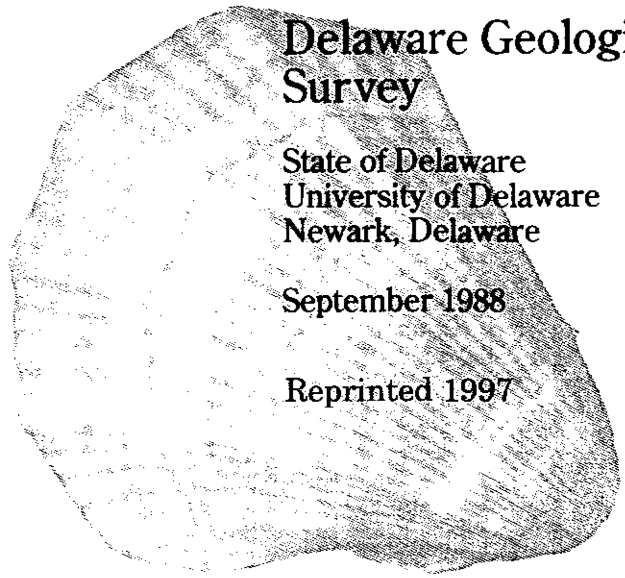
Cretaceous Fossils from the Chesapeake and Delaware Canal

A Guide for Students and Collectors

Edward M. Lauginiger

Special Publication No. 18

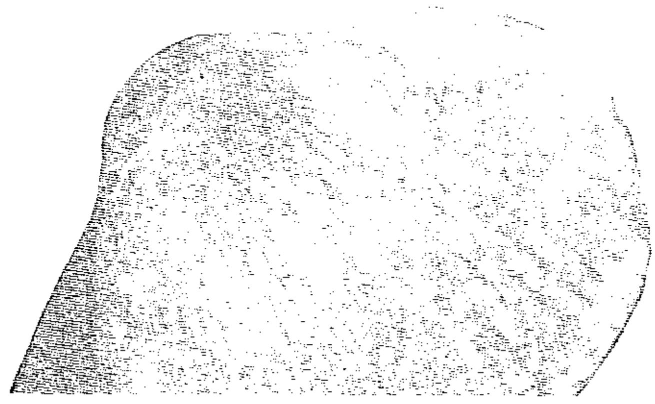


Delaware Geological Survey

State of Delaware
University of Delaware
Newark, Delaware

September 1988

Reprinted 1997



CRETACEOUS FOSSILS FROM THE CHESAPEAKE AND DELAWARE CANAL: A GUIDE FOR STUDENTS AND COLLECTORS

By

Edward M. Lauginiger
Biology Teacher
Academy Park High School
Sharon Hill, Pennsylvania

September 1988

Reprinted 1997

CONTENTS

FIGURES

CRETACEOUS FOSSILS FROM THE CHESAPEAKE AND DELAWARE CANAL: A GUIDE FOR STUDENTS AND COLLECTORS

Edward M. Lauginiger

INTRODUCTION

Fossil collectors have been attracted to Delaware since the late 1820s when the excavation of the Chesapeake and Delaware (C&D) Canal first exposed marine fossils of Cretaceous age (Fig. 1). Since then, many technical and non-technical works have been written about the fossils. However, there has not been a single source for casual or student collectors to turn to for help in the identification of typical finds. This paper is written to fill that void as well as provide general information about fossils and specific information on geologic formations and collecting localities at the Canal.

This report is not designed to be an encyclopedia on the fossils of the Canal but focuses on those fossils found most frequently. The majority of the fossils collected today are from the spoil areas in the vicinity of the Reedy Point Bridge. Thus, the chapter on classification concentrates on the fossils of the Mount Laurel Formation, the stratigraphic unit dredged in that area.

Fossils not described in this paper may be identified from other sources listed in the bibliography or by contacting one of the universities or museums that have collections of Cretaceous age fossils from Delaware. The University of Delaware, the Academy of Natural Sciences of Philadelphia, the Delaware Museum of Natural History, and the New Jersey State Museum are a few of these places. The U. S. Army Corps of Engineers museum at Chesapeake City, Maryland, has fossils on display. Rare or unusual finds of fossils should be donated for future study. There is nothing worse than having a "one of a kind" fossil spend years in a cardboard box only to be discarded when the collector moves on to other interests.

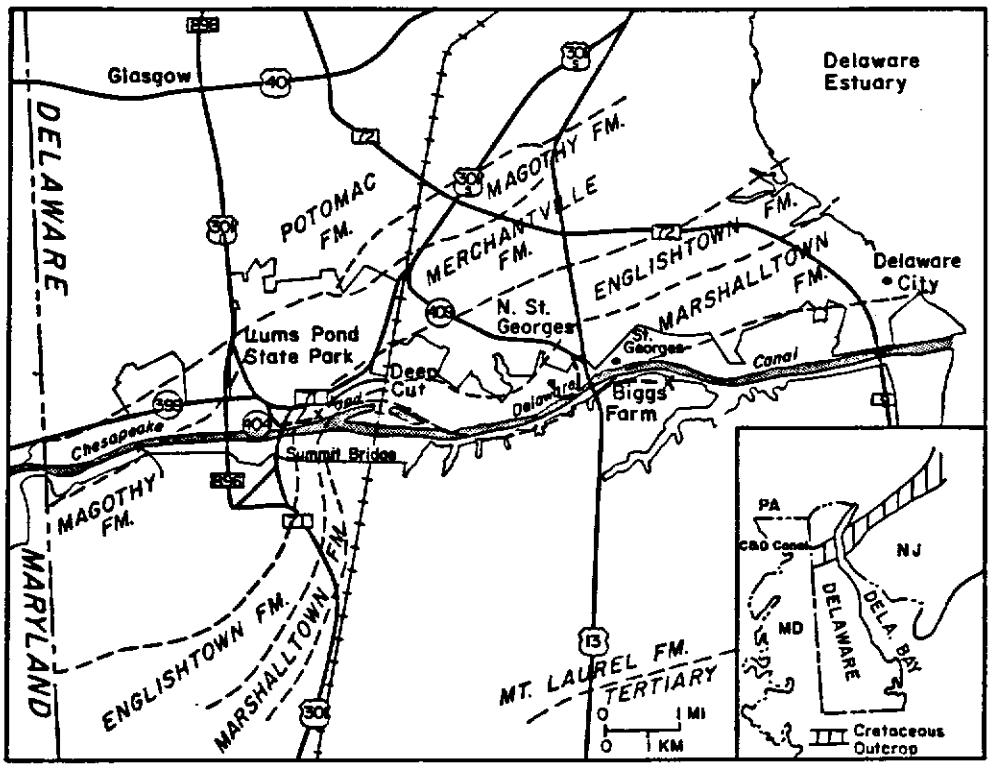


Figure 1. Index map of the Chesapeake and Delaware Canal Area (from Pickett, 1987).

ACKNOWLEDGMENTS

The author thanks Richard N. Benson of the Delaware Geological Survey (DGS) for editing and preparing the manuscript for publication. Thomas E. Pickett encouraged submittal of the manuscript for publication by the DGS.

Sophie Homsey and D. Kenneth Gagon provided most of the line drawings. The Delaware Valley Paleontological Society (DVPS) and, particularly, members Paul Sorton and Bob Walters kindly allowed the use of drawings previously published in the Society newsletters.

Photographic support was provided by Eugene F. Hartstein of the Delaware Mineralogical Society and the DVPS.

I thank Thomas E. Pickett of the DGS, Ronald E. Martin of the University of Delaware Department of Geology, and Ellis L. Yochelson of the United States National Museum for their reviews of the manuscript and helpful suggestions for its improvement.

This work is dedicated to the students and fossil hunters who come to Delaware to collect and admire some of the first inhabitants of the First State.

PREVIOUS STUDIES

There is no record of who discovered the first fossil at the Chesapeake and Delaware Canal. S. C. Morton (1829) published the first scientific report, in which he described six different types of fossils found in the Cretaceous deposits of Delaware. Delaware's first State Geologist, James C. Booth, described Canal area outcrops and identified Cretaceous fossils (Booth, 1841).

During the next hundred years a great deal of work was done by geologists as they attempted to describe the lithology of the formations at the Canal and relate the stratigraphy to that of the surrounding strata of New Jersey and Maryland. A review of this early work was provided by Groot, Organist, and Richards (1954).

A comprehensive systematic study of the Cretaceous fossils of New Jersey by Richards et al. (1958, 1962) includes many invertebrate fossils that are also found in the Canal area. Both Olsson (1960) and Mumby (1961) studied the large variety of microscopic foraminifera found in the marine Cretaceous formations. Plant microfossils were studied by Groot and Penny (1960) and Gray and Groot (1966). The publication of Richards and Shapiro (1963) served for many years as the handbook for invertebrate fossil identifications, but it is now out of print.

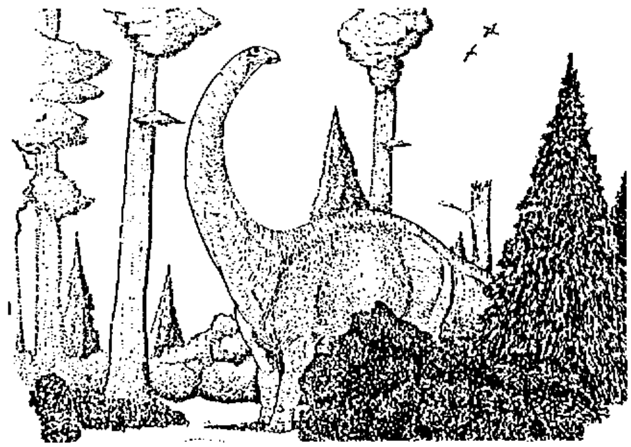
Owens *et al*. (1970) studied the lithology and fossils of the Upper Cretaceous rocks of New Jersey, Delaware, and Maryland. Pickett (1970) remapped the stratigraphy of the Canal formations and reprinted the plates of previous publications (Pickett, 1972).

Pickett, Kraft, and Smith (1971) published a report on arthropod burrows. Cynthia Miller (1971), an amateur collector, reported on Delaware's fossils in *Earth Science* magazine. The U. S. Army Corps of Engineeers (1972) published their own "Facts on Finding Fossils" and planned to establish two permanent areas for the collection of fossils by amateurs. The areas were excavated but were soon abandoned by both collectors and the Corps. Selected papers on the geology of Delaware were presented to the Delaware Academy of Science in 1976 (Kraft and Carey, 1979).

Vertebrate remains are also present in the formations at the Canal. Fossil dinosaur bones from New Jersey and Delaware were studied by Baird and Horner (1977). Baird and Galton (1981) figured pterosaurian (flying reptile) bones collected by amateurs from dredge spoils of the Merchantville Formation. The Delaware Mineralogical Society published a general guide by Lauginiger and Hartstein (1981) that included sketches of both vertebrate and invertebrate fossils. Gallagher (1982) and Hartstein (1985a) continued the renewed interest in Delaware's vertebrate fossils by publishing articles in the newsletter of the Delaware Valley Paleontological Society. Lauginiger and Hartstein (1983) provided a detailed analysis of the fossil teeth of sharks, skates, and rays. Lauginiger (1984) expanded that work with a report on the microvertebrate teeth found in dredge spoils of the Marshalltown Formation.

As the latest works, Curran (1985) studied trace fossils from the Englishtown Formation at the Deep Cut, and Pickett (1987) described the Canal stratigraphy for a Geological Society of America field guide.

Much work remains to be done on the fossils of the Chesapeake and Delaware Canal. Many comprehensive collections of the large and varied assemblage from the Bigg's Farm locality are available for study. The first detailed systematic study of an incomplete collection from there was by Richards and Shapiro (1963). Additional work on pelecypods (clams and oysters) and gastropods (snails) is needed, and bryozoans (moss animals) have not been studied nor have the fragmentary vertebrate remains. This work needs to be done before the site disappears by erosion and the various collections of dedicated amateurs become scattered and the material unobtainable. If this were to happen, a chance to study an important aspect of the geologic history of Delaware will have been lost.



FOSSILS AND FOSSILIZATION

The remains or traces of living things from the earth's geologic past are called fossils. Not only are they a record of ancient life, but they provide important clues to the age and origin of the rock units in which they are found. Fossils also have practical as well as aesthetic value. Some are used to guide geologists in the search for oil and gas deposits; others are collected by individuals just as a hobby and for display in museums. Fossils provide important evidence of evolution and are useful in interpreting ancient environments and sea levels.

The scientific study of fossils is known as paleontology. Most paleontologists study fossils of animals without backbones (invertebrate paleontology) and remains of microscopic, usually single-celled, plant and animal life (micropaleontology). Vertebrate paleontology is the study of fossil animals with backbones. Paleobotanists study the remains of plants, not only leaves, stems, and trunks, but also seeds and pollen. The study of traces of ancient life, such as tracks, trails, burrows, and nests, is called ichnology. Paleontologists representing all of these categories have studied the remains of ancient life in the rocks exposed at the C & D Canal.

