A Field Guide to the Fossils of Scientists' Cliffs

A brief introduction to the geological history of the area,
with descriptions of the common (and not so common) fossils found here.

July 2004

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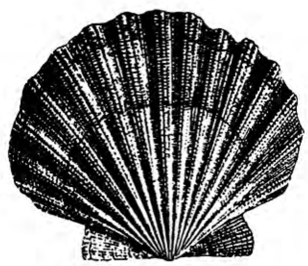

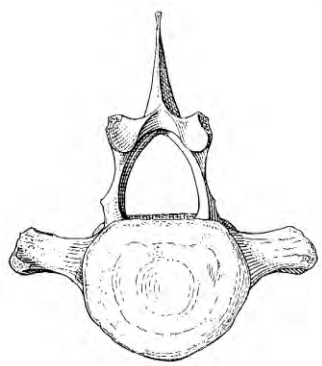
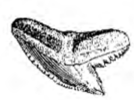


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October 2002

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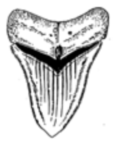
1. Introduction

The fossils of Southern Maryland are world famous. Virtually every natural history museum



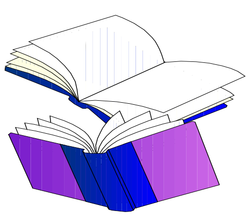
worthy of that designation anywhere on earth has in its collection, fossil specimens from the Calvert Cliffs (see Figure 1). The sediments beneath and around Southern Maryland (Scientists' Cliffs in particular) are filled with an extraordinary variety and abundance of fossils. Moreover, erosion over the last few thousand years has left this material magnificently exposed. For over three centuries, amateur fossil collectors and professional geologists have been able to find and collect fossils in and around the Calvert Cliffs of Maryland. Scientists' Cliffs reputation for producing museum quality specimens is unrivaled in the region.

1.1 Background

Fossils are evidence of ancient life preserved in the earth's crust. During the middle of the Miocene epoch, 10 to 20 million years ago, a shallow ocean covered Southern Maryland. At times the sea spread as far west as the present site of Washington, D.C. Rivers flowing from the Appalachian Mountains to the Miocene sea carried the mud and sand, which built up layers of sediments now exposed in the cliffs along the western shore of the Chesapeake Bay. Over the centuries, shells and bones of dead animals, buried in sand and mud under the sea, built up layer upon layer of fossil deposits. Later the seas receded and the area was exposed, largely as a result of the lowering of the sea level.

As present-day rain and waves erode the Calvert Cliffs, new fossils are exposed daily. The vast majority of these fossils are the shells of clams and snail species that lived in this warm, shallow ocean. A variety of shark and stingray teeth are also fairly common. Sometimes the remains of fish, turtles, crocodiles, oceanic birds, extinct whales, long snouted dolphins, seals, and sea cows are also discovered. Since the sediments were accumulating in a marine environment, the remains of land animals are much less common. Nevertheless, occasionally parts of Miocene peccaries, camels, horses, elephants, and rhinos among others, are found.

Formal study of the fossils of Calvert County began early in the 19th century, culminating with



the publication by the Maryland Geological Survey of the Maryland Miocene report in 1904. This report summarized the stratigraphy of the cliffs, and described and illustrated all the fossils then known from this area. Although written many years ago, it is still the standard reference for these fossil remains.

1.2 Objectives

This field guide aims to aid the collector in the collection, identification, and enjoyment of the fossils found in and around Calvert County. This guide attempts to describe both the fossils found and the organisms from which they came through text and drawings, and to suggest techniques for finding, preparing, and labeling the fossils.

1.3 Scope

To keep this guide from becoming overwhelming, the scope has been limited to the Miocene fossils found on the beaches of Calvert County, Maryland. The fossil location section briefly describes a few locations outside this geographic boundary, but the specimens to be found there are similar in nature and in age.

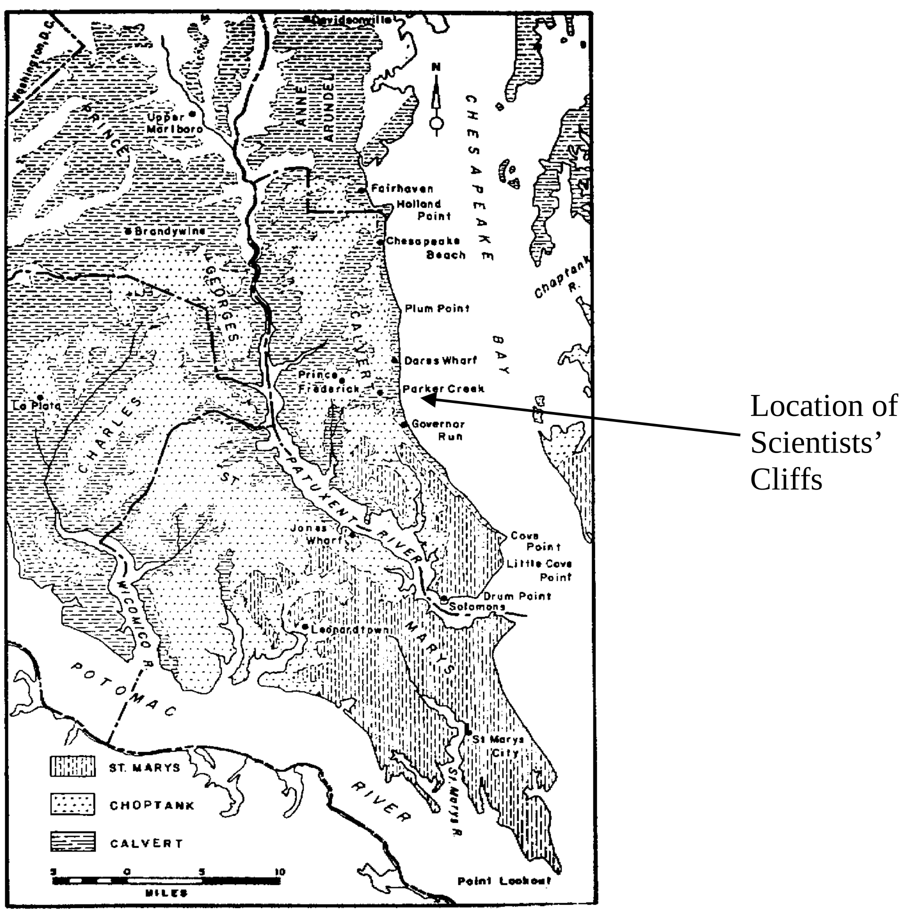


Figure 1. Southern Maryland Geologic Map

1.4 Assumptions

Description of a collecting site in this document does not constitute permission to collect without authorization; this is considered trespassing. Always check with the property owners (or manager in the case of parks) regarding specific regulations and courtesies that need to be followed. Please, under no conditions, should you dig in the cliffs without expressed permission (and then only with good health or life insurance).

1.5 Applicable Documents

The following documents were instrumental in the preparation of this field guide. I highly recommend these to collectors as they provide a basis for gathering further information and knowledge.

- Ashby, W.L., 1995, 3rd ed. Fossils of Calvert Cliffs. Calvert Marine Museum Press.
- Burns, J., 1991. Fossil Collecting in the Mid-Atlantic States. John Hopkins University Press
- Clark, W.B., G.B. Shattuck, and W.H. Dall, editors, 1904. The Miocene Deposits of Maryland. Maryland Geological Survey, Miocene. Two volumes- text, 543 pp., and plates, 129 pp. Reprinted 1970.
- Glaser, J.D., 1979. Collecting Fossils in Maryland. Maryland Geological Survey Educational Series No. 4. Revised 1995.
- Gernant, R.E., T.G. Gibson, and F.C. Whitmore, Jr., 1971. Environmental History of Maryland Miocene. Maryland Geological Survey. Guidebook No. 3, 58 pp. Reprinted 1977
- Kent, B.W., 1994. Fossil Sharks of the Chesapeake Bay Region. Egan Rees and Boyer, Inc.
- Vokes, H.E., 1957. Miocene Fossils of Maryland. Maryland Geological Survey, Bulletin 20, 85 pp. Reprinted 1987.

1.6 Document Organization

This guide is divided into the following sections:

- Section 1 is an introduction; defining the objectives, scope, and background of the document.
- Section 2 describes the geology of Calvert County, now and during the Miocene Epoch.
- Section 3 describes the fossils found in the area.
- Section 4 discusses strategies for successful collecting

- Section 5 defines the needs for labels and approaches to accomplish it.

- The Appendices contain detailed drawings of many of the fossils found in the area to assist in specimen identification.

2. Geology

It is easy to dismiss fossils as curiosities or as merely the basis of an arcane science, but the study of fossils produces a vast body of knowledge that has both direct and indirect economic value, in addition to biological, evolutionary, and historical value. The sediments of the world were laid down; one atop the other, in grand sequences called systems, which may be found throughout the world. Whereas systems can be constructed for a particular area or region, it is difficult to correlate the layers from one locality to another without knowledge of their fossil content.

2.1 Naming Rock/Soil Units

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

- One basis was time. The body of rock (or sediment) deposited during the Tertiary Period is called the Tertiary System.

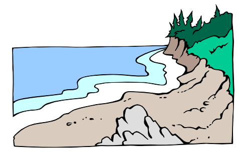
- Another basis for subdividing and naming bodies rocks (or soil) is lithology -- the composition, size, shape, and arrangement of the particles which make up the rock. The basic lithostratigraphic unit ("lith-" means "rock") is the formation. Similar or related formations may be joined to comprise a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

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

Today it is customary to name lithostratagraphic units after some geographic locality or feature (our formations here are called the Calvert, Choptank, and St. Mary's). It is also the rule nowadays to name biostragraphic units after the fossils which characterize them. Unfortunately, the standard practices of today were not so standard in years past. Hence, in former times, geologists studying the rocks and fossils in many parts of the world, including the Calvert Cliffs, sometimes delimited the so-called formations and members on the basis of their fossil content.

2.2 Calvert Cliffs' Geologic Structure

Calvert Cliffs extend for 26.3 miles from Fairhaven south to Drum Point, rising in some places to a height of more than 100 feet. They form the most complete sequence of marine Miocene sediments on the East Coast of North America. The Miocene deposits (Figure 2) of the Mid-Atlantic coastal plain are part of the Chesapeake Group and are composed of clay, sandy clay, sand, marl and diatomaceous earth. On the western shore of the Chesapeake Bay, the Chesapeake Group is found in Anne Arundel, Calvert and southern St. Mary's counties, but is seldom seen on the surface. Good exposures, however, are found along the Bay shore, the Patuxent River and its tributaries, and in the banks of the St. Mary's River. The most extensive exposure is found in the cliffs in Calvert County bordering the bay shore from Chesapeake Beach to Drum Point.



The Chesapeake Group in Southern Maryland comprises three formations, which signify major intervals of the lowering and rising of the sea level and which are designated, beginning with the oldest, as the Calvert Formation, followed by the Choptank formation and the St. Mary's formation (Figure 3). There are certain faunal differences which separate the three formations. At Scientists' Cliffs, we have exposures of Calvert and Choptank formation materials. The St. Mary's Formation is not exposed here, and does not tend to surface until further south in Calvert County.

The lowest formation, the Calvert Formation, named from Calvert County, reaches the surface in a belt 20 to 30 miles long extending across the state from northeast to southwest. Beginning in southern Kent County near the Delaware line, it crosses Queen Anne's and the northern portions of Caroline and Talbot Counties. On the Western Shore it forms much of northern Calvert and St. Mary's Counties, most of Charles County, and the southern parts of Prince George's and Anne Arundel Counties. The most westerly exposure is probably that of Good Hope Hill in the District of Columbia. The formation crops out in stream valleys and ravines, but in the inter-stream areas it is usually covered with a thin veneer of terrace deposits.

The lower part of the Calvert Formation is known as the Fairhaven member and is composed of fine sand, clay, and diatomaceous earth that is an accumulation of microscopically small tests (shells) of diatoms -- aquatic plants that form pillbox like coverings of silica. The lower twenty feet of the member is composed almost wholly of diatoms and is light gray to white in color. This was formerly mined for use in filters and cleansers. The upper beds contain a mixture of clay and diatoms, too impure to have been of commercial value. The overall thickness of the Fairhaven Member in the Calvert Cliffs is about 60 feet.

Overlying the Fairhaven Member is a series of dark sandy clays, some beds of which are crowded with fossils. Foraminifera and Mollusca are most abundant, but shark teeth, whale bones and other vertebrate remains are not rare. This member, known as the Plum Point Marl, has a thickness of about 135 feet in the Calvert Cliffs.

The Choptank Formation overlies the Calvert and is easily distinguished from it by its yellowish sands that contrast sharply with the dark gray clays, silt, and sand of the lower formation. Although the Choptank is named for its exposures on the Choptank River on the Eastern Shore, the formation is best known from the Calvert Cliffs, where its abundantly fossiliferous exposures have been the goal of innumerable collecting trips by amateur and professional geologists. The Choptank reaches the surface in a belt about twenty miles wide immediately to the southeast of that formed by the Calvert formation. In general, the formation is buried under younger deposits and few exposures are found on the Eastern Shore. The formation dips to the southeast at about ten feet to the mile. The thickness of the Choptank formation ranges from about 50 feet to nearly 100 feet.

The St. Mary's Formation takes its name from St. Mary's County where it is well developed, especially along the St. Mary's River in the vicinity of St. Mary's City. It crosses Maryland from northeast to southwest in a belt immediately to the southeast of the Choptank Formation. On the Eastern Shore it is buried beneath a mantle of later deposits and no outcrops are known; on the Western Shore it crops out only in Calvert and St. Mary's Counties. It is excellently exposed at Little Cove Point at the south end of the Calvert Cliffs. Here the beds are composed of bluish sandy clays, silts, and fine sands that are abundantly fossiliferous, especially in gastropods. The formation dips seaward at ten feet to the mile.

Era	Period	Epoch	Beginning of Interval (Millions of Yrs. ago)	Important Events
Cenozoic (2%)	Quaternary	Recent	.01	Modern man spreads worldwide
		Pleistocene	1.5 - 2	Many mammals vanish
	Tertiary	Pliocene	5	Oldest-known hominids
		Miocene	22 - 23	Mammals reach their maximum diversity Grasslands - grazing mammals
		Oligocene	37 - 38	
		Eocene	53 - 54	Modern types of flowering plants appear
		Paleocene	65	Spread and diversification of mammals
Mesozoic (4%)	Cretaceous		136	Dinosaurs and many other organisms become extinct Peak of dinosaur diversity Flowering plants appear
	Jurassic		195+	First birds. Dinosaurs increasingly abundant
	Triassic		225	First dinosaurs, first mammals Abundant cycads and conifers
Paleozoic (10%)	Permian		280	Extinction of many animals
	Carboniferous	Pennsylvanian*		First reptiles. Great coal forests, first conifers, first cycads
		Mississippian*	345	
	Devonian		395	First amphibians First insects (?) Fishes abundant
	Silurian		435	First land life (plants and invertebrates)
	Ordovician		500	First tabulate and rugose corals First bryozoa
	Cambrian		570	First abundant record of marine life: trilobites common, first vertebrates
Precambrian (approximately 84% of the history of life)				First living things - perhaps 3.5 billion years ago

Figure 2. Geologic Time Table

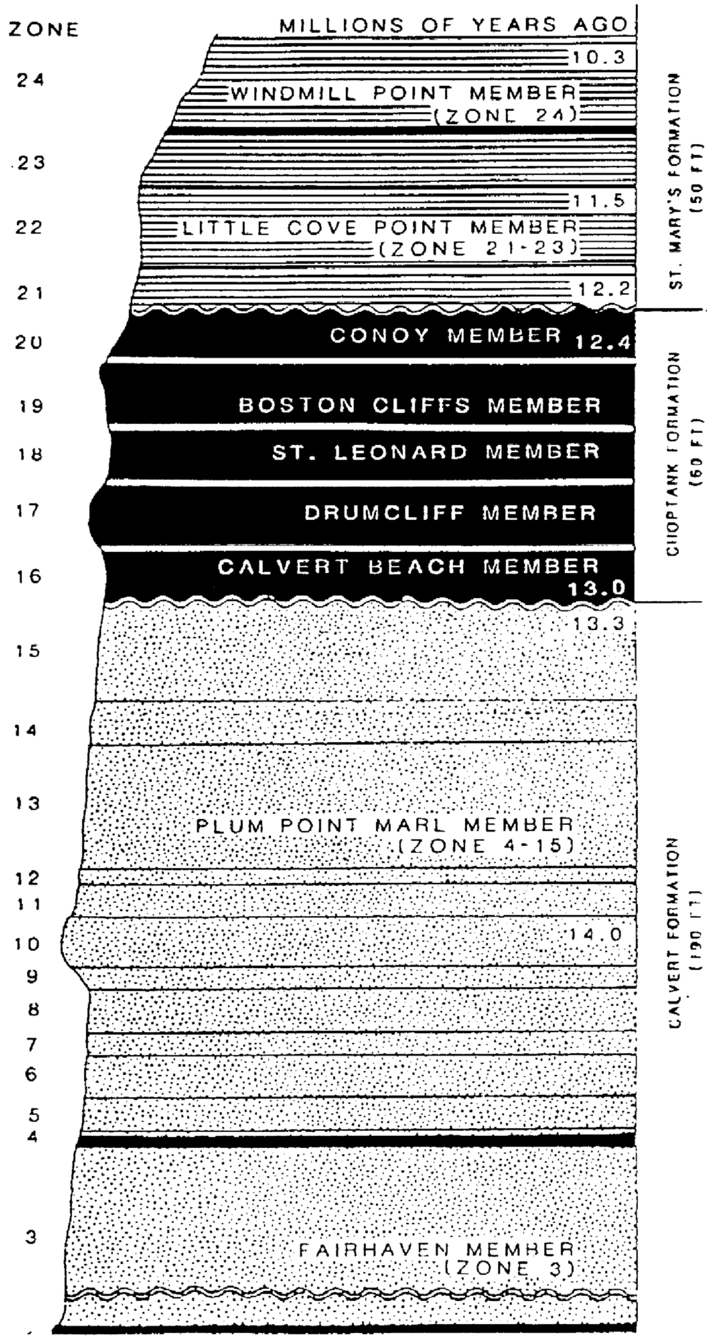


Figure 3. Generalized Composite Section Through Calvert Cliffs

2.3 Stratigraphy

To assist in identification, Shattuck (author of the Maryland Geological Survey's book on the Maryland Miocene) subdivided the formations in 1904 into "zones," which are really geologic units or beds. To aid the amateur collector, the beds that are present at Scientists' Cliffs are describe below in very brief fashion, along with a short list of "typical" fossils to be found in each bed.

