

PLEISTOCENE MOLLUSCAN FAUNAS OF THE CASTALIA DEPOSIT,
ERIE COUNTY, OHIO

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INTRODUCTION

Nature and Purpose of Investigation

This is a paleoecological and quantitative investigation of the molluscan faunas of a marl deposit. The purpose of the study is to ascertain what species are present in the deposit, their variation in kind and in numbers with time, and the reasons for the variation. These data yield information useful in reconstructing the development of the lake in which the marl accumulated and in ascertaining the age of the deposit. They permit comparison of the Castalia deposit with other deposits in Ohio and elsewhere and evaluation of the differences and similarities that exist between them. Investigations of the same kind have been carried out in other parts of Ohio. Similar methods and presentation of results permit close comparison between deposits of different age and from various ecological situations which may eventually yield data for detailed correlations.

Location of Deposit

In the Lake Plains section of north-central Ohio in Erie County is the town of Castalia. To the west and north of this town in Margaretta Township, Erie County, and in Townsend Township, Sandusky County, lies the Castalia Prairie. The prairie is a sequence of marl and peat beds more than 4,000 acres in area at elevations of 610 to 630 feet. It is the most extensive and continuous marl deposit known in Ohio.

The deposit studied is a part of this prairie and lies at an elevation of approximately 610 feet at a distance of 1.8 miles northwest of the town of Castalia. (See fig. 1). The site may be reached by proceeding northwest from Castalia on State Route 269 a distance of 1.6 miles. At this point a gravelled road runs in a westerly direction. By following this road a distance of 0.7 mile the site of former diggings by the Medusa Cement Company is reached. The deposit is located on a bank at the eastern side of the diggings where the road forks to the south. The exact location for the deposit is: Erie County (Bellevue Quadrangle), Margaretta Township, T. 6 N., R. 17 E., section 3, longitude 82° 49' 53", latitude 41° 25' 10".

Methods of Investigation

Collection and storage. The collections were obtained from a measured section (see below). Each collection is 12 by 12 by 2 inches or 288 cubic inches. The material from each collection was placed in a plastic bag and stored until used. Water was added to each bag to keep the material from becoming too hard. The day before a collection was to be sieved, it was emptied into four two-liter beakers and covered with water, which made the task of sieving much faster.

Sieving and drying. Sieves of 10, 20, 40, and 50 mesh were used to separate the silt from the Mollusca. When the material had dried sufficiently, it was placed in containers labelled with the proper collection number.

Sorting and identification. The total amount of dried material in each collection was divided into representative fractions taken impartially by means of a mechanical quartering device. One of these fractions (or more than one if necessary) was taken from each collection and the shells sorted from it. A total of 1,000 individuals was taken in all collections except 11 and 12; only 140 individuals were found in the fraction sorted from collection 11 and 780 individuals were obtained from the fraction in collection 12. The shells were then separated into species and the number of shells of each species counted. This number was expressed graphically so that each species was shown as a percentage of the total number of individuals in each collection. By studying each collection separately changes in faunal composition were related to time.

STRATIGRAPHY

Description of Deposit

Bedrock geology. The oldest formation underlying the Castalia area is the unexposed Ty-mochtee dolomite of late Silurian age. Above this, and also late Silurian, is the Put-in-Bay dolomite. This formation is not exposed at Castalia but forms Crystal Rock Hill three miles northwest of it (Carman, 1927, p. 491). Overlying this dolomite are the Columbus and Delaware limestones of middle Devonian age.

Lacustrine sediments and topographic features. Overlying the bedrock formations is approximately 30 feet of glacial drift and lake deposits. The lacustrine deposits smoothed out the uneven surface produced by glaciation so that a very gentle, northward sloping plain was formed. This lacustrine plain, whose southern limit is the shoreline of Lake Maumee III, was developed by the various lake levels within the Erie basin. Near Castalia are a number of bedrock hills 50 feet above the level of the plain. These hills, capped by the Columbus limestone, existed as shoals, islands, and peninsulas during the different lake stages. The only other feature breaking the surface of the plain is a series of long, low ridges of sand and gravel which are beaches of the former lake levels. It is on one of these beaches that the Castalia deposit formed (see fig. 2).

DESCRIPTION OF FIGURES ON OPPOSITE PAGE

Fig. 1. Index map showing the location of the Castalia deposit, Margaretta Township, Erie County, Ohio.

Fig. 2. Diagram showing the Great Lakes stages in the vicinity of the Castalia Deposit.

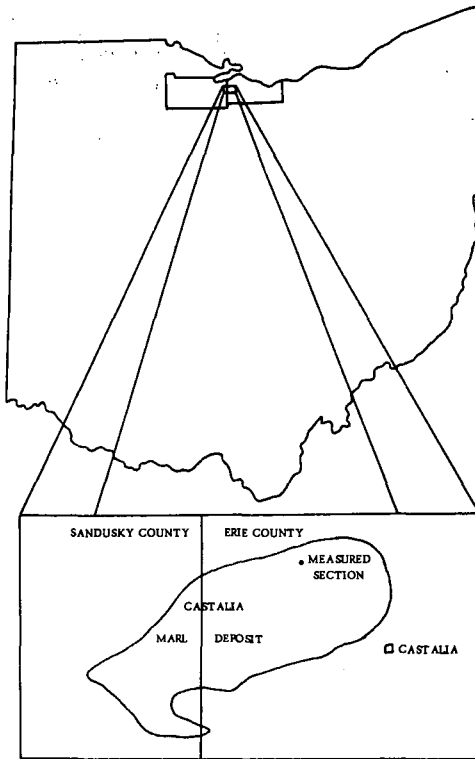


FIGURE 1

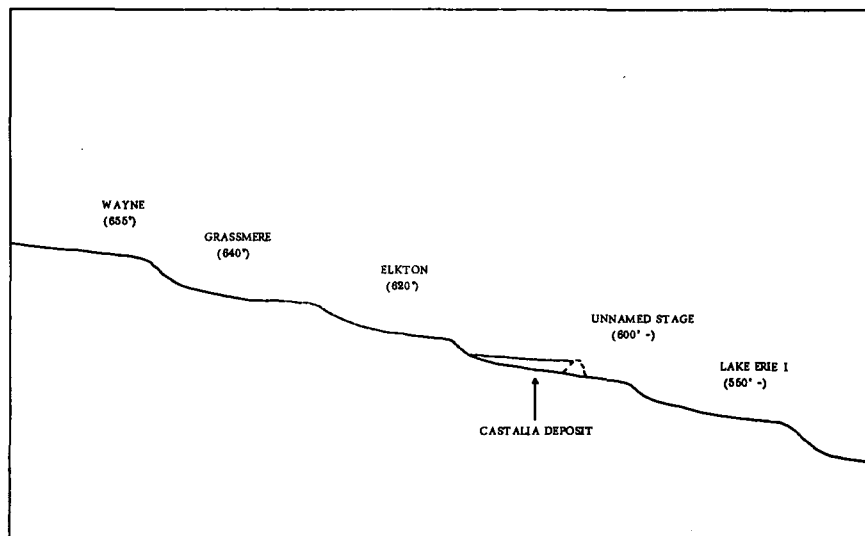


FIGURE 2

Great Lakes stages in the Castalia deposit. In the history of Lake Erie a series of lake stages began with the formation of Lake Maumee I at an elevation of 790 feet and continued to the present level of Lake Erie at 573 feet. The only stages that need be considered here, however, are the ones directly concerned with the Castalia deposit.

Between the Wayne shoreline (655 feet) and the first stage of the present Lake Erie (550 feet) are fragments of four shorelines representing the various stages of Lake Lurdy. These are transitional stages caused by a cutting down of the outlet south of Syracuse, New York. Unlike the Wayne and some higher shorelines, these were never submerged but produced under conditions of a falling water level. The two uppermost shorelines, at elevations of 640 and 620 feet, correspond to the Grassmere and Elkton stages of Lake Lurdy, respectively. The third shoreline (615 feet) represents the Dana stage of Lake Lurdy. Campbell (1955, p. 136) found evidence of a fourth shoreline, left unnamed, at slightly less than 600 feet. Segments of both the Grassmere and Elkton stages cross the marl deposits of the Castalia Prairie. The Dana level is not represented here but occurs elsewhere in the Erie basin. Traces of the fourth shoreline are found at the northern edge of the marl deposits. Since the elevation of the Castalia deposit is approximately 610 feet, the deposit had to form after the Elkton shoreline and during recession of the water to the present lake level.

