in these ancient mountains.

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PLATE SECTION

I

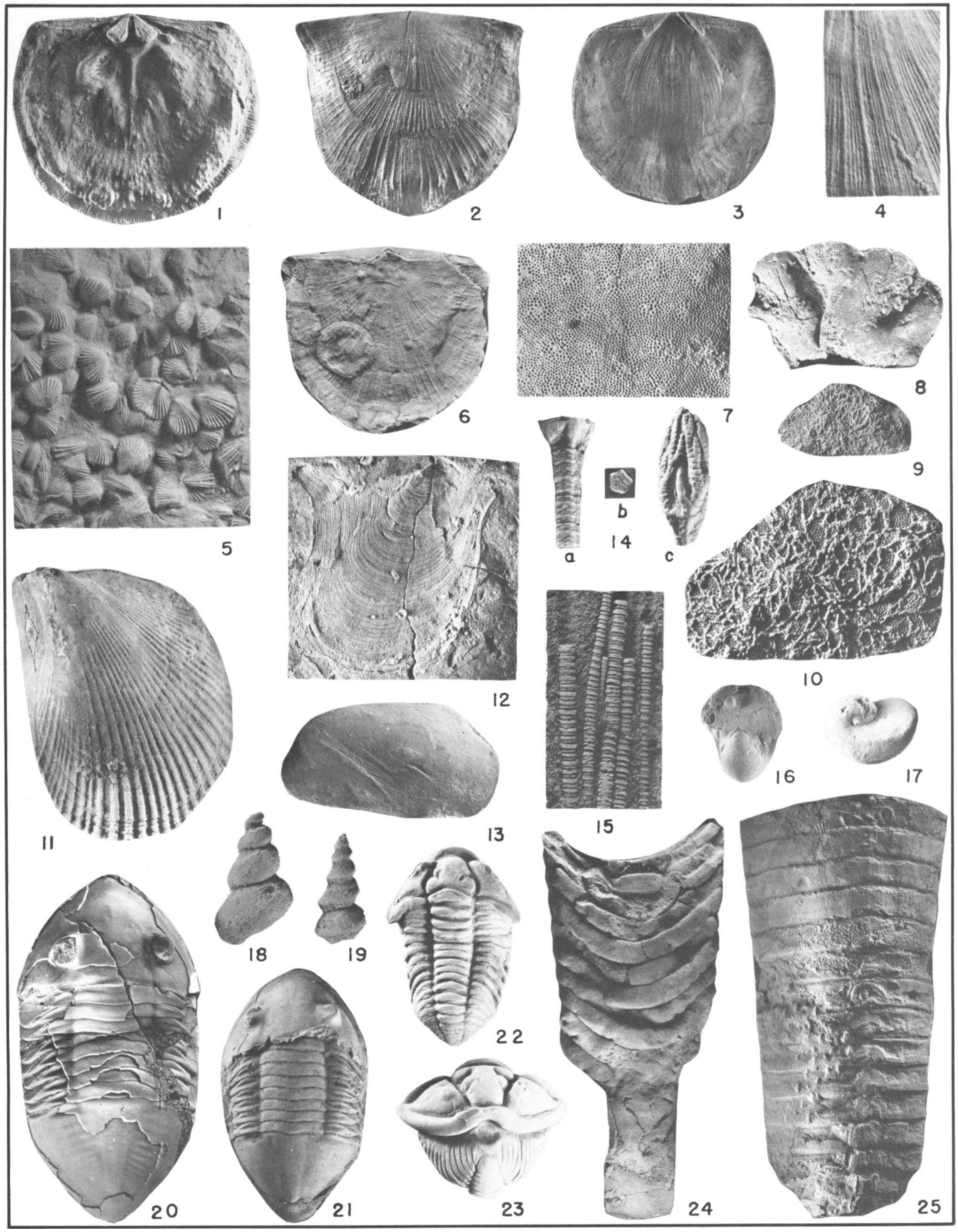

PLATE I

1–4 *Rafinesquina ponderosa.*
Articulate brachiopod. Fig. 1: Interior of brachial valve; note forked cardinal process and muscle impressions. Fig. 2: Exterior of pedicle valve. Fig. 3: Interior of pedicle valve; note teeth and fan-shaped muscle impression. Fig. 4: Enlargement of outer surface of shell. Entire Cincinnatian.

5 *Zygospira modesta.*
Articulate brachiopod. Figure somewhat enlarged. Entire Cincinnatian. (The less common Z. *cincinnatiensis* is larger, pentagonal in shape, and has fewer plications; it occurs in the upper Kope and the Fairview.)

6 *Petrocrania scabiosa.*
Inarticulate brachiopod. Thin oval shell grown so closely onto *Rafinesquina ponderosa* valve that striations of latter show on its surface. Entire Cincinnatian.

7,8 *Peronopora vera.*
Bryozoan. Fig. 8: Typical fan shape. Fig. 7: Surface enlarged, showing apertures. This genus differs from all others by having zooecia on both sides of fan separated by thin wall which may be seen best in thin-sections. Entire Cincinnatian. (Specimens of *Peronopora* from above the Edenian may have relatively larger apertures; these are *P. decipiens.)*

9,10 Cyclostome bryozoan.
A number of different bryozoan genera (for example, *Corynotrypa, Proboscina,* and *Stomatopora)* form delicate networks of tubular zooecia on other objects (in this case, another bryozoan colony). Although figure 10 is enlarged, a much greater enlargement would be necessary to identify just which genus is figured.

11 *Ambonychia* sp.
Pelecypod. Note byssal gape on left, down from beaks. Maysvillian and Richmondian. (Almost certainly not *A. radiata,* which seems limited to Edenian and older rocks.)

12 ***Caritodensdemissa.***
Pelecypod. Flattened valve in limestone showing concentric growth lines. Note broad left "wing", shorter right "wing". Entire Cincinnatian.

13 *Modiolopsis modiolaris.*
Pelecypod. Internal mold. Genus found throughout Cincinnatian; this species restricted to Fairmount.

14 *locrinus subcrassus.*
Crinoid. a: Pentagonal stem with a portion of the calyx on top. b: Pentagonal columnal. c: Calyx and arms (crown).

15 Fragments of crinoid columns on the surface of a limestone slab.

16,17 *Sinuites cancellatus.*
Gastropod. Planispirally coiled. Fig. 16: View toward aperture. Fig. 17: Side view. Entire Cincinnatian.

18,19 *Loxoplocus bowdeni.*
Gastropod. Fig. 18: Internal mold. Fig. 19: Exterior of shell, showing keel on each volution. Maysvillian and Richmondian.

20,21 *Isoteius maximus.*
Trilobite. Large pygidium matches cephalon in size and shape. Largest specimens exceed 0.6m (2 ft) in length. Entire Cincinnatian.

22,23 *Flexicalymene meeki.*
Trilobite. Cephalon characterized by sharply defined glabella with three deep lateral grooves. Pygidium small, continuing pattern of body segments. Fig. 23: Enrolled specimen. Maysvillian and Richmondian.

24 *Endoceras proteiforme.*
Cephalopod. Top view of a fragment of internal mold of a straight, conical shell, broken lengthwise. Note siphuncle protruding where rest of the specimen is missing; in *Endoceras* the siphuncle is large and well off the center of the conical shell. Figure about 1/3 nat. size. Exact range unknown, thought to be entire Cincinnatian.

25 *?Onbonybyoceras* sp.
Cephalopod. Part of internal mold. Several cephalopods smaller than *Endoceras* occur in the local rocks; they cannot be identified without careful study of their internal structures.

