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Record in Rock: A Handbook of the Invertebrate Fossils of Nebraska

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SALLY LYNNE HEALD

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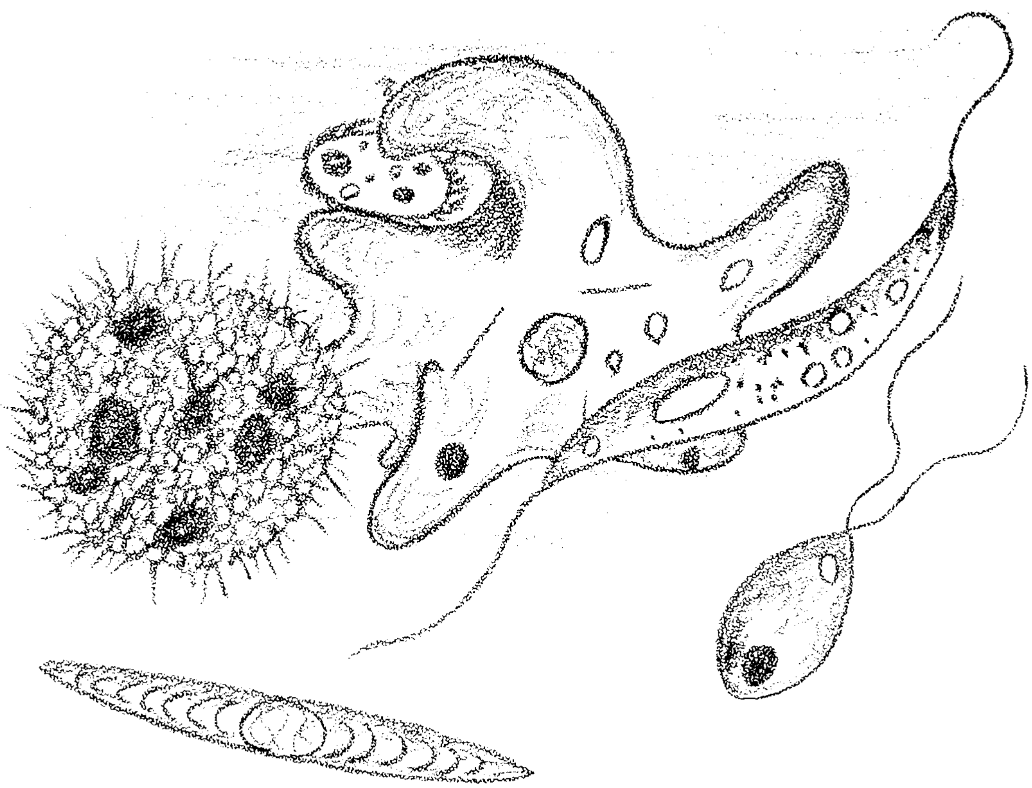
INTRODUCTION

Long before the coming of man, the earth was populated with a wide variety of plants and animals, many of which are now extinct. Over 600,000,000 years ago the seas swarmed with countless single-celled organisms which were the ancestors of more complex forms of life. Through long spans of time the trilobites, crinoids, fish, dinosaurs, and, finally, mammals dominated the earth. Their "fossil" remains provide us glimpses of the grand procession of life down the avenue of geologic time. Evidence of the various forms of life that dwelled in the area which is now Nebraska is briefly described in the following pages.



WHAT ARE FOSSILS? HOW DO THEY FORM?

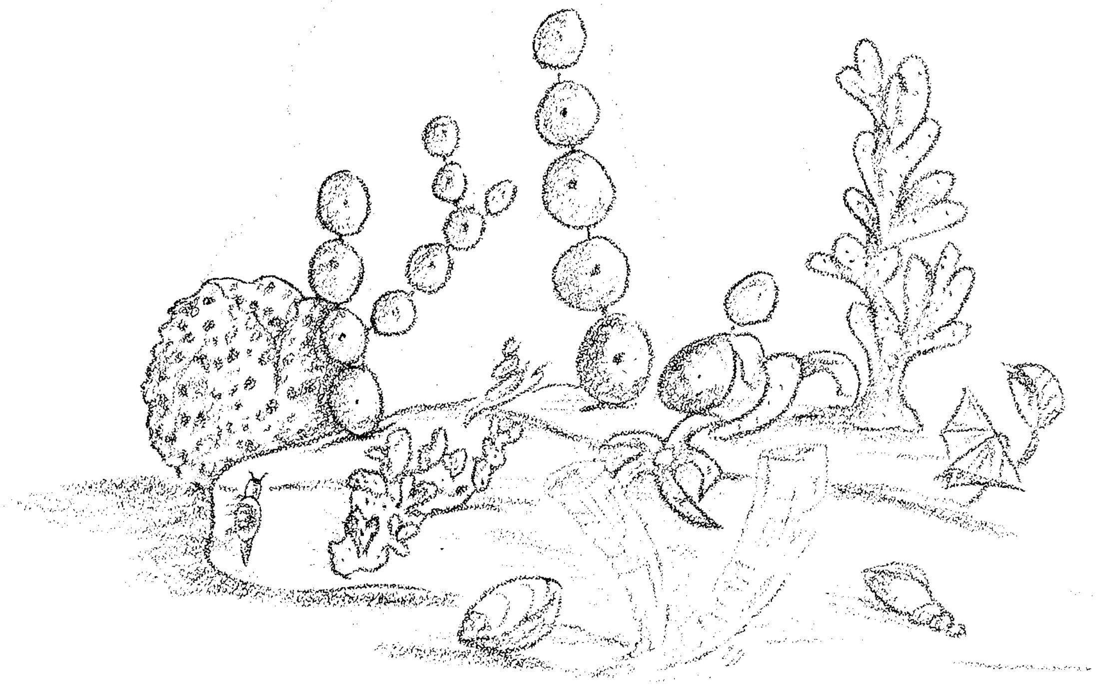
A *fossil* is evidence of prehistoric life, either plant or animal, which gives some indication of the shape, structure, or habits of an organism. Fossils reveal either *direct* or *indirect* evidence of the organism. The hard parts (for example: bones, shells, teeth, or scales) of the organism, or mineralized replacements of these parts, are direct evidence and will reveal something of the size, shape, and physical appearance of the organism. Indirect evidence includes such things as tracks, burrows, and excrement of animals, and imprints of leaves and stems of plants.

Most frequently we think of a fossil as being some part of the physical remains of a once-living organism. When a plant or animal dies, one of several things can happen to it. Usually, the organism will drop to the ground, cease to move in its underground burrow, or settle to the bottom of the sea or pond. It may then decay, returning nutrient elements to the environment, or it may be devoured by scavengers. However, when physical and chemical conditions are favorable, an organism becomes buried so quickly after its death that its hard parts remain intact. The parts of the organism may be mineralized or completely replaced by another substance, and the final product is a fossil.

FOSSILIZATION

Organisms or parts of organisms are commonly preserved (fossilized) in four general conditions: (1) with the hard parts unaltered or slightly altered, (2) with the hard parts completely remineralized, (3) as molds, or (4) as casts and steinkerns.

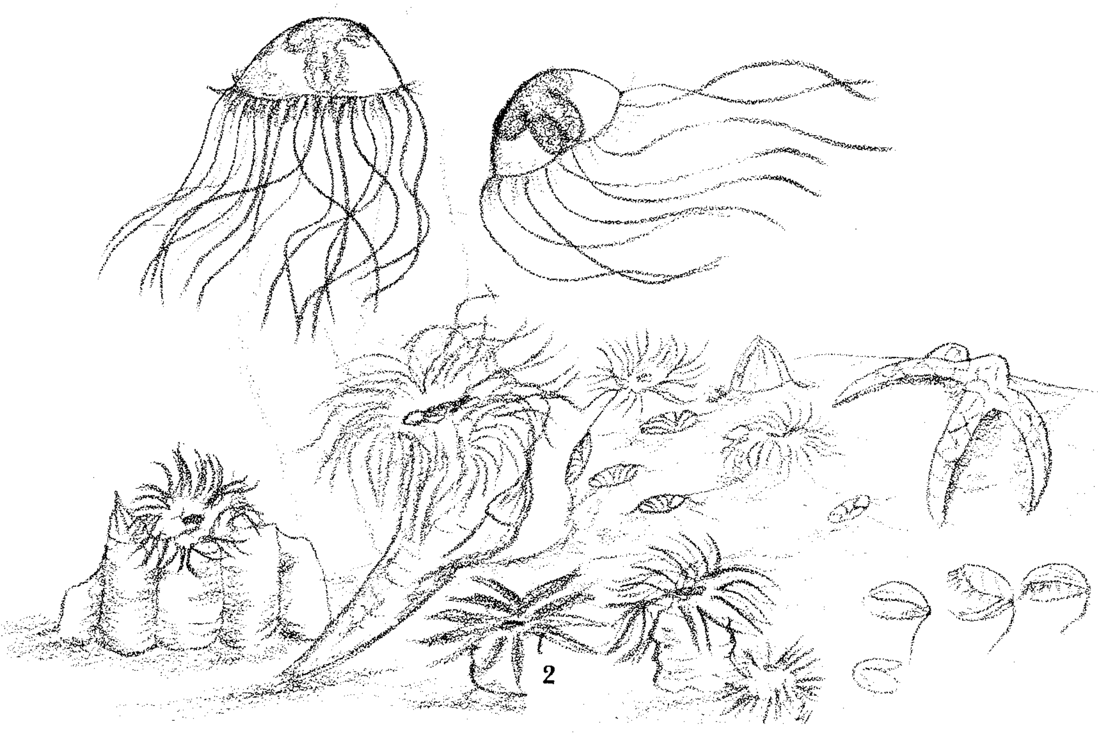
Many modern invertebrate animals have shells composed of calcium carbonate in the form of the mineral aragonite. Aragonite may remain unaltered or it may recrystallize to a more stable form of calcium carbonate, called calcite. Chitinous or cellulose skeletons, such as those of crabs, and calcium phosphate bones and teeth of fish and other vertebrate animals are frequently left intact. The resulting fossils are unaltered or slightly altered.



Remineralization of fossils occurs when original skeletal material of the organism is dissolved and the resulting void is filled by some less soluble mineral such as quartz, opal, pyrite, marcasite, or sphalerite. Pyrite fossils are commonly associated with black shales. Limestones contain fossils that are either infiltrated with calcium carbonate or are replaced with silica.

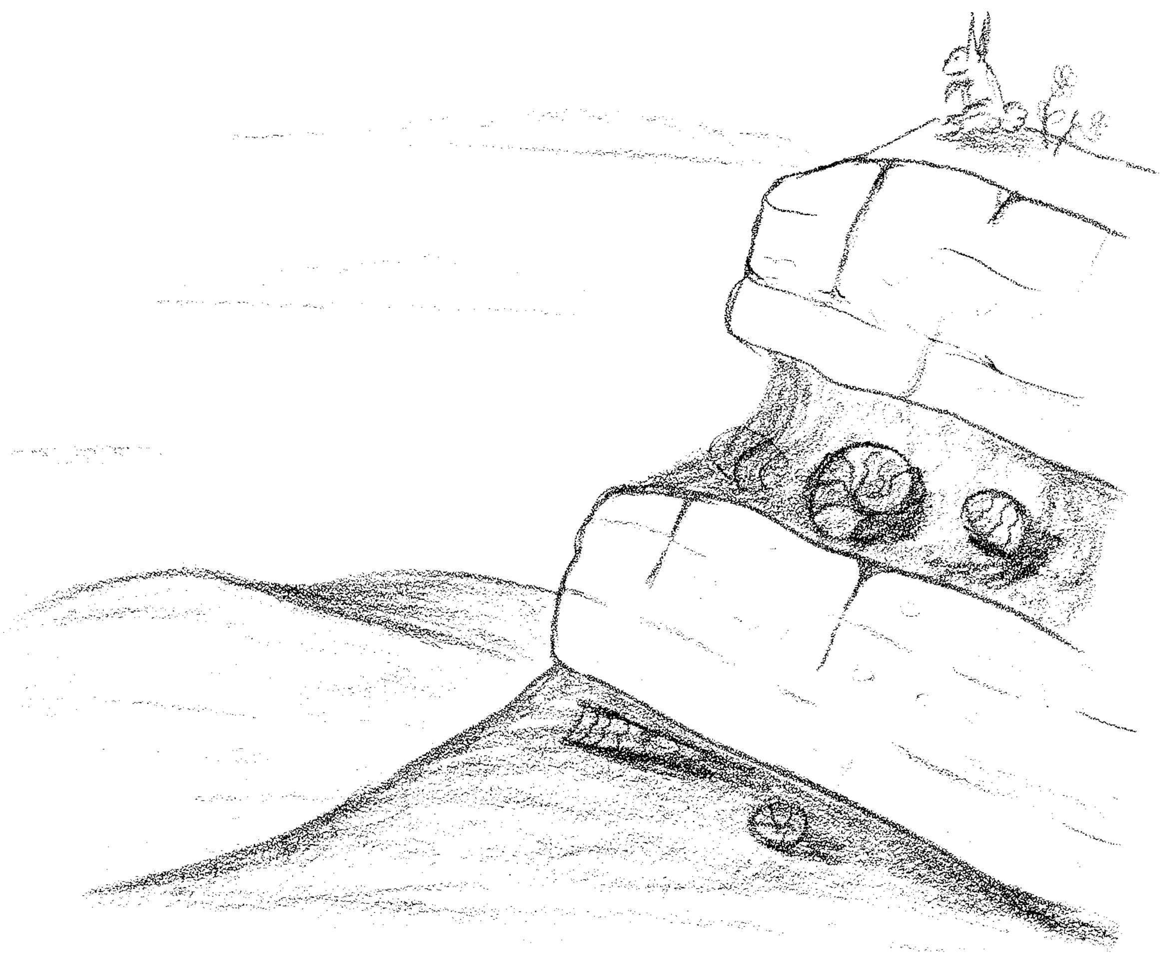
Occasionally, the buried hard parts of an organism are dissolved by groundwater, or the impression of a soft-bodied organism is made and left intact in soft sediments. These processes form cavities, containing the shape of the organism, and are called *molds*. A *cast* results if a mineral or a clay is deposited in the void, or mold, left by the organism. If the cast is of only the internal part of the shell, a *steinkern* results. Steinkerns can rarely be identified with certainty.

Fossils are extremely abundant but represent only a small percentage of the organisms that have lived on this planet. For every fossil we see embedded in rock, many thousands of plants and animals were destroyed before their burial, or altered beyond recognition after their burial. Ocean currents have washed away many of the smaller shells, leaving a concentration of large shells in one spot and depositing a concentration of small ones in another. Many animals had no hard parts such as bones or shells to be preserved. Nevertheless, through careful collecting of fossils and interpretation of their relationships, it is possible to reconstruct the changes in life that have taken place on the land and in the sea and air.



HOW ARE FOSSILIFEROUS ROCKS FORMED?

The rocks in which fossils are found were formed in several ways. At one time, rocks may have been the sediment of a shallow sea bottom, the sand of an ancient beach, the silty floor of a dried-up lake, the muddy bottom of a sluggish river, or dust and sand laid down by wind. As time passed, layers of sand, silt, clay, and lime were deposited, one upon the other. Winds laid down dunes of sand and hills of loess. Compaction forced water and air from these sediments and the sediment particles were closely squeezed together; often a cementing substance, such as lime, silica, or limonite, was added. The result of these geological processes was layered, sedimentary rock—limestone, shale, siltstone—and in these rocks are housed the remains of the animals which lived and died while the rocks were being formed.



WHAT IS PALEONTOLOGY?

Paleontology is the study of fossils in order to determine the origin and historical development of life on earth. Paleontology has several branches, each concentrating upon a different form of ancient life. *Invertebrate Paleontology* is the study of fossil animals which have no backbones, while *Vertebrate Paleontology* studies animals having backbones. *Paleobotany* is the study of fossil plants, and *Palynology* the study of fossil pollen. This paper will discuss mainly the fossil invertebrates, although a few comments about fish and plant fossils that are often associated with invertebrates are included.

WHAT CAN FOSSILS TELL US?

Collecting fossils is an enjoyable pastime whether one does it for a livelihood or merely as a hobby. Each collecting trip can be looked upon as a visit to an ancient beach, a diving expedition to the bottom of a former inland sea, or a walk along the banks of a once-flowing river. It is hoped that this book will help to identify some of these former landscapes. Although this report is designed for students, it may also be of value to amateur collectors or *rock hounds.*

The earth is several billion years old. Although the fossil record of the first 90 percent of the earth's history is scant, well-preserved fossils of the last 10 percent are quite common. Study of these fossils has given us some idea of the development of life on earth, as well as knowledge of the changes that have taken place in our own area. A stop at an abandoned quarry or a roadcut may give us a glimpse of this past history. For example, roadcuts in the loess bluffs of Nance County yield fossil air-breathing snails, whereas quarries in

Cass County produce fossil marine snails, while rock exposures in Frontier County contain fossil fresh-water snails. Thus, we have examples of several of many different periods of the geologic past. To interpret this history, we must be able to read the story fossils can tell.

FOSSILS AND GEOLOGIC TIME

William Smith, an 18th and 19th Century English canal builder and engineer, discovered that rocks of like age contain similar assemblages of fossils. He observed that the same fossil species occurred in rocks at varied localities. A geologist may wish to know if rocks in Cass County are the same age as those in Pawnee County. Similar fossil assemblages from rocks in both areas would indicate that the rocks in question are of the same age. By the process of matching similar assemblages of fossils, one method of correlation of rock strata is accomplished.

Fossils form the basis for the geologic time scale, or geologic time column, illustrated in Figure 1. Recognition of every geological period, from Cambrian through Recent, is based, in part, upon a study of the assemblages of fossil organisms preserved in the rocks. We know that different groups of organisms lived at different times during the earth's history. When we learn to identify the various fossil organisms, we are then able to recognize the geologic period from which they came.

Rocks of all geologic periods are seldom exposed together in one place. Figure 2 shows a condensed time-life chart based on the rocks which are exposed in Nebraska.

In Nebraska, only Pennsylvanian, Permian, Cretaceous, Tertiary, and Pleistocene rocks are exposed at the surface. Their distribution at the surface as possible outcrop areas is shown by Figure 3, a geologic bedrock map of Nebraska. The Pennsylvanian, Permian, and Cretaceous rocks are often covered by Pleistocene glacial deposits and wind-deposited loess or dune sand. In much of Nebraska, especially in the central and eastern parts, exposures of rock are restricted to deeply incised stream valleys or to man-made exposures, as seen in quarries and roadcuts.

The oldest fossils that can be collected from the surface in Nebraska are found in shales, sandstones, and limestones of middle Pennslyvanian age. Generally, these are the remains of marine invertebrates and, sometimes, of a few fishes and sharks. Unfamiliar or extinct forms, such as protozoans, sponges, corals, ectoprocts, clams, snails, trilobites, and echinoderms are found in the Pennsylvanian rocks. Some of these fossils are abundant but others are very rarely found.

Many of the fossils found in the Permian rocks of Nebraska are similar to those in the Pennsylvanian rocks. However, a few new species have been introduced and some of the older ones have become extinct. Corals and echinoderms are scarce in Permian rocks, while clams and snails are more numerous.

Cretaceous rocks contain fossils much different from those found in the Pennsylvanian and Permian rocks. Protozoans, ectoprocts, clams, ammonites, and belemnites are very common, whereas sponges, corals, brachiopods, snails, and echinoderms have not yet been found in the Cretaceous of Nebraska. Cretaceous rocks are exposed in northeastern, northwestern, and south-central Nebraska.

The Tertairy and Pleistocene fossils are completely different from the earlier ones. The Tertiary and Pleistocene fossil record consists chiefly of terrestrial vertebrates and fresh-water clams and snails; marine organisms are absent. Roots of yucca and grasses and grains of grasses and seeds of trees are fossils commonly found in these younger rocks.

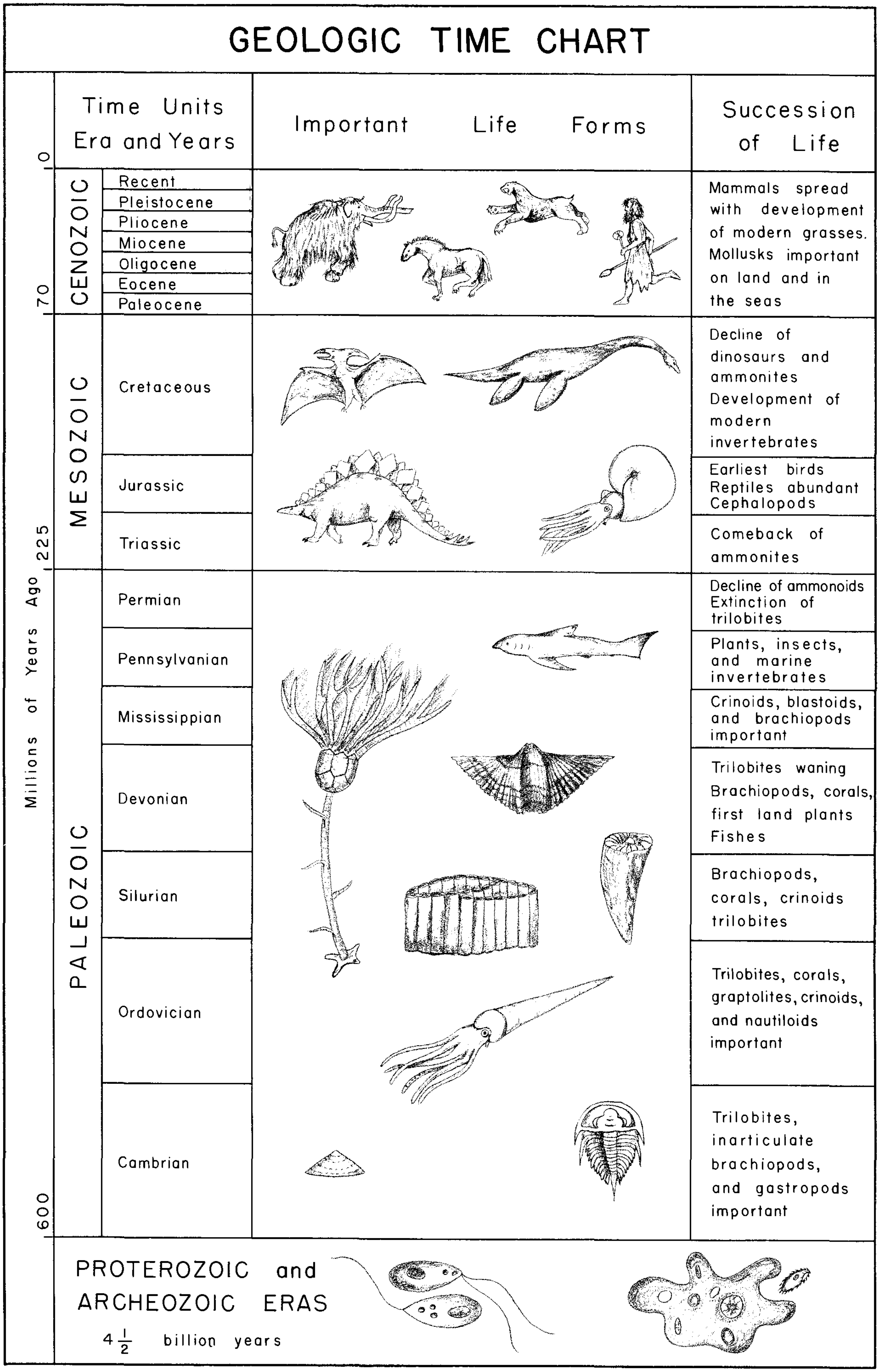


FIGURE 1. Standard Geologic Time Column.

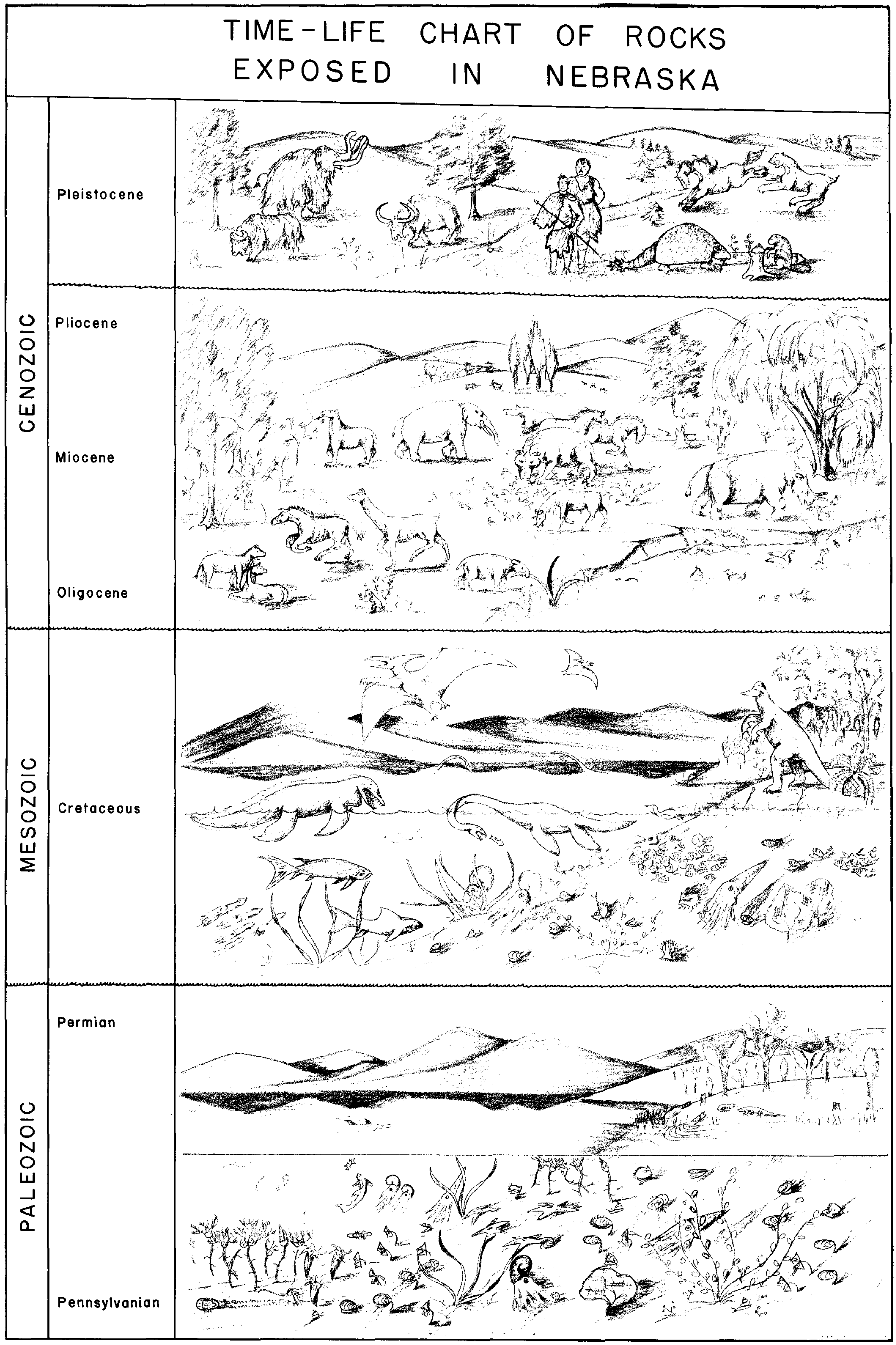


FIGURE 2. A time-life chart of rocks exposed in Nebraska depicting the important life forms of each geological period.

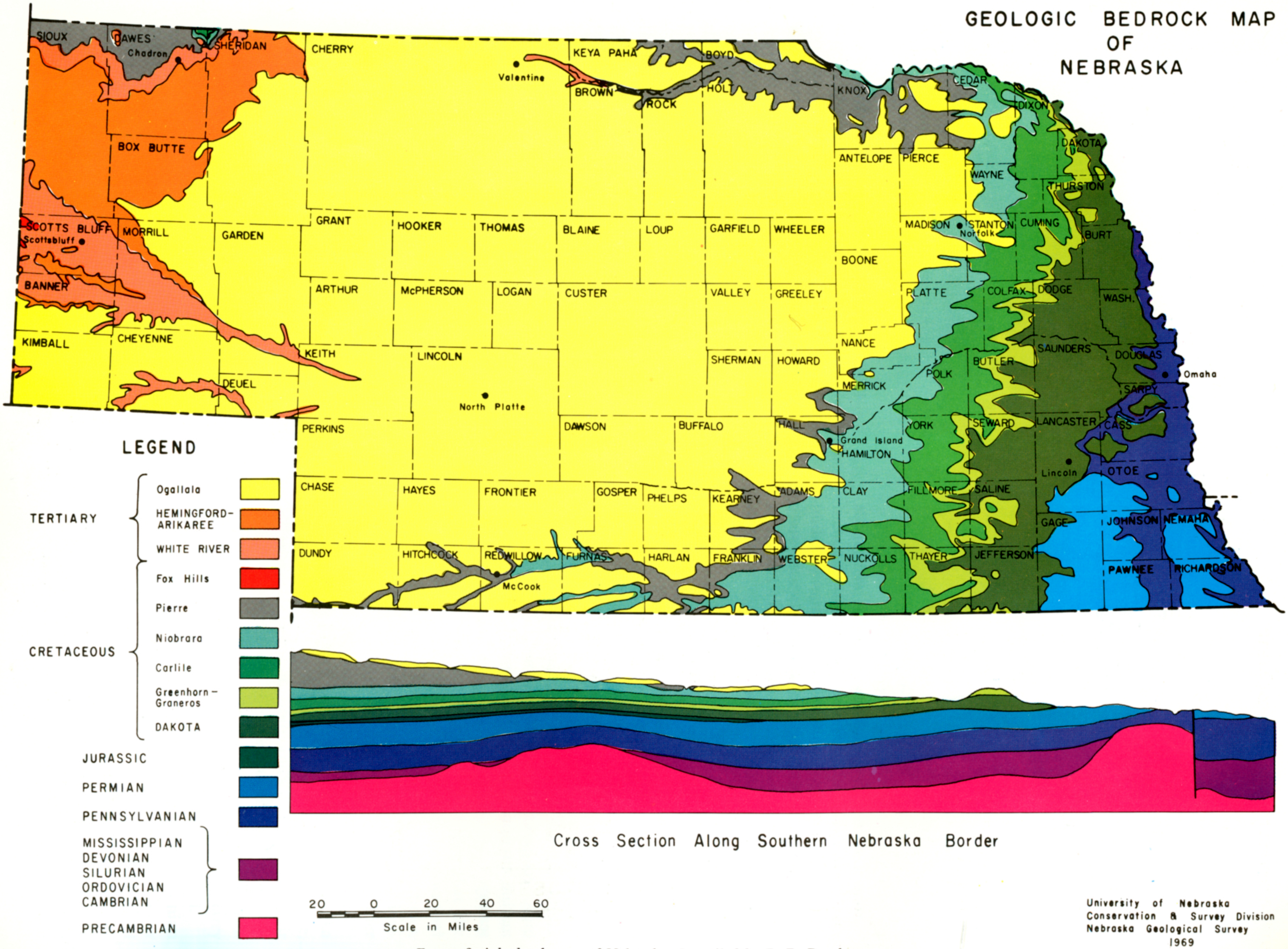


FIGURE 3. A bedrock map of Nebraska. Compiled by R. R. Burchett.

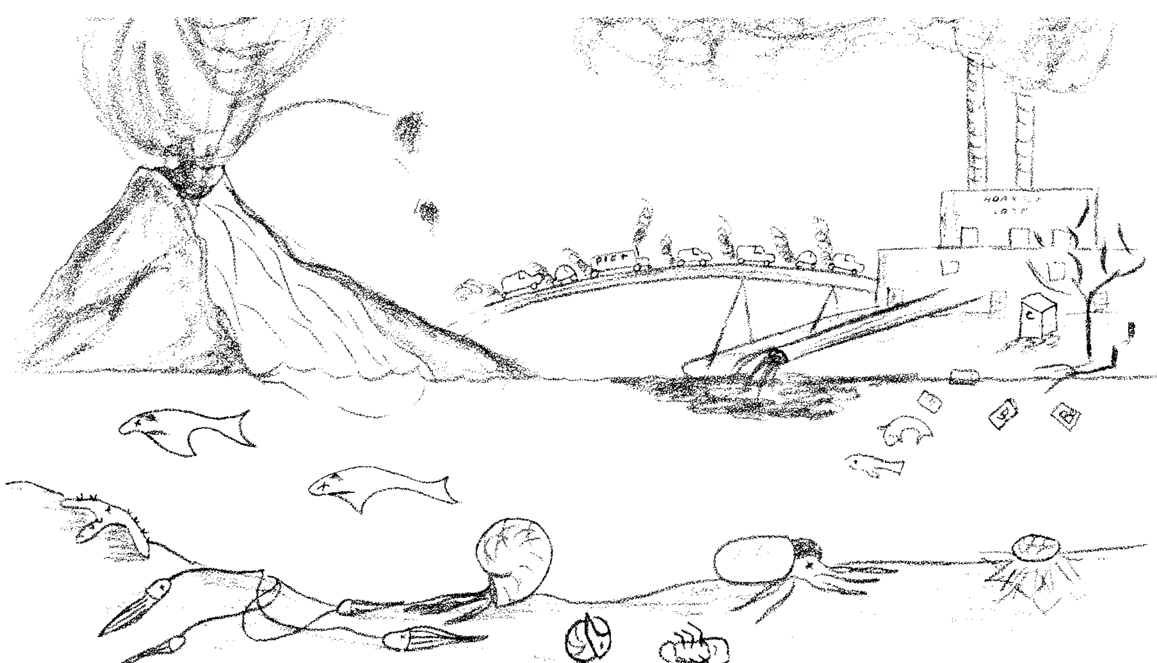
Some fossils were formed by worms or arthropods that burrowed through the soft muds on the ocean floor or through ancient soils in their never-ending search for food. Although these animals are rarely found, their burrows or trails are indirect indicators of life and are considered to be fossils.

FOSSILS AS ENVIRONMENTAL INDICATORS

Fossils are useful in *Paleogeography,* the science of determining the boundaries of such features as ancient continents and seaways. Insects and plants generally live in a fresh-water or terrestrial environment rather than in a marine environment. Their fossil remains would indicate an ancient lake or land mass. Trilobites, ectoprocts, and echinoderms indicate a true marine environment and the presence of an ancient seaway.

Fossils play an important role in *Paleoclimatology,* the science of determining ancient climates. Water temperatures below 70 degrees Fahrenheit are not favorable to modern reef corals; thus, the presence of corals in Nebraska rock strata may possibly indicate that temperatures of ancient seas were quite warm. The presence of cold-climate snails in Pleistocene deposits of east-central and southwestern Nebraska tells of the great ice sheets that were present in adjacent areas.

Fossils provide evidence of the increasing biological complexity in both plants and animals since the beginning of life on earth. These changes in organisms can be viewed on a large scale—e.g., as vertebrates evolving from invertebrates—or as a series of small changes in a particular group of animals—e.g., ancestral crinoids developing into several different descendant crinoid families.



FOSSILS AND CONSERVATION

What do fossils have to do with conservation? Today we are faced with problems of air and water pollution from both civil and industrial waste. Our environments are becoming contaminated. Contamination, however, is not a new hazard. The fossil record contains ample evidence of environments that became polluted and unsuitable for all forms of life. Black shales indicate waters that became polluted because of a lack of circulation of water and oxygen. Volcanic eruptions have always released fine particles of glass and poisonous gasses, resulting in pollution of both air and water. Contamination of environments by slow, natural processes was tragic for many forms of life in the distant past. It is not difficult to imagine what rapid contamination of environments by civil and industrial waste will do to modern forms of life.

HOW ARE FOSSILS NAMED?

To add order to the identification and study of living or fossil plants and animals, it is essential that all forms be classified. The science of classification of living and fossil organisms is known as *taxonomy* and each taxonomic category is known as a *taxon* (plural *taxa*). Plants and animals are divided into taxa called *kingdoms*. Each kingdom is subdivided into progressively smaller taxa. The fundamental unit is the *species*.

A species is a group of closely related, interbreeding individuals possessing one or more features which distinguish it from all other species. The definition of a living species, and of most fossil species, takes into account individual differences.

To illustrate the higher units of taxonomy, the classification of the fossil species *Graffhamicrinus stullensis* Strimple and the man John Doe are given below:

Kingdom	Animalia	Animalia
Phylum	Echinodermata	Chordata
Class	Crinoidea	Mammalia
Subclass	Inadunata	
Order	Cladoidea	Primate
Family	Erisocrinidae	Hominidae
Genus	*Graffhamicrinus*	*Homo*
Species	*stullensis*	*sapiens*
Individual	UNSM-52799*	John Doe

*Obviously, a fossil has no proper name. This individual is a particular specimen in the University of Nebraska State Museum collections.

A group of closely related species forms a *genus* and closely related *genera* constitute a *family*. Similar families form *orders* and similar orders compose *classes*, which are grouped into *phyla*. Under this system, each species, whether living or extinct, is known by its italicized generic and specific name. The first letter of the generic name is always capitalized, whereas the first letter of the specific name is lowercased. The proper name following a specific name is that of the person who first described the species.

Many scientific names describe a particular characteristic of an animal. For example, the familiar Nebraska brachiopods *Composita elongata* Dunbar and Condra and *Composita ovata* Mather are, respectively, long and tear-drop-shaped, and stubby and fat.

Some generic names are applied to honor a certain geologist, paleontologist, or biological scientist. *Graffhamicrinus nodosus* Strimple, a Pennsylvanian crinoid with nodes on its plates, was named for Mr. Graffham by Mr. Strimple; *Derbya benetti* Hall and Clarke, a Pennsylvanian brachiopod, was named for Mr. Bennett by Messrs. Hall and Clarke.

Often a fossil is named for the locality at which it is first found. The crinoid genera *Nebraskacrinus, Oklahomacrinus*, and *Texacrinus* were named for the states in which they were first discovered. The brachiopod species *Juresania nebrascensis* Owen is named for Nebraska and the crinoid *Paradelocrinus iolaensis* Strimple is named for Iola, Kansas.

Scientific names may appear clumsy and hard to pronounce but such a system enables scientists, even those of different nationalities, to communicate their findings to one another more easily and clearly. Common names change from place to place but scientific names are almost universal. Also, there are many more species than could ever be described with common names.

WHERE ARE FOSSILS FOUND?

Fossils are found wherever there are exposures, either natural or man-made, of fossil-bearing strata. Some rocks, such as limestones and gray shales, commonly are very rich in fossils while other rocks, such as red and green shales and some sandstones, are almost devoid of fossils.

Abandoned rock quarries, building-material locations, road cuts, and natural exposures along streams are usually good sites for fossil collecting. Piles of shales which have weathered to the degree that the small particles such as silts and clays have been washed out or blown away have residues of large particles, many of which are fossils, on the upper surface. Limestone slabs which have been exposed to the weather may also have residual fossils on the upper surfaces.

Some of the better collecting localities in Nebraska are located along the major rivers—the Missouri, Platte, Niobrara, Republican, Blue, and Nemaha, and their tributaries. Because of the downcutting action of these streams, there is little overburden or cover on the bedrock. Many exposures have been created by quarry operations and highway and railroad construction.

Many well-known collecting sites for Pennsylvanian marine fossils are in quarries and roadcuts which occur on either side of the Platte River valley from Ashland to Plattsmouth and along the Missouri River valley from Fort Calhoun to the vicinity of Nebraska City. Collectors come from far and wide to obtain specimens from these areas and many fossils have been described from these outcrops.

Good exposures of Pennsylvanian and Permian rocks are found along the valley of the North Fork of the Nemaha River and its tributaries at Tecumseh, Elk Creek, Table Rock, and Humboldt. Many well-preserved fossils can be found in this area.

Permian rocks are exposed along Salt Creek valley near Roca and the Little Nemaha River near Bennet, Palmyra, Douglas, and Burr. Permian limestone is quarried at Douglas.

Road cuts with fossiliferous Pennsylvanian and Permian rocks are exposed near Unadilla, Salem, Du Bois, Humboldt, Gretna, Louisville, Cedar Creek, and Papillion.

Cretaceous rocks are exposed along the Niobrara River eastward from approximately the eastern border of Cherry County to the Missouri River, and southeastward down the Missouri River to near Blair. Some of these exposures contain fossiliferous strata.

Cretaceous rocks are also exposed along the entire length of the Republican River valley and many fossiliferous exposures can be found in this area. Both Permian and Cretaceous rocks are exposed along the Big Blue River and Cretaceous rocks are found along the Little Blue River.

Cretaceous and Tertiary rocks are well-exposed in the Chadron Dome area north of Hay Springs and Chadron.

Tertiary (Oligocene and Miocene) rocks are exposed in the northwestern panhandle along the Pine Ridge escarpment. Pliocene rocks are exposed along the North Platte valley from the Wyoming-Nebraska border eastward to Lake McConaughy, and also along the Lodgepole Creek valley and the South Platte River valley from the Colorado-Nebraska border eastward to Sutherland.

COLLECTING COURTESY

If one plans to collect fossils on private property, it is necessary to obtain permission from the land owner or quarry operator. This creates a feeling of good will and collecting is much more enjoyable if one feels welcome.

There are several rules which must be obeyed, once permission to collect is obtained. *Leave the gates as found*; opened gates are to be left opened—closed gates are to be left closed. *Never cut wires* to get through a fence. *Never litter the area* with lunch sacks, paper wrappers, or beverage containers. Not only is this litter unsightly but it creates a feeling of ill will on behalf of the property owner; furthermore, broken bottles or rusted metal cans create a hazard to livestock and to future collectors. *Never molest animals*, either wild or domestic ones. Do not take the family dog on collecting trips; if he must come along, leave him in the car. Your amiable pet can become a vicious killer of livestock or poultry. *Be sure to thank the owner*. Show the owner some of the things that have been collected, to satisfy his natural curiosity about what you are seeking.

TOOLS FOR COLLECTING FOSSILS

Proper tools are essential to effective fossil collecting; without them, a trip to even the most productive sites may be fruitless.

A geologist's rock hammer, shown in Figure 4, is a must. A brick mason's hammer or a light sledge may also be used. Suitable hammers may be obtained from hardware stores, rock shops, or scientific supply houses. A carpenter's hammer is made from a much softer metal than a rock hammer and may be unsafe. When collecting in quarries or pits, hammers with wood

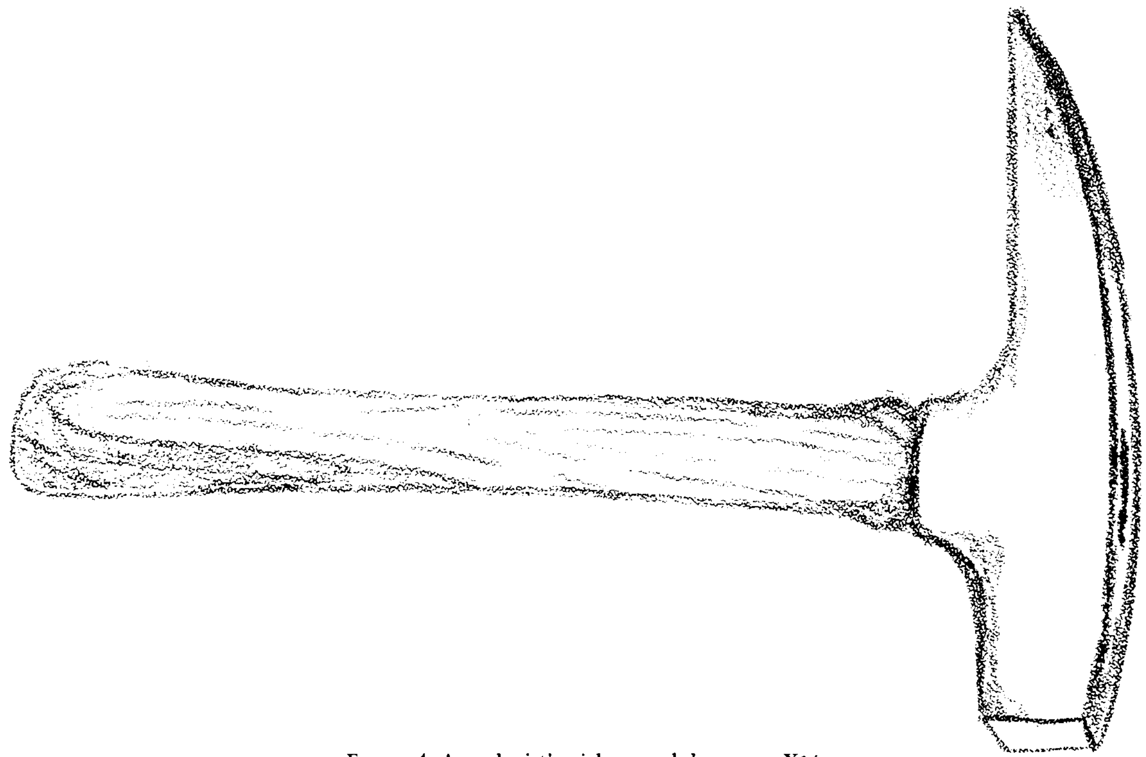


FIGURE 4. A geologist's pick or rock hammer, X½.

handles are preferable. If a hammer with a metal handle is lost and eventually runs through some machinery, a great deal of damage results. Wood-handled hammers are usually rejected by the machinery's safety devices.

Cold chisels are much better than ripping chisels for cutting rock. Several chisels, each a different size, are essential tools. They should be kept well dressed and sharp by removing the burr which hammering causes to be formed on the end of the chisel (Fig. 5).

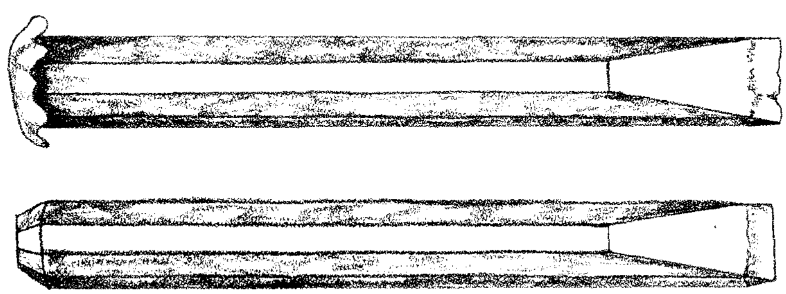


FIGURE 5. A dull, poorly-dressed, unsafe chisel (above) compared to a sharp, well-dressed, safe chisel (below).

If the burr is not removed, it may fly off when struck with a hammer and cause serious injury. A flying burr has almost the mass and velocity of a 22-caliber slug and can deeply penetrate the flesh. A dull chisel cuts slowly and is unlikely to stay in the groove, with the result that such instability may cause the chisel to slip and damage the fossil.

If the collecting site is an active rock quarry or gravel pit, it is absolutely necessary that hammers, chisels, and other metal tools be accounted for at all times. These tools can cause considerable damage to quarry machinery if they should happen to become lodged in it. Tools not in use should be kept in their containers and out of the way of machinery. Paint the handles of your tools yellow or orange to make them readily visible.

A knapsack is useful for carrying both tools and specimens. Moreover, it leaves both hands free when moving about on a rock exposure, thus allowing for better balance and easier collecting.

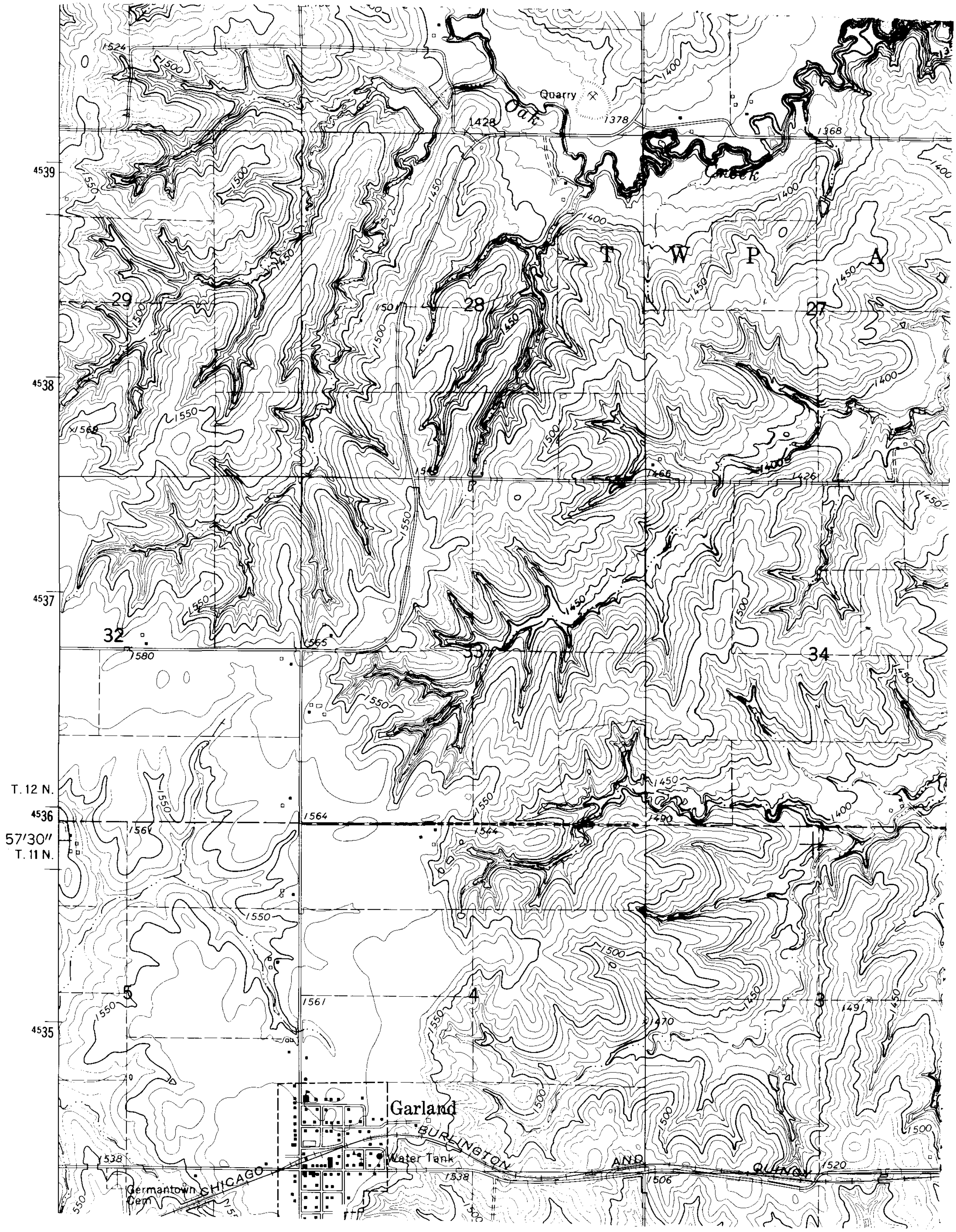


FIGURE 6. A section of a topographic map (Garland, Nebraska, Quadrangle) showing elevations, drainage, vegetation, roads, and other man-made structures.

Tissue, paper towels, and newspapers are useful for wrapping fossils. Tissue is best for wrapping small or fragile specimens. Newspapers are more suitable for wrapping large specimens. Papers should not be allowed to scatter over the collecting area; such litter is unsightly and offensive to property owners.

A small magnifying glass is useful but not absolutely essential. Because rock particles are likely to damage the lens, an inexpensive, second-quality glass is better for field use than an expensive one. Furthermore, tools are easily lost in the field, and it is much cheaper, obviously, to replace a low-priced tool. For more detailed study of fossils, an expensive, first-quality glass is much better for observing minute characteristics.

Pencil and paper are essential for recording information as to where, when, and how each fossil was collected. Such information should be placed with each specimen. Fossils lose much of their value if appropriate identification is not available.

Small boxes and sacks are useful as containers for small specimens. Small boxes can be obtained from gift shops, stationery counters in department stores, drug stores, rock shops, or from any of the established scientific supply houses.

Maps are useful not only for locating oneself in the field but also for recording collecting sites. Excellent topographic maps of Nebraska are available from either the Nebraska or United States Geological Surveys (Fig. 6). Many quarries and outcrops are shown on these maps and thus the user has a few locations "given" to him. The topographic maps present a detailed picture of the landscape by means of brown contour lines. Water is denoted in blue and roads in red. Some maps also show stands of trees in green, and man-made structures such as farm houses, churches, and schools in black. County maps are available from the State Department of Roads; the scale ¼ inch = 1 mile is satisfactory for most purposes. These maps show roads, drainage courses, water bodies, man-made structures, and building-material locations.

TIPS ON COLLECTING FOSSILS

When collecting on gently sloping or flat rock surfaces, it is wise to sit or kneel. Knee pads help relieve the discomfort of kneeling. Small areas should be examined carefully with eyes about 16 inches from the surface. As many of the invertebrates are small—less than 1 inch in diameter—they are likely to be overlooked if viewed from a standing position. Good finds that more casual collectors have passed up may be yours by being careful.

Fossils generally are more clearly visible if the rock surface is wet. Thus, it is most profitable to collect during or right after a rain. If, however, the rock surface is dry, it can be wetted easily by using an insect spray gun loaded with water. As water is used up quickly, an ample supply should be taken on expeditions during dry weather.

If the fossil being collected is imbedded in rock, it generally can be cut out by using a hammer and chisel. First, an adhesive bandage should be placed over the fossil; then a trough a little deeper than the fossil should be cut around it, as shown in Figure 7. Striking at the base of the pillar thus formed, in the direction of the fossil, will dislodge the specimen.

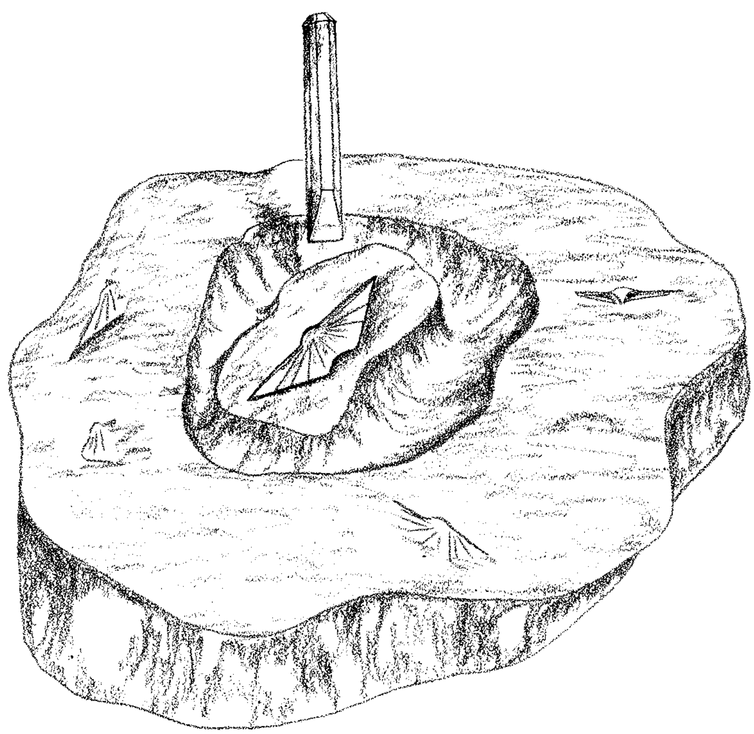


FIGURE 7. The correct procedure for cutting a fossil from a block of hard rock.

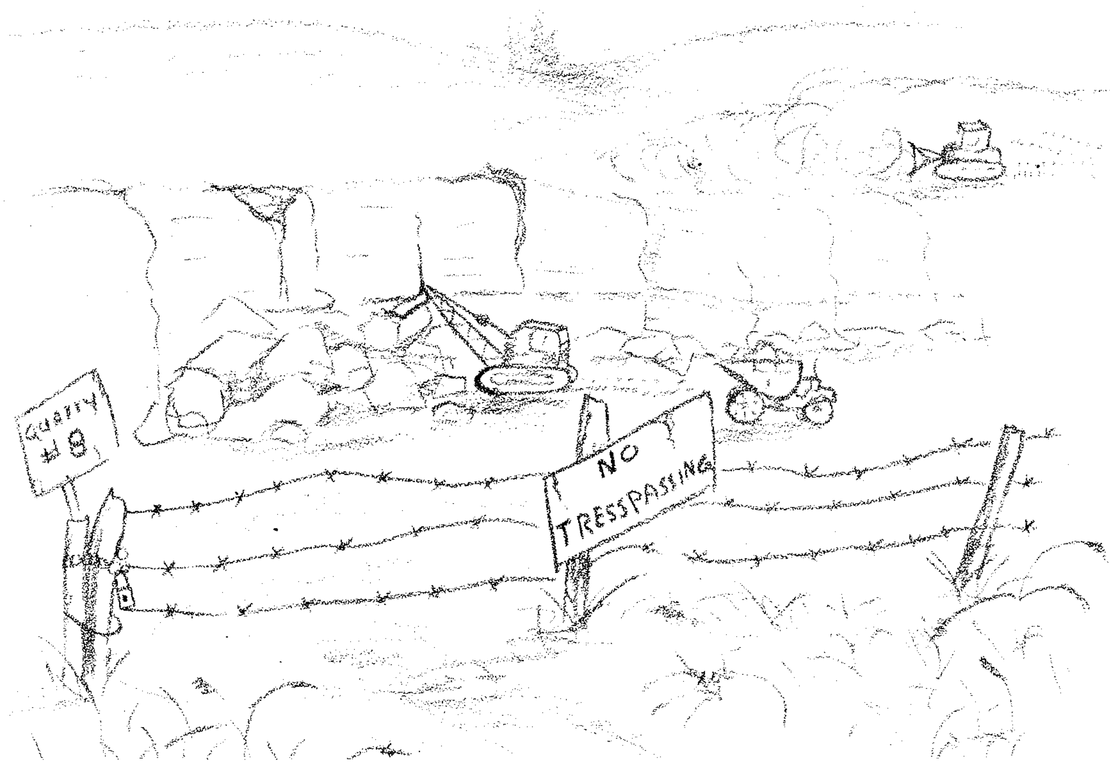
SAFETY RULES

No collecting guide is complete without a few pointers on safety. Serious accidents not only ruin the fun of a field trip but may result in lifelong crippling of the victim, and may lead to good collecting localities being closed to later collectors.

QUARRY SAFETY

1. *Always obtain permission to collect.* Even if the quarry operator says you may enter his property without first visiting him, be sure to let him know you are on the premises. It is to your advantage that the quarry people know where you will be so they will not "shoot" (detonate explosives) and will be on the lookout for you when dumping overburden from large trucks.
2. *Never pull loose wires you may find in rock quarries.* These may be connected to explosives which did not go off during the regular blasting operations. The friction resulting from pulling a wire may generate sufficient heat to detonate the charge. Hapless collectors have lost life and limb from this type of accident.
3. *Never climb on the rock faces in a quarry.* The fossils you need will almost always be on the dump piles. This is where you are expected to be. If rock faces have been severely shattered by blasting, kicking loose a key stone may bring several tons of rock down on the members of the collecting party. Digging fossils from the face of the quarry should be done only by mature, experienced collectors.
4. *Never swim in quarries.* Although the water holes are inviting, the water is usually quite deep and abrupt dropoffs are not uncommon. The water in rock quarries often has fewer dissolved solids and considerably less buoyancy than waters in swimming pools. Sometimes the water is acidic and may cause serious skin or eye irritations. Therefore, this rule also applies to accomplished swimmers. Also, do not fish without the quarry operator's permission as the water holes may have been stocked privately.
5. *Keep off the machinery.*

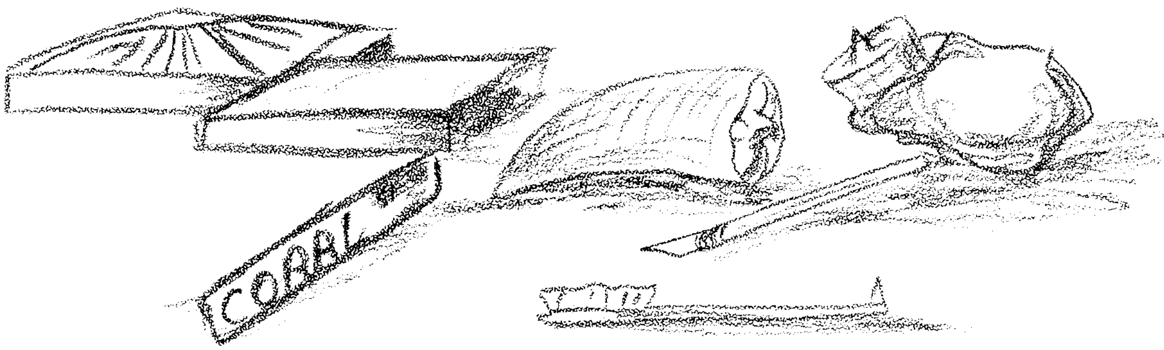
Remember that violation of any of the above rules may lead to the localities being closed to you and other collectors.