Requirements for Fossilization

For a living organism to become a fossil a number of conditions must be met. Unfortunately, the vast majority of once-living organisms did not meet one or more of the requirements and have been lost from the fossil record. It has been estimated that only about one in every thousand types of previous life forms have left their remains as fossils.

There are exceptions to the requirements for fossilization; however, certain general rules can be used to explain the occurrence of most of the specimens in the fossil record.

1. The presence of hard parts - The main part of the fossil record began about 600 million years ago when living things developed shells and outside skeletons for support and protection from predators. Organisms with hard parts such as shells, bones, teeth, woody tissue, and outside skeletons are more likely to be found in the fossil record because the softer body parts are either eaten or decompose. It is only in very rare circumstances that the soft parts are preserved.

2. Rapid burial under the correct conditions - In order to become a fossil an organism has to be buried before it can be eaten, crushed, or weathered. Most would-be fossils are destroyed by scavengers, decomposers such as bacteria, or natural forces of weathering and erosion.

   An organism must also be buried in the right type of sediment. Generally speaking, the finer grained the sediment, the better the chance for preservation. Sediments such as clays, silts, and lime muds usually best preserve the fossils.

3. The presence of a large population - The greater the number of organisms and the larger their geographic range, the better the chance that at least some of the population will meet the conditions necessary to become a fossil. Types of living things that have small populations and are only found in a few places rarely are found as fossils.

This may be one reason why there are intermediate evolutionary forms ("missing links") missing from the fossil record.

Types of Fossilization

1. Preservation with little change - This type of preservation gives clues to the soft as well as hard parts of once-living organisms.

   (a) Freezing - This occurs when an organism is rapidly frozen before the process of decay can set in. One example is the remains of mammoths which have been recovered from frozen ground in Alaska and Siberia and are now on display at museums in the United States and Soviet Union.

   (b) Desiccation - Sometimes an organism dies in a very dry environment, and the water is driven out of the body before decomposition sets in. This may result in a natural mummy that can give clues about the soft parts of the animal. Mammals of the glacial (Pleistocene) age and some dinosaurs have been found preserved in this manner.

   (c) Chemical preservation - Organisms may die and become trapped in material that preserves even the flesh and hair. Ancient peat bogs and tarpits in Europe and North America have provided fine examples of this type of preservation.

   (d) Original hard parts - Some parts of plants and animals are capable of resisting the efforts of nature to change or destroy them. The calcium carbonate shells of clams, oysters, and other shelled animals, the calcium phosphate teeth and bones of vertebrates, the siliceous shells of microscopic radiolarians, and the exoskeletons (external skeletons) of chitin covering crabs and other arthropods have been found preserved as original hard parts.

2. Preservation with change - The majority of fossils are formed by the alteration of their original material.

(a) Permineralization - This type of fossilization takes place when the cavities or pores within the bone, shell, or plant material are filled with substances such as silica or calcite. Most of the reptile and dinosaur bones found in New Jersey and Delaware have been preserved in this manner.

(b) Replacement - When the original hard parts of an organism are replaced chemically by another substance, usually silica or calcite, the result is a duplicate of the external form of the hard part. Molecule by molecule replacement usually does not occur, and, consequently, internal shell microstructure is destroyed. Many of the mollusk shells from the Canal are preserved by replacement.

(c) Carbonization - When the only element remaining from the alteration of organic matter is carbon, it may be preserved as a thin film, usually within fine-textured rocks such as shales, siltstones, limestones, and dolomites, or as a large mass of material we know as coal. Leaves, insects, and fishes are types of organisms that have formed carbonized impressions in rocks.

(d) Molds and casts - These are the most common types of fossils found in the Cretaceous deposits of Delaware. If, after the death of a shelled animal and its burial by sediments, the original shell is dissolved, a cavity or mold is formed. The impression of the outer part of the shell is known as an external mold. If sediment fills in the hollow space inside the shell before it dissolves, the result will be an internal mold or "steinkern." Steinkerns of clams, snails, and ammonites are the most common fossils found at the C & D Canal area.

3. Traces of Past Life - An organism itself may not become a fossil but may provide evidence that it once existed. Sometimes the evidence can be linked to a specific plant or animal, but most often the information is only of a general nature. Several types of animals might produce similar looking traces.

(a) Tracks and trails - Some animals have left footprints preserved in the hardened sediments as records of their existence. These tracks can help paleontologists gain information about the size, weight, and speed of the animal that made the track. Trails of invertebrate animals in limestones and shales were formed by the organisms while they were wandering about on the soft muddy seafloor, usually in search of food.

(b) Burrows - One of the most common types of fossils found in Delaware is the remains of the homes of the "ghost shrimp." These nodular, branched tubes were formed as the shrimp burrowed into the sediment. Other burrows or animal homes have been formed by worms, clams, and other types of sea life. After the animal dies or moves away the burrow is then filled by sediment and preserved as a trace fossil. Occasionally a burrow is found with the former resident preserved inside. Other burrows are feeding burrows that show where an animal has been while passing sediment through its gut to extract organic matter for its food.

(c) Coprolites - Fossil feces or solid waste from an animal is sometimes found preserved. Coprolites from sharks, bony fish, and arthropods are very common fossil finds in the Cretaceous sediments of Delaware. These remains give clues to the diets and internal digestive structures of the animals that made them.

GEOLOGY

The geologic formations exposed at the C & D Canal (Fig. 2) originated from sediments eroded from the Appalachian Mountains to the west. Those mountains were formed during the latter part of the Paleozoic Era (over 250 million years ago). The varicolored clays, silts, and sands of the oldest formation at the Canal, the Potomac Formation, were deposited by rivers draining the highlands to the west and northwest during early Late Cretaceous time (approximately 95 million years ago). A long period of erosion or nondeposition followed (perhaps 10 million years or so, Benson *et al.*, 1985). The surface separating the Potomac from the overlying Magothy Formation is called an unconformity and represents a significant interval of time without a sedimentary record. The Magothy, characterized by interbedded sands and lignite-containing silts, was deposited in a marginal marine environment as the sea began to rise across the eroded surface of the Potomac Formation.

The marine deposits record cycles of rise and fall of sea level during the Late Cretaceous. This can be better understood by studying the lithology (physical character) of the sediments.

The base of the Merchantville Formation is a glauconitic sand which is covered by the silt of the upper Merchantville that, in turn, grades into the quartz sands of the Englishtown Formation. The sands that contain the mineral glauconite were deposited in deep water whereas the quartz silts and sands indicate shallow water. Curran (1985) interpreted the Englishtown as having been deposited in the upper shoreface - lower foreshore zone.

Exposure of the Englishtown Formation as sea level fell is marked by another unconformity separating it from the Marshalltown Formation above. Rise in sea level repeated, marked by the glauconitic sands of the Marshalltown. A shallowing of the marine waters is recorded as those sands grade into the silts at the base of the Mount Laurel and then into the quartz sands in the upper Mount Laurel.

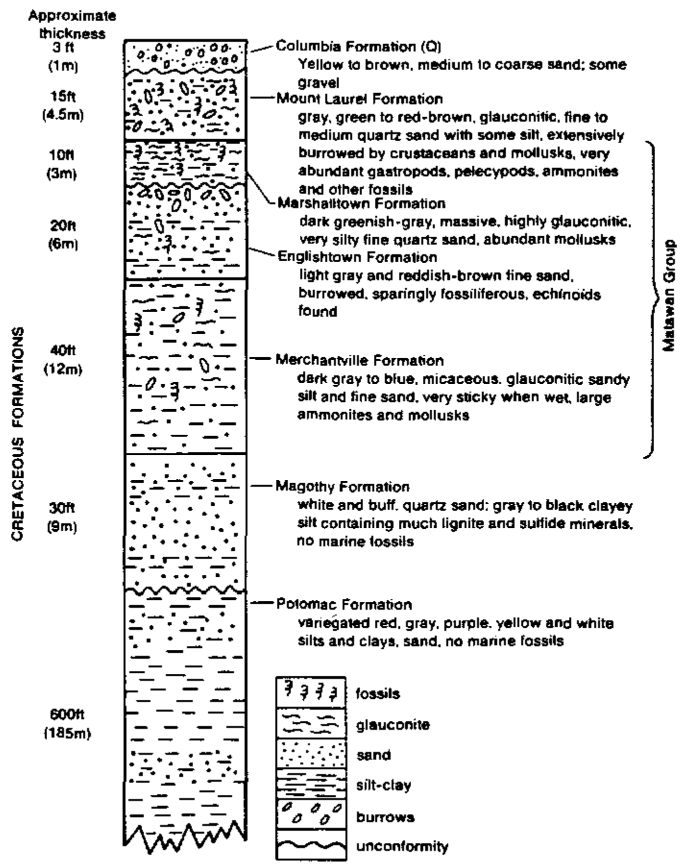


Figure 2. Generalized stratigraphic column of the formations exposed at the C & D Canal (from Pickett, 1987).

The transition from the Cretaceous to the Paleocene (about 65 million years ago), which is also the transition from the Mesozoic to the Cenozoic eras, occurs within the Hornerstown Formation. This formation is missing in the area of the Canal because of erosion, but it and the overlying Vincentown Formation occur several miles south (down dip) of the Canal.

At the Canal, all younger geologic formations were removed by erosion prior to deposition of the Columbia Formation, which, therefore, is separated from the underlying formations by an unconformity. The Columbia Formation consists of river-deposited sands and gravels that cover all older formations. Jordan (1964) attributes the deposition of the Columbia to conditions that prevailed during the transition from a glacial to interglacial stage of the Pleistocene epoch.

CLASSIFICATON OF FOSSILS

All living things and fossils are named in a system first proposed by the Swedish naturalist Carolus Linnaeus in 1758. They are assigned to distinct categories called species which are groupings of individuals having identity or near identity of form and physical features. A test of a living species is whether or not individuals of the species interbreed with one another. The scientific name of a species consists of two parts, each of which is derived from Greek or Latin, or has classic form. The classic languages were used because they were widely known by the academic community and were unlikely to change through time. The first word under Linnaeus's system of binomial nomenclature is the name of the genus to which the species belongs and is spelled with an initial capital letter. The second word is the trivial name, written with an initial lower case letter. The combination of generic and trivial names is the full name of a species; a trivial name cannot stand alone but a generic name can. The generic and trivial names are always written in italics or are underlined. The scientific name for modern humans is *Homo sapiens*; for lions it is *Felios leo*.

Linnaeus also devised a hierarchical system of categories to arrange all living things with similar characteristics into groups. This system has been modified over the years and now is:

- Kingdom
  - Phylum (Division for plants)
    - Class
      - Order
        - Family
          - Genus
            - Species

Presumably, organisms belonging to the same group are closely related. A kingdom may have more than one phylum (plural form phyla), a family may have more than one genus (plural form genera), and, typically, a genus has more than one species assigned to it.

Descriptions of fossils from the C & D Canal that follow are arranged in hierarchical order. Species and genera are named and illustrated by text-figure drawings and/or photographs (Plates 1-9), but they are not described systematically. Systematic descriptions are in many of the references listed in the bibliography.

Kingdom Monera

The members of this kingdom are some of the oldest and most primitive types of living things found on the earth. They are single-celled, microscopic, and do not contain an organized nucleus. Examples include bacteria, blue-green algae (cyanobacteria), and stromatolites. Even though some members of this kingdom have been found as fossils which date back as far as 3.5 billion years, they have not been reported in the formations of Delaware.

Kindgom Protista

These are more complex one-celled or colonial organisms which have one nucleus or more in each cell. They are usually divided into the plant-like members, the algae, and the animal-like members, the Protozoa. Important fossil groups of algae are microscopic siliceous diatoms and the calcareous coccolithophorids. They are present in Delaware's rocks but are invisible to the naked eye.

Protozoa are grouped into four classes (Sarcodina, Mastigophora, Sporozoa, Ciliophora) by their method of locomotion. Of these four classes only members of the Sarcodina usually are recovered as fossils. This is because these amoeba-like protozoans secrete a hard outer covering of chitin, silica, or calcium carbonate in order to provide support and protection. These outer coverings or "tests" are the parts preserved as fossils.

The Class Sarcodina is represented in the fossil record by the two orders Foraminifera and Radiolaria. Generally speaking, the Foraminifera ("forams") with their many-chambered shells of calcium carbonate are the most common protozoans found in Delaware; Radiolaria are common in marine rocks of Tertiary age. "Forams" usually are collected by special filtration and flotation techniques because of their microscopic size, but two genera, Dentalina and Citharina (Fig. 3) are large enough to be seen and are fairly common in the Mount Laurel dredge spoils.

Dentalina sp. Citharina sp.

Figure 3. Foraminifera (3x).

One hundred sixty-two species and subspecies of Foraminifera were reported from the Upper Cretaceous deposits at the Canal by Mumby (1961). Olsson (1964) studied planktonic (floating) Foraminifera from Canal outcrops.

