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PLEISTOCENE LACUSTRINE DEPOSITS AND MOLLUSCAN PALEONTOLOGY OF WESTERN OHIO, EASTERN INDIANA AND SOUTHERN MICHIGAN

*MARK J. CAMP**

ABSTRACT

A paleoecologic study of Late Wisconsin lacustrine deposits at Castalia Prairie, Rushcreek Lake, and Silver Lake in Ohio; Fourmile Lake in Michigan; and Big Turkey Lake and Wabee Lake in Indiana, using short stratigraphic sections, revealed that contained molluscan faunas were similar in composition. *Amnicola limosa, A. lustrica, Valvata tricarinata, Gyraulus parvus, Helisoma anceps striatum, Physa gyrina hildrethiana,* and Sphaeriidae occurred in each of the deposits with the exception of Castalia Prairie. The latter lacked members of the Amnicolidae and Valvatidae, families which require permanent water bodies. The Castalia Prairie deposit is thought to have consisted of shallow temporary lakes fed by springs. The other lacustrine deposits were formed in typical permanent marl lakes.

Amnicola lustrica and *Helisoma anceps* no longer live in Ohio, Indiana, and southern Michigan lakes because with the retreat of glacier ice northward, water temperatures rose, forcing organisms that preferred cooler water to migrate northward into Wisconsin, Minnesota, northern Michigan, and Canada. *Gyraulus parvus* was the most significant mollusk, occurring in large numbers in each deposit. *Goniobasis livescens* was common only in the Wabee Lake deposit, where it occurred in oncolites. *Pomatiopsis lapidaria* was found only in the Castalia Prairie section, recording the presence of flowing water, probably from springs.

The stratigraphic sections revealed the slow filling in of the lakes as a result of marl buildup, influx of terrigenous detritus, encroachment of shoreline plants, and drainage.

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* Department of Geology, University of Toledo, Ohio. Present address, Department of Geology and Mineralogy, Ohio State University, Columbus, Ohio 43210.

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INTRODUCTION

NATURE AND PURPOSE

A study was made of six Late Wisconsin lacustrine deposits located in Ohio, Michigan, and Indiana with emphasis on the quantitative distribution and paleoecology of the molluscan fauna. The resulting information was used in the reconstruction of environmental conditions existing in each area during the interim recorded by each stratigraphic section.

STUDY AREA

The six localities studied were selected from early state geologic reports, soil surveys, and topographic quadrangle maps for areas once mined for marl—a clay-size lacustrine sediment rich in calcium carbonate. They are Castalia Prairie (Erie County), Rushcreek Lake (Logan County), and Silver Lake (Miami County) in Ohio; Fourmile Lake (Washtenaw County) in Michigan; and Big Turkey Lake (Lagrange and Steuben Counties) and Wabee Lake (Kosciusko County) in Indiana. These localities are indicated on Figure 1.

GENERAL PLEISTOCENE GEOLOGY AND NATURAL HISTORY OF THE STUDY AREA

The study area (Figure 1) was affected by Nebraskan glaciation, but deposits appear to have been deeply buried or destroyed by later ice advances. Till of probable Kansan age has been identified in the vicinity of Cincinnati, Ohio (La Rocque, 1966, p. 14). Illinoian deposits are not known from the study area, but occur in a lobate band from eastern central Ohio to Cincinnati; across southeastern Indiana; into south-central Indiana; and through extreme southwestern Indiana. The southeastern part of Ohio is unglaciated, as is south-central Indiana.

Wisconsin glacial features dominate the study area. Three major lobes of Wisconsin glaciation—the Huron-Erie, Saginaw, and Lake Michigan lobes, covered this region. The Wisconsin ice sheets retreated and advanced in a lobate pattern forming arcuate end moraines across the area. In northern Indiana and southern Michigan the Huron-Erie lobe overrode Saginaw Lobe deposits (Zumberge, 1960, p. 1182). When the Huron-Erie lobe retreated into the Lake Erie basin, snd then into Canada, a series of glacial lakes ancestral to Lake Erie formed along the ice front. Waters from these lakes inundated Wisconsin features in northwestern Ohio and southeastern Michigan. As the ice mass moved slowly out of the area, ancestral Lake Erie was lowered in elevation exposing large lake plains of silt and clay.

Smaller lakes dotted the post-Wisconsin landscape of the study area, but were concentrated in extreme northern Indiana and southern Michigan. These smaller postglacial lakes were formed in a number of ways. Many resulted from the melting of buried or partially buried stagnant ice blocks in outwash or terminal moraine deposits (Prescott, 1962, p. 14). Some formed from the irregular deposition of ground moraine

(Blatchley and Ashley, 1900, p. 35). Low areas in the ground moraine became lake basins if the bottom material was impervious to water. Others were created from the damming of preglacial valleys or formed in basins made by the parallel arrangement of end moraines (Prescott, 1962, p. 14). Many of these lakes became a part of the newly developed post-Wisconsin drainage system. Many others were slowly to evolve back into terrestrial environments. These lakes were drained either by low level natural outlets or drainage ditches, or they were filled in by the process of hydroseric succession (Blatchley and Ashley, 1900, p. 36-37).

Hydroseric succession involves a combination of factors including plant encroachment on the lake, decrease in water supply, influx of terrigenous detritus, and the deposition of marl from certain aquatic plants or from springs. The typical lake is encircled by several concentric plant communities which move slowly inward, restricting, and finally eliminating, the open water area (Figure 2). The open water is dominated by plankton and, near shore, by *Lemna, Wolffia,* and various genera of algae (Dachnowski, 1912, p. 229). *Chara,* if it occurs, is an open water bottom dweller. Immediately surrounding the open water is a zone of semi-aquatic plants including for example, *Nymphaea, Nuphar,* and *Polygonus* (Dachnowski, 1912, p. 227). The next zone shoreward is an association of marsh plants which may consist of *Calla, Decodon, Eleocharis, Phragmites, Typha,* and others (Dachnowski, 1912, p. 231-235). Surrounding the fringing marsh zone is a shrub association with *Rhus, Alnus,* and *Salix* (Dachnowski, 1912, p. 249). Behind the shrub association exists a swamp forest containing *Quercus, Acer,* and *Larix.* Finally, in the drier regions about the hydrosere is a mesophytic forest zone. In the study area, this zone is dominated by *Ulmus, Acer,* and *Fraxinus* (Dachnowski, 1912, p. 256).

It is not known when mollusks and other invertebrates entered the small lakes of the study area. It may have been while the ice sheet was still in the immediate srea or long after it had retreated. They may have been washed into the environment through connected waterways or marshy lowlands during flood periods. Others may have been transported by aquatic or semi-aquatic mammals, birds, reptiles, and amphibians (La Rocque, 1966, p. 5). Thus, the dispersal of mollusks and other invertebrates into the newly opened habitats was probably a slow, but ultimately profound change.

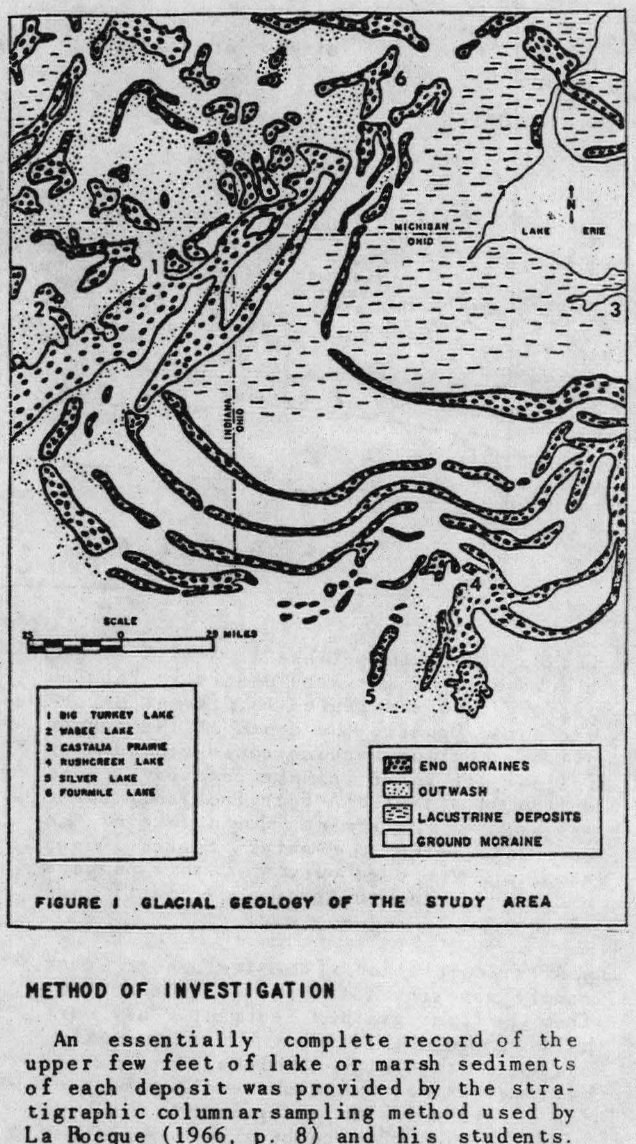
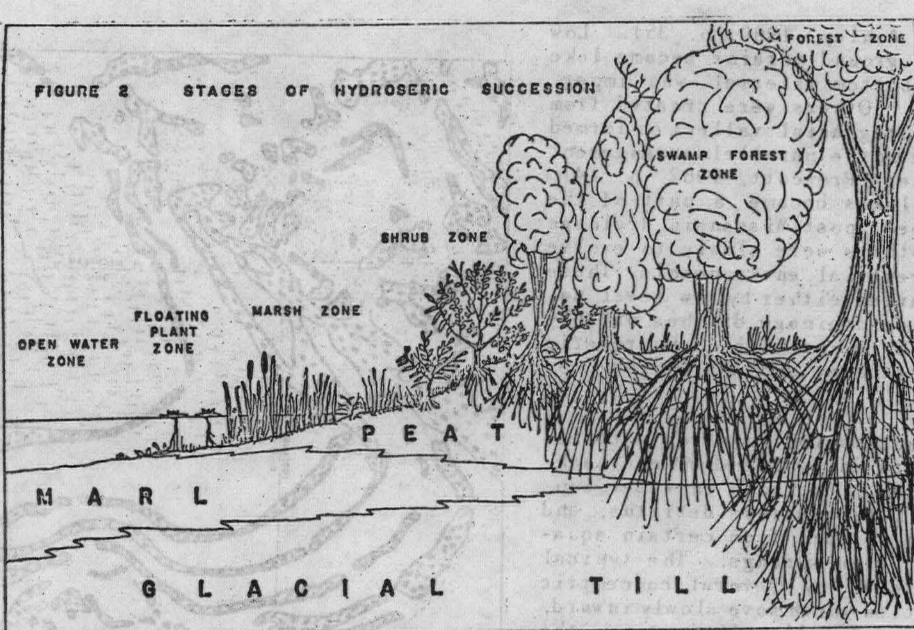


FIGURE 1 GLACIAL GEOLOGY OF THE STUDY AREA

METHOD OF INVESTIGATION

An essentially complete record of the upper few feet of lake or marsh sediments of each deposit was provided by the stratigraphic columnar sampling method used by La Rocque (1966, p. 8) and his students. Environmental inferences drawn from analysis of these sediments and their fossils are applicable only to the immediate vicinity of the stratigraphic section. Ideally, a lacustrine deposit should be sampled in several areas; in this study, time limited the sampling to just one stratigraphic section per lake. This does not necessarily decrease the value of the data if its limitations are realized.

The sampling techniques utilized a spade in the excavation of a pit and the removal of a column of sediment with surface dimensions of 12 inches by 12 inches. A sediment sample was taken normally every 2



inches of depth. These 12 X 12 X 2 inch blocks of sediment were placed in labeled plastic bags and sealed to prevent moisture loss. Usually the depth of the sample pit was shallow because rapid groundwater inflow prevented sample recovery beyond depths of 3 feet. A four-foot soil auger was used to determine the nature of the sediment below the water table. Auger sampling was used only for this purpose and not for the collection of fossil specimens.

After completion of the field work, each sample was sieved to separate the fossils from the finer grained sediment. Only one-half of the collected sample was sieved because of the large sample size. The remaining portion of each sample was saved for possible pollen analysis in the future. Each sample to be sieved was first soaked in a pan of water overnight to disaggregate the sediment. Then each was carefully washed through 6.35, 2.00, 0.841, and 0.420 mm sieves by applying a slow stream of water and slightly agitating the sieves. The largest mesh sieve caught large shells, oncolites, and pebbles; the next held immature and small adult shells; and the smallest mesh sieve held ostracodes, plant seeds, and shell fragments. The pan fraction, which contained ostracodes and shell fragments, also was saved.

Each sieved sample was labeled and spread to dry on paper towels laid over screens. They were placed in labeled plastic bags for storage after drying. Each sieve fraction was then picked for fossil mollusks, ostracodes, and plant remains. A similar volume of each was picked under a magnifier or, for the finer fractions, under a binocular microscope. Each fraction was picked for a time interval of 30 minutes. The large mesh fractions were picked by hand; the smaller ones were separated by an electric sample picker and a dampened camel-hair artists' brush.

The picked fossil assemblages were then identified to species and placed in labeled gelatin capsules and coin envelopes for future reference. The smallest mesh sieve and pan fraction yielded mostly unidentifiable shell fragments and immature specimens. Commonly, immature specimens of mollusks have not developed their total number of shell whorls and could be identified as different species, although they are the same species as those in the larger mesh fractions. Thus, in this study, 2 or 3 specimens of each fossil species found in the fine sediment fractions were removed and mounted on labeled micropaleontology slides. The immature mollusks were assumed to be the same species as those found in the coarser fractions. The main reason for collecting the finer sediment fractions was to provide data on ostracodes and plant seeds in the sample.

QUANTITATIVE DISTRIBUTION

A chart was prepared for each of the six localities showing the fauna and the changes in percentage abundance throughout the stratigraphic section. In this study several terms are used for describing the occurrence of mollusks in an environment. First, they may be indigenous species or intruders. Indigenous species are those species that lived in the environment where they are preserved. They are found consistently throughout the section, often in large percentages. The identity of species must be taken into account, however, for some species are known to be extremely prolific (e. g. *Valvata tricarinata, Fossaria,* and *Gyraulus*. La Rocque, 1966, p. 18) whereas others (e. g. freshwater limpets) are very scarce even in favorable habitats. Intruders were foreign to the area where they are preserved. They are usually scattered throughout the stratigraphic section and are less abundant than the indigenous species. All terrestrial snails are considered intruders in a lacustrine deposit.

Among the indigenous species and intruders, certain species may be considered significant species. A significant species refers to one that makes up a significant volume of the sample, that is, it is either extremely abundant or of a large shell size (e. g. *Helisoma*). Thus, not all indigenous species are necessarily significant nor are all intruders necessarily insignificant.

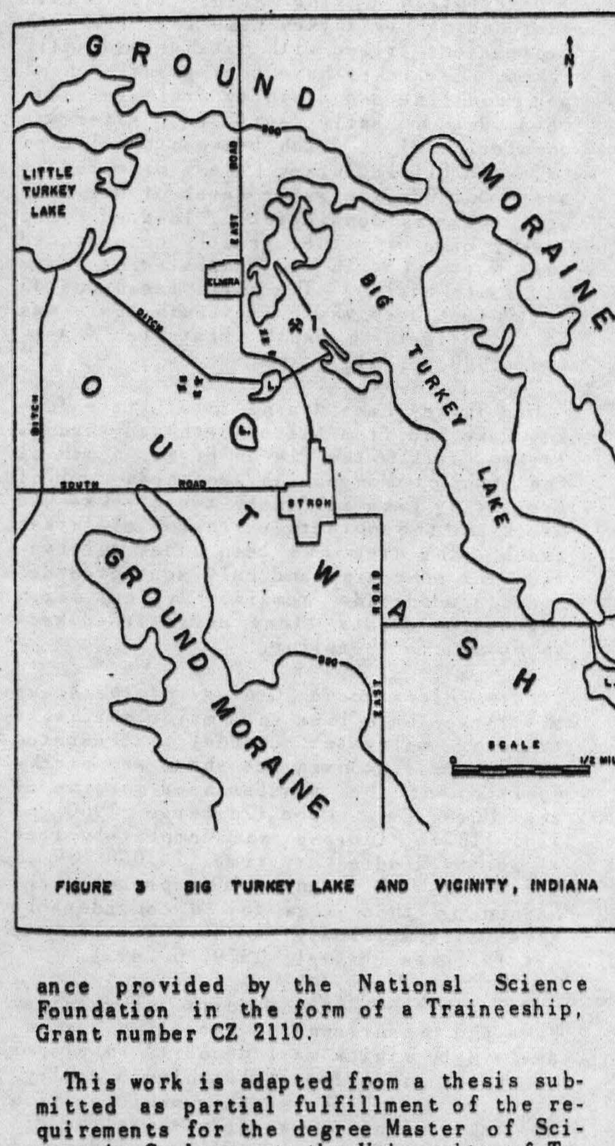


FIGURE 3 BIG TURKEY LAKE AND VICINITY, INDIANA

ACKNOWLEDGEMENTS

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STRATIGRAPHY AND PALEONTOLOGY

BIG TURKEY LAKE DEPOSIT, STROH, INDIANA

Location of Deposit. Big Turkey Lake lies on the border of Lagrange and Steuben Counties of Indiana, just east of the town of Stroh. A stratigraphic section was obtained from the eastern shoreline, directly opposite the abandoned plant of the Wabash Portland Cement Company (Figure 3).

Description of the Area. The terrain surrounding Big Turkey Lake is hilly, with depressions filled with marshes and small lakes. The lakes have been greatly changed in outline and depth by drainage channels dug by early settlers. After the completion of a ditch between Big Turkey Lake and Little Turkey Lake, ¾ mile to the west in 1900, the water level of Big Turkey Lake was considerably lowered. Big Turkey Lake was then greatly constricted just north of Stroh and consisted of north and south basins. The north basin was 45 to 50 feet deep, while the south basin was 25 to 75 feet in depth (Blatchley & Ashley, 1900, p. 111).

Big Turkey Lake drains into Little Turkey Lake and from there, northward through Turkey Creek to the Pigeon River, south of the town of Mongo. The southern end of Big Turkey Lake is fed by two creeks—Mud Creek and the southern extension of Turkey Creek. The area has been under cultivation for some time and only scattered deciduous woodlands remain. Typical marsh vegetation exists along undisturbed sections of the shoreline.

Late Pleistocene Geology of the Area. Big Turkey Lake lies in a major northwest trending meltwater channel that existed while the Wisconsin ice sheet was at the position of the Mississinewa moraine of the Huron-Erie Lobe (Zumberge, 1960, p. 1181-1182). Indiana was completely free of ice by Middle Cary time (14,000 B.P.), but blocks of stagnant ice probably remained in this area for a considerable time, melting slowly to form kettles and kettle lakes (Wetzel, 1970, p. 495).

Stratigraphy of the Deposit. Big Turkey Lake and the surrounding shoreline are underlain by a thick marl deposit, in places as thick as 45 feet (Blatchley & Ashley, 1900, p. 112). The stratigraphic section was taken along the western shoreline directly east of the old office building of the cement company in an area devoid of vegetation. Dull-gray-brown fossiliferous marl was continuous to the bottom of the 4-foot pit. Testing with the auger revealed at least another 4 feet of marl below this.

Unit	*Description*	*Thickness (Inches)*
1	Dull-gray-brown marl, fossiliferous, plant remains, fine-grained, some tufa-coated reeds in upper part. (Collections Nos. 1-24).	48

Faunal Abundance. All species are considered indigenous except *Fossaria obrussa decampi*, *Helisoma trivolvis*, and *Stagnicola* cf. *S. umbrosa*. No terrestrial snails were found. Naiad fragments are scattered throughout the section. Significant species are *Amnicola limosa*, *A. lustrica*, *Valvata tricarinata*, *Gyraulus parvus*, and *Helisoma anceps striatum*. The ctenobranchs are particularly favored in the Big Turkey Lake environment. Seven species of aqustic pulmonates are found, but are proportionately less common than the three ctenobranch species. *Sphaerium* occurs in all but the first four collections; *Pisidium* occurs only in the first eleven collections. Naiad fragments seem to be present in about the same abundance throughout. The ostracodes, *Candona* and *Cypridopsis*, were present as traces in each collection. Insect exoskeletons were found in trace amounts in the lower half of the section.

Floral Abundance. At a depth of 1 foot from the top of the section, plant remains become common. Calcium carbonate coated stems of *Phragmites* various rush genera, *Chara* strands and oogonia are common below this depth. Carbonate coatings were found only in collections 6 through 13. Seeds were scarce; only *Lotus* was identified in collection 24.

Nature of the Environment. The mollusks of the Big Turkey Lake deposit appear to have lived in a shallow, somewhat protected zone. The absence of land snails indicates that the environment was at a considerable distance from favorable habitats of terrestrial mollusks. The significant aquatic mollusk species record an approximate depth from 3 to 6 feet (Zimmerman, 1960; Mowery, 1961). The lake experienced moderate wave action, but the bottom environment was little disturbed in this zone because shell fragments were not present in large percentages in the samples. Fine-grained marl accumulated from decomposing algal remains. *Chara* and *Nitella* was probably the dominant bottom vegetation. Abundant shells of *Amnicola* record non-turbid water (Frye and Leonard, 1967, p. 434). During storms, however, the fine-grained substratum may have been stirred up, imparting a cloudy appearance to the water. The presence of abundant ctenobranchs, particularly *Amnicola*, probably indicates a cool water temperature (Frye and Leonard, 1967, p. 433). *Helisoma anceps striatum* is also an inhabitant of cooler water (La Rocaue, 1968, p. 501). An ice sheet still existed to the north of Big Turkey Lake, creating a somewhat cool-

TABLE 1 PLEISTOCENE FAUNA AND FLORA OF BIG TURKEY LAKE DEPOSIT, STROH, INDIANA

DEPTH(INCHES)	2	4	6	8	10	12	14	16	18	20	22	24
NUMBER OF INDIVIDUALS	357	217	280	378	391	394	512	407	490	364	353	321
CTENOBRANCHS												
Amnicola limosa	.8	.5	1.1	1.3	6.1	6.6	15.0	14.0	7.6	10.4	9.9	10.6
Amnicola lustrica	27.7	14.7	26.8	25.1	29.7	21.1	15.2	19.9	19.6	11.5	16.4	12.8
Valvata tricarinata	15.7	15.2	18.2	29.6	31.7	27.9	30.3	18.7	23.3	17.0	31.4	25.2
AQUATIC PULMONATES												
Fossaria obrussa decampi	9.2	12.9	6.1	.3	1.5	2.0	1.0	5.9	2.6	4.1	7.1	11.8
Gyraulus parvus	35.8	39.6	36.8	26.4	19.7	34.5	29.9	32.7	26.9	34.6	22.7	22.4
Helisoma anceps striatum	5.0	9.2	6.8	8.7	3.1	3.6	4.1	3.4	3.1	5.2	3.4	4.7
Helisoma trivolvis								.7	3.1	1.4	1.1	.9
Physa gyrina hildrethiana	1.7	4.1	1.4	5.3	3.8	2.3	1.9	2.4	10.4	13.2	4.5	4.0
Promenetus exacuous	.8	1.8	.4		.8	.5			1.2			
Stagnicola palustris	1.4					.2	.4	.2		.3	.3	.6
SPHAERIIDAE												
Pisidium sp., Sphaerium sp.	1.7	1.8	3.5	3.2	3.6	1.3	2.1	2.0	2.2	2.2	3.1	6.8
NAIADES(FRAGMENTS)	T				T	T						
OSTRACODS(Candona, Cypridopsis)	T	T	T	T	T	T	T	T	T	T	T	T
INSECT REMAINS									T			T
CHARA OOGONIA							T		T		T	
$CaCO_3$ COATED REEDS						X	X	X	X	X	X	
UNIDENTIFIABLE PLANT REMAINS	T						X				X	X
LITHOLOGY: Gray-brown marl	X	X	X	X	X	X	X	X	X	X	X	X

DEPTH(INCHES)	26	28	30	32	34	36	38	40	42	44	46	48
NUMBER OF INDIVIDUALS	253	329	311	307	321	306	340	278	258	204	235	263
CTENOBRANCHS												
Amnicola limosa	12.2	8.2	9.6	16.3	11.2	13.0	15.9	11.5	15.1	10.8	4.3	3.8
Amnicola lustrica	14.2	19.1	1.2	15.3	20.9	9.2	17.6	14.4	9.7	16.2	23.8	30.0
Valvata tricarinata	23.3	32.2	34.1	31.9	28.7	33.7	31.2	35.2	31.0	24.5	31.0	25.1
AQUATIC PULMONATES												
Fossaria obrussa decampi	7.9	2.7	2.9	.7	.3	10.1	3.5	3.2	7.0	6.4	.8	3.8
Gyraulus parvus	22.9	24.3	22.8	24.4	25.2	18.0	22.0	25.2	26.7	28.4	28.9	23.2
Helisoma anceps striatum	3.9	4.6	2.9	.6	3.4	2.3	2.9	.4	.4	1.0	3.8	5.7
Helisoma trivolvis	2.4	1.2	3.2	4.6	2.5	1.6	1.5	1.1	1.2	1.0		.4
Physa gyrina hildrethiana	3.6	2.7	6.1	1.6	2.5	6.5	.3	4.3	1.6	3.4	.4	2.3
Promenetus exacuous	1.2										2.1	1.5
SPHAERIIDAE												
Pisidium sp., Sphaerium sp.	8.3	4.9	7.1	4.6	5.3	5.6	5.0	4.7	7.4	8.3	4.7	4.2
NAIADES(FRAGMENTS)	T	T			T						T	T
OSTRACODS(Candona, Cypridopsis)	T	T	T	T	T	T	T	T	T	T	T	T
INSECT REMAINS	T	T	T	T	T	T	T	T	T	T		T
CHARA OOGONIA	T	T	T	T	T	T	T	T	T	T	T	T
UNIDENTIFIABLE PLANT REMAINS	X	T	X	X	X	X	X	X	X	X	X	X
LITHOLOGY: Gray-brown marl	X	X	X	X	X	X	X	X	X	X	X	X

T Trace

X Present in large amounts

er climate than exists in the area today. Today, molluscan faunas similar to those of Late Wisconsin age at Big Turkey Lake are found only in more northern lakes, such as those located in Minnesota, Wisconsin, and Canada.