SAFETY DON'TS TO REMEMBER!

1. Don't climb to any place from which getting down will be hazardous. Ordinarily, it is much easier to climb than to descend.
2. Don't go alone. If you *must* go alone, however, notify someone where you are going and when you expect to return.
3. Don't neglect your tools—keep them clean, dressed, and sharp.
4. Don't throw tools—someone may happen to be within hitting range.
5. Don't neglect to wear plastic safety goggles when hammering on rocks or chisels.
6. Don't forget to wear a hard hat.*

*The Federal Mine-Safety Act now requires that hard hats, safety shoes, and safety goggles must be used in quarries that have Federal contracts. This law also applies to visiting collectors. Many Nebraska quarries and pits fall under this Act.



PREPARATION OF SPECIMENS

Fossils are rarely found in the clean condition in which they are displayed in museums. To prepare a fossil for display, all dirt and excess matrix (rock containing the fossil) must be removed.

If a fossil occurs in a water-soluble matrix, it may need only to be washed and scrubbed gently with a soft-bristled brush. Removal of harder matrix may require use of a scouring agent, such as a household cleanser, or a brush with brass bristles, of the type used for cleaning suede shoes.

Hard or insoluble matrix generally can be cut away with a hobbyist's knife, obtainable at any hobby store, or with some other type of sharp, stiff-bladed tool. A small hone is needed to keep the tools sharp; dull tools cut slowly and may damage the fossil. Excess material should be *scraped* away from the fossil; gouging with a tool is likely to damage the fossil and/or injure the preparator.

Acid should not be used to clean fossils, as most of them are acid soluble.

A BIT OF ADVICE

Above all, don't become discouraged if your first field trip does not yield an abundance of fossils. Each geologic setting requires a special "bag of tricks" to find fossils, as the following professional advice points out:

> "In 1943 I was sent into northeastern Colombia to study the marine Cretaceous of the region. From previous reconnaissance by others it was known that ammonites were abundant in some of the limestones and shales. It was nearly two weeks before I recognized my first ammonites even though I was searching for them. I then found that I had been overlooking them (sometimes in beds where they were abundant) because I had not previously learned how to recognize them in rock (my previous experience had all been with specimens in the laboratory)."
> —From J. Wyatt Durham, Presidential address to the Paleontological Society: "The incompleteness of our knowledge of the fossil record;" published in Journal of Paleontology, Volume 41, pages 559–565, May, 1967.

Fossil collecting is a skill that is developed only through many years of practice. It should also be remembered that skillful collecting is only a beginning for a good paleontologist. The final goal of this science is the proper interpretation of fossil evidence.

GENERAL CHARACTERISTICS OF NEBRASKA'S IMPORTANT FOSSILS

Following are short descriptions of some of the more common, and a few of the uncommon, fossils that occur in Nebraska rocks. The list, although far from complete, is intended to help students and collectors to identify and understand many of the fossils likely to be found.

Fossil animals are listed in order of their increasing biological complexity. Thus, the simple protozoans are listed first and the complex chordates are listed last. Fossil animals are followed by a brief section dealing with fossil plants.

It is important to remember that fossils are not merely pieces of rock or oddly shaped particles, but were once active parts of the earth's history. For this reason, a brief description of the living organism within each major group is included, followed by brief descriptions of the major characteristics of the individual fossil animals and of the more important fossil genera occurring in Nebraska. Tabulation of the stratigraphic distribution of fossil species occurring in Nebraska may be found in the Appendix.

The illustrations accompanying the text are designed to acquaint the reader with those parts of the organisms which are important for proper identification. In most cases, the fossils were illustrated from actual specimens. When good specimens were not available, the illustrations were modified after specimens shown in plates and figures appearing in one or more of the references listed in the appendix.

Many of the idealized fossil diagrams do not represent a known species but are composites of several species, as often a part that is common to one species is absent in another.

It is important that the reader understand that the materials described in the text have been collected by several hundred individuals over a period of about 100 years. Thus, one should not expect to find the described fossils in large quantities.

Throughout the remainder of the text reference will be made to named geologic beds. The collector will be more successful if he familiarizes himself with local geology. Information can be obtained from geologic maps and reports, study of collections on display in the University of Nebraska State Museum, and by consulting the offices of the Conservation and Survey Division in Nebraska Hall, University of Nebraska. For additional source material, the reader is encouraged to consult the Selected Bibliography and the references cited in the Appendix.

Assistance given by the staffs of the Conservation and Survey Division, Department of Botany, Department of Geology, and the State Museum of the University of Nebraska has been deeply appreciated by the author.

Phylum Protozoa (Single-Celled Animals)

The Living Protozoan

Protozoans are very simple animals. Their bodies consist of a single cell, yet they eat, breathe, and reproduce. Most protozoans are capable of movement. The majority are so small that they can be seen only with the aid of a microscope.

Fossil Protozoans from Nebraska

The most numerous fossil protozoans found in Nebraska rocks are of the Order Foraminifera (Fig. 8). Notice the magnification of the illustration. Living Forаmininfera build small shells which are either single- or multi-chambered. The walls between the chambers are called *septa* (sing. *septum*). The impressions in the shell between the chambers are called *sutures*. The animal protrudes through an opening called an *aperture*. Small pores in the walls and septa are called *foramina*—thus the name Foraminifera.

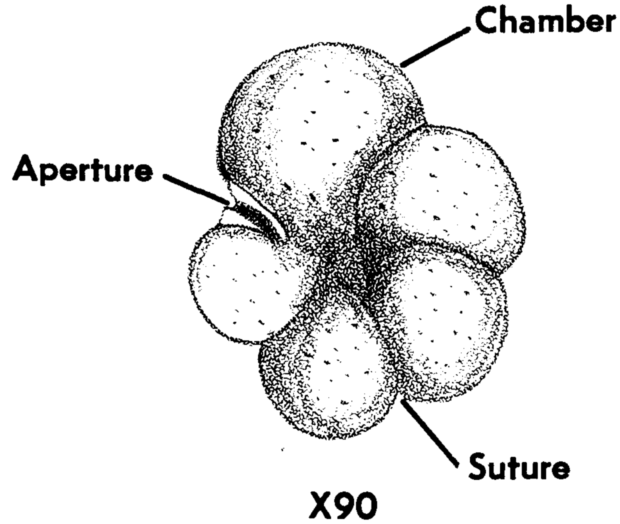


FIGURE 8. A side view of a typical foraminiferan (Protozoan) showing the positions of the aperture, chambers and sutures.

The most commonly collected foraminifers from Nebraska rocks are the fusulinids (Fig. 9). They are quite large for protozoans and their shells resemble a grain of wheat or rice in both size and shape. Siliceous rock containing fusulinids is sometimes referred to as "rice agate." Fusulinids were abundant during Pennsylvanian and Permian time in Nebraska. Their shells make up as much as 70 percent of some limestones. *Triticites*, *Fusulina*, and *Schwagerina* are the most important genera of fusulinids from the Pennsylvanian and Permian rocks of Nebraska. These genera all have very similar external features. Thus, unless the internal wall structure is studied, one can identify them no more specifically than their family, Fusulinidae.

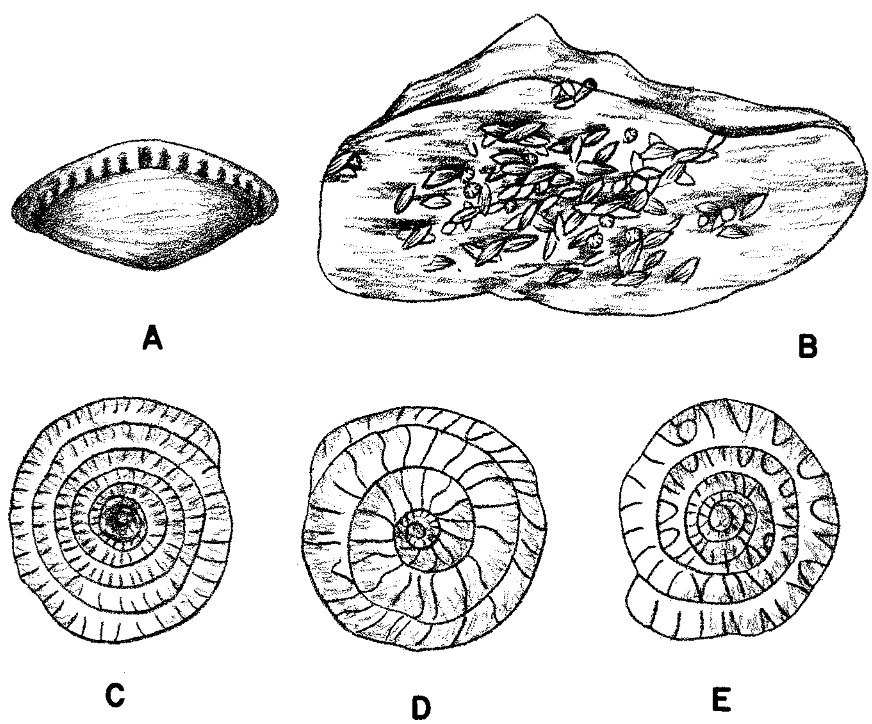


FIGURE 9. Pennsylvanian and Permian foraminiferans (Protozoans). (A) A fusulinid, anterior view, X10. (B) Limestone slab containing abundant fossil fusulinids, X2. (C-E) Thin sections showing differences in wall structures of three different genera: (C) *Triticites*, X15, (D) *Fusulina*, X15, (E) *Schwagerina*, X15. A, C, D, and E after Dunbar and Condra, 1927.

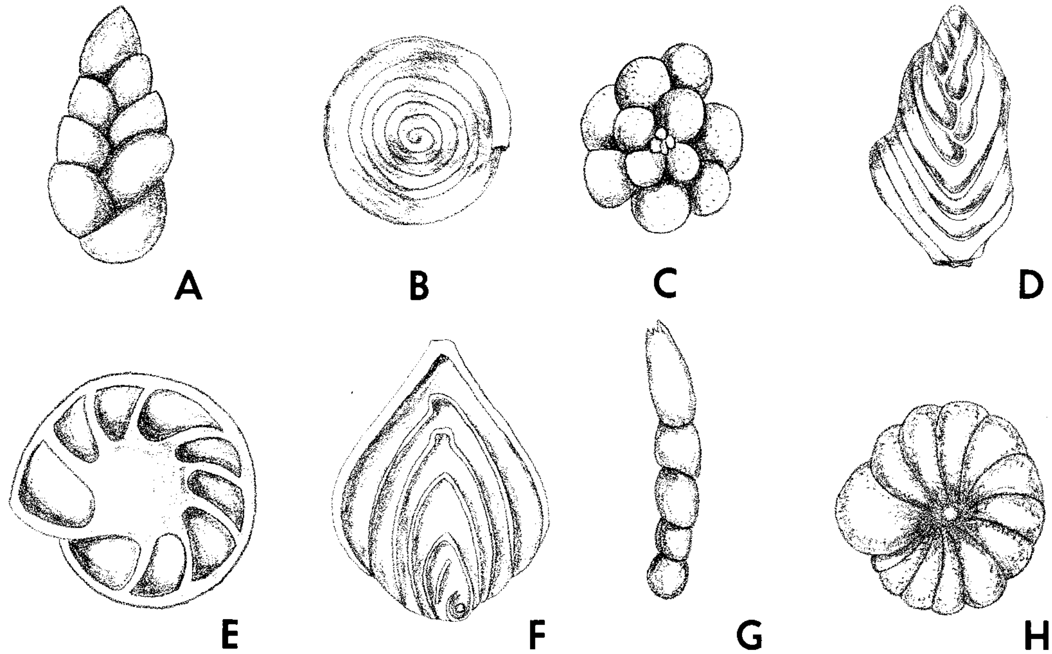


FIGURE 10. Some Cretaceous foraminiferans (Protozoan). (A) *Gaudryina*, X60. (B) *Ammodiscus*, X25. (C) *Globigerina*, X60. (D) *Kyphopyxa*, X30. (E) *Lenticulina*, X30. (F) *Palmula*, X40. (G) *Dentalina*, X50. (H) *Planulina*, X60. Modified after Loetterle, 1937.

Triticites frequently occurs in thick limestone units of Pennsylvanian and Permian age, which are exposed in southeastern Nebraska. *Triticites* has been collected from the Winterset, Westerville, Drum, Raytown, Argentine, Stoner, and South Bend Limestones, which are exposed along the lower Platte River valley in Saunders, Sarpy, and Cass Counties, and in the Haskell, Plattsmouth, Kereford, and Ervine Creek Limestones, which are exposed along Weeping Water Creek and the Missouri River in Cass County. *Triticites* also occurs in the Howard Limestone near Du Bois and in the Tarkio Limestone near Tecumseh and Table Rock.

Fusulina and *Schwagerina* occur in the Permian Neva and Cottonwood Limestones which are exposed near Roca, Douglas, Burr, and Pawnee City.

More than 30 species of Foraminifera have been found in the Cretaceous rocks of Nebraska. These forms are very small and can be seen only with the aid of a microscope. Some of the highly variable Cretaceous Foraminifera are shown in Figure 10.

Many species of Cretaceous Foraminifera have been described and identified from the Niobrara Chalk in northeastern, northwestern, and south-central Nebraska and from the Pierre Shale in northwestern Nebraska.

A tabulation of the genera of fossil Foraminifera which have been reported from rocks in Nebraska is included in the Appendix.

Phylum Porifera (Pore Bearers or Sponges)

The Living Sponge

Sponges are hollow, vase-shaped animals which may be attached to rocks or shells of other animals. The walls of a sponge consist of two well-defined cell layers: an outer layer of protective cells, and an inner layer of cells which circulate water (Fig. 11). The inner-layer cells draw water in through pores in the wall. Food particles are removed from the water and the water is then expelled from a large opening called an *osculum*. The walls of sponges are supported by a

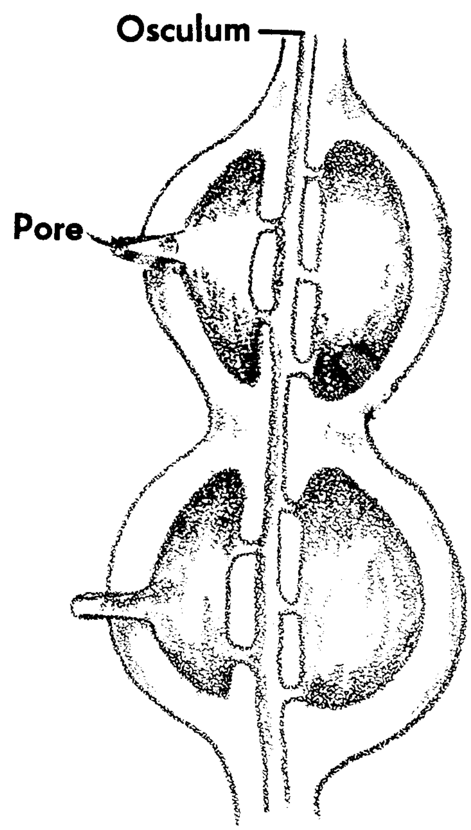


FIGURE 11. A cut-away diagram of a typical Pennsylvanian sponge, *Girtyocoelia*, showing the interior structure. X3.

loose, flexible network of *spicules* which are made up of calcium carbonate or silica.

Fossil Sponges from Nebraska

Fossil sponges have been collected from the Pennsylvanian rocks of Nebraska. *Girtyocoelia* (Fig. 12A) resembles a string of beads. A similar form, *Heterocoelia,* consists of a branching string of beads. *Amblysiphonella* (Fig. 12B) resembles a segmented twig. Sponges are commonly found in the Ervine Creek Limestone near Weeping Water, Union, and Plattsmouth.

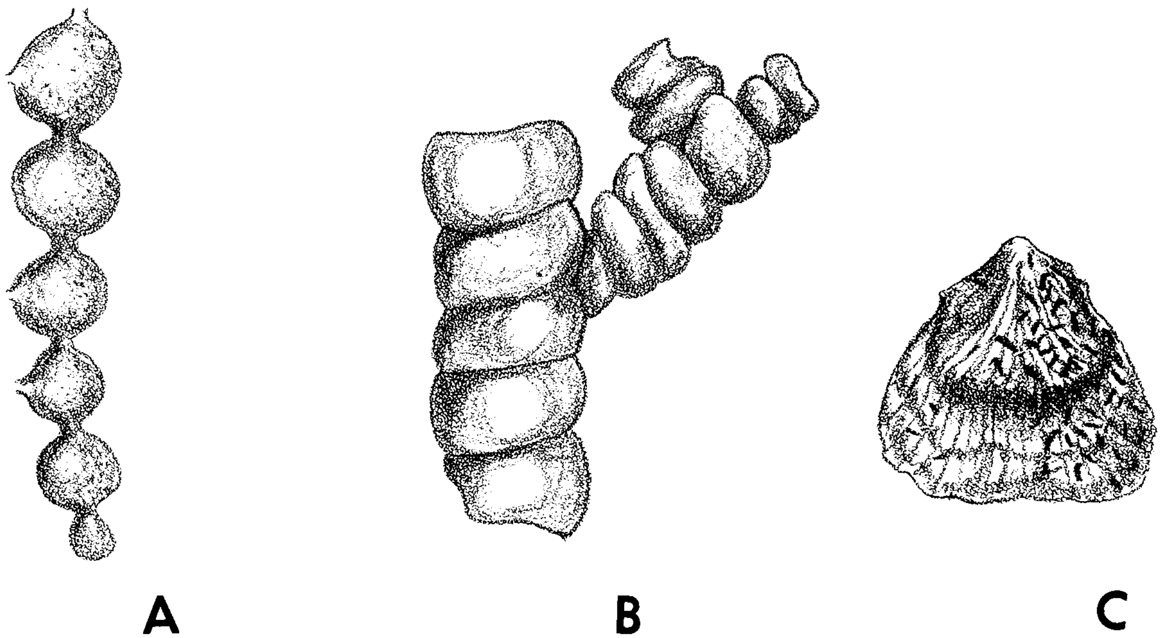


FIGURE 12. Two common Pennsylvanian sponges. (A) *Girtyocoelia,* X1; and (B) *Amblysiphonella,* X1. (C) Sponge borings on a brachiopod (*Derbyia*) valve, X1.

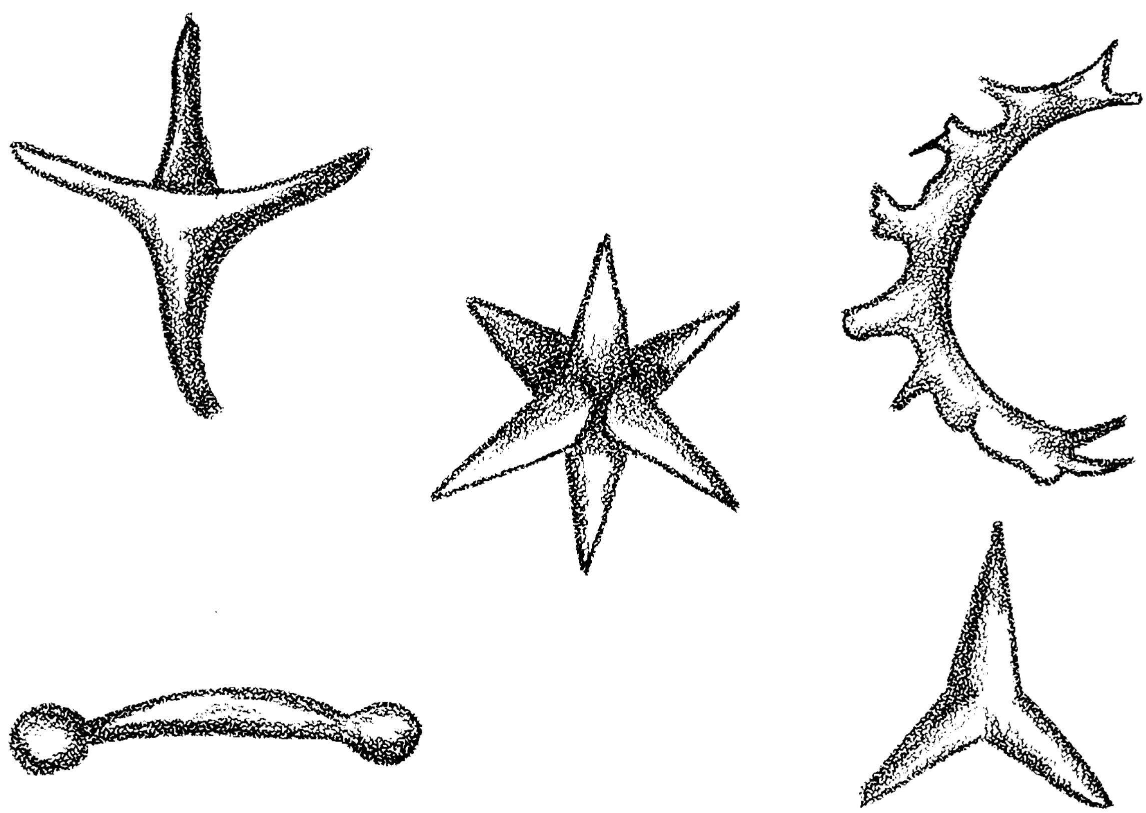
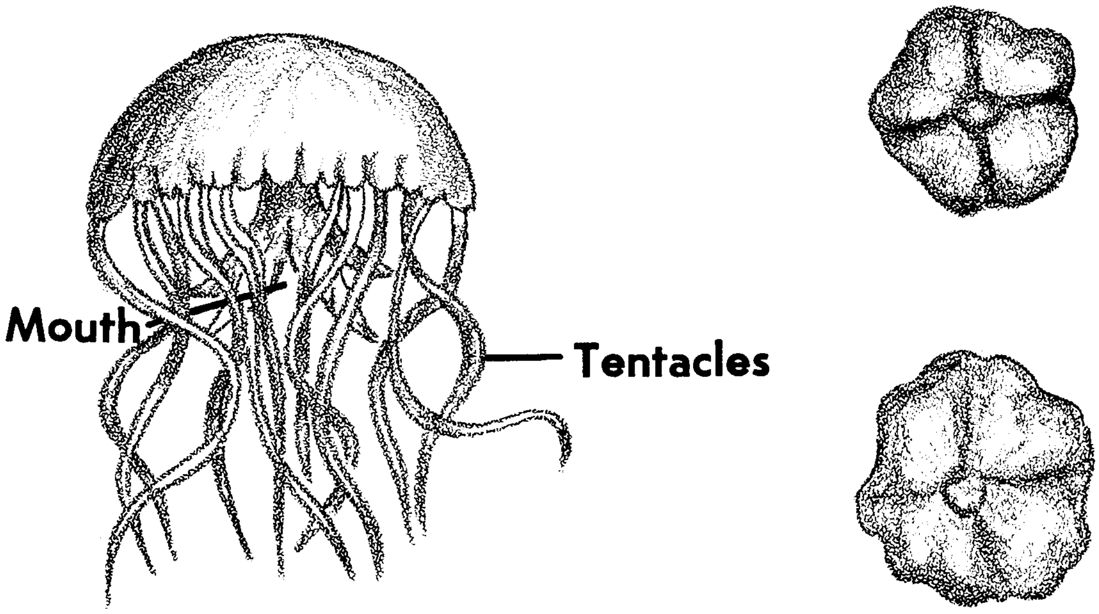


FIGURE 13. Fresh-water Pleistocene Sponge spicules, X175.



A B

FIGURE 14. Medusae or jellyfishes. (A) A typical jellyfish, X½. (B) Fossil casts attributed to jellyfish, X1

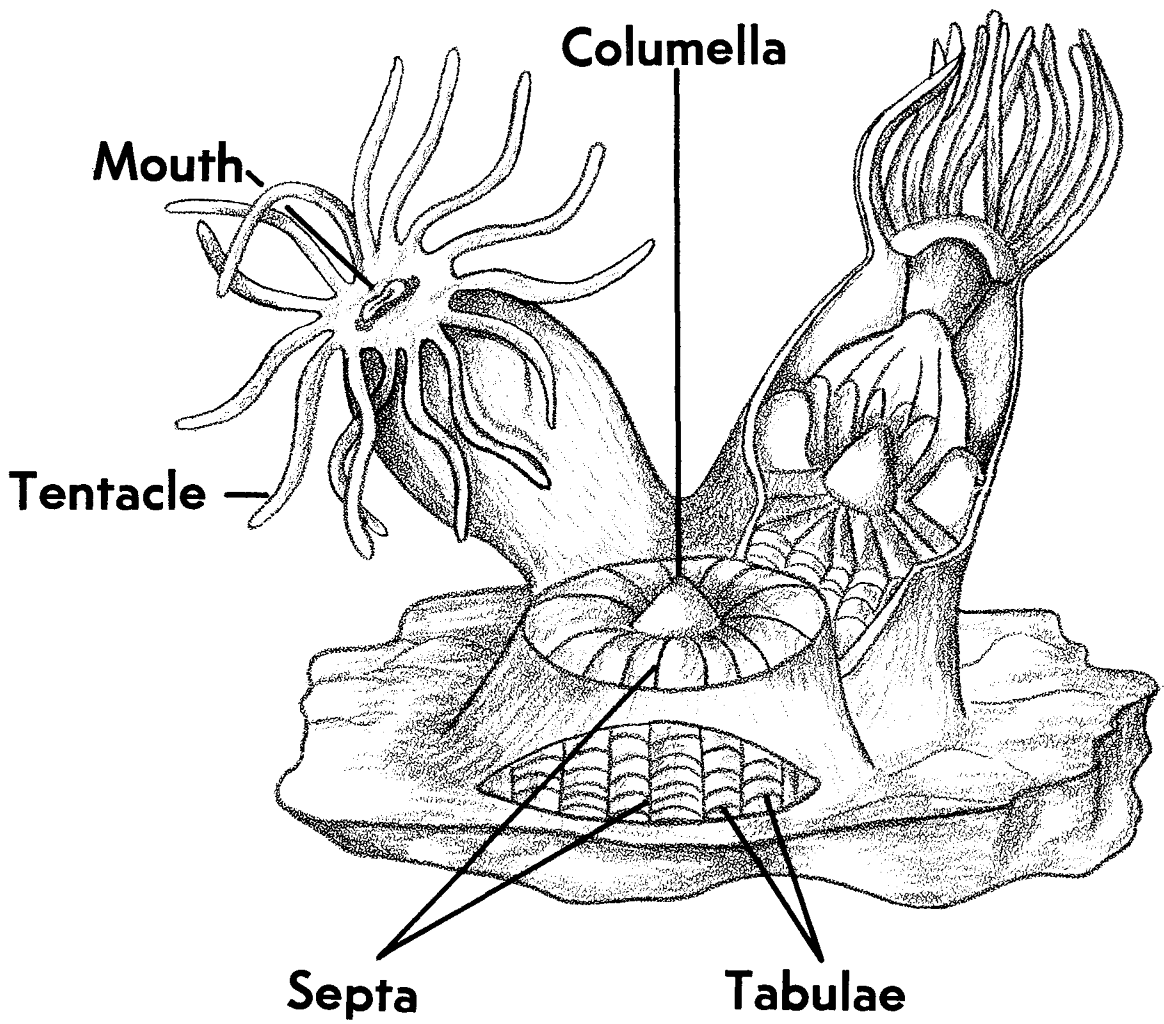


FIGURE 15. A typical coral showing some of the more important features. Note the relationship between the tabulae, septa, and columella.

Borings which are attributed to sponges are found on the shells of bivalves (clams) and brachiopods in the Bonner Springs Shale and Stoner Limestone near Louisville (Fig. 12C). Sponge borings appear as short, deep gouges and show where the animal was anchored. Similar borings have been observed on shells of a giant species of the bivalve *Inoceramus* in the Niobrara Chalk of Cretaceous age, which is exposed along the Republican River near Franklin.

Spicules of fresh-water sponges (Fig. 13) are abundant in diatomaceous earth deposits of Pleistocene age in Hooker, Thomas, Blaine, Garfield, Wheeler, Valley, Greeley, Sherman, and Nance Counties. These spicules can be seen only with the aid of a microscope.

A tabulation of the genera of fossil sponges which have been reported from rocks in Nebraska is included in the Appendix.

Phylum Coelenterata (Jellyfishes and Corals)

The Living Coelenterate

Coelenterates include such animals as jellyfishes and corals. The jellyfishes (or medusae) are free-floating forms and have no skeleton. They resemble an umbrella (Fig. 14A) with tentacles hanging down from the rim.

Corals are actually the exoskeletons (a hard supporting or protective structure) of animals called *polyps.* Polyps live either in colonies made up of hundreds of individuals or as solitary animals. The polyp (Fig. 15) has a *mouth* encircled by *tentacles* equipped with stinging cells. Its skeleton may have vertical internal calcareous dividers called *septa,* which may converge inward to form a rod-like structure called a *columella.* Horizontal dividers are called *tabulae.*

Occurrences of Coelenterates in Nebraska

Molds of jellyfishes (Fig. 14B) have been collected from the Stoner and Ervine Creek Limestones of Pennsylvanian age, near South Bend and Weeping Water respectively. They range in size from about 1 inch to 8 inches in diameter. They are characterized by having four grooves which lead to a deep, centrally located pit.

Solitary or "horn" corals are common in the Pennsylvanian and Permian rocks of southeastern Nebraska. *Pseudozaphrentoides* (Figs. 16A, B) may be as long as 18 inches, whereas *Lophophyllum* (Fig. 16C) is commonly less than an inch long and has a prominent columella. *Pseudozaphrentoides* commonly reproduced by "budding" a new offspring from part of the exoskeleton, and specimens with buds are common (Fig. 16A). Thin sections must be prepared and studied (Fig. 16D, E) to identify most corals.

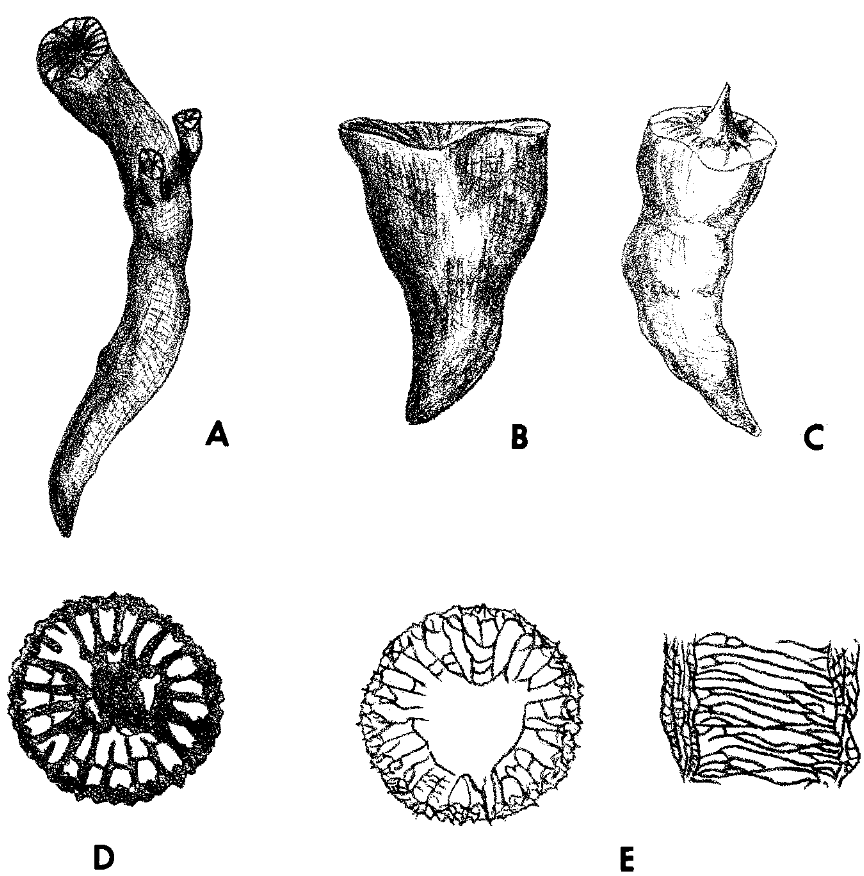


FIGURE 16. Pennsylvanian and Permian Horn Corals. (A) *Pseudozaphrentoides*, a mature specimen with buds of young corals, X½. (B) *Pseudozaphrentoides*, X½. (C) *Lophophyllum*, X1. (D) *Lophophyllum*, a polished section showing septa, X4. (E) *Pseudozaphrentoides*, polished sections showing septa (left) and tabulae (right), X1.

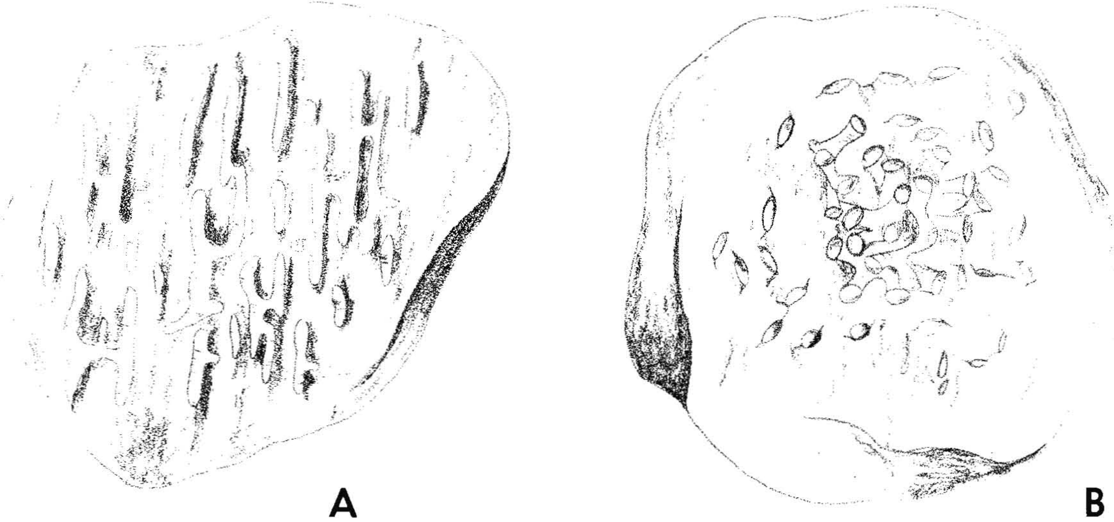


FIGURE 17. Pennsylvanian and Permian Colonial corals. (A) *Syringopora*, a polished section showing tabulae, X1. (B) *Cladochonus*, a surface view of a small colony, X1.

Pseudozaphrentoides has been collected from the Beil and Plattsmouth Limestones near the villages of Weeping Water and Nehawka and from the abandoned Snyderville quarry near Nehawka. *Lophophyllum* occurs in the Argentine and Stoner Limestones near Louisville, from the Stull Shale and Ervine Creek Limestone near Louisville, and in several quarries near Plattsmouth and Louisville.

Colonial corals (Fig. 17) are commonly represented by *Syringopora* and *Cladochonus*, both of which form compacted, tube- or straw-like networks in limestone. Large colonies of *Syringopora* and *Cladochonus* have been collected from the Kereford and Plattsmouth Limestones at Weeping Water.

Conularids (Fig. 18) are small coelenterates which have chitinous shells. They are easily distinguished by their pyramid-like form. Several specimens of the genus *Conularia* have been collected from the Stoner Limestone near Louisville and from the Stull Shale near Weeping Water. A Permian conularid has been found in the Florence Limestone at Holmesville.

The fossil record of coelenterates in Nebraska is restricted to the Pennsylvanian and Permian rocks of the southeastern part of the state. None have been recorded from the Cretaceous rocks in Nebraska. This is surprising, since these rocks appear to have been deposited in warm, shallow water, ideal for coral development. Failure to find representatives of this phylum from the Nebraska Cretaceous may be simply a reflection of the need for additional paleontological work.

A tabulation of genera of fossil coelenterates which have been reported from rocks in Nebraska is included in the Appendix.

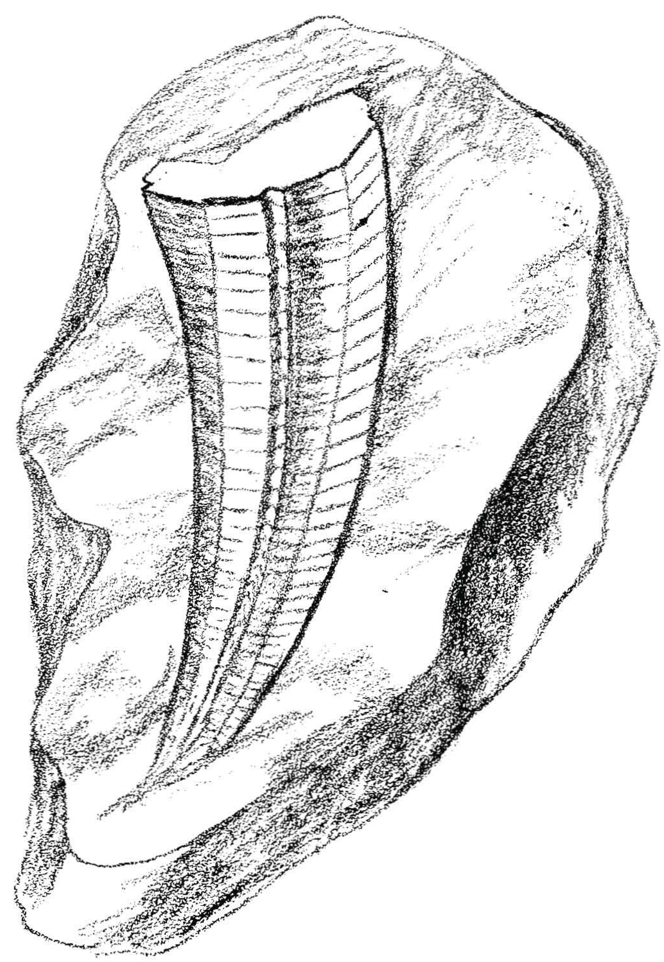


FIGURE 18. A fossil conularid, *Conularia*, X1.

Worm Phyla (Excluding Annelida)

The phyla Platyhelminthes, Nemathelminthes, and Trochhelminthes make up the "lowly worms." These have no direct fossil records since they had no hard parts. However, scars attributed to parasitic worms of Phylum Platyhelminthes are frequently found on stems of Pennsylvanian and Permian crinoids. These appear as irregularly perforated lumps, as shown in Figure 19. They differ from gastropod borings (Fig. 44) which are perfectly circular and show no swelling.

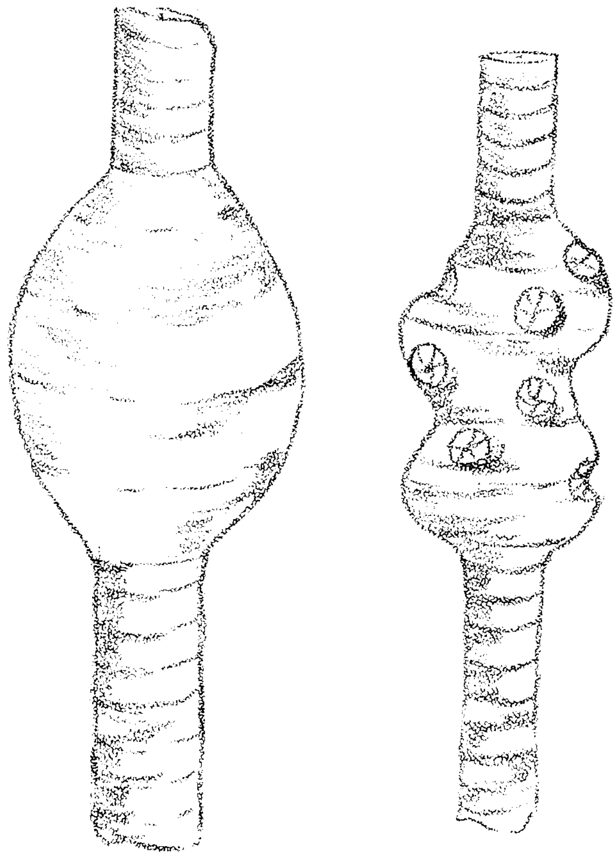


FIGURE 19. Scars on crinoid stems which are attributed to parasitic worms of Phylum Platyhelminthes, X2.

Phylum Ectoprocta* (Moss Animals; formerly Phylum Bryozoa)

The Living Ectoproct

Ectoprocts are commonly called moss animals because their colonies look like small clumps of moss. An entire colony is called a *zooarium* and each living chamber is called a *zooecium*. The individual animal is called a *zooid*. An idealized ectoproct is illustrated in Figure 20.

Fossil Ectoprocts from Nebraska

Many species of ectoprocts are commonly found in the Pennsylvanian and Permian rocks of Nebraska (Fig. 21). *Septopora* (A) forms large fans. *Fistulipora* (B) is an encrusting ectoproct with a large, rounded colony. *Stenopora* (C) is found encrusting the shells of many brachiopods or the stems of crinoids. *Rhombopora* (D) has a colony which looks like a miniature log of wood. *Cyclotrypa* (E) forms large, heavy branches. *Fenestella* (F) is a very fine, lacy form. Specific identification of ectoprocts can usually be made only by studying thin sections of a colony (Fig. 22).

Although a few lacy ectoprocts are found in the Cretaceous rocks of northwestern Nebraska, most are re-

*Because of differences in morphology and growth in two forms of the now defunct Phylum Bryozoa, this phylum has now been divided into two new phyla—Ectoprocta and Entoprocta. The latter has no fossil record and is not discussed here.

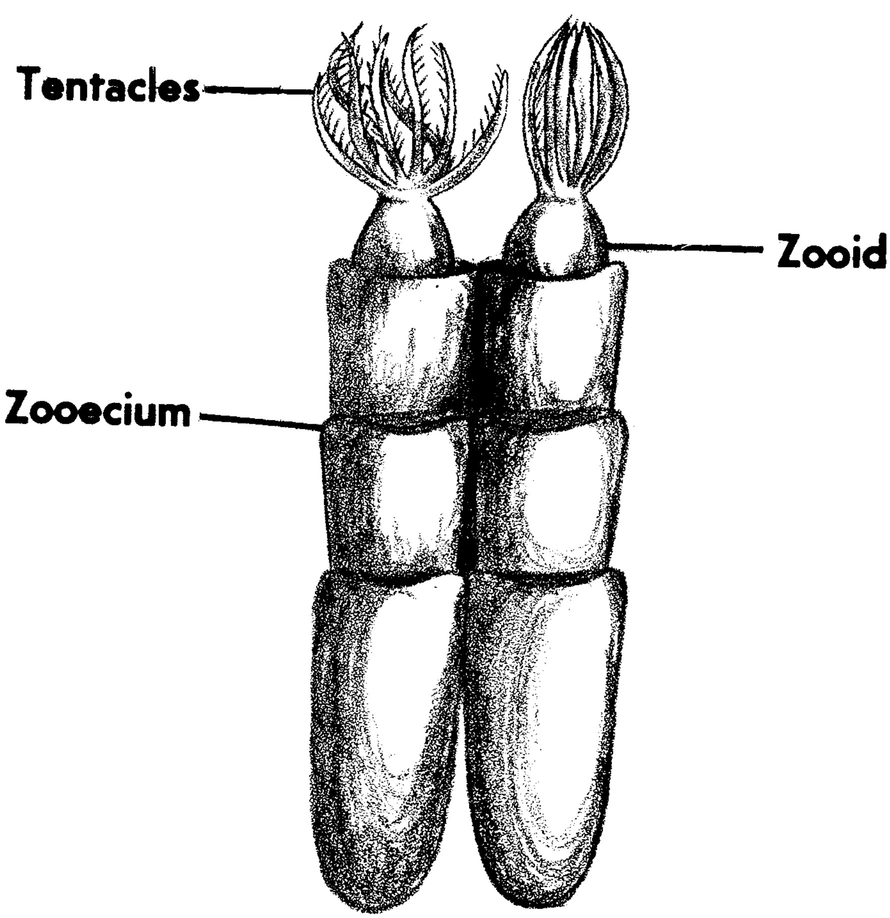


FIGURE 20. An idealized ectoproct showing some of the more important features. X50.

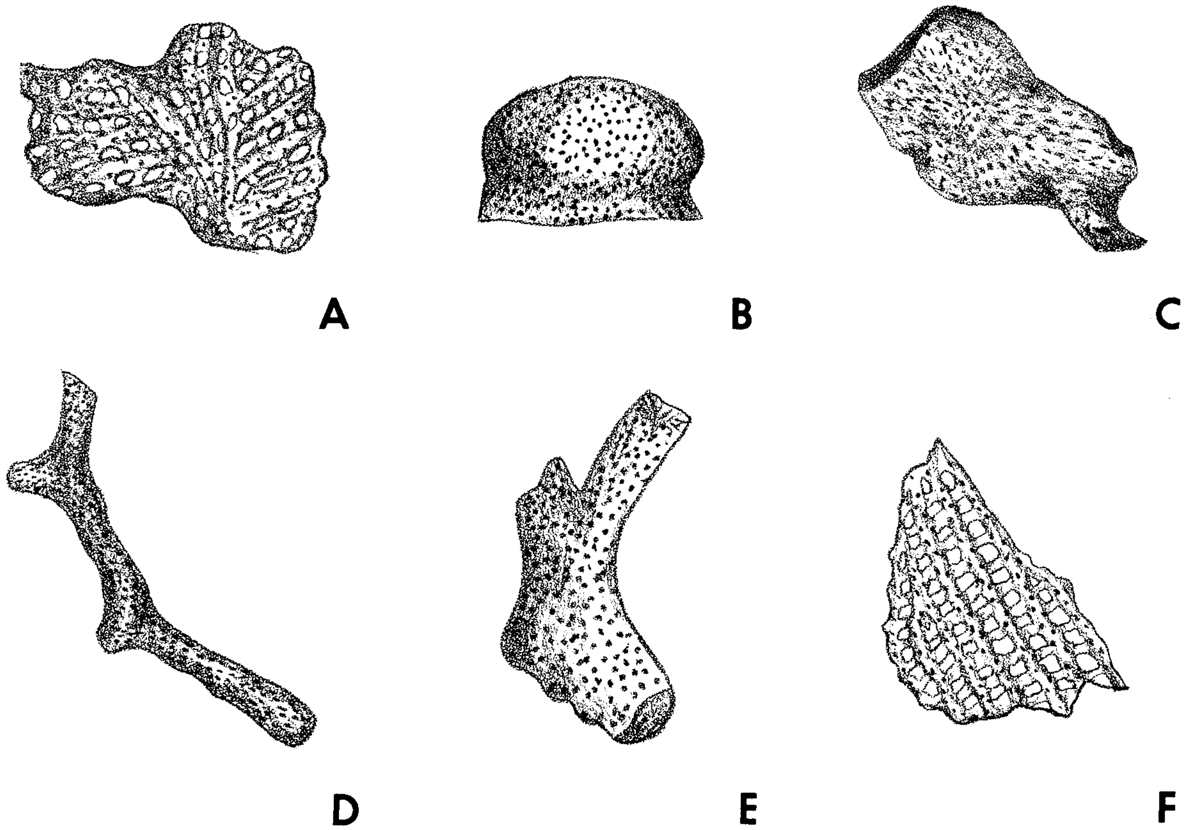


FIGURE 21. Fossil zooaria of Pennsylvanian and Permian ectoprocts. (A) *Septopora,* (B) *Fistulipora,* (C) *Stenopora,* (D) *Rhombopora,* (E) *Cyclotrypa,* and (F) *Fenestella.* All Figures X2.

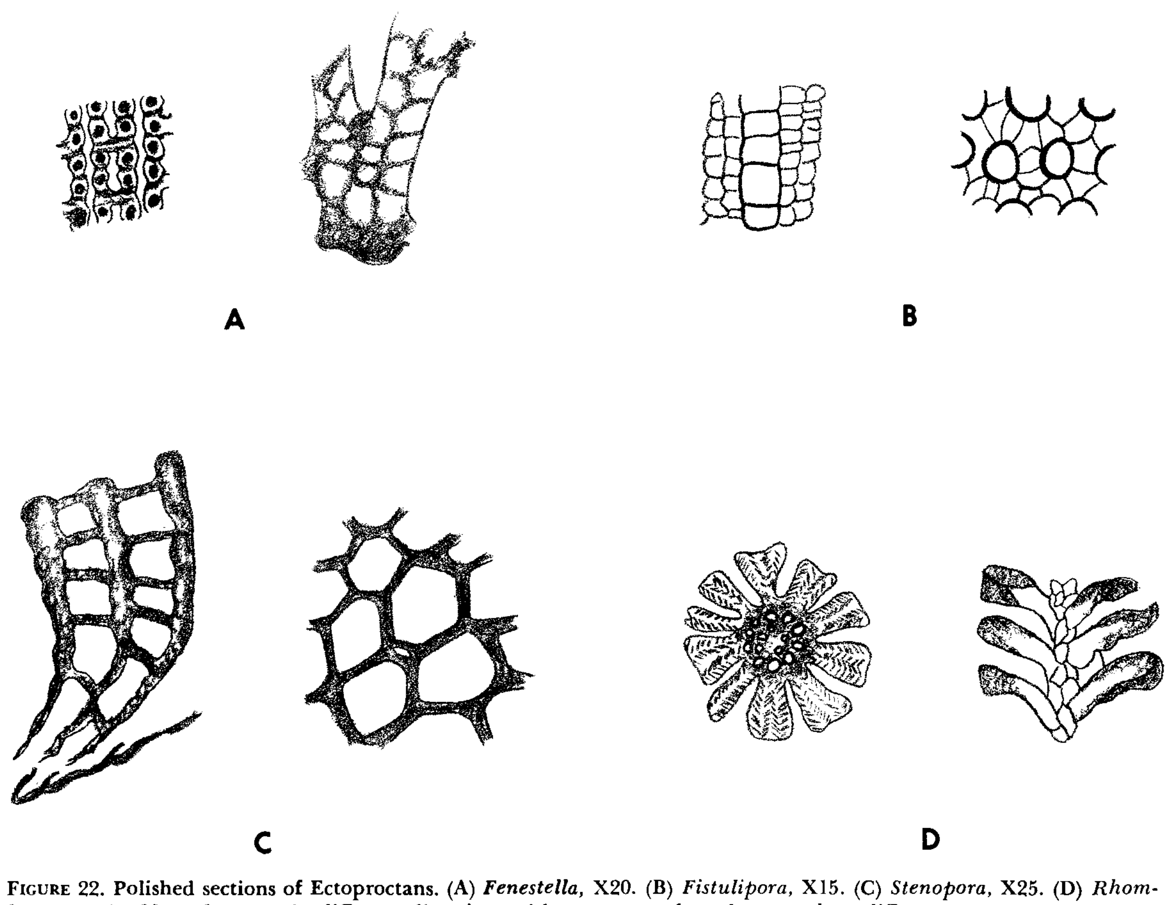


FIGURE 22. Polished sections of Ectoproctans. (A) *Fenestella,* X20. (B) *Fistulipora,* X15. (C) *Stenopora,* X25. (D) *Rhombopora,* X20. Note that cuts in different directions with respect to the colony produce different patterns.

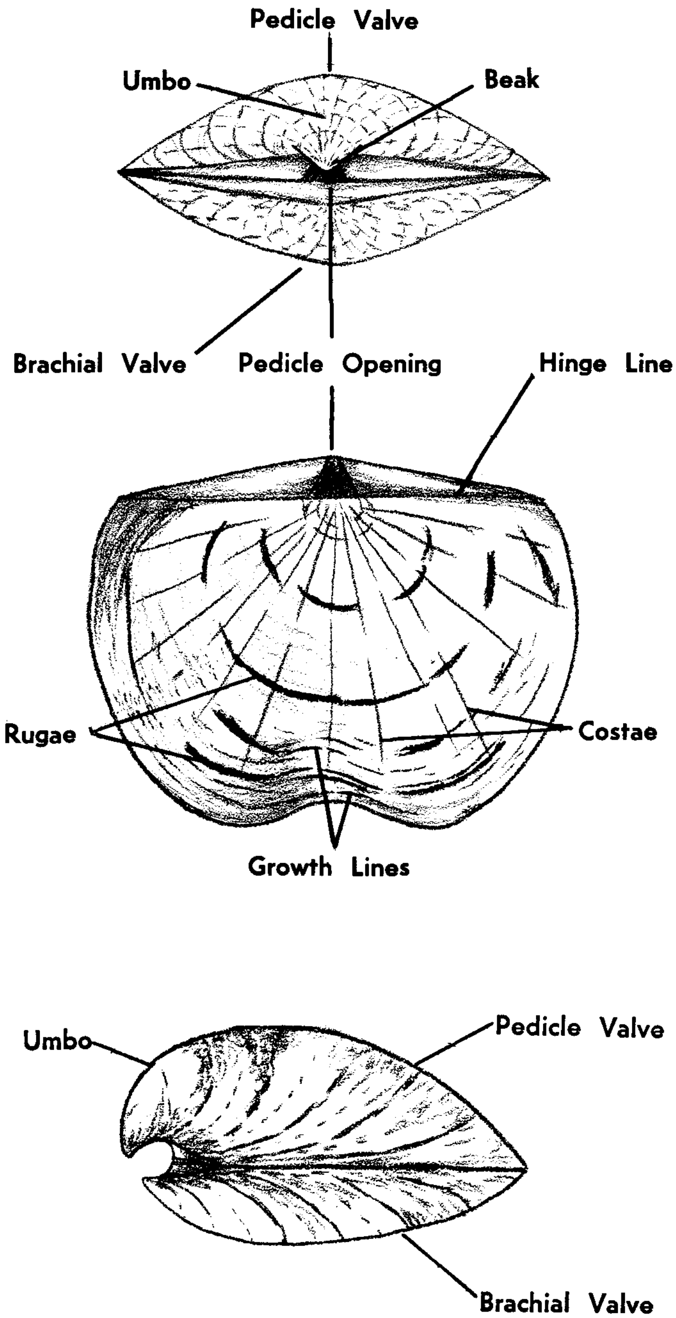


FIGURE 23. Posterior, ventral, and side views of a typical brachiopod, showing some of the important features used in classification.

stricted to the Pennsylvanian and Permian strata of southeastern Nebraska. Many well-preserved specimens have been collected from the Stull Shale; from the Plattsmouth, Beil, Kereford, and Ervine Creek Limestones near Weeping Water and Plattsmouth; the Ervine Creek and Beil Limestones at Union; the Plattsmouth Limestone at Nehawka; the Stoner Limestone and Bonner Springs Shale at Louisville; the Soldier Creek Limestone at Unadilla; and the Wakarusa Limestone near Table Rock. Permian ectoprocts have been collected from the Hughes Creek Shale near Bennet, the Neva Limestone near Roca, and the Fort Riley and Florence Limestones near Holmesville and Wymore.

A tabulation of genera of fossil ectoprocts which have been reported from rocks in Nebraska is included in the Appendix.

Phylum Brachiopoda

Brachiopods form perhaps the most important single group of fossils in the Pennsylvanian and Permian rocks of Nebraska. However, only a few have been found in Cretaceous rocks.

The Living Brachiopod

Brachiopods are small, exclusively marine animals having two shells or valves that are unequal in size and shape. They are more highly developed than ectoprocts and have simple digestive and excretory systems, reproductive organs, and efficient muscles.

The two valves are called the *pedicle valve* and the *brachial valve.* They open along a *hinge line* (Fig. 23) and each may have a *beak.* The *umbo* is a highly inflated area behind the beak (Fig. 23). The valves may be ornamented with closely spaced *growth lines,* or coarse banding called *rugae.* The valves may have fine ribbing called *costae* or coarse ribbing called *plications.* Many brachiopods have a fleshy *pedicle* which extends from a *pedicle opening* in the *pedicle valve* and is used for attachment or burrowing.

Some of the more important parts of the interior of a brachiopod are illustrated in Figure 24. The valves may be held together by a system of *teeth* and *sockets* located along the hinge line. In fossil brachiopods, the positions of the muscles which opened and closed the valves are indicated by *muscle scars.* Muscles are also attached to the *cardinal process* of the brachial valve. The shape of the cardinal process is highly variable and is important in brachiopod classification.

A common question is: "How does a brachiopod differ from a clam?" The plane of symmetry cuts *between* the valves of a clam (Phylum Mollusca) and *through* the valves of a brachiopod. Although both are bivalved animals (Fig. 25), the clam has equal valves that are mirror images of each other, while brachiopod valves (pedicle and brachial) differ from one another in both size and shape.

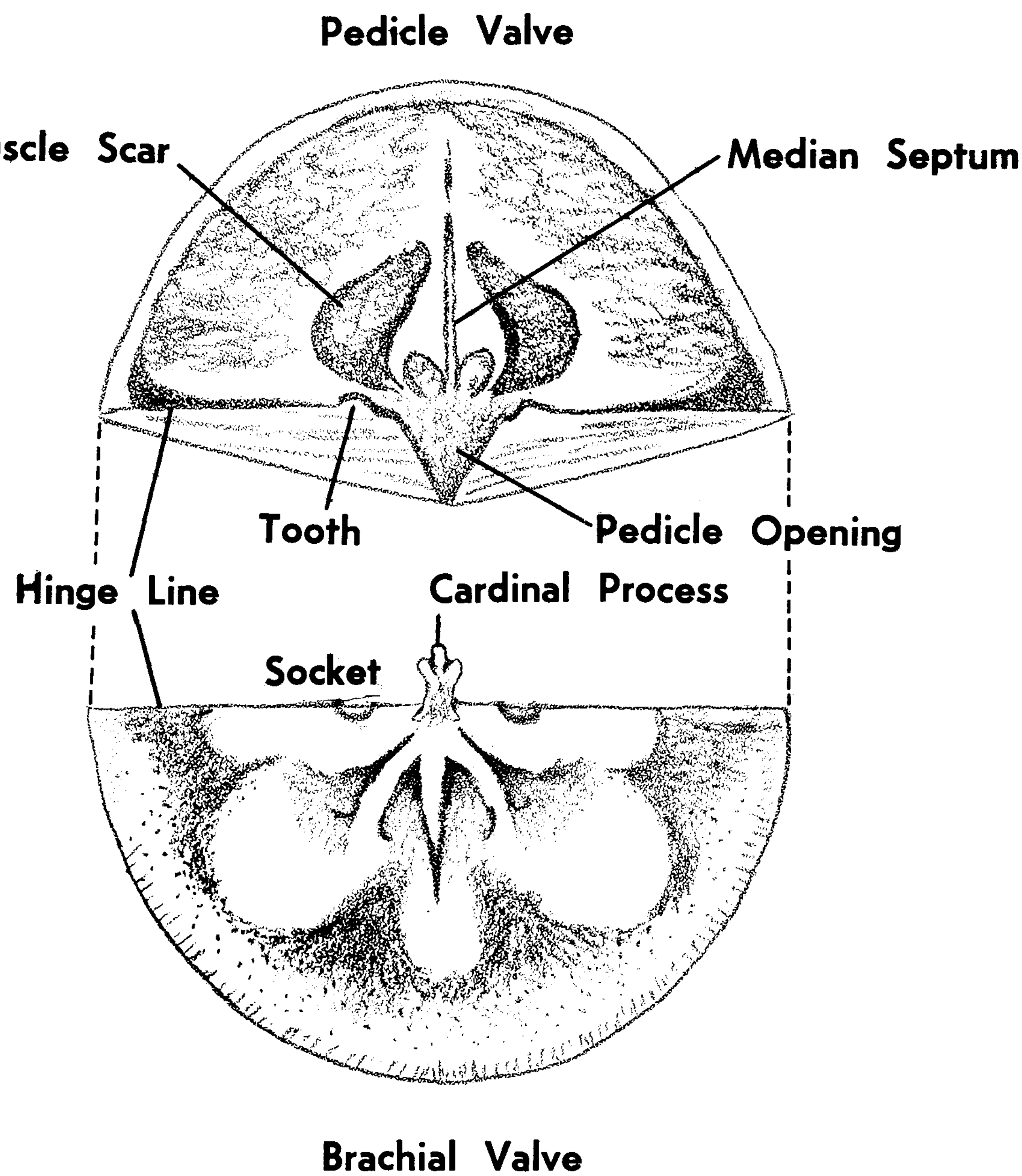


FIGURE 24. Interior views of the pedicle (above) and brachial (below) valves of a typical brachiopod, showing some of the important parts. Note the relationship between the pedicle and brachial valve.