Unit	Measured Section	Thickness Inches	Cont. Nos.
4	Humus, black, fine-grained, fossiliferous	4	29-30
3	Marl, composed of alternating layers of cream-colored and gray marl; very sandy in the two bottom collections. At the level of collection 23 the lines of stratification between the cream-colored and gray marl layers become indistinct, giving an overall grayish appearance to the remaining layers in the unit.	36	11-28
	Collections 23-28. Alternating, irregular layers of cream-colored and gray marl giving these collections an overall grayish appearance; fossiliferous, with <u>Chara</u> stems.		
	Collections 21-22. Cream-colored, <u>Chara</u> stems, fossiliferous.		
	Collections 18-20. Gray, very fossiliferous, some tufa present.		
	Collections 16-17. Cream-colored, <u>Chara</u> stems, fossiliferous.		
	Collections 13-15. Gray, very fossiliferous, minor amounts of sand, silt, and tufa present.		
	Collection 12. Cream-colored, <u>Chara</u> stems; contains less sand and more fossils than coll. 11.		
	Collection 11. Cream-colored, very sandy, <u>Chara</u> stems, fossils rare.		
2.	Peat, black, fossiliferous, with a little sand and tufa in collections 7 and 10; collections 8 and 9 contain wood fragments.	8	7-10
1.	Marl, cream-colored, consisting of <u>Chara</u> stems and nodules; fossiliferous; contains some clay in the three lower collections and minor amounts of sand and tongues of peat in the upper three collections; masses of tufa irregularly located throughout the unit.	12	1-6

PALEOECOLOGY

General Statement

Ecology for the individual species of mollusks in the Castalia deposit represents a compilation of facts assembled from articles by various authors. The data for the fresh-water species have been summarized from the following articles: Baker, 1911, 1916, 1918, 1919, 1920, 1922, 1928, 1929, 1931, 1935, 1937, and 1939a; Baker and Cahn, 1931; Dawson, 1911; Dennis, 1928; Dundee, 1957; Goodrich, 1945; Herrington, 1957; Leonard, 1950; Morrison, 1932; Russell, 1934; Taylor and Hibbard, 1955; Whittaker, 1921; and Winslow, 1921.

Data for the terrestrial species were summarized from the following articles: Archer, 1934 and 1938; Baker, 1935; Call, 1900; Dexter, 1956; Franzen, 1947; Franzen and Leonard, 1943; Goble and Leonard, 1943; Goodrich, 1932; Harry, 1952; Leonard, 1950; Levi and Levi, 1950; Morrison, 1939; Oughton, 1948; Pilsbry, 1940, 1946, and 1948; and Van Cleave, 1933.

This molluscan assemblage is unusual for its absence of Amnicolidae and Valvatidae. Their absence in the humus and peat units is expected because of the shallow water and deep mud bottom. In the marl units, however, the water was not only too shallow but also too warm. Some operculates are present but are confined wholly to the upper half of the deposit and are present only in very small numbers.

Sphaeriid Pelecypods

Pisidium casertanum (Poli) is found in smaller lakes and streams where it lives in the following habitats: protected bays where fine sand, mud, and ooze collect and where the animal lives among roots of vegetation or buried in the soft, black mud; a swampy shore with the water a few inches to a foot in depth and the bottom composed of soft, sticky mud filled with algae; and small ponds or swampy pools 1 to 1.5 feet in depth containing vegetation of Iris and Typha. The pH for this species is 7.6 and the fixed carbon dioxide 16.7 p. p. m.

Freshwater Operculate Gastropods

Pomatiopsis lapidaria (Say) is an amphibious species found in a variety of habitats which include marshes, temporary pools on the floodplains of small creeks, on grassy hummocks in wet pastures, in upland artesian-fed marshes, and under leaves. In one peculiar situation this species was found associated with Fossaria modicella on vertical sandstone bluffs, the two species intermingled on the same seepage area. P. lapidaria is not limited by stream size; it has been reported from bodies of water varying from temporary streams to fairly large rivers. The pH of the water in which it is found varies from 7.5 to 8.0. The features common to all the habitats of this species are a very moist substratum with enough sand to prevent the bottom from becoming mucky and an abundance of shade.

Pleurocera acutum tractum (Anthony). This species is a river or small lake form which occupies many kinds of habitats. It is decidedly a shallow water form, rare in water deeper than 1.5 feet. It is common on rocky shores in a swift current or on shores subject to violent wave action but is rarely found on a sand and mud bottom in slow currents.

Goniobasis livescens (Menke). A marly-clay bottom, among Chara, at a depth of 1 to 4 feet or a sand bottom, 6 feet deep, protected from wave action, are habitats for this species. It is also found on boulder and gravel bottoms, on exposed shores or points in water 0.5 to 4

feet in depth, and in streams among water-soaked leaves, branches, and logs. G. livescens lives in places containing abundant vegetation as well as places devoid of it. It is not found on muck, however, probably due to the muck's high acidity. This species flourishes best where the bottom is rocky, the depth of water from 3 to 20 feet, and there is little wave action and some vegetation. The pH of the water ranges from 7.4 to 8.0.

Freshwater Inoperculate Gastropods

Stagnicola umbrosa (Say) is an inhabitant of pond-like areas where the water is quiet and the vegetation thick. It is also found in ponds and sloughs which become more or less dry in summer. Additional information as to its ecology may be inferred from Stagnicola palustris elodes to which it is closely related. The latter is found in both clear and stagnant bodies of water and prefers a habitat where the water is not in motion and the vegetation abundant. It prefers protected bays of lakes and ponds and the margins of rivers most often but is sometimes found in swales. It is found on floating sticks, submerged vegetation, and stones. The malleated forms inhabit stagnant pools where the bottom is muddy and decayed vegetation present. The food of S. palustris elodes consists of both animal and vegetable matter. It feeds on algae, diatoms, rotten food, dead animals, and decayed vegetable matter. It lives in water with a pH of 7.4 and carbon dioxide content of 21.0 p.p.m.

Fossaria modicella (Say). This species is an inhabitant of small pools and is rarely found living in large bodies of water. F. modicella is usually found on mud flats along the edge of the water or a strip of muddy beach which is kept rather moist. It has also been found living among cat-tails associated with Physa gyrina and on rocks in shallow water near shore. It has even been observed clinging to vertical sandstone cliffs, in areas moistened by seepages from small springs. This species inhabits bodies of water whose pH is 7.0 and carbon dioxide content 13.0 p.p.m.

Fossaria obrussa decampi (Streng). This species is thought to occupy the same habitats as Fossaria obrussa. These situations include small bodies of water such as creeks, ponds, sloughs, bays, and marshy spots along river banks. The water is shallow and the bottom of soft, sticky mud filled with algae. F. obrussa decampi is found on sticks, stones, and any other debris that may be in the water or along its edge. It is sometimes seen upon mud flats of small streams and other such places. While seemingly rare today, it has been found living on a sandy silt bottom in water two feet deep on vegetation. F. obrussa decampi inhabits waters whose pH varies from 7.42 to 7.7 and whose fixed carbon dioxide ranges from 10.65 to 18.87 p.p.m.

Helisoma trivolvis (Say). This species is an inhabitant of quiet, shallow, more or less stagnant water. It flourishes in ponds or sloughs, even though they are choked with vegetation or polluted with decaying organic materials and is invariably absent from flowing streams. It also lives behind beach barriers, in large open swamps, and at the edges of lakes and streams. It may occasionally be found in stagnant pools by the roadside, clinging to rocks an inch or two below the water line, and adhering to the stems or lower surface of water lilies. The pH of the water in which it lives varies from 6.6 to 8.37 and the carbon dioxide content ranges from 7.5 to 30.56 p.p.m. The bottom is muddy or boggy and covered with vegetation which consists chiefly of Typha latifolia and several species of sedge. This species feeds on algae and other small organisms.

