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**Paleontology of Cretaceous Coon Creek**

Editors Dana Ehret, Lynn Harrell & Sandy Ebersole



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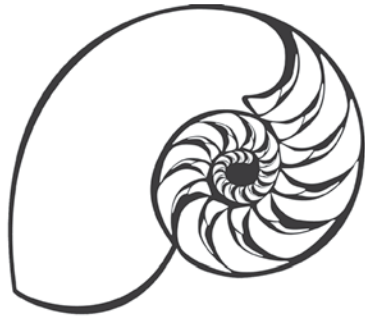
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# The Late Cretaceous Coon Creek Formation type section; an introduction to the lithofacies and time-equivalent units

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## INTRODUCTION AND SETTING

The Coon Creek and Ripley Formations are fossiliferous Late Cretaceous shallow marine clastic units that extend along the eastern side of the Mississippi Embayment (Figs. 1 and 2) and Eastern Gulf Coastal Plain in North America. In Tennessee, the Coon Creek has formation status with an upper and lower facies. In Mississippi, however, the Coon Creek facies is a part of the time-equivalent Ripley Formation. The Ripley lithology also more closely resembles that of the Coon Creek upper facies in Tennessee.

Following the Coon Creek Formation type locality's first comprehensive taxonomic review by Bruce Wade (1926), the Coon Creek Formation type section (Figs. 1 and 2) located in McNairy County, Tennessee, and its equivalent facies in the region have for decades been of great interest to paleontologists, geologists, and stratigraphers in the southeastern U.S. and Gulf Coastal Plain (see Brister and Young, this volume). This bulletin highlights some of the paleontological interests, collection history, and research at the type section and other Coon Creek and Ripley outcrops.

## AGE AND BIOSTRATIGRAPHIC CORRELATIONS

The definition of the Maastrichtian Stage base includes the auxiliary taxa ranges of the last occurrence (LO) of the ammonite *Nostoceras hyatti* (Odin and Lamaurelle, 2001a) and the LO of the calcareous nannofossil *Quadrum trifidum* (Odin and Lamaurelle, 2001b). Samples collected

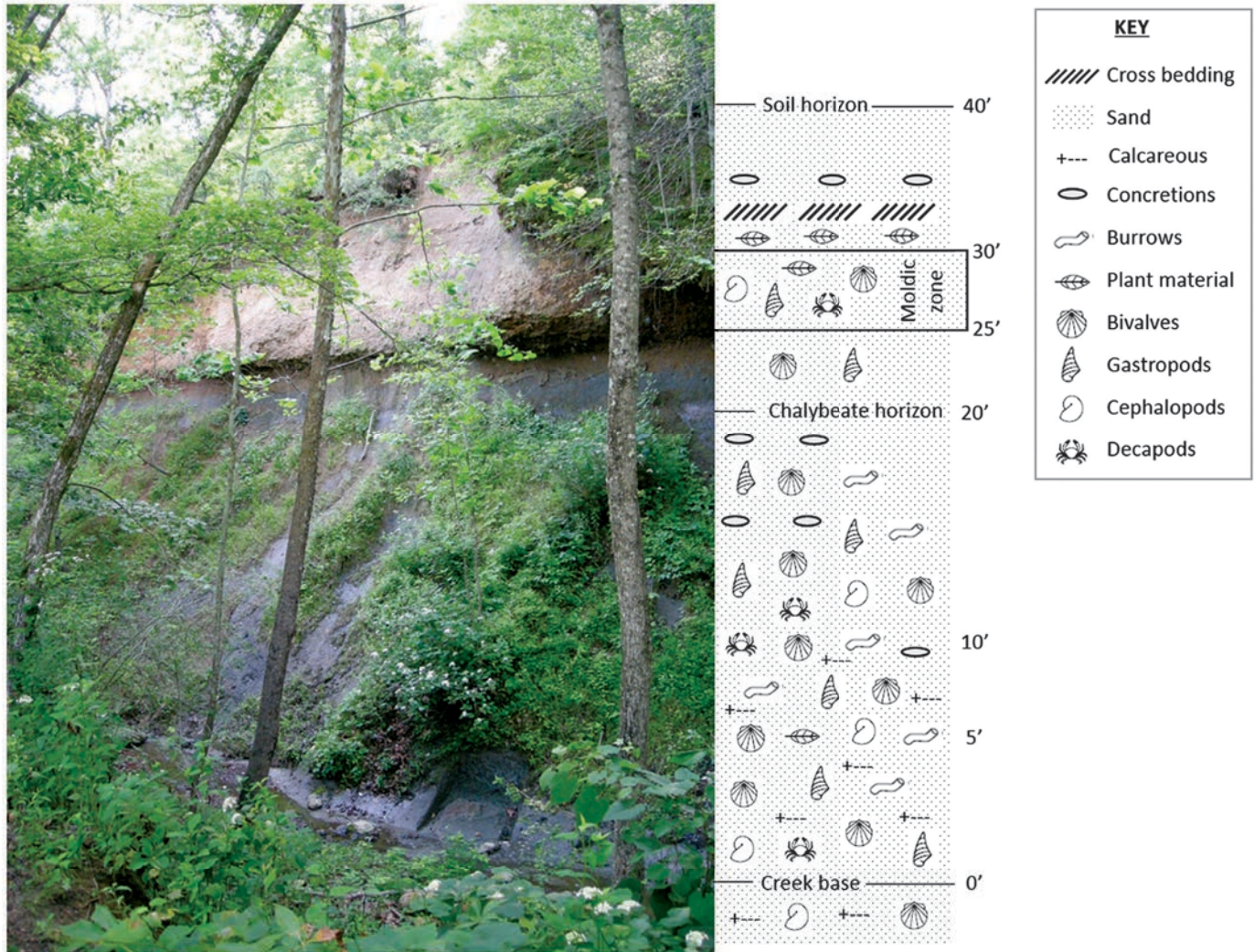
in 2005 by this author from the Coon Creek type section at creek level to 10 feet (~3 m) above creek level contained *Q. trifidum* (pers. comm. C. Smith), and Wade (1926) noted *N. hyatti* present at the type section, placing the Coon Creek in the uppermost Campanian. Additional samples taken in the Ripley Formation in Mississippi ranged from latest Campanian to early Maastrichtian based on nannofossil assemblages (Ebersole, 2010). The continuation of research on cephalopods (such as Larson's article, volume 2) and fossil pollen (such as Baghai-Riding's article, volume 2) will continue to help correlate units within the region.

## LITHOLOGY OF THE COON CREEK FACIES

The upper facies of the Coon Creek and much of the Ripley consists of dark gray (sometimes brownish or greenish), micaceous, glauconite-bearing, silty to clayey sand, with local siderite concretions. While fossiliferous in some locations (see the article by Harrell, Gibson, and Langston, volume 2), this upper facies is generally poorer in preservation when compared with the Coon Creek lower lithofacies. The lower facies of the Coon Creek (present at the type section) is gray (sometimes bluish or greenish, and brownish when more weathered), micaceous, clayey sand. The Coon Creek and Ripley are overlain by the McNairy Sand and underlain by the Demopolis Chalk (Russell and Parks, 1975).

The type section itself is approximately 40-feet-thick





**FIGURE 1.** The Coon Creek type section in McNairy County, Tennessee, with horizons and fossil material as discussed in the text. For a correlated stratigraphic chart with other formations in the region, see Brister and Young, this volume.

(~12.2 m) from the base of the creek to the soil horizon of the forested hill top (Fig. 1). The color of the sediment varies from medium bluish gray for fresh exposures in the creek (and down section closer to the underlying Demopolis Chalk), to medium dark gray and dark olive gray above the creek, and progressing to more brown and yellow tones up to 25 feet (~7.6 m) from the base. Above this, light brown and dark yellowish orange colors dominate. Multiple samples from the lower 20 feet (~6.1 m) of the type section were collected in 2005 by this author and were sieved and found to be 65–75% fine- to very- fine-grained quartz sand. X-ray diffraction analyses of Coon Creek lower facies samples in the McNairy County area collected in 2003 showed a mineralogical makeup averaging 15–20% illite, 10–15% kaolinite, 60–65% quartz, ~5% muscovite, and traces of glauconite, biotite, and heavy minerals such as ilmenite (Keller, 2003). Illite, a gray clay, is the main contributor to the color (Fig. 3) at the type section, and may also contribute to preservation quality.

The lower 23 feet (~7 m) is the most fossiliferous in terms of well-preserved bivalve and gastropod fauna, with specimens from the lower 10 feet (~3 m) in particular having the best shell preservation (Fig. 3), including some with preserved nacre. Cephalopods, scaphopods, and decapods are found throughout the lower 30 feet (~9.1 m), with some horizons containing a greater abundance of decapods that is traceable down the creek. Burrows are found in most of the section and lignitic plant material is found in at least two horizons (5 feet (~1.5 m) and ~30 feet (~9.1 m)). The lower 10 feet (~3 m) and below the stream base is calcareous, and samples collected in 2005 were rich in calcareous nannofossils.

Concretions can be found at multiple horizons (9, 16, and 36) and some contain decapod and ammonite material. At ~20 feet (~6.1 m) is a chalybeate horizon, with iridescent ochre- to rusty-colored leachate. A reddish brown moldic, condensed zone creates an overhang from ~25 to 30 feet (~7.6 to 9.1 m). This resistant, condensed, iron-cemented sandstone (Figs. 1 and 3) contains a wide variety of taxonomically diverse internal and external molds and some body fossils. Above this zone, the



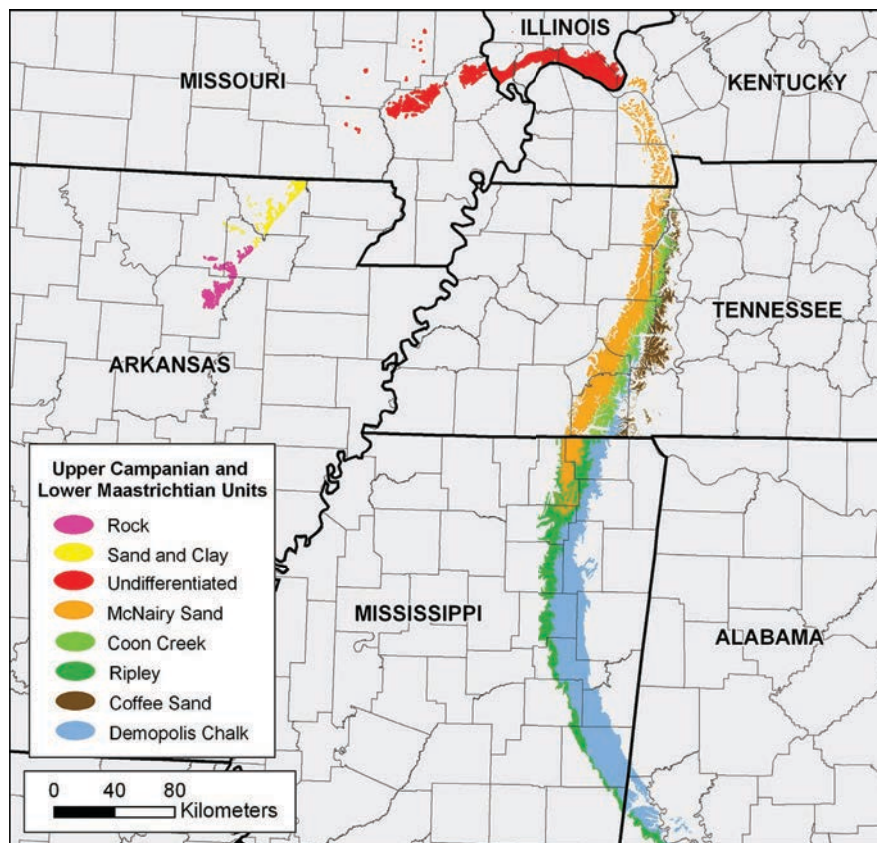


FIGURE 2. The Coon Creek Formation type section (black star) in McNairy County, Tennessee, and its correlated upper Campanian to lower Maastrichtian outcropping lithostratigraphic units outlining the upper Mississippi Embayment. Modified from Ebersole, 2010. Formations on map are geospatial data from state geologic maps (Miller et al., 1966; Bicker, 1969; McDowell et al., 1981; Szabo et al., 1988; Haley et al., 1993; Middendorf et al., 2003; Kolata, 1981).

sand is brownish in color, coarser, and has some cross bedding and sand-clay laminations.

### PRESERVATION AND DEPOSITIONAL ENVIRONMENT

The lower Coon Creek facies is highly fossiliferous in many locations (Fig. 3, and image on the front of this volume) with high preservation quality and high molluscan diversity. This has been identified as a lagerstätte as noted by Dunagan and Gibson (1993) and Gibson and Dunagan (2003). High preservation quality of the lower facies may be due, in part, to the highly impermeable non-swelling (illite) and very low-swelling (kaolinite) clay component. The preservation quality and diversity may also be associated with the protected environment of deposition. Elongate, cross-bedded lenses of lower McNairy Sand are found within the Coon Creek Formation in some locations (Russell and Parks, 1975). These relict barrier bars and islands are age-equivalent to the Coon Creek, and, in the late Campanian, would have provided wave protection for the back-barrier setting of the Coon Creek depositional environment (Ebersole, 2010). Upper facies of the Coon Creek and the Ripley are interpreted as open marine



FIGURE 3. An example of the Coon Creek fossiliferous matrix with *Crassatellites*, *Pterotrigonia*, and other bivalves. Coon Creek type section in a bank of the Coon Creek, McNairy County, Tennessee. Brown rocks in the photo are talus from the overhanging resistant sandstone above the creek.

nearshore environments (not behind barrier islands), as described by Russell and Parks (1975) and Ebersole (2010). For illustrations of the paleogeography of this area, see Brister and Young (this volume).

## THIS BULLETIN

This Museum Bulletin highlights some of the unique paleontology of the Coon Creek including multiple molluscan taxa (Wingard, volume 1), gastropods (Bandel and Dockery, volume 1), cephalopods (Larson, volume 2), decapods (Bishop, volume 2), echinoids (Ciampaglio and Phillips, volume 2), bryozoa (McKinney and Taylor, volume 2), plants (Dilcher, volume 2), pollen (Baghai-Riding, volume 2), fish (Stringer, volume 2), and pterosaur (Harrell, Gibson, and Langston, volume 2). This comprehensive volume on the Coon Creek Formation has been a long time in the making, and we are grateful to the many authors who submitted manuscripts to this effort. Appreciation is also extended to the reviewers of the manuscripts within this bulletin as well as the Alabama Museum of Natural History for allowing these research efforts to be printed as a collection.

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# Review of the discovery, research, and preservation of the Coon Creek type section locality

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**Abstract**—The history of research at the Coon Creek site begins with a briefly mentioned visit from Tennessee State Geologist Gerard Troost in the 1830's. Bruce Wade rediscovered the site in 1915, and published a comprehensive manuscript on its fauna eleven years later. Originally purchased by the Weeks family in 1867, the farm was sold to Margaret and A. Z. Smith in 1952. Over the years, the Weeks and the Smiths graciously hosted scores of geologists studying their property. The most comprehensive investigations include Norman Sohl's research on Coon Creek gastropods in the 1950s and Ernest Russell's studies of the stratigraphy of the Cretaceous and Tertiary deposits of West Tennessee in the 1960s - 70s. Coon Creek foraminifers, ostracods, and stratigraphy were the topics of several graduate theses from the 1950s to the 1990s. Memphis Museums, Inc. purchased the site from A. Z. and Margaret Smith in 1987 and opened the Coon Creek Science Center the next year. The site is now used for educational programs in paleontology, geology, astronomy, and ecology.

## INTRODUCTION

The Coon Creek Science Center is the type locality for the Coon Creek Formation of the Maastrichtian Stage of the Upper Cretaceous Senonian Epoch (Russell and Parks, 1975). The site is located in northeastern McNairy County, Tennessee, about 90 miles east-northeast of Memphis (Fig. 1).

Coon Creek, located in West Tennessee farmland, is characterized by gently rolling hills covered with second growth forest. Numerous creeks flow northward and eastward into the Tennessee River draining the land. The sandy soil is susceptible to rapid and extensive erosion forming deep gullies and ravines. Coon Creek flows through the science center from south-southwest to north-northeast (Fig. 2). The eastern part of the site is marked by a steep, forested bluff along the creek about 30 feet high and cut by deep ravines. On the western side of the creek is a narrow floodplain. Abandoned cornfields, now planted with grass, occupy this floodplain. The western margin of the site is also hilly, but with a gentler slope than the western side (Brister, n.d.).

The sandy-clay deposits at Coon Creek reflect the flooding of western Tennessee by a bay of the Gulf of Mexico about 73 million years ago (Fig. 3). A zone of crustal weakness centered in the modern Mississippi valley sagged into a shallow, wide trough called the Mississippi Embayment (Figs. 4 and 5). This extended from Little Rock, Arkansas, on the west, to the Tennessee River on the east. Southern Illinois marks the northernmost extension. Memphis, located in the center of the ancient bay, is built on 3,200 feet of marine and continental sediment (Brister, n.d.).

The margins of the bay (Fig. 6) teemed with marine life. Crabs, snails, lobsters, clams, scallops, whelks, nautilus, sharks, and other familiar animals lived in the warm, shallow sea, eating, reproducing, and being eaten. Giant reptilian mosasaurs, highly ornamented cephalopods, and other less familiar sea creatures lived in the water. Their shells, carapaces, teeth, and other hard parts were constantly being buried in the sandy mud of the seafloor. The lack of distinct layering indicates that

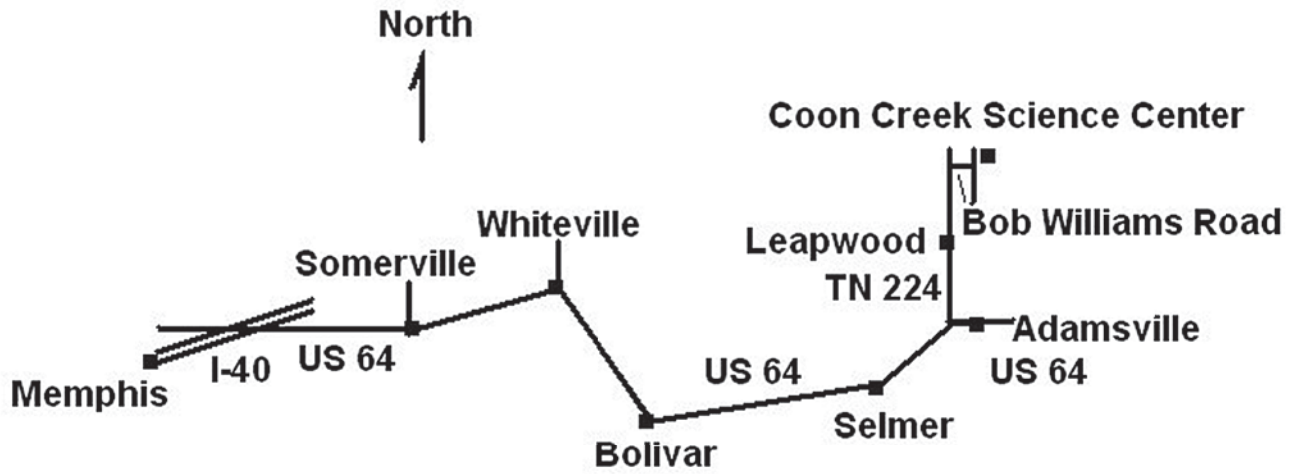


FIGURE 1. The Coon Creek site is located in northeastern McNairy County, Tennessee, about 100 miles east-northeast of Memphis. Image courtesy of the Memphis Pink Palace Museum.

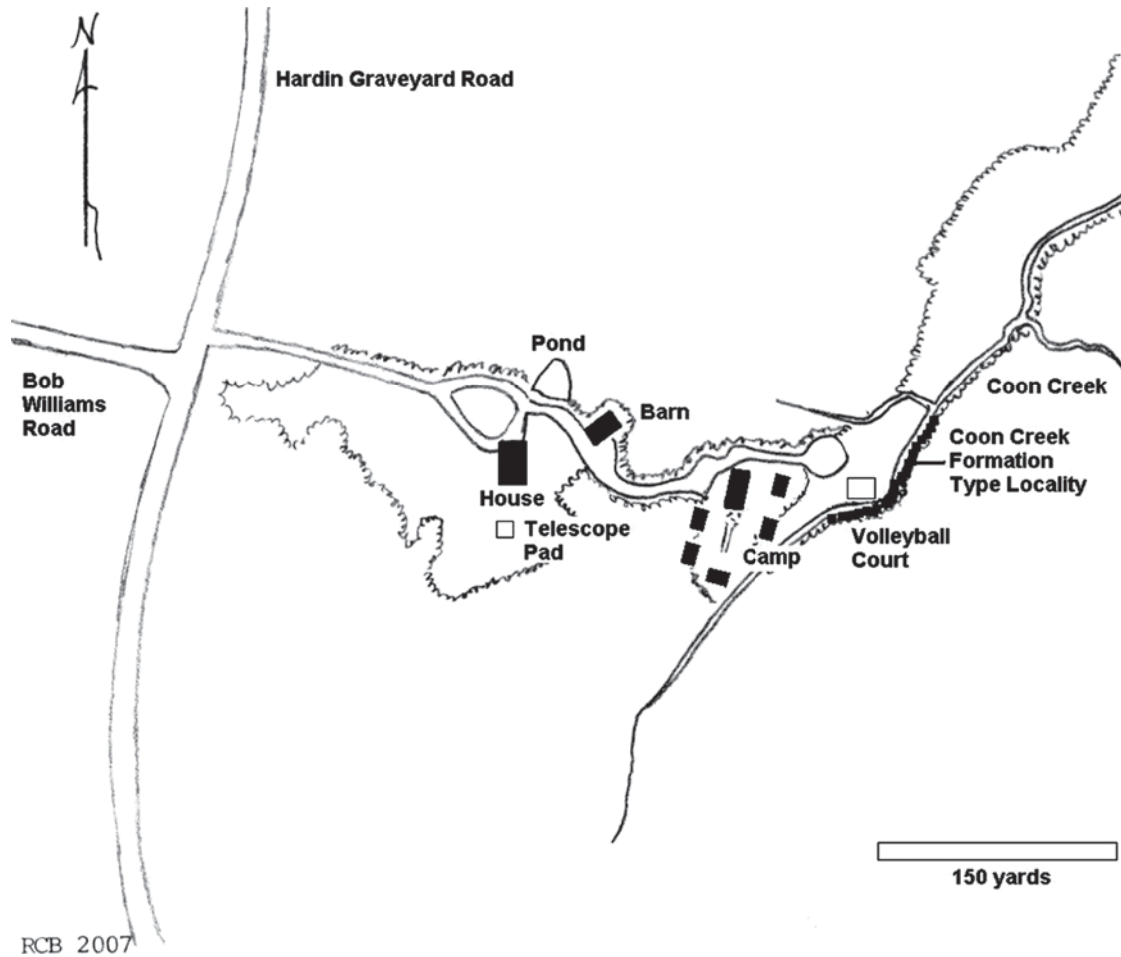


FIGURE 2. Sketch map of the Coon Creek Science Center. It is located on 240 acres of West Tennessee farmland about 100 miles East of Memphis. The center features a dining hall, three sleeping cabins, a research office, and site office. Image courtesy of the Memphis Pink Palace Museum.



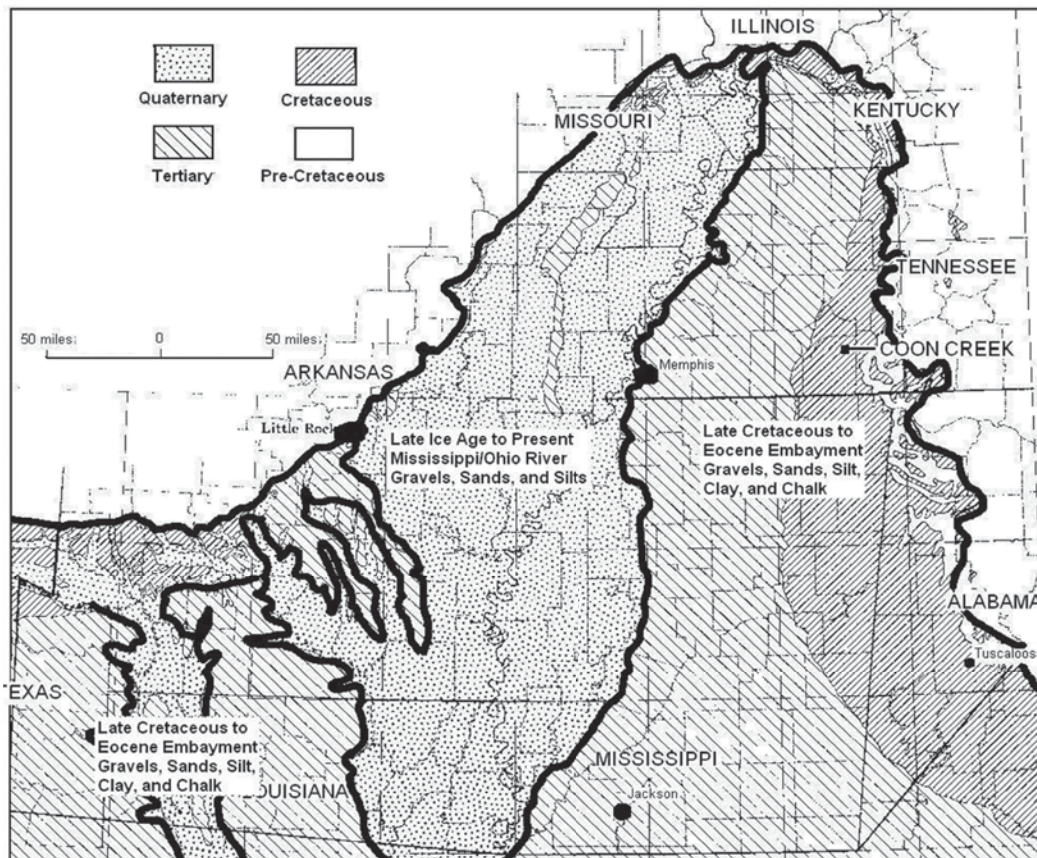
**FIGURE 3.** Shallow seas overflowed the eastern and western coasts and covered the interior of North America from the Gulf of Mexico to the Arctic Ocean during the Late Cretaceous Period around 71 million years ago. This rise in sea level was probably caused by expansion of the mid-oceanic ridges during increased periods of plate formation. Modified from Schlee, 1991.

burrowing organisms disturbed the bottom sediments. Periodic hurricanes may have brought in heavy loads of river sediment to bury the plants and animals living there. Conditions for life were ideal; the water was warm and of normal salinity. Wave action insured sufficient oxygenation (Wade, 1926).

### THE DAVE WEEKS PLACE

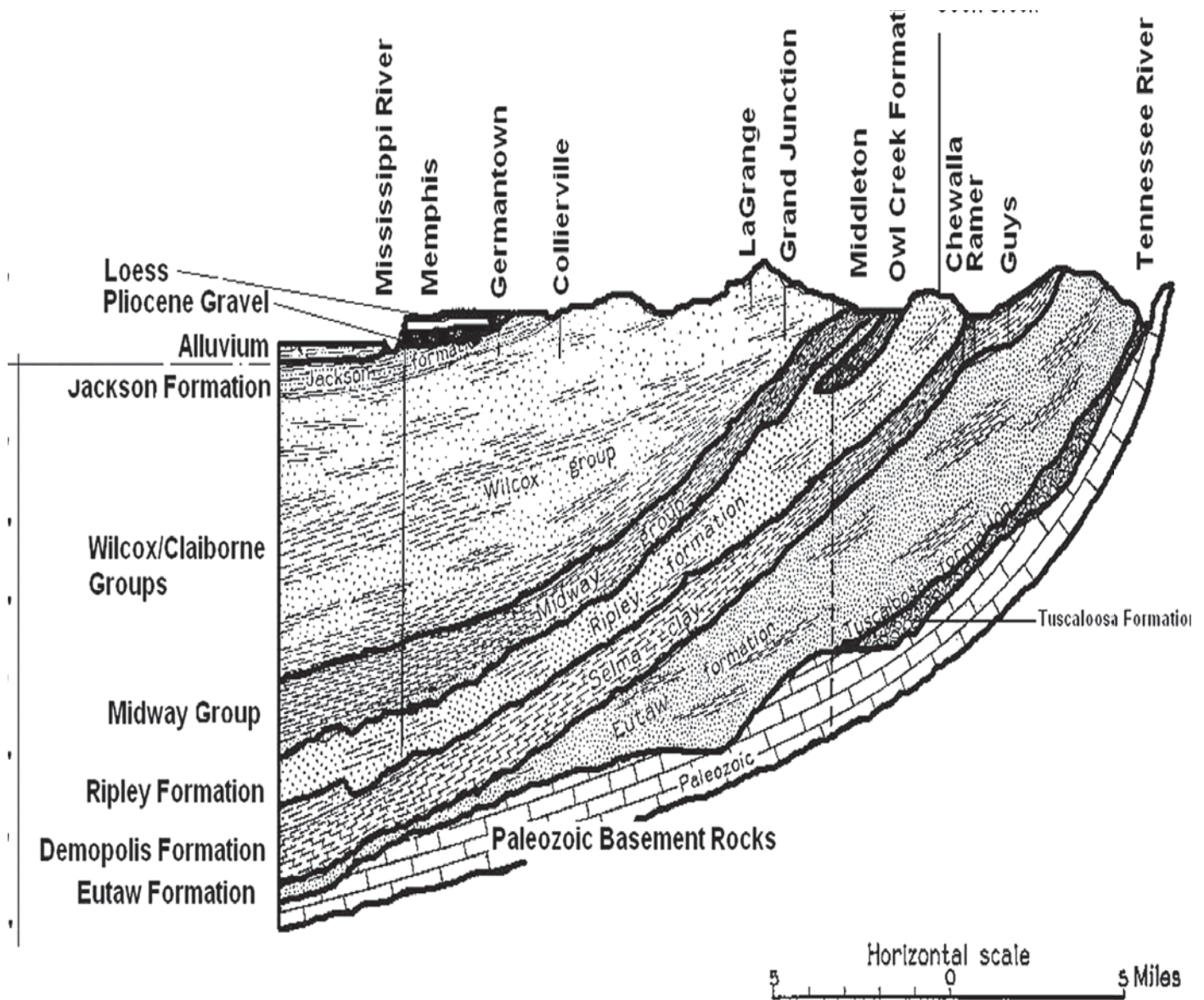
Dave Weeks (Fig. 7) told the history of his family’s and their purchase of the Coon Creek farm to his grandson, John D. Mills, in the 1930s. Mills told the story to the McNairy County newspaper in 1988.

In the spring of 1834, Dave’s parents, Gerry Weeks and Eliza Ann Rhodes Weeks, along with their children, started out from North Carolina and migrated about 1000 miles to the Iowa territory in a covered wagon. The children and all the family’s belongings rode in the wagon, while their parents walked the entire trip which lasted nine weeks. The family stopped at streams along the



**FIGURE 4.** A general geologic map of the Mississippi Embayment. The embayment is a shallow trough filled with sediment from two major geologic events. To the East of Memphis are sands, clays, and gravels from the invasion and subsequent retreat of the Gulf of Mexico. To the West are alluvial soils resulting from the formation of the Mississippi/Ohio valley and its later modification by glacial filling and scouring. This map is from E. H. Boswell, G. K. Moore, and L. M. McCary “Cretaceous Aquifers in the Mississippi Embayment,” United States Geological Survey Professional Paper 448-C, Figure 2.





**FIGURE 5. Cross section of The Mississippi Embayment. Although some of the stratigraphy is dated, this section shows how sediments filled a shallow around 75 million years ago. The trough formed by rifting when North America almost pulled apart hundreds of millions years earlier. The vertical scale of the deposits are greatly exaggerated. Modified from Francis G. Wells' 1933 "Ground Water resources of Western Tennessee," United States Geological Survey Water-Supply Paper 656, plate 5.**

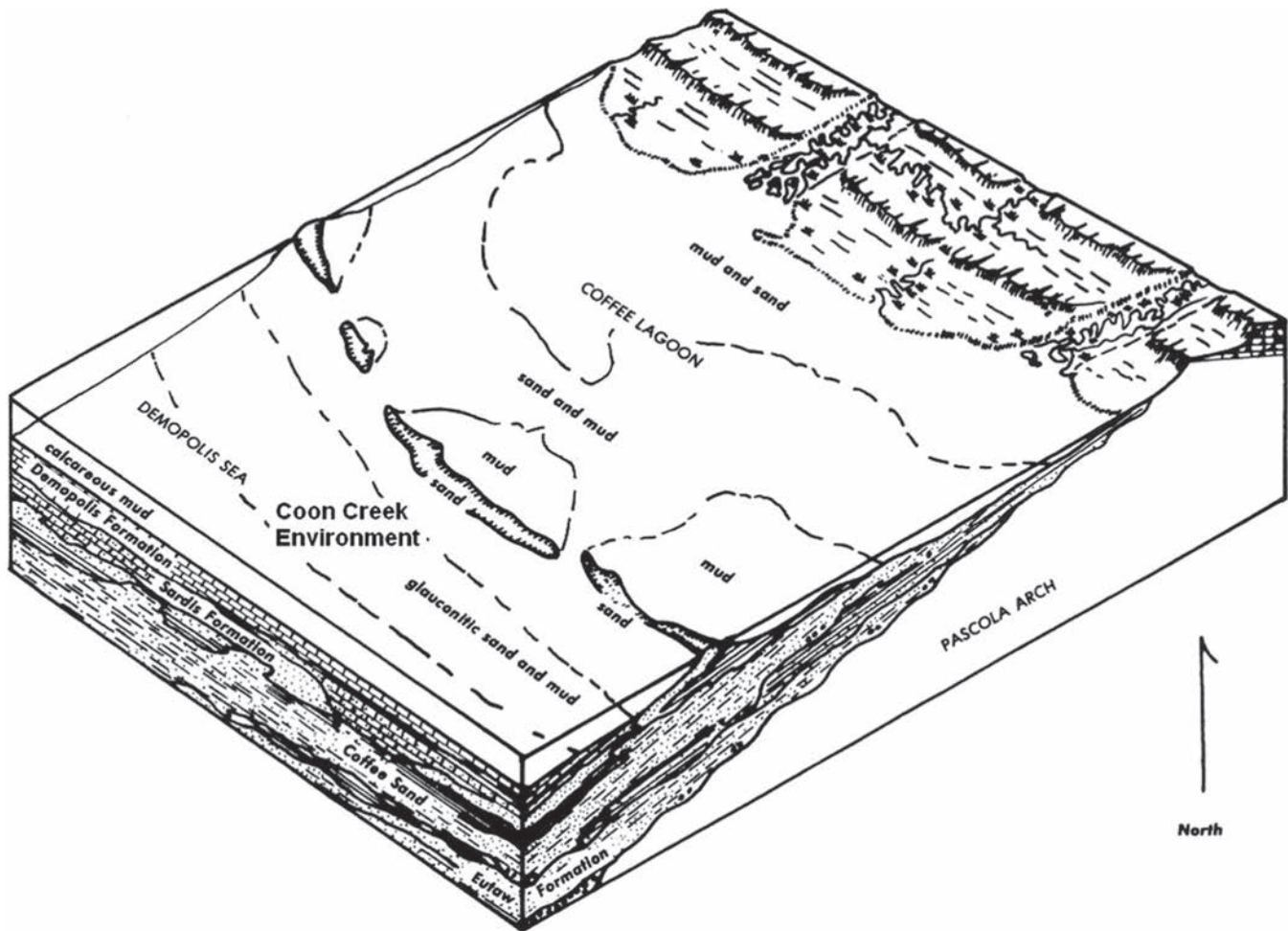
way to wash their clothes, hanging them on the side of the wagon to dry as they traveled across the country.

It is unclear just how long the Weeks family stayed in Iowa, but it was not long due to extremely cold weather and unfriendly Indians. They soon became unsatisfied and moved back South, this time settling near Henderson, Tennessee. On Dec. 8, 1852, Dave Weeks was born in Henderson and lived there during his early childhood. He was the youngest of nine children in the Weeks family.

On Aug. 7, 1856, Dave's father purchased a tract of land in McNairy County from James M. Hunter. The Weeks family lived at this place during the Battle of Shiloh. In fact, Dave later told me that he was 9 years old at this time and he could actually hear the blast of the cannons during that two day battle on April 6 and 7, 1862.

On Jan. 9, 1867, the Weeks family purchased 176 acres of the Coon Creek place for \$1000 from W. S. Wisdom. Two months later, Dave's father died on March 14, 1867. During a seven-year period, Dave's mother finished paying off the place and continued to own it until Jan. 14, 1888, when Dave purchased it from her for \$125. An additional 75 acres or so was purchased by him from sources unknown to me bringing the total acreage to about 250. From then on, until 1953 when A. Z. Smith purchased it from the Weeks family, it was known by geologists worldwide as the Dave Weeks Place Coon Creek, Enville, Tn.

When the Weeks family moved onto Coon Creek place in 1867, it was mainly all in virgin timber. Because it was at the headwaters of Coon Creek, at this point it was only a small ditch and the fossils were still deep underground.



**FIGURE 6.** Dr. Ernest Russell's interpretation of the paleogeography of the Coon Creek site. Coon Creek was located in the glauconitic sand and clay zone between the still waters of the Demopolis sea and the brackish waters of the Coffee lagoon. Image modified from Russell and Parks' "Stratigraphy of the Outcropping Upper Cretaceous, Paleocene and Lower Eocene in Western Tennessee, including descriptions of younger Fluvial Deposits." Tennessee Division of Geology Bulletin 75, figure 37, page 53A.

With all the land primarily in huge timber, it had to be cleared for farming. There was not much of a market for timber in those days and no way to get it to market if there was, so the only thing they could do was to cut the trees into logs, pile them up and burn them. Neighbors were few and far between, but they would manage to get a few men together to cut logs. The events were called "log rolling". The women prepared food for the log rollers, which was all the pay the men received.

After clearing his land, Dave later told me he used his shovel to dig the creek deeper in places so it would carry more rain water from his bottom land. After some twenty years or so of washing out by rain water, the fossils were uncovered beneath the site where he had dug.

During the teens and early 1920's, Bruce Wade, a geologist, spent a great deal of time with Dave, collecting and cataloguing fossil specimens. He even named one fossil (sic) in honor of my grandfather- the "Cerithium Weeksi" (sic) and is pictured on page 246 of a hard cover

book titled "Coon Creek Fauna." In 1932, a copy of this book was presented to Dave by the Department of Geology of Vanderbilt University, Nashville, in recognition of the contribution his fossils had made to the science of geology. This book contains autographs of many of the geologists (from all over the United States as well as Johannesburg, So. Africa and London, England) who visited Coon Creek between 1933 and 1941. Today, the book still remains in the possession of the Weeks family.

My grandfather, Dave Weeks died on November 20, 1941, just a few weeks short of his 89th birthday. (Wagoner: 1988, p. 1)

Weeks lived on the farm with his family in a comfortable white frame house (Fig. 8), growing cotton on the hills and corn in the bottoms. Farming was hard and not very profitable work so he supplemented his income as a brick mason, building some of the stores in nearby Leapwood (Barnes, 1989)





**FIGURE 7. Dave Weeks, 1852-1941, was owner of the Coon Creek site from 1888 until his death. Image courtesy of Dave Week's daughter, Mrs. Bertha Tidwell, Memphis Pink Palace Museum collections.**

Weeks met 26 year old student geologist Bruce Wade in the summer of 1915. Wade was systematically mapping the outcropping Cretaceous deposits of West Tennessee for his doctoral dissertation at Johns Hopkins University. His advisor, the aptly named Edward W. Berry, was a renowned paleobotanist with extensive field experience studying the Eocene deposits of western Tennessee. Berry had arranged for Wade to spend several weeks in northern Mississippi with Lloyd W. Stephenson and E. N. Lowe, familiarizing himself with established Cretaceous and Tertiary stratigraphy. Wade then extended the known formations into nearby, uncharted McNairy County.

Weeks had first noticed an abundance of shells on his property around the turn of the century after he deepened a drainage ditch in the Coon Creek bottoms (Wade, 1926). The creek rapidly eroded downward exposing bluish sandy clay and its well preserved fossils (Fig. 9). According to family tradition, Weeks ground up some of the fossil shells to feed his chickens to strengthen their eggshells. When Wade (Fig. 10) drove his rented team and wagon from Selmer up to the Weeks place in July of 1915, Dave was ready to talk about the shells in his backyard.

Wade made a quick collection of fossils and sent them to Professor Berry in Baltimore. Berry was impressed by the perfect condition, abundance, and large variety of the ancient animals found at Coon Creek. The perfect preservation of the ornamentation and anatomical features was unheard of in fossils of their age. Wade was advised to change his dissertation to a monograph on the gastropods at Dave Weeks' farm. Wade agreed and began researching several reports on the site and its uniquely preserved fauna.

Wade developed a close relationship with Dave Weeks, his wife, and children. Bertha Weeks Tidwell, who had



**FIGURE 8. Grandson Hurshel Weeks photographed by Dave Week's modest white frame home on Coon Creek. Image courtesy of Dave Week's daughter, Mrs. Bertha Tidwell, Memphis Pink Palace Museum collections.**

been a young girl during the Wade era, was still living in the 1990s. She had saved a carefully folded photo of Wade. Around the edge she had written in a childish hand "my sweetheart". The impact of the visits from the sophisticated scholar on the isolated family must have been immense. Whenever Wade dropped by the farm to collect, Dave and his sons were quick to help (Figs. 11 and 12). Photographs taken by Wade show Dave and the barefoot boys dressed in overalls digging with rock hammers in the overgrown creek bed. The fresh, uncollected exposure furnished exceptional specimens with little effort. Wade's final 272-page monograph on Coon Creek is based on only two-week's collecting at the site (Wade, 1926).

## THE JOHNS HOPKINS UNIVERSITY CONNECTION

The early years of the 20th century saw a flurry of geological research in western Tennessee, all with a Johns Hopkins University connection (Wilson, 1981:20). Vanderbilt University geology professor L. C. Glenn, PhD, Johns Hopkins 1899, published "Underground Waters of Western Kentucky and Tennessee" (Glenn, 1906) summarizing the area's Cretaceous and Tertiary geology. His use of well logs helped refine and expanded on earlier work by Gerard Troost (Troost, 1840), James M. Safford (Safford, 1869) and others in the mid-to-late 19th century.

Shortly after, Johns Hopkins paleobotanist Edward W. Berry visited West Tennessee as part of his research on the Eocene deposits and their beautifully preserved fossilized plant remains (Berry, 1916).





**FIGURE 9.** A member of the Weeks family in Coon Creek around 1917. Wade's first view of Coon Creek was very different from what is seen today. Rapid erosion has significantly deepened the creek in the 85 years since Wade's last visit. This photo is from Wade's article "Recent Studies of the Upper Cretaceous of Tennessee" published in the *Administrative Report of the State Geologist*, 1919. *Tennessee Geological Survey Bulletin 23*, facing page 60.

Berry's close friend, Lloyd W. Stephenson of the United States Geological Survey, was also a Johns Hopkins PhD (Monroe, 1964). Stephenson devoted his long and productive career to study of the geology of the Atlantic and Gulf Coastal Plain in North Carolina, Georgia, Alabama, and Mississippi and Texas. Unfortunately, there was friction between the federal and state surveys and Stephenson was not welcome to work in Tennessee. He needed a proxy geologist to provide information. His friend Berry assigned new doctoral student Bruce Wade to refine the general geology of outcropping Cretaceous beds in Western Tennessee in 1915 (Sohl, 1990).

### BRUCE WADE

This section is an updated and expanded version of a biography of Bruce Wade published in *Earth Science History* (Brister, 1994). Robert Bruce Wade was born near Trenton, Tennessee, to Robert Bruce Wade and Sara Mitchell Wade on November 11, 1889 (Wade 1917f). Young Wade, named after his father, was also known by his middle name Bruce (Lawrence, oral communication, 1991).

There was a strong academic tradition in the family and all the children were educated in prominent colleges. Tuition and living expenses were met by selling blocks of



**FIGURE 10.** Bruce Wade, 1889-1973, published the first comprehensive description of the Coon Creek fossils and the Cretaceous geology of West Tennessee in 1926. Image courtesy of the Memphis Pink Palace Museum.



**FIGURE 11. Unidentified fossil collectors in Coon Creek. Members of the Weeks family generously assisted Bruce Wade in his collecting efforts from 1915 to 1920. This photo is from Wade's article "Recent Studies of the Upper Cretaceous of Tennessee" published in the Administrative Report of the State Geologist, 1919. Tennessee Geological Survey Bulletin 23, facing page 60.**

land as each child reached college age (Lawrence, oral communication, 1991). One of the six Wade children died young. Two brothers entered the apple industry in Washington State and another became a commission merchant in Galveston, Texas. Wallace Wade became a renowned football coach at the University of Alabama and Duke, where the stadium is named after him. Several of his teams went to the main East-West championship game, the Rose Bowl (Culp and Ross, 1961).

Young Bruce was educated in Trenton, graduating from Peabody High School in 1907. He enrolled in the Fitzgerald and Clark School for Boys in Trenton to prepare for college. While there, Wade won medals for excellence in Greek and Latin. He entered Vanderbilt University in 1909, earning his Bachelor's degree in 1913 and his Masters in 1914 (Wade, 1917f).

Bruce Wade's years at Vanderbilt are best summarized by the 1914 Commodore yearbook description of his 1913 election as winner of the coveted Bachelor of Ugliness (most popular student) award.

In the fall of 1909, Bruce Wade entered Vanderbilt University from the Fitzgerald and Clark School, Trenton, Tennessee, and enrolled in the Academic Department as a

candidate for the degree of Bachelor of Science. Through his whole college course, Wade stood high in his class and was extremely popular.

For three years he was a member of the Reserve eleven and was elected captain in the fall of 1912. He was a star on the 'Varsity Track Team for two years. He was prominently identified with the Vanderbilt Y.M.C.A. and the West Side Association, and served one term as post-master at Kissam Hall.

In his senior year he was elected to the Commodore Club and closed his brilliant career as undergraduate by being elected Bachelor of Ugliness, the highest honor conferred by the student body at Vanderbilt. Upon receiving his B.S. degree in June, he was elected to the teaching fellowship in Geology and became connected with the Tennessee State Geological Survey. Wade receives his M.S. degree this June. (Sims, 1914, p. 353).

The silver headed cane presented to Bruce Wade as part of the unique Bachelor of Ugliness award is preserved in the collections of the Memphis Pink Palace Museum.

Wade studied under Dr. L. C. Glenn, who also worked for the Tennessee Geological Survey and served briefly in 1918 as State Geologist (Jewell and Wilson, 1952). He was instrumental in finding summer work at the survey





**FIGURE 12. Dave Weeks generously helped collect fossilized seashells in the creek on the farm for his friend Bruce Wade. Image from the collections of the Tennessee Division of Geology.**

for Wade. Glenn, another Johns Hopkins PhD, probably influenced Wade's choice for doctoral study.

Wade worked his way through graduate school at Vanderbilt by teaching in the geology department during the school year and doing geological survey during the summer. He served as a United States Geological Survey field assistant in the summer of 1913, surveying the Waynesboro quadrangle in South-Central Tennessee under the supervision of Hugh D. Miser (Miser, 1921). Wade spent the Thanksgiving vacation of 1913 in the field in Lawrence County (Purdue, 1914) providing detail for Olaf P. Jenkin's Geologic Map of Tennessee (Jenkins, 1915).

"The Geology of Perry County and Vicinity", Wade's first publication, was issued by the Tennessee Geological Survey in October of 1914 in Resources of Tennessee. This reconnaissance report was based in part on three month's work in the adjacent Waynesboro quadrangle with Miser in the summer of 1913 and four weeks work on the geology of Perry County for Jenkins' Geologic Map of Tennessee in January and February, 1914 (Wade, 1914).

Wade worked under challenging field conditions. The base map upon which he traced rock outcrops was scaled at eight miles to the inch making it difficult to precisely locate rock outcrops. Travel conditions on country roads

were primitive at best and he had little time to complete his work. Unable to produce a detailed report in the time allotted for his fieldwork, Wade tried to clearly depict the general geology of the area (Wade 1914).

Carl O. Dunbar acknowledged Wade's contributions in his 1919 study of the Devonian of West Tennessee.

In 1914, Wade published an important account of the geology of Perry County and vicinity, which described the nature of the Devonian formations in these their most eastern outcrops. His geologic map is the first detailed geologic map of any portion of the (Tennessee) valley (Dunbar, 1919: p. 32).

Bruce Wade entered the Johns Hopkins University as a graduate student on October 5, 1914. He worked in the Geological Laboratories of Dr. W. B. Clark. His advisor was Edward W. Berry whose comprehensive monographs on the fossil plants and ancient ecology of the Southeastern United States made him one of the outstanding paleontologists of the day. (Berry, 1916, 1919, 1925, and 1930). Berry suggested that Wade describe and map the Cretaceous deposits of Western Tennessee for his dissertation (Wade, 1926).