Class Articulata

Articulate brachiopods have teeth and sockets (excluding chonetoids and productoids) and calcium carbonate shells.

Spiriferoid brachiopods usually have long hinge lines (Fig. 26A-C), well-developed teeth and sockets (Fig. 24), and a *plicated* or coarsely ribbed shell. They probably attached themselves to the bottom of the sea by means of a fleshy pedicle which protruded through a large, V-shaped pedicle opening (Figs. 24, 26). Their name is derived from a pair of internal structures, the *spiralia* (Fig. 26B), which were shaped like coil springs and supported the food-gathering mechanism. Some common spirifer brachiopods of Nebraska are shown in Figure 26. *Neospirifer* (Fig. 26A-C) may have a very short or a very long hinge line. *Punctospirifer* resembles *Neospirifer* but its valves are perforated with many tiny holes (punctae) that can be seen with slight magnification.

Atrypoid brachiopods (Fig. 26D-G) are similar to spirifers inasmuch as they also have spiralia. However, atrypoids have short hinge lines and their shells may be either smooth or plicated. Most of them are smaller than adult spirifers. Figure 26 illustrates some of the atrypoid brachiopods found in Nebraska. *Composita* (D) is an oval-shaped brachiopod with a smooth shell. *Hustedia* (E) is a small, tear-drop-shaped brachiopod with very coarse plications. *Phricodothyris* (F) is a small, oval brachiopod similar to *Composita* but having a large, triangular-shaped pedicle opening and granular

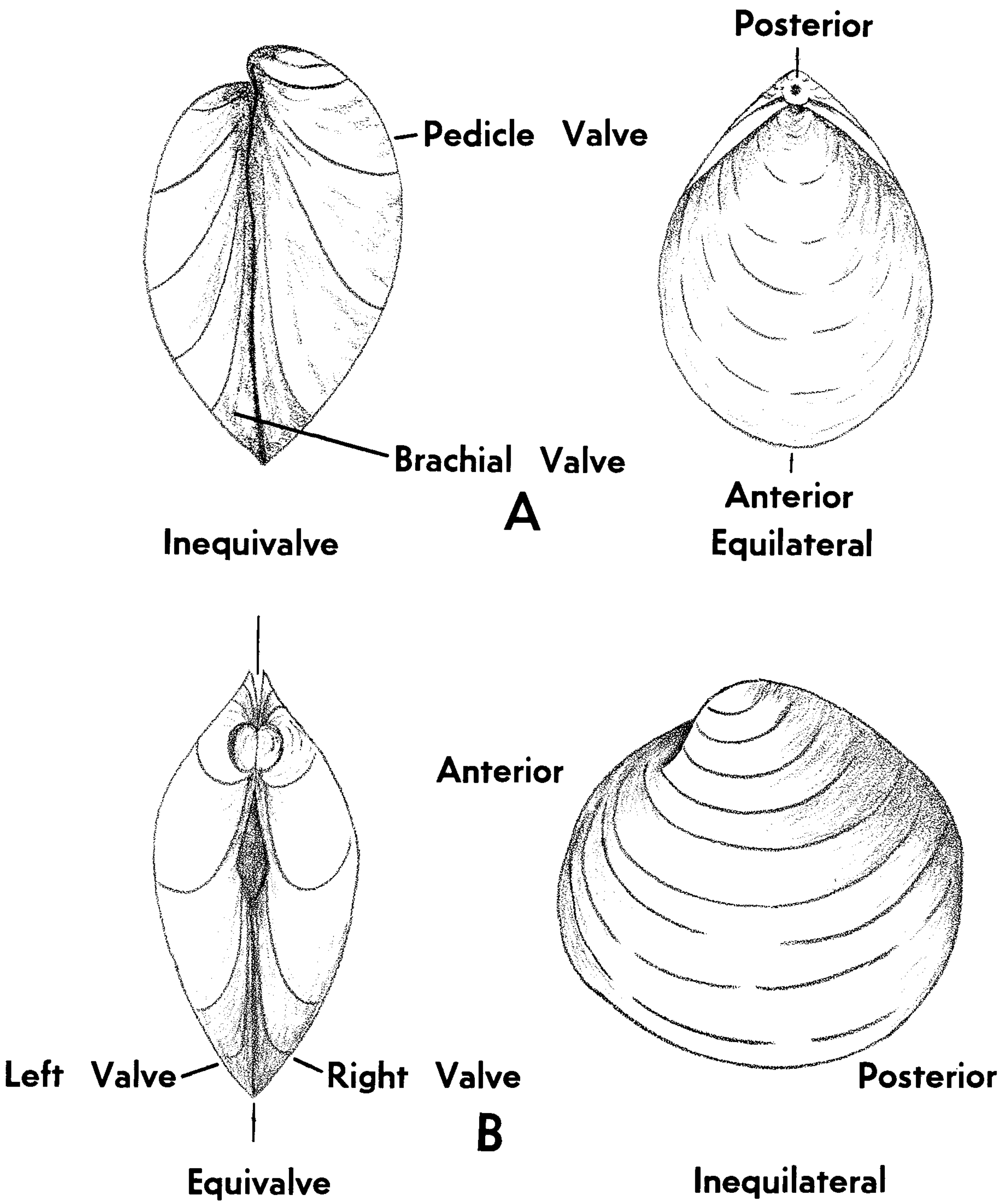


FIGURE 25. A diagram showing the morphologic differences between a brachiopod (above) and a clam (below). Note especially the position of the plane of symmetry in each.

ornamentation running parallel to the growth lines (Fig. 23). *Crurithyris* (G) has a large, inflated pedicle valve and a nearly flat brachial valve.

Productoid brachiopods (Fig. 27) are characterized by having large spines on their pedicle valve. These spines apparently supported the animal on the sea floor as there is no pedicle opening to indicate that the brachiopod would have had a pedicle for attachment. They have neither teeth nor sockets, but usually have very long hinge lines. The pedicle valve is usually deep and semispherical. The brachial valve is nearly flat and contains an ornate cardinal process and elaborate muscle scars (Fig. 24).

Several important productoid brachiopods from Nebraska are illustrated in Figure 27. *Juresania* (A) has fine spines on both valves. *Pulchratia* (B) resembles *Juresania* but its shell is more oval and it grew much larger. *Reticulatia* (not illustrated) resembles *Antiquitonia* (C) but its brachial valve has a smaller cardinal process and the entire animal is usually smaller. *Hys-*

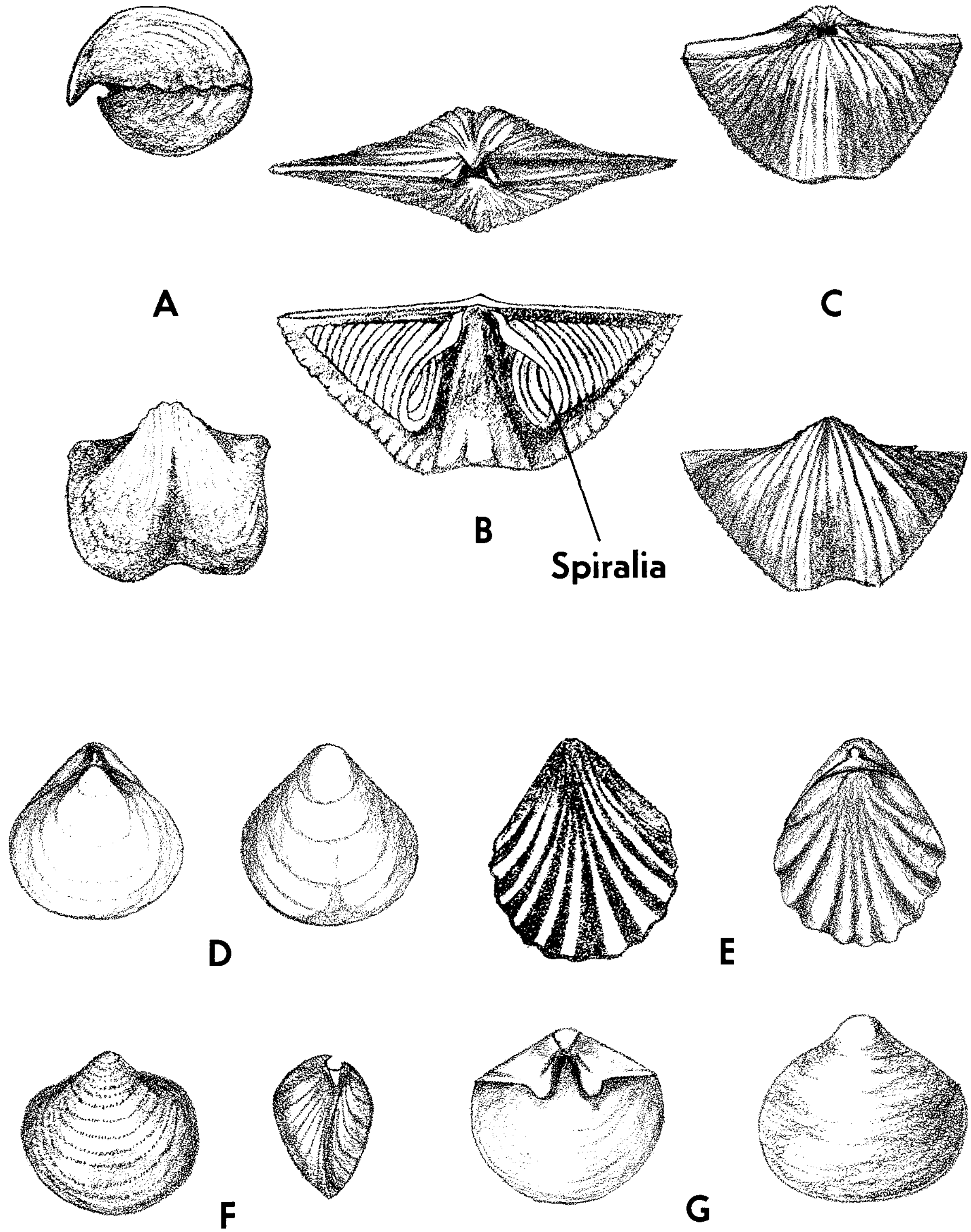


FIGURE 26. Spiriferoid and atrypoid brachiopods. (A) *Neospirifer*, side view (above) and pedicle valve (below), X1. (B) *Neospirifer*, posterior view (above) and internal view showing spiralia (below), X1. (C) *Neospirifer*, view of brachial valve (above) and pedicle valve (below), X1. (D) *Composita*, view of brachial (left) and pedicle (right) valves, X1. (E) *Hustedia*, views of pedicle (left) and brachial (right) valves, X3. (F) *Phricodothyris* (=*Squamularia*), pedicle valve (left) and side view (right), X1. (G) *Crurithyris*, internal (left) and external (right) views of pedicle valve, X3.

triculina (D) has small spines scattered over the pedicle valve but has no prominent rugae. *Marginifera* resembles *Hystriculina* but has less well-defined costae and rugae and occurs only in Permian rocks in Nebraska. *Krotovia* (E) looks much like *Juresania* but has a more circular outline and much smaller spines on the valves. *Leptolosia* (F) is a very small productoid brachiopod, usually attached to the atrypoid brachiopod *Composita* (Fig. 26). *Linoproductus* (G) has very fine costae and rugae and scattered spines on the pedicle valve.

Chonetoid brachiopods are characterized by a series of spines projecting from the hinge line of the pedicle

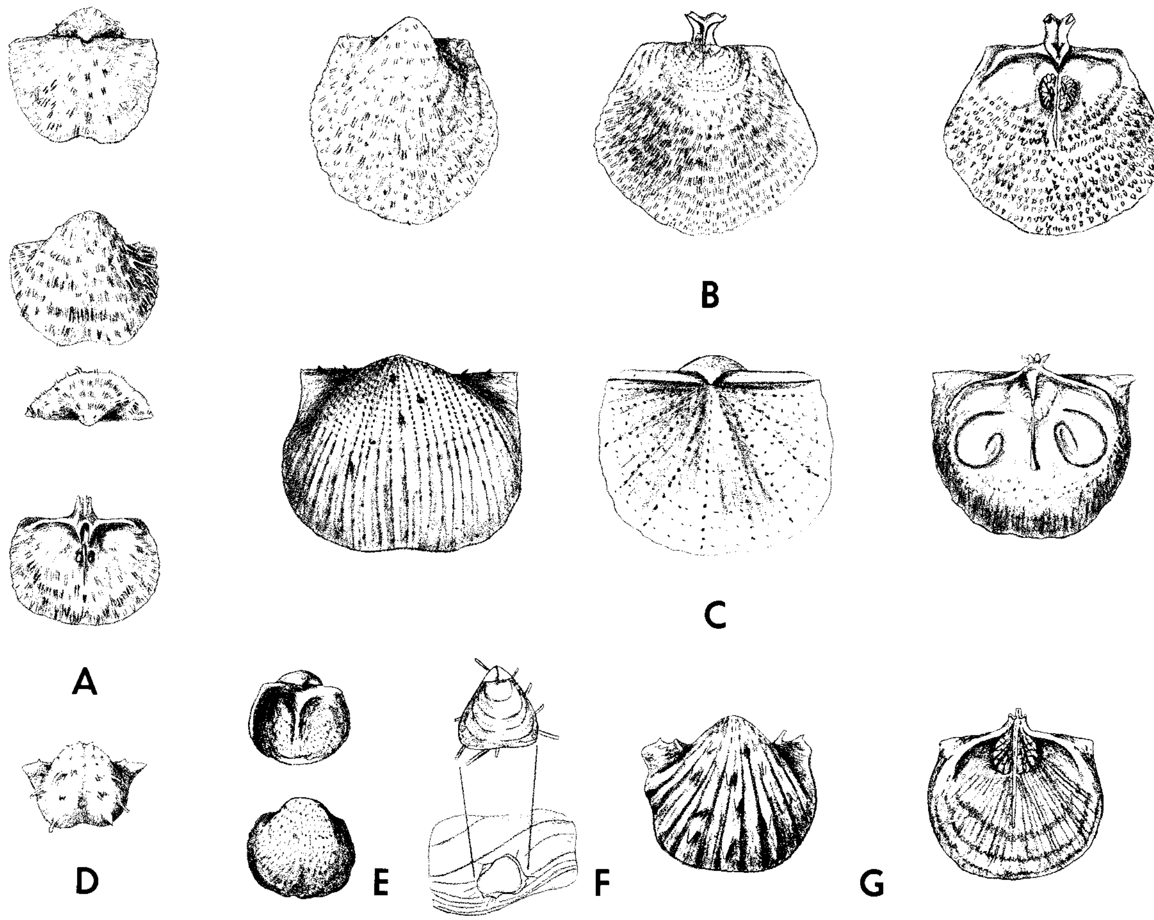


FIGURE 27. Productoid brachiopods of Nebraska. (A) *Juresania*, brachial and pedicle valves, posterior view, and internal view of brachial valve (top to bottom), X1. (B) *Pulchratia*, pedicle valve, brachial valve, and internal view of brachial valve (left to right), X1½. (C) *Antiquatonia*, pedicle valve, brachial valve, and internal view of brachial valve (left to right), X1½. (D) *Hystriculina*, pedicle valve, X1. (E) *Krotovia*, brachial (above) and pedicle (below) valves, X1½. (F) *Leptolosia*, a parasitic form attached to a shell fragment of *Composita*, X1. (G) *Linoproductus*, a pedicle valve (left) and internal view of a brachial valve (right), X1.

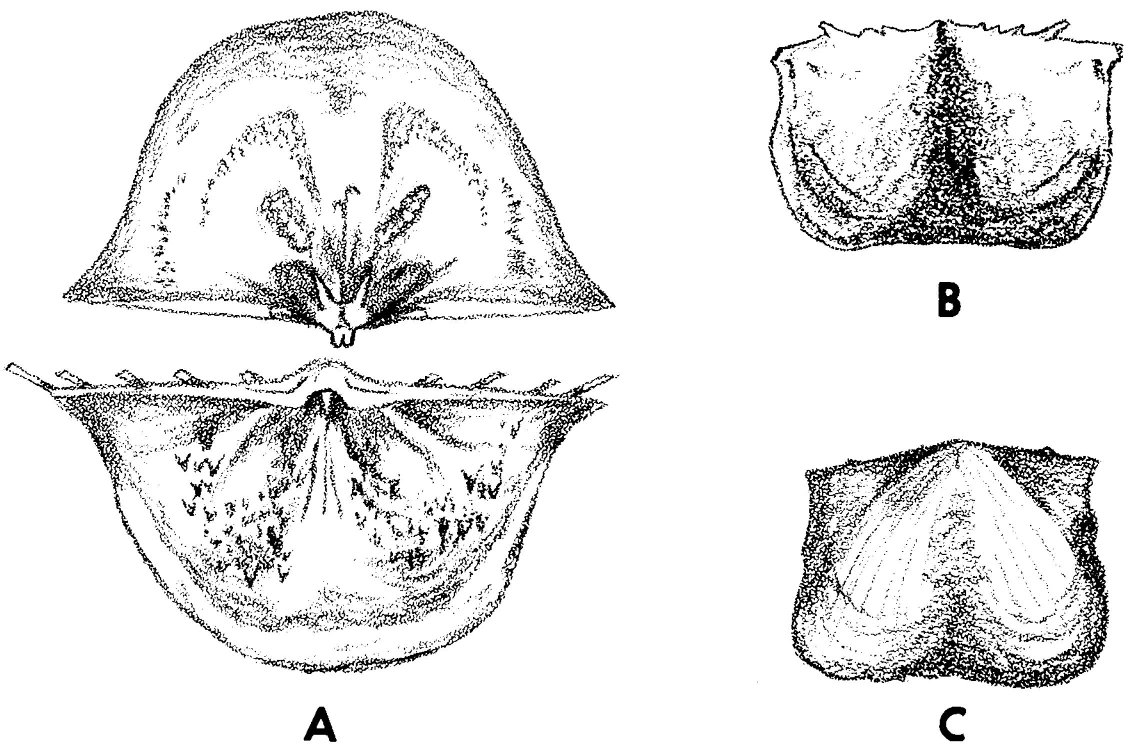


FIGURE 28. Chonetoid brachiopods. (A) *Neochonetes*, internal views of brachial (above) and pedicle (below) valves, X2. (B) *Lissochonetes*, a pedicle valve, X2. (C) *Chonetina*, a pedicle valve, X2.

valve. They are similar to productoids in outline but their semicircular shells are flat rather than inflated. Unlike productoids, chonetoids have a rudimentary tooth-socket arrangement. Their valves are frequently found *disarticulated* (broken apart). Internally they often have elaborate muscle scars and a large median septum (Fig. 24). Chonetoid brachiopods are usually much smaller than productoids and spiriferoids. Some chonetoid brachiopods of Nebraska are illustrated in Figure 28. *Neochonetes* (A) has rather flattened valves with fine spines covering the interior. *Chonetinella* resembles *Neochonetes* but has a deeply concave pedicle valve with a deep fold. *Lissochonetes* (B) has a rectangular outline and a shallow, concave, smooth pedicle valve. *Chonetina* (C) has a deeply concave, smooth pedicle valve.

Most orthoid brachiopods have very large beaks which they may have pressed into the soft mud of the sea bottom. Orthoids have highly inflated valves with short hinge lines. A few orthoid brachiopods of Nebraska are shown in Figure 29. *Enteletes* (A) has highly inflated, very coarsely plicated valves. *Rhipidomella* (B) is a small, nearly round brachiopod with fine costae.

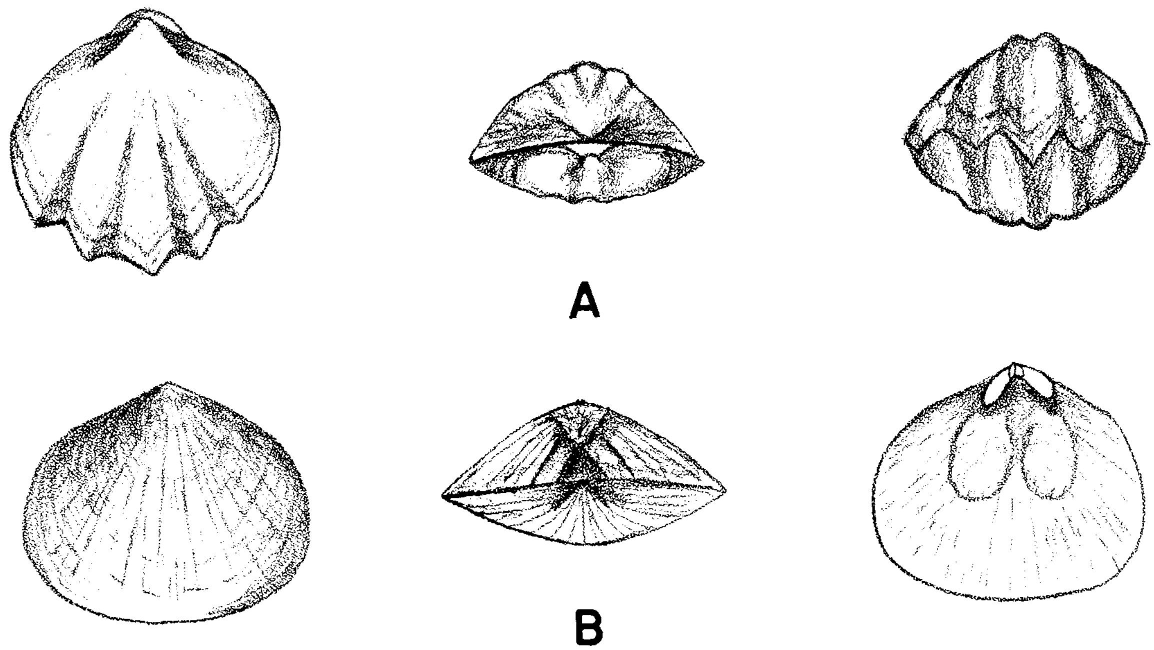


FIGURE 29. Orthoid brachiopods. (A) *Enteletes*, brachial valve, posterior and anterior views (left to right), X1. (B) *Rhipidomella*, pedicle valve, posterior view, and interior of brachial valve (left to right), X2.

Strophomenoid brachiopods often have pedicle openings that are filled with small calicte plates. These brachiopods probably remained immobile in the bottom muds. Strophomenoids usually have flattened valves with long hinge lines and fine costae. Examples of strophomenoid brachiopods from Nebraska are shown in Figure 30. *Derbyia* (A) has a large, semicircular shell. The pedicle opening of *Derbyia* is usually filled with small calcite plates and frequently shows strongly developed muscle scars and a median septum. *Meekella* (B) has a coarsely plicated shell and a highly inflated umbo and its pedicle opening is also filled.

Rhynchonelloid brachiopods are small and wedge-shaped with sharply pointed beaks and minute pedicle openings. They often have deeply plicated folds. In Nebraska they are represented only by *Wellerella* (Fig. 31A) which occurs in Pennsylvanian and Permian rocks.

Terrebratuloid brachiopods are ovate, smooth-shelled forms with a pedicle opening. Their food-gathering mechanism is supported by a loop (Fig. 31B). Terrebratuloids can be distinguished from atrypoid brachiopods only by this internal feature. *Beecheria*, the only important fossil terrebratuloid found in Nebraska, is shown in Figure 31.

Occurrence of Fossil Articulate Brachiopods in Nebraska

Articulate brachiopods can be collected in large numbers in southeastern Nebraska from Pennsylvanian and Permian rocks. Many of the groups are found together in the same rock unit. Spiriferoid, productoid, and chonetoid brachiopods are especially abundant in the Stoner Limestone at Louisville. Productoids and strophomenoids can be collected in great numbers from the Bonner Springs Shale and Merriam Limestone at Louisville and Cedar Creek. Well-preserved productoids and spiriferoids occur in the Stull Shale and Plattsmouth and Ervine Creek Limestones at Plattsmouth and Weeping Water. The Ervine Creek Limestone at Weeping Water and Union contains chonetoids, productoids, spiriferoids, rhynchonelloids,

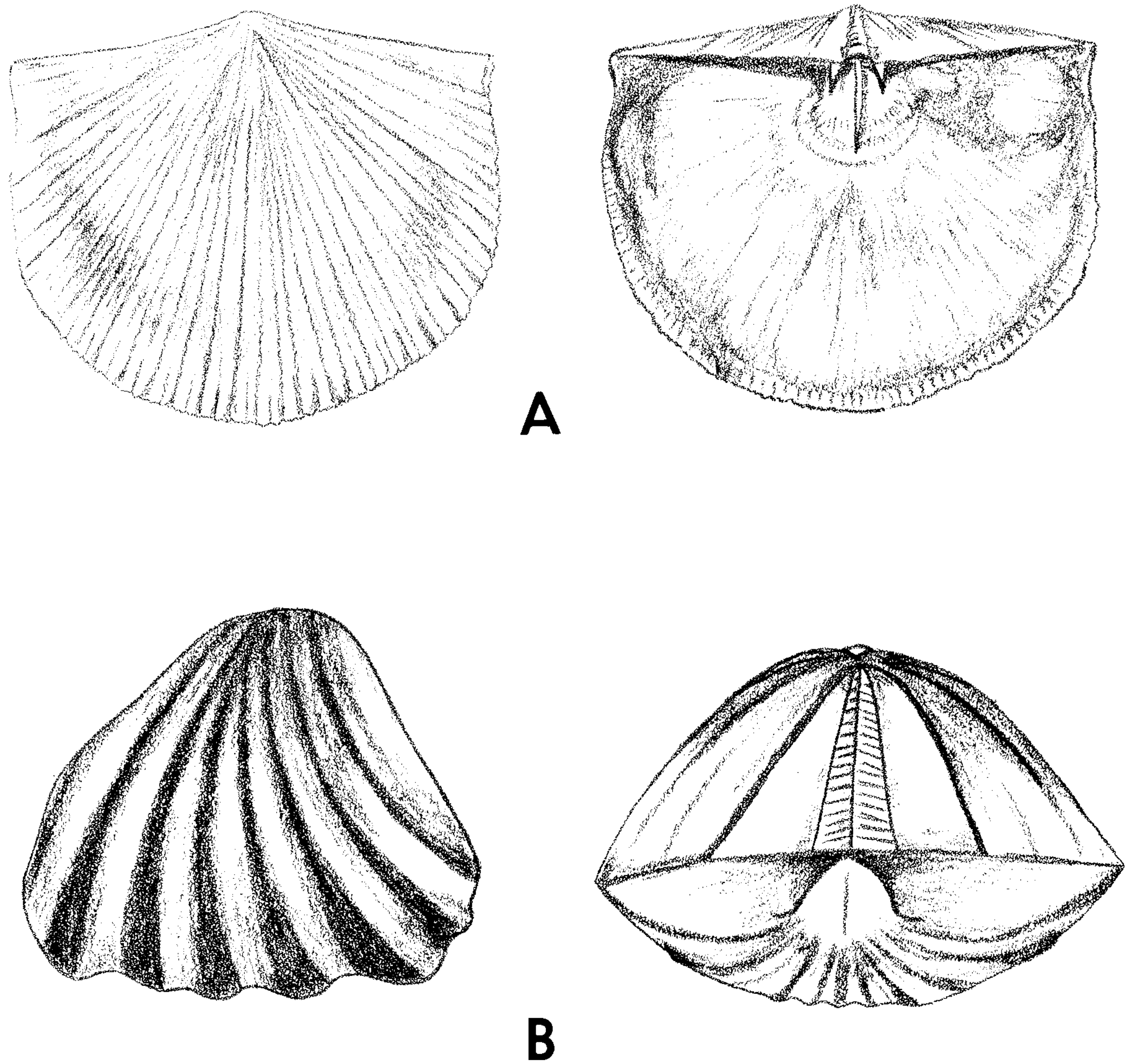


FIGURE 30. Strophomenoid brachiopods. (A) *Derbyia*, a pedicle valve, external view (left) and internal view (right), X1. (B) *Meekella*, pedicle valve (left) and posterior view (right), X1. Note the highly inflated umbo and small plates filling the pedicle opening.

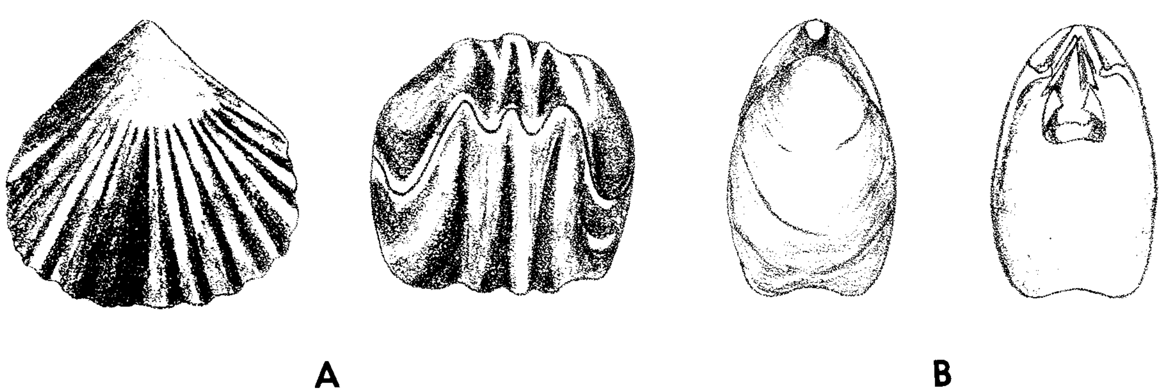


FIGURE 31. (A) A rhynchonelloid brachiopod, *Wellerella*, pedicle valve (left) and anterior view (right), X5. (B) A terrebratuloid brachiopod, *Beecheria*, brachial valve and posterior portion of pedicle valve, X1.

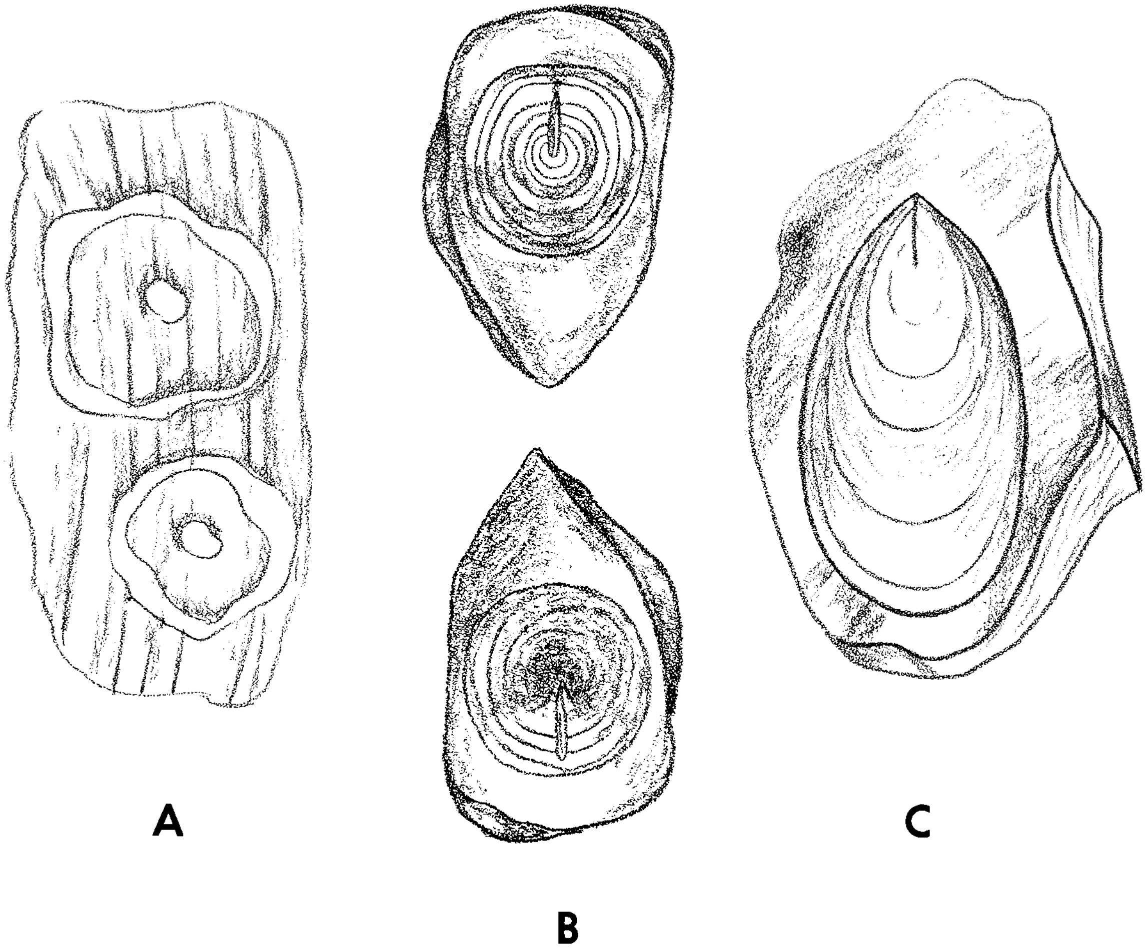


FIGURE 32. Inarticulate brachiopods. (A) *Crania*, two individuals attached to the pedicle valve of *Antiquatonia*, X2. (B) *Orbiculoidea*, imprints of an individual as they appear when found in black shale, X1. (C) *Lingula*, imprint of a pedicle valve on shale, X2.

and terrebratuloids. Terrebratuloids are found in the Stull Shale and Ervine Creek Limestone at Weeping Water and Plattsmouth. Spiriferoid and Chonetoid brachiopods are especially abundant in outcrops of Soldier Creek Shale near Unadilla. Strophomenoid, spiriferoid, and chonetoid brachiopods are quite common in outcrops of the Emporia Limestone at Table Rock and Elk Creek. Productoid and chonetoid brachiopods are abundant in the Canville Limestone at Fort Calhoun. Productoids are very common in the Severy Shale near Du Bois.

Permian rocks, such as the Hughes Creek Shale near Bennet and the Neva Limestone at Roca, contain abundant fossil brachiopods of all groups. Imprints of strophomenoid brachiopods occur in the Fort Riley Limestone near Wymore. Well-preserved brachiopods have been found in the Morrill and Cottonwood Limestones near Humboldt.

Articulate brachiopods have been described from well cores of Silurian Age rocks in Richardson, Cass, and Gage Counties. Pennsylvanian-age brachiopods occur in reworked chert cobbles in the Oligocene, Chadron Formation near Crawford.

Class Inarticulata

Inarticulate brachiopods have neither teeth nor sockets but have calcium phosphate shells. Inarticulate brachiopod fossils are found almost exclusively in black shales of the Pennsylvanian and Permian in southeastern Nebraska. Their shells are generally very fragile. Some have very long pedicles and dig deep burrows in the ocean floor. Some inarticulate brachiopods are found attached to the shells of larger articulate brachiopods. *Crania* (Fig. 32A) is a small, disk-shaped brachiopod often found attached to the brachial valve of the productoid brachiopod *Antiquitonia*. *Orbiculoidea* (Fig. 32B) has a coolie-cap-shaped shell and *Lingula* (Fig. 32C) has a tear-drop-shaped shell.

Occurrence of Inarticulate Brachiopods in Nebraska

Lingula and *Orbiculoidea* commonly occur in black shales such as the Eudora and Quindaro near Louisville; the Stark and Wea Shales near Richfield and Fort Calhoun; and the Larsh Shale near Union and Weeping Water; the Severy Shale near Du Bois; and

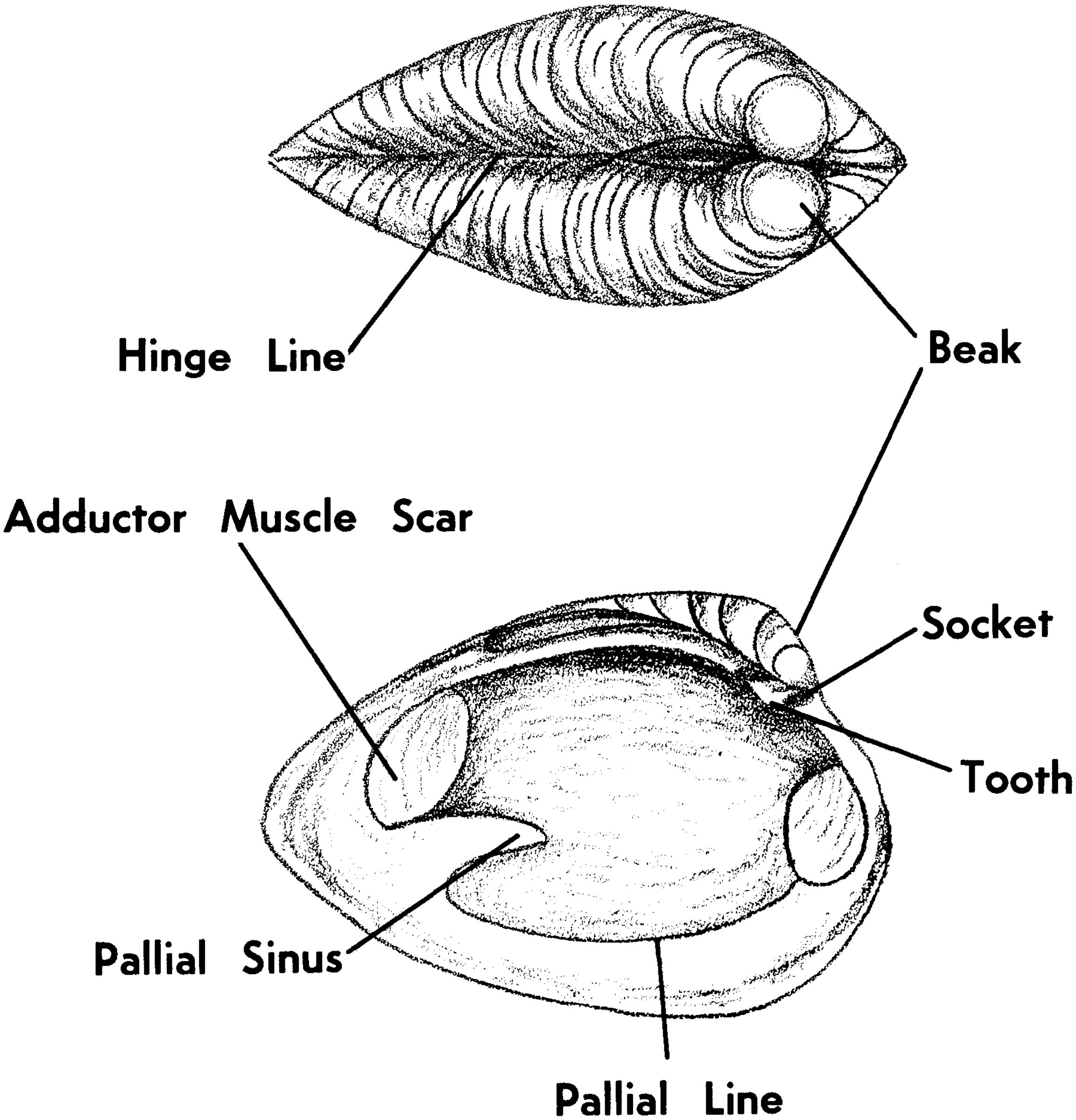


FIGURE 33. A typical bivalve shell showing some of the more important features used in classification. Dorsal view (above) and internal view of left valve (below).

the Hughes Creek Shale near Bennet. Inarticulate brachiopods are usually flattened in black shales. Undistorted specimens of both *Lingula* and *Orbiculoidea* occur in the Stull Shale near Weeping Water.

Crania occurs in the Permian Hughes Creek Shale near Bennet and is usually attached to the valves of large articulate brachiopods or large bivalves.

Only fragmentary inarticulate brachiopods have been recorded in Cretaceous strata of Nebraska.

Phylum Mollusca (Clams, Snails, Nautiloids, Ammonoids, Squids, and Octopi)

Molluscs comprise an important part of the fossil record in Nebraska since they are found in every age of exposed rock: Pennsylvanian, Permian, Cretaceous, Tertiary, and Pleistocene. Bivalves (clams) and gastropods (snails) live in both marine and fresh-water environments. Some gastropods are terrestrial. Nautiloids, ammonoids, and belemnites (the cephalopods) are found only in marine environments.

Class Bivalvia (Clams, Oysters, and Scallops)

The Living Bivalve

Bivalves, as the term implies, have two shells, or valves. In clams, the two shells are usually mirror images of each other. This is not true of oysters and scallops, however. Figure 33 shows some of the important features of a bivalve.

Each valve has a *beak* where growth began and which is surrounded by a series of concentric growth lines. The valves are commonly joined by *teeth* and *sockets* and an organic ligament. Their normal feeding position is with the valves held open by muscles. The *pallial line* marks the margin of the internal area which was occupied by the living animal. Some bivalves move freely about the bottom of a water body by means of a muscular foot. Others, such as scallops, swim by opening and closing their valves. Some make deep burrows and feed by filtering organic particles from the water.

In most cases, a bivalve can be properly oriented if the observer holds it in such a way that the beak points upward and away from himself. Then the *right valve* is in the right hand and the *left valve* in the left hand.

Bivalve shells typically have three layers: an outer organic layer to protect the shell, a middle calcite layer, and an inner *nacreous* or *mother-of-pearl* layer. The outer organic layer decays soon after the death of the organism and is almost never preserved as a fossil. The inner layer ordinarily changes from the mineral aragonite to the mineral calcite. The mother-of-pearl layer is preserved on many Cretaceous bivalves but is rarely, if ever, preserved on Pennsylvanian or Permian bivalves. Many of the older bivalve fossils of Nebraska are represented merely by casts or molds.

Guide to Pennsylvanian and Permian Bivalve Identification*

Pennsylvanian and Permian bivalves are roughly separable into two groups: those resembling modern clams and those resembling modern scallops. In the latter group, the scallop-like bivalves simply resemble scallops. It is not to be assumed that these bivalves were true scallops or even closely related to them.

Clam-like bivalves (Figure 34). *Wilkingia* (A) has a nearly oval shell with a short anterior end and concentric growth lines; its valves are rarely found separated. *Septimyalina* (B) has a triangular-shaped shell, a very long hinge line, and an extremely elongated beak. *Myalina* (C) has a sharply pointed beak, a short hinge line, and a semi-oval shell with the margins at about right angles to the hinge line. *Myalina* is frequently bored by sponges, or encrusted with foraminiferans, ectoprocts, or algae. *Parallelodon* (D) has a long, straight hinge line, and the anterior and posterior margins of the valves are nearly parallel to each other. *Anthraconeilo* (E) has an oval shell with a slightly curved hinge line, and numerous small teeth and sockets. *Anthraconeilopsis* (F) has a short, oval shell with a straight hinge line and a tiny beak. *Edmondia* (G) has a small, oval shell with a large beak and strong, sharp, concentric ornamentation. *Permophorous* (H) has an elongate, swollen shell with a long hinge line and a large beak. *Volsellina* (I) has a nearly tear-drop-shaped outline, with a blunt anterior beak and closely spaced growth lines; there is an angulation between the anterior and posterior portions of the shell. *Schizodus* (J) has a tear-drop-shaped outline, a large beak, a short hinge line, and fine, concentric ornamentation. *Astartella* (K) has a nearly trapezoidal outline, with very coarse, concentric ornamentation. *Aviculopinna* (L) is a large "razor clam" (a clam having a shell with the outline of a straight-edged razor) that may grow to three feet in length. *Aviculopinna* has a long hinge line with numerous perpendicular growth lines. *Yolida* (M) is a small bivalve with a large beak, fine growth lines and a deep pallial sinus. *Yolida* often occurs only as a steinkern. *Nuculana* (N) closely resembles *Yolida* but has a very shallow pallial sinus. *Nuculana* often occurs only as a steinkern. *Nucula* (O) has a small shell that varies in outline from triangular to circular, but which always has a very large beak. *Promytilus* (P) has an elongated beak and a nearly smooth shell ornamented with only a few growth lines.

Scallop-like bivalves (Figure 35). *Aviculopecten* (A) is typified by having a strong radial ornamentation. *Pteria* (B) has a very long hinge line which is extended to form a posterior wing-like stricture. *Pernopecten* (C) has smooth, unornamented valves. *Clavicosta* (D) has large radial ribs that may extend posteriorly to form long spines, and which are separated by fine ribs. *Lima* (E) has large, evenly spaced radial ribs. *Acanthopecten* (F) has large, angular, radial ribbing and a saw-tooth-like margin. *Pseudomontis* (G) has a blunt beak and coarse, scaly radial ornamentation. *Dunbarella* (H) is nearly circular in outline, has a long hinge line, and evenly spaced radial ribs.

Occurrence of Pennsylvanian and Permian Bivalves in Nebraska

Fossil bivalves are common in both the Pennsylvanian and Permian rocks of Nebraska. Most of them are easy to identify and form an important part of the fossil record. Although there are many occurrences of bivalves in Nebraska, only the noteworthy ones are listed below.

Bivalves have been collected from quarries near Richfield. These include: *Schizodus* from the Bethany Falls Limestone; and *Pseudomontis*, *Wilkingia*, and *Acanthopecten* from the Winterset and Westerville Limestones. *Volsellina*, *Yolida*, and *Septimyalina* occur in the Winterset Limestone near Cedar Creek. *Wilkingia* and *Schizodus* have been collected from the Winterset and Drum Limestones and Quivira Shale near Louisville and Cedar Creek.

Wilkingia, *Aviculopinna*, and *Myalina* occur in the Chanute Shale near Cedar Creek and Louisville. A number of very large specimens of *Aviculopinna*, some as long as three feet, have been collected from the Iola Limestone near Louisville, Richfield, and Cedar Creek. *Aviculopecten*, *Aviculopinna*, *Edmondia*, *Septimyalina*, and *Schizodus* occur in large quantities in the Argentine and Farley Limestones near Louisville and Plattsmouth.

A notable faunule of fossil bivalves occurs in the

*The reader must keep in mind that the identification guides are to be used strictly for the purposes of identifying fossils. In no way are any relationships between different genera implied in the identification keys.

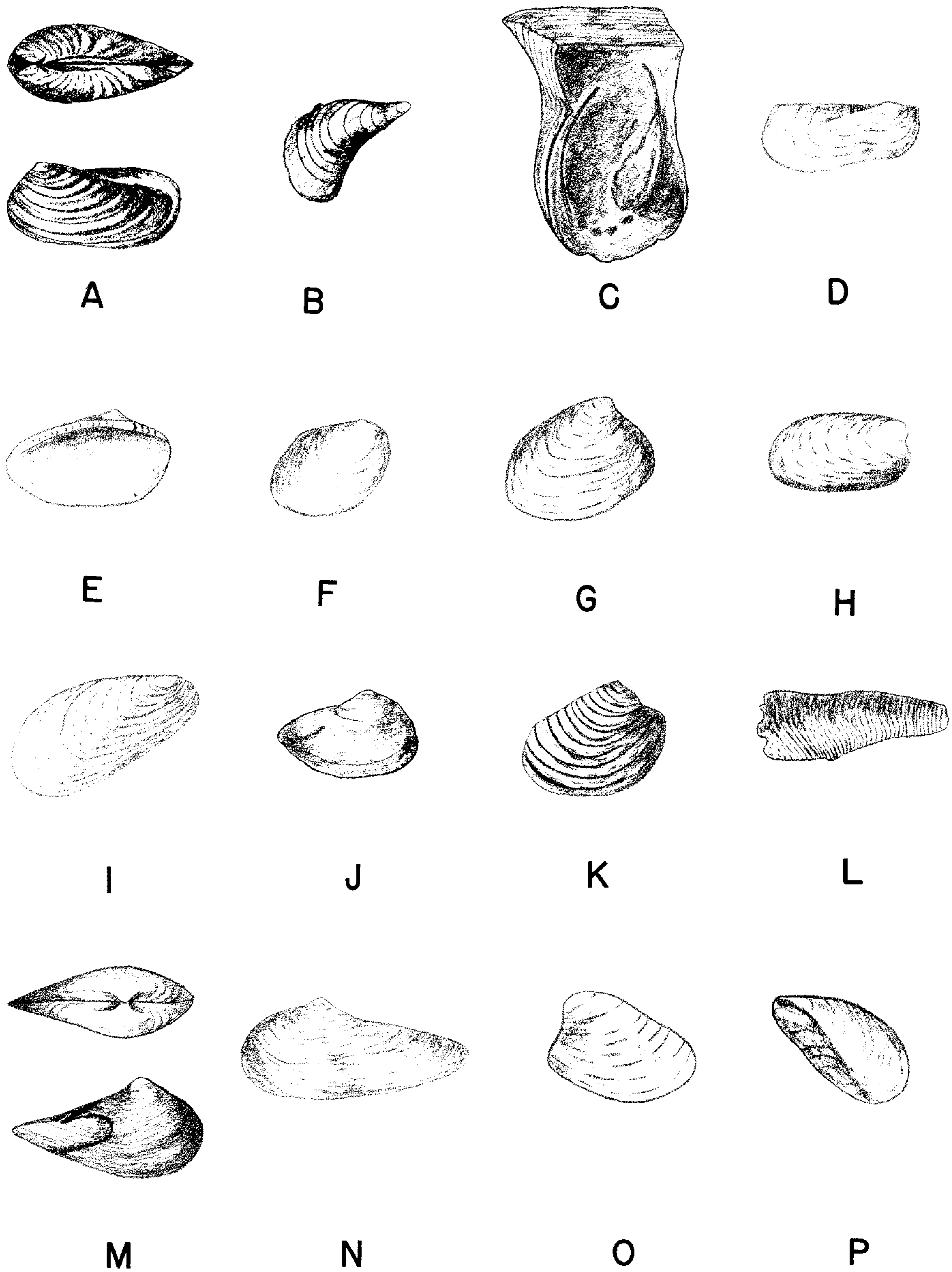


FIGURE 34. Pennsylvanian and Permian clam-like bivalves. (A) *Wilkingia*, dorsal view (above) and exterior of left valve (below), X1½. (B) *Septimyalina*, exterior of right valve, X1. (C) *Myalina*, interior of right valve. X1. (D) *Parallelodon*, exterior of right valve, X1. (E) *Anthraconeilo*, interior of left valve, X1. (F) *Anthraconeilopsis*, exterior of right valve, X1. (G) *Edmondia*, exterior of right valve, X1. (H) *Permophorous*, exterior of right valve, X1. (I) *Volsellina*, exterior of right valve, X1⅓. (J) *Schizodus*, steinkern of interior of right valve, X1. (K) *Astartella*, exterior of right valve, X1. (L) *Aviculopinna*, exterior of a partial section of a left valve, X1/10. (M) *Yolida*, steinkerns of dorsal (above) and right valve (below), X1. (N) *Nuculana*, steinkern showing left valve, X1. (O) *Nucula*, exterior of left valve, X1. (P) *Promytilus*, exterior of left valve, X1⅓.

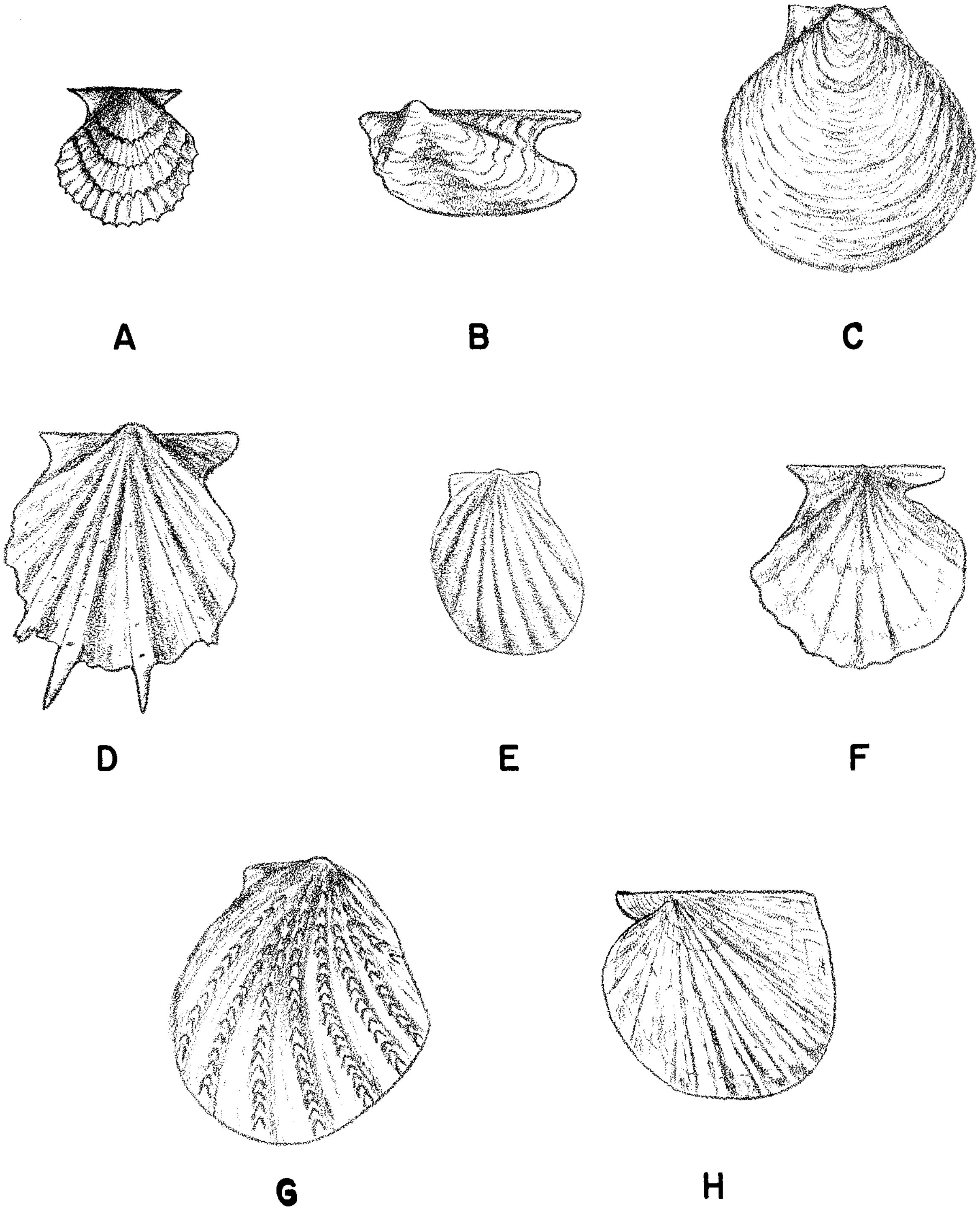


Figure 35. Pennsylvanian and Permian scallop-like bivalves. (A) *Aviculopecten*, X½. (B) *Pteria*, left valve, X½. (C) *Pernopecten*, X1. (D) *Clavicosta*, X1. (E) *Lima*, X½. (F) *Acanthopecten*, X1. (G) *Pseudomontis*, X1. (H) *Dunbarella*, X1.

Bonner Springs Shale near Louisville. Included are *Schizodus*, *Myalina*, *Yolida*, *Nuculana*, *Aviculopecten*, *Permophorous*, and *Anthraconeilo*. This fauna is unusual as the fossil bivalves are much smaller than they normally are in other horizons and areas.

The Cass and Toronto Limestones which are exposed in quarries near South Bend, Ashland, Weeping Water, and Nehawka contain a large variety of fossil bivalves. These include many well-preserved specimens of *Edmondia*, *Wilkingia*, *Aviculopinna*, *Astartella*, *Nucula*, *Permophorous*, *Acanthopecten*, *Aviculopecten*, *Pteria*, and *Clavicosta*.

A large variety of fossil bivalves have been collected from the Stull and Doniphan Shales near Weeping Water, Nehawka, and Plattsmouth. The scallop-like bivalves in these units are represented by *Aviculopecten*, *Acanthopecten*, *Pernopecten*, *Pseudomontis*, and *Lima*. Clam-like bivalves include *Septimyalina*, *Edmondia*, *Myalina*, *Schizodus*, *Wilkingia*, *Aviculopinna*, *Yolida*, *Promytilus*, and *Astartella*.

An impressive variety of bivalves also occurs in the Rakes Creek Shale which is exposed near Plattsmouth and Weeping Water. One can find fossils of *Nucula, Edmondia, Astartella, Myalina, Schizodus, Wilkingia, Permophorous, Aviculopecten, Acanthopecten, Pseudomontis,* and *Pteria.*

Parallelodon, Yolida, Edmondia, Wilkingia, Astartella, Aviculopecten, Pteria, and *Acanthopecten* occur in the Ervine Creek Limestone and Larsh Shale near Weeping Water, Union, and Plattsmouth. These fossils occur as imprints in soft shale but sufficient detail is present to make identification easy. The Jones Point Shale, which is exposed near Union, contains all of the above fossil bivalves, as well as *Myalina, Permophorous,* and *Lima.*

Some exceptionally large specimens of *Wilkingia, Edmondia, Schizodus,* and *Aviculopecten* occur in the Sheldon Limestone near Union.

Aviculopinna, Myalina, Permophorous, Wilkingia, Pteria, Aviculopecten, Lima, and *Pseudomontis* have been found in the Du Bois Limestone near Du Bois and Union. *Permophorous, Myalina, Astartella, Aviculopecten, Dunbarella, Acanthopecten, Septimyalina, Aviculopinna, Wilkingia, Edmondia, Pseudomontis,* and *Yolida* occur in the Severy Shale and Howard Limestone near Du Bois.

In the vicinity of Table Rock, one can find fossils of *Yolida, Schizodus, Wilkingia, Myalina, Parallelodon, Edmondia, Lima,* and *Acanthopecten* in the Winnebago Shale which is exposed along road cuts and in the abandoned brick-pit quarries.

Wilkingia, Yolida, Edmondia, Permophorous, Nucula, Myalina, Astartella, Lima, and *Pernopecten* have been reported from the Soldier Creek Shale at Nebraska City and Unadilla.

The Auburn Shale which is exposed in the vicinity of Nebraska City and Table Rock contains a large variety of fossil bivalves, including *Myalina, Nucula, Astartella, Edmondia, Pseudomontis,* and *Acanthopecten.* Some very large specimens of *Wilkingia* have been collected in the Reading Limestone near Tecumseh.