(All figures natural size unless stated otherwise.)

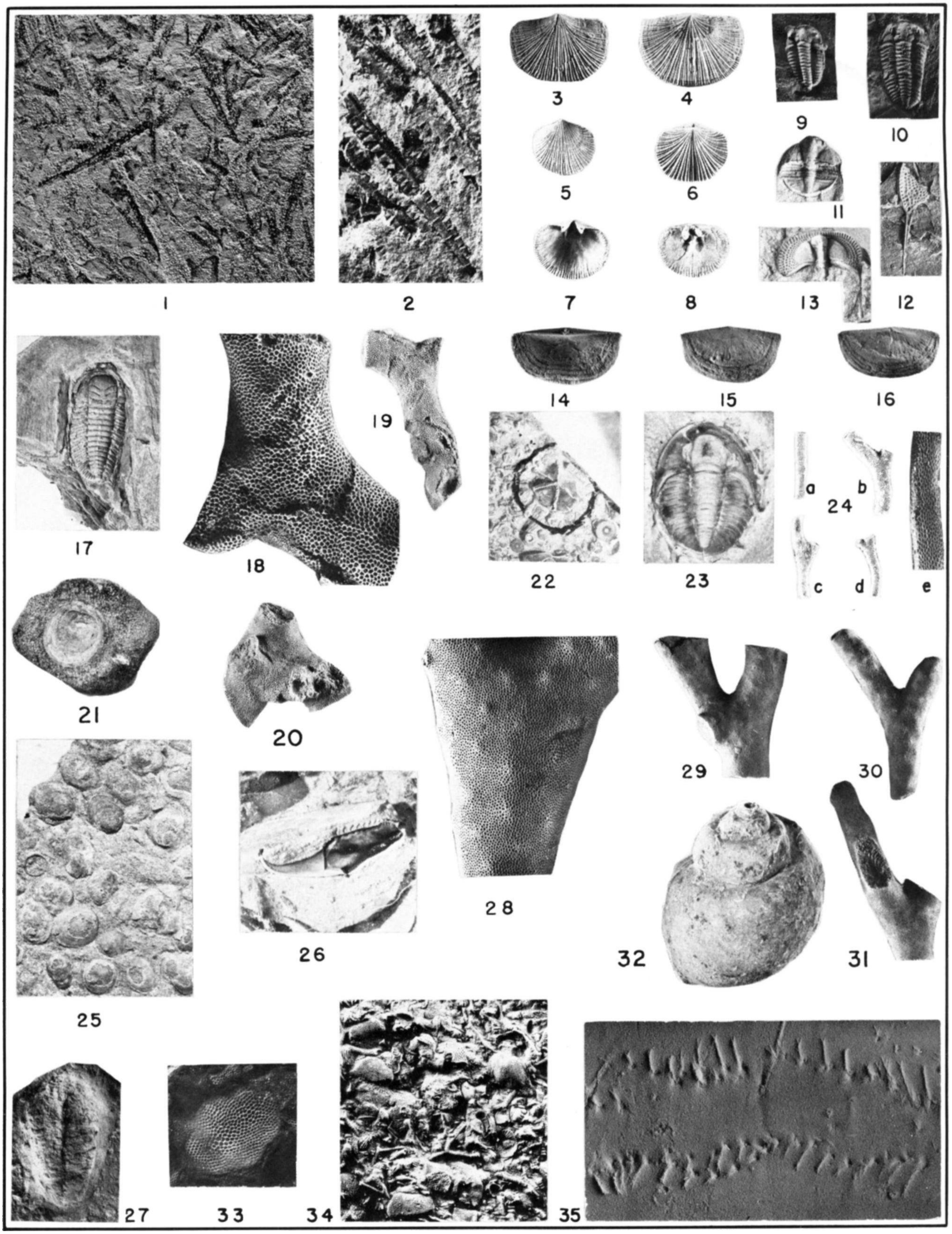
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PLATE II
FOSSILS, MOSTLY EDENIAN

1,2 *Climacograptus typicalis.*
Graptolite. Fig. 1: Slab showing fragments of many rhabdosomes. Fig. 2: Enlargement, showing nearly square thecae on each side of a rhabdosome. Edenian.

3,4 *Onniella emacerata.*
Articulate brachiopod. Differs from the next species by greater size, flatter valves, more rectangular outline, and lack of a median sinus in the brachial valve. Fulton through Southgate.

5-8 *Onniella multisecta.*
Articulate brachiopod. Compare with preceding species. Fig. 5: Exterior of pedicle valve. Fig. 6: Exterior of brachial valve. Fig. 7: Interior of pedicle valve; note triangular pedicle opening. Fig. 8: Interior of brachial valve; note double cardinal process. Economy through Fairmount.

'),!() *Flexicalymene granulosa.*
Trilobite. Differs from *F. meeki* (Pl. I, Figs. 22, 231 in smaller size and granular surface (the lattei is loo fine to be visible in these figures). Edenian.

11-13 *Cryptolithus bellulus.*
Trilobite. Fig. 11: Almost complete specimen showing the cephalon with protruding glabella, the few thoracic segments, and the short, broad pygidium. Fig. 1 1: Cephalon showing the broad, semi-circular fringe which runs around the edge of the cephalon and is piltecl in such a way as to have earned this species ilie name "l.u e i oll.n trilobite". Fig. 12: A fragment of the "lace collar" and one long genal spine. Edenian and Maysvillian; common in the Southgate. (Specimens of C. *bellulus* commonly have been misidentified as C. *tesselatus,* which does not occur in the local rocks.)

14-16 *Sowerbyella rugosa.*
•\iii< ul.lie brachiopod. Fig. It: Exterior of brae hial valve (concave); note cardinal area of pedicle valve above hinge line and concentric wrinkles along front margin. Figs. 15, 16: Exterior of pedicle valve (convex). Edenian.

17 *Triarthrus eatoni.*
Trilobite. Note rectangular glabella and nodes down the center of the axial lobe. Specimen slightly enlarged. Fulton and top of Southgate.

18-20 *Batostoma jamesi.*
Bryozoan. Note the irregular thickening of the branches. Fig. 18: Branch enlarged to show the large apertures. Entire Edenian, common in Southgate.

21 *Orbiculoidea tenuistriata.*
Inarticulate brachiopod. Concave interior of valve adhering to bryozoan. Note faint concentric growth lines.

22 *Glyptocystites fultonensis.*
Cystoid. Single plate. Note hexagonal ridges. Complete animal unknown. Common in Edenian and Maysvillian; exact range unknown.

23 *Proetus parviusculus.*
Trilobite. Note large cephalon and glabella, few thoracic segments, small pygidium, and wide, oval outline. Enlarged X3. Uncommon. (A similar species, *Proetus spurlocki,* also occurs in the local rocks, but is much more rare).

24 *Parvohallopora onealli.*
Bryozoan. Fig. 24e: Surface, enlarged to show relatively large apertures.

25 *Pholidops cincinnatiensis.*
Inarticulate brachiopod. Slab with many oval, imperfectly preserved valves. Note concentric growth lines. Enlarged X3.

26 *Nereidavus vjrians.*
Scolecodont (worm tooth). Partly missing on right side. Enlarged X3. Entire Cincinnatian.

27 *Rusopbycus pudicum.*
Trace fossil. These convex objects are found on the underside of limestone layers. They represent hollows dug into the underlying mud by trilobites and later filled by the calcareous mud which became the limestone. Entire Cincinnatian.