Planorbula armigera (Say). This species is found in large, open swamps, small ponded areas, the upper marshy portions of a bay, at the edges of marshes, and in ditches and small streams. The water is shallow (1 to 3 feet) and the bottom silty, muddy or boggy. P. armigera is sometimes found on deciduous logs and sticks. The vegetation growing on the bottom consists of

Typha, Scirpus, Potamogeton, Nymphaea, Castalia, Lemna, and Chara. The animal feeds on Castalia leaves and algae. The pH of the water varies from 6.6 to 7.6 and the fixed carbon dioxide ranges from 7.5 to 16.7 p.p.m. P. armigera prefers the quiet waters of a small lake or pond where there is abundant vegetation and a mud bottom. It is apparently capable of lying dormant in dry mud during the greater part of the year.

Promenetus exacuus (Say). This species generally lives near shore in quiet, shallow water on the under side of lily-pads, on sticks, and on stones along the margins of ponds just under the water. It is sometimes found in the shallow waters of streams where the current is slow and vegetation established, and on mud flats in quiet water. P. exacuus lives in water whose pH varies from 7.0 to 7.64 and whose carbon dioxide content ranges from 9.3 to 22.5 p.p.m. The bottom may be sandy silt, silt, or mud. The types of vegetation on which it is found are varied. The animal feeds on Castalia leaves and algae. The most important factors in its habitat seem to be its preference for cold water and the presence of vegetation.

Gyraulus altissimus (F. C. Baker). This species is the common planorbid of all Pleistocene deposits. Its status as a living form is most uncertain. Winslow (1921, p. 11) found it living in a fresh pond and small lake in North Dakota and Russell (1934, p. 35) reported it living in southern Saskatchewan. With the exception of these two occurrences, all other reports have listed G. altissimus as occurring only in fossil deposits. In these deposits, usually marl, it occurred most often with the following species: Fossaria obrussa decampi, Physa gyrina, Helisoma campanulatum, Promenetus exacuus, and Helisoma trivolvis.

The replacement of G. altissimus by Gyraulus parvus in the living fauna indicates a close association between the two species both in distribution and environment; therefore, the ecology of G. altissimus will be inferred from that of G. parvus.

G. altissimus was an inhabitant of quiet, shallow bodies of water, generally of small size. It may also have inhabited the shallow water of streams where the current was slow and vegetation flourished. The water in which it lived varied from 1.5 to 6.5 feet in depth and the bottom, which was sand, silt, or mud, supported a relatively dense cover of vegetation. The animal lived on and around the vegetation as well as on sticks and stones. The pH of the water in which it lived varied from 7.0 to 8.16 and the carbon dioxide content ranged from 8.16 to 30.56 p.p.m.

Gyraulus crista (Linnaeus). This species lives in shallow water among vegetation, under the bark of submerged logs, and on water-logged sticks and rotting leaves in stagnant water. The bottom is composed of mud or silt and is mucky in most places; the vegetation consists of Typha, Scirpus, Potamogeton, Nymphaea, Castalia, Lemna, and Chara. The food of this species is largely vegetal and algal in nature. G. crista may be restricted only to temporary bodies of water.

Ferrissia parallela (Haldeman). This species is found in enclosed bays, open swamps or small ponds, and swampy pools or swales. It is almost strictly a pond or small lake species, found in quiet waters whose depth varies from 1 to 6 feet and rarely occurs in sluggish streams. This species usually lives near the surface of the water but may be found on the lower part of such plants as Scirpus, near the bottom. It also lives on the under side of lily leaves (which gives a broad, flat look to the shell) and on sticks in boggy swales (here the shell is higher and more compressed). F. parallela lives in waters whose pH ranges from 6.05 to 8.37 and whose fixed carbon dioxide varies from 2.75 to 25.75 p.p.m. The bottom may be sand or mud covered with vegetation. The limiting factors for the distribution of this species are wave action (since it is found only in quiet water) and the presence of vegetation.

Physa gyrina (Say). This species lives in almost any kind of water body except swift-flowing streams. It has been found on muddy banks of rivers near the edge of the water, in small ponds, on lake beaches, and in swampy tracts along the edges of rivers. P. gyrina flourishes best in

newly isolated ponds in which there is inoderate growth of pondweed. It is a shallow-water form which inhabits a sandy silt or mud bottom, but is found most often on vegetation, generally on the upper side of pond lily leaves. The optimum conditions for its survival are shallow water which is unshaded, except by tall sedges; protection from wave and current action; a moderate amount of water weeds; and well aerated water. P. gyrina lives upon both animal and vegetable food, either fresh or partly decayed. This species does not attack or feed on living snails but will devour them once they are dead. It is an inhabitant of waters whose pH ranges from 7.1 to 8.37 and whose fixed carbon dioxide varies from 9.5 to 25.75 p.p.m.

Terrestrial Gastropods

Stenotrema monodon (Rackett) is a woodland snail found in marshes, wooded swamps along the banks of streams, on river floodplains, on shores of lakes, and in ravines adjacent to rivers. It is also present in tall grass prairies and open fields. This species thrives best in rather humid forests where its favorite hiding places are under logs, old stumps, leaves, and flat stones. The typical form of S. monodon is gregarious.

Triodopsis tridentata juxtidentis (Pilsbry). This species is a forest dweller found among leaves and humus in open woods and in leaf mold on wooded hillsides. It has also been found living in stream drift which had been deposited on the roof of a limestone cave.

Haplotrema concavum (Say). This snail is seldom found in large numbers in any one locality. It prefers moist situations and has been found upon floodplains and in stream drift. It also lives in the loam deposits of forests, under logs, on stumps, in marl beds, and thickets of prickly ash; burrowing in clay. This species sometimes feeds on other snails.

Euconulus fulvus (Müller). This species is common in places which are moist and well-shaded but is sometimes found in open pastures. It is generally not found in large numbers. The favorite habitat of E. fulvus is the damp under side of decaying logs but it is also found living among damp leaves or other vegetation, in the cracks of bark, and between the bark and wood of fallen trees. It is quite common in lake and stream drift.

Retinella binneyana (Morse). This species is common in forests of birch, aspen, maple, cedar, fir, hemlock, spruce, and pine. Here it is found in several different situations but is most common under forest debris, at the base of stumps, under logs, and under the loose bark of fallen trees. This species also lives on lowlands which border lakes.

Retinella indentata (Say). This species is found in a variety of ecological situations. It prefers a drier habitat than does Retinella electrina although they are occasionally found together in moist situations. This species is found under rotten logs, loose bark and other forest debris, rocks in the grass of open fields, and decaying vegetation. It often burrows to a considerable depth in the under side of rotten logs and also frequents old stumps. R. indentata is rare in open country but sometimes lives on rocky slopes having only a sparse cover of trees and shrubs. It also lives in wooded ravines and along the banks of streams wherever trees and shrubs are present.

Hawaila minuscula (Binney). This species prefers a woodland environment where it lives under leaves, among grass roots, under decaying logs, beneath the bark of trees, among mosses, beneath stones, on rocky ledges, and in loose, moist soil under a light layer of decaying vegetation. It is also common in stream drift. This species has also been reported near the borders of streams and lakes, but never in greater numbers than four or five individuals. H. minuscula is capable, in spite of its habitat preferences, of withstanding long periods of drought and high temperature.

Ventridens demissus (Binney). This is a woodland snail found crawling about at the base of grasses on damp ground in deciduous forests. It has also been reported on the bluffs overlooking the Kaskaskia River in Illinois, and on a railroad right of way near there.

Zonitoides arboreus (Say). This species occupies a wide range of ecological situations but prefers one that offers protection from the sun and provides a moderate amount of moisture. This species lives in woodlands under loosened bark, sticks, leaves, logs and stones. Its favorite habitats are around decaying logs, between the bark and wood of old fallen trees, and among decaying vegetation. It is also found in stream drift. This species is somewhat gregarious.

Helicodiscus parallelus (Say). This is primarily a woodland snail that lives among forest debris of various sorts. It may be found under bark, in cracks or creases of bark on fallen trees, under moss, in damp leaves, on decaying wood, and on stream drift. It also occurs in grassy fields, on sparsely timbered slopes, and on rocky ledges. The favorite habitats of this species are limestone ledges, on forest debris in stands of oak and hickory, under decaying vegetation, and among grass roots.

Punctum minutissimum (Draparnaud). This is a woodland species which lives under sticks, chips, decaying logs, and on damp leaves. It prefers the bark of beech trees and is frequently found in the large forms of fungi, such as Polyporus and Boletus. Hardwood growths appear to be its favorite habitat.