The Emporia Limestone and Willard Shale are exposed near Dunbar, Nebraska City, Elk Creek, and Tecumseh and these units contain the following bivalve fauna: *Aviculopecten, Dunbarella, Acanthopecten, Edmondia, Myalina, Wilkingia, Schizodus, Pinna, Yolida, Anthraconeilo, Astartella, Permophorous, Parallelodon,* and *Volsellina.*

Most of the genera of bivalves that lived in the Pennsylvanian period continued onward into the Permian period. The earliest Permian bivalves in Nebraska occur in the Aspinwall Limestone and Hawxby Shale which are exposed near Dunbar and Brownville. These early Permian bivalves include *Aviculopecten, Permophorous, Wilkingia, Edmondia, Aviculopinna,* and *Schizodus.*

The Stine Shale, exposed in abandoned quarries near Syracuse, Salem, and Pawnee City, contains a large number of fossil bivalves. These include *Wilkingia, Myalina, Volsellina, Aviculopinna, Edmondia, Lima, Pseudomontis,* and *Aviculopecten.*

The Hughes Creek Shale near Bennet contains only a small variety of bivalves, in sharp contrast to the diversity of the other classes. These bivalves include *Nuculana, Myalina,* and *Wilkingia.*

Volsellina, Wilkingia, and *Aviculopecten* have been reported from the Neva Limestone near Roca. *Myalina, Aviculopecten,* and *Pseudomontis* have been found in the Florence Limestone near Holmesville and Wymore.

The scarcity of Permian bivalve occurrences in Nebraska is probably a reflection of shortage of collections and data, since large and diverse faunas of Permian bivalves have been collected from rocks of the same age in neighboring states.

Guide to Cretaceous Bivalve Identification

Cretaceous bivalves can be separated roughly into three groups: those resembling modern clams, those resembling modern scallops, and the oysters.

Clam-like bivalves (Figure 36). *Brachidontes* (A) has a long, straight hinge line, a large beak, and radial ornamentation. *Cyrena* (B) has a small, triangular shell with a large beak and concentric ornamentation. *Callista* (C) has a small, oval shell, concentric ornamentation, and often occurs only as a steinkern. *Margaritana* (D) has an oval shell with a large beak from which several large undulations extend posteriorly. *Leptosolen* (E) has an elongated, oval shell with a small, blunt beak, and concentric growth lines. *Mactra* (F) has a triangular shell with a prominent beak and evenly spaced, concentric ornamentation. *Anomia* (G) has a thin, nearly circular or irregular shell, a large rounded beak, and fine concentric ornamentation. *Pharella* (H) has an elongated, oval shell with nearly parallel sides, a very small, centrally located beak, and concentric growth lines. *Inoceramus* (I) has a long, straight hinge line and prominent, concentric undulations. *Thetis* (J) has a very thin, nearly circular smooth shell with a large, forward-curved beak. *Trigonarca* (K) has a long, straight hinge line, a large beak, and radial and concentric ornamentation.

Scallop-like bivalves (Figure 37). *Pteria* (A, B) has a long hinge line and may have either a smooth or radially sculptured shell. *Pteria (Pseudoptera)* (C) has radial ornamentation but the hinge line does not extend to form the wing-like structures common to *Pteria. Chlamys* (D) has a relatively short hinge line and coarse, radial ornamentation.

Oysters (Figure 38). *Exogyra* (A) has a deep, spiral shell; its beak points outward; and it is concentrically ornamented with many rough growth lines. *Gryphea* (B) resembles *Exogyra* but the shell has a much

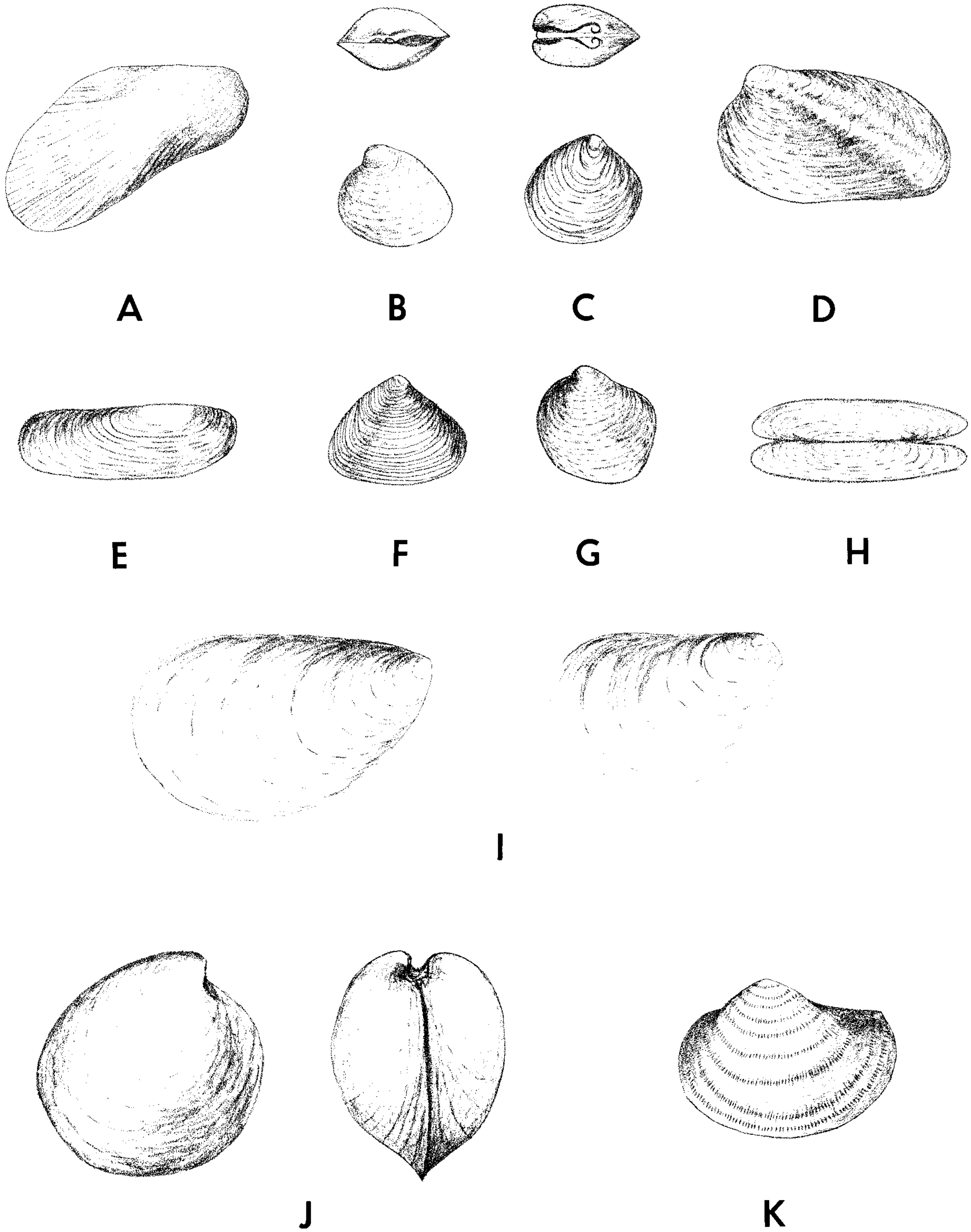


FIGURE 36. Cretaceous clam-like bivalves from Nebraska. (A) *Brachidontes*, right valve, X3. (B) *Cyrena*, dorsal view (above) and left valve (below), X1. (C) *Callista*, posterior view (above) and right valve (below), X1. (D) *Margaritana*, left valve, X1. (E) *Leptosolen*, right valve, X1. (F) *Mactra*, right valve, X1. (G) *Anomia*, left valve, X1. (H) *Pharella*, opened pair of valves, X1. (I) *Inoceramus*, left valves of two species, X½. (J) *Thetis*, a right valve (left) and posterior view (right), X2. (K) *Trigonarca*, a left valve, X1.

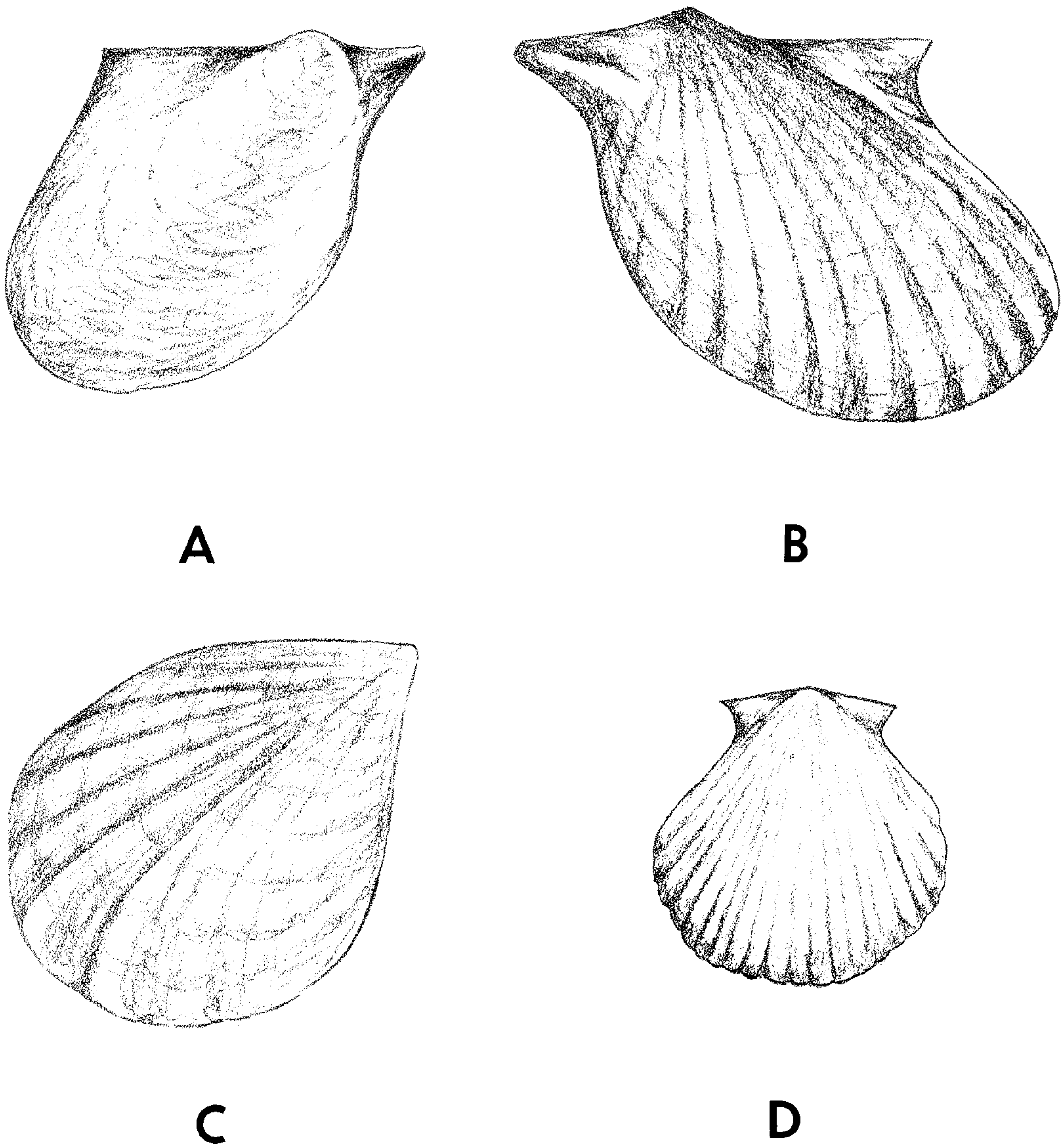


FIGURE 37. Cretaceous scallop-like bivalves from Nebraska. (A) *Pteria*, a right valve, X1. (B) *Pteria*, a different species, left valve, X1. (C) *P.* (*Pseudoptera*), X1. (D) *Chlamys*, a left valve, X1.

smoother surface. *Ostrea* (C) occurs as many tightly-squeezed, irregularly shaped individuals often attached to the shells of larger bivalves, especially *Inoceramus*.

Occurrence of Cretaceous Bivalves in Nebraska

Margaritana occurs associated with *Cyrena* ". . . opposite Sioux City, on the Missouri River, in Dakota County, Nebraska . . ." (Meek, 1876, p. 115, *see* Appendix). *Mactra* occurs in sandstones of the Dakota Group in Dakota County. *Pharella* occurs in the Dakota Group in Dixon County across from the mouth of the Vermillion River. *Brachidontes* and *Leptosolen* have been found in shales in the Dakota Group in Jefferson County, near Fairbury and Endicott. The above genera of Cretaceous bivalves contain fresh, brackish, and marine water species. The fresh and brackish water species have been useful in determining the location of the shore line of the Cretaceous sea. The appearance of marine species shows the transgression of the late Cretaceous sea.

The oyster *Exogyra* occurs in Dakota Group Sandstones in Jefferson County, near Fairbury. The oyster *Gryphea* occurs in the Greenhorn Limestone near Gilead, in Thayer County.

Inoceramus occurs in the Greenhorn Limestone in Dakota, Thurston, Saunders, Seward, Saline, Jefferson, and Thayer Counties. Gypsum replacements of shells of *Inoceramus* (Fig. 39) occur in the Carlile Shale in

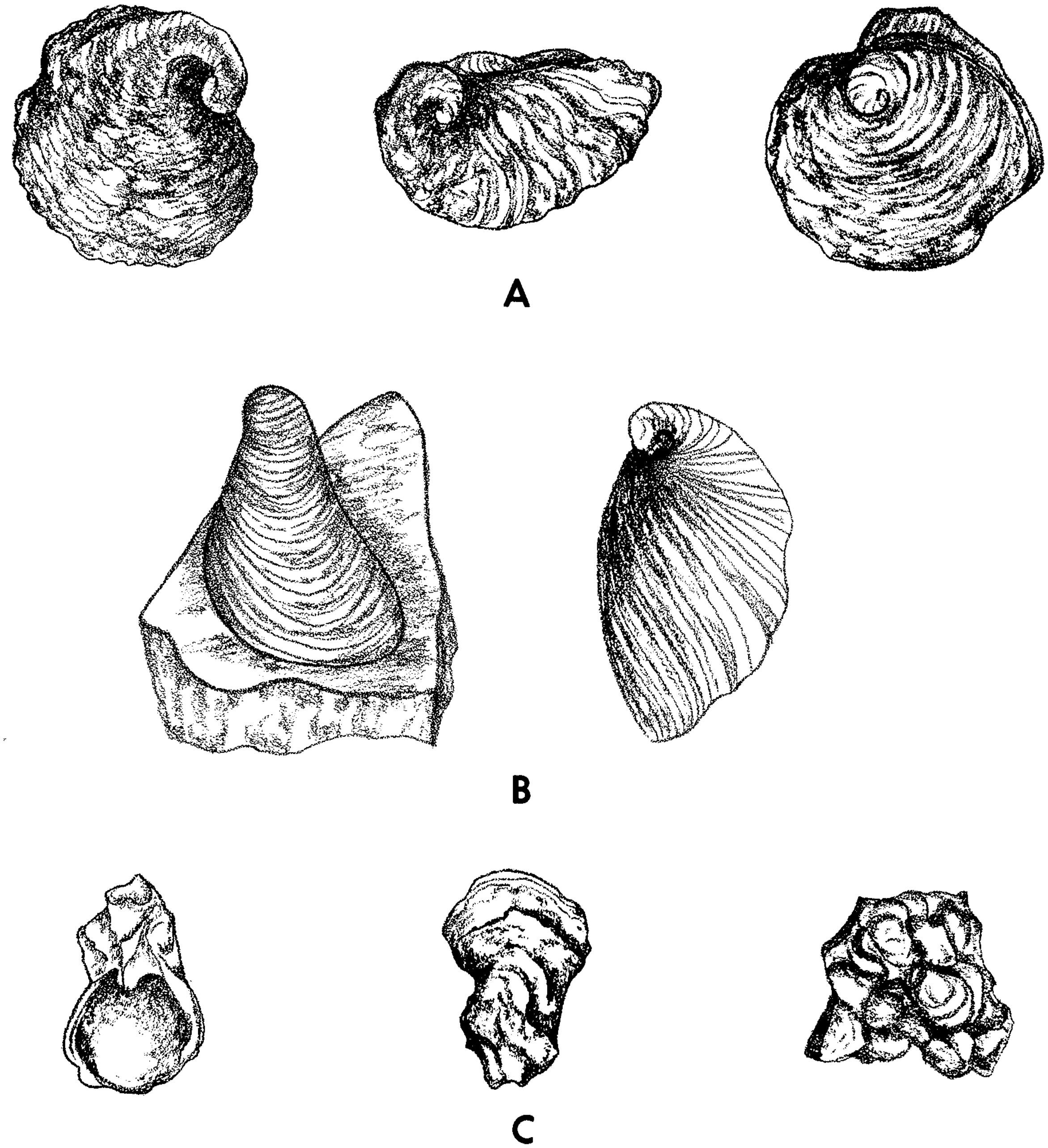


FIGURE 38. Cretaceous oysters from Nebraska. (A) *Exogyra*, three views, X½. (B) *Gryphea*, two views, X½. (C) *Ostrea*, two views (left, center) of single shells, and cluster of shells (right) attached to a shell fragment of a larger bivalve, X½.

Nuckolls and Thayer Counties. These specimens are poorly preserved and appear as thin seams of gypsum in the outcrop. *Inoceramus* also occurs in the Niobrara Chalk in Knox and Harlan Counties and specimens are frequently covered with numerous small oysters, *Ostrea*. *Inoceramus* has also been collected from the Pierre Shale near Chadron and north of Crawford.

Callista and *Anomia* occur in the Niobrara Chalk in Knox and Cedar Counties.

Thetis and *Trigonarca*, and all of the scallop-like Cretaceous bivalves have so far been reported only from the Pierre Shale near Chadron and Crawford. It is likely that future workers will find many more genera of Cretaceous bivalves in Nebraska.

Occurrence of Pleistocene Bivalves in Nebraska

Only a few genera of fossil fresh-water, river clams have been reported from Nebraska. Many more genera probably exist in the Pleistocene deposits of Nebraska. This field has been studied but slightly.

Sphaerium (Fig. 40A) has a trapezoidal outline and a long hinge line. *Pisidium* (Fig. 40B) is tear-drop-shaped and has a short hinge line. Both genera have been reported from Pleistocene terrace fills. (*See* Occurrences of Pleistocene gastropods in Nebraska.)

Class Gastropoda (Snails, Slugs)

Gastropods are commonly called *snails*. Snails with small internal shells are called *slugs*. They may have

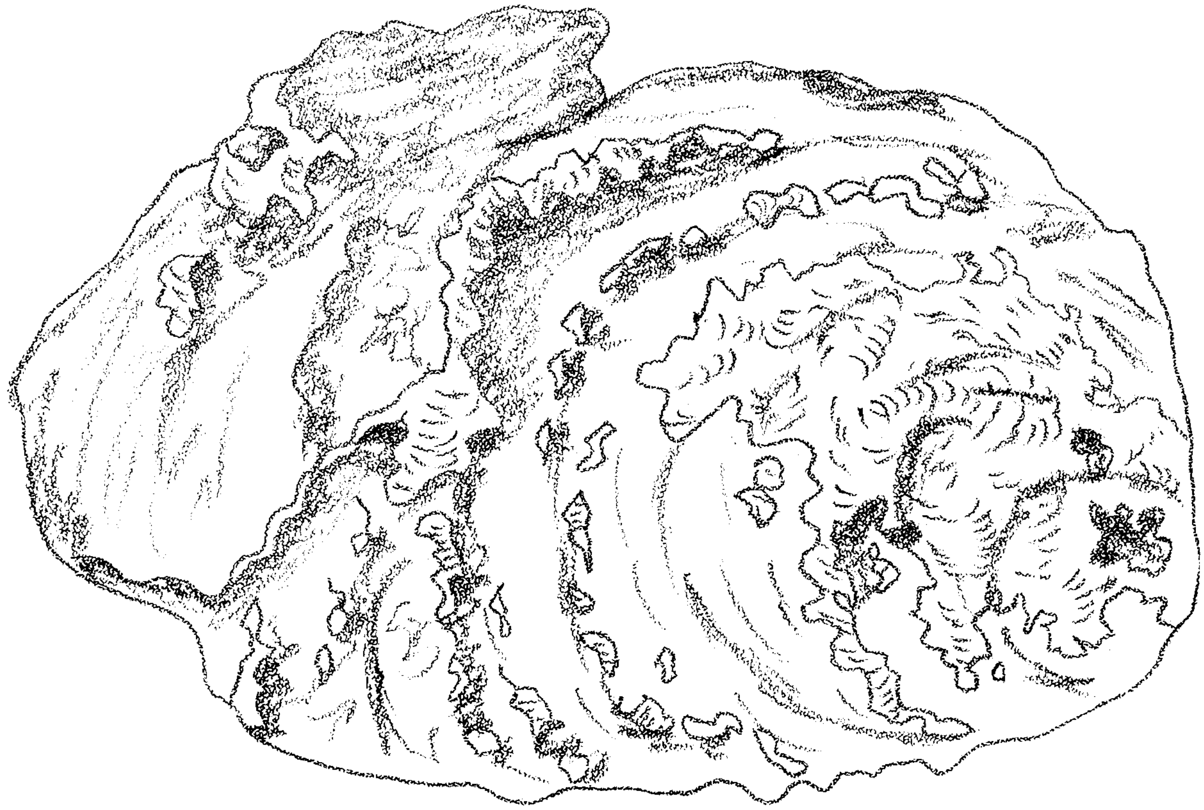
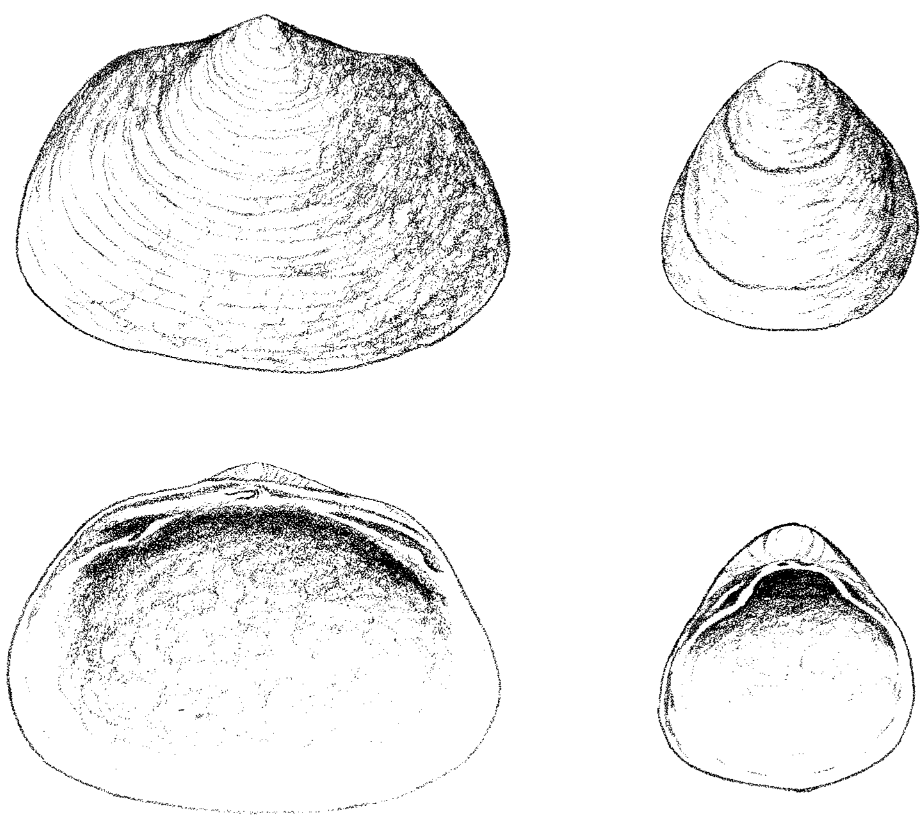


FIGURE 39. A gypsum replacement of a left valve of *Inoceramus*, X1. Note that the preservation is very poor and that the bivalve outline, though present, is masked by crystal growth.



A **B**

FIGURE 40. Pleistocene bivalves from Nebraska. (A) *Sphaerium*, exterior of left valve (above) and interior of right valve (below), X6. (B) *Pisidium*, exterior view of left valve (above) and interior view of right valve (below), X4.

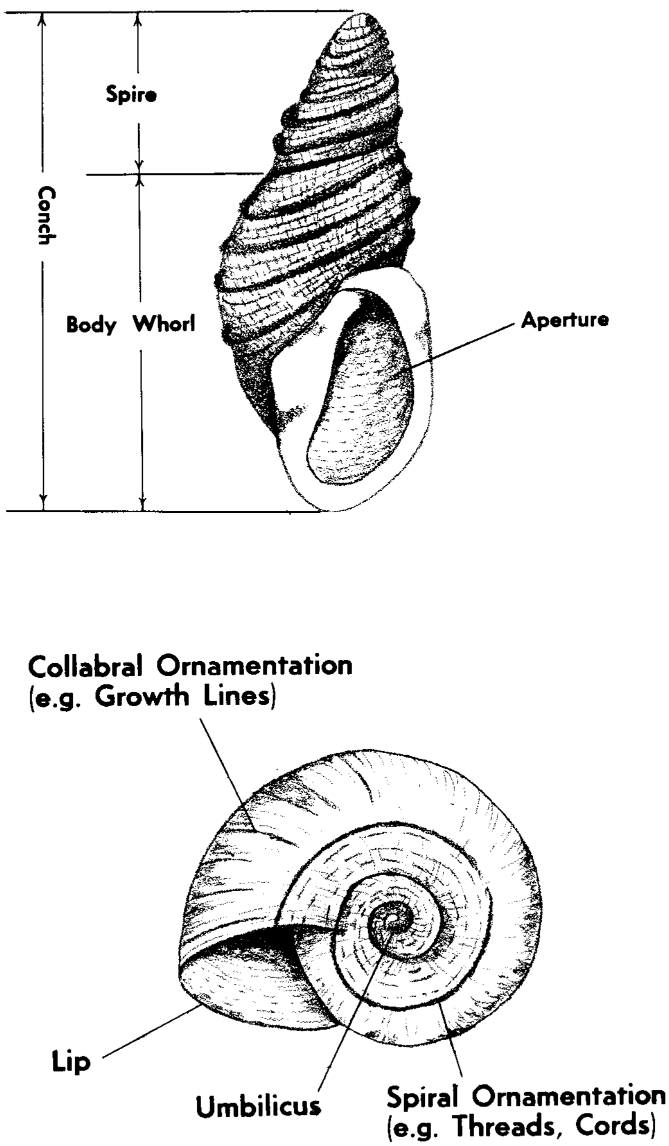


FIGURE 41. Idealized gastropods showing some of the features used for classification.

a spired shell, a cone-shaped shell, an internal shell, or no shell at all. Figure 41 shows some of the more important features of the shell. A complete revolution of the shell about the axis of coiling is called a *whorl*. The last complete whorl is called the *body whorl*, and all of the smaller whorls form the spire. The *umbilicus* is a hollow along the axis of coiling. *Spiral ornamentation*, as *cords* (coarse) and *threads* (fine) follow the whorls about the axis of coiling. *Collabral* or *radial ornamentation* (as growth lines) is essentially "perpendicular" to spiral ornamentation, or "parallel" to the *lip* about the aperture. Such ornamentation is important in gastropod classification.

Guide to Pennsylvanian and Permian Gastropod Identification

For the purposes of this booklet only, a practical key to the identification of Pennsylvanian and Permian gastropods has been devised. The key is based on the relative height of the spire. There are four groups of gastropods, as follows: (1) gastropods with symmetrical shells (e.g. *Bellerophon*); (2) gastropods with low-spired shells (e.g. *Straparollus*); (3) gastropods with medium-spired shells (e.g. *Phymatopleura*); and (4) gastropods with high-spired shells (e.g. *Palaeostylus*).

Symmetrical gastropods (Figure 42). *Bellerophon* (A) is a common genus that is typified by having very closely spaced growth lines. *B.* (*Pharkidonotus*) resembles *Bellerophon* but has an undulating ornamentation. *Knightites* (B) has a peculiar paired ornamentation that may have housed canals for passing oxygenated water to the soft body of the animal. *Euphemites* (C) has approximately ten spiral cords which reach far into the whorls but do not reach to the aperture. *Warthia* (D) closely resembles *Euphemites* (C) but lacks ornamentation. *Retispira* (E) has ornamentation consisting of growth lines and the lip around the aperture does not flare out as it does in *Knightites*.

Low-spired gastropods (Figure 43). *Straparollus* (*Straparollus*) (A) has a discoid to low-spired shell with a very deep umbilicus and only a slight shoulder along the outer, upper margin. *S.* (*Amphiscapha*) (B) also has a flat discoid-shaped shell, but has a concave "spire" and a rough ridge or shoulder along the outer, upper margin. S. (*Euomphalus*) (C) has a sub-discoidal shell with a concave or slightly elevated spire, a shoulder on the outer, upper edge, and is commonly ornamented with fine growth lines.

Omphalotrochus (D) has a low-spired shell with a moderately wide umbilicus and a lip with a broad, rounded sinus.

Anomphalus (E) has a low-spired shell that ranges from having a completely sealed umbilicus to having a very broad, opened one. It has rounded, deeply embraced whorls, and only very faint growth lines.

Trepospira (F) has a lenticular-shaped shell with a very small umbilicus. It has a single row of small nodes just below the upper suture.

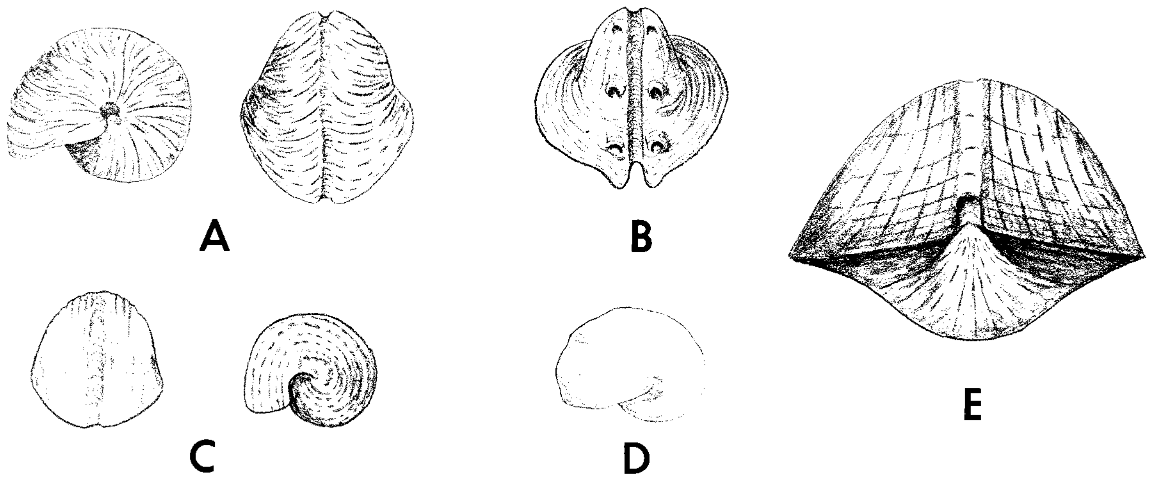


FIGURE 42. Pennsylvanian and Permian symmetrical gastropods. (A) *Bellerophon*, side (left) and dorsal (right) views, X2. (B) *Knightites*, dorsal view, X2. (C) *Euphemites*, dorsal (left) and side (right) views, X2. (D) *Warthia*, side view, X2. (E) *Retispira*, anterior view, X4.

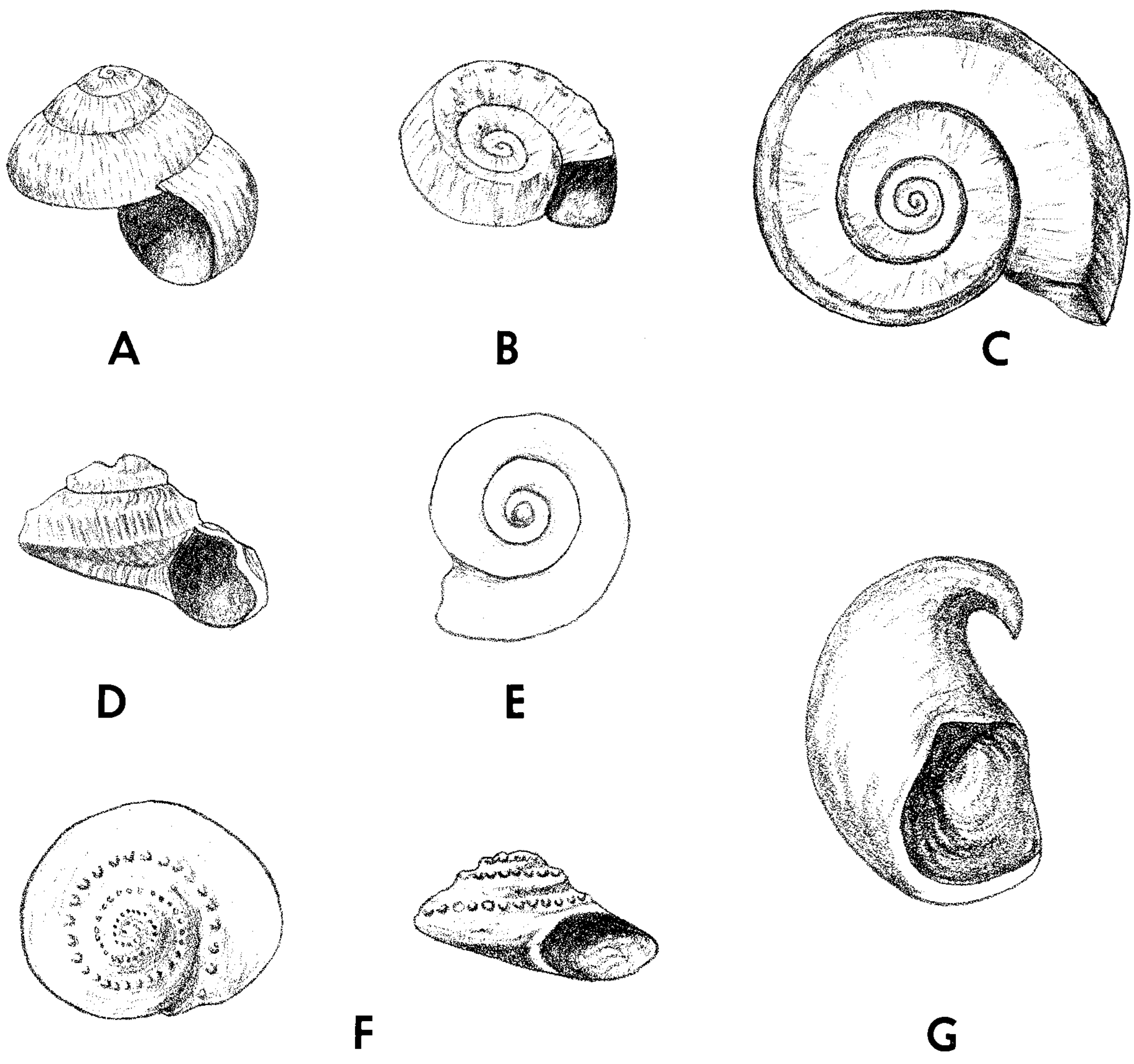


FIGURE 43. Pennslyvanian and Permian low-spired gastropods. (A) *Straparollus* (*Straparollus*), anterior view, X1. (B) *S.* (*Amphiscapha*), anterior view, X1. (C) *S.* (*Euomphalus*), dorsal view, X2. (D) *Omphalotrochus*, anterior view, X1. (E) *Anomphalus*, dorsal view, X2. (F) *Trepospira*, dorsal (left) and anterior (right) views, X1. (G) *Platyceras*, anterior view, X2.

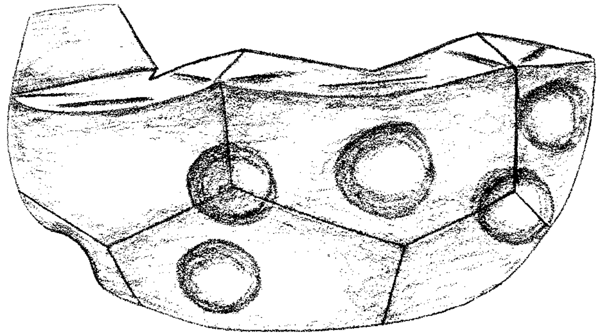


FIGURE 44. Side view of a cup of *Graffhamicrinus*, showing borings attributed to the gastropod *Platyceras*.

Platyceras (G) is an inornate gastropod resembling a horn-of-plenty. *Platyceras* frequently has been found attached to the anal areas of crinoids, especially *Stellarocrinus*, and less frequently, to the anal area of sea urchins. Borings attributed to the gastropod *Platyceras* are frequently found on cups of the crinoid *Graffhamicrinus* (Fig. 44).

Medium-spired gastropods (Figure 45). *Naticopsis* (*Naticopsis*) (A) has a large globular shell with a slightly protruding spire and is ornamented only with very fine growth lines. *Colpites* (B) resembles *Naticopsis* but has a row of nodes just below the upper suture. *Trachydomia* (C) resembles *Naticopsis* but has small nodes covering its entire upper surface. *Ianthinopsis* (D) has faint spiral ridges and a highly variable spire, some individuals having globular shells with a pointed apex and others having shells with high spires.

Amaurotoma (E) has a turban-like (turbanate) shell which is ornamented with several rows of strong spiral cords and fine threads between the cords. *Rhabdotochilus* (F) has strong spiral cords like *Amaurotoma* but lacks the fine threads between the cords and is usually quite small. *Araeonema* (G) resembles *Rhabdotochilus* but is ornamented only with faint spiral threads or is inornate.

Glabrocingulum (*Glabrocingulum*) (H) has a conical spire and an umbilicus and is ornamented with spiral threads and nodes. *Phymatopleura* (I) has a turbanate shell with sharp spiral threads and one or more rows of spiral nodes. *Dictyomaria* (J) has a turbanate shell and deep sutures with spiral and collabral threads which give a checkered appearance to the shell. *Pleurotomaria* (K) has a turbanate shell without an umbilicus, has flattened whorls, and spiral cords and tubercles along the shoulders.

Baylea (L) is a turbanate form ornamented with strong threads and spiral cords. *Hypselentoma* (M) resembles *Baylea* but is ornamented only with spiral threads on the sides. *Worthenia* (N) resembles *Hypselentoma* and *Baylea* but is highly ornamented with both spiral and collabral threads.

High-spired gastropods (Figure 46). *Anematina* (A) is a high-spired, unornamented form with a small umbilicus. *Hemizyga* (B) resembles *Anematina* but has both spiral and collabral ornamentation. *Soleniscus* (C) has a very high-spired, unornamented shell that tapers evenly to a point. In cross section, *Soleniscus* appears smooth whereas *Anematina* appears lumpy. *Girtyspira* (D) has a very high body whorl, about two thirds the height of the entire shell.

Glyptomaria (*Glyptomaria*) (E) may have either a high, beehive-shaped shell or a nearly discoidal shell. *Glyptomaria* has both sharp collabral and spiral ornamentation.

Meekospira (F) has a very sharply pointed, slender, unornamented shell. *Palaeostylus* (*Palaeostylus*) (G) has a very high spire with many low, broad whorls and collabral ornamentation. *Palaeostylus* (*Pseudozygopleura*) (H) may have collabral threads or cords on all whorls, on the early whorls only, or may have no ornamentation at all. *Donaldina* (I) is ornamented with spiral threads that are confined to the lower part of the whorl. *Orthonema* (J) has a very conspicuous pair of spiral cords.

Goniasma (K) has angular whorls which are smooth above but have spiral threads below. *Murchisonia* (*Murchisonia*) (L) resembles *Goniasma* but has less angular whorls and paired spiral cords.

Occurrence of Pennsylvanian and Permian Gastropods in Nebraska

Several noteworthy gastropod occurrences are in quarries near Louisville, Cedar Creek, and Richfield. *Goniasma, Bellerophon, Naticopsis, Bucanopsis, Euphemites, Straparollus, S.* (*Euomphalus*), and *Murchisonia* occur in the Winterset Limestone. *Bellerophon* and *Euphemites* occur in the Westerville Limestone, and *Trachydomia* has been collected from the Drum Limestone. *Ianthinopsis, Bellerophon,* and *Pleurotomaria* are found in the Argentine Limestone near Louisville and Cedar Creek. The Bonner Springs Shale, exposed near Cedar Creek, contains steinkerns of a diverse gastropod fauna, including the low-spired *Straparollus* (*Straparollus*) and *Anomphalus*; the high-spired *Anematina* and *Pseudozygopleura*; and unidentifiable steinkerns of several species of high-spired gastropods.

Anomphalus, Bellerophon, Straparollus, and *S.* (*Eumophalus*) occur in the Stoner Limestone in the area around Louisville. The Stoner Limestone also contains fossils of *Platyceras*, which are almost always associated with crinoid remains.

An abundant and diverse gastropod fauna has been recorded from the Kereford Limestone from exposures near Weeping Water and Nehawka. *Amaurotoma, Anomphalus, Baylea, Colpites, Donaldina, Euphemites, Girtyspira, Hemizyga, Murchisonia, Naticopsis. Orthonema, Phanerotrema, Retispira, Rhabdotochilus, Straparollus,* and *Trachydomia* make up this variable fauna. Most of the above genera also occur in the Stull and Doniphan Shales near Weeping Water, Plattsmouth, and Nehawka.

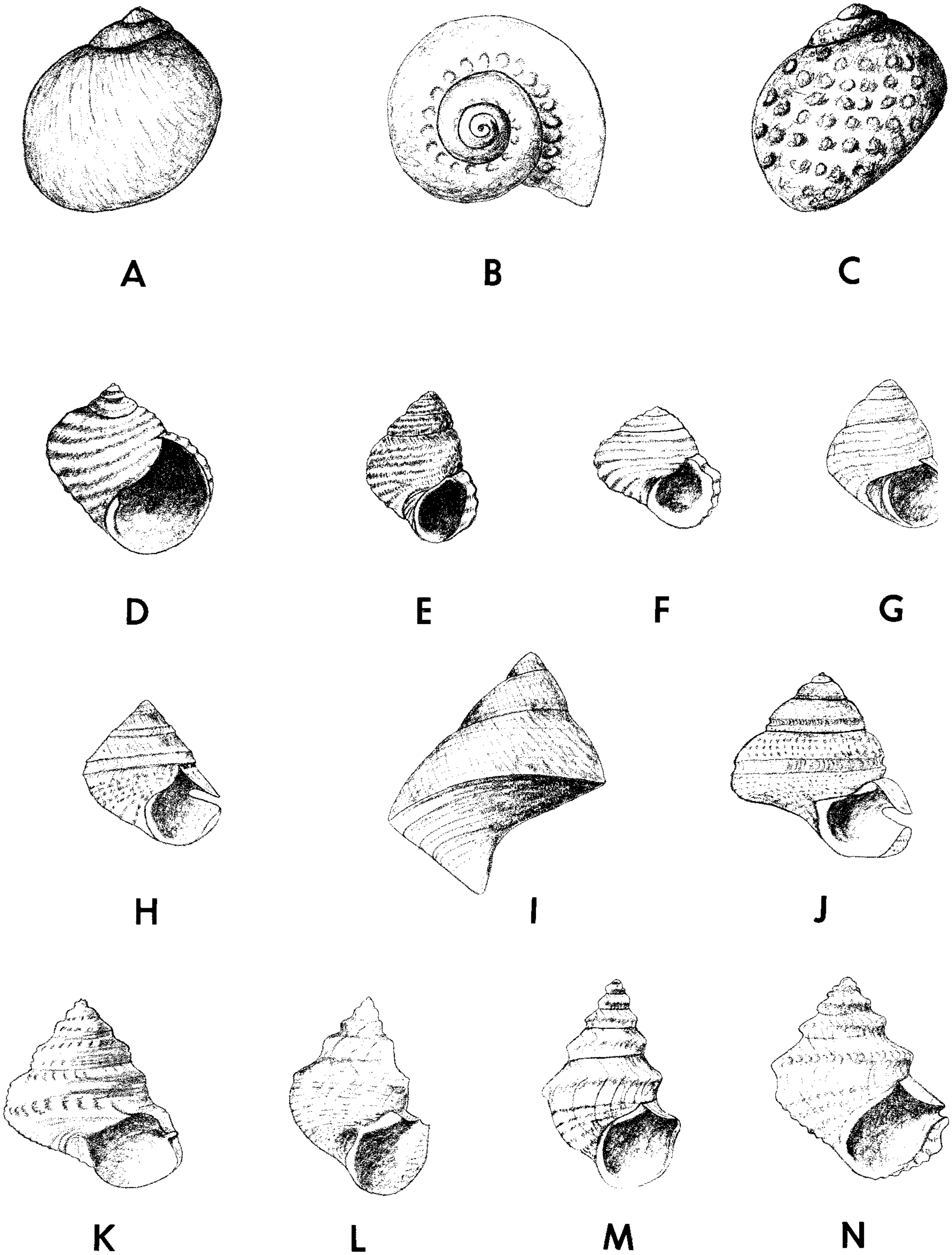


FIGURE 45. Pennsylvanian and Permian medium-spired gastropods from Nebraska. (A) *Naticopsis*, side view, X2. (B) *Colpites*, dorsal view, X2. (C) *Trachydomia*, side view, X2. (D) *Ianthinopsis*, anterior view, X2. (E) *Amaurotoma*, anterior view, X10. (F) *Rhabdotochilus*, anterior view, X2. (G) *Araeonema*, anterior view, X2. (H) *Glabrocingulum*, anterior view, X2. (I) *Phymatopleura*, posterior view, X1. (J) *Dictyomaria*, anterior view, X2. (K) *Pleurotomaria*, anterior view, X2. (L) *Baylea*, anterior view, X2. (M) *Hypselentoma*, X2. (N) *Worthenia*, X2.

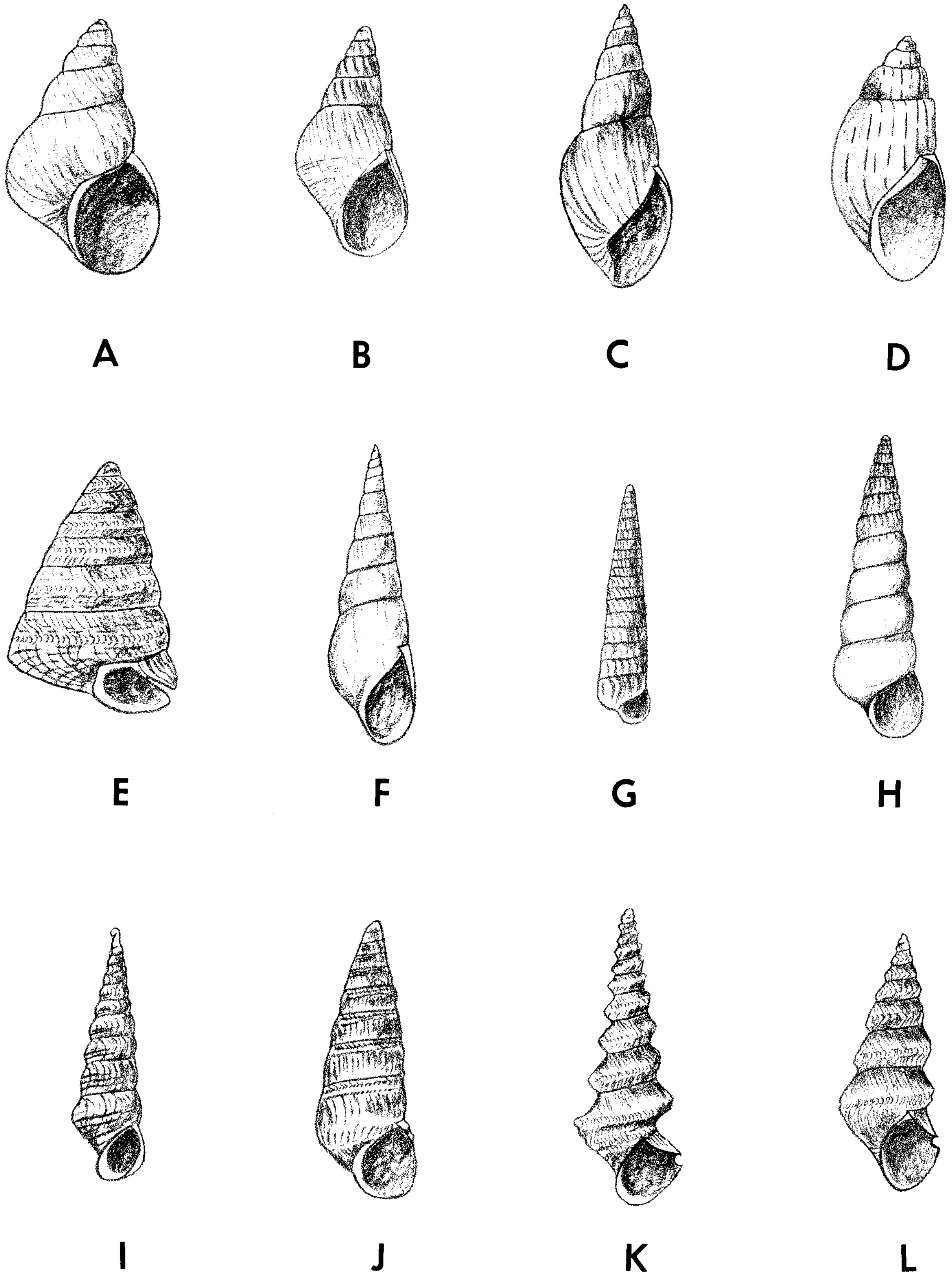


FIGURE 46. Pennsylvanian and Permian high-spired gastropods. (A) *Anematina*, (B) *Hemizyga*, (C) *Soleniscus*, (D) *Girtyspira*, (E) *Glyptomaria* (*Glyptomaria*), (F) *Meekospira*, (G) *Palaeostylus* (*Palaeostylus*), (H) *P.* (*Pseudozygopleura*), (I) *Donaldina*, (J) *Orthonema*, (K) *Goniasma*, and (L) *Murchisonia* (*Murchisonia*). All views anterior. All Figures X2.

Some very large specimens, up to several inches in diameter, of *Phymatopleura, Straparollus (Euomphalus)*, and *Naticopsis* have been collected from the Plattsmouth Limestone near Weeping Water.

Abundant gastropod fossils occur in the Larsh Shale and Ervine Creek Limestone near Union and Weeping Water. Although quantity is high, variety is small and only *Straparollus, Phanerotrema*, and *Trepospira* have been collected from these beds.

Phymatopleura, Anomphalus, Platyceras, Bellerophon, Straparollus, S. (Straparollus), S. (Euomphalus), Euphemites, Phanerotrema, Trepospira, Bellerophon, Retispira, and *Naticopsis* are found in the Severy Shale near Du Bois, Union, and Wabash. Pyritized replacements of all of the above genera, and also *Anematina, Ianthinopsis*, and *Glabrocingulum*, occur in concretions in the Severy Shale near Du Bois. Most of the above genera also occur in the Howard Limestone near Du Bois.

Limonite steinkerns of minute low- and medium-spired gastropods are abundant in the Winnebago Shale near Table Rock, and in the Soldier Creek Shale near Unadilla.

Naticopsis, Phanerotrema, Euphemites, Platyceras, Trepospira, Straparollus, and *Bellerophon* are found in exposures of the Auburn Shale near Nebraska City and Table Rock.

The Emporia Limestone and Willard Shale, which are exposed near Nebraska City, Du Bois, Elk Creek, and Tecumseh, contain a large, diverse fauna of fossil snails. *Euphemites, Retispira, Bucanopsis, Straparollus, S. (Euomphalus), Ianthinopsis, Anomphalus, Phymatopleura, Phanerotrema, Pleurotomaria, Bellerophon*, and *Plagioglypta* have been collected from these rock units. Many of the above genera can be found in the Dover Limestone exposed near Nebraska City and Humboldt.

Worthenia makes up as much as 50 percent of the rock in some zones of the Table Creek Shale near Humboldt.

The earliest Permian gastropods in Nebraska are found in the Aspinwall Limestone near Brownville, Dunbar, and Pawnee City. These fossil gastropods include *Anematina, Euomphalus*, and *Bellerophon*.

Bellerophon, Naticopsis, Phanerotrema, Straparollus, S. (Euomphalus), Bucanopsis, and *Paleostylus* are among the gastropods found in the Stine Shale near Salem, Syracuse, and Pawnee City.

The gastropods occurring in the Hughes Creek Shale near Bennet include *Straparollus, S. (Omphalotrochus), Trepospira, Bucanopsis*, and *Bellerophon*. The same fossil snails occur in the Neva Limestone near Roca.

Permian gastropods from Nebraska represent a wide-open field of investigation. It is likely that future work will turn up many new species and perhaps some new genera of gastropods.

Guide to Cretaceous Gastropod Identification

Only a few Cretaceous Gastropods (Fig. 47) are known in Nebraska. *Anisomyon* (A) has a flattened shell that resembles a coolie cap. It looks much like the inarticulate brachiopod *Orbiculoidea* (Fig. 32B), or a modern-day limpet. *Haminea* (B) has a shell with a body whorl that encloses all of the previous whorls. *Vanikoro* (C) has a medium spire, is ornamented with spiral cords and threads, and may have collabral ornamentation. *Amauropsis* (D) has a high-spired shell, and its whorls are more or less flattened near the sutures. *Anchura* (E) has a high-spired shell and faint spiral cords; the outer lip of the aperture is drawn out into a large wing-like structure, which is usually damaged. *Drepanochilus* (F) resembles *Anchura* but the lip is drawn out into a long, scythe-shaped, pointed structure.

Occurrence of Cretaceous Gastropods in Nebraska

Meek (1876, *see* Appendix) described many Cretaceous gastropods and reported that a number of them were found in Nebraska. Many of these fossils were even given the specific name *nebrascensis*. However, none of the Cretaceous gastropods described by Meek and given the specific name *nebrascensis* were collected from what is now the state of Nebraska. It should be pointed out that Meek and Hayden referred to Nebraska in the sense of the Nebraska Territory, which included not only the area that is now the state of Nebraska, but also the Dakotas, Montana, and Wyoming.

The Cretaceous section of Nebraska includes rocks of the same ages as the ones from which Meek and Hayden's "Nebraska" Cretaceous gastropod species were collected. Therefore, it is reasonable to assume that future collecting expeditions will recover large and diverse faunas of Cretaceous gastropods from the state of Nebraska.

At the present time, Cretaceous gastropods have been collected only from concretions in the Pierre Shale in the vicinity of Chadron and Crawford.

Guide to Tertiary Gastropod Identification

Only a few genera of land snails (Fig. 48) have been reported from the Oligocene Chadron Formation near Crawford, Chadron, and Harrison.

Helix (A) is a large, medium-spired form. *Physa* (B) has a very high body whorl. *Lymnaea* (C) is a high-spired form with a lower body whorl than that of *Physa*. Molds of high-spired Pliocene gastropods are found in chalk deposits at the Chalk Mine State Wayside area near Scotia.

Guide to Pleistocene Gastropod Identification

Pleistocene gastropod shells are divisible into the following groups: (A) nearly flat and coolie-cap-like gastropods; (B) low-spired gastropods; (C) medium-spired gastropods; and (D) high-spired gastropods. There is a large variety of Pleistocene gastropods.

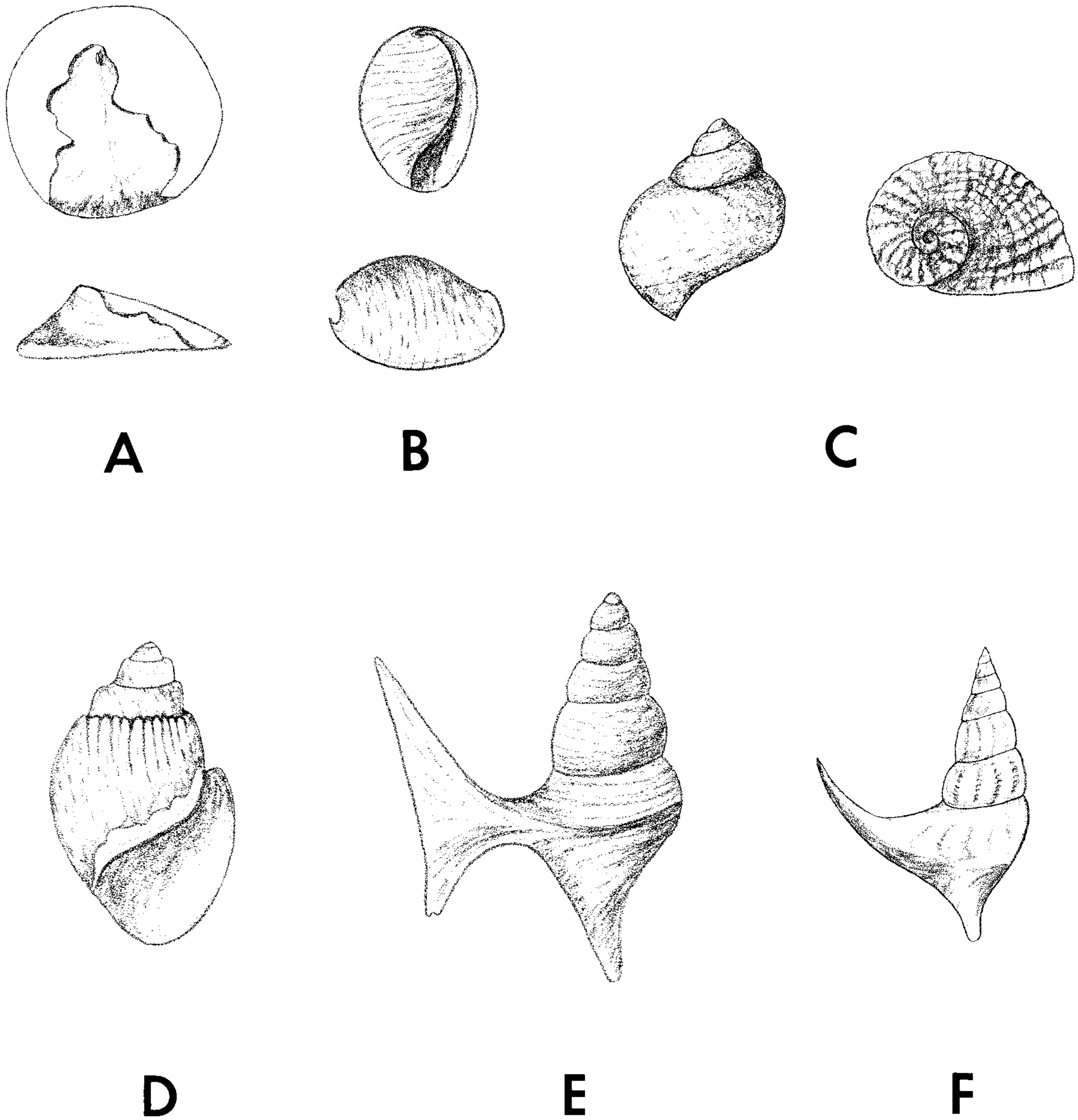


FIGURE 47. Nebraska Cretaceous gastropods. (A) *Anisomyon*, dorsal view, X1. (B) *Haminea*, anterior (above) and dorsal (below) views, X1. (C) *Vanikoro*, two species, X1. (D) *Amauropsis*, anterior view, X2. (E) *Anchura*, side view, X2. (F) *Drepanochilus*, side view X2.

Although fossil Pleistocene gastropods are abundant wherever they occur, many exposures of these rocks are unfossiliferous.