A study (Wetzel, 1970) of sedimentary chlorophyll and carotenoid degradation in the sediments of nearby Pretty Lake located three miles to the west, provided some interesting data which may be used in interpreting the early history of Big Turkey Lake. Analyses of organic matter, C-14, and pollen samples from cores taken at Pretty Lake indicate a warming interval at about 11,000 B.P., which corresponds with the retreat of the Valders Substage in Michigan (Wetzel, 1970, p. 495). *Picea* was the dominant vegetation until this time, when it was replaced by *Pinus*. *Quercus, Fagus,* and *Ulmus* replaced *Pinus* about 10,500 B.P. (Wetzel, 1970, p. 497). Wetzel (1970, p. 496) has also reported that between 6,500 and 5,500 B.P. and after 200 B.P. the carbonate deposition rate greatly increased and the deposition of organic matter decreased. Thus, it is thought that major marl deposition at Big Turkey Lake began approximately 5,000 B.P. and continued with only minor fluctuations to the present day.

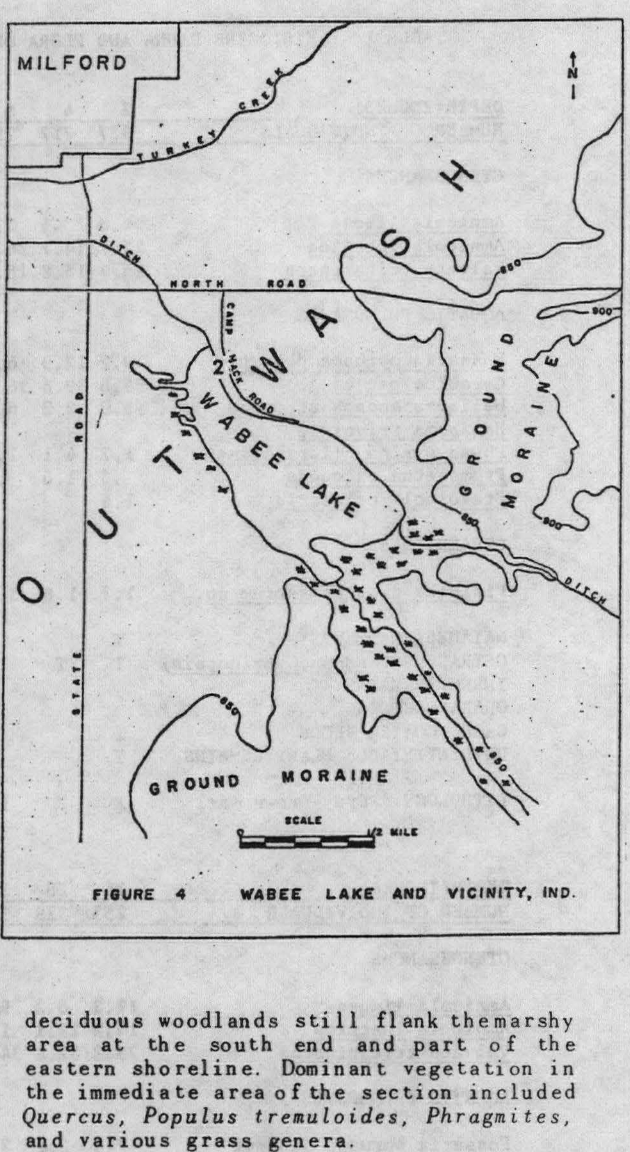

FIGURE 4 WABEE LAKE AND VICINITY, IND.

WABEE LAKE DEPOSIT, MILFORD, INDIANA

Location of Deposit. Wabee Lake is located one mile south of the town of Milford in Kosciusko County, Indiana. A short stratigraphic section was obtained from the northwest shoreline in a small marsh at the southern end of a roadside park along Camp Mack Road (Figure 4).

Description of the Area. Wabee Lake is bordered by flat-lying farmlands on the north and west, a marsh on the south, and an upland region to the east. The greatest depth in the lake is 51 feet, just off the central northeastern shore. The outlet is to the northwest through an artificial channel to Turkey Creek. The inlet is from Dewart Lake to the east, through a ditch entering at the easternmost corner of Wabee Lake. Artificial channels and channel straightenings have increased the drainage efficiency in this area. Abandoned marl pits of the Sandusky Portland Cement Company are present along the northwest shore of the lake.

Most of the natural forest growth on the north and west shores has been removed to permit farming and marl excavation, but deciduous woodlands still flank the marshy area at the south end and part of the eastern shoreline. Dominant vegetation in the immediate area of the section included *Quercus, Populus tremuloides, Phragmites,* and various grass genera.

Late Pleistocene Geology of the Area. The New Paris moraine of the Saginaw Lobe of Wisconsin glaciation is situated to the north and east of Wabee Lake (Leverett & Taylor, 1915, p. 138; Zumberge, 1960, map). The lake is surrounded by outwash deposits and occupies part of an old meltwater channel through which underfit Turkey Creek now flows. Wabee Lake appears to have formed from a stagnant ice block left when the ice was at the New Paris moraine in Early Cary time (Zumberge, 1960, chart).

Stratigraphy of the Deposit. Test boring made by the Indiana Portland Cement Company around 1900 indicated that more than 18 feet of marl lay beneath 8 inches of muck at the mouth of the Wabee Lake outlet (Blatchley and Ashley, 1900, p. 187). Marl of this thickness was also found underlying the immediate flatland to the west. Marl deposits on the northeastern side of the lake were found to be less than 18 feet in thickness (Blatchley and Ashley, 1900, p. 187).

The area chosen for the stratigraphic section was located approximately 700 feet southeast of the lake outlet. Four lithologic units were distinguished, as listed below.

Unit	*Description*	*Thickness (Inches)*
4	Marl, dark brown, fossiliferous plant remains. (Collections 1 to 3).	6
3	Marl, gray, fossiliferous, clayey. (Coll. 4).	2
2	Marl, yellow-brown, fossiliferous. Iron stains, with oncolites in lower part. (Collections 5 and 6).	4
1	Gravel, sandy, yellow-brown, with oncolites in upper part. (Collection 7).	4

Faunal Abundance. Indigenous species in the Wabee Lake deposit are *Amnicola limosa, A. lustrica, Goniobasis livescens, Fossaria obrussa decampi, Gyraulus parvus, Helisoma anceps striatum,* and *Pisidium* sp. Intruders are *Valvata tricarinata Physa* sp., Naiades, and nine species of terrestrial gastropods.

Goniobasis livescens shows an overall trend of increasing abundance downward in the section. *Gyraulus parvus* decreases in abundance from collection 1 to 7, as does *Helisoma anceps striatum.* The relative abundances of Wabee Lake mollusks show that *Gyraulus parvus* and *Goniobasis livescens* are the most significant forms.

Molluscan abundance is directly related to lithology in the Wabee Lake section. In unit 1, the sand and gravel horizon, mollusks are rare except in the uppermost part. *Goniobasis livescens* is the most characteristic species. Unit 2 contains a slightly more abundant molluscan fauna. *Goniobasis livescens* and *Amnicola lustrica* are again the dominant species, but *Fossaria obrussa decampi, Gyraulus parvus, Helisoma anceps striatum, Amnicola limosa, Valvata tricarinata,* and *Pisidium* sp. are more prevalent. Unit 3, a thin clayey marl, contains the greatest abundance of aquatic mollusks. Terrestrial gastropods are represented for the first time. Unit 4, the uppermost unit, contains 10 species of aquatic mollusks and 9 species of terrestrial mollusks. *Fossaria obrussa decampi, Gyraulus parvus,* and *Pisidium* sp. are the most significant species. Mollusks were the dominant members of the Wabee Lake fauna. Ostracodes of the genus *Candona* occur in trace amounts in collections 2 through 5. A trace of unidentified insect remains was found in Unit 4.

Floral Abundance. Plant remains are common in Units 4 and 3 and are present in trace amounts in Units 2 and 1. *Chara* strands and oogonia were found only in the lower part of Unit 3 and in the upper part of Unit 2. Seeds from *Polygonum, Bambucus,* and *Carex* were discovered in trace amounts in the upper three units.

Nature of the Environment. The mollusks of the Wabee Lake deposit inhabited a shallow, near shore area of a typical small post-glacial lake. The lake bottom was composed of glacial till which in certain areas was covered with algae. The water temperature was lower than that of present day Wabee Lake for *Amnicola lustrica* and *Helisoma anceps striatum* are found today only in more northern lakes.

During the deposition of Unit 1 the lake habitat was evidently not particularly favorable to mollusks. *Goniobasis livescens* was the most abundant species present. Adult specimens occur as the nuclei of oncolites; other species (which are smaller) and young *Goniobasis livescens* are found as free shells. Oncolites were found along the shoreline in an earlier study (Blatchley and Ashley, 1900, p. 187). The oncolites formed from the growth of algae on firm objects such as pebbles and shells. Algal mats probably were present on the shells of living *Goniobases,* but were prevented from completely enclosing the snail (Weiss, 1970). Upon death of individuals, the algae continued to grow and often plugged the apertures forming oncolites of a generally cone-shaped outline. The water was probably more than 3 feet in depth. Most mollusks are found in shallow water with sandy or muddy bottom. Wabee Lake, during this stage, had a gravelly bottom. *Goniobasis livescens* would tolerate such an environment (Krecker, 1924).

In Unit 2 *Goniobasis livescens* was still the most significant species, occurring again in oncolites. The water had shallowed and now supported more vegetation and mollusks. Fine-grained marl formed among decaying algal remains.

The marl of Unit 3 was then deposited, and together with encroaching marsh plants

TABLE 2 PLEISTOCENE FAUNA AND FLORA OF WABEE LAKE DEPOSIT, NEAR MILFORD, INDIANA

DEPTH (INCHES)	2	4	6	8	10	12	14
NUMBER OF INDIVIDUALS	65	94	93	279	257	208	122
CTENOBRANCHS							
Amnicola limosa		1.1	4.3	1.8	.4	.5	
Amnicola lustrica	6.2	3.2	18.3	23.6	21.8	23.0	20.5
Coniobasis livescens	1.5	6.4	6.4	4.6	14.0	36.0	32.0
Valvata tricarinata	4.6	2.1	1.1	3.6	3.1	1.0	
AQUATIC PULMONATES							
Fossaria obrussa decampi	12.3	15.9	14.0	13.3	19.1	11.0	13.9
Gyraulus parvus	53.8	37.2	35.5	40.1	35.8	20.2	22.1
Helisoma anceps striatum	4.6	3.2	2.2	4.6	1.2	2.9	2.4
Physa sp.				.7			
TERRESTRIAL PULMONATES							
Gastrocopta sp.	1.5	1.1	1.1				
Hawaiia minuscula	1.5						
Helicodiscus parallelus	1.5	1.1	2.2				
Oxyloma retusa				.4			
Retinella indentata	1.5	5.3	2.2				
Succinea avara	1.5						
Succinea ovalis	1.5	1.1		.4			
Vallonia pulchella		3.2	1.1				
Vertigo sp.		1.1					
SPHAERIIDAE							
Pisidium sp.	7.7	11.7	11.8	7.2	4.7	5.3	9.0
NAIADES (FRAGMENTS)		T			T		
OSTRACODS (Candona sp.)	T	T	T	T	T		
INSECT REMAINS	T						
PLANT SEEDS							
Bambucus sp.		T					
Carex sp.			T				
Polygonum sp.		T	T	T	T		
CHARA OOGONIA				T	T		
UNIDENTIFIED PLANT REMAINS	X	X	X	X	T	T	T
LITHOLOGY:							
Unit 4 Dark-brown Peat	X	X	X				
Unit 3 Gray Marl				X			
Unit 2 Gray-yellow Marl					X	X	
Unit 1 Yellow sandy Gravel							X

T Trace
X Present in large amounts

from the shoreline, began to fill in shallow areas. The area probably supported marsh growth far out into shallow waters. Either the shoreline was some distance away or terrestrial snail habitats were rare along the shore for terrestrial gastropod remains are very rare. *Oxyloma retusa* and *Fossaria obrussa decampi* may have lived above the water line on emergent reeds and grasses, but mollusks are mainly restricted to aquatic species.

Unit 4 represents the completion of the filling in process. A peat layer was deposited on top of the marl as marsh vegetation became extremely dense. *Gyraulus parvus*, which can withstand dry periods, was the most common molluscan inhabitant. *Helisoma anceps striatum* and *Pisidium* sp., which favor shallow plant-rich zones (La Rocque, 1967, 1968), were also significant during this stage. The great diversity of land snails indicates the proximity of shoreline.

CASTALIA PRAIRIE DEPOSIT, CASTALIA, OHIO

Location of the Deposit. Castalia Prairie lies north and west of the community of Castalia in Erie County, Ohio. A short stratigraphic section was obtained in a forest clearing 1.8 mile north and ¼ mile east of the intersection of Oxbo and Northwest roads in Resthaven Wildlife Area (Figure 5).

Description of the Area. Castalia Prairie is located in a lowland bordered on the north by Lake Erie and on the south by the Columbus Limestone escarpment. This study is concerned with a portion of the prairie located northwest of Castalia which was extensively strip-mined for marl and artificially drained. Today, the abandoned marl pits form the nucleus of the Resthaven Wildlife Area of the Ohio Department of Natural Resources, Division of Wildlife. The area has reverted back to beech-maple and mixed mesophytic woodlands (Sears, 1967, p. 80) and *Typha* marshes.

The manager of Resthaven Wildlife Area helped locate areas in the preserve that had not been disturbed by mining or plowing. The area selected for the stratigraphic section was a small grassy field in a clearing of a swamp forest. An examination of the vegetation indicated that this clearing was a filled-in hydrosere. The marsh zone had disappeared, but the shrub zone of hydroseric succession (Dachnowski, 1912, p. 248-250) was still present. *Phragmites*, *Calamagrostis*, *Phalaria*,

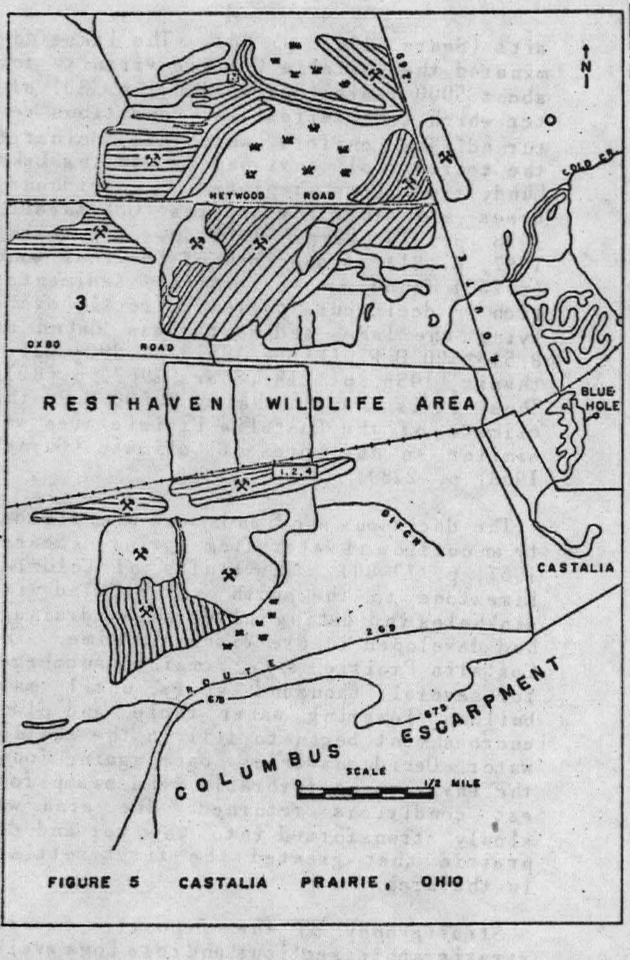

FIGURE 5 CASTALIA PRAIRIE, OHIO

Hypericum virginicum, *Solidago ohioensis*, *Daucus carota*, *Rhus* sp., and *Populus tremuloides* were identified in the immediate vicinity of the section. The swamp forest zone contained *Acer*, *Populus*, and *Quercus*. Sampson (1930, p. 349) has reported the following trees from the swamp environment: *Acer*, *Betula*, *Fraxinus*, *Nyssa*, *Populus*, *Quercus*, and *Ulmus*.

Late Pleistocene Geology of the Area. The Erie Lobe of the Wisconsin ice sheet covered the Castalia Prairie site until about 13,000 B. P. (Goldthwait *et al.*, 1965). As the ice began to recede slowly into the Erie Basin, a series of ice-dammed lakes formed along the southern edge (Leverett and Taylor, 1915; Hough, 1958; Forsyth, 1959; and others). With the continual retreat of the ice mass and the opening of new drainage outlets, the water level of these ancestral lakes generally lowered. The southern shorelines of these lakes supported coniferous forests as indicated by pollen found in the lake deposits (Sears, 1967, p. 86). The lakes dominated the Castalia Prairie vicinity for about 5000 years (Sears, 1967, p. 83) after which time terrestrial conditions returned. The conifers, which had dominated the terrestrial environment during Lake Lundy time, were replaced by deciduous trees and other angiosperms (Goldthwait, 1958, p. 218; Burns, 1958, p. 227; Sears, 1967, p. 81). A specimen of *Fraxinus* wood (c-256) found in terrestrial sediments, rich in deciduous pollen, directly overlying the lake sediments, was dated at 8,513±500 B.P. (Libby, 1951, p. 292; Goldthwait 1958, p. 218; Sears, 1967, p. 82). Thus, it is thought that by 8,500 B.P. the climate of the Castalia Prairie area was similar to the present climate (Burns, 1958, p. 228).

The deciduous woodlands were then flooded by an outflow of water from springs (Sears, 1967, p. 79-80). The bluffs of Columbus Limestone to the south are riddled with sinkholes indicating subterranean drainage had developed in pre-Wisconsin time. The Castalia Prairie site remained submerged for several thousand years, until marl buildup, lowering water table, and plant encroachment began to fill in the shallow water. Deciduous trees once again, found the environment favorable, and swamp forest conditions returned. The area was slowly transformed into the wet and dry prairie that greeted the first settlers in the area.

Stratigraphy of the Deposit. Several stratigraphic sections and core logs available for the Castalia Prairie vicinity are listed below. The numbers refer to their location on Figure 5.

Section No. 1

Description	*Thickness (Inches)*
Marl	12-14
Peat	10
Marl, cream, fine-grained, mainly Chara nodules	48
Coarse Chara nodules and tufa	4
Tufa	12
Peat, black slightly fibrous, shell marl at bottom	24
Marl, *Chara* remains, tufa	18
Peat	?
Blue clay	?

(Adapted from Dachnowski, 1912, p. 56-57)

Section No. 2

Description	*Thickness (Inches)*
Humus, gray	18
Marl, gray to buff, fossiliferous thin black peat layers (2-6")	18-48
Tufa, buff	12-24
Marl, gray, thick black peat layers (3")	6-12
Tufa, coating plants, mollusks, logs at base	12-30
Peat, forest bed, logs, stumps *in situ,* lower and upper parts calcareous, c-256 (8,513-500 B.P.)	
Sand, blue-gray	12-42
Clay	576

(Adapted from Goldthwait, 1958, p. 218)

Section No. 3

Description	*Thickness (Inches)*
Humus, black, fine-grained, fossiliferous	4
Marl, alternating layers of cream and gray, very sandy at base, *Chara* remains	36
Peat, black, fossiliferous, some sand, tufa, and wood fragments	8
Marl, cream, fossiliferous, tufa, *Chara* remains and nodules	12

(Clark, 1961, p. 21)

Section No. 4

Description	*Thickness (Inches)*
Muck, black, very friable, calcareous	0-7
Muck, very dark gray, fine-grained very friable, strongly calcareous	7-11
Marl, light gray, prominent mottles of yellowish brown, coarse-grained, very friable	11-60

(Adapted from Redmond *et al.*, 1971, p. 150)

The author's short stratigraphic section (3) from Castalia Prairie exhibits lithologic units similar to those of the earlier sections from other parts of the Castalia area.

Section 3

Unit	*Description*	*Thickness (Inches)*
4	Humus, peat, dark-brown fossiliferous, tufa (coating plant remains.	8
3	Marl, tan, fossiliferous, tufa (coating plant remains), thin peat lenses (22") (Collections No. 5-14)	28
2	Peat, dark brown, fossiliferous, tufa (coating plant remains). Coll. No. 15)	4

1 Marl, tan, fossiliferous, tufa (coating plant remains). (Collection No. 16) 4

Unit 4 is a member of the Warners Soil Association of poorly drained soils underlain by marl and clay (Redmond *et al.*, 1971, map). Tufa deposits are common in the Castalia area. In some areas examined by the author in the southwestern sector of the Resthaven Wildlife Area, the tufa was so dense that the soil was impenetrable with a spade. The tufa of the Castalia area was produced when underground water, containing CO_2 under pressure and a larger amount of carbonates than it could otherwise hold in solution without the presence of CO_2, escaped into lakes and onto the surface through springs (Grabau, 1913, p. 342; Pettijohn, 1957, p. 409). A reduction of pressure immediately permitted the CO_2 to escape and $CaCO_3$ to precipitate as a fine slimy material. Very often plant material is found encrusted with this material.

Faunal Abundance. The indigenous mollusks of the Castalia Prairie deposit are *Ferrissia parallela Gyraulus parvus*, *Helisoma trivolvis*, *Physa gyrina hildrethiana*, *Planorbula armigera*, and *Pisidium* sp. *Stagnicola* cf. *S. palustris* is indigenous in collections 9 through 11, but is considered an intruder in other collections. Intruders in the Castalia deposit are *Goniobasis livescens*, *Pomatiopsis lapidaria Fossaria obrussa decampi*, *Laevapex diaphanus*, *L. kirklandi*, and all 19 species of terrestrial gastropods.

Ctenobranchs were greatly outnumbered in absolute abundance and diversity by aquatic pulmonates. Only two species of ctenobranchs, *Goniobasis livescens* and *Pomatiopsis lapidaria*, are present; compared to 9 species of aquatic pulmonates. Significant molluscan species are *Gyraulus parvus*, *Physa gyrina hildrethiana*, *Pomatiopsis lapidaria*, and *Fossaria obrussa decampi*. Among the terrestrial snails, *Carychium exiguum*, *Nesovitrea binneyana*, and *Retinella indentata* are the most abundant. Terrestrial gastropods occur throughout the deposit. Freshwater limpets are represented by 3 species and occur in traces throughout the section, with *Ferrissia parallela* being the most common. Sphaeriidae are found in each collection, but nowhere in abundance. Ostracodes exist in trace amounts in each of the 16 collections. They are represented by *Candona* and *Cypridopsis*. Insect remains are present only in the upper part of Unit 1.

Lithology does not seem to influence molluscan abundance to any great extent. Unit 2, a thin peat layer, does show a rapid decrease in several aquatic species, but the other units show no faunal differentiation with lithology. The molluscan fauna is very similar to that reported by Sterki (1920) and Clark (1961).

Floral Abundance. Plant remains, mostly *Phragmites* coated by calcium carbonate, are found throughout the section. No *Chara* remains were noticed. The pollen diagrams of Sears (1967) indicate the most significant species are *Picea* and *Pinus* among the coniferous trees; the Betulaceae, *Platanus*, *Quercus*, and *Salix* among deciduous trees, and *Ambrosia*, the Compositae, Cyperaceae, Gramineae, *Hamamelis*, Liliaceae, and Umbelliferae among the herbaceous plants.

Nature of the Environment. The aquatic mollusks of the Castalia deposit were inhabitants of a small, shallow, spring-fed lake in the Castalia Prairie. The molluscan fauna of the Castalia Prairie deposit is dominated by pulmonates, suggesting that the water areas were only temporary and subject to drying up. Ctenobranchs require permanent water bodies (Frye and Leonard, 1967, p. 432). The lake was part of a network of small, temporary lakes or pools in the area, interconnected by small streams or marshy areas and separated by small islands. Deciduous woodlands must have encircled the lake environment as evidenced by the abundance and diversity of certain terrestrial snails such as *Nesovitrea binneyana*, *Retinella indentata*, and *Stenotrema leai*, which occur in most of the collections. *Stenotrema leai* is reported to inhabit only forests and forest-border areas by Frye and Leonard (1967, p. 433). The genus *Retinella* is also primarily a woodland type according to various authors (La Rocque, 1970, p. 619-622). The section represents the progressive filling of the lake by marl and peat deposits.

Unit 1, the lower marl layer, was deposited during a shallow water stage of the lake. *Phragmites* and other reeds were abundant growing in the shallows. Unit 2 represents a period in which the water was extremely shallow at this locality. Peat formed at this time. It is not known if the peat is laterally continuous or is a local lens. Vegetation was dense and probably produced stagnant conditions. This resulted in a slight reduction of aquatic mollusk species; only 5 species are present.