Oxyloma retusa (Lea). This is a species of marshes and other wet places. It commonly lives on mud flats above high water level along swampy shores, caused by a raising of the water level in a lake or pond. It is also found upon partly submerged sticks, on rotting weeds and often high on the stems of cat-tails. Other occurrences include: on plants along the edges of streams; on pieces of bark and wood on grass covered shores a few feet above water line; and on pond lily leaves in a community of Nymphaea and Castalia. It is frequently found in the company of lymnaeids.

Succinea avara (Say). This species has a wide range of habitat preferences. It lives in low, swampy areas crawling on the muddy banks of ditches, often exposed to the sun; under vegetable debris thrown up on muddy shores; on sticks, chips, or moss-covered rocks; under decaying logs; and in swampy places in pastures. This species has been observed climbing to a height of three feet on tall fronds in the water. It apparently thrives best on grass and reeds near or above the water in roadside ditches and similar situations. But it is an upland species as well, seen under stones, leaves, or logs with Pupillidae, or crawling up the trunks of trees after rains. In these dryer places it is of smaller size. Unlike Oxyloma retusa, it never congregates in large numbers.

Strobilops aenea (Pilsbry). S. aenea is an uplands species, in forests of oak, elm, hickory, dogwood, walnut, sassafras, and ironwood. It is rarely found in a floodplain valley and then only when the situation is dry. This species is most abundant under the loose bark of fallen trees, on the underside of decaying wood, and on chips from forest cuttings. It occurs both in old woods and recent cut-overs wherever logs and decaying wood have accumulated. S. aenea is often found associated with Strobilops labyrinthica.

Strobilops labyrinthica (Say). This species is generally confined to moist woodland habitats and is only rarely found far from the edge of the forest. It occurs most often around moist logs, among dead leaves, and in sod at the foot of trees. S. labyrinthica occasionally

lives close to the water line under sticks, crawling about on old stumps and logs, and in the mossy crevices of rocks. It is often associated with Zonitoides arboreus and Retinella electrina.

Gastrocopta contracta (Say). This species is an inhabitant of shaded, wooded slopes where it lives under leaf mold and the bark of fallen logs. It also lives in the deep grass of marshes; on ferns in meadows; under sticks and driftwood; in loose soil around the roots of small trees, shrubs, tall grass, and weeds; and under leaves on the banks of small streams. This species is most numerous under forest litter in poorly drained areas near the bottom of hillsides. It is also abundant where loose limestone rock provides a cover.

Gastrocopta tappaniana (C. B. Adams). This species is found in low, moist places, in damp leaf mold, and under sticks, logs and stones on wooded slopes and poorly drained floodplains. It also lives under logs in swamps and among grass roots on open slopes. The wide latitudinal range of this species indicates that the annual mean temperature is not a primary factor in its distribution. G. tappaniana is often found with Vertigo ovata.

Pupoides albilabris (C. B. Adams). This species has a wide range of environmental conditions. It thrives in woodlands under leaf mold, loosened bark of dead trees, and stones. It is also found on wooded slopes in areas high enough not to be scoured of vegetation and mollusks by flooding during seasonal rains. This species has been found on trees a few feet above the ground following rains. In open country it lives in deep grass, among roots of short grass in unshaded areas, and in loose soil around roots of short grass in unshaded areas, and in loose soil around roots of tall grass and weeds. P. albilabris is generally more abundant in limestone areas than elsewhere. This species is unusual in its ability to flourish in arid regions as well as those of moderate annual rainfall. P. albilabris can withstand more heat and aridity than any other land snail of its area of distribution. It is abundant in places where almost no other mollusks occur.

Vertigo milium (Gould). This snail is an inhabitant of humid places, such as those afforded by marshes and wooded slopes near streams. It is found under sticks, bark, and stones, generally on low ground, but may also be found on hillsides under leaves. This species does not occur in regions where the humidity is low or there are high extremes of summer temperature. V. milium is a gregarious species.

Vertigo morsei (Sterki). This snail is found most often on the floodplains of creeks and rivers. It also occurs near the shores of lakes where it is found under dead woods, wood, etc. This species thrives in forests where there is abundant shade and moisture and prefers a stand of aspens as its favorite habitat.

Vertigo ovata (Say). This species prefers a moist environment afforded by shaded slopes near streams and the shores of ponds. It is found in swampy areas, along stream banks and other bodies of water, and under sticks and flat stones. V. ovata is abundant in meadows which have swampy areas in which Carex grows. The limiting factor for this species is a relatively high moisture requirement.

Carychium exiguum (Say). This species lives near the water or permanently moist situations. It is found on the wet underside of logs on the edges of ponds and swamps, on the margins of damp woods, and under leaves. This species prefers places that are very damp and is able to live for a long time in situations where most other land snails would be drowned. Constant high moisture and decaying vegetation appear to be the essential factors in its environment.

Carychium exile canadense (Clapp). This species lives on forest hillsides but is found most often in low, marshy woods on the forest floor. Here it may be found under rotting stumps, strips of bark, wet pieces of bark or wood, and under debris. C. exile canadense is found in drier places than C. exiguum and always at some distance from the water.

General Nature of the Castalia Deposit

Depth of water. The Castalia deposit was formed in the quiet waters of a large, shallow lake. The depth of water varied from a few inches to as much as six feet and this is clearly shown by quantitative changes of the species in the faunas. The presence of peat in the deposit is also indicative of an unsteady fluctuation of the water level. During formation of the marl, the water was deeper but where peat formed, the water level was lowered, often less than a foot. In changing from a low water level to a higher one, necessary for the formation of marl, additional water was supplied by seasonal rainfall and artesian-fed springs which abound throughout the area. Replenishment by springs is confirmed by block-like masses of tufa found in the different lithologic units of the deposit. The abundance of land snails indicates that the deposit was near shore and that a plentiful forest cover was present in the immediate vicinity.

Nature of the bottom. The composition of the bottom varied throughout the period of deposition. The deposit formed on blue lake-clay and the bottom consisted of sand, mud, and mixtures of the two.

Vegetation. The amount of vegetation varied during formation of the deposit but generally ranged from moderate to luxuriant in degree.

Hydrogen ion concentration and carbon dioxide content. The water in which the faunas lived had pH limits of 6.0 to 8.5 but the normal value was probably nearer 7.5. The carbon dioxide content may have varied from 2.85 to 30.56 p. p. m. throughout the history of the deposit but a mean value of 14.0 p. p. m. is more probable.

Food. The majority of the fresh-water species feed on vegetal matter consisting of the soft parts of plants, algae, and desmids. Some species, such as Ferrissia parallela, prefer dead and decaying vegetation. A fine detritus composed of disintegrated, decaying plant material floats about in the water and is also a source of food for many of these fresh-water snails. A number of species are omnivorous, eating dead animals as well as rotting and living plants; Physa gyrina is an excellent example. This species has been observed feeding on green shoots of Chara and Elodea, partly decayed leaves of grass and trees, and dead animal matter.

The food of terrestrial gastropods consists mainly of the fungal hyphae of decaying wood and leaves. The larger, fleshy fungi and seed plants also provide food but to a lesser extent. A source of lime is also needed for the continued growth of the shell. The snail obtains this supply from the skeletons of other animals, limestone rocks, soils rich in calcium, and plant food. The only predator among the land snails is Haplotrema concavum, but even it is not invariably a flesh eater.

Enemies. A large number of animals prey upon fresh-water mollusks, using them as food. Fish consume a large amount of snails. However, the proportion varies in different species. Some fish subsist entirely upon mollusks in the adult stage, and may be easily recognized by

their flat, crushing teeth. Other fish eat only a few mollusks and many eat none. Fresh-water gastropods are also eaten by predatory insects such as dragon-fly nymphs, horse-fly larvae, giant water bugs, and water beetles. Crawfish, leeches, frogs, newts, salamanders, and turtles consume small quantities of snails. Water birds such as ducks and geese include snails in their diet. Mammals like the muskrat, mink, and otter feed on large quantities of mussel shells.

Nature may exterminate fresh-water gastropods through raising and lowering of the water level in the various bodies of water during droughts and floods. The overabundance of vegetation in shallow water is harmful to species like *Physa gyrina*. Man becomes an exterminator by polluting streams, rivers, and lakes with refuse from factories and mills; also by draining swamps and swampy areas. The shells of some mollusks are affected by boring plants (algae) which perforate the shell, thus destroying the epidermis and permitting carbon dioxide in the water to dissolve the calcium carbonate of the shell.