Flat or coolie-cap-shaped Pleistocene gastropods (Figure 49). *Ferrissia* (A) is a rather common gastropod; its shell ranges from about 1.7 to 3.5 mm. long; it has many fine growth lines that may coalesce and form heavy ridges. *Acroloxus* (B) is a rare form resembling *Ferrissia*; its shell is about 4 mm. long; it has been reported only from one locality in Brown County. *Ferrissia* and *Acroloxus* are aquatic forms. *Deroceras* (C), a slug, has a flat, oval shell with faint growth rings on one side and irregular bumps on the other; its shell ranges from about 3.5 to 6 mm. in length.

Low-spired aquatic Pleistocene gastropods (Figure 50A-E). *Gyraulus* (A), *Promenetus* (B), *Planorbula* (C), and *Helisoma* (D) all have shells with sharp lips about the aperture and with about 4½ whorls separated by well-defined sutures. *Gyraulus* has a small shell about 2.0 to 6.0 mm. in diameter with a wide, shallow umbilicus and is ornamented with growth lines. *Promenetus* has a shell about 2.5 to 5.0 mm. in diameter with a narrow, shallow umbilicus and a flattened or evenly depressed spire ornamented with coarse, radial ribs. *Planorbula* may be up to about 7.5 mm. in diameter and the shell has a broad, round umbilicus; the terminal part of the body whorl may have coarse growth lines whereas the earlier parts have fine growth lines or are smooth; there are six teeth inside the aperture. *Helisoma* has a large shell, some species being up to about 30 mm. in diameter, with a large, deep, round umbilicus, moderately coarse radial ribbing, and spiral ridges on each side. *Valvata* (E) has a small, turbanate shell about 4 mm. in diameter with

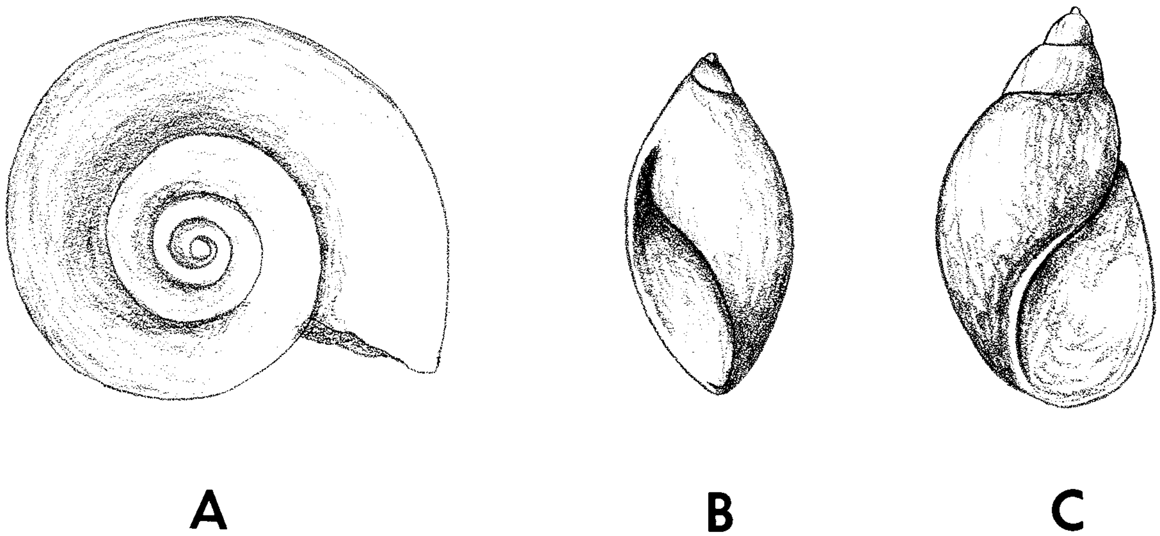


FIGURE 48. Nebraska Tertiary gastropods. (A) *Helix*, dorsal view, X1. (B) *Physa*, anterior view, X2. (C) *Lymnaea*, anterior view, X1.

about 4 whorls separated by a distinctly impressed suture; the shell is ornamented with fine growth lines and three spiral ridges (carinae); the lip is sharp.

Low-spired terrestrial Pleistocene snails (Figure 50F-K). *Hawaiia* (F), *Retinella* (G), and *Discus* (H) all have shells with sharp lips about the aperture and with about 4½ whorls. *Hawaiia* has a tiny shell about 3.0 to 3.1 mm. in diameter that may be striated on the upper side and smooth on the under side; it has a broad umbilicus about ⅓ the diameter of the shell. *Retinella* has a small shell about 4 mm. in diameter, ornamented with numerous small, radial grooves, and a deep, narrow umbilicus. *Discus* (H) has a larger shell than *Retinella*, about 6.3 to 6.5 mm. in diameter, ornamented with coarse, radial riblets and has a broad, deep umbilicus about ⅓ the diameter of the shell. *Helicodiscus* (I) has a small shell about 3.5 mm. in diameter with 5 whorls and a flattened or slightly convex spire, radial lines, spiral ridges, a broad, shallow umbilicus, and teeth within the aperture. *Zonitoides* (J) has a shell about 5.0 to 5.2 mm. in diameter with about 4¾ whorls, irregular growth lines, and a narrow umbilicus about ¼ the diameter of the shell. *Vallonia* (K) has a very small shell about 2.5 to 2.8 mm. in diameter with about 3½ whorls, obliquely radial ribs, a wide umbilicus, and an outflared lip about the aperture.

Medium-spired terrestrial Pleistocene gastropods (Figure 51). *Strobilops* (A) has a small shell about 2.5 to 2.8 mm. in diameter, a deep, narrow umbilicus and about 5½ whorls, the outer ones of which are obliquely ribbed; the aperture contains a single tooth and the lip is outflared. *Euconulus* (B) has a small shell, about 3.0 to 3.2 mm. in diameter, with about 5½ whorls, ornamented with fine growth lines and faint spiral lines, a deep narrow umbilicus, and a sharp lip. *Hendersonia* (C) has a very solid shell ranging from about 5.0 to nearly 7.5 mm. in diameter with a closed umbilicus, and 5 whorls, the outer ones being ornamented with fine, oblique lines; the lip is thick. *Stenotrema* (D) has a large shell about 6.5 to 8.7 mm. in diameter with a deep, narrow umbilicus and about 5½ whorls, the outer ones having fine, oblique growth lines; the narrow aperture is closed to a wide slit by a large tooth.

High-spired aquatic Pleistocene gastropods (Figure 52A-D). *Amnicola* (A) has a turbanate shell about 3.5 to 4.0 mm. high with about 5½ whorls, the large ones having faint radial lines; the oval to circular aperture is enclosed by a thin lip. *Physa* (B) has a large body whorl and a left-handed spire and is normally 10 to 30 mm. long. *Stagnicola* (C) has a right-handed spire that is much larger than the aperture and is about 15 to 30 mm. long; it is ornamented by growth lines crossed by spiral lines. *Fossaria* (D) is usually less than 10 mm. long and has a spire as long as or longer than the aperture.

High-spired terrestrial Pleistocene gastropods (Figure 52E-L). *Succinea* (E) has a shell from 7 to more than 15 mm. long; there are 3½ whorls, the body whorl being greatly inflated; the aperture is more than half the length of the shell, and the lip is sharp. *Columella* (F) has a small, commonly amber-colored shell less than 3.4 mm. long with about 7 whorls, all but the smallest ones being finely striated; the oval aperture is enclosed by a thin lip. *Pupilla* (G) also has a small, commonly amber-colored shell about 3 to 4 mm. high, with 6 to 7 whorls, the larger ones having fine, irregular lines; the oval aperture is enclosed by a mildly outflared lip. *Pupoides* (H) has a small shell about 3.5 to 5.5 mm. in length with about 7 uniformly enlarging whorls, the larger ones being obliquely lined; the lip flares outward. *Gastrocopta* (I) has a small shell that ranges from 2.0 to 4.5 mm. in length with about 7 whorls marked by oblique lines; the aperture is irregularly rounded, and always has at least four, and may enclose as many as seven, prominent teeth and is sur-

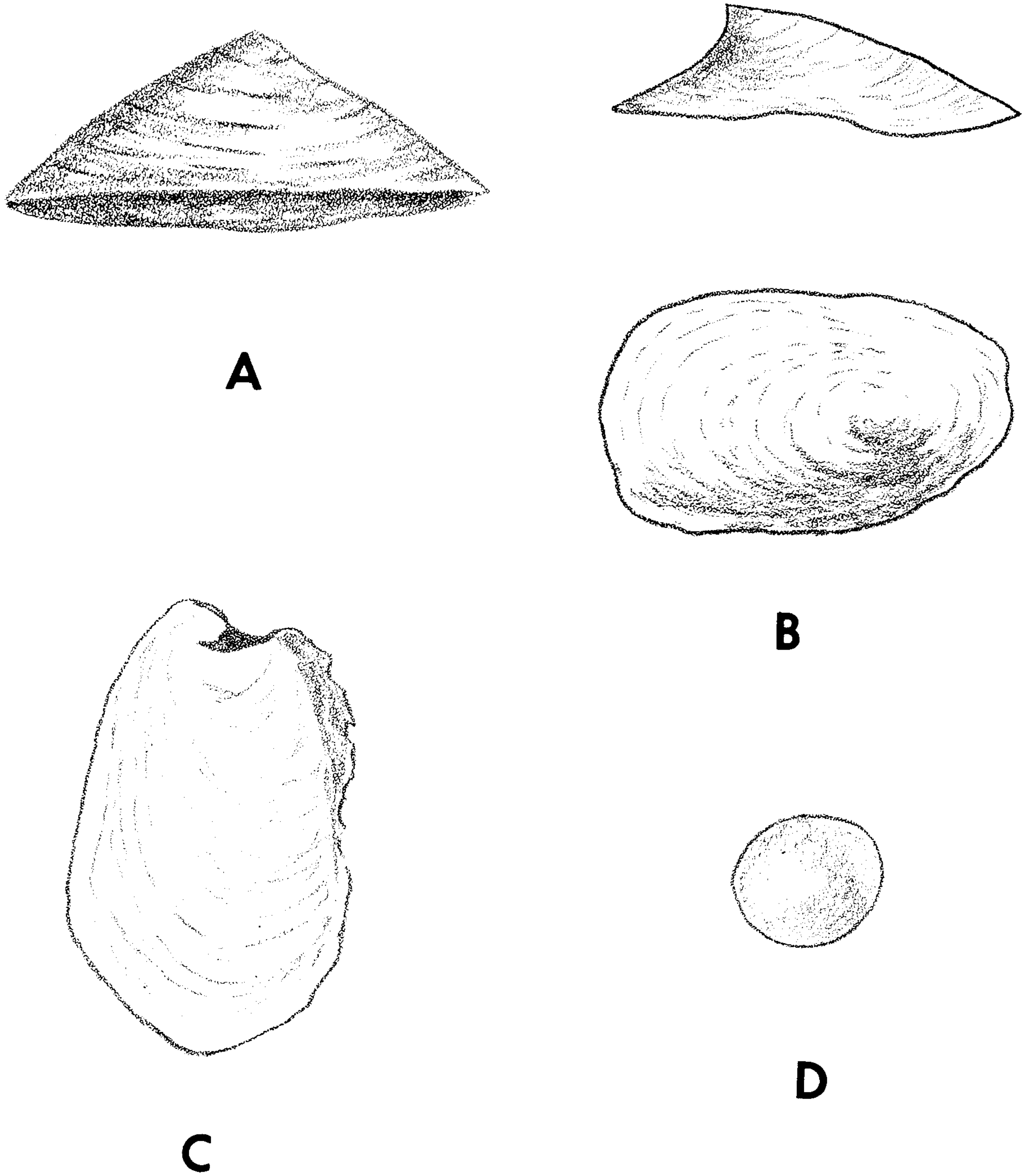


FIGURE 49. Flat or coolie-cap-shaped Pleistocene gastropods. (A) *Ferrissia*, side view, X20; (B) *Acroloxus*, side view (above) and apical view (below), X15. (C) *Deroceras*, apical view, X15. (D) Fossil gastropod egg, X20.

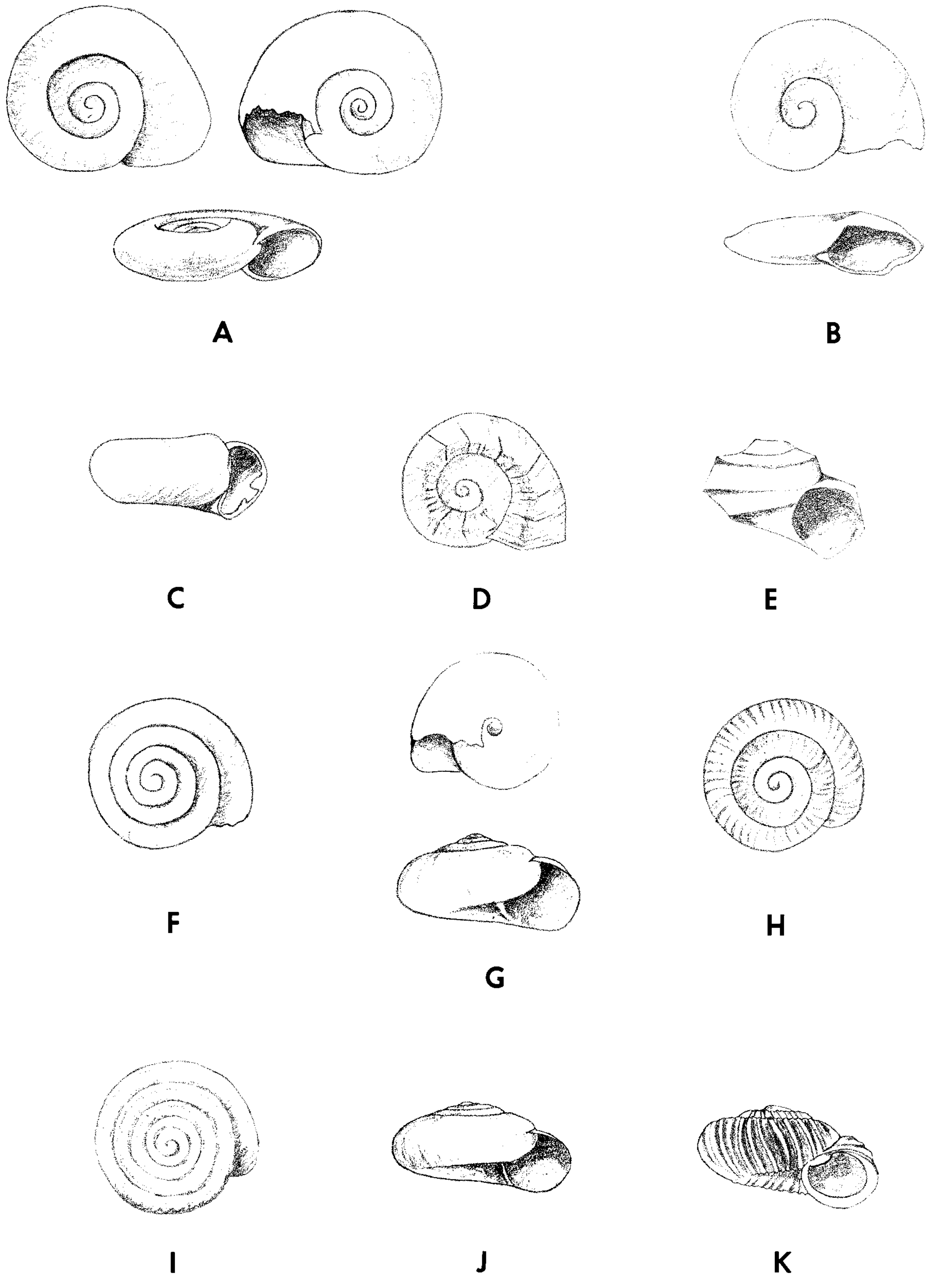


FIGURE 50. Low-spired Pleistocene gastropods. A-E aquatic forms: (A) *Gyraulus*, apical (above, left), umbilical (above right) and apertural (below) views, X10. (B) *Promenetus*, apical (above) and apertural (below) views, X10. (C) *Planorbula*, apertural view, X4. (D) *Helisoma*, apical view, X2. (E) *Valvata*, apertural view, X6. F-K land forms: (F) *Hawaiia*, apical view, X10. (G) *Retinella*, umbilical (above) and apertural (below) views, X7. (H) *Discus*, apical view, X4. (I) *Helicodiscus*, apical view, X8. (J) *Zonitoides*, apertural view, X6. (K) *Vallonia*, apertural view, X10.

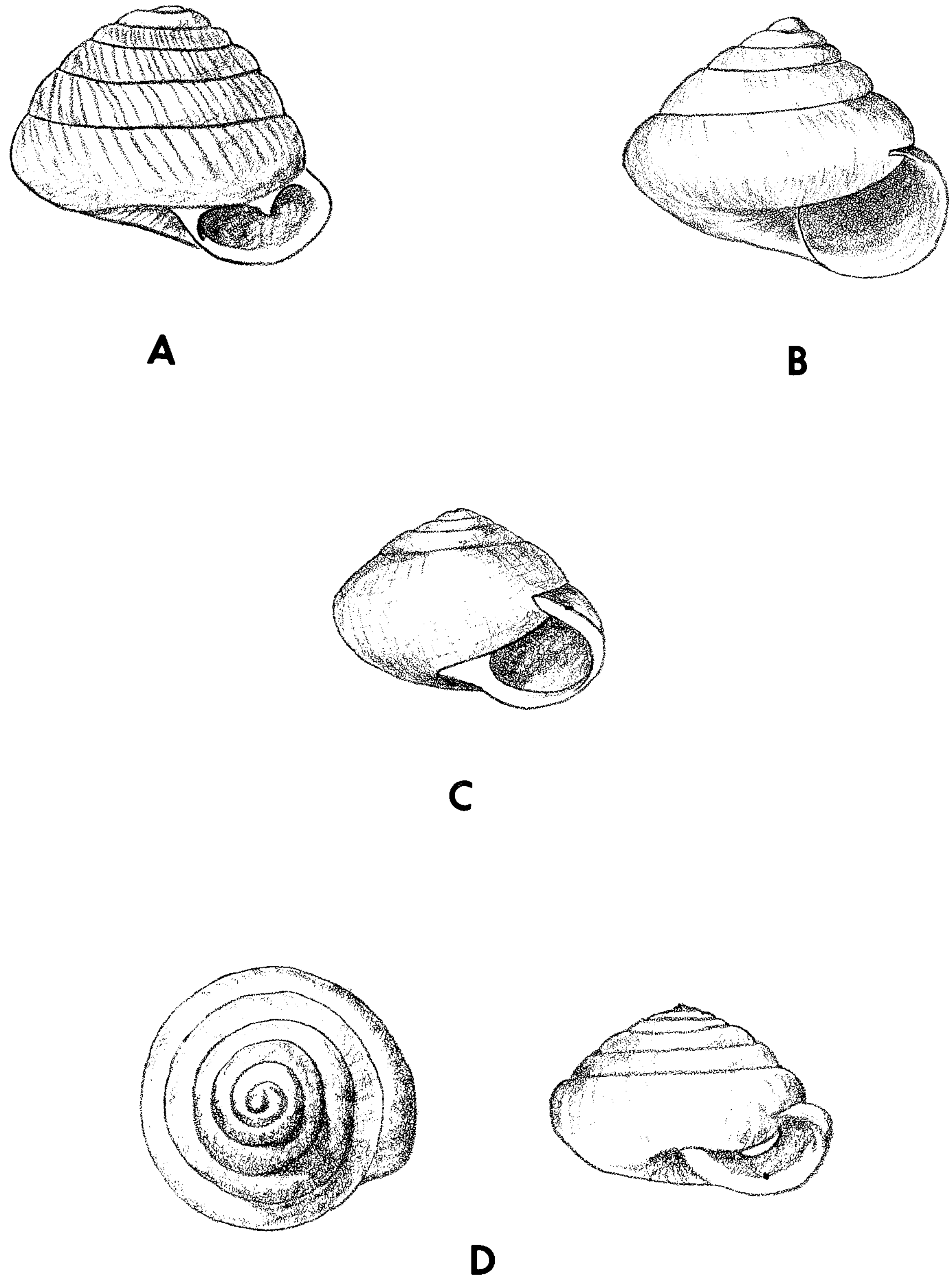


FIGURE 51. Medium-spired Pleistocene terrestrial gastropods. (A) *Strobilops*, apertural view, X20. (B) *Euconulus*, apertural view, X20. (C) *Hendersonia*, apertural view, X8. (D) *Stenotrema*, apical (left) and apertural (right) views, X7.

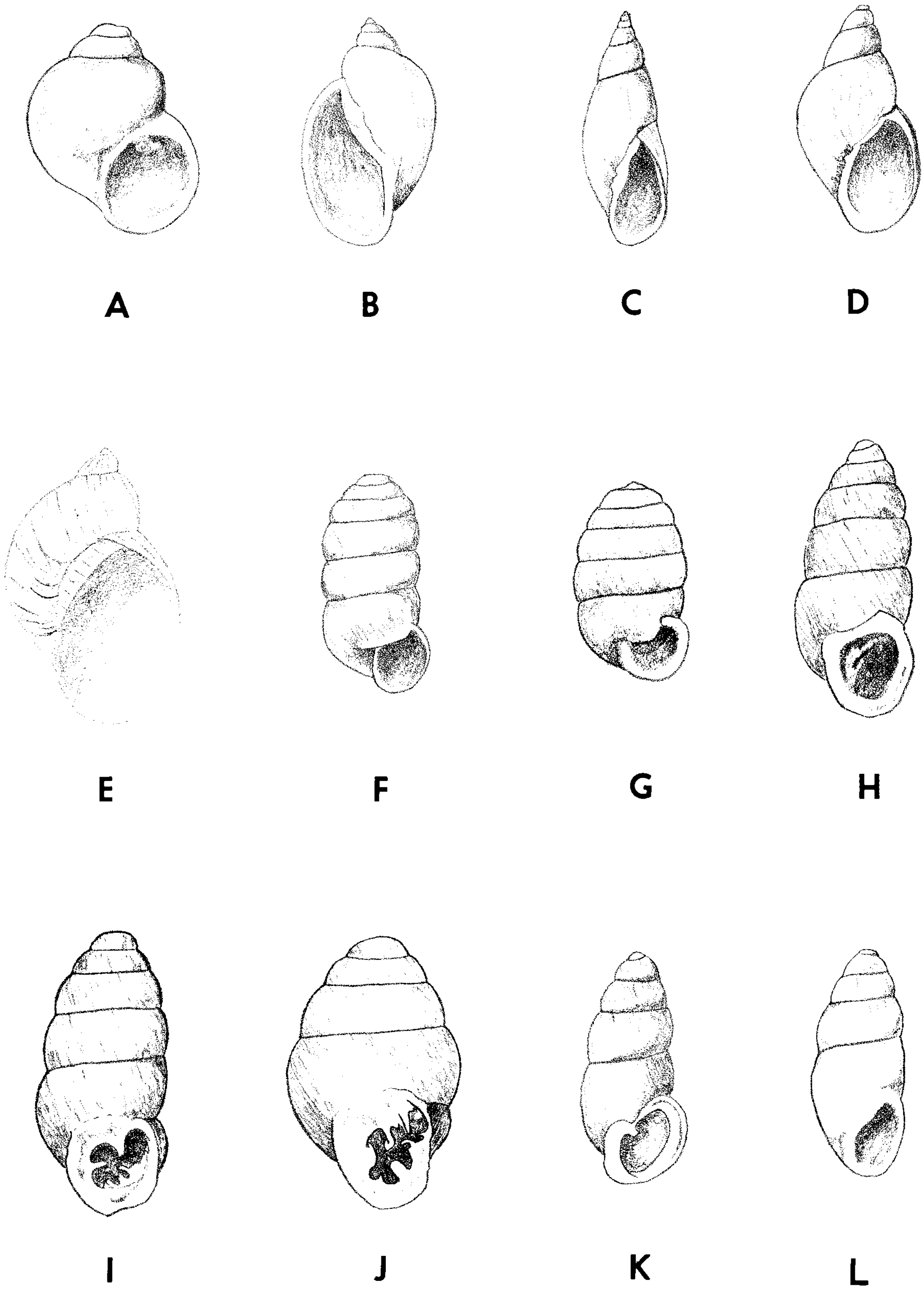


FIGURE 52. High-spired Pleistocene gastropods. A-D Aquatic forms: (A) *Amnicola*, X8. (B) *Physa*, X2. (C) *Stagnicola*, X2. (D) *Fossaria*, X4. E-L Terrestrial forms: (E) *Succinea*, X4. (F) *Columella*, X15. (G) *Pupilla*, X10. (H) *Pupoides*, X8. (I) *Gastrocopta*, X15. (J) *Vertigo*, X20. (K) *Carychium*, X20. (L) *Cionella*, X7. All views apertural.

rounded by an outflaring lip. *Vertigo* (J) has a minute shell about 2.0 mm. in length with 5 whorls, the outer ones being obliquely lined; the body whorl is contracted but expands toward the aperture which enclosed from three to six teeth and is surrounded by a slightly outflaring lip. *Carychium* (K) has a minute shell less than 2.0 mm. high with 5½ whorls, the last two of which are finely lined; the lip flares outward. *Cionella* (L) has a small shell about 5.5 mm. in length with 5½ to 6 smooth whorls; the aperture is oval and the lip simple.

Occurrence of Pleistocene Gastropods in Nebraska

Pleistocene gastropods have been noted at many locations in southern and eastern Nebraska. They are common in many road cuts that are more than a few feet deep.

Fossil land snails have been reported from the Pleistocene Peorian Loess in exposures near the State Hospital and Pioneers Park in Lincoln.

Terrace fills along the Elkhorn River have yielded a large variety of fossil gastropods. Many specimens have been collected from exposures along Humbug Creek near Pilger in Stanton County. Many fossil gastropods have also been collected from terrace fills near Wisner and West Point in Cuming County, Hooper in Dodge County, and Fontanelle in Washington County, and in terrace fills along Pebble Creek near Scribner in Dodge County.

Fossil land snails have also been collected from terrace fills along the Platte River. Many specimens have been collected near Fremont, Schuyler, Silver Creek, Kearney, and North Platte, to mention a few localities. Many roadcuts through the bluffs along the Platte and Missouri Rivers contain abundant specimens of fossil gastropods.

Exposures of Pleistocene deposits along the Loup Rivers contain many fossil snails. Notable occurrences are in roadcuts on Highway 22 west of Fullerton.

Pleistocene gastropods have been collected in large quantities from terrace fills along Red Willow Creek in Hayes County and Medicine Creek in Frontier County and along the Republican River near Franklin.

Many genera of Pleistocene land snails have been collected from exposures along Sand Draw and Deep Creek in northern Brown County. Several of the occurrences here are unique (e.g., *Acroloxus*), being found only in this locality in Nebraska.

Lesser quantities of fossil gastropods have been collected near Geneva in Fillmore County, and near Hartington in Cedar County. Any exposure of Pleistocene loesses or Pleistocene terrace fills potentially may contain fossils of Pleistocene gastropods. There are probably many undiscovered collecting localities for Pleistocene gastropods in Nebraska.

Small, spherical bodies that have been interpreted as eggs of Pleistocene gastropods (Fig. 49) have also been reported from Nebraska.

Class Scaphopoda

Scaphopods are molluscs with tubular, slightly curved shells that are opened on both ends (Fig. 53). Scaphopods have been reported from Pennsylvanian, Permian, and Cretaceous rocks of Nebraska but do not form an important part of the fossil record.

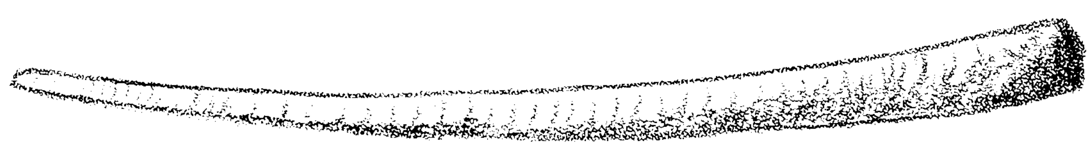


FIGURE 53. A fossil scaphopod, *Dentalium*, X4.

Class Cephalopoda

The Living Cephalopods

Cephalopods include nautiloids, ammonoids, belemnites, squids, and octopi, and are the most highly developed molluscs. They are strictly marine and their fossils are found only in the Pennsylvanian, Permian, and Cretaceous rocks of Nebraska. An idealized cephalopod is shown in Figure 54. They have a well-developed head with keen eyes and strong tentacles. The tentacles are equipped with suckers. The head has a tube through which the animal can force a jet of water in order to propel itself through the water. Some cephalopods (e.g., octopi) can eject an inky fluid through this tube in order to escape predators. The most important cephalopods in the Nebraska fossil record are the nautiloids and ammonoids.

As the cephalopod grows it adds additional chambers to its shell (Fig. 55). The chambers are connected by a tube called a *siphuncle*. The walls between previously occupied chambers are called *septa* (sing. *septum*). Septa appear as *sutures* on steinkerns of cephalopods and are important in cephalopod classification. Figure 56 illustrates the four major suture patterns.

Nautiloids and ammonoids have either straight or coiled shells. Squids and octopi have straight internal shells and modern nautiloids have tightly coiled shells. Belemnites have cigar-shaped internal shells. Cephalopod shells usually coil in a plane, whereas gastropod shells usually coil in a spire. The gastropod *Bellerophon* coils in a plane but its lack of sutures distinguishes it from a cephalopod.

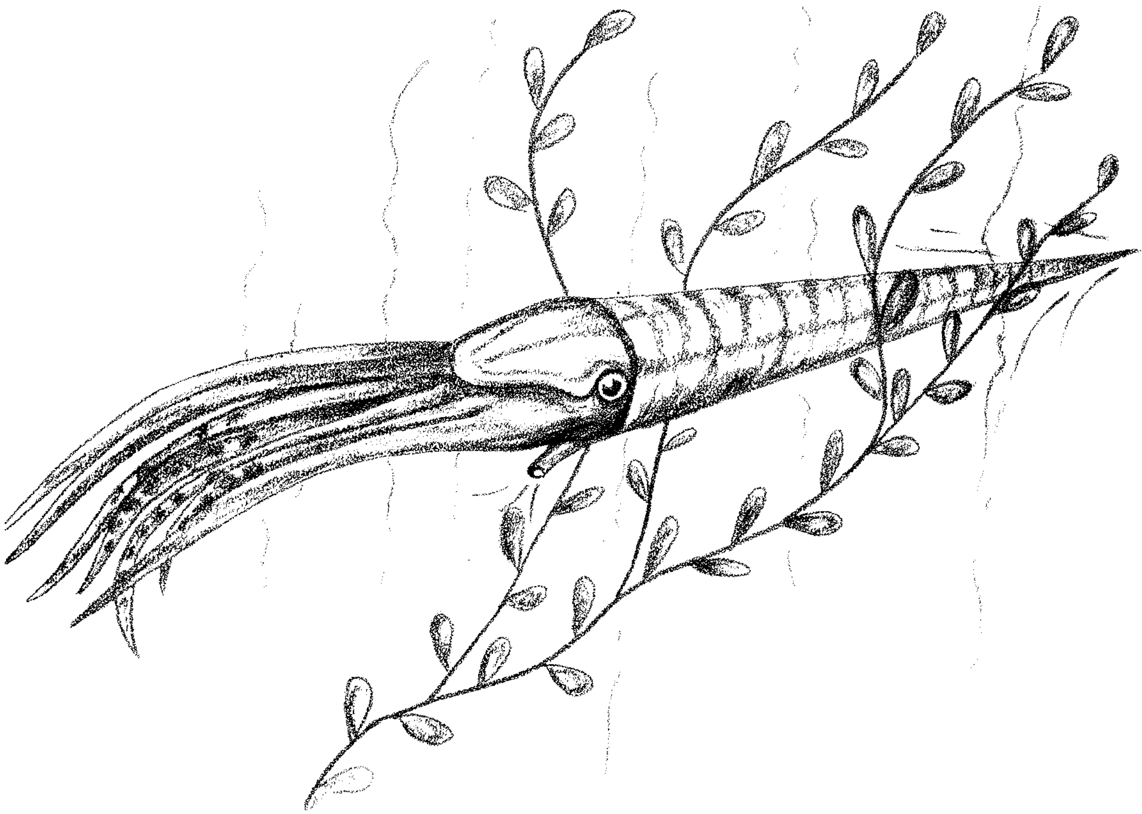


FIGURE 54. An idealized cephalopod.

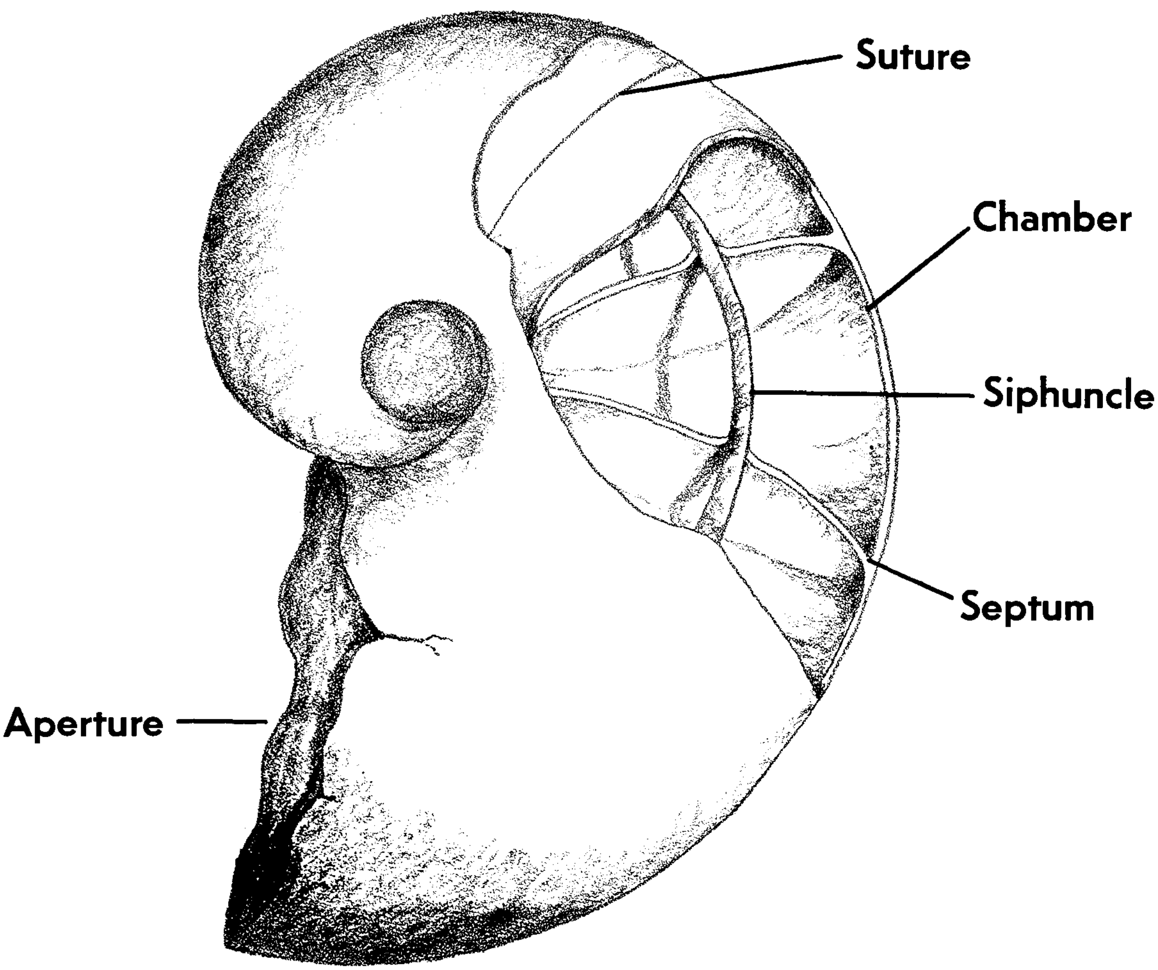


FIGURE 55. A typical cephalopod showing some of the more important features used in classification.

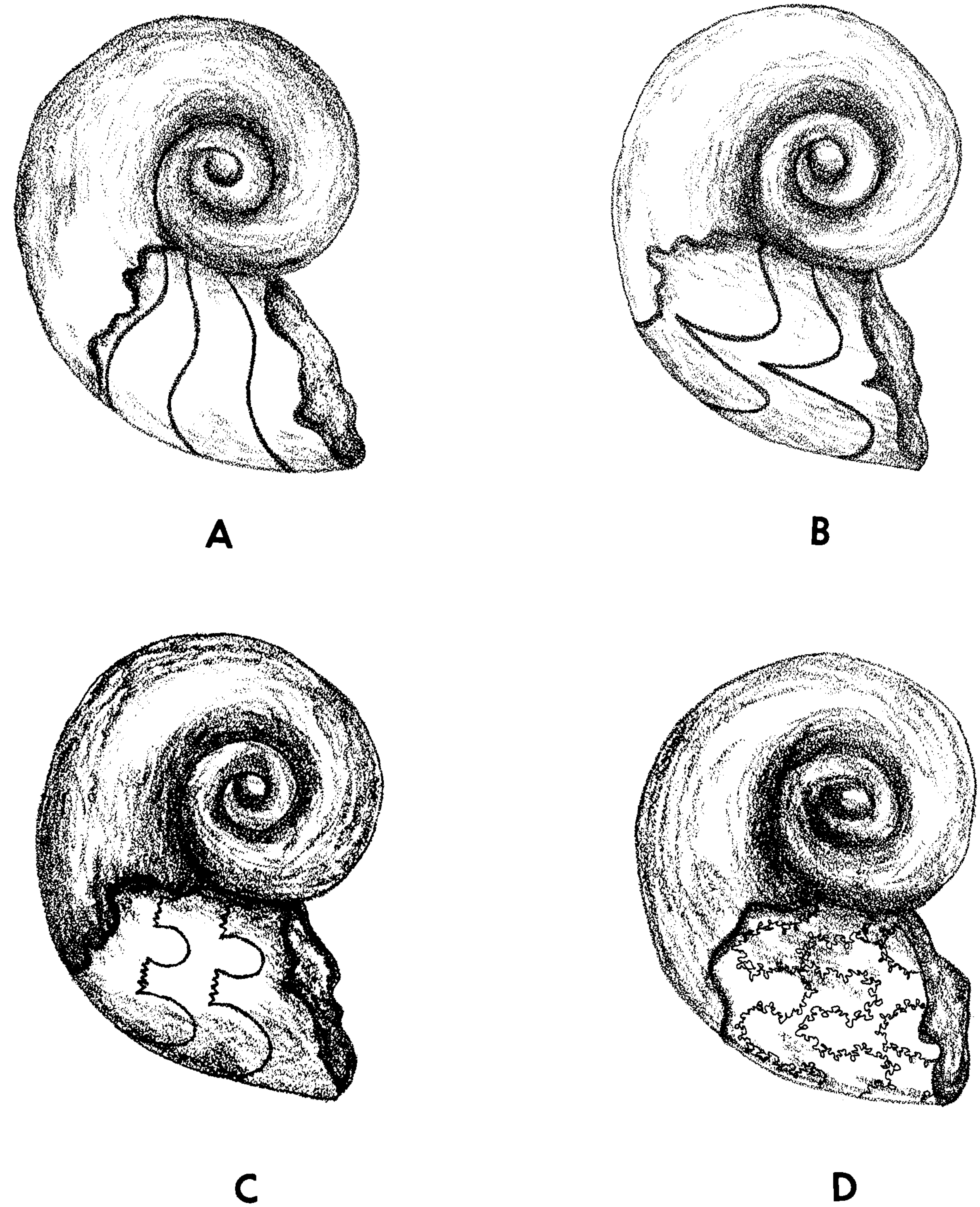


FIGURE 56. Cephalopod suture patterns. (A) Nautiloid suture. (B-D) Ammonoid sutures: (B) Goniatite type, (C) Ceratite type, and (D) Ammonite type.

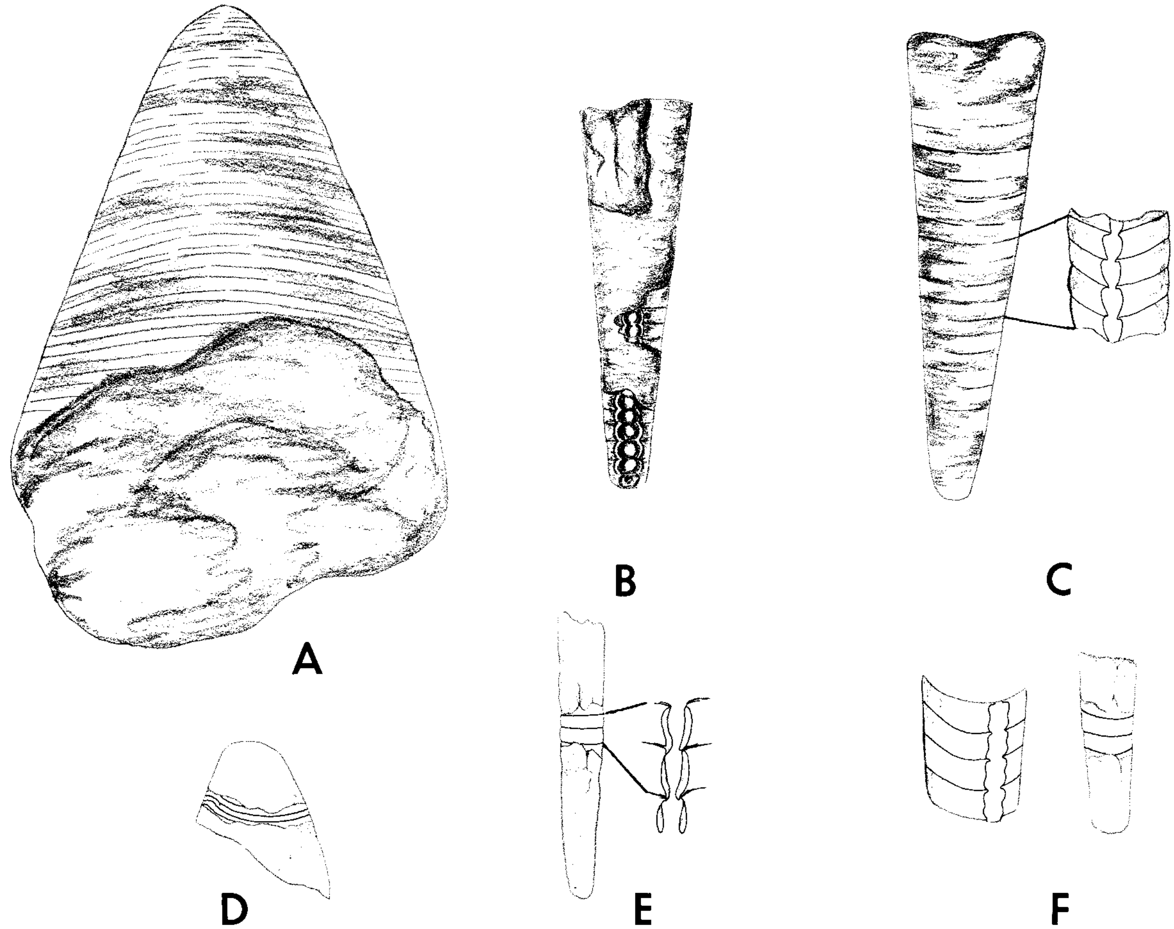


FIGURE 57. Straight-shelled Pennsylvanian and Permian cephalopods with nautiloid sutures. (A) *Poterioceras*, dorsal view, X½. (B) *Mooreoceras*, dorsal view showing siphuncle, X1. (C) *Pseudorthoceras*, dorsal view (left) and cross-section (right) showing siphuncle, X1. (D) *Brachycycloceras*, dorsal view, X½. (E) *Dolorthoceras*, dorsal view (left) and siphuncle (right), X1. (F) *Euloxoceras*, cross section showing siphuncle (left) and dorsal view (right) X1.

Guide to Cephalopod Identification

Cephalopods with nautiloid sutures are commonly found in the Pennsylvanian and Permian rocks of Nebraska. Both straight (Figure 57) and coiled forms (Figure 58) are found. True nautiloids (Figure 58N) occur in Cretaceous rocks of Nebraska. Cephalopod classification is based largely on the shape of the shell, the suture pattern, and the siphuncle.

Straight-shelled cephalopods with nautiloid sutures (Figure 57). *Poterioceras* (A) is a large, cone-shaped cephalopod with closely spaced sutures. *Mooreoceras* (B) has an elongated cone-shaped shell with a siphuncle resembling a string of beads. *Pseudorthoceras* (C) resembles *Mooreoceras* but has a different siphuncle. *Brachycycloceras* (D) has very closely spaced sutures but its shell is a rounded one. *Dolorthoceras* (E) has a long shell with a distinct siphuncle. *Euloxoceras* (F) resembles *Mooreoceras* but has a very distinct siphuncle pattern.

Coil-shelled cephalopods with nautiloid sutures (Figure 58). *Titanoceras* (A) has gently undulating sutures and a shell that may be as large as 18 inches in diameter. *Tainoceras* (B) has gently undulating sutures but has a pair of nodes on the outer wall of each chamber. *Temnocheilus* (C) has coarse nodes on the walls of each chamber. *Liroceras* (D) has a nearly straight suture. *Coelogasteroceras* (E) resembles *Liroceras* but its suture has gently undulating lobes. *Ephippioceras* (F) resembles *Liroceras* but the suture forms a deep saddle. *Megaglossoceras* (G) resembles *Ephippioceras* and *Liroceras* but has a suture with a very deep saddle.

Endolobus (H) has a slightly curved suture and an oval aperture. *Metacoceras* (I) has gently undulating sutures, a rectangular cross section, and nodose ornamentation. *Planetoceras* (J) has a rectangular whorl section, straight sutures, and a living chamber that does not touch the preceding whorl. *Solenochilus* (K) is a very tightly coiled form with a pair of prominent spines. *Stenopoceras* (L) has a disc-shaped shell with gently undulating, closely spaced sutures. *Domatoceras* (M) has a flattened, disc-shaped shell, an oval whorl section, and a strongly undulating suture.

Cretaceous nautiloids are represented only by *Eutrephoceras* (N) which has a slightly sinuous suture.

Ammonoids are much more common than nautiloids in the Cretaceous rocks of Nebraska, but are less

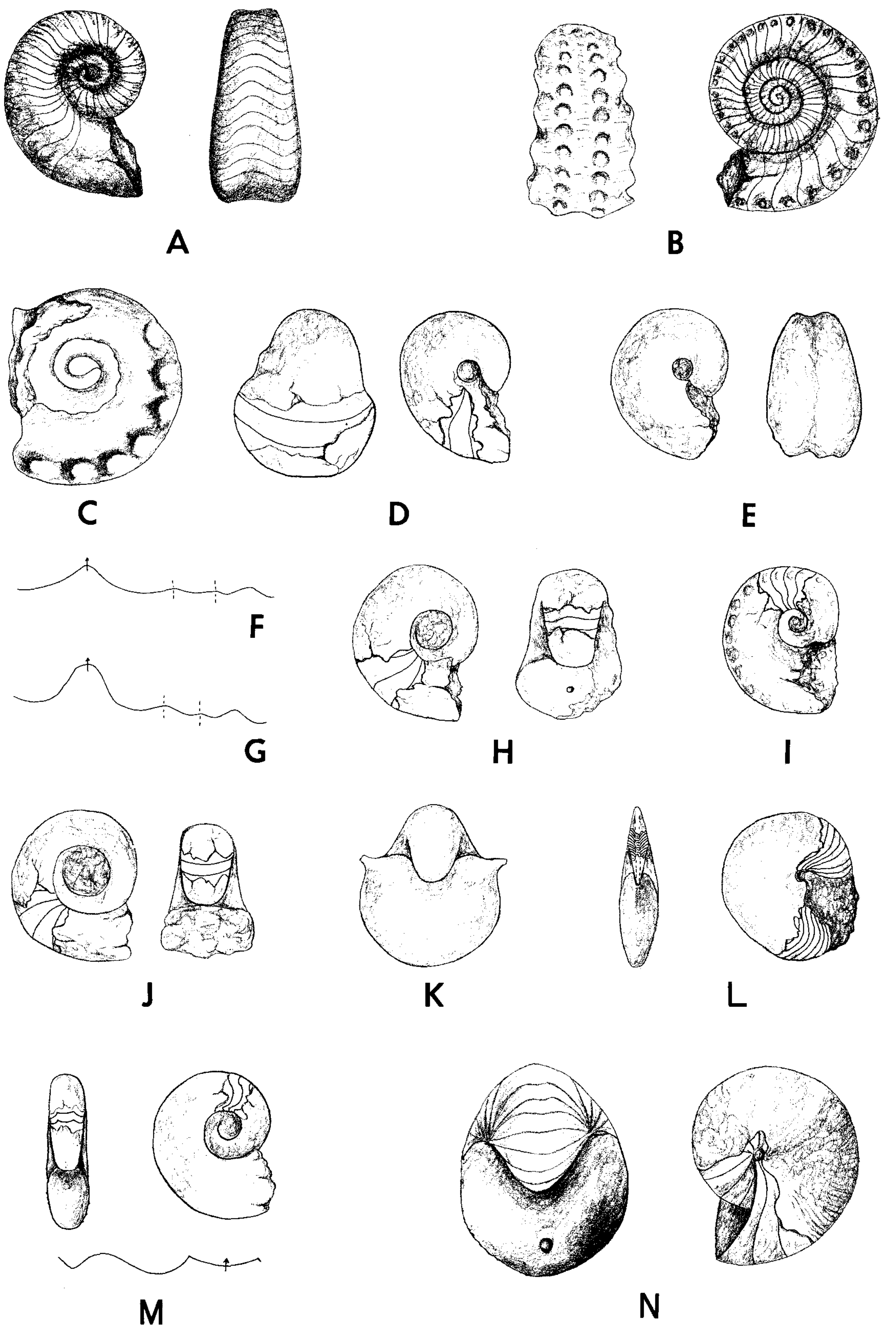


FIGURE 58. Coil-shelled cephalopods with nautiloid sutures from Nebraska. (A) *Titanoceras*, side (left) and posterior (right) views, X$^1/_{10}$. (B) *Tainoceras*, posterior (left) and side (right) views, X$1/_2$. (C) *Temnocheilus*, side view, X1 (D) *Liroceras*, posterior (left) and side (right) views, X1. (E) *Coelogasteroceras*, side (left) and posterior (right) views, X1. (F) *Ephippioceras*, suture only. Arrow points anteriorly. (G) *Megaglossoceras*, suture only. (H) *Endolobus*, side (left) and anterior (right) views, X$1/_3$. (I) *Metacoceras*, side view, X$1/_3$. (J) *Planetoceras*, side (left) and anterior (right) views, X$1/_2$. (K) *Solenochilus*, anterior view, X$1/_3$. (L) *Stenopoceras*, anterior (left) and side (right) views, X$1/_4$. (M) *Domatoceras*, anterior (above, left) and side (above, right) views and suture (below), X$1/_4$. (N) *Eutrephoceras*, anterior (left) and side (right) views, X$1/_3$.

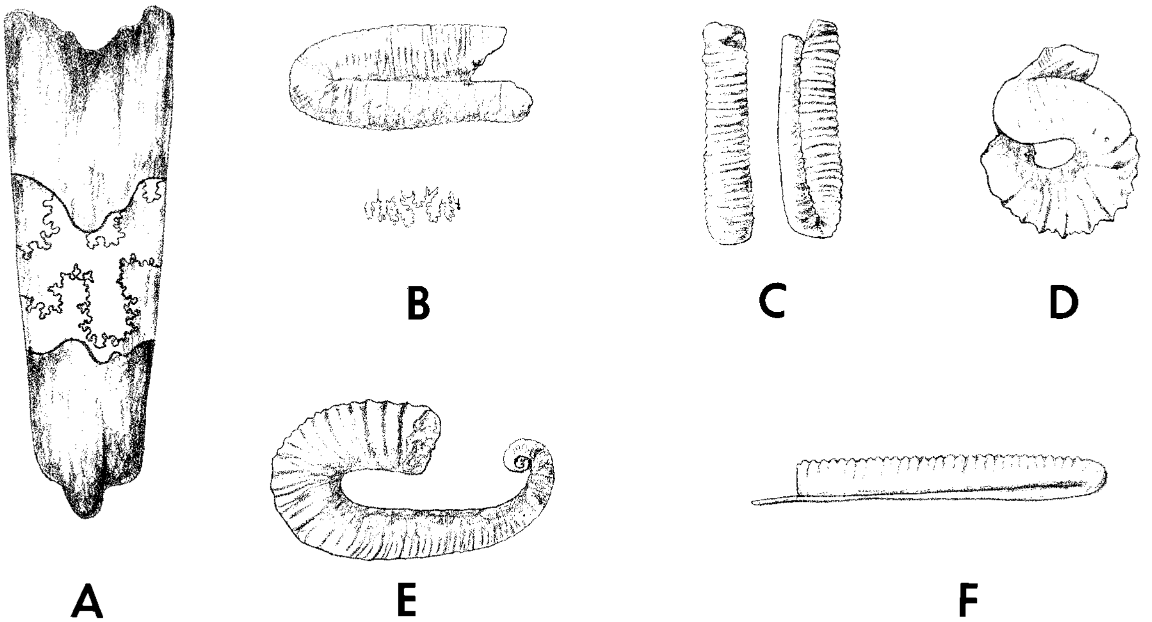


FIGURE 59. Cretaceous partially coiled or straight-shelled ammonoids. (A) *Baculites*, X½. (B) *Hamites*, side view (above) and suture below, X½. (C) *Solenoceras*, top (left) and side (right) views, X½. (D) *Cirroceras*, X¼. (E) *Heteroceras*, X¼. (F) *Ptychoceras*, X½.

common than nautiloids in the Pennsylvanian and Permian rocks. Ammonoid classification, like nautiloid classification, is based on shape of the shell, suture pattern, and siphuncle structure. As with nautiloids, ammonoids can be divided into two groups, those with straight and those with coiled shells.

Cretaceous partially-coiled or straight-shelled ammonoids (Figure 59). *Baculites* (A) has a long, straight shell that may reach several feet in length. *Hamites* (B) is a small, straight-shelled ammonoid that curves tightly like a hairpin, and has a more delicate suture than *Baculites*. *Solenoceras* (C) recurves like *Hamites* but shell ornamentation is much coarser. *Cirroceras* (D) coils along an axis like a high-spired

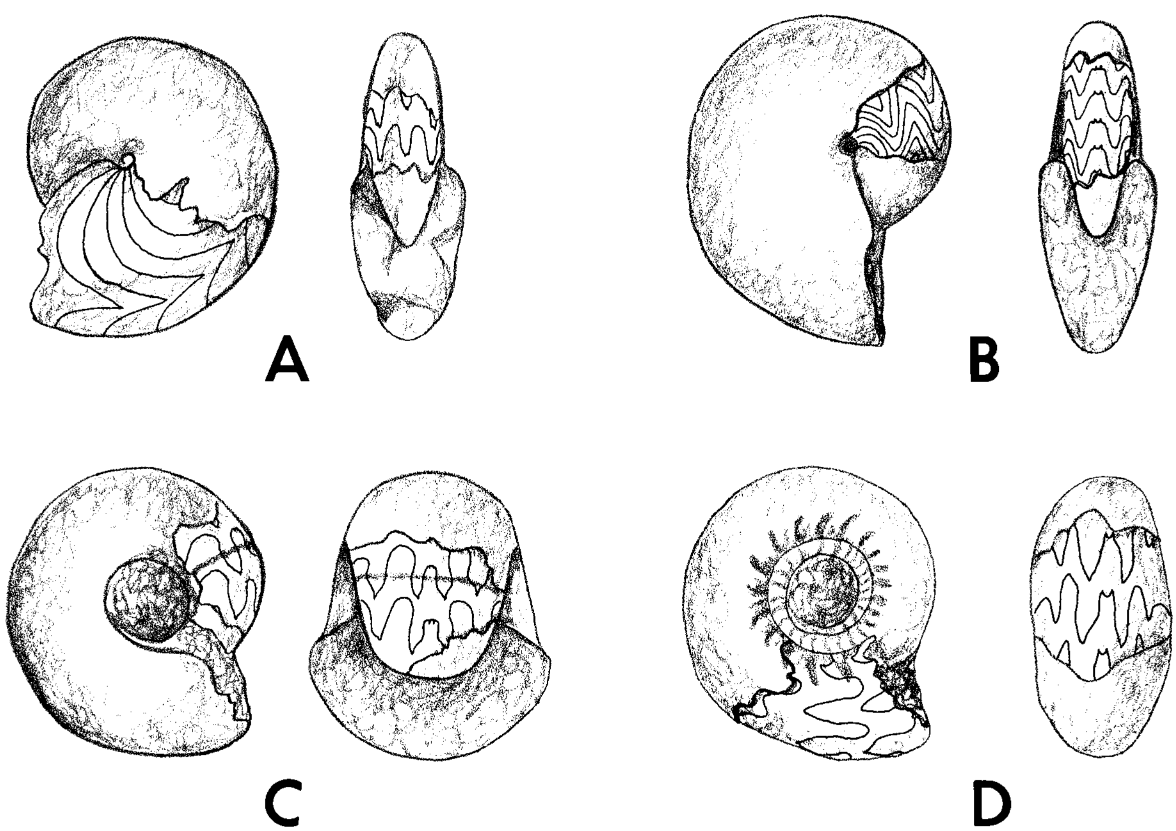


FIGURE 60. Pennsylvanian-Permian coil-shelled ammonoids. (A) *Imitoceras*, X2. (B) *Gonioloboceras*, X1. (C) *Eoasianites*, X1. (D) *Schistoceras*, X1. Side (left) and apertural (right) views.

gastropod. *Cirroceras* usually occurs only as short, nearly straight fragments of a large conical shell. *Heteroceras* (E) starts growth with a small, coiled shell which becomes straight and later recurves. Fragments of *Heteroceras* differ from *Baculites*, the former having coarse ornamentation, the latter having a smooth shell. *Ptychoceras* (F) has a recurving shell which expands uniformly from early to late growth stages.

Pennsylvanian-Permian coil-shelled ammonoids (Figure 60). *Imitoceras* (A) is a small ammonoid and the outer whorl of its shell covers all of the inner whorls. *Gonioloboceras* (B) resembles *Imitoceras*, except that the suture pattern is different. *Eoasianites* (C) has a wide, smooth shell that leaves the inner whorls exposed. *Schistoceras* (D) resembles *Eoasianites*, but has ornamentation on the inner portions of the whorls, and has a somewhat different suture pattern.

Cretaceous coil-shelled ammonoids (Figure 61). *Placenticeras* (A) has a nearly discoidal shell on which the inner whorls are barely visible. *Mortoniceras* (B) has a coarsely ornamented shell on which all of the whorls are visible. *Prionocyclus* (C) resembles *Mortoniceras* but has large nodes along the outer edges of the whorls. *Scaphites* (D) has a coiled shell that straightens out for a short distance and then recurves. *Clioscaphites* (E) has a coarsely ornamented shell on which only the outer whorl is visible. *Acanthoscaphites* (F) resembles *Clioscaphites* but has very coarse ornamentation near the aperture and a different suture pattern. *Discoscaphites* (G) has fine ornamentation and rows of concentric nodes which become larger toward the outer edge of the shell. *Trachyscaphites* (H) resembles *Discoscaphites*, but has fewer large nodes. *Hoploscaphites* (I) resembles *Scaphites* but does not recurve as extremely. *Haresiceras* (J) has a row of paired nodes along the outer edge of the shell. *Anapachydiscus* (K) has a smooth shell with evenly spaced ornamentation. *Barroisiceras* (L) has coarse, radial ornamentation. *Rhaeboceras* (M) has a smooth shell, except for ornamentation along the inner edge of the outer whorl.

Subclass Coleoidea

Belemnitella (Figure 62) is the only genus of belemnites reported from Nebraska thus far. It has a long, cigar-shaped shell without sutures and is composed of radiating fibers of the mineral aragonite.