28-31 *Dekayia ulrichi.*
Bryozoan. Figs. 29-31: Fragments of branches showing the characteristic broadly rounded monticules. Fig. 28: Enlarged branch showing apertures and monticules. Edenian.

32 *Holopea obliqua.*
Gastropod. Note rounded shoulder and lack of ornament. Sub-Edenian.

33,34 *Aspidopora newberryi.*
Bryozoan. Fig. 33: Enlargement of zoarium. Note rounded, discoid form. Fig. 34: Three zoaria on a limestone slab (natural size). Edenian.

35 *Diplichnites multipartitum.*
Trace fossil. Trilobite tracks on the upper surI.H e ol limestone slab. I ntire I inc innatian.

(All figures natural size unless stated otherwise.)

III

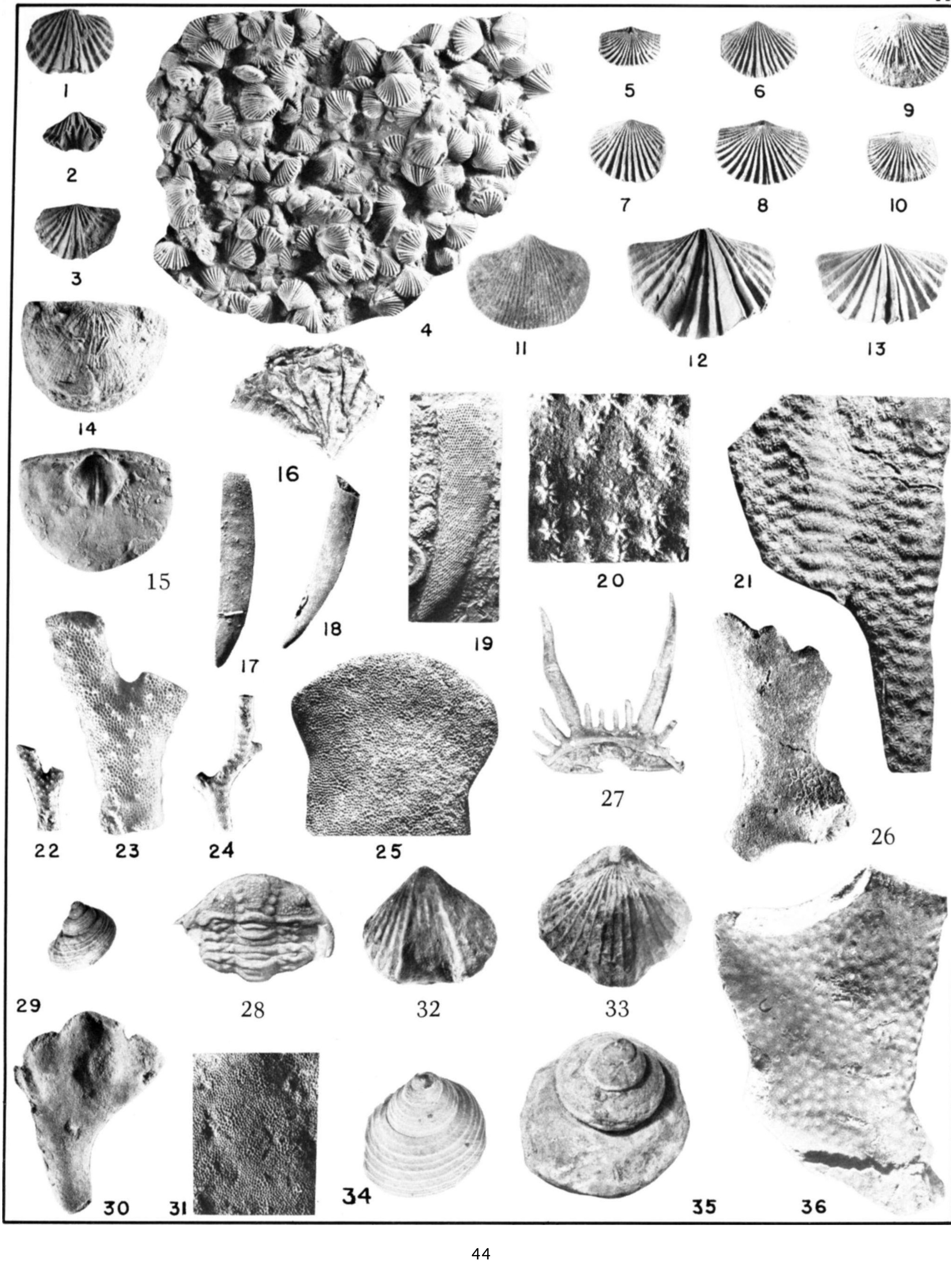
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PLATE III
FOSSILS FOUND IN THE FAIRVIEW

1–3 *Platystrophia hopensis.*
Articulate brachiopod. Note small size, coarse plications, fold in brachial valve, and sulcus in pedicle valve. Mt. Hope.

4 *Zygospira modesta.*
Articulate brachiopod. (See Plate I, Figure 5.)

5,7 *Plectorthis plicatella.*
Articulate brachiopod. Fairmount.

6,8–10 *Plectorthis fissicosta.*
Articulate brachiopod. Differs from preceeding species in larger maximum size, more numerous plications, splitting of plications, and slight sulcus and fold.

11 *Pionodema bellula.*
Articulate brachiopod. Brachial valve (convex). Note fine costae. Enlarged X4. Fairmount.

12,13 *Platystrophia laticosta.*
Articulate brachiopod. Differs from *P. hopensis* (Fig. 1–3) in larger size and sharper, higher fold. Characteristic of the Bellevue and Corryville. (P. *sublaticosta,* a similar form, occurs in upper Fairmount.)

14,15 *Strophomena planoconvexa.*
Articulate brachiopod. This genus differs from *Rafinesquina,* (Pl. I, Figs. 1–4) by having the brachial valve convex to the exterior (Fig. 14), and the pedicle valve concave to the exterior (Fig. 15). Note characteristic muscle scar (Fig. 15), also the irregular coarse striations (Fig. 14). Fairmount. (S. *planoconvexa* has been tentatively referred to *Trigrammaria* by some workers.)

16 *Cornulites corrugatus.*
Annelid worm tube. Illustration shows many conical tubes radiating from a common point. Note crooked tubes and coarse transverse corrugations. Entire Maysvillian.

17–19 *Escharopora falciformis.*
Bryozoan. Has characteristic flat, blade shape, and pattern of diamond-shape apertures. Fig. 19 enlarged. Mt. Hope and Fairmount.

20,21 *Constellaria florida.*
Bryozoan. Covered with star-shaped monticules. Fig. 20 enlarged. Fairmount.

22–24 *Parvohallopora dalei.*
Bryozoan. Differs from *P. onealli* (Pl. II, Fig. 24) in its larger size and widely spaced, sharply conical monticules. Mt. Hope and Fairmount.

25,26 Defcayia *aspera.*
Bryozoan. Figs. 25 and 26 are typical forms. Pl. IV, Fig. 9, a surface enlargement, shows the acanthopores projecting as minute spines. Fairmount.

27 *Acidaspis cincinnatiensis.*
Trilobite. Underside of pygidium. Very rare.

28 *Ceraurus milleranus.*
Trilobite. Exceedingly spiny. Has a short, wide, pustulose cephalon with prominent glabella, long genal spines and small eyes. Fairmount and Corryville.

29,34 *Cyclonema inflation.*
Gastropod. This species characterized by two orders of spiral lirae (as opposed to one in C. *gracile* and three in C. *bilix).* Fairview.