Wade applied for the degree of Doctor of Philosophy on February 2, 1916, with the intention to take his examinations in paleontology and physical chemistry in June of 1917. His principal subject was geology. Paleontology was his first subordinate and physical chemistry was his second subordinate subject (Johns Hopkins University, 1916).

During summer vacations from classroom work, Wade surveyed, first by horse and wagon and then by motorcycle, the Upper Cretaceous deposits of McNairy, Decatur, and Chester Counties of Tennessee (Nelson, 1919 and Wade, 1915). He prepared a geological map and made rock and mineral collections for county reports. These studies proved to be especially valuable to Professor Berry (Berry, 1919 and 1925). Berry's "The Flora of the Ripley Formation" credited Wade for most of the specimens used in the report.

Special acknowledgement is due to Bruce Wade for the industry and skill with which he has studied the Cretaceous of Tennessee and collected the material upon which the present paper is presented (Berry, 1925: p. 1)... Those (determinable plant fossils) discovered in West Tennessee are due almost entirely to the field work of Bruce Wade, and the localities, with the exception of Big Cut in McNairy County, have not been visited by me... (Berry, 1925: p.5).

In the course of his work, Wade found the first reported North American insect in amber in the Cretaceous deposits at Coffee Landing, Hardin County, Tennessee, (Cockrill, 1917).



Bruce Wade discovered the Coon Creek fossil site on the Dave Weeks farm in northeastern McNairy County, Tennessee, on June 29, 1915. His field notes record:

**Dave Week's place**

20' white clayey material not well exposed

30' iron concretion and clay

25' fos. Micaceous shale yellowish-red

10' bluish micaceous, extremely fossiliferous, shells beautifully preserved. Exposure 1/4 mile down creek. Important that a good collection be made here (Wade, 1915)

Wade collected the locality several times during the 1915 field season. His eight publications from 1917 and 1918 reflect the extent of his work on the Coon Creek fauna, the extent of the Tuscaloosa Formation, and the gravel resources of the Lower Tennessee Valley (Wade, 1917a, b, c, d, e and 1918 a, b).

Wade noted in his 1917 report, "A Remarkable Upper Cretaceous Fauna from Tennessee (Wade, 1917a), that he had found nearly 300 species of fossil animals. The preservation and variety of fossils from Coon Creek filled a major gap in the fossil record, proving critical to understanding Cretaceous-Tertiary trends in molluscan evolution. Berry suggested that Wade change his dissertation topic from the Cretaceous geology of Western Tennessee to the fossils of Coon Creek (Wade, 1926). Wade's dissertation "The Gastropoda of the Ripley Formation, Tennessee", was successfully defended in May of 1917 (Wade, 1917f).

The United States entered World War I before Bruce's graduation. The new Dr. Wade volunteered for the United States Army.

**Gibson County Boys to Officer's Camp**

Five Gibson County boys were successful in their application to the second officers in training camp at Ft. Oglethorpe, Georgia. They were Hector Yates, Bruce Wade, Chas. B. Shankland, and Frank Knox of Trenton... (Herald Democrat, 1917a)

The many men who received their commissions at Camp Warden McLean will be sent to all parts of the country, but the Gibson County boys will report to Camp Pike (Little Rock, Arkansas). ... Bruce Wade, Trenton, was commissioned second lieutenant, field artillery (Herald Democrat, 1917b).

Lt. Wade was sent to Europe with the 350th Field Artillery of the famed 92nd "Buffalo" Division, serving as an officer in this traditionally black unit. In addition to courage under fire, the 350th's band was credited with introducing American jazz to Paris.

Tim Brymn and his Black Devil Orchestra were an all

African-American 70 piece, musical unit that represented the 350th Field Artillery Regiment during World War I. Tim Brymn's band was described at the time as "A military symphony engaged in a battle of jazz" (Alexander, 2002).

Wade served honorably and was wounded in battle (Lawrence, oral communication, 1991).

Wade returned to the Tennessee Geological Survey and his studies of the Cretaceous of West Tennessee after the war. He wrote corrections to several of his pre-war papers, admitting that they were prepared in haste prior to leaving for military service (Wade, 1918b)

Wade's Coon Creek faunal studies were expanded to include all animals in 1919 and 1920. The reorganized report was developed into a general monograph on the Coon Creek fauna and Cretaceous geology of West Tennessee. It was published as a Professional Paper by the United States Geological Survey. "The Fauna of the Ripley Formation on Coon Creek, Tennessee" reported 350 species from the site including significant populations of bryozoans, gastropods, bivalves, cephalopods, crabs and lobsters, along with shark teeth and mosasaur remains (Wade, 1926). Interestingly, Wade reported that he found no foraminifera at the site (Wade, 1926) an inconsistency



**FIGURE 13. Photo of Bruce Wade in his Transcontinental Petroleum Company offices in Mexico in 1923. Image courtesy of the Memphis Pink Palace Museum.**

quickly corrected by two micropaleontological studies (Berry and Kelly, 1929 and Cushman, 1931). Additional scholarly articles on the Upper Cretaceous deposits of Tennessee and the genus *Hamulus* (Morton) were published during this period (Wade, 1920a, b, and 1922).

Wade left academic research in 1921 to join the Transcontinental Petroleum Company in Tampico, Mexico, as an oil exploration geologist (Fig. 13). He attended the September 1923 Los Angeles meeting of the American Association of Petroleum Geologists and was listed in the AAPG journal as an active (professional) member through 1924 (American Association of Petroleum Geologists, 1923). Wade did not lose interest in the Cretaceous or in the work of his former USGS colleagues. Lloyd W. Stephenson, in his seminal 1933 article “The zone of *Exogyra cancellata* traced twenty-five hundred miles”, credited Wade with supplying three specimens of the mollusk from Ciudad del Maiz and near Cardenas in the state of San Luis Potosi, Mexico, establishing the southern extent of the zone (Stephenson, 1933). Rural eastern Mexico was often a lawless and wild place during the oil boom years of the 1920s (Hamilton, 1966). Photos of Wade in the field show him armed with a revolver (Memphis Pink Palace Museum, Bruce Wade Archive).

While working in Mexico in 1925, Wade suffered a severe illness that robbed him of his memory. His sister, Lucile Lawrence, recalled that not too long after Bruce had returned to Mexico from a visit home, her father received a call from the Trenton stationmaster saying Bruce had returned. He had been put on the train in Mexico and sent home alone. The family never knew if he had become ill before the trip or if the symptoms of memory loss and deep depression developed during the long train ride. They felt that Bruce’s incapacitating illness resulted from overwork in the hot and humid climate (Lawrence, oral communication, 1991).

His long years of study and work at the same time, his long hitch in the service, and the humid location of his research finally took their hold on this large, strong, energetic fellow. He was in and out of the best hospitals his company could find for a long time, finally accepting the inevitable “he must rest for a long time” the doctors say. (Culp and Ross, 1961: p. 118)

Bruce wrote to his mother from the Veterans Hospital in Augusta, Georgia, on Christmas Day of 1925. Hospitalization and separation from his family must have been difficult.

December 25, 1925

To-day has been cheerful and pleasant with little evidence of sickness or suffering to be seen. I hope that you are at home having a most delightful and pleasant holiday season. I wish very much I might be at home with

you. It has been a number of years since I was at home on Christmas (Wade: 1925).

Sister Lucile recalls Wade begging his mother to allow him to come home, if only to be allowed work in the fields (Lawrence, oral communication 1991).

For years Wade was a patient in several southern Veterans Hospitals. Hugh Miser, his old USGS colleague of the 1913 Waynesboro quadrangle survey, visited him regularly (Sohl, personal communication, 1990). Illness prevented Wade from preparing his the Coon Creek manuscript for publication. Timothy W. Stanton, Chief Paleontologist of the United States Geological Survey, edited the manuscript and assembled the plates into USGS Professional Paper 137, “Fauna of the Ripley Formation on Coon Creek, Tennessee” (Sohl, personal communication, 1990). This major contribution to the geology of Tennessee was published in 1926, a year after Wade’s incapacitation by illness.

The advent of strong tranquilizers apparently improved Wade’s health late in life. He wrote a letter in the late 1950s to the Smithsonian requesting a copy of his published Coon Creek monograph. He had never seen it. He also requested information on fossil collecting sites near his hospital in Murfreesboro, Tennessee. The hospital was contacted for permission and the book and information sent. Nothing more was heard of Wade by his colleagues in the USGS (Sohl, personal communication, 1990). Wade had lived in VA hospitals for 47 years when he died on June 25, 1973, at the Alvin York Veterans Hospital in Murfreesboro. He is buried alongside his parents and brother in the Oakland Cemetery in Trenton, Tennessee (Fig. 14).

Bruce Wade’s geological research ended almost eight decades ago, but his memory has not been lost. Memphis Museums, Inc., the not-for-profit support organization for the Memphis Pink Palace Museum purchased



**FIGURE 14. Photo of Bruce Wade’s Grave in Trenton, Tennessee. Photo courtesy of the Memphis Pink Palace Museum. [planned for 1 column width]**



the Coon Creek site in 1987 and converted it into a modern geological and environmental education center. Thousands of visitors have been told the story of the hard working young man from Trenton, Tennessee, who first described and interpreted the unique and important natural treasure that is the Coon Creek fossil site. The Pink Palace Museum presented a copy of "The fauna of the Ripley Formation on Coon Creek, Tennessee" to the Gibson County Public Library in Wade's memory in 1991.

The Memphis Pink Palace Museum has established a Bruce Wade archive containing personal memorabilia, photographs, and copies of his publications and manuscripts in 1991. An exhibit at the Coon Creek Science Center on Wade's contributions to the geology of West Tennessee was installed in 1993.

### THE FOSSIL FARM

Dave Weeks died in 1941, and ownership of the farm passed to his son, Tad. In 1953, Margaret and A. Z. Smith purchased the place from the Week's family. They built a four-bedroom, brick retirement home in 1975. A. Z. added a large barn and put up a mailbox identifying the "Fossil Farm". Paleontologists and amateur fossil hunters came from all over the world and were charged a small fee for the privilege of collecting on one of the country's premier fossil localities (Independent Appeal, 1988). Roy Young, Roger Van Cleef, and Ron Brister, began regular collecting trips for the Pink Palace Museum in 1971 (Fig. 15).

Farm maintenance had become a burden by the mid-1980s. The Smiths approached the State of Tennessee about buying the unique site to preserve its fossil treasures. Negotiations with the state broke down when officials



**FIGURE 15. Photo of the Mosasaur Dig. Excavators are (left to right): Larry Anderson, George Brown, Ron Brister, and Roy Young. Image courtesy of the Memphis Pink Palace Museum. [planned for 1 column width]**



**FIGURE 16. Doug Noble, Director of Museums, was instrumental in acquiring and developing the Coon Creek Science Center. Image courtesy of the Memphis Pink Palace Museum.**

refused to recognize the value of the fossils in determining the purchase price (Independent Appeal, 1988). Tom Miller and Roy Young of the Pink Palace learned of the situation. With the support of curator Ron Brister they approached Museum System Director Doug Noble (Fig. 16). Concerned about preserving the site, developing it for educational uses and building a respectable collection for the Museum, they urged Noble to acquire the property. Noble had visited the site with Young and Brister on several earlier collecting trips and was enthusiastic about buying Coon Creek for use as a science and nature center.

Noble presented a proposal to purchase the site to the Pink Palace's private support group, Memphis Museums, Inc. After a detailed study of the feasibility of a private not-for-profit, science center, negotiations for purchase were begun with the Smiths. They were eager to sell the farm to an institution that would protect and interpret its paleontological resources. The Smiths agreed to sell on February 28, 1988 and the property was transferred to Memphis Museums, Inc. for \$200,000 (Gaither, 1988).

Noble later noted,

A plan quickly emerged to develop physical facilities suitable for use by school groups, teachers, scouting groups, church groups, and researchers. Programming would center on hands-on learning and would include fossil collecting, identification, cleaning, and preparation of the specimens, and studies of paleo-environments and stratigraphy. Visual astronomy programs would take advantage of the rural area's magnificent nighttime skies, which are unobscured by light pollution. Environmental programming was developed utilizing open field habitat,



the creek, the woodlands, and five artificial ponds (Noble, 1996, p. 46).

Memphis architect Larry Bronson donated the development of a site master plan. Five cabins (Fig. 2), with a capacity of 15 people each, were built in a rustic style to fit in with the forested site. A large 27'x72' building featured a commercial kitchen and combination lecture hall/dining with facilities for 50 visitors. Modern restrooms with flush toilets and hot water showers were especially appreciated after a long day's work. A clever wetlands system was constructed to overcome sewage drainage problems. Outflow from the septic system went into two ponds where it was purified by cattails and other plants. Tests revealed that the water leaving the wetlands was biologically purer than water in the creek. The constructed wetlands recycling system served as a living laboratory for ecology classes.

The Coon Creek Science Center provides a unique adjunct to the Memphis Museums System as a field school experience. It has involved the Pink Palace Museum's planetarium staff, education department, and collections departments in instructional and collecting activities. And it has afforded an opportunity for the Museum System's Lichterman Nature Center to become involved in environmental education and interpretation.

The science center has allowed a high degree of interdepartmental cooperation. The center has provided a remarkable opportunity to add significantly to the Pink Palace Museum's fossil collection. The reference collections now include only the most perfect and complete specimens including those focusing on stages of growth and development. Those fossils with physical abnormalities reflecting injury or disease are held in the collections as well (Noble, 1996, p 47).

Doug Noble's vision and willingness to take a chance in purchasing and developing Coon Creek were critical in establishing the science center. Education manager Roger Van Cleef, with a strong background in the biological sciences and museum education, immediately saw the site's potential. He hired Bobby King, an experienced environmental teacher, as the first site manager. Doug Noble noted "Bobby's experience in the environmental field and as a Boy Scout executive and high school biology teacher will be a definite asset to our program (Barnes, 1989, p. 9)". King's dedication to Coon Creek rapidly became apparent with student friendly programming, unique signage, and landscaping. Museum botanist Larry Wilson provided a botanical survey for development of nature trails. With help from geology instructors Alma Larsen and Pam Riddick, Van Cleef produced the core of geology programs still used today. A quarry was opened to provide children with a safe collecting environment and to preserve the original type section of the creek. Planetarium director George Brown and his staff established astronomy programs and worked to build a suitable observatory (Fig. 2). Nearby residents were hired



**FIGURE 17. Roy Young, Memphis Pink Palace Museum Conservator, preparing the Coon Creek mosasaur skull with a compressed air micro-pick. The fossil was so fragile that a touch with the tool would cause the teeth to shatter. Cleaning, hardening, and reassembling the skull fragments took hundreds of hours of tedious and nerve-racking work. Image courtesy of the Memphis Pink Palace Museum.**

to care for the site, cook, and teach programs. The science center has been fortunate in having a number of local instructors who were consistently eager to learn and teach about the site.

Collections staff Roy Young, Margaret McNutt, and Mary Montgomery, assisted by Tom Miller, Nancy Albonetti, Mike Karam, Joyce Godfrey and Phyllis Whittington, began building the Museum's Coon Creek reference and research collection. Young's painstaking cleaning, preserving, and preparation of the fossils resulted in exquisitely beautiful specimens (Fig. 17). The fossils they collected were incorporated into a new 1987 "Geology" exhibit at the Pink Palace.

Coon Creek Science Center began formal programs on September 1, with a Grand Opening on September 17, 1989. Tennessee Conservation Commissioner Elbert Gill helped Noble and Memphis Museums, Inc. officials cut the ribbon allowing over 1,100 excited visitors access to the famed fossils (Reed, 1989).

Noble's belief in the importance Coon Creek was later affirmed by famed paleontologist and popular science writer Stephen J. Gould, who remarked that Coon Creek was one of the twelve most important fossils sites in the United States.

Museums traditionally have constructed buildings to house collections, care for objects, and make them available to the public. The acquisition of the Coon Creek Science Center has allowed the Memphis Museum System

to engage in education, conservation, management, and research at a most unique fossil site. Unlike many sites that are preserved as parks with visitor centers, the programming at the Coon Creek Science Center engages children and adults in the scientific process. (Noble, 1996: p. 47).

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# Review of Norman F. Sohl's contributions to research at Coon Creek, Tennessee

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Abstract—Norman F. Sohl (1924-1993) has a worldwide reputation as an authority on the biostratigraphy, evolution, taxonomy, biogeography and paleoecology of Cretaceous molluscs throughout the eastern United States, the Western Interior, and the Caribbean, but it is perhaps his seminal work on the Coon Creek fossil beds of Tennessee for which he is most remembered. His University of Illinois graduate advisor Bernhard Kummel directed Norm toward working on the excellently preserved and diverse gastropods of the Upper Cretaceous of the Gulf Coastal Plain. The first visit Norm made to Coon Creek was in August 1950 and his work there and in the surrounding region between 1950 and 1953 developed into his master's thesis and dissertation. Eventually this research formed the foundation of his U.S. Geological Survey Professional Papers on the gastropod fauna and stratigraphy of the Ripley, Owl Creek, and Prairie Bluff Formations. Norm was hired in 1954 by the U.S. Geological Survey (USGS) and spent the next 39 years of his career and his life working for the USGS. During those years his research expanded to other regions, but Coon Creek remained a place of special interest and it was here that he sent numerous graduate students and colleagues over the years. These researchers, who have been directly or indirectly influenced by Norm's work at Coon Creek, serve as perhaps his greatest testimonial. Norm's original notes and his reflections on his work at Coon Creek offer insight to the starting point for much of the research that followed.

## INTRODUCTION

In August 1990, following the purchase of the Coon Creek fossil site by the Memphis Museum System, Ron Brister, Chief Curator of Collections for the Museum, contacted Norm Sohl about developing a series of exhibits at the Coon Creek Science Center. In his letter to Norm, Brister stated, "I would like to develop a series of exhibits at the Center honoring the geologists who have conducted research on Coon Creek over the past 74 years. Your 1960 and 1964 USGS publications on the Upper Cretaceous gastropods of Coon Creek and adjacent areas serve as the primary reference on the taxonomy of the snails at the site and the stratigraphy of the area, updating the 1926 publication of Bruce Wade." (R. Brister, pers. comm. to N. Sohl, 8/13/1990; Wade, 1926). Norm Sohl's publications

(Sohl, 1960, 1964) still serve as the primary reference for the gastropods at the Coon Creek site, and it is for the same reasons cited by Ron Brister in 1990 that the history of Norm's work at Coon Creek specifically, and in the region in general, is included in this volume.

Part of Norm's contribution to the museum exhibit, as requested by Brister, was an autobiography. Norm wrote the autobiography between September 1990 and March 1991 and was published in its entirety by David Dockery (1993). Norm's autobiography is the primary source for much of the information included in this manuscript and to a large extent, he is quoted directly because no one could say it better than Norm himself.

## FROM ILLINOIS TO COON CREEK

### Early Years

Norman Frederick Sohl (Fig. 1) was born in Oak Park, Illinois on July 14, 1924. Norm states that his first contact with geology:

Came when I read a high school text for a course taken by my older brother. . . Although suburban Chicago lies within the glaciated area and offers no nearby rock outcrops, I lived near the main line of the Chicago, Burlington and Quincy Railroad, extending to the west from Chicago. Most of the roadbed riprap was composed of Silurian dolomites that commonly bore recognizable remains of corals, brachiopods or other such fossil treasures. However, these rocks were of secondary interest to me at this stage, as my main passion was playing shortstop in pickup games. (Sohl, 1991)

Norm's father died when he was fifteen years old and as he states, "the course of my life changed greatly" (Sohl, 1991). He completed high school in 1942, and was drafted into the Army and sent to Europe, landing on Omaha Beach in Normandy on D-Day, June 6, 1944. He served his country valiantly earning the Bronze Star for his heroic actions at the Battle of Aachen, Germany, and a Purple Heart when he was wounded in the Hurtgen Forest in Germany in late November 1944, which ended his combat role.

### College Years

Returning from the war, Norm took advantage of the



**FIGURE 1. Norman Frederick Sohl in the field in Belgium, November 1987. Photograph by Carl Koch.**

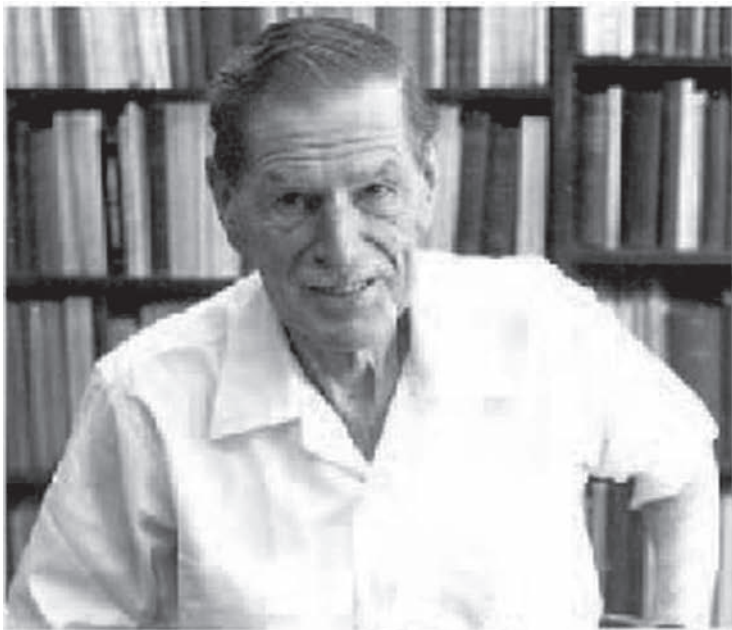
Serviceman's Readjustment Act (G.I. Bill) and entered the University of Illinois in 1946. He married Dorothy Jansen of Sycamore, Illinois in 1947. Norm originally intended to major in history and philosophy, but as he states:

During my junior year I took a beginning course in Geology as an elective. To me the initial appeal of Geology was that it was a discipline that took all of the earth as its natural laboratory. It was the amalgam of all the other scientific specialties applied to solving problems relating to our immediate surroundings. Because of my interest in history, I found stratigraphy and the chronologic aspects of the science especially appealing. (Sohl, 1991)

Norm completed his Bachelor of Science in Geology in 1949 and had hoped to find employment in the oil industry, however, the industry was in a post-war decline and few jobs were available. With more support available under the G.I. Bill, he continued at the University of Illinois at Urbana-Champaign (UIUC) and entered graduate school. Concurrently, he began work as a research assistant with the Industrial Minerals Division of the Illinois Geological Survey. Both the UIUC faculty of the Geology Department and the Illinois Survey staff encouraged Norm to pursue a career in the industrial mineral field, but fortunately for the field of paleontology and stratigraphy other factors intervened.

During my first year of graduate work, I fell under the thrall of a young Professor of Paleontology and Stratigraphy, Bernhard Kummel. I signed up for his course in Mesozoic and Cenozoic Stratigraphy, an action that changed my life. The arena that Bernie used as his setting for stratigraphy was the world and not the classical U.S. approach to which I had been accustomed. Emphasis was on global relationships and basin evolution, not the rote memorization of stratigraphic columns. By the end of that year I had decided that I wanted to develop a career in biostratigraphy. I left the Illinois Survey and accepted a position as a teaching assistant with Kummel and the sedimentary petrologist, Jack L. Hough. Both men remained close friends until their deaths, and I owe both a great debt for all the support they gave me in getting started with my career.

Eventually the time came to decide on a topic choice for my thesis. Kummel and I worked up a list of possible areas of study, one of which was work with the Mesozoic Gastropoda, a likely area, because there were no active specialists in this field in the United States at that time. Bernie submitted the list to paleontologist[s] he knew. Among the replies was one from Lloyd W. Stephenson [Fig. 2], Ralph Imlay [Fig. 2], and John B. Reeside of the USGS at the National Museum, who suggested that I work in the Upper Cretaceous of the Gulf Coastal Plain. Because of the exceptional state of preservation of mollusks that were contained in the Late Cretaceous of Tennessee and Mississippi, we decided on that as the place to work. A significant contribution to knowledge of Cretaceous Gastropoda lay there waiting to be unearthed. (Sohl, 1991)



A. — Woodring



B. — Imlay



C.

**FIGURE 2.** These photographs were hanging over Norm's desk for at least the last ten years of his career, and probably longer. They were the men Norm admired and turned to for advice as he began his career with the USGS. A, Wendell Woodring (date unknown); B, Ralph Imlay (date unknown); C, Lloyd Stephenson, ca. 1950.

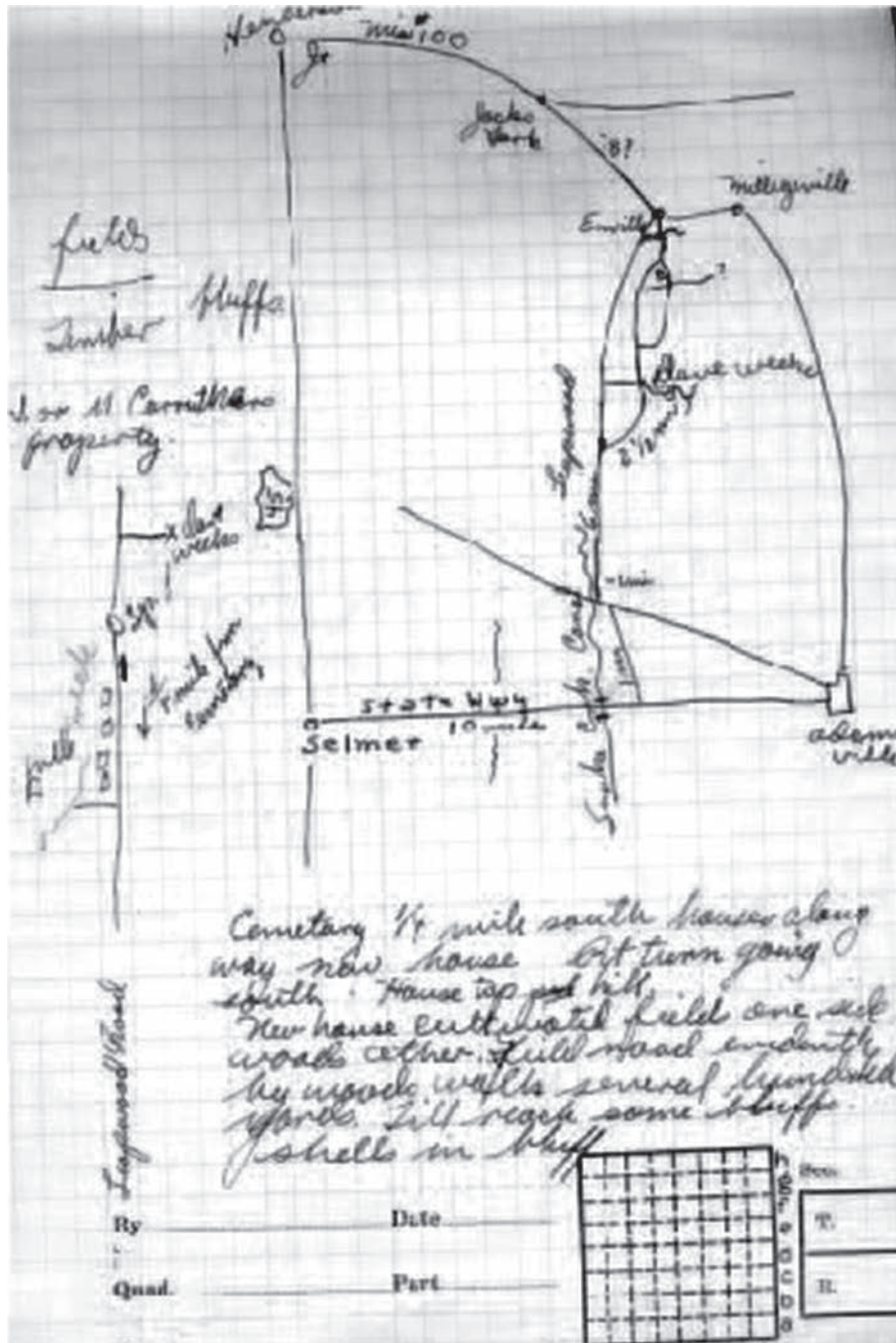
#### COLLECTING AT COON CREEK, TENNESSEE – EARLY 1950S

The selection of his thesis topic was the beginning of Norm Sohl's 44-year career researching the Late Cretaceous gastropod faunas of the Gulf and Atlantic Coastal Plains, the Caribbean Province, and the western

interior. He began his fieldwork for his dissertation in 1949 (although no field notes can be found from that year) and he made his first trip to Coon Creek, Tennessee in August 1950:

My first objective was to locate and collect Bruce Wade's fauna from Coon Creek, Tennessee. This may





**FIGURE 3. Norm's sketch map of Coon Creek type location from his field notes. No date on page, but probably from first visit in 1950. Page style and ink match field notes for August 24, 1950.**

seem an easy task now that the site is so famous and has been developed as a study center by the Memphis Museum Center. However, in 1950 the area was considerably remote, especially to a young man raised in the wilds of suburban Chicago. The only paved roads in the area were U.S. Route 45 and the new Memphis Highway, U.S. Route 64 [Fig. 3]. Local topographic maps were non-existent; residents did not know of any place called Coon Creek or 'Dave Weeks Place.' I finally encountered a Mr.

Crumby, who remembered Dave Weeks and knew of the shelly exposures in the creek, which he referred to as remnants of the 'Great Flood.' In fact, Mr. Crumby rather informally kept track of the property, which was no longer being farmed. In subsequent years I always stopped to visit with this old gentleman, and we became friends.

When I first visited the site, the old Weeks house was still there [Fig. 4], but deserted, and only an old rutted track, running along the field border led down toward



**FIGURE 4. The old homestead at Coon Creek. Photo and label from Norm's field photograph album (Norm's handwriting). Photograph taken between 1951 and 1953.**

the creek. My car, a passenger vehicle, could not manage this passage, and all collections had to be carried up to the old homestead. Coon Creek was a wonderful place to collect when I first saw it. At that time not a scar of a previous collector's efforts could be seen, the exposures were washed smooth and the stream banks were steep along the full course of the bank [Figs. 5,6].

During the course of my early trips to the locality, I removed several tons of material [Fig. 7]. Most block[s] were placed in nail kegs, which are no longer available, for shipment. At that time hardware stores sold their nails from such containers, and on each trip I scoured these establishments for them. To seal them one removed the upper steel retainer band, placed burlap across the opening, tapped down the band over the burlap and nailed the keg shut. They were the strongest shipment containers I have ever encountered.

While collecting at Coon Creek, I stayed in Selmer, Tennessee at the Gooch Hotel, located next to the railroad tracks. Both Mr. and Mrs. Gooch were elderly but very hospitable, and additionally charged only \$2.00 a night for a room, a price a graduate student could almost afford. Seldom did they have another guest while I was there. Mrs. Gooch once showed me the family silver that she maintained had been buried by her forebearers [sic] at the time of the Battle of Shiloh to save it from 'Yankees.'

Collecting to the south in Mississippi followed much the same pattern. There were no motels in most towns then. Usually I inquired at a gas station for the location of a rooming house. After finding a place to stay, my next move was to contact the county road commissioner for a county road map. Because topographic maps did not exist for these areas at this time, these blueprint county maps were invaluable for making road traverses and locating

outcrops. Such maps served as the basis both here and elsewhere for my work in the Coastal Plains in the early 1950s. (Sohl, 1991)

Norm's field notebooks document two visits to Coon Creek between 1950 and 1953 (see Appendix 1), but only a photographic record remains of his trip to Coon Creek in 1951. It is possible additional trips were made, for which there is no surviving record. The field notes were removed from the original notebooks to be organized by site, so it is possible that pages were lost in this process. However many trips he made, it was his observations, collections and notes from these trips that constituted his masters thesis and dissertation (Sohl, 1951, 1954) and eventually formed the foundation of USGS Professional Papers 331A and 331B, on the gastropod fauna and stratigraphy of the Ripley, Owl Creek, and Prairie Bluff Formations (Sohl, 1960, 1964).

## EXPANDING HORIZONS

In 1952, while completing his dissertation research, Norm was offered a temporary teaching position at Bryn Mawr College in Pennsylvania. The proximity of Bryn Mawr to Washington, D.C. allowed Norm to spend time working with the type collections at the National Museum of Natural History (USNM) researching the taxonomy of many of the species he was describing in his thesis. He returned to Illinois and finished his doctorate in 1954 (Sohl, 1954).

Norm had planned to pursue an academic career at a university but an interview with Preston E. Cloud, Chief of the United States Geological Survey (USGS) Paleontology and Stratigraphy Branch, changed his mind:

We met at a Geological Society of America convention and during the interview, I told him [Preston Cloud] of my career and research goals. He indicated interest in my joining his group, and eventually a firm offer was forthcoming for employment as a paleontologist with the Survey at the National Museum of Natural History in Washington, D.C. The opportunity to work with such geologists as Lloyd Stephenson, John Reeside, and Ralph Imlay offered a unique opportunity to learn more of Mesozoic paleontology and stratigraphy. In addition there were other renowned workers on fossil and recent mollusks, such as Wendell Woodring [Fig. 2], Ralph Stewart, Julia Gardner, Harold Rehder, [and] J. Brooks Knight on the Survey or Museum staff, which presented an extraordinary opportunity to tap an incredible reservoir of accumulated knowledge. An offer to join such a group was not to be denied. (Sohl, 1991)

Norm officially began working for the USGS in September 1954. His initial research at the USGS was a continuation of the Cretaceous coastal plain studies that Lloyd Stephenson started in the early 1900s. A part of that work entailed incorporating the vast collections





**FIGURE 5.** Type section of Coon Creek (April, 1951). Contact between “Ripley” below and “valley fill” above, marked on photograph by Norm with dotted line. Note concretions protruding from bluff. Photo and label from Norm’s field photograph album. Person in photo is unidentified but is probably S.H. Patterson.

of the USGS and the NMNH into his dissertation, in preparation for publication as a USGS Professional Paper. In addition, he conducted field studies of the Upper Cretaceous of the Chattahoochee River region of Georgia and Alabama.

In the spring of 1955, these various aspects of his job came together. Lloyd Stephenson (Fig. 2) and Norm Sohl went in the field together for over five weeks, beginning in the Chattahoochee River region and working west through Alabama and into Mississippi, revisiting many of Stephenson’s localities. Watson Monroe joined them for a few days in Alabama. Norm took copious notes on

this trip. Interestingly, they do not appear to have gone to Coon Creek, even though they were as close as Union County, Mississippi and were collecting material from the Coon Creek “tongue” (Sohl, 1960, p. 33, localities 22, 23). Many of the collections and observations from that trip were incorporated into Professional Papers 331A and B (Sohl 1960, 1964).

Norm returned to northern Mississippi and Tennessee in the fall of 1956, accompanied by Harold I. Saunders (USGS). On this trip he spent three days collecting at Coon Creek (Figs. 8, 9; see Appendix 1); however, the collections he made at Coon Creek were not included

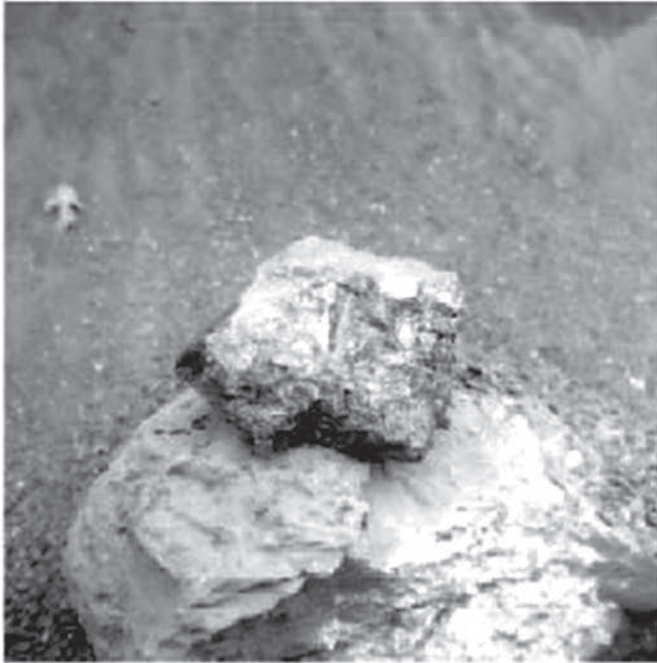




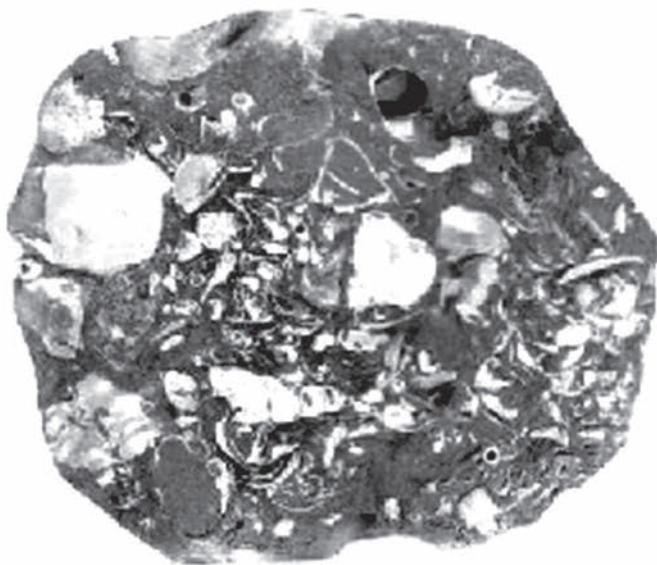
**FIGURE 6.** Section at Coon Creek. Photo from Norm's field photograph album, labeled "S-100 as before but upstream" and dated December 27, 1953. This is placed below the photograph of the section taken in 1951 shown in Figure 5.

in the locality register of Professional Paper 331 A (Sohl, 1960, p. 27), but other collections on that trip were included in the final paper. As Norm stated, "the government's publication mills grind slowly, and the work on Coon Creek and Mississippi was not to appear until

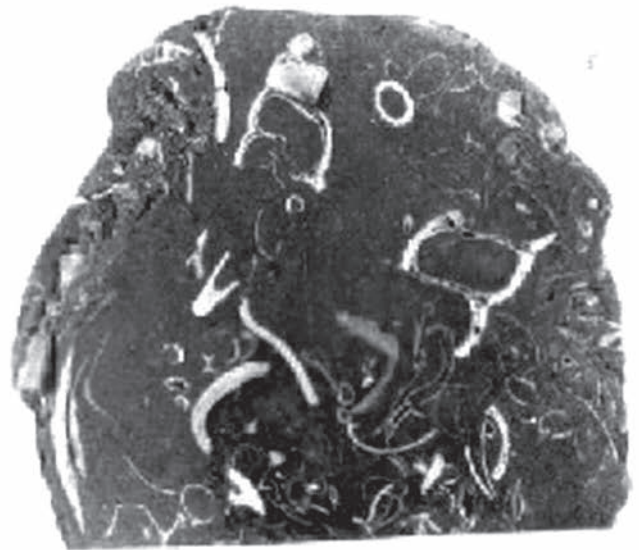
1960-1964 (Sohl, 1991)". The publication of his thesis in USGS Professional Papers 331A and 331B represented the culmination of his graduate studies and the foundation upon which he built his long and remarkable career.



6-100 - views of fossiliferous sandstone concretions from the type section of the Coon Creek tongue 12/27/53



near view of a fossiliferous concretion from Coon Creek



cut section of a concretion from loc. 5-100

**FIGURE 7. Concretions from Coon Creek Type section. Photos and labels from Norm's field photograph album (Norm's handwriting), taken December 27, 1953.**

#### CONTINUING INFLUENCE

Norman F. Sohl went on to conduct extensive biostratigraphic and paleontological investigations in the Western Interior, the Atlantic and Gulf Coastal Plains, and

the Caribbean and gained a worldwide reputation as an authority on Mesozoic mollusks, particularly Cretaceous gastropods. His taxonomic descriptions are considered by many paleontologists to be the ideal for which we



should all strive. Raup and Stanley, in their 1971 textbook "Principles of Paleontology" provide Norm's description of *Calliomphalus conanti* (Sohl, 1960, p. 57) as "an example of effective use of descriptive terminology" (Raup and Stanley, 1971, p. 35). Norm received many accolades and awards during his career, including the Department of Interior's Meritorious Service Award (1974) and Distinguished Service Award (1981) (the Department of Interior's highest award). In 1991 he received The Paleontological Society Medal. The medal, "the most prestigious honor bestowed by the Society . . . is awarded to a person whose eminence is based on advancement of knowledge in paleontology (The Paleontological Society, 2014)".

Norm Sohl retired from the USGS on April 7, 1993. He entered the hospital that evening and died one week later, on April 14, 1993. He left behind a legacy of over 78 publications and articles, but more importantly he inspired a number of young researchers. It was often to Coon Creek that he sent graduate students to be amazed by the site he described as "the most prolific single locality for collecting Upper Cretaceous fossil mollusks in the world (Sohl, 1960, p. 27)." The list of researchers who have been directly or indirectly influenced by Norm is long (see Appendix 2) and is perhaps the greatest testimonial to Norm. His influence will continue to grow as new generations of students pick up his papers, read his taxonomic descriptions, and examine his collections.

Norm's philosophy about his science was that "solid taxonomic studies form the building blocks for theoretical studies . . . . We must continue such basic studies or the progress of our science will stagnate and become only an exercise in massaging or manipulating old data sets. Conversely, we must also remember that such taxonomic studies are sterile if undertaken without any thought as to what they will contribute to evolutionary history and theory, or what importance they may have relative to the solution of other geologic problems (Sohl, 1992)." Sound advice for the new millennium.

### ACKNOWLEDGEMENTS

I would like to thank Michael Gibson, University of Tennessee, Martin, for giving me the opportunity to write this account of Norm Sohl's research at Coon Creek. I had the privilege of working as Norm's research assistant from 1983 until 1991, when I was hired as a Cenozoic molluscan paleontologist by the USGS. Norm continued to advise me on many matters until his death (April 14, 1993). In his autobiography (Sohl, 1991), Norm credits his mentor, Bernhard Kummel, and later Lloyd Stephenson and others at the USGS and the National Museum of Natural History, for changing his life and contributing to his professional growth. Norm was all of those men rolled into one for me, so I am grateful for this opportunity to honor him and his research.

I would like to thank my reviewers Gregory Gohn (USGS, retired), and John Pojeta, (USGS, retired) for their careful reviews of the manuscript. James Murray (USGS) scanned the original photographs and field notes and prepared them for publication. Many people have helped me compile the list of references in Appendix 2. I would like to thank David Dockery (Mississippi Department of Environmental Quality), Thor Hansen (Western Washington University), David Jablonski (University of Chicago), Patricia Kelley (University of North Carolina, Wilmington), Matthew Kosnik (Macquarie University, New South Wales, Australia), and Andrew Rindsberg (University of West Alabama) for contributing information and forwarding my request to other colleagues. Charles C. Smith (Geological Survey of Alabama, retired) provided Figure 10.

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## APPENDIX 1. COMPILATION OF SOHL'S FIELD NOTES FROM COON CREEK

The following is a compilation of Norm Sohl's field notes from his trips to Coon Creek. These constitute the complete record of existing field notes, but there appears to be some chronologic gaps. It is possible that on subsequent trips to Coon Creek, Norm did not always keep a record in his field notebooks, although this was not characteristic for him. Typically on field excursions he kept road logs, so even if detailed site descriptions are not recorded, a record of the stop at a site would be listed in the log. Some of the pages of notes were removed from the original notebooks, which may account for missing information. Norm had a habit of compiling his field notes into notebooks organized by general location. Beginning around 1955, these compilations were often copies of the original field notes (either handwritten or typed) but the 1950–1953 notes transcribed below appear to be the original notes.

Norm's field notes, copies of the notes, maps, and photographs are currently held at the U.S. Geological Survey, Eastern Geology and Paleoclimate Science Center, Reston, Virginia. The fossil collections and type material have been turned over to the Smithsonian Institution National Museum of Natural History.

The notes that follow have been transcribed as written. Taxonomic assignments have not been updated and are listed here as written by Norm, but spelling was corrected in some cases. If a word or a portion of a word is placed in square brackets and underlined then the transcription is a guess. If a word is placed in square brackets, but not underlined, then it has been inserted during the transcription.

*August 24, 1950 – S-100 Classic Coon Creek collecting locality McNairy Co., Tennessee.* [Both original field notes and copy (in Norm's handwriting) examined. Transcription primarily from copy, but where content differed from original, original notes also included as indicated below.] (Fig. 3)

Exposures in creek bed near head of Coon Creek, Tenn. Creek has cut steep sided (8' ditch) in clay material. The clay is grey-blue when fresh, micaceous and sandy, fairly fine grained [from original notes]. Collections were made from the higher exposures where creek has cut a steep sided 8' ditch in the marl. Marl is grey-blue when fresh, micaceous; sand fraction medium to fine grained [from copy].

Fossils occur singly or in clusters and bedded concen[trations]. Fossils in great concentration around the majority of the concretions with the concretions themselves frequently composed of a high percent of fossil material [from copy; example in Fig. 7]. The concretions themselves are generally hard and sandy with little or no clay but generally a great deal of fossil matter is present [from original].

No attempt to measure section at this time 8/24/50.

Fossils were found in all attitudes – flat lying and at various angles to the bedding.

*April 1951 – S-100, with S.H. Patterson.* [Photographs labeled by Norm with his field number (Fig. 5) indicate Norm was at Coon Creek in April 1951, but no field notes, road logs, or other written records exist for Spring of 1951 for either Tennessee or Mississippi. Field notes in Mississippi for 1951 are dated July and August.]

*December 27, 1953 – S-100 Revisited* [Both original field notes and copy (in Norm's handwriting) examined. Transcription from copy, but content nearly the same.]

Ground frozen – collecting no good. [Fig. 6]

Flood plain of Coon Creek 0.0'

"Marl" typical of Coon Creek member measures 26' but probably more present.

At above 45' McNairy Sand thin bedded, typical of transition zone exposed in gullies below house.

At about 60' thin bedded clayey sands of McNairy appear in house road and continue to top of hill at about 75'

Found a *Ptychosyca inornata* Gabb. Good *Tuba* cf. *T. parabella* and a *Turritella vertebroides* more than 4 3/4" long and 1 1/4" wide but was squashed. This specimen had 5 spirals appearing on last whorl.

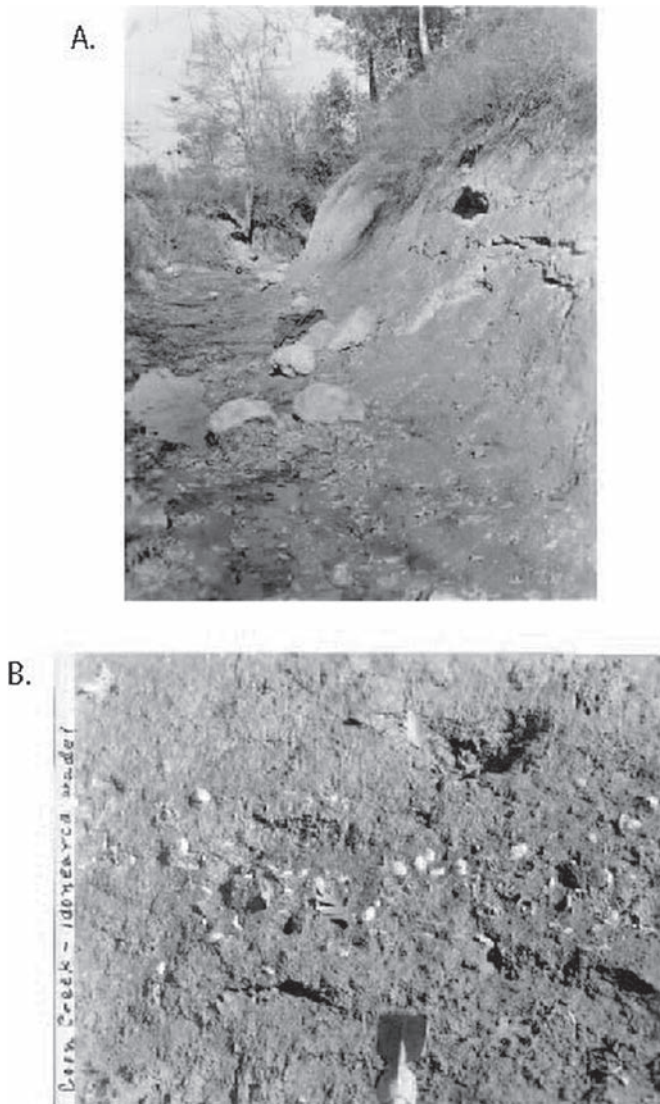
In lower reaches of Creek found many masses of *Gervillioopsis* in phosphatic bearing concretions and in bunches. Some concretions here contain great concentrations of *Corbula* (*Caestocorbula*) *crassiplica* Gabb. [Fig. 7]

During freezes acicular crystals of ice form growing from outcrop face and normal there to. About the first 7" of the face is frozen and the contained fossils become mushy when a thaw sets in.

November 7, 1956 – Loc. 389 (See S-100 USGS 25406) Revisited Coon Creek, McNairy County, Tennessee; collected with Harold I. Saunders. [Both original field notes (Fig. 8) and copy (typewritten) examined. Transcription from copy, but content virtually identical.]