Occurrence of Cephalopods from Nebraska

Although fossil cephalopods are widespread in their occurrence, they are not abundant and occur only as scattered individuals. Ancient cephalopods may have schooled, as do modern squids. The bodies of dead cephalopods frequently fill with gasses and float, often for many hundreds of miles, before the soft parts decompose and the shell sinks. Fossil cephalopods are not so rare as to render impractical their use as reliable index fossils.

Pennsylvanian and Permian Cephalopods

Pseudorthoceras commonly occurs in the Winterset and Westerville Limestones and in the Chanute Shale and Argentine Limestone near Louisville, Richfield, and Cedar Creek.

The Argentine Limestone exposed near Louisville has yielded a large variety of cephalopods, including *Megaglossoceras, Poterioceras, Tainoceras, Titanoceras, Domatoceras, Pseudorthoceras*, and *Solenochilus*.

Cephalopods are also common in the Bonner Springs Shale which is exposed near Louisville. The minute forms, *Imitoceras* and *Eoasianites*, and the larger forms, *Tainoceras, Temnochilus, Mooreoceras*, and *Pseudorthoceras* are found in this unit. *Pseudorthoceras, Ephippioceras*, and *Tainoceras* occur in the South Bend Limestone near Louisville.

Dolorthoceras, Planetoceras, and *Pseudorthoceras* occur in the Toronto Limestone near Weeping Water. The Plattsmouth Limestone has yielded specimens of *Mooreoceras, Pseudorthoceras, Dolorthoceras, Titanoceras*, and *Pseudometacoceras* from exposures near Weeping Water, Ashland, Plattsmouth, and Nehawka. *Liroceras* occurs in the Queen Hill Shale at Plattsmouth.

The Larsh Shale and Ervine Creek Limestone exposed near Union and Weeping Water contain a diverse population of fossil cephalopods including: *Domatoceras, Tainoceras, Metacoceras, Dolorthoceras, Pseudorthoceras*, and *Brachycycloceras*. The Ervine Creek Limestone has produced large specimens of *Titanoceras*, up to 18 inches in diameter, as well as smaller specimens of *Pseudometacoceras* and *Pseudorthoceras*.

Pseudorthoceras, Mooreoceras, and *Temnochilus* have been found in the Howard Limestone near Du Bois. Minute pyrite fossils of the nautiloid *Pseudorthoceras*, and the ammonoids *Imitoceras* and *Eoasianites* occur in concretions in the Severy Shale near Du Bois. *Dolorthoceras, Pseudorthoceras*, and *Tainoceras* have been collected from the Reading Limestone and Willard Shale near Nebraska City and Du Bois.

Permian nautiloids are represented by *Metacoceras, Domatoceras, Solenochilus, Endolobus, Tainoceras, Pseudorthoceras*, and *Mooreoceras*, all of which have been collected from the Hughes Creek Shale near Bennet, Douglas, Unadilla, and Syracuse. *Metacoceras* has been reported from the Neva Limestone at Roca and *Tainoceras* from the Fort Riley Limestone near Holmesville.

Cretaceous Cephalopods

Impressions of the ornamented ammonite *Prionocyclus* are common in several localities where the Greenhorn Limestone and Graneros Shale are exposed, near Newcastle, Garland, Milford, Crete, Wilber, Fairbury, Gilead, and Hebron. Belemnites of the genus *Belemnitella* are often associated with the ammonites *Mortoni-*

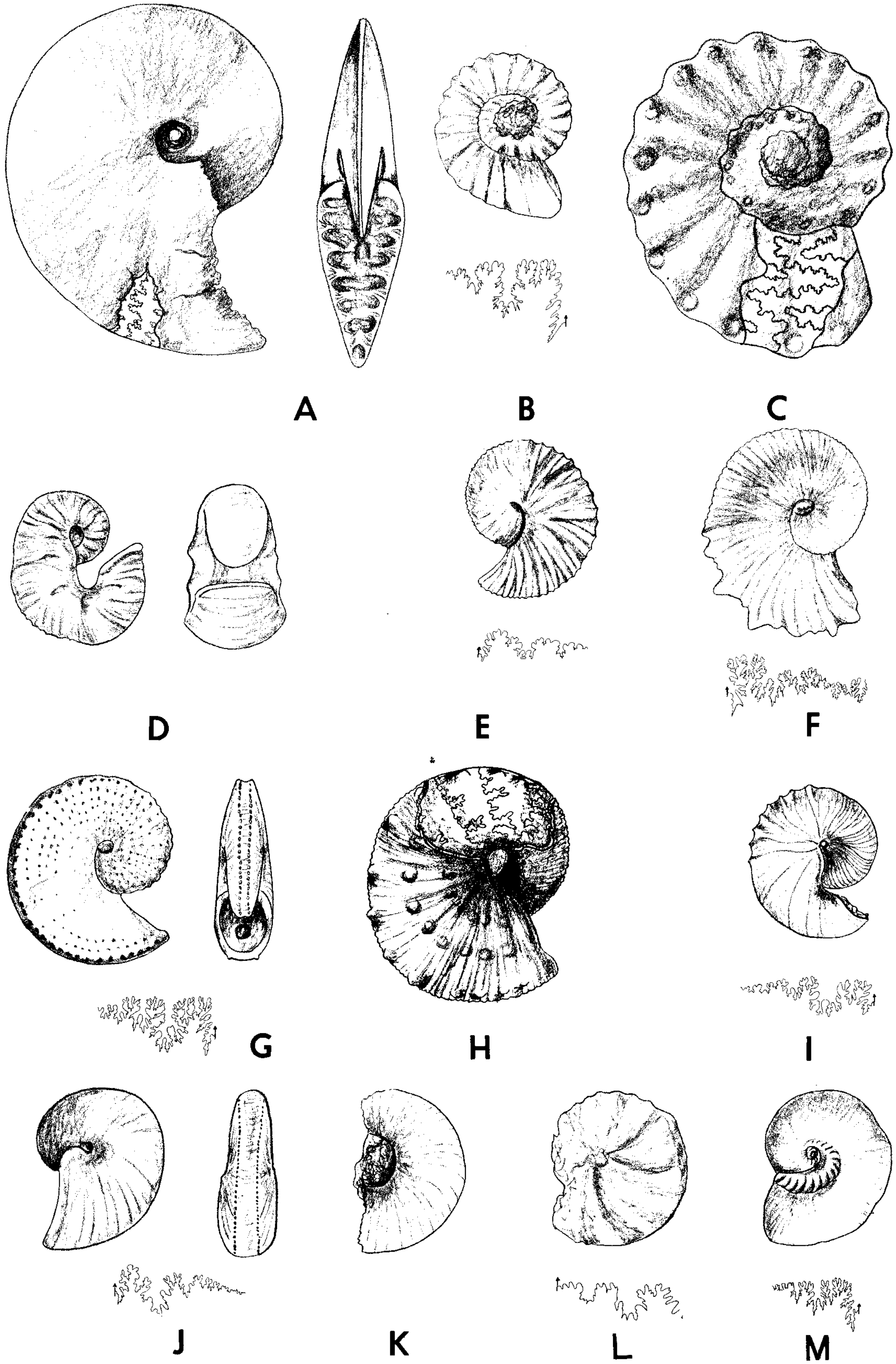


FIGURE 61. Coil-shelled Cretaceous ammonoids of Nebraska. (A) *Placenticeras*, side (left) and anterior (right) views, X¼. (B) *Mortoniceras*, side view (above) and suture (below) X½. (C) *Prionocyclus*, side view, X½. (D) *Scaphites*, side (left) and anterior (right) view, X¼. (E) *Clioscaphites*, side view (above) and suture (below), X½. (F) *Acanthoscaphites*, side view (left) and suture (right), X½. (G) *Discoscaphites*, side view (above, left) and anterior (above, right) view, and suture (below), X½. (H) *Trachyscaphites*, side view, X½. (I) *Hoploscaphites*, side view (left) and suture (right), X½. (J) *Haresiceras*, side (above, left), posterior (above, right) views, and suture pattern (below), X1. (K) *Anapachydiscus*, side view, X½. (L) *Barroisiceras*, side view (above) and suture (below), X½. (M) *Rhaeboceras*, side view (above) and suture (below), X¼.

FIGURE 62. A Nebraska fossil belemnite, *Belemnitella*, X1.

ceras and *Prionocyclus* in the Greenhorn Limestone near Newcastle and Gilead.

Eutrephoceras, Scaphites, Placenticeras, and *Baculites* occur in concretions in the Pierre Shale which is exposed north of Chadron and Crawford. All of the other genera of Cretaceous ammonites illustrated in the figures occur in the Pierre Shale in Nebraska but make up only a very small percentage of the total cephalopod fauna.

Phylum Annelida (Segmented Worms)

Annelid worms are not an important part of the Nebraska fossil record. Except for their jaws, they have no hard parts to be preserved. Typical modern annelid worms include the earth worm and night crawler. The body of the annelid worm is segmented. Each segment may have a pair of legs, and some annelid worms have jaw-like structures called *scolecodonts* which may be preserved as fossils. Scolecodonts look much like conodonts (Fig. 84) but the former are black and opaque, whereas the latter are brown and translucent. Some annelid worms form an elongated, cylindrical, hard chitinous or calcareous tube which may be preserved as a fossil (Fig. 63).

Phylum Arthropoda

The Living Arthropod

Arthropods are segmented, joint-legged animals that grow by shedding their exoskeletons (moulting). Modern arthropods include insects, crustaceans, spiders,

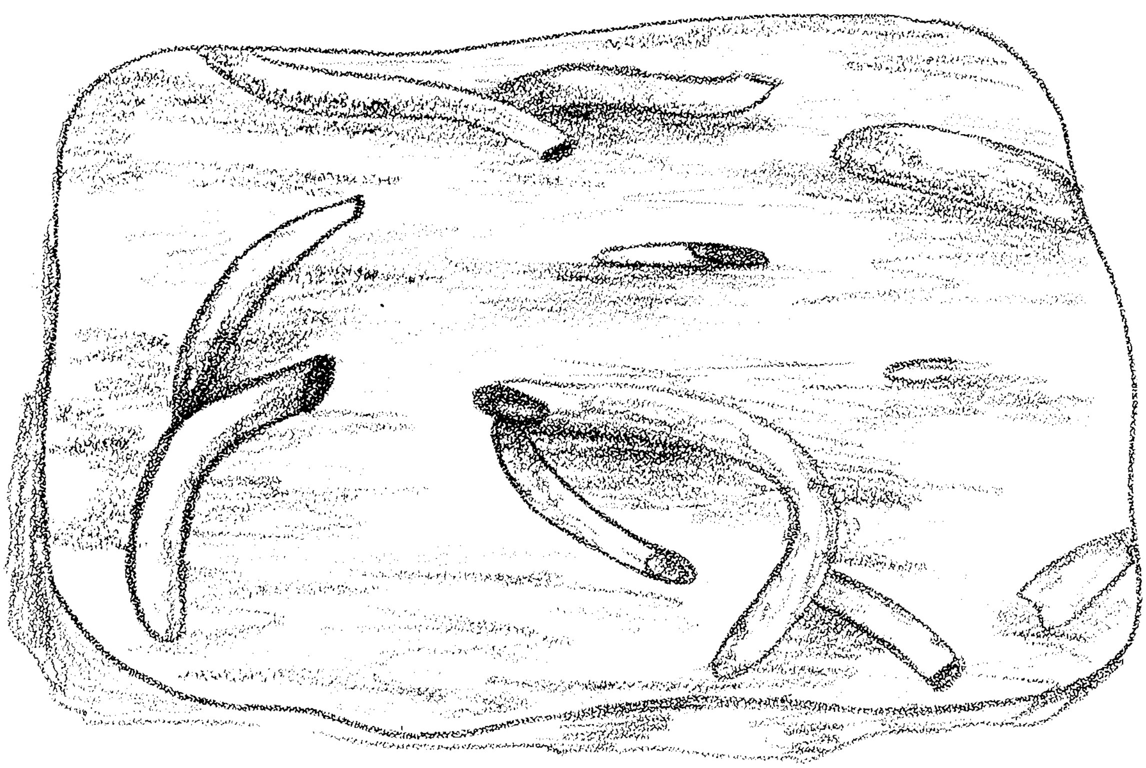


FIGURE 63. Fossil worm tubes, *Serpula*, X1.

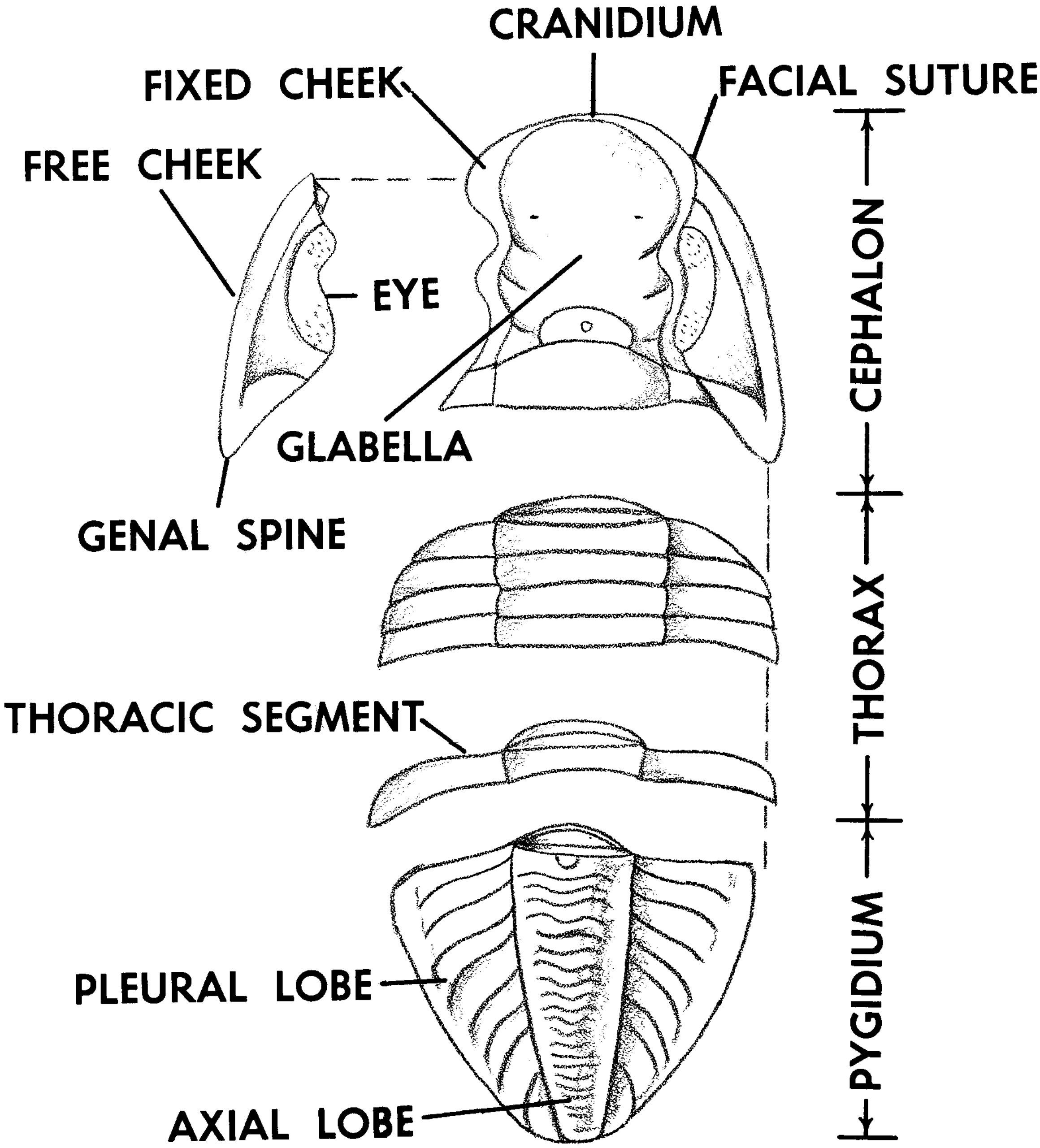


FIGURE 64. A break-away diagram of typical Pennsylvanian trilobite showing some of the important features used in classification and the relationships between the cephalon, thorax, and pygidium, and the free cheek and cranidium.

scorpions, and horseshoe crabs. Some arthropods have well developed circulatory, respiratory, and nervous systems which enable them to live in many different environments. Many have multifaceted eyes, well-developed muscles, and all arthropods have a digestive tract.

Class Trilobita

Trilobites are one of the most primitive of arthropods. As their name suggests, they were divided into three lobes: a middle (axial) lobe and two side (pleural) lobes. A diagram of a trilobite is shown in Figure 64. The three-fold division is made not only from side to side but also from head to tail. The head (*cephalon*) and tail (*pygidium*) are made up of fused, immobile segments. The intermediate body (*thorax*) is made up of movable segments which enabled the animal to curl up for protection. Some trilobite species had well developed sensory antennae extending forward from the head. Some trilobites moulted by breaking along a *facial suture,* which separates the *fixed cheek* and *free cheek.* Each segment of the animal had a pair of leg-like appendages, one of which served for locomotion and the other for respiration.

Guide to Trilobite Identification

Only three genera of trilobites are known from the fossil record of Nebraska. These are restricted to the Pennsylvanian and Permian rocks of the southeastern part of the state. A complete trilobite is found but rarely; however, because of the habitual moulting process of trilobites, their parts are commonly found. *Ameura*, *Ditomopyge*, and *Anisopyge* are the three genera of trilobites found in Nebraska.

In *Ditomopyge* (Fig. 65A) the glabella extends to or overhangs the anterior of the cranidium. *Ditomopyge* has a small jelly-bean-shaped lobe directly behind the glabella (Fig. 64), which is absent on *Ameura*. The genal spine extends to the fifth or sixth thoracic segment. *Ditomopyge* has a semicircular pygidium; very small pygidia have a pair of spines behind the axial lobe.

In *Ameura* (Fig. 65B), the *glabella* (Fig. 64) is commonly widest between the eyes and it does not reach the front of the *cranidium*. The *fixed cheek* of *Ameura* is broad in the front becoming narrow toward the rear, and the genal spine, a posterior extension of the *free cheek*, extends to the 5th or 6th thoracic segment. The pygidium of *Ameura* is sub-triangular shaped and the axial lobe does not extend all the way to the posterior.

In *Anisopyge* (Fig. 65C), there is the jelly-bean-shaped lobe behind the glabella, as in *Ditomopyge*, but the glabella does not overhang the front of the cranidium. The genal spine of *Anisopyge* is short, reaching only to the third or fourth thoracic segment. The pygidium of *Anisopyge* is similar to that of *Ameura* in outline, but its axial lobe extends to or overhangs the rear of the pygidium and has numerous (about 20 to 30) segments. There are only about eight segments in the pleural lobes of the pygidium of *Anisopyge*.

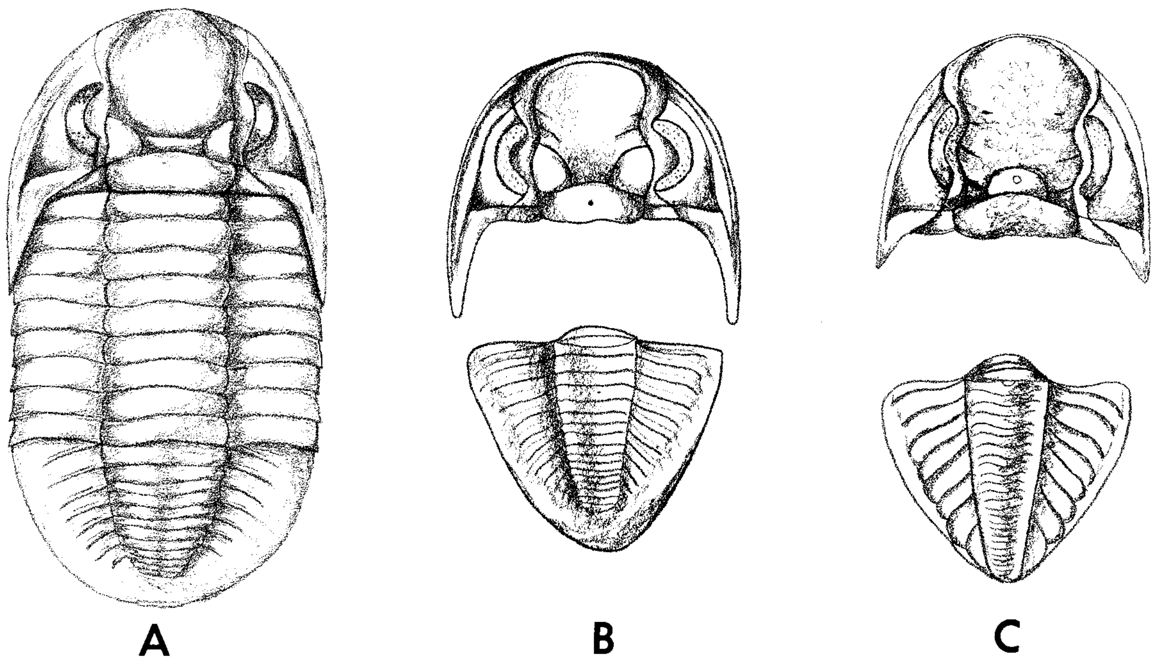


FIGURE 65. Fossil trilobites from Nebraska. (A) *Ditomopyge*, a complete specimen, X5. (B) *Ameura*, cephalon (above) and pygidium (below), X2. (C) *Anisopyge*, cephalon (above) and pygidium (below), X5.

Occurrence of Trilobites in Nebraska

Well-preserved specimens of *Ameura* have been collected from the Winterset Limestone at Louisville and Richfield. *Ameura* occurs in the Frisbie Limestone at Richfield, and in the Argentine, Merriam, and Stoner Limestones near Louisville. Many specimens of *Ameura* have been collected from the Bonner Springs Shale at an abandoned quarry near Cedar Creek. *Ameura* has also been found in the Plattsmouth and Ervine Creek Limestones near Weeping Water, Nehawka, and Plattsmouth, in the Soldier Creek Shale near Unadilla, in the Reading Limestone near Table Rock, and the Curzon Limestone near Union. *Ameura* has been found in the Permian Hughes Creek Shale, near Bennet.

Ditomopyge occurs in the Stoner Limestone near Louisville, the Stull Shale near Weeping Water and Union, the Ervine Creek Limestone near Weeping Water, Plattsmouth, and Union, and in the Soldier Creek Shale near Unadilla. *Ditomopyge* has also been collected from the Permian Hughes Creek Shale near Bennet, the Neva Limestone near Roca, and the Cottonwood and Morrill Limestones near Humboldt.

Anisopyge has been collected from the Permian Hughes Creek Shale near Bennet and the Cottonwood Limestone near Humboldt.

Specimens of an Ordovician trilobite, *Flexicalymene*, have been collected from gravel pits near Crete but these specimens were transported into Nebraska by either stream or glacial activity and are not native to Nebraska. Pennsylvanian-age cherts containing fossils of *Ameura* are sometimes found in the base of the Oligocene, Chadron Formation, but these too have been carried into the state by stream activity.

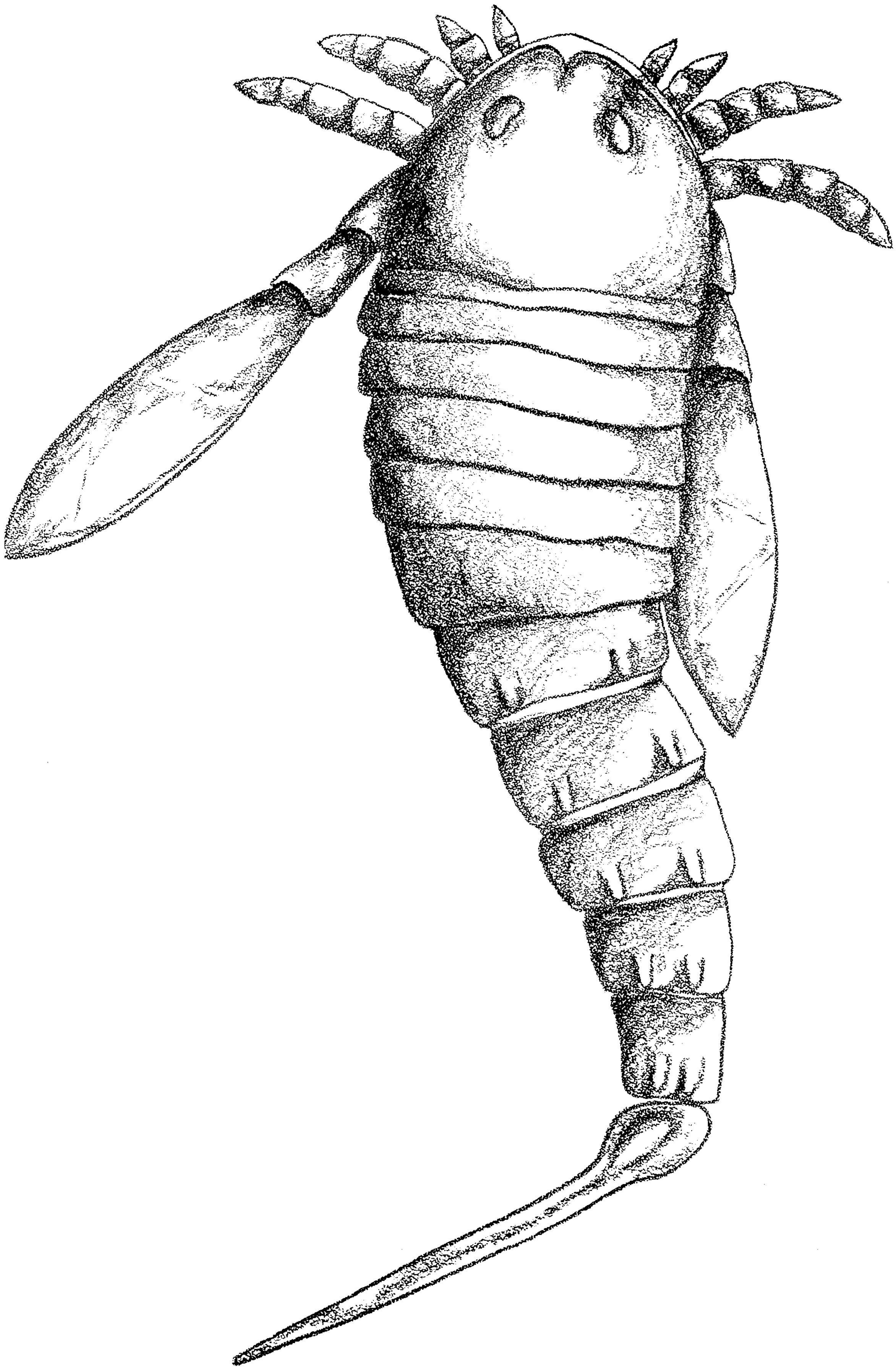


Figure 66. A fossil eurypterid from Nebraska, *Eurypterus*, X15. Note that only five pairs of appendages are visible—the sixth pair is short and hidden on the underside of the animal.

Class Arachnoidea
Subclass Merostomata

Order Eurypterida. Eurypterids are extinct arthropods which were very likely the ancestors of modern-day scorpions. They had six pairs of appendages, one pair of which frequently was greatly flattened to serve as paddles for swimming. The body tapered toward the *abdomen*, terminating with a long spine called a *telson* (Fig. 66).

In Nebraska, eurypterids are an extremely rare fossil and have been found only in the Permian, Indian Cave Sandstone. Several dozen specimens were found in the vicinity of Peru in 1915. It is interesting to note that the specimens found at Peru are among the last-known eurypterids to have lived; they became extinct near the end of Permian time. Because of their rarity, it is unlikely that a collecting trip will yield a fossil eurypterid.

Class Crustacea
Subclass Ostracoda

Perhaps the most common fossil arthropod is the ostracod, which occurs abundantly in Pennsylvanian, Permian, Cretaceous, Tertiary, and Pleistocene rocks. Ostracods are not easily recognized since they can be observed only with a microscope. Ostracods often have bean-shaped shells enclosing a typical arthropod body with segments, legs, and antennae. During growth ostracods moult their shells.

A Permian ostracod, *Amphissites* (A), and a Cretaceous form, *Bairdia* (B), are greatly magnified in Figure 67.

Subclass Cirripedia (Barnacles)

Barnacles are crustaceans that are free-swimming as larvae but, as adults, attach themselves to some surface. Fossil barnacles have been reported from Cretaceous rocks of the neighboring states of South Dakota and Kansas, and possibly may be found in rocks of this age in Nebraska. A fossil barnacle, *Loricula*, is shown in Figure 68.

Class Hexapoda
Subclass Insecta

Typical adult insects are six-legged, air-breathing arthropods, usually bearing one or two pairs of wings. Wings of "roach-like" insects have been found in Permian rocks in Nemaha and Richardson Counties (Fig. 69A).

Silicified cocoons, representing one life stage of insects, have been collected from the Oligocene, Chadron Formation in both Sioux and Dawes Counties (Fig. 69B). Cocoons infiltrated by aragonite are found in cracks in Pennsylvanian and Permian Limestones in southeastern Nebraska, although these are probably quite recent and should not be considered as fossils.

Phylum Echinodermata
(Spiny-skinned animals)

Echinoderms include sea urchins, star fish, brittle stars, sea cucumbers, heart urchins, sand dollars, cystoids, blastoids, and crinoids. They are primitive-appearing, exclusively marine animals. Because of their larval development, echinoderms are classified with the highly advanced groups. They have a *water-*

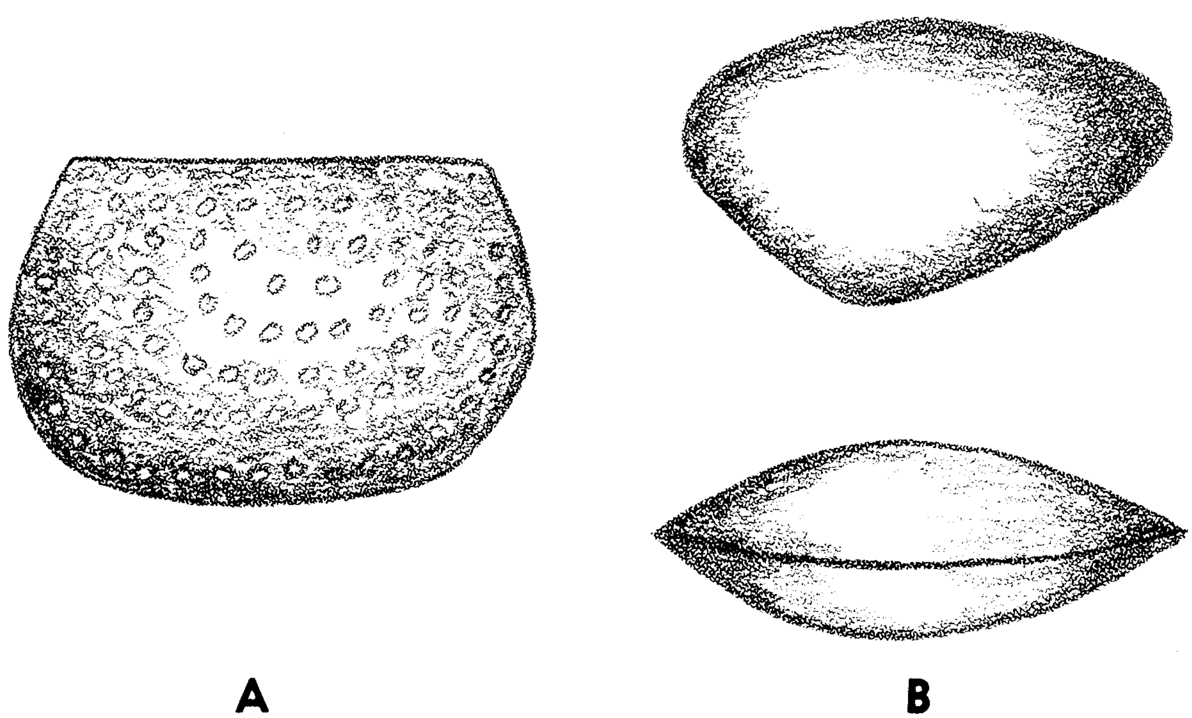


FIGURE 67. Fossil ostracods from Nebraska. (A) *Amphissites*, side view, X100. (B) *Bairdia*, side (above) and ventral (below) views, X60.

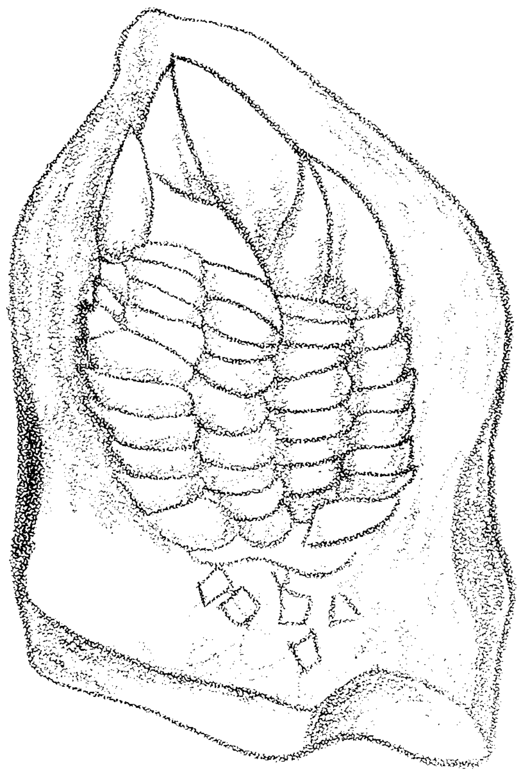


FIGURE 68. A fossil barnacle, *Loricula*, X1.

vascular system which circulates water and assists them in both feeding and locomotion.

The geologic range of echinoderms is from Cambrian through Recent but in Nebraska they are recorded almost exclusively from outcrops of Pennsylvanian and Permian rocks. Although few echinoderm fossils have been reported from Cretaceous rocks in Nebraska, crinoids have been found in Kansas and echinoids in Wyoming. Crinoid and echinoid remains are abundant in the Pennsylvanian and Permian rocks of Nebraska. Ophiuroids (brittle stars) have a scanty record.

Class Crinoidea

The Living Crinoid

Crinoids are stalked echinoderms that have a *crown* attached to a more-or-less flexible *stem* or *column* which may or may not have a root-like structure called a holdfast (Fig. 70). The crown consists of a *cup* or *calyx* and *arms* or *brachials.* The relationship of the arms and plates is shown in Figure 71. The stem consists of numerous segments and may have short branches or *cirri.*

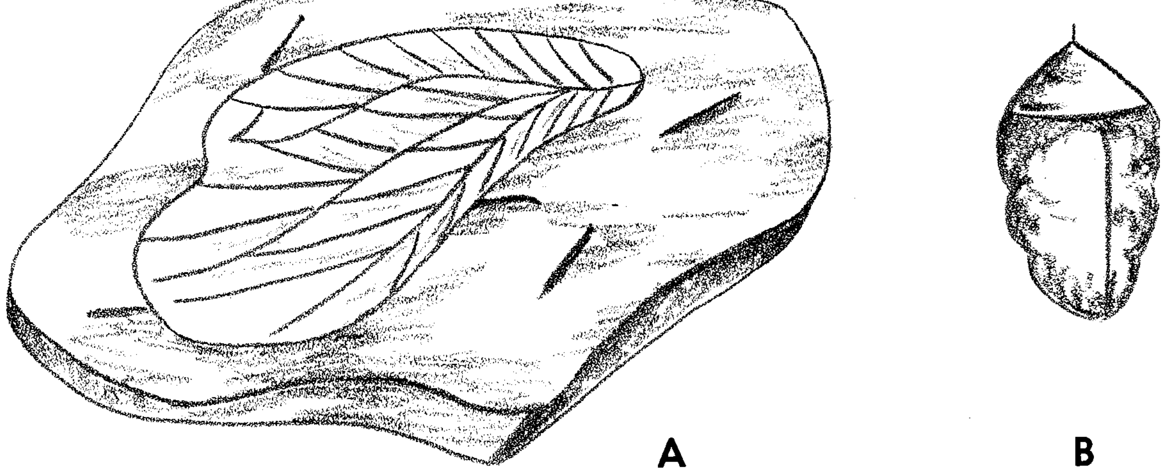


FIGURE 69. Fossil insect remains from Nebraska. (A) Wing of a roach-like insect, X2. (B) A cocoon, X2.

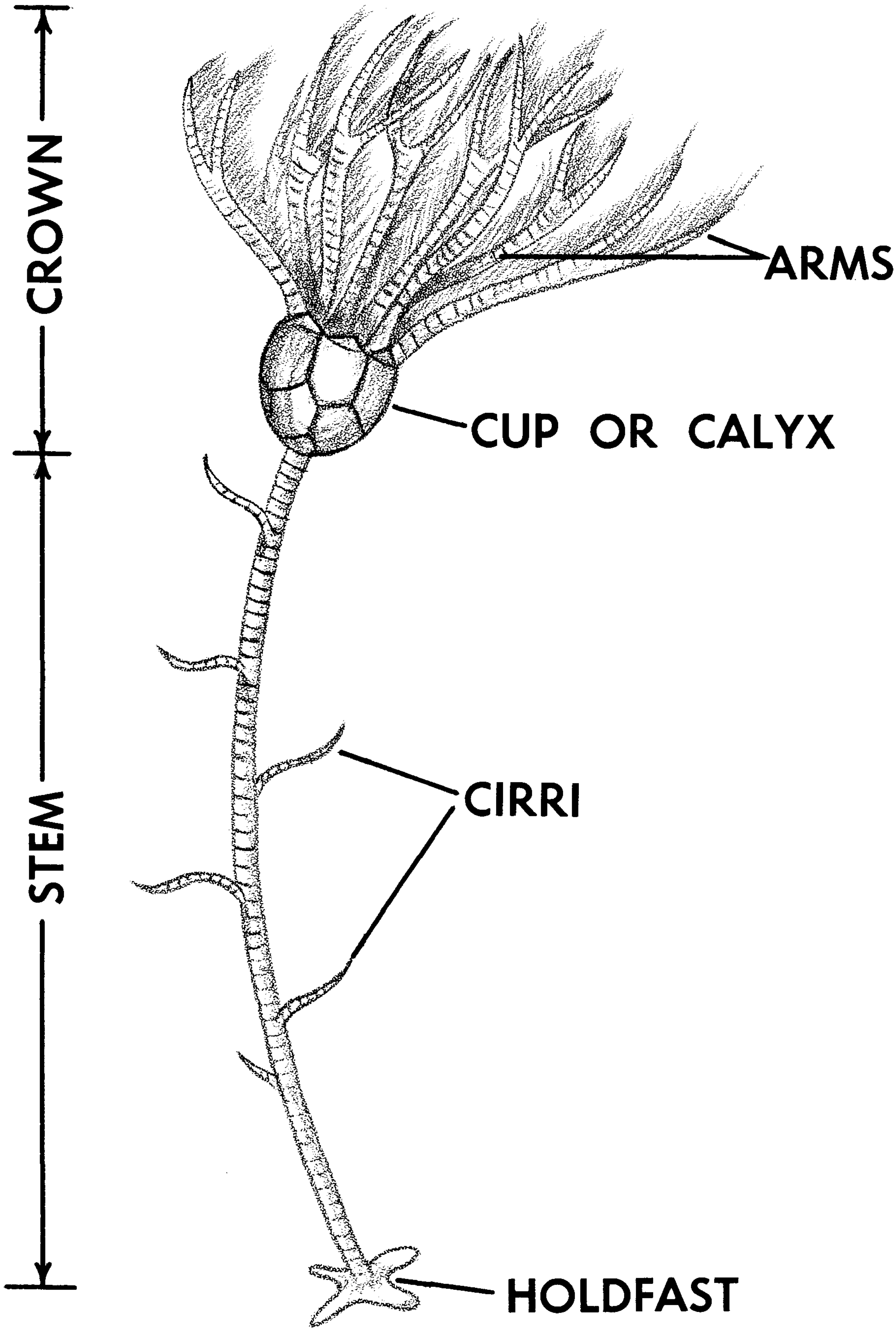


FIGURE 70. A typical crinoid showing the major divisions of the animal.

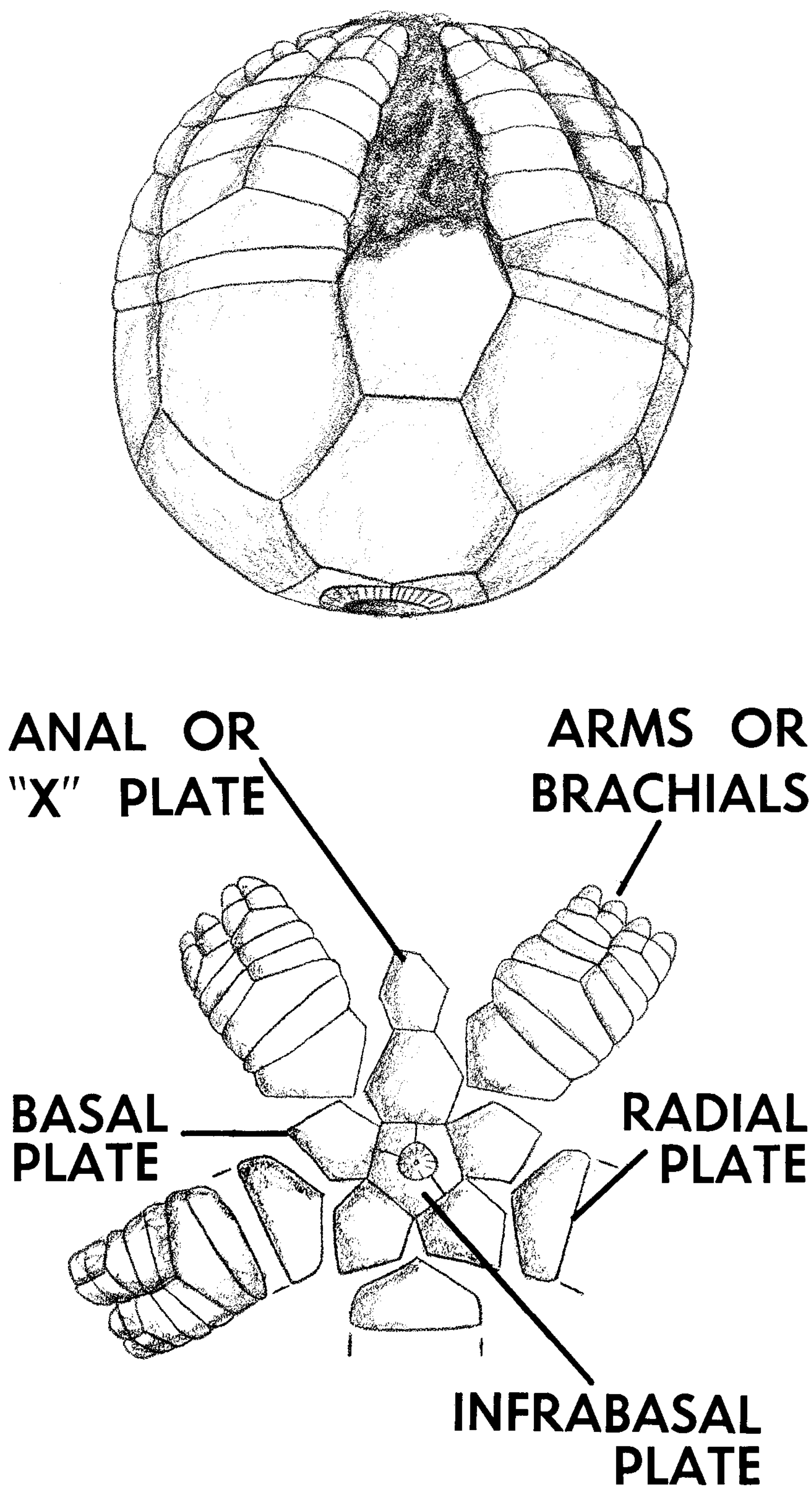


FIGURE 71. A crown of *Cibolocrinus*, above, X4. Below, an outstretched crown of *Cibolocrinus* illustrating the relationships of the plates and arms, X2.

Guide to Crinoid Identification

Parts and fragments of crinoids, rather than the complete fossils, are most commonly found. Some of these parts are illustrated in Figure 72. It is difficult to identify crinoids from their parts only. Crinoid crowns (Fig. 73) are easier to identify. Usually the dorsal cup is the smallest part of the crinoid that is identifiable. The basal concavity (depth of impression of the infrabasal circlet), the number of plates in the anal series, the distinctness of sutures between plates, and ornamentation on the plates are important criteria for crinoid identification. Although fossil crinoids are not numerous in Nebraska, many different genera are present (Figs. 71 through 78).

The following includes the more important genera of Nebraska crinoids and characteristics for their identification.

Crinoids having no anal plate or having a single, recessed anal plate (Figure 74). Some crinoids have no anal plate. Others have a very small, wedge-shaped anal plate that is not seen from the side of the cup, or a recessed anal plate. Nebraska crinoids having no anal plate include the following genera: *Erisocrinus*, *Exaetocrinus*, and *Parerisocrinus*. Crinoids having a recessed anal plate include the following genera: *Parerisocrinus*, *Sublobalocrinus*, and *Neocatacrinus*. Diagnostic criteria for the above genera are given in Figure 74.

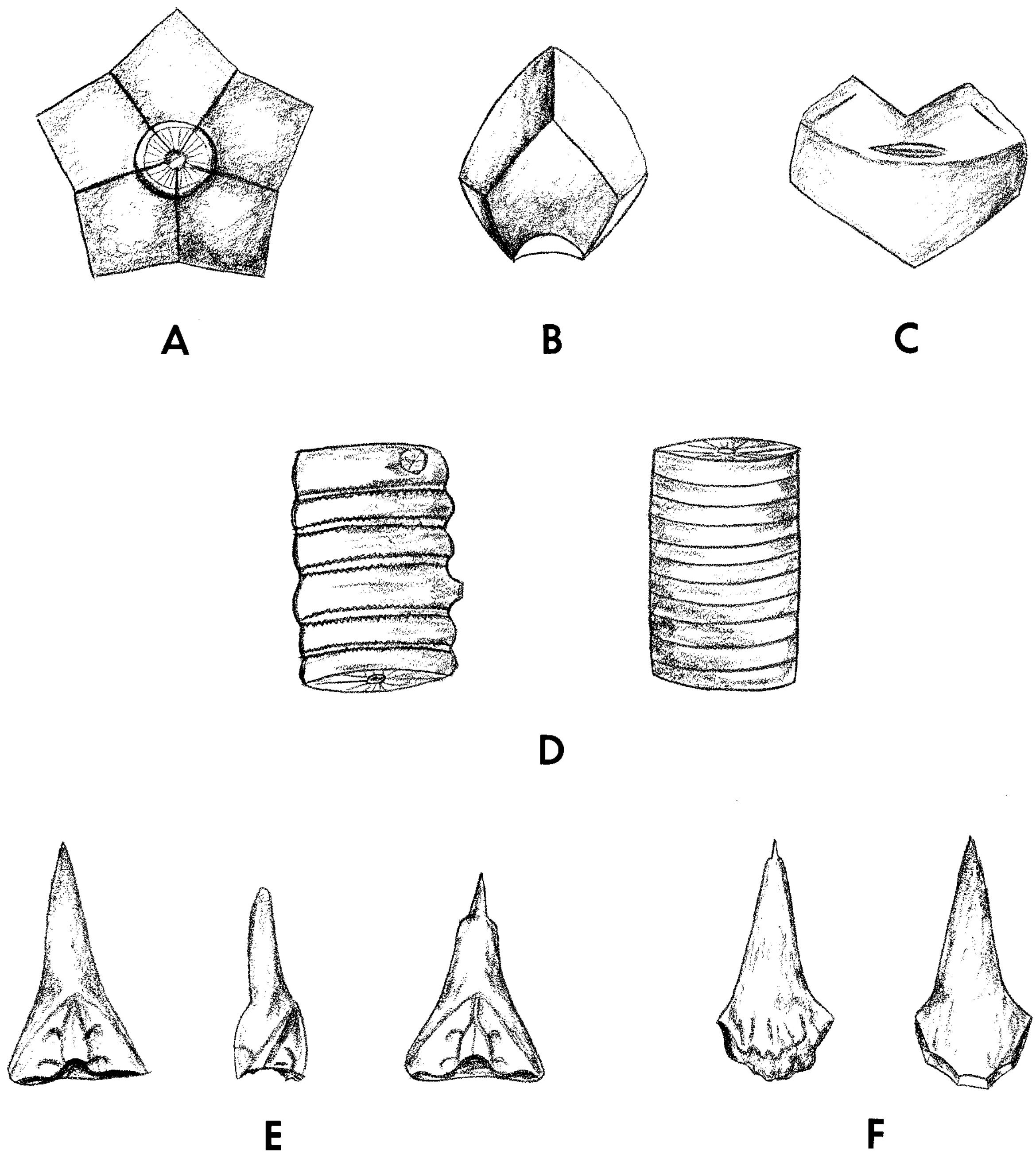


FIGURE 72. Crinoid parts. (A) An infrabasal circlet, X2. (B) Basal plate, X2. (C) Radial plate, X2. (D) Stem fragments, X1. (E) Primibrachials or first arm plates, X1. (F) Sac spines. See *Stenopecrinus*, Fig. 73C, X1.

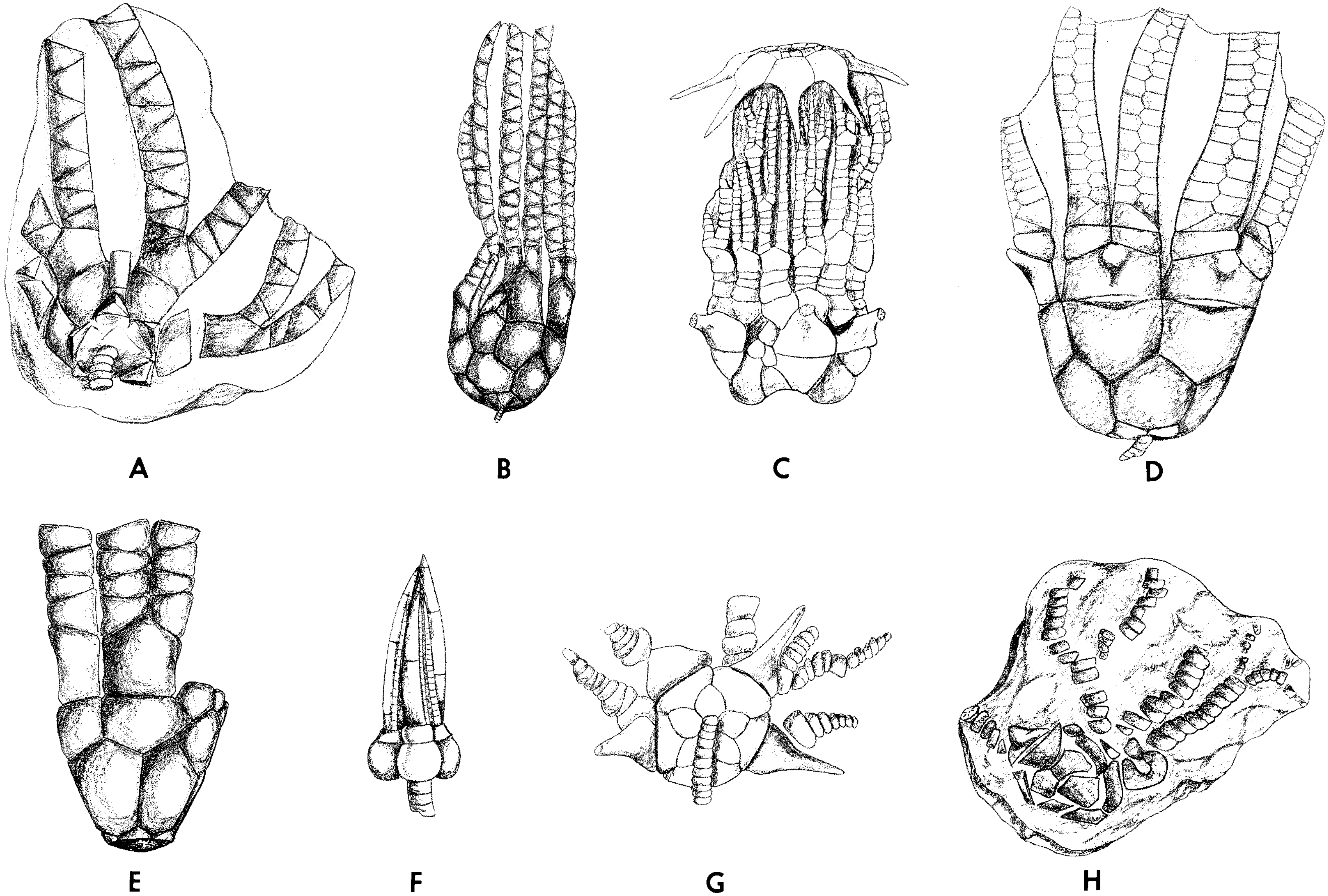


FIGURE 73. Crinoid crowns. (A) *Stellarocrinus*, X1. (B) *Apographiocrinus*, X2. (C) *Stenopecrinus*, X1. (D) *Exaetocrinus*, X2. (E) *Melbacrinus*, X5. (F) *Isoallagecrinus*, X4. (G) *Aatocrinus*, X1. (H) *Parethelocrinus*, X1.

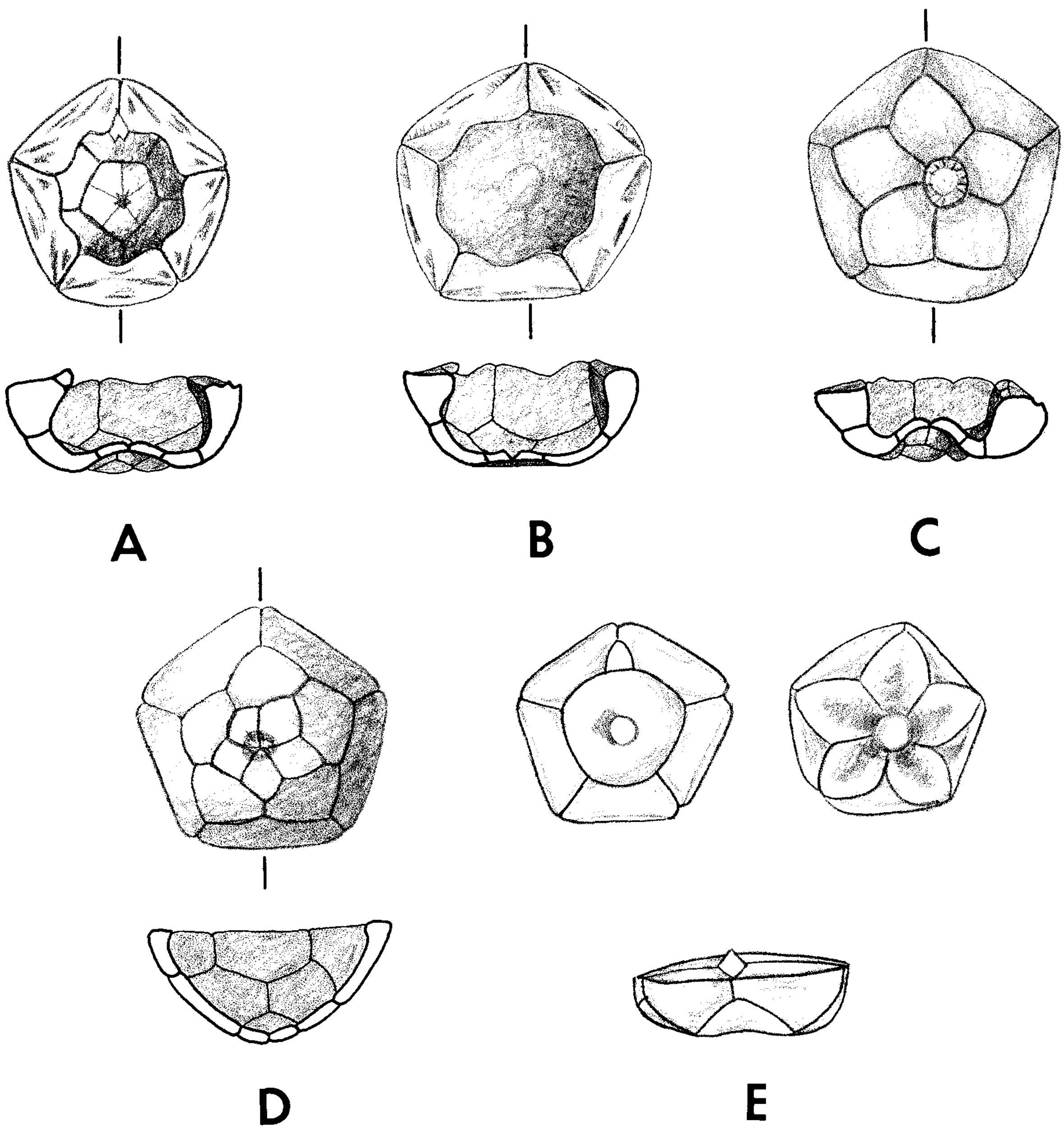


FIGURE 74. Cups of crinoids with no anal plate or a recessed anal plate. (A) *Parerisocrinus*, (B) *Erisocrinus*, (C) *Neocatacrinus*, (D) *Exaetocrinus*, and (E) *Sublobalocrinus*. All figures X1. Note the differences in plate configurations and bases of the cups of different genera.

Crinoids having a single anal plate exposed on the side of the cup (Figures 75 and 76). Some Nebraska crinoids have a single anal plate that is exposed on the side of the cup. This group includes the following genera: *Graffhamicrinus, Delocrinus, Cathetocrinus, Palmatocrinus, Subarrectocrinus, Arrectocrinus, Catacrinus, Pyndaxocrinus, Lobalocrinus, Endelocrinus, Tholiacrinus* (Fig. 75), and *Cibolocrinus, Euonychocrinus, Amphicrinus, Aesiocrinus, Allosocrinus, Polusocrinus, Oklahomacrinus, Contocrinus,* and *Apographiocrinus* (Fig. 76). Diagnostic criteria for the above genera are given in Figures 75 and 76.

Crinoids having two or three plates in the anal series (Figure 77). Some crinoid genera have two anal plates, some genera have three, and some genera have either two or three. Genera included in this group include the following: *Parulocrinus, Ulocrinus, Ethelocrinus, Parethelocrinus, Aglaocrinus,* and *Tarachiocrinus*. Diagnostic criteria for the above genera are given in Figure 77.