30,31 *Homotrypa obliqua.*
Bryozoan. Shape variable, from cylindrical to fan-like. Fig. 31 shows an enlargement of the surface with patches where the apertures are enlarged (called maculae). Fairmount through Corryville.

32,33 *Orthorhynchula linneyi.*
Articulate brachiopod. Resembles *Rhynchotrema* but has a more triangular outline, finer plications, a small but definite cardinal area, and a lower fold and sulcus. Fig. 32, pedicle valve; Fig. 33, brachial valve. Fairmount. Rare.

35 *Clathrospira conica.*
Gastropod. Internal mold, showing unornamented volutions and a moderately high spire. Shell itself is subconical, with sharply angulated whorls. Fairmount.

36 *Heterotrypa subfrondosa.*
Bryozoan. Generally appears in thick, broad, fan-shaped colonies, covered with broadly rounded monticules. Fairmount.

(All figures natural size unless stated otherwise.)

IV

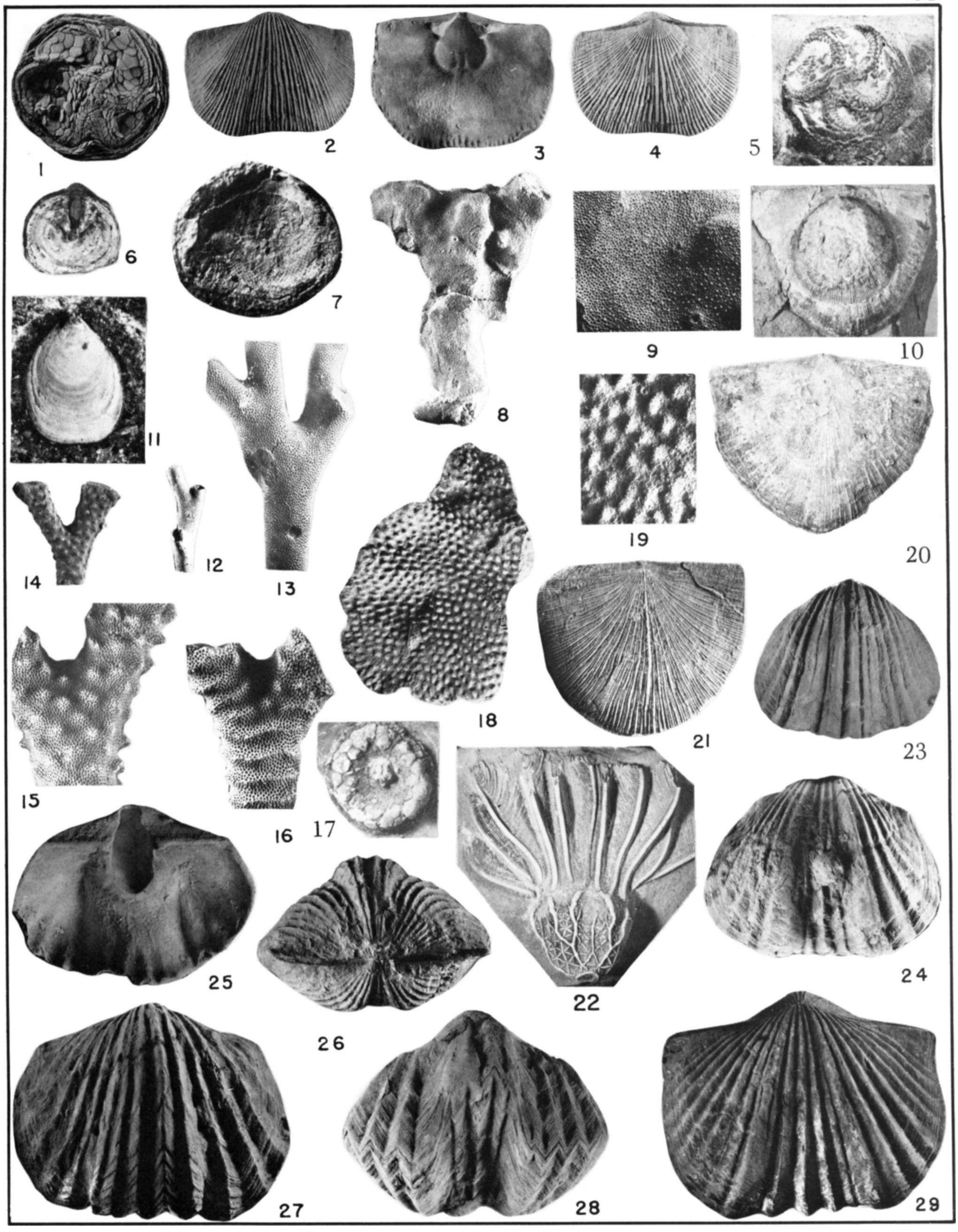

PLATE IV
FOSSILS FOUND IN THE McMILLAN/GRANT LAKE

I *Isorophus < in< innatiensis.*
Edrioasteroid. Characterized by numerous plates and long, curved ambulacra. May exceed 2'/-' cm (1") in diameter. Fairmount up into Ml. Auburn.

2–4 *Hebertella occidentalis.*
Articulate brachiopod. Fig. 2, exterior of brachial (dorsal) valve. Fig. 3, interior of pedicle valve with triangular pedicle opening. Note the trilobed, central muscle impression. Fig. 4, the relatively flat pedicle valve with the raised hcik. Fairmount up into the Ric hmondian.

5 (*arneyella pilea.*
Edrioasteroid. Differs from *Isorophus cincinnatiensis* in smaller size, fewer plates (especially over the mouth area at the junction of the ambulacra), and shorter, less curved ambulacra. Specimen slightly enlarged. Fairmount through Waynesville.

6,7 *Trematis millepunctata.*
Inarticulate brachiopod. Fig. 6, low, convex pedicle valve, with lenticular pedicle opening. Fig. 7 (enlarged), brachial valve less convex than the pedicle valve; figure shows characteristic pitting which covers the shell in diagonal rows.

H *Chiloporella flabellata.*
Bryozoan. Branches of zoarium characteristically flattened and expanded. Corryville.

9 *Dekayia aspera.*
Bryozoan. Enlarged surface-view. Other specimens shown on PI. Ill, Figs. 25, 26.

10 Si /»/<)(ran/a *(ilosa.*
Inarticulate brachiopod. Crown to a valve of *Kalmcsquina.* Brachial valve. Note fine striations and convexity of valve. Fairmount through Oregonia.

II *Pseudolingula* sp.
Inarticulate brachiopod. Note triangular outline, white, phosphatic shell material, and concentric growth-lines. Enlarged X4. Genus found throughout Cincinnatian.

12,13 *Ralostumclla gracilis.*
Bryozoan. Note small angle between branches, small apertures, and smooth surface. Fig. 13, enlarged.

14–16 *Parvohalhpora ramosa.*
Bryozoan. Characterized by high, sharp monticules or by monticules fused into ridges (latter formerly called *Hallopora rugosa).* Branches relatively thick. Figs. 15 & 16, enlarged. Bellevue through Mt. Auburn.

17 *Lichenocrinus dyeri.*
Crinoid. The base or "root" of a very small crinoid. Note the numerous plates, convex form, and central, broken stem. Genus occurs throughout the Cincinnatian; this species, limited to the Corryville. Enlarged.

18,19 *Monticulipora mammulata.*
Bryozoan. The form varies from lumpy masses to fans. Surface covered with crowded, sharp monticules. Fig. 19, surface enlargement.