Kingdom Plantae

Plants are multicellular nucleated organisms that have cellulose cell walls, contain the pigment chlorophyll, and are autotrophic (produce their own food). Chlorophyll is essential to the production of sugars and starches by photosynthesis which uses sunlight as energy and water and carbon dioxide as raw materials.

The plant kingdom is divided into divisions. The two major divisions of plants are the Bryophyta, plants that have no vascular system, and the Tracheophyta, plants that do. The Bryophyta include the mosses, hornworts, and liverworts. The Tracheophyta include the ferns, evergreens, and flowering plants.

Plant material in the form of lignite can be found in the various Cretaceous formations, and some probable pine cones have been recovered from the Merchantville Formation at the Deep Cut (Fig. 15).

Twenty-seven species of plants were identified from their pollen and spores by Gray and Groot (1966) in their study of the Upper Cretaceous of Delaware and New Jersey. The specimens recovered include material from ferns, gymnosperms (evergreens), and angiosperms (flowering plants).

Kingdom Animalia

Animals are multicellular nucleated organisms that do not have individual cell walls, do not use the pigment chlorophyll, and are heterotrophic, thus must get their food from other living organisms. They can be herbivorous (plant eaters), carnivorous (animal eaters), omnivorous (plant and animal eaters), or parasites which live off other living things usually without killing them.

Members of the animal kingdom that have backbones are known as vertebrates, while those without backbones are invertebrates. The invertebrates or "lower animals" are the most numerous and make up the majority of the fossils found by collectors. The remains of vertebrates or the "higher animals" are usually found as isolated teeth and bones. There is a great deal of literature devoted to the study of the fossil invertebrates of Delaware, but, unfortunately, most of it is either out of print or contains outdated information. The vertebrates, on the other hand, have received more attention during the past ten years (see Bibliography).

Phylum Porifera

The sponges are the most primitive of the multicellular animals and produce skeletons of calcium carbonate, silica, or a soft organic material called spongin for support and protection of their soft bodies. In the Cretaceous of Delaware, this group is represented by *Cliona*. These sponges lived by filtering their food as they grew on the rocks and shells on the seafloor. In order to anchor themselves, they dissolved pits and tubes in shells of other organisms as they expanded along their surfaces of attachment. This fossil is very common in the Mount Laurel both as isolated sections of colonies and as growths covering most of the larger shells.

Cliona cretacica

Figure 4. Porifera (1x).

Phylum Cnidaria (Coelenterata)

These soft-bodied animals have saclike digestive cavities and tentacles containing rows of stinging cells for defense and capturing of food. Many secrete calcium carbonate to support and partly enclose the soft parts; the most familiar of these are the corals. The only members of the phylum found at the Canal are solitary corals belonging to the Class Anthozoa or "flower-animals." One of these corals, Micrabacia, may be the most common fossil found. Another common fossil, a solitary horn-shaped coral, has been given different names by different authors.

Micrabacia hilgardi

Solitary horn-shaped coral

Figure 5. Cnidaria (2x).

Phylum Bryozoa

The "moss-animals" are microscopic, solitary, filter-feeders that live in branching colonies with protective coverings of organic material or calcium carbonate. There are few records of bryozoans being collected "in place" from outcrops of formations. The spoil banks in the Reedy Point area have at least three species which are fairly common, but their source has been the subject of debate among collectors and professionals over the years. Richards et al. (1962)

claim that no bryozoan species have been reported from the Cretaceous of New Jersey but that they are present in the Vincentown Formation of Eocene age. Some claim that the bryozoans found at the C & D Canal are from the overlying Vincentown Formation which is exposed to the south, and that they have been washed into the eastern end of the Canal by the Delaware River and then dumped on the spoils with the other dredgings (Bill Gallagher, New Jersey State Museum, personal communication).

Frurionella sp. *Heteropora* sp. *Cyolostome* sp.

Figure 6. Bryozoa (2x).

Phylum Brachiopoda

Brachiopods are commonly called "lamp shells" because some of them resemble the outline of Grecian oil lamps. They are often confused with clams because both types of animals have shells consisting of two hinged valves. The brachiopods have valves covering the top and bottom of the animal that are of different sizes and shapes. Clams have valves on either side which are generally the same size and shape although mirror images of one another. Each valve of a brachiopod is symmetrical whereas each clam valve is asymmetrical.

Brachiopods spend their adult life as sessile (attached) filter-feeders. They have generally decreased in abundance and diversity since the Paleozoic Era. Some types are fairly common, easy to identify, and are restricted to certain periods of time. These features make them important index or guide fossils. The brachiopod species *Terebratulina cooperi* is an index fossil for the Mount Laurel Formation in Delaware.

Terebratulina cooperi

Figure 7. Brachiopoda (2x).

Phylum Mollusca

Over ninety percent of the fossil species found in the Cretaceous formations of Delaware belong to the Phylum Mollusca. In the Marshalltown Formation there are over seventy genera of mollusks, and the Mount Laurel has been reported to have well over a hundred (Owens et al., 1970).

Three classes of mollusks are common as fossils: gastropods (snails), pelecypods (clams), and cephalopods (ammonites).

Most gastropods secrete a single coiled or uncoiled shell for protection. They spend their lives crawling along the sea floor, eating algae from the rocks, bottom debris, or clams and oysters which they drill into with their "radula" or rasping tongue. Many clams and oysters fell victim to these, their distant cousins, as evidenced by the numerous shells with small bore holes in them.

Most of the gastropod fossils from the Canal are internal casts (steinkerns). They are very difficult to identify, and most can only be assigned to a family or a genus. A few snail fossils are found either with the shell still preserved or as external casts and are easier to identify because ornamentation is preserved. A good, but somewhat outdated, source of information on the gastropods and other mollusks is Richards et al. (1958, 1962).

The shells of pelecypods, or bivalves, consist of two valves generally of equal size, hinged at the back, that enclose the soft parts of the animal. Some bivalves live in large groups so abundant they form beds, particularly the

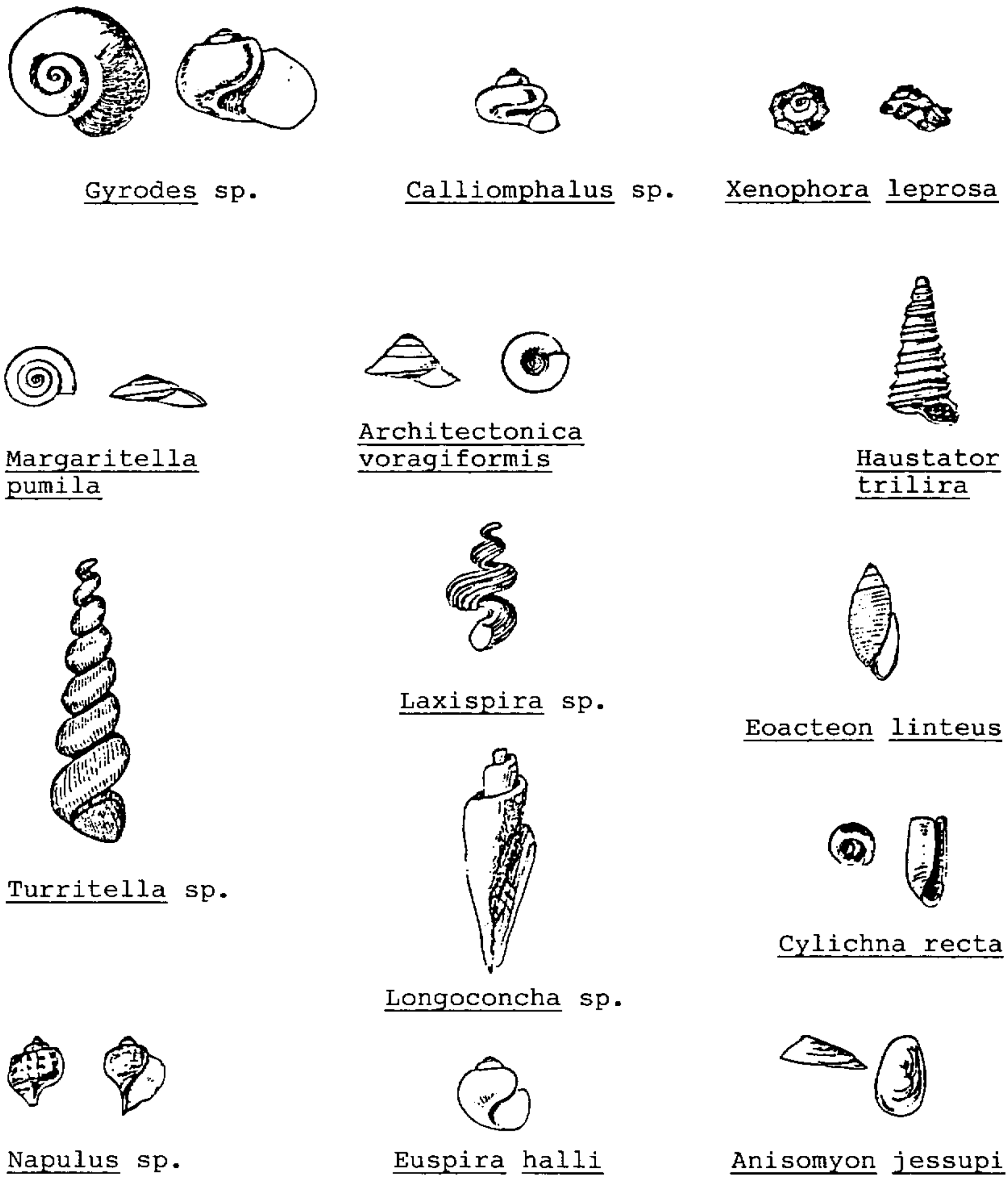


Figure 8. Mollusca-Gastropoda (2x).

oysters; these forms filter plankton and organic debris from the water. Others burrow through the mud and feed on debris or swim about in search of food.

Some pelecypod fossils are found at the Canal as internal molds; others, such as *Exogyra* and *Pyncnodonte*, have had their calcitic shells preserved with little or no change. In part, this is because the mineral matter of these shells is resistant to solution.

The internal molds of bivalves are somewhat easier to identify than those of the gastropods, but much work also needs to be done with this group. Pelecypods and gastropods are abundant in the spoils from the Mount Laurel Formation on both sides of the Canal in the vicinity of Reedy Point.

The cephalopods are the most advanced and largest mollusks found in Delaware. Their subdivisions are the Nautiloidea (chambered *Nautilus*), Ammonoidea (the extinct ammonites), and Dibranchiata (squids, the extinct belemnites, and octopuses).

The ammonite can be thought of as an octopus stuffed inside a straight, coiled, or spiral shell. They are uncommon finds, usually as broken pieces; a complete one is a rare and exciting find. Most of the larger coiled ones are found in the Merchantville Formation. Sections of the straight-shelled *Baculites* are more common in the Mount Laurel Formation.

The bullet-shaped, amber colored, internal skeletons of the free-swimming belemnites are index fossils of the Mount Laurel and are very common finds on the spoil piles. This ancestor of the modern cuttlefish and squids must have traveled in large schools and were an important part of the diets of fishes and reptiles.

Clavagella armata

Liopistha protexta

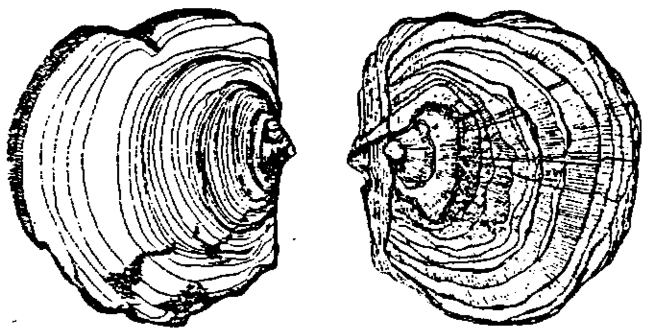
Postligata crenata

Cucullaea sp.

Trigonia sp.

Crassatella sp.

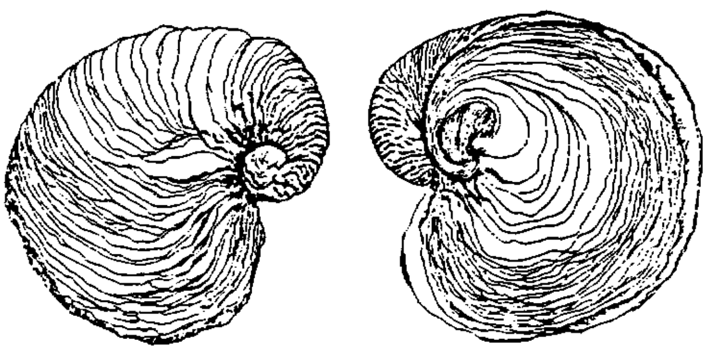
Nuculana sp.