Crinoids having three or more plates in the anal series (Figure 78). Some crinoids have three or more anal plates. This group includes the following: *Plaxocrinus, Laudonocrinus, Aatocrinus, Athlocrinus,*

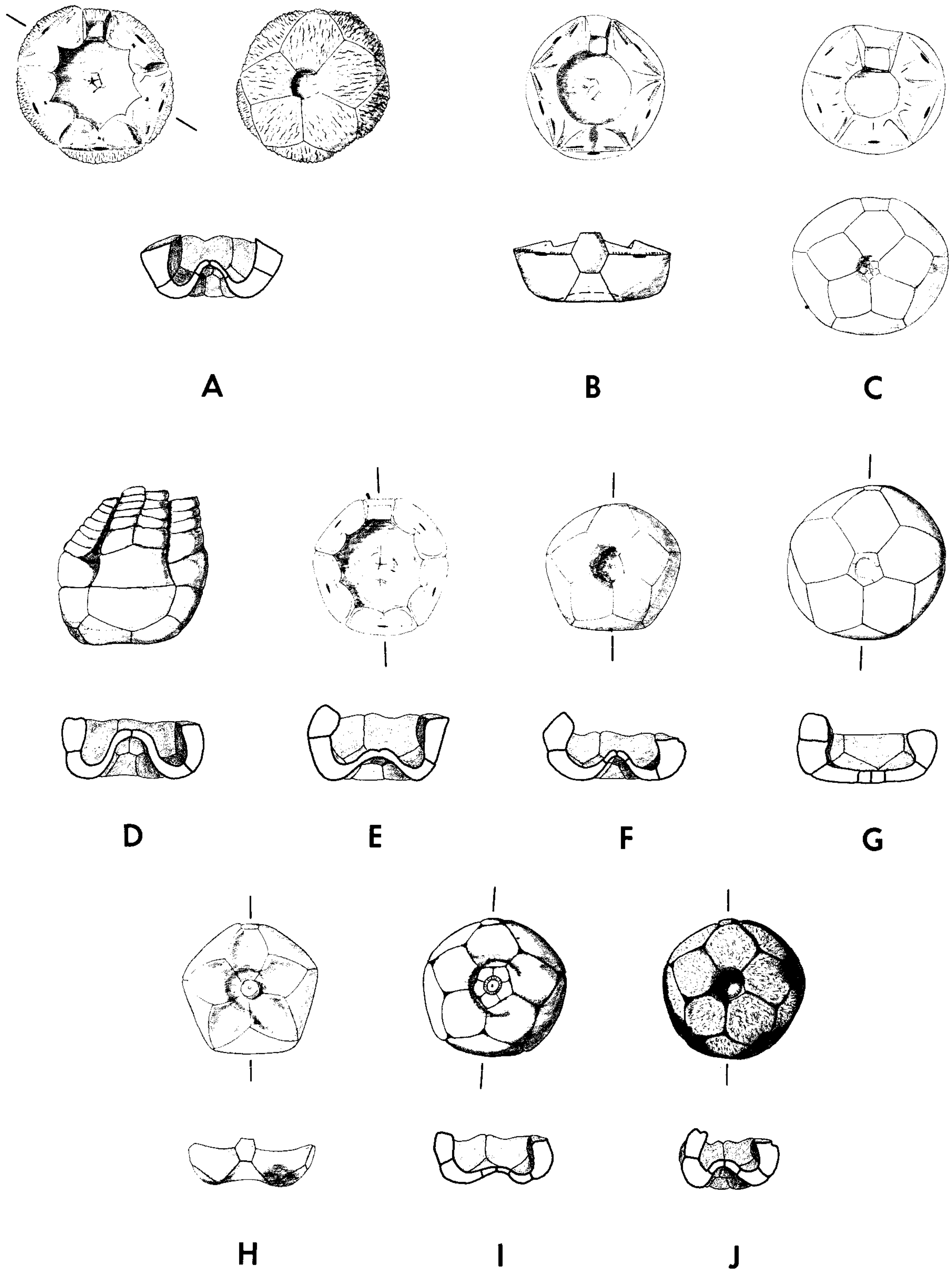


FIGURE 75. Cups of crinoids with a single anal plate. (A) *Graffhamicrinus,* (B) *Cathetocrinus,* (C) *Palmatocrinus,* (D) *Subarrectocrinus,* (E) *Arrectocrinus,* (F) *Catacrinus,* (G) *Pyndaxocrinus,* and (H) *Lobalocrinus.* A-H all X1. (I) *Endelocrinus,* and (J) *Tholiacrinus.* I and J both X2. Note the differences in plate configurations and bases of the cups of different genera.

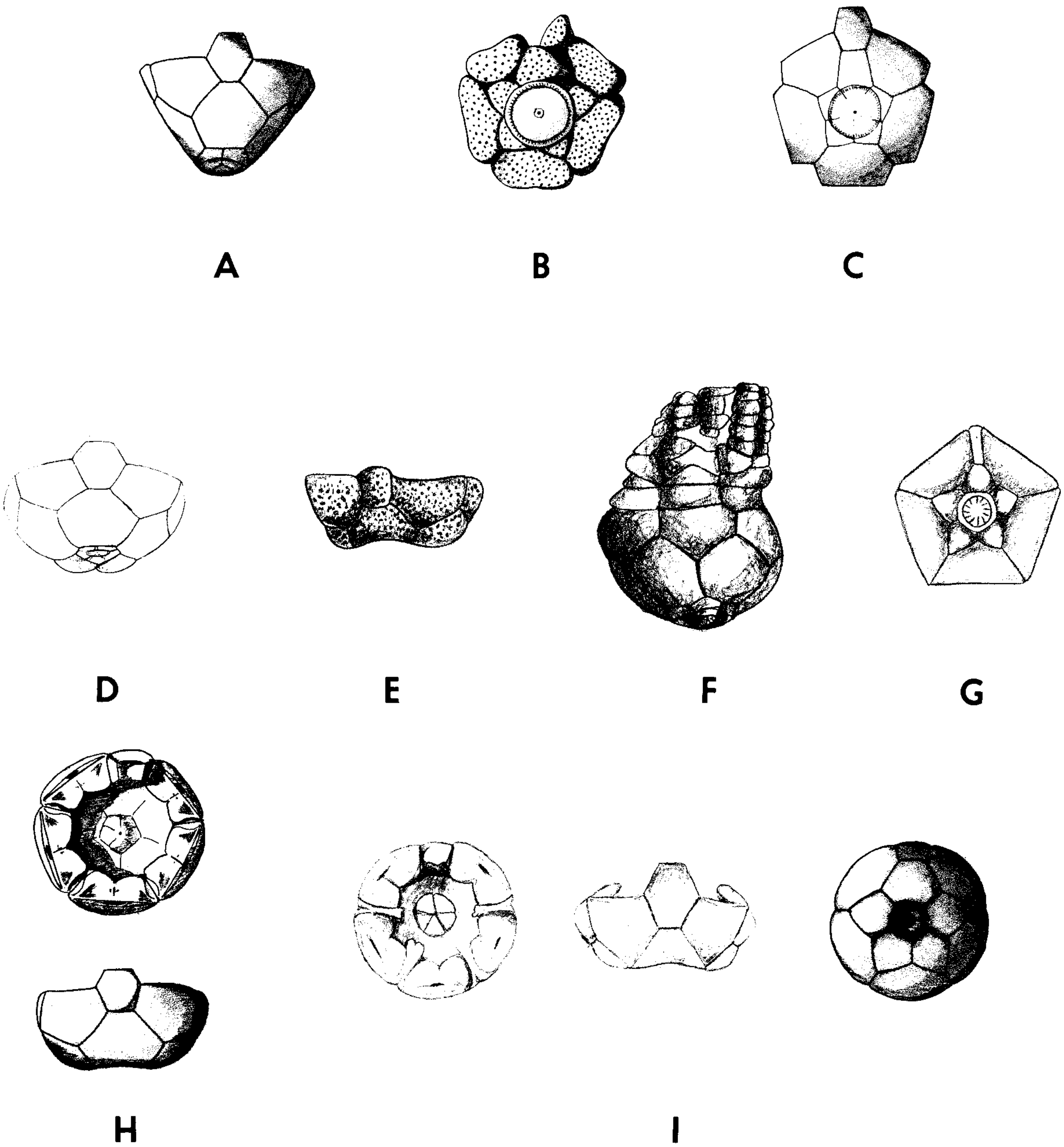


FIGURE 76. Crinoids with cups having a single anal plate. (A) *Cibolocrinus*, X1. (B) *Euonychocrinus*, X2. (C) *Amphicrinus*, X2. (D) *Aesiocrinus*, X2. (E) *Allosocrinus*, X2. (F) *Polusocrinus*, X1. (G) *Oklahomacrinus*, X1. (H) *Contocrinus*, X2. (I) *Apographiocrinus*, X3.

Hypermorphocrinus, Schistocrinus, Simocrinus, Retusocrinus, Vertigocrinus, Sciadiocrinus, Galateacrinus, Stenopecrinus, Perimestocrinus, Exocrinus, Melbacrinus, Nebraskacrinus, and *Elibatocrinus*. Diagnostic criteria for the above genera are given in Figure 78.

Miscellaneous crinoids (Figure 79). Several genera of crinoids found in Nebraska do not readily fit into any of the above categories. These are *Caucacrocrinus, Dinacrocrinus, Lecythiocrinus,* and *Coenocystis*.

Occurrence of Crinoids in Nebraska

Parerisocrinus has been collected from the Westerville Limestone near Richfield. *Aesiocrinus* has been found in the Raytown Limestone and Lane Shale near Louisville and Richfield.

Graffhamicrinus, Graphiocrinus, Parulocrinus, Polusocrinus and *Plaxocrinus* have been collected from the Bonner Springs Shale and Merriam Limestone near Louisville.

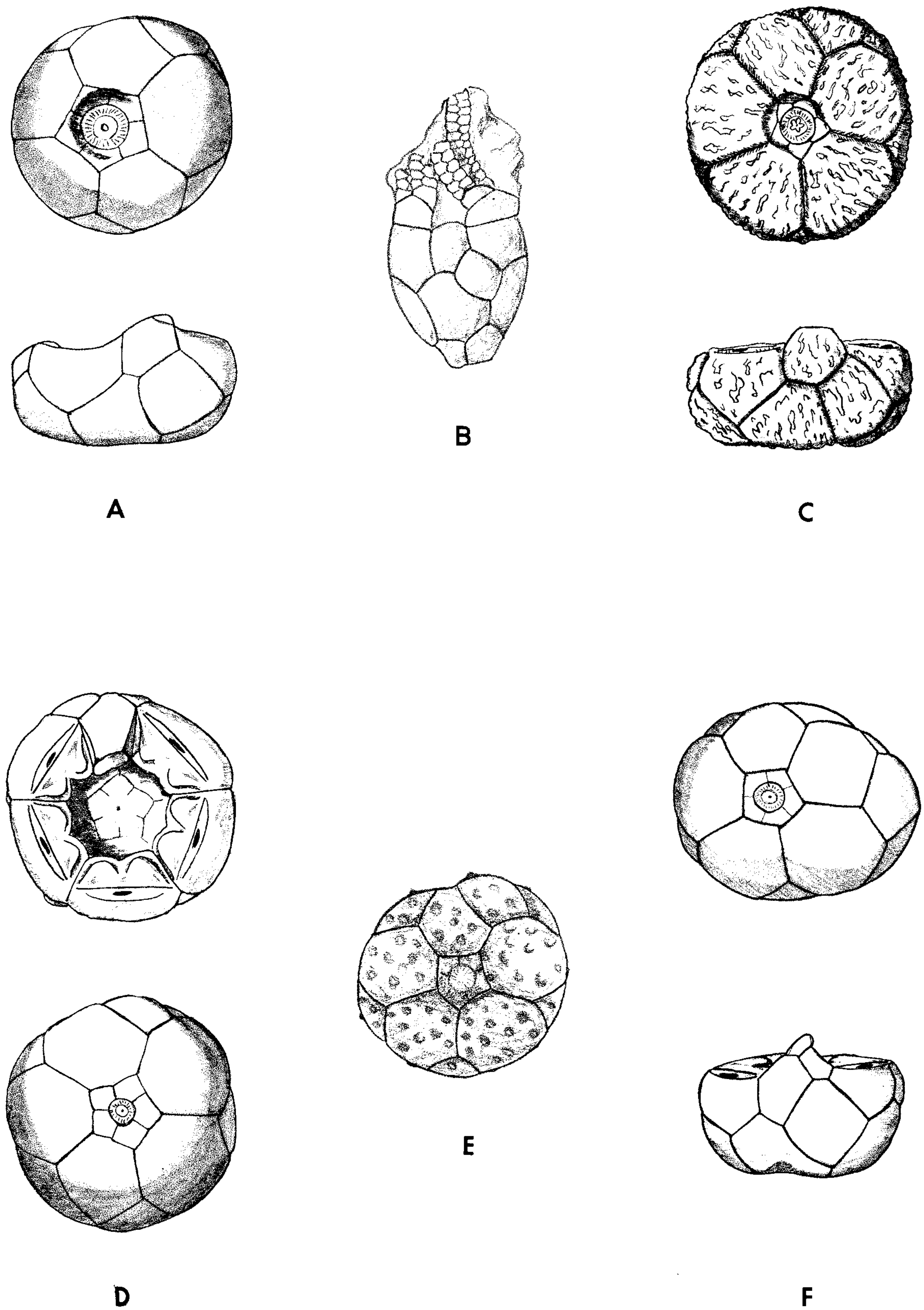


FIGURE 77. Cups of crinoids with two or three plates in the anal series. (A) *Parulocrinus*, (B) *Ulocrinus*, (C) *Ethelocrinus*, (D) *Parethelocrinus*, (E) *Aglaocrinus*, and (F) *Tarachiocrinus*. All figures X1. Note the differences in the plate configuration and bases of cups of different genera.

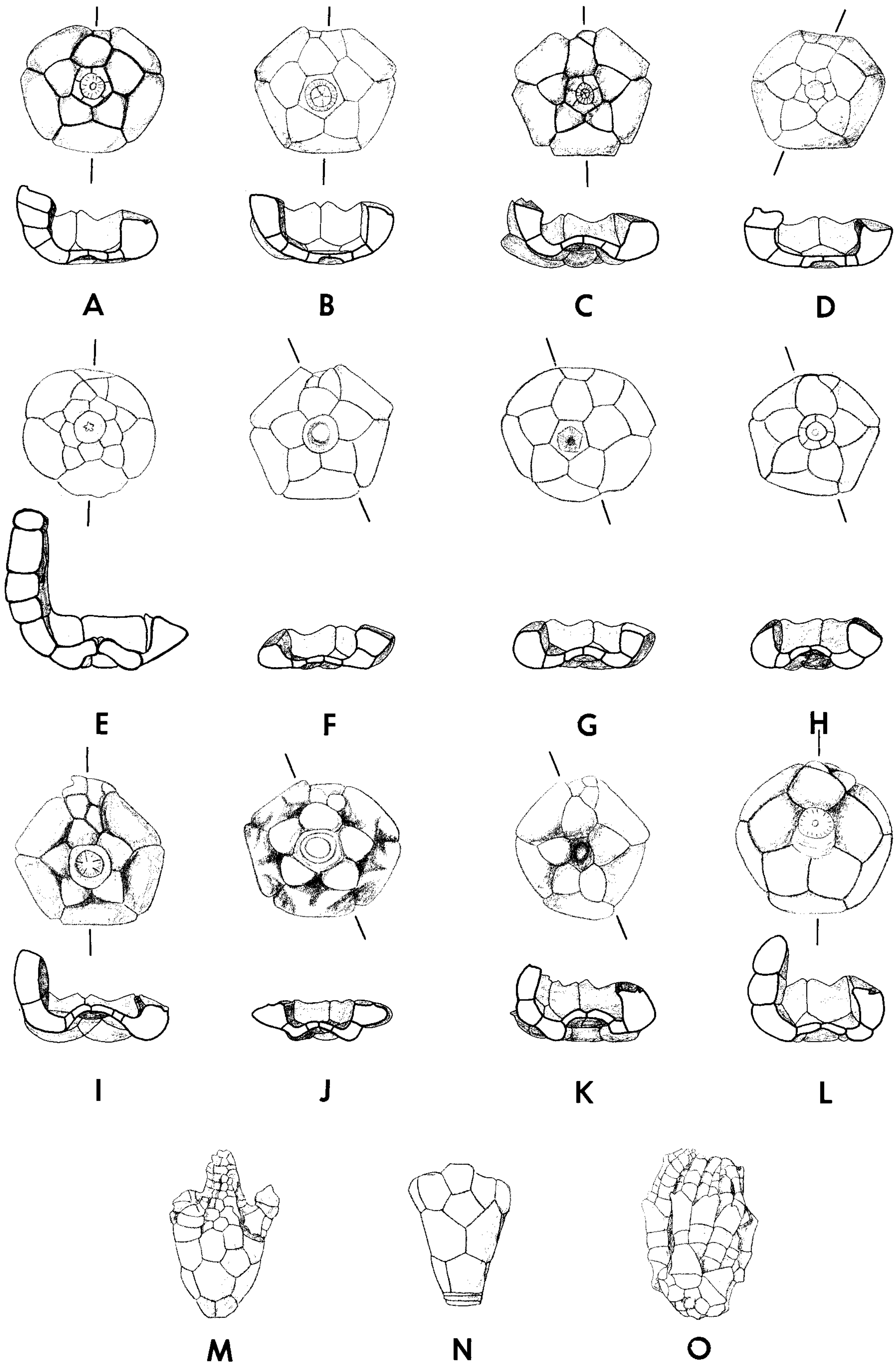


FIGURE 78. Cups and crowns of crinoids having three or more plates in the anal series. (A) *Plaxocrinus*, (B) *Laudonocrinus*, (C) *Aatocrinus*, (D) *Athlocrinus*, (E) *Schistocrinus*, (F) *Simocrinus*, (G) *Retusocrinus*, (H) *Vertigocrinus*, (I) *Sciadiocrinus*, (J) *Galateacrinus*, X3. (K) *Stenopecrinus*, (L) *Perimestocrinus*, (M) *Nebraskacrinus*, (N) *Elibatocrinus*, X3. (O) *Exocrinus*, X3. All figures X1 except where indicated. Note the differences in the plate configuration and bases of cups of different genera.

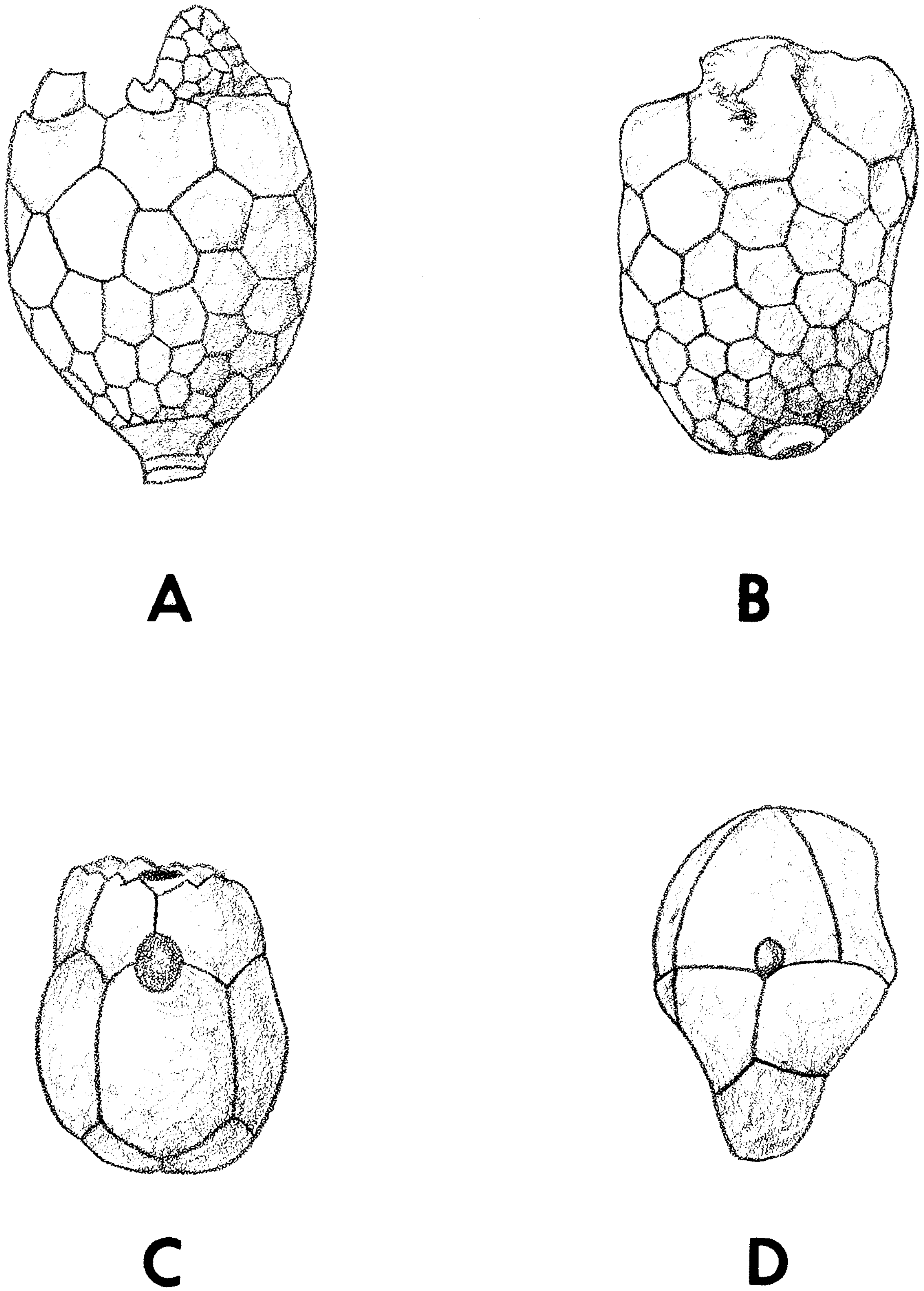


FIGURE 79. Miscellaneous crinoids. (A) *Caucacrocrinus*, X10. (B) *Dinacrocrinus*, X10. (C) *Lecythiocrinus*, X4. (D) *Coenocystis*, X15.

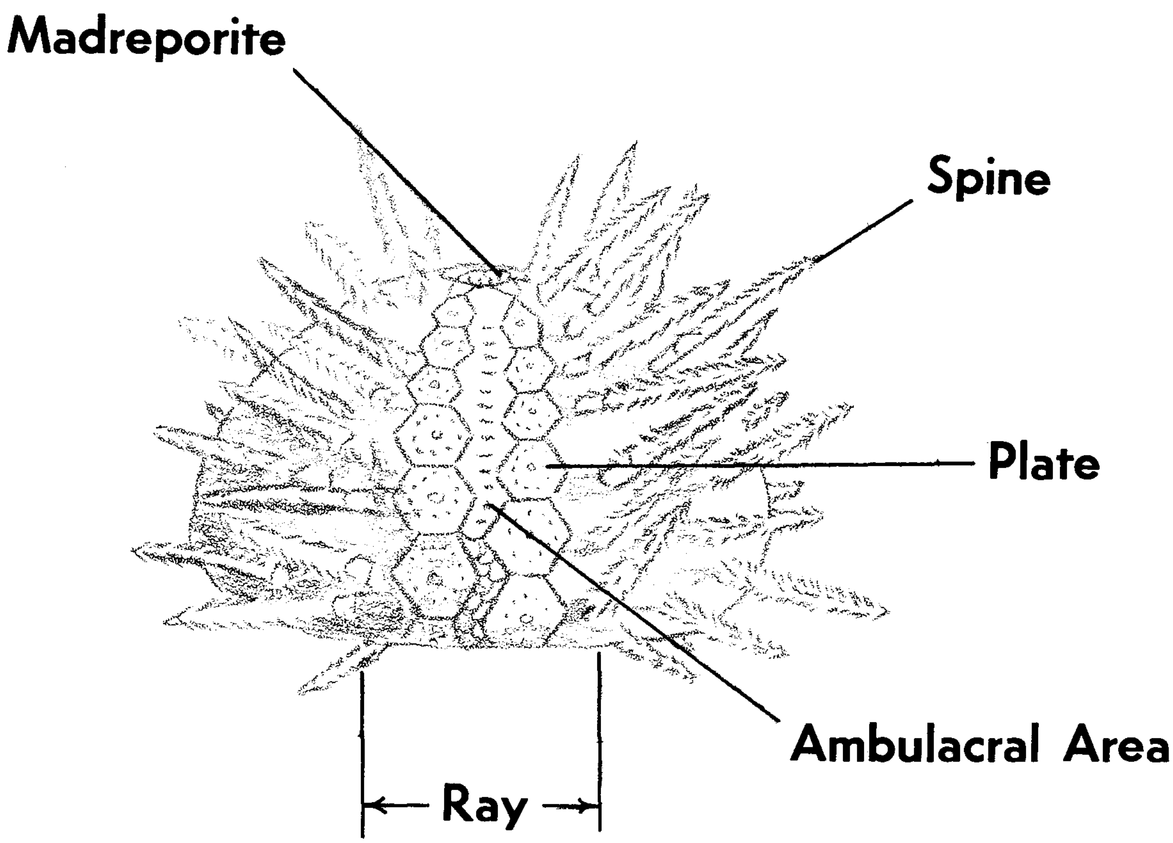


FIGURE 80. A typical echinoid showing some of the important features, X2.

Shale seams between thick limestones are often good areas to search for fossil crinoids. A good example is in the Stoner Limestone near Louisville, which has produced the following genera: *Graffhamicrinus, Erisocrinus, Contocrinus, Exocrinus, Apographiocrinus, Isoalagecrinus, Paradelocrinus, Graffhamicrinus, Scytalocrinus, Nebraskacrinus, Elibatocrinus, Melbacrinus, Parulocrinus, Mooreocrinus, Ulocrinus, Ethelocrinus, Stellarocrinus, Parethelocrinus, Plaxocrinus, Laudonocrinus, Stenopecrinus, Athlocrinus, Oklahomacrinus, Bathronocrinus, Cibolocrinus, Euonychocrinus,* and *Amphicrinus.*

A large crown of *Parulocrinus* has been collected from the South Bend Limestone near the Gretna Fish Hatchery.

A large variety of crinoids have also been collected from the Plattsmouth and Beil Limestone near Weeping Water, Plattsmouth, and Union. Included are *Graffhamicrinus, Galateacrinus, Parethelocrinus, Erisocrinus, Plaxocrinus,* and *Apographiocrinus.*

Oklahomacrinus, Syctalocrinus, Graffhamicrinus, Plaxocrinus, Ethelocrinus, Parethelocrinus, Erisocrinus, Endelocrinus, Exocrinus, and *Tholiacrinus* have been collected from the Stull Shale near Weeping Water and Plattsmouth.

The Ervine Creek Limestone, exposed near Weeping Water, Union, and Plattsmouth, contains a large variety of crinoid fossils. Among these are *Triceracrinus, Graffhamicrinus, Delocrinus, Apographiocrinus, Isoalagecrinus, Elibatocrinus, Apographiocrinus, Plaxocrinus, Aatocrinus, Graphiocrinus, Exocrinus, Laudonocrinus, Endelocrinus, Ulocrinus,* and several yet undescribed genera.

Large specimens of *Graffhamicrinus, Triceracrinus, Stellarocrinus, Endelocrinus,* and *Bathronocrinus* have been collected from the Curzon Limestone near Union.

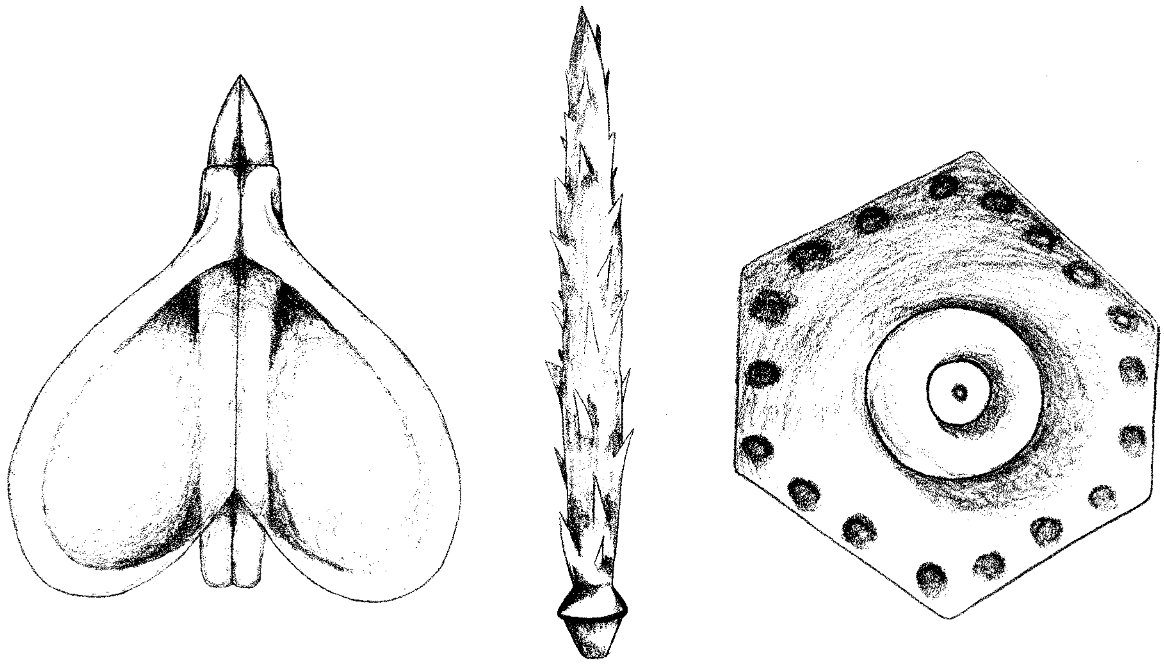
Crinoids become scarce in rocks younger than the Coal Creek Limestone. Single cups of *Graffhamicrinus* have been found in the Howard Limestone near Du Bois, the Soldier Creek Shale near Unadilla, and the Dover Limestone near Nebraska City

Permian crinoids from Nebraska are represented only by a cup of *Graffhamicrinus* and a cup of an undescribed genus from the Hughes Creek Shale near Brock. *Nebraskacrinus* was named for a partial crown collected from the Grant Shale near Odell.

Cretaceous crinoids from Nebraska are known only from several fragments of stem collected from the Greenhorn Limestone near Wilber and the Pierre Shale near Crawford. It is possible that further collecting will yield more complete fossil Cretaceous crinoids.

Class Echinoidea (Sea Urchins, Sand Dollars, Heart Urchins)

Echinoids include sea urchins, sand dollars and heart urchins, but only sea urchins are of importance in the Nebraska fossil record. Typical echinoids (Fig.



A B C

FIGURE 81. Commonly found echinoid parts. (A) Lantern ray, X4. (B) A spine, X3. (C) A Plate, X3.

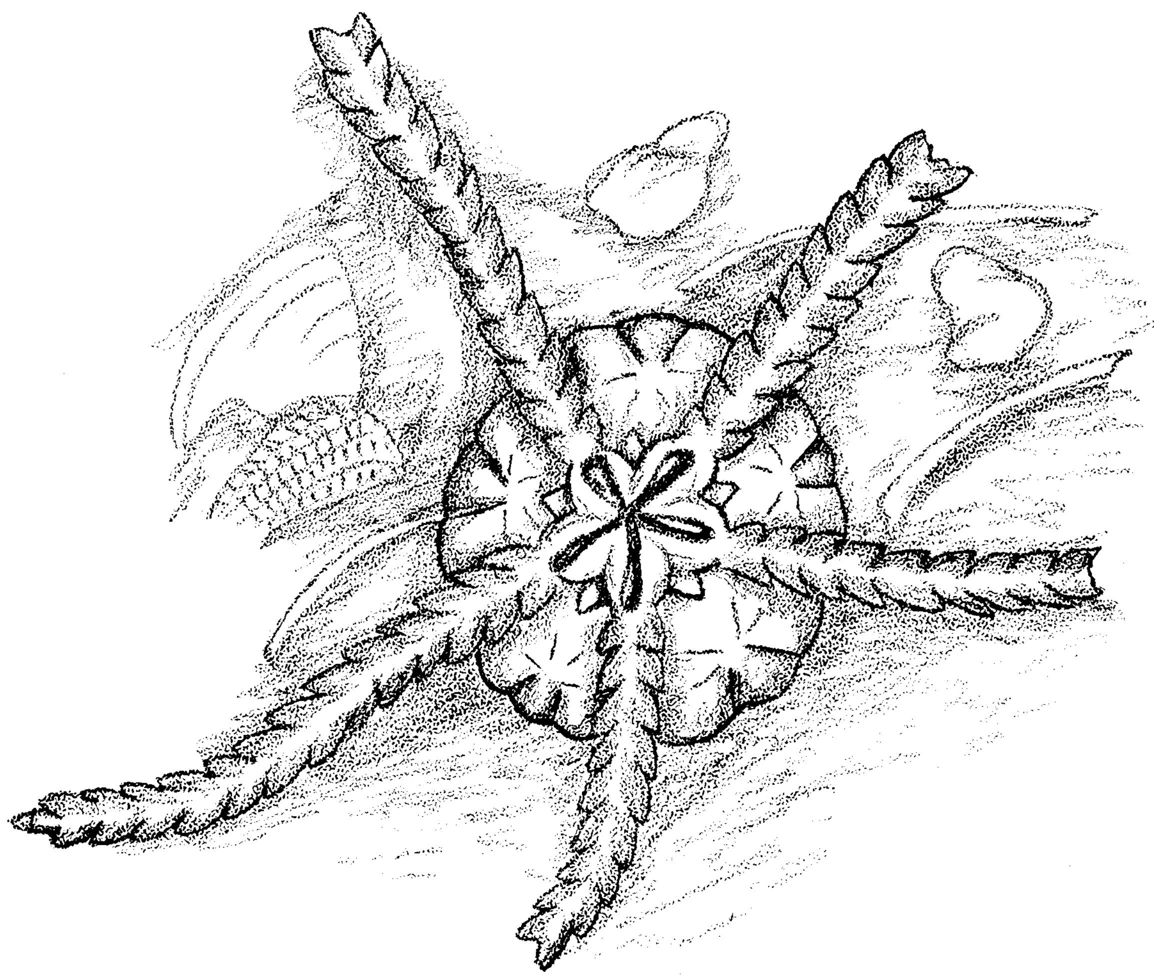


FIGURE 82. A Pennsylvanian brittle-star from Nebraska, *Ophiura*, X5.

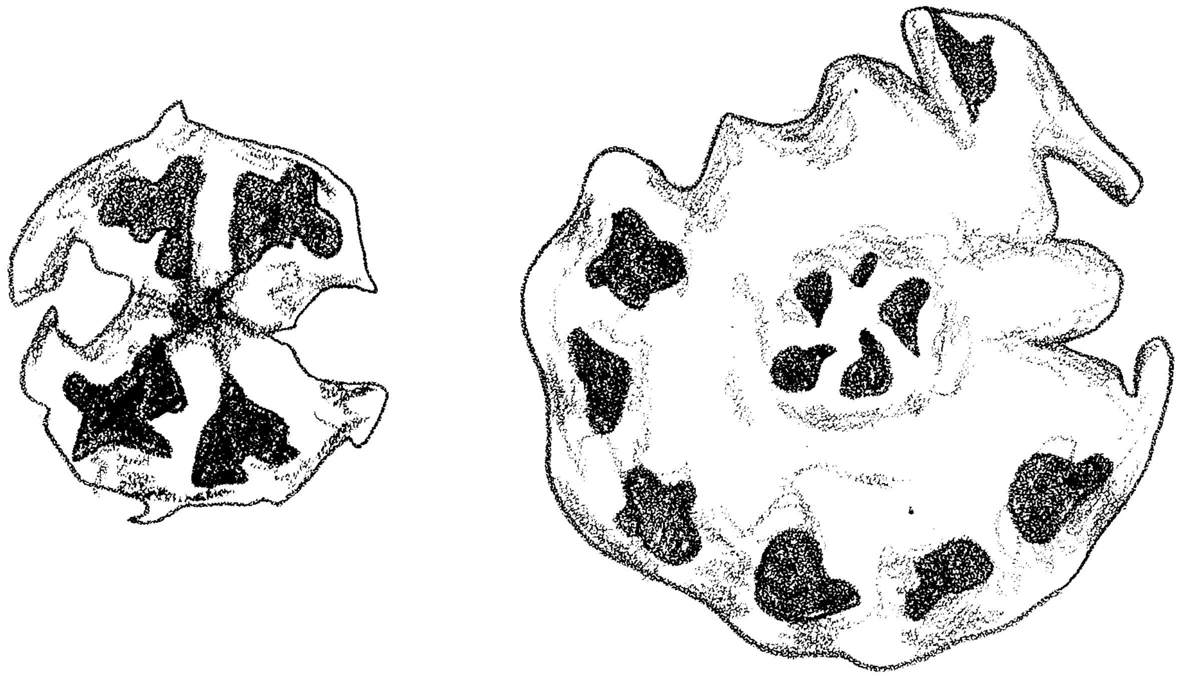


FIGURE 83. Holothuroid sclerites, X250.

80) have a globular, or heart-shaped body that is covered with many sharp spines. The plates are arranged in rays and each echinoid skeleton has 5 rays. Five *lantern rays* make up the chewing mechanism, which is called an "Aristotle's Lantern." Complete sea urchins are rarely found but their parts (Fig. 81) are abundant.

Occurrence of Echinoids in Nebraska

Echinoid parts are known from almost every fossiliferous unit in the Nebraska Pennsylvanian. A few nearly complete echinoids, mostly of the genus *Archeocidaris,* have been collected from the Stoner Limestone at Louisville, the Plattsmouth and Beil Limestones near Weeping Water, and the Ervine Creek Limestone near Plattsmouth. Complete fossil echinoids are rare.

Cretaceous echinoids have been found in the Pierre Shale in Wyoming, just a few miles from the Nebraska border. It is therefore highly possible that fossil echinoids eventually will also be found in Cretaceous rocks of Nebraska.

Class Stelleroidea (Star Fishes)
Subclass Ophiuroidea (Brittle Stars)

Ophiuroids form a minor part of the Nebraska fossil record. They are represented only by a few specimens which have been collected from the Pennsylvanian near Plattsmouth. Ophiuroids are usually quite small, some being no larger than a dime. The ophiuroid has a large central disk and five thin arms. A typical fossil Ophiuroid is illustrated in Figure 82.

Several fossils of the brittle star, *Ophiura,* have been reported from Nebraska. All have come from the Doniphan Shale near Plattsmouth and Weeping Water.

Class Holothuroidea (Sea Cucumbers)

Only the parts of sea cucumbers called *sclerites* have been reported from Pennsylvanian and Permian rocks in southeast Nebraska. Sclerites do not have uniform sizes or shapes. Several are illustrated in Figure 83.

Phylum Uncertain

Class Uncertain

Order Conodontophorida. Conodonts (Fig. 84) are small, tooth-like fossils of uncertain origin that are relatively common in Pennsylvanian and Permian rocks of Nebraska. However, due to their small size, they are rarely observed. They resemble scolecodonts, the teeth of annelid worms, except in color. Conodonts are brownish and transparent, whereas scolecodonts are black and opaque. It is not known whether conodonts represent a vertebrate or an invertebrate organism and they have been attributed to molluscs, worms, and fishes.

Phylum Chordata (the Vertebrates)
Subphylum Hemichordata

Class Graptozoa

Order Graptoloidea. Members of the Order Graptoloidea are commonly referred to as graptolites. They are small, colonial animals with chitinous skeletons. Their geologic range is from Ordovician to Devonian. Although rocks of these ages are not exposed in Nebraska, graptolites have been recovered from well cores of Ordovician rocks in southeastern Nebraska (Fig. 85). Graptolites include both attached and floating forms and many are useful index fossils. Graptolite fragments resemble a small, single- or double-edged saw blade.

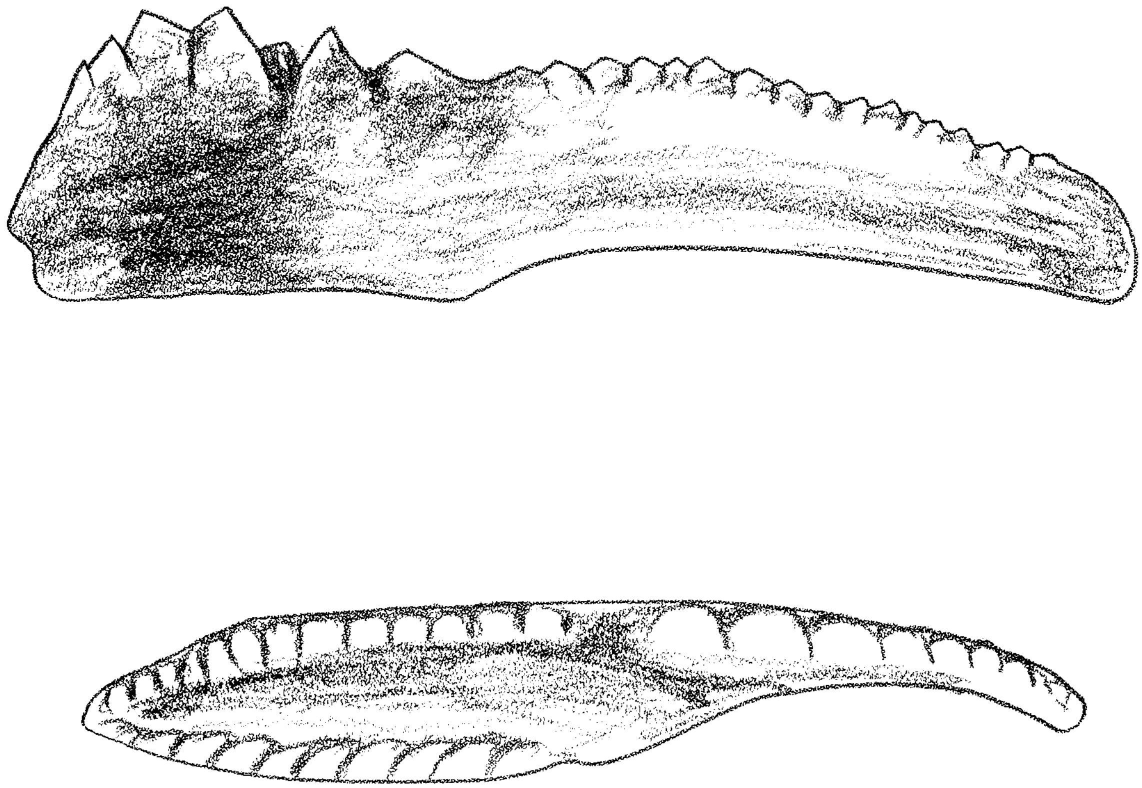


FIGURE 84. Side view of conodont *Gnathodus* (above) and ventral view (below), X300.

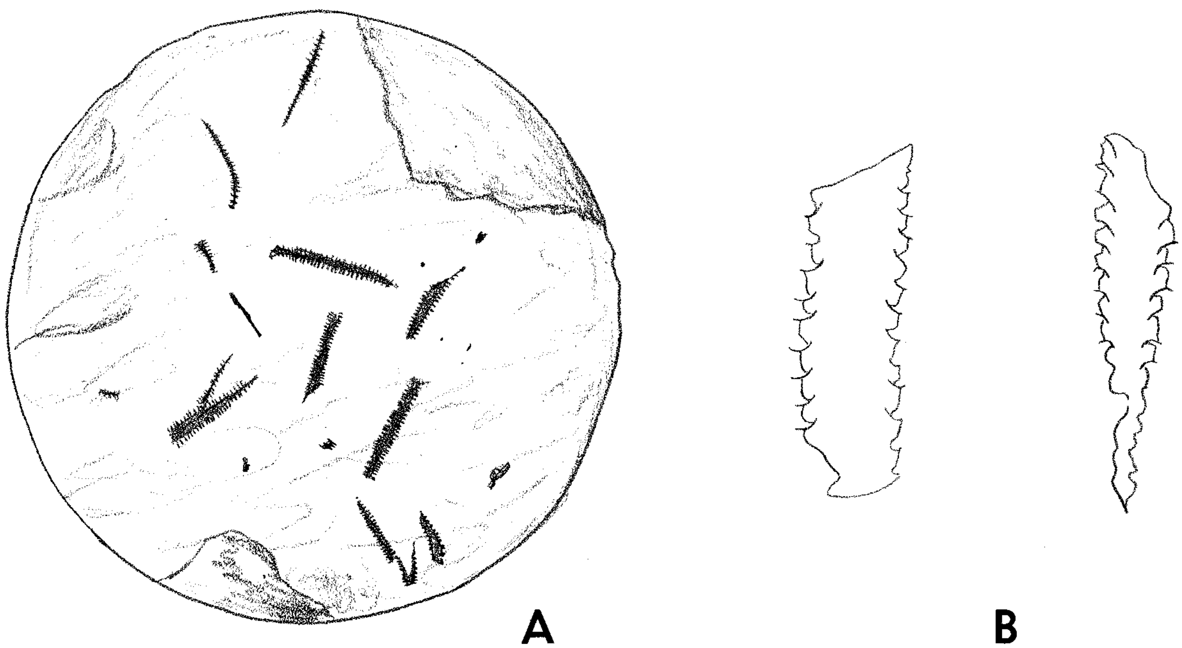


FIGURE 85. Graptolites. (A) Graptolites as they appear on a bedding surface in a well core, X1. (B) Graptolite exoskeletons, X10.

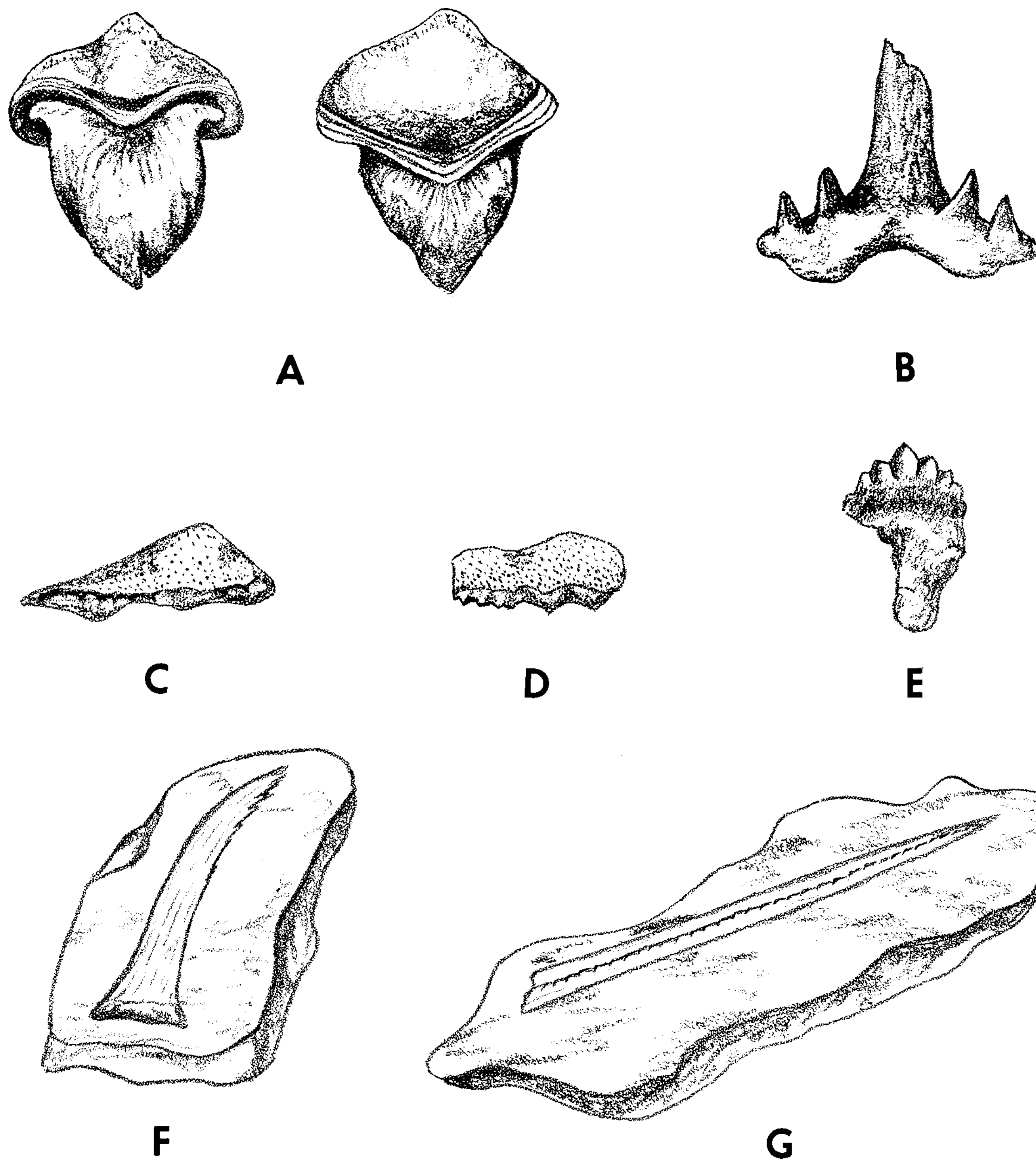


FIGURE 86. Pennsylvanian and Permian fish remains. (A) *Petalodus*, posterior (left) and anterior (right) views, X1. (B) *Cladodus*, posterior view, X1. (C) *Orodus*, anterior view, X1. (D) *Campodus*, anterior view, X1. (E) *Ctenoptychius*, anterior view, X1. (F) *Listracanthus*, a fin, X1. (G) *Xenacanthus*, a fin, X1/3.

Subphylum Vertebrata

Although most vertebrates, animals with backbones, fall outside the scope of this publication, vertebrate fossils of several types are commonly found associated with marine invertebrates in Nebraska.

Fins, teeth, and, occasionally, complete specimens of shark-like fishes are found in the Pennsylanian and Permian rocks of southeastern Nebraska. The teeth, especially, of these animals are usually well preserved and serve as a means of identification. *Petalodus* had large, wedge-shaped teeth (Fig. 86A) that may be up to three inches high. *Petalodus* teeth have been found in the Pennsylvanian Merriam Limestone near South Bend, the Stoner Limestone near Louisville, the Plattsmouth Limestone near Weeping Water, the Stull Shale and Ervine Creek Limestone near both Weeping Water and Plattsmouth, the Soldier Creek Limestone near Unadilla, the Permian Hughes Creek Shale near Bennet, and in the Permian Oketo Shale near Wymore.

Cladodus has a "T"-shaped tooth (Fig. 86B) with a long central crown and sometimes four smaller prongs, two on each side of the crown. It is found in the same horizons and locations as *Petalodus*, and also in the Emporia Limestone near Table Rock.

Edestus had a large "V"-shaped tooth. Several complete whorls of these teeth have been found in the Pennsylvanian of Nebraska. It has been reported from the Stark and Wea Shales near Papillion, and from the Ervine Creek Limestone from near Weeping Water and Union.

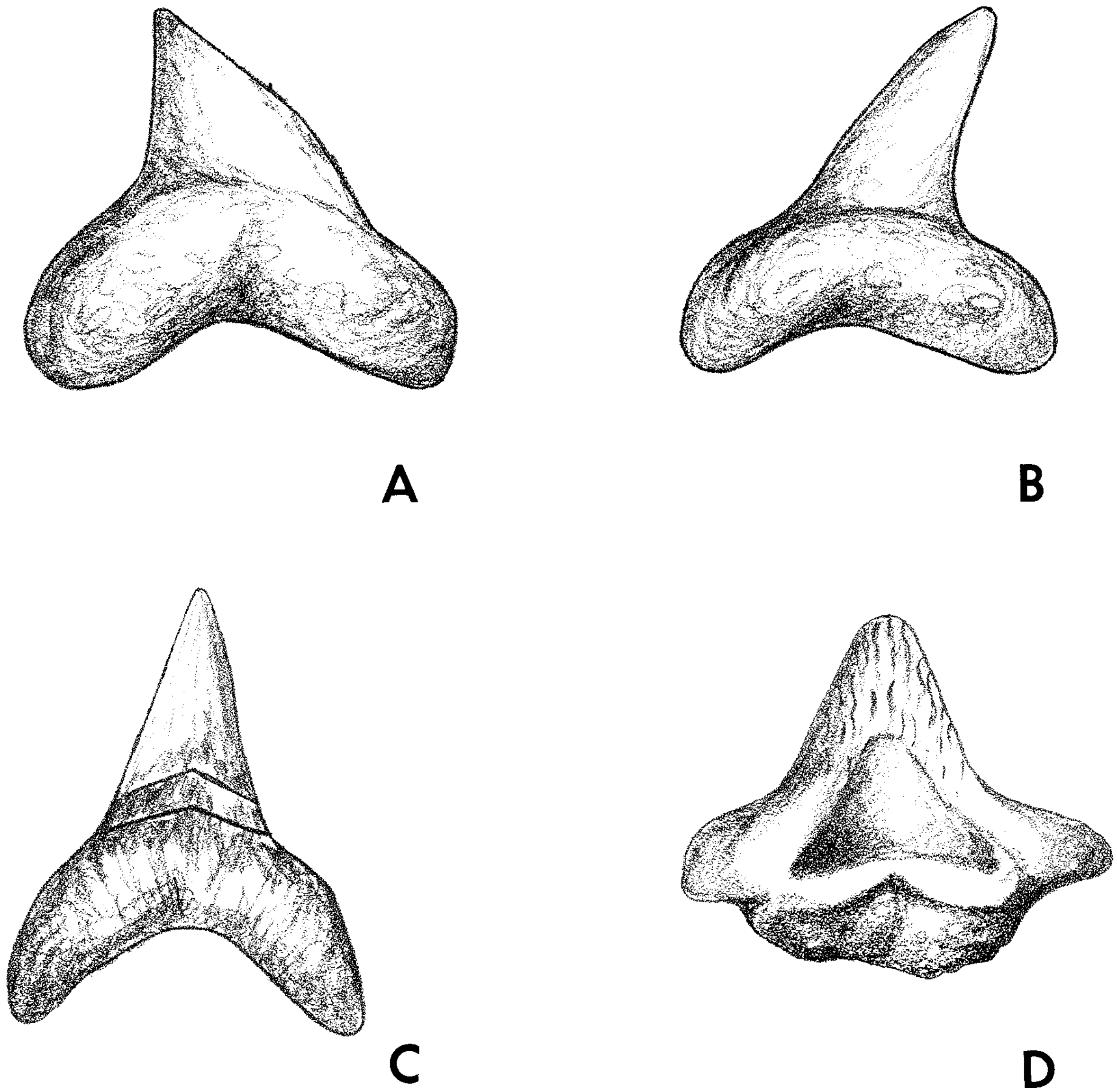


FIGURE 87. Cretaceous shark teeth. (A) *Squalicorax*, X5. (B) *Lamna*, X5. (C) *Scapanorhynchus*, X1. (D) *Ptychodus*, X4.

Orodus and *Campodus* had pavement-type teeth (Fig. 86C, D) which have a flat crown designed for crushing rather than cutting. A complete jaw of *Orodus*, which contained more than 300 teeth, was collected from the Rakes Creek Shale at Weeping Water, and a complete whorl of *Orodus* teeth was collected from the Ervine Creek Limestone near Plattsmouth. Several smaller groups of *Orodus* teeth have been collected from the Heebner Shale near Ashland and the Queen Hill Shale near Plattsmouth. Single teeth have been collected from the same units and locations as have *Petalodus* and *Cladodus*.

Teeth of *Ctenoptychius* (Fig 86E) have jagged cutting edges which form five prongs. They have been collected from the Stoner Limestone near Ashland and Louisville, the Merriam Limestone near South Bend, and the Plattsmouth, Beil, and Ervine Creek Limestones near both Weeping Water and Plattsmouth.

Janassa had a flattened, spoon-shaped tooth that occurs in many of the previously listed locations.

Keep in mind that if a single tooth is found, several more teeth or an entire jaw may be close at hand. Fish remains such as teeth, scales, and occasional complete specimens are commonly found in black shales of Pennsylvanian and Permian age. Several complete small sharks have been collected near Plattsmouth and a complete fish superficially resembling a trout, about 8 inches long, was collected there in 1953 by a high school student.

Fins of sharks and shark-like fishes are rather common finds. *Listracanthus*, (Fig. 86F) a shark-like fish, had a small fin, rarely more than two inches long. They are frequently found in pairs, almost exclusively in black shales such as the Stark, Wea, Quindaro, Eudora, Heebner, Queen Hill, or Holt. *Listracanthus* has been found at Fort Calhoun, Papillion, Richfield, Louisville, Weeping Water, Union, Plattsmouth, and many other localities.

Xenacanthus is a large, shark-like fish whose spines (Fig. 86G) are also found in Pennsylvanian and Permian rocks. It has been reported from the Drum Limestone near Richfield, the Bonner Springs Shale near Louisville, the Stoner Limestone at South Bend, and the Neva Limestone near Roca.

Cretaceous rocks contain a large assemblage of fossil fish materials. Teeth, vertebra, and a number of complete Cretaceous fishes have been found in Nebraska. Vertebra of a shark, *Lamna*, and the tarpon-like fish, *Portheus*, have been found in the Greenhorn Limestone near Garland, Milford, Crete, and Gilead; in the Graneros Shale near Valparaiso and Hebron; and in the Niobrara Chalk near Alma, Franklin, and Superior.

Squalicorax (Fig 87A), *Lamna* (Fig. 87B) and *Scapanorhynchus* (Fig. 87C) are rather common shark teeth which are found in the previously listed locations.

The pavement-type tooth of *Ptychodus* (Fig. 87D) has been found in the Greenhorn Limestone near Gilead, Garland, and Fairbury, and in the Graneros Shale near Hebron.

Plant Fossils

Throughout Nebraska, plant remains of various kinds form an important part of the fossil record. Many plant fossils are found in association with invertebrate fossils. This is to be expected since plants were an important food source for many of the animals.

Algae

Perhaps the most important members of the entire plant kingdom are the algae. Algae are found in both fresh and marine water and some forms can exist wherever there is a small amount of light and water. Large heads of fossil algae and other algal structures are found in the Pennsylvanian and Permian rocks of southeastern Nebraska. These algal heads, called *stromatolites*, are shaped much like round loaves of bread and may be as large as 12 feet in diameter. A cross section of a *stromatolite* is illustrated in Figure 88. *Stromatolites* have been collected from the Ozawkie Limestone in Cass County.

Algal mats generally consist of many thin layers of algae, giving a banded appearance. The upper surfaces of algal mats are usually quite lumpy. Some large algal structures have been observed in the Permian Johnson Shale near Burchard in Pawnee County.

Egg cases of *charophytes* (Fig. 89) have been observed from Cretaceous-age shales in the Dakota Group in Jefferson County. The egg cases are small, spiral-shaped structures that appear as tiny brown spots barely visible to the naked eye. No other algae have been reported from the Cretaceous rocks of Nebraska, but as our knowledge and exploration increase, so also increases the likelihood of additional discoveries.

The *clay-ball* limestones found in the Oligocene, Chadron Formation in northwest Nebraska are considered to be algal remains that were deposited in ancient ponds. Egg cases of the charophyte *Chara* are found in Pliocene rocks in north-central and southwestern Nebraska.

Diatoms, although extremely small, form an important part of the Nebraska fossil record. A few fossil diatoms are illustrated in Figure 90. *Diatomite*, a rock made up of the siliceous shells of diatoms, occurs near Agate in Sioux County, and more than 70 species are known to occur in this deposit. Diatomite also occurs in Hooker, Thomas, Blaine, Garfield, Wheeler, Valley,

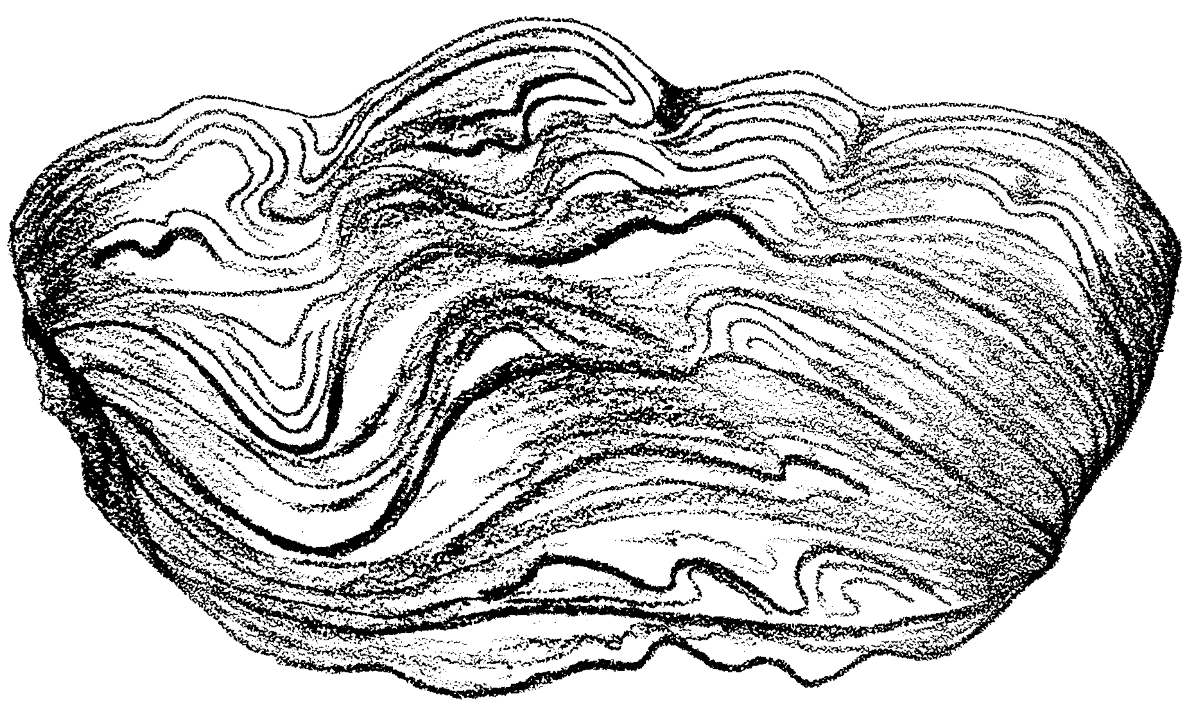


FIGURE 88. Cross section of a stromatolite, X½.