The enemies of terrestrial gastropods are legion. The occurrence of forest fires, modifications of the environment by changes in the plant community, and periods of prolonged drought are adverse factors. Man is also important as an exterminator of gastropods by burning large tracts of brush and draining soil to prepare land for farming or construction. The chief enemies of land snails in the animal world are the various kinds of mice and birds. A few insects are known to attack land snails and some of them, especially the Succineas, are infested with parasitic worms. Raccoon, squirrels, chipmunks, shrews, and moles all include snails as a part of their diet. Toads, frogs, and snakes also eat a limited quantity of them.

Environmental History

General Statement. Utilizing the data just given, a brief account of the geologic history of the deposit can be outlined. The units are discussed from oldest to youngest as they appear in the measured section, p. 21.

Unit 1, lower marl. The indigenous species of the first three collections in this unit lived in comparatively shallow water. Proof of this may be found by comparing the relative abundance of land versus freshwater shells. In these collections, the percentage of both types is approximately equal. Also, *Gyraulus altissimus* does not exceed 22 percent of the total individuals in any collection and *Carychium exiguum* has a maximum value of 22.5 percent. In collections 4 and 5, however, the water became deeper as may be observed by the great increase of freshwater species. In collection 6, the land genera became dominant again and introduced a longer period of numerical supremacy that continued throughout half of the peat unit.

Unit 2, peat. Domination by the land forms continued through collections 7 and 8. The swampy terrain was ideal for the hygrophilic land species and this is confirmed by their total abundances of 73 percent and 55 percent in these collections. *Carychium exiguum* increased to 38.5 percent while *Gyraulus altissimus* decreased to 20 percent. The bottom had now become choked with mud and vegetable debris and the water, though present the year round, was quite shallow. Conditions such as these were not suitable for such freshwater species as *Physa gyrina* and this is reflected by its low percentage (3.0 and 3.5) in these collections.

As the formation of peat drew to a close in collections 9 and 10, the freshwater species regained numerical supremacy just as the land genera did in collection 6. Vegetation became less dense as indicated by an increase of *Physa gyrina*. The water was shallow but increased in

depth, confirmed by the high percentage of Planorbula armigera present. Ferrissia parallela another shallow water, vegetation-dwelling form, also increased beyond its normal percentage.

Unit 3, upper marl. The paucity of shells in collection 11 denotes an environment unfavorable for the freshwater snails. The critical event was a sudden influx of sand into the shallow water overlying the peat. The sand was carried by a sluggish stream from the higher beach line above and dropped around the vegetation in the shallow waters overlying the deposit. Microscopic examination of samples of the sand revealed no frosted grains verifying its origin as beach rather than dune sand. The presence of vegetation is readily confirmed by an extremely high percentage of Ferrissia parallela in the collection. As Gyraulus altissimus may live under a great variety of conditions, its presence is to be expected. The high percentage of Physa gyrina is a result of the snail inhabiting the waters of the sluggish stream and being transported by it into the depositional area.

Collection 12 also contained sand but in a minor amount. Stream deposition of the sand was reduced and then terminated altogether either because the stream was an intermittent one or because it changed course and emptied into another portion of the lake. With the end of sand deposition, the snails became more abundant. The bottom was mucky in the upper part of the collection and Helisoma trivolvis became abundant. The shallow water and moderate growth of vegetation continued to make Physa gyrina the most abundant species. Gyraulus altissimus was found in greater numbers than in collection 11.

In the next three collections the water deepened a little, although the level of the water was still rather low. Thus Gyraulus altissimus increased and Physa gyrina showed a considerable decrease in numbers. In collections 16 to 18 the depth of water reached the optimum level for Gyraulus altissimus to flourish while Physa gyrina continued to decrease. Following this the water became shallower once again and Gyraulus altissimus decreased as Physa gyrina increased. Fossaria obrussa decampi found conditions most favorable for its development and is more abundant here than in any other collection.

Collections 23 to 26 show a slight increase in the depth of water with a consequent rise in numbers of Gyraulus altissimus and a decrease of Physa gyrina. Conditions were still favorable for Fossaria obrussa decampi. In the last two collections of the marl unit the depth of water decreased once more. Vegetation became more abundant and the bottom muddy. Gyraulus altissimus decreased somewhat as did both Physa gyrina and Fossaria obrussa decampi.

Unit 4, humus. In the last two collections the total percentage of land snails became greater than the freshwater species. The water level once again was very low and the bottom choked with vegetation. A deep mud bottom was present and the formation of peat took place.

QUANTITATIVE DISTRIBUTION

Variation with Lithology

General Statement. The faunas of the Castalia deposit begin in the collection immediately overlying the blue lake-clay and continue throughout the various lithologic units. The change in abundance of shells from one collection to another is the direct result of a change in environmental conditions. A graphic representation of the total number of shells in each collection is shown in fig. 3 (opposite p. 32).

Unit 1, lower marl. Collection 1 contains 2,400 shells but was undoubtedly more populated than is shown. The factor here is one of human error. The collection, when extracted from the section, was saturated with running water making it difficult to judge the normal amount of sample. Were it not for this, the collection should have contained as many shells as the two directly above it since all three collections have the same lithology. In collections 5 and 6 the shells increase abruptly. Collection 6 contains more than twice the number of shells as the collection below it. The land snails constitute the greatest percentage of individuals in collection 6 due to a change in lithology. The clay and sand of the previous collections are replaced by peat, which indicates more favorable conditions for the land snails.

Unit 2, peat. Collection 7 is as replete with shells as collection 6 and the land snails are still dominant. The collection includes a little sand and contains more shells than any other collection in the peat unit. There is a sharp drop in the number of shells in collection 8 but the land snails are still more abundant. In collections 9 and 10 the amount of shells increases once again and the freshwater species regain numerical superiority. A small amount of sand is present in collection 10.

Unit 3, upper marl. Collections 10 and 11 contain large amounts of sand and very few shells. The number of shells increases as rapidly in collections 13 to 15 as they decreased in 11 and 12. There is less sand and more peat members appear in the gray marl. A band of cream-colored marl occurs above this in the next two collections and the number of shells decreases. The gray marl reappears in collections 18 to 20 and collection 18 contains the greatest number of shells in the deposit. In collections 21 and 22 the cream-colored marl reappears and the shells decrease. Collections 23 to 28 are a mixture of gray and cream-colored marl and, with the exception of collections 27 and 28, show a nearly uniform abundance of shells. The land snails become dominant in collections 27 and 28 and remain so for the last two collections in the deposit.

Abundance by Groups

Of the four groups represented, the freshwater pulmonates are the most numerous, constituting a majority in two-thirds of the collections. The freshwater gill-breathers are present in twelve of the collections but only in very small numbers. The land snails constitute a majority in one-third of the collections but are present throughout the remaining collections in minor amounts. The pelecypods are an insignificant group in the Castalia deposit. They are represented in small numbers by only one species.

Abundance by Species

Indigenous freshwater species. The indigenous species are those which lived and flourished where the deposit formed. They generally comprise the greatest percentage of the faunas. Some species, however, were present in minor amounts and still inhabited the depositional area. They, therefore, must also be considered indigenous. The following four species, all lung breathers, are indigenous.

Gyraulus altissimus is the most abundant species in the deposit. It varies from 13 to 55 percent throughout the collections and is most abundant in the cream-colored marl (collections 5, 16, 17, and 18) where it exceeds 50 percent of the total individuals in the collections (see fig. 4, opp. p. 32). Fossaria obrussa decampi is the second most abundant species in the deposit.

It is most abundant in the gray marl (collections 14, 15, 18, 19, and 20) and least abundant in the peat unit and sandy collections (11 and 12) of the upper marl unit. (See fig. 5). Physa gyrina shows its greatest abundance in the sandy collections (11 and 12) of the upper marl unit. Excluding these high percentages, it is still more abundant in the marl units than elsewhere in the deposit. (See fig. Ferrissia parallela is present in twenty-six collections. It is most abundant in collections 9 and 10 of the peat unit and the very sandy marl collection (11) above it. Ferrissia parallela is not present in collections 14 to 17, but reappears in smaller numbers throughout the remaining collections of the deposit (Fig. 7, opp. p. 34).