Weather fine, foggy early but clearing to a fine sunny day. Fall leaves covered much of outcrop but due to lack of rain many slump blocks remained which when broken yielded some good specimens. Others were exposed as weathered on the surface.

Collected the lower reaches of the creek [Fig. 9A]. A concretionary ledge rests at approximately 5-6 feet above base of creek. Below this layer fauna differs to some extent. Throughout *Exogyras* scarce but appear to be more scattered above concretion level. The marls as a whole are massive and no X bedding seen. Occasional pockets of cleaner sand appear but they assume the shape of borings or lenticular bodies, of only a few inches in extent never very great. Fossil wood is uncommon but broken and worn shells are not too uncommon.

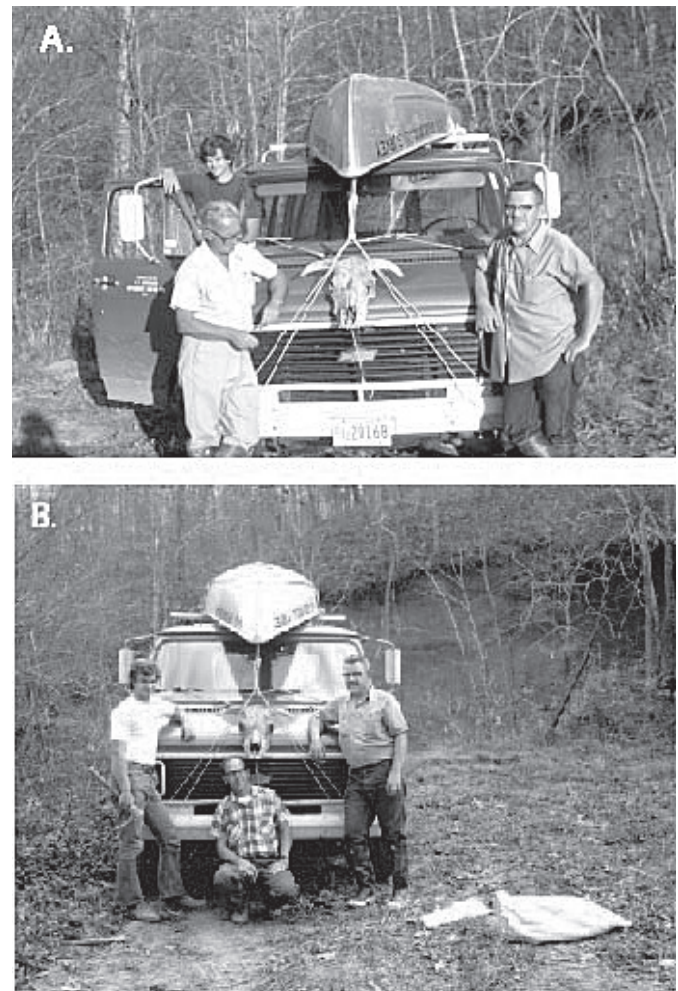


**FIGURE 9.** Photographs of Coon Creek from Norm's field notebook, November 7, 1956. A, View of section; B, close up of *Idonearca wadei* in section.

In the lower zones certain of the univalve species seem more abundant. *Turritella tippiana* is here well represented but I recall no specimens in the upper reaches of the section although some may be present but certainly not in the profusion that they appear in the upper parts of the section. In general univalves are more diversified. With the *Midionopus* type being well represented. *Gervilliopi* [sic – *Gervillia*? Or *Gervilliopsis*?] occurs in circular patches. But throughout the total section the specimens are more concentrated in certain layers. Both *Trigonia* and *Crassatellites* and *Polinices* are abundant throughout the section but above the concretion zone *Idonearca* is more abundant than below. Also *Turritella vertebroides* appears to be more common here and reaches 4" in length or more. Farther upstream earlier collections showed the large volutes, *Volutoderma* and *Volutomorpha*, to be more common.

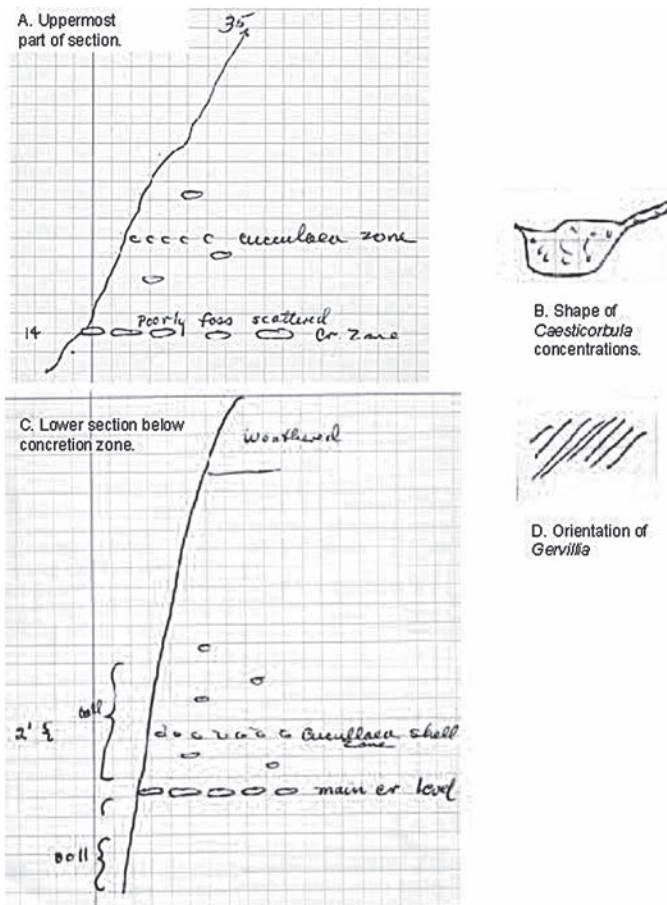
These concretions themselves bore more cephalopod remains than the rest of the section and should be sought therein as well as the more fragile members of the remainder of the fauna. This trip revealed many specimens of species I had had [sic] poor past experiences in collecting, i.e. *Liopelum "subjugosum"* Wade of which I found 3 specimens although never before having collected any.

Also in the upper zone (above the concretion zone and below the upper falls) I found *Idonearca* occurring in layers [Fig. 9B] and *Corbula (Caestocorbula) crassaplica* (Gabb) occurring in pockets of spheroidal shape and occasionally with a lithified center as at the southern Tennessee exposures. *T. trilira* occurs similarly at 115 and *Graciliala calcaris* at 113. [These numbers probably refer to field localities S-113 and S-115, collected between 1950 and 1953. There is no measured section or other obvious



**FIGURE 10.** Collecting at Coon Creek, November, 1974. Skull on hood is an example of Norm's ever-present sense of humor. A, From left to right: Norm Sohl, Jim Swanson, Bill Ross. Photograph taken by Charlie Smith. B, From left to right Jim Swanson, Charlie Smith, and Bill Ross. Photograph taken by Norm Sohl; photograph and label from Norm's field photograph album.





**FIGURE 11.** Sketches from Norm's original field notes at Coon Creek, November, 1974. **A,** Uppermost part of section (measurements in feet); **B,** shape of *Caesticorbula* concentrations; **C,** lower section below concretion zone (measurements in feet); **D,** orientation of *Gervillia*.

numbering system that these numbers could be related to. Norm frequently referred back to his original collection numbers in his field notes throughout his career. S-113 is "Tallahatchie bottom SE Dumas section measured in road cut." S-115 is "section along road cut Molino, road cut east facing slope of Hall Branch, Union County" from Sohl, original field notes (1950-1953). In the Professional Paper, S-115 corresponds to locality 17 (Sohl, 1960, p. 31) and to USGS Mesozoic Locality # 30760 (field # 74-M-6 - collected in 1974 with C. Smith), but not to USGS Mesozoic Locality Register #25410.]

November 1-3, 1974 - 74-M-9 Type Locality; Exposures on East and West Bank of Coon Creek, Tennessee; collected with Charlie Smith (CS-TENN-74-1) and Jim Swanson. [Fig. 10]

Spent 3 days collecting the old locality. First two days we spent on the uppermost part of the section. [Fig. 11A].

*Corbula* concentrations occur at all levels - some are circular others [see Fig. 11B]. *Mataxa* seems most

common in such concentrate[d] pockets. *Cucullaea* seems concentrated in a zone that is readily distinguishable above the most prominent concretion zone.

Between the concretion zone and the *Cucullaea* zone, *Cyprimeria* is very common. *Crassatella* and *Turritella vertebroides* are ubiquitous. *Anchura* immature forms are also common throughout this interval but snails in general are uncommon.

Burrows are common at most levels - some are backfilled. *Chondrites* not seen as well as shell lined burrows.

Snails are not especially diverse in these levels. They occur as scattered individuals except for *Anchura* and *Turritella*. One concentration of *Syncyclonema* in the same form as those of *Caesticorbula* was noted. Two concentrations of a thin-shelled form (*Isocardia*) were also seen. These seemed oriented and not like the *Caesticorbula* types, which have disoriented specimens.

*Sagana* also occurs sporadically throughout the upper part of this sequence in only somewhat less abundance than *Exogyra* - neither is as common as *Turritella* or immature *Anchura*.

In overall impression one might characterize the gastropod component of these sands as a *Turritella vertebroides* - *Anchura* assemblage. In decreasing abundance the bivalves are probably *Cucullaea*, *Crassatella*, *Cyprimeria* (occasional *Cyprimeria* occur bivalved and in living position).

In some levels *Cucullaea* are most abundant and may concentrate into a zone. *Crassatella* on the other hand are scattered but common. Shell linings of burrows have a dominance of thin-shelled bivalves, especially *Syncyclonema* as a major component.

Rare finds - *Anisomyon*, *Pterocerella*, *Tuba*, *Anchura convexa*.

The concentration zones may represent burrow fills or accumulations of [mat] forming byssal threads of *Caesticorbula*.

Collect[ed] oriented concretion with *Caesticorbula*. Collected 12 bags of concentrate for washing.

**Sunday:** Collected mainly from the lowest part of the section [Fig. 11C] below the concretion zone. In general fossils concentrated or more abundant in certain layers.

The most common gastropod is *Euspira*. *Calliomphalus* seems well represented and *Drilluta* occurs moderately commonly. Burrows of shell lined type common.

Among the clams both *Cyprimeria* and *Cucullaea* are significantly more rare than higher in the section. *Crassatella* seems to dominate among the clam assemblage being bivalved at some levels.

*Gervillia* in concentrations occur low in the sequence. Concentrations may be 8 or 10" in diameter and most lie parallel to the bedding. One mass, however, seemed inclined and may reflect some living orientations. [Fig. 11D]

*Panopea* occurs locally about 5-7' below the concretion zone. The specimens are oriented vertically in living position.



## APPENDIX 2. PUBLICATIONS LINKED TO SOHL'S ORIGINAL COON CREEK RESEARCH

The following is a partial list of publications (primarily compiled as of November, 2002) that utilize biostratigraphic or paleontologic data gathered by Norm Sohl in his initial work at Coon Creek, and/or specimens collected by him at Coon Creek. Norm's own subsequent works that developed from the initial research at Coon Creek also are included below.

- Buzas, M.A., C.F. Koch, S.J. Culver, N.F. Sohl. 1982. On the distribution of species occurrence. *Paleobiology* 8(2):143–150.
- Ebersole, S.M. 2009. Biostratigraphy, paleogeography, and paleoenvironments of the Upper Cretaceous (Campanian) northern Mississippi embayment. Ph.D. dissertation, University of Alabama, Tuscaloosa, Alabama, 189 pp.
- Hansen, T.A. 1988. Early Tertiary radiation of marine molluscs and the long-term effects of the Cretaceous–Tertiary extinction. *Paleobiology* 14:37–51.
- Hansen, T.A., R.B. Farrand, H.A. Montgomery, H.G. Billman, and G. Blechschmidt. 1987. Sedimentology and extinction patterns across the Cretaceous–Tertiary boundary interval in east Texas. *Cretaceous Research* 8:229–252.
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- Hansen, T.A., P.H. Kelley, V.D. Melland, and S.E. Graham. 1999. The effect of climate-related mass extinctions on escalation in molluscs. *Geology* 27:1139–1142.
- Hansen, T.A. and B. Upshaw III. 1990. Aftermath of the Cretaceous–Tertiary extinction: rate and nature of the Early Paleocene molluscan rebound; pp. 401–410 in E.G. Kauffman and O.H. Walliser (eds.), *Extinction events in Earth history. Lecture Notes in Earth Sciences* 30.
- Hansen, T.A., B. Upshaw, E.G. Kauffman, and W. Gose. 1993. Patterns of molluscan extinction and recovery across the Cretaceous–Tertiary boundary in east Texas; report on new outcrops. *Cretaceous Research* 14:685–706.
- Jablonski, D. 1980. Apparent versus real biotic effects of transgression and regression. *Paleobiology* 6:397–407.
- Jablonski, D. 1982. Evolutionary rates and modes in Late Cretaceous gastropods: Role of larval ecology. *Proceedings, 3rd North American Paleontological Convention*:257–262.
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- Jablonski, D. 1986. Larval ecology and macroevolution of marine invertebrates. *Bulletin Marine Science* 39:565–587.
- Jablonski, D. 1986. Causes and consequences of mass extinctions: a comparative approach; p. 183–229 in D.K. Elliott (ed.), *Dynamics of extinction*. Wiley and Sons, New York, New York.
- Jablonski, D. 1987. Heritability at the species level: analysis of geographic ranges of Cretaceous mollusks. *Science* 238:360–363.
- Jablonski, D. 1995. Extinction in the fossil record; pp. 25–44, in R.M. May and J.H. Lawton (eds.), *Extinction rates*. Oxford University Press, Oxford.
- Jablonski, D. 1996. Body size and macroevolution; pp. 256–289, in D. Jablonski, D.H. Erwin, and J.H. Lipps (eds.), *Evolutionary Paleobiology*. University of Chicago Press, Chicago, Illinois.
- Jablonski, D. 1997. Body-size evolution in Cretaceous molluscs and the status of Cope's rule. *Nature* 385:250–252.
- Kelley, P.H. and T.A. Hansen. 1993. Evolution of the naticid gastropod predator-prey system: An evaluation of the hypothesis of escalation. *Palaios* 8:358–375.
- Kelley, P.H., and T. A. Hansen. 1995. Recovery of the naticid gastropod predatory-prey system from the Cretaceous–Tertiary and Eocene–Oligocene extinctions. *Geological Society of America, Special Publication* 102:373–386.
- Kelley, P.H. and T.A. Hansen. 1996. Naticid gastropod prey selectivity through time and the hypothesis of escalation. *Palaios* 11:437–445.
- Kelley, P.H., and T.A. Hansen. 2003. The fossil record of drilling predation on bivalves and gastropods; pp.113–139, in P.H. Kelley, M. Kowalewski, and T.A. Hansen (eds.), *Predator–Prey Interactions in the fossil record. Topics in Geobiology* 20. Kluwer Academic/Plenum Publishers, New York, New York.
- Kelley, P.H., T.A. Hansen, S.E. Graham, and A.G. Huntoon. 2001. Temporal patterns in the efficiency of naticid gastropod predators during the Cretaceous and Cenozoic of the United States Coastal Plain. *Palaeogeography, Palaeoclimatology, Palaeoecology* 166:165–176.
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# Mollusca of the Coon Creek Formation in Tennessee and Mississippi with a Systematic Discussion of the Gastropoda

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**Abstract**—Cretaceous molluscan faunas, such as those present in the Coon Creek Formation, included a great diversity of morphologic types and taxa, many of which became extinct at the Cretaceous-Tertiary boundary and are thus not available for modern molecular studies. For extinct gastropods, the larval shell may provide information useful to the species' systematic placement. Earlier studies of Cretaceous gastropods forced many extinct taxa into extant families based solely on the morphology of the teleoconch, some of which were imperfectly preserved. Gastropod faunas from the Coon Creek Formation (Late Campanian to early Maastrichtian) of Tennessee and Mississippi and the Coffee Sand (Campanian) of Mississippi are so well preserved that even their protoconchs, as well as juvenile shells and larval shells, are unaltered and add information concerning their systematic position. The following systematic treatment of some 262 gastropod species from the Coon Creek Formation is weighted toward the larval shell morphology, which can be very conservative within broader gastropod taxa. A systematic discussion of the Coon Creek Formation gastropods is following by a systematic list of other mollusks present in the formation.

## INTRODUCTION

Dr. Spillman and Hilgard (Hilgard, 1860, p. 84) collected the first well preserved Cretaceous mollusks known from the Gulf Coastal Plain. Their collections came from the Owl Creek Formation at its type locality on Owl Creek in Tippah County, Mississippi, and were sent to Conrad (1858), who described 56 new species. Conrad named additional Cretaceous species from Mississippi and Alabama in 1860. Of these latter taxa, Sohl (1960, p. 6) recognized 10 molluscan and one echinoid species to be restricted to the Ripley Formation and suggested

that these came from Union County, Mississippi, which was a part of Tippah County at the time of Conrad's publication. Conrad's Ripley mollusks included *Dircella spillmani* (Conrad), *Trobus corona* (Conrad), *Liopeplum leioderma* (Conrad), *Morea cancellaria* Conrad, *Anchura abrupta* Conrad, *Pyrifusus subdensatus* Conrad, *Hercorhyncus tippanus* (Conrad), *Stantonella ripleyana* (Conrad), *Trigonia thoracia* Morton, and *Vetericardia crenulirata* (Conrad). These species are known from well preserved shells found only in the Coon Creek Formation, a formation



originally named as a horizon or member of the Ripley Formation (Wade, 1917a and 1917b) and later as a tongue of the Ripley Formation (Wade, 1926). In addition to these, Sohl (1960) noted that the specimen of *Pugnellus densatus* figured by Conrad (1860) was more typical of those from the Coon Creek Formation than from the Owl Creek Formation and that *Thylacus cretaceus* Conrad was common in the Coon Creek but was rare in the Owl Creek Formation.

Wade was the first to report the well preserved fauna of the type locality of the Coon Creek Formation in McNairy County, Tennessee, with publications in 1916, 1917a, 1917b, 1920, and his 1926 monograph published by others after he was stricken with an infection that led to mental illness. According to Sohl (1960, p. 27), Wade's 1926 monograph included 170 genera and 297 species of mollusks from the Coon Creek Formation's type locality, making it the "most prolific single locality for collecting Upper Cretaceous fossil mollusks in the world." Moore (1974) listed gastropod species cited by Sohl (1960, 1964a) from the type Coon Creek locality along with the corresponding synonyms of Wade and others and updated some of Wade's generic nomenclature for the Bivalvia.

In 1939, the Pleasant Ridge Lake locality containing the Coon Creek fauna in Union County, Mississippi, was discovered in a borrow cut for the dam of a WPA lake project. This locality was collected by Conant and Brown in June of 1939 and was published by Conant and Brown (1940) and Conant (1942). Conant and Brown (1940) noted the lower one to two feet of the exposed fossiliferous beds to contain concretions with fossil crabs and the overlying ten feet contained a marl with well-preserved gastropods and bivalves. They credited the site as probably affording the "finest collecting of Ripley fossils of any place known in Mississippi."

Harbison (1945) was the first to publish new molluscan species from the Pleasant Ridge Lake locality. Sohl (1960, p. 31) collected from Pleasant Ridge Lake, which he designated as his locality 18, during the period 1950-1952 and in 1955. Sohl noted fossil shells at this site to have an almost perfect preservation when collected in unweathered matrix and to have original color patterns commonly preserved. However, he also noted that each year the locality became more overgrown. The faunal check lists of Sohl (1960, 1964a) show the Pleasant Ridge Lake locality to rival the type Coon Creek locality in its molluscan diversity even though it had a more limited exposure.

Sohl (1960) noted that the Pleasant Ridge Lake locality was above the *Exogyra cancellata* zone of Stephenson (1914) and was thus younger than that of the type Coon Creek locality. In his work on the Coffee Sand gastropods of Mississippi, Sohl (1964b) include a molluscan check list that provided an updated nomenclature for Cretaceous bivalve and cephalopod species. Sohl and Koch (1987) provided a checklist of the larger invertebrates of the

*Haustator bilira* Assemblage Zone (Maastrichtian) in the Atlantic and eastern Gulf Coastal Plains. Sohl (1987) contrasted the molluscan faunas of the tropical, equatorial "Tethyan Realm," including the Caribbean and southern Gulf, with those of the "Temperate Realms" of the northern Gulf and Atlantic coastal plains. The Gulf and Atlantic faunas contained a high diversity of mesogastropods and neogastropods, while the faunas of the "Tethyan Realm" included rudist reefs and a high proportion of archaeogastropods and actaeonellid gastropods. Sohl (1987) stated that no species of either the ophistobranch superfamily Nerineoidea or the Family Actaeonellidae were known to occur in the Coon Creek faunas of the northern Gulf.

Other notable works on Late Cretaceous molluscan faunas of the Gulf and Atlantic coastal plains include Weller (1907) on the Cretaceous faunas of New Jersey, Gardner (1916) on the Cretaceous Mollusca of Maryland, and the following publications of Stephenson: *Exogyra* zones (1914), Cretaceous formations (and mollusks) of North Carolina (1923), additions to the upper Cretaceous invertebrate faunas of the Carolinas (1927), the larger invertebrate fossils of the Navarro Group of Texas (1941), the larger invertebrate fossils of the Woodbine Formation of Texas (1952), and the Owl Creek fossils from Crowley's Ridge in Missouri (1955). Young (1963) published a monograph on the Upper Cretaceous ammonites of the Gulf Coast region. The Houston Gem and Mineral Society published volumes on the Cretaceous bivalves (Offeman and Ganshirt, 1982) and gastropods (Akers and Akers, 1997) of Texas. The later work on gastropods included hand-drawn illustrations of specimens from the Coon Creek fauna of Mississippi and Tennessee.

Around 1970, the junior author revisited the Pleasant Ridge Lake locality and found bleached shell fragments in the soil of a grassy lakeside field. A small excavation uncovered entire well-preserved shells. Not long afterwards, commercial collectors excavated the site for fossil crabs, and Coon Creek crabs began to appear on the fossil market, with complete specimens ranging in price from \$1,000 to \$2,000. As all the crabs from the Pleasant Ridge Lake (MGS locality 127) locality represent only one species *Avitelmessus grapsoides*, the diversity of fossil mollusks at the site were of far more value to science, and excavations for crabs were a waste of good mollusk specimens.

The preservation of aragonitic gastropod shells at the Coon Creek and Pleasant Ridge Lake localities is so exceptional that their larval shells can be studied in great detail by scanning electron microscope (SEM) imagery. Such studies have led to the reclassification of several gastropod genera (i.e. Dockery, 1993; Bandel and Dockery, 2001). So important are larval shells to gastropod systematics that SEM imagery of Cretaceous larval shells from Mississippi and Tennessee, including the Campanian Coffee Formation in Mississippi, have been

widely published. In addition to the studies mentioned above, other publications include the following. Specimens illustrated from Coon Creek in Tennessee are indicated by asterisks:

- Bandel, 1991a: *Anchura* sp., fig. 9-10; *Cerithiella* sp. A (Coffee Sand, MS), fig. 37; *Cerithiella* sp. B (Coffee Sand, MS), fig. 39; *Acirisa* (*Plesioacirsa*) sp. (Coffee Sand, MS), fig. 43; *Aciculiscala* sp. (Coffee Sand, MS), fig. 44; *Ctenoglossa* larval shell (Coffee Sand, MS), fig. 45; *Acirisa wadei* (Coon Creek Formation, TN), fig. 46\*; *Acirisa* sp. (Coon Creek Formation, TN), fig. 47\*; *Seila meeki* (Coffee Sand, MS), fig. 48.
- Bandel, 1993b: *Tympanotonus* sp. (Coffee Sand, MS), pl. 3, fig. 2; *Nozeba crassa* (Coffee Sand, MS), pl. 6, fig. 5; *Solariorbis clara* (Coffee Sand, MS), pl. 6, fig. 6; *Laxispira lumbricalis* (Coffee Sand, MS), pl. 7, fig. 5-6; *Eulima laevigata* (Coffee Sand, MS), pl. 10, fig. 1; *Cerithiopsis meeki* (Coffee Sand, MS), pl. 10, fig. 2; *Eulima gracilistylis* (Coffee Sand, MS), pl. 10, fig. 4; *Cerithiella* sp. (Coffee Sand, MS), pl. 10, fig. 5; *Tylacus cretaceus* (Coffee Sand, MS), pl. 12, fig. 2; *Cerithioderma* sp. (Coffee Sand, MS), pl. 12, fig. 6; *Sargana stantoni* (Coon Creek Formation, TN), pl. 13, fig. 3\*; *Weeksia* cf. *amplificata* (Coon Creek Formation, MS), pl. 13, fig. 4; *Sassia* sp. (Coffee Sand, MS), pl. 13, fig. 6; *Ephora proquadricostata* (Coffee Sand, MS), pl. 14, fig. 5; neogastropod (Coffee Sand, MS), pl. 15, fig. 1-2.
- Bandel, 1994: *Tornatellaea cretacea* (Coon Creek Formation, MS), pl. 4, fig. 3; *Nonacteonina* sp. (Coon Creek Formation, TN), pl. 4, fig. 4\*; *Eoacteon* (Coon Creek Formation, MS), pl. 4, fig. 5; *Zikkuratia* (Coon Creek Formation, MS), pl. 4, fig. 12.
- Bandel and Riedel, 1994a: *Thylacus cretaceus*, pl. 1, fig. 1-5.
- Schröder, 1995: *Bittum* sp. (Coffee Sand, MS), pl. 3, fig. 19-21; *Gegania* sp. (Coffee Sand, MS), pl. 9, fig. 19-21.
- Riedel, 1994, *Gyrineum gwinae* (Coffee Sand, MS), fig. 34.
- Bandel, 1997, neogastropod, pl. 3, fig. 7-8.
- Bandel and Kowalke, 1997a, *Laxispira lumbricalis* (Coon Creek Formation, TN), pl. 1, fig. 3- 4\*.
- Nützel, 1998: *Variseila meeki* (Coffee Sand, MS), pl. 17, fig. F-G; *Ataxocerithium dockeryi* (Coffee Sand, MS), pl. 17, fig. R; *Vatopsis aequalirata* (Coffee Sand, MS), pl. 17, fig. S-V; *Vatopsis nodoliratum* (Coffee Sand, MS), pl. 17, fig. W-X; *Eccliseogyra heliiclina* (Coffee Sand, MS), pl. 18, fig. V-W; *Aciculiscala coffea* (Coon Creek Formation, TN), pl. 19, fig. A-G\*; *Opaliopsis* aff. *faearium* (Coon Creek Formation, TN), pl. 19, fig. K\*; *Opaliopsis faearium* (Coon Creek Formation, TN), pl. 19, fig. K.
- Kowalke, 1998, *Schroederium cowickeense*, pl. 1, fig. 1, 10, *Laxispira lumbricalis*, pl. 8, fig. 1-2\*.
- Bandel, 1999, *Gyrodes* sp., pl. 3, fig. 6\*.
- Riedel, 2000, *Sargana* sp., pl. 17, fig. 6.

## SYSTEMATICS

The following is a systematic discussion of gastropod taxa from the Coon Creek Formation's type locality in Tennessee (as indicated by asterisks) and from localities in Mississippi, after which is a systematic listing of other molluscan groups from the Coon Creek Formation at the same localities.

The Class Gastropoda is the most diverse group of mollusks, with members that live in habitats ranging from the deepest oceans, to the surf zone, to estuaries, to freshwater streams and lakes, and on land, under rocks, up trees, and in deserts. Most have shells, but some do not. Thus, it is not surprising that Gastropod Volume is the one volume unfinished in the series published as the *Treatise on Invertebrate Paleontology*. For many years the German works of Thiele (1929, 1931) and Wenz (1938-1944) were the standards for gastropod systematics. Moore (1960) published the Archaeogastropoda in "Part I, Mollusca 1" of the *Treatise on Invertebrate Paleontology*. Taylor and Sohl (1962) divided the Gastropoda into two subclasses, the Streptoneura with 4,218 genera and subgenera and the Euthyneura with 3,106 genera and subgenera. Their "Outline of Gastropod Classification" was intended as a model for the forth-coming gastropod volumes of the *Treatise*, volumes that remain unpublished.

A more recent gastropod classification by Ponder and Warén, 1988, was used by Dockery, 1993 for Campanian gastropods from the Coffee Sand of Mississippi. This classification is followed below with modifications from Bandel and Riedel, 1994a and 1994b, Bandel and Dockery, 2001, and Bandel and Dockery, 2012. Bandel (1991b) noted that the morphology of the larval shell was often sufficient to place the gastropod species into one of four subclasses, the Archaeogastropoda, Neritimorpha, Caenogastropoda, or Heterostropha. This shell-morphology-based classification works well for Cretaceous faunas that contain many extinct taxa. Within the Heterostropha, Bandel (1996, p. 358) recognized three superorders, the Allogastropoda Haszprunar, 1985, Opisthobranchia Milne Edwards, 1848, and the Pulmonata Cuvier, 1817. Species listed below and marked by an asterisk occur at the Coon Creek Formation's type locality in Tennessee.

The bivalve classification of Moore (1969) is followed here. More recent works concerning Coon Creek bivalves include Moore (1974) on the Coon Creek paleoecology (Bivalvia, Table III), Pojeta and Sohl (1987) on the Clavagellidae, Wingard and Sohl (1990) on the *Nucula percassa* lineage, and Wingard (1993) on the Crassatellidae. The cephalopod systematics and species listed below are from Wade (1926), Cobban (1974), Cobban et al. (1992), Kennedy and Cobban (1993), Cobban and Kennedy (1994), and Larson et al. (1997).

## Class Gastropoda Cuvier, 1797

### Subclass Archaeogastropoda Thiele, 1925

The ontogeny of the Archaeogastropoda does not include a planktotrophic larval stage, and the embryonic shell is usually mineralized after being deformed and just prior to the beginning of benthic life (Bandel, 1982). The earliest known representatives are of Ordovician age.

#### Order Docoglossa Troschel, 1866

These archaeogastropod limpets have the most primitive anatomy among the Gastropoda, a special docoglossate radula (few teeth in each row), a calcitic outer shell layer, and a crossed-lamellar inner shell layer. The earliest known representatives are of Triassic age.

### Superfamily Patelloidea Rafinesque, 1815

#### Family Acmaeidae Carpenter, 1857

##### 1. *Acmaea galea* Sohl, 1960\*

A single small specimen described by Sohl (1960, Pl.5, fig.34, 39) represents the cast of an internal shell surface and cannot be considered a reliable report of a docoglossan gastropod from the Ripley Formation. As the shells of patelloid limpets are usually, to a large part, of calcitic composition, their preservation should be no problem.

#### Order Vetigastropoda Salvini and Plawen, 1980

These archaeogastropods usually have a ripidoglossate radula (many teeth of different shape in each row), a slit- or not-slit-bearing shell that may have nacreous or crossed-lamellar structure; their shells are commonly trochiform in shape. The earliest known representatives are of Ordovician age.

### Superfamily Trochoidea Rafinesque, 1815

The Trochoidea have been evaluated by Hickman and McLean (1990), and, according to their diagnosis, they can be characterized as having a shell without slit or foramen. The shell shape is conical with the whorls increasing slowly in diameter, with the exception of some derived genera. An umbilicus may or may not be present. The aperture is commonly rounded; the anterior margin is free, and the apertural plane is commonly inclined in regard to the shell axis. The operculum is organic or calcified. Other features characterizing trochoideans concern the soft body; the shell shows numerous convergences, therefore, the assignment of fossils to Recent family groups is problematic.

### Family Trochidae Rafinesque, 1815

Few trochoid vetigastropods live on sandy or muddy unconsolidated substrates, thus, this family is rare in the Ripley Formation.

#### Subfamily Solariellinae POWELL, 1951

Shells are usually smaller than 10 mm, have rounded whorls with impressed sutures, the umbilicus is usually open and has a beaded margin. Hickman and McLean (1990) noted that recent members of this genus usually live offshore on unconsolidated sediment and feed on detritus.

#### Genus *Calliophalus* Cossmann, 1888

Plate 1, figures 1-2

The trochiform shell has a stair-step spire, a nacreous inner layer, and the characteristic protoconch of the archaeogastropods. Sculpture consists of beaded or spine-bearing spiral ribs crossed by axial ribs. The base is striated, and the wide umbilicus has an angulate margin. The aperture is round to almost round in shape. The type species is the modern *Turbo squamulosus* Lamarck, 1804.

Late Cretaceous shells of *Solariella*, *Calliophalus* and *Planolateralus* Sohl, 1960, are difficult to distinguish based on their adult shell alone. Members of *Calliophalus* and *Planolateralus* possess axial ribs on the first teleoconch whorl (Dockery, 1993) and are therefore placed in the Tribe Calliotropini (Hickman and McLean, 1990, p. 79-86; Bandel, 1993a). *Solariella montsecana* (Vidal, 1921) described by Kiel and Bandel (2001a, Pl.4, fig.8-10) from the Campanian of northern Spain is similar to *Calliophalus* and its subgenus *Planolateralus*. The two species *C. paucispirilus* and *C. tuberculosus* figured by Dockery (1993) from the Coffee Sand show that their teleoconch sculpture starts with axial ribs in contrast to the spiral cords of *Solariella montsecana*. Recent members of the Solariellinae and Calliotropini are both known to live on soft sediment in deeper waters (Herbert, 1987; Hickman and McLean, 1990). According to Dockery (1993), there are 10 species of *Calliophalus* present in the Upper Cretaceous deposits of the Gulf and Atlantic coast. Perrilliat et al. (2000) recognized three species of *Calliophalus* (*Planolateralus*) in the Mexcala Formation of southern Mexico, including *C. (P.) cf. decoris* Sohl, 1960.

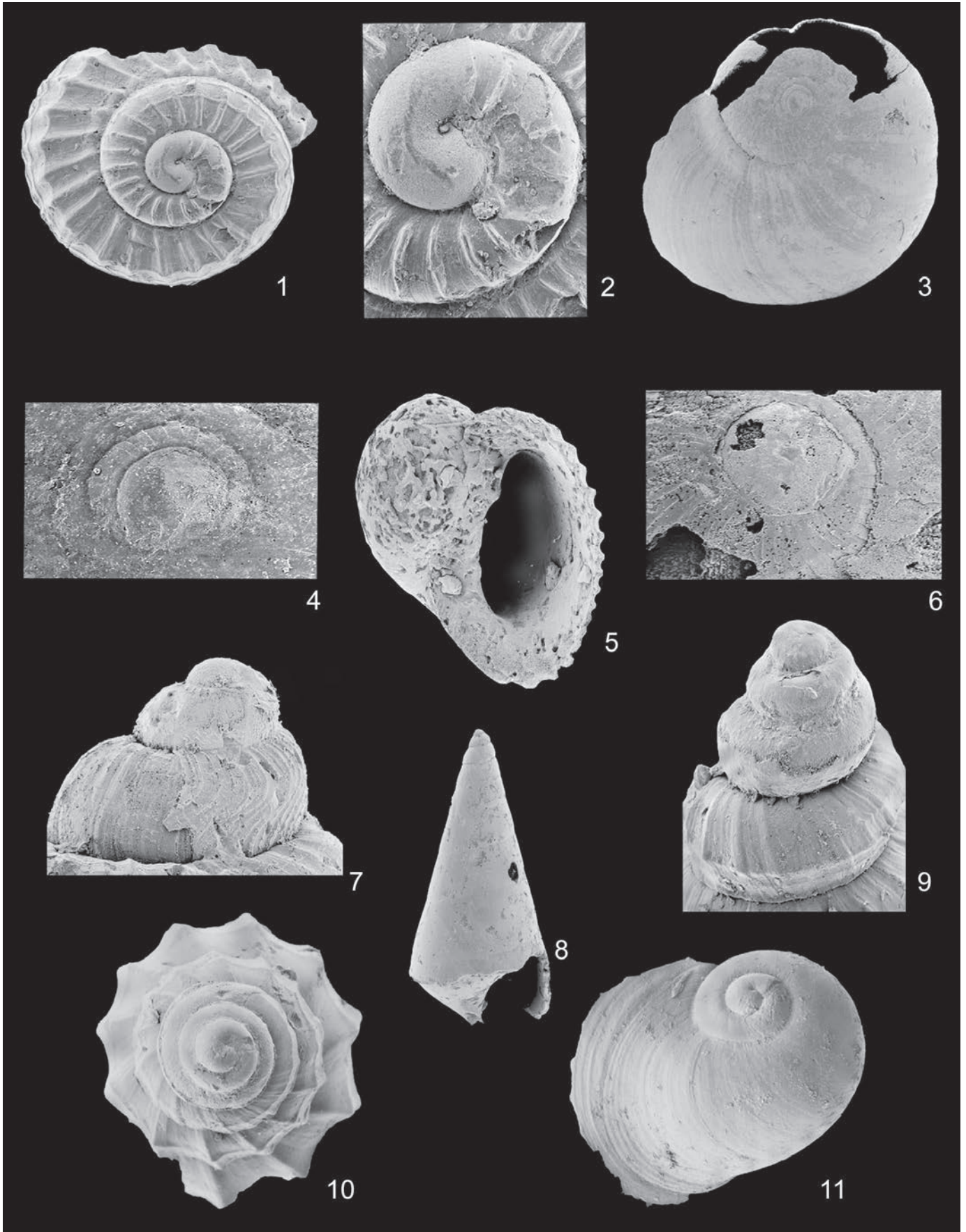
##### 2. *Calliophalus* (*Calliophalus*) *americanus* Wade, 1926\*

##### 3. *Calliophalus* (*Planolateralus*) *argenteus* Wade, 1926\*

##### 4. *Calliophalus* (*Planolateralus*) *argenteus spinosus* Sohl, 1960\*

##### 5. *Calliophalus* (*Planolateralus*) *decoris* Sohl, 1960\*





## Plate 1

Figure 1. The juvenile shell of *Calliomphalus* (*Planolateralus*) sp. from the Coon Creek Formation at Coon Creek has a teleoconch ornament of axial ribs. The shell measures 1.2 mm in width.

Figure 2. An enlargement of figure 1, that shows the protoconch of typical archaeogastropod shape with a fold that creates the impression of a suture and a little less than one whorl. The protoconch measures 0.25 mm across.

Figure 3. *Neritoptyx* sp. from the Campanian Coffee Sand in Mississippi (see Dockery, 1993, p. 180, MGS locality 129) has an early teleoconch that is almost smooth, apart from fine, closely spaced growth laminations. The shell measures 1.1 mm across.

Figure 4. An enlargement of figure 3, that shows the smooth, globular and strongly convolute protoconch. The visible protoconch measures only 0.1 mm across but is largely covered by subsequent whorls.

Figure 5. *Neritoplica* sp. from the Coffee Sand in Mississippi is tightly coiled, globular, and has one columellar plait in a posterior position and one minor fold at the base of the columella. The shell measures almost 1.2 mm in height.

Figure 6. An enlargement of figure 5, that shows the globular and smooth protoconch to be typical of those found among modern species of *Nerita*. The visible protoconch measures 0.1 mm across, but is partly covered by the following whorls.

Figure 7. The highly ornamented protoconch from the Coffee Sand in Mississippi is 0.35 mm high and belongs to an unknown species.

Figure 8. The smooth protoconch and teleoconch of this juvenile *Eulima* shell from the Coon Creek Formation at Coon Creek are difficult to tell apart. The shell is 2.5 mm high.

Figure 9. The smooth protoconch of this *Urceolabrum* sp. from the Coffee Sand in Mississippi consists of almost three whorls. The embryonic whorl measures 0.13 mm in width, and the whole protoconch is 0.35 mm high with rounded whorls.

Figure 10. An apical view of figure 9, which shows the transition from the protoconch to the teleoconch as indicated by increased growth lines and the beginning of ribbing.

Figure 11. The protoconch of *Thylacus* sp. from the Coffee Sand in Mississippi is large and consists of three whorls after which the shell expands to assume a limpet shape. The shell is almost 1 mm wide.

6. *Calliomphalus* (*Planolateralus*) *angustus* Sohl, 1960\*

7. *Calliomphalus* (*Planolateralus*) *conanti* Sohl, 1960\*

The six forms of *Calliomphalus* in the Coon Creek horizon differ little from each other (Sohl, 1960, Pl.5, fig.1-33). The species *Calliomphalus paucispirilus* Sohl, 1964a, has a flat subsutural ramp and an ornament of granular spiral cords; the shell may be 8 mm high and 10 mm wide. The protoconch measures almost 0.25 mm across and is sculpture by three spiral lirae and fine tubercles scattered on the smooth surface between them. The aperture is not thickened but is clearly set off from the teleoconch as was noted by Dockery (1993). A sculpture of axial ribs predominates on the first whorl; four spiral ribs appear on the second whorl. The exterior shell layer is calcitic, and the inner layer is composed of nacreous aragonite.

In the case of *Calliomphalus tuberculosus* Sohl, 1964a, the protoconch is archaeogastropod-like, is a bit more than 0.25 mm in diameter, and has a rounded apex. The surface sculpture consists of a very fine granulation and is otherwise well rounded and smooth. The protoconch apertural margin is simple and straight, and the transition to teleoconch ornament is abrupt. The onset of the teleoconch features axial and spiral ribs in contrast to *C. paucispirilus*, where spiral lirae appear later.

#### Subfamily Umboniinae Adams and Adams, 1854

Recent members of the genus *Umbonium* LINK, 1807, live as filter feeders on soft bottoms in shallow, commonly intertidal water. Sohl (1960, pl. 7, fig.1, 2, 9) identified a related species, with a nacreous shell, as an architectonicid,

a group with crossed-lamellar shell structure. Shell nacre places this small species (8 mm wide and about 1 mm high) with the archaeogastropods, and the shell shape indicates a place near *Umbonium*, an extant genus with a history ranging to the base of the Triassic (Bandel, 1993a). Dockery (1993) described *Ataphus kerri* from the Coffee Sand, which resembles *Umbonium* and has the archaeogastropod protoconch and the nacreous shell preserved as well.

8. *Margaritella pumila* Stephenson, 1941

**Subclass Neritimorpha Golikov and Starobogatov, 1975**

Mesozoic and modern Neritimorpha can be recognized by their early ontogenetic shell, which differs in character from all other subclasses of the Gastropoda (Bandel 1982, 1997, 2000a; Bandel et al., 1997). The marine species of the Neritimorpha have a characteristic tightly coiled, almost globular, larval shell of “neritimorph shape” ranging back to Carboniferous times (Bandel 2000a). Members of the families Neritidae Rafinesque, 1815, and Pileolidae Bandel, Grüdel, and Maxwell, 2000, dissolve their inner shell walls, while members of the superfamily Neritopsoidea Gray, 1847, do not (Bandel and Frýda, J., 1999).

**Order Cycloneritimorpha Bandel and Frýda, 1999**  
**Superfamily Neritoidea Rafinesque, 1815**

Anatomically neritimorphs resemble archaeogastropods, especially regarding the arrangement of the teeth in their radula, but they have a planktotrophic larval stage during which they secrete a characteristic larval shell (Bandel 1982). The superfamily Neritoidea, of the Neritimorpha order Cycloneritimorpha, is characterized by the dissolution of the inner shell walls in the teleoconch as well as in the protoconch. They have been documented to occur since Triassic time. Usually species of this group live on hard substrates and graze on algal or fungal growths.

**Family Neritidae Linné, 1758**

Species of the nerities have a roundish shell with a low spire, enveloping body whorl, and dissolved inner walls. The protoconch is smooth, consists of several aragonitic whorls, and is globose and involute (Bandel, 1982, 2000a, 2001). The aperture is semicircular in outline, has a denticulate or smooth columellar lip, and has an outer lip with a crenulated interior margin. The teleoconch is composed of an outer calcite layer, which is underlain by an inner aragonite layer with crossed-lamellar structure. The planktotrophic larva usually has

an enlarged protoconch with smooth whorls in a strongly convolute arrangement. As in the teleoconch, inner walls are dissolved in the protoconch. Here the shell consists of a very thin organic periostracum underlain by aragonite mineral deposits.

**Genus *Neritoplica* Oppenheim, 1892**

The smooth neritinid shell has an oblique, semicircular aperture that has a strong fold on the apical side of the columellar edge of the inner lip, which continues into the shell's interior. Some weak denticles may be present below. The type species is *Neritina uniplicata* Sowerby, 1823 (= *Neritina globulus* Deshayes, 1824) from the Late Paleocene of the Paris Basin.

9. *Neritoplica* sp.

Plate 1, figures 5-6

This *Neritoplica* from the Coon Creek Formation, Union County Lake, Mississippi, is tightly coiled, globular, and has one columellar plait in a posterior position and one minor fold at the base of the columella. It has the typical neritiform larval shell (Bandel and Kiel, 2003) and aperture (Dockery, 1993: pl. 4, fig. 3-4). *Neritoplica* sp., as illustrated by Bandel and Kiel (2003, pl. 2, fig. 12-14), has a globular neritid shell with concave columella. The shell is light brown and shows a color pattern of three dark-brown spiral stripes and irregular white splotches. Its relation to the shells documented by Sohl (1960, pl. 6, fig. 12-14) is unproven due to their poor preservation, and they could also belong to *Neritoptyx*.

**Genus *Neritoptyx* Oppenheim, 1892**

Plate 1, figures 3-4

The neritiform shell has an ornamentation of spiral ribs crossed by collabral growth elements in a regular way, and there is one fold on the columellar edge of the inner lip. The type species is *Nerita goldfussi* Keferstein, 1829, from the Late Cretaceous of Europe.

Bandel and Kiel (2003, pl. 2, fig. 19, 20) placed *Nerita reticulirata* Dockery, 1993, from the Campanian Coffee Sand in the genus *Neritoptyx*. The shell has a smooth neritid protoconch and a strongly lirated teleoconch with a single tooth on the upper part of the inner lip. The early teleoconch is almost smooth, apart from fine, closely spaced growth laminations. A first spiral lira is present here but is covered by the succeeding whorl. Spiral lirae appear abruptly after two smooth whorls. The aperture is semicircular, and the inner lip bears a columellar fold. It resembles the type species but differs in lacking juvenile sculpture.



### Subclass Caenogastropoda Cox, 1959

The shell is coiled in one direction throughout life, and the early ontogeny includes the potential of a planktotrophic larva. The embryonic whorl is always spirally coiled in the same direction as the larval shell and the teleoconch and represents the shell of the hatchling from the egg-capsule. In cases with planktotrophic development, most of the embryonic shell usually lacks growth lines. The larval shell has growth lines and is usually clearly distinguished from the teleoconch by an apertural thickening, by change in growth line pattern, by change in general shape, and by change in ornament. The teleoconch is constructed predominantly of an aragonitic shell with a crossed-lamellar structure and rarely with an external calcitic layer. Species that live on land have a simplified protoconch without a larval shell. Marine species with a lecithotrophic ontogeny also have a simplified protoconch shape.

### Superorder Palaeocaenogastropoda Bandel, 1993b

The Palaeocaenogastropoda include the most primitive Caenogastropoda such as the Orthonematoidea (Nützel and Bandel, 2000; Bandel, 2002) of late Paleozoic age and the Cerithimorpha and Littorinimorpha, which have fossil records extending back to Triassic time.

### Order Cerithiimorpha Golikov and Strarobogotov, 1975

This order holds the Cerithioidea and relatives among the caenogastropods, usually with males lacking a penis.

### Superfamily Cerithioidea Férrusac, 1819

Fossil gastropods that are close to members of this superfamily range from Triassic to Recent times. Modern species usually graze on algae and plants. The transition from Mesozoic groups into the modern families of the Cerithioidea is still problematic, and the exact placement of the Coon Creek members of this taxon in regard to modern families is still somewhat uncertain. A more reliable classification can be made as soon as protoconchs are known for the Cretaceous species.

### Family Potamididae H. and A. Adams, 1854

This family contains medium-size to large snails with 20- to 100-mm-long turreted shells, reaching up to 16 cm in length with high spires and commonly strongly sculptured shells. The aperture has a deep notch at its base.

Members of the family Procerithiidae can be recognized by the spiral ornament of their protoconchs, however, they grade into the Potamididae as well as the Cerithiidae.

Jurassic cerithiform gastropod species can usually be placed into the Procerithiidae without problems. Only Tertiary species, belonging to the Potamididae and Cerithiidae, can be traced with certainty to living forms. Cretaceous species of Cerithioidea are insufficiently known to be placed in a satisfying taxonomic position.

### Genus *Tympanotonos* Schumacher, 1817

The turreted conical shell has an almost quadrangular aperture and straight columellar lip. The labrum has a hood-like anterior projection. Ornament is variable and changes with growth. It consists of crenulate spiral threads with or without nodes and/or spines. The type species is the recent *Tympanotonos fluviatilis* Schumacher, which lives in estuarine environments in Angola.