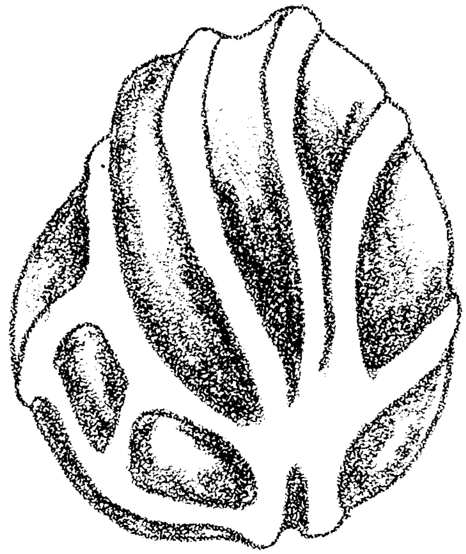


FIGURE 89. Egg case of a fossil Charophyte, X60.

Greeley, Sherman, and Nance Counties, in beds up t several feet thick. The hard, siliceous shells of the diatoms give diatomite abrasive properties. A commercially made abrasive using diatomite is called by the trade name *Tripoli.*

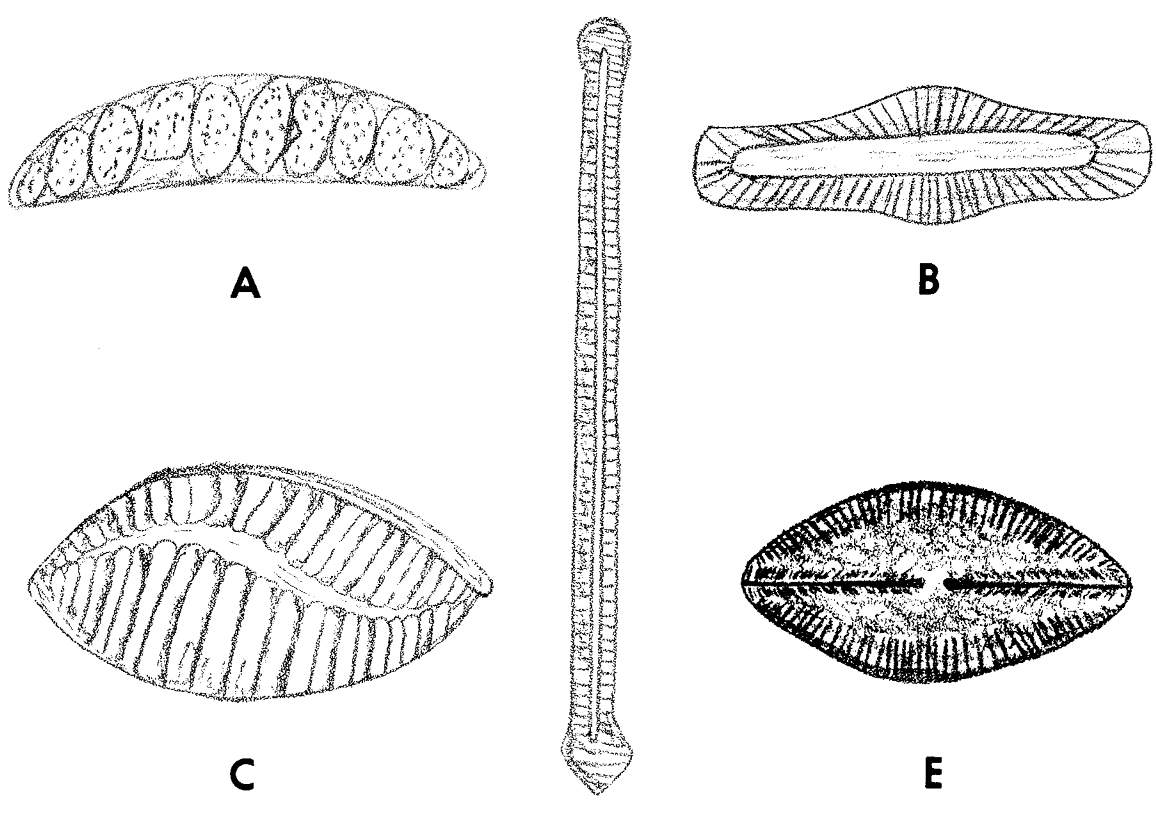
Ferns and Seed Ferns

Ferns and seed ferns, although not closley related, were common in Pennsylvanian and Permian forests. Some seed ferns (not true ferns) attained great heights. Fern and seed-fern *fronds* are made up of compound leaves that are divided into many segments or leaflets. The true ferns produce spores that occur in clusters underneath the leaves, whereas seed ferns produce seeds that are borne on modified leaves. *Megaphyton* is a common fern and *Neuropteris* (Fig. 91 B, C) is a common seed fern of the Pennsylvanian in Nebraska. Fossil ferns and seed ferns occur in the Pennsylvanian and Permian rocks in Nemaha and Richardson Counties.

Fronds of several ferns have been reported from the Cretaceous, Dakota Group in Jefferson County. They are very similar to the Pennsylvanian and Permian ferns. *Tempskya,* a false stem of a Cretaceous fern, is found in the Oligocene, Chadron Formation where it was transported by ancient streams. A cross section of *Tempskya* is illustrated in Figure 92.

Scale and Seal Trees

Scale and seal trees were very common in Pennsylvanian and Permian time and were important contrib-



A

B

C

D

E

FIGURE 90. Fossil diatoms from Nebraska. (A), (B) *Cystopleura,* two species, (C) *Surriraya,* (D) *Gomphonema,* (E) *Gomphonema.* All figures X500.

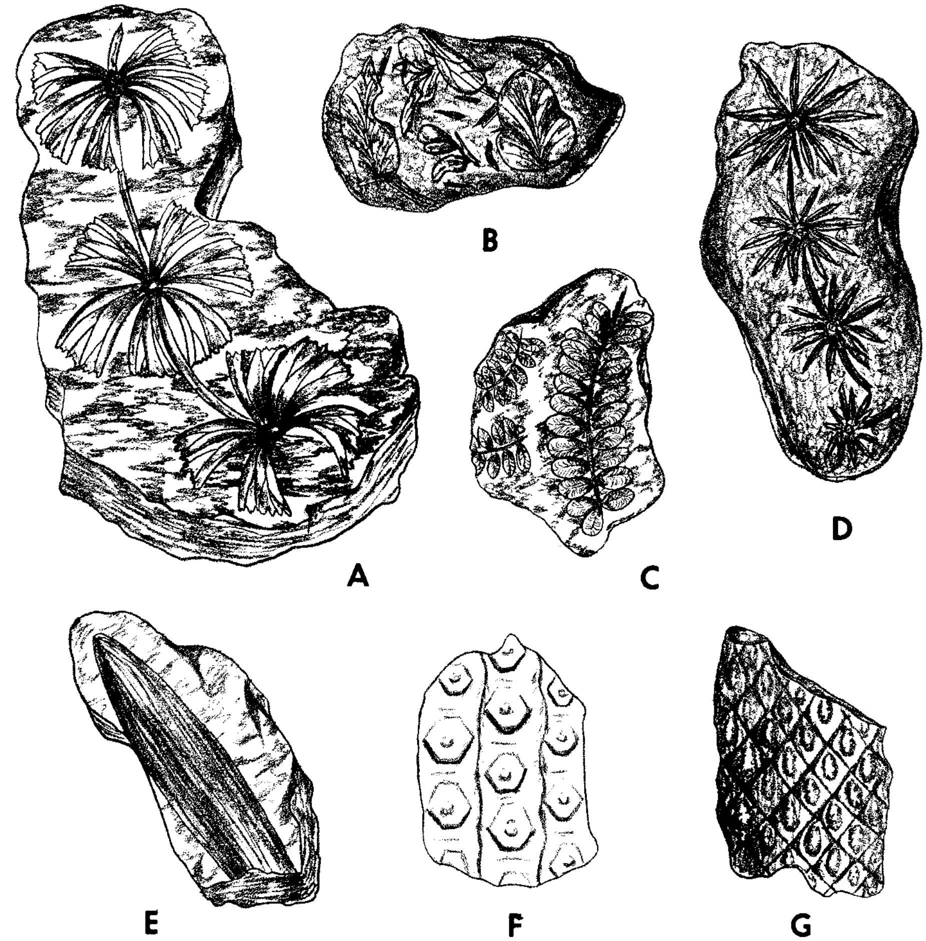


FIGURE 91. Pennsylvanian and Permian plant remains from Nebraska. (A) *Sphenophylum*, a rush, X1. (B), (C) *Neuropteris*: (B) A single leaf, right, X1. (C) A leaf frond, right, X1. (D) *Annularia*, a scouring rush, X1. (E) A cordaite leaf, *Cordaites*, X½. (F, G) Seal and scale trees: (F) *Siggilaria*, X½; (G) *Lepidodendron*, X½.

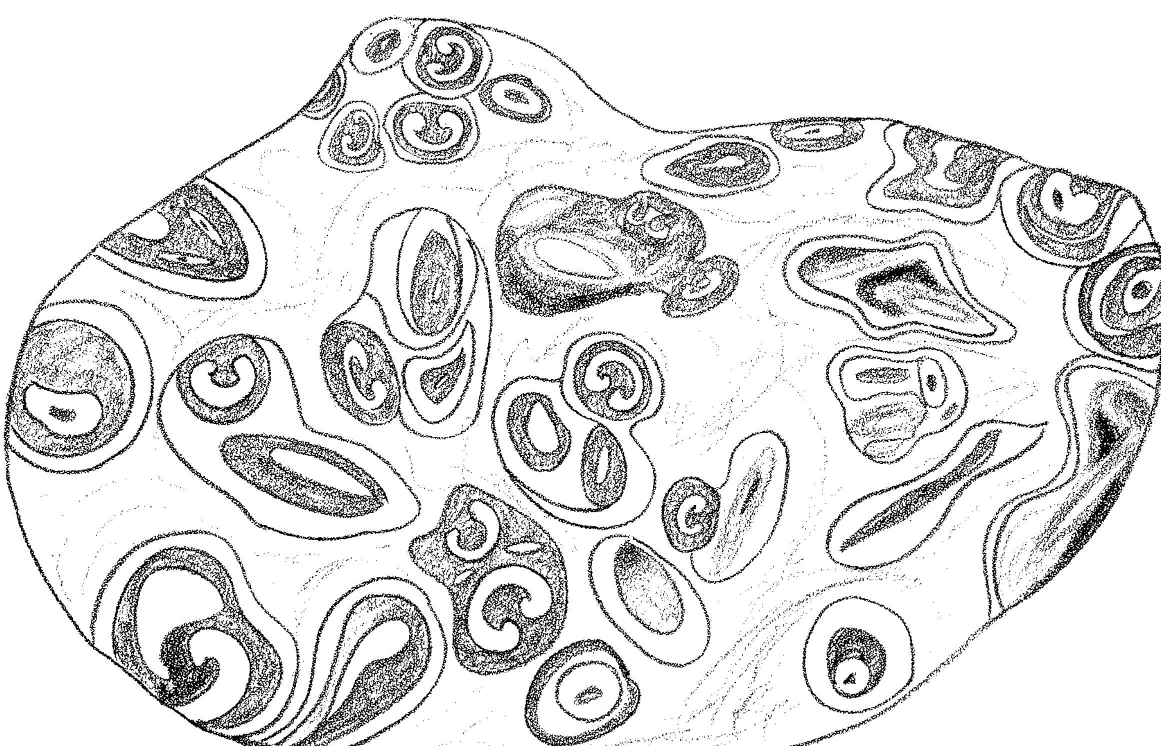


FIGURE 92. A cross section of a Cretaceous false fern stem, *Tempskya*, X1. After Arnold, 1958.

utors to coal formation. Although some grew to heights of 100 or more feet, their closest living relatives are the small club mosses and ground pines.

Scale trees are so called because the leaf scars on the branches and trunk give them a scaly appearance. *Lepidodendron* (Fig. 91G) is a common scale tree and its fossils have been reported from the Permian age Indian Cave Sandstone in Nemaha County. Seal trees derive their name from the resemblance their leaf scars bear to ancient signets (seals). *Sigillaria* (Fig. 91F) is a common seal tree that is found associated with *Lepidodendron*.

Cordaites

Cordaitean trees were perhaps ancestors to the modern pine and spruce. They were abundant throughout the world during the Pennsylvanian and Permian periods and were important contributors to coal deposits. *Cordaites* (Fig. 91E) frequently occurs in the same localities and horizons as scale and seal trees.

Scouring Rushes

Scouring rushes are important Pennsylvanian and Permian plant fossils. They are related to the small "horse tails" of today, although they commonly grew to heights of 40 feet in Pennsylvanian and Permian times. Trunks of fossil scouring rushes are commonly referred to the genus *Calamites*, whereas the leaves are assigned to the genus *Annularia* (Fig. 91D). *Sphenophyllum* (Fig. 91A) is related to the scouring rush *Annularia* and commonly occurs with it.

Trees

Tree fossils, represented by wood, leaves, or seeds, are commonly found in Nebraska. Carbonized wood occurs in the Pennsylvanian, Permian, and, especially, in the Cretaceous rocks of Nebraska. Large logs have been found in the Cretaceous rocks of the Dakota Group near Lincoln, Tekamah, and Fairbury. This wood is collectible but cannot be preserved easily for it contains a great deal of marcasite which quickly oxi-

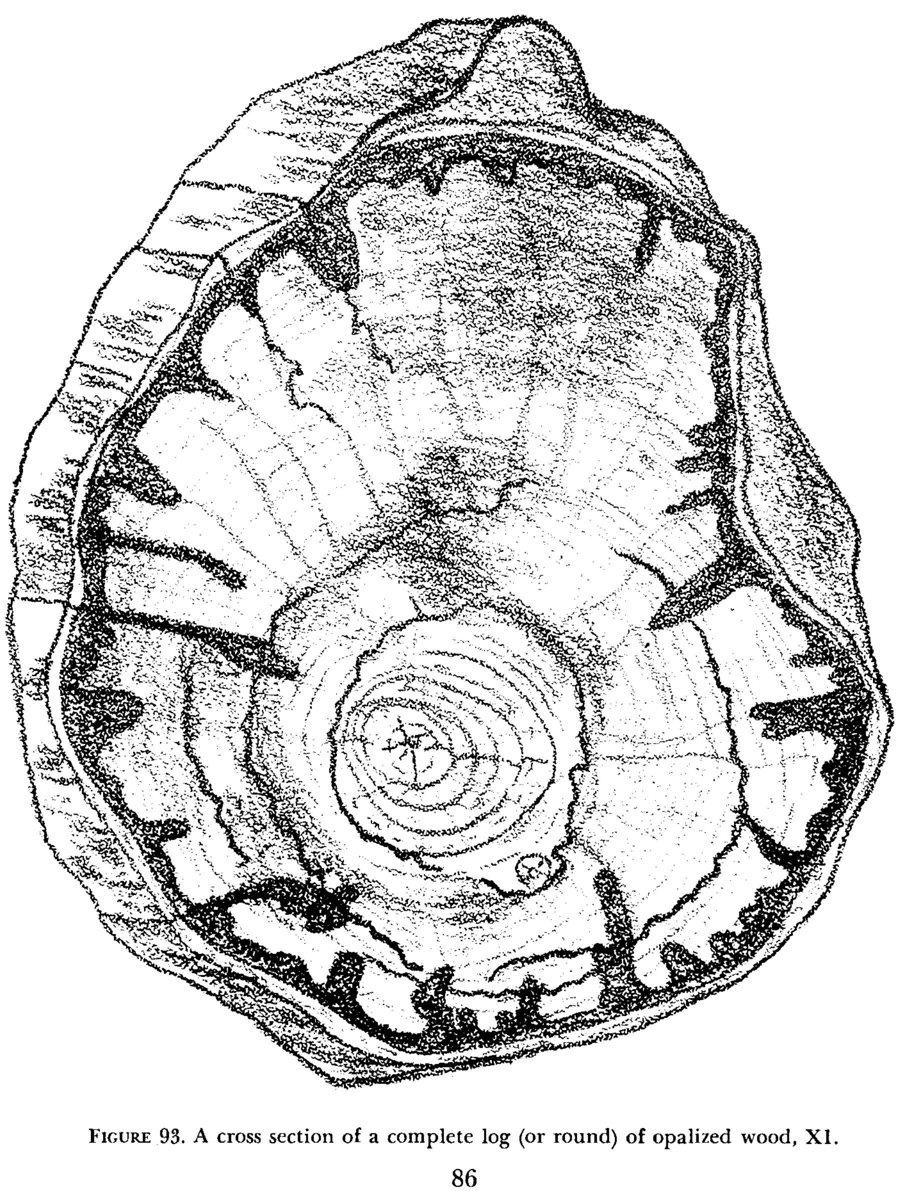


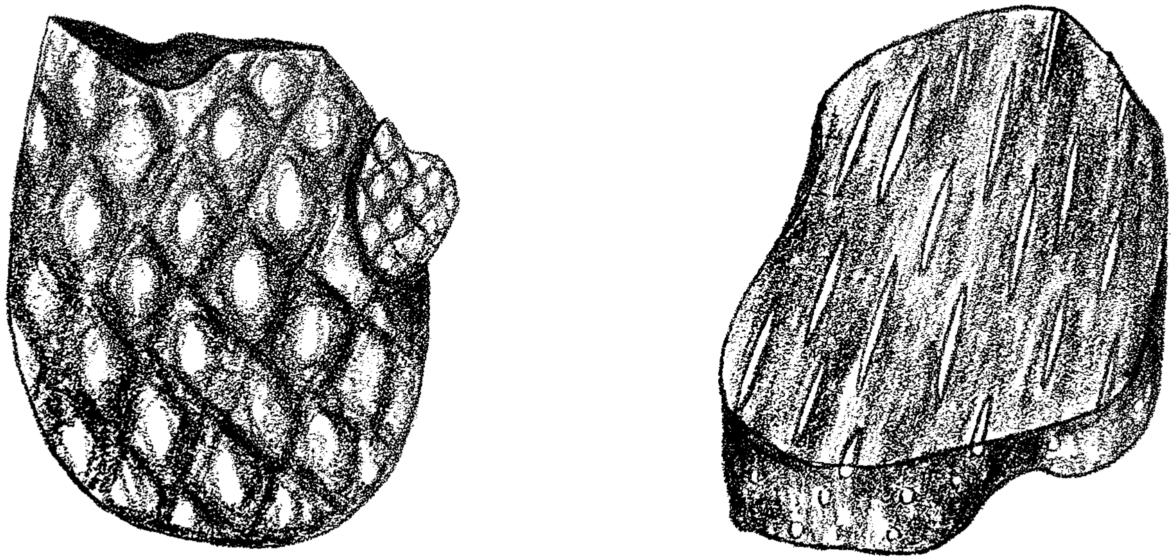
FIGURE 93. A cross section of a complete log (or round) of opalized wood, X1.

dizes. The reaction of water, air, and marcasite forms dangerous sulphuric acid. Carbonized woods are also found in the Pierre Shale in the northwestern panhandle.

Silicified wood is most common in the Tertiary and Pleistocene deposits of Nebraska. Silicified woods occur in the basal part of the Chadron Formation and were transported into the state by stream activity. These woods are common in the Cretaceous rocks in Wyoming. Silicified black logs, some weighing as much as 100 pounds, occur in the Chadron Formation near Crawford. Soaking this black wood in bleach for several days will reveal the structure and grain.

Silicified logs, weighing up to several tons, occur in the Pliocene, Ogallala Group near Valentine in north-central Nebraska. These woods are quite colorful and are sought by rock polishers because of the fine finish that can be obtained. A section of a complete log (a round) of Pliocene wood is illustrated in Figure 93.

Silicified woods have been transported and deposited with Pleistocene terrace gravels along the entire courses of both the North Platte and Platte Rivers. These woods are frequently very colorful and take very fine polishes. Palm wood, which is characterized by many large, tubular cells (Fig. 94B), is sought after by many collectors.



A B

FIGURE 94. (A) A cycadophyte showing a bud, X½. (B) Cross section of a piece of palm wood, X1.

Leaf imprints are commonly found in sandstones of the Cretaceous, Dakota Group (Fig. 95). *Ficus* (A, B) is a large, spade-shaped leaf. *Sassafras* (C) is a three-lobed leaf with gently curved junctures between each lobe. *Aralia* (D) also is a three-lobed leaf but the junctions between each lobe are sharp. *Populus* (E, F) is a small, spade-shaped leaf, whereas *Liquidamber* (G) is a large, five-lobed leaf. Leaf imprints have been found in Dakota Group Sandstones and Shales near Tekamah, Ashland, Lincoln, Pleasant Dale, and Fairbury. Cretaceous leaf fossils that have the original cuticle (cellulose material) preserved have been found in shales in the Cretaceous, Dakota Group. The cuticle shows exquisitely preserved imprints of the underlying cells.

Some excellently preserved leaf imprints have been found in the Pliocene, Ogallala Group near Kilgore. These are much like modern leaves and many retain cuticle.

Seeds and nuts have been reported from several localities in Nebraska. Casts of walnuts of the genus *Archihicoria* have been reported from the Oligocene and Miocene rocks in northwestern Nebraska. Fossil walnuts are illustrated in figure 96A. Hackberry seeds have been reported from Miocene rocks in Sioux County. Hackberry (*Celtis*) seeds (Fig. 96B) occur near Lake McConaughy in Keith County and have been reported from the Ogallala Group in north-central and southwestern Nebraska.

Cycadophytes

Cycadophytes are primitive seed plants. Superficially, they might resemble modern-day pineapples (Fig. 94A), although the two are not even closely related. Their outer stem surface shows diamond-shaped leaf scars. Cycadophytes have been found in the base of the Oligocene, Chadron Formation, in Sioux and Dawes Counties and in Pleistocene terrace gravels of the South Platte River in Deuel County. Cycads have not been found in the Cretaceous rocks of Nebraska, even though all of those described above originated in Cretaceous rocks in Wyoming and Colorado.

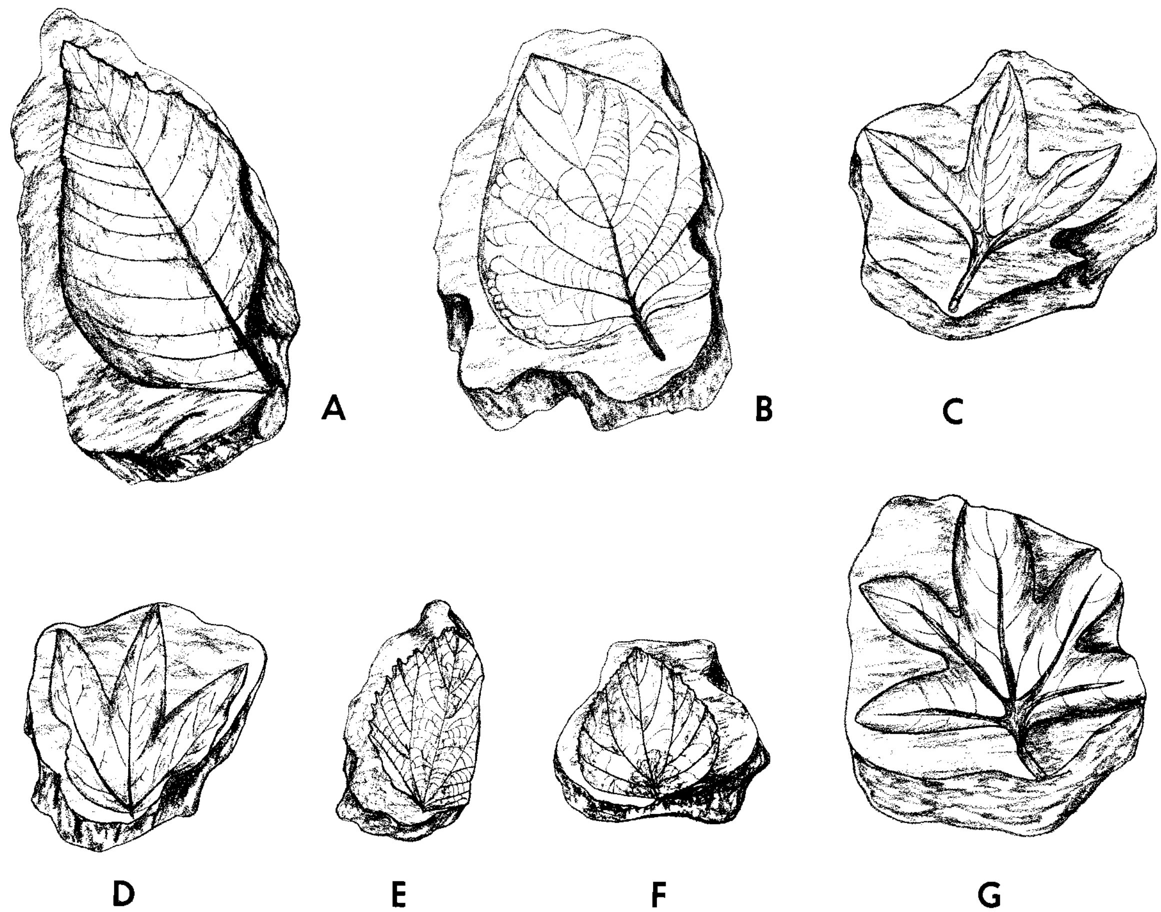


FIGURE 95. Cretaceous leaf fossils from Nebraska. (A, B) *Ficus*, X1. (C) *Sassafras*, X1. (D) *Aralia*, X1. (E, F) *Populus*, X1. (G) *Liquidamber*, X1.

Grasses

Fossils of grass grain (Fig. 97) are important in Miocene and Pliocene rocks of Nebraska. *Stipidium* (A) is a long, slender grain that resembles oats or wheat. *Panicum* (B) is an unornamented, stubby grain resembling rice. *Berrichloa* (C) has a tiny, smooth, tear-drop-shaped grain. *Biorbia* (D) has a tiny, ornate grain. *Krynitzkia* (E) is a very highly ornamented grain.

Tubular, branching structures that are opalized are found vertically oriented in Pliocene rocks in Lincoln, Keith, and Cherry Counties. These have been interpreted as being fossilized root systems of prairie grasses.

Yucca Roots

Structures that have been interpreted as being fossilized yucca roots occur in Pliocene rocks in association with grass seed. These are vertical, tubular structures that may be 30 feet tall.

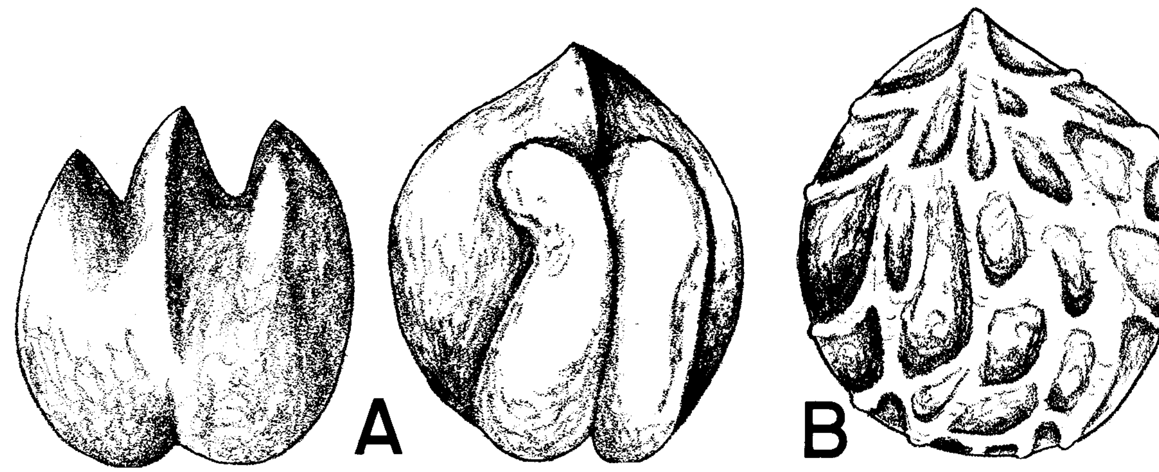


FIGURE 96. Seed fossils from Nebraska. (A) *Archihicoria*, X3. (B) *Celtis*, X10.

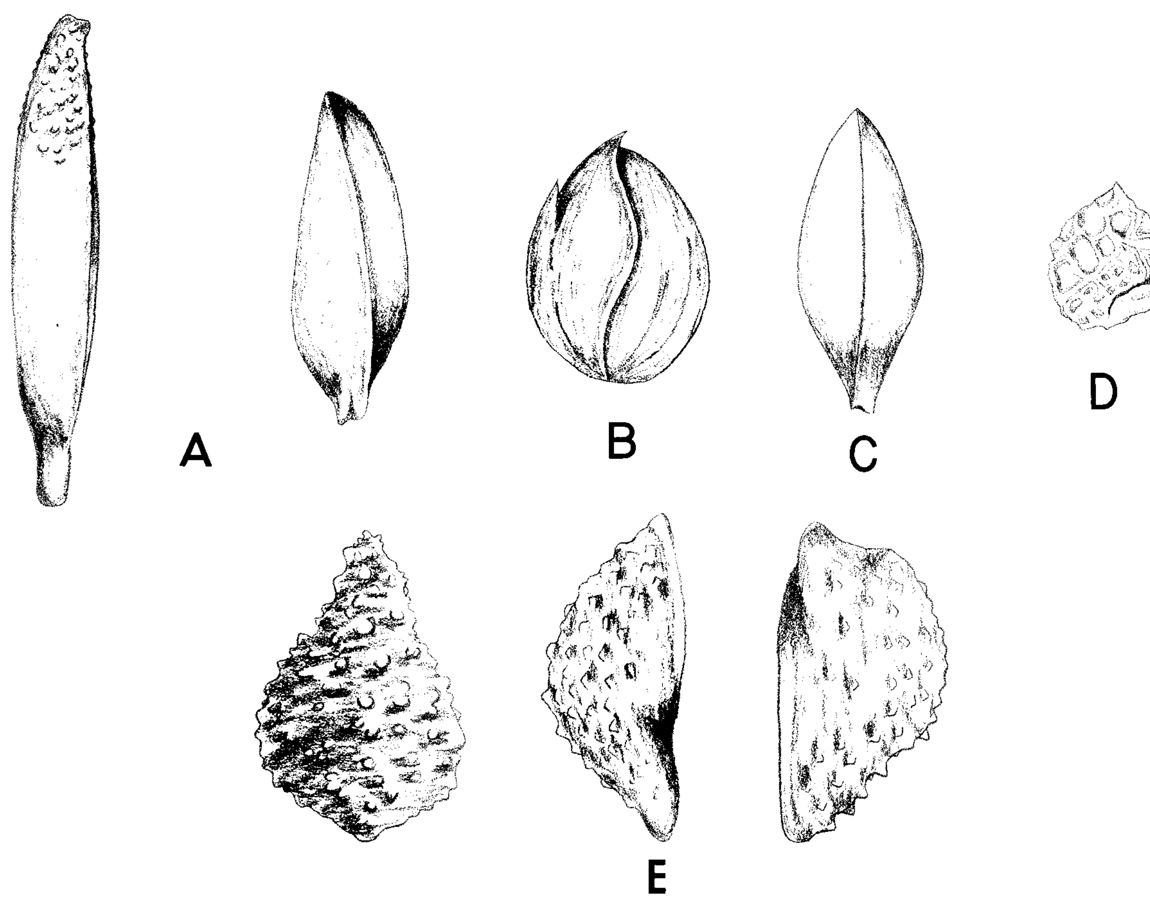


FIGURE 97. Fossil grass grains. (A) *Stipidium*, two species, X10. (B) *Panicum*, X10. (C) *Berrichloa*, X10. (D) *Biorbia*, X10. (E) *Krynitzkia*, three views, X10.

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APPENDIX

This appendix is a listing of fossil invertebrate animals, plants, and fishes that have been collected in Nebraska. The Phyla are arranged alphabetically and are followed by a reference list. The generic names are used in the same sense that they were used by the author of the numbered reference. The age of the rocks in which the fossils have been found is shown by the "x" (Pennsylvanian-Permian, Cretaceous, Oligocene, Miocene, Pliocene, and Pleistocene).

For example:

Genus	References	Penn. Perm.	Cret.	Olig.	Mio.	Plio.	Pleis.
Gaudryina	3, 7, 8		x				

These notations indicate that, in this report, genus *Gaudryina* is used in the same manner as it was used by the authors of references 3, 7, and 8 (Dietrich, Loetterle, and Lubert), and has been collected from Cretaceous rocks in Nebraska.

Phylum Protozoa

Genus	References	Penn. Perm.	Cret.	Olig.	Mio.	Plio.	Pleis.
Allomorphina	3		x				
Ammodiscus	3, 5, 7, 9	x					
Anomalina	2, 3, 5, 8		x				
Astacolus	3		x				
Asterigerina	3		x				
Bathysiphon	3		x				
Bigenerina	3		x				
Bolivina	2, 3, 7, 8		x				
Bolivinoides	8		x				
Bolivonopsis	3		x				
Bradyina	9	x					
Bulimina	2, 3, 5, 7, 8		x				
Buliminella	2, 3, 7		x				
Bullopora	7		x				
Calcarina	5		x				
Cassidulina	3		x				
Ceratobulimina	3		x				
Cibicides	3, 8		x				
Clavulina	7		x				
Climacammina	1, 9	x					
Cribrogoesella	3		x				
Cribrogenerina	1	x					
Dentalina	3, 7, 8		x				
Dictyomitra	3		x				
Dorothia	3, 7		x				
Eouvigerina	7, 8		x				
Epistomina	3, 7		x				
Eponides	3		x				
Frondicularia	7, 8		x				
Fusulina	4	x					
Fusulinella	4	x					
Gaudryina	3, 7, 8		x				
Gaudryinella	3, 7		x				
Geinitzina	9	x					
Globigerina	2, 3, 5, 7, 8		x				
Globigerinella	2, 3, 5, 7		x				
Globivalvulina	1, 6, 7	x	x				
Globorotalia	2, 7		x				
Globotruncana	2, 3, 5, 7, 8		x				
Globulina	3, 7		x				
Glomospira	3		x				
Goesella	3		x				
Gumbelina	2, 3, 5, 7, 8		x				
Gumbelitria	2, 5		x				
Gyroidina	2, 3, 5, 7, 8		x				
Hantkenina	2		x				
Haplophragmoides	3, 5		x				
Hastigerinella	7, 8		x				
Hopkinsina	2		x				
Hyperammina	1, 3	x	x				
Hyperamminoides	6	x					
Kyphopyxa	7		x				
Lagena	3, 8		x				
Lenticulina	3, 7, 8		x				
Lituotuba	5		x				
Loxostoma	7		x				
Loxostomum	3, 8		x				
Marginulina	3, 7, 8		x				
Marssonella	3, 7		x				
Miliammina	5		x				
Millerella	9	x					
Neobulimina	3, 7, 8		x				
Nodosarella	3		x				
Nodosaria	3, 7		x				
Nodosonella	1	x					
Nonionella	3, 8		x				
Oligostegina	3		x				
Palmula	7		x				
Parella	3		x				
Pelosina	5		x				
Planularia	7, 8		x				
Planulina	3, 5, 7, 8		x				
Pleurostomella	2, 7, 8		x				
Proetonia	3		x				
Pseudoclavulina	3, 5		x				
Pseudsfusulina	9	x					
Pseudoglandulina	3		x				
Pseudoparella	3		x				
Pullenia	3, 7		x				
Pyrulina	3		x				
Quinqueloculina	3		x				
Ramulina	3, 7		x				
Rectogumbelina	8		x				
Reophax	3		x				
Rhabdaminna	1, 3	x	x				
Robulus	3, 7, 8		x				
Ruttenia	2		x				
Saccamina	2		x				
Saccorhiza	3		x				
Saracenaria	3, 7, 8		x				
Schackoina	7, 8		x				
Schubertella	9	x					
Schwagerina	4	x					
Siphonina	3, 8		x				
Spirillina	3		x				
Spiroloculina	3		x				
Spiroplectammina	5		x				
Tetrataxis	1, 9	x					
Textularia	1, 3, 5		x				
Triloculina	3		x				
Triticites	4, 9	x					
Trochammina	1, 3, 7	x	x				
Trochamminoides	5		x				
Uvigerina	3		x				
Vaginulina	7		x				
Valvulineria	3, 5, 7, 8		x				
Ventilabrella	2, 7, 8		x				
Verneuilina	3, 5		x				
Virgulina	3, 5		x				

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Phylum Porifera

Genus	References	Penn. Perm.	Cret.	Olig.	Mio.	Plio.	Pleis.
Amblysiphonella	1, 2	x					
Girtycoelia	1, 2	x					
Girtyocoelia (=*Heterocoelia*)	1, 2	x					
Spicules	1, 2	x					x

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Phylum Coelenterata

Genus	References	Penn. Perm.	Cret.	Olig.	Mio.	Plio.	Pleis.
Aulopora	1, 7	x					
Campophyllum (See *Caninia*)							
Caninia	1, 7	x					
Cladochonus	5, 7	x					
Conularia	5, 7	x					
Craterophyllum (See *Pseudozaphrentoides*)		x					
Jelly fish molds	3	x					
Lophophyllidium	1, 5, 6, 7	x					
Lophophyllum (=*Lophophyllidium* of some authors)		x					
Medusina	3	x					
Microcyclus	1	x					
Monilopora (See *Cladochonus*)	7						
Pseudozaphrentoides	1, 2, 4, 5, 6, 7	x					
Stereostylus	5	x					
Syringopora	1, 5, 6, 7	x					
Zaphrentis	1, 5	x					

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Phylum Ectoprocta

Genus	References	Penn. Perm.	Cret.	Olig.	Mio.	Plio.	Pleis.
Batostomella	1, 3	x					
Conopeum	2		x				
Cyclotrypa	1,3	x					
Cystodictya (See *Sulcoretopora*)							
Fenestella	1, 3	x					
Fistulipora	1, 3	x					
Meekopora	1, 3	x					
Microstizia?			x				
Penniretopora (=*Pinnatopora*)	1, 3	x					
Polypora	1, 3	x					
Pyripora	2		x				
Rhombopora	1, 3	x					
Septopora	1, 3	x					
Stenopora	1, 3	x					
Streblotrypa	1, 3	x					
Sulcoretopora (=*Cystodictya*)	3	x					
Thamniscus	1, 3	x					

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Phylum Brachiopoda

Class Inarticulata

Genus	References	Penn. Perm.	Cret.	Olig.	Mio.	Plio.	Pleis.
Crania	1, 5	x					
Cranioid brachiopods			x				
Lingula	1, 2, 5, 6	x	x				
Linguloid brachiopods			x				
Lindstroemella	1, 5	x					
Orbiculoidea	1, 3, 5, 6	x					
Petrocrania	3, 5	x					
Trigonoglossa	1, 5	x					

Class Articulata

Genus	References	Penn. Perm.	Cret.	Olig.	Mio.	Plio.	Pleis.
Atrypoid group							
Ambocoelia	1	x					
(=*Crurithyris*)							
Cleiothyridina	1, 6	x					
Condrathyris	6	x					
Composita	1, 5, 6	x					
Crurithyris	1, 3, 5	x					
(see *Ambocoelia*)							
Hustedia	1, 3, 5, 6	x					
Phricodothyris	1	x					
(=*Squamularia*)							
(=*Condrathyris*)							
"Chonetoid" group							
Chonetes	1, 3	x					
Chonetina	1, 5	x					
Lissochonetes	1, 3, 5, 6	x					
Neochonetes	6						
"Orthoid" Group	7						
Enteletes	1, 3, 5, 6	x					
Rhipidomella	1, 3, 5, 6	x					
Schizophoria	1, 6	x					
"Productoid" group							
Antiquitonia	1, 4, 5	x					
(=*Dictyoclostus*)							
Buxtonia	1, 4, 5	x					
Cancrinella	1, 3, 4, 5, 6	x					
Dictyoclostus							
(See *Antiquitonia*)							
Hystriculina	5, 6	x					
Isogramma	1	x					
Echinaria	1, 3, 6	x					
(=*Echinoconchus*)							
Krotovia	1, 4, 6	x					
Juresania	1, 3, 4, 5, 6	x					
Linoproductus	1, 3, 4, 5, 6	x					
Leptolosia	1, 3, 4	x					
Marginifera	1, 3, 4, 5	x					
Poikilosakos	1, 5	x					
Pulchratia	1, 4, 5, 6	x					
Pustula	1	x					
Reticulatia	5, 6	x					
Teguliferina	1, 4, 5	x					
"Rhynchonelloid" Group	7						
Leiorhynchus	1	x					
Rhynchopora	1, 5	x					
Wellerella	1, 3, 5, 6	x					
"Spiriferoid" Group	7						
Neospirifer	1, 3, 6	x					
Punctospirifer	1, 5, 6	x					
Spirifer	1, 6	x					
"Strophomenoid" Group	7						
Derbyia	1, 3, 5, 6	x					
Derbyoides	1, 6	x					
Meekella	1, 3, 5, 6	x					
Schuchertella	1, 6	x					
Streptorhynchus	1, 6	x					
"Terrebratuloid" Group							
Beecheria	6						
(=*Dielasima*)							
Cryptacanthia	1, 6						
Dielasma	1, 3, 5	x					
(see *Beecheria*)							
Uncertain Classification							
Aulacorhynchus	1, 5	x					
(=*Isogramma*)							

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Phylum Mollusca

Class Bivalvia

Genus	References	Penn. Perm.	Cret.	Olig.	Mio.	Plio.	Pleis.
Acanthopecten	4	x					
Allorisma							
(See *Wilkingia*)							
Anodonta	5						x
Anomia	1, 3		x				
Anthraconeilo	2	x					
Anthraconeilopsis	2	x					
Aviculopecten	2, 4	x					
Aviculopinna	2, 4	x					
Callista	1		x				
Chlamys	1		x				
Clavicosta	2, 4	x					
Cyrena	1		x				
Dunbarella	4	x					
Edmondia	2, 4	x					
Exogyra	1	x					
Fasciculiconcha	4	x					
Gryphea	1, 3		x				
Inoceramus	1, 3		x				
Lima	2	x					
Mactra	1, 3		x				
Margaritana	1		x				
Myalina	2, 4	x					
Nucula	2, 4	x					
Nuculana	2, 4	x					
Ostrea	1, 3		x				
Parallelodon	4	x					
Peromorphus	2	x					
Peronopecten	4	x					
Pharella	1		x				
Pleurophorus	4	x					
Pisidium	5, 6						x
Promytilus	2, 4	x					
Pseudomontis	2, 4	x					
Pteria	1, 2, 3, 4	x	x				
P. (Oxytoma)	1		x				
Schizodus	2, 4	x					
Septimyalina	2, 4	x					
Sphaerium	5, 6						x
Streblochondria	2, 4	x					
Thetis	1		x				
Trigonarca	1, 3		x				
Wilkingia	4	x					
Yolida	1, 3, 4	x	x				

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Class Gastropoda

Genus	References	Penn. Perm.	Cret.	Olig.	Mio.	Plio.	Pleis.
Acroloxus	14						x
Amauropsis	6		x				
Amaurotoma	1, 7	x					
Amnicola	5, 15						x
Amphiscaphia	7, 9	x					
Anchura (See *Drepanochilus*)							
Anematina	7	x					
Anisomyon	6, 12		x				
Anisus (=*Gyraulus pattersoni*)	14						x
Anomphalus	1, 7	x					
Aplexa	14						x
Araeonema	9	x					
Baylea	1, 7	x					
Bellerophon	8, 9	x					
Bulimnea	14						x
Carychium	2, 3, 4, 5, 11, 13, 14, 15						x
Cionella	2, 5, 11, 13, 15						x
Colpites	1, 7	x					
Columella	2, 3, 11, 13, 15						x
Deroceras	2, 3, 4, 5, 11, 13, 14, 15						x
Dictyomaria	7	x					
Discus	2, 3, 4, 11, 13, 15						x
Donaldina	1, 7	x					
Drepanochilus	12		x				
Ellipsoscapha	12		x				
Euconulus	2, 3, 5, 11, 13, 15						x
Euomphalus	7, 9	x					
Euphemites	1, 7, 8, 9, 10	x					
Ferrissia	3, 4, 5, 11, 13, 15						x
Fossaria	13						x
Gastrocopta	3, 4, 5, 11, 13, 14, 15						x
Girtyspira	1, 7	x					
Glabrocingulum	9	x					
Glyptomaria	7, 9	x					
Goniasma	10	x					
Gyraulus	4, 5, 11, 13, 14, 15						x
Hawaiia	2, 4, 5, 11, 13, 14, 15						x
Helicodiscus	2, 3, 4, 5, 11, 13, 14, 15						x
Helisoma	4, 5, 14, 15						x
Helix	2, 6			x			
Hemizyga	1, 7	x					
Hendersonia	2, 3						x
Hypselentoma	9	x					
Ianthinopsis (=*Strobeus*) (=*Sphareodoma*)	7	x					
Knightites	7, 8, 9	x					
Lymnaea	3, 4, 5, 6, 11, 13, 15			x			x
Meekospira	10	x					
Murchisonia	1, 10	x					
Naticopsis	1, 7, 9, 10	x					
Nesovitrea (=*Retinella*)	14						x
Omphalotrochus	9	x					
Orthonema	1, 7	x					
Palaeostylus (=*Pseudozygopleura*)	6, 7	x					
Phanerotrema	1	x					
Phymatopleura	9	x					
Physa	3, 4, 5, 6, 11, 13, 14, 15			x			x
Planorbula	14, 15						x
Platyceras		x					
Pleurotomaria	1	x					
Pomatiopsis	4, 5						x
Promenetus	5, 14						x
Pupilla	2, 3, 4, 11, 13, 15						x
Pupoides	2, 3, 5, 11, 13, 14, 15						x
Retinalla (See *Nesovitrea*)							
Retispira	1, 7, 9	x					
Rhabdotochilus	1, 7	x					
Soleniscus		x					
Sphaerodoma (See *Ianthinopsis*)							
Stagnicola	14						x
Stenotrema	2, 5, 11						x
Straparolus	1, 7	x					
Striatura	2, 3, 5, 11, 15						x
Strobeus (See *Ianthinopsis*)							
Strobilops	2, 5, 13						x
Succinea	2, 3, 4, 5, 11, 13, 14, 15						x
Trachydomia	1, 7	x					
Trepospira	10	x					
Vanikoro	6, 12		x				
Warthia	7	x					
Worthenia	7	x					
Vallonia	2, 3, 4, 5, 11, 13, 14, 15						x
Valvata	3, 14						x
Vertigo	2, 3, 4, 5, 11, 13, 14, 15						x
Zonitoides	2, 3, 4, 5, 11						x

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Class Cephalopoda
(Nautiloid Sutures)

Genus	References	Penn. Perm.	Cret.	Olig.	Mio.	Plio.	Pleis.
Brachycycloceras	2, 3, 6	x					
Coelogasteroceras	2, 3, 6	x					
Coloceras							
(See *Liroceras*)							
Dolorthoceras	2, 3, 6	x					
Domatoceras	2, 3, 6	x					
(=*Pseudometacoceras*)							
Endolobus	2, 3, 6	x					
Ephippioceras	2, 3, 6	x					
Euloxoceras	2, 3, 6	x					
Eutrephoceras	3		x				
Liroceras	2, 3, 5, 6	x					
(=*Coloceras*)							
Metacoceras	2, 3, 4, 6	x					
(=*Nautilus sangamonensis*)							
Mooreoceras	2, 3, 4, 6	x					
Megaglossoceras	2, 3, 6	x					
Nautilus (see also		x	x				
Temnocheilus, *Metacoceras*)							
Planetoceras	2, 3	x					
Poterioceras	3	x					
Pseudorthoceras	2, 3, 4, 6	x					
Pseudometacoceras							
(See *Domatoceras*)							
Solenochilus	2, 3, 6	x					
Stenopoceras	2, 3	x					
Tainoceras	2, 3, 4	x					
Titanoceras	2, 3, 6	x					
(=*N. ponderosus*)							
Temnocheilus	2, 3, 6	x					
(=*N. coronatus*)							

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Subclass Ammonoidea
(Goniatite, Ceratite, and Ammonite Sutures)

Genus	References	Penn. Perm.	Cret.	Olig.	Mio.	Plio.	Pleis.
Acanthoscaphites	4, 8, 11, 15		x				
Anapachydiscus	6, 8		x				
Ancycloceras							
(See *Didymoceras*)							
Baculites	3, 4, 5, 6, 7, 8, 10, 12, 14, 15		x				
Barroisiceras	8, 14		x				
Cirroceras	5, 6, 7, 8		x				
(=*Didymoceras*)							
Clioscaphites	1, 2, 8, 14		x				
Didymoceras							
(See *Cirroceras*)							
Discoscaphites	4, 7, 8, 11, 15		x				
(=*Scaphites conradi*)							
Eoasianites	8, 15	x					
(=*Glaphyrites*)							
Exiteloceras	5, 8, 15						
Glaphyrites							
(See *Eoasianites*)							
Gonioloboceras	8, 13, 15	x					
Haresiceras	2, 8, 12, 14		x				
Imitoceras	8, 9, 15	x					
(=*Neoaganides*)							
Menuites	8		x				
Mortoniceras	7, 10, 12, 14, 15		x				
Neoaganides							
(See *Imitoceras*)							
Placenticeras	4, 7, 8, 10, 12, 15		x				
Prionocyclus	7, 8, 15		x				
(=*Prionotropsis*)							
Rhaeboceras	7, 8		x				
(=*Phylloceras halli*)							
Scaphites	1, 2, 4, 7, 8, 10, 11, 12, 14, 15		x				
Schistoceras	8, 13, 15	x					
Solenoceras	8		x				
Trachyscaphites	3		x				

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Phylum Arthropoda

Class Trilobita

Genus	References	Penn. Perm.	Cret.	Olig.	Mio.	Plio.	Pleis.
Ameura	1	x					
Anisopyge	2	x					
Ditomopyge	2	x					
Griffithides (See *Ditomopyge*)							
Neophillipsia (See *Ditomopyge*)							
Phillipsia (See *Ameura*)							

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Class Arachnoidea

Genus	References	Penn. Perm.	Cret.	Olig.	Mio.	Plio.	Pleis.
Order Eurypterida							
Eurypteris	1	x					

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Class Crustacea

Subclass Ostracoda

Genus	References	Penn. Perm.	Cret.	Olig.	Mio.	Plio.	Pleis.
Amphissites	1, 3	x					
Argilloecia	1	x					
Bairdia	1, 3	x					
Brachycythere	2		x				
Bythocypris	1, 2, 3	x	x				
Cavellina	1, 3	x					
Cornigella	1	x					
Coryella	3	x					
Cytheridea	2		x				
Cythereis	2		x				
Cytherella	2, 3	x	x				
Ellipsella	1	x					
Geisina	1	x					
Gregaria	1	x					
Glyptopleura	1	x					
Healdia	1, 3	x					
Hollinella	1, 3	x					
Jonesina	1, 3	x					
Kirkbya	1, 3	x					
Knightina	1, 3	x					
Knoxina	3	x					
Macrocypris	1, 3	x					
Moorites	1	x					
Morrowina	2		x				
Offa (?)	1	x					
Paracypris	2		x				
Paraparchites	3	x					
Roundyella	1	x					
Sansabella	1	x					
Silenites	1	x					
Sulcella	1	x					
Triceratina	3	x					
Ulrichia	1, 3	x					

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Phylum Echinodermata

Class Crinoidea

Genus	References	Penn. Perm.	Cret.	Olig.	Mio.	Plio.	Pleis.
Aatocrinus	5	x					
Acrocrinus (See *Caucacrocrinus*, *Dinacrocrinus*)							
Aesiocrinus	3, 5	x					
Agassizocrinus	5	x					
Aglaocrinus	11	x					
Allagecrinus (See *Isoallagecrinus*)		x					
Alossocrinus	10, 11	x					
Amphicrinus	12	x					
Anobasicrinus	11	x					
Apographiocrinus	5, 10	x					
Apollocrinus (See *Stelacrocrinus*)							
Arrectocrinus	1	x					
Ataxiacrinus (See *Tarachiocrinus*)	11	x					
Athlocrinus	5	x					
Bathronocrinus	12	x					
Cathetocrinus	1	x					
Caucacrocrinus	6	x					
Cibolocrinus	3, 5	x					

Genus	References	Penn. Perm.	Cret.	Olig.	Mio.	Plio.	Pleis.
Coenocystis	5	x					
Contocrinus	1	x					
(=*Graphiocrinus stantonensis* Strimple)							
Crinoid Parts		x	x				
Delocrinus		x					
(See *Palmatocrinus, Subarrectocrinus, Metarrectocrinus, Catacrinus, Lobalocrinus*)							
Dicromyocrinus	5, 11	x					
Dinacrocrinus	6	x					
Elibatocrinus	3, 11	x					
Endelocrinus	5, 10	x					
Erisocrinus	5	x					
Ethelocrinus	5, 10	x					
Euerisocrinus	7	x					
Euonychocrinus	9	x					
Exocrinus	10	x					
Galateacrinus	3	x					
Graffhamicrinus	11	x					
Graphiocrinus		x					
(See *Contocrinus*)							
Haeretocrinus	5, 11	x					
Hydreionocrinus	11	x					
Isoallagecrinus	13	x					
Laudonocrinus	5	x					
Lecythiocrinus	7	x					
Melbacrinus	7	x					
Metaperimestocrinus	11	x					
Metarrectocrinus	1	x					
Moundocrinus	7	x					
Nebraskacrinus	2	x					
Neocatacrinus	1	x					
Oklahomacrinus	11	x					
Pachylocrinus	3, 5	x					
Palmatocrinus	1	x					
Paradelocrinus	5, 12	x					
(See *Parerisocrinus, Sublobalocrinus, Neocatacrinus*)							
Parerisocrinus	1	x					
Pargaassizocrinus	5	x					
Parethelocrinus	11	x					
Parulocrinus	5, 11	x					
Perimestocrinus	5, 11	x					
(See *Vertigocrinus*)							
Plaxocrinus	3, 4, 5, 11	x					
(See *Simocrinus, Retusocrinus, Separocrinus*)							
Polusocrinus	11	x					
Retusocrinus	1	x					
Sciadiocrinus	4, 5, 11	x					
Schitsocrinus	5, 11	x					
Separocrinus	1	x					
Simocrinus	1	x					
Stellarocrinus	11	x					
Stenopecrinus	11	x					
Subarrectocrinus	1	x					
Tarachiocrinus	11	x					
(=*Ataxiacrinus*)							
Sublobalocrinus	1	x					
Texacrinus	5, 11	x					
Tholiacrinus	1	x					
Triceracrinus	1	x					
Ulocrinus	5, 10, 11	x					
Utharocrinus	3, 4	x					

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Pennsylvanian and Permian Fish and Shark Remains

Genus	Reference
Chomatodus	2
Cladodus	1, 2
Ctenoptychius	2
Dactylodus	2
Helodus	2
Listracanthus	1
Orodus	1, 2
Petalodus	1, 2

Cretaceous Fish and Shark Remains

Genus	Reference
Enchodus	1
Ichthyodectes	1
Lamna	1
Leptostyrax	1
Ptychodus	1
Scapanorhynchus	1
Squalicorax	1

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Plant Fossils

Pennsylvanian and Permian Plants

Genus	Reference
Annularia	3
Asterophyllites	3, 9
Calamites	3, 9
Calamostachys	9
Cordaites	5
Epidermis	12
Equisetalis	9
Lepidodendron	6
Lepidostrobus	9

Genus	Reference
Neuropteris	9
Odontopteris	9
Pecopteris	3
Siggilaria	6
Sphenophyllum	3
Sphenopteris	3

Cretaceous Plants

Genus	Reference
Abietites	7
Acer	7
Acerites	7
Alnites	7
Ampellophyllum	7
Andromeda	7
Ansiophyllum	7
Anona	7
Aralia	2, 7, 8
Araucaria	7
Aristolochia	7
Aspidiophyllum	2, 7
Betula	7
Betulites	2, 7
Carpolithes	7
Caudex	7
Celastrophyllum	7
Cinnamomum	7
Cissites	7
Dioscorea	7
Diospyros	7
Dryophyllum	7
Equisetum	7
Eremophyllum	7
Fagus	7
Ficus	2, 7
Flabellaria	7
Gleichenia	7, 8
Grewiopsis	7
Hamamelites	7
Hedera	7
Hymenophyllum	7
Ilex	7
Inolepis	7
Juglans	7
Laurus	7
Liquidambar	2, 7
Liriodendron	2, 7
Lomatia	7
Lygodium	7
Magnolia	2, 7
Menispermites	7
Myrica	7
Negunoides	7
Ovularites	11
Oreodaphne	7
Paliurus	7
Pecopteris	7
Persea	7
Phragmites	7
Phyllites	7
Pinus	7
Plant cuticle	8, 10
Platanus	7
Podozamites	7
Populites	7
Populus	2, 7
Proteoides	7
Protophyllum	7
Prunus	7
Pyrus	7
Quercus	7
Rhamnus	7
Salix	2, 8
Sapotacites	7
Sassafras	2, 7
Sequoia	7, 11
Sphenopteris	7
Sterculia	7
Thinfeldia	7
Thuites	7

Tertiary and Pleistocene Seeds, Nuts, and Grass Fruits

Genus	Reference	Olig.	Mio.	Plio.	Pleis.
Archihicoria	2	x			
Berrichloa	4		x	x	
Biorbia	4			x	
Celtis	4			x	x
Chaetochloa	4			x	
Krynitzkia	4			x	
"Panicum"	4			x	
Setaria	4			x	
Stipidium	4		x	x	

Tertiary and Pleistocene Diatoms

Genus	Reference	Olig.	Mio.	Plio.	Pleis.
Achnanthes	1		x		
Amphora	2				x
Baccilaria	2				x
Cocconeis	2				x
Cocconema	1		x		
Cymatopleura	2				x
Cymbella	2				x
Cystopleura	2				x
Encyonema	2				x
Epithemia	1		x		
Eunotia	2				x
Fragillaria	2				x
Gomphonema	2				x
Hantzschia	2				x
Melosira	1		x		
Meridion	2				x
Navicula	2				x
Nitzschia	1		x		
Opephora	2				x
Stauroneis	2				x
Suriraya	2				x
Surirella	1		x		
Synedra	2				x
Tabellaria	2				x
Tetracyclus	2				x

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