20 *Rafinesquina nasuta.*
Articulate brachiopod. Like *R. ponderosa* but with anterior extension (may even take the shape of a minor fold) which gives the shell a triangular outline. Corryville.

21 *Rafinesquina fracta.*
Articulate brachipod. Like *R. ponderosa,* but very thin, almost flat, and tending to be longer than wide. Abundant in the Bellevue.

22 *Pycnocrinus dyeri.*
Crinoid. A large crown showing the stellate pattern on the calyx, and the arms with attached pinnules. Genus found throughout the Cincinnatian; this species, limited to the Corryville.

23–29 *Platystrophia ponderoia.*
Articulate brachiopod. This form differs from all other species of *Platystrophia* in the Cincinnatian by the size and thickness of the shell. Fig. 25, interior of pedicle valve, showing deep muscle impression and triangular pedicle opening. Figs. 26–29 show the typical subspecies *P. ponderosa ponderosa.* Figs. 23 & 24 show the subspecies *P. ponderosa auburnensis,* which is characterized by the short hinge line and great depth of shell. The species range is Maysvillian-Oregonia. *P. ponderosa auburnensis* is limited to the Mt. Auburn, but both forms are very abundant in that unit.

(All figures natural size unless stated otherwise.)

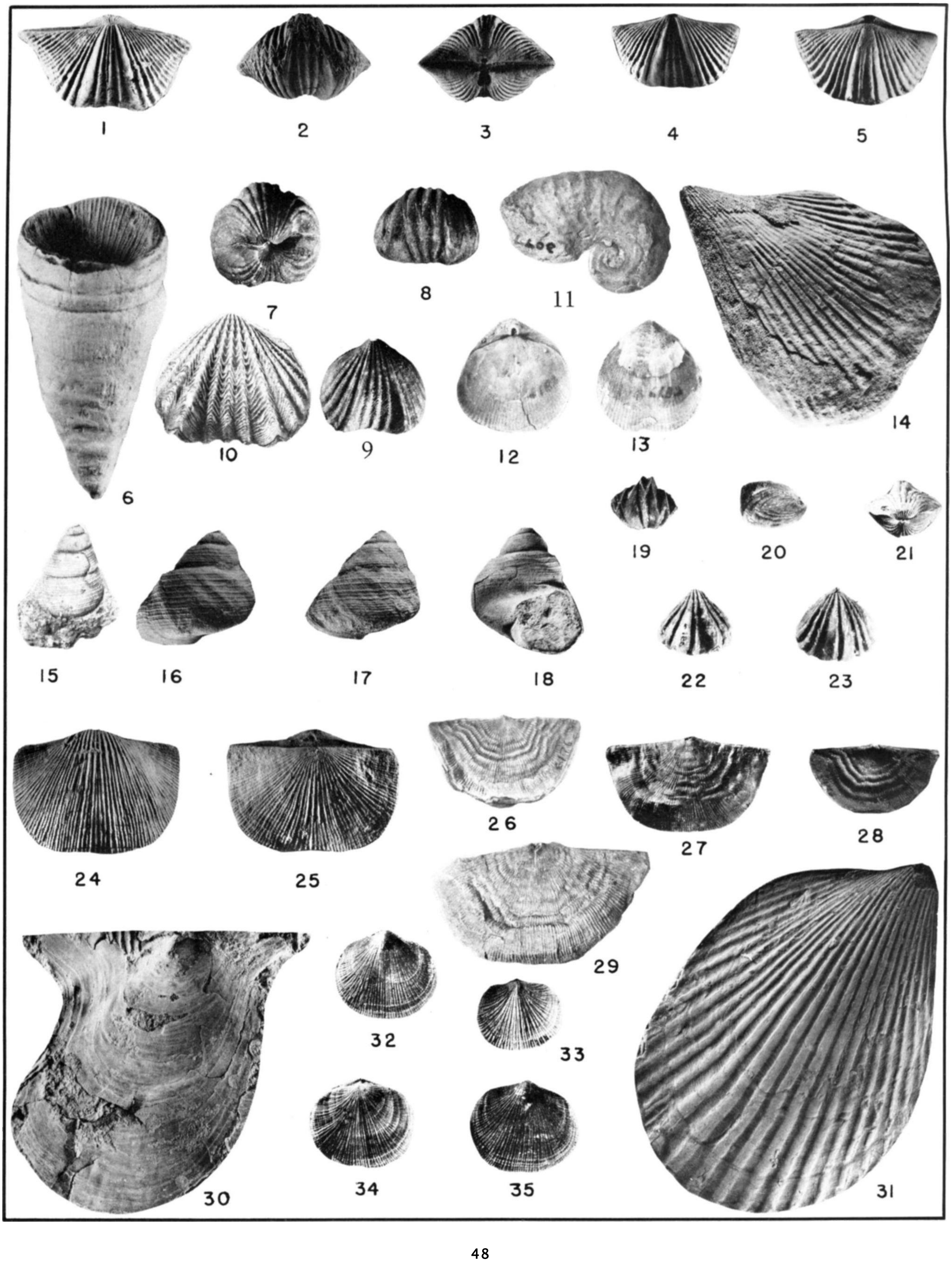
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PLATE V
FOSSILS FOUND IN THE RICHMONDIAN

1–5 *Platystrophia acutilirata.*
Articulate brachiopod. Characterized by three nearly equally developed plications in the sulcus, by the numerous plications (ten or more) on each side of the sulcus, and by the low, rounded fold. Whitewater.

6 *Crewingkia canadensis.*
Coral. Note numerous septa on the interior and growth-lines on the exterior. Specimens of this species are larger and longer than specimens of species of *Streptelasma.* Entire Richmondian except lower Arnheim. Specimens of *Crewingkia* commonly are marked by borings; those that form a dendritic or reticulate network have been referred to *Dictyoporus,* and solitary holes have been called *Irypanites* (for details, see Elias, 1980).

7–9 *Hiscobeccus capax.*
Articulate brachiopod. Note the three major plications in the sulcus, the rounded beak, and the growth-lines crossing the plications. Entire Richmondian.

10 *Lepidocyclus perlamellosus.*
Articulate brachiopod. Differs from the previous species in characteristics of the shell interior, but it tends to be larger than the previous species and to have more distinct growth-lines. Entire Richmondian, except the Arnheim.

11 *Cyrtolites ornatus.*
Monoplacophoran. Coil in one plane. Final whorl does not contact earlier whorls. Note transverse ridges. Fairview – Waynesville.

12,13 *Catazyga headi.*
Articulate brachiopod. Smooth, rounded shells with faint costae. Fig. 12, brachial valve view, note pedicle opening on pedicle valve. Fig. 13, pedicle valve with shallow sulcus. Waynesville. Rare.

14 *Ambonychia robusta.*
Pelecypod. Large, imperfect specimen, showing convex form and distinct plications. Waynesville to Whitewater.

15 *Cyclonema bilix lata.*
Gastropod. Characterized by a medial groove in the largest whorl.

16–18 C yc *lonema* sp.
Gastropod. This form has been called Cyc*lonema bilix bilix;* this is incorrect, because it is, in fact, a distinct species that has yet to be named formally.

19–23 *Rhynchotrema dentatum.*
Articulate brachiopod. Differs from *lepidocyclus* and *Hiscobeccus* (Figs. 7–10) in having only one plication in the sinus, a more pointed beak, and a smaller size. Waynesville – Whitewater.