#### 10. *Tympanotonus* (*Tympanotonus*) *cretaceus* (Wade, 1926)\*

Dockery (1993) described three species of *Tympanotonos* from the Coffee Sand in Mississippi. The sculpture of these three species shows a gradation from strong axial nodes in *T. cretaceus* (Wade, 1926) to axial nodes that change to double nodes on the last two whorls in *T. coffea* Dockery, 1993, to axial nodes that become binodose on the last four whorls in *T. mississippiensis* Dockery, 1993. Kowalke (1998) interpreted the relations of *Potamides cowickeensis* of Sohl (1964b) = *Tympanotonos* (*Exechocirsus*) *cowickeensis* of Dockery, 1993, as belonging to the family Procerithiidae Cossmann, 1906, instead to the family Potamididae, and placed it in the genus *Schroederium* Kowalke, 1998. The type species of this genus is *Bittium valanginensis* Schroeder, 1995, from the Early Cretaceous of Poland.

### Genus *Dircella* Sohl, 1960

The type species is *Dircella spillmani* (Conrad, 1860), a 7-cm-high cerithiid from Owl Creek that somewhat resembles a modern *Bittium* in the shape of the teleoconch.

### Family Cerithiidae Férrusac, 1819

Members of this family frequently are of median size and commonly measure several centimeters in length. The aperture commonly has a flared outer lip and may have a long siphonal canal twisted to one side. The shell is usually turritiform and ornamented by ribs, and the aperture has a channeled anterior. The protoconchs of the three species must be better known before they can be placed satisfactorily in a modern cerithioid genus. They could prove to belong to another family of the Cerithioidea than is indicated here. Perrilliat et al. (2000) indentified "*Cerithium*" *nodoliratum* Wade, 1926, in the Mexcala Formation of southern Mexico and placed it in the genus *Cerithiella*.

11. *Cerithium weeksi* Wade, 1926\*
12. *Cerithium nodoliratum* Wade, 1926\*
13. *Cerithium semirugatum* Wade, 1926\*

#### **Genus *Nudivagus* Wade, 1917b**

The type species is *Nudivagus simplicus* from the Coon Creek Formation type locality (Sohl, 1960, pl.8, fig.14), which has a smooth shell. Though it is common at Coon Creek, the placement of this species is still problematic. The size and shape of the specimen illustrated by Sohl (1960, pl. 8, fig. 14) resembles that of the genus *Pseudomelania* Pictet & Campiche, 1862. Here the shell is slender, conical, and has an oval aperture without a siphonal notch. Growth lines are sinuous. The type species is *Pseudomelania gresslyi* Pictet and Campiche, 1862. *Pseudomelania* is also a problematic taxon and was placed by Wenz (1938) in the Pseudomelaniidae. Some modern Potamididae are similar in shell shape (Houbrick 1991), but *Pseudomelania* has no apertural siphon as is usually found among the former. Pseudomelaniidae are more conical than most Turritellidae, but *Pseudomelania undosa* (Forbes, 1846) from the Trichinopoly Group has similar growth lines (Bandel 2000b, fig.11, 12). In general shell shape, *Nudivagus simplicus* is like *Pseudomelania* from the Campanian of India or the Santonian of South Africa. *Nudivagus* sp. could represent a juvenile shell of the *N. simplicus*.

Elder (1990) described a new *Tibia*-like, aporrhaid genus *Tibiaporrhais* for newly discovered specimens of the species “?*Nudivagus*” *cooperensis* Stephenson, 1941, from the Campanian Pierre Shale in Colorado. The new specimen preserved two spine-like extensions of the outer lip, which resembled the digitate outer lip of *Tibia*. Elder (1990, p. 296) did not reassign the type species of *Nudivagus* Wade, 1917b, as specimens of this species lacked evidence of spine-like apertural processes.

14. *Nudivagus simplicus* Wade, 1917b\*
15. *Nudivagus* sp.

#### **Genus *Trobus* Stephenson, 1955**

According to Sohl (1960, Pl.8, fig. 19, 22), *Trobus* resembles *Turritella* in size and shape but could also be interpreted as close to *Pseudomelania* (*Nudivagus*). Before *Nudivagus* and *Trobus* can be placed in a more secure taxonomic position, their protoconch morphology must first be known.

16. *Trobus corona* (Conrad, 1860)

#### **Genus *Melanatria* Bowdich, 1822**

The type species is the living *Trochus flumineus* Gmelin, 1790, from Madagascar. The fossils documented by Sohl (1960, pl. 9, fig. 38, 39) as *Melanatria?* sp. from the Owl Creek Formation represent a fragmentary and doubtful species, which Dockery (1993) compared with a *Pyrazus*-type cerithoid. Another large sized cerithoid with apertural sinus from the Coffee Sand was placed in the genus *Gymnentome* by Dockery (1993, pl.12, fig. 5, 8-10), who described *Gymnentome unicarinata* n. sp. as about 19 cm high.

17. *Melanatria?* *cretacea* Wade, 1926\*

#### **Family Turritellidae Lovén, 1847**

The high-spired shell has numerous whorls and a simple aperture. Members of this group are known from the Middle Jurassic to the Recent.

#### **Genus *Turritella* Lamarck, 1799**

The slender, turreted-conical shell has numerous whorls and is sculptured with spiral threads or costae and curved growth lines. The aperture is rounded or quadrate and not large. The columella is smooth and concave. The type species is the modern *Turbo terebra* Linné, 1758. Species of *Turritella* usually live on or in the sediment and feed by filtering suspended matter from seawater with the aid of ciliary pumping by the gill. A number of species of *Turritella* were described by Sohl (1960, pls.7, 8) to occur in the Ripley Formation, but Sohl (1964b) later placed *T. bilira* and *T. trilira* in the genus *Haustator*. Serna (1979) placed those species recognized as *Haustator* by Sohl (1964b) in a new genus *Sohlitella*. Perrilliat et al. (2000) found *T. vertebroides* and *T. trilira* to occur in the Mexcala Formation of southern Mexico.

18. *Sohlitella bilira* Stephenson, 1941
19. *Turritella howelli* Harbison, 1945
20. *Turritella tippiana* Conrad, 1858\*
21. *Turritella vertebroides* Morton, 1834\*
22. *Turritella macnairyensis* Wade, 1926\*
23. *Turritella hilgardi* Sohl, 1960
24. *Sohlitella trilira* Conrad, 1860\*

#### **Family Vermetidae Rafinesque, 1815**

Characteristically the vermetid teleoconch is attached, and the shell uncoils either right after settling and attaching to hard substrate or during juvenile life. Feeding is by filtering seawater with the gill and is sometimes

aided by the production of a mucus net with the foot. The group first appeared during the Late Cretaceous. In the Vermetidae there are three protoconch types, one like that of *Vermetus nielsenii* Bandel and Kiel, 2000, from the Campanian of northern Spain, with a spiral shape, a second like *Petalococonchus* with a barrel-like shape (Bandel and Kowalke, 1997a, pl. 1, fig. 7), and a third like *Laxispira* with a pitted surface (see Sohl, 1960; Dockery, 1993; and Bandel and Kowalke, 1997a).

25. *Laxispira lumbricalis* Gabb, 1877\*

The protoconch of *L. lumbricalis* is trochoid in shape and consists of three convex whorls, the second of which has rows of very fine punctae. The embryonic shell measures about 0.1 mm and consists of 0.7 whorls with smooth surface. The larval shell has a sculpture of tubercles and ends in a rounded apertural projection after 2.5 whorls are added. The protoconch measures about 0.5 mm in height and 0.45 mm in width. Uncoiling of the shell becomes obvious at the beginning of the teleoconch and spiral ribbing becomes evident as well. According to Bandel and Kiel (2000), *Vermetus* s.str. co-existed with *Laxispira* in the Campanian.

**Superfamily Rissoidea Gray, 1847**

**Family Rissoidae Gray, 1847**

**Genus *Alvania* Risso, 1825**

The ovate to elongate-conical shell is usually less than 5 mm in height and is ornamented with strong axial and similar or weaker spiral ribs. The type species is the modern *Turbo cimex* Linné, 1758. Larval shells of modern species within this genus usually have an ornament of spiral rows of tubercles, and the embryonic shell has the more usual pattern of spiral lines with tubercles between them. Lecithotrophic development is indicated in case of the *Alvania* from the Coon Creek Formation and Coffee Sand, and here the ornamental pattern on the protoconch consists of a pattern of spirally arranged grooves and pits.

This species *Alvania tallahatchiensis* (Sohl, 1960, pl. 9, fig. 37, 40-43) is small and stout with a conical shell that is ornamented by strong transverse costae and weaker spiral cords. The shell has an evenly tapered spire. The whorls are rounded and ornamented, while the base is smooth. The outer lip of the simple aperture is thickened in the adult shell. The shell is less than 3 mm high. The protoconch consists of 1.5 whorls and is ornamented by rows of pits on a smooth surface. Sohl (1960) placed the species in the genus *Turboella*, Dockery (1993) preferred *Alvania*.

26. *Alvania tallahatchiensis* (Sohl, 1960)

27. *Alvania costata* (Wade, 1926)\*

(Sohl, 1960, Pl.9, fig.25, 26)

28. *Alvania crebricostata* (Sohl, 1960)

(Sohl, 1960, Pl.9, fig.32-34)

**Genus *Anteglosia* Vokes, 1948**

According to Sohl (1960) and Dockery (1993), the glossy elongate-conical shell has an angulate periphery and is ornamented by spiral and axial threads of equal strength with pits in the interspaces on the whorls of the upper spire; the remainder of the teleoconch is smooth. The aperture is elongate oval with weak angulations. The outer lip is prosocline and thickened with a narrow posterior notch and no anterior canal. The columella is deeply excavated. The protoconch is ornamented.

*Rissoina tennesseensis* Wade, 1926, is a small (up to 7 mm high) elongate conical shell with about 6 convex whorls, which are microscopically pitted, and an ovate aperture that has a small posterior canal, a notched anterior canal, and a thickened outer lip. The protoconch is conical with an impressed suture and consists of about three convex whorls sculptured on the lower half with spirally arranged fine granules (Dockery, 1993). New scanning photos reveal that the protoconch consists of a little more than 4 whorls and is almost 0.9 mm high. The embryonic shell measures 0.14 mm across and is a little less than one whorl. It is sculptured by a dense pattern of rounded grooves surrounded by irregular ridges. The larval shell develops an apertural projection within the growth of the first larval whorl, which becomes more prominent and forms a large basal projection on the pediveliger shell. Above it, the outer lip forms a deep indentation that is well rounded. The ornament consists of spiral lirae in the lower part of the whorl ending in the upper portion of the larval hook. These lirae are indistinct on the first larval whorl and are connected to oblique rows of granules on the second larval whorl (third shell whorl); on the last larval whorl, only three spiral lirae are present. The teleoconch is almost smooth with indistinct rows of pits and curving growth lines.

Dockery (1993) placed the species in the genus *Cossmannia* Newton, 1891, the type species of which is *Rissoina expansa* Deshayes, 1861. Neither the protoconch nor aperture fit the description of *Cossmannia*, therefore *Rissoina tennesseensis* Wade, 1926, from the Coffee Sand may not belong to this genus. Whether *Anteglosia* is the correct genus will be shown as soon as the type to the genus *A. essoensis* Vokes, 1948, from the Cenomanian of New Jersey is known in more detail. At present, the ornament of pitted whorls appears to indicate the relation as discussed by Sohl (1960). A smooth form of this genus is *Anteglosia subornata* (Wade, 1926).



29. *Anteglosia tennesseensis* (Wade, 1926)\*  
(Sohl, 1960, Pl.9, fig.1-3)

30. *Anteglosia subornata* (Wade, 1926)\*

#### Family Adeorbidae Monterosato, 1884

The genus *Adeorbis* S. Wood, 1842, with the extant type species *Helix subcarinata* Montagu, 1815 from the Northern Atlantic, has been documented from the Coffee Sand by Dockery (1993, pl. 11, fig. 6, 7) as "*Tornus*" *planocarinatus* Dockery, 1993, representing the oldest known *Adeorbis* according to Kowalke (1998).

#### Genus *Teinostoma* A. Adams, 1851

The small discoidal glossy shell is sculptured by fine spiral striae or is smooth. The umbilicus is covered by a broad flat callus. The type species is *Teinostoma politum* A. Adams, 1853.

The species *Teinostoma prenanum* Wade, 1926, is small in size (almost 2 mm wide) and is involute so that only the body whorl and about one fourth of the penultimate whorl are visible in the apical view. Juvenile specimens are ornamented by spiral rows of pits. A smooth umbilical plug occupies the central region of the base. The protoconch consists of about two smooth whorls (Dockery, 1993). This can be further detailed from additional observations according to which the embryonic shell measures about 0.1 mm in width and is covered by a minute ornament of rounded grooves surrounded by irregular ridges. The larval shell consists of at least another whorl ornamented only by growth lines reflecting the simple outline of the outer lip. The protoconch measures about 0.3 mm across and is of low, rounded, trochospiral shape. Wade (1927), Sohl (1960), and Dockery (1993) illustrated this species from the Upper Cretaceous deposits of the Gulf Coast.

Sohl (1960, Pl.6 fig.1-11) distinguished *T. prenanum* from *T. clara* by the ornament of the juvenile shell, which is actually alike in both species, but variable among individuals. The only difference lies in the absence of an umbilical plug in *T. clara*.

31. *Teinostoma prenanum* Wade, 1926\*

32. *Teinostoma clara* Sohl, 1960

#### Family Pickworthiidae Iredale, 1936

This group was considered a questionable representative of the Rissoidea by Ponder and Warén (1988) and seen as a separate family by Ponder (1985). Wenz (1938) considered *Urceolabrum* to be an acaegastropod in the family Turbinidae. Sohl (1960) accepted this placement, but Dockery (1993) found a larval shell, which clearly indicated that it was a caenogastropod. Dockery (1993)

also suggested a connection to the modern *Sansonia* (= *Pickworthia*).

#### Genus *Urceolabrum* Wade, 1916

Plate 1, figures 9-10

The small trochiform shell has prominent axial costae and a circular, heavily reinforced aperture. The protoconch is trochiform, smooth, and consists of several whorls. The base is umbilicate (Sohl, 1960, pl. 6, fig. 15-17, 18-20). The type species is *Urceolabrum tuberculatum* Wade, 1916, which has a smooth protoconch of almost three whorls. The embryonic whorl measures 0.13 mm in width, and the whole protoconch is 0.35 mm high with rounded whorls. The apertural margin appears to be smooth.

The genus *Sansonia* Jousseaume, 1892, with the type species *Iphitus tuberculatus* Watson, 1886, from the Caribbean Sea, differs from *Urceolabrum* in its larval shell. The teleoconch is smaller than 2 mm and is turbinate with a high spire and flattened whorls. The outer lip of the fully-grown individual is thickened and forms a strong varix. The aperture thus resembles that of *Urceolabrum*. However, the larval shell is barrel shaped, sculptured by spiral lines, and ends with a large apertural projection (Bandel and Kowalke, 1997b).

33. *Urceolabrum tuberculatum* Wade, 1916\*

34. *Urceolabrum tuberculatum callistum* Harbison, 1945

#### Family Pseudamauridae Kowalke and Bandel, 1996

This family holds caenogastropods of *Natica*-like shape with globular to egg-conical shells, with whorls rounded or flattened at the sides, and a large final whorl of globular or egg-like shape. The protoconch is low, conical, and with rounded whorls, which are ornamented by fine collabral lirae that reflect an apertural projection. While the teleoconch of Pseudamauridae is convergent with that of some Naticoidea, the protoconch is different in size (smaller), in ornament (collabral curving lirae), and in shape (not naticoid).

#### Genus *Pseudamaura* Fischer, 1885

*Pseudamaura* is based on the type species *Natica bulbiformis* Sowerby, 1831, from the Late Cretaceous Gosau deposits in the northern Alps. This species lived in the environment of a tropical lagoon. Its thick-walled, egg-shaped shell consists of rounded, posteriorly tabulated whorls and a narrow umbilical slit that is wider in younger individuals. The aperture is almost oval or spindle shaped, and the inner lip may have a columellar callus and a callus pad that covers the shell (Kowalke and Bandel, 1996, pl. 6,

fig. 3-6). The Late Cretaceous *Pseudamaura lirata* (Wade, 1926) from Coon Creek (Sohl, 1960, pl. 17, fig. 20, 21, 23) is a typical representative of the family (Kowalke and Bandel 1996). Here the protoconch consists of 1.7 whorls, has a diameter of 0.31 mm, and a large first whorl (0.18 mm across), which indicates a lecithotrophic development.

*Pseudamauralepta* Sohl, 1964b, with a high-spined naticoid shell, channeled sutures, and delicate spiral sculpture, from the Coffee Sand (Late Campanian of Mississippi, Sohl, 1964b, pl. 55, fig. 3-5; Dockery, 1993, pl. 20, fig. 5, 6) and *Pseudamaura lirata* (Wade, 1926) from the Coon Creek Formation are similar species from a less tropical environment than that of the type species. *Pseudamaura nobilis* (Stoliczka, 1868) from the Trichinopoly group in southern India represents a related species in the former Southern Hemisphere (Bandel 2000b). Stephenson (1952, pl. 35, fig. 27-38) described *Natica humilis* Cragin, 1893, *Natica striaticostata* Cragin, 1893, *Natica dorothiensis* Stephenson, 1952, *Natica rivulana* Stephenson, 1952, from the Cenomanian Woodbine Formation of Texas, all of which may represent one somewhat variable species of the Pseudamauridae, predating the genus *Pseudamaura*. Perrilliat et al. (2000) identified a species in the Mexacala Formation of southern Mexico as *Pseudamaura* cf. *lepta* Sohl, 1964b.

35. *Pseudamaura lirata* (Wade, 1926)\*

### Genus *Ampullina* Bowdich, 1822

*Ampullina* typically has a large, thick, high-spined, rather globose naticoid shell with stepped whorls and spiral rows of fine punctae. Its umbilicus is small and limited by a well-defined margin. The aperture is narrowly semilunar. Its inner lip has thick columellar and parietal callus. The genus is based on the type species *Ampullina depressa* (Lamarck, 1804) from the Middle Eocene of the Paris Basin. Dockery (1993, pl. 20, fig. 15) placed the Campanian *Ampullina potens* Wade, 1926, from Coffee Sand of Mississippi, in this genus. It is also described from the Coon Creek Formation (Sohl, 1960, pl. 17, fig. 24, 25). The protoconch of *Ampullina* from the Eocene of the Paris Basin and from the Eocene of the northern Pyrenees has a sinusigera shape (Bandel 1999, pl. 3, fig. 7, pl. 4, fig. 4). Here the embryonic whorl measures about 0.1 mm in diameter and is succeeded by more than one larval whorl ending in a strongly sinuous, thickened, apertural margin. The protoconch measures about 0.3 mm in width and is of rounded trochiform shape with sinuous growth lines as the only ornament.

36. "*Ampullina*" *potens* Wade, 1926\*

### Genus *Amaurellina* Fischer, 1885

*Amaurellina* has a medium-size naticoid shell with

a tabulate spire and a last whorl comprising about two-thirds of the height. The shoulders are excavated with a narrowly channeled suture. The aperture is ovate with the inner lip expanded and reflected at its anterior end. The base has a notched umbilicus due to a slender cord, arising at the anterior of the inner lip, which is directed into the umbilicus. The type species is *Amaurellina spirata* (Lamarck, 1804) from the Middle Eocene of the Paris Basin. An *Amaurellina* from that locality has a protoconch with a smooth embryonic whorl measuring a little more than 0.1 mm in diameter and clearly set off from the larval shell by its initial growth lines. The larval shell consists of 1.5 whorls and is ornamented by regular and sinuous collabral lines on a smooth surface. The whole protoconch is of similar height as width, consists of a little more than two whorls, and measures about 0.3 mm across (Bandel, 1999, pl. 4, fig. 2, 3, 4). *Amaurellina stephensoni* Wade, 1926, is known from both the Coon Creek Formation (Sohl, 1960, pl. 17, fig. 15-19, 22) and the Coffee Sand (Dockery, 1993, pl. 20, fig. 7, 8). The protoconch of this species is unknown.

37. *Amaurellina stephensoni* (Wade, 1926)\*

### Genus *Globularia* Swainson, 1840

#### Subgenus *Ampullella* Cox, 1931

38. *Globularia (Ampullella) umbilica* (Wade, 1926)\*

Sohl (1960, pl. 18, fig. 39, 40) described and reassigned *Polinices umbilica* Wade, which probably belongs to the Pseudamauridae. The protoconch could solve the question but is still unknown.

### Order Ctenoglossa Gray, 1853

#### (= *Ptenoglossa* Gray, 1853)

The Ctenoglossa represent a diverse group of caenogastropods with a rather distinctive ecology. Recent members of this group include the superfamilies Janthinoidea, Eulimoidea, Triphoroidea and Cerithiopsoida, all of which have been in existence since Late Cretaceous times. Living species of Janthinoidea, Triphoroidea, and Cerithiopsoida usually dwell in and feed on coelenterates and sponges, while the Eulimoidea have become specialized parasites on echinoderms. The Ctenoglossa diverged from other caenogastropods in the Carboniferous and, thus, have a 350-million-year history that is independent from that of the other gastropods (Bandel, 1991a, 2002; Nützel, 1998).

### Superfamily Cerithiopsoida

#### H. and A. Adams, 1854

This group has a slender, dextral, and usually small, cerithiiform shell composed of many whorls; its species live in and feed on sponges. According to Nützel (1998), the superfamily holds the two families, the Cerithiopsidae and Eumetulidae, which can be distinguished from each other by the ornament of the larval shell. The larval shell of the Cerithiopsidae is smooth, while the larval shell of the Eumetulidae has axial ribs.

### **Family Eumetulidae** **Golikov and Starobogatov, 1975**

According to Nützel (1998), all Cerithiopsidae with a larval shell bearing collabral ornament are included in this family. Nützel stated that this placement represented a simplified mode of classification and needed refining. This may also be indicated in the somewhat doubtful placement of the "loxonematid" protoconchs noted by Sohl (1960, pl. 6, fig. 21-24), which may be recognized in the Eumetulidae (Cerithiopsidae) as well as with the Nystiellidae (Lanthinoidea).

Nützel (1998) considered the *Seila*-like teleoconch to have evolved twice within the Cerithiopsidae. In the case of *Seila*, it is connected with a smooth, *Cerithiopsis*-like protoconch, while it is of the collabrally-ribbed, *Eumetula*-type in the case of *Variseila*. Nützel (1998) supposed that the *Seila*-type of ornament was easily generated by the subpression of the axial ribs, a process observable in the ontogeny of the Recent *Specula styliformis* Suter, 1908 (see Nützel, 1998, pl. 3, fig. I-K).

### **Genus *Variseila* Dockery, 1993**

The teleoconch has spiral ornament resembling that of a modern *Seila*, while the larval shell has collabral ribs. The type species is *Cerithiopsis meeki* Wade from the Ripley Formation. The protoconch, as illustrated by Dockery (1993) and Nützel (1998, pl.17, fig. F, G), is high-spined; the teleoconch is very slender, flat sided, and spirally ribbed; and the anterior canal is twisted. *Ataxocerithium dockeryi* Nützel, 1998, from the Campanian Coffee Sand of Mississippi, has a protoconch with similar ornament as is found in *Variseila*, but the teleoconch resembles that of *Vatopsis* (Nützel 1998, pl.17, fig. R). The placement below of "*Mathilda?*" *cedarensis* Stephenson is problematic.

39. *Variseila meeki* (Wade, 1926)\*
40. *Variseila quadrilirata* (Wade, 1926)\*
41. *Variseila* sp.
42. "*Mathilda?*" *cedarensis* Stephenson, 1941

### **Genus *Ataxocerithium* TATE, 1894**

The slender, high-spined shell is ornamented with five

or more spiral ridges and axial ribs. The planktotrophic larval shell is high-spined and sculptured with collabral axial ribs. The type species is the Recent *Cerithium serotinum* Adams, 1855, from southern Australia. *Ataxocerithium* is distinct from *Eumetula* in having five or more spiral cords; *Eumetula* has four or less.

The species *Ataxocerithium helicina* (Dockery, 1993) was again documented by Kiel (2001, pl. 16, fig. 4) from the Maastrichtian of Temalac, Mexico; it had originally been placed in the genus *Eccliseogyra* Dall, 1892, by Dockery (1993, pl. 25, fig.1-5; pl.26, fig.15-16) and Nützel (1998, pl. 18, fig. V-W). Here the conical protoconch consists of four and one half whorls with oblique axial ribs and is 0.65 mm high and 0.53 mm wide. The teleoconch consists of convex whorls with five spiral cords and weak axial ribs. *Eccliseogyra* was considered to represent a member of the Lanthinoidea by Nützel (1998).

Loxonematid C of Sohl (1960, pl.6, fig. 23) resembles *Ataxocerithium dockeryi* Nützel, 1998, from the Coffee Sand (Nützel 1998, pl.17, fig. R), however *Opaliopsis* aff. *faarium* of Nützel (1998, Pl.19, fig. H-J) is also similar. Even though a common ancestry of the Cerithiopsidae and the Lanthinoidea can be assumed, it is unlikely that species with the protoconch type as suggested by Sohl (1960) represent loxonematid gastropods and as recognized by Dockery (1993) belong to the Lanthinoidea instead of belonging to two different superfamilies of the Ctenoglossa.

43. "loxonematid" gastropod, type A, Sohl, 1960
44. "loxomenatid" gastropod, type B, Sohl, 1960
45. "loxomenatid" gastropod, type C, Sohl, 1960

### **Genus *Vatopsis* Gründel, 1980**

The teleoconch is axially and spirally ribbed, and the protoconch has larval whorls characteristically ornamented by axial ribs below the suture and spiral ribs low on the whorl. According to Nützel (1998, pl.17, fig. P, Q), *Vatopsis* sp. from the Coon Creek Formation type locality resembles *Vatopsis aequilirata* (Dockery, 1993) from Coffee Sand.

46. *Vatopsis* sp.\*

### **Genus *Eumetula* Thiele, 1912**

The shell is axially and spirally ornamented, and the protoconch has a larval shell with collabral ribs. The type species is *Eumetula dilecta* Thiele, 1912, a cold-water marine species.

Kiel (2001, pl.17, Fig. 1) recognized a species from the Coffee Sand, identified by Dockery (1993, pl. 23, fig.1-2) as *Cerithiella* sp., which also occurs in the Maastrichtian



of Temalac, Mexico. This E. (*Cerithina*) has a slender, multiwhorl protoconch and a teleoconch with four beaded spiral cords and axial ribs, which are in a vertical order. Its embryonic shell is smooth and globular (0.1 mm wide), and the larval shell has collabral ribs. The first teleoconch whorls have three spiral ribs and equally strong axial ribs. The adult shell consists of numerous whorls with flattened sides, which are ornamented by axial ribs crossed by four spiral cords having nodules where they cross each other. The basal margin has two strong keels; the base is concave, and the aperture is rounded.

### Superfamily Ianthinoidea Lamarck, 1810

The Epitoniidae feed on coelenterates, the larger species searching for them, and the smaller species commonly living in or on them as parasites. Nützel (1998, pl. 19, fig. A-G) documented the protoconchs of four different species, of which one called *Aciculiscala coffea* consisted of two species, one having a protoconch with sinuous growth lines, the other having a protoconch as found in modern *Epitonium* with fine axial lirae as ornament (fig. F, G). The other two are close to the modern Nystellinae but differ from them in having collabral ribs that reflect an apertural sinus (Nützel 1998, pl. 19, fig. H-K); these have been identified as *Opaliopsis* aff. *faerium* and *O. faerium*. *O. faerium* was identified as *Epitonium* cf. *faerium* by Perrilliat et al. (2000) from the Mexcala Formation of southern Mexico. The Ianthinoidea of the Ripley Formation clearly are in need of revision. Their protoconchs appear to document the transition to modern groups as was suggested by Nützel (1998).

### Family Epitoniidae S. S. Berry, 1910

The family is based on the genus *Epitonium* Röding, 1798, which has a turreted shell with simple axial ribs and has a rounded aperture. The larval shell has fine axial lirae as an ornamental pattern. *Opalia* differs in having a basal keel and a flattened base.

### Genus *Opalia* H. and A. Adams, 1858

The turritiform shell has rounded whorls and is ornamented by strong axial ribs that end in a basal rib bordering the flattened base. The type is the modern *Scalaria australis* Lamarck, 1822.

The species described by Sohl (1964a, pl.52, fig.1, 2, 5, 6) are similar to each other and closely resemble the species of *Striaticostatum*.

47. *Opalia* (*Opalia*?) *fistulosa* Sohl, 1964a\*

48. *Opalia* (*Pliciscala*) *wadei* Sohl, 1964a\*

### Genus *Acirsa* Mörch, 1857

The slender teleoconch has many rounded whorls and a round and simple aperture; the ornament consists of wide axial ribs and fine spiral ribs. The type species is *Scalaria eschrichti* Holböhl in Möller, 1842.

### Subgenus *Acirsa* (*Hemiacirsa*) de Boury, 1890

The elongate shell consists of many whorls, which are rounded and flattened at their base. Ornament is of axial ribs crossed by finer spiral lirae. Sohl (1964a) placed four species from the Ripley Formation in this subgenus.

49. *Acirsa* (*Hemiacirsa*) *cretacea* (Wade, 1926)\*

According to Sohl (1964a, pl.51, fig.22, 23), the characteristic feature of the shell is its change from straight axial ribs in the early whorls to curving ones in later whorls.

50. *Acirsa* (*Hemiacirsa*) *americana* (Wade, 1926)\*

According to Sohl (1964a, pl.51, fig.24-28), this species closely resembles *A. cretacea* but has coarser and straighter ribs and a more flattened base.

51. *Acirsa* (*Hemiacirsa*) *flexicostata* Sohl, 1964a

According to Sohl (1964a, pl. 51, fig.29-31), this species differs from *A. americana* and *A. cretacea* in having less developed spiral ornament.

52. *Acirsa* (*Hemiacirsa*) *clathrata* Sohl, 1964a

According to Sohl (1964a, pl.51, fig. 32-36), this species is distinguished from the other three species by a punctate-spiral ornamentation and an aperture with a more angular outline.

### Subgenus *Acirsa* (*Plesioacirsa*) de Boury, 1909

In this *Acirsa*, the ornament consists of subequal axial and spiral ribs forming a fine cancellate pattern.

53. *Acirsa* (*Plesioacirsa*) *microstriata* Wade, 1917b\*

According to Sohl (1964a, pl. 51, fig. 37, 38), the relatively large shell has axial ribs on the early whorls, which become indistinct on later whorls.

54. *Acirsa* (*Plesioacirsa*) *wadei* Cossmann, 1925\*

According to Sohl (1964a, pl.51, fig.14-16), the shell is smaller, has more rounded whorls, and has narrower ornament than *A. microstriata*.

55. *Acirsa* (*Plesioacirsa*?) *implexa* Sohl, 1964a

According to Sohl (1964a, pl.51, fig.17, 18), the axial ornament is a little too well developed here to interpret this species representing a true *A. (Plesioacirsa)*.

### Genus *Belliscula* Stephenson, 1941

56. *Belliscula* cf. *B. rockensis* Stephenson, 1941\*

According to Sohl (1964a), the ornament consists of strong axial ribs connected to fine spiral ribs, and the base is simple, but the species and genus are too poorly known to place in any secure systematic position.

### Genus *Striatocostatum* Sohl, 1964a

According to Sohl (1964a, pl. 52, fig. 24-27), this genus, with the type species *Striatocostatum harbisoni* Sohl, 1964a, is characterized by numerous rounded whorls composing a high-spined shell with a basal carina and flattened base. The strong axial ribs are crossed by fine spiral lirae, forming a honeycombed pattern. The protoconch appears to consist of a slender larval shell with a typical epitoniid axial lirate pattern (Dockery, 1993).

57. *Striatocostatum harbisoni* Sohl, 1964a

58. *Striatocostatum bexarense* (Stephenson, 1941)

59. *Striatocostatum pondi* (Stephenson, 1941)\*

The species are very close to each other in shape and ornament. *S. pondi* differs from *S. bexarense* in having a slimmer outline (Sohl, 1964a, pl. 52, fig. 7-9, 13, 14, 19, 20), and both of these have fewer axial ribs than *S. harbisoni*.

### Genus *Cylindriscala* BOURY, 1909

The slender teleoconch has broad, non-lamellar, varix-like axial ribs, and a fine spiral sculpture may occur. The type species is the Recent *Cylindriscala acus* (Watson) from the northern Atlantic, which has a smooth protoconch. According to Kiel (2001), *Aciculiscala coffea* Dockery, 1993, should be transferred to *Cylindriscala* since the larval whorls of its protoconch have no median keel.

The larval shell of *Cylindriscala coffea* (Dockery, 1993) has the characteristic pattern of modern *Epitonium* with smooth whorls having only fine axial lirae. Nützel (1998, pl. 19, fig. A-G) regarded this species as the oldest known epitoniid with the typical smooth protoconch. But actually this protoconch is not typical, since it has an ornament of collabral growth lines that reflect the presence of an apertural projection, and not the characteristic straight lirae present among modern members of *Epitonium*.

Kiel (2001 pl. 17, fig.5) described a new species of *Cylindriscala* from the Maastrichtian of Temalac, Mexico, which has transverse axial ribs and fine spiral lirae. Its protoconch is smooth and egg-shaped, is made of two and a half whorls, and is about 0.5 mm wide and 0.6 mm high. It resembles *Aciculiscala coffea* Dockery, 1993, with axial ribs, more convex whorls, no spiral ornament and deeper sutures.

### Genus *Aciculiscala* SOHL, 1964a

The genus holds small, slender epitoniids with shells consisting of numerous whorls, simple axial ribs on a smooth background, and a carinate edge to the flattened base. Sohl (1964a, pl. 51, fig. 19-21) pointed out that the protoconch shows a carinate pattern. Nützel (1998, pl.19, A-G) noted that a carinate protoconch ornament is quite unusual for the Epitoniidae.

60. *Aciculiscala acuta* Sohl, 1964a\*

Sohl (1964a) indicated that the protoconch consists of 3 to 3.5 whorls that develop a median keel on their larval portion and that this keel ends at the beginning of the teleoconch. This feature distinguishes *Aciculiscala* and is very different from sculpture of other epitoniids; it may be that it is of a larger taxonomic importance than realized with our current knowledge.

### Family Nystiellidae Clench & Turner, 1952

This family of the Ianthinoidea has a larval shell with collabral ornament.

### Genus *Opaliopsis* Thiele, 1928

The teleoconch resembles that of *Epitonium*, and the protoconch has a collabral ornament on its larval whorls (Nützel, 1998, pl. 19, H, J). The type species is the Recent *Opaliopsis elatum* Thiele, 1928, from the shores of South Africa. This genus includes the high-spined Nystiellidae with non-lamellar teleoconch ribs and occasional spiral cords. The genus *Proscala* is distinguished from *Opaliopsis* by its subsuturally constricted whorls, and *Confusiscala* differs by the absence of a basal plate.

61. *Opaliopsis* aff. *faearium* (Dockery, 1993)

The protoconch of this species from the Coon Creek Formation of Union County Lake is larger than that of *Opaliopsis faearium* (Dockery, 1993) from the Coffee Sand, but both have collabral ribs that reflect an apertural sinus (Nützel 1998, pl. 19, fig. H-K).

### Superfamily Eulimoidea H. and A. Adams

#### Family Eulimidae Troschel, 1853

#### Genus *Eulima* Risso, 1826

Plate 1, figure 8

Apparently Eulimidae evolved during the Cretaceous, and there is a good chance that they came from an epitoniid stock. They are parasites on all kinds of echinoderms. Characteristic is their smooth shell, acicular shell shape, and smooth protoconch, which can hardly be

differentiated from the teleoconch. All the species listed below are very similar to each other as can be seen in the figures of Sohl (1964a, pl. 50, fig. 28-36).

62. *Eulima persimplica* Wade, 1926\*

63. *Eulima laevigata* Wade, 1926\*

64. *Eulima gracilistylis* Sohl, 1964a

65. *Eulima? clara* Wade, 1926\*

### Suborder Alata Lamarck (Stoliczka, 1868)

The outer lip of the fully-grown shell is expanded. Members of this caenogastropod suborder first appear in the Early Jurassic, and their most important families, the Strombidae and the Aporrhaidae, have protoconch types that can be recognized since the Jurassic (Bandel 1993b).

### Superfamily Stromboidea Rafinesque, 1815

The low conical to turreted shell has a more or less fusiform shape with the columella sometimes produced; the aperture is channeled in its anterior portion. The outer lip is often reflected, widened, and with finger-like protrusions. The taxon includes the families Aporrhaidae, Colombellinidae, Strombidae, and Terebellidae (Seraphsidae).

### Family Aporrhaidae Gray, 1850 (Aporrhaidae Mörch, 1852)

According to Wenz (1938), the only difference between the Aporrhaidae and the Strombidae lies in the construction of the foot and is therefore not visible in fossil species. According to Abbott (1960), the Aporrhaidae is represented by only two extant genera, *Aporrhais* and *Arrhoges*, with five species, only one of which belongs to *Arrhoges*.

### Genus *Graciliala* Sohl, 1960

The medium-size, high-spined shell has six to eight whorls, which are well rounded and sculptured with fine spiral threads and curved transverse ribs that die out below the periphery. The aperture has an elongate oval shape with a short, narrow, anterior canal. The outer lip is expanded with a long, narrow, tapering spur having an internal groove and a corresponding external ridge that dies out on the body. The inner lip is covered with callus over its entire length. The type species is *Anchura calcaris* Wade, 1926, from the Maastrichtian Ripley Formation of the southeastern United States (Sohl, 1960, pl. 11, fig. 1-4, 6).

According to Kiel and Bandel (2002b), the genus

*Graciliala* differs from *Latiala* and *Perissoptera* in having a keeled wing and differs from *Drepanocheilus* and *Anchura* in having no keels on the body whorl. When the wing of the outer lip is broken off it is difficult or impossible to distinguish *Latiala*, *Perissoptera* and *Graciliala* from each other.

66. *Graciliala calcaris* (Wade, 1926)\*

### Genus *Drepanocheilus* Meek, 1864 Subgenus *Drepanocheilus* (*Drepanocheilus*) Meek, 1864

The small to medium-size shell has initially smooth whorls and later whorls with an ornament of sloping axial ribs and spiral lirae. The body whorl has two or more keels. The aperture is narrow and ends anteriorly with a short siphonal canal. The upper keel continues onto the single, upturned wing. The inner lip of the aperture is thickened with callus. The type species is *Rostellaria evansi* Cossmann, 1904, from the Maastrichtian Fox Hills Sandstone, South Dakota.

According to Kiel and Bandel (2002b), *Anchura* is quite similar to *Drepanocheilus* but differs in having only one keel on the body whorl and often a forked wing. Species of *Drepanocheilus* were quite abundant in the temperate regions and were less common towards the tropics. This is in contrast to *Anchura* which was widely distributed in tropical regions and less so in temperate regions. When North American species are considered (Sohl, 1987: tab. 2), it appears that *Anchura* dominated the southern localities, while *Drepanocheilus* dominated the northern localities.

67. *Drepanochilus quadriliratus* (Wade, 1926)\*

68. *Drepanochilus triliratus* Stephenson, 1941

### Genus *Latiala* SOHL, 1960

The medium-sized, high-spined shell has a broad, thick, outer lip that is thickened and bilobed at the terminus with one lobe directed upward and a second blunter lobe directed downward. The interior of the outer lip is not grooved, and the inner lip is only slightly callused. The type species is *Anchura lobata* Wade, 1926, from the Ripley Formation.

The wing of *Perissoptera* TATE, 1865, is formed by an upward directed horn and a blunt lobe below, separated by a more or less developed sinus. The wing of *Graciliala* Sohl, 1960, is keeled and not smooth as in *Latiala* (see Kiel and Bandel, 2002b).

69. *Arroges (Latiala) lobata* (Wade, 1926)\*



### Genus *Anchura* Conrad, 1860

The medium to large, high-spired shell shows an ornate sculpture of strong axial and spiral elements, commonly noded. Its aperture is of lenticular shape with a long and narrow anterior rostrum that is straight or bent to the left. The outer lip expands into a wing or spine that might fork and/or be ornamented with spikes or lobes. The third or fourth spiral cord on the body whorl extends onto the wing, while the first cord might continue onto the occasional posterior spur. The type species is *Anchura abrupta* Conrad, 1860, from the Ripley Formation of Mississippi (Sohl, 1960, pl. 12, fig. 1, 4-9, 12).

According to Kiel and Bandel (2002b), members of the *Anchura* clade first occur and have their highest diversity in the Atlantic Gulf plains and Pacific slope of North America (Stephenson, 1941, 1952; Sohl, 1960; Dockery, 1993; Elder & Saul, 1996). *Helicaulax* is considered to represent a subgenus of *Anchura* with a long posterior spur and rostrum. Kiel and Bandel (2002b) noted that *Anchura* is highly variable in shape and in the extent of its wing, posterior spur, and rostrum. In contrast, the ornamentation of the body whorl, which is formed by axial ribs and spiral cords with knobby intersections, is very consistent through time.

70. *Anchura abrupta* Conrad, 1860

71. *Anchura substriata* Wade, 1926\*

72. *Anchura convexa* Wade, 1926\*

### Genus *Pterocrella* Meek, 1864

The shell is of moderate height with either smooth whorls or with an ornament of spiral ridges. The aperture has a lenticular shape and is inclined to the axis of coiling. The outer lip expands greatly with six thin digitations, which are connected with variable amounts of shell webbing. The type species is *Aporrhais* (*Pterocrella*) *tippanus* Conrad, 1858, from the Maastrichtian Owl Creek Formation in Mississippi (Sohl, 1960, pl.13, fig. 3, 5, 19).

Sohl (1960, p. 109) found *Cultrigera* Böhm, 1885, and its synonym *Tridactylus* Gardner, 1875, to be distinct by "number and arrangement of the digitations and some features of the aperture." As the arrangement of digitations is quite variable in aporrhoids, and the apertures of *Pterocrella* and *Cultrigera* are comparable, *Cultrigera* is herein regarded as a synonym of *Pterocrella* (Kiel and Bandel, 2002b). The genus *Pterocrella* is, thus, known from both sides of the Atlantic Ocean and ranges from the Campanian to the Maastrichtian.

*Pterocrella poinsettiformis* and *P. maryae* differ from *P. tippanus* in having prominent spiral ribs, one forming the shoulder on the spire and two on the body whorl. *P. maryae* and *P. tippanus* differ from *P. poinsettiformis* in having the webbing of the outer lip attached to the spire and in their smaller size and less inflated body whorl.

*P. maryae* extends from the Campanian Coffee Sand in Mississippi to the late Campanian to Maastrichtian *Exogyra cancellata* Zone of the Coon Creek Formation at its type locality, where beautifully preserved specimens have been found with the outer lip preserved. In the *Exogyra costata* Zone of the Coon Creek Formation in Mississippi, only *P. poinsettiformis* occurs.

73. *Pterocrella poinsettiformis* Stephenson, 1941

74. *Pterocrella* sp. A

75. *Pterocrella maryae* Dockery, 1993\*

### Family Pugnelliidae Kiel and Bandel, 1999

The shell has a low spire, an enlarged and reinforced outer lip, often with horn-like extensions, and a callus-coated inner lip. The callus is commonly spread out to cover large parts of the shell (Sohl, 1960, pl. 14, fig. 4, 5, 9, 13-16, 19, 20). The protoconch of *Pugnellus* shows close affinities to that of the Aporrhaidae, as was pointed out by Dockery (1993, p. 66). According to this author, the protoconch of *Pugnellus densatus* is conical and composed of four smooth convex whorls. The protoconch of *Strombus*, in contrast, is high spired and shows an ornamentation of tubercles (Bandel, 1993b; Bandel et al., 1997: fig. 3, 4 A-D).

### Genus *Gymnarus* Gabb, 1868

The medium-size shell has a body whorl that makes up about two thirds of the total shell height. Ornament consists of axial ribs on the body whorl; sometimes fine spiral lirae are present as well. The outer lip is expanded with a thick outer margin, shoulder, and posterior horn. The inner lip is also strongly callus-covered, and callus commonly covers parts of the spire and body whorl. The rostrum is short and sometimes bent to the right (Sohl, 1960, pl.15, fig. 1, 6, 9, 13). The type species is *Pugnellus manubriatus* Gabb, 1864, from the Cenomanian Cottonwood Creek, Siskiyou County, California.

76. *Gymnarus abnormalis* Wade, 1926\*

### Genus *Pugnellus* Conrad, 1858

These low-spired species developed a thick and expanded outer lip at maturity. Their aperture is of an elongate oval shape with the anterior canal generally short. The outer lip is reinforced and thick; the inner lip is smooth. Callus coats the body whorl and spire in the latest growth stages and obscures the original shape and ornamentation of the shell (according to Sohl, 1960, p. 111). The type species is *Pugnellus densatus* Conrad, 1860, from the Maastrichtian Ripley Formation of Mississippi. According to Kiel and Bandel (1999), *Pugnellus* has no horn on the outer lip, which distinguishes it from *Gymnarus*.

77. *Pugnellus densatus* Conrad, 1858\*

### Family Xenophoridae Troschel, 1852

The low, trochiform shells often have foreign objects attached, such as gastropod or bivalve shells or rocks. Protoconch morphology separates the xenophorids and stromboideans. *Xenophora* possesses a low, trochiform protoconch with typically three to four whorls and a diameter of 0.9-1.2 mm. The embryonic shell measures 0.08-0.11 mm across (Bandel, 1993b). Based on their protoconch morphology, habits, and anatomy, the Xenophoridae are placed here as members of the Stromboidea.

#### Genus *Xenophora* Fischer von Waldheim, 1807

The large, depressed-conical shell has a narrow to wide peripheral flange and flattened to concave base, which may or may not be umbilicate. The spire usually has foreign objects attached. The protoconch is depressed-conical and consists of several whorls. Sculpture usually consists of only growth lines and a single spiral cord (Ponder, 1983). The type species is *Xenophora laevigata* Fischer von Waldheim, 1807 (= *Trochus conchyliophorus* Born, 1780).

The teleoconch and protoconch shape of *Acanthoxenophora sinuosa* Perrilliat and Vega, 2000, as illustrated by Kiel and Perrilliat (2001) and Perrilliat and Vega (2001, p. 76, fig. 3-13) from the Maastrichtian of Temalac, Mexico, resemble *Xenophora leprosa* (Morton, 1834) from the Coffee Sand of Mississippi as figured by Dockery (1993, pl. 20, fig. 1-4). Those figured by Sohl (1960, pl. 10, fig. 19, 23-27) have a lower spire.

78. *Xenophora leprosa* (Morton, 1834)\*

### Family Colombellinidae Fischer, 1884

This exclusively fossil family has traditionally been included in the Stromboidea, but this placement has not been proven. In case of the species found in the Ripley Formation, it may well be that *Colombellina americana* can better be placed with the Cassoidea.

#### Genus *Colombellina* Orbigny, 1842

The small, thick, medium- to low-spined, coarsely sculptured shell has a thickened denticulate outer lip, heavily callused and reflexed inner lip, short anterior canal, and short to extended posterior canal. The type species is *Rostellaria monodactylus* Deshayes, 1842, from the Early Cretaceous of France.

The species *Colombellina americana* was illustrated by Sohl (1960, pl. 14, fig. 1-3, 6, 7). The species *Colombellina cancellata* from the Upper Campanian Coffee Sand

described and illustrated by Dockery (1993, pl. 16, fig.10) resembles a sculptured *Erato* in shape.

79. *Colombellina americana* Wade, 1926\*

### Superorder Latrogastropoda RIEDEL, 2000

Members of this taxon with a planktotrophic larval stage have an embryonic shell that is usually larger than that of non-latrogastropod caenogastropods; the larval shell also commonly exceeds the size of that found in other Caenogastropoda. Though not recognized before Aptian-Albian time, from its earliest occurrence this taxon was well diversified with most of the neomesogastropod superfamilies present in the Late Cretaceous and the modern neogastropod groups present in the Paleogene. Modern neogastropod superfamilies appear to merge with each other when Cretaceous "neogastropods" are compared. These also merge with some of the Neomesogastropoda (Bandel, 1993b, 1997, 1998, Bandel and Riedel, 1994a, Riedel, 2000).

Latrogastropods evolved during the late Early Cretaceous from some still unknown ancestral caenogastropod stock and have a characteristic ontogeny. They are considered to represent a monophyletic group possibly close to genera such as the Triassic *Angularia* Koken, 1892, or the Jurassic *Matwifusus* Szabo, 1983. The Coon Creek fauna holds some species that could represent transitional forms, which connect modern taxonomic groups in which the living species are quite independent from each other.

### Order Neomesogastropoda Bandel, 1991

Characteristic of all Neomesogastropoda and Neogastropoda is a large protoconch, which in case of the Naticidae is globular in shape, with an almost flattened apical portion, and fairly large in size, commonly reaching 1 mm in diameter in fully-grown larvae. This larval shell has a fossil record extending to Santonian time (Bandel, 1993b, pl.12, fig. 3; Bandel, 1998). Neomesogastropoda unite all latrogastropods with taenioglossate (seven teeth in each row) radulae.

#### Suborder Troschelina Bandel & Riedel, 1994

The Troschelina includes all neomesogastropods with pleurembolic proboscis (Bandel and Riedel, 1994a). Riedel (2000) placed the superfamilies Calyptraeoida and Capuloidea in this suborder.