2.3.1 Calvert Formation

The Plum Point Marl Member occupies the remainder of the Calvert Formation above the Fairhaven Member. Plum Point in Calvert County where the beds are typically developed, is the source for the name of this member, which consists of a series of sandy-clays and marls in which are imbedded large numbers of organic remains. The color of the material is bluish-green to grayish-brown and buff. Fossil remains, although abundant throughout the entire member, are particularly numerous in two prominent beds which in section are 30 to 35 feet apart. These beds vary in thickness from 4 1/2 feet to 13 feet. They may be traced along the Calvert Cliffs from Chesapeake Beach to a point 2 miles south of Governor's Run.

Bed 11: This layer consists of a greenish-blue to a brown sandy clay changing locally to a sand. It is exposed in the bluffs at Chesapeake Beach south to the cliffs immediately south of Parker's Creek. It is unfossiliferous or carries a few imperfect fossil casts.

Bed 12: This bed usually consists of a brownish sandy clay, although at times it changes to a bluish color. While bed 12 contains a considerable number of poorly-preserved invertebrate fossils that are usually too soft to be collected, it has yielded more vertebrate fossils than any other layer. These include shark teeth, crocodile teeth, and whale and porpoise bones.

Bed 13: The material of this bed consists of a bluish sandy clay and is essentially unfossiliferous. When vertebrate fossils are found in this layer, however, they are often in remarkably good condition. Well-preserved articulated skeletons have come from this bed in recent years, including the most complete seal specimen known from the Maryland Miocene.

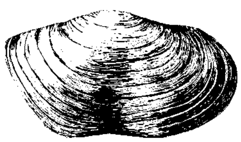
Bed 14: This layer is the upper richly-fossiliferous bed of the Calvert Formation. The materials which make up this stratum consist of a brownish to grayish sandy clay abundantly supplied with *Glossus marylandica* and other mollusks, and contain numerous vertebrate fossils. The layer varies in thickness from 2 to 7 feet.

Bed 15: This bed is the upper member of the Calvert Formation and consequently has been considerably eroded so that its true thickness is not definitely known. It is difficult, if not impossible, to distinguish beds 15 and 16 from each other. Shattuck may have been misled by the varying amounts of clay and yellow sand in the transitional strata between the Calvert and Choptank formations and, as a result, assigned the stratum at times to the top of the Calvert as bed 15 and at times to the base of the Choptank as bed 16.

2.3.2 Choptank Formation

Bed 16: This bed varies in composition from yellowish sand to bluish or greenish sandy clay. It is about 10 feet thick and may be found exposed from near Parker's Creek southward to a point a little north of Flag Ponds, where it disappears beneath the beach. Bed 16 is for the most part unfossiliferous, although within the Scientists Cliffs boundaries a few fossils have been found, including the rare *Echinocardium marylandiense* or heart urchin, as well as the barnacle, *Balanus concavus,* and the sand dollar, *Abertella aberti*.

Bed 17: This unit is the lower of two especially well-defined layers found in the Choptank formation. It is composed almost entirely of fossil invertebrates. Yellow sand fills the space between the stacked mollusks and other invertebrates. Among the extremely long list of invertebrates found in bed 17 are *Ecphora* sp., *Turritella plebia, Panopea americana, Bicorbula idonea, Glossus marylandica, Chesacardium laqueatum,* and *Dallarca elnia*. Vertebrate fossils are not as common here as they are in the Calvert Formation. Bed 17 initially appears near Parker's Creek, where it is about six feet in thickness, and is continuously exposed until it dips beneath the beach a little north of Flag Ponds.



Bed 18: This bed is for the most part unfossiliferous, although in places it carries some imperfect fossils and fossil casts. It is composed mostly of yellowish sand grading down to bluish clay. Its thickness varies from 18 to 22 feet, and it is continuously exposed from Parkers Creek to a point a few miles south of Flag Ponds.

Bed 19: This constitutes the upper of the two great fossiliferous layers of the Choptank Formation. Like bed 17 it is composed of closely-packed fossils with the gaps filled in with reddish and yellow sand. It varies in thickness from twelve to fifteen feet and is continuously exposed from near Parkers Creek southward to Cove Point, where the layer dips beneath the beach. The fossil list from this layer is very similar to that from Bed 17.

2.3.3 St. Mary's Formation

The St.Mary’s Formation lies unconformably on the Choptank Formation. Clays, loams, sands, and gravels belonging to various members of the Columbia Group overlie it. The St. Mary’s Formation is not exposed along the cliffs at Scientists’ Cliffs

2.4 Cross Sections of the Cliffs

Described below are two cross sections (stratigraphic columns) of the cliffs in areas near Scientists’ Cliffs in Calvert County. These should help collectors recognize the various formations and identify the origin of the fallen material at the base of the cliffs. In collecting fossils, it is very important to gather data on the formations from which the fossils came, as without this data the scientific value of the specimens is diminished. It is not possible to collect this data on specimens collected in the surf or washed up on the beach.

AGE	FORMATION	DESCRIPTION	THICKNESS (in feet)
Pleistocene			
		Reddish sandy loam	5
Miocene			
	Choptank Formation:		
		Reddish sand (Bed 20)	13
		Reddish sandy clay containing *Balanus concavus, Bicorbula idonea, Astarte sp., Dallarca elevata, Chesapecten nefrens.,* etc. (Bed 19)	19
		Yellowish sandy clay containing fossil casts (Bed 18)	18
		Yellow sand containing: *Ecphora* sp., *Turritella plebeia, Panopea americana, Dallarca elnia Chesapecten nefrens*, etc.(Bed 17)	5
		Yellowish sand (Bed 16)	13
	Calvert Formation:		
		Bluish clay (Bed 15)	4
		Brownish sandy clay containing *Glossus marylandica* (Bed 14)	4
		Bluish sandy clay (Bed 13)	1
Total			**75**

<u>Table 1. Cross section of the cliffs at Governor's Run</u>

AGE	FORMATION	DESCRIPTION	THICKNESS (in feet)
Pleistocene			
		Reddish sandy loam	2
Miocene			
	Choptank Formation:		
		Reddish sand (Bed 20)	2
		Reddish sandy clay containing *Balanus concavus*, *Bicorbula idonea*, *Astarte sp.*, *Dallarca elevata*, *Chesapecten nefrens.*, etc. (Bed 19)	14
		Yellowish sandy clay containing fossil casts (Bed 18)	20
		Yellow sand containing: *Ecphora* sp., *Turritella plebeia*, *Panopea americana*, *Dallarca elnia* *Chesapecten neferns*, etc.(Bed 17)	6
	Calvert Formation:		
		Bluish clay (Bed 15)	9
		Brownish sandy clay containing *Glossus marylandica* (Bed 14)	4
		Bluish sandy clay (Bed 13)	10.5
		Brownish sandy clay carrying *Ecphora* sp. (Bed 12)	1.5
		Bluish clay (Bed 11)	4
Total			**73**

Table 2. Cross section of the cliffs .5 miles south of Parker's Creek

3. Fossil Identification

There is no precise definition of a fossil. Generally, fossils are the remains of animals or plants, usually turned to stone, but this is not always the case (remains under 40 million years old are usually not yet completely replaced by rock forming minerals). Mammoths frozen in ice or insects trapped in amber are considered to be fossils, even though much of their original composition has not been altered. While bones, teeth, shells and wood are the most common types of fossils, pollen, excrement, tracks, and even eggs can also be fossilized**.** To keep life simple, let's define a fossil as any **evidence of previous life over 10,000 years old**.

Paleontologists (those who study fossils) decode the fossil record and infer how animals and plants lived in the ancient world. Usually, it is only the hard parts of an animal or plant that become fossilized. Only parts of a skeleton may be found, but a small part is often enough to make an identification of the animal. Fossils tell us more than what an extinct organism looked like. Analysis of teeth, claws, and even the contents of the gut (which are sometimes fossilized) can tell us what the animal ate. The association of different fossils in a single deposit allows scientists to partially reconstruct the past environment.

3.1 Vertebrate Fossils

Vertebrate fossils are common along the beaches at Scientists'Cliffs. Teeth and bones are composed largely of calcium phosphate, an extremely durable compound, which persists, unaltered over very long periods of time. Mineralized teeth and bones tend to be heavier and appear darker in color than their modern counterparts. Most commonly found are the teeth of sharks (Figure 4a); a great variety occur throughout the deposits. Associated with these are the plate-like dental pavements of rays, shark cousins that fed upon mollusks and used their flat mouth plates to crush the shells in order to get at the flesh (Figure 4b). These plates are usually broken and black in color. Other fish remains include vertebrae, large scales**,** and spines.

Carapaces of sea turtles are found, as are the teeth of the marine crocodile, *Thecachampsa antiqua*. The crocodile teeth can be recognized by their lack of a root-like structure, which the shark teeth have. They are usually round in cross section and have longitudinal striations. The remains of whales and porpoises are common. Isolated vertebrae are often found and may be recognized by their rather porous structure. The terminal disks (epiphyses) of the vertebrae are sometimes separated from the rest of the structure (centrum) in young animals and are commonly mistaken for other items by the amateur collector. Land mammal bones and teeth are occasionally found. Figure 5 shows some of the vertebrate fossils found at Scientists' Cliffs.

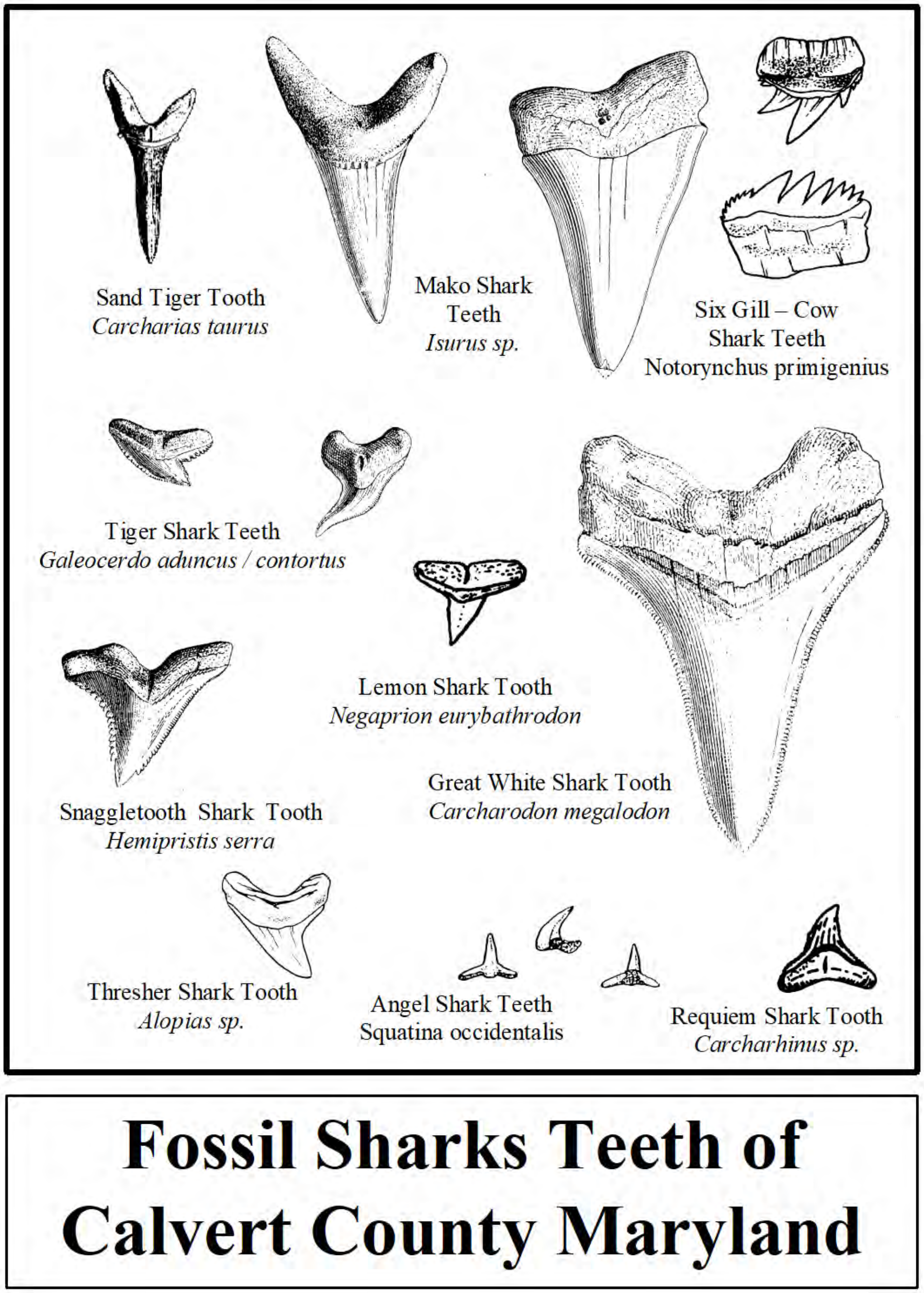


Figure 4a. Fossil Shark Teeth of Scientists' Cliffs

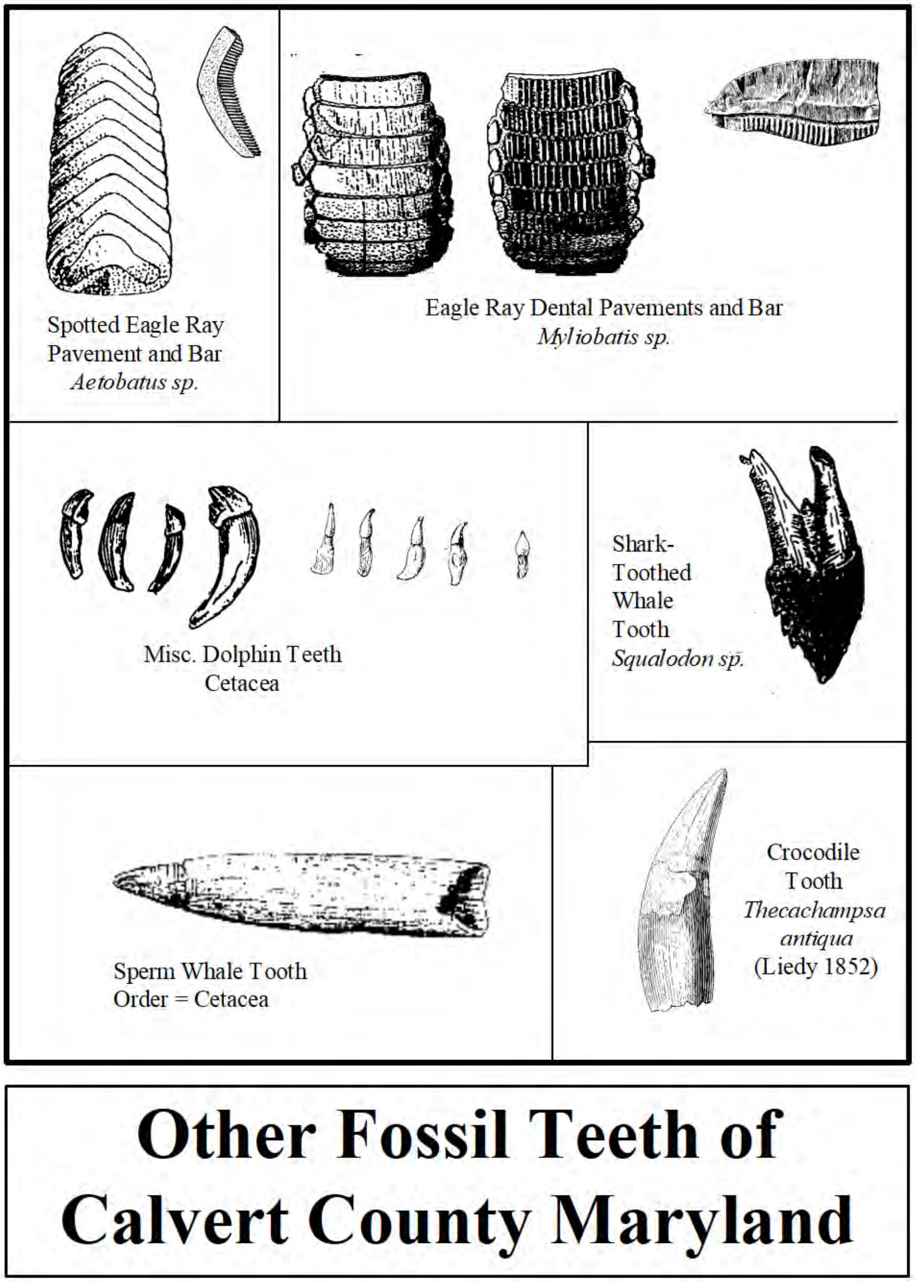


Figure 4b. Other Fossil Teeth of Scientists' Cliffs

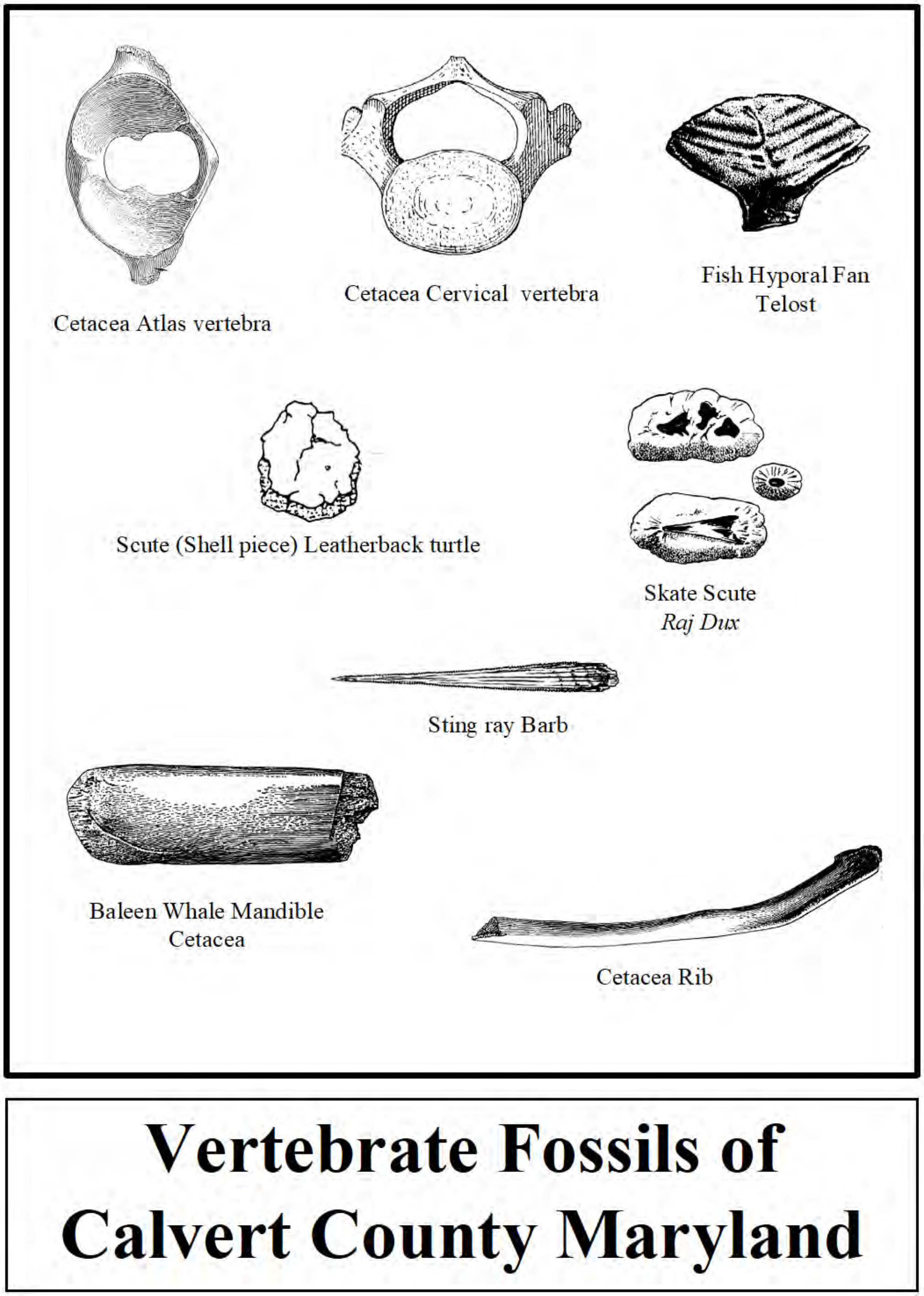
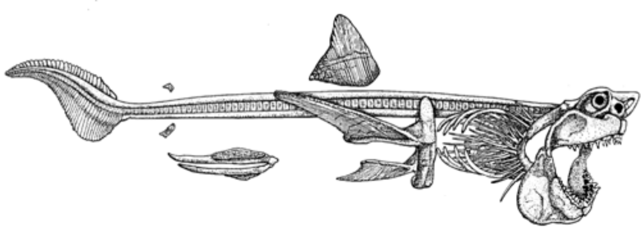