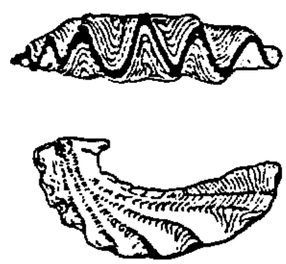
Pyncnodonte mutabilis

Gryphaeostera vomer

Neithea quinquecostata



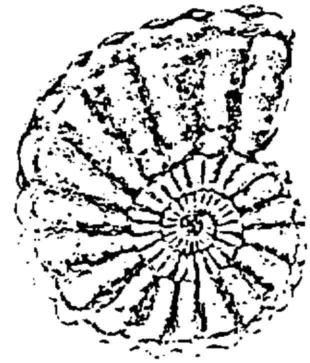
Exogyra cancellata
(small specimen)



Ostrea falcata

Figure 9. Mollusca-Pelecypoda (1.5x).

Placenticeras placenta



Menabites delawarensis

Belemnitella americana

Oxybeloceras sp. (1x)

Baculites ovatus

Figure 10. Mollusca-Cephalopoda (0.5x unless otherwise noted).

Phylum Annelida

The remains of the soft-bodied segmented worms are not usually preserved as fossils. Some of the marine (salt water) types, however, secrete tubes of calcium carbonate to use both as a home and to provide protection from their enemies. These tubes can be found as isolated specimens or attached to larger shells. Two genera, *Serpula* and *Hamulus*, are fairly common finds.

Serpula implicata

Hamulus sp.

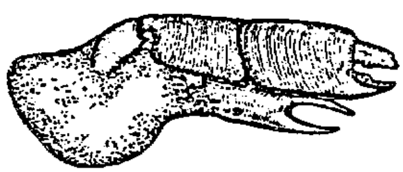
Figure 11. Annelida (2x).

Phylum Arthropoda

The arthropods are some of the most common animals found on earth, both today (insects belong to the Anthropoda) and in the fossil record. Of the many classes, only the members of the Malacostraca (crabs, shrimps, lobsters) and the microscopic Ostracoda are found as fossils in Delaware.

The ostracodes, along with other microfossils such as the Foraminifera, can be collected by studying the sand-size residue from screenings of the Mount Laurel Formation. With a microscope plus tools for picking and sorting, the collector will be rewarded with the great variety of beautiful forms represented by microfossils.

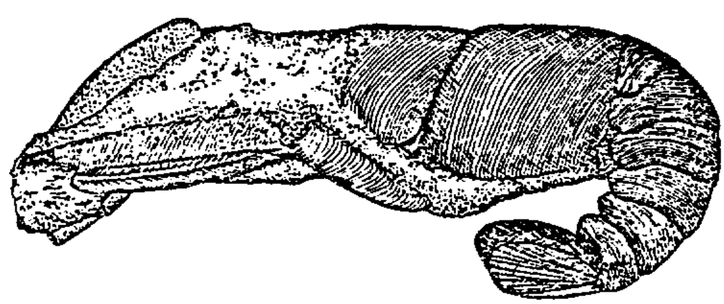
Pieces of the claws and pincers of the ghost shrimp Callianassa can be found in almost all of the Cretaceous formations, but complete appendages with the claws and pincers intact are usually found only in the vicinity of the Deep Cut.



Callianassa mortoni

Tetracarcinus subquadratus

Ophiomorpha nodosa
(burrow of a ghost shrimp)



Hoploparia gabbi

Figure 12. Arthropoda (0.5x).

In addition to the body parts, the burrows of this shrimp, called *Ophiomorpha nodosa*, are also found as trace fossils. The burrows are very common in the Englishtown and Marshalltown formations and have been studied in detail by Pickett *et al*. (1971) and Curran (1985).

Occasionally, small crabs (*Tetracarcinus subquadratus*) or fragments of lobsters (*Hoploparia gabbi*) can also be found on some of the spoil areas from the Merchantville and Marshalltown formations.

Phylum Echinodermata

This group of "spiny-skinned" animals lives only in the marine environment. Two major divisions are recognized by biologists, the Pelmatozoa (attached, usually stalked forms) and the Eleutherozoa (unattached free-moving forms).

Fossil Pelmatozoa are represented in Delaware by stem fragments or columnals from crinoids or sea lilies (Fig. 13). The columnals, belonging to the Cretaceous crinoid *Dunnicrinus*, are common finds on the Reedy Point spoils. The calyx or head of this crinoid has not been found, possibly because of its fragile nature.

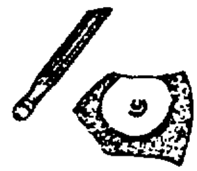
Eleutherozoan fossils include a group of starfish-like, free-moving forms, the brittle stars, and a group of armless spiny forms, the sea urchins. Complete sea urchins are rare and highly prized specimens (Fig. 13), whereas their isolated spines and plates are common finds as are small fragments of brittle stars.

Phylum Chordata

This phylum includes the vertebrates. Although not as common as the invertebrates, teeth and bones from three different classes of vertebrate animals can be found at Canal sites.

Members of the Chondrichthyes or "cartilage fish" include the sharks, skates, and rays. Teeth and vertebrae from these animals are the most common types of vertebrate fossil found. They may be found by close examination of the surface of an outcrop or by sieving the material from the various spoil piles.

Dunnicrinus sp. (2x)



Echinoid spine and plate (2x)

Hemiaster delawarensis (1x)

Catopygus williamsi (1x)

Phymosoma sp (1.5x)

Boletechinus sp (3x)

Figure 13. Echinodermata.

The most commonly found shark teeth belong to the extinct shark Squalicorax. These relatively broad and serrated teeth are easy to identify to the genus level, but it is more difficult to distinguish between the species. Teeth of the goblin shark Scapanorhynchus are the largest shark teeth found at the Canal, with some specimens reaching over two inches in length. The teeth of this shark have caused workers much confusion because teeth from different parts of the mouth have different and distinct shapes. At one time there were three different names given to the teeth of this single shark species. More detailed information on the dozen or more types of shark teeth found in the Cretaceous of Delaware is given by Lauginiger and Hartstein (1983).

The Osteichthyes or "bony fish" are represented by the dagger-like teeth of the Cretaceous predator Enchodus. Single, isolated teeth and small sections of the jaw with teeth still attached are relatively common finds. Teeth from other bony fish include Anomoeodus and Stephanodus. Vertebral columns of bony as well as cartilaginous fish are also found on the spoil piles.

Reptile remains are rare and thus the most treasured finds from the Delaware Cretaceous. Teeth of the sea-going reptile Mosasaurus (illustrated below) and fragments from the upper and lower shells of turtles are the usual finds. Most collectors have to hunt for years before they find a single mosasaur tooth.

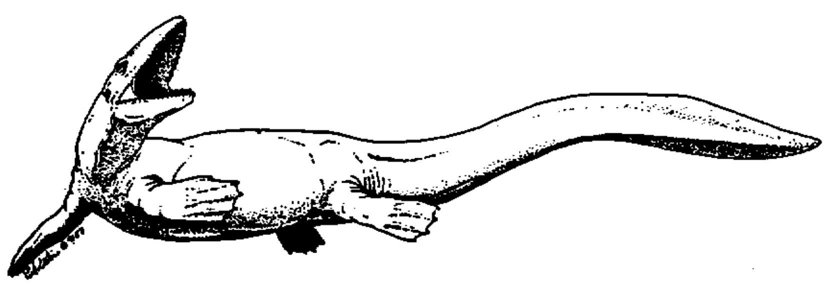


Figure 14. Chordata (1x).

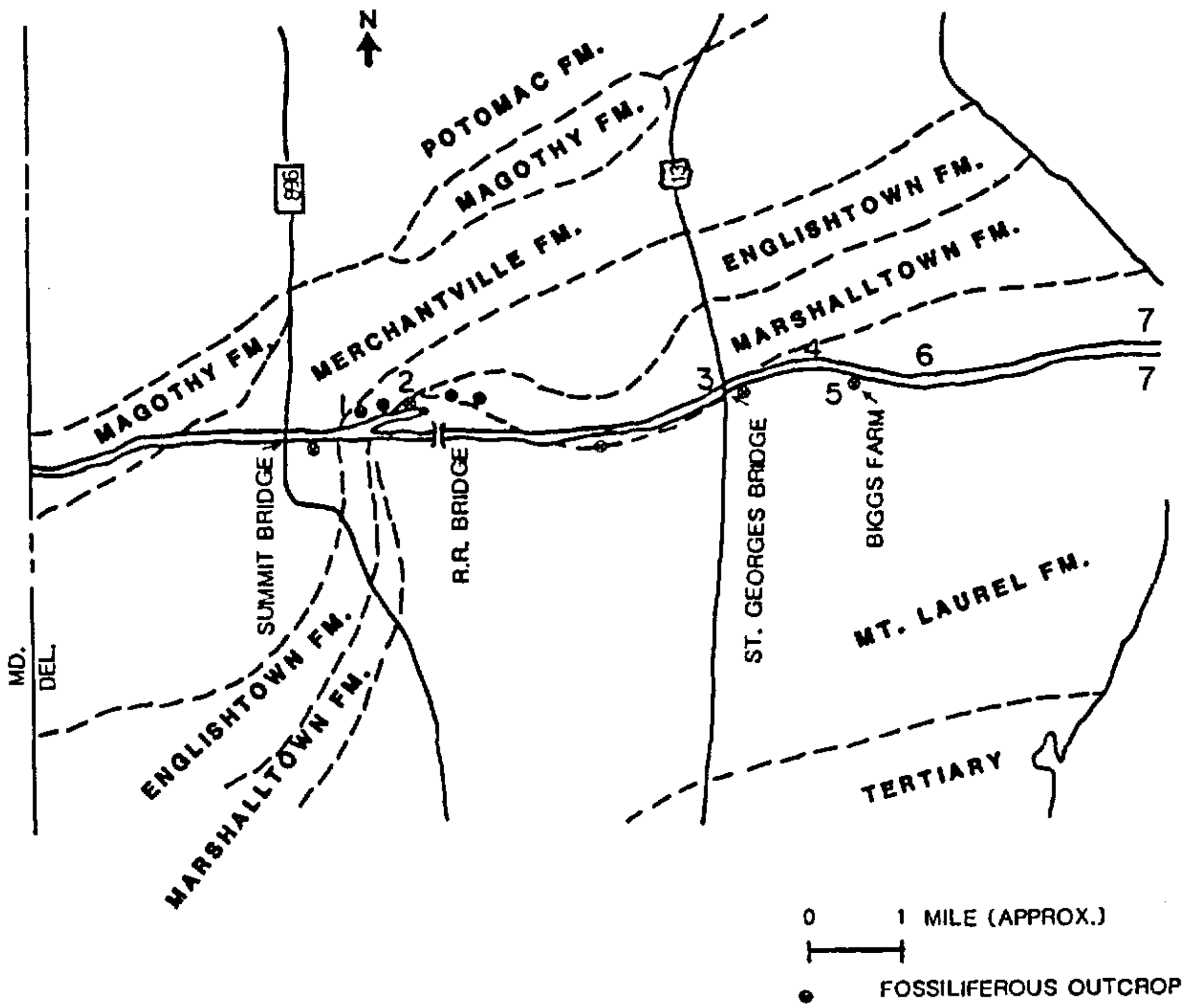
COLLECTING LOCALITIES

Fossiliferous outcrops and good areas for collecting from dredge spoils along the Chesapeake and Delaware Canal are indicated in Figure 15. Collecting conditions vary widely depending on the time since the last maintenance dredging by the Corps of Engineers, rainfall, location of dredging activity, and degree of collector activity; therefore, the number of fossils found can vary from a very few to many. No assurance of finding specific fossil types described in this guide is implied.

Collecting is always better after the U. S. Army Corps of Engineers does their periodic dredging and dumps loads of fossil-bearing spoils on the sides of the canal. The areas on the northern and southern sides near the Reedy Point Bridge have sediments from the Mount Laurel Formation and are excellent collecting localities. Spoil areas to the west of St. Georges, on the north side of the canal, usually contain Marshalltown sediments with shark material. The Bigg's Farm locality, on the southern side of the canal just east of the St. Georges Bridge, is no longer productive because of erosion and the placement of large rocks to stabilize the bank. The Deep Cut, located on the north side near the Railroad Bridge, was once an excellent locality for Marshalltown and Merchantville specimens. Today it is only useful for the study of the stratigraphy of the Canal formations and trace fossils.

The U. S. Army Corps of Engineers has jurisdiction over most of the Canal and requires that bank stabilization not be destroyed by over-collecting. It is against federal law to collect fossils from the Canal reservation for later sale; however, small-scale collecting for private collections is permitted. It is wise to avoid wading in the water as there is a 35-foot deep channel just offshore. The Corps prefers that collections be made from spoil areas, away from the water.

The Delaware Geological Survey urges the conservation of these scientifically and educationally important fossil localities. It would be appreciated if unusual "finds" are brought to the attention of the Survey.