24,25 *Hehertella occidentalis.*
Articulate brachiopod. Fig. 24, dorsal (brachial) valve; Fig. 25, ventral (pedicle) valve. Fairmount up into the Richmondian. (H. *al*wjf.i is also found in Richmondian strata but the sulcus in its dorsal valve runs to the anterior margin; in addition, *H. alveata* has a long ventral interarea.)

26–29 *Leptaena richmondensis.*
Articulate brachiopod. Distinguished by the irregular concentric wrinkles and by the sharp flexure in the shell near the anterior margin. Mt. Auburn – Elkhorn.

)() *Caritodens demissa.*
Pelecypod. (See PI. I, Fig. 12.)

31 *Anomalodonta gigantea.*
Pelecypod. Characterized by its outline, large size, broad, deep plications, and tooth structure (not visible in this illustration). Richmondian.

32–15 ***()nniella meeki.***
Articulate brachiopod. Differs from *O. multisecla,* (PI. II, Figs. 5–8) by rectangular outline, and greater size and thickness. Waynesville; peaks in Ft. Ancient. (Walker, 1982, has referred both (). *meeki* and O. *multisecta* to the genus *Dalmanella. Onniella* and *Dalmanella* are difficult to tell apart, and it may well be that these two species actually belong in a separate genus, as yet unnamed.)

(All figures natural size unless stated otherwise.)

VI

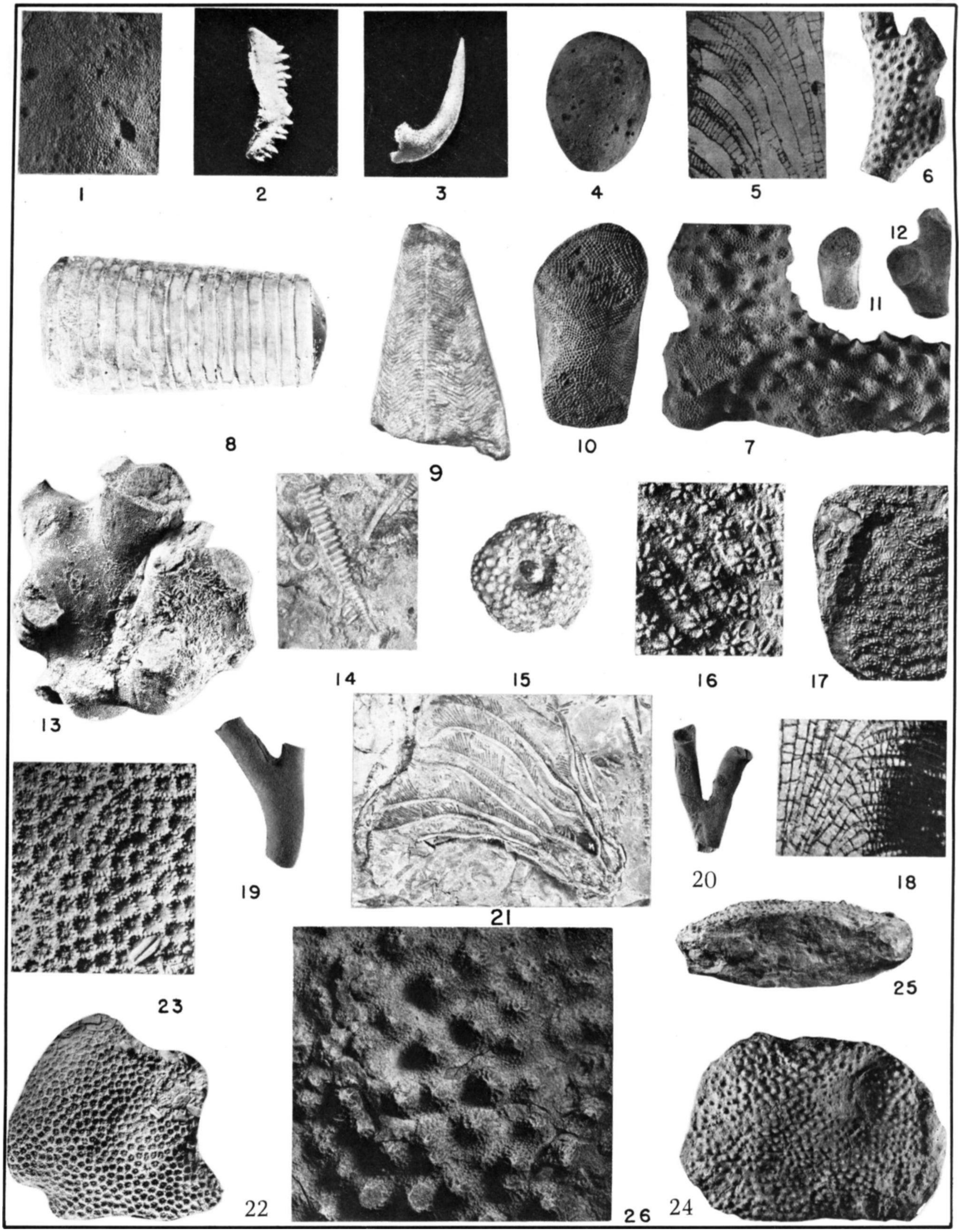

PLATE VI
FOSSILS FOUND IN THE RICHMONDIAN

1,4 *Homotrypella hospitalis.*
Bryozoan. More or less hemispherical masses. Surface without distinctive features. Entire Richmondian.

2 *Plectodina furcate.*
Conodont. Ozarkodinid element. Enlarged X50.

3 *Drepanoistodus* suberectus.
Conodont. Enlarged X30.

5–7 *Parvohallopora subnodosa.*
Bryozoan. Differs from *P. ramosa* (PI. IV, Figs. 14–16) in the more rounded, knob-like monticules, seen in Fig. 6 and Fig. 7 (enlarged). Fig. 5 shows a longitudinal thin-section. Note larger zooecia lack diaphragms. In *P. ramosa* diaphragms are numerous near the inner and outer ends of the zooecia; in *P. onealli,* the diaphragms are widely spaced throughout the zooecia. This genus lacks acanthopores. Entire Richmondian except Elkhorn.

8 *fOrlhonybyoceras duseri.*
Cephalopod. One of numerous cephalopods of the Richmondian. (See PI. I, Fig. 25.) Especially abundant in Waynesville.

9 *Conularia formosa.*
Conularid (scyphozoan coelenterate). Note fine, curved transverse striations, which disappear at the junction of two sides. Maysvillian and Richmondian.

10–12 *Rhombotrypa quadrata.*
Bryozoan. Unique in the rhombic or quadratic cross-section of the zooecia, as shown on the enlarged specimen, Fig. 10. All Richmondian except Arnheim.

13 *Batostoma varians.*
Bryozoan. Externally like *B. jamesi;* internally, 6. *varians* has fewer mesopores than 6. *jamesi.* Arnheim and Waynesville.

14 *Tentaculites richmondensis.*
Cricoconarid mollusc. Straight, conical shell with bold transverse ridges. Waynesville through Whitewater.

15 *Lichenocrinus tuberculatus.*
Crinoid base. One of many Richmondian species, this form has many, rounded, nodose plates. (Compare with PI. IV, Fig. 17.) Waynesville through Elkhorn.

16–18 *Constellaria polystomella.*
Bryozoan. Differs from C. *florida* (PI. III, Figs. 20–21) in having more numerous ridges in the "stars" and a clearer distinction between the stars. Fig. 16 enlarged. Entire Richmondian.

19,20 *Batostomella gracilis.*
Bryozoan. (See PI. IV, Figs. 12,13.)