Unit 3 contains 16 inches of the sec-

TABLE 3 PLEISTOCENE FAUNA AND FLORA OF CASTALIA PRAIRIE DEPOSIT, CASTALIA, OHIO

DEPTH(INCHES)	2	4	6	8	10	12	14	16	18	20	24	28	32	36	40	44
NUMBER OF INDIVIDUALS	138	145	155	164	142	148	295	253	233	195	259	234	247	114	67	225
CTENOBRANCHS																
Goniobasis livescena											.4	.4				7.1
Pomatiopsis lapidaria	15.9	9.0	22.6	15.8	15.5	8.8	12.9	13.4	9.9	14.9	10.8	6.8	12.1	21.9	6.0	8.9
AQUATIC PULMONATES																
Ferrissia parallela		1.4	.6	.6	1.4	.7	.3	.4			.4	.4		.9	4.5	.9
Fossaria obrussa decampi	23.2	18.6	14.2	12.2	9.1	18.9	14.2	12.2	17.2	13.8	32.8	9.8	28.3	20.2	44.8	27.6
Gyraulus parvus	15.9	17.9	18.7	20.1	20.4	15.5	23.7	19.4	18.4	21.5	15.0	21.8	12.1	13.2	4.5	11.1
Helisoma trivolvis	2.2	.7	4.5	2.4	.7	2.0	.7	7.9	1.7	.5	.8	.4	.8	1.8		.4
Laevapex diaphanus										.5						
Laevapex kirklandi							.3		.4							
Physa gyrina hildrethiana	13.0	5.5	5.2	3.6	11.9	10.8	20.3	22.5	27.0	10.8	22.8	19.6	8.5	13.2	13.4	10.7
Planorbula armigera	1.4	1.4			3.5	3.4	2.0			.5	2.3	4.7	1.6	3.5		11.1
Stagnicola cf. palustris	1.4			.6	.7	2.0	1.0	.4	5.2	5.1	5.8	5.1				
TERRESTRIAL PULMONATES																
Carychium exiguum	.7	4.8	10.3	12.2	10.6	14.2	5.4	5.9	6.0	9.2	2.3	5.1	5.7	5.3	7.5	4.4
Discus cronkhitei	.7	1.4	3.9	.6				.4	.4							
Euconulus fulvus		1.4	.6	1.2	3.5		.3		.4	.5				.9		
Gastrocopta sp.	1.4	5.5	7.7	9.8	3.5	4.0	3.7	1.6	.8	3.6	1.9	2.6	7.3	3.5		2.2
Haplotrema concavum						1.3		.8		1.0		.8				
Hawaiia minuscula	5.8	7.6	1.3	7.3	4.2	.7	.3		.4				.4	.9		.9
Helicodiscus parallelus	6.5	4.8	1.3	2.4	1.4		2.0	.8		.5		1.7	2.4	2.6	3.0	.9
Nesovitrea binneyana	.7	2.1	1.3	1.2	4.2	2.0	4.4	4.0	3.0	3.1	1.2	4.3	4.0	3.5	4.5	2.2
Oxyloma retusa				.6					.4			.4	.8	.9		
Pupoides albilabris	.7	4.1		.6												
Retinella indentata	4.3	6.9	.6	1.8	1.4	2.0	2.0	1.2	2.6	1.0	.4	7.3	4.9	2.6	4.5	1.3
Stenotrema leai			.6	.6	.7	2.7	1.0	1.2			.4	1.7	2.8	.9		.4
Strobilops aenea	2.2	2.1	2.6	2.4	2.1	.7	.7	.8		1.0	.8	.8	1.2	.9		1.8
Succinea avara	2.2	.7		.6		.7		.4		1.5	.8		2.8		4.5	3.6
Succinea ovalis		.7	1.3	1.8		1.3	.3	1.6	.8	5.1	.4	5.6	2.8	1.8		2.2
Triodopsis albolabris								.4								
Vallonia pulchella		.7	.6													
Ventridens demissus		1.4				.7										
Vertigo sp.	.7		1.3		1.4	2.0	.7			2.0	.4		1.2			.4
SPHAERIIDAE																
Pisidium sp.	.7	.7	.6	1.2	3.5	5.4	3.4	4.7	5.2	3.6	.4	.4	.4	1.8	3.0	1.8
OSTRACODS(Candona, Cypridopsis)	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
INSECT REMAINS	T	T	T													
$CaCO_3$ COATED REEDS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
UNIDENTIFIABLE PLANT REMAINS	T	T					T	T	T	T	T	T	T	T	T	T
LITHOLOGY:																
Unit 4 Dark-brown Peat	X	X	X	X												
Unit 3 Tan Marl					X	X	X	X	X	X	X	X	X	X		
Unit 2 Peat															X	
Unit 1 Tan Marl																X

T Trace
X Present in large amounts

tion and makes up the upper marl layer. The water had deepened from the time in which Unit 2 was deposited, but still was probably less than one foot deep. Two of the most abundant snails, *Gyraulus parvus* and *Physa gyrina hildrethiana* favor depths of 0.5 to 2.2 m and less than 0.3 m. Unit 4 records the lowering of water level, allowing marsh plants to grow throughout the lake basin. Successive plant zones developed, peat accumulated, and the lake and marsh environments were replaced by a meadow habitat.

RUSHCREEK LAKE DEPOSIT, BELLEFONTAINE, OHIO

Location of the Deposit. Rushcreek Lake is located approximately 9 miles northeast of the city of Bellefontaine, in Logan County, Ohio. A short stratigraphic section was taken from the K.L. Woodward farm about 7/8 mile north of Rushcreek Lake and 1/8 mile west of Rush Creek. A sample was obtained in an area undisturbed by farming (Figure 6).

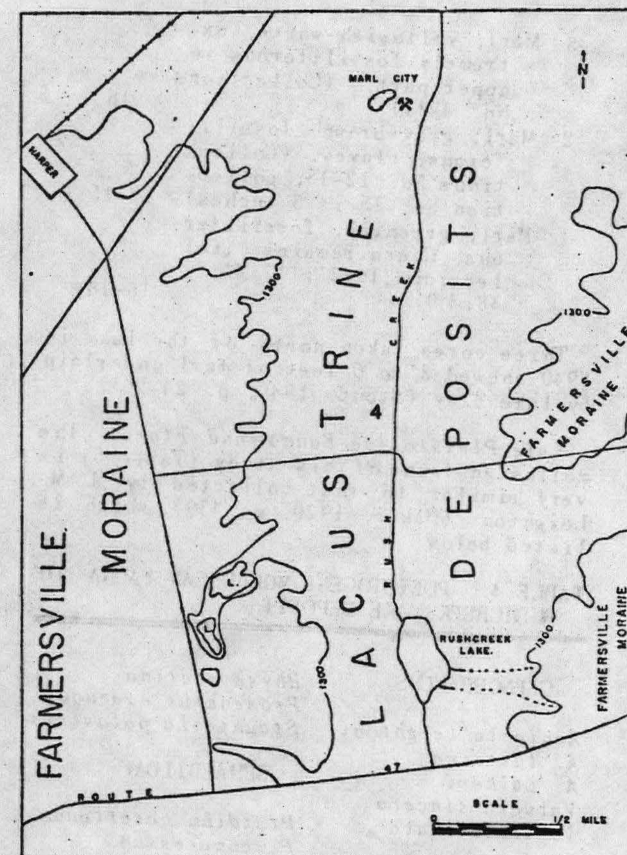

FIGURE 6 RUSHCREEK LAKE AND VICINITY, OHIO

Description of the Area. Rushcreek Lake and Rush Creek occupy a north-south elongated lowland, averaging about 1750 feet in width. This flat lowland extends from the town of Rushsylvania to just north of the town of Zanesfield. The surrounding terrain consists of glacial end moraines and hilly uplands supported by bedrock. The land has been cleared for pasture and crops, but the more rugged areas maintain a forest cover.

Rushcreek Lake drains northward into Rush Creek through a ditch constructed to alleviate marshy conditions in the valley. Several drainage ditches enter the southern part of Rushcreek Lake.

Late Pleistocene Geology of the Area. The existing Rushcreek Lake lies in the northern part of the Farmersville moraine of Wisconsin glaciation (Forsyth, 1972, personal communication). It has been mapped as an area containing lacustrine deposits by Goldthwait *et al.* (1961). Directly north of the lake At Rushsylvania, the Powell moraine is present.

When the ice was at the Farmersville moraine, a stream flowed south through the valley that now contains Rushcreek Lake. The stream passed through a narrow cut in a rocky ridge just north of the town of Zanesfield and emptied into a major meltwater channel at Zanesfield (Forsyth, 1972, personal communication). An ice-dammed lake, much larger than present Rushcreek Lake existed in the upper reaches of the stream. As the ice retreated from the Farmersville moraine, a topographically lower northern outlet was freed of ice, and the early Rushcreek Lake began slowly to drain northward. A readvance of the ice to the Powell moraine temporarily halted the drainage (Forsyth, 1972, personal communication). The retreat of ice from this moraine permitted a renewal of the northward drainage. As the water level was lowered, Rushcreek Lake became restricted to its present basin. The outlet to the north became reduced to a marshy lowland in the vicinity of the remaining lake basin.

Stratigraphy of the Deposit. Four lithologic units have been identified in the Rushcreek Lake sample, as listed below.

Unit	*Description*	*Thickness (Inches)*
4	Loam, brown, fossiliferous. (Collections No. 1-3)	6

3	Marl, yellowish-white, extremely fossiliferous in upper part. (Collections No. 4-11)	16
2	Marl, gray-brown, fossiliferous, clayey. (Collections No. 12-15; collection no. 15 is 3 inches)	12-15
1	Marl, greenish, fossiliferous, *Chara* remains. (Collections 16:3"; 17:4"; 18:4")	16-18

Three cores taken north of the lake in 1940 showed 3 to 6 feet of marl underlain by lake clay (Stout, 1940, p. 24-26).

Late Pleistocene Fauna and Flora. The molluscan fauna of this study (Table 5) is very similar to that collected by M. M. Leighton (Baker, 1920, p. 439) which is listed below.

TABLE 4. PLEISTOCENE MOLLUSCAN FAUNA OF RUSHCREEK LAKE DEPOSIT

CTENOBRANCHS	*Physa anatina*
	Promenetus exacuous
Amnicola leightoni	*Stagnicola palustris*
A. lustrica	
A. walkeri	SPHAERIIDAE
Valvata sincera	
V. tricarinata	*Pisidium casertanum*
	P. compressum
AQUATIC PULMONATES	*P. ferrugineum*
	P. nitidum
Ferrissia parallela	*P. variabile*
Fossaria obrussa decampi	*Sphaerium lacustre*
	Sphaerium sulcatum
Gyraulus altissimus	
G. deflectus	
G. hirsutus	NAIADES
Helisoma anceps striatum	
	Anodonta sp., fragments
H. campanulatum	

Two other studies conducted in Logan County, south of Bellefontaine, one at Newell Lake (Zimmerman, 1960) and the other at Jewell Hill (Mowery, 1961) yielded similar faunal lists.

Faunal Abundance. Indigenous species are *Amnicola limosa, A. lustrica, Valvata tricarinata, Gyraulus parvus, Helisoma anceps striatum, Helisoma campanulatum, Physa gyrina hildrethiana,* and species of Sphaeriidae. *Fossaria obrussa decampi,* an amphibious snail, is considered an intruder. *Stagnicola* sp., Naiades, and the 7 species of terrestrial gastropods are considered to be intruders for they occur only as traces in the total sample. *Helisoma anceps striatum* is the most significant mollusk, followed by *Sphaerium, Valvata tricarinata,* and *Gyraulus parvus.*

Molluscan abundance seems to be directly related to lithologic changes in the Rushcreek Lake deposit. Unit 1, the lowest, does not contain a great number of individuals or great diversity of species. No terrestrial gastropods are present. *Anguispira alternata* was found, but it is probably a contaminant from the surface. Unit 2, a clayey marl, contains a slightly more abundant molluscan fauna than Unit 1. Unit 3, a shell marl, makes up 16 inches of the stratigraphic section. Most of the species experience their greatest abundance in this zone. Terrestrial snails are present in small numbers. Unit 4, a loam, contains the smallest molluscan fauna of the sample section. Living *Anguispira alternata* were found in large numbers on the surface.

Floral Abundance. Units 1 and 2 contain the remains of *Chara,* principally oogonia, in small amounts. Unit 3, which contains profuse plant debris, mostly of recent origin. Seeds of *Carex, Cerastium, Polygonum,* and *Potamogeton* are present in trace amounts in all the units.

Nature of the Environment. The aquatic mollusks of the Rushcreek Lake deposit inhabited a quiet body of water in an end moraine complex. The successive quantitative distribution of mollusk species in each of the collections of the four lithologic units indicates a small lake which was drained fairly rapidly.

The abundance of ctenobranchs and *Helisoma anceps striatum* indicates a cool water environment (Frye and Leonard, 1967, p. 433). *Amnicola* is a sensitive indicator of clear, cool, permanent waters (Frye and Leonard, 1967, p. 434). The water was shallow, as indicated by the presence of numerous *Helisoma anceps striatum,* a species which is reportedly most common in depths less than 3 feet (Mowery, 1961, p. 10).

The lake bottom during the deposition of Unit 1 probably consisted of a fine-grained gray marl supporting *Chara* plants. The *Chara* was, no doubt, the source of much of the marl at this stage, for mollusks are not overly common and springs are not evident. The water depth was probably greater than 6 feet, for this depth would account for the paucity of the molluscan fauna. Most species prefer depths less than this (La Rocque, 1968).

TABLE 5 PLEISTOCENE FAUNA AND FLORA OF RUSHCREEK LAKE DEPOSIT, NEAR BELLEFONTAINE, OHIO

DEPTH(INCHES)	2	4	6	8	10	12	14	16	18	20	22	24	26	28	31	34	38	42
NUMBER OF INDIVIDUALS	29	25	128	276	285	332	276	284	281	262	352	166	107	99	117	185	164	108
CTENOBRANCHS																		
Amnicola limosa	6.9	8.0	8.6	4.0	13.7	7.8	12.0	4.9	10.0	9.9	16.5	11.4	11.2	3.0	16.2	27.0	38.4	45.4
Amnicola lustrica	3.4	16.0	14.8	24.3	22.4	17.2	15.6	10.9	8.5	5.7	9.6	10.2	9.3	10.1	5.1	4.9	1.8	1.8
Valvata tricarinata	31.0	12.0	22.6	17.8	10.9	14.2	14.5	19.0	16.4	21.4	29.0	31.9	17.8	23.2	26.5	35.1	32.3	34.2
AQUATIC PULMONATES																		
Ferrissia parallela			.8												.8			
Fossaria obrussa decampi	3.4			9.0	4.2	9.0	3.6	14.8	13.2	9.9	1.7	4.2	4.7	8.1	.8	.5		
Gyraulus parvus	44.8	44.0	32.0	19.6	23.5	18.4	19.9	21.1	13.9	17.6	16.8	15.1	17.8	24.2	20.5	21.1	19.5	13.0
Helisoma anceps striatum		8.0	5.5	7.6	14.0	16.0	15.2	19.0	25.6	21.0	17.3	18.1	33.6	28.3	20.5	7.0	2.4	.9
Helisoma campanulatum				.4	2.4	1.5	2.2	1.8		5.7	1.4	2.4						2.8
Physa gyrina hildrethiana				7.6	3.5	5.7	5.4	3.5	3.2	6.1	4.8	3.0	.9		4.3	1.6	3.0	
Promenetus exacuous										.4								
Stagnicola sp.								.4	.4									
TERRESTRIAL PULMONATES																		
Anguispira alternata		4.0	.8									.6					.6	
Discus cronkhitei			.8															
Gastrocopta sp.	3.4																	
Helicodiscus parallelus									.4									
Retinella indentata		4.0		.4														
Succinea sp.								.4										
Zonitoides arboreus						.3	.4		.4									
SPHAERIIDAE																		
Pisidium sp.			10.2	2.5	1.6	1.8	2.2						3.7					
Sphaerium sp.	6.9	4.0	3.9	7.2	3.5	8.1	6.9	4.2	8.5	2.3	2.8	3.0	.9	3.0	5.1	2.7	1.8	1.8
NAIADES(FRAGMENTS)					T				T									
OSTRACODS (Candona)	T			T	T	T		T	T	T	T	T		T	T	T	T	T
INSECT REMAINS													T		T	T	T	T
PLANT SEEDS																		
Carex sp.	T	T																
Cerastium sp.	T							T							T			
Polygonum sp.																		T
Potamogeton sp.							T	T		T	T		T	T			T	
CHARA OOGONIA								T		T	T		T	T	T	T	T	T
UNIDENTIFIABLE PLANT REMAINS	X	X	X	X				T			X	T	T	T	X	T	T	X
LITHOLOGY:																		
Unit 4 Dark-brown Humus	X	X	X															
Unit 3 Yellow-brown Marl				X	X	X	X	X	X	X	X							
Unit 2 Clayey-brown Marl												X	X	X	X			
Unit 1 Gray Marl																X	X	X

T Trace
X Present in large amounts

Unit 2 represents a slight lowering in water level and the addition of fine clastics from the surrounding terrain. *Chara* is still the dominant aquatic vegetation. The molluscan fauna is also more prevalent. *Helisoma anceps striatum*, an inhabitant of shallow waters with abundant vegetation (La Rocque, 1970, p. 501), is common in this unit. At this time, Rushcreek Lake must have begun to drain.

Lake level continued to lower as evidenced by Unit 3. *Chara* plants are still present in lower Unit 3, but are not found in the upper part. The marl that makes up this unit appears to be predominantly a result of an accumulation of shells and shell fragments in a very nearshore zone. *Helisoma anceps striatum* is very common and seven other aquatic species are common. The high percentages of molluscan abundance in this zone indicate a very favorable molluscan habitat was afforded. The high percentage of shell fragments suggests a nearshore zone or beach where small waves have resulted in the accumulation of large quantities of shells and shell fragments. The mollusks preserved in this unit probably lived on vegetation in the area. A present day deposit very similar to this was observed at Goose Lake near Cement City, Michigan. The beach and nearshore zone at this lake were covered by shells, mainly *Helisoma campanulatum*.

During the deposition of Unit 4, Rushcreek Lake was reduced to its present basin. In some of the scattered small pools of water still remaining certain aquatic mollusks continued to thrive. *Gyraulus parvus* was one of the most common, perhaps because it could survive minor periods of drought by burrowing into the substrate. Terrestrial gastropods were present, but not in great numbers. *Anguispira alternata* became the most common terrestrial snail in the uppermost part of the unit and still lives in great numbers in the fields of Rush Creek valley.

SILVER LAKE DEPOSIT, NEW CARLISLE, OHIO

Location of the Deposit. Silver Lake is located about 2 miles northwest of the town of New Carlisle, in Miami County, Ohio. A short stratigraphic section was taken along the southeastern shore of the lake in a marshy area (Figure 7).

Description of the Area. Silver Lake lies in an east-west trending valley some 50 feet below the surrounding terrain. The lake does not presently have an outlet.

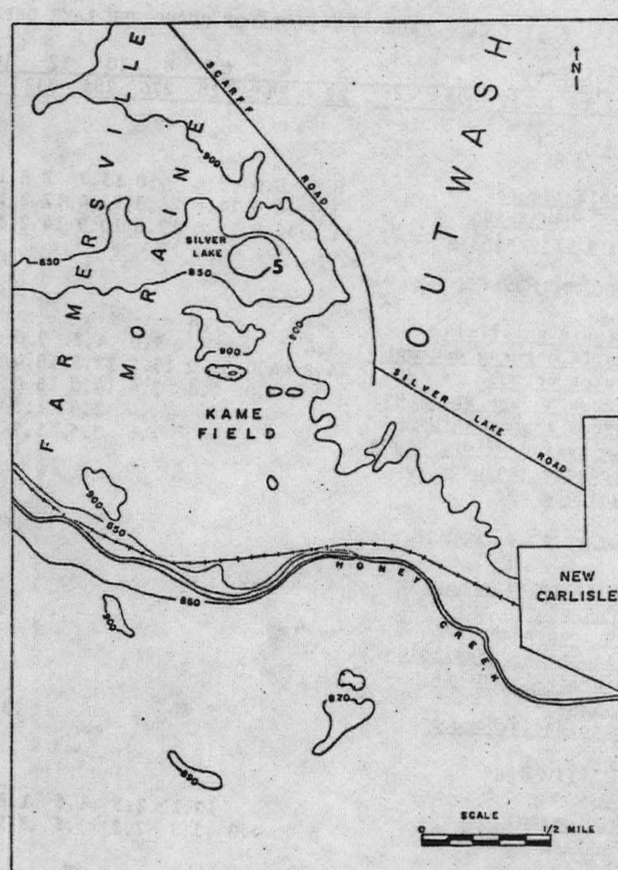

FIGURE 7 SILVER LAKE AND VICINITY, OHIO

The vicinity is well drained, and few marshes and lakes are present. Marsh vegetation does exist along the western perimeter of Silver Lake. The eastern shoreline has been filled in with sand to create a beach for a private swim club now located at the lake. Earkier, the lake had been dredged for marl by the New Carlisle Marl and Humus Company (Stout, 1940, p. 27).

Most of the land in the New Carlisle area has been cleared for farming, but deciduous woodlands remain in the hilly terrain around Silver Lake. Vegetation in the immediate area of the stratigraphic section was scant; it consisted mainly of *Populus tremuloides*, *Phragmites*, *Pontederia*, and *Rudbeckia hirta*. Marl was exposed on the surface.

Late Pleistocene Geology of the Area. The Miami Lobe of Wisconsin glaciation was the last ice sheet to cover the Silver

Lake area (Petro, 1958, p. 7). The lake itself lies on the eastern edge of a north-south trending section of the Farmersville moraine (Goldthwait, in Norris, 1952), and directly west of the Mad River valley train (Ohio Academy of Science, 1960, map). Kettles and kames are well developed in the area directly south of the lake, so it is likely that Silver Lake was the result of the melting of a buried ice block. Silver Lake was probably a much larger lake in its earlier history and was drained after ice retreated from the area. The lake level was gradually lowered so that the stream flow became insignificant, and the lake was left stranded without an outlet. The dry channel of this stream is very evident on the 7.5' New Carlisle quadrangle.

Stratigraphy of the Deposit. Only one lithologic unit was identified at Silver Lake—a brownish-gray fossiliferous marl.

Unit	*Description*	*Thickness (Inches)*
1	Marl, brownish-gray, fossiliferous, *Chara* remains. (Collections No. 1-9; last 3 collections are 4 inches each.	24

A deep sample could not be obtained because of water inflow into the pit. An auger sample showed the same lithology for at least another 4 feet.

Late Pleistocene Fauna and Flora. Just to the south of Silver Lake is Crystal Lake in Clark County. Nave (1969) has made a study of the mollusks found in a marl deposit at this lake (Table 6).

TABLE 6. PLEISTOCENE MOLLUSCAN FAUNA OF CRYSTAL LAKE DEPOSIT (Nave, 1969)

CTENOBRANCHS	*Physa gyrina*
	Promenetus exacuous
Amnicola limosa	
*A. lustrica**	
*Valvata sincera**	SPHAERIIDAE
V. tricarinata	
AQUATIC PULMONATES	*Pisidium compressum*
	*P. ferrugineum**
Acella haldemani	*P. milium*
Armiger crista	*P. nitidum**
Fossaria obrussa decampi	*P. variabile**
	*P. ventricosum**
Gyraulus deflectus	*P. walkeri*
G. parvus	*Sphaerium lacustre*
Helisoma campanulatum	
H. anceps striatum	*S. rhomboideum*
Lymnaea stagnalis jugularis	*S. securis*
	S. sulcatum

* Indigenous species

The molluscan fauna of Silver Lake was found to be very similar to that of Crystal Lake (refer to Table 7).

Faunal Abundance. The indigenous mollusks are *Amnicola limosa*, *A. lustrica*, *Valvata tricarinata*, *Gyraulus parvus*, *Helisoma anceps striatum*, *H. trivolvis*, *Physa gyrina hildrethiana*, and *Sphaerium* sp. *Pleurocera acutum*, *Fossaria obrussa decampi*, *Pisidium* sp., Naiades, and *Succinea avara* are considered to be intruders. All indigenous species and *Fosssria obrussa decampi* are considered to be significant. Aquatic pulmonates have a greater diversity and are more abundant than ctenobranchs. The most common mollusk, however, is the ctenobranch *Amnicola lustrica*. *Amnicola limosa,* though, occurs in only trace amounts in the lower three collections of the section. The only terrestrial mollusk, *Succinea avara,* was found as an individual shell in collection 8. Mollusk shell fragments were extremely common throughout the section.

The ostracodes, *Candona* and *Cypridopsis*, are present in traces in each of the collections. Insect exoskeletons occur in a few collections.

Floral Abundance. Chara strands and oogonia and unidentifiable plant remains were found in each collection. The only seeds identified were those of *Polygonum* in collection 5.

Nature of the Environment. The mollusks of the Silver Lake deposit lived in a small lake formed in an end moraine complex. They migrated into this environment through a now non-existent stream after the retreat of the Wisconsin ice sheet. The lake has since shrunk in size due to slow draining and marl buildup. *Chara* was probably the dominant aquatic vegetation. Peat was not present at the sampled locality, but surely occurs in the surrounding marsh. Peat and muck were reported by Nave (1969, p. 8) at the Crystal Lake marl deposits.

The Silver Lake section probably represents a locality far enough from shoreline so that little terrigenous detritus, including land snails, was received. The presence of large numbers of *Amnicola lustrica*, *Fossaria obrussa decampi*, *Gyraulus parvus*, and *Helisoma anceps striatum*, however, indicates a shallow water environment, less than 3 feet in depth (Mowery, 1961; La Rocque, 1968).

The Silver Lake habitat was apparently very similar to that described by Nsve (1969) for nearby Crystal Lake. *Amnicola lustrica*, *Valvata tricarinata*, *Gyraulus parvus*, and *Helisoma anceps striatum* are indigenous species in both deposits. *Fossaria obrussa decampi* is significant in

TABLE 7 PLEISTOCENE FAUNA AND FLORA OF SILVER LAKE DEPOSIT, NEAR NEW CARLISLE, OHIO

DEPTH(INCHES)	2	4	6	8	10	12	16	20	24
NUMBER OF INDIVIDUALS	216	178	224	265	210	304	244	284	303
CTENOBRANCHS									
Amnicola limosa	5.1	1.1	1.3	10.9	5.5	8.2	.8	.7	.3
Amnicola lustrica	39.8	33.7	27.7	22.3	16.4	18.8	24.2	33.1	33.3
Pleurocera acutum		.6	.4						
Valvata tricarinata	9.7	13.5	10.3	17.7	19.4	13.5	9.4	10.6	15.5
AQUATIC PULMONATES									
Fossaria obrussa decampi	7.9	11.8	9.4	8.7	10.3	11.2	9.0	6.3	6.6
Gyraulus parvus	17.6	18.5	26.8	14.7	15.8	15.5	17.2	18.3	13.9
Helisoma anceps striatum	14.8	13.5	11.2	9.0	12.9	15.1	19.3	16.2	9.6
Helisoma trivolvis		.6	.4	.8	6.4	3.3	.4	3.2	8.2
Physa gyrina hildrethiana	3.2	4.5	6.7	10.9	7.4	7.6	15.2	7.0	6.3
Promenetus exacuous								1.0	
TERRESTRIAL PULMONATES									
Succinea avara								.4	
SPHAERIIDAE									
Pisidium sp.	1.8	2.2	5.8	4.9	5.8	6.9	4.5	3.5	6.3
NAIADES(FRAGMENTS)	T	T	T		T				
OSTRACODS (Candona, Cypridopsis)	T	T	T	T	T	T	T	T	T
INSECT REMAINS		T		T	T	T			
PLANT SEEDS (Polygonum sp.)					T				
CHARA OOGONIA	T	T	T	T	T	T	T	T	T
UNIDENTIFIABLE PLANT REMAINS	T	T	T	T	T	T		T	T
LITHOLOGY; Brown-gray Marl	X	X	X	X	X	X	X	X	X

T Trace
X Present in large amounts

both deposits. Sphaeriidae, however, are more abundant in the Crystal Lake deposit.