1 - Deep Cut
2 - Merchantville spoils
3 - Marshalltown spoils
4 - Marshalltown spoils
5 - Bigg's Farm
6 - Mount Laurel spoils
7 - Reedy Point spoils

Figure 15. Collecting localities at the Chesapeake and Delaware Canal.

FOSSIL CHECK LIST

	Kml	Kmt	Ket	Kmv
FORAMINIFERA				
Dentalina sp.	x			
Citharina sp.	x			
PORIFERA				
Cliona cretacica	x	x		x
CNIDARA				
Micrabacia hilgardi	x			
Solitary horn-shaped coral	x			
BRYOZOA				
Frurionella sp.	x			
Heteropora sp.	x			
Cyolostome sp.	x			
BRACHIOPODA				
Terebratulina cooperi	x			
GASTROPODA				
Gyrodes sp.	x	x	x	x
Calliomphalus sp.	x			x
Xenophora leprosa	x			x
Margaritella pumila	x	x		
Architectonica voragiformis	x			
Haustator trilira	x	x		
Turritella sp.	x	x	x	x
Laxispira sp.	x	x		x
Longoconcha sp.	x	x		x
Eoacteon linteus	x			
Cylichna recta	x			
Napulus sp.	x			x
Euspira halli	x		x	x
Anisomyon jessupi	x			
PELECYPODA				
Exogyra cancellata	x			
Exogyra ponderosa		x	x	x
Pyncnodonte mutabilis	x	x		
Ostrea (Lopha) falcata	x	x		
Clavagella armata	x			
Neithea quinquecostata	x	x		x

Fossil Check List (continued)

	Kml	Kmt	Ket	Kmv
Gryphaeostrea vomer	x	x		
Trigonia sp.	x	x		
Liopistha protexta	x		x	x
Crassatella sp.		x	x	x
Nuculana sp.	x	x		x
Cucullaea sp.	x	x		x
Postligata crenata	x			x
Anomia sp.	x	x		x
Cardium sp.	x	x		x
Nemodon sp.	x			
CEPHALOPODA				
Placenticeras placenta				x
Menabites delawarensis				x
Belemnitella americana	x			
Oxybeloceras sp.	x			
Baculites ovatus	x			
ANNELIDA				
Serpula implicata	x			x
Hamulus sp.	x			x
ARTHROPODA				
Callianassa mortoni	x	x		x
Tetracarcinus subquadratus		x		x
Hoploparia gabbi		x		x
Ophiomorpha nodosa	x	x	x	
ECHINODERMATA				
Dunnicrinus sp.	x			
Catopygus williamsi	x			
Phymosoma sp.	x			
Boletechinus sp.	x			
Echinoid spines and plates	x			
CHONDRICHTHYES				
Scapanorhynchus texanus		x		x
Squalicorax kaupi	x	x		x
Odontaspis sp.	x	x		x
Ischyrhiza mira	x	x		x
Shark vertebrae	x	x		x
Ray vertebrae	x	x		x

Fossil Check List (continued)

	Kml	Kmt	Ket	Kmv
OSTEICHTHYES				
Enchodus ferox	x	x		x
Anomoeodus phaseolus	x	x		x
Bony fish vertebrae	x	x		x
REPTILIA				
Mosasaurus sp.	x	x		x
Turtle shell fragments		x		x

Explanation:

x means fossil occurs in formation
Kml - Mount Laurel Formation
Kmt - Marshalltown Formation
Ket - Englishtown Formation
Kmv - Merchantville Formation

BIBLIOGRAPHY

Baird, D., and Galton, P. M., 1981, Pterosaur bones from the Upper Cretaceous of Delaware: Journal of Vertebrate Paleontology, v. 1, p. 67-71.

Baird, D., and Horner, J. R., 1977, A fresh look at the dinosaurs of New Jersey and Delaware: New Jersey Academy of Sciences Bulletin, v. 22, p. 50.

Benson, R. N., Jordan, R. R., and Spoljaric, N., 1985, Geological studies of Cretaceous and Tertiary section, test well Je32-04, central Delaware: Delaware Geological Survey Bulletin No. 17, 69 p., 3 pls.

Booth, J. C., 1841, Memoir of the Geological Survey of the State of Delaware: S. Kimmey, Dover, 188 p.

Cappetta, H., and Case, G. R., 1975, Contribution a l'etude des selaciens du Groupe Monmouth (Campanian-Maestrichtien) du New Jersey: Palaeontographica (A), No. 151, p. 1-46.

Carter, C. W., 1937, The Upper Cretaceous deposits of the Chesapeake and Delaware Canal: Maryland Geological Survey, Volume XIII, p. 237-281.

Case, G., 1972, Handbook of fossil collecting: Grafco Inc., 64 p.

______, 1982, A pictorial guide to fossils: Van Nostrand Reinhold, 515 p.

Cassanova, R., 1970, An illustrated guide to fossil collecting: Naturegraph Publishers, 128 p.

Cobban, W. A., 1970, Occurrence of the Late Cretaceous ammonites _Didymoceras stevensoni_ (Whitfield) and _Exiteloceras jenneyi_ (Whitfield) in Delaware: U. S. Geological Survey Professional Paper 700-D, p. D71-D76.

Curran, H. A., 1985, The trace fossil assemblage of a Cretaceous nearshore environment: Englishtown Formation of Delaware, U. S. A., _in_ Curran, H. A., ed., Biogenic structures: Society of Economic Paleontologists and Mineralogists Special Publication 35, p. 261-276.

Decina, L., 1985, Third reported occurrence of a Hadrosaurian tooth found at the C. & D. Canal: Newsletter of the Delaware Valley Paleontological Society, v. 7, p. 2.

Fowler, H. W., 1911, A description of the fossil fish remains of the Cretaceous, Eocene and Miocene formations of New Jersey: New Jersey Geological Survey, Bulletin 4, 192 p.

Gallagher, W. B., 1982, Hadrosaurian dinosaurs from Delaware: Newsletter of the Delaware Valley Paleontological Society, v. 4, p. 3.

Gray, T. C., and Groot, J. J., 1966, Pollen and spores from the marine Upper Cretaceous formations of Delaware and New Jersey: Palaeontographica (B) No. 117, (4-6), p. 114-134.

Groot, J. J., Organist, D. M., and Richards, H. G., 1954, Marine Upper Cretaceous formations of the Chesapeake and Delaware Canal: Delaware Geological Survey Bulletin No. 3, 64 p.

Groot, J. J., and Penny, J. S., 1960, Plant microfossils and the age of nonmarine Cretaceous sediments of Maryland and Delaware: Micropaleontology, v. 6, p. 225-236.

Hartstein, E. F., 1982, Bone pickers-Banks of the C & D Canal source of fossils: The Mariner, Sept. 2, 1982.

______, 1985a, A new C & D Canal dredge site: Newsletter of the Delaware Valley Paleontological Society, v. 7, p. 3.

______, 1985b, Fossil echinoid from the C. & D. Canal: Newsletter of the Delaware Valley Paleontological Society, v. 8, p. 3.

Jordan, R. R., 1962, Stratigraphy of the sedimentary rocks of Delaware: Delaware Geological Survey Bulletin No. 9, 51 p.

______, 1964, Columbia (Pleistocene) sediments of Delaware: Delaware Geological Survey Bulletin No. 12, 69 p.

Kraft, J. C., and Carey, W., eds., 1979, Selected papers on the geology of Delaware: Transactions of the Delaware Academy of Science, v. 7, 268 p.

Lauginiger, E. M., 1978, Spoil bank collecting at the C. and D. Canal: Earth Science, v. 31, p. 119-120.

______, 1979, Field tripping at the C. and D. Canal: Rockhound Magazine, v. 8, p. 48-50.

______, 1982, Fossils and formations of the Chesapeake and Delaware Canal, Delaware: Fossils Quarterly, v. 1, p. 39-43.

______, 1984, An Upper Campanian vertebrate fauna from the Chesapeake and Delaware Canal, Delaware: The Mosasaur, Journal of the Delaware Valley Paleontological Society, v. 2, p. 141-149.

______, 1988, Raiders of the lost sharks: MAPS Digest (Mid-America Paleontology Society) , v. 11, p. 40-42.

Lauginiger, E. M., and Hartstein, E. F., 1981, Delaware fossils: Delaware Mineralogical Society, 38 p.

______, 1983, A guide to fossil sharks, skates and rays from the Chesapeake and Delaware Canal area, Delaware: Delaware Geological Survey Open-File Report 21, 64 p.

Macdonald, J. R., 1983, A fossil collector's handbook: Prentice-Hall, Inc., 193 p.

Matthews, W. H., 1962, Fossils - An introduction to prehistoric life: Barnes and Noble Books, 337 p.

McAlester, A. L., 1968, The history of life: Foundations of Earth Science Series, Prentice-Hall, Inc., 152 p.

Miller, C. T., 1971, Delaware's Cretaceous fossils: Earth Science, v. 24, p. 247-251.

Morton, S. C., 1829, Description of the fossil shells which characterize the Atlantic Secondary Formation of New Jersey and Delaware including four new species: Journal of the Academy of Natural Sciences of Philadelphia, v. 6, p. 72-100.

Mumby, J. L., 1961, Upper Cretaceous Foraminifera from the marine formations along the Chesapeake and Delaware Canal: unpublished Ph.D. dissertation, Bryn Mawr College, 174p, 11 pls.

Olsson, R. K., 1960, Foraminifera of latest Cretaceous and earliest Tertiary age in the New Jersey Coastal Plain: Journal of Paleontology, v. 34, p. 1-58.

______, 1964, Late Cretaceous planktonic foraminifera from New Jersey and Delaware: Micropaleontology, v. 10, p. 152-188.

Owens, J. P., Minard, J. P., Sohl, N. F., and Mello, J. F., 1970, Stratigraphy of the outcropping post-Magothy Upper Cretaceous formations in southern New Jersey and northern Delmarva Peninsula, Delaware and Maryland: U. S. Geological Survey Professional Paper 674, 60 p.

Pickett, T. E., 1970, Geology of the Chesapeake and Delaware Canal area: Delaware Geological Survey, Geologic Map Series No. 1, scale 1:24,000.

______, 1972, Guide to common Cretaceous fossils of Delaware: Delaware Geological Survey Report of Investigations 21, 28 p.

______, 1987, Upper Cretaceous and Quaternary stratigraphy of the Chesapeake and Delaware Canal: Geological Society of America Centennial Field Guide-Northeastern Section, p. 23-24.

Pickett, T. E., and Windish, D., 1980, Delaware: Its rocks, minerals, and fossils: Delaware Geological Survey, 18 p.

Pickett, T. E., Kraft, J. C., and Smith, K., 1971, Cretaceous burrows, Chesapeake and Delaware Canal, Delaware: Journal of Paleontology, v. 45, p. 209-211.

Richards, H. G., et al., 1958, The Cretaceous fossils of New Jersey, Part I: New Jersey Geological Survey Paleontology Series, 266p., pls. 1-46.

______, 1962, The Cretaceous fossils of New Jersey, Part II: New Jersey Geological Survey Paleontology Series, Bulletin 61, 237 p., pls. 47-94.

Richards, H. G., and Shapiro, E., 1963, An invertebrate macrofauna from the Upper Cretaceous of Delaware: Delaware Geological Survey Report of Investigations No. 7, 37 p.

Spoljaric, N., and Jordan, R. R., 1966, Generalized geologic map of Delaware: Delaware Geological Survey Special Publication No. 4, scale approximately 1:300,000.

U. S. Army Corps of Engineers - Philadelphia District, 1967, Inland Waterway-Delaware river to Chesapeake Bay - historic Chesapeake & Delaware Canal: U. S. Government Printing Office, 16 p.

______, 1972, Helpful hints for fossil collecting in Chesapeake & Delaware Canal: U. S. Government Printing Office, 4 p.

______, 1974, The Chesapeake & Delaware Canal: U. S. Government Printing Office, 20 p.

______, 1979, The Chesapeake and Delaware Canal: U. S. Government Printing Office, 2 p.

PLATES

Photographs of specimens are arranged approximately in the same order on plates 1 through 9 as they are discussed in the chapter on classification. Formation abbreviations are given in the explanation of the fossil check list on page 32. Measurements are of either the maximum horizontal, marked H, or vertical, marked V, dimension of each specimen as shown by the orientation of the photograph on the plate.

Foraminifera:	Plate 1, fig. 1
Porifera:	Plate 1, figs. 2-3.
Cnidaria:	Plate 1, fig. 5.
Bryozon:	Plate 1, figs. 6, 9.
Brachiopoda:	Plate 1, fig. 4.
Gastropoda:	Plate 5.
Pelecypoda:	Plates 2-4.
Cephalopoda:	Plate 6.
Annelida:	Plate 1, figs. 7-8.
Arthropoda:	Plate 7, figs. 10-15.
Echinodermata:	Plate 7, figs. 1-9.
Chondrichthyes:	Plate 8, figs. 8, 9; Plate 9.
Osteichthyes:	Plate 8, figs. 4-7.
Reptilia:	Plate 8, figs. 1-3.