21 *Caurocrinus nealli.*
Crinoid. Delicate crown, showing small calyx, and long, thin arms with pinnules attached. Specimen turned slightly from upright position. Waynesville and Liberty.

22,23 *Protaraea richmondensis.*
Coral. A compound coral which grew as a crust over other objects. Each depression marks a corallite. The short septa give the margin of the corallite a crenulated appearance.

24–26 *Labechia huronensis.*
Stromatoporoid. Note sharp nodes in enlargement, Fig. 26.

(All bryozoan thin-sections enlarged; other figures natural size unless stated otherwise.)

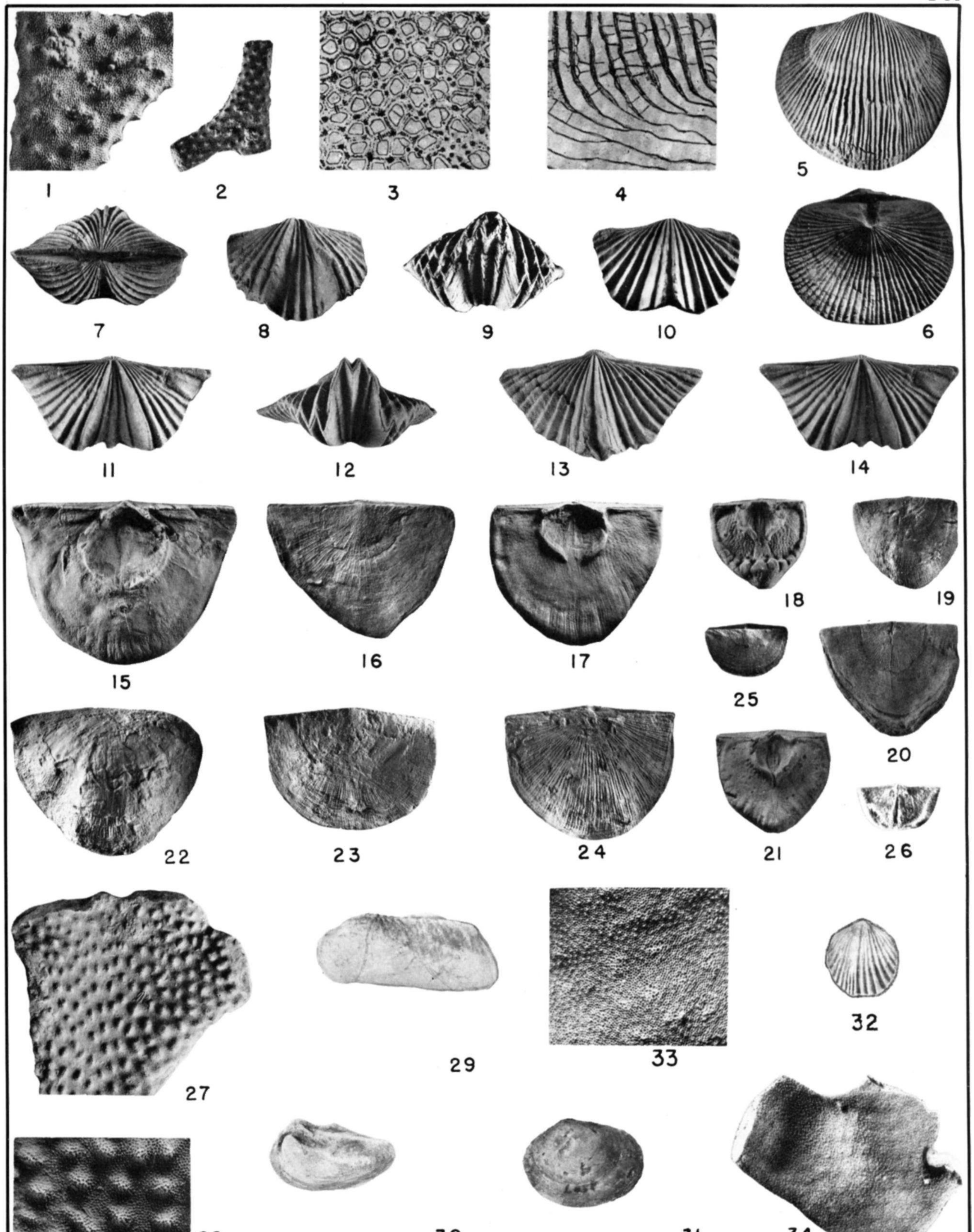
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PLATE VII

FOSSILS FOUND IN VARIOUS RICHMONDIAN FORMATIONS

1–4 *Homotrypa wortheni.*
Bryozoan. Externally resembles those *Parvohallopora* with sharp, high monticules. Fig. 1, enlarged. Fig. 3, tangental thin-section showing numerous small acanthopores and practically no mesopores. Fig. 4, longitudinal thin-section showing cystiphragms limited to the outward-curved (mature) part of the zooecia. Whitewater.

5,6 *Retrosirostra carleyi.*
Articulate brachiopod. This species is easily distinguished by the outward slant of the interarea of the pedicle valve. Limited to a thin zone in the Arnheim.

7,8,10 *Platystrophia* t *larksvillensis.*
Articulate brachiopod. Differs from other species of *Platystrophia* by having three almost equally strong plications in the median sinus, by both valves being convex almost to the outer edge, and by having only 8 or 9 plications on each side of the sulcus. Waynesville and Liberty.

9 *Platystrophia moritura.*
See Plate 8, Figures 14–17.

11–14 *Platystrophia* typha.
•\rtii ulate brat hiopod. I)iffers from othei species of *Platystrophia* by having a very strong median plication in the sulcus, by having the sides of the pedicle valve flattened and hollowed out, by having more than 9 plications on each side of the fold or sinus, and by having somewhat alate cardinal extremities. Ranges from McMillan to Liberty.

15–17 *Strophomena concordensis.*
Articulate brachiopod. For generic characters, see Pl. III, Figs. 14,15. Differs from similar species by its large size, triangular outline, delicate striations, absence of sulcus and fold, absence of conspicuous thickening of anterior margin, and muscle area on inside of pedicle valve not strongly fan-shaped nor ornamented with radial ridges. Arnheim and Waynesville.

18–21 *Strophomena nutans.*
Articulate brachiopod. Differs from similar sjx'c ies by its small size, triangular outline, delicate striations, conspicuously thickened anterior margin, small and deep muscle impression inside pedicle valve, and absence of suli tis .mil told. Waynes\ ille.

22–24 *Tetraphalvn'lla neglecta.*
Articulate brachiopod. Ditters from similar species by its medium to large size, outline not strongly triangular, delicate striations, anterior margin not strongly thickened, muscle impressions inside pedicle valve fan-shaped with radial ridges, and absence of well defined sulcus and fold. Waynesville.

25,26 *Thaerodonta clarksvillensis.*
Articulate brachiopod. Differs from *Sowerbyella rugosa* (Pl. II, Figs. 14–16) in having hinge-line denticulations and a normally smooth exterior and in being somewhat less wide, relative to length. Waynesville and Liberty.

27,28 *Homotrypa dawsoni.*
Bryozoan. Characterized by low, rounded monticules, flattened branches, and diaphragms present in immature parts of zooecia. Fig. 28, enlarged. Waynesville.

29 *Cymatonota typicalis.*
Pelecypod. Internal mold. Note straight hinge-line and lack of muscle impressions. Shell very thin, rarely seen. Waynesville.