As evidenced by the abundant ctenobranchs and *Helisoma anceps striatum*, the water temperature during Wisconsin time at Rushcreek Lake was somewhat cooler than that of the present-day lake. The temperature was similar to that of present-day lakes in Canada due to the climatic effect of glacier ice still existing in the Erie Basin. The prevalence of *Amnicola* also suggests that the water was essentially free of turbidity. The fine-grained marl bottom was little disturbed by wave action, except during storms when the water probably became milky with suspended particles.

FOURMILE LAKE DEPOSIT, CHELSEA, MICHIGAN

Location of Deposit. Fourmile Lake is situated in Washtenaw County, Michigan, midway between the towns of Chelsea and Dexter. The lake is now part of the Chelsea State Game Area. A short stratigraphic section was obtained along the eastern shore of an abandoned marl pit at the southwestern end of the lake (Figure 8).

Description of Area. Fourmile Lake occupies a marshy lowland in irregular glaciated terrain. Abandoned, water-filled marl and clay pits lie to the north and southwest of the lake. The lake has no major outlets, although several intermittent creeks drain into it from the sur-

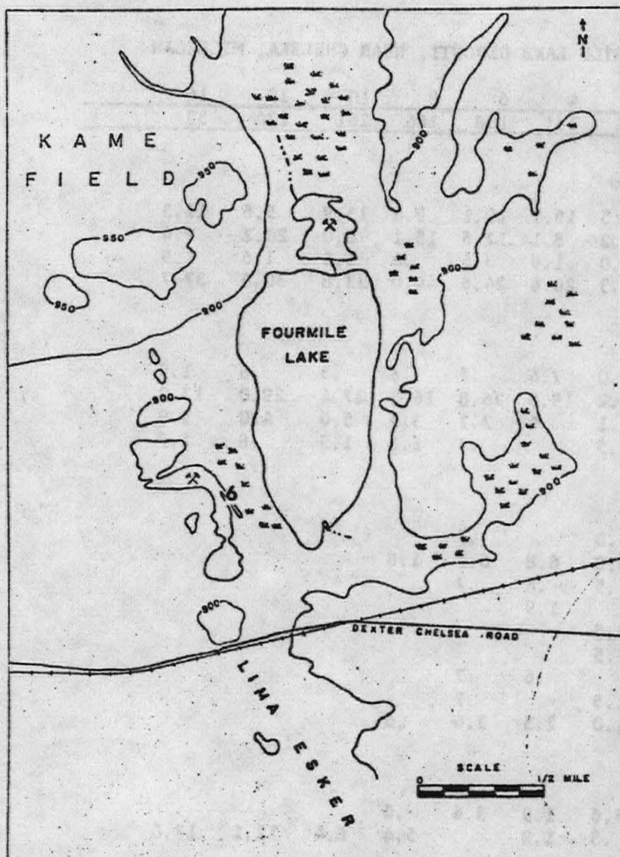

FIGURE 8 FOURMILE LAKE AND VICINITY, MICH.

rounding marshes. Deciduous forest cover is present along the southern boundary and on scattered topographic highs in the marshlands. The most extensive marsh vegetation is found directly encircling the lake and north and west of it.

The flora in the immediate area of the section included *Typha, Carex, Asclepias syriaca, Daucus carota, Osmorhiza, Eupatorium, Plantago, Taraxacum officinale, Rhus toxicodendron, Rhus vernix, Salix, Campanula,* and *Lemna minor*.

Late Pleistocene Geology of the Area. Kneller (1964) mapped lake deposits in the area surrounding Fourmile Lake. An esker, indicating flowage of meltwater to the northwest, extends from just south of the lake to a point approximately 2 miles southeast of the town of Lima Center (Bay, 1938, map; Kneller, 1964, map). To the north of the esker are several kames and a kame complex on the northwest edge of the lake. (Bay, 1938, map, Kneller, 1964, map). This evidence seems to indicate that ponded conditions existed along the ice front of the Huron-Erie Lobe in the Fourmile Lake area (Kneller, 1972, personal communication). The present Fourmile Lake is only a remnant of this once more extensive glacial lake.

Stratigraphy of the Deposit. The short stratigraphic section obtained at Fourmile Lake yielded only one lithologic unit—a gray fossiliferous marl. The sampling was terminated at a depth of 16 inches because of rapid water inflow. An auger test indicated that the marl continued for at least another 4 feet.

Unit	*Description*	*Thickness (Inches)*
1	Gray-brown marl, fossiliferous, plant remains. (Coll. No. 1-3)	6
1	Gray-yellow marl, fossiliferous, plant remains, some oncolites. (Coll. No. 4-7)	10

Faunal Abundance. The indigenous species are *Amnicola limosa, A. lustrica, Valvata* cf. *V. perdepressa, V. tricarinata, Gyraulus parvus, Helisoma anceps striatum, Physa gyrina hildrethiana, Pisidium* sp., *Sphaerium* sp., and Naiades. *Pleurocera acutum, Fossaria obrussa decampi* and nine species of terrestrial gastropods are considered to be intruders. Ctenobranchs are more diverse and abundant than the aquatic pulmonates. All species are significant except for *Foss sria obrussa decampi, Physa gyrina hildrethiana,* Naiades, and the terrestrial snails. The insignificant aquatic species occur in most of the collections, but are present only in minor percentages. The terrestrial species are present only in the upper four collections of the section. Ostracodes of the genus *Candona* occur at sporadic intervals. Collection 3 yielded a trace of insect exoskeletons.

Floral Abundance. *Chara* strands and oogonia occur throughout the deposit. Seeds of *Lotus, Cerastium, Carex,* and *Najas* are also present in many of the collections.

Nature of the Environment. The mollusks of the Fourmile Lake deposit were inhabitants of a large body of quiet water. The present Fourmile Lake is the deeper part of this basin. Apparently, the section was taken in an srea where marl deposits filled in the shallower shoreline areas of the lake while it was in the process of

TABLE 8 PLEISTOCENE FAUNA AND FLORA OF FOURMILE LAKE DEPOSIT, NEAR CHELSEA, MICHIGAN

DEPTH (INCHES)	2	4	6	8	10	12	16
NUMBERS OF INDIVIDUALS	194	161	138	166	201	124	53
CTENOBRANCHS							
Amnicola limosa	15.5	16.1	10.1	9.6	13.9	5.6	11.3
Amnicola lustrica	7.2	8.1	11.6	15.1	8.0	20.2	9.4
Goniobasis sp.	1.0	1.9	3.6	.6	1.5	1.6	1.9
Valvata tricarinata	27.3	20.4	24.6	44.0	33.8	30.6	37.7
AQUATIC PULMONATES							
Fossaria obrussa decampi	1.0	7.4	.7	.6	.5	.8	1.9
Gyraulus parvus	25.2	19.9	26.8	16.3	27.4	29.0	17.0
Helisoma anceps striatum	4.1	.6	2.2	3.6	5.0	4.0	1.9
Physa gyrina hildrethiana	.5		.7	1.8	1.5	.8	1.9
TERRESTRIAL PULMONATES							
Carychium exiguum	1.0		.7				
Cionella lubrica	8.8	6.8	6.5	1.8			
Discus cronkhitei	.5	.6	.7				
Hawaiia minuscula		1.9					
Retinella indentata	.5						
Stenotrema sp.	.5						
Succinea avara		.6	.7				
Vallonia pulchella	1.5		.7				
Zonitoides arboreus	1.0	2.5	3.6	.6			
SPHAERIIDAE							
Pisidium sp.	3.6	1.9	3.6	.6			
Sphaerium sp.	.5	1.2		5.4	8.4	12.1	17.0
NAIADES (FRAGMENTS)	T	T	T	T	T	T	T
OSTRACODS (Candona)							
INSECT REMAINS	T					T	T
			T				
PLANT SEEDS							
Carex sp.							
Cerastium sp.		T	T		T		
Lotus sp.	T	T					
Najas sp.	T						
					T		T
CHARA OOGONIA							
UNIDENTIFIED PLANT REMAINS		T			T	T	T
	X	X	X	X	X	X	X
LITHOLOGY: Gray-brown Marl							
	X	X	X	X	X	X	X

T Trace
X Present in large amounts

slowly draining into adjacent lowlands. The absence of a peat layer seems to indicate that luxuriant marsh growth was not able to establish itself in the immediate area of the sample section.

The mollusks lived in a very shallow (less than 3 feet) nearshore zone. *Zonitoides arboreus, Retinella indentata,* and *Retinella rhoadsi* indicate that a deciduous forest zone probably existed near the shore (Frye and Leonard, 1967, p. 433; La Rocque, 1970). *Amnicola* is a good indicator of clear, permanent, usually cool water, according to Frye and Leonard (1967, p. 434). Naiades also indicate permanent water for their presence demands the presence of fish for the development of Naiad larvae. Ctenobranchs, as a group, are adapted to cooler water environments (Frye and Leonard, 1967, p. 433) as is *Helisoma anceps striatum* (La Rocque, 1968, p. 501). The bottom material was a fine-grained marl which supported strands of *Chara* and *Nitella*.

DISCUSSION

From available radiocarbon dates, the sequence of formation of the six lacustrine environments can be hypothesized. The Late Wisconsin ice sheet reached its maximum southward extent in the study area some 18,000 to 20,000 years B.P. (Forsyth, 1965, p. 226). At this time all of the localities studied were covered by thick glacier ice. The ice sheet had completely retreated from Ohio by approximately 14,000 B.P. (Forsyth, 1965, p. 226). Thus, Rushcreek Lake and Silver Lake, the two southernmost localities, were freed of ice some time between 20,000 and 14,000 B.P. Indiana was also freed of Wisconsin ice by 14,000 B.P. (Wetzel, 1970, p. 495). Big Turkey Lake and Wabee Lake probably were created around this time. Dorr and Eschman (1970, p. 161) state that all glacial features below the Port Huron moraine in Michigan date from 13,500 to 16,000 B.P. This would include the site of Fourmile Lake. Thus, this lacustrine environment is slightly younger than this time range. The Castalia Prairie deposit has been dated as having formed around 7,000 to 8,000 B.P. (Clark, 1961, p. 36), making it the youngest of the localities studied.

The lakes had their origin in several ways. Big Turkey, Silver, and Wabee Lakes were probably formed from the melting of stagnant ice blocks. Rushcreek and Fourmile Lakes are believed to be ice dammed lakes that existed along the ice front. Castalia Prairie seems to have been a lowland flooded by a rise in the water table and consequent spring outflow.

All of the stratigraphic sections illustrate the final stages of the lake history in that area. The uppermost part of the section at most localities is a peat-humus layer of varying thickness. This layer is absent at Big Turkey, Fourmile, and Silver Lakes as a result of erosion or possibly nondeposition. The next lower sediment type is a marl, usually much thicker than the overlying peat. This zone is dominated by *Chara* remains and mollusk shells. The underlying sediment type is sand, grading downward into gravel. Only at Wabee Lake was this unit reached. The other localities contain so great a thickness of marl that sampling was terminated before the gravel was struck.

Castalia Prairie, Silver Lake, and Big Turkey Lake are the only localities in which calcareous tufa was found. Irregular masses and coated reeds of tufa were found throughout the Castalia section, in the upper half of the Big Turkey Lake section, and as traces in the Silver Lake section. This indicated the flow of carbonate-rich groundwater into the environment. Oncolites were found only at Fourmile and Wabee Lakes. The origin of these is due to the growth of algal mats on living and empty mollusk shells (Weiss, 1970).

The molluscan faunas of the deposits of the study area are very similar in composition and vary mainly in abundance of the individual species. Table 9 shows the total fossil aquatic molluscan fauna at each of the localities in this study, in addition to several living assemblages known to exist in lakes (having similar environments of this area and those farther north.

The comparison of the fossil faunas with living assemblages is hampered by the lack of sufficient data. Comparatively little information is available on molluscan assemblages from present-day lakes, let alone Late Pleistocene ones. The data which are available have been complicated by taxonomic lumping and splitting, or in some cases by misidentification, all of which hampers comparison of faunal lists.

The fossil molluscan faunas of Big Turkey, Rushcreek, Silver, and Fourmile Lake deposits show that *Amnicola limosa, Amnicola lustrica, Valvata tricarinata, Gyraulus parvus, Helisoma anceps striatum, Physa gyrina hildrethiana,* and Sphaeriidae are more characteristic of shallow water environments with abundant vegeta-

TABLE 9 LACUSTRINE MOLLUSCAN ASSEMBLAGES

DL DOLLAR LAKE
SoL SODON LAKE
NSL-1 NORTH STAR LAKE 1 ft. depth
NSL-3 NORTH STAR LAKE 3 ft. depth
McL McKAY LAKE
CL CHILCOTT LAKE

X PRESENT
XX SIGNIFICANT
No abundance data available for SoL, NSL, McL, and CL.

SPECIES FOUND IN STUDY AREA	WISCONSIN AGE ASSEMBLAGES: INDIANA		OHIO			MICHIGAN	LIVING ASSEMBLAGES: OHIO	MICH.	MINN.	MINN.	ONTARIO	QUEBEC
	BTL	WL	CP	BL	SL	FL	DL	SoL	NSL-1	NSL-3	McL	CL
CTENOBRANCHS												
Amnicola limosa	XX	X		X	XX	XX	XX	X	X	X	X	X
Amnicola lustrica	XX	X		X	XX	XX		X	X	X	X	
Goniobasis livescens		XX	X									
Pleurocera acutum					X							
Pomatiopsis lapidaria			XX									
Valvata tricarinata	XX	X		XX	XX	XX	XX	X	X	X		X
AQUATIC PULMONATES												
Ferrissia parallela			X	X				X				
Ferrissia shimekii												
Fossaria obrussa decampi	X	X	XX	X	XX	X	X					X
Gyraulus parvus	XX	XX	XX	XX	XX	XX	XX	X	X	X		X
Helisoma anceps striatum	XX	X		XX	XX	XX			X	X	X	X
Helisoma campanulatum				X			XX		X	X	X	X
Helisoma trivolvis	X		X		X				X	X	X	X
Laevapex diaphanus			X									
Laevapex kirklandi			X									
Physa gyrina hildrethiana	X	X	XX	X	XX	X		X	X			
Planorbula armigera			X									
Promenetus exacuous	X		X	X								
Stagnicola palustris	X		X				X					
SPHAERIIDAE												
Pisidium sp.	X	X	X	X	XX	XX	X		X	X	X	X
Sphaerium sp.	X			XX		XX	X		X	X	X	X
NAIADES	X	X		X	X	X				X	X	

tion in the study area. *Fossaria obrussa decampi* was also found in each of these localities, but it is amphibious and probably lived outside the aquatic habitat.

Similar living assemblages were found in North Star and Little North Star Lakes in Minnesota in waters up to 3 feet deep (Baker, 1935, in La Rocque, 1966, p. 69-70). *Amnicola limosa* and *Valvata tricarinata* were found clinging to *Chara* in water up to 4 feet deep. *Gyraulus parvus, Helisoma anceps striatum*, and *Physa gyrina* were discovered on the underside of pond lily leaves and on other aquatic vegetation. McKay Lake near Ottawa, Ontario, has yielded a living assemblage which includes *Amnicola limosa, A. lustrica, Valvata tricarinata, Gyraulus parvus, Helisoma anceps, Physa heterostropha*, and Sphaeriidae (La Rocque, 1966, p. 92). Chilcott Lake, a marl lake in Quebec, also contains a similar fauna of living mollusks (La Rocque, 1966, p. 93). Many lakes in northeastern Wisconsin were found to contain living faunas virtually identical with the fossil faunas of this study (Morrison, 1932, in La Rocque, 1966, p. 95-110). Cain *et al.* (1950, p. 541) reported that *Amnicola limosa, A. lustrica, Valvata tricarinata, Fossaria obrussa, Gyraulus parvus, Helisoma anceps, Physa integra*, and Sphaeriidae along with a few other aquatic species were found living in Sodon Lake, a typical marl lake in Oakland County, Michigan.

Living mollusks collected in present-day Ohio lakes reveal a slightly different fauna. This may, however, be due to the incompleteness of available data and inadequate collecting methods. Studies of northeastern Ohio aquatic molluscan habitats by Dexter (1950, 1953, in La Rocque, 1966, p. 86-88) have revealed the absence of *Helisoma anceps striatum* and *Amnicola lustrica*. From the available records, La Rocque (1968, p. 390-391 and 500-501) has reported these species as living today in Minnesota, Wisconsin, and New York, Minnesota, Ontario, and Wisconsin respectively. Sterki (1899 in La Rocque, 1966, p. 89) has listed *Amnicola lustrica* from Tuscarawas County, Ohio, but this may be a misidentification because it has not been found in other Ohio localities to the author's knowledge. *Helisoma anceps striatum* and *Amnicola lustrica* are probably cool water species that now find lake temperatures in Ohio, Indiana, and extreme southern Michigan unfavorable.

The terrestrial environment of the localities cannot be described reliably from this study, for many of the terrestrial snails listed have a wide ecological tolerance of environment types. Exceptions are *Stenotrema leai*, *Zonitoides arboreus* (Frye and Leonard, 1967, p. 433) and possibly *Retinella indentata* (La Rocque, 1970, p. 619) which are good indicators of the proximity of a forest area.

Wabee Lake differs from the previously discussed deposits of this study by the great abundance of *Goniobasis livescens* throughout the section. This species seems to be mainly a river, stream, and large lake form (Goodrich, 1945). In nearby Lake Wawasee, *Goniobasis livescens* was found to make up 97 percent of the gastropods in the 'open littoral zone' and 74 percent in the 'weedy littoral zone' (Scott *et al.*, 1928, in Goodrich, 1945, p. 27). In the early stage of Wabee Lake, *Goniobasis livescens* lived on the gravelly bottom of nearshore zones. The mollusk species indicated as typical of other lake environments did not favor such a coarse bottom and were present in small numbers. The gradual buildup of marl and organic debris on the bottom led to shallowing of the water in this area. *Goniobasis livescens* no longer found this a favorable habitat and moved to other areas in the lake. Other lacustrine deposits may show a predominance of *Goniobasis livescens* and related species and genera in the early stages, but most samples show only later stages of lacustrine history.

The Castalia Prairie deposit also differed from the others studied. *Pomatiopsis lapidaria* was found in great numbers throughout the stratigraphic section. *Pomatiopsis lapidaria* is amphibious and is commonly found near a stream or river (La Rocque, 1968, p. 413). Thus, the presence of abundant *Pomatiopsis lapidaria* at Castalia indicates the presence of flowing water, probably originating from springs. The species inhabited the moist banks of these bodies of water. The extensive tufa deposits in the area lend support to this interpretation of the Castalia Prairie deposit. This deposit is also the only one not containing members of the Amnicolidae and Valvatidae. The absence of these gill breathers can be attributed to their requirement of permanent bodies of water in which to live (Frye and Leonard, 1967, p. 432-433). The Naiades are also absent from this deposit for the same reason.

CONCLUSION

1. Big Turkey Lake and Wabee Lake in Indiana and Silver Lake in Ohio were formed from melting ice blocks left behind by the retreating Wisconsin ice sheet. Rushcreek Lake in Ohio and Michigan's Fourmile Lake were formed by the damming of water at the ice sheet front. Castalia Prairie in Ohio was subjected to flooding by springs.

2. Of the lakes studied, Rushcreek Lake and Silver Lake in Ohio formed first, followed by Big Turkey Lake and Wabee Lake in Indiana, then Fourmile Lake, and finally the lakes in Castalia Prairie.

3. Lakes of Wisconsin age are in the process of filling in due to a combination of plant encroachment, marl and peat deposition, influx of terrigenous detritus, and a lowering of water level by natural and artificial drainage.

4. *Amnicola limosa*, *A. lustrica*, *Valvata tricarinata*, *Gyraulus parvus*, *Helisoma anceps striatum*, *Physa gyrina hildrethiana*, and Sphaeriidae are characteristic molluscan species of shallow water plant-rich zones of a typical marl lake within the study area.

5. *Gyraulus parvus* is the dominant mollusk in the shallow (less than 3 feet) water zones of marl lakes within the study area.

6. The presence of *Goniobasis livescens* in a lacustrine assemblage indicates a large lake with coarse bottom material or the nearness of a stream or river.

7. The presence of *Pomatiopsis lapidaria* in a lacustrine assemblage discloses the proximity of a fluvial environment for it is typically a stream bank inhabitant.

8. The existence of *Fossaria obrussa decampi* in a lacustrine fauna indicates the nearness of shoreline or exposed mud bars and flats.

9. The absence of indigenous cteno-

branchs in lacustrine deposits shows that the water body was ephemeral or possibly contained high amounts of suspended silt. Both conditions are detrimental to ctenobranch populations.

10. *Helisoma anceps striatum* and *Amnicola lustrica* are probably cooler-water species, for they are now found only in regions north of the study area.

11. The dominant plant fossil of the study area was the *Chara* oogonia.

12. *Candona* was the dominant ostracode genus of the study area.

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THE RECENT GASTROPODA OF OKLAHOMA, PART VII. THE ZONITIDAE

BRANLEY A. BRANSON

Eastern Kentucky University, Richmond, Kentucky 40475

ABSTRACT

Data for the genera and species of Oklahoma zonitid snails are compiled from the literature and from new distribution records.

INTRODUCTION

Considerable time has elapsed since the last installment of this series appeared (1), more than intended. This contribution attempts to summarize what is known about the systematically very difficult family Zonitidae in Oklahoma. However, several papers have appeared during the interim which address themselves to the Oklahoma gastropod fauna, and a synopsis of these is given below.

I wish to thank Mr. Steve Stacy, graduate student at Eastern Kentucky University, for making the excellent photographs.

Hubricht (2), in discussing the trans-Mississippian distribution of *Strobilops aenea* Pilsbry, reported some river-drift specimens (possibly Pleistocene wash-outs) from near Whitefield, Haskell County, Oklahoma. In an accompanying note (3), he transferred *Pilsbryna tridens* Morrison (discussed herein) from the Zonitidae to the family Endodontidae, placing the species in *Helicodiscus*. In a third paper, Hubricht (4) added his recently described *Helicodiscus jacksoni* to the known fauna of Oklahoma (Mayes County). Finally, Hubricht (5) elevated *Mesodon indianorum lioderma* (Pilsbry) to full-species rank and removed it from *Mesodon* to *Triodopsis*. He *(loc. cit.)* also reported *Succinea indiana* Pilsbry (Muskogee and Sequoyah counties) and *Succinea witteri* Shimek (Craig, Ottawa, Sequoyah and Wagoner counties) from Oklahoma for the first time, and included *Retinella zikmundi* Branson in the synonymy of *R. wheatleyi* (Bland) (see also below) and considered *Stenotrema abaddona* Branson to have been based upon immature specimens of *Stenotrema labrosum* (Bland).

Branson (6) described a new slug *(Philomycidae)* from LeFlore County, reported (7) *Glebula rotundata* (Lamarck) (Pelecypoda: Unionidae) from an arm of Grand Lake in Ottawa County, and (8) statistically analyzed shell variation in *Polygyra dorfeuilliana* from many Oklahoma localities. Since Taylor (9) indicated that *Physa anatina* Lea was probably the only *Physa* in Oklahoma outside of the Ozarkian region, I (10) have prepared a complete synonymy (as now understood) for the species. In this same paper *(op. cit.)*, *Pupoides inornatus* Vanatta and *Vallonia cyclophorella* Sterki are recorded for the first time for the state.

COLLECTING SITES

In addition to published data from the literature, a considerable number of heretofore unpublished records for Oklahoma zonitids have accumulated in my files; these are presented here. In the annotated list which follows, specimens are referred to the sites listed below by number, and the number collected appears in parentheses.

1. Mud flat, Big Grassy Lake, near Tom, McCurtain Co., Oklahoma; 14 July 1961.
2. Blue River at Connorville, Johnston Co.; 3 June 1961.
3. Two miles N of Talequah, Cherokee Co.; 26 April 1953.
4. Little River bridge, U. S. Highway 71 S of Broken Bow, McCurtain Co.; 16 May 1963.
5. Spring River, State Highway 10, 5 mi. E of Miami, Ottawa Co.; 29 August, 1963.
6. Hillside at Ft. Gibson Dam, Cherokee Co.; 14 May 1963.