#### Superfamily Calyptraeoida Lamarck, 1809

The shell of these suspension-feeding, taenioglossate limpets is cap-shaped with the outer lip being joined to and encircling the whole base. The shell rests on hard

substrates, and the inner lip lies above the basal rim and is reduced in size and may be totally absent. The operculum is usually lost during the ontogeny, commonly when the limpet-style life has begun but may also be totally abolished. The original protoconch is large, about as wide as high, has rounded whorls and a straight outer lip of the aperture. The sculpture resembles that of larval shells of the basal representatives of the other Neomesogastropoda such as the Naticoidea, Cypraeoidea, and Cassoidea. Lecithotrophic development changes the original shell morphology and sculpture up to the total disappearance of the larval shell in cases where metamorphosing (pediveligers) or metamorphosed young hatch from the egg.

#### **Family Hipponicidae Troschel, 1861**

These conical limpets are provided with or without internal shell walls. The protoconch of those species with a planktotrophic veliger larval shell is rounded and composed of several ornamented whorls with spiral ridges and axial ribs that may produce a pattern of rectangles. With more yolk available to the developing embryo, this sculpture is reduced or changed, and the number of whorl decreases. When a pediveliger or a crawling young hatches, only the embryonic shell is formed, which may be highly sculptured or almost smooth. Individuals, after metamorphosis to benthic life, attach themselves solidly to the substrate, and the foot commonly produces a calcareous attachment plate or etches itself into the calcareous attachment surface. Egg capsules are attached to the parental individual.

#### **Genus *Thylacus* Conrad, 1860**

Plate 1, figure 11

The limpet-like, elongate shell has only short, fragmentary, marginal lamellae as remnants of the inner lip (shelf) and a horseshoe-like muscle scar. The protoconch is large, lies in the posterior position of the shell, and belongs to a planktotrophic veliger. The naticoid protoconch consists of three whorls after which the shell expands to assume a limpet shape. The juvenile teleoconch has an umbilical spiral shelf (inner lip). When fully developed the muscle support has a horseshoe shape, and the inner shelf is absent. The type species is *T. cretaceus* Conrad from the Upper Cretaceous of the southeastern US.

80. *Thylacus cretaceus* Conrad, 1860\*

*Thylacus cretaceus* lived on the columella of gastropods as is indicated by the shape of the shell and the sinuous apertural lip (Sohl, 1960). Dockery (1993, pl. 17, fig. 3) illustrated a specimen attached to the columella of a young *Volutomorpha* from the Coffee Sand. Wade (1926),

Sohl (1960), Dockery (1993), and Bandel and Riedel (1994a) described this species in detail.

#### **Family Calyptraeidae Lamarck, 1809 (=Crepidulidae Fleming, 1822)**

The limpet-like, cup-shaped shell has a round to oval outline and carries an internal lamina or shelf (the inner lip) for muscle attachment, which may be spiral, flat, or conical, or it may be totally reduced. The embryonic and larval shell of the planktotrophic veliger either have fine spiral lirae or rows of tubercules and are commonly smooth and widely conical, almost planspirally coiled. Spiral coiling becomes less prominent in the last whorls of the teleoconch. Egg capsules are attached to the hard substrate below the shelter of the shell of the mother.

#### **Genus *Crucibulum* Schumacher, 1817**

The cup-shaped shell has an internal, cup-like, supporting cone, which is attached by its base or along one side and open downwards. The ornament consists of radial striae or ribs, and the shell margin reflects the attachment surface. Sohl (1960, pl.10, fig. 20, 21) documented only incomplete shells of this genus.

81. *Crucibulum?* sp.

#### **Superfamily Capuloidea Fleming, 1822**

According to the family characterization presented by Bandel and Riedel (1994), this taxon holds filter-feeding species that have a larval stage in which the shell has a gelatinous outer cover, the scaphoconcha or echinospira, and which represent taenioglossate Caenogastropoda.

#### **Family Trichotropidae Gray, 1850**

If the echinospira-bearing larval shell is of the Subfamily Capulinae, it develops into a limpet after metamorphosis and discards its operculum. The Trichotropinae, in contrast, have a conical to spiral shell with a large aperture and a wide umbilicus and usually have a thick periostracum. Similar species as in the trichotropines most probably represent the ancestors to the limpet-like Capulinae.

#### **Subfamily Trichotropinae Gray, 1850**

#### **Genus *Lirpsa* Stephenson, 1952**

The shell has a short spire, rapidly expanding whorls, a single, sharp and prominent keel-like spiral rib, subquadrate aperture, and sinuous umbilicus. The type species is *Lirpsa cornuata* from the Woodbine Formation in



Texas. *Trichotropis* Broderip & Sowerby, 1829, has a similar shell shape, but differs in lacking an ornamentation of axial ribs crossed by spiral lirations. *Pyropsis*, such as *P. cancellata*, has an ornament very similar to that of *Lirpsa*, but differs in having a lower spire and a more regular ornamentation. *Turbinopsis* differs in not having a body carination.

Specimens of *Lirpsa squamosa* (Gabb, 1876) from the Coffee Sand of Mississippi have a medium-size (2-3 cm), umbilicate shell with a strongly carinate spire and a body whorl with two keels. The carinae bear spines where they intersect stronger growth increments, and spiral threads cover the upper peripheral margin of the upper carina. The last whorl has a sinus below the carina at its juncture with the teleoconch. Growth increments produce an imbricate pattern on the base. The large umbilicus has a sharply raised and spiny margin.

In the Coffee Sand specimen described by Dockery (1993, pl. 17, fig. 11, 12), the distance between the two marginal keels is about the same as the distance between the lower carina and the umbilical margin, while on the type species for *Lirpsa* from the Black Creek Formation in North Carolina figured by Stephenson (1923), the distance between lower carina and the umbilical margin is twice that between the marginal keels. The type species of *Trichotropis* is *Turbo bicarinata* Sowerby, 1825, from the Sea of Japan; Recent species of this genus live in the cold water of the Atlantic as well as in the Pacific.

#### 82. *Lirpsa mississippiensis* (Sohl, 1960)

According to Sohl (1960, pl. 10, fig. 22), the shell of this species has two strong peripheral cords that form two keels on the body whorl. The ornament consists of spiral lirae. The narrow, deep umbilicus is bound by a round-topped carina. The protoconch consists of two whorls and is smooth. *Trichotropis imperfecta* Wade, 1926, does not belong here and is interpreted to represent a species of the genus *Trochifusus* (see below). *Lirpsa squamosa* differs from *L. mississippiensis* in having more numerous spiral lirae in the concavity between the keels. *Trichotropis konincki* Müller, 1868, from the Campanian of Aachen and Vaals in Western Europe has a wider umbilicus than *L. mississippiensis*. It differs from *Lirpsa garudamangalami* Bandel, 2000, from the Trichinopoly group, Kulakkalnattam Formation of India in having a narrower umbilicus and more distinct spiral lirations.

### Genus *Cerithioderma* Conrad, 1860

The small to medium-size, high-spined, turbiniform shell has a short, pointed, anterior canal that is deflected to the left. The aperture is almost round to quadrate and often has a thickened outer lip. The columellar callus of the inner lip sometimes does not completely cover the umbilicus, leaving a small opening. The sculpture consists of axial and spiral elements with the axial ribs

sometimes becoming obsolete on the last whorls of the fully-grown shell. The type species is *Cerithioderma prima* Conrad, 1860, from the Middle Eocene of Alabama.

The species *Cerithioderma nodosa* Dockery, 1993, according to Dockery (1993, pl. 17, fig. 13-15, pl. 19, fig. 4), has a turbiniform shell with the oval aperture extending into a short anterior canal. The fenestrate sculpture of the juvenile whorls grades into a pattern of axial nodes in later whorls. Spiral lirae cover the base. The protoconch consists of 3 low-coiled whorls of about 1 mm in height and width. In it, the embryonic whorls, of 0.15 mm in width, have a pattern of grooves and ridges; they form a flat top at the apex of the smooth larval whorls, which have fine growth lines and an apertural projection on the anterior part of the outer lip. In the late larval whorls, spiral ribs cross the collabral ribs. The beginning of the teleoconch is indistinct as the axial ribs of the protoconch continue into the ribs of the teleoconch. The end of the apertural projection marks the terminus of the protoconch.

#### 83. *Cerithioderma? americana* (Wade, 1926)\*

### Genus *Turbinopsis* Conrad, 1860

The turbiniform shell has a conical spire with channeled sutures and deep umbilicus. The type species is *Turbinopsis hilgardi* Conrad, 1860, from the Ripley Formation (Sohl, 1960, pl.10, fig.17, 18). It is ornamented with broad spiral ribbons. The aperture is rounded on its posterior end and is angulate at the anterior end. The protoconch consists of more than 2 upright smooth whorls. *Lirpsa* resembles *Turbinopsis* in its high spire and wide umbilicus, which is bordered by a keel, but differs by having a carination. *T. hilgardi* resembles *Lirpsa mississippiensis* in regard to the ornament of spiral ribbons but is lower in height and has only prominent ribbons on the margins where the latter has keels.

#### 84. *Turbinopsis hilgardi* Conrad, 1860

### Genus *Astandes* Wade, 1917b

This genus represents a medium-size turriform shell with round-sided whorls marked by numerous spiral lirae and with thick collabral ribs; it may be a synonym of *Cerithioderma*. The type is *Astandes densatus* Wade, 1917b, from Ripley Formation in Tennessee. This species could very well be the same described under the name *Cerithioderma nodosa* by Dockery (1993). Wade (1917) suggested that the genus *Astandes* included *Tritonium cretaceum* Müller from the Cenomanian of Vaals near Aachen.

#### 85. *Astandes densatus* Wade, 1926\*

### Subfamily Capulinae Fleming, 1822

Probably neither of the species below is actually a member of the genus *Capulus*.

86. *Capulus monroei* Sohl, 1960\*

87. *Capulus corrugatus* Wade, 1926\*

The placement of these ribbed and limpet-like species (Sohl, 1960, pl. 10, fig. 8-12) is rather weakly based. Their confirmation as *Capulus* should be supported by data on the protoconch (see Bandel and Riedel, 1994a).

### Genus *Damesia* Holzapfel, 1888

*Damesia* Holzapfel, 1888, was introduced as a genus within the Neritidae and was considered a subgenus of *Otostoma* by Wenz (1938-44). Dockery (1993) illustrated the supposedly heterostrophically-coiled protoconch of *Damesia*, thus, indicating that *Damesia* was a *Nerita*-shaped allogastropod, belonging to the pyramidellid-limpet family Amathinidae in the subclass Heterostropha. Two of the specimens from the Coffee Sand (Dockery, 1993, pl. 2, fig. 5-6 and 7-9) show the initial whorl of the larval shell to be inclined and possibly anastrophic. However, another specimen from the Coon Creek Formation (Dockery, 1993, pl. 38, fig. 1) lacks this condition and shows the larval shell to be attached to a *Capulus*-like limpet. This protoconch has spiral keels and is similar to protoconchs noted among modern representatives of *Capulus* (Bandel, own data).

88. "*Damesia keownvillensis* Sohl, 1960"  
(with a capulidlarval shell, Dockery, 1993)

### Superfamily Naticoidea Forbes, 1838

The Naticoidea are a natural group among the Caenogastropoda that have existed since mid-Cretaceous time. From the beginning, the earliest Naticoidea probably exhibited their specific mode of life as carnivores of shelled epifaunal and infaunal animals living in soft marine substrates. The hallmark of their carnivorous habit is their ability to penetrate the shell of their prey by drilling a hole into it.

Characteristic of this group and of all Neomesogastropoda and Neogastropoda is a large protoconch, which, in case of the Naticidae, is of globular shape with an almost flattened apical portion and fairly large size, commonly reaching 1 mm in diameter in fully-grown larvae. This naticid-type of protoconch has been documented as early as Santonian time (Bandel, 1993b, pl. 12, fig. 3; Bandel, 1998). Riedel (2000) elevated this group to the rank of order, the Naticina.

### Family Naticidae Forbes, 1838

#### Subfamily Gyrodinae Wenz, 1938

The naticiform shell is usually wider than high, has a flattened spire and a sculpture of delicate spiral lirations crossed by inclined growth lines or is smooth. The body whorl is large, and the shell usually has a wide umbilicus that is not covered by the callus of the inner lip (Wenz, 1938) or may have a tongue-like callus (Popenoe et al., 1987). The umbilicus may have an umbilical ridge that separates it from the rounded base. The shell surface is sculptured with growth lines and is not glossy. Naticinae differ in having a less prosocline growth line, which lacks the broadly U-shaped, umbilical sinus.

*Xsosaites herberti* (Bandel, 1999) from the Umzamba Formation of South Africa resembles species of *Gyrodex* with a strong carina around the umbilicus (Bandel, 1999, fig. 1b, pl. 4, fig. 7-8; Bandel and Dockery, 2001, fig. 53). It differs from these in having a narrow siphon, which is never present in *Gyrodex* or any other naticoid species. *Schizobasis* differs in the presence of spiral ornament, which is absent in *Xsosaites herberti*. The columella with the surrounding lamellar ridge resembles that found in *Sargana* and *Hippocampoides* Wade, 1916 (Sohl, 1964a, pl. 21, fig. 5-7, 11-13).

Dockery and Manning (1995) and Dockery (1996) published a steinkern of *Gyrodex abyssinus* (Morton, 1834) from the Prairie Bluff Formation at Moscow Landing on the Tombigbee River in Sumter County, Alabama, with the impression of a brood of 24 *Gyrodex* larval shells. Additional steinkerns with the impressions of partial broods have been found in the Prairie Bluff Formation along Highway 45 near Shuqualak in Noxubee County, Mississippi. According to Dockery (1996), these larvae-possessing steinkerns are the first evidence that *Gyrodex* was an ovoviparous gastropod and the first report of egg brooding in any naticid. He also suggested that the rapidly expanding body whorl of *Gyrodex*, which is larger than that of most naticids, might be a special accommodation for brooding. Evidence of brooding might also support the arguments of some that *Gyrodex* does not belong in the Naticidae. However, *Gyrodex* is the largest naticiform shell known in the Late Cretaceous of the Gulf Coast and is the only one capable of drilling a 6-mm-diameter borehole, such as that noted by Dockery (1996) in a large *Cyprimeria* (bivalve) shell from the Coffee Sand of Mississippi.

### Genus *Gyrodex* Conrad, 1860

The rounded, low-spined shell has a deep umbilicus with a sharp umbilical margin and is crenulated near the suture. Growth lines near the suture may be notched (Popenoe et al., 1987). The aperture is oval in outline and inclined. The type species is *Gyrodex crenatus* Conrad, 1860, from Coon Creek according to Wenz (1938), which is a synonym of *Rapa supraplicatus* Conrad, 1858, according

to Stephenson (1941). The later (Stephenson, pl. 51, figs 13-16) and Sohl (1960, pl. 16, fig. 1-5, 9, 13, 19) illustrated the type *Gyrodos supraplicata* (Conrad, 1858) from the Maastrichtian Owl Creek Formation. Perrilliat et al. (2000) recognized *Gyrodos major* Wade, 1926, and *Gyrodos supraplicatus* (Conrad, 1858) occurring in the Mexcala Formation of southern Mexico.

### Subgenus *Gyrodos* (*Gyrodos*) Conrad, 1860

The low-spired shell has a subsutural ribbon. The open umbilicus is free of callus deposits. The aperture is notched at its anterior end with the ribbon formed behind the notch. The type species is *Gyrodos supraplicata* (Conrad, 1858) from the Maastrichtian of Mississippi (Sohl, 1960, pl. 16, fig. 1-5), which may be 9 cm in width and 7 cm in height (Stephenson, 1941). According to Bandel (1998), *Gyrodos* (*Gyrodos*) differs from the other subgenera of *Gyrodos* in having a subsutural ribbon that arises from a posterior apertural notch.

#### 89. *Gyrodos supraplicatus* (Conrad, 1858)

This species has a large shell with distinct suture bordered by a broad shallow sulcus that is accompanied by a low crenulated ridge. The suture has a narrow notch, forming a subsutural ribbon with sinuous growth increments as present in the Pyrifusidae. The umbilicus is wide and of conical shape. Curved ribs ornament the flattened shoulder and the margin of the umbilicus. With 5 whorls, the shell is about 2.5 cm wide. The aperture is oblique and oval in shape with a narrow notch next to the suture (Sohl, 1960, pl. 16, fig. 1-5).

### Subgenus *Gyrodos* (*Dockeryella*) Bandel, 1999

The large shell has a slightly concave subsutural ramp, which is not connected to an apertural notch, and a broad umbilicus with smooth margin. The type species is *Gyrodos major* Wade, 1926, from the Coon Creek Formation (Sohl, 1960, pl. 16, fig. 6, 7, 10) and from the Coffee Sand (Dockery, 1993, pl. 20, fig. 13, 14). According to Dockery (1993), the protoconch of *Gyrodos* (*Dockeryella*) *major* has 2.25 whorls and an indistinct transition into the teleoconch.

*G. (Dockeryella)* differs from *G. (Gyrodos)* in lacking a notch on the posterior margin of the aperture and the accompanying subsutural ribbon produced by the growth trace of the notch. The wide shell shape and the ridge around the broad umbilicus distinguishes this subgenus from *G. (Sohlella)*, and the additional absence of any callus sheets extending into the umbilicus distinguishes it from *G. (Hypterita)* and *G. (Banis)*.

#### 90. *Gyrodos major* Wade, 1926\*

### Subgenus *Gyrodos* (*Sohlella*) Popenoe, Saul, and Suzuki, 1987

The shell is wider than high or about as wide as high with a low spire. The suture is accompanied by a shallow groove that forms a tabulate shoulder. The whorl profile is obliquely rounded, and the umbilical margin has two rounded corners at the steeply sloping umbilicus. The aperture is nearly rounded and oblique with a straight inner lip that overhangs the conical umbilicus; the outer lip has no posterior notch. The inner lip borders the umbilicus with a thin wall in its posterior columellar portion. The type species is *Gyrodos canadensis* Whiteaves, 1903, from the Campanian of Vancouver Island.

*G. (Sohlella)* has no subsutural ribbon rising from a notch as is characteristic of *G. (Gyrodos)*, and it has a narrower umbilicus than *G. (Dockeryella)* and a higher shell shape. If an umbilical callus sheet is developed, it is short and not extended as in *G. (Hypterita)* or *G. (Banis)*.

Very similar species are *Gyrodos (Sohlella) spillmani* Gabb, 1861 (Dockery, 1993, pl. 20, fig. 11-12) from the Campanian Coffee Sand in Mississippi, also from the Coon Creek Formation (Sohl, 1960, pl. 16, fig. 14, 17, 18, 20, 21) and *Gyrodos subcarinatus* Stephenson, 1941 (Stephenson, 1941, pl. 52, fig. 20-26) from the Navarro Group of Texas. Dockery (1993) described the protoconch of *Gyrodos (Sohlella) spillmani* as consisting of 2.25 whorls with an indistinct transition into teleoconch but did not illustrate it. It probably resembles that of *Gyrodos* sp. illustrated by Bandel (1999, pl. 3, fig. 6) from Coon Creek.

#### 91. *Gyrodos spillmani* Gabb, 1861\*

#### 92. *Gyrodos americanus* (Wade, 1926)\*

### Genus *Euspira* Agassiz in Sowerby, 1842

#### 93. *Euspira rectilabrum* (Conrad, 1858)\*

As long as the protoconch of this species, illustrated by Sohl (1960, pl. 17, fig. 5-7, 12-14), is unknown, its place among the Naticoidea is in doubt. It may also represent a member of the Pseudamauridae. Perrilliat et al. (2000) reported *Euspira rectilabrum* from the Mexcala Formation in southern Mexico.

## Superfamily Cypraeoidea RAFINESQUE, 1815

### Family Cypraeidae RAFINESQUE, 1815

The cowrie-shell form of the Cypraeidae has changed little since their first appearance in the Cenomanian (Anderson, 1958).

### Genus *Cypraea* Linné, 1758

The adult shells are convolute, glossy and smooth, and the aperture occupies the entire length of the shell and



is bordered with denticles. The type species is *Cypraea tigris* Linné, 1758, living in the Indopacific. Groves (1990) named a new species of cypraeid *Bernaya (Procypraea) mississippiensis* from the Campanian Coffee Sand of Mississippi. The paratype of this species was illustrated by Dockery (1993, pl. 21, fig. 1-3) and showed an ornament of rectangles on its spire through the enveloping outer whorl.

**Superfamily Cassoidea LATREILLE, 1825**  
 (=Superfamily Tonnoidea Suter, 1913)

The species of the Cassoidea developed a characteristic larval shell with an ornamental pattern of rectangles. Cassoid larval shells are the largest of all gastropod larvae with diameters from 1 to 5.4 mm (Riedel, 1995). They are smooth or sculptured with a cancellate pattern. The adult shells are fusiform, often show varices, and, in a few cases, have a fold on the columella.

Ancestral species belonging to various groups of the Neomesogastropoda are probably related to the most primitive Cassoidea and Trichotropidae, and perhaps also to the Cancellarioidea of the Neogastropoda. These species can be recognized by their characteristic protoconchs with rounded or flattened apex and reticulate ornament, or traces of such, and the absence of a posterior apertural notch in the teleoconch. The protoconchs of genera like *Anomalofusus* and *Lomirosa* clearly separate them from their suggested relatives among the Pyrifusidae. Confusing in this respect is that *Weeksia* could be interpreted as related to the modern Capuloidea, and the Cretaceous Trichotropidae resembles some modern Cancellarioidea. This creates problems in the classification of Cretaceous neomes- and neogastropod species, a problem due to their common origin with other Latrogastropoda Riedel, 2000, in the Early Cretaceous.

**Family Ranellidae Gray, 1854**

**Genus *Gyrineum* Link, 1807**

The fusiform to turbinated shell has angular whorls and two opposing rows of grooved varices. The aperture bears a short, rather straight columella and an anterior canal. Sculpture consists of crenulated spiral threads. The type species is *Murex gyrinum* Linné, 1758.

Dockery (1993, pl. 21, fig. 6, 7, 9, pl. 22, fig. 1-5) described *Gyrineum guinae* from the Coffee Sand, and Kiel (2001) found a specimen of this species in the Campanian of northern Spain that has an adult shell about four times larger than the biggest one figured by Dockery (1993). The moderate-size shell has at least six whorls with two varices per whorl. The axial and spiral cords form a nodular pattern. The axial ribs disappear below the sixth spiral cord on the body whorl, where undisturbed spiral cords

follow, and there are three to four fine spiral lirae between all spiral cords. The aperture is lenticular, and the inner lip is lightly callused so that the body ornamentation shows through.

**Genus *Anomalofusus* Wade, 1926**

The globular protoconch with several whorls has a diameter of at least 1 mm and is smooth. The teleoconch is fusiform and is sculptured by sinuous axial ribs, which are crossed by fine spiral lirae. The columella is smooth, and the outer lip is dentate within. The type species is *Anomalofusus substriatus* Wade, 1926, from the Ripley Formation. *Anomalofusus* resembles *Paladmete* with exception of the siphon and missing columellar fold. *Lomirosa* is a bit shorter but has the same apertural outline. The protoconch of *Anomalofusus substriatus*, according to Sohl (1964a, pl. 31, fig. 1-4), consists of about 3 smooth, regularly coiled whorls, the first of which is submerged in the level of the second. In *Anomalofusus subnodosus* Sohl, 1964a, the protoconch is described as proportionally large, consisting of 3.5 normally-coiled smooth whorls, the first whorl depressed to the same level as the second. The ornamentation begins with four spirals that later develop into the primary spiral ribbons of the spire (Sohl, 1964a, pl. 31, fig. 5, 6). The protoconch of *Anomalofusus lemniscatus* Sohl, 1964a, from Owl Creek Formation has the same shape and number of whorls. The junction of the teleoconch is characterized as abrupt with the addition of both spiral and transverse elements to form a cancellate pattern (Sohl, 1964a, pl. 31, fig. 7, 8, 11-13).

94. *Anomalofusus substriatus* Wade, 1926

95. *Anomalofusus subnodosus* SOHL, 1964a

**Genus *Cantharulus* Meek, 1876**

The fusiform shell has angular whorls formed by a subsutural ramp without constriction and a rounded base. The aperture is elongate egg-shaped, and the columella has no folds. The type species is *Fusus vaughani* Meek and Hayden from the Campanian of the Fox Hill Group of North Dakota (according to Wenz, 1938). *Anomalofusus* lacks the subsutural ramp of *Cantharulus*, and, consequently, its whorls are more rounded; additionally, *Anomalofusus* appears to have a higher spire. *Cantharulus* is like *Lomirosa* in general shell shape but differs from it in having spiral ridges on the shoulder, while the shoulder of *Lomirosa* is smooth. Both have rounded protoconchs with a cancellate ornamentation.

*Cantharulus lemniscatus* Sohl, 1964b, from Coffee Sand has no subsutural collar but has two spiral ribs on the upper flank, which are broader and have a wider space between them than occurs between the ribs on the lower flank. The columellar lip has a thick layer of callus, and the

shell has no varices. A similar species *Cantharulus eximia* (Stoliczka, 1868) (Bandel 2000b, fig. 24, 25) occurs in the Trichinopoly Formation of India. This species is a bit more slender than the type species *Cantharulus vaughani* from the USA but is otherwise quite similar. Other related species include *Cantharulus cretaceum* (Müller, 1851) from the Aachen greensands, *C. kaffraria* (Rennie, 1930) from the African Umzamba Formation, and *Cantharulus conica* (Riedel, 1932) from Cameroon.

### Genus *Caveola* Stephenson, 1941

According to Sohl (1964a, pl. 44, fig. 5-8), the shell has a longer spire than aperture, and the whorls are well rounded over the periphery. The shell bears one to three varices per whorl, and the ornament consists of rectangles. The aperture is nearly lenticular, with a short and broad siphonal canal, and has an outer lip that is denticulate within. The columellar lip is glazed over and bears two folds. The protoconch consist of about 4 rounded whorls. The type species is *Cancellaria acuta* Wade, 1926, from Coon Creek. *Caveola acuta* has an apical angle of 25°, which increases in earlier whorls. The protoconch is apically flattened and has the typical reticulate sculptural pattern found among the Cassoidea.

96. *Caveola acuta acuta* (Wade, 1926)\*  
 97. *Caveola acuta speciosa* Sohl, 1964a

### Genus *Charonia* Gistel, 1848

The type species is the living *Murex triotonis* Linné, 1757.

98. *Charonia? univaricosum* (Wade, 1926)\*

Sohl (1960, pl. 18, fig. 44) questioned the placement of this species in the genus *Charonia*, and this placement is also questioned here.

### Genus *Plesiotriton* Fischer, 1884

The type species is *Cancellaria volvutella* Lamarck, 1803, from the Eocene of the Paris Basin.

99. *Plesiotriton cretaceus* Sohl, 1960

This *Plesiotriton* documented by Sohl (1960, pl. 18, fig. 35, 41, 42) may represent a member of the genus *Sassia*; Dockery (1993, p. 77) placed it in *Gyrineum*. The protoconch resembles that of *Caveola* and the modern *Bursa*.

### Genus *Tintorium* Sohl, 1960

100. *Tintorium pagadiforme* Sohl, 1960\*

This problematic species (Sohl, 1960, pl. 18, fig.1, 2) could be related to *Caveola*, which includes forms from the Coffee Sand with a large protoconch comprised of more than 4 whorls.

### Genus *Profusinus* Bandel, 2000

The shell is spindle-shaped and elongate with a median siphonal canal and an ornamentation of rounded ribs crossed by small, sharply raised spiral cords. The columellar lip is callus-glazed and smooth. The type species is *Profusinus indicus* Bandel, 2000 (= *Tritonidea requienia* Orbigny of Stoliczka, 1868) from the Trichinopoly Formation, Tamil Nadu, India. Cossmann placed *Euthriofusus? mesozoicus* (Wade, 1917b), with a long siphonal canal, and *Euthriofusus convexus* (Wade, 1926) in the genus *Euthriofusus* Cossmann, 1901.

101. *Profusinus convexus* (Wade, 1926)

102. *Profusinus mesozoicus* (Wade, 1917b)

*Profusinus* has a *Fusinus*-like shell, but its relation to modern Neo- or Neomesogastropoda is unknown. *Profusinus convexus* is very similar in size and shape to *P. indicus*, which differs in having stronger axial ribs. *Profusinus mesozoicus* differs in having a much longer siphonal canal (Sohl, 1964a). Very similar species are *Woodsella typica* Wade, 1926, and *Boltenella excellens* Wade, 1917b (Sohl, 1964a, pl. 31, fig. 29-32).

### Family Paladmetidae Sohl, 1964a

The shell has a reticulate sculpture pattern and varices. The protoconch has a flat top and an ornamentation of collabral and spiral lirae on part of the larval shell. According to Sohl (1964a), the teleoconch resembles that of the Cancellariidae but without columellar folds. Sohl (1964a) suggested a relationship between *Caveola* and *Cancellaria? macnairyensis*, which he considered to be cancellarids. The ornament of the protoconch, especially that of the larval shell, indicates that *Paladmete* belongs to the Cassoidea instead, a group where varices on the teleoconch are a common feature.

### Genus *Paladmete* Gardner, 1916

Plate 2, figure 7

The medium-size shell is about 1 cm in height and littoriniform in shape with a rounded aperture, having a short siphonal notch at the end of a straight columellar lip. The ornament is a network of axial and spiral ribs. The protoconch is characterized by its conical rounded shape,





## Plate 2

**Figure 1.** The juvenile shell of this *Weeksia* sp. from the Coon Creek Formation at Coon Creek has a naticiform protoconch and an angular teleoconch. The first whorl of the teleoconch measures about 1.8 mm across.

**Figure 2.** An enlargement of figure 1, which shows the protoconch to consist of 2.5 whorls; the embryonic whorl is 0.19 mm in diameter and the larval shell is 0.7 mm in width and about the same in height. The two rounded and smooth larval whorls have a slightly inclined position with respect to the planispiral coil of the teleoconch.

**Figure 3.** The protoconch of *Sargana* sp. from the Coon Creek Formation at Coon Creek has a low helicoid to almost planispirally-coiled shape and consists of smooth whorls. It has a diameter of almost 1 mm.

**Figure 4.** The same shell as in figure 3, showing the juvenile shell that is 3.3 mm wide.

**Figure 5.** The protoconch of *Paramorea* from the Coon Creek Formation at Coon Creek consists of about 4 whorls, which are smooth and well rounded. The protoconch measures about 0.8 mm in height in its visible portion and is well distinguished from the teleoconch with a smooth outer lip.

**Figure 6.** The same shell as figure 5, showing the 2.2-mm-high juvenile teleoconch ornamented by spiral ribs. **Figure 7.** The protoconch of *Paladmete* sp. from the Coffee Sand in Mississippi has a conical rounded shape, almost flat top, and rounded and ornamented larval whorls, the ornament consisting of a network of rectangles. The protoconch is 1.4 mm high. **Figure**

**8.** The protoconch of *Pyropsis* sp. from the Coon Creek Formation at Coon Creek is smooth and low coiled, consisting of 1.5 whorls of about 0.7 mm in width. The transition to the teleoconch is indicated by a strong increment in growth lines.

**Figure 9.** The juvenile shell of *Pseudecphora* sp. from the Coon Creek Formation at Coon Creek has a protoconch of 0.8 mm in width; the teleoconch begins at the spiral rib. The shell measures almost 3 mm in width.

**Figure 10.** The larval shell of *Amuletum* sp. from the Coon Creek Formation in Union County, Mississippi (see Dockery, 1993, p. 180, MGS locality 127), is 1.2 mm high.

**Figure 11.** An enlargement of figure 10 that shows the embryonic whorl to be ornamented by tubercles and well set off from the rest of the protoconch. It is 0.22 mm in diameter.

**Figure 12.** The protoconch of *Bellifusus* sp. from the Coon Creek Formation in Union County, Mississippi, in apical view consists of 3.5 whorls and is about 0.6 mm in width.

**Figure 13.** An enlargement of figure 12, showing the embryonic whorl to be distinguished from the larval shell by growth lines, which indicate the time of hatching from the egg mass. The embryonic shell measures 0.13 mm in width and is tuberculate, which is characteristic of many latrogastropods.

flat top, and rounded and ornamented larval whorls, the ornament consisting of a network of rectangles. The teleoconch commonly has varices, indicating interrupted growth of about one half whorl at a time as is commonly found among modern cassoids.

The protoconch of *Paladmete* resembles that of *Cerithioderma* (Trichotropidae), however, the larval shells of modern cancellariids and trichotropids may resemble each other superficially. Under close observation, the embryonic shells of the two groups exhibit different morphologies (Bandel and Riedel, 1994a), and the larval shells show a marked difference. Trichotropids develop

echinospira-bearing larvae, which have a periostracal cover around the inner, weakly calcified shell, while the cancellariids do not. The protoconch of *Paladmete* closely resembles that found in modern *Bursa* and other members of the Cassoidea (Bandel, 1993b; Kiel, 2001).

The type species, *Trichotropis cancellaria* Conrad, 1858 (Sohl, 1964a, pl. 45, fig. 28-34), has strong axial ribs crossed by finer spiral ribs and may reach 2 cm in height. The protoconch is flat-topped and consists of almost 3 whorls. The aperture of the adult shell may show denticles on the inner side of the outer lip. *Paladmete gardnerae* has a finer ornamental pattern and better developed varices

(Sohl, 1964a, pl. 45, fig. 36-40, 43-45). The ornament is even finer and varices are lacking in *Paladmete laevis* (Sohl, 1964a, pl. 45, fig. 35, 41, 42, 46-48).

103. *Paladmete cancellaria* (Conrad, 1858)\*  
 104. *Paladmete gardnerae gardnerae* Wade, 1926\*  
 105. *Paladmete gardnerae pygmaea* Sohl, 1964a  
 106. *Paladmete laevis* Sohl, 1964a

#### Family Thalassoscynidae Riedel, 1994

This family was introduced to define a more primitive branch of the Ficoidea Meek, 1864, in which the modern *Thalassoscyon* closely resembles the Cretaceous *Hippocampoides*. Riedel (1994, 2000) suggested that the concentration of the nerves along the construction of the extensible proboscis placed Ficoidea Meek, 1864, in its own order Ficina close to the Neogastropoda, especially rachiglossan genera such as *Vasum* Röding, 1798, *Busycon* Röding, 1798, *Turbinella* Lamarck, 1799, and *Melongena* Schumacher, 1817. Within the superfamily Ficoidea, Riedel (2000) recognized two families, Ficidae Meek, 1864, and Thalassoscynidae. Ficoidea could be interpreted to represent the only neogastropod group with a taenoglossate radula, while all others have reduced the number of teeth in each row (Riedel, 1994). But Riedel (2000) preferred to place the order Ficina more traditionally with the Neomesogastropoda.

If the Thalassoscynidae are interpreted to hold members of the genus *Hippocampoides*, they must be related to the Sarganidae and Weeksidae, since transitions are noted between the genera contained within these taxa, both regarding the teleoconch and the protoconch.

#### Genus *Hippocampoides* Wade, 1916

Sohl (1964a) placed *Hippocampoides* with the modern *Latiaxis* Swainson, 1840, and, thus, the Coralliophilidae (=Magilidae). The protoconch is in disagreement with this placement (Bandel et al., 1997), even though the teleoconchs are closely convergent in shape. The planispiral protoconch places *Hippocampoides* in close relation with *Sargana*. The siphonal canal of *Hippocampoides* resembles that of *Sargana*, but the smooth surface of the shell of *Hippocampoides* distinguishes it from *Sargana*, which also has a more clearly developed posterior notch of the aperture. *Lowenstamia* differs from *Hippocampoides* in having an erect protoconch, heavy spiral ornament, and a flaring aperture with a wide and short anterior canal that forms a gutter like extension of the outer lip (Sohl, 1964a, pl. 21, fig. 15, 19, 23). *Hippocampoides* differs from *Pseudecphora* in its larger shell, flat apex, and serrated peripheral keel with a narrow canal. The protoconch of Cretaceous *Pseudecphora* is rather similar in size, shape,

and ornament (Bandel and Dockery 2001, pl. 2, fig. 39, 40) to that of modern *Ficus*, as illustrated by Riedel (2000).

107. *Hippocampoides serratus* (Wade, 1916)\*

#### Family Sarganidae Stephenson, 1923

The low-spined, subpyriform shell has anteriorly constricted whorls with a prominent umbilicus. The aperture is posteriorly notched and anteriorly drawn out to form a narrow, curved, siphonal canal. The pyriform posterior notch is connected to a narrow apical canal, which creates a scalenoid subsutural collar. The ornament consists of axial and spiral elements commonly of equal width and often producing a granular to tubercular pattern. The protoconch has a low helicoid to almost planispirally-coiled shape and consists of two to few whorls (see Bandel and Dockery, 2001).

The flat-topped Sarganidae, with *Sargana* having a short siphon and rounded tuberculate whorls, resemble *Hippocampoides*, with a similar general shell shape but with flattened and smooth whorls. *Lowenstamia* has a short columella, and *Weeksia* is almost planispirally coiled. Of the Moreidae, the genus *Schizobasis* has a similar shell to that of *Sargana*, but its siphon is twisted to the left. The morphology of the protoconch places *Sargana*, *Weeksia*, and *Hippocampoides* close to each other and clearly differentiates all of them from the Muricidae (Bandel and Dockery, 2001). The protoconchs of modern Muricidae provide some evidence of a connection with those Pyrifusidae having a slender cone-like larval shell with apertural projection, but not with members of the Sarganidae, which have low, rounded protoconchs with straight margins.

#### Subfamily Sarganinae Stephenson, 1923

The low-spined subpyriform shell has anteriorly constricted whorls with a hollow spindle. The aperture is posteriorly notched and anteriorly drawn out to a narrow curved siphonal canal. There is a subsutural collar that appears on the first whorls of the teleoconch. The ornament consists of axial and spiral elements commonly of equal width and often producing a granular to tubercular pattern. The protoconch is low to almost planispirally coiled and consists of one to a few whorls. The characteristic genus is *Sargana*.

#### Genus *Sargana* Stephenson, 1923

Plate 2, figures 3-4

The spire is depressed, and the aperture is subcircular with a narrow anterior canal and thickened lips. A posterior notch is formed by a narrow canal, which creates a subsutural collar. The ornament of the adult shell consists

of strong spiral ribs separated by wide rounded furrows. Vertical ribs or growth increments cross the spiral ribs at more or less variable intervals, forming nodes or spines at intersection. The protoconch is smooth, low, helicoidally or planispirally coiled and consists of well-rounded whorls with little overlap at their margins. The type species is *Rapana stantoni* Weller, 1907, from Nacatoch Sand of Texas (Stephenson, 1941, pl. 60, fig. 15-17). This species is common in the Ripley Formation of Mississippi and Tennessee (Sohl, 1963; 1964a, pl. 19, fig. 7, 9, 11-25).

108. *Sargana stantoni* (Weller, 1907)\*

Sohl (1964a) noted that *Sargana geversi* differed from *S. stantoni* only in lacking a second spiral cord on the upper whorl face. There is also one less spiral ridge on the flanks, and axial elements are less common in *S. geversi* (Bandel and Dockery, 2001). The other two species of *Sargana* from the Coffee Sand in Mississippi, *S. chapelvillei* and *S. mississippiensis*, lack a spinous, sharp, upper edge on the flattened apical flank. According to Sohl (1964a, pl. 19, fig. 7, 9, 11-25), the shell of *Sargana stantoni* is up to 4 cm in width and height. Its protoconch consists of more than two planispiral whorls with the embryonic whorls about 0.15 mm wide. The protoconch measures 0.7 mm in width, and the aperture seems to be simple.

*Sargana chapelvillei* Bandel and Dockery, 2001, has a low-spined subpyriform shell consisting of almost 3.5 whorls of the teleoconch, has a depressed spire with rounded periphery, and is as wide as high, or a little wider than high (up to 2.5 cm). *Sargana chapelvillei* has a more rounded apex than *Sargana stantoni*, has low nodes at intersections, lacks gutter-like spines, and the siphon is more inclined to the left. *Sargana chapelvillei* differs from *Sargana mississippiensis* and from *S. kieli* Bandel and Dockery, 2001, from the Santonian of South Africa, in having a more nodulose ornament and a less twisted siphonal canal. *Sargana geversi* and *S. xsosaensis* Bandel and Dockery, 2001, from South Africa differ in having a coarser ornament and fewer spiral ribs.

*Sargana mississippiensis* Bandel and Dockery, 2001, has a low-spined subpyriform shell that is wider (about 1.8 cm) than high (about 1.3 cm) and has a medium-size umbilicus that is surrounded by a narrow and acute ridge with spines and is inclined away from the apertural plane. The shell of *Sargana mississippiensis* is smaller and has fewer whorls than found in the other species of *Sargana*.

**Genus *Praesargana* Saul and Popenoe, 1993**

The low-spined shell consists of a few whorls of which the body whorl nearly completely envelops the previous whorl. Ornament consists of several spiral ribs, with large tubercles, separated from each other by deep grooves. The aperture is round with a posterior notch on the outer lip. The inner lip is thick with a sharp fold at the basis of the columella and the beginning of the short deep siphonal

canal, which is bent to the left. The columella is open and bound by a roughened fasciole. The type species is *Trophon condoni* White, 1889, from the Californian Chico Group, Turonian (Saul and Popenoe, 1993, fig. 27-37).

*Praesargana tupeloensis* Bandel and Dockery, 2001, has a low-spined shell consisting of a bit more than four whorls; the protoconch was not preserved. The last whorl envelops the previous whorls nearly completely, and the spire is low and rounded. The shell is 2.4 cm high and 2.1 mm wide with well-rounded flanks. Ornament consists of eight spiral cords and a raised and rounded subsutural ribbon. The spiral elements are crossed by collabral ribs, which form an interstecting pattern of rounded nodes. The aperture is roundish with a posterior notch on the outer lip that gives rise to the subsutural ribbon, which has an ornament of prosocline growth increments extending onto the former whorl and forming an undulose suture. The columella is open and bounded by a rough fasciole displaying the termini of former siphonal canals.

*Praesargana* lacks the deep spiral sulcus present in *Sargana* at the base of the body whorl. It has a fine nodular rather than spinose sculpture. *Praesargana* has a transitional shell to the Pyropsinae on one side and the Moreinae on the other.

**Subfamily Pseudecphorinae  
Bandel and Dockery, 2001**

The sub-pyriform shell has anteriorly constricted whorls with a hollow spindle. The aperture is indistinctly notched at its posterior end and lacks a subsutural band; the anterior end is extended to produce a weakly curved siphonal canal. The concave inner lip ends with a strong plica at the onset of the siphonal canal. The umbilicus is surrounded by a ridge, which is formed by the termini of previous siphonal canals. Ornament consists of few strong spiral ribs and weak growth lines. The protoconch is a low coil with rounded smooth whorls and is almost 1 mm in diameter. The characteristic genus is *Pseudecphora*.

The Pseudecphorinae is distinguished from the Sarganinae by a higher spire, an ornamentation of spiral ribs, and the absence of a subsutural ribbon. The protoconch and umbilicus of these subfamilies are similar in shape. *Pseudecphora* is distinguished from *Lowenstamia* and *Weeksia* by a low, coiled protoconch, the lack of fine spiral lirations on the teleoconch, and by the presence of a siphonal canal. *Hippocampoides* of the Thalassoscynidae is distinguished by a flattened apex and protoconch and by a spinous umbilical margin.

**Genus *Pseudecphora* Bandel and Dockery, 2001**

Plate 2, figure 9

The small shell (about 10 mm high) has a large



umbilicus surrounded by a high rim. The teleoconch consists of four or five whorls, which increase markedly in size; the spire is low and acute, but flattened in the location of the protoconch. The ornament consists of regular spiral ridges on the body whorl. The aperture is almost round and forms a short, narrow, slightly curved, siphonal canal at its anterior end. There is a short but distinct posterior notch at the margin of the outer lip. The protoconch is large and planispirally coiled. The type species is *Ephora proquadricostata* Wade, 1917b, from Coon Creek in Tennessee (Sohl, 1964a, pl. 19, fig.1, 5).

109. *Pseudephora proquadricostata* (Wade, 1917b)\*

*Ephora proquadricostata* Wade, 1917b, and *Latiaxis serratus* (Wade, 1916) are not muricids as assumed by Sohl (1964a) and, thus, do not belong to muricid genera. Their protoconch morphologies and the occurrence of transitional forms indicate they may be related to *Sargana* and genera like *Morea* and *Weeksia*.

**Subfamily Schizobasinae  
Bandel and Dockery, 2001**

According to Bandel and Dockery (2001, fig. 51-53), the shell is low and of rounded to depressed *Nerita*-like shape, is more than 1 cm in size, has a strong basal constriction, and has an open umbilicus, which is surrounded by a ridge formed by the termini of previous siphonal canals. The protoconch has a low spiral shape with rounded and smooth whorls. The aperture is notched at its posterior end and has rounded outer and inner lips, which extend anteriorly into a deep, narrow, twisted, siphonal canal. The callus covering the inner lip ends in a ridge against the columellar lip. The subfamily is based on the genus *Schizobasis*, and it includes the less coarsely ornamented *Hillites* and the smooth *Xsosaites*.

**Genus *Schizobasis* Wade, 1916**

The depressed rounded shell has a strong and deep basal constriction. The ornament consists of nodular spiral cords. The aperture is ovate, is notched at its posterior end, and is drawn out at the posterior end to form a narrow, moderately long, curving, siphonal canal, which is strongly bent and pressed against the shell base. The outer lip is simple and inclined. The inner lip bears a sharp fold at the base of the columella and immediately above the siphonal canal (Sohl, 1964a, pl. 21, fig.1-4). The type species is *Schizobasis depressa* Wade, 1916, from Coon Creek, Tennessee.

The distinctive siphonal canal allies *Schizobasis* with *Hillites* Stephenson, 1952, but the ornament differs, consisting of spiral ribs in *Hillites* and coarse spiral lines of nodes in *Schizobasis*. In general shape, *Schizobasis* resembles *Sargana* but has a more nodular ornament and a more

rounded apex. The protoconch resembles that of *Weeksia*.

Stephenson (1952) placed *Sargana*, *Schizobasis*, and *Hillites* in the family Sarganidae. Sohl (1964a) placed *Schizobasis* together with *Paramorea* and *Morea* in the subfamily Moreinae and *Sargana* in the Rapaninae and placed both subfamilies in the Muricidae. Bandel and Dockery (2001) defined the Sarganidae as containing *Sargana* and other such Late Cretaceous gastropods genera, having a *Sargana*-like, planispirally-coiled protoconch (Bandel, 1993b, pl.13, fig. 3). Thus, *Schizobasis* and the Schizobasinae are related to the Moreinae with a rounded, low-spiral protoconch as found in *Morea*.

A transition can be noted from *Schizobasis* with ornamentation like that of *Morea*, but with a short and inclined siphon, to *Xsosaites* with a similar shell shape but no ornament (Bandel 1999). This later genus from the Umzamba Cretaceous in South Africa was suggested to be transitional to naticids of the morphology as found in *Gyrodes* (*Gyrodes*).

110. *Schizobasis depressa* Wade, 1916\*

111. *Schizobasis immersa* Wade, 1926\*

*Schizobasis depressa* Wade, 1916, from Coon Creek, Tennessee (Sohl, 1964a, pl. 20, fig. 27-30, 33, 34; Bandel, 1999, fig. 1b, pl. 4, fig. 9, 10) differs from *Schizobasis immersa* Wade, 1926, by having whorls with 7 spiral noded ribs (Sohl, 1964a, pl. 20, fig. 31, 32, 35, 36).

**Genus *Lowenstamia* Sohl, 1964a**

The very low to flat-spired shell has a broad umbilicus. The erect protoconch consists of several smooth and rounded whorls. Teleoconch whorls possess a flattened upper face, a peripheral carination that carries nodules, and whorl sides that slope inward to a sharp acute umbilical margin. Ornament consist of few lirae covering the entire shell surface and spiral cords on the whorl sides. The aperture flares with a short open V-shaped siphonal canal (Sohl, 1964a, pl. 21, fig. 10, 14, 15, 18-20, 22, 25). The type species is *Lowenstamia funiculus* Sohl, 1964b, from Coffee Sand of Mississippi.

112. *Lowenstamia lirata* (Wade, 1926)\*

The shell of this species bears only a single spiral cord on the body whorl between the peripheral and umbilical keels. It was named as *Hippocampoides liratus* by Wade, 1926. *Lowenstamia funiculus* Sohl, 1964b, of the Coffee Sand in Mississippi, is almost 3.5 cm in diameter and bears two spiral cords; *L. lirata* is up to 2.6 cm in diameter and bears two cords; and *L. cucullata* is 1.2 cm in diameter and is smooth. These differences may represent only growth stage differences and not species distinctions. Perhaps the genus *Lowenstamia* only includes *L. lirata*. Even though its shell is similar to that of *Weeksia*, the

protoconch of *Lowenstamia* resembles that of *Sargana* and *Hippocampoides*.