Non-indigenous freshwater species. The intruders did not inhabit the place of deposition but were washed, floated, or blown into it. Some species lived in other parts of the lake and others were washed into the lake by streams that emptied into it. The ten remaining freshwater species are intruders. The first six species discussed are lung breathers, the next three are gill-breathers, and the last species is a pelecypod.

Helisoma trivolvis occurs in only eight collections and these are all below collection 14. Collection 12 contains seven specimens and represents its greatest abundance in the deposit. This would seem significant, in view of its large size, but the fact that it is found in a sandy marl where no much bottom exists would discount its importance. Planorbula armigera is found in all but eight collections. It reaches its greatest abundance in the first ten collections. Found in considerable numbers throughout the lower marl, it becomes most numerous in collections 8 and 9 of the peat unit. Its preference for stagnant, shallow water would account for this. It is virtually absent in collections 11 to 22, but is present in very small amounts in the collections above. Gyraulus crista is present in small numbers in the top part of the upper marl unit. There are also individual specimens in four of the remaining collections of the deposit. Fossaria modicella occurs mainly in the lower marl. It is more numerous in collections 2 and 3, and the top seven collections of the upper marl unit. Promenetus exacuus is represented by individual specimens in collections 20, 23, 24, and 25 of the upper marl unit. Stagnicola umbrosa occurs as individual specimens in collections 4 and 6 of the lower marl unit and 23 and 25 of the upper marl unit.

Pomatiopsis lapidaria is present in small numbers mainly in the top part of the upper marl unit and in the humus unit. Pleurocera acutum tractum occurs as a single specimen in collection 4 of the lower marl unit. Goniobasis livescens is represented by two specimens in collection 26 of the upper marl unit and one specimen in collection 30 of the humus unit.

Pisidium casertanum is present in twenty-three collections but does not exceed 5 percent of the total individuals in any collection. It is most abundant in collections 24 and 25 of the upper marl unit.

DESCRIPTION OF FIGURES 3 - 6 (OPPOSITE PAGE)

Fig. 3. Graphic representation of the total individuals in each collection of the Castalia deposit.

Fig. 4. Quantitative distribution of Gyraulus altissimus (F. C. Baker) in the Castalia deposit.

Fig. 5. Quantitative distribution of Fossaria obrussa decampi (Streng) in the Castalia deposit.

Fig. 6. Quantitative distribution of Physa gyrina (Say) in the Castalia deposit.

COLLECTION AND UNIT	TOTAL INDIVIDUALS	GRAPHIC REPRESENTATION OF TOTAL INDIVIDUALS					
		5	10	15	20	25	30
4	30	12,000	██████████				
	29	6,000	██████████				
	28	5,755	██████████				
	27	3,702	██████████				
	26	9,600	██████████				
	25	12,000	██████████				
	24	12,000	██████████				
	23	12,000	██████████				
	22	7,636	██████████				
	21	14,000	██████████				
3	20	19,500	██████████				
	19	28,000	██████████				
	18	31,200	██████████				
	17	16,666	██████████				
	16	3,328	██████████				
	15	26,400	██████████				
	14	27,333	██████████				
	13	12,727	██████████				
	12	1,560	██████████				
	11	280	██████████				
2	10	9,454	██████████				
	9	7,077	██████████				
	8	4,560	██████████				
	7	22,500	██████████				
1	6	22,666	██████████				
	5	10,240	██████████				
	4	6,470	██████████				
	3	5,176	██████████				
	2	5,200	██████████				
1	2,400	██████████					

FIGURE 3

COLLECTION NUMBER	NUMBER OF INDIVIDUALS	PERCENT OF TOTAL INDIVIDUALS	GRAPHIC REPRESENTATION OF PERCENTAGE OF TOTAL INDIVIDUALS			
			10	20	30	40
30	220	22.0	██████████			
29	243	24.3	██████████			
28	276	27.6	██████████			
27	287	28.7	██████████			
26	406	40.6	██████████			
25	437	43.7	██████████			
24	431	43.1	██████████			
23	447	44.7	██████████			
22	315	31.5	██████████			
21	275	27.5	██████████			
20	284	28.4	██████████			
19	405	40.5	██████████			
18	530	53.0	██████████			
17	528	52.8	██████████			
16	504	50.4	██████████			
15	273	27.3	██████████			
14	286	28.6	██████████			
13	400	40.0	██████████			
12	192	24.6	██████████			
11	22	15.7	██████████			
10	326	32.6	██████████			
9	315	31.5	██████████			
8	203	20.3	██████████			
7	130	13.0	██████████			
6	171	17.1	██████████			
5	552	55.2	██████████			
4	482	48.2	██████████			
3	220	22.0	██████████			
2	164	16.4	██████████			
1	190	19.0	██████████			

FIGURE 4

COLLECTION NUMBER	NUMBER OF INDIVIDUALS	PERCENT OF TOTAL INDIVIDUALS	GRAPHIC REPRESENTATION OF PERCENTAGE OF TOTAL INDIVIDUALS				
			10	20	30	40	50
30	111	11.1	██████████				
29	135	13.5	██████████				
28	135	13.5	██████████				
27	122	12.2	██████████				
26	100	10.0	██████████				
25	204	20.4	██████████				
24	236	23.6	██████████				
23	234	23.4	██████████				
22	290	29.0	██████████				
21	367	36.7	██████████				
20	443	44.3	██████████				
19	395	39.5	██████████				
18	328	32.8	██████████				
17	219	21.9	██████████				
16	211	21.1	██████████				
15	267	26.7	██████████				
14	245	24.5	██████████				
13	165	16.5	██████████				
12	147	18.8	██████████				
11	6	4.3	██████████				
10	111	11.1	██████████				
9	74	7.4	██████████				
8	60	6.0	██████████				
7	50	5.0	██████████				
6	69	6.9	██████████				
5	76	7.6	██████████				
4	75	7.5	██████████				
3	92	9.2	██████████				
2	164	16.4	██████████				
1	177	17.7	██████████				

FIGURE 5

COLLECTION NUMBER	NUMBER OF INDIVIDUALS	PERCENT OF TOTAL INDIVIDUALS	GRAPHIC REPRESENTATION OF PERCENTAGE OF TOTAL INDIVIDUALS				
			10	20	30	40	50
30	41	4.1	██████████				
29	43	4.3	██████████				
28	35	3.5	██████████				
27	44	4.4	██████████				
26	50	5.0	██████████				
25	56	5.6	██████████				
24	94	9.4	██████████				
23	150	15.0	██████████				
22	150	15.0	██████████				
21	150	15.0	██████████				
20	108	10.8	██████████				
19	67	6.7	██████████				
18	72	7.2	██████████				
17	101	10.1	██████████				
16	90	9.0	██████████				
15	133	13.3	██████████				
14	181	18.1	██████████				
13	173	17.3	██████████				
12	261	33.5	██████████				
11	53	37.9	██████████				
10	239	23.9	██████████				
9	134	13.4	██████████				
8	35	3.5	██████████				
7	30	3.0	██████████				
6	60	6.0	██████████				
5	155	15.5	██████████				
4	164	16.4	██████████				
3	79	7.9	██████████				
2	82	8.2	██████████				
1	61	6.1	██████████				

FIGURE 6

Land snails. The following three species are considered indigenous. While not actually living in the body of water, they were nevertheless found in abundance at or near the edge of it. Carychium exiguum is the most abundant land species. It is absent only in collection 19 and elsewhere ranges from 0.4 to 39 percent. It is present in considerable numbers in all collections except 16 to 21 of the upper marl unit. Carychium exiguum is most abundant in collection 6 of the lower marl unit and collection 7 of the overlying peat unit (See fig. 8, opp. p. 34). Gastrocopta tappaniana is the second most abundant land snail in the deposit. It is present in all collections and varies from 1.3 to 19.5 percent. This species is most abundant in collections 13 to 15 of the upper marl unit. It is also numerous in collections 1, 2, and 6 of the lower marl, collections 27 and 28 of the upper marl, and the humus unit. (See fig. 9, opp. p. 34). Oxyloma retusa, while not as numerous as Gastrocopta tappaniana or Carychium exiguum, was still an inhabitant of the water's edge. It is generally more numerous in the upper marl unit and percentages in the other units are considerably lower. See fig. 10, opp. p. 34.