7. Kiamichi Mountains, 0.9 mile N of Honobia, Pushmataha Co.
8. Near U. S. Highway 59, 1¼ mile N of Watts, Adair Co.; 5 March 1963. Also in the nearby Illinois River.
9. East side of Lake Tenkiller Dam, Sequoyah Co.; 24 August 1963.
10. Banks of Lost Creek, 2 miles E of Wyandotte, Ottawa Co.; 13 June 1963.
11. Pipe Springs, W end of Rich Mountain, State Highway 259, LeFlore Co.; 20 August 1963.
12. Rich Mountain, 1.7 miles S of Page on State Highway 259, LeFlore Co.; 20 August 1963.
13. Jackfork Mountain (base), 26.6 miles S of Hartshorne, Pittsburgh Co.; 23 August 1963.
14. Shaded hillside, Ft. Gibson Reservoir, west side, Wagoner Co.; 9 May 1963.
15. Hill overlooking Lake Talihina, 2 miles W of Talihina, Latimer Co.; 27 August 1963.
16. Bluffs of Sand Creek, Osage Hills State Park, Osage Co.; 27 August 1963.
17. West side Dam, Tenkiller State Park; dry, shaded; 24 August 1963.
18. Round Mountain, 9.5 miles NW Walnut Tower on Wwlnut tower road, LeFlore Co.; 20 August 1963.
19. Banks of Flint Creek (from the creek, for aquatics), 2 miles E of Westville, Adair Co.; 16 April 1963.
20. Walnut Mountain, 5.9 miles NW of Walnut tower, Walnut tower road, LeFlore Co.; 20 August 1963.
21. Walker Mountain, 2.8 miles S on U.S. Highway 59 and 11.1 miles E on Walker Mountain road, of Page, LeFlore Co.; 19 August 1963.
22. Base of Poteau Mountain, 1.4 miles SE of Monroe on State Highway 83, 0.9 mile E on County Road C and 0.7 mile on County Road fl; 19 August 1963.
23. Kiamichi Mountain, 0.2 mile W Kiamichi tower, LeFlore Co.; 21 August 1963.
24. Blue Mountain, 0.5 mile 3 of Blue Mountain tower on Blue Mountain tower road, LeFlore Co.; 22 August 1963.
25. Shaded leaf litter on bluffs, 7.4 miles E of junction of U.S. Highway 59 and State Highway 259, on U.S. 59, Adair Co.; 4 June 1963.
26. Crow's Nest, 11 miles NW Walnut tower, LeFlore Co.; 19 August 1963.
27. Brush Mountain, 5 miles E of Stillwell on U.S. 59, Adair Co.; 23 August 1963.
28. Near Disney Dam, State Highway 20, limestone bluffs, Mayes Co.; 26 August 1963.
29. Bluffs of Rock Creek, 2 miles S of Eufala on U. S. 69, McIntosh Co.; 27 August 1963.
30. Burned-over hillside, 3 miles W of Bernice, Ottawa Co.; 29 August 1963.
31. Potato Hills, 5 miles W of Talihina on State Highway 63, Latimer Co.; 21 August 1963.
32. Bluffs of Neosho River, Cherokee Recreation Area #1, near Langley, Mayes Co.; 29 August 1963.
33. Heavily shaded hillside, 5.5 miles E Salina, State Highway 85, Mayes Co.; 25 August 1963.
34. Billy Creek Recreation Area, 0.5 mile E of Muse, LeFlore Co.; 22 August 1963.
35. Hillside, 1.2 miles E of Flint, State Highway 33, Delaware Co.; 26 August 1963.
36. North side of Rich Mountain, 5.6 miles E of Page on U.S. Highway 59, LeFlore Co.; 20 August 1963.
37. Lost Creek Bluffs, 15 miles SE of Miami, Ottawa Co.; 16 May 1963.
38. Lowlands, 2 miles E of Wyandotte, Delaware Co.; 21 September 1963.
39. Robbers Cave State Park, 5 miles N of Wilburton, Latimer Co.; 20 August 1963.
40. Oak hillside, 0.8 mile N of Childers, Nowata Co.; 28 August 1963.
41. Cavanal Mountain, 2 miles W of Poteau, LeFlore Co.; 23 August 1963.
42. San Bois, 6.1 miles NW of Wilburton, on State Highway 2, LeFlore Co., 23 August 1963.
43. Bluffs of Limestone Creek, 19 miles N of Atoka on old U.S. 69, Atoka Co.; 27 July 1963.
44. Hillside overlooking Spavinaw Creek, Spavinaw, Mayes Co.; 26 August 1963.
45. Turkey Ford, Delaware Co.; 21 September 1963.
46. Buffalo Mountain, 2 miles E of Talihina, Latimer Co.; 21 August 1963.
47. Lowlands, 7.4 miles E of Highways U.S. 59 and State 259, on U.S. 59, Adair Co.; 4 June 1963.
48. Shaded talus, east side of Tenkiller State Park, Sequoyah Co.; 24 August 1963.
49. Bluffs of Verdigris River, 4 miles E of Nowata on U.S. 60, Nowata Co.; 28 August 1963.
50. Sandstone bluffs of Sand Creek Osage Hills State Park, Osage Co.; 27 August 1963.
51. Banks of South Csnadian River, State Highway 33, 4 miles NE of Thomas, Custer Co.; 17 June 1960.
52. Arkansas River bluffs, 0.5 mile E of Keystone Dam on old State Highway 51, Tulsa Co.
53. 'Old Indian Trail,' 0.9 mile N of Honobia, Kiamichi Mountains, Pushmataha Co.; 12 September 1963.
54. Campus pool, Northeastern Oklahoma State Teachers' College, Talequah, Cherokee Co.; 12 September 1963.

55. Elk River near mouth, Delaware Co.; 23 April 1963.
56. Winding Stair Mountain Road, 0.5 mile Wofjunction with State Highway 259, LeFlore Co.; 18 August 1963.
57. 'Coody's Bluff,' 4 miles E of Nowata, U.S. 60, Nowata Co.; 28 August 1963.
58. Elk City, Beckham Co.; 31 May 1963.
59. Lowlands, 1 mile 3 of Baron, Adair Co.; 24 August 1963.
60. Haw Creek, 5 miles 2 of Page, LeFlore Co.; 18 August 1963.
61. North fork of Red River, State Highway 44, S 33, R 20 W, T 5 N, Greer Co.; 29 December 1963.
62. Banks of Charley Creek, 0.5 mile NW of Burbank, Osage Co.; 27 February 1964.

THE FAMILY ZONITIDAE

Taxonomically, the family Zonitidae is quite a confusing taxon. Many of the shell characteristics are matters of degree, and hence are liable to subjective decision-making. Many of the definitive traits are ones of the genitalia and other soft parts and, since many of the species are small to minute, are difficult to determine for the novice malacologist. Consequently, the keys which follow are not intended to portray natural relationships. Moreover, at some points difficulty may be encountered; the descriptive comments should be utilized to clarify all identifications. Characters of the family follow.

Shell depressed-heliciform, helicoid or biconvex to conical; colorless, white, or amber to various shades of brown; 2½ to 8 or more narrow to slowly expanding, convex to flattened whorls; narrowly to widely phaneromphalous; aperture thin, unexpanded, rounded to lunate; smooth to distinctly cross- and/or longitudinally striated. Animal colorless to quite black; foot entire to tripartite, wrinkled to smooth; white to dark gray; jaw smooth and undivided to partially divided into indistinct plates; radula bearing squarish plates centrally and laterally, but oblong (wider than high) marginally, one to three cusped; dart apparatus present or lacking; penis duct forked or simple; tail with or without a caudal pit.

KEY TO OKLAHOMA GENERA OF ZONITIDAE

1. a. Shell conic or biconvex, very narrowly perforate; marginal radula teeth bi- or tricuspid; penis duct with an appendix 2
   b. Shell depressed to heliciform, toothed or toothless, cryptomphalous to narrowly umbilicate; marginal radular teeth unicuspid 3

2. a. Shell with thread-like striations; marginal teeth bicuspid .. *Euconulus*
   b. Shell without axial striations; marginal teeth tricuspid ...... *Guppya*

3. a. Shell widely phaneromphalous, possessing 2 or more teeth in aperture of body whorl 4
   b. Shell narrowly perforate, with or without shell teeth 5

4. a. Minute shell with three teeth in the aperture (see text) .... *Helicodiscus tridens*
   b. Minute shell with two teeth in the aperture (see text) .... *Helicodiscus roundyi*

5. a. Shell bearing ribs ...... *Striatura*
   b. Shell lacking ribs 6

6. a. Last whorl of shell much wider than those preceding it; no teeth in aperture 7
   b. Last whorl of shell not much wider than those preceding it; teeth present or not 8

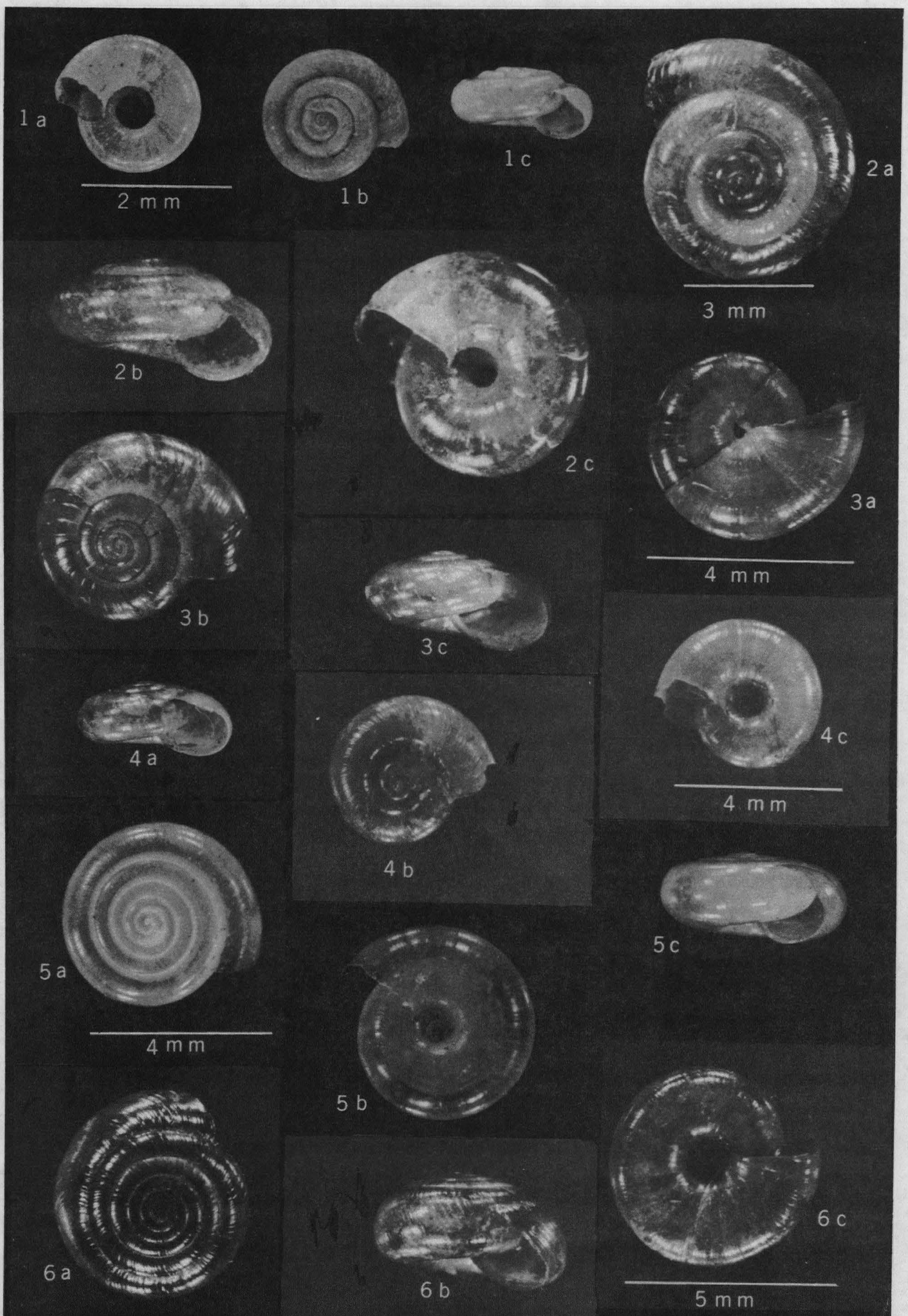
7. a. Shell larger than 15 mm in diameter .... *Mesomphix*
   b. Shell much smaller than 15 mm in diameter, and usually with radiating indented lines .... *Retinella*

8. a. Shell small, less than 4 mm in diameter 9
   b. Shell larger, more than 4 mm in diameter 10

9. a. Shell with 6 or nore whorls and usually teeth in the body whorl .... *Paravitrea* (part)
   b. Shell with fewer than six whorls; teeth lacking in body whorl..*Hawaiia*

10. a. Shell usually with more than 5 whorls; no callus within the aperture (often with transverse rows of teeth .... *Paravitrea* (part)
    b. Shell either with a callus or possesses fewer than 5 whorls; teeth-when present, not in a transverse row 11

11. a. Shell with either a callus pad or a transverse row of teeth and 5 or more whorls .... *Ventridens*
    b. Shell lacking a callus pad and teeth; whorls 5 or less .... *Zonitoides*



1a
2 mm
1b
1c
2a
3 mm
2b
2c
3a
4 mm
3b
3c
4a
4b
4c
4 mm
5a
4 mm
5b
5c
6a
6b
6c
5 mm

Genus EUCONULUS Reinhardt

Shell small, 2.4 to 3.5 mm in height, 2.4 to 3.4 mm in diameter; spire strongly convex; whorls 5½ to 7¾, closely coiled, smooth to minutely striated, hyaline to yellowish-brown in color; minutely phaneromphalous; aperture lunate, the lip thin. Animal pale gray with darker gray tentacles; mantle marked by oblong or squarish black blotches. Two species reported from Oklahoma.

KEY TO OKLAHOMA EUCONULUS

a. Shell brownish, glossy; 4½ to 6 whorls .... *Euconulus fulvus*
b. Shell corneous to white, less glossy; 6 to 8 whorls .. *Euconulus chersinus*

Euconulus fulvus (Müller) Fig. 17a

Published Records: Murray and Johnston counties (11); Caddo and Canadian counties (Pleistocene) (2); Adair, Beckham, Cherokee, Creek, Haskell, Osage, Ottawa, Pottawatomie, Roger Mills, and Sequoyah counties (13); Oklahoma County (14); Payne County (15, 16); Beaver and Harper Counties (17); Lincoln, Noble, and Comanche counties (18); Muskogee and Pontotoc counties (19); Comanche, Kiowa, McCurtain, Noble and Woodward counties (20).

The thin, fragile shell is broadly conical, 2.5 to 3.2 mm in diameter, 2.2 to 2.5 mm in height; reddish-brown to pale yellowish-brown, the apex nearly white; 4½ to 6 whorls marked by crowded and faint spiral and radial striae, glistening; umbilicus minute; aperture lunate, lip thin and simple, but slightly reflected near the columella; periphery rounded to very slightly angular. The animal is light to dark gray with nearly black tentacles, the mantle being heavily blotched with black; spermatheca short, its sac distinct and ovoid in shape; epiphallus nearly lacking; penial retractor stout, inserting on penial sheath below penis. Habitat: moist leaves and debris on forest floors; in and on decaying wood.

Euconulus chersinus (Say) Fig. 16a

Published Records: Cimarron, Marshall, and Choctaw counties (21); Pawnee and Murray counties (11); Alfalfa, Kiowa and Jackson counties (10); Bryan, Haskell, Hughes, LeFlore, Osage and Ottawa counties (13), McClain, Cleveland and Muskogee counties (16); Sequoyah County (22); Blain, Johnston, Kay, Payne, Pontotoc counties (19); Caddo, Garfield, Grady, Lincoln, Logan, McCurtain, Noble, Tillman, and Woodward counties (20).

New Records: 14(1); 40(3).

Shell similar to that of *E. fulvus*, but higher, 2.7 to 3.0 mm in height, 2.4 to 3.1 mm in diameter; yellowish-white to pale brown in color; 6 to 8 whorls marked by very crowded spiral and radial striations, less glossy than *E. fulvus;* umbilicus minute; aperture narrow, lunate; periphery slightly angular to rounded. Animal nearly white to light gray with slightly darker tentacles, the mantle bearing a few grayish blotches; spermatheca short without a clearly distinguished sac; epiphallus large, thick-walled; penial retractor branched, inserting on both sides of penis apex. Habitat: similar to that of *E. fulvus*, but somewhat more tolerant of dry conditions.

The subspecies of *E. chersinus* discussed by Pilsbry (22) are difficult to separate. As regards Oklahoma, all specimens have been traditionally referred to *E. chersinus trochulus* (Reinhardt), 1883, but this is by way of range rather than the result of detailed study.

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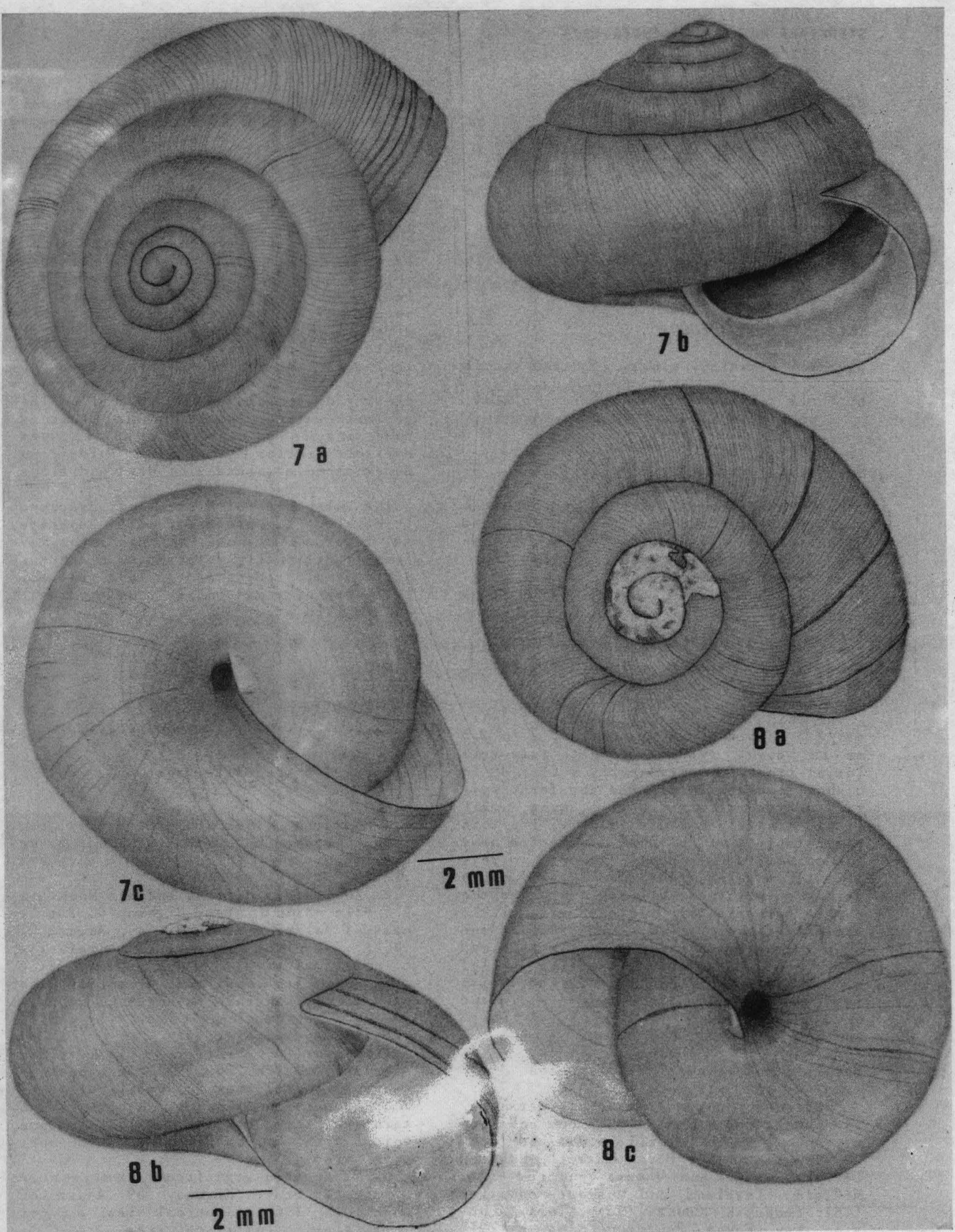
Figures 1–6 (opposite page)

1. *Hawaiia minuscula,* Darby Boy Scout Camp, Cherokee Co., May 24, 1963; a, umbilical view; b, apical view; c, apertural view.
2. *Zonitoides nitidus,* Buffalo Mountain, 0.6 mile north on State Highway 63, 2 miles east of Talihina, Latimer Co., August 21, 1963; a, apical view; b, apertural view; c, umbilical view.
3. *Retinella indentata,* Greenleaf Lake, Amphibious Landing, Muskogee Co., April 7, 1951; a, umbilical view; b, apical view; c, apertural view.
4. *Retinella wheatleyi,* Clarksville, Arkansas, March 25, 1951; a, apertural view; b, apical view; c, umbilical view.
5. *Paravitrea simpsoni,* Kiamichi Mountain, LeFlore Co., August 21, 1963; a, apical view; b, umbilic view; c, apertural view.
6. *Paravitrea significans,* 1¼ miles north of Watts, State Highway 59, Adair Co., August 25, 1963; a, apical view; b, apertural view; c, umbilical view.


7 a
7 b
8 a
7c
2 mm
8 b
2 mm
8 c

Genus GUPPYA Mörch

Shell similar to that of *Euconulus*, but much lower, with fewer whorls (3 to 4 2/3). and of smaller size (1 to 3 mm diameter, less than 1 mm in height); radial striae lacking on apex; lip thin and simple; aperture lunate; white to yellowish-white. Animal white to nearly colorless; tentacles light gray. Primarily tropical, but one species in eastern Oklahoma.

Guppya sterkii (Dall) (See Branson, 1) Fig. 12

Published Records: Cherokee County (1); Sequoyah County (4).

This species lives under leaf litter and decaying wood.

Genus RETINELLA Fischer

Shell thin, pale golden to colorless, and small (4.0-7.5 mm; excluding immature ones), somewhat depressed; minutely umbilicate to cryptomphalous; 3½ to 5½ whorls; Sculpture of microscopic, crowded growth lines, either crossed by minute spiral lines or the latter lacking, superimposed upon which are series of impressed radial grooves (lacking in *R. electrina)*; apical 1 to 1½ whorls smooth. Animal white to dark gray or black. Five species reported from Oklahoma.

Some workers have elevated some of the subgenera of *Retinella* to generic status (23), whereas others (24, and in other papers) utilize all the subgenera as genera. Baker (25, 26) on the other hand, followed by Pilsbry (22), was of the opinion that *Retinella* consisted of 'a continuous series of minor groups' rather than a series of genera. This is the rationale followed here.

KEY TO OKLAHOMA SPECIES OF RETINELLA

1. a. Shell lacking impressed (major series) radial grooves .... *Retinella electrina*
   b. Shell possessing impressed radial grooves 2

2. a. Shell umbilicate to narrowly perforate 3
   b. Shell with umbilicus closed .... *Retinella cryptomphala*

3. a. Shell umbilicate 4
   b. Shell very narrowly perforate .... *Retinella indentata*

4. a. Major grooves weakly developed on umbilical side of shell .... *Retinella wheatleyi*
   b. Major grooves well-developed on umbilical side of shell .... *Retinella zikmundi*

Retinella electrina (Gould) Fig. 19 a,b

Published Records: Canadian and Caddo counties (Pleistocene) (12); Harper County (Pleistocene) (27); Muskogee County (20).

New Records: 44(1).

Shell moderately depressed, the spire only slightly everted; 3.5 to 5.0 mm in diameter, 2.0 to 2.8 mm in height; usually transparent (when fresh), glossy, amber to pale honey colored; 3¼ to 4¼ whorls; sculpture of crowded growth striae above, lacking on the highly polished base, and very weak microscopic spiral striae; the slightly ovoid umbilicus is deep, about 4.5 times in shell diameter. The animal is dark gray to black, the tripartite foot being lighter. Habitat: forest litter, decaying logs, etc.

Retinella wheatleyi (Bland) Fig. 4 a,b,c

Published Records: Cherokee County (5); Muskogee County (20).

Shell somewhat depressed, spire slightly everted; 4.3 to 5.5 mm in diameter, 1.7 to 2.3 mm in height; pellucid amber to tan in color; radial sculpture well-developed but quite weak to lacking; 4½ to 5 1/3 whorls; umbilicus deep, distinctly oval in shape, 5 to 5½ times in shell diameter. Animal black, including the foot. Habitat: Moist hardwood forest litter, mostly along streams at moderate to low elevations.

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Figures 7, 8 (opposite page)

7. *Ventridens ligera,* 1¼ miles north of Watts, State Highway 59, Adair Co., August 25, 1963; a, apical view; b, apertural view; c, umbilical view.

8. *Mesomphix capnodes*, Octavia, LeFlore Co., October 18, 1959; a, apical view; b, apertural view; c, umbilical view.

Retinella zikmundi Branson (Illustrated in Branson, 1).

Published Records: Adair, Latimer, LeFlore, and Mayes counties (Branson, 1).

Since this species was described, and many data given, in part VI, there is no reason to repeat the material here. In the introduction (above), I indicated that Hubricht (5) had synonymized this species with *R. wheatleyi*. However, as I indicated in the original description, the species seems to be quite closely related to *R. pentadelphia* (Pilsbry) from the Great Smokies. In support of this conclusion: 'The *Retinella* is a most interesting find, obviously extremely closely related to *R. pentadelphia* from the Smokies. Indeed, I would not describe it as distinct unless anatomical differences were found' (Alan Solem, Curator of Lower Invertebrates, Chicago Nat. Hist. Mus.) In view of this, I am retaining the form pending an investigation of the soft anatomy.

Retinella indentata (Say) Fig. 3 a, b, c

Published Records: Pawnee, Washington, and Pittsburg counties (11); Garvin, Carter, and Marshall counties (21); Comanche and Caddo counties (10); Caddo and Canadian counties (Pleistocene) (12); Adair, Bryan, Choctaw, Craig, Haskell, Hughes, LeFlore, Love, Mayes, Nowata, Osage, Ottawa, Pottawatomie, Rogers, and Sequoyah counties (13); Murray, Cleveland, LeFlore, Mayes, Bryan, Coal, Okmulgee, and Latimer counties (28); Payne County (15); Oklahoma, Cleveland, and McClain counties (28); Payne County (15); Oklahoma, Cleveland, and McClain counties (16); Ottawa, Delaware, LeFlore, Atoka, and Pittsburg counties (29); Cherokee, Creek, Johnston, Kay, McCurtain, Murray, Muskogee, Payne, and Pontotoc counties (19); Comanche, Grady, Lincoln, Logan, Noble, McCurtain, and Creek counties (20); Payne, Grady, and Pottawatomie counties (18).