### Family Weeksiidae Sohl, 1960

The flatly coiled teleoconch has angular corners and is connected to a simple, smooth, rounded, naticoidal protoconch. The aperture is angular and wide, and the outer lip forms a sinus between the angulations. The family is based on the unique *Weeksia amplificata* of the Ripley Formation.

#### Genus *Weeksia* Stephenson, 1941

Plate 2, figures 1-2

The medium-size shell is about 1 cm high and 2.5 cm wide and consists of about 4.5 whorls, which are planispirally coiled. The last whorl can detach from the former ones, and the shell may acquire a cow-horn shape. In contrast, the protoconch is coiled and of a rounded low spiral outline with 2.5 whorls; the embryonic whorl is 0.19 mm in diameter and sits atop the flattened and inclined, barrel-like, larval shell, which is 0.7 mm in width and about the same in height. The two rounded and smooth larval whorls have a slightly inclined position with respect to the planispiral coil of the teleoconch (Bandel, 1988, pl. 2, fig. 7, pl. 5, fig. 8) and resemble the embryonic and larval whorls of a neogastropod or a neomesogastropod.

*Weeksia* and *Lowenstamia* are related regarding the shape of the teleoconch and that of protoconch. *Hippocampoides* differs from *Weeksia* in its flatly coiled protoconch and its aperture with a narrow siphonal canal.

#### 113. *Weeksia amplificata* (Wade, 1926)\*

The shell is up to 2.5 cm wide and 1 cm high and consists of about 4.5 whorls, which are planispirally coiled with the last whorl commonly detaching. The whorl profile of the teleoconch is subrectangular with two keels provided with gutter-like spines, which mark intermissions during growth of the shell.

### Family Moreidae Sohl, 1964a

The low-spined, ovate to almost round shells have a short siphonal canal and a siphonal fasciole developed as a pseudumbilicus. Ornament consists of intersecting strong spiral ribbons and more or less strong radial ribs. The aperture bears a posterior canal between the body whorl and the outer lip. The outer lip is rounded and may have folds; the columellar lip bears one or more strong oblique folds immediately above the siphonal canal. The protoconch consists of several whorls and is of globular or egg-like shape with a smooth surface.

Genera with an ovoid shell shape and short siphon like *Morea*, *Paramorea*, and *Buccinopsis* are contained

within this subfamily. A relationship can be seen between the shorter *Schizobasis* and the ficoid *Ficulimorpha*, which lacks axial ribs. *Napulus* has a longer columella, which lacks a fasciole. *Buccinopsis* has species that are very close to species of *Pyrifusus* and *Pseudorapa*, documenting a transition between these genera, which are placed in the Neomesogastropoda on one side and the Neogastropoda on the other. The problematic position of *Buccinopsis* among the Neomesogastropoda and Neogastropoda is related to the divergence of these groups from a common latrogastropod ancestor in the Early Cretaceous.

#### Genus *Morea* Conrad, 1860

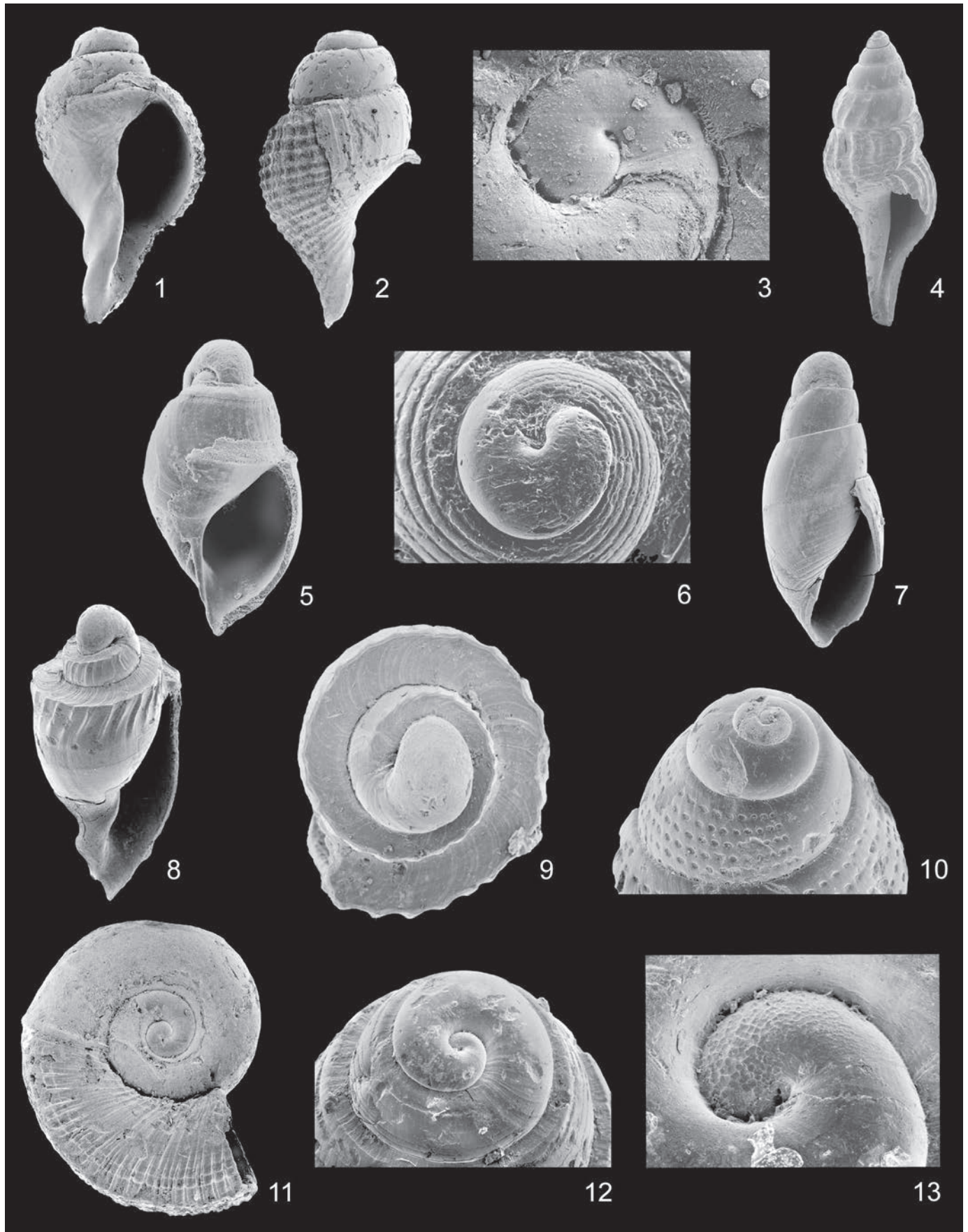
Plate 3, figures 1-3

The low-spined rounded shell has a basal sulcus, a siphonal fasciole, and a pseudo-umbilicus. Its ornament consists of intersecting strong spiral ribbons and weaker transversal ribs. The aperture is notched at its poster end and is produced at the anterior end to form a short broad canal ending in a siphonal notch. The uppermost spiral rib forms a subsutural ribbon with strong growth increments, which trace the growth of the posterior apertural notch. This notch is behind a callus pad on the inner lip and points a little to the side, more so than is seen in *Sargana*. The outer lip is wavy, and the base of the columellar lip has a strong (two in the young) oblique fold (Sohl, 1964a, pl. 20, fig. 1-26). The type species is *Morea cancellata* Conrad, 1860, from the Ripley Formation.

*Morea* has an ornament of similar axial and spiral ribs that form a sculpture of tubercles, while in *Buccinopsis* the axial ribs are strong and spiral elements are less dominant. *Praesargana* differs from *Morea* only in its lower spire, and *Napulus* differs in having no umbilicus.

The protoconch of a *Morea* similar to *Morea marylandica* as described by Sohl (1964a, pl. 20, fig. 4, 6) has a characteristic shape with flattened apex and 3.8 smoothly round-sided whorls. The well-preserved embryonic shell consists of almost one whorl of about 0.2 mm in diameter and is ornamented with scattered tubercles on a smooth background. The succeeding first larval whorl surrounds the embryonic whorl in planispiral manner but increases rapidly in height forming an ovoid egg-shaped smooth protoconch. Very fine growth lines indicate the presence of a low rounded projection on the anterior corner of the outer lip of the aperture. The beginning of the teleoconch is abrupt with spiral ridges as the main ornamentation and with the formation of a siphonal canal. The columellar lip bears two inclined folds and curves slightly outwards. If this juvenile shell belongs to *Morea marylandica*, the columellar folds are reduced during later growth of the shell.

#### 114. *Morea corsicanensis corsicanensis* Stephenson, 1941





### Plate 3

**Figure 1.** The juvenile shell of *Morea* sp. from the Coon Creek Formation in Union County, Mississippi, is 2.2 mm high and shows the flat top of the protoconch.

**Figure 2.** Another view of figure 1 showing the smooth larval shell to be well distinguished from the teleoconch.  
**Figure 3.** An enlarged apical view of figure 2 showing the embryonic whorl with an ornament of tubercles and a width of 0.2 mm.

**Figure 4.** The juvenile shell of *Amuletum* sp. from the Coon Creek Formation in Union County, Mississippi, has a protoconch of more than four whorls. The shell is 4 mm high.

**Figure 5.** The protoconch of the pyramidellid *Lacrimiforma secunda* from the Coon Creek Formation at Coon Creek is sinistrally coiled and held within the apex of the teleoconch; its characteristic subsutural groove is already present in the first whorl. The shell is 0.9 mm high.

**Figure 6.** The ringiculid protoconch from the Coon Creek Formation at Coon Creek twists from sinistral to dextral before metamorphosis, which is indicated by change from smooth to ribbed sculpture. The protoconch measures about 0.2 mm in width.

**Figure 7.** The pyramidellid *Creonella* sp. from the Coon Creek Formation at Coon Creek has a similar arrangement of the protoconch in the apex of the teleoconch as in *Lacrimiforma* (fig.5) but has smooth teleoconch whorls. The juvenile shell is about 2 mm high.

**Figure 8.** The protoconch at the apex of *Goniocylichna* sp. from the Coon Creek Formation at Coon Creek coils around an axis at about 90° to that of the teleoconch. The shell is about 1.2 mm high.

**Figure 9.** The enlarged apical view of figure 8 shows the twist in coiling direction. The protoconch measures 0.3 mm in width.

**Figure 10.** The protoconch at the apex of *Actaeon pistilliformis* from the Coon Creek Formation at Coon Creek is sinistrally coiled only in its embryonic shell portion and the larval shell is largely dextrally coiled.

**Figure 11.** *Pseudomalaxis* sp. from Coffee Sand in Mississippi has a smooth planispiral protoconch with a sinistral coiling mode, followed by a differently ornamented teleoconch with dextral coiling mode. The protoconch is 0.8 mm wide and consists of 2.5 whorls.

**Figure 12.** In contrast to *Actaeon pistilliformis*, *Bullina* sp. (Non-Acteonina) from the Coon Creek Formation at Coon Creek changes from sinistral to dextral coiling at the end of the larval shell, which measures 0.42 mm across. The end of the protoconch is indicated by change in ornamental and growth lines.

**Figure 13.** The enlargement of figure 12 shows the embryonic shell to be ornamented by a ridge and groove pattern. The embryonic shell measures 0.1 mm across.

115. *Morea corsicanensis coonensis* Sohl, 1960\*

116. *Morea rotunda* Sohl, 1964a

*Morea rotunda* Sohl, 1964a, of the Ripley Formation (Bandel and Dockery, 2001, fig. 42-44), is a convincing transitional form connecting *Morea* to *Praesargana* and *Sargana*, as was documented by Saul (1996). This transition connects shells of very similar ornament but with continuously shorter spires and continuously flatter apical shoulders.

117. *Morea marylandica marylandica* Gardner, 1916\*

118. *Morea marylandica halli* Sohl, 1964a

#### Genus *Paramorea* Wade, 1917b

Plate 2, figures 5-6

The ovate-fusiform shell has a short spire, which is less than half the total shell height. The body is shouldered above the periphery and rounded down to the siphonal

fasciole. Ornament consists of raised spiral ribbons. The aperture has an anterior notch, and the evenly curved outer lip has crenulations within and forms a rounded periphery. The inner lip twists into an umbilical chink, and the columella bears a fold above the siphonal canal (Sohl, 1964a). The type species is *Paramorea lirata* Wade, 1917b, from Ripley Formation, Tennessee. *Paramorea* has a less reflected lip, only spiral ornament, a narrower umbilical chink, and lacks as strong a fold on the columella immediately above the siphonal canal as is found in *Morea*.

119. *Paramorea lirata* Wade, 1917b\*

According to Sohl (1964a, pl.19, fig. 2-6, 8, 10), *Paramorea lirata* is ornamented with spiral ribbons, and the protoconch consist of three whorls, which are smooth and well rounded. This is seen in a juvenile shell, which may belong to this species; it has a protoconch of almost 3 whorls and flattened top. The embryonic whorl measures about 0.18 mm with the transition into the larval shell not preserved. The protoconch is 0.8 mm wide and measures at least 1 mm in height without the teleoconch. Whorls are rounded and bear delicate growth lines that reflect a slightly sinuous outer lip with a low saddle near the anterior edge. The larval shell of *Paramorea* resembles that of *Weeksia* and is higher than that of *Sargana*.

**Genus *Buccinopsis* Conrad, 1857**  
(= *Seminola* Wade, 1918)

The ovoid, low-spined shell has well-rounded shouldered whorls, which are constricted forming a subsutural collar and a twisted short siphonal pillar. The columellar lip forms a corner with the concave inner lip. There is a siphonal notch, and ornament is variable consisting of both axial and spiral elements (Sohl, 1964a). The type species is *Buccinopsis perryi* Conrad, 1857, from Texas. *Buccinopsis*, as represented by *B. solida* from Ripley Formation (Sohl, 1964a, pl. 22, fig. 4-7), is very similar in shape to *Morea*, differing from it in not having a pseudo-umbilicus. *Buccinopsis* is also comparable to *Napulus*, such as *N. excavatus* from Trichinopoly Group, but differs in having a smooth and not angled columellar lip. *Schizobasis* is much shorter, and *Sargana* like *S. chapelvillei* has a flatter spire and wider pseudumbilicus. *Buccinopsis* can be connected to *Pyrifusus*, such as *P. subliratus* Wade, 1926 and *P. crassus* Sohl, 1964a.

*Buccinopsis* could be placed with the Neomesogastropoda, as it is done here, due to its resemblance to *Morea*, or it could be placed with the Neogastropoda due to its resemblance to several members of the Pyrifusidae. This uncertainty regarding the correct place in taxonomy is interpreted to be a result of the evolution of the Latrogastropoda stemming from the same ancestral group of Caenogastropoda that lived during the Early Cretaceous. It has been assumed that the

genus *Maturifusus* Szabo, 1983, from the Jurassic, which resembles the Late Triassic *Pseudotritonium* Wenz, 1938, has too large a protoconch and a fusiform teleoconch to be a member of that group (Bandel, 1993b; Gründel, 1998; Riedel, 2000)

*Buccinopsis dorothiella*, as illustrated by Sohl (1964a, pl. 23, fig. 11), has a spiral groove at the base of the body whorl that terminates in a labial tooth at the base of the outer lip. This is also seen in a *Buccinopsis* species from the Coffee Sand and is perhaps present in all *Buccinopsis* species where the outer lip is well preserved. This ornament type was named by Vermeij (1998) as a pseudolivid groove and is present in the neogastropod family Pseudolivididae Cossmann, 1901, of the Superfamily Muricoidea. The labial tooth is not unique to the Pseudolivididae; Vermeij (1998, p. 55) and Marko and Vermeij (1999) also noted it to occur in the Muricidae (subfamilies Muricinae, Ocenebrinae, and Rapaninae), Buccinidae (in *Cantharus* R ding, 1798, *Phoracanthus* Cossmann and Martin in Martin, 1914, *Cornulina* Conrad, 1853, and *Protobusyscon* Wade, 1917b), Fasciolaridae (in *Opeatostoma* Berry, 1958), Turbinellidae (in *Ceratoxancus* Kuroda, 1952), Olividae (in many member of the Ancillinae), and various other "buccinoids" such as the Cretaceous *Buccinopsis* and *Odontobasis* Meek, 1876, as well as the recent *Tritonidea dentate* Schepman, 1911.

120. *Buccinopsis crassa* (Wade, 1917b)\*

121. *Buccinopsis solida solida* (Wade, 1917b)\*

122. *Buccinopsis dorothiella* Sohl, 1964a

**Order Neogastropoda Thiele, 1929**

The core group of Late Cretaceous caenogastropods, having larval shells of the neogastropod shape, includes the genera *Pseudorapa* Holzapfel, 1888, *Pyrifusus* Conrad, 1858, *Bellifusus* Stephenson, 1941, *Cryptorhytis* Meek, 1876, *Pholidotoma* Cossmann, 1896, *Drilluta* Wade, 1916, *Paleopsephaea* Wade, 1926, *Volutoderma* Gabb, 1877, *Hercorhyncus* Conrad, 1868, and *Pyropsis* Conrad, 1860. All of these have species in the Ripley Formation of Mississippi and Tennessee with the protoconch preserved, and some with protoconchs have also been found in the Coffee Sand of Mississippi. Protoconchs of these genera consist of a large (about 0.5 mm high) conical shell. The initial embryonic shell is fairly large and well differentiated from the remaining protoconch, which usually consists of several whorls of larval shell (Bandel, 1993b).

**Suborder Rachiglossa**

**Superfamily Pyrifusoidea Bandel, 2000**

According to Bandel and Dockery (2001), the solid, medium-size to large shells (1-10 cm high) are usually

ornamented by spiral and collabral ribs. The aperture usually has a siphonal canal and a posterior notch or canal next to the suture on the posterior part of the outer lip. This notch gives rise to a subsutural ribbon. The protoconch usually consists of several smooth whorls, which form a trochispiral to planispiral coil. Its embryonic portion consists of almost one whorl, is smooth or ornamented by tubercles, and measures more than 0.15 mm in diameter. The larval part is smooth, bears a subsutural ridge or row of tubercles, and may or may not have a small median or anterior projection of the outer lip.

The shell of the Muricoidea Rafinesque, 1825 (= Muricina Riedel, 2000) commonly has a planktotrophic veliger with a strongly ornamented protoconch and a pronounced projection of the outer lip. The teleoconch in Muricoidea and Buccinoidea Rafinesque, 1815, is mostly without the posterior notch of the aperture and the subsutural ribbon created by it. Based on the protoconch alone, no species of the Pyrifusoidea can be placed in any particular Recent neogastropod family, most of which have rather characteristic protoconch shapes (Bandel et al., 1997, Riedel, 2000).

The Cenomanian fauna described by Stephenson (1952) from Texas includes members of 4 taxonomic units, including the Pyrifusidae, the Pseudorapinae/Pholidotominae/ Dillutinae with *Paleopsephaea*, the Moreinae/ Sarganinae with *Hillites*, and the Voltutoderminae with *Carota*. While *Hillites* seems far from the general origin (stemgroup) and thus from the Pyrifusidae, the others have similarly fusiform shells with a few folds on the columella, the normal ornament of axial folds crossed by fine ribs, and the clear posterior notch of the aperture. These features represent the uniting factors of the stem group of the Pyrifusidae, and their origin can be interpreted to lie in a species with a fusiform shell shape as is more or less preserved within the core subfamilies: Pseudorapinae with a short shell, Pyrifusinae with a medium-size shell, Dillutinae with a slender shell, and Beretrinae with slender shell and long siphon. Here transitions are such that, among several genera, it is very difficult to place a species in one or the other.

Regarding the teleoconch shape, transitions connect species with pyriform shells with fine ornament (*Pyropsis*) and coarse ornament (*Napulus*) to median-size spindle shaped species with axial ornament (*Hercorhyncus*, *Rhombopsis*, *Protobucyon*), with fusiform species such as *Pseudorapa*, *Pyrifusus*, *Bellifusus* to species with slender shells like *Paleopsephaea*, and *Drilluta*, and such with long siphons as *Beretra* and *Fusimilis*. The species with broad apertures and enlarged body whorls like *Gosavia*, *Volutomorpha*, *Longiconcha*, *Liopeplum* are also interconnected with each other by the presence of a subsutural collar arising from a posterior notch of the outer lip and their simple and smooth protoconchs.

### Family Pyrifusidae Bandel, 2000

The family is based on the genus *Pyrifusus*. This family contains shells that are fusiform in the broadest sense, from slender to broad, from high to low-spired; sculpture consists of axial and spiral ribs, and the columella may be smooth or have one to numerous plaits. The larval shell is smooth, conical, consists of several whorls, and measures between 0.6 and 1.0 mm in diameter.

Quite a number of genera can be included within the Pyrifusidae, and it is not easy to differentiate them from each other. Subfamilies included here are the Pseudorapinae Bandel and Dockery, 2001, which have a pointed spire that is usually shorter than the last whorl, the Pyrifusinae Bandel, 2000, with an even shorter spire, an inclined and often concave shoulder, and a large rounded body whorl, the Pholidotominae Wenz, 1938, with slender shell and spire as long or longer than the last whorl, the Beretrinae (new subfamily) with similar shell shape but elongate siphon, the Volutoderminae Sohl, 1964a, with ovoid shape and commonly large shell, the Pyropsinae Stephenson, 1941, with rounded body and long siphon.

### Subfamily Pyrifusinae Bandel, 2000

Shells of this subfamily have a fusiform shape with a long siphon and a short turreted spire. A subsutural collar is well developed from the posterior notch of the aperture. The shoulders are pronounced, and the anterior is constricted, forming an elongate siphonal canal, which may be inclined to the left. The inner lip of the aperture is callus-covered and smooth and may form an angulation where the siphonal canal begins, or may have one or more folds. This group contains the genera *Pyrifusus*, *Bellifusus*, *Ornopsis*, *Trichifusus*, *Cryptorhytis*, *Concepcionella* Bandel and Stinnesbeck, 2000, and *Protobusyon*.

### Genus *Pyrifusus* Conrad, 1858

The low-spired pyriform shell has sub-shouldered whorls and a spire less than half the shell height. The ornament consists of strong spiral cords and transverse costae. The aperture is elongate and notched at its posterior end and has a well-developed siphonal canal that is straight or curved. The columella is thick and smooth. The type species is *Pyrifusus subdensatus* Conrad, 1858, from the Owl Creek Formation of Mississippi (Sohl, 1964a, pl. 24, fig.1-4).

*Pyrifusus* has a smooth columellar lip, which distinguishes it from the rather similar shaped *Bellifusus*, *Ornopsis* and *Cryptorhytis*, which have one, two, and three folds on their respective columellar lips. Kiel (2001) in his study of representatives of this group from the north Spanish Campanian Torallola and the Maastrichtian of Temalac, Mexico, noted transitions in the case of species that are placed with *Bellifusus*, *Drilluta*, *Graphidula*, and *Paleopsephaea*. In the case of *Hercorhyncus*, the upper



whorls are more flattened, and the shell is thus of more angular shape than *Pyrifusus*. *Hydrotribulus* and *Lupira* differ from each other by the shape of their siphon and have a shorter spire and broader shell than is found in *Pyrifusus*, *Bellifusus*, *Ornopsis* and *Cryptorhytis*.

### Subgenus *Pyrifusus* (*Pyrifusus*) Conrad, 1858

The subgenus is like the genus, with strong axial ribs and narrower but also strong spiral lirae, rounded body, and short spire. The type species is *P. (P.) subdensatus* Conrad of the Owl Creek Formation; a similar species *P. (P.) subliratus* Wade, 1926 (Sohl, 1964a, pl. 24, fig. 11, 21), with less shouldered whorls, fewer spiral cords, and more numerous axial ribs, is common in the Coon Creek Formation as is *P. (P.) crassus* Sohl, 1964a, with less slender outline (Sohl, 1964a, pl. 24, fig. 12, 16, 17). The protoconch is unknown. The very similar *P. (Koenenia)* has a higher spire than *P. (Pyrifusus)*.

123. *Pyrifusus (Pyrifusus) crassus* Sohl, 1964a

124. *Pyrifusus (Pyrifusus) subliratus* Wade, 1926\*

125. *Pyrifusus ejundicus* Sohl, 1964a\*

*Pyrifusus oldhamianus* (Stoliczka, 1868) from Trichinopoly Formation of southern India (Bandel, 2000b, fig. 32, 33) is quite similar to *Pyrifusus ejundicus* Sohl, 1964a (pl. 24, fig. 22, 25) from the Ripley Formation, but seems to have denser ornament. *Pyropsis subdensatus* Conrad, 1858, from the Ripley Formation has a more rounded outline and fewer ribs (Sohl, 1964a, pl. 24, fig. 1-4). None of the species from the American Gulf Coast have gutter-like spines on the upper edge as is present in *P. (Beisselia) oldhamianus* of India.

### Subgenus *Pyrifusus (Koenenia)* Holzapfel, 1888 (=*Deussenia* Stephenson, 1941)

The spire is about half of total shell height. Ornament consists of coarse transverse ribs that are strongest at the shoulder and terminate on the periphery (below) and the collar (above). Spiral ornament is weak on the broad subsutural collar and strong below. The aperture has a posterior notch and an anterior, wide and short, siphonal canal that twists to the left. The type species is *Koenenia speciosa* Holzapfel, 1888, from the Senonian greensands of Vaals in Holland (Wenz, 1938, fig. 3746).

The shell of *P. (Koenenia)* resembles that of *Pyrifusus* s.s. but has a higher spire and is very similar to the type of *Pseudorapa* Holzapfel, 1888. *Deussenia* Stephenson, 1941, can either be regarded as synonym or can be differentiated from *Koenenia* by its less constricted base, which is not a good character when the different species placed in *Deussenia* by Sohl (1964a, pl. 25) are taken into consideration.

In general shape, the shell of *P. (Koenenia = Deussenia)* resembles that of *Volutomorpha* but has a shorter body, a more prominent shoulder, and a smooth columella. The spire is less than half the shell height, and ornament consists of broad axial ribs that die out at the middle of the whorl and coarse spiral lirae. The subsutural ridge is well developed. The siphon twists slightly to the left, and, at the turning point, the inner lip is thickened. *Pseudorapa (Pseudorapa)* differs in having coarser ornament, a less rounded last whorl, and a stronger twist of the siphon to the left. *Pseudorapa (Stantonella)* is shorter and more rounded in outline.

126. *Pyrifusus (Koenenia) ripleyana* (Harbison, 1945)

127. *Deussenia* sp.

128. *Deussenia? microstriata* (Wade, 1926)\*

### Genus *Bellifusus* Stephenson, 1941

Plate 2, figures 12-13

The medium-size fusiform shell has a spire of little more than one-third the total shell height. Whorls are generally inflated above their mid-height and are constricted anteriorly at a transversely wrinkled collar. The shoulder is more or less rounded, and ornament consists of strong collabral ribs that die out on the basal slope and fine spiral cords and lirae. The aperture is a little elongated with a moderately long siphonal canal. The columella is slightly twisted with a strong plication anterior to a weaker fold. The type species is *Odontofusus curvicostatus* Wade, 1926, from Coon Creek, Tennessee (Sohl, 1964a, pl. 25, fig. 23, 24).

*Drilluta* is more slender in shape but has a relatively higher spire and less rounded whorls. *Bellifusus* has a twisted plicate columella; the columella is smooth in *Pyrifusus*, and the shell has a less rounded-fusiform shape. *Bellifusus* can be considered transitional to *Pholidotoma* on one side and *Pyrifusus* on the other. Perrilliat et al. (2000) recognized *Bellifusus curvicostatus curvicostatus* (Wade, 1926) in the Mexcala Formation of southern Mexico.

129. *Bellifusus curvicostatus curvicostatus* (Wade, 1926)\*

130. *Bellifusus angulicostatus* Sohl, 1964a\*

According to Sohl (1964a, pl. 25, fig. 23, 24, pl. 26, fig. 18, 19, 23, 24), *Bellifusus curvicostatus* is up to 5 cm long and 2.1 cm wide with 6-7 whorls and ornament consisting of 12-14 strong collabral ribs and only the faintest of spiral ornament over the periphery. The elongate aperture is angulate at its posterior end in harmony with the subsutural collar that begins on the last portion of the first whorl of the teleoconch. The aperture continues anteriorly into a slightly twisted siphonal canal, which is smooth in early whorls but bears one strong and two weak

folds on the columellar lip of later whorls. Sohl (1964a) found the trochiform protoconch to consist of 2.5 rounded whorls. Additional observations show the protoconch to contain 4.2 whorls, which are 0.85 mm wide and about 1mm high but are covered by the teleoconch on their anterior quarter. The embryonic whorl has an ornament of rounded granules on a smooth background and measures 0.16 mm in diameter. It is clearly distinguished from the larval shell by the beginning of growth lines, which are the only ornament of the round larval whorls. They reflect the presence of an anterior projection of the outer lip of the aperture. This projection continues to form the collabral rib pattern of the teleoconch but is less strongly developed here.

The Indian *Bellifusus indicus* Bandel, 2000, which has a prominent subsutural collar and whorls ornamented with about 14 axial ribs in early whorls and 9-10 ribs on late whorls and spiral cords that are stronger on the lower body, is very similar to *Bellifusus angulicostata* Sohl, 1964a (Sohl, 1964a, pl. 25, fig. 21, 22; Bandel, 2000b, fig. 34, 35) from Ripley Formation of Mississippi and Tennessee.

### Genus *Ornopsis* Wade, 1916

The shell is fusiform and of medium to moderately large size. The whorls are constricted at the subsutural collar, inflated medially, and elongated anteriorly into a narrow twisted canal. Ornament consists of both spiral and transverse elements of variable strength. The aperture is ovate and anteriorly constricted into a sharp channel. The columella bears a thin fold immediately above the anterior canal. The type species is *Ornopsis glenni* Wade, 1916 (Sohl, 1964a, pl. 29, fig. 8-10, 15, 16). Subgenera, in addition to *Ornopsis* s.st., include *Ripleyella* Harbison, 1945, with the type species *Ornopsis elevata* Wade, 1916 (Sohl, 1964a, pl. 29, fig. 22-25), and *Pornosis* Sohl, 1964a, with the type species *Ornopsis digressa* Wade, 1926 (Sohl, 1964a, pl. 29, fig. 12-14).

#### 131. *Ornopsis (Ornopsis) glenni* Wade, 1916\*

*Ornopsis glenni* is common at Coon Creek, but its protoconch is unknown. That of *Ornopsis digressa*, according to Sohl (1964a), consists of about 3.5 round-sided whorls with an abrupt junction with the teleoconch. It is similar to the trochiform protoconch of *Ornopsis (Pornosis) modica* Sohl, 1964a, from Mississippi.

#### 132. *Ornopsis (Ripleyella) elevata* Wade, 1916\*

#### 133. *Ornopsis (Pornosis) digressa* Wade, 1926\*

#### 134. *Ornopsis (Pornosis) modica* Sohl, 1964a

All species of *Ornopsis* possess a twisted siphonal canal with a strong fold above the canal. This distinguishes them from species of *Pseudorapa* and *Pyrifusus* where the corner from the inner lip to the columellar lip is not supported

by a fold. Otherwise, the genera are very similar to each other. In *Bellifusus*, the canal is somewhat less twisted and has two folds. *Cryptorhytis* has three folds on the columella, but otherwise is similar. Regarding shell shape, *Ornopsis* resembles *Pseudorapa* in shape and ornament.

### Genus *Trichifusus* Bandel, 2000

The fusiform shell has a long siphon, a narrow subsutural ribbon only on late whorls, and an ornament of broad axial ribs and fine spiral ribbons. The inner lip bears three folds of which the anterior one is the strongest. The type is *Trichifusus reussianus* (Stoliczka, 1868) from the Trichinopoly Formation of southern India.

*Trichifusus* is intermediate in shape between *Bellifusus* and *Drilluta*, but in contrast to these has a much narrower and, in early whorls, rather indistinct subsutural ribbon. *Trichifusus torquatus* (Sohl, 1964a) from the Owl Creek Formation is very similar in shape and ornament, but differs in having only two plications on the inner lip in contrast to *Trichifusus reussianus* (Stoliczka, 1868) (Bandel, 2000b, fig. 36, 37), which has three such folds.

### Genus *Cryptorhytis* Meek, 1876

The medium-size fusiform shell has posteriorly constricted whorls, a relatively long siphonal canal, and several oblique plaits that occur relatively high on the columella but are not visible at the aperture. The type species is *Gladius? cheyennensis* Meek and Hayden, 1860, from the U.S. Western Interior.

The species of this genus are probably closely related to *Ornopsis* (Sohl, 1964a), but the columellar folds are not as sharp and oblique, and there is usually one more present than in *Bellifusus*. In shell shape, *Cryptorhytis* closely resembles *Aliofusus*, but clearly differs in having three columellar folds, and *Aliofusus* tends to have a more sharply developed periphery.

#### 135. *Cryptorhytis nobilis* Wade, 1926\*

The elongate fusiform shell has a well-developed subsutural collar and a body whorl that is a little higher than the spire. The ornament consists of 8-9 strong axial ribs on each whorl, which die out anteriorly, and fine spiral ridges. The elongate aperture has a slightly flexed siphonal canal and a short posterior channel. The columellar lip has two or three folds.

*Cryptorhytis gravida* (Stoliczka, 1868) from from the Trichinopoly Group (Bandel, 2000, fig. 40, 41) is slightly larger than *Cryptorhytis nobilis* Wade, 1926, from Coon Creek in Tennessee, but otherwise could represent the same species (Sohl, 1964a, pl. 32, fig. 2, 3). *Ornopsis (Pornosis) modica* Sohl, 1964a, is a little wider and has similar ornament but has only one fold on the columellar lip (Sohl, 1964a, pl. 29, fig. 4-7). *Odontobasis sulcata* Sohl, 1964a (Sohl, 1964a, pl. 23, fig. 1-4) is similar in general shell

shape and has two folds on the beginning of the siphonal canal but differs in regard to its stronger ornament of spiral ribbons.

### Genus *Rhombopsis* Gardner, 1916

The pyriform shell of medium size (about 4 cm) has moderately shouldered whorls, which are constricted at a broad subsutural collar or inclined ramp. The elongate aperture extends into a moderately long, straight siphonal canal. Ornament consists of discontinuous collabral ribs and numerous spiral lirae or cords. The columella is smooth. The type species is *Fusus newberryi* Meek and Hayden, 1876, from the Cretaceous of the Western Interior, USA.

*Rhombopsis* is very close in shape to *Protobusyon*, but, in contrast to the later, the upper body whorl of *Rhombopsis* is inclined and weakly shouldered. *Pyrifusus* (*Koenenia*) (= *Deussenia*) has a more clearly developed subsutural collar and more rounded flanks. In the case of *Pyrifusus* s.s., the flanks are more rounded. Sohl (1964a) noted the similarity of *Rhombopsis* with *Deussenia* and *Pyropsis*, but made no mention of the similarity also seen towards the genus *Protobusyon*. This is so because the species found in the Ripley Formation, like *Rhombopsis molinoensis*, are more coarsely spirally ribbed, while *Rhombopsis umzambiensis* Kiel and Bandel, 2002, is less spirally ornamented and thus closer to the ornament found in *Protobusyon*, like *P. binodosum* Sohl, 1964a.

136. *Rhombopsis molinoensis* Sohl, 1964a

137. *Rhombopsis?* *orientalis* Wade, 1926\*

### Genus *Lomirosa* Stephenson, 1941

This genus closely resembles *Anomalofusus*, which is a bit longer and has the same apertural outline. *Lomirosa* may also belong to the Cassoidea, as suggested in the case of *Anomalofusus*, since there is no subsutural ribbon.

138. *Lomirosa cretacea* (Wade, 1917b)\*

### Genus *Protobusyon* Wade, 1917b

The shell is bi-conical with whorls ornamented by one or two rows of nodes, the upper of which lies on the shoulders. The aperture is notched at its posterior end. The type species is *Protobusyon cretaceum* Wade, 1917b, from Ripley Formation (Sohl, 1964a, pl.23, fig. 23, 24).

139. *Protobusyon cretaceum* Wade, 1917b\*

140. *Protobusyon binodosum* Sohl, 1964a

*Protobusyon binodosum* differs from *P. cretaceum* in having two rows of nodes instead of one (Sohl, 1964a, pl.

24, fig. 23, 24, 26, 27).

### Subfamily Pseudorapinae Bandel and Dockery, 2001

The shell has a fusiform shape with a moderately long siphon and turreted spire that is shorter than the last whorl. The shell is constricted at the node-bearing subsutural collar. The shoulders are pronounced, and the body narrows anteriorly to form an elongate siphonal canal that is bordered by a swelling of the columellar lip. The siphon may be inclined to the left. The subfamily is based on the genus *Pseudorapa*, which occurs in the Campanian Vaals greensands near Aachen, Germany.

The subgenus *Pseudorapa* (*Pseudorapa*) Holzapfel, 1888, with the type species *Murex pleurotomoides* Müller, 1847, is from the Campanian Greensand of Aachen in Germany and has a fusiform shell resembling that of modern *Latirus*. The body is sharply constricted anteriorly to form an elongate siphonal canal that is usually twisted to the left. Ornament consists of strong collabral ribs, and the shoulders and periphery are crossed by close-spaced spiral lirae. *Pseudorapa* (*Pseudorapa*) *pleurotomoides* closely resembles the subgenera *Pseudorapa* (*Stantonella*) and *Pseudorapa* (*Aliofusus*). Pseudorapinae differ from the Pyrifusinae, which have an even shorter spire and inclined, often concave, shoulders and rounded large body whorl.

### Subgenus *Pseudorapa* (*Stantonella*) (Wade, 1926)

As is the case in *P. (Pseudorapa)*, the shoulders of the shell are strong, and the body is sharply constricted to form an elongate twisted siphonal canal that is bordered above by a distinct oblique swelling at the base of the columellar lip. The turreted spire has constricted whorls forming a posterior nodular collar. The posterior apertural notch is well developed. The type is *Stantonella subnodosa* Wade, 1926, from Coon Creek, Tennessee (Sohl, 1964a, pl. 22, fig.14, 15).

141. *Pseudorapa* (*Stantonella*) *subnodosa* (Wade, 1926)\*

142. *Pseudorapa* (*Stantonella*) *ripleyana* (Conrad, 1860)

Sohl (1964a, pl. 22, fig.14, 15) characterized *P. (Stantonella) subnodosa* as wider and shorter than the more common *P. (Stantonella) riplelyana* (see Sohl, 1964a, pl. 22, fig. 8, 9, 18-21). The protoconch consists of 3.5 smooth round-sided whorls (Sohl, 1964a). The protoconch of *P. (S.) riplelyana* from Coffee Sand in Mississippi consists of 4 whorls and is of a rounded conical shape, about 1 mm high and 0.8 mm wide. The embryonic shell measures about 0.15 mm across with ornament not preserved. Fine growth lines on the smooth larval whorls reflect an apertural projection of the outer lip.



### Subgenus *Pseudorapa* (*Aliofusus*) (Stephenson, 1941)

143. *Pseudorapa* (*Aliofusus*) *stamineus* Sohl, 1964a

In general shell shape, *P. (Stantonella)* and *P. (Aliofusus)* are similar, but the later is less spirally ornamented, and its subsutural ribbon appears to be rather indistinct (Sohl, 1964a, pl. 22, fig.10, 11).

### Genus *Odontobasis* Meek, 1876

144. *Odontobasis?* *australis* Wade, 1926\*

145. *Odontobasis sulcata* Sohl, 1964a

### Subfamily Pholidotominae Wenz, 1938 (=Drillutinae n. subfam.)

These slender shells of the Pholidotominae are thought to combine *Pholidotoma* Cossmann, 1896, with *Drilluta* and *Paleopsephaea*. A notable characteristic is that the spire is as long or longer than the last whorl. If Pholidotoma reveals, when newly studied, that it does not have a subsutural ribbon as found in *Drilluta*, this subfamily should be renamed and called Drillutinae.

### Genus *Drilluta* Wade, 1916

The rather slender fusiform shell has a spire of about half the total shell height. The whorls have a roughened subsutural collar. Their ornament is usually dominated by strong, collabral, transverse ribs. The spiral sculpture is well developed on the basal slope, less frequently on the periphery. The aperture is notched at its posterior end. The siphonal canal is of moderate length and is slightly inclined to the left. The callus of the inner lip is thin, and the columella has a strong plait that lies anterior to one or two weaker folds. The type species is *Drilluta communis* Wade, 1916, from Ripley Formation, Tennessee.

In respect to the high spire, *Drilluta* appears to be close to *Bellifusus*. *Pholidotoma* (*Fusimilis*) is very similar, while *Pholidotoma* (*Beretra*) has a more slender shell, but both have a smooth columellar lip and lack the posterior notch of *Drilluta*. In *Paleopsephaea*, the ramp is less distinct, and there are more folds present on the columellar lip.

146. *Drilluta communis* Wade, 1916

147. *Drilluta distans* (Conrad, 1860)\*

148. *Drilluta major* Wade, 1916\*

149. *Drilluta lemniscata* Sohl, 1964a

Sohl (1964a) described and illustrated the 4 species of *Drilluta* from the Ripley Formation, *D. communis* Wade, 1916 (Sohl, 1964a, pl. 27, fig.12, 13, 20-22), *D. distans* (Conrad, 1860) (Sohl, 1964a, pl. 27, fig.1-7, 14, 15, 23, 27,

28), *D. lemniscata* Sohl, 1964a (Sohl, 1964a, pl. 27, fig.16-19), *D. major* Wade, 1916 (Sohl, 1964a, pl. 26, fig. 20-22), and one species, *D. buboanus* Sohl, 1964a (Sohl, 1964a, pl. 27, fig. 8-11, 25), from the Owl Creek Formation. He described no protoconchs.

The protoconch of *Drilluta lemniscata* or a very similar species was studied and had a pointed trochospiral shape with 4.2 round-sided whorls. The embryonic shell measured 0.15 mm across and was ornamented by tubercles on a smooth background. The protoconch was 0.8 mm wide and 0.9 mm high in its visible part; without the teleoconch, it measured somewhat more than 1 mm in height. The larval whorls were ornamented only by fine growth lines, which indicated the presence of an anterior projection of the outer lip. The onset of the teleoconch was indistinct at first but was soon indicated by the presence of spiral lirations. The slim, up to 7-cm-long, teleoconch has a narrow collar below the suture, which forms only in the second whorl of the teleoconch. Ornament consists of axial ribs crossed by spiral cords (25 on the body whorl) over the entire surface. The spiral cords are weaker in *D. distans* and *D. communis*. The spire is less than half of the total shell height, and the apical angle is 30 to 35°. The siphonal canal is long, and the columellar lip has an anterior fold, which is not present on the first and second whorl of the teleoconch.

### Genus *Paleopsephaea* Wade, 1926

The medium-size fusiform shell has a spire of about half the total shell length, which consists of whorls that are constricted below the suture. The anterior tapers to a siphonal canal of moderate length. The subsutural collar is indistinct and narrow. The ornament is dominated by strong, collabral, transverse ribs on the swollen body, and spiral sculpture is infrequently well developed. The aperture is elongate with an acute angle at its posterior end. The siphonal canal is slightly curved and is inclined to the left. The columella generally bears three oblique folds. The type species is *Paleopsephaea mutabilis* Wade, 1926, from Coon Creek, Tennessee (Sohl, 1964a, pl. 28, fig.1-6). Perrilliat et al. (2000) also recognized this species occurring in the Mexcala Formation of southern Mexico.

*Paleopsephaea* differs from *Drilluta* in lacking a strong and wide subsutural collar. *Bellifusus* is shorter and has more rounded whorls. The subsutural ramp of *Paleopsephaea* is less distinct than that in *Drilluta* and *Pholidotoma*. In this regard, *Paleopsephaea* is intermediate to the Amuletinae n. subfam.

A protoconch that could well belong to *P. mutabilis* is smooth with a blunt apex and is somewhat egg-shaped with 3 whorls and an embryonic whorl of 0.22 mm in width. The protoconch is 0.8 mm wide; the visible height is 0.7 mm, and the whole larval shell is about 0.9 mm in height. The rounded whorls of the larval shell are sculptured only by growth lines, which reflect a rounded projection of the

anterior outer lip of the aperture. The transition into the teleoconch is gradual, and one or two axial collabral ribs appear in the last portion of the larval shell; the beginning of the teleoconch is indicated by the onset of faint spiral lirae and the less-curving course of the axial ribs. The protoconch shape resembles that of *Morea*.

150. *Paleopsephaea mutabilis* Wade, 1926\*

151. *Paleopsephaea pergracilis* Wade, 1926\*

152. *Paleopsephaea tenuilirata* Sohl, 1964a

*Paleopsephaea latisepta* (Stoliczka, 1868) from southern India (Bandel, 2000b, fig. 44, 45) is very similar to the Gulf Coast *P. mutabilis* (Sohl, 1964a, pl. 28, fig. 1-6) regarding shell shape, size, ornament, features of the siphonal canal, and the columellar lip. The American species also has only faint traces of spiral ornament and three oblique columellar folds. *P. mutabilis* is slightly more slender.

#### Subfamily Beretrinae n. subfam.

The fusiform shell with elongate siphonal canal has a spire composing almost half the shell height. The posterior corner of the aperture forms a deep notch that gives rise to a well-developed subsutural ribbon. The ornament consists of collabral ribs crossed by finer spiral ribs. The inner lip is smooth. The protoconch is conical in shape and consists of several smooth whorls and has a low-lying apertural projection in its larval whorls. The subfamily contains the genera *Beretra* and *Fusimilis*.

Regarding the shape of the teleoconch, there appears to be a transition to the Amuletinae, which shares a fusiform shell shape and elongate siphon. The difference lies in the absence of a strong subsutural ribbon connected to an apertural notch as found in the Beretrinae, while the Amuletinae have a low sinus or a sinus that lies in a more anterior position on the outer lip.

#### Genus *Beretra* Stephenson, 1941

The fusiform shell has a high spire of a little less than half shell height. Ornament includes a strong subsutural collar, axial ribs, and closely spaced spirals. The elongate aperture ends in a very elongate siphon and is notched at its posterior end. The type species is *Beretra firma* Stephenson, 1941, from the Maastrichtian Navarro Group of Texas. According to Stephenson (1941), the straight-sided whorls have weak spiral sculpture, however, *Beretra ripleyana* (Sohl, 1964a, pl. 46, fig. 19-21) of the Owl Creek Formation and *Beretra gracilis* (Sohl, 1964a, pl. 46, fig. 15-18) have quite well developed spirals. The same holds true for *Beretra speciosa* (Sohl, 1964a, pl. 46, fig. 22, 23). A strong subsutural collar distinguishes *Beretra* from *Amuletum*, *Remnita* and *Gemmula*. It is similar to *Fusimilis* in the position of the posterior sinus on the shoulder of the outer lip.

153. *Beretra gracilis* (Wade, 1926)\*

154. *Beretra speciosa* Sohl, 1964a\*

According to Kiel (2001), *Beretra* differs little from *Pyrifusus* (*Koenenia*), and he noted a *Beretra ornatula* Stephenson, 1941, from the Maastrichtian of Temalac, Mexico. Here the subsutural constriction forms a broad collar, and the whorls are shouldered and bear numerous axial ribs crossed by five spiral cords.

#### Genus *Fusimilis* Stephenson, 1941

The fusiform shell has a spire less high than half of the shell height and has a very long siphon. The whorls have a strong subsutural ribbon that lies behind a notch on the posterior end of the outer lip. This lip has a sinus near the shoulder. The inner lip is smooth. The type species is *Fusimilis robustus* Stephenson, 1941, from Texas. *Fusimilis* is less slender than *Beretra* and has the sinus located in a more anterior position on the outer lip as indicated by the growth lines. Otherwise both genera are very close to each other.

155. *Fusimilis proxima* (Wade, 1926)\*

156. *Fusimilis kummeli* Sohl, 1964a

*F. proxima* is more slender (Sohl, 1964a, pl. 46, fig. 26, 27, 34, 35) than *F. kummeli* (Sohl, 1964a, pl. 46, fig. 29, 30, 32, 33, 39, 40). The later is a bit smaller and has finer ornament, but both species can easily be confused.

157. *Fusinus?* *macnairyensis* (Wade, 1926)\*

This species is intermediate in shell shape between *Drilluta* and *Fusimilis* in having a long curved siphonal canal and a relatively long spire (Sohl, 1964a, pl. 31, fig. 24-26). It also looks like an elongate species of *Bellifusus* and could be placed in either of these genera or receive a new generic name. The three genera mentioned above probably have a common ancestor, as all share a similar ornament and a strong subsutural ribbon connected to a posterior notch in the apertural lip.

#### Genus *Woodsella* Wade, 1926

158. *Woodsella typical* Wade, 1926

This species resembles *Boltenella excellens* and could be placed near *Profusinus* among the Cassoidea (see above).

#### Subfamily Volutoderminae Pilsbry and Olson, 1954

According to Sohl (1964a), the *Voluta*-shaped, more or less elongate, fusiform shell has a more or less high spire. The whorls are constricted in the posterior direction and

may be shouldered. Ornament consists of spiral cords and strong transverse ribs. The aperture is elongate and narrow with a posterior notch and a long broad siphonal canal. Three columellar folds are usually present on the inner lip, but some species have more and others have none. The protoconch consists of several whorls.