PLATE 1

1. *Dentalina delicatula* Cushman, side view, 8 mm V, Kml.

2. *Cliona cretacica* Fenton and Fenton, top view of an isolated colony, 16 mm H, Kml.

3. *Cliona cretacica* Fenton and Fenton, encrusted shell, top view, 38 mm H, Kml.

4. *Terebratulina cooperi* Richards and Shapiro, top view, 6 mm V, Kml.

5. *Micrabacia hilgardi* Stephenson, top view, 5 mm H, Kml.

6. *Frurionella* sp., side view of a colony, 12 mm V, Kml?.

7. *Serpula implicata* Stephenson, top view, 5 mm H, Kml.

8. *Hamulus* sp., side view, 8 mm V, Kml.

9. *Heteropora* sp., side view, of a colony, 18 mm V, Kml?.

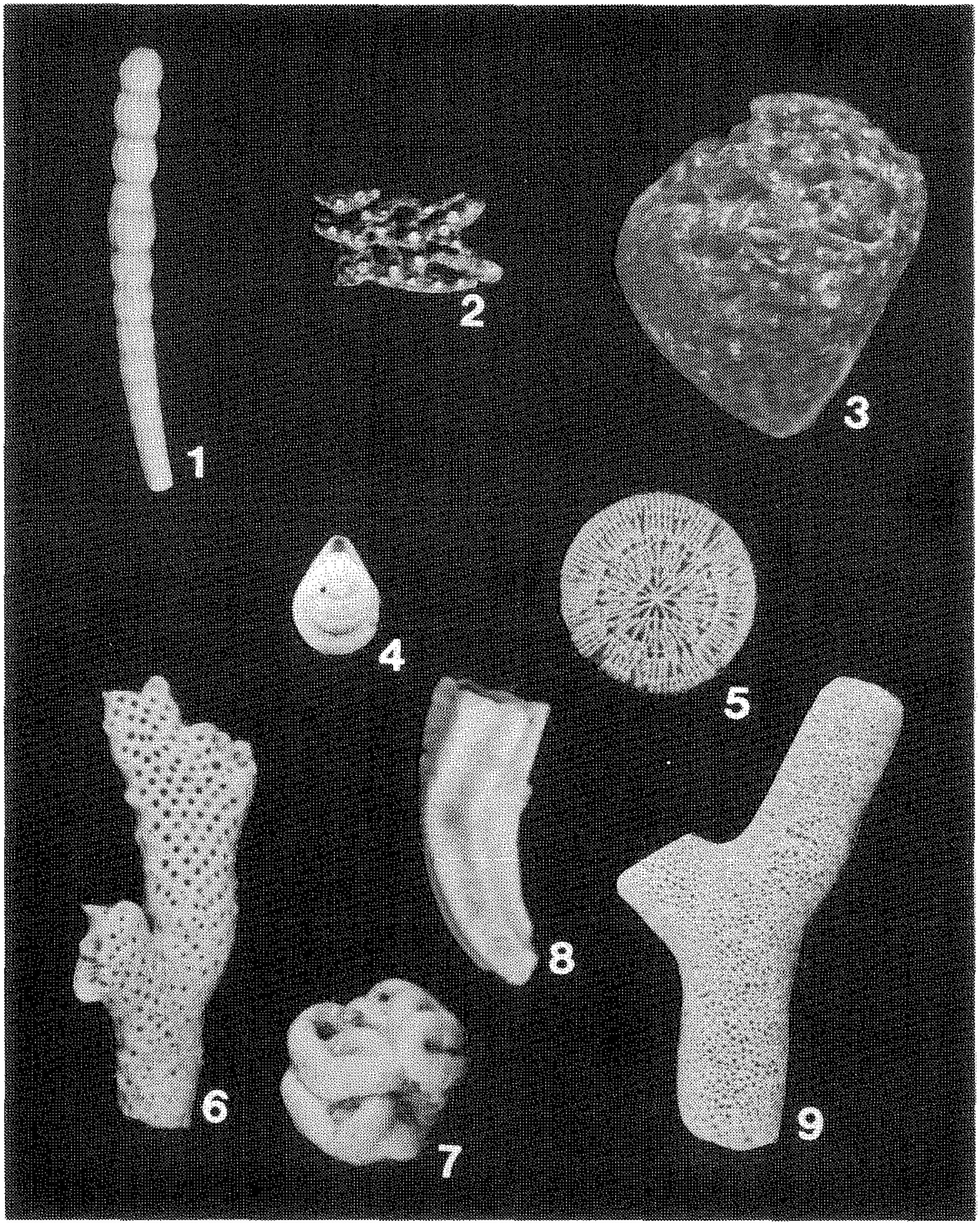

1
2
3
4
5
6
7
8
9

PLATE 2

1. *Exogyra cancellata* Stephenson, exterior view of left valve, 130 mm H, Kml.

2. *Exogyra cancellata* Stephenson, interior view of left valve, 55 mm H, Kml.

3. *Pyncnodonte mutabilis* Stephenson, exterior view of left valve, 113 mm H, Kml.

4. *Pyncnodonte mutabilis* Stephenson, exterior view of right valve, 113 mm H, Kml.

5. *Ostrea (Lopha) falcata* Morton, exterior view of left valve, 35 mm H, Kml.

6. *Ostrea (Lopha) falcata* Morton, interior view of right valve, 35 mm H, Kml.

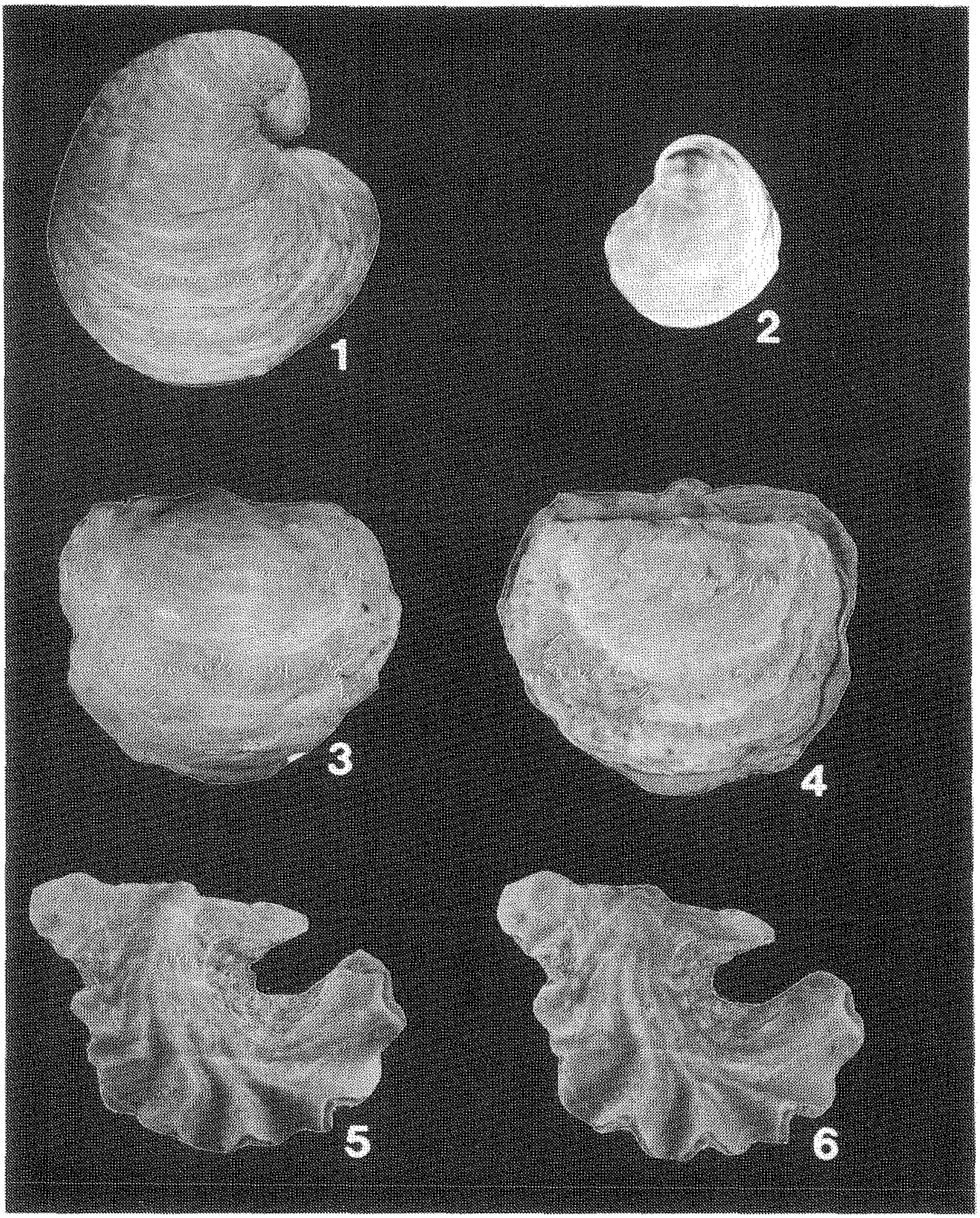

1
2
3
4
5
6

PLATE 3

1. *Neithea quinquecostata* (Sowerby), exterior view of right valve, 21 mm H, Kml.

2. *Trigonia* sp., view of left side of internal cast, 17 mm H, Kml.

3. *Anomia* sp., exterior view of right valve, 28 mm H, Kml.

4. *Liopistha protexta* (Conrad), internal cast, 22 mm H, Kml.

5. *Cardium* sp., view of left side of internal cast, 14 mm H, Kml.

6. *Cardium* sp., internal cast of both valves, 14 mm H, Kml.

7. *Clavagella armata* Morton, view of left side of internal cast, 14 mm H, Kml.

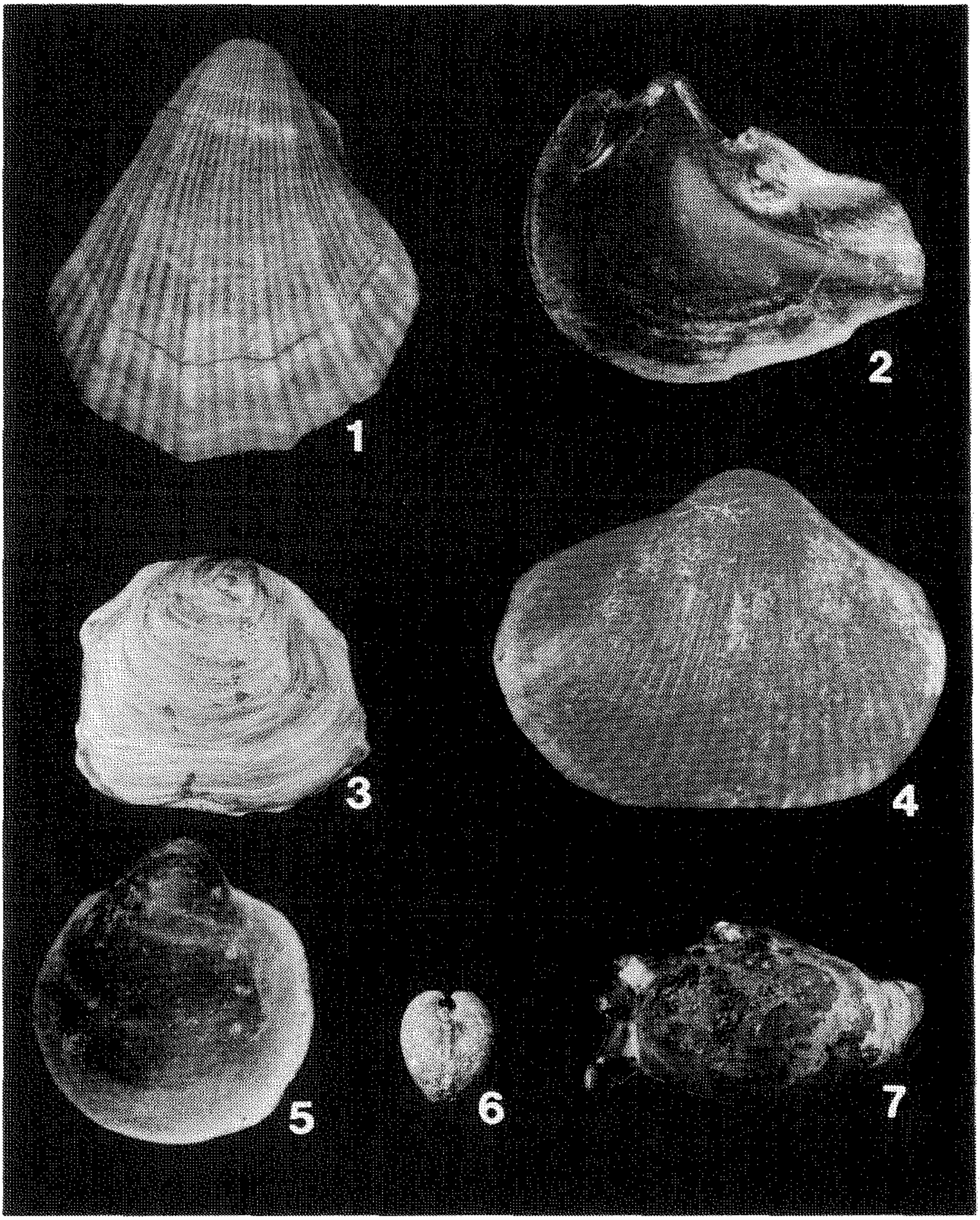

1
2
3
4
5
6
7

PLATE 4

1. *Anomia* sp., interior view of one valve, 21 mm H, Kml.