New Records: 3(1), 8(3), 9(19), 10(13), 13(3), 14(4), 15(1), 16(7), 17(27), 18(2), 19(2), 22(4), 24(2), 27(6), 28(2), 29(6), 39(2), 31(4), 32(1), 33(8), 38(3), 39(5), 40(36), 41(1), 42(1), 43(4), 44(2), 45(5), 50(3), 52(3), 53(1).

Shell somewhat depressed, spire moderately everted; diameter 2.0 to 5.3 mm; height 1.1 to 2.5 mm; whorls 2½ to 4¼; pellucid brown to nearly white; radial sculpture well-developed, majors being equally spaced (7 on last 3 mm of body whorl—a total of 31 on last whorl—in shell of 5 mm diameter) and as strong below as above; spiral sculpture minute to lacking; umbilicus minute to nearly lacking. The animal is intensely black. Habitat: as in species discussed above.

Retinella cryptomphala (Clapp) (See Branson, 1).

Published Records: Adair, Latimer, LeFlore and Mayes counties (1); Carter County (10); Latimer and Pushmataha counties (4).

Shell moderately depressed, thin (heavier than preceding species, however), translucent, whitish to pinkish-brown; diameter 5.5 to 7.6 mm, height 4.0 to 5.3 mm; 5 to 5½ whorls; very fine growth striae and evenly spaced, well-developed major grooves as strong below as above and distinct spiral sculpture; umbilicus completely closed by a tongue-like extension from the columella; animal blue-black, but tending to mottling. Habitat: moist forest debris.

Hubricht (24) has elevated the subspecies *R. cryptomphala solida* (H. B. Baker) to full species. However, since he has not found the two forms together, it seems best at this time to consider the Oklahoma populations *R. cryptomphala*.

Genus MESOMPHIX Rafinesque

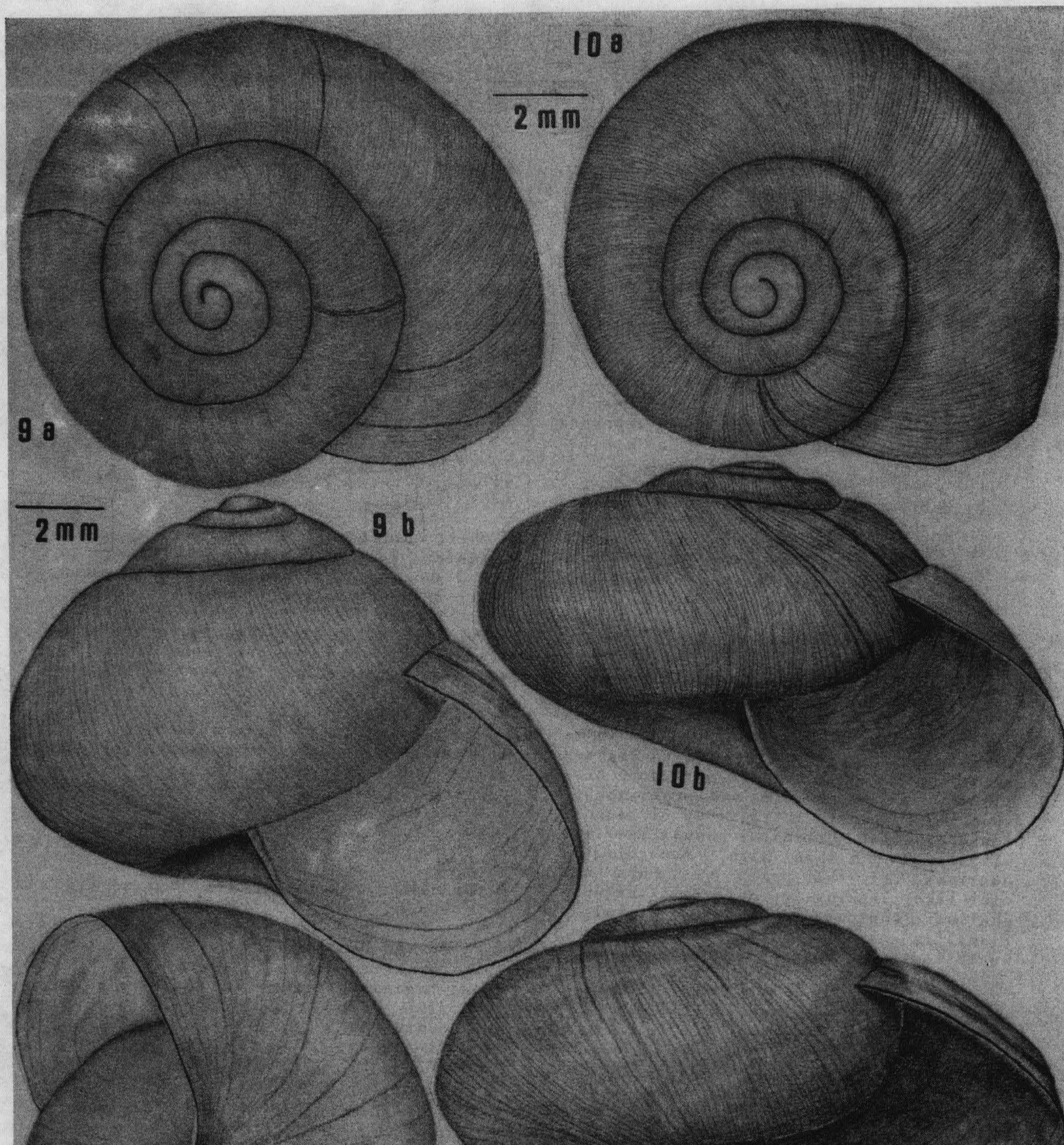
Shell 12.5 to 26.5 mm in height, 19 to 35 mm in diameter, heliciform; whorls 4½ to 5 1/3, the last much larger than the others, smooth to radially striate, some species with revolving sculpture as well; brown to yellowish-green or yellowish-brown; umbilicus varying from a mere per-

Figures 9-11a (opposite page)

9. *Mesomphix friabilis*, 1.2 miles east of Flint, State Highway 33, Delaware Co., August 25, 1963; a, apical view; b, apertural view.

10. *Mesomphix vulgatus*, 1.4 miles southeast of Monroe on State Highway 83, near Poteau Mountain, LeFlore Co., August 19, 1963; a, apical view; b, apertural view; c, umbilical view.

11. *Mesomphix cupreus*, near dam, Lake Spavinaw, Spavinaw, Mayes Co., August 26, 1963; a, apertural view.


10a
2 mm
9a
2mm
9 b
10b
10c
11 a
2mm

foration to widely phaneromphalous; aperture simple, thin, lunate to oval. Animal gray to black; foot tripartite; epiphallus well-developed; verge lacking. Four species known from Oklahoma.

KEY TO SPECIES OF OKLAHOMA MESOMPHIX

1. a. Umbilicus minute, more than 12 times in shell diameter *Mesomphix vulgatus*
   b. Umbilicus larger, 12 or fewer times in diameter 2

2. a. Shell with spiral sculpture (rows of papillae) .... *Mesomphix capnodes*
   b. Shell lacking spiral rows of papillae 3

3. a. Umbilicus large, 6 or fewer times in shell diameter . *Mesomphix cupreus*
   b. Umbilicus smaller, more than 6 times in shell diameter .... *Mesomphix friabilis*

Mesomphix vulgatus Baker Fig. 10 a, b, c

Published Records: LeFlore County (16).

Shell depressed-loe conoidal, 19.0 to nearly 30 mm in diameter, 11.5 to 18 mm in height, chamois-brown to olive, lighter below; 4½ to 4 1/3 whorls marked by distinct radial sculpture and superimposed upon it, distinct, spiral rows of microscopic papillae; umbilicus minute; aperture slightly wider than high. According to Hubricht (30), the penis is short and club-like, lacking an appendix; the epiphallus is stout and enlarged distally. Primarily a snail of upland situations beneath logs and decaying vegetation.

Mesomphix capnodes (Binney) Fig. 8 a, b, c

Published Records: Osage County (as *M. cupreus ozarkensis)* (21); Adair and LeFlore counties (as *M. c. ozarkensis)* (28); Cherokee and LeFlore counties (4); LeFlore County (as *M. c. ozarkensis)* (29); Cherokee, McCurtain and Muskogee counties (as *M. c. ozarkensis)* (19).

Shell thin, depressed-globose, 20.0 to 34.0 mm in diameter, 12.5 to 25.6 mm in height, brown to olive; apex usually entire; 4¾ to 5 1/3 whorls marked by fine radial striae and very small spiral papillae (may be obscure in old shell material (4); umbilicus moderate, 7 to 10 times in shell diameter; aperture oblique, wider than high, ovoidal. Animal with very black pallial markings. Under moist forest debris.

For years this species, in Oklahoma and adjacent Arkansas, has been referred to as a subspecies, *Mesomphix cupreus ozarkensis* (Pilsbry and Ferriss) 1906. However, Hubricht (4, and elsewhere) has referred the form to *M. capnodes*.

Mesomphix cupreus (Rafinesque) Fig. 11a, b.

Published Records: Delaware and Cherokee counties (11); Adair, Haskell, LeFlore, and Wagoner counties (21); McCurtain County (20).

New Records: 1(4), 8(8), 4(10), 1(14), 11(19), 26(22), 24(23), 5(25), 10(36), 1 (38), 2(44).

Shell substantial, 10.2 to 22.6 mm in diameter, 2 to 14 mm in height; 3 4/5 to 4 2/3 whorls; umbilicus 5 to 6 times in shell diameter; olive to brownish-yellow, smooth but of dull luster; growth striae very fine, but rest-marks (dark-brown to black) common in large specimens; aperture rounded rather than lunate, whitish to bluish within. Sole a light, dirty white with one pedal line rather than two; side of body granular and reticulated, but less so than in *M. friabilis*, the anterior end being smoky gray; top of head grayish; posterior tentacles gray, the anterior ones white. Habitat as in the two species above.

Mesomphix friabilis (W. G. Binney) Fig. 9 a, b.

Published Records: Sequoyah and McCurtain counties (28); 'Oklahoma' (31); Ottawa, Rogers, Muskogee and LeFlore counties (16); Ottawa County (22, 29); Cherokee County (32).

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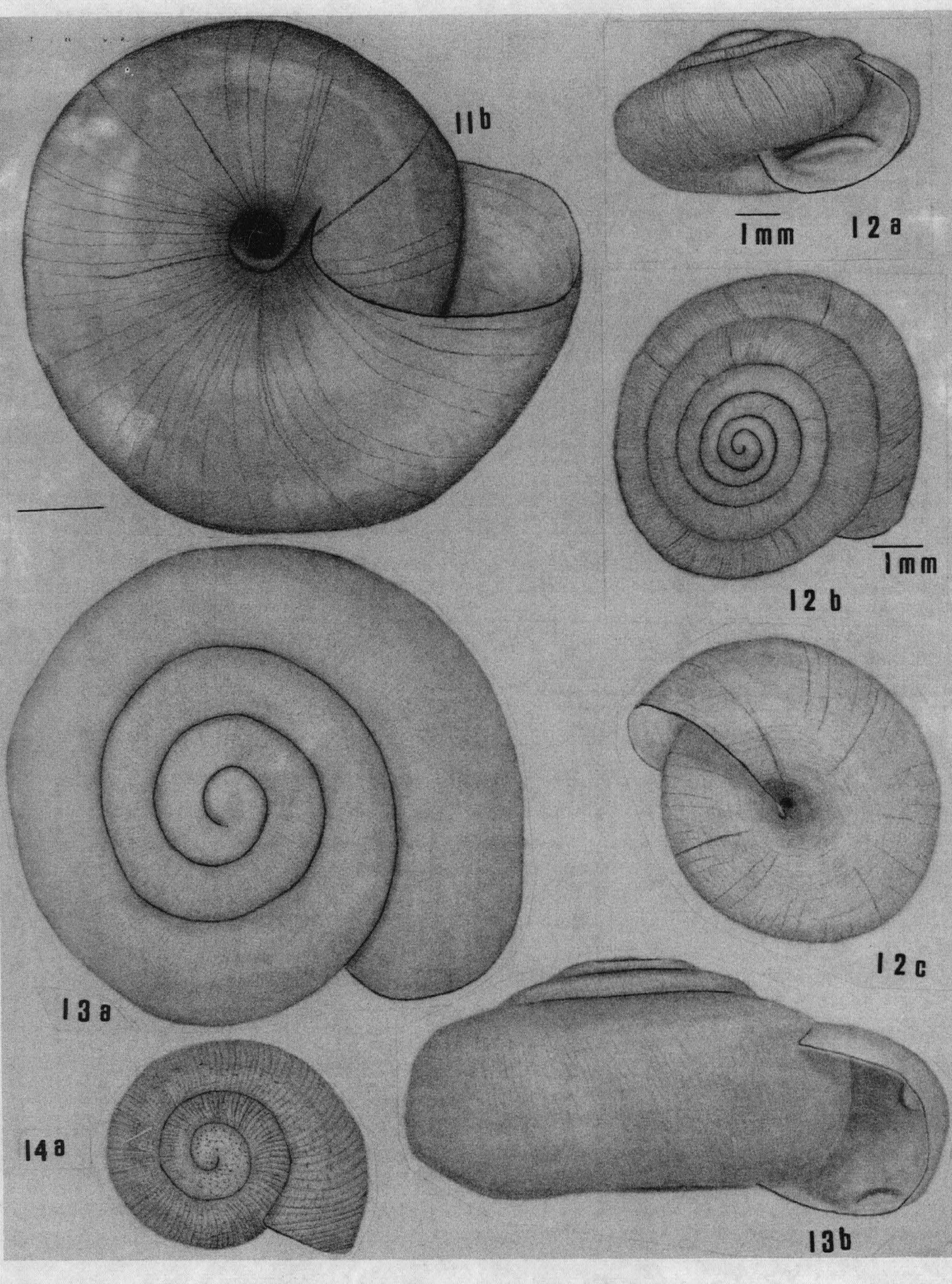
Figures 11b-13 (opposite page)

11b. *Mesomphix cupreus*, near dam, Lake Spavinaw, Spavinaw, Mayes Co., August 26, 1963; b, umbilical view.

12. *Ventridens demissus*, Lake Talihina, 2 miles west of Talihina, Latimer Co.; August 21, 1963; a, apertural view of immature shell; b, apical view; c, umbilical view.

13. *Helicodiscus roundyi*, bluffs of Roaring River, Cassville, Barry Co., Mo., April 18, 1963; a, apical view; b, apertural view.


11b
1mm
12a
1mm
12b
12c
13a
14a
13b

New Records: 2(19), 4(25), 1(27), 15(30), 13(36), 4(40), 3(44), 1(45).

Shell globose-conical, metallic, translucent to practically transparent, reddish-brown to brown (measurements and whorl counts in Table 1); apical whorls unworn (usually worn in *M. cupreus*); umbilicus very small, 12 or more times in shell diameter; aperture circular, about as wide as high; sculpture as in *M. cupreus*. Sole dead white, except at posterior extremity where it is faintly flesh-gray along the edges and tip, definitely tripartite and microscopically longitudinally streaked by creases. Just above foot periphery, there are two bluish, longitudinal vessels connected to each other by many dorsoventrally arranged ones (ladder-like) (pedal lines); dorsum reticulated by faint grayish lines and blotches, the mantle with some intensely black or bluish-black, jagged-edged vessels; anterior edge of collar dead-white with faint gray reticulations.

TABLE 1. Some meristics of Oklahoma specimens of *Mesomphix friabilis*. (Measurements in mm.)

Diameter	Height	Diameter of Umbilicus	No. Whorls
5.5	4.0	-	2 1/2
9.0	5.0	1.0	3
9.7	5.8	1.7	3 1/2
11.3	8.5	-	3 3/4
12.1	11.0	2.0	3 5/6
12.5	7.5	1.5	3 2/3
12.5	6.5	1.5	3 1/2
14.5	9.5	1.3	4 1/5
15.0	10.0	2.3	4 1/3
16.8	9.0	2.5	4 1/4
17.0	10.5	2.2	4 1/3
17.6	10.5	-	4 1/4
17.7	11.5	-	4 -
19.0	13.0	2.5	4 1/4
20.0	6.7	-	3 1/2
22.4	15.5	3.4	4 2/3

Genus PARAVITREA Pilsbry

Shell small, 1.5 to 6.0 mm in diameter, 0.7 to 3.0 mm in height; depressed to discoidal; umbilicate; whorls 4 to 6½, mostly closely coiled, polished, radially striated; aperture lunate, lip simple, thin; colorless through white to yellowish-brown. Animal colorless, white, or pale gray; foot simple, undivided; epiphallus strongly developed, as is penis. Six species reported from Oklahoma, two erroneously, and a third one (*Paravitrea roundyi*) removed from the genus (see below.)

KEY TO SPECIES OF OKLAHOMA PARAVITREA

1. a. Diameter of shell 2.0 mm or more... 2
   b. Diameter of shell less than 2 mm .. ..*Helicodiscus roundyi*

2. a. Last whorl not obviously wider than preceding ones 3
   b. Last whorl much wider than preceding ones .... *Paravitrea petrophila*

3. a. Periphery of body whorl sloped outward; shell diameter about 6.0 mm .. .. *Paravitrea significans*
   b. Periphery of body whorl rounded; shell diameter 5.0 mm or less .... *Paravitrea simpsoni*

Helicodiscus roundyi (Morrison) Fig. 13 a, b

Published Records: Cleveland, Grady, Nowata, and Washington counties (16, 33); Blaine County (20).

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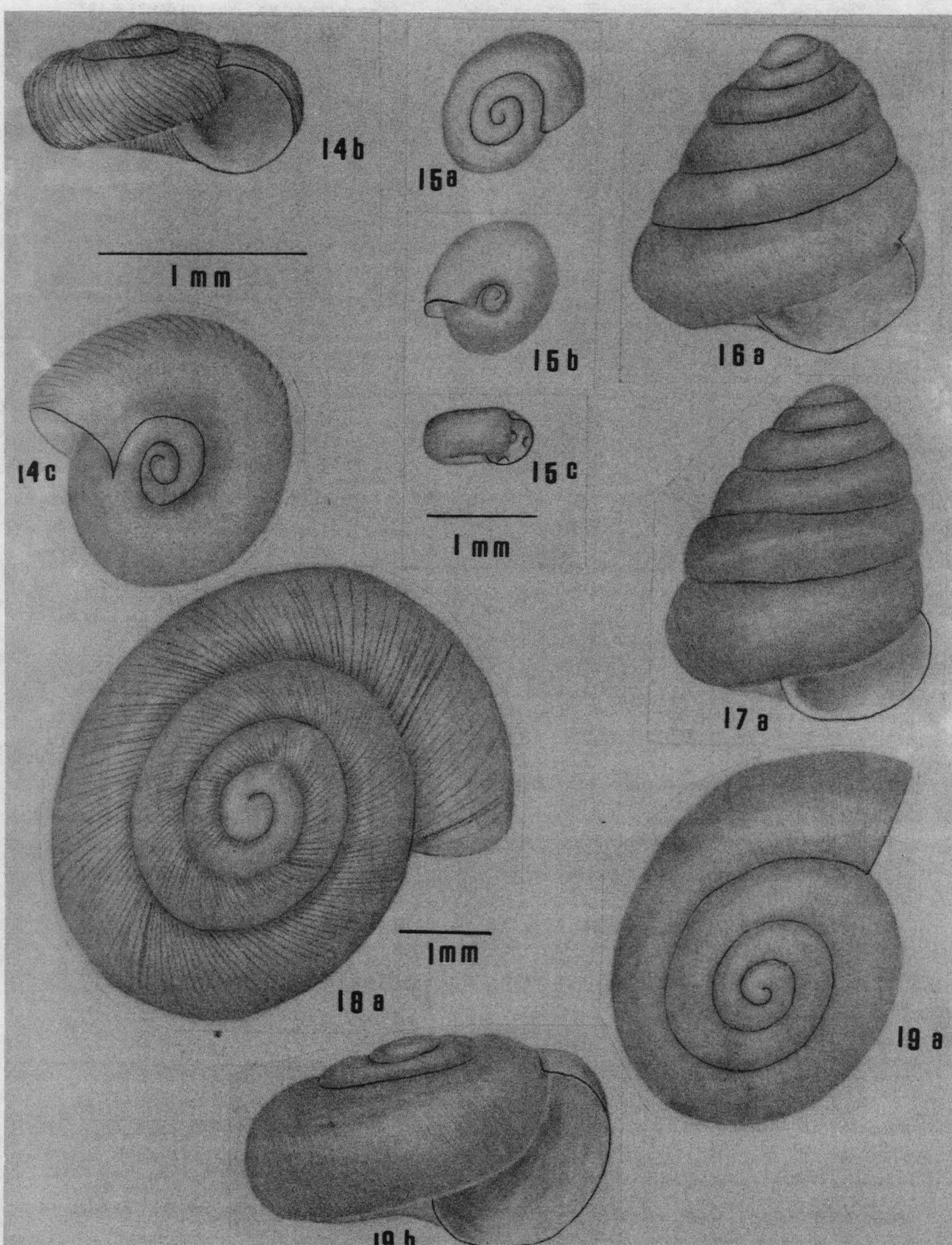
Figures 14-19 (opposite page)

14. *Striatura meridionalis*, junction State Highway 2 and South Canadian River, Haskell Co., May 6, 1955; a, apical view; b, apertural view; c, umbilical view.
15. *Helicodiscus tridens*, 9.1 miles northwest of Walnut Tower, Round Mountain, LeFlore Co., August 20, 1963; a, apical view; b, umbilical view; c, apertural view.
16. *Euconulus chersinus*, 9.1 miles northwest of Walnut Tower, Round Mountain, LeFlore Co., August 20, 1963; apertural view.
17. *Euconulus fulvus*, McSpadden Falls, Dripping Cliffs, Cherokee Co., April 19, 1958; apertural view.
18. *Zonitoides arboreus*, near Disney Dam, State Highway 20, Mayes Co., August 26, 1963; apical view.
19. *Retinella electrina*, 1.2 miles east of Flint, State Highway 33, Delaware Co., August 25, 1963; a, apical view; b, apertural view.


14 b
15a
1 mm
16 a
15 b
14 c
15 c
1 mm
17 a
1mm
18 a
19 a
19 b

Shell minute, 1.5 to 1.7 mm in diameter, 0.7-0.9 mm in height, white to waxen-white; 4 to 4½ whorls, flat above and rounded below, marked by crowded, low radial striae; umbilicus large, 2 to 2½ times in diameter of shell; sutures channeled; aperture rounded, about as wide as high, constricted a short distance within by two large teeth. Animal not seen. Drift material only.

Because of the channeled sutures and small number of whorls, Pilsbry (33) questioned the generic designation of *Paravitrea* for this species. Hubricht (34) transferred the form to *Helicodiscus*. The species is included here for the sake of completeness.

Paravitrea petrophila (Bland)

Published Records: LeFlore County (Hubricht, 5).

New Records: 5(10).

Shell 3.0 to 6.0 mm in diameter, 1.5 to 3.0 mm in height, depressed, rounded at the periphery, clear to pale white; 5 to 6 whorls, the last much wider than the preceding ones, all with irregularly dispersed growth striae; umbilicus moderately large, 4 to 4.3 times in shell diameter; aperture lunate. Animal pale; head and tentacles light bluish-black. Habitat: beneath rock rubble and forest debris. Best collected by means of sieve-sorting.

Paravitrea significans (Bland) Fig. 6 a, b, c

Published Records: Mayes and Adair counties (21); Atoka, Cherokee, Delaware, Latimer, and Sequoyah counties (4); Muskogee County (16, 33).

New Records: 18(8), 1(22), 1(24), 1(30), 17(32), 4(33), 3(38), 7(44), 4(45), 50(50).

Shell dome-like (adult), white to pale tan, marked by crowded, irregular growth striae; adult shells strongly concave around the moderate umbilicus (5 times in shell diameter); aperture greatly depressed, lunate and strongly oblique; adult shells toothless, but immature ones with 2 to 3 pairs of tubercular teeth. Habitat: in deeply stacked, broken, and moist limestone rocks replete with fungi.

Simpson (32) reported *Paravitrea placentula* (Shuttleworth) and *P. capsella* (Gould) from Cherokee and Atoka counties, respectively. This author, however, doubts the validity of these two records. Immature shells of *P. significans* are very similar to those of the two species in question (33).

Paravitrea simpsoni (Pilsbry) Fig. 5 a, b, c

Published Records: Delaware County (21); Adair, Cherokee and Haskell counties (13); Mayes, Cherokee, LeFlore, Latimer, and Pittsburg counties (4); Atoka, Cleveland and Ottawa counties (16); LeFlore County (35); Atoka and Ottawa counties (33); LeFlore, Ottawa and Atoka counties (29); LeFlore and Muskogee counties (19); McCurtain County (20).

New Records: 1(8), 30(9), 8(13), 3(15), 1(18), 1(23), 1(28), 24(29), 10(33), 5(39), 53(43) (topotypes), 6(44), 1(56).

Shell small (Table 2 for meristics and whorl counts); sculpture light, and no spirals seen; colorless to a brown color, transparent; nearly flat above (slightly convex), the periphery rounded; umbilicus small (4.5 to 5 times in shell diameter), the base not markedly excavated around it; no shell teeth. Animal very pale gray, nearly white.

TABLE 2. Some meristics for Oklahoma specimens of *Paravitrea simpsoni* (measurements in mm).