The Volutoderminae as interpreted by Sohl (1964a) are fusiform in shape and hold the genera *Gosavia* Stoliczka, 1865, *Volutoderma* Gabb, 1877, *Ficulopsis* Stoliczka, 1867, *Volutomorpha* Gabb, 1877, *Liopeplum* Dall, 1890, and *Myobarum* Sohl, 1964a.

**Genus *Volutoderma* Gabb, 1877**  
**Subgenus *Volutoderma (Longoconcha)***  
**Stephenson, 1941**

The elongate, slim, almost cylindrical shell has an evenly tapering spire of one-third to one-fifth the total shell length. The body whorl is elongate, almost flat-sided with a subsutural constriction ornamented by strongly raised, imbricated, growth lines. The sculpture is dominated by widely spaced spiral cords and intersecting growth lines, which trace the position of a posterior sinus. The aperture is elongate with a posterior channel, is anteriorly expanded, and has a gradually narrowing siphonal canal. The posterior notch gives rise to a scaly subsutural ribbon accompanied by a deep subsutural groove in the case of *V. (L.) imbricata*. The outer lip is wavy and the inner lip is covered by callus that is expanded onto the body. The columella bears three or more strong folds. The type species is *Volutoderma tennesseensis* Wade, 1926, from Coon Creek, Tennessee (Sohl, 1964a, pl. 36, fig. 17, 21, pl. 37, fig. 21, 22).

The protoconch consists of at least 3 smooth whorls forming a cone, and it is differentiated from the ribbed whorls of the teleoconch. The first teleoconch whorls are about as high as they are wide and are ornamented by about 8 inclined axial ribs, which are crossed over by 4-6 narrow spiral ribbons in case of *V. (L.) imbricata* from Coffee Sand.

*Volutoderma (Longoconcha)* is a slender *Volutomorpha* with a callus glaze on the inner lip. *V. (Longoconcha)* differs from *Volutoderma* s.s. in having a more slender body and spire, in having more flattened flanks, and by an aperture that flares more anteriorly. With exception of the early stages of growth, transverse ribs are almost absent; the spiral cords are not granulated; and there is a corrugated subsutural collar and a heavy inner lip callus, which is not found in *Volutoderma*. *Volutoderma (Volutoderma) kulakulnattamia* Bandel, 2000, from the Indian Trichinopoly Group of Santonian- Early Campanian age is an intermediate form between *Gosavia* with a shorter shell and *Volutoderma (Longoconcha)* as is found in the American Gulf Coast fauna of the Late Campanian and Maastrichtian.

159. *Volutoderma (Longoconcha) tennesseensis* (Wade, 1926)\*

160. *Volutoderma (Longoconcha) quadrilirata* Sohl, 1964a

**Genus *Volutomorpha* Gabb, 1877**

The large elongate somewhat fusiform shell has a low to moderately low spire and a surface glazed by callus, which also covers the ornament and sutures. The whorls are constricted on their posterior side and may be shouldered. The ornament consists of spiral cords and strong transverse ribs that are suppressed in the last whorls. The aperture is elongate and narrow with a deep posterior notch and a broad anterior siphonal canal. The type species is *Volutilithes conradi* Gabb, 1860, from the Upper Cretaceous of New Jersey. Perrilliat et al. (2000) recognized *Volutomorpha* cf. *retifera* Dall, 1907, occurring in the Mexcala Formation of southern Mexico.

Juvenile stages of *Volutomorpha* are similar to *Pyrifusus*, but, in later more fully-grown stages, the last whorl is comparatively larger. A related genus is *Volutoderma (Volutoderma)* where axial ornament is only weakly developed, and the whorls have no shoulders. Also, the shell is not fully glazed, and the columellar folds number three or more. In *Volutomorpha*, the shell is coated by callus, whorls are shouldered, axial sculpture is dominant over spiral elements, and there is only one major fold present on the columella. *Volutoderma (Longoconcha)* is much slimmer, lacks surface glaze, and possesses three or more oblique columellar folds. *Liopeplum* is more slender and much more coated on the exterior surface.

According to Sohl (1964a), of all the species from the Ripley Formation, only parts of the protoconch of *Volutomorpha producta* Sohl, 1964a, were known and were described as smooth and erect. Sohl (1964a, pl. 38-42) described the following species from the Coon Creek Formation:

161. *Volutomorpha valida* Sohl, 1964a

162. *Volutomorpha dumasensis* Dall, 1907

163. *Volutomorpha mutabilis* Wade, 1926\*

164. *Volutomorpha gigantea* Wade, 1926\*

165. *Volutomorpha retifera* Dall, 1907

166. "*Volutomorpha*" *aspera* Dall, 1907\*

**Genus *Liopeplum* Dall, 1890**

The strombiform shell has a spire that is shorter than the body whorl and that is covered by smooth callus, which envelops the axial ribs of the early teleoconch and the sutures. The ornament of axial ribs is generally restricted to the early whorls. The outer lip forms a narrow and indistinct posterior notch and a low median lobe. The



anterior aperture extends to form a deep siphonal canal. The columella has several folds in differing numbers. The type species is *Volutilithes (Athleta) leioderma* Conrad, 1860, from the Ripley Formation in Tennessee (Sohl, 1964a, pl. 43, fig.1, 2, 6, 7).

With its elegant strombiform and glazed shells, *Liopeplum* is a conspicuous element of Late Cretaceous gastropod faunas. Sohl (1964a) wrote that *Liopeplum* is restricted to the Gulf Coast deposits of the Upper Cretaceous of the USA. This may have influenced, Saul and Popenoe (1993) to name a new genus *Varens* to encompass *Liopeplum*-like species from the Turonian of California. Kiel (2001) noted that the diagnosis of *Varens* also fits that of *Liopeplum* in almost all details, and, thus, considered *Varens* to be a synonym of *Liopeplum*. In a subsequent discussion with one of the authors (Saul), Kiel (personal communication) was convinced that several characters do allow the two genera to be distinguished. The protoconch of the type species of *Liopeplum* from the Ripley Formation is of the pyriform type and rests on a sculptured teleoconch, which is not coated with callus in juvenile stages. The first teleoconch whorl has about 12-15 axial ribs and few spiral ribbons, which are later coated over by callus glaze.

167. *Liopeplum leioderma* (Conrad, 1860)\*

168. *Liopeplum coronatum* Sohl, 1964a\*

169. *Liopeplum nodosum* Sohl, 1964a

Sohl (1964a, pl. 43, fig.1-25) illustrated the species from Coon Creek along with the similar *Liopeplum cretaceum* (Conrad, 1858) and *L. canalis* (Conrad, 1858) from the Owl Creek Formation. Perrilliat et al. (2000) reported *Liopeplum* cf. *cretaceum* (Conrad, 1858) to occur in the Mexcala Formation of southern Mexico.

### Genus *Myobarum* Sohl, 1963

According to Sohl (1964a), the small (about 2 cm high) oliviform shell has a spire about one third of the total shell height and has a smooth glaze over the surface that obscures the sutures. The aperture is elongate and has a broad posterior notch as is present in *Liopeplum*. The anterior end has a shallow siphonal canal. The columellar lip has two strong folds. The blunt protoconch consists of about two round-sided whorls and is obscured by callus coating. The type species is *Myobarum laevigatum* Sohl, 1963 (Sohl, 1964a, pl. 44, fig.15-17). *Myobarum* sp. from Coffee Sand of Mississippi represents a stout type of *Liopeplum* with two columellar folds.

170. *Myobarum laevigatum* Sohl, 1963

This species somewhat resembles the species of *Parafusus* in its olive-shell-like shape and largely callus-covered shell. Sohl (1964a) differentiated *Myobarum* from *Parafusus* of the same locality by its smaller size, its less

developed siphonal groove, and the presence of a strong fold bordering the siphonal canal at the base of the columella.

### Subfamily Pyropsinae Stephenson, 1941

The fusiform shell has peripherally-swollen whorls and a low spire with a broad subsutural collar or inclined ramp. These characteristics are found in the common genus *Pyropsis*. Some genera have almost flat-spined shells. Below the carinate and spine-bearing shoulder, the body is more or less roundly constricted to the siphonal canal. The spiral ornament of ribbons or strong cords is developed below the carination. Axial ornament consists of rounded ribs or straight ridges and may become obsolete. The aperture is notched at its posterior end and narrows anteriorly to form a well-developed siphonal canal that may be straight or inclined to the left. The columellar lip commonly begins with a swelling and is otherwise smooth or bears oblique folds. The early ontogenetic shell is low-coiled and consists of rounded smooth whorls. The protoconch is not high and pointed as in the Pyriformidae but low and rounded like that of *Lowenstamia* and *Weeksia*. The Pyropsinae includes the genera *Pyropsis*, *Trochifusus*, *Napulus*, *Lupira* and *Hydrotribulus*.

### Genus *Pyropsis* Conrad, 1860

Plate 2, figure 8

The medium to large-size subpyriform shell has a low to very low spire, peripherally expanded whorls that are shouldered, and is strongly constricted in the anterior direction. The dominant ornamentation consists of granular or spiny spiral cords. The aperture is thickened on the inside, with the inner lip covered by a thick callus, and has a long tapering siphonal canal. The inner lip is simple and smooth except for a broad, weak to strong swelling above the siphonal canal. The type species is *Pyropsis perlata* (Conrad, 1860) from the Ripley Formation.

The sculpture of *Pyropsis* is not as strong as that of *Napulus*. *Lupira* differs in having columellar folds, and *Hydrotribulus* has a tubercle-like callus pad on the upper portion of the inner lip.

The protoconch of *Pyropsis perlata* from Coon Creek consists of two smooth round-topped whorls, which are slightly inclined to the axis of the teleoconch like those of *Weeksia*. The first whorls of the teleoconch are stair like and are quite low-coiled in the case of *P. cornutus* from the Coon Creek Formation in Union County, Mississippi. The protoconch of *Pyropsis cornutus* Sohl, 1964a, has 1.5 to 2 round-topped whorls. The beginning of the teleoconch is indicated by a flattened upper whorl surface and by the addition of a single spiral cord (Sohl, 1964a, pl. 34, fig. 7, 9, 10). According to Sohl (1964, pl. 33, fig.19, 21), *Pyropsis spinosus* (Wade, 1926) has a protoconch with about two

round-topped whorls, which are elevated above the plane of the teleoconch whorls, as is the case with *Pyropsis prolixa* (Sohl, 1964a, pl. 33, fig. 12, 13, 17) of the Owl Creek Formation.

- 171. *Pyropsis perlata* Conrad, 1860\*
- 172. *Pyropsis proxima* Wade, 1926\*
- 173. *Pyropsis cornutus* Sohl, 1964a
- 174. *Pyropsis spinosus* (Wade, 1926)\*
- 175. *Pyropsis interstriatus* (Wade, 1926)\*
- 176. *Pyropsis perornatus* (Wade, 1926)\*
- 177. *Pyropsis imperfecta* (Wade, 1926)\*

The Indian species *Pyropsis nodifera* (Stoliczka, 1868) from the Trichinopoly Formation closely resembles juvenile shells of *Trochifusus perornatus* (Sohl, 1964a, pl. 34, fig. 2-4, 11, 13). *Pyropsis cancellata* (Stoliczka, 1868) from Siranattam and Garudamangalam (Tamil Nadu) has a shape that is very close to that of *Pyropsis proxima* Wade and *P. perlata* Conrad (Sohl, 1964a, pl. 33, fig. 1, 7, 8, 10, 11, 16, 18, 20, 22), but its rectangular ornament resembles that of *Napulus* (Bandel, 2000b).

Sohl (1964a, p. 239-240) placed *Trochifusus perornatus* Wade, 1926, in the genus *Pyropsis*. The large shell of this species has an almost flat apical spiral and an inflated last whorl, which is characteristically thickened and drawn up to form a varix. The teleoconch consists of 4 to 5 whorls and has a low spire, rounded shoulders, and a rounded periphery. The whorls are inflated peripherally and constricted anteriorly. The ornament consists of strong nodular spiral cords, which later develop into spines. The protoconch is erect and has rounded whorls, which differ from the flat-sided and rapidly expanding whorls of the teleoconch. The aperture has a strong curving posterior canal and an inclined siphonal canal. The outer lip is thick, and the inner lip forms a thick callus that is detached from the columella and flexed as a swelling, leaving an umbilical fissure. The last whorl in the fully-grown shell expands forming a varix.

*Trichotropis imperfecta* Wade, 1926 (see Sohl, 1960, pl. 10, fig. 29, 33) is close to other species identified as *Trochifusus*, a taxon placed here as a synonym of *Pyropsis*. The shell has a low spire, channeled sutures, and a large and much expanded body that is roughly bicarinate at the periphery. It is ornamented by coarse spiral ribbons, which are crossed by coarse growth lamellae. Like *Pyropsis perornatus*, it has a narrow umbilical slit formed by the thick upturned callus of the inner lip. This species is probably close to *Trochifusus africanus* (Woods, 1906) from the Umzamba Formation (Santonian) of South Africa and to *Trochifusus hombroniana* (Orbigny, 1846) as described by Bandel and Stinnesbeck (2000, pl. 2, fig. G, H) from the Quiriquina Formation (Maastrichtian) of Chile.

### Genus *Lupira* Stephenson, 1941

The pyriform shell has a moderately low spire, and the pleural angle increases greatly with increased size. The body is inflated peripherally and rapidly constricted anteriorly to form a moderately curved siphonal canal; the later whorls are excavated below the suture. The ornament consists of strong peripheral ribs and coarse spiral cords. The aperture is notched at its posterior end; the outer lip is crenulated; the inner lip is callused; and the parietal lip bears two to four folds. The type species is *Xancus variabilis* Wade, 1926, from Coon Creek, Tennessee (Sohl, 1964a, pl. 32, fig. 14-16, 24, 25).

In general features the shell resembles that of *Pyrifusus*, but is broader, and the spire is shorter. With a more flattened flank, *Lupira* would resemble *Pyropsis*; the main difference between the genera is the presence of columellar folds in *Lupira*. *Lupira disparita* from Mississippi has a high and slender protoconch, which rests on the rather slender whorls of the juvenile teleoconch with 6 axial ribs as ornament. The early ontogenetic whorls are, thus, very close to those of the Pyrifusidae. Sohl (1964a, pl. 32, fig. 10, 11, 13, 19, 20) also described the protoconch of *Lupira pyriformis* and found it to consist of more than 1.5 smooth rounded whorls with a gradual junction to the teleoconch.

- 178. *Lupira variabilis* (Wade, 1926)\*
- 179. *Lupira pyriformis* Stephenson, 1941
- 180. *Lupira turbinata* Sohl, 1964a\*

### Genus *Napulus* Stephenson, 1941

The medium-size, low-spined, pyriform shell has a moderately long, slightly curved siphonal canal, comprising about one third the total shell length. The body whorl is well rounded, inflated, shouldered to weakly shouldered, strongly constricted below and marked by nearly evenly and widely-spaced strong spiral cords or ribbons crossed by lower transverse ribs. The columella is smooth and nearly straight with a small swelling at the upper end of the siphonal canal. The protoconch is elevated. According to Stephenson (1941), *Napulus whitfieldi* (Weller, 1907) is the type species, while Sohl (1964a) selected *Napulus reesidei* Sohl, 1964a, from Coon Creek, Tennessee, because of better preservation.

The spire and the shape of the long siphonal canal indicate that *Napulus* is related to *Pyropsis* (Sohl, 1964a). *Praesargana* differs by having a columellar swelling along with ridges forming a pseudo-umbilicus, which are found in neither *Napulus* nor *Pyropsis*. All these genera may have species with rather similar shell shape and ornament of crossing ribs. Sohl (1964a, pl. 35, fig. 16-20, 24) described the protoconch of *Napulus reesidei* as consisting of about 1.5 smooth, well-rounded whorls, which grade gradually into the teleoconch. In *Napulus fragilis*, the protoconch

has two tightly coiled and well-rounded whorls, which also grade gradually to the teleoconch but are distinguished by the presence of two spiral cords. In *Napulus octoliratus* (Conrad, 1858) from the Owl Creek Formation, a similar protoconch of two low well-rounded whorls grades into the teleoconch as three spiral cords appear on the rounded whorl sides (Sohl, 1964a, pl. 35, fig. 7, 14).

181. *Napulus reasidei* Sohl, 1964a\*

182. *Napulus fragilis* Sohl, 1964a

The Indian species *Napulus excavatus* Stoliczka, 1868 from the Trichinopoly Formation is intermediate in shape between *Morea* and American Gulf Coast species of *Napulus* in regard to ornament and the shape of the aperture (Bandel, 2000b, fig. 55, 56). It differs from *Morea* in lacking a twisted columella. *Napulus fragilis* from Mississippi (Sohl, 1964a, pl. 35, fig. 12, 21-23) closely resembles *Napulus tuberculatus* Stephenson, 1941, from Texas, and both closely resemble *N. excavatus*. *Napulus reasidei* from the Ripley Formation (Sohl, 1964a, pl. 35, fig. 16-20, 24) is another similar species, which differs in being somewhat larger and a little more slender than *N. excavatus*. With the exception of the columellar fasciole, *Napulus excavatus* also closely resembles *Morea marylandica* of the Moreidae, indicating a possible relation. The similarity of *Napulus excavatus* from the Santonian-Campanian of Tamil Nadu with the stratigraphically younger *Napulus reasidei* from the Maastrichtian of the American Gulf Coast indicates a connection between these widely separated faunas (Bandel, 2000b).

### Genus *Hydrotribulus* Wade, 1916

The medium-size ovoid shell has an acute apex and base and shouldered whorls, which are constricted posteriorly to form a collar and are medially inflated. The ornament consists of strong, widely spaced, spiral cords, which override the transverse ribs of the periphery and basal slope. The aperture is almost oval in outline and notched at its posterior end. The siphonal canal is curved and narrow. The outer lip is crenulate and denticulate where it meets the siphonal canal. Also the inner lip has a tooth. Above the siphonal canal, the columellar lip has a strong ridge. According to Sohl (1964a, pl. 36, fig. 13-16, 18), the protoconch of *Hydrotribulus elegans* consists of about two regular smooth-surfaced whorls, having a gradual junction with the teleoconch and the addition of spiral cords to the whorl sides. The type species is *Hydrotribulus nodosus* Wade, 1916, from Coon Creek, Tennessee.

The tooth below the posterior notch on the inner lip differentiates *Hydrotribulus* from *Pyropsis*, while the columellar swelling is very similar in both. The sculpture of *Hydrotribulus* is closer to that of *Napulus*, but the latter has usually a straight siphonal canal. In general, the shell shape of *Lupira* resembles *Hydrotribulus*, which differs in

its denticulate lips and in the siphonal canal's twist to the left.

183. *Hydrotribulus nodosus* Wade, 1916\*

184. *Hydrotribulus elegans* Sohl, 1964a

### Genus *Hercorhyncus* Conrad, 1868

The fusiform shell has a spire a little less than one-third of the total shell height. Whorls are peripherally swollen, constricted above a tuberculated shoulder that is of variable strength, and rather strongly constricted below the sinus on the base of the body whorl. Ornament consists of coarse transverse ribs that are strongest at the shoulder but that die out below on the periphery and on the collar above. Spiral ornament is weak on the collar and strong below. The aperture has a posterior notch and a narrow, elongate, anterior, siphonal canal. The outer lip is crenulate, and the inner lip is heavily callused with an umbilical chink developing opposite the beginning of the siphonal canal. The type species is *Fusus tippiana* Conrad, 1860, from the Ripley Formation Mississippi (Sohl, 1964a, pl. 30, fig. 8-10, 13-16).

*Hercorhyncus* is transitional in shape between members of the Pyrifusinae on one side and those of the Pyropsinae on the other. With the broad subsutural ramp and angular shape of the flank, it closely resembles *Rhombopsis* and, in the general shape, the more rounded species of *Pyropsis*. *Buccinopsis* is similar but is distinguished from *Hercorhyncus* in having a less apparent constriction on the lower whorl flank and a shorter siphon. The shell shape of *Hercorhyncus* is very similar to that of *Pseudorapa*, but the constriction on the lower whorl flank differs, being angular in *Hercorhyncus* and rounded in *Pseudorapa*. *Hercorhyncus* is transitional between *Hydrotribulus* of the Pyropsinae on one side and *Pseudorapa* of the Pseudorapinae on the other, differing from the latter mainly in its straight siphon. Also *Protobusyon* resembles *Hercorhyncus tennesseensis* (Sohl, 1964a, pl. 30, fig. 11, 12) with less axial ornament and a thicker and straighter siphon.

185. *Hercorhyncus (Hercorhyncus) tippianus* Conrad, 1860

186. *Hercorhyncus (Hercorhyncus) tennesseensis*  
(Wade, 1926)\*

### Subgenus *Hercorhyncus (Haplovoluta)*

Wade, 1918

The subgenus differs from *H. (Hercorhyncus)* in having more pronounced axial ribs and lower nodes on the shoulders (Sohl, 1964a, pl. 30, fig. 17-21, 23-26).

187. *Hercorhyncus (Haplovoluta) bicarinatus* (Wade, 1917b)\*



188. *Hercorhyncus (Haplovoluta) triliratus* Sohl, 1964a

### Family Pseudolividae Fischer, 1884

The ovate to fusiform shells are usually spirally sculptured and have a groove on the basal half of the last whorl. The last whorl comprises more than 60% of the total shell height. Vermeij (1998) considered the spiral groove on the lower part of the last whorl the most characteristic feature of the Pseudolividae; he named *Sulcobuccinum* D'ORBIGNY, 1850, as the only Cretaceous pseudolivid. The following genera and species are placed here due mainly to their *Oliva*-like shape; these taxonomic placements may change once more detail is known.

### Genus *Ptychosyca* Gabb, 1877

The medium-size pyruliform shell (up to 4 cm high and 2.5 cm wide) has a smooth surface that is almost completely devoid of ornament and a double groove on the basal part of the body whorl that is divided by a raised median band. The siphonal notch is rather broad and deep, and the columella is straight. The type species is *Ptychosyca inornata* Gabb, 1876, from the Ripley Formation (Sohl, 1964a, pl. 35, fig.1-6).

189. *Ptychosyca inornata* Gabb, 1876\*

*Ptychosyca inornata* differs from *Volutomorpha* in shape and ornament as well as in its fasciolar characters. It also lacks columellar folds. According to Sohl (1964a), the fasciolar characters, as well as the basal grooves, connect *Ptychosyca* with the modern Pseudolivinae. Columellar folds are present in *Ptychoris* Gabb, 1877, which has an elongate oval shell with a pointed spire, the last whorl embracing more than two-thirds of the previous whorls and leaving only a short spire visible. The young teleoconch is spirally grooved. The mature shell is coated with enamel. The aperture is enlarged and ovate and has a thickened posterior margin, especially where it unites with the outer lip to form a narrow posterior notch. The siphonal canal is well developed, and the columella has three outer and two inner folds. The type species is *Voluta purpuriformis* Forbes, 1846, from the Trichinopoly Group in India.

### Genus *Eoancilla* Stephenson, 1941

The subcylindrical oliviform shells may be up to 13 mm high and 7 mm wide. The proportionally high spire is about one third of the shell height and is covered by a callus glaze, which hides the sutures. A broad median band, which lacks callus glaze, lies below the mid-height. The siphonal notch is broad and deep, and the callus on the inner lip is thick, ascending to the spire. The protoconch consists of a few rounded whorls. The type species is *Eoancilla acutula* Stephenson, 1941, from the

Owl Creek Formation (Sohl, 1964a, pl. 36, fig.1-7, 10).

The glazed-over oliviform *Eoancilla* differs from *Ptychosyca* in its more slender shape. According to Sohl (1964a), the Cretaceous *Eoancilla* can be placed in the modern genus *Ancilla* Lamarck, 1799, subgenus *Ancillus* Montfort, 1810. The other glaze-covered genera from the Cretaceous lack the double groove on the basal part of the body whorl.

### Genus *Fulgerca* Stephenson, 1941

According to Sohl (1964a, pl. 36, fig. 8, 12), the small fusiform shells have blunt spires of more than half the total shell length and have an ornament of intersecting fine spiral and axial cords. A fasciolar band is present low on the base, relating it to the pseudolivids, and the aperture is elongate with a broad, open, siphonal canal and a short notch. The shell is similar to that of *Ancilla*. The protoconch consists of 3.5 rapidly increasing whorls. The type species is *Fulgerca venusta* Stephenson, 1941.

The ornament distinguishes *Fulgerca* from *Eoancilla*, as *Fulgerca* is not callus covered. The typespecies has a smooth trochiform protoconch.

190. *Fulgerca attenuata* (Wade, 1926)

### Genus *Parafusus* Wade, 1918

According to Sohl (1964a, pl. 44, fig. 22, 23, 26), the large ovoid shell is as high as 9 cm and about 6 cm wide and has an evenly tapering spire that makes up one third of the total height. The whorls are rounded, unornamented, and glazed by callus. The growth lines show a sinus near the suture and are curved below. The broad aperture has a posterior notch and has a broad siphonal notch. Its columella carries one or two folds. The type species is *Hyllus callilateris* Wade, 1917b (= *Wadia* Cossmann, 1920) from Coon Creek, which has a weak indication of a low groove around the siphon (Sohl, 1964a, pl. 44, fig. 22, 23, 26). The posterior notch of the aperture indicates a possible relationship with Volutoderminae genera like *Longoconcha*. *Parafusus* could be related to *Liopeplum*; *Liopeplum creatceum* (Conrad, 1858) (Sohl, 1964a, pl. 43, fig. 3, 21, 22, 24, 25) is just a bit more slender but otherwise very similar to *Parafusus callilateris*.

191. *Parafusus coloratus* Wade, 1917b\*

192. *Parafusus callilateris* Wade, 1917b\*

### Genus *Mataxa* Wade, 1916

According to Sohl (1964a, pl. 45, fig. 20-27), the shell is about 2 cm high and has a rounded body whorl and an ornament of spiral lirae. The siphonal canal is twisted, short, and inclined to the left. It is narrow near the end

of the body whorl with a groove that could be interpreted to be pseudolivid. The protoconch is flattened in its apical portion, has four rounded whorls, and has a low larval hook on the anterior portion of the outer lip. Early whorls of the teleoconch are spirally ridged, later the shell is smooth and callus-coated on the outside. The inner lip of the aperture has two folds and several teeth on the columella. The type species is *Metaxa elegans* Wade, 1916, from Ripley Formation.

193. *Metaxa elegans* Wade, 1916\*

### Subfamily Cryptoconinae Wenz, 1938

The spindle-shaped or biconical shells are ornamented mainly by spiral ribs and may or may not have axial ornament. They differ from the Conidae in that the interior shell walls are not thinned by dissolution or are only weakly thinned. The taxon is based on the genus *Cryptoconus*.

The validity of the use here of the taxon Cryptoconinae depends on the relationship of *Cryptoconus* with species from Coon Creek. The placement of *Tectaplica* in this subfamily is also uncertain; its relation to *C. macnairyensis* is based here only on similarities of general shell shape.

### Genus *Cryptoconus* Koenen, 1867

The biconical shell has a spire of about half of the shell height, has flattened sides, and has an ornament of spiral lirae. The growth lines have a sinus below the suture. The aperture is narrow and simple. The type species is *Pleurotoma filosa* Lamarck, 1804, from the Eocene of Europe. A comparably small neogastropod was described as *Cryptoconus macnairyensis* (Wade, 1917b) from the Ripley Formation and is characterized by angular whorls and a smooth columella (Sohl, 1964a, pl. 47, fig. 6-9). There is no groove on the flank of the siphonal pillar.

194. *Cryptoconus macnairyensis* (Wade, 1917b)\*

Kiel (2001, pl. 30, fig.15-17) noted a similar species from the Maastrichtian of Temalac, Mexico, but it differed in lacking sinuous growth lines as are characteristic for *Cryptoconus*. In the Mexican species, the embryonic portion of the protoconch measured about 0.1 mm across; the larval shell was smooth and made of 2.5-3.0 whorls and was 0.6 mm wide and 0.5 mm high. The teleoconch was sculptured with a cancellate pattern of equally strong axial and spiral ribs, while in *C. macnairyensis* spiral ribs dominate.

### Genus *Tectaplica* Wade, 1916

The *Voluta*-form small shell has a short conical spire and a flattened basal flank. Strong axial ribs and close-spaced spiral lirae form the ornament. The aperture is elongate, ending in a short siphonal canal. The inner and outer lips

are smooth, but the columella bears three low folds, which are only visible in the interior of the shell (Sohl, 1964a, pl. 44, fig. 19-21). This genus is not well known and resembles a little *Cryptoconus* in shell shape.

195. *Tectaplica simplica* Wade, 1916\*

### Suborder Toxoglossa Troschel, 1847?

#### Family Turridae Swainson, 1840?

Turrid shells are slender, high-spined to bi-conical, and their growth lines show a well-developed subsutural or marginal posterior sinus. The radulae of many Turridae have been modified to form a poisonous dart, which is used to paralyze prey. Commonly the protoconch of modern turrids is highly ornamented, but there are also smooth ones. No protoconchs of the modern turrid type are known from the Coon Creek fauna, and therefore the placement of the following genera in the Turridae is in doubt.

#### Subfamily Amuletinae n. subfam.

The slender turritiform shell has a spire of about half of shell height and a long narrow siphon. The large smooth conical protoconch consists of several whorls and has a projection on the lower portion of the outer lip. The teleoconch has a wide subsutural or median sinus on the outer lip of the elongate aperture. The inner lip is smooth, and shell ornament consists of straight axial ribs and spiral ribs in variable arrangement. *Amuletum*, *Remnita*, and *Gemmula* represent species from the Ripley Formation, which resemble modern Toxoglossa species of the subfamily Turrinae as interpreted by Wenz (1938). The teleoconch of the *Amuletum* closely resembles that of a *Crassispira* Swainson, 1940, from the modern sea, but the protoconch is like that found in the Pyrifusidae. Shell shape also connects this subfamily to *Remera* and *Graphidula*.

*Beretra* and *Fusimilis*, in contrast, have a shell shape resembling that of the *Amuletum* group but have a subsutural furrow as result of the formation of an anterior apertural notch like that found in *Drilluta*, *Bellifusus*, and *Pyrifusus*.

#### Genus *Amuletum* Stephenson, 1941

Plate 2, figures 10-11; Plate 3, figure 4

The slender shell has a spire comprising about half the shell height and has a large smooth protoconch consisting of 3-4 whorls. The siphonal canal is elongate, and there is a subsutural groove and a subsutural shallow sinus on the outer lip of the elongated aperture. The inner lip is smooth, and shell ornament differs among the species of this genus. The type species is *Turricula macnairyensis* Wade, 1926 (Sohl, 1964a, pl. 45, fig.1-5).

### Subgenus *Amuletum* (*Amuletum*) Stephenson, 1941

Spiral ornamental elements are dominant on the late whorls of this subgenus.

196. *Amuletum* (*Amuletum*) *macnairyensis macnairyensis* (Wade, 1926)\*
197. *Amuletum* (*Amuletum*) *macnairyensis torquatum* Sohl, 1964a
198. *Amuletum* (*Amuletum*) *dumasensis* Sohl, 1964a
199. *Amuletum* (*Amuletum*) *wadei* Harbison, 1945
200. *Amuletum* (*Amuletum*) *fasciolatum* (Wade, 1926)\*

### Subgenus *Amuletum* (*Lutema*) Stephenson, 1941

The ornament of the late whorls of the teleoconch distinguishes this subgenus. Here both spiral and axial sculptural elements are present. The type species is *Lutema simpsonensis* Stephenson, 1941. The more prominent axial ornament of *A. (Lutema) limbatum* creates the impression of gradating into the species of *Remnita*, which have such ornament throughout (Sohl, 1964a, pl. 46, fig. 4-6).

201. *Amuletum* (*Lutema*) *limbatum* Sohl, 1964a
202. *Amuletum* (*Lutema*) sp.

### Genus *Remnita* Stephenson, 1941

As noted by Sohl (1964a, pl.46, fig. 7-11), *Remnita* is closely related to *Amuletum* but has an initial teleoconch ornament of spiral rather than axial elements, and the spiral elements dominate throughout shell growth. The type species is *Turricula biacuminata* Wade, 1926 (Sohl, 1964a, pl. 46, fig. 7, 8).

203. *Remnita biacuminata* (Wade, 1926)\*
204. *Remnita anomalocostata* (Wade, 1926)\*

### Genus *Gemmula* Weinkauff, 1875

*Gemmula cretacea* Sohl, 1964a, of the Owl Creek Formation, is very similar to *Amuletum* and somewhat resembles *Amuletum* (*A.*) *fasciolatum* regarding ornament (see Sohl, 1964a, pl. 46, fig.12-14), but the sinus of the outer lip lies lower so that growth lines have the sinus on the shoulder and not right below the suture. The type species is *Gemmula gemmata* Hinds, 1843, a living species

### Genus *Remera* Stephenson, 1941

The fusiform shell has a spire comprising more than half of the shell height. The whorls are flattened and ornamented by stronger axial ribs and finer spiral ribs. The aperture is angular at its posterior end and continues anteriorly into a moderately long siphon. The type species is *Remera microstriata* Stephenson, 1941 (Sohl, 1964a, pl. 31, fig.16). *Graphidula* is very similar in shell shape but has columellar folds on its inner lip. *Amuletum* has a relatively shorter spire and more elongate siphon, but is otherwise quite similar.

205. *Remera stephensoni* Harbison, 1926\*
206. *Remera microstriata* Stephenson, 1941?

There is little difference between *Remera stephensoni* and *R. microstriata* (Sohl, 1964a, pl. 31, fig.17-19, 22, 23), the former having less sinuous axial ribs. The protoconch is described as consisting of three smooth rounded whorls, forming a cone.

### Genus *Graphidula* Stephenson, 1941

The shell resembles that of *Remera* in shape and ornament but has a fold on its columellar lip, which is not seen from the outside. The type species is *Graphidula terebriformis* Stephenson, 1941 (Sohl, 1964a, pl. 28, fig. 24-26). It is very close in shape to *Paleofusimitra* but differs in having a more cancellate ornamental pattern and only one columellar fold.

207. *Graphidula cancellata* (Wade, 1926)\*
208. *Graphidula pergracilis* (Wade, 1926)\*
209. *Graphidula obsura* (Wade, 1926)\*
210. *Graphidula terebriformis* Stephenson, 1941
211. *Graphidula melanopsis* (Conrad, 1860)

### Genus *Paleofusimitra* Sohl, 1963

The fusiform shell is ornamented only by subsutural incised spiral grooves and by spiral lirae on the siphon. The columellar lip of the elongate aperture has two folds. Based on the columellar folds, Sohl (1964a, pl. 37, fig.1-3, 6, 7) placed the only species of this genus within the Mitrinae of the Mitridae. The protoconch was described as consisting of 2.5 rounded smooth whorls, having a gradational transition with the teleoconch.

212. *Paleofusimitra elongata* Sohl, 1963

### Genus *Mitridomus* Sohl, 1963

The fusiform shell has an ornamentation of axial ribs



and fine spiral lirae. The aperture bears four low folds on its columellar portion. The type species is *Fasciolaria? ripleyana* Wade, 1926

213. *Mitridomus ripleyana* (Wade, 1926)\*

### Suborder Nematoglossa Olsson, 1970?

#### Family Cancellariidae Gray, 1853?

The fusiform shells have a reticulated ornament, columellar and parietal folds on the inner lip of the aperture, and a truncate-conical to flat-topped protoconch. Cancellariids have a modified radula with distinctive, elongate teeth used to suck liquids, like blood, from fish or yolk from egg capsules. Due to the similarity in the shape of protoconchs of the Cancellariidae and Trichotropidae, a distinction of fossil species belonging to these widely different gastropod groups is difficult. The two species listed here do not present sound evidence for the presence of cancellariid (nematoglossan) neogastropods in the Ripley Formation.

#### Genus *Cancellaria* LAMARCK, 1799

The type species is the living *Cancellaria reticulata* Linné, 1758. Sohl (1964a, pl. 44, fig. 1, 2) placed one shell of cancellariid shape from Coon Creek in this genus. He described the protoconch as of a rounded low-spined shape, consisting of almost three smooth whorls with an abrupt juncture with the teleoconch. The inner lip of the aperture has three folds.

214. *Cancellaria macnairyensis* Sohl, 1964a\*

#### Genus *Trigonostoma* Blainville, 1827

The type species is the modern *Delphinula trigonostoma* Lamarck, 1822. According to Sohl (1964a, pl. 44, fig. 25, 27), the shell is 17 mm high and 12 mm wide and has a double keel and a narrow umbilicus. A protoconch was not noted. Three whorls of the spire have only one carina, but there are two on the body whorl, the lower of which is the weakest. A subsutural ramp slopes to the peripheral carination. Between carinations there is a concave excavation. A third strong cord is present on the steep basal slope and finer spiral lirae cover the shell surface. The aperture is of a rounded triangular shape, and the columella bears two strong plaits. Only the presence of columellar folds distinguishes *Trigonostoma ripleyana* from a member of the Trichotropidae such as *Lirpsa (Trichotropis) mississippiensis*.

215. *Trigonostoma ripleyana* Sohl, 1964a

Sohl (1964a, pl. 44, fig. 25, 27) placed this species from the Ripley Formation in the genus *Trigonostoma*, which is based on a type species representing a cancellariid living in the Indo-West Pacific. If the columellar folds

were absent, this species would be identified as *Lirpsa mississippiensis* (Sohl, 1960, pl. 10, fig. 22)

### Subclass Heterostropha Fischer, 1885

Heterostropha unite gastropods that change from sinistral to dextral coiling during the embryonic or larval part of their ontogeny or have evolved from ancestors that had this development. They include the orders Allogastropoda and Euthyneura.

### Order Allogastropoda Haszprunar, 1985

The order includes shell-bearing Heterostropha such as the Pyramidelloidea, Mathildoidea, and Architectonicoidea, which are not Euthyneura.

### Superfamily: Mathildoidea DALL, 1889

Members of this superfamily have elongate shells with many whorls, which are usually ornamented with spiral and axial elements. The protoconch has a sinistral embryonic shell and twists into dextral coiling at the end, or still within, the course of the larval shell.

#### Family: Mathildidae DALL 1889

The elongated shell has many whorls and is sculptured by spiral carinae that may be crossed by collabral costae or growth lines. The aperture is subcircular. The protoconch is sinistral and rests on the dextral teleoconch at a right angle or an angle smaller than 90° between the axis of the larval shell and the axis of the adult shell. The larval shell has a low conical shape with rounded whorls, which may have some axial folds on the apical and umbilical sides. Just before the onset of the teleoconch, the shell twists into a planispiral coil before the dextral coiling of the teleoconch begins. The onset of the teleoconch is always abrupt and connected with a change in sculpture. The family is based on the genus *Mathilda* with a type species living in the Mediterranean Sea.

#### Genus *Mathilda* Semper, 1865

The smooth protoconch is abruptly succeeded by a sculpture consisting of 4-6 strong spiral costae crossed by fine to coarse collabral ribs, forming a reticulated pattern. The whorls have one or two keels, and the first whorl of the teleoconch whorl carries 3-4 spiral ribs on its exposed upper surface, often with finer ribs in the interspaces. Only the anterior 1 or 2 of these are more prominent than the others and form the whorl shoulder. The aperture is almost round, and the margin of the apertural lip is not continuous at the inner lip, which represents only a glazed over surface on the prior whorl. There is usually an indistinct anterior apertural notch. The protoconch is

sinistral, forms a low helical coil, and is immersed in the apex of the teleoconch at 90° or less. The embryonic shell may lie free at the apex or may be partly covered by the first whorl of the teleoconch. The type species *Mathilda quadricarinata* (Brocchi, 1814) is from the Mediterranean Sea.

216. *Mathilda (Mathilda) ripleyana* Wade, 1926\*

*Mathilda ripleyana* has no axial ribs and only growth increments crossing the spiral ribs (Sohl, 1960, pl. 18, fig. 13, 18, 20-23), while *Turritilla pentalira* and *T. hexalira* have collabral ribs and differ regarding the spirals seen below the keel-like peripheral rib.

**Subgenus *Mathilda (Echinimathilda)* Sohl, 1960**

The whorls of the protoconch of *M. (Turritilla)* are sinistrally coiled along the same axis as the normally dextral teleoconch, a condition termed anastrophic (Dockery, 1993, pl. 30, fig. 1-3). In the later whorls of the teleoconch, spiral ornament dominates over axial ribs in *M. (Echinimathilda)*, in contrast to *M. (Turritilla)* where both elements retain similar dimensions. The type species is *Echinimathilda parvula* (Sohl, 1960) from the Ripley Formation (Sohl, 1960, pl. 18, fig. 17, 29-31).

217. *Mathilda (Echinimathilda) parvula* Sohl, 1960

Dockery (1993, pl. 29 and pl. 30) described three species of *Echinimathilda* from the Campanian Coffee Sand of Mississippi. *M. (E.) corona* Sohl, 1960, has more rounded whorls than *E. microstriata* Dockery, 1993, and *E. parvula*.

218. *Mathilda (Echinimathilda) unionensis* Sohl, 1960

*Mathilda (Echinimathilda) unionensis* (Sohl, 1960, pl. 18, fig. 3-9) is a relatively broad mathildid, while *Mathilda? cedarensis* Stephenson, 1941 (Sohl, 1960, pl. 18, fig. 14-16) does not belong here and represents a cerithiopsis species.

**Subgenus *Mathilda (Turritilla)* Schröder, 1995**

The turritiform shell has 4 or more spiral ribs present at the beginning of the teleoconch. These spirals are overrun by collabral ribs forming a regular pattern of rectangles. The whorls are convex, and the sutures are deep. The aperture is rounded, with the inner lip slightly thickened and almost straight. The protoconch is sinistrally coiled and clearly separated from the teleoconch. The type species is *Turritella opalina* Quenstedt, 1858, from the Middle Jurassic (Aalenian) of northern Germany.

*Mathilda pentalira* Dockery, 1993, and *M. hexalira* Dockery, 1993, from the Coffee Sand belong in the subgenus *Turritilla*. *M. (Turritilla) pentalira* has two spiral ribs below the keel in later whorls of the teleoconch, while *M. hexalira* has three in this position (Dockery,

1993, pl. 28). *Mathilda campania* Kiel and Bandel (2001b, pl. 1, fig. 1) from the Campanian of Torallola, northern Spain, resembles *Mathilda pentalira* Dockery, 1993, from the Campanian of Mississippi.

219. *Mathilda (Clathrobaculus) cretacea* (Wade, 1926)\*

This species is based on a small shell fragment (Sohl, 1960, pl. 18, fig. 19) and may not belong to the mathildids, which can only be decided when the protoconch is found.

**Genus *Gegania* Jeffreys, 1884**

The dextral teleoconch is turbiniform with rounded whorls; the sinistral protoconch lies inverted in its apex and is anastrophic with the same axis of coiling as the teleoconch. The protoconch consists of 1.5 to 2.5 whorls with a wide umbilicus. The spiral ornament of the teleoconch begins with more than three ribs visible above the suture and with more spiral ribs appearing during whorl growth. The axial sculpture consists of fine growth ridges that are crenulate or nodulate where they cross the spiral cords. The aperture is subcircular with the inner lip sometimes expanding over the umbilicus, which may be wide, narrow, or closed. The type species is *Gegania pinguis* Jeffreys, 1884, living in the Atlantic ocean.

220. *Gegania parabella* (Wade, 1926)\*

221. *Gegania bella prodiga* Sohl, 1960

**Genus *Lemniscolittorina* Sohl, 1960**

The *Littorina*-like shell has rounded whorls and nodular spiral ornament. The protoconch is smooth and sinistrally coiled, while the teleoconch is dextral. The type species is *Littorina berryi* Wade, 1926, from the Ripley Formation (Sohl, 1960, pl. 9, fig. 29-31, 36). *Lemniscolittorina* may be related to *Gegania*.

222. *Lemniscolittorina berryi* (Wade, 1926)\*

*Lemniscolittorina kuthurense* Bandel, 1999, from the Santonian/Campanian Trichinopoly Formation of India is larger than *L. berryi* and has more spiral ribs. The latter differs from the Campanian *L. yonkersi* Dockery, 1993, in having a closed umbilicus and is also of larger size and has more ribs (Dockery, 1993, pl. 4, fig. 5, 6, pl. 5, fig. 1-4). *Lemniscolittorina elongata* Kiel and Bandel, 2001b, from the Campanian of northern Spain is larger and more elongate than *L. berryi* from the Ripley Formation, USA.

**Genus *Acrocoelum* Cossmann, 1888**

223. *Acrocoelum cereum* Sohl, 1960

*Lemniscolittorina elongata* Kiel and Bandel (2001b, pl. 1, fig. 7-8) from the Campanian of Torallola, northern Spain

looks very similar to *Acrocoelum cereum* from the Ripley Formation (Sohl, 1960, pl. 18, fig. 23, 24). It represents an elongate *Lemniscolittorina* with four finely ribbed spiral cords and no umbilicus. The relatively high-spired shell has at least five whorls and is sculptured with four axially ribbed spiral cords. Its base is rounded, sculptured with similar spiral cords, and has no umbilicus. The roundish aperture shows a smooth columella. *Lemniscolittorina elongata* differs from *Lemniscolittorina cereum* in having less deep sutures and one more spiral rib on the whorls of the spire. Both are more elongate than *L. berryi* from the Ripley Formation, USA.

### Superfamily Architectonicoidea Gray, 1850

This superfamily includes planispiral, discoidal, and low conical dextral shells with sinistral protoconchs. Species similar to the modern *Helicacis* existed as early as the late Triassic (Bandel, 1988). Genera of the architectonicids like the flatly coiled *Pseudomalaxis* are known from the Campanian and Maastrichtian of Tennessee and Mississippi (Dockery, 1993). The Amphitomariidae with *Amphitomaria* continue with Cretaceous and Tertiary members of *Neamphitomaria*.

### Family Architectonicidae Gray, 1850

The conically to planspirally coiled shell is usually of low profile with different types of ornamentation present. The aperture is round or angular and about as wide as high. The umbilicus is usually open. The protoconch is anastrophic. The family is based on the modern genus *Architectonica* Röding, 1798.

### Genus *Pseudomalaxis* Fischer, 1885

Plate 3, figure 11

This genus unites discoidal shells with a very wide umbilicus, a flat or low spire, and whorls angulated at peripheral and umbilical margins so that the whorls have a subrectangular cross section. The protoconch is smooth and anastrophic, forming an angle of 180° with the teleoconch (after Dockery, 1993). The type species is *Bifrontia zanclea* Phillipi, 1836, from the Pliocene of Messina in Sicily, Italy.

*Pseudomalaxis pateriformis* Stephenson, 1955, was described by Sohl (1960, pl. 6, fig. 35, 38) from the Owl Creek Formation and has also been recognized by Kiel et al. (2002) from the Maastrichtian of Temalac, Mexico. Here the protoconch is smooth, made of one and a half whorls and has a diameter of 0.75 mm. It forms an angle of 180° with the teleoconch, terminates in a reinforced lip, and has a ridge on the last quarter whorl. The teleoconch

has angular whorls and deep sutures with jagged margins, and the sides of the upper whorl are ornamented with beaded cords. The umbilicus is very wide with transverse lirae and nodular spiral keels. The aperture is round.

224. *Pseudomalaxis ripleyana* Wade, 1926\*

225. *Pseudomalaxis pilsbryi* Harbison, 1945\*

226. *Pseudomalaxis* sp. A\*

227. *Pseudomalaxis* sp. B

### Genus *Granosolarium* Sacco, 1892

The medium-size, discoid shells have a moderately broad umbilicus and are sculptured with beaded spiral elements. The umbilical margin is beaded and is not separated from remainder of base by a groove; the umbilical wall bears a spiral cord between the margin and suture, and a beaded carina is present at shell periphery (after Dockery, 1993). The type species is *Solarium milligranus* Lamareck, 1822, from the Tertiary of Italy. Recent species of *Granosolarium* live in deeper waters (Bieler, 1985). *Granosolarium coffea* Sohl, 1964b, occurs in the Campanian Coffee Sand (Dockery, 1993, pl. 28, fig. 1, 2, 6). Perrilliat et al. (2000) also reported this species to occur in the Mexcala Formation of southern Mexico.

### Genus *Helicacis* d'Orbigny in Sagra, 1842

These relatively high-spired, small architectonicids with dominant spiral sculpture are umbilicate and have a field of five spiral lirae on the base (Dockery, 1993). The type species is *Helicacis heberti* (Deshayes, 1830) from the Recent of Martinique. *Helicacis* (*Helicacis*) possesses a broad umbilicus (15-40% of the basal diameter) whereas, in the subgenus *Helicacis* (*Gyriscus*) Tiberi, 1867, the umbilicus is rather narrow occupying around 10% of the basal diameter (Bieler, 1985). *Helicacis reticulatus* Dockery, 1993, from the Campanian Coffee Sand of Mississippi is ornamented by spiral cords, which are of equal strength, and the whorls are well rounded (Dockery, 1993, pl. 27, fig. 6, 7).