Figure 5. Common Vertebrate Fossils of Scientists' Cliffs

3.1.1 Sharks

Sharks have a long and rich fossil history preceding the Miocene epoch. There is fossil evidence of sharks back as far as the Silurian Period (~400 million years). Many different parts of the sharks potentially could become a fossil, though the fossil record is predominately populated with their teeth. There are two reasons for this fact. First, the process of fossilization favors hard material. Softer material tends to be less resistant to decay and thus less likely to be preserved. Shark teeth are made primarily of a material called dentine, which is extremely tough and is perfectly suited for the preservation process. With the exception of their teeth, other parts of the shark are only rarely fossilized (sharks skeletal systems are made of cartilage (like your nose and ears), not bone). Second, in a shark's lifetime it produces thousands of teeth. In order to keep the teeth sharp, a shark's mouth is in a process of constant change, discarding dull teeth and replacing them with sharp ones. A shark has numerous rows of teeth, with only the front row visible and ready for use. When a tooth is lost, the next one in line starts to move up and replace it. The older teeth eventually fall to the sea floor and are covered by sediment. At some point later in time, some of these teeth may fossilize. One scientific paper estimates that some sharks lose over 20 thousand teeth in their lifetime. Fossil shark teeth vary in color; they can be gray, blue, brown, tan, red and black. The color of a tooth is not determined by their age, but rather by the chemical conditions of the matrix around the buried fossil.

Children and first time collectors frequently ask, "Where are the shark bones?" The answer is easy. A shark has no bones, its skeleton being entirely cartilaginous. In addition to the shark's teeth, occasionally a collector can find other parts of the shark, including dermal denticles, vertebrae, coprolites, and pieces of internal cartilage. The skeleton contains in varying amounts a complex mixture of calcium phosphates and carbonates called apatite. The only skeletal elements of a shark that are commonly collected are the vertebral centra (vertebra). The



cylindrical or disk-like structure collectively forms the vertebral column, or backbone. Unfortunately, centra are rarely found associated with teeth and are consequently difficult to classify to genus or species. Apatite gives the flexible cartilage, particularly the vertebrae, the appearance and strength of bone. When a Miocene shark died, those parts of its abbreviated skeleton that contained only small amounts of apatite rapidly decomposed. Vertebrae, with their heavy concentration of the mineral, hay have survived long enough to fossilize.

The ends of a fossilized vertebra are concave, and the sides contain four large cavities -- two located on the top and two on the bottom of the centrum. These cavities in life contained soft, cartilaginous processes or appendages. Centra from the tail of the shark, where flexibility was needed for swimming, are relatively narrow, their sides being roughly half that of the diameter. Anterior centra are thicker, with sides being nearly equal to the diameter of the centrum. With a few exceptions, shark vertebra are classified as being either lamnoid or scyliorhinoid in form. The primitive lamnoid centra are characterized as having paired dorsal and ventral cavities, plus numerous long narrow slots ringing the sides of the centrum. These openings once held thin slivers of cartilage. The more highly developed scyliorhinoid vertebrae, while similar to the lamnoid, differ in having only the paired dorsal and ventral cavities.

While the comparatively fragile lamnoid centra of the sand, nurse, thresher, mackerel, mako, white, and whale sharks are relatively rare finds, the more sturdily built scyliorhinoid vertebra of the snaggletooth, requiem, tiger, lemon, and hammerhead sharks are more common.

Occasionally, isolated fragments of fossilized calcified cartilage are found, which resemble bone but have a less porous texture. This distinctive texture is due to large numbers of closely packed prismatic structures surrounded by one or more irregular layers of the mineral apatite. Dermal denticles form the protective covering of the shark's skin. These are rarely found due to their minute size. Fossils that record the activities of an animal, rather than actual body parts, are referred to as trace fossils. Examples of shark trace fossils include coprolites (feces) and bite marks on fossil bone.

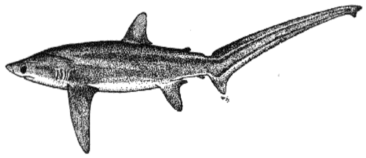
Originally thought to be fossilized fir cones, shark coprolites (petrified dung) were discovered to be of animal origin early in the nineteenth century by a certain Mr. Konig of the British Museum. He noted a most peculiar smell, unlike any to be found in the plant kingdom, when he applied hydrochloric acid to the fossil.

A Miocene shark, like its modern counterpart, possessed a primitive digestive system. Its intestine was a short, cigar-shaped tube. Had there not been located inside the tube a strange, twisted membrane called a spiral valve, food would have swept through it with little chance of digestive action. The spiral valve served to increase the area of absorptive tissue and to slow the passage of food through the hindgut. Composed of cellular tissue called epithelium, it assumed, with many variations, two basic shapes: a coiled cork-screw twist and a scroll-like roll. In more primitive sharks, like the sand and the spiny dogfish, it resembled a spiraling staircase or a series of elongated trumpets. The more complex mako and hammerhead have spiral valves possessing the rolls and folds or an antique scroll. Unabsorbed waste material passing through a spiral valve was molded to its particular form. When voided and eventually fossilized, a coprolite retained the characteristic bands and folds produced by its passage through the valvular intestine. An oval pellet deeply banded or grooved at one end is the product of a coiled valve, while the scroll-type valve produced a more elongated, rolled coprolite.

An enterospira is an internal cast of a valvular intestine. Rarely found, it is intriguing evidence of the morphological relationship that exists between fossil and modern-day sharks.

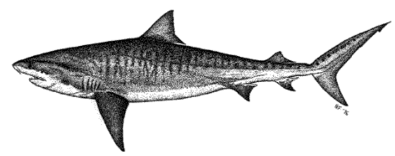
3.1.1.1 Thesher Sharks

Easily recognizable by its tail, which is about as long as its body, the modern thresher (*Alopias sp.*) occurs almost entirely in the open seas. Growing to lengths of 20 feet and weights of as much as 1,000 pounds, this species is found at or near the surface in the cooler ocean waters. Using its tail to herd and stun its prey, this shark feeds almost entirely on schooling fish. There are no indications that it is dangerous to man. The teeth of the thresher are relatively small for a fish its size. The fossil teeth tend to resemble those of a bull shark except that the thresher's teeth do not have any serrations.



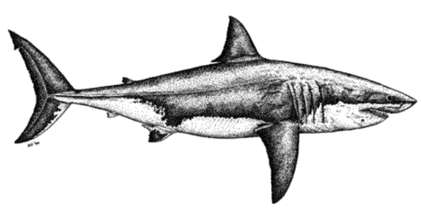
3.1.1.2 Tiger Sharks

This genus (*Galeocerdo*) is very common and should be anticipated in any Maryland Miocene deposit where small teeth are collected. They occur with a close relative, *Carcharhinus* and a somewhat less common but slightly larger form, *Hemipristis*.
The teeth vary quite a bit from one of the two species (*G. aduncus* & *G. contortus*) to the other. Serrations may be fine to fairly large, depending on the species, but there will always be serrations on the edges of these teeth. Cusps never occur on this shark's teeth. All types have a recurved tip that may be extreme in some teeth. The inner surface is smooth and convex in all types, while the outer surface is concave in some types and nearly flat in others. One species (*G. contortus*) has a twisted crown unlike any other shark tooth. Certain teeth exhibit serrations that do not extend all the way up the blade or are too tiny to notice readily.

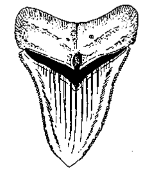


3.1.1.3 Giant White Shark

Carcharodon megalodon, the probable gigantic ancestor of the modern white shark (note!, several authorities dispute this lineage) , has left behind only its teeth and an occasional bobbin-like vertebra to prove that it once swam in the Miocene seas of Southern Maryland. The giant white shark is believed to have been the largest carnivorous fish to ever live in the sea. The name *Carcharodon megalodon* is formed by a combination of three Greek words meaning a great jagged or sharp pointed tooth. It is an apt name. Found on the beach or protruding from the sandy clay of Calvert Cliffs, a fossil *Carcharodon* tooth may weigh over three-quarters of a pound, and exceed six inches in length. The blade is triangular in shape and marked by striations. It is finely serrated on the cutting edges with some fifty serrations to the inch. The root is rough and stonelike. Color varies greatly, depending on the mineral composition of the deposit in which the tooth was embedded. The face of the blade is flat or slightly concave in appearance. The back has a curved or convex surface. It is marked between the root and the enamel by a dark brown or gray chevron or an inverted "V shaped" area.



By comparing living *Carcharodon* teeth to fossil teeth, it is possible to estimate the approximate length of the extinct shark. With this information and by plotting a known weight-length ratio of a large white shark, the probable size of the largest *Carcharodon megalodon* has been calculated at about Fifty-two feet and 23,000 pounds with a tail fifteen feet high. The pectoral fins would have stretched eight feet on either side of the body, and the dorsal fin would have extended over six feet above the animal's back. The largest great white tooth from this area is over six inches.

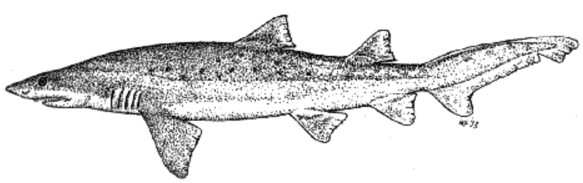


Carcharodon megalodon was never common in the Maryland Miocene. Its spectacular teeth have long been prizes sought by professional collectors and amateurs alike.

3.1.1.4 Sand Tiger Sharks

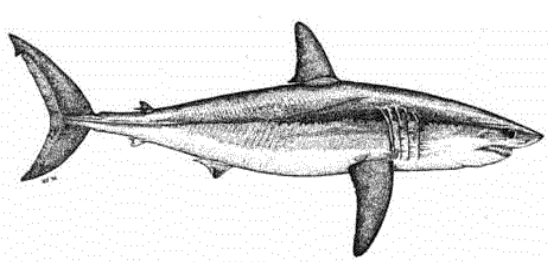
The sand tiger shark (or just sand shark) is often put into one of two genera, either *Carcharias* or *Odontaspis*. It is not possible for this booklet to settle the issue so they are shown as one type; just be aware of the issue. All types of the teeth have a slender crown, which is usually straight but may be oblique. Cusps are a characteristic, but they may be rather small. Some teeth will be found where the cusps are either broken or worn off. In these cases, look for the attachment point where the cusp was located. Some roots are very slender and arched with others being typically "C" shaped and rather thin. Serrations are never found in this genus. They can be confused with one species of the Isurus teeth, so be careful.

The living sharks of this type have a staring yellow eye and a mouth-full of the wickedest-looking teeth in sharkdom. The sharks are grayish-brown above, lighter below, and often have a series of irregular dark spots on the flanks. They have a pointed, slightly upturned snout, and teeth that are always erect and decidedly "fang-like". The fins are heavy and fleshy, often tipped with black on the posterior margins. The first dorsal is situated fairly far back, and is close to the second dorsal, which is almost as large as the first. The base of the tail is stocky. They reach a maximum length of about ten feet in the Atlantic, but larger ones have been reported in other locations. Sand tigers appear to be omnivorous, feeding on many fishes, including slow swimmers and bottom dwellers, and even crabs. *Carcharias taurus* is considered to be unaggressive and fairly easy to catch, and so it is often used as an aquarium specimen, where its snaggle-toothed face makes it a popular shark for viewing and photography.



3.1.1.5 Mako Sharks

Makos (*Isurus*) are among the larger sharks whose teeth are found as fossils along Scientists' Cliffs. The common name mako is of Maori origin, but its precise meaning is unclear. Living makos are open-sea sharks, very streamlined and



built for speed. They are thought to be the fastest swimmers among living sharks. *Isurus hastalis* is the Miocene species that is found locally. This species reached a possible length of nearly twenty feet and may have weighed close to four thousand pounds. The scientific name *hastalis* means spear or spear-like, and accurately describes the large teeth of this shark. The crowns are broad, triangular, and shaped like the blade of a spear. They are flattened and somewhat concave on the front or outer surface, with roots that are short and blunt and bear abbreviated lobes. On unworn specimens the cutting edges of the crown are literally razor sharp. *Isurus* is closely related to the great white shark *Carcharodon*, which has large teeth that are similar in shape to those of *Isurus*, but with serrated cutting edges.

3.1.1.6 Snaggletooth Sharks

Perhaps some of the most interesting and attractive teeth found among the fossils of Scientists' Cliffs are those of an extinct requiem shark, *Hemipristis serra* Agassiz, commonly called the Snaggletooth shark. Although common during the early Tertiary Period, *H. serra*, a member of the family *Charcharhinidae*, had disappeared from North American waters by the end of the Miocene epoch. The only living species in the genus *Hemipristis* is *H. elongatus*, of which a few specimens have been recorded from the Red Sea, the east coast of Africa, the west coast of India, and the Gulf of Thailand. It is curious to note that scientists were aware of the extinct *H. serra* before they discovered the existence of H. *elongatus*. It is, however, through the study of this extant fish that we are able to gain some knowledge of the fossil shark.

Similarities of teeth and vertebrae indicate that in all probability *H. serra* resembled *H. elongatus* in appearance and habit. It would have been a gray colored shark inhabiting the shallow coastal waters of temperate or tropical seas. The first dorsal fin would have been large and located far in front of the pelvic fin. The upper lobe of the tail would have been longer than the lower. Uncharacteristic spiracles -- water intake organs located behind the eyes -- coupled with characteristic asymmetrical teeth would have readily distinguished it from other Carcharhinids. *Hemipristis serra* would have been a fairly large shark; *Hemipristis elongatus* reaches lengths of almost eight feet. Its teeth, however, are much smaller than the fossilized teeth of *H. serra*, specimens of which from North Carolina have been reported to measure close to two inches. A large lateral tooth from Calvert Cliffs would average around an inch to an inch and one-half in length.

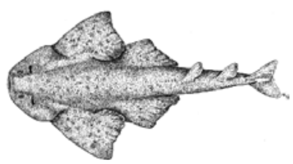
Hemipristis serra means, "A serrated half saw" and is an apt description of one of the shark's lateral or side teeth. Broad-based and triangular-shaped, the tooth has a rounded, swollen ridge running down the rear of the crown. The tip curves gently backward and both cutting edges of the blade are strongly serrated. These serrations increase in size from the base of the crown to a point near the tip where they cease altogether. A deep nutritive groove penetrates the base of the root giving it a particular "gull wing" cross section.

The stout lower and upper teeth are sharp and narrow with piercing prong-like tips that twist backward over a bulging tripod-shaped root. The serrations on these anterior teeth are missing or reduced to small slender cusps at the base of the tooth. As the location of the tooth shifts towards the rear of the mouth, the crown broadens and the serrations increase in size and number.

3.1.1.7 Angel Sharks

One of the rarest and most interesting of fossil teeth found at Scientists' Cliffs is that of *Squatina occidentalis*, an extinct angel shark. It is a small, single-cusped tooth, rarely exceeding a quarter of an inch in length. The erect, smooth crown is pointed with sharp cutting edges, and, for its size, stoutly built. The root is relatively broad. On the outer face of the crown the enamel extends down over the medial surface of the root, forming a diagnostic characteristic. The inner face of the crown lacks this enamel elongation. The inner face of the root is raised and extended to the rear. Teeth of both jaws are similar in appearance.

Squatina occidentalis (Latin for western skate) is thought to have been about five feet long and to have weighed about sixty pounds. It was probably a shallow-water dweller and a bottom feeder, using its needle sharp teeth to feed upon fish and crustaceans. Skate-like, its eyes and large spiracles (vestigial gill clefts) would have been located on the top of its head, and a wide mouth would have been in front of its snout. Five partly lateral gill slits would have been located on each side of its neck in front of enlarged cloak-like pectoral fins. In spite of its batoid shape, it probably swam like a true shark with a sculling motion of its tail.



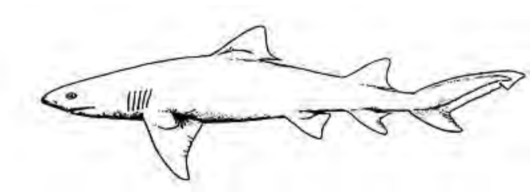
The angel shark received its unusual name when pious medieval observers saw its free-flowing pectorals as wings and its tapering body and tail as angelic robes. Later, it was called a "monk", and finally dubbed a "bishop". One Australian species, richly decorated with ornate denticles, even managed to reach the rank of "archbishop".

Interestingly, the original tooth found of *S. occidentalis* from the Calvert Formation at Plum Point was the first of its kind to be definitely recognized as coming from the North American continent.

3.1.1.8 Lemon Sharks

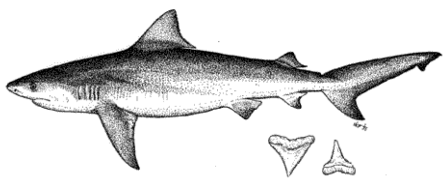
The lemon shark (*Negaprion eurybathrodon*) has a very small tooth. Usually they are under three-fourths of an inch tall. The tooth is usually very straight with very slight serrations, more likely to be seen along the thin enamel ridge extending along the root in both directions. The tooth has a "T" shape. They are very similar to *Sphyrna* and *Carcharhinus* and may be confused with them.