Diameter	Height	No. Whorls
2.1	1.9	4 7/8
2.1	1.4	3 7/8
2.2	1.5	4 1/3
3.0	1.5	4 1/2
3.0	1.8	5
3.8	1.7	5 1/5
4.0	2.0	5 1/5
4.0	2.0	5
4.0	1.7	4 3/4
4.2	2.0	5 1/5
4.4	2.0	4 7/8
4.5	2.2	5 1/5
4.6	2.0	5 1/4
4.8	2.7	5 7/8
5.3	2.3	5 7/8
5.5	2.7	5 7/8

Genus HAWAIIA Gude

Shell small, 1.3 to 2.6 mm in diameter, 0.8 to 1.5 mm in height; depressed, very low spire of 3 to 4½ whorls, distinctly and unevenly striate, the widely umbilicate base being nearly smooth; colorless to white; aperture circular, simple, and thin. Animal white to pale gray. A single species reported from Oklahoma.

Hawaiia minuscula (Binney) Fig. 1 a, b, c

Published Records: Craig, Pawnee and Murray counties (11); Major, Custer, Garvin, Carter, and Marshall counties (21); Cimarron, Alfalfa, Woodward, Kiowa, Caddo, Major, Murray, Carter (8); Caddo and Canadian counties (Pleistocene) (12); Bryan, Choctaw, Creek, Ellis, Garfield, Haskell, Hughes, LeFlore, Love, McCurtain, Noble, Nowata, Osage, Ottawa, Pottawatomie, Rogers, Roger Mills, Sequoyah and Washington counties (13); Latimer County (28). Oklahoma County (14); Payne County (15); Beaver County (Pliocene) (36); Payne, Beckham, Grady, Cleveland, and McClain counties (16; 33); Beaver County (Pleistocene) (27); Harper County (Pleistocene) (27); Lincoln, Noble, Grady, Comanche and Pottawatomie counties (18); Blair, Cherokee, Johnston, Kay, Logan, Muskogee, and Pontotoc counties (19); Beaver, Caddo, Canadian, Comarron, Comanche, Cotton, Dewey, Grady, Greer, Harman, Jackson, Kioww, Texas, Tillman, Washita, Woods, Woodward, Alfalfa, Garfield, Grant, Johnston, Kay, Lincoln, Logan, McCurtain, Muskogee, Noble, and Pontotoc counties (20).

New Records: 3(9), 5(14), 1(32), 19(40), 1(44), 2(51).

The nominate subspecies *Hawaiia minuscula neomexicana* (Cockerell and Pilsbry), often reported from Oklahoma and surrounding areas, has a range that is essentially sympatric with the typical form. It is distinguished from the latter by crowded, microscopic spiral sculpture. The soft anatomy has not been investigated. This should be accomplished in order to determine the true relationships of this form, which well may be a distinct form, probably in the genus *Striatura*.

Genus PILSBRYNA Baker

Although one representative of this genus has been often reported from Oklahoma, Hubricht (3) has recently transferred the species to *Helicodiscus*. This species is included here for completeness.

Helicodiscus tridens (Morrison) Fig. 15 a, b, c

Published Records: Caddo County (7); Canadian and Caddo counties (Pleistocene) (12); Beckham, Ellis, Haskell, LeFlore, Mayes, Payne, Pottawatomie and Roger Mills counties (13); Haskell County (3); Cleveland County (16); Alfalfa, Besver, Blaine, Caddo, Comanche, Dewey, Garfield, Grady, Greer, Harper, Lincoln, McCurtain, Tillman, Washita, Woods, and Woodward counties (20).

Shell flattened above and rounded below, 1.3 to 1.6 mm in diameter, 0.6 to 0.7 mm in height; waxy to dull white, probably transparent in life; 3½ to 4 whorls; sculpture poorly developed, the shell being nearly smooth; umbilicus large, 2.5 to 3 times in shell diameter; aperture circular, constricted by three large teeth, parietal, basal, and palatal. Animal not seen.

Genus VENTRIDENS W. G. Binney

Shell small, nearly imperforate in one species. 4.8 to 2.2 mm in height, 7.5 to 15.0 mm in diameter, convex above and below; whorls 6 to 7+ dull to slightly glossy, marked by weak to strongly developed oblique striae; light tan to golden yellow in color; umbilicus a mere perforation; aperture lunate, the lip simple; young often possessing shell teeth, but these are replaced (in one species) by a thickened callus within the aperture in adult shells. Two species known from Oklahoma.

KEY TO OKLAHOMA SPECIES OF VENTRIDENS

A. Shell 12 mm or more in diameter; no lamina at any stage of growth ... *V. ligera*
B. Shell 11 mm or less in diameter; lamina present in shells smaller than 7.0 mm, and a well-developed basal callus present in adults .... *V. demissus*

Ventridens demissus (Binney) Fig. 12 a, b, c

Published Records: Latimer County (21); Adair County (28)(as *V. brittsi)*; LeFlore and Pushmataha counties (16; 33); LeFlore County (35) (as typical *V. demissus*) (29) (as *V. brittsi)*; McCurtain County (20) (as *V. brittsi*).

New Records: 11(111), 13(16), 14(1), 15(2), 18(12), 20(9), 21(19), 22(38), 23(23), 24(15), 26(2), 31(24), 33(10), 34(9), 39(1), 41(11), 46(1), 47(7), 53(1), 56(35).

Shell more or less depressed, but biconvex; diameter 4.0 to 12.0 mm, height 2.0 to 8.3 mm, whorls 4 to 6 7/8; tan to yellowish-brown in color and glistening; periphery angular in subadults (in some 11.0

mm) becoming rounded; growth striae distinct, the base usually with spiral sculpture or well; umbilicus small (13 or more times in shell diameter) to closed; aperture lunate, with a white or yellowish callus within in large specimens but possessing a single transitory lamellate plait in immature to subadult forms (up to 8.5 mm in diameter). Habitat: on forest floor beneath leaves, debris and logs.

The degree and direction of variation includes the characters of typical *V. demissus*, hence *V. brittsi* (Pilsbry) and *V. demissus lamellata* (Pilsbry) are deemed inappropriate and are considered as synonyms of *V. demissus*. Simpson's (32) record for *V. acerra* (Lewis) from Fort Gibson, Muskogee County was doubtless based upon a large specimen of *V. demissus* (33).

Ventridens ligera (Say) Fig. 7 a, b, c

Published Records: Nowata County (11); Choctaw and LeFlore counties (20); LeFlore County (5); Craig and Muskogee counties (16; 33; 29); Muskogee County (32); Osage County (19); Kay County (20).

New Records: 4(1), 11(3), 25(14), 32(91), 33(2), 36(10).

Shell biconvex, spire elevated; diameter 7.0 to 14.0 mm, height 4.0 to 9.5 mm, whorls 4 7/8 to 7; glistening yellow to pale brown, translucent in life; oblique, coarsely raised sculpture, much weaker below; callus present or wanting, but shell lamellae lacking at all stages of growth; umbilicus minute, about 12 times in shell diameter. Mantle, sides, back and foot immaculate, very pale; tentacles smoky-gray with small granules; head grayish to black; anterior part of sole with a few transverse grooves; sides of body granular. Habitat: forest floor, beneath moisture-conserving logs, leaves, rocks. Specimens retained alive in terraria with other species devoured the latter, as well as the cement holding the terrarium together.

Genus ZONITOIDES Lehmann

Shell small, 5.0 to 7.0 mm in diameter, 2.5 to 4.0 mm in height, depressed, the spire low; 4 to 4¾ whorls in our species; glistening, with light sculpturing; aperture lunate to rounded, the lip thin and simple; no shell teeth; umbilicus 4 or 5 times in shell diameter. The foot is undivided longitudinally, and there is a thin, slit-like caudal pore. Two species reported from Oklahoma.

KEY TO OKLAHOMA SPECIES OF ZONITOIDES

A. Umbilicus 4 or 5 times in diameter; animal gray ...... *Zonitoides arboreus*
B. Umbilicus 10 to 12 times in diameter; animal black ...... *Zonitoides nitidus*

Zonitoides nitidus (Müller) Fig. 2 a, b, c

Published Records: Atoka County (32); Muskogee (20).

New Records: 46(2), 56(2).

Shell small, 6.0 to 7.0 mm in diameter, 3.6 to 4.0 mm in height; spire low; glossy, transparent-amber to yellow; 4 to 4¾ whorls, apical one very smooth, the others marked by weak growth striae; aperture lunate, the lip thin; umbilicus about 12 times shell diameter. Animal black with a few paler flecks and spots. Habitat: forest floor litter, and under moist rocks. Uncommon in Oklahoma.

Zonitoides arboreus (Say) Fig. 18 a

Published Records: Carter, Comanche, Caddo and Murray counties (10); Caddo and Craig counties (11); Pawnee, Mayes, Canadian, Oklahoma, Latimer, Choctaw, and Cimarron counties (21); Canadian and Caddo counties (Pleistocene)(12); Bryan, Creek, Haskell, Nowata, Osage, Ottawa, Pottawatomie and Sequoyah counties (13); Adair, Coal, Okmulgee and Hughes counties (28); Oklahoma County (14); Payne County (15); Payne, Tulsa, Cleveland and McClain counties (16; 33); Muskogee and Atoka counties (29); McIntosh County (32); Harper County (Pleistocene) (27); Grady County (18); Cherokee, Johnston, LeFlore, Logan, McCurtain, Murray, Muskogee, Pontotoc counties (19); Beaver, Comanche, Grady, Harper, Noble and Tillman counties (20).

New Records: 5(1), 8(1), 9(1), 10(2), 11(1), 13(1), 15(1), 16(2), 18(2), 19(1), 22(3), 23(1), 24(2), 27(2), 29(26), 33(2), 39(3), 40(4), 44(2), 45(1).

Shell small, diameter 1.5 to 5.2 mm, height 1.5 to 3.0 mm, whorls 3 1/6 to 4 7/8; glossy, olive-brown to olive-yellow, translucent, depressed; whorls with weak but discernible growth striae (except for smooth apical 1½), much smoother on base; aperture broadly lunate; umbilicus 4 to 5 times in shell diameter. Animal gray, the tentacles and head darker; foot dark gray below. Habitat: as in *Z. nitidus*.

Genus STRIATURA Morse

Shell minute, 1.3 to 1.7 mm in diameter, 0.6 to 0.8 mm in height, strongly depressed, yellowish brown to nearly transparent-gray; 3 to 3½ whorls, marked by distinctly raised radial riblets cut across by spiral threads; umbilicus wide. Two species reported from Oklahoma.

KEY TO OKLAHOMA SPECIES OF STRIATURA

A. Interspaces between growth riblets wider than riblets; spiral striae developed to apex, minute, not causing beading as they cross riblets...... *S. meridionalis*
B. Interspace widths about equal to widths B of growth riblets; spiral striae, absent on apical whorl, producing beading as they cross riblets. *S. milium*

Striatura meridionalis (Pilsbry and Ferriss) Fig. 14 a, b, c

Published Records: Alfalfa, Comanche, Woodward counties (10); Murray County (11); Marshall County (21); Canadian and Caddo counties (Pleistocene) (12); Haskell, Hughes, LeFlore, Ottawa, Pontotoc, Pottawatomie and Sequoyah counties (13); Cleveland County (16; 33); Muskogee County (19); Comanche, Lincoln, McCurtain and Payne counties (20).

Shell minute, 1.6 to 1.8 mm in diameter, 0.6 to 0.8 mm in height, corneous brown to yellowish in color, the 3 to 3½ whorls marked by coarse growth riblets crossed by very fine spiral striae that reach the apex and which do not 'bead' the riblets at the point of crossing; interspaces between riblets wider than the riblets themselves; aperture obliquely lunate; umbilicus about 3 times in shell diameter. Animal not seen.

Striatura milium (Morse) (not illustrated)

Published Records: Carter and Murray counties (10).

Shell minute, 1.3 to 1.5 mm in diameter, about 9.6 mm in height, yellowish to grayish white in color, the 3 to 3+ whorls marked by crowded growth riblets, the interspaces between which are about equal to the width of the riblets; first whorl smooth, the remainder bearing rather distinct spiral lirae which produce 'beads' at the point where they cross the riblets; aperture obliquely lunate; umbilicus 2.8 to three times in shell diameter. Animal not seen.

CONCLUDING REMARKS

I had intended to include the slug families with this contribution, but the pressure of other duties has not allowed me to complete the illustrations. Hence, the final contribution in this series will

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THE MOLLUSKS OF THE DUCK RIVER DRAINAGE IN CENTRAL TENNESSEE

HENRY VAN DER SCHALIE

Museum of Zoology, University of Michigan, Ann Arbor, Michigan 48104

Relatively few papers have been written on the mollusks of the Tennessee River drainage. The most important are those of A. E. Ortmann (1912, 1913, 1918, 1920, 1921, 1924a, 1924b, and 1925). Ortmann, collaborating with Bryant Walker, essentially developed the basic classification for the Naiades, or freshwater mussels. They were also sufficiently versed in the ecology and distribution of mussels to provide broad and significant outlines of zoogeographic relationships. With the meager gear then at their disposal, the best and only method to survey smaller streams was by hand-picking; for large rivers as the Tennessee itself (except in such shallow areas as 'Muscle Shoals') larger boats and clammer's gear were needed. Walker often identified mussels for those making surveys for the U. S. Bureau of Fisheries when intensive work was done in connection with the clamming industry and he was thus able to obtain valuable locality records. In that heyday of collecting, scuba diving had not come into use and, consequently, it was necessary to work at low water stages so that most of those early surveys were accomplished in late summer or fall. Even with modern gear low water stages are best for collecting.

Studies in the lower Tennessee and in the region of the mouth of the Duck River were principally made by M. M. Ellis of the (then) U.S. Bureau of Fisheries during July and August of 1931. He lived on a quarter boat and, with the use of a catamaran and a dredge, was able to make the most extensive collections of the mussels in the lower Tennessee that have ever been done. A study of these collections by H. van der Schalie was published in 1939. With the completion of the dam at Paducah and the formation of Kentucky Lake, Bates (1962) reported on the impact of that impoundment on the mussel fauna. All of the data compiled clearly indicate that the mussels in the lower Tennessee are typically a Mississippi assemblage; there are no Cumberlandian species.**

The Duck River and its major tributary, the Buffalo River, form an important part of the drainage system in central Tennessee. Mollusks (both mussels and pleurocerid snails) were formerly the most significant elements in the benthic fauna of those rivers. It should be stressed that such elements must be known in their original state to be of value in terms of their contribution to the biomass, as well as in their use for determining zoogeographic relations. Unfortunately, a measure of biomass was never attempted, although where the mussel beds occurred it is established that the bottom was paved with them. The virtual loss of practically all mussels in both these rivers at the present time is the occasion for this report, which essentially serves as a **supplement** to the report by Ortmann (1924) based on his collections made in 1921, 1922 and 1923. Calvin Goodrich and the author did some extensive collecting about ten years later (fall of 1931) and obtained a substantial number of additional records

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** Cumberlandian fauna is associated with the geologic Cumberlandian uplift and harbors a number of endemic species usually confined to the upper Tennessee drainage.

(see Map 1). Since records on the original fauna will never again be available, later studies should serve primarily to supplement Ortmann's paper, *The Naiad-Fauna of Duck River in Tennessee*. The collections made by Goodrich and van der Schalie in 1931 (see Table 1) were quite similar in the number of species and differed only to a small degree in composition as compared with those obtained by Ortmann (1924b:14-38).

Table 1. Species of Mussels Collected in the Duck River

Species and Forms	Localities				
	Wilhoite (1)*	Hardinson's Mill (2)	Columbia (3)	Centre-ville(4)	South of Waverly(5)
Actinonaias *carinata* Barnes	x	-	x	-	-
Actinonaias *pectorosa* Conrad	x	x	x	-	-
Alasmidonta *marginata* Say	x	x	x	-	-
Amblema *costata* Rafinesque	x	x	x	-	-
Amblema *peruviana* Lamarck	-	-	-	-	x
Anodonta *grandis* Say	x	x	-	-	-
Anodonta *imbecillis* Say	-	x	x	-	x
Carunculina *cylindrella* Lea (= *moesta* Lea)	x	x	x	-	-
Conradilla *caelata* Conrad	-	x	-	-	-
Cyclonaias *tuberculata* Rafinesque	x	x	x	x	-
Dysnomia *brevidens* Lea	x	x	-	-	-
Dysnomia *capsaeformis* Lea	x	-	-	-	-
Dysnomia *florentina* f. *walkeri* Wilson and Clark	x	x	x	-	-
Dysnomia *triquetra* Rafinesque	x	x	x	-	-
Elliptio *dilatatus* Rafinesque	x	x	x	-	-
Fusconaia *barnesiana* Lea	x	x	-	-	-
Fusconaia *barnesiana* f. *bigbyensis* Lea	x	-	-	-	-
Lampsilis *anodontoides* Lea	-	-	x	x	-
Lampsilis *fasciola* Rafinesque	x	x	-	-	-
Lampsilis *ovata* Say	x	x	x	-	-
Lampsilis *ovata* f. *ventricosa* Barnes	x	-	x	-	x
Lasmigona *complanata* Barnes	-	-	x	-	x
Lasmigona *costata* Rafinesque	x	x	x	-	-
Leptodea *fragilis* Rafinesque	-	x	x	x	x
Lexingtonia *dolabelloides* Lea	-	x	x	-	-
Medionidus *conradicus* Lea	x	x	-	-	-
Megalonaias *gigantea* Barnes	-	-	x	-	x
Obliquaria *reflexa* Rafinesque	-	-	-	x	x
Obovaria *subrotunda* Rafinesque	x	x	x	-	-
Obovaria *subrotunda* f. *lens* Lea	x	-	x	-	-
Pleurobema *cordatum* Rafinesque	-	x	-	-	-
Pleurobema *cordatum* f. *catillus* Conrad	x	-	x	-	-
Pleurobema *cordatum* f. *pyramidatum* Lea	-	x	x	-	-
Pleurobema *oviforme* Conrad	x	-	x	-	-
Proptera *alata* Say	-	x	x	x	x
Ptychobranchus *fasciolaris* Rafinesque	-	-	x	-	-
Quadrula *cylindrica* Say	x	x	x	-	-
Quadrula *intermedia* Conrad	-	x	-	-	-
Quadrula *pustulosa* Lea	-	x	x	-	x
Quadrula *quadrula* Rafinesque	x	x	-	-	x
Strophitus *rugosus* Swainson	x	x	x	-	-
Tritogonia *verrucosa* Rafinesque	x	x	-	x	x
Truncilla *donaciformis* Lea	-	-	-	x	x
Truncilla *truncata* Rafinesque	-	-	-	x	x
Villosa (*Micromya*) *fabalis* Lea	x	x	-	-	-
Villosa (*Micromya*) *nebulosa* Conrad	-	x	-	-	-
Villosa (*Micromya*) *taeniata* Conrad	-	x	-	-	-
Villosa (*Micromya*) *vanuxemensis* Lea	x	x	x	-	-

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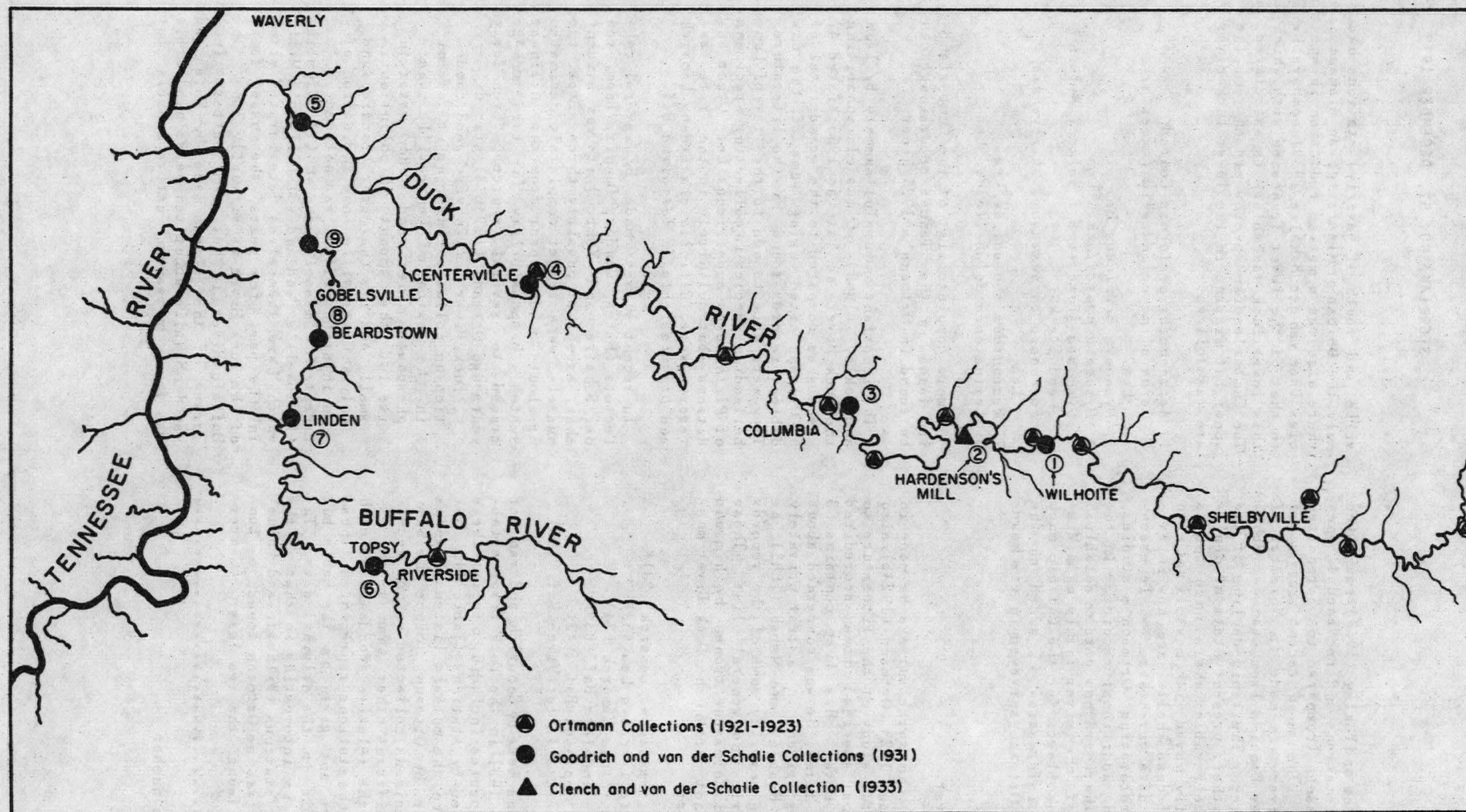
Actinonaias pectorosa Conrad	x	x	x	-	-
Alasmidonta marginata Say	x	x	x	-	-
Amblema costata Rafinesque	x	x	x	-	-
Amblema peruviana Lamarck	-	-	-	-	x
Anodonta grandis Say	x	x	-	-	-
Anodonta imbecillis Say	-	x	x	-	x
Carunculina cylindrella Lea (= moesta Lea)	x	x	x	-	-
Conradilla caelata Conrad	-	x	-	-	-
Cyclonaias tuberculata Rafinesque	x	x	x	x	-
Dysnomia brevidens Lea	x	x	-	-	-
Dysnomia capsaeformis Lea	x	-	-	-	-
Dysnomia florentina f. walkeri Wilson and Clark	x	x	x	-	-
Dysnomia triquetra Rafinesque	x	x	x	-	-
Elliptio dilatatus Rafinesque	x	x	x	-	-
Fusconaia barnesiana Lea	x	x	-	-	-
Fusconaia barnesiana f. bigbyensis Lea	x	-	-	-	-
Lampsilis anodontoides Lea	-	-	x	x	-
Lampsilis fasciola Rafinesque	x	x	-	-	-
Lampsilis ovata Say	x	x	x	-	-
Lampsilis ovata f. ventricosa Barnes	x	-	x	-	x
Lasmigona complanata Barnes	-	-	x	-	x
Lasmigona costata Rafinesque	x	x	x	-	-
Leptodea fragilis Rafinesque	-	x	x	x	x
Lexingtonia dolabelloides Lea	-	x	x	-	-
Medionidus conradicus Lea	x	x	-	-	-
Megalonaias gigantea Barnes	-	-	x	-	x
Obliquaria reflexa Rafinesque	-	-	-	x	x
Obovaria subrotunda Rafinesque	x	x	x	-	-
Obovaria subrotunda f. lens Lea	x	-	x	-	-
Pleurobema cordatum Rafinesque	-	x	-	-	-
Pleurobema cordatum f. catillus Conrad	x	-	x	-	-
Pleurobema cordatum f. pyramidatum Lea	-	x	x	-	-
Pleurobema oviforme Conrad	x	-	x	-	-
Proptera alata Say	-	x	x	x	x
Ptychobranchus fasciolaris Rafinesque	-	-	x	-	-
Quadrula cylindrica Say	x	x	x	-	-
Quadrula intermedia Conrad	-	x	-	-	-
Quadrula pustulosa Lea	-	x	x	-	x
Quadrula quadrula Rafinesque	x	x	-	-	x
Strophitus rugosus Swainson	x	x	x	-	-
Tritogonia verrucosa Rafinesque	x	x	-	x	x
Truncilla donaciformis Lea	-	-	-	x	x
Truncilla truncata Rafinesque	-	-	-	x	x
Villosa (Micromya) fabalis Lea	x	x	-	-	-
Villosa (Micromya) nebulosa Conrad	-	x	-	-	-
Villosa (Micromya) taeniata Conrad	-	x	-	-	-
Villosa (Micromya) vanuxemensis Lea	x	x	x	-	-

*Numbers refer to these localities on Map 1.


WAVERLY
DUCK
RIVER
CENTERVILLE
GOBELSVILLE
BEARDSTOWN
LINDEN
COLUMBIA
HARDENSON'S MILL
WILHOITE
SHELBYVILLE
BUFFALO
RIVER
TOPSY
RIVERSIDE
TENNESSEE
RIVER
1
2
3
4
5
6
7
8
9
Ortmann Collections (1921-1923)
Goodrich and van der Schalie Collections (1931)
Clench and van der Schalie Collection (1933)

In 1965 Isom and Yokley (1968) revisited the Ortmann stations and recorded 47 species of mussels (compared to 63 reported by Ortmann). The most recent survey of the Duck River was made in November of 1972 by Bates, Dennis, Isom, van der Schalie and Yokley. The rapid decline of the mussels and their present state of depletion is unbelievable; where once shoals were literally paved with mussels not even fragments of dead shells are now in evidence! The data given here, while essentially corroborating Ortmann's studies, are new and additional records. In the lower Duck there are now data to establish that part of the river firmly as a Mississippi assemblage; for the Buffalo much substantial information is added to the one station Ortmann surveyed in its headwaters.