30 *LyrrxJesma major.*
Pelecypod. Internal mold. Shell small, moderately convex. Note the prominent beak areas. Corryville and Waynesville.

31 Cyc/oconcha ***milleri.***
Pelecypod. Shell small, ovoid, compressed. The surface of the shell smooth, showing only faint growth-lines. Waynesville.

32 *Zygospira* sp.
Articulate brachiopod. Enlarged X2.

33,34 *Homotrypa ilabellaris.*
Bryozoan. Forms flat, expanded branches without monticules. Internally, this species differs from similar species by having numerous mesopores concentrated in small patches (maculae) and few diaphragms in the immature part of the zooecia. Entire Richmondian.

(Bryozoan thin-sections enlarged; other figures natural size unless stated otherwise.)

VIII

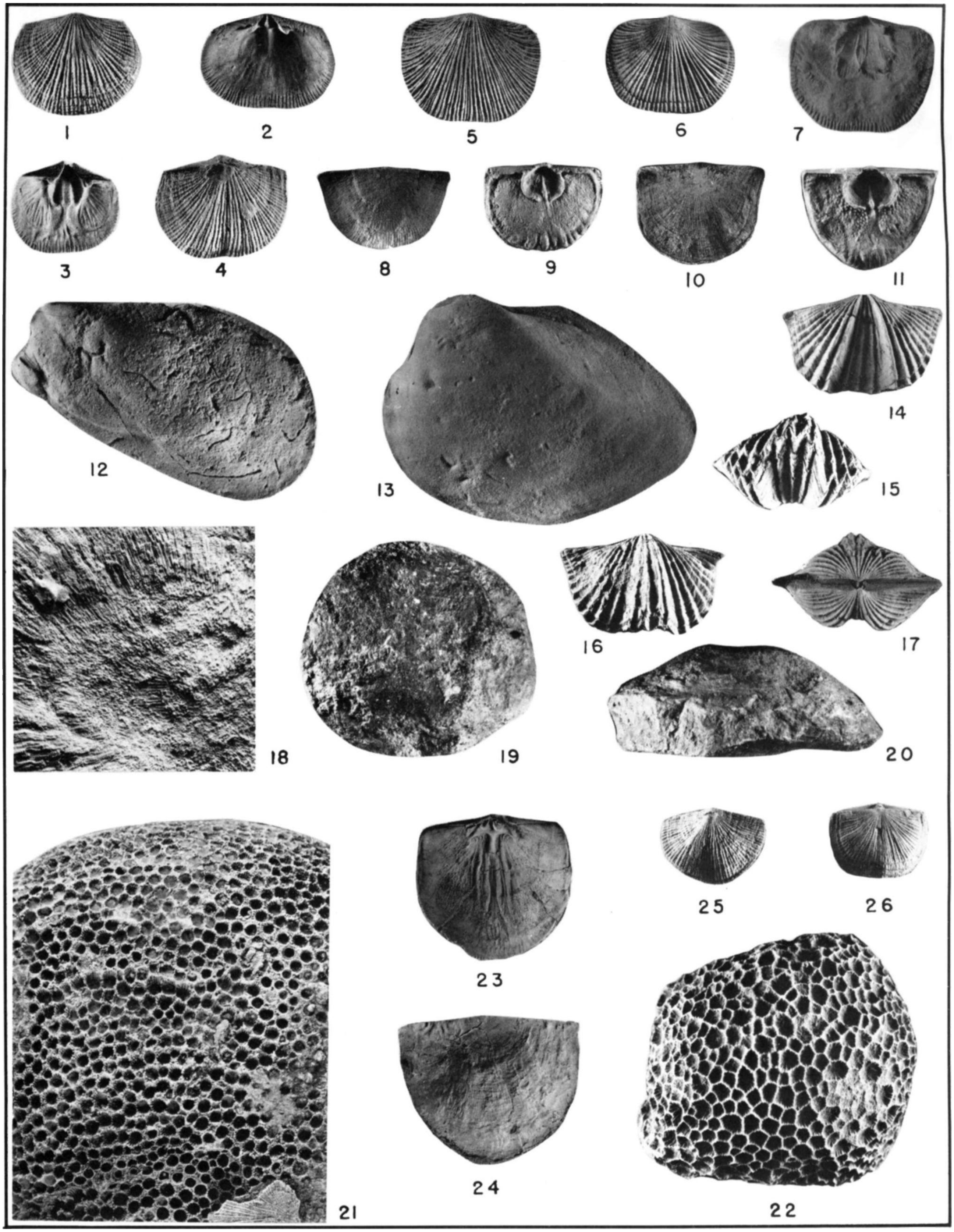

PLATE VIII
FOSSILS FOUND IN RICHMONDIAN

1–4 *Glyptorthis insculpta.*

Articulate brachiopod. Differs from similar species by the reticulate pattern produced on the surface by the intersection of the coarse radial striae and the concentric growth lines. Waynesville and basal Liberty.

5–7 *Plaesiomys subquadrata.*

Articulate brachiopod. The shape of the muscle impressions on the interior surface of the pedicle valve is characteristic of this genus and is very different from that of the externally similar genus *Glyptorthis* (compare Figs. 3 and 7). This species is distinguished by its somewhat rectangular outline and the coarse, irregularly bifurcating costae that characteristically curve near the margin of the shell. Liberty and Whitewater.

8–11 Strophomena *planumbona.*

Articulate brachiopod. Differs from similar species by having delicate striations, a relatively small size, and a rectangular form, and by lacking a fold and sulcus. Arnheim through Liberty.

12 *Ischyrodonta elongata.*

Pelecypod. Internal mold of a form that resembles *Modiolopsis,* but differs from it in the presence of a diagonal ridge that runs from the beak toward the lower margin. In an internal mold, this ridge appears as a groove. Whitewater.

13 *Crytodontula umbonata.*

Pelecypod. Identified by large size, by broad, prominent beaks, by the characteristic angle of the hinge line and by the posterior shape of the shell. Whitewater.

14–17 *Platystrophia moritura.*

Articulate brachiopod. Differs from similar species by having three equally developed plications in the sulcus, more than ten plications on each side of the fold or sulcus, medium size, and by the pedicle valve being convex almost to the outer edge and not conspicuously flattened. Elkhorn.

18–20 *Tetradium approximatum.*

Coral. Colonies form hemispherical masses of large size. Fig. 18, natural size, showing long, narrow corallites. Figs. 19 & 20, several times reduced. Entire Richmondian, especially abundant in the Saluda, upper Whitewater, and Elkhorn.

21 *Calapoecia huronensis.*

Coral. Differs from the superficially similar *Favistina* (following figure) in having the walls of each corallite perforated by rows of rather large pores that are lined up in each space between two septa. Entire Richmondian, especially in upper part.

22 *Favistina stellata.*

Coral. Walls of corallites solid. Entire Richmondian, especially in upper part.

23,24 *Strophomena vetusta.*

Articulate brachiopod. Differs from similar species by having the edge of the shell along the hinge line marked by wrinkles (Fig. 24) and by having the interior of the brachial valve marked by four parallel ridges (Fig. 23). Liberty and Whitewater.

25,26 *Holtedahlina sulcata.*

Articulate brachiopod. Differs from similar forms by the deep sulcus in the pedicle valve. Waynesville to Elkhorn.

(All figures natural size unless stated otherwise.)

INDEX TO FOSSILS

Pages numbered in **bold type** have illustrations.

COMMON NAMES AND AND HIGHERTAXA

GENERA AND SUBGENERA

SPECIES AND SUBSPECIES