The living lemon shark is a large, stout-bodied reef shark that has a pale yellow-brown body with no obvious markings and a broad, flattened head. It is easily identified by its large dorsal fins, which are about equal in size. The anal fin, immediately below the second dorsal fin, is also large. The pectoral fins are long and curve back on the trailing edge. There is no lateral keel, and, unlike many requiem sharks, it has no interdorsal ridge. Its diet consists of bony fishes, rays, crustaceans, guitar fishes, and mollusks. Maximum size is about eleven feet.



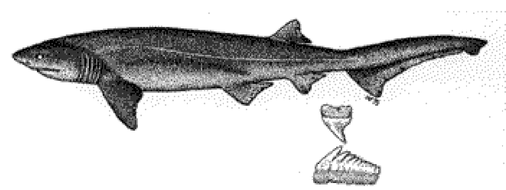
3.1.1.9 Requiem Sharks

The requiem sharks are in a genus (*Carcharhinus*) that includes the dusky, silky, and the bull sharks. This is the most common genus in most Miocene areas. They have small teeth, generally less than one inch high. Serrations can be present; they are normally very slight. Cusps are never found in this type. Roots are slightly curved or near straight. The shape is slightly oblique in most samples. Profile of the teeth is convex on the inside and flat on the outside.



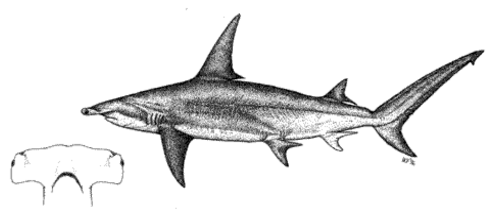
3.1.1.10 Seven Gill Sharks

The seven-gill shark (*Notorynchus primigenius*) is also commonly called a cow shark. The living species of this genus are immediately recognizable because of its seven pairs of gill slits -- most sharks only have five pairs. Its other unusual feature is a single, small dorsal fin. It has a wide head with a short, blunt snout and small eyes. It is a large and powerful shark with lengths up to 10 feet. The teeth of the seven-gill shark are very effective for cutting. The teeth of the upper jaw are jagged with cusps, except for a single middle tooth; the teeth of the bottom jaw are comb-shaped. The shark's diet includes other sharks, rays, bony fishes, seals, and carrion.



An extremely interesting and unusual type of dentition occurs in this shark. The upper jaw tends to have a three-bladed oblique tooth while the lower jaw has a six-bladed tooth that is less oblique. Appearing as a fusion of several teeth that decrease in size from front to rear, each tooth will have several blades, which have no serrations. On the anterior edge of the lower tooth, a semi-circular area often has a serrated appearance. The area may be considered a serrated cusp, which is actually separate from the leading blade. The shape is very jagged and shows the cusps decreasing towards the posterior. This type is unmistakable and shouldn't be confused with any other genus.

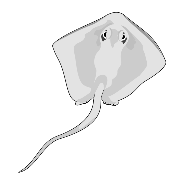
3.1.1.11 Hammer Head Sharks



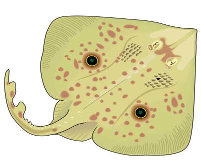
The hammerhead's (*Sphyrna sp*.) teeth are VERY similar to *Carcharhinus* and are found in the same general areas. Both types are common and because of this, confusion exists. The best rule here is to remember *Sphyrna* never has serrations. If you set them on a flat surface, the tooth tends to curve up at the tip. Cusps are not found in this genus. Profile, size, and shape are essentially like *Carcharhinus*.

3.1.2 Skates and Rays

Skates and rays are fish, and members of the group called batoids. Skates and rays are highly specialized forms of cartilaginous fishes that have gone beyond the shark in developing modifications for living on the sea bottom. Their fossils are common throughout the Maryland Miocene deposits from Chesapeake Beach down to the Chesapeake Ranch Estates. Their dental plate segments are common as fossils, there exists a large amount of confusion as to the differences between them and how to identify the varied fossils we find.



Rays resemble skates, but several rather technical differences set the two apart. Unlike the skates, which produce their young oviparously in egg cases, the rays are all believed to be ovoviviparous, bring forth their young alive (after they have hatched from eggs within their mother). Another way to differentiate them is to remember that skates are generally long-nosed and rays are generally not. (Note: this is a very loose generalization with plentiful exceptions.)



There is another difference between skates and rays. As far as is known, skates are harmless, but some rays exist with rather fearsome defenses, including barbed spines which may contain a poison. A ray may have one or a series of these barbs located on their whip-like tails, and they are capable of inflicting very painful injuries. These barbs are found as fossils, but are rarely intact. Skates on the other hand have a more passive means of defense; they have scutes or hard bony plates that float under their skin and provide some means of protection from predation. These scutes are found in a line down the middle of the skate from the head to the tail.

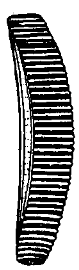
3.1.2.1 Ray Teeth

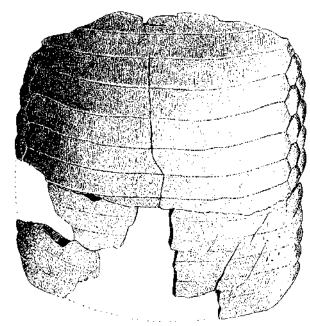
In the beachwash at the foot of Scientists' Cliffs are often found fragmented bars and wing-shaped pieces broken from the fossilized dental plates of rays. Equipped with powerful, nutcracker-like teeth, these flattened relatives of sharks cruised the bottom of the Miocene sea probing for crustaceans and shellfish.

The teeth of the *chondrichthyes* (class to which rays and sharks belong) are not rooted into the jaw but are attached to the gum by tissue and fibrous membranes. Worn or missing teeth are continually replaced by new teeth, which lie in rows directly behind them. Until they are needed, these replacement teeth are protected by a thin membrane, then, guided by fibrous connections and the gradually increasing pressure exerted by surrounding cells, they move forward as a unit to replace those worn or lost.

While a variety of rays lived in the ancient Calvert Sea, most of the fossilized ray material that we find today comes from one family, that of the Myliobatidae or eagle rays. The principal members of this group were and still are, *Myliobatis* (the eagle ray), and *Aetobatus* (the spotted-eagle or duck-billed ray), additionally *Rhinoptera* (the cow-nosed ray) remains are found as fossils which members of another family. These three genera may be distinguished by their teeth.

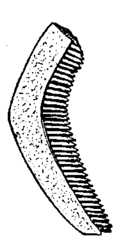
3.1.2.1.1 Eagle Rays (*Myliobatis*)





The dentition of *Myliobatis* is very specialized. The teeth are flat and arranged in transverse bands of seven, like paving stones in a mosaic work. Those in the center of the jaws form long hexagonal bars. Those at the sides are smaller, but also six-sided. It is these fragmented bars that we find so often on the beach. The grinding surfaces of the teeth are covered with a thin, enamel-like dentine and are usually marked with a series of striations. The dental plate of the lower jaw is flat, while that of the upper jaw curves around the supporting cartilage. It is hard to separate species due to lack of documentation. The teeth are similar to *Aetobatus*, except there are multible sections of teeth in a row, fitting together like a puzzle. So instead of having flat ends on each tooth section, they are pointed. We tend to find *Myliobatis* teeth in greater numbers than *Aetobatus*, and they are usually larger.

3.1.2.1.2 Spotted-Eagle or Duck-Billed Ray (*Aetobatus*)



The upper dental plate of *Aetobatus* is composed of single rows of very broad, flat teeth. The dentition of the lower jaw is very nearly flat and the individual tooth bands are all more or less strongly curved or angularly bent in the middle. These are the wing-like fragments that we find in the beachwash. The crown surface is smooth or slightly striated and the lower surface or part attached to the gum is longitudinally ridged or grooved. Like *Myliobatis*, their teeth are large, flat and arranged in serried, tongue-shaped rows creating a continuous surface for crushing and grinding food. These teeth are almost always found singularly rather than in complete sets or plates. The major distinction between *Aetobatus* species and the other rays are the single rows on each plate, thus having closed or rounded ends on each tooth section.

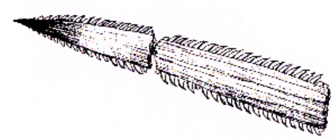
3.1.2.1.3 Cow-Nosed Ray (*Rhinoptera*)

Tooth bands of the *Rhinoptera* are composed of between seven to thirteen hexagonal bars. The three teeth in the middle of each row are wider than those on either side. The dentition of the *Rhinoptera* and the *Myliobatis* is so similar that it is necessary to have a whole tooth band to distinguish between the two.

3.1.2.2 Caudal Spine of the Miocene Stingrays

Stingrays were a common occurrence in the coastal waters of the Maryland Miocene. Most of these rays belonged to the *Myliobatidae* (Eagle) or *Rhinopteridae* (Cownose) families. We find their teeth and caudal spine in beachwash and matrix of Scientists' Cliffs.

The spine of a stingray is a defensive weapon. It is a sharp, stiletto-shaped barb firmly anchored to the dorsal surface of the ray's whip-like tail, usually about a third of the distance from its base. If lost or broken, it will replace itself. Running along each side of the spine is a row of saw-like enamel teeth recurved backward toward the base of the tail. The spine is covered with a sheath of skin. The teeth can be seen only if this sheath has been worn away by abrasion or when it is pushed backward when a lashing tail thrusts the spine into a molester. Along the underside of the barb are two deep groves containing strips of soft, spongy, grayish tissue; there are venom glands. The groves are the major site of poison production, although lesser amounts are produced by the sheath near the spine. The entire poison-producing apparatus – spine, sheath, and venom glands – is called the "sting" or "stinger."



The fossil stingers found at Scientists' Cliffs appear to differ little from those of living Myliobatidae. Usually brown or gray, they range in length from needle size to over six or more inches. It is rare to find a large spine intact, although spinal fragments are plentiful with venom grooves still plainly visible. Spines found in the beachwash, eroded by sand and water, have often taken on the appearance of plastic. Those taken from the fallen matrix of the cliffs have a more dull or wood-like texture, although the enamel of the sharp, recurved teeth is still bright and shining.

3.1.3 Bony Fishes

The Calvert Cliffs are well known for their fossil remains, the most common of which are a wide variety of shells, numerous shark specimens (primarily teeth), marine mammals, reptiles, and birds. Little attention has been directed towards the bony fish fauna, however, probably because most bony fish remains are fragmentary, small, relatively fragile, and often poorly preserved.

Bony fish remains are usually discovered on exposures of the Calvert formation outcrops located along the western shore of the Chesapeake Bay and the banks of the lower Potomac River in Maryland and Virginia. Skeletal finds often include isolated units: individual vertebra (i.e., backbone segments); defensive spines, such as pectoral spines of catfish, drumfish, or other larger fish; isolated dentaries; premaxillary bones (the lower jaw and two bones of the upper jaw); shed teeth; or hypural fans, which are uniquely modified tail vertebra.

Conditions leading to preservation of a fragile fish fossil depend on numerous biological, chemical, and mechanical processes, the most important being the rate of decomposition and the specific type of bacteria (aerobic or anaerobic) involved. Aerobic bacteria utilize oxygen and therefore decompose the remains at a rapid rate. A fish carcass can be carried away or partially destroyed when exposed under aerobic conditions to surface air to such possible scavengers as birds or mammals and to the elements. Conversely, anaerobic bacteria require no atmospheric oxygen and decompose fish remains at a slower rate. Ideal conditions for anaerobic preservation exist when a specimen is rapidly buried within silt, sand, mud, or clay; when little or no prior scavenging has occurred; and when decomposition has progressed at a slow but steady pace. Other favorable conditions leading to preservation must include some mineralization. Leaching from the organic acids produced during the biological and nonbiological processes impedes preservation.

When fossil fish remains are found in situ, often only a small part of the cranium or spinal column is exposed. The fish should then be removed intact in a block of clay and sand matrix. The block is excised so that only the clay and sand far away from the bone are disturbed. The process of cleaning a fish fossil is slow, since the bones may be brittle, fragile, and hollow. After dental picks havebeen used to remove the clay and sand matrix, the skeleton is treated with a chemical hardener to prevent further deterioration. Often, however, the specimen is too fragile to be removed completely from the surrounding matrix.

The historical compilation of bony fish remains from the Calvert Cliffs or its equivalents includes identification of specimens based on shed teeth. In the middle 1800s Joseph Leidy described a tooth assigned to *Sphyraena speciosa* from the Kirkwood formation in New Jersey; this fossil barracuda is also common in the lower Calvert formation of Maryland. Also in the middle 1800s, Edward Drinker Cope described shed teeth from an extinct drumfish, *Pogonias multidentatus*. The buttonlike teeth and isolated jaw fragments of *P. multidentatus* are commonly found along the Miocene exposures of Maryland and Virginia. During the 1930s, Lynn and Melland described a fossil catfish found at Plum Point, Maryland. From the 1960s onward, remains of the Tautog, billfish, and ocean sunfish were described, as well as otoliths ("ear stones").

Identification of fossil fish remains found along the Calvert Cliffs is challenging detective work.

Attempts to identify specimens can be frustrating because of the lack of systematic data; such data are limited to very few conclusive studies of the cranial and postcranial skeletons of modern fish. Those interested in identification should first find a good text that describes a fish skeleton in detail, then learn the different structures common to the construction of the fish's cranium and its postcranial elements. Information is available from a variety of sources. The collection of recent fish skeletons on display at the Smithsonian's National Museum of Natural History provides an excellent overview of the major fish families, and good university libraries contain texts on comparative anatomy and maintain collections of journal articles and monographs devoted to vertebrate paleontology.

In attempting to identify fossil remains, one must determine the structure of the specimen and its potential placement in the fish. The most common specimens such as the teeth, upper and lower jaws, and other fragments comprising the skull, are easily placed into context when a diagram of the basic bony fish is examined. Consider the morphology when examining specific structures. Are the teeth pointed for tearing flesh, or are they buttonlike and modified for crushing? Are the vertebra small, or are they over one-half inch or larger? Does the dentary or maxillary bone have a single set of alveoli (tooth sockets), or are the alveoli arranged in rows or a different pattern? Is the spine barbed? Does the spine have minute bony serrations, or is it entirely smooth?

If a tooth has a smooth blade with prominent enamel edges and no serrations, and it is triangular in shape and flattened, it may be identified as a wahoo mackerel (*Acanthocybium solanderi*). If a tooth has small serrations (visible with a magnifying glass) and is triangular, it may be identified as a barracuda (*Sphyraena sp*.). If a tooth is not serrated, has numerous lines running down the blade, and is conical at the base, it can be assigned to the mackerel (*Cybium sp*.). If a tooth is conical at the base, lacks serrations, and tapers towards the middle, it can be assigned to the cuttlefish (*Trichiurus sp*.). If a tooth is conical and comes to an extreme point at the tip, it belongs to the goosefish or monkfish (*Lophius sp*.). A tooth that is conical at the base and is rather oblong to the tip, with very fine lines running from the base to the tip of the blade, can be identified as the red drum (*Sciaenops sp*.). The dentary of this genus can be identified by the alternating alveoli.

Other forms less confusing to identify include the buttonlike teeth of the black drum (*Pogonias multidentatus*). A beak-like structure often mistaken for a turtle jaw is assigned to the ocean sunfish (Ranzania sp.). These specimens do not have teeth, but rather have modified, hardened enamel on the outer surface of the cutting edge. If a large, flattened, snout-like specimen is not marine mammal in origin, is rounded near the base, contains two small openings, and has fine markings running up and down its length, it can be assigned to the fossil billfish Istiophorus. Hypural fans of bony fish may also be found. A unique bottom-dwelling fish, *Chilomycterus*, commonly known as the spiny puffer, porcupinefish, or burrfish, is known only from isolated dental pavements and has modified, flat, layered teeth that were used in crushing shellfish and other bottom-dwelling organisms.

Although not as impressive as their cartilaginous counterparts, the bony fish have left us a large and assorted array of hard body parts. Hake jaws (*Merluccius sp*.) And tuna vertebra (
sp.) can be found in addition to vertebra from a variety of other fish. Most bony fish ha

cycloid scales or ctenoid scales. Both types are modified ganoid scales that have lost their hard enamel surface as well as most of the bone; they are therefore thin and flexible (prior to becoming a fossil). The two types differ only in minor respects; both are smooth and roundish, with growth lines visible on exposed surfaces. Ganoid scales have been left behind by the sturgeon (*Acipenser sp*.); whereas fragile ctenoid and cycloid scales tell us that perch, sunfish, carp, black drum, and the like swam in Calvert waters.

3.1.3.1 Hyperostoses "Tilly Bones"

Strange, curiously shaped, nodule-like fossils are often found in the cliffs, slumps, and beachwash of Scientists' Cliffs. These small swollen bones have been identified as hyperostoses (from the Greek <u>hyper</u> + <u>ostos</u> meaning abnormal (or to much) bone) , they are more commonly called "Tilley Bones" in honor of the late Dr. Tilly Edinger, a Harvard paleontologist who had made a long special study of them.

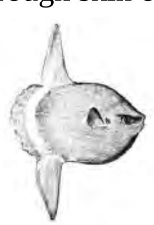
Hyperostoses are as common in certain families of modern salt water fish as they were in their teleost ancestors. Dr. Edinger's study at Harvard's Museum of Comparative Zoology have shown that these swollen lumps can develop at the base of dorsal and lateral fins, at the base of the skull, and on the ribs and vertebrae of such bony fish as the jack, spade, and haddock. They are apparently caused by a normal aging process, although they can also be the result of disease.

Fossilized hyperostoses are heavy and composed of a dense, bony material. They are usually oblong or oval-shaped, convoluted, and vary in size and color according to the species of fish from which they came and the type of matrix in which they were buried.

Paleontologists have found that "Tilly Bones" have proven useful in their studies of the ecology and climate of geological periods and locales as well as helpful in establishing the evolutionary development of the modern bony fish.

3.1.3.2 Ocean Sunfish

The family name, Molidae (from the latin for "a millstone"), aptly describes the round shape and rough skin of the ocean sunfish. Two species of fossil molids appear in the Miocene deposits of Scientists' Cliffs. *Ranzania grahami*, the more commonly found, appears in the Calvert Formation, while *Mola chelonopsis* has been identified in Unit 19 of the Choptank Formation. A third species, *Ranzania tenneyorum,* is represented in the



Miocene beds of central Virginia.

The largely cartilaginous skeleton of these early sunfish is not normally preserved, and fossil remains are generally limited to the premaxillae (fused upper jaws), the dentaries (fused lower jaws), and such isolated skull bones as the jugular, nasal, and dermal plates. One specimen of *R. grahami* did have vertebral spines associated with it. Either of these elements would be hard to identify if found as isolated fragments.

The most diagnostic bones for the identification of the genus is the premaxilla. It is a solid, bony

wedge closely resembling a turtle's jaw. The dorsal surface is pitted and rough. The ventral surface of *R. grahami* contains ill-defined rows and clusters of poorly developed teeth embedded in a bony plate. The teeth lack enamel and are difficult to see. The premaxilla of *M. chelonopsis* is nearly toothless and does not have the palatal development shown by *R. grahami*..