The Duck River

Following the three surveys he made in 1921, 1922 and 1923, Ortmann (1924b) also made a careful study of the literature to determine what species had been accredited to the Duck River. His list contains 63 species and forms. He was concerned about some records given in a list privately printed by Hinkley and Marsh (1885); he was not able to verify some of the records in that early and general list. Those species and forms questioned by him and presumably not part of the Duck River mussel fauna are:

1. *Elliptio crassidens* Lamarck (20)*
2. *Cyprogenia irrorata* Lea (33)
3. *Obovaria retusa* Lamarck (34)
4. *Plagiola lineolata* Raf. (39)
5. *Leptodea leptodon* Raf. (42)
6. *Ligumia recta* f. *latissima* Raf. (53)

Collections made by Goodrich and van der Schalie in 1931 in the Duck River established 48 species, including 6 forms; these are tabulated by stations (Table 1). Not included are the mussels listed above as questionable by Ortmann. Since the number of specimens collected is not necessarily significant other than as an expression of the relative abundance of each species at the stations represented, these figures were not given in the table but sre available in the original data. The tabulation is interesting in that in the **upper** river stations (Wilhoite and Columbia) there was, as Ortmann found, a **Cumberlandian** fauna; the two **lower** (Centerville and South of Waverly) stations had only the **Ohioan** or **Mississippian** elements; there also was a marked reduction in species (see van der Schalie, 1939) comparable to that of the lower Tennessee with which this lower Duck assemblage is associated. The Cumberlandian species present in the upper but missing in the lower Duck River are, as follows:

1. *Actinonaias pectorosa* Conrad
2. *Carunculina cylindrella (=moesta)* Lea
3. *Dysnomia brevidens* Lea
4. *Dysnomia capsaeformis* Lea
5. *Dysnomia florentina* f. *walkeri* Wilson and Clark.
6. *Fusconaia barnesiana* f. *bigbyensis* Lea
7. *Medionidus conradicus* Lea
8. *Lexingtonia dolabelloides* Lea

A more complete list of the Cumberlandian fauna in the Tennessee drainage can be found in Ortmann's 1925 paper.

The important and useful summary by Isom and Yokley (1968) of mussels inhabiting the Duck River as late as 1965 listed 47 species as compared to the grand total of 63 Ortmann cited, using some of the now dubious records found in the literature. They were able to add to the list of Cumberlandian species in collecting specimens of *Plethobasus cooperianus* Lea. Other additions—but definitely in the 'rare' category—were *Elliptio crassidens* Lamarck and *Ligumia recta* f. *latissima* Raf.

In recent surveys made by several collectors (Bates, Condor, Dennis, Isom, van der Schalie and Yokley) it was evident that, except at possibly three sites, the mussels were either completely decimated or about to disappear from that drainage system. Responsibility for this may be traced to several sources. Even forty years ago Ortmann (1924b:4) stated:

> 'Duck River is in very good condition, no pollution entering it, except in the region of Centreville, where phosphate mines send muddy water to it; but the amount of pollution is small, and its character obscure, and only at Centreville some indication of an injurious effect was noticed....'

Except for mussel beds at (1) Columbia, (2) Sowell's Bend and (3) Lillard's Mill, which have themselves deteriorated within the past few years, the mussel fauna of the Duck River is virtually gone. The Buffalo River is not much better. In a survey of that stream made by Bates and van der Schalie about ten years ago little was found by way of native mussels, but

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* Ortmann's number.

the introduced *Corbicula* were there in abundance! Isom and Yokley (1968: 40-41) also indicated that the change in the fauna of Duck River 'can be explained in terms of water use. Pollution below cities and industries has affected some areas. Phosphate ore mining is extensive in the Duck River basin as it was in Ortmann's day. Ore washings from this enterprise have contributed to the siltation of habitat.'

The disappearance of the mussels in streams may well be due to 'pollution,' channelization and dam construction (impoundments) but it is not a foregone conclusion that those processes are solely responsible, or that they will necessarily eliminate the mussel fauna. Bates and van der Schalie have records on several years of survey work in the channels within the impoundments of the Tennessee River. The mussels did not disappear there following dam construction as many of us presumed they would. Bates (1962) studied the impact of impoundment in Kentucky Reservoir and verified the fact that many tons of mussels from that area are sent annually to Japan for the pearl industry. Also, cooperating agencies such as the TVA, who have their own survey teams, maintain regions below each dam where normal flow prevails; the original fauna usually remains in these areas which then can serve as 'pockets' for basic studies. Work has been under way for some time assessing the stocks in the old channels, in the 'overbank' areas and in the tailrace areas. Obviously, by coordinating their interests with programs already in the developmental stage, malacologists could more effectively achieve their goals to protect and sustain the fauna than by attempting to block, in areas badly decimated, the construction of dams and/or other projects scientifically planned to prevent pollution.

The Buffalo River

The Buffalo River is the only major tributary to the Duck, paralleling the Tennessee as it flows south through Perry and Humphreys counties, with its mouth only a short distance east of the point where the Duck empties into the Tennessee River. Ortmann established only one station and that was in the headwaters at Riverside, Lewis County. The four sites on the Buffalo visited in 1931 by Goodrich and van der Schalie contained fauna definitely **Cumberlandian** in makeup. The assemblages as shown in the tabulations (Table 2) reveal their usual ecological pattern with creek, small-, medium- and large-river species. Ortmann's collection included 18 of the 42 species here recorded for the Buffalo. His records (shown in a separate column in Table 2) indicate a creek or small-river assemblage. The trend toward an increase in the number of mussel species downstream as the river gets larger can be seen, with 18 species recorded from Topsy Bridge but 31 found at the station downstream south of Lobelville.

The Lobelville station serves to reaffirm Ortmann's observations (1924: 46) of the Duck River fauna:

'Thus it is seen, that Duck River has a *mixed fauna*, consisting of *two elements: a small-river fauna*, composed largely of *Cumberlandian types* (about 38%), and an element belonging to the *interior basin* (about 62%); the latter consists chiefly of *large-river* types ....'

The Buffalo (Table 2), with the same number of species and almost the same assemblage as the Duck, represents a striking contrast to the fauna shown by van der Schalie (1939: 456) to inhabit the lower Tennessee. The species list for the Tennessee, roughly only a 'stone's throw' away, is entirely an **interior basin** assemblage. The upper Buffalo, at least, is definitely a **Cumberlandian assemblage**, clearly set apart from the **Mississippian interior basin** faunal elements of the lower Tennessee (Table 3).

The Duck and Buffalo rivers had a surprisingly rich mussel fauna, both in the numbers of species and in individuals. Both streams have some of the finest shoals in the world but, as previously indicated, the mussels have now been depleted drastically. In a summary of the data obtained by Goodrich and van der Schalie, as based on their collections in 1931 (Tables 1 and 2), it will be observed that these rivers had not changed materially from the conditions observed by Ortmann ten years earlier (1924b). However, in the more recent collections (1972 survey work) there are now scarcely any mussels. In contrast, the pleurocerids remain abundant and in many places unusually so. The data obtained in this recent survey are now being prepared for publication.

Some reference should be made to the statements by more recent investigators who use the generic name *Epioblasma* rather than the well-established *Dysnomia*. That this change is not warranted is eminently clear, as explained by Ortmann and Walker (1922:71), as follows:

'As to *biloba*, its recognition is important with regard to the validity of the subgenus *Epioblasma* (as against *Dysnomia*). Ferussac is not sure about the identity of his authentic specimen *biloba* .... '

'Thus the description of *biloba* is not recognizable, and with this name also that of the subgenus, *Epioblasma*, goes into the discard.'

Table 2. Species of Mussels Collected in the Buffalo River.

Species and Forms	Localities (Ortmann) Above Topsy	(Goodrich and van der Schalie)* Topsy Bridge	Above Linden	At Beardstown	5 mi n of Cobelsville
Actinonaias carinata Barnes	-	-	-	-	x
Actinonaias pectorosa Conrad	x	x	x	x	x
Alasmidonta marginata Say	x	-	-	-	-
Alasmidonta minor Lea	x	-	-	-	-
Amblema peruviana Lamarck	-	-	-	-	x
Anodonta grandis Say	-	x	-	x	-
Anodonta imbecillis Say	-	x	-	-	-
Carunculina cylindrella Lea (= moesta Lea)	x	-	-	-	x
Cyclonaias tuberculata Raf.	-	-	-	x	x
Dysnomia capsaeformis Lea	-	-	-	-	x
Dysnomia florentina f. walkeri Wilson and Clark	-	-	x	-	x
Elliptio crassidens Lamarck	-	-	-	-	x
Fusconaia barnesiana Lea	x	-	-	-	x
Fusconaia barnesiana f. bigbyensis Lea	x	-	-	-	-
Lampsilis anodontoides Lea	-	-	-	-	x
Lampsilis fasciola Raf.	x	-	-	-	-
Lampsilis ovata Say	-	-	-	-	x
Lampsilis ovata f. ventricosa Barnes	x	x	-	x	x
Lasmigona complanata Barnes	-	-	-	-	x
Lasmigona costata Raf.	x	x	-	-	x
Lastena lata Raf.	-	-	-	-	x
Leptodea fragilis Raf.	-	-	-	-	x
Lexingtonia dolabelloides Lea	-	-	-	-	x
Lexingtonia dolabelloides f. conradi Vanatta	x	-	-	-	x
Obliquaria reflexa Raf.	-	-	-	-	x
Obovaria subrotunda Raf.	-	x	x	x	x
Obovaria subrotunda f. lens Lea	x	-	-	-	x
Pleurobema cordatum Raf.	-	-	-	-	x
Pleurobema cordatum f. catillus Conrad	-	-	-	-	x
Pleurobema oviforme Conrad	x	x	-	x	x
Pleurobema oviforme f. argenteum Lea	x	-	-	-	-
Proptera alata Say	-	-	x	x	x
Ptychobranchus subtentum Say	x	-	-	-	-
Quadrula cylindrica Say	-	-	-	-	x
Quadrula pustulosa Lea	-	-	-	-	x
Quadrula quadrula Raf.	-	-	-	-	x
Strophitus rugosus Swainson	x	x	x	x	x
Tritogonia verrucosa Raf.	-	-	-	-	x
Truncilla truncata Raf.	-	-	-	-	x
Villosa (Micromya) nebulosa Conrad	x	-	-	-	x
Villosa (Micromya) taeniata Conrad	x	-	-	-	-
Villosa (Micromya) vanuxemensis Lea	x	-	-	-	x

*Goodrich and van der Schalie collections represented on Map 1 by the following numbers:

(6) Topsy Bridge
(7) Above Linden
(8) At Beardstown
(9) 5 miles north of Gobelsville

TABLE 3. Species and forms of mussels collected in the Buffalo River by Goodrich and van der Schalie, arranged by subfamilies and showing Cumberlandian and Mississippian faunal elements.

MISSISSIPPIAN	*CUMBERLANDIAN*
UNIONINAE	
Amblema peruviana Lamarck	**Fusconaia barnesiana* Lea
Cyclonaias tuberculata Raf.	**F. barnesiana* f. *bigbyensis* Lea
Elliptio crassidens Lamarck	*Lexingtonia dolabelloides* Lea
Pleurobema cordatum Raf.	*L. dolabelloides* f. *conradi* Vanatta
P. cordatum f. *catillus* Conrad	
P. oviforme Conrad	
P. oviforme f. *argenteum* Lea	
Quadrula cylindrica Say	
Q. pustulosa Lea	
Q. quadrula Raf.	
Tritogonia verrucosa Raf.	
ANODONTINAE	
**Alasmidonta marginata* Say	
Alasmidonta minor Lea	
Anodonta grandis Say	
Anodonta imbecillis Say	
Lasmigona complanata Barnes	
L. costata Raf.	
Strophitus rugosus Swainson	
LAMPSILINAE	
Actinonaias carinata Barnes	*Actinonaias pectorosa* Conrad
****Carunculina cylindrella* Lea	****Csrunculina moesta* Lea
Lampsilis anodontoides Lea	*Dysnomia capsaeformis* Lea
**Lampsilis fasciola* Raf.	*D. florentina* f. *walkeri* Wilson and Clark
Lampsilis ovata Say	***Villosa nebulosa* Conrad
Lampsilis ovata f. *ventricosa* Barnes	*Villosa taeniata* Conrad
Leptodea fragilis Raf.	*Villosa vanuxemensis* Lea
Obliquaria reflexa Raf.	*Ptychobranchus subtentum* Say
Obovaria subrotunda Raf.	
O. subrotunda f. *lens* Lea	
Proptera alata Say	
Truncilla truncata Raf.	

* Small river or creek forms found at Riverside by Ortmann.
** Ortmann uses *Micromya* as the generic name.
*** *cylindrella* = *moesta*? Synonymy uncertain.

In addition, the use of the genus *Toxolasma* for *Carunculina* was considered unacceptable (see Ortmann and Walker, 1924b: 54) as indicated in their statement:

> 'The revival of the generic name *Toxolasma* depends on the identity of *U. lividus* Raf. As will be shown under *Car. moesta*, *lividus* is not recognizable, and thus the name *Toxolasma* should be discarded.'

The problems encountered when well established names are changed without proper justification has recently beed discussed by Isom (1973), who pointed out some of the difficulties those working in the immediate, or related, fields had had.

Of ten species considered by some 'endangered' in the Duck River, none is restricted to that drainage. Except for some healthy stocks of *Conradilla caelata* taken recently, few specimens of the other relatively rare species remain. In connection with the '*Epioblasma (=Dysnomia) turgidula* (Lea, 1858)' one has a problem of identity. The Museum of Zoology at the University of Michigan houses collections which are among the most extensive for mussels available. Because it appears that *Dysnomia turgidula* is a synonym of *D. deviata* (Reeve) and also seems to be synonymous with *D. curtisi* Frierson and Utterback, the distribution records would indicate a far wider range than is usually ascribed to it. Reliable records show its distribution as: Hardy, Sharp Co., Arkansas (U. M. #90742; Holston River, Rogersville, Hawkins Co., Tennessee (#90745); Bear Creek, Burleson, Franklin Co., Alabama (#90746). Under *Dysnomia curtisi*, it was reported from White River, Forsyth, Taney Co., Missouri. In brief, while the mussel fauna has almost disappeared from the Duck River drainage, the 'endangered' species may yet survive in other drainages.

The importance of the Duck and Buffalo rivers both in their rich faunal relations to the Tennessee drainage and in their use in interpreting the zoogeographic and physiographic relationships of the area, has been well stated by Ortmann (1924). His great interest and perceptive analyses were expressed to Calvin Goodrich in letters urging Goodrich to look for similar 'clinal' relations in pleurocerids as found by Ortmann in the mussels of those streams. While the concepts were well defined in Ortmann's publication, he stated in a letter to Goodrich (dated September 17, 1923):

> 'I think I have the Naiad fauna of Duck River rsther complete now. It is peculiar in containing certain Cumberland-Tennessee elements, but not all, and then again Ohio-Mississippi (Big-river) elements, but again not all forms belonging to this, some shells, common elsewhere, being missing ....'

Later, in a letter dated October 31, 1923, Ortmann stated:

> 'The Naiad-fauna of Duck River is peculiar in its affinities. Partly Cumberlandian-Tennesseean, partly Ohioan. (For instance, the 'Mucket' *(ligamentina)* is not the southern Mucket, but the *northern)*. But then again several important members are missing.'

Collaboration between the two did, indeed, follow over a period of years; the recognition of clinal relations among pleurocerid species was also expressed (again in the October 31 letter to Goodrich) by Ortmann as follows:

> 'I am very interested in what you say about the grading of forms of Pleuroceridae of the upper streams into those of the lower. You remember, I have similar instances among the Naiades, and Walker also, in the beginning, did not want to believe this. I feel rather sure that a similar phenomenon exists at least in *L. geniculata-fuliginosa;* my finds *in the field* immediately suggested this to me, and remember, Adams has shown long ago that this is also the case in *Io*, and I have been able to confirm this. *So I am much in favor of your idea.*'

These clines among nominal species of the pleurocerids are a source of differences among some malacologists who would list as many as 18 species of snails belonging to those groups, while Goodrich recognized mainly nine. To date, the late Calvin Goodrich is still recognized as the best authority on the pleurocerid groups, and the nine species and forms listed here are those determined and collected in the surveys made by Goodrich and van der Schalie in the Duck and the Buffalo drainages. These species' differences will be considered in more detail in another publication.

Pleurocerid Snails

In his studies of the mussels (naiades) of these rivers, Ortmann did not include his observations about the pleurocerids—the most abundant snails there. When considered in their patterns of distribution, it would remain a moot question as to which group, the mussels or the snails, represents the larger portion of the biomass. In the 1931 survey Goodrich concentrated on collecting pleurocerid snails, which were his main interest, while van der Schalie undertook the mussel work. Ortmann, in his correspondence previously mentioned urged Goodrich to examine the pleurocerids in terms of their distributions and their clinal tendencies. Such studies were made and Goodrich published a series of papers in which he attempted to show variations in sculpture (Goodrich, 1941) as well as relationships of the Ohio River drainage species to those of the Cumberlandian region (Goodrich, 1940).

The species listed by Goodrich to represent the pleurocerid fauna of both the Duck and Buffalo drainages (determined by him and now housed in the U. M. Museum of Zoology) are given in tabular form (Tables 4 and 5). One could, without regard for their clinal tendencies, increase the number to 18 species but Goodrich's identifications here limit the number to nine, including three forms. In any case, the Duck River had, and still has, a very rich pleurocerid fauna both in the mainstream and in its tributaries. It would still be possible to conduct basic studies to resolve many of the problems that relate to species assemblages, clinal tendencies, etc., with this widely distributed group of snails.

TABLE 4. Species of pleurocerid snails collected by Goodrich and van der Schalie in 1931 at stations in the Duck River, Tennessee. (Specimens deposited in the U.M. Museum of Zoology. Numbers for each locality are those of the U.M. Museum of Zoology.

MANCHESTER, Coffee County: (Nos. 51390-91; 51580).
Goniobasis edgariana Lea
Goniobasis laqueata Say
Lithasia geniculata f. *pinguis* Lea

WILHOITE, Marshall County: (Nos. 53194-98)
Goniobasis laqueata Say
Anculosa praerosa Say
Lithasia duttoniana Lea
Lithasia geniculata f. *fuliginosa* Lea
Pleurocera canaliculatum f. *filum* Lea

COLUMBIA, MAURY County: (Nos. 53199-203).
Anculosa praerosa Say
Goniobasis laqueata Say
Lithasia duttoniana Lea
Lithasia geniculata f. *fuliginosa* Lea

CENTERVILLE, Hickman County: (Nos. 53204-06).
Lithasia geniculata Haldeman
Anculosa praerosa Say
Pleurocera canaliculatum f. *filum* Lea

SOUTH OF WAVERLY, Humphreys County: (Nos. 53207-12).
Anculosa praerosa Say
Lithasia duttoniana Lea
Lithasia geniculata Haldeman
Pleurocera canaliculatum undulatum Say
Pleurocera curtum Haldeman

TABLE 5. Species of pleurocerid snails collected by Goodrich and van der Schalie in 1931 at stations in the Buffalo River, Tennessee.

TOPSY BRIDGE, Wayne County: (Nos. 53225-27)
Anculosa praerosa Say
Lithasia geniculata f. *fuliginosa* Lea
Pleurocera canaliculatum f. *filum* Lea

ABOVE LINDEN, Perry County: (Nos. 5322-24).
Anculosa praerosa Say
Lithasia geniculatum Haldeman
Pleurocera canaliculatum Say

BEARDSTOWN, Perry County: (Nos. 52318-21).
Anculosa praerosa Say
Goniobasis laqueata Say
Lithasia geniculata Haldeman
Pleurocera canaliculatum Say

5 mi. north of GOBELSVILLE, Perry County: (Nos. 53214-16)
Anculosa praerosa Say
Lithasia geniculata Haldeman
Lithasia geniculata f. *fuliginosa* Lea

SUMMARY AND CONCLUSIONS

If we combine the information given by Ortmann (1924b) with that given here and consider the latter as supplementary to his data, the following conclusions are warranted:

(1) Ortmann (1924) reported 63 species and forms of freshwater mussels (Naiades) in the Duck River drainage; the Goodrich and van der Schalie collections made in 1931 verify that there were at least 48; some credited by Ortmann from literature records were erroneously reported. Isom and Yokley reported 48 and added **Plethobasus cooperianus.**

(2) **"The Cumberlandian fauna is the original fauna of Duck River...' as stated by Ortmann** (1924b: 46), has been verified. The additional records also substantiate that below Centerville, and as far downstream as south of Waverly (1931 collections), only the 'interior' or **Mississippian (Ohioan)** faunal assemblage existed. The 1931 collections further confirm Ortmann's contention that: **"Duck River originally was more directly connected with the Cumberland and Tennessee, and, at that time, it was a rather small river ...'**

(3) Since Ortman was able to establish only one station in the headwaters of the Buffalo River, he could not show (as the 1931 survey did) that the Buffalo drainage also has a **Cumberlandian** fauna as far downstream as 'below Lobelville.' The richness of the fauna in the Buffalo (with 42 species and forms) was essentially the same as listed for the Duck. Isom and Yokley (1968) attest also to the disappearance of the mussels in the Buffalo.

(4) While the Buffalo River runs parallel to the lower Tennessee and relatively close to it, the Buffalo has a **Cumberlandian** aspect; the lower Tennessee is wholly **Mississippian** or an Interior basin fauna.

(5) The evidence available from the earlier collections shows that neither the Buffalo nor the Duck ever had an appreciable mussel assemblage in their tributaries or creeks; all of them have an abundance of pleurocerid snails. The absence of mussels in most tributaries remains unexplained.

(6) Since the time of the Ortmann surveys (1921-1923), the Goodrich and van der Schalie collections in 1931, and the Isom and Yokley studies, the mussels of both the Duck and Buffalo rivers have virtually disappeared; only small pockets remain between Columbia and Centerville on the Duck; they, too, are rapidly being altered.

(7) The oriental clam *(Corbicula)* hasmade serious inroads into both the Duck and Buffalo drainages, as was also indicated by Sinclair and Isom (1963). It may crowd out the native mussels where they still remain. Fortunately, the *Corbicula* clams serve as food for muskrats and mink, replacing, in that sense, the formerly abundant mussel fauna.

(8) The rapid changes, as well as the multiple use of rivers (discussed by Cairns in his 1972 paper), make the information available from earlier surveys indispensable for studies involving a knowledge of our natural heritage, past and present ecological conditions, and the prospects for using faunal assemblages in tracing former stream confluences. The Duck and the Buffalo definitely have a Cumberlandian fauna, a knowledge of which should be helpful in studies involving geology, physiography and zoogeographical faunal relations.

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CLAUDE W. HIBBARD (1905-1973)

All scientists working in Pleistocene geology and paleontology will mourn the death of Claude William Hibbard on October 9, 1973. Death came suddenly as he was preparing for the day's work in the Museum of Paleontology of the University of Michigan at a characteristically early hour. Death came some time before 8 A.M., apparently of a heart attack. Professor Hibbard, Hibbie to his friends, is survived by his wife, Fay, a daughter and two granddaughters, his mother, four brothers, and one sister.

To all those who studied paleontology at Ann Arbor after 1946, he was a friend and counselor, ever ready with a helping hand and a cheery word. Dean Frank Rhodes has well characterized him as 'A man of immense energy, dedicated with a fierce commitment to unraveling the secrets of the earth ....' The other side of his character was an equally strong commitment to his fellow man, especially his students and colleagues at the University of Michigan.

Claude William Hibbard was born March 21, 1905 in Toronto, Kansas, at a time when the pioneer virtues of hard work, scrupulous honesty, and the duty of helping one's neighbor were still held in high honor. All through his life he practiced them but never preached except by example.

He graduated from the University of Kansas in 1933 and earned a M.S. degree from that university in 1934. He received his Ph.D. from the University of Michigan in 1941. The dates hint at the fact that in those depression years he had to finance his education by hard work in school and out of it.

In 1946, Hibbie returned to the University of Michigan as assistant professor and curator of fossil vertebrates. His duties included teaching which he enjoyed and excelled in, the multitudinous chores involved in caring for an already large collection of fossil vertebrates, and research in between. He won promotion to associate rank in 1949 and to full professor and curator in 1953.

Those of us who burned the midnight oil in graduate work two and three years after World War II learned to turn to him as an ever-present source of help in emergencies and of wise counsel for those in need of it. When early classes brought us to the Museum before 8 A.M. there was always light burning in his office and he had already done at least an hour's work before other members of the staff arrived. These work habits he continued to observe to his dying day.

In late spring, as soon as his teaching duties were over, he would leave for a season of field work in his native Kansas returning to Ann Arbor a week or so before classes resumed, ready to begin his indoor work and to show the fruits of his collecting to all interested parties.

His main field of endeavor was vertebrate paleontology and he specialixed in the small mammals of the Cenozoic particularly those of the Pleistocene. His collecting methods were highly successful, mainly because they were so thorough. He often said jokingly that he had to collect the whole outcrop to get enough specimens for study—and he literally did.

In doing so, he collected much ancillary material, in particular non-marine Mollusca carefully pinpointed to locality and stratigraphic position. He was ever generous in lending his collections to others for study and he co-operated with several colleagues in papers dealing with Mollusca.

His services to malacology were manifold. First, he has written extensively on the paleoecology of the Mollusca living at the same time as his mammals. Secondly, he has assembled a massive amount of material which he intended to work up after retirement but which he left in good order for his successors. Most of all, he encouraged all those who came in contact with him and who sought his advice on Pleistocene paleontology.

Those of us who were privileged to know him personally and benefited from his kindness and friendship will long remember him as a teacher and friend.

Aurèle La Rocque