The following species, while not indigenous, inhabited the mud flats not far from the edge of the water. Vertigo morsei is most abundant throughout the upper marl unit. It is also fairly numerous in the peat and humus units. Strobulops labyrinthica, generally a woodland species, is occasionally found close to the water under sticks and stones. This was probably the case in collections 1, 2, 3, and 6 of the lower marl unit; collections 7 and 8 of the peat unit; collections 27 and 28 of the upper marl unit; and the humus unit. The species is much more numerous in these collections than elsewhere in the deposit. Succinea avara is found chiefly in the upper marl unit but in very small numbers. This is normal as this species is not known to congregate in large numbers.

The following forest species number less than 1 percent in most collections and never more than 4 percent. The higher percentages are usually in collections where the forest cover was more abundant. These species are: Retinella binneyana, Punctum minutissimum, Carychium exile canadense, Zonitoides arboreus, Retinella indentata, Helicodiscus parallelus, Euconulus fulvus, Vertigo milium, and Gastrocopta contracta.

The remaining forest species are represented in insignificant numbers. None of the species exceeds six specimens in any one collection or totals more than seventeen in the entire deposit. These species are: Ventridens demissus, Haplotrema concavum, Pupoides albilabris, Stenotrema monodon, Strobulops aenea, Vertigo ovata, and Triodopsis tridentata juxtidentis.

AGE AND CORRELATION OF DEPOSIT

Comparison with Pleistocene Faunas

General Statement. The Castalia deposit is compared with other deposits from the standpoint of both similarities and differences. The comparison is made on geologic geographic, and ecologic bases. In this way, a more accurate determination of age may be established.

Middletown, Ohio deposit. Sterki's (1907) "pre-glacial" deposit contains no quantitative data. Both land and freshwater species are present. Those marked with an asterisk in the following list are present in the Castalia deposit. The list is composed of the following species (names have been brought up to date): Mesodon elevatus, *Haplotrema concavum, Anguispira alternata, Stenotrema hirsutum, *Stenotrema leafi, Mesodon thyroidus, Allogona profunda, Triodopsis tridentata, Goniobasis sp., *Helisoma trivolvis, Anguispira kochi, *Pomatiopsis lapidaria.

Wayne's (1958, p. 11) quantitative study of a pro-Kansan loess reveals a total of twenty species, eighteen of which are terrestrial. Only six of these are found in the Castalia deposit. The dissimilar species are the following: Stenotrema hirsutum, Oxyloma decampi gouldi, Retinella electrina, Gastrocopta proarmifera, Discus cronkhitel, Columella edentula, Valonia cf. V. excentrica, Cionella lubrica, Hendersonia occulta, Pupilla muscorum, Vertigo alpestris oughtoni, Vertigo elatior, Vertigo gouldi hubrichti, Vertigo cf. modesta.

Cleveland loess, Ohio. This early Wisconsin loess described by Leonard (1953) contains essentially terrestrial faunules. Five freshwater species are present but only Gyraulus pattersoni is represented by more than one specimen. This deposit is included here to show the composition of early Wisconsin terrestrial faunules and to compare them with the terrestrial species in the Castalia deposit. Twenty species occur in the loess but only six of them also occur in the Castalia deposit.

Orleton Mastodon Site, Ohio. The Orleton deposit, of late Wisconsin age, contains both land and freshwater species (La Rocque, 1952). It is much smaller than the Castalia deposit, but contains a surprising number of identical species. Of the twenty-one species present, the following eleven are found in the Castalia deposit: Helisoma trivolvis, Planorbula armigera, Gyraulus altissimus, G. crista, Promenetus exacuus, Physa gyrina, Ferrissia parallela, Oxyloma retusa, Stenotrema leafi, Hawaila minuscula, Vertigo ovata. Five of the remaining species, while not identical, nevertheless occupy the same type of environment as five of the species in the Castalia deposit. Another similarity exists in the absence of annicolid in both deposits. Valvata lewisi, an operculate, is not found in the Castalia deposit but three other operculates are present. A significant ecological difference between the two deposits is the presence of Musculium and Sphaerium in the Orleton deposit. The Castalia deposit compares favorably with the black layer of the Orleton deposit but not with the gray layer and the percentages of identical species in each of the deposits are quite different.

Rush Lake, Ohio. This molluscan assemblage, post-Wisconsin in age, is thought to have lived in a larger Rush Lake (Baker, 1920, p. 441). It is discussed here because it contains both Amnicola and Valvata, both of which are not found in the Castalia deposit. Amnicola lustrica and Amnicola leightoni compose the greatest percentage of total specimens in the deposit. Two species (four varieties) of Valvata are present but in rather small numbers. Gyraulus altissimus, third in abundance, is found in the Castalia deposit. This deposit is also distinct from the Castalia deposit by the presence of Naiad fragments and the absence of land snails. The only species common to the Castalia deposit are Gyraulus altissimus, Promenetus exacuus, Fossaria obrussa decampi, and Ferrissia parallela.

Toronto Interglacial Fauna. This fauna, described by Baker (1931), whose exact age is still in dispute, is given to show the contrast between a Great Lakes fauna and that of the

DESCRIPTION OF FIGURES 7 - 10, OPPOSITE PAGE

Fig. 7. Quantitative distribution of Ferrissia parallela (Haldeman) in the Castalia deposit.

Fig. 8. Quantitative distribution of Carychium exiguum (Say) in the Castalia deposit.

Fig. 9. Quantitative distribution of Gastrocopta tappaniana (C. B. Adams) in the Castalia deposit.

Fig. 10. Quantitative distribution of Oxyloma retusa (Lea) in the Castalia deposit.

COLLECTION NUMBER	NUMBER OF INDIVIDUALS	PERCENT OF TOTAL INDIVIDUALS	GRAPHIC REPRESENTATION OF PERCENTAGE OF TOTAL INDIVIDUALS				
			1	2	3	4	5
30	2	0.2					
29	3	0.3					
28	5	0.5					
27	3	0.3					
26	8	0.8					
25	4	0.4					
24	5	0.5					
23	3	0.3					
22	4	0.4					
21	2	0.2					
20	3	0.3					
19	1	0.1					
18	1	0.1					
17	0	0.0					
16	0	0.0					
15	0	0.0					
14	0	0.0					
13	3	0.3					
12	1	0.1					
11	30	21.4					21.4
10	84	8.4					8.4
9	55	5.5					
8	15	1.5					
7	2	0.2					
6	4	0.4					
5	6	0.6					
4	25	2.5					
3	13	1.3					
2	19	1.9					
1	30	3.0					

FIGURE 7

COLLECTION NUMBER	NUMBER OF INDIVIDUALS	PERCENT OF TOTAL INDIVIDUALS	GRAPHIC REPRESENTATION OF PERCENTAGE OF TOTAL INDIVIDUALS				
			10	20	30	40	50
30	135	13.5					
29	165	16.5					
28	192	19.2					
27	192	19.2					
26	207	20.7					
25	94	9.4					
24	80	8.0					
23	68	6.8					
22	27	2.7					
21	16	1.6					
20	7	0.7					
19	0	0.0					
18	4	0.4					
17	11	1.1					
16	14	1.4					
15	42	4.2					
14	55	5.5					
13	103	10.3					
12	35	4.6					
11	1	0.7					
10	46	4.6					
9	84	8.4					
8	234	23.4					
7	385	38.5					
6	390	39.0					
5	93	9.3					
4	73	7.3					
3	215	21.5					
2	200	20.0					
1	225	22.5					

FIGURE 8

COLLECTION NUMBER	NUMBER OF INDIVIDUALS	PERCENT OF TOTAL INDIVIDUALS	GRAPHIC REPRESENTATION OF PERCENTAGE OF TOTAL INDIVIDUALS				
			10	20	30	40	50
30	150	15.0					
29	112	11.2					
28	112	11.2					
27	108	10.8					
26	63	6.3					
25	36	3.8					
24	33	3.3					
23	43	4.3					
22	70	7.0					
21	85	8.5					
20	78	7.8					
19	68	6.8					
18	13	1.3					
17	27	2.7					
16	82	8.2					
15	195	19.5					
14	169	16.9					
13	104	10.4					
12	57	7.4					
11	10	7.1					
10	33	3.3					
9	40	4.0					
8	57	5.7					
7	81	8.1					
6	100	10.0					
5	36	3.6					
4	32	3.2					
3	80	8.0					
2	115	11.5					
1	109	10.9					