2. *Nemodon grandis sohli* Richards and Shapiro, view of left side of internal cast, 21 mm H, Kml.

3. *Gryphaeostrea vomer* (Morton), exterior view of left valve, 10 mm H, Kml.

4. *Gryphaeostrea vomer* (Morton), exterior view of right valve, 12 mm V, Kml.

5. *Nemodon grandis sohli* Richards and Shapiro, exterior view of shell, 13 mm H, Kml.

6. *Lima reticulata* Lyell and Forbes, exterior view of right valve, 12 mm H, Kml.

7. *Nuculana pittensis* (Stephenson), view of right side of internal cast, 16 mm H, Kml.

8. *Cucullaea* sp., internal cast , 42 mm H, Kmt.

9. *Cucullaea* sp., view showing both valves of same specimen as no.8, Kmt.

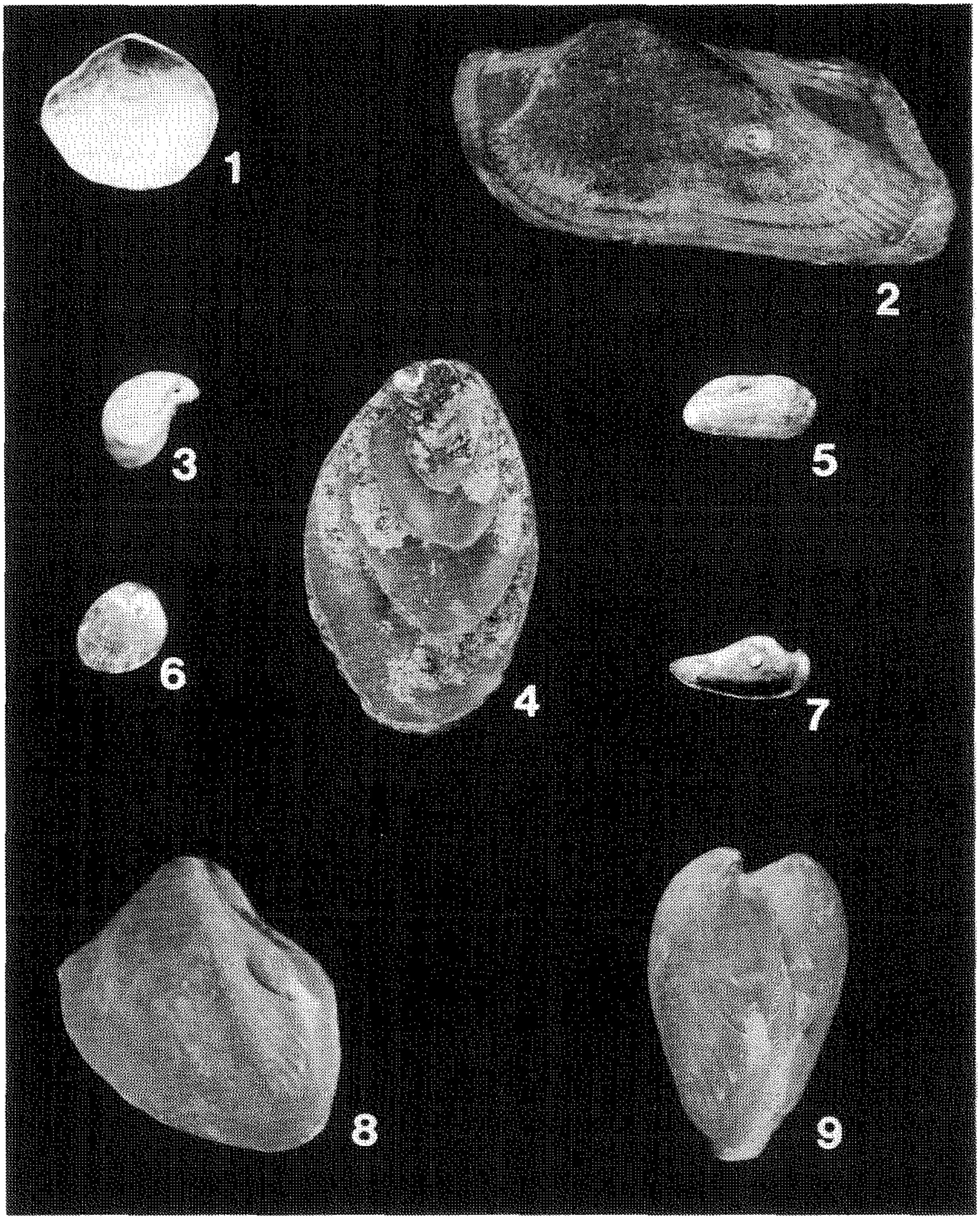

1
2
3
4
5
6
7
8
9

PLATE 5

1. *Turritella* sp., side view of internal cast, 44 mm V, Kmt.
2. *Gyrodes* sp., top view of internal cast, 18 mm H, Kml.
3. *Gyrodes spillmani* Gabb, top view of internal cast, 58 mm H, Kmv.
4. *Architectonica voragiformis* Stephenson, top view of internal cast, 12 mm H, Kml.
5. *Architectonica voragiformis* Stephenson, bottom view of internal cast, 12 mm H, Kml.
6. *Haustator trilira* (Conrad), side view of partial internal cast, 8 mm V, Kml.
7. *Margaritella pumila* Stephenson, top view of internal cast, 9 mm H, Kml.
8. *Margaritella pumila* Stephenson, bottom view of internal cast, 9 mm H, Kml.
9. *Eoacteon percultus* Sohl, side view of internal cast, 16 mm V, Kml.
10. *Eoacteon* sp., side view of internal cast, 20 mm V, Kml.
11. *Cylichna secalina* Shumard, front view of internal cast, 12 mm V, Kml.
12. *Cylichna secalina* Shumard, rear view of internal cast, 12 mm V, Kml.
13. *Laxispira* sp., side view of partial internal cast, 14 mm V, Kml.
14. *Calliomphalus* sp., side view of internal cast, 9 mm V, Kml.
15. *Calliomphalus* sp., top view of the internal cast, same specimen as no. 14, 7 mm H, Kml.