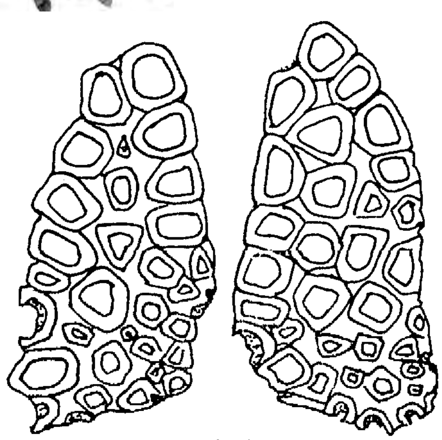
Jugular plates are best described as looking like rough-textured hot dog rolls. When found broken lengthwise, as is often the case, a low ridge may be seen in the center of the bone where the two halves were joined. Nasal bones are stony knobs with a wide wedge-like slice missing from one side. The dermal scutes or plates of *R. grahami* resemble somewhat those of the leatherback turtle *Psephophorus*. They are, however, more irregular in shape and have a very rough, bony, uneven texture.

3.1.3.3 Black Drum

Finally, collectors should stay alert for the dental pavement and associated round pharyngeal teeth of the black drum, *Pogonias multidentatus.* The teeth are commonly found loose in the beach wash by careful collectors.

In all probability, the Miocene black drum, *Pogonias multidentatus*, was an inshore fish, a sandy

bottom feeder with a special liking for oysters. It belonged to a noisy family of grunts, croakers, and drums called the



Pogonias multidentus Cope,
upper pharyngeals
(crushing teeth missing)

P. multidentatus Cope,
lower pharyngeals
(crushing teeth missing)

Sciaenidae. Like the modern black drum, *Pogonias cromis*, which occurs in the bay today, *P. multidentatus* was probably a huge, lumbering, black-finned fish with a large under-slung mouth filled with teeth specially adapted for crushing mollusks. Whiskery appendages, called "barbels" would have fringed its chin. These tactile sensory organs would have allowed the drum to feel and taste its food before eating it.

P. multidentatus was aptly named: it was indeed a "bearded, many toothed" animal. Its jaws contained hundreds of small, close set, peg-like teeth. Deep within its throat were pharyngeal plates covered with flat, polysided, crushing teeth. Roughly triangular in shape, there were two major upper plates and a single, broad, tooth-studded lower plate that had developed sometime in the fish's evolutionary past when two separate plates had fused together.

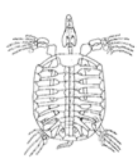
Fossil plates when collected are usually fragmentary and missing most, if not all, of their teeth. They may be recognized, however, by the unique pattern of their shallow, multisided sockets, each of which is outlined with a narrow, polysided border. Since *P. multidentatus* replaced its pharyngeal teeth throughout its life, individual fossil teeth are common finds. The small (a quarter inch is a good sized tooth), shiny, black or brown enamel teeth may be further identified by an indentation or pit on the bottom of each tooth. They are found in the gravel beach wash of the Chesapeake Bay.

P. multidentatus Cope,
single crushing teeth

3.1.4 Reptiles

3.1.4.1 Turtles

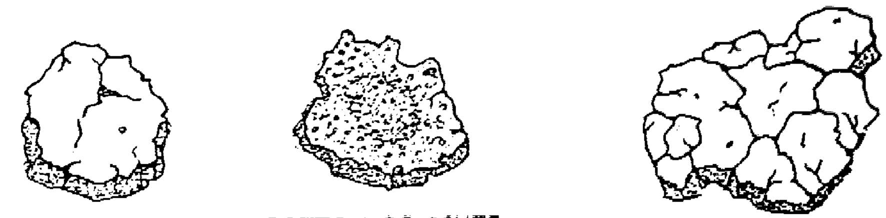
There were both fresh and saltwater turtles during the Miocene epoch. Fragments of their shells are common along the beach, but skeletal parts of these animals are extremely rare.



3.1.4.1.1 Leatherback Turtles

Psephophorus calvertensis was a Miocene marine turtle of great size, the largest of several fossil turtles found at Scientists' Cliffs. Reaching lengths of almost eight feet and weights of nearly a ton, it probably traveled regular migratory routes for many, many miles.

Psephophorus calvertensis (from the Greek, *psephos*, pebble, + *phoros*, bearing) had a thick, leathery skin stretched over approximately seven longitudinal ridges. Beneath this hide-like covering was a mosaic of bony scutes, or platelets, interlocked like the pieces of a jigsaw puzzle to form the carapace (upper shell) and plastron (lower shell). The vertebrae and ribs were not fused to the carapace, a condition different from that in most turtles in which the vertebrae and ribs are fully fused to the carapace.



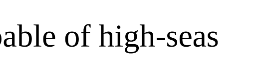
TOP OF SCUTE BOTTOM OF SCUTE PORTION OF CARAPACE

Often mistaken for bits of Indian pottery, these irregular shaped platelets are among the more commonly found fossils of Scientists' Cliffs. They range on average from about a half inch to two inches in size and are usually dark brown or black in color. The dorsal (upper) surface of an individual scute is flat, stone-like, and smooth to the touch. Its sides and undersurface have a more porous, bony texture. Platelets that formed the outer and posterior edges of the carapace are much thinner than those that formed the dorsal ridges. The most easily recognized of these fossil platelets are those that formed the bony ridges of the carapace: these are always nearly twice as long as they are wide and are heavy and roof shaped. Examples of these fossils are illustrated above.

3.1.4.2 Crocodiles

The teeth of the extinct salt-water crocodile *Thecachampsa antiqua* are a fairly frequent occurrence on the beach. Scutes (dermal bony plates) and skeletal remains occur much less often, but have been found in both the Calvert and Choptank formations. Their hollow-rooted cone shape readily identifies the fossil teeth. The crown is marked by vertical striations and by two sharp-edged ridges that extend on opposite sides of the tooth, from the top of the tooth down to the round or slightly oval root. Vertebrae may be recognized by their unusual shape. The sixty bones composing the crocodilian vertebral column have ball-and-socket appearance; concave in front and convex in back. In addition, they have a some-what saddle-like profile.

Thecachampsa was protected by a dorsal armor of bony, hide-covered plates or scutes, which were neither fused nor joined to the underlying skeleton. These cookie-sized plates are more or less round or oval in shape and slightly thicker in the middle than on the edge. One side is covered with random-sized pits or shallow indentations, causing them to be confused at times with the similar-looking dental pavement of the Miocene black drum *Pogonias*. *Thecachampsa* was a marine crocodile and may have been capable of high-seas migration.



3.1.5 Mammals

Mammals are the dominant large land animals of the modern world. But, for about two-thirds of their evolutionary history, while dinosaurs dominated the earth, they were small and probably rather insignificant. The earliest mammals from about 210 million years ago were shrew-sized and are known mainly from fossils of tiny teeth. There is little fossil evidence of large mammals until about 65 million years ago. Perhaps dinosaurs were so successful that there was no place in the world's ecological niches for larger mammals with the lifestyles familiar today.

After the mass extinction of many dinosaurs 65 million years ago, mammals diversified widely and rapidly. They became the dominant land animals with an average size, perhaps that of a cat. Size, however, can vary from the tiny (shrew) to the enormous (larger than an elephant) for some extinct land mammals. New environments were invaded worldwide, from seashore to mountains. Some mammals moved underground; others took to the treetops or to the air. Several groups took to the water.

3.1.5.1 Marine Mammals

The land-dwelling relatives of early cetaceans (e.g., whales and dolphins) were even-toed hoofed mammals, the cud-chewing artiodactyls. Supporting evidence for this comes from studies on living species, particularly on DNA, chromosomes, blood composition, and soft-tissue anatomy. So, sheep and cattle are among the closest living relatives of whales and dolphins.

To identify the exact ancestors, we must turn to the fossil record. One extinct group, the mesonychids, appears to include the ancestors of archaic whales. These comprise a range of mostly medium-sized (perhaps dog-sized) animals that lived in ancient Asia, Europe, and North America. They showed diverse feeding habits. Perhaps cetaceans evolved when one line of mesonychids took to feeding on fish in rivers or estuaries, rather like otters.

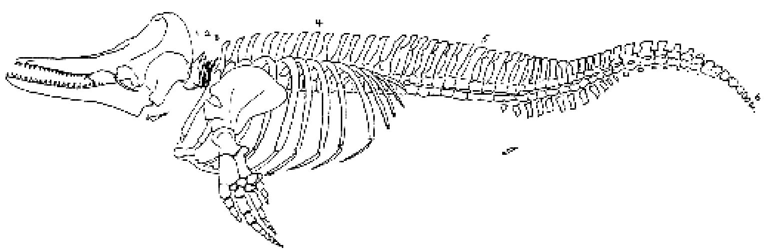
Cetaceans show many fish-like features that are adaptations to life in water. These are overprinted on basic, underlying mammalian structures. Perhaps the most obvious fish-like features are the dorsal fin and tail flukes. These are both new structures that represent adapation to an aquatic environment. Demands of aquatic life also have been solved in different ways by the other two marine mammal groups: the pinnipeds (walrus, sea lions, and seals) and the sirenians (manatees and dugongs).

3.1.5.1.1 Whales and Dolphins (*Cetaceans)*

The words "whale," "dolphin," and "porpoise" are misleading. They have little or no scientific basis and are the cause of much confusion. In theory, whales are the largest members of the scientific order called cetacea; dolphins are of medium size; and porpoises are the smallest. But this does not always work: some whales are smaller than the largest dolphins, and some dolphins are smaller than the largest porpoises. The problem is worse among the fossil collectors at Scientists' Cliffs, where small cetaceans of all kinds are commonly referred to as porpoises.

The solution is to think of cetaceans in terms of two groups, instead of three: the toothed whales or odontocetes, which possess teeth; and the baleen whales or mysticetes, which do not. These groups have a strong scientific basis, and avoid all the confusion normally associated with "whales," "dolphins," and "porpoises."

The vast majority of living cetaceans are odontocetes. There are currently about 70 species in all, including all the oceanic dolphins, river dolphins, porpoises, beaked whales, and sperm whales, as well as the narwhal and beluga. The number, size and shape of their teeth varies enormously. The long-snouted spinner dolphin, for example, has the most teeth with the number being between 172 and 252. At the other extreme, a number of other species have only two teeth.

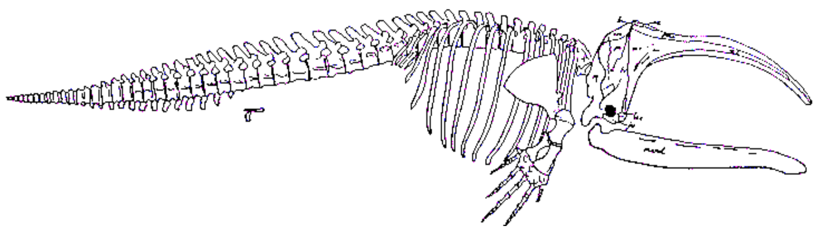


In the main, *odontocetes* feed on fish and squid, although some also take a variety of crustaceans, and a few take marine mammals.

Suborder	Family	Descriptions
Baleen Whales (*Mysticetes*)		
	Balaenidae	Right whales and bowhead whale
	Neobalaenidae	Pygmy right whale
	Eschrichtiidae	Gray whale
	Balaenopteridae	Rorqual whales
Tooth Whales (*Odontocetes*)		
	Kogiidae	Pygmy and dwarf sperm whales
	Physeteridae	Sperm whale
	Monodontidae	Narwhal and beluga
	Ziphiidae	Beaked whales

	Delphinidae	Oceanic dolphins, killer whales
	Iniidae	Boto (Amazon River dolphin)
	Pontoporiidae	Yangtze River dolphin
	Platanistidae	Indus and Ganges River dolphins
	Phocoenidae	Porpoises

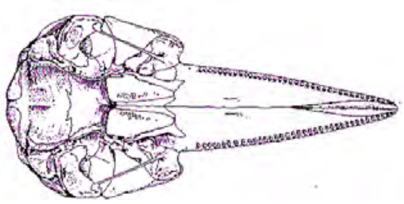
The modern mysticetes comprise a smaller number of species but make up for their lack of numbers by including many of the largest and most popular whales, such as the blue, gray, humpback, and bowhead. Instead of teeth they have hundreds of furry, comb-like baleen plates, often referred to as whalebone, which hang



from their upper jaw. These are tightly packed inside the whale's mouth, and have stiff hairs that form a sieve-like structure to filter food from the sea water. Mysticetes feed mainly on small schooling fish or crustaceans, such as krill or copepods.

There are other, more subtle differences between odontocetes and mysticetes. Toothed whales, for example, are recognizable by their single blowholes, while baleen whales have two blowholes side by side.

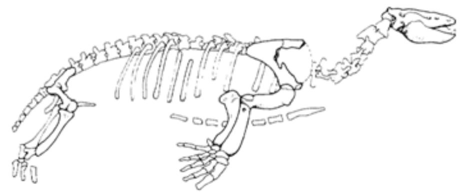
The Miocene deposits in Southern Maryland are among the world's richest in regards to fossil whales. About thirty kinds of these mammals have been identified, including both long - and short-beaked dolphins, several kinds of primitive whalebone or baleen whales, sperm whales, and shark-toothed whales. These bones are often so common that it is difficult to walk far on the beach without finding at least some small remnant of a rib or vertebra. Nearly complete dolphin and whale vertebrae occasionally can be found on the beach or in a fallen block of matrix or seen in the cliffs. These marine mammal bones are often found with scrapes and cuts on them indicating attacks



or scavenging by sharks and other predators. Ear bones, which have been found to be useful in identification (as opposed to the vertebra and ribs), also show up. Cetacean teeth are sometimes found when excavating a skull (usually they have fallen out), but they are rare beach finds.

3.1.5.1.2 Seals

All pinnipeds (walrus, sea lions, and seals) are powerful swimmers and are superbly adapted to life in the sea, yet they have not made a total break from land. All their feeding is done at sea, but they have to come ashore (or in some cases onto ice) to molt, rest, and breed. It is this need to return to land that accounts for the more typical mammalian features found in pinnipeds, but which have been lost in cetaceans and sirenians. In particular, pinnipeds are unusual in having four webbed limbs, armed with claws at the ends of all digits, and ,in most cases, a dense coat of fur. The fur seals and sea lions can even use all their limbs to walk around on land (in true seals, the hind limbs are greatly modified for swimming, and cannot support the body.) Unlike cetaceans, seals have a social system which is clearly adapted for the land: smell, body posture, size (sexual dimorphism), and development of hair (such as the "mane" in some male fur seals and sea lions) all play a behavioral role.



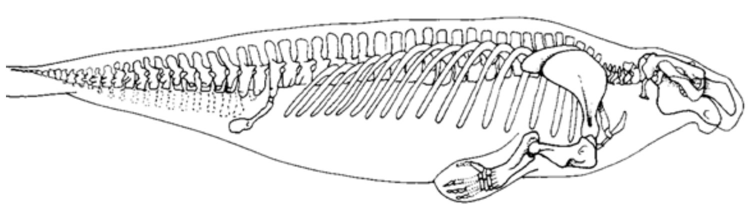
Seal and sea cow bones are occasionally found here, though they are much rarer then their cetacean counterparts. One of the oldest true seals is from the Calvert Formation, and the most complete specimen of a Miocene seal from Maryland was found at Scientists' Cliffs.

3.1.5.1.3.1 Sea Cows (Dugongs)

Sirenians (manatees and dugongs) are fully aquatic. They also lack external hind limbs and have tail flukes, but sirenians are quite different from cetaceans in body form and habits. These slow-moving shallow-water herbivores feed on sea grass and live only in warm water.

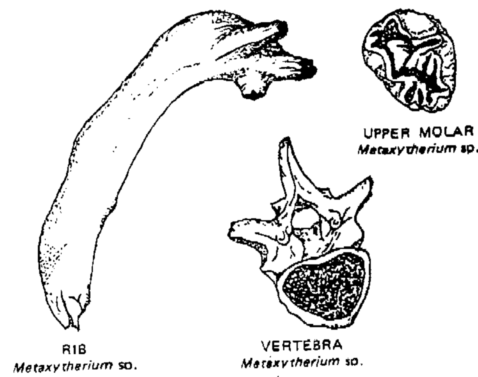
Fossil hunters searching the cliffs and slumps of Scientists' Cliffs occasionally find bone fragments of that "mermaid" of folklore, the dugong or sea cow. Distant relatives of the elephant, the family Dugongida*e* (from the Malay "duyong") first appeared during the Eocene epoch, and having disappeared from North Atlantic waters by the end of the Miocene, survives today only in Indo-Pacific seas.

The appearance of the Miocene dugong can only be conjectured, but to judge from a comparison of fossil bones with those of the modern dugong, the earlier dugong would have been a bulky, slow-moving animal with a hairless, whale-shaped body ending in a notched, horizontal tail. The paddle-like flippers would have been without nails and the head grotesque with small eyes and huge, mobile lips fringed with bristles. Able to live in both fresh and salt water, its habitat could have been either a river flowing into the sea or a warm, brackish bay with a preferred water depth of around fifteen



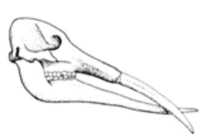
feet. Almost exclusively a plant-eater, the dugong would have been distinguished by its teeth. The male probably would have had two tusk-like incisors above, while the four or five cheek teeth in each jaw would have lacked enamel or any demarcation between root and crown. The large molars, superficially resembling those of a pig, would have had two transverse, curved crests and a wrinkled surface complicated by numerous small, knobby cusps.

Most dugong fossil remains have been found in the Calvert formation which has produced the several species – or perhaps genera – of dugong known to exist in the Calvert Cliffs. The largest and most commonly found bones are those belonging to *Metaxytherium calvertense*, an animal that reached an estimated length of about ten feet. The fossil bones have a heavy, dense quality. Ribs and vertebrae are most often found; teeth are rare. The ribs are identifiable by their density and a rounded, banana-like shape. Cross section appear solid, lacking any indication of marrow. Vertebrae may also be recognized by their density and, in particular, by their unusual heart-shaped centra.



3.1.5.2 Land Mammals

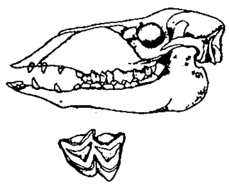
As might be expected in a marine deposit, few land mammal fossils are found in Southern Maryland. Some of these animals, killed by drowning or other mishaps, were carried into the ocean by rivers and buried on the shallow sea floor. The most common (or least rare) land mammal fossils come from peccaries (wild, pig-like creatures) and consist of teeth and bones. In addition, remains of mastodons, deer, tapirs, rhinoceros, camels, and horses have been found along the beaches of Calvert County.