### Family Amphitomariidae BANDEL, 1996

These small, planispirally coiled architectonicids have a sinistral protoconch and one or two angular keels on the flanks of the teleoconch. When there is no free larval stage present within the ontogeny of a species, the embryonic shell has a planispirally-coiled shape like that of the teleoconch. The Architectonicidae usually have larger shells, including the protoconch, which usually shows evidence of an extended planktotrophic existence. Characteristic representatives have existed since the late Triassic (Bandel, 1996). The type species of *Amphitomaria*



Koken, 1897, is *Euomphalus cassianus* Koken, 1889, from the late Triassic St. Cassian formation. A Campanian representative is *Amphitomaria dockeryana* Kiel and Bandel, 2001b, from Torallola in northern Spain.

### Genus *Neamphitomaria* Bandel, 1993b

The small disc-like shell has a planispiral protoconch that differs in ornament according to its developmental mode. The teleoconch has angular whorls with corners, is less than 3 mm in diameter, and has one or two strong spiral ribs on its base. The protoconch is planispiral and ornamented by one or two spiral ridges. These continue into a ridge forming the edge of the teleoconch. The whorl is of a rounded quadrangular shape, and ornament consists of fine spiral lirations. The type species is *Neamphitomaria stantoni* (Sohl, 1960) from the Maastrichtian Ripley Formation.

*N. stantoni* and *N. planospira* Dockery, 1993, of the Coffee Sand, differ from *N. toralloensis* Kiel and Bandel, 2001b, from the Campanian of northern Spain in having smaller but sculptured protoconchs. In addition, *L. stantoni* has a keel on the upper side of the whorls.

#### 228. *Neamphitomaria stantoni* (Sohl, 1960)

This *Neamphitomaria* has a convex apical side and a concave umbilical side. The protoconch consists of one one whorl ornamented by two spiral keels on the apical side (Dockery, 1993, pl. 35, fig.1-3; Kiel and Bandel, 2001b, pl. 1, fig. 13-14). Teleoconch ornament consists of collabral ribs, and angular ridges that form the apical and basal margins. The area between the margins is slightly concave and carries a central spiral ridge. The base is a wide concave cone showing all the whorls. The aperture is angular (Sohl, 1960, pl. 6, fig. 29, 39, 43, 44).

*Neamphitomaria planospira* Dockery, 1993, from the Coffee Sand is flat on its apical surface, has an angular shoulder, a nearly vertical side, and an angular corner to the base, which is concave. The protoconch demonstrates a polygonally ornamented embryonic shell, and a larval shell with inclined spirally arranged ribs. The teleoconch consists of about two whorls, which are ornamented by collabral ribs. The concave base exhibits all the whorls, including the protoconch. The aperture is subcircular (Dockery, 1993, pl. 35, fig.4-8, pl. 36, fig.1-4).

### Superfamily Pyramidelloidea Gray, 1840

Pyramidelloidea represent a large and diverse taxon of marine ectoparasitic snails. Shell shape ranges from acicular to flat-coiled and from multiwhorled to limpet-like. The protoconch is sinistrally coiled, while the teleoconch is dextral; the switch from sinistral to dextral coiling usually occurs in the transition of the protoconch

to the teleoconch, and the first teleoconch whorl is dextral. The two families included here, the Amathinidae and the Pyramidellidae, possess gills on differing sides of the pallial cavity.

### Family Pyramidellidae Gray, 1840

Shells are usually small, but some are up to 20 mm high. Many are slender and elongate but others are short and with fewer whorls; some species are trochiform to even planispirally coiled with few whorls. The protoconch is sinistrally coiled, smooth, trochiform, helical or almost planispiral and is often at a large angle to the coiling axis of the dextral teleoconch. Those species with a planktotrophic larval stage have a protoconch of about 2 whorls, while those species with lecithotrophic development have a simplified protoconch of around one whorl. The heterostrophic protoconch is smooth and oriented 90-150° to the teleoconch. The change from sinistral coiling to dextral coiling occurs at the end of the protoconch shell (not within its last whorl) and the beginning of the adult shell. The teleoconch surface can be smooth or ornamented. Sculpture may consist of axial ribs or growth lines, spiral ribs or grooves, or a combination of both. The aperture lacks an anterior siphonal canal, and the columellar lip may be smooth or have one to three folds.

### Genus *Creonella* Wade, 1917b

This smooth slender shell has the sinistral protoconch at a right angle with the coiling axis of the teleoconch (Sohl, 1964a, pl. 51, fig. 8). The columella bears three folds.

#### 229. *Creonella triplicata* Wade, 1917b\*

#### 230. *Creonella subangulata* Sohl, 1964a\*

#### 231. *Creonella turreiformis* Sohl, 1964a

*Creonella triplicata* differs from *Creonella subangulata* primarily in the presence of a subangulate periphery, and thus a more rectangular outline of the aperture (Sohl, 1964a, pl. 51, fig. 7, 8 and fig. 3-6, 9). *Creonella turreiformis* has a narrow subsutural groove (Sohl, 1964a, pl. 51, fig.10-13).

### Genus *Lacrimiformia* Sohl, 1964a

#### Plate 3, figure 5

The aperture is auriform, and there is one low sharp fold on the columellar lip. The protoconch is sinistral and is coiled at an angle to that of the teleoconch. The type species is *L. secunda* (Wade, 1926) (Sohl, 1964a, pl. 50, fig. 21-27).

232. *Lacrimiforma secunda* (Wade, 1926)\*

This species differs from the species of *Creonella* by a broader shell, a well-developed subsutural groove, and in having only one columellar fold instead of three.

**Family Amathinidae Ponder, 1987**

The shell of the amathinids is small to 20 mm in size; they are limpets living in the marine environment. The shells are either limpet-like or littoriniform or ovate-conic. The protoconch is sinistral. Sculptures are predominantly spiral crossed by more or less developed collabral elements. Amathinids are parasitic on bivalves, producing an attachment pit on the host shell. The limpet-like species of this family could well be related to the *Nerita*-like *Damesia* with heterostrophic protoconch from the Upper Cretaceous of Europe and North America.

Dockery (1993) placed *Damesia keownvillensis* Sohl, 1960, here based on the presence of a heterostrophic protoconch (see the Capulidae above).

**Superorder Euthyneura Spengler, 1881**

**Order Opisthobranchia Milne Edwards, 1884**

The distinction between the opisthobranchs and the pulmonates is sometimes problematic, especially regarding marine and shell bearing species. The determination of fossils species, therefore, is not always possible. The placement of a species into a genus and even a family is often based on the presence or absence of columellar folds and on their number. This may not be a very good character as columellar folds may have been lost or gained independently within different lineages. As the modern actaeonids have not been well studied, there is disagreement to their systematic relationships. The system adopted here is, therefore, somewhat artificial.

**Suborder Architectibranchia Haszprunar, 1985.**

Most representatives of this group, also known as the Cephalaspidea, have a nearly cylindrical shape with either an erect or submerged spire. The aperture of the shell is commonly narrow and high, and folds may be present or absent on the columellar edge of the inner lip. Water leaving the pallial cavity usually runs via a slit or sinus of the aperture that is next to, or near to, the suture of the shell. The shell surface is commonly ornamented with growth lines and fine spiral furrows and/or rows of pits.

**Superfamily Actaeonoidea d'Orbigny, 1842**

Actaeonidae with *Actaeon*-like shell shapes are characterised by an ornament of spiral furrows with a pitted appearance. The families Actaeonidae, with solid

shells, and Hydatinidae, with thin and reduced shells, have living species (Burn and Thompson, 1998), and the Actaeonoidea can be traced from the Middle Jurassic (Cossmann, 1895; Schröder, 1995; Gründel, 1997) in a continuous line to the modern species.

**Family Actaeonidae d'Orbigny, 1842**

Here three subfamilies can be distinguished; of these, the Acataeoninae have one columellar fold; the Bullininae have no columellar fold; and the Tornatellinae have two columellar folds on the inner lip. The Bullininae differ from Ringiculidae in having a simple aperture, while the protoconchs of both families are similar. The oldest representatives of the actaeonids are from the Jurassic; these were placed in the family Sulcoactaeonidae Gründel, 1997, a family that resembles *Bullina* in all essential features.

**Subfamily Bullininae Rudman, 1972**

The *Actaeon*-like shell has a smooth columellar edge. The shell is spindle-like or broadly oval in shape with the sinistral protoconch forming an angle with the teleoconch that may reach 90°. The spire may form a more or less distinct ramp with the last whorl. Ornament consists of spiral furrows or incisions that may be transected by fine collabral axial lirae. The aperture has a drop-like shape with an indistinct anterior notch, and the inner lip callus may cover the umbilical region.

**Genus *Bullina* Férussac, 1822**

Plate 3, figure 12-13

The shell has an actaeonid shape, a short spire, an ornament of dot-like grooves, no columellar fold, an open and narrow umbilicus, is rounded, and its protoconch is inclined. The type species is the modern *B. scabra* (Gmelin, 1791).

**Subgenus *Bullina* (*Nonacteonina*) Stephenson, 1941**

The shell is close to *Eoacteon* in shape but lacks a columellar fold. The shell is slender and elongate in shape with a high spire that amounts to more than one third the total shell height. The sutures are flat, and ornament consists of impressed spiral grooves and curved growth lines that appear as raised transverse threads in the grooves. The posterior end of the aperture is narrow, the anterior end is rounded, and callus is restricted to a narrow band on the columellar lip. The columellar edge is smooth. The protoconch consists of smooth whorls with sinistral coiling sometimes only indistinctly present in the embryonic whorl. Here the embryonic part of the shell may have a hammered ornament but is covered partly by the first whorl of the larval shell. The larval shell is

evenly and dextrally coiled, and its aperture is simple. The beginning of the teleoconch sculpture is abrupt with the appearance of spiral rows of pits. The type species is *Nonacteonina graphoides* Stephenson, 1941, from the Upper Cretaceous of Texas (Navarro Group). *Bullina* (*Nonacteonina*) has a little lower spire than *Bullina* (*Bullina*).

233. *Bullina* (*Nonacteonina*) *orientalis* (Wade, 1926)\*

The shell is slender and of elongate shape with a high spire that amounts to more than one third total shell height. Ornament consists of impressed spiral grooves. This species is from Coon Creek, Tennessee (Wade, 1926, pl. 34, fig. 8, 9).

### Family Actaeoninae Orbigny, 1842

The external shell is strong, and the foot carries a chitinous operculum. The genera are mainly distinguished by the presence of columellar folds and secondarily by features of the ornament. The protoconch does not contribute to the generic and specific differentiation. The family contains *Acateon*-like shells with a plicate columellar edge. *Voluta tornatilis* Gmelin, 1788, from the Atlantic, is the type species for *Actaeon* Montfort, 1810. It has only one fold on the columella, while *Tornatellaea* has two folds, and *Bullina* has no folds.

### Genus Actaeon Montfort, 1810

#### Plate 3, figure 10

The ovate shell has a low spire and a sinistral protoconch that is often partly buried within the teleoconch. The teleoconch whorls are convex with a very capacious body whorl. The ornament consists of narrow spiral grooves and spiral rows of pits, typically with fine axial costae within. The columella carries a single plait at its posterior end.

234. *Actaeon pistilliformis* Sohl, 1964a\*

235. *Actaeon cicatricosus* Sohl, 1964a

The small shell is almost 5 mm high and has a moderately high spire, composing about 1/3 of total shell height. The protoconch is sinistral and attached to the teleoconch with an inclined axis. The teleoconch has a channeled suture and rounded whorls. The ornament consists of incised spiral grooves with thin raised collabral elements crossing over and is wider below than above. The raised interspaces are wider than the grooves. The aperture is elongate, narrow at its posterior end, and bears a strong oblique fold on the columellar lip. *Actaeon cicatricosus* has wider incised grooves than *A. pistilliformis* and has secondary grooves (Sohl, 1964a, pl. 47, fig. 17, 18, 22, 24-28).

### Subgenus Actaeon (*Eoacteon*) Stephenson, 1955

The ovate elongate shell has a spire of one fourth to one third of the total shell height. The sculpture consists of incised spiral grooves crossed by fine axial threads. The aperture is elongate, and the columella bears one low fold that is not visible in the aperture or only present as a weak fold. The type species is *Solidulus linteus* Conrad, 1858 (Sohl, 1964a, pl. 47, fig. 5, 10-12) from the Owl Creek Formation of Mississippi. *Eoacteon* is close to *Actaeon* but is usually larger. The larval shell is deviated almost 90° from the teleoconch. According to Sohl (1964a), the protoconch of *Actaeon* is immersed in the teleoconch, but otherwise *Eoacteon* is very similar to *Actaeon*. *Bullina* (*Nonacteonina*) is very similar to *Actaeon* (*Eoacteon*), but more slender and without a fold on the columellar lip.

*Actaeon* (*Eoacteon*) *lindeus* (Conrad, 1858) has an ovate elongate shell that may be as high as 3 cm and has a spire of one fourth to one third of the total shell height. The sculpture consists of incised spiral grooves crossed by fine axial threads and much wider interspaces, except on the base. The aperture is elongate, and the columella bears one low fold that is not visible in the aperture (Sohl, 1964a, pl. 47, fig. 5, 10-12). *A. (Eoacteon) percultus* differs from *A. (E.) linteus* in its slimmer outline, broader spiral grooves, a distinctly channeled suture, and by a proportionally higher spire.

236. *Actaeon* (*Eoacteon*) *percultus* Sohl, 1964a\*

The ovate elongate shell has almost flat sides, may be as high as 17 mm, and has a spire of more than one third of the total shell height. Sutures are distinctly channeled. The sculpture consists of incised spiral grooves crossed by fine axial threads and much wider interspaces, except on the base. The aperture is elongate, and the columella bears one low fold (Sohl, 1964a, pl. 47, fig. 15).

237. *Actaeon* (*Eoacteon*) *ellipticus* (Wade, 1926)\*

The ovate elongate shell has almost flat sides, is about 15 mm high, and has a very low spire. Sutures are distinctly channeled. The sculpture consists of incised spiral grooves crossed by fine axial threads and much wider interspaces, except on the base. The aperture is elongate, and the inner lip has a narrow band of callus. The columella bears one low fold (Sohl, 1964a, pl. 47, fig. 13, 14).

### Genus Troostella Wade, 1926

The almost oval shell of medium size has a spire that composes about one third of the total shell height. The sutures are angular and ornament consists of irregularly spaced narrowly incised grooves and a few secondary incised lines that may be crossed by collabral raised threads. The aperture is elongate with a thick callus on the columellar edge of the inner lip, which bears one highly oblique fold and has a slit-like depression with the whorl



it covers. The type species is *Troostella perimpressa* Wade, 1926. The more ovate shape distinguishes it from *Actaeon* (*Eoacteon*) with which it has many features in common. Its difference from *Actaeon* is not clear.

238. *Troostella perimpressa* Wade, 1926\*

The shell is almost 3 cm in height and has smoothly rounded sides. The aperture bears one highly oblique fold on its columellar lip and has a slit-like depression with the whorl it covers (Sohl, 1964a, pl. 47, fig. 19, 20).

239. *Troostella substriata* (Wade, 1926)\*

The shell is thin and is about 2.5 cm in height (Sohl, 1964a, pl. 47, fig. 16, 21). *Troostella substriata* differs from *Troostella perimpressa* in having a thinner shell, finer spiral sculpture, and stronger growth lines.

**Genus *Parietiplicatum* Sohl, 1964a**

The small shell has few whorls and has an evenly tapered spire of greater than one third of the total shell height. The whorls are flat-sided above and rounded over the periphery to an evenly sloping base. Ornament consists of prominent growth lines and deeply incised spiral furrows that are irregularly spaced. The outer lip of the aperture is dentate within, and the inner lip has a strong columellar fold and a weaker fold on the parietal surface. The type species is *Actaeon conicus* Wade, 1926, from Coon Creek. *Parietiplicatum* differs from *Actaeon* in having a weak fold on the parietal wall, by lacking dot-like sculpture, by a higher spire, and by lacking a channeled suture. The parietal fold resembles that found among ringiculid species, but the genus lacks the thickened outer lip and has a higher spire than is normal for the Ringiculidae (Sohl, 1964a).

240. *Parietiplicatum conicus* (Wade, 1926)\*

The shell is about 11 mm high and 6 mm wide shell and has four to five whorls (Sohl, 1964a, pl. 48, fig. 3-5). It differs from *Actaeon* in having the fold higher up on the inner lip callus and not on the anterior columellar lip and by the littoriniform shape of the shell. It is quite possible that it actually is a spirally ornamented pyramidellid species.

**Subfamily Tornatellaeinae n. subfam.**

The subfamily Tornatellaeinae is characterized by an *Actaeon*-like shell with a columellar edge bearing two folds. The genus characteristic of the subfamily is *Tornatellaea*.

**Genus *Tornatellaea* Conrad, 1860**

The shell is of ovoid shape resembling that of *Actaeon*, but with two columellar folds. The spire is less than half

of total shell height. Sculpture consists of narrow spiral furrows, which are occasionally punctate. The aperture has a narrow posterior end and rounded anterior end. The outer lip is thickened and has a crenulated inner side. The inner lip forms a callus covering the columellar surface, which bears two oblique columellar plaits. The type species is *T. bella* Conrad, 1860, from the Eocene of Alabama.

241. *Tornatellaea cretacea* Wade, 1926\*

The ovoid shell reaches 1 cm in height, is about half as wide as high, and the spire is less than one third of total shell height. Sculpture consists of narrow spiral furrows. The columellar surface bears two oblique plaits (Sohl, 1964a, pl. 47, fig. 23, 29, 33).

242. *Tornatellaea globulosa* Wade, 1926\*

*Tornatellaea globulosa* is distinguished from *Tornatellaea cretacea* by its shorter body and lower spire (Sohl, 1964a, pl. 47, fig. 1, 2).

**Genus *Bullopsis* Conrad, 1858**

The rounded shell has a truncate apex with a broad and open depression. The protoconch is raised and heterostrophic. Ornament consists of faint incised spiral grooves and weak transverse small ribs, which are restricted to the posterior part of the whorl. The aperture is flaring, and the columella bears two strong oblique folds. The type is *Bullopsis cretacea* Conrad, 1858, from the Niobrara Formation in Wyoming and the Owl Creek Formation in Mississippi.

*Bullopsis cretacea* Conrad, 1858, is about 2 cm high and more than 1 cm wide. The spire is low, and the open apical depression is wide. The protoconch is raised and heterostrophic. Ornament consists of only scattered faint incised spiral grooves and weak radial ribs restricted to the posterior part of the whorl. The species is from Owl Creek Formation of Mississippi (Sohl, 1964a, pl. 50, fig. 9-16). The shell bears similarities to the Actaeonellidae and looks like a *Trochactaeon* with a flattened apex.

243. *Bullopsis demersus* Sohl, 1964a

*B. demersus* (Sohl, 1964a, pl. 50, fig. 6-8) differs from *B. cretacea* in its small size of only 2 mm in height and by its transverse ornament.

**Superfamily Ringiculoidea Fischer, 1883**

**Family Ringiculidae Philippi, 1853**

The shells resemble miniature helmet shells like *Cassis* or *Phalium* but with folds on the columellar lip. The whorls of the spire are not apically flattened and lack a ramp. The apertural margin of the fully-grown shell is strongly thickened and callus covered in the columellar

region. The columellar lip bears one or several folds, and there may also be denticles on the inner side of the outer lip. *Ringicula* Deshayes, 1838, has been common since the Lower Cretaceous (Valangien of Poland; Schröder, 1995); by the end of the Cretaceous, it had diversified into several genera, including *Ringinella* Orbigny, 1843, *Avellana* Orbigny, 1843, *Biplica* Popenoe, 1957, *Eriptycha* Meek, 1867, which is present in the Aptian /Albian of Japan (Kase, 1984), and *Oligoptycha* Meek, 1876.

### Genus *Ringicula* Deshayes, 1838

Plate 3, figure 6

The small low-spined globose to subglobose shell is either smooth or ornamented with incised spiral lines or furrows. The aperture is narrow with the outer lip thick and smooth or dented within and the inner lip with strong callus and three denticles, two strong folds on the columellar part and further up on the parietal portion a single tooth or fold. The type species is *R. ringens* (Lamarck, 1804) from the Eocene of the Paris Basin.

244. *Ringicula (Ringicula) pulchella* Shumard, 1861\*

245. *Ringicula (Ringicula) yochelsoni* Sohl, 1964a

*Ringicula pulchella* differs from *R. yochelsoni* in its larger size and in having a less rounded outline (Sohl, 1964a, pl. 49, fig. 1, 2, 6-17, 20-26).

### Subgenus *Ringicula (Ringiculina)* Monterosato, 1884

According to Sohl (1964a, pl. 48, fig. 18, 19) an incomplete shell was placed here. Perrilliat et al. (2000) also reported this species from the Mexcala Formation of southern Mexico.

246. *Ringicula (Ringiculina) cf. R. clarki* Gardner, 1916

### Genus *Avellana* d'Orbigny, 1843

*Avellana* is characterized by its rounded shell shape, low dome-shaped spire, and thickened inner lip callus. There is one strong fold on the columellar lip, and the inner side of the outer lip is dented within or smooth. Additional denticles and folds may be present on the inner and outer lip, distinguishing the subgenera. The outer lip has a thickened rim, and there is a shallow canal on the posterior side of the aperture and a rounded notch at the anterior side of the aperture. The ornament consists of a pattern of spiral grooves that are crossed by collabral ridges to form a row of pits.

### Subgenus *Avellana (Oligoptycha)* Meek, 1876

The rounded shell has a depressed spire and an ornament of incised spirals. The inner lip bears a strong anterior fold. The type species is *Actaeon concinnus* Meek and Hayden, 1854, from the Fox Hills Formation, which closely resembles *Oligoptycha corrugata* Sohl, 1960, and *O. americana* (Wade, 1926), both from the Ripley Formation.

247. *Avellana (Oligoptycha) americana* (Wade, 1926)\*

*A. (Oligoptycha) americana* is the smaller of the late Cretaceous American Gulf Coast species and possesses the typical single columellar fold but also has two parietal folds, one of which lies in the siphonal notch. Strong denticles occur on the inner side of the outer lip.

248. *Avellana (Oligoptycha) corrugata* Sohl, 1964a

The shell is about 7 mm high, has a depressed spire and ornament of about 25 incised spirals that appear like spiral chains. The protoconch consists of 1.5 smooth whorls, which are depressed. The teleoconch consists of about 2.5 whorls. The outer lip of the aperture is dentate on its inner edge. The inner lip bears a strong anterior fold; its callus is continuous with the outer lip callus. *A. (Oligoptycha) corrugata* is larger than *A. (Oligoptycha) americana* and possesses only one parietal fold and weaker denticulations in the outer lip. *Oligoptychus concinnus* has only the columellar folds, has no parietal folds, and is faintly denticulated in the outer lip. Sculpture is of the same type in all three species (Sohl, 1964a, pl. 48, fig. 27-33, 36, 37).

The South African species *Oligoptycha perampla* Woods, 1906, from the Santonian of Umzamba, has a similar size, shape, and an ornament of furrows, and has an incised suture. *Avellana ampla* Stoliczka, 1868, from the Santonian-Campanian Trichinopoly Group of Tamil Nadu, redescribed by Bandel (2000b) as *Oligoptycha ampla* (Stoliczka, 1868), has a higher spire, fewer spiral grooves on the body whorl, and a subsutural groove. It resembles *Oligoptycha corrugata* Sohl, 1960, from Ripley Formation, but the American species is smaller.

### Family Cylichnidae A. Adams, 1850

Burn and Thompson (1998) included the Scaphandridae, the bullomorph *Cylichna*, the actaeonomorph *Acteocina*, and *Tornatina* in this family. According to Sohl (1964), Scaphandridae like *Cylichnella*, *Mamillocylichna*, and *Meloscapander* have a shell in which the initial whorls remain exposed in contrast to the Cylichnidae s.s. and Philinidae, where this portion of the shell is covered by later whorls. The *Scaphander*-type morphology with an exposed protoconch is believed to be the primitive condition, while that of *Cylichna* with a covered protoconch is the derived condition.

### Genus *Ellipsoscapha* Stephenson, 1941

*Ellipsoscapha mortoni* (Forbes, 1845) from the Prairie Bluff and Owl Creek formation has a nearly elliptical shell, which is tightly coiled with a perforate and submerged apex. Ornament consists of pitted spiral grooves. The aperture is narrow on the posterior end and is rounded and broad on the anterior end. The inner lip is callus covered and bears a weak fold on the columellar lip. The type species is *Cylichna striatella* Shumard, 1861. In contrast to *Ellipsoscapha*, species of the genus *Scaphander* have an imperforate apex and are umbilicate. *Bulla* lacks spiral sculpture over the medial parts of the shell. *Haminaea* is more ovate in shell shape. Sohl (1964a) placed *Ellipsoscapha* from the Gulf Coast Upper Cretaceous in the Scaphandridae, but it may also be a member of several other groups of convergent shell shape within the Opisthobranchia.

249. *Ellipsoscapha* sp.

### Genus *Scaphander* Montfort, 1810

250. *Scaphander? rarus* Wade, 1926\*

According to Sohl (1964a, p. 299), this species is somewhat problematic.

### Genus *Cylichna* Lovén, 1846

The small shell has an elongate cylindrical shape with 3-4 whorls, of which the last one surrounds and covers the earlier ones completely, and has a truncated apex that is perforate in early growth stages. The spire is depressed below the apex of the shell. The surface is smooth or with fine incised spiral grooves. The aperture has a narrow apical end and expands to a rounded anterior end. The columellar lip has a low fold. The type species is *C. cylindracea* (Pennant) from the northern Atlantic Ocean. Sohl (1964a) suggested that *Cylichna* is present from the Cenomanian to the Maastrichtian in marine deposits of the American Gulf Coast area.

251. *Cylichna secalina* Shumard, 1861

252. *Cylichna incisa* Stephenson, 1941\*

253. *Cylichna intermissia intermissia* Sohl, 1964a\*

254. *Cylichna intermissia curta* Sohl, 1964a\*

255. *Cylichna pessusmata* Sohl, 1964a\*

Of the species distinguished by Sohl (1964a) from the Ripley and Owl Creek formations, *Cylichna secalina* Shumard, 1861 lacks the strongly incised grooves and dots

found in *C. incisa*. *Cylichna diversilirata* of the Owl Creek Formation differs from all other species of the Gulf Coast in having a strongly reinforced columellar lip (Sohl, 1964a, pl. 49, fig. 34-36). *Cylichna secalina* from Texas is similar but slimmer and smaller. *Cylichna incisa* is distinguished by its ornament of dots, and it has a narrower apical depression than the other species of the region. *Cylichna intermissia intermissia* is distinguished from the other *Cylichna* species of the Gulf Region in lacking a pronounced columellar fold, the presence of an umbilical slit, and the absence of sculpture upon the medial parts of the body (Sohl, 1964a, pl. 49, fig. 22, 23). *Cylichna pessusmata* has a similar ornament as *C. intermissia* but possesses an apical plug.

### Genus *Cylindrotruncatum* Sohl, 1963

The cylindrical shell is small and has a truncated apex with the early whorls visible in the concave apical depression. The anterior whorl margins terminate in a sharply carinate edge, which borders the apical depression. Ornament consists of faint spiral grooves that are pitted and fine collabral transverse elements restricted to the posterior part of the whorl. The aperture is narrow except for the expansion at the anterior end. The columella is basally truncate. The type species is *Cylindrotruncatum demersum* Sohl, 1964a, from the Maastrichtian Ripley Formation (Sohl, 1964a, pl. 49, fig. 8-12). The unusual depressed open spire and carinate upper whorl edge distinguish *Cylindrotruncatum* from *Cylichna* and other similar genera.

256. *Cylindrotruncatum demersum* Sohl, 1963\*

### Genus *Goniocylichna* Wade, 1926

Plate 3, figures 8-9

The small, nearly cylindrical shell has a low to flat spire. Sculpture is axial on the upper margin of the whorl and spiral on the basal portion of the whorl. The aperture is narrow, and the columella is smooth. The type species is *Goniocylichna bisculpturata* Wade, 1926, from Coon Creek in Tennessee (Sohl, 1964a, pl. 49, fig. 32, 33, 37, 38). Members of *Cylindrotruncatum* have similar shell shapes with slender, truncate, cylindrical shells, and with whorls that terminate in a sharply carinate edge, bordering the apical depression. Except for the columellar plait, *Goniocylichna* is like *Retusa*.

257. *Goniocylichna bisculpturata* Wade, 1926\*

258. *Goniocylichna elongata* Sohl, 1964a

*Goniocylichna bisculpturata* is smaller and less slender than *Goniocylichna elongata* (Sohl, 1964a, pl. 49, fig. 39, 40).



### Genus *Zikkuratia* Sohl, 1963

The turreted spire is about one-quarter of the total length and has an erect protoconch that is sinistrally coiled. The whorls are anteriorly rounded, marginally convex, and square shouldered. Sculpture consists of widely spaced spiral furrows and transverse elements and is present only on the posterior part of whorls. The aperture has a posterior notch and an expanded anterior margin. The columella is smooth. The type species is *Z. tabanneensis* Sohl, 1963, from the Ripley Formation in Georgia (Sohl, 1964a, pl. 49, fig. 13-17). *Acteonina* d'Orbigny differs in lacking an entirely erect protoconch and by the presence of a columellar fold.

259. *Zikkuratia tabanneensis* Sohl, 1963

### Genus *Scobinidola* Sohl, 1963

The small bulliform, rounded shell has the protoconch covered except for a small apical perforation. Sculpture consists of intersecting axial ribs and spiral threads. The aperture is as long as the shell. The outer lip is straight, and the inner lip has callus on the parietal wall. The columellar portion has a sharp edge, is partly expanded over an umbilical perforation, and bears a plait. The type species is *Scobinidola guttata* from the Maastrichtian of Georgia (Sohl, 1964a, pl. 50, fig. 1-5).

.260. *Scobinidola guttata* Sohl, 1963

### Family Retusidae Thiele, 1926

Members of this family have a cylindrical or pear-shaped shell. The posterior end of the shell is often truncate, and the protoconch is sunken.

### Genus *Sulcoretusa* Burch, 1945

The small, cylindrical, slender, involute shell expands a little toward the anterior end. It has a wide and deep apical pit. Ornament consists of collabral threads. The aperture is narrow and expanded toward the anterior with the inner lip expanded over a narrow umbilical slit. The columella is short and smooth. The type species is *Bulla sulcata* Orbigny, 1841, from the recent of Florida and the Caribbean region.

### Subgenus *Sulcoretusa* (*Moniliretusa*) Sohl, 1963

The shell is like that of the genus but possesses spiral threads in addition to the transverse threads. The type species is *S. (M.) spinosa* Sohl, 1963, from the Ripley Formation (Sohl, 1964a, pl. 49, fig. 6, 7).

261. *Sulcoretusa (Moniliretusa) spinosa* Sohl, 1964a

### Suborder Archaeopulmonata Morton, 1955

Within the Pulmonata, the habitat of the Archaeopulmonata is usually along the shoreline with only a few inhabiting fresh water or a moist terrestrial environment, while the Basommatophora prefer the freshwater environment, and the Stylommatophora live on land. Many Archaeopulmonata have a larval stage in the marine plankton. This distinguishes them from the other pulmonates, which do not have a free-swimming larval stage and hatch as miniature adults.

### Superfamily Siphonarioidea Gray, 1840

The patelliform shell is small to medium in size and has an internal siphonal groove on the right side, which appears as an external ridge. The only family is the Siphonariidae.

### Family Siphonariidae Gray, 1840

The shell is more or less bilaterally symmetrical and limpet shaped, with a smooth surface or radial ribs. The apex lies to the posterior of, or near, the center. Often the siphonal side of the shell is extended. Within the genus *Siphonaria*, the shell muscle scar has a horseshoe shape. In the anterior portion, the muscle scar is weakly imprinted, and the mantle opening lies at the right side with muscle scar ending near it.

### Genus *Siphonaria* Sowerby, 1823

The limpet-like shell is elliptical in outline with the apex off center. Ornament consists of growth lines and concentric ribs. A siphonal groove may be present internally on the right side of the shell and may be seen externally as a more or less clearly developed ridge. The interior horseshoe-like muscle scar opens to the right. The protoconch of the cap-like shell is sinistrally coiled. The type species is the Recent *Patella laciniosa* Linné, 1758, of the Solomon Islands.

*Siphonaria* from Coffee Sand (Dockery, 1993) and from Ripley Formation of Tennessee (Wade, 1926; Sohl, 1964a) has a muscle scar that is interrupted as located at the upper right in the manner of modern species of this genus. Similar patelliform shells from the late Cretaceous such as *Siphonaria antiqua* Binkhorst, 1873, and *Siphonaria variabilis* Holzapfel, 1888, from the Campanian Aachen Sands of Germany lack a preserved muscle scar.

262. *Siphonaria wieseri* (Wade, 1926)\*

*Siphonaria revillaria* Kiel and Bandel, 2001b, from the Campanian of northern Spain has about equally strong axial ribs and concentrically oriented growth lines that form minute tubercles where crossing each other. The

limpet-like shell has an ovate, almost circular aperture, an ornament of fine radial and concentric lines, and a sinistrally coiled protoconch. The protoconch is about 0.6 mm in diameter, but the transition to the teleoconch is indistinct as was noted by Dockery (1993) in the case of *Anisomyon*.

### Genus *Anisomyon* Meek and Hayden, 1860

The patelliform shell has an ovate, almost circular aperture, fine radial and concentric lines, and a sinistrally coiled protoconch. The type species is *Anisomyon patelliformis* (Meek and Hayden, 1860) from the late Cretaceous of Nebraska. Dockery (1993, pl. 17, fig. 8-10) described the sinistrally coiled protoconch for *Anisomyon* from the Campanian Coffee Sand in Mississippi. Sohl (1964a, p. 323) pointed out that the siphonal groove is on the left side of the shell in *Anisomyon*, while it is on the right in *Siphonaria*. Additionally, *Anisomyon* is smooth or shows concentric growth lines but no radial sculpture in contrast to *Siphonaria*; it also has a higher conical shell than the rather flat-shelled limpets of *Siphonaria*. *Siphonaria wieseri* has only radial sculpture.

Bandel and Stinnesbeck (2000) described *Anisomyon patelliformis* from the Maastrichtian of Chile (Quiriquina Formation), where the species has a medium-size, cup-like shell that is about 2 cm wide. The apex is situated between the middle and anterior the end, or is nearly central. The shell is thin, longer than wide, and has an oval base. The anterior part of the shell is a little wider than the posterior. The sides are weakly convex or nearly flat, with the surface marked by fine concentric growth lines and very indistinct radial lirae.

Systematic List of Other Molluscan Taxa from the Coon Creek Formation's type locality in Tennessee (as indicated by astericks) and localities in Mississippi.

#### Class BIVALVIA

##### Subclass PALAEOTAXODONTA Korobkov, 1954

##### Order NUCULOIDA Dall, 1889

##### Superfamily NUCULOIDEA Gray, 1824

##### Family Nuculidae Gray, 1824

1. *Nucula percrassa* Conrad, 1856\*
2. *Nucula amica* Gardner, 1916\*
3. *Nucula microconcentrica* Wade, 1926\*

##### Superfamily NUCULANOIDEA H. & A. Adams, 1854

##### Family NUCULANIDAE H. & A. Adams, 1854

4. *Leda australis* Wade, 1926\*
5. *Leda whitfieldi* Gardner, 1916\*
6. *Yoldia longifrons* (Conrad, 1860)\*
7. *Yoldia multiconcentrica* Wade, 1926\*

##### Subclass PTERIOMORPHIA Beurlen, 1944

##### Order ARCOIDA Stoliczka, 1871

##### Family ARCIDAE Lamarck, 1809

8. *Arca mcnairyensis* Wade, 1926\*
9. *Arca securiculata* Wade, 1926\*
10. *Arca pergracilis* Wade, 1926\*
11. *Barbatia fractura* Wade, 1926\*
12. *Barbatia cochlearis* Wade, 1926\*
13. *Striarca saffordi* (Gabb, 1860)\*

##### Family PARALLELODONTIDAE Dall, 1898

14. *Nemodon eufaulensis* (Gabb, 1860)\*
15. *Nemodon grandis* Wade, 1926\*
16. *Nemodon stantoni* Gardner, 1916\*

##### Family CUCULLAEIDAE Stewart, 1930

17. *Idonearca vulgaris* Morton, 1830\*
18. *Idonearca littlei* (Gabb, 1877)\*

##### Superfamily LIMOPSOIDEA Dall, 1895

##### Family LIMOPSIDAE Dall, 1895

19. *Limopsis meeki* Wade, 1926\*
20. *Limopsis perbrevis* Wade, 1926\*

##### Family GLYCYMERIDIDAE Newton, 1922

21. *Glycimeris subcrenata* Wade, 1926\*
22. *Glycimeris microsulci* Wade, 1926\*
23. *Glycimeris lacertosa* Wade, 1926\*
24. *Postligata crenata* Wade, 1926\*

##### Order MYTILOIDA Férussac, 1822

##### Superfamily MYTILOIDEA Rafinesque, 1815

##### Family MYTILIDAE Rafinesque, 1815

25. *Crenella serica* Conrad, 1860\*
26. *Crenella elegantula* Meek and Hayden, 1862\*
27. *Lithophaga ripleyana* Gabb, 1862\*
28. *Lithophaga conchafodentis* Gardner, 1916\*
29. *Inoperna carolinensis* Conrad, 1875\*

##### Order PTERIOIDA Newell, 1965

##### Suborder PTERIINA Newell, 1965

##### Superfamily PTERIOIDEA Gray, 1847

##### Family PTERIIDAE Gray, 1847

30. *Pteria petrosa* (Conrad, 1853)\*
31. *Pteria percompressa* Wade, 1926\*

##### Family BAKEVELLIIDAE King, 1850

32. *Gervilliopsis ensiformis* (Conrad, 1858)\*

##### Family INOCERAMIDAE Giebel, 1852

33. *Inoceramus proximus* Tuomey, 1854\*
34. *Inoceramus sagensis* Owen, 1852\*

##### Family ISOGNOMONIDAE Woodring, 1925

35. *Isognomon periridescens* (Wade, 1926)\*

##### Family PULVINITIDAE Stephenson, 1941

36. *Pulvinites argentea* Conrad, 1858\*

##### Superfamily PECTINOIDEA Rafinesque, 1815

- Family PECTINIDAE Rafinesque, 1815
37. *Camptonectes burlingtonensis* Gabb, 1860\*
  38. *Pecten argillensis* Conrad, 1860\*
  39. *Pecten simplicius* Conrad, 1860\*
  40. *Neithea (Neitheopsis) quinquecostatus* (Sowerby, 1814)\*
- Superfamily ANOMIOIDEA Rafinesque, 1815
- Family ANOMIIDAE Rafinesque, 1815
41. *Anomia argentaria* Morton, 1833\*
  42. *Anomia perlineata* Wade, 1926\*
  43. *Anomia tellinoides* Morton, 1833\*
  44. *Paranomia scabra* (Morton, 1834)\*
- Suborder OSTREINA Férussac, 1822
45. *Ostrea plumosa* Morton, 1833\*
  46. *Ostrea tecticosta* Gabb, 1860\*
  47. *Ostrea monmouthensis* Weller, 1907\*
  48. *Ostrea falcata* Morton, 1827\*
  49. *Ostrea penegemnea* Wade, 1926
  50. *Ostrea mcnairyensis* Wade, 1926\*
  51. *Exogyra cancellata* Stephenson, 1914\*
  52. *Exogyra costata* Say, 1820
  52. *Pycnodonte vesicularis* (Lamarck, 1806)\*
- Subclass PALAEOHETERODONTA Newell, 1965 51.
- Order TRIGONIOIDA Dall, 1889
- Superfamily TRIGONIOIDEA Lamarck, 1819
- Family TRIGONIIDAE Lamarck, 1819
54. *Linotrigonia thoracica* Morton, 1834\*
  55. *Linotrigonia eufalensis* Gabb, 1860\*
- Subclass HETERODONTA Neumayr, 1884
- Order VENEROIDA H. & A. Adams, 1856
- Superfamily LUCINOIDEA Fleming, 1828
- Family LUCINIDAE Fleming, 1828
56. *Lucina ripleyana* Wade, 1926\*
- Family MACTROMYIDAE Cox, 1929
57. *Unicardium concentricum* Wade, 1926\*
- Superfamily CARDITOIDEA Fleming, 1820
- Family CARDITIDAE Fleming, 1828
58. *Vetericardia crenalirata* (Conrad, 1860)\*
  59. *Vetericardia subangulata* Wade, 1926\*
  60. *Vetericardia gregaria* (Meek and Hayden, 1856?)\*
  61. *Vetericardia subcircula* Wade, 1926\*
- Superfamily CRASSATELLOIDEA Férussac, 1822
- Family CRASSATELLIDAE Férussac, 1822
62. *Crassatella vadosus* (Morton, 1834)\*
  63. *Crassatella gardnerae* Harbison, 1945
  64. *Crassatella linteus* (Conrad, 1860)\*
  65. *Scambula perplana* Conrad, 1869\*
- Superfamily CARDIOIDEA Lamarck, 1809
- Family CARDIIDAE Lamarck, 1809
66. *Granocardium (Criocardium) dumosum* (Conrad, 1870)\*
  67. *Cardium tenuistriatum* (Whitfield, 1885)\*
  68. *Cardium kummeli* Weller, 1907\*
  69. *Protocardia (Pachycardium) stantoni* (Wade, 1926)\*
70. *Protocardium parahillana* Wade, 1926\*
- Superfamily MACTROIDEA Lamarck, 1809
- Family MACTRIDAE Lamarck, 1809
71. *Cymbophora gracilis* (Meek and Hayden, 1860)\*
- Superfamily SOLENOIDEA Lamarck, 1809
- Family CULTELLIDAE Davies, 1935
72. *Leptosolen biplicata* Conrad, 1858\*
- Superfamily TELLINOIDEA de Blainville, 1814
- Family TELLINIDAE de Blainville, 1814
73. *Tellina multiconcentrica* Wade, 1926\*
  74. *Aenona eufalensis* Conrad, 1860\*
  75. *Linearia metastrata* Conrad, 1860\*
  76. *Linearia ornatissima* Weller, 1907\*
  77. *Liothyris (Liothyris) carolinensis* Conrad, 1875\*
  78. *Tellinimera eborea* Conrad, 1860\*
- Family I CANOTIIDAE Casey, 1961
79. *Icanotia pulchra* Wade, 1926\*
- Superfamily DREISSENOIDEA Gray in Turton, 1840
- Family DREISSENIDAE Gray in Turton, 1840
80. *Dreissensia tippiana* Conrad, 1858\*
- Superfamily ARCTICOIDEA Newton, 1891
- Family ARCTICIDAE Newton, 1891
81. *Artica incerta* (Wade, 1926)\*
  82. *Etea carolinensis* Conrad, 1875\*
  83. *Veniella conradi* (Morton, 1833)\*
  84. *Tenea parilis* Conrad, 1860\*
- Superfamily GLOSSOIDEA Gray, 1847
- Family GLOSSIDAE Gray, 1847
85. *Isocardia (=Glossus) conradi* Gabb, 1860\*
- Superfamily VENEROIDEA Rafinesque, 1815
- Family VENERIDAE Rafinesque, 1815
86. *Aphrodina tippiana* Conrad, 1858\*
  87. *Aphrodina cretacea* (Conrad, 1870)\*
  88. *Aphrodina eufaulensis* (Conrad, 1860)\*
  89. *Cyclina parva* Gardner, 1916\*
  90. *Cyclina magna* Wade, 1926\*
  91. *Cyclina parva* Gardner, 1916\*
  92. *Cyclina magna* Wade, 1926\*
  93. *Cyprimeria alta* Conrad, 1875\*
  94. *Legumen planulatum* (Conrad, 1853)\*
- Order MYOIDA Stoliczka, 1870
- Suborder MYINA Stoliczka, 1870
- Superfamily MYOIDEA Lamarck, 1809
- Family CORBULIDAE Lamarck, 1818
95. *Corbula monmouthensis* Gardner, 1916\*
  96. *Corbula paracrassa* Wade, 1926\*
  97. *Corbula willardi* Wade, 1926\*
  98. *Caesticorbula crassiplica* Gabb, 1860\*
  99. *Corbulamella suffalciata* Wade, 1926\*
- Superfamily GASTROCHAENOIDEA Gray, 1840
- Family GASTROCHAENIDAE Gray, 1840



100. *Gastrochaena americana* Gabb, 1860\*  
 Superfamily HIATELLOIDEA Gray, 1824  
 Family HIATELLIDAE Gray, 1824  
 101. *Panope decisa* Conrad, 1853\*  
 Suborder PHOLADINA H. & A. Adams, 1858  
 Superfamily PHOLADOIDEA Lamarck, 1809  
 Family PHOLADIDAE Lamarck, 1809  
 102. *Martesia truncata* Wade, 1926\*  
 103. *Martesia procurva* Wade, 1926\*  
 Family TEREDINIDAE Rafinesque, 1815  
 104. *Teredo rectus* Wade, 1926\*  
 Order HIPPURITOIDA Newell, 1965  
 Superfamily HIPPURITOIDEA Gray, 1848  
 Family CAPRINIDAE d'Orbigny, 1850  
 105. *Caprinella coraloidea* Hall and Meek, 1854\*  
 Subclass ANOMALODESMATA Dall, 1889  
 Order PHOLADOMYOIDA Newell, 1965  
 Superfamily PHOLADOMYOIDEA Gray, 1847  
 Family PHOLADOMYIDAE Gray, 1847  
 106. *Pholadomya occidentalis* Morton, 1833\*  
 107. *Pholadomya conradi* Gardner, 1860\*  
 Superfamily PANDOROIDEA Rafinesque, 1815  
 Family LATERNULIDAE Hedley, 1918  
 108. *Anatimya lata* (Whitfield, 1885)\*  
 Family PERIPLOMATIDAE Dall, 1895  
 109. *Periplomya elliptica* (Gabb, 1862)\*  
 110. *Periplomya applicata* Conrad, 1858\*  
 Superfamily POROMYOIDEA Dall, 1886  
 Family POROMYIDAE Dall, 1886  
 111. *Liopistha protexta* (Conrad, 1853)\*  
 112. *Liopistha inflata* Whitfield, 1885\*  
 Superfamily CLAVAGELLOIDEA d'Orbigny, 1844  
 Family CLAVAGELLIDAE d'Orbigny, 1843  
 113. *Ascaulocardium armatum* (Morton, 1834)\*  
 Class SCAPHOPODA Bronn, 1862  
 Family DENTALIIDAE Gray, 1834  
 1. *Dentalium intercalatum* Wade, 1926\*  
 2. *Dentalium inornatum* Wade, 1926\*  
 3. *Dentalium ripleyanum* Gabb, 1860\*  
 Family SIPHONODENTALIIDAE Simroth, 1894  
 4. *Cadulus orbmutus* (Conrad, 1869)\*  
 Class CEPHALOPODA  
 Order NAUTILIDEA Agassiz, 1847  
 Superfamily NAUTILOIDEA de Blainville, 1825  
 1. *Eutrophoceras planoventer* Stephenson, 1941\*  
 Order AMMONOIDEA Zittel, 1884  
 Suborder AMMONITINA Hyatt, 1899  
 Superfamily DESMOCERATOIDEA Zittel, 1895  
 Family PACHYDISCIDAE Spath, 1922  
 2. *Pachydiscus (Pachydiscus) arkansanus* (Stephenson, 1941)\*  
 Suborder ANCYLOCERATINA Wiedmann, 1966

- Superfamily TURRILITOIDEA Gill, 1871  
 Family BACULITIDAE Gill, 1871  
 3. *Baculities claviformis* Stephenson, 1941\*  
 4. *Baculities undatus* Stephenson, 1941\*  
 Family DIPLOMOCERATIDAE Spath, 1926  
 5. *Lewyites oronensis* (Lewy, 1969)\*  
 6. *Parasolenoceras pulcher* Cobban and Kennedy, 1985\*  
 7. *Solenoceras reesidei* Stephenson, 1941\*  
 8. *Solenoceras texanum* (Shumard, 1861)\*  
 Family NOSTOCERATIDAE Hyatt, 1894  
 9. *Cirroceras conradi* (Morton, 1841)\*  
 10. *Didymoceras navarroense* (Shumard, 1861)  
 11. *Didymoceras* sp.\*  
 12. *Nostoceras (Nostoceras) approximans* (Conrad, 1855)\*  
 13. *Nostoceras (Nostoceras) helicinum* (Shumard, 1861)\*  
 14. *Nostoceras (Nostoceras) hyatti* Stephenson, 1941\*  
 15. *Solenoceras nitidum* Cobban, 1974  
 16. *Exiteloceras* sp.  
 17. *Axonoceras sohli* Cobban, 1974  
 18. *Axonoceras?* sp.  
 Family SCAPHITIDAE Gill, 1871  
 19. *Discoscaphites* sp.\*  
 20. *Hoploscaphites* sp.\*  
 21. *Jeletzkytes reesidei* (Wade, 1926)\*

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