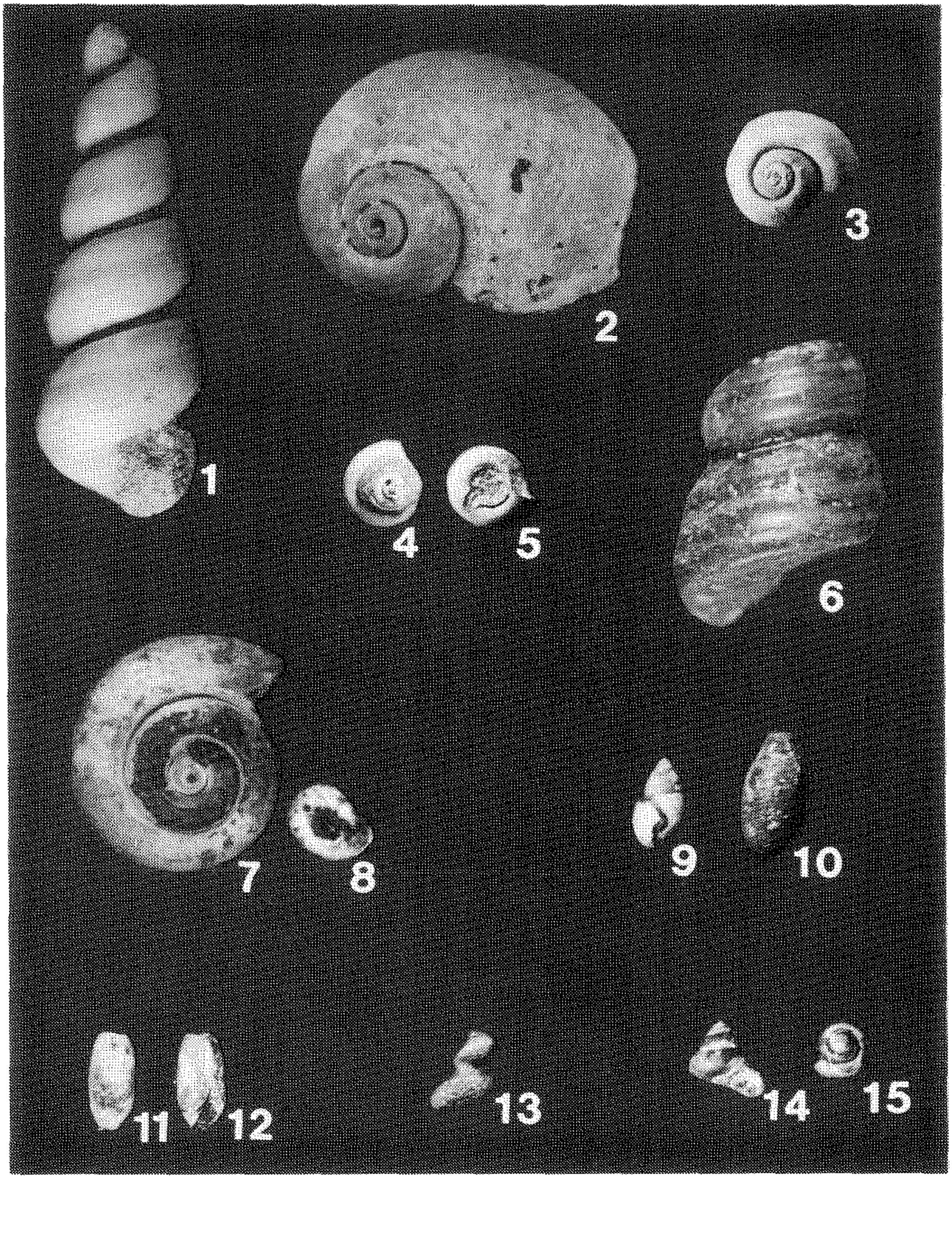

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

PLATE 6

1. Placenticeras placenta (DeKay), side view of internal cast, 74 mm H, Kmv.

2. Menabites (Delawarella) delawarensis (Morton), side view of internal cast, 85 mm H, Kmv.

3. Oxybeloceras sp., side view of internal cast, 24 mm H, Kml.

4. Baculites ovatus Say, side view of internal cast, 25 mm V, Kml.

5. Baculites ovatus Say, side view of internal cast, 40 mm V, Kmv.

6. Belemnitella americana (Morton), side view, 80 mm H, Kml.

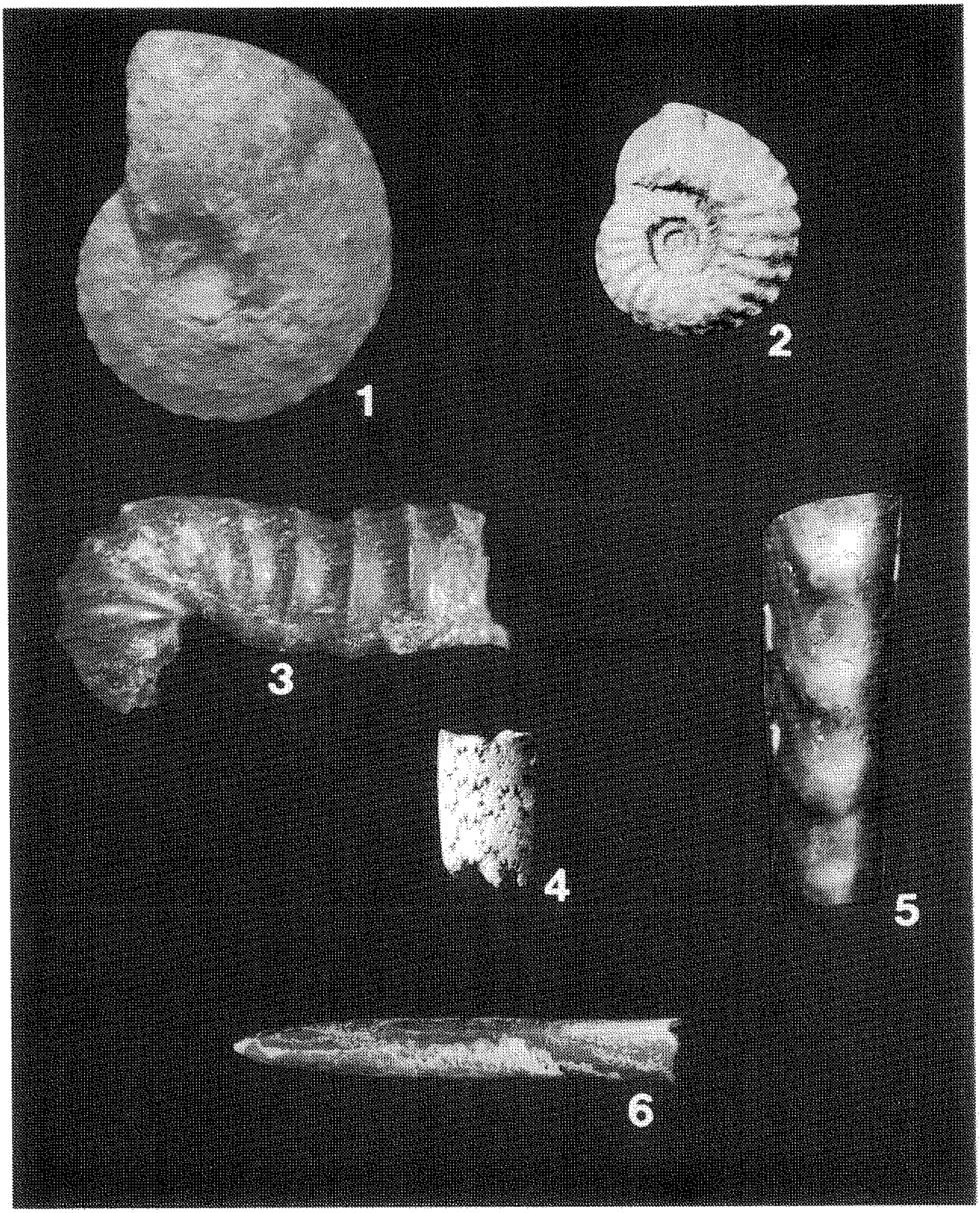

1
2
3
4
5
6

PLATE 7

1. *Hemiaster delawarensis* Clark, top view, 25 mm H, Kml.

2. *Hemiaster delawarensis* Clark, bottom view, 25 mm H, Kml.

3. *Catopygus williamsi* Clark, top view, 17 mm H, Kml.

4. *Catopygus williamsi* Clark, bottom view, 17 mm H, Kml.

5. *Phymosoma* sp., top view, 15 mm H, Kml.

6. *Phymosoma* sp., bottom view, 15 mm H, Kml.

7. *Dunnicrinus* sp., top views of isolated crinoid sections, each specimen is about 3 mm in diameter, Kml.

8. *Boletechinus* sp., top view, 6 mm H, Kml?.

9. *Boletechinus* sp., bottom view, 6 mm H, Kml?.

10. *Callianassa mortoni* Pilsbry, side view of a near complete carapace with legs and claw, 54 mm H, Kmv.

11. *Hoploparia gabbi* Pilsbry, side view of a near complete individual, 100 mm H, Kmv.

12. *Callianassa mortoni* Pilsbry, isolated major claw, 50 mm H, Kmv.

13. *Ophiomorpha nodosa* Lundgren, side view of an isolated burrow of a ghost shrimp, 110 mm V, Kmt.

14. *Ophiomorpha nodosa* Lundgren, side view of an isolated burrow of a ghost shrimp plus a discarded appendage, 122 mm V, Kmv.

15. *Tetracarcinus subquadratus* Weller, top view of an internal mold of a carapace of a crab, 14 mm H, Kmv.

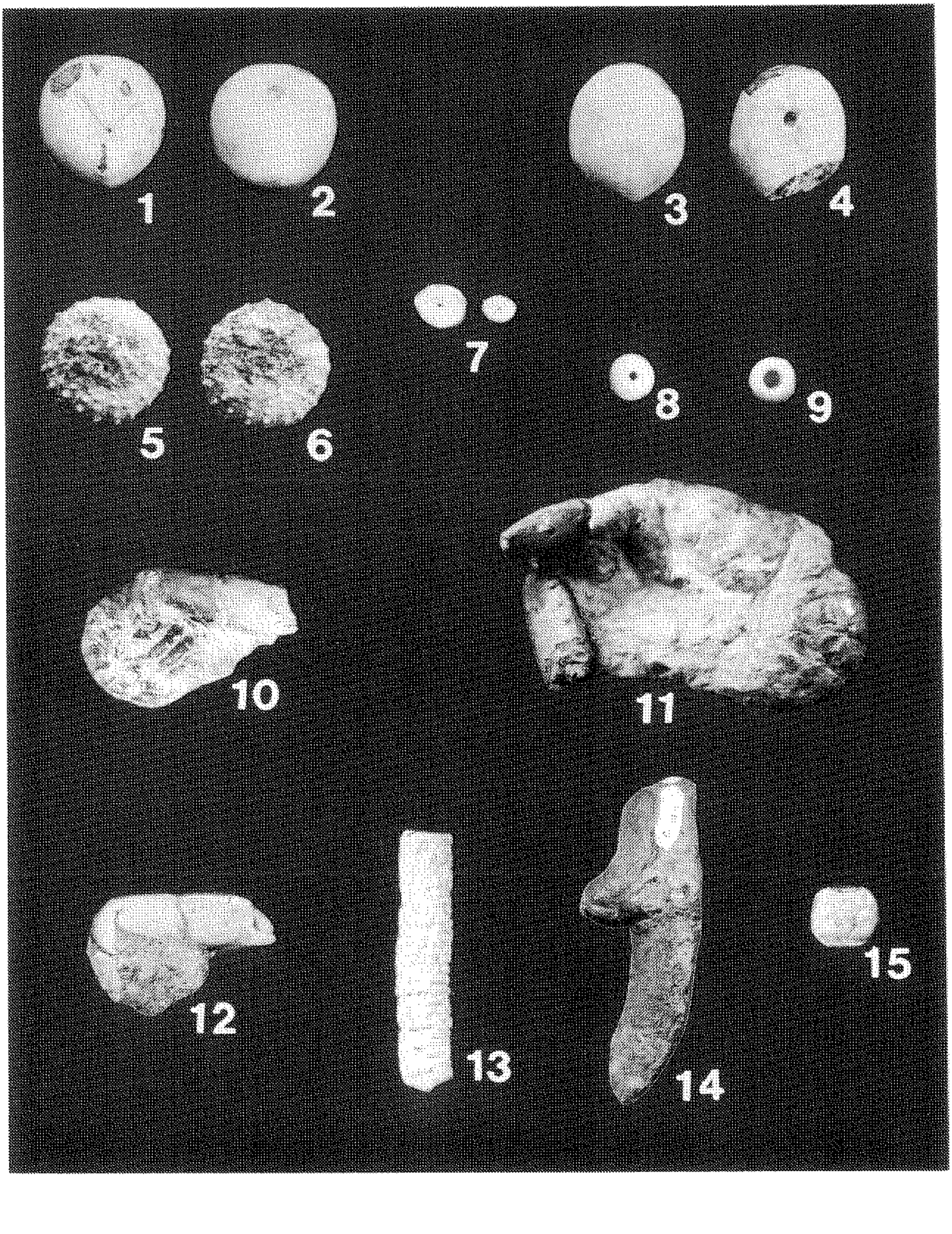

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

PLATE 8

1. Turtle shell fragment from the plaston, 85 mm H, Kmv.

2. Trionyx sp., middle scute from the carapace of a soft shelled turtle, 30 mm H, Kmv.

3. Mosasaur teeth, isolated teeth from a sea-going reptile, each tooth is 30 mm V, Kml.

4. Anomoeodus phaseolus (Hay), complete lower jaw section of a bony fish, 52 mm H, Kmt.

5. Enchodus ferox Leidy, side view of an isolated tooth, 32 mm V, Kml.

6. Teleost fish vertebra, axial view of an isolated vertebra from a bony fish, 8 mm H, Kml.

7. Teleost fish vertebra, side view of an isolated vertebra from a bony fish, 21 mm H, Kml.

8. Batoid vertebra, axial view of an isolated vertebra from a ray, 34 mm H, Kmt.

9. Shark vertebra, axial view of an isolated vertebra from a shark, 35 mm H, Kmv.

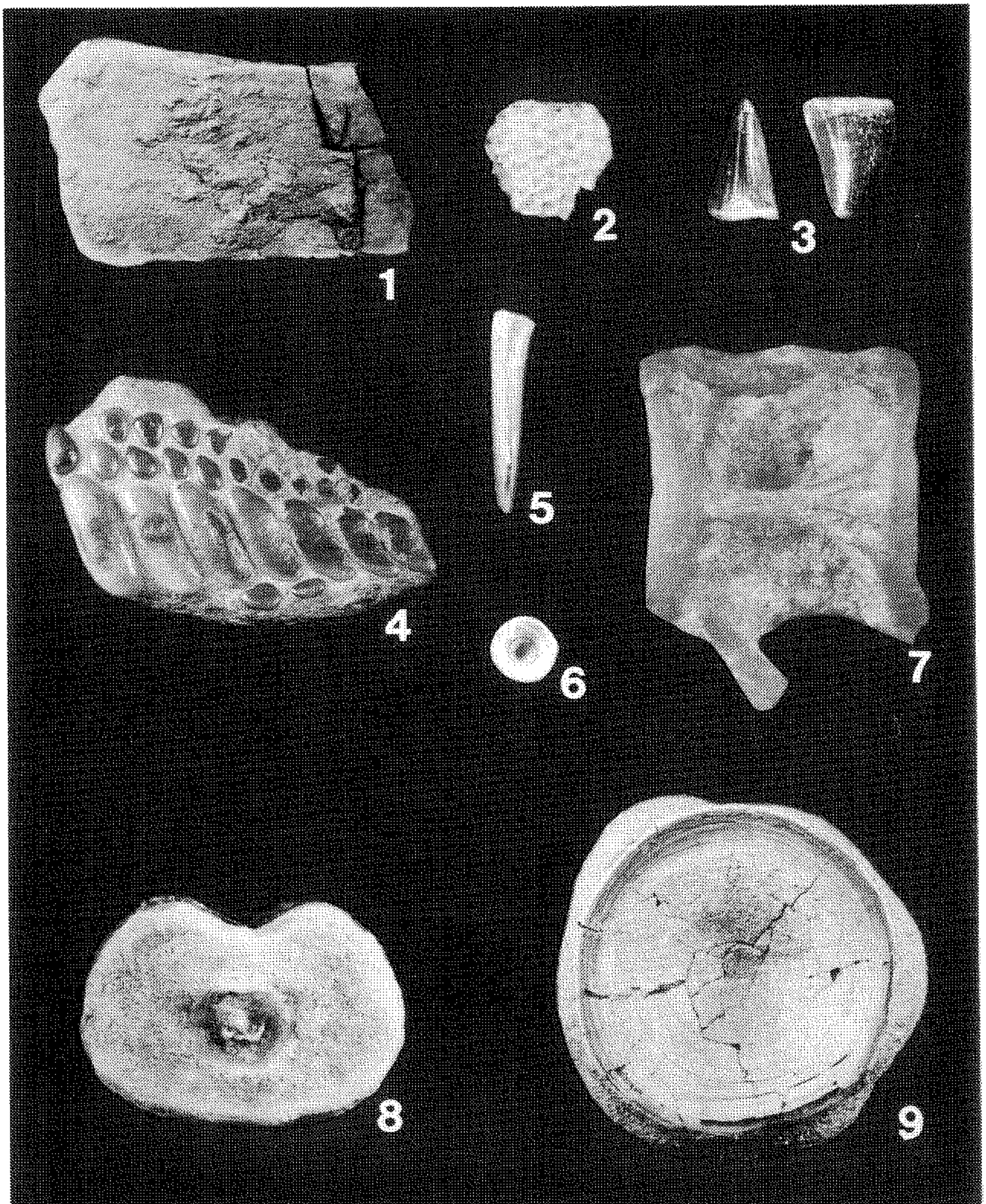

1
2
3
4
5
6
7
8
9

PLATE 9

1. *Scapanorhynchus texanus* (Roemer), front view of an anterior tooth, 31 mm V, Kmt.

2. *Scapanorhynchus texanus* (Roemer), rear view of a lateral tooth, 25 mm V, Kmt.

3. *Scapanorhynchus texanus* (Roemer), front view of a lateral tooth, 25 mm V, Kmt.

4. *Squalicorax kaupi* (Agassiz), rear view of a typical tooth, 16 mm H, Kmt.

5. *Squalicorax pristodontus* (Agassiz), front view of a typical tooth, 27 mm H, Kmt.

6. *Squalicorax pristodontus* (Agassiz), rear view of a typical tooth, 27 mm H, Kmt.

7. *Odontaspis* sp., front view of an anterior tooth, 13 mm V, Kmt.

8. *Odontaspis* sp., front view of a lateral tooth, 15 mm V, Kmt.

9. *Ischyrhiza mira* Leidy, side view of an isolated rostral spine from a sawfish, specimen is 38 mm in length, Kmv.