3.1.5.2.1.1 Camels

The family Camelidae includes the living Old World camels and the llamas of South America. Camelids first appear in the fossil record during the late Eocene, about forty million years ago. Their early evolution and diversification took place in North America. During the Pliocene (a few million years ago), some camelids migrated via a northern land bridge to Eurasia and Africa, where they survive today as the familiar dromedary (one-humped) and bactrain (two-humped) camels. They also spread to South America over a southern land bridge during the Pliocene, and today are represented by the llama, alpaca, guanaco, and vicuna. Camels were extinct in North America by the end of the Pleistocene (the ice age).

The Eocene "proto-camel" *Protylopus* was a rabbit-sized herbivore with four-toed feet and low-crowned teeth. The Oligocene *Poebrotherium* was a goat-sized, two-toed beast. During the Miocene, coincident with the expansion of grasslands in North America, camelids underwent a major radiation. They increased in variety, size, and shape, with lengthening necks and limbs. Two splayed toes, supported by foot-pads, carried the animals at a pacing gait over the open terrain. Dental changes also occurred: the first two upper incisors were lost and replaced by a horny pad; the lower incisors inclined forward; and a diastema, or space, separated the chopping incisors and the grinding molars. These molars became increasingly hypsodont (high crowned), and their grinding surfaces developed raised crescent-shaped cusps well suited to feeding upon the tough grasses.



Land mammals, such as camels, are unexpected finds in the marine sediments of the Calvert Cliffs Miocene. Camelid fossils are particularly rare. A partial scapula, belonging perhaps to the giraffe-like camel *Aepycamelus*, was found at Chancellors Point in the St. Mary's formation. In 1976 a lower left molar of the llama-sized *Procamelus* was found at the Chesapeake Ranch Club in Lusby.

Camelops, the last North American camelid, survived until near the end of the Pleistocene, disappearing some twelve thousand years ago. Camels have since vanished from the land of their origin, except in zoos, until reintroduced from Asia by the United States Army in the 1850s as beasts of burden for frontier garrisons in the southwest. The experiment proved infeasible, and the animals were turned loose. The last of these wild camels was seen around 1900.

3.1.5.3 Epiphysis

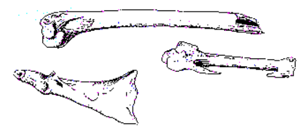
Bony discs sticking out of the cliffs or on the beach are not uncommon finds at Scientists' Cliffs. These discs are called epiphyses, a Greek word meaning "growth or growing upon." Epiphyses are produced as part of the growth of some bones in mammals. All the long bones in the human arms, hands, legs, and feet have epiphyses, as well as the vertebrae that make up the backbone. At the mammal's birth, the epiphysis is separated from the shaft of the long bone or from the drum-shaped centrum of a vertebra by a layer of cartilage. As the animal grows, its development slows and part of the cartilaginous layer is converted to bone. When adult size is reached, the epiphysis fuses with the main bone. If an animal dies before reaching adult size, bacteria and rot destroy the cartilage between the bones and the epiphysis falls away from its host. When a fully grown animal dies, however, no separation takes place; the two bones are ossified and remain so even in death.

It is this characteristic that makes an epiphysis so useful for ascertaining the age of an animal when it died. A fossil vertebra found without its two epiphyses would have come from a juvenile animal; a vertebrae with both epiphyses in place would have belonged to an adult beast; and a fossil vertebra found having one epiphysis in place and one missing would indicate a Miocene "teenager."

Paleontologists use fossils as diagnostic keys to unlock the mysteries of prehistoric life. The large number of whale epiphyses and juvenile vertebrae found at Calvert Cliffs have been used to argue that the area was the site of a "nursery." Occasional dugong or seal epiphyses are also found. Epiphyses vary in size and shape depending on the animal and bone that they came from. They may be round, oval, or, in the case of dugongs, heart-shaped discs. The outside (anterior) surface of epiphyses from vertebrae are smooth and flat with rounded edges and a slight dip in the center. The inside (posterior) surfaces are rough and covered with deep wrinkles and ridges. The centrum of a juvenile vertebra exhibits this same rough surface.

3.1.6 Birds

Most of the Miocene birds that have left fossils in Calvert County were pelagic (i.e., spending much of their lives at sea.) In the past few years the number of bird bones found has gone up, partly due to education on how to recognize and collect them, and partly due to increased interest in studying them. Even with this increase, bird bones rate as one of the more rare fossils found. This is due to the physical structure of bird bones. They are hollow, and this makes them very fragile and decreases the chances for fossilization.



The birds which have been found and described range from very small pelagic birds to a very large pelican-like bird with a wingspan of over 18 feet. The most common bird bones found come from auks and gannets.

3.2 Invertebrate Fossils

The shells of clams or snails, and, indeed, most mollusks, are composed of the minerals calcite or aragonite (calcium carbonate), relatively durable substances which commonly escaped immediate destruction on the sea floor. Once buried beneath successive layers of sediment, many shells persist in unaltered form until exposed at the surface of the earth by erosion. This is the case with the rich fauna of the molluscan shells found in the Miocene strata of the Calvert Cliffs.

3.2.1 Mollusks

The phylum Mollusca includes several groups of superficially diverse organisms that are alike in having bilateral symmetry and a soft fleshy body with certain essential similarities. Most, but not all, mollusks secrete external calcareous shells well-suited for preservation as fossils, and, because of their abundance, variety of form, and long geologic history, they are extremely important components in the geologic record. Five classes of organisms make up the Mollusca, but only two are common in Calvert County: bivalves (clams and oysters) and gastropods (snails). Figure 6 shows several of the more common fossil shells found at Scientists' Cliffs.

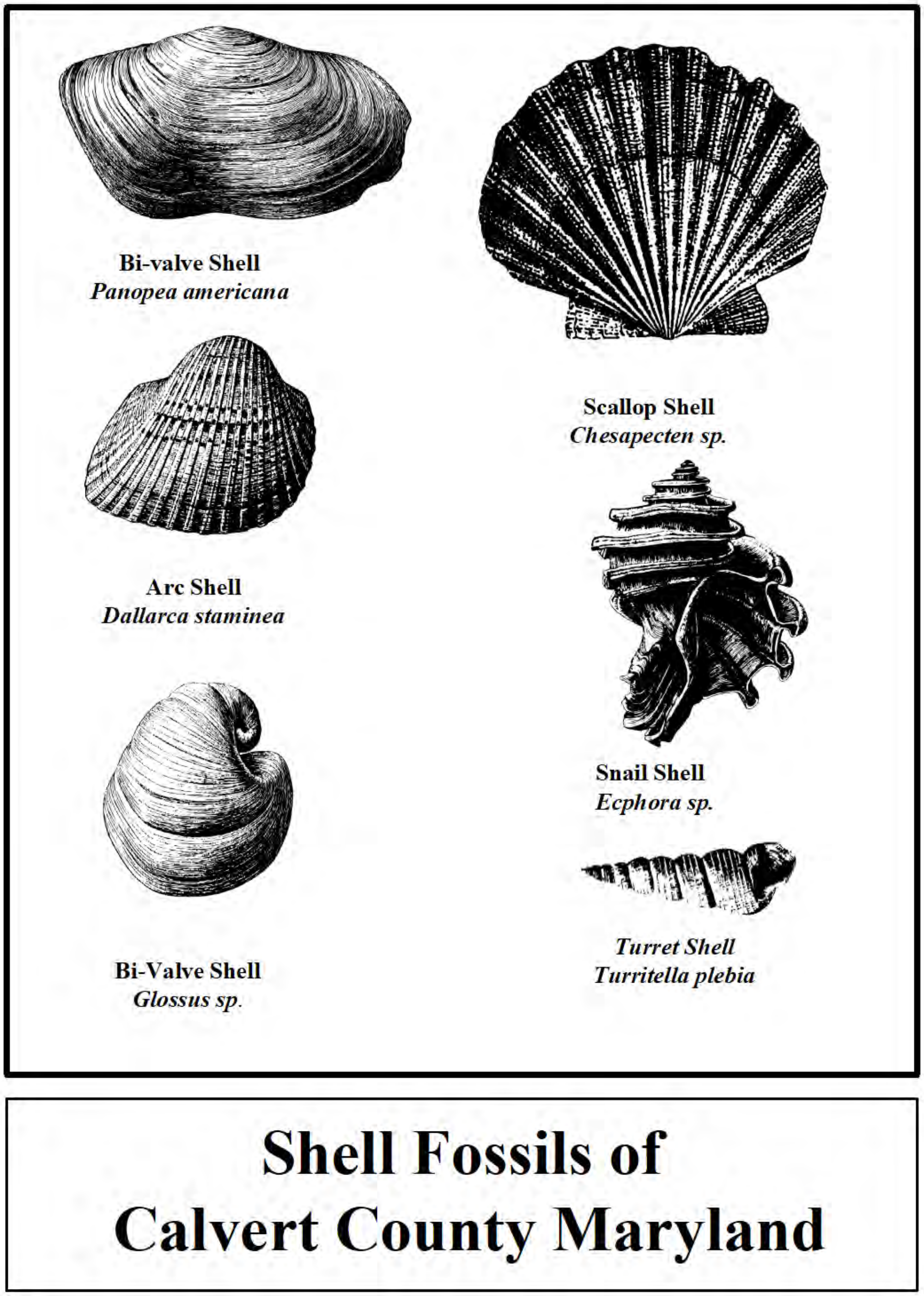
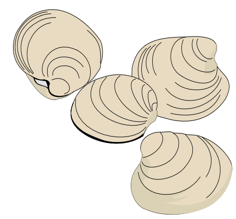


Figure 6. Common Shell Fossils of Scientists' Cliffs

3.2.1.1 Bivalves

Also known as pelecypods, bivalves include clams, and scallops and have bodies encased between two calcareous shells, or valves, that are joined along a flat hinge plate by an elastic ligament. Superficially, bivalves bear a resemblance to brachiopods, and amateurs often confuse the two. In brachiopods, which also have two valves, one shell is usually larger than the other. Unlike brachiopods, bivalve mollusks have a plane of symmetry that passes between the shells, making the left and right valves in many forms mirror images of one another (the exceptions include oysters and scallops that typically secrete valves unequal in size and form), whereas in brachiopods the plane of symmetry passes evenly through the shell. Bivalves have a set of muscles for closing the shells, but they open automatically when the muscles relax. Where the shells join at the beak, or umbo, there are ridges, or teeth, of various types that help to keep the valves aligned while the animal is alive. Bivalves are exclusively aquatic, mostly marine animals, with most forms being attached and immobile as adults, although some are capable of limited movement by jet propulsion. A shape much like the common clam is characteristic of the majority of bivalves. Some knowledge of shell morphology will aid considerably in the successful identification of fossil bivalves; study of Figure 7 will enable the collector to become familiar with the various parts of the bivalve shell and their names.



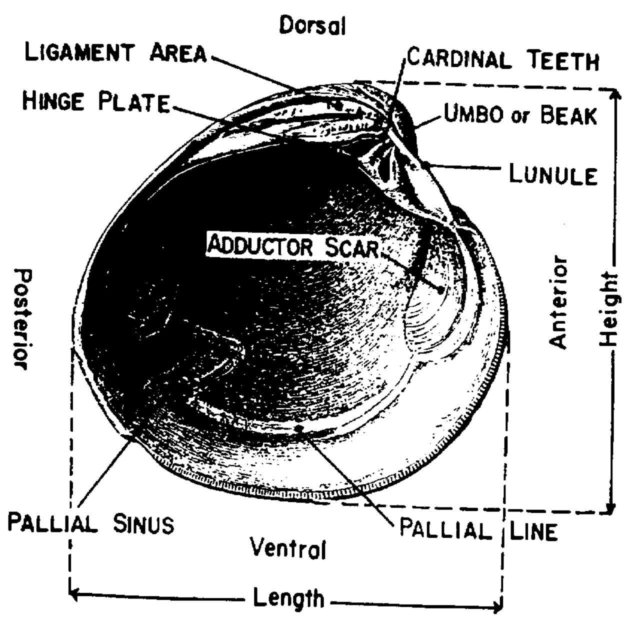


Figure 7. Bivalve Morphology

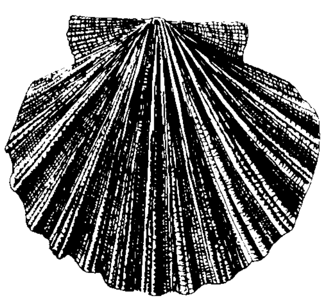
3.2.1.1.1 Scallop Shells

Chesapecten, an important genus of extinct scallop, was the first scientifically described North American fossil. In 1687 Martin Lister, an English doctor and naturalist, published his *Historiae Conchyliorum, Liber III*. In it he described and illustrated an unnamed American fossil that in recent times has been identified as *Chesapecten jeffersonius* from the Yorktown formation in Virginia. The Maryland state fossil, *Ecphora gardnerae gardnerae*, formerly considered to have been the first New World fossil to receive European recognition, was first described as *Ecphora quadricostata* in an appendix to *Lister's Historiae Conchyliorum*, published in 1692.

Named after the Chesapeake Bay, where outcrops provide the best collecting sites, deposits containing *Chesapecten* are found along the Atlantic coastal plain from New Jersey to Florida. The genus first appears in the lower Miocene and disappears in the lower Pliocene epoch.

"Zone" 10 of the Calvert formation contains two of the earliest *Chesapecten* species to be found at Calvert Cliffs. The first, *C. coccymelus*, has a smallish, rounded, ribbed shell, heavily armored with briar-like scales. The second, an unnamed species, is similar in appearance, but lacks the scaliness of *C. coccymelus*. This unnamed species also occurs in the somewhat older "zones" 2 and 4 of the Calvert formation. These early scallops are followed by *C. nefrens* ("toothless comb") found higher in the section of the Calvert and Choptank formations ("zones 14 to 20"). A still younger variety, *C. covepointensis* appears in the St. Mary's formation at Little Cove Point while *C. santamaria*, also apparently derived from *C. nefrens* is to be found in the uppermost or youngest portion of the St. Mary's formation of Maryland and Virginia.

Formally known as *Chlamys (Lyropecten) madisonius* (Say), *Chesapecten nefrens* Ward and Blackwelder has been classified as a new species and designated "type" species for the genus *Chesapecten*. Especially abundant in bed 17 of the Choptank formation, it is a large (some exceeding seven inches in diameter), sturdy, scallop-shaped bivalve. The valves of mature animals are slightly wider then they are high. The left valve is more curved or arched than the right and is often found with a large specimen of the Miocene barnacle Balanus concavus attached to it. Evenly spaced ribs, usually about 16 in number, span both valves and are surmounted by about three rows of scaly riblets. More spiny concentric ribs cross these ribs. The flat right valve, which the living scallop rested on the sea floor, has an opening or notch under the auricle, and ear-like protrusion near the dorsal hinge of the valve. (Interestingly, it is the more arched valve, not the flat one that rests against the sea floor in modern scallops.) A single closing muscle scar on the interior of the valve is large and round. The colors of these fossils range from blue-gray to sandy beige, depending upon the matrix in which they were buried.



The relatively thin, light shells of the older Maryland *Chesapecten* species suggests that they could jet propel themselves along the sea floor to escape predators. The later *Chesapecten* species are heavier, and thus were probably sessile.

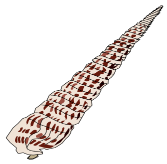
3.2.1.1.2 Isognomon maxillata

The large bivalve *Isognomon maxillata* is common in Scientists' Cliffs exposures of the Calvert and Choptank Formations. The genus first appeared some 210 million years ago (in the upper Triassic) and survives today throughout many of the world's oceans. The thick, white shell has a somewhat quadrangular outline. Its beak is pointed and curves slightly forward, while the posterior edge of the shell is gently rounded. The two valves are nearly equal in size and moderately convex. Concentric growth lines show on the outer surface, while the inside surface of the shell bears a single muscle scar.

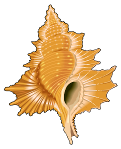
Isognomon maxillata is readily identified by its broad heavily grooved ligamental area, where an elastic ligament joins the two valves and pushes them apart when the adductor muscle is relaxed. The ligamental area in *I. maxillata* is composed of a series of fifteen to twenty wave-like ridges separated by shallow grooves. These run transversely on a raised, flat surface across the margin of the shell.

Despite its large size - five or more inches - *I. maxillata* is a somewhat fragile fossil. In life the shell is highly nacreous, with layers of organic material interspersed between limy layers. In fossil specimens this organic material has long since decayed and disappeared, causing the limy layers to flake and separate in layers perpendicular to the ligamental area. A whole specimen of *I. maxillata* is a rare find.

3.2.1.2 Gastropods



The gastropods are distinguished by their asymmetric body with distinct head and a muscular foot on the ventral surface and, in most cases, a calcareous shell consisting of a tapering coiled tube. In some cases, the shell opening can be sealed by a flat horny plate (operculum) attached to the foot. Gastropod means "stomach foot", and these mobile mollusks use their muscular "foot" to propel themselves. They have a mouth and true eyes. Most gastropods secrete a single, whorled, calcareous shell that fossilizes readily. Ecologically, they run the gamut from carnivores to herbivores. Many gastropods have a hardened radula, a type of toothed tongue that they use to scrape away at food. Gastropods are the only group of mollusks that have successfully adapted to life on land. However, most fossils and living species, are marine or freshwater. Gastropod shells are incredibly varied in shape, ornamentation, and coloring, so much so that among collectors of modern shells, the gastropods are great favorites. The basic plan for the gastropod shell is a spirally coiled tube, in its simplest form flat and smooth (planispiral), but varying to conical, turreted, or cylindrical. In addition, the smooth prototype gives way in many cases to complex ornamentation such as ribbing and projecting spines. The essentials of gastropod shell morphology are illustrated in Figure 8.



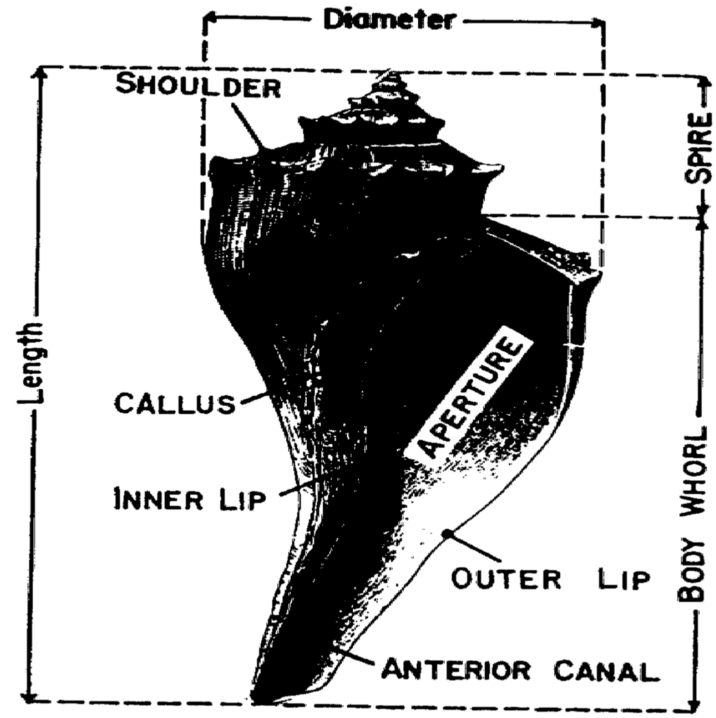


Figure 8. Gastropod Morphology

3.2.1.2.1 Turret Shells

Gastropods, or snails, with some 214 different species and varieties, are the most abundant of all Maryland Miocene taxa. *Turritella plebeia* Say is among the most numerous representatives of this vast fossil snail population. Turret snails feed on plants.