FIGURE 9

COLLECTION NUMBER	NUMBER OF INDIVIDUALS	PERCENT OF TOTAL INDIVIDUALS	GRAPHIC REPRESENTATION OF PERCENTAGE OF TOTAL INDIVIDUALS				
			1	2	3	4	5
30	24	2.4					
29	30	3.0					
28	25	2.5					
27	20	2.0					
26	15	1.5					
25	12	1.2					
24	10	1.0					
23	34	3.4					
22	55	5.5					
21	55	5.5					
20	78	7.8					7.8
19	43	4.3					
18	56	5.6					
17	71	7.1					7.1
16	63	6.3					6.3
15	48	4.8					
14	30	3.0					
13	32	3.2					
12	67	8.7					8.7
11	14	10.0					10.0
10	21	2.1					
9	8	0.8					
8	4	0.4					
7	2	0.2					
6	3	0.3					
5	7	0.7					
4	8	0.8					
3	3	0.3					
2	14	1.4					
1	22	2.2					

FIGURE 10

Castalia deposit. No quantitative data are given but the contrast becomes most apparent in the presence and abundance of Naiades. Of the twenty-six species present, only Gyraulus altissimus is found in the Castalia deposit. The species are as follows: Amblema rariplicata, Ligumia recta, Lampsilis siliquoidea rosacea, Elliptio dilatatus, Pleurobema coccineum solidum, Lampsilis ventricosa, Obovaria olivaria, Anodonta grandis, Quadrula pustulosa, Sphaerium n. sp., S. emarginatum, S. sulcatum, S. solidulum, Pisidium compressum, Pleurocera acutum, Gonlobasis haldemani, Stagnicola palustris elodes, Gyraulus altissimus, Helisoma anceps striatum, Vancleaveia emarginata canadensis, Cincinnatia cincinnatiensis, Physa niagarensis, P. sayii, Birgella subglobosa, Valvata tricarinata, Campeloma rufum.

Castalia marl. Perhaps the most interesting comparison is with Sterki's (1920, pp. 178-183) list of species from the Castalia marl. From his total of eighty species, fifty are land snails and thirty are freshwater species. The writer's list of fourteen freshwater species and twenty-three land snails totals only thirty-seven species. Eighteen species of land snails and eight freshwater species are common to both lists. The species are as follows (the nomenclature has been brought up to date): Freshwater species, Fossaria modicella, Helisoma trivolvis, Gyraulus crista, Planorbula armigera, Physa gyrina, Goniobasis livescens, Pomatiopsis lapidaria, Pisidium casertanum; Terrestrial species, Zonitoides arboreus, Hawaiiia minuscula, Retinella indentata, Euconulus fulvus, Haplotrema concavum, Helicodiscus parallelus, Punctum minutissimum, Stenotrema monodon, Strobilops labyrinthica, Pupoides albilabris, Gastrocopta contracta, G. tappaniana, Vertigo ovata, V. morsei, V. milium, Oxyloma retusa, Succinea avara, Carychium exiguum.

The vast difference in total number of species between the two lists results from Sterki's method of collection. His specimens, instead of being taken from a measured section, were obtained in the following manner (1920, p. 177): "At some places they (the shells) were found in extraordinary numbers; for example, in a perpendicular, artificial bluff at the end of a digging, about four feet from the surface, there was a layer about three inches thick, which was chiefly composed of small and minute shells. The marl of this layer was quite soft, loose, and of finer grain than above and below, and through atmospheric influences had disintegrated to fine sand and dust. The dust and clean shells had accumulated on a narrow ledge at the foot of the bluff. Somewhat less than a quart of it was scooped up and taken along Most of the larger shells were picked up at various places where a steam shovel had been working but many were taken in situ. Siftings for the smaller ones were gathered here and there, especially where they had been washed together by rains."

Sterki (1920, p. 177) also states that not only do the land snails predominate in the number of species, but also that "the proportion is still more marked with the number of specimens." In the writer's measured section the land snails were more abundant in only 9 of the 30 collections but never exceeded 60 percent of the total individuals in any of these collections.

Age of the Faunas

General Statement. An age determination by means of molluscan faunas is sometimes uncertain, not only due to the close similarity of Pleistocene and living faunas, but also to the fact that few assemblages have received enough detailed treatment to compare with newly discovered faunas. The age of the Castalia deposit has been established with reasonable certainty, however, not only from molluscan faunas but also from a radiocarbon dating of wood fragments in one of the peat layers in the Castalia marl.

Age determination by molluscan faunas. There can be no doubt that the Castalia deposit was formed during the Pleistocene. Of the 37 species present, only four are found in Pliocene deposits. Age ranges for all of the species were sought in the literature but only 24 were found. These 24 include all of the species important from a quantitative standpoint. An exception to this statement is *Physa gyrina*, one of the more abundant species in the deposit. This is not as important as it might seem, however, as the identifications of species of *Physa* have been changed too frequently to be reliable.

Records of the 24 species reveal the following facts: only three species are absent from sediments of early Wisconsin time; six species are absent from sediments of Kansan age; 11 species are not present in sediments of Aftonian age; and 16 species are not found in deposits of Nebraskan age. These data alone would rule out an age older than a Kansan one. A late Wisconsin age seems to be the most probable. All of the species of the deposit are found living today except *Gyraulus altissimus* and this would indicate at least a Wisconsin age. The inference that *G. altissimus* is extinct must be made with some reservations. While extinct in Ohio, it has been reported living in southern Saskatchewan (Russell, 1934) and in North Dakota (Winslow, 1921). From a quantitative standpoint, it should also be kept in mind that *G. altissimus* is the most abundant species in the deposit. A land species, *Carychium exile canadense*, is also extinct in Ohio but has been found living in other states. This would also support a late Wisconsin age.

Fossaria obrussa decampi, second most abundant in the deposit, has not been found as yet in deposits older than late Wisconsin. Although abundant as a Pleistocene fossil, it is rare in recent faunas. Baker (1935, p. 270) believes the form to be nearing extinction. The only living occurrence in Ohio is noted by Sterki (1920, p. 174) who states that it has been found living in Summit County. This identification could be wrong, however, as he states that the few specimens found little resembled the normal *decampi*. Considering that this is a variety of a species, Sterki's identification may not bear much weight because it is possible that the form has merely been misidentified in earlier deposits. It may be also added that misidentifications are not always restricted to varieties. One has only to consider the present state of the genus *Physa* and the former confusion which existed in identification of the Sphaeriids. Assuming that Sterki's identification could be wrong, the two most abundant species in the deposit are extinct in Ohio. This furnishes additional evidence from a quantitative standpoint. With the facts and assumptions presented above, a late Wisconsin age is therefore advocated for the Castalia deposit.

Age determination by radiocarbon dating. While it is a fact that the stages of the Great Lakes occurred during Wisconsin time, the times at which the different shorelines were formed was not known. Radiocarbon dating has supplied the answers and is used here as additional and more exact evidence for a dating of the Castalia deposit. Wood from a layer in front of the Grassmere level in the Castalia marl has been dated at 8,513 years by radiocarbon, plus or minus 500 years (Libby, 1951, p. 292). Since the Castalia deposit is located on the Elkton level just below the Grassmere (see fig. 2), the age of the Castalia deposit is probably a thousand years less than the figure given above, making the period of formation between 7,000 and 8,000 years ago. Thus the late Wisconsin age indicated by the Mollusca is substantiated.

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MOLLUSCS in ARCHAEOLOGY and THE RECENT, 2

Number 2 of this mimeographed circular (pages 8-15, December 15, 1960) has just reached us. It is edited by Robert J. Drake, Department of Zoology, University of British Columbia, Vancouver 8, B.C., Canada. This number contains brief reviews of 31 papers dealing with ethnoconchology, some of which may also be of interest to readers of *STERKIANA*. These notes are a valuable supplement to the paper on Ethno-Conchology by R. J. Lambert, Jr. (*STERKIANA*, No. 2, pp. 1-8, 1960) and it is hoped that our friend Bob Drake will continue to collect and distribute this kind of information.