Turritella plebeia, the common fossil turret or tower snail, is relatively small. It has a shell composed of approximately 12 convex or rounded whorls. These whorls are marked with fine, uniform spiral ribs. *T. plebeia* is found in the St. Mary's formation in addition to both the Choptank and Calvert formations.

Gastropods, for their small size, have voracious appetites. The many drill holes found in the fossilized remains of *T. plebeia* indicate that countless numbers were victims of other meat eating snails.

3.2.1.2.2 Moon Snail Shells

The Naticidae or Moon Snails are a fairly common form in the fossil beds of Scientists' Cliffs. Unless stained by matrix, their whorled, globular, or moon-shaped shells have usually been leached to a dead white color.

Polinices duplicatus (Say) has a fairly thick shell with a heavy callus or thickening on the rim of its inner lip, the tongue of which completely covers the lower umbilicus, or navel-like swirl of the shell. With an approximate height of 45mm and a diameter of 52mm, it is relatively common in both the Choptank and St. Mary's formations and does occur occasionally in the Calvert.

The slightly flattened ovate shell of *Lunatia heros* (Say) is larger than that of *P. duplicatus*. The callus on the inner lip is thinner and does not extend to the umbilicus. *L. heros* has a height of close to 65mm and a diameter of around 60mm. It is commonly found in all three formations of the Calvert Cliffs.

These naticids were, and still are, voracious carnivores that burrow into the sand and attack other burrowing mollusks. Holding their prey with a large mobile foot, they use a gland at the tip of a peculiar "tongue," or tooth ribbon called a radula, to secrete a drop of acid onto the shell, then numerous rows of transverse file-like teeth on the radula rasp and drill a perfectly round (~1/8 inch) hole into the mollusk's shell. The radula then extends into the hole, becoming a combination straw and conveyor belt, carrying the juices and flesh of the unfortunate mollusk into the mouth and esophagus of the snail. Small telltale holes seen so often in fossilized shells are mute reminders of the unpleasant deaths suffered so long ago by their victims.

3.2.1.2.3 Ecphora Shells

The shells of the genus *Ecphora* constitute one of the more unusual and diagnostic types of fossils in the Maryland Miocene fauna. One of these shells furnished one of the first illustrations of a fossil from North America by Martin Lister in 1685 (it was the second fossil illustrated, a *Pecten* was the first), and these shells are still one of the most sought after prizes by collectors of Maryland fossils. The form illustrated by Lister was later named the Maryland state fossil. Continued research showed that the *Ecphora* shells found in the Maryland Miocene are not in fact of the species *quadricostata*, which is found only in the Miocene formations of Virginia. The particular species of *Ecphora* that was used as the Maryland state fossil was renamed *Ecphora gardnerae gardnerae* Wilson, and the name of the official state fossil was also changed in 1994.

The *Ecphora* shell has become a taxilogicial dream or nightmare depending upon where you sit. Some scientists believe that the shells represent an evolutionary sequence and all are members of one species. The "splitters" in the scientific community feel that the different forms of the shell represent different species hence have named many different species of *Ecphoras,* both from Maryland and up and down the entire North American Coast. For this reason, this document will only define the shells to the genus level, and will leave the species definition up to the collectors.

Specimens of *Ecphora* are found in all three formations, with larger and heavier shelled ones tending to come from the St. Mary's formation and thinner-shelled ones coming from the older Calvert Formation. A noteworthy feature of the specimens of the genus *Ecphora* is that the shells retain a brown color even when most other fossils in the Miocene fauna have assumed a chalky white tint.

3.2.1.3 Brachiopods

Brachiopods are a phylum of marine invertebrates. Bottom dwellers, they rest directly on the sea floor or are attached to it by a fleshy stalk or pedicle. The bodies of brachiopods are surrounded by two shells, or valves, that are joined along a common hinge, as in bivalve mollusks, such as clams. Unlike bivalve mollusks, brachiopods have dorsal (brachial) and ventral (pedicle) valves, while bivalve mollusks have left and right valves. For most brachiopods, the plane of body symmetry passes through the center of the valves, with each side being a mirror image of the other. The two halves, or valves, can differ greatly in shape and ornamentation.

Brachiopods, or "lamp shells" are exclusively marine to brackish water bivalves which have survived from the Early Cambrian Period to the present. The Paleozoic seas abounded in brachiopods, which reached a maximum diversity at that time. During almost every subsequent period new major types made their appearance. However, many major groups disappeared at the beginning of the Mesozoic, and since then brachiopods have held a position of steadily declining importance until now they are very inconspicuous in our seas.

Brachiopods are divided into two classes, inarticulata and articulata, according to shell composition, embryology, muscle placement, and the presence or absence of a hinge between the two valves. Inarticulate brachiopods lack hinges and are held together by muscles alone. The more sophisticated articulate brachiopods possess hinged shells and complicated muscle attachments.

3.2.1.3.1 Discinisca lugubris

There is only one species of fossilized brachiopod found in Calvert County, *Discinisca lugubris*. It is not uncommon in the Calvert Formation, is abundant in the Choptank, and is occasionally found in the St. Mary's. The shell of this inarticulate brachiopod is made of calcium phosphate. It is one of the few Calvert Cliff fossils to retain its original coloration. The dorsal (upper) valve is readily recognized by its light to dark brown color and by its resemblance to the "Marianne" cap, a knitted roundish cap with a lopsided peak favored by the proletariat during the French Revolution. The exterior of the shell has concentric growth rings and the interior contains prominent muscle scars. The fragile, flat ventral (lower) valve is very seldom found. A large *D. lugubris* may be an inch or more in diameter.

The family *Discinidae* appeared during the Ordovician Period (500 million years ago) and is still found today along the coasts of North America, Europe, and Asia.

3.2.2 Other Invertebrate Fossils

3.2.2.1 Echinoderms

Echinoderms are attached or mobile organisms with an external skeleton made of interlocking calcite plates (echinoderm means "spiny skin"). They are unique among animals in having an internal hydraulic system, or water vascular system that pressurizes their numerous inflatable tube feet. The attached forms are filter feeders, while the mobile forms, such as sea stars and sea urchins, may be carnivores, herbivores, or deposit feeders.

Echinoderms (Phylum Echinodermata) include a number of familiar animals such as starfishes, sea urchins, and sand dollars, as well as less familiar forms such as sea lilies or crinoids, cystoids, and blastoids. Echinoderms are fairly complex organisms with well-developed nervous and digestive systems. The soft body parts are housed in a calcareous exoskeleton (reversed from humans) made up of many individual plates joined together in intricate fashion, then covered with a spiny skin. Most echinoderms display a conspicuous fivefold radial symmetry. The phylum contains two broad groupings - Pelmatozoa (stalked forms fixed to the sea floor), and Eleutherozoa (free-moving bottom dwellers).

Among the Pelmatazoa are the crinoids, cystoids, and blastoids. Crinoids are most common in Paleozoic rocks. In Maryland, stem pieces and columns can readily be collected from most of the Silurian, Devonian, and Mississipian marine units. Relatively complete crinoids have been found in Maryland in the Ridgeley Sandstone and in the shales of the Hamilton Group. Cystoids were most abundant during the Ordovician and Silurian periods, and have been found in Maryland in the Keyser Limestone of western Allegany County. Blastoids may possibly be found in the Greenbrier Limestone of Garrett County, although none have thus far been reported.

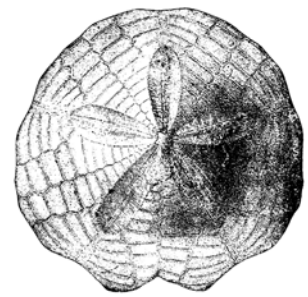
The Eleutherozoa includes two groups of interest to collectors in Calvert County - the stelleroids and the echinoids. The most abundant stelleroids are the starfishes, which include the brittle stars. Brittle stars are rare as fossils because their skeletons tend to fall apart after death, and the parts to scatter over the ocean floor. Collectors will occasionally find brittle star fossils in the St. Mary's Formation, either preserved inside the valves of large bi-valve shells or preserved in limonite concretions. Either way, they are rare, and have been found only in the Chesapeake Ranch Estates.

Echinoids include the sea urchins and sand dollars. An echinoid skeleton or test is constructed of numerous flat calcite plates arranged in radial rows. The skeleton is covered with skin, which is commonly studded with many movable spines of varying size. The spines enable the echinoid to move freely over the sea bottom and are also utilized for protection. In Maryland, fossil echinoids are rarely collected complete. The most common form appears to be a Miocene sand dollar, *Abertella aberti*, found largely in the Choptank Formation. Also found in the Choptank, is the heart urchin, *Echinocardium marylandiense*, which like most urchins was a colonial animal. These colonies have tended to weather out about every 20 years, and give collectors a short period of time to find them, since the surf tends to dismantle them quickly.

Collectors should keep a sharp eye out for these unusual invertebrate fossils, their rarity makes them interesting components of any Maryland collection.

3.2.2.1.1 Sand Dollars

A clean, unbroken five-to-six inch sand dollar is an exciting find. Perfect specimens are rare, although broken fragments are abundant in cliff slides and on the beach. Well-preserved individuals are sometimes found in sandy layers, particularly in the Choptank Formation. Sand dollars do appear in other strata of Calvert Cliffs, but they are usually broken, encrusted with hard matrix, and difficult to clean. Wearing its intricately patterned skeleton on the outside, this disk-shaped animal had short spines and is related to the spiny sea urchins (both are echinoids). Stone-textured and bleached through the ages, *Abertella aberti* may have shared the strange feeding habits of its modern counterpart. Many modern sand dollars assume a vertical position, half in the water and half buried in the sand. They always place themselves across the flow of the current so that they can easily filter out microscopic food from the passing water. When necessary, sand dollars drop flat, dig into the sand and rest, or creep to a new feeding ground.



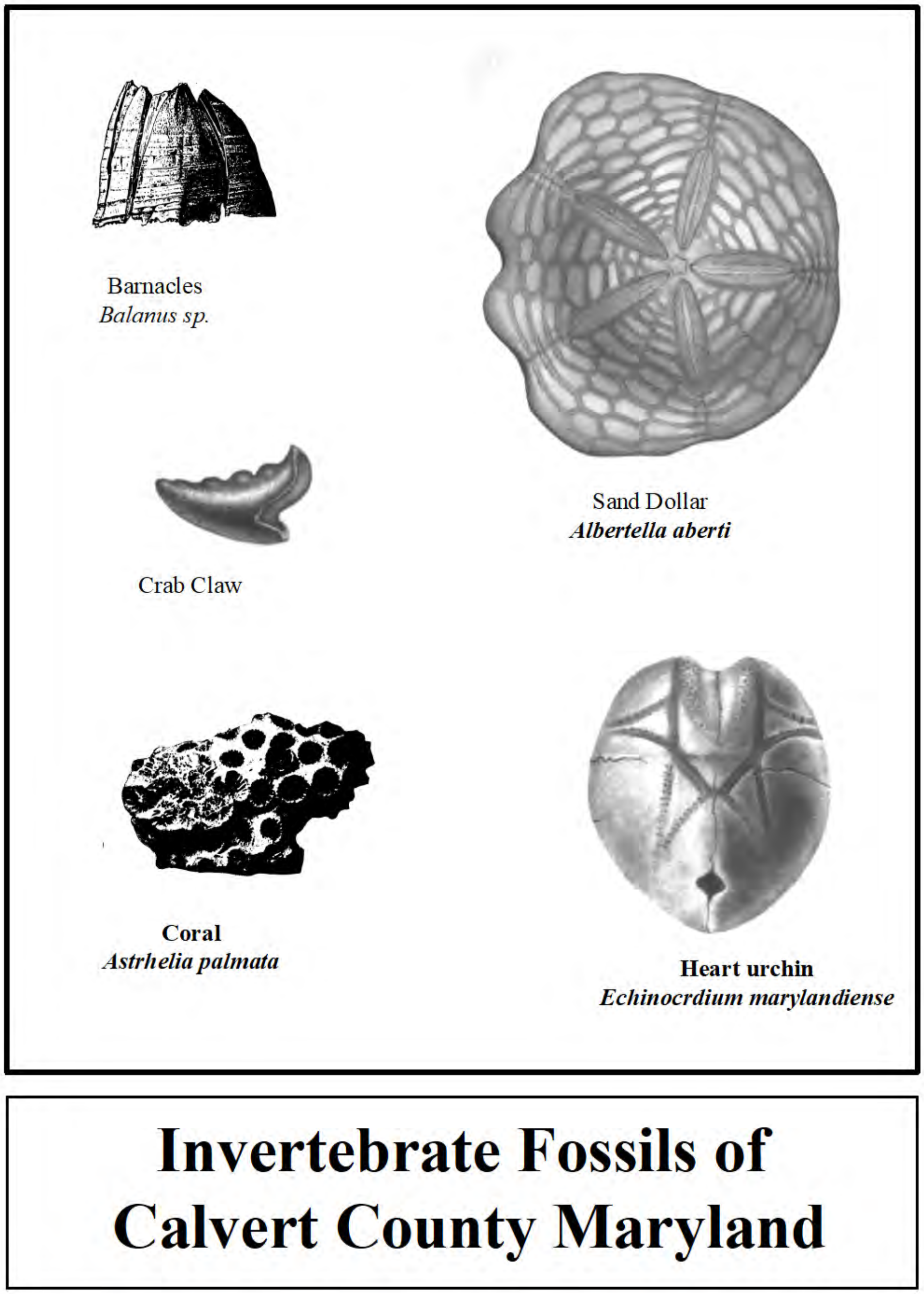
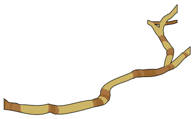


Figure 9. Other Invertebrate Fossils from Scientists' Cliffs

3.2.2.2 Plants

Fossilized plant material is common in many of the beds, usually in the form of lignitic sections

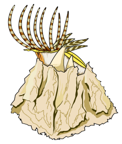


of wood, which tend to fall apart when, dried. Also found are nuts and pine cones that should be preserved in alcohol to keep them from drying out.

3.2.2.3 Misc. (Corals, Arthropods, etc.)

Fragmentary crab claws are found in all three Maryland Miocene formations. More common

than the crab claws are the shells of *Balanus concavus*, an exceedingly large barnacle, which often occurs in large numbers, especially when attached to other shells. Annelid worms have left their tube like shells as trace fossils, usually covering small Mollusk shells and looking like miniature drinking straws. Bryozoans, commonly known as cold water corals or lace corals, are a distinct group of marine colonial animals that are primarily found in the Choptank



Formation. Only one species of true coral, *Astrhelia palmata*, is known to occur at Scientists Cliffs. It is most abundant in the Choptank formation. Occasionally, a “blister peral” is found embedded inside the bivalve shell *Panopea* sp. *Panopea* "pearls" tend to be amber in color with a coating of white shell material. Figure 9 shows some of the other invertebrate fossils found at Scientists’ Cliffs.

3.2.2.3.1 Barnacles

Balanus concavus Bronn (Miocene to Recent) is an unusually large acorn barnacle. Its name, in reference to its shape, is a combination of Greek and Latin words meaning a "hollowed out or concave acorn." It belongs to a distinct and remarkable group of crustacea known as cirripedes or "fringed-footed" animals.

Free swimming at birth, the barnacle undergoes several developmental changes before eventually turning itself upside down and anchoring itself to a rock or shell by means of cement secreted from a gland in its head. A series of six hollow plates are fused to make a calcified protective outer mantle or shell. The central opening is covered by a divided trapdoor composed of two pairs of plates which can be opened to collect food, or tightly closed to give protection against desiccation (drying out) to those barnacles living in intertidal zones. Inside its turret, the shrimp-like creature, its head fastened permanently to the base of its shell, rotates its body so that its mouth and limbs point upwards. Opening its trapdoor it extends fringed, feather-like legs to sweep rhythmically to and fro in the water capturing food which it then rakes off with comb-like organs located near its mouth.

At Scientists' Cliffs, the largest individuals and the most abundant deposits of fossilized *Balanus concavus* are found in the Choptank Formation. The specimens found in the Calvert Formation tend to be smaller with rough, corrugated mantles. Like their present day descendents, Miocene barnacles were gregarious creatures, and those in the Choptank and St. Mary's formations are often found heavily clustered on the shells of large mollusks, particularly those of the fossil scallop, *Chesapecten nefrens*.

3.2.2.3.2 Scuta and Terga

Parts of barnacles called the scuta and terga are probably often seen but seldom recognized by amateur fossil collectors at Scientists' Cliffs. The Miocene barnacle, *Balanus concavus* Bronn, like the modern acorn barnacle, probably lived between the high and low tide lines securely cemented to a hard surface. The famous nineteenth-century biologist, Louis Agassiz, once described a barnacle as "nothing more than a little shrimp-like animal standing on its head and kicking food into its mouth." This is an accurate description - barnacles are shrimp-like, and their cup-shaped houses are composed of six overlapping calcareous plates. In addition to these six stationary plates, there are four movable interlocking plates that form a domed cover or "door" that may be opened for feeding or closed when danger or low tides threaten. They are known as the scuta (Latin for "shield") and the terga ("posterior"). There are two of each.

The scuta, or the anterior plates, are roughly triangular and wing-like in shape. They are easily distinguished from the posterior tergal plates by the absence of a projecting spur. Tergal plates are slightly beaked at the top. They have a vertical groove running down their centers and a process or projection called the tergal spur running down one side. Both scuta and terga are etched with growth lines and striations. The size and color of the fossilized plates depend on the size of the barnacle from which they came and the type of sediment in which they were buried. Fossilized barnacles seldom contain their scuta and terga because these usually separate from the rest of the barnacle soon after it dies.

3.2.2.3.3 Bryozoa

Bryozoa, or "Moss-animals", are a fairly common fossils in many of the local formations. They are known from the late Cambrian period to the present and, although exclusivly aquatic, inhabit both fresh and marine waters.

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

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

3.2.2.3.4 "Worms"

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

Because "worms" are basically soft-bodied organisms, they generally do not fossilize well. They leave trace fossils, but commonly its tough to identify just what creature produced a given burrow, tube, or groove in the sediment, however some kinds of "worms" do produce identifiable fossils.

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

Some annelid worms have tooth-like jaw structures called scolecodonts. These are composed of a complex organic material similar to your fingernails. These "worms" produced small tubes which are common finds attached to shells and barnacles

4. Collecting Methods

Collectors should limit themselves to collecting from the beach, shell marls, or from exposures in

the talus slopes. Digging into the cliffs is not allowed for both safety reasons and because they are private property. Permission to excavate any material from the cliffs must be obtained from the property owners prior to disturbing the cliffs.

Knowing what the different fossils are and what they look like is one thing, knowing the general geographic area to go to find them is another thing, but actually finding them is still another. A collector needs to know where to look, what techniques work best, and what, if any, tools to carry with you.

4.1 Beach Collecting

Lets face it, fossil collecting in Southern Maryland normally consists of one basic type of collecting, walking the beaches. While this sounds pretty easy, there are several different ways to go about it and some techniques that will make your time spent in the awful tiring (?) activity more productive. Just remember one thing, there are no set rules. One thing may work on a particular day, and something else will work another one. When you combine this with the fact that each of us works a bit differently, flexibility is key. Try different approaches, and see what works best for you.

4.1.1 Basic Beach Combing

This is the way most of us start, and even after many years, still spend many hours enjoyably. At its simplest, a collector is just walking down the beach looking for the fossils lying on the beach. This technique works best for hard fossils, such as shark teeth. Bones tend to get rounded off and broken up fairly fast in the surf and shells tend to become the beach. Shark tooth collecting is by far the most popular form of fossil collecting in Southern Maryland, so the limitations on this style of collecting do not hurt many folks.

Remember, to mother nature a shark tooth is just another piece of gravel. As a result, the best place to look for teeth is where you see larger bits of sand and gravel piled up. This tends to be at the high tide line and either at the low tide line or just into the water from the low tide line. The lighter teeth tend to get thrown up on the beach more then the heavier ones, so keep that in mind. If all you are after is "the big one", keep a sharp eye around the sharp drop off that likes to occur just past the low tide line. A heavy tooth has a problem getting over the hump to get out onto the beach and will often remain out in the shallow water. On the other hand, smaller and lighter teeth (including several rather rare or at least uncommon ones) will get tossed up close to the high tide line and then get dragged back and forth. Don't make the mistake of ignoring the neat little guys and only look for those 4"+ guys. There are just not very many of them out there and you will never have a well balanced collection if you are only looking for one thing.

Some collectors think the only time to walk the beach is at low tide. While this does tend to expose the most material, there are other times that are worthwhile also. Just after low tide, when the water is starting to come back in, is a great time to look. The teeth that are in the sand and gravel are pushed up the beach and separated from the sand for a few seconds by each wave. Good eyes and fast reflexes will do well at this time of day. High tide, or just after high tide when the water is falling back to the bay (or river), is often very productive. If there is a heavy wind or storm blowing, much material is pushed up to the top of the beach just waiting for a collector to come and give it a good home.

Time of day and lighting make a big difference to many folks. Early in the morning is often good because you will tend to be out before the majority of people are out walking and playing on the beach. Anything washed up by the tides over night will be waiting for the early bird (first collector). From a lighting point of view there are several things that will impact your ability to see small items in the wate, including the amount of light and direction of the light. Bright sunny days are good for seeing the reflection on a wet tooth in the sand, but poor for being able to see into the shallow water for the same reasons, i.e., reflections. Polarized sunglasses will cut the glare off the water and let you see into the shallow areas much easier. Direction of the light is not something we can do much about. No matter which way you walk on the beach you probably have to walk back as well. As a result, if the sun in at you back one direction, it will be in your face coming from the other direction. If the sun is at your back, quite often your shadow will block part of your viewing area; if the sun is in your eyes, the reflections will hurt your visibility. As a result, many collectors find it is best if the sun is at an angle to where you are walking. This will light up the whole area and the reflections will not be right in your eyes. The fact that most of us cannot control the sun is a good reason to make sure you look just as carefully on the way back down the beach as you did on the way up. What was not visible one time is sometimes much easier to see in a different light.

4.1.2 *Collecting From Fallen Blocks*

If the area you are collecting at has cliffs near by, there is a good chance there are some blocks of material on the beach which have fallen down. These blocks are a great place to collect good quality shell and bone fossils. Just remember, they fell there and more could fall anytime. Be careful! When looking at these blocks, if there are any whole shells visible which are not broken up by the fall, a collector can remove parts of the block to take home and prepare later. When shells are wet, they are very fragile. Try to remove a section of the matrix (the clay or sand around the specimen) and wrap it carefully. Check the section on tools (paragraph 4.3) for more info on this process. The same thing goes for any bone the collector sees while examining the blocks. Remember, if you see a little bit of bone sticking out of a block, there may be quite a bit more inside the block. Work around it carefully so you do minimal damage. Glue will repair some damage but remember the story of Humpty Dumpty i.e., "all the kings horses and all the kings men, could not put poor Humpty Dumpty together again".

4.2 *Water Collecting*

The category of water collecting can cover many things. At one extreme, it cover the folks that go diving for fossils out in the bay. It is not the intent of this booklet to describe that area in detail. While there are many fossils out in the deep water, they tend to be worn down more then the ones that have recently left the formations in the cliffs. Further, fossils collected from the bay bottom are no longer in situ and may have been derived from a considerable distance away, hence, they lack stratigraph significance. Also, it is just not a large part of the hobby at this time.

Many more collectors will work the sand deposits that tend to occur just out past the low tide line. There is commonly a drop off of a few inches to almost a foot that tends to gather the heavier sand, gravel, and rocks. Mixed in with this material are often some nice fossils. Sometimes collectors will just wade out and try to look down in the water to and see the material, but often they will use some mechanical aids in their hunt. While these are really "tools", since they are used in just one aspect of collecting, we will discuss them here.

One item that is used is a "spotting scope". It can be as simple as a bucket with the bottom cut out. It will improve your vision by cutting both the glare from the sun and much of the wave action. If you see a fossil using this item, just reach down and pick it up. Another version of this tool is a bucket with the bottom removed and replaced with a sheet of clear plexiglass. This gives a clearer view but it is harder to handle in the water since it will try to float on top of the water and not stay down in and show you all the big fossils that are trying to hide from you.

Another tool is a screen. These can be as small as a tin can or many feet across. Do not use window screen if you make one since the idea is to put a load of sand and grave in it and have all the sand and small gravel wash out leaving you with some rocks and fossils. Using 1/4 inch hardware cloth is a good idea since it is strong enough to hold a big load and the holes are big enough to separate a lot of the sand. This technique is common for collecting shark teeth. All that is required is a shovel to dig up sand and gravel and put it in the screen, then put the screen in the water and let the sand separate out. Check the material left on the screen for teeth, bones, arrowheads, and even shells. If you are in an area where there are normally a lot of teeth, but there are none on the beach and the gravel beds are just off shore, give it a try sometimes. Another tool is a variation on the screen. Small heavy-duty screens are mounted on a pole, and used like a rake. A collector will stand on the beach, reach out into the surf with one of these and rake in the sand and gravel. Pulling back the screen will let the fine sand run out and expose the larger material. This is a good method both to find shark teeth and to build up muscles.

4.3 *Tools - Supplies*

The collector's kit of tools should include wrapping material and a pack for carrying the

specimens home. One final addition to the kit might be a screwdriver or sturdy knife for freeing specimens from clay or shell matrix. Any specimens found in an exposed slump (i.e., a fallen block of clay) should be handled very carefully. While the fossils are still in matrix, they are usually very wet and, as a result, very fragile. Pack and/or wrap the specimen carefully for removal and storage until preparation can take place. Remember, while the fossil has beaten astronomical odds to survive for over 12 million years, it is your responsibility to preserve it once collected. A camera is also a great idea to document a collection location and orientation of specimens to be plaster jacketed.

4.4 *Clothing*

When you are out collecting, clothing becomes very important for several reasons, and style is not one of them. Folks that play in the mud for fun are not usually heavy into style; safety and comfort count much more.

In the summer, collectors around Scientists' Cliffs tend to be near or in the water. This has several hazards that need to be addressed. The most common "injury" caused by collecting along our beaches is sunburn. If you spend several hours walking down a beach with you head pointed down, the back of your neck is exposed much more then normal. Also take note that there are many sharp item (broken shells, glass, shark teeth) on the beach, and they can ruin your day if you step on them with bare feet. It may sound funny when you read this, but stepping on a sharp tooth is no joking matter (those sharks are still hungry 15 million years later). I saw a young child playing with a nice Mako tooth, throwing it up in the air and catching it, until she missed it and stepped on it instead; the result after a long walk back down the beach and a trip to the emergency room at the nearest hospital, was six stitches. Also remember that during the summer we tend to get a lot of jelly fish and that they can sting your legs if you wade into the water with bare legs. What all these things have in common are not wearing the proper clothes when you are going to be out for a while on the beaches. Wear long sleeve shirts to protect yourself from the sun (suntan lotion or sun block is also a good idea), wear shoes or sandals to protect your feet, and if you really need to wade in the water with the jelly fishes, wear long pants or bring some meat tenderizer and/or vinegar to take care of the pain afterwards.

In the winter, wear warm clothes with either boots or waders, and bring extra clothes to change into afterwards if you get wet, dry clothes will make the trip home warmer and more comfortable.

6. Fossil Preparation

It happens to fossil collectors from time to time. You are out in the field and you come upon a fine specimen of *Fossilus whatsis* which is , unfortunately, locked in a chunk of matrix about the size of Cleveland (well, maybe the size of a Geo Metro) and cannot be moved. With judicious use of a screwdriver or oyster knife you manage to remove the section of the block containing the fossil and, huffing and puffing along, you trot back to the car and hit the road for home. So far so good (?).

The real problems arrive when you get your specimen (or specimens after a good pot-hole/speed bump or two) home and attempt to remove the remaining matrix encasing the fossil in question. More often than not, the heavy-handed treatment in the field proves too much for a goodly number of delicate fossils, and many collectors damage their specimens beyond all redemption. Haste and impatience are a fossil's worst enemies.

Thankfully, learning the techniques to properly extricate fossils from the field and their matrix, and to clean them up so that they look their best is easy to accomplish. Learning the patience, however, may take a bit longer.

6.1 Field Preparation

Collecting fossils from spoil banks and fallen blocks sometimes turns up specimens that are too fragile to remove from the matrix. Immediate removal would create an impossible jig-saw puzzle to piece back together. In such cases it is well worth devoting a little time to properly preparing a plaster jacket. The following section is from the Handbook of Paleo-Preparation Techniques by Howard H. Converse with minor modifications to suit collecting in the Southern Maryland region.

6.1.1 Plaster Jackets

A plaster jacket is one of the paleontologist's most important field tools. It provides the same first-aid for a broken fossil as a plaster cast does for a broken arm or leg. It holds everything in place and stabilizes the surrounding matrix until proper repairs can be made back at home or in the laboratory.

Plaster jackets can be prepared for quite small specimens, and even for very large ones that require very heavy equipment for removal from the site. Two forms of jacketing material currently are used by the amateur fossil collector. The oldest form consists of strips of burlap cloth material saturated with a mixed solution of plaster of Paris and applied over the specimen. A faster and more convenient form is the plaster impregnated gauze bandage, commercially available for medical purposes and found in many medical supply houses or pharmacies. This form just requires a short dip in a pail of water (or the bay) and is ready to be applied to the job. Its size, makes it inappropriate for large specimens; however, it is fine for most of what we will find along the Chesapeake Bay.

6.1.2 Specimen Preparation

The first step required when a plaster jacket is needed is preparing the specimen to receive the jacket. The matrix sediments must be carefully removed from the top of the specimen. This allows the complete outline of the fossil to become visible. A generous amount of sediment must be left surrounding the specimen, so that there will not be any shifting of the fossil once jacketed. A trench must then be dug down around the outer perimeter deeply enough to insure that the complete fossil will be safely held within the jacket. This is best done with careful cutting of the clay or sand with a knife, and not jabbing at the specimen with a screwdriver. In harder material than what we have in Southern Maryland, such as cemented sandstone or limestone, geologists' picks and chisels are required, and it will take much longer to prepare the jacket.

Once safely below the specimen, a deeper undercutting must be performed, giving the prospective jacket a "mushroom profile." This will allow the jacketing material to be tucked far enough under the specimen so that the jacket will not shift or slip off when breaking loose from the ground. Allow a wide enough trench during the above operations so that one can work comfortably around the fossil and still have a space into which it can be turned.

After the specimen has been generously undercut, the fossil needs a protective layer of some form of paper. Paper toweling or toilet tissue (another good reason to carry some) works very well for this job. All exposed bone must be covered with paper to prevent it from sticking to the plaster. Any very low pockets can be filled with loose sand or clay. Dampen the paper so that it will conform to the bone contours more easily--sprinkling water over the paper with a brush or your fingers usually does a fine job.

6.1.3 Applying the Jacket

The plaster bandage, or whatever material is preferred, is applied over the entire pedestalled section of matrix. Wrap the jacketing material in all directions over the specimen and matrix, making sure to cover the under cut portions with a generous supply of the material. Depending on the size of the plaster jacket, thickness should range from about 1/4-inch on smaller jackets to over an inch on very large ones. The thickness of the jacket is very important in providing the necessary strength to prevent its collapse. For jackets larger than a foot or two in diameter, reinforcement is required. This can be accomplished by using tree limbs that may be found near the site, or pieces of lumber. The wood is incorporated within the manufacture of the jacket with several layers of jacketing material applied over them.

6.1.4 Extracting the Specimen

Once the jacketing material has dried, the specimen is ready for removal from the ground. In softer soils a knife is all that is needed to separate the base from the ground. Carefully push the knife under the jacket (in several places if needed) until it breaks free. Once the jacket is turned over, additional plaster material should be applied around the base. This will completely seal the specimen and sediments tightly within the jacket for safe removal to home or the laboratory. Sealing the plaster jacket will also insure its security during long term storage, should its final preparation be delayed.

The final label on the outside of the jacket should be applied with a broad-tipped marking pen, giving all the data and the orientation of the specimen. The label should be visible when the jacket is stored on the shelf.

6.2 Preparation of Specimens

In paleontology, the word “preparation” has been used to describe several operations; from the extraction of fossils from the matrix, to the consolidation and repair of fossils, and finally their display. Most material coming in from the field requires work to some degree prior to displaying it. These operations can range from just washing away the sediments to a major three-dimensional restoration of a flattened (ancient road kill ?) specimen.

6.2.1 Specimen Removal from the Plaster Jacket

As mentioned earlier, the plaster jacket serves as protection for a fragile specimen within its own matrix, until the preparator can slowly clean away the sediment, and repair the specimen as the jacket is worked down.

When a jacketed specimen has been selected for preparation, the task of opening the bandage must be performed. The most common tool to use is a small hand saw; a keyhole saw works well for this operation. Simply cut a thin straight line around the top of the jacket. As the saw penetrates the plaster and begins to enter the soft paper protection, one must avoid going any deeper. This operation requires caution when dealing with fragile specimens; depths of cuts must be gauged so they they only penetrate the plaster shell. This is one reason that labels on jackets should indicate the orientation of the specimen inside.

Once the jacket has been opened, the slow process of matrix removal is performed. With the softer sediments (clay and sand) which we have in southern Maryland, the use of dental picks and soft brushes is all that is demanded. The dental pick is used to carefully scrape one thin layer at a time, down through the matrix while the brush sweeps away the loosened debris. Harder material like cemented shell hash will require mechanical removal. During the entire matrix removal process, careful observation must be made of the specimen itself. When cracks are noticed, a thinned solution of consolidant must be applied immediately. Apply only to the specimen surface, avoiding contact with the matrix. This thinned solution will penetrate deep into the cracks, sealing and hardening the specimen for safe removal. As one works down into the jacket, the high walls left behind can be trimmed. If the specimen was properly hardened as it was excavated from the jacket and all matrix has been removed, the specimen can be carefully lifted from the jacket and the opposite side cleared of sediments.

Specimens that are unearthed in a fragmented state require very careful attention. As the sediments are removed and the specimen has been cleaned of as much debris as possible, a thin coating of consolidant must be applied. Do not try to reassemble the specimen while it is still in the matrix. Keep all specimen fragments in their broken alignment. The specimen is consolidated and all sediments are removed prior to its removal from the jacket.

Once removed, the painstaking process of slowly removing each fragment, cleaning it thoroughly, and gluing it back to its proper contact must be done. No more than one or two pieces should be removed at a time, this prevents disorganization if the preparator is disrupted. Each piece should fit to its mating section, and finally a three-dimensioned specimen is prepared.

6.3 Preserving the Fossil

There are two basic methods and four product types used to preserve or consolidate the fossil after it has been removed from the matrix, they are either acetone based or water based. The best method to use will depend upon what the fossil is, how it is preserved, and what you have available at the time.

6.3.1 Acetone Based

Use an acetone-based consolidation chemical such as Polyvinyl Acetate or Polyvinyl Butyral (or its common name of Butvar B-76), a white powder which is soluble in alcohol or acetone. Acetone is the most useful due to its high evaporation rate. Use a thick solution for glue, a thin one to penetrate and preserve the fossil. They tend to be expensive and hard to find, but are considered the best consolidation materials. Of these products, Polyvinyl Acetate is the preferred one at this time. **Be Careful**, *<u>you must be certain that the fossil is absolutely dry</u>* or it will turn white. If this occurs, you must remove the build-up and start over again.

6.3.2 Water Based

Use a water-based white glue such as Elmer's Glue-All, Wilhold White Glue, Flexbond, etc. Dilute the glue to a consistency of milk, and submerge the fossil for two or three minutes, dry slowly. Do not heat or air blow.

Use polyethylene glycol, a water soluble wax to preserve wood, nuts, cones, etc. Soak fossils for several weeks; dry slowly. Use the water-based glue treatment if the specimen starts to crack as it is drying.

6.4 Identifying Your Finds

The final step before entering specimens into your collection is identification - - the application of the appropriate scientific name to your fossil. Fossils are classified in the same way as living organisms; that is, each is assigned a generic and specific name, which is unique and belongs only to that organism. This scheme, known as the Linnaean system of binomial nomenclature, has been in use for over 200 years and is worldwide in its application. The names themselves are derived from Greek or Latin words to insure that scientists everywhere use the same terminology regardless of their native tongue.

By comparing your find with the illustrations in this text, you will in may cases be able to identify the genus and, in some instances, the species of your fossil. However, in order to name less common or rare forms which you may find, you will wish to consult some of the paleontologic literature listed in the bibliography. If you still cannot identify your specimen, paleontologists at the Calvert Marine Museum and the National Museum of Natural History (the Smithsonian) are available to help.

6.5 Labels

Collectors need to take the next step after collecting, preparing, and identifying their fossils and should label their finds. An example of several styles of labels that could be used are shown below (see figure 11). The important thing is not to depend upon your memory to know what the identify of the fossil is or where it came from. An unlabeled fossil is of no use to the scientific community and amateur collectors should get in the habit of labeling all their finds.

Name:
Location:

Common Name:
Scientific Name:
Age:
Formation:
Location:

Figure 11